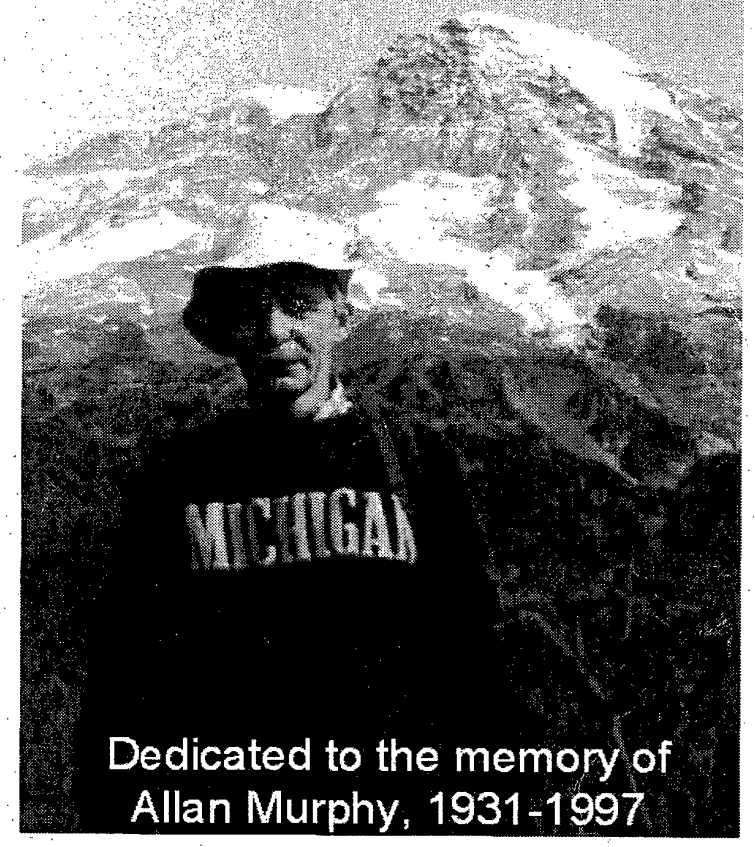
IMSC

7th International Meeting on Statistical Climatology



Whistler, BC, Canada, May 25-29, 1998

7th International Meeting on Statistical Climatology

Whistler Resort, British Columbia, Canada
May 25-29, 1998

Steering committee chair: Francis Zwiers
Program chair: Peter Guttorp
Local organizer: Richard Lockhart

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A Quasigeostrophic Model with Empirical Linear Corrections and Reduced Order for Climate Simulations

Abstract Number 1
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This work discusses the formulation and testing of a simplified model of atmospheric dynamics. The model, which has only 200mb and 700 mb streamfunction as prognostic fields, is designed to have a climate which approximates that of a comprehensive perpetual January general circulation model. Its governing equations are based on a Lorenz-type quasi-geostrophic model, but its linear terms are replaced by an empirically-determined operator; the simplified model is semi-empirical. Its basis consists of three-dimensional empirical orthogonal functions which are calculated using a total energy metric. The linear operator is intended to serve as a parameterization of fields, patterns and dynamics not explicitely represented in the model. The operator is found through an optimization procedure which insures that the semi-empirical model optimally predicts streamfunction tendencies observed to occur in an extended control integration of the general circulation model.

It turns out that the models determined in this way simulate the GCM climatology quite well. The time-mean state, time-mean transient fluxes and leading patterns of variability are all very similar to those in the GCM. Notable superiority over the behaviour of a standard quasi-geostrophic two-layer model is also found. In order to understand this, calcualations are undertaken to identify processes, not explicitely represented in a standard quasi-geostrophic two-layer model, which can be especially well parameterized linearly. Results point to a dynamical balance in the GCM such that deviations of its tendencies from tendencies given by a standard quasi-geostrophic two-layer model are smaller and more nearly a linear function of streamfunction anomaly than are individual terms contributing to the deviations. An analysis of the possibility of reducing the number of basis functions in the semi-empirical models shows that, whereas short-time prediction is best for the nontruncated model, in the simulation of climate mean state and transient fluxes the optimum is rather at small pattern numbers (between 30 and 70).

The leading eigenmodes of the empirically determined linear component of the simplified model are found to be nearly neutral.

Fingerprinting techniques in the detection and attribution of climate change

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Optimal fingerprinting (a variant of generalised linear regression in which the noise characteristics are estimated from a control integration of a climate model) has emerged as the de facto standard approach to the detection and attribution of anthropogenic influence on global climate. As applications have become more sophisticated, it has been necessary to refine the technique, in particular to consider the implications of non-linearity in the climate system for this essentially linear approach. We argue that non-linearity need not seriously compromise a fingerprint-based analysis provided diagnostics are based on time-averages which are long relative to the horizon of predictability of the chaotic system. Adequate treatment of non-linearity requires, however, an experimental design in which uncertainty in model-predictions (both due to sampling error and model mis-specification) must play an important role, not taken into account in standard fingerprinting. We discuss a variant of the Adcock (1878) regression algorithm which accounts for model prediction uncertainty, illustrated with the comparison of surface and free-troposphere temperature changes observed over recent decades and simulated by the Hadley Center coupled climate model, HadCM2.

Statistical Model of an Inverse Problem in Theory of Climate

Abstract Number 3
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An algorithm to solve the inverse problem for the restoration of detailed structure of regional geophysical field by large-scale global field was proposed. The problem was solved in space of the expansion coefficients with respect to empirical orthogonal components filtering off high-frequency

components and estimating a reliability parameter. It was found that an increase in accuracy of the inverse problem solution is achieved by using optimum summing up of the Fourier series of a field restored on the basis of taking into account an additional a priori information about the dispersion of the expansion coefficients. This algorithm was checked using numerical experiments. It was shown that 73 percent of monthly mean anomalies of 500 hPa height field over Europen region can be restored using the functionals that were received by averaging the global field over the territory 40x25 degrees in the Northern hemisphere. The experiments on the restoration of high-frequency component of anomalies of 500 hPa height field by the low-frequency component of this field were carried out. On the basis of numerical experiments on the restoration of the high-frequency component 500 hPa height field, using low-frequency component and restored regional field, using large-scale values of this field, it was scientifically grounded that it is necessary to divide the atmosphere states into classes and to build set of multivariate statistical models that must be used to solve the inverse problem. The choice of concrete model must be carried out on on the basis of a reliability parameter of the model.

Linking Rainfall Extremes of Different Durations

Abstract Number 4
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How are the extremes of 1-hour rainfall related to extremes of rainfall over longer durations? This question is relevant to the estimation of rainfall depth-duration-frequency curves and to the possibility of augmenting data on hourly extremes by (often more plentiful) data on daily extremes. The paper describes the development of bivariate extreme value models to give a methodology for the analysis of linkages of this kind. The results are applied to data from the Southern Uplands of Scotland.

Monthly Anomalies in Geopotential Height Fields Over Southern South America

Abstract Number 5
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Monthly anomalies in 1000 and 500 hPa geopotential height fields over southern South America and adjacent seas are examined. Regional objective analyses elaborated at the Servicio Meteorológico Nacional of Argentina are used. The period under consideration covers from January 1990 to December 1996. Standard deviations of 1000 hPa monthly fields increase south of 50S over the oceans, mainly over the Pacific Ocean in the south-west of the continent. Higher variability is observed for the months of May and September. In December it appears a maximum of 70 mgp about 50S between 50W and 40W over the Atlantic Ocean. For 500 hPa monthly fields, higher variability is observed at middle latitudes over the oceans, and south of 60S during the warm months (November-April). Over the continent, standard deviations are very low, and they increase for the cold months. Maximum deviations in monthly means are observed about 60S in the cold months (May-October). The relationship between monthly precipitation in the humid area of Argentina and monthly anomalies in geopotential height fields is also investigated.

Reliability and resolution of probabilistic forecasts based on Ensemble Prediction Systems

Abstract Number 6
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The performance of Ensemble Prediction Systems (EPS) is investigated from the verification of the probability distribution of 500hPa geopotential height over Europe. The (half) Brier Score or Probability Score is used to evaluate the quality of probabilistic forecasts based on this distribution. A skill-score is defined by comparison to a reference normal distribution based on the control forecast and the standard deviation of the control forecast error. A decomposition of the skill-score is applied in order to distinguish

the two main aspects of the forecast performance: reliability and resolution. Normal distributions based either on the ensemble mean and ensemble standard deviation, or on the ensemble mean and the standard deviation of the control forecast error, are used to compare the relative contributions to the skill of ensemble mean and ensemble spread. The performance of the European Centre for Medium-range Weather Forecasts (ECMWF) EPS is reviewed. The system proves skilful from +96h onwards, although there is no significant skill before +120h/+144h in terms of reliability. The performance comes mainly from the ensemble mean contribution. The ensemble spread contributes positively to the skill after calibration only, this improving the forecast reliability. The skill of the ECMWF EPS decreases steadily when reducing the number of ensemble members. This is mainly due to the ensemble spread negative contribution affecting the resolution. A poorman's EPS, comprising the current forecasts of different NWP centres, proves more skilful than the ECMWF EPS up to +144h, with a much better resolution, and despite a negative contribution of the spread due to a smaller population.

Non-parametric forecasting of snowpack in Utah, USA

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The impact of the El Niño/Southern Oscillation (ENSO) phenomenon on snowpack in Utah is analyzed to aid in forecasting. A small number of records are chosen based on length of record and location. The locations to be analyzed include the northern and southern part of the state so that regional differences in ENSO response can be identified. A number of statistical techniques will be employed. Changes in the probability distribution of snowpack in ENSO years will be identified. The functional relationship between snowpack and the ENSO phenomenon will be examined using locally weighted regression (loess).
The utility of ENSO and other indices such as the Central North Pacific (CNP) sea level pressure and North Pacific sea surface temperature in forecasting snowpack for these stations in Utah is analyzed. Snowpack forecasts of various lead times using non-parametric regression methods will be presented.

The North Atlantic Oscillation: Definition, Climate Effects, Interaction with ENSO

Abstract Number 8
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The North Atlantic Oscillation (NAO) is defined here using rotated principal components analysis (RPCA) on 3-month mean Northern Hemisphere sea level pressure (SLP) and 700 mb height fields for the 1950-96 period. The details of the RPCA are found to affect the resulting NAO pattern more than would be desired, illustrating that the NAO is a less well defined, more amorphous, structure than, say, the Pacific/North American pattern. The sensitivity of the NAO patern is most marked in spring and fall. The resulting RPCA indices of the NAO are compared with one another and with the traditional Azores-Iceland SLP index of the NAO. The three indices are found to be in good agreement in winter, but the Azores-Iceland index is only in moderate agreement with the RPCA indices in summer. The RPCA spatial patterns show that the pattern assumes a more northerly position in summer than winter, especially west of 50W. The RPCA pattern is regarded as a more complete definition of the NAO than a two-point index and is thus implicitly considered as relative ground truth. The Azores-Iceland SLP index is therefore concluded to well represent the NAO since 1865 for the cold portion of the year.

The Northern Hemisphere surface climate patterns associated with the NAO are examined; these are shown to be dependent on season because of the marked northerly migration of the NAO pattern during summer as compared with winter. The NAO has a substantial influence on the temperature, and to a lesser extent precipitation, in much of North America, Europe and the North Atlantic.

The combined effects of the NAO and ENSO during winter are found to be strongest when the two both phenomena assume mutually enhancing phases (e.g. a warm ENSO plus a negative NAO). The regions affected by both mechanisms are eastern and central portions of Canada and the U.S. The 700 mb height pattern corresponding to the mutually enhancing ENSO/NAO combination is so strong that it appears as the first unrotated PC of 700 mb height in winter.

Lagged association between the NAO and the Atlantic sea surface temperature (SST) indicate that the atmospheric aspects of the NAO arise without apparent forcing from the SST; the SST responds to the atmospheric aspect of the NAO. Other than a weak hint of positive winter-to-winter autocorrelation of the atmospheric NAO, reliable atmospheric precursors to NAO extremes are not detected. Thus, it remains an important challenge to predict onsets of high amplitude NAO episodes. Without evidence that the NAO is forced by the lower boundary, its prediction will be particularly difficult.

Comparing ENSO related PNA and NAO signals

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It has been demonstrated that large scale oscillation phenomena (e.g., ENSO, NAO, PNA,...) have a great importance in determining many climatic variables at different regions of the Earth. These phenomena do not take place independently, however, the mechanisms and inter-relationships are not completely understood so far. The main idea of this paper is to develop a statistical relationship between indices of these atmospheric oscillations and large-scale patterns of atmospheric circulation over the area examined. Then, an analysis of atmospheric circulation patterns (CPs) is used to explain the linkage between large-scale forcing and local climatic response via a conditional probability framework. Given such a relationship the accuracy of estimating local climatic variables from ENSO and other atmospheric oscillations can be expected to increase. The following procedure is used for midlatitudes in the Northern hemisphere (Atlantic European and Western U.S. region). First, the CPs will be defined and the CP time series will be described. Then, the time series of large-scale circulation will be compared for the different oscillations events. The frequency distributions of time series of CP types under different phases of large-scale oscillations will be examined.

Restrospective Summary of Long-Range Forcasting in the Central European Region

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In the past half century long-range forecasting techniques are increasingly being used all over Central Europe. The national weather services, following the governmental and public demand developed or adapted their own long-range weather forecasting system. This lecture is trying to give a retrospective overview of the many differing techniques and methodology have been used over the region. The term long-range forecast was not consequently used: in some country it signed the 10 days - 1 month prognoses,

in some other cases the 1 - 6 month or even the 6 month -10 years interval were the target period. Generally the final long-range forecasts contains average or anomaly values of temperature and precipitation amount for the time interval in question.

The two simplest empirical forecasting method were commonly used till the early seventies: the persistence forecast and a large number of different analogue techniques. Several researcher still tried to apply the atmospheres periodic nature or some external forcing mechanism as for example the direct influence of the Suns and Moons cycles on weather parameters. The governing ideas and methodology of the late 70s and early 80s were: 1. to introduce the probability view of the long-range forecasts, 2. to use principal component or factor analysis to separate the most relevant weather predictors, 3. to use expansion procedures to extract information for the forecasting model, 4. to use linear regression, autoregression, multiple regression model for forecasting. Some model improvement and other developments were carried out at the late 80s, early 90s: 1. alternative operative model running, parallel 2-3 different forecasting techniques, 2. to create macrocirculation classification for describing circulation processes on daily base (cluster techniques, EOF analysis), link macrocirculation processes, due circulation patterns to local temperature, and precipitation networks. Since that time the national services mostly developed a decision strategy, how to combine, how to weight different results of different long-range models. Recently there are some initiative around the region to use ensemble sets as an input parameter of long-range forecast models, but there are many science political and local difficulties to make them available for the operational practice. There is as yet no real evidence that any of these latest methods are definitely superior to any other. Generally verification techniques are the right tools for those comparisons. But in this case so many different methods, geographical regions, time scales and missing information are present, that it has no sense to deal with this problem. The used verification techniques and results will be discussed, without comparison.

Testing Climate Models Using Variational Assimilation

Abstract Number 11
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Taking measurements always constitutes a scientific experiment, even if the express purpose is only 'monitoring'. The science can be good or bad, but

there is no escaping from the scientific framework. There is always some prior information about scales of phenomena, or even just intuition as to what is "out there". This information constitutes an hypothesis, and the subsequent measurement process becomes a test of the hypothesis. From a "monitoring" point of view, it would seem desirable to find that the data tend to confirm the hypothesis. From a scientific point of view, it would seem desirable for the data to reject the hypothesis, so that the experiment would be extending our knowledge of the ocean.

Our experiences seem to lie somewhere between these two extreme points of view, but the machinery is there for accommodating both. We are all familiar with Optimal Interpolation (0I), or best-linear-unbiased-estimation of fields. We provide a first-guess or background field, the error covariance for this first-guess, we provide first and second moments of measurement errors, and we provide the data themselves. The field may be multivariate, while its moments may be inhomogeneous and nonstationary. Powerful hardware and software now make the estimation algorithm feasible for very large data gets (10^5 numbers). Thus, we can in principle observe and then map complex fields in space and time. The algorithms provide posterior error statistics, that is, confidence intervals for the maps. Ideally, the residual error in the map would be comparable with the measurement errors in the data. It is less widely known that the algorithms provide significance tests for the prior information, that is, for the choice of the first-guess field, and for the error covariances in the first-guess and in the data. An example will be given in which the posteriors are comparable with the measurement errors, indicating an internally self-consistent mapping of the observations, but the significance tests failed grossly. The example involves the NOAA Tropical Atmosphere-Ocean (TAO) array, and an 0I scheme in which the background is the solution of a simple coupled model after Zebiak and Cane, while the prior error statistics are those of solutions of the model subject to random forcing fields having prescribed first and second moments. These moments were estimated by consideration of the scales of resolvable processes that are neglected in such intermediate models. The entire mapping process is formulated as a nonlinear generalized inverse problem, for a system of differerential equations. The circulation estimate or map is a weighted least squares best fit to the dynamics, to the initial and boundary conditions and to the data. The weights are operator-inverses of the prior covariances for the errors in each piece of information. The process shows that the TAO array is well designed to observe the hypothetical phenomena, that is, for observing fields obeying all the constraints to within the prior statistical criteria, but the process also summarily rejects that hypothesis. Thus, we should be using more complete models, or other statistical estimators that do not presuppose Gaussian processes. Designing an El Nino observing system will tax all our physical insight and mathematical skill, as it should.

Bayesian methods in atmospheric sciences

Abstract Number 12
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Bayesian modeling is a powerful approach to scientific problems involving uncertainty. The essence of the approach is the quantification of uncertainty through probability; the mechanics then are applications of probability theory. A brief review of these notions, including selected comparisons and relationships to other statistical viewpoints, is presented. The goal of the talk is to outline Bayesian analysis as a paradigm for posing and dealing with complex settings as in the atmospheric sciences. The primary tool is hierarchical Bayesian modeling. The discussion will focus on using Bayesian analysis to (i) manage uncertainty and (ii) combine information sources, including observational data (of possibly disparate types), models, and physical reasoning. The formulations are intended to lead into space-time modeling of physical processes. Example implementations are to be presented in other talks during the meeting.

Rainfall estimation by kriging in the EOF space of the SLP field

Abstract Number 13
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The term downscaling denotes a procedure in which local climate information is derived from large-scale climate parameters. In this contribution we explore the possibility of using the geostatistical interpolation technique known as kriging for downscaling proposes. The idea is based in representing the large-scale field in a low-dimensional space of its EOFs. Each observed point in this space is associated to a simultaneously observed local variable. New values of the large-scale field, simulated for instance by a GCM, can be represented in the EOF space, and the value of the local variable associated to it can be estimated by kriging interpolation. The method is applied to winter precipitation in the Iberian peninsula and the North Atlantic SLP field, at monthly and daily time scale. The results are

compared to the ones obtained by a simple analog method, also operating in the EOF space of the large-scale field.

Evolutionary and Moving Response Functions in Dendroclimatology

Abstract Number 14
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Response functions are statistical techniques routinely used in dendrochronology to identify climatic signals in tree rings, but they are usually reported for a single calibration interval. Evolutionary response functions (ERF) employ a progressively longer number of years to compute the response coefficients. They allow for forward or backward evolution by maintaining a fixed beginning or ending year, respectively. Moving response functions (MRF) are based on a fixed number of years progressively slid across time to compute the response coefficients. Bootstrapped confidence intervals are used in each response function to identify significant predictors, which are then mapped by month and year in a pseudo-color plot. The application of ERF and MRF is illustrated by applying them to two tree-ring collections, one from Torrey pines growing along the Southern California coast, the other from Douglas firs in east-central Idaho. The dominant (and temporally stable) climate signal in Torrey pine is a positive response to November through April precipitation. The climate signal in Douglas fir is more complex and less temporally stable than in Torrey pine, hence it becomes obscure when calibration is performed on a limited number of years. From its ERF and MRF, Douglas fir shows a negative response to July temperature and a positive response to May precipitation. Because evolutionary and moving response functions convey immediate, comprehensive information on dynamical climate-tree growth relationships, they are particularly valuable to identify subtle and complex climate signals, as well as to discern spurious effects caused by insufficient degrees of freedom for dendroclimatic calibration.

The Climatological Probability of Clouds At Altitude

Abstract Number 15
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There are many models but few climatological measurements of clouds at altitude. These few studies include: deBarry and Moller(1963), Matveev(1984), and Willand and Boehm(1995). Most cloud measurements are actually CFLOS (Cloud-Free Lines-Of-Sight) either from space to the top of the cloud (satellite) or from the ground to the base of the cloud (ceiling data). The CUB algorithm, described below, is used to convert these CFLOS measurements along with a model of vertical correlation into probability of cloud at a specific altitude for any location or time of year. The CUB (Coverage Using the Boehm distribution) algorithm was originally developed for areal coverage of clouds. However, its underlying theory is applicable to any domain - volumes, hyper-volumes, or in this case, lines. Details of the CUB algorithm are found in Boehm(1992). Coverage is defined as the fraction of a domain that has a specified event, in this case, opaque clouds. Each point in the domain has a probability, P_o, that the event will occur there. In general, there is a correlation between events at pairs of points, particularly points that are close. The overall effect of correlation is taken into account by calculating the mean correlation using all possible pairs of points in the domain. For a continuous line, a double integral (convolution) of correlation over the line for all possible pairs of points. This mean correlation is a measure of how continuous the event is in the domain: Is it many small areas or just one or two large areas? If the correlation between pairs of points for a continuum is set up in a matrix, that matrix will have an effective rank which is equal to the effective number of eigenvalues and is called the degrees of freedom in CUB. Given the point probability, mean correlation, and degrees of freedom, CUB quickly calculates the probability of a given domain coverage, for this application, all clear of opaque clouds along a line-of-sight. The vertical correlation structure of clouds including thickness, between layers, and obscuration of further layers due to nearer layers has many models, some case studies, but few climatological measurements. The general shape of the vertical correlation can be found in Willand and Boehm(1995) to approximate a 3D sawtooth wave correlation function which is the isotropic correlation resulting from an infinite number of three dimensional sawtooth waves with random phases and orientations. See Boehm(1997). The parameters of P_o and correlation structure are stored as spherical harmonics over the earth. A triangular 18 set of spectral harmonics is used. Thus, the parameters needed by CUB can be calculated for any location.

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Predicting atmospheric transient eddy fluxes given the seasonal mean state

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Devising a means of representing the effects of scales that are either spatially smaller or temporarily briefer than those explicitly represented in a given model atmosphere is an outstanding problem in meteorology. For those who work with planetary wave models of low-frequency variability, it is the representation of the effects of high-frequency eddies which is of prime interest because these disturbances are known to have a significant influence on the slow dynamics of the system. In this work we propose and test means of dealing with this problem. As a first step we consider three basic questions that can be addressed by analyzing observations. 1) Are the statistical effects of momentum fluxes by transient eddies a function of the seasonal mean state? 2) If so, is it sufficient to know the barotropic component of the mean state to predict the eddy fluxes? 3) Is the functional relationship between the mean state and the eddy fluxes linear? These questions are answered using analogue and compositing techniques. For all three the answer turns out to be a qualified 'yes'. For example, analogues indicate that about 50% of the variance in seasonal mean transient eddy momentum fluxes can be explained by the configuration of the seasonal mean circulation. Given the affirmative answers to these three questions,

we then construct a linear parameterization of the effect of the eddy momentum fluxes by regressing the tendency produced by these fluxes against the concurrent time average barotropic state of the atmosphere. Using this empirical parameterization we find that the behavior of a barotropic planetary wave model is significantly altered when the eddy feedbacks are represented. For example for northern winter conditions, the fastest growing mode of the model e-folds in less than three days when the effect of the eddies is included whereas it e-folds in 15 days without the effect.

Effective Degrees of Freedom and Significance Testing for Data with Strong Spatial and Temporal Correlations

Abstract Number 17
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Geophysical data analysis often involves observations of one or more fields of data at a sequence of times. Such data usually exhibits considerable spatial and/or serial correlation. This affects the statistics of space or time averaged quantities derived from the data, such as the spatial correlation coefficient between the field observed at two different times, or the time-mean of the variance of the field averaged over a certain region in space. It is often of interest to place confidence bounds on such quantities. We discuss one method of doing so, which is to estimate an effective number of independent spatial (and/or temporal) degrees of freedom (EDOF). This method was first developed for time series in the 1950s, and for spatially varying fields in the 1970s, but has not yet achieved popularity. To estimate spatial EDOF, we consider a quadratic functional of the field, such as the spatially averaged squared field anomaly. Were it not for spatial correlations, this functional would have a chi-squared distribution with as many dof as spatial observation points. Spatial correlation will broaden the distribution, but in general, we can match the mean and variance of a time series of the functional to those of a chi-squared distribution with appropriately reduced dof; this gives the EDOF. The EDOF can easily be computed either from a time series of the functional, or from the covariance matrix of the data. A similar approach can be used for serial correlation in time series. Approaches like this have been taken in estimating the mean of a quantity such as global mean temperature, which has considerable low frequency variability, but that work uses a linear, rather than a quadratic functional of the observations.

We present two atmospheric applications of this methodology. We show

that EDOF are remarkably accurate for deriving accurate confidence bounds and significance tests, even (with caveats) when the observations are far from normally distributed. We discuss bias and scatter of estimated EDOF when the number of observation times is small, and we also propose approaches for quantifying EDOF of the coupling between fields. Lastly, we discuss temporal EDOF in the presence of serial correlation, and relate EDOF to the power spectrum of the data. We show that this estimate of EDOF is superior to Leith's formula (based on the e-folding time or distance of the lag-correlation), which is widely used in atmospheric applications.

Point and marked point processes in meteorology

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The presentation will begin with some specific situations in which point and marked point processes occur in climatology and meteorology. This will be followed by a review of basic concepts and approaches from the theory of stochastic point processes and their uses in addressing basic scientific questions arising. The final material will be the results of some data analyses.

Practical Upper and Lower Bounds on Skill of Forecasts of Hazardous Weather

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The evaluation of the quality of forecasts of discrete, rare events is challenging, particularly with respect to the development of meaningful baselines of skill. Often, a relatively large number of forecasts may be regarded easy, in that a necessary ingredient for the occurrence of the event is clearly absent, so that skill relative to a lower baseline such as climatology may appear inflated. This problem can be addressed by conditioning the forecasts on some atmospheric variable to eliminate trivially easy forecasts. At

the other extreme, it is unreasonable to expect forecasts of rare events to be absolutely perfect in a strict sense. Development of a practically perfect forecast as a reasonable upper bound on forecast skill is much more difficult. In order to address this problem, a method to filter and smooth observed hazardous weather events (e.g., tornadoes, severe thunderstorms, freezing rain) to create Artificial Perfect Forecasts is being developed for testing by the Storm Prediction Center of the National Weather Service. The concept allows for increasing uncertainty as the lead time of the forecast increases and for constraining the Artificial Perfect Forecasts to have similar spatial characteristics as real forecasts. The Artificial Perfect Forecasts attempt to represent the best forecasts that are possible given the information available at the lead time and spatial scale of actual forecasts. Even though the specific application being developed is for short-range weather forecasts, the ideas should be applicable at all temporal and spatial scales.

The Evolution of Forecast Verification Concepts and Practices Through the Contributions of Allan Murphy

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Allan Murphy's early (and continuing) interest in the problem of probabilistic forecasting naturally led him to the question of how to verify probabilistic forecasts (e.g., Murphy and Epstein, 1967). Some of Murphy's earliest contributions concerned verification of multi-category probabilistic forecasts, including development and interpretation of the ranked probability score (e.g., Murphy, 1969). This research evolved to include verification of other types of forecasts and to practical applications of verification methodologies. In a landmark paper, Allan Murphy and Robert Winkler outlined a general framework for forecast verification, which encompassed verification methodologies that had been developed previously, and those which have followed (Murphy and Winkler, 1987). This framework consists of the joint distribution of forecasts and observations, and decomposition of this distribution into two pairs of conditional and marginal distributions. Practical application of this framework was detailed in two studies concerned with diagnostic or distributions-oriented verification approaches (Murphy et al., 1989; Murphy and Winkler, 1992). In addition, Murphy considered methods used to verify model forecasts (e.g., Murphy and Epstein, 1989; Murphy, 1995).

A review of Allan Murphy's work indicates he viewed verification as part of

a "holistic" forecasting process, in which the quality, consistency and value of forecasts are intertwined. This holistic view is encompassed in Murphy's remarkable article on characteristics of the "goodness" of forecasts (Murphy, 1993). This view also led to consideration of the concept of sufficiency as applied to comparative verification of forecasts (e.g., Ehrendorfer and Murphy, 1988). Finally, Allan Murphy was cognizant and respectful of work done by others in the past, and lessons that can be learned from that work, as represented by his review of the "Finley affair" (Murphy, 1996). The summary presented here represents only a small portion of Allan Murphy's contributions to the science and practice of forecast verification. Fortunately, he provided a written legacy in the meteorological and forecasting literature, which will form a basis for future work in this field.

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Trends in Western North America Wildland Fires

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Wildland fire activity is closely linked to interannual and decadal variability of climate through precipitation, temperature, lightning and vegetation growth patterns, among other factors. For example, a drought period will deplete soil moisture and dry out vegetation, thus increasing the risk of fire starts. Vegetation type change or succession may occur which is more susceptible to fire starts. The relationships between ecosystems and climate in terms of fire are not well documented. Yet it is highly desirable to know these relationships in order to make decisions regarding fire suppression, prescribed burns, and natural resource management.

This paper will address wildland fires in context of climate variability and change through statistical analyses of historical fire data for western North America. Trends of wildland fires will be examined using empirical non-parametric methods. In particular, multi-response permutation procedures (MRPP) will be used examine data clumping and auto-regressive properties. These methods were chosen because the fire data exhibit high variance (strong interannual variability) and occurrences of outliers.

The analysis regions have been divided into two general vegetation classes; forest and shrub/grassland. Locations of natural (lightning caused) fire starts were collected for the period 1964-96. Results show that little trend has occurred over the past 30 years on forest land. However, substantial trends are found on grassland regions. We hypothesize that this is due primarily to changes in vegetation type over the past three decades (new species invasion), rather than a specific change in climate (changes in lightning activity). However, regional changes in temperature and precipitation may be related to the vegetation changes.

Measuring the intensity of a storm track - An EEOF approach

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The intensity of a storm track is commonly measured in terms of Eulerian diagnostics such as the eddy kinetic energy of those disturbances with periods between 2 and 6 days. Such storm track measures distinguish between disturbances according to their velocity relative to the ground which is the sum of their velocity relative to the mean flow and their advection speed. Therefore the advection speed has a strong influence on whether or not a disturbance is included in the storm track measure.
An Eulerian storm track measure may be misleading in several ways. First, the temporal variability of the storm track intensity may be incorrectly determined during a time of strong variations of the advection speed, for example during a blocking event. Secondly, the spatial contrast between the intensity of the storm track over the continents and over the oceans may not be well captured due to strong spatial variations of the mean zonal wind. Thirdly, in model validation or intercomparison studies, a poor simulation of the zonal wind component may cause an incorrect estimation of the storm track intensity. Disturbances may be included in the storm track measure even though moving with velocities relative to the mean flow which are not comparable to those of the observed disturbances.
A method is proposed to eliminate the influence of the variability of the advection speed by introducing a Doppler correction to the Eulerian storm track measure. The method consists of filtering the data by an Extended EOF (EEOF) analysis. The high-pass filtered 300 hPa meridional wind anomaly is decomposed into space-time EOFs and the spatial and temporal scale of the wave-like patterns is estimated. Using this information, a filtered data set can be constructed. By changing the frequency band of the filter according to the temporal variability of the advection speed of the disturbances a Doppler correction is introduced. The method is demonstrated in the area of central Europe for the winter season 1984/85, a season which includes a European blocking event.
The Doppler correction strongly modifies the time series of the storm track intensity over central Europe, especially during the time of the blocking. At that time, a significant amount of variability with frequencies relative to the ground which are lower than those included in the usual storm track measure is found. This variability is shifted into the storm track measure by the Doppler correction, indicating a strong underestimation of the intensity of the storm track by the non-Doppler corrected measures during the time of blocking. At a time of very strong wind speeds, variability which has a high frequency relative to the ground is shifted out of the Doppler corrected storm track measure.

Verifying the Validity of Statistical Downscaling Procedures in Climate Changes Applications

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A major caveat in any estimation of climate change, whether derived from statistical or dynamical models, is that the parameters of these models are fitted to current climate conditions. In climate models, this is done by representing subgrid-scale processes through empirical parameterizations which are calibrated against the present-day climate.In statistical downscaling models, regional variables are parameterized directly by large-scale climate variables. These parameterizations represent empirical relationships which are not known to remain valid inchanged climates.
The present paper proposes a technique for verifying the validity of the statistical downscaling procedures in climate change applications by considering downscaled estimates as well as GCM-simulated grid- point estimates of the regional parameter. The case considered is regional seasonal precipitation in Romania. The climate model considered in this paper is the T42 version of the Hamburg ECHAM3 atmospheric GCM run in "time slice" mode. Two steps are used to achieve this purpose.

First, the skill of the downscaling model and the performance of the GCM with respect to regional precipitation are evaluated. The downscaling model is a multivariate regression based on Canonical Correlation Analysis (CCA) between the observed regional precipitation and European-scale sea level pressure (SLP). The GCM is considered reliable with respect to regional precipitation if it reproduces the observed large-scale flow variability (given by the most important EOFs of SLP) as well as the link between SLP and regional precipitation variability (given by the most important CCA pairs). In our case both conditions, the skill of the downscaling model and the reliability of the GCM on the regional scale, are satisfied by the T42 model for the winter and autumn seasons. It is concluded, therefore, that the GCM is able to capture the basic physical features that determine the link between large-scale SLP and regional precipitation during these seasons. Since the GCM incorporates many more processes than the simple regression-based downscaling procedure we might also place confidence in the GCM-simulated regional precipitation under changed climate conditions, i.e. that the GCM is able to reliably simulate the link between European-scale SLP and regional precipitation in a changed climate.

In the second step this is used to verify that the SLP-precipitation link which was derived from the observations and which builds the basis of the statistical downscaling procedure is still valid in these changed climates. For this purpose, estimates of precipitation change at 14 stations in Ro-

mania are derived by applying this downscaling model to SLP anomalies simulated by the ECHAM3 model in two climate change scenarios with 2xCO2 resp. 3XCO2 concentrations. These downscaled estimates of climate change are then compared to the estimates derived directly from the grid-point precipitation simulated by the GCM. If these two signals are similar on the regional scale we argue that this fact might be considered to support the notion that the empirical link between large-scale SLP and regional precipitation continues to be valid under changed climate conditions. Therefore, we are confident that we can use the downscaling model for climate change applications. The advantage of using the downscaling model over using the GCM is that, obviously, the downscaling is consuming much less computing resources and that it can be used to derive scenarios at the station level which still couldn't be obtained from the GCM grid-point output.

In our case, the similarity between the two climate change signals is entirely satisfied only for the 2XCO2 scenario. In the winter case for the 3XCO2 scenario the two climate change signals are only partially similar (an increase over the entire region except for the northwestern part) even if, as an average over the entire country, they are similar.Therefore, we conclude that under 2XCO2 climate conditions (more than for 3XCO2) we might place confidence into climate change estimates of Romanian winter precipitation derived through the considered statistical downscaling model.

This approach is not a proof that the downscaling technique can be used for changed climates, we only believe that this is an improvement in the sense of increased confidence over the mere assumption commonly made in downscaling studies that the downscaling relationship can still be used in climate change applications. If, for a climate change experiment, the GCM-simulated and downscaled estimates are different no conclusions can be drawn about the validity of either model. It could be that the GCM is correct but the single relationship (e.g. SLP- precipitation), and thus the downscaling model, is not sufficient to represent regional precipitation. On the other hand, it is also possible that the downscaling relationship remains valid but some other parameterizations in the GCM do not.

Comparing Downscaling Schemes: Sufficiency and Evaluation of Relative Information

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When using two different downscaling schemes A, B being based on different large scale information, one may ask the following question: Which additional amount of local information can be gained from the second scheme given the forecast of the first one. A's forecast is termed sufficient for B, if B's forecast can be reproduced by randomization of A's forecast. In this case A is clearly superior to system B. On the other hand, A being sufficient for (A,B) means that, given A's forecast, B's forecast will be independent of the observations. In this case no additional information can be gained from B.
However, in most practical applications, system A (or B) will not be strictly sufficient for the combined system (A,B). In such cases the Kullback-Leibler information divergence provides a measure to evaluate the relative advantage of using B's (or A's) forecast as a second source of information. The procedure is illustrated assuming a joint trivariate Normal distribution for A, B and the observations. It is shown how graphical models provide an appropriate language to describe problems of the present type. Using the very simple example, the fundamentally different views of graphical modelling and multivariate linear regression are compared.

Discussion of the Successful Prediction Method on Floods/Droughts in Regions of China

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The severe floods/droughts are climatic anomalies phenomena, it brought disasters to people's lives and social economic. With a vast territory and complicated climatic and geographic conditions in China, China is the strength monsoon country and summer is floods season. Among disasters, summer floods/droughts are Chinese main disasters, the successful prediction to summer floods/droughts which could hold human to disaster reduction and prevention. In this paper, it is discussed that the successful

prediction method on floods/droughts of the regions, which is the model of scientific comprehensive high correlation physical factors. The high correlation physical factors are indicated circulation factors, meteorological elements factors, sea surface temperature factors and astronomical factors etc. It is researched that scientific comprehensive prediction model, including several kinds of high correlation coefficient of physical factors of prediction object. The model has high resolution to all regional floods and droughts in the past recorded years. Such as, the model is used to prediction on floods/droughts in past several years, we have got for a lot of times successful results of long-range prediction from 1978 to 1996. For example, Fig.1-Fig.4 show the successful results of prediction to regional severe floods between the Yangtze River and the Huai River in summer 1991 and in the Yangtze River valley in summer 1996.

Comparison of Climate Model Output and Historical Global Temperatures via Smoothing Spline ANOVA

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Observed winter global surface air temperatures, are analyzed and compared with climate model output. The historical data set is taken from the Global Historical Climatology Network Temperature Database. The climate model simulations consist of two parts: forced run and unforced run. Both runs have been interpolated via spline quasi-interpolation on the sphere to obtain model output at the observation points. By quasi-interpolation, it means that a small amount of smoothing has been implemented to account for model round off errors. The data sets were then fitted by the spline ANOVA model proposed by Luo, Wahba, and Johnson (1998). The ANOVA model decomposes functions of time and space into stationary main effects, trends and anomalies. Components in the decomposition are climatologically meaningful, and the components from observations and climate model are directly comparable. Given the spatially varying linear trend component from a forced run minus its corresponding unforced run as the signal, methods of comparing the signal with historical data will be discussed.

Nature of rainfall variability in Botswana over the 1961 to 1990 period

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Botswana's climate is semi-arid and rainfall occurrence is sporadic from year to year. In spite of the sporadic nature of rainfall, its variability has not been easy to analyze because of few long term spatially-distributed datasets. The spatial and tempoeral variability of rainfall were studied over a 30 year period covering the recent climatic normals. The analysis consisted of decomposing the spatial/temporal complexity of rainfall into its major patterns of variability. These patterns were then related to forcing factors, i.e synoptic scale disturbances including the ITCZ and migratory westerly storms. Patterns were arranged in order of importance, i.e., the first or dominant mode is the one that explains the greatest amount of variance, followed by the second, third, fourth etc., which explain correspondingly less of the variance. The spatial patterns of precipitation as analyzed are of interest for forecasting, climate classification, and assessing the vulnerability of locations to moisture deficiencies and droughs.

Principal Sequence Patterns of 1000 hPa Geopotential Height Fields

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A new aspect of T-mode Principal Components Analysis is used so as to obtain Principal Sequences Patterns of 1000 hPa geopotential heights. For the traditional tecnique, the correlation matrix (R) is obtained by regarding spatial fields as variables (m) and time series from the network as observations (n). This turns out a matrix R:mxm, whose entries are the correlations among variables. The (standarized) Components Scores are the new variables and represent type-fields and the corresponding Component Loadings give the correlation time series between those and the original variables from the analysed sample.
In this application each variable is a sequence of daily 1000 hPa geopotential height fields. When k sequences are analysed from a m-daily fields and

n-network points data set, the input matrix has got (m-k+1) variables and (kn) observations. Each standarized Component Score is formed by k-fields of the type-sequence and the coresponding Component Loadings time series means the correlations between each type-sequence and each k-fields sequence from the original dataset.
The analysed dataset come from the Servicio Meteorologico Nacional Argentino (SMNA) Diagnostic Model Analysis covering the Southern Cone of South America. Different trials on 3, 5 and 7 day-sequences are made.
The results show the significative type-sequence number is similar to the number of significative patterns obtained by regarding the traditional technique with the single-fields as varables. Principal Sequences Patterns envolve those patterns obtained through the use of single-field Analysis. The longer time sequence is (i.e., k increases), the lower explained variance is for the first type-sequence increasing the explained variance for the type-sequences of superior order. The Component Loading time series corresponding to the type-sequences and those from single-fields Analysis are alike.
The resulting type-sequences show the time behaviour of the more frequently synoptic patterns. It can be reckoned and indentified blocking situations, cyclogenesis, anticyclogenesis and systems passages. Moreover, Andean Mountain effects can be appreciated on the systems passages.
Same technique will be applied for different geopotential height together from 1000hpa to 200hpa regarding all the levels as one single variable in order to analyze 3D-space behavior

Measurement of sea-surface velocities from sequential satellite sensor images using the Hopfield neural network

Abstract Number 29
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The knowledge of ocean surface circulation is of major importance in various applications such as the study of climate, resources exploitation, containment of chemical spills and strategic routing of trans-oceanic ships. Ocean surface in situ velocity measurements are usually expensive to obtain. Therefore, the prospect of measuring these velocities from ocean surface features on sequential satellite sensor images has led to the development of 2 classes of methods, based either on surface feature tracking or on thermal equation inversion.
A popular implementation of the feature tracking method is based on the

maximum cross-correlation (MCC) technique. However, it suffers from many limitations, including the sensitivity to image noise, to limited feature radiometric intensity, to inter-feature size variation and to feature temporal deformation. In this work, a new method for sea-surface feature tracking based on the Hopfield neural network has been developed. Although it uses cross-correlation for comparing templates, the choice of the best match is based on the minimisation of an energy function. It provides several advantages over previous methods, such as the capacity to easily incorporate contextual information and prior knowledge of flow, to track features of all sizes without compromises and the flexibility to use images from various data sources.

Tested on real satellite sensor images, the method was shown to generate displacement vectors that were in better agreement with in situ measurements than the MCC method. The use of contextual information and prior knowledge of flow enables the method to generate smooth and high resolution vector field showing details that could not be observed with the MCC method. The new method can be used on various kind of images for tracking, and finds other applications in image registration and pattern recognition. Therefore, it would be an appropriate candidate for the development of operational systems for the measurement of sea-surface velocities from sequential satellite sensor images.

New Directions in Space-Time Modeling With Applications to Atmospheric Science

Abstract Number 30
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Atmospheric and oceanic processes involve complicated variability over both space and time. One approach to characterizing the variability of such processes is to extend traditional geostatistical methods, such as kriging, to the space-time domain. Although simple in principle, these methods are limited in application by the need to specify models for space, time, and space-time interaction components. That is, it is nearly impossible to specify a realistic joint space-time covariance function for the complicated and multiscale variability inherent in atmospheric/oceanic processes. Alternatively, one can consider dynamical space-time models, which are dynamic in time yet descriptive in space. The elements of these models have existed in the meteorological community for several years, but only recently have been addressed rigorously in the statistics literature. We shall present a brief overview and historical perspective of these methods. We shall then discuss how, with probability theory, we can naturally extend these space-time dynamic models into a hierarchical framework that

allows, through conditioning, the modeling of a larger class of stochastic processes. These methods will be demonstrated with a classic problem in atmospheric/oceanic statistical prediction: the long-lead prediction of sea surface temperature fields in the tropical Pacific. Some areas of discussion will be estimation, measurement error, combining data sources, non-stationarity, non-separability, and off-site prediction.

Stochastic Modeling of Shorter Time Scale Rainfall over India

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A long historic dataset of ninety years (1901- 1990) of daily rainfall observations over irregularly spaced 360 Indian stations is transformed into 3-day, 5-day and 7-day rainfall over 52 areal units(blocks) each of uniform size of 2.5 × 2.5 latitude/longitude grid square. The variability in rainfall of shorter durations within the northern summer monsoon over India is examined to understand the contribution of stochastic component after removing deterministic components like mean and seasonality from the time series of normalised spatially averaged 3-day, 5-day and 7-day rain fall over 52 blocks comprising India. The objective of the study is to explore the stochastic models from class of Box-Jenkins type of ARMA(p,q) models. The study is extended for spatial scales from point station through blocks up to 2.5 latitude/longitude grid square. The broad conclusions drawn are as follows :

1. The various ARMA(p,q) models are identified for different regions of India,the substantial variance is contributed by such models for some regions.
2. The Autoregressive models of 2 nd order, AR(2) for 3-day, 5-day and 7-day rainfall monsoon series are identified for some regions show low frequency Oscillations of Madden Julian type.

The performance of southwest monsoon season is also discussed for the identified stochastic models.

Adjusting Surface Ozone for Meteorology : Incorporating Regional Information Using the SVD.

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Daily 1 hour maximum surface ozone data were adjusted for meteorological influence at both regional and local scales preliminary to an investigation of association between surface ozone and emission estimates. The ozone data are from a network of 11 sites along the Puget Sound corridor of western Washington, collected over a span of twenty years from 1976 to 1996. Not all sites were active simultaneously. A June - September 'Ozone Season' was used to avoid the impact of spring transport of ozone from the stratosphere. The available meteorological data consist of reanalysis upper atmosphere data (geopotential heights and temperatures at 850 and 1000 mb, mean noon temperature at 2m, wind magnitude and direction at 10m, and precipitation) and local surface data (maximum daily temperature and precipitation). The upper atmosphere data are recorded as grid cell averages covering the area under investigation while the surface data are recorded at the local sites nearest each ozone monitor.

We have analyzed the data in two stages in order to incorporate meteorological information at both a regional and local scale. At the first stage, after finding optimal transformations, upper air meteorological variables recorded over grid cells were weighted to construct regional versions incorporating the information from the whole area under consideration. A site by site analysis of ozone was then carried out using these regional variables. In stage II, the residuals from the models in stage I were adjusted for local meteorology and associations between these and emissions were investigated.

The optimal transformations in stage I were found non parametrically using ACE : transformations were found for each grid cell-ozone site combination and these were averaged over sites to get optimal transformations for each grid cell. Then a singular value decomposition (SVD) of the cross correlation matrix of the ozone sites with these transformed, gridded variables was carried out to detect the dominant modes of association between the ozone field (as defined by the ozone monitoring network) and the transformed, gridded meteorological field. Only one singular value was found to be of interest. The singular vector for this dominant mode of association was used to quantify the relevance of each grid cell and, using these as weights, regional versions of the variables were constructed. We present results from this analysis for a selected site.

Detection and Attribution of the Current Warming by Means of Wavelet Transforms of the Hemiaspheric and Regional Temperature Time Series

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Using a frame of the continuous wavelet transform we study the problem of the current climate change in a general framework of fractal geometry. The well-known hemispheric and also very extended Central England and DeBilt near surface air temperature time series were decomposed by means of their wavelet transform into statistically stationary oscillatory components and trend-like residual ones because a seeming crossover scale (about 50 - 70 years) from a dendritic structure to a monotonous temporal growth of wavelet transform values was observed in the WT-patterns of the hemispheric series. The hemispheric trend-like components, extracted by such manner, may be approximated well by a quadratic polinomial that is the same for both hemispheres. So, a single global warming trend seems to be detectable. But, a careful analysis of the hemispheric WT-patterns allows to recognize some other (shorter) seeming crossover scales under condition that some parts of the hemispheric series are transformed. It is important that scaling (fractal) properties of all dendritic structures (for the whole series and their parts) are very similar. So, all of the seeming crossover scales may be tractable as signs of oscillatory behaviours of the bare time series as realizations of a fractal process like the so-called Brownian motion. Thus, the current global climate dynamics may be tractable as a Brownian motion (directed by the radiative balance equation) with inevitable inherent super-low- frequency oscillations that imitate a trend-like behaviour of every finite temperature time series for certain. This conclusion also is supported well by the same WT-analysis of the very extended Central England and DeBilt temperature series. By the reason of their more elongation, the main seeming crossover of their WT-patterns is near the scale about 150 years. An incessant linear warming trend over 3 centuries seems to be a reason of the uniquity of the present-day warming. It may suppose that this trend is an ascending branch of a hyper-low-frequency climate variation (from the Medival Warm Epoch through the Little Ice Age and to present days) evidenced by proxy data. As to the above main seeming crossover of the hemispheric series, the regional series display a super- low-frequency oscillation instead the transition to the afore-mentioned quadratic polinomial global trend. This oscillation includes within itself the well-known Maunder cooling - post-Maunder warming, the 65-70 year-long warming-cooling transition centered at 1940s recognized by Schlesinger and Ramankutty,

and the present-day global warming as an current ascending branch of the indicated super-low-frequency oscillation. Unprecedentness of the present day warming may be tractable as a result of superposition of this ascending branch and the above incessant linear warming trend.

Statistical Prediction of Seasonal Cold Temperature for Locations in British Columbia

Abstract Number 34
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A variety of predictive models for seasonal cold temperature have been developed at the Canadian Institute for Climate Studies in response to the needs of the natural gas industry imn British Columbia. Forecast models for cold temperature class and for heating degree day class have been developed using logistic regression for two locations in B.C. - the greater Vancouver region and the Okanagan region. In addition, predictive models for minimum seasonal temperature and heating degree day totals have been developed using multiple regression.

The response variables - temperature class, heating degree day class, minimum temperature, heating degree day total - are seasonal values for the 182 day season from October 1 based on mean daily temperatures for the 45 year period 1952 - 1996. The set of candidate explanatory variables includes the ENSO (El Nino/Southern Oscillation) class, monthly (April-August) values of the SOI (Southern Oscillation Index), and monthly (April-August) values of the SST (Sea Surface Temperature) at four Pacific Ocean locations: Nino3.4 (equatorial east Pacific), Hawaii (30N 165W), Aleutians (40N 170W), B.C. Coast (50N 130W).

Estimates of return values (quantiles) and return periods (reciprocal of the distribution function) for minimum seasonal temperature have been obtained using both the extreme value and the normal distributions, and for heating degree day totals using the normal distribution.

Temporal Downscaling A Method to Reduce the Climatic Input Requirements of Impact Models

Abstract Number 35
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Dynamic models used to study possible impacts of climatic change often require daily or even hourly weather data as inputs. Reducing the input requirements of these models can help to match the limited precision of the climatic scenarios simulated by global climate models, and generally to increase the robustness of impact assessments. A strategy termed temporal downscaling, which aims at reducing the climatic input requirements of impact models is presented and discussed in the context of two case studies.
In analogy to spatial downscaling, which serves the estimation of changes in regional-scale weather and climate from large-scale weather patterns, the basic idea in temporal downscaling is to simulate weather at a high (e.g., hourly) temporal resolution conditional on a small set of coarse-resolution (e.g., monthly) weather inputs.
A temporal downscaling procedure for local weather has been implemented in the form of a computer program named WeathGen. WeathGen stochastically simulates based on 22 monthly weather inputs 11 daily weather variables, which are in turn used to simulate 5 hourly weather variables related to precipitation, temperature, global radiation, vapour pressure and wind speed. Each of these transitions is accomplished with the aid of a Richardson-type stochastic model whose parameters are adjusted in function of the inputs given at the respectively coarser temporal resolution. In order to ensure consistency among temporal aggregation levels, WeathGen further repeatedly simulates daily (hourly) weather sequences until the statistics of a weather sequence for a given month (day) are sufficiently close to the prescribed monthly (daily) inputs.
The proposed temporal downscaling approach was tested by driving a dynamic snow and a grassland ecosystem model with temporally downscaled hourly weather data and comparing the model outputs with observed, or based on measured weather data simulated, system responses. All parameters required by WeathGen were estimated from only 5 years of hourly measurements. It was found that the long-term means and the within-season to decadal-scale variability of several system outputs of interest, such as the annual numbers of days with snow depths exceeding a given threshold (Fig. 1), or the annual grass yield and growing season evapotranspiration, can be reproduced at very good accuracy. Our results show that: 1) Temporal downscaling allows to drastically reduce the number of parameters that need to be considered for climatic impact assessments. This is accomplished without having to develop new parameterizations for fast

processes in an impact model. 2) The appropriateness of parsimonous climatic scenarios can be objectively tested. 3) Past system responses can be readily simulated using only monthly weather data as an input, e.g. for the long-term validation of an impact model. 4) The here proposed approach is general, flexible, efficient, and can provide an arbitrary number of realizations for the daily or hourly weather. Climate change estimates obtained from spatial downscaling of climate model output can be easily incorporated (e.g., by perturbing the monthly inputs) and flexibly combined with any additional assumptions on possible future changes in climate, including its variability.

Modelling daily precipitation occurrence process

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Time series of consecutive wet and dry days are frequently modelled with the aid of Markov chains. A substantial test for the generated data is the length of long drought failed in most of the cases. On the lecture we are going to introduce a model based on the sequence of clearly dry and wet days and give some illustration for Hungarian stations. This work is a part of developing stochastic weather generator.

Evolution of the Mediterrannean Basin Rainfall Precipitationon

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The Mediterranean basin is considered generally as a climatic entity, but such a point of view can be disputed when studies concerning the basin itself are carried on. We have tried to determine if (i) it exists a common evolution in time representative of the precipitation evolution during the 20th century in the whole basin and the adjoining lands along the Atlantic coast from Morocco to Portugal and (ii) such a temporal evolution is connectd with the evolution of sea-level pressure (SLP)during the same period.

Two databases have been used: (i) seasonnal and annual mean precipitation for 38 stations spread all over the area for a period from 1915-1916 to 1987-1988 and (ii) seasonnal and annual mean SLP estimated at gridpoints (25 by 25) from 30 to 45alt and 30W to 45E for the same period. Principal component analysis with Varimax rotation have been applied to the two series of precipitation and SLP anomalies for each rainy season , from Autumn to Spring and for the whole rainy season for the whole period and for two subperiod. Before rotation they allow to estimate the common temporal evolution of the precipitation and the SLP in the area and after rotation the possible regionalisation of the evolution in time.
The unity of the temporal evolution of the precipitation in the Mediterranean basin is limited (about 21% of explained variance) to an oscillation existing all along the rainy season between the far west of the area (the Atlantic coast and part of the Iberian peninsula) and the east of the Mediterranean basin.Its influence is more significant for the west area than for the east. This precipitation oscillation is correlated significantly with a low -frequency pattern of the SLP during the same period, with higher level of correlation in the west than in the east of the area.The division of the initial series into two successsive ones for both variables allow to determine if they have presented variations during the 20th century to compare results obtained with the Mediterranean Oscillation determined at 500 hPa between 1946 and 1988 by Conte et al.(1991). Such an oscillation appears as a major phenomenon for climate and atmosphere circulation in the Mediterranean basin.
Central Mediterranean presents a second centre of specific temporal evolution for precipitation. It includes areas which are not concerned by the oscillation. It is connected with other low-frequency configurations of SLP anomalies.
In conclusion, the temporal evolution of the precipitation in the Mediterranean has revealed no real unity during the 20th century. The area is split into several subareas with different evolutions in time, an oscillation between west and east being the major feature determined.

Ensemble forecasting for the prediction of the uncertainty of numerical weather forecasts

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Errors in the specification of the initial state of numerical weather prediction (NWP) models represent one of the major limiting factors on the

accuracy of weather forecasts that is achievable when forecasts are made with dynamical models of the atmosphere. In addition to errors in the specification of the initial state of the model, errors in the model formulation itself degrade the quality of forecasts. To treat most generally forecast uncertainty introduced through these two error sources requires viewing the atmospheric prediction problem in a probabilistic framework that is provided by the Liouville equation (LE). The LE describes the time evolution of the probability density function (pdf) of the model state vector. Within the framework of the LE, the problem of predicting the uncertainty of model forecasts can be reduced to the question of time–evolving the initial pdf.
The LE will be introduced as starting point for discussing approaches to the prediction of forecast uncertainty, such as stochastic–dynamic prediction and the Monte Carlo (MC) approach. The MC approach is (in modified forms) at the basis of all currently operational efforts that are aimed at gaining information about the time–evolved pdf. This approach is referred to as ensemble forecasting, because an ensemble of initial states (representing some of the properties of the initial pdf) is time–evolved with an NWP model. The time–evolved ensemble is used to estimate properties of the time–evolved pdf. The problem of selecting these initial states will be discussed with special emphasis on techniques based on the so–called singular vectors (SVs). The important property of the SVs to evolve into the eigenfunctions of the forecast error covariance matrix will be discussed. Results for covariance prediction in simple atmospheric models will be presented. Issues related to the role of SVs when perturbation evolution becomes increasingly nonlinear will be briefly discussed.

On the Climatology of surface marine winds near the western coast of Canada

Abstract Number 39
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An empirical-statistical technique named CANFIS (Burrows et al, 1998) was used to reconstruct six-hourly surface marine winds at 13 Canadian buoy sites along the western coast of Canada for the 40-year period 1957-1996. CANFIS combines Classification and Regression Trees (CART) and the Neuro-Fuzzy Inference System (NFIS) in a two-step procedure to build empirical relationships for continuous output. CART is a tree-based algorithm used to optimize the process of selecting a series of predictors from a large pool of potential variables. NFIS is used to do the modeling from

subtractive clustering while removing CART discontinuities. This procedure links large scale atmospheric variables from the NCEP/NCAR 40-year reanalysis project and regional wind observations from the Canadian Atmospheric Environment Service (AES) buoy network during the learning phase from 1990 to 1995. The relationships are used to "hindcast" six-hourly wind data at the buoys prior to 1990 and in 1996.
Validation results with independent buoy data show a good performance of CANFIS. In particular, the correlation coefficient for 10 different events varies between 0.61 and 0.98. Histograms of the amplitude and direction of observed winds at 4 buoys in the inner and outer coast exhibit specific shapes, illustrative of the climatological characteristics of British Columbia coastal meteorology. Histograms of CANFIS winds for the same locations and periods reproduce observed wind distributions relatively well. By comparison, reanalyzed NCEP winds, interpolated to the shelf-buoys location, exhibit amorphous histograms. In most cases, NCEP reanalyzed winds, after height correction, are stronger than observed winds and are at an angle with respect to the latter. In all cases, CANFIS winds recover more than 60variance. In addition, Hotelling's T Squared tests indicate no evidence of significant differences between CANFIS and observed winds at 95% confidence for at least 6 events.
Our results suggest that CANFIS is a successful downscaling method to reproduce the dynamics of surface marine winds, especially along the coast where ageostrophic effects are relatively important.

The Neyman-Scott Rectangular Pulses Model for precipitation : parameter estimation and confidence interval determination

Abstract Number 40
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In the context of hydrology, it is necessary to be able to generate series of precipitation at small time steps. Such series provide simulated input for rainfall-runoff models. The stochastic model used for this purpose is the Neyman-Scott Rectangular Model (NRSPM). NSRPM belongs to the theory of point processes. The model is based on a Poisson cluster process (Cox and Isham, 1980), in which the points in the cluster are independently and identically distributed about the cluster center (Kavvas and Delleur, 1981). Storm arrivals are governed by a Poisson process. At a point in the ground the storm is conceptualized as a random number of rain cells. The cell origins are independently separated from the storm origin, no cell

origins being located at the storm origin. A rectangular pulse is associated independently with each cell origin, its duration and depth being independent variables. The fitting of the five parameters of such a model and the assessment of the adequacy of its fit raise major statistical issues. Even if a likelihood function could be calculated, it would not be an appropriate basis for fitting at least the simplest form of the model, because the idealisation involved leads to sample paths with some (short-term) deterministic features. The proposed estimation procedure is based on the method of moments. The analytical form of moments is strongly non linear. As a direct exact solution cannot be found (Entekhabi et al., 1989), the problem turns into a minimization of an objective function. We propose an approach based on the separation of the fitting procedure into two steps. First, estimate two parameters by minimization with two moments, then solve the equations for the other parameters. Thus this approach reduces the minimization numbers parameter. A confidence interval for each parameter is derived based on the delta method. The method is then validated using a large number of simulated series. Based on the Neyman-Scott model, a theoretical framework has been developed (Favre et al.) to assess impacts on flow regime and flood peaks of precipitation changes resulting from potential climate change scenarios. Variations in rainfall characteristics can be introduced in the NSRPM model with modified sets of parameters. Rainfall is transformed into runoff with a "storage oriented" conceptual hydrological model. Analytical relations have been derived to describe the monthly mean and variance of flows at various time steps as a function of NSRPM and the hydrological parameters.

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Analog-Forcasting: Error Recycling and Metric Adaption

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Analogs are used to estimate dynamic and static properties of dynamical systems; that is, the atmospheric predictability, the dimension of the atmospheric phase space, or the number of weather regimes. Practical issues based on analog techniques are related to short-range and long-term forecasting.

Two methods are presented to improve the performance of analog predictions: (1) Error recycling: Errors produced by a non-linear predictive scheme contain information about both the observed and the prediction system. Therefore, its error history is expected to contribute to increasing the skill of the predictions if included in the forecast. An error recycling procedure is developed and incorporated into to the simplex analog forecast scheme, which is based on a prescribed metric and dimension. (2) Metric adaption: The performance of analog forecasts is sensitive to the selection procedure of analogs from the history of observed time series. A method is presented to iteratively minimise a user defined forecast error measure by adapting suitable metric weights for the components of the reconstructed states to be selected.

Practical and theoretical applications are analysed: (1) Low order model time series are subjected to analog forecasting a) to demonstrate the potential of the proposed techniques and b) to obtain the first guess of the degrees of freedom of systems for which the dimension is difficult to estimate by scaling. (2) Tropical cyclone track forecast experiments are performed by a) standard simplex-analog predictions using of observed positions only, b) simplex predictions improved by error forecasts based on libraries of both observations and recycled forecast errors, and c) including NWP model forecasts and their errors as predictors. Given the low computational costs required, the gain in 24/48 hour predictions, showing distance errors of about a) 160/260 km, b) 135/230 km, c) 130/220 km, is substantial compared to the standard statistical forecast scheme CLIPER with 160/340 km. Finally, d) metric adapted analog forecasts yield considerable skill (up to 20after linear error minimising combination with independent CLIPER-forecasts.

A Neural Network for Environmental Applications: Incorporating Theory and Domain Knowledge

Abstract Number 42
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This work addresses the topic of enhancing design and performance characteristics of neural network models for environmental applications. Due to the spectrum of time and space scales typically associated with environmental studies, particularly atmospheric and oceanic areas, numerical models are often limited in the level of detail that can be practically resolved. The limitations can be associated with the physics of the processes, the availability of observations of the processes, or computational resources. The motivation for this work is derived from recent literature discussing the concept of blending theoretical knowledge and empirical or domain knowledge of the behavior of environmental systems. Some techniques for incorporating theory and domain knowledge into a neural network model formulation and training will be described. An example application will be presented in the area of algal bloom modeling in freshwater lakes and reservoirs. For example, a relatively complex numerical model of the processes and interactions of atmospheric, climate, biologic, and chemistry is used to produce realistic scenarios of environmental progression. This information can be introduced into a traditional neural network training algorithm as the theoretical component. Inclusion of domain knowledge, as represented in the observed data, is typically introduced to the neural network directly. Observed data is used to formulate a neural network training data set reinforces particular process behaviors associated with the environmental system of interest. Preliminary results show improvements in model predictions of particular algal species using this approach.

Variability and Trend in Precipitation Extremes

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Long-term series (1862-1997) of precipitation parameters have been studied for meteorological observatory Zagreb-Gric located north of the Di-

naric mountains where the continental precipitation climate is also under the maritime influence of the Mediterranean. Fluctuations are discussed after elimination of short-term ones by means of 11-year binomial filter. Linear trend is tested for significance according to the Mann-Kendall rank statistic. The first information about time variations of the precipitation regime is given after the annual totals, which have had a tendency for smaller decrease (-2.3%/100years). At the same time number of rainy days showed increase of 9.2 days/100 years. These could be reflected in precipitation rates. As indicated by number of days with precipitation equal or exceeding 20.0 mm, higher precipitation events showed slight decrease (-0.7days/100years). As extreme precipitation for shorter time intervals is of special concern for the practice, special attention was given to the daily precipitation maxima, the parameter that is available on the dense network, contrary to the pluviograph data. Trend analysis of annual daily precipitation maxima indicated at practically no tendency (-0.7mm/100years). What is occuring in time with the estimated daily maximum for certain return period that is often applied in the engineering design? The fitting of several theoretical distributions (Gumbel, Gulton, Frechet, Pearson III, log Pearson III, and the generalised distribution of extreme values) to the annual daily precipitation maximum series in Croatia pointed out the generalised distribution of extreme values according to Jenkinson as the best adjustment. It was tested according to the Kolmogorov-Smirnov test and quantile-quantile (Q-Q) graph. The estimates for 50-year return interval calculated for 45-year moving periods during the observed 136 years created a new time series. A strong influence of one upper outlier was pronounced in the series of estimated values. In spite of its presence, linear trend shows a slight decreasing tendency.

Trend Analysis of K-day Extreme Precipitation Over Belgium by Means of Principal Components

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K-day extreme precipitation depths over Belgium have been assessed from daily precipitation measured at the climatological network (mean density around one station per 200 km^2) on the 1951-1995 reference period. They are analysed to detect a possible evolution in the occurrence of extreme rainfall events for the calendar year and the hydrological summer (April-September) and winter (October-March).
The study of the correlation between the extreme k-day precipitation by

means of the Spearman test shows at first the existence of a strong spatial correlation of extreme precipitation events, depending on the period of the year (smaller during summer than during winter) and increasing with k. In some cases distances of decorrelation are found to exceed 200 km, i.e. the same size as the country.
Due to this correlation the study of the stationarity has been carried out on the most relevant principal components (PC) determined by means of the covariance matrix. The number of components needed to reproduce 95 the total variance varies, with larger values during summer than during winter and values dropping down with k. Fisher test is used as global test to combine individual Mann-Kendall trend tests carried out on the PCs. Significant trends have been found for all the winter k-day precipitation and none for the summer. Annual k-day precipitation is showing a mixture of the characteristics of the two seasons: no trend for small k dominated by the summer events and a significant trend for k larger than 7 produced by the winter events.
The study of a few stations with long record period shows that on the period 1910-1995, stable as concerns instruments, no significant trend was detected while reproducing almost the same trends as those mentioned above on the shorter 1951-1995 period.

Modelling Multivariate Spatio-Temporal Weather Data Using Latent Gaussian Processes

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Weather variables such as temperature can be modelled as Gaussian processes, whereas others, such as rainfall, are far from Gaussian. We show how latent Gaussian variables can be used to model multivariate spatio-temporal weather data. Computationally-fast algorithms are considered for parameter estimation when values of the latent variable may be censored or missing. Spectral estimators and least-squares fits of auto- and cross-covariances are found to be of similar efficiency for fitting models to rainfall and solar radiation data.

Markov Chain Monte Carlo Methods

Abstract Number 46
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Hierarchical modelling, especially in a Bayesian setting, is proving a powerful and flexible framework for modelling complex stochastic systems arising in many areas of science and technology. However, inference and prediction with hierarchical models pose serious computational challenges, compared to longer-established methodologies such as linear modelling, especially if the full flexibility often needed to encode scientific beliefs about the systems is to be achieved. Happily, there is a general- purpose computational methodology for fitting Bayesian hierarchical models allowing full freedom in modelling and inference, and even permitting the careful sensitivity analysis that complex models demand. I shall discuss the role of Markov chain Monte Carlo methods in hierarchical modelling, with particular reference to change-point problems, and introducing a new model for emission of atmospheric pollutants.

Multivariate Analysis of Mountain Glacier Equilibruim-Line Altitudes Using Gridded Climate Data

Abstract Number 47
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A series of multiple regression analyses is conducted on a dataset of regional snowline elevations, as compiled from reports of many workers over a considerable time span. The independent variables employed are a set of climate parameters extracted from several gridded datasets, and include elevation of the atmospheric freezing isotherm, seasonal precipitation and cloud amount. Subsets of the data are used to investigate the changes in regression coefficients associated with differing precipitation regimes, variations in continentality, and regional diversity within a given population. Despite the known idiosyncratic behavior of glaciers in responding to small-scale variations in climate and topography, much of the variance in snowline

elevations does appear to be explicable by the gridded climate data. Thus, when viewed on the appropriate scales, snowline elevations may provide a useful quantitative index of regional climate.

Signal Analysis of Global and Hemispheric Mean Temperature Variations by Means of an Energy Balance Model

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An energy balance model (EBM) is presented which is calibrated with respect to satellite data, general circulation model calculations and palaeoclimatic reconstructions. A particular analytic solution of this model can be used as a recursive filter for time series analysis. This solution is applied to two natural and two anthropogenic forcing mechanisms which are expressed in heating rate anomaly time series: volcanism, solar activity, greenhouse gases, and tropospheric sulfate aerosols. Thus modelled global and hemispheric mean temperature variations since 1866 are obtained.
In addition, it is shown that the observed (ENSO-corrected) global mean temperature time series can be explained by the external forcing mentioned above and additional white noise forcing. In this way it is also possible to separate different signals and compare them.
As a result global anthropogenic climate change can be detected at a significance level of 99 % whithout considering spatial pattern but including natural forcing in a multiforced model as it is usually not done. Furthermore, the related model forecasts of anthropogenic signals (with respect to different forcing scenarios) are in close agreement with the results of other approaches. Finally, the climate response delay time with respect to anthropogenic forcing is obtained and a statistical-observational verification using a multiple regression model (MRM) is carried out.

Indices and Indicators of Climate Variability and Changes

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The statistical climate structure and variability are investigated using the best available instrumental data and statistical tools including scaling analysis of the current climate dynamics in order to obtain qualitative and quantitative characteristics of the natural variability of the climate over wide range of time scales from seasonal up to century, especially for the region of Russia. The method is proposed for the estimation of climate change magnitudes, based on an index, used as a probability criterion for the detection of significant climate changes. Special indices and indicators appropriate for the assessment of climate variability and changes in extreme events, their intensity and frequency are suggested. The time series of these indices and indicators were prepared to analyze them on regional basis. Strong correlation is found between the popular in the West climate extremity index, calculated as a fraction of area, covered with the extreme (recorded maximum once in 10 years) anomaly of both signs, and the Bagrov's index of anomality. The diagnosis of large climatic anomalies, trends and cycles including results of dimensionality analysis, scaling structure functions, characteristics of the natural climate variability for the purposes of the climate change detection and attribution in order to clarify the state of the global warming during the XX century and the beginning of the XXI century are considered. The improved data on current trends in climate and weather extremes for the Northern Hemisphere and Russia are shown. It is shown that in 20th century average over the RF territory and, in particular, over its western permafrost free part, temperature increased, while precipitation decreased, drought index increased, and extremity weakly increased. These changes were spatially non-uniform. The linear trend poorly characterizes interannual variability, while the role of interdecadal changes seems to be more important. Specific features of monthly and seasonal mean SAT fields within 2-year intervals with centers traditionally associated with the maximum development of the El Niño (or La Niña). Large areas are found, where mean temperatures for developed El Niño (La Niña) significantly deviate from climatic normals. These ENSO signals, including those on the territory of Russia, found for the first time, may be used for the forecasting. The work was supported by the Project RFBR 96-05-64883

Updating a Non-Stationary Space-Time Rainfall Model Using Climate Model Predictions: A Downscaling Example

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In order to produce climate scenarios based on historical data with stochastic approaches, model predictions can be updated as new weather information becomes available. Historical data usually comes from a ground based network and new weather information could be obtained from complex numerical climate models at a regional scale which incorporate the effects of land cover changes or any other landscape disturbances. The climate point model values are usually given on a spatial grid of few kms of resolution. A methodology is presented to update the predictions based on the stochastic model with the information produced by the regional climate model. A multivariate non-stationary time series model is presented by which rainfall data are modelled at locations $z_1, z_2, \ldots, z_n$ using a multivariate truncated normal distribution on an auxiliary random variable W, to account for the mass points at zero. A serial structure is imposed on W, using a dynamic linear model, and a Fourier representation allows for the seasonality of the data if necessary. The model is fitted using a Markov Chain Monte Carlo method that uses latent variables to handle both dry periods and missing values. Averaging of the predictions on a very fine mesh produces areal estimates at a given spatial resolution. Areal values are now modeled using a univariate dynamic time series model whose parameters are updated once the new observation from the regional model becomes available. The methodology is applied to daily rainfall data of an area of Central US where predictions from the RAMS (Regional Atmospheric Model System) are available.

Cyclo-stationary Maximum Cross Covariance Analysis

Abstract Number 51
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Environmental systems are often characterized by a strong annual cycle, low signal-to-noise ratios, delayed cause-effect mechanisms, while the data record is generally short. Therefore a statistical method for data analysis assuming stationarity between exogeneous forcings and the system variables is often not adequate. Cyclo-stationary Maximum Cross Covariance Analysis (MCCA) concentrates the information about the cross covariance structure of forcing and system variables. For single input and single output MCCA defines orthonormal patterns in time which maximize a covariance criterion over the annual cycle. The temporal patterns are estimated without a numerical optimization procedure by a singular value decomposition of the cyclo-stationary cross covariance matrix. A beforehand truncation or an arbitrary selection of phases is not necessary.

Constructing a Homogeneous Time Series for the Calculation of U.S. Climatic Normals

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Climatic normals, according to the WMO, should represent the observed climate at a fixed location for a 30-year period. In the U.S., non-climatic instrument changes and station location changes often occur within a 30-year period so that the data record becomes inhomogeneous. In the past, inhomogeneous data have been adjusted for the purpose of constructing a homogeneous time series. The adjustment methods have used the records at surrounding stations to develop an adjustment factor that is applied to the inhomogenous series. These methods are based on the assumption that regional weather patterns affect all sites within the region equally. Two critical problems arise in the application of the methods to climatic normals. First, a discontinuity in a station's record must be determined by evaluating the time series and/ or by evaluating metadata for the station.

Second, a set of representative stations within the region must be found so that all stations have the same response to the region's weather.
This presentation evaluates, from a statistical and practical view, the procedures for solving the two critical problems, Assessments are made of discontinuity detection methods such as the Peterson-Easterling and the Kolmogorov- Zurbenko adaptive filter algorithms. Assess- ments are also made of methods used to construct a set of stations that all have the same response to climate. These methods include using stations for which spatial correlations are highest, using closest neighboring stations, and using multivariate regression and dis- cordancy criteria. The evaluations are summarized into recommendations for when and how adjustments should be made to construct a homogeneous time series for normals calculations.

Variation of Precipitation and Soil Moisture in the Lower Yellow River Valley 1736-1911

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From 1736 to 1911 the Yu-Xue-Fen-Cun (YXFC) data were recorded at 157 stations covering 19 provinces in China. Most of the quantities measured relate to agricultural water use, including the number of rain days, intensity of rain, soil moisture depth, starting and ending dates of snowfall and snow depth. Some of the records are digital while others are qualitative. We discuss procedures for quantifying the YXFC records. This paper presents statistical properties of the monthly averaged variables recorded in the lower Yellow river valley. Study of interannual variations suggests that there was a change of climate around 1840 in this region. A statistical relation between duration of precipitation and soil moisture depth is tested for the different seasons and climate regimes.

Statistical Estimation of Salinity Profiles

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Knowledge of salinity of ocean waters is becoming recognized as essential for diagnosis, modeling, and prediction of climate processes. Salinity is a primary determiner of density in high latitudes, and of secondary, but significant, importance even in the tropics. Its variations therefore are reflected in geopotential thickness needed for accurate modeling of ocean currents when temperature profile data are assimilated into ocean analyses, and for relating ocean variability to satellite altimetric measurements. Density gradients also enter into all of the more physically based mixing algorithms, and may induce shear flows and barrier layers. Salinity variations also can carry information about the hydrology of oceanic regions.

Salinity profile data are too technically demanding and costly to be collected except from research vessels or in other special situations. Even surface salinity observations are presently being made in quite modest numbers, although the capability for making these inexpensively from buoys and volunteer observing ships is available, and some exploitation of this capability is being planned for the GOOS.

In some circumstances oceanographers have used regional climatological temperature/salinity correlations to estimate salinity profiles from temperature measurements. This procedure often gives useful results for the lower part of the thermocline and deeper waters, but provides little useful information about salinity in the critical region between the surface and the upper part of the thermocline. In this talk we will present a scheme for estimation of salinity profiles from temperature profiles using climatological temperature/salinity correlations and an additional measurement (or analysis) of surface salinity. Tentative results for a large-variance region of the eastern tropical Pacific suggest that approximately half the vertically integrated variance of salinity can be captured, with the greatest improvement near the surface where the variance is largest.

Detection of Anthropogenic Climate Change: Results and Problems

Abstract Number 55
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Fingerprint studies analyzing surface temperature trends over several decades show that recent temperature trends are inconsistent with estimates of natural climate fluctuations (with an estimated risk of less than 5and agree best with model simulations which take greenhouse gas and sulfate aerosol forcing into account. However, there are a number of uncertainties and questions in the interpretation of the surface temperature record, which influence the outcome of fingerprint methods for detection and attribution:
- Estimates of natural climate variability on interdecadal timescales are mostly based on coupled climate models. Although the recent warming is unusual relative to variability estimates from a number of coupled climate models, there are pronounced differences between the preferred patterns of interdecadal variability in different models and in the observations. These uncertainties influence estimated significance levels, and are particularly important in optimal detection methods.
- Differences in the response to greenhouse gas and sulfate aerosol forcing in coupled climate models introduce uncertainty when it is attempted to attribute an observed climate change to a cause. Applying the same optimal fingerprint method to results from two different coupled climate models (ECHAM3/LSG and HADCM2) yielded relatively similar results for the estimated amplitude of a greenhouse gas pattern in the observations, but quite different results for the amplitude of a direct sulfate aerosol induced pattern.
- Some features of the twentieth century warning are poorly understood, and it is not clear if they are consistent with present model predictions. For example, the recent very strong warming in Eurasia in the NH cold season is associated with changes in cold season dynamics of unclear origin. Also, the strong and near-global warming in the early part of the century can only be reconciled with model predictions if either a very extreme event or a solar induced warming component is considered.
While the basic result that the best explanation for the present temperature evolution is anthropogenic climate change seems robust and not affected by these uncertainties, these problems show where more understanding is needed for the interpretation of the 20th century warming.

Climate Change and Circulation Modes Related to Extreme Events

Abstract Number 56
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In recent years concern over climate change have generated a range of methodologies for interpreting potential impacts. Primary among such methodologies have been projects based on downscaling regional climate, either empirical or through nested modeling. However, little attention has been paid to interpreting the atmospheric processes giving rise to the derived regional change scenarios, and in particular, the processes associated with extreme events. This paper considers the use of Self Organizing Maps (SOMs) as a means to evaluate Global Climate Model (GCM) performance in terms of simulating the circulation modes related to such events, and how such circulation modes may change under future climates.

SOMs, otherwise known as Kohonen nets, are a form of artificial neural nets, and represent a non-linear form of classifier or clustering procedure. However, unlike traditional clustering, SOMs identify modes of behavior across the continuum of possibilities, and maps each observation to one of N-modes (equivalent to a cluster) in a 2-dimensional space. A useful analogy in this regard is an optical camera, which maps 3-dimensional space onto a 2-dimensional surface, and the SOM does the same with n-dimensional data. As such, similar observations will map to adjacent modes, and in this manner allow the continuum of states to be easily visualized. The frequency of observations per mode may then be graphed as a contour map, and changes and trajectories in time of circulation states identified.

A SOM is used to initially identify modes within the NCEP reanalysis data used to represent observations. GCM data is then subsequently mapped with the same SOM and compared to the reanalysis data in a validation procedure. Subsequently, data from the GCM simulations of future climate are mapped with the SOM and the circulation changes related to regional climate extreme events of precipitation. Potential impacts of the climate change at the regional scale are then interpreted in the light of the changes in frequency of the circulation modes.

Detecting Possible Relationships Between the Interannual Variability in Ecological Timeseries and Climate Records Using a Multivariate Statistical Approach - A Case Study on Helgoland Roads Zooplankton

Abstract Number 57
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A multivariate statistical approach is presented that allows a systematic search for parallels between the interannual variability in ecological timeseries and climate records. In a case study, zooplankton observations from Helgoland Roads are examined with respect to a relationship with climate. Statistical models are built between climatological predictor fields and abundances of zooplankton. Relationships are sought on different temporal scales, for different seasons and timelags. Several significant correlations between climate and zooplankton abundance are detected and discussed.

Identifying Key Sources of Uncertainty in Climate Change Projections Over 1990-2100

Abstract Number 58
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How sensitive are climate change projections to inaccurate knowledge about the CO2 cycle? Or to inaccurate aerosol forcing, or to uncertainty about the climate sensitivity of climate models? In other words, what causes uncertainty in climate change projections and what gain can be reached if specific models would become more accurate by more research? To answer these questions an Integrated Assessment model has been used in which consistent estimates of temperature and impacts are generated from scenarios of anthropogenic emissions (CO2, CH4, N2O, the halocarbons, and SO2). The model is called DIALOGUE and serves as a fully interactive decision-support system. Climate change is calculated through a chain of 'modules'. Modules are (i) emission scenarios, (ii) gas cycle models, (iii) radiative forcing models, (iv) climate models and (v) impacts. In each modul

a number of parallel models have been implemented. The four different carbon cycle models in DIALOGUE are an example of a set of parallel models.
As an indicator for climate change we have taken anthropogenic induced global warming, relative to pre-industrial times (1765). To quantify uncertainty and reductions thereof, we introduced the term 'maximum uncertainty range' (MURt). The MURt is defined as the difference between the maximum and the minimum temperature projection generated by all modules, using all models. Maximum uncertainty starts at 1.1 K in 1990 and increases steadily to 5.5 K in the year 2100. The uncertinty in 1990 originates from the fact that radiative forcing and climate change are simulated over the historic period 1765-1990. Historic emissions and concentrations of greenhouse gases are assumed to be known. If we compare the MURt with the situation where only the 'median' model within a specific set of parallel models is taken, a quantitative estimate is found for the gain of reducing scientific or socio-economic uncertainty due to this specific set of models.
The following conclusions can be drawn from our simulations. First, uncertainty is underestimated in the literature. Second, the key source of uncertainty in global temperature projections appears to be the uncertainty in radiative forcing models. Within the radiative forcing module a dominant role is played by direct and indirect aeroasol forcing. Third, the lowest source of uncertainty is formed by the global cycle models. The differences between these modules partly originate from the fact that historic forcing introduces substantial uncertainty in 1990, while global cylce models introduce no uncertainty over the period 1765-1990. Finally, there is a perfect linear relationship between maximum uncertainty in the year 2100 on the one hand and cumulative emissions of CO2 on the other hand. High emissions lead to more uncertainty and vice versa.

Connecting Neural Network Models and Dynamical Models via Adjoint Data Assimilation and Spectral Analysis

Abstract Number 59
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The neural network (NN) model is an empirical modelling technique which originated from the field of Artificial Intelligence (and has recently been applied to El Niño forecasting), whereas adjoint data assimilation is com-

monly used for assimilating meteorological and oceanographic data into numerical models. Due to their very different origins and uses, these two powerful methods have evolved to prominence completely independently, and thus far a relation between the two methods has not been appreciated. We show that the NN model can be formulated as an adjoint data assimilation model. Furthermore, the NN model can be coupled with dynamical models under adjoint data assimilation, leading to a new class of neural-dynamical models. Spectral analysis also allows the retrieval of linear and quadratic nonlinear relations from NN models.

Multiresolution Spectral Analysis and Its Application to Studying the Relationship between NAO and ENSO

Abstract Number 60
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In this study, we introduce multiresolution spectral and cross-spctral analysis technique to study the temporal spectral structure of NAO and its relation to ENSO. This newly developed technique is based on the multiresolution Fourier transform which combines the windowed Fourier Transform and the wavelet transform into a single transform. In contrast to the usual Fourier transform analysis, which yields a time mean spectrum, it provides a continuous view of the spectrum as a function of time and frequency. A new finding from this study identifies the intermittent nature of the coherent relationship between NAO and ENSO, a feature which could not be obtained by a conventional time series analysis. The NAO mode and SST in the eastern tropical Pacific (Niño3 SST) show significant coherence (at the 95% confidence level) during the 72% of the warm ENSO events from 1900 to 1991, of which 32% and 40% are associated with a 5.5-year period (E1) and a 2.7-year period (E2) oscillations. Comparatively, only about 35% of the cold ENSO (La Niña) events show any significant relationship between NAO and Nino3 SST. During a typical E1 or E2 event, the NAO index changes from positive to negative about two months after the onset of El Niño. The negative NAO index persists for another six months or so. These changes are also accompanied by changes in the mean atmospheric circulation patterns over the Northern Hemisphere. The dominant teleconnection patterns during the initial winters of E1 and E2 are the negative phase of the Tropical/Northern Hemisphere (TNH) and the positive phase of the Pacific/North America (PNA) pattern, respectively.

Statistical Downscaling of Precipitation: An Example Using the AMIP Simulations.

Abstract Number 61
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Although the spatial resolution and physical detail of dynamical climate models has increased over the last 10 years, realistic simulation of local precipitation still requires a secondary downscaling step. Approaches to downscaling include both nested physical models, in which the physical processes generating precipitation are modelled on an increasingly finer scale over a limited area, and empirical (statistical) models, which model the historical relationship between precipitation and synoptic scale atmospheric processes.

In this work we describe a general framework for statistical downscaling based on nonhomogeneous hidden Markov models (NHMM). In most statistical downscaling models, synoptic atmospheric patterns are explicitly classified into a (small) number of discrete "weather states". The precipitation process is then modelled conditional on the weather state. In the model we propose the researcher need not specify the weather states apriori (although models with explicitly defined weather states are a special case). Instead, only the atmospheric measures which are thought to influence precipitation need be identified. The relevent weather states, and their relationship to precipitation, are then derived automatically. This approach to downscaling can be used to model the joint distribution of point precipitation occurences and/or amounts at an arbitrary number of stations. In addition, since the model explicitly includes the atmospheric measures which influence precipitation, it can potentially be used to investigate the effects of climate variability and climate change on precipitation. Extensions to model multivariate outcomes (e.g. precipitation and temperature) are also possible.

As an example we use the NHMM to downscale atmospheric simulations generated according to the Atmospheric Model Intercomparison Project (AMIP) protocol. We compare the dowscaled precipitation over Washington state for the period 1979-1988 to the observed precipitation record for that period and to the AMIP precipitation simulation. In addition, we examine the variability in downscaled precipitation among several AMIP-protocol runs.

Statistical Downscaling of Daily Local Temperature From Large-Scale Upper-Air Fields: Intercomparison of Methods

Abstract Number 62
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This contribution deals with the task of specifying local daily temperatures from large-scale upper-air fields using statistical techniques. The aim is to find the optimum set of predictors and the optimum method. As predictand, daily mean temperatures at about 40 stations in central Europe (Austria, Belgium, Czech Republic, Germanz, Slovakia, Switzerland) are used. The analysis is performed for winter (DJF). The potential large-scale predictors included gridded 500 hPa height (Z500), sea level pressure (SLP), 850 hPa temperature (T850), and 1000/500 hPa relative topography (RT) over Europe and adjacent parts of the Atlantic Ocean. The methods examined are: multiple linear regression (both on raw data and its principal components), canonical correlation analysis, and singular value decomposition. The performance of the methods is assessed on ten years of observed data using cross-validation. Adding upper-air temperature variables (T850, RT) to the circulation ones (Z500, SLP) considerably improves the accuracy of specification of station temperatures. Among the methods, multiple linear regression performs worse than the other ones, which are comparable in their performance.

Applications of Circulation Classification Methods in General Circulation Model Studies

Abstract Number 63
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In this presentation we discuss several issues related to a possible application of classification methods to investigating circulation (i.e., geopotential height and/or pressure fields) in GCM studies. 1. Classification of circulation patterns: Its general aims are stated. Several circulation classification methods (correlation, sums-of-squares, cluster analysis, principal

component analysis - PCA) are briefly compared in their characteristics such as separability of groups, stability in space and time, reproducibility of predefined types, etc. Their strong and weak points are identified. The ability to uncover predefined types, i.e., to reproduce the underlying structure, is considered the most important property, which favours the PCA method. 2. Application in GCM studies: Circulation classification may be used both in validating GCM outputs (i.e., comparing GCM's control and observed climates) and in examining climate change response (i.e., comparing GCM's perturbed and control climates). In both cases, circulation types are compared between the two climates as for their frequency, mean patterns, persistence, etc. The classification method applicable in GCM studies should be computer-based, be able to cope with large datasets, and allow a comparison of, e.g., i) characteristics of individual types such as the intensity and position of jets, cyclones, anticyclones, troughs, ridges, ii) associated surface climate elements, iii) probability of transition between types. 3. Three ways of comparing types. Three different approaches have been adopted to identifying circulation types in the climates to be compared: CIrculation types can be determined 1) independently in each climate; 2) a priori (e.g., from a subjective catalogue); 3) in one climate and then projected onto the other. Their advantages and deficiencies are discussed and the third approach is selected as the best. 4. Suggested classification method. A classification method based on multiple application of PCA to considerably reduced datasets and a subsequent projection on both full datasets (e.g., observed and control) is proposed. One of its advantages consists in creating multiple classifications (i.e., sets of pairs of types). This makes it possible to identify relatively subtle differences between the climates, which would have remained hidden if only one classification were performed. 5. Application. The classification method is applied to daily 500 hPa heights in March through October over Europe. 30 years are analyzed in observations and the control and 2xCO2 runs of the ECHAM GCM. The method uncovers several deficiencies of the model, which would be difficult to find by ohter means: too low a frequency of several meridional types, weakened meridional circulation for some meridional types, northward displacement of the jet, incorrect persistence of types dominated by blocking ridges. In the 2xCO2 climate, the meridional circulation is less frequent and weaker than in the control climate.

Mixture Model Clustering for Multiple Regimes in the Northern Hemisphere Winter Atmosphere

Abstract Number 64
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Objective identification of multiple flow regimes is an active area of atmospheric research. We apply mixture modeling to describe clusters in 700-mb geopotential heights of 44 winters. Cross-validated likelihood is used to determine the optimal value of the number of clusters k. There is clear evidence that the data set supports exactly 3 clusters, agreeing with Cheng and Wallace's (1993) hemispheric analysis. Separating the data into the Pacific and Atlantic sector, though, indicates that the most likely k-value is 2 for both sectors, i.e., blocked and zonal flow regimes occur fairly independently in either sector (cf. Kimoto and Ghil, 1993 a,b). We discuss the connections between this hemispheric and sectorial classification, on the one hand, and low-frequency atmospheric variability, on the other.

Decadal and Multi-Decadal Variability in a Coupled Ocean-Atmosphere Model

Abstract Number 65
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Decadal and multi-decadal variability in the atmosphere-ocean system has become a subject of recent study using both observations and coupled ocean-atmosphere models. Typically, these studies focus on a particular area of the globe where low frequency variability has been suspected and/or where observations are relatively plentiful. This work attempts an assessment or inventory of decadal and multi-decadal variability considering the global atmosphere-ocean system as a whole by means of a rotated EOF analysis on a time series of global sea surface temperature fields. The SST time series is obtained from a multi-century integration of a coupled ocean-atmosphere model.
A new coupled model, called FOAM (Fast Ocean Atmosphere Model), has been constructed for this program. Extant models of the atmosphere and

ocean designed for execution on distributed memory parallel computing platforms were combined via a new parallel component called the coupler to form the new model. The use of parallel computing techniques achieves the combination of resolution, representative physical parameterizations, and integration throughput needed for studies of low frequency climate variability. The atmosphere component is a distributed memory parallel version of NCAR's Community Climate Model and includes the physics of the latest version, CCM3.2. The ocean model is dynamically similar to the Modular Ocean Model of GFDL but contains new numerics developed at the University of Wisconsin-Madison for maximum parallel efficiency and parallel scalability. FOAM has a river runoff model and a simple sea ice model and no flux corrections or other restraints on the model climate are employed. The current solar geometry and atmospheric composition is used throughout the integration. A simulation of over 600 years was performed and the simulated mean climate compares well with other coupled models. An assessment of the model's low frequency variability was made with a rotated EOF analysis of time series of monthly averaged sea surface temperature in each of three frequency bands. The first EOF in the highest frequency band (less than five years) is related to the model ENSO. In the midband frequencies (five to thirty years), a decadal mode in the Tropical Pacific is most prominent followed by an Antarctic mode and decadal variability in the gyres of the North Pacific and Atlantic. The multi-decadal (thirty years and longer) variability is mostly in the form of a thermohaline oscillation in the North Atlantic with a period of nearly fifty years. Other multi-decadal variability centers occur near locations of model deep water formation.

Changes in the Midwestern U.S. Precipitation: Observations and Modeled Greenhouse Warming Scenarios

Abstract Number 66
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Investigations into the changes in the mean and variance of monthly precipitation over the midwestern United States are presented. Analysis of precipitation data from the historical record (1900-1991) and from the CSIRO GCM transient CO_2 run are performed with a view of examining the combinatory influence of the El Niño/Southern Oscillation (ENSO) related variability and the greenhouse warming signal. The 1900-1991 record

of precipitation in the Great Lakes region shows a trend for increased precipitation as well as increased interannual variability in the annual precipitation amount. There is a corresponding increase in the magnitude of annual maximum monthly precipitation and a delay in its month of occurence. The probability distribution of annual maximum monthly precipitation amounts shows a tendency for strong droughts till 1940 and a significant shift towards larger extreme precipitation since. While some of the trends in the historical mean precipitation and the mean annual maxima are supported by the CSIRO GCM analysis, those pertaining to the timing of the monthly maxima or the interannual variability and its structure are not. Atmospheric circulation patterns usually responsible for precipitation in July (the usual month with maximum precipitation) are identified in the model in terms of the strength and position of the four high and low pressure centers in the North American region. Precipitation variations are associated with influence of these key pressure centers and trends in the precipitation are related to trends in specific spatial patterns associated with the precipitation trends

Contribution to the Study of the Climatic Variability Patterns in the South of Spain

Abstract Number 67
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Analysis of the monthly mean maximum and minimum temperatures, precipitation, atmospheric pressure, relative humidity and sunshine duration in 10 stations in the south of Spain have been studied in a multivariate analysis to find variability patters. The method used to make this work has been principal component analysis to reduce the dimensionality of the series in the data base, hierarchic cluster analysis and a technique call the "subjective method" by Blasing et al, based on the design of an algorith to establish the patterns by comparison of multivariate anomaly vectors. The most important question in using this method is the selection of the estimator, usually the correlation coefficient, and the characterisctics of the algorithm. In this work we show the five major anomaly patters found using the correlation coefficient as estimator, and also using an estimator introduced by Ballester and Jimenez (1985) based upon the distance of the representative points of the anomaly vectors projected on the unity hypersphere. We study the consistency of the estimator and compare the results of both methods. The first two anomaly type patters are the representatives of the mediterranean climate in the eastern and western parts of the

Andalousian Region and in according with the principal component results. For the other patterns we try to make a physical explanation of its origin and consequences.

Cluster Analysis: Some Recent Developments and Teir Relevance to Climatology

Abstract Number 68
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A common objective in climatology is to partition a large set of data into groups, clusters or regions, each of which is relatively homogeneous compared to the between-group variability. 'This may be done either because it is believed that genuine groups exist, or simply for convenience. Many methods exist for constructing the partition, a large proportion of which fall under the heading 'cluster analysis'. Relatively few of the very many available clustering techniques have gained popularity in climatology. Most of these are rather ad hoc, and investigation of their properties has been empirical rather than theoretical. A class of clustering techniques which has been around for some years, but which has seen renewed research interest recently from statisticians, is that of mixture models. The recent developments are outlined. At present the assumptions imposed in published work are rather restrictive, compared to the scope of climatological examples, but given sufficient computing power there is no reason why the methodology should not be extended to make it more relevant. If the objects being clustered correspond to consecutive time periods, over a short enough time-scale to expect autocorrelation, it is desirable to adapt traditional clustering methods which assume independence to be more relevant to this case. One such scheme for adaptation, which enhances the chances of consecutive time periods being assigned to the same cluster, is described and illustrated. The time-constrained approach is less model-based than that underlying mixtures. Diverging further still from a model-based approach, projection pursuit techniques are descriptive in nature. Some versions of projection pursuit which are designed to find clusters are outlined and illustrated.

Investigation of the Climatic Influence on Air and Precipitation Chemistry Over Europe, and Applications to a Downscaling Methodology to Assess Future Acidic Deposition.

Abstract Number 69
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Climate exerts a well-researched influence on transport and deposition of atmospheric pollutants. This work investigates the synoptic influences on air and precipitation chemistry over Europe for five stations from the European Monitoring and Evaluation Programme (EMEP) monitoring network. A circulation classification has been derived using orthogonally rotated principal components analysis of observed sea level pressure, from the dataset of Jones (1987), for the North Atlantic/European sector. This was undertaken for the four standard climatological seasons, for ten years of daily data for the period 1982-1991. These years were chosen for the greatest data availability for the network at the time analysis began. Between twelve and sixteen components were retained in each season. Correlations between monthly mean component scores and monthly frequencies of the established classifications of the Lamb Weather Types and Grosswetterlagen established that the components reflected reality. Sensible relationships with the Central England Temperature and England and Wales Rainfall series also confirmed this.

The stations used in this analysis were located in Scotland, western and southwestern Norway, northwest France and Hungary. Relationships between these components and station data were investigated by calculating correlations between the component scores and daily and monthly concentration and deposition data. The data used were aqueous sulphate, nitrate and ammonium, sulphur dioxide gas and sulphate aerosol. The relationships were physically sensible. For example, components representing easterly flow from central Europe contrasted with southwesterly flow from the Atlantic, exhibited strong relationships with concentrations at all five stations. Other flow directions identified as conducive to high concentrations were southwesterly from the UK to the two Norwegian stations, and southeasterly flow, due to low pressures centred in the Mediterranean, for all stations. The relationships were less easily interpretable for the Hungarian station. This is partially due to its location in an area surrounded by sources, and also because it is in a region frequently under the influence of weak pressure gradients.

One potential outcome of anthropogenically-induced climate change is alteration of atmospheric circulation. Extension of downscaling methodologies to the question of acid deposition is thus a logical progression of the

synoptic climatological methods already applied to acid deposition studies. This work describes the first step of the development of such a methodology, to investigate how such circulation changes may influence acidic deposition over Europe, as modelled by the transient integration of the United Kingdom Meteorological Office coupled ocean-atmosphere model (UKTR). These projections are briefly summarised.

Jones, P.D., 1997, The early twentieth century Arctic high - fact or fiction, Climate Dynamics, 1, 63-75.

Persistence-Cimatology Forecasts for Meteorological Elements With Irregular Empirical Distributions

Abstract Number 70
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For the evaluation of weather forecasts it is necessary to have a referent forecast that can serve as a benchmark showing how far our forecasts is from a perfect one. In the meteorological practice there is a wide variety of such forecasts in use. Most often these are the forecasts based on climatology or persistence. However, in short range forecasting neither of these forecast are suitable. This is especially evident for meteorological elements with marked diurnalvariation. Many authors (Gringorten, Sanders, Daan and Murphy, etc.) have suggested that forecasts based on some combination of climatology and persistence is optimal for the reference point in the verification procedure. These forecasts are based on the assumption that anomalies of meteorological elements have a tendency to persist with a slow tendency for decay. This sort of forecast is known in statistical and meteorological literature as a forecast based on autoregression or as AR(1) model. This forecasts sometimes be called "naive" and "no-skill" forecasts although the term "intuitive" seems more appropriate. Some authors have suggested more sophisticated models as AR(2) or multiple regression as a standard of reference for various skill scores.

The reason such forecasts have not found wide use in verification practice is, perhaps, because detailed climatological data and estimates of autocorrelation coefficients are needed for their use. Another reason is that large number of meteorological elements do not have normal distribution, and so direct application of linear regression is not possible. In this talk, we will demonstrate how described difficulty can be overcome with the example of autoregressive forecast formulation for visibility. The values of meteorological elements with irregular statistical distribution can be transformed to the equivalent normal deviates according to the empirical cumulative

function. The transformed values then become a basis for the estimation of the correlation coefficient and the entry values in the regression equation. Estimated future values can be obtained by applying the inverse transformation. Our example is based on climatological data for visibility at airports Zagreb-Pleso and London-Heathrow. Final form of these forecasts is variable making it possible to apply them in verification of categorical and probabilistic forecasts

Climatic Variation and Malaria Epidemic in South Africa

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This paper deals with the relationship between climate variability and malaria epidemic in the Northern province with a particular attention to the Northern Region in South africa. It is evident that there has been an increase in malaria cases in the recent years.The most striking appearance is that, above normal rainfall season episodes leads malaria outbreaks while cases of El-Niño events reveal reduction in malaria cases. Temperature variations contribute highly on the life cycle of the mosquitoes and this depends on different mosquito species. Further research to enhance the understanding of the relationship between malaria outbreak and climate is suggested in the summary and conclusion.

Climate Extremes and Natural Disasters: Trends and Loss Reduction Prospects

Abstract Number 72
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Trends and multi-decadal variations of weather and climate extremes have only recently received attention from the climate community. Interest has stemmed from exponentially increasing economic losses related to climate and weather extremes. Deaths attributed to these events have essentially

remained constant over the past several decades, despite increases in population, but the increase in inflation-adjusted economic losses suggests that past climate records are not being optimally used. The need for data on climate extremes in disaster mitigation activities such as the International Decade for Natural Disaster Reduction also has provided another motivation for focus in this area.

Of particular interest here, is the extent to which we can document changes in climate and weather extremes. Attribution of ongoing trends to specific climate forcings, such as anthropogenic effects or other factors related to natural climate variability are still equivocal. Nonetheless, a recent GCOS/CLIVAR global assessment of trends and variations of climate and weather extremes provides us with considerable information related to trends of extremes for temperature, precipitation, and storms. For some areas and variables increases in the frequency of extreme events are apparent. A review of this information suggests that further understanding of the causes of the apparent increase in climate and weather extremes is strongly dependent upon progress in our ability to monitor and detect these multi-decade trends. Based on these analysis we show that this will likely require increased attention in the following areas: 1) The development of more effective international data exchange for high resolution historical climate and weather records. 2) Increased emphasis on rescuing data with appropriate resolution from deteriorating manuscripts and other non-electronic media, 3) A greater emphasis on removing inhomogeneities in the instrumental record and ongoing weather monitoring programs (that provide much of our information about changes and variations of weather and climate extremes), 4) More effective use of space-based measurements and reanalysis products derived from models, 5) More robust monitoring of local extreme weather events such as tornadoes, hail, lightning, and wind, and 6) More effective means to integrate and communicate information about what we know and do not know about changes in climate extremes. Progress in each of these areas is reviewed in context with outstanding remaining challenges, and the benefits that can be expected if we meet these requirements.

Economic Value of Weather and Climate Forecasts: Contributions of Allen Murphy

Abstract Number 73
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The contributions of Allan Murphy to the research topic of assessing the economic value of imperfect weather and climate forecasting systems are reviewed. Recent sources of information for this review include Katz and Murphy (1997) and Murphy (1994). For the most part, this research in-

volves the so-called prescriptive/normative approach to valuing imperfect information. It is based on the Bayesian decision-theoretic concept of the value of information, in which a decision maker is assumed to follow a course of action that maximizes expected utility. Roughly speaking, forecast value is a measure of the extent to which the decision maker is better off with the forecasting system than without it. Over the past few decades, Murphy was the most vocal and persistent advocate of valuing weather forecasts, especially through the use of this methodology.

Murphy's work on valuing weather forecasts is closely related to his other primary research foci. With regard to forecast verification, both the framework which he proposed and the concept of sufficiency arise in consideration of forecast value. With regard to probability forecasting, issuing forecasts in the form of probabilities is the most straightforward way to convey the uncertainty in the forecast to the decision maker (as required to maximize expected utility). In fact, one of Murphy's early arguments in support of probability forecasting consists of a demonstration of the reduction in economic value if categorical forecasts were disseminated instead.

Murphy's research on valuing weather forecasts can be classified into the two categories: (i) relationships between the quality and value of forecasts; and (ii) case studies of the economic value of forecasts. The first subtopic was especially motivated by the need to demonstrate the inadequacy of any verification measure as a substitute for forecast value. Being inherently multidisciplinary in nature, the second subtopic involved extensive collaboration. He instigated such studies, with the details necessarily reflecting the influence of the collaborators. Nevertheless, he was well aware of the limitations of such studies. The review concludes with some speculation about why Murphy's research, as well as research in general on valuing weather forecasts has not received as much attention as that on verification.

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A Neural Network as a Chlorophyll Estimation Algorithm for Ocean Color Imagery

Abstract Number 74
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Regression analysis has traditionally been used to develop empirical algorithms for the estimation of ocean surface chlorophyll from ocean color satellite data. This approach has its limitations, however, in part because of the non-linear nature of the transfer function. Standard linear regression does not model non-linear relationships well, except over small ranges, and non-linear regression requires a priori knowledge of the nature of the non-linear behavior, something that is not usually available. With new satellite sensors such as the Sea-viewing Wide Field of view Sensor (SeaWiFS) now in orbit, it is important to have accurate chlorophyll algorithms with which to process the incoming data. Neural networks can flexibly model a variety of non-linear behavior and have been shown to be useful in modeling a large range of transfer functions. A single neural network can easily be trained to estimate chlorophyll in both Case I and Case II waters, to a higher accuracy than is now possible using regression with cubic and power polynomials. Results will be presented from a study using SeaWiFS algorithm evaluation data to develop a neural network functioning as a global chlorophyll estimation algorithm. Results from the application of the neural network to SeaWiFS imagery and comparison with in-situ data will also be presented.

Reconstruction of Monthly Mean 700 mb Heights from Surface Data by Reverse Specification

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This paper demonstrates an objective method of coputing monthly mean 700 mb height anomalies (H) at 108 grid points in the western hemisphere for a 40-year period as a function of concurrent anomalies of monthly mean sea level pressure (P), at the same 108 points used for H, and monthly mean surface air temperature (T) averaged over 112 areas in North America. We applied a forward stepwise program to derive linear multiple regression equations that explained 81% of the variance of H by means of only 3.5 variables, averaged over all months and grid points. The stability of these

equations held up well in six years of independent data in terms of explained variance, root-mean-square error and the spatial anomaly correlation coefficient. Therefore, it seems feasible to reconstruct maps of H for the first half of the 20th century as a function of data on P and T only.

Prediction of the 1997/98 Rainfall Season in South Africa

Abstract Number 76
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Rainfall over southern Africa is highly seasonal (Keen and Tyson, 1973; Tyson, 1986). Except for the south-western Cape, the southern coastal regions and adjacent interior, more than 80 percent of the annual rainfall occurs between October and March during the austral summer season. The El Niño/Southern Oscillation (ENSO) phenomenon involves interannual variations in the thermal circulation of the tropics and affects the atmospheric circulation outside the tropics in a more indirect way (Philander, 1990). For southern Africa, rainfall of the south-eastern African region, including portions of all African countries south of 15° S is influenced by ENSO events (Ropelewski and Halpert, 1987, 1989). Drier than normal conditions are associated with warm events during the rainfall season from November to May.

The drought experienced in southern Africa which was associated with the 1982/83 ENSO caused estimated damages close to US 1 billion (Moura, 1994). Rainfall variations in South Africa have an important impact on agriculture, housing of, and water supply to rural communities, industries and tourism, to name but a few. With an increasing population and the associated demand for fresh water, the development of objective and reliable methods for long-range predictions is becoming increasingly more important.

In 1994 the South African Weather Bureau embarked on developing models and issuing forecasts on a monthly to seasonal timescale. During the 1997/98 season the group actively issued warnings and forecasts of an developing El Niño and anticipated drought associated with it. For the first time in history the South African government and policymakers realised the importance of such information and developed a strategy of "better safe than sorry". At the end of this season it is now necessary to evaluate how the season progressed, how accurate forecasts were, and even what the impact of El Niño was on South Africa.

This paper aims at evaluating the forecasts issued during the 1997/98 major El Niño event in South Africa. Rainfall probabilities on monthly and

seasonal time scales were issued. The T30 version of the Center for Ocean-Land-Atmosphere Studies (COLA) model with a 400 km resolution is used at the South African Weather Bureau to produce forecasts in advance for a 30-day period. An ensemble of model simulations is used to provide an probabilistic estimate of the atmospheric circulation. Rainfall forecasts are then derived from anomalies in the general circulation as forecast by the model (Tennant, 1998).

A canonical correlation analysis (CCA) forecast model is used to predict seasonal (3- month mean) rainfall and temperature over South Africa (Landman, 1997; Klopper, 1997). The predictor field consists of stacked global scale sea-surface temperature for four consecutive, non-overlapping 3-month periods. Categorical above-normal, near- normal and below-normal predictions are made for a 3-month period.

During the 1997/98 South African summer rainfall season (October to March) the impact of the major El Niño developing in the equatorial Pacific Ocean would have been felt. Early seasonal forecast already suggested a relative good start to the rainfall season (October), but by mid-December South Africa would receive below-normal rainfall and above-normal temperature conditions over the summer rainfall regions. This paper will evaluate how good this forecasts were for the season as a whole as well as for individual months. Also, the possible reasons for incorrect forecasts will be identified. To conclude, the authors will indicate what precautions were taken by end-users and if this information was sufficient enough to reduce the risk in their decision making processes.

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Neural Networks for the Empirical Solution of Remote Sensing Problems

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OUTLINE: 1. NNs as a generic tool for nonlinear mapping, and comparison with a regression approach; 2. Examples of nonlinear mapping problems in climatology and related fields which are approached using NNs; 3. Toward general methodology for using NNs for various applications; 4. Solving forward and inverse problems in remote sensing with nonlinear mappings; 5. NN solutions for SSM/I retrieval algorithm and forward model Neural Network (NN) techniques are introduced in the context of the nonlinear mapping problems. It is shown that NNs provide a generic tool for modeling any continuous mapping. The NN approach is compared with regressions and is shown to be more general. Several problems in climatology and related fields, which can be formulated as nonlinear mappings and approached using NNs, are briefly reviewed as examples. These problems include estimation of climatological precipitation, short-term climate prediction, and time-series prediction. A general methodology of applying NNs to a variety of applications is outlined and illustrated with empirical solutions of forward and inverse problems in remote sensing. Forward and inverse problems in remote sensing (for SSM/I in particular) are chosen for illustration because they are representative and well established applications; and also many different methods, including NNs, have been applied there, and are available for comparison. The NN SSM/I retrieval algorithm and NN SSM/I forward model are introduced to demonstrate advantages of NN techniques, such as accuracy, robustness, simplicity, and speed, in different applications.

Allan Murphy, Footprints in Europe

Abstract Number 78
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A significant part of the scientific and educational work of Allan Murphy was performed as visiting scientist. In this paper some examples of this ty pe of work in Europe are given and discussed.

1. Introduction.

During his active period Allan Murphy visited or organized a large number of conferences, workshops etc. Apart from that he spent several periods as visiting scientist or invited expert at meteorological offices throughout the world. In this paper we will give some examples of such periods which Allan spent in Europe. The scientific results of these activities will be described briefly.

2. Examples of European Visits.

2.1 The Netherlands.

In the summer of 1981 Allan Murphy worked as visiting scientist at KNMI. During this period two verification studies were initiated. The first study concentrated on the verification of probability forecasts and the need of feedback of verification results to forecasters (Daan and Murphy, 1982), (Murphy and Daan, 1984). The second study verified the probabilistic forecasts derived from the analogue forecasting procedure that was in use in the Netherlands at that time. The items studied were different types of credibility intervals and skill forecasting (Kruizinga and Murphy, 1983).

2.2 European Centre for Medium range Weather Forecasting. In 1982 Allan worked for two month as consultant at ECMWF. Together with other experts Allan developed a training course on the use and verification of ECMWF products. The contribution of Allan to this training course was never documented.

In recent years Allan visited ECMWF several times and contributed significantly to the verification activities of ECMWF. His contribution was acknowledged very clearly during a recent meeting of the Scientific Advisory Committee of ECMWF where it was concluded that the scientific work of Allan Murphy provided a fundamental approach to the verification of the products of the Ensemble Prediction System.

2.3 Sweden.

During the period June-October 1984 Allan was visiting scientist at the Swedish Meteorological and Hydrological Institute (SMHI). He participated in a verification study on the probabilistic forecasting system in Sweden (Ivarsson et al., 1986)

2.4 Finland.

In the years 1986 and 1987 Allan Murphy visited the Finish Meteorological Office for two short periods. Together with Pertti Nurminen he analyzed the economic value of wintertime road weather services.

2.5 Hungary.
In 1988 Allan visited the Hungarian Meteorological Service. This visit resulted in a paper on the use of probability and statistics in weather forecasting (Murphy, 1989).
2.6 WMO workshop in Wageningen, the Netherlands.
In the summer of 1991 Allan participated as one of the main teachers in an international workshop of WMO (Glahn et al., 1991). The students in this workshop represented about 35 nationalities mainly from Africa, Asia and South America. Apart from contributing a major part about verification
2.7 Germany.
Allan also acted as "activity center" outside the classroom. In autumn 1993 Allan was guest professor at the University of Hamburg. During this period he completed together with Erik Liljas a paper on early Swedish work on probability forecasting and evaluation of wheather forecasts (Liljas and Murphy, 1994).
3 Conclusions.
The list of visits given above shows that Allan Murphy had a lot of interaction with researchers all over Europe. His impulses to research in Europe were, of course, mainly in the field of his own expertise and during his visits he spotted several sources of data worthwhile to analyze. In some cases his visit resulted in a paper in a referenced journal. His impact on the research activities in the institutes he visited is hard to quantify but in the opinion of the author is undoubtedly most significant.

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Quasigeostrophic Low-Order Models of Large-Scale Atmospheric Flow

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Empirical low-dimensional dynamical models (10-50 degrees of freedom) capturing the principal properties of the large-scale dynamics of atmospheric flow are constructed. A spectral model of the governing equations of motion in the quasi-geostrophic approximation is used as dynamical framework. The high-dimensional system is projected onto a linear subspace spanned by only a limited number of characteristic spatial structures called principal interaction patterns (PIPs). The expansion coefficients of these patterns are assumed to be governed by a dynamical system of the Lorenz type, i. e. a forced dissipative system with quadratic nonlinearity. Careful attention is paid to the integral quantities conserved by the nonlinear terms of the low-order model. The optimal low-dimensional model is determined by identifying the basic spatial modes and the interaction coefficients simultaneously from a time series of the high-dimensional spectral model by minimizing the mean squared error between trajectories of the full spectral model and trajectories of the reduced model. This leads to a high-dimensional nonlinear optimization problem which is solved numerically using an adjoint technique originating from the theory of optimal control of dynamical systems. Hence, in contrast to the classical approaches by Lorenz and Charney and deVore taking the basisfunctions as large-scale spherical harmonics and projecting the equations of motion onto these modes, in the present study both the basisfunctions and the interaction coefficients of the reduced model are obtained according to a variational principle based on a dynamical optimality criterion taking into account spatial as well as temporal features of the system.

A barotropic low-order model

A spectral model of the equivalent barotropic vorticity equation on the northern hemisphere, truncated to T21 (231 degrees of freedom), is used as dynamical framework. The streamfunction anomalies are expanded into a series of PIPs. The nonlinearity in the reduced model conserves the turbulent kinetic energy and the turbulent enstrophy of the flow leading to a triadic structure in the nonlinear interaction coefficients. A PIP model with ten degrees of freedom succeeds in well capturing some principal properties of the long-term behaviour of the T21 model such as first and second moments, temporal power spectra and leading Lyapunov exponents. A dynamical description based on PIPs substantially improves on models using empirical orthogonal functions (EOFs) as basis patterns and is far more efficient than low-order models based on spherical harmonics.

A baroclinic low-order model

A spectral multi-layer model of the quasi-geostrophic potential vorticity

equation on the northern hemisphere, truncated to T42, is used as dynamical framework. In the vertical direction, the equations of motion are projected onto the leading two EOFs (a barotropic and a baroclinic mode) calculated from ECMWF reanalysis data using a total energy metric. This yields a spectral model with 1806 degrees of freedom. The model has a mean state and a variance pattern similar to wintertime ECMWF reanalysis data. In the low-order model, the horizontal structure of the streamfunction anomalies is represented by PIPs. The nonlinear terms in the PIP model conserve the turbulent total energy and the turbulent potential enstrophy of the flow. Reduced models based on about 30-50 degrees of freedom are capable of capturing some essential features of the long-term behaviour of the high-dimensional spectral model.

Seasonal Forcasting Experiments Over Korea Using Linear Regression Model

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We have developed a long-range forecasting system of monthly precipitation and temperature for Korea using linear regression method. The major goal of the study is to provide a monthly temperature and precipitation prediction model with at least two or three months leads with some predictability. In this paper the results of the experiments for summer and winter are presented.

Kang et al. (1992) and Kang and Baek (1993) have shown that January temperature and summer precipitation of South Korea could be predicted with high skill. They have developed regression models based on 15 years of data and forecasted for five years with high skills. METRI (1995) also reported the multiple regression models for monthly temperature and precipitation can be constructed with five or less predictors at high R2 value. All predictors were selected from the Northern Hemispheric 500 hPa height and the sea surface temperature (SST) fields. As a first approximation, predictands, monthly mean temperature and precipitation, are averaged over twelve stations in Korea with records longer than 45 years. The Northern Hemispheric 500 hPa heights of NMC (National Meteorological Center, U. S. A.) octagonal grid and GISSTs from 60oE to 60oW and 40oS to 60oN are used as predictors.

The experiment is designed to use the most recent 20 years of data to produce a regression model using the 500 hPa height and SST fields. For example, to forecast August precipitation in 1973, the model base period

is defined from August 1953 to July 1973 and the base period for 1974 is defined from August 1954 to July 1974. The pre-predictors are selected based on the lag correlation analysis between predictands and the 500 hPa height and Pacific SST fields for the base period. We scan the prdictor fields with lags from 1 to 12 months. If any area with more than three adjacent points is highly correlated with predictand, we have selected the area as a pre-predictor. To improve linear regression model, the stability of predictors is tested using the time series of 10-year correlation coefficients. Those with large variability are removed from the pre-predictor set before model construction. In some cases, the 10-year running coefficients exhibited very pronounce decadal-scale variability. Multiple regression models are constructed for January temperature and August precipitation using the previous 20-year data for each year. We used stepwise method to select the predictors and the significance tests for the selected predcitors and model are performed at 1level. The results of monthly temperature and precipitation forecasting experiments for summer and winter over Korea will be presented. There is some improvement in predictability using this sliding method for model construction.

Modeling Climate Normals in the Canadian Rockies/Foothills Using Cokriging, Collocated Cokriging, Kriging with External Drift, and Residual Kriging

Abstract Number 81
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It is often difficult to spatially-predict climate data in physiographically heterogeneous regions. In the Canadian Rockies/foothills, seasonal temperature and precipitation are strongly influenced by, elevation, continental air masses, physiography, and latitude. The complexity of climatic processes and sparse station networks in these regions can preclude accurate deterministic predictions and univariate interpolations. This study compares the results of several multivariate geostatistical procedures to spatially predict air temperature and total precipitation normals in the Canadian Rocky Mountain/foothill system. Modeled results were compared using traditional cross-validation procedures and maps of the kriged results.
The primary data (Z) used for analysis were thirty-year minimum and maximum daily air temperature (MNT, MXT) and total precipitation (PRCP) for months representing each season and the year. Station Z data were extracted (40-62 stations depending on variable and month) for a region in southwest Alberta/southeast British Columbia (Lat. 113^o to 116^o; Long.

49° to 51°). Geographic indices, such as; elevation (ELEV), windward and leeward-side of Rockies (WIND), slope (GRAD), aspect (ASPT), and visibility (VIS) were estimated at each station and at each gridcell in a 3-km x 3-km grid of the study area. After visual inspection of Z vs. geographic variable scatter plots, physically meaningful regression models were used to predict climate data from the geographic variables at all grid and station locales (data normalized if needed). The spatially-exhaustive sets of secondary data (Y) used in geostatistical analysis were, i) geographic data having high correlations with primary variables (i.e., ELEV), or, ii) multiple regression estimates of Z data. If regional gradients in the data existed, the Z and/or Y data were detrended via quadratic trend models. Covariance and cross-covariance functions of the detrended data were subsequently modeled. Kriging was performed using 5, 10, or 20 stations in the search neighborhood.

Preliminary analysis for January MXT suggested that ELEV, northing, and WIND were the most useful geographic variables for estimating Y data. As a result, a multiple regression model ($R^2 = 0.46$; outlier deleted model) was generated to predict January MXT over the site (Y data). Covariance functions of detrended Z and Y data consisted of short (6-15 km) and long range (50- 80 km) spherical and exponential models. The small ranges reflected the short range influence of elevation. Preliminary relative mean-square errors (RMSE) for cokriging, kriging with external drift (non-detrended Y data), and residual kriging (kriging regression residuals at station sites) were around 0.40 for all search constraints imposed. Simple kriging and multiple regression model RMSE were 0.54 and 0.87, respectively. Unlike the univariate techniques, multivariate geostatistics provided physically meaningful maps of MXT. These, and preliminary results from the other monthly data sets also indicated that; i) collocated cokriging, kriging with external drift, and residual kriging were effective shortcuts to the modeling-intensive cokriging, ii) residual kriging often provided good RMSE results even though it did not utilize the full potential of the spatially-exhaustive Y data, iii) multiple regression predictions of Z data were useful secondary Y data, and, iv) Y data typically required some expression (e.g., WIND) of windward and leeward climatic influences (e.g., continentality).

Classification of Storms off the North Coasts of the Iberian Peninsula

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With the aim of improving the existing wave forecasting tools, a method is derived that identifies and classifies all synoptic situations generating sea-surface waves in the North Atlantic affecting the North coasts of the Iberian Peninsula. Classical discriminant analysis and Bayesian inference for classification and discrimination are proposed and tested with the aid of a buoy network in the Cantabric Coast of Spain. The chosen storms during three consecutive years are used to create the discriminant functions that classify any new situation into one of the characteristic SLP patterns found. In addition, the classification algorithm is the basis to carry out a climatology of the storms of this area using a wave hindcast covering the North Atlantic for the period 1955-1994. As a result it seems that the number of annual storms has undergone a reduction with a parallel decrease in the average and the 90 and 99 percentiles of significant wave height off the Northwest Coasts of the Iberian Peninsula, during the last 20 years.

Estimation Accuracy on Models for Correcting Precipitation

Abstract Number 83
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A comprehensive model for correction of wind induced errors in measurements of liquid, mixed and solid precipitation has been constructed. In this model wind speed, temperature and rain intensity enter as controlling variables.
The model is implemented in a system for operational correction of point precipitation. For application of this system Denmark is subdivided into subregions each of them being as homogeneous as possible with respect to the precipitation pattern, An automatic station (basic station) measuring wind speed, temperature and rain intensity is placed in the centre of the subregions. The daily precipitation measured at all stations within a subregion will be corrected by a correction value based on data of wind,

temperature and intensity from the basic station in question since all these climatic parameters are not available at any of the stations.
Due to regional variations of these parameters, and since the distance between a basic station and the most distant stations in a subregion is some 50 km, it is very important to see, how sensitive the correction model is toward changes in these parameters, and study the influence on the level of corrections due to all types of precipitation.

The Characteristics of the Transformations of the Atmospheric Circulations Types, Conditioned by the Ocean State, Using a Markovian Dependence

Abstract Number 84
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The purpose of this study is establishing the stochastic characteristics of the transformation of the predominant atmospheric circulation types, conditioned on the ocean state using a Markov chain dependence. The state of the atmosphere is represented by the 500 hPa geopotential field which is defined in 70 grid points situated in the region (50W-40E; 35N-65N).Atmospheric circulation was classified in zonal and blocking type circulation.Each of these patterns was associated with the state of the Atlantic Ocean in the tropical zone (39N-3N; 74W-10E),for the period 1965-1987. This association has been achieved using canonical correlation between the both fields with different lags.The months with the best dependence have been considered in order to define the state of the ocean (cold and warm), which determines occurrence or non-occurrence of the blocking type circulation. In this way, 4 states of the atmospheric circulation were defined and they were studied using a first order Markov chain. In order to find the statistical significance of the elements of transition matrix,with a prescribed level, a Monte Carlo simulation has been made.By means of transition matrix, the probability distribution of the states using a simulation method by generating uniform random numbers in the (0,1) interval,is estimated. In this way, the limiting matrix of the chain is obtained giving us the probabilities of appearance of states after n given transitions,which represents a measure of predictability.The limiting matrices for the atmospheric circulation associated with the Sea Surface Temperature (SST), are estimated for the 3 sectors over the European-Atlantic region. The atmosphere conditioned by the ocean state has been found to persist at the most 12 months over Europe and at the most 14 months over the Northern sector of the Atlantic Ocean.

Relations Between NAO, PNA, and ENSO Oscillations in Seasonal Winter Simulations with Four AGCMs

Abstract Number 85
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In the framework of the European project PROVOST (PRediction Of climate Variations On Seasonal and interannual Timescales), nine simulations of each of the winter seasons of the period 1980-1994 have been performed with four different atmospheric models in SST-forced mode : the UKMO unified model, the ECMWF model, Arpege Climat model (T42), and Arpege Climat with a higher resolution of T63 (this latter set of simulations being calculated at EDF). This provides an important multimodel ensemble to study the reproduction of the main low frequency oscillations occuring at extratropical latitudes (PNA and NAO patterns) and their possible modulation by different oceanic factors. We identify clusters (Ward clustering scheme) or modes (SVD analysis) of atmospheric low frequency variability in these sectors and we look for typical structures of the oceanic forcing associated to each of these atmospheric patterns. A particular attention is paid to the possible modulation of the NAO by different possible external sources : NAO-PNA interactions, extratropical or tropical oceanic forcing influence on the NAO (in particular : interactions with the three El Nio and one La Nia events involved in the period studied).

The Effect of Climate Change Scenarios and Extreme Events

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I view changes in the frequency of extremes from an impacts perspective. A typical extreme in an agricultural context would be high temperature stress (above 32 degrees C) for ten days during silking in maize. In this talk I discuss several different aspects of how frequencies of extreme events change and provide some examples of how frequency of extremes may change with

changing climate.

I analyze changes in the frequency of extreme climate events resulting from climate change, in contexts of varying spatial and temporal resolution. The spatial resolutions of climate change considered are high resolution (horizontal resolution of 50 km) climate change scenarios generated from results of control and doubled CO2 runs of a regional climate model (RegCM2), and low resolution scenarios from control and doubled CO2 runs of the CSIRO general circulation model (horizontal resolution of approximately 400 km), which provided the initial and lateral boundary conditions for driving the RegCM over two spearate domains: one encompassing the western two thirds of the U. S. (Giorgi et al., 1998; Mearns et al., 1998) and the other encompassing the southeastern U.S. In the first domain I focus on the central Great Plains, where we had developed a 10-year gridded daily observational data set. In the southeast we consider the entire domain where a 30-year gridded daily temperature and precipitation dataset has been developed.

For each region I analyze differences in the spatial pattern of the frequency of certain extremes, such as daily maximum temperature exceeding 35 deg. C or changes in the value (in mm) of the 90th percentile of daily precipitation intensity. I find that the pattern of changes in extremes differs (compared to current observed climate) between the large and small scale climate change scenarios, but more so for precipitation extremes than for temperature.

I also examine the effect of including changes in daily climatic variability from climate model experiments (in addition to changes in mean climate) on the frequencies of extremes. This is accomplished using the method developed by Mearns et al. (1996, 1997), whereby the weather generator developed by Richardson (1981) was modified to allow for separate manipulation of parameters that alter the mean and variance of the generated daily time series of temperature and precipitation. There are indications that in the mid-latitudes, under conditions of greenhouse-gas-induced-warming, that variability of daily temperature may decrease in the winter, which would lead to fewer extreme low temperatures, but may increase in the summer, which would increase the frequency of high temperature extremes. Which type of change (mean or variability) is more important depends on the relative size of the change in the mean and in the variance. For the climate modeling experiments considered here, including changes in daily variability results in larger changes in the frequencies of extremes than does varying the spatial resolution of the climate change scenarios.

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Functional Data Analysis of Vertical Ozone Profiles

Abstract Number 87
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Stratospheric ozone plays a vital role in restricting the ultraviolet radiation that reaches the surface of the earth, as well as in controlling the atmospheric temperature distribution. The study of seasonal, chemical and dynamical sources of variation in ozone levels is thus an important component of climate research. Observations from ozonesondes (balloon-based recording instruments) of the vertical ozone profile over a geographic location may be considered as samples from vertical profile "curves" which evolve in time, leading us to use functional data analysis methodology for studying variability in the vertical ozone profile. Functional data analysis is the study of curves represented by irregular samples from the curves, which may be contaminated by measurement error. Functional data analysis approaches differ from those of multivariate analysis in their use of the underlying continuity of the domain and smoothness of the curves. In this talk we consider a class of varying-coefficient functional data models for vertical ozone, where the coefficients of a basis function expansion depend on covariates, such as the quasi-biennial oscillation and season. These models are sensitive to the complex interactive effects of the covariates on the shape of the vertical ozone profile. Specifically, we investigate our ability to detect altitude and seasonal dependent trends in ozone as well as the interactive effects of the QBO and seasonal cycle in observations from ozonesondes launched from a mid-latitude site.

Past, Present and Future Wave Climate in the Proper Baltic Sea Basin

Abstract Number 88
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The present paper characterizes the Empirical Orthogonal Functions of daily maximum values of the total significant wave height and corresponding wind waves and swell heights in the Proper Baltic Basin using 5 years hindcast data set, April 1988-March 1993. For this data set and particular seasons the empirical transfer functions between large scale air-pressure and the mesoscale wave fields were computed by means of Canonical Correlation Analysis. In this semi-enclosed basin, computed canonical pairs show dependence of wave fields on the wind, the distance from the shore and on the bathymetry. Further, air-pressure data for 42 years were used to reconstruct wave climate in the considered basin. The reconstructed time series show annual/seasonal and multi-annual/multi-seasonal variability. Statistically significant trends could not be detected for the reconstruction period. Results of ECHAM-3, T42, time slide experiment for doubled concentration of CO2 were used to estimate a future wave climate. In the respect to "control run" wave heights for 2xCO2 are varying in range of -2.5m - +2.5m for points located in open sea area with long-term means equal to zero.

Nonlinear Principal Component Analysis

Abstract Number 89
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Traditional Principal Component Analysis (PCA), or Empirical Orthogonal Function (EOF) analysis, is an often-used tool in the statistical analysis of multivariate geophysical datasets; in particular, it is useful for the reduction of data dimensionality. The first N EOFs of an M-dimensional data set span an N-dimensional hyperplane such that the sum of the squares of deviations of the data from this hyperplane is a minimum. EOF analysis is an optimal data dimensionality reduction algorithm for a dataset whose underlying probability distribution is Gaussian, ie, linear. However,

traditional PCA is suboptimal in characterising datasets whose underlying structure is inherently nonlinear. It has recently been recognised that, through the use of Artificial Neural Networks (ANN), the PCA algorithm can be generalised to minimise the mean squared error of a dataset from a curve, or curved surface, of lower dimensionality, rather than from a line or a plane. This Nonlinear Principal Component Analysis (NLPCA) algorithm could be a powerful tool in the detection and characterisation of lower-dimensional nonlinear structure in large multidimensional geophysical data sets. We will introduce this technique and discuss the results of some preliminary experiments looking for the underlying structure in a Lorentz attractor contaminated with noise; we show that the curve discovered by NLPCA is a more faithful characterisation of the Lorenz attractor, and explains substantially more variance, than the first mode obtained by traditional PCA.

An Analysis of a Super-Ensemble

Abstract Number 90
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AMIP-type ensemble atmospheric general circulation model (AGCM) experiments forced with the time-varying observed SST patterns are now a common tool for climate variability studies. Several multi-decadal ensemble experiments have been made using different models. This paper is concerned with the extraction of the most skilful model signals (i.e. the capacity of the model to match observed temporal variability) and the most reproducible model signal (i.e. the variance that is not sensitive to the initial conditions and which is therefore presumably linked to the time-varying sea-surface temperature forcing which is identical for each member). Gridpoint verification is frequently over-pessimistic because the resolution of a GCM may miss the reproduction of important local-scale features. Moreover an AGCM may often skilfully capture the large- scale atmospheric anomaly pattern, but systematically shift the structure so degrading skill averaged across individual grid-boxes. Multivariate coupled pattern analyses such as Singular Value Decomposition Analysis (SVDA) enable the extraction of the most skilful and reproducible modes of atmospheric variability forced by SST by focussing on the skilful and reproducible portions of the total variance and allowing spatial shifts between the leading modelled and observed teleconnection structures. We present several results at regional and global scale, analyzing 9 runs from three different AGCMs (ECHAM 4.0, ECHAM 3.2, LMD 6) forced by the same (GISST) Sea Surface Temperatures over the period 1961 to 1993. Pooling all runs together from the different model s and applying SVDA also enables extraction of

the common skilful and reproducible modes across the super-ensemble, and provides a basis for an optimum combination of the super ensemble. From the results, it is clear that the most skilful mode is very close to the most reproducible one. Also, The source of skill and reproducibility is not only located in the Tropical Pacific. Substantial contributions from the Tropical Atlantic emerge especially in boreal spring and summer.

A Comparison of Downscaling Approaches for Alpine Precipitation

Abstract Number 91
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Analyses of long-term measurements, simulations with regional climate models, and first scenarios obtained by means of statistical downscaling of global climate model outputs all suggest the potential for a general increase in precipitation in the European Alps under a warmer climate. In particular, the statistically downscaled scenarios indicate a strong north-south gradient in the precipitation signal with large increases in the southern Alps. However, the synoptic background of these scenarios is only little understood. Moreover, until now no systematic comparison of the performance of different statistical downscaling methods and the resulting scenarios has been undertaken for the Alpine region.
Such a comparison is presented for selected representative stations at the northern and southern rim of the Alps. The focus is on possible changes in seasonal precipitation. The following methods are compared: 1) Downscaling from seasonal fields using Canonical Correlation Analysis in the EOF space; 2) Downscaling based on the search of daily analogues for the atmospheric state using data from the last ca. 30 years. The effects of different combinations of predictor variables and of the choice of the large-scale sector used to describe the atmospheric state are investigated. Preliminary results of the application of both downscaling approaches to two climate change experiments with the HADCM2 General Circulation Model (increasing greenhouse gases and increasing greenhouse gases plus aerosols) are presented. The validity of past analogues to infer future regional climate in the Alps is discussed.

Statistical Climate Prediction in the Southern Hemisphere

Abstract Number 92
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Statistical climate prediction has a long history in the Southern Hemisphere. Several papers published early this century indicated that seasonal climate anomalies could be predicted using predictors associated with the El Niño - Southern Oscillation. In recent years there has been exuberant activity in the design and implementation of new forecast systems (many still based on the Southern Oscillation). Many of these new systems are almost certainly infected with artificial skill. The approaches adopted to minimise artificial skill in the development of operational forecast systems for the Bureau of Meteorology will be described. Problems with user acceptance of climate predictions (especially during the 1997/98 El Niño) will be discussed. An integrated approach to climate prediction, aimed at ensuring that forecasts are both scientifically-valid and useful to potential customers, will be outlined.

Detecting Forced Climate Signals in the Surface Temperature Field

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No abstract available.

A Stochastic Model for Spatial-Temporal Rainfall Data

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The spatial distribution of rainfall is of fundamental importance to hydrological studies, and yet procedures for the representation of spatial rainfall in hydrological modelling are primitive. Stochastic rainfall models, which represent the rainfall process using a small number of physically interpretable parameters, have been used to model raingauge data at a single site. The fitted models have been used to produce synthetic rainfall sequences for input into rainfall-runoff models.

A spatial-temporal generalisation of such models is presented and fitted to rainfall radar data from the Wardon Hill radar in the south west of England. The model is based on a clustered spatial-temporal point process of rain cell origins, each origin giving rise to an elliptical rain cell with a random area, intensity, duration and velocity. A set of theoretical model properties, aggregated in space for calibration against rainfall radar data, is used in a generalized method of moments parameter estimation procedure. Adequacy of fit is assessed using a further set of properties, using simulation where necessary. In particular, analyses based on the coverage and volume of rainfall over a series of thresholds provide an assessment of the spatial structure of simulated data sequences relative to the empirical data. These analyses are carried out on the spatial fields of rainfall intensities and accumulated rainfall depths over the duration of a rain event. Models fitted using the generalized method of moments are able to reproduce many of the statistical properties of the empirical data, but there is scope to refine the method and address issues of the precision and identifiability of the parameter estimates.

Model fitting has concentrated on the interior (in both space and time) of rain events. The aim is to simulate long sequences (up 100 years) of synthetic data over the area of a catchment. These data will be used as input into distributed rainfall-runoff models of a particular catchment for the purpopse of flood prediction. Thus, the final model will need to account for the effects of seasonality and the motion of each rain event across the catchment. A first approximation to the latter involves simulating the model within an idealised rain band whose width is determined using the estimated velocity and the period of time that the rain event covers the catchment.

Radar data only give an indirect measurement of the amount of rainfall that falls on an area. A separate study has modelled the monthly rainfall totals recorded by a network of raingauges in a generalized linear model framework. The explanatory variables used include information on the

rainfall of previous months and geographical variables such as latitude, longitude and gauge elevation. The spatial dependence between gauges is also modelled. This model provides a predictive distribution for the monthly rainfall totals at the raingauge sites which can be used, in a rejection sampling framework, to accept or reject simulations from the spatial-temporal model above. Thus, the effects of spatial heterogeneity are introduced into the simulated images.

Analysis of Spatial Covariance Structure From Monitoring Data

Abstract Number 95
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We discuss a method for estimating non-stationary spatial covariance structure from space-time monitoring data. A simple version of our approach constructs a process honouring a given spatial covariance matrix at a collection of monitored sites and uses a stationary process to describe conditional behaviour given monitoring site values. A more sophisticated variant of the technique reproduces the covariance at the monitored sites while giving a description of conditional behaviour through a collection of stationary processes. The method is computationally attractive, and can be extended to the multivariate case. The method will be illustrated for some data describing Sydney wind patterns, and results of some simulation studies will be reported.

Spatial Statistics, Hierarchical Models and Massive Datasets

Abstract Number 96
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A different perspective on modeling spatial data provides a route to handling large problems. Standard methods for analyzing spatial fields focus on the covariance of the spatial process. The problem with this approach for geophysical problems is the difficulty in formulating non stationary fields

and, even when this is successful, computing spatial estimates using large covariance matrices. This talk considers the advantages of modeling the process directly instead of short cutting to the second order moments. This basic change of emphasis from covariance function to the process is the key ingredient of a hierarchal model for spatial or space/time data. In the simplest case the idea is to expand the spatial field with respect to a basis and then model the variances of the basis coefficients. This alone is not a new idea. But recent developments in multiresolution bases such as wavelets allow one flexibility in capturing nonstationary structure and also permit rapid evaluation of the basis functions. The spatial estimates for a large number of locations can be found using iterative techniques, such as the conjugate gradient method, in place of standard solutions of linear systems. Such methods are common in the field of meteorological data assimilation, but have had minor impact in statistics. Here the use of the wavelet basis is important, making the matrix multiplications in the iterations efficient. As an example of this approach we consider monthly precipitation records at approximately 5000 sites in the continental US. Here the goal is to produce spatial predictions on a regular and also to impute readings at sites where data is missing.

Entropy Based Inference of Models for Recurrence of Extreme Events Applied to Climate Variability Analysis

Abstract Number 97
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One aspect associated with climatic change could be a change in the frequency of occurrence of extreme events. Most often, statistical modeling methods employed when dealing with this question have been developed in a frequentist probability framework. They face two major difficulties: model selection and scientific validation of inferred models, especially when observed data are scarce, which are put forward by "robustness" and tail-sensitivity" analysis, but are in fact never solved. In addition, such techniques relate this change with the return period, which is a concept whose meaning is not sufficiently clarified form a physical and logical point of view.

Since extreme events are usually high impact events with important associated costs, there is the demand that the making of decisions concerning them, should be subjected to public scrutiny. In particular the logical foundations of the methods developed to model these events should be transparent and made explicit, and ad-hocness avoided.

A fundamental modeling problem is presented which is of interest for climate variability analysis and at the same time allows to examine critically the logical consistency of available statistical methods. Given the observational data associated with a scalar observable uncertain quantity that represents the time interval between occurrences of characteristic extreme events or interarrival time, the problem is the selection of a probabilistic model for the uncertain quantity which take into account the time elapsed since the last occurrence, based only on the available evidences.
Two alternative inference ways are considered. In the first way, the observer can make inference by assigning a probability distribution onto a domain of possible interarrival times, regarding the observed data, and then condition the domain by the elapsed time information. In the second way the observer can make inference by censoring the original data by considering a domain conditioned by the time elapsed since the last occurrence, and then assign a probability distribution onto it.
A desirable probable inference theory should assign the same probability distributions when using the same dataset information and reference models. In the former two conditioning ways, when the factual and contextual evidences are the same, that is, when the elapsed time by which the domain is conditioned is equal to an observed datum, invariance requires that the assigned distributions be the same in he two ways.
When the conditioning elapsed-time is not equal to an observed datum, a new inference problem arises, and the inference procedure should be able to choose the proper conditioning way from only the information of the available data.
The inference problems formulated in a plausible logical language using logical probabilities. A new Entropy probable inference procedure has been proposed for data based uncertain quantities modeling. When observed data are encoded as fractile probability constraints it is named the Relative Entropy method with Fractile constraints. It is applied to the afore said interarrival time modeling at the successive inference levels, including a level for selecting a conditioning way.
This procedure is used to study how the selected models change as the elapsed time information is taken into account and new data is considered, in what constitutes a new type of dynamical inference modeling useful for the analysis of variability of the interarrival time between extreme event occurrences. An example illustrates its application to characteristic extreme floods or droughts in Spain.

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Multi-Site Multi-Variable Climate Change Scenarios

Abstract Number 98
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A set of multi-site scenarios of temperature and precipitation were required for a catchment in southern Italy. These were generated by statistical downscaling from the Hadley Centre second-generation time-dependent GCM simulation, to produce daily time series for three decades, 1970-79, 2030-39 and 2090-99. Because these scenarios are to be used as input to hydrological models it is important, first, that the temperature and rainfall scenarios at a single site are consistent on a day-by-day basis and, second, that the rainfall (and temperature) scenarios are consistent between sites.

Multi-site rainfall scenarios are generated using a weather-typing approach. First, a key site is selected. On the basis of sea level pressure patterns in the GCM, the circulation type for each day of the three decades is then determined over the key site. The observed probability of rainfall on a day of that circulation type is then used in conjunction with a random number generator to assign the scenario day to either wet or dry. This is the information which ties the temperature and rainfall scenarios together so that the temperature on any scenario day is consistent with the occurrence of rainfall. Second, the rainfall observations at the sites for which scenarios are required are formed into a single file of multi-site daily observations. Each day is classified according to the season, circulation type and whether the day at the key site was wet or dry. Then, taking the key-site reference scenario described above, each scenario day can be assigned to a class. A random number generator is used (with replacement) to select one multi-site rainfall day from the observations in that class. By repeating the process, a multi-site scenario can be built up.

A corollary of this approach is that the variable in the future scenarios of rainfall is the frequency of occurrence of circulation types. The method assumes that the relationships between circulation types and rainfall will remain constant.

Temperature scenarios are generated using a deterministic transfer function approach, in which free atmosphere variables (sea level pressure and 500 hPa geopotential height) are used to predict maximum and minimum temperature. The principle of consistency is maintained by constructing transfer functions separately for wet days and dry days.

The Southern Oscillation Impact on rainfall in the central-east of Argentina

Abstract Number 99
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This paper examines the relationship between monthly rainfall and the Southern Oscillation phenomenon in a region located in the humid zone of Argentina. This study is part of a whole research which has the objective to develop a system for seasonal forecasting of rainfall likelihood, based on 'phase locking' of the Southern Oscillation Index.
The data base consists of a dense network of monthly totals precipitation of stations with long time series (1912-1990). The studied area represents one of the regions in the world with greatest agricultural and farming possibilities. This study is focused on the extreme opposite phases of the Southern Oscillation (warm and cold events. Neutral events are also analyzed to be used as reference. Cold, warm and neutral events are analyzed separately, using statistical techniques to examine the climatic signals associated with either extreme of the Southern Oscillation.
The spatial patterns of rainfall for the first statistical moments for each month and event are analyzed. These results confirm that the studied region has more rainfall and more variability during the warm events (from November to the next January, even in March). The probability of exceeding the neutral-median rainfall for each extreme event and month is investigated. The same spatial pattern is presented in every months (November to March) associated with the Southern Oscillation. During the cold events, the studied region presents 'low' probability of exceeding the neutral-median rainfall while during the warm events, the region presents the opposite pattern ('high' probability). The temporal analysis of these spatial patterns shows that the area with the highest/lowest probability moves from north to south, showing how the region, with more risk for the agriculture due to this external input, is moving through the months.

Downscaling of precipitation from HADCM2 Regional Weather Regimes

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Based on principal component analysis (PCA) and k-means clustering algorithm, daily mean sea level pressure (MSLP) fields over the north-eastern Atlantic and western Europe, simulated by the second Hadley Centre coupled ocean-atmosphere GCM (HADCM2) control run (HADCM2CON), are validated by comparison with observed daily MSLP fields. It is clear that HADCM2 is able to reproduce very well daily MSLP fields and its seasonal variability over the region, despite suffering from some deficiencies, such as the systematic displacement of the atmospheric centers of action. Four daily circulation patterns, which were identified from the observed daily MSLP fields over the area associated with daily precipitation in Portugal, were also well classified from the simulated daily MSLP fields. The model also simulated successfully the relationships between the four daily circulation patterns and daily precipitation at vora, Southern Portugal. Model output indicates a clear improvement relative to that from the UKTR experiment. However, the model simulated local daily precipitation intensities in Portugal are too weak, compared with observations. The results described here imply that local and regional precipitation scenarios provided by the model cannot be directly used in impact studies and that a downscaling technique based on daily circulation patterns is needed. Therefore, a weather generator has been developed to generate future climate scenarios of daily precipitation in Portugal, based on daily circulation patterns. A first-order Markov chain is applied to simulate the occurrence of rain and a two parameter Gamma distribution is employed to generate daily rainfall amounts. This weather generator can well simulate the occurrence of rain, as well as the properties of rainfall amounts, and even useful information on extreme rainfall. Two different precipitation scenarios in Portugal are obtained, by applying the weather generator to simulated daily mean sea level pressure fields over the north-eastern Atlantic and western Europe, provided by the Hadley Centre second generation coupled ocean-atmosphere GCM (HADCM2 OAGCM) in two separate experiments. In the first experiment (HADCM2GHG) forcing is due only to increasing concentrations of greenhouse gases (GHG) while in the second (HADCM2SUL) forcing comes from the combined effect of GHG and sulphate aerosols (SUL). Precipitation scenarios are obtained for the next century and changes relative to present climate are analyzed and interpreted.

Changes in Evaporation Patterns Detected in Northernmost South America. Homogeneity Testing

Abstract Number 101
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This research on climate change detection shows that in the area, northernmost South America (Venezuela) the evaporation of water, as measured by meteorological evaporimeters installed in climatological stations, has been decreasing during the last years starting in 1980. 26 climatological stations were first selected for their relatively long records (> 40-years of data); 22 out of the stations were finally left as they have both the fewest missing information and most consistent and homogeneous data (Alexandersson's Homogeneity Test was applied). The downward trend is particularly noticeable during the last 15 years (1981-1995) of the period 1951-1995 covered in this study. Evaluations of the anomalies detected (deviations from mean values) were made after testing for homogeneity (Alexandersson, 1995) and adjustments of the evaporation series were also made when needed (only for 4 stations' records). The data used were totals and averages of mean daily evaporation values from January to December. The results point out that a group of 14 stations (2/3 of the total) present the downward trends during the subperiod 1981-1995, which was also highly significant (t-test) when compared with the 1951-1980 previous period. Averaged time series of evaporation were compared with similar time series of maximum and minimum temperatures and diurnal temperature ranges, DTR (Peterson, 1995) for the region, accordingly with another research carried out recently for the same area (Quintana-Gomez, 1995). It is concluded that evaporation and DTR have varied (decreased) similarly during the last 15-20 years in Venezuela, similarly like in many other large areas of the world. Perhaps for the same reasons affecting those regions in the northern hemisphere, mostly, i.e., as a result of the continuous increase of the greenhouse gases into the atmosphere and greater cloudiness among the main causes.

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Climate Change During the 20th Century for the Russian Federation

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Observed climate changes over the Russian Federation (RF) territory are considered. Several indicators based on monthly mean temperature and precipitation station data are used to uantify regional climate changes. A sufficient number of observing stations have been in operation over the past 100 years only over the western part, the "Russian Permafrost Free (RPF) territory", to perform a reliable analysis. For considering climatic change over the country as a whole the scope of the investigation was restricted to the past 50 years. Also, the former USSR territory and USA territory were considered for comparison. So, the century and its second half are examined both. For all territories of concern changes in surface air temperature are investigated, together with changes in precipitation and drought indices, and also the fraction of the region experiencing climatic anomalies below and/or above certain specified percentiles. Composite indices CEI-3 (the Climate Extremes Index) and GCRI-3 (the Greenhouse Climate Response Index), based on three parameters (air temperature, precipitation and drought indices) are examined, as well as the Climate Anomaly Index (CAI), known in Russia as Bagrov's coefficient of "anomality". It is shown, that over the area of the RPF as a whole air temperature and the occurrence of drought has increased somewhat during the 20th century, while precipitation has decreased: these changes were non-uniform in space. The linear trend accounts for only a small fraction of the total variability, but the role of climate variations on decade scales seems more substantial. The CEI, determined as the percentage of the area, experiencing extreme (with a 10or less frequency of occurrence) anomalies of either sign increased for mean annual temperature, decreased for total precipitation and increased slightly for the occurrence of drought conditions; the aggregated index based on all three of these quantities increased slightly. There was also an increase in the GCRI-3 index, which is indicative of an agreement between the observed climate changes and the changes owing to the greenhouse effect as predicted by climatic models. Then, regional climates and climate changes in the second half of XX century on territories of Russia and USA are analyzed in detail using the technique developed. It is shown, that the territory of Russia in the past 50 years compared to the century is characterized by the temperature increase (somewhat less for the warm season and even more for the cold one), precipitation decrease in eastern regions (but some increase over the RPF territory), increase in the drought index, and weak increase of climate extremity. In contrast with this, in the USA territory precipitation increased, while the drought index increase was very weak, and practically stopped to the second half of the century. The ob-

served climate changes are too small to enable us confidently to reject a hypothesis that they are a reflection of the natural variability of climatic parameters within the context of a stationary climate. However there is no doubt about the reality and practical importance of the observed changes. The work was supported by the Project RFBR 97-05-65102

Comparison of Temporal and Unresolved Spatial Variability in Multiyear Averages of Air Temperature

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When compiling climatological means of air temperature, station data usually are selected on the basis of whether they exist within a fixed base period (e.g., 1961-90). Within such analyses, station records that do not contain sufficient data during the base period or only contain data from other base periods are excluded. If between- station variability is of interest (e.g., a map or gridded field is needed), then removing such stations assumes that spatial interpolation to the location of culled stations is more reliable than using a temporal mean from a shorter or different averaging periodthe latter is a process that we call temporal substitution.' Data from the United States Historical Climate Network (HCN) are used to examine whether spatial interpolation or temporal substitution is more reliable for multiyear averages of monthly and annual mean air temperature. After exhaustively sampling all possible 5-, 10-, and 30-year averaging periods from 1921-94, spatially averaged interpolation and substitution errors are estimated for all months and for annual averages. For all months, temporal substitution produces lower overall error than traditional spatial interpolation for both 10- and 30-year averages. Maps of mean absolute error (for all averaging periods) show that spatial interpolation errors are largest in mountainous regions while temporal substitution errors are largest in the north-central and eastern USA, especially in winter. A spatial interpolation algorithm (TAI) that incorporates elevation data reduces interpolation error, but also produces larger errors than temporal substitution for all months when using 30-year averages and for all months except January, February, and March when using 10-year averages. For 5-year averages, however, TAI produces lower errors than temporal substitution, especially in winter. For the USA, therefore, it is suggested that for averaging periods less than 10 years in length, elevation-aided spatial interpolation is preferable to temporal substitution. Conversely, for averaging periods longer than 10 years in length,

temporal substitution is preferable to spatial interpolation. Analysis of the 1961-90 period using a wide range of network densities demonstrates that temporal substitution generally is more reliable than spatial interpolation of 30-year averages, regardless of network density.

Cross Validation of Different Discriminant Analysis Methods Used in Statistical Climatology

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Three statistical methods of discriminant analysis with an important application in the field of the Low Frequency Variability, have been deeply studied in order to develop three differents statistical simple models. These three methods are the popular Canonical Correlation Analysis (CCA), the Singular Value Decomposition (SVD) and the combined Empirical Orthogonal Function/Canonical Correlation Analysis (EOF/CCA). A validation technique known as cross validation has been used to validate the skill of these models. The simulations have been done using two artifitial data sets for both, the predictor and the predictand fields. The predictor field (Y) consist in a signal s plus a noise r (Y=s +r). The noise is incremented in differents cases. The predictand field (Z) is the Y field multiplied by a function h , plus noise rr which is also incremented in different cases (Z= h *Y +rr). Knowing the part of the variance that is due to the signal we could know how all of these procedures (SVD,EOF/CCA and CCA) can predict the noise , which of these techniques is less sensible to the noise and, comparing the results, which of these three methods provides a better skill.

Winter Precipitation Variability Over the Iberian Peninsula and Its Relationship to Atmospheric Circulation Indices

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The characteristics of winter precipitation variability over the Iberian peninsula are examined using time series of precipitation observations. The spatial patterns are obtained by means of principal component analysis while the interannual fluctuations are detected by spectral and singular spectrum analysis. The impact of some Atlantic Circulation Indices and Southern Oscilation Index on the winter precipitation is obtained by correlation methods. Trying to explain part of the interannual precipitation variability, regional statistical models are proposed based on the relationships between the modes of precipitation variability and the circulation indices, also the interannual oscillations are considered.

Clustering an Ensemble Into Meaningful Patterns for Forecasters

Abstract Number 106
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ECMWF Ensemble Prediction System (EPS) forecasts are used by forecasters for the medium range, but the techniques to aggregate similar forecasts often fall short of bench forecasters requirements. ECMWF use cluster vectors which merge 500 hPa values on a chosen grid and over a sequence of days. In the UKMO, a number of different choices have been tested on forecasters to see if forecasts can be clustered in a manner acceptable to forecasters. A number of forecasters were asked to group a set of EPS forecasts by hand. No two forecasters chose the same grouping, of course, but there were some large differences. However when asked to explain their selection criteria, most used phrases such as pattern, contour shape, wind fetch etc. This focused attention on the data on which the clustering is done, and examples are shown which attempt to distinguish patterns of the contours between different members of the EPS set.

Simulated and Observed Trends of Precipitation in South-western Europe. Evidence for Climate Change?

Abstract Number 107
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Sea level pressure (SLP) in the North Atlantic exerts a dominant influence on south-western Europe precipitation during winter. Canonical correlation analysis has been applied to the NCAR SLP dataset and a new dataset of precipitation developed at UCM (SED South-western Europe Dataset) in order to detect coupled modes of variability between these two variables. Three patterns that describe the large to localscale relationships between SLP and precipitation have been found. These coupled modes have been used to develop a statistical downscaleing model.
The same procedure has been applied to outputs from the Hadley Centre AOGCM in order to validate both the dynameical model and the application of the statistical downscaling model in climate change scenarios. Results show agreement between simulated and observed coupled modes even in the regional scales and good performance of the downscaling model under forced conditions.
The long term trends reproduced by the model and the observations have been compared. An evolution of observations to the dedicated climate change patterns is observed some evidence e for climate change?

Some Aspects of 200 HPA Circulation over Argentina in Relation to Precipitation

Abstract Number 108
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The relationship between large-scale circulation at higher levels of the troposphere over the southern part of South America and local precipitation is examined. The cordillera de los Andes exerts a great influence on mid-latitude synoptic systems. One of the purposes of this study is to find out if such an influence is still evidenced in the atmospheric circulation of higher

levels and to what extent it affects precipitation in the east of the Andes, from a statistical point of view. Synoptic climatology of 200 hPa geopotential height fields in relation to local precipitation is performed by means of constructing biserial correlation fields. Daily local rainfall at Buenos Aires is considered. Moderate and heavy precipitation events are also analyzed. 200 hPa geopotential height fields at 12:00 UTC produced at ECMWF are used. Statistical momenta associated to these fields are evaluated. Preferential positions of jet streams in association with precipitation occurrence are analyzed through 200 hPa relative geostrophic vorticity configurations. There exist statistically significant geopotential height and vorticity anomalies in the 200 hPa level in relation to precipitation occurrence. This suggests the probable areas affected by disturbances in the mid-latitude flow in order to favour synoptic-scale precipitation in a given location. The patterns of cyclonic and anticyclonic vorticity anomalies vary according to the synoptic

Cold and Heat Waves Over Argentina. Interannual to Interdecadal Variability

Abstract Number 109
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Climatic aspects of cold and heat waves as a manifestation of some particular synoptic situations over Argentina is studied.These waves are defined as a sequence of same sign temperature anomalies and there were studied in some particular locations where the extreme waves best revealed. Temporal evolution for their parameters is analized in annual to interdecadal periods. The frequencies joint distribution between maximum and longitude of these waves have significantly changed between decades. Northern heat waves changed their maxima upward trend after the 70's into a negative trend. Extreme cold waves (related with cold surges over Southern Brasil) had a negative trend up to 80's when they started to increase their maximum values. The interannual variability of these waves is partially explained by ENSO, e.g.there is a significant correlation between cold winter waves persistence and the SST in El Niño 4 region.

A Trend Analysis of United States Temperatures

Abstract Number 110
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A reliable statistical assessment of linear temperature trends - including a measure of their uncertainty - is considered for stations in the United States. A model that accounts for changes in the site location of each station, the seasonal means and variances inherent in monthly temperature series, and the temporal correlation found in such data is first proposed. Least squares estimates of the linear trends are then derived. Emphasis is given to obtaining an accurate standard error for these trend estimates that takes into account the aforementioned data features. By examining the trend estimates and standard errors for each station, one obtains an accurate spatial assessment of warming and cooling rates in the United States.

ENSO-related Precipitation Characteristics in Canada

Abstract Number 111
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Precipitation charcteristics over Canada associated with the two extreme phase of ENSO, namely El Niño and La Niña, are identified. Both the spatial and temporal behaviour of the responses from the ENSO onset to several seasons afterwards are analyzed for the period 1911 to 1994. Both composite and correlation analyses indicate that precipitation over a large region of southern Canada extending from B.C coast, through the Prairies, and into the Great Lakes' region is significantly affected by the ENSO phenomenon. The results show a distinct pattern of negative (positive) precipitation anomalies in this region during the first winter following the onset of the warm (cold) events. Statistical significance of the response is tested by the Student's t-test and the Wilcoxon ran-sum test, while field significance is established through the Monte Carlo procedure. All of the significant precipitation anomalies can be explained by the associated atmospheric circulation patterns, which during the first winter following the onset of warm (cold) events, resemble the positive (negative) phase

of the Pacific North American (PNA) pattern. In the areas where ENSO response is the largest, both amounts and frequency of daily precipitation is also examined. Daily precipitation events are stratified to determine whether there are statistically significant differences from ENSO-neutral years in the occurence of heavy and light precipitation.

Optimal Estimation of Climate Parameters

Abstract Number 112
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This talk discusses two optimal assessments of a climate state: optimal averaging and optimal gridding of the historical climate data.

1. *Spectral approach to optimal averaging*: An optimal scheme is developed that minimizes the mean square error when using finitely many surface stations to measure the various orders of spherical harmonic components of a climate field. An important formula is derived to demonstrate that the sampling error is relatively insensitive to the exact shapes of EOFs. Two examples are the global average of the annual surface air temperature using 63 stations and the regional average of the monthly tropical Pacific SST.

2. *Adaptive data gridding*: The validation of climate models requires to reconstruct climate fields for the past, say 1885-1930, from the scarce observation data. A field can be reconstructed on a one-by-one degree regular grid. A systematic theory for the interpolation is described that uses the recent and more accurate observational data.

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Variability and Prediction of the Indian Northeast Monsoon

Abstract Number 113
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An attempt has been made to provide a detailed information about variability of the northeast monsoon circulation and associated rainfall of October-December period over India. These details about the summer monsoon (June through September period) of the country are extensively documented in the literature. The study is carried out in four segements: large scale features, small scale (or regional) features, correlation with regional/global circulation parameters and prediction of future trend. Large-scale interannual features are derived from examination of variations in the size of the area under wet conditions (October-December total rainfall greater than 200mm) over the period 1871-1984, using data of well spread 306 stations. Year to year variation in the wet area is large, free from Markovian type persistence and does not possess any significant long term trend. Broadly wet/dry epochs are identified in the low frequency mode fluctuations which showed good match with that identified in some of the regional/global circulation parameters. Overall large-scale feautes of the northeast monsoon are broadly coherent with the summer monsoon (CC=0.38). The northeast monsoon wet area (NEMWA) is highly correlated with the area-averaged northeast monsoon rainfall (NEMR) of the country (CC=0.92), which suggests that high/low magnitude of the all-India rainfall is dependent on good/poor rainfall activities over different parts of the country rather than confined to only in the key northeast monsoon regime, which is generally believed to be.

Regional NEMR series are analyzed to understand small scale features of the northeast monsoon circulation as well as to provide some detailed information about rainfall for practical purposes. For each of the six zones, including all India, the longest possible instrumental NEMR series has been reconstructed using optimum observations (with a provision to update them on a real-time basis) identified by applying an established objective selection technique. For the North West India (NWI) the series could be reconstructed for the period 1844-1996, for the North Central India (NCI) 1842-1996, for the North East India (NEI) 1829-1996, for West Peninsular India (WPI) 1841-1996, for the East Peninsular India (EPI) 1848-1996, for the South Peninsular India (SPI) 1813-1996 and for the whole country (all-India) 1813-1996. The distribution of WPI, EPI and SPI series is Gaussian, all India and NEI suffer from significant positive skewness and NWI and NCI from significant both skewness and kurtosis. The different series are free from Markovian type persistence and do not possess significant long

term trend. Among themselves the zonal series are weakly correlated which emphsises the need of regional studies.

To explore the possible causes of variations in the northeast monsoon correlation between zonal as well as all india NEMR series and twenty selected regional/global circulation parameters is examined. Southern Oscillation, El-Nio, Quasi-biennial oscillation (QBO), surface air temperatures and sea surface temperatures have shown the correlation of the same sign, albeit weaker, as they have shown with the large scale features of the summer monsoon. Sources of variations for the two monsoons of the country appear to be the same.

Lastly an estimate of 10 years future projections is provided by modeling either actual series or any smoothed version of the series, containing only a fraction of the actual variance, obtained through the singular spectrum analysis (SSA) and late reconstruction of the series of the full length by recombining the first few principal components (Pcs). The time series modeling involved two processes, firstly a continuous harmonic (power spectrum) analysis and secondly estimation of the series using a subset of limited wavelengths whose combination showed a high correlation of 0.85 with the series being modeled. The modeled series is extrapolated for 10 years period to make prediction of a future scenario of the NEMR activities across the country. There are differences in the future rainfall trend over different parts of the country.

A Comparison of Homogenization Techniques

Abstract Number 114
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Two different techniques used for the homogenization of climatic time series without a homogeneous reference series are investigated and compared for their relative strengths and weaknesses. Fifty one time series of mean monthly surface pressure values over Europe, ranging in length from 125 to 240 years have been tested. The first method is a subjective comparison method based on visual inspection of the difference series between selected neighbouring stations to detect discontinuities. These discontinuities, or breaks points, define periods of inhomogeneity within each individual series. These break points are compared to those found using an objective test procedure (the CAUMES test) based on a Bayesian multidecision rule. The results of both these methods are compared to the results of the standard normal homogeneity test (SNHT), an objective statistical test which relies on a homogeneous reference series for the detection and correction

of inhomogeneities. The results of these three methods are also verified against the available metadata. A further comparison is done between different procedures for determining the correction factors. The subjective comparison method uses a homogeneous part of an individual time series to calculate average deviations for the inhomogeneous periods. This assumes stationarity of the series and artificially reduces the temporal variability of the series. Other methods of correction base the correction factors on surrounding stations, which may reduce the spatial independence of the set of series. The impact of these different correction procedures on subsequent analysis is considered.

Trends in Meteorological Extremes

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Recent climatological research has suggested that, while the evidence for overall trends in climatological variables remains questionable, there is much stronger evidence for trends in the extreme values. For instance, in one study Karl and Knight (1998) have shown that, for precipitation data collected from the U.S. Historical Climatological Network (HCN), there is a strong trend in the frequency of events within the top 5% of the distribution, which is much stronger than any trend based on average precipitations levels.

In this study, we examine these issues from a different point of view. Data from a single station may be analyzed using methods based on crossings of a high threshold (Davison and Smith 1990). Data from different stations may be combined by using multivariate extreme value theory to represent the joint distribution of extremes at different stations, or alternatively by using hierarchical models to represent the variation of model parameters over the country. Various model forms and statistical procedures will be discussed, with preliminary results derived from the HCN database.

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Averaging of Surface Temperature

Abstract Number 116
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Surface land and sea temperatures are averaged using a form of optimal averaging (OA) based on EOFs, and variations in the average temperature over the 20th century are discussed. The reliaility of the theoretical error computed by the OA is evaluated using cross-validation tests. Also discussed are implications about the reliability of the OA in different historical periods, and the sampling necessary to determine global averages of temperature accurate enough to detect climate variability.

A Bayesian scheme for El Niño prediction

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A Bayesian scheme for El Niño prediction is described. This scheme uses information about the long-run frequency of El Niño events to construct a prior probability, which is then combined via a likelihood function with a model-based prediction. The results of a cross-validation experiment are presented showing that the Bayesian prediction is superior to predictions based on long-run frequency or model-based prediction alone.

Scaling Analysis of the Spatial-Temporal Variations of the Surface Air Temperatures of the Northern Euroasia

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The problem of the current climate warming is a topic of incessantly increasing interest during the latest decades. Although all atmospheric models

beginning from the simplest energy-balance ones up to the very detailized general atmospheric circulation nodels reveal a similar scenario of the climate warming in result of the greenhouse gases concentration growths, there is a doubt that this warming is induced by this external forcing. The reason is that the real atmosphere, like every essentially nonlinear dynamical system, is capable to display variability over a very wide range of the temporal and spatial scales of its motions without any variation of its external forces.

In this report we consider the surface air temperature variations of the Northern EuroAsia over the latest 100-150 years as a kind of Brownian motion. Combining the well-known empirical orthogonal function (EOF)-expansion for the spatial representation of the data with a scaling analysis of the expansion coefficients, we recognized some fractal properties of the dynamics of interest. In particular, majority of the eigen values of the above spatial EOF-expansion reveals a single temporal scaling behaviour governed by the Hurst parameter value of about 0.60. So, the dynamics of interest may be attributed as a persistent fractional Brownian motion.

This finding adds a fuel to the flame of our doubts concerning the expernal origin of the current climate warming because the really observed trend-like behaviour of the hemispheric temperature time series, that are the main objects in the discussion of the problem, turns out to be very likelyhood to the typical behaviour of the Brownian motions with the indicated Hurst parameter value. Moreover, the first eigen value of the spatial EOF-expansion, that corresponds to the weighted spatial mean temperature of the area under analysis, has the same scaling. So, we may conclude that any signal of the externally induced warming is absent in the temporal dynamics of this spatial structure of the temperature fields.

Climate Variability and Multi Year Prediction of SW Monsoon Rainfall Over North East India

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The climate of North East India (east of 88° E, north of 21° N) is distinct from rest of the country due to its location in the geographical subtropics, hilly and steep orography and proximity to the Bay of Bengal. The region experiences a long rainy season of 7 to 8 months: pre-monsoon thunderstorms during March-May (2%), SW monsoon during June-September (70%), and NE monsoon during October-November (8%). Rains are very heavy and Cherrapunji, one of the wettest place on earth, comes in this

region. Temperatures over the region are highest in July and August when SW monsoon rains occur.

To understand climate variability longest possible rainfall series have been reconstructed for each of the four seasons (winter, summer and post monsoon: 1829-1996; SW monsoon: 1848-1996), for each of the four SW monsoon months (June, July and September: 1829-1996; August: 1848-1996) and annual total: 1829-1996. An objective technique of optimizing the network for representative climatological series has been used for this purpose. In the low frequency mode winter, summer and SW monsoon rainfall fluctuations showed decreasing tendency while NE monsoon increasing tendency. The monthly temperature series over the region have been reconstructed from 1816 onwards (discontinuities from 1824-1832, 1839, 1855-1869 due to no data). Examination of seasonal temperature series reconstructed from 1870-1996 brings out that temperatures showed rising tendency upto first five to six decades of the present century and dropped thereafter upto 1970 in all the seasons. Except summer in other seasons they revived marginally in the latest decade.

Correlations of the SW monsoon rainfall variations over NE India with selected parameters that have reportedly shown significant correlation with all-India SW monsoon rainfall have been examined. Indices of southern oscillation, NH temperature, Indian temperature, Pakistani temperature, Puerto Chicama SST, and 10mb QBO at Balboa have shown significant correlation. Cooler than normal surface-100mb layer over north temperate region during spring is an indication of good SW monsoon rainfall activities over NEI.

An attempt has been made to estimate 10 year future SW monsoon rainfall over NE India by modeling desired smoothed version of the series through Singular Spectrum Analysis. First a continuous power spectrum analysis has been done of smoothed version and then the series has been estimated using a subset of limited wavelengths whose combination showed a high CC 0.85 with the series being modeled. The modeled series is extrapolated for 10 years period for future scenario.

Multiple Analysis of Series for Homogenization (MASH)

Abstract Number 120
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The homogeneous data series are indispensable in respect of the examination of climate change and climate variability. However, the observed climatic data series are often affected by inhomogeneities as a result of certain local influences. Climate change studies using observed data must always take into account the possible inhomogeneities, in order to avoid false conclusions.

The aim of the homogenization is to obtain homogeneous data series in climatic respect, without losing information about the assumed climate change. The typical statistical way is the so called "relative homogeneity test", which is based on the comparison of the candidate data series with one or more reference data series belonging to nearby stations. In general the homogeneity of reference series is doubtful too, consequently the homogenization of data series is a complex space-time problem.The MASH method was developed by us and it is a relative homogeneity test procedure that does not assume the reference series are homogeneous. Possible break points and shifts can be detected and adjusted through mutual comparisons of series within the same climatic area. The candidate series is chosen from the available time series and the remaining series are considered as reference series. The role of series changes step by step in the course of the procedure . Depending on the climatic elements, additive or multiplicative models are applied. The second case can be transformed into the first one by logarithmization.

Several difference series are constructed from the candidate and weighted reference series. The optimal weighting is determined by minimizing the variance of the difference series, in order to increase the efficiency of the statistical tests. Providing that the candidate series is the only common series of all the difference series, break points detected in all the difference series can be attributed to the candidate series.

A new multiple break points detection procedure has been developed which takes the problem of significance and efficiency into account. The significance and the efficiency are formulated according to the conventional statistics related to type one and type two errors, respectively. This test obtains not only estimated break points and shift values, but the corresponding confidence intervals as well. The series can be adjusted by using the point and interval estimates.Since a MASH program system has been developed for the PC, the application of this method is now relatively easy.

Evaluationof Meteorological Ensemble Prediction Systems

Abstract Number 121
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Ensemble Prediction Systems (EPS's), now used operationally in several major meteorological centers around the world, define, through a finite sample, a probability distribution for the state of the atmospheric flow. The value of an EPS lies in the conjunction of two independent qualities, namely statistical consistency or reliability, i. e. the quality that the a posteriori observations are statistically distributed according to the a priori predicted probability distributions, and resolution, i. e. variability in the predicted probability distributions. A number of scores commonly used for evaluating the quality of EPS's are discussed in terms of which of these two qualities they measure. In particular, the classical Brier score can be decomposed into the sum of two terms which independently measure reliability and resolution (Murphy, 1973, J. Appl. Meteor., 12, 595-600).
The impact of the finiteness N of forecast ensembles on various scores is discussed. The Brier score is degraded by an additive term proportional to 1/N, which shows rapid saturation of the score with increasing N.
The reliability and resolution of two operational EPS's (the ones of the European Centre for Medium-range Weather Forecasts and of the National Centers for Environmental Prediction) are evaluated at various forecast ranges. The performance of both systems is also compared with the performance of an economical 'poor man's EPS' which, being based on a search for past analogues, does not require explicit integration of the forecasting model from 'perturbed' initial conditions.

Seasonal Forecasts of Sea Surface Temperatures of Tropical Pacific - Comparing Neural Networks and Canonical Correlation Analysis

Abstract Number 122
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Of the statistical methods in seasonal climate forecasting, canonical corre-

lation analysis (CCA) is a well established one. CCA is basically a more sophisticated version of the simple linear regression method (LR). Recently, advances have been made on applying neural networks (NN) to seasonal climate forecasting. Unlike CCA and LR, NN is a nonlinear statistical method, which leads to the question whether the nonlinearity of NN brings any extra forecast skill.
In this study, we compare the three methods (CCA, LR and NN) in forecasting the tropical Pacific sea surface temperatures (SST). We found that CCA and NN are generally better than LR, and the results of comparing CCA and NN depend on the regions, leadtimes, decades and seasons of the forecasts.
In the Nino4 region located in the western Pacific, CCA has better skills than NN, probably indicating nonlinearity is not important in the region. In the Nino3.4 region located in the central Pacific, CCA and NN have about the same skills. In the Nino3 region located in the central-eastern Pacific, NN has better skills than CCA, indicating that nonlinearity may be important in the region. In the Nino12 region located in the far eastern Pacific, NN again has better skills than CCA, but the advantage is not as much as in the Nino3 region.
CCA generally has better skills than NN in the decade of 1960s, and NN generally has better skills than CCA in the decade of 1980s.
The skill difference between CCA and NN is small, about 0.01 to 0.05 in correlation coefficient skills. However the pattern of the difference is quite persistent across different decades and different leadtimes. Why NN fails to gain more skill over CCA is also discussed.

Modelling Extreme Rainfall Events

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Statistical methods for estimating the frequency of extremes for rainfalls at a particular site and a given aggregation duration are routinely used. The methods are based on extreme value techniques, which are used to model either the annual maximum rainfall or the peaks over a high threshold. For example, the annual maximum rainfall, M_d, for aggregation d hours is taken to follow a generalized extreme value distribution. These techniques/models are separately applied for each d of interest.
In practice, interest is often in more general temporal features of extreme rainfall events. For example

1. Temporal Aggregation: The estimates of the extreme rainfall aggregated over a duration d_1 hours are not guaranteed to be less than for

duration d_2 hours when d_1

2. Linkage: Extremes of the d hour rainfall ($d < 24$) are of interest, but there is only a short set of such data available. However at the same site there is a long run of historical daily rainfall data. This historical data carries information about the d hour extremes.

3. Discretisation: 24 hour extreme rainfalls may be of interest, but the available data are daily measured data, i.e. only one particular period of 24 hours. We wish to convert from the extreme value analysis of the data to hand to extremes of the variable of interest.

To address these problems hypothetical rainfall models are often used to simulate these variables. One problem with this approach is that these models are estimated using typical rainfalls which may not adequately represent either the marginal or dependence features of the rainfall extremes. In this talk I will discuss how dependence models for extreme values can be used to address a variety of these problems. The problems, in turn, call for the use of models for extreme events, ordered variable bivariate extreme value distributions and results concerning the extremal index as a measure of clustering of extreme values in a stationary sequence.
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Causes of Twentieth Century Climate Change

Abstract Number 124
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An optimal space-time detection methodology is used to compare model predicted patterns of twentieth century surface temperature change due

to natural and anthropgenic causes with those observed. A linear combination of model predicted patterns of climate change were found to be consistent with the observations. The analysis suggests that it is highly unlikely that natural forcings are responsible for the warming observed since 1945. However, possible errors in the model response to different forcings, errors in the forcings and observational errors were neglected. During this period the strength of the anthropogenic signal in the observations gives an estimate of climate sensitivity to doubling CO_2 of 2.5°C with a 20 % probability of being less than 2.0°C and a 20 % probability of being greater than 3.1°C. Changes earlier in the century are more difficult to disentangle from natural internal variability but the best explanation for the climate changes during the 1920s and 1930s involves a combination of solar forcing and anthropogenic forcings.

Principal Predictors for Low-Dimensional Modelling

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Principal predictors are a generalization of principal components to two sets of variables: linear combinations of those in the first set that efficiently explain the variability of those second set. If the first set of variables lead the second in time, then a few of their principal predictors might capture the information they carry about the future values of those in the second set.

Principal predictors are defined by an eigenproblem involving three matrices, which is similar to the that of canonical-correlation analysis. However, whereas canonical correlates need not account for a significant amount of the total variance of either set (and generally don't for large numbers of variables, e.g. meteorological and oceanographic fields), principal predictors do not suffer from this problem. In this regard, this analysis is similar to the singular-value decomposition of the cross-correlation matrix.

This talk explores the possibility of capturing the low-frequency behavior of high-resolution numerical forecast models with a small number of principal predictors. A shallow-water model of the circulation in the Gulf of St. Lawrence is used as an example.

Neural Networks and Statistics

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The lecture will describe some of the most commonly applied types of artificial neural network, the links with corresponding activities in the statistical literature and current research trends at the interface between the two literatures. Much of the time will be devoted to the feed-forward networks called perceptrons, in the context of classification/regression problems. Issues of training the networks (i.e. parameter estimation) and design of the architecture (model choice) will be discussed. Other types of network to be mentioned will include associative memories and self-oganising maps, and the relationship to cluster analysis will be mentioned. The discussion of current trends at the statistics/neural-computing interface will include graphical models, latent-structure models and the implementation of Bayesian ideas.

New Technologies for Very Large Empirical Decompositions of Simulated Climate

Abstract Number 127
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The most cost effective use of computing power is in circumstances where problems can be effectively decomposed into subproblems having limited interdependency. The decomposed subproblems may then be assigned to independent computing elements, most effectively in a distributed memory massively parallel platform. Obtaining empirical orthogonal functions from a data set containing a time record of spatial fields is one such application. An empirical orthogonal function decomposition program has been implemented on an 80 processor IBM SP supercomputer platform at Argonne National Laboratory. It makes use of the standard MPI message passing library for parallel computation, including new extensions to that library which allow for parallelization of input and output.
The algorithm is memory and input/output intensive rather than computationally intensive. Dividing the memory and input/output requirements

among a large number of processors makes practical the extraction of empirical orthogonal functions from very large data sets.
The program has been used in analyzing output data from the ocean component of a coupled atmosphere-ocean general circulation model, where the ocean resolution is 128x128x16. Simulated monthly snapshots of the horizontal velocity field have been analyzed over a simulated period of 500 years, a data set comprising over 3 billion floating point numbers.
This quantitative improvement in the ability to analyze large data sets may lead to a qualitatively new application in combination with an ability to perform very long coupled GCM simulations. It is hoped that the long simulations may suffice to capture the statistical properties of the atmospheric flow which affect ocean circulation. To the extent that the statistics of the atmosphere are determined by the distribution of sea surface temperature, a closed system may be formed by coupling a dynamic ocean to a statistically generated atmosphere.
The successful completion of this endeavor would allow for a practical method for performing studies of the thermohaline circulation of the ocean over very long time scales, a mechanism of climate change that is poorly understood and potentially extremely important.

Operational Aspects of Ensemble Forecasting

Abstract Number 128
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In chaotic systems like the atmosphere or the coupled ocean-atmosphere system, predictability is limited due to the fact that small initial errors amplify with time. No matter how accurate the initial conditions or the model are, after a period of time the state of the system can only be defined in probabilistic terms. Therefore the goal of weather and climate forecasters is to predict probability distributions of relevant variables. It is possible to base these probabilistic forecasts on a single dynamical model integration, using also verification statistics of such forecasts from the past. However, such a practice may not be optimal because (1) a single forecast does not provide the best estimate for the expected state of the system, and (2) it cannot provide case dependent information on the degree of uncertainty in the forecast. Running an ensemble of forecasts, instead of only one integration, offers the only practical solution to address these issues. This is true both for the time period where there is still predictability due to the knowledge of the initial value of the system, and beyond that time, when the system's response to known boundary conditions is sought.
There is not adequate theoretical foundation regarding what can or should

be done if using imperfect models in ensemble forecasting. Operational applications, however, are under these constraints. One can assume, on one hand, that ensemble forecasting (as any kind of forecasting) requires a certain level of model performance - otherwise the model solutions will not have any correspondence with reality. On the other hand, an ensemble of forecasts can be more efficiently used to correct for systematic biases in the model - both in a postprocessing sense and in terms of correcting errors/deficiences in the models. Beyond introducing initial uncertainty in the model solutions, one can also attempt to perturb the numerical model in different ways - however, doing so may raise questions about the likelihood of the model runs created this way.

Another important factor in the operational application of ensemble forecasting is efficiency. On the computational level, procedures used, including the generation of initial perturbations, should be efficient. At a more general level, the value of the products derived from an ensemble of forecasts should surpass that derived from the traditional use of a single, higher resolution forecast. Different verification statistics, focusing possibly on the users' requirements, should be used to compare the ensemble vs. the single higher resolution forecast strategies, both using the same computational resources. There are a number of important issues in operational ensemble forecasting that may benefit from statistically oriented research. For example, should we use an unbiased sample of initial perturbations, or rather use a dynamically constrained (and therefore statistically "biased") sample in the hope of more accurate predictions? What are the best ways of correcting the case dependent, model-related bias in ensemble forecasts? What are the best ways of looking at the large amount of data generated by the ensemble forecasts? Are there practical ways of verifying probabilistic ensemble forecasts in two dimensions (instead of the traditional point statistics)?

Variational Applications in Atmospheric Dynamics and Prediction

Abstract Number 129
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Recently, variational techniques have found increasing application in studying the dynamics, predictability and sensitivity of atmospheric flows. There has also been an increased awareness in the use of variational techniques in the solution of statistical-dynamical problems associated with data assimilation and dynamically produced probability forecasts. Because the con-

dition of maximum likelihood can be expressed as in a variational context there is a unique relationship between the solutions of variational problems in dynamical meteorology and statistical-dynamical problems. Oftentimes, however, the probabilistic aspects of the study are ignored and focus is concentrated on the dynamical interpretation of the results. This is of particular concern in variational analyses in which results are strongly dependent on the norm used and therefore strongly dependent upon the underlying assumed probability density.
In this talk the intrinsic probabilistic interpretation of past studies examining rapid amplification of disturbances, sensitivity of dynamical forecasts, blocking sensitivity and stability, and methods of forecast perturbations for a priori predictability estimation will be given. Solutions to alternative variational constructions which incorporate more realistic probabilistic assumptions will also be given.

Downscaling of Precipitation, Tmax and Tmin over Portugal Using a Neural Network Model Approach

Abstract Number 130
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In recent years several workers have adopted Artificial Neural Nets (ANNs) as a tool to downscale from the large-scale atmospheric circulation to local or regional climate variables (Hewitson et al., 1992, Cavazos, 1997). Despite this more widespread use, most applications do not compare the results obtained from complex non-linear ANN models with those from more standard linear techniques such as multi-linear regression models (which can, in fact, also be obtained from an ANN linear model). Furthermore, cross-validation procedures which quantify the skill of ANNs and also the weight stability are not, as yet, standard. Here, we develop linear and non-linear ANN models to predict local values of precipitation, Tmax and Tmin for a site located in central Portugal (Coimbra). The iterative actualization of weights in the feed-forward configuration was performed using the Levenberg-Marquardt algorithm. Four different fields of large-scale data were extracted from the ECMWF re-analysis dataset for 1979-1993 for a window containing the Iberian Peninsula: 1000 hPa and 500 hPa height, 1000 hPa relative humidity and the 500 hPa vorticity field.
Linear models were developed to predict the precipitation amount on wet days. To allow for the highly skewed distribution of precipitation in Portugal a cubic root transformation was applied. Best results revealed a

correlation coefficient of 0.8 between predicted and observed daily rainfall in a 5 year independent validation period. The non linear models were developed for all days (wet and dry). After several experiments, the best results were obtained with a network with just 2 neurons at the input layer and 4 neurons at the hidden layer (2+4+1 structure) with a correlation coefficient of 0.84 for the independent validation period. We applied a similar approach to compare the performance of linear and non-linear ANN models to predict Tmax and Tmin temperatures at Coimbra. Seasonal modulation was obtained by introducing sine and cosine functions as predictors. R-squared values computed between the modeled and observed time series reveal an improvement from the linear (90%) to the non linear (92%) ANN models.

All results obtained with the non-linear ANN models were cross-validated with an adaptation of the bagging procedure (Breiman, 1997). We divided the 15 years data into a 10 year training period and a 5 year testing period. The training set was then used to generate an ensemble of 20 neural networks models; each member of the ensemble was trained with a subset of values from the original training set. This approach allows the study of model weight stability. The final ANN model output is an average of the outputs from all 20 models.

Using the GMS Digital Data to Analyze the Variation of Cloud Amount in the West Pacific and Southeast Asia Area

Abstract Number 132
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From the cloud imageries scanned by GMS, we can obtain the hourly variation of synoptic scale cloud amount and weather system over the west Pacific and southeast Asia area. First, we analyze the cloud amount from digital data. The variation of cloud amount in these areas can be also shown. Then, by comparing the cloud amount with the rain amount, more deviation between them can be obtained.

Concern with the mean value of cloud amount from 1987 to 1994, the cloud amount can divide into two remarkable main broken cloud regions: one is a wide mid-latitude cloud band which extends southwesterly from Japan and it's southern ocean to central mainland China, the other is a wide low latitude cloud band which covers between 10 N and 10 S and stretches from Malaysia to New Guinea. Due to the geographical site effect, the latter one presents more convective form and higher cloud top than the former one.

Rainfall Estimation from Spaceborne Microwave Data Using Neural Nets

Abstract Number 133
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Rainfall is a key parameter in the study of global climate budget and climate change. Various techniques exist that use microwave (MW) brightness temperature (BT) data, obtained from remote sensing orbiting platforms, to estimate rain rates. The most commonly used techniques are based on regressions (single- or multivariate) or other statistical methods. An emerging tool in rainfall estimation using satellite data is neural networks (NN's). NN's are non-linear mathematical models that are capable of learning complex relationships. They consist of highly interconnected, interactive data processing units. NN's are implemented in this study to estimate rainfall, and backpropagation is used as a learning scheme. The inputs for the training phase are BT's (at various frequencies and horizontal and vertical polarizations) and the outputs are rainfall rates, all of the above generated by simulations based on a 3-D stochastic, space-time rainfall model, and a 3-D radiative transfer model. The rainfall rates are also estimated using a log-linear regression model. Comparison of the two approaches, using simulated data, shows that the NN's can represent more accurately the underlying relationship between BT and rain rate than the regression model. Once the training is complete the NN's and the regression model are then presented with observed BT data with the same frequencies and polarizations as the training data. The BT data were obtained by the Special Sensor Microwave/Imager (SSM/I) instrument onboard the F10 and F11 polar-orbiting meteorological satellites. This way, rain rates corresponding to real BT measurements are generated. Comparison of the rates, estimated by both methods, with radar-estimated rain rates shows that NN's outperform the regression approach. This study demonstrates the great potential of NN's in estimating rainfall from remotely sensed data.
Currently, NN's of various architectures are used in an attempt to estimate rainfall from satellite images in visible, infrared, and far-infrared wavelengths.

Long-Term Changes in Nordic and Arctic Extreme Temperatures

Abstract Number 134
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The Nordic meteorological institutes produced a comprehensive data set of climatic extremes containing stations from Fenno-Scandia, Nordic Seas, and Greenland. Long-term time series of extreme temperatures (daily mean maximum, daily mean minimum, absolute highest and absolute lowest) and temperature ranges were analysed for trends. Indices of atmospheric circulation and cloudiness were used to explain the observed temperature changes.

In total, 68 stations were retrieved from data archives. Almost all the stations have records starting before 1950 and about 65% of them started in 1910 or earlier, most of them located in Fenno-Scandia. Standard normal homogeneity test and station histories were used in homogeneity testing. The reliability of daily mean maximum and minimum temperatures were evaluated against good quality, independent mean temperature series. It was found that without homogenisation data prior to the 1950s can be systematically biased due to changes in radiation screening and station relocations.

Mean maximum and minimum temperatures show statistically significant negative trends in West-Greenland during the period 1950-1995, while the trends are generally positive in Nordic Seas and Fenno-Scandia. The highest and lowest temperatures seem to follow the variations in the mean values. The absolute temperatures have not become more extreme compared to mean maximum and minimum. The diurnal temperature range (DTR) is decreasing significantly throughout study area despite the fact that regional temperature trends show both warming and cooling.

The strengthening of North Atlantic Oscillation (NAO) causes the opposite temperature trends between West-Greenland and Fenno-Scandia since the 1950s. However, NAO index fails to explain the decrease of DTR in West-Greenland and explains only partly DTR narrowing in Fenno-Scandia.

In Fenno-Scandia, reliable mean maximum and minimum temperatures show cooling in winter, and warming in spring and summer from 1910-1939 to 1966-1995. Simultaneously, DTR has been decreasing in all seasons except winter (-0.30K/100y on annual level).

Atmospheric circulation indices defined as zonal and meridional sea level pressure differences, sea level pressure anomalies, and cloud cover were used to build multiple linear regression model for Fenno-Scandian DTR during the period 1910-1995. Seasonally, the linear models explain from 53Cloud cover dominates as the most important predictor, but circulation give sub-

stantial support. On annual level, the independent estimate of the linear trend is smaller than observed. The residual trend of DTR is -0.04K/100y.

Climatological Analysis for Norway by Spatial Statistics Supported by GIS.

Abstract Number 135
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The spatial variability of climatological elements are strongly influenced by physiographical parameters like elevation, slope, exposition, distance from coast etc. Comprehensive use of this kind of information has traditionally been difficult to handle in traditional methods used in climatology. Development of new methods for spatial interpolation, and introduction of geographical information systems (GIS) have opened new possibilities in mapping climatological elements. Geostatistics offer a wide variety of approaches estimating values at locations without observations. During the last years, such methods have been widely applied also within climatology. Geostatistical methods are however restrained by assumptions which are difficult to fulfil for climatological elements. Especially in hilly terrain, e.g. the intrinsic hypothesis cannot directly be assumed to be valid.
In a study carried out in Norway, it was assumed that the spatial variability of climatological processes can be expressed by two terms, a deterministic component and a stochastic component. The deterministic component should be related to some physical understanding of the variability of the process, and describes the trend in the process as a function of e.g. topography or continentality. The lapse rate of air temperature could be interpreted as one possible deterministic component. Regional and local anomalies are mapped by the stochastic component, which is represented by a spatial structure function (semivariogram, correlogram). Application of this method is a three step process:
1. Remove the trend (deterministic components) from the observations. (E.g. expressed as a function of elevation, distance from coast, etc.).
2. Establish a spatial structure function for the reduced field, and interpolate a continuos surface by applying kriging or equivalent methods.
3. Add the deterministic components to the interpolated field, applying the inverse of the functions used in step 1.
This approach is carried out for southern Norway, estimating mean monthly temperatures for the standard normal period 1961-90. The deterministic component used is the temperature lapse rate. The approach shows good results, but for some months there are problems estimating temperature in the mountain areas. The stations are mostly located in or near the bottom

of the valleys, where winter temperatures are influenced by inversions.
For comparison, a multiple regression analysis was performed applying station altitude and distance to coast as independent variables. One analysis was performed for all of southern Norway, which includes both maritime and continental climate. The regression generally shows good skill for the study area. In some regions, however, large deviations from the observed values were detected. Regression cannot be regarded as a regional method such as the spatial interpolation approach. It is therefore not very applicable for larger areas with large variations in climatological characteristics. Under such conditions, spatial interpolation taking local and regional patterns into account is a better approach.
Advantages obtained by using GIS and spatial interpolation in climatological mapping are objective, consistent and time efficient calculations. The established procedures are important in establishing detailed consistent water balance maps for Norway. They may also be used in downscaling large- and meso-scale model output to values at local (small) scale.

Significant Periodicities of Regional Climatcic and Agroclimatic Parameters in Greece

Abstract Number 136
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It is know that significant periodicities consinst a major component fo time series analysis along with trends. In this study an effort was undertaken to deal with the computation of significant periodicities of regional climatic and agroclimatic parameters. More particularly, as climatic parameters used were the air temperature, the precipitation and cloud cover, whereas as agroclimatic parameters were the Palmer's Drought Severity Index (PDSI) and the Moisture Anomaly Index (or Z-Indes). The emphasis was mainly giveen on the caluculation of significant periodicities from time series of air temperature, precipitation and cloud cover, and of PDSI and Z-Index as well. This was carried out by applying power spectrum analysis over homogenous monthly data for the climatic and agroclimatic parameters concening the erios of 1950-1987. The data had previously been detreanded and de-seasonalized. The whole country was classified into homogeneous regions with regards to droughts by using Factor Analysis, but only two regions were selected for this analysis namely western and northern ones. The results have shown that for each processed parameter the most frequent significant periods were shorter than four months, whereas the category of half-year periods (5.1-*.0 months) was relatively frequent and that of approximately one year length occur very rarely due to the

removal of the 12-month seasonality. Similarly, for the agroclimatic parameters the most frequent periods were also shorter than four months, whereas there was no period longer than that of two years. Moreover, in some stations the power spectrum of Z-Index was equally distributed in all frequencies and it resembled a white noise more or less, even if there were some significant periods ineach series. It was apparent that very high power spectrum values were typical for low frequencies (less than four motnths) whereas for frequencies higher than six months the power spectrum values were low although statitically significant at 0.95 confidence level.

Review of Possibilities and Limitations of Natural and Constructed Analogues

Abstract Number 137
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Using the modem NCEP-NCAR Reanalysis data set 1958-1996, fresh calculations have been made to review and illustrate some of the potential and limitations of the search for pairs of natural analoaues in the earth's atmosphere. This subject has of course a long history. In general, there is a three way relationship between the size of the library of observed past flow patterns (M-40years), the number of degrees of freedom in the problem (N-1-100) and the desired accuracy of matching (epsilon). For an area the size of the Northern Hemisphere, and a field like 500 mb height (instantaneous; N-30), we, unfortunately, cannot expect a better match, on average, than a 0.5 correlation. There are very few cases where AC $>= O.70$, the maximum being 0.74 for one case in the SH. We present results of rather exhaustive searches in Reanalysis data for natural analogues for both hemispheres and the tropics as a function of season. On many days the climatology is the nearest neighbor, not a flow observed in the past. The main limitations are; shortness of data set (we cannot change that, except by resorting to model generated data); and the large number of degrees of freedom in many problems. The latter can be reduced in various ways, for instance by chosing a smaller area, or by truncation in some phase space (3 EOFS) - the utility of these two options will be discussed. Because good analogues over a large area are improbable, their inherent strength, non-linear forecast by a perfect model, remains largely or completely elusive. For instance, at an initial matching accuracy of only 0.6, an analogue forecast cannot beat persistence of the initial state as a forecast for day 1. Unexplored options involving ensembles of forecasts by the analogues method may aleviate this problem. Also, antilogues are no worse as a forecast than analogues, thus implying that the non-linear terms do not contribute to skill. Use of antilogues effectively increases the library size by a factor of two. Another finding is that the ramping up towards the most analogous state (such as

it is) is similar to the divergence once the point of closest encounter is past. This does raise possibilities of reversing time and increasing the effective data set size by another factor of two.
Some limitations can be overcome by constructine an analooue. We have made a linear combination of states observed in the past, such that the constructed field is a very close match of the present state in all its details. The shortness of record is no longer a problem. However, forecast potential is limited to those problems where time tendencies are dominated by linear processes (advection of anomalies by a background flow is a linear process). A constructed analogue approach has much in common with calculating a linear operator from past data, as in POP or 'inverse modelling', without the need to know the underlying equations. Even though CA can beat persistence handily, short-term forecasts of 500 mb height is an unlikely practical application. However, applications to forecasts of Pacific SST (out to a year) and soil moisture over the US (a few months) appears promising.

Evaluating EV1-techniques for estimating upper quantiles of TCEV-data

Abstract Number 138
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This paper deals with the quality of estimators of quantiles in the upper tail of TCEV-distributed annual maxima, where the estimation technique is based on an EV1-approach of bi-annual maxima. The relative root mean square error of the quantile estimator is quantified by simulation.

Assessment of the Technique for Identification and Adjustment of Inhomogeneities in Canadian Temperature Series

Abstract Number 139
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Canada and other countries around the world have carefully monitored temperature changes over the last century. It is well known that the global mean temperature has increased by about 0.5C during the last 100 years, and that temperature series show periods of warming and cooling over time. However, temperature variations at individual sites are not always the result of climate variations only. Human activities such as station relocations, replacement of instruments, changes in observing procedures, urbanization, automation and others often cause patterns in temperature series totally unrelated to climate behaviour. Using datasets that are not adjusted for non-climatic variations can affect the correct assessment of climate trends in global-scale, and more seriously in regional-scale analyses. For this reason, investigation and development of new techniques for homogeneity assessment and adjustment of climatological time series is ongoing.

Several methodologies have already been presented in the scientific literature. They have addressed a variety of problems and many different objectives. Recently, a new technique was developed for the identification and correction of "inhomogeneities" in Canadian temperature series. The technique was designed with the following objectives. First, homogeneous and inhomogeneous intervals are identified in order to focus the search for the inhomogeneities. Second, non-climatic steps and trends are detected separately with adequate estimates of their magnitude and position in time. Finally the most probable position of the inhomogeneity is identified in the absence of prior knowledge of the real time of change at the station in order to minimize the dependency on station history files.

This new technique consists of the successive application of four linear regression models to determine the following situations in a tested series: whether it is homogeneous, if there is a non-climatic trend, a step, or trends before and/or after a step. The dependent and independent variables are the annual temperature series at the tested site and at a number of surrounding sites respectively. Additional independent variables are also used to describe steps and trends in the tested series. After the application of each model, the residuals are analysed to assess the fit. The autocorrelation in the residuals are obtained for several distances apart. Consecutive significant values of the autocorrelation identified at low lags indicate the

poor fit of the model and in this case, the next model is applied. If there is still significant autocorrelation after the application of the fourth model, the series are then divided at the identified step, and each segment is re-tested separately. In this manner, the procedure systematically divides the tested series into homogeneous segments, and adjustments are applied to bring each segment into agreement with the most recent homogeneous part of the series.

During the presentation, the technique will be briefly described. The main objective is to present an assessment of its ability to properly identify inhomogeneities. To evaluate its performance, it is necessary to test a large number of series representing a variety of situations. Annual temperature series are simulated using an autoregressive process, creating series of 100 time elements. Steps and trends of various magnitudes and starting at different positions in time are introduced in the simulated series, and each situation is tested 1000 times. Results show that the date of the step within 2 years and its magnitude within 0.2C are correctly identified most of the time, when artificial steps vary from 0.75 to 2.0C; however, steps of 0.5C are not as frequently identified, and steps of 0.25C are not detected very often. This new technique has also been tested using archived temperature datasets for which it is possible to confirm the cause of the identified inhomogeneities through the station history files.

Long-term, complete and homogeneous monthly mean maximum and minimum temperature series have been assembled for 210 Canadian sites. Missing values have been estimated, segments were sometimes combined to extend the data back in time, and datasets were tested and adjusted for inhomogeneities using this new technique. Results of homogeneity assessment, position and magnitude of each identified inhomogeneity, and data adjustments have been tabulated along with potential contributing causes retrieved from the station history files. The Canadian Historical Temperature Datasets are the best Canadian temperature data assembled to date, and now they are available to researchers for the analyse of climate change and climate variability in Canada.

Variability of the Present-Day Thermohaline Circulation: Spectral Shapes and Spatial Scales

Abstract Number 140
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Statistical properties of the variability of the present-day thermohaline circulation are estimated from four 1000-year integrations with the coupled general circulation models of the Geophysical Fluid Dynamics Laboratory

(Princeton, USA) and the United Kingdom Meteorological Office and with the Hamburg ECHAM1/LSG and ECHAM3/LSG models. Two types of properties are considered. The first one concerns the spectral features of mass transports. The analysis is focused on the spectral power laws, rather than on the spectral peaks at particular frequencies. It is shown that the spectra increase with decreasing frequency at the rate of about 1/frequency for transports of Atlantic deep water. The result indicates that the spectral power laws are functions of transport properties of different water masses. The second statistical property concerns the spatial structures of mass transport. It is shown that the most dominant covariance structures describe recirculations within each ocean basins. In contrast to the time-mean state which is a cross-basin phenomenon, large-scale variations around the mean reveal weak cross-basin connections and have therefore much smaller spatial scales than the mean circulation. A mechanism responsible for such spatial patterns is discussed.

Redundancy Analysis as a Downscaling Tool

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In Statistical Downscaling, a functional dependence between a large-scale climate variable and a local climate-sensitive variable is empirically determined. Usually both, the large-scale and the local variable is a multidimensional field, so that in both variables sub-spaces are determined, and the downscaling operator is established between these subspaces. In this situation, usually Canonical Correlation Analysis has been used for the determination of both the subspaces and the link.
As an alternative to Canonical Correlation Analysis, which optimizes the strength of the link in terms of its correlation, a technique labeled "Redundancy Analysis" may be used. This technique, which seems no to have been used in climate applications, maximizes the amount of variances of the local variable represented by the downscaling link.
The Redundancy Analysis is introduced and its merits are illustrated by an example. The local variable (predictand) is a vector of intra-monthly percentiles of wave heights at selected locations on the European shelf, and the large-scale variable (predictor) is the monthly mean air pressure in the Northeast Atlantic. The downscaling model is applied to climate change scenarios, indicating a weak increase of wave heights at the time of doubling CO2 concentrations.

Checking Multiple Time Series for Intrinsic Correlation

Abstract Number 142
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We examine the computation of Empirical Orthogonal Functions (EOFs) for autocorrelated time series from stations in geographical space. *Coregionalized EOFs* are defined in the framework of a linear model of coregionalization. In the case of *intrinsic correlation*, i.e. when the auto- and cross-correlation functions of the time series are all proportional to one basic auto-correlation function, the coregionalized EOFs are equivalent to the classical EOFs built under the assumption of iid time replications. When the correlation between the stations is not intrinsic, the classical EOFs are meaningless from a geostatistical point of view. It is thus important to check multiple time series for intrinsic correlation before doing EOF computations.

Variational Methods in Three and Four Dimensional Climate Data Analysis Problems

Abstract Number 143
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We discuss variational approaches to analyzing three and four dimensional global historical data sets, with and without climate models. Several new and old models are included as special cases. In particular the smoothing spline ANOVA model of Luo, Wahba and Johnson is included. For raw data interpolation and filtering, the models have an ANOVA decomposition which provides direct estimates of various anomalies of interest to atmospheric scientists. The models are fitted by a global optimization procedure, and the most important smoothing and tuning parameters can be identified and estimated by *GCV* or *GML*. Data may be scattered in time and space. An EM-like backfitting and imputation algorithm along with randomized trace methods may be used to fit data sets of the order of several times 10^4. Various diagnostics are available. This class of methods also has the ability to easily identify outliers or unusual observations. The method is applied to the estimation of winter surface temperature trends

as a function of space, based on the Global Historical Climate Network data set, and to obtain direct comparisons to various functionals of climate model output, including time trends as a function of space of forced minus unforced climate model output as a function of space. Four dimensional data assimilation with models will be briefly mentioned.

Simulation of global and hemispheric temperature variations and signal detection studies using neural networks

Abstract Number 144
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The concept of neural network models (NNM) is a statistical strategy which might be used if a superposition of any forcing mechanisms leads to any effects and if a sufficient related observational data base is available. In comparison to multiple regression analysis (MRA), the main advantage of NNM is that it is an appropriate tool in the case of non-linear cause-effect relations, too. Furthermore interactions of the forcing mechanisms are allowed. In addition to that it is not necessary that details of the physical background, like feedbacks, are known, as it is when using more sophisticated methods like general circulation models (GCM). NNM learn from observations which reflect feedbacks implicitly.
The disadvantage of the NNM approach is, of course, that the physical background is neglected. In addition, the results prove to be highly sensitive to the network architecture (e.g. number of processing units, learning constants, length of time series in question).
We used a supervised learning backpropagation network (BPN) with three neuron layers as well as an unsupervised learning counterpropagation network (CPN). This network architecture consists of a so-called Kohonen-layer, where the features of the data are trained plus the so-called Grossberg layer. Here the "learned" internal representations are adjusted to the observed time series to be simulated.
Both concepts (BPN, CPN) were tested in respect to their ability to simulate the observed global as well as the hemispheric mean surface air temperature annual variations 1874 - 1993. For this the parameter time series of the following forcing mechanisms were incorporated: equivalent CO_2 concentrations, tropospheric sulfate aerosol concentrations (both anthropogenic), volcanism, solar activity and ENSO (all natural).
Hence follows that up to 83% of the observed temperature variance can be

explained, which is significantly more than by MRA. On a global average, the greenhouse gas (GHG) signal is so far assessed to be 0.9-1.3 K (warming) and the sulfate signal 0.2-0.4 K (cooling). These results are very similar to the GCM findings published in the recent IPCC Report. The related signals of the natural forcing mechanisms considered cover amplitudes of 0.1-0.3 K.

Characteristics of El Niño-La Niña Variability in a Low Dimensional Phase Space Derived From Observational Data

Abstract Number 145
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The variability of El Niño - La Niña events were analyzed in a low dimensional phase space – a concept derived from dynamic system theory. The space-time extended EOFs derived from diagonalizing the space-time covariance matrix of the observed monthly mean SST field over tropical Pacific were used as the basis (or coordinates) of the phase space to describe the time evolution of the SST associated with El Niño - La Niña dynamics. It was shown that the basic features of the ENSO variability, such as the irregular oscillation, the phase-locking to the annual cycle and the inter-decadal changes, can be effectively represented by a 3-dimensional phase space. This provides an example of a complex system of the coupled ocean and atmosphere generating relatively simple dynamics in terms of a low dimensionality. The conclusion regarding the dimensionality of the ENSO system is derived from dynamic insights rather than through calculating the fractal dimensions. It is argued that derivation of a fractal dimension is less plausible in many instances of physical realities, such as the ENSO dynamics. Besides, it is indeed more relevant to know the minimum number of variables to describe the system than the fractal dimension. Our conclusion of low dimensionality of the ENSO, derived from observational study, is in consistent with those from dynamic model studies. The subsequent phase space analysis shows that the typical ENSO life cycle is 4 years and that El Niño and La Nina are the opposite phase of the same dynamics, referred to as the ENSO signal. The observed biennial component is a sub-harmonic of the 4-year life cycle. The role of annual cycle in the ENSO dynamics is most clearly demonstrated in the phase portraits; The inter-decadal variability is associated with the regime behavior and intermittency of the ENSO system, which is clearly revealed from the phase diagrams and the associated ENSO intensity.

Interannual Variability in an Ensemble of GISST Simulations Conducted With the CCC GCM2

Abstract Number 146
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Interannual variabilities arising from slowly varying boundary conditions, i.e., signals of the boundary forcing, which are potentially predictable, are of great importance in terms of seasonal climate forecast. Here, we analyze the interannual variability and potential predictability in an ensemble of climate simulations, in which the observed time-evolution of global sea surface temperature (SST) and sea-ice extent for the 1948-1994 period, as contained in the Hadley Centre's GISST data set, is prescribed as the atmosphere's bottom boundary. Using the analysis of variance (ANOVA) approach combined with principal component analysis (PCA), we discuss both the distribution of the forcing signal over the globe and leading spatial patterns of variability that carry the forcing signal. Also, we apply correlation analysis to further examine the relationships between the leading patterns and the global SST anomalies.

Significant externally forced signals are diagnosed in all four seasons of year. Most of these signals are exposed in the mid to lower latitudes. Little signal was diagnosed outside 60S-60N in DJF and outside 50S-50N in other seasons. The signal was found to be strongest in DJF. Particularly, a distinct PNA-like structure is observed in the maps of externally-forced variance ratios in DJF and MAM of ENSO years, which is not seen in non-ENSO years. It is shown that such a structure is a stamp of an intimate connection between the PNA mode and the external forcing/ENSO. Actually, ten leading modes of atmospheric variation were diagnosed to be significantly (at 1% level) related to the prescribed forcing. Among these modes, the PNA and NP modes were found to be most sensitive to the forcing and significantly associated with ENSO in all seasons except JJA. In particular, over northern North America, little signal was found in non-ENSO years. In JJA, the most dominant mode SZ was found to be most sensitive to the forcing but not strongly related to ENSO.

It has also been shown that the prescribed bottom boundary conditions substantially strengthen some modes, such as PNA, NP and SZ, while relatively damping other modes (e.g., NAO).

How Large Do Ensembles of Climate Simulations Need To Be?

Abstract Number 147
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Much current interest focuses on the natural variability of the climate system. One method to investigate this aspect of the climate is to perform ensembles of model simulations starting from slightly perturbed initial conditions. Natural chaos inherent in the system causes the synoptic histories of each realization to be quite different after a short period of integration. Longer term climatic average quantities also differ between such realizations. The magnitude of the inter-realization variance in these calculated climate statistics is a measure of the model climate's internal variability.
The high computational expense of lengthy integrations of general circulation models places severe constraints on the number of realizations that most modeling groups can afford. Therefore, credible estimates of the minimum required ensemble size are extremely important to the design of model experiments. Rigorous determination of the minimum ensemble size must consider not only the internal variability of the model but also what is hoped to be learned from the model experiment. Hence, the questions asked by the experimenters as well as the precision to which they must be answered are important considerations in determining how many realizations are necessary.
In this talk, we examine the ensemble size issue by asking how many realizations are required to determine a model's average seasonal mean quantities to within a specified tolerance and statistical certainty. A simple application of standard statistical analysis tools and assumptions yields the answer. We test this method using the results obtained from an ensemble of 20 AMIP realizations of the LLNL AGCM. Not surprisingly, we find that the minimum ensemble size is a strong function of the variables being analyzed. The temporal and spatial scales defining the climatic average, as well as the time of year, also strongly influence our results.

Bivariate Wavelet Analysis with Application to the Madden-Julian Oscillation

Abstract Number 148
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The Madden-Julian oscillation (Madden and Julian 1971) was originally detected using bivariate spectral analysis. The oscillation has been described as having a period anywhere from 30-60 days. We propose to investigate this apparent "broadband" feature using the discrete wavelet transform (DWT). The DWT is known to decompose the variance of a univariate process on a scale by scale basis. We show the wavelet covariance decomposes the covariance between two stationary processes on a scale by scale basis. We define the wavelet cross-covariance and wavelet cross-correlation, and derive their statistical properties. We then apply these techniques to the data used in Madden and Julian (1971) in order to gain additional insight into the properties of this atmospheric phenomenon.

Relations Between Trends in Swiss Wintertime Precipitation and Large-Scale Pressure and Temperature Changes

Abstract Number 149
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Wintertime (DJF) precipitation in Switzerland has increased during the periods 1961-1990 and 1901-1990 by up to 30%. Here we attempt to relate these trends to changes in the atmospheric circulation over the domain 40°W-30°E and 30°N-70°N, using singular value decomposition (SVD).
For the winters 1961-1990, the North Atlantic Oscillation Index (NAOI) has a positive trend. Yet it can not explain the precipitation trend, since NAOI and Swiss precipitation are almost uncorrelated on a monthly time scale. However, 80% of the precipitation trend are attributable to changes in sea level pressure (SLP) by means of the leading mode of a SVD between monthly SLP and Swiss precipitation. The trends of both the NAOI and the

SVD mode represent an increasingly westerly flow towards central Europe, but only the latter filters out the component of the SLP trend which is actually linked to Swiss precipitation.
These results indicate that the commonly used NAOI might not be optimal to describe large-scale influences on parts of the central European sector. Our SVD analysis shows that alternative SLP anomalies exist whose time series correlate well with precipitation but only poorly with the NAOI.
With respect to the winters 1901-1990 there is a small decrease of zonality in the SLP field over western Europe, which is associated with a slightly negative trend in the leading SLP mode. Higher SLP modes also reveal only very small trends. Thus the precipitation increase in this period can not be attributed – by means of SVD – to changes in SLP. Note that this does not rule out that SLP changes, which are neither captured by the NAOI nor by the leading SVD modes, are related to the Swiss precipitation trend.
In contrast to the 30 year period, the leading mode of a SVD between monthly temperature and precipitation allows to attribute a substantial fraction (55%) of the 90 year precipitation trend to changes in near surface temperature. The temperature trend DJF 1901-1990 and its projection on the first SVD mode show both increasing temperatures over central and southern Europe and decreasing temperature over parts of northern Europe and parts of the Atlantic.

Evaluating GCM Predictors for Statistical Downscaling

Abstract Number 150
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Statistical downscaling has emerged as a promising technique for relating mesoscale atmospheric predictor variables (such as mean sea level pressure patterns) to station scale, surface climate variables (such as daily precipitation or temperature). By employing the same empirical relationships, it is then possible to generate high resolution data sets for climate change impact assessments using grid-point predictors obtained from General Circulation Models (GCMS). However, a growing number of studies have considered the inherent limitations of downscaling and have pointed to the need for more rigorous examinations of model uncertainty. Simulations with a statistical downscaling model are used to investigate the significance of uncertainties associated with GCM forcing variables to the downscaled climate. The GCM used was the U.K. Meteorological Office, Hadley Centre's coupled ocean/atmosphere model (HadCM2) forced by combined CO2 and sulphate

aerosol changes. Climate model results for 1980-99 (present) and 2080-99 (future) were used to downscale daily precipitation, temperature, humidity, sunshine totals and wind speeds for six regions in the USA. Analyses of the GCM predictors suggests that variable realism, internal consistency and sensitivity to anthropogenic forcing are major factors affecting downscaled scenarios. Biases in downscaling model accuracy and the choice of predictor variables used also significantly affect future climate scenarios at local and regional scales.

Low-Frequency Characteristics of Several Stochastic Daily Precipitation Models

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Monthly and seasonal variances exhibited by nine stochastic daily precipitation models, each constructed using one of three models for precipitation occurrence, and one of three probability distributions for nonzero precipitation amounts, are examined. The three occurrence (renewal) models are: first-order Markov dependence (geometric distributions of wet and dry spells), separate negative binomial distributions for wet and dry spells, and separate mixed geometric (a probability mixture of two geometric distributions) distributions for wet and dry spells. The three precipitation amount distributions examined are: 2-parameter gamma distributions; three gamma distributions with common shape parameter but separate scale parameter for isolated wet days, leading wet days of wet spells, and subsequent days of multi-day wet spells; and mixed exponential distributions (probability mixture of two exponential distributions). The models are evaluated using daily precipitation data from locations across the U.S., and for a group of stations in the Czech Republic. Goodness-of-fit evaluations indicate that simple first-order Markov dependence is quite adequate in many cases, and that negative binomial distributions are preferred over mixed geometric distributions according to the BIC statistic for nearly all of the remaining series.

It is commonly observed that the low-frequency variability exhibited by models of this kind (expressed for example as the interannual variance of monthly or seasonal total precipitation) is smaller than in the corresponding observations. Following Katz and Parlange (Journal of Climate, in press), the interannual variability of monthly or seasonal total precipitation was decomposed into two terms: 1) the average number of wet days multiplied by the variance of wet-day amounts, and 2) the variance of the number of

wet days times the square of the mean wet-day amount. Since the individual occurrence and amounts models capture the respective means essentially exactly, the variation in these two terms can be attributed to the variance of the number of wet days per month (i.e., to the occurrence models), and to the variance of wet-day amount (i.e., to the precipitation amount distributions), respectively. It is found that a commonly used daily stochastic model, involving first-order Markov dependence and gamma distributions, yields interannual variance that is too small by approximately 20that using negative binomial and mixed exponential distributions reduces this overdispersion to approximately 4renewal models are compared in terms of their capacity to represent the extrema of the empirical spell-length distributions. For the U.S. stations at which first-order Markov dependence appears to be adequate overall, the extrema are also well captured. However, the longest spells are underestimated at locations for which a negative binomial distribution with a longer tail is required – typically for dry spells at locations in the western U.S. In these cases both negative binomial and mixed geometric distributions perform well. For the Czech stations, first-order Markov dependence strongly underestimates the extrema of dry-spell distributions. The negative binomial is much more accurate in this regard, and the mixed geometric is somewhat better still.

Statistical Downscaling of Daily Precipitation using Stochastic Weather Models

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The problem of downscaling precipitation climates, i.e., inferring local changes in the precipitation climate on the basis of control and perturbed GCM integrations, is approached through adjustment of parameters of respective daily stochastic precipitation models. The stochastic model employed involved first-order Markov dependence for daily precipitation occurrence, and mixed exponential distributions for nonzero daily precipitation amounts. The procedure involves two stages. The first, termed "extrapolation," involves adjusting parameters fit to observed area-averaged precipitation series according to differences in the respective statistics derived from the two GCM series. The actual "downscaling" transfers these changes to the local scale, using observed relationships between station- and area-averaged precipitation statistics. The procedure is illustrated using five station series in each of six gridbox-scale regions in the U.S.
The extrapolation is achieved by adjusting the unconditional wet-day prob-

ability (a function of the Markov-chain transition probabilities) and the mixing probability for the precipitation amounts distributions additively on the log-odds scale. The autocorrelation of the (binary) precipitation occurrence series (also a function of the transition probabilities) is adjusted additively on the the Fisher Z-transform scale. The two scale parameters of the mixed exponential distribution are then adjusted in a way that yields proportional changes in the monthly or seasonal mean precipitation, and in the interannual variance of the monthly or seasonal precipitation totals. The downscaling then proceeds by fitting box-specific regression relationships for the climatological wet-day probability, and then determining the remaining downscaled station-level parameters in a way that preserves the extrapolated monthly or seasonal means and variances at the area-average scale. Linear regressions for (log-odds transformed) station wet-day probabilities are developed, using box-scale log-odds wet-day probabilities and geographic location parameters as predictors. These relationships are reasonably consistent through the annual cycle, and apparently reflect systematic effects of topographic and stable climatic gradients within the boxes. Next, it is observed that the variance of the number of wet days at the station and box levels are approximately proportional, and that (empirically) the proportionality involves the 2/3 power of the station's wet-day probability. This relationship appears to hold reasonably throughout the year for all of the 30 stations ($R^2 = 87.2\%$). The station-level occurrence-series autocorrelations are specified using this relationship, (the variance of the number of wet days depends on the wet-day probability, the autocorrelation, and the number of days in the month or season), which appears to help ensure consistency between the first two moments of the number of wet days per month or season. Corrections can be applied to compensate for the imperfect fits of these relationships.

Finally, the parameters of the mixed exponential distributions are downscaled in a way that ensures consistency between the first two moments of total monthly or seasonal precipitation at the station and box scales, by assuming that changes in the means and variances of this quantity are proportional: the ratio of downscaled to observed station mean (or variance) equals the ratio of extrapolated to observed area-average mean (or variance).

A Verification Method for Ensemble Forecasts

Abstract Number 153
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A new verification method for assessment of the output from an ensemble prediction system (EPS) is described and illustrated. An EPS presents a

particular challenge to verification methodology because the EPS forecast consists of a collection of estimates of the output variables, all of which are to be matched to single values of the variables at the verifying point and time. Essentially, the problem is to verify an estimated probability distribution against a single realization extracted from a different distribution. The new verification method comprises an accuracy measure and a skill measure, and is conceived in a Bayesian context. The ensemble forecast can be considered to estimate the posterior distribution of the model variables following the "experiment" of the model run, while the climatological distribution may be considered to be the prior distribution of the variables, representing what was known before the model run. An accuracy score can then be defined by calculating the probability of obtaining the observed value of the variables given the ensemble distribution, a suitable "unskilled" score can be obtained by calculating the probability of occurence of the observation given the climatological distribution. A skill score can be defined in the usual format, as a percentage improvement of the score over the unskilled forecast.

To test the score and the skill score, we have used two seasons of forecasts from the ECMWF EPS. We have tested the score for surface weather elements 2 m temperature, quantitative precipitation,and 10m windspeed, and for 500 mb heights. To facilitate computation of the scores, we first fitted probability distributions to the EPS forecasts, and used these to estimate the probability of occurrence of the observations. As a first estimate, we assumed the predicted ensemble distribution might be of the same shape as the climatological distribution for the corresponding weather element, normal for upper air variables and 2 m temperature, gamma for precipitation, and Weibull for wind speed. Distributions were fitted to a large climatological sample for each verification location, and for each day of the year. Calculation of the scores also meant choosing a reasonable range of values about the observation that would be considered correct. Although somewhat arbitrary, these choices allow the selection of meaningful ranges for each variable. For example, all light winds were assigned to a single range, since these are less important to forecast accurately. Results show the score to be severe, but sensitive to the location and spread of the ensemble with respect to the observation. Skill for temperature forecasts was found to be positive with respect to climatology for all stations tested, for all 10 days of the forecast, but precipitation forecasts rarely showed skill beyond two or three days. Although we had only one case for tests of 500 mb height verification, the results indicated considerable potential for diagnostic use of the score to represent spatial variations in accuracy of the ensemble forecasts. The presentation will include a description of the score, illustration of its application, and disucussion of its use both for short and medium range ensemble forecasts and potential applications to ensemble seasonal forecasts.

Probability Forecasting: The Legacy of Allan Murphy

Abstract Number 154
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Allan Murphy was instrumental in moving forward probability forecasting, forecast verification, and the use and value of forecasts. His work had great influence beyond meteorology, in fields such as statistics, decision analysis, and forecasting. His interdisciplinary contributions spanned conceptual issues, methodology development, empirical studies, behavioral experiments, development of decision-making models, and applications. This talk will highlight his contributions outside of meteorology and will briefly discuss current research issues in probability forecasting.

Analysis of ENSO Events using Earth Radiation Budget Experiment Observations

Abstract Number 155
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The El Niño/Southern Oscillation (ENSO) is a large-scale climatological phenomenon of the ocean-atmosphere system. While ENSO events originate in the deep tropics, their effects can be felt worldwide through the disruption of normal atmospheric general circulation patterns. In addition, ENSO can also significantly alter the distribution of the Earth's radiation energy balance at top of the atmosphere (TOA) through the changes in sea surface temperature (SST) and the subsequent changes in meteorological parameters (such as, temperature, moisture, and cloud conditions) due to the feedback interaction between SST and the atmosphere.
This study uses TOA broadband shortwave (SW; 0.2 to 5.0 microns) and broadband longwave (LW; 5.0 to 50.0 microns) radiation data collected from the NASA Earth Radiation Budget Experiment (ERBE) non-scanner instruments between November 1984 and August 1997 and SST data of the same period. Statistical analyses (both in time and space) are carried out to examine the variability of TOA broadband radiation budget (both the SW and the LW) and their association with the changes in SST pattern during the past ENSO events observed in the ERBE data records. Time-lag correlation analysis are used to determine the phase-lag relationship between changes in SST and the corresponding transformation in the

ERBE TOA SW and LW radiation fields. Spatial and temporal analysis of the SST and TOA radiation fields are performed to establish the strength (both in time and space) of the El Niño events. Finally, comparisons are made to access both the differences and the similarities among the 1986/87, 1991/92, 1994/95, and the current ENSO events.

Specification and Prediction of Ethiopian Rainfall using S-mode Component and Canonical Correlation Analysis Based on Global Sea Surface Temperature Anomalies.

Abstract Number 156
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A reconstructed global sea surface temperature of NOAA with 6 degree by 6 degree resolution has been used to investigated predictive linear relationship between near-global SST and Summer rainfall over Ethiopia, based on 1954 to 1992 period using S-mode principal component and canonical correlation analyses. S-mode principal component analysis is used to filter out the noise from the signal of rainfall and sea surface temperature data. The canonical correlation analysis is used to measure the strength of the linear combination of the several strong leading modes.
The cross-validation and correlation between and the rainfall forecast and the observed used to represent the skill.
The results of the study strongly indicate that the rainfall over eastern, southwestern, northwestern, western, central and northwestern Ethiopia can be predicted with a significant skill using near-global sea surface temperature in the linear mode at various lead time up to twelve moth leads. The results found in his study are very important and have economic value for the country where the economy is rain-fed agriculture.

Ensemble Seasonal Climate Prediction: Model Intercomparison and Likelihood Estimation

Abstract Number 157
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Due to the chaotic nature of the atmospheric dynamics, the future behavior of the atmosphere on both weather and climate timescales should be described in probabilistic terms. Our research approaches the problem of probabilistic climate forecasting by assessing and comparing ensemble forecast skills of the following atmospheric general circulation models (GCMs) runs:
-25 years of 10-member ensemble of Max-Planck-Institute for Meteorology, Hamburg ECHAM-3 model
-23 years of 13-member ensemble NCEP model
-16 years of 9-member ensemble COLA model.
The models were forced with the observed sea surface temperature anomalies (SSTA). Using a new method to effectively expand the ensemble size, we calculated maximum likelihood esti mates of parameters for theoretical probability density functions (PDFs) of the ensemble seasonal integrations from these GCMs. This approach to the description of the predicted state of the atmo sphere is shown to be much more informative and useful than the conventional ensemble mean diagnostics. The obtained PDFs are compared with each other and with the observations, and the probabilities of individual forecasts are evaluated. Probabilistic skill score distributions (including the newly suggested Relative Operating Characteristics) and internal ensemble consistency are studied for different geographical regions.
In related work, t tests have been applied to interannual variabilities on seasonal timescales to estimate theoretical effective ensemble sizes for the chosen regions. To validate these estimates, a 100-member ensemble simulation was conducted with the ECHAM-3 model, and the information and forecast skill scores from these ensemble seasonal integrations were compared to those from 10-member ensemble subsets. The optimal regional ensemble sizes were evaluated. The results of this research show to what degree the new methodology can expand traditional seasonal climate forecast ensemble sizes, and how this information can be used to provide more complete and skillful climate prediction.

Regionalization of Daily Rainfall in Morocco

Abstract Number 158
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The precipitation in Morocco, although mainly associated with extratropical atlantic cyclons or depressions that originate in the Mediterranean basin, is strongly influenced by local orographic effects. This lets this country divided into sub-regions of homogeneous pluviometric regime. This is the first paper which provides a regionalization of daily rainfall in Morocco. For this purpose a hierarchic cluster analysis was carried out using a daily and 10 day totals rainfall data of 25 stations for the period 1979-1996. The classification procedure have been developed with a contiguity-constraind algorithms and using the Ward method as aggregation criteria, The analysis was applied for every month and season, also for all the rainy season october - april for comparative purposes. Results permits the division of Morocco into five major rainfall areas. the distribution of this clusters experiments some changes among the winter, fall and spring seasons and all the rainy season october-april, this reflects the spatio-temporal distribution of storm tracks that produce rains in Morocco.

Interannual and Interdecadal Variability of Pacific SST as Revealed by Singular Spectrum Analysis

Abstract Number 159
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The multi-channel singular spectrum analysis has been used to characterize the spatio-temporal structures of interdecadal and interannual variability of the sea surface temperature (SST) over the Pacific Ocean from 20^oS to 58^oN. Using COADS data from 1950 to 1993, three modes with distinctive spatio-temporal structures were found. They are an interdecadal mode, a quasi-quadrennial (QQ) oscillation with a period of 51 months and a quasi-biennial (QB) oscillation with a period of 26 months. The interdecadal mode is a standing mode with opposite signs of SST anomalies in

the North Pacific and in the tropical Pacific. The amplitude of this mode is larger in the central North Pacific than in the tropical Pacific. This mode contributes 11.4% to the total variance. It is associated with cooling in the central North Pacific and warming in the equatorial Pacific since around 1976-77. The QQ oscillation exhibits propagation of SST anomalies northeastward from the Philippine Sea and then eastward along 40^oN, but behaves more like a standing wave over the tropical Pacific. It explains nearly 20% of the total variance. The QB oscillation is localized in the tropics and is characterized by the westward propagation of SST anomalies near the equator. This mode accounts for 7.4% of the total variance. Since the interdecadal mode is apparently independent of QB and QQ oscillations, it may play an important role in configuring the state of the tropical SST anomalies, which in turn affects the strength of the El Niño-Southern Oscillation (ENSO) phenomenon. It seems likely that the higher phase of the interdecadal mode since 1976-77 has raised the background SST state, on which the superposition of the QQ and QB oscillations produced the strongest warm event on record in 1982-83, as well as more frequent warm events since 1976.

Structural Time Series Models and Trend Detection in Global and Regional Temperature series

Abstract Number 160
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A unified statistical approach to identify suitable structural time series models for annual mean temperature is proposed. This includes a generalised model that can represent all the commonly used structural time series models for trend detection, and explicit methods for comparing the validity of no-trend random stationary increment models relative to trend models. Its application to IPCC global and regional temperature series reveals that a linear trend model (starting in 1890, with soi signal removal and red noise residuals) is the optimal model for most of the globefrom the northern hemisphere subtropics through the tropics to the southern hemisphere midlatitudesbut that a random stationary increment process is the optimal model for the northern part of the northern hemisphere, owing to high natural variability and a quasi-periodic 70 year variation. The result for these northern hemisphere belts does not exclude the possibility of a trend existing there. The hemispheric and global series will contain a mixture of the two models, but are best represented by the linear trend model. A distinction between ocean and land is apparent, with the linear

trend model performing better for the global ocean and the largely oceanic southern hemisphere, and worse for the hemispheric land series, especially in the northern hemisphere. The intrinsic detectability of trends is thus oppositely matched to the regions where GCMs indicate greatest anthropogenic trend, i.e. it is best for the tropics and the oceans, rather than for the high latitudes and continents. The results reinforce the view that the global temperatures are affected by a long term trend that is not of natural origin.

Comparison of the ECMWF Ensemble with an Ensemble Consisting of Four Operational Models

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So far, operational ensemble forecasting schemes in Numerical Weather Prediction have been based on the assumption that the main sources of the forecast errors are the uncertainties in the initial state of the atmosphere. The aim of this contribution is to demonstrate that such ensemble forecasts which differ only in the initial states are of limited use as long as the models with which to integrate the forecasts contain systematic errors. For this purpose two basically different ensembles are compared: The 50 member ECMWF ensemble and a "poor man's ensemble" consisting of the 4 operational models of the NCEP, ECMWF, UKMO, DWD. The verification of ensemble mean and probabilistic forecasts was carried out for the 500 hPa geopotential height over Europe and lead times ranging from 1 to 6 days. The results indicate, that despite of the comparatively much larger size of the ECMWF ensemble, the poor man's ensemble is difficult to outperform.

The Analog Method of a Simple Statistical Downscaling Techniques: Comparison with Linear, Classification and Neural Network Methods

Abstract Number 162
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The derivation of local scale information from integrations of coarse-resolution General Circulation Models (GCM) with the help of statistical models fitted with present observations is generally referred to as statistical downscaling. In this paper a relatively simple analog method is described and applied for downscaling purposes. According to this method the large-scale circulation simulated by a GCM is associated to the local variables observed simultaneously with the mo st similar large-scale circulation pattern in a pool of historical observations. The similarity of the large-scale circulation patterns is defined in terms of their coordinates in the space spanned by the leading observed Empirical Orthogon al Functions (EOFs).
The method can be checked by replicating the evolution of the local variables in an independent period. Its performance for monthly and daily winter rainfall in the Iberian peninsula is compared to other, more complicated techniques, each belonging to one of the broad families of existing statistical downscaling techni ques: a method based on Canonical Correlation Analysis (CCA) as representative of linear methods; a method based on Classification and Regression Trees (CART) a s representative of a weather generator based on classification methods; and a neural network, as an example of deterministic non-linear methods. It is found that the analog method performs in general as well as the more complicated methods, and it can be applied to both normal and non-normal distributed local variables. Furthermore it produces the right level of variability of the local variable. On the other hand linear multivariate methods offer a clearer physical interpretation that supports more strongly its validity in an altered climate. Classification and neural networks are the most complicated methods and do not directly offer a physical interpretation.
Acknowledgments:

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Decadal and Longer Changes of the Winter Sea Level Pressure and Related Synoptic Activity over the North Atlantic.

Abstract Number 163
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Based on the National Centers for Environmental Prediction (NCEP) data set analysis of the climatic changes of the winter mean anomalies of sea level pressure (SLP) and its intramonthly root mean square deviations (RMSD) is carried out. Climatic changes are considered in terms of linear trends, low-pass filtered anomalies and decadally averaged anomalies. It is demonstrated that linear trends of winter RMSD anomalies are in a good agreement with winter SLP trends attributed to the periods of decrease (increase) of the North Atlantic Oscillation (NAO) index. Analysis of the detrended and low-pass filtered anomalies of winter SLP revealed both propagating and standing patterns. The standing patterns have a period of about 8 years. There is no good agreement with related changes of RMSD. On the contrary, we defined the periods with high (low) values of the NAO index, which associated with negative (positive) anomalies of RMSD. Decadally averaged anomalies of RMSD are not always linked to the North Atlantic storm track. Spatial distribution of both winter SLP and RMSD anomalies demonstrates meridional dipole-like patterns. For the period 1981-1990 which is characterized by the high value of the NAO index, the negative anomalies of RMSD over the most of the North Atlantic are observed.

Contributions at the Interface between Atmospheric and Statistical Science.

Abstract Number 164
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Perhaps more than anyone else, Allan Murphy devoted his career to work at the interface between atmospheric and statistical science. This talk briefly examines how this overriding concern was expressed in Allan's research and in the IMSC series of meetings.

Climate Change Detection: A Review of Techniques and Applications

Abstract Number 165
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This paper reviews some of the techniques that have been proposed for climate change detection during the past fifteen years and describes several applications. We also briefly consider the question of the attribution of climate change.

The methodologies fall into two groups; those that use 'optimal detectors' and those that use 'pattern similarity' statistics. Both approaches require the use of climate models for estimating the signals that are to be searched for, and also for estimating the natural variability of the detectors in the absence of signal. The latter is necessary because the detection statistics are influenced by low frequency climate variations that are not well sampled in the relatively short instrumental record that is currently available. Formally, the use of optimal detectors enhances the prospects for early climate change detection by increasing the signal-to-noise ratio by of the order of 20%. However, real-world differences in performance are likely more strongly affected by how well models represent the climate's response to changes in forcing from human activity and by variations in the intricate processing of the data that precedes the formal detection step. Recent applications of both types of detection methodology have uncovered 'smoking gun' evidence that human activity is having an effect on the recent climate.

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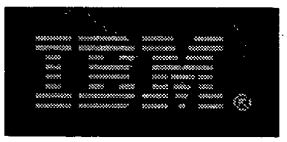

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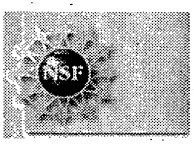

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