HOW CAN RCMS REPRODUCE THE ANNUAL CYCLE AND WHAT WE CAN LEARN FROM IT

Tomáš Halenka, Petr Skalák, Peter Huszár, Michal Belda
tomas.halenka@mff.cuni.cz
Annual Course

• reproducing the annual course - indication of quality of different atmospheric processes description
• affects the overall model performance
• to compare the annual course patterns with those based on observational data is not simple and unambiguous task
• weighting methods in ENSEMBLES - objective method is required
• three patterns are of importance, i.e. bias, amplitude and shift in period, either as a whole or partly in some seasons
• Taylor (2001) - so called Taylor diagram, which is used for presenting the data in terms of RMS error, standard deviation and correlation and show just the analysis of models simulations with emphasis on annual cycle.
• analogue between the bias and RMS error, as well as in between amplitude and standard deviation, correlation being good representation of the shifts in the annual course. For purpose of the weighting we propose to use the score index
Score Index (1\textsuperscript{st} order)

\[ S = \frac{4(1 + R)}{(\sigma + \frac{1}{\sigma})^2 (1 + R_0)} \]

where \( R_0 \) is the maximum correlation attainable. For simplicity we used maximum value \( R_0 = 1 \). Parameter \( R \) is the correlation coefficient with respect to the observation dataset used for comparison, \( \sigma = \sigma_m / \sigma_o \) is standard deviation of the model results \( \sigma_m \) normalized by standard deviation of the observational dataset used for validation \( \sigma_o \).
Score Index (4th order)

where $R_0$ is the maximum correlation attainable. For simplicity we used maximum value $R_0 = 1$. Parameter $R$ is the correlation coefficient with respect to the observation dataset used for comparison, $\sigma = \sigma_m/\sigma_o$ is standard deviation of the model results $\sigma_m$ normalized by standard deviation of the observational dataset used for validation $\sigma_o$. 

$$S = \frac{4(1 + R)^4}{\left(\sigma + \frac{1}{\sigma}\right)^2 (1 + R_0)^4}$$
PRUDENCE regions
Temperature – annual cycle

BI

IP

FR

ME

SC

AL

MT

EE
Precipitation – annual cycle
Temperature – Taylor’s diagram

- Region BI
- Region IP
- Region FR
- Region ME
- Region SC
- Region AL
- Region MT
- Region EE

Symbols:
- CCCCI
- CHMI
- CNRM
- DMI
- ETHZ
- HC
- HC_high
- HC_low
- ICTP
- KNMI
- METNO
- MPI
- OURANOS
- SMHI
- UCLM
Taylor’s score - temperature

**1st order**

**2nd order**

**4th order**

<table>
<thead>
<tr>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI</td>
</tr>
<tr>
<td>IP</td>
</tr>
<tr>
<td>FR</td>
</tr>
<tr>
<td>ME</td>
</tr>
<tr>
<td>SC</td>
</tr>
<tr>
<td>AL</td>
</tr>
<tr>
<td>MT</td>
</tr>
<tr>
<td>EE</td>
</tr>
<tr>
<td>ALL</td>
</tr>
</tbody>
</table>
Regions comparison – 1st order

TEMP

0.974 0.976 0.978 0.980 0.982 0.984 0.986 0.988 0.990 0.992

BI IP FR ME SC AL MT EE ALL

PREC

0.76 0.78 0.80 0.82 0.84 0.86 0.88 0.90 0.92 0.94

BI IP FR ME SC AL MT EE ALL
Combination for total score
Annual cycle extraction using multiple linear regression

\[ X(t) = a_0 + b \times t + c_{s1} \times \sin\left(\frac{2\pi t}{12}\right) + c_{c1} \times \cos\left(\frac{2\pi t}{12}\right) +
\]
\[ c_{s2} \times \sin\left(2 \times \frac{2\pi t}{12}\right) + c_{c2} \times \cos\left(2 \times \frac{2\pi t}{12}\right) +
\]
\[ c_{s3} \times \sin\left(3 \times \frac{2\pi t}{12}\right) + c_{c3} \times \cos\left(3 \times \frac{2\pi t}{12}\right) +
\]
\[ (d \times \text{NAO}) + \epsilon \]

- good approximation (R² around 0.95, very rarely below 0.90) for temperature.
- rather poor and very variable depending on the region and RCM for precipitation (mostly 0.2 – 0.3).
- inclusion of NAO index (Jones et al., 1997, Osborne, 2006) for precipitation improved the quality of the approximation a little, for some regions quite significantly, especially IP, SC and MT with R² mostly above 0.5.
- this sometimes increased the significance of individual contributions of harmonic terms, however, it should be mentioned that the higher harmonics were quite often non-significant anyway, in those cases mostly rather negligible.
T4-P1 combination for total score
comparison of original and reconstructed assessment
Final ranking and normalized weights
Conclusions

- More demanding assessment for temperature - 4th order formulation for temperature, 1st for rather poor performance of precipitation
- Overall assessment precipitation dominant anyway, both for original series and extracted annual cycle
- Higher confidence for capturing annual cycle of temperature than for the precipitation
- Although the choice of an averaging method can affect the values of the scores a little, it does not matter for the models ranking
- Original time series analysis of the annual cycle and the refinements of the method extracting the pure harmonics of the annual cycle from the time series results in some differences, however, not so big and even smaller when evaluating the normalized values as applied in final weighting method (Christensen, 2010)
- Although for some models the bigger changes in the ranking can appear, it is rather within the uncertainty of the evaluation within the group of models with rather small differences of the scores. The reasons for rather big differences of ETHZ and UCLM would require further analysis.
Conclusions (cont.)

• the results of the simple application of Taylor score on the original time series (and thus readily available rough assessment) coincide reasonably well with the results of Taylor score evaluation applied on more sophisticated extraction of pure annual cycle from time series
• since the original technique provides basically the overall assessment of the model performance, then we can imply from the discussion above that the quality of the annual cycle reproduction in the model is one of the critical factors affecting the overall model performance, i.e. model errors
• thus, the emphasis on the model ability to capture the annual cycle can contribute significantly to develop the model of higher accuracy and overall performance. Further analysis should be done to evaluate the impact of annual course performance on the model error quantitatively.
THANKS FOR YOUR ATTENTION

We acknowledge the E-OBS dataset from the EU-FP6 project ENSEMBLES (http://www.ensembles-eu.org) and the data providers in the ECA&D project (http://eca.knmi.nl). This study was performed within the ENSEMBLES project, funded by the European Commission's 6th Framework Programme through contract GOCE-CT-2003-505539. Partial support was provided under Research Plan of MSMT under No. MSM 0021620860.