Scientific report from STSM:

Relations between atmospheric circulation and climatic changes

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Purpose of the visit

The main goal of this STSM is to provide a list of existing methods describing the influence of long-term changes in atmospheric circulation on local and regional climatic trends. The relations of various circulation classifications with large-scale patterns, namely the NAO, shall be identified. The NAO index and similar large-scale circulation patterns could serve as an "independent" variable for the mutual comparison of the quality or "skill" of the classifications to reproduce the natural circulation variability.

Work summary

During this STSM, I have collaborated with Inger Hanssen-Bauer and Rasmus Benestad at the Norwegian Meteorological Institute (DNMI). Main part of the work was devoted to the use of "clim.pact" package (developed by R. Benestad) within the "R" environment. Using this software, several statistical downscaling analyses have been conducted on station data from the Czech Republic together with large-scale gridded datasets [see (1)]. An analysis of links between circulation classifications and daily NAO index was made (2), and an overview of existing methods for finding the relationships between circulation changes and climatic trends has been compiled (3). Most of these outcomes were presented at the COST733 6th WG4 meeting in Ioannina, Greece, and posted at the COST733 internal website.

Main results

(1) Statistical downscaling results for the Czech Republic

The aim of statistical downscaling is to find relationships between large-scale predictor and local predictand. In the "clim.pact" tool, this is accomplished by fitting a multiple linear regression model between the leading EOFs of the predictor and the local predictand time series.

Mean monthly air temperature at 2 meters and monthly precipitation totals from 21 Czech stations in the period 1961-1998, together with monthly large-scale precipitation in the region 12-19E/48.5-51N (NCEP/NCAR data), were taken as predictands. Three sources of gridded large-scale SLP and temperature data were employed as predictors: the ECMWF ERA40, DNMI (Norwegian Meteorological Institute) data, and NCEP/NCAR reanalysis.

First, the connection of station and large-scale (10W-40E/35-65N) air temperature was studied for January and July. All the station temperature time series yield very high positive correlations with Central European temperatures, but in the case of DNMI data, the center with highest correlations is shifted from the actual position of the stations to the northwest (i.e. to Northern Germany and the Netherlands). Apart from this spatial discrepancy, also the correlations are slightly lower than with NCEP/NCAR. The downscaled station temperature, reconstructed by leading EOFs of the large-scale temperature, corresponds very well with the actual station data. Again, better results are obtained for NCEP/NCAR as a predictor. Large-scale temperature variations explain on average 87 % (DNMI) and 94 % (NCEP/NCAR) of the interannual variability of temperature. Differences between January and July are both positive and negative at individual stations, and therefore negligible on average. In the case of DNMI data in January, the R^2 value between model and observations is positively correlated with station elevation, thus the temperature at mountain stations being more closely related to large-scale temperatures.

Similar analysis was conducted with SLP as predictor for monthly station air temperature. In January, the main feature of the correlation field between station temperature and large-scale SLP is a clear dipole NAO-like pattern, with positive correlations in the southern center and negative in the northern. Thus the winter temperatures in Central Europe are governed mainly by the strength (or absence) of the mild westerlies. In July positive correlations are centered over the Baltic countries. Variations in the SLP field from DNMI explain on average 71 and 80 % of interannual temperature variability in January and July, respectively. Results obtained by using NCEP/NCAR and ERA40 SLP fields as predictors are about 5 percentage points higher. Temperature at stations at higher elevation is better represented by the downscaling model.

Precipitation dependence on large-scale SLP is, not surprisingly, lower than that of temperature. In January, the R^2 value between model and observations is on average 50 % for

DNMI data, and 58 % for both ERA40 and NCEP/NCAR. In July it is only 40 % for all the predictors, with large differences between individual stations. Summer precipitation is mostly governed by local convective activity and less by large-scale circulation.

Keeping in mind the substantial differences of precipitation behavior at stations, I have repeated the analysis with spatial average precipitation in the region 12-19E/48.5-51N, obtained from NCEP/NCAR. There are again differences of results obtained using the three SLP data sources, ERA40 performing the best. Also, SLP field on a smaller spatial domain (0-30E/37-60N) seems to be more connected to Central European precipitation than the COST733 Domain 00 (37W-58E/30-76N). The model skill has a clear annual cycle with maxima from November to February (R^2 values between 40 and 80 % in the smaller domain).

The main result from these downscaling exercises is that care should be taken not only of the method itself or the spatial scale employed, but also of the source of gridded reanalysis data taken as predictors. Namely the DNMI dataset performance in Central Europe (both temperature and SLP) was a bit lower compared to ERA40 and NCEP/NCAR.

(2) Atmospheric circulation classifications and the daily NAO index

The study of connections between circulation classifications and daily NAO index (obtained from Climate Prediction Center) stemmed from a presentation given by M. J. Casado and M. A. Pastor at COST733 5^{th} WG4 meeting, and by further discussion with these two scientists. I have studied the frequencies of NAO phases (positive, negative, and “normal”) within the circulation types of the COST733 classifications release 1.1 in extended winter season (DJFM). Chi-square test was used to see if the frequencies of NAO phases within the CTs differ from the overall NAO distribution, i.e., if some of the CTs occur preferably in NAO positive/negative/normal phase. This analysis was done in spatial domains 01 (Iceland) and 04 (the British Isles). To handle the varying number of CTs in different classifications, the percentage rather than the number of CTs with some desired properties was studied. Results show that in all the classifications there are some CTs that prefer NAO positive/negative/normal phase, but large differences occur. The lowest connection with NAO was found in LWT2, NNW, PCAXTRKM, and TPCA07. In catalogues with a high number of CTs, the chi-square test could not be used for a substantial part of CTs due to their rare occurrence.

Further the explained variance (EV) index was employed to NAO daily time series to study the within-type variability (or the inter-type separability) of all the scalable circulation classifications in domains 00 (whole Europe), 01, 04, and 09 (Iberia). The EV index theoretically ranges from 0 to 1, higher values indicating better skill. The highest average explained variance (0.27) was obtained in domain 00, the lowest (0.12) in D09. In all the domains the best classifications were SANDRA and SANDRAS. The explained variance is generally higher in classifications that have a higher number of CTs, although this relationship is only statistically significant in D01. This quite obvious dependence of almost every studied measure on the number of CTs will be fortunately solved in COST733 by recalculating the classifications with pre-defined numbers of types.

(3) List of methods on relationships between circulation changes and climatic trends

In recent decades, many authors have employed circulation classifications in various synoptic-climatological studies. The problem is the huge number of classification methods and catalogues used, and therefore the limited comparability of the results. The COST733 action provides a basis for future development in the field of circulation classifications, enabling the simultaneous use of many circulation catalogues and identifying their strengths and weaknesses. I hope that this brief outline of methods that were used in previous studies for the assessment of links between climatic trends and circulation changes will be beneficial for the future work within the COST733 WG4.

These methods include:

(a) Identifying typical (average) weather conditions of CTs on a seasonal or monthly basis (e.g. extreme temperatures, precipitation, snowfall,…). This is only a “first look” on the classification, as it doesn’t take into account the within-type variability and trends. Nevertheless, it is a necessary step for understanding the synoptic causes of observed weather patterns on a local to regional scale (e.g. Twardosz and Niedźwiedź, 2001; Fragoso and Tildes Gomes, in press; Goodess and Jones, 2002; Kostopoulou and Jones, 2007). This kind of analysis has been done within the COST733 by producing composite maps of SLP, air temperature, and precipitation under each CT on a seasonal basis.

(b) Simple or multiple regression of CTs frequencies with monthly (seasonal) means of climatic variable (or teleconnection pattern), e.g. Trigo and DaCamara, 2000; Goodess and Jones, 2002; Sepp, 2005; Lorenzo et al., in press. Again, it doesn't take into account the within-type variability and trends.

(c) CT as a "predictor": construction of a new daily time series of a specific climatic element, whose value on each day is equal to the long-term average (monthly or seasonal) within the CT present on that day. A new, "hypothetical" or "reconstructed" daily time series is produced and can be handled in many ways:

- Correlation of monthly means from the "reconstructed" series with observed data. Depends on the within-type variability of a climatic element (Bárdossy and Caspary, 1990).

- "Skill" of the new daily series to represent the observed data (Buishand and Brandsma, 1997).

- Analysis of trends in this new time series, comparison with observed climatic trends. This can tell us what proportion of the observed trends is caused by circulation changes (e.g. Huth, 2001).

- All these methods assume stationarity of the connection between CTs and local weather (do not account for within-type climatic trends).

(d) Assessment of within-type climatic trends, which can sometimes be quite different from the observed overall changes (e.g. Huth, 1999).

(e) Decomposition of frequency-related and within-type related climatic changes between subsequent 31-year moving time slices, separately for months, since 1780 (Beck et al., 2007). This kind of analysis requires very long time series. Due to this requirement, circulation classification was applied only on a monthly basis.

(f) "Conditional downscaling" separately for every circulation type (Enke and Spekat, 1997; Huth et al., in press). This method assumes that the relationship between large-scale predictor and local predictand can be different under every circulation type. However, Huth et al. (in press) did not find its results superior to the standard downscaling methods.

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Confirmation by the host institute of the successful execution of the mission

... Inger, please type in a few words, thanks!

...something like “I hereby state that the analyses and results presented in this Scientific report have been the focus of Monika Cahynová’s work during her COST STSM at the Norwegian Meteorological Institute (April-May 2008)...... “