New Dataset of Highly Resolved Atmospheric Forcing Fields for 1850-2009

Frederik Schenk[1] and Eduardo Zorita[1]

[1] Institute for Coastal Research, GKSS Research Centre, Geesthacht, Germany (frederik.schenk@gkss.de)

1. Introduction

For the detection and attribution of changes in the ocean-climate system of the Baltic Sea, long, homogeneous and spatiotemporal highly resolved data sets are needed. Besides their possible use as forcing fields for regional climate and biochemical ocean models, these date sets are important for a better estimation of model uncertainties on a high resolution level.

Resulting from the relatively shallow and complex basin of the Baltic Sea, the marine ecosystem is highly sensitive to changes also on short timescales. Most prominently, the occurrence of extreme events like storms can have a high impact on oxygen and salinity exchange with the North Sea.

In order to attribute short-term variability and extremes, highly resolved daily atmospheric forcing fields for Northern Europe are reconstructed from long historical station measurements for 1850-2009 with a horizontal resolution of 0.25° x 0.25°.

2. The Analog-Method

Underestimating the variability by more than a factor of two, linear regression techniques are not useful if the variability of the reconstruction is of great importance (von Storch et al. 2004). In order to obtain a comparably good variance in the reconstruction, we use the analog-method as a simple non-linear upscaling method of station data to related atmospheric fields. The large-scale atmospheric circulation fields (predictand) are taken from a pool of atmospheric fields from a regional climate model. The best fitting atmospheric fields to the given variables from station measurements (predictor) are found by searching the smallest Euclidian distance between the vector field of the analogs and the vector field of the provided station data for each time step.

3. Data

As predictor for the analog-method, time series for SLP and T2m of 23 stations are used. Daily SLP data from 1850 is mainly taken from the EMULATE project (Mean Sea Level Pressure data set, EMSLP) (Ansell et al. 2006), updated till 2009 with data provided by the European Climate Assessment & Dataset (ECA&D) project (Klein Tank et al. 2002). As not all stations are contributing anymore to ECA&D, many station updates were kindly made available by the SMHI, FMI and the University of Jena, Germany.

In addition to daily SLP, monthly T2m station data is used as predictor for the T2m field reconstruction. This data is taken from Jones & Moberg (2003), updated by WMO.

For the predictands (analogs), daily atmospheric fields of SLP, wind, T2m, precipitation, rel. humidity and total cloud cover are used from a simulation of the Swedish Rossby Centre regional Atmosphere-Ocean model (RCAO) for 1957-2007. The simulation was interpolated from rotated grid to a regular grid and from a horizontal resolution of 0.5° to 0.25°. The model domain spans from 70.5° N to 48° N and from 5° W to 36.75° E (see fig. 1).

4. Settings

In a first step, the analog-method is tested using the RCAO model as a surrogate climate. Spanning from 1958 to 2007, 25 years of the simulation are used crosswise for calibration and validation. Different numbers of grid points are used as synthetic stations (predictors) providing daily SLP (or T2m) information to find the best fitting atmospheric fields for SLP, U-/V-wind, precipitation, rel. humidity, total cloud cover and T2m.

The tests already show very good reconstruction skills for SLP and wind using only four to ten equally distributed grids/stations, if daily SLP is used as predictor. Due to the weak physical link between SLP and T2m, only T2m as predictor yields good skills for the reconstruction of T2m fields. Precipitation, cloud cover and humidity are showing low but significantly higher skills than their climatological mean on daily scale but good skills when comparing their monthly means.

As the analog of a given day in one month could also occur in the next surrounding months, the sample size for finding an analog is set to two months around the month of the searched day. This significantly improves the reconstruction skills with exception of T2m. Here, the analog is only searched in one month.

5. Results

In a second step, the calibration and validation is now repeated like before with real station data for 25 years, respectively. The general reconstruction skills are close to the testing results within the model environment.

The most important variables on daily scale, SLP and wind, show very good skills in winter (fig. 1 for January) and good skills in summer (fig. 2 for June). Lower skills in summer in the east and southeast part of the domain are caused climatically by the generally low wind speed off the sea and technically by partly missing data in this region.

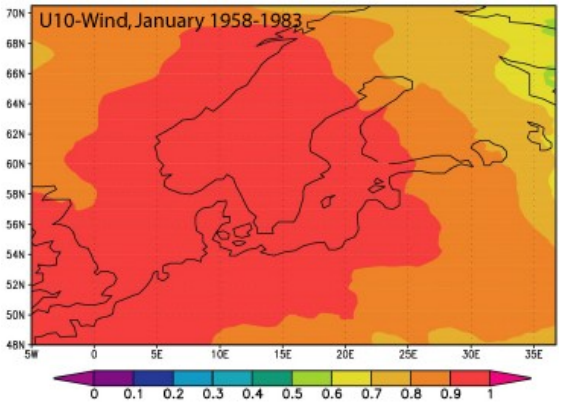

Fig. 1: Field correlation of the reconstructed U-wind field with the original RCAO field for January over the calibration period 1958-1983 (calibration 1984-2007).

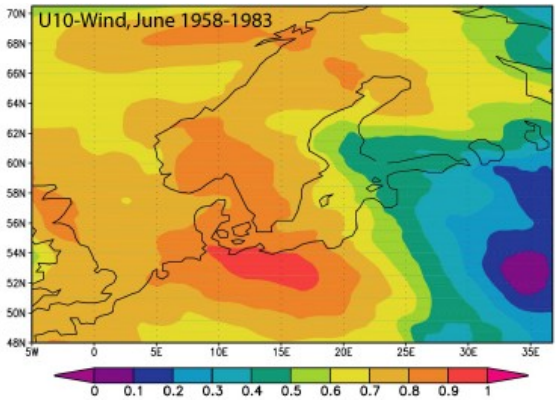

Fig. 2: Field correlation of the reconstructed U-wind field with the original RCAO fields for June over the validation period 1958-1983 (calibration 1984-2007).

In a third step, the analog-method is now applied for the reconstruction from 1850 to 2009 using 1958-2007 as calibration period. The reconstruction skills for the calibration period are shown for January in the Taylor-diagram in fig. 3. In addition to the mean cross-correlation of the reconstructed and the original field, the Taylor radius shows the standardized deviations which are calculated as the variance of the reconstruction divided by the variance of the reference fields from RCAO. For daily scale, the analog-method always leads to a ratio around one (blue dots). For monthly means, the variance of the reconstruction generally decreases while the correlation increases (red dots). Note, that only SLP and wind are important on daily scale while the other variables are needed on monthly to seasonal resolution.

As SLP is a too weak predictor for T2m also on monthly scale (fig. 3, blue dot Nr. 2), T2m is additionally reconstructed using monthly T2m data. The reconstructed monthly T2m fields are then interpolated on daily values and added on the daily anomalies of T2m reconstructed by daily SLP. While the skill for daily values is only slightly increasing (fig. 3, green dot), the monthly skill is now very good (fig. 3, orange dot) due to the added information from T2m predictor.

6. Discussion

The analog-method as a simple non-linear upscaling technique from daily station data is an excellent method to reconstruct daily SLP and wind with correlations up to 0.9. Although the physical link between SLP, humidity, cloud cover, and T2m is weak, these reconstructions are still showing better skills than their climatological mean on the daily scale.

However, these variables are more important on a monthly to seasonal scale. Here, their skills highly recommend also the use of the analog-method. This is also the case for precipitation which shows good daily skills in winter and generally good skills on monthly and seasonal scale.

Using the analog-method, T2m reconstructions generally need T2m as predictor because very similar SLP patterns are leading to very different T2m fields i.e. in spring and autumn. In addition, T2m is also influenced by other effects (e.g. SST, solar activity etc.) than SLP which also makes the analog-method blind for climate change signals in T2m when SLP is used as predictor.

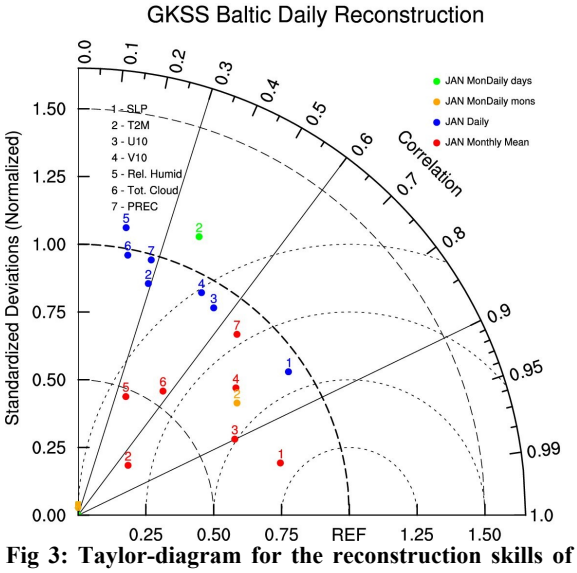

Fig 3: Taylor-diagram for the reconstruction skills of January over the calibration period 1958-2007 on daily and monthly scale.

References

Ansell, T. J. et al. (2006): Daily mean sea level pressure reconstructions for the European - North Atlantic region for the period 1850-2003, Journal of Climate, Vol. 19, No. 12, pp 2717-2742.

Jones, PD and A. Moberg (2003): Hemispheric and large-scale surface air temperature variations: An extensive revision and an update to 2001. J. Climate, Vol. 16, pp. 206-223.

Klein Tank, A.M.G. et al., (2002): Daily dataset of 20th-century surface air temperature and precipitation series for the European Climate Assessment. Int. J. Climatol., Vol. 22, pp. 1441-1453.

Storch, H. v. and A. Omstedt (2008): Assessment of Climate Change for the Baltic Sea Basin. (BACC-Report)

Storch, H. v., Zorita, E., Jones, J.M., Dimitriev, Y., González-Rouco, F. and S.F.B. Tett (2004): Reconstruction Past Climate from Noisy Data. Science, Vol. 306, No. 5696, pp. 679-682.

Zorita, E. & H. von Storch (1999): The Analog Method as a simple statistical Downscaling Technique: Comparison with more complicated Methods, Journal of Climate, Vol. 12, No. 8, pp. 2474-2489.