High Resolution Re-analysis for the Baltic Sea Region During 1965-2005 Period

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1. Introduction

Regional reanalysis database BaltAn65+ comprising meteorological data for Baltic Sea region for the time period 1965-2005 is described. For observational data assimilation and hindcasts, the numerical weather prediction model HIRLAM 7.1.4 is applied, with 11 km horizontal and 60-layer vertical resolution. Reanalysis includes three-dimensional weather analysis data. Standard surface observations and meteorological soundings together with ship and buoy measurements from WMO observational network are used in analysis. Boundary fields are obtained from ECMWF ERA-40 global re-analysis. The BaltAn65+ can be considered as a regional refinement of ERA-40 for Baltic Sea region, providing the historical weather and climate data with enhanced spatial resolution, which is main motivation for creation of this novel reanalysis database. More information can be found in [Luhamaa et al., 2011]. Reanalysis data will be made available to anyone on www.emhi.ee.

2. Reanalysis domain and model setup.

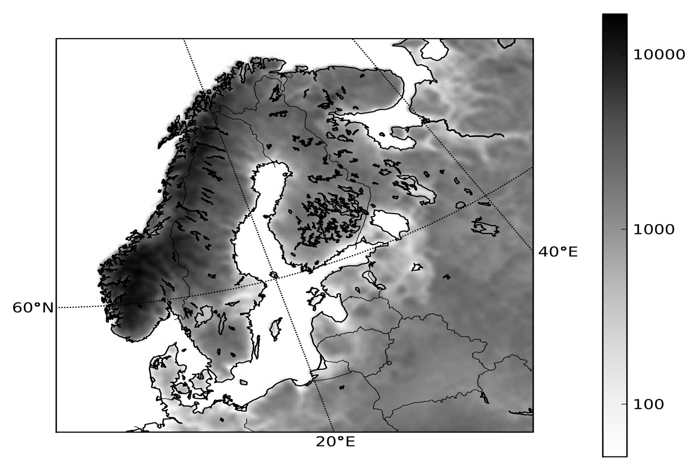
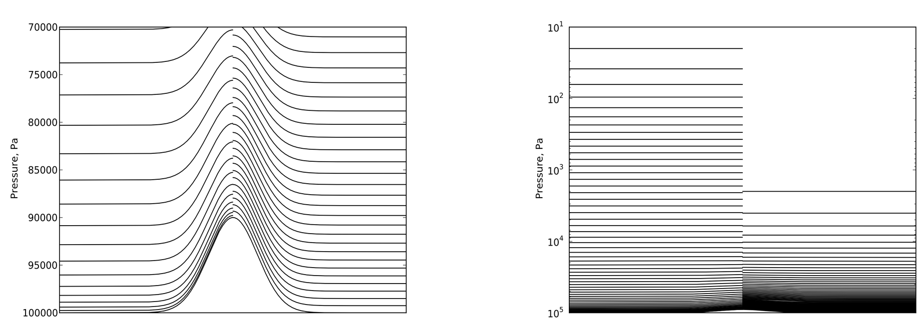


Figure 1: *Modelling area of BaltAn65+. Bar of grey tones shows the geopotential [m^2/s^2] of the underlying sea (= 0) and ground (>0) surface.*

The applied modelling area is shown in figure 1. Horizontal grid resolution is 0.1 degrees (about 11 km), providing 206x206 points in horizontal and 60 levels in vertical. The lowest model level layer is located at 30 m height and the model top is located at approximately 30 km with the layer depths varying from 60 m at the ground to approximately 3 km at the topmost levels. BaltAn65+, like ERA-40 makes use of 60 levels in vertical, but distribution of levels is different (figures 2(a), 2(b)).



(a) Lower 300 hPa (b) Full atmosphere

Figure 2: *Comparison of ERA-40 and BaltAn65+ vertical grids. 2(a) is lower part of the atmosphere and 2(b) is the full domain. On the left is ERA-40 grid and on the right BaltAn65+ on both figures.*

The created reanalysis database for the Baltic Sea region describes the development of the climate system according to HIRLAM model analyses and prognoses. The period of the reanalysis is 01.01.1965-31.12.2005. The interval of saving model states (snapshots) is 6 hours, four times a day in standard meteorological hours 00, 06, 12, 18 UTC. Each record of the time stamp of the database consists of three data files in World Meteorological Organization (WMO) GRIB (GRIdded Binary) version 1 format.

Fields, that are a direct result of 3D-Var upper air data assimilation, are surface pressure, wind, temperature and humidity, the latter three at the model levels. Surface data assimilation, which is performed before upper air, upgrades values for surface and deep surface temperature and moisture, 2m temperature and humidity. All other fields (precipitation, clouds, etc) are taken from the background (previous cycle) forecast. Snow cover is not analysed.

3. Performance of the analysis system, quality of BaltAn65+ data

While 3D-Var scheme can use different kind of observations, radiosonde (TEMP) measurements have by far the biggest influence on upper air analysis. Number of radiosonde measurements used in observations is illustrated by figure 3

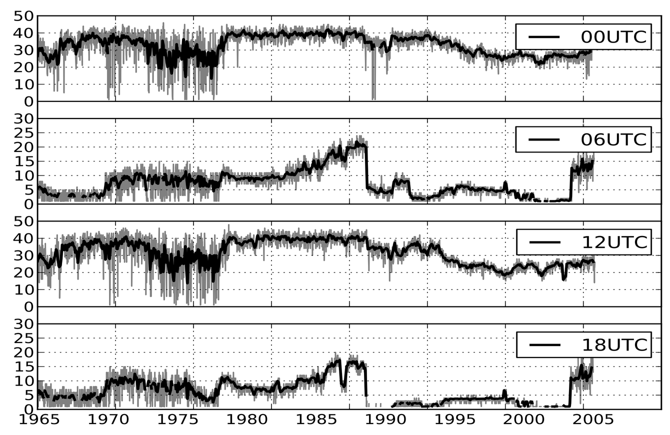
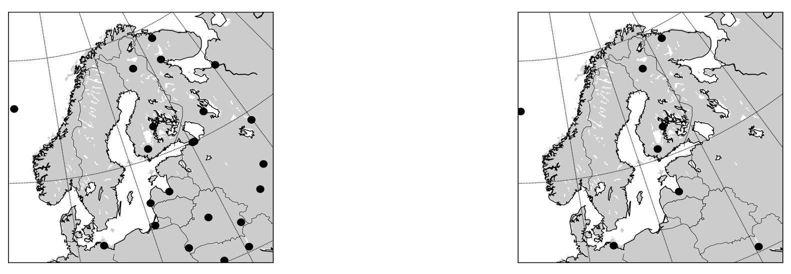


Figure 3: *Number of TEMP measurements*

The number of observations at 00'UTC and 12'UTC remains fairly constant over time, showing drop from around 40 to 25 at 1990, but there is a major drop for the 06'UTC and 18'UTC measurements near 1990. Geographic locations for this drop are shown on the figures 4(a) and 4(b), showing that they disappeared from the former USSR territory.



(a) 1990 (b) 1992

Figure 4: *Radiosonde measurements locations*

Ship, DRIBU and AIREP measurements follow start times similar to ERA-40, SHIP and buoy since 1965, AIREP since 1973.

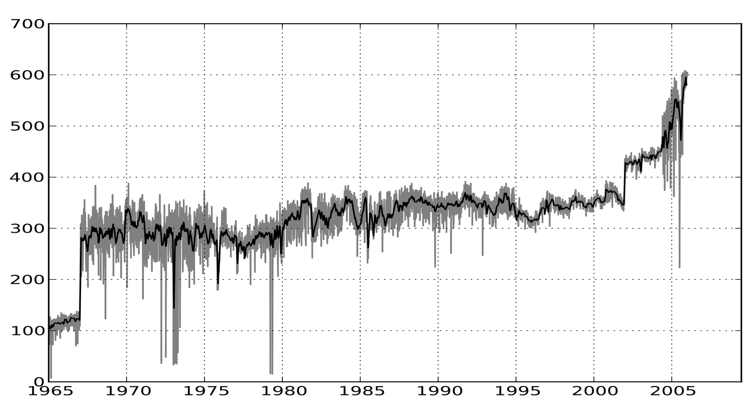


Figure 5: *Number of SYNOP measurements*

Number of surface synoptic (SYNOP) measurements is shown in figure 5. Years before 1967 do not cover Norway, Sweden, Finland and Poland.

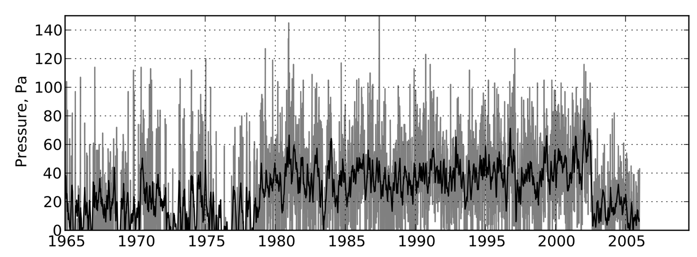


Figure 6: *Background mean sea level pressure bias at 00'UTC. Grey line represent exact values, black line 30-day moving average.*

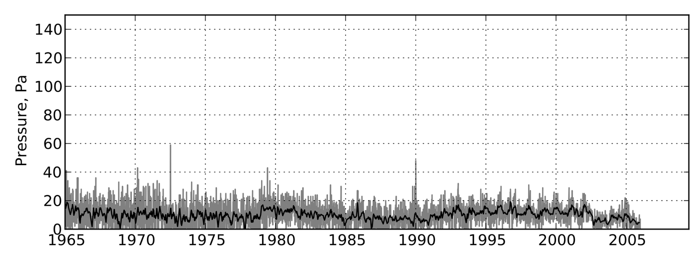


Figure 7: *Analysed mean sea level pressure bias at 00'UTC.*

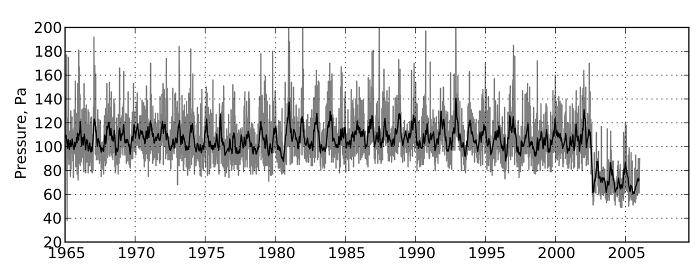


Figure 8: *Background mean sea level pressure RMS error at 00'UTC.*

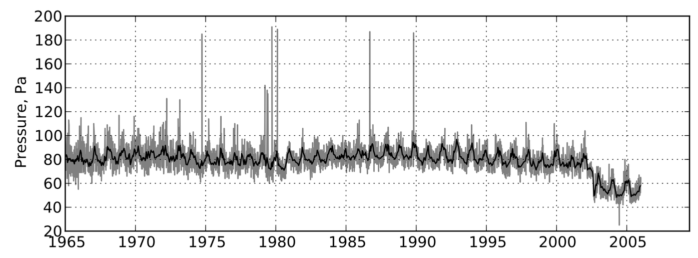


Figure 9: *Analysed mean sea level pressure RMS error at 00'UTC.*

Standard verification scores for mean sea level pressure at 00'UTC are presented in figures 6 - 9.

The most notable feature seen in these graphs is that both analysis and background errors decrease significantly after 2002. While slight increase in number of surface observations (figure 5) takes place at similar time, most of the effect is probably caused by the change of boundary fields from ERA-40 to ECMWF operational model. RMS error values differ from bias mainly by showing clear annual variability, with colder seasons having larger errors and variances.

Statistics of calculated analysis increments (the RMS error of the analysed and background field difference) is presented in figures 10 - 12. Figure 10 presents 500 hPa geopotential height analysis increment. Though this characteristic has large annual variance, significant systematical improvement can be seen over the forty-year period. For comparison, similar plots for 06'UTC and 12'UTC are presented in figures 11 and 12. While the three plots look similar, analysis increments for 06'UTC tend to be smaller. This can be explained by different number of radiosonde measurements: bigger number of observations at 00'UTC and 12'UTC is the cause for better backround forecast for 06'UTC and 18'UTC analysis.

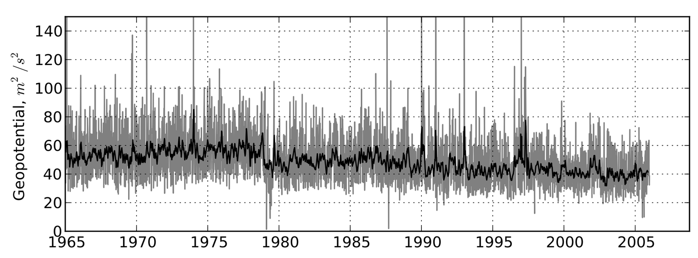


Figure 10: *500 hPa geopotential height analysis increment at 00'UTC. Grey line represent exact values, black line 30-day moving average.*

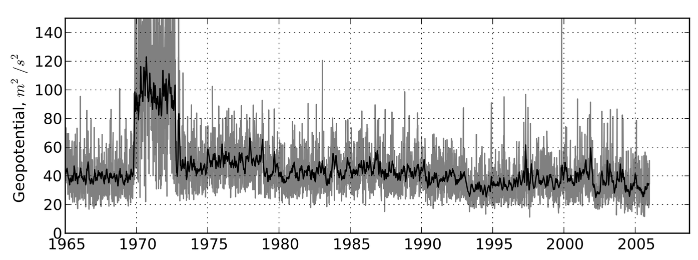


Figure 11: *500 hPa geopotential height analysis increment at 06'UTC. Grey line represent exact values, black line 30-day moving average.*

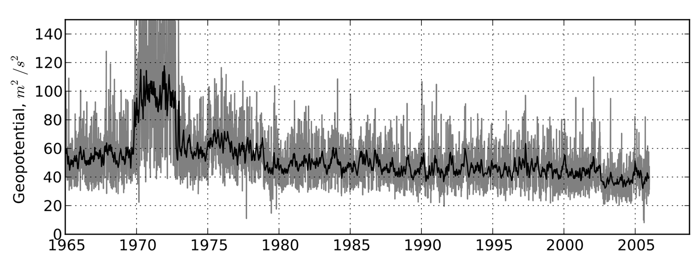


Figure 12: *500 hPa geopotential height analysis increment at 12'UTC. Grey line represent exact values, black line 30-day moving average.*

Acknowledgements.

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References

[Luhamaa et al., 2011] Luhamaa, A., Kimmel, K., Männik, A., and Rõõm, R. (2011). High resolution re-analysis for the baltic sea region during 1965-2005 period. *Climate Dynamics*.