Reanalysis of BRIDGE. An estimation of the water and heat budgets over the Baltic Sea drainage basin through variational data assimilation

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1. Introduction

The main purpose of BALTEX is to calculate the water and heat budgets of the Baltic Sea. The HIRLAM-BALTEX data assimilation project uses a special version of the HIRLAM system that is specially designed for quantifying the water and energy budgets of the area relevant to BALTEX. The project is organized by the meteorological services of Finland and Sweden. The project has its own web site, http:\\hirlam.fmi.fi/bridge, which is linked, to the site of the BALTEX project. This site describes the assimilation system, the data archive and progress of the work. The aim is to present a reanalysis of one year of the BRIDGE period (October 1999 – October 2000) with special emphasis on the quality of the reanalysis and the components crucial for the water and heat budgets.

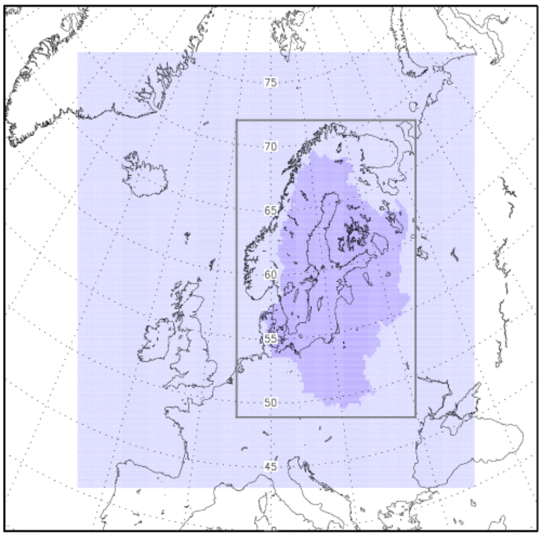

Figure 1. HIRLAM-BRIDGE reanalysis domain. The light shaded area is the model domain and the dark shaded area is the Baltic Sea catchment area.

2. BRIDGE assimilation system

The model horizontal resolution is 22km with 31 levels in the vertical. The model domain is showed in Figure 1. Initially the idea was to stay as close to the reference system as possible (*Fortelius & Andræ, 2000*). However, problems with overestimation of evaporation over land during the test month (December 1999) and the well-known problems with low level clouds led to major modification of the physical parameterization. The parameterization of large-scale condensation changed to *Rasch & Kristjansson* (1998) and the convection to *Kain & Fritsch* (1998). The surface scheme borrowed ideas from the Rossby Centre (*Bringfelt, 2000*). The evaporation from land surfaces now includes transpiration from the vegetation, evaporation of water intercepted on the canopy, and evaporation from bare ground soil. Parameterization of soil moisture and runoff is based on soil moisture variability functions traditionally used in hydrological models (*Bergström*, 1998). At the lateral boundaries the model is forced with ECMWF operational analyses updated every three hours. The frequency of the boundary update is important for reproducing the semi-diurnal tidal motions in the atmosphere (*Fortelius & Andræ, 2000*).

The assimilated observations come from the archives of the ECMWF. During the BRIDGE period SMHI and FMI have also reported climate SYNOP stations and thereby strengthened the observation amount. The analysis of atmospheric variables is based on a HIRVDA 3DVAR. The minimization is performed on 44km and interpolated to the model resolution. The SST and ice evolution in the Baltic Sea is described with a coupled ice-ocean model (*Gustafsson et al.*, 1998). The model SST is adjusted through a nudging process with observations from the SMHI marine service twice a week. The numerous inland lakes in Scandinavia are described with slab and 1-D lake model (*Ljungemyr*, 1996). The lake model as well as the Baltic Sea model are forced with atmospheric data from the forecast model, and are coupled back through the updated temperature and ice fields. The assimilation cycle is 6 h and at every cycle a 30-h forecast is run.

3. Monitoring

The system is run on the VPP5000 at the ECMWF and the system performance is monitored by timeseries of the different actions. Observation usage, analysis increments and observation verifications are calculated continuously together with budget components in order to keep the system on track. Large efforts have been taken to optimize the system usage, thus minimize access to ECFS and perform some calculations on Ecgate. As can be seen in Figure 2 the preparations and the post-processing takes about 100 seconds while the analysis and the forecast takes 800 seconds. Peaks are usually due to delayed access to the ECFS file system.

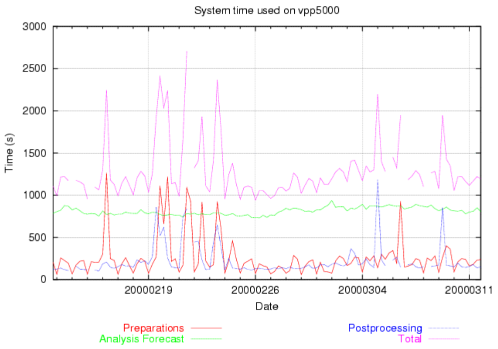

Figure 2. Example of monitoring. Timing on the VPP5000 computer at ECMWF. Preparations and post-processing uses one PE. Analysis and forecast uses 4 PEs.

4. Preliminary Result

The performance of the system is given in the verification of analyses and forecasts against observations in Figure 3. The system has a slightly positive bias in low level wind and temperature and a negative bias in the cloud cover and the low-level relative humidity. Mean sea level pressure has earned from the frequent boundary update and has got a fairly small bias and RMS. The upper air analysis, Figure 4, shows that the system has small biases in wind, temperature and height. The bias in relative humidity, however, increases with height.

Figure 5. shows the mean precipitation and evaporation over the Baltic Sea. The net precipitation (P-E) is negative during the autumn and the first part of the winter when the water is still warm. Later on, the temperature difference between the air and the sea diminish, the northern part becomes ice covered, which turns the net precipitation positive. A correct description of the ice extent and the SST in the Baltic Sea is highly important for the calculation of the fluxes of latent and sensible heat flux. So far the ice-ocean model has managed to simulate the ice and SST evolution well (figure not shown).

Precipitation have been compared with BALTRAD data (Fortelius & Andræ, 2001). Figure 6 shows histogram of precipitation amounts for BALTRAD and HIRLAM. The respective distributions are very similar for both months, and bring out clearly the contrast between winter, with mainly frontal precipitation, and summer when convective rain prevails. The principal difference between BALTRAD and HIRLAM is that the latter underestimates the number of winter days without any rainfall at all, and overestimate the days with very little precipitation.

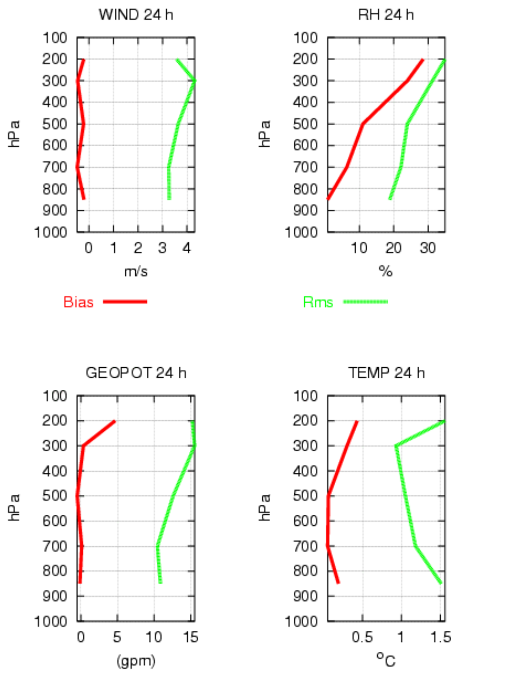

Figure 3. Verification of TEMP observations (according to the EWGLAM list) over Europe from January 2000. Shown are RMS and bias for 24h forecasts.

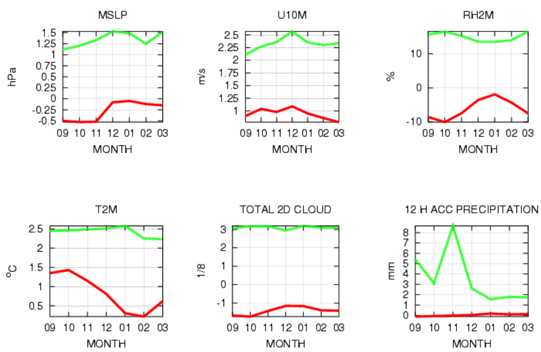

Figure 4. Verification of SYNOP observations (according to the EWGLAM list) over Europe from September 1999 to March 2000. Shown are RMS and bias for 24h forecasts.

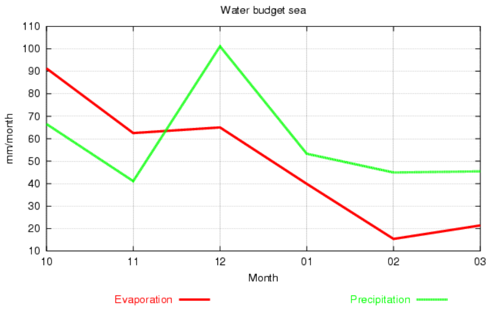

Figure 5. Mean precipitation and evaporation for the Baltic Sea, October 1999 to March 2000.

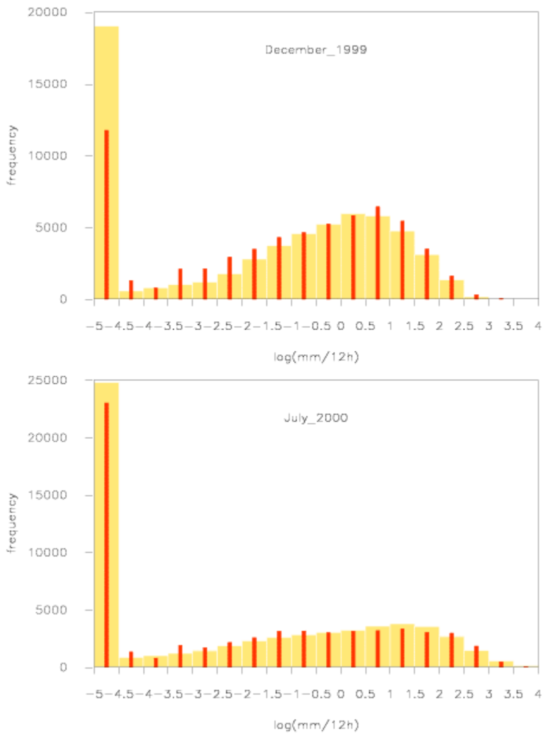

Figure 6. Histograms of semi-diurnal precipitation amounts during December 1999 and July 2000 as given by BALTRAD (wide columns) and by HIRLAM (narrow columns). In both panels the first columns to the left contain the cases with zero precipitation.

Mean precipitation and evaporation for

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