Developments in Satellite Data Assimilation at DWD

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Deutscher Wetterdienst
Wetter und Klima aus einer Hand

I) Operational NWP system & satellite usage

Gobal:
- GME: 20km triangular grid, 60 Levels up to 5 hPa
- 3Dvar for conventional and satellite data, 3h cycling

Regional:
- COSMO-EU: 7km, 40 Levels (up to ~22 km, non-hydrostatic)
- COSMO-DE: 2.8km, 50 Levels (non-hydrostatic)
  COSMO-DE-EPS ensemble at 2.8 km, 20 members (soon 40 members)
- Nudging assimilation scheme for conventional and radar data

Satellite data/ global GME:
- AMSU-A, HIRS
- IASI, AMSU-B/MHS, and ATMS are pre-operational
- GPS-RO bending angles
- AMVs (GEO, LEO), Scatterometer winds (ASCAT, OSCAT)

Technical aspects:
- RTTOV-10
- Flexible data ingestion & pre-processing
- Monitoring: Automatic problem detection & alert system
- Online bias correction

II) Developments in radiance assimilation

- **Improved observation errors:** Analysis and tuning updates based on Desroziers et al. method; scan-angle dependent errors for ATMS (see poster 1.p12 by R. Faulwetter).
- **Variational bias correction** is under testing with the aim to replace the current online bias correction for all satellite radiances.
- **IASI:** Positive impact in pre-operational tests using 46 channels (LW band) over sea in a first implementation (Fig. 1). Clear channels are selected using the McNally and Watts (2003) approach. Further tuning and development explores changes to the background error covariances B (Fig. 2) and the inclusion of more channels (WV band, over land).

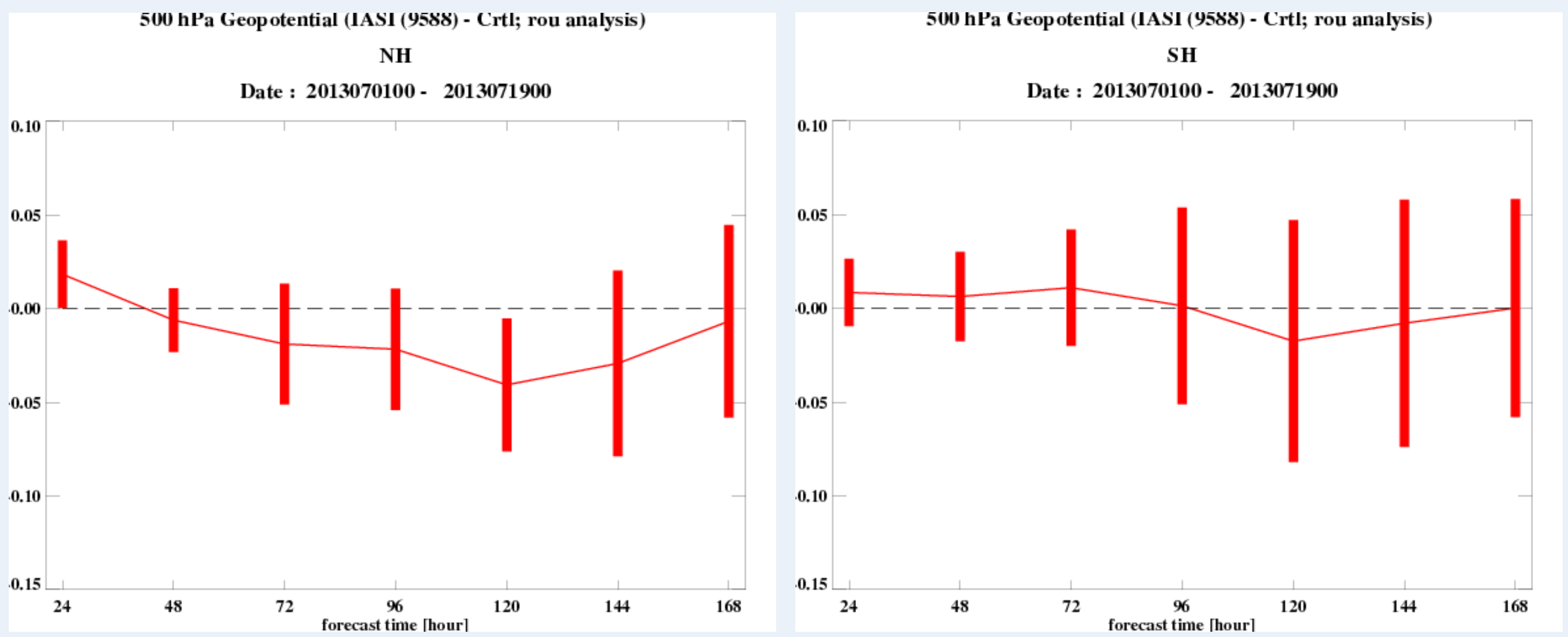


Fig 1: 500 hPa RMS error difference between IASI and control experiment (negative values correspond to improvement in IASI experiment; 95% confidence intervals as bars) for NH (left), SH (right) for 19 days in July 2013.

→ Positive impact from IASI METOP-A+B. Magnitude of impact varies with experiment season (not shown).

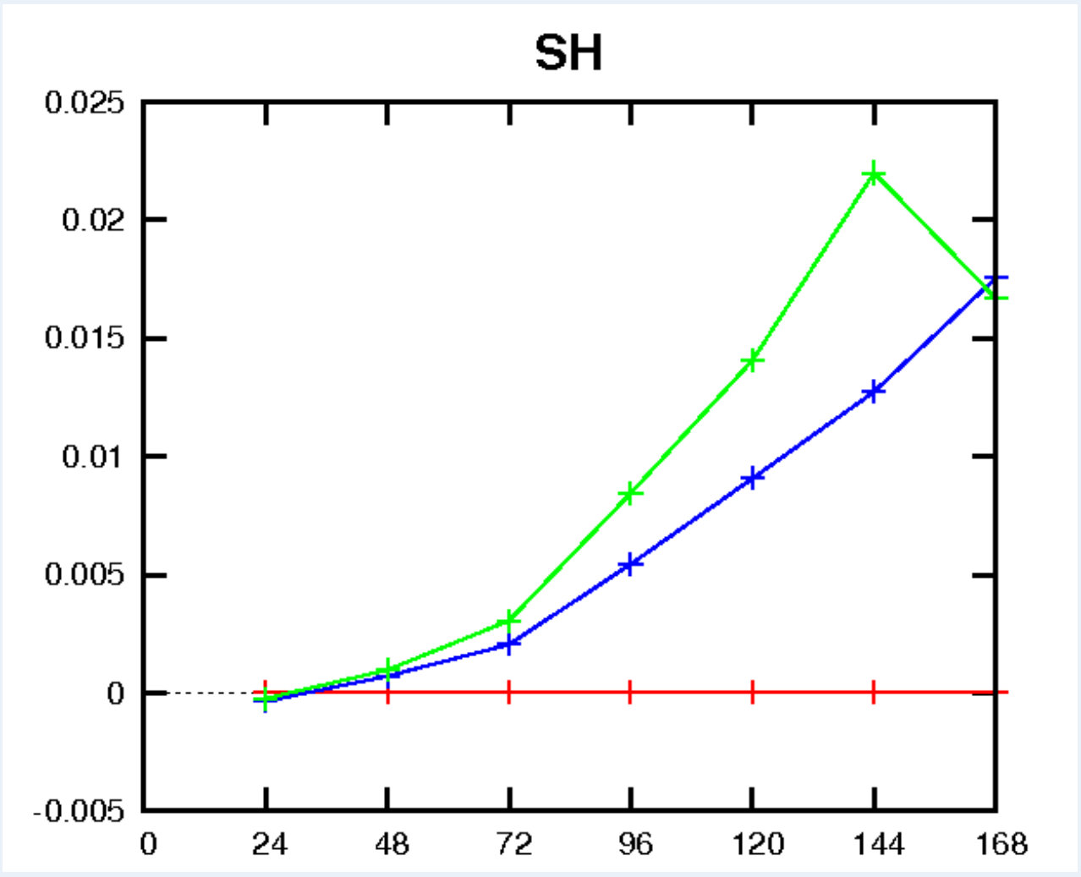


Fig 2a: Difference in 500 hPa geopotential anomaly correlation between IASI experiments and control (no IASI, red) all run at lower 40km resolution. Standard 3Dvar setup (blue, like in Fig.1) and revised background errors for humidity (green).

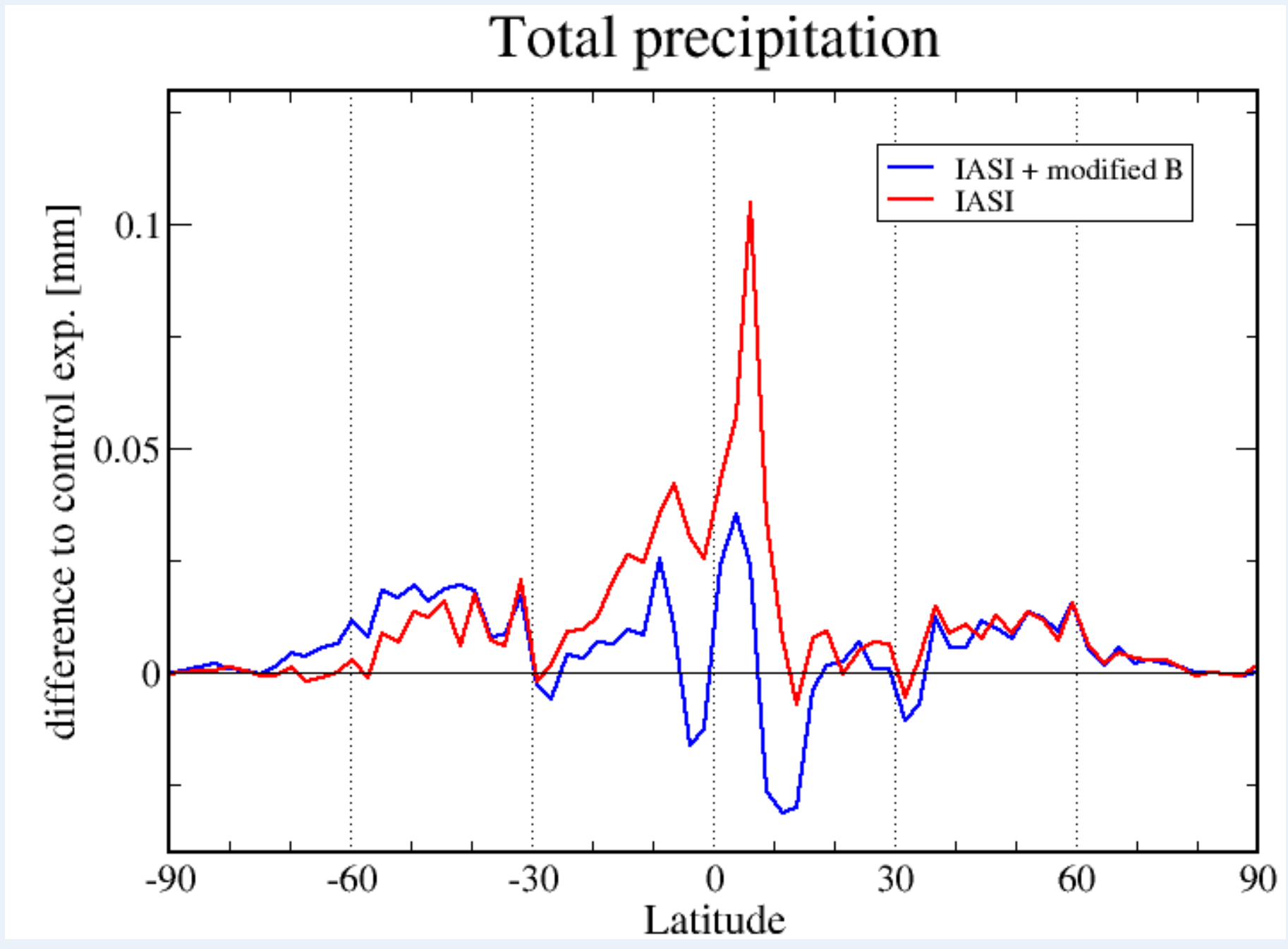


Fig 2b: Difference in total precipitation (longitudinal average) between IASI experiments and control (no IASI) for 2-30 Nov 2013. Standard 3Dvar setup (red) and revised background errors for humidity (blue).

→ Impact of the radiances and interaction with model physics depends strongly on the specification of B (see Fig. 2a, 2b). Tuning (here: reduced standard deviations for humidity) improves the positive impact and also helps to reduce undesirable precipitation spin-up effects in the tropics. Further improvements are expected with the introduction of the VarEnKF assimilation (see IV).

III) 1Dvar as development & pre-processing tool

A 1Dvar as special mode of the 3Dvar code is being implemented. The aim is to use this tool primarily for research and also as radiance pre-processor for the treatment of more complex situations prior to the 3Dvar or VarEnKF analysis. Principal applications:

- **Analysis of cloud parameters**: The retrieval of cloud parameters is explored to allow using more channels in overcast situations.
- **Analysis of surface emissivity and skin temperature** based on a principal component decomposition approach for the emissivity spectrum and an emissivity first guess derived from atlases (e.g. Seeman et al. for IR).
- **Quality control of radiances:** A new quality control scheme will be tested which checks the consistency of the observation departures against the statistical expectations based on the full B and O matrix specification, H operator and other observations (O. Stiller, to be submitted).

IV) New global ICON model & VarEnKF assimilation

The ICON model will be used both for operational NWP and climate prediction applications and is developed in cooperation with the MPI for climate research (Hamburg). Improvements (compared to GME) enabling particularly an easier and much better use of radiances are a significantly raised model top (Fig 3b) and a much improved physics parameterizations package reducing biases. Currently the tuning of the cycled ICON+3DVar system is underway with operational implementation intended for end 2014. Subsequently the assimilation system is going to be updated to an ensemble based VarEnKF approach. The improved and flow dependent B matrix will allow a much better exploitation of satellite radiance information compared to the current climatological 3Dvar setting.

ICON:
- Non-hydrostatic, icosahedral grid at 13 km (Fig 3a)
  90 z-coordinate levels up to 75 km (~ 0.026hPa) (Fig.3b)
- Two-way nesting for refined grid (to replace current COSMO-EU)
- In the final setup ICON will also be used for high-resolution forecasts and replace COSMO-DE.
- Physics: DWD developments for turbulent transfers, cloud cover and microphysics, and land/lake/soil/snow schemes. IFS/ECMWF schemes for radiation, gravity wave&orographic drag and convection.

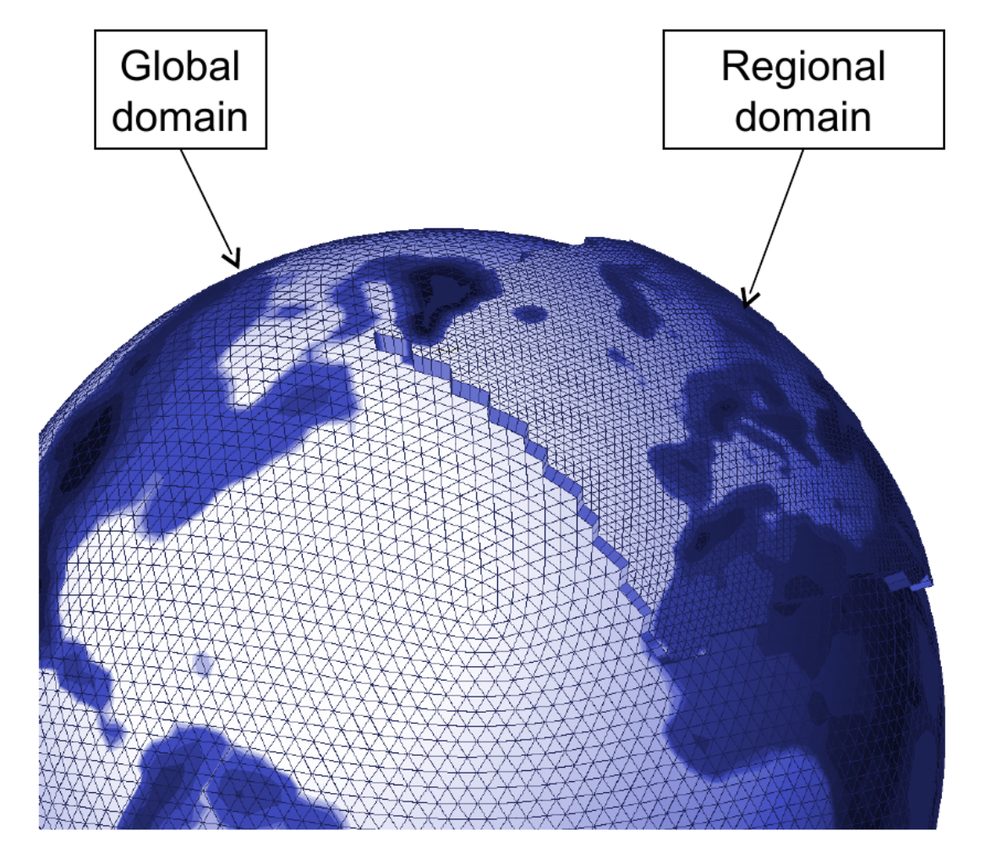


Fig 3a: Schematic diagram of ICON grid with regional nest.

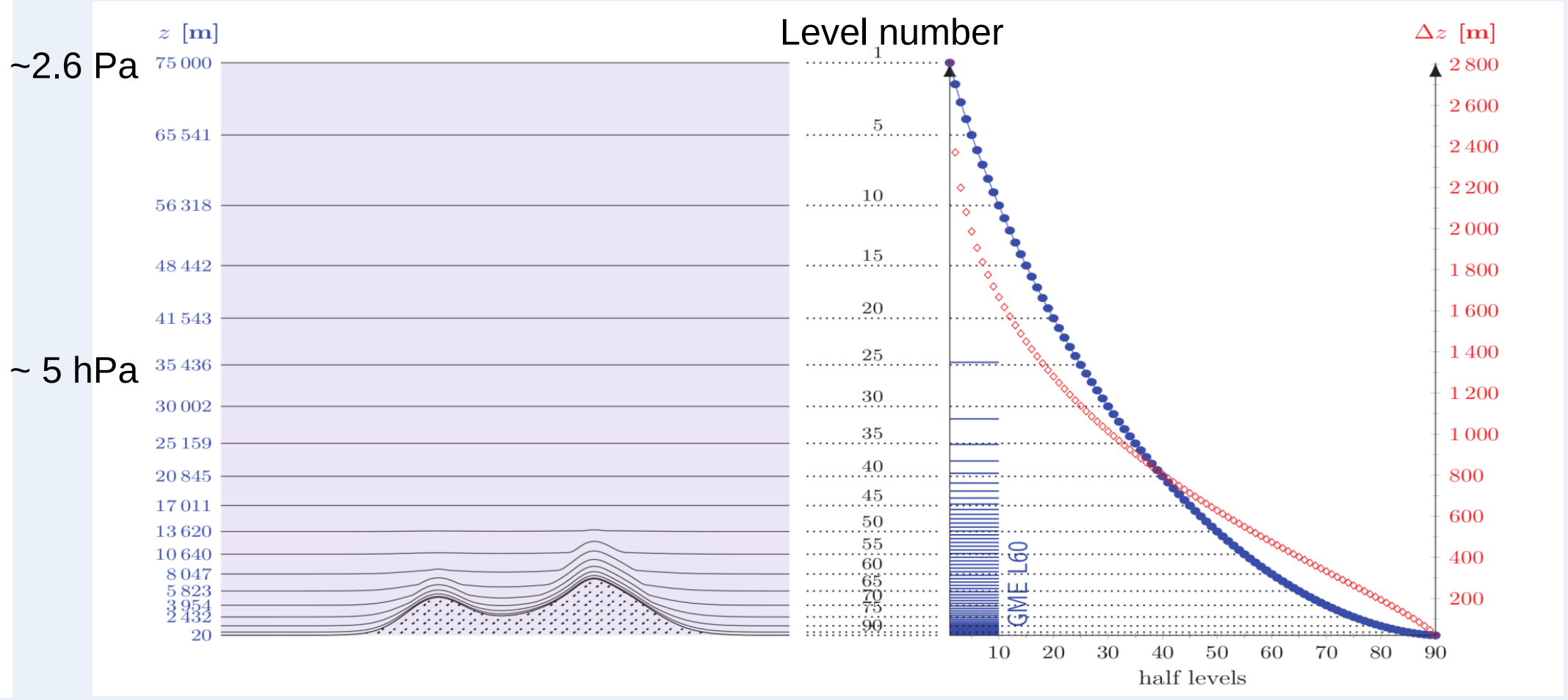
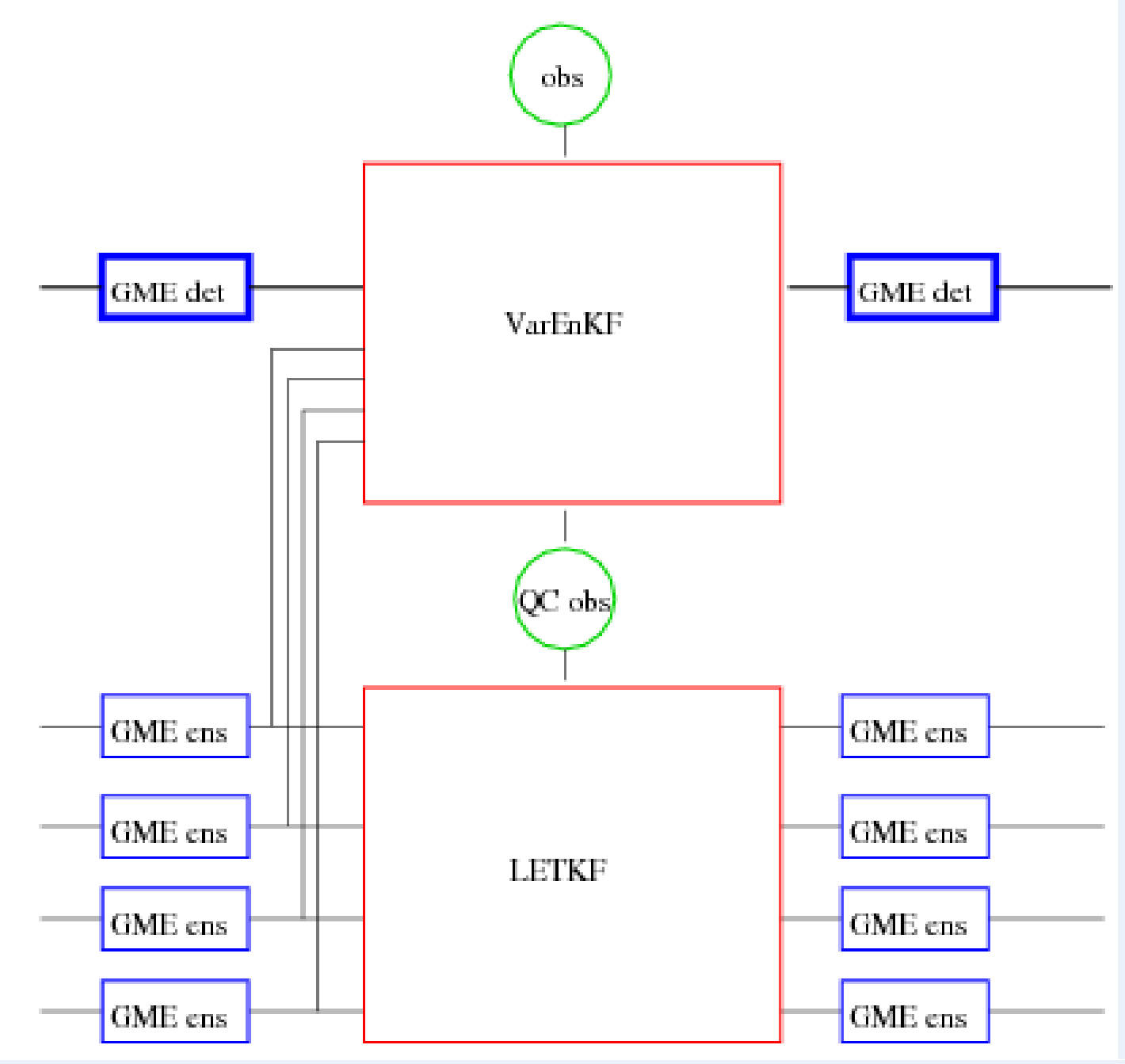


Fig 3b: vertical level distribution (level height: blue scale and dots; thickness: red scale and dots) compared to current 60 level GME..

VarEnKF:
- LETKF: 40 member ensemble at 30 km resolution
  (provides boundary conditions to regional 2.8km LETKF)



- Deterministic 3Dvar analysis using B matrix from LETKF ensemble (weighted with climatological B):
  $P_b(VarEnKF) = \alpha P_b\,(clim) + \beta P_b\,(LETKF)$
- Non-linear observation operators and quality control as in previous 3Dvar

Fig 4: Schematic diagram of interaction between global ensemble prediction and analysis (LETKF) and deterministic forecast with VarEnKF analysis: VarEnKF uses flow dependent background errors from ensemble; observation processing and quality control (QC) is performed by the VarEnKF and used in the ensemble LETKF analysis.

V) Convective-scale assimilation: LETKF development

For regional high resolution analyses, the KENDA system (km-scale ensemble-based data assimilation) based on the LETKF (Hunt et al.) will replace the current nudging scheme. Current developments use a 40 member ensemble and focus on localization issues and the exploitation of additional observations from volume radar scans, satellites and GPS (slant) delays.

Experiments are being conducted **using cloud top height and cover information from SEVIRI (METEOSAT)** as cloud cover, cloud top height and humidity constraints in the LETKF. First experiments focus on wintertime low stratus situations:

- Single observation experiments illustrate improvements in cloud cover and cloud liquid water profiles despite the very non-gaussian distributions of the observation increments. The LETKF also strengthens inversions in the analyses due to RH - T cross-correlations in the ensemble background perturbations (not shown).
- 20h of 1-hourly cycling with real SEVIRI cloud top information (from NWC-SAF with correction based on radiosonde data) followed by 24h forecasts (14-15 Nov 2011):

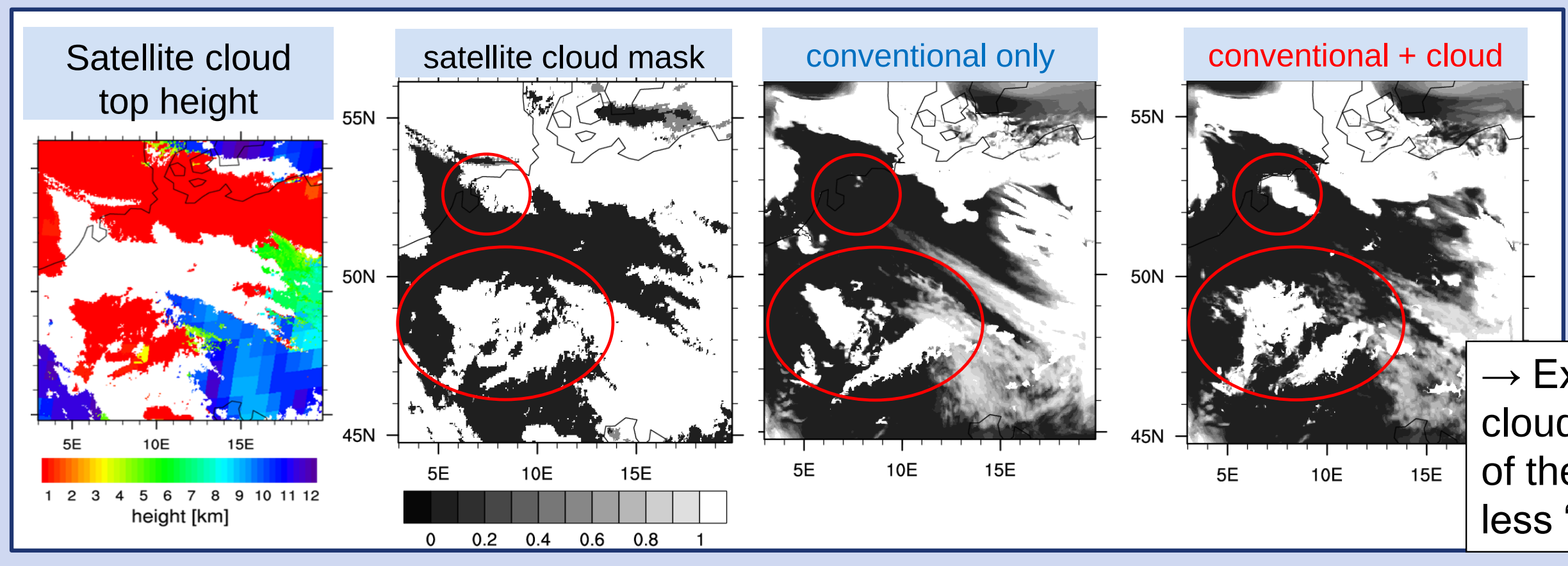
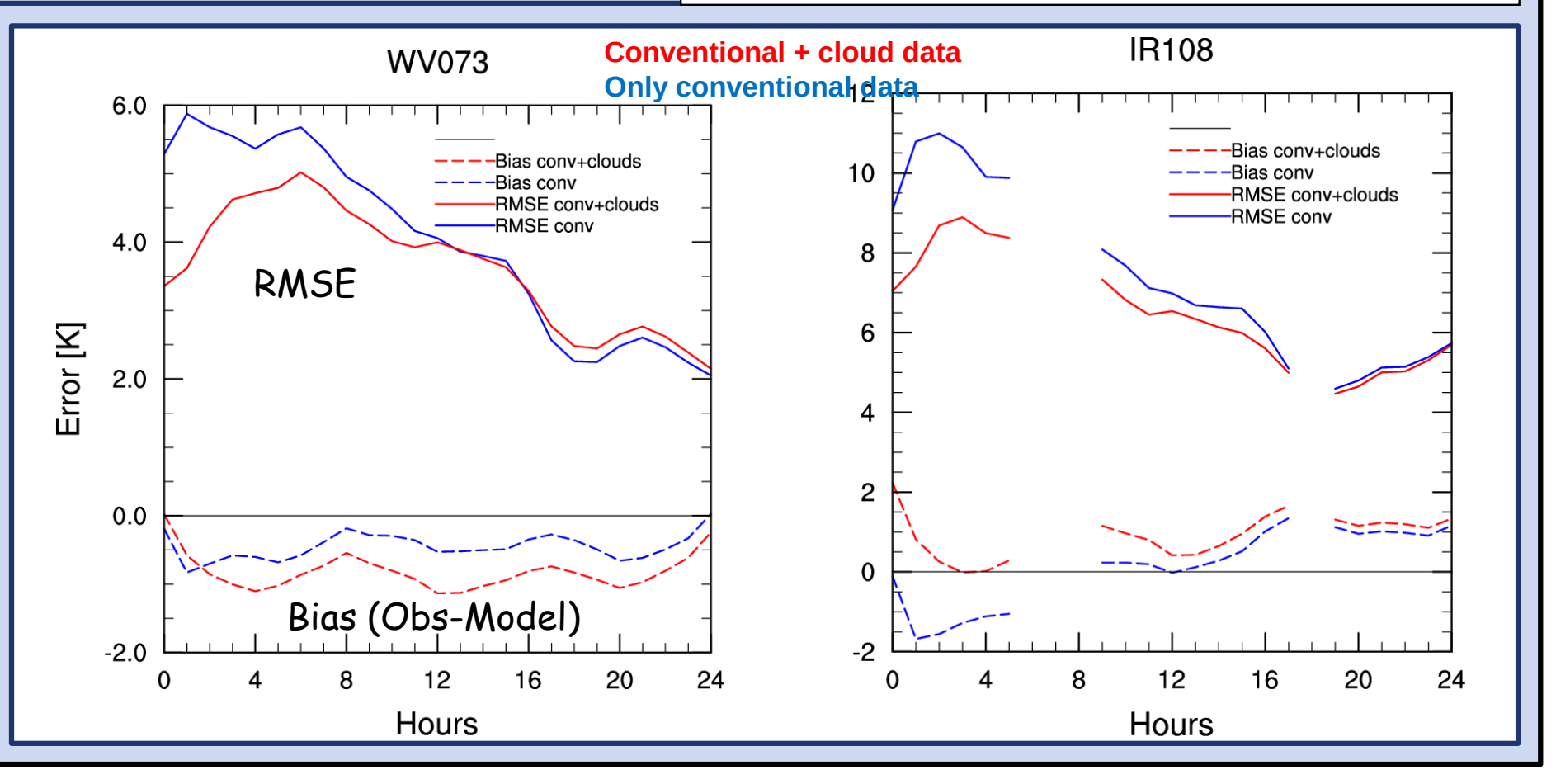


Fig 5: Satellite cloud top height and cover (left) and model cloud fraction after 20 hours of assimilation cycling (middle, right).

→ Experiment with assimilation of cloud information (right) has more of the observed stratus clouds and less “false alarm” clouds

Fig 6: Brightness temperature difference between SEVIRI observations and corresponding model values (using RTTOV-10) for 7.3 µm and 10.8 µm for a forecast starting on 14 Nov., 9 UTC.



→ The assimilation of cloud information (red) leads to improved RMS fit to SEVIRI observations for about 12h into the forecast.

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