Operational assimilation of remote sensing data in the global model GME

The 3-D-var assimilation system at the DWD

The Global Meteorological Model (GME) is the global model of the DWD for use in the numerical weather prediction (NWP). The GME is a hydrostatic model based on an isentropic horizontal grid. The model boundary and initial conditions for the local model COSMOG are prescribed in various global data assimilation products (e.g. CFSR). In the current version, the GME has a horizontal resolution of 9 km. Vertically it is composed of 30 layers, reaching up to 15 hPa (sigma hybrid coordinates).

The MRF model is connected by observational information in the data assimilation step, resulting in the analysis. For the GME, data are assimilated from three-dimensional data of any type: spatial and/or temporal, in observation space or in physical space. The observational information is combined in a statistically optimal way, taking into account background error covariance matrices B and R. A cost function

\[ \chi = \frac{1}{2} \left( \mathbf{x}^T \mathbf{B}^{-1} \mathbf{x} + \mathbf{r}^T \mathbf{R}^{-1} \mathbf{r} \right) \]

is minimized to yield the analysis \( \mathbf{x} \).

The minimization is done in observation space (physical space assimilation system is minimized to yield the analysis). Areas of remarkably high numbers of received IASI retrievals are west of India and the western Caribbean Sea.

Satellite data operationally assimilated in the GME

Datasets:
- Currently, AMSU-A radiance from NOAA-15, -16, -19 and Metop-A are operationally assimilated (cloud free FOVs of upper air channels only, thickness to 290 km horizontal distance). Work on assimilation of AMSU-B/MHS is in the way.
- Assimilation of AMSU-B radiance is under development. At present, the cloud detection scheme is being tuned for use in the 3-D-var system (scheme according to A/FM/ERIS of high resolution AMSU system). The system is run on the test platform.
- Satellite data currently from ASCAT onboard Metop-A is assimilated.
- GRIP mass calculation: Assimilation of radiances data from the COSMOG and Metop-A (GRIP instrument) is in an experimental level.

The IASI instrument

The Infrared Atmospheric Sounding Interferometer (IASI) on-board Metop-A is a Fourier transform spectrometer, providing infrared spectra with high resolution between 255 and 675 cm⁻¹. The IASI measures atmospheric emission spectra in order to derive temperature and humidity profiles at different altitudes. In the analysis system of the GME, IASI observations allow the determination of trace gases such as ozone, carbon dioxide, and water vapor. Other parameters to be derived from IASI radiances are cloud properties as well as cloud top and surface temperature and emissivity.

IASI Level 2 products

IASI Level 2 products permit the assimilation of the IASI data in the GME, e.g. the IASI 2.5 product containing temperature, atmospheric water vapor and surface temperature retrievals. In this study, we used the IASI 2.0 feature. This level 2.0 product not only includes all of the DOV products but also a number of flag and code tables, giving additional information on retrievals and the preprocessing. The IASI 2.0 product contains horizontally gridded temperatures, humidity and pressure fields, cloud property fields, and a number of other products. It is available in NetCDF format.

Derivation of layer thicknesses from IASI level 2 retrievals

The IASI level 2 data set contain temperature and humidity mixing ratios on 10 levels in the temperature range T = -15°C to 400°C. The humidity mixing ratio is supposed to be close to the value of the specific humidity:

\[ q_v = \frac{M_v}{M_a} \cdot \frac{\rho_v}{\rho_a} \]

The calculation of relative humidity depends on the specific humidity, temperature, pressure, and the partial pressure of water vapor. The IASI level 2 data set contains the retrievals of relative humidity, temperature, and pressure which are used to calculate the specific humidity. The IASI level 2 data set does not contain liquid water mixing ratio, and therefore the water vapor pressure is calculated from the specific humidity. The relative humidity can then be calculated from the partial pressure of water vapor and the saturation pressure of water vapor at the given temperature.

Layer thickness observational error:

\[ \sigma_{\text{LTH}} = \sqrt{\sigma_{\text{LTH}}^2 + \sigma_{\text{RHO}}^2 + \sigma_{\text{TEMP}}^2 + \sigma_{\text{PRES}}^2} \]

where \( \sigma_{\text{LTH}} \) is the layer thickness observational error, \( \sigma_{\text{RHO}} \) is the relative humidity observational error, \( \sigma_{\text{TEMP}} \) is the temperature observational error, and \( \sigma_{\text{PRES}} \) is the pressure observational error.

Impact study: Assimilation of geopotential layer thickness observations derived from IASI level 2 retrievals within the 3-D-var

A numerical experiment is performed to assess the impact of the assimilation of IASI level 2 retrievals in the weather forecasting system.

- global assimilation with 3-D var assimilation time window
- observational information from IASI is assimilated as layer thickness observations (see box bottom left) in addition to observation systems of the control experiment
- only IASI level 2 "clear sky" observations (flag 0L0, CLOUDFRM in the IASI level 2 data set)
- IASI data over sea only, no ice area
- high horizontal thinning of IASI 2 data to about 50 km (narrows the data volume)
- control experiment: Assimilation of ground measurements, reanalysis, boundary, ocean, aircraft data, ARPS, AMV-A

The high horizontal thinning of IASI 2 data to about 50 km (narrows the data volume). During the assimilation window, the data are assimilated within a 3-D var assimilation time window.

Ongoing work: Satellite bias correction

Study 1: Online estimation of bias correction coefficients

There are many sources of systematic errors that can affect the assimilation of observational data, in particular satellite observations. A bias correction is applied to the assimilation of data to remove part of these systematic errors. This is done by multiplying the observation by the bias correction coefficient.

With the observation vector \( \mathbf{y} \), the model vector \( \mathbf{x} \), and the observation operator \( \mathbf{H} \), the bias correction is applied to the observation vector, which is equivalent to the definition of a modified observation operator

\[ \mathbf{y}_\text{bias cor} = \mathbf{y} \cdot \mathbf{b} \]

where \( \mathbf{b} \) is a vector of the different predictors and the corresponding observation error correlations.