Status of Assimilating Satellite Data

at Deutscher Wetterdienst (DWD)

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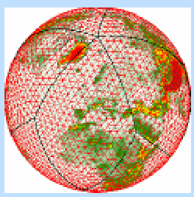
Model System: GME 40/40

GME (Global Model):
hydrostatic, icosahedral-hexagonal grid, mesh size 40km
terrain following hyb. coordinate,
40 layers, bottom layer at 10m, top 10 hPa,
7 soil layers, freezing and melting
of soil water
forecast range: 174h initial dates 00, 12 UTC
and 48h for 18 UTC
prognostic cloud ice, prognostic sea ice



Analysis:
OI optimal interpolation,
3-hourly intermittent analysis,
observation window: +/- 1.5h,
observations: conv., AIREP, AMDAR, ACARS,
BUFR AMV (NOAA 15, 16),
SATOBS (GOES E and W, GMS, Meteosat 5 and 7), PAOB
MODIS-Winds, pseudo-temps
cutoff: 2h30 (for forecasts)

Monitoring of ATOVS (AMSU-A)

Monitoring with routine GME available on internet in real time:
http://www.dwd.de/en/FundE/Analyse/Assimilation
-> Monitoring

Observed minus background (o-b) statistics for ATOVS and different areas.

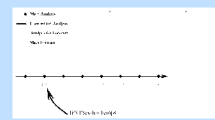
Diurnal cycles in statistics because of different model climates of GME and IFS (using pseudo-temps).

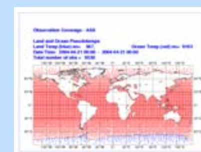
Pseudo-temps cool down GME at 0 UTC leading to negative o-b differences. During the next 24 model hours the analysis-forecasting system warms up again to reach for its own climatic equilibrium.

Use of ECMWF-Pseudo-Temps

(operational since Dec 17 2003)

Idea: use profiles of IFS/4D-Var analyses (temperature, humidity and wind) of ECMWF and assimilate them as temps in OI/GME.
In this way satellite data that is assimilated at ECMWF is used for GME giving a significant boost in forecast quality especially in the southern hemisphere.





Assimilation is done only one time per day for 0 UTC into update (main) analysis of GME. In this way an almost independent analysis-forecast system is still maintained. Pseudo-temps are to be substituted with the assimilation of radiances (ATOVS/IASI) with 1D-Var or directly with 3D-Var once the forecast skill of pseudo-temps is reached.

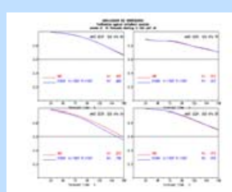
Data coverage of pseudo temps: about 100 km over sea and Antarctica.

Humidity is assimilated only above 700 hPa to not affect the humidity equilibrium of GME in the lower troposphere, which is different to the IFS climate.

Development: 1D-Var for AMSU-A

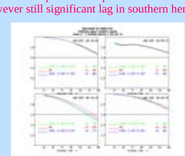
(NOAA 15, 16 and Aqua)

Setup:
- Receive level 1c ATOVS from UKMO (NOAA 15, 16 and Aqua)
- Radiative transfer computation: RTTOV-7
- Use IFS/ECMWF forecasts for radiative transfer in stratosphere
- Channel choice: AMSU-A 5-14 (HIRS deferred)
- Assimilation of temperature only
- Bias-Correction: UKMO-Style (scan angle and mass, A4 and A9)
- MW Rain/Ice-detection (Kelly and Bauer/ECMWF)
- Assimilation as SATEMS in OI (geopotential thicknesses), Assimilate temperature increments to avoid spurious biases
- B-Matrix based on GME-Statistics (NMC-Method)

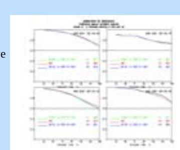


Status:
Pre-operational experiments:
In northern hemisphere and Europe almost equal to use of pseudo-temps, however still significant lag in southern hemisphere.

Comparison to SATEMS:
Significant improvement of 1D-Var in southern hemishere.



Use of AMUA-Aqua (not introduced in above statistics):
Small but significant improvement in southern hemisphere.

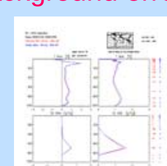


Tuning of observation and background errors

Independent data is required to estimate observation and background errors simultaneously
Idea: use pseudo-temps:
- Tune magnitudes of R and B for the correct size of the 1D-Var cost function at its minimum
- Tune relation of R and B for best collocation of retrievals with pseudo-temps

Reduced observation errors:

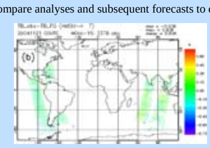
Channel	4	5	6	7	8	9	10	11	12
SQRT(R)	0.28	0.15	0.11	0.10	0.16	0.18	0.18	0.18	0.23



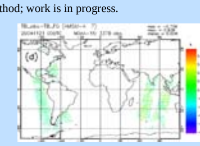
Tuning of horizontal thinning

Apply methods from information and image theory: keep most information with fewest fields of view, e.g.:
- estimation method: take that point that can be derived worst from its neighbours
- cluster method: take most representative field of view
- etc.

Compare analyses and subsequent forecasts to define best method; work is in progress.



ATOVS data coverage from regular (naïve) thinning



date coverage resulting from estimation method

Development of PSAS (3D-Var)

(physical space assimilation system, dual space, observation space)

Minimisation in Observation Space rather than Model Space

Conventional 3D-VAR (MSAS, Model Space Assimilation System)
solve:

$$x_a = x_b + \left(\mathbf{B}^{-1} + \mathbf{H}^T \mathbf{R}^{-1} \mathbf{H}\right)^{-1} \mathbf{H}^T \mathbf{R}^{-1} \left(y - H(x_b)\right)$$

PSAS (OSAS, Observation Space Assimilation System)
solve:

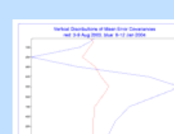
$$x_a = x_b + \mathbf{B}\mathbf{H}^T \left(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R}\right)^{-1} \left(y - H(x_b)\right)$$

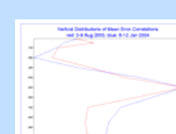
Comparison of PSAS with conventional 3D-Var:
- PSAS has more flexibility in definition of **B**
  flow dependent background errors can be introduced more easily.
- Observation space is smaller than model space
  (however high resolution infrared sounders may change situation)
- When using the flexibility specifying **B**, the minimisation costs become quadratic in number of observations
  (thus 1D-Var retrievals remain interesting even with 3D-Var)

Adaptive Error Correlations derived from NMC-statistics

(depending e.g. on vorticity, geopotential)

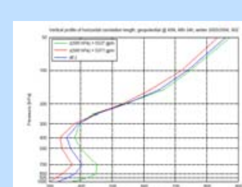
Forecast error correlations depend on the synoptic situation
(as derived from NMC-method)
Left: Vertical error covariances for *good* weather (red line) are much smaller than for *bad* weather (blue line).
Right: Vertical error correlations for *good* weather are sharper than for *bad* weather
Good and bad weather is defined by vorticity in this case.





Strategy:
Improve analysis with adjusted background error specification
Improve retrieval of vertical resolution of high spectral resolution sounders

Also horizontal correlation lengths depends on synoptic situation, right:



Open question: How much can you improve the analysis/forecast with adaptive variances and correlations?