Validation using NWP and performance monitoring

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- Cycling data assimilation
- The monitoring methodology
- Examples of operational monitoring results
- Conclusions
Cycling data assimilation

- The observations are used to correct errors in the short forecast from the previous analysis time.
- Every 12 hours we process 2 – 4,000,000 observations to update the 100,000,000 numbers that define the model’s virtual atmosphere.
- This is done by a careful space-time (4D) interpolation of increments in $u$, $v$, $T$, $q$, $O_3$, $P_s$ to better fit the available observations.
- One 12-hour assimilation cycle takes about as much computer power as the 10-day forecast.
Major assimilated data sets

- Surface stations
- Radiosonde balloons
- Aircraft
- Polar, infrared
- Polar, microwave
- Geostationary, IR
Observations are compared against a short-range 3-15 hour forecast

Horizontal resolution
\(T_L799 \approx 25\) km

Vertical resolution
91 levels
Forecast versus observations

12-hour forecast temperature change

Correction as a result of data assimilation

The analysis corrections are ~10 times smaller than the 12-hour forecast temperature change
The new information

The innovations provide the new information to the assimilation.

The innovations \( d \) = The observed departures from the background

\[
d = y - Hx_b
\]

If the distribution of the data in time is accounted for, then

\[
d = y - HMx_b
\]

The calculations of the departures are carried out as accurately as practically possible:

- We use the full non-linear forecast model \( M \), at highest affordable resolution (T799 = 25km)
- A large effort has been put on developing \( H \) to closely mimic the real observation; observation operators
Unfortunately, the observations $y$, the background $x_b$, and the observation operators $H$ are all affected by errors.

Let $\hat{h}$ denote ‘the truth’, and $\varepsilon$ the error, then

\[
y = \hat{y} + \varepsilon_o \quad \langle \varepsilon_o, \varepsilon_o^T \rangle = O \quad \text{Observation error covariance}
\]
\[
x_b = \hat{x}_b + \varepsilon_b \quad \langle \varepsilon_b, \varepsilon_b^T \rangle = B \quad \text{Background error}
\]
\[
H\hat{x}_{(t)} = H\hat{x}_{(t)} + \varepsilon_f \quad \langle \varepsilon_f, \varepsilon_f^T \rangle = F \quad \text{Representativity error}
\]
The innovation covariance can be written

\[ \langle d, d^T \rangle = HBH^T + O + F - (HX^T + XH^T) \]

(Joiner and Dee, QJ 2000)

\[ \langle d, d^T \rangle \approx HBH^T + R \]

Definition:
- \( HBH^T = \) Error in the background, expressed in terms of the observed quantity (HLOS wind)
One vertical column = one observation

\[
\begin{align*}
\frac{\partial H}{\partial u} & \quad \frac{\partial H}{\partial v} & \quad \frac{\partial H}{\partial T} & \quad \frac{\partial H}{\partial \psi} \\
B_u & \quad B_v & \quad B_T & \quad B_{ps} \\
H \quad B \quad H^T &= \quad HBH^T \\
\text{(a scalar)}
\end{align*}
\]
U-component wind HBHT (m/s) shaded

Z 250 hPa contoured

exp:0001 /DA 2006030100-20060314
TEMP-Uwind N.Hemis used U

RMS

Pressure (hPa)

ADM Workshop 26-28 Sept 2006, ESTEC
Monitoring of (simulated) ADM winds has been prepared (D. Tan)

Radiosonde obs-bg and obs-an

Simulated ADM HLOS winds obs-bg and obs-an
TOA modelled TB vs observed TB

Monitoring: Potential Results

TB

obs

fg

Time ...
Quality of NRT L2 ENVISAT data
SCIAMACHY ozone retrievals (Rosanna Dragani)

Statistics for Ozone from ENVISAT / SCIAMACHY
Layer = 1, 0.10 - 1013.25 hPa, All Data
Area: lon_w= 0.0, lon_e=360.0, lat_n= 90.0, lat_s= -90.0 (all surface types)
EXP = 0001, Data Period = 2006010100 - 2006083118

Statistics for Ozone from ENVISAT / SCIAMACHY (KNMI)
Layer = 1, 0.10 - 1013.25 hPa, All Data
Area: lon_w= 0.0, lon_e=360.0, lat_n= 90.0, lat_s= -90.0 (all surface types)
EXP = 0001, Data Period = 2006010100 - 2006083118
Recent MET-5 incident (Carole Peubey)
CMOD4 versus ECMWF (Hans Hersbach)

ECMWF FGAT winds versus CMOD4 winds
from 2006081600 to 2006091918
= 721216, db contour levels, 5 db step, 1st level at 3.6 db
m(y-x) = -0.86 sd(y-x) = 1.45 sd(x) = 3.56 sd(y) = 3.34 PCxy = 0.956
CMOD5 versus ECMWF

ECMWF FGAT winds versus CMOD5 Winds
from 2006081600 to 2006091918

721211, db contour levels, 5 db step, 1st level at 3.6 db
m(y-x) = -0.38, sd(y-x) = 1.42, sd(x) = 3.56, sd(y) = 3.54, pxy = 0.959
SSMI/S: Problems for T sounding channels

Main issues for temperature-sounding channels:

- Warm load solar intrusions (currently flagged, 30-40% of data)
- Reflector emission (correction applied)

These are dealt with in the SSMIS pre-processor (Met.Office, Bill Bell).
SSMI/S monitoring for T-sounding channels:
FG departures vs solar zenith angle (Niels Bormann)

Ch 3,
13 March 2006,
12 Z
Conclusions

- NWP monitoring of satellite data is now a well established practise
- Instrument anomalies, biases and drifts are detected
- Comparison with a short-range forecast effectively takes out a large part of the atmospheric variability from the measured signal. The remainder (departure) should be small – within relatively well known error bounds (the background error)
- If departures show variation with satellite/instrument parameters, then corrections may need to be developed.

Timeliness of data delivery is an important issue.
Near-Real Time (NRT) is often required in order to fit with the tight production schedule of operational NWP centres.
Data availability as soon as possible after launch is also required.