Preliminary results and tuning of Météo-France’s pre-operational ALADIN 3D-Var

Thibaut Montmerle, C. Fischer, L. Auger
Météo-France/CNRM
ALADIN France:

- A spectral Limited Area Model covering Western Europe, coupled with ARPEGE

- **Simulation Domain:** 2740 km², centered over ARPEGE’s gridpoint that has the maximum horizontal resolution

- 3DVar version pre-operational since 20th of March, 2005
**General algorithm:**

**Ensemble Jb**: Background error covariances are sampled from an ensemble of Aladin forecasts, with initial conditions from an ensemble of ARPEGE analyses (Stefanescu et al, 2005)

**Continuous assimilation cycle**, 6 hour frequency, coupled with ARPEGE

**Observations** are those that enter the ARPEGE assimilation (cf Florence Rabier's talk)

+ Met-8/SEVIRI radiances

**Incremental 3D-VAR**, using 80-90% of the common Arpège/IFS code
Test period: July 2004

Example of total rain forecast (P12 – P6)

Known drawback: positive bias for the precipitation forecast
Scores of the pre-operational suite:

22nd of March -> 15th of June 2005  
rms error (Dyn. Adap / TEMP) – (Oper/TEMP)

⇒ Reduction of the variances before 12h of forecast, neutral afterwards except for T and q which show a weak degradation of the mid-tropospheric bias.
Scores of the pre-operational suite:

22nd of March -> 15th of June 2005

Bias + RMS compare to SYNOP

⇒ Strong MSLP and Hu$_{2m}$ biases in the analysis: balance problem due to badly tuned and/or biased observations?
Sensitivity of the analysis to observations:

The DFS ("Degrees of Freedom for Signals") has been computed:

\[
\text{DFS} = Tr\left(\frac{\partial \mathbf{H} x_a}{\partial \mathbf{y}}\right) = Tr(\mathbf{HK})
\]

Where \(x_a\) denotes the analysis vector, \(\mathbf{H}\) the observation operator linearized in the vicinity of the background state (composed of an interpolation operator and RTTOV-8 fast radiative transfer model for the radiances), and \(\mathbf{K}\) the Kalman gain matrix (\(\mathbf{K} = \mathbf{B}\mathbf{H}^T(\mathbf{H}\mathbf{B}\mathbf{H}^T + \mathbf{R})^{-1}\)).

\(Tr(\mathbf{HK})\) is computed following a Monte Carlo method.

\[⇒ \text{DFS is very high for SEVIRI}\]
\[⇒ \sigma_o \text{ have been increased for SEVIRI}\]
Channels 11 and 12 for HIRS and WV channels for SEVIRI are the most informative.
Tuning

- Tuning of the background error variances:

Use of Desroziers et Ivanov (2001) algorithm $B_{\text{true}} = s_b B$ with $s_b = \frac{2J_b(x_a)}{\text{Tr}(KH)}$ gives $s_b = 0.7$ => The fit to the observations has been reduced by decreasing $\sigma_b$.

- Computation of the bias for SEVIRI:

Flat bias tuned on the July 2004 period.

Addition of surface observations \((P, T_{2m}, Hu_{2m})\) (L. Auger):

Prevent mid-tropospheric analysis increments due to radiances assimilation to spread out into the boundary layer

⇒ More realistic initial conditions that reduce the positive bias in precipitations forecast

Vertical cross-sections of humidity increments
Scores after the tuning and the addition of surf. Obs

23\textsuperscript{rd} of march -> 4\textsuperscript{th} of april 2005

Bias + RMS

\Rightarrow Important improvement compare to the pre-operational suite

\Rightarrow Reduction of the mid-tropospheric T and q biases
Conclusions

The ALADIN 3DVar is run pre-operationally at Météo-France since March

First evaluations show obvious tuning problem:

• DFS have been computed for each type of observations and each channel of ATOVS and SEVIRI radiometers

⇒ DFS show that analyses are too sensitive to SEVIRI radiances: their $\sigma_o$ have been increased in consequence

• the $s_b$ coefficient has been estimated in order to tune the background error variances ($\sigma_b$)

• Flat biases initially used for SEVIRI have been replaced by air mass dependent biases
Conclusions

Surface observations have been introduced in the variational process:

• Increment patterns show good complementarity with SEVIRI WV radiances
• Positive bias in precipitation forecast has been reduced

All these modifications notably improve forecast scores
⇒ This new version will become operational after validation at the end of June

Perspectives

3DFGAT, $J_k$ (variational term of relaxation towards large scale), revisit the formulation of humidity analysis, impact of denser data (ATOVS, Quikscat)
Seviri in Aladin 3DVar

1st configuration:

- **Use of 1 pixel over 5** (~25 km horizontal resolution over France)
- Thinning within 66 km² boxes
- Channels 3.9µ and 9.7µ (Ozone) blacklisted
- **Flat bias** for each channel
- Empirical $\sigma_o$
**Seviri in Aladin 3DVar**

- **Use of the cloud classification for the channel selection**: 
  
  i) Channels IR 8.7\(\mu\)m, 10.8\(\mu\)m and 12\(\mu\)m only in clear air 
  
  ii) 13.4\(\mu\)m kept above low clouds 
  
  iii) WV 6.2\(\mu\)m and 7.3\(\mu\)m kept above mid-level clouds 

- **Test Runs 6 to 22 July 2004** (4 cycled assimilations per day)

  **CNTRL** uses (as shown by Claude Fischer):

  i) a B matrix deduced from an ensemble of ARPEGE/ALADIN assimilation/forecasts (as shown by Simona Stefanescu)

  ii) Complete set of observations (conventional data, IR radiances from HIRS and AMSU-A) within a +/- 3 h assimilation window.

  **SEV** : CNTRL with SEVIRI data
Conclusions

- A lot of information coming from SEVIRI radiances is taken into account in the analysis through the 3DVar, producing realistic mesoscale increments.

- The cloud type classification is very useful to keep only data non contaminated by clouds in the variational process.

- Results deduced from the 15 days test period are encouraging, notably for short term (i.e < 12h) precipitation forecast.
Perspectives

QPF scores show however that SEV produces too much precipitations (i.e better ETS and POD but worse FAR and FBias) + relative weight of SEVIRI data is important in the analysis: should the fit to observation be relaxed?

⇒ Tunning of the error statistics (B. Chapnik) and of the thinning

Assimilation of proxy humidity profiles for convective clouds (see the poster of M. Nuret), computed from the cloud top pressure and a convection detection algorithm.

Monitoring as soon as ALADIN 3DVar becomes operational
SEVIRI radiometer onboard MSG (henceforth called Meteosat-8):

=> Information about the variation rates of T and q fields at high spatial and temporal resolutions (complete image every 15 min)
Cloud Types

Cloud Top Pressure
Seviri in Aladin 3DVar

Cloud types:
(computed by CMS in the SAF/NWC MSG framework)

(T10.8\(\mu\) – T12\(\mu\)) & (T10.8\(\mu\) – T12\(\mu\))
& \(\sigma^2\) (T10.8\(\mu\))
Daytime R0.6\(\mu\) & \(\sigma^2\) (R0.6\(\mu\))

Fractional & semi-transparent Clds

(T8.7\(\mu\) – T10.8\(\mu\)) or R0.6\(\mu\)

Fractional
Semi-transparent

Low/medium/high opaque Clds

T10.8\(\mu\) \(\Leftrightarrow\) \(H(x)\) for different pressure levels

Low
Medium
High