Data assimilation aspects at Météo-France

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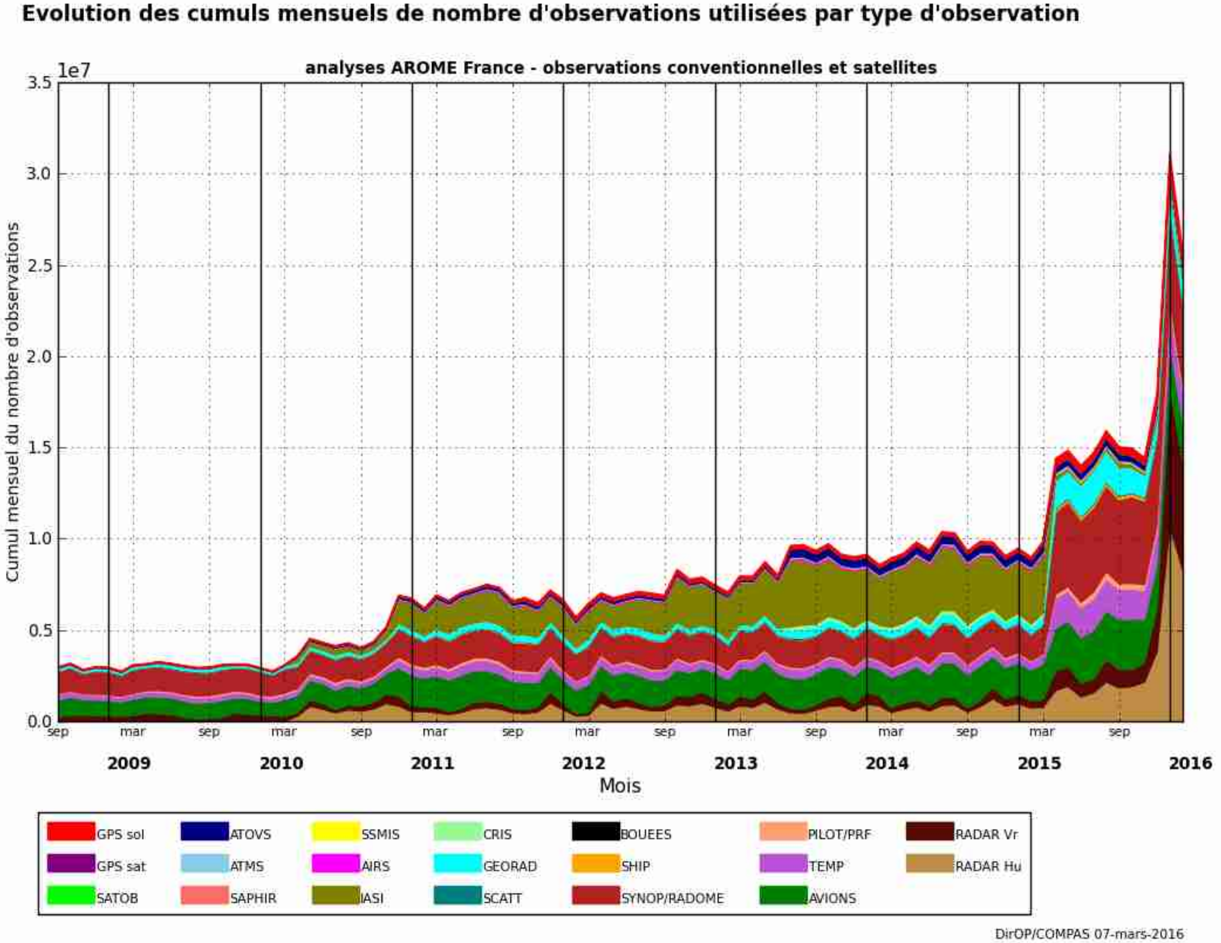
Outline of talk

- Radar obs assimilation
- 4DEnVar
- Plans: obs, applications

Evolution of total number of assimilated observations in AROME-France



Nov'08 : Arome oper with Vr
Spring'10 : Refl oper
Autumn'10 : Improved assim of NoRain Refl
Spring'15 : 1.3km resol Arome
Autumn : Higher density radar obs

Use of foreign data; OPERA; plans

- Tested impact of foreign radars (Spain) : beneficial
- Wish to implement OPERA data directly in AROME
=> requirements for ODIM-HDF5
- Both raw data and cleaned data are required
- Quality flags have to contain the identification of anomalies and the quantification of the quality for an optimal use in NWP

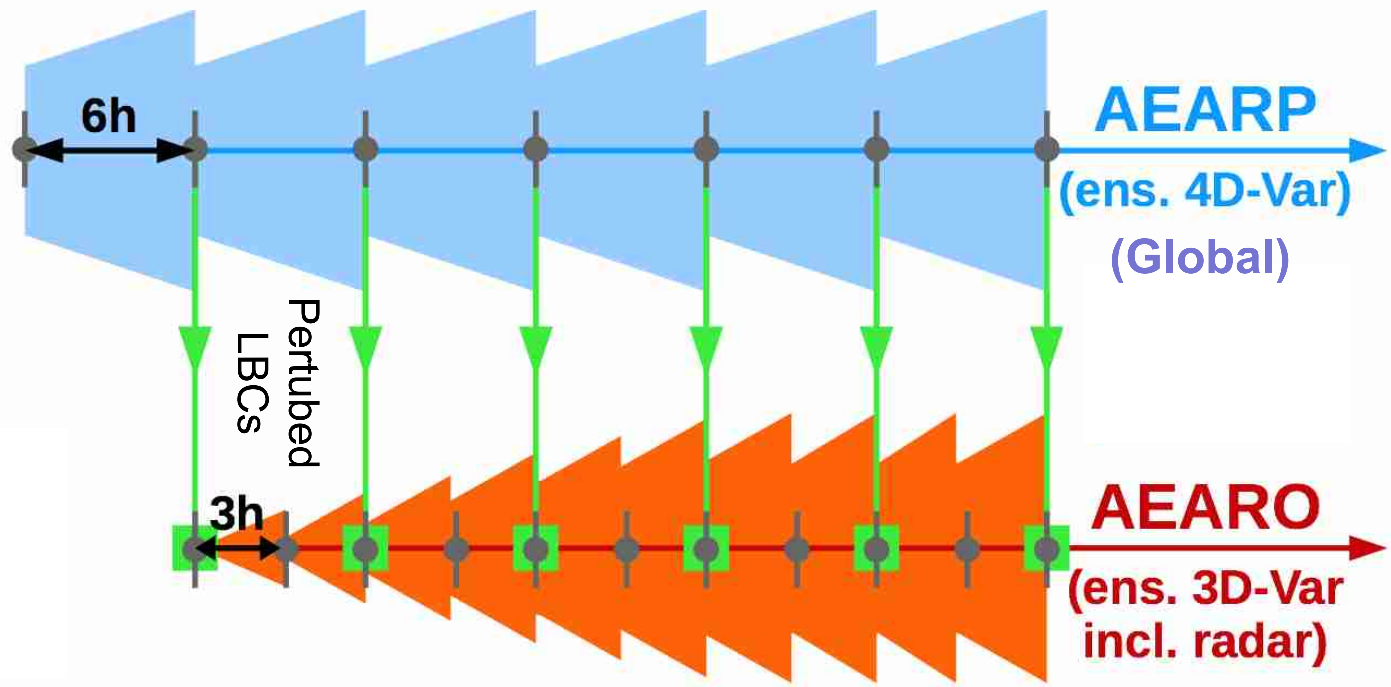
- Near future : improve obs operator (DPOL, X-band),
- Implement some foreign radars in e-suite (D, Be, NL),
- Increase number of radar data in screening in next e-suite,
- Assess importance of initializing precipitating hydrometeors (DPOL)

EnVar for ARPEGE or AROME : perturbations

Use an ensemble data assimilation (EDA) with *L* members to compute background perturbations :

$$\delta\tilde{\mathbf{x}}^b_p = \frac{1}{\sqrt{L-1}}\left(\tilde{\mathbf{x}}^b_p - \langle\tilde{\mathbf{x}}^b\rangle\right) \longrightarrow \tilde{\mathbf{B}} = \frac{1}{L-1}\sum_{p=1}^{L}\left(\tilde{\mathbf{x}}^b_p - \langle\tilde{\mathbf{x}}^b\rangle\right)\left(\tilde{\mathbf{x}}^b_p - \langle\tilde{\mathbf{x}}^b\rangle\right)^{\mathsf{T}}$$

- Explicit obs. perturb.
- Implicit Bckgd perturb.



- Explicit obs. and LBCs perturb.
- Implicit bkgd perturb.

Fisher 2003 ; Kucukkaraca and Fisher (2006); Berre et al 2006

Comparison of 4D-Var / 4DEnVar formulations for ARPEGE

- deterministic 4D-Var at Météo-France

- already uses an ensemble to evolve $\mathbf{C}_0$ (auto-correlations).

- wavelet representation of $\mathbf{C}_0^w$: provides smoothed correlations.

- covariances evolve implicitly with time : $\mathbf{B}_k = \mathbf{M}_k \mathbf{K}_0^b \Sigma_0^b \mathbf{C}_0^w \Sigma_0^{bT} \mathbf{K}_0^{bT} \mathbf{M}_k^T$.

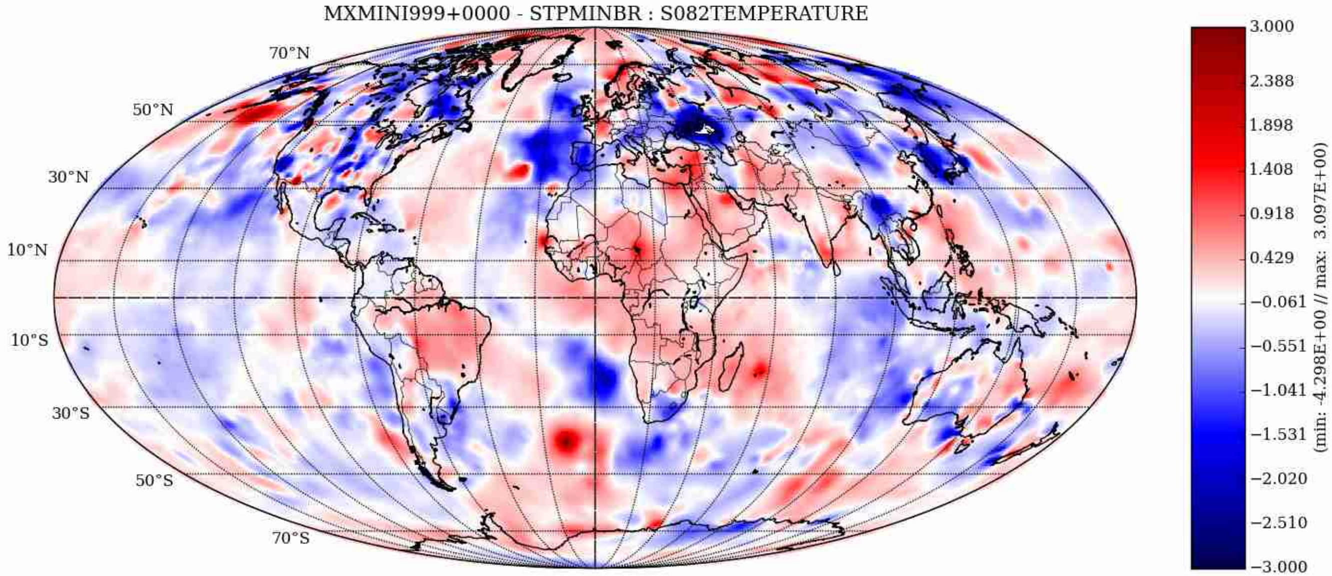
- 4DEnVar using evolved $\delta \underline{\mathbf{x}}^b$ perturbations derived from an ensemble of fcts

- Ensemble of L=150 members.

- In the present tests, the 150 members also are used to generate the $\mathbf{B}_0$ "climatological" matrix for 4D-Var.

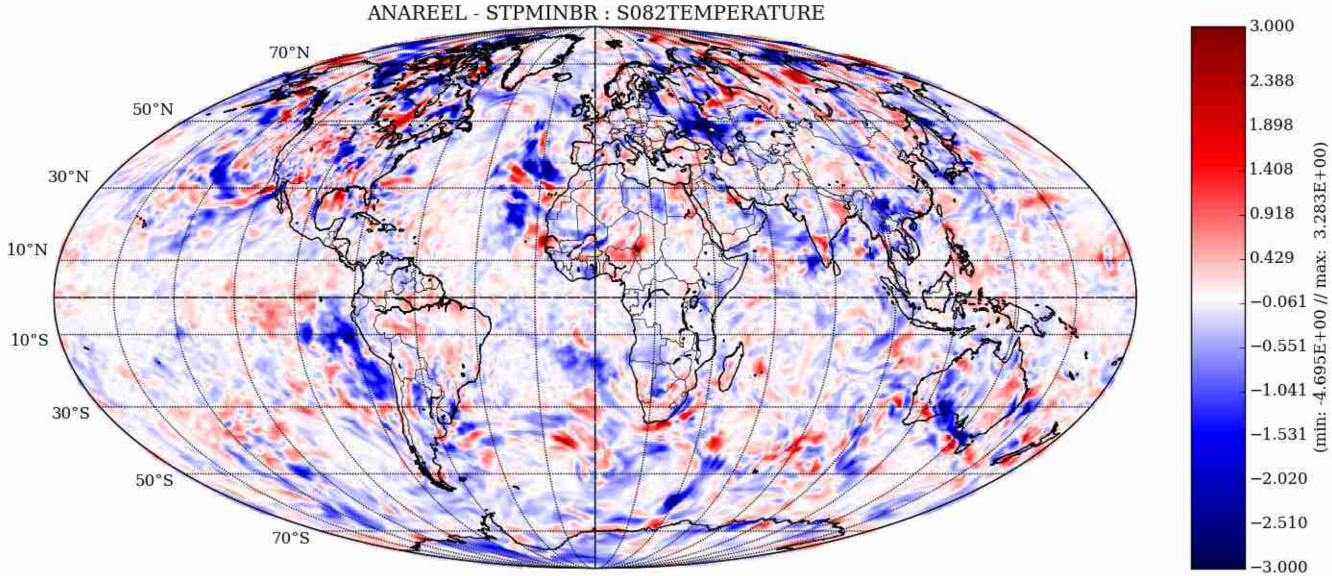
Comparison 4D-Var / 4DEnVar "δx^b ens" (L = 150)
Temperature increment at t_0 and ~ 850 hPa

4D-Var



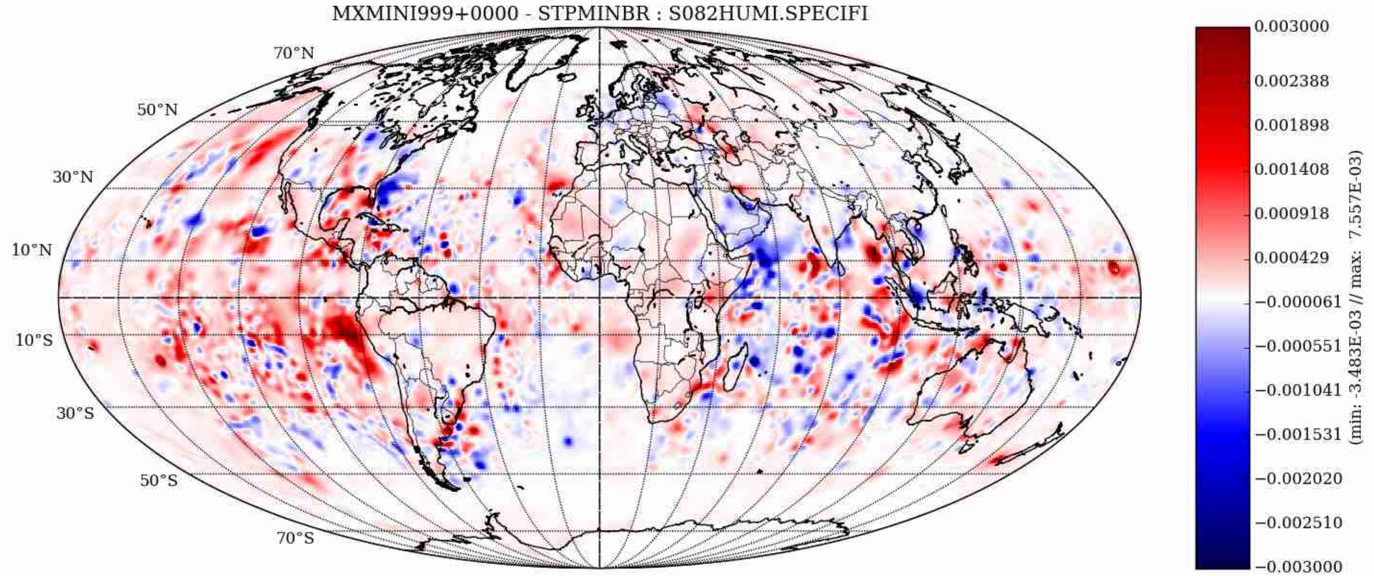
4DEnVar

δx^b ens



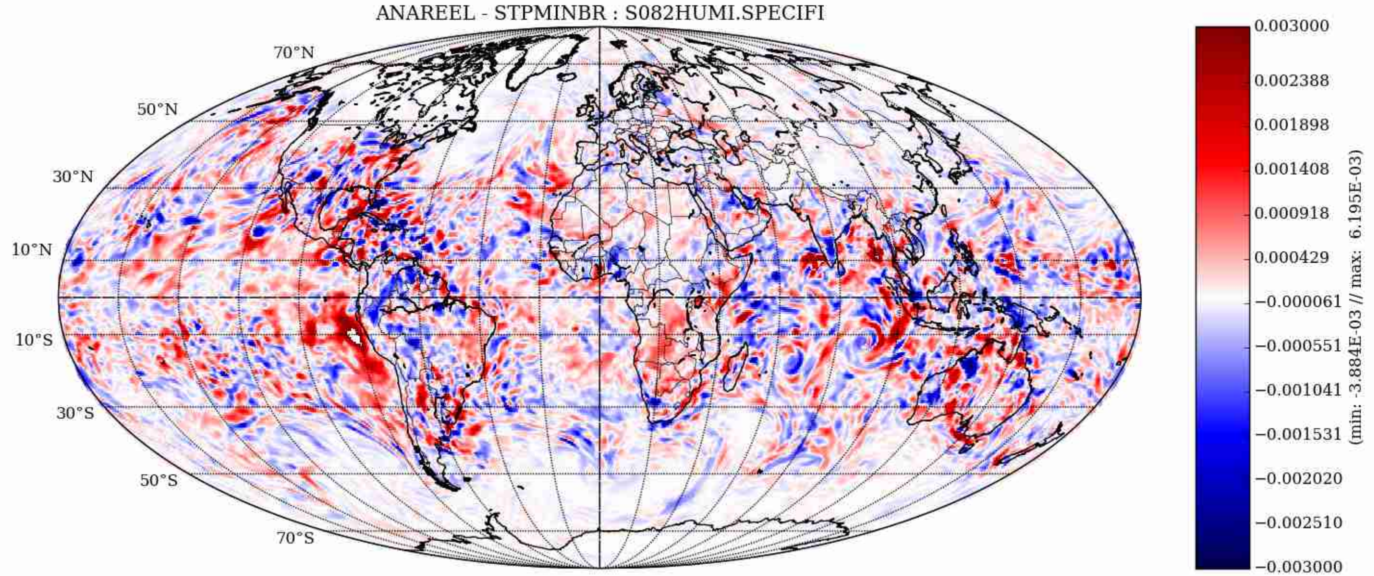
Comparison 4D-Var / 4DEnVar "δx^b ens" (L = 150)
Specific humidity increment at t_0 and ~ 850 hPa

4D-Var



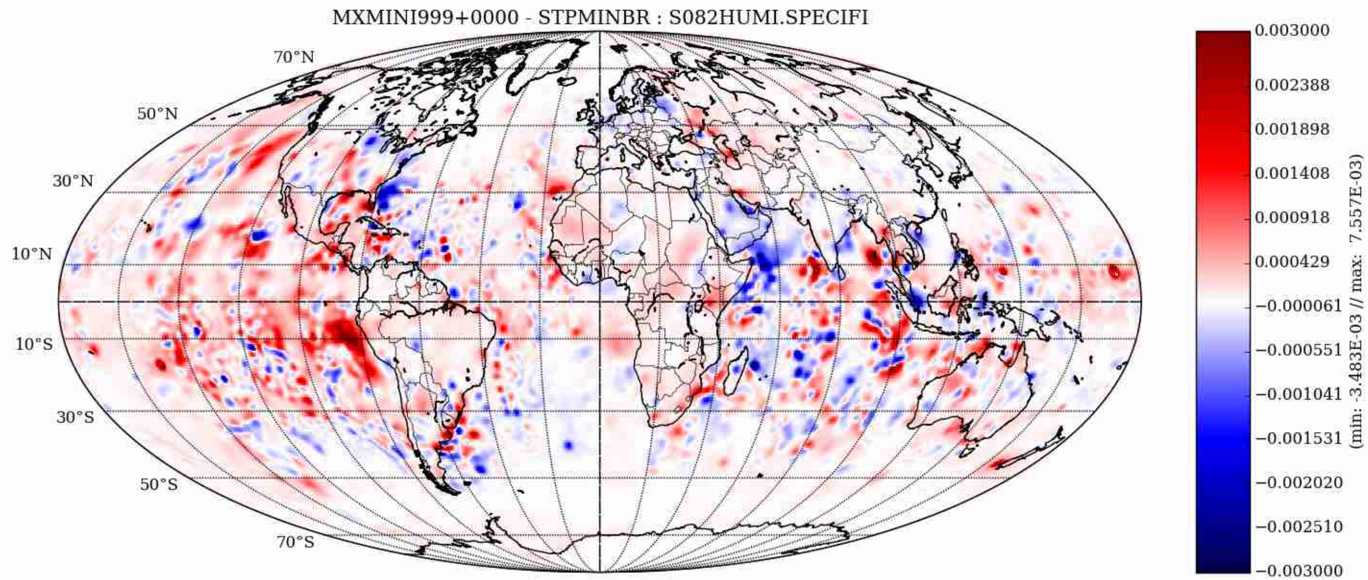
4DEnVar

δx^b ens



Comparison 4D-Var / 4DEnVar "δx^b ens" (L = 150)
Specific humidity increment at t_0 and ~ 850 hPa

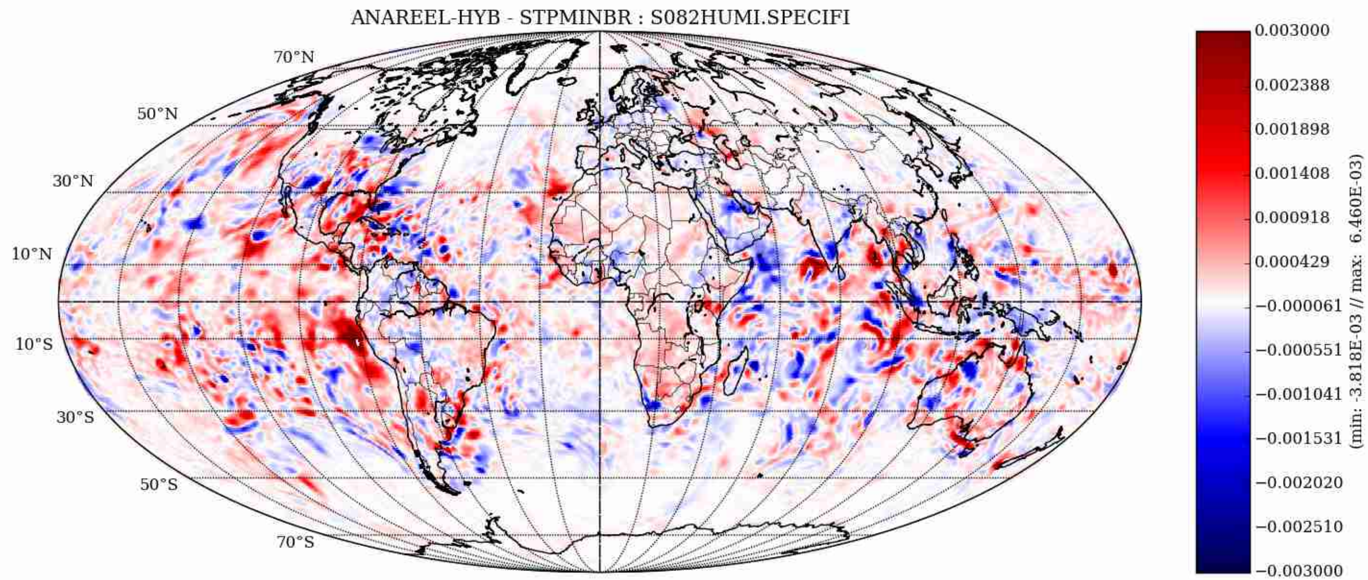
4D-Var



4DEnVar

δx^b ens

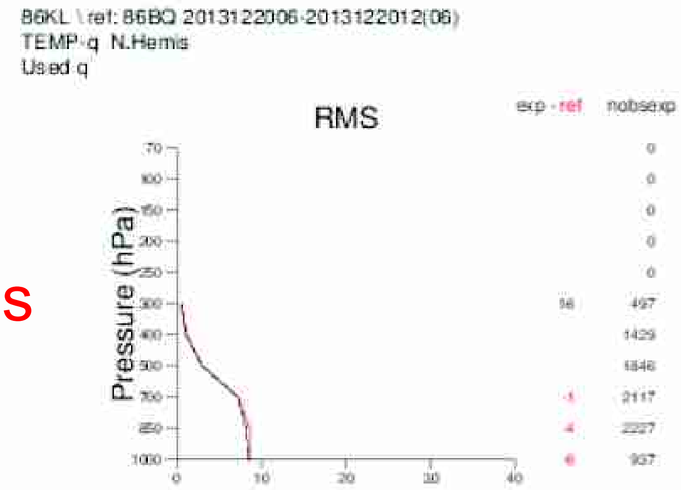
hybrid



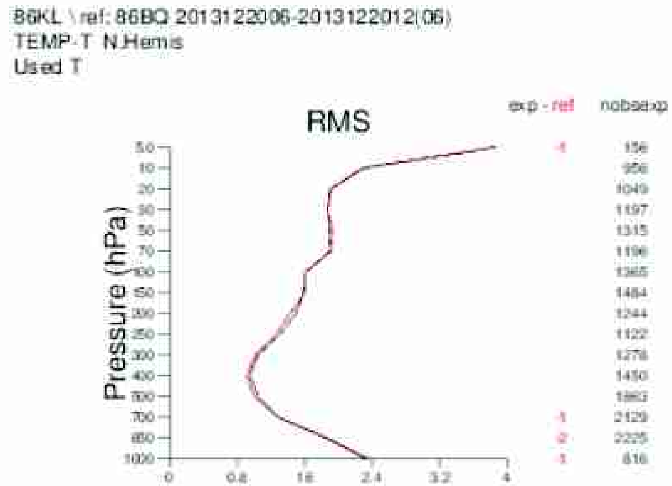
4D-Var / 4DEnVar 150 δx^b « ens » hybrid

TEMP q NH

δx^b ens

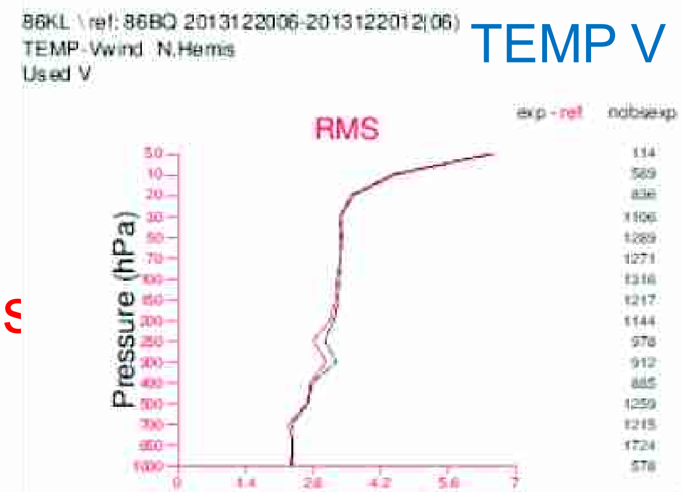


TEMP T NH

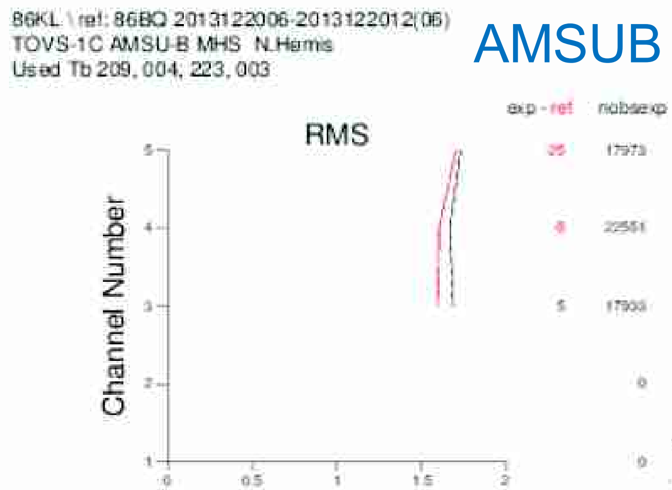


TEMP V NH

δx^b ens



AMSUB NH



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Overview about EnVar

- 4DEnVar ARPEGE/AROME already possesses quite a few options:

✓ Renormalize perturbations using a filtered σ^b field.
✓ B hybrid.
✓ Change of variable in order to allow a unique localization.
✓ Advection of localization.
✓ Advection of the so-called "climatological" B.
✓ Optimizations to decrease the numerical cost of the localization ("spectral").
✓ Various possible formulations for the localization.
✓ Reminder: all this is coded starting from the OOPS/C++ layer

- State-of-the-art results with 4DEnVar ARPEGE

✓ Obstats scores to read with some caution.
✓ Randomized B tested in 4DEnVar against pure ensemble B: "ens" version seems better than "rand".
✓ Increments of 4D-Var and 4DEnVar still look quite different.
✓ 4D aspects require more studies and optimization.

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Strategy for further testing for 4DEnVar in ARPEGE

- ✓ Which size of ens is needed, which one is tractable on HPC ?
- ✓ Ensemble generation methods.
- ✓ Test 4DEnVar in T149.
- ✓ Hybridization seems necessary and promising.
- ✓ Obtain a quasi-optimal and cheap localization approach.
- ✓ Use all available observations.
- ✓ Add VarBC.
- ✓ 4D aspects, external loops, initialization.
- ✓ Port VAR prototypes to OOPS-IFS based on CY42R3
- ✓ Documentation.

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Plans for observations in ARPEGE and AROME

- ✓ assimilation of Lidar winds from ADM-AEOLUS (provided these data are made available by Eumetcast dissemination),

- ✓ assimilation of new scatterometer data (ScatSat),

- ✓ get prepared for using data from IRS/MTG,

- ✓ consider new satellites: China (FY3-C, FY3-D), ATMS and CrIS obs. from JPSS1 (USA, successor of Suomi-NPP),

- ✓ AROME:
  - ✓ start using radar data provided by OPERA (technical throughput enabling to monitor a few OPERA radars should be available by the end of 2016)
  - ✓ study the potential of Mode-S data (ASD-B format),
  - ✓ all-sky microwave radiances using a Bayesian inversion approach,

Plans for MF's NWP applications in a general overview

- Migration to new BULL HPC Phase 2 (ongoing)
- Transfer to operations of Arome-EPS (2.5kmL90, 12 members, twice a day)
- Next E-suite : starting mid 2016 (CY42_op1 ?), includes a new convection scheme and Surfex in Arpège; operational switch beginning of 2017
- 2017-2018 :
  - Arome-EDA,
  - Arome-EPS 4 times/day,
  - Arpège new resolution (about 5km over Western Europe),
  - very likely also an increase of the horizontal resolution of Arpège EDA and EPS,
  - GRIB2, etc.

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End of the talk

- Obrigado pela sua atenção. Questões por favor.

Present configuration
of the operational global assimilation in ARPEGE

- deterministic 4D-Var:
  - ✓ Time window of 6 h.
  - ✓ 2 external loops:
    T1198 C2.2 (7.5 km min) L105 / T149 (~135 km), T399 (~ 50 km).
  - ✓ Jc-DFI, VarBC.
  - ✓ $\mathbf{B}_0^{1/2} = \mathbf{K}_0^b \, \Sigma_0^b \, \mathbf{C}_0^{1/2}$, $\mathbf{C}_0$ in wavelet, $\mathbf{K}_0^b$ = spectral + NL balances.

- ensemble assimilation:
  - ✓ 25 perturbed 4D-Vars.
  - ✓ 1 external loop T479 C1.0 (40 km) / T149 C1.0.
  - ✓ multiplicative inflation of perturbations applied to the 3h fcts.

➢ Σ_0^b filtered, with the last 25 perturbations and updated every 6 h.

➢ $\mathbf{C}_0$ wavelet with the 6 x 25 last perturb. 3h (30 h), updated every 6 h.

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EnVar for ARPEGE or AROME : formulation

From these *L* sampled perturbations, a localized $\mathbf{B}_e$ is computed

$$\mathbf{B}_e = \widetilde{\mathbf{B}} \circ \mathbf{C} = \mathbf{X}^b \mathbf{X}^{b^T} \circ \mathbf{C}$$

$$\mathbf{X}^b = [\delta\widetilde{\mathbf{x}}_1^b, \ldots, \delta\widetilde{\mathbf{x}}_L^b]$$

with :

The localization matrix **C** aims at reducing sampling noise by damping covariances with …)

Use of a simplified **C** :

$$\mathbf{C} = \begin{pmatrix} \mathbf{I}_N \\ \vdots \\ \mathbf{I}_N \end{pmatrix} \mathcal{C} (\mathbf{I}_N \ldots \mathbf{I}_N) = \mathbf{1}_N \mathcal{C} \mathbf{1}_N^T$$

$\mathbf{I}_N$ is a *N* x *N* identity matrix, $\mathbf{1}_N$ is composed of *M* (x (*K*+1)) $\mathbf{I}_N$ blocks, and $\mathcal{C}$ is a *N* x *N* correlation matrix