The 2013 and 2014 improvements in the Arpège and Arome-F data assimilation suites

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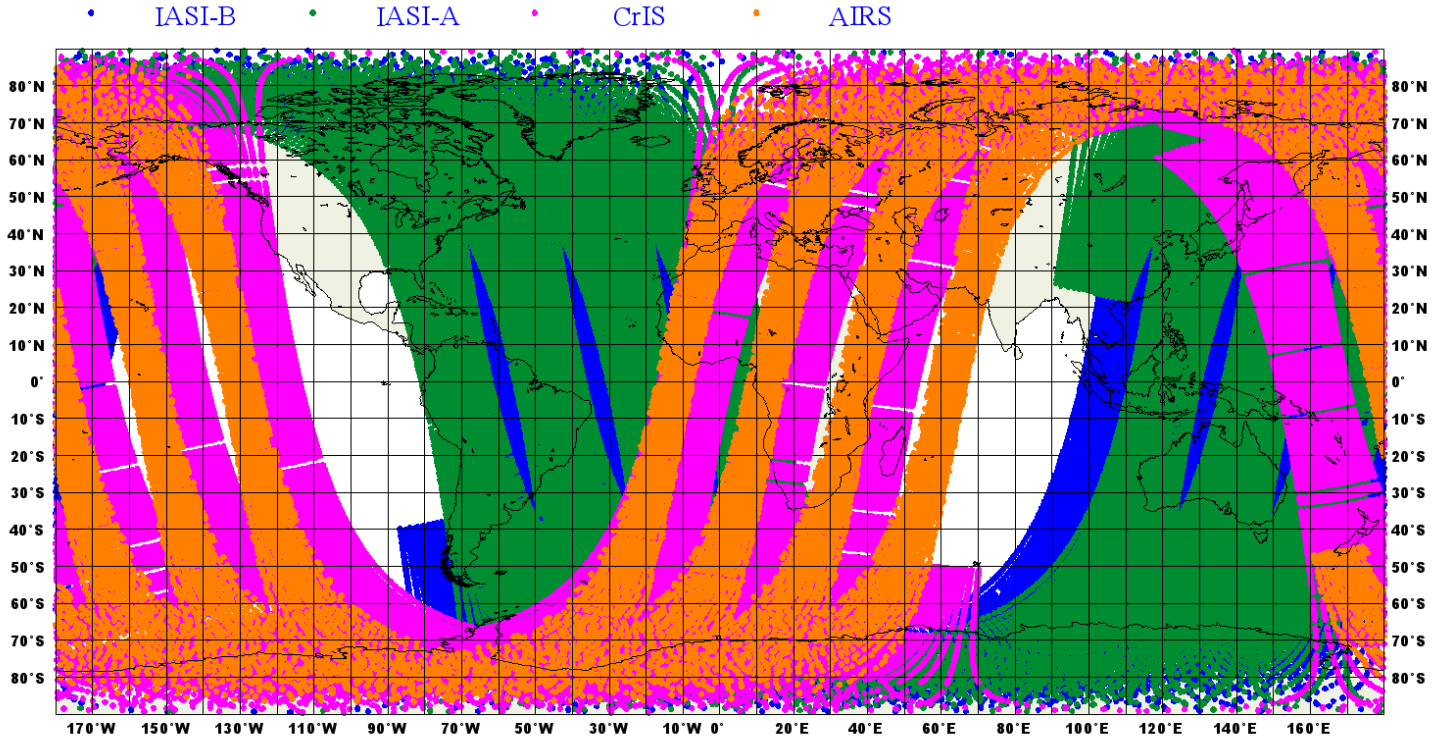
CY38T1 E-suite: observations and Arpège aspects

- OBS: NPP/CrIS, Metop-B, ATMS, OceanSat-2/OSCAT, GOES-13, GOES-15, new tuned σo, selection of ground-based GPS ZTD via screening namelist, …
- Wavelet structure functions in Arpège 4D-VAR and AEARP
- New tunings of thermal inertia, albedo & roughness length over ice shells (glaciers); changes in shallow convection scheme KFB; stiffer relaxation of SST towards OSTIA
- (…)
- Switch to operations on July 2, 2013.

Coverage of IR hyper-spectral sounders: MetOp-A/IASI (green), MetOp-B/IASI (blue), AIRS (orange), CrIS (pink)



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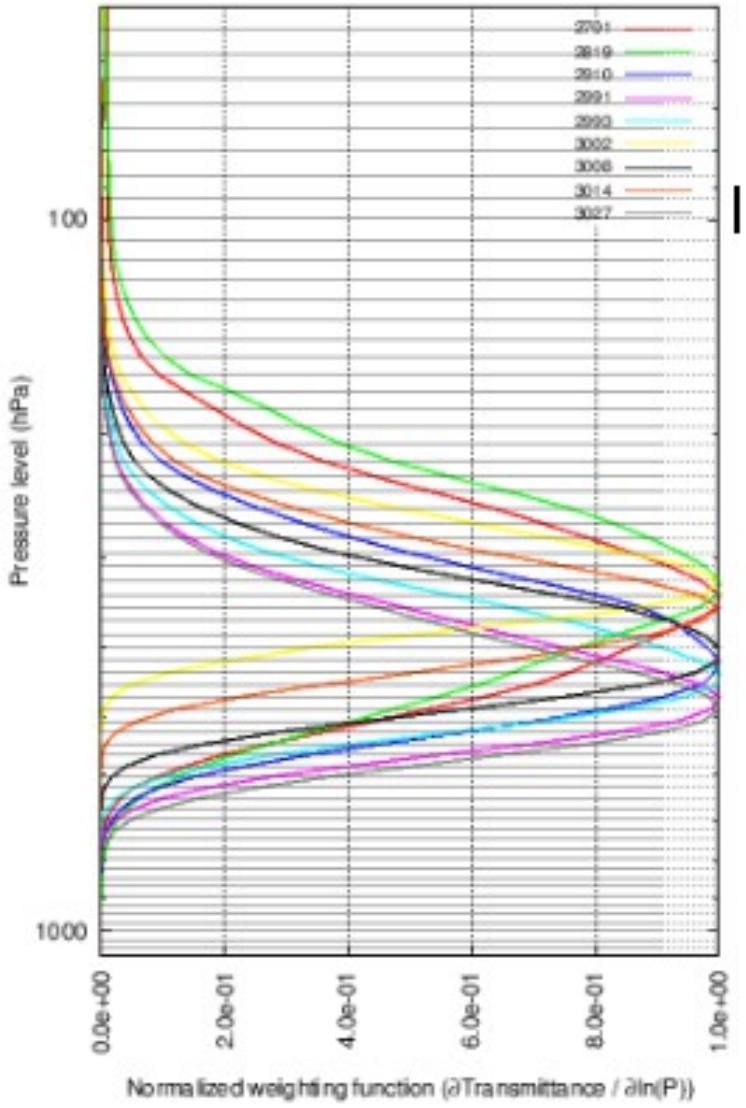
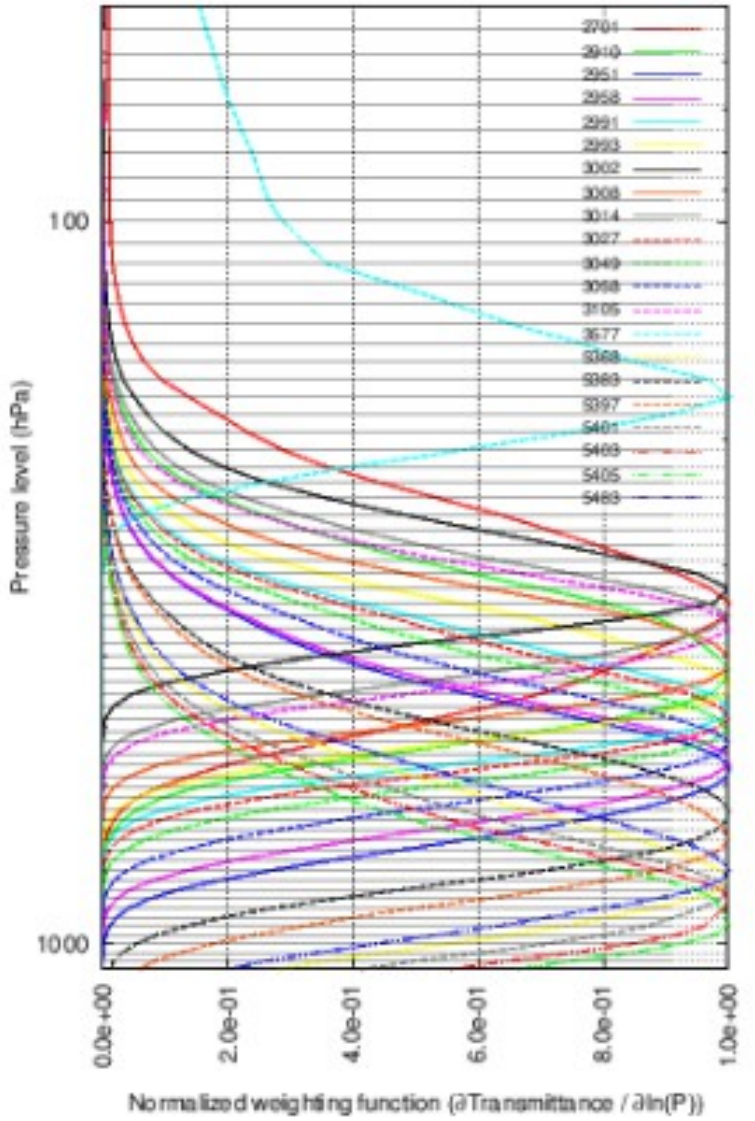
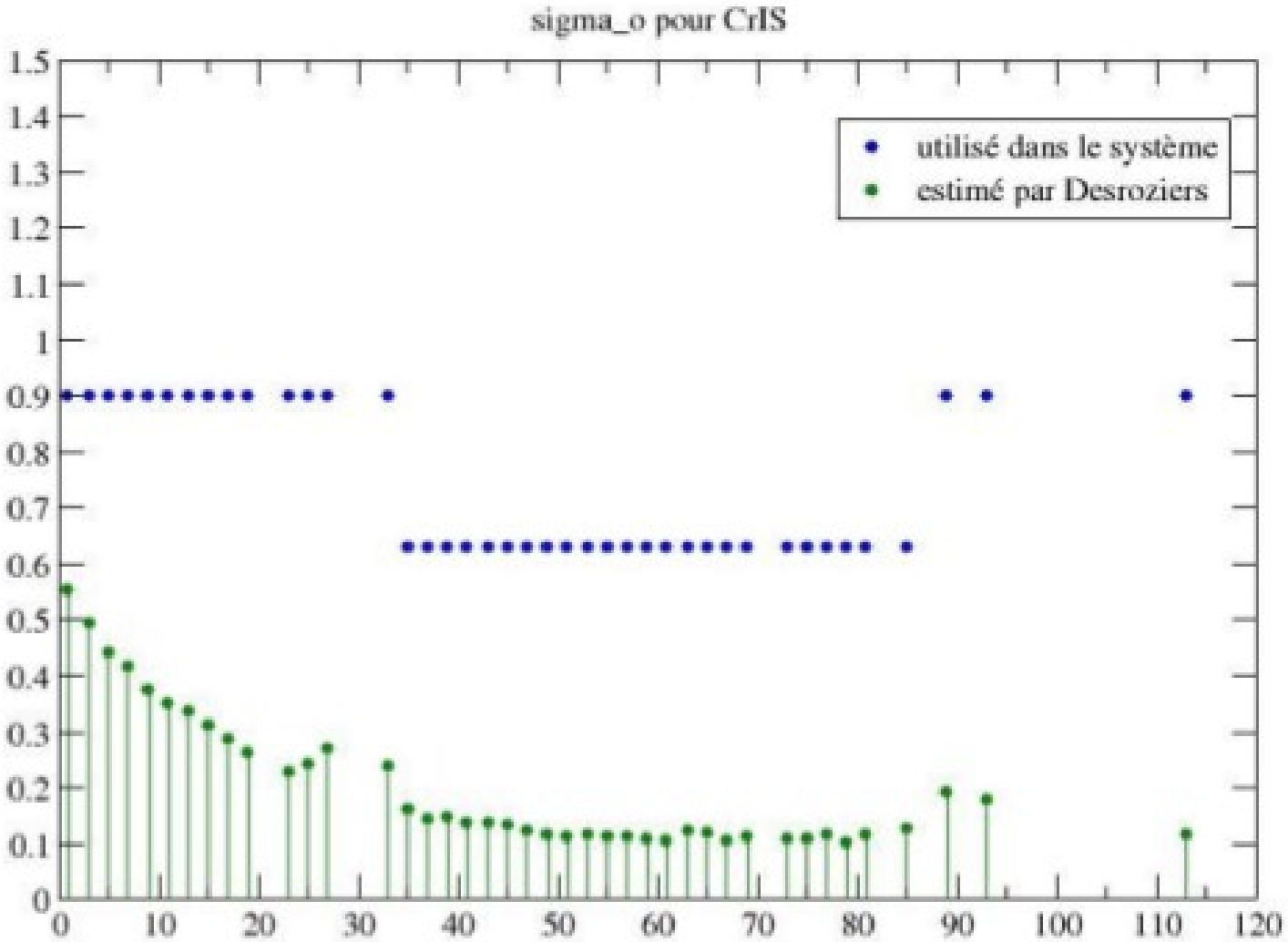
Weighting functions of IASI WV channels



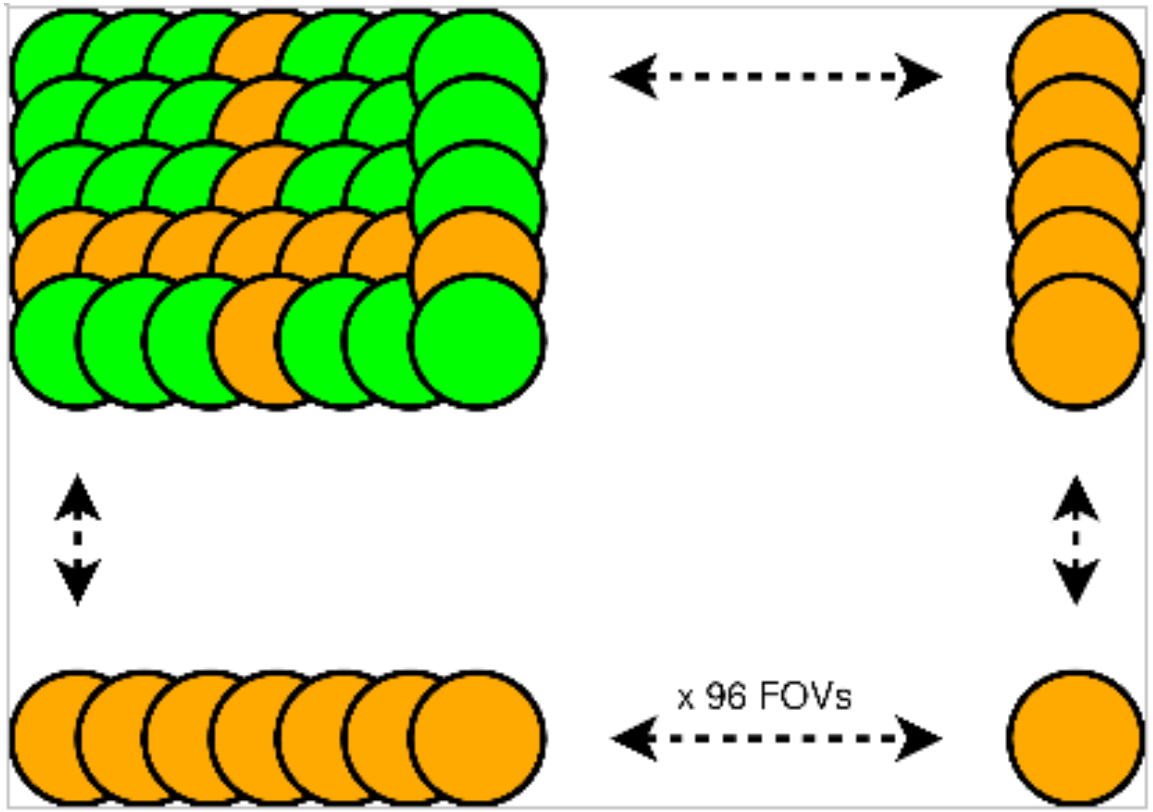


Obs error stdev specified for the assimilated CrIS channels

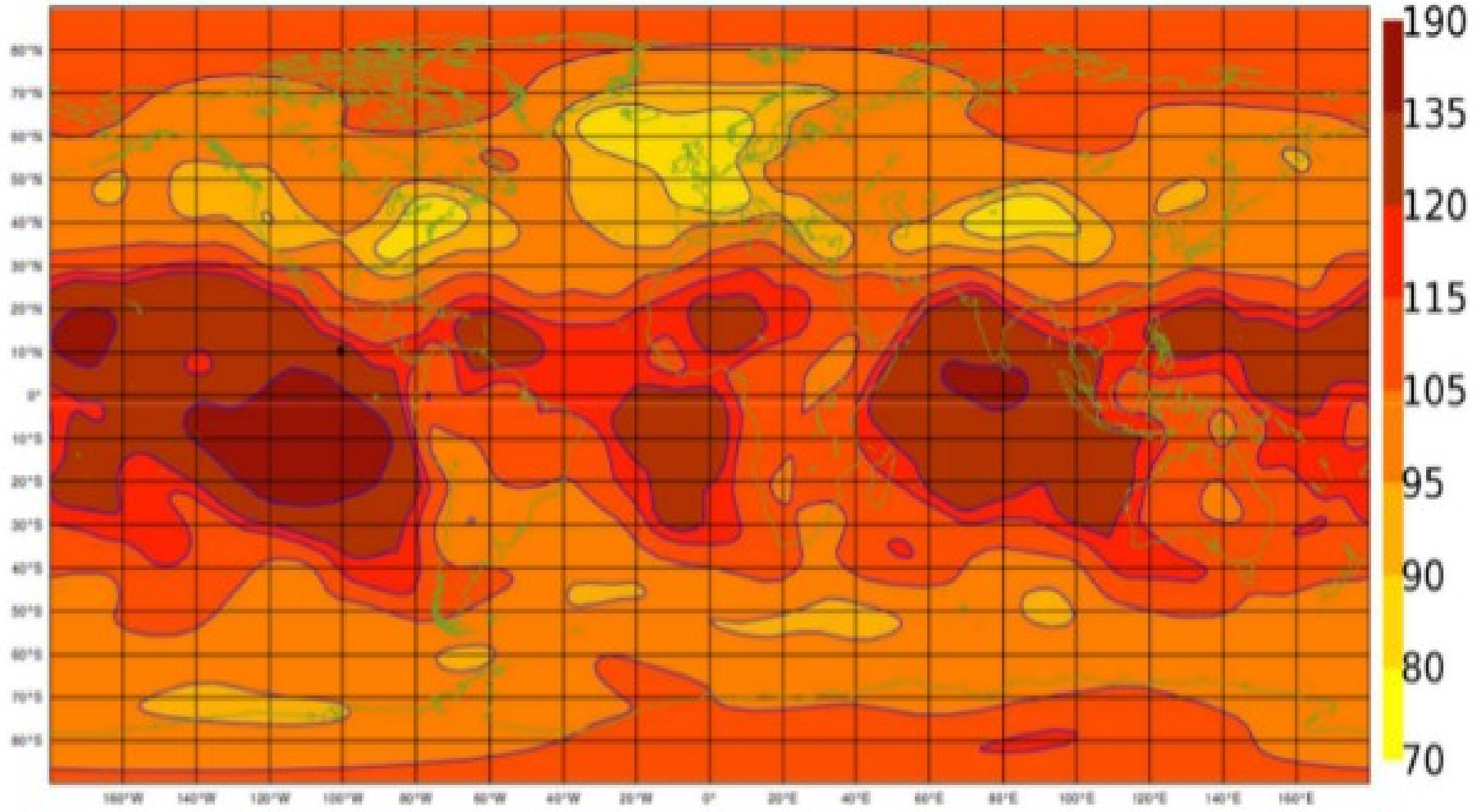


ATMS MW sounder

- Relatively large instrumental noise but very fine spatial resolution
- Pixels are averaged: take every 4th FOV and average values over 3 successive pixels in all directions
- This processed data are assimilated using choices very similar to what's done for AMUS-A and MHS
- 14 channels are kept in assimilation



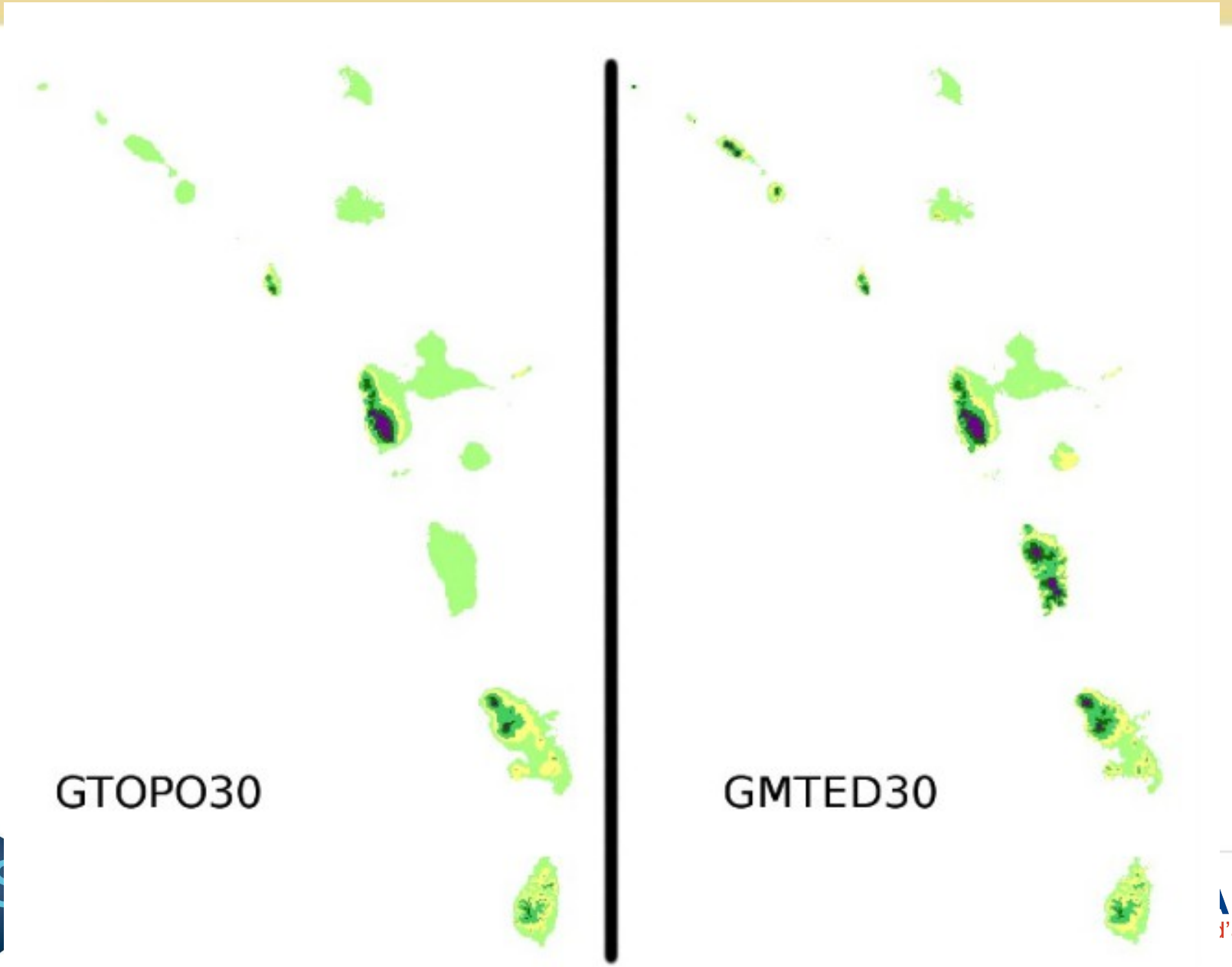
Wavelets in Arpège Bg Err Cov Matrix: horizontal lengthscales for wind at 500 hPa



CY38T1 E-suite: LAMs

- Aladin-Overseas models: new clim data for sand & clay (HSWB) and for orography (GMTED2010)
- Arome-France:
  - denser thinning of AMSU-A (80km) and SSMI/S (139km);
  - Doppler winds from one X-band radar are assimilated (Mont-Maurel, Var);
  - more SEVIRI radiances over land, using climatological maps of surface emissivity and retrieval of Ts (Karbou etal. Method based on solving the RT equation at the surface for one surface-sensitive SEVIRI channel)
  - (…)
- Switch to operations on July 2, 2013.

Comparison of old (left) and new (right) orography over the Eastern Antilles



Topics under evaluation for 2014 and 2015

- **Re-adjust the use of satellite obs** in assimilation cycle and production analyses
- **Revisit tuning of some σo**
- **VarBC for GPS**
- More **band-X radars** in Arome assimilation; assess potential of a new MF/CMR product of reflectivity filtered by the signal of windmills; assess potential impact of **OPERA extra radar data**
- **Preparations for new observations**: ADM-Aeolus, GPM, MTG/IRS, IASI-NG
- Take part in the development of, and prepare MF pre-processing tools to, the Continuous Obs Pre-processing Environment (COPE) triggered by ECMWF for IFS
- **Re-visit choices of basic parameter design for new resolution Arpège 4D-VAR** (T1198C2.2L105)
  - Number of outer and inner loops
  - Resolution of increments
  - Preconditioning

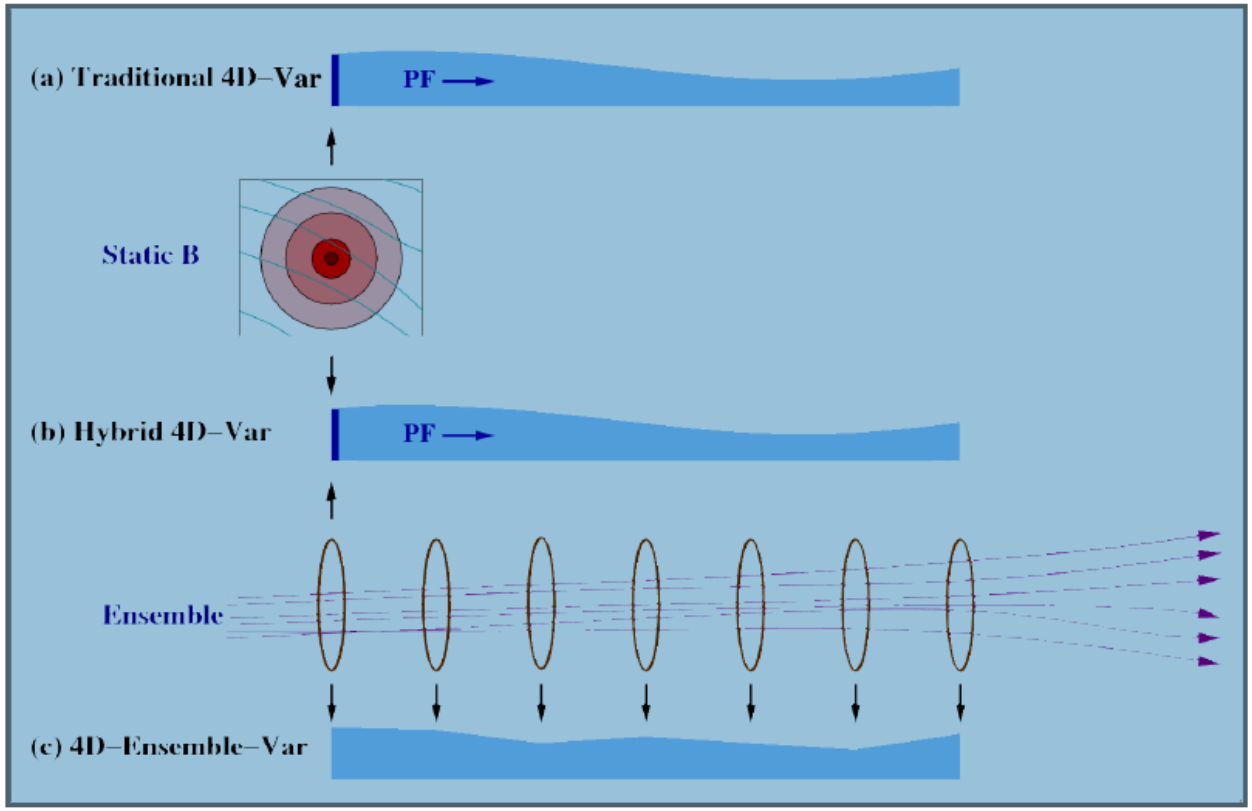
Plans in overview: NWP and DA evolutions

- **Arpège T1198L105; Arome-1.3kmL90**: start handover to Operations in June 2014, official E-suite scheduled over Sept-Dec 2014
- **Arome nowcasting** and SESAR applications: to be ported to oper in autumn'14 to spring'15
- **Arome EPS**: operationally tested by end of first semester 2015
  - 10 members; BC from PEARP (clustering); IC = Arome analysis + PEARP pert. (later from EnDA); surface pert = specific surface and physiographic fields; model error by SPPT
- **Arome EnDA**: pert of obs (3D-Var); model error by time varying inflation; 2.5km; 6 members (at present)
- Spatial objective filtering of error variances (Raynaud & Berre); correction of displacement error by deformation of bg; vertical deformation

Plans in overview

- **Installation of BULL HPC clusters**:
  - Cluster 1: Acceptance Test completed mid-August; mirror suite CY38T1 in autumn; switch of operations expected end of 2013
  - Cluster 2 (*to be confirmed*) : installation end of 2013 (in remote computing center); validation expected to be completed in April 2014; then switch operations from C1 to C2
  - Phase 2: will start July 2015
- **COPE project**: modernized obs pre-processing (IFS/Arpège/LAM)
- **OOPS project: object-oriented assimilation code; development of 4D-En-Var as an alternative to 4D-Var**

4D-Var / Hybrid 4D-Var / 4D-En-Var



Barker and Clayton, 2011

Investigations into an alternative 4D DA method (G. Desroziers, J-T Camino, L. Berre)

- 4D-Var

✓ Simplified description of **B** at initial time , and linear evolution of covariances.

✓ Possible improv. via an ens. of pert. 4D-Var (Météo-France, ECMWF) : spat./temp. variations of error variances and correlations (wavelets).

✓ Difficult development and maintenance of TL/AD.

✓ Poor scalability of TL/AD.

- 4D-Var based on a 4D ensemble : 4D-En-Var

✓ Similar to En-KF.

✓ Keeps benefits of 4D-Var (global analysis, add. terms, outer-loop, …)

✓ Localization of the raw covariances made in model space.

✓ Minimization cost similar to 3D-Var.

✓ Natural parallelization, and NL evolution of covariances.

4D-En-Var formulation

- Minimization of

$$J(\delta \underline{\mathbf{x}}) = \delta \underline{\mathbf{x}}^{T} \underline{\mathbf{B}}^{-1} \delta \underline{\mathbf{x}} + (\underline{\mathbf{d}} - \underline{\mathbf{H}}\ \delta \underline{\mathbf{x}})^{T} \underline{\mathbf{R}}^{-1} (\underline{\mathbf{d}} - \underline{\mathbf{H}}\ \delta \underline{\mathbf{x}}), \text{ with}$$

$\underline{\mathbf{d}}$ 4D vector of the innovations distributed in time,

$\underline{\mathbf{H}}$ 4D linearized observation operator,

$\underline{\mathbf{R}}$ 4D (but diagonal !) covariance matrix of obs. errors,

$\delta \underline{\mathbf{x}}$ 4D vector of the increments to be added to the 4D bg $\mathbf{x}^{b}$, composed of K sub-elements (K slots for the pert. in time)

$\underline{\mathbf{B}}$ 4D covariance matrix of bg errors, given by an ensemble.

(Lorenc, 2012)

4D-En-Var formulation

$$\underline{\mathbf{X}}^f = (\underline{\mathbf{x}}^{f'}_1, \ldots, \underline{\mathbf{x}}^{f'}_L),$$

where L is the ensemble size and

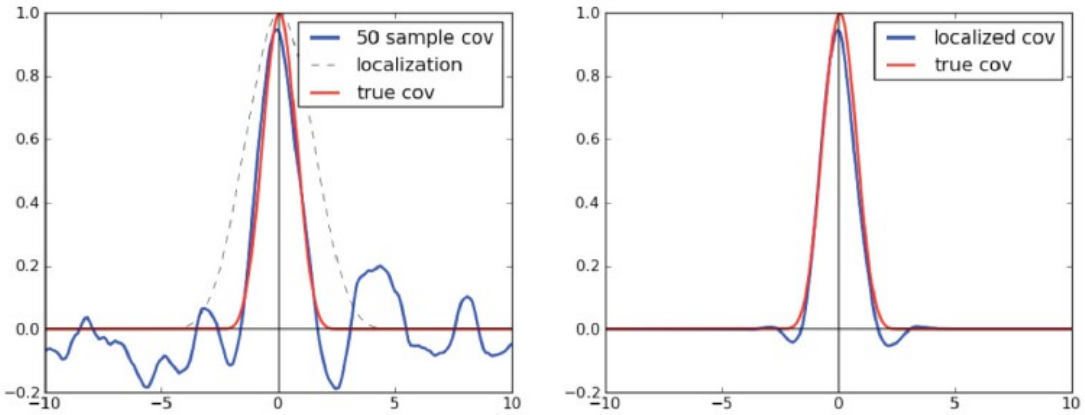
$$\underline{\mathbf{x}}^{f'}_l = \underline{\mathbf{x}}^{f}_l - \langle \underline{\mathbf{x}}^f \rangle / (L-1)^{1/2}, \; l=1,L,$$

are the deviations of the 4D pert. forecasts from the ens. mean traject.

$$\underline{\mathbf{P}} = \underline{\mathbf{X}}^f (\underline{\mathbf{X}}^f)^T$$

Localization of bg error cov. (Schurr product):

$$\underline{\mathbf{B}} = \underline{\mathbf{P}} \circ \underline{\mathbf{C}}$$



Whitaker, 2011

Implementations of 4D-En-Var

- $\delta \mathbf{x} = \mathbf{B}^{1/2} \chi$
  $= (\mathbf{P} \circ \boldsymbol{C})^{1/2} \chi$
  $= \Sigma_{\ell=1,L} \mathbf{x}^{f'}{}_{\ell} \circ (\boldsymbol{C}^{1/2} \chi_{\ell})$

$J^b(\chi) = \Sigma_{\ell=1,L} \chi_{\ell}^T \chi_{\ell}$, dim χ = N(N_c)xL (or KxN$_c$xL in 4D with model error)

Use of a Conjugate Gradient (*CG*) with $\mathbf{B}^{1/2}$ change of variables.

(Buehner 2005, 2010)

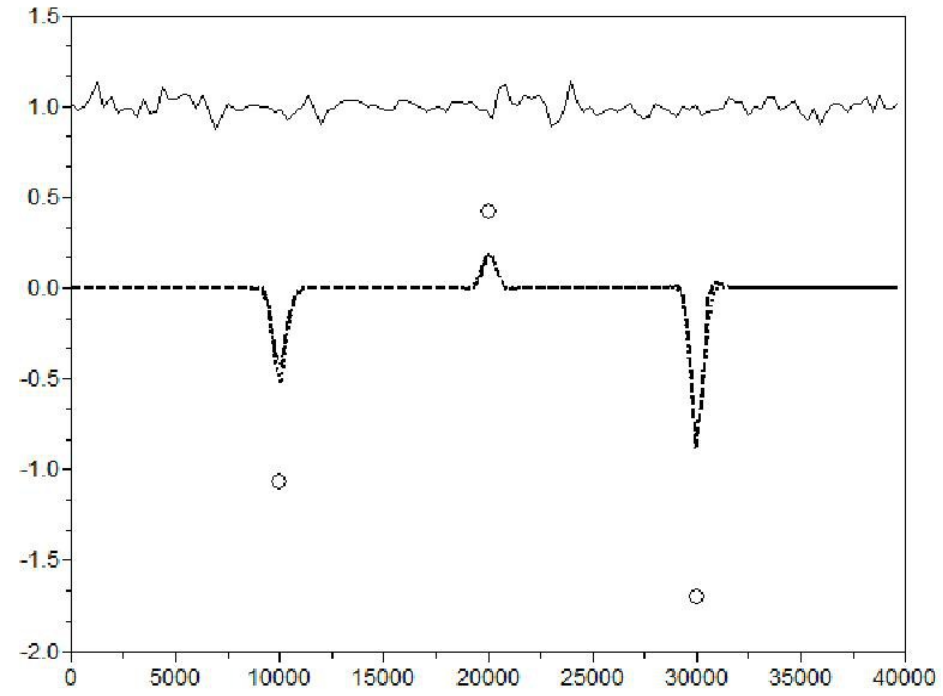
- $\delta \mathbf{x} = \Sigma_{\ell=1,L} \mathbf{x}^{f'}{}_{\ell} \circ \alpha_{\ell}$, with $\alpha_{\ell} = \boldsymbol{C}^{1/2} \chi_{\ell}$

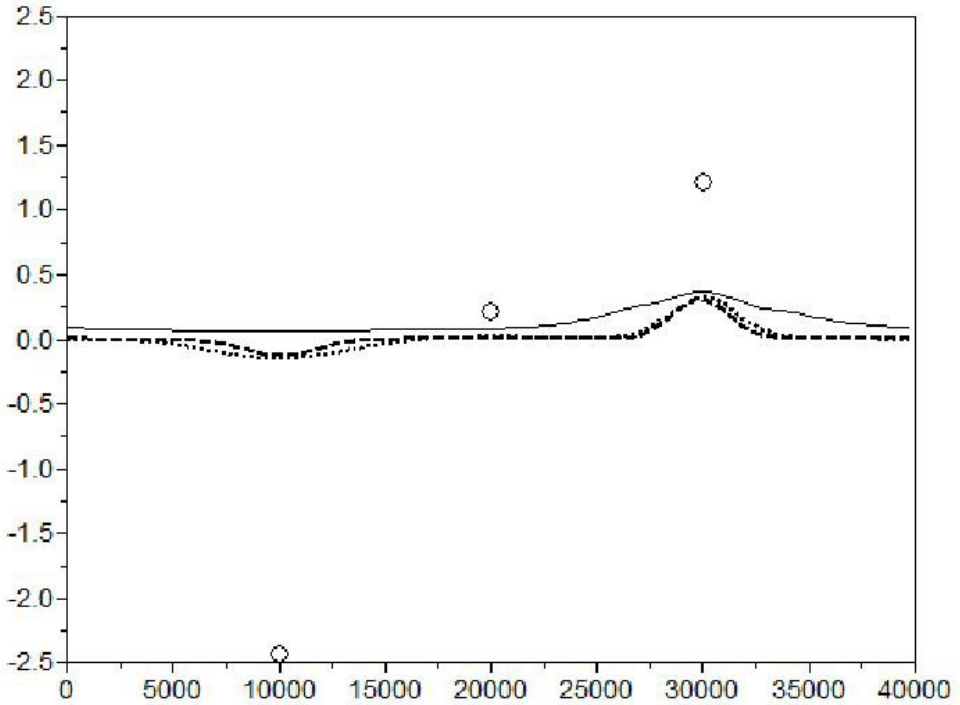
$J^b(\alpha) = \Sigma_{\ell=1,L} \alpha_{\ell}^T \boldsymbol{C}^{-1} \alpha_{\ell}$, dim α = N(N_c)xL (or KxN$_c$xL in 4D with mod. error)

Use of a Double Preconditioned *CG* (DP*CG*) with $\boldsymbol{C}$ preconditioning.

(Lorenc, 2003; Wang et al 2007; Wang 2010)

Comparison of increments 4D-En-Var / 4D-Var (Burgers model; *paper in preparation*)





Observations at t_0

$\delta \mathbf{x}_0$ at t_0 :

- 4D-En-Var (dashed)
- 4D-Var (dotted)
- bg error square-root (solid)

Observations at t_f (t_0+6h)

$\delta \mathbf{x}_f$ at t_f :

- 4D-En-Var (dashed)
- 4D-Var (dotted)
- bg error square-root (solid)

cnrs dépasser les frontières

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- sunom bitti. İlginiz için teşekkür ederim