Towards an operational implementation of a 3DEnVar data assimilation scheme in Arome-France using the OOPS framework

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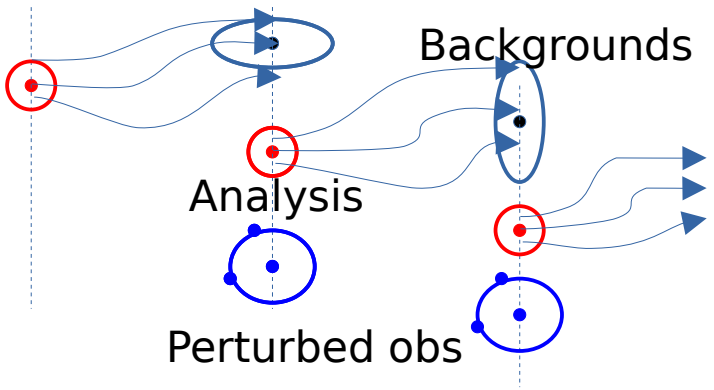
ACCORD All Staff Workshop, March 2023

Plan

- Reminder on the B matrix in 3DEnVar and the OOPS framework
- Results
  - Selection of a 3DEnVar configuration : sensitivity tests
  - Full results over a 6-month period
- Conclusions and perspectives

3DEnVar : flow-dependent specification of the B matrix

- Need for an ensemble of forecasts => provided by an EDA :



- **Flow dependent** perturbations are deduced from this ensemble :

$$\epsilon_l^b = \frac{1}{\sqrt{N_e - 1}}(\tilde{\mathbf{x}}_l^b - \langle \tilde{\mathbf{x}}^b \rangle) \qquad \mathbf{X}^b = \left[\epsilon_1^b, \ldots, \epsilon_{N_e}^b\right]$$

- Background error covariances are directly sampled from the perturbations of the forecasts, with a **localization step** (C)

$$\mathbf{B} = \mathbf{C} \circ \mathbf{X^b X^{bT}}$$

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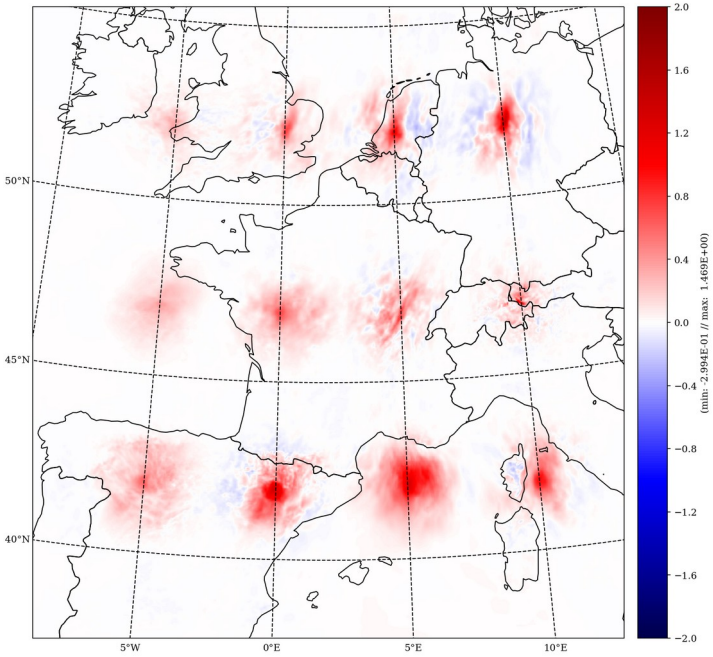
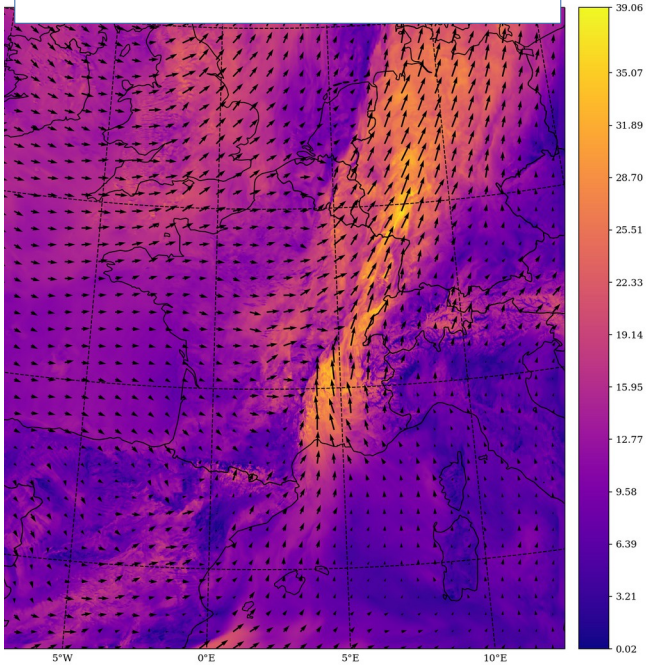
Illustration of flow-dependent covariances in AROME-France

Analysis increment
of temperature at 850 hPa
resulting
from 12 innovations of 4 K



3DEnVar (localized covariances)

Wind at 850 hPa



Increment of different intensity
and geographical structure
related to the weather situation

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Illustration of flow-dependent covariances in AROME-France

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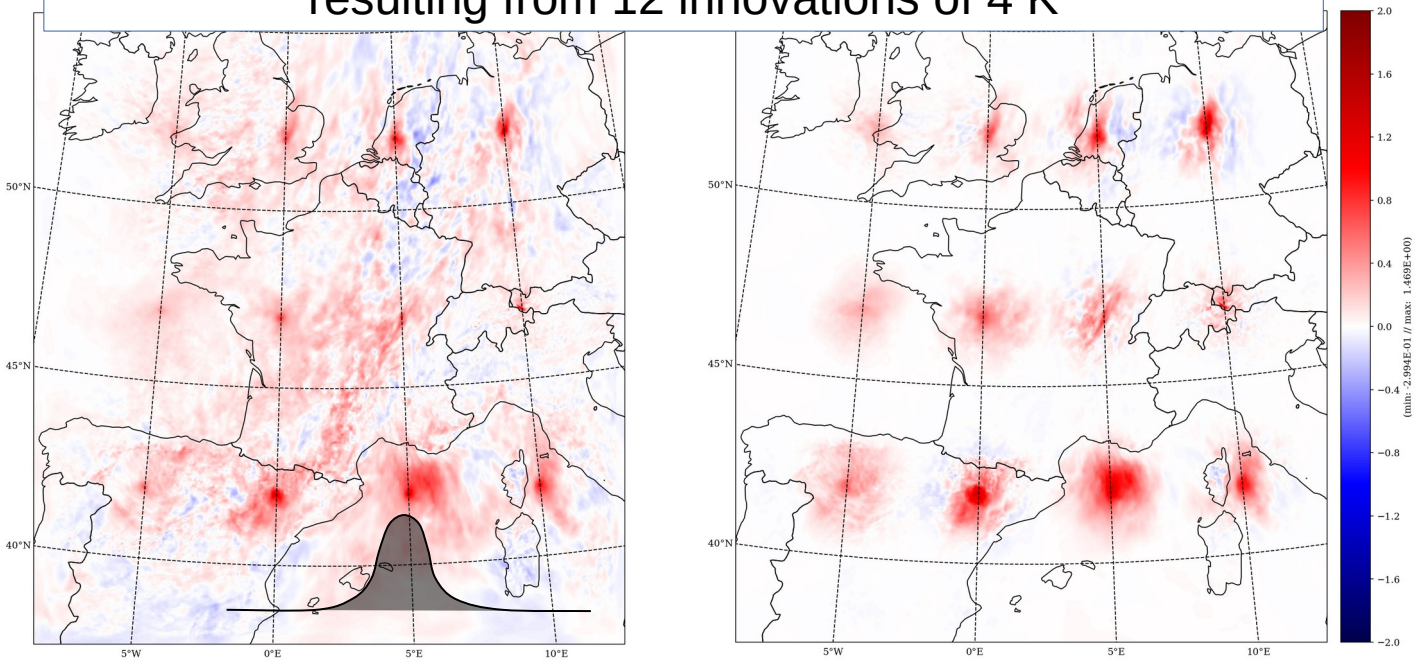
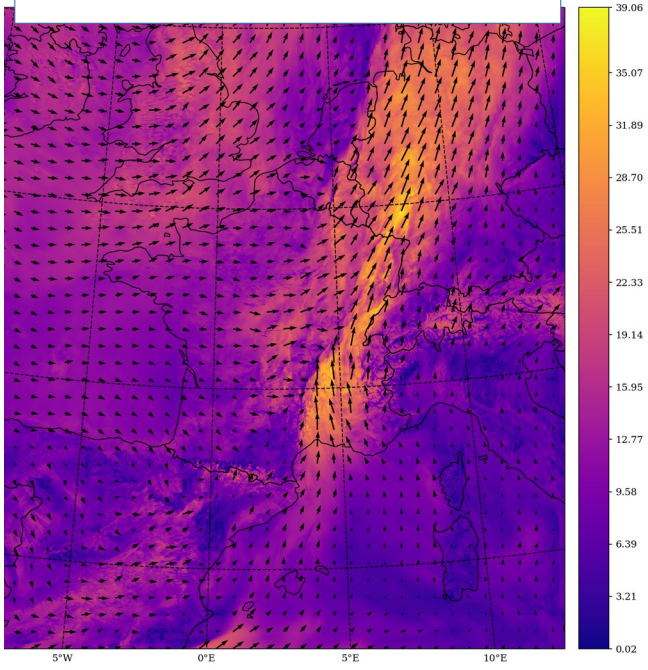


3DEnVar (raw covariances)

3DEnVar (localized covariances)

Wind at 850 hPa



Need to localize
to filter out the sampling noise

Increment of different intensity
and geographical structure
related to the weather situation

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

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OOPS framework

- OOPS : incremental development of a data assimilation framework
  - First prototype in cycle 40t1 (localization, 3D/4D/EnVar minimization, limited observations)
  - New components available and tested in cycles 43 and 46 (full set of observations, compilation with GMKPACK, …)
  - In cycle 48t1 missing components are now available to perform a full 3DVar analysis in Arome with OOPS : sqrtMinimizer, screening, VARBC handling, ….. and other features not used in Arome but in Arpege assimilation processing (VARQC, incremental DFI, fullpos inline,…)

  => Validation of a cycled OOPS 3DVar AROME experiment against the operational chain achieved in 2022

  => A reference to evaluate the impact of a 3DEnVar scheme in a pre-operational configuration

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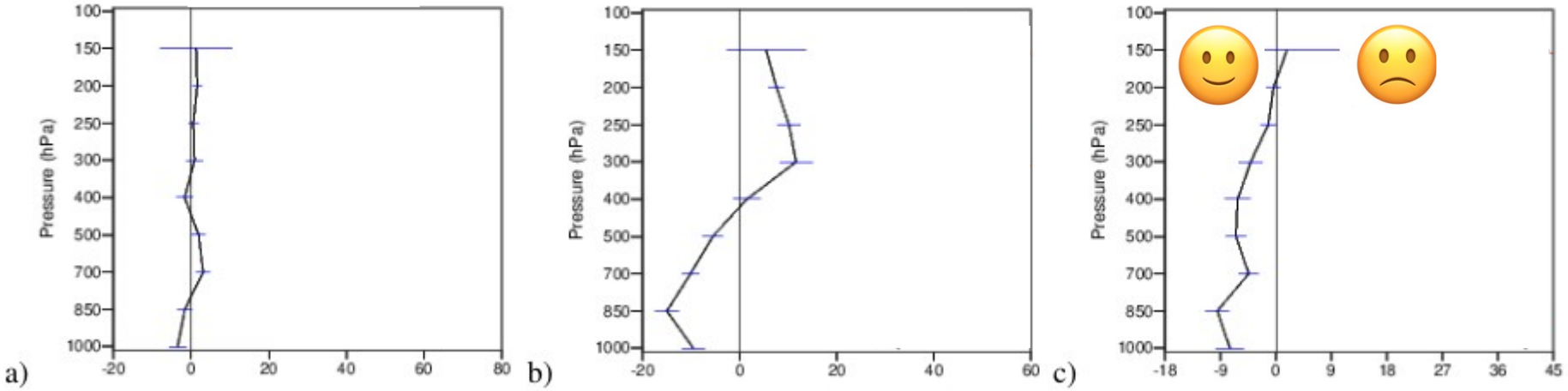
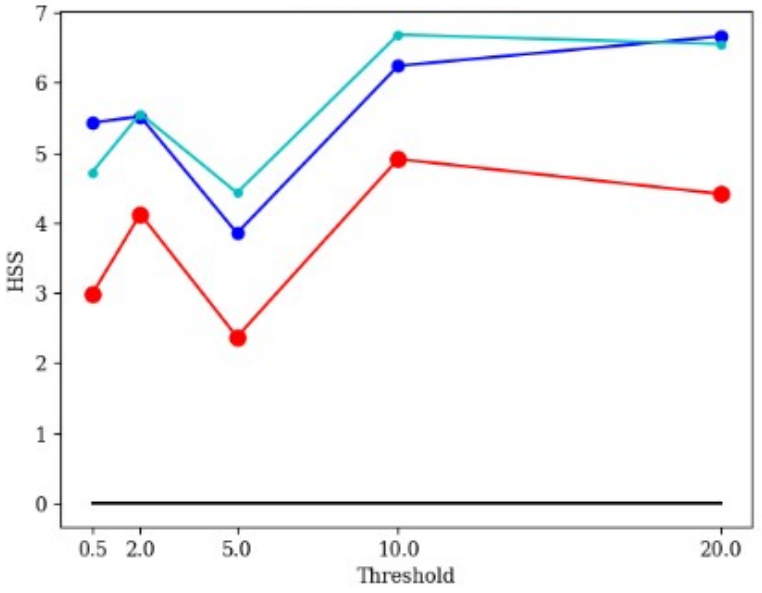
In search of an optimal 3DEnVar configuration : Localization length scale

1 month period : 16/09/2020-15/10/2020

Loc 150 km | Loc 25 km | Loc 25 – 150 km



Relative difference (%) of RMS of background departures for aircraft winds
for several localization length scales (ref = 3DVar)



Comparison between the 24-hour accumulations
observed by radars and raingauges
and reconstructed by summing the accumulations
from the 1h forecasts of the DA cycle.
Relative difference (%) of HSS values
for different thresholds (ref = 3DVar)

Loc 150 km
Loc 25 km
Loc 25 – 150 km

In search of an optimal 3DEnVar configuration : Other sensitivity experiments

Parameter	Impact on the DA system	Impact on previous diagnostics
Increased ensemble size (25=>50 members)	Reduction of the sampling noise	positive
Vertical Loc = 0,2hPa	« Thinner » filtering of the background error vertical correlations	neutral
Vertical Loc = 0,4hPa	« Broader » filtering of the background error vertical correlations	slightly negative
Inflation = 0,8	Smaller sigmab => the analysis fits less the observations	neutral/slighly positive
Inflation = 1,2	Higher sigmab => the analysis fits more the observations	slightly negative
Hybridization = 0,8 ens/0,2 clim	Reduction of the flow dependency and of the sampling noise	negative
Incremental analysis update	Filtering of the higher spin-up due to the 3denvar	neutral/slighly positive

AROME 3DEnVar at Météo-France : Selected configuration

- Same resolution as operational configuration :

  1,3km, 90 vertical levels

- Ensemble of Data Assimilations (EDA) Arome :

  50 members, 3,25km, 90 vertical levels, 3-hourly cycling

- Horizontal localization scale :

  varying between 25 km at low levels and 150 km near the model top

- Vertical localization : 0.3log[hPa]

- Pure 3DEnVar (no hybridization)

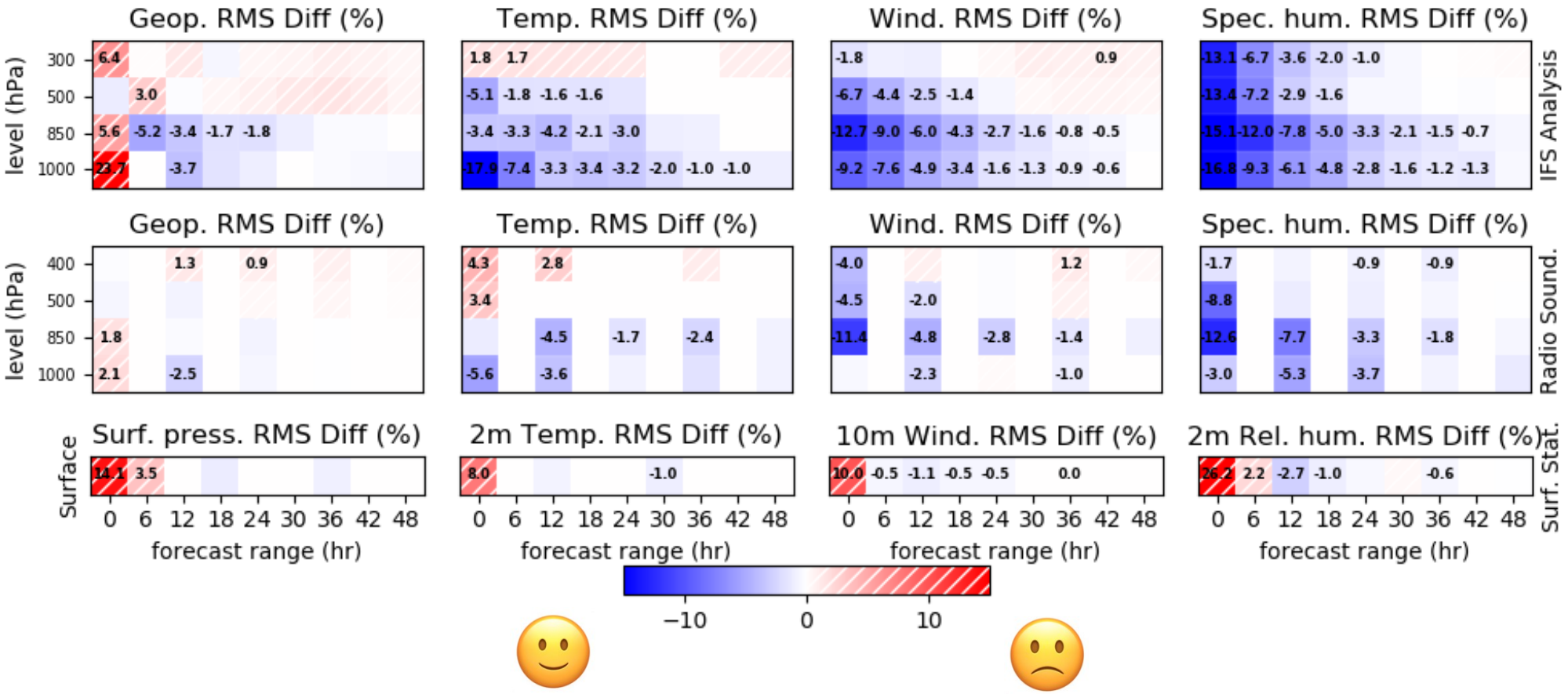
  => facilitates further developments as the extension of the control variable to hydrometeors for example since the background error covariances for these variables are directly available from the EDA

  => allows pure 4DEnVar (without TL/AD models)

- Increment Analysis Update (IAU)

  => to cope with 4 numerical explosions during the heatwaves of summer 2022 (no other numerical problems reported during more than 1 year experiment including numerous storms)

Pre-operational AROME 3DEnVar at Météo-France : Impact results over 6 months



% of reduction of RMSE
for different parameters over 6 months (16/09/2020-01/03/2021)
(ref = IFS analysis, radiosondes, surface stations)

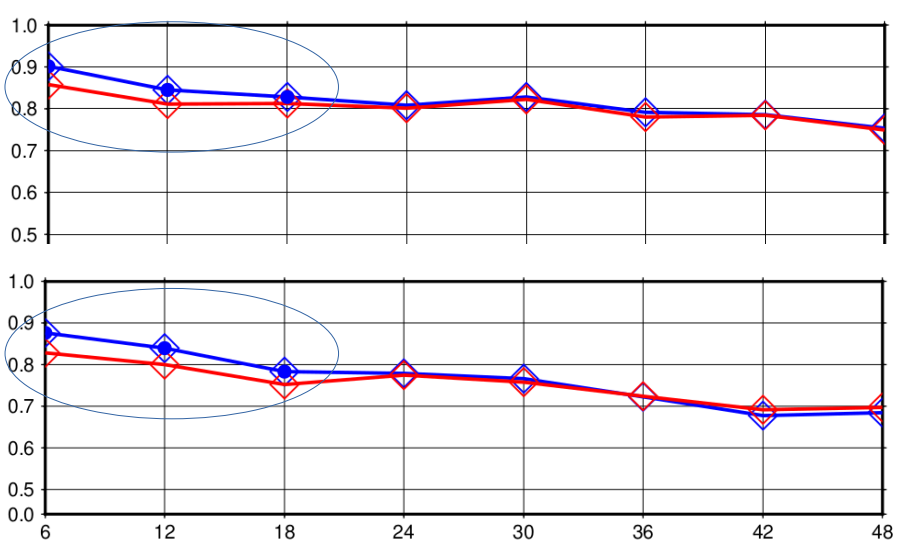
Pre-operational AROME 3DEnVar at Météo-France with OOPS : impact on precipitations

- general performances over a **6-month period** (stronger during convective season)

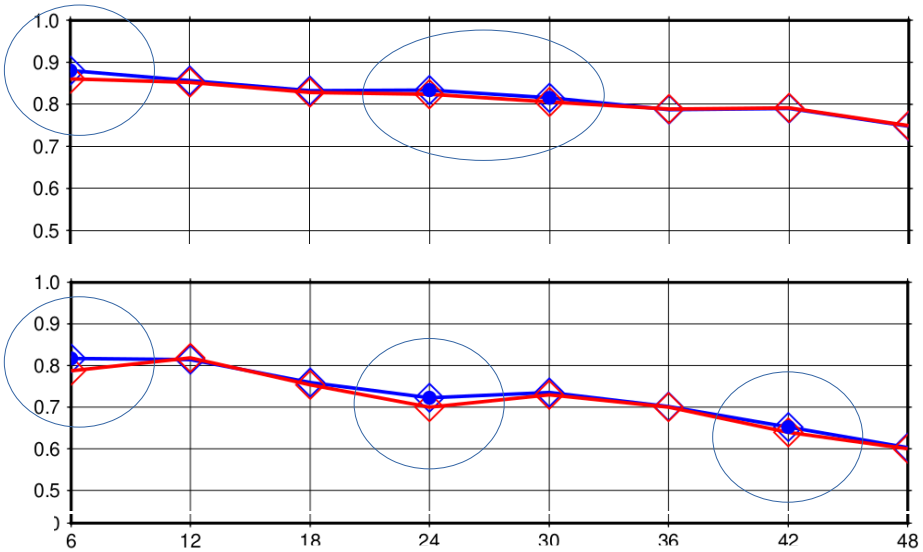
3DEnVar
3D-Var

BSS for 6h cumulated rain (50 km neighbourhood)

15 Sept – 30 Nov 2020



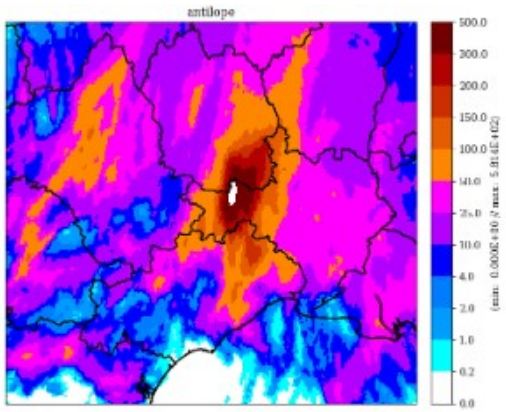
1 Dec 2020 – 1 Mar 2021

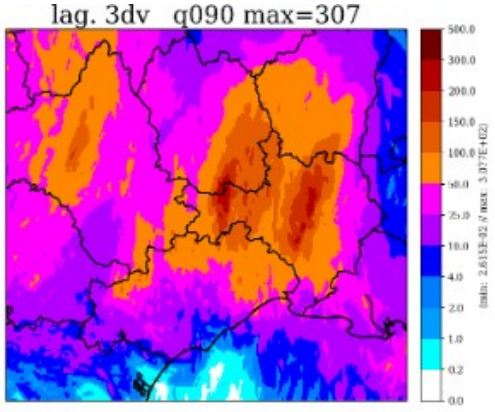


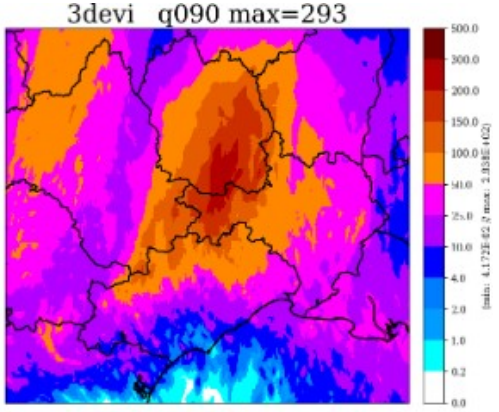
0,5mm/6h

5mm/6h

- simulation of **HPE** (8 cases) : example of the 19 septembre 2020 : 90th percentile of the 16 hourly forecasts covering the event period (lagged-ensemble)







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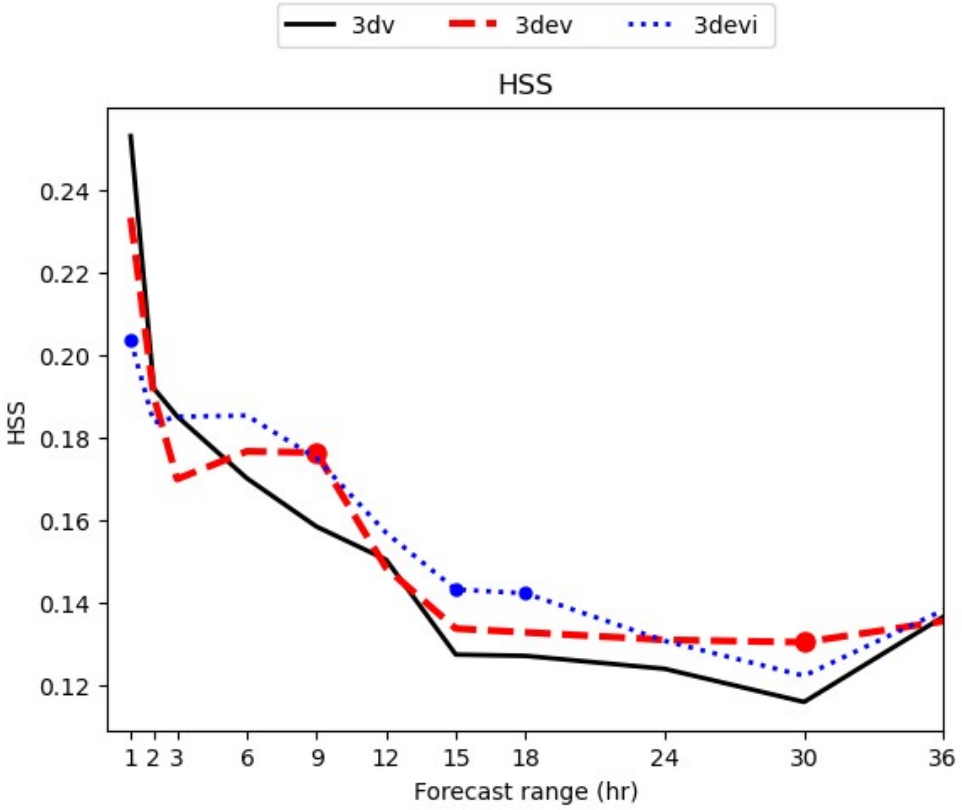
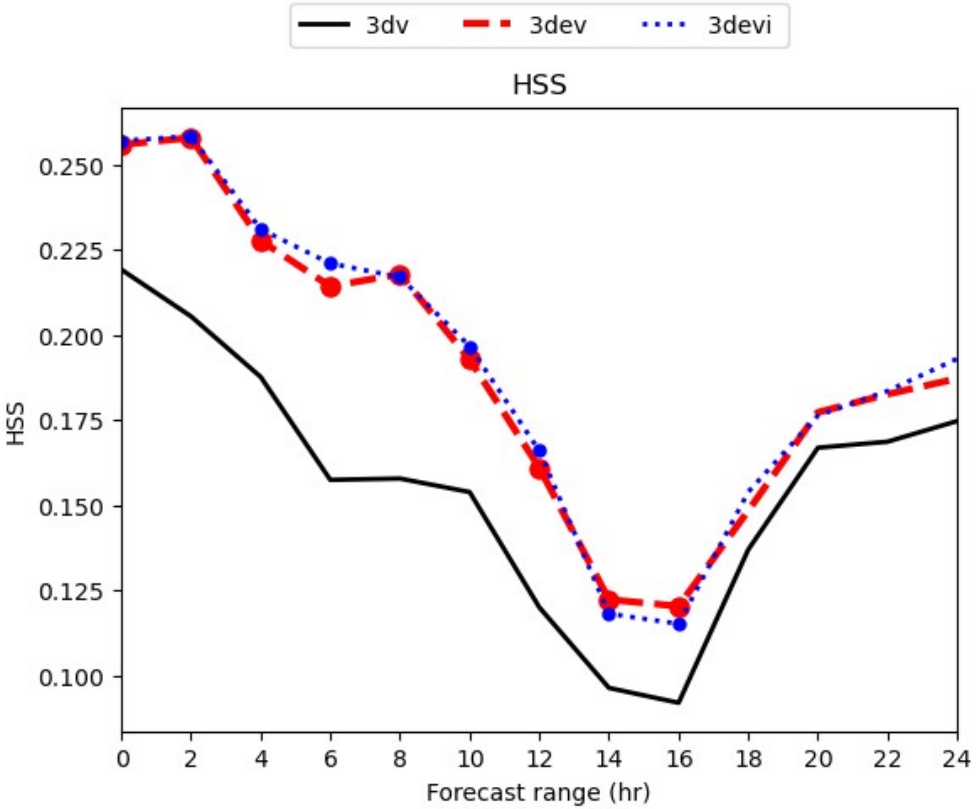
Pre-operational AROME 3DEnVar at Météo-France with OOPS : impact results

Positive impacts on :

6 winter storms (Daniel, Fabien, Jorge, Alex, Barbara and Bella) :
HSS for wind gust exceeding 90km/h using surface station and 192 hourly forecast (lagged-ensemble)



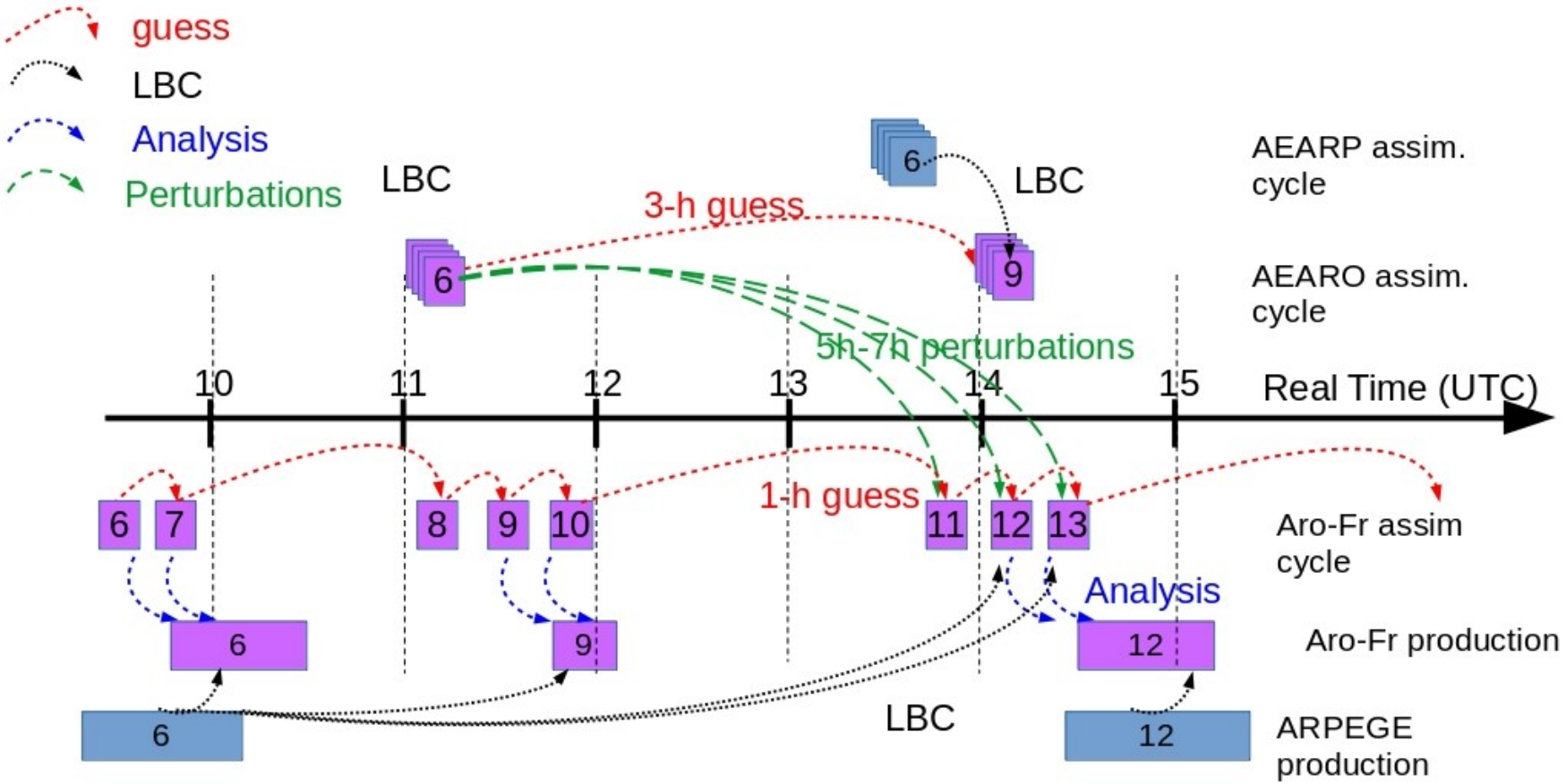
18 winter fog cases :
HSS for visibility lower than 1000m using surface station and 126 forecasts (lagged-ensemble)



Conclusions and perspectives

- Arome 3DEnVar is well advanced and will be part of the real time double E-suite which should start this spring (additional simulations, including 3DEnVar and other contributions, are underway for the period from summer 2022 to today)
- The move to the OOPS framework and a pure EnVar DA scheme allows the implementation of new assimilation algorithms :
  - Hydrometeors in the control variable and direct assimilation of radar reflectivities
  - 4DEnVar and the assimilation of radar and seviri data at a 15-minute frequency
  - Scale Dependant Localization
  - Extension of the control variable (NH variables, coupled assimilation ocean/atmosphere,...)

Thank you for your attention !


guess
LBC
Analysis
Perturbations
LBC
6
LBC
AEARP assim. cycle
3-h guess
6
9
AEARO assim. cycle
5h-7h perturbations
10
11
12
13
14
15
Real Time (UTC)
1-h guess
6
7
8
9
10
11
12
13
Aro-Fr assim cycle
Analysis
6
9
12
Aro-Fr production
LBC
6
12
ARPEGE production

5

Spin up diagnostic