A 3DEnVar data assimilation scheme for Arome-France using OOPS in Météo-France current double E-suite

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(Météo-France)

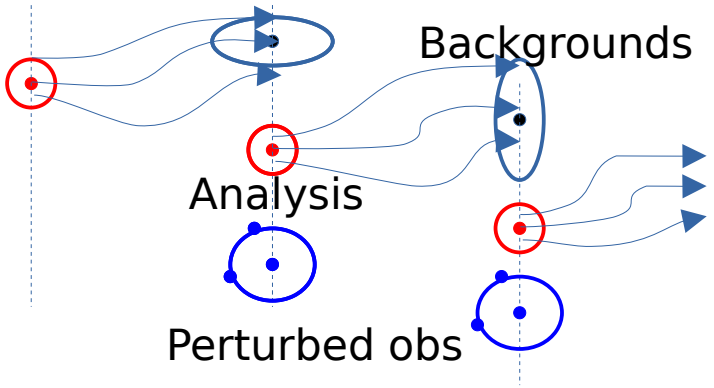
EWGLAM/SRNWP meeting, September 2023

Plan

- Reminder on the B matrix in 3DEnVar using OOPS
- Tuning of the 3DEnVar scheme and evaluation
- Current Arome E-suite
- 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 :

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

- 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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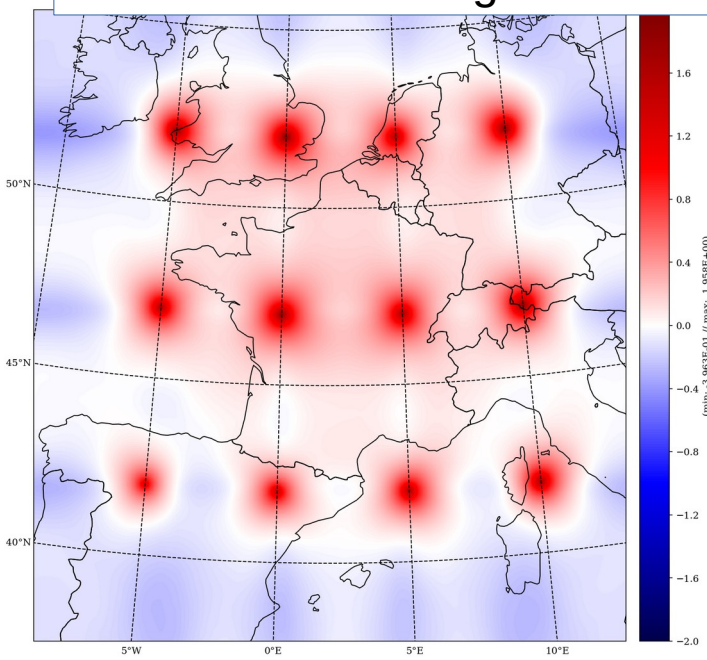
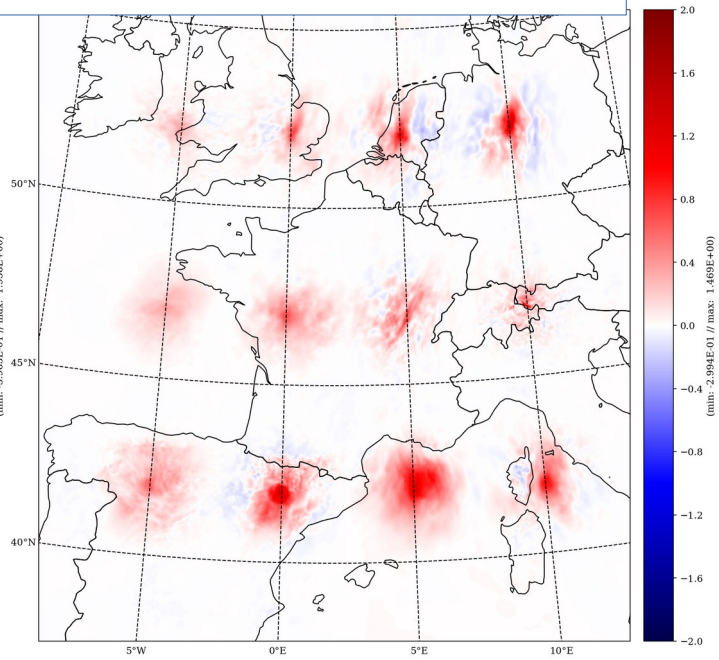
Illustration of flow-dependent covariances in AROME-France

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

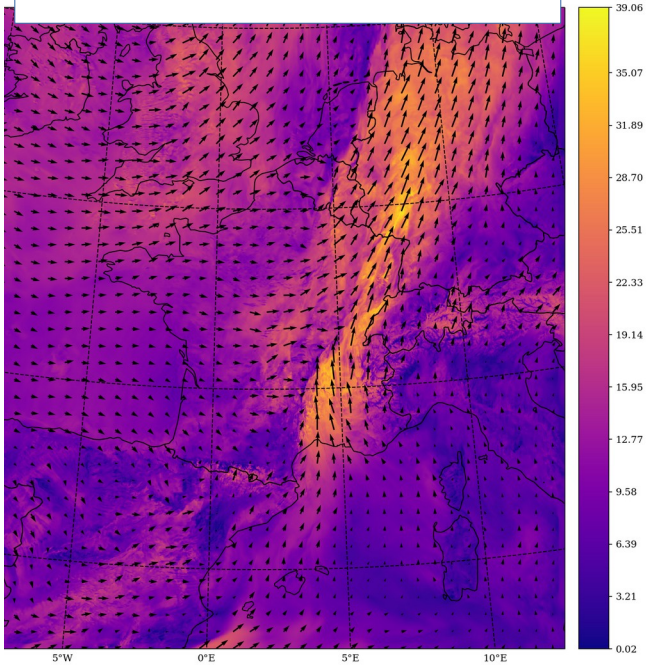


3DVar



3DEnVar

Wind at 850 hPa



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

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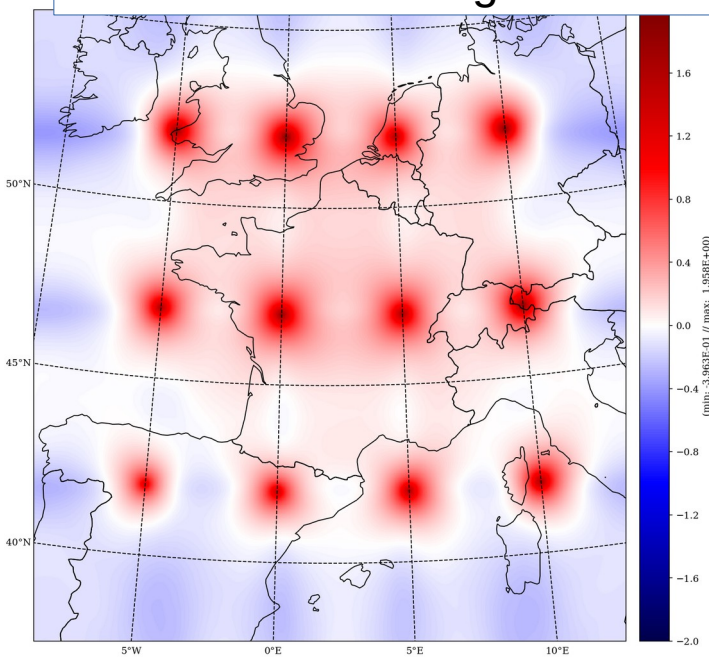
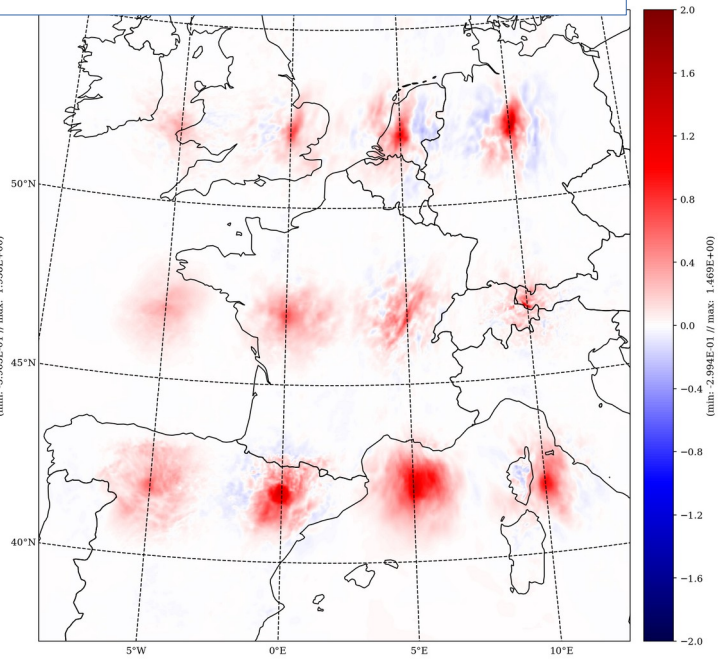
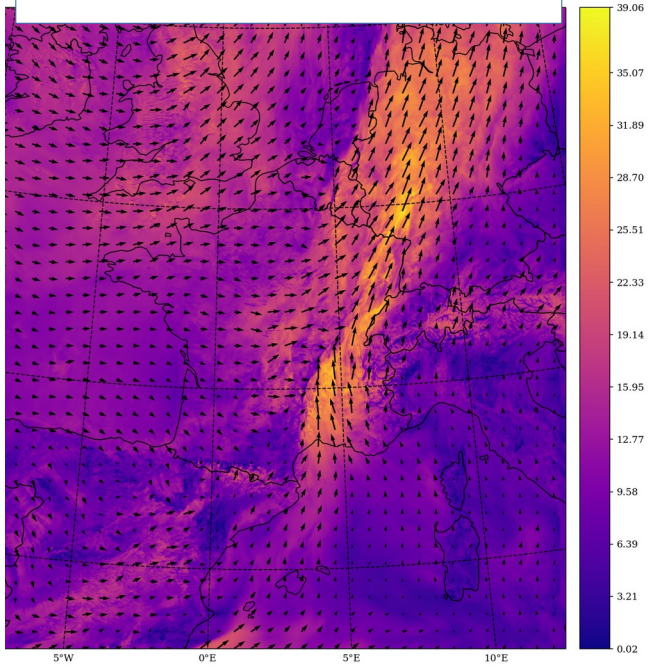


3DVar



3DEnVar

Wind at 850 hPa



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

=> Background error covariances computation can be extended to new variables (hydrometeors, NH variables, surface, ocean)
=> A 4DEnVar scheme, without TL/AD models, can be considered

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Implementation of 3DVar and 3DEnVar in OOPS

- Decision made several years ago at Météo-France to develop 3DEnVar within the OOPS framework

- First step : switch to a OOPS system without any scientific modification

  Validation of a AROME experiment including a 3DVar assimilation cycle using OOPS against the operational suite

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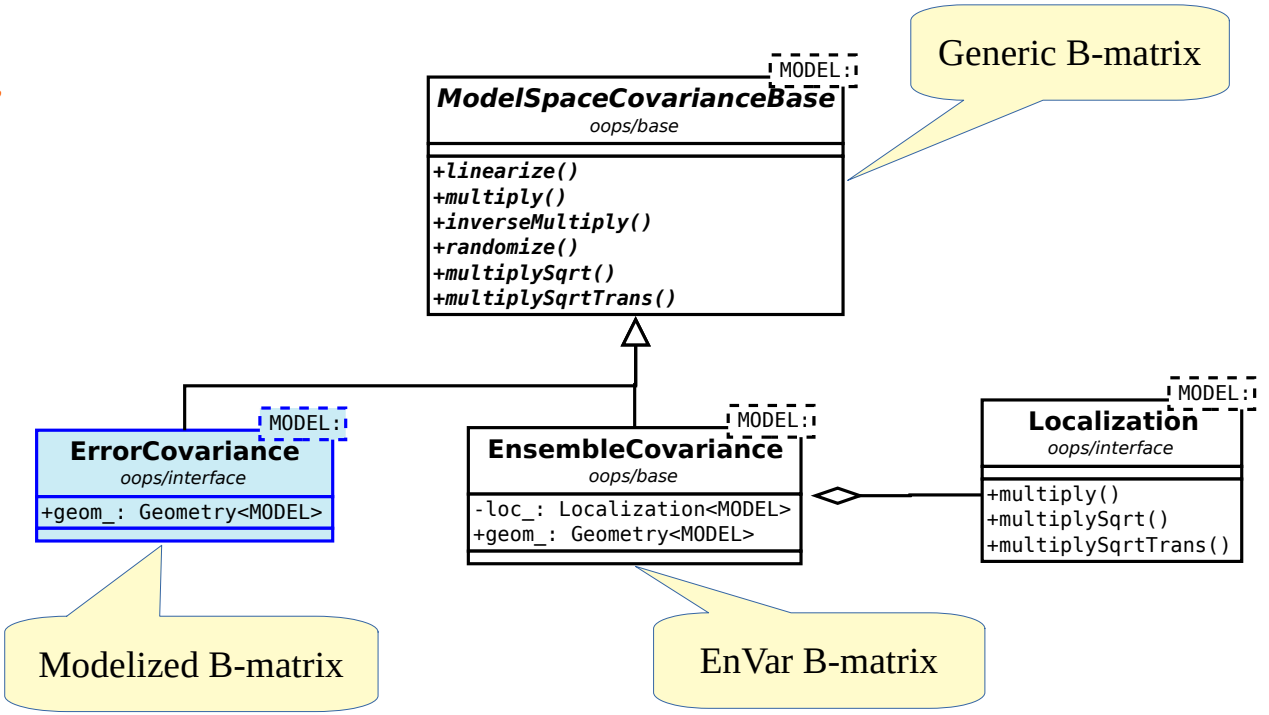

Implementation of 3DVar and 3DEnVar in OOPS

- Second step : Activation of the 3DEnVar

  Previous experiment has been the reference to evaluate the impact of a 3DEnVar scheme in a pre-operational configuration

- All individual contributions to the current e-suite have been evaluated against the OOPS 3DVar reference

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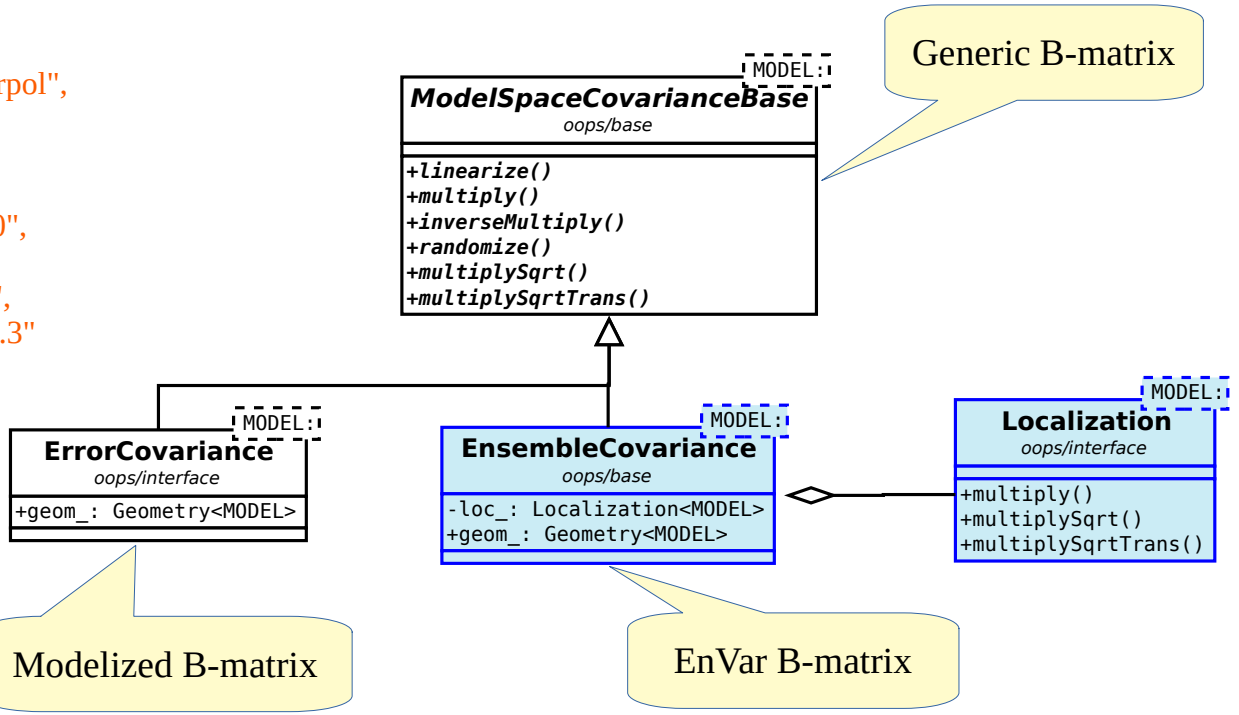
      {   ....
       },
},
```



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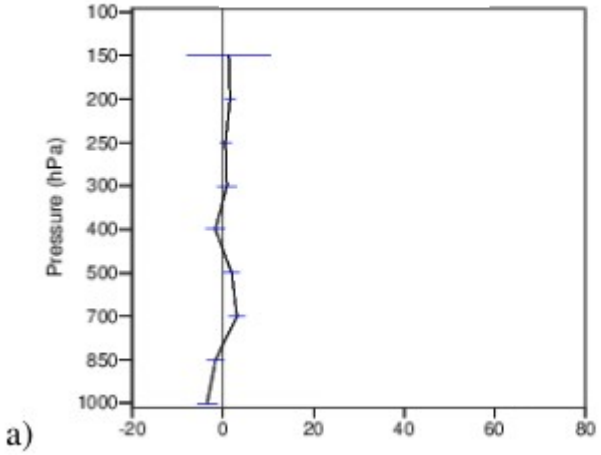
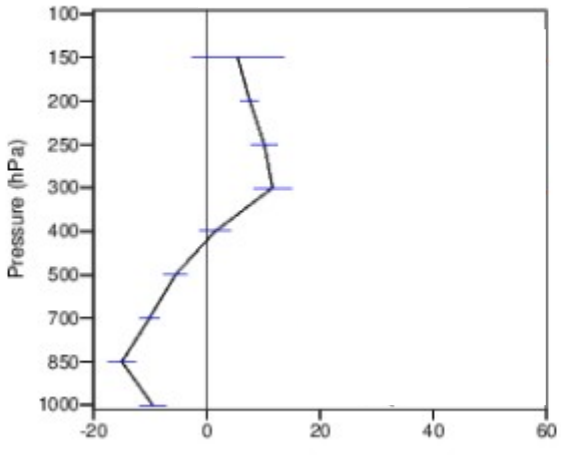
In search of an optimal 3DEnVar configuration : Localization length scale

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

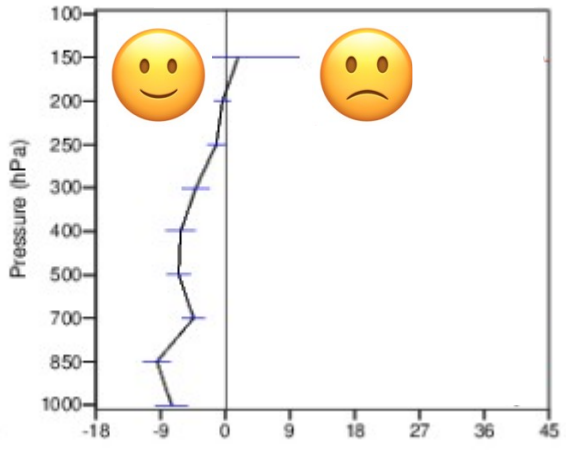
Loc 150 km



Loc 25 km



Loc 25 – 150 km



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

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 length scale :

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

- Vertical localization : 0.3log[hPa]

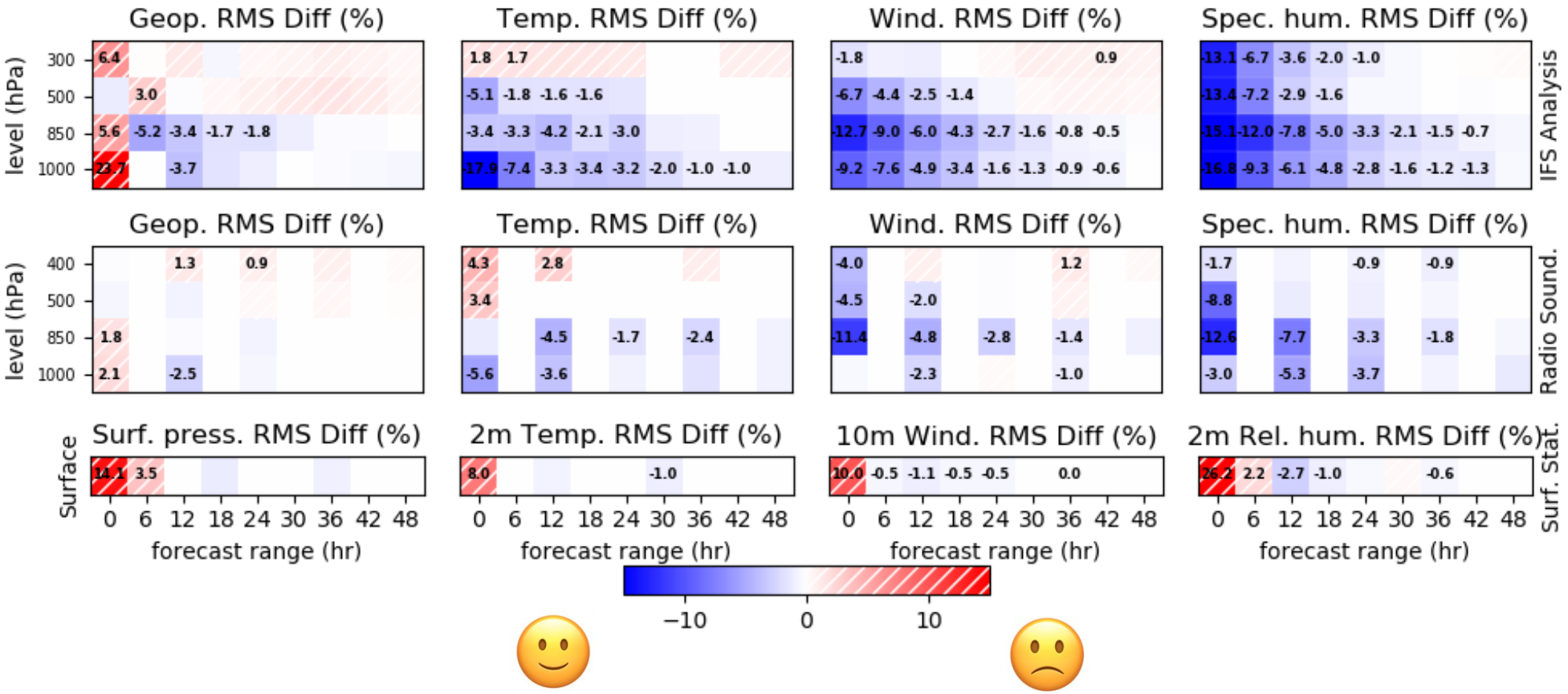
- Pure 3DEnVar (no hybridization)

  => experiment carried out on more than 1 year, including numerous storms
  => no numerical problems reported until the heatwaves of summer 2022 (4 numerical explosions)

- Increment Analysis Update (IAU)

  => to cope with these instabilities

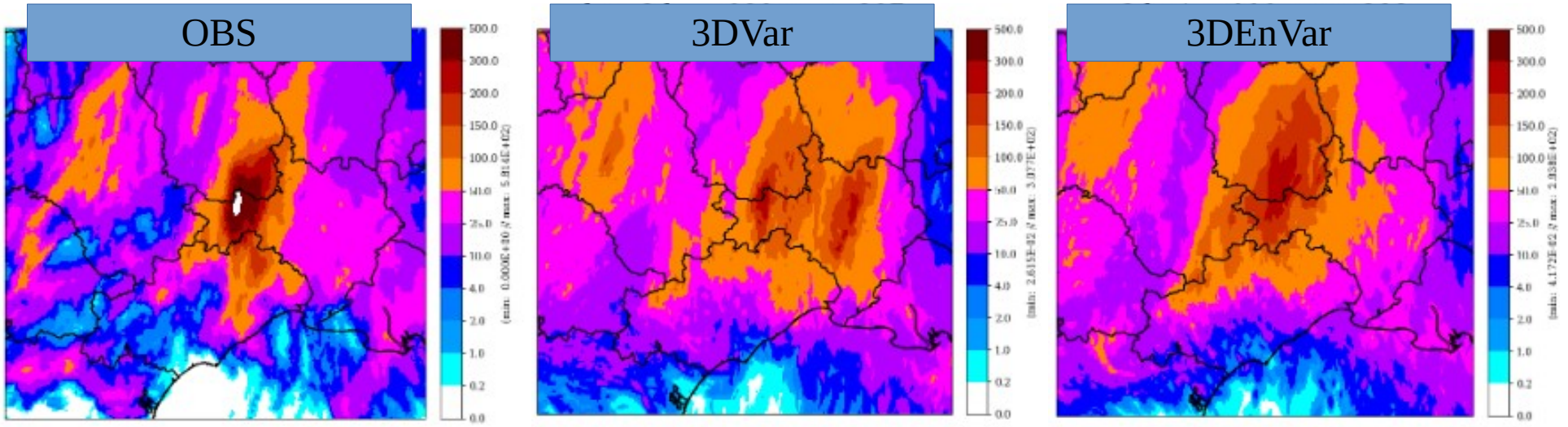
Pre-operational AROME 3DEnVar at Météo-France : Impact results over 6 months



% 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

- Simulation of **HPE** (8 cases)



Example of September 2020, 19th
90th percentile of the 16 hourly forecasts covering the event period (lagged-ensemble)

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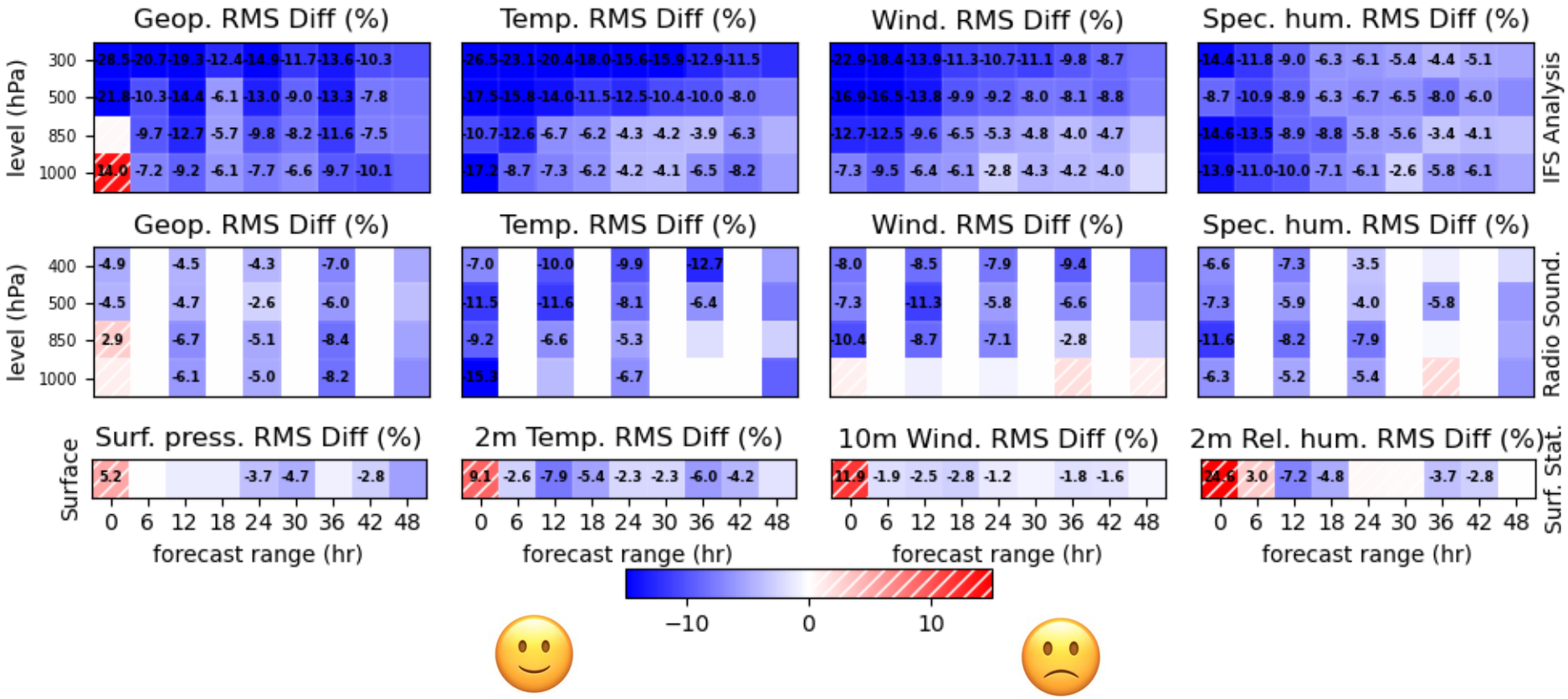
Arome-France double E-suite

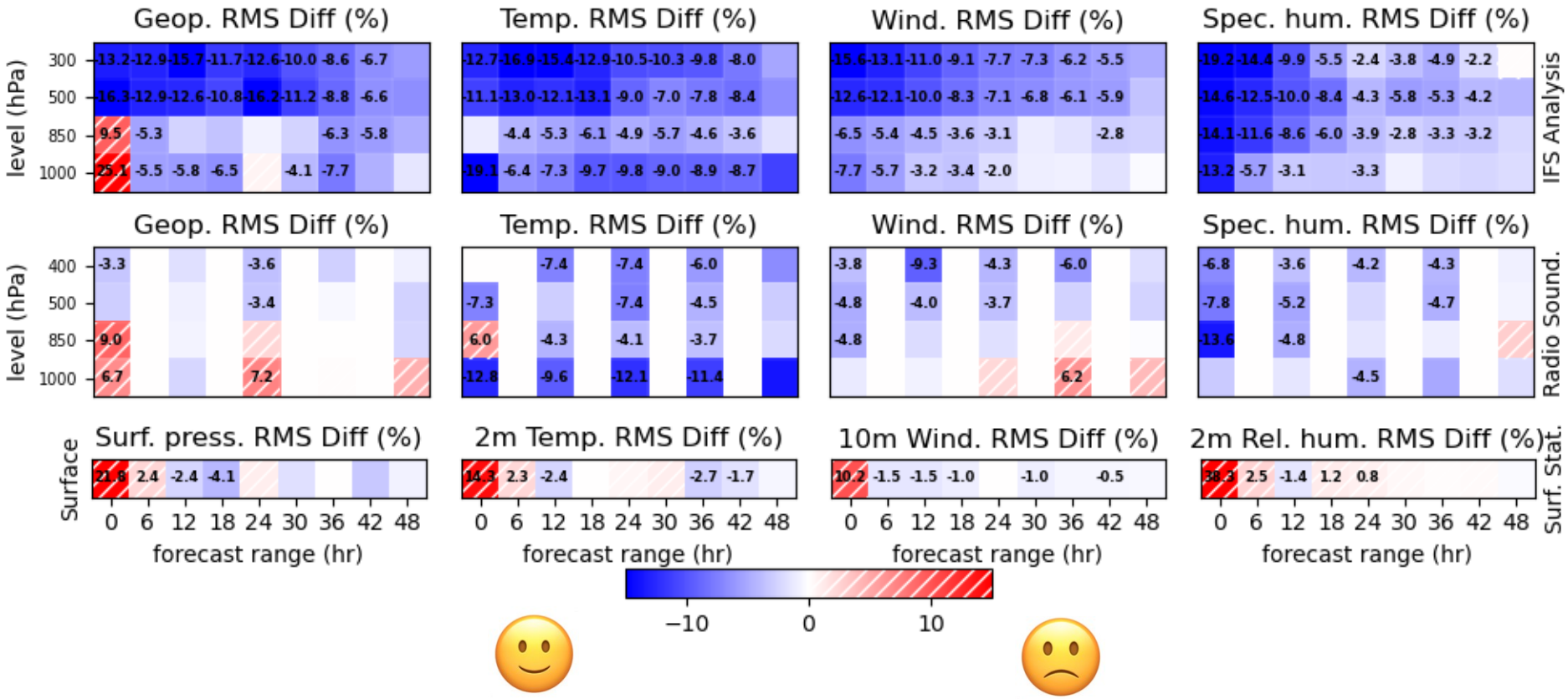
- Assimilation
  - 3D Ensemble variational scheme « 3DEnVar », replacing 3DVAR
  - First step toward direct assimilation of microwave radiances in « all-sky » conditions as in ARPEGE E-suite, currently limited in Arome from clear sky scenes to weakly scattering scenes while hydrometeors are not in the control variable. (Philippe Chambon, Mary Borderies)
  - Assimilation of wind and temperature data derived from Mode-S (+900.000 wind,+500.000 temp. observations per day) - data acquired from EMADDC (Vivien Pourret)
  - Assimilation of wind scatterometer HY-2B and HY-2C (Christophe Payan)
- Surface and physics
  - SST from Mercator (Adrien Napoly)
  - Radiation : switch to EcRad (Yann Seity)
  - Include the effect of solar eclipses on radiation (Jean-Marcel Piriou)
  - Some improvements in the turbulence scheme (Yann Seity)

Pre-operational AROME-France : Impact results (1/2)



% of reduction of RMSE
for different parameters over 3 months (30/07/2022-01/11/2022)
(ref = IFS analysis, radiosondes, surface stations)

Pre-operational AROME-France : Impact results (2/2)



% of reduction of RMSE
for different parameters over 2 months (01/12/2022-01/02/2023)
(ref = IFS analysis, radiosondes, surface stations)

Conclusions and perspectives

- Arome 3DEnVar is part of the real time double E-suite which has started this summer
- 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 observations at a 15-minute frequency
  - Scale Dependant Localization
  - Extension of the control variable (NH variables, coupled assimilation ocean/atmosphere,...)

Thank you for your attention !