EnVar in OOPS for ACCORD

Loïk Berre, with main contributions from
Valérie Vogt, Pierre Brousseau, Maud Martet, Etienne Arbogast (Météo-France),
Benedikt Strajnar (ARSO), Florian Meier (ZAMG), Roel Stappers (MetNo)

EWGLAM/SRNWP meeting, 29 September 2022

Plan

- Reminder about OOPS
- First experiments with 3D-Var and 3DEnVar in OOPS
- Pre-operational 3DEnVar at Météo-France with OOPS
- Further developments : 4DEnVar ; hydrometeors & reflectivities
- Conclusions

OOPS : Object-Oriented Programing System

Next major evolution of DA systems, e.g. at Météo-France : towards EnVar schemes

Using OOPS :

- project started in 2009 at ECMWF, in collaboration with Météo-France and LAM partners.

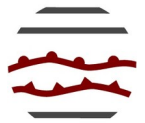
- renovation of common data assimilation codes,
  in order to enable the development of new algorithms and ease maintenance.

- object-oriented design, upper level code in C++.

- important refactoring of the IFS-Arpege-LAM FORTRAN codes.

- main part of the coding effort now completed.

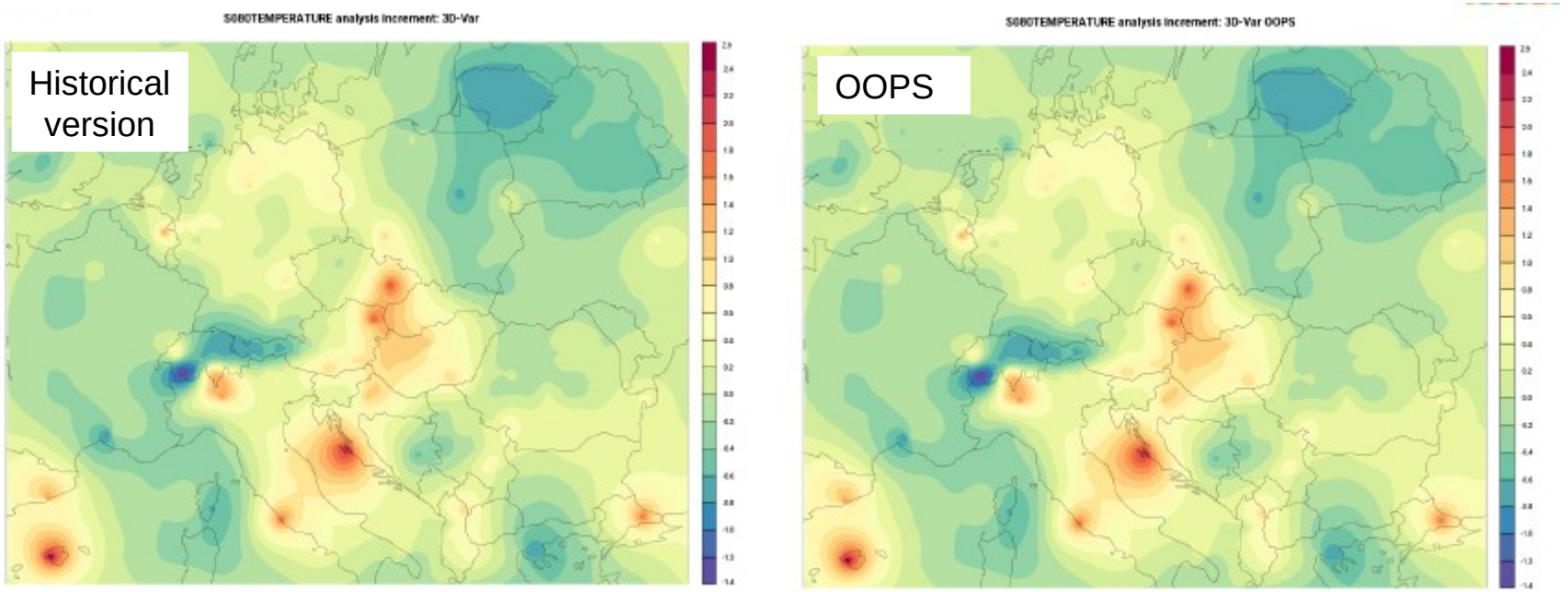
- precursor of the JEDI project at JCSDA (US) also used now at MetOffice.



3D-Var with OOPS

Experiments to reproduce 3D-Var with OOPS have been achieved successfully by several ACCORD members :

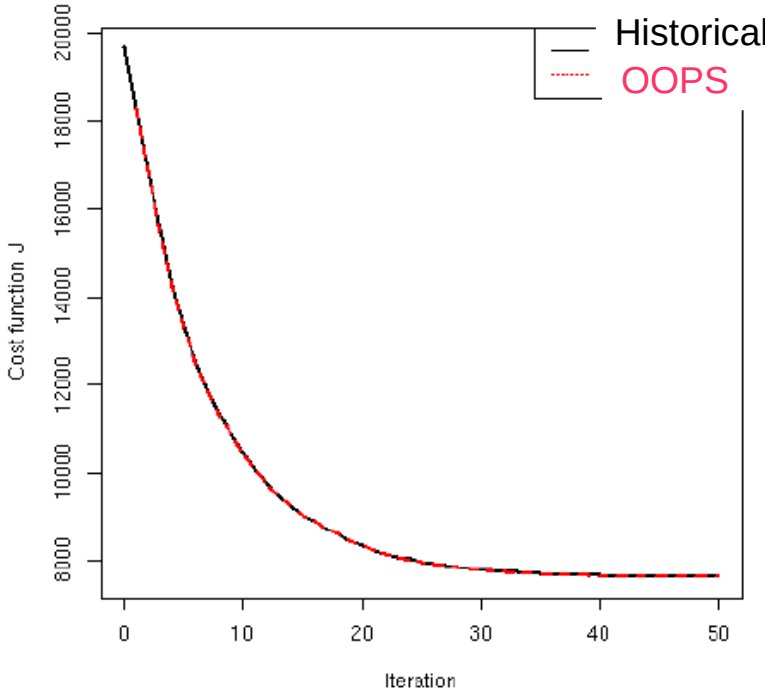
V. Vogt (Météo-France), B. Strajnar (ARSO), R. Stappers (MetNo), F. Meier (ZAMG), ...



Analysis increments of temperature at level 80 (PBL)

(B. Strajnar, ARSO)

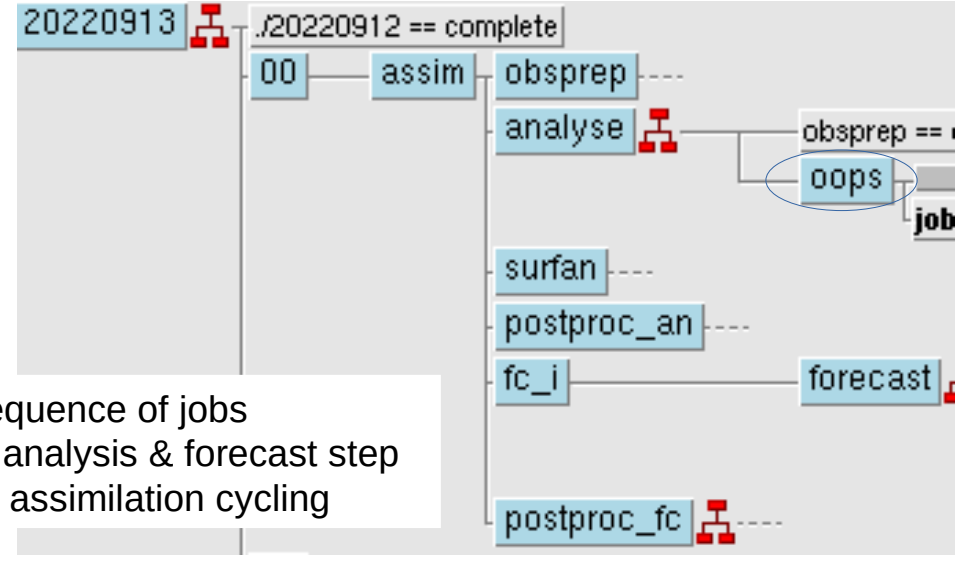
3D-Var with OOPS



Convergence of J
during the 3D-Var minimisation

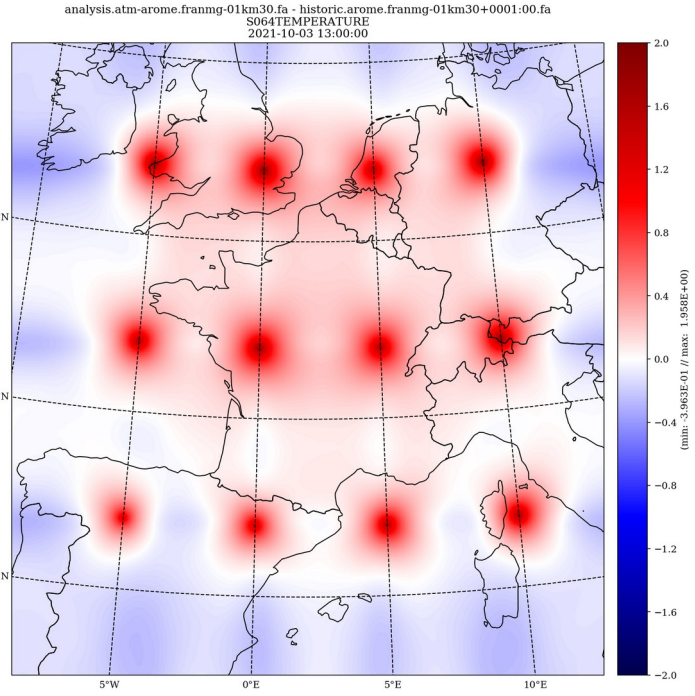
(B. Strajnar)

Screening and minimisation are now run within a single OOPS task, in order to easen handling of variational bias correction (VarBC) of obs.

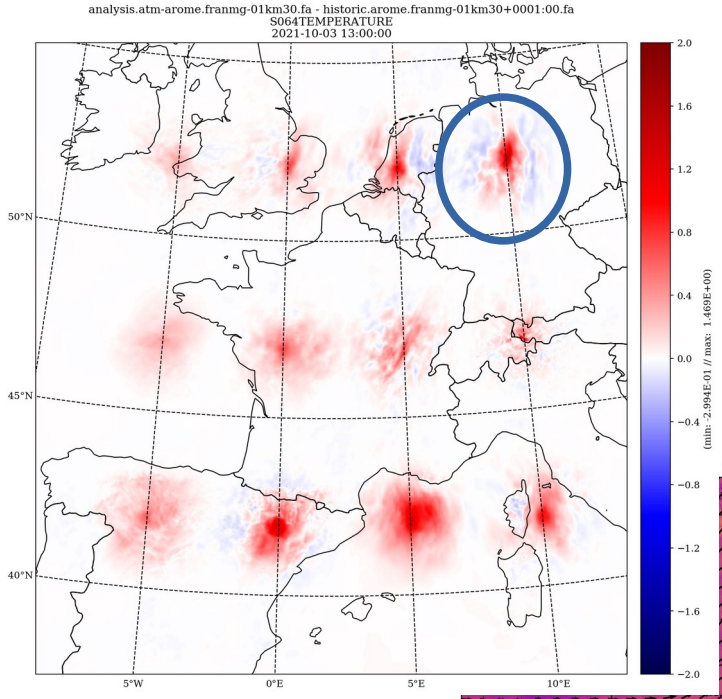


Sequence of jobs
for a given analysis & forecast step
in data assimilation cycling

AROME-France 3DEnVar with OOPS : illustration of flow-dependent covariances

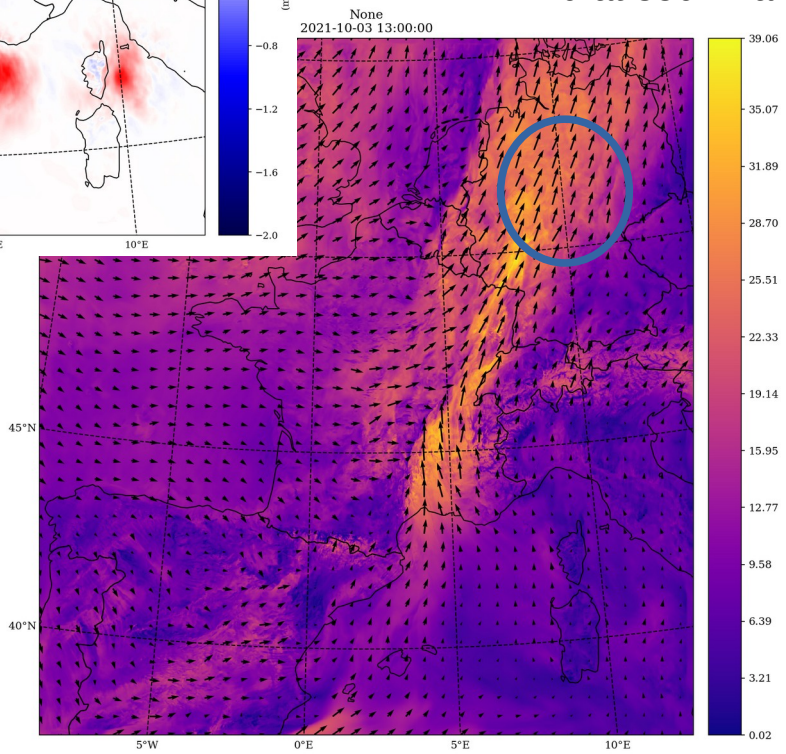


3D-Var



3DEnVar

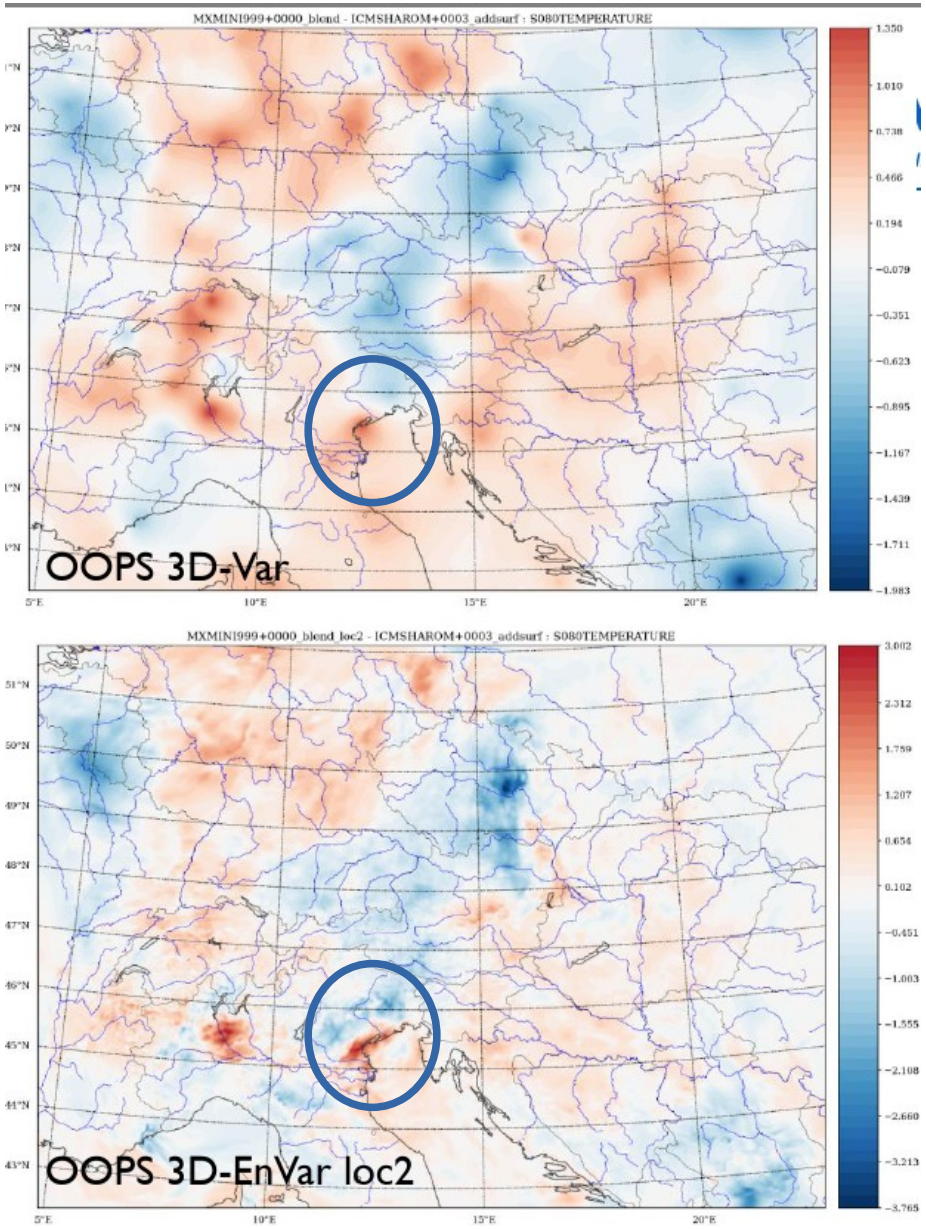
Wind at 850 hPa



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

(V. Vogt and P. Brousseau)

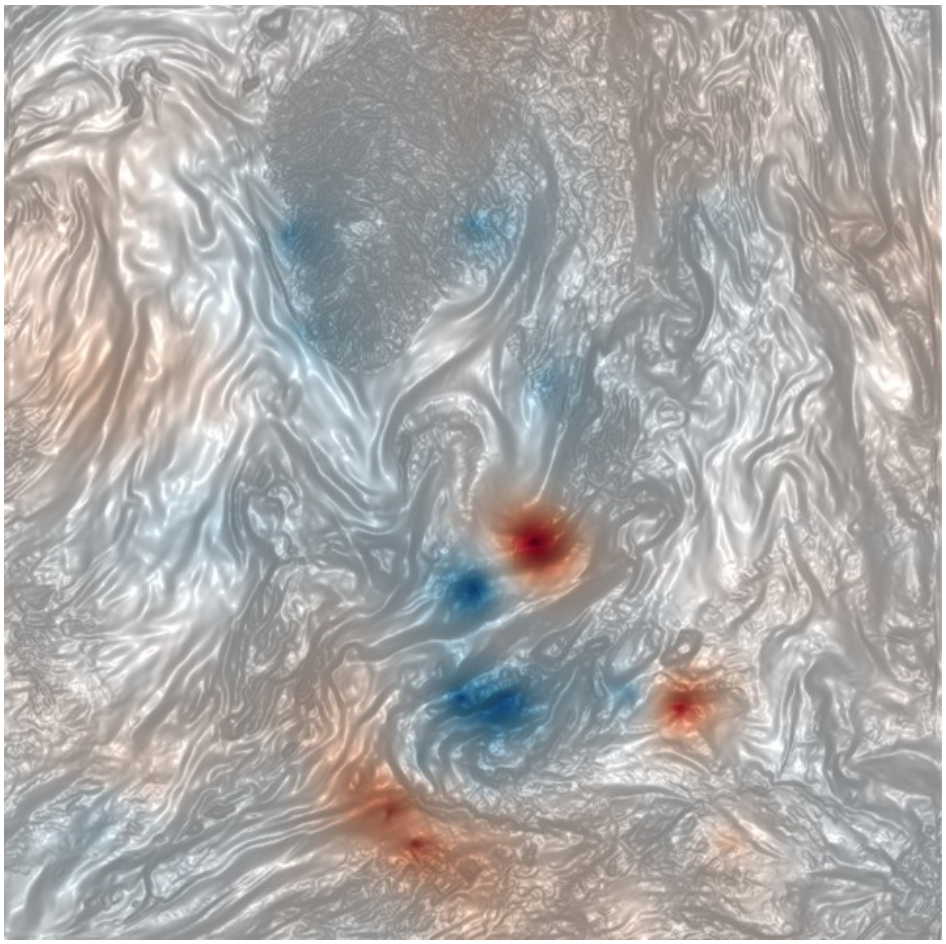
AROME-Austria 3DEnVar with OOPS : effects of flow-dependent covariances

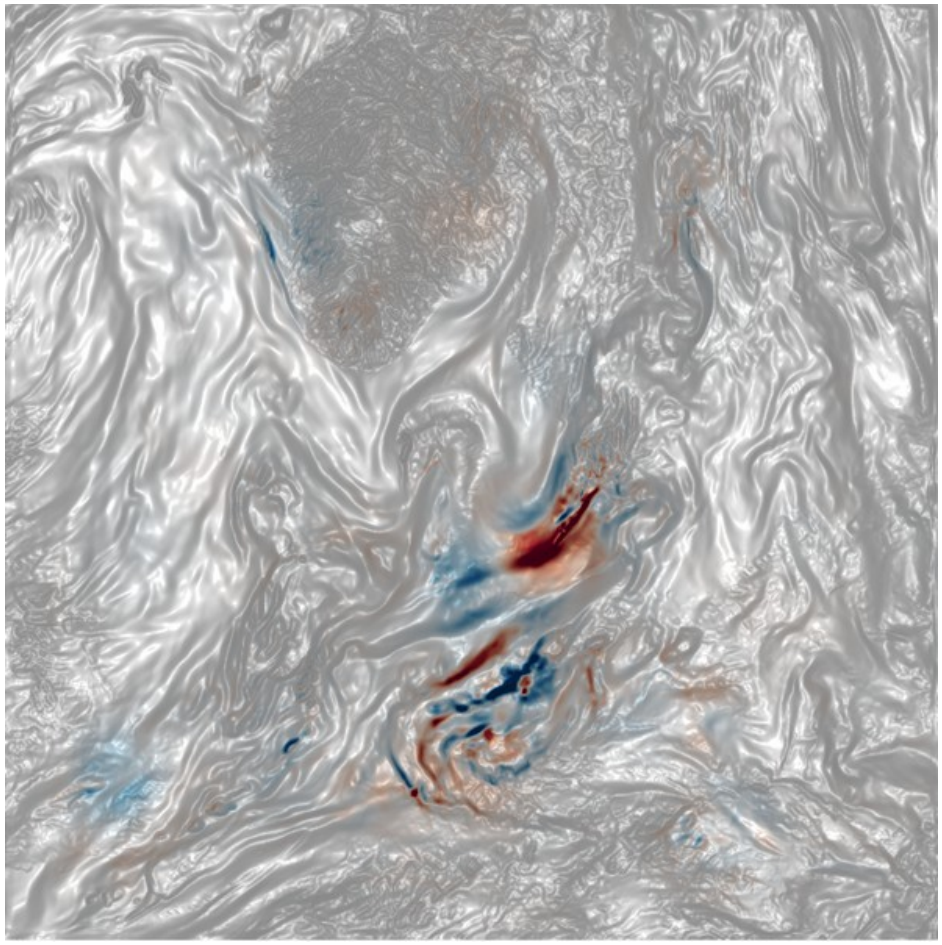


Analysis increments of temperature at 850 hPa

(F. Meier, ZAMG)

Harmonie-AROME 3DEnVar with OOPS : effects of flow-dependent covariances





3D-Var

Analysis increments (in color)
for specific humidity near 800 hPa,
superimposed with the background field (in gray)
(over North Europe)

3DEnVar

(R. Stappers, MetNo)

Pre-operational AROME 3DEnVar at Météo-France with OOPS : experimental setup

3DEnVar is being experimented at Météo-France (preparation of double suite), in order to specify flow-dependent **B** for Arome:

- Same resolution as operational configuration (1.3 km).
- Use 50 ensemble members from AROME EDA (3.2 km).
- Horizontal localisation scale varying between 25km at low levels and 150km near the model top.
- Vertical localisation scale = 0.3.
- Pure 3DEnVar version (no hybridation in the next slides).

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(V. Vogt and P. Brousseau)

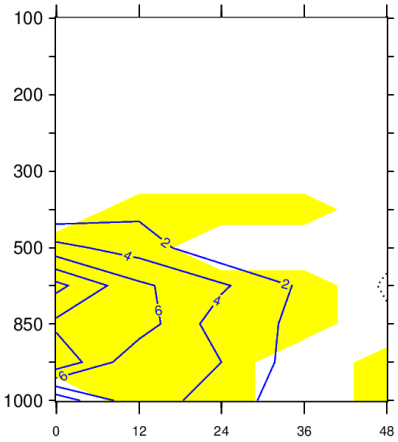
Pre-operational AROME 3DEnVar at Météo-France with OOPS : impact results

Postive impacts on 4 aspects (at least) :

- general performances over a **6-month period**

  (stronger during convective season)

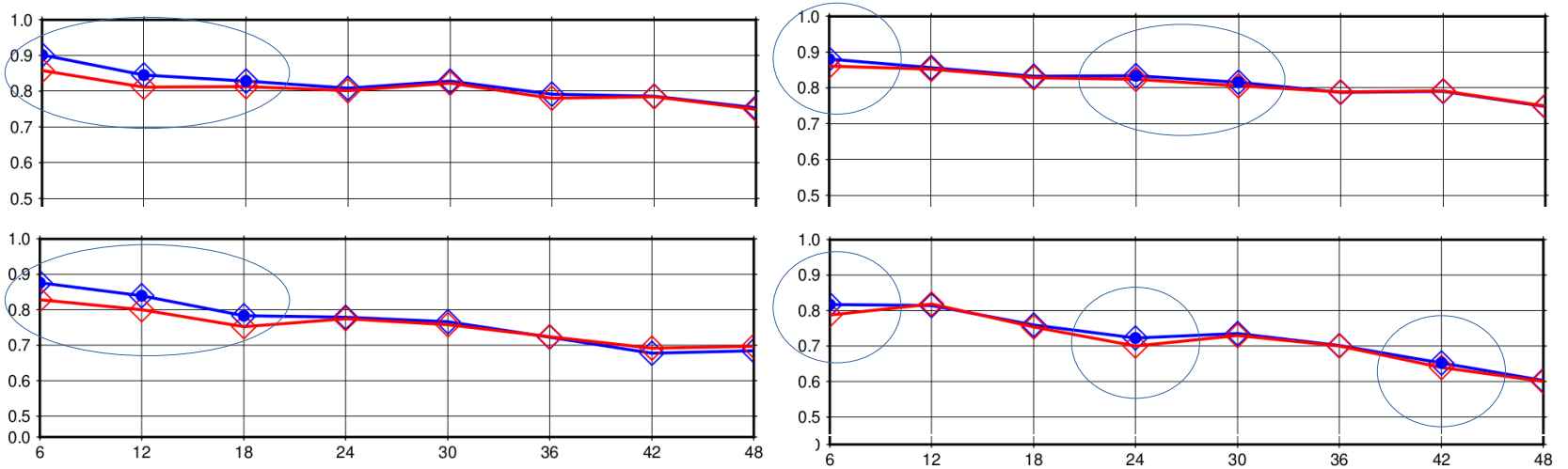
% of reduction of RMSE
for relative humidty
over 6 months
(ref = radiosondes)



BSS for 6h cumulated rain (50 km neighbourhood)

15 Sept – 30 Nov 2020

1 Dec 2020 – 1 Mar 2021



0,5mm/6h

5mm/6h

Forecast range (h)

Forecast range (h)

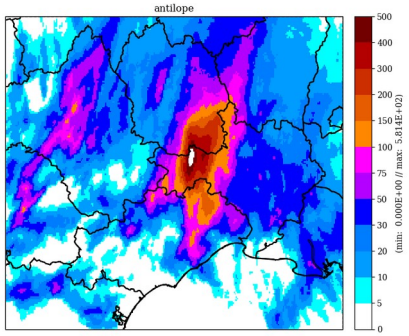
3DEnVar

3D-Var

- simulation of **fog events** (20 cases investigated)
- simulation of **wind gusts** during winter storms (6 cases)
- simulation of **HPE** (8 cases)

(V. Vogt and P. Brousseau)

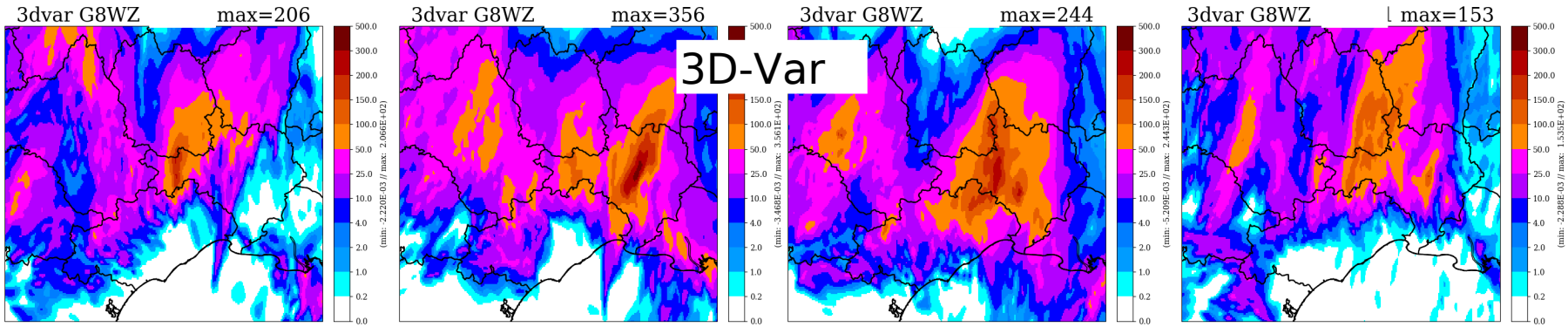
AROME 3DEnVar : case study 19/09/2020



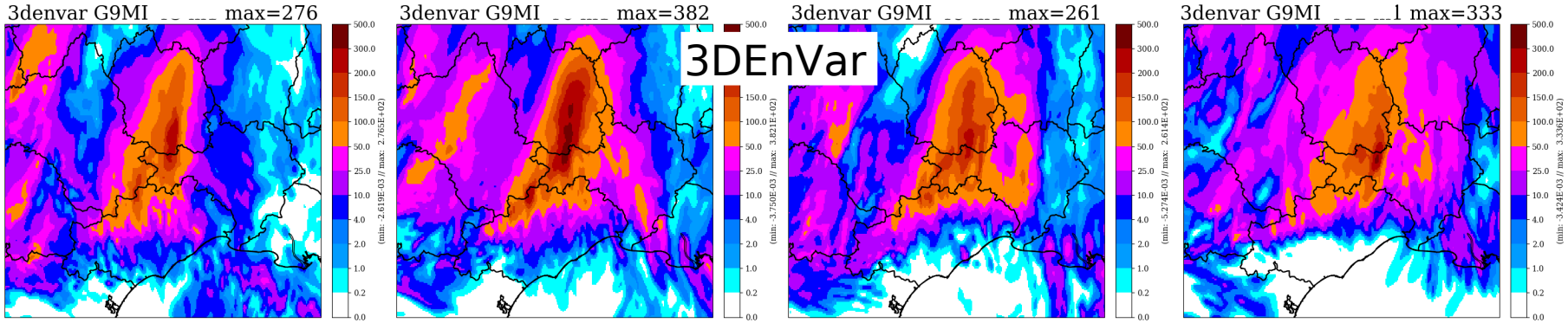
Radar : 20h accumulated rain between
19/09/04UTC and 20/09/00UTC

r3 on 19/09 | r0 on 19/09 | r21 on 18/09 | r18 on 18/09

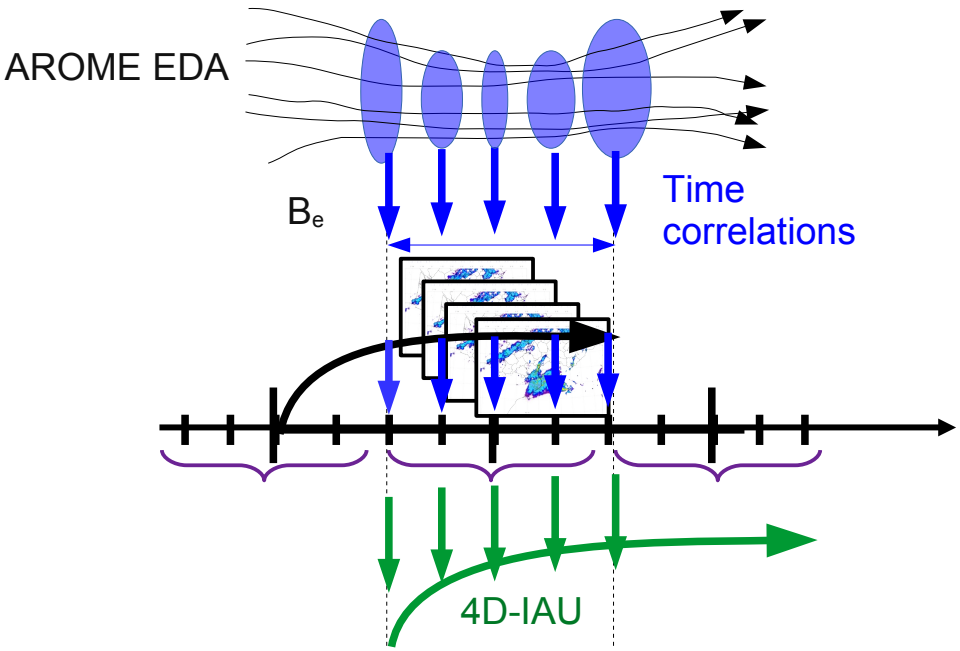
3D-Var



3DEnVar



AROME 4DEnVar with OOPS



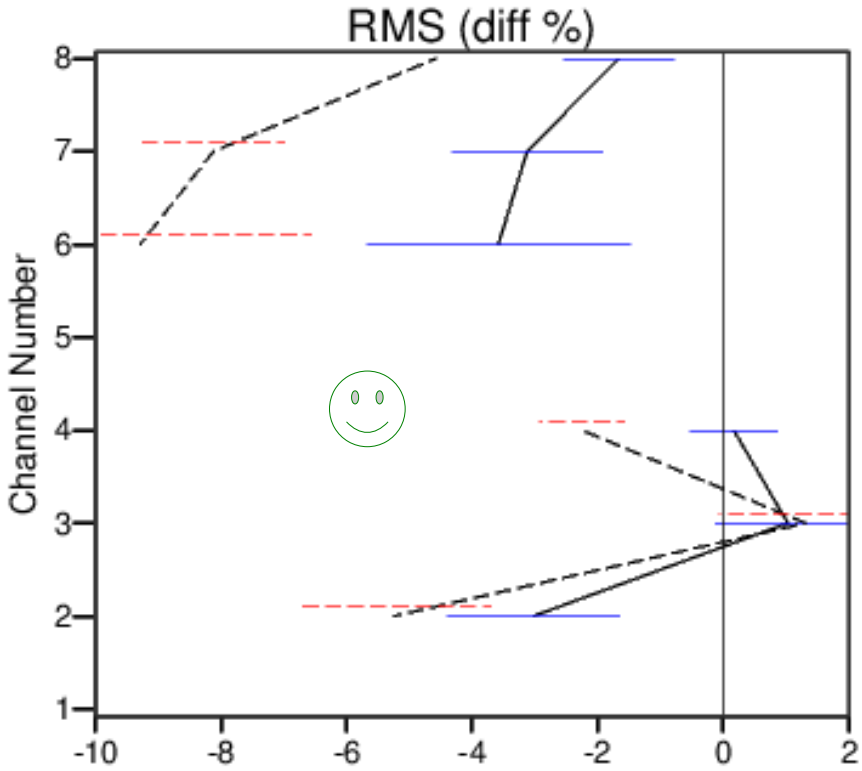
- 4DEnVar : 1h cycle with 5 timeslots : 3*15min + 2*7min
  => use 4D increment (e.g. 4D-IAU).

- 4D perturbations provided by AROME EDA.

(P. Brousseau)

AROME 4DEnVar with OOPS

SEVIRI



O-B

O-A

4DEnVar obs 15min
vs 4DEnVar obs 1h

- 1-month experiment using same observations as in 3DEnVar :
  neutral / slightly positive impacts.

- Use of 15 minute observations :
  radar, surface stations, SEVIRI, ground-based GNSS : nb obs x 3
  encouraging results on cases studies ; first long experiments are ongoing.

(P. Brousseau)

Direct assimilation of reflectivities, with hydrometeors in the control variable

- Ground based radar reflectivities are currently assimilated in AROME with a 1D+3DVar method, using Bayesian inversion to produce pseudo-observations of relative humidity.

- With hydrometeors in the control variable of OOPS-3DEnVar, it is possible to assimilate radar reflectivities directly.

- TL/AD versions of radar reflectivity operator have been developped.

- We can compare both assimilation methods in AROME 3DEnVar experiments.

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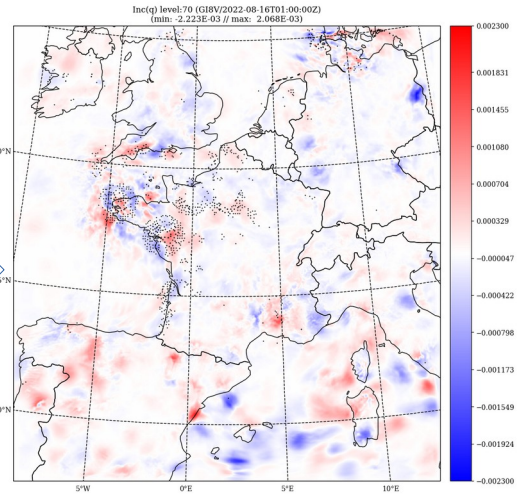
(M. Martet)

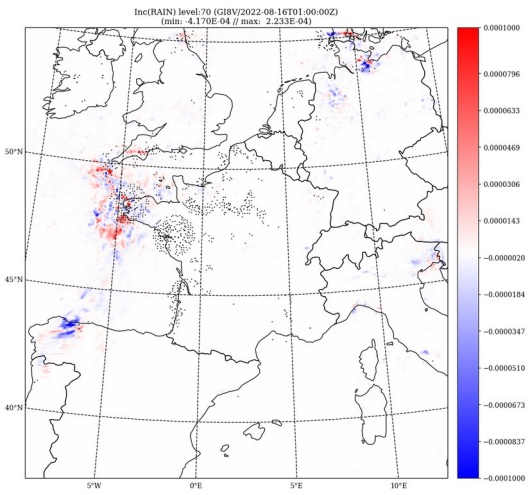
Direct assimilation of reflectivities, with hydrometeors in the control variable (3DEnVar)

Specific humidity
Increment
Level 70

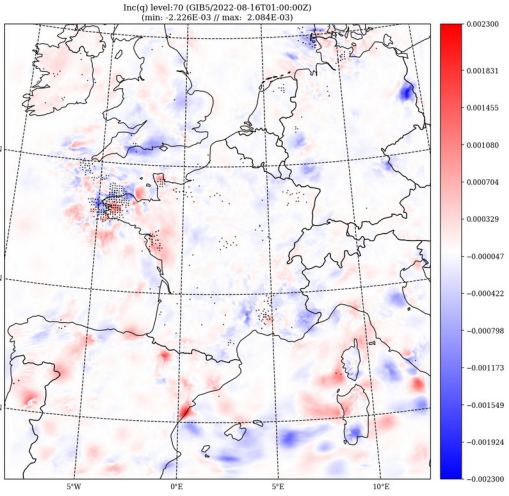


Assimilation of pseudo observations of humidity, using Bayesian inversion from radar reflectivities

Cross-covariances

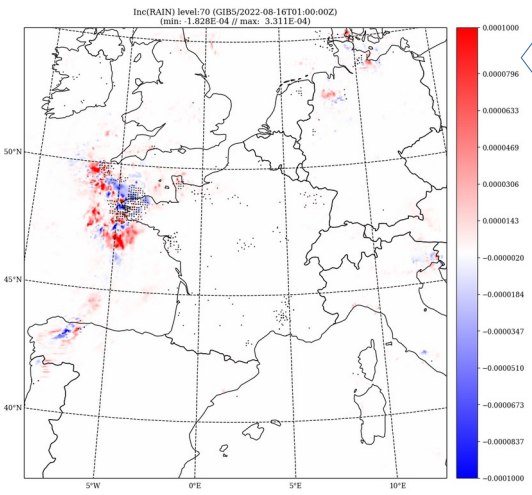


Rain increment
Level 70



Specific humidity
Increment
Level 70

Cross-covariances



Assimilation of radar reflectivities directly

Rain increment
Level 70

16/08/2022 1h UTC

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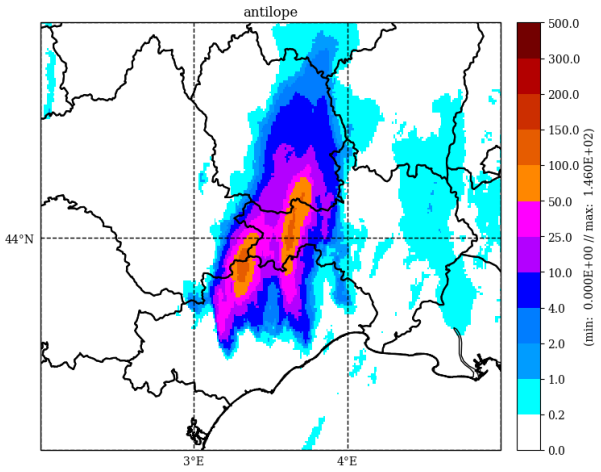
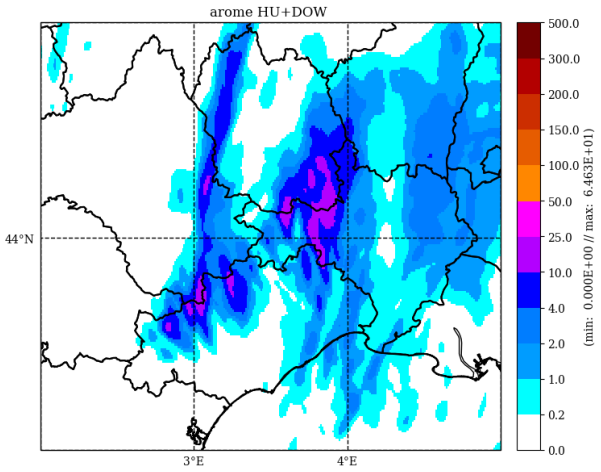
(M. Martet)

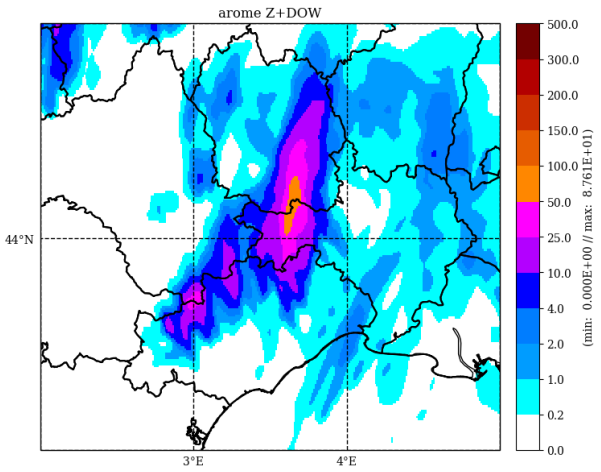
Direct assimilation of reflectivities, with hydrometeors in the control variable (3DEnVar)



Radar (reference)



With Bayesian inversion



With reflectivities directly

- One example : 6-hour precipitation forecast on 19/09/2020
- Better position and intensity using direct assimilation of reflectivity although some underestimation remains in this case.

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(M. Martet)

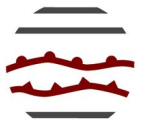
Conclusions

- Setup and validation of **OOPS/3D-Var** has been achieved by several ACCORD members, which will easen research, development and maintenance of DA algorithms.

- **AROME 3DEnVar** with OOPS is well advanced, e.g. with positive results over a 6 month period ; a real-time double E-suite will start in 2023 at Météo-France to achieve operational implementation.

- Development of **AROME 4DEnVar** is also progressing well thanks to OOPS, with encouraging results, which are pursued with high frequency observations (15 min), for possible double E-suite in 2024.

- OOPS also allows new approaches to be considered :
  hydrometeors in the control variable and direct assimilation of reflectivities,
  NH variables in the control variable, scale dependent localisation (SDL), …



Thanks for listening !