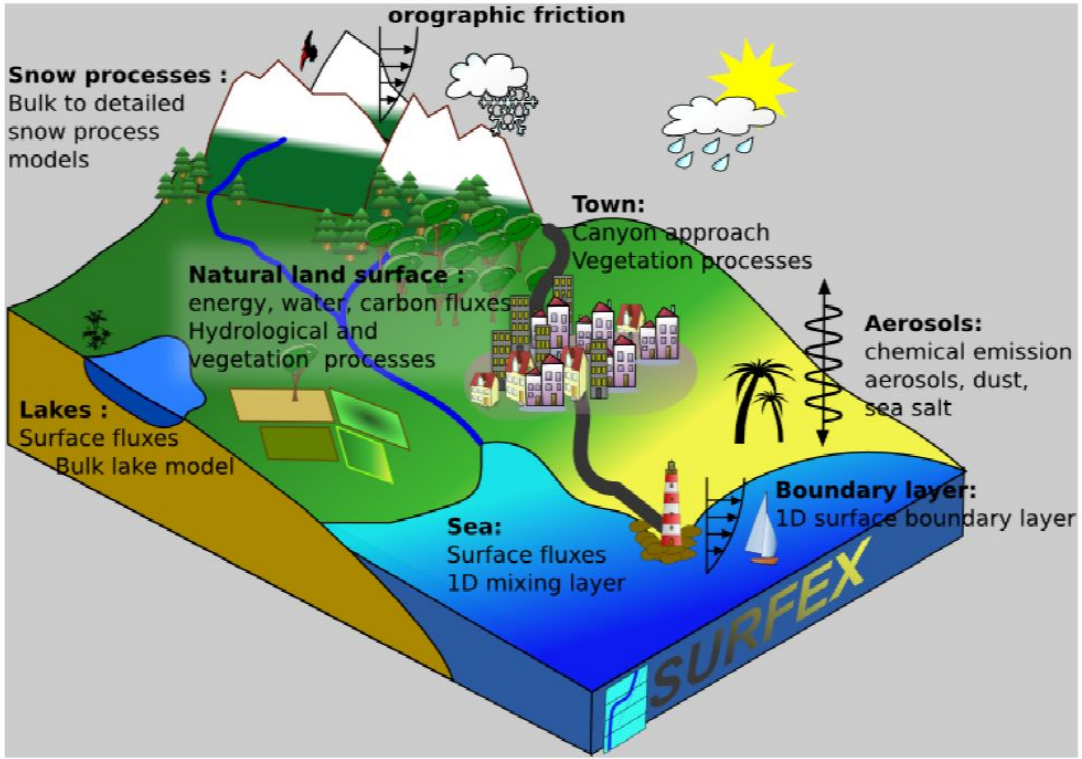
Towards an ensemble approach to surface analysis within the NWP model AROME-France

Sophie Marimbordes, Camille Birman, Nadia Fourrié, Etienne Arbogast, Jean-François Mahfouf
CNRM/GMAP/OBS & CNRM/GMAP/ASSIM

Surface-atmosphere interface



Importance of an accurate representation of surface-atmosphere coupling

Strong sensitivity of initial surface conditions

Masson et al. 2013, The SURFEXv7.2 land and ocean surface platform for coupled or offline simulation of earth surface variables and fluxes

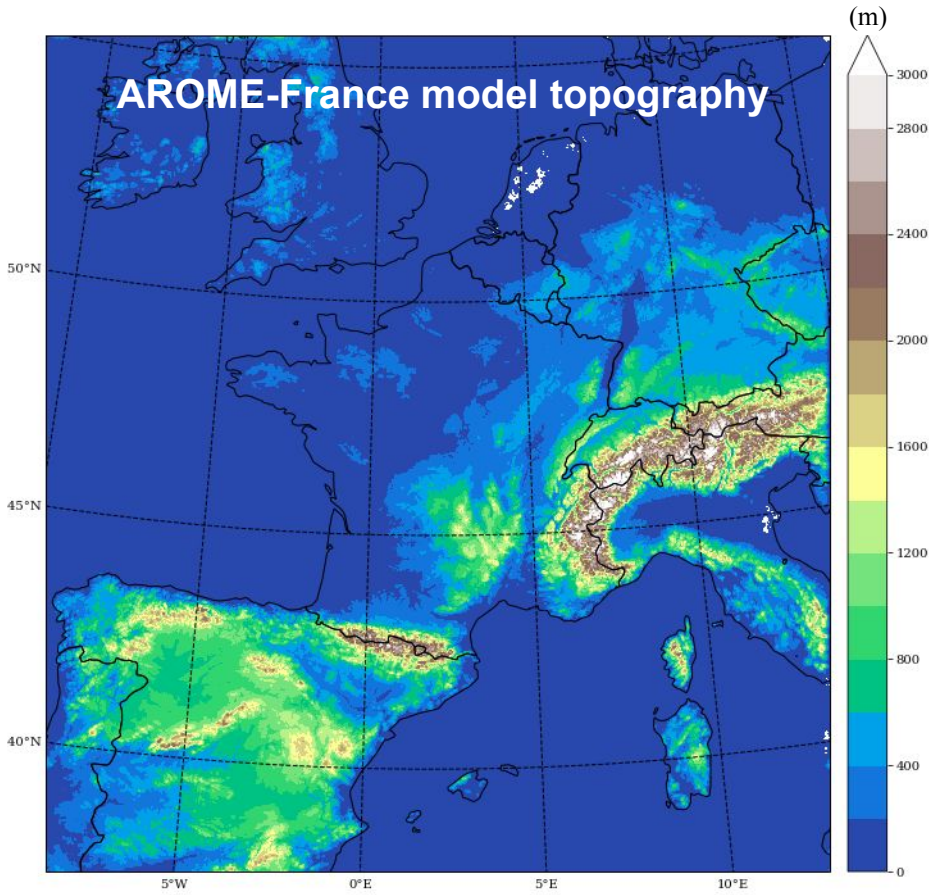
AROME-France atmospheric model

Limited Area Model
1.3 km horizontal resolution
90 vertical levels from 5 m to 10 hPa

Surface model : SURFEX

Coupled forecasts
Uncoupled analysis

E-suite in 48t1 :
* OI surface assimilation 3-hour cycle
* **3D-EnVar** atmospheric assimilation 1-hour cycle

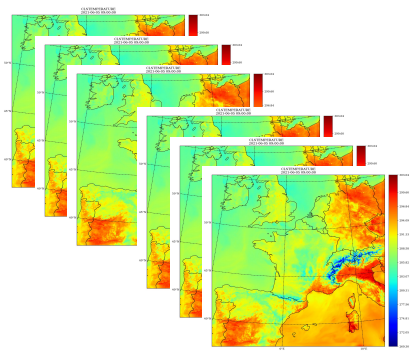


AROME-France atmospheric model

E-suite 48t1 : H-operators and R-matrix the same as in 3D-Var, but **B-matrix updated**

3D-Var ⟶ **3D-EnVar**

Flow-dependent B-matrix with **AROME EDA - 3.2 km - 50 members**



Statistics on

atmospheric fields from

AROME EDA

3.2 km 50 members

Fully 3D-EnVar
Dynamical

B

matrix

+ ***Localization filter necessary***

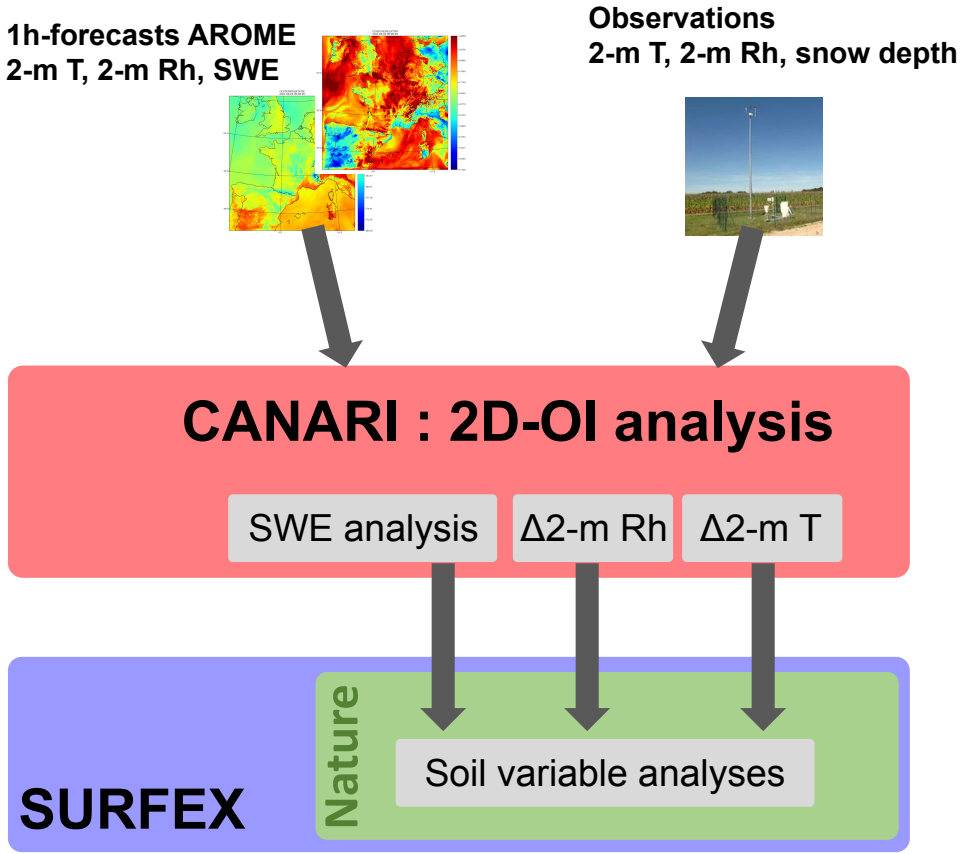
AROME-France surface analysis

Nature tile in SURFEX (ISBA3L)

Assimilation of **2-m temperature, 2-m relative humidity and snow depth observations**

CANARI : **2D-OI analysis** of **2-m temperature, 2-m relative humidity and SWE**

Initialisation of **soil variables** in SURFEX



AROME-France surface analysis

Nature tile in SURFEX (ISBA3L)

Assimilation of **2-m temperature, 2-m relative humidity and snow depth observations**

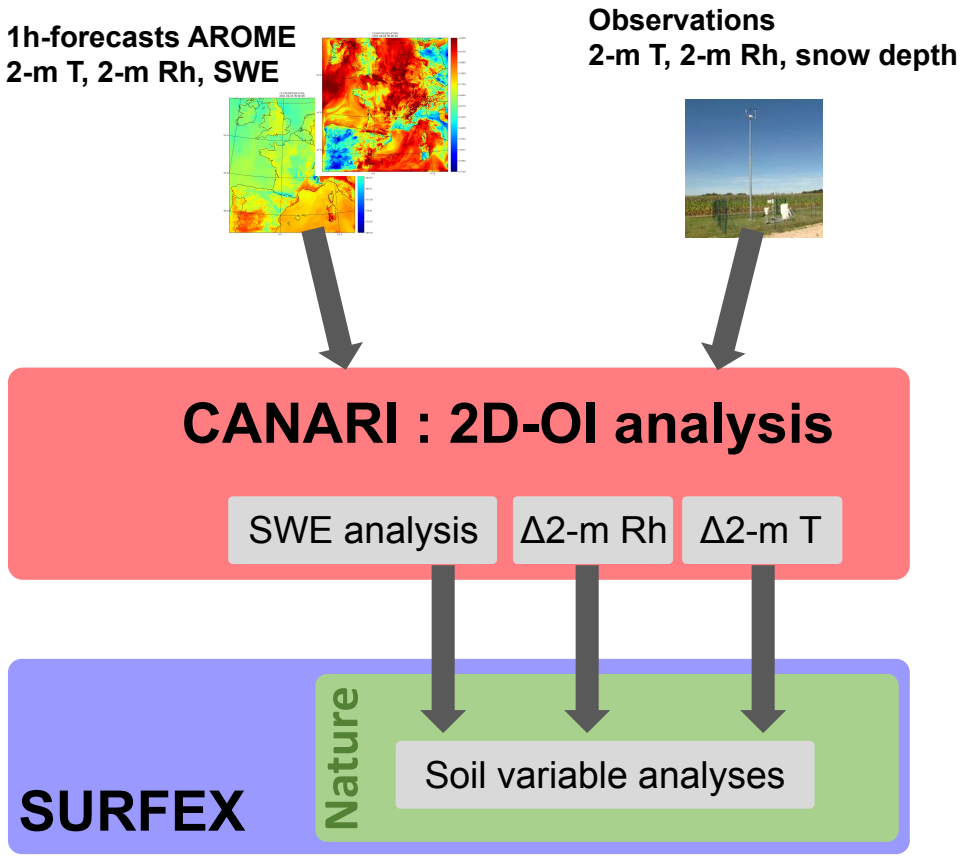
CANARI : **2D-OI analysis** of **2-m temperature, 2-m relative humidity and SWE**

Initialisation of **soil variables** in SURFEX

Drawbacks

1. Outdated surface analysis

2. Implement a system close to the upper air analysis :
   - to **facilitate code maintenance** and evolution
   - for future **coupled DA**



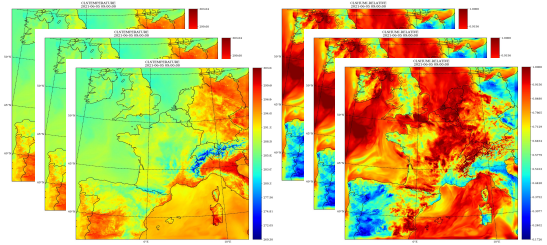
Objective

Development of an **ensemble-based surface analysis**
in a **coupled SURFACE-ATMOSPHERE system** for more realistic forecasts of **low-level processes**

2D-EnVar approach in OOPS similar to 3D-EnVar

1) Implement a **2D-Variational approach** to replace the 2D-OI surface analysis

2) Use AROME-France EDA to implement a **2D-Ensemble Variational** surface scheme



2-m T and 2-m Rh fields
EDA AROME 50 members

→

2D-EnVar
Dynamical

B

Matrix

→

Compute 2-m T and 2-m Rh increments

OUTLINE

1. **2D-Var** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

2. **2D-EnVar** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

OUTLINE

1. **2D-Var** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

2. **2D-EnVar** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

1. 2D-Var : background-error covariances

- **Gaspari & Cohn** function (Gaspari and Cohn, 1999),
  with Daley length = 25 km

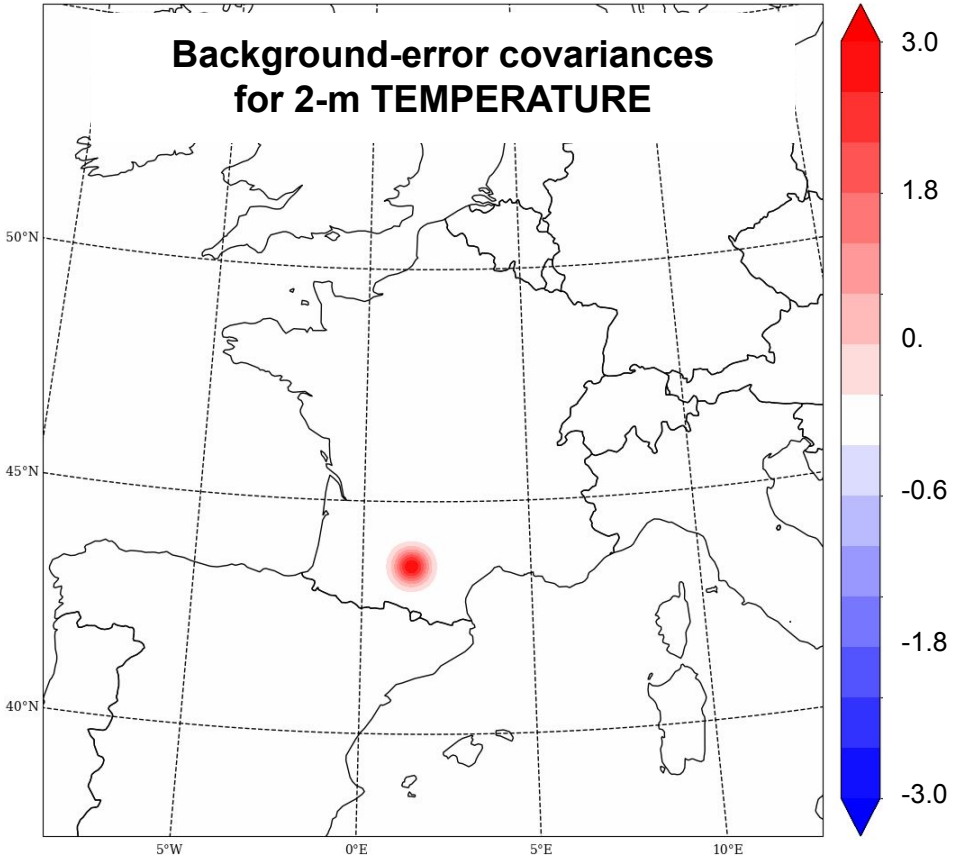
- Univariate, Homogeneous and Isotropic

- 2-m temperature : $\sigma_b = 1.6\,K$

  $(\sigma_b^{\,2} = 2.56)$

- 2-m relative humidity : $\sigma_b = 0.1$

- **Similar** to **MESCAN** spatial correlations defined in **CANARI-OI** (Häggmark et al. 2000)



1. 2D-Var : 2-m temperature increments

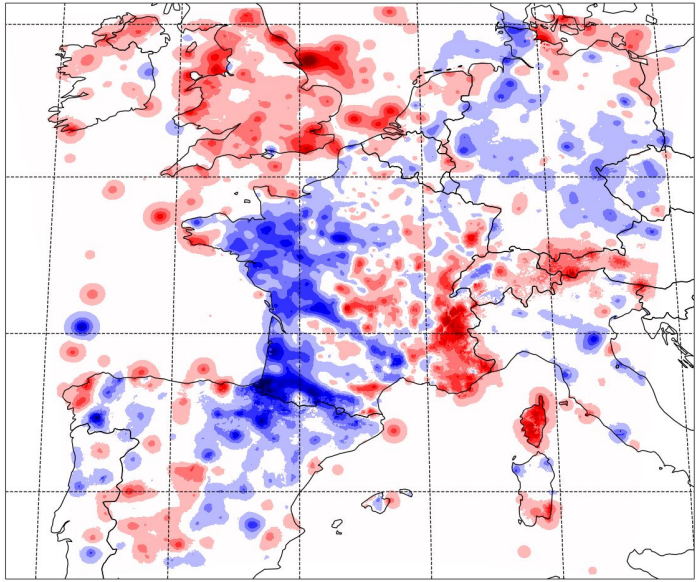
7/09/2021 12h

AROME-France domain

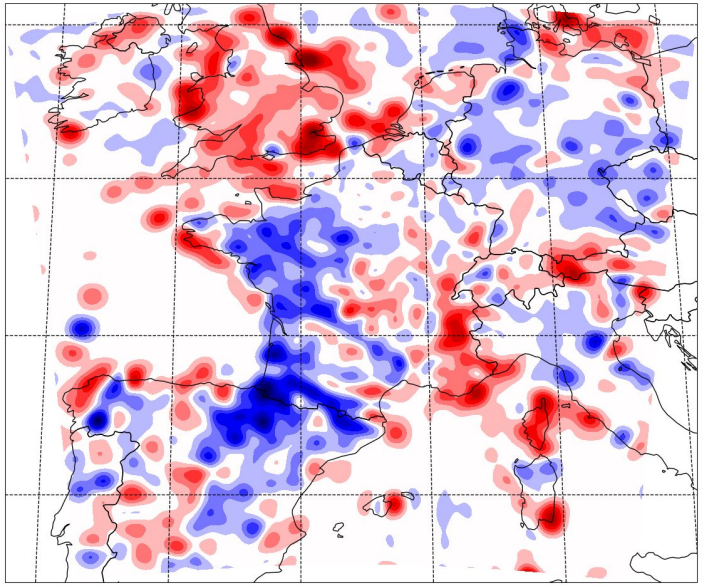
1.3 km resolution

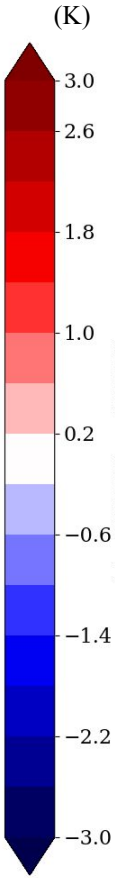
Similarities *: same patterns at the same places*

CANARI-OI



2D-Var





MESCAN function

correlation length = **25 km**

Gaspari & Cohn function

correlation length = **25 km** (Daley length)

1. 2D-Var : 2-m temperature increments

7/09/2021 12h

AROME-France domain

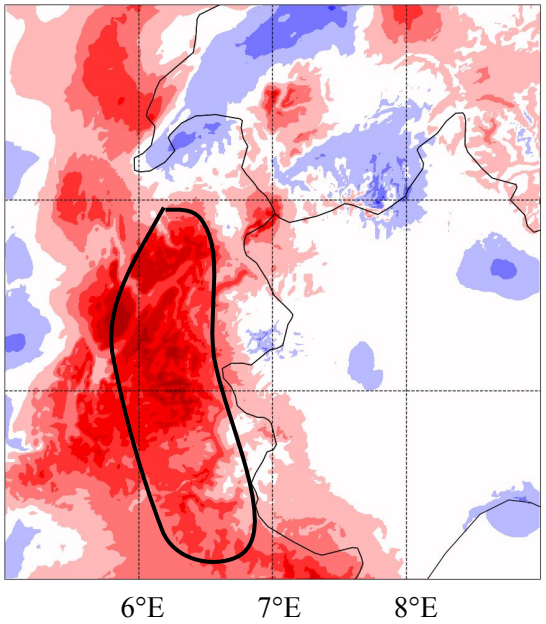
1.3 km resolution

*CANARI-OI takes into account the **topography***

*but **spreads the increment** over large area as 2D-Var*

Focus on the French Alps

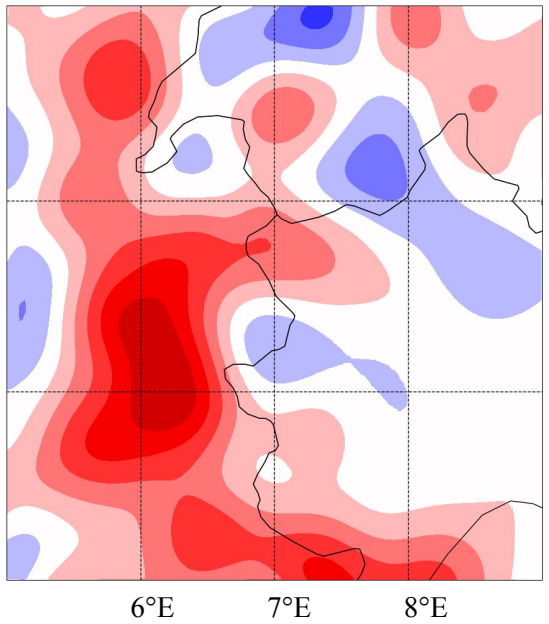
CANARI-OI



MESCAN function

correlation length = **25 km**

2D-Var



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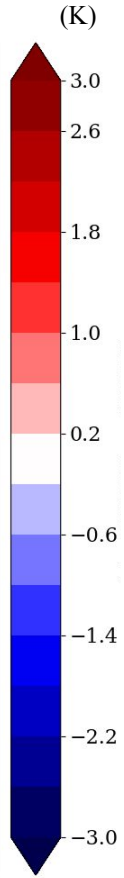


1. 2D-Var : Forecast scores

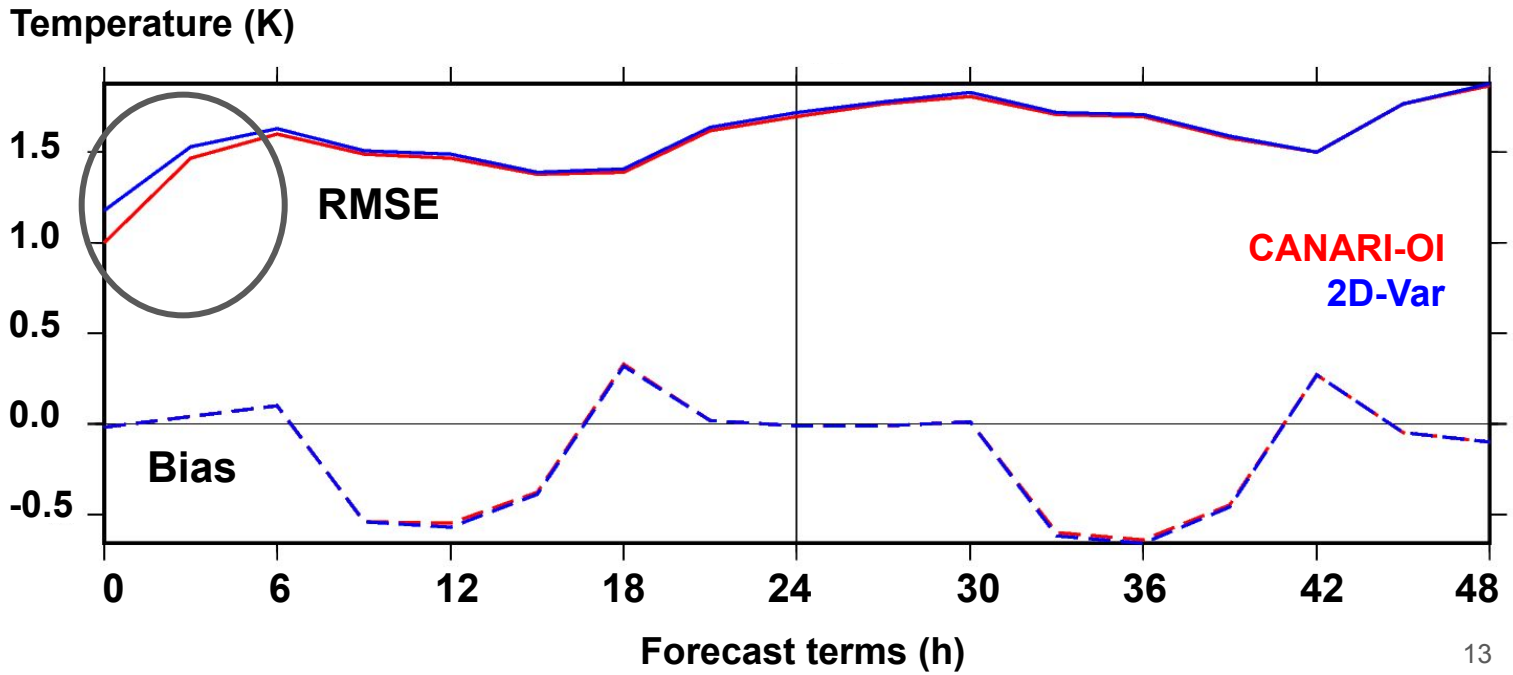
Forecast Bias and RMSE over **2 months** using **surface station observations** : 7/ 09/ 2021 - 5/ 11/ 2021

2-m temperature over **FRANCE**

Between 0 - 6 h : slight degradation for 2D-Var

*CANARI-OI and 2D-Var **similar***

2D-Var : robust results



OUTLINE

1. **2D-Var** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

2. **2D-EnVar** surface analysis

   Background-error covariances + 2-m temperature **increments** + **Scores**

1. 2D-EnVar : background-error covariances

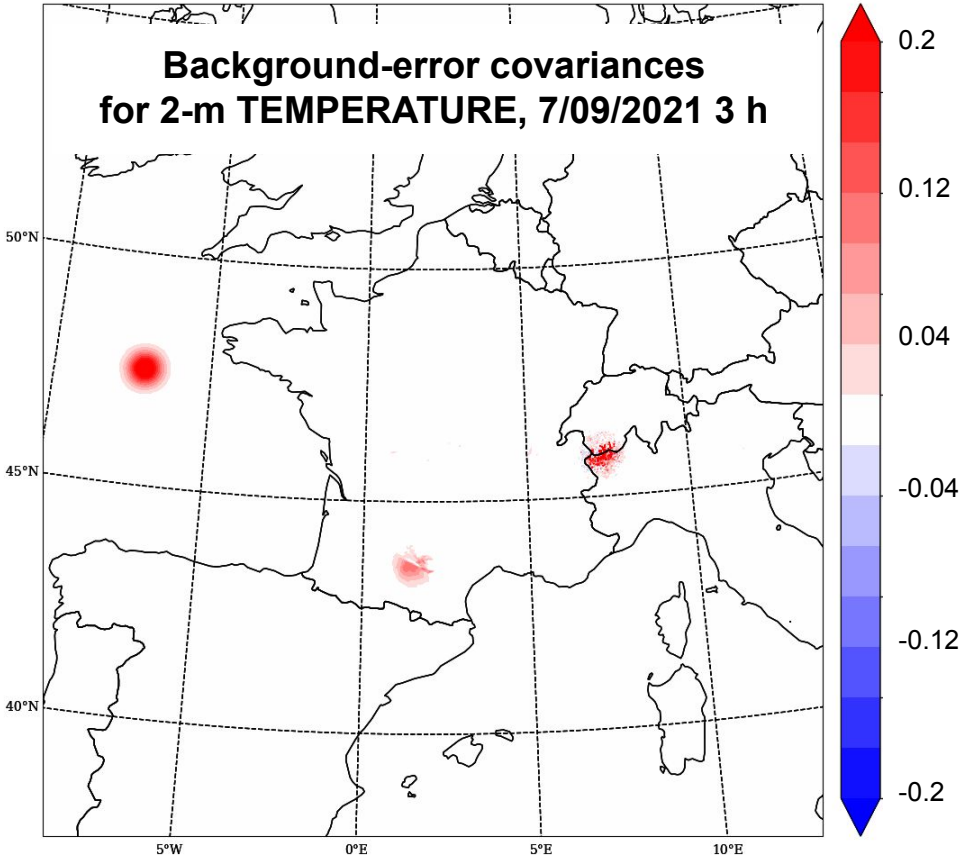
- **AROME EDA** 50 members :
  1.3 km resolution, **3 h** range forecast
  = *Research experiment*

- **Flow-dependent** B-matrix

  multivariate covariances : temperature / relative humidity

  non-homogeneous and **anisotropic** covariances : different shapes at different locations

- **Gaspari & Cohn** localization filter**,** 1999 with Daley length = 25 km



2. 2D-EnVar : 2-m temperature increments

7/09/2021 12h

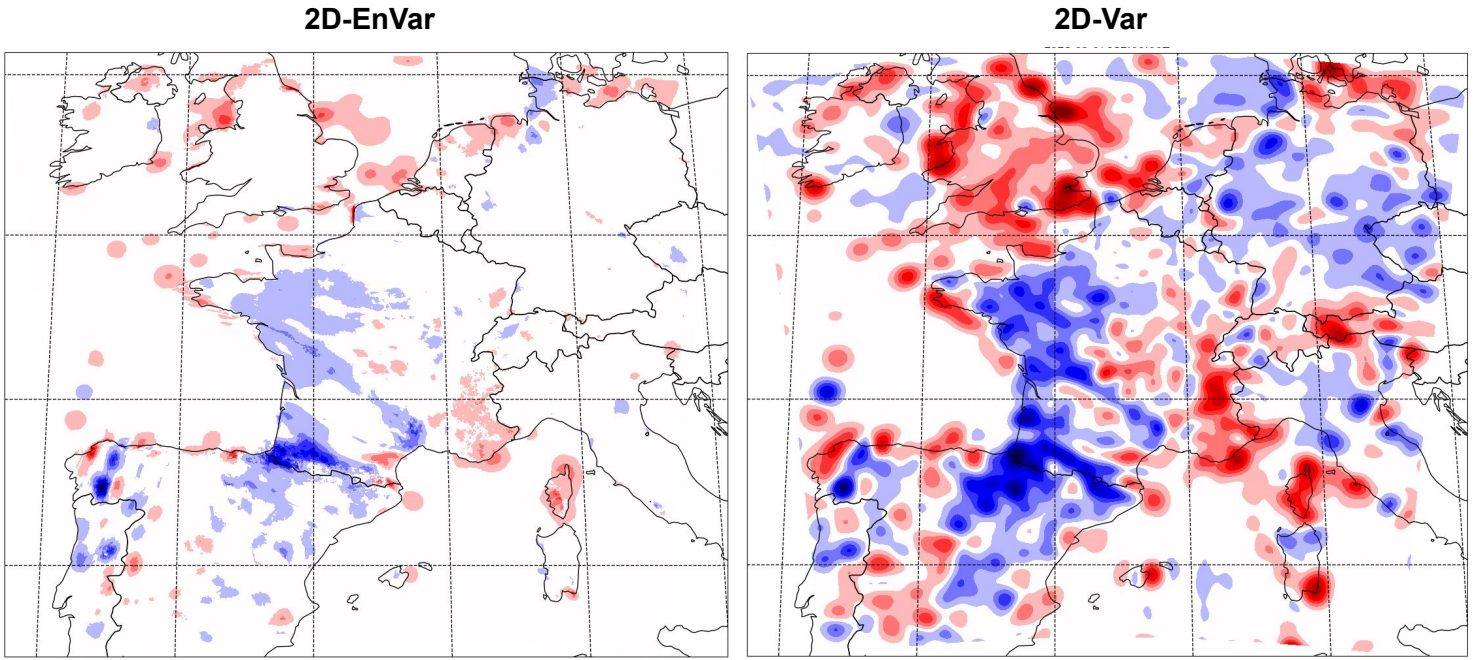
AROME-France domain

1.3 km resolution

Similar shapes but…

2D-Envar << 2D-Var

due to low σ_b



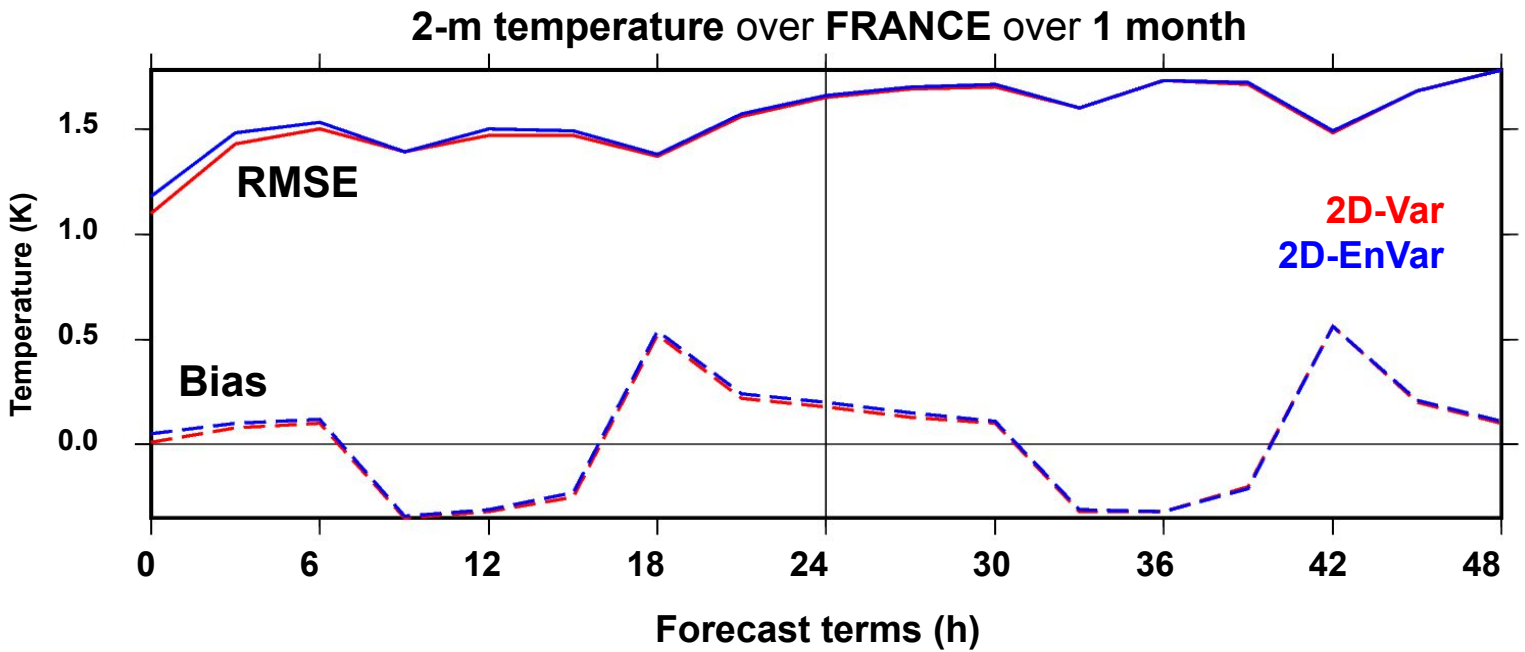
EDA AROME 1.3 km
Gapari & Cohn localization filter
localization length = **25 km**

Gaspari & Cohn function
correlation length = **25 km**

2. 2D-EnVar : Forecast Scores

- **Encouraging results** on forecast scores **over 1 month**
  2D-EnVar **similar** to 2D-Var
  Slight degradation between 0 and 6 h for 2D-EnVar **due to low** σ_b

- Evaluation over **2 months** required



Conclusion & Perspectives

Conclusion

Implementation of **2D-Var** in OOPS ⇒ **Robust results** of **2D-Var** compared to CANARI-OI

Implementation of **2DEn-Var** in OOPS ⇒ **Encouraging results** with **2D-EnVar** (ARO EDA 1.3 km)

Perspectives

- **Evaluation** of **2D-EnVar** with ARO EDA 1.3 km over a **longer period** (2 months) and **another season**
- **2D-EnVar** with **ARO EDA 3.2 km** (oper)
- **Sensitivity tests** : localization length, background-error variances,...
- Article in preparation (Marimbordes et al., 2023)

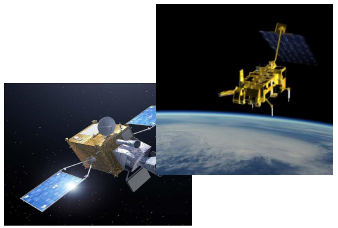
- Assimilation of **new observations**

Surface temperature
Superficial soil water content
Precipitations

Rain gauge

Meteorological radar

Metop satellite, ASCAT instrument



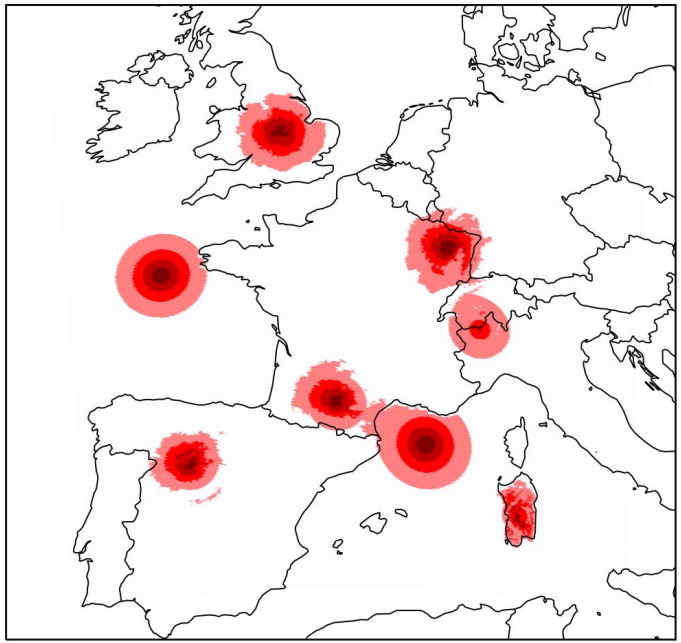
MTG satellite, FCI radiometer

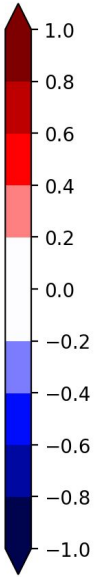
Thank you!

Error correlations in CANARI-OI

CANARI-OI : MESCAN function

2-m T error correlations





MESCAN function formula

Land/sea mask **Topography**

$$(1 - min(0.5\,;\, 0.4 * \Delta lsm)) * (1 - min(0.5\,;\, 0.002 * \Delta alti)) * 0.5 * (e^{-\frac{dist}{L}} + (1 + 2 * \frac{dist}{L}) * e^{-\frac{2*dist}{L}})$$

MESAN function (Häggmark et al. 2000)

with correlation length L = 100 km (oper),
fixed to 25 km in our experiment