Towards the introduction of horizontal correlations of satellite observation errors into the DA system of the model AROME

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ITSC 2025 - Goa, India

May 12th, 2025

Agenda

- **Data assimilation in AROME**

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- Horizontal correlations of SEVIRI observation errors

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- **Experimental framework**

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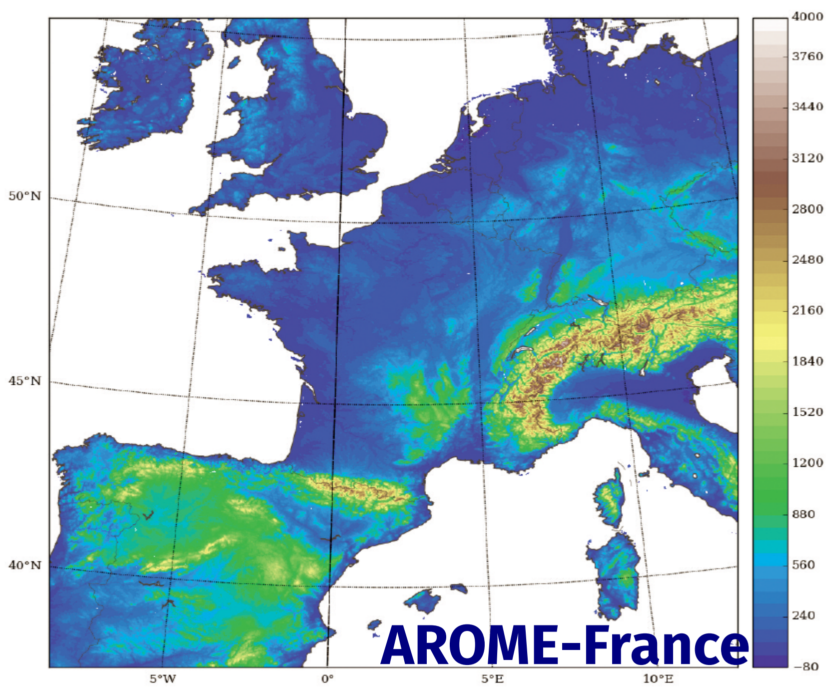
Limited-area model AROME

- **Météo-France high-resolution model**



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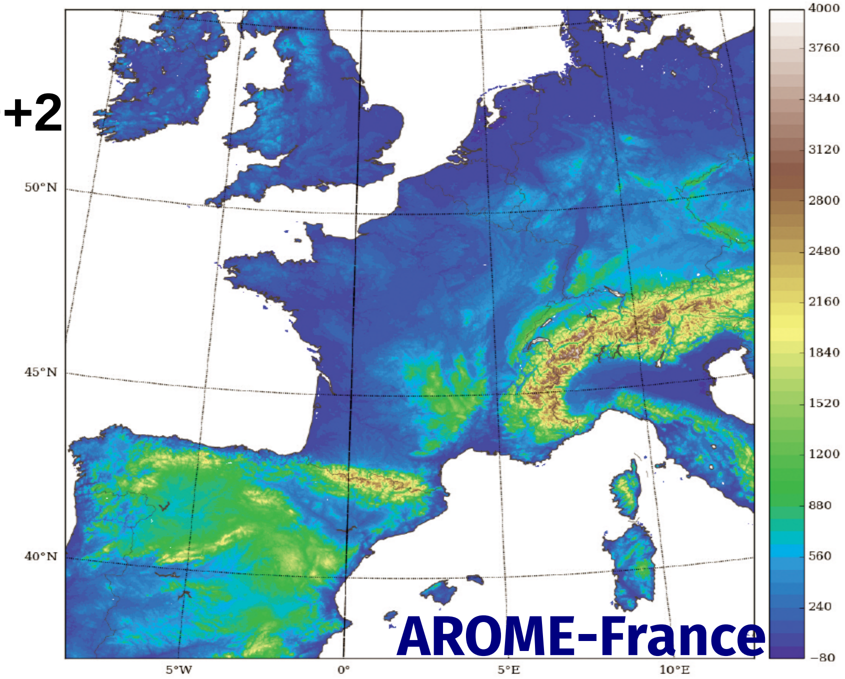

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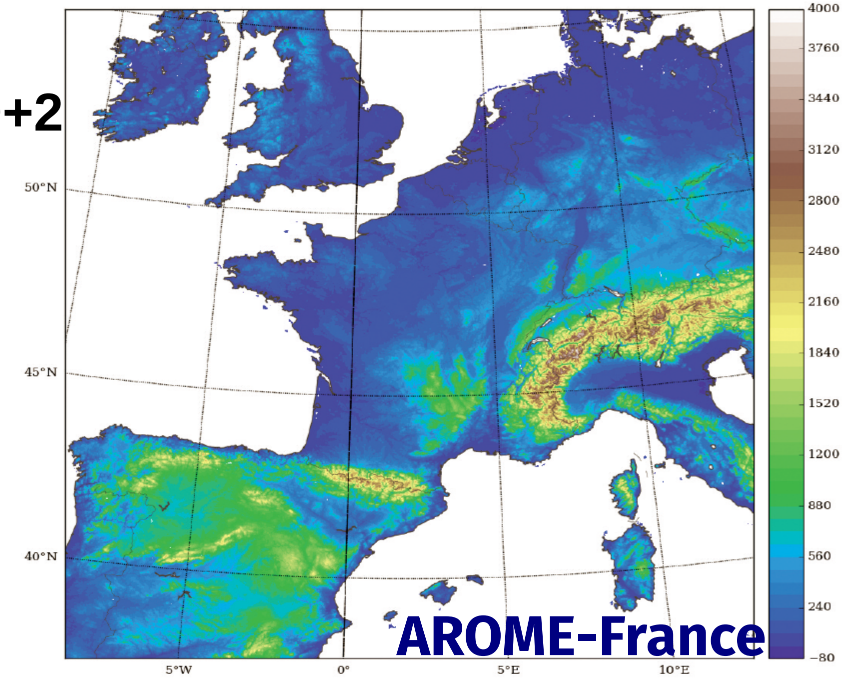

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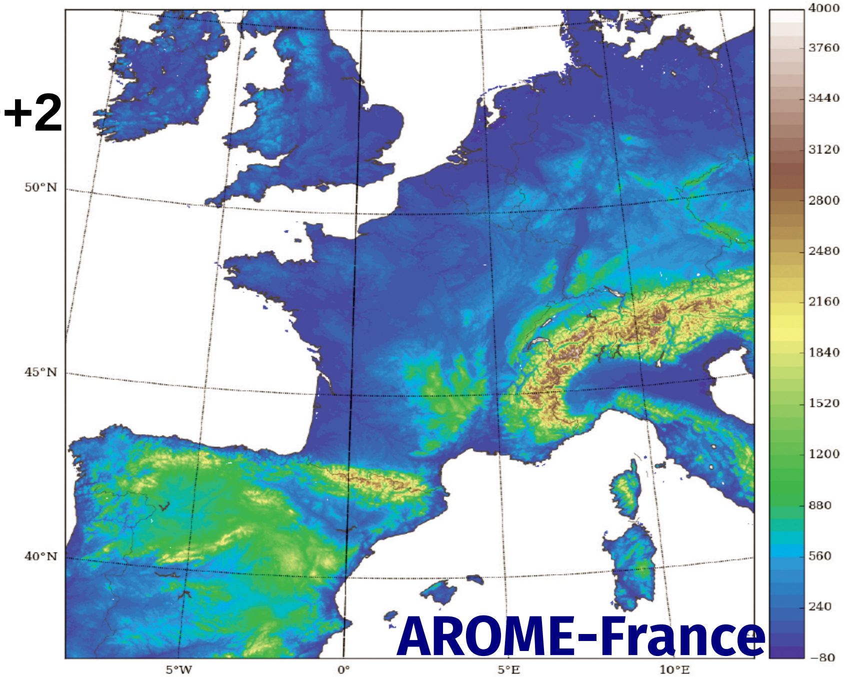

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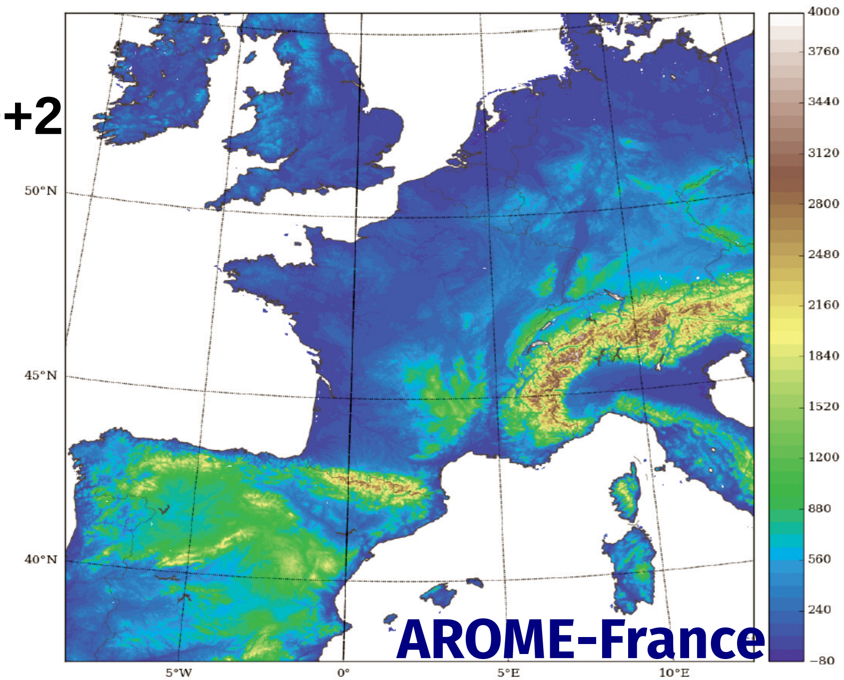

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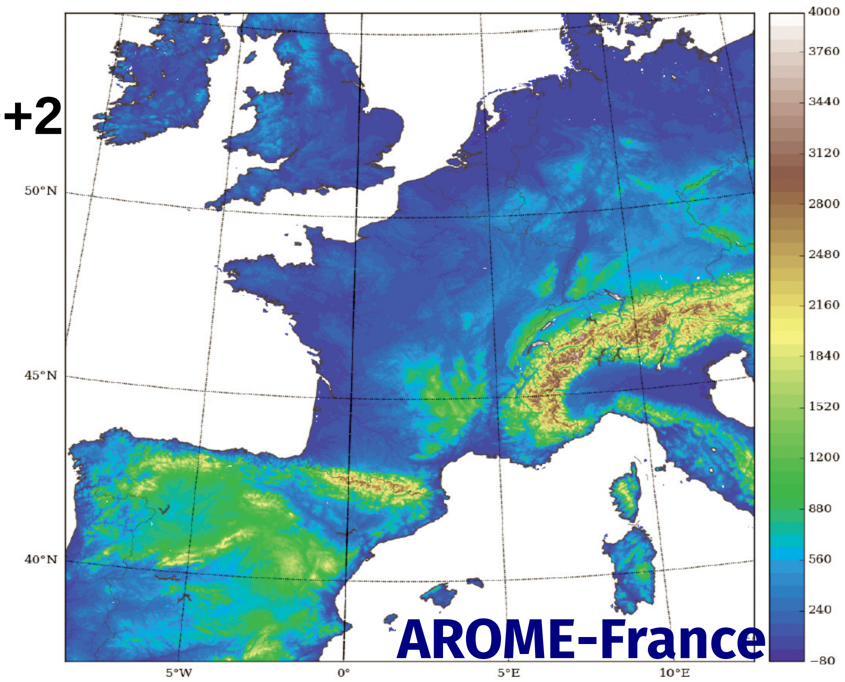

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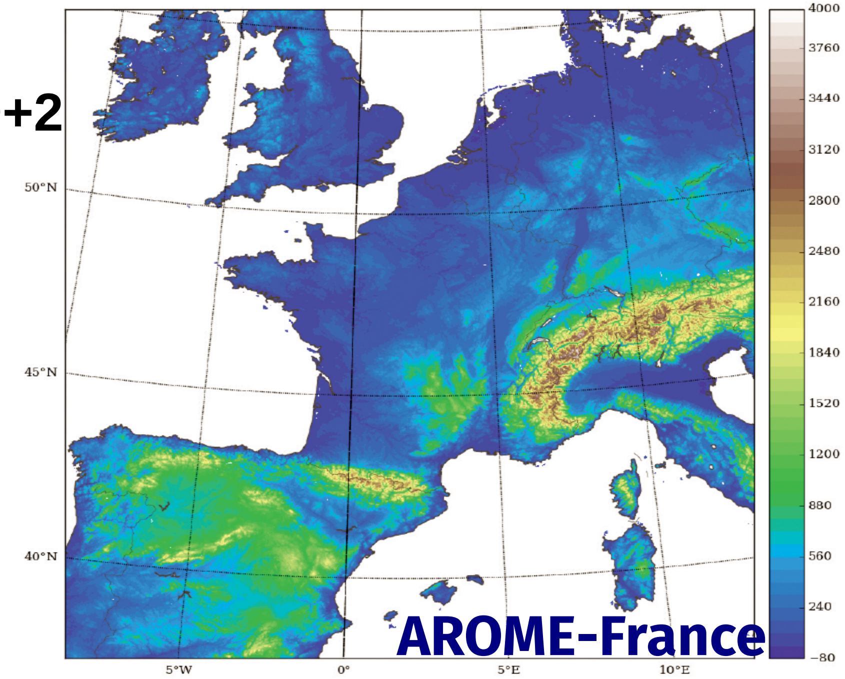
  - **Satellite observations (MW, RO, AMV, IR)**



Data assimilation in AROME

SEVIRI radiometer

- **Meteosat Second Generation (MSG)**

Data assimilation in AROME

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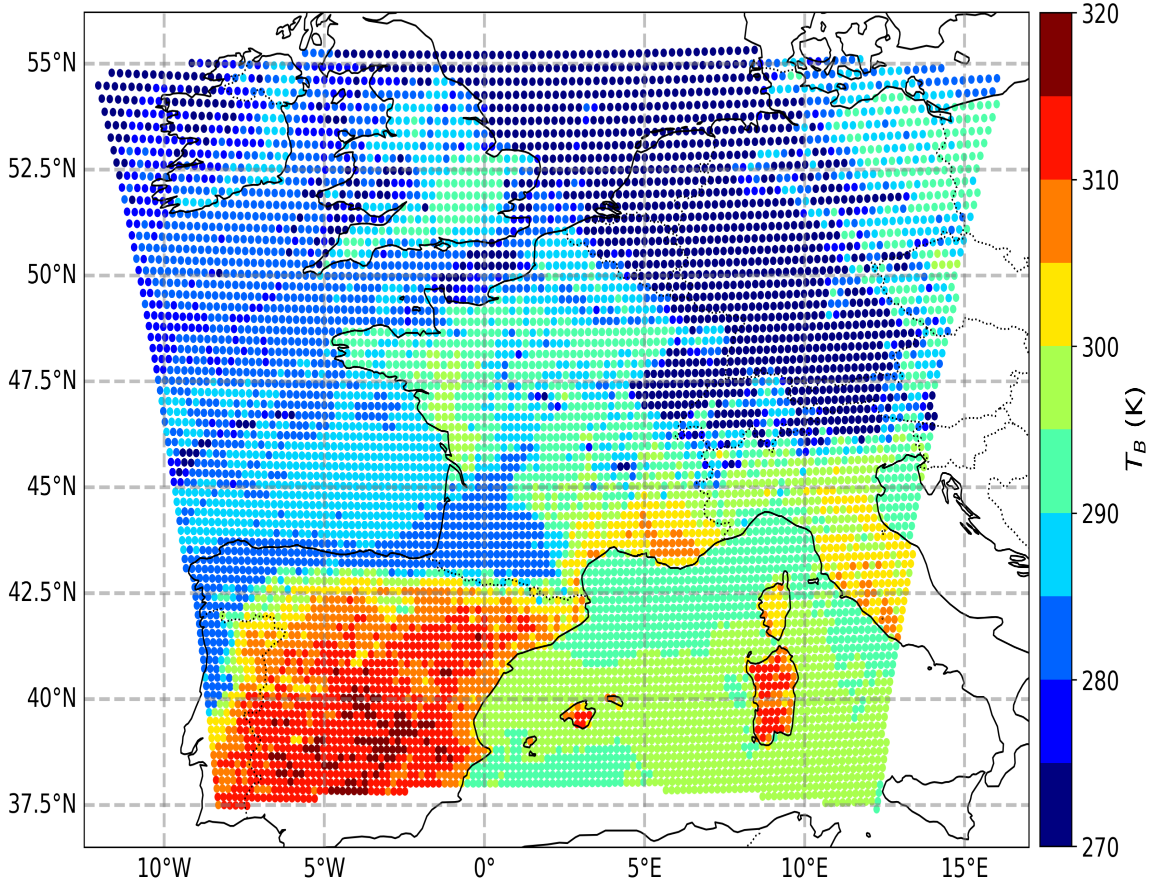
- **Temporal resolution : 15 min**
- **Temperature and humidity information**

SEVIRI observations available



2024/08/01 12h UTC – SEVIRI radiances channel 8.7 μm

Number of available observations before quality control and cloud detection : 8323

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Observations $\mathbf{y}^{\mathrm{o}}$ $\xrightarrow{\mathbf{R}^{-1}}$ **Data assimilation**

Data assimilation $\rightarrow$ **Analysis** $\mathbf{x}^{\mathrm{a}}$

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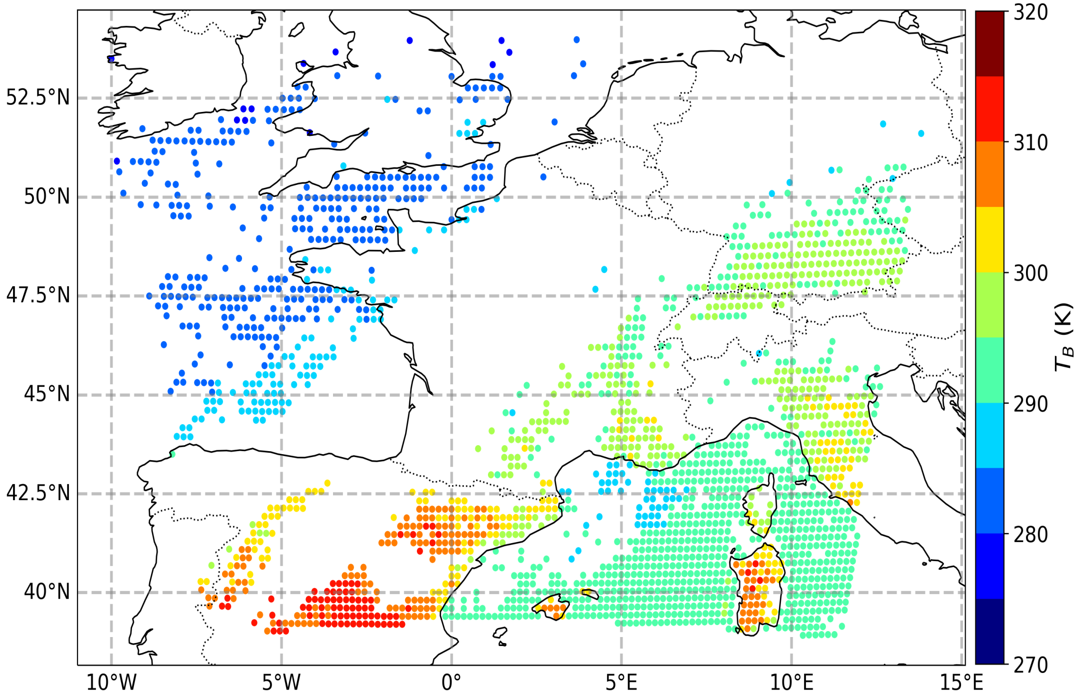
Correlations of observation errors

- **Temporal correlations** → **neglected**
- **Interchannel correlations** → **neglected for SEVIRI in AROME**
- **Horizontal correlations** → **implicit treatment (thinning & variance inflation)**

Impact of 70 km thinning in AROME for SEVIRI channel 8.7 µm

2 056 obs available



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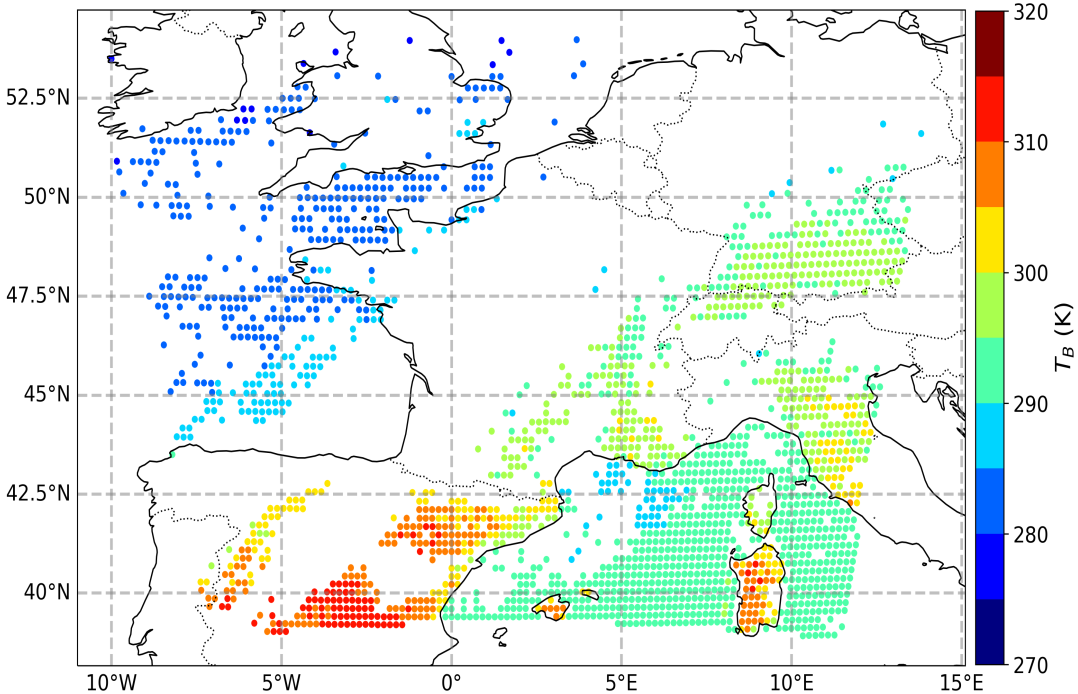
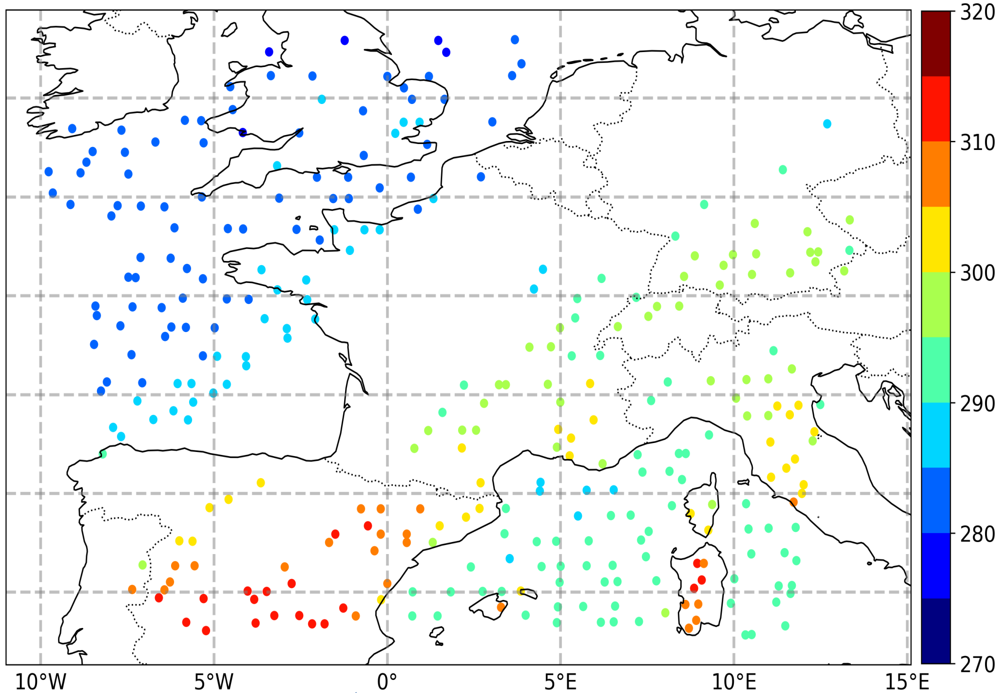
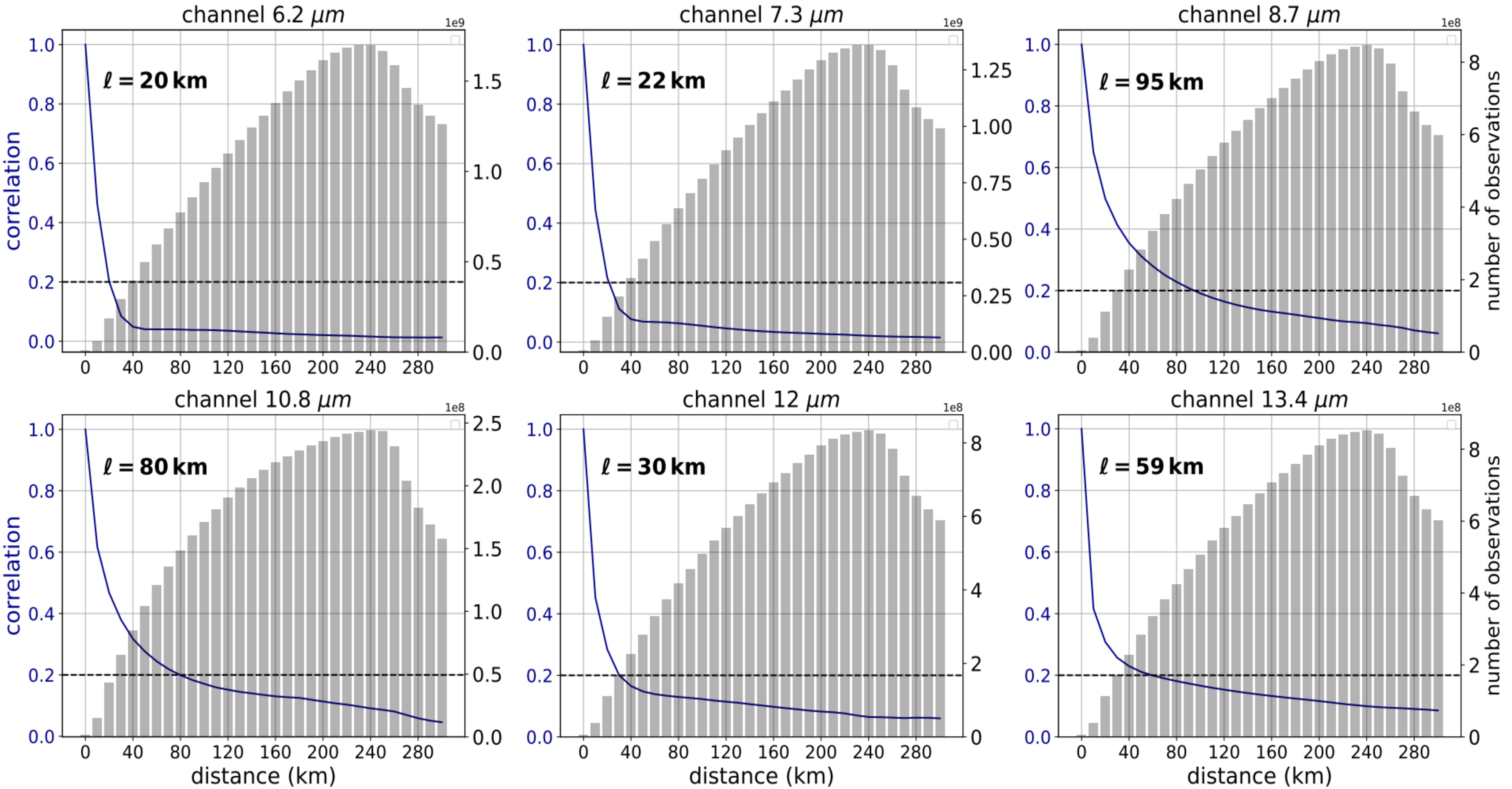


310 obs assimilated



85% of observations discarded

Horizontal correlations diagnosed for SEVIRI in AROME



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- **Large-scale matrix-vector products**
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Evaluation

- **Numerical performance (convergence of the inner loop)**
- **Quality of the analysis**

Horizontal correlations modeling

Horizontal correlations modeling

Diffusion-based method (Guillet at al. 2019)

- **Specify R^{-1} (sparse matrix)**
- **Saves computing time and memory**
- **Models only one class of correlation function**

Experimental framework

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Exponential model (Simonin et al., 2019, Hu et Dance., 2024)

- **Specify R (full matrix)**
- **More costly in computing time and memory**
- **Allows use of multiple correlation lengths**

$$\mathbf{C}_{i,j} = e^{-\frac{\Delta_{i,j}}{L_d}}$$

$\Delta_{i,j}$ **distance between 2 observations**

L_d **correlation length**

Horizontal correlations modeling

$$\mathbf{C}_{ij} = \alpha e^{-\frac{d_{i,j}}{L_1}} + (1-\alpha)e^{-\frac{d_{i,j}}{L_2}}$$

L_1, L_2	**correlation lengths**
$d_{i,j}$	**distance between observations**
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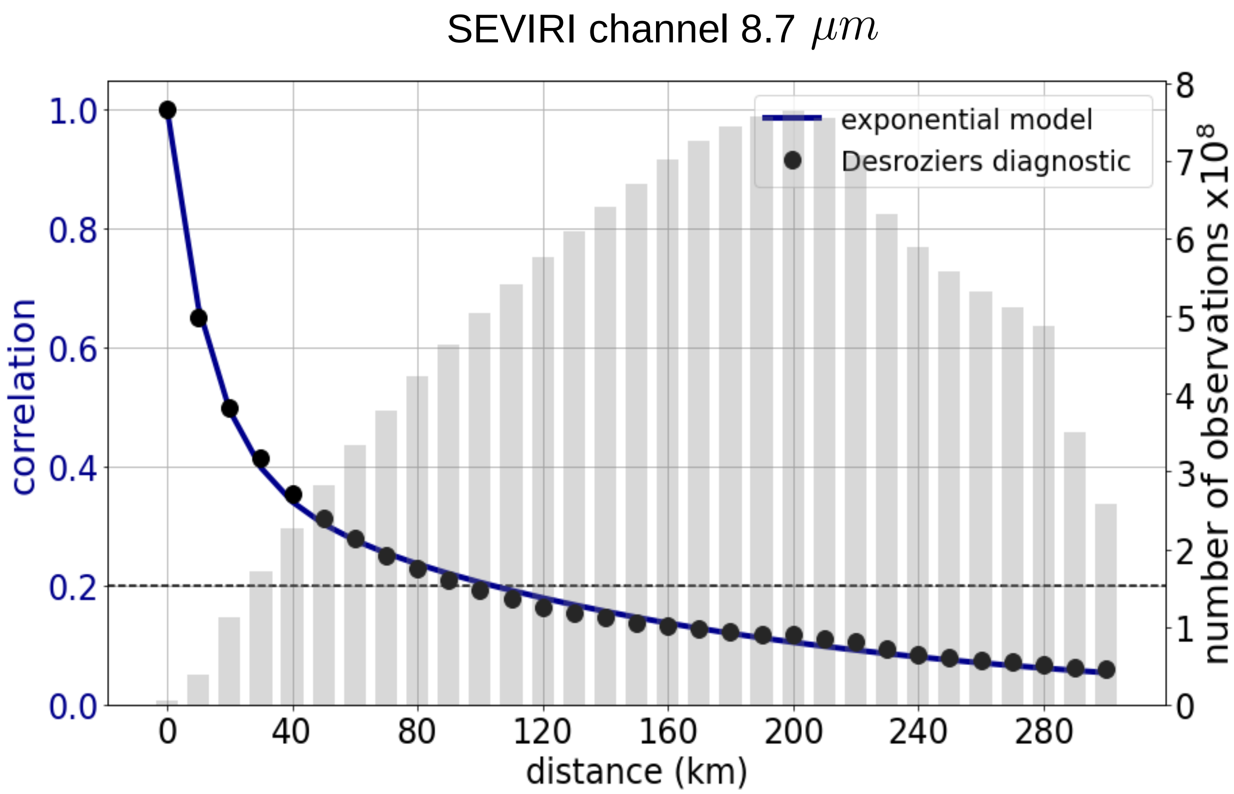

Adequate fit between modeling and diagnostic

Experimental framework

Simplified minimization environment

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- One single processor
- Reduced observations dataset
- Degraded resolution 10 km
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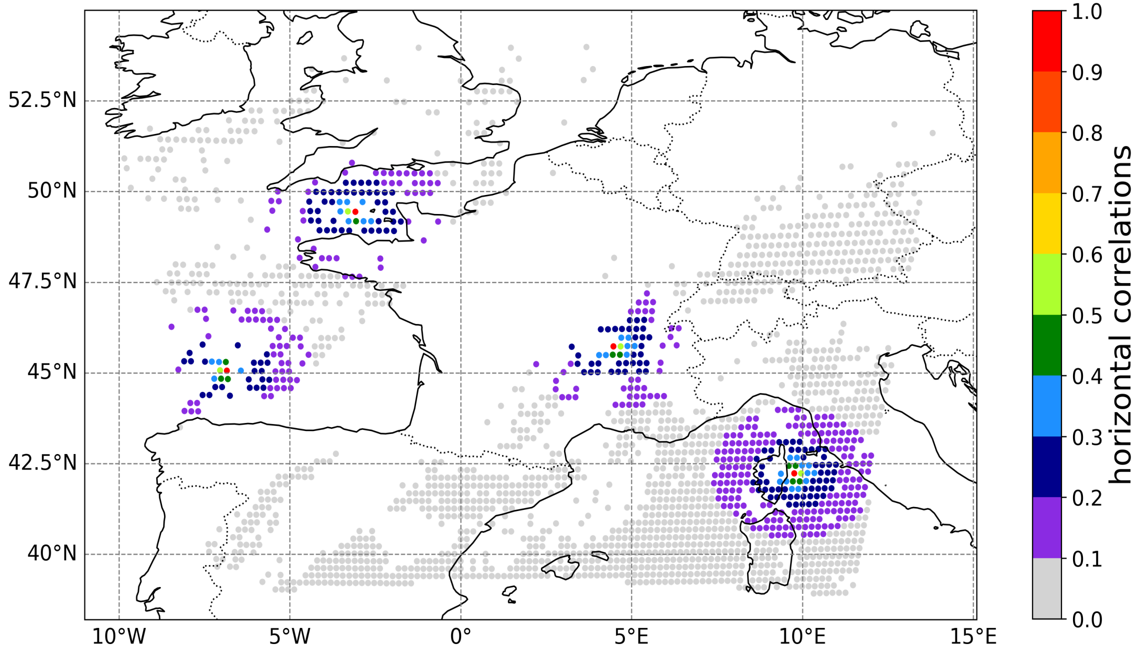

Horizontal correlation fields for SEVIRI observation errors channel 8.7μm

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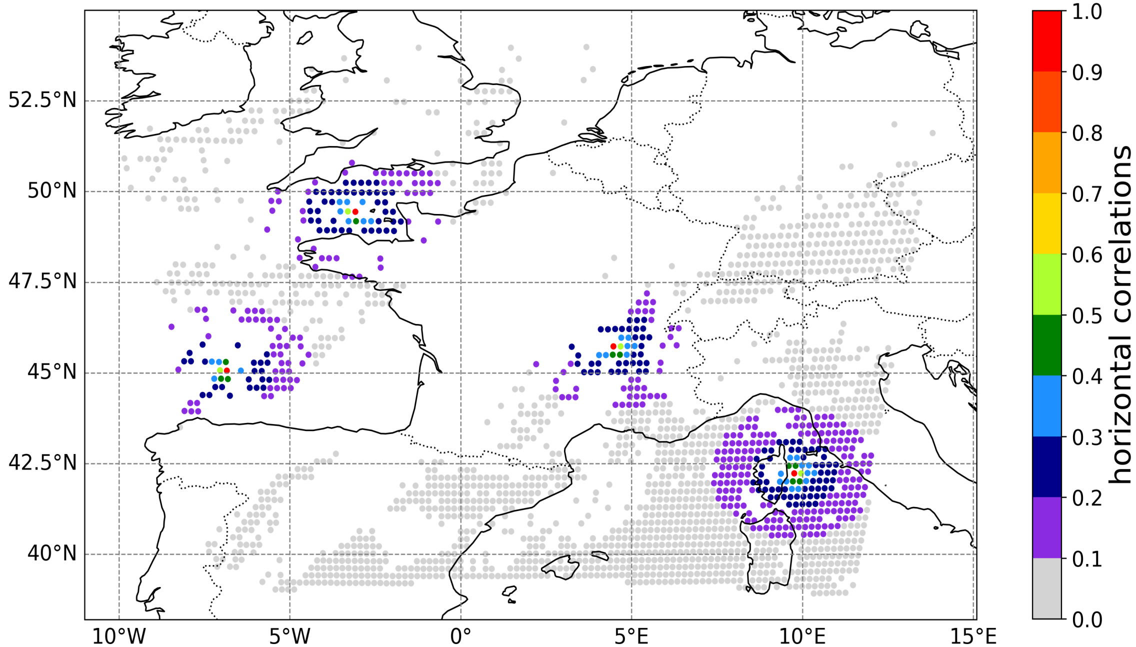

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Minimization experiments

diag_70

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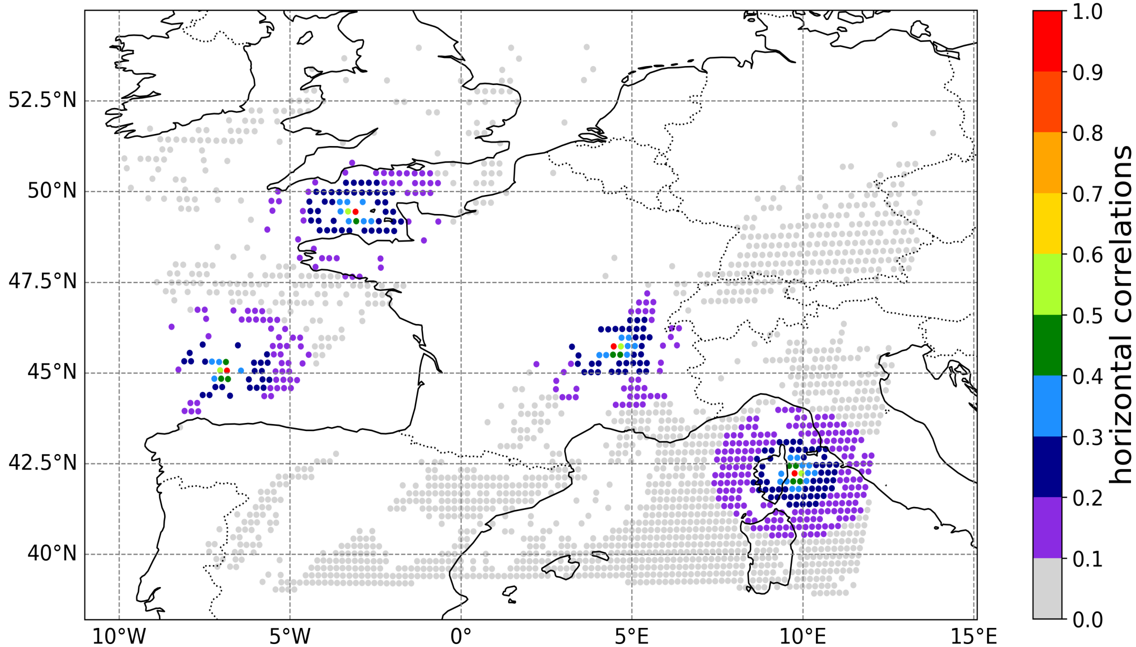

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↓ correlations

hcorr_70

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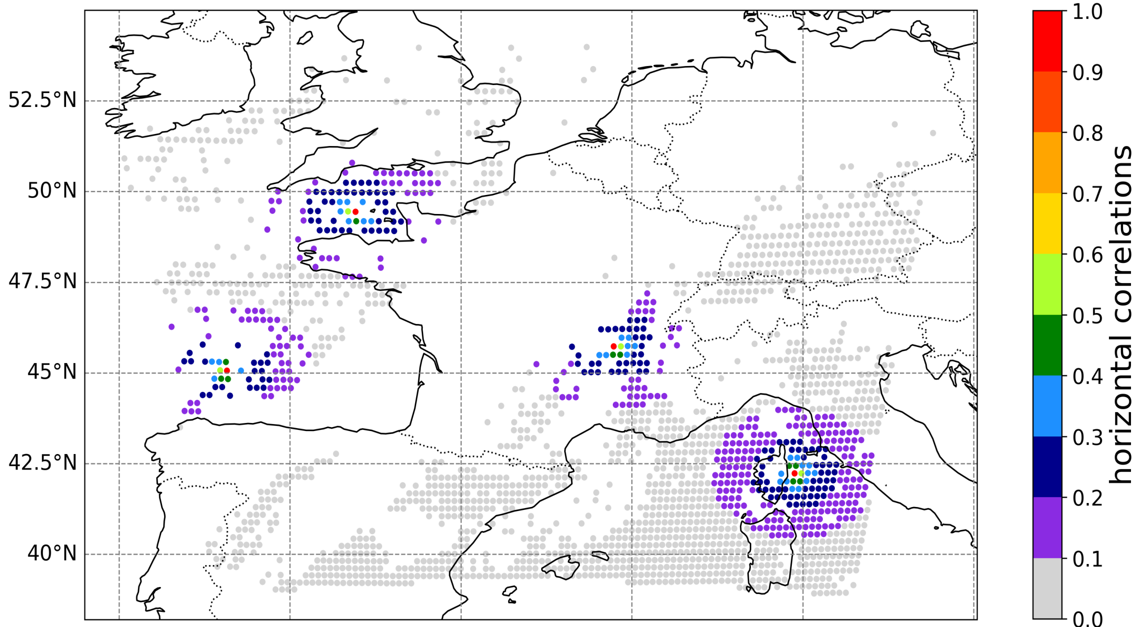

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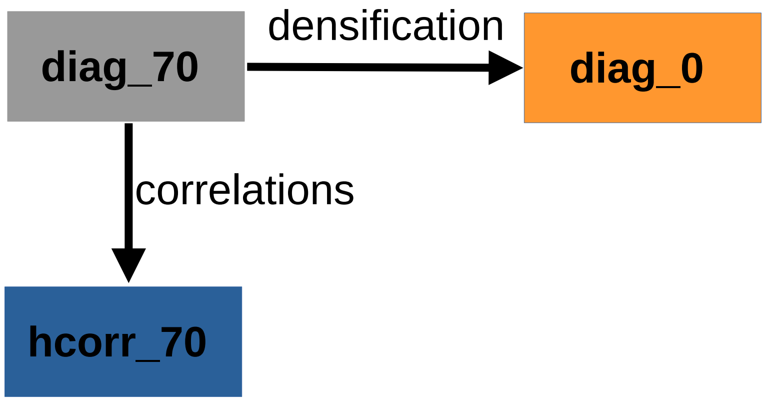

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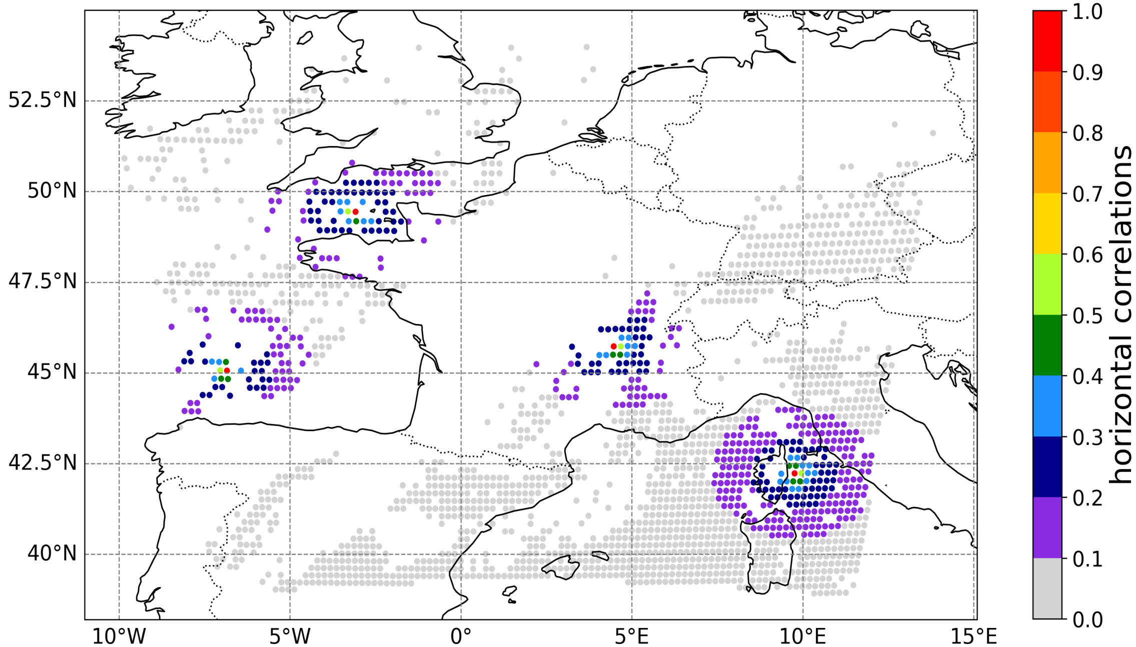

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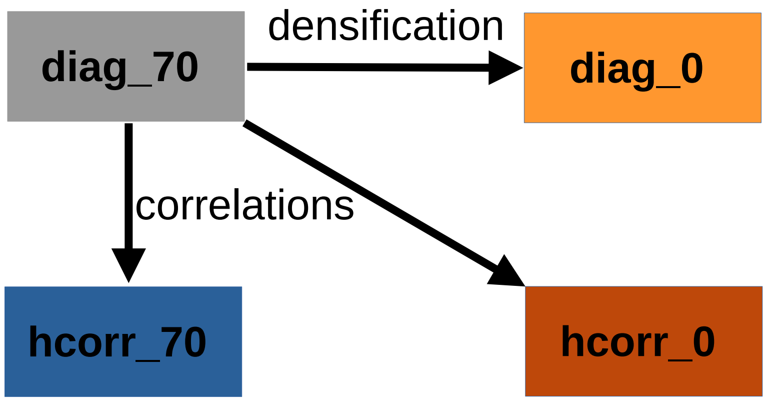

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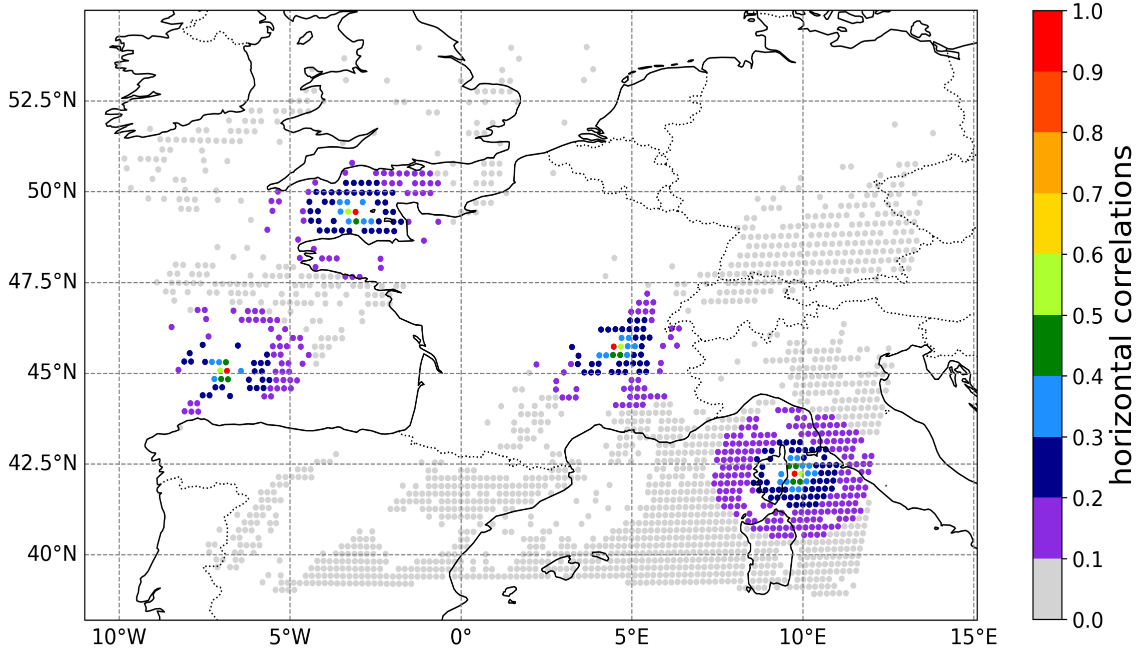

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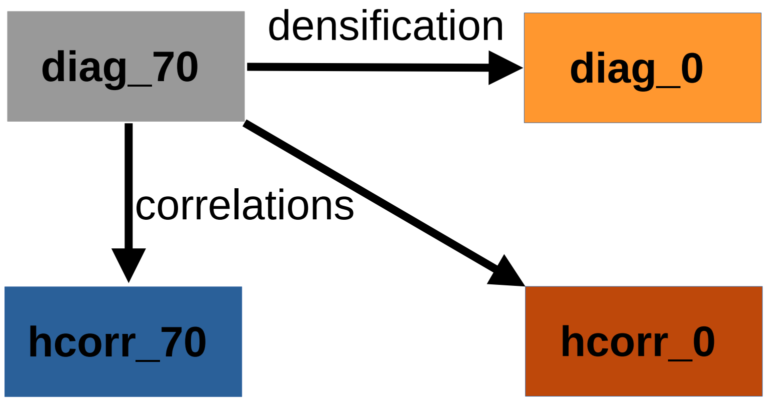
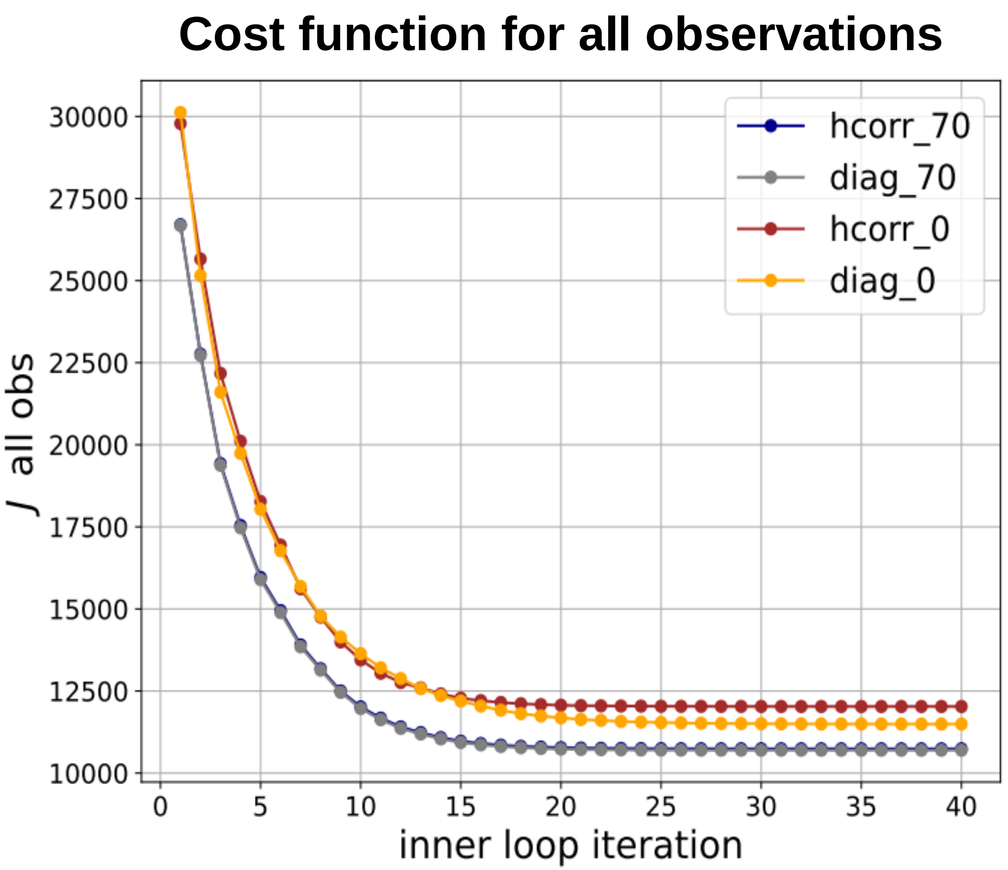


Evaluation of impact

- **Minimization algorithm (inner loop)**
- **Analysis increments**

Results

Minimization algorithm (inner loop) convergence



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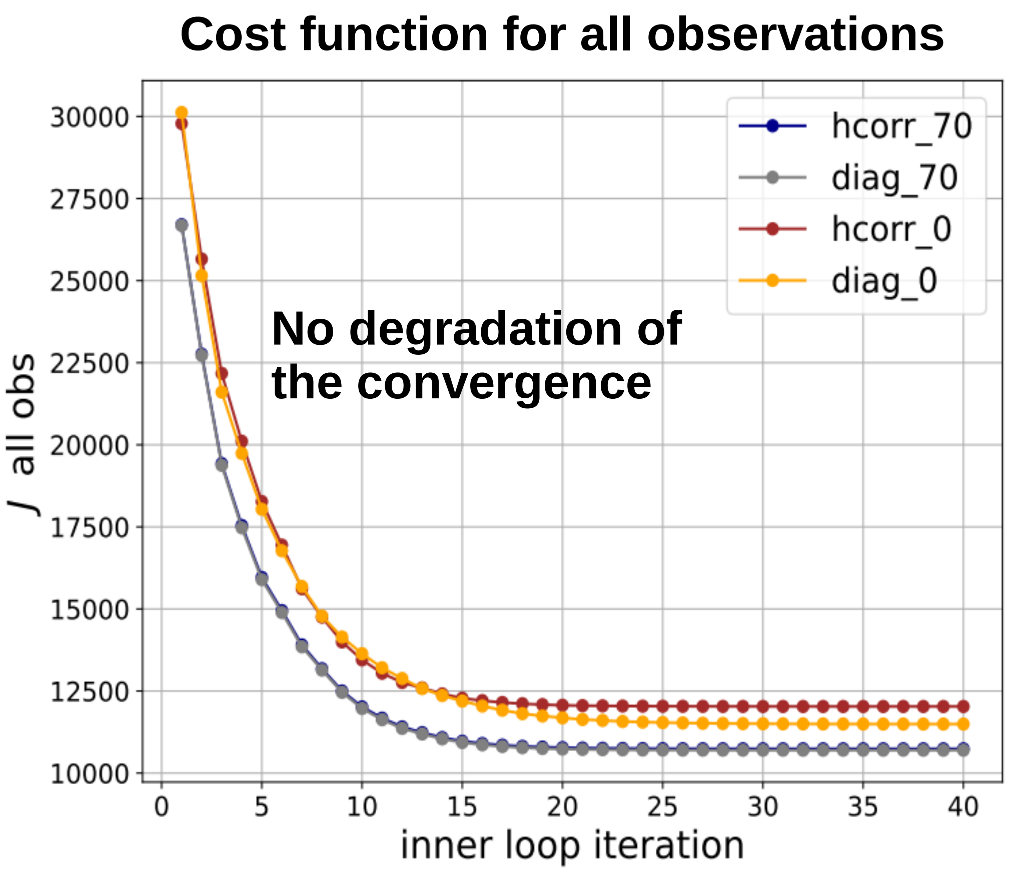
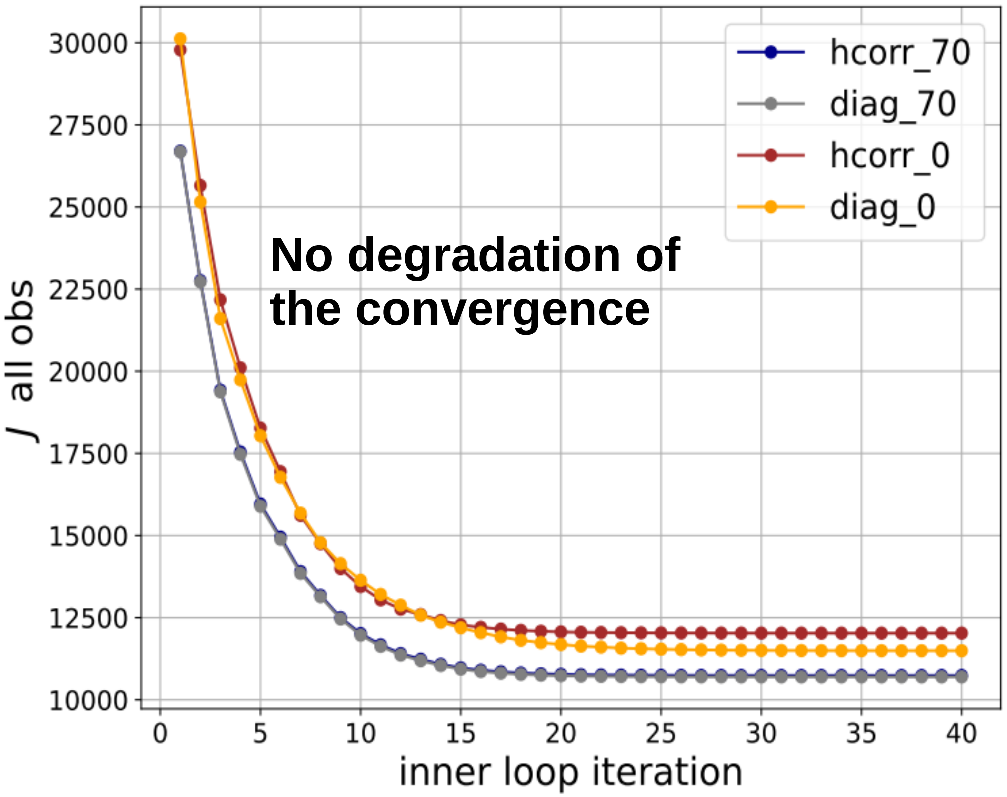
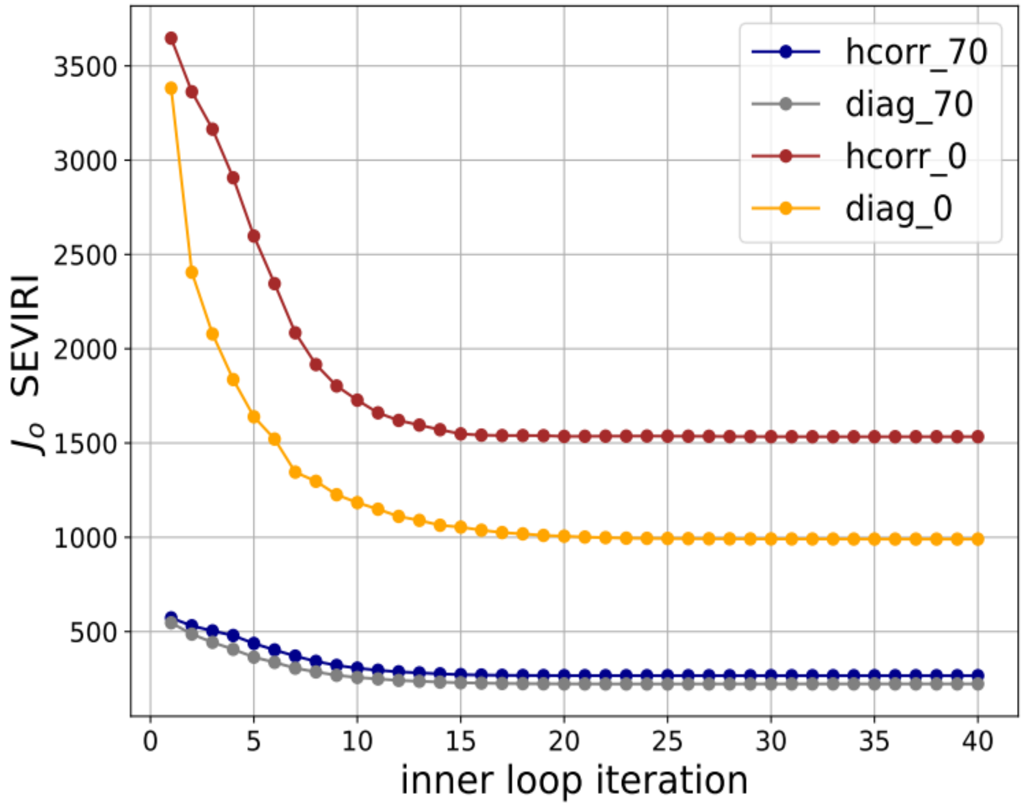


Minimization algorithm (inner loop) convergence

Cost function for all observations



Observations cost function for SEVIRI



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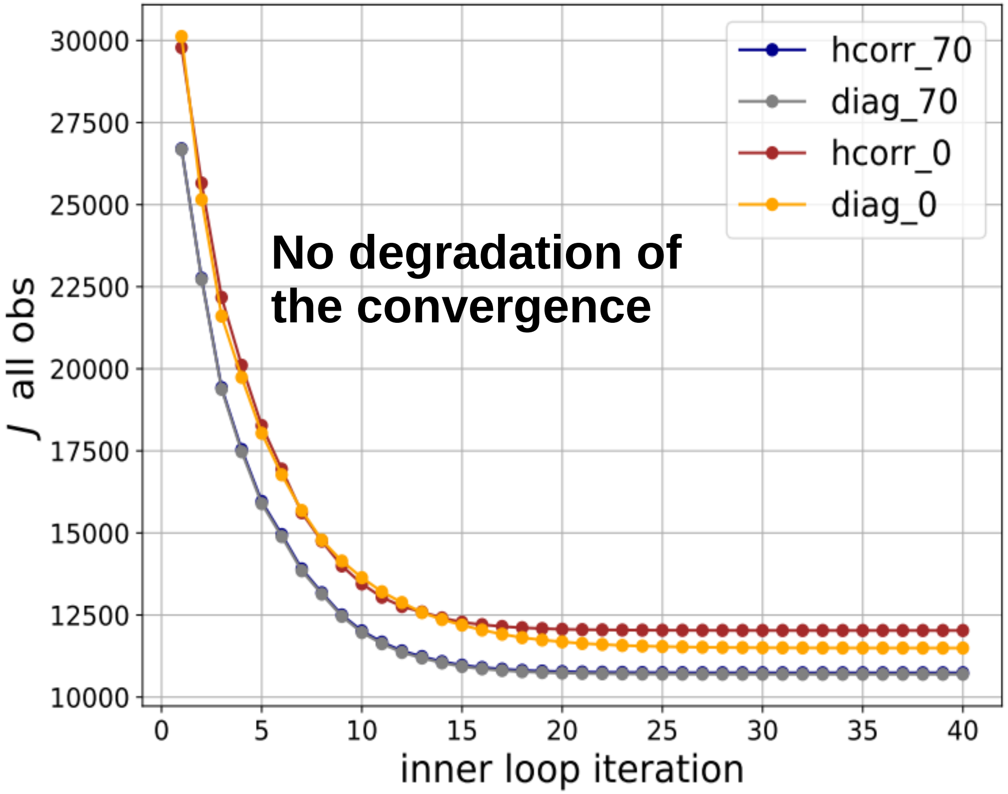

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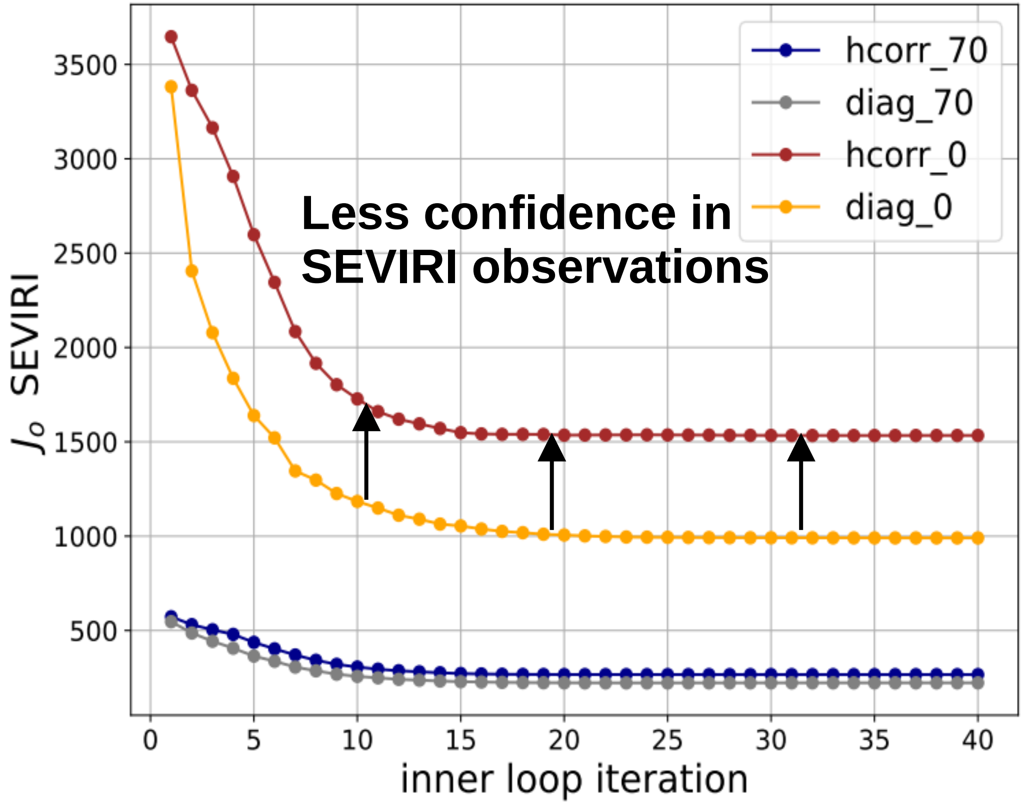
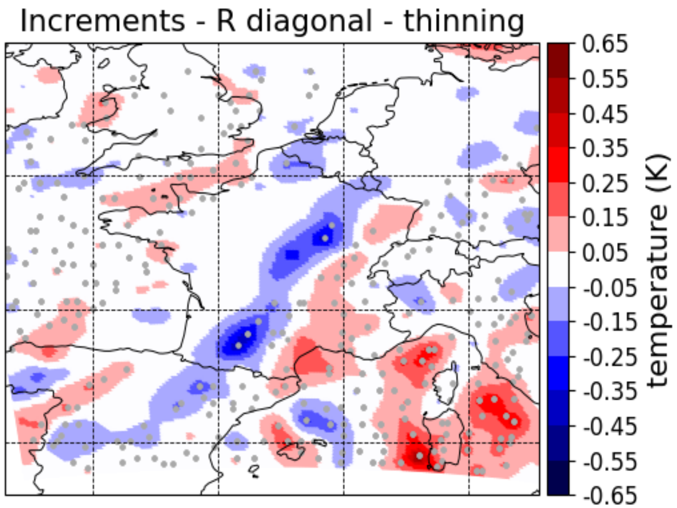


Impact of modeling correlations - thinning - temperature - 1012 hPa



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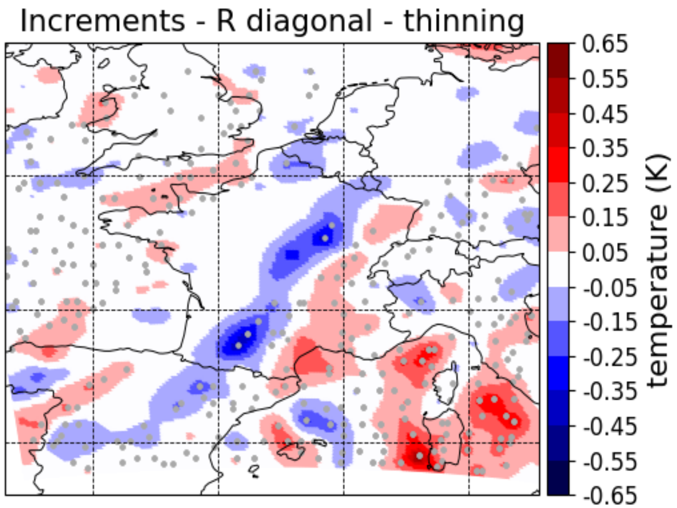
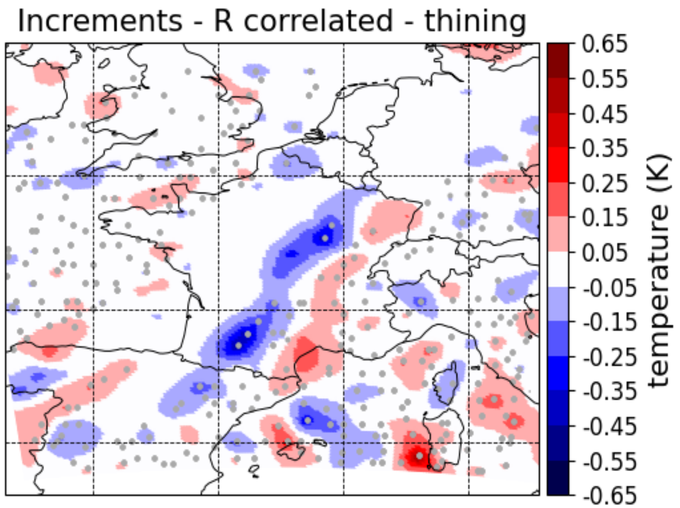


R correlated



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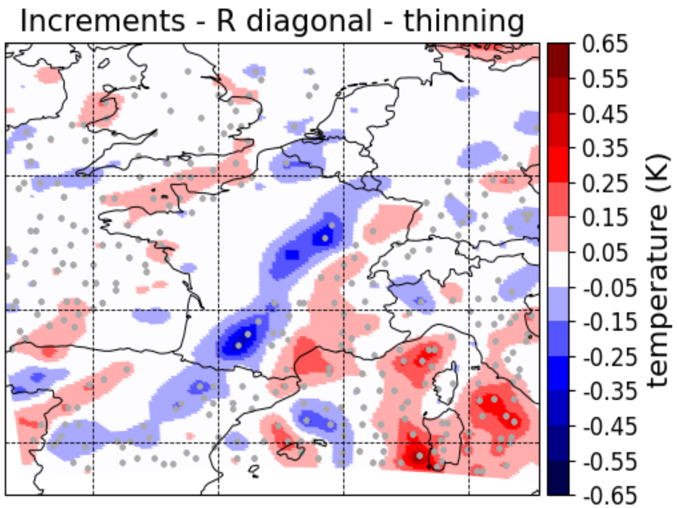

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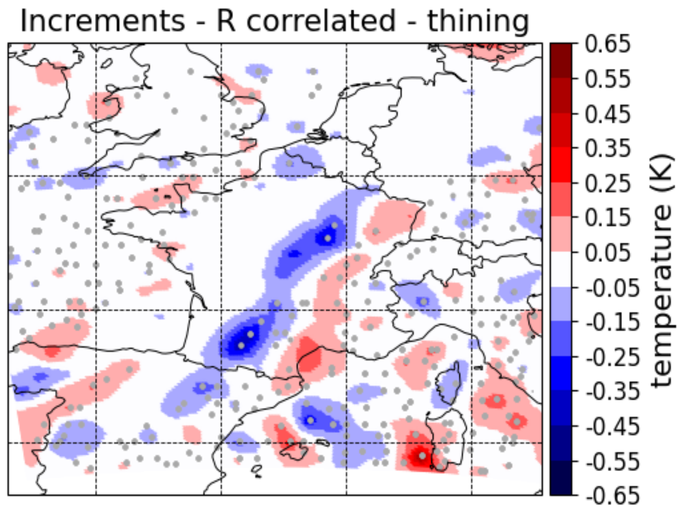

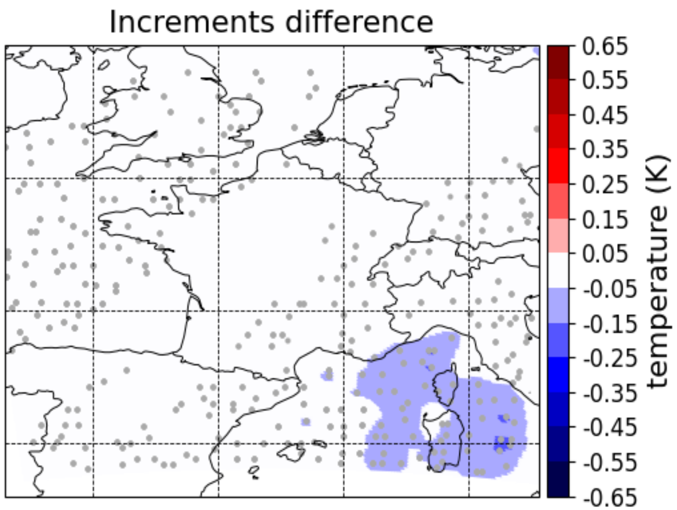

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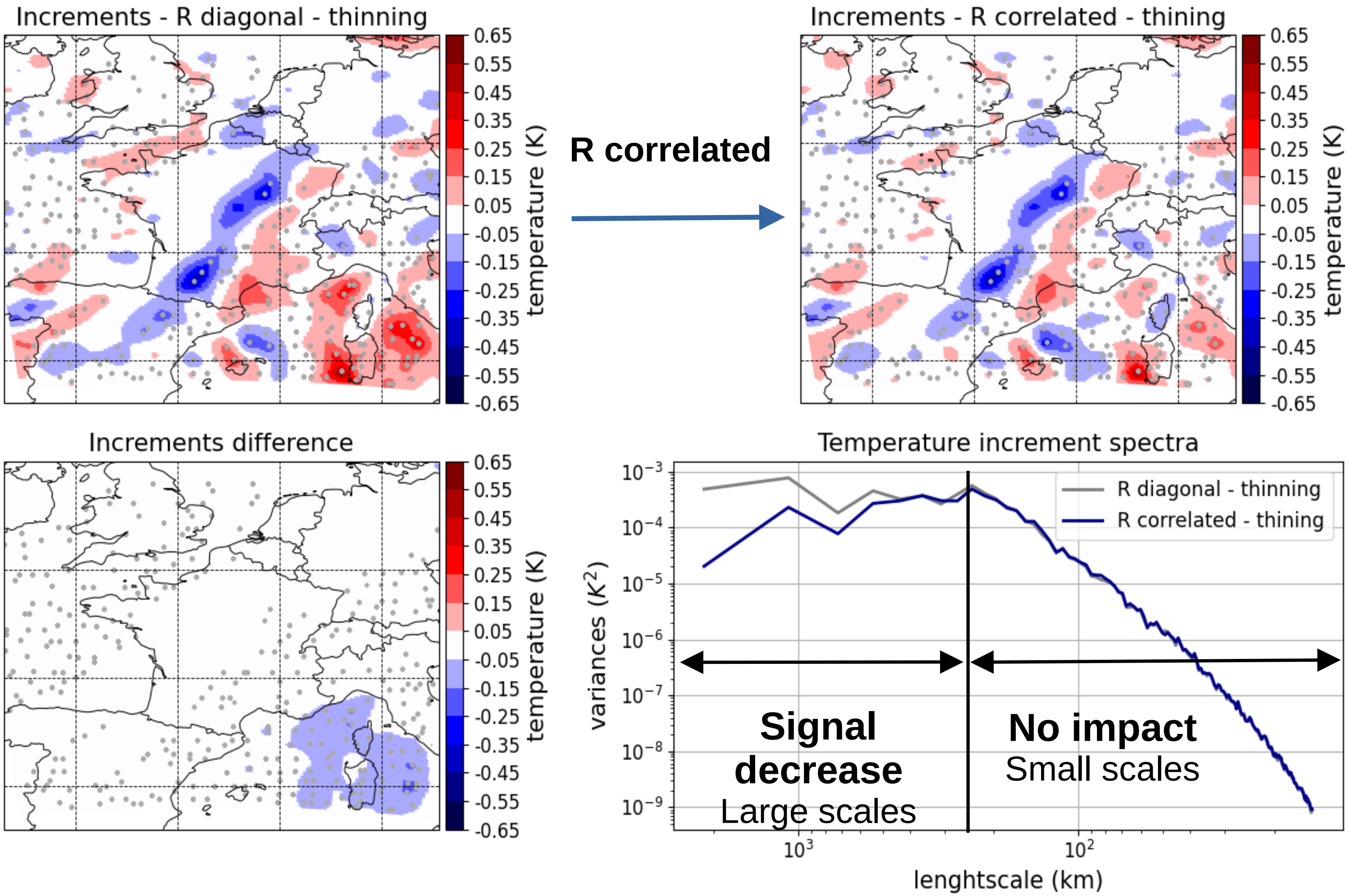

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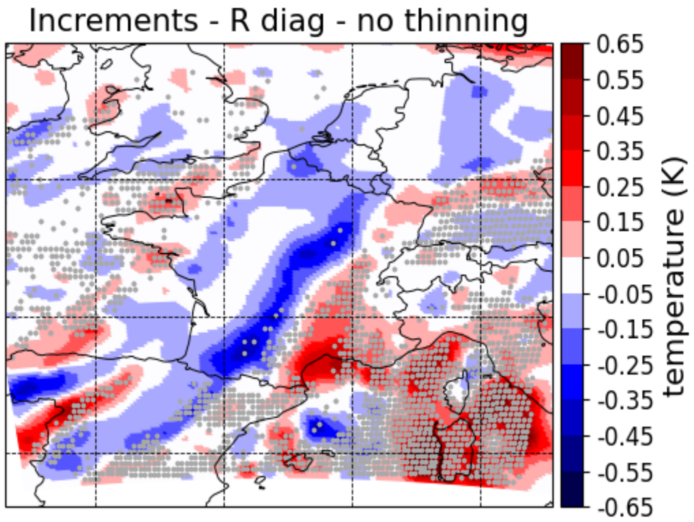

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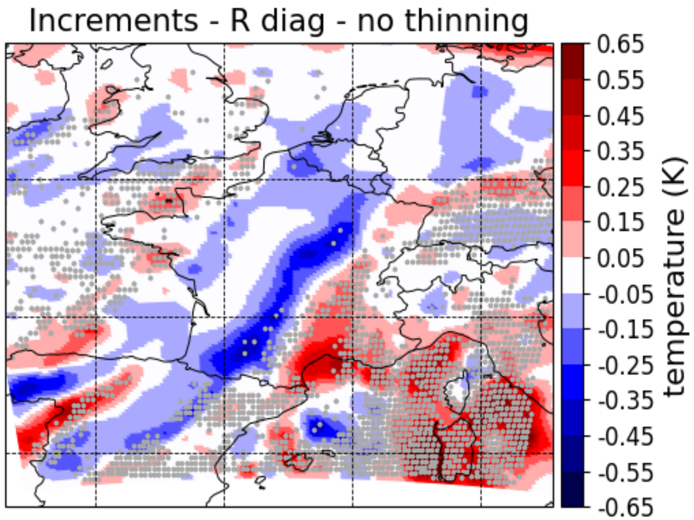

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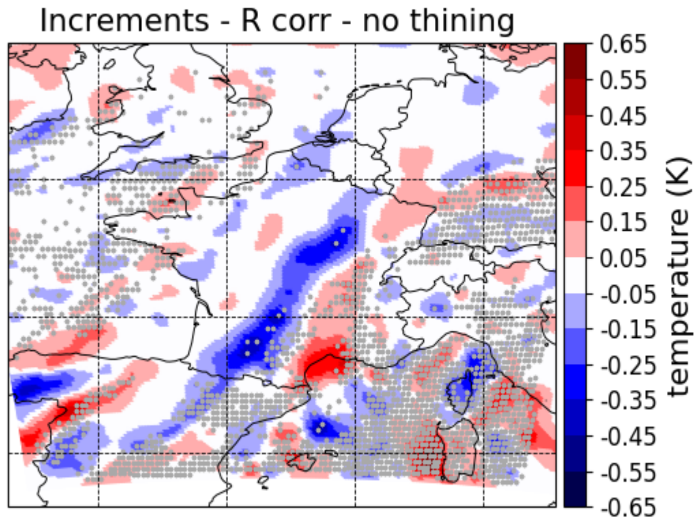

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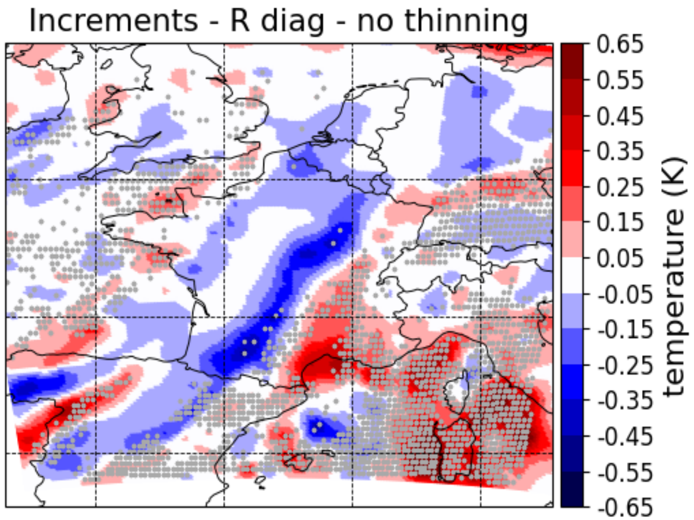

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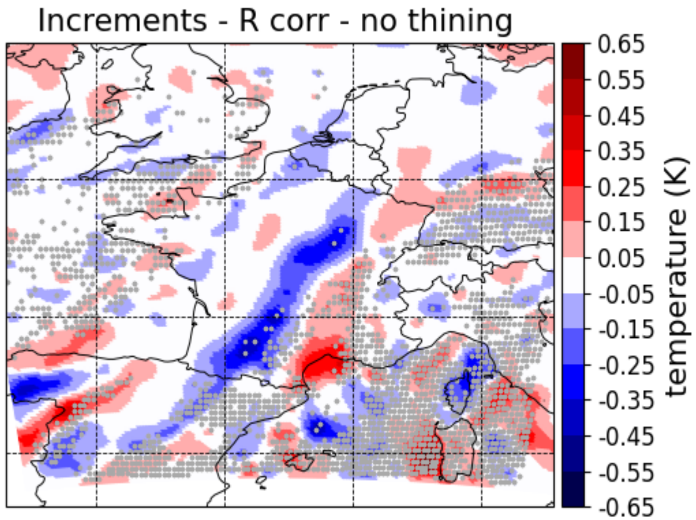

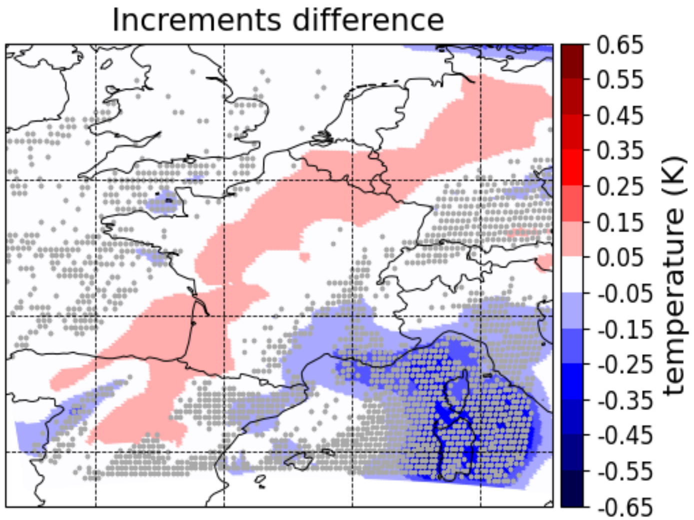

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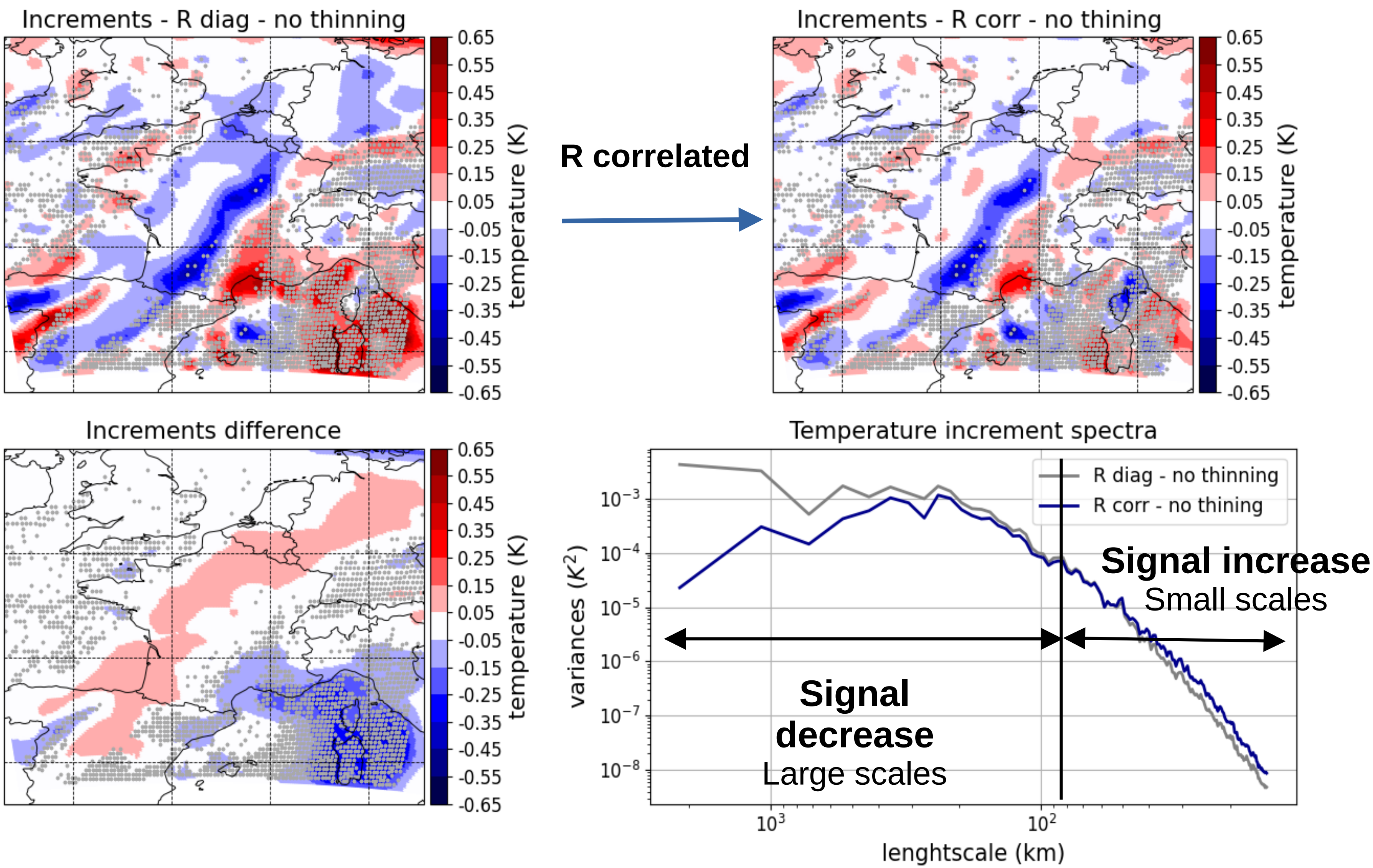
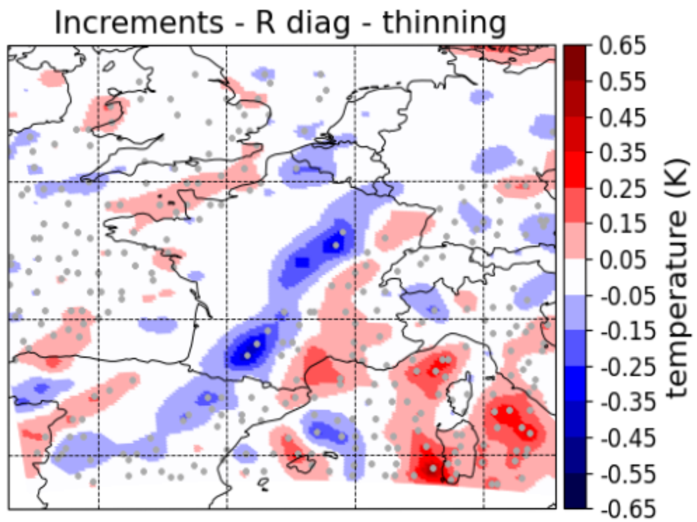


Impact of modeling correlations + thinning - temperature - 1012 hPa



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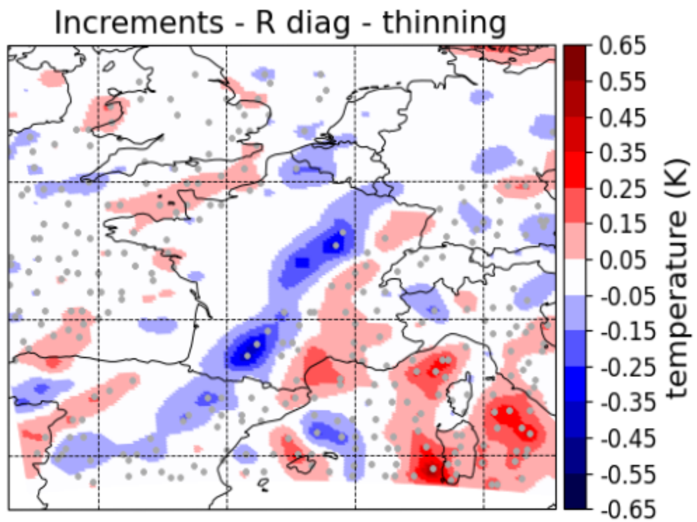

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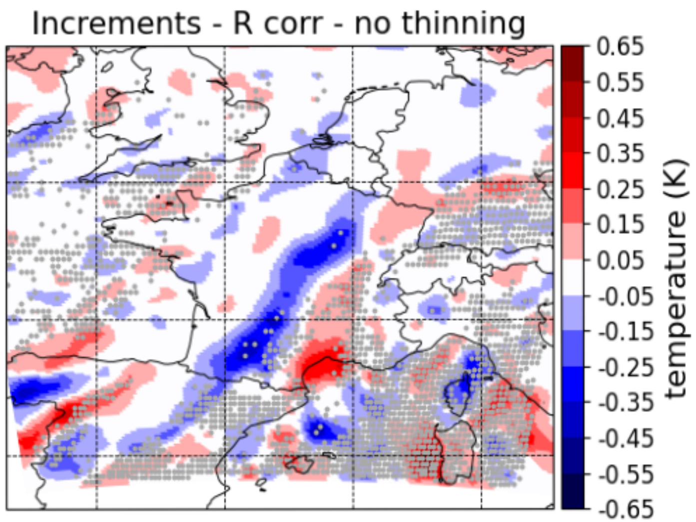
densification



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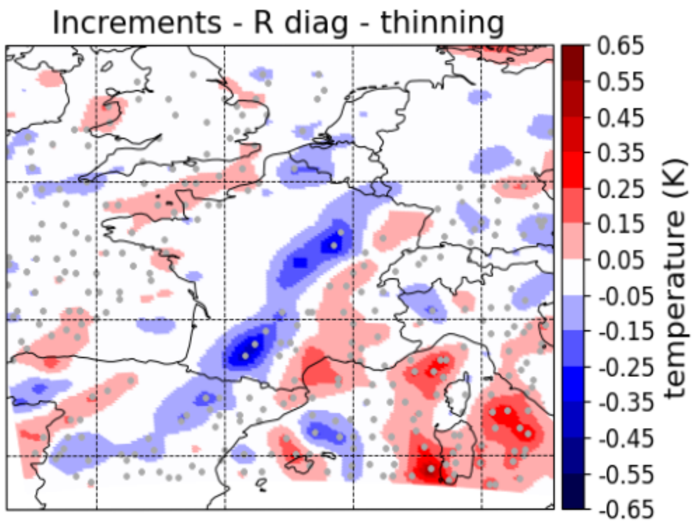

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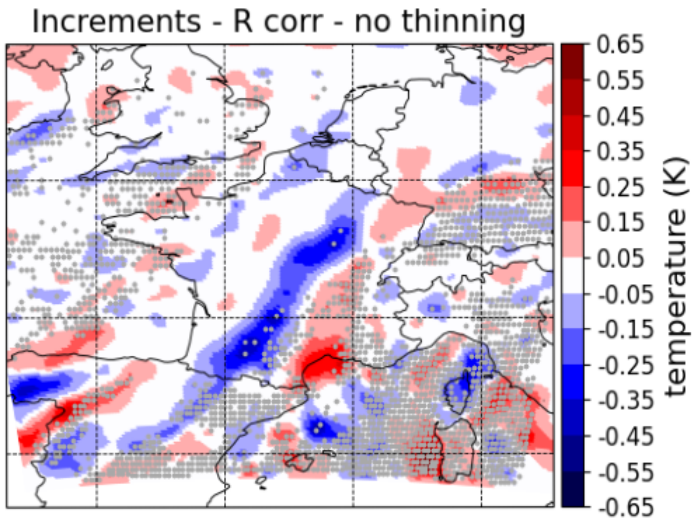
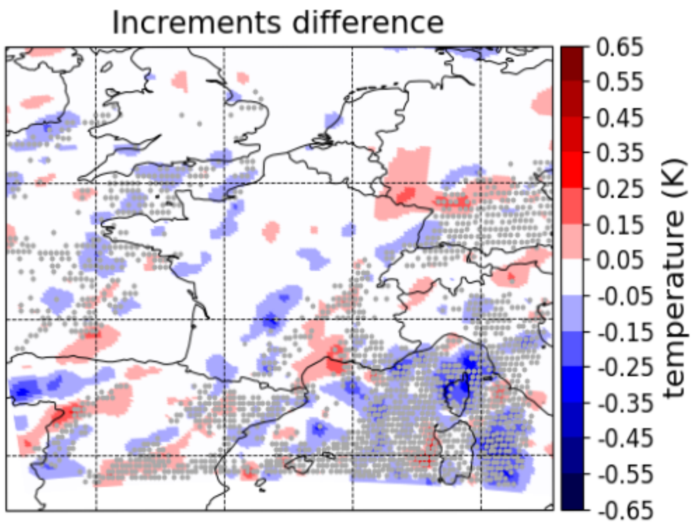
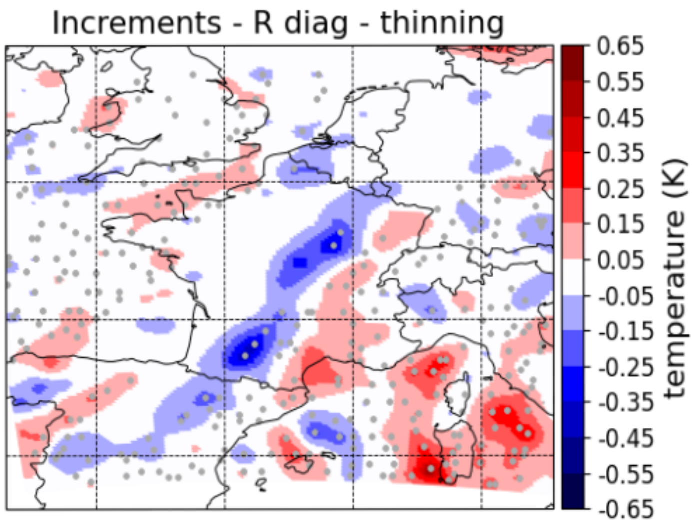


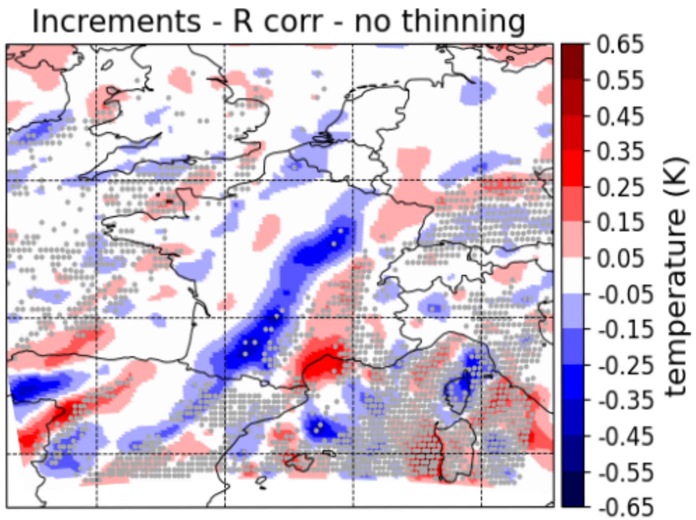


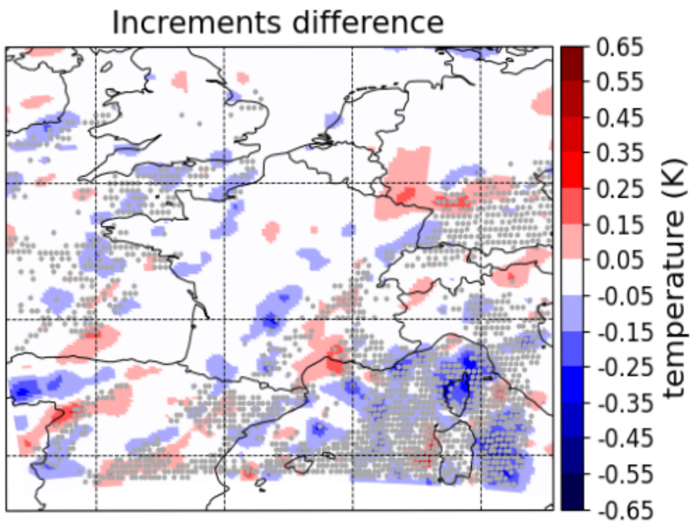
Impact of modeling correlations + thinning - temperature - 1012 hPa

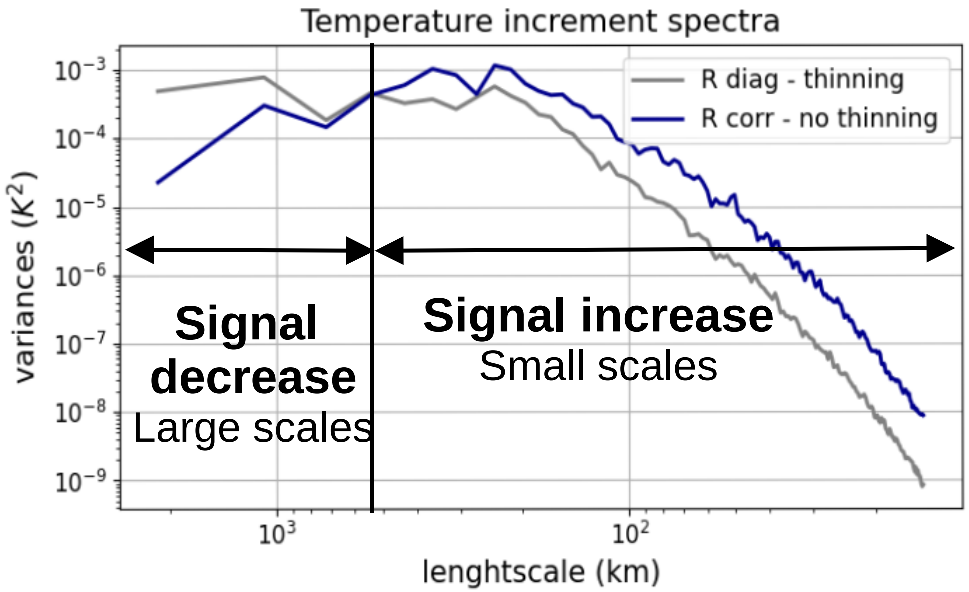


R correlated

densification







Main results with introducing horizontal correlations

Conclusion

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- **No degradation of the inner loop convergence**

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  - **small-scales signal increase**
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→ **article in progress – submission June 2025 (QJRMS)**

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- **Variances still inflated**

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→ **Assess the impact of introducing horizontal correlations in terms of forecasts scores**

End of presentation

Thank you for listening

Any questions ?