Still uncertainties in the physics at very high resolutions ?

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Outline

- Increase resolution → less problems in the physics ?

- “pseudo 3D effects” in the turbulence @ 500m and 200m in AROME

  - The TEAMx Cold pool case

- Experiment with AROME-500 during MOSAI Dec2023

Less problems or uncertainties in the physics ?

- Below ~1km shallow convection is partially resolved (Honnert et al. 2011)
→ Mass flux (shallow) parametrization should be less active → scale aware scheme = automatic tuning with the effective resolution and/or updraft velocity ?

- at 200m/100m we can expect to switch-off the shallow scheme → less problem ?
  - only turbulence mainly based on a 1.5 closure (TKE scheme), Radiation scheme and micro-physics
  - No problems in dynamics/horizontal diffusion at 100/200m ? especially in complex terrain ?

Less problems or uncertainties in the physics at 100/200 m ?

- For the TKE scheme:
  - Several ways to compute mixing length, uncertainties for the dissipation length (Ldiss=Lm by default in many schemes)
  - TKE strongly depend on Lm computation
- 3D effects
  - Pseudo 3D effects in the TKE with Goger et al. 2018 or Goecke et Machulskaya (2021) → Need to estimate Lh
  - A real full 3D scheme ?
  - 3D effect in the radiation available in EcRad with Spartacus ?

- Micro-physics: Ice3 (1-moment scheme), LIMA (2-moments) many tuning parameters such as auto-conversion, ice/liquid partition … etc

Less problems or uncertainties in the physics at 100/200 m ?

- Surface with more complex scheme, input data at high resolution for surface characteristics → more parameters and prognostic variables → more spatial variability → more local circulation → 3D effects ?

- Vertical levels and height of the first level → very important for fog and stable boundary layer

TKE scheme used in ARPEGE/AROME : Cuxart et al. (2000)

- Same scheme in AROME and in ARPEGE but not the same code !
- Since the beginning of AROME in 2008 and since Since February 2009 in ARPEGE.

$$\frac{\partial e_T}{\partial t} = advec - \left(\overline{u'w'}\frac{\partial u}{\partial z} + \overline{v'w'}\frac{\partial v}{\partial z}\right) + \beta\left(\overline{w'\theta'}\right) - \frac{1}{\rho}\cdot\frac{\partial \overline{\rho w' e_T'}}{\partial z} - c_\varepsilon \cdot \frac{\bar{e}_T^{3/2}}{l}$$

Impact of a « pseudo 3d effect » in AROME

Since cy48t2 horizontal gradients are available in the AROME physics (Honnert and El Khatib (2020))

For complex terrain: Goger et al. (2018) suggest an additional source term for the TKE

$$\left.\frac{\partial \overline{e}}{\partial t}\right|_{\text{shear}} = (C_s \Delta x)^2 \left[\left(\frac{\partial \overline{u}}{\partial x}\right)^2 + \left(\frac{\partial \overline{v}}{\partial y}\right)^2 + \frac{1}{2}\left(\frac{\partial \overline{u}}{\partial y} + \frac{\partial \overline{v}}{\partial x}\right)^2 \right]^{\frac{3}{2}}$$

where C_s is chosen to be the Smagorinsky constant. Cs=0.2

Preliminary results showed during the ACCORD ASM (March 2023) :

- Very small impact of this additional term even at 500m over the Alps
- The horizontal component of the TKE dynamical production is only 5-8% of the total

Horizontal mixing length :

$$L^{(1)}_{\text{smag}} = c_{\text{smag}} \sqrt{\Delta x \cos\alpha_x \, \Delta y \cos\alpha_y}$$

$$\alpha_x = \arctan \frac{\partial z_S}{\partial x} \qquad \alpha_y = \arctan \frac{\partial z_S}{\partial y}$$

Modified Smagorinsky (1963) with the slope

$$L_{\text{W}} = \left(\frac{\Delta_0}{\sqrt{\Delta x \Delta y}} \right)^{\alpha} \frac{\sqrt{U^2 + V^2}}{\left[(\partial_x V)^2 + (\partial_y U)^2 \right]^{1/4} \left[(\partial_x U)^2 + (\partial_y V)^2 \right]^{1/4}}$$

Wang et al. (2021)

$\alpha = 1.5$ et $\Delta_0 = 500\text{m}$

$$L^{(0)}_{\text{W}} = \min \left[L_{\text{W}}, L^{(0)}_{\text{smag}} \right]$$

$$L^{(1)}_{\text{W}} = \min \left[L_{\text{W}}, L^{(1)}_{\text{smag}} \right]$$

From Leo Rogel, F. Voitus

Pseudo horizontal dyn. prod derived from TKE (Cuxart et al. 2000)

$$P_d^h = L_H^2 \sqrt{C_{mh}^3 / C_\varepsilon} \left(\sqrt{\mathrm{DEF}^2 + C_1^2 \mathrm{DIV}^2} - C_1 \mathrm{DIV} \right)^3$$

Also used in ICON
Goecke and Mashulskaya 2021

$$\mathrm{DIV} = \frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} \qquad \mathrm{DEF}^2 = \mathrm{DST}^2 + \mathrm{DSH}^2$$

$$\mathrm{DST} = \frac{\partial U}{\partial x} - \frac{\partial V}{\partial y}$$

$$\mathrm{DSH} = \frac{\partial V}{\partial x} + \frac{\partial U}{\partial y}$$

$$C_1 = \frac{1}{2\sqrt{C_{mh} C_\varepsilon}},$$

$$C_{mh} = \frac{C_h}{C_{pv}}$$

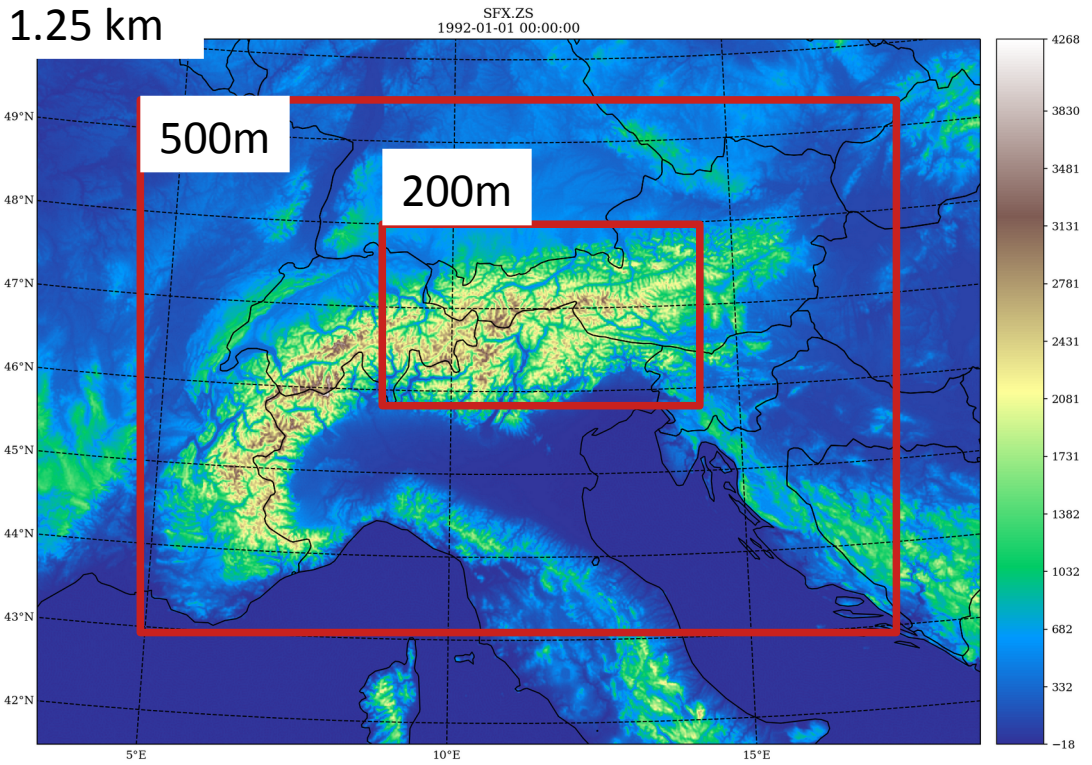
From Leo Rogel, F. Voitus

For Lh Wang et al. (2021) or following Deardorff (1980) idea ?

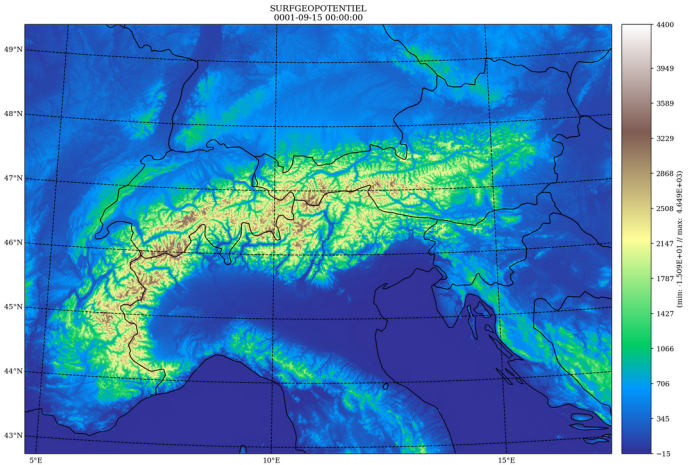
$$L_H = \min\left(0.76 \frac{e^{1/2}}{N}, (\Delta x \Delta y)^{1/2} \right)$$

Domains for TEAMx and the Cold pool case

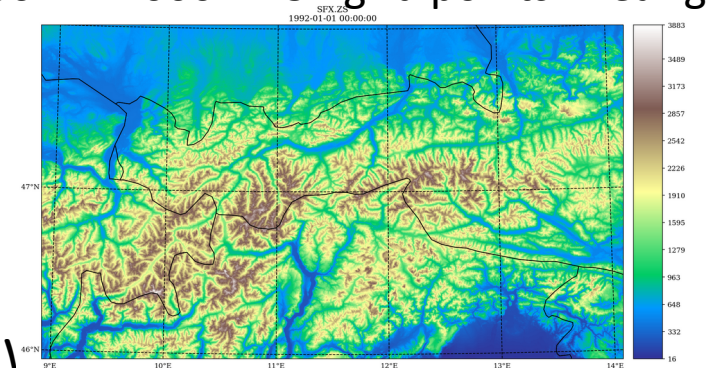
1.25 km



500 m : 2037x1489 grid points



200 m : 2000x1152 grid points linear grid



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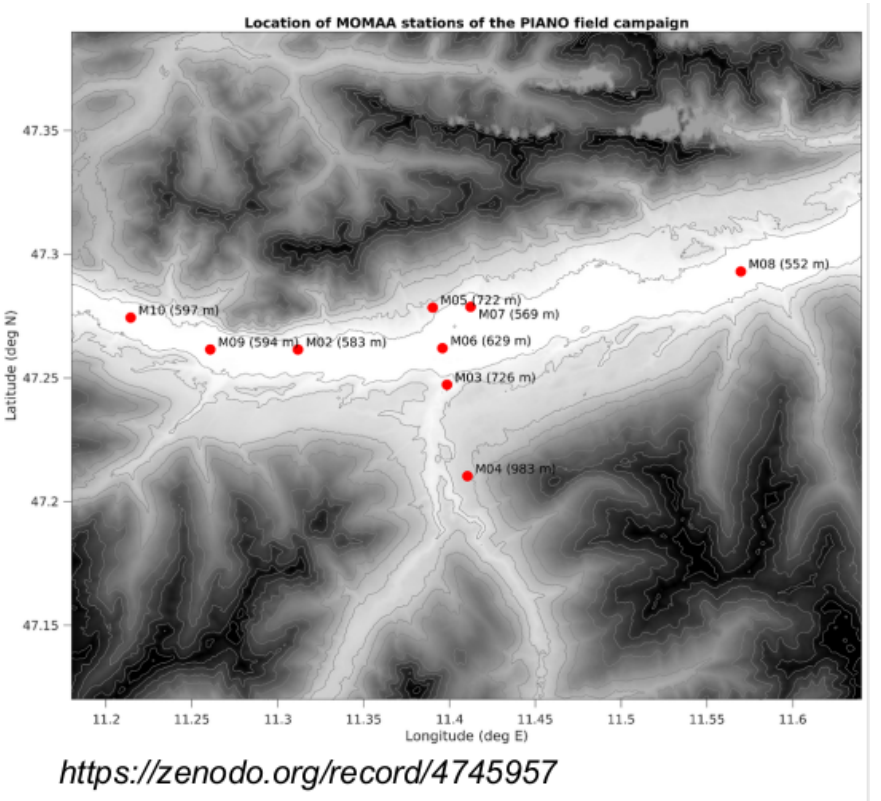
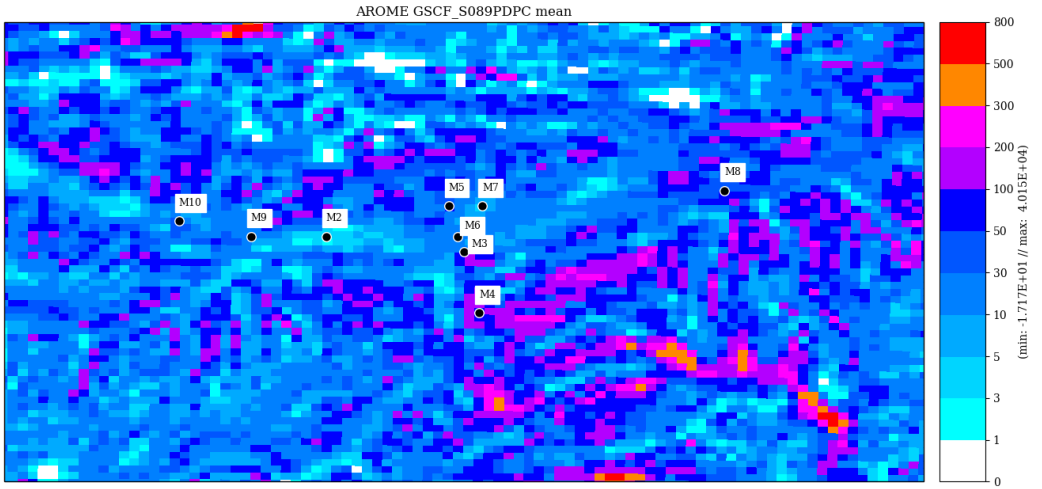
PIANO measurement : 9 stations and 1 RS per day

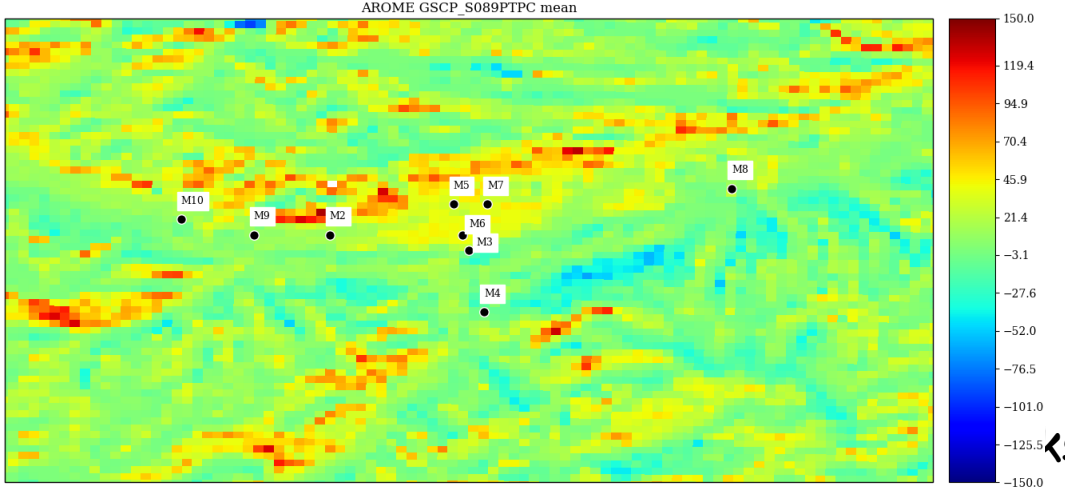


https://zenodo.org/record/4745957

TKE budget m2/s2 for 24h at 500m Cold Pool case

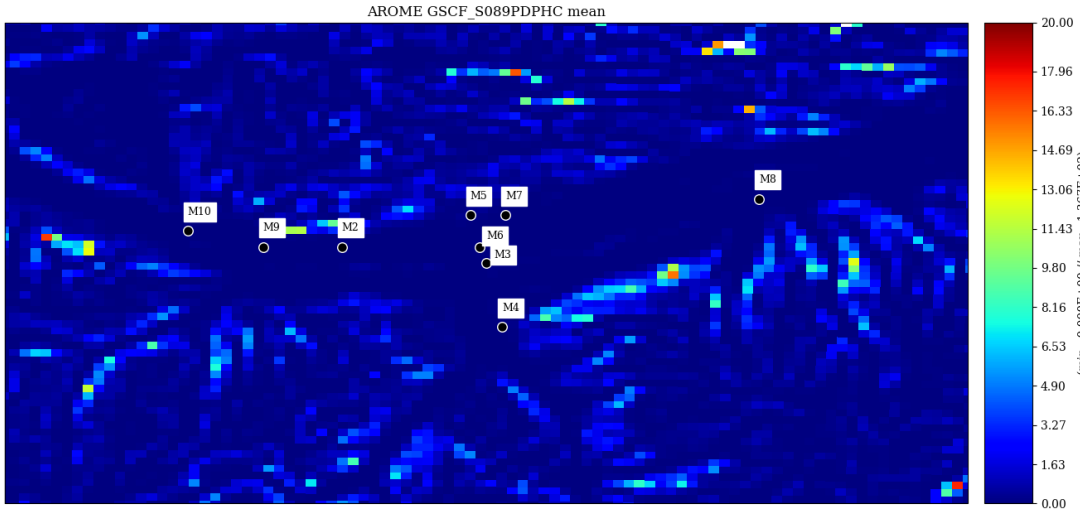


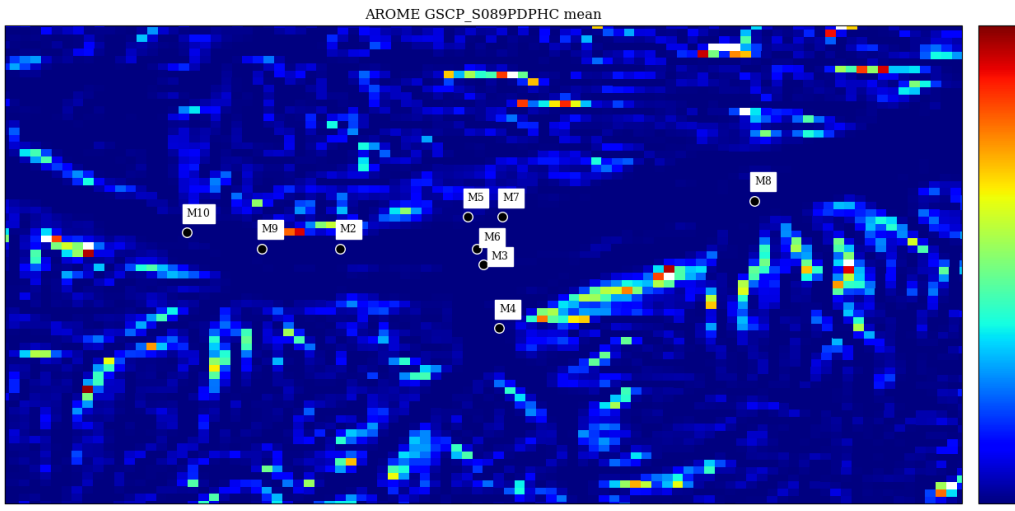
Vert. Dyn Prod. Level ~16.7m



Thermal Prod. Level ~16.7m

TKE budget m2/s2 day : Pseudo Horiz effect (passive mode)





$$\left[\left(\frac{\partial \overline{u}}{\partial x}\right)^2 + \left(\frac{\partial \overline{v}}{\partial y}\right)^2 + \frac{1}{2}\left(\frac{\partial \overline{u}}{\partial y} + \frac{\partial \overline{v}}{\partial x}\right)^2\right]^{\frac{3}{2}}$$

$$\sqrt{C_{mh}^3/C_\varepsilon}\left(\sqrt{\mathrm{DEF}^2 + C_1^2\mathrm{DIV}^2} - C_1\mathrm{DIV}\right)^3$$

For both formulation we need to estimate Lh !

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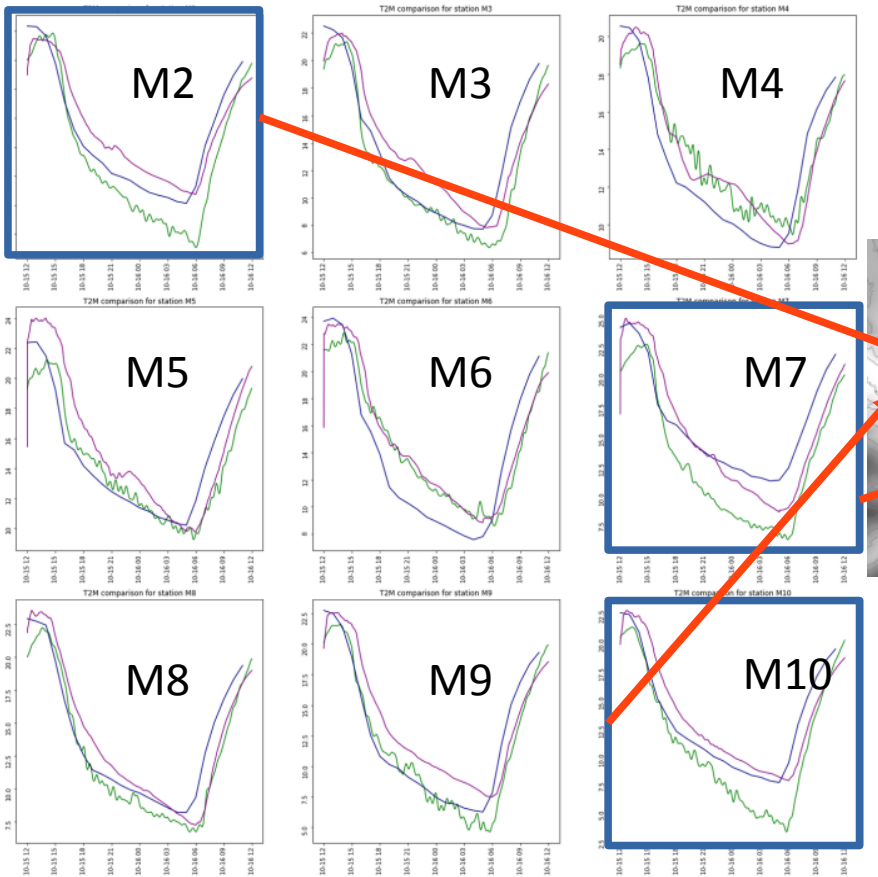
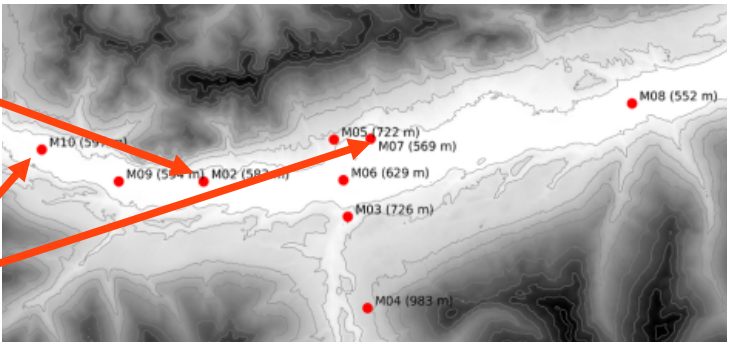


From A. Bettira, M. Peyrot, Q. Rodier



AROME 1.3km LBC ARPEGE

Observations
AROME
Méso-Nh

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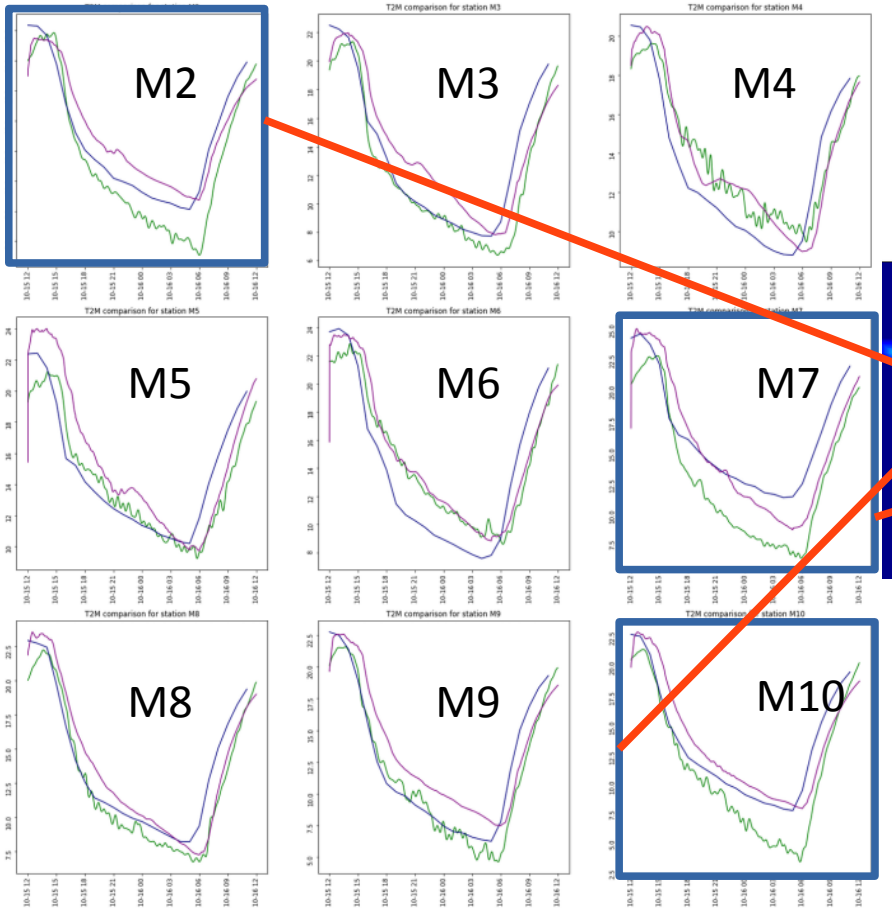
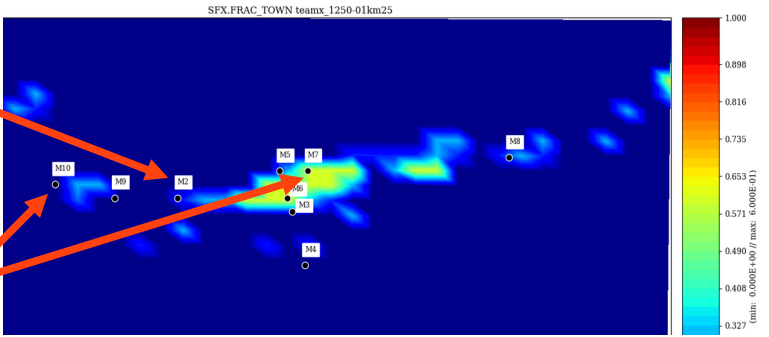


From A. Bettira, M. Peyrot, Q. Rodier

Urban area : town fraction



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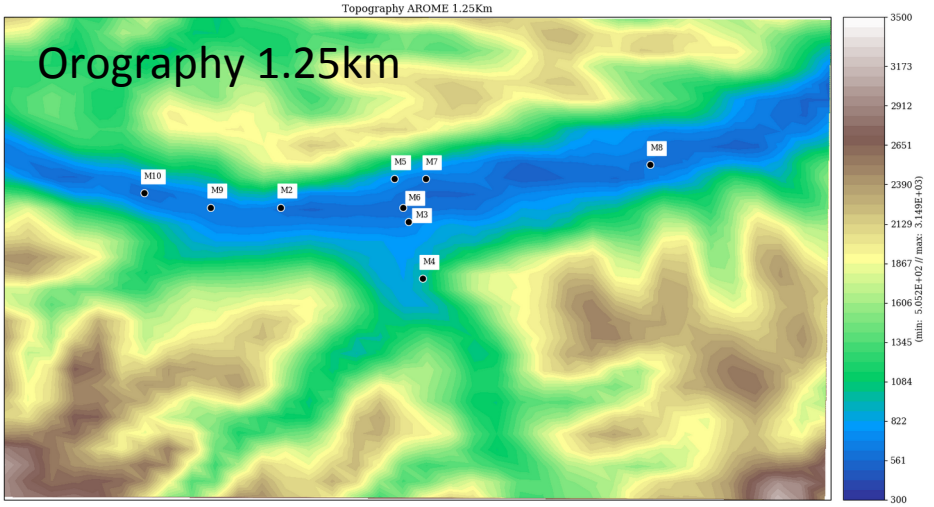

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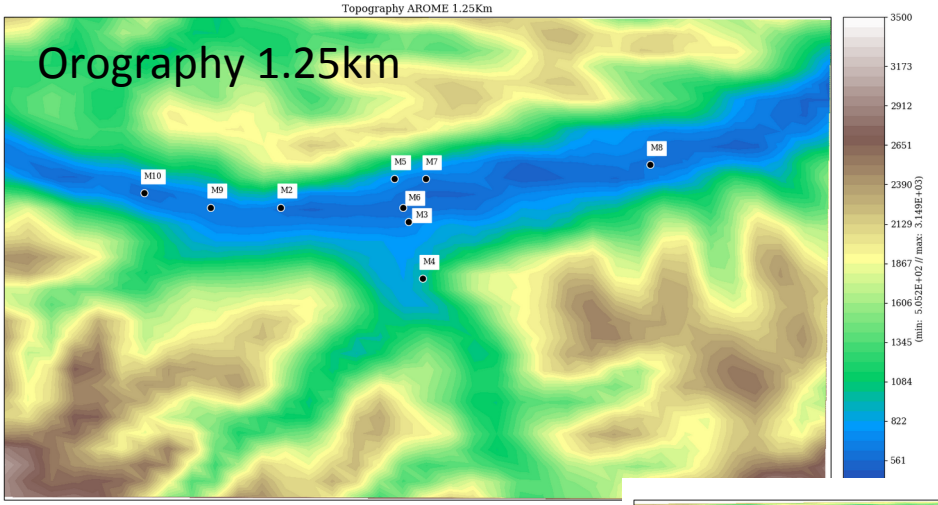

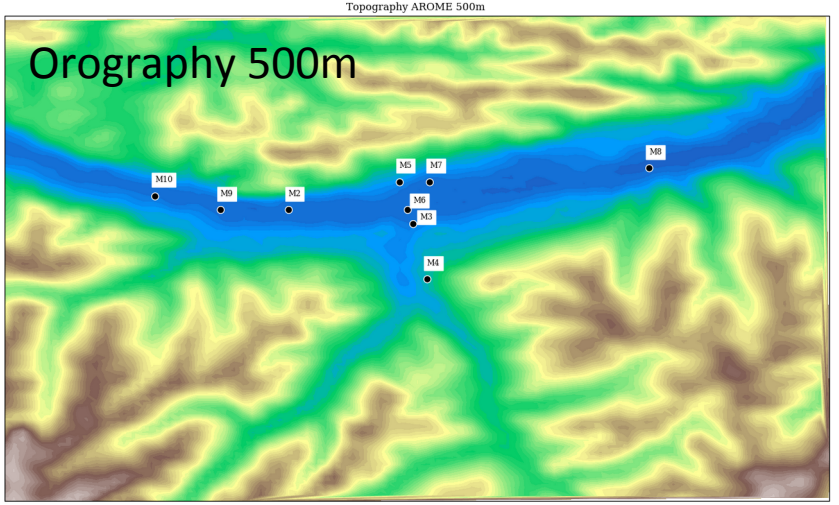

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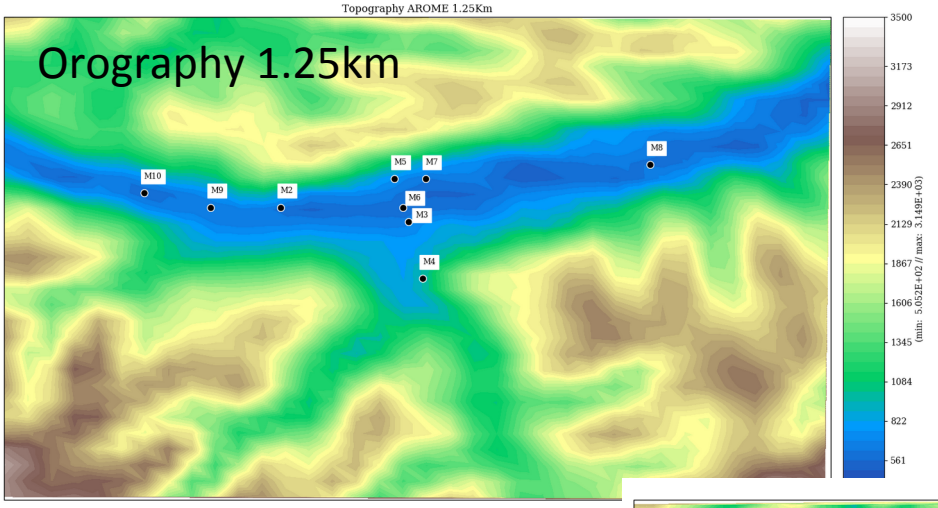

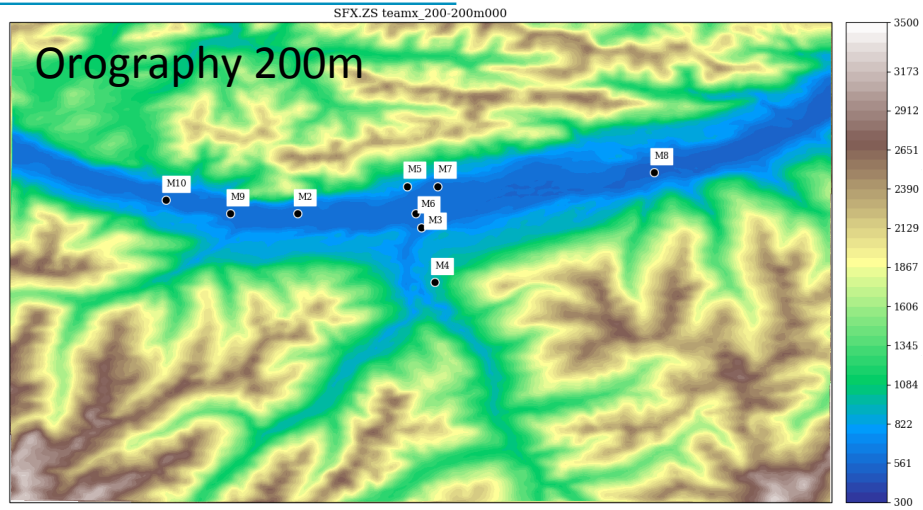

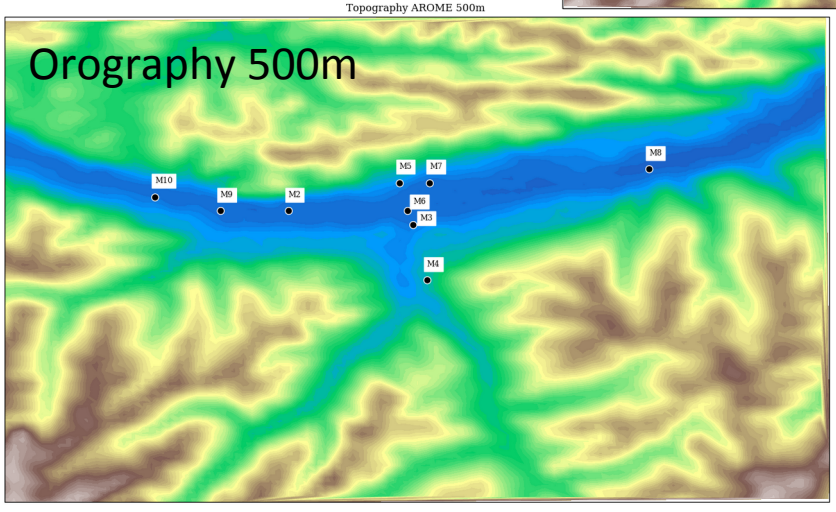

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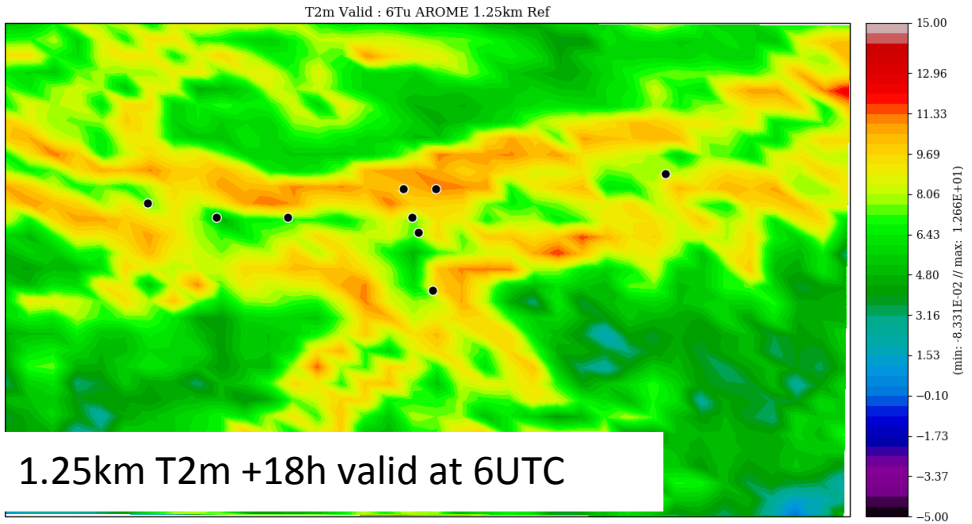

1.25km T2m +18h valid at 6UTC

 200m T2m +18h valid at 6UTC

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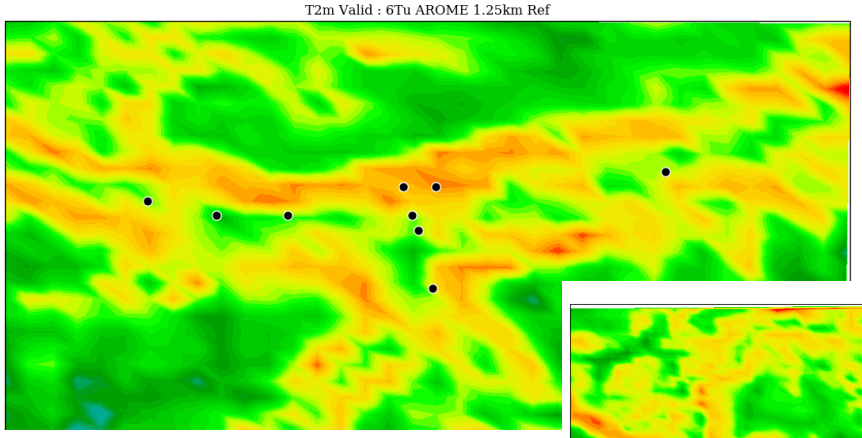
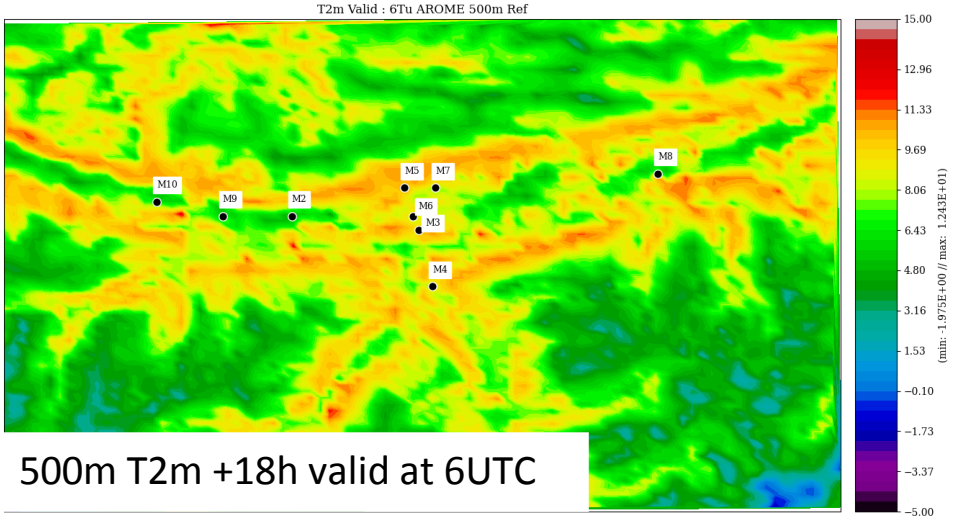


1.25km T2m +18h valid at 6UTC



500m T2m +18h valid at 6UTC

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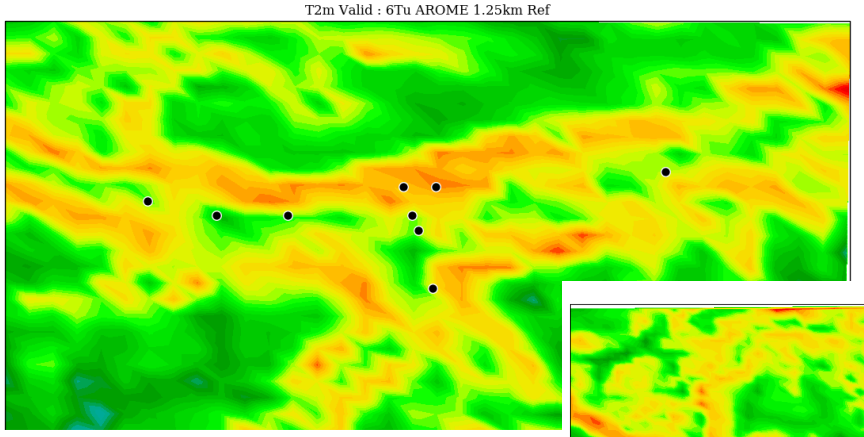
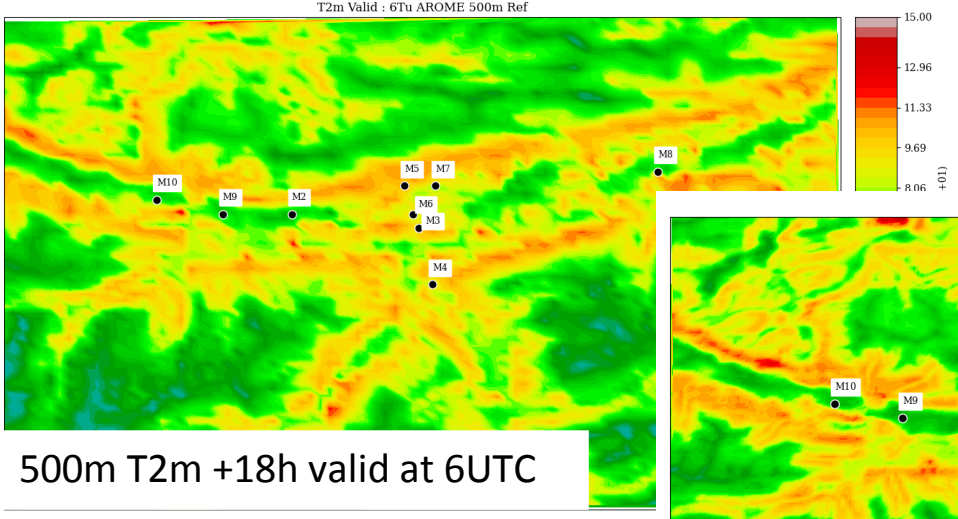
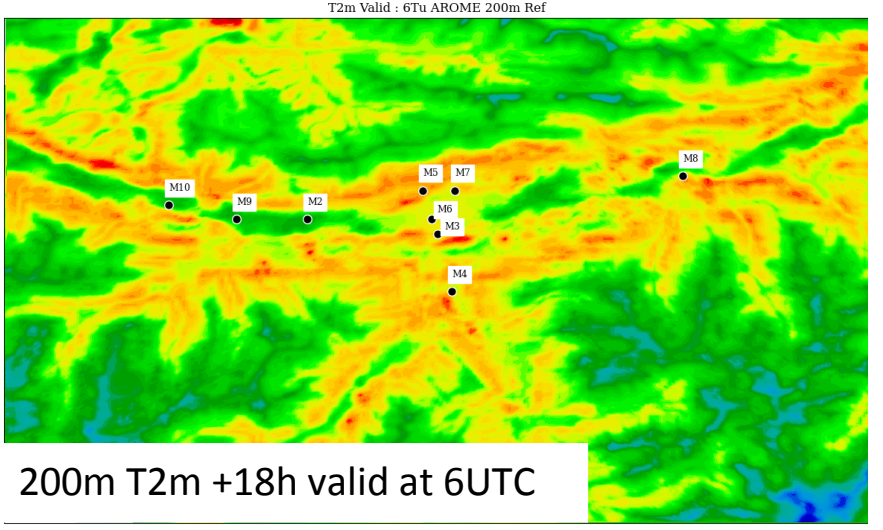


1.25km T2m +18h valid at 6UTC



500m T2m +18h valid at 6UTC



200m T2m +18h valid at 6UTC

Bias a 18H

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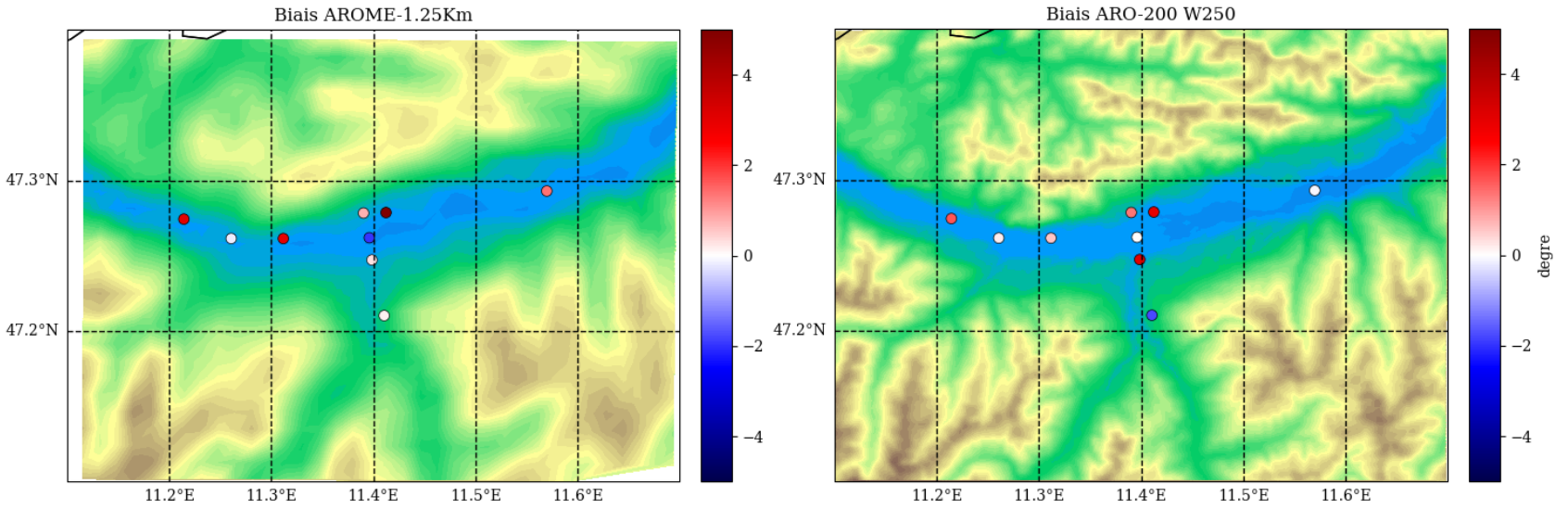

Bias a 18H

AROME 1.25km

AROME 200m with pseudo 3D with Goger-Wang

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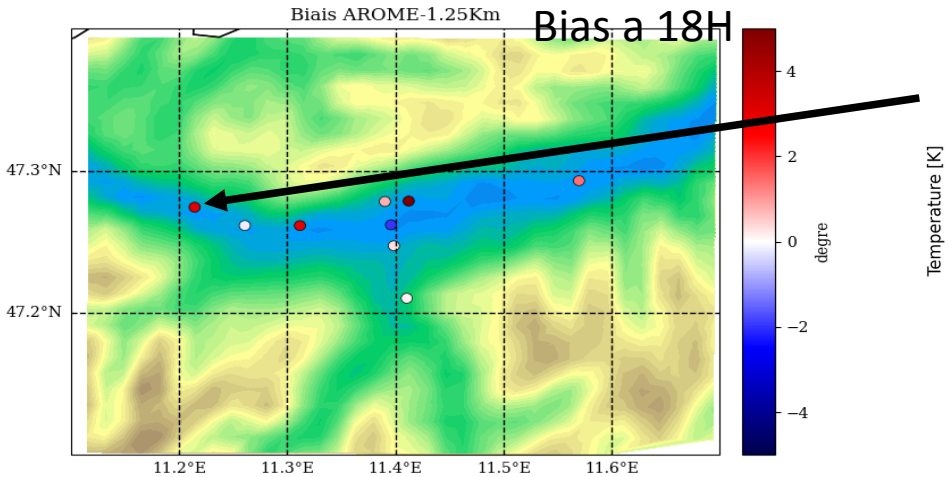

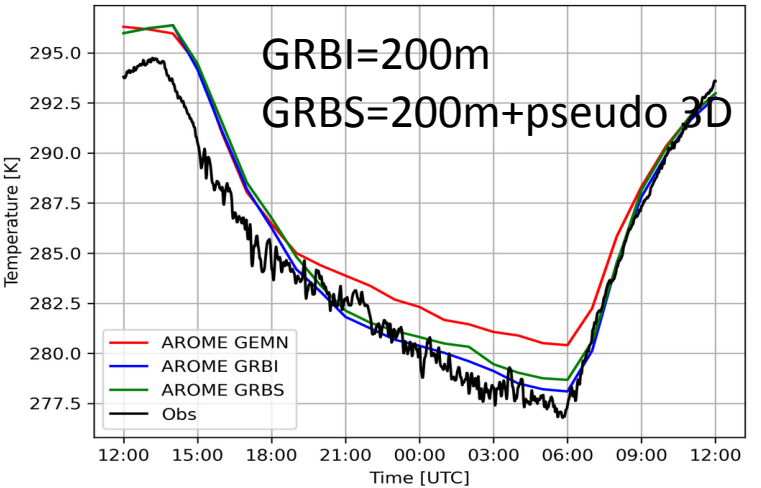

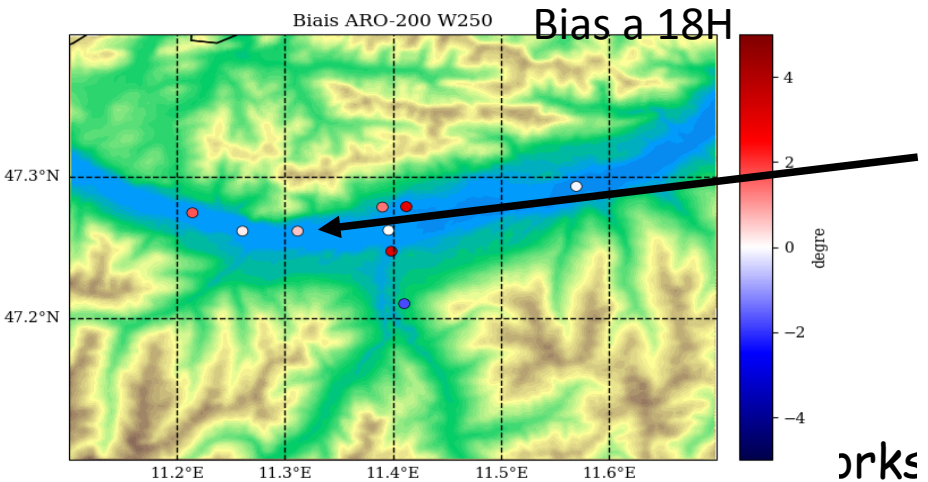

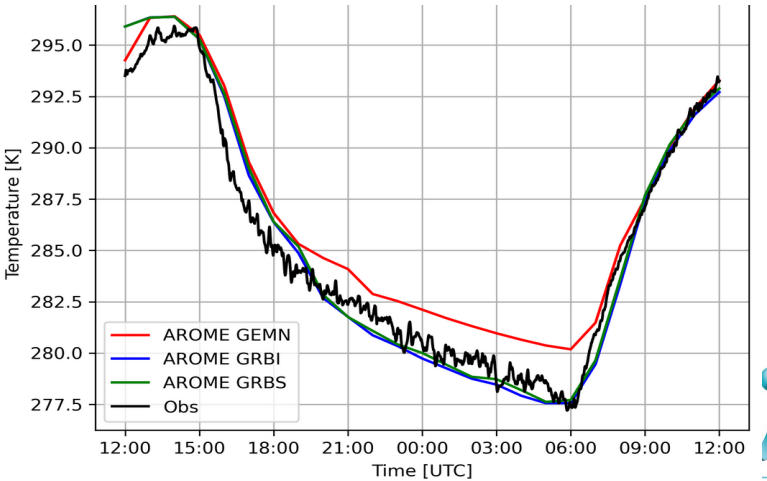

Bias a 18H

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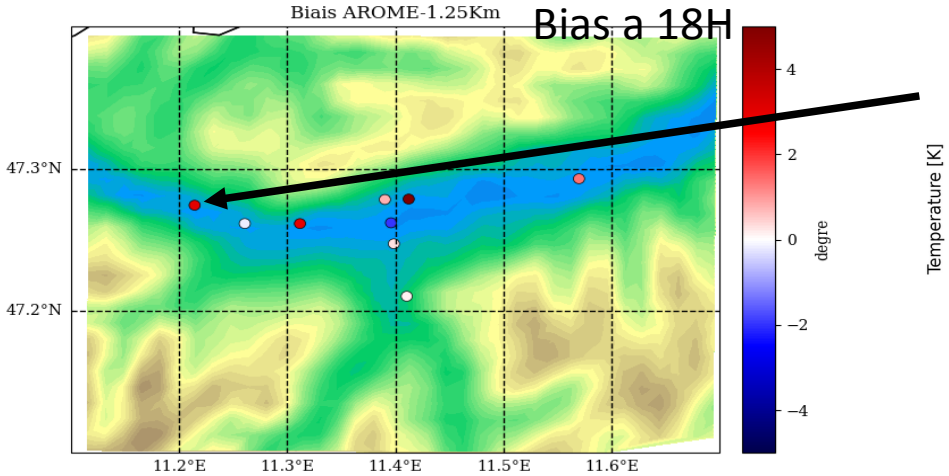

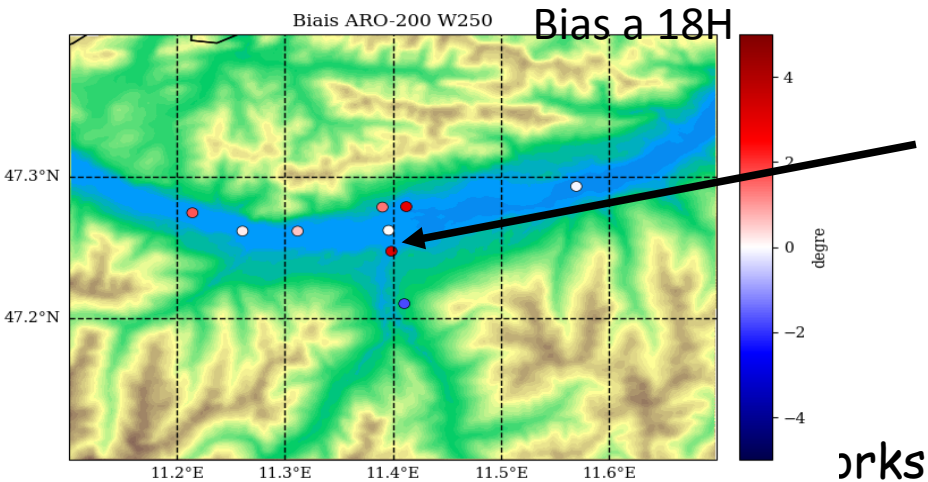

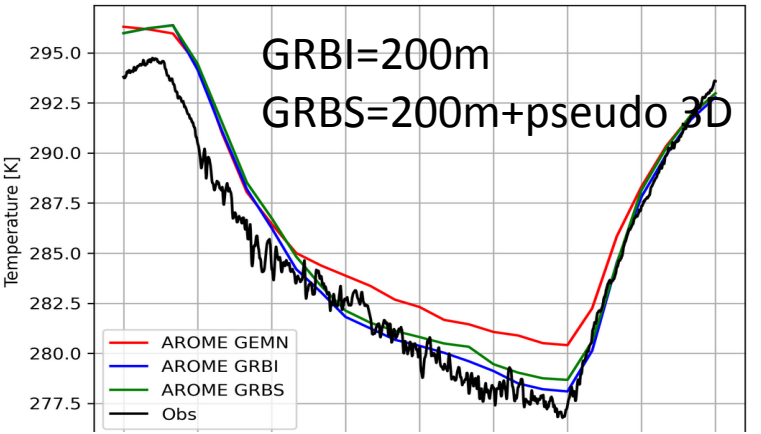

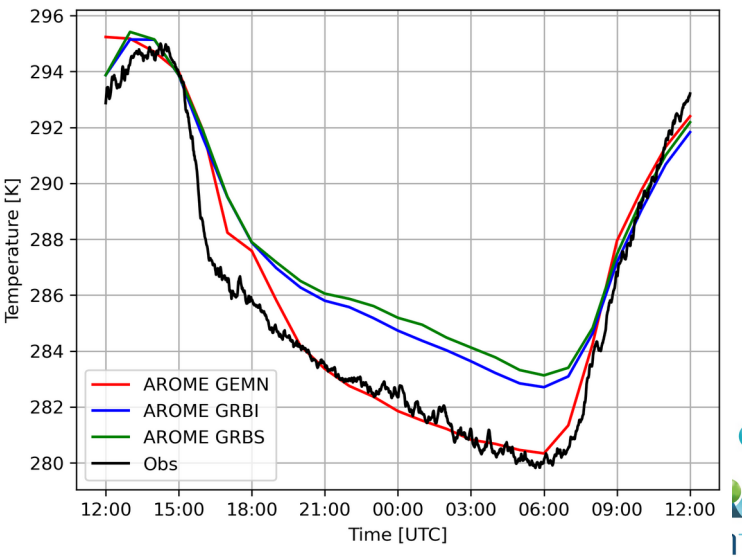

Bias a 18H

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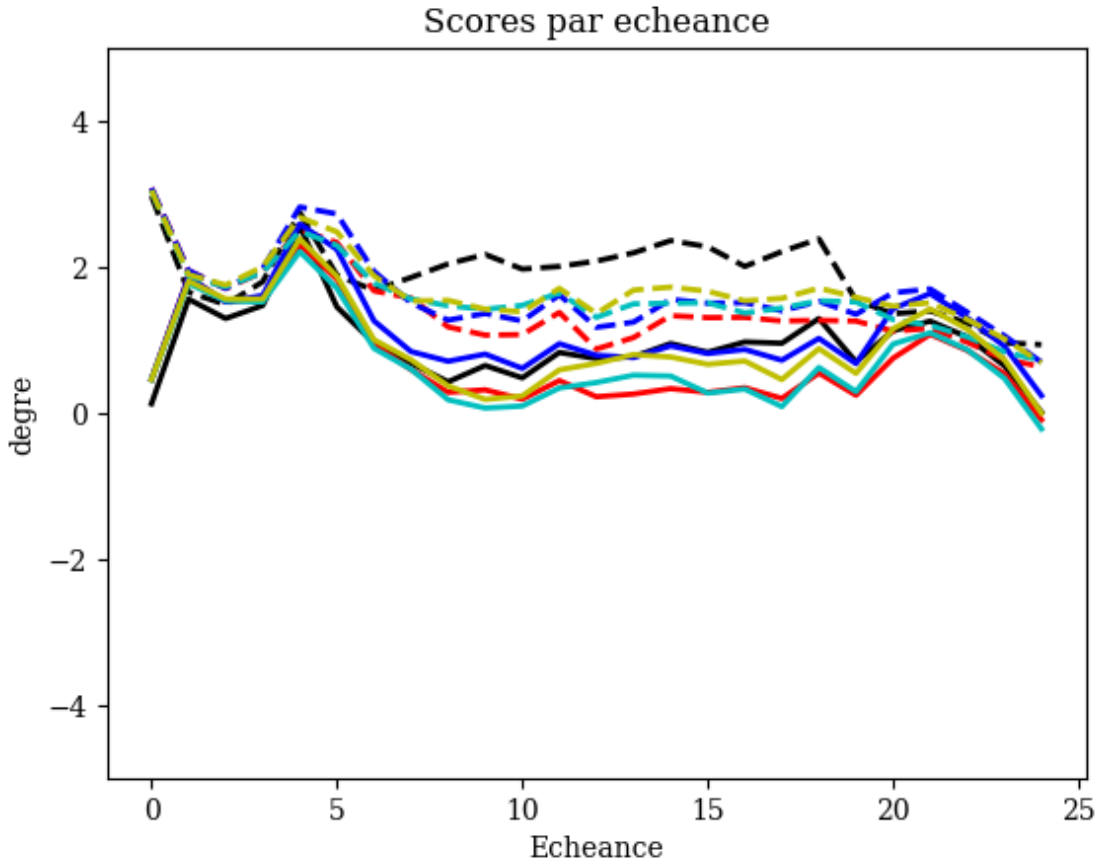

No clear positive impact of the pseudo 3D at 500 or 200m ?

Why ? Choice of Lh ? Or compensating error with other physics part ?

Bias à 18H

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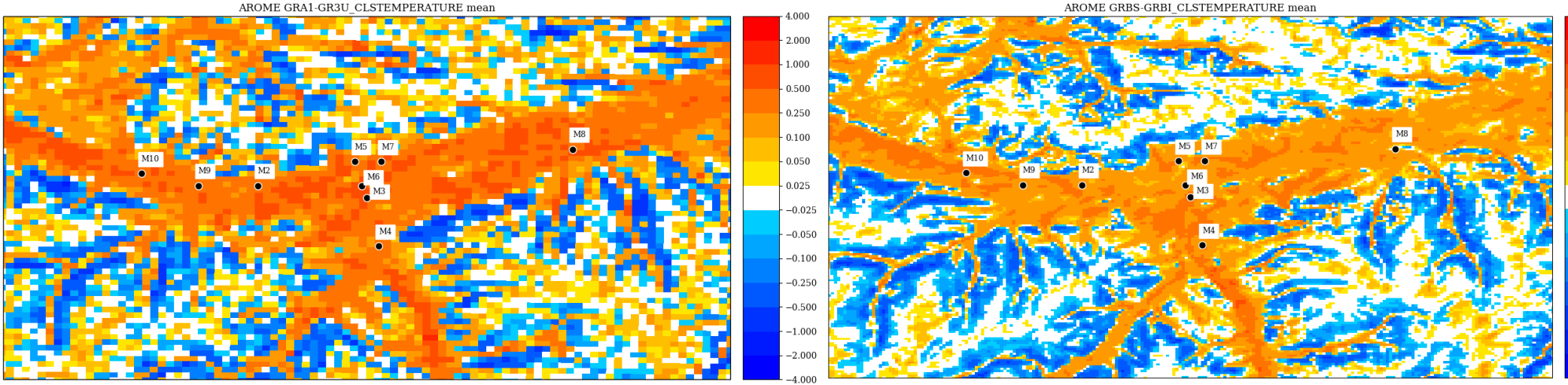

Daily mean T2m Impact of the pseudo 3D 500m (left) and 200m (right)

Stronger impact at 500m ?! Warmer due to more mixing ?

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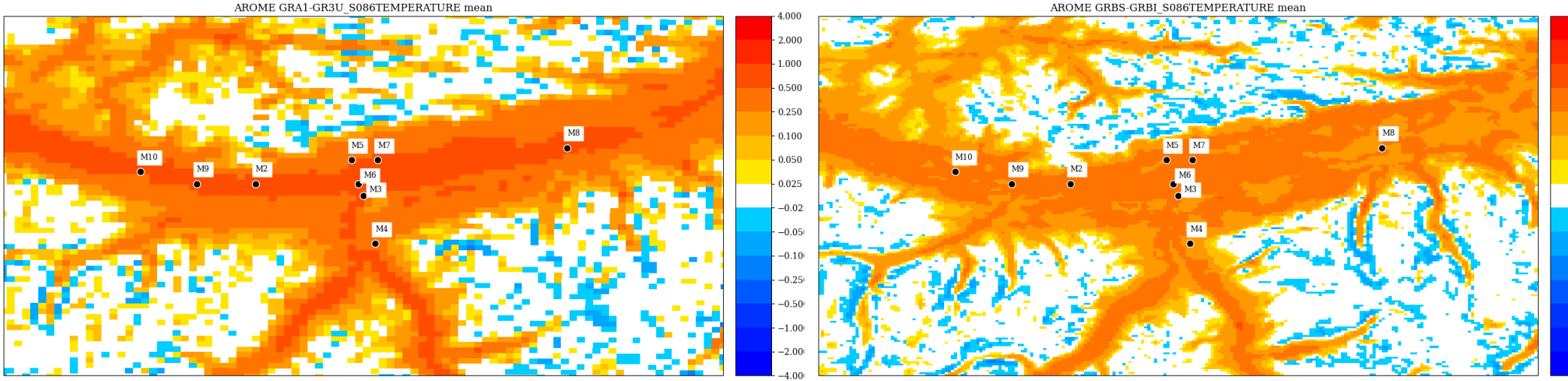
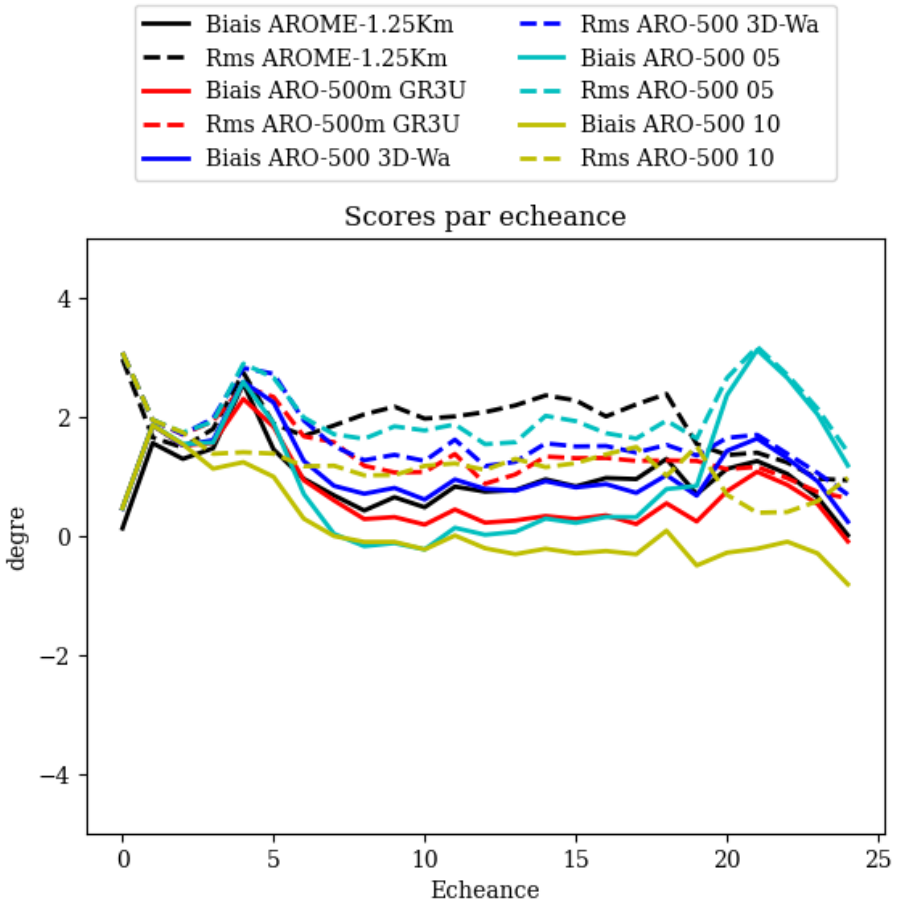


Daily mean temperature impact at level 86 (~ 87m above the surface) of the pseudo 3D 500m (left) and 200m (right)

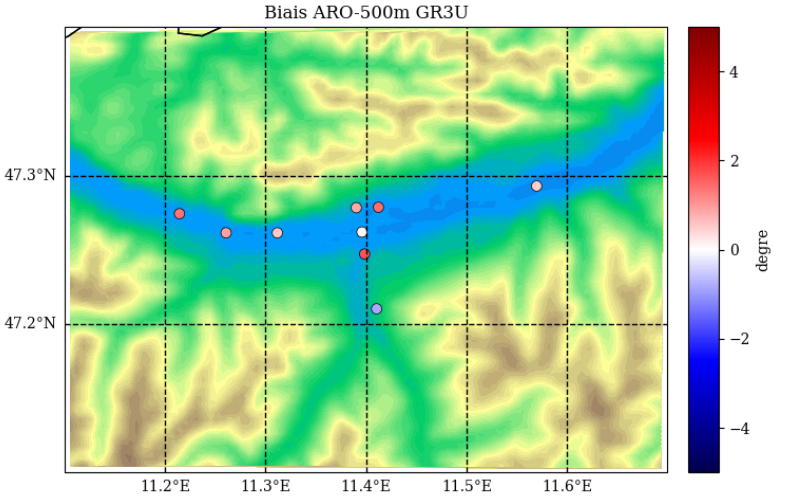
Impact of the Ric for the surface layer

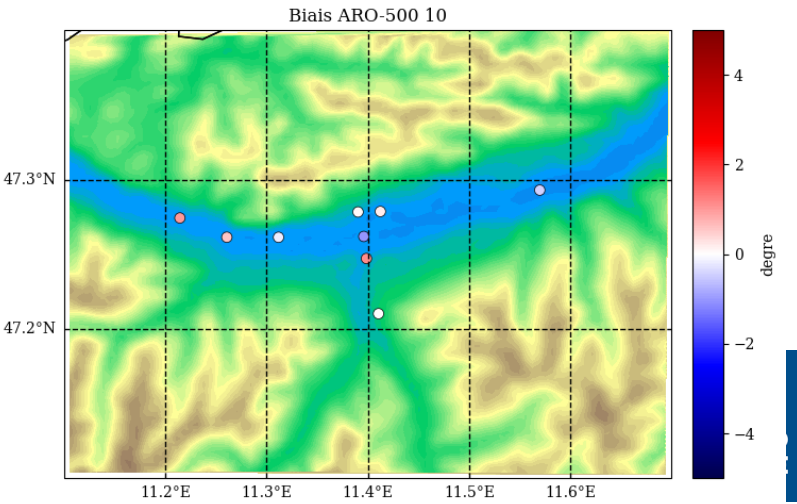


Ric=0.2 (default)

Ric=0.05

Ric=10



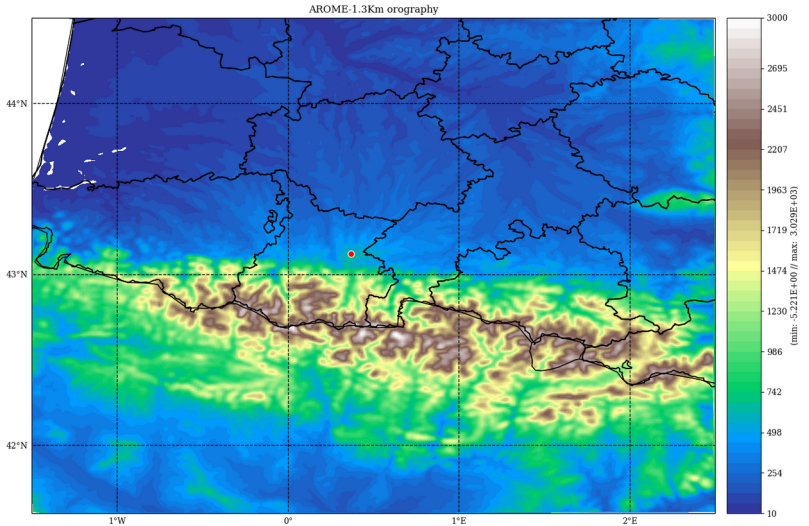


MOSAI : Model and Observations for Surface-Atmosphere Interactions

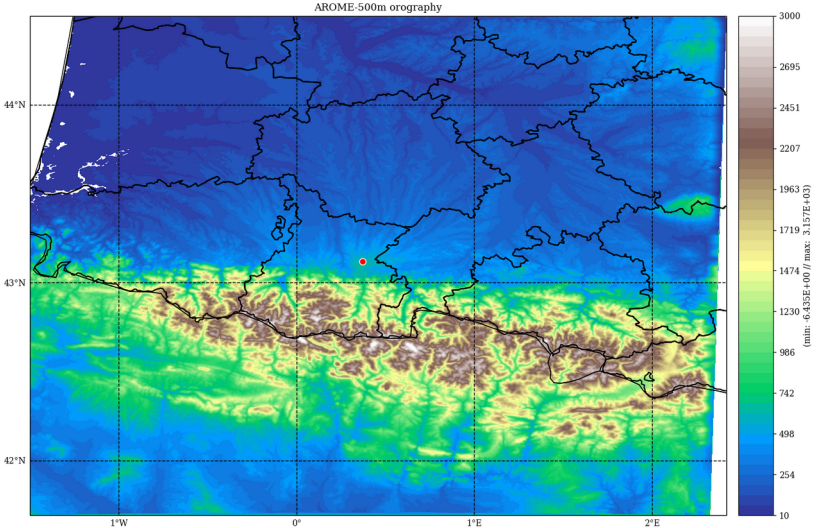
https://mosai.aeris-data.fr/

3 sites during one year : 2021 Toulouse, 2022 Sirta-Paris, 2023 Lannemezan
In Dec 2023 2 weeks for SOP in Lannemezan with 4 RS, drones, etc …

AROME OPER 1.3KM

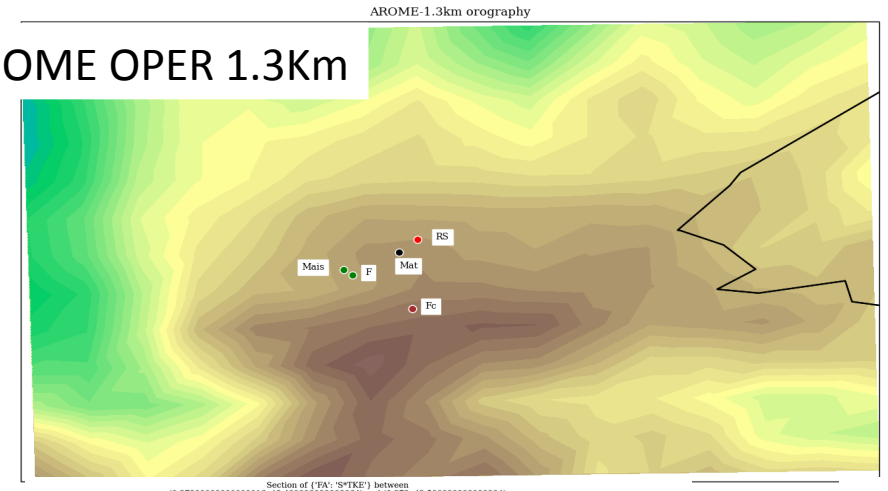


AROME 500m

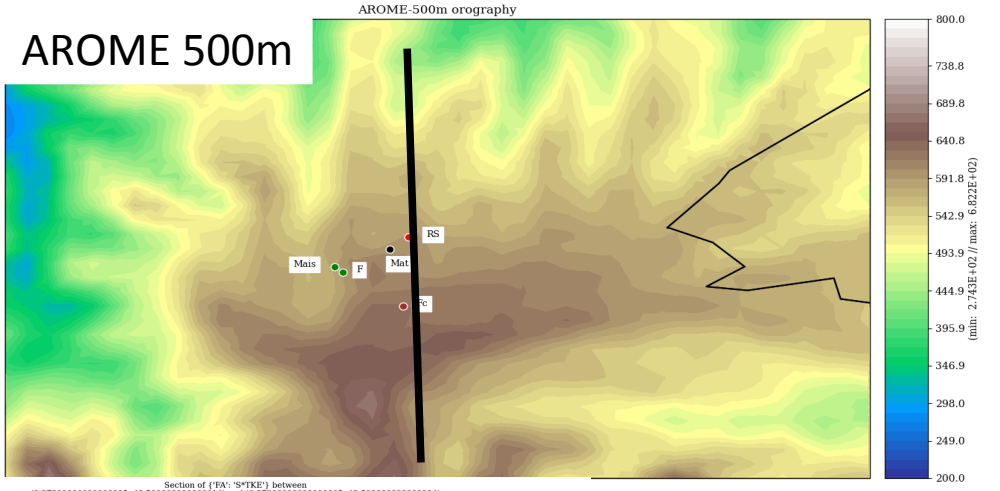


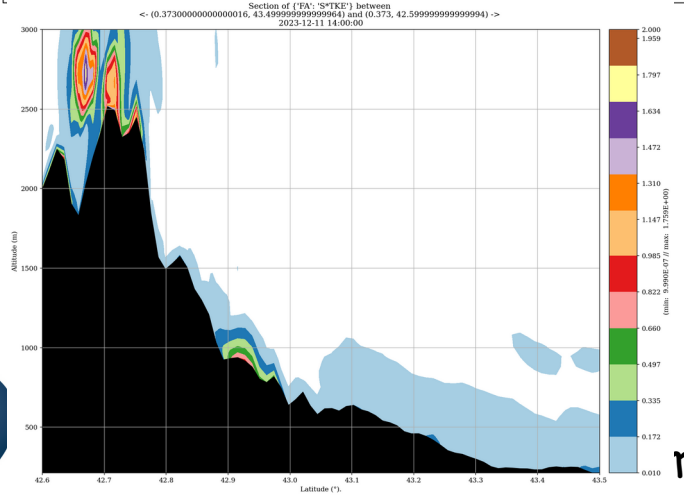
MOSAI : Model and Observations for Surface-Atmosphere Interactions

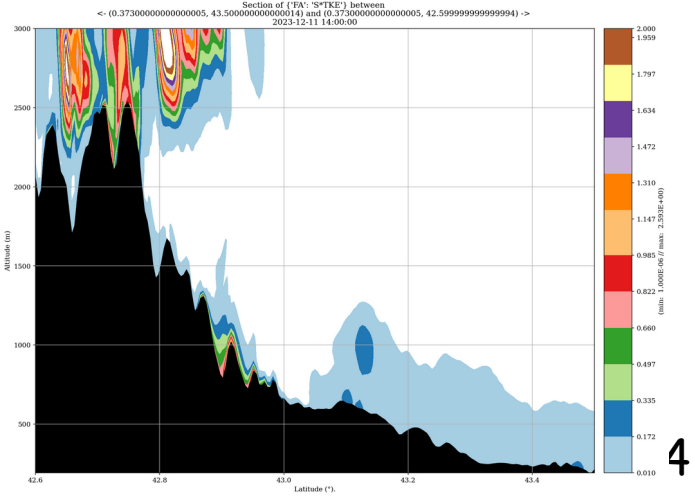
AROME OPER 1.3Km



AROME 500m







TKE (m2/s-2)

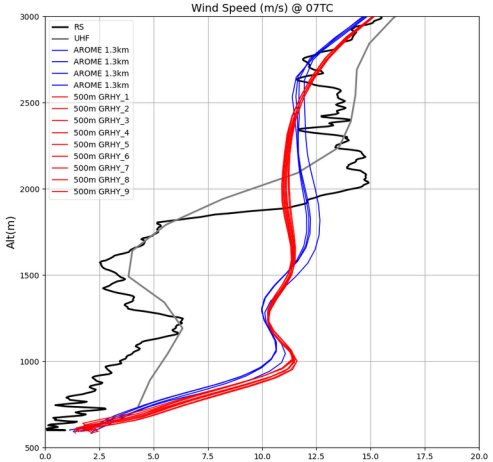
netric

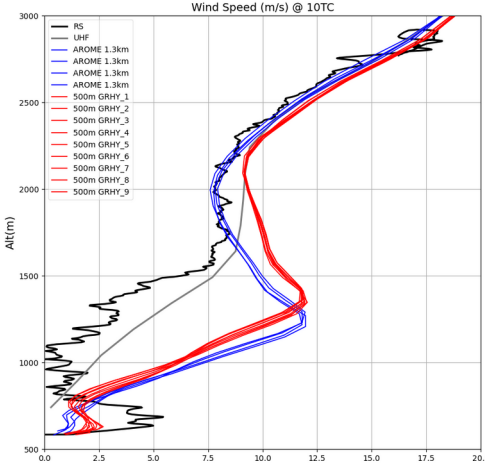
4

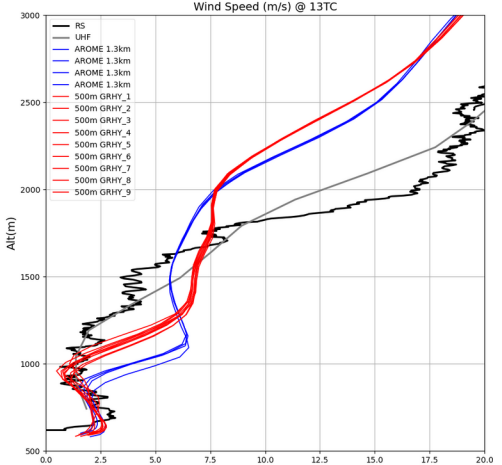
11 dec 2023 AROME-Oper and AROME-500m (red)

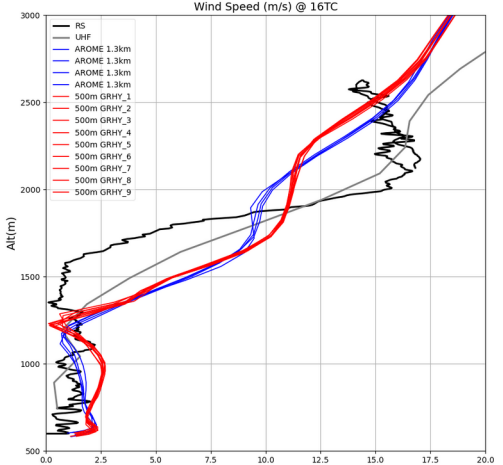
Base 00UTC FC+ 7h, +10h, +13h, +16h

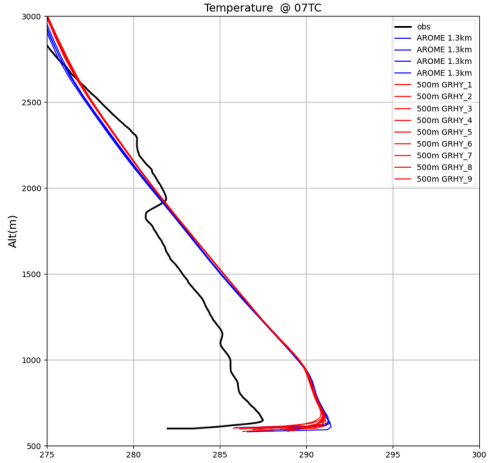
Data Rs & UHF
Provided by Fleur

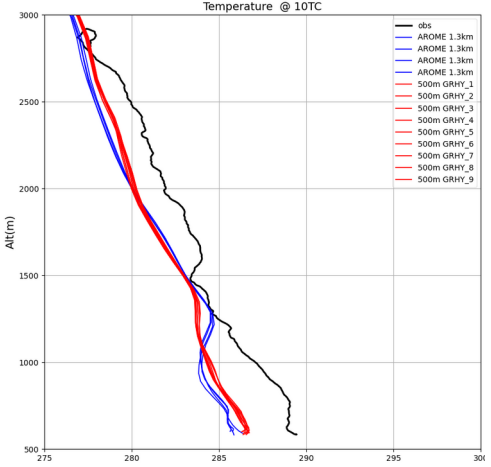


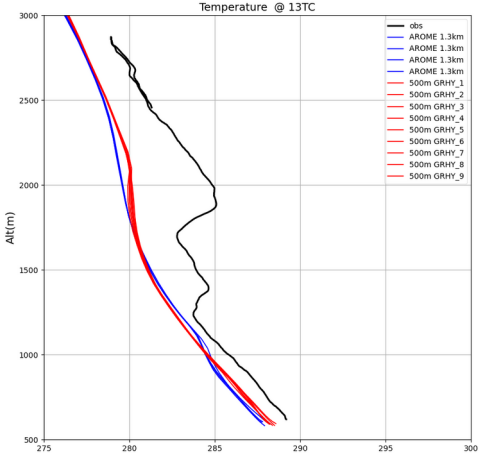


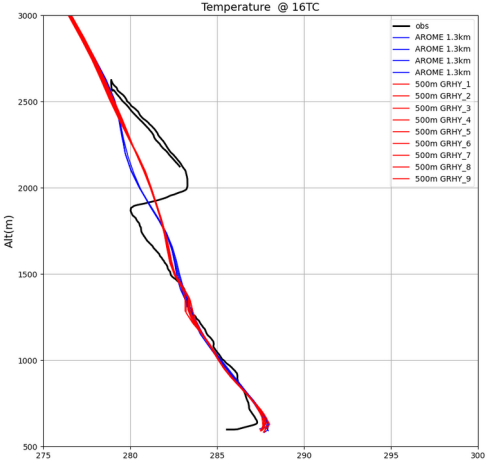








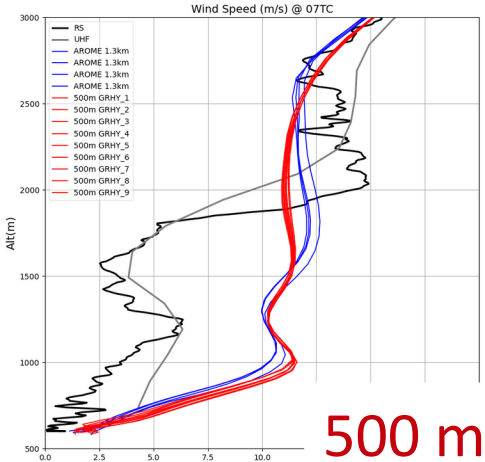


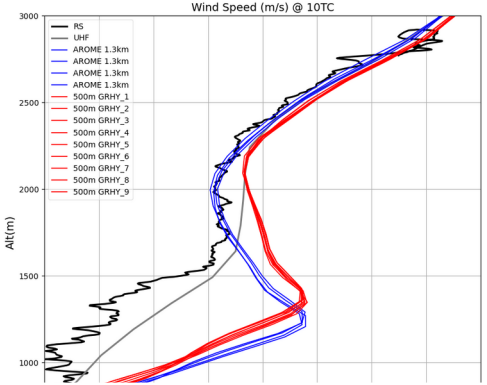


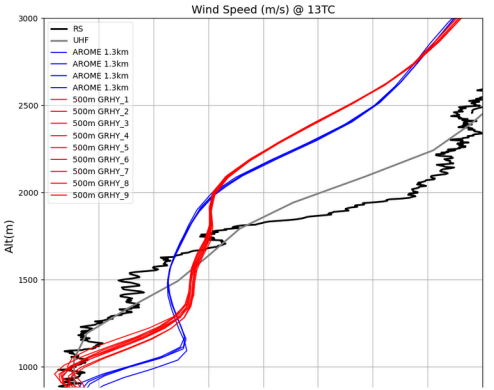
11 dec 2023 AROME-Oper and AROME-500m (red)

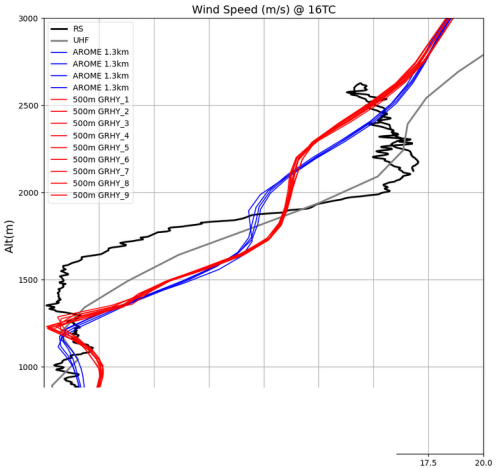
Base 00UTC FC+ 7h, +10h, +13h, +16h

Data Rs & UHF
Provided by Fleur

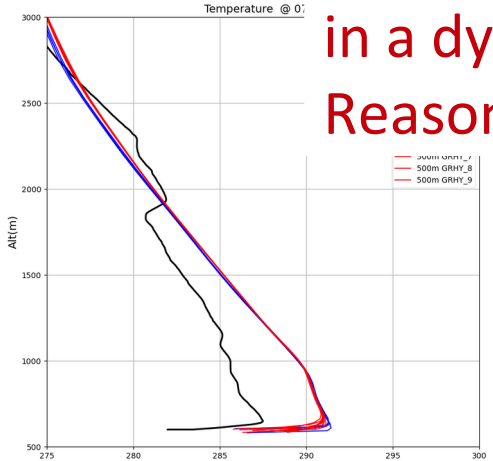


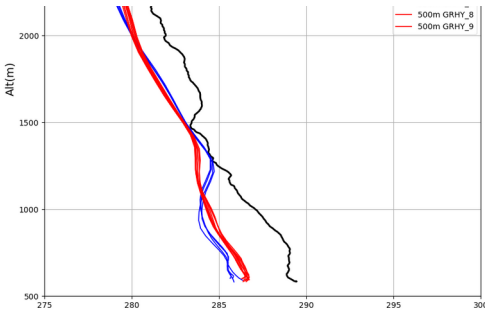


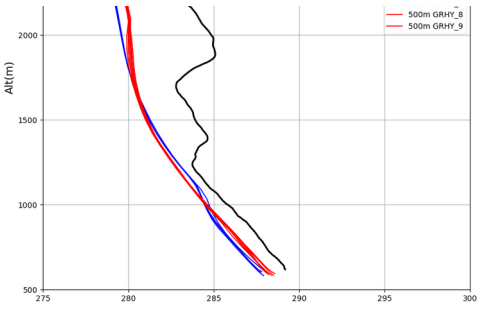


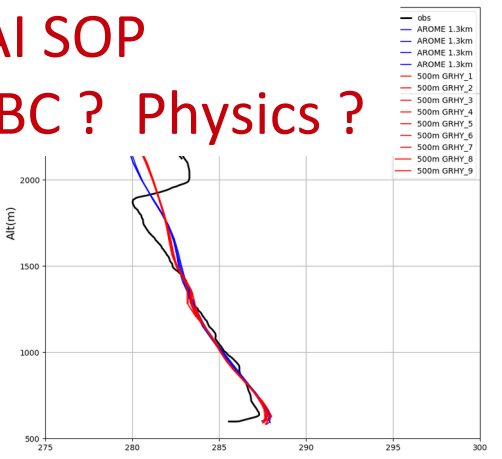


500 m do not really improve the vertical profile
in a dynamical adaptation at least for this MOSAI SOP
Reasons : too small domain ? Initial analysis ? LBC ? Physics ?



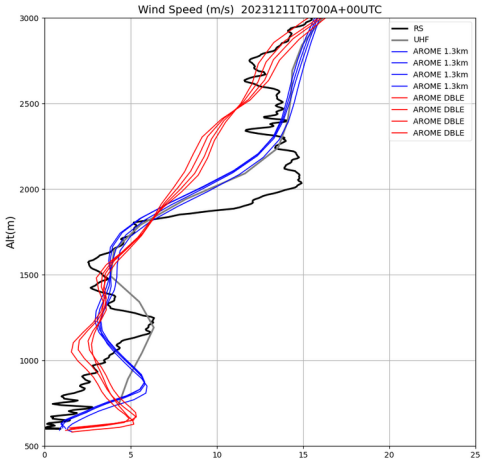


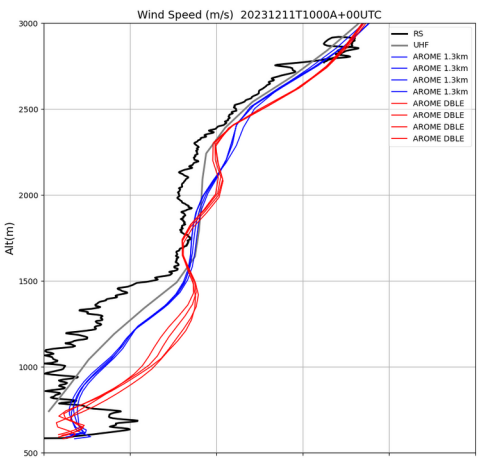


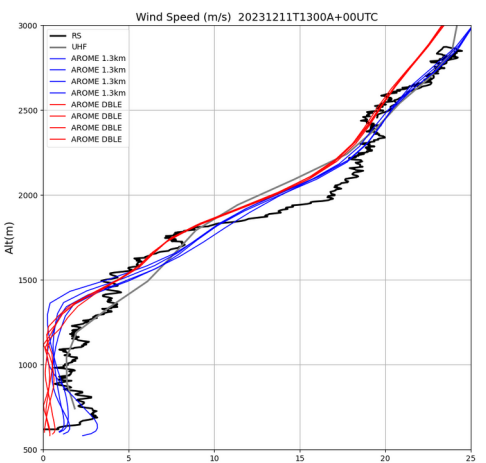


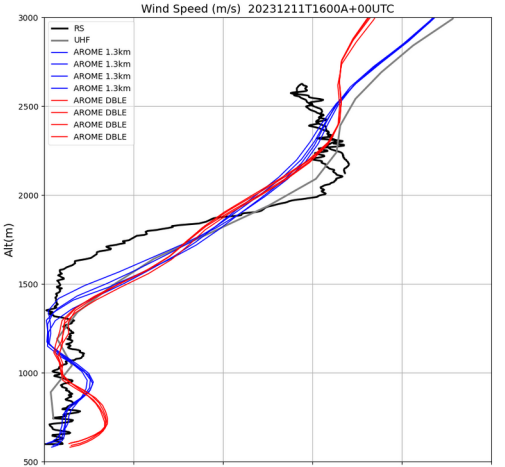
11 dec 2023 AROME-Oper and AROME-DBLE with 3dEnVar (red)
Comparaison des analyses + 7h, +10h, +13h, +16h

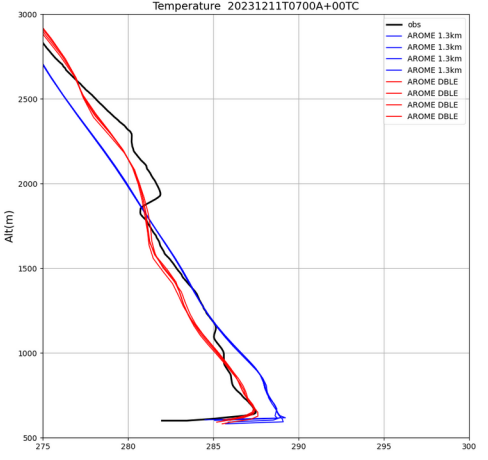
Data Rs & UHF
Provided by Fleur

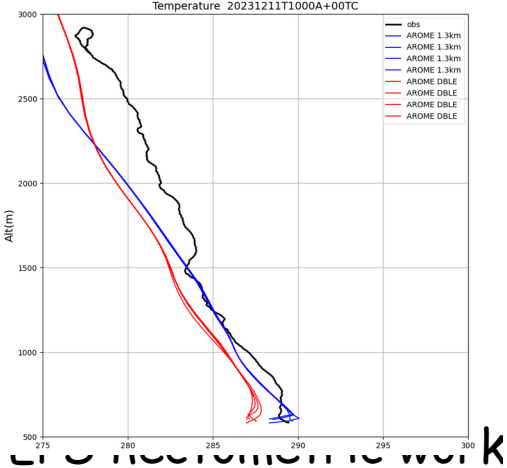


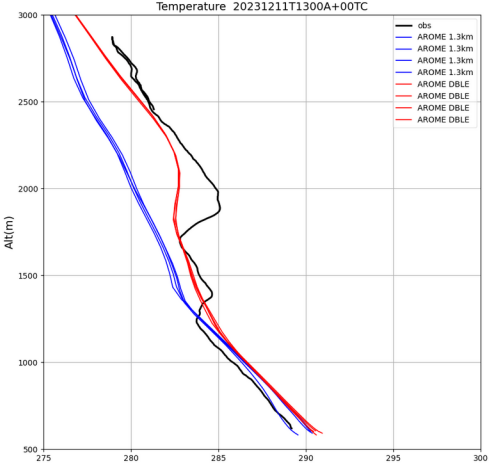


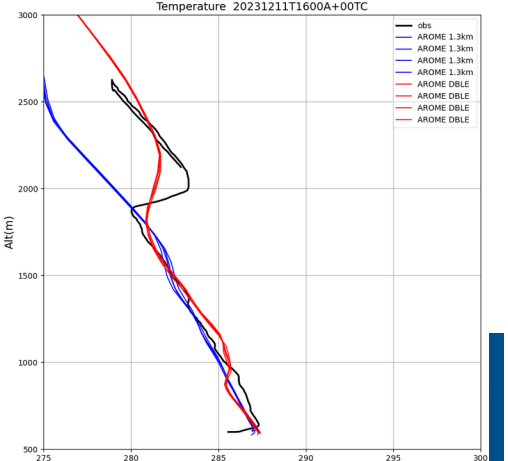












Only some thoughts and questions ...

- “Pseudo 3D formulations” are now available in AROME for evaluation below 1km
  - Need to work on the horizontal length scale: it is THE KEY parameter and later probably on the dissipation length ...
  - Preliminary evaluation with the Cold pool case : not really positive in terms of “classical evaluation”
  - Pseudo-3D → reduce the cooling during night in the valley → some retuning in the surface layer is probably necessary especially with the Ric value should depend on the subgrid scale variability but also of the height of the layer → **3D turb can probably help to remove completely the use of Ric ?**
  - How to avoid/reduce compensating error → we need fluxes
- Not easy to show the added value of the 500m or 200m even some times in complex terrain → spatial variability in the model → double penalties not only for precipitation even for surface parameter such as T2m ?