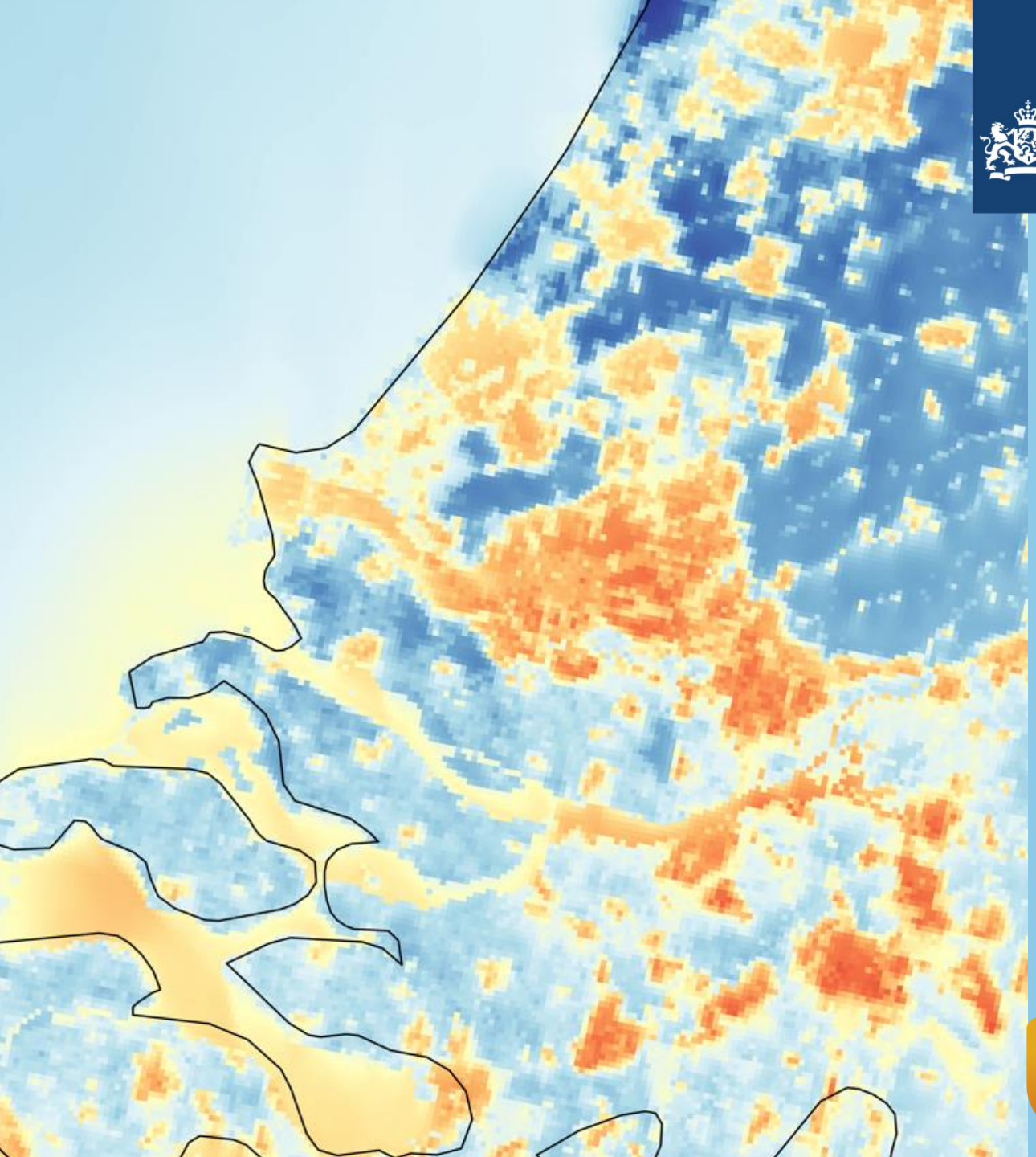


Royal Netherlands
Meteorological Institute
Ministry of Infrastructure
and Water Management

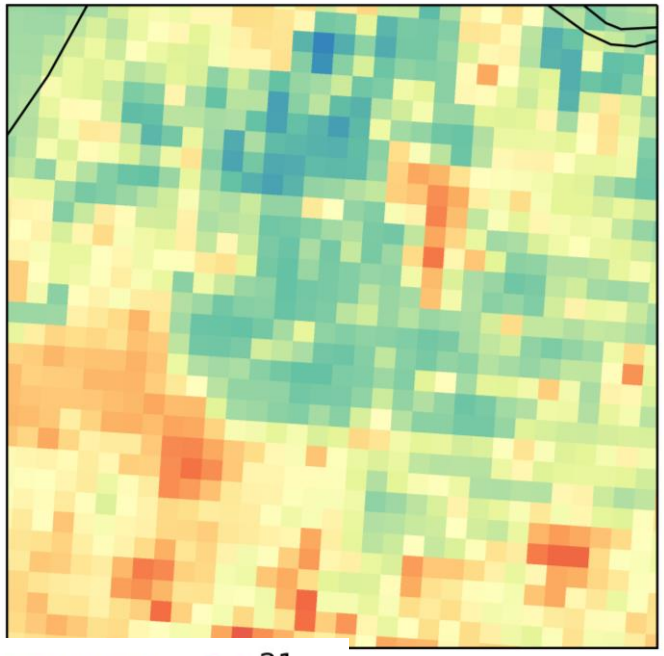
Developments and Process-Based Evaluation of Hectometric-Scale NWP

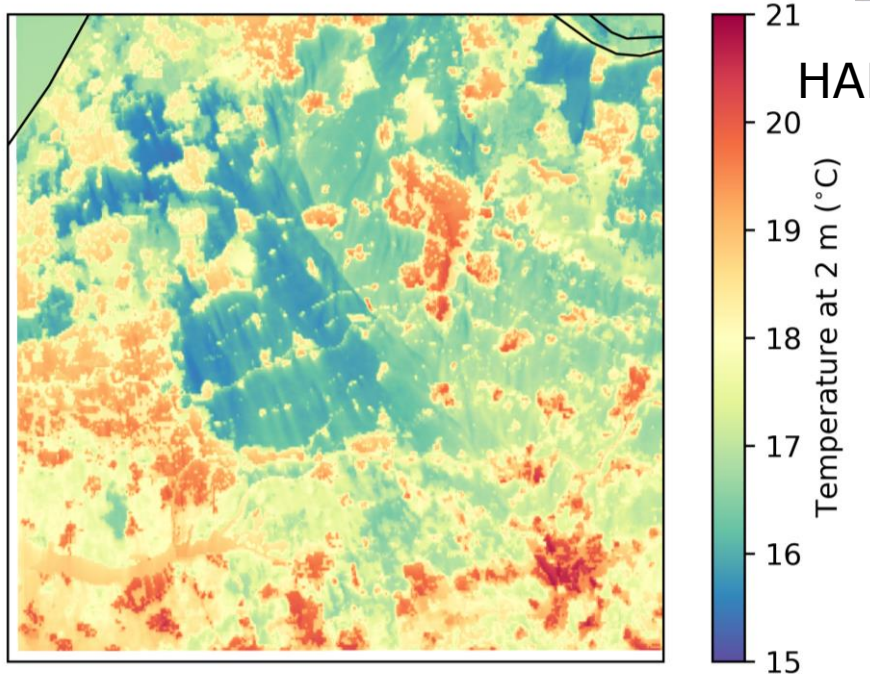
Natalie Theeuwes[1], Ulf Andrae[2], Abhilash Murlidharan Menon[2], Metodija Shapkalijevski[2], Eric Bazile[3],Jean Wurtz[3], Matthias Zeeman[4], Andreas Christen[4], Wim de Rooy[1]

1. KNMI, the Netherlands. 2. SMHI, Sweden 3. Meteo France, France
4.University of Freiburg, Germany

Destination Earth

Operational
HARMONIE-AROME
@ 2 km





HARMONIE-AROME
@ 100 m

Lean, Theeuwes et al., 2024

Benefits of sub-km weather forecasts

Definite benefits:

- Detailed wind, temperature and moisture fields
- Urban heat (e.g. during heat waves)

Possible improvements:

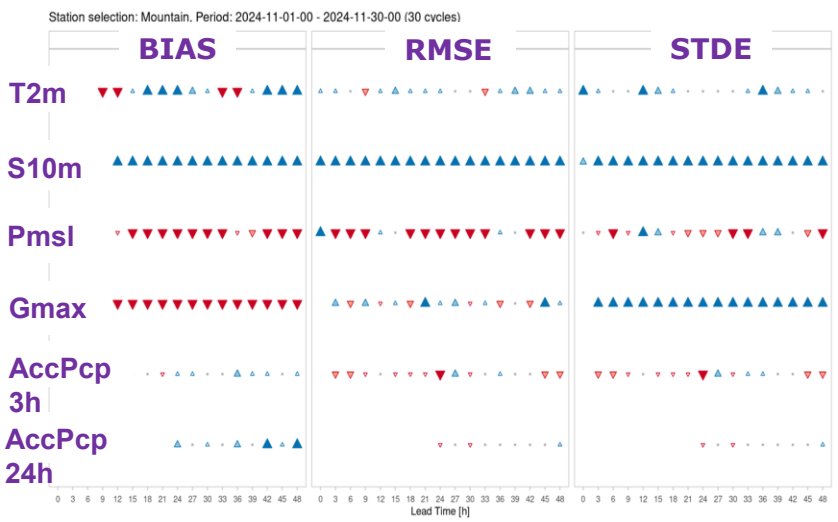
- Wind gusts
- Fog
- Convective precipitation
- *Possible coupling with air quality*

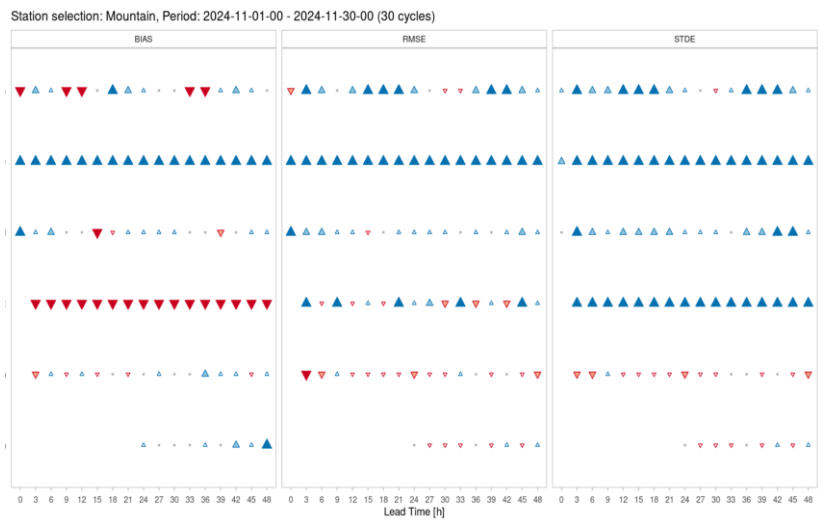
Long-term scorecards against IFS @ 4.5 km

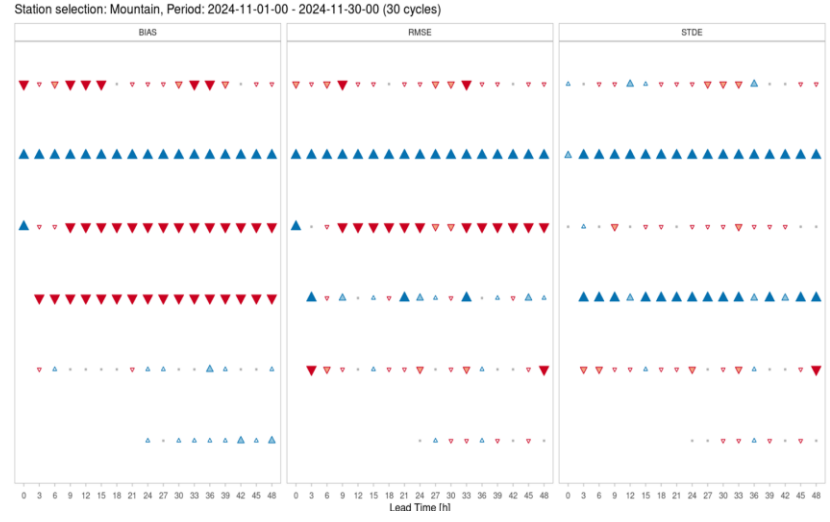
MERGED Mountain stations

Standard deviation of filtered subgrid orography > 120

November 2024

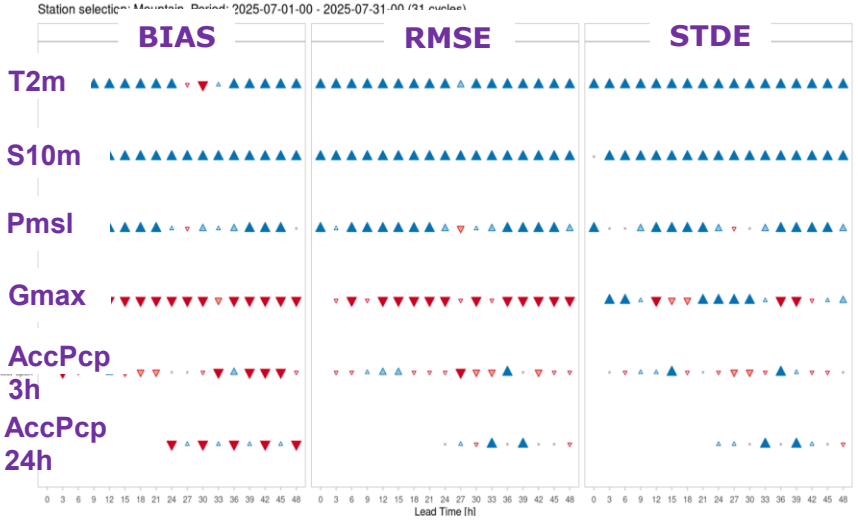




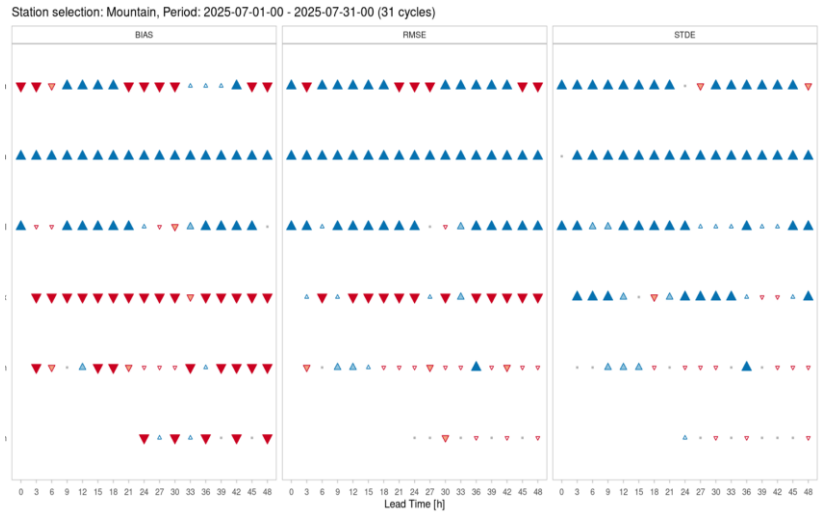


July 2025

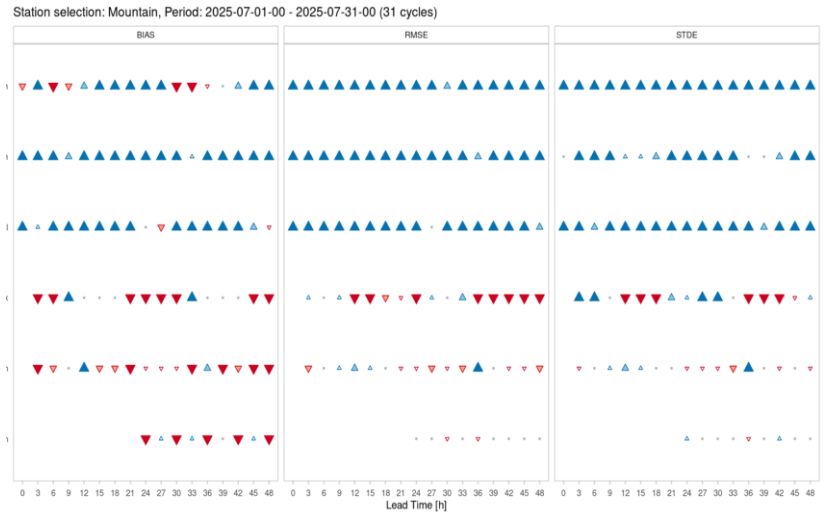
ALARO



AROME



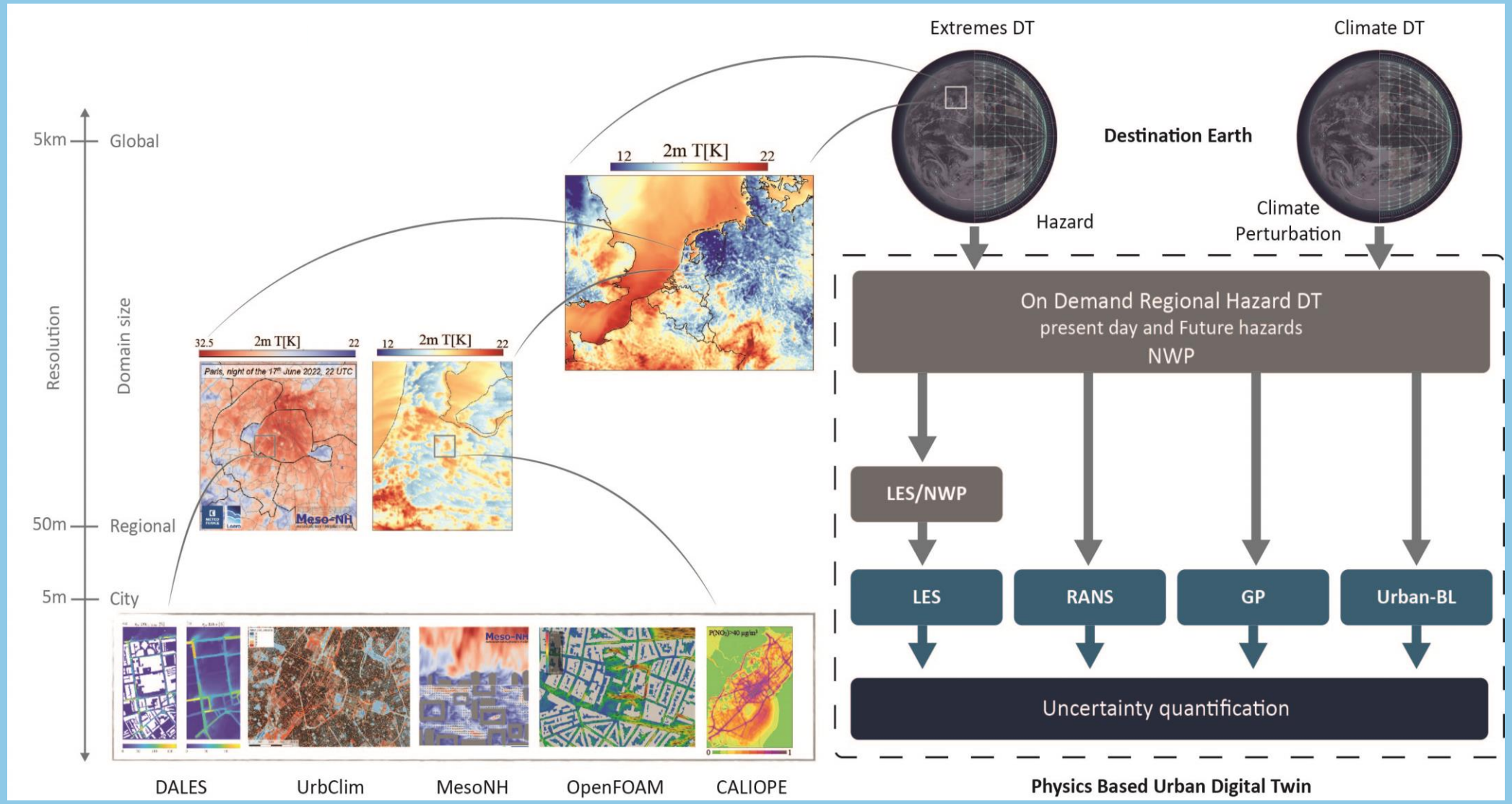
HARMONIE-AROME



Mauri Martínez Sánchez, Laura Esbrí Corbella, Samuel Viana (AEMET)

Cascading atmospheric models

Royal Netherlands Meteorological Institute
Ministry of Infrastructure and Water Management



Cascading atmospheric models

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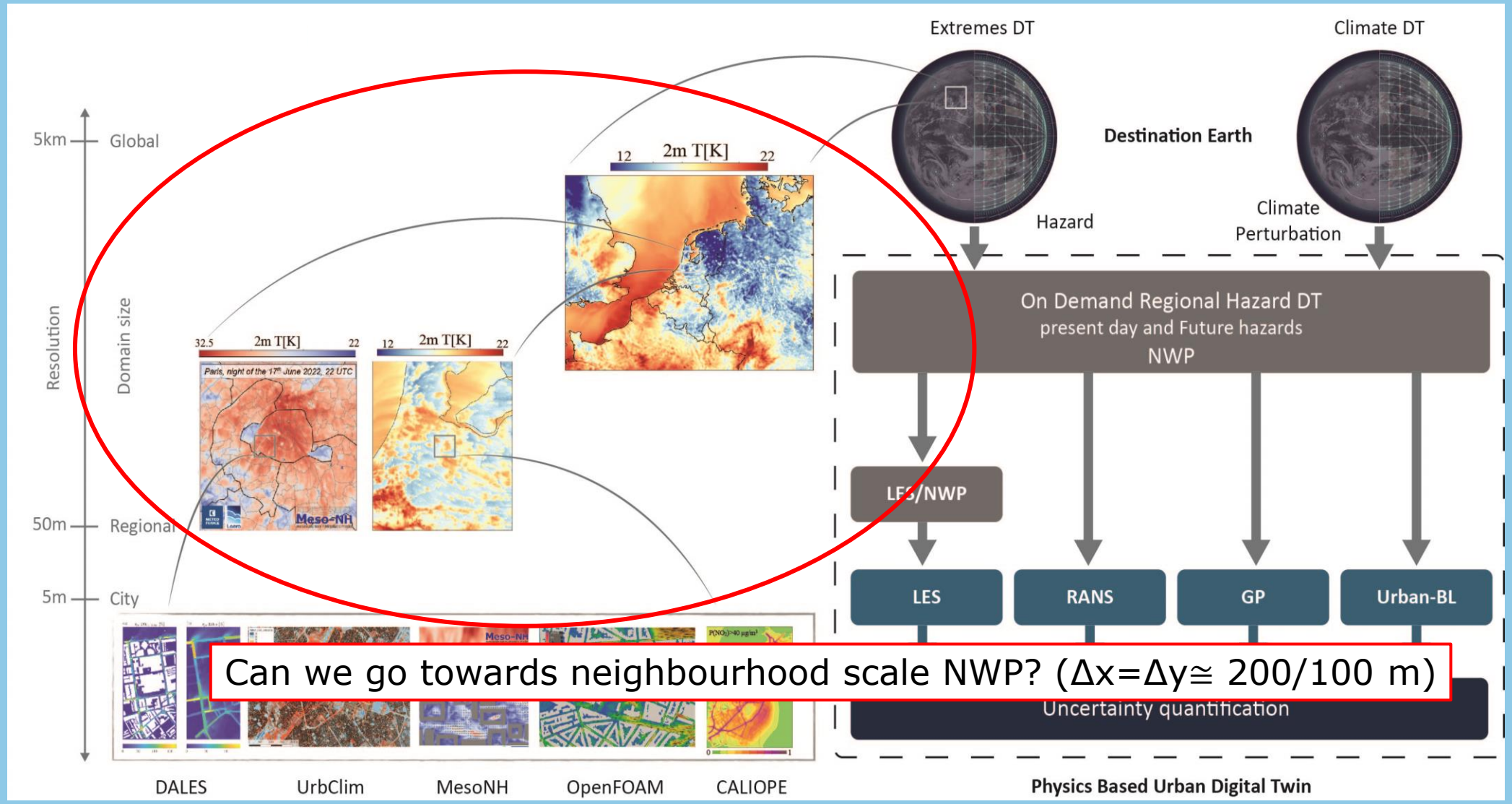
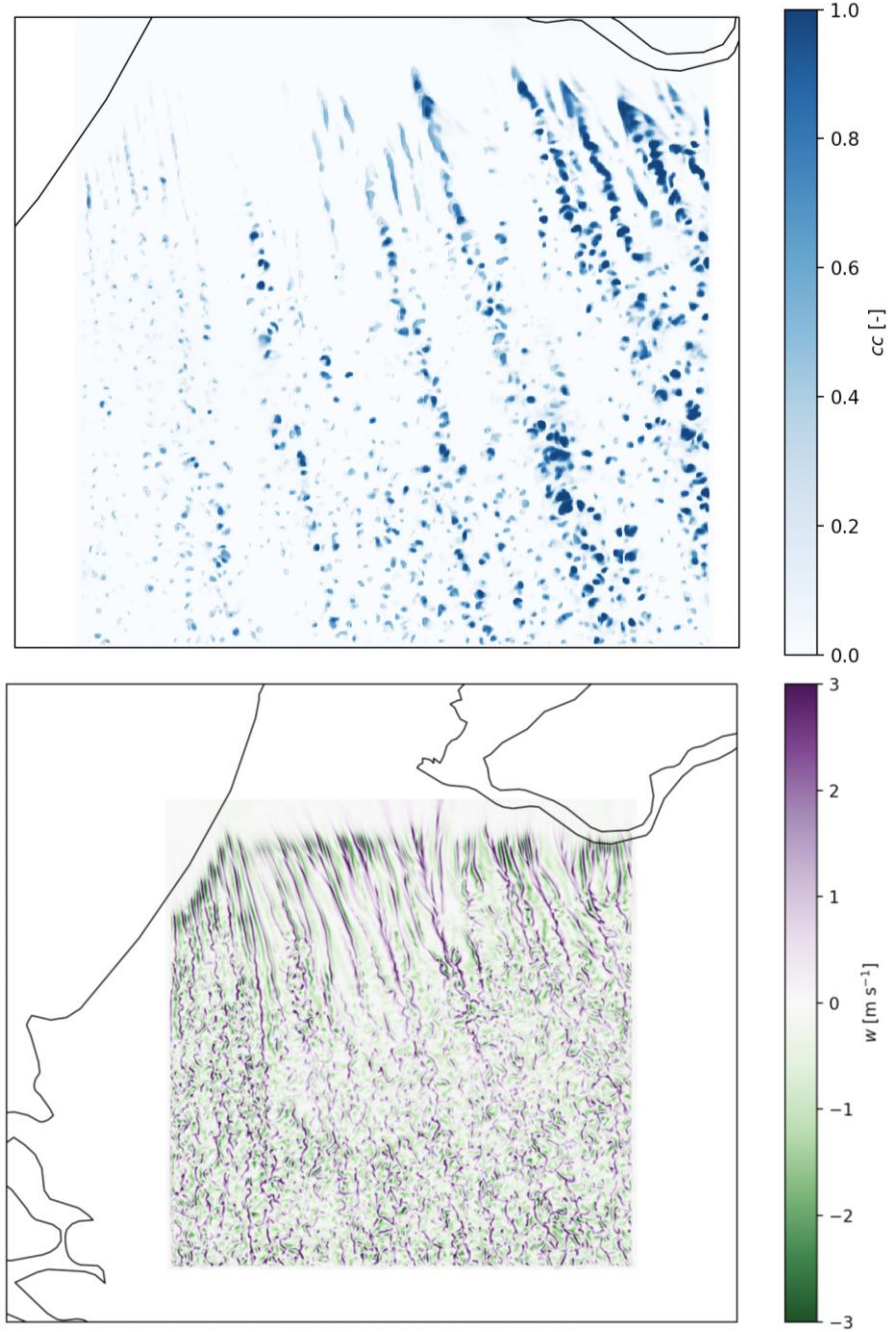


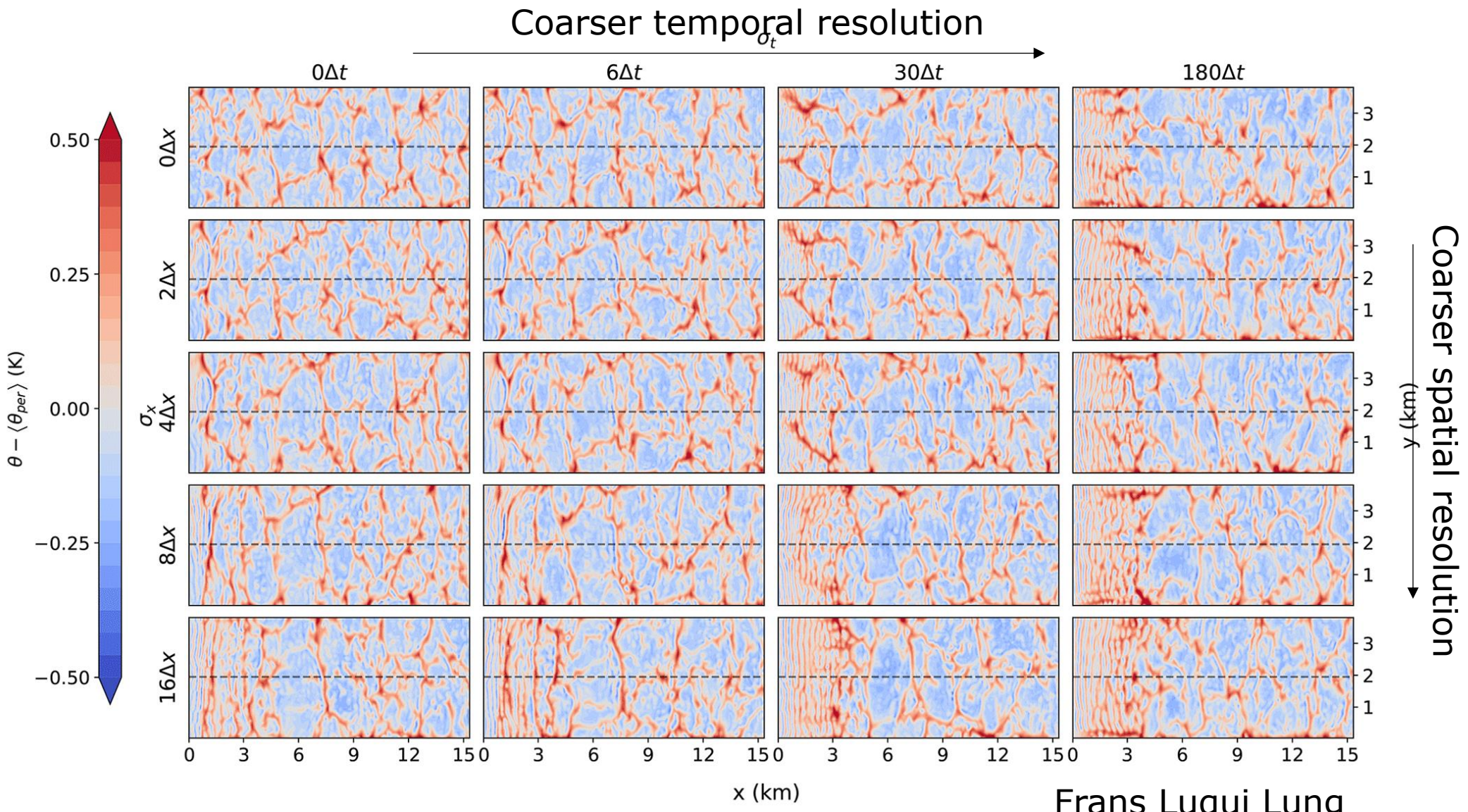
Can we go towards neighbourhood scale NWP? ($\Delta x=\Delta y \cong$ 200/100 m)

Spinup of convection and turbulence

- Loose >1/3rd of your domain due to this spinup
- Options to elevate this need to be explored
  - Coupling frequency
  - Synthetic turbulence/pertubations

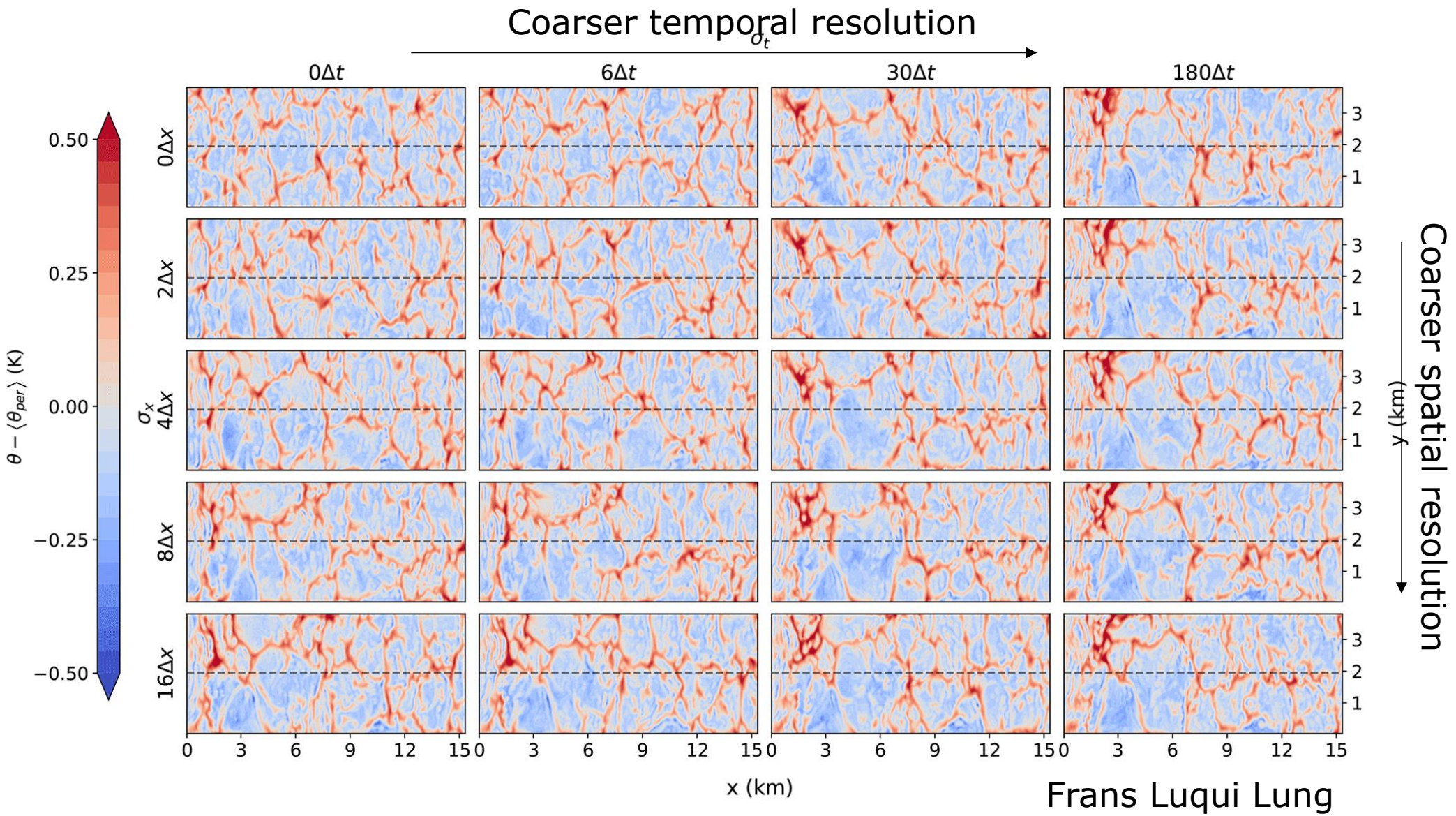


HARMONIE-AROME @100 m over Cabauw
16 July 2022



Frans Luqui Lung
Liqui Lung et al 2024 GMD

Adding synthetic turbulence



Frans Luqui Lung
Liqui Lung et al 2024 GMD

Spin-up of convection and turbulence

Starting from convective PBL theory:

- $e = \frac{1}{2}(\sigma_u^2 + \sigma_v^2 + \sigma_w^2)$
  - $\sigma_w^2 = f(z_i, z, Q_H)$ Lenschow, 1980
- $\sigma_\theta^2 = f(z_i, z, Q_H)$ Sorbjan, 1989
- $\sigma_u^2 = \sigma_v^2 = f(e, \sigma_w^2)$
- $t_* = \frac{z_i}{w_*}$
- $L \approx z_i$

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- Using the SPP infrastructure with the stochastic pattern generator (SPG)
- Applying a uniform distribution around zero scaling U/V/T
- Scaling with a normalized TKE (from the host model)
- Applied in ecoupl1.F90
- Including a change to change the width of the coupling zone runtime

Spin-up of convection and turbulence

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- $\sigma_u^2 = \sigma_v^2 = f(e, \sigma_w^2)$
- $t_* = \frac{z_i}{w_*}$ ~30 min
- $L \approx z_i$ ~1000 m

- Using the SPP infrastructure with the stochastic pattern generator (SPG)
- Applying a uniform distribution around zero scaling U/V/T
- Scaling with a normalized TKE (from the host model)
- Applied in ecoupl1.F90
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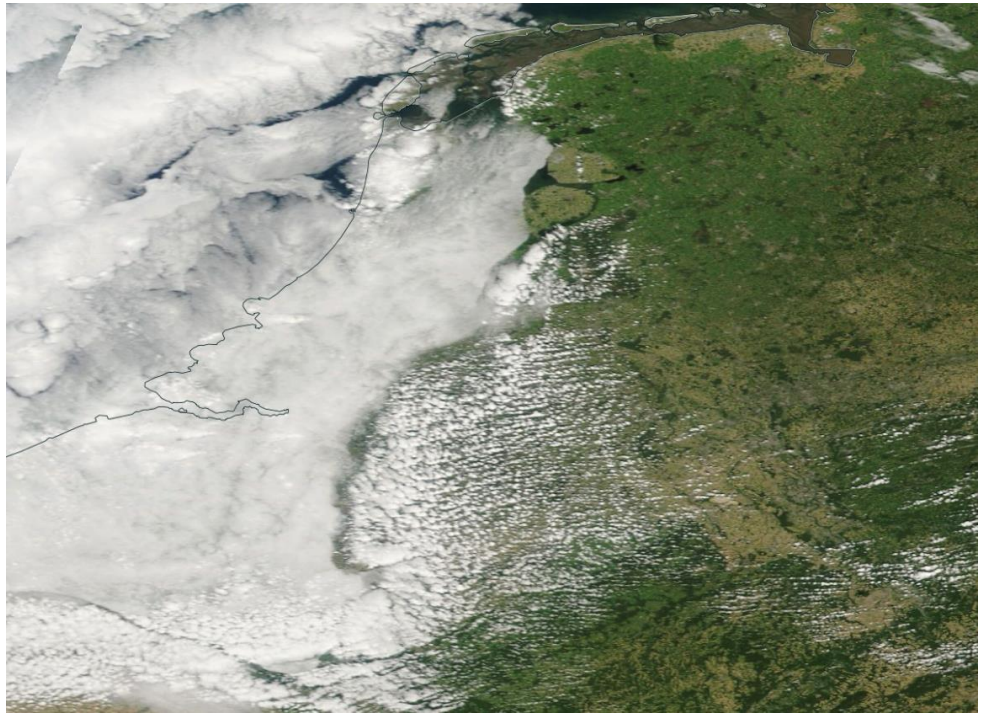
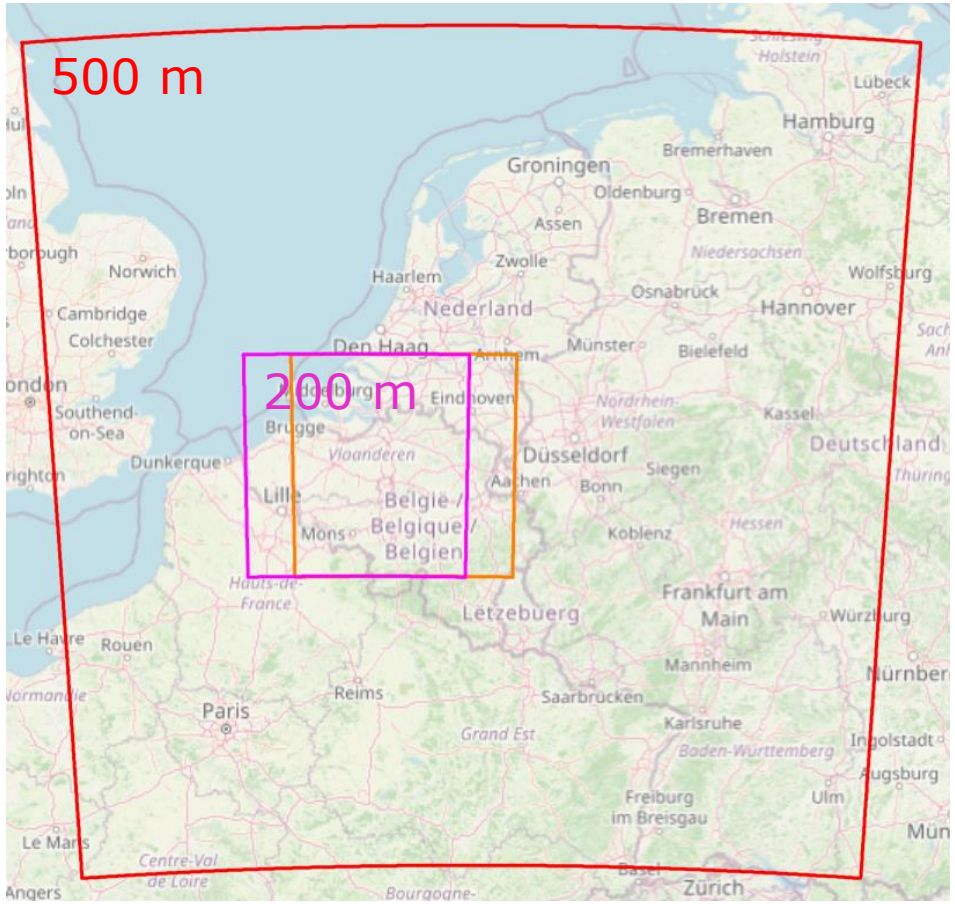


First test case

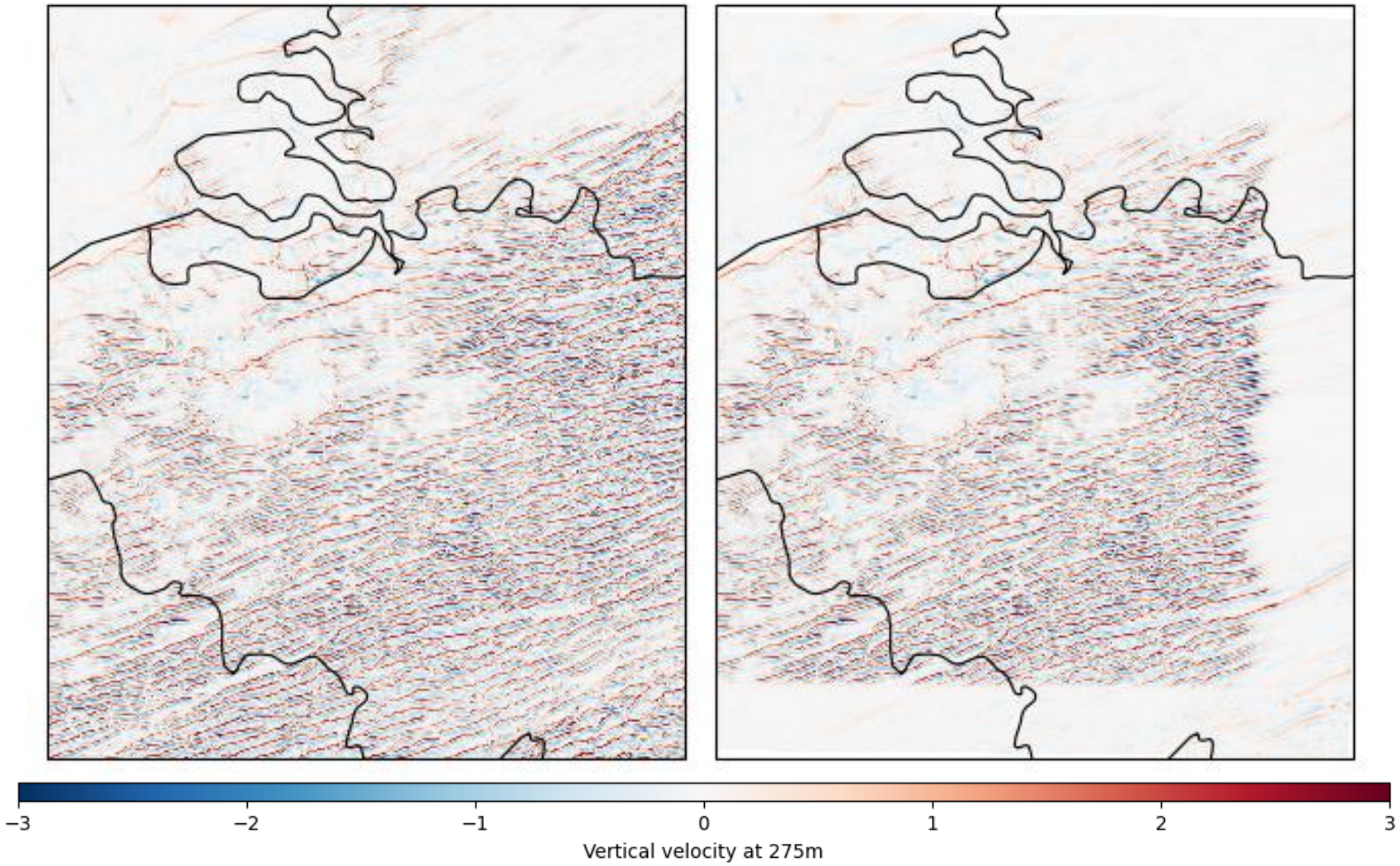


18 August 2025

Default experiments @ 200 m

Large reference domain

'Normal'-sized domain



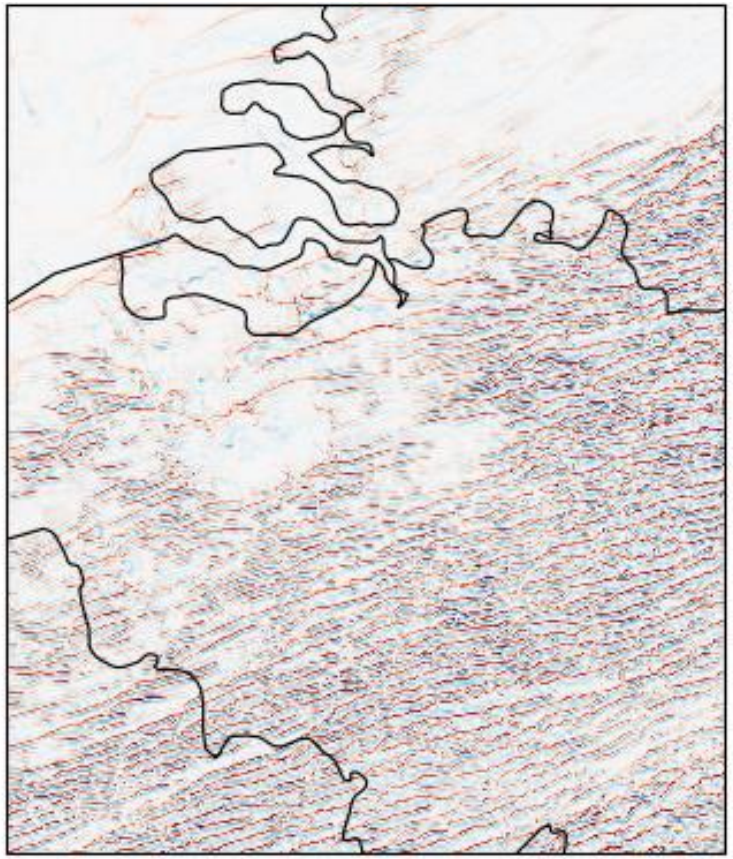
Set-up:

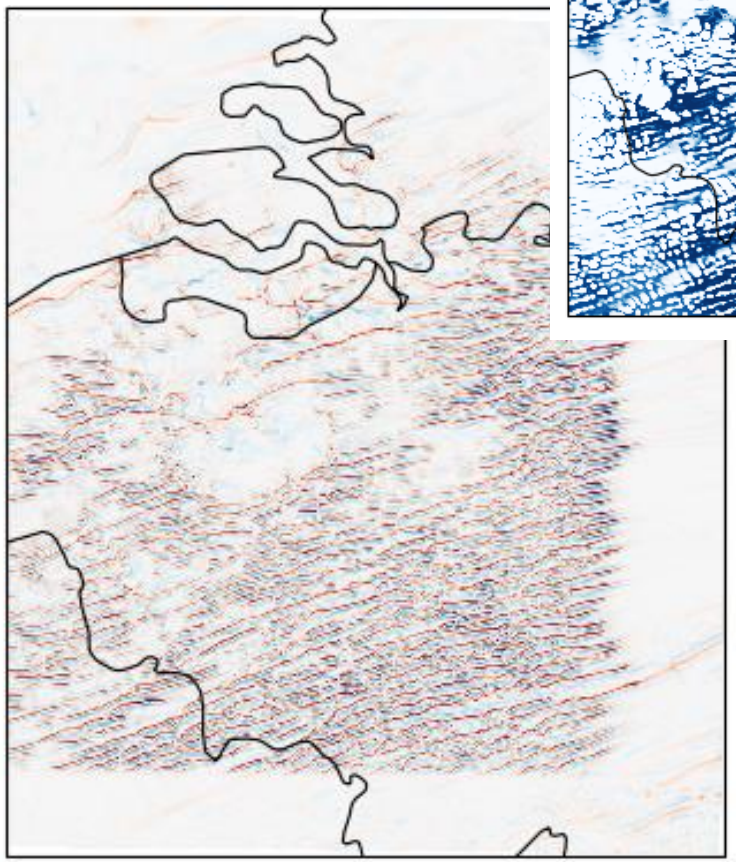
- HARMONIE-AROME O(200m)
- Scale-aware convection
- Hourly coupling

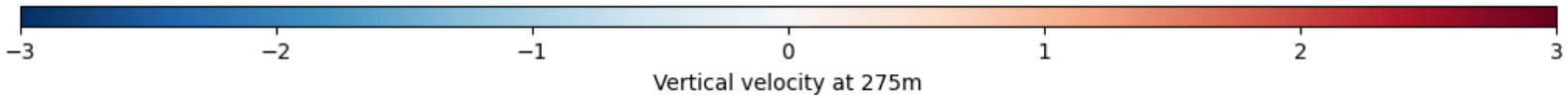
Default experiments @ 200 m

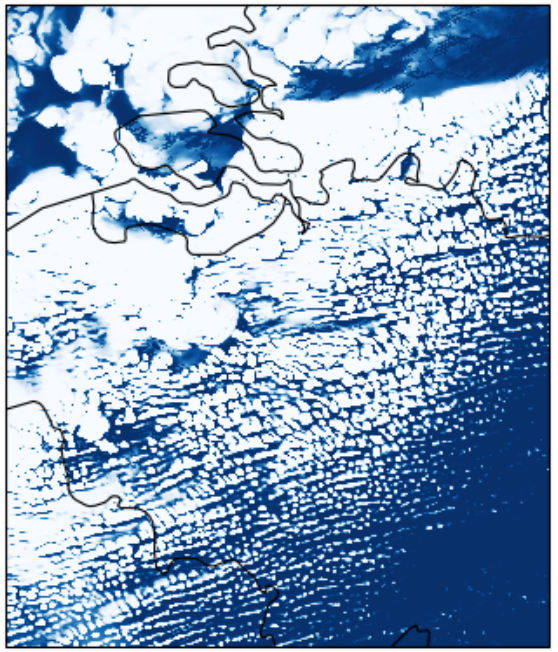
Large reference domain

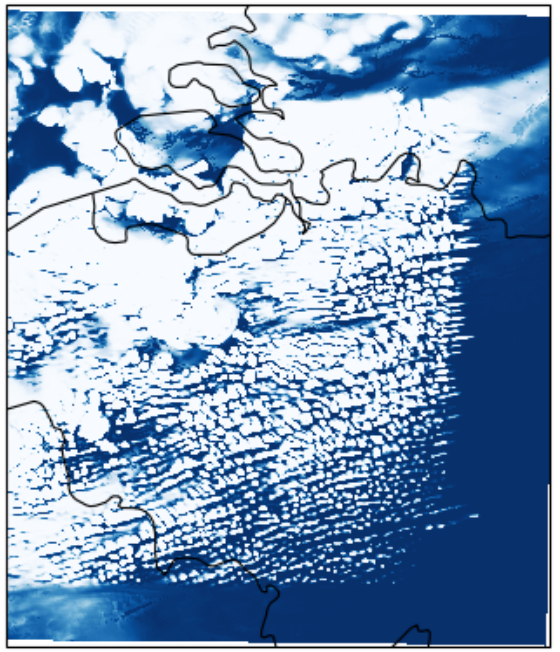
'Normal'-sized dom











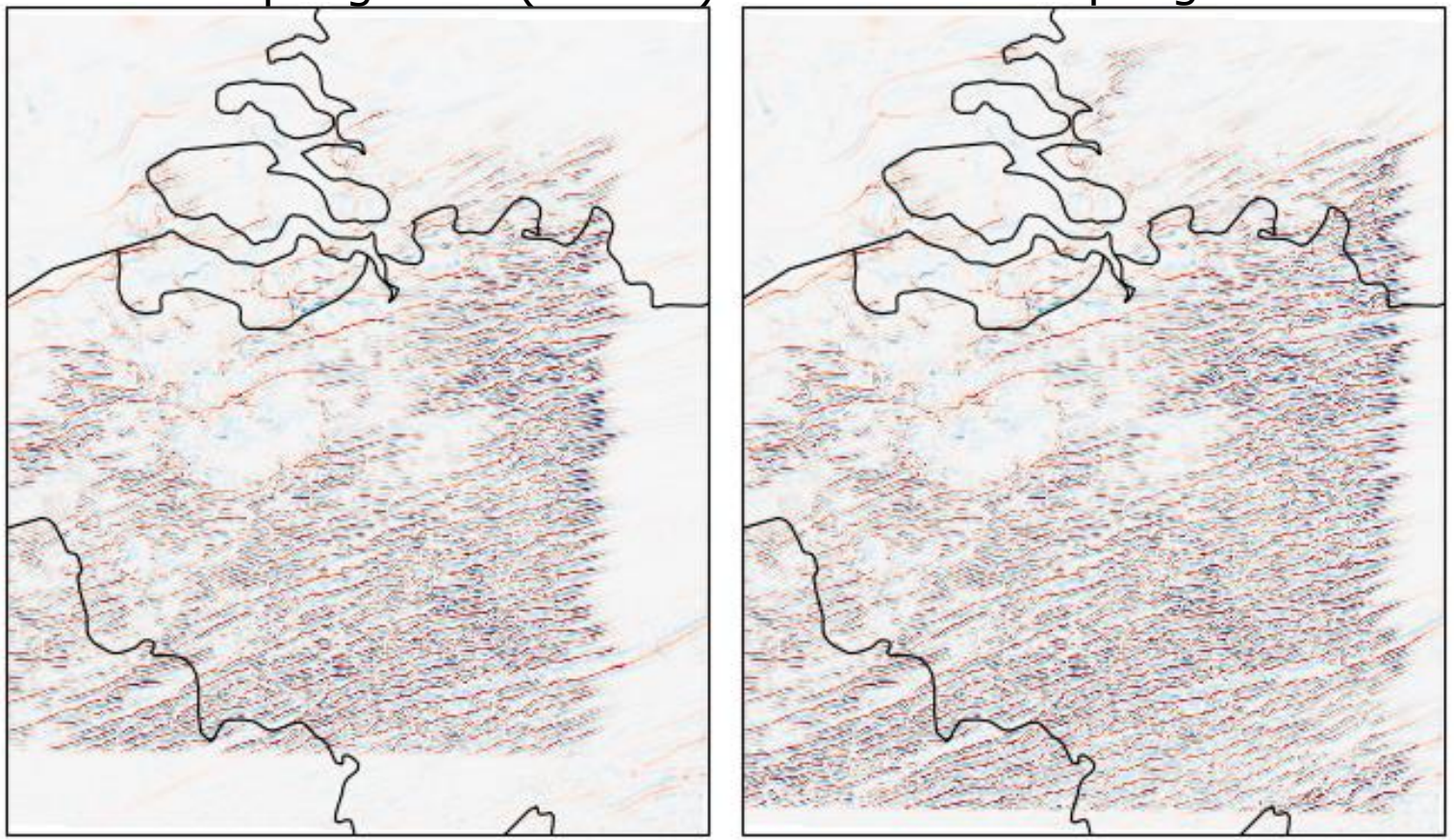
Set-up:

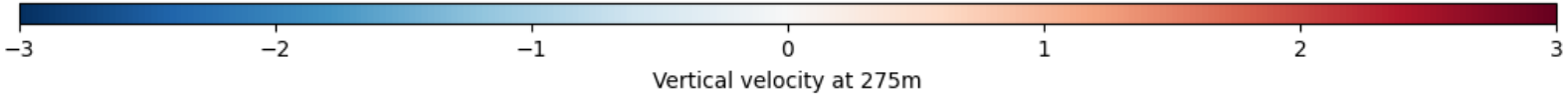
- HARMONIE-AROME O(200m)
- Scale-aware convection
- Hourly coupling

Reducing the coupling zone

20-km coupling zone (default)

5-km coupling zone



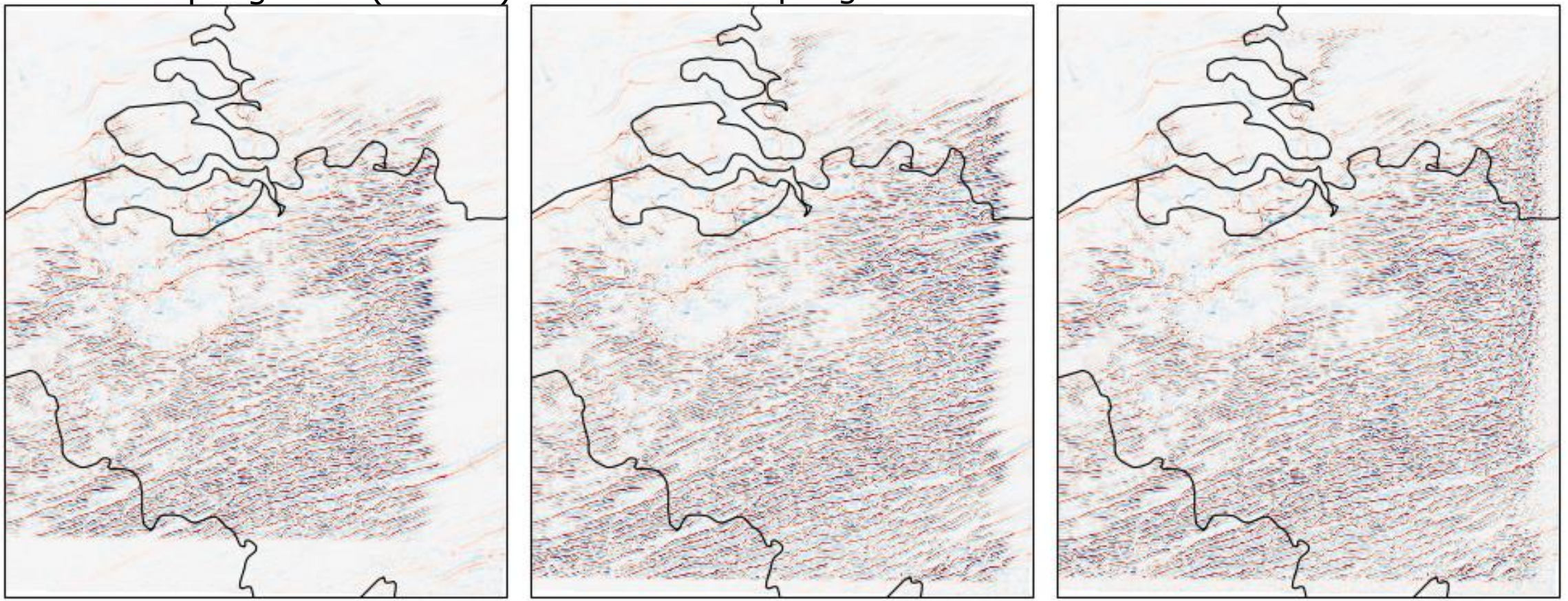


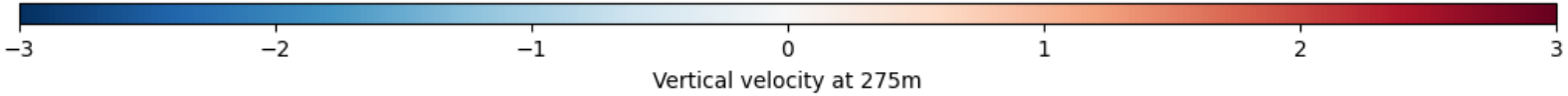
Adding white noise at the boundaries

20-km coupling zone (default)

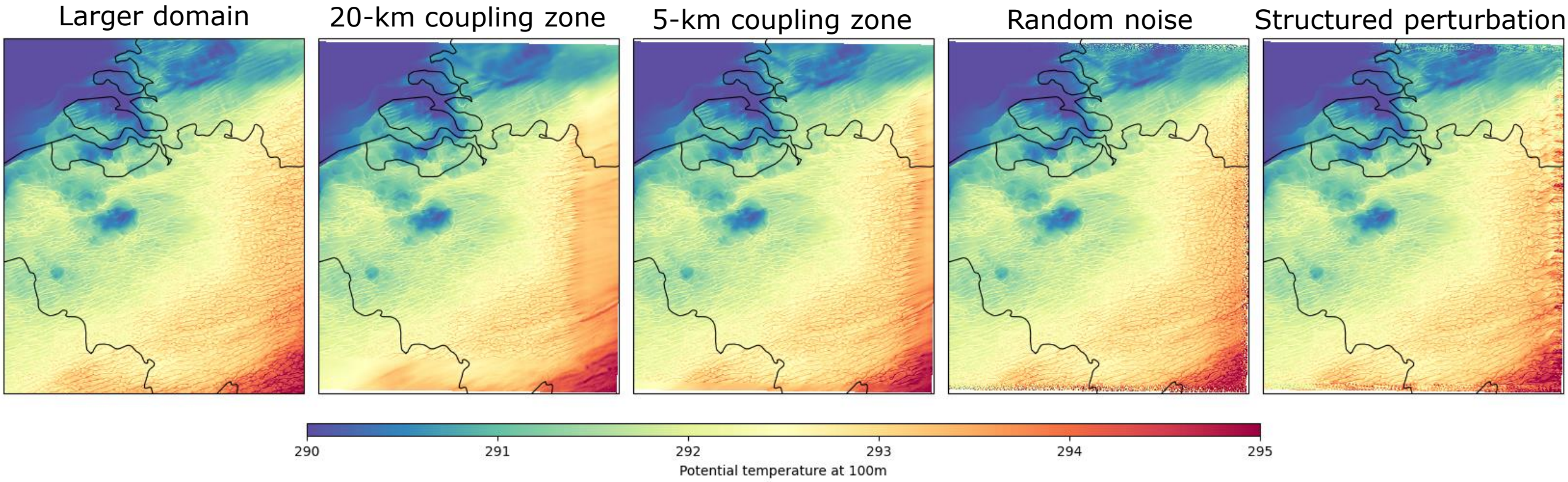
5-km coupling zone

Random noise

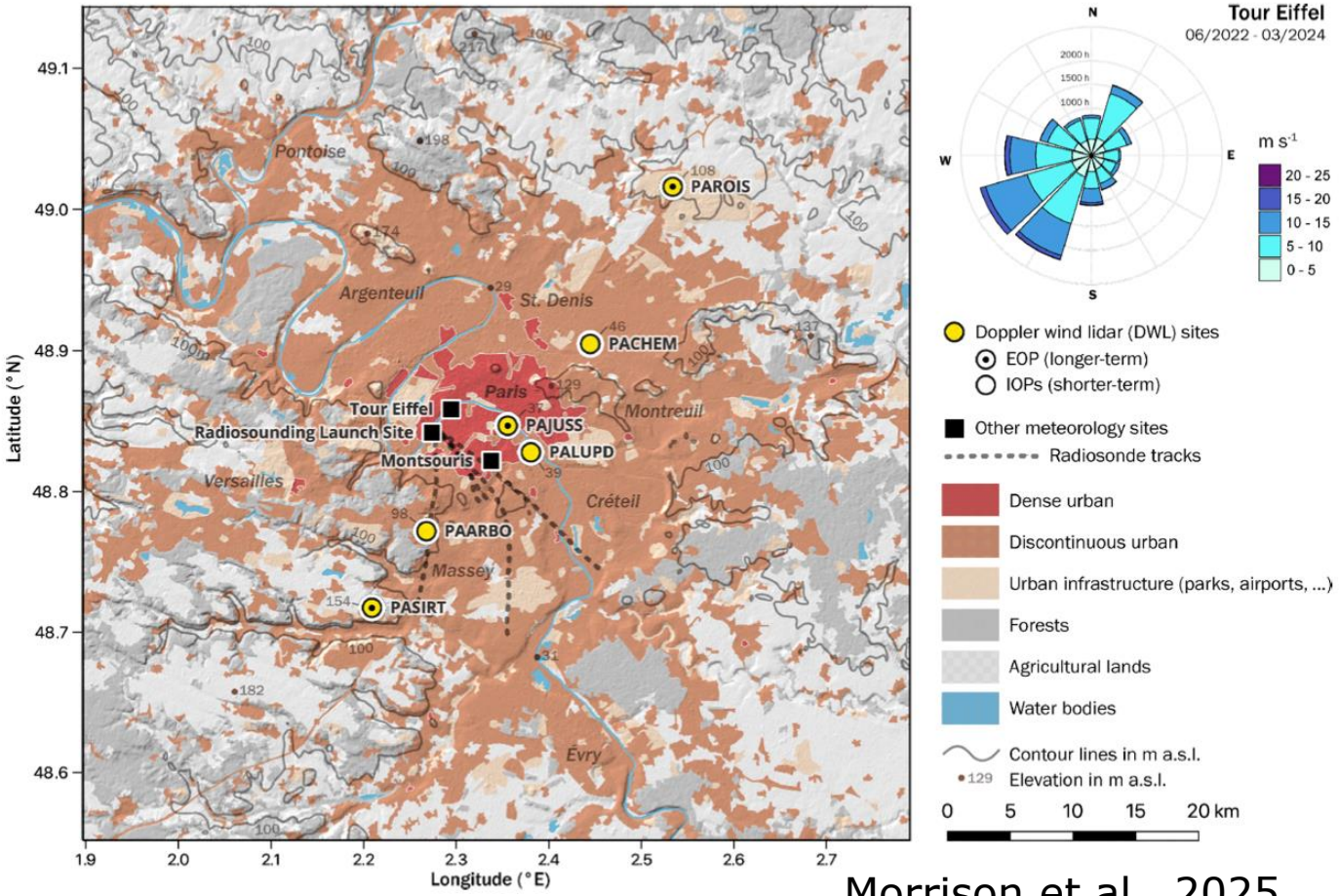




Adding perturbations

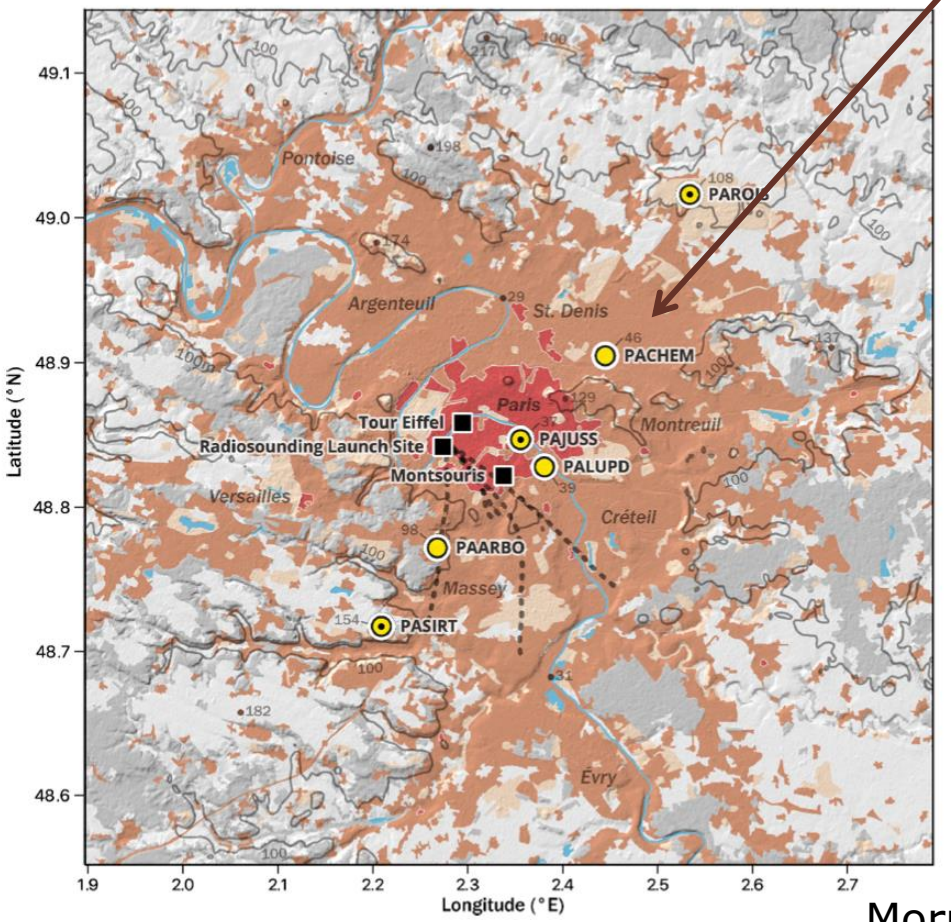


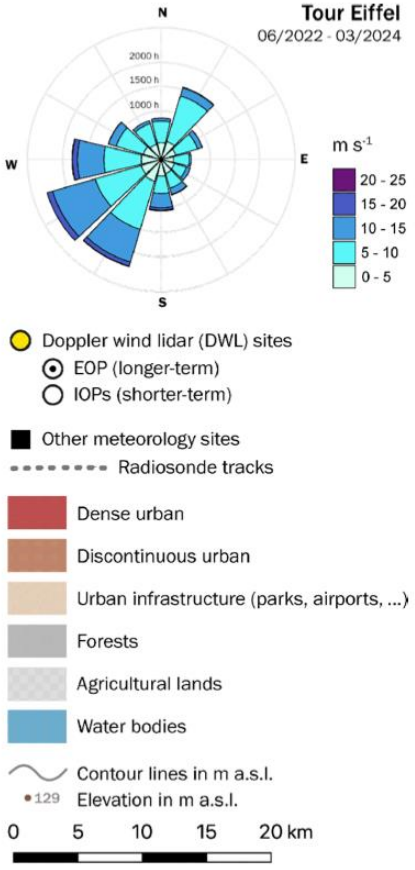
Observational campaign in Paris

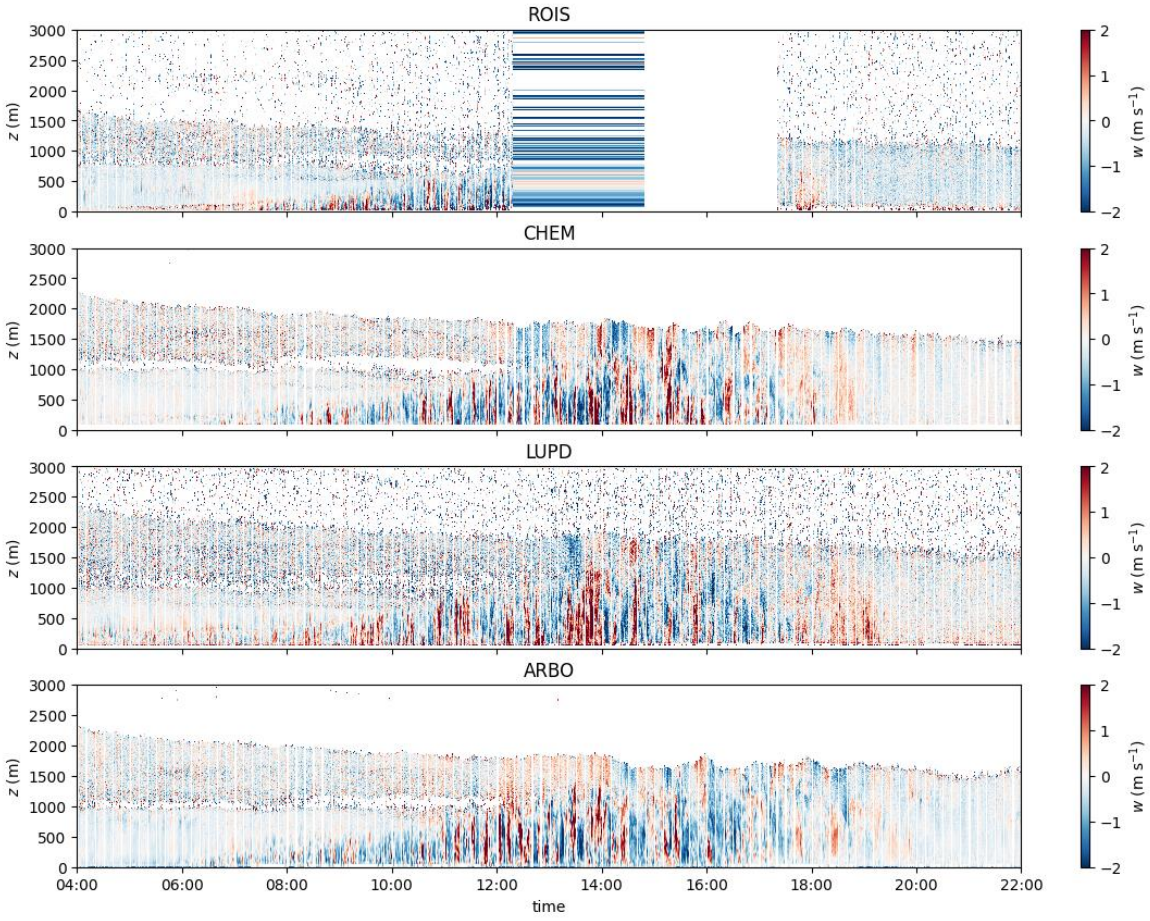


Morrison et al., 2025

Observational campaign in Paris

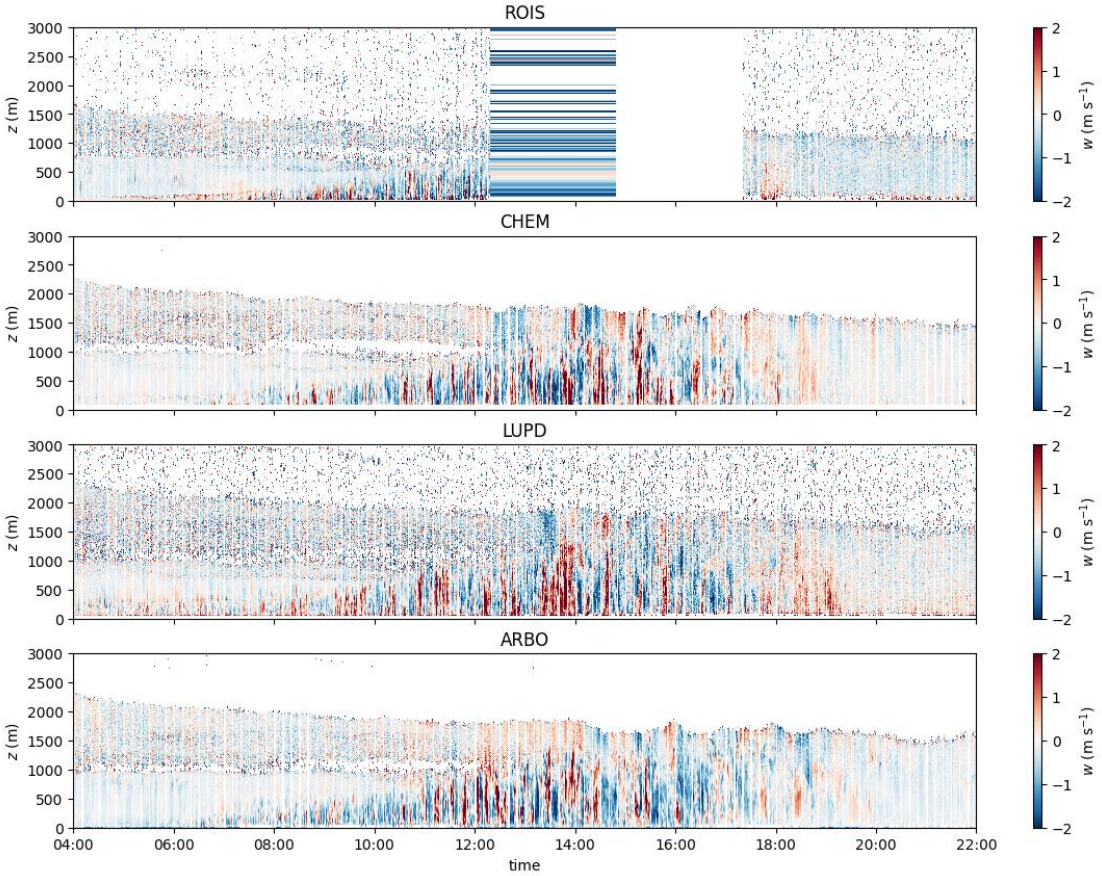


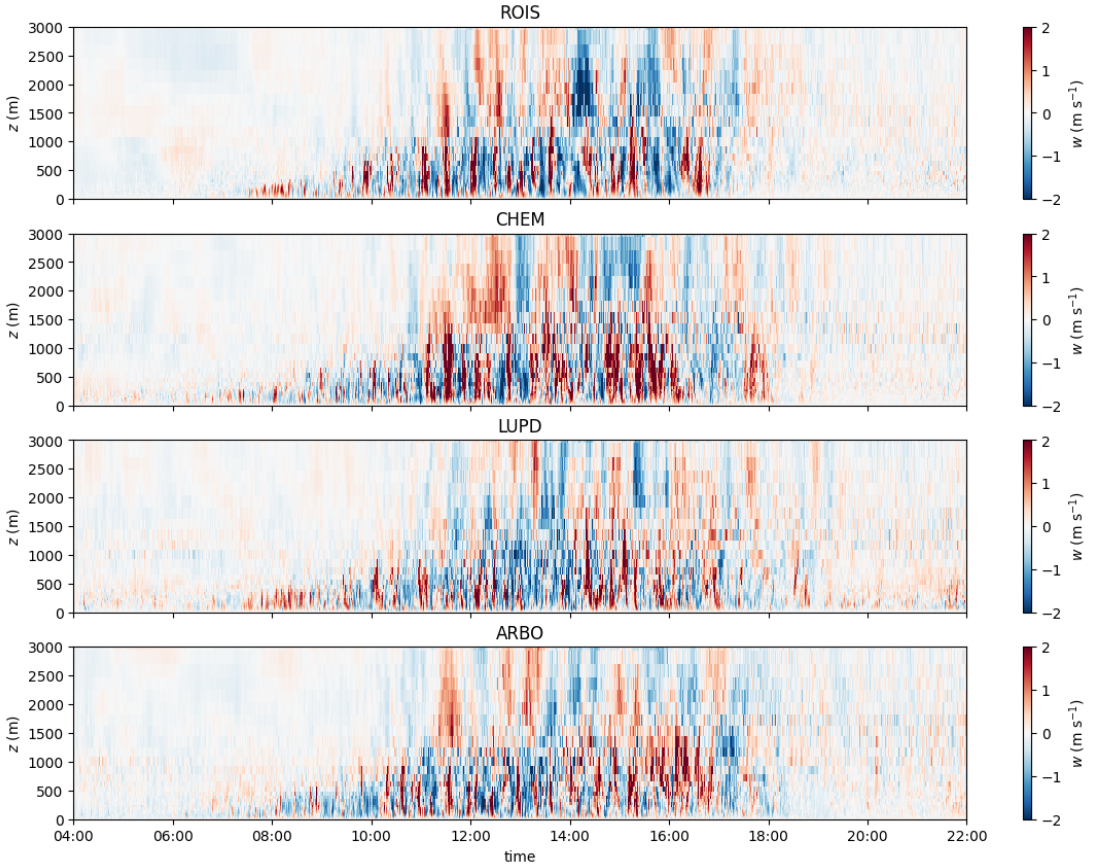




Morrison et al., 2025

Vertical velocities from measurements and models

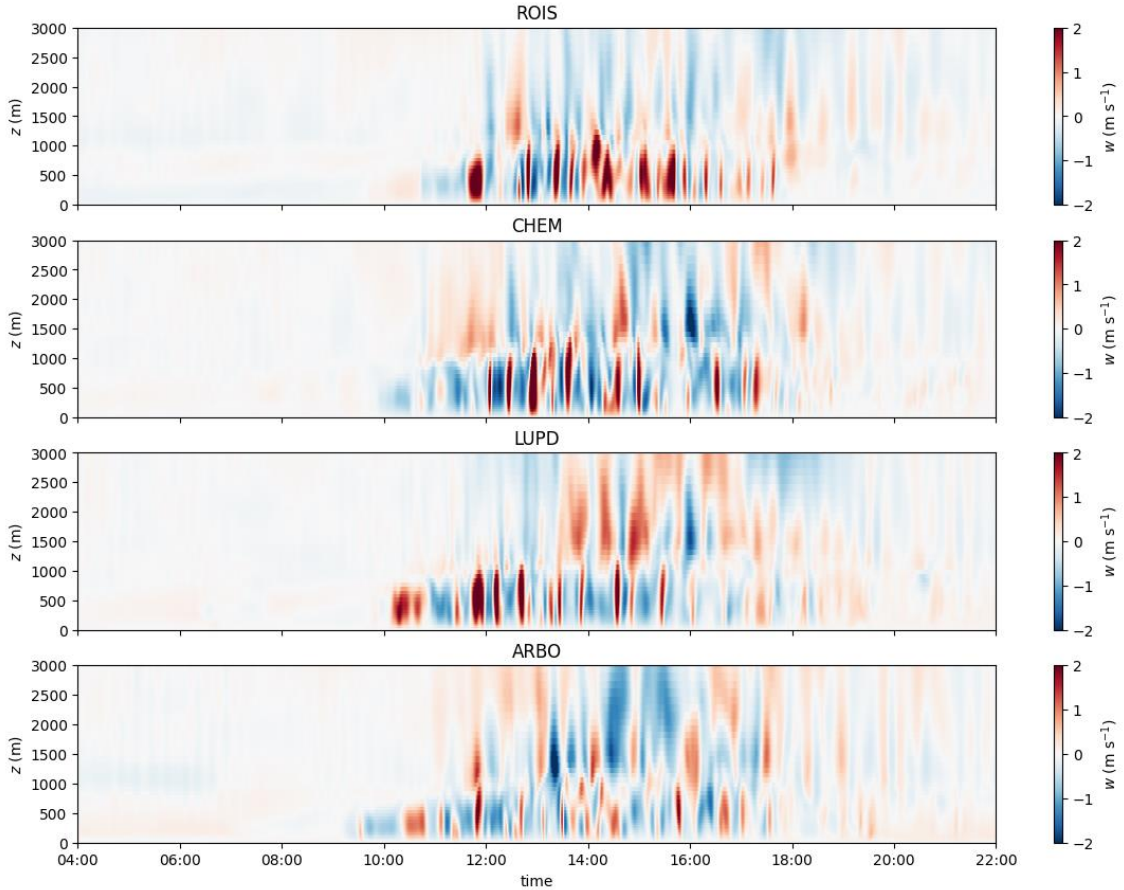


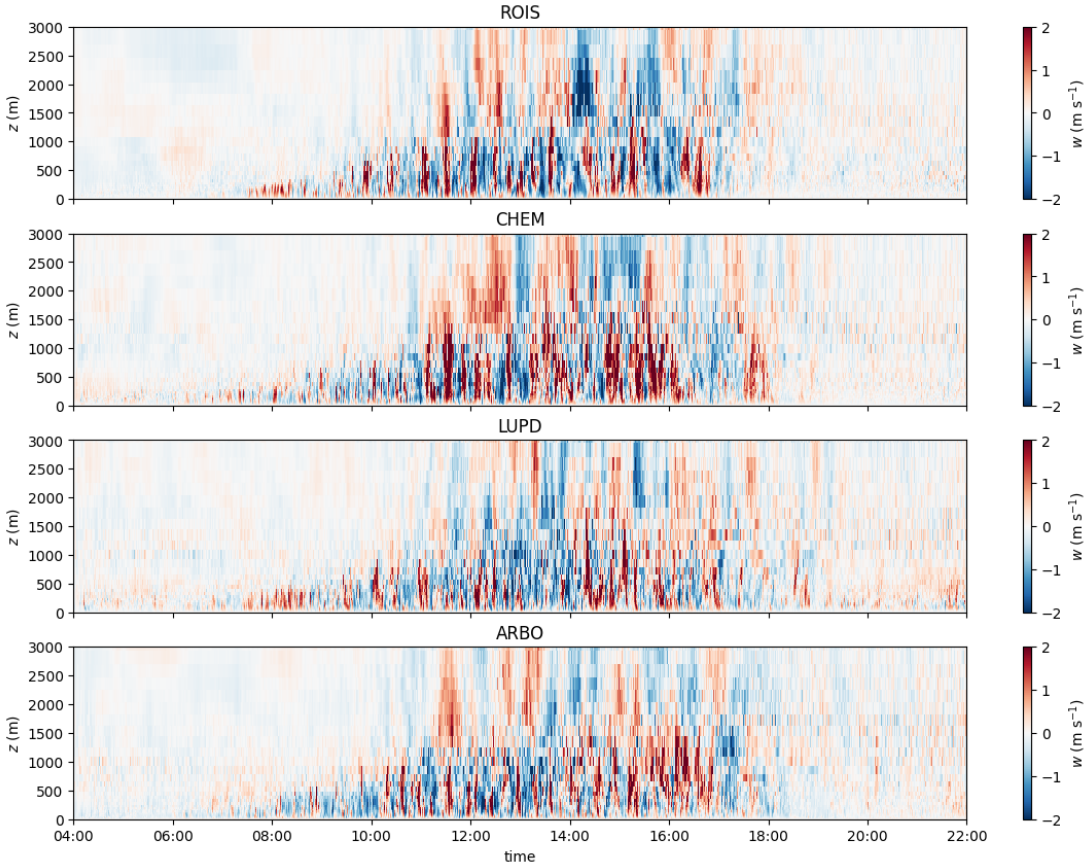


Doppler lidar measurement @ 1 Hz

MesoNH simulations @ O(50m) and 1.33 Hz

Vertical velocities from measurements and models



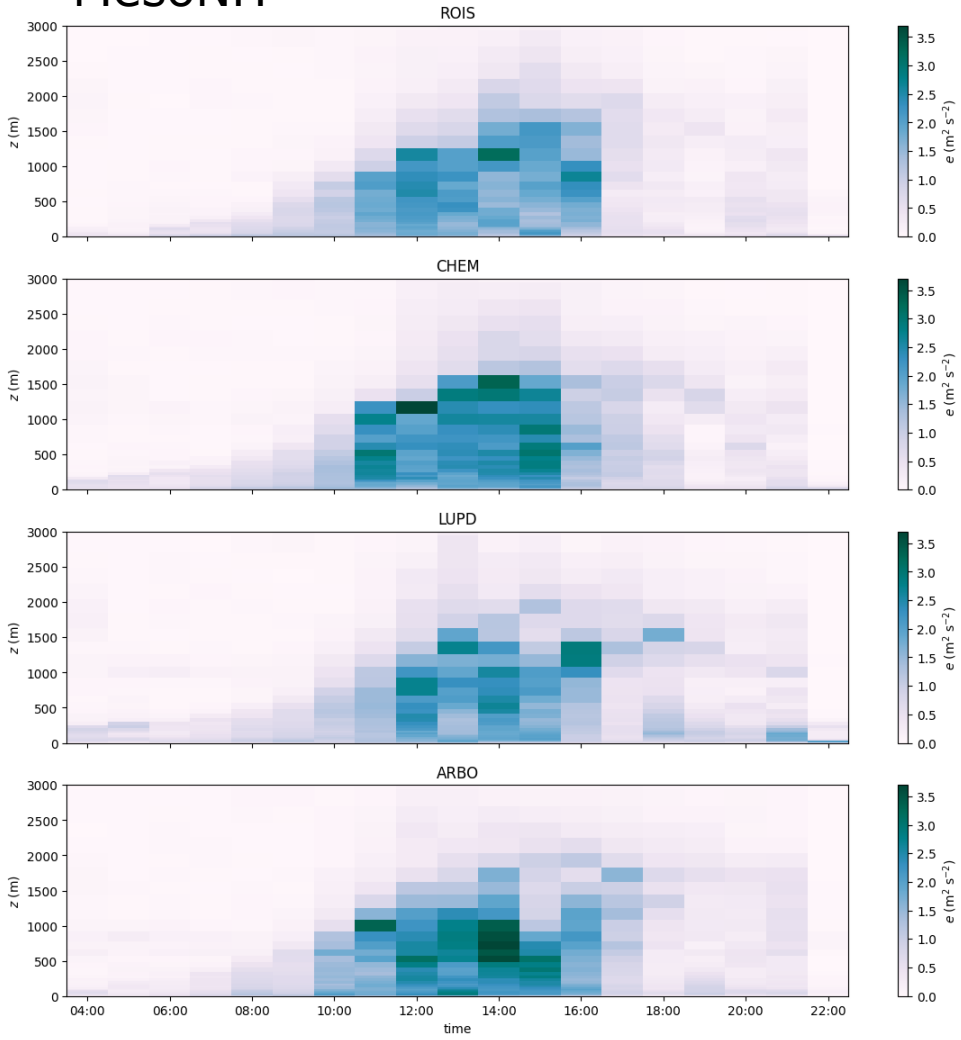


HARMONIE-AROME @ O(200m) and 0.2 Hz

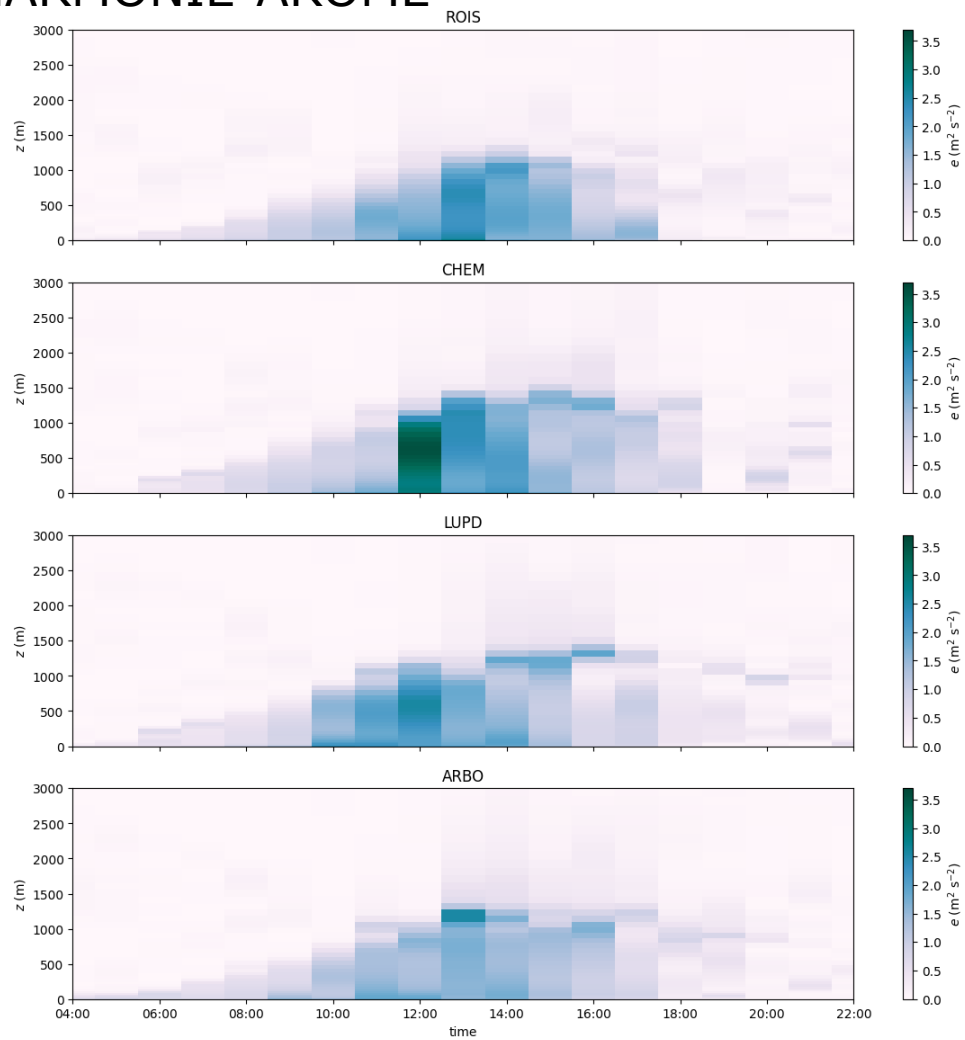
MesoNH simulations @ O(50m) and 1.33 Hz

Turbulent Kinetic Energy: parameterised + resolved

MesoNH



HARMONIE-AROME



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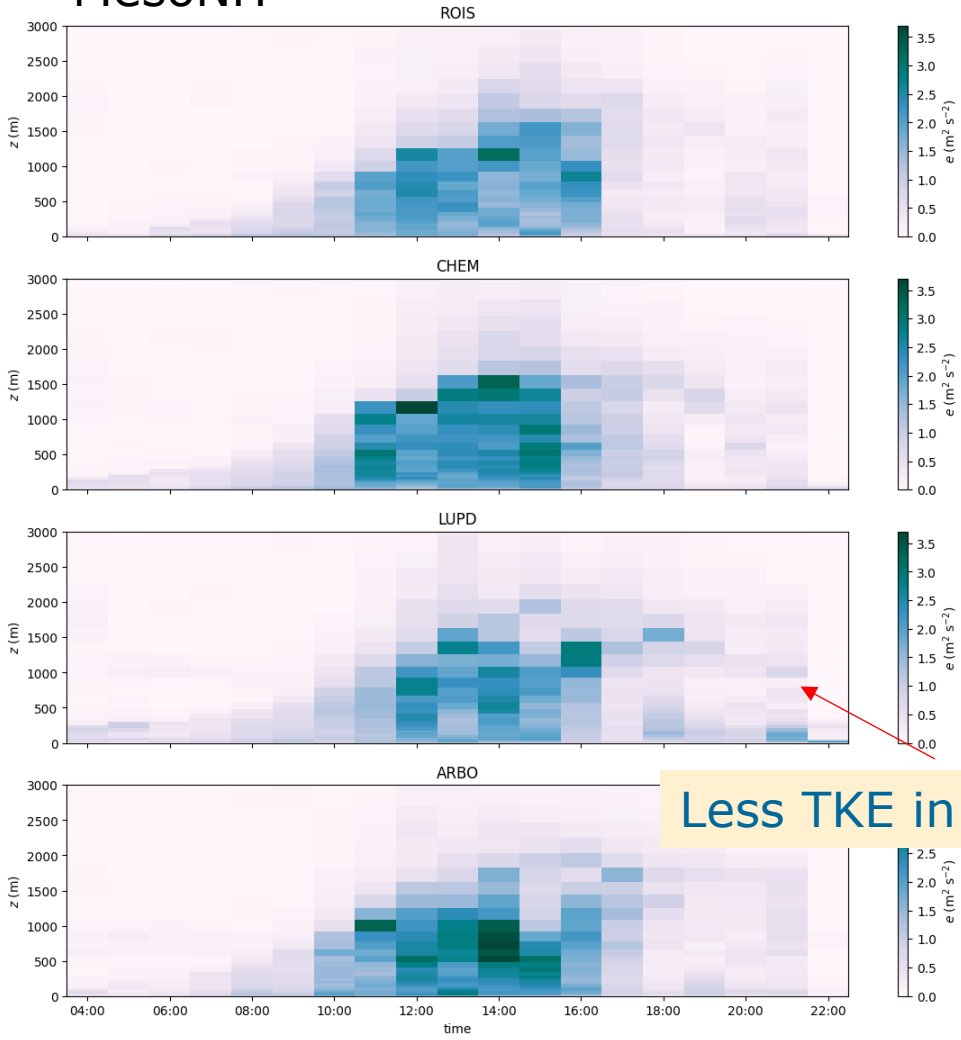

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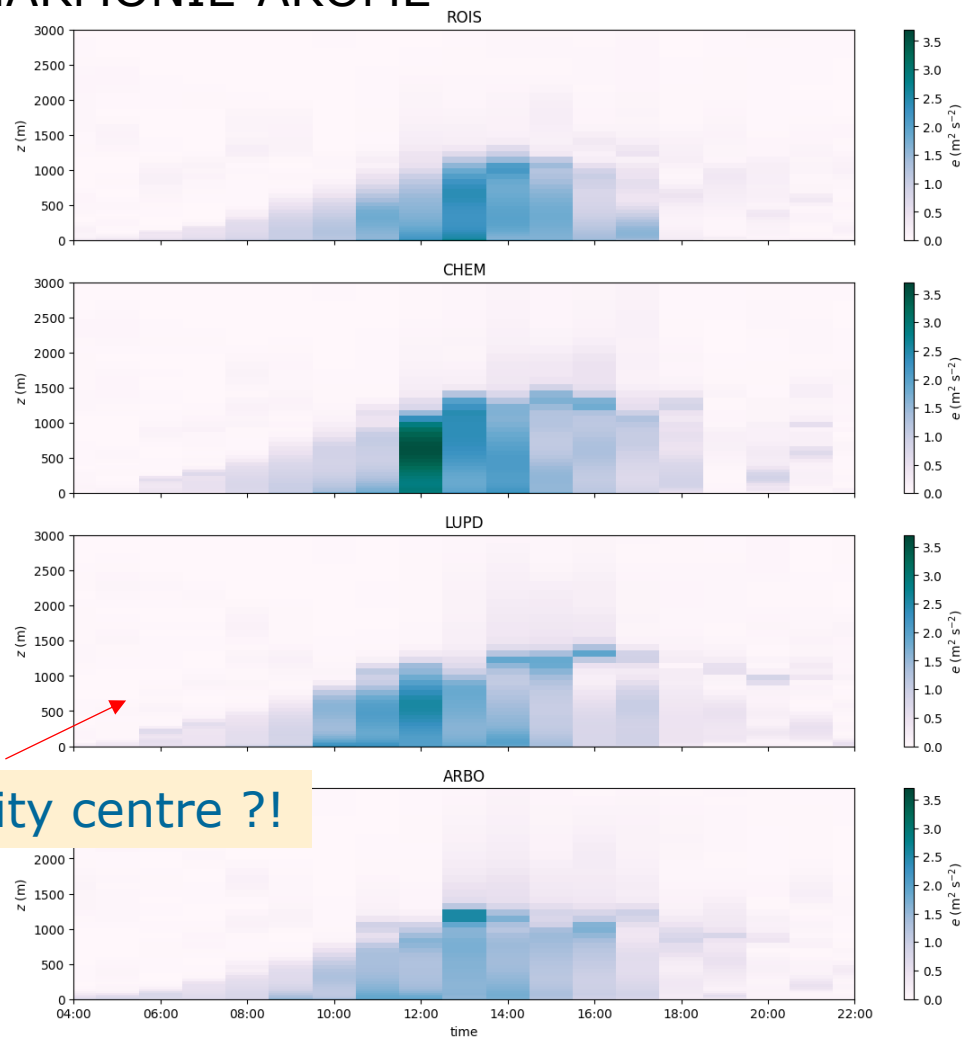
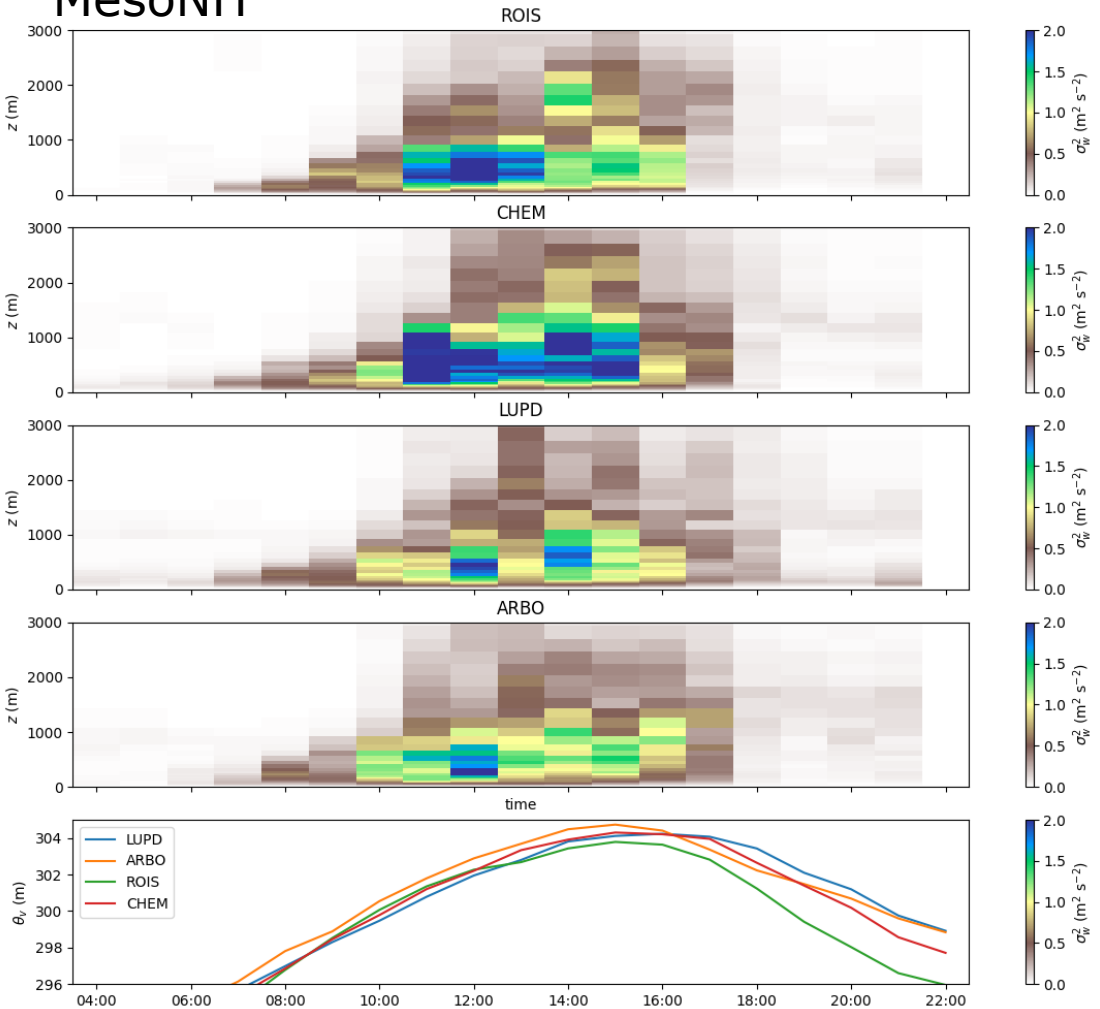


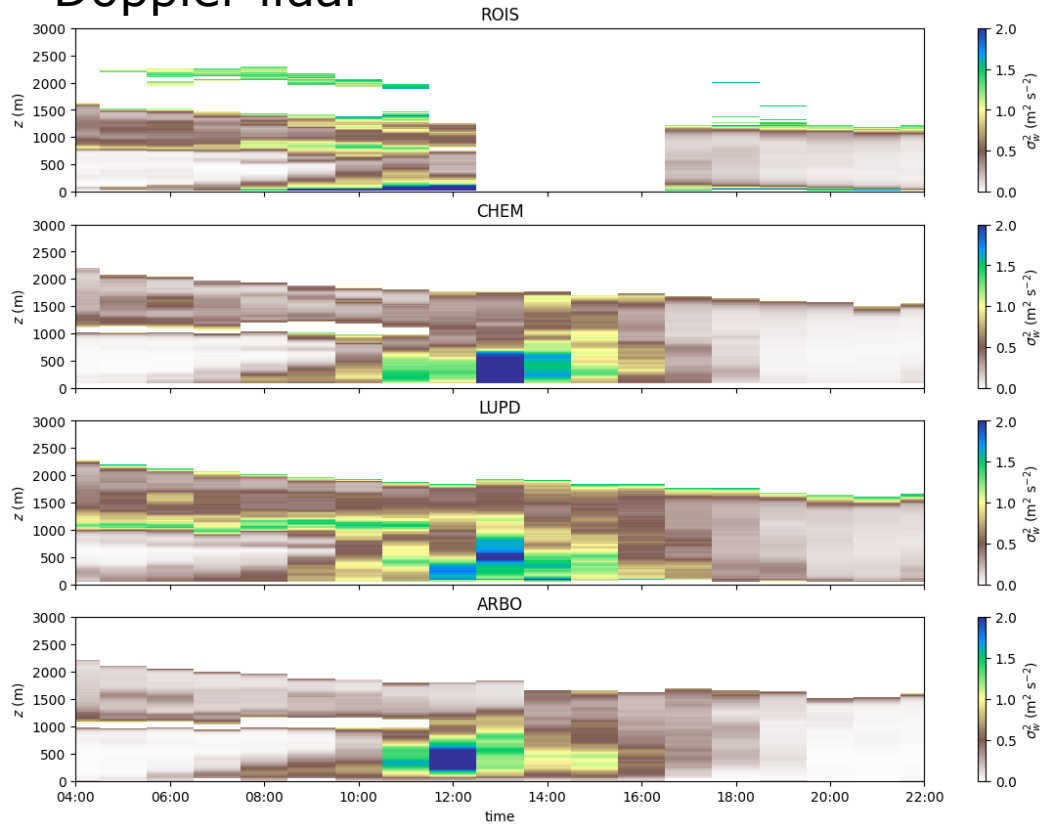
Less TKE in the city centre ?!

Comparison of the vertical velocity variance with

MesoNH

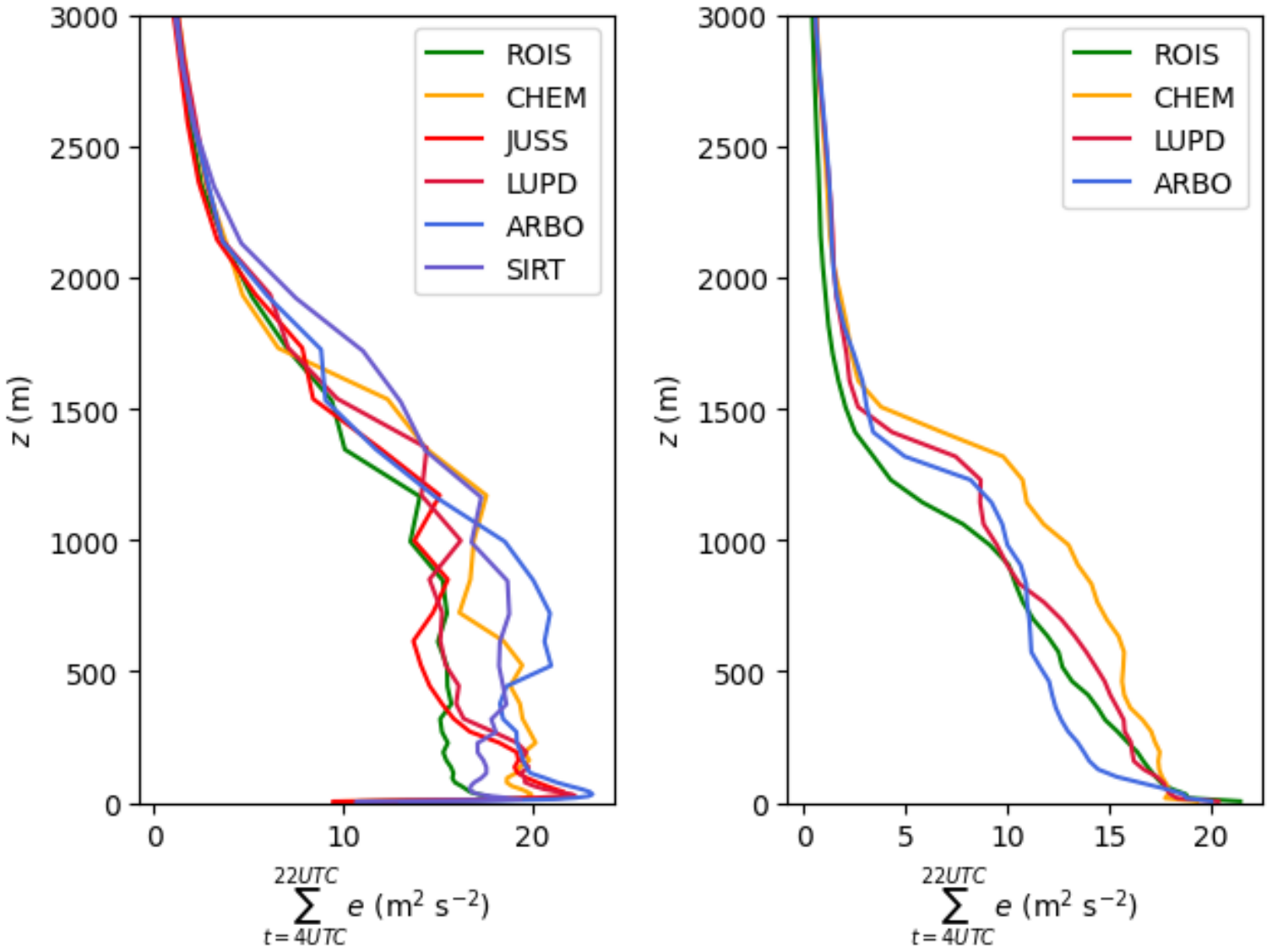


Doppler lidar



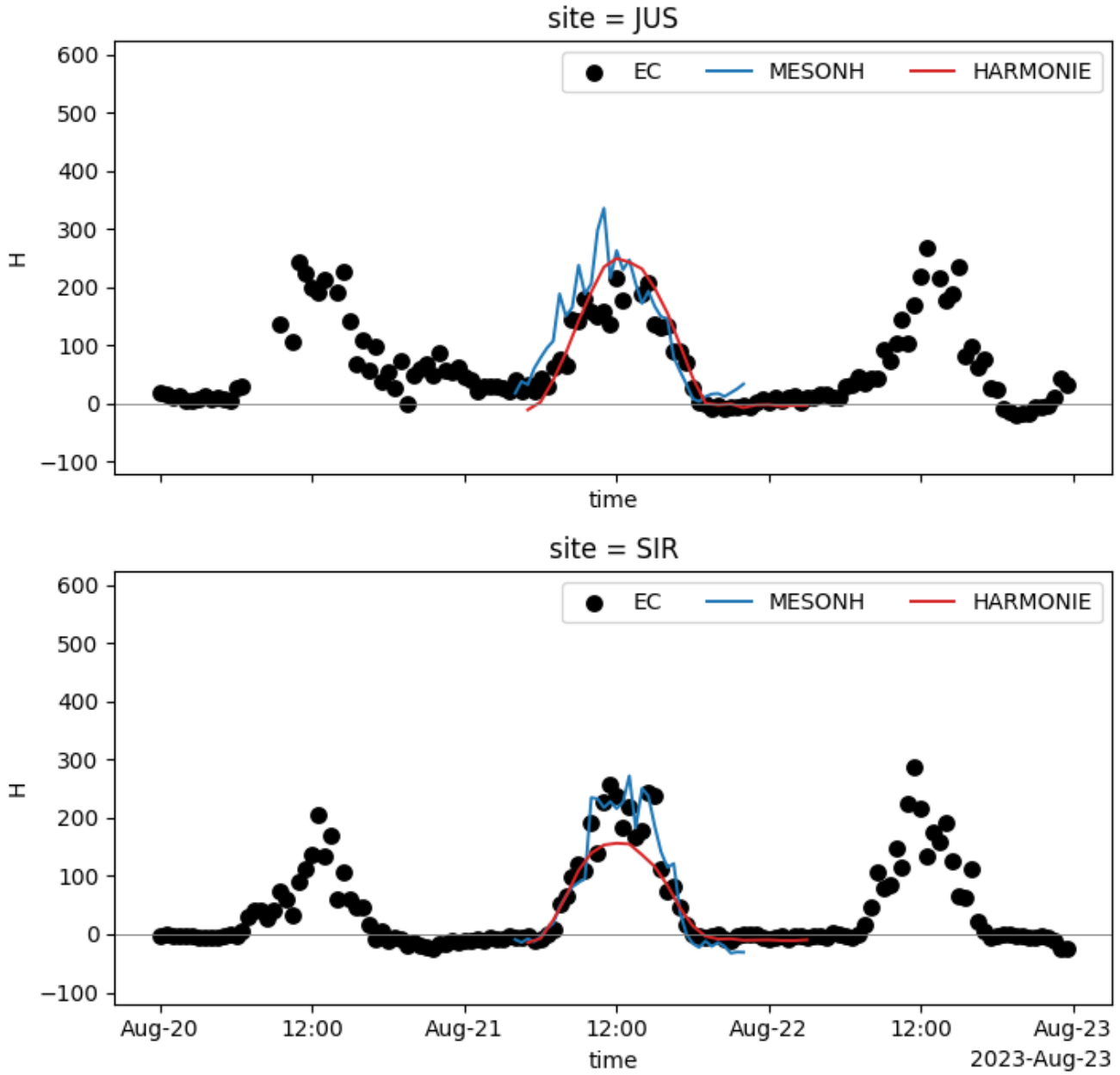
Sum of TKE over the day

- Extra urban site (mesoNH) shows similar behaviour
- TKE urban site H-A higher TKE sum than in meseoNH
- H-A does not capture the urban plume,
- Urban plume seen in mesoNH and measurements



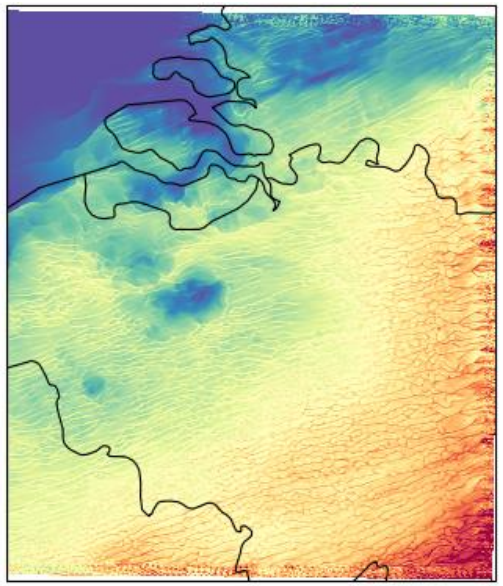
Energy balance

- Sensible heat fluxes:
  - Central urban site (top)
  - Downwind site (bottom)
- Both sites have similar magnitude during day
- Both models do very well!
- Missing buoyancy help explain missing TKE?



Summary

- Reducing boundary spin-up needed at O(200m)
- Reducing coupling zone
- Adding perturbations of u,v,T
  - Structure size, timescale and magnitude from convective PBL theory
- <u>Next steps</u>
  - More verification
  - Are we not creating inconstancies?
  - Other regimes?



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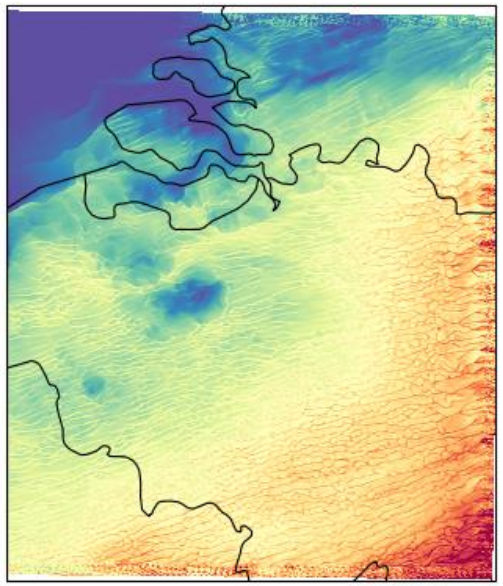
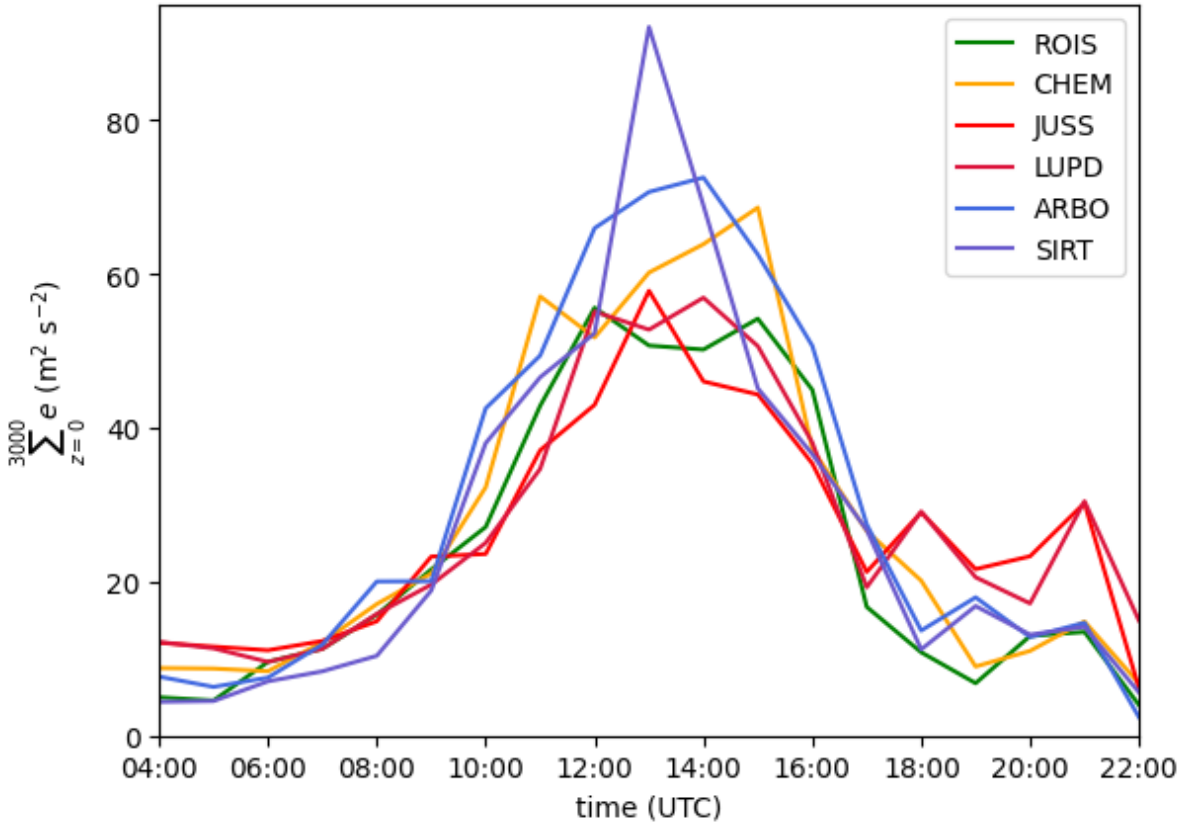


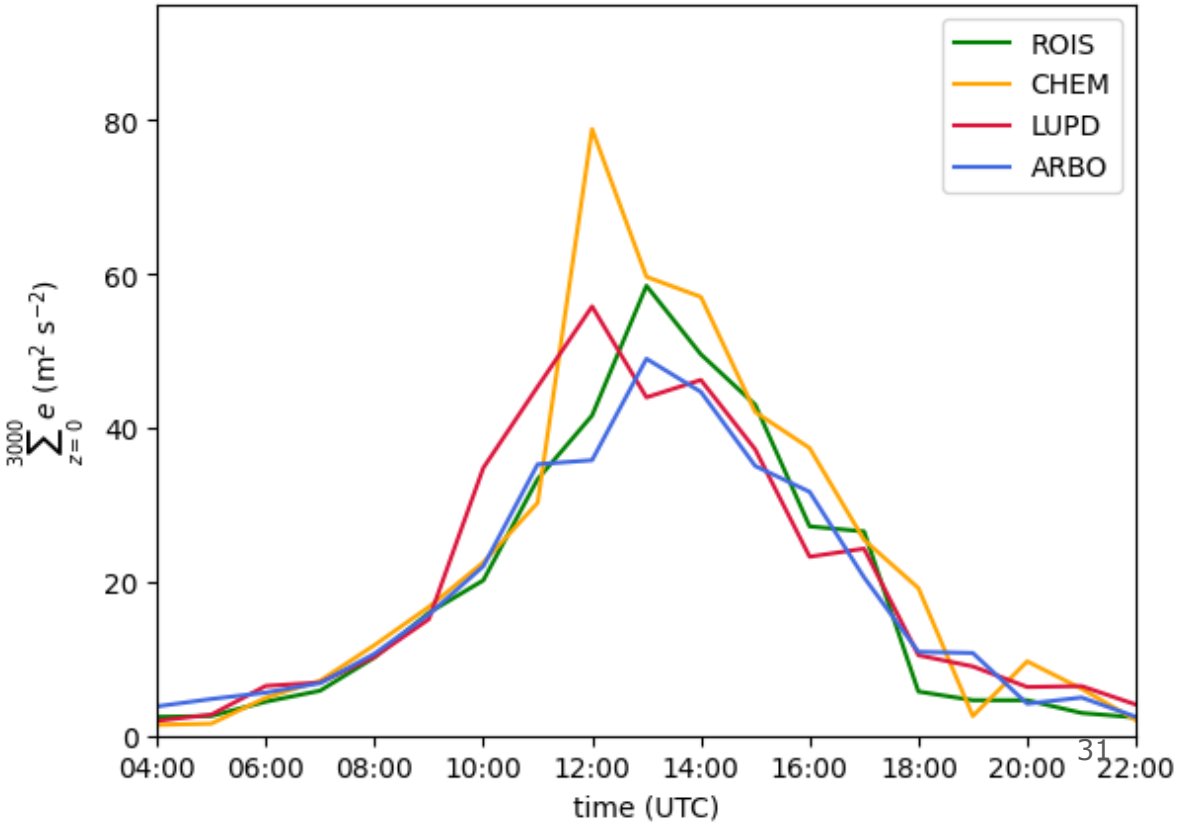
- <u>Case of the missing turbulence…</u>
- Comparison between measurements, LES, and NWP valuable to evaluate processes
- Urban plume missing in NWP

  Multilayer urban scheme?
- Missing buoyancy help explain missing TKE?
- This is not the full story … yet…

Backup stuff

Diurnal cycle of vertically summed TKE





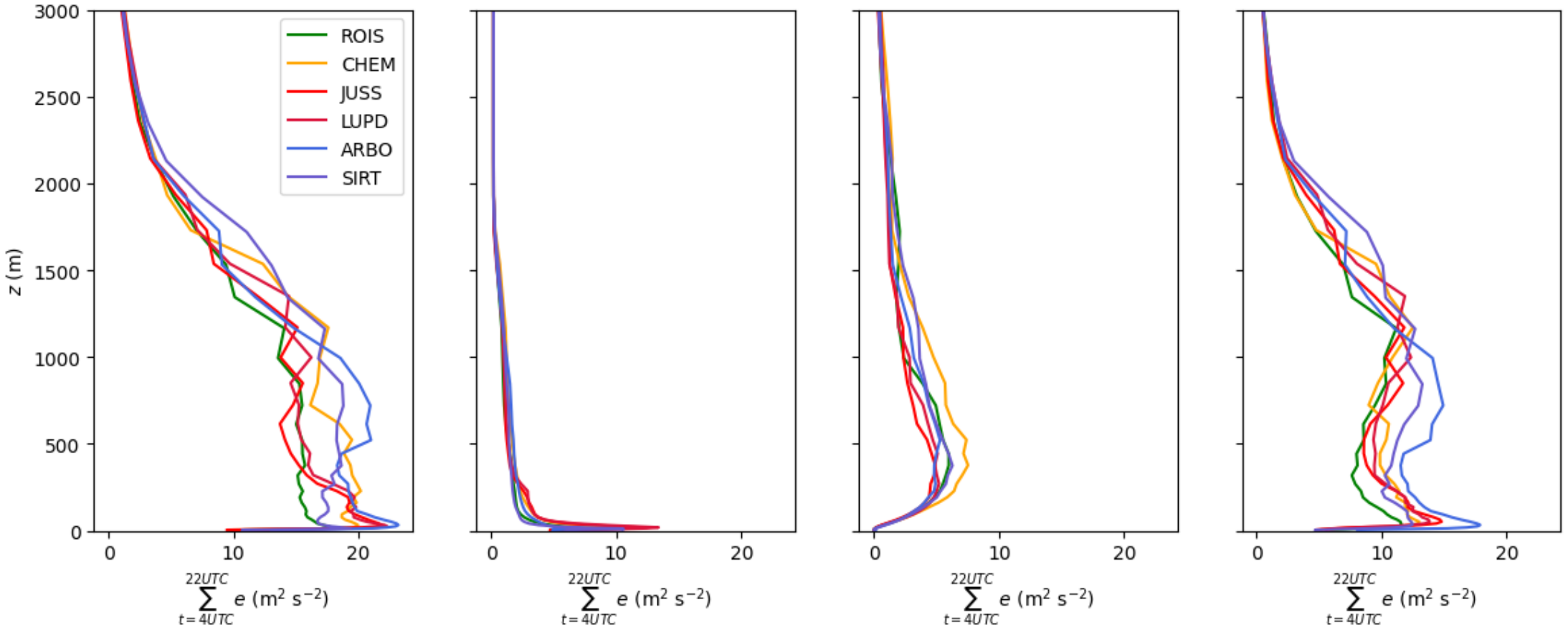
Decomposing MesoNH TKE

TKE total

TKE parameterised

$0.5\ \sigma_w^2$

$0.5\ (\sigma_u^2 + \sigma_v^2)$



Latent heat fluxes