# Verification of climatological ERA5 and WRF convective environments using radiosonde data

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# Objectives and motivation

- The main objective is to evaluate the mean climatological distribution of convective proxies calculated from the ERA5 reanalysis and WRF regional climate model simulations against sounding observations

- We investigate the effects of refined vertical (in case of ERA5) and horizontal (in case of WRF) resolution

- The work is motivated by and adopts the analysis methodology of Taszarek et al. (2018)

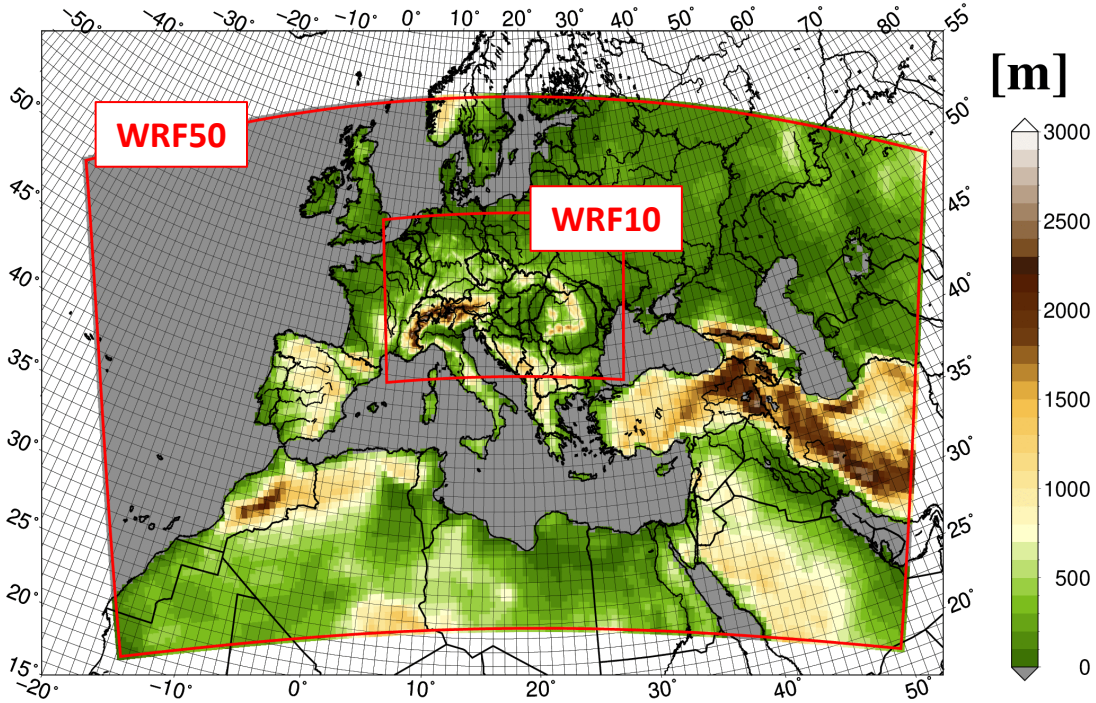
- The accurate representation of convective environments in convection-parameterizing regional climate simulations enables us to examine their projected changes in the 21$^{st}$ century using a wide range of available model data

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# Observational and model data

**OBS**

- Radiosonde measurements from the University of Wyoming website (http://weather.uwyo.edu/upperair/sounding.html)




Geographical coverage and terrain height of the WRF domains

- ERA5 reanalysis (ECMWF, Hersbach et al. 2020)
  - 0.25° horizontal grid spacing
  - State-of-the-art 4DVAR data assimilation

**ERA5PL** 29 pressure levels from 1000 hPa to 50 hPa

**ERA5ML** 137 hybrid sigma–pressure levels (native)

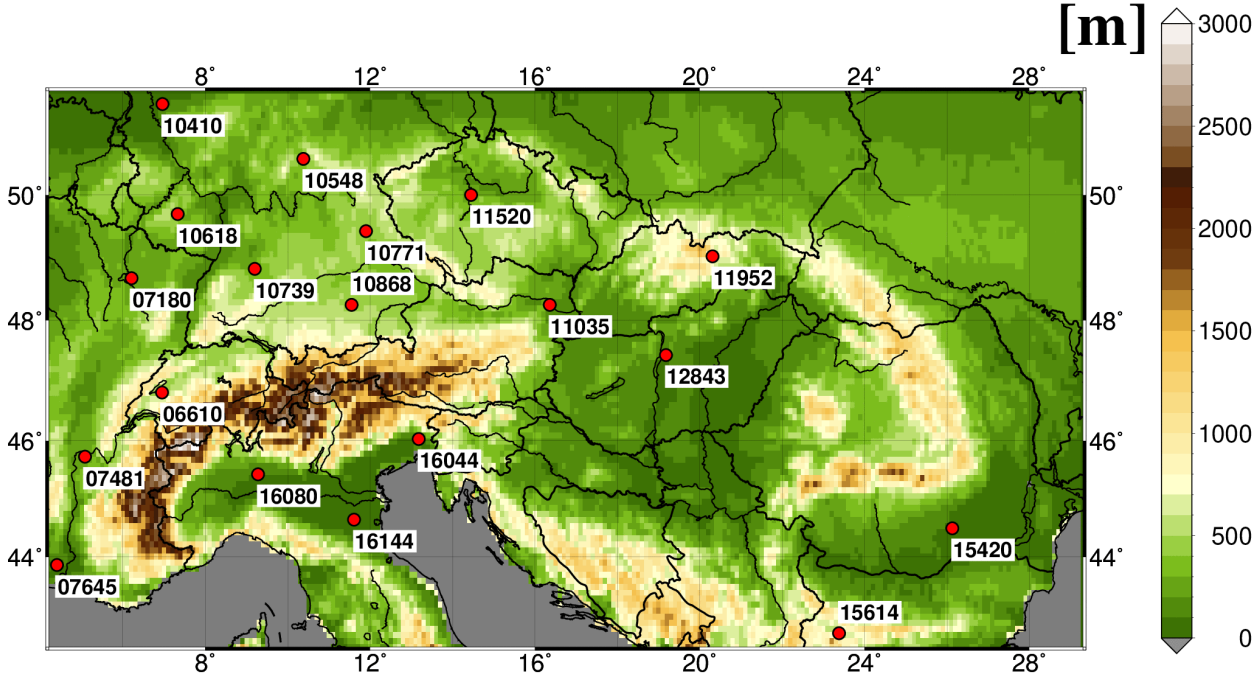
- WRFv4.2 (Skamarock et al. 2019) regional climate simulations
  - Continuous integration (1985–2010) with ERA5 ICBCs
  - 61 hybrid σ–p levels (50 hPa top layer)
  - Identical physical parameterizations for the two domains (Aerosol-aware Thompson microphysics (Thompson and Eidhammer 2014), BouLac PBL (Bougeault and Lacarrere 1989), MM5 Similarity surface layer (Jiménez et al. 2012), RRTMG radiation (Iacono et al. 2008), Noah-MP LSM (Niu et al. 2011), Kain–Fritsch deep convection (Kain 2004))

**WRF50** 50 km grid spacing **WRF10** 10 km grid spacing

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# Methods

- Daily 1200 UTC radiosonde data are used from 19 synoptic stations in the 1985–2010 period
- Strict quality control is applied to the profiles to exclude erroneous observations
- ERA5 and WRF pseudo-profiles are extracted from the nearest grid point to the sounding site
- Convective environmental proxy parameters are calculated from the observed and modeled profiles (p, z, T, q, u, v), with the surface as an additional level in ERA5 and WRF (a linear interpolation is first performed to a vertical resolution of 1 hPa)



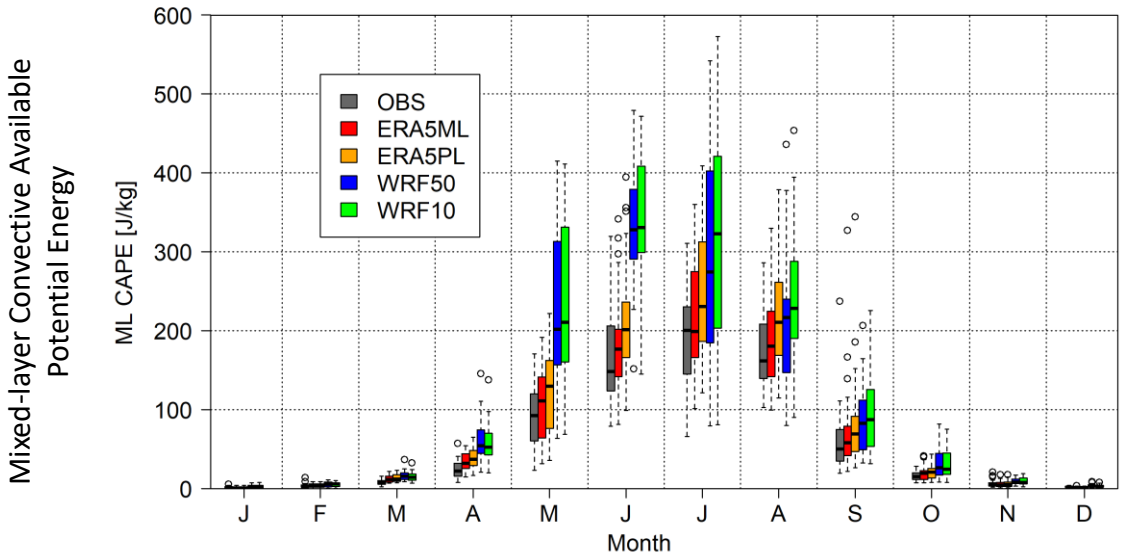

Sounding stations with the respective identification numbers

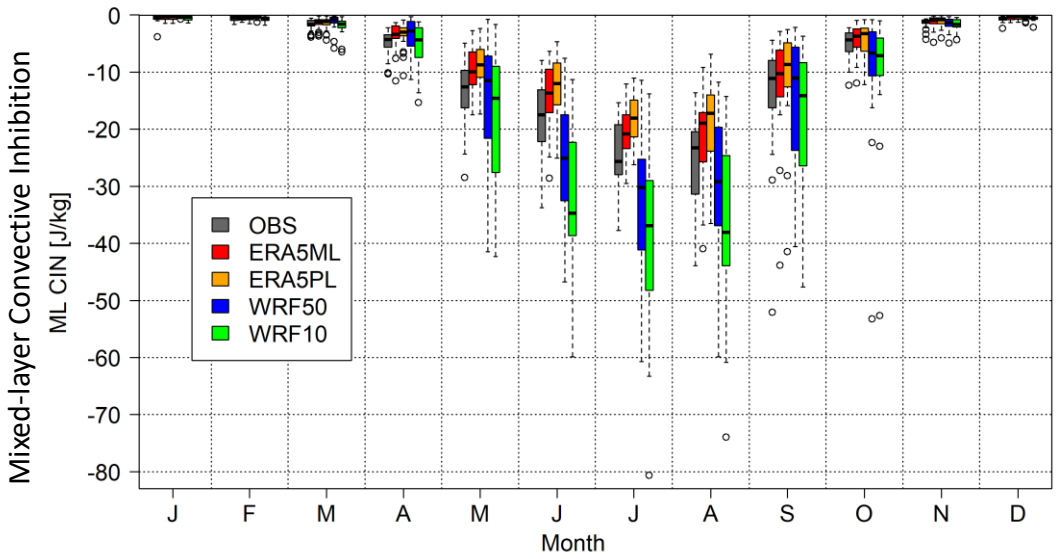
| Short name | Description | Unit |
|---|---|---|
| ML CAPE | 0–500 m mixed layer convective available potential energy | [J/kg] |
| ML CIN | 0–500 m mixed layer convective inhibition | [J/kg] |
| ML LI | 0–500 m mixed layer Lifted Index | [°C] |
| DLS | Deep layer shear (0–6 km bulk wind shear) | [m/s] |
| MLS | Mid-level shear (0–3 km bulk wind shear) | [m/s] |
| LLS | Low-level shear (0–1 km bulk wind shear) | [m/s] |
| PW | Precipitable Water | [mm] |
| MLR85 | 850–500 hPa mean lapse rate | [°C/km] |

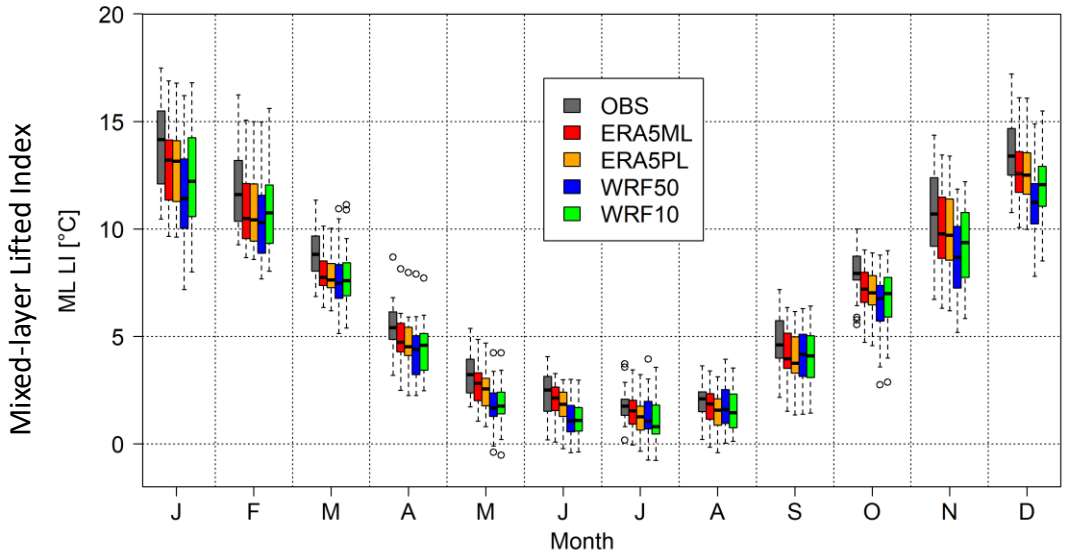
Convective environmental parameters
(virtual temperature correction included)

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# Results – parcel thermodynamic parameters



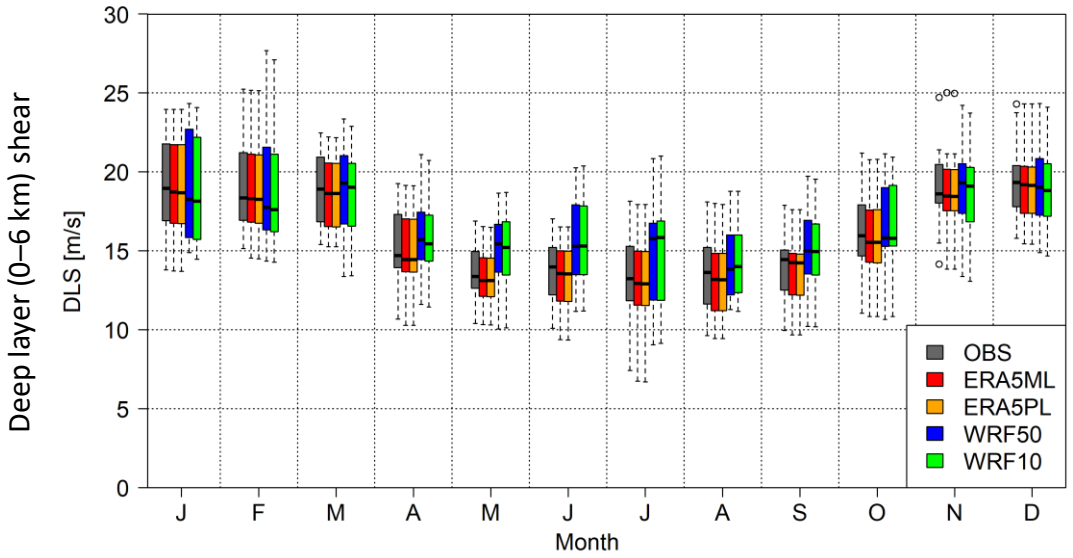



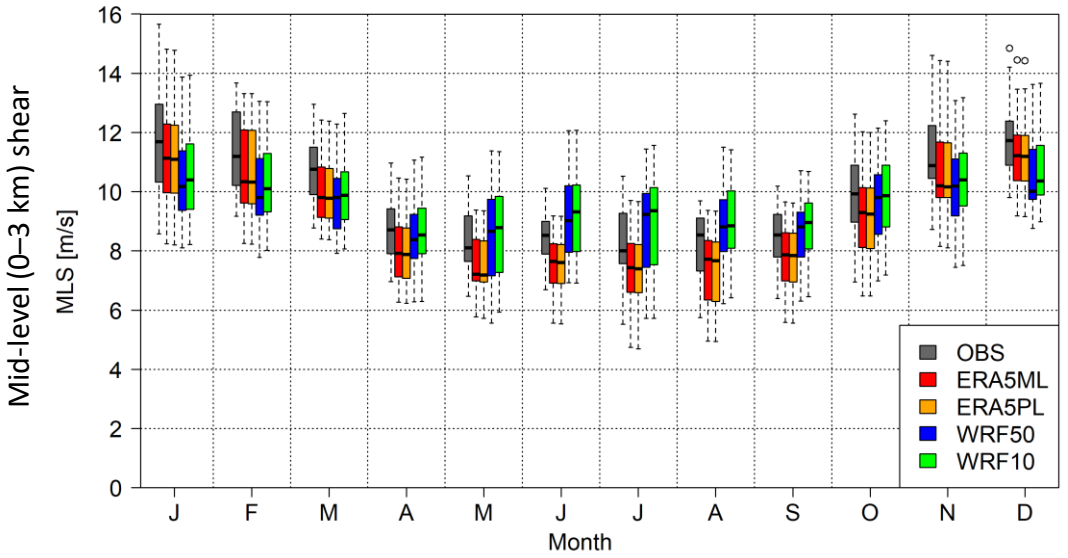



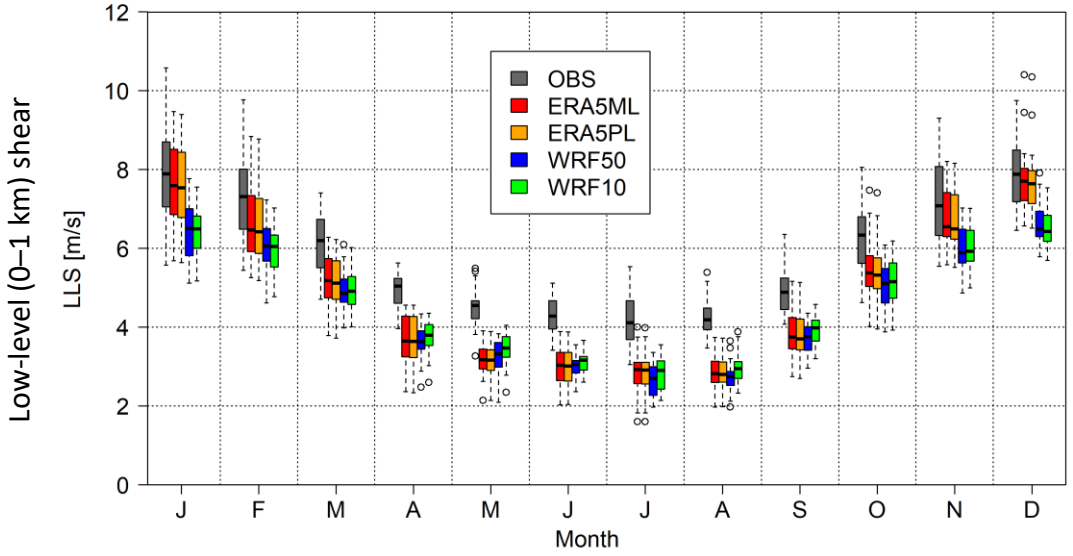

- ERA5 depicts the annual cycle of ML CAPE, ML CIN, and ML LI with low errors
- The native ERA5 is closer to the observations than its pressure level version
- WRF overestimates ML CAPE and ML CIN due to excessively warm and dry near-surface conditions, ML LI is better represented
- Differences between WRF50 and WRF10 can be explained by topographical discrepancies (the high-resolution simulation represents the actual terrain height better, thus WRF50 being closer to the observations is mostly error compensation)

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# Results – wind shear parameters



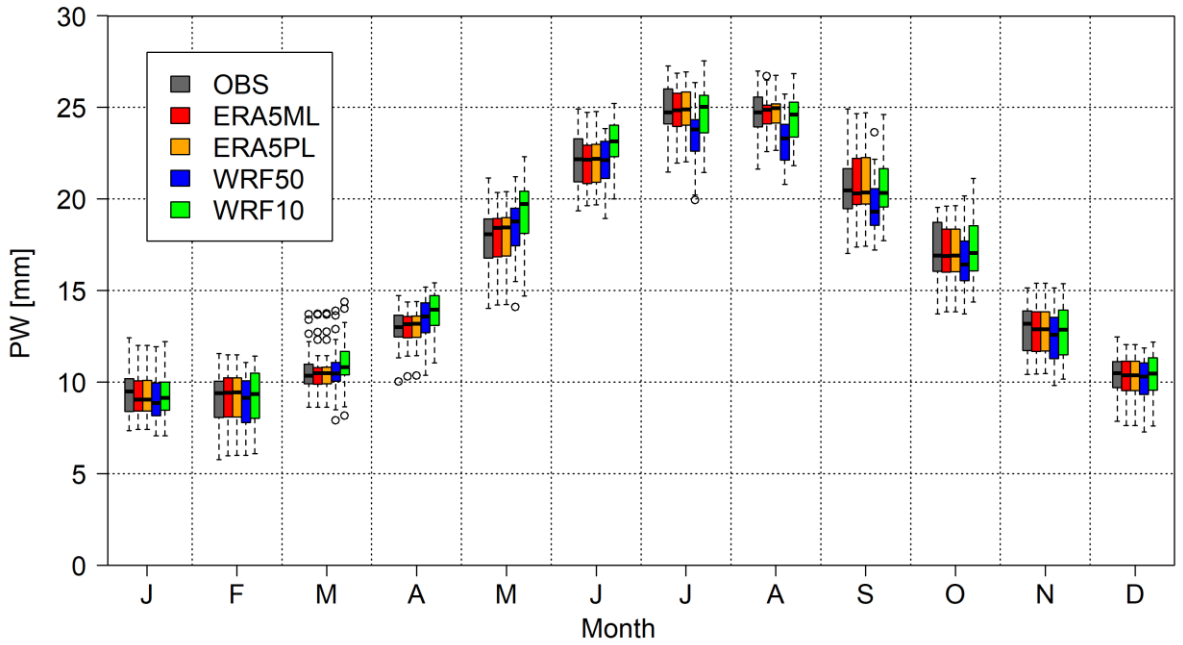




- ERA5 errors are negligible for DLS and increase for MLS and LLS
- No differences between the model and the pressure level version of ERA5
- LLS errors of WRF are comparable to those of the reanalysis in spring and summer but are larger in winter
- WRF tends to perform better than ERA5 for MLS

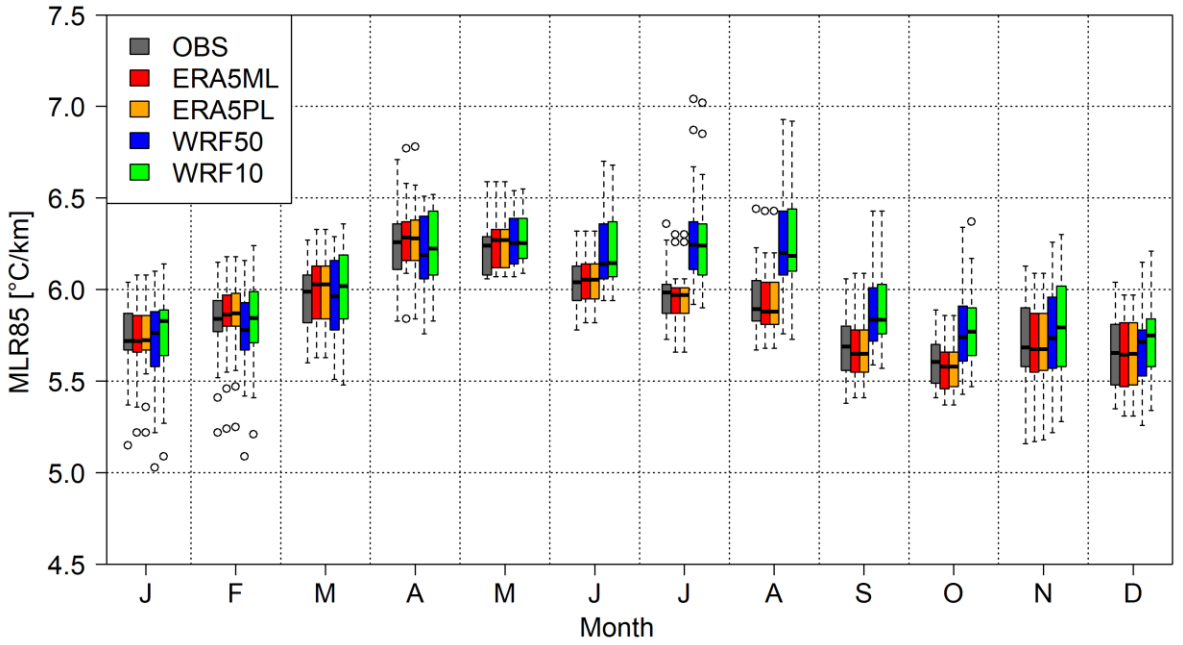
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# Results – precipitable water and lapse rate

Precipitable Water




Mean 850–500 hPa lapse rate



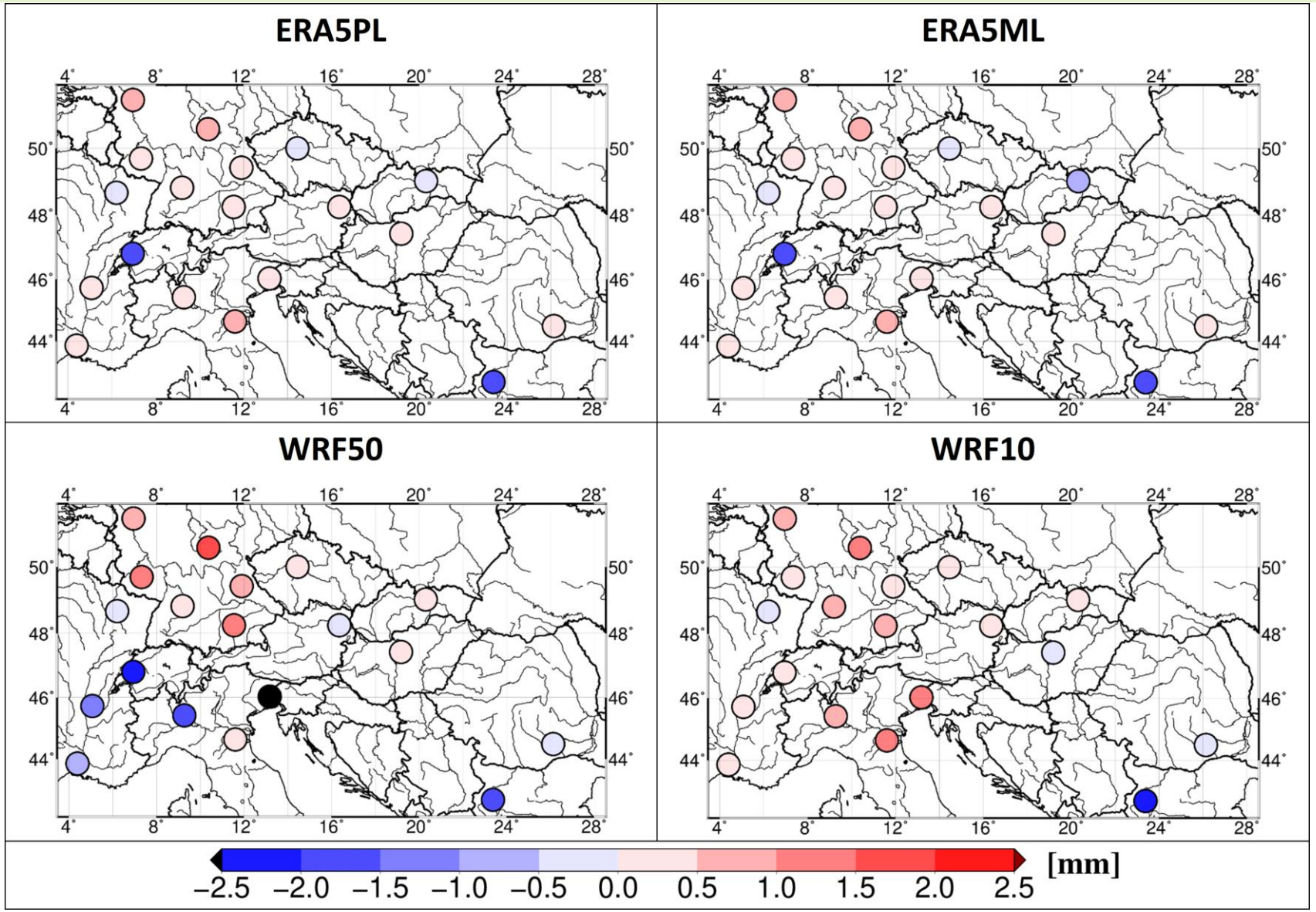

- ERA5 represents PW and MLR85 very skillfully
- No differences between the model and the pressure level version of ERA5
- PW underestimation from July to October in WRF50 is caused by the too high surface elevation of the corresponding grid points
- Mean mid-tropospheric lapse rate in WRF is overestimated from July to October due to the excessive dryness of the climate model simulations

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# Results – importance of resolution

Mean error of precipitable water in the 1985–2010 period for the reanalysis and the WRF simulations






- Precipitable water is low-biased in WRF50 over Northern Italy because the surface elevation of the grid points are higher in the model than in reality
- This topography difference also affects CAPE and CIN values and might lead to false error compensations in the models

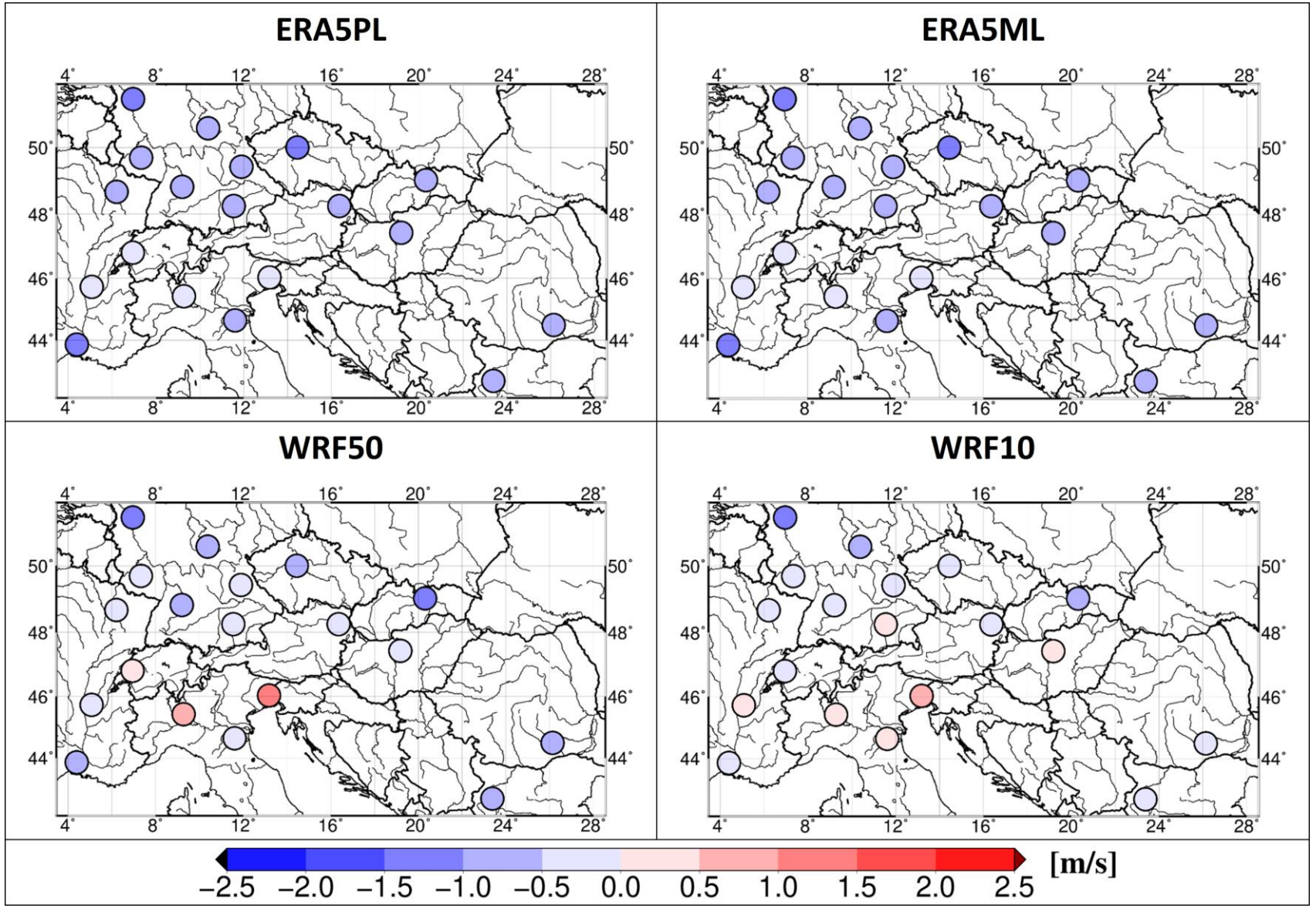
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# Results – mid-level shear

Mean error of 0–3 km wind shear (MLS) in the 1985–2010 period for the reanalysis and the WRF simulations



- MLS biases are lower in the WRF simulations than in ERA5 for most of the stations




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# Summary and outlook

- ERA5 and WRF represent the annual cycle of convective environmental parameters well, although magnitude biases exist, especially in the regional climate model

- The native ERA5 data is more suitable for calculating parcel thermodynamic parameters (CAPE, CIN) than the pressure level version, but the differences are negligible for wind, temperature, and moisture variables

- In the 50-km climate simulation, the surface elevation is significantly higher for some grid points than the corresponding station elevation, which negatively affects the accuracy of convection-related variables

- Further WRF sensitivity studies are required to improve the general performance of the model and consequently the accuracy of convective environmental parameters

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