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CLIMXTREME Climate Change and Extreme Events

Bundesministerium für Bildung und Forschung

Scale dependency of heavy precipitation processes.
Assessment of COSMO-CLM present climate simulations

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Regional Climate and Weather Hazards
Institute of Meteorology and Climate Research – Department Troposphere Research (IMK-TRO)

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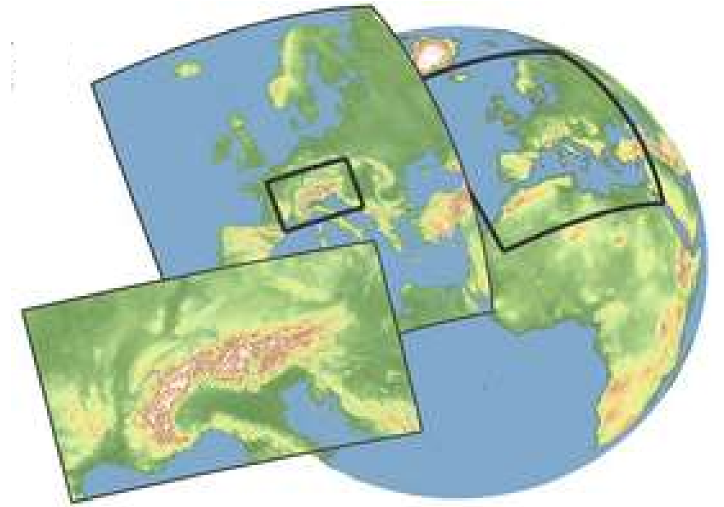


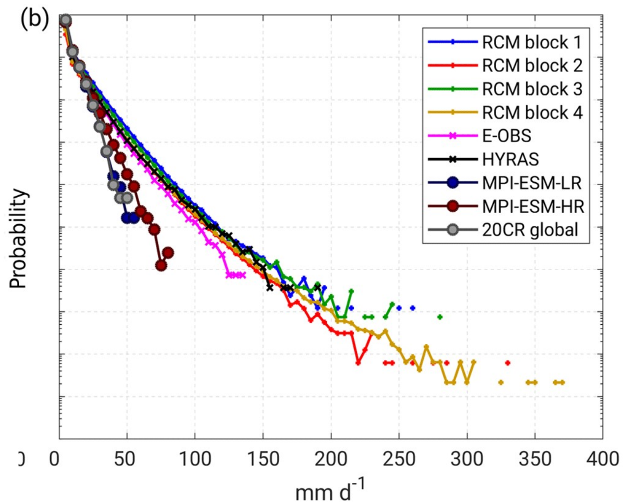
Prein et al., (2017)

Introduction

Due to the large damaging potential of heavy precipitation, there is great interest in high-resolution climate simulations

- Added value of convection-permitting modelling
  (Prein et al., 2015, 2017; Ban, et al., 2018; Meredith et al., 2020)
  - Larger extreme precipitation
  - Improved structure
  - No drizzle overestimation
  - Improved diurnal cycle

- Scale-dependency of dynamic precipitation processes *(Barthlott and Hoose, 2015; Langhans et al., 2012)*
  - More intense convective updraughts
  - Larger number of cells triggered
  - Enhanced orographic triggering



Ehemele et al., (2020)

Introduction

Due to the large damaging potential of heavy precipitation, there is great interest in high-resolution climate simulations

- Scale-dependency of thermodynamic precipitation processes *(Knote et al., 2010; Langahns et al., 2012; Prein et al., 2013; Vanden-Broucke et al., 2019 ; Hoehneeger et al., 2015, 2019)*
  - More T, MFC, KE variability
  - Improved average T2M
  - Negative soil-moisture atmosphere feedback
  - Better coastal winds
  - Moisture flux?
  - Surface moisture?
  - Equivalent Potential Temperature?
  - CAPE?
  - Surface fluxes?

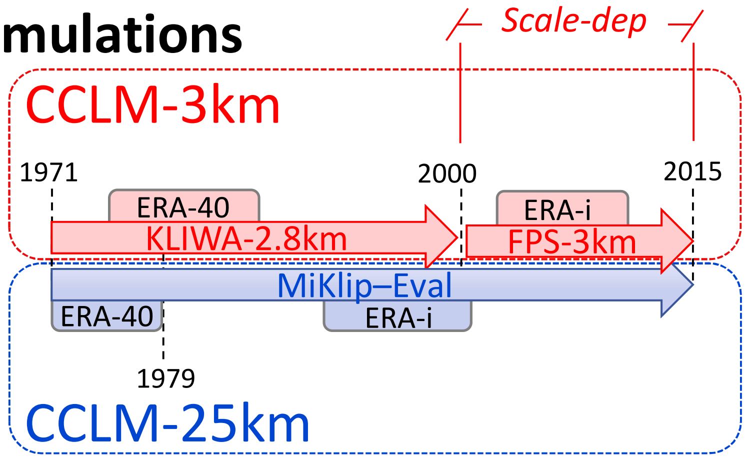
What is the scale-dependency of precipitation thermodynamic processes in COSMO-CLM simulations of the present Climate?

Methodology

COSMO-CLM downscaled reanalyses at 25 km and 3 km

Simulations

- CCLM-3km



- CCLM-25km

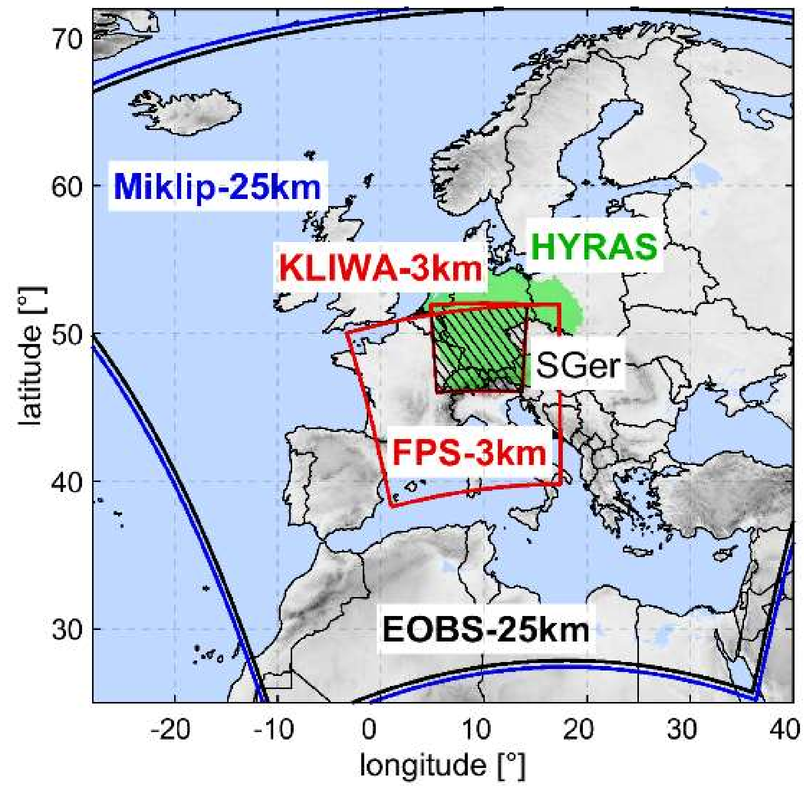
Validation against observations

- E-OBS-25km
- HYRAS-5km

1971-2015

Scale-dependency of processes

- Principal Component Analysis



Principal Component Analysis

PCA transforms the data into a new space of less, uncorrelated dimensions, providing an estimation of the explained variability.

Joliffe (2002)

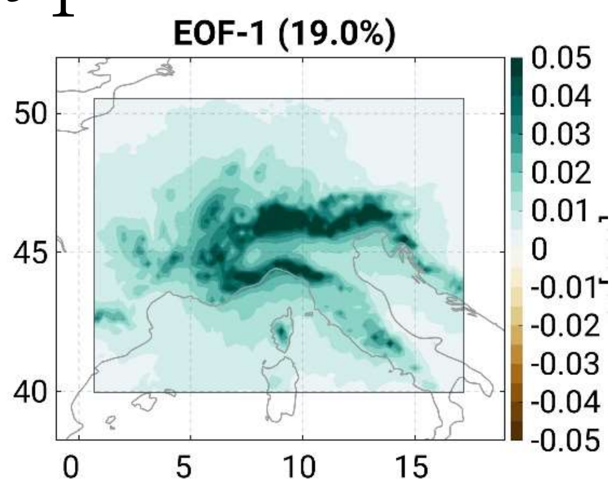
$$\boldsymbol{\Sigma} = \boldsymbol{\alpha} \cdot \boldsymbol{\lambda} \cdot \boldsymbol{\alpha}'$$

$\boldsymbol{\Sigma} = Variance\ array\ of\ \boldsymbol{x}$

$\boldsymbol{\alpha} = Eigenvectors\ (orthogonal\ functions)$

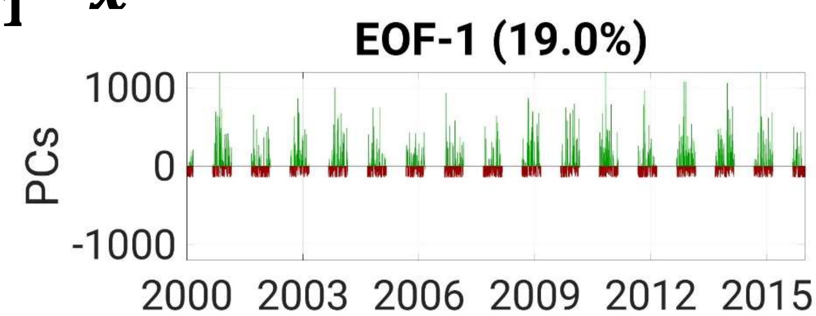
$\boldsymbol{\lambda} = Eigenvalues\ (variability)$

$$\boldsymbol{\alpha}_1 =$$



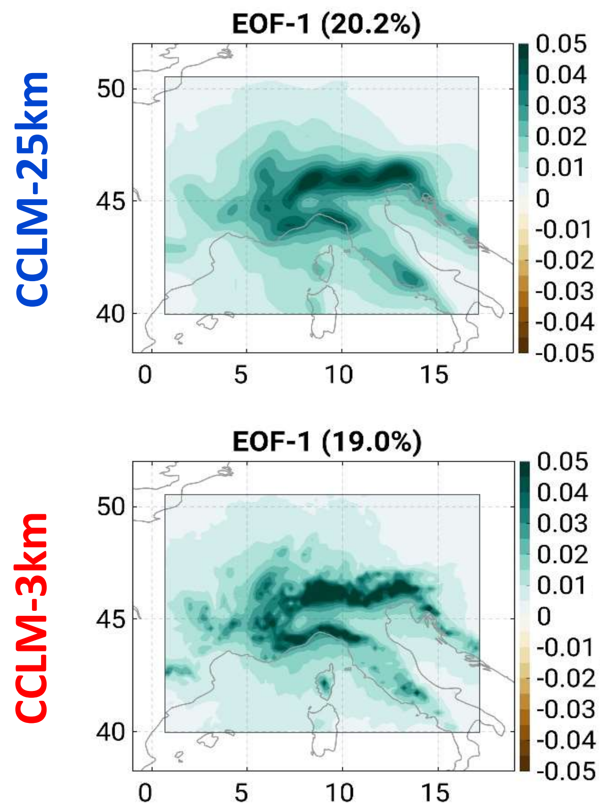
CCLM-3km *(Winter, 2000-2015)*

$$\boldsymbol{\alpha}'_1 \cdot \boldsymbol{x} =$$

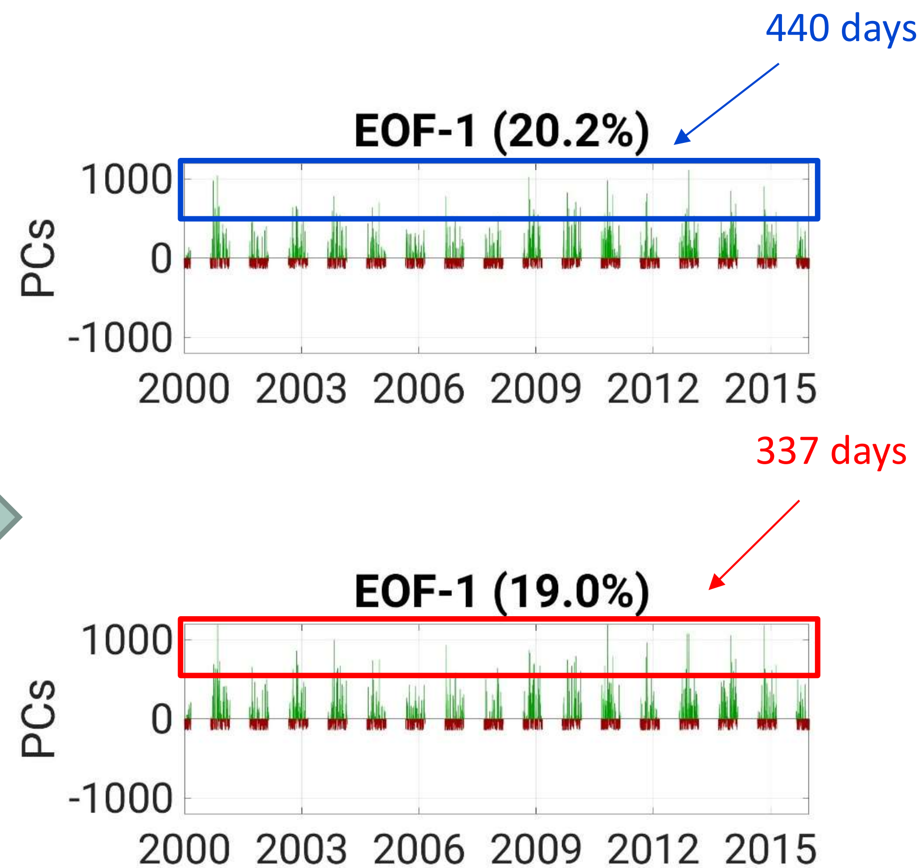


First precipitation variance mode and composites

Winter (2000-2015)



$\alpha'_1 \cdot x$

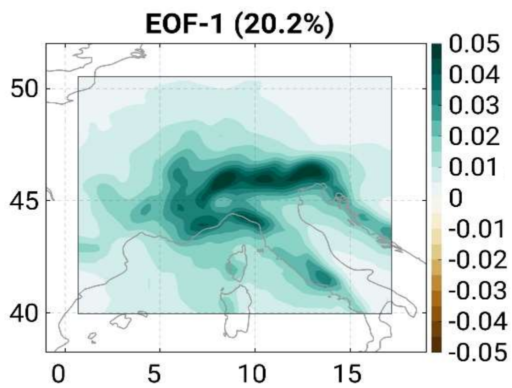


We calculate differences (CCLM-25km – CCLM-3km) of timely averages with 440 and 337 days for model variables

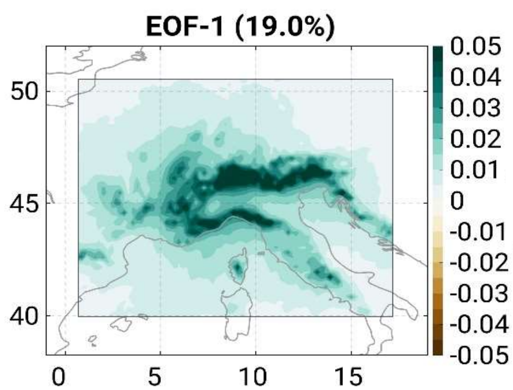
First precipitation variance mode and composites

Winter (2000-2015)

CCLM-25km

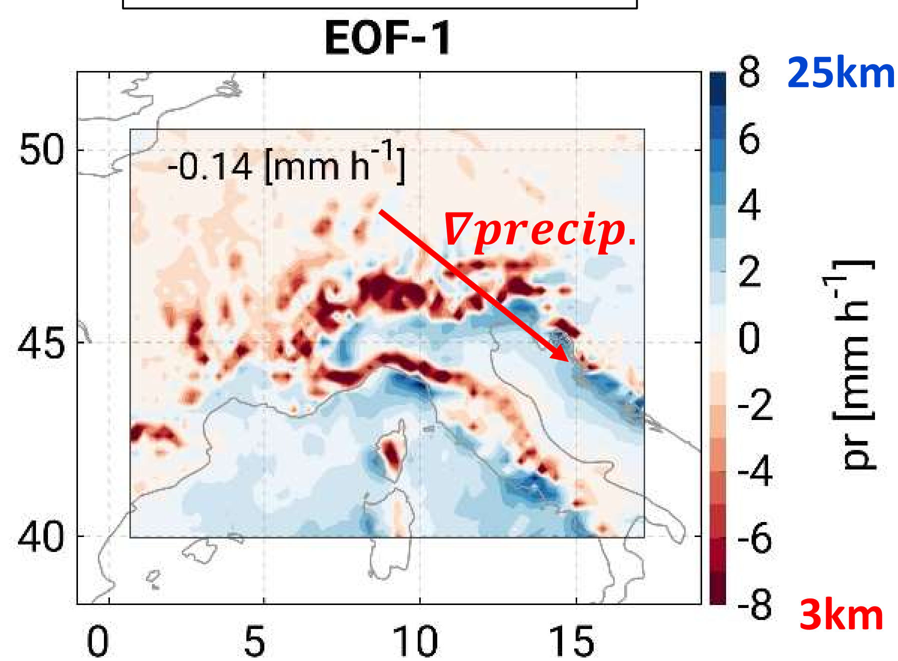


CCLM-3km



$\alpha'_1 \cdot x$

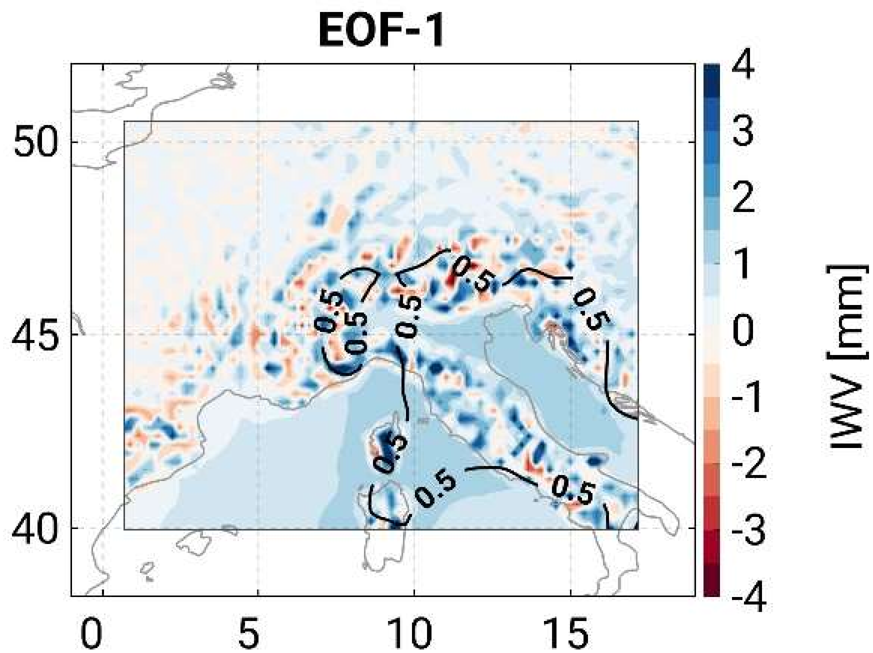
(CCLM-25km – CCLM-3km)



The larger intensities in CCLM-3km occur in the mountain tops

Atmospheric moisture

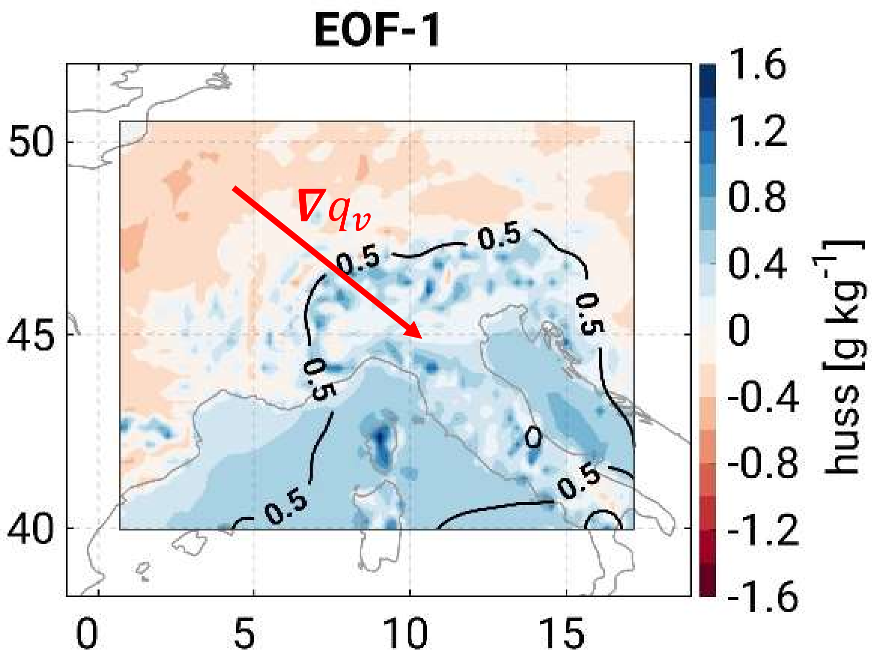
Integrated water vapour was systematically higher in 25 km compared to 3 km, especially at the lower free troposphere (850 – 500 hPa).



- For all EOFs
- Winter and Summer
- Larger differences in summer
- Differences up to 4 mm

Surface specific humidity

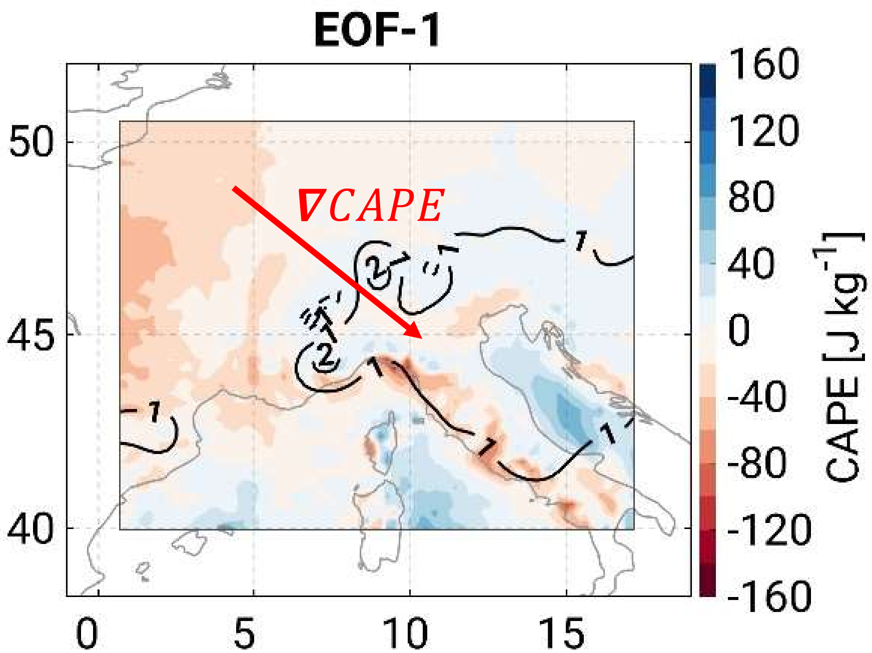
Closer to the surface, we observe a north to south gradient, also seen for moisture between 1000 hPa and 850 hPa.



- Summer and Winter
- Related to precipitation differences over low terrain
- Related to CAPE differences

Instability and Equivalent Potential Temperature

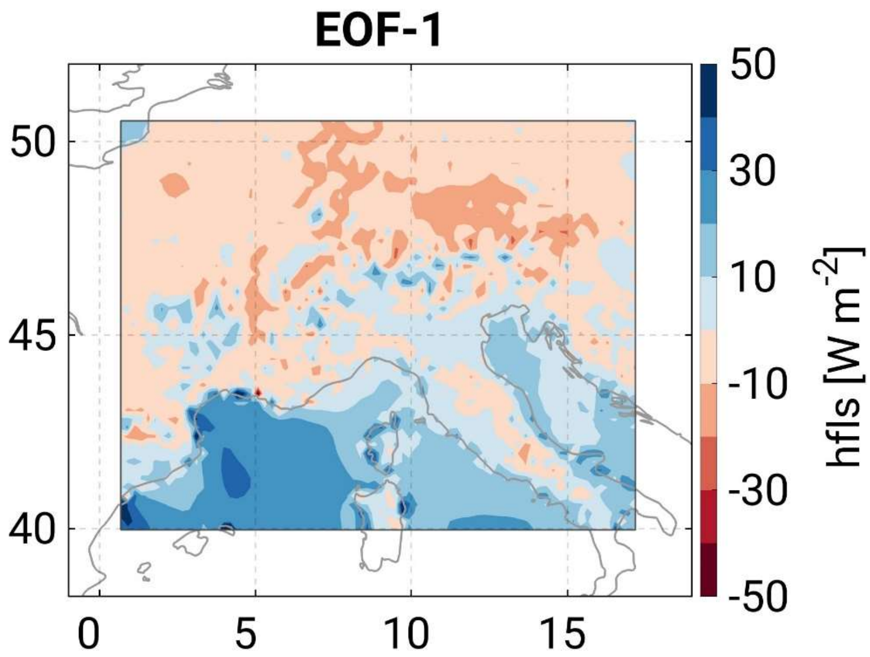
Given the resolution differences in surface specific humidity, the studied EOFs also showed a strong gradient of CAPE differences



- CAPE differences related to precipitation differences
- θ_e^{850} is systematically larger in 25 km.
- Differences at the surface are more relevant than differences at the free troposphere

Soil-atmosphere Evaporation

CCLM-3km evaporates more moisture overland, CCLM-25 km evaporates more over water, systematically.



- The southerly flow pushes the moisture excess in CCLM-25km up the Avignon and Po Valleys
- All EOFs and both seasons
- Explain observed surface humidity and CAPE differences

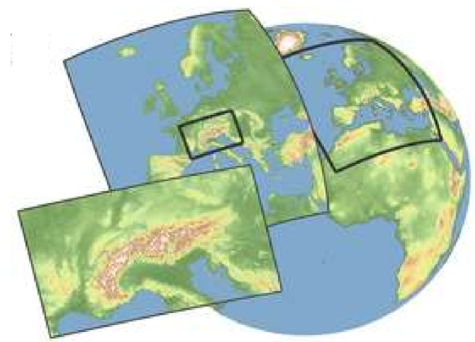
Conclusions

- The scale-dependency of dynamic processes (intensified wind updrafts, orographic triggering) explains the larger precipitation intensities over complex orography

- The scale-dependency of thermodynamic processes (surface fluxes and CAPE) explains precipitation differences over low terrain

- Systematic wetter atmosphere and larger θ_e^{850} in 25 km

- North-south gradient of resolution differences for surface specific humidity and CAPE



Thank you for your attention