Reanalysis Datasets for Climate Services in Italy: Validation and Inter-Comparison

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15th EUMETNET Data Management Workshop

Shaping climate services for the future

Oslo & online, 4–6th of November 2025

Data Services session

Outline:

1. Reanalyses in Climate Services and the need for validation
2. Insights on temperature validation
3. Insights on precipitation validation
4. An application on climate indices
5. Discussion

1. Reanalyses

What is a reanalysis

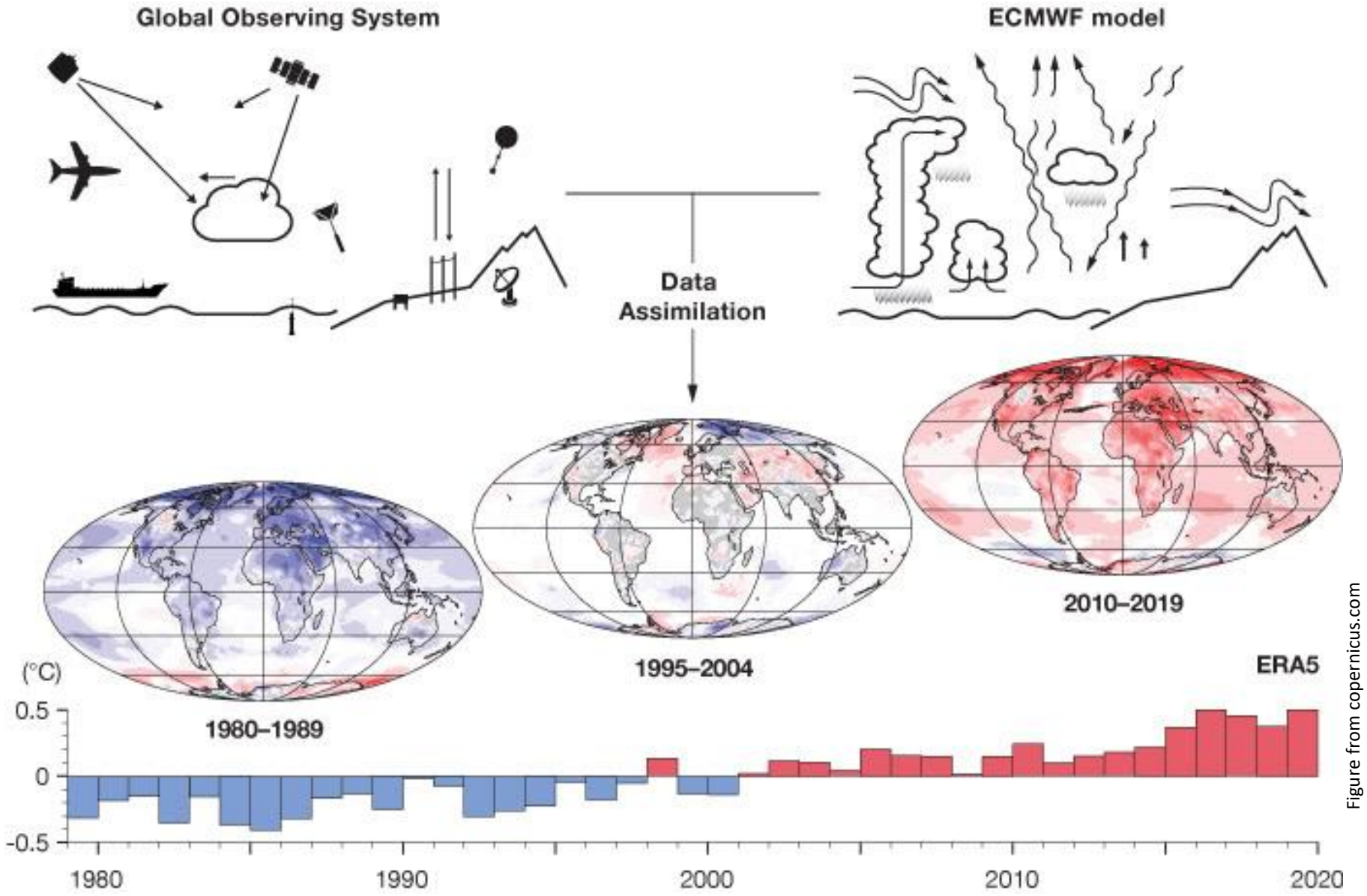
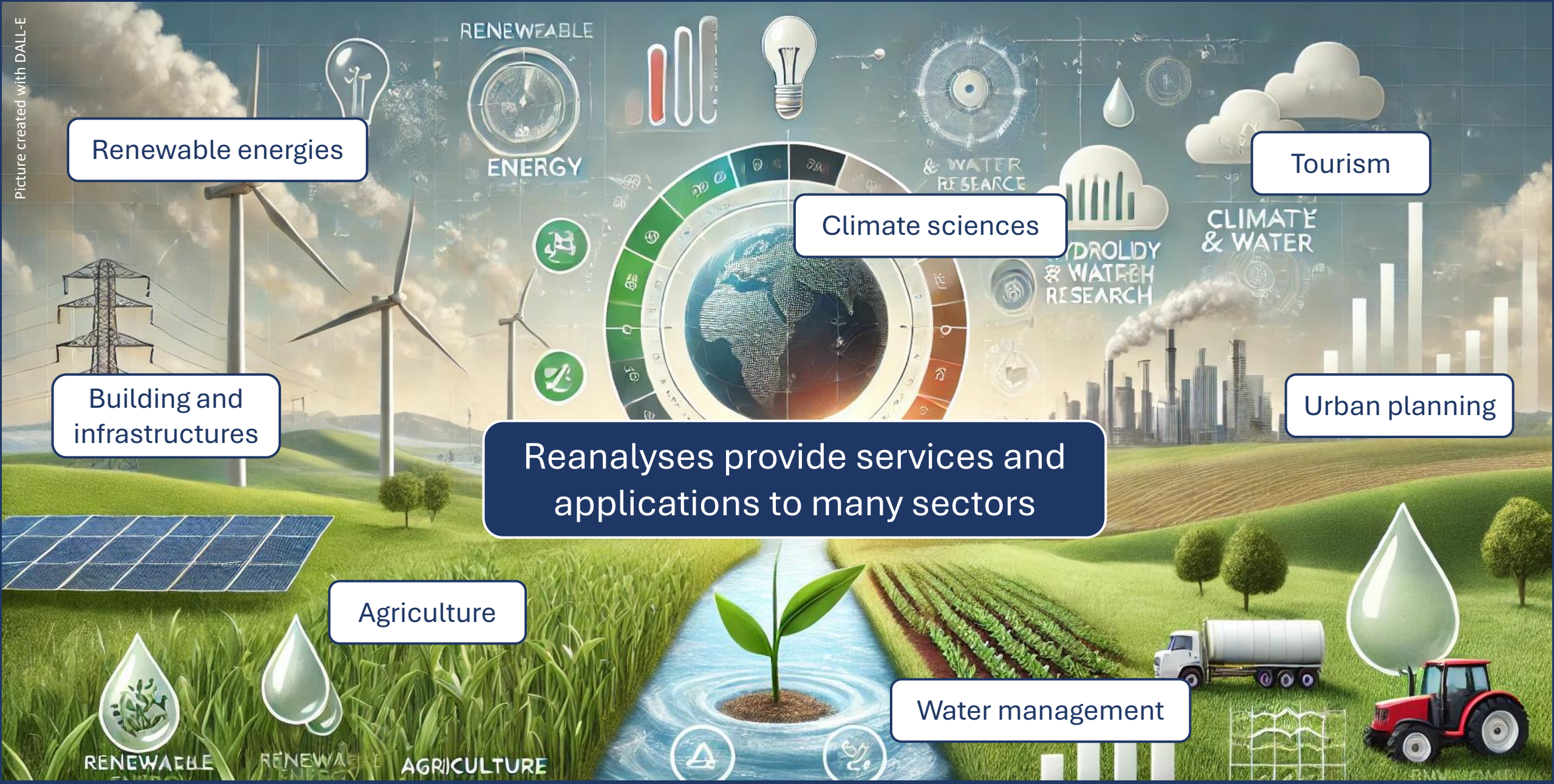


Figure from copernicus.com



Francesco Cavalleri et al.,
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EUMETNET DMW - Oslo & online, 4–6th of November 2025

e.g. ERA5

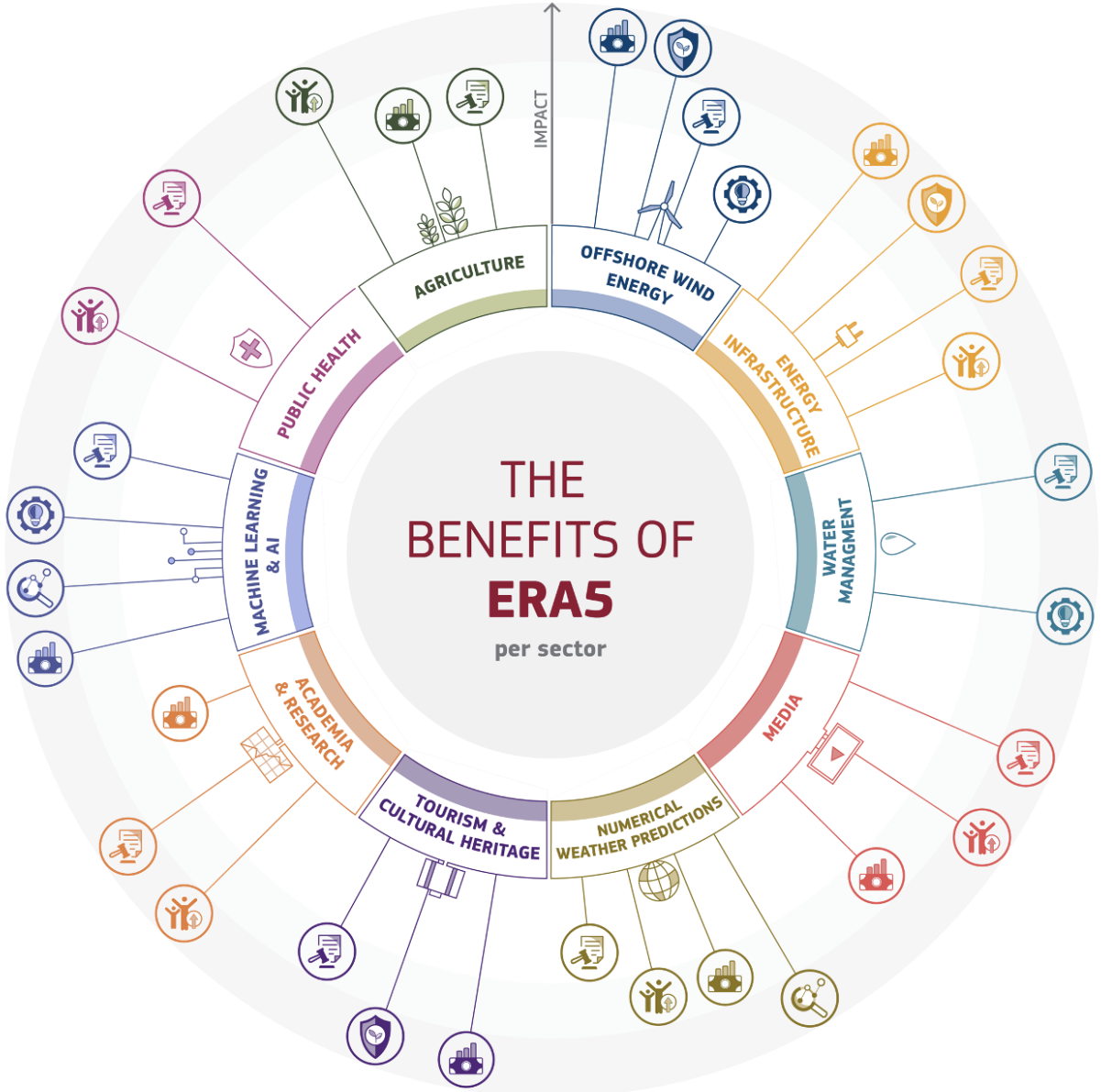


Figure from copernicus.com

Regional downscaling

- Global reanalyses are too coarse for capturing some processes
- Regional reanalyses can start from global ones and refine them
- May add further data (nudging) or not
- Improve terrain description, processes (e.g. convection) but also complexity

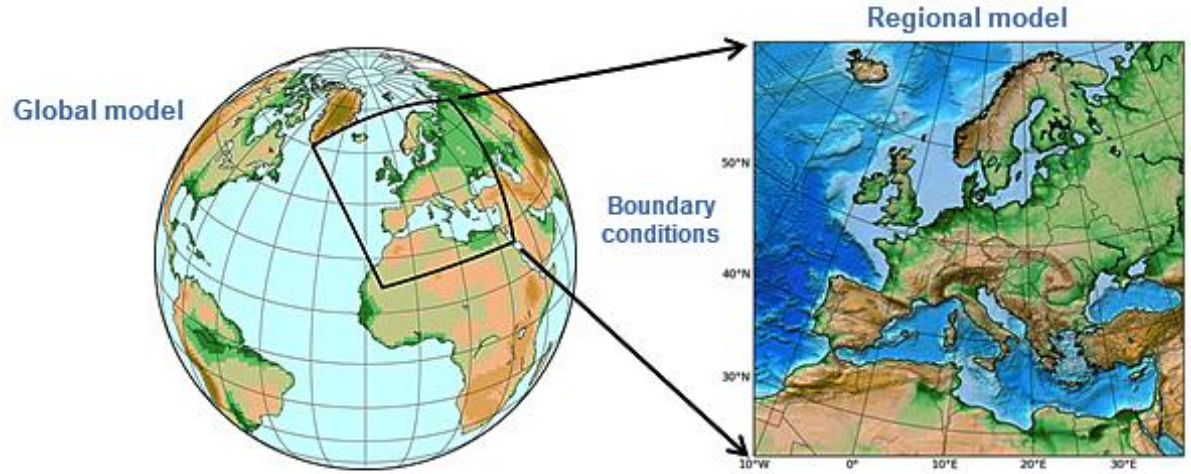
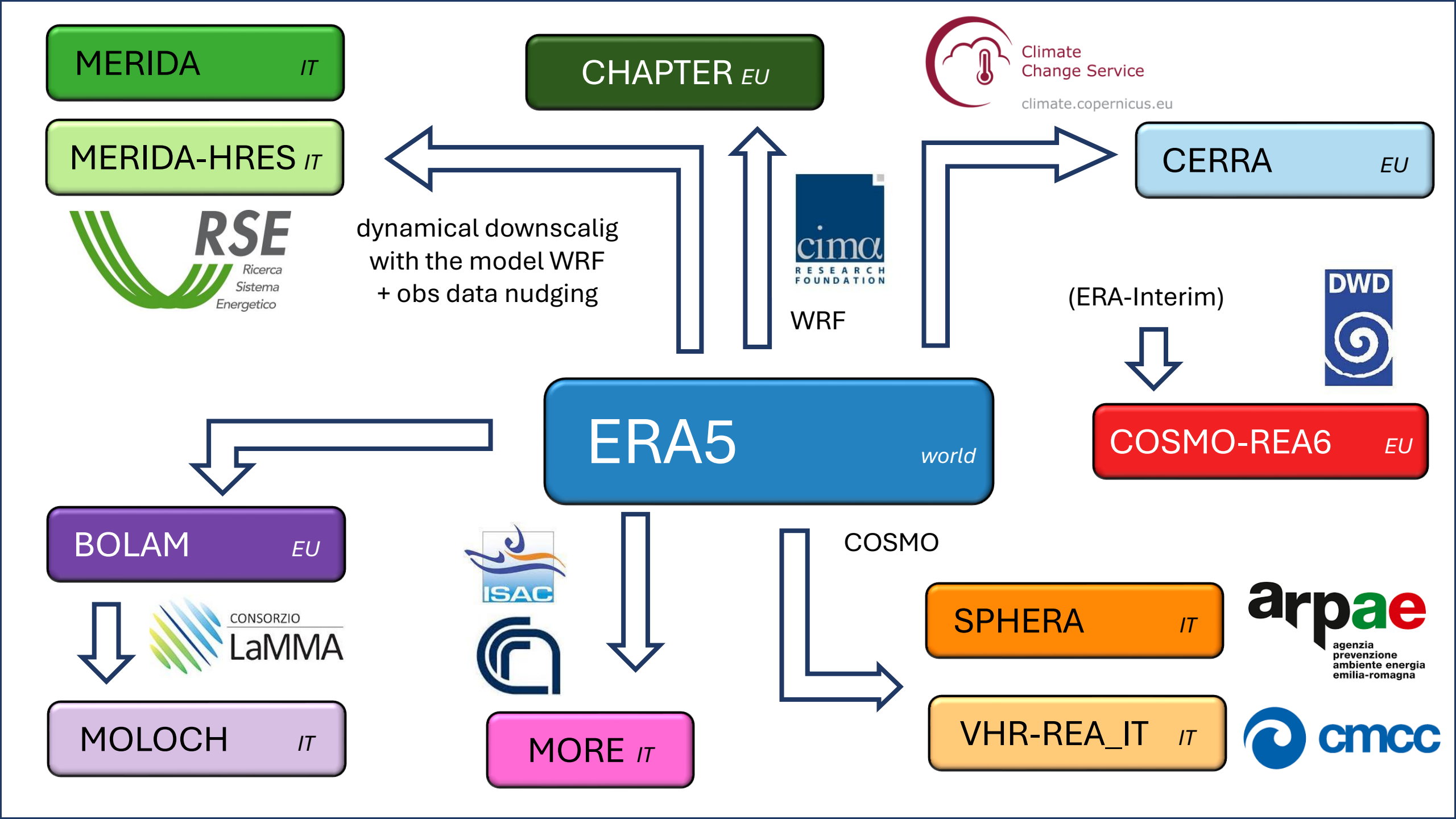


Figure from dwd.de


MERIDA IT
MERIDA-HRES IT
RSE Ricerca Sistema Energetico
dynamical downscalig
with the model WRF
+ obs data nudging
CHAPTER EU
cima RESEARCH FOUNDATION
WRF
Climate Change Service
climate.copernicus.eu
CERRA EU
(ERA-Interim)
DWD
COSMO-REA6 EU
ERA5 world
BOLAM EU
CONSORZIO LaMMA
MOLOCH IT
ISAC
MORE IT
COSMO
SPHERA IT
arpae agenzia prevenzione ambiente energia emilia-romagna
VHR-REA_IT IT
cmcc

Reanalyses

Strengths

- no gaps in time and space
- physical coherence of the fields and among variables
- near real-time availability

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Limitations

- orographic representation
- atmosphere dynamics is chaotic, and models too
- assimilated data change in time

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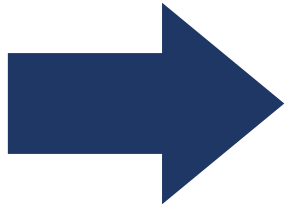
summarizing…

- Variety of product
- Diversity among them
- General and specific limitations



Inter-compare and Validate Reanalyses over Italy

- Used in many sectors, often taken as the truth.

2. Temperature

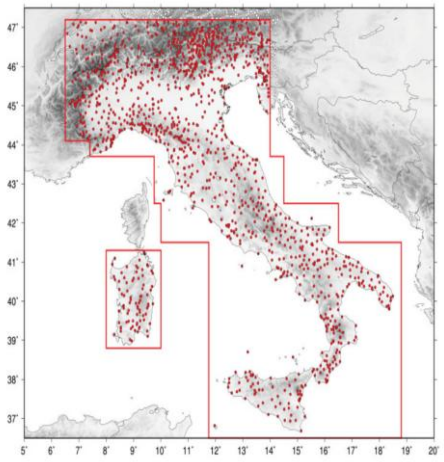
Insights from t2m validation

- Strong dependence of t2m on elevation
- Different representation of orography between reanalysis and reality
- How can we correctly compare with observations?
- How can we go beyond the error caused by differences in altitude?

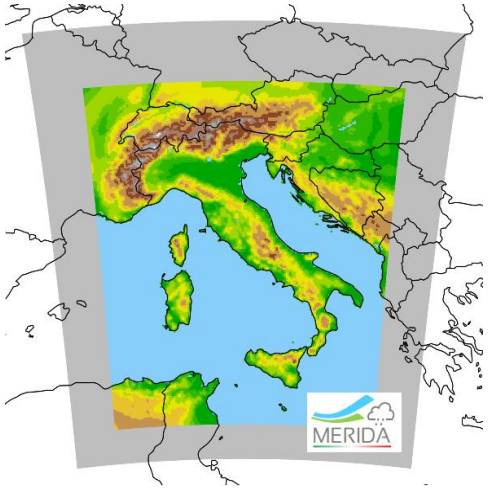
Picture created with DALL-E

Separate reconstruction of climatologies and anomalies

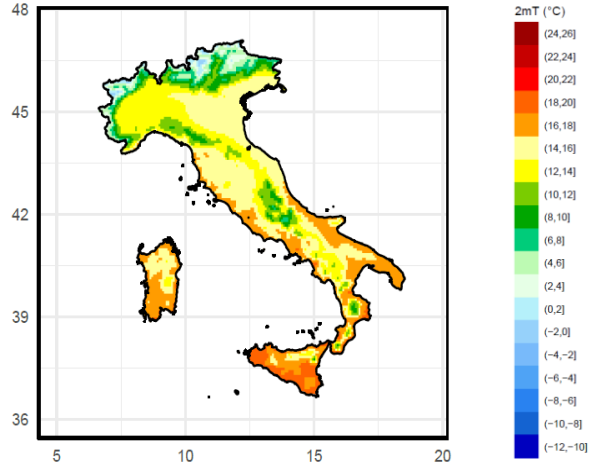
onto the grid points and elevation of each reanalysis to validate



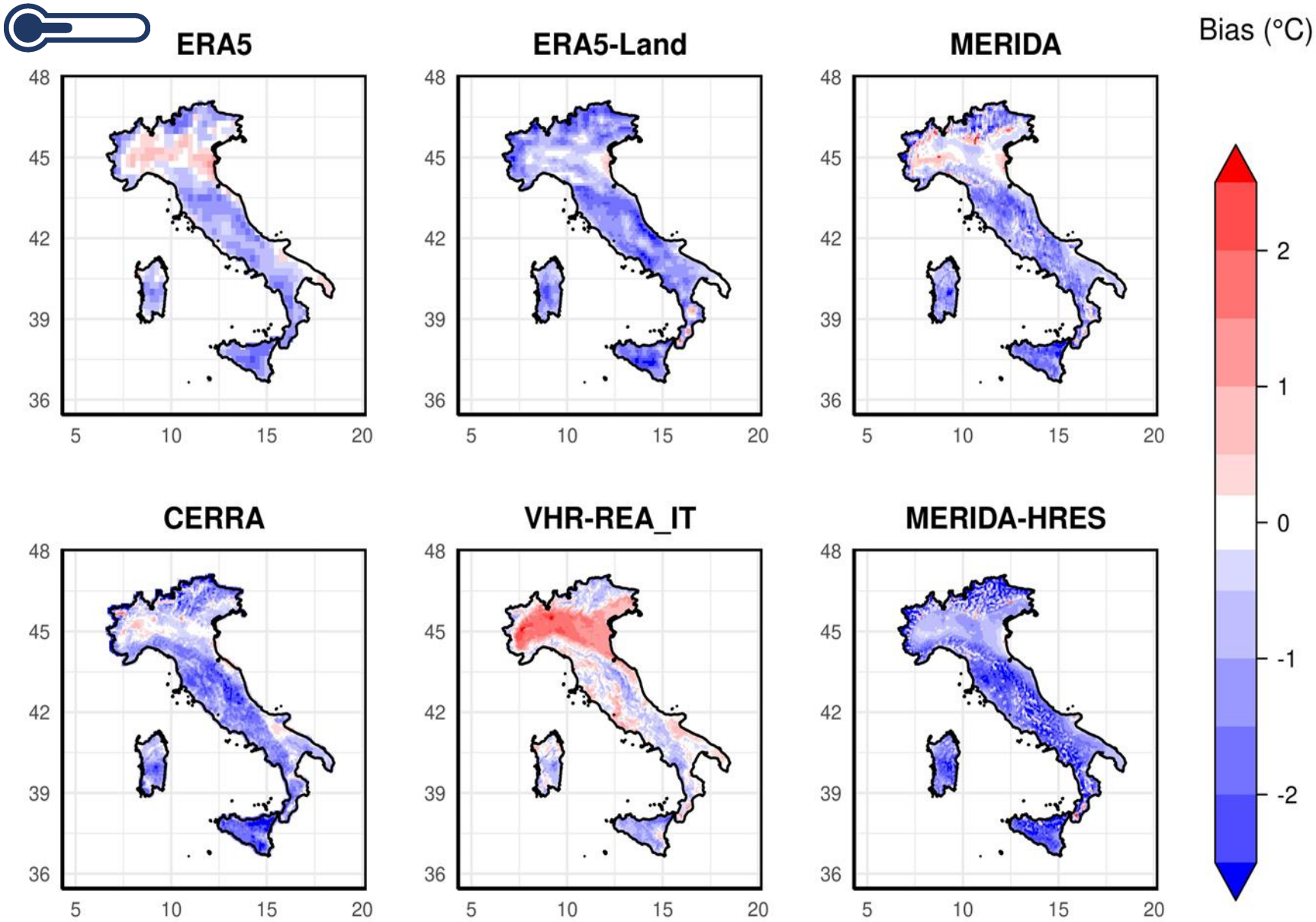
Station observation



Reanalysis grid and orography



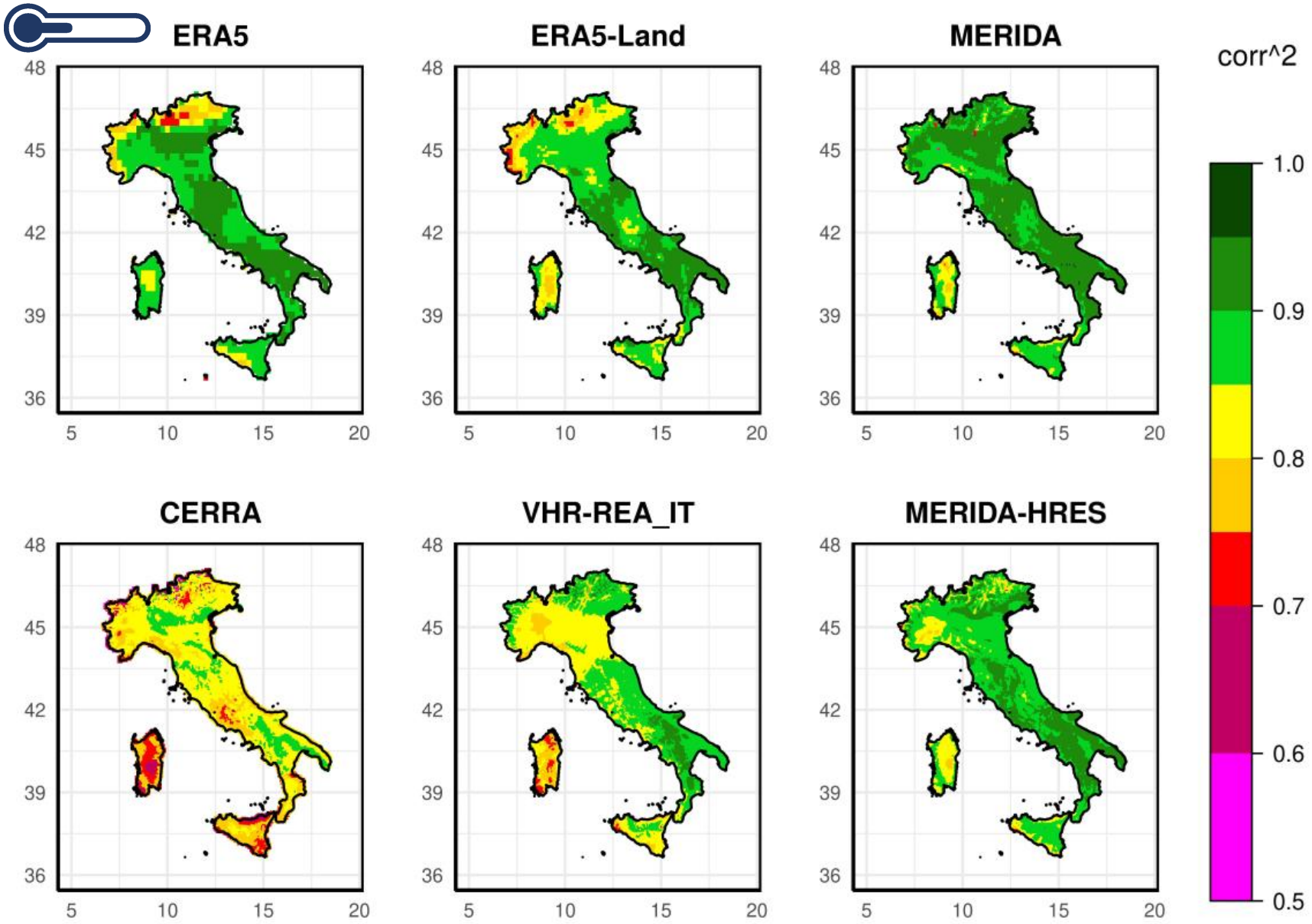
Observational dataset gridded on the reanalysis lon, lat and elevations



Systematic deviations

- 1991-2020 average of daily mean T2M
- bias = reanalysis – observed
- maps at the native resolution of each product
- cold bias over the Alps, Apennines, South, and islands
- warm bias in the Po Valley

Cavalleri et al. (2024a); Viterbo et al (2024)



Cavalleri et al. (2024a)

Correlations

- The climatological value is subtracted from the daily values of both reanalysis and observations, respectively.
- Local downscaling is more homogeneous than global and European products.
- In absolute terms, errors are smaller than climatological ones.

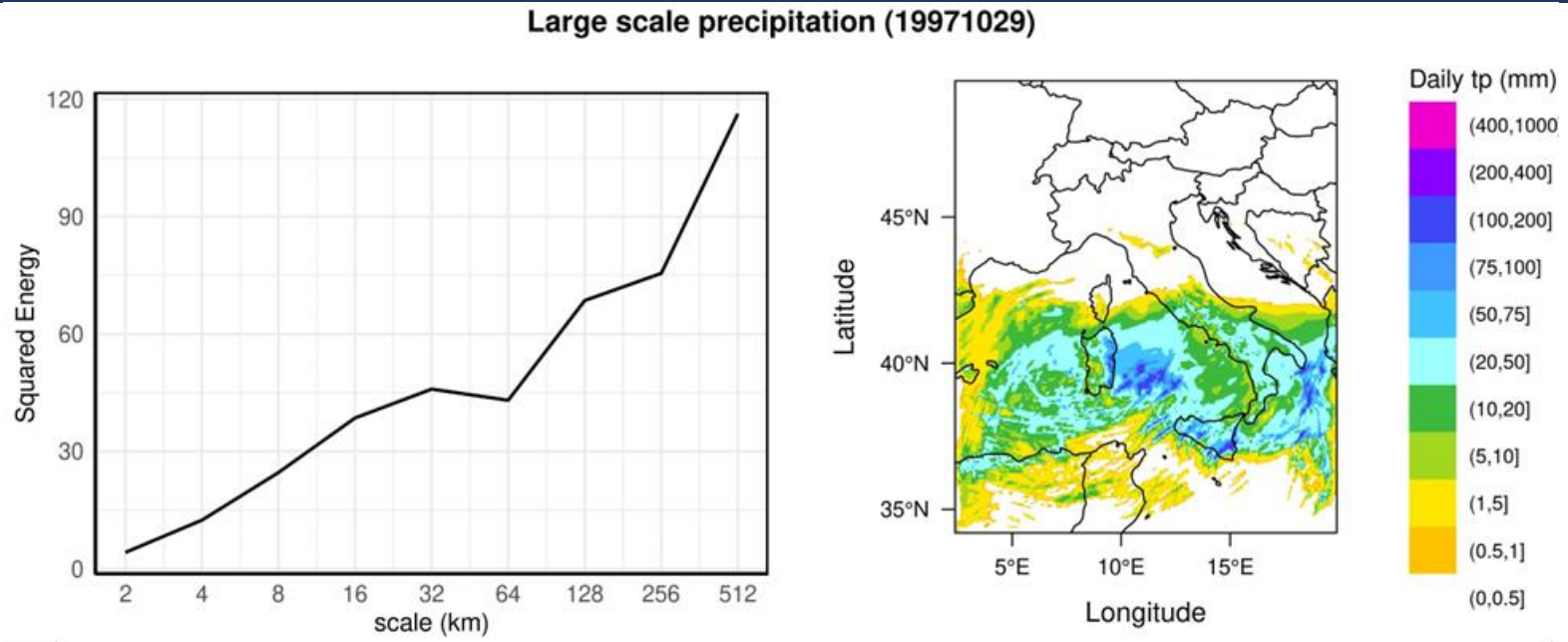
3. Precipitation

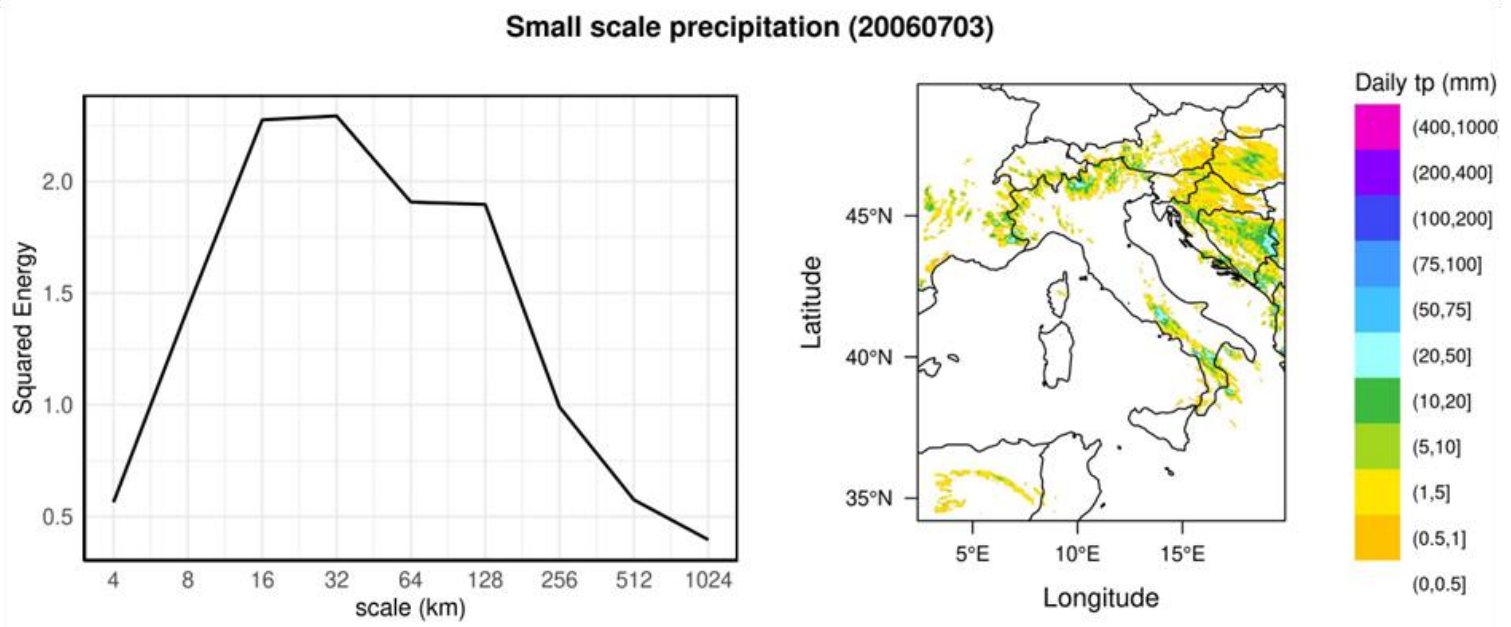
Insights from prec validation

- Which spatial scales can the reanalyses reproduces?
- What is the misplacement errors?
- What are the systematic deviations?

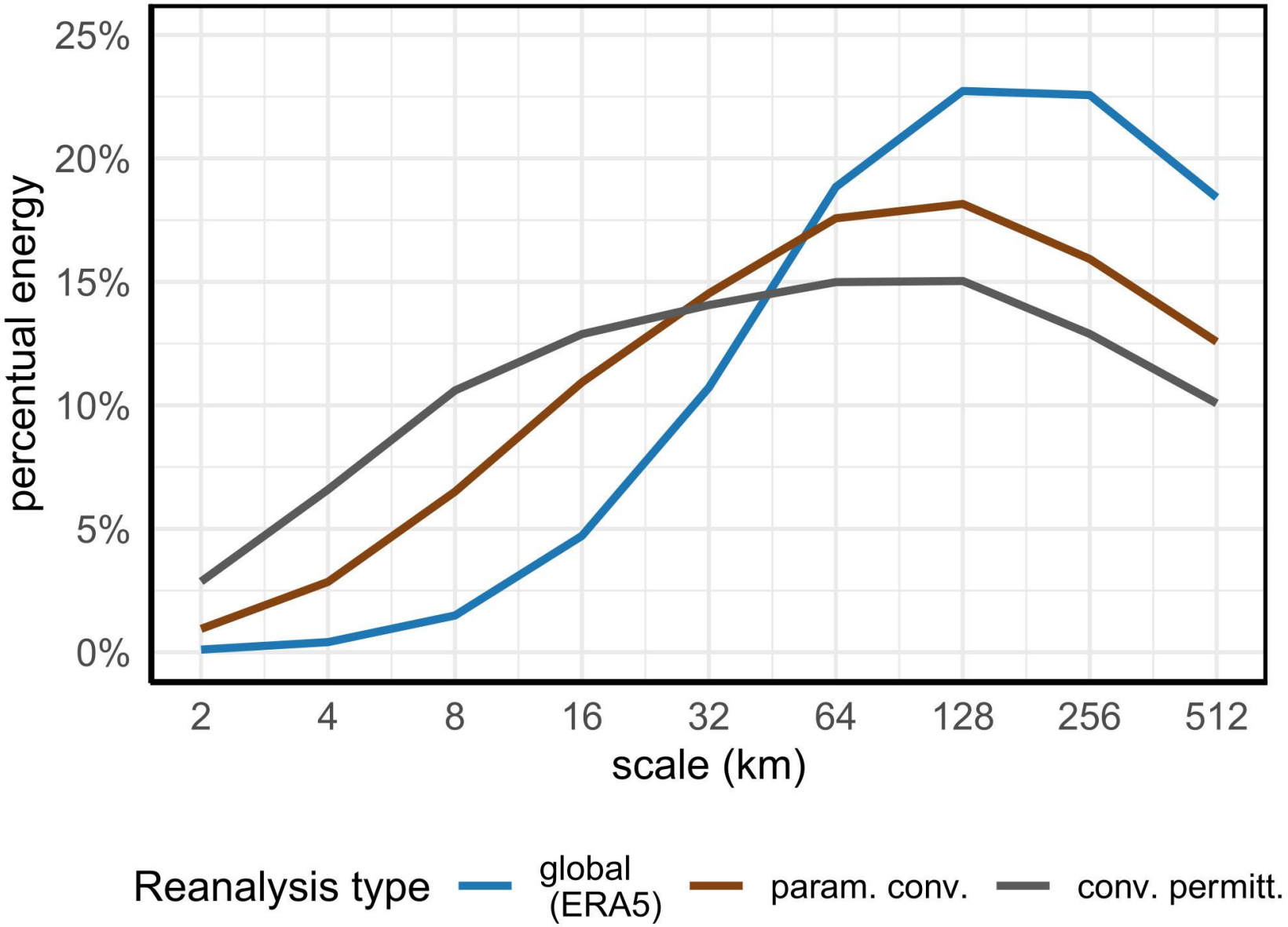
Wavelet decomposition

- The grid spacing does not correspond to the actual resolution of the field.
- Spectral decomposition allows quantifying the spatial scale at which a phenomenon occurs, for example:
  - Synoptic (100-500 km)
  - Convective (< 20 km)
- Energy distribution of precipitation across different spatial scales.

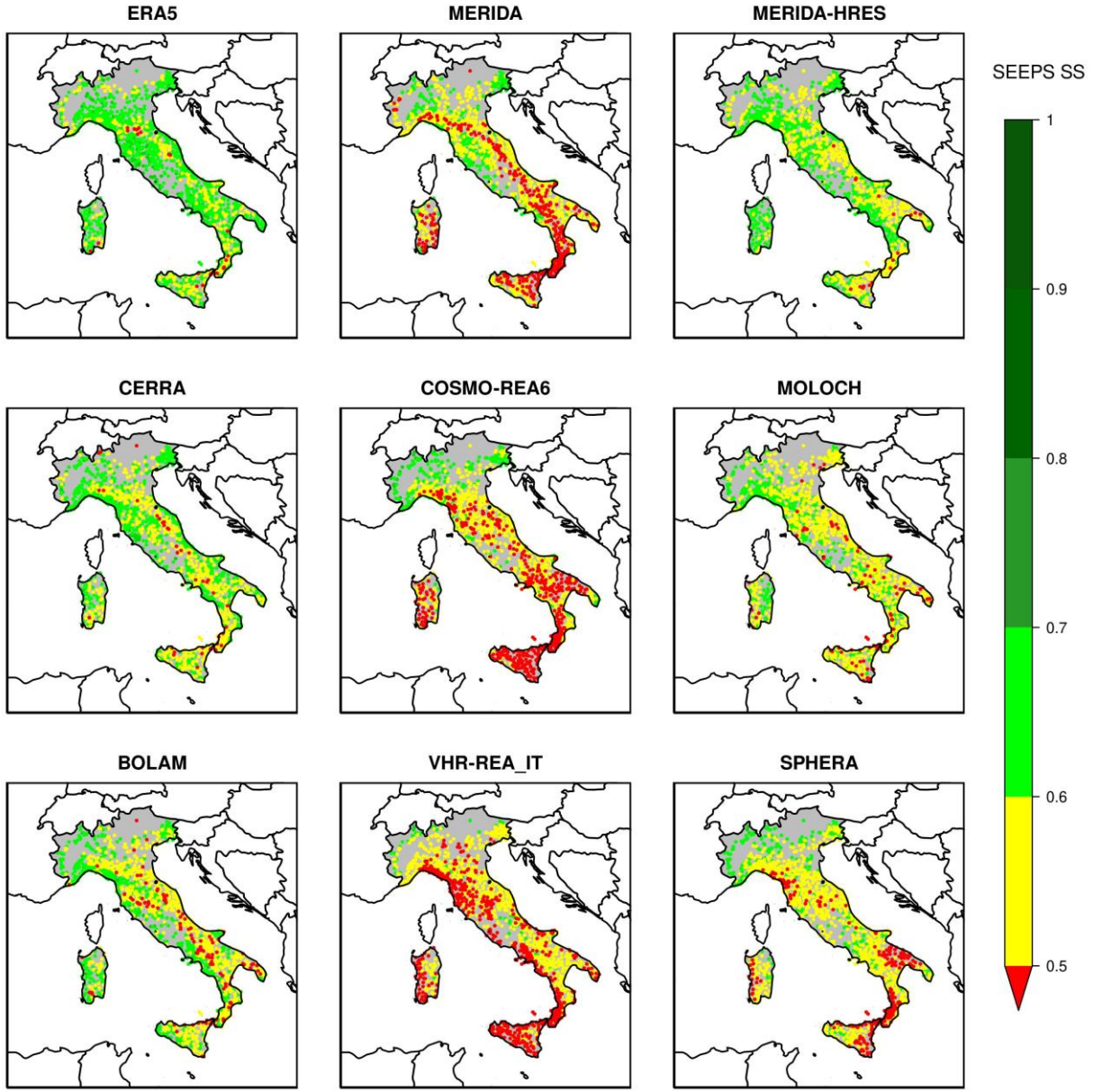




Average energy spectra



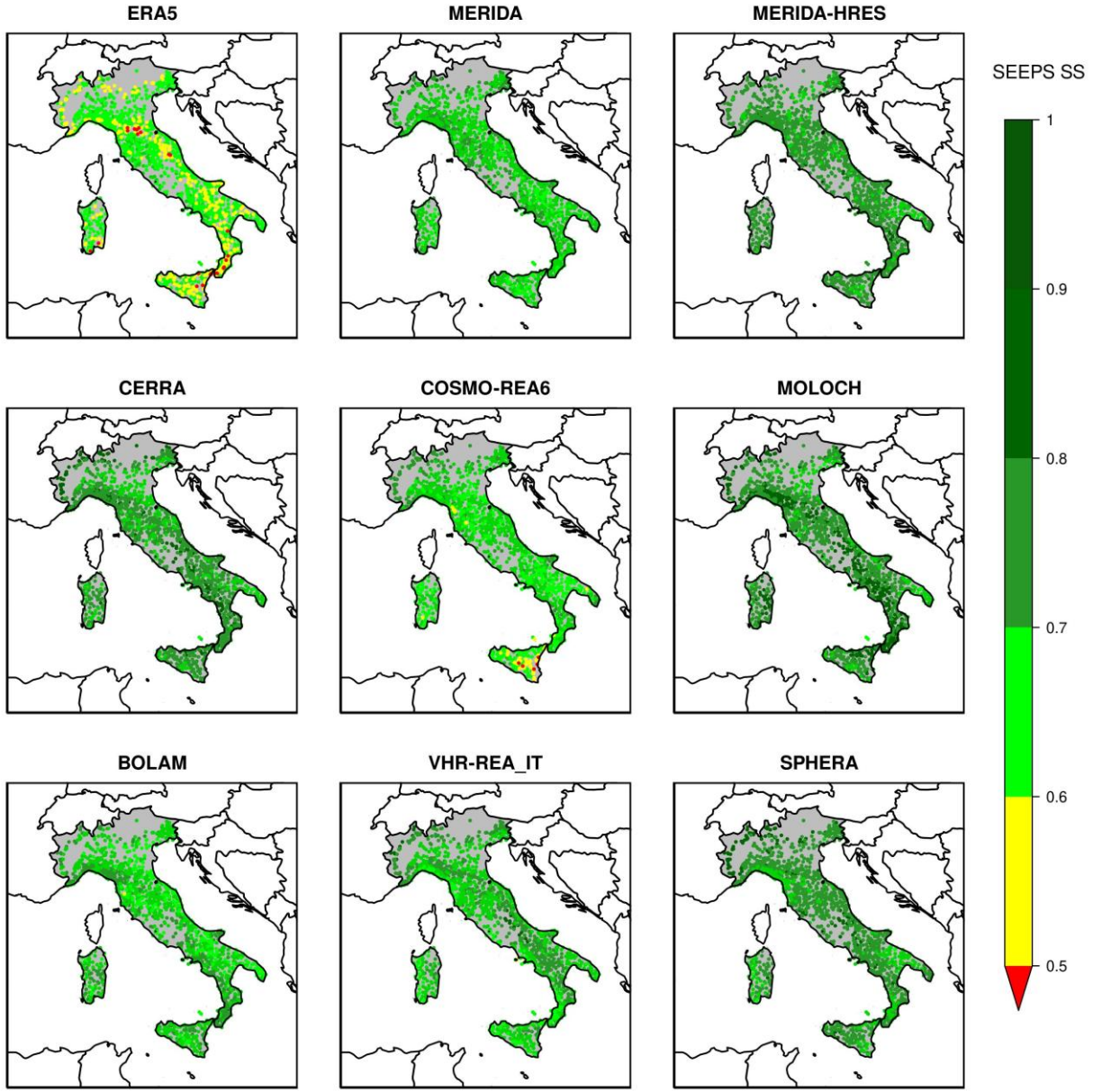
Cavalleri et al. (2024b)



Cavalleri et al. (2024b)

Daily prec vs stations

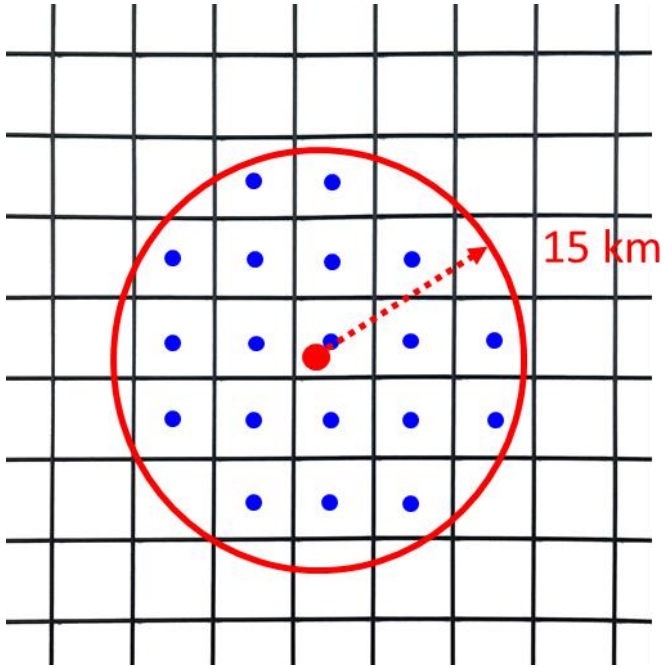
- Compare station measured value against the nearest grid cell from each reanalysis
- Verification of total daily precipitation vs stations: Stable Equitable Error in Probability Space (SEEPS), which assesses the ability to distinguish between:
  - No rain (< 1 mm)
  - Light rain
  - Heavy rain
- Low scores linked to certain geographical features.
- Scores worsen in summer due to convective events.
- Which component of the error is related to misplacement?



Cavalleri et al. (2024b)

Daily prec vs stations

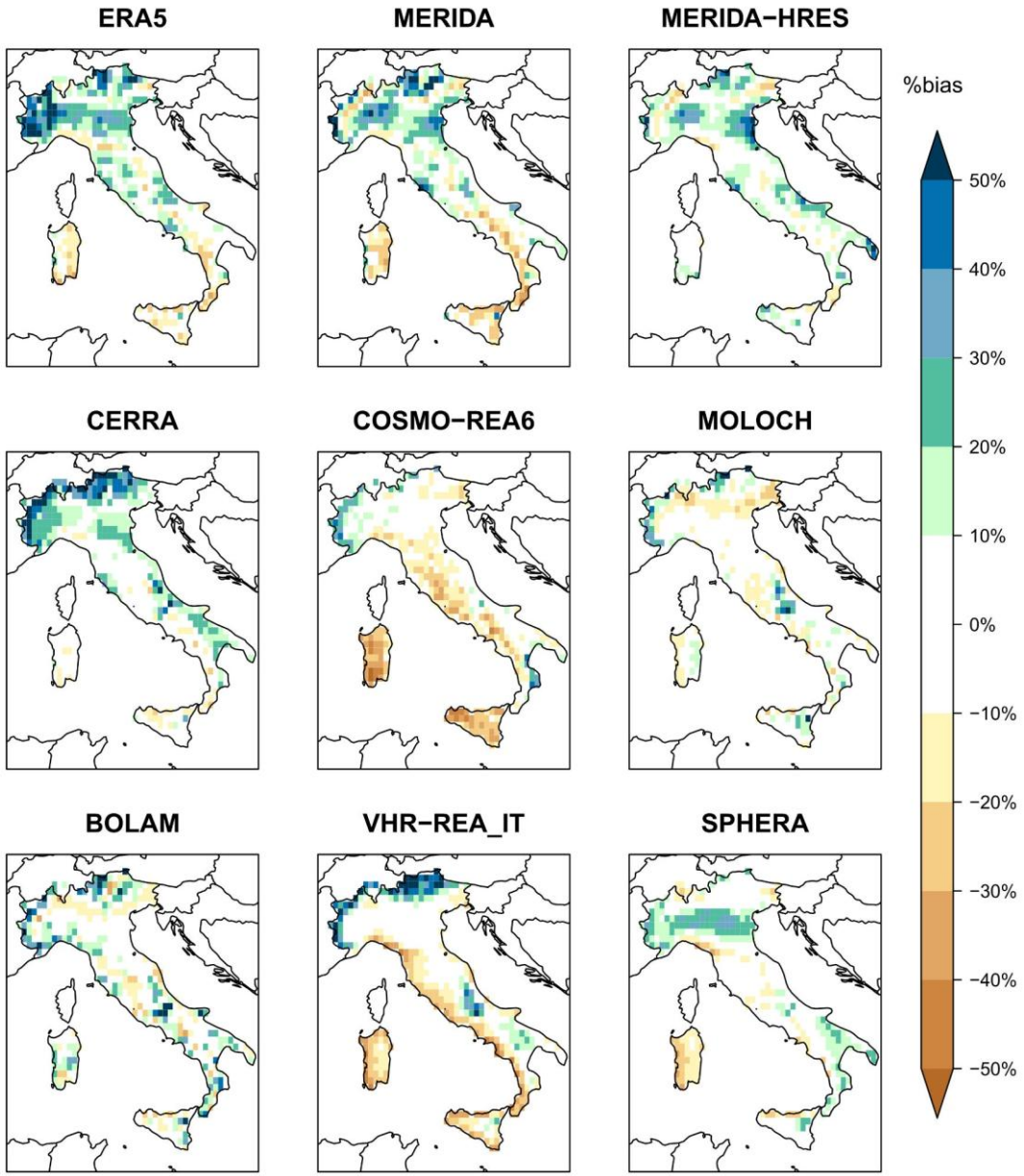
- By selecting the grid point closest to the station's measured value within a 15 km radius, the score improves.



station position

reanalysis grid centre positions

→ At smaller scales, a positioning error within 15 km is intrinsic to the chaotic nature of models.

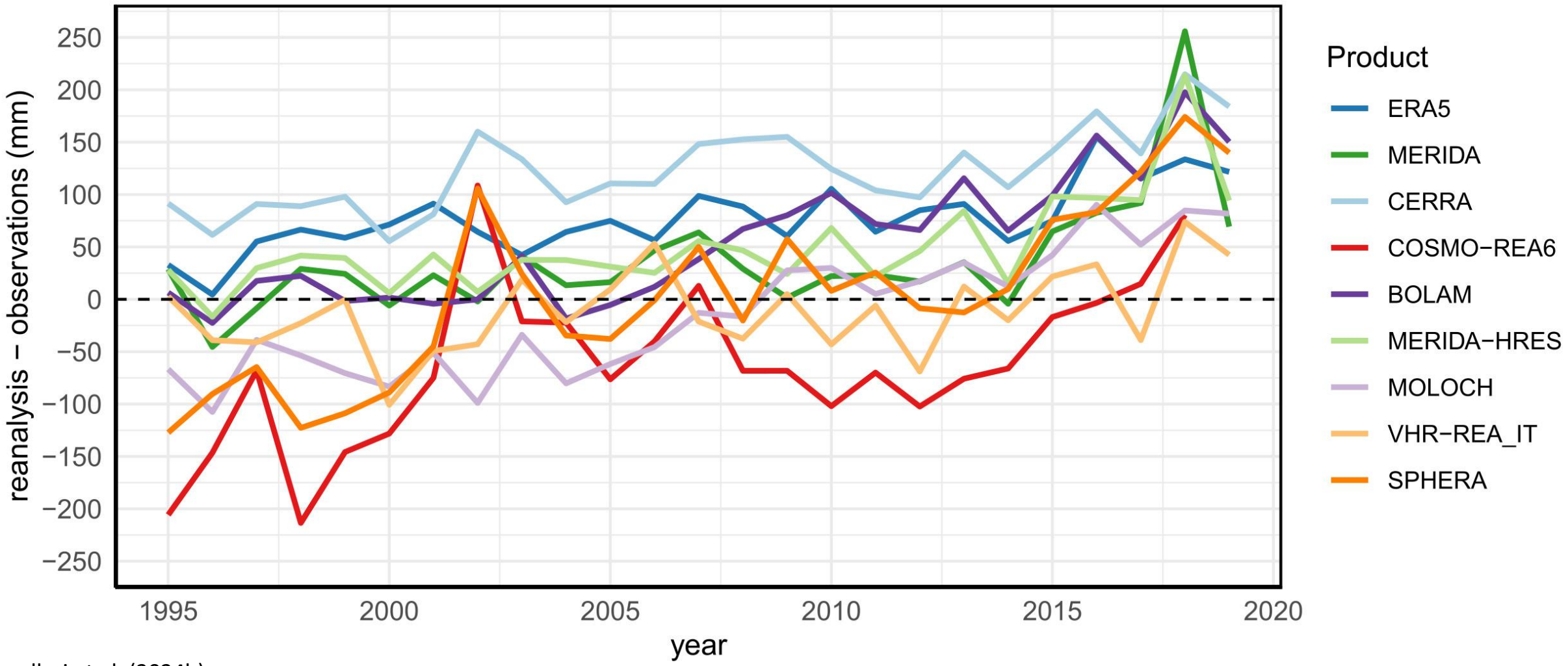


Cavalleri et al. (2024b)

Systematic deviations

- Conservative upscaling to ERA5 resolution and comparison with the UniMi/ISAC-CNR observational dataset.
- Indicator: relative bias between climatologies (1995-2019).
- **Wet** bias: Alps, Po Valley, Central Apennines.
- **Dry** bias: Southern Apennines, west coast, islands.
- Even using the same model (e.g., COSMO), results differ (e.g., SPHERA vs. VHR): humidity nudging?

Non-constant bias over time

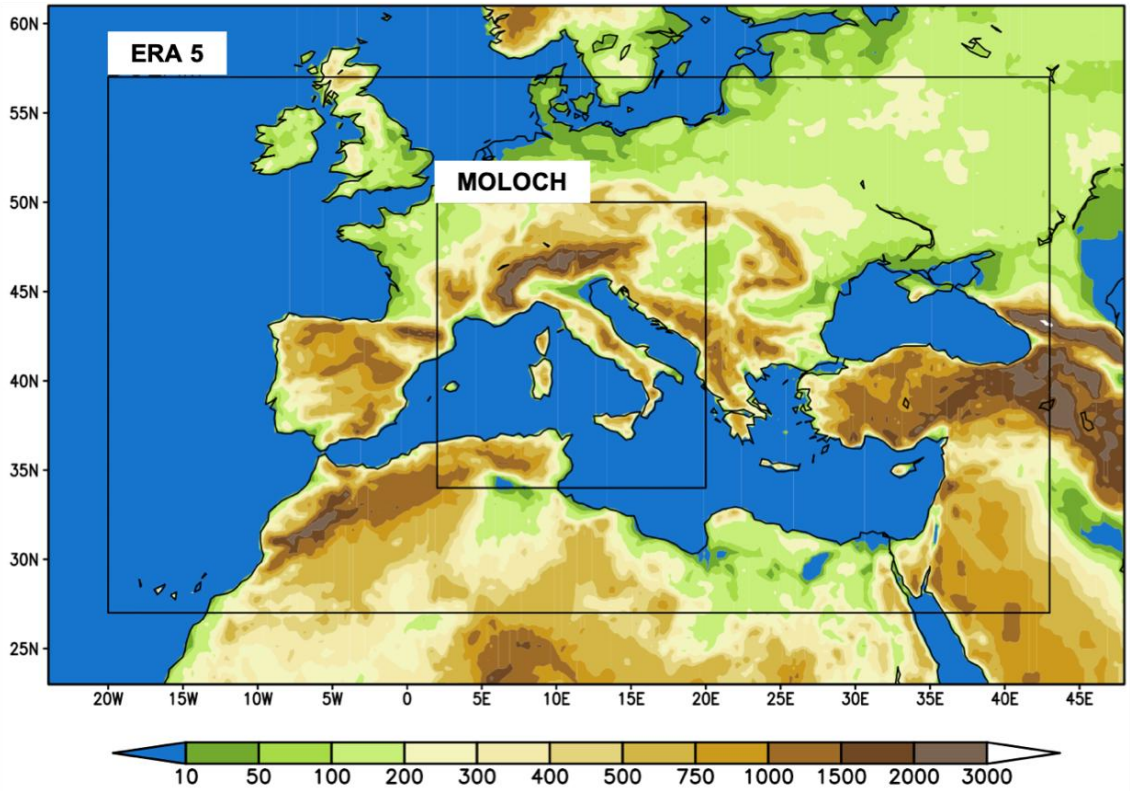


Cavalleri et al. (2024b)

4. A climate application

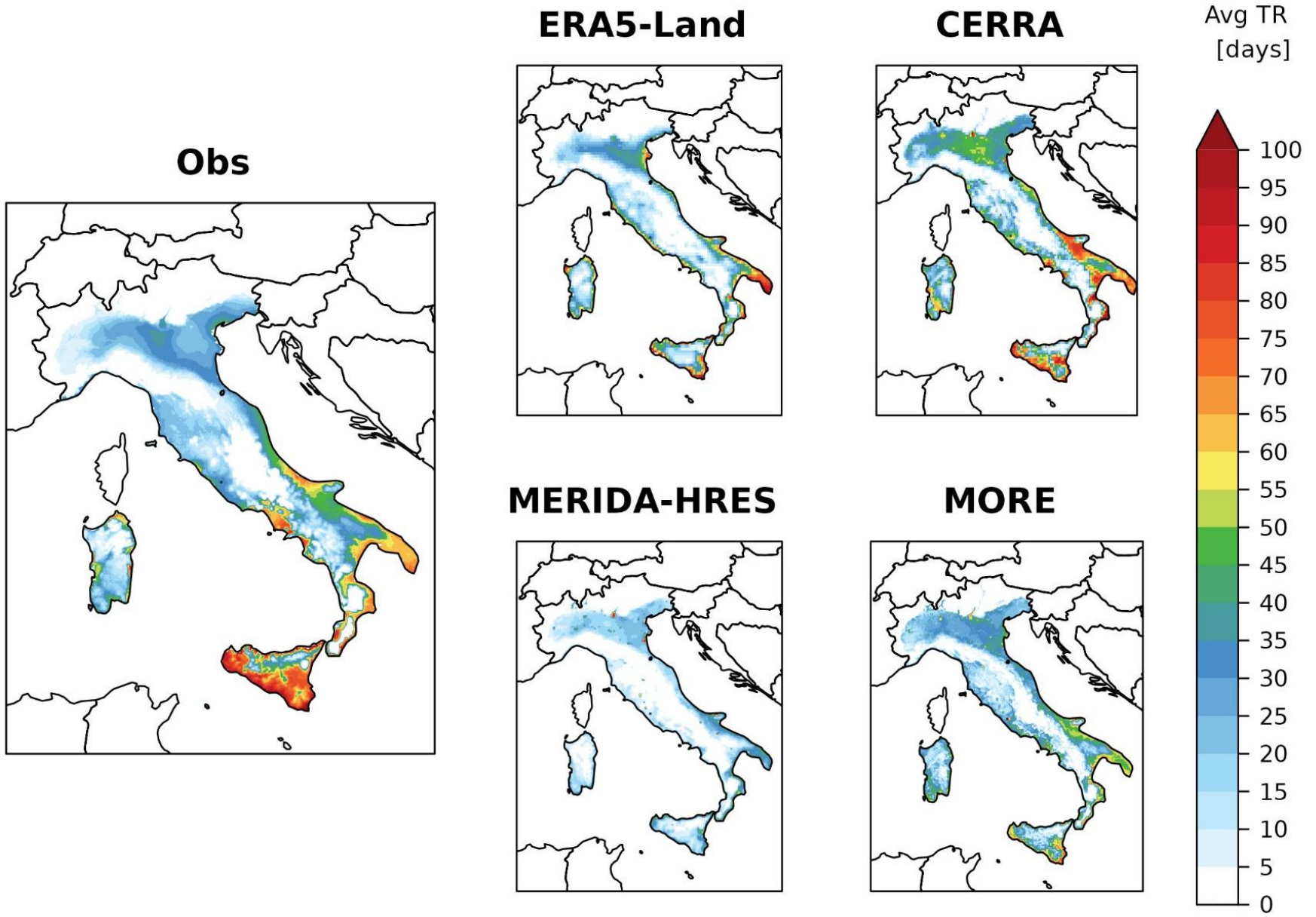
Climate indices

- Used to measure extreme conditions (e.g. ETCCDI)
- Reanalyses can offer a clearer picture than observations alone
- When we do have observations, validation can assess reanalysis ability
- For these analyses, I will use MORE (Moloch-downscaled REanalysis) a new convection-permitting reanalyses at 1.8 km resolution developed by ISAC-CNR

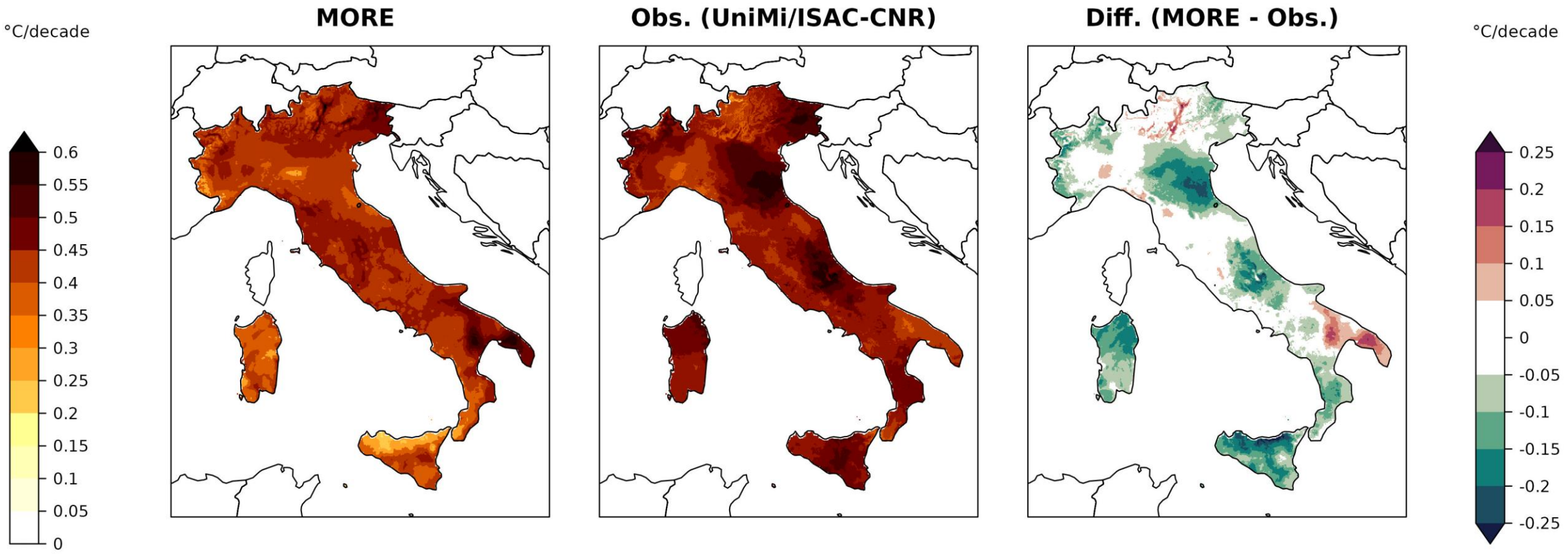


Tropical Nights (Tmin > 20°C)

- Reanalyses get the general pattern
- The cold bias impact the number of TR
- Differences among the products

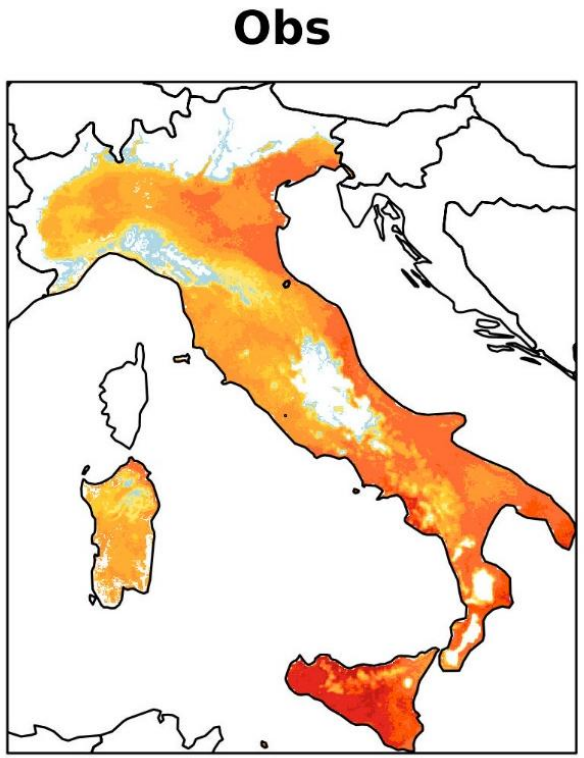


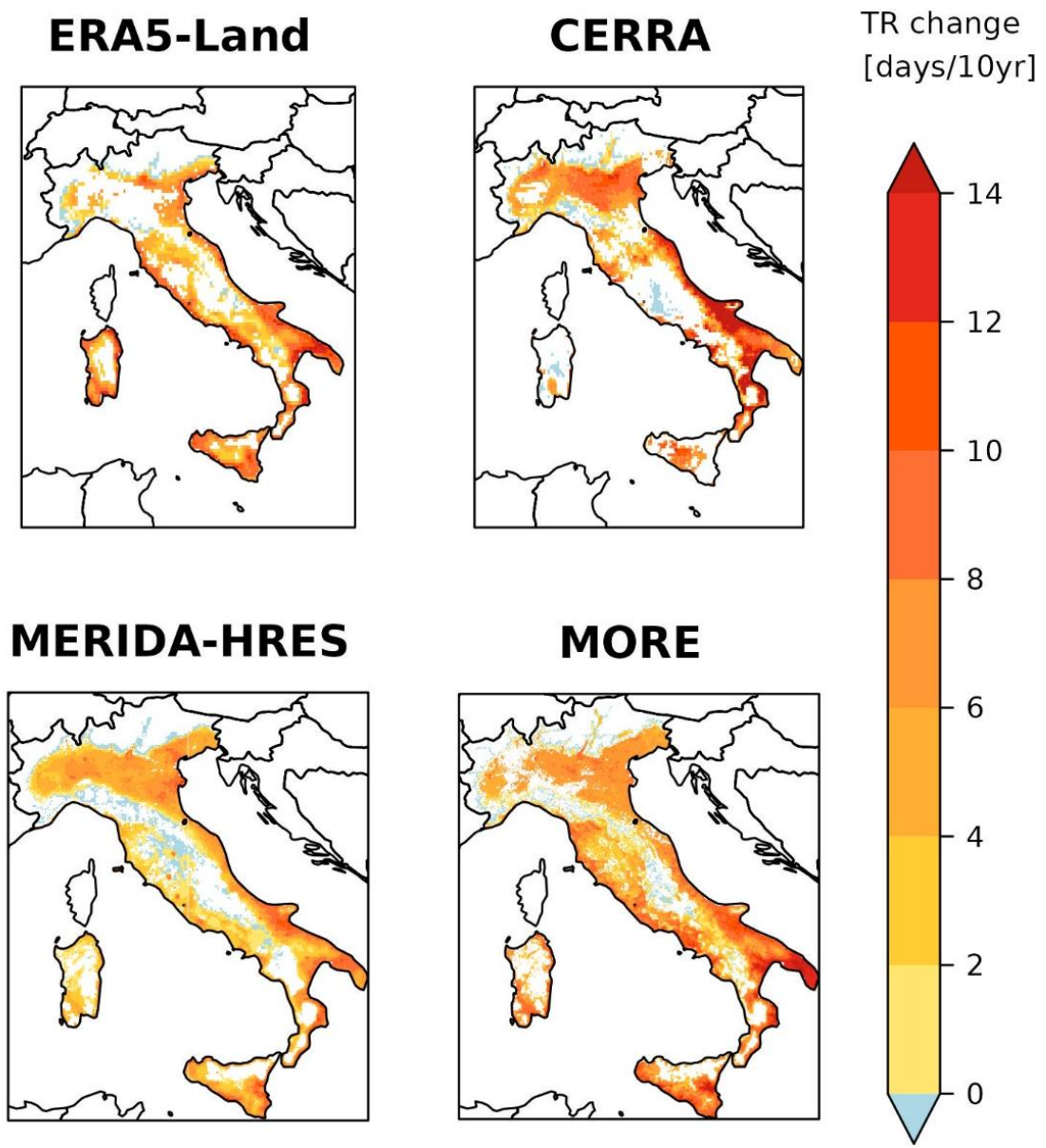
Are reanalysis able to reproduce warming trends?



Trends in Tropical Nights

- Reanalyses get the general pattern
- The cold bias has minimal impact on the trend
- In some regions in Southern Italy, there are about 1 month more of tropical nights than 30 years ago!





5. Discussion

Some open questions:

- For which purpose do you use reanalysis?
- Do you employ ERA5 or regional downscaling?
- Do you assessed strenghts and limitation of them?
- If multiple products exist, which do you choose and how?
- What features you will like to see in future reanalyses?

Thank you for the attention and the discussion!