Inter-comparison and validation of high-resolution surface air temperature reanalysis fields over Italy

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1. Motivations

- **Regional reanalyses** are constantly evolving to **finer resolutions**, compared to global reanalyses, in order to **better describe the atmospheric processes at the small scales** [1];
- previous studies [2] showed some **difficulties of the regional reanalyses in reproducing surface air temperature**, especially in areas like **Italy** that are characterized by **complex orography and strong sea-land interactions**;
- **inter-comparison** and **validation** among different regional reanalysis products are needed to assess the robustness of each product, to understand its strengths and limitations [3].

→ Therefore, **this study evaluates the air surface temperature fields from different reanalysis products, comparing them with gridded observational data**.

2. Main goal

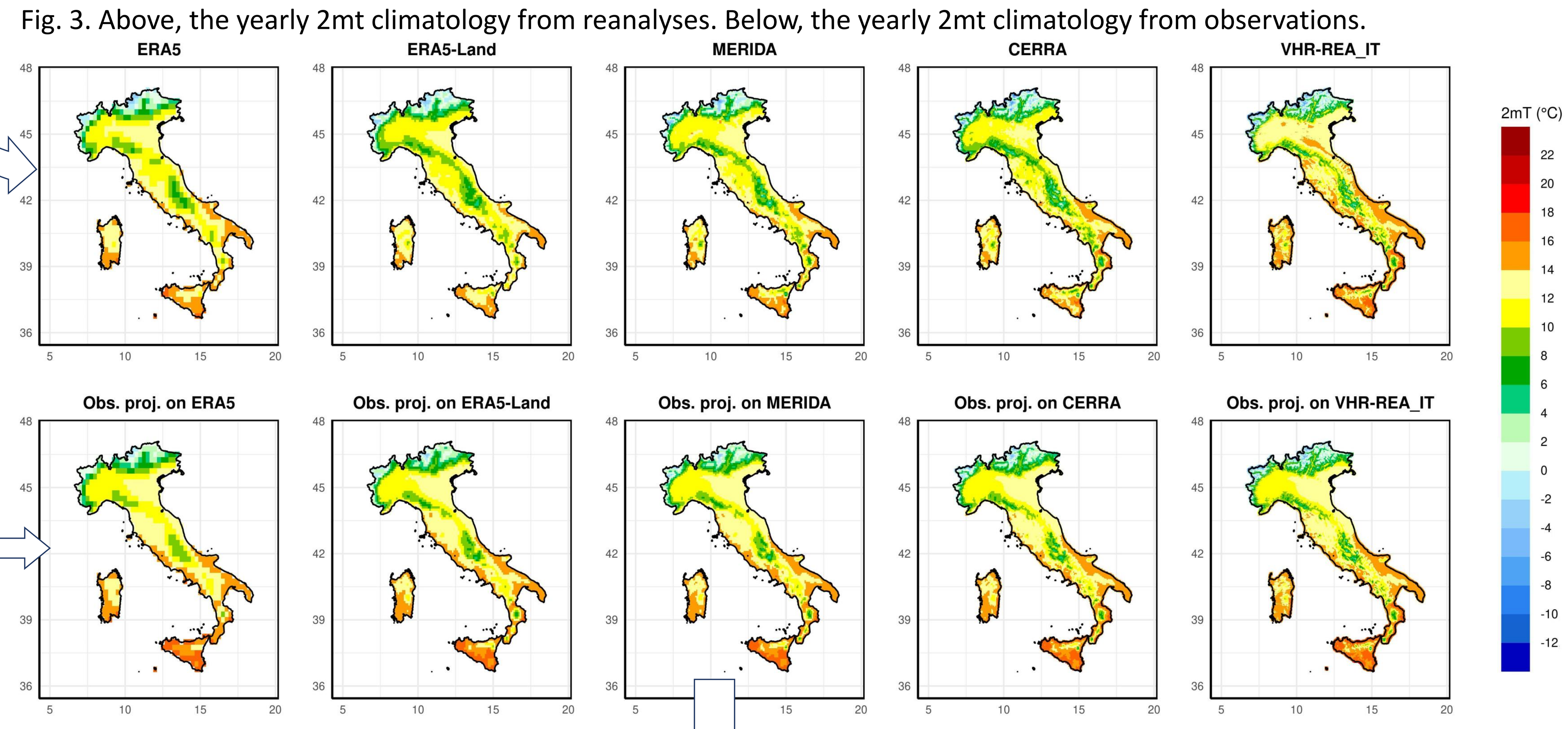
The **1991-2020 monthly climatology of surface air temperature is evaluated over the Italian territory** for different reanalysis products (Table 1). For each product, the temperature **bias** is characterized both in terms of **spatial distribution** and function of different **seasons** and **elevation**.

3. Reanalyses

Four regional reanalysis products are evaluated in this study (Table 1). The global reanalysis ERA5 is also considered in the comparison, since all the regional reanalyses in the study are **derived from ERA5**.

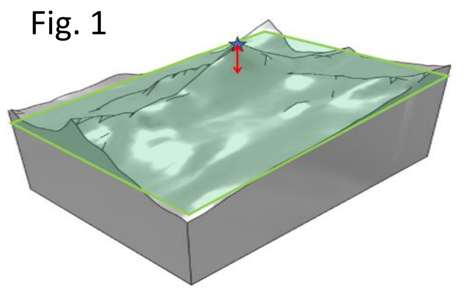
Table 1	Released	Produced by	Model used	Temporal resolution	Spatial extention	Spatial resolution
ERA5 [7]	14/06/2018	ECMWF	IFS	1 h	global	0.25° (≃31 km)
ERA5-Land [8]	12/07/2019	ECMWF	H-TESSEL	1 h	global	0.1° (≃9 km)
MERIDA [9]	25/03/2019	RSE	WRF-ARW	1 h	Italy	0.07° (≃7 km)
CERRA [10]	02/08/2022	ECMWF	HARMONIE	3 h	Europe	≃0.06° (5.5 km)
VHR-REA_IT [11]	01/08/2021	CMCC	COSMO CLM	1 h	Italy	0.02° (≃2.2 km)

Fig. 3. Above, the yearly 2mt climatology from reanalyses. Below, the yearly 2mt climatology from observations.



4. Observational dataset

Fig. 1



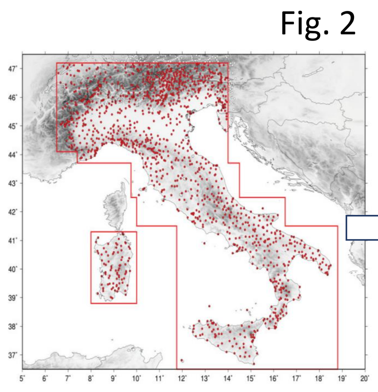
- **Elevation** is one of the main factors that affects the spatial variability of temperature [4];
- the **differences between the real-world topography and the model representation of topography in the reanalysis models** (Fig.1) have a predominant influence on surface air temperature biases [5].

We compared the reanalyses with **observational data that are specifically interpolated to each grid-point (lon, lat, elevation)** of the reanalysis fields, to reduce possible biases deriving from elevation.

The gridded observational climatology is the result of a **weighted linear regression of temperature versus elevation** as described in [6] starting from an **extended version of a dataset consisting of about 1100 stations,** a subset of the dataset used in that paper and shown in Fig. 2 (figure from [6]).

The results are the observational climatologies at the native resolution of each reanalyses show in Fig. 4.

Fig. 2



5. Results & Discussion

A) Spatial maps of the bias (yearly, seasonally, monthly) at native resolutions of each reanalysis

- **ERA5 underestimates temperature** over most of the Italian territory. **ERA5-Land** results **on average 0.5 °C colder** than ERA5.
- **MERIDA and CERRA** present a **bias spatial distribution similar to ERA5** over the Italian region with **some local intensification of cold biases** (mostly in complex orography areas and in the south of Italy).
- **VHR-REA_IT** is on average **0.5 °C warmer than** ERA5 and with a peak of **1.5 °C warmer over the Po valley.**

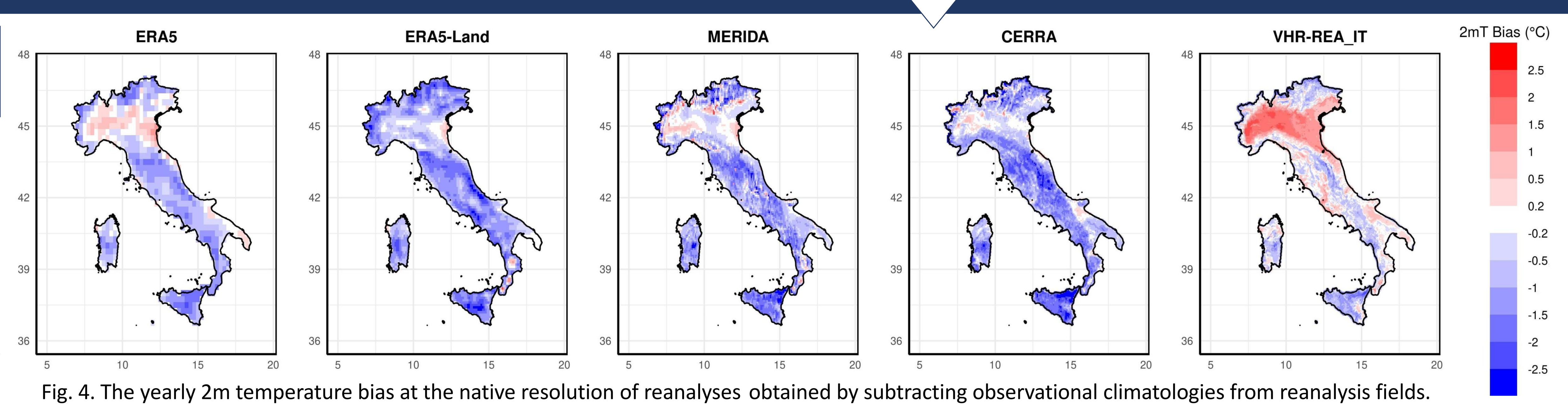


Fig. 4. The yearly 2m temperature bias at the native resolution of reanalyses obtained by subtracting observational climatologies from reanalysis fields.

B) Seasonal Bias and MAE spatial averages

Table 2 summarizes the seasonal bias and MAE.

- **ERA5** presents the **highest differences in winter, compared to the other seasons.**
- This tendency in **winter** is also reflected by **all the other reanalyses products**, except **VHR-REA_IT** that has the **highest errors** (both BIAS and MAE) in **summer**.
- In winter the rest of the **regional reanalyses tends to amplify the winter error from ERA5**, with higher average values of bias and MAE.

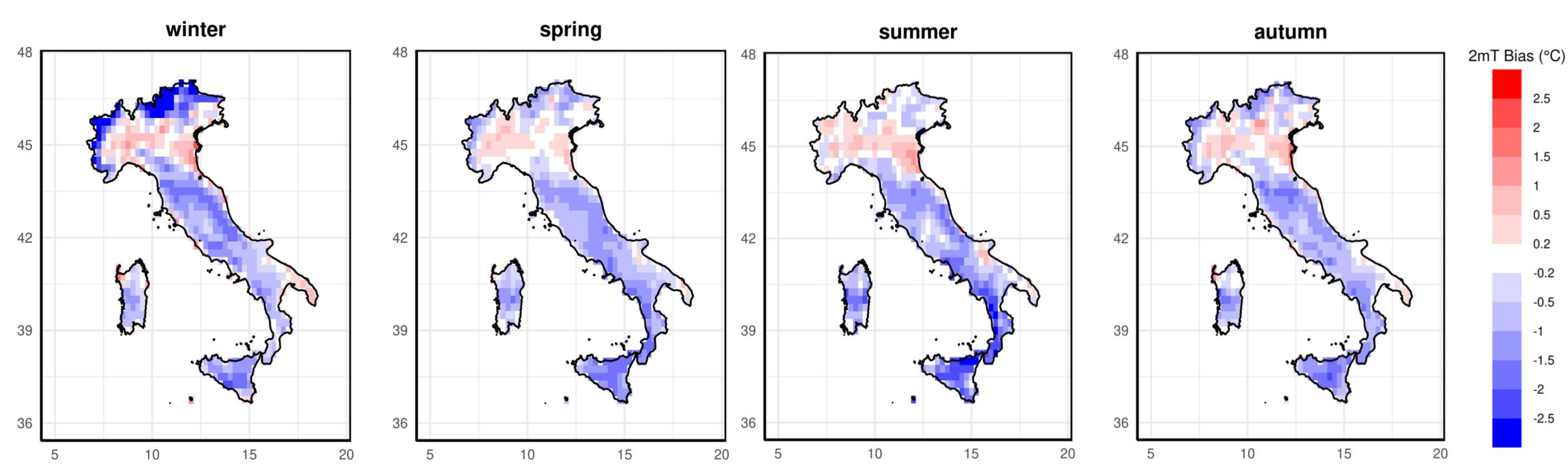


Fig. 5. Seasonal bias maps for the ERA5 reanalysis.

ERA5 seasonal bias maps (Fig. 5) highlight a **cold bias in winter over the Alps.**
The **ERA5 negative bias increases with elevation during winter in the north of Italy** (1st panel in Fig. 6). The **other reanalyses show similar trends**, shown in Table 3.

Table 2	Average Bias (°C)					MAE (°C)				
	winter	spring	summer	autumn	yearly	winter	spring	summer	autumn	yearly
ERA5	-0.70	-0.62	-0.64	-0.53	-0.62	0.98	0.73	0.82	0.72	0.77
ERA5-Land	-1.31	-1.25	-0.92	-0.97	-1.11	1.39	1.26	0.98	1.03	1.14
MERIDA	-0.84	-0.86	-0.75	-0.76	-0.80	1.15	0.96	0.90	0.95	0.95
CERRA	-1.19	-0.92	-0.85	-1.15	-1.03	1.25	1.02	1.04	1.18	1.08
VHR-REA_IT	-0.89	0.09	1.22	0.09	0.12	1.01	0.65	1.39	0.73	0.70

(°C) 1.5 1.5 / -1.5 0.5

Table 3	winter		summer		
ERA5	↘	-4	=	0	N
	=	-1	=	-1	S
ERA5-Land	↘	-4	=	-0.5	N
	=	-1.5	=	-1.5	S
MERIDA	↘	-3	=	-0.5	N
	=	-1	=	-1	S
CERRA	↘	-5	=	-1	N
	=	-1.5	↘	-2	S
VHR-REA_IT	=	-1.5	↖	3	N
	=	-1.5	=	1	S

C) Combined bias dependence by elevation, season, north/south

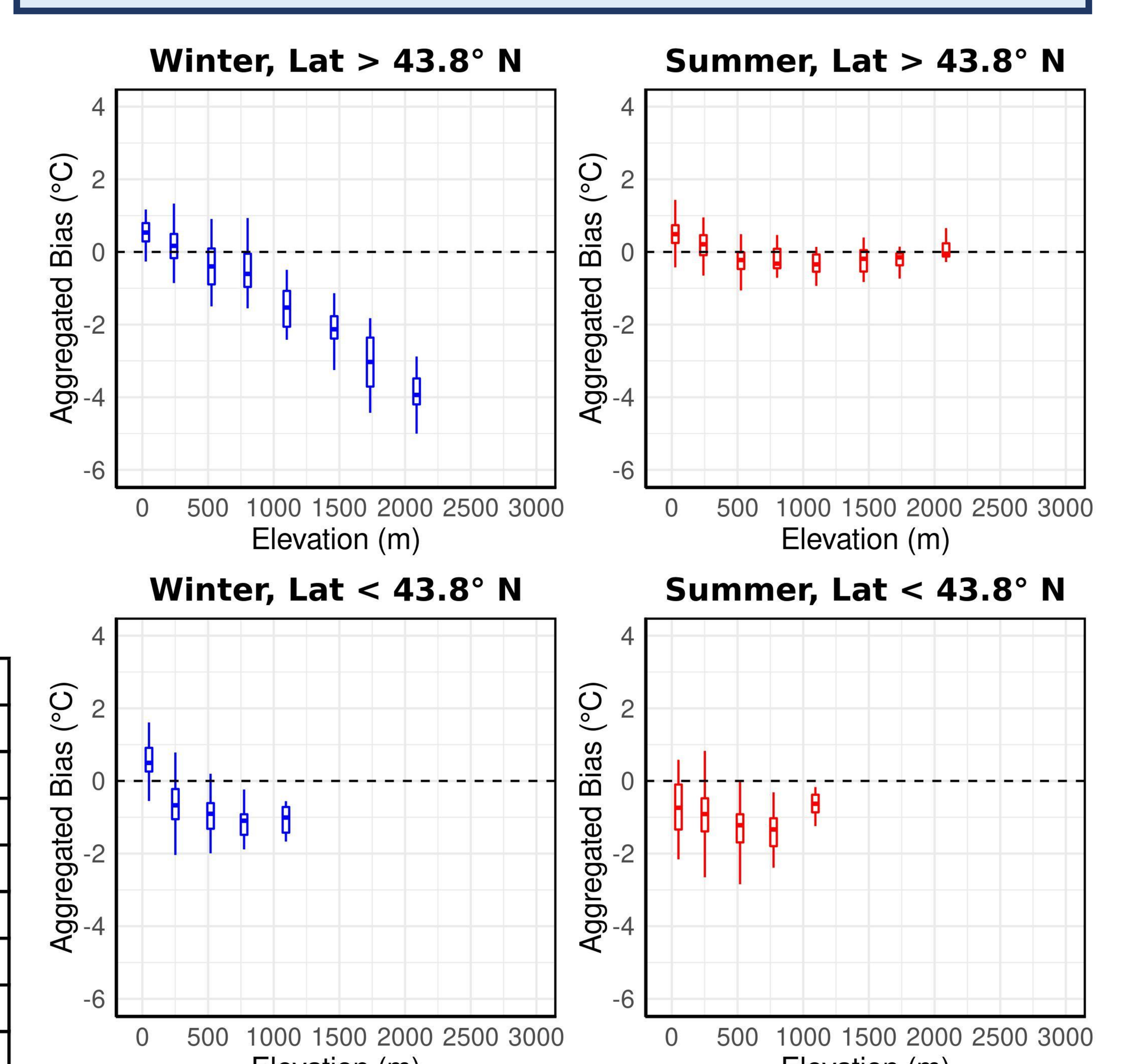


Fig. 6. Box plots of the ERA5 2mt bias aggregated by 300m elevation ranges, varying winter/summer and north/south

6. Conclusions

- **Reanalyses reproduce the temperature climatology over Italy** for spatial scales ranging from 31 km to 2.2 km, losing only little skill when simulating the more challenging small-scale processes. **A cold bias is usually present over the Alps**.
- **MERIDA is the regional reanalysis that performs best** in reproducing surface air temperature climatology throughout the year, even if it has a **slightly higher bias and MAE than ERA5 global product**.
- The increase of cold bias with elevation suggests **further investigation needed on snow processes**.

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