VHR-REA_IT dataset: a dynamical downscaling of ERA5 reanalysis at very fine resolution 2.2 km over Italy

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Centro Euro-Mediterraneo sui Cambiamenti Climatici

Overview

- the HIGHLANDER project (https://highlanderproject.eu/)

Highlander
High performance computing to support smart land services

- A new additional gridded dataset over Italy, labelled as VHR-REA_IT (**V**ery **H**igh-**R**esolution **REA**nalysis for **IT**aly), derived from the dynamical downscaling of ERA5 reanalysis
  - Experimental setup
- Evaluation:
  - temperature and precipitation
  - ETCCDI Climate Indices
- Conclusions

Soil erosion

Forest fires prediction

Crop water requirements forecast

Animal welfare and land suitability for farming

HIGHLANDER project

HIGHLANDER project will be able to develop new cutting-edge applications and services for supporting planning and **decision-making** when considering **territorial resources and systems** modifying under medium-term climate projections, including **extreme events** and related **climate risks**, e.g.:

- a **smarter management of agriculture** – through irrigation schedules, land capability for specific crops;
- the **maintenance of animal and human wellbeing**, looking at differences between rural and urban areas;
- an **improved water management**, considering the **sustainability of competing uses** (hydropower, domestic, agricultural, ecological);
- a better planning of landscape ecosystems and resources by considering shift in **forest habitat suitability** and changes in **soil erosion potential**.

Land suitability for vegetation

Human wellbeing in rural and urban areas

Water cycle and sustainability of competing uses

Soil erosion

Forest fires prediction

Natural parks environmental management

Crop water requirements forecast

IoT for Animal wellbeing

Animal welfare and land suitability for farming

Highlander
High performance computing to support smart land services

Coordinator

CINECA
Cineca Interuniversity Consortium

https://highlanderproject.eu/

Dynamical downscaling of ERA5

Topic

Sensitivity test for dynamical downscaling of ERA5 Reanalysis

Main objective

The assessment of downscaling exercise of ERA5 Reanalysis at ~2.2 km over Europe, to reproduce past precipitation pattern

Domain

Central Europe

Periods

2007-2011 | evaluation

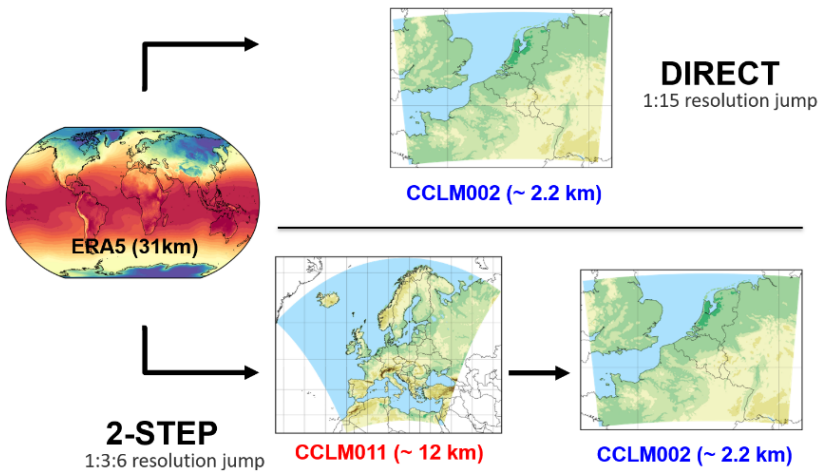
Model

COSMO-CLM

Spatial Resolution

2.2 km | Central Europe
12 km | EURO-Cordex domain

Model	CCLM011	CCLM002-Nest	CCLM002-Direct
Boundary forcing	ERA5-Reanalysis	CCLM011	ERA5-Reanalysis
Horizontal resolution	0.11° (~12 km)	0.02° (~2.2 km)	0.02° (~2.2 km)
Time step (s)	75 s	20 s	20 s
N° grid points	450 × 438	455 × 330	455 × 330
N° vertical levels	40	50	50
Radiation scheme	Ritter and Geleyn [48]	Ritter and Geleyn [48]	Ritter and Geleyn [48]
Convection scheme	Deep and shallow convection based on Tiedtke [49]	Shallow convection based on Tiedtke [49]	Shallow convection based on Tiedtke [49]
Microphysics scheme	Doms et al. [50]; Baldauf and Schulz [51]	Doms et al. [50]; Baldauf and Schulz [51]	Doms et al. [50]; Baldauf and Schulz [51]
Land surface scheme	TERRA-ML [50]	TERRA-ML [50] with TERRA-URB [42] parametrization	TERRA-ML [50] with TERRA-URB [42] parametrization
Land use	GLC2000 [52]	GLC2000 [52]	GLC2000 [52]
Planetary boundary layer scheme	Mellor and Yamada [53]	Mellor and Yamada [53]	Mellor and Yamada [53]
Lateral Boundary Condition (LBC) update frequency	1 h	1 h	1 h
Soil initialization	Temperature and moisture obtained by interpolation from ERA5-Reanalysis	Temperature and moisture obtained by interpolation from CCLM011	Temperature and moisture obtained by interpolation from ERA5-Reanalysis



Raffa M., Reder A., Adinolfi M., Mercogliano P. (2021). A Comparison between One-Step and Two-Step Nesting Strategy in the Dynamical Downscaling of Regional Climate Model COSMO-CLM at 2.2 km Driven by ERA5 Reanalysis. Atmosphere, 2021, 12, 260

VHR-REA_IT: experimental setup

Topic

Very high-resolution dynamical downscaling of ERA5 reanalysis over Italy

Main objective

Providing VHR climate data over Italy as input for downstream services (e.g., for decision support system), in different sectors highly affected by changes in climate trends, variability, and extreme events

Domain

Italian Peninsula

Periods

1989-2020 | evaluation

Model

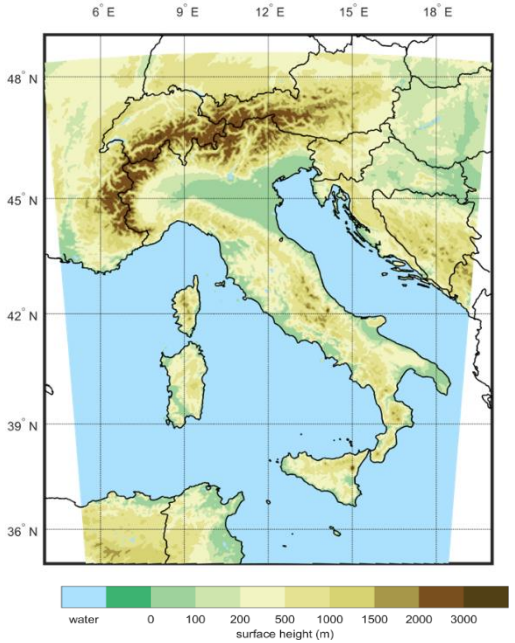
COSMO-CLM

Spatial Resolution

2.2 km

HPC

GALILEO (Cineca)

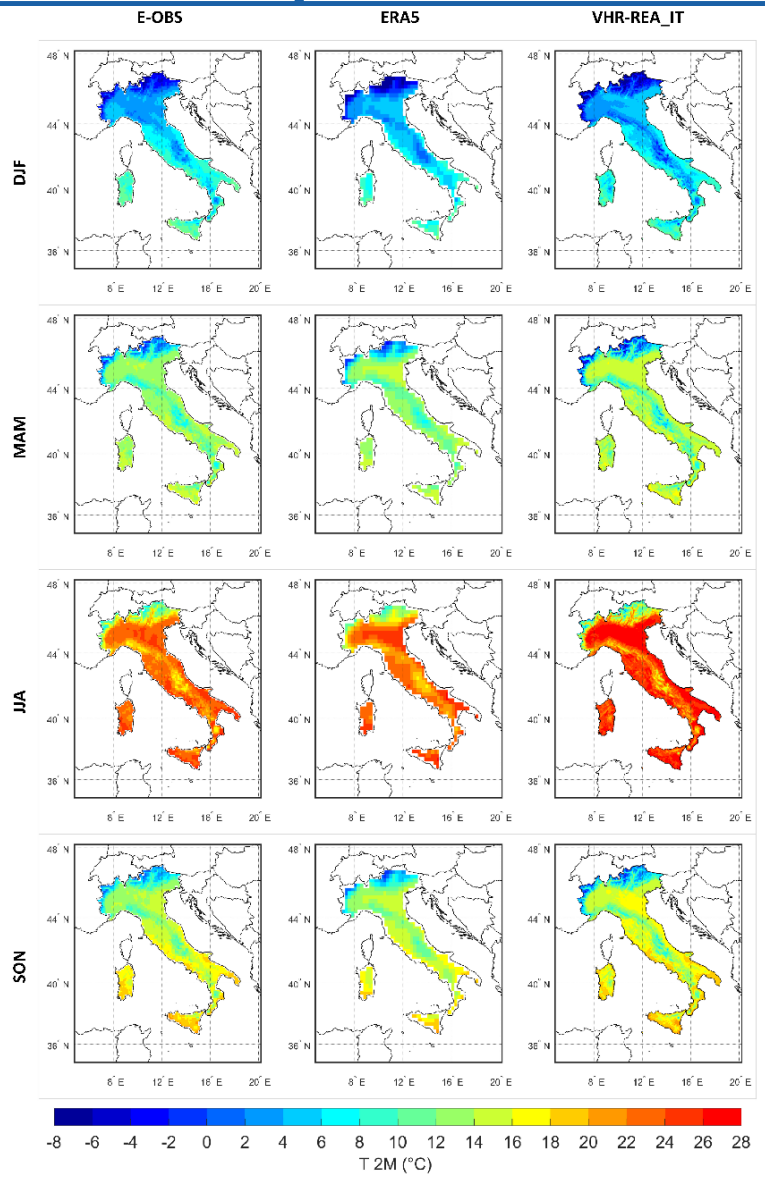


Raffa M., Reder A., Marras G., Mancini M., Scipione G., Santini M., and Mercogliano P., VHR-REA_IT dataset: very high resolution dynamical downscaling of ERA5 reanalysis over Italy by COSMO-CLM, 2021, Data, Volume 6, Issue 8, DOI: 10.3390/data6080088

Output variables	Short-Name	Units
2m temperature	T_2M	K
2m dew point temperature	TD_2M	K
Total precipitation	TOT_PREC	kg m^{-2}
U-component of 10m wind	U_10M	m s^{-1}
V-component of 10m wind	V_10M	m s^{-1}
2m maximum temperature	TMAX_2M	K
2m minimum temperature	TMIN_2M	K
mean sea level pressure	PMSL	Pa
specific humidity	QV_2M	kg kg^{-1}
total cloud cover	CLCT	1
Surface Evaporation	AEVAP_S	kg m^{-2}
Averaged surface net downward shortwave radiation	ASOB_S	W m^{-2}
Averaged surface net downward longwave radiation	ATHB_S	W m^{-2}
Surface snow amount	W_SNOW	m
Soil (multi levels) water content	W_SO	m

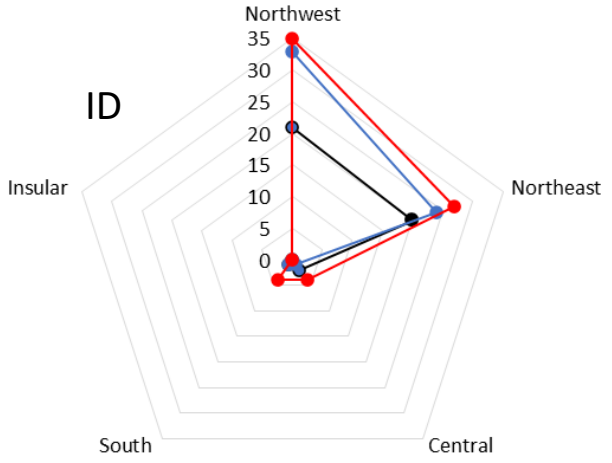
Highlander
High performance computing to support smart land services

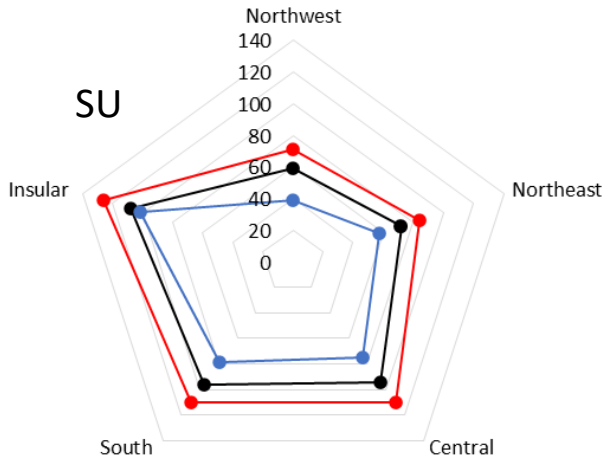
Preliminary evaluation: 2m temperature

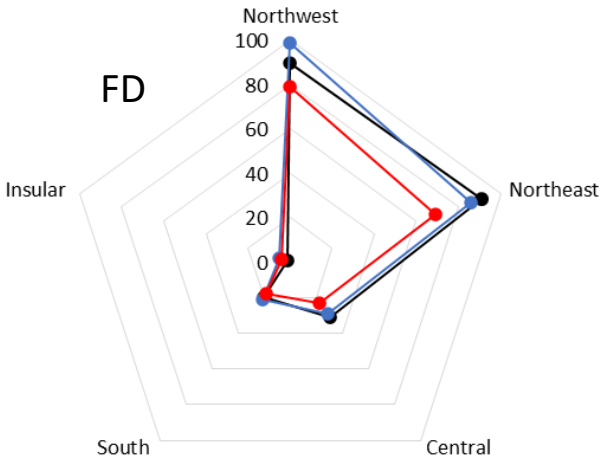


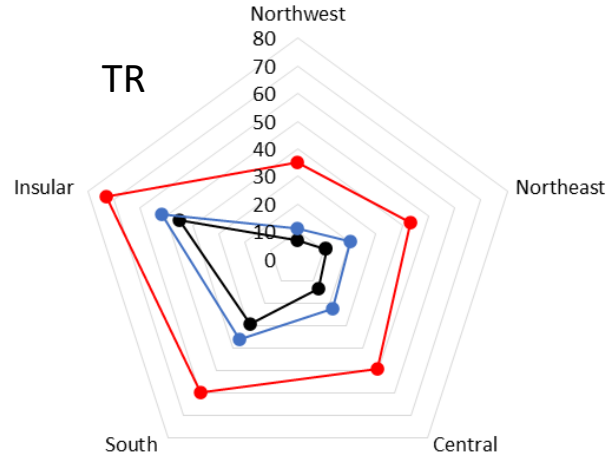
		Bias (°C)				$\sigma_{mod}/\sigma_{obs}$			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Italy	E-OBS	***5.3***	***11.7***	***21.4***	***13.9***	***4.1***	***3.6***	***3.8***	***4.1***
	ERA5	-0.5	0.0	0.1	-0.1	1.1	1.0	1.0	1.0
	VHR-REA_IT	-0.7	0.6	1.9	0.5	1.0	1.2	1.2	1.1
Northwest Italy	E-OBS	***1.8***	***9.1***	***18.4***	***10.3***	***0.8***	***1.1***	***1.2***	***0.9***
	ERA5	-1.8	-0.7	-0.3	-0.7	1.8	1.3	1.1	1.3
	VHR-REA_IT	-0.8	0.1	1.7	0.4	1.3	1.2	1.2	1.3
Northeast Italy	E-OBS	***1.6***	***9.7***	***19.4***	***10.8***	***0.6***	***1.0***	***1.0***	***0.8***
	ERA5	-0.5	0.1	0.2	0.0	1.6	1.0	1.0	1.0
	VHR-REA_IT	-0.1	0.7	2.1	0.9	1.6	1.3	1.3	1.5
Central Italy	E-OBS	***6.3***	***12.4***	***22.1***	***14.7***	***0.6***	***0.6***	***0.6***	***0.6***
	ERA5	-0.2	-0.1	0.0	-0.1	1.2	1.1	0.9	1.1
	VHR-REA_IT	-0.8	0.6	1.8	0.5	0.9	1.1	1.1	1.1
South Italy	E-OBS	***7.5***	***12.7***	***22.7***	***15.9***	***0.8***	***0.8***	***0.8***	***0.8***
	ERA5	-0.2	0.0	-0.1	-0.2	1.0	1.0	1.0	0.9
	VHR-REA_IT	-1.0	0.5	1.5	0.1	1.1	1.2	1.1	1.1
Insular Italy	E-OBS	***10.4***	***14.3***	***23.7***	***18.3***	***0.5***	***0.5***	***0.4***	***0.5***
	ERA5	-0.4	-0.1	0.2	-0.3	1.1	0.9	0.9	1.0
	VHR-REA_IT	-1.0	0.4	1.2	-0.3	1.4	1.4	1.3	1.3

Climate indices: 2m temperature







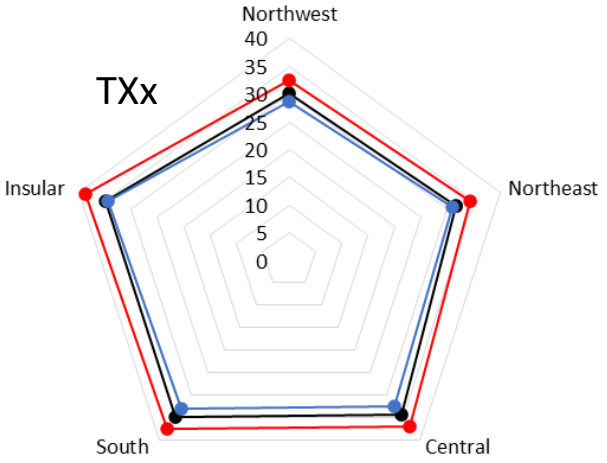


E-OBS **ERA5** **VHR_REA IT**

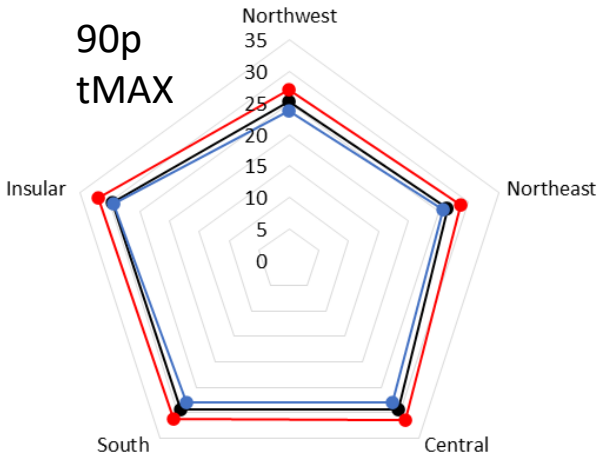
Label	Description	Units
ID	Ice days – annual count of days when the daily Tmax ≤ 0 °C	days year−1
SU	Summer days – annual count of days when the daily Tmax ≥ 25 ° C	days year−1
FD	Frost days – annual count of days when the daily Tmin ≤ 0 ° C	days year−1
TR	Tropical nights – annual count of days when the daily Tmin ≥ 20 °C	days year−1

Climate indices: 2m temperature

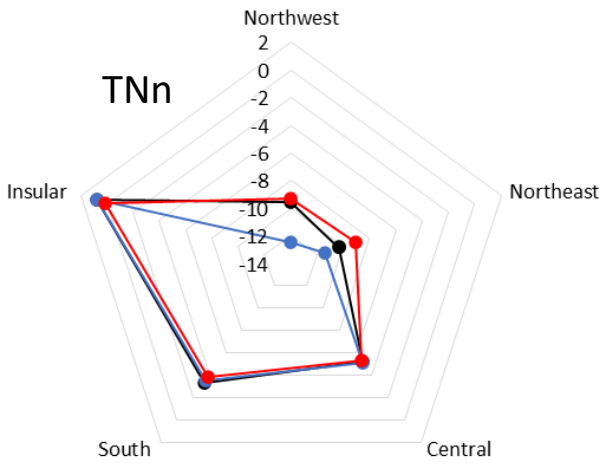
TXx



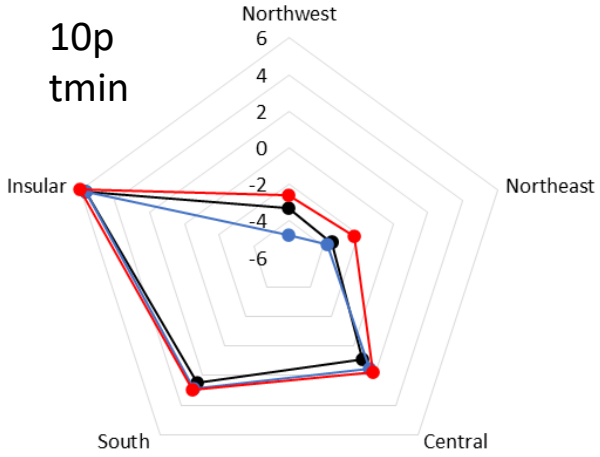
90p tMAX



TNn



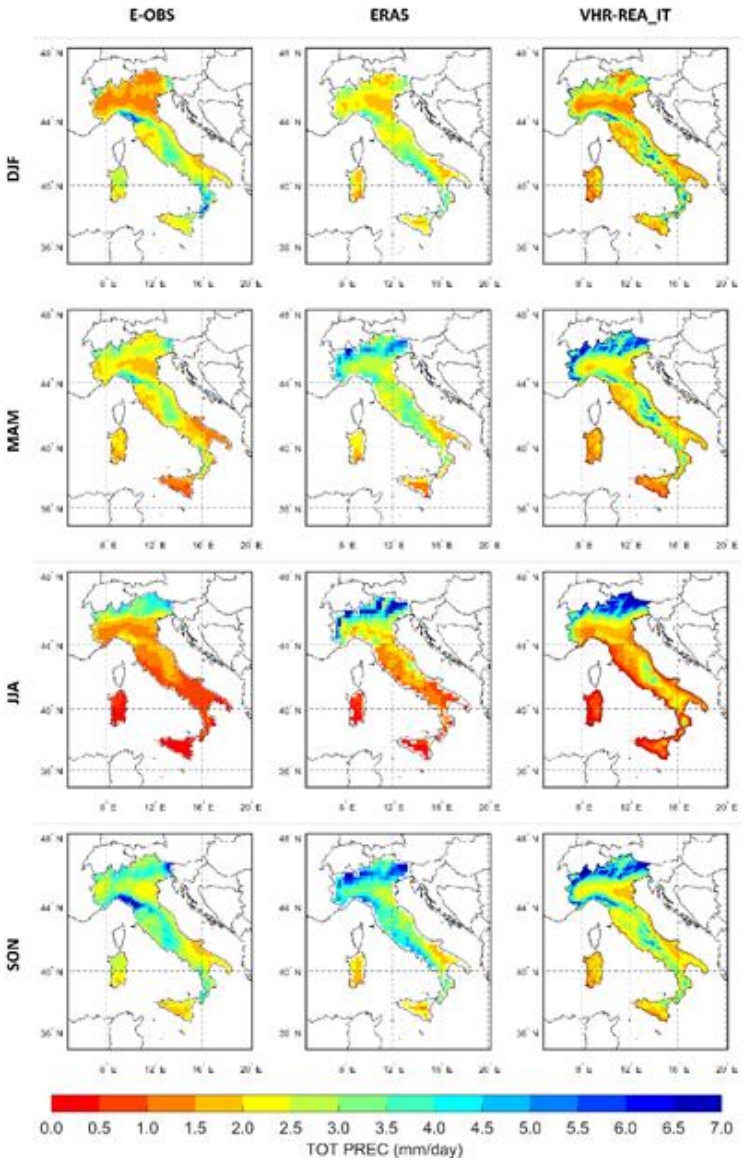
10p tmin



E-OBS **ERA5** **VHR_REA IT**

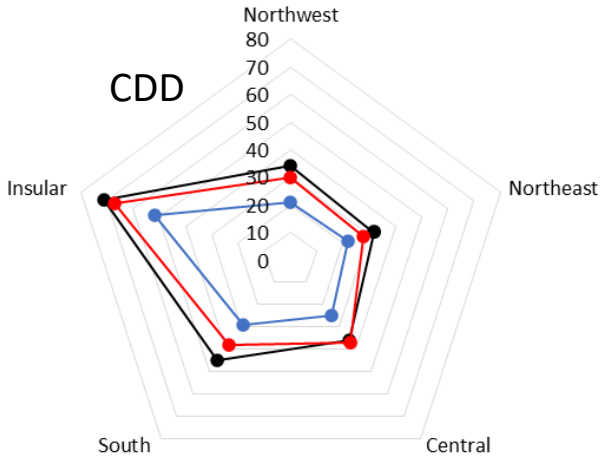
Label	Description	Units
TXx	Annual maximum value of daily Tmax	° C
90p tmax	90th percentile of daily Tmax	° C
TNn	Annual minimum value of daily Tmin	° C
10p tmin	10th percentile of daily Tmin	° C

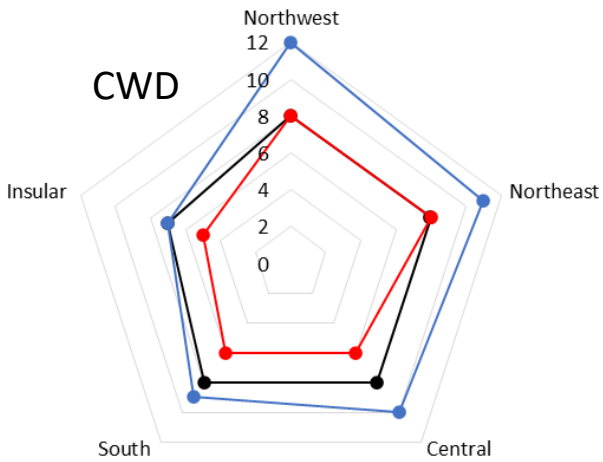
Preliminary evaluation: total precipitation

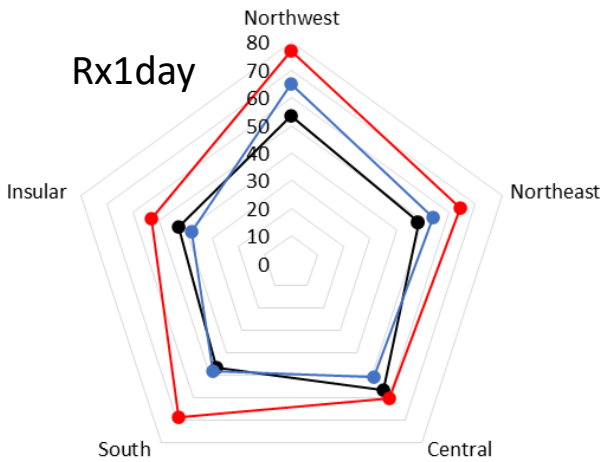


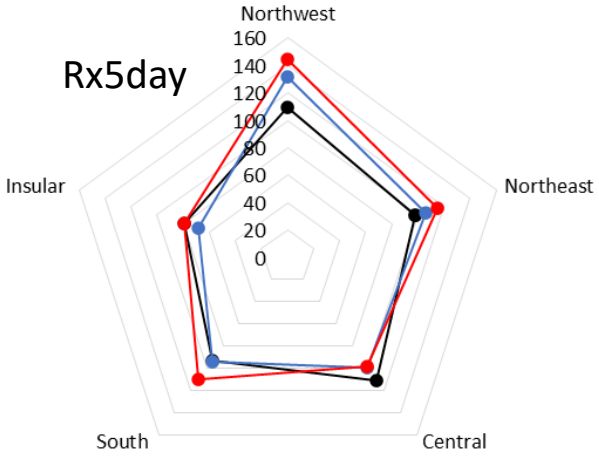
		Bias (%)				$\sigma_{mod}/\sigma_{obs}$			
		DJF	MAM	JJA	SON	DJF	MAM	JJA	SON
Italy	E-OBS	***2.27***	***2.15***	***1.44***	***3.02***	***0.88***	***0.70***	***1.09***	***0.97***
	ERA5	12%	33%	50%	17%	0.7	1.5	1.7	1.3
	VHR-REA_IT	0%	24%	42%	-2%	1.1	1.9	1.6	1.4
Northwest Italy	E-OBS	***1.91***	***2.42***	***2.15***	***3.40***	***0.39***	***0.22***	***0.18***	***0.37***
	ERA5	30%	51%	70%	31%	0.5	1.4	2.9	1.2
	VHR-REA_IT	29%	51%	42%	22%	0.7	1.6	1.5	0.9
Northeast Italy	E-OBS	***1.78***	***2.37***	***2.52***	***3.27***	***0.38***	***0.26***	***0.21***	***0.50***
	ERA5	30%	39%	42%	20%	0.6	1.2	3.1	0.9
	VHR-REA_IT	27%	44%	43%	9%	1.1	1.5	2.0	0.9
Central Italy	E-OBS	***2.97***	***2.56***	***1.24***	***3.86***	***0.24***	***0.16***	***0.08***	***0.27***
	ERA5	1%	11%	16%	3%	0.8	1.2	1.8	1.0
	VHR-REA_IT	-15%	-4%	11%	-24%	1.1	1.6	2.7	0.7
South Italy	E-OBS	***3.01***	***2.06***	***0.77***	***2.83***	***0.30***	***0.17***	***0.09***	***0.19***
	ERA5	-1%	23%	61%	6%	0.9	1.2	1.9	2.0
	VHR-REA_IT	-9%	17%	86%	-9%	1.3	2.0	3.0	1.5
Insular Italy	E-OBS	***2.39***	***1.47***	***0.33***	***2.21***	***0.12***	***0.09***	***0.02***	***0.08***
	ERA5	-10%	15%	29%	-5%	1.0	1.2	3.7	1.8
	VHR-REA_IT	-28%	-12%	42%	-22%	2.5	1.7	6.2	2.2

Climate indices: total precipitation





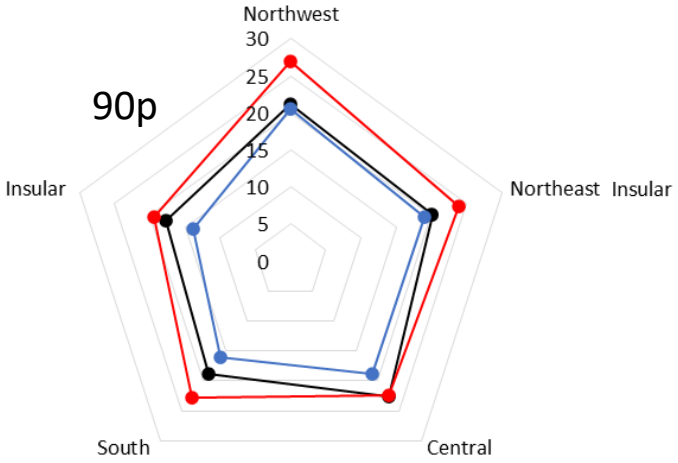


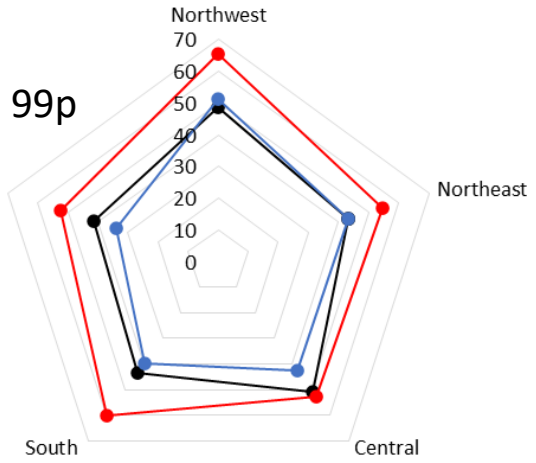


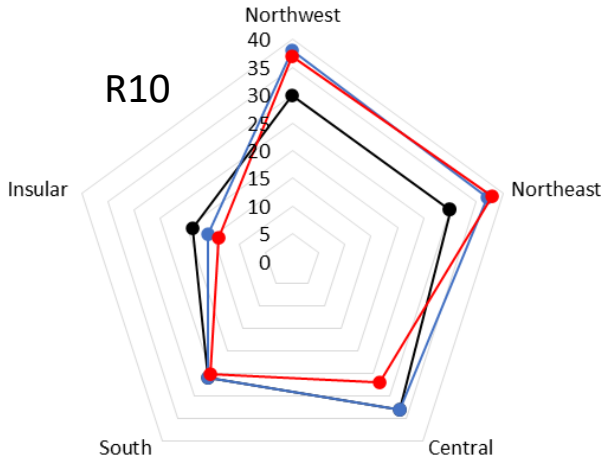
E-OBS **ERA5** **VHR_REA IT**

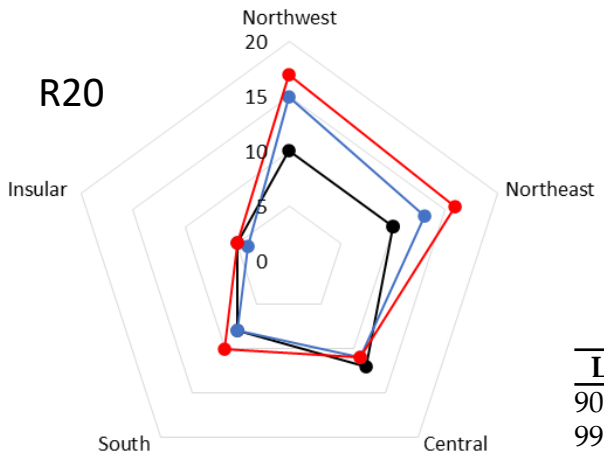
Label	Description	Units
CDD	Maximum number of consecutive dry days (<1 mm)	days year^{-1}
CWD	Maximum number of consecutive wet days (≥1 mm)	days year^{-1}
Rx1day	Maximum of daily precipitation	mm day^{-1}
Rx5day	Maximum of 5-day accumulated precipitation	mm 5 days^{-1}

Climate indices: total precipitation









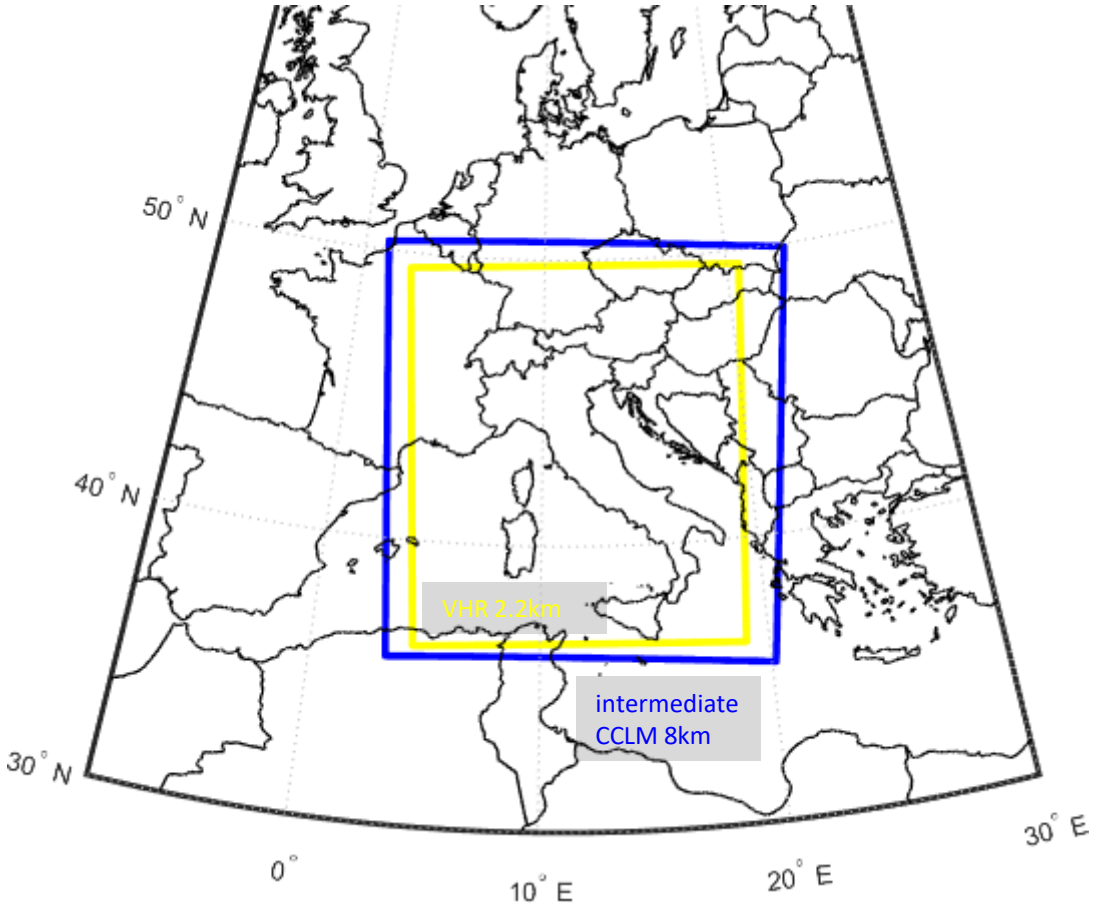
E-OBS **ERA5** **VHR_REA IT**

Label	Description	Units
90p	90th percentile of daily precipitation considering only the wet days (>1 mm)	mm day^{-1}
99p	99th percentile of daily precipitation considering only the wet days (>1 mm)	mm day^{-1}
R10	Number of days with precipitation ≥ 10 mm day^{-1}	days year^{-1}
R20	Number of days with precipitation ≥ 20 mm day^{-1}	days year^{-1}

What come next:
VHR-PRO_IT dataset for HIGHLANDER project

Dynamical downscaling of CMCC-CM global model GCM (through 2 step nesting approach) under the IPCC RCP8.5 scenario. The driving data provided by the GCM CMCC-CM were downscaled first at an intermediate resolution (8km) and then further downscaled at 2.2 km over Italy.

Domain	Italian Peninsula
Period	1989-2050 | HIST + scenario RCP8.5
Model	COSMO-CLM
Forcing	GCM CMCC-CM → intermediate CCLM 8km → VHR 2,2 km
Spatial resolution	0,02° - 2.2km
HPC	Cineca#GALILEO100



Highlander
High performance computing
to support smart land services

Conclusions

The dataset VHR-REA_IT aims to provide a set of unprecedented **high-quality** and **very high-resolution historical climate data** for **Italy** in the period **1989-2020**

Eval

- VHR-REA_IT shows good agreement of 2m temperature with the observations in MAM, SON and DJF seasons and a slight warm bias over all the Italian peninsula in JJA.
- VHR-REA_IT presents major variability of precipitation with respect to ERA5 driving model, especially in the Southern and Insular Italy. The wet bias is more relevant in JJA over all the domain.
- The analysis of extreme climate indicators (ETCDDI) reflects the tendency of VHR-REA_IT to amplify climate dynamics due to the spatial resolution refinement

Application

Typical use of this dataset is research and downstream services, e.g., for decision support systems in different sectors highly affected by changes in climate trends, variability, and extreme events, as in the case of Italy.

- Process-based hydrological modelling can be applied to simulate water cycle components
- Production of indicators related to meteorological–hydrological–agricultural drought attributes.
- Crop or forest growth models assessing vegetation productivity through reproduction of carbon, water, and energy exchanges, as well as feed fire hazard indicators and fire behavior simulations

The VHR-REA_IT is available on Data Delivery System (DDS) of CMCC (http://dds.cmcc.it), through the DDS web user interface (UI), using the DDS Python client.

Thanks

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Acknowledgments

The ongoing activity is performed using the COSMO model in CLimate Mode (COSMO-CLM). We acknowledge the members of the CLM-Community for their common efforts to provide the reference model setup, the forcing data and maintain the codes.

Coordinator CINECA Cineca Interuniversity Consortium

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