26 novembre 2020

Scenari futuri di temperatura e di altre variabili meteorologiche

Paola Faggian

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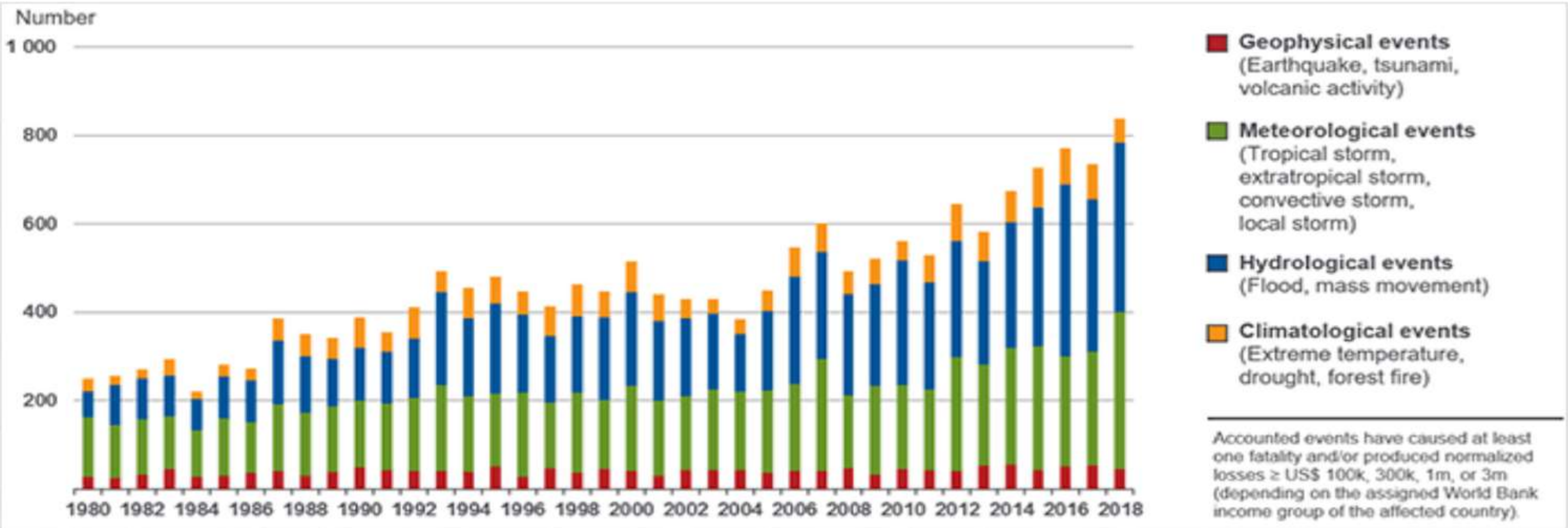
Cambiamenti Climatici

Danni a scala globale

Loss events worldwide (1980-2018): number of relevant events by peril



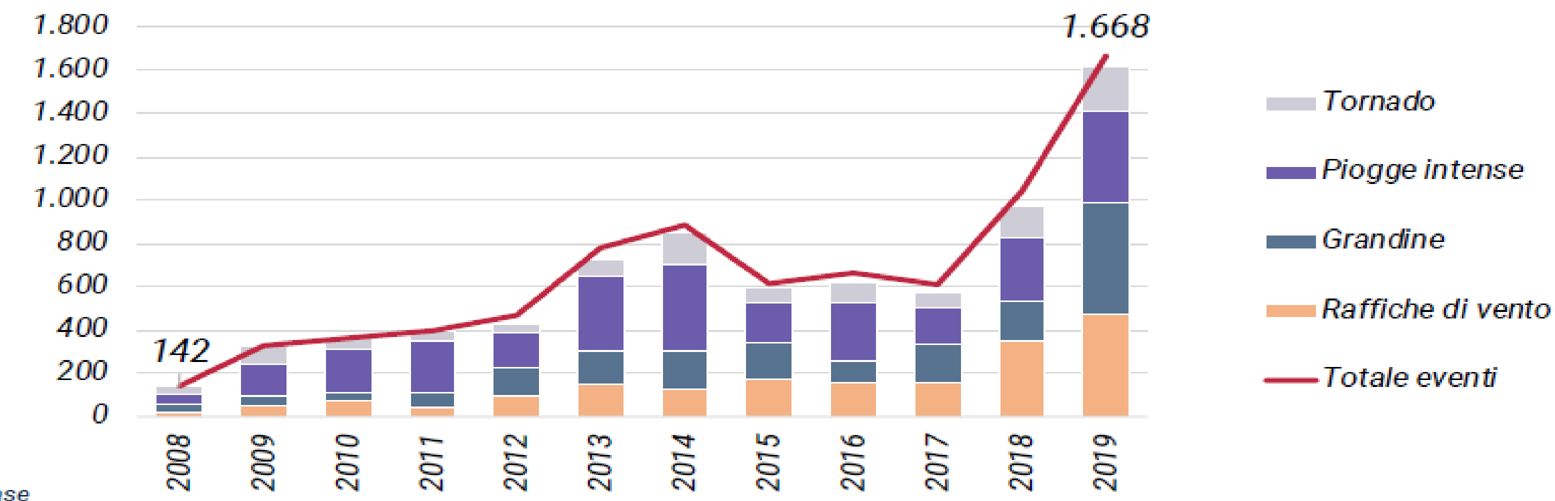
Source: © 2019 Munich Re, Geo Risks Research, NatCatSERVICE. As of March 2019.

Climate–related hazards are at historically high levels

Cambiamenti Climatici

Danni in Italia

L'Italia è un Paese particolarmente esposto alla crisi climatica, con danni sempre più evidenti all'economia e alle persone



Fonte dei dati:
European Severe Weather Database

Italy for Climate

Italy Climate Report - ICR 2020

La Roadmap I4C per la neutralità climatica dell'Italia

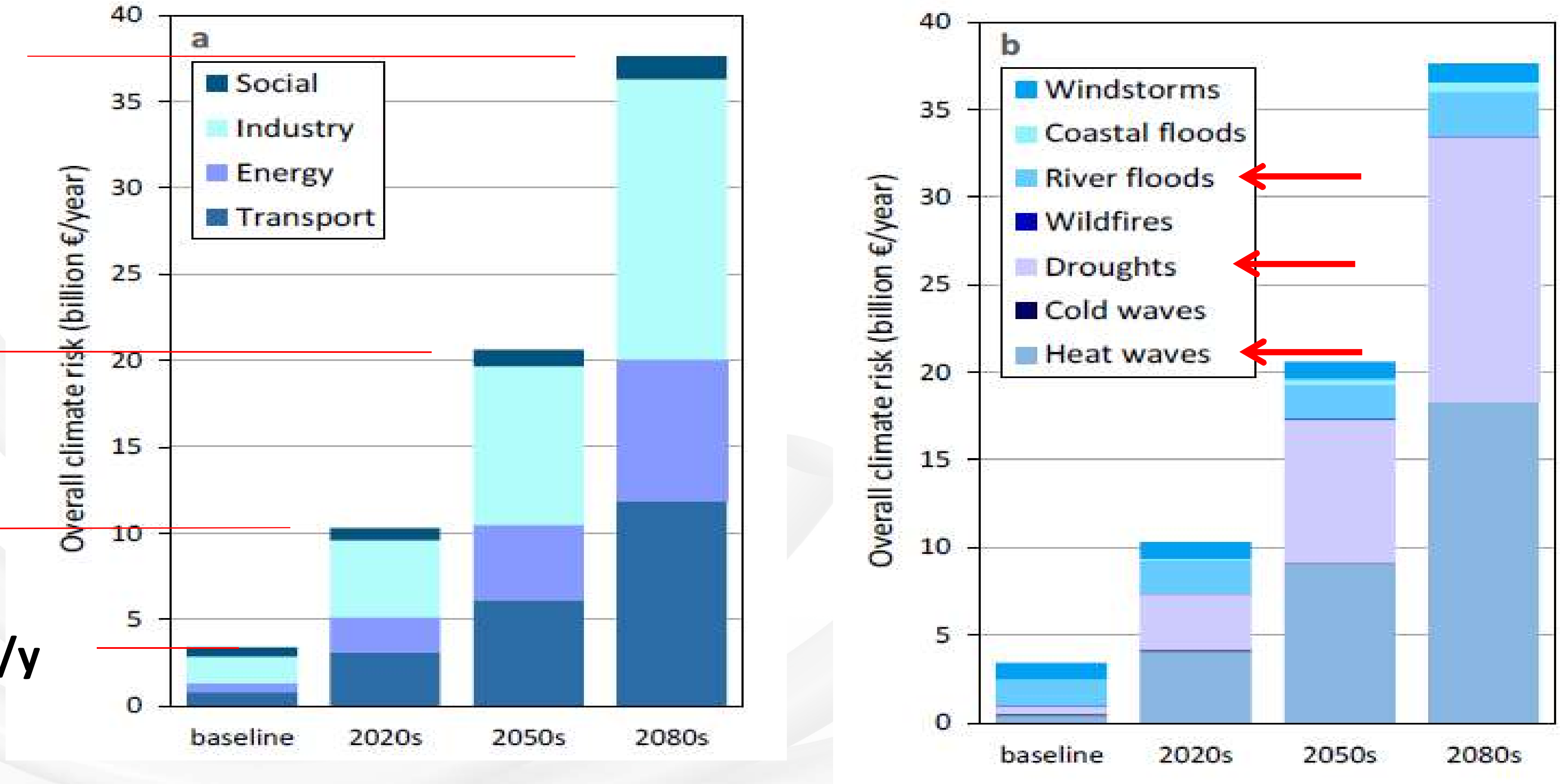
Evolution in the 21 century of the climate hazard damages to critical infrastructures in EU28 + Switzerkand, Norway ,Iceland (2016)

>10 x

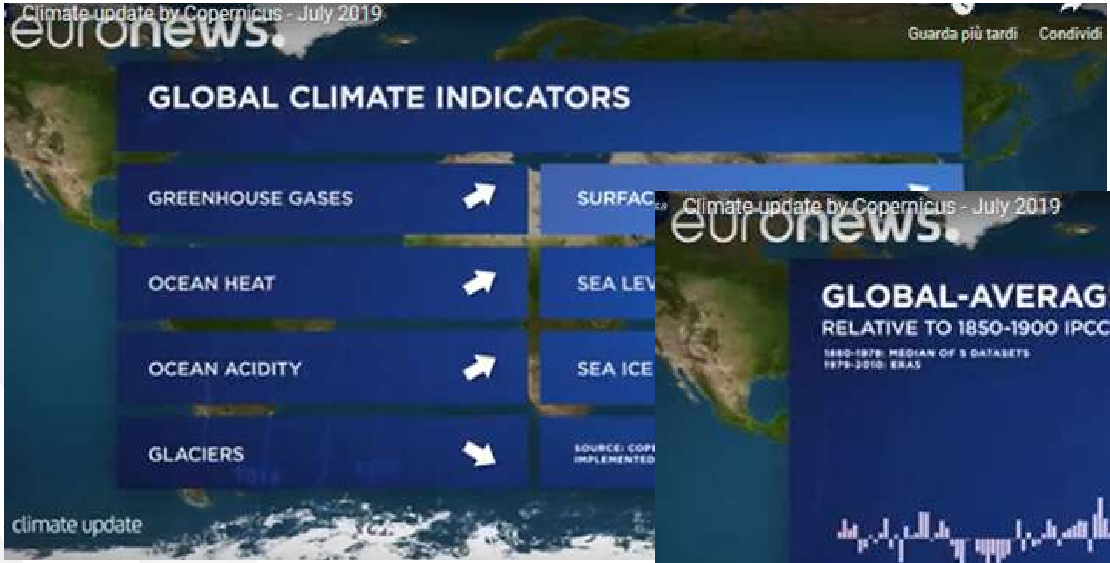
6 x

3 x

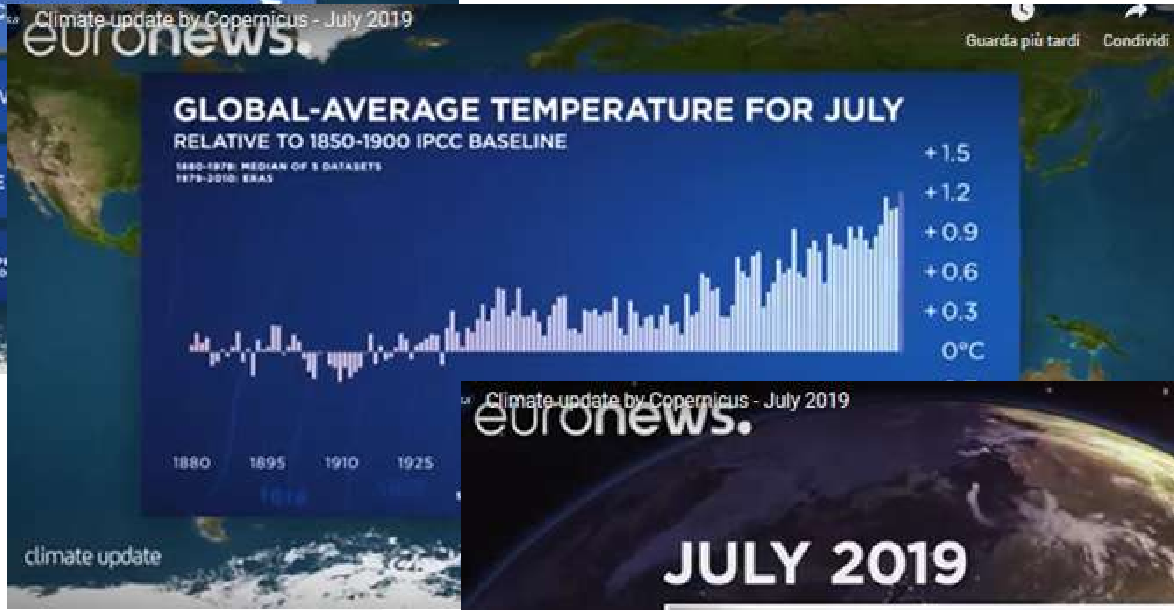
3.5bn €/y



2. Come si studiano i CC: Dati e Metodologia di analisi



https://climate.copernicus.eu/



Paris agreement:
global temperature rise well below 2 ℃ above pre-industrial levels

The latest five-year average global temperature is the highest on record

Come si studiano i Cambiamenti Climatici

I modelli numerici

Coordinates: (x,y,z)
Velocity Components: (u,v,w)

Time : t   Pressure: p
Density: ρ   Stress: τ
Total Energy: Et

Heat Flux: q
Reynolds Number: Re
Prandtl Number: Pr

Continuity: $\frac{\partial \rho}{\partial t}+\frac{\partial(\rho u)}{\partial x}+\frac{\partial(\rho v)}{\partial y}+\frac{\partial(\rho w)}{\partial z}=0$

X – Momentum: $\frac{\partial(\rho u)}{\partial t}+\frac{\partial(\rho u^2)}{\partial x}+\frac{\partial(\rho uv)}{\partial y}+\frac{\partial(\rho uw)}{\partial z}=-\frac{\partial p}{\partial x}+\frac{1}{Re_r}\Big[\frac{\partial \tau}{\partial} \ldots$

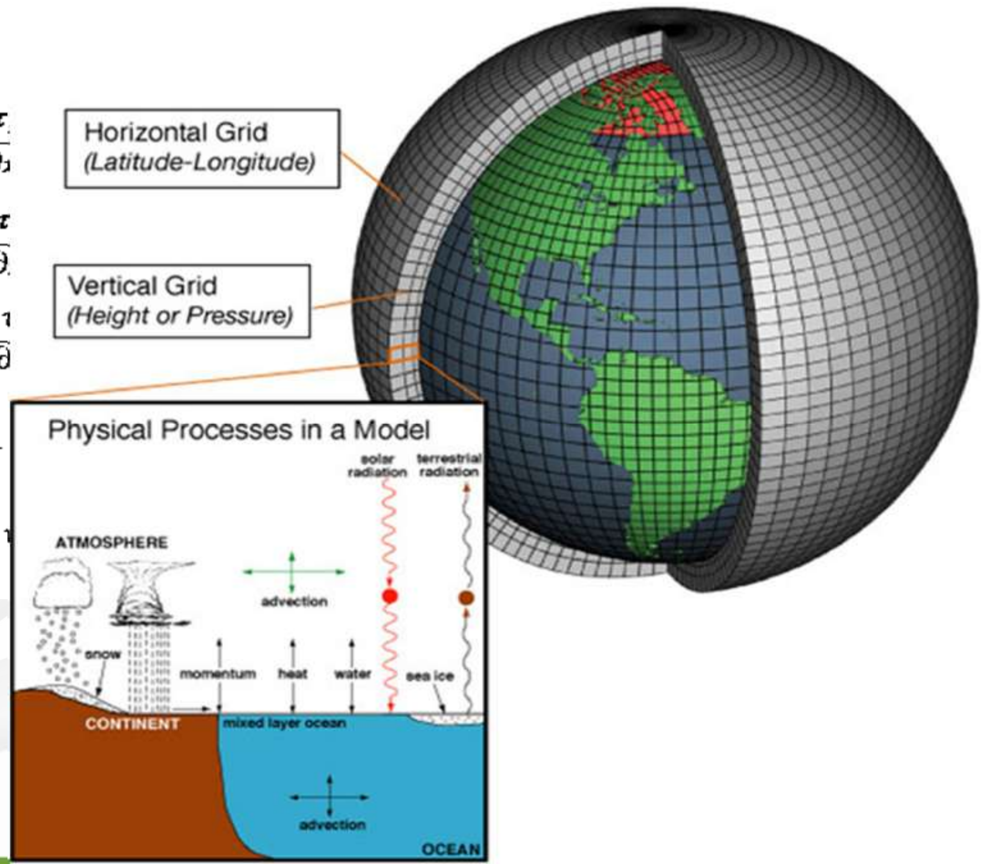
Y – Momentum: $\frac{\partial(\rho v)}{\partial t}+\frac{\partial(\rho uv)}{\partial x}+\frac{\partial(\rho v^2)}{\partial y}+\frac{\partial(\rho vw)}{\partial z}=-\frac{\partial p}{\partial y}+\frac{1}{Re_r}\Big[\frac{\partial \tau}{\partial} \ldots$

Z – Momentum $\frac{\partial(\rho w)}{\partial t}+\frac{\partial(\rho uw)}{\partial x}+\frac{\partial(\rho vw)}{\partial y}+\frac{\partial(\rho w^2)}{\partial z}=-\frac{\partial p}{\partial z}+\frac{1}{Re_r}\Big[\frac{\partial \tau}{\partial} \ldots$

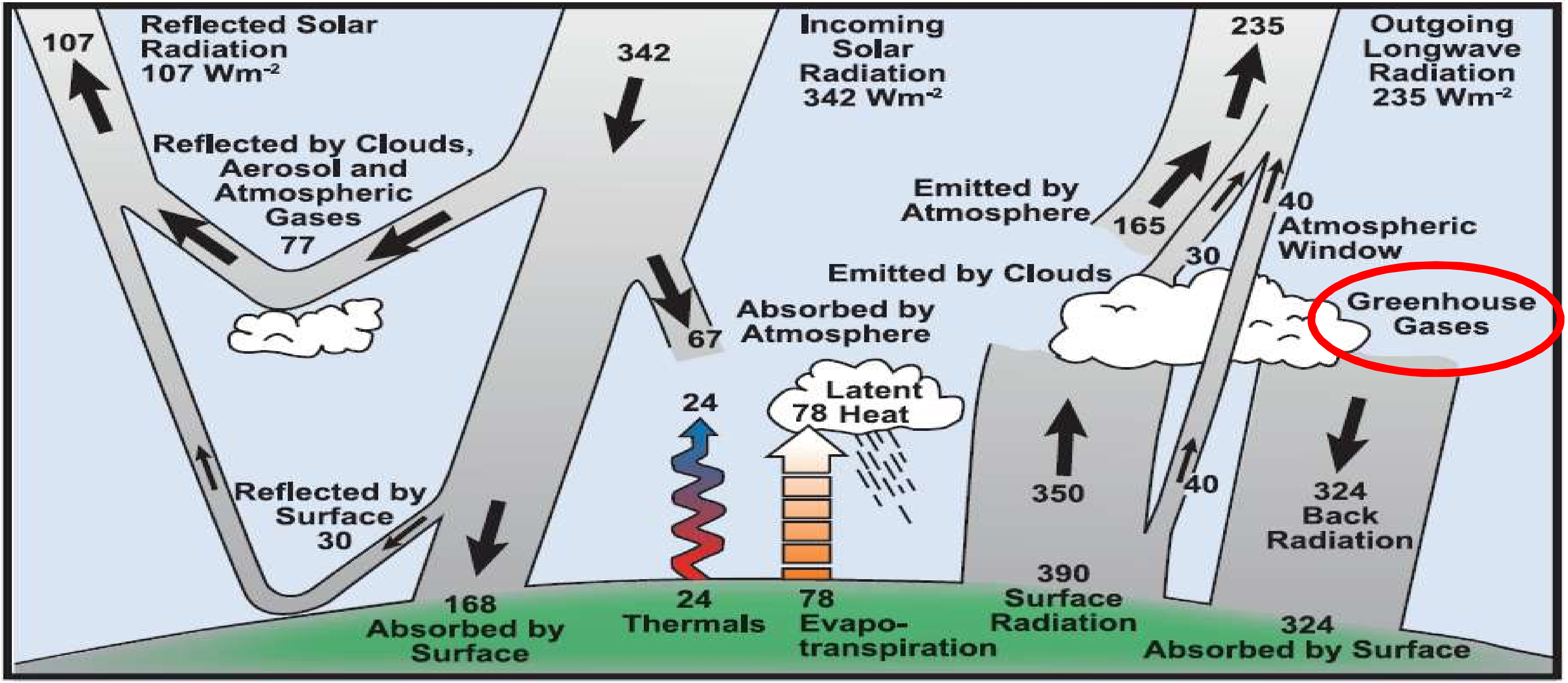
Energy:

$$\frac{\partial(E_T)}{\partial t}+\frac{\partial(uE_T)}{\partial x}+\frac{\partial(vE_T)}{\partial y}+\frac{\partial(wE_T)}{\partial z}=-\frac{\partial(up)}{\partial x}-\frac{\partial(vp)}{\partial y}-\frac{\partial(wp)}{\partial z}-\frac{1}{Re_r Pr_r}\ldots$$

$$+\frac{1}{Re_r}\Big[\frac{\partial}{\partial x}(u\,\tau_{xx}+v\,\tau_{xy}+w\,\tau_{xz})+\frac{\partial}{\partial y}(u\,\tau_{xy}+v\,\tau_{yy}+w\,\tau_{yz})+\frac{\partial}{\partial z}(u\,\tau_{xz}+\ldots$$

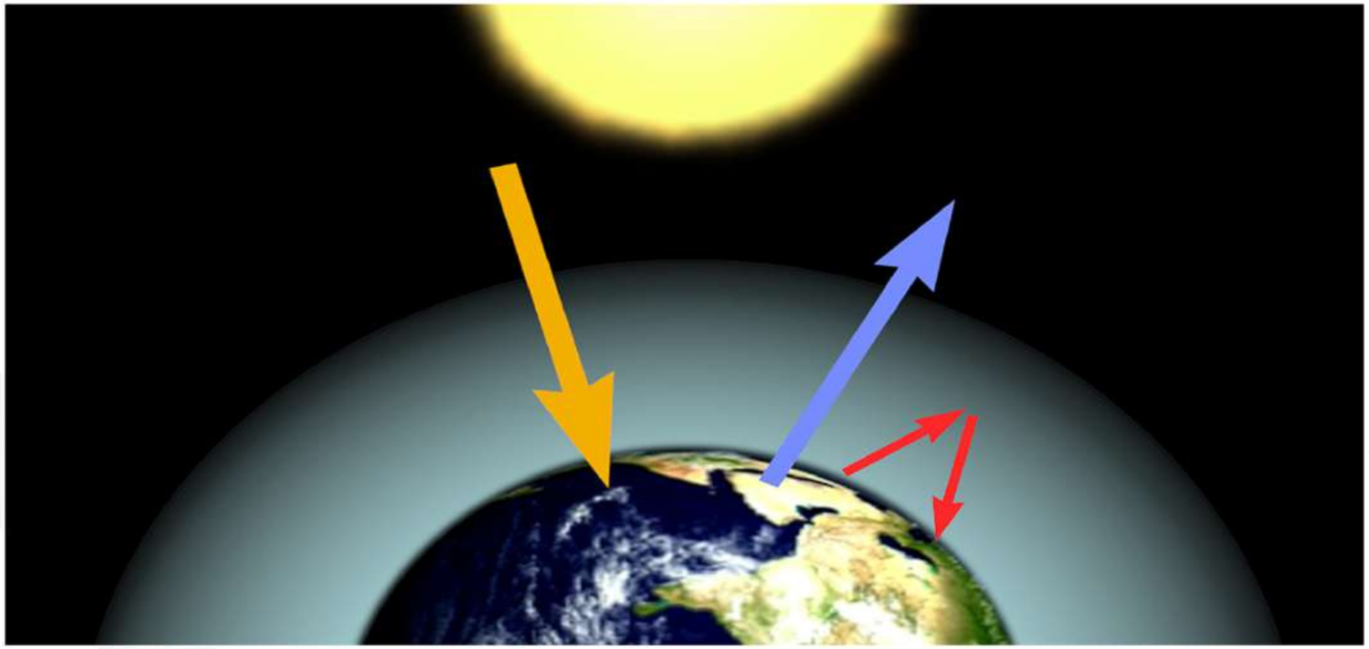


Global Mean Energy Balance



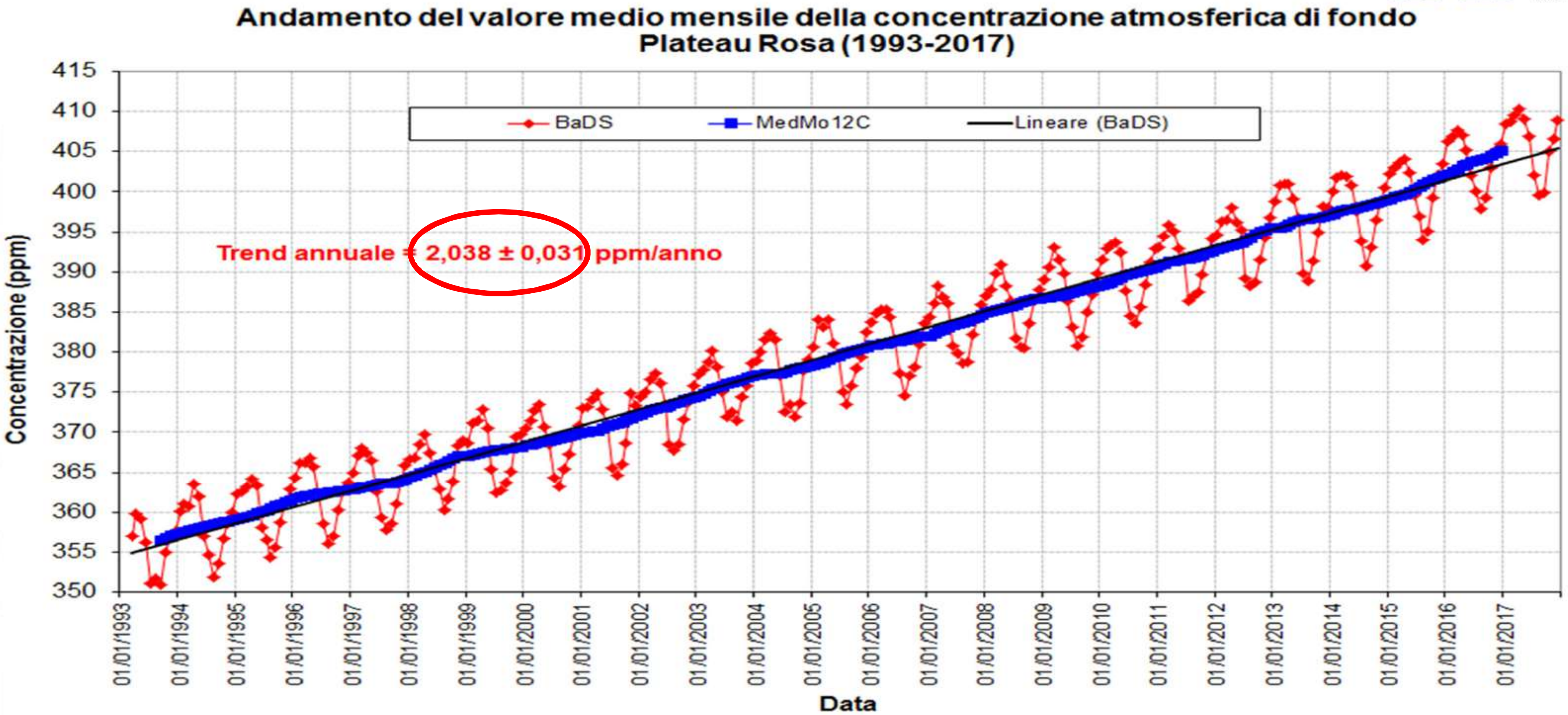
FAQ 1.1, Figure 1. *Estimate of the Earth's annual and global mean energy balance. Over the long term, the amount of incoming solar radiation absorbed by the Earth and atmosphere is balanced by the Earth and atmosphere releasing the same amount of outgoing longwave radiation. About half of the incoming solar radiation is absorbed by the Earth's surface. This energy is transferred to the atmosphere by warming the air in contact with the surface (thermals), by evapotranspiration and by longwave radiation that is absorbed by clouds and greenhouse gases. The atmosphere in turn radiates longwave energy back to Earth as well as out to space. Source: Kiehl and Trenberth (1997).*

IPCC AR4, 2007



https://www.britannica.com/video/152194/overview-role-greenhouse-gases-climate-Earth

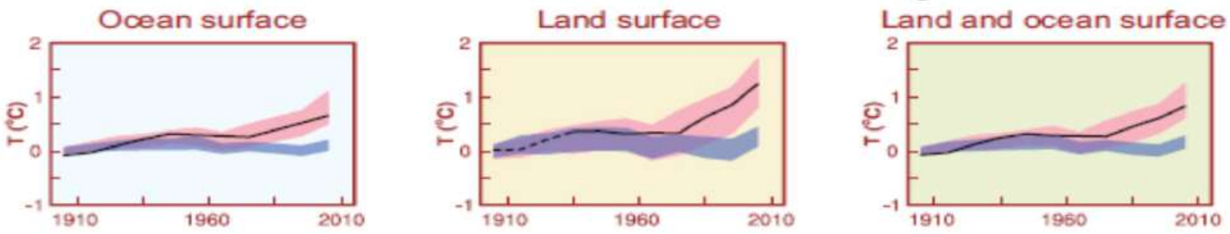
Monitoring Station Plateau Rosa
CO2 BaDS (Background Data Selection)



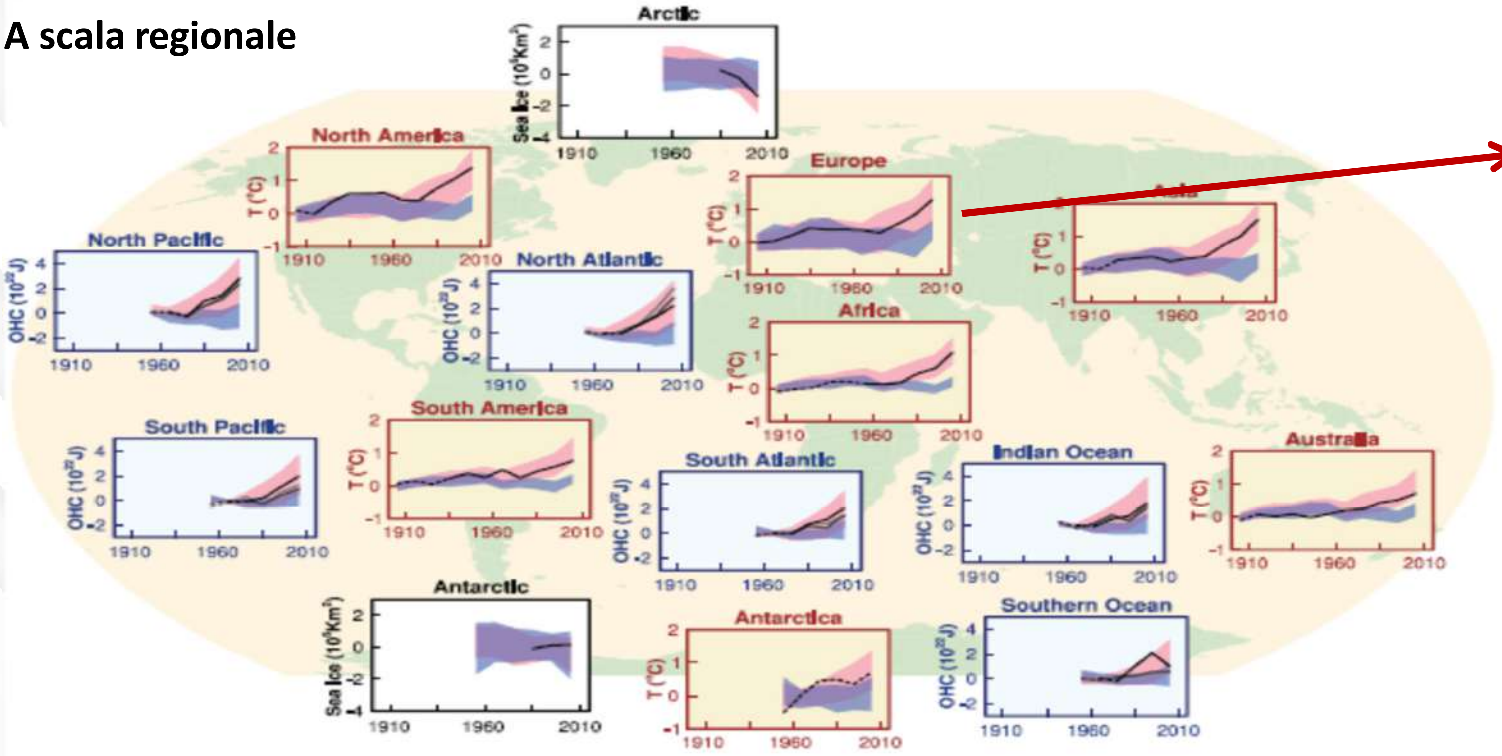
OASI http://oasi.rse-web.it/

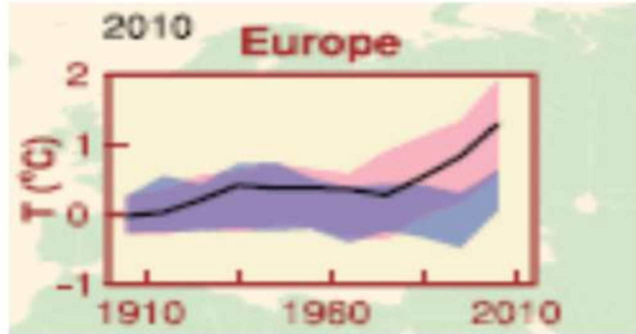
IPCC AR5

A scala globale



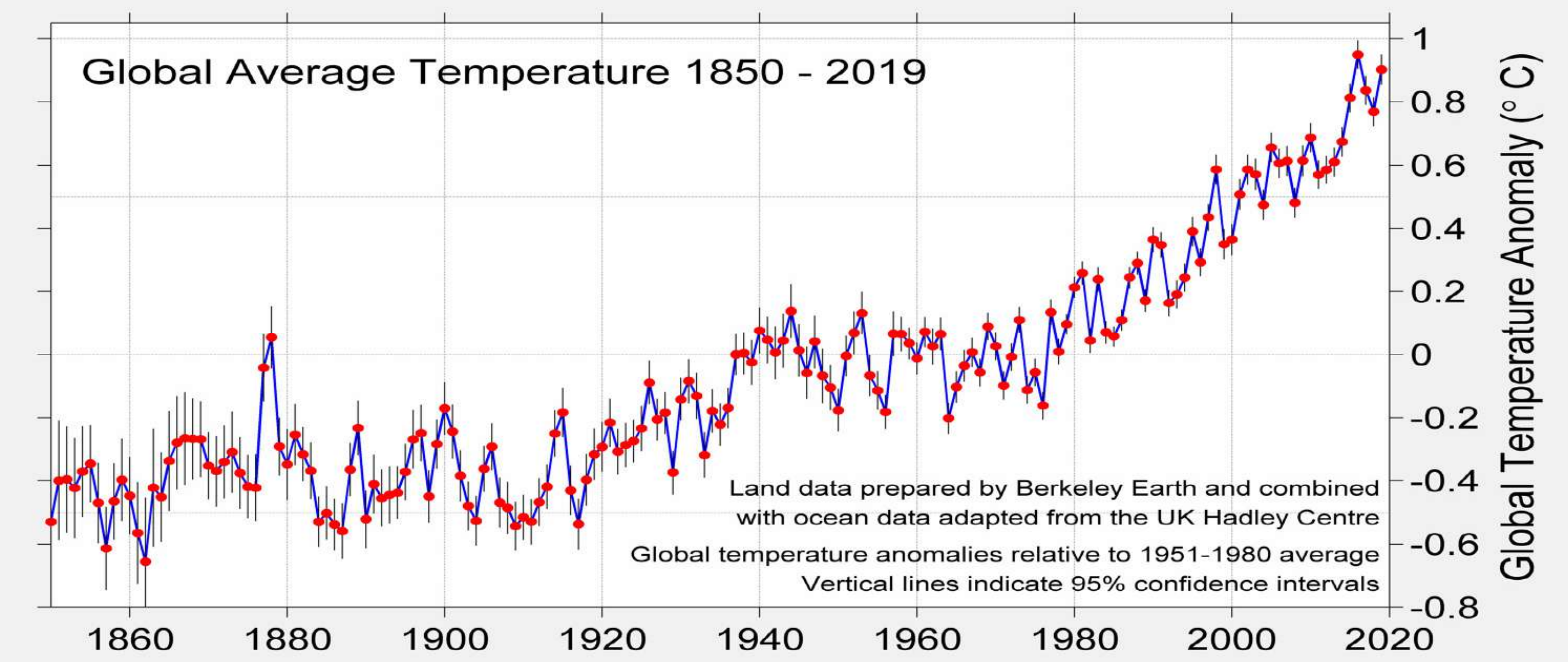
A scala regionale





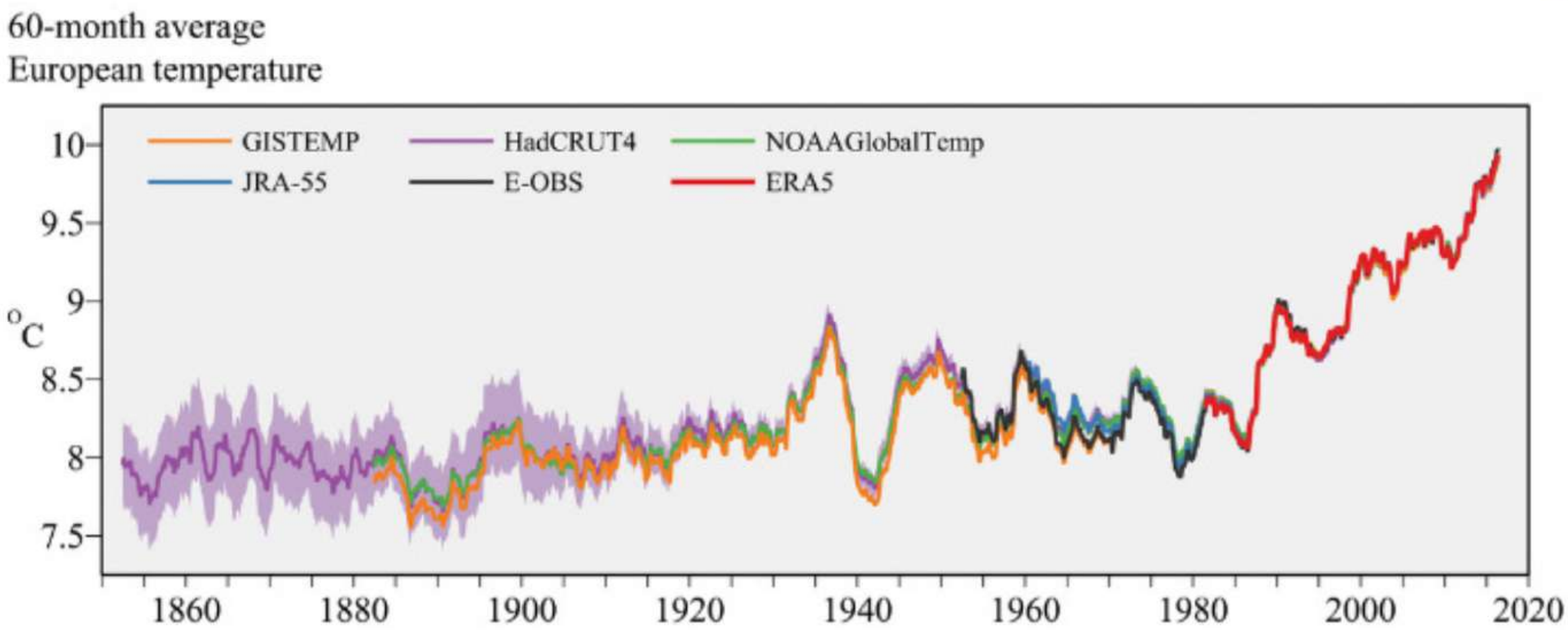
Mediterraneo
Hot spot

Trend della temperatura: dati osservati



http://berkeleyearth.org/archive/2019-temperatures/

Surface European Air Temperature over land



https://climate.copernicus.eu/surface-temperature

In Europe: an increase of almost 2°C since the latter half of the 19th century

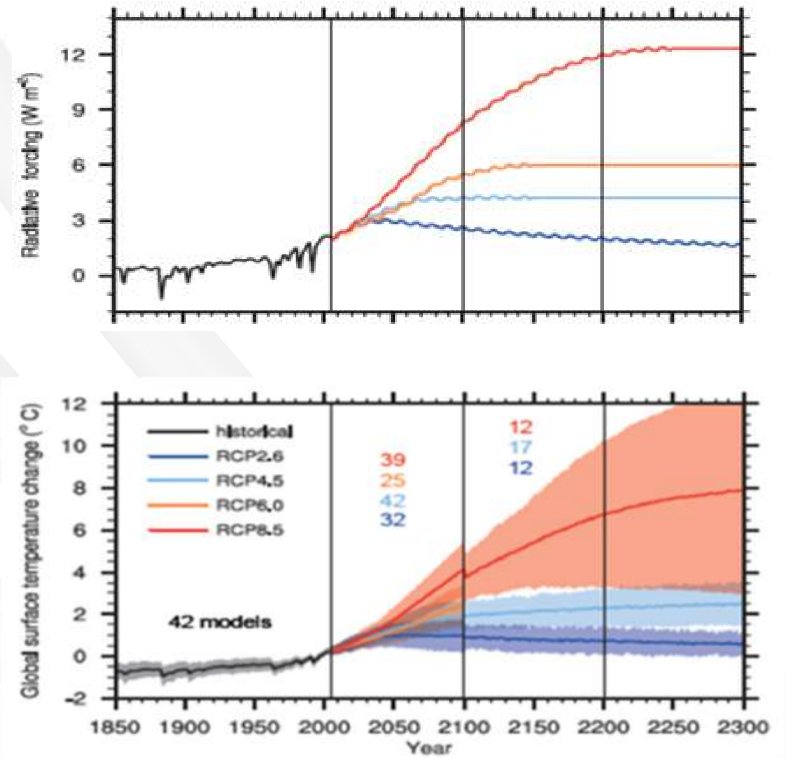
Atmospheric Predictability

- **Predicibilità del 1°tipo - *initial value problem***
  Initial Conditions
  Meteorological Forecast
  time-frame: 10 days
  spatial resolution ~ 1 km

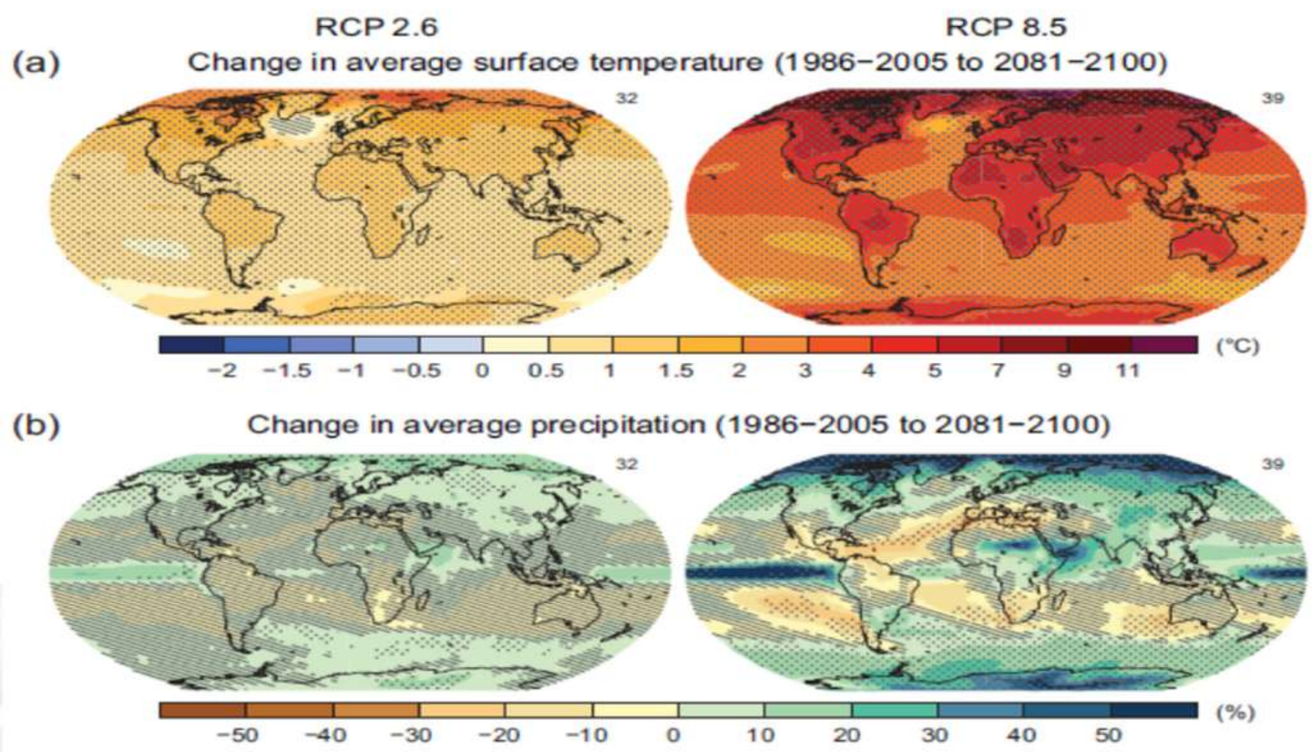
- **Predicibilità del 2°tipo - *boundary value problem***
  External forcings
  Climate Projections (statistical properties)
  time-frame: 10-100 years
  spatial resolution ~ 50 km

Serie temporali di dati osservati
modelli numerici

Scenari futuri:
quali variazioni sono attese?

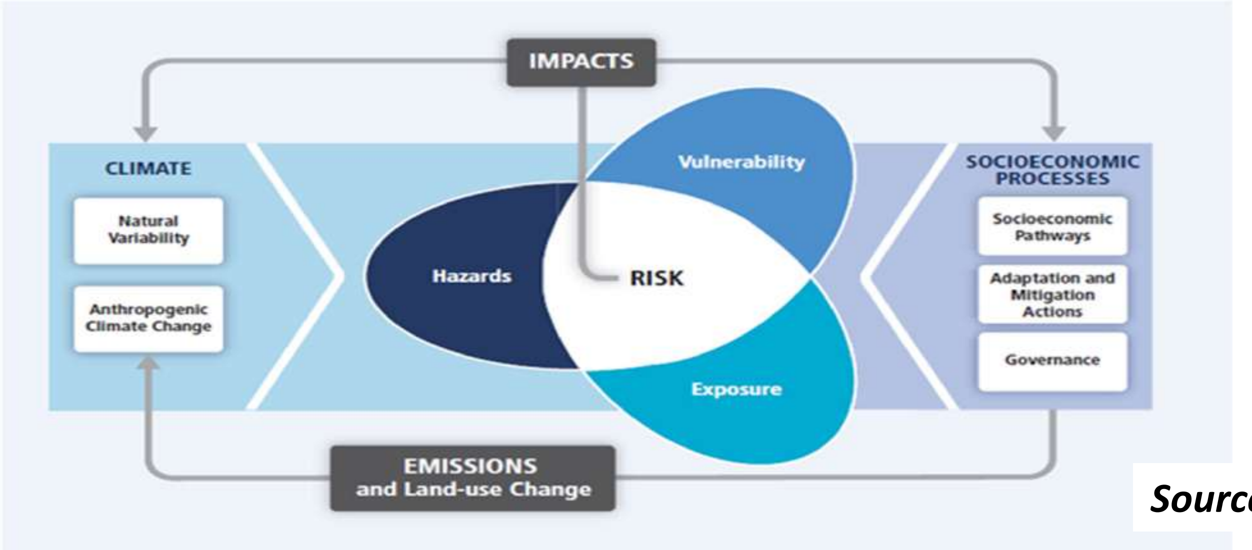


IPCC AR5 Proiezioni future



IPCC, AR5

Risk Assessment



Source IPCC- SREX, 2012

Guide lines:

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
CLIMATE ACTION

Non-paper - Guidelines for Project Managers: Making vulnerable investments climate resilient

Resilience of large investments and critical infrastructures in Europe to climate change (CCMFF) (JRC, 2016)

U.S. Department of Energy

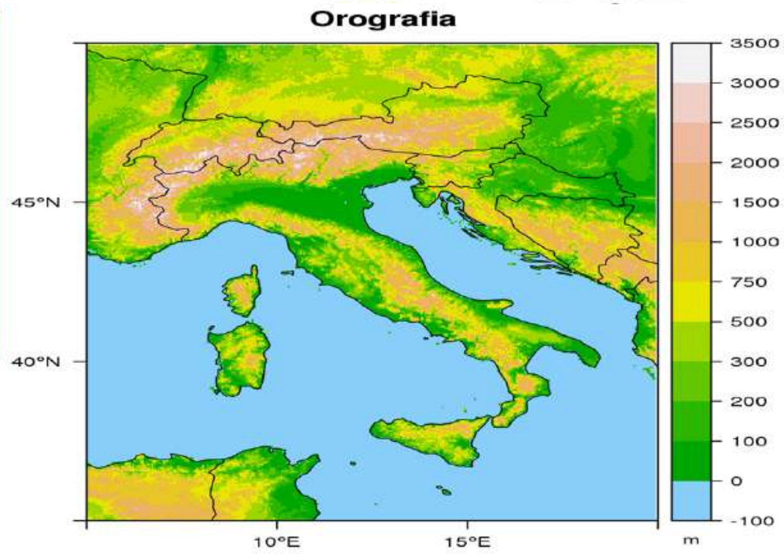
Climate Change and the Electric Sector

Data-sets

Reference data
- SYNOP
- E-OBS (25km)
- MESAN (~5 km)
- MERIDA (4 km, 7 km)

Climate Simulations

EU Projects
- ENSEMBLES (25 km, 1961-2100)
- Euro-CORDEX (~12km) 1971-2100



Euro-CORDEX

	GCM	Institute	RCM	Acronym
1	ICHEC-EC-EARTH	KNMI	RACMO22E	EC EARTH - RACMO
2	ICHEC-EC-EARTH	CLMcom	CCLM4-8-17	EC EARTH - CCLM
3	MPI-M-MPI-ESM-LR	CLMcom	CCLM4-8-17	MPI ESM LR - CCLM
4	CNRM-CERFACS-CNRM-CM5	CLMcom	CCLM4-8-17	CNRM CM5 - CCLM
5	ICHEC-EC-EARTH	DMI	HIRHAM5	EC EARTH - HIRHAM
6	MOHC-HadGEM2-ES	KNMI	RACMO22E	HadGEM2 ES - RACMO
7	MOHC-HadGEM2-ES	CLMcom	CCLM4-8-17	HadGEM2 ES - CCLM
8	IPSL-IPSL-CM5A-MR	SMHI	RCA4	CM5A MR - RCA
9	CNRM-CERFACS-CNRM-CM5	SMHI	RCA4	CNRM CM5 - RCA
10	MPI-M-MPI-ESM-LR	SMHI	RCA4	MPI ESM LR – RCA
11	ICHEC-EC-EARTH	SMHI	RCA4	EC EARTH - RCA
12	MOHC-HadGEM2-ES	SMHI	RCA4	HadGEM2 ES - RCA
13	IPSL-IPSL-CM5A-MR	IPSL	WRF331F	CM5A MR – WRF331F
14	CNRM-CERFACS-CNRM-CM5	CNRM	ALADIN53	CNRM CM5 – ALADIN5

ENSEMBLES

GCM	RCM	Simulazione
ARPEGE_RM5.1	Aladin	CNRM-RM5.1_ARPEGE
ARPEGE	HIRHAM5	DMI-HIRHAM5_ARPEGE
BCM	HIRHAM5	DMI-HIRHAM5_BCM
HadCM3Q0	CLM	ETHZ-CLM_HadCM3Q0
ECHAM5-r3	ICTP-REGCM3	ICTP-REGCM3_ECHAM5
ECHAM5-r3	RACMO	KNMI-RACMO2_ECHAM5
HadCM3Q0	HadRM3Q0	METO-HC_HadCM3Q0
HadCM3Q0	RCA	SMHIRCA_HadCM3Q3
ECHAM5-r3	RCA	SMHIRCA_ECHAM5
BCM	RCA	SMHIRCA_BCM

3. Proiezioni future: distribuzione spaziale, trend temporali

- gradual changes
  - temperature
  - total precipitation
  - wind speed

- *extreme weather events*
  - Hot Days
  - Droughts
  - Extreme precipitation
  - Cold waves
  - Wet-snow

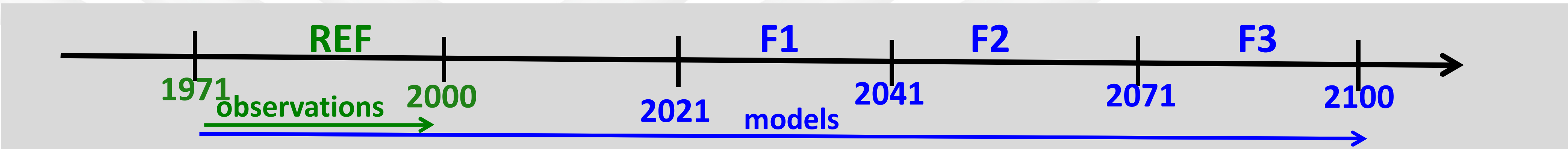
for different 30y periods

Baseline period REF = 1971-2000 reference scenario

Future scenarios F1 = 2021 – 2050 at short term
F2 = 2041 – 2070 at medium term
F3 = 2071 – 2100 at long term

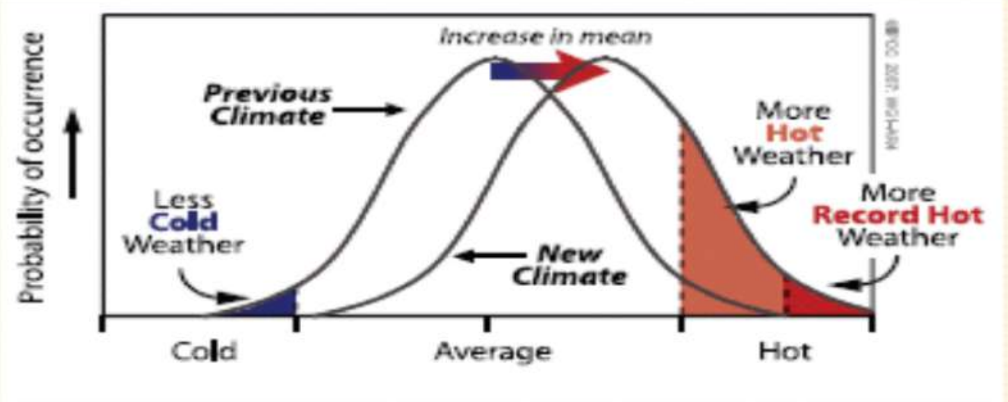
Different Scenarios of anthropogenic forcing, Representative Concentration Pathways RCPs:

1. RCP 8.5 (BAU)
2. RCP 4.5 (partial mitiagtion actions)
3. RCP 2.6 (mitigation actions)

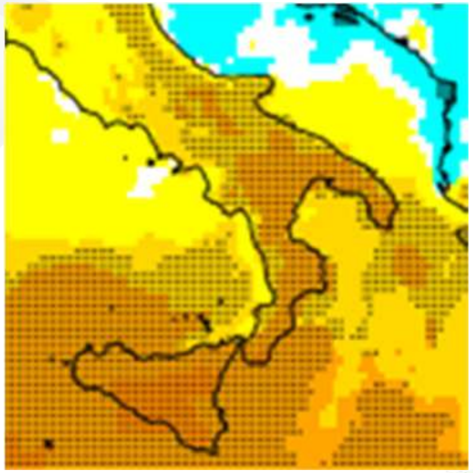


Extreme Weather Events

Probability Density Function

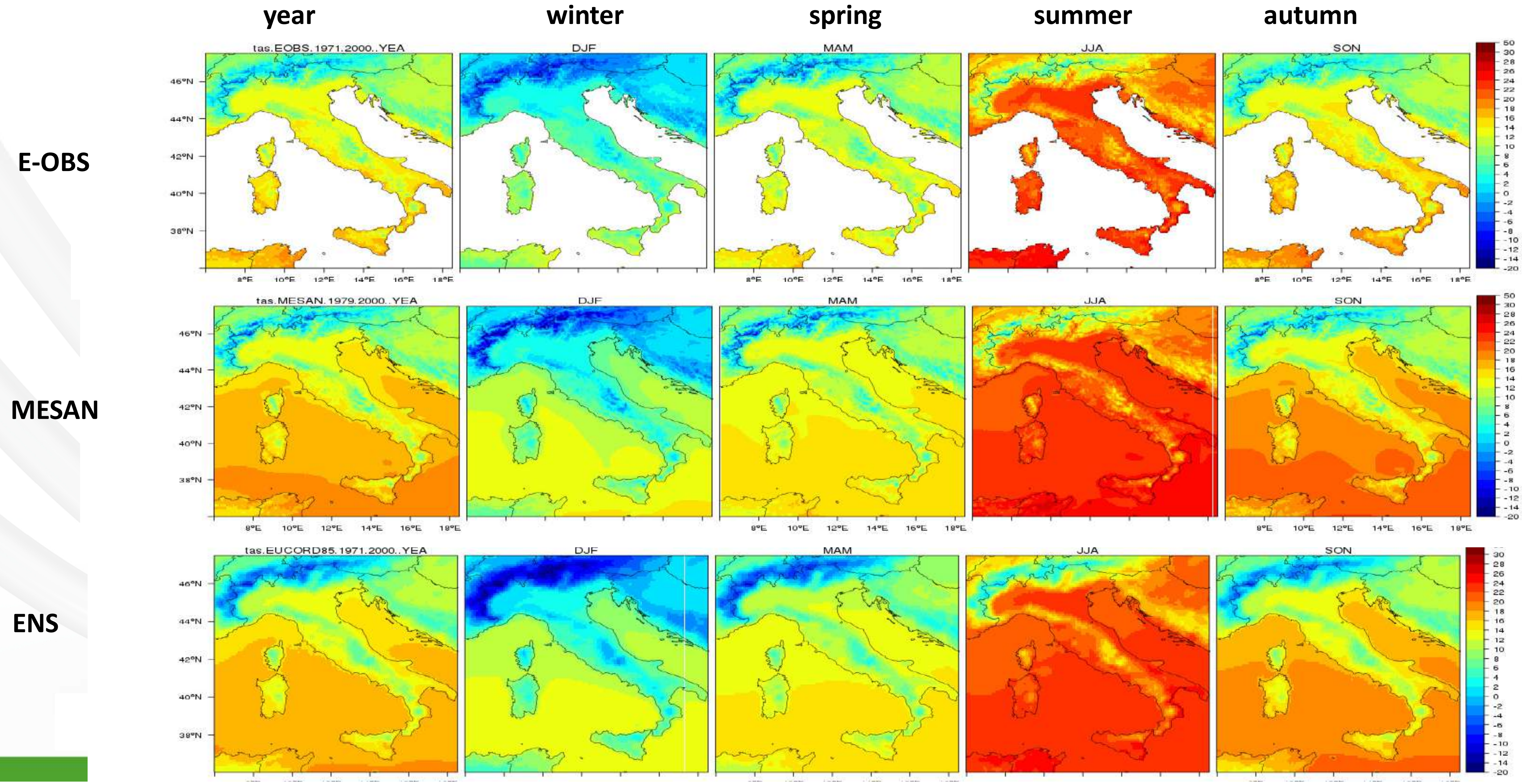


Box TS.5, Figure 1. Schematic showing the effect on extreme temperatures when the mean temperature increases, for a normal temperature distribution.



Wilcoxon rank-sum test

tas –Reference values (REF=1971-2000)



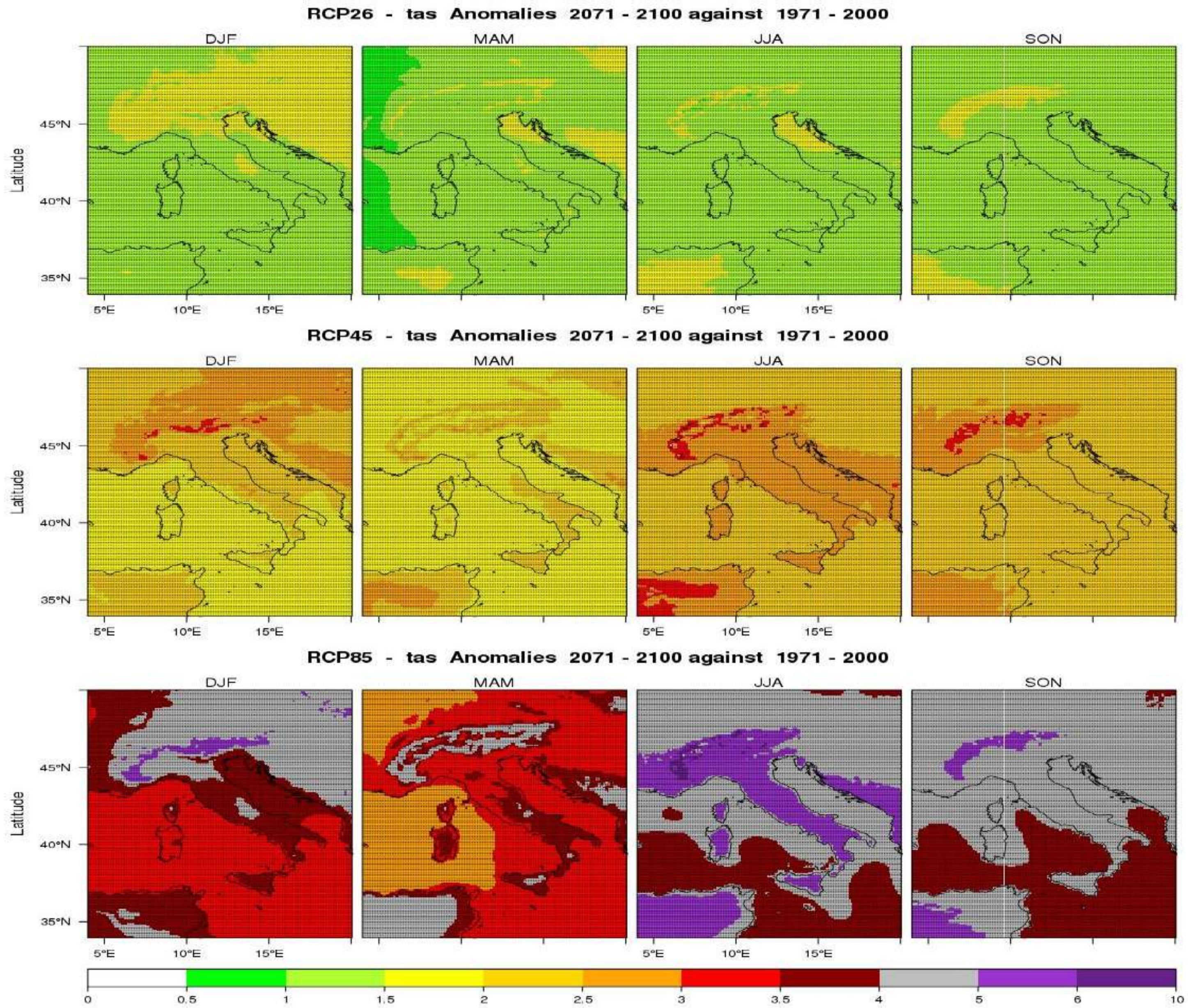
tas

Anomalies: Δ° C

RCP 2.6

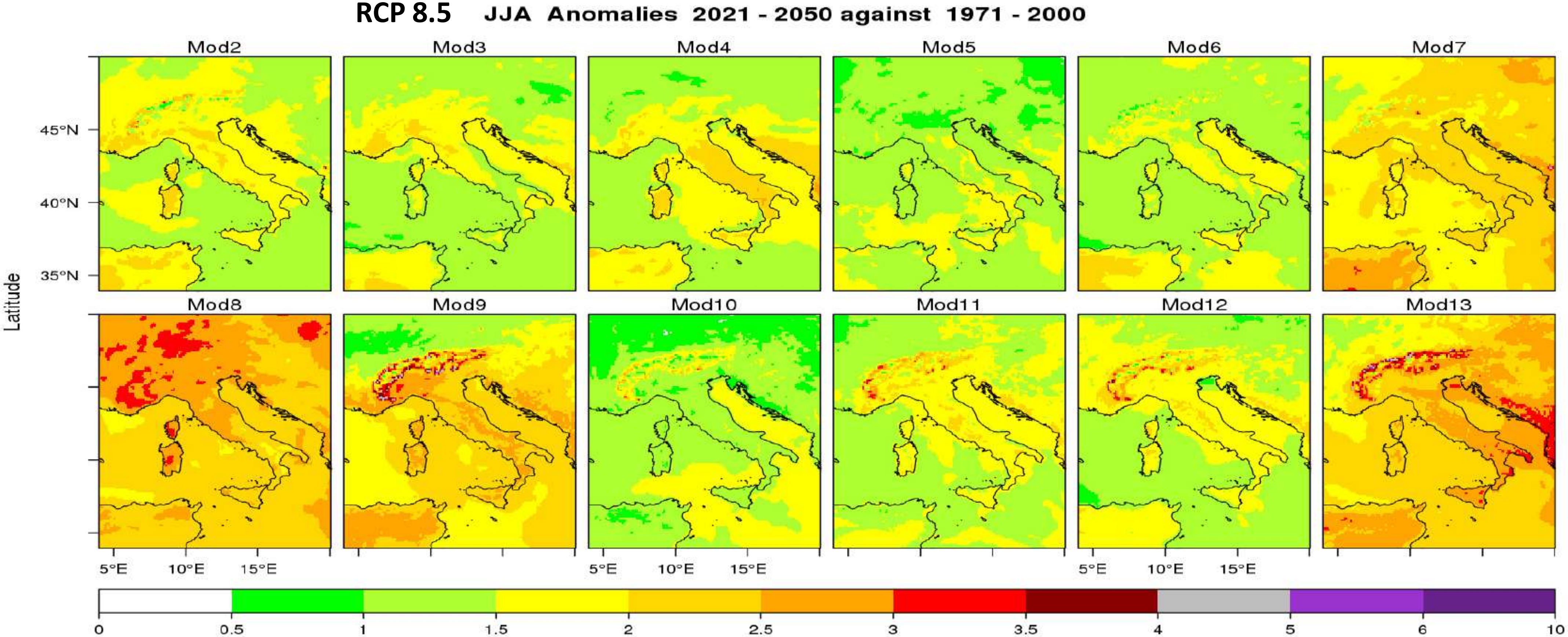
RCP 4.5

RCP 8.5

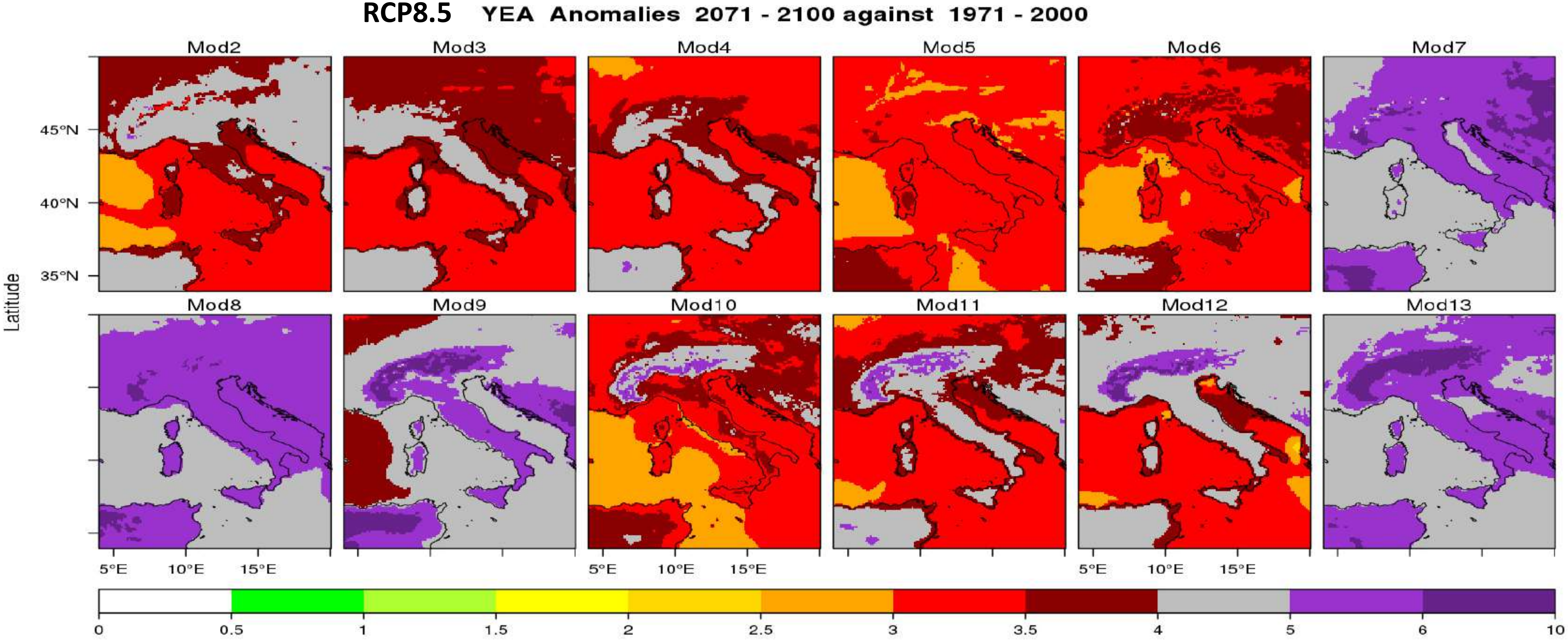


tas: Confidence on results

RCP 8.5



tas: Confidence on results



SU REF

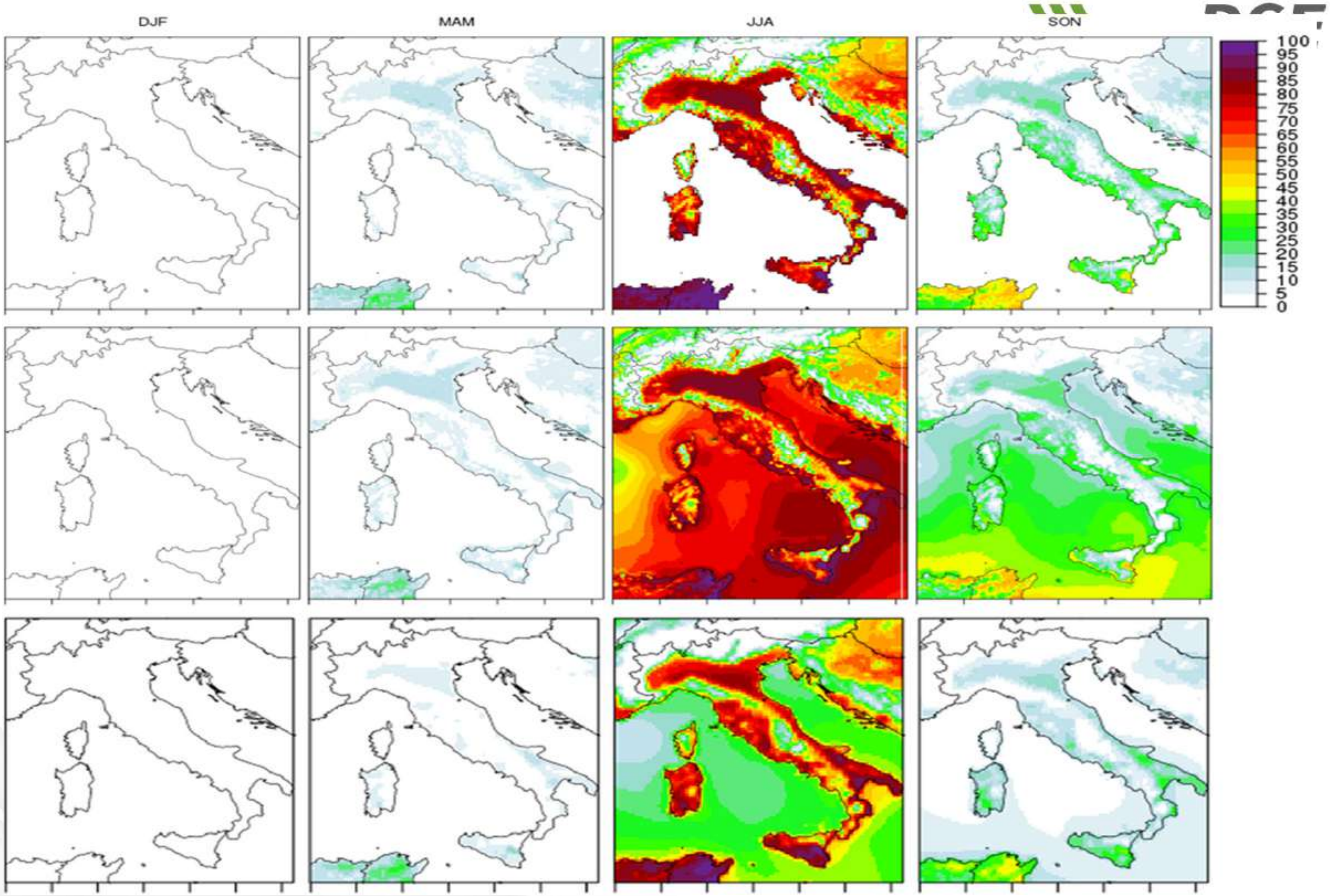
TMX > 25°C

winter | spring | summer | autumn

E-OBS

MESAN

ENS



%

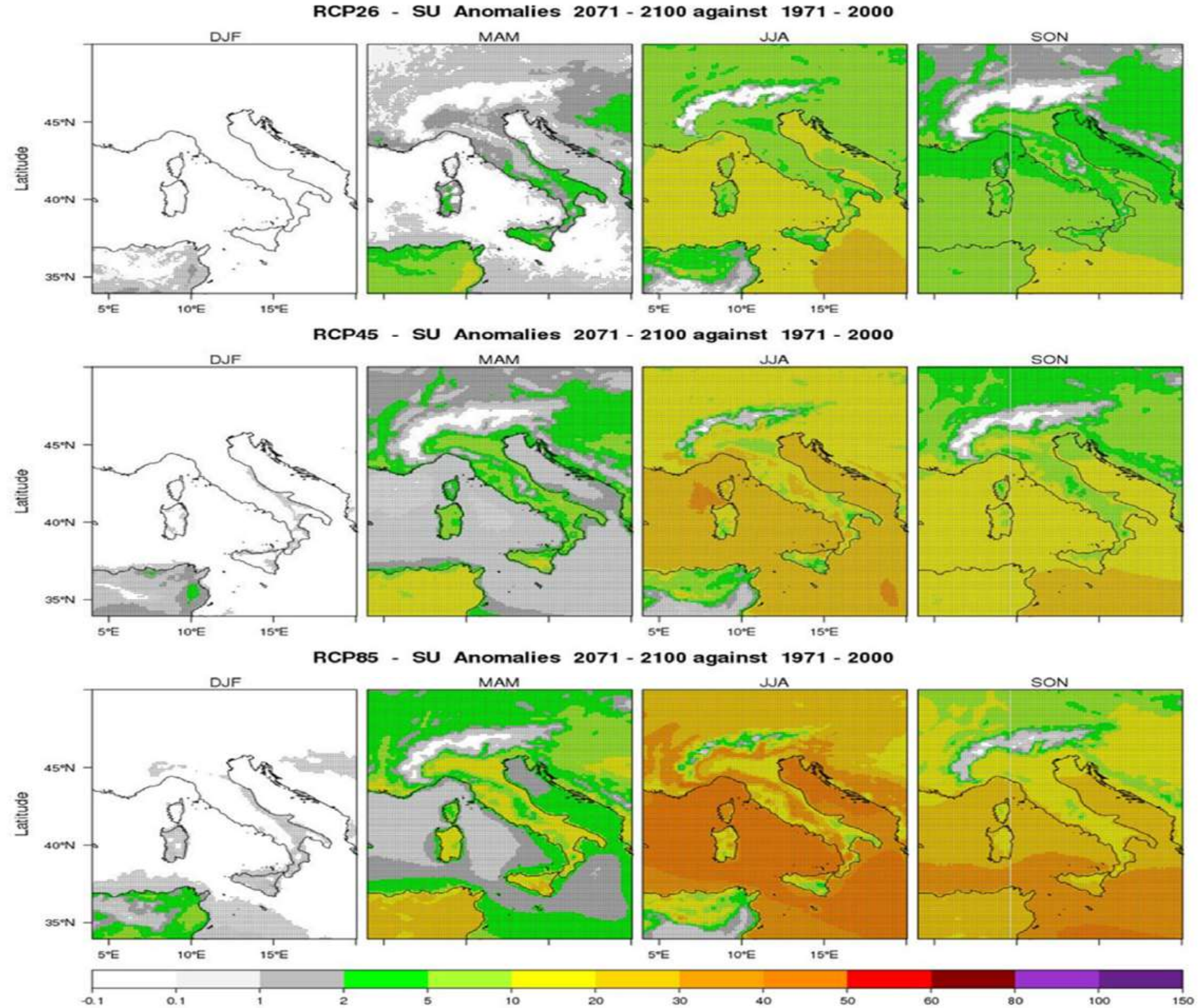
SU TMX>25°C

Anomalies: ΔN

RCP 2.6

RCP 4.5

RCP 8.5



TR REF

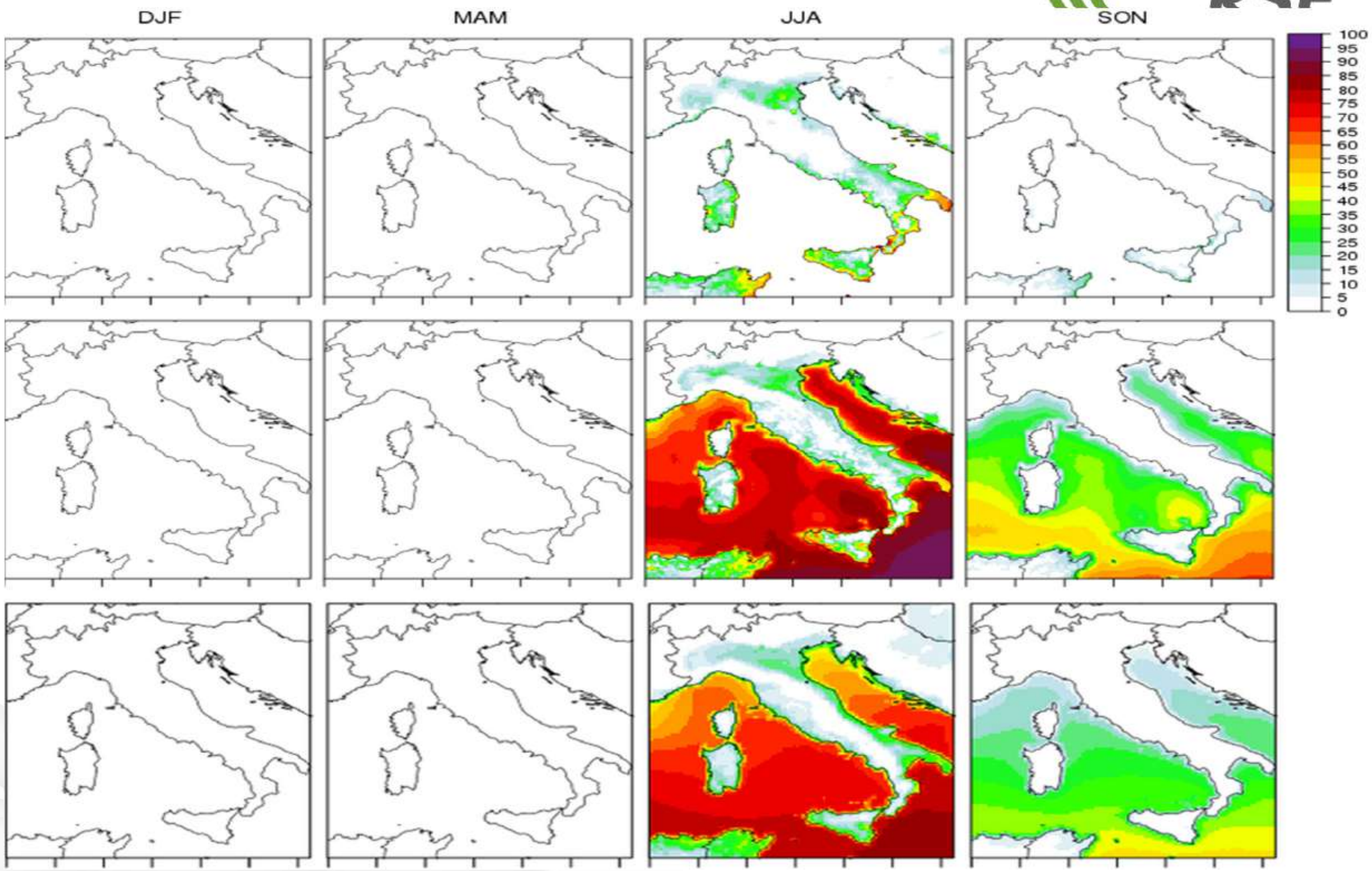
TMN > 20°C

winter spring summer autumn

E-OBS

MESAN

ENS



%

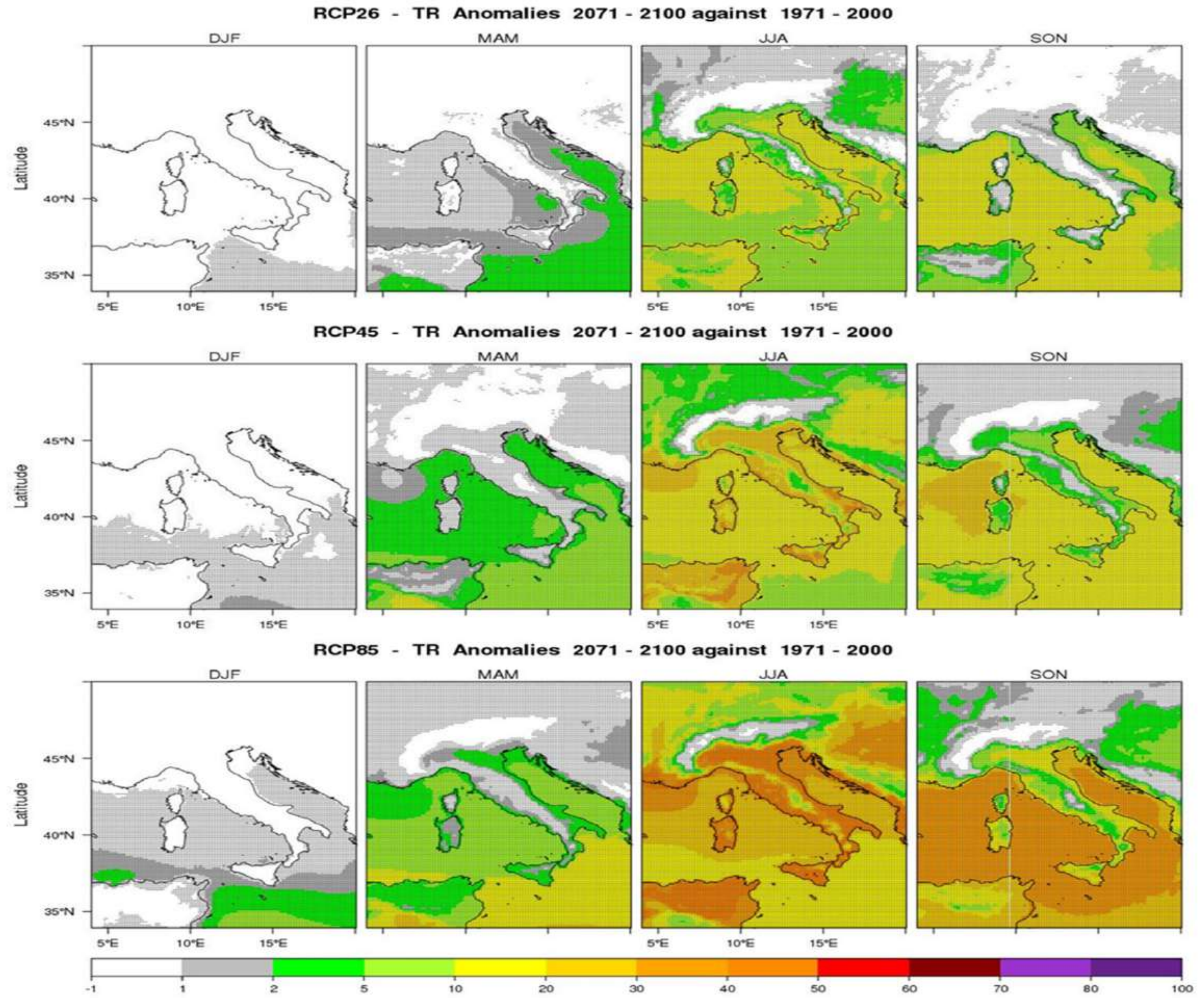
TR *TMN>20°C*

Anomalies: ΔN

RCP 2.6

RCP 4.5

RCP 8.5



FD REF

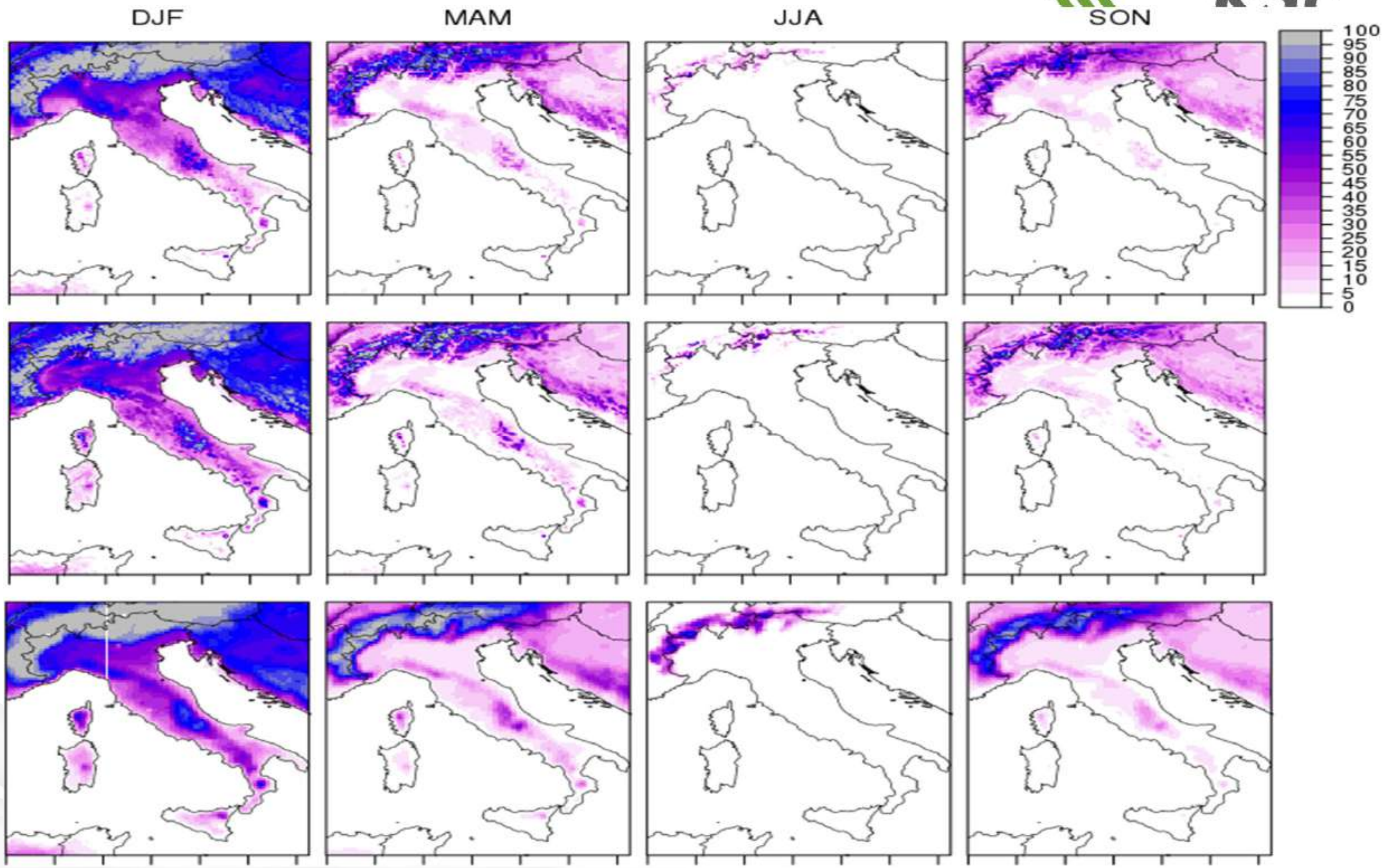
TMN < 0°C

winter spring summer autumn

E-OBS

MESAN

ENS



%

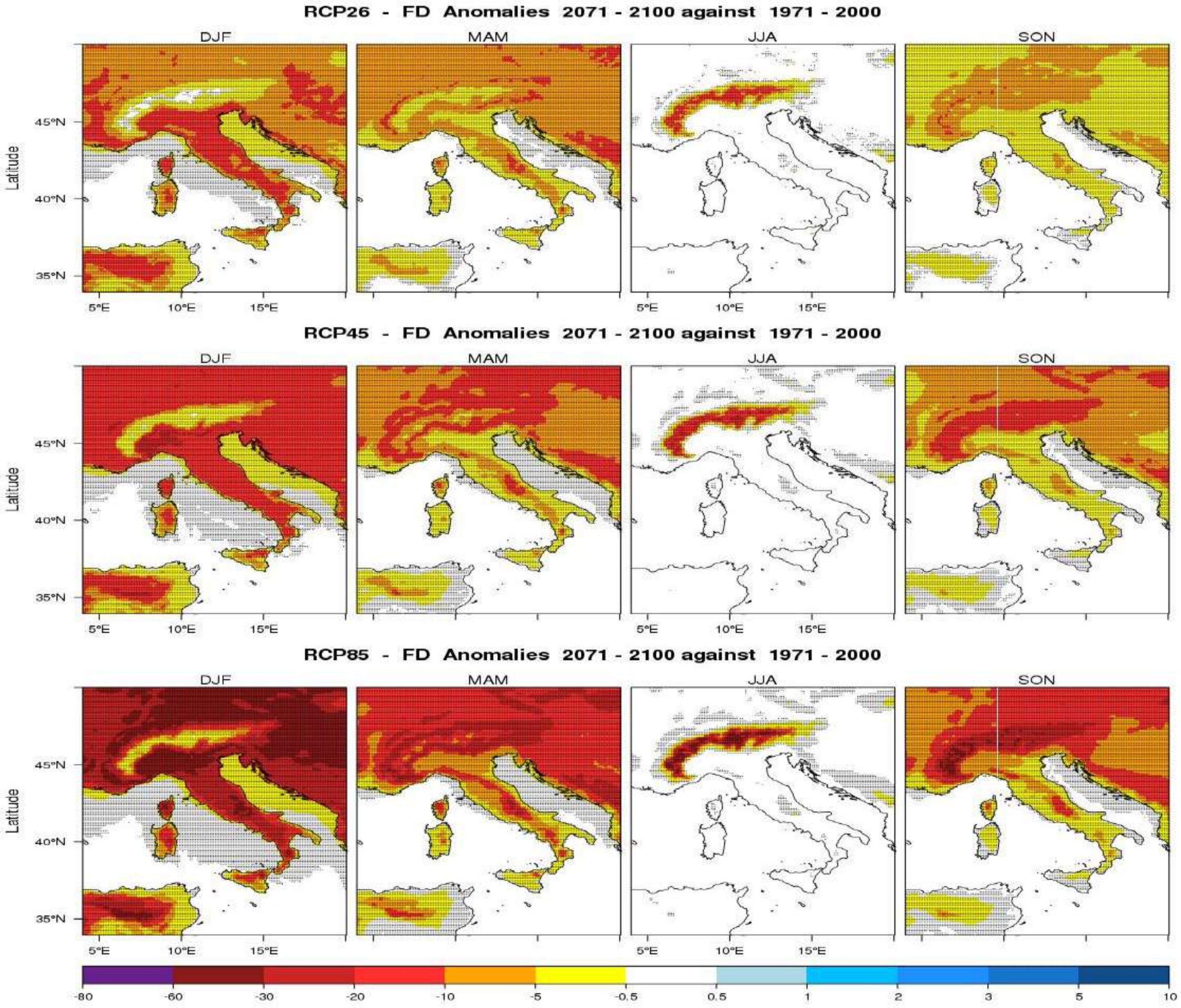
FD TMN < 0°C

Anomalies: ΔN

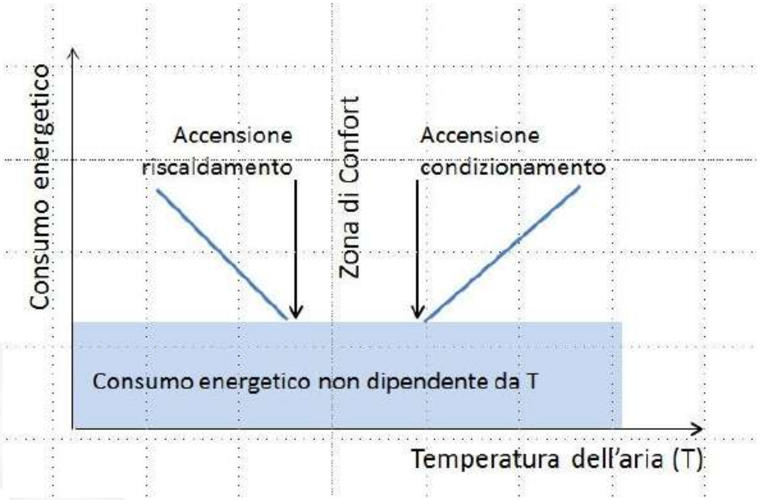
RCP 2.6

RCP 4.5

RCP 8.5



4. Proiezioni future: Gradi Giorno (Degree Days)



EUROSTAT (J)

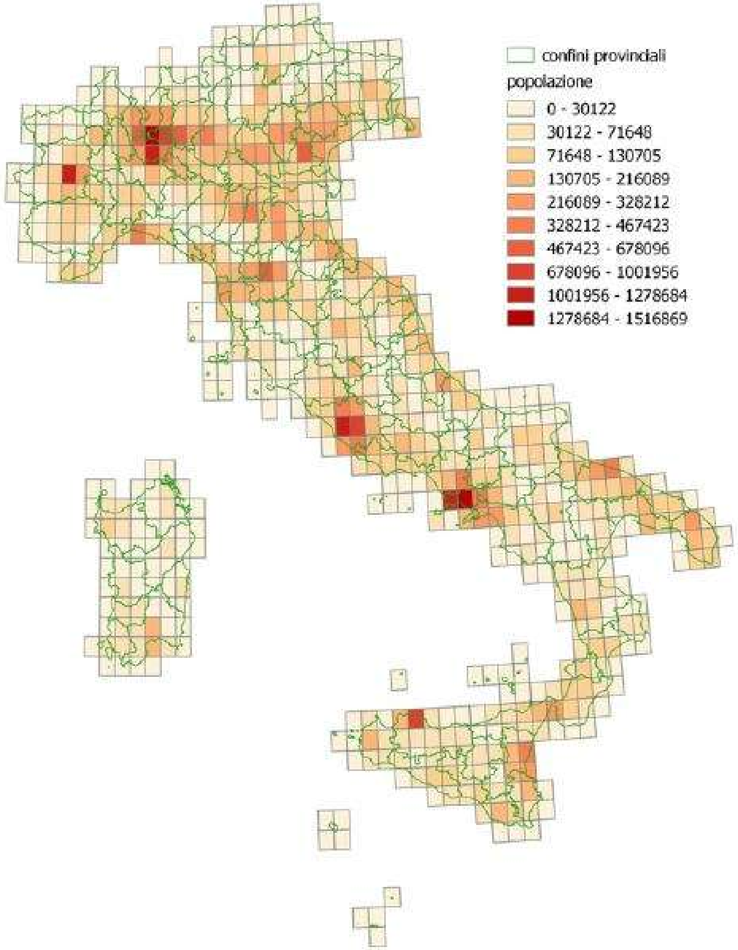
hdd = max (T – Tm , 0)   T* = 18 °C se Tm < 15 °C*

*cdd = max (Tm – T**, 0) T** = 21 °C se Tm > 24 °C*

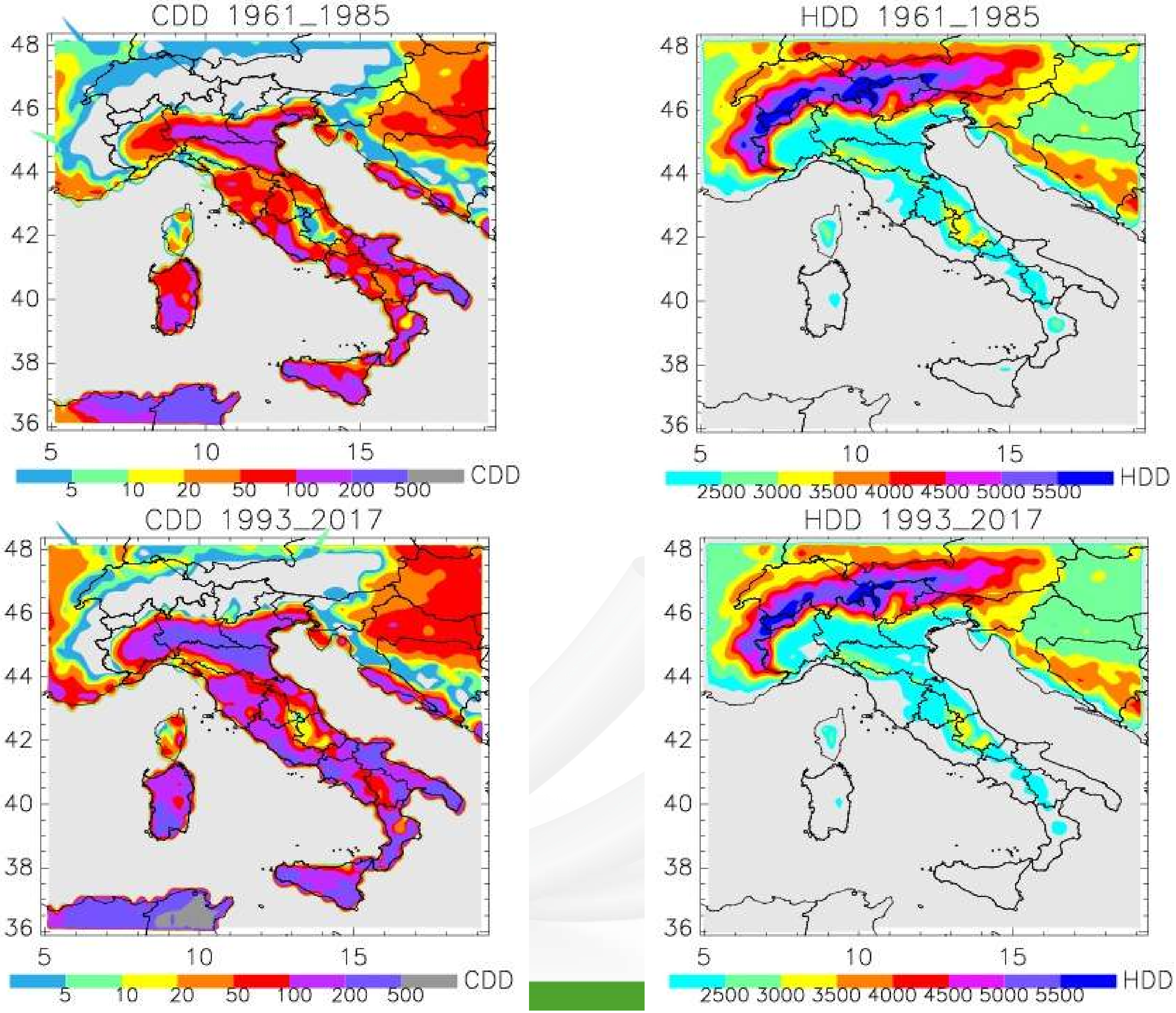
Cumulate annuali

$$HDD(iy) = \sum_{ig=1}^{ngy} \sum_{k=1}^{N} weight_k hdd_k(ig)$$

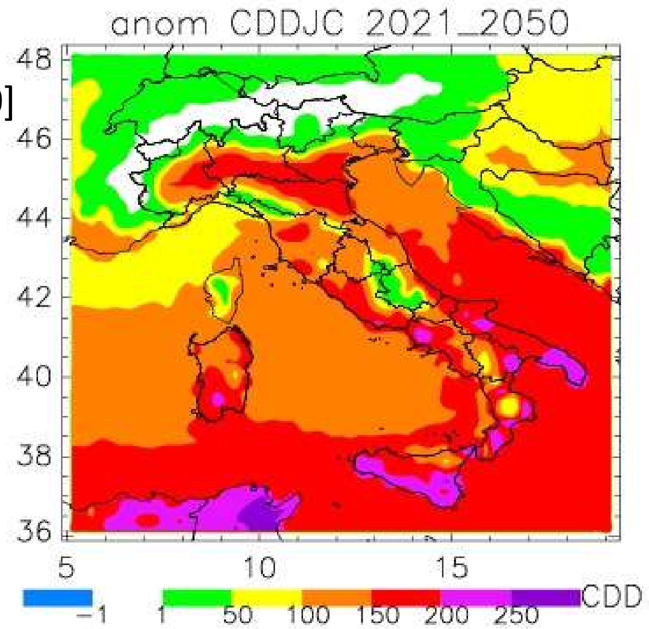
$$CDD(iy) = \sum_{ig=1}^{ngy} \sum_{k=1}^{N} weight_k cdd_k(ig)$$

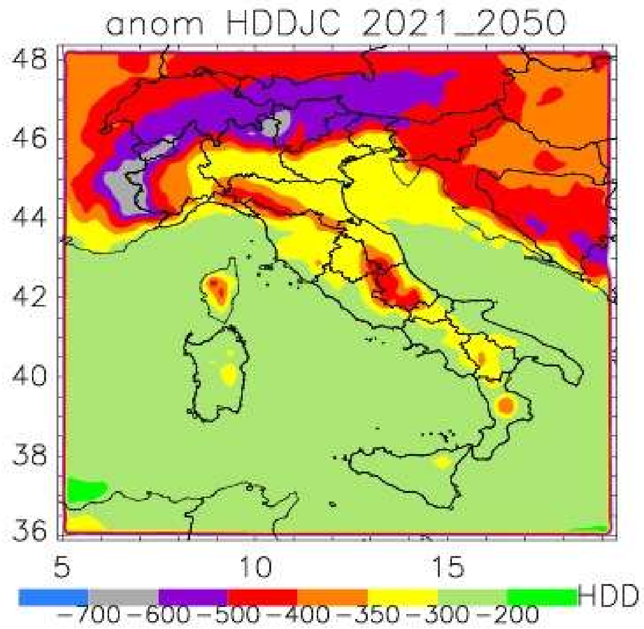


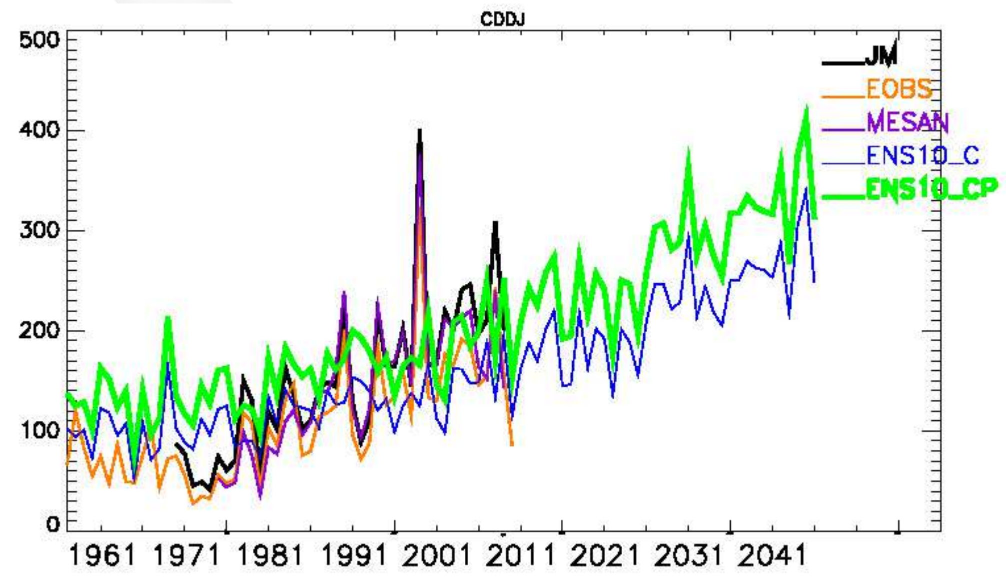
Faggian et al, Ingegneria dell'Ambiente Vol. 5 n. 4/2018

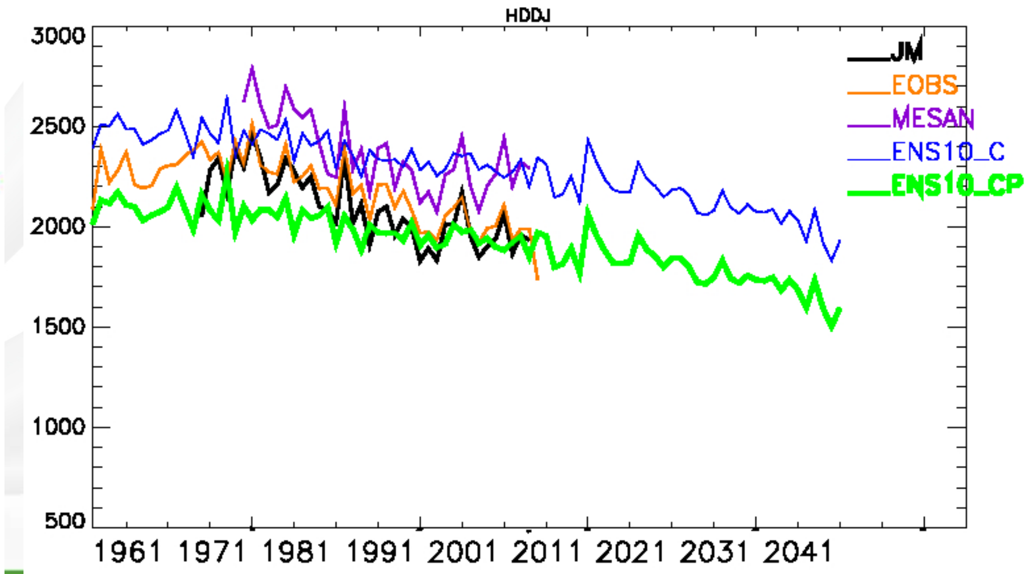

CDD 1961_1985
HDD 1961_1985
CDD 1993_2017
HDD 1993_2017
48 46 44 42 40 38 36
5 10 15
5 10 20 50 100 200 500 CDD
2500 3000 3500 4000 4500 5000 5500 HDD

FUT – REF
Ref = [1961, 1990]









5. CONCLUSIONS

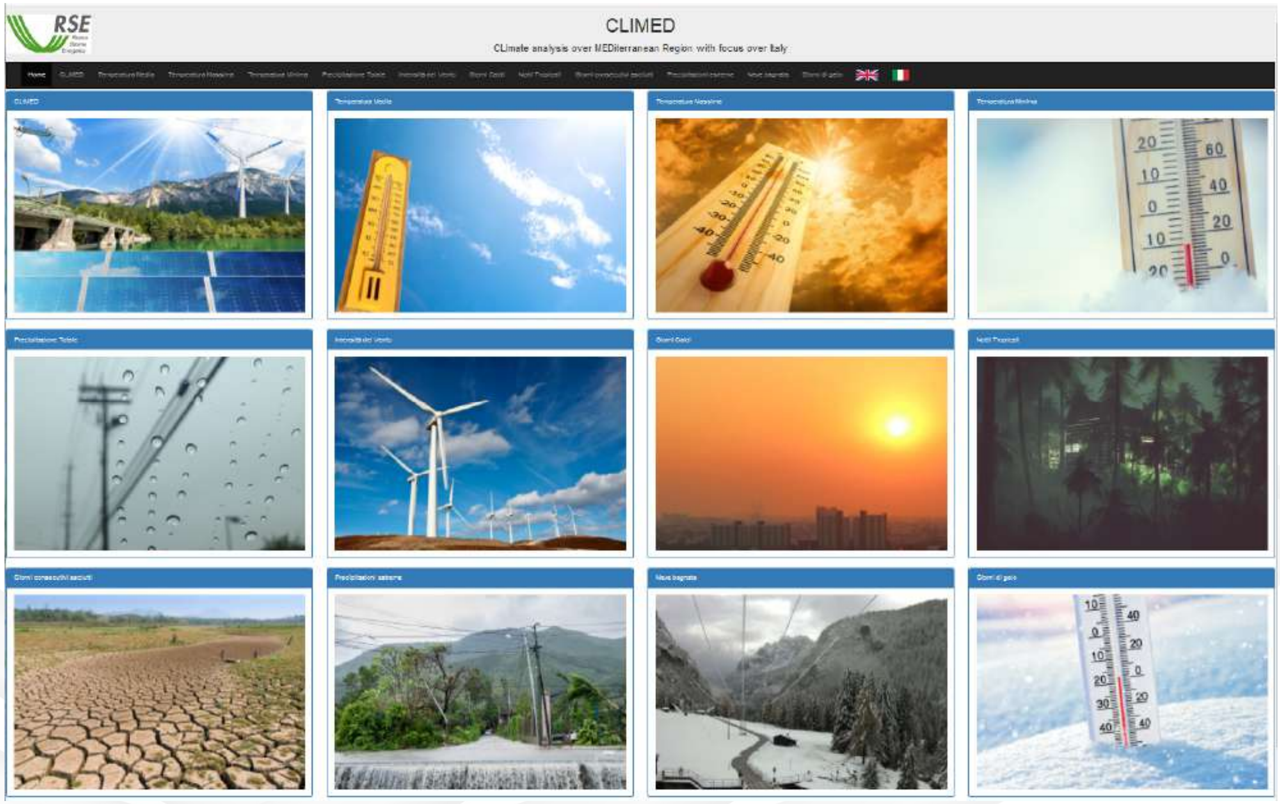
Climate change projections over the Mediterranean region (with focus over Italy) point out a significant warming and drying, especially in the warm season.

By 2050 it is expected:

a) a mean warming of 1-1.5 ℃ in winter , ~ 2 ℃ in summer
b) a warming over 2 ℃ in extreme temperature values
c) an increases in droughts, floods and wind storms
d) HDD reduction ~25% ; CDD increasing ~100%

An exacerbation of the hazards, projected to become more serious in the second part of the century

CLIMED CLImate analysis over MEDiterranean Region
http://climed-rse-web.it



Grazie per l'attenzione

This work has been financed by the Fund for Research on the national Power System (RdS) under Programme Agreements between RSE and the Italian Ministry for economic development (MiSE).