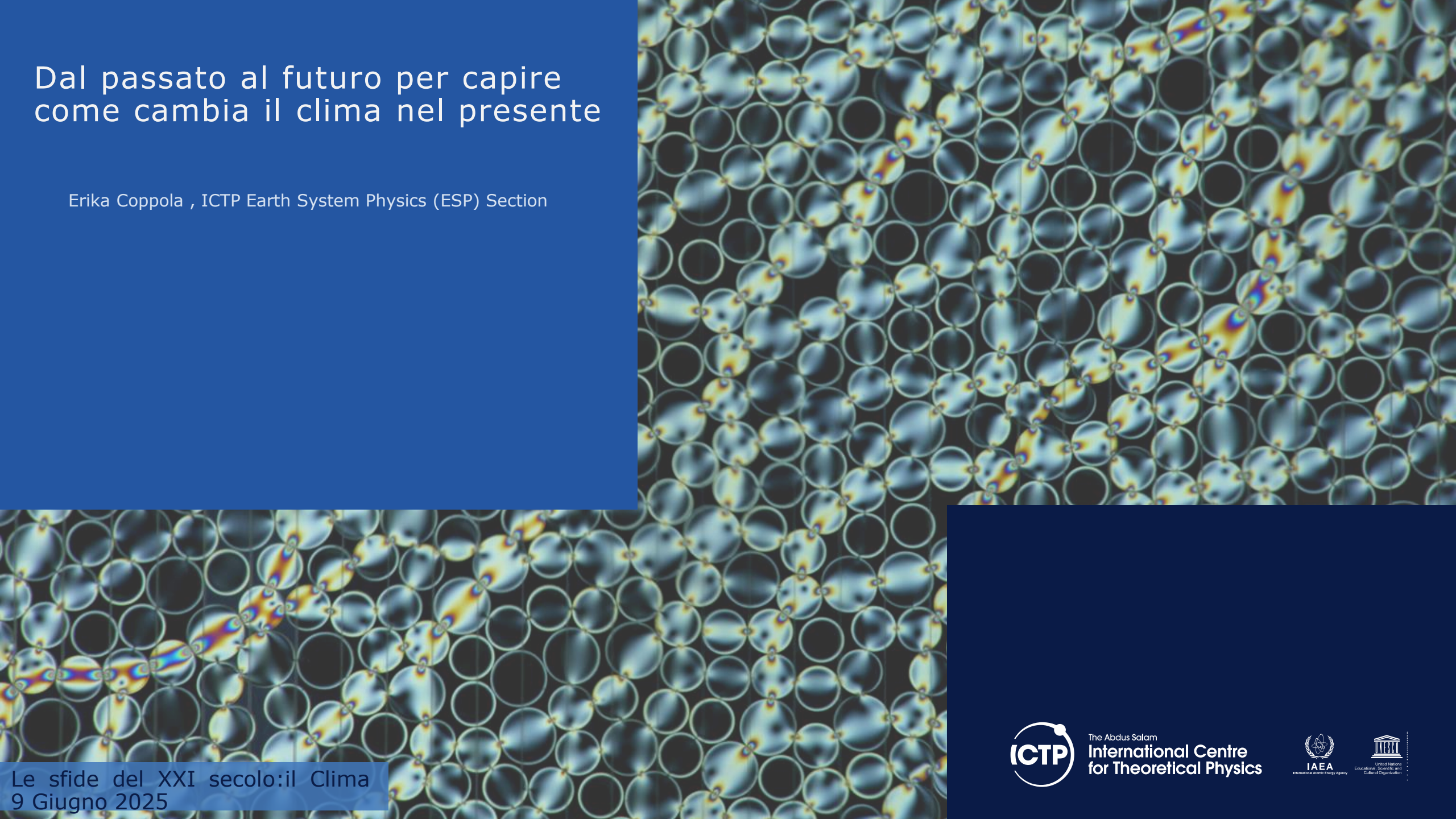
Dal passato al futuro per capire come cambia il clima nel presente

Erika Coppola , ICTP Earth System Physics (ESP) Section



Le sfide del XXI secolo:il Clima
9 Giugno 2025

The Abdus Salam International Centre for Theoretical Physics

Observed warming is driven by emissions from human activities

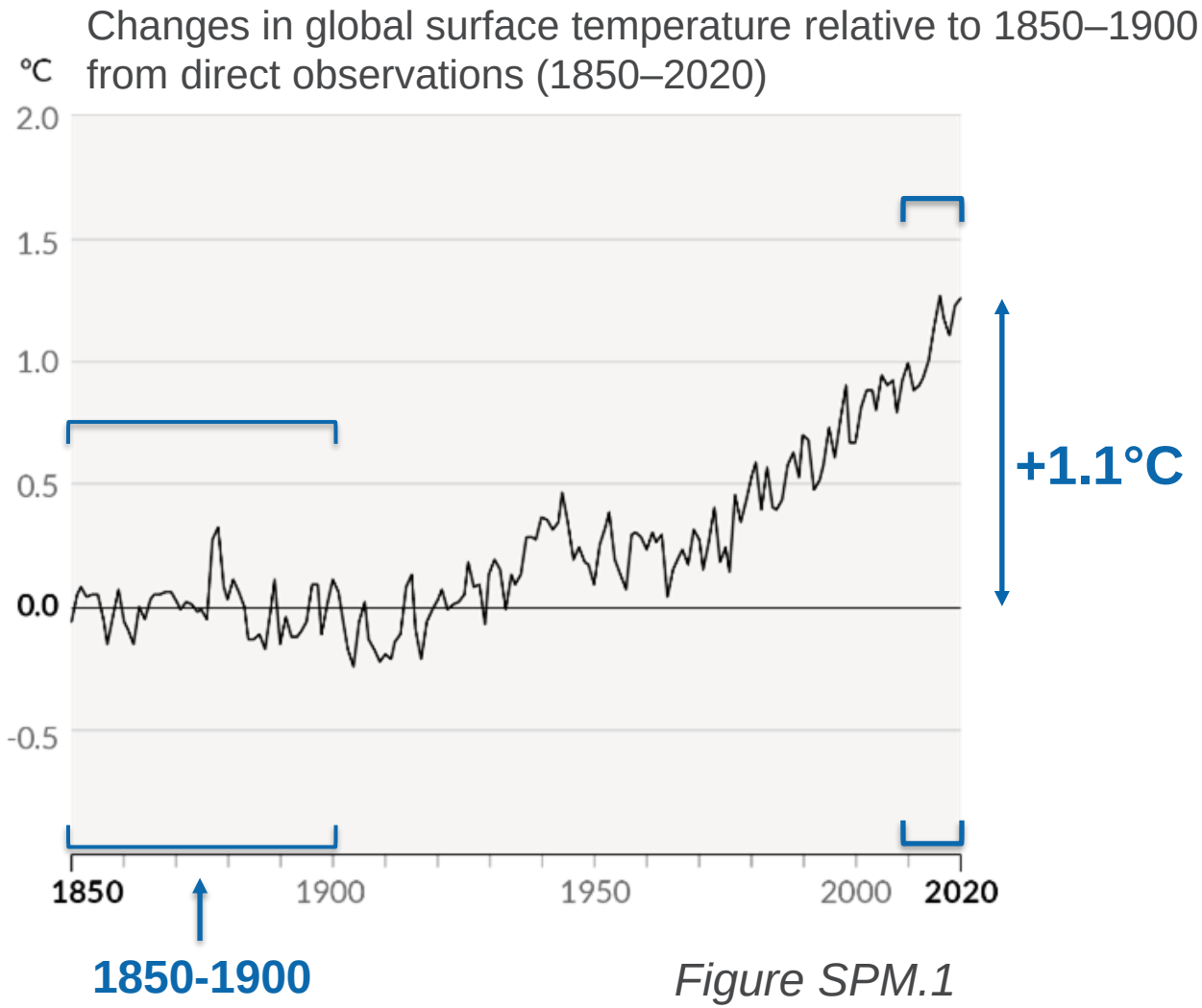


Figure SPM.1

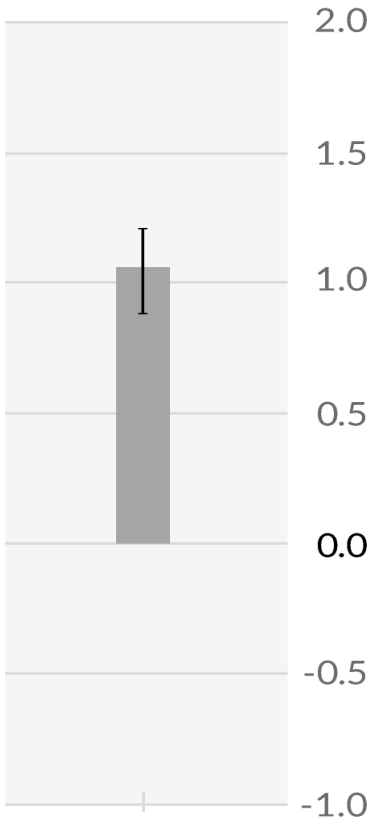
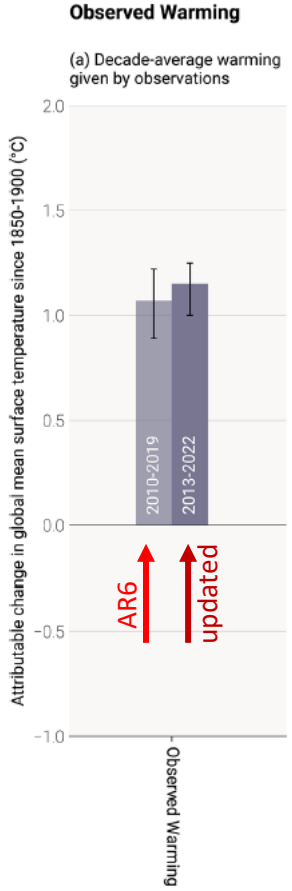


Figure SPM.2

Observed warming and Carbon Budget updates

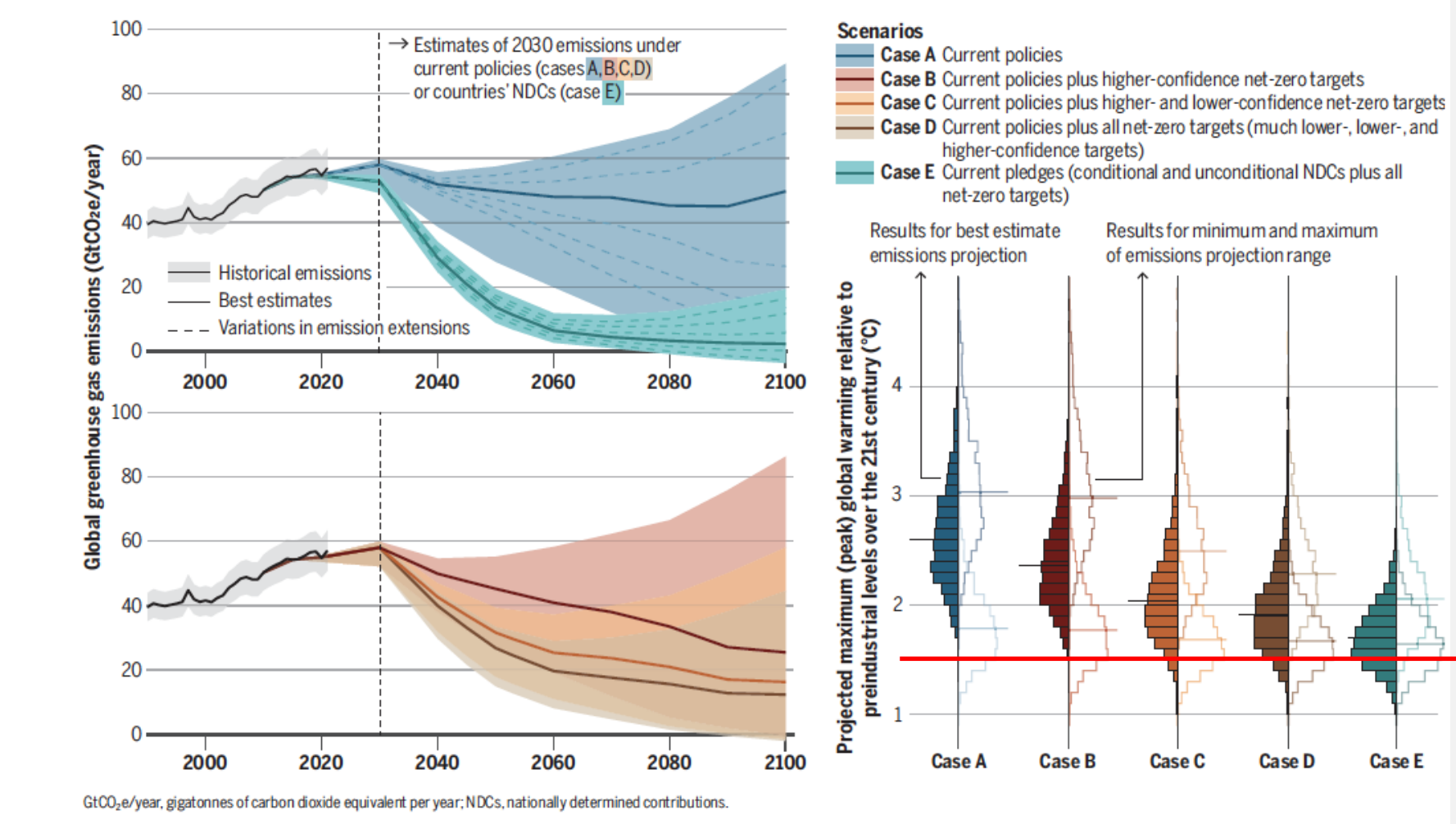
+ 1.14 ^{o}C averaged over the 2013–2022



Historical cumulative CO_2 emissions (1850–2019) AR6 WGI Table SPM.2	2390 (±240; *likely* (66 %–100 % probability) range)					
Remaining carbon budgets Case/update	Base year	Estimated remaining carbon budgets from the beginning of base year ($GtCO_2$)				
Likelihood of limiting global warming to temperature limit.		17 %	33 %	50 %	67 %	83 %
1.5 °C from AR6 WGI	2020	900	650	500	400	300
+ AR6 emulator update	2020	750	500	400	300	200
+ as above with AR6 scenario update	2020	750	500	400	300	200
+ as above with warming update (2013–2022) (best estimate)	**2023**	**500**	**300**	**250**	**150**	**100**
1.7 °C from AR6 WGI	2020	1450	1050	850	700	550
+ AR6 emulator update	2020	1250	900	700	600	450
+ as above with AR6 scenario update	2020	1300	950	750	600	500
+ as above with warming update (2013–2022) (best estimate)	**2023**	**1100**	**800**	**600**	**500**	**350**
2 °C from AR6 WGI	2020	2300	1700	1350	1150	900
+ AR6 emulator update	2020	2050	1500	1200	1000	800
+ as above with AR6 scenario update	2020	2200	1650	1300	1100	900
+ as above with warming update (2013–2022) (best estimate)	**2023**	**2000**	**1450**	**1150**	**950**	**800**

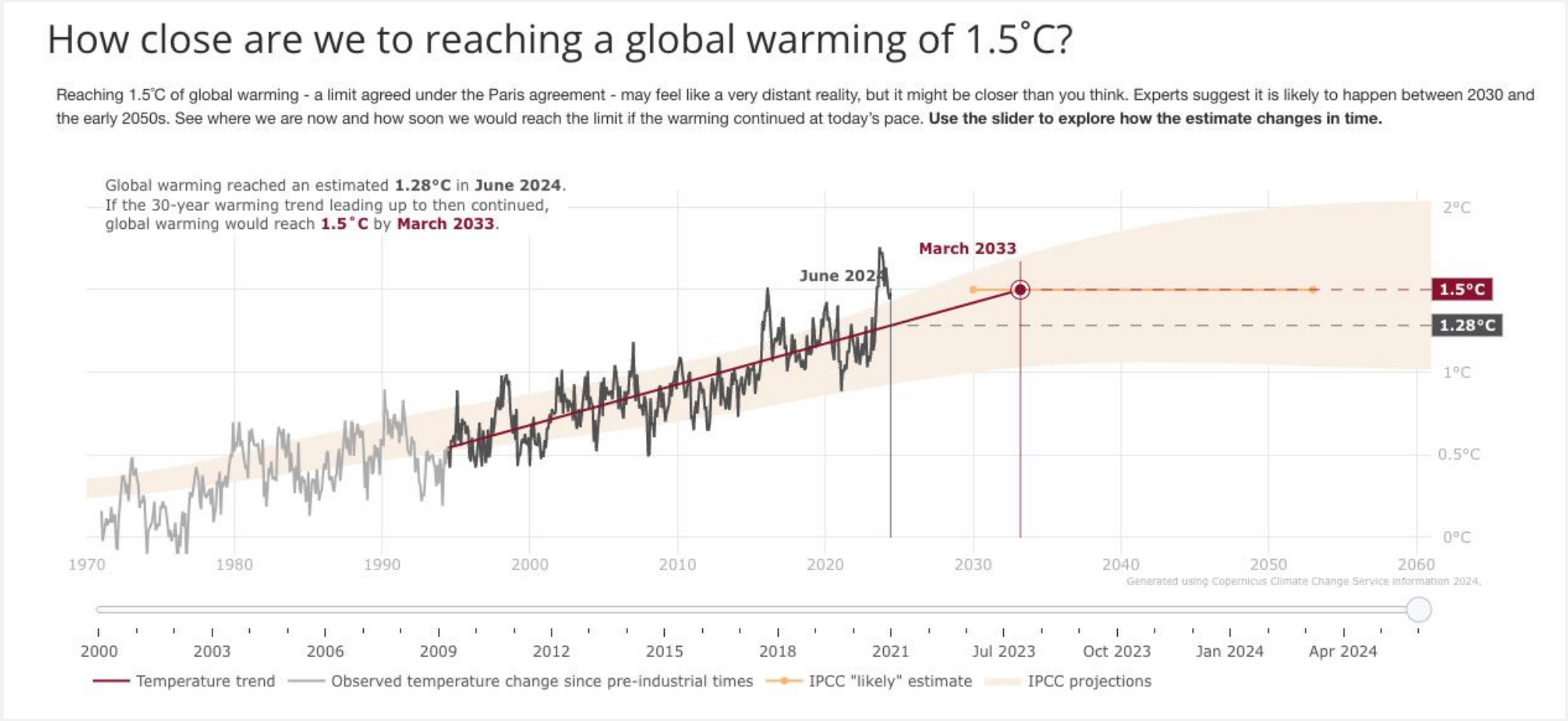
Forster et al.,(2023) Indicators of Global Climate Change 2022: annual update of large-scale indicators of the state of the climate system and human influence. Earth System Science Data https://doi.org/10.5194/essd-15-2295-2023

Likelyhood to reach global climate targets



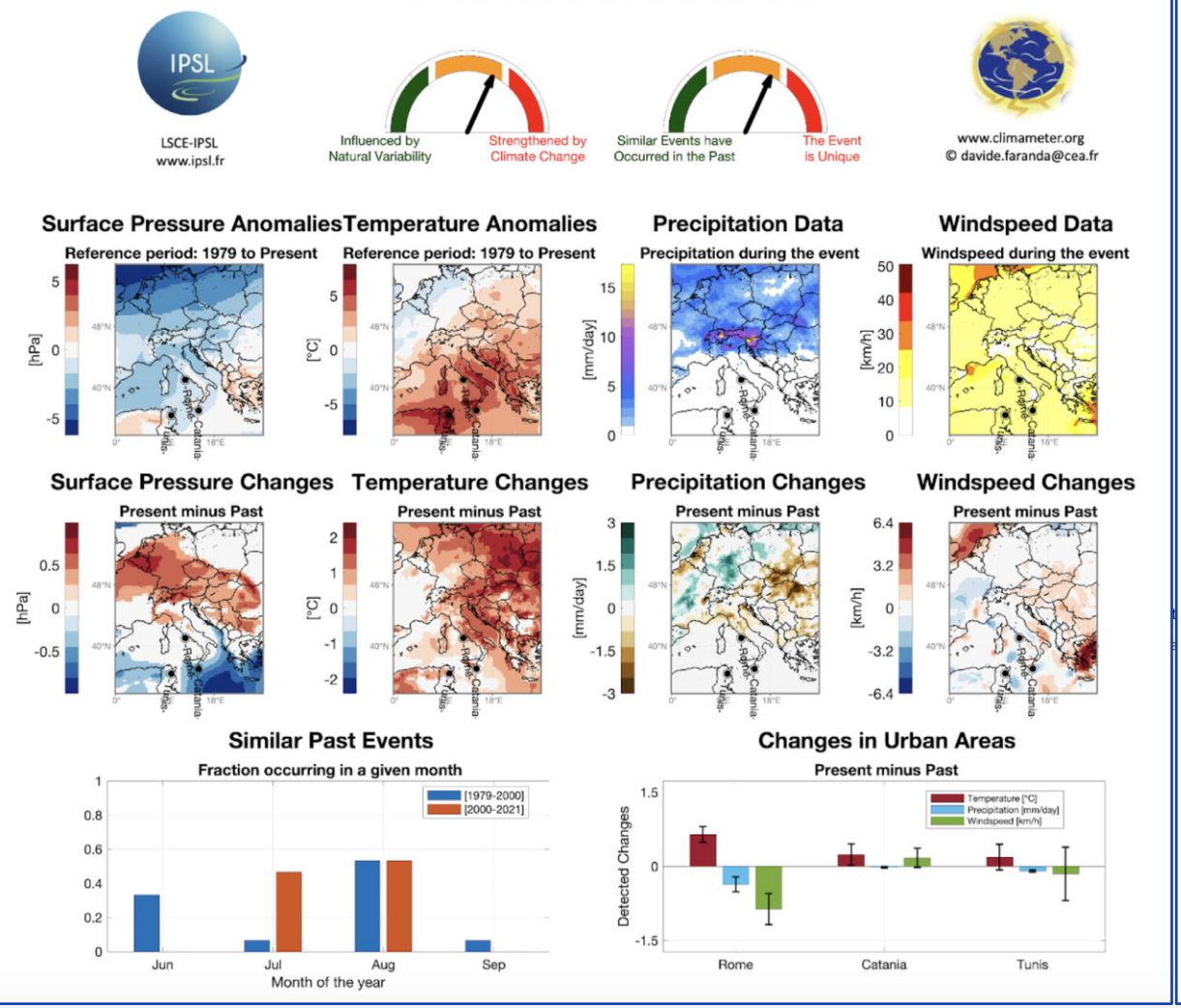
Rojet et al.,(2023) Credibility gap in net-zero climate targets leaves world at high risk. Science DOI: 10.1126/science.adg6248

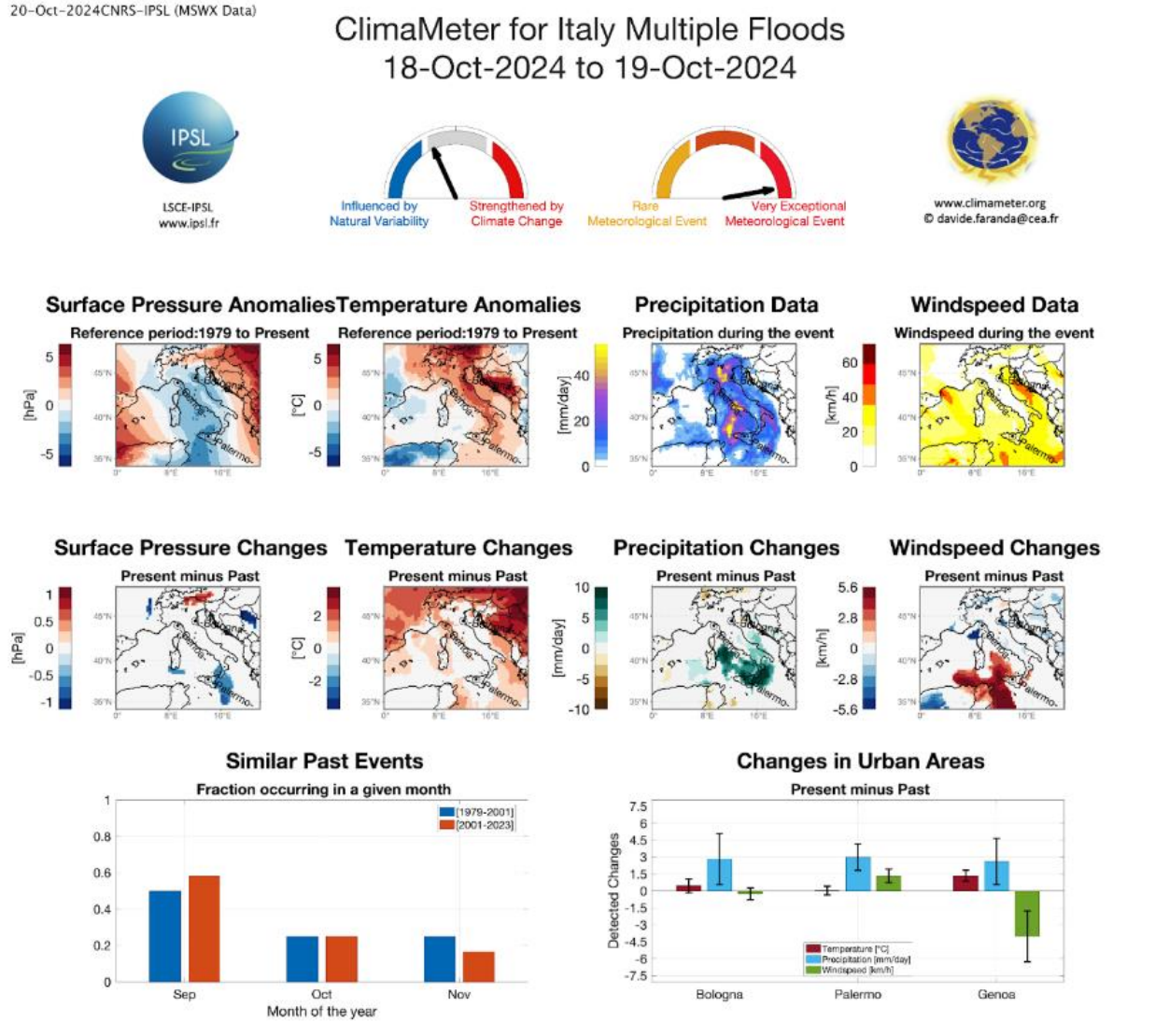
Copernicus Climate Change Service



https://climate.copernicus.eu/

Present: attribution

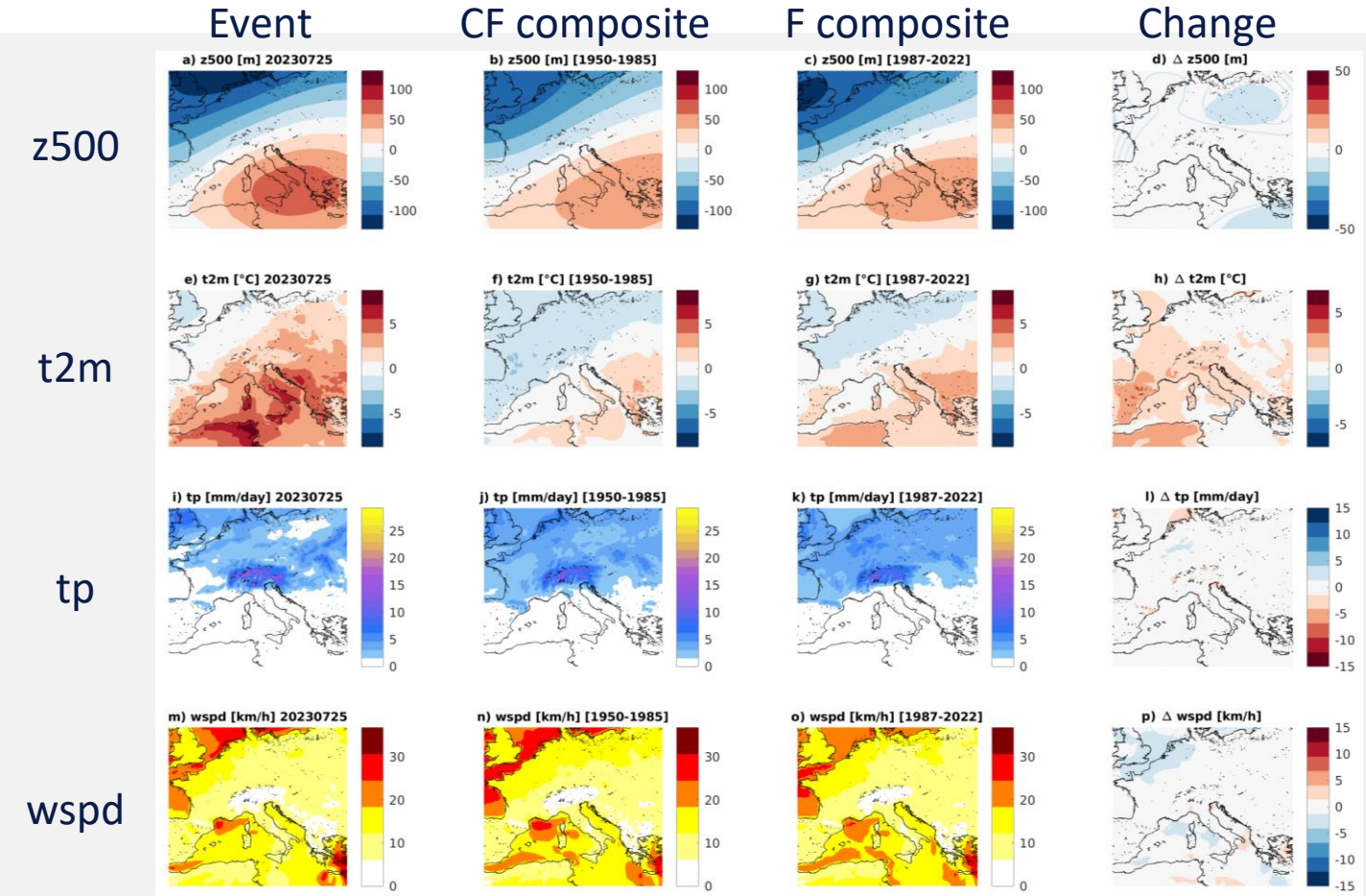




2023/07/15-25 Cerberus Heatwave in Southern Europe

Results based on ERA5

- Event associated with a high-pressure system over southern Italy.
- Strong positive anomalies in temperature observed.
- No significant change identified in geopotential height.
- Significant increase in temperature can be observed in the factual period.



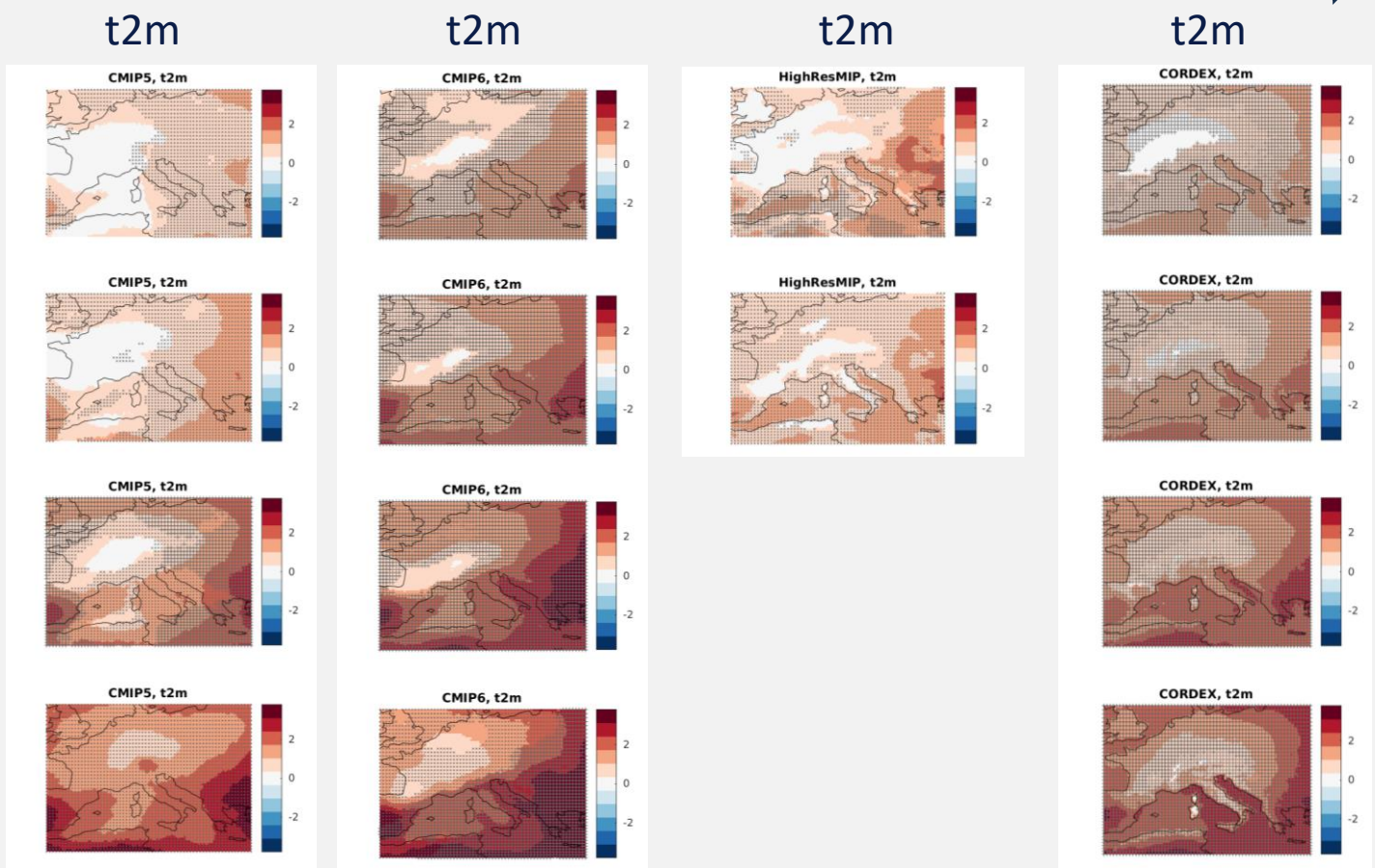
2023/07/15-25 Cerberus Heatwave in Southern Europe

Results based on

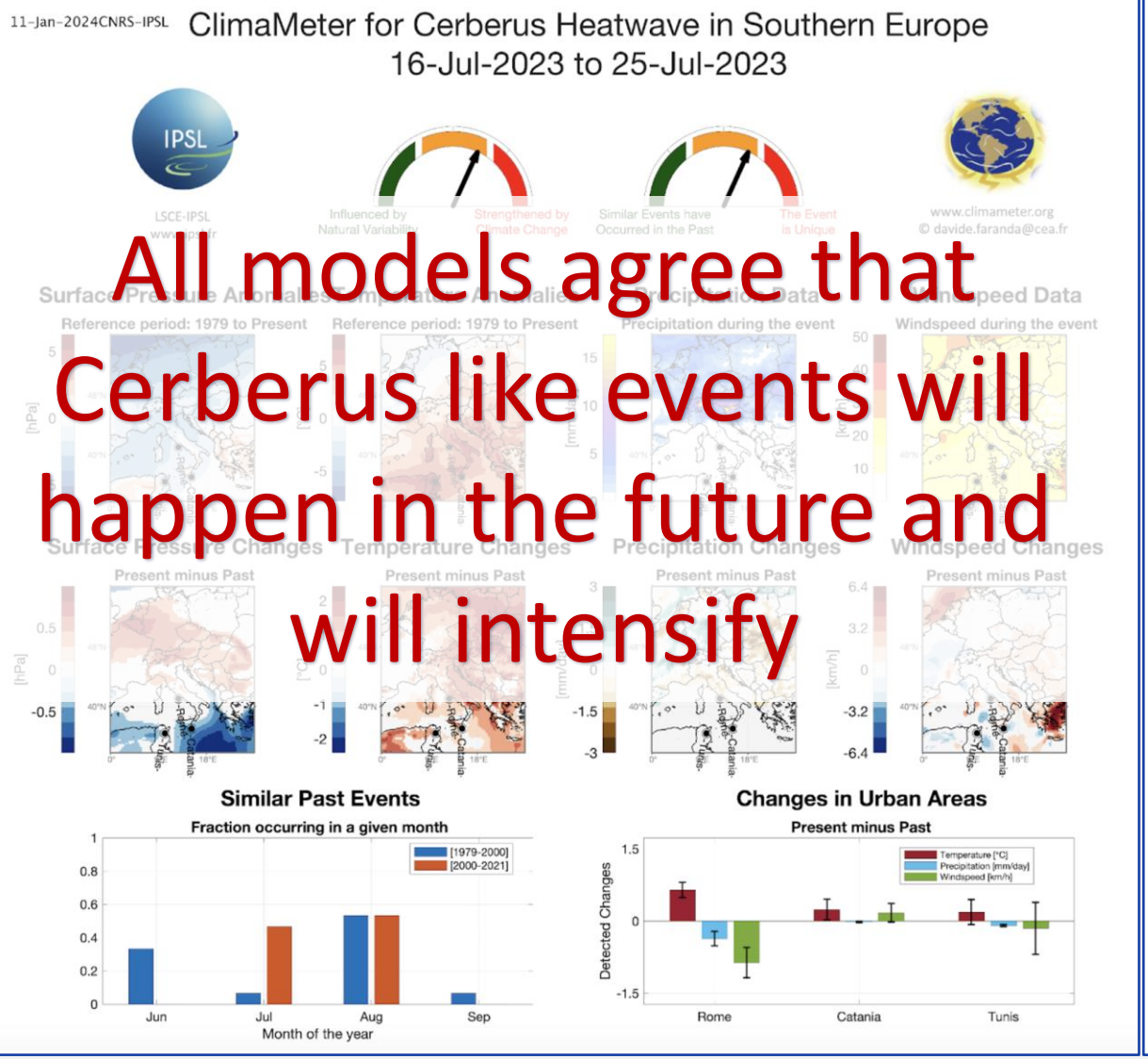
CMIP5 CMIP6 HighResMIP CORDEX

Higher Resolution

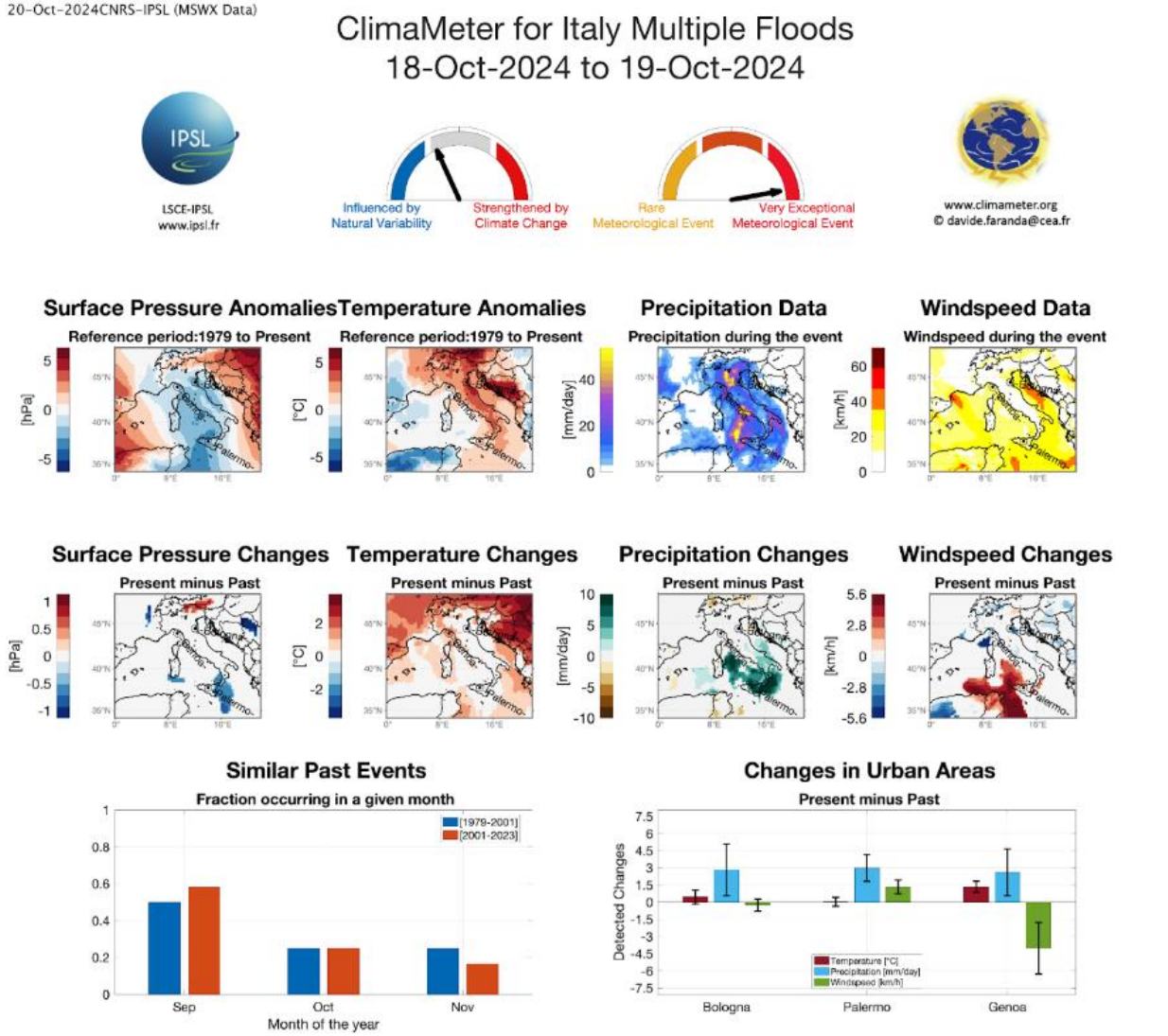
- Ensemble average of changes at 1.5, 2, 3, and 4 K global warming levels.
- "+": significant change (based on t-tests at α = 0.05, controlled for false discovery rate at α_{FDR} = 0.05).
- "x": consistent change with 80% of ensemble members agrees on sign of change.



Summary so far



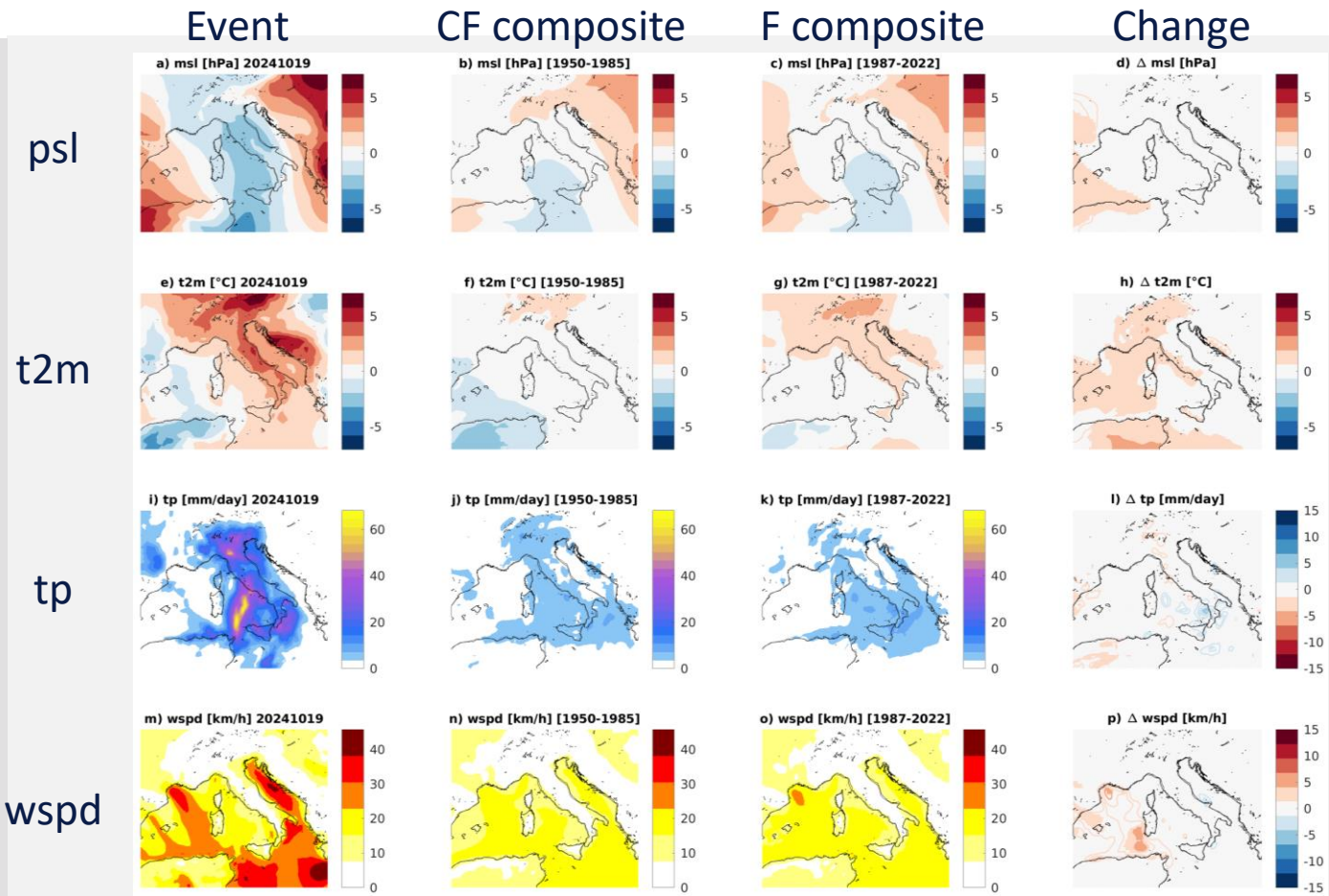
All models agree that Cerberus like events will happen in the future and will intensify



2024/10/18-19 Italy Multiple Floods

Results based on ERA5

- Event associated with a low-pressure system over Italy.
- Strong positive anomalies in precipitation observed.
- No significant change identified in mean sea level pressure.
- Significant increase in precipitation can be observed in parts of southern Italy in the factual period.



2024/10/18-19 Italy Multiple Floods

Results based on

CMIP5 CMIP6 HighResMIP CORDEX

Higher Resolution

- Ensemble average of changes at 1.5, 2, 3, and 4 K global warming levels.
- "+": significant change (based on t-tests at α = 0.05, controlled for false discovery rate at α_{FDR} = 0.05).
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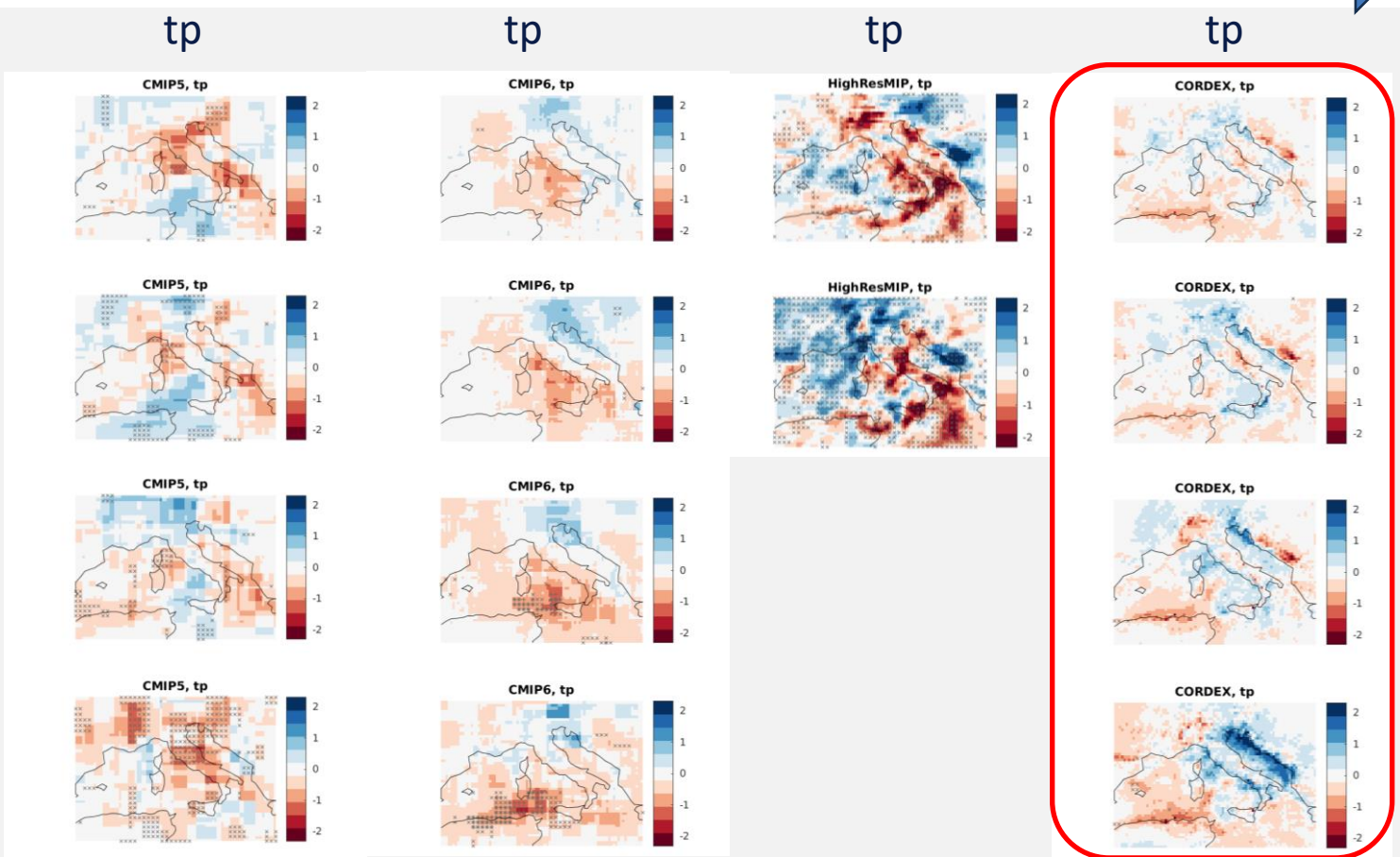
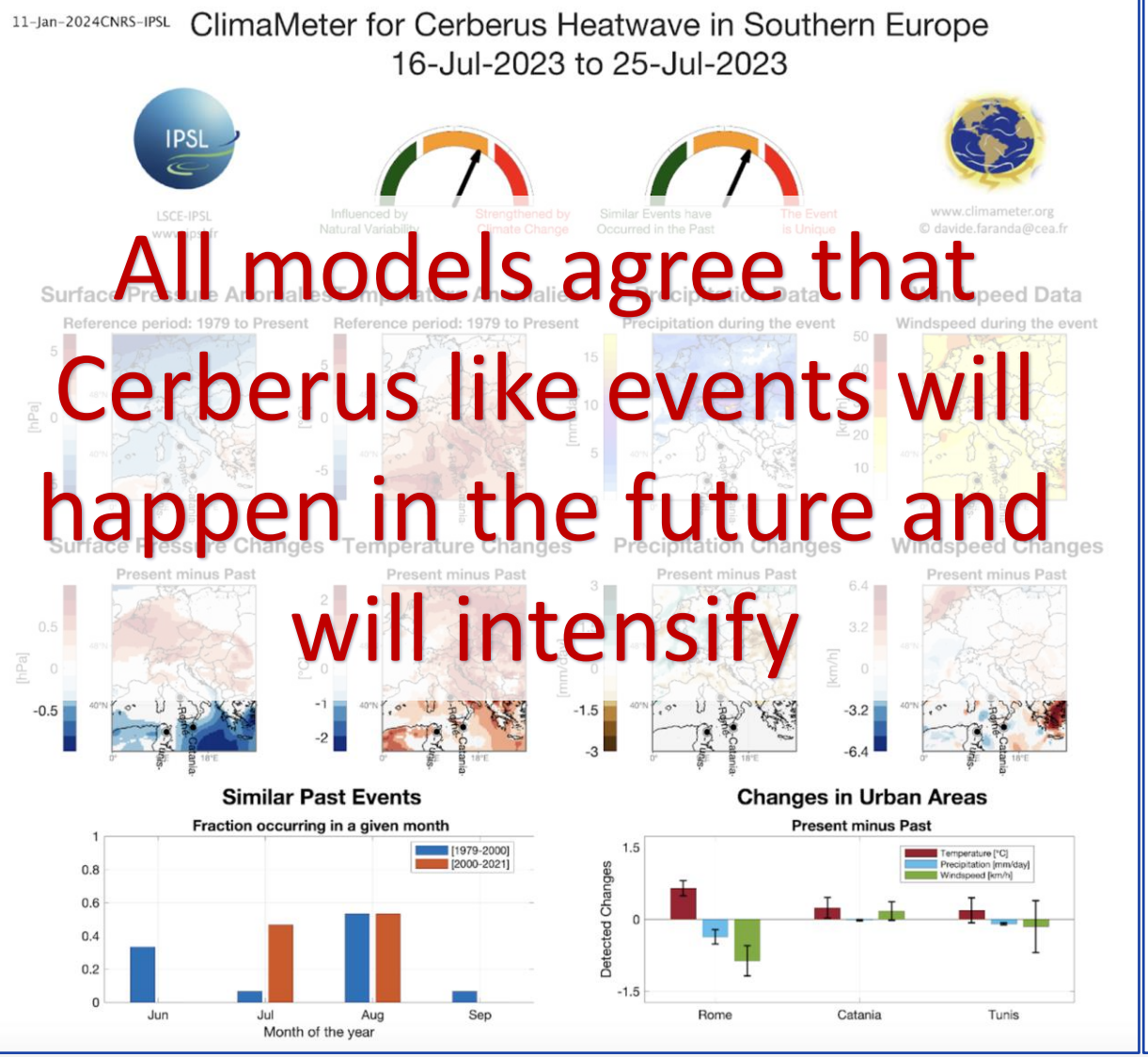


Summary so far

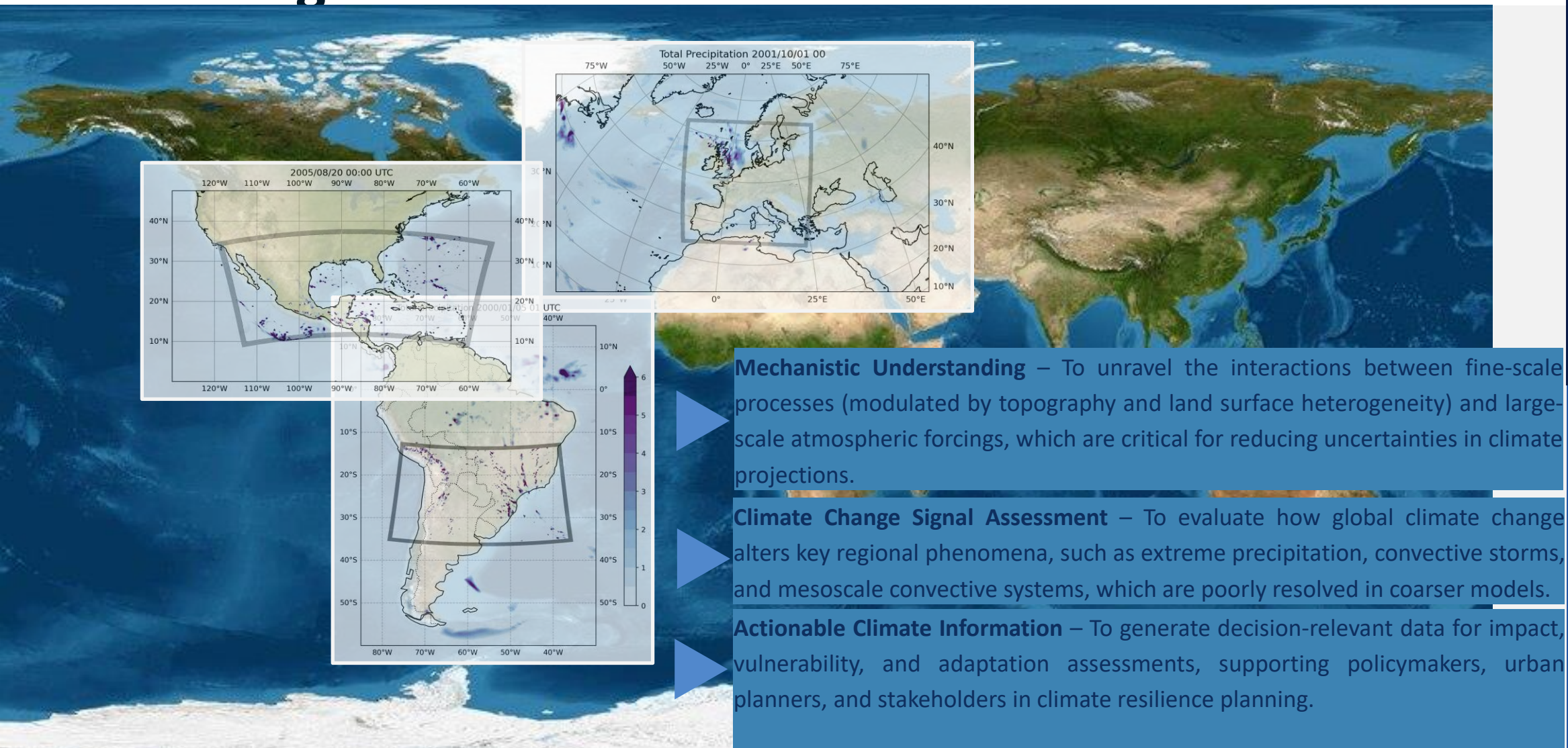


All models agree that Cerberus like events will happen in the future and will intensify

Higher resolution models agree that multiple flood events similar to October 2024 will happen in the future and will intensify

A New Scientific Frontier in Climate Science

High-Resolution Kilometer-Scale Regional Climate Modeling

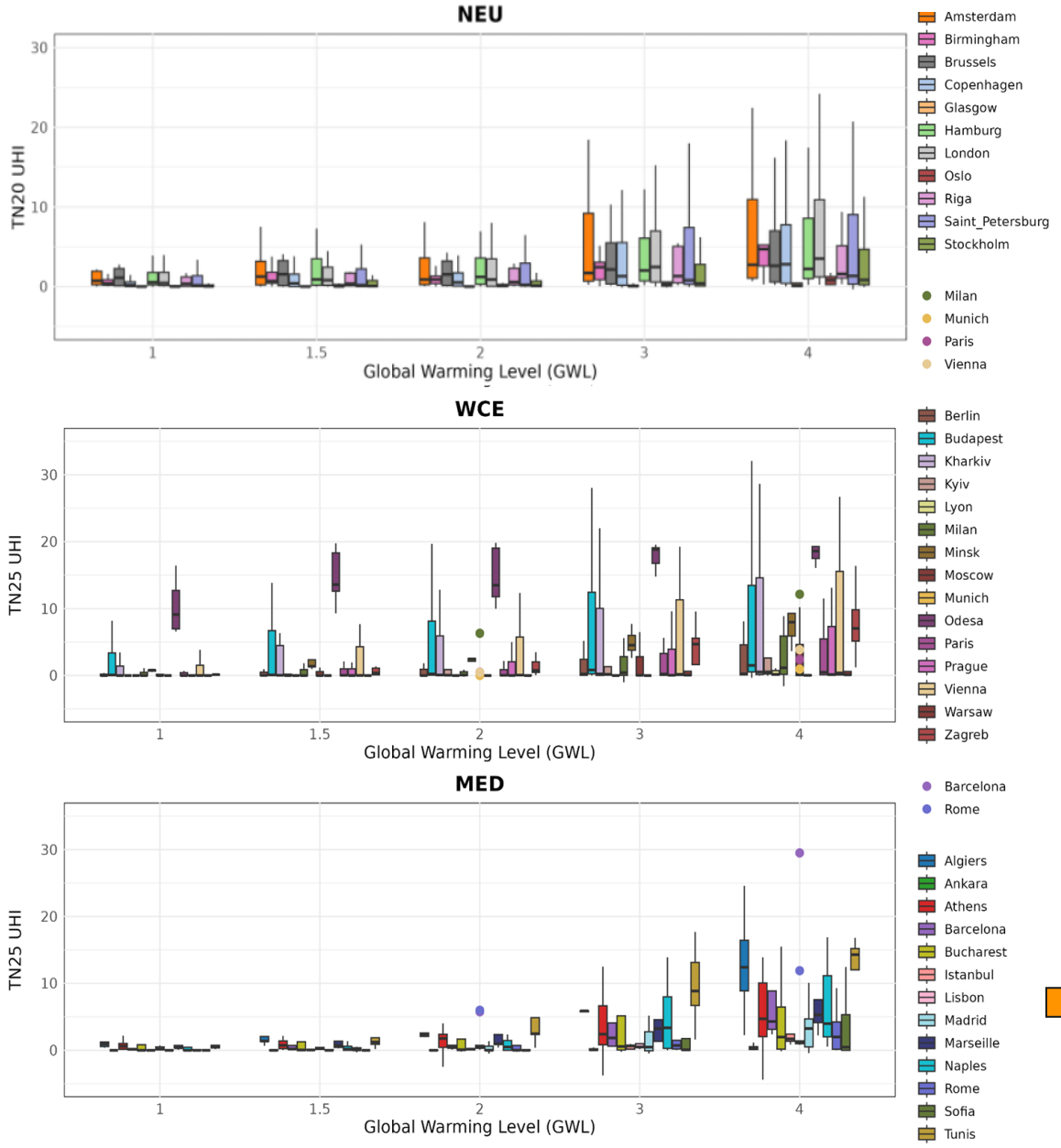


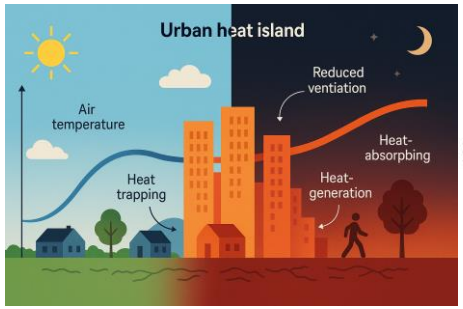
Mechanistic Understanding – To unravel the interactions between fine-scale processes (modulated by topography and land surface heterogeneity) and large-scale atmospheric forcings, which are critical for reducing uncertainties in climate projections.

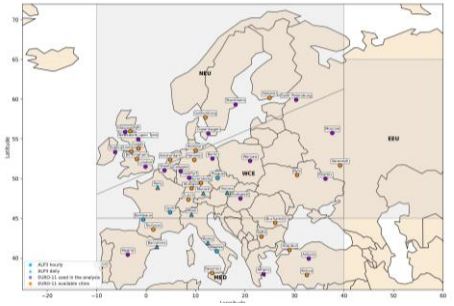
Climate Change Signal Assessment – To evaluate how global climate change alters key regional phenomena, such as extreme precipitation, convective storms, and mesoscale convective systems, which are poorly resolved in coarser models.

Actionable Climate Information – To generate decision-relevant data for impact, vulnerability, and adaptation assessments, supporting policymakers, urban planners, and stakeholders in climate resilience planning.

UHI







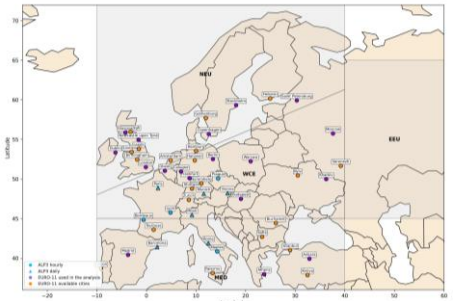
Urban Heat Island for TN20 & TN25:

Difference between urban and countryside at each GWL (1,1.5, 2, 3 and 4) for cities in Northern Europe (NEU) using "TN20 index" and for Western Central Europe (WCE) and Mediterranean (MED) using "TN25".
The analysis is done with different thresholds, depending on the region considered: 20 ℃ is the right value to highlight the UHI effect across the GWLs for Northern cities; 25 ℃ is instead used for WCE and MED.

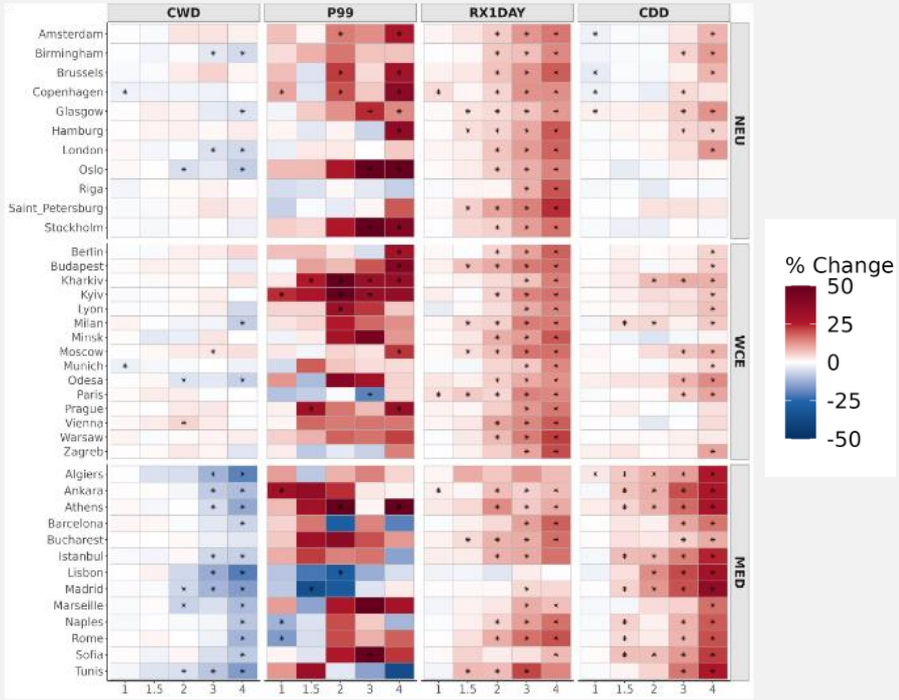
Boxplots for EUR-11 and Dots for CPCMs ALP-3 median.

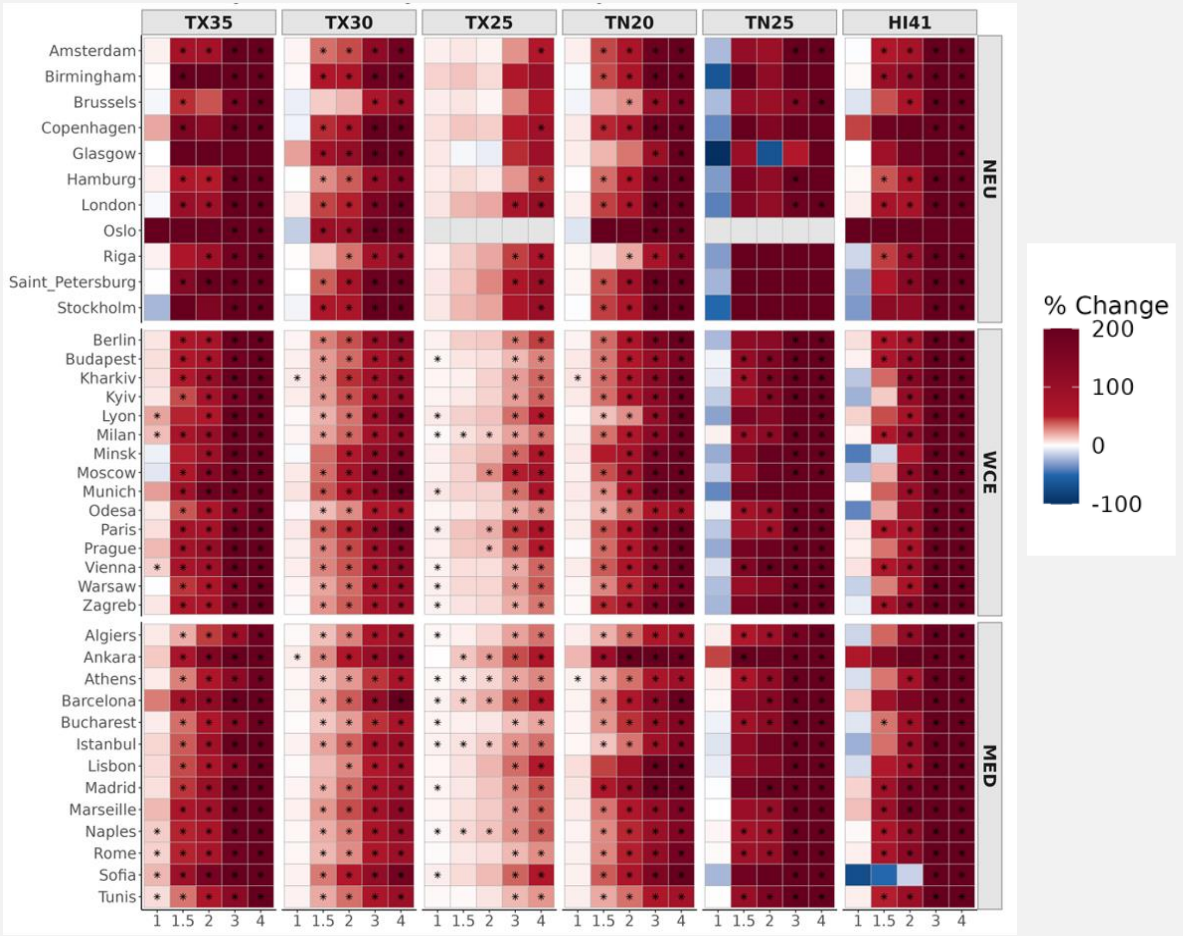
Increased effect of UHI with GWLs, enhanced in CPCMs.

Change (%) and Significance at Global Warming Levels for several Hazard Indices:



The mean percent change computed with respect to the reference period for each index and the selected cities of Europe, as detected by the urban masks of the models. The asterisk (*) marks the significant changes at 95%.
The average is computed over the cities using the urban masks available for each model. The idea is to see if cities are "Hot spots" of climate change or they reflect the regional climate response.





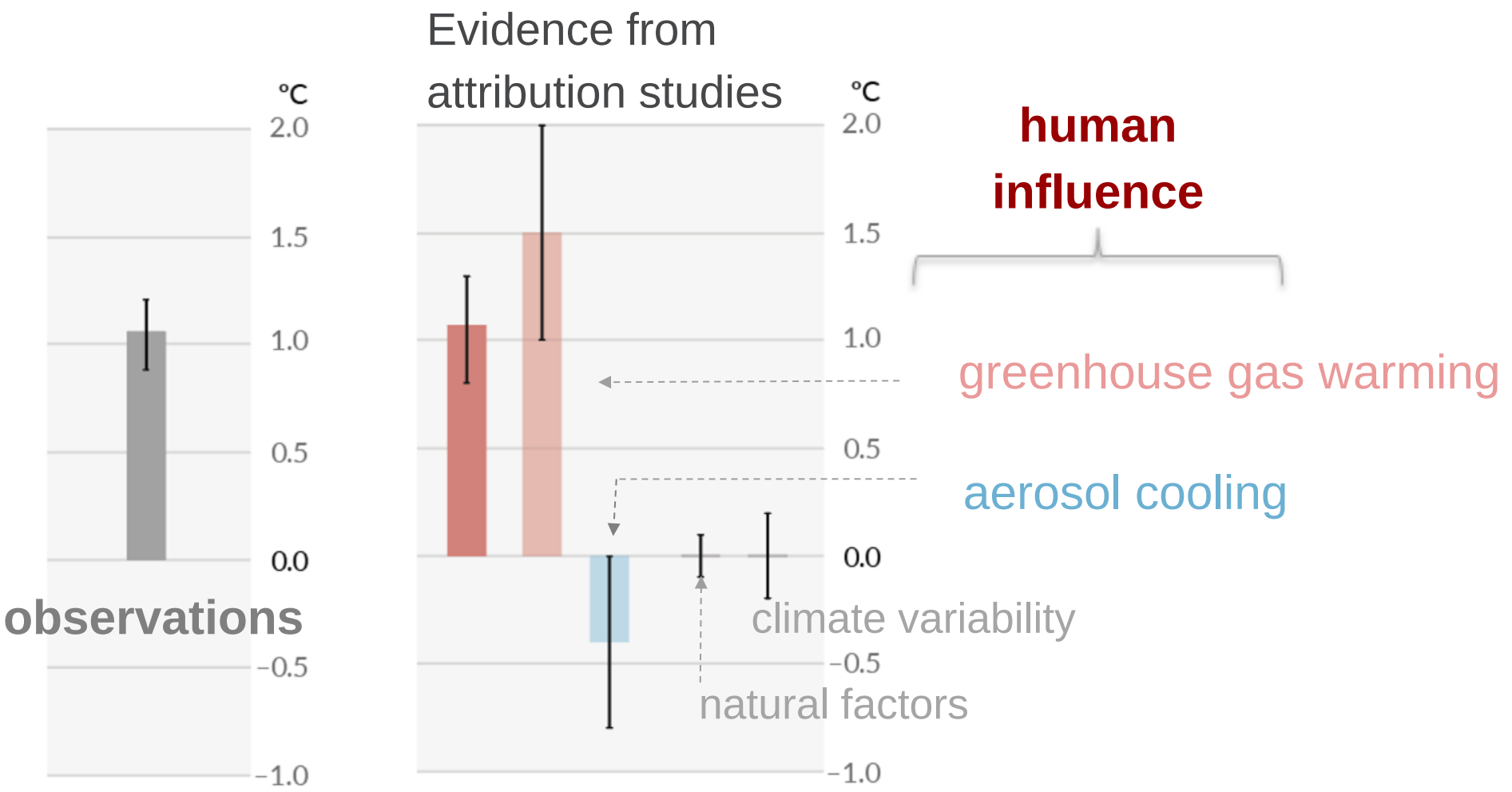
Summary

- **Global warming is already intensifying present-day extreme events** in many regions around the world.
- **Current climate events can be studied** to better understand the role of **human-induced warming**.
- **Model ensembles help evaluate future event evolution** and assess the **suitability of different models** for specific types of extremes.
- **High-resolution climate projections are essential** for accurately analyzing events at **local scales**.
- **Increasing availability of kilometer-scale projections** enables the study of for example **urban climate impacts**, providing valuable insights for **adaptation and mitigation strategies**

Thank you

coppolae@ictp.it

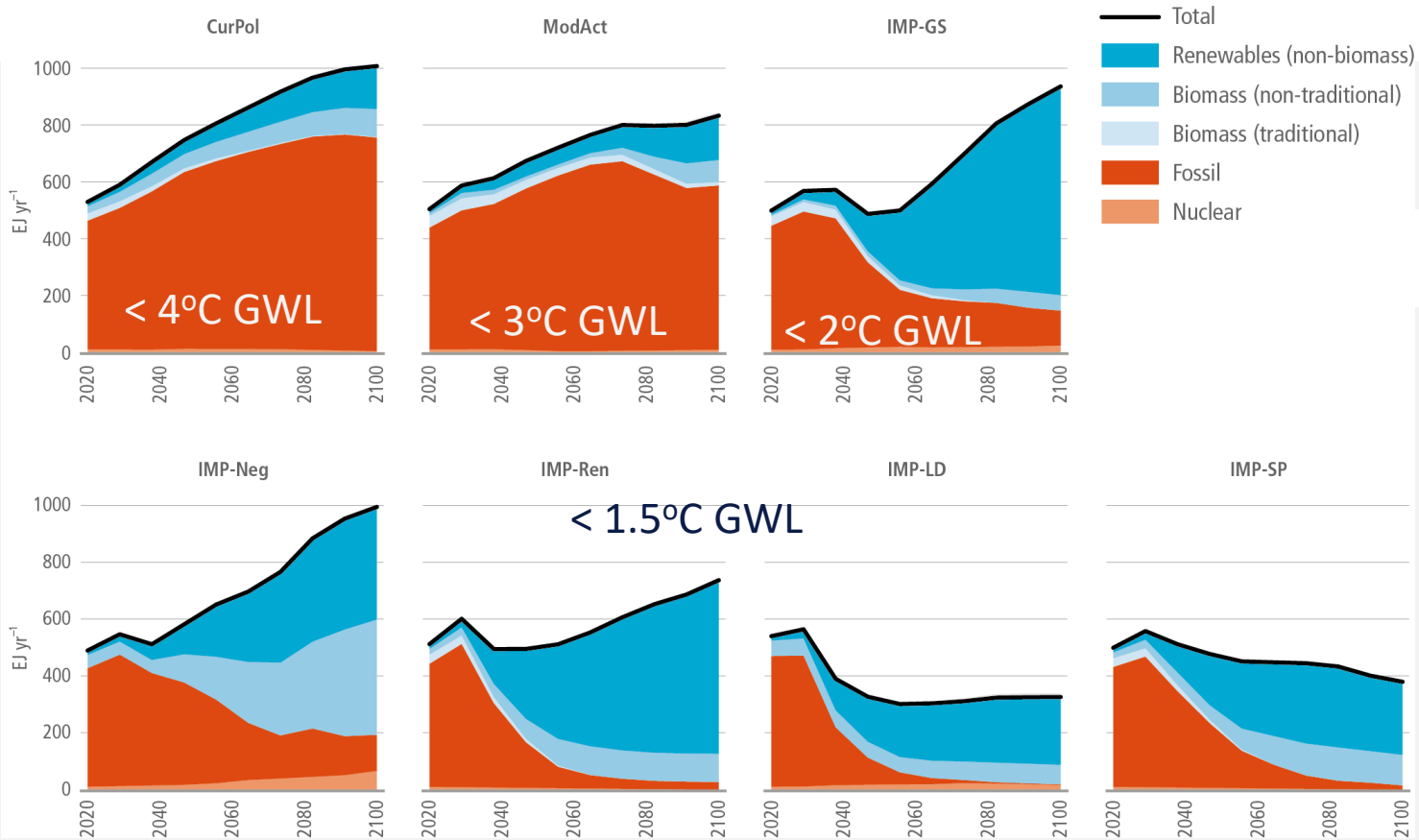
Observed warming is driven by emissions from **human activities**, with **greenhouse gas** warming partly masked by **aerosol cooling**

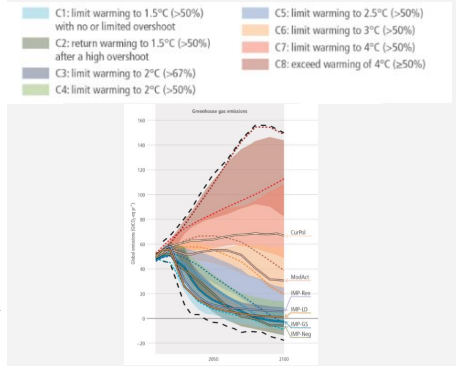


Adapted from Figure SPM.2

Temperature < 2ºC GWL

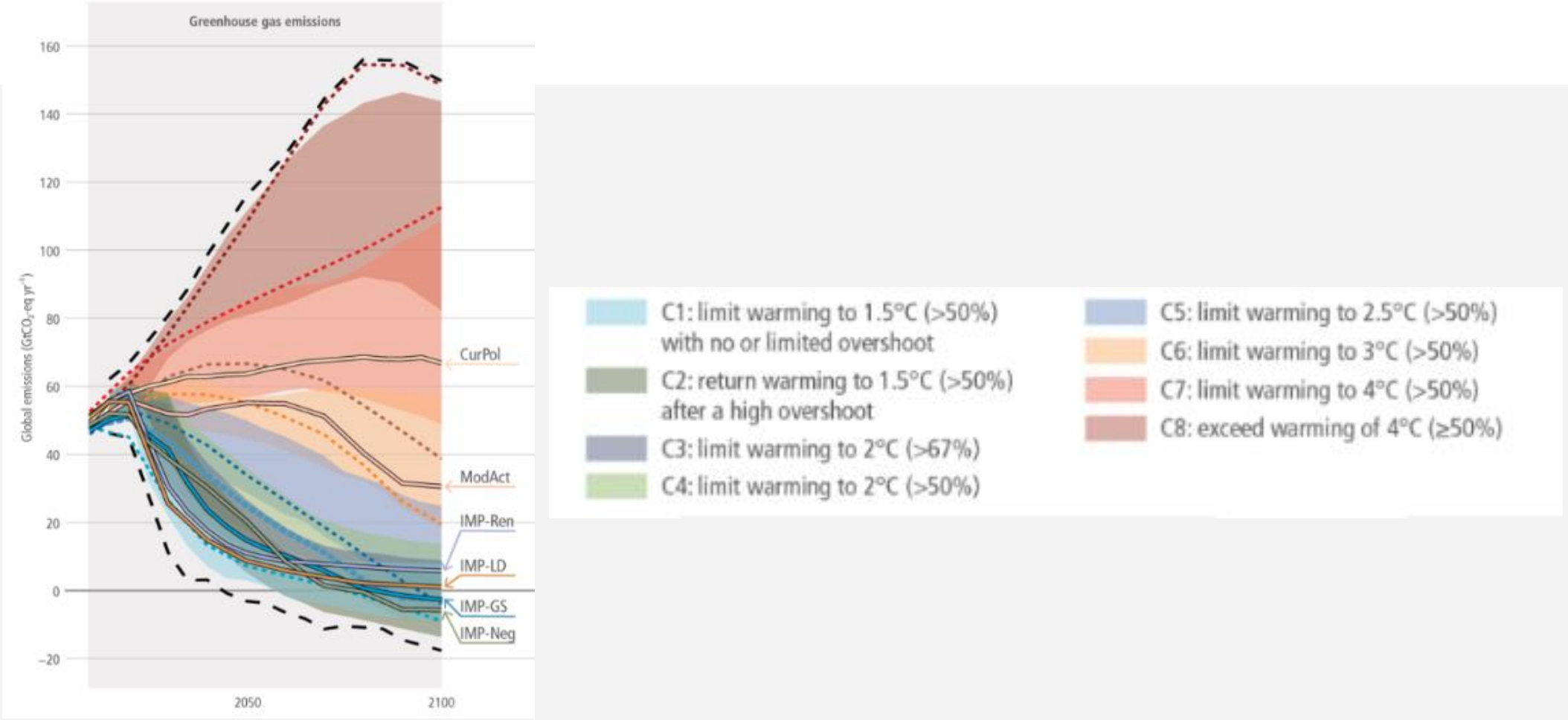
Energy production scenarios





AR6 WGIII Chapter 3 : Figure 3.5 (a) Process for creating the AR6 scenario database and selecting the illustrative (mitigation) pathways.

AR6 WGIII Chapter 3 : Figure 3.8 |The energy system in each of the illustrative pathways (IPs).



AR6 WGIII Chapter 3 : Figure 3.5 (a) Process for creating the AR6 scenario database and selecting the illustrative (mitigation) pathways.