Attribution of the destructive Mediterranean derecho in 2022 to anthropogenic warming

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MOTIVATION

- Climate change is increasingly affecting the intensity of severe weather events in the Mediterranean.

AIM

- Given the severity of the derecho event and the presence of the record-breaking marine heatwave, investigate the possible influence of the anthropogenic warming on the case study.

OUTLINE

- INTRODUCTION
- ATMOSPHERIC PERSPECTIVE
- OCEANIC PERSPECTIVE
- NUMERICAL SIMULATIONS (SENSITIVITY TO SST AND PSEUDO-GLOBAL WARMING)
- CONCLUSIONS

Derecho (AMS definition)

A widespread convectively induced straight-line windstorm.

Specifically, the term is defined as any family of particularly damaging downburst clusters produced by a MCS. Such systems have sustained bow echoes … and can generate considerable damage from straight line winds. Damage must be incurred either continuously or intermittently over a swath of at least 650 km and a width of approximately 100 km or more.

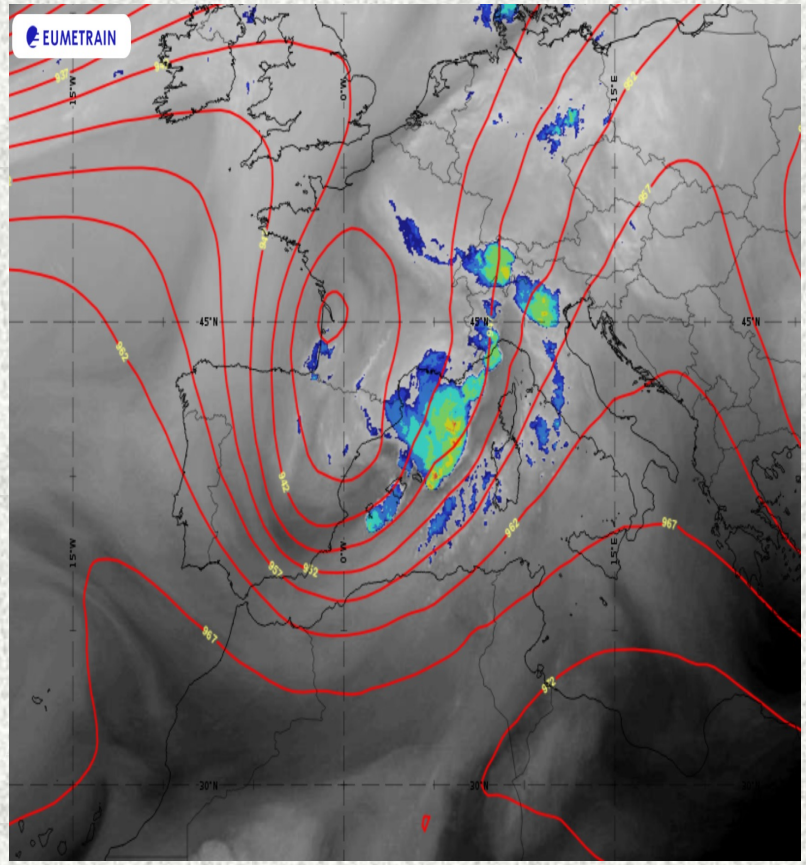
The term derecho derives from a Spanish word that can be interpreted as "straight ahead" or "direct" and was chosen to discriminate between wind damage caused by tornadoes, which have rotating flow, from straight-line winds.

Introduction

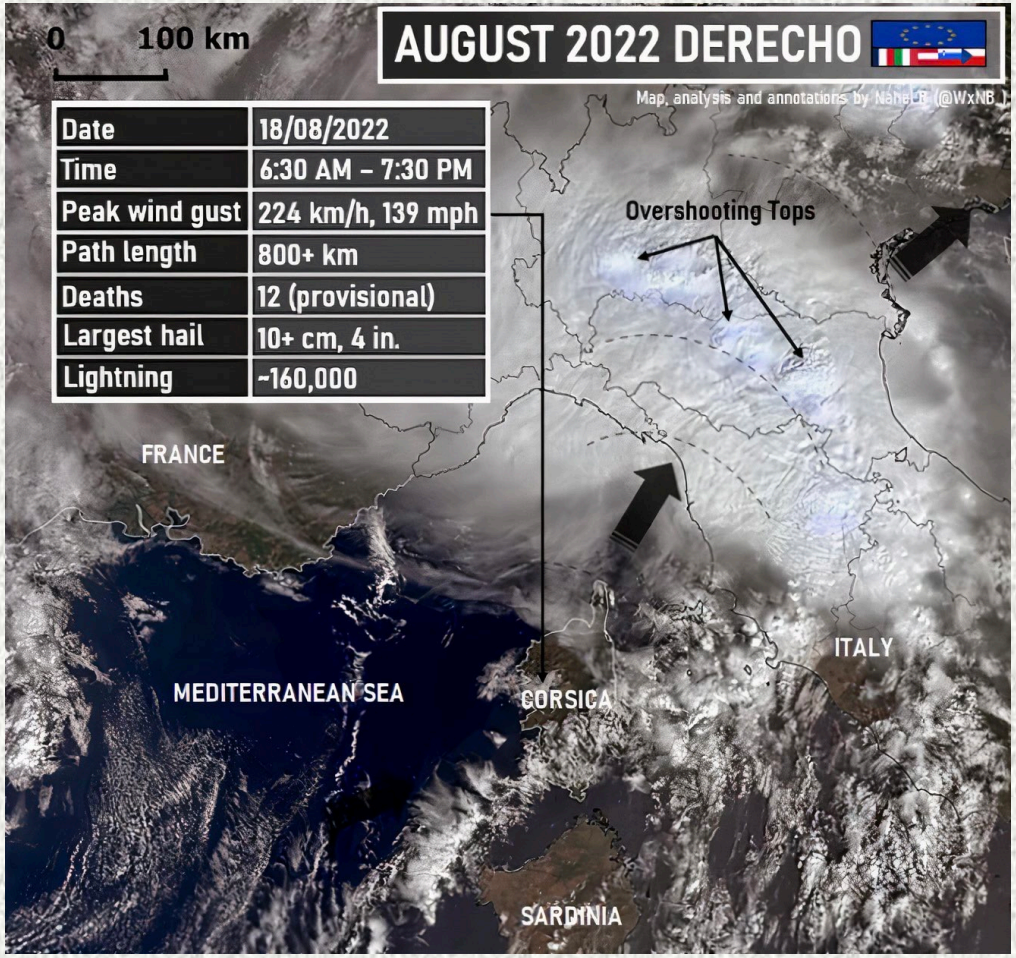
On 17 August 2022, strong instability and strong wind shear developed over the western Mediterranean.

Concurrently, a record-breaking marine heatwave (MHW) was present over the Mediterranean Sea during summer 2022, peaking in July.

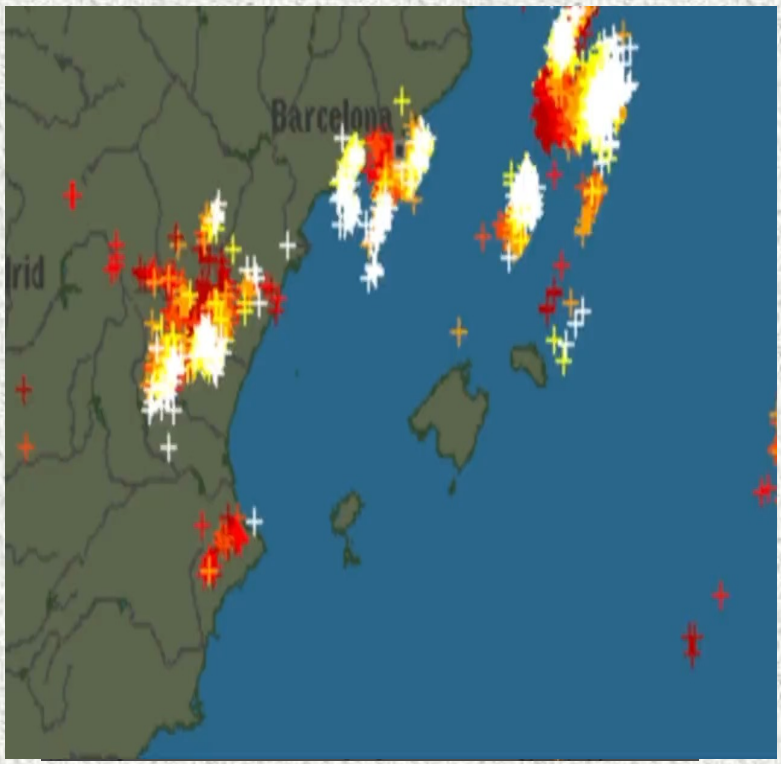
- Long swath of severe winds from the Balearic Islands to southern Czech Republic on August 18, 2022, with maximum wind gusts of 62.2 m/s, measured by Météo France at Marignana, Corsica.
- In total, 12 people died and 106 people were injured.



Introduction



lightning activity



Introduction

Ahead of the eastward moving shortwave trough, convective cells organized into a bow-shaped system

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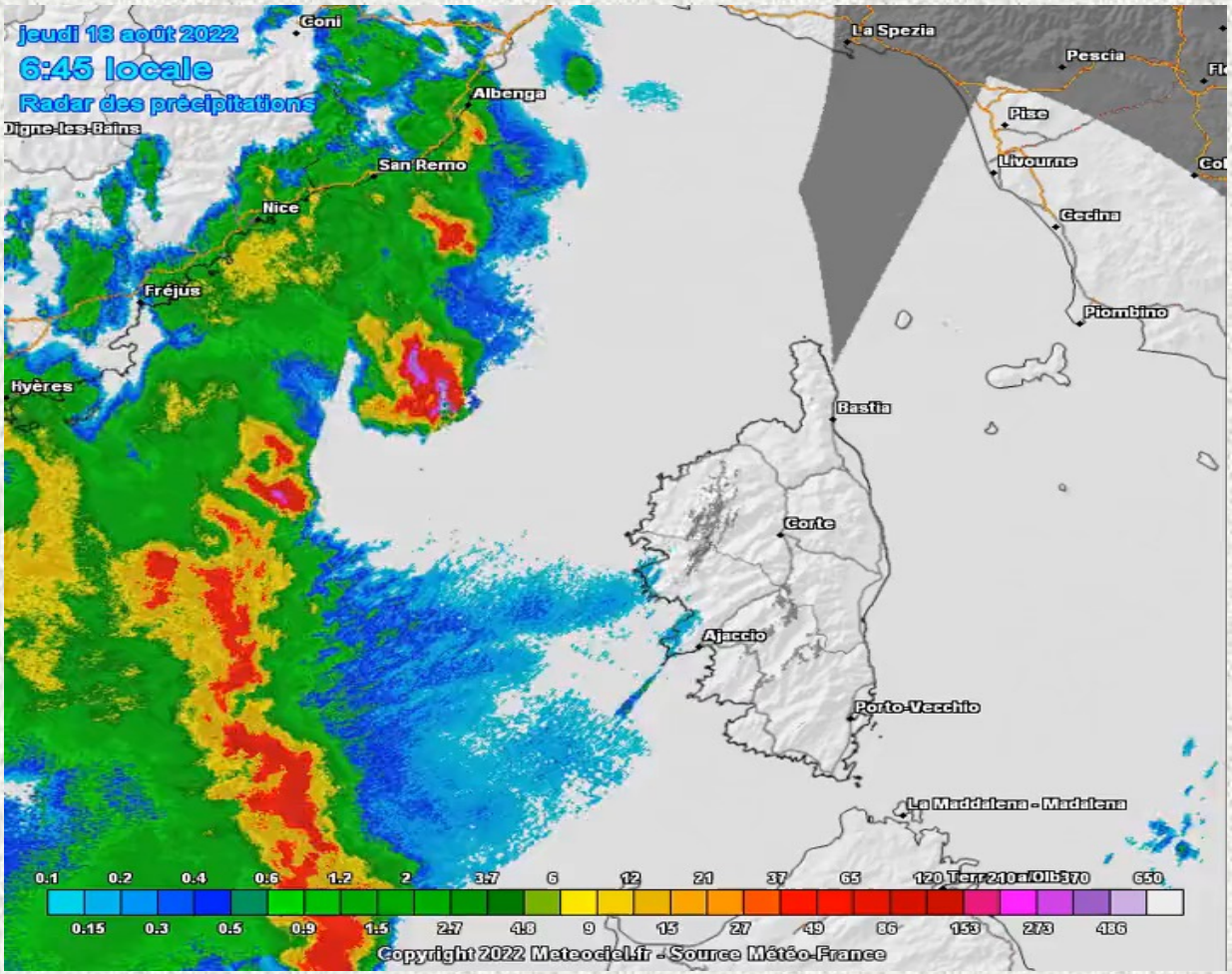
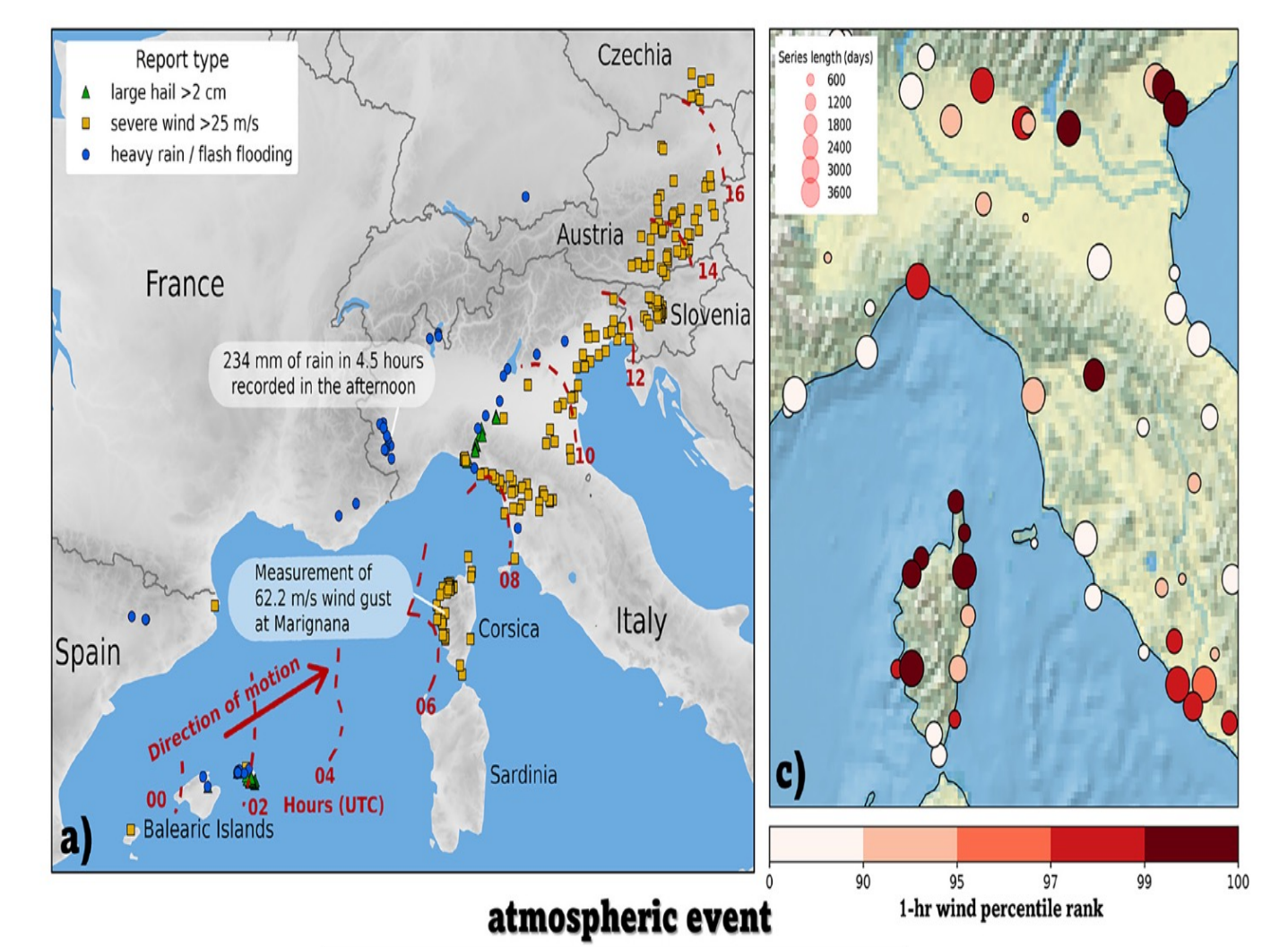


From an atmospheric perspective:



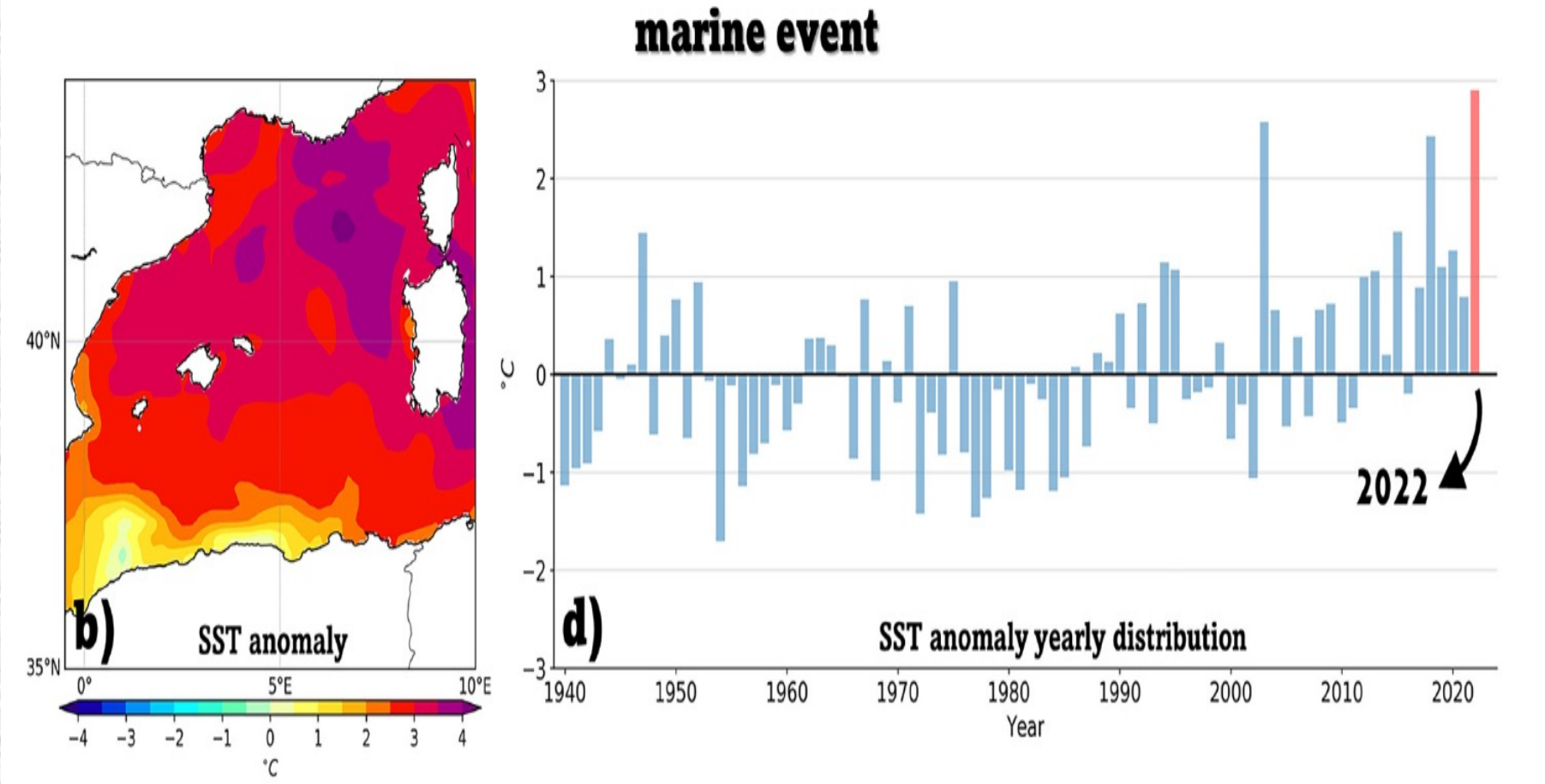
Percentile of daily maximum of mean 1-h wind recorded on 18 Aug with respect to the climatology JJAS (global hourly Integrated Surface Database)

From an atmospheric perspective:

Station	Max Wind Gust (ms^{-1})	Monthly Record (ms^{-1})	Annual Record (ms^{-1})
Marignana [Ma]	62.4	27.3	49.0
Calvi [Ca]	54.7	28.0	44.0
Bocognano [Bo]	52.2	31.5	42.8
Ile Rousse [Ir]	51.3	39.0	59.0
Ajaccio-La Parata [Aj]	44.0	36.8	46.1
Renno [Re]	37.5	26.0	40.2
Pietralba [Pi]	35.9	30.0	36.0
Sampolo [Sa]	34.3	34.2	47.0
Oletta [Ol]	34.3	25.0	38.4
Corte [Co]	23.4	21.9	40.5
Cap Corse [Cs]	49.4	-	-
Cap Sagro [Cs]	48.3	-	-
Santo Pietro Di Tenda [Sa]	27.5	-	-
Bastia [Ba]	34.2	35.0	51.4
Calacuccia [Cl]	46.4	-	-
Sponde-Nivose [Sn]	41.7	-	-
Maniccia-Nivose [Mn]	27.2	-	-
Alistro [Al]	31.1	-	-
Ajaccio-Campo dell'Oro [Ac]	36.4	36.7	36.7
Sari d'Orcino [Sd]	30.8	-	-
Solenzara [So]	25.8	28.9	48.1

From an oceanic perspective:

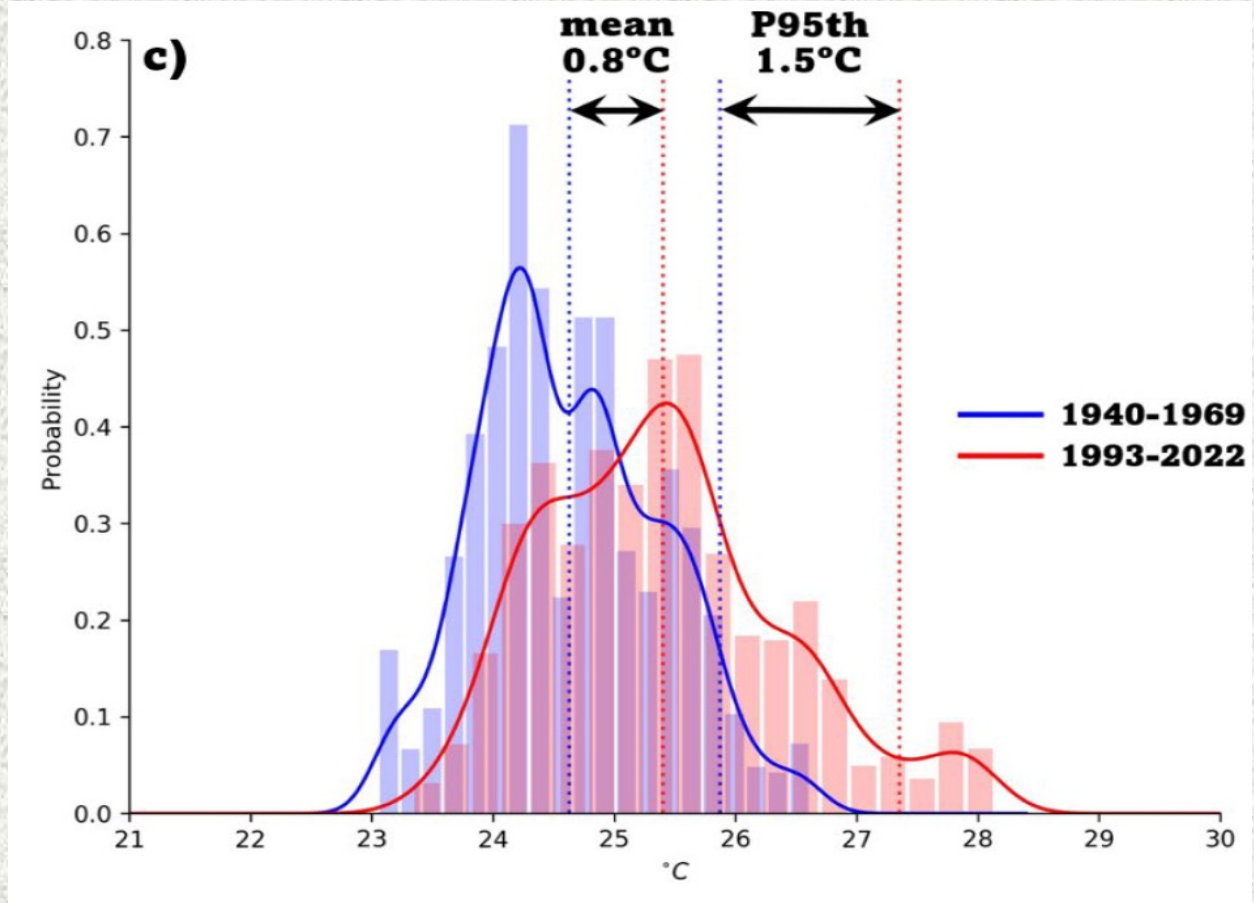
Record-breaking marine heatwave



ERA5 Western Mediterranean b) SST anomalies (exceeding $3°C$) and d) time series of SST anomalies with respect to the period 1940–2022 averaged over 1–17 Aug (i.e., before the event)

From an oceanic perspective:

SST probability distribution in August



Methods

Sensitivity test by perturbing SSTs with the operational Meteo-France AROME model [~1.3 km; **3DVAR** to reduce spinup].

Pseudo-global warming simulations (storyline attribution) with MPAS model [3 km to 60 km; i.c. 00 UTC, 17 Aug]: All the **initial** thermodynamic variables as well as GHG were perturbed to reflect preindustrial and future conditions in mid-August.

Factual (observed): GFS analysis --> MPAS

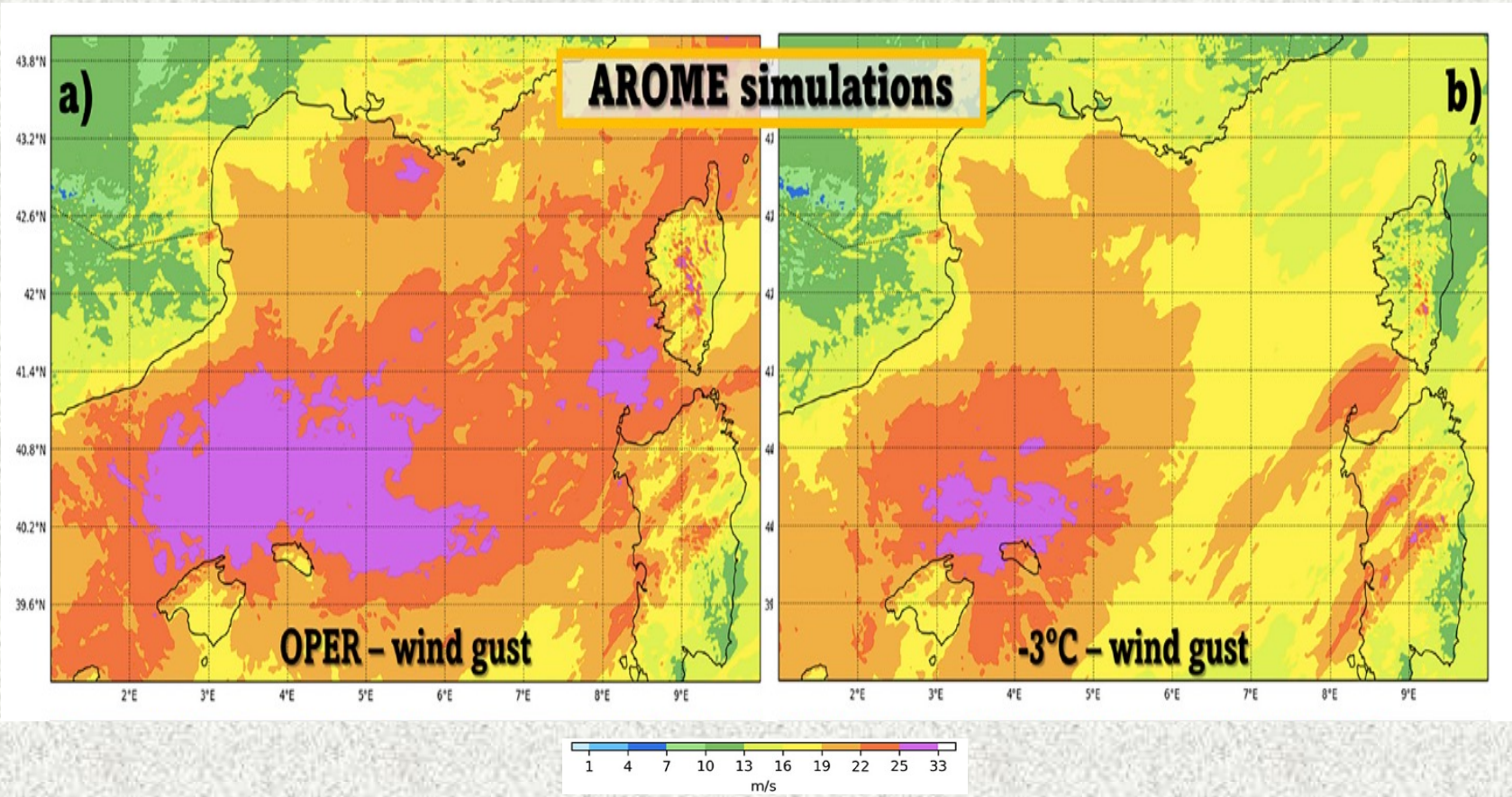
Counterfactual past (preindustrial): GFS – [anthropogenic forcing from CMIP6 models] --> MPAS

Counterfactual future (SPS5-8.5): GFS + [anthropogenic forcing from CMIP6 models] --> MPAS

Results

AROME simulations with SST perturbations.

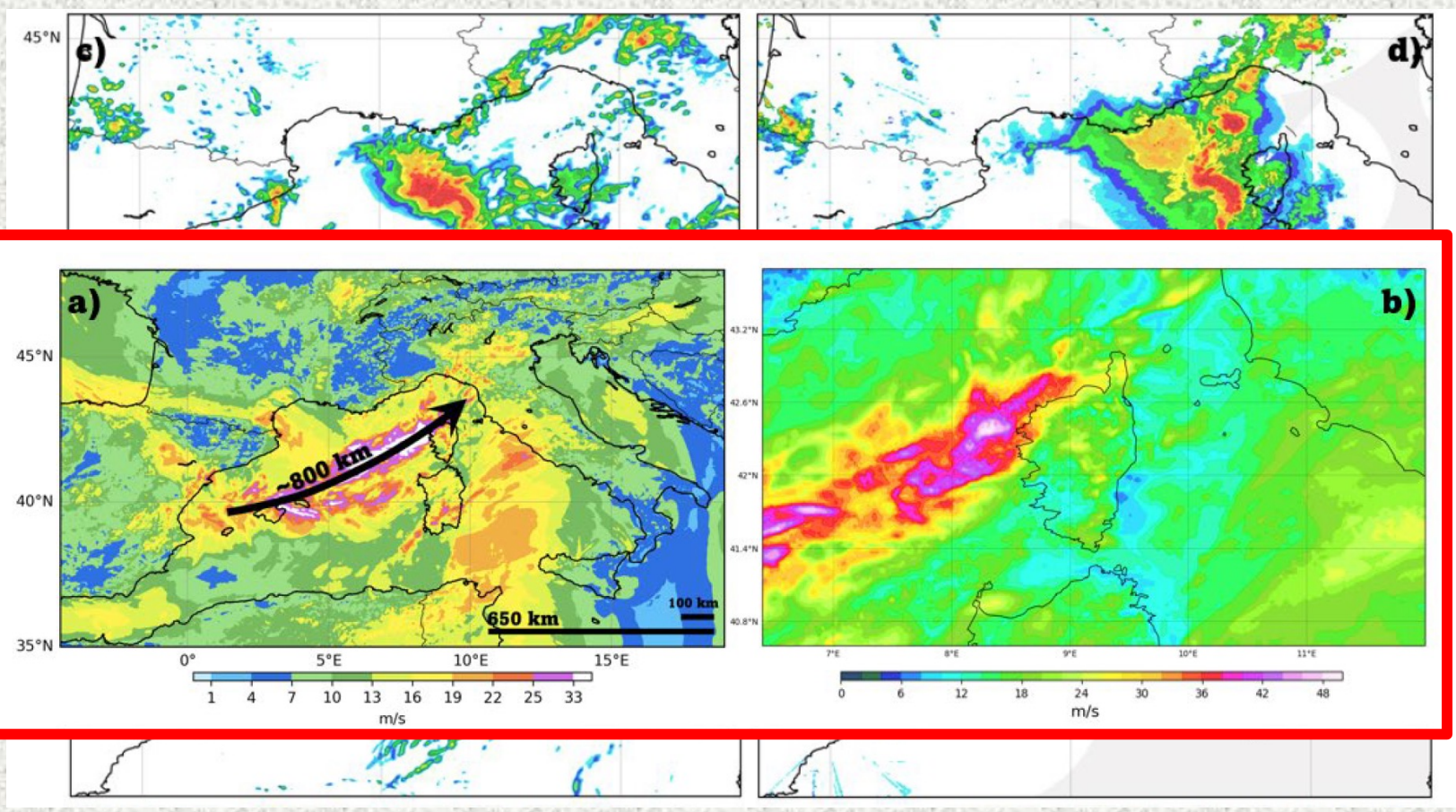
Lagged ensemble (all initializations; 1708 00Z – 1708 21Z; every 3 hours) mean



Results

MPAS pseudo-global simulations

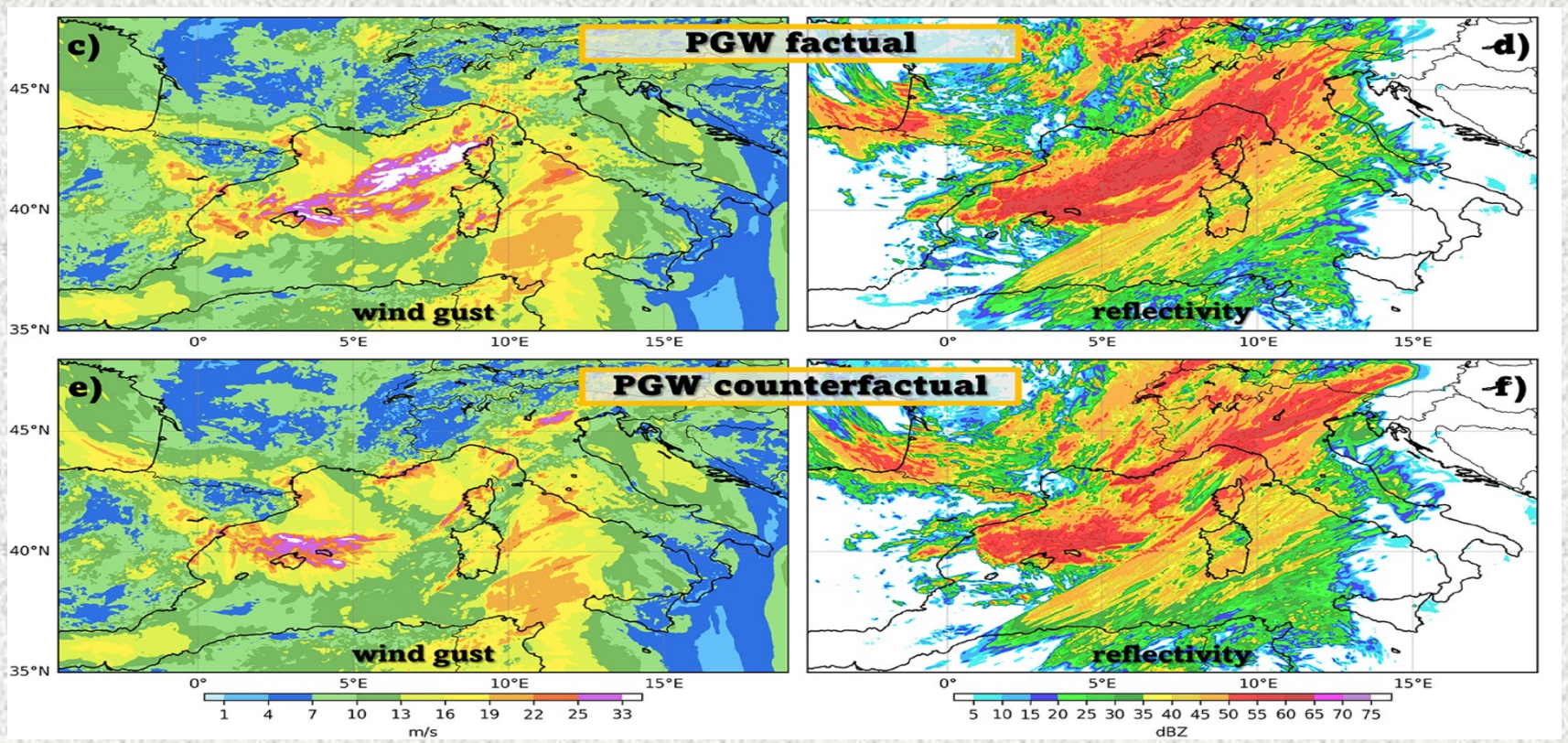
MPAS factual reflectivity **Observed radar reflectivity**



Results

MPAS pseudo-global simulations (perturbed with the EC-Earth3 CMIP6 model)

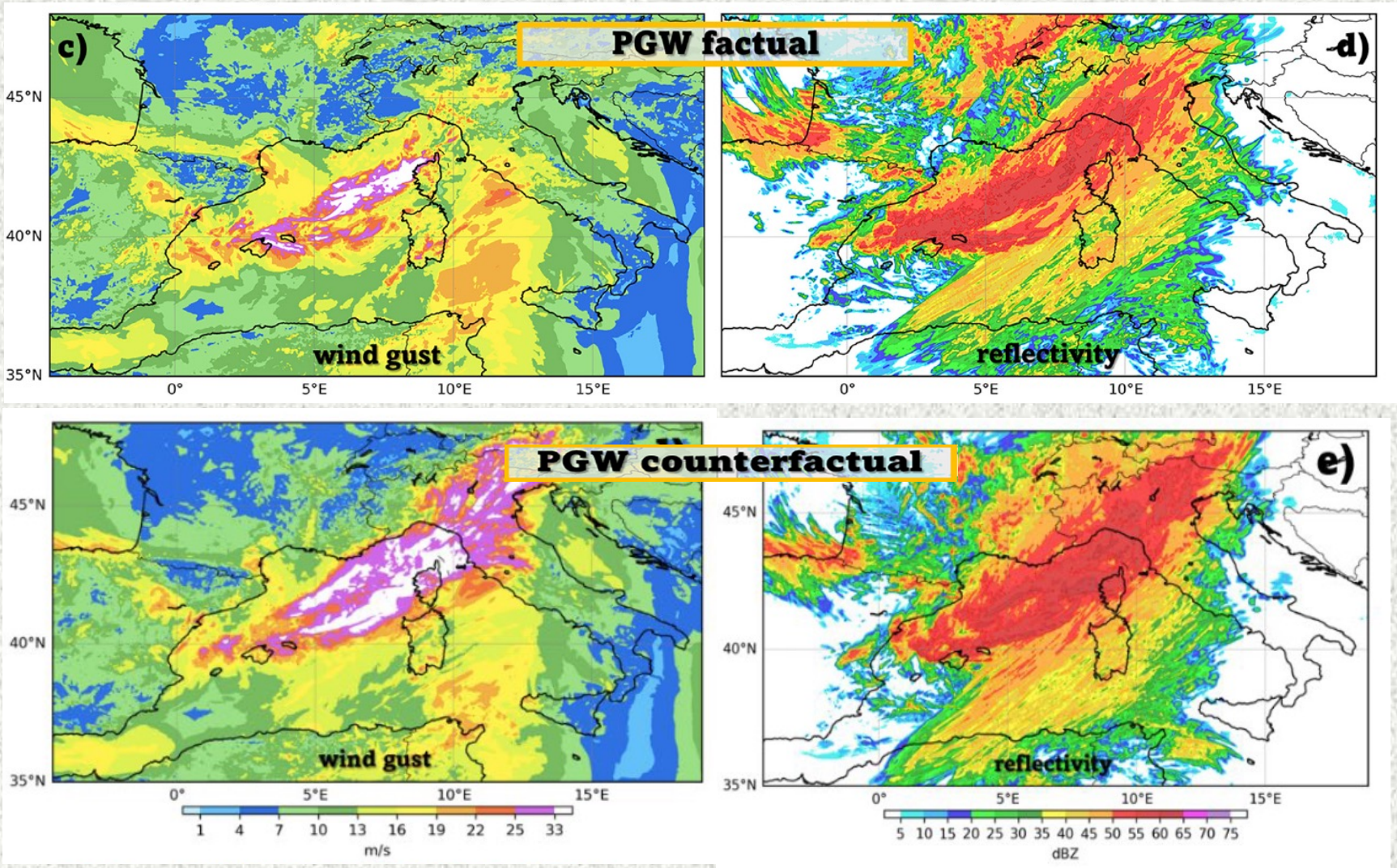
Past evolution



Results

MPAS pseudo-global simulations (perturbed with the EC-Earth3 CMIP6 model)

Future evolution (SSP5-8.5)



Results

MPAS pseudo-global simulations

CMIP6 Model	Past (piControl)		Future (SSP5-8.5)	
	Δ(SST)°C	Δ(area>33ms^{-1})%	Δ(SST)°C	Δ(area>33ms^{-1})%
CESM2-WACCM	-1.44	-58.4	3.64	+94.0
EC-Earth3	-1.88	-93.1	4.39	+300.9
MPI-ESM1-2-HR	-1.23	-62.2	2.84	+225.9
MRI-ESM2-0	-1.19	-98.4	2.88	+105.3
NorESM2-MM	-1.34	-98.8	3.68	+192.8
Mean	-1.42	-82.2	3.49	+183.8

Table 1. More information on the pseudo-global warming simulations performed, extended to all the CMIP6 models used in this study. The first column indicates the changes in SST between the factual and counterfactual [past (piControl)] runs over the same region as in Fig. 1b. The second column indicates the same as the first column but for changes in the area with wind speed above 33 m s^{-1}. The third and fourth columns indicate the same as the first and second columns, but for future (SSP5–8.5) runs. The last row indicates the mean for all the simulations.

Conclusions

- The severe convective windstorm developed over the western Mediterranean Sea in August 2022 was substantially amplified by the extreme marine heatwave.
- Pseudo-global warming simulations showed that current anthropogenic climate change forcing contributed to the triggering of the derecho by making environmental factors more favorable for convective amplification:
- in the past climate, only ordinary convective cells would have formed, without the development of any derecho;
- continued warming may even lead to larger and stronger derechos in the future.

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Anthropogenic Warming Had a Crucial Role in Triggering the Historic and Destructive Mediterranean Derecho in Summer 2022

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A record-breaking marine heatwave and anthropogenic climate change have substantially contributed to the development of an extremely anomalous and vigorous convective windstorm in August 2022 over the Mediterranean Sea.

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On 17 August 2022, very high atmospheric instability and strong wind shear developed over the western Mediterranean. Ahead of an eastward moving shortwave trough, convective cells organized into a bow-shaped system, producing a long swath of severe winds from the Balearic Islands to southern Czech Republic on August 18 (Fig. 1a), with maximum wind gust of 62.2 m s^{-1}, measured by Météo France at Marignana, Corsica. In total, 12 people died and 106 people were injured. This system can easily be classified as a derecho (ESSL 2022), a particularly long-lived and severe convective windstorm (Johns and Hirt, 1987; Corfidi et al, 2016). Concurrent with the derecho, a record-breaking marine heatwave (MHW) was present over the Mediterranean Sea during summer 2022, peaking in July. The sea surface temperature (SST) anomalies exceeded 3°C (see Fig. 1b) over the region where the storm developed.

Derechos have been reported in different parts of Europe (e.g., Gatzen 2004; Punkka et al. 2006; Gatzen

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