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 (~400 mi) and a width of approximately 100 km (~60 mi) 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.

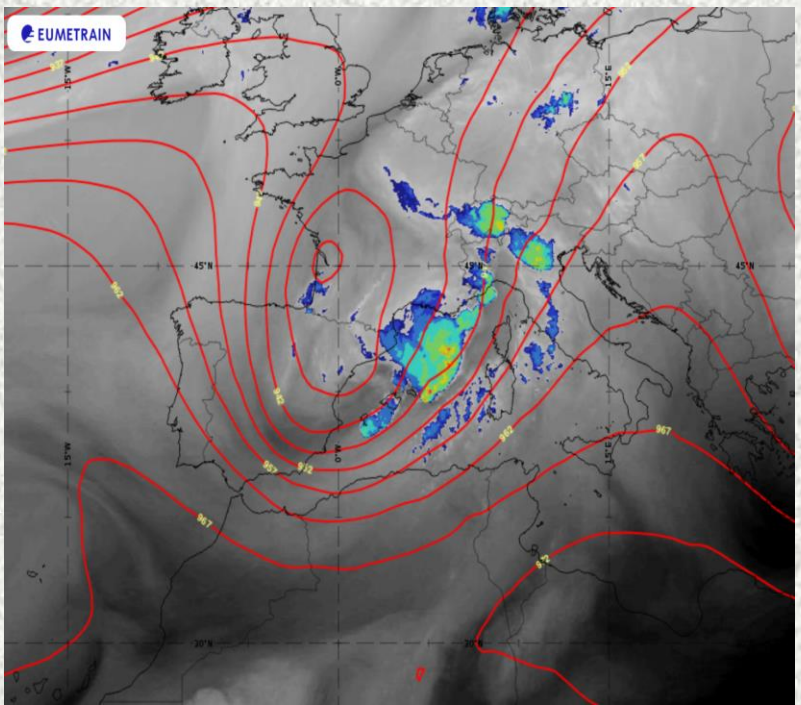
Introduction

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

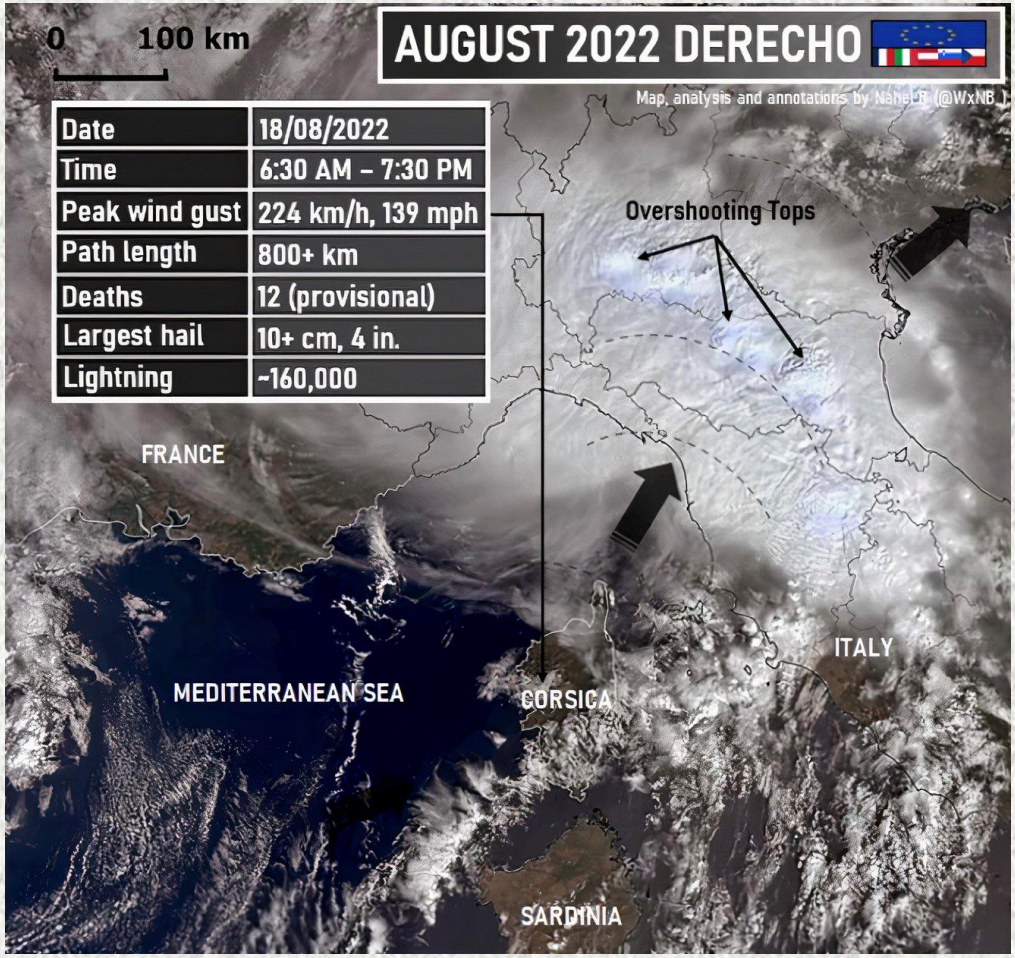
Concurrently, a record-breaking marine heatwave (MHW) was present over the Mediterranean Sea during summer 2022, peaking in July. The SST anomalies exceeded $3°C$ above the region where the storm developed.

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

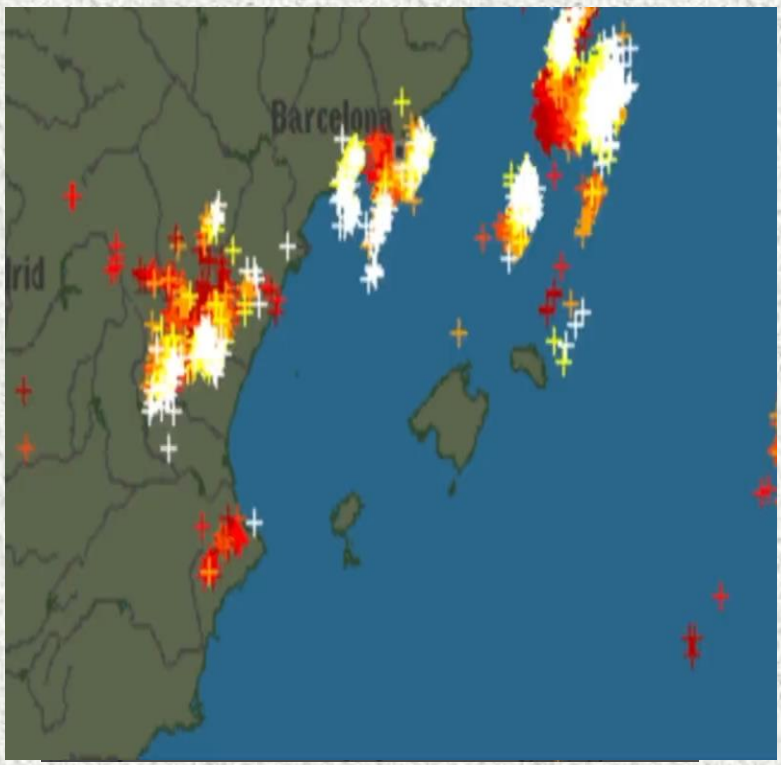
- Long swath of severe winds from the Balearic Islands to southern Czech Republic on August 18, 2022, with maximum wind gusts of 62.2 m/s, measured by Météo France at Marignana, Corsica.
- In total, 12 people died and 106 people were injured.



Introduction

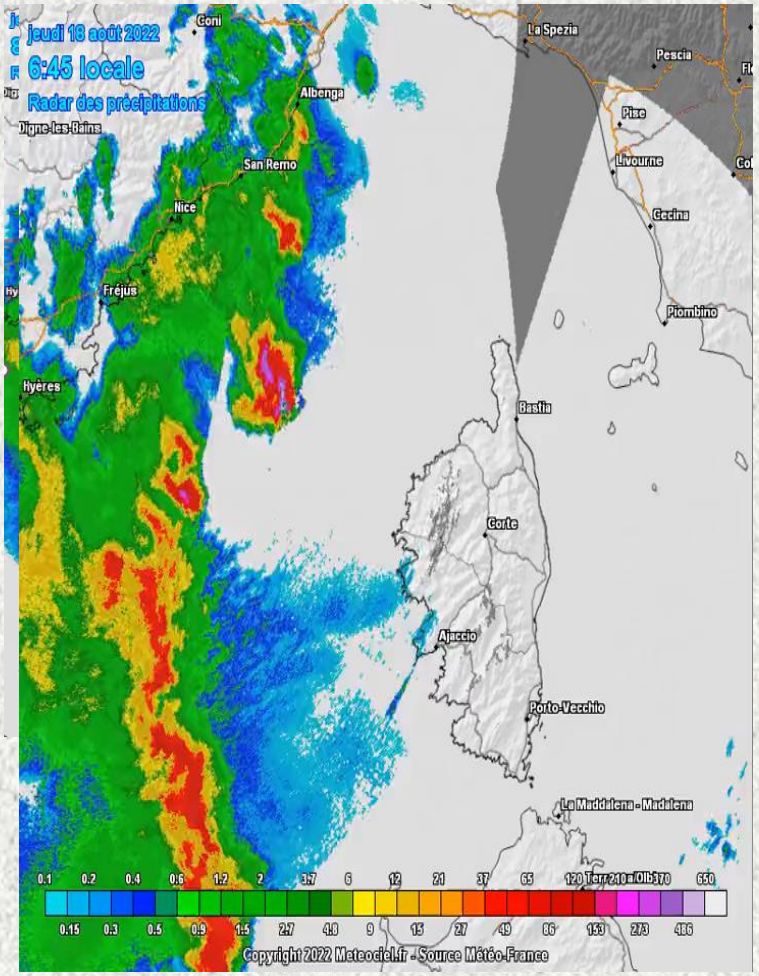


lightning activity

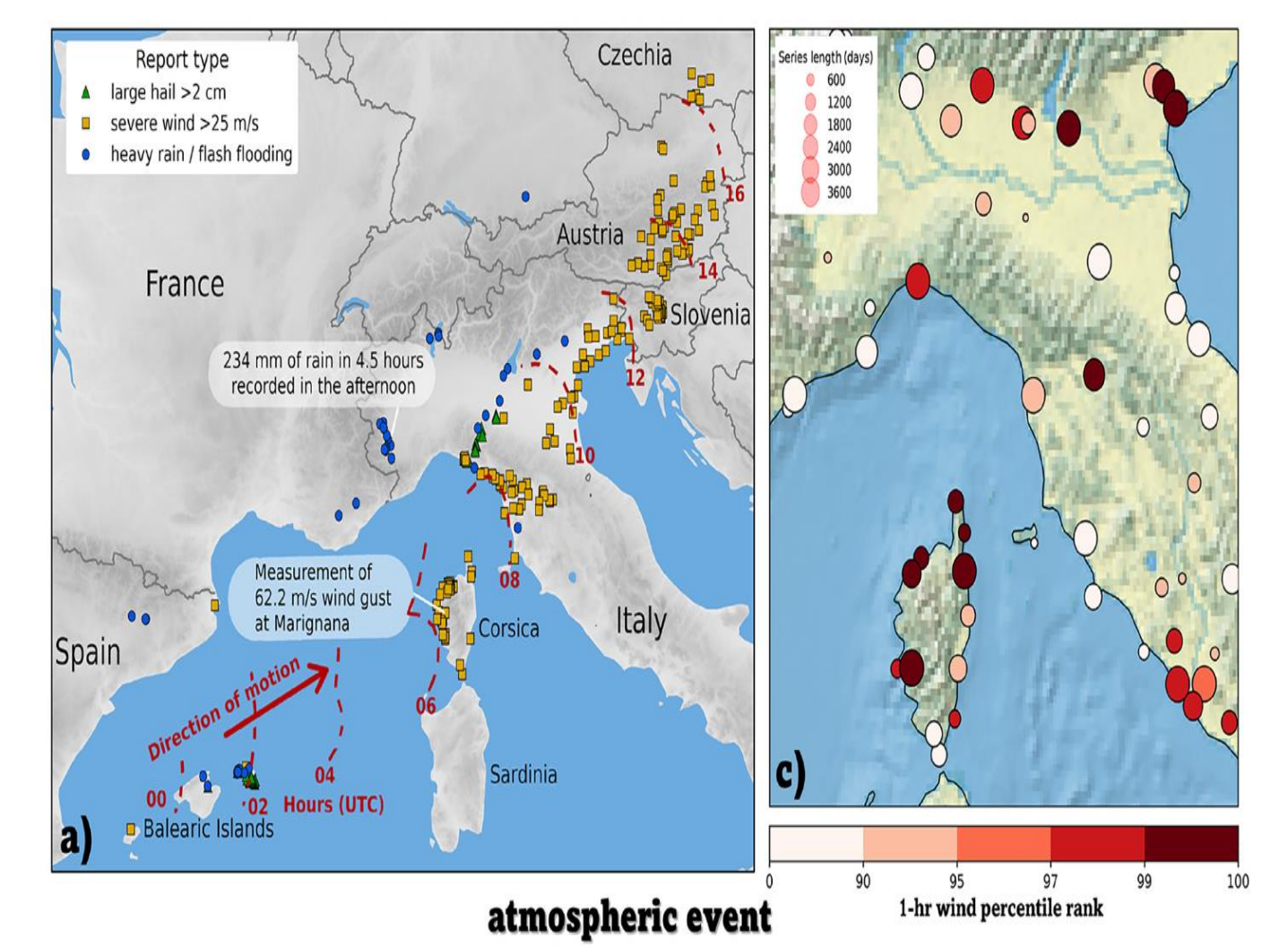


Introduction

Bow echo:



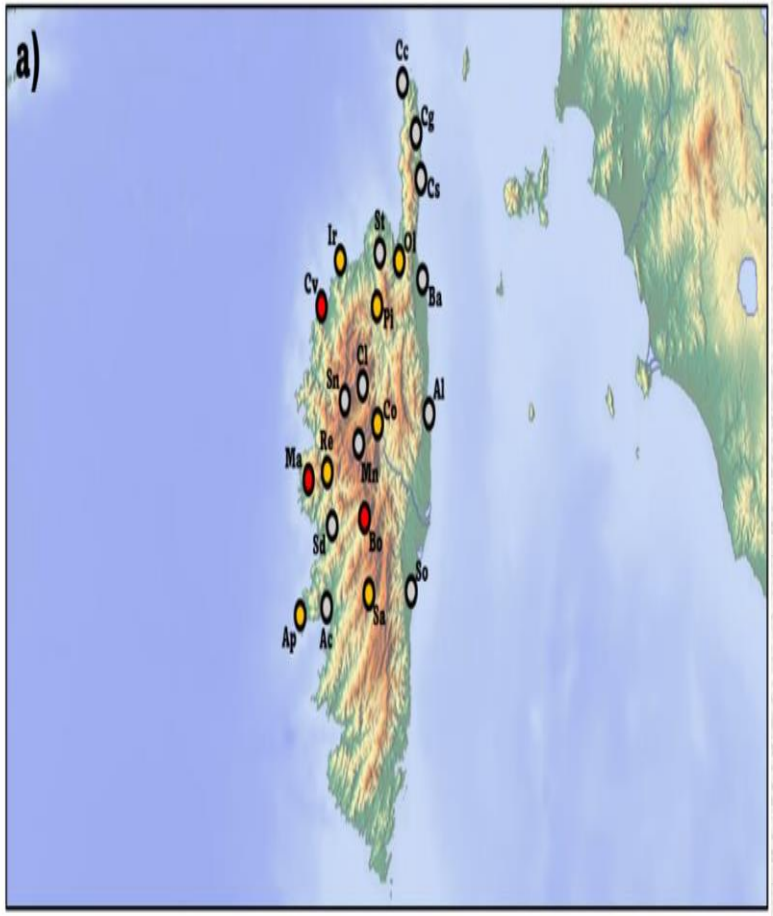
From an atmospheric perspective:



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

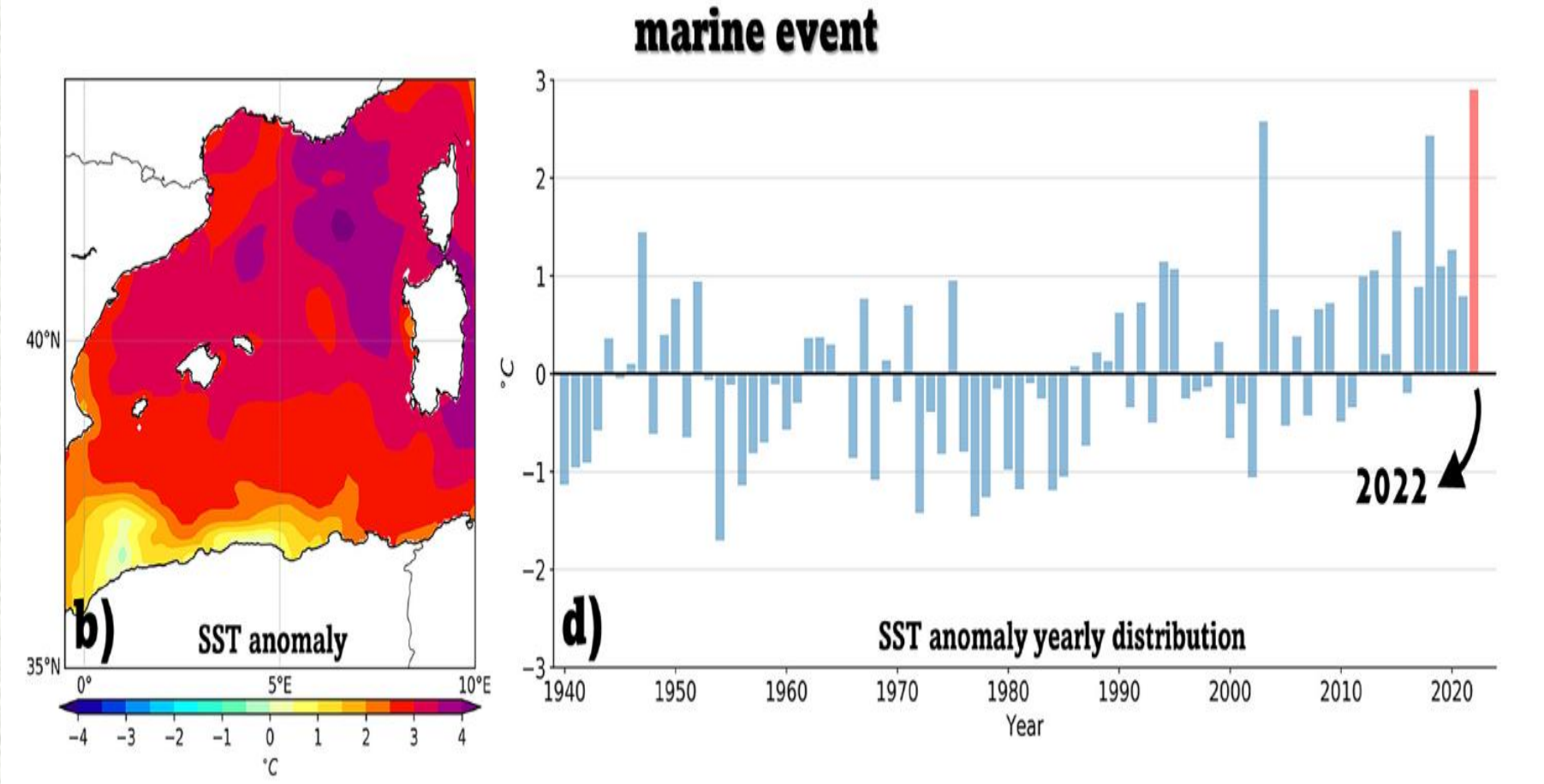
From an atmospheric perspective:

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:

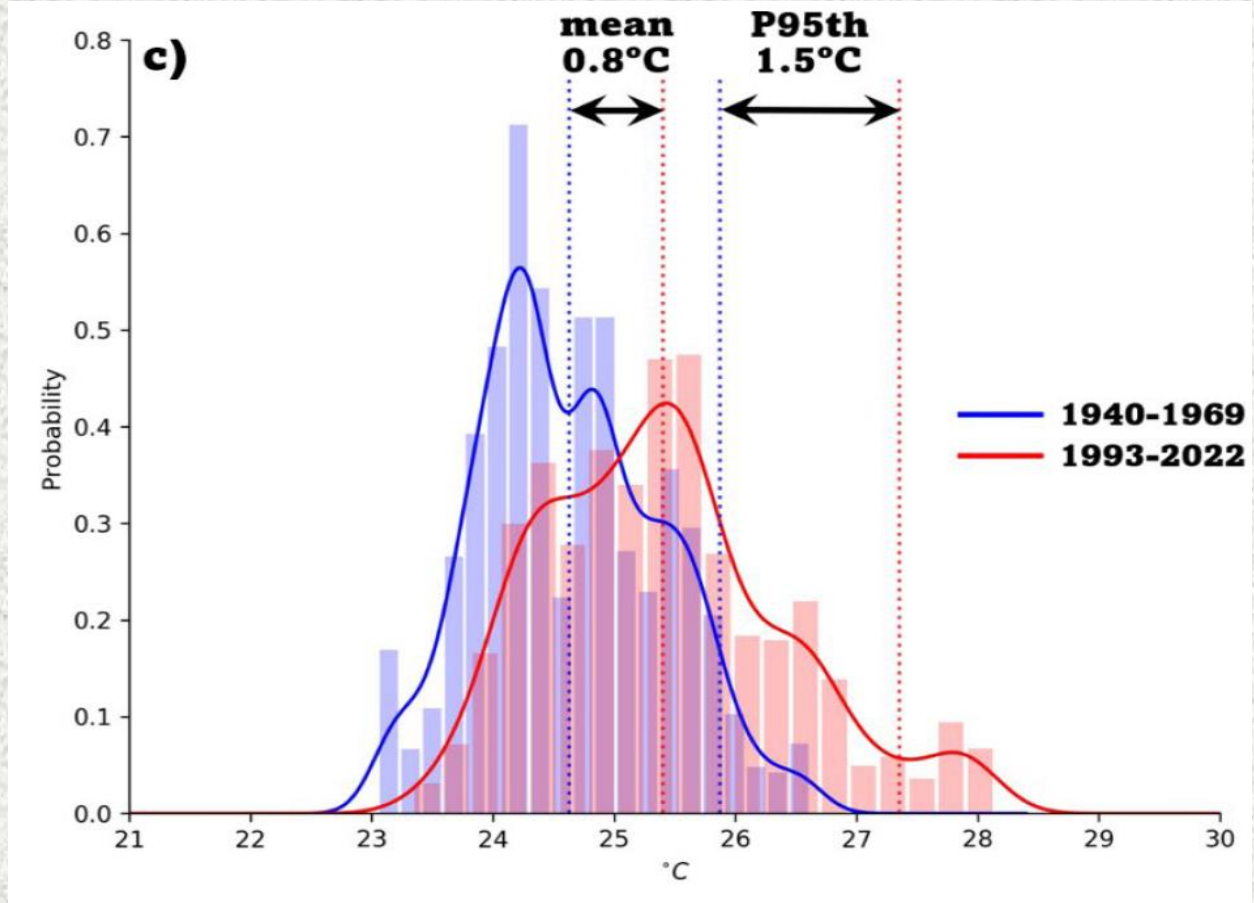
Record-breaking marine heatwave



ERA5 Western Mediterranean b) SST anomalies 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 frequency distribution



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

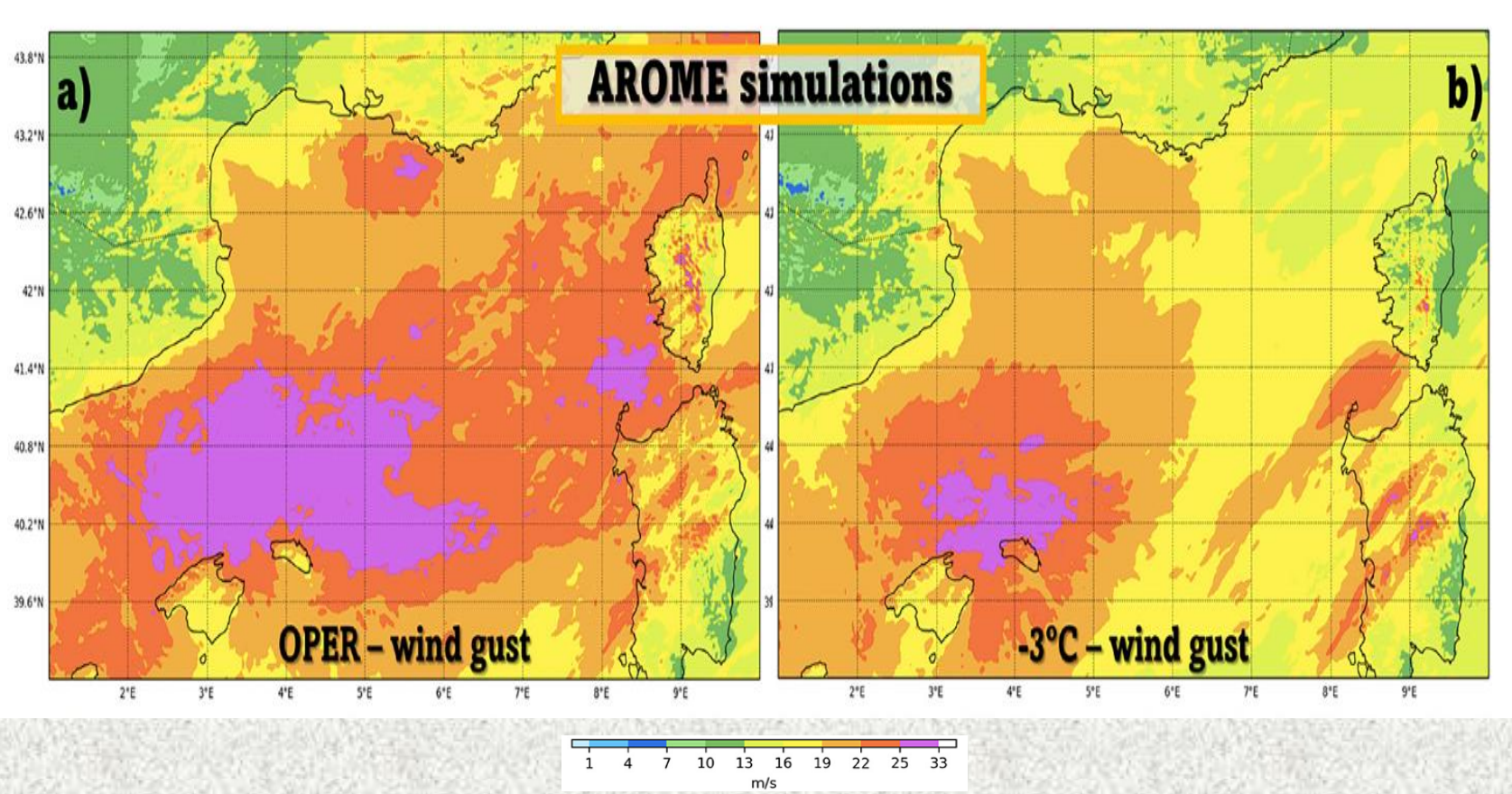
Counterfactual past (preindustrial): GFS – [anthropogenic forcing from CMIP6 models] --> MPAS

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

Results

AROME simulations with SST perturbations.

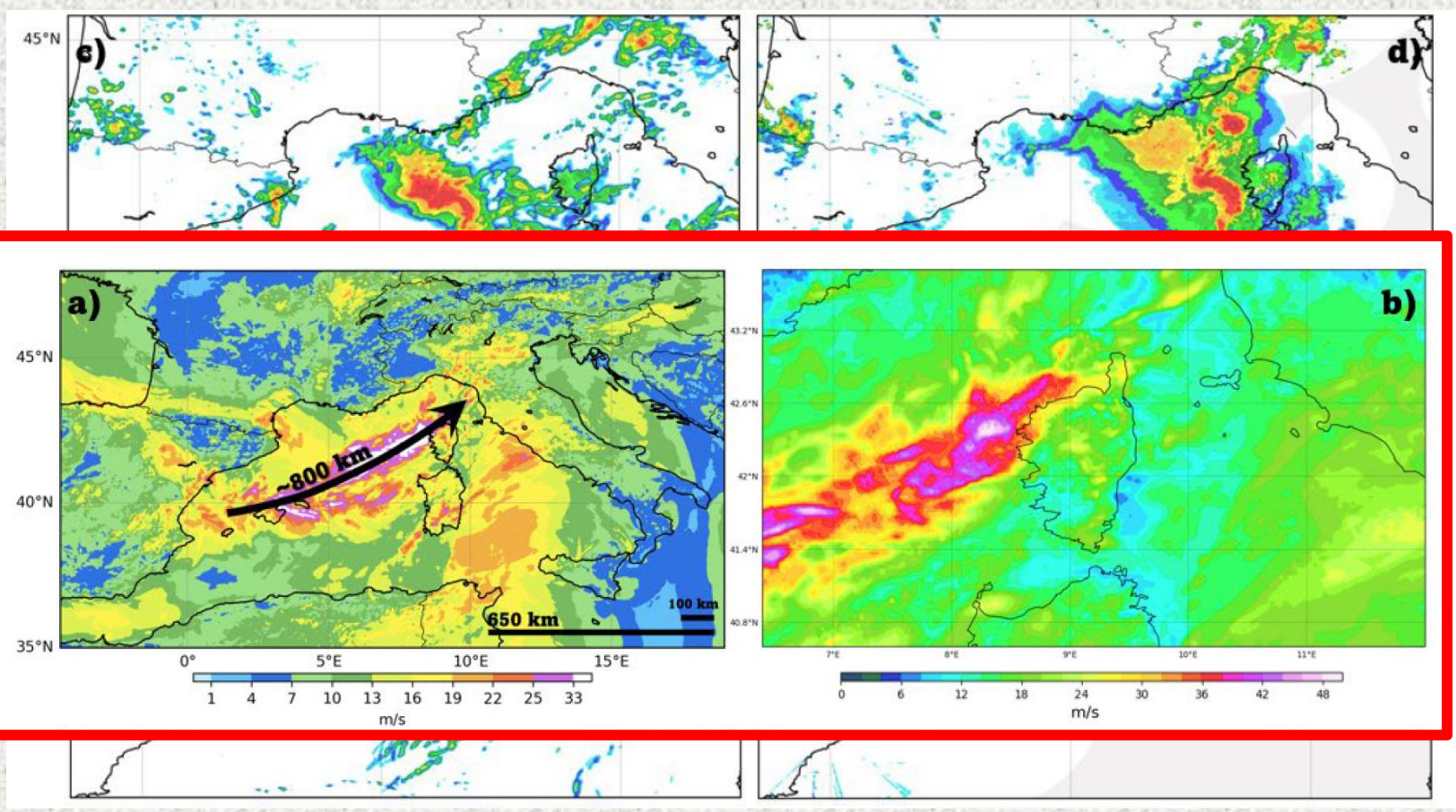
Lagged ensemble (all initializations; 1700 00Z – 1708 21Z; every 3 hours) mean



Results

MPAS pseudo-global simulations

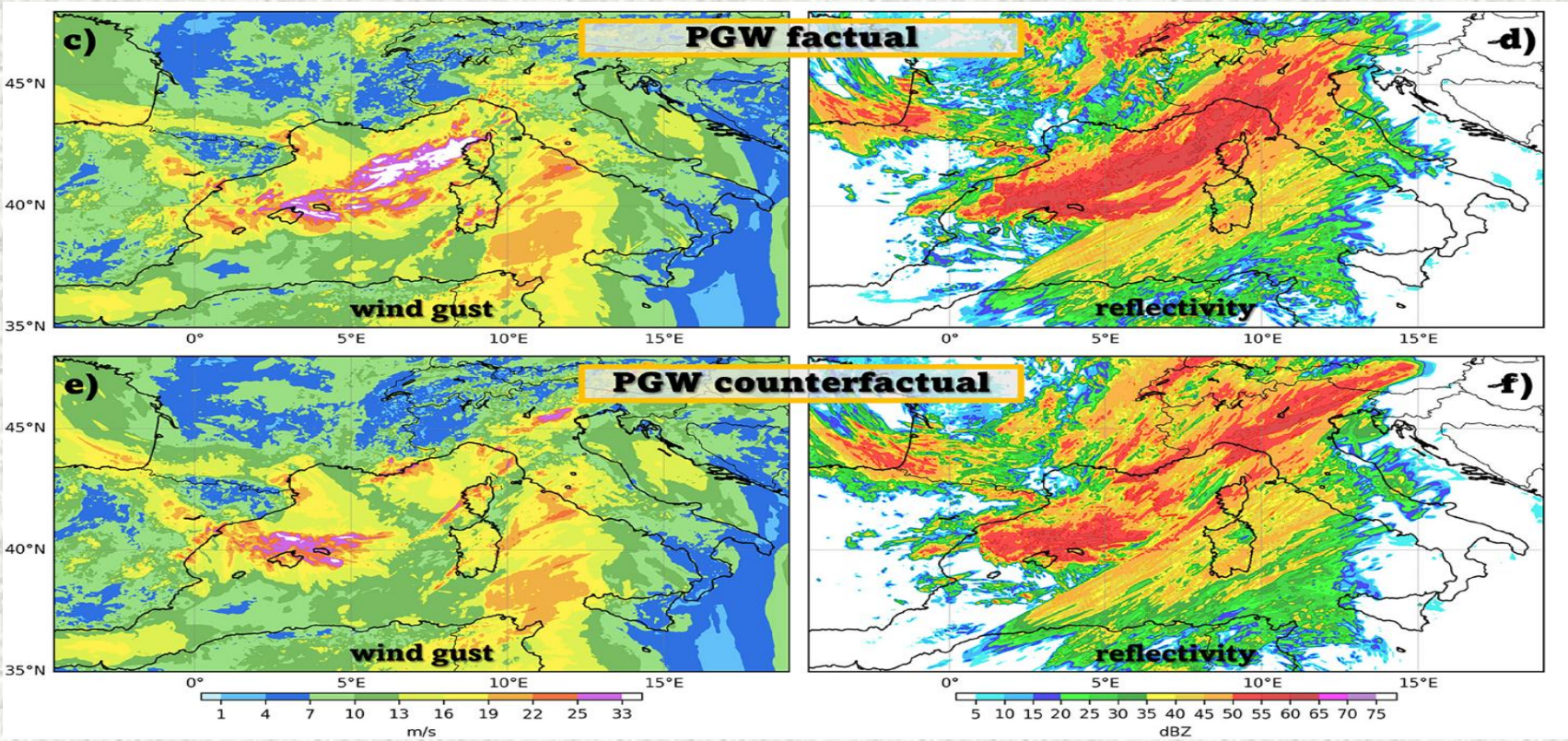
MPAS factual reflectivity **Observed radar reflectivity**



Results

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

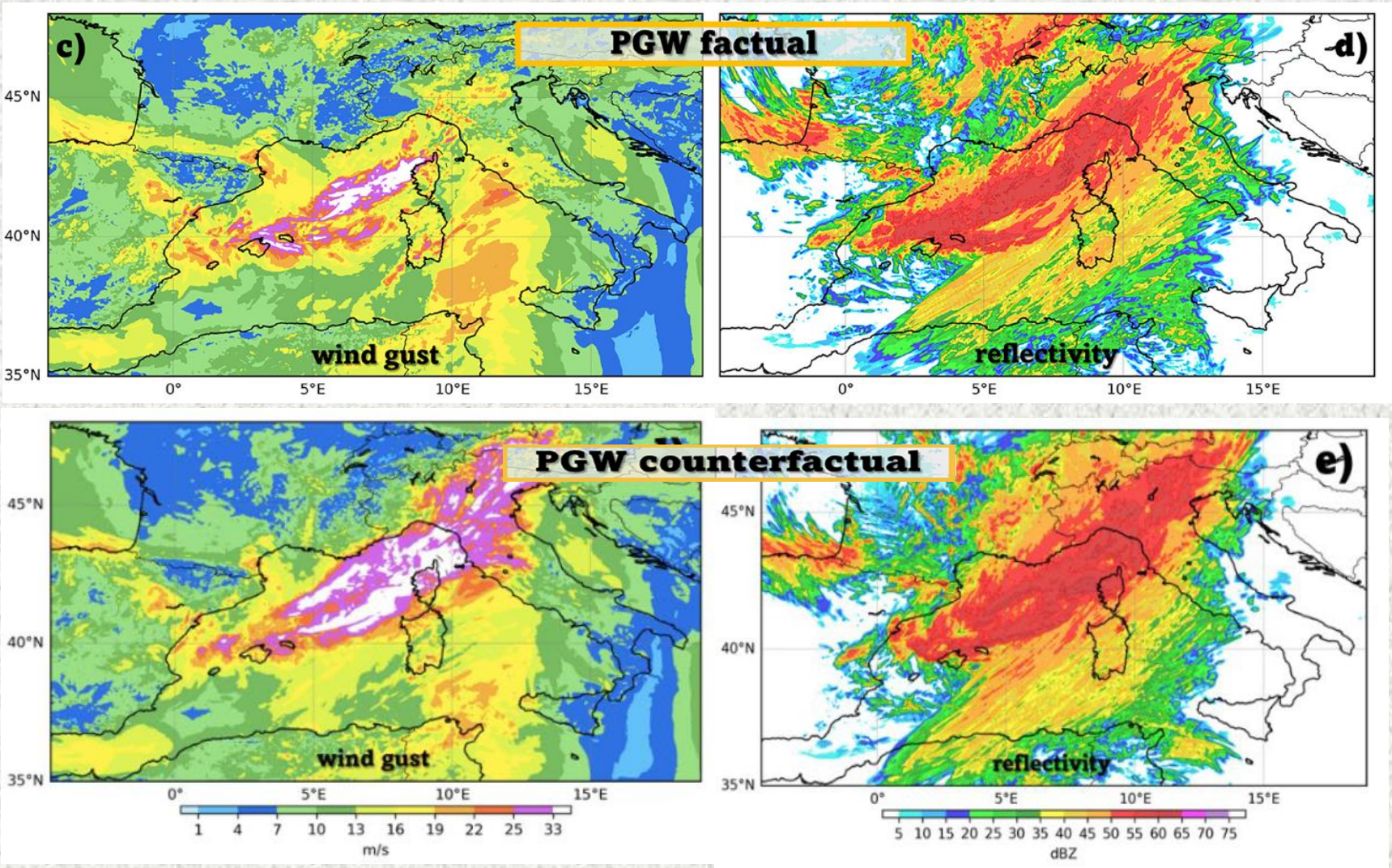
Past evolution



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