For “derechos” to “medicanes”: climate change and severe convective events in the Mediterranean

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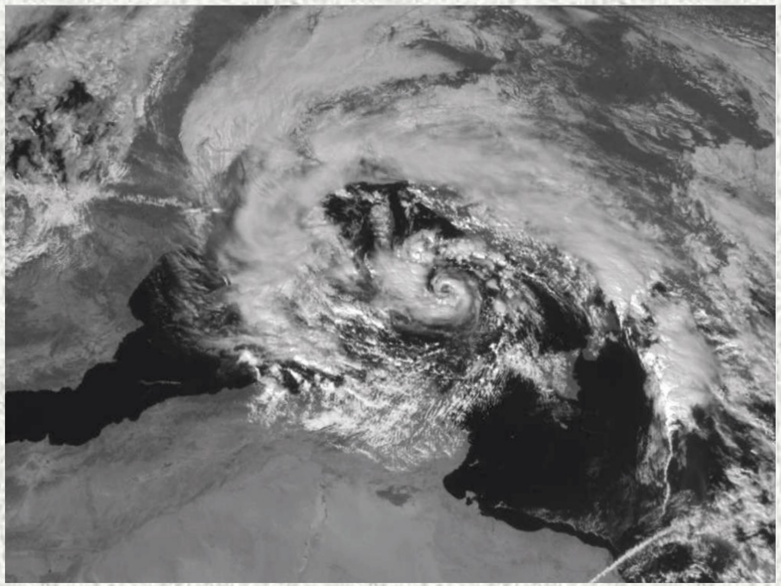
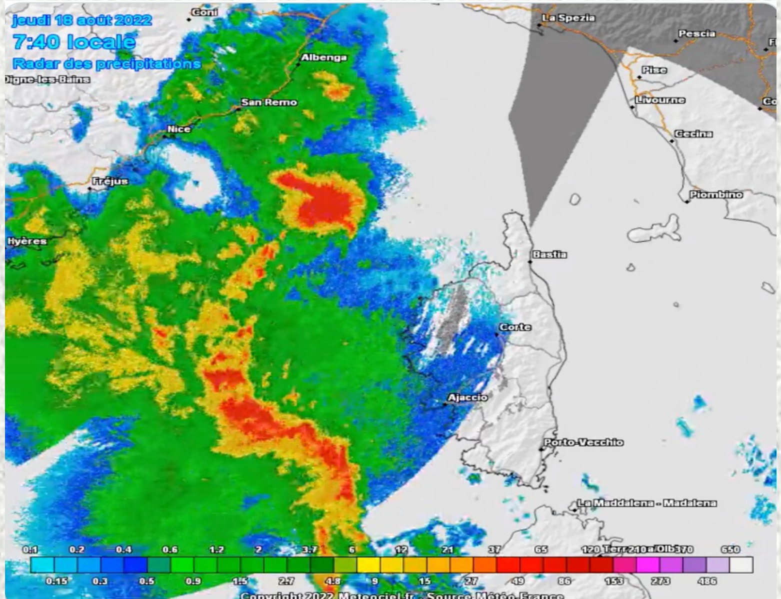
ISAC





Environment, Climate and Earth Sciences, ECES2024, Dep. Physics, Uni. Tirana, Albania, 9-10 May 2024

MOTIVATION

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

AIM

- Better understanding the impact of climate change on severe convection events.

OUTLINE

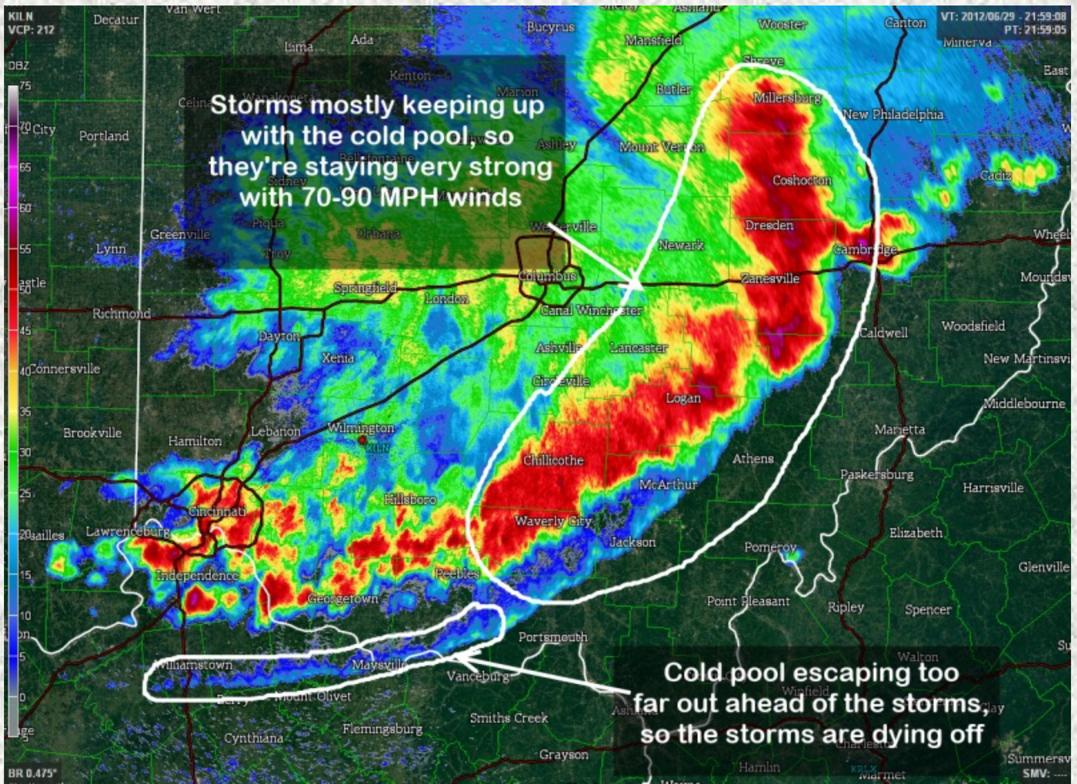
- «Derecho» of 18 August 2022
- Tornado in Taranto of 28 November 2012
- Impact of climate change on Medicanes

Derecho

A long-lasting (up to one day) severe wind event that extends over at least 250 nm (463 km) and contains multiple 65+ kts (33.5 m/s) wind gusts (Johns and Hirt, 1987).

A sequence of one or more severe bow echoes.

Often the damaging winds occur within several distinct episodes.



Introduction

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

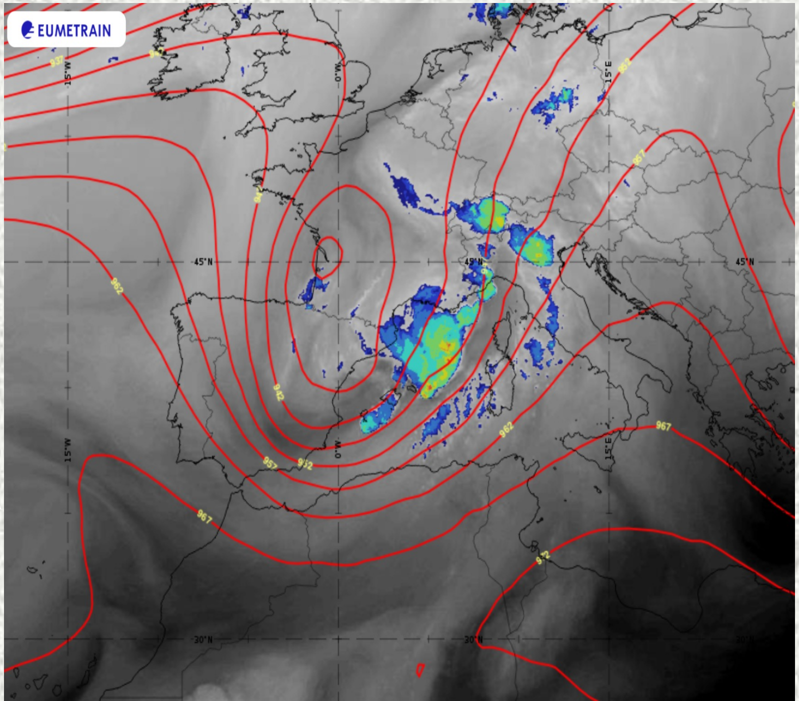
Concurrently, a record-breaking marine heatwave (MHW) was present over the Mediterranean Sea during summer 2022, peaking in July. The SST anomalies exceeded 3° C above the region where the storm developed.

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

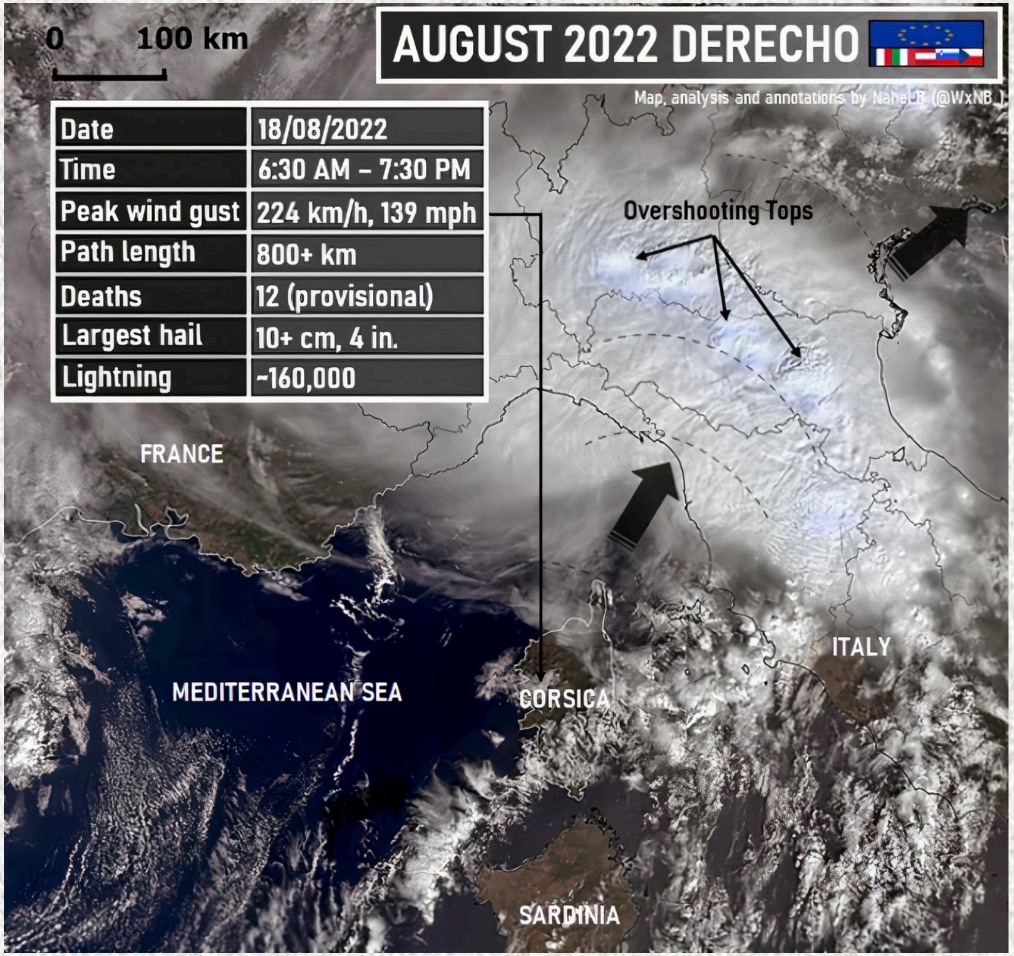
- Long swath of severe winds from the Balearic Islands to southern Czech Republic on August 18, with maximum wind gust of 62.2 m/s, measured by Météo France at Marignana, Corsica.

European Meteorological Society 2023 - 4-8 September 2023 - Bratislava, Slovakia

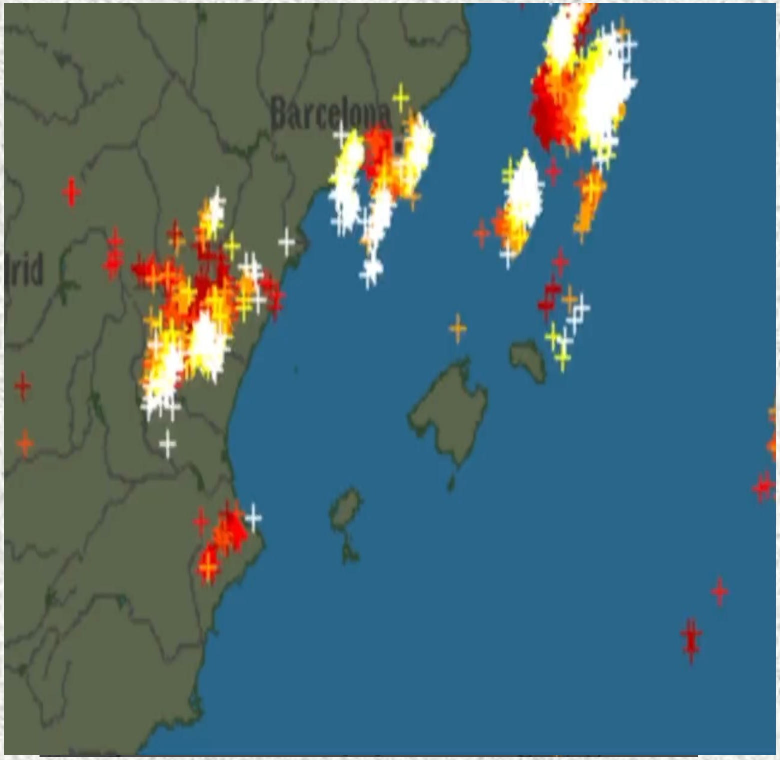
- In total, 12 people died and 106 people were injured.



Introduction

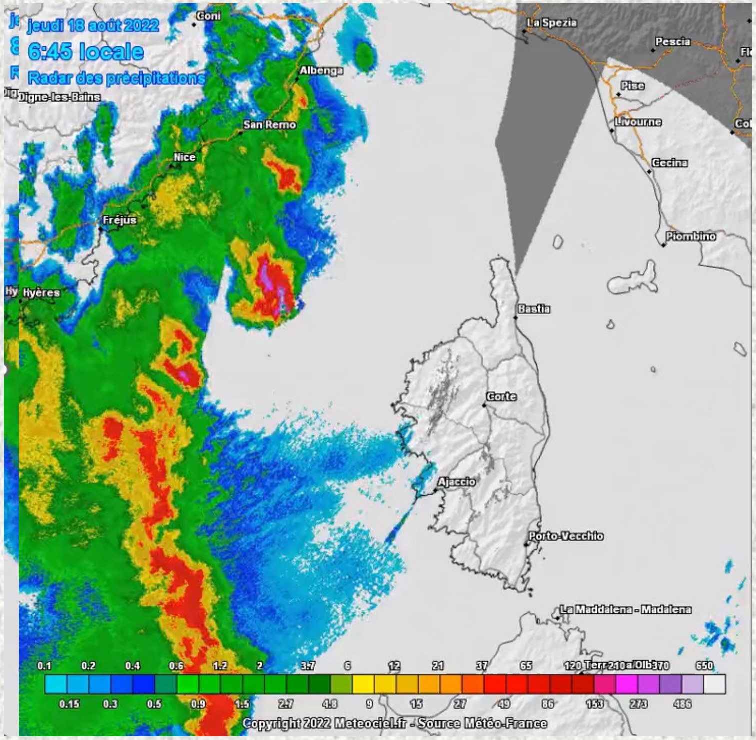


lightning activity



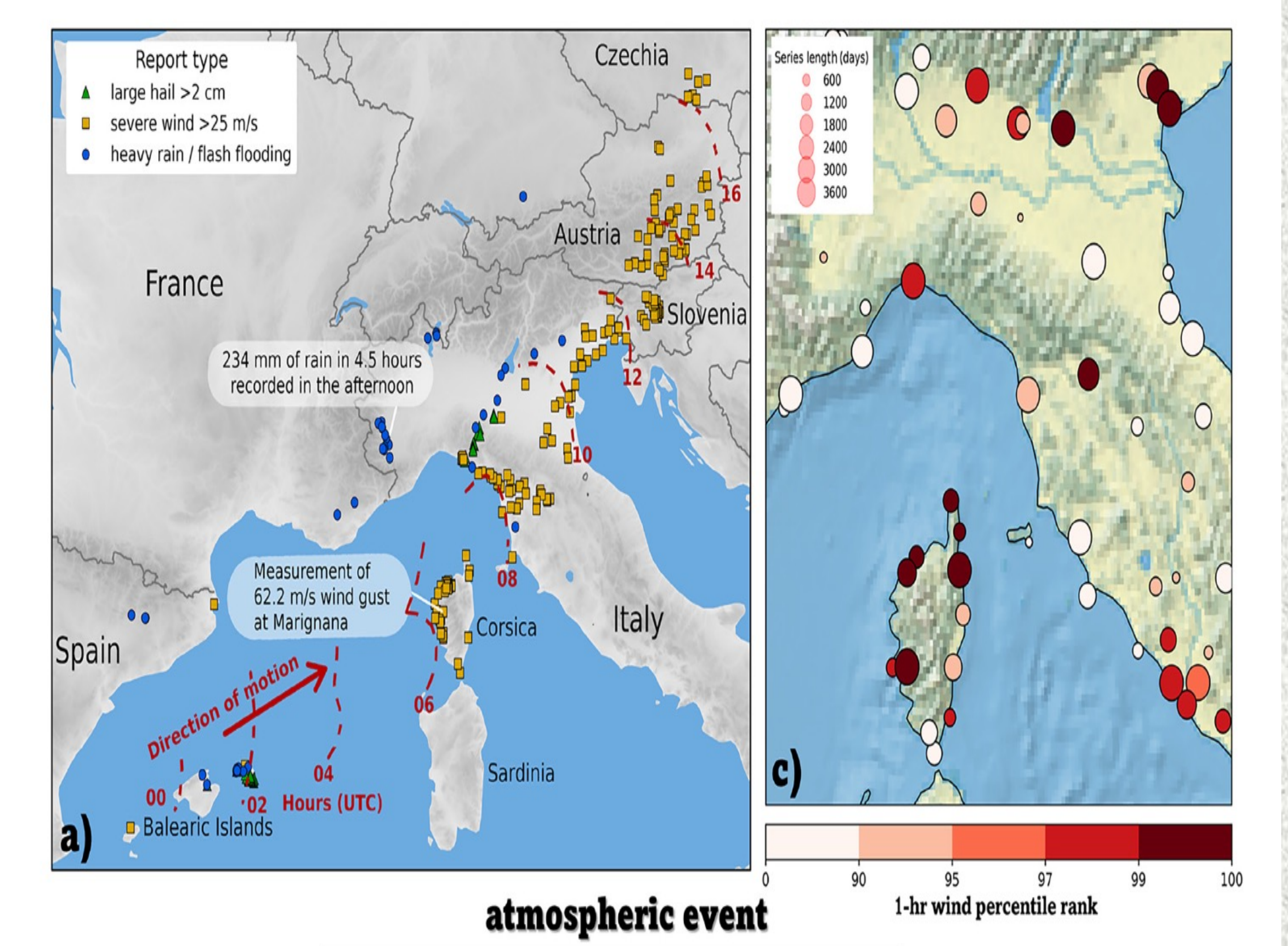
Introduction

Bow echo:



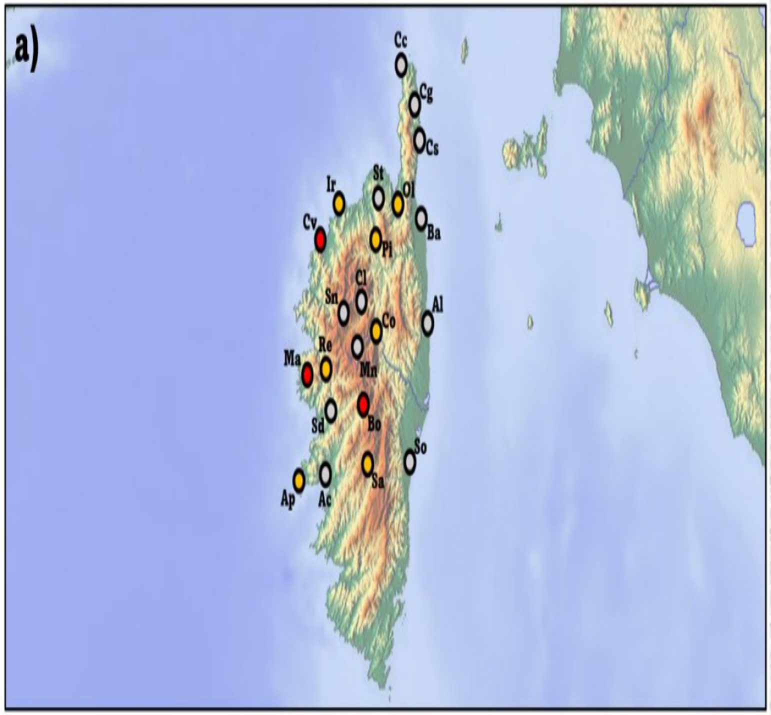
Introduction

From a climate perspective (atmosphere):



Introduction

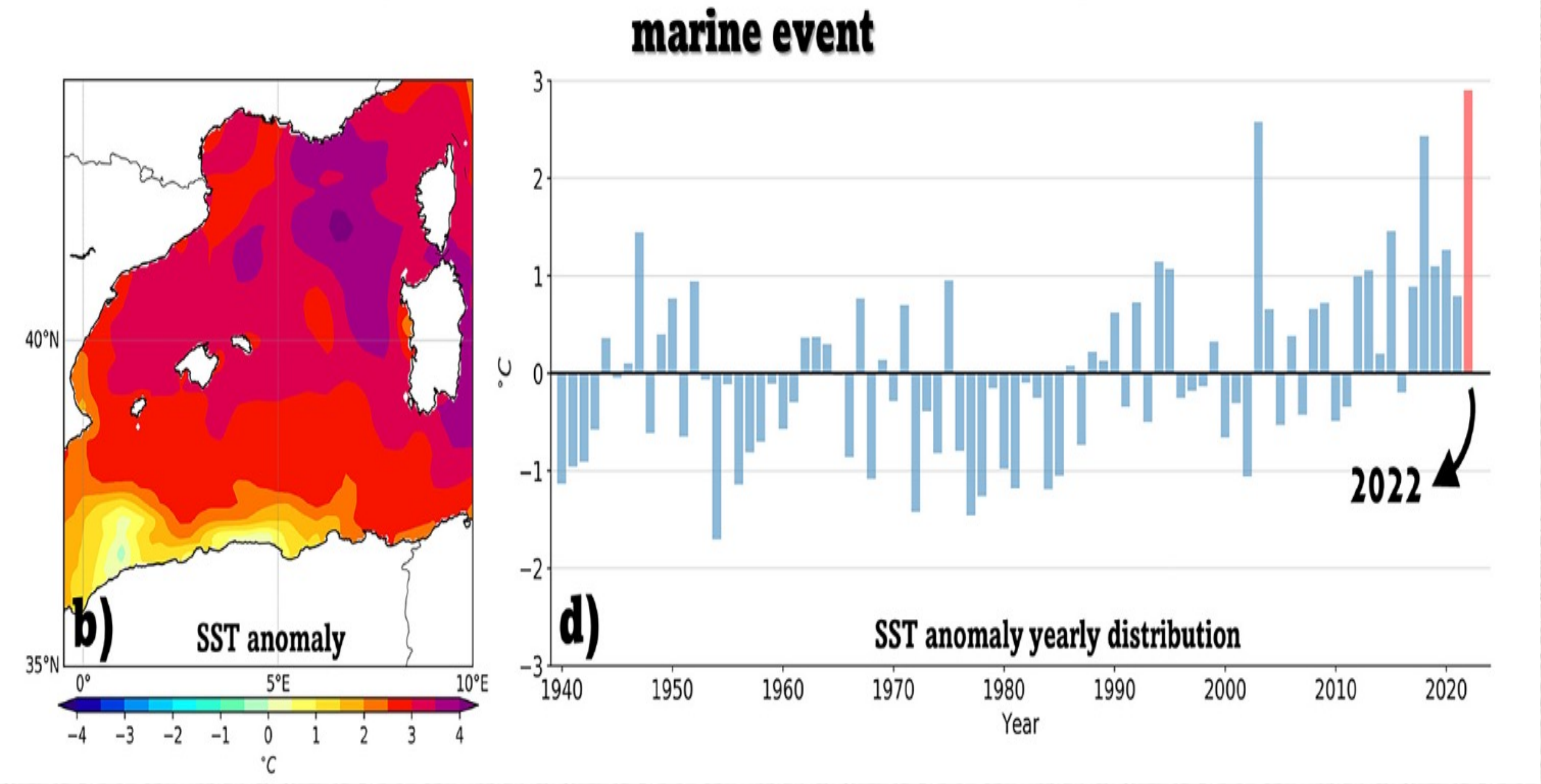
Station	Max Wind Gust (ms^{-1})	Monthly Record (ms^{-1})	Annual Record (ms^{-1})
Marignana [Ma]	62.4	27.3	49.0
Calvi [Ca]	54.7	28.0	44.0
Bocognano [Bo]	52.2	31.5	42.8
Ile Rousse [Ir]	51.3	39.0	59.0
Ajaccio-La Parata [Aj]	44.0	36.8	46.1
Renno [Re]	37.5	26.0	40.2
Pietralba [Pi]	35.9	30.0	36.0
Sampolo [Sa]	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



Introduction

From a climate perspective (ocean):

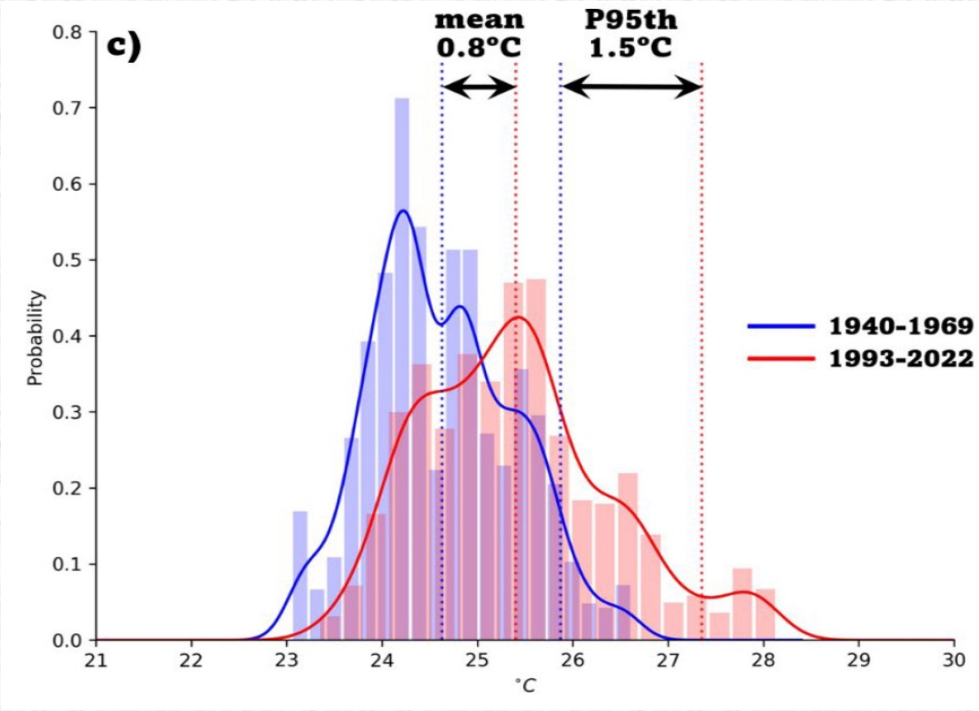
Record-breaking marine heatwave



Introduction

From a climate perspective (ocean):

SST probability distribution



Introduction

Goal:

Given the extremeness of the derecho event and the presence of the record-breaking marine heatwave, investigate the possible influence of the marine heatwave and anthropogenic warming in the event.

Methods

Sensitivity test by perturbing SSTs with the operational Meteo-France AROME model [~1.3 km].

Pseudo-global warming simulations with MPAS model [~3 km]:

Factual (observed): GFS analysis --> MPAS

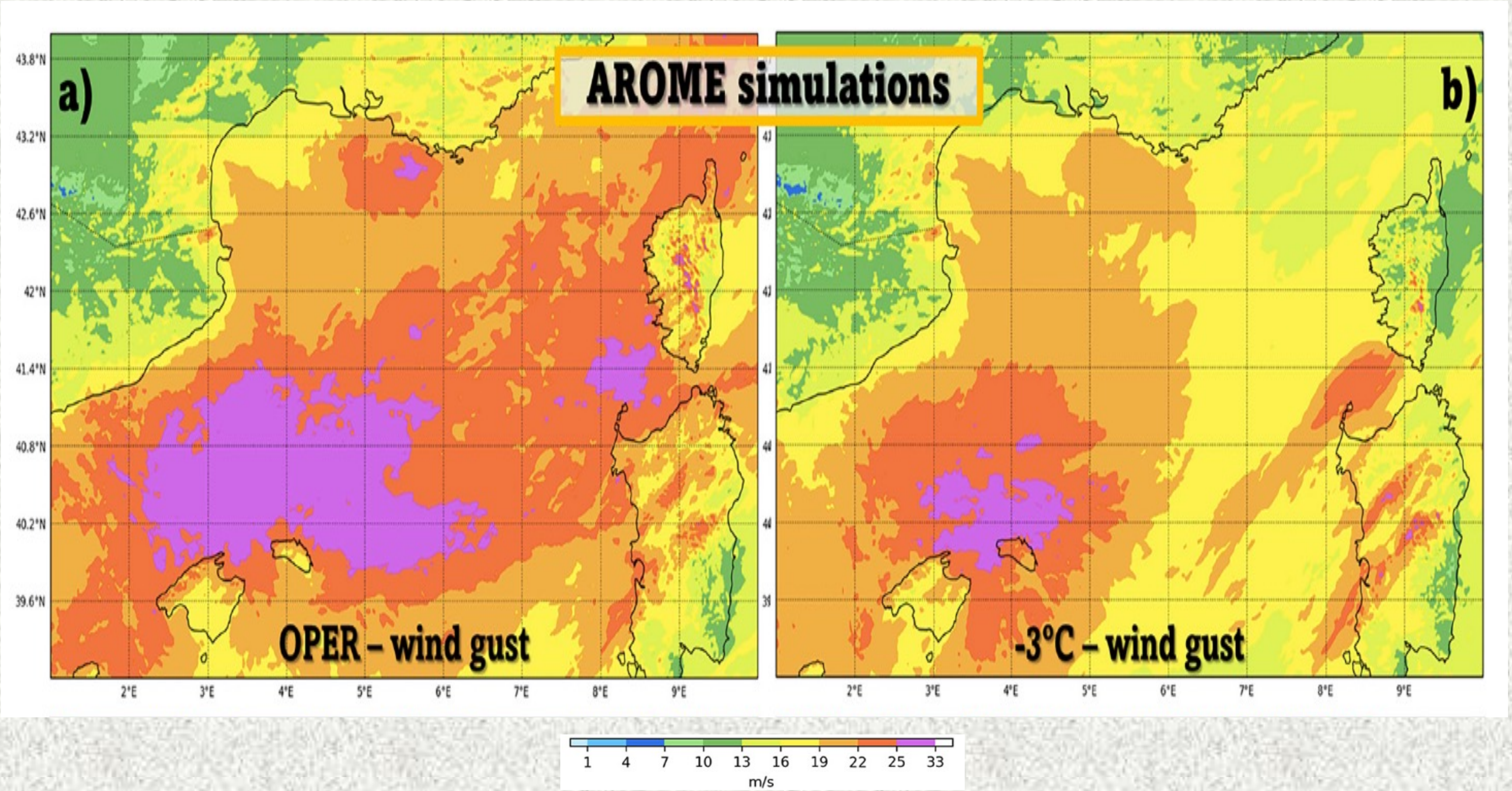
Counterfactual past (preindustrial): GFS – [anthropogenic forcing from CMIP6 models] --> MPAS

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

Results

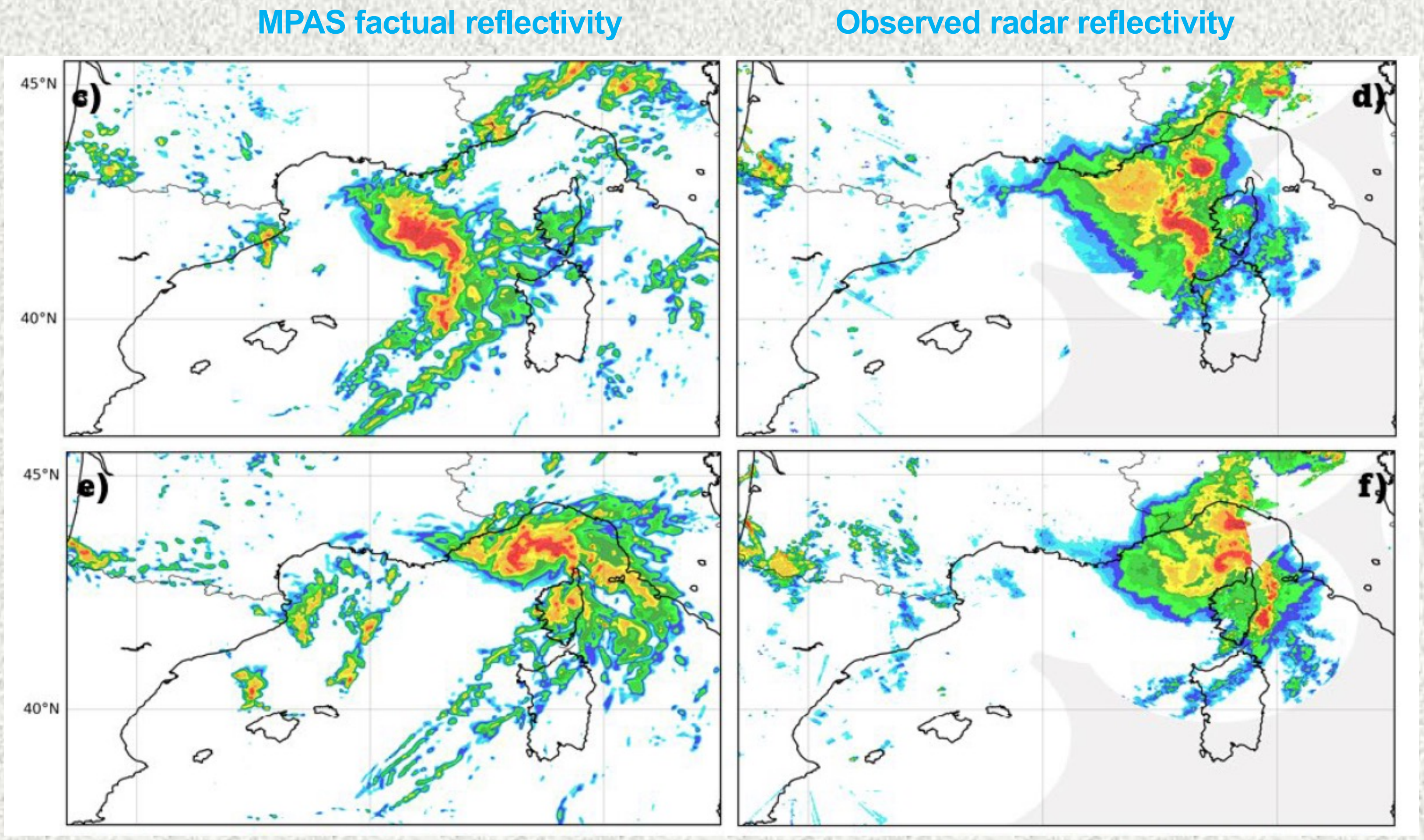
AROME simulations with SST perturbations.

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



Results

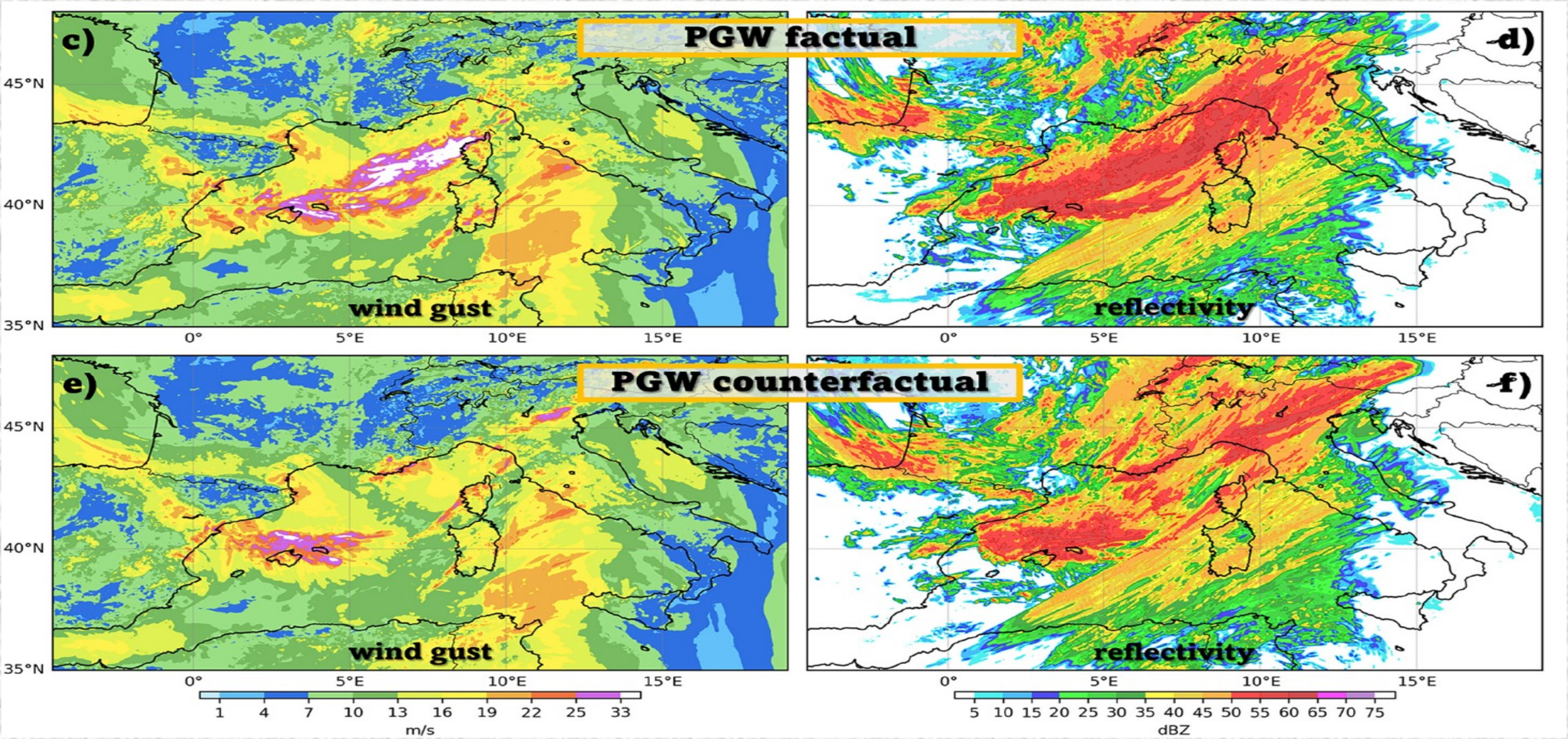
MPAS pseudo-global simulations.



Results

MPAS pseudo-global simulations.

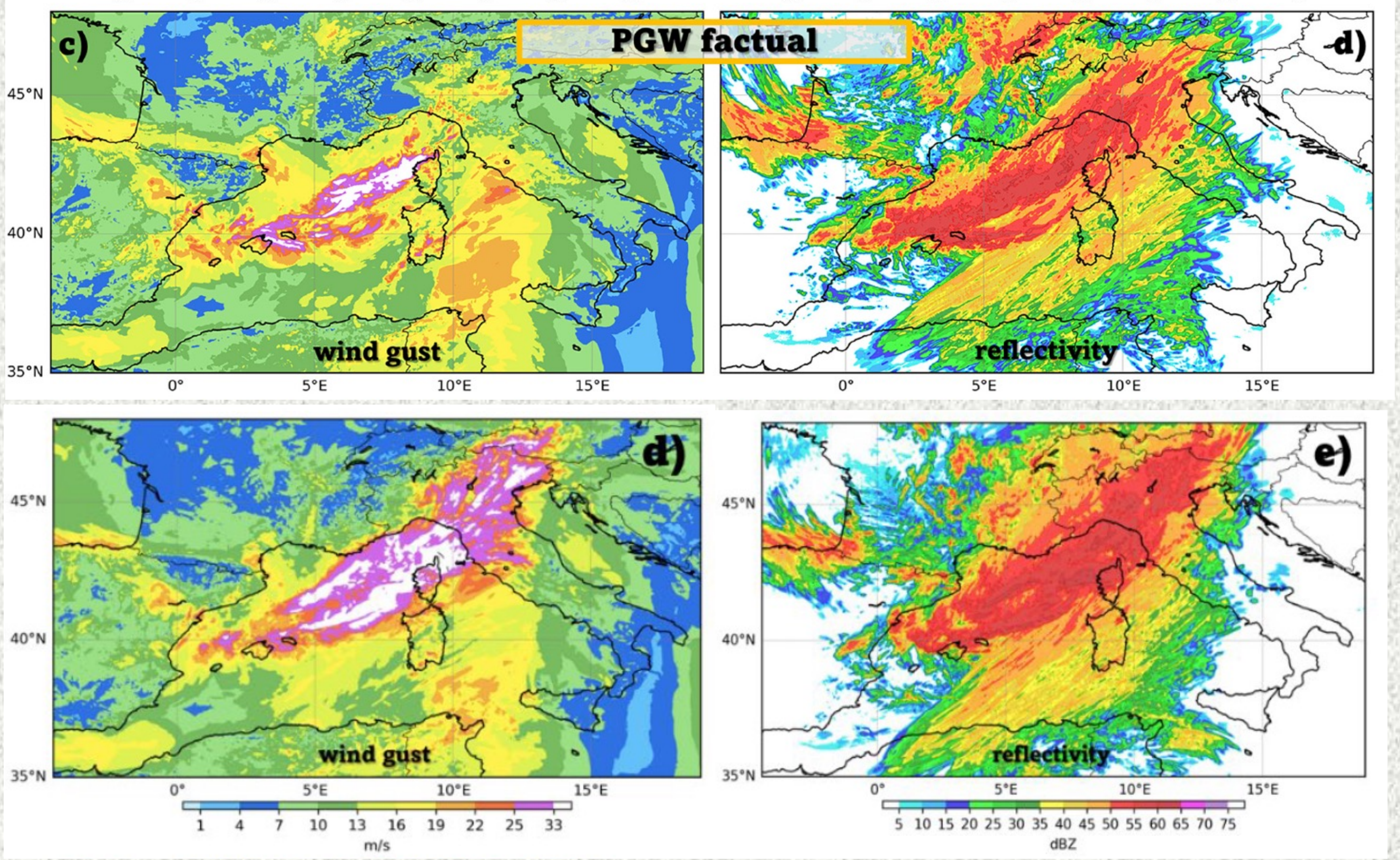
Past evolution (SSP5-8.5)



Results

MPAS pseudo-global simulations

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.

AMS American Meteorological Society
Bulletin of the American Meteorological Society
BAMS Our New Century

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

Juan Jesús González-Alemán, Damián Insua-Costa, Eric Bazile, Sergi González-Herrero, Mario Marcello Miglietta, Pieter Groenemeijer, and Markus G. Donat

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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OUTLINE

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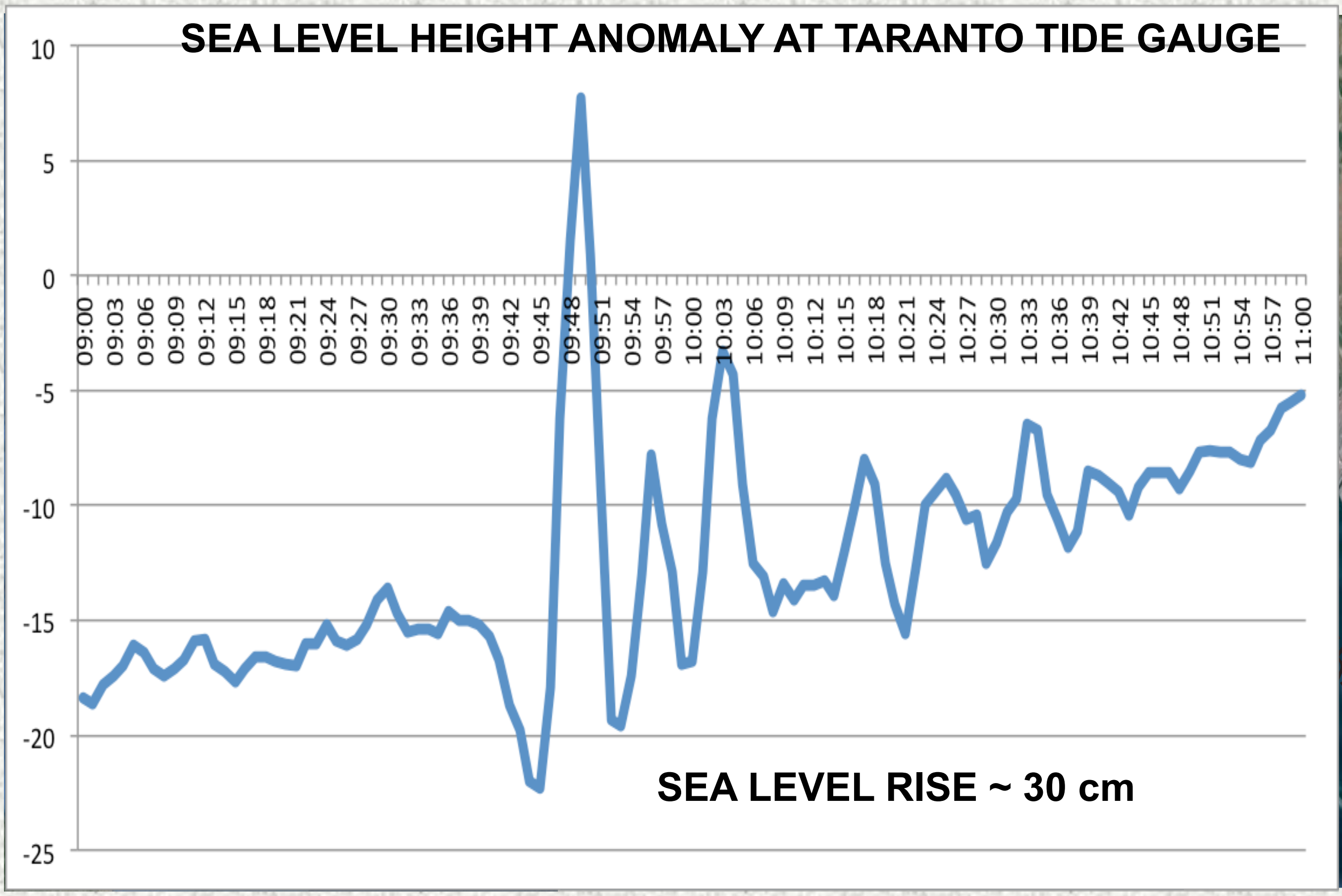
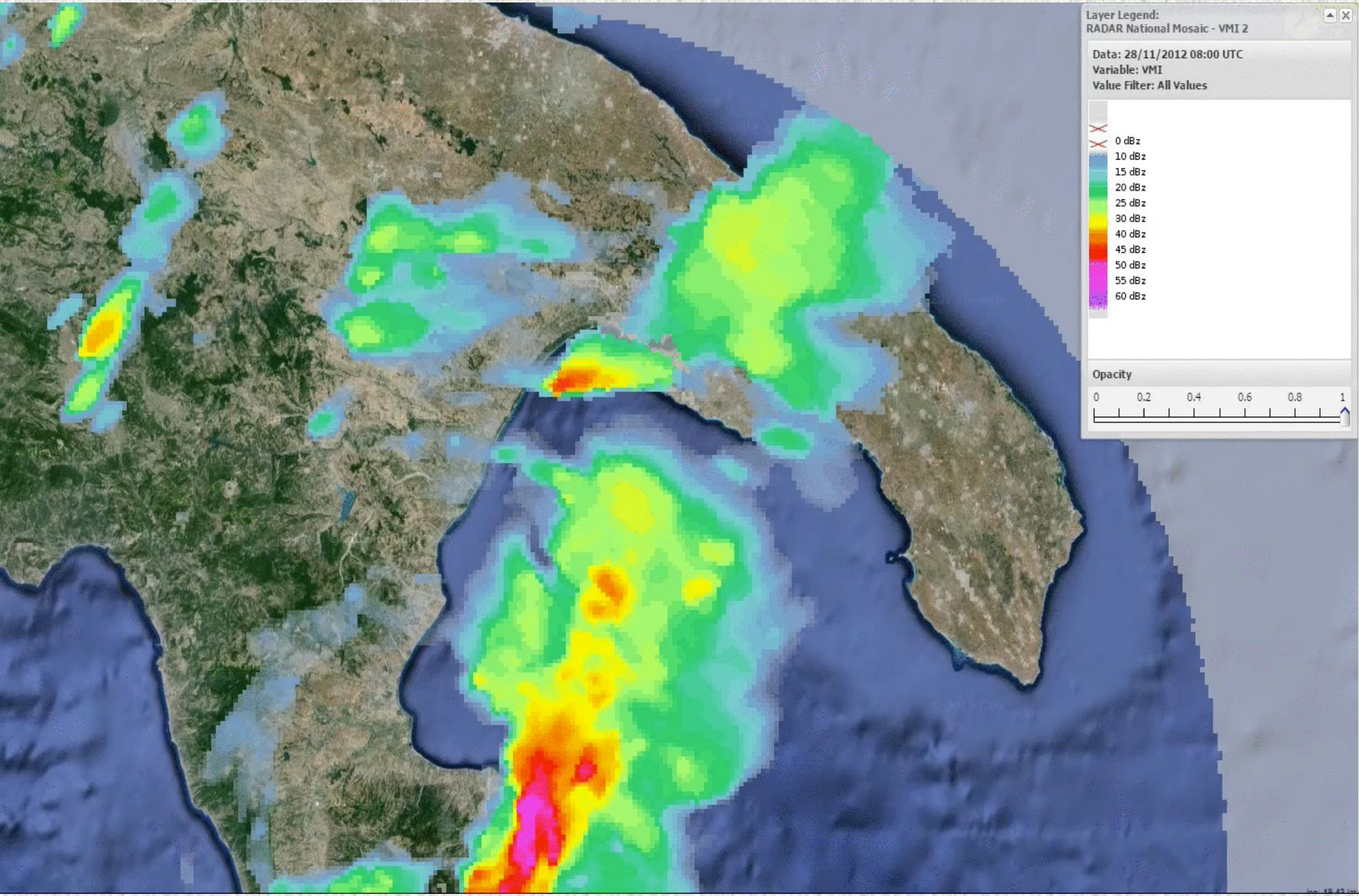
TORNADO TRACK



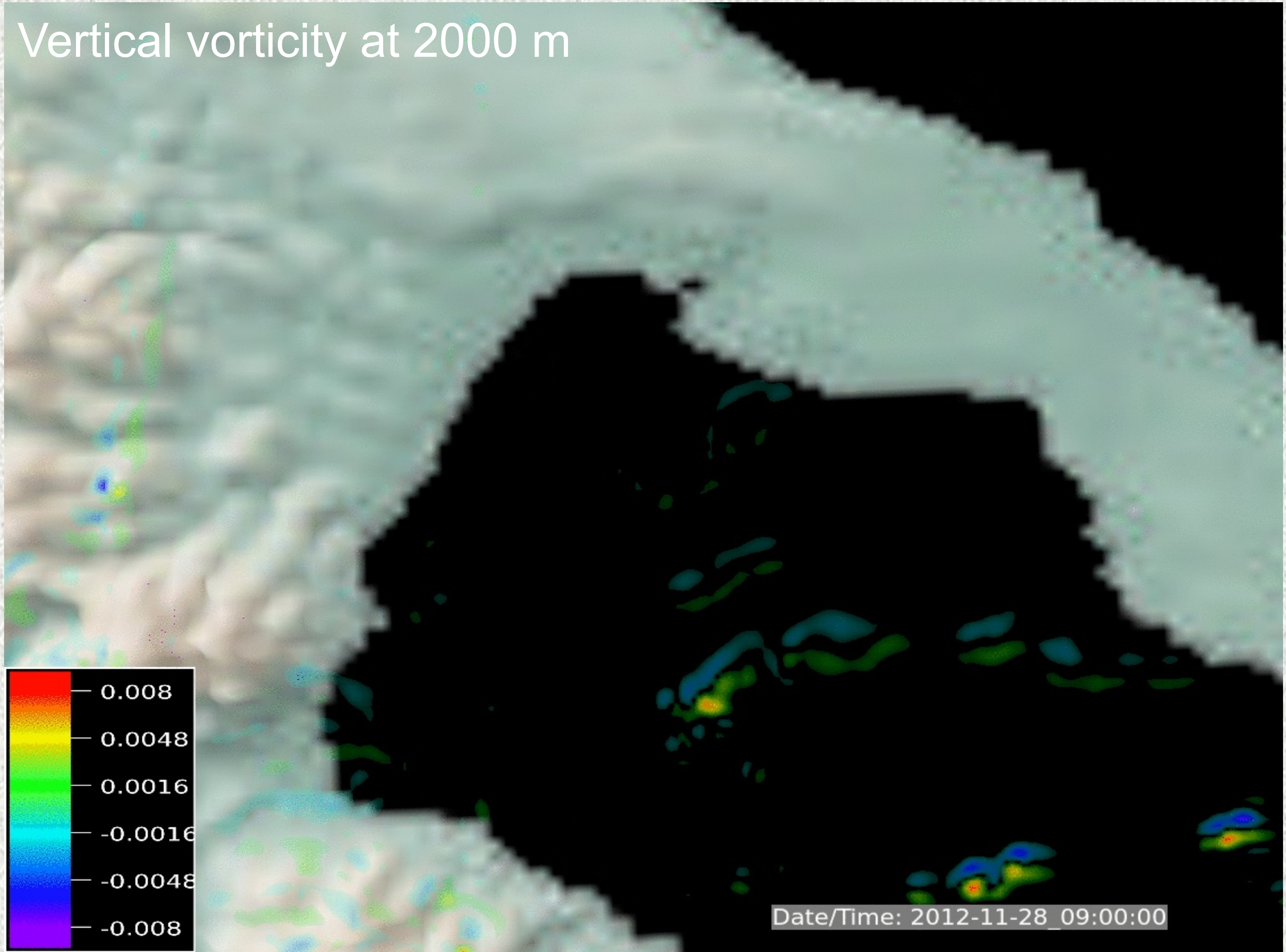
LANDFALL ~ 09:50 UTC, 28 NOV 2012

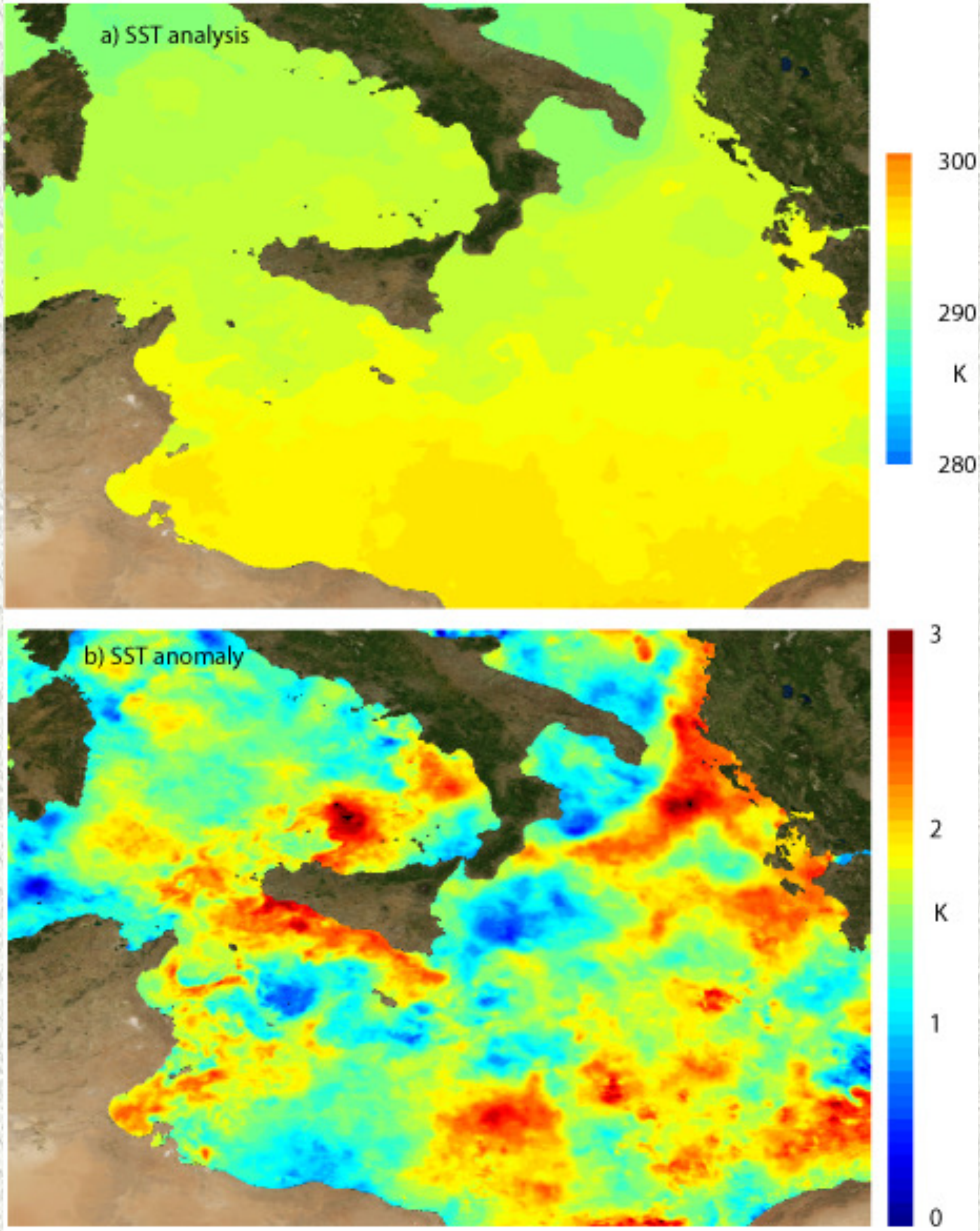
DAMAGE AT ILVA, THE LARGEST STEEL PLANT IN EUROPE

Radar Reflectivity (Vertical Maximum Intensity)

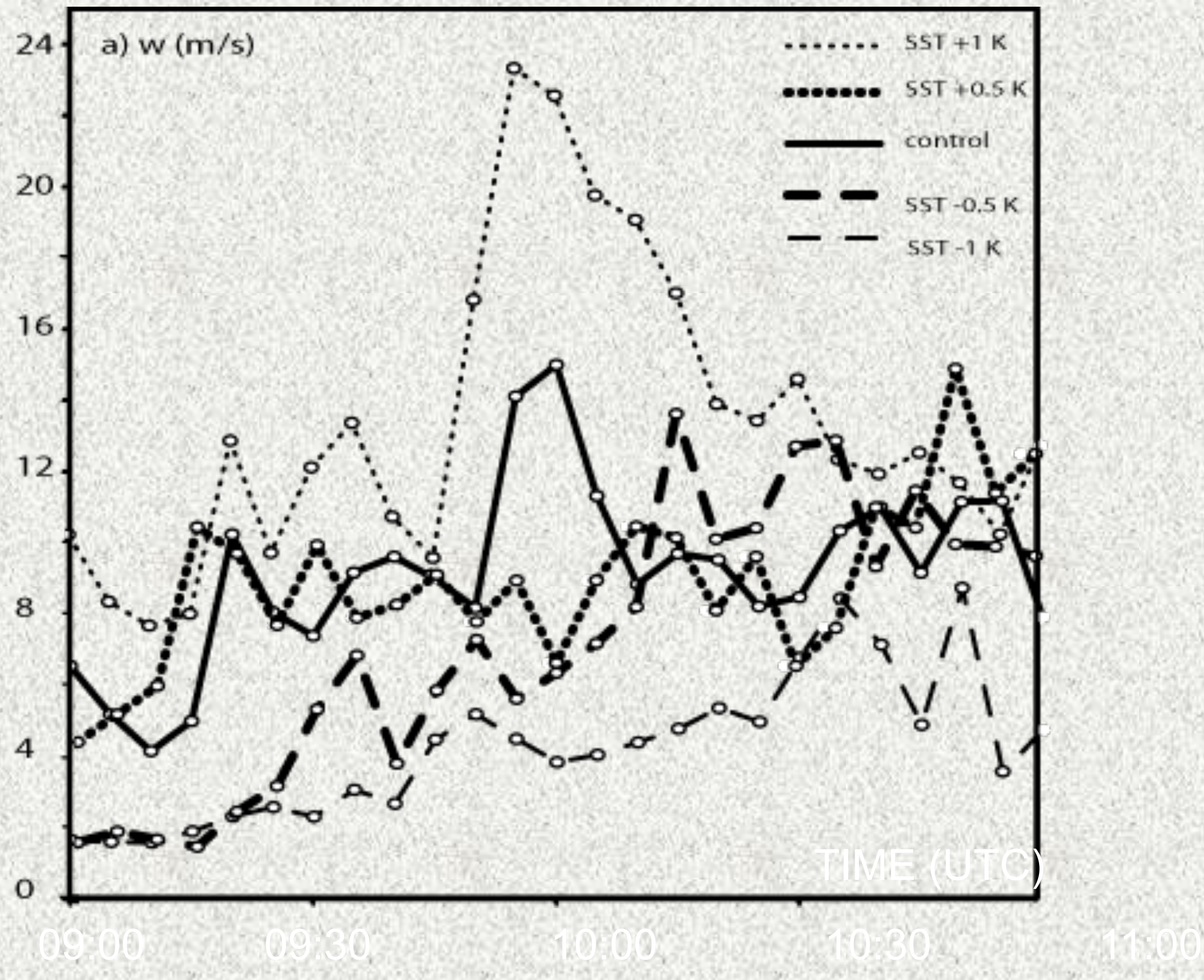


https://www.youtube.com/watch?v=ijzck7TYOLs

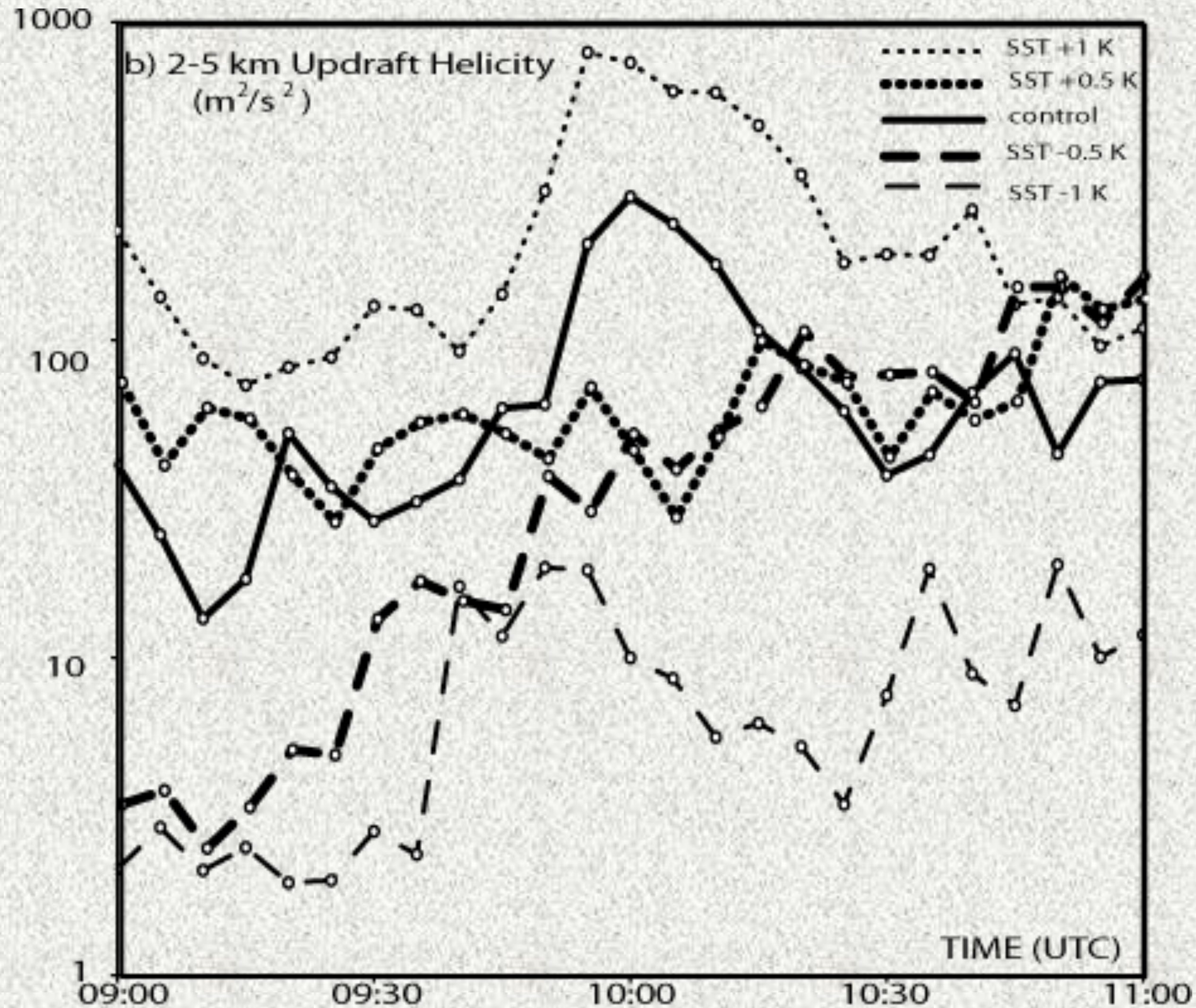



a) SST analysis
300
290
K
280
b) SST anomaly
3
2
K
1
0

600 hPa vertical velocity max



2-5 km Updraft Helicity max



OUTLINE

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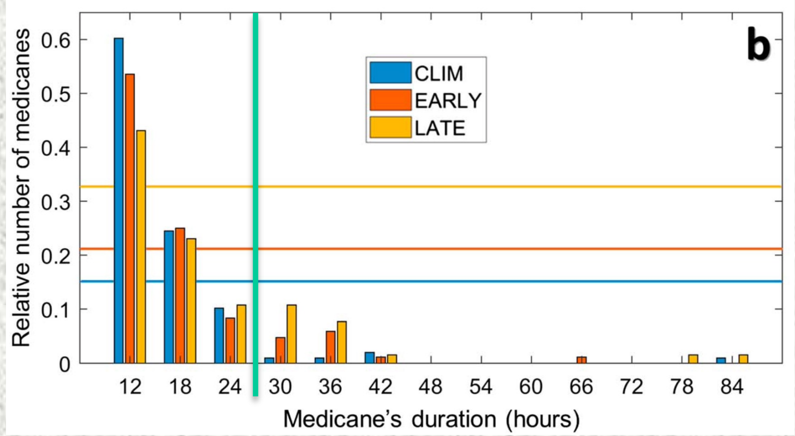
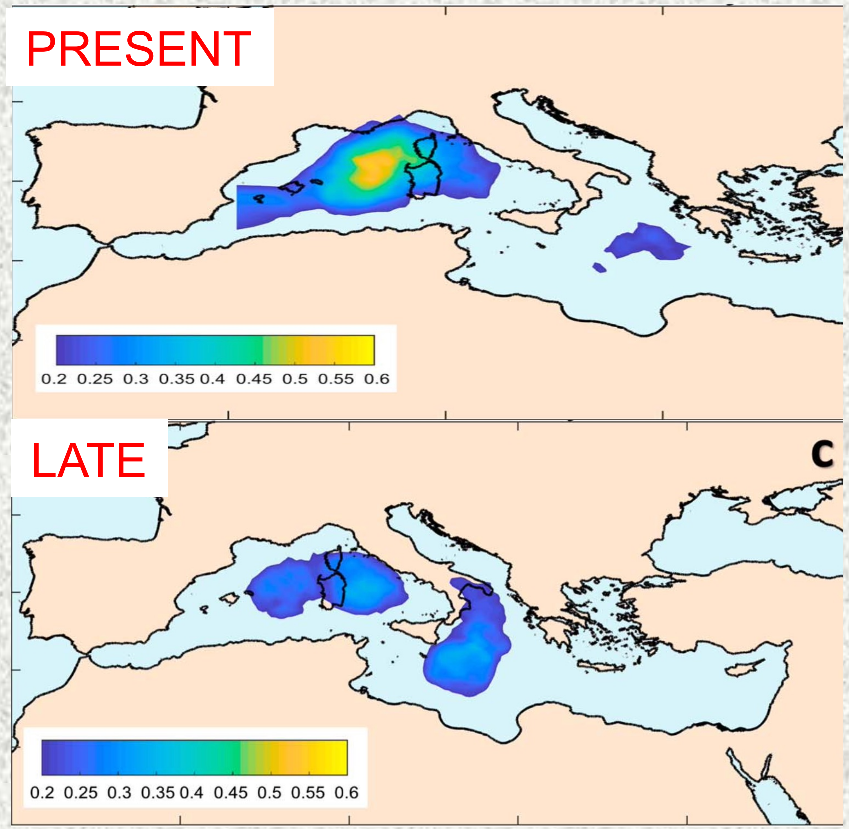
MEDICANES AND CLIMATE CHANGE

(Gonzalez-Aleman et al., 2019)



HiFLOR atmospheric-ocean coupled GCM
Intermediate Scenario: **RCP4.5**
Horizontal resolution: **25 km**



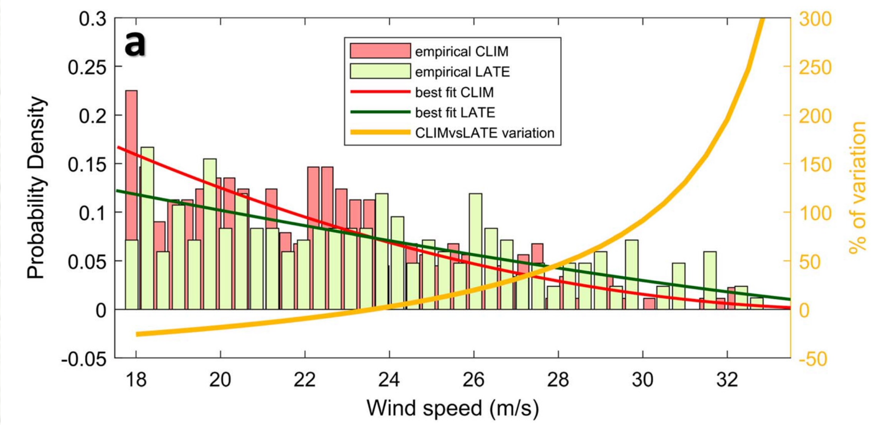
MEDICANES AND CLIMATE CHANGE (Gonzalez-Aleman et al., 2019)

HiFLOR atmospheric-ocean coupled GCM

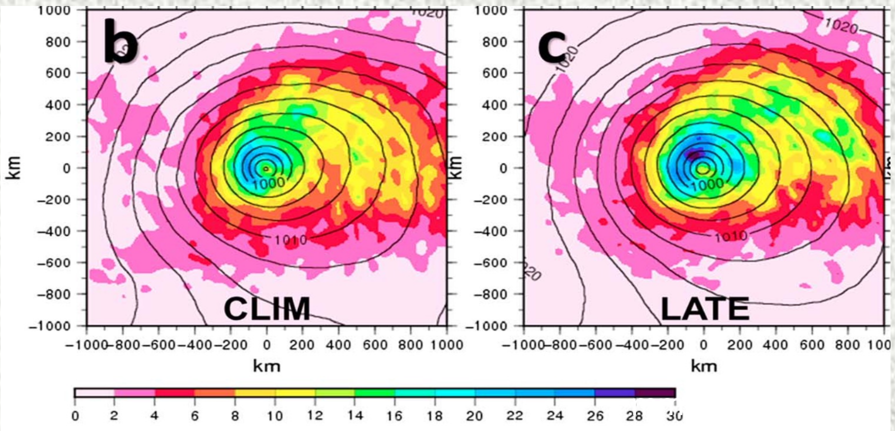
Intermediate Scenario: **RCP4.5**

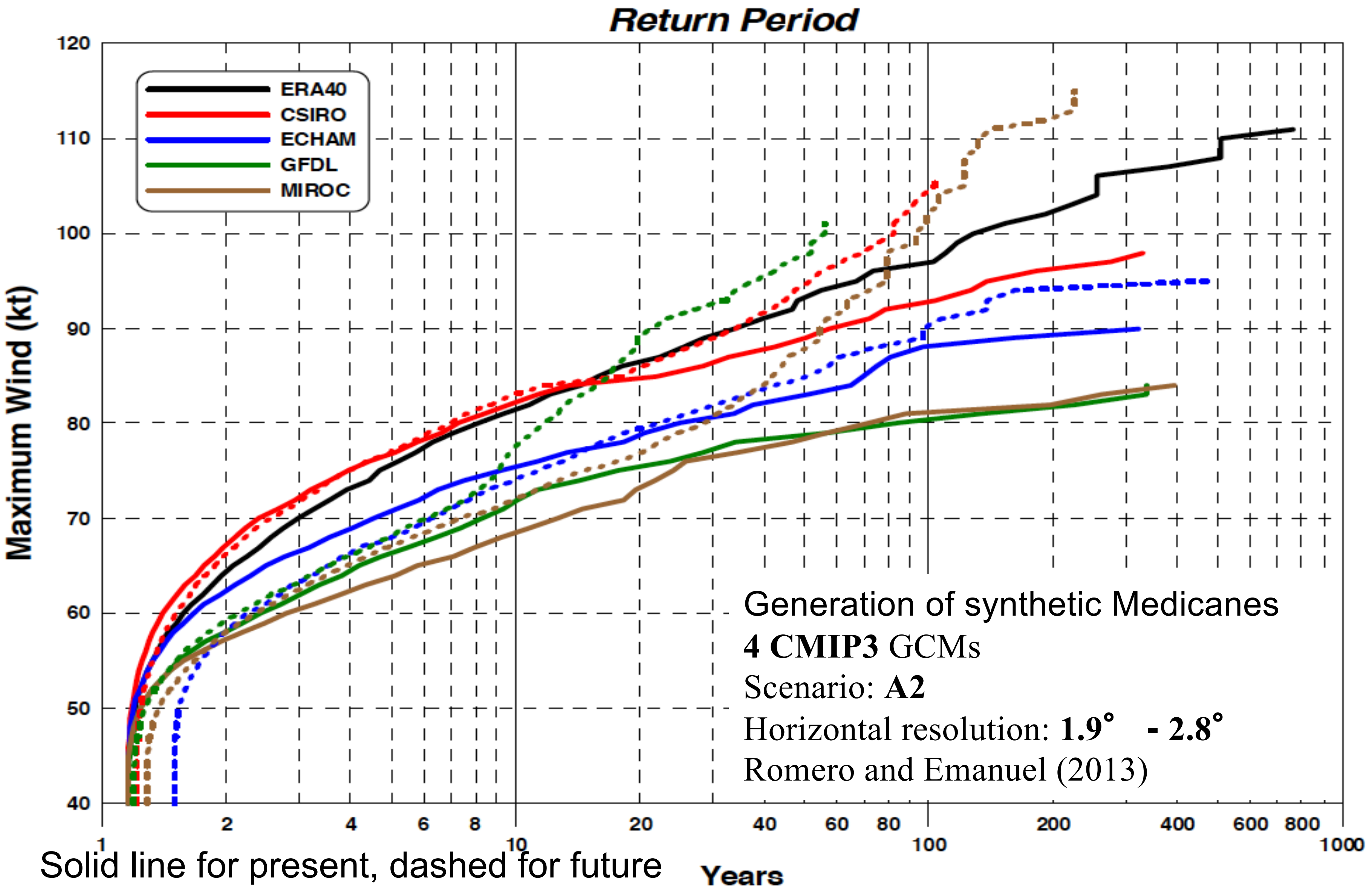
Horizontal resolution: **25 km**

WIND



PRECIPITATION





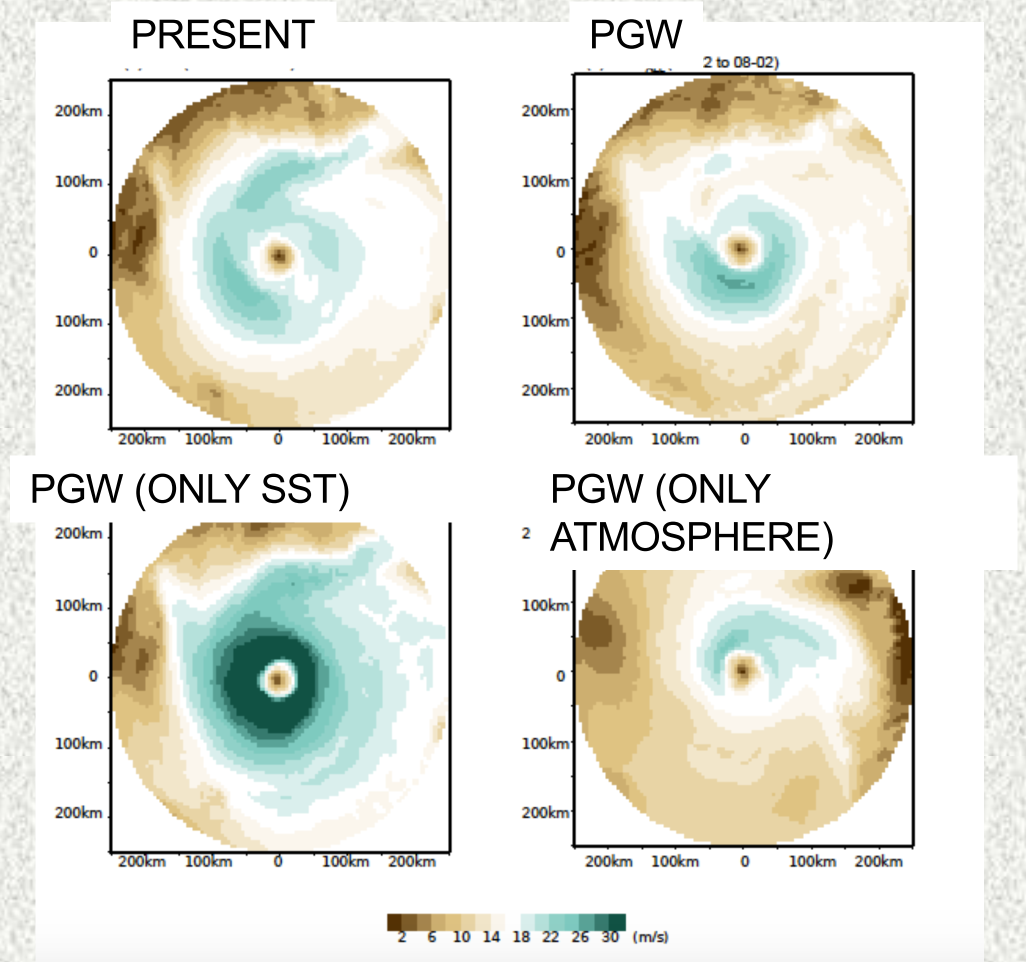
Solid line for present, dashed for future

4 models: Fewer medicanes but a higher number of violent storms in the future

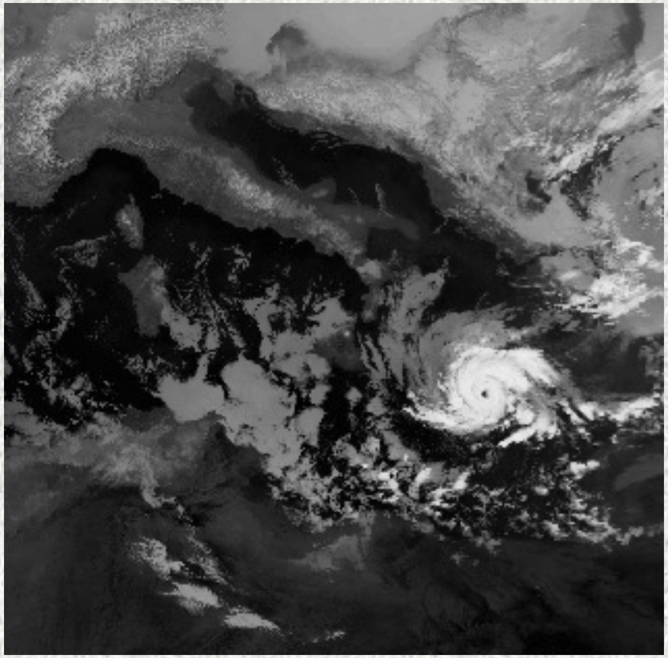
ROLF – PSEUDO GLOBAL WARMING (PGW) Simulation

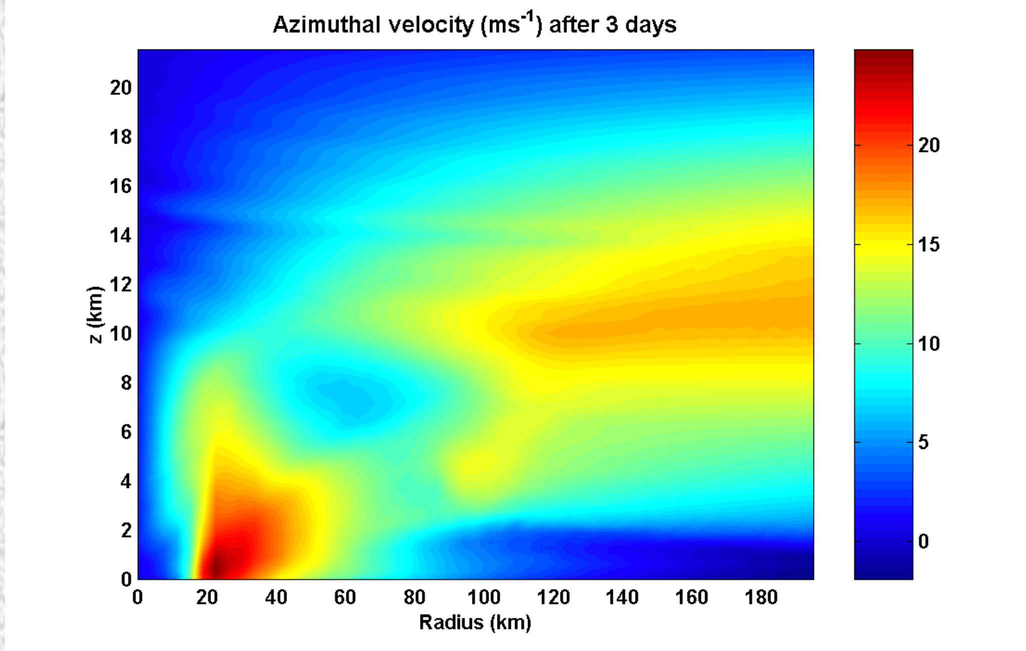
Koseki et al. (2020)

Surface wind speed during SLP minimum for (a) PRS, (b) PGWALL, (c) PGWSST, and (d) PGWATMS around the cyclone centre, respectively



Genesis and maintenance of “Mediterranean hurricanes” (Emanuel, 2005)





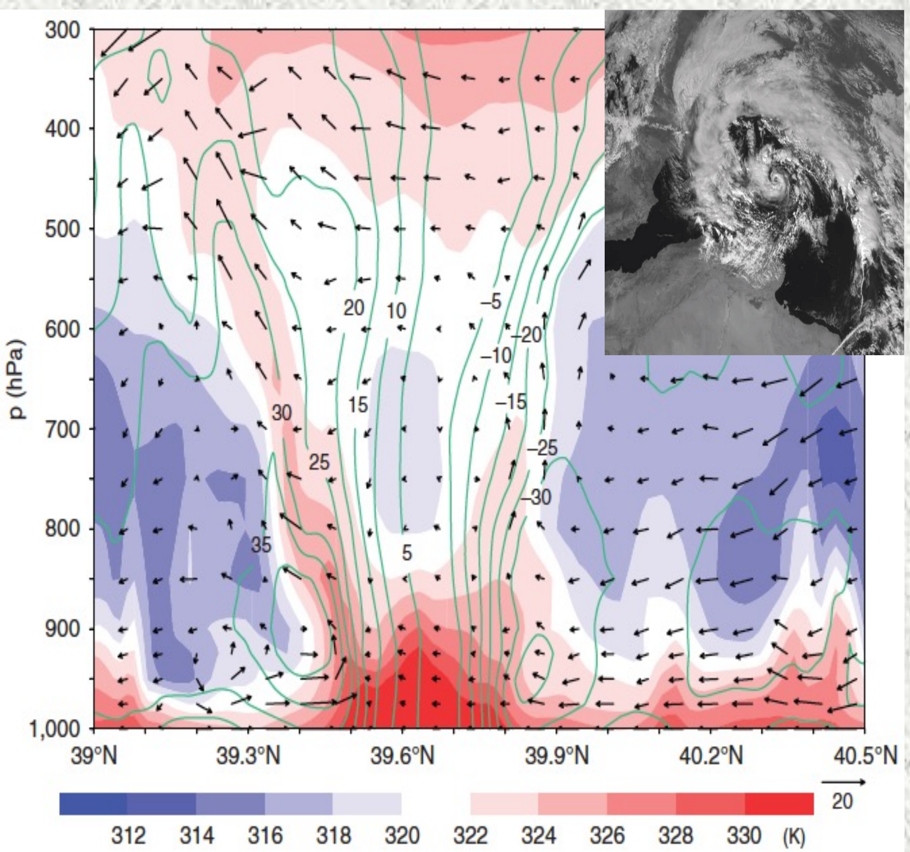
An **axisymmetric, cloud-resolving model** - in which any development may occur only due to the **feedback between surface enthalpy fluxes and wind** – was applied to show that a **upper-level cold low** can produce high potential intensity in an Ionian cyclone

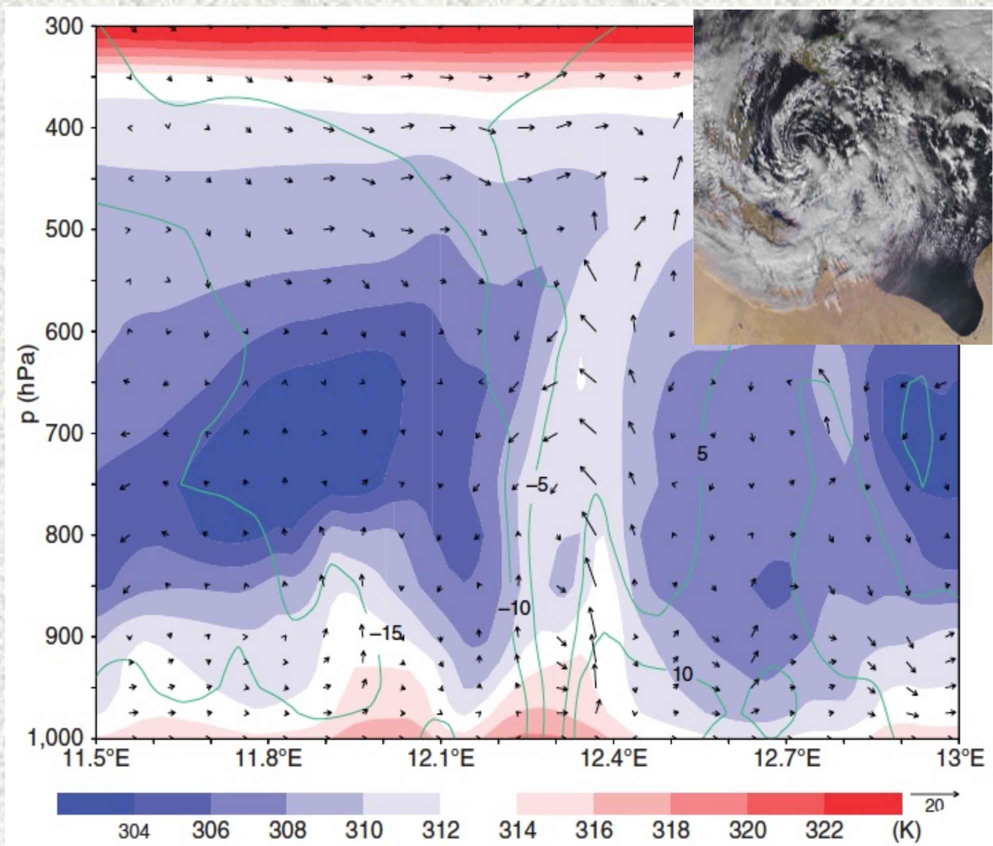
CELENO (15-17/01/1995)

CROSS SECTION ALONG THE CYCLONE CENTER

In both cases symmetric, deep warm core structures but only the first one shows the upward transport of warm/moist air typical of TC

Different contribution of baroclinic versus diabatic processes



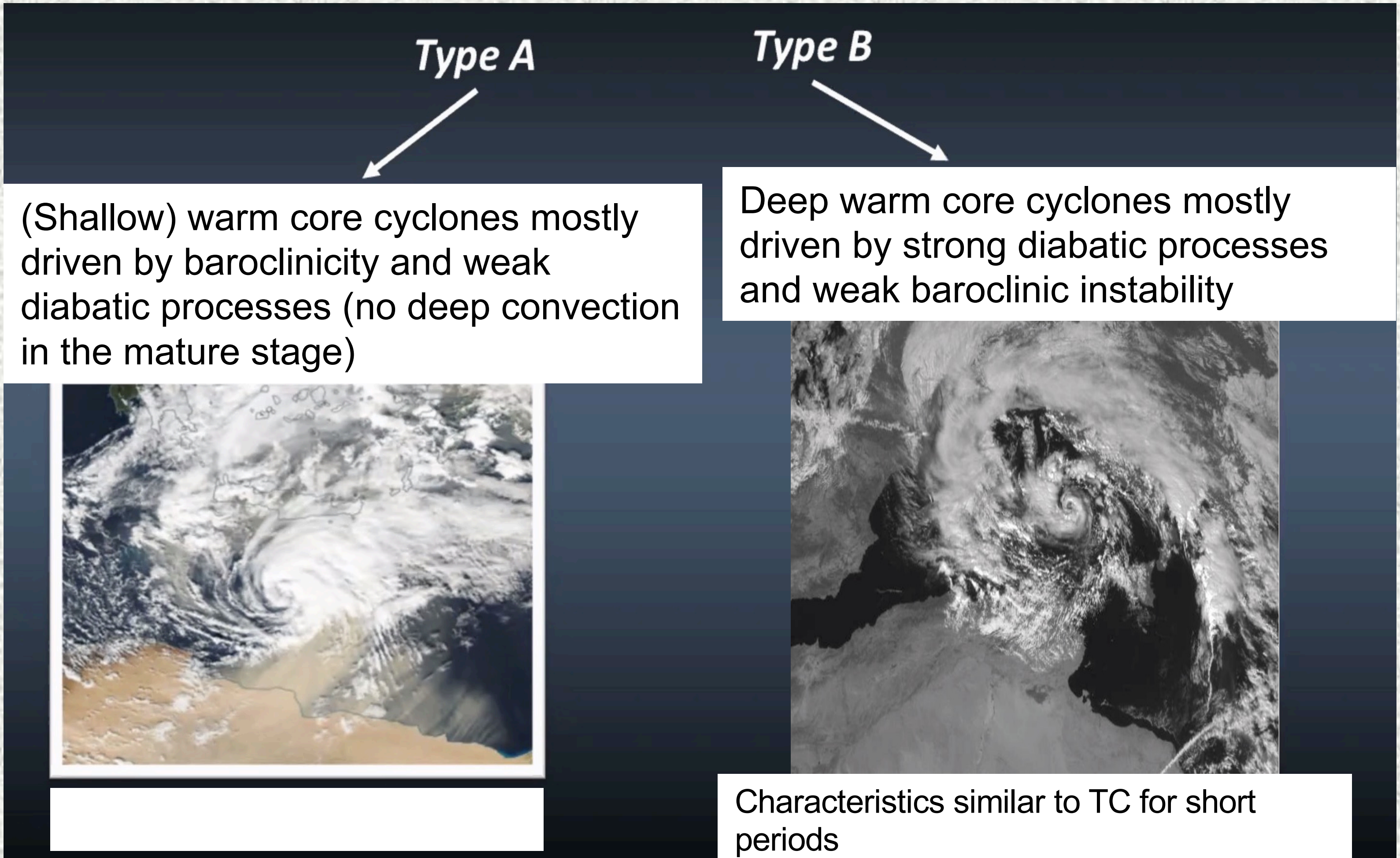


CORNELIA (OCTOBER 1996) ZEO (DECEMBER 2005)

Vertical cross-section of θe (colours), storm-relative winds (vectors), absolute momentum (lines, contour interval=5m/s; zero not shown) near the cyclone centre

Miglietta and Rotunno (2019)

Proposed classification in **categories**, depending on the dominant process in the mature stage



Miglietta and Rotunno (2019); Dafis et al. (2020)

Conclusions

Warm SST will provide conditions more favorable to the development of intense storms, although the total number of events will not be significanly affected (slight decrease)

Acknowledgements

- “Earth Observations as a cornerstone to the understanding and prediction of tropical like cyclone risk in the Mediterranean (MEDICANES)”, ESA Contract No. 4000144111/23/I-KE, In response to: ESA CfP/5-50033/23/I-KE
- COST action CA19109 - MEDCYCLONES “European network for Mediterranean cyclones in weather and climate”