On recent climate changes over the Mediterranean area

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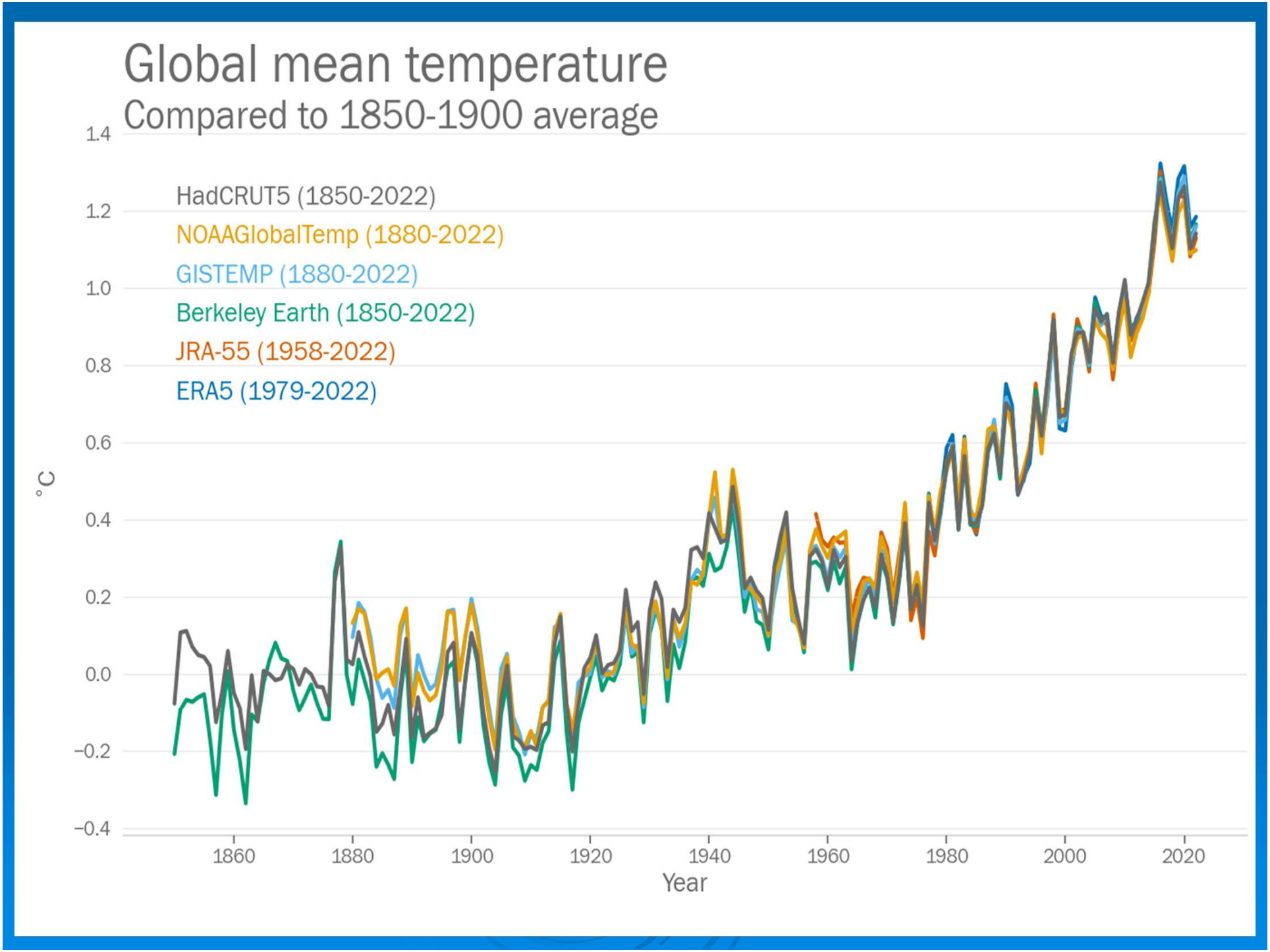
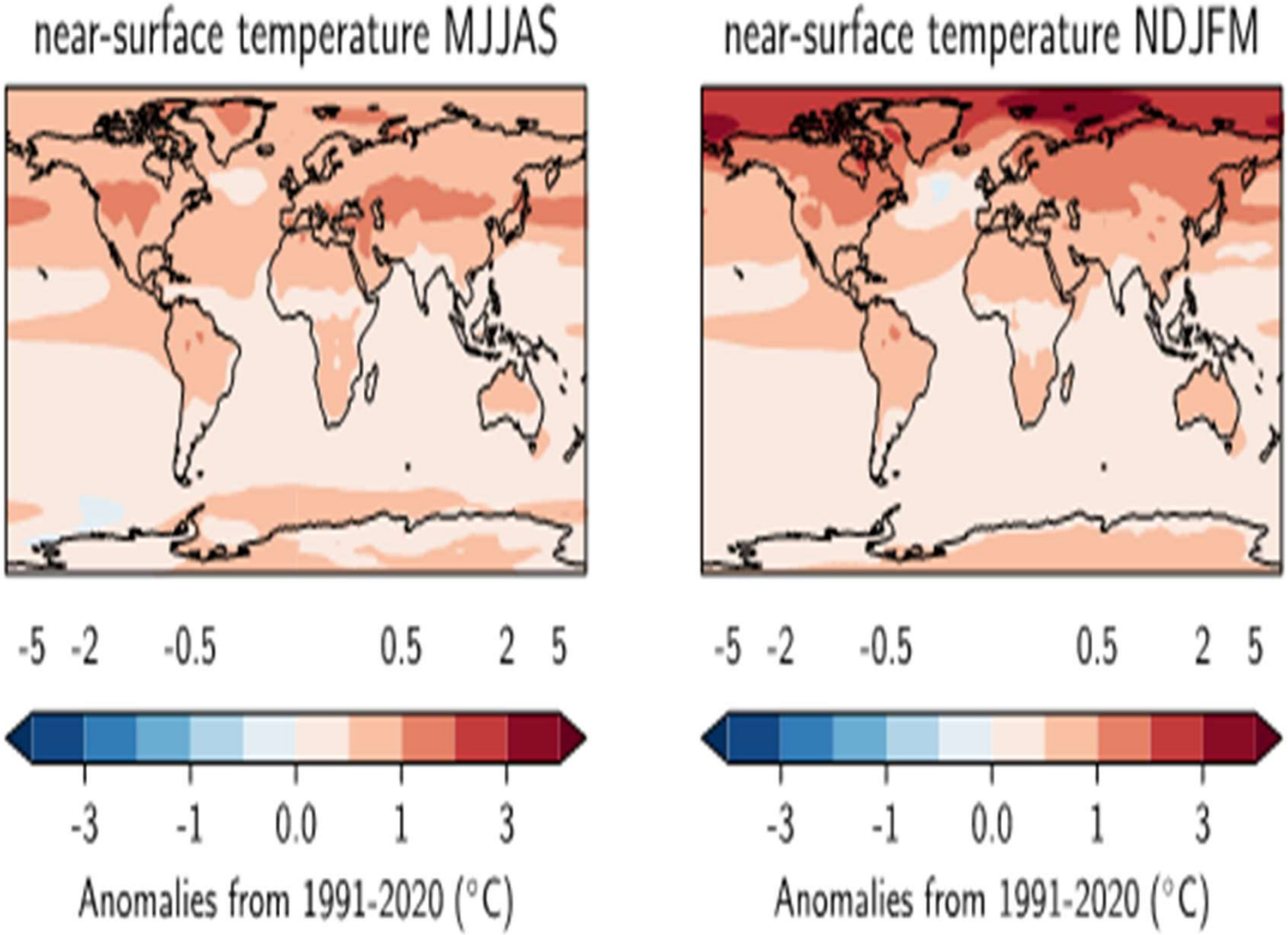
OVERVIEW

- *Recent climate changes – five key facts:*
- *CO_2↑, <T_{2m}>↑, sea level↑, OHC↑, glaciers ↓*
- *Tele-connections ⇔ Mediterranean, Adriatic, …*
- *Fishery, Forestry, Energy, Agriculture-overall, Traffic, Insurance, Research, Education…*

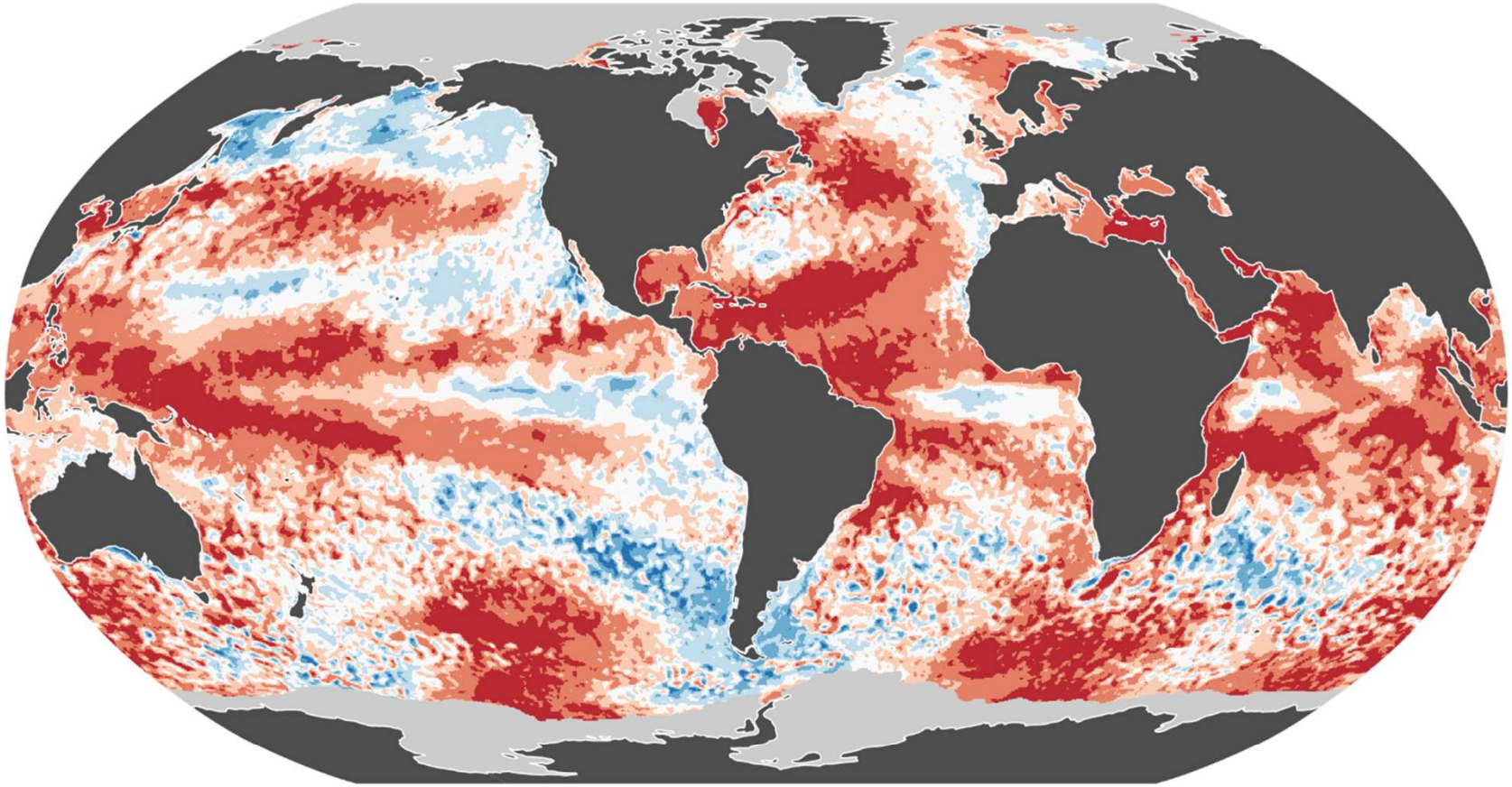

Global mean temperature
Compared to 1850-1900 average
HadCRUT5 (1850-2022)
NOAAGlobalTemp (1880-2022)
GISTEMP (1880-2022)
Berkeley Earth (1850-2022)
JRA-55 (1958-2022)
ERA5 (1979-2022)
°C
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
−0.2
−0.4
1860
1880
1900
1920
1940
1960
1980
2000
2020
Year

Ensemble mean forecast 2023-2027



Anomalies and extremes in sea surface temperature in June 2024

Data: ERA5 1979–2024 • Reference period: 1991–2020 • Credit: C3S/ECMWF



Sea ice & ice shelves | Coolest | Much cooler than average | Cooler than average | Near average | Warmer than average | Much warmer than average | Warmest

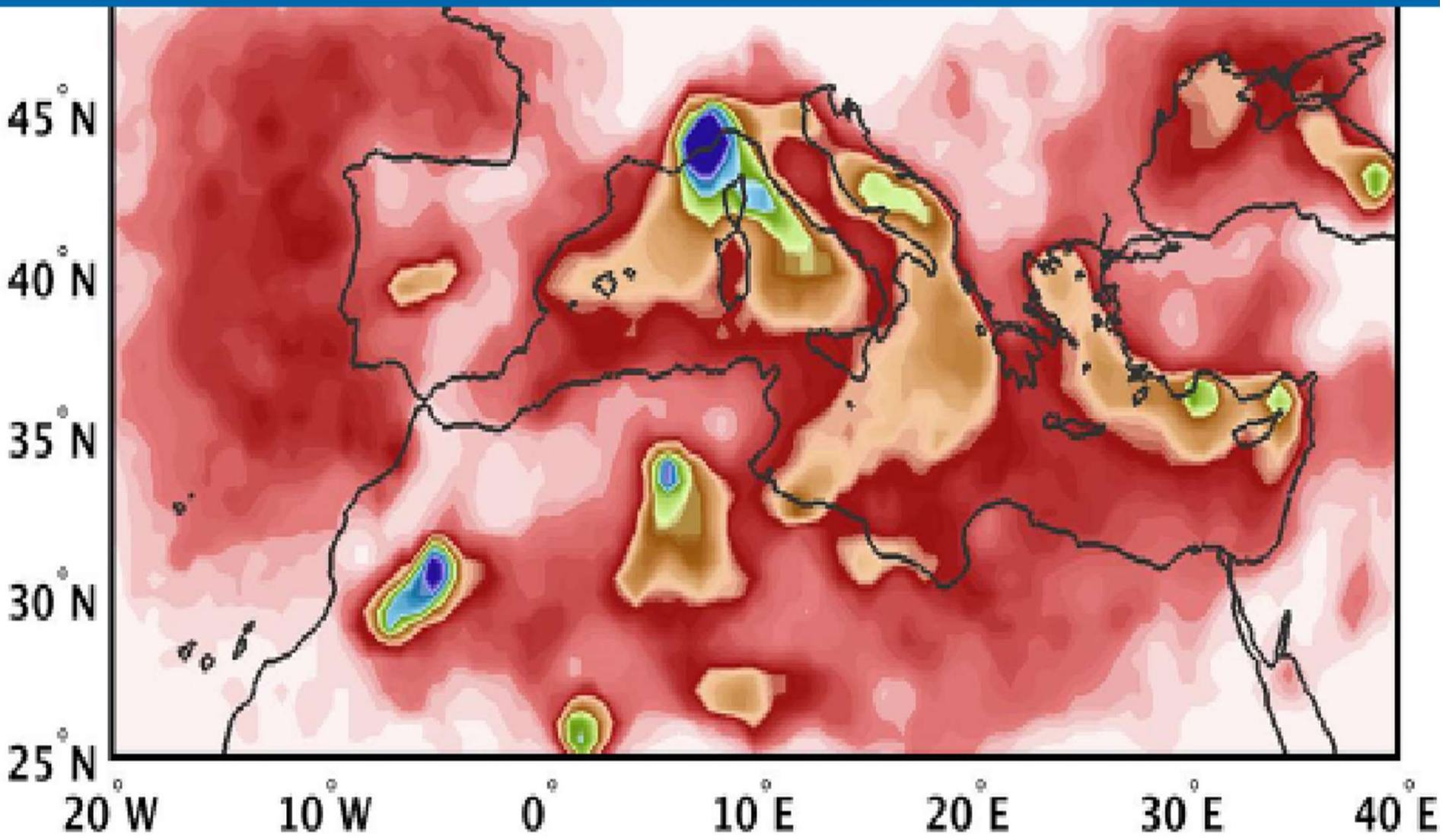
PROGRAMME OF THE EUROPEAN UNION

Copernicus Europe's eyes on Earth

IMPLEMENTED BY ECMWF

Climate Change Service climate.copernicus.eu

Med cyclones climatology

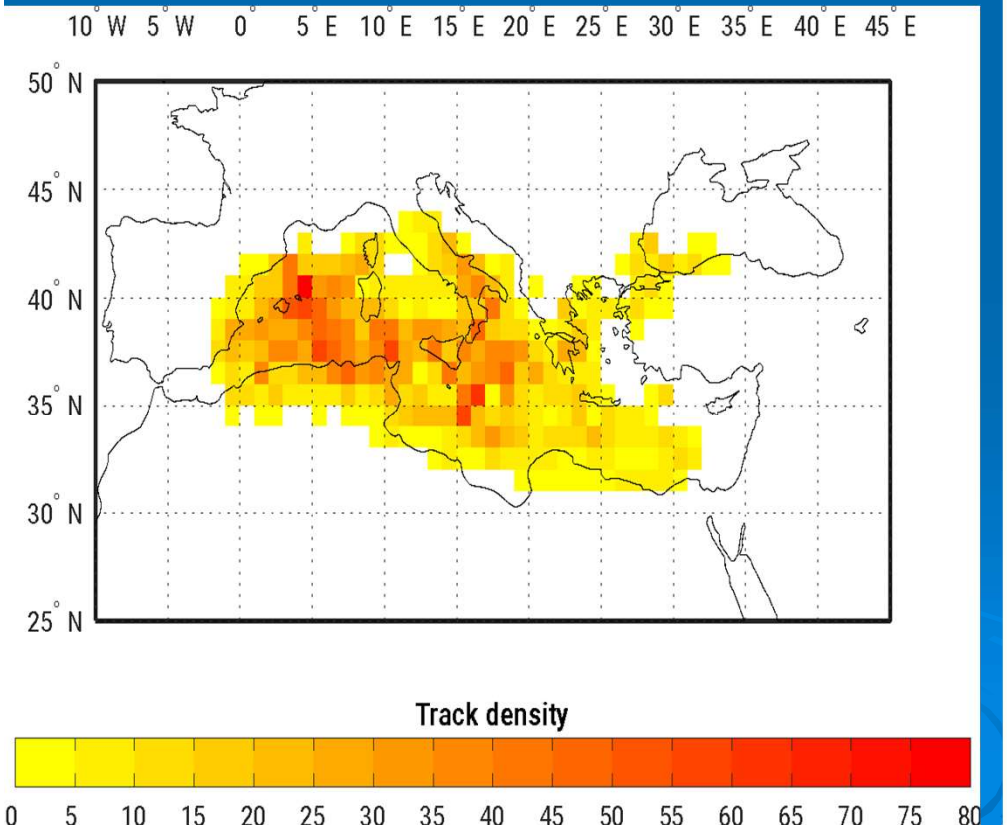


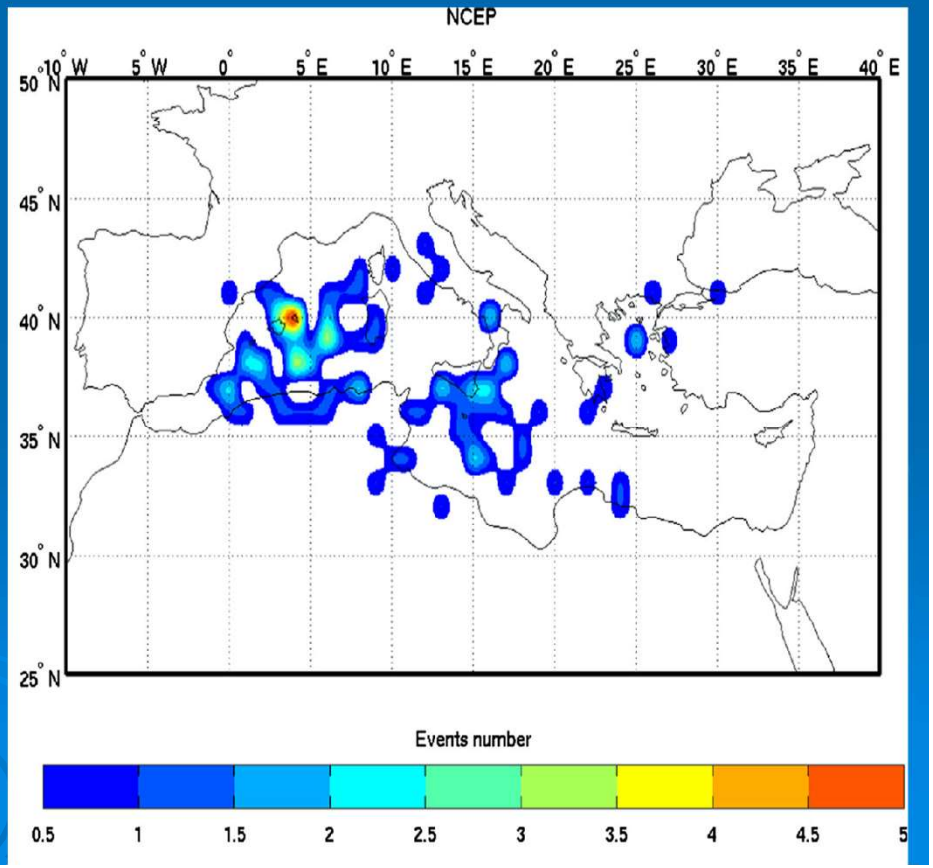
Mediterranean tropical-like cyclones climatology

Most Mediterranean cyclones are extratropical cyclones
Some of them develop tropical-like characteristics: medicanes, biscanes, adricanes…
A frequency of 1-2 events per year is estimated in climatological studies

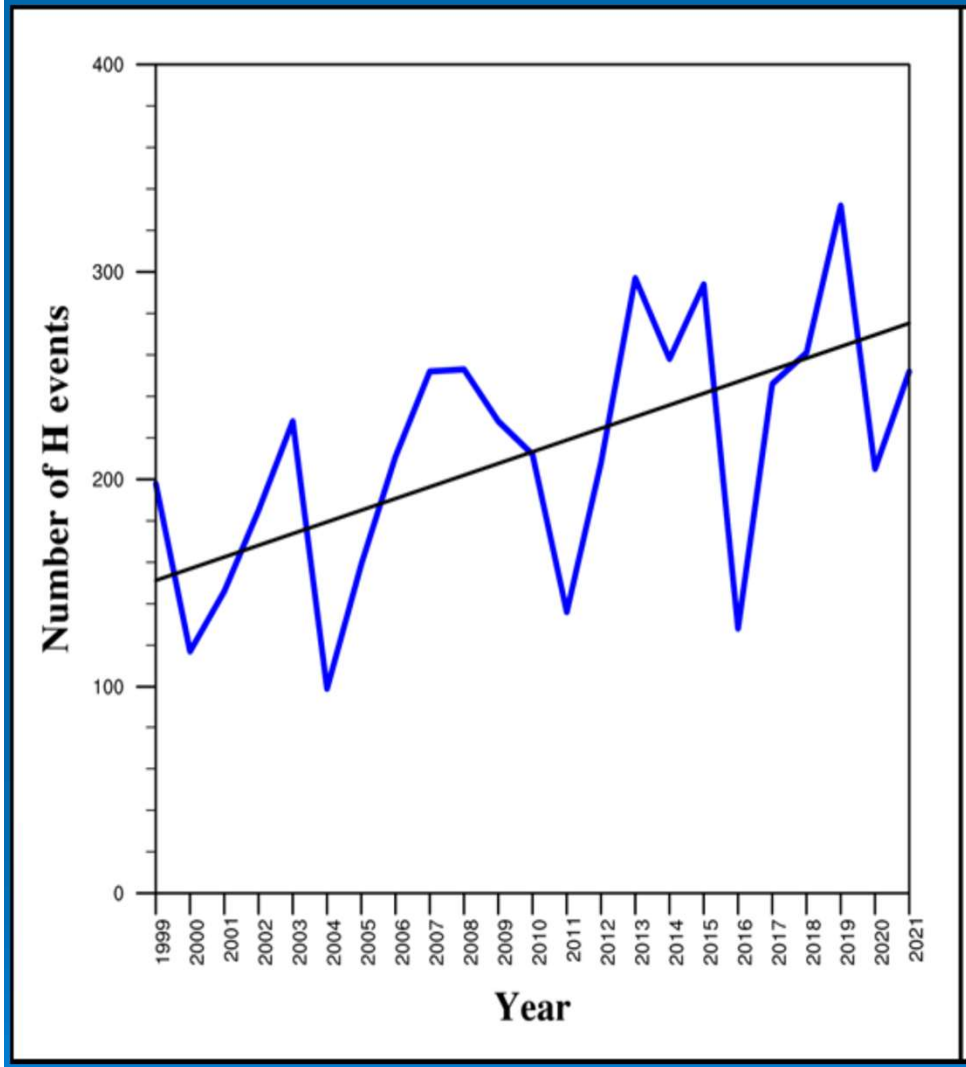
Dynamical downscaling of NCEP reanalysis

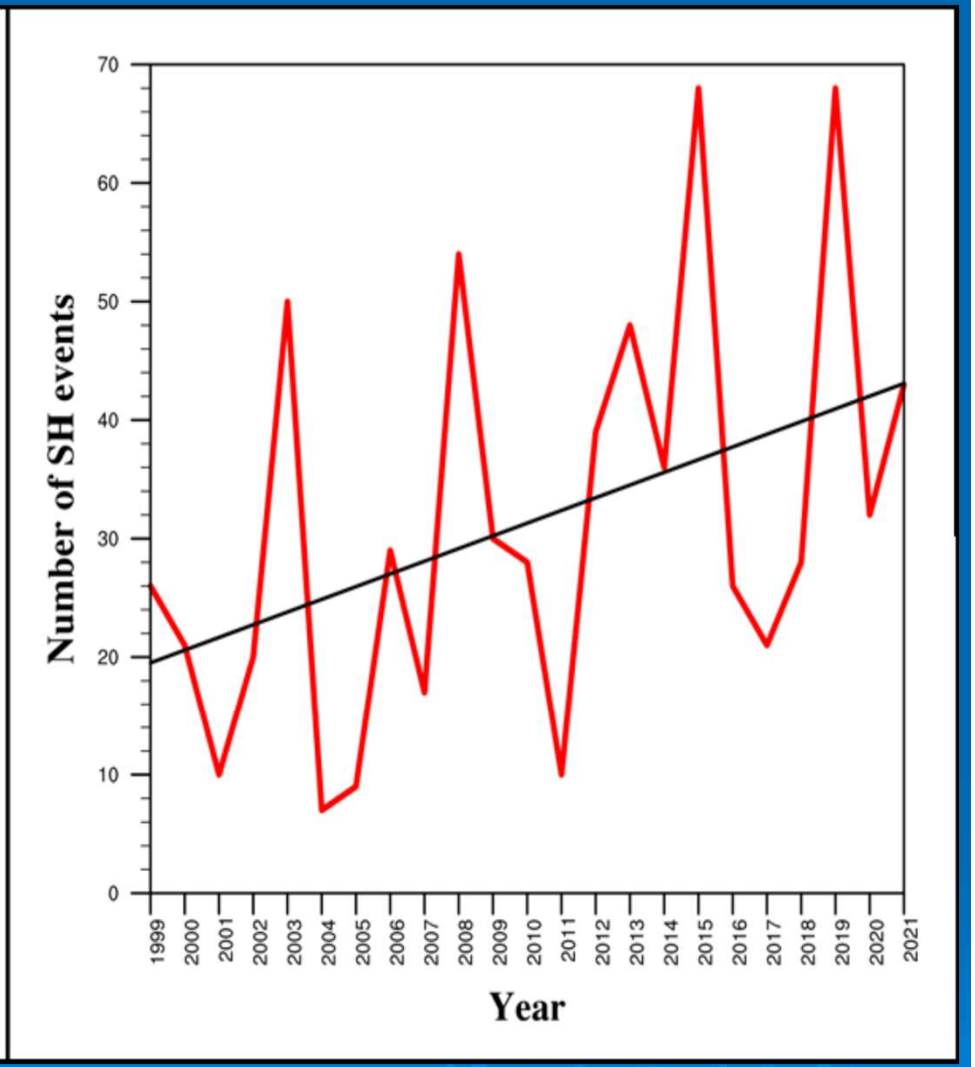
Cavicchia Leone et al. 2014





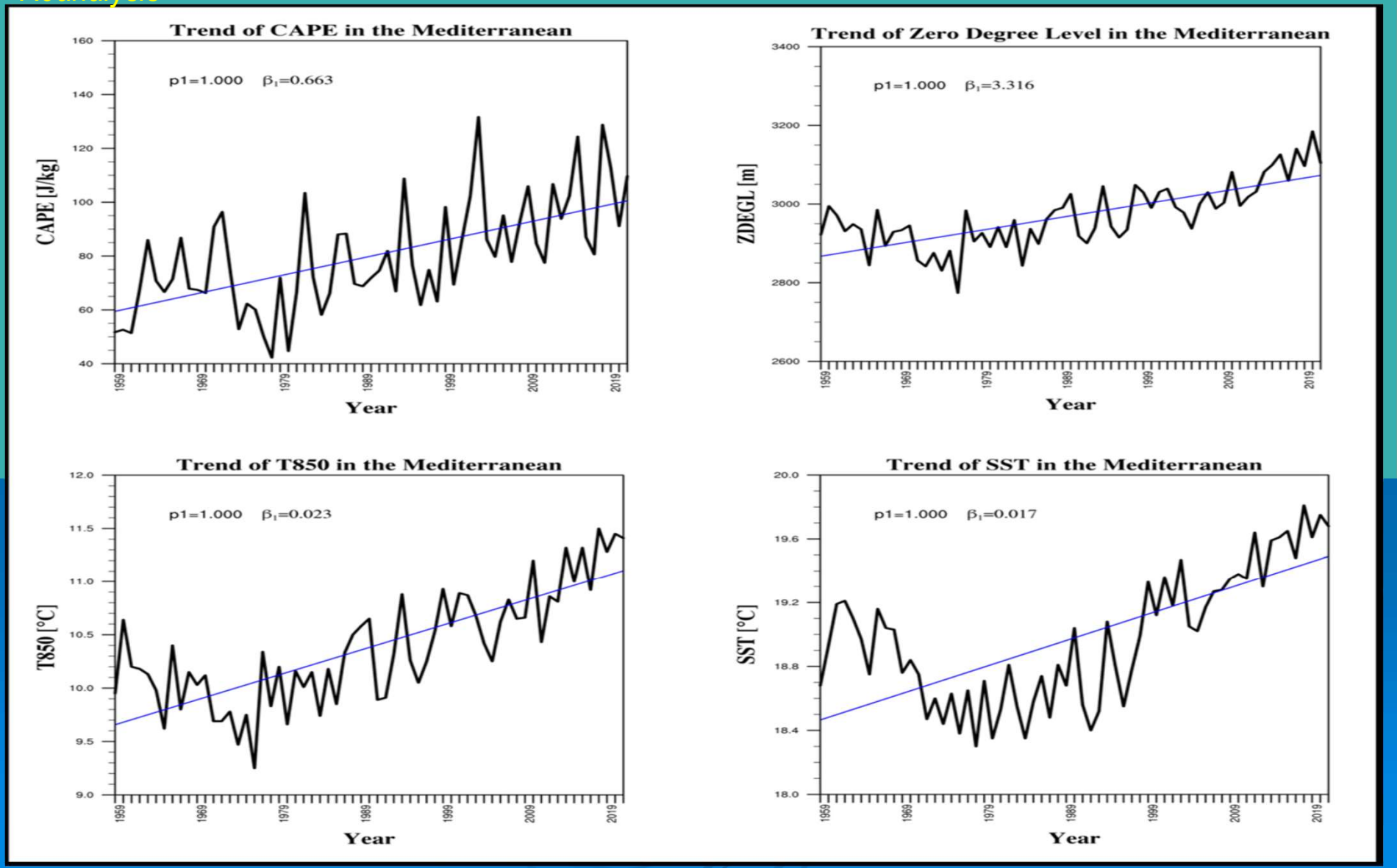
Hail & Severe Hail, H & SH, Mediterranean events





Temporal evolution 1991-2021 of annual numbers of H & SH events for ***entire Mediterranean Basin*** *considering combined measurements from NOAA 15, MetOp-A & MetOp-C satellites. Black lines ⇔ linearized trends of the data. Credit: Adapted from Laviola et al. (2022)*

*Annual trends 1959-2021 for **C**onvective **A**vailable **P**otential **E**nergy (**CAPE**, J/kg), 0-deg. level (**ZDEGL**, m) altitude, **T**emp. at **850** mb (**T850**) & **S**ea **S**urface **T**emperature (**SST**) calculated over entire Mediterranean Sea. Blue = linearized trends of the data. Credit: Laviola et al. (2022), ERA 5 = ECMWF Reanalysis*

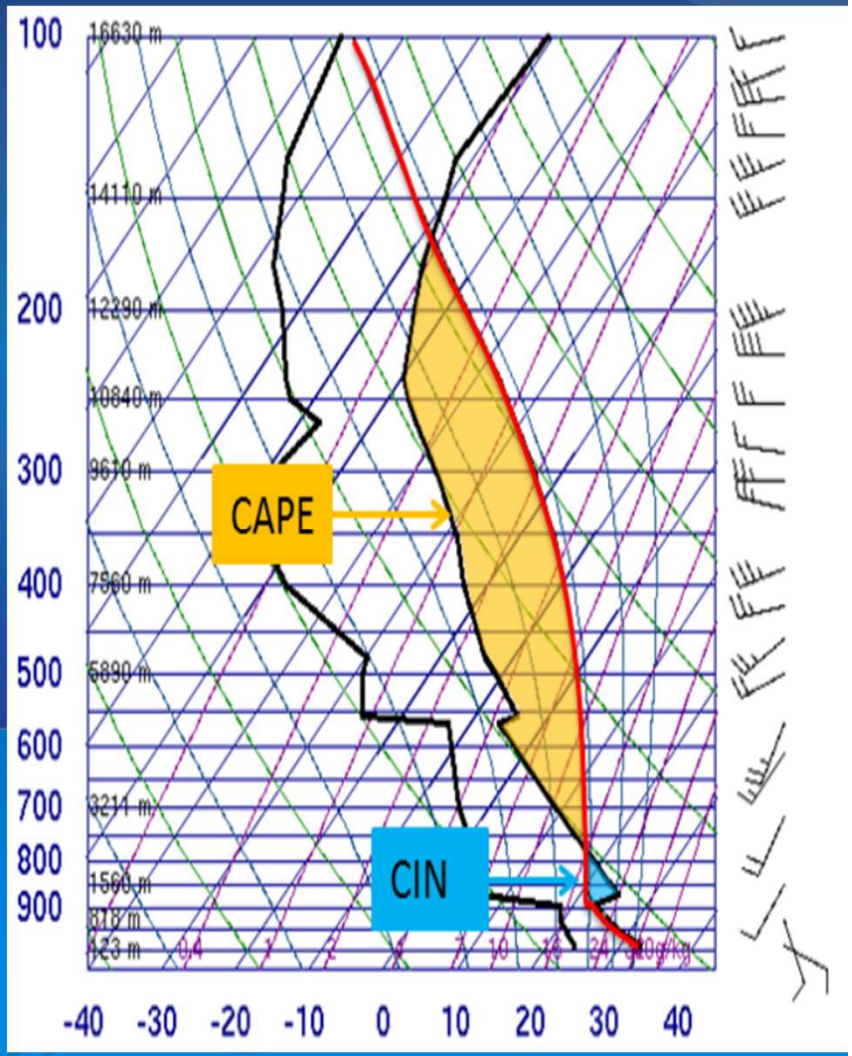


Deep Moist Convection – Ingredients based forecasting

- *Each convection cell needs 3 things:*

1. *Moisture in the lower troposphere*
2. *Instability, CAPE*
3. *Mechanism to break 'the lid' above, CIN*

CAPE –Convective Available Potential Energy



Air sounding ⟶ ZGB
Maksimir, 19.7.2023

DRŽAVNI HIDROMETEOROLOŠKI ZAVOD
CROATIAN METEOROLOGICAL AND HYDROLOGICAL SERVICE

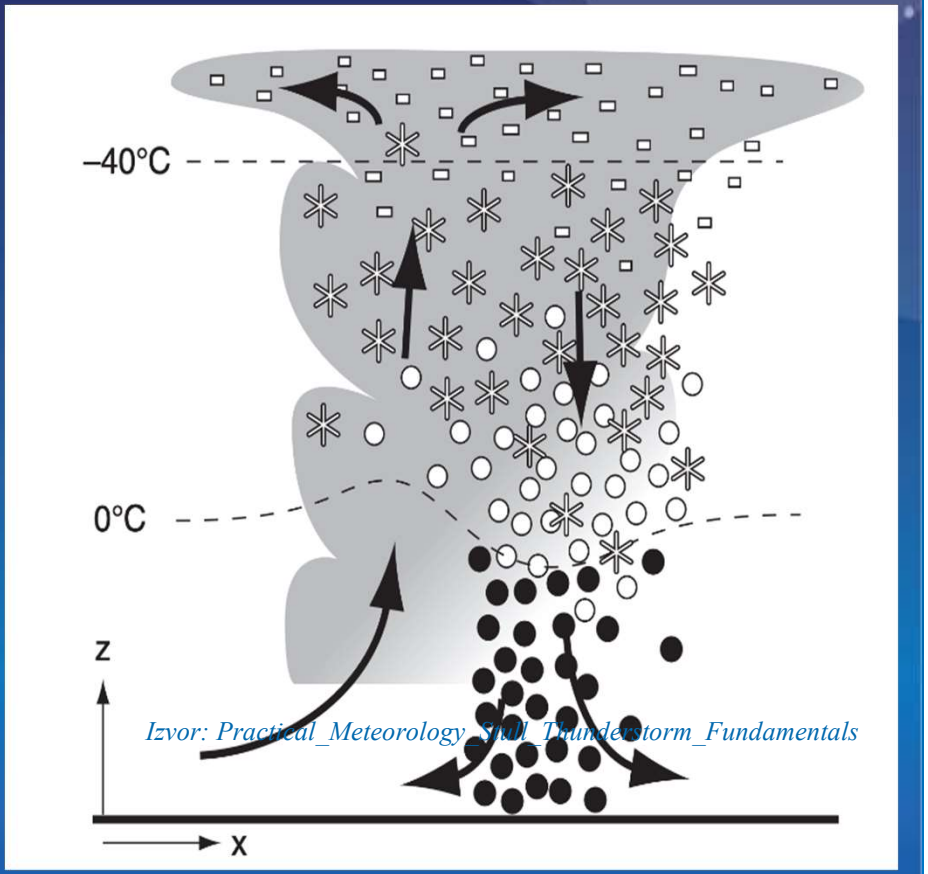
Forecasting deep moist convection – in general

Convection spread

- *CIN – convection inhibition*
- *Triggering & strength of forcing*

Convection organization

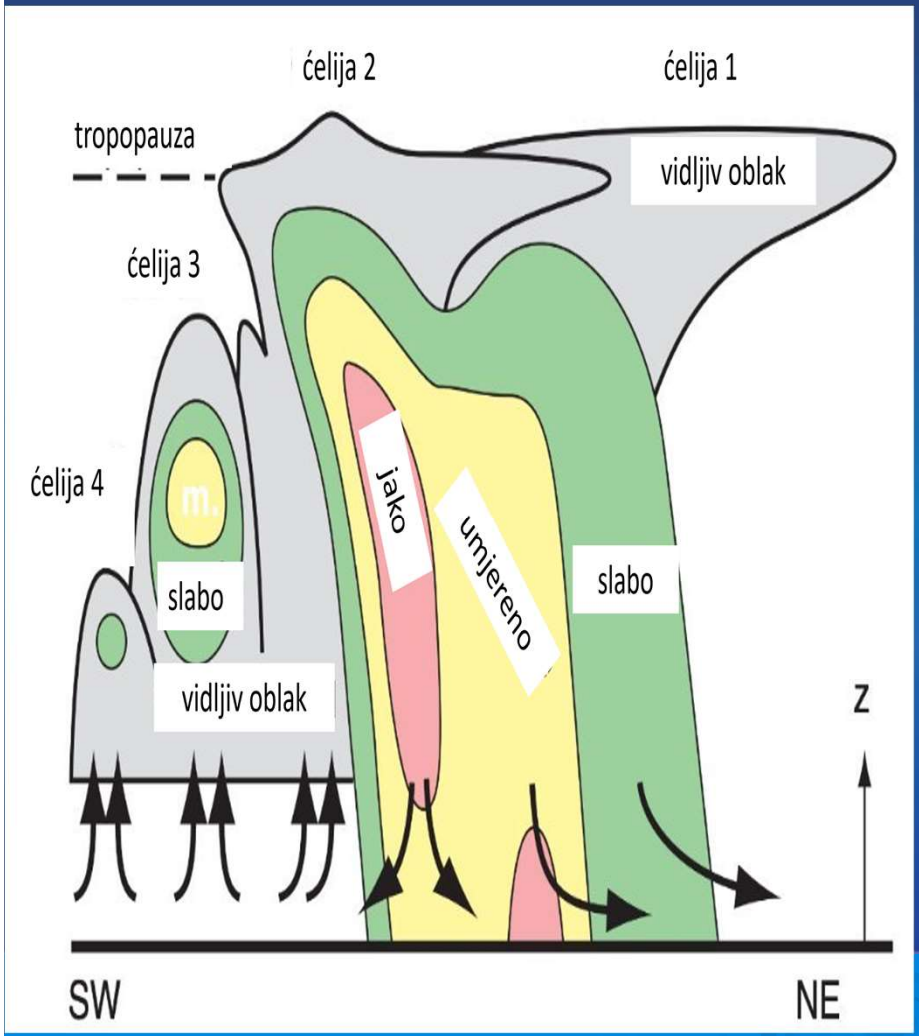
- *Spatio-temporal distribution*
- *Vertical wind shear within 0 – 3 km & 0 – 6 km altitude*



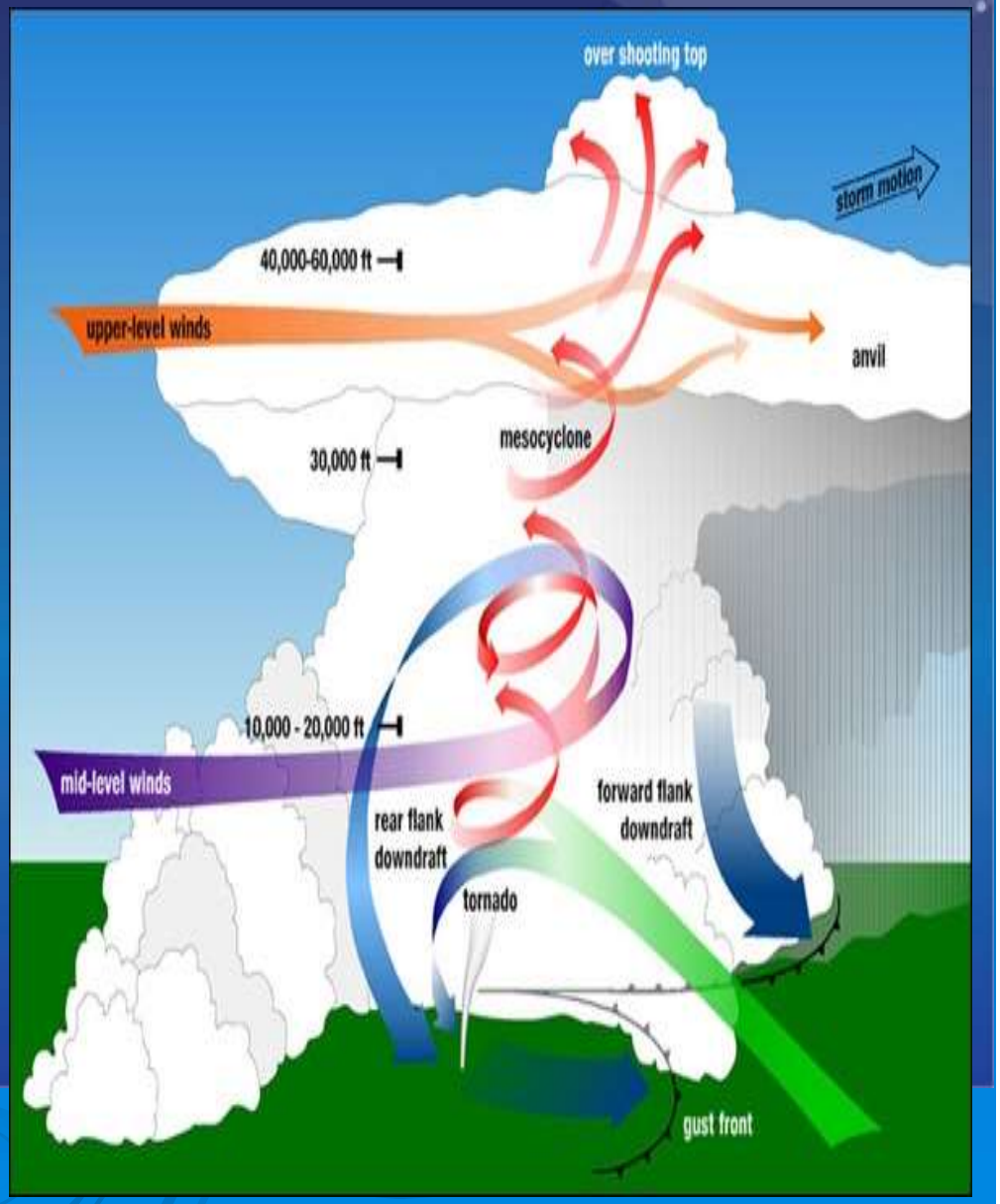
Izvor: Practical_Meteorology_Stull_Thunderstorm_Fundamentals

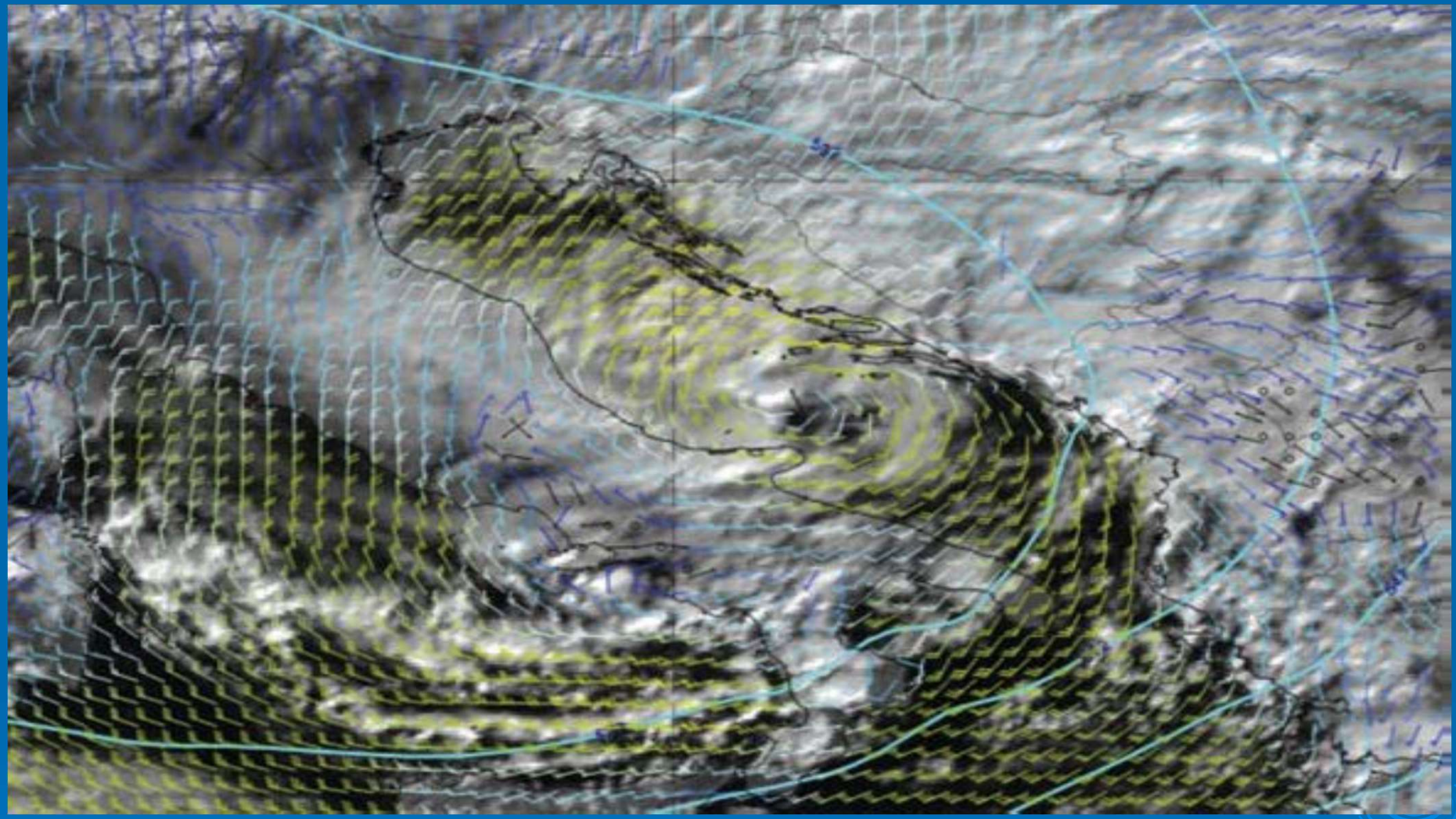
More organized → more intensive → more extreme-wise !

Multicell convective system

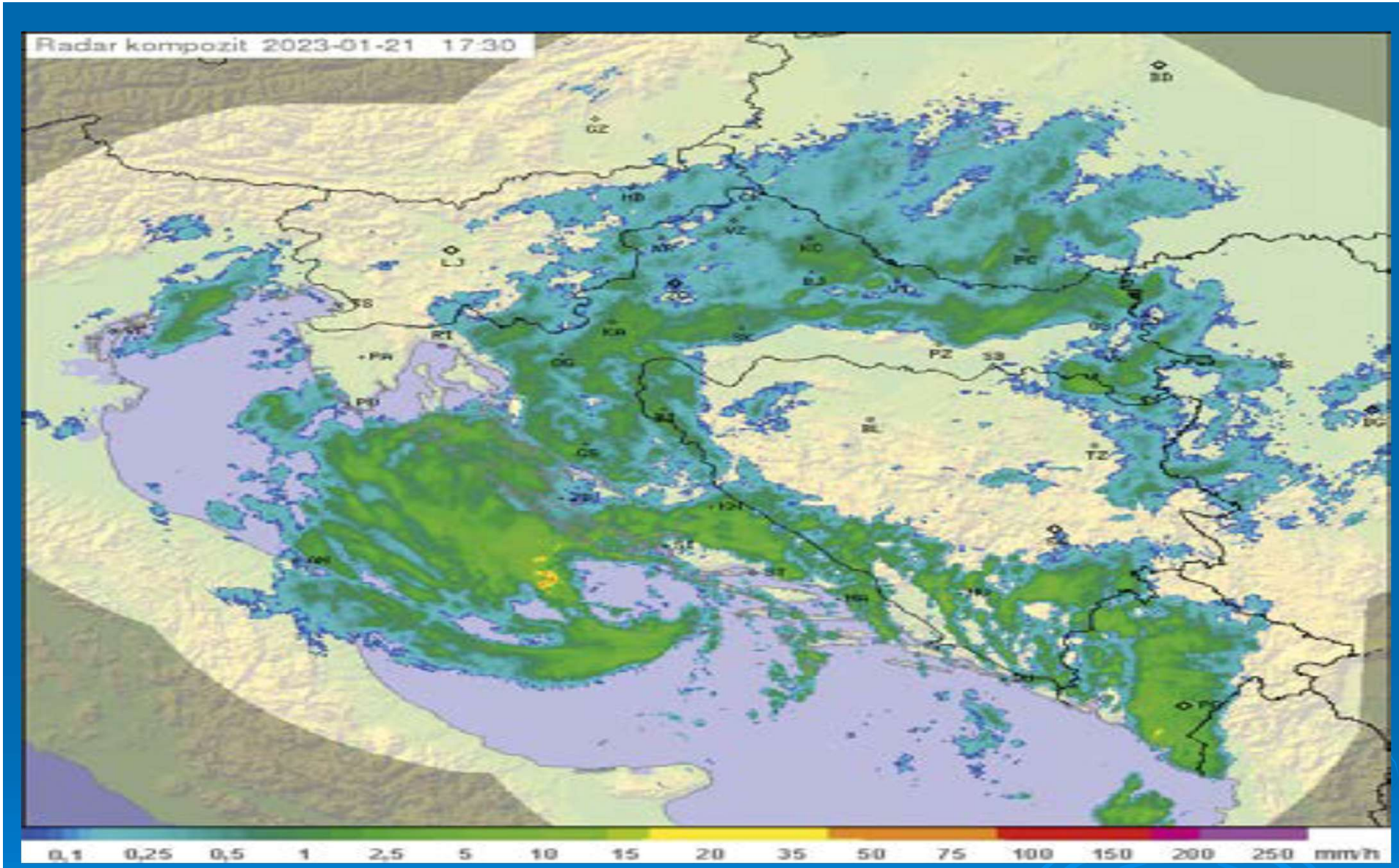


Supercell

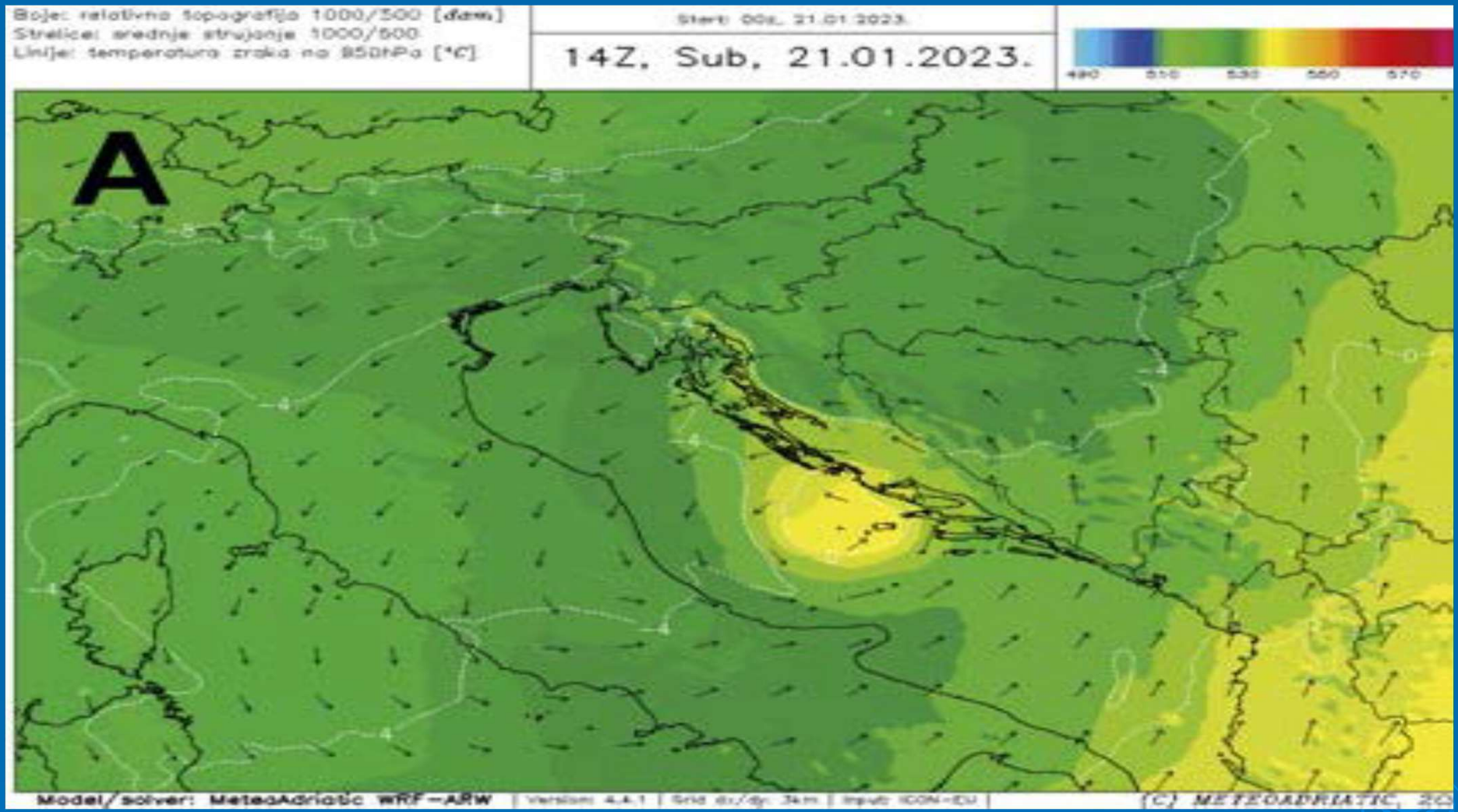




Satellite image in the visible spectrum at 09 UTC on 21.1.2023 (EUMETSAT); barbs show 10 m wind speed and direction; blue lines are geopotential at 500 hPa (ECMWF analysis). The cyclonic eye near the center of rotation was clearly visible. Source: eumetrain.org



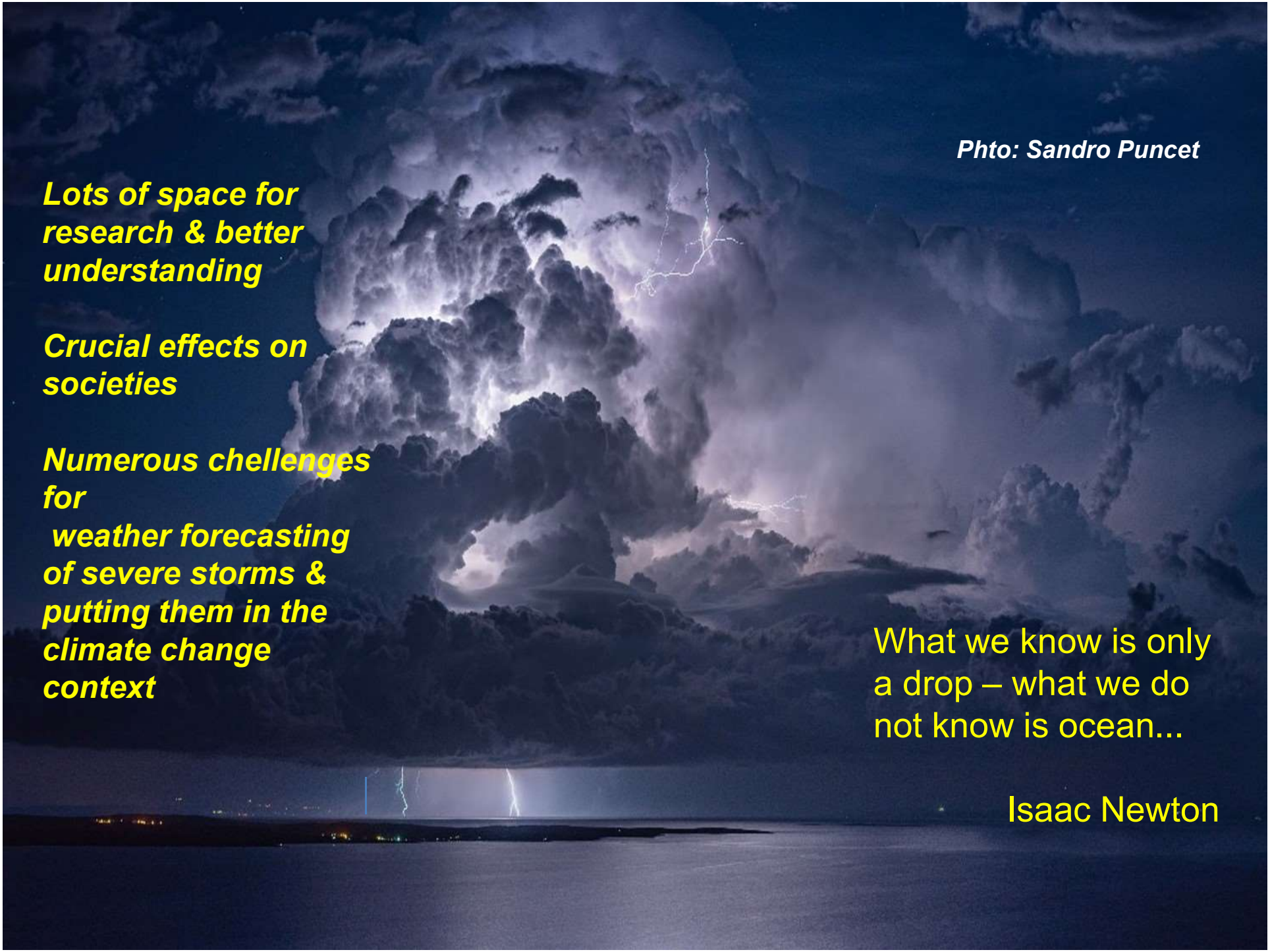
Composite radar image from the Cro. Wea. Service radar network for 21.1.2023 16:30 UTC. Relatively symmetric precipitation bands were noticeable around the clear cyclonic eye. Source: meteo.hr



WRF-ARW model output. The predicted field of 1000 to 500 hPa thickness (i.e., relative topography, color shading) for 21.1.2023 at 14 UTC shows a well-isolated warm core of the vortex embedded within the cold air mass inside a larger upper trough. The track of the system led to "landfall" and dissipation around Ancona city during the night hours, 22.1.2023; Source: meteoadriatic.net (Toman and Grisogono, CMJ 2023)

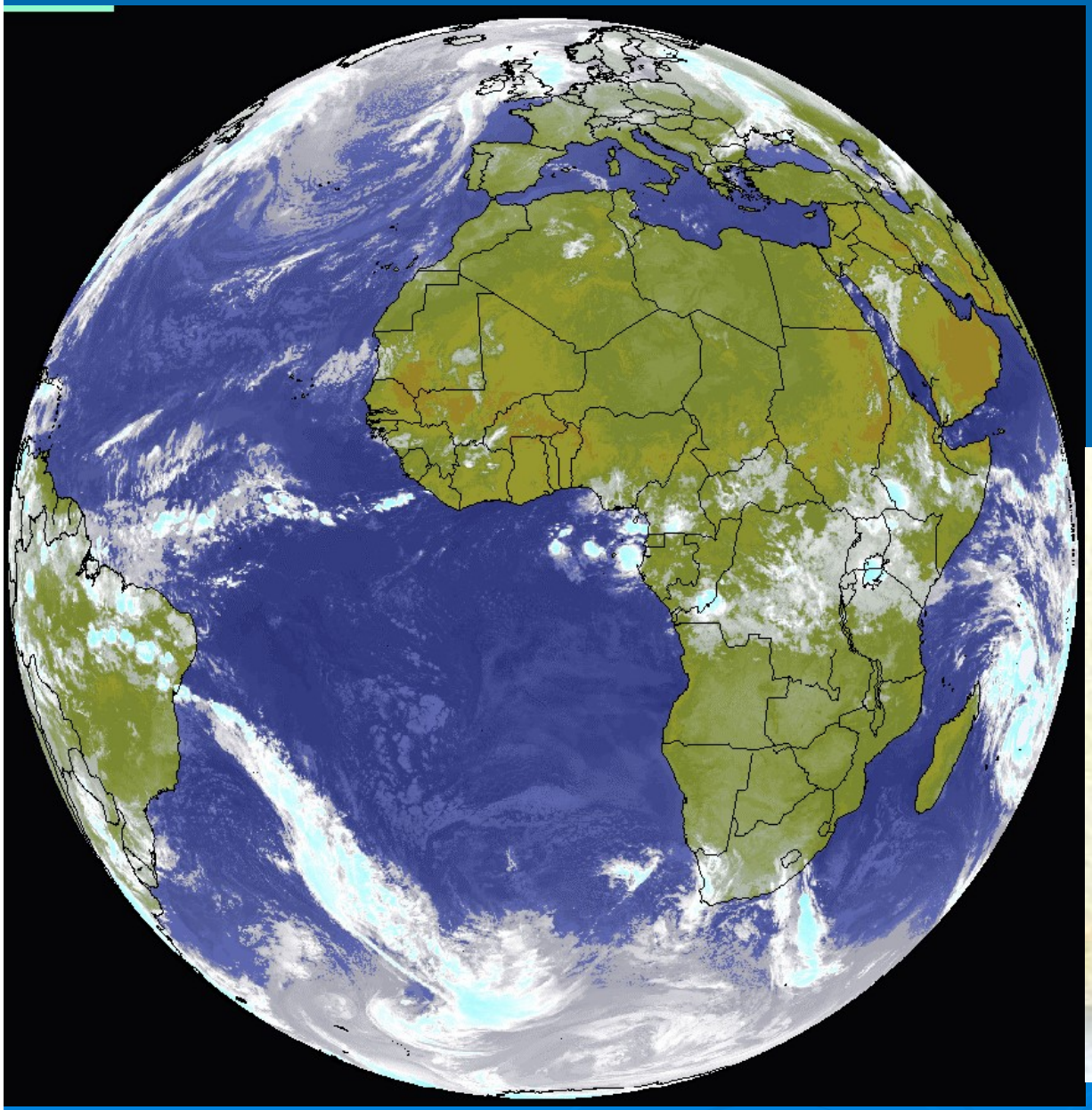
The Adriatic & significant parts of the Mediterranean sea:

1. *Warming up from above*
2. *Layering more intensively*
3. *Loosing O2*
4. *Loosing its bio-diversity*


Phto: Sandro Puncet
Lots of space for research & better understanding
Crucial effects on societies
Numerous chellenges for weather forecasting of severe storms & putting them in the climate change context
What we know is only a drop – what we do not know is ocean...
Isaac Newton

Conclusions

- *Recent climate changes accelerate – contrary to political etc. promises, eh …*
- *Tele-connections ⇔ interactive nonlinear multi-scale geophysical/chemical/biological/social processes …*
- *Longer sub-seasonal forecasts, 1-4 weeks ahead should be very beneficial for the society*
- *Fine scale climate simulation projections with ever finer postprocessing for sea, agriculture, forestry,…*



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