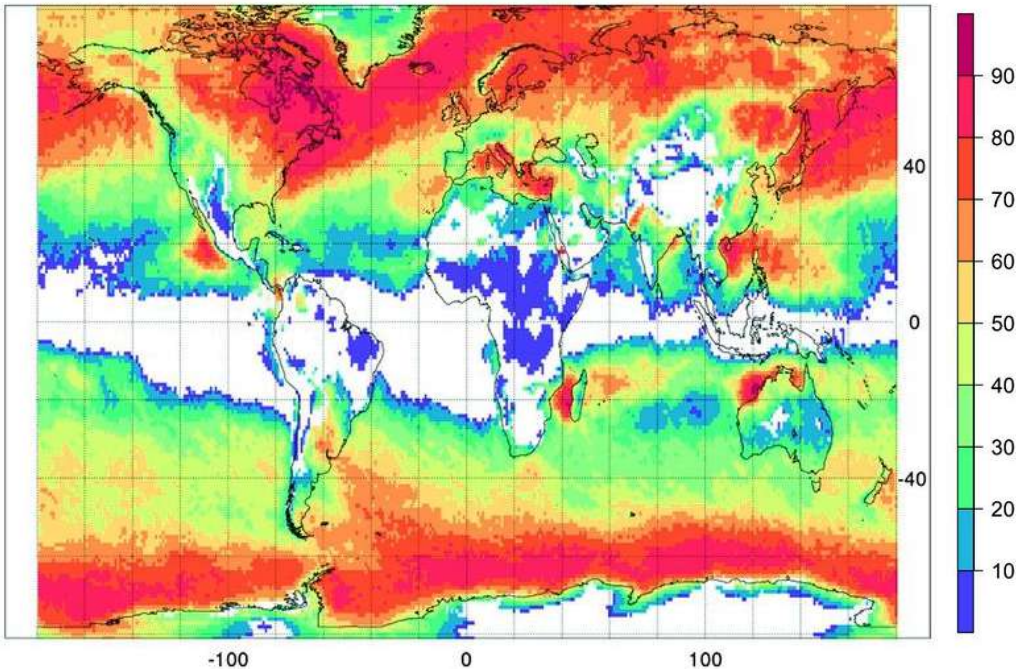
UNIVERSITÄT BERN

Lagrangian and Eulerian viewpoints on the link between Mediterranean cyclones and compound extremes

A Portal, R Rousseau-Rizzi, S Raveh-Rubin, J L Catto, Y Givon, O Martius
Contributions by B Doiteau

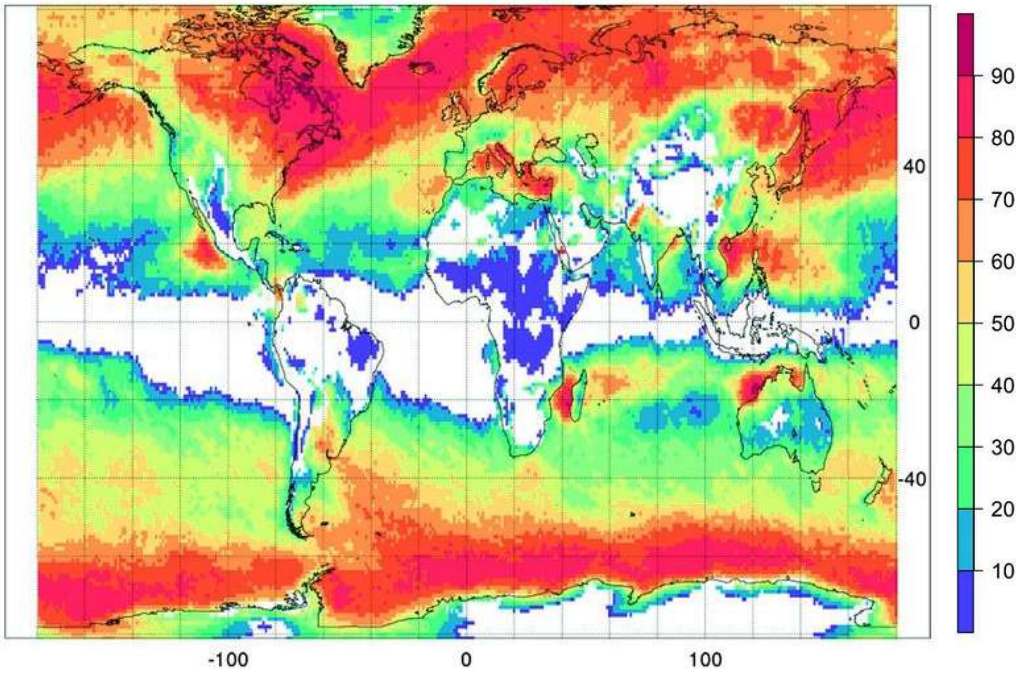
17 July 2024 - 3rd MedCyclones Workshop, ESA-ESRIN, Frascati (Rome)

Cyclones and precipitation extremes ☔



Percentage of precipitation extremes occurring with a cyclone
Pfahl and Wernli 2012

Cyclones and precipitation extremes ☔

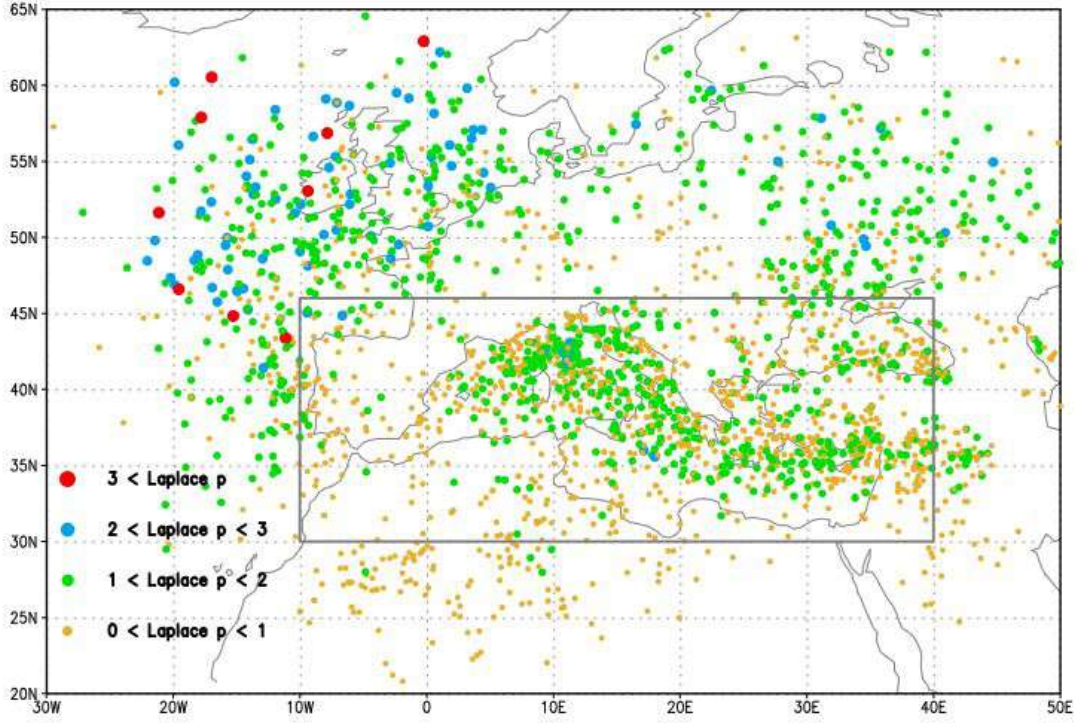


Percentage of precipitation extremes occurring with a cyclone
Pfahl and Wernli 2012

Most heavy rain events (>60 mm/24h) in the Western Mediterranean are located within 600 km from a cyclone center
Jansa et al. 2001

Cyclones and wind extremes

Cyclones causing wind extremes in the Mediterranean region



Nissen et al. 2010

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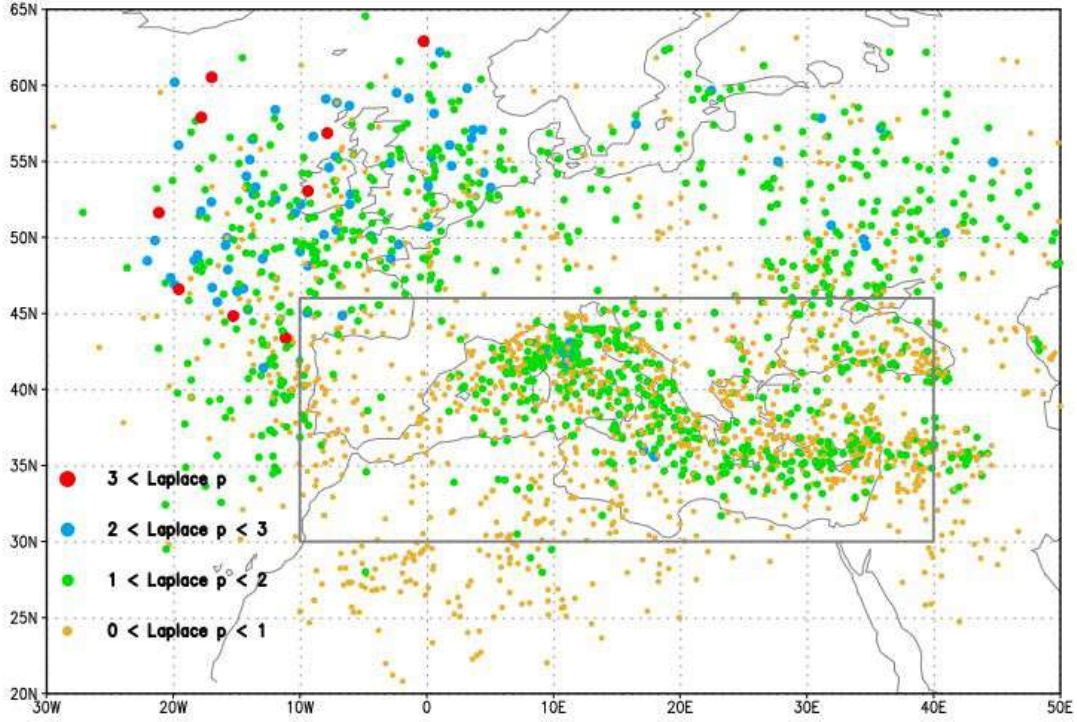
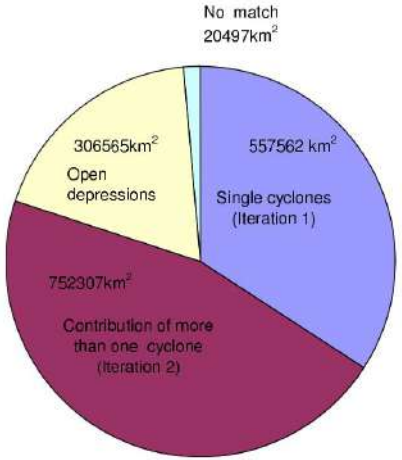


Area of wind extreme: dependence on cyclone association



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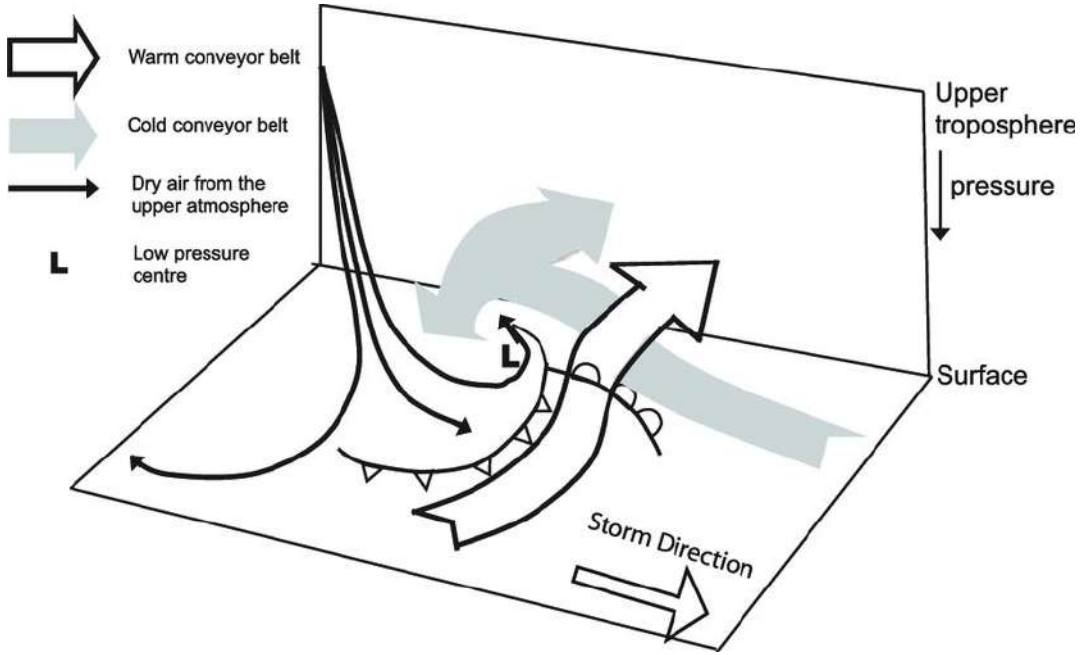
Cyclone circulation and air-stream properties 🌡️💦



Catto 2013

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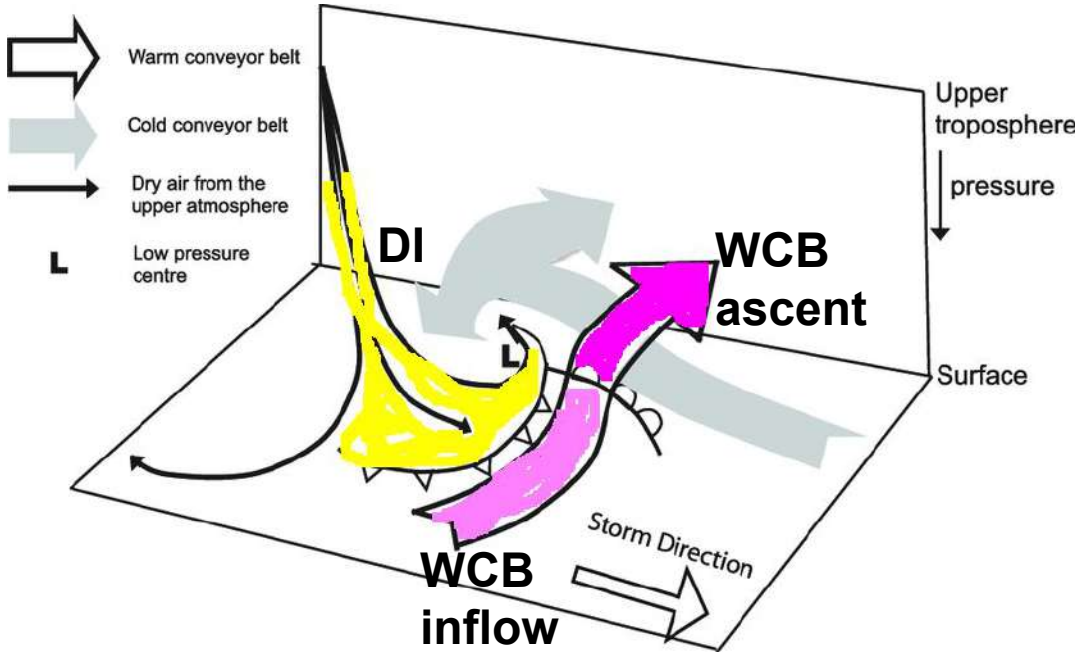

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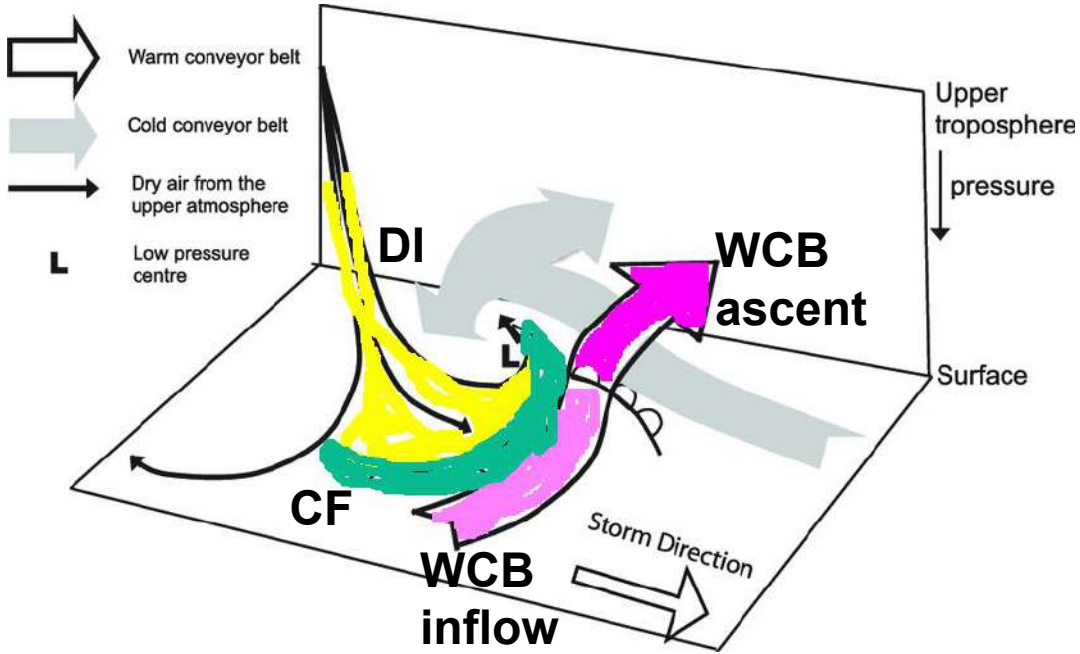

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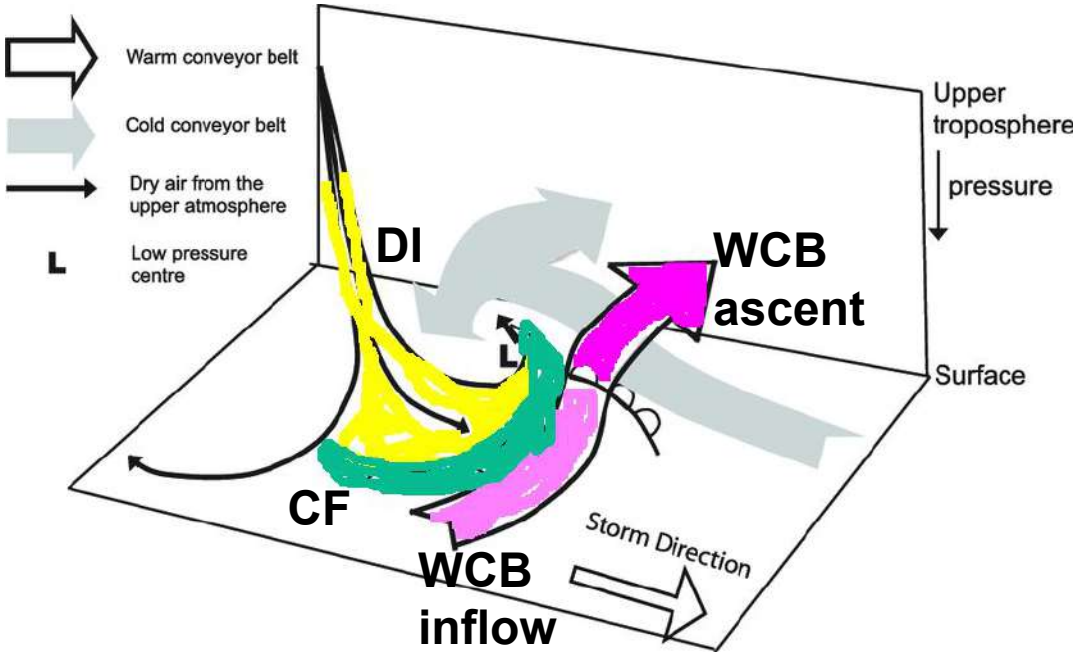

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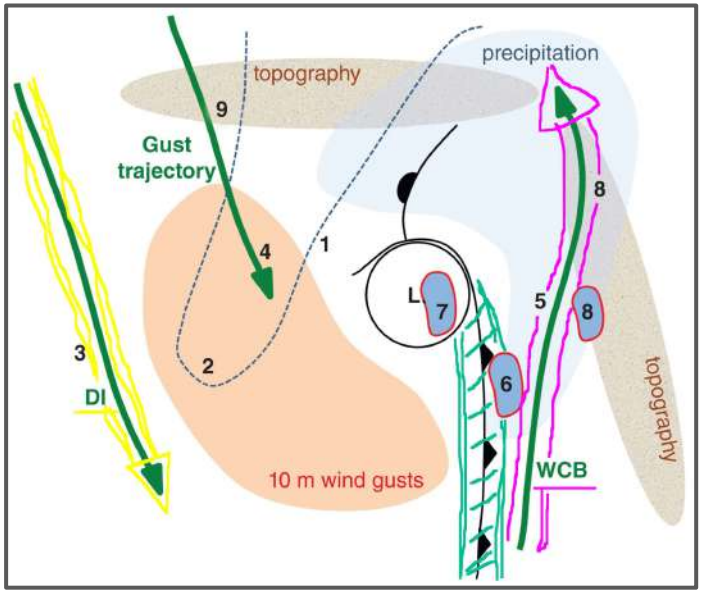
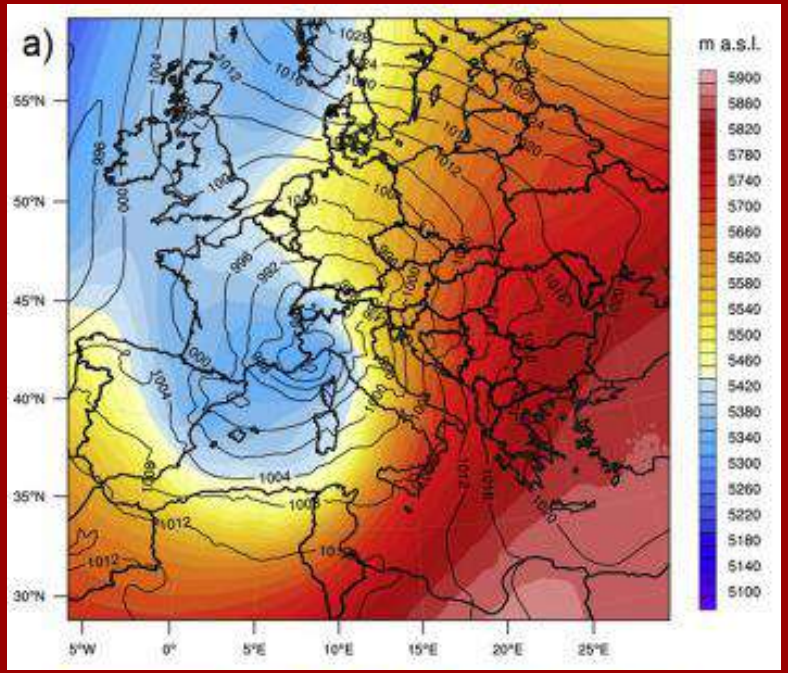


Raveh-Rubin and Wernli 2016

Striking events

Storm Vaia, 27-29 October 2018

500-hPa GptH and slp (hPa)

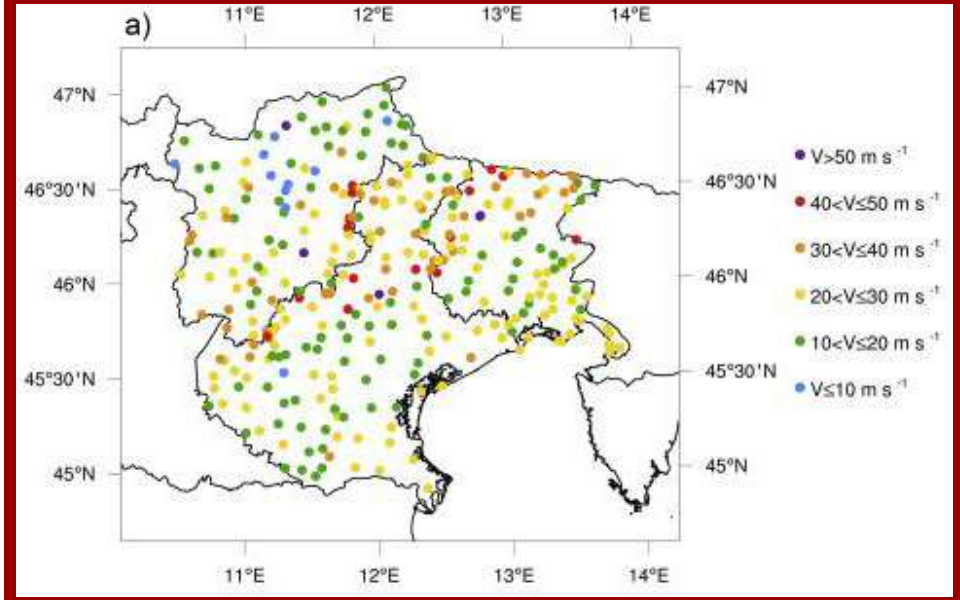


Giovannini et al. 2021

Striking events

Storm Vaia, 27-29 October 2018

Maximum wind gust at 10 m over the entire event at available weather stations

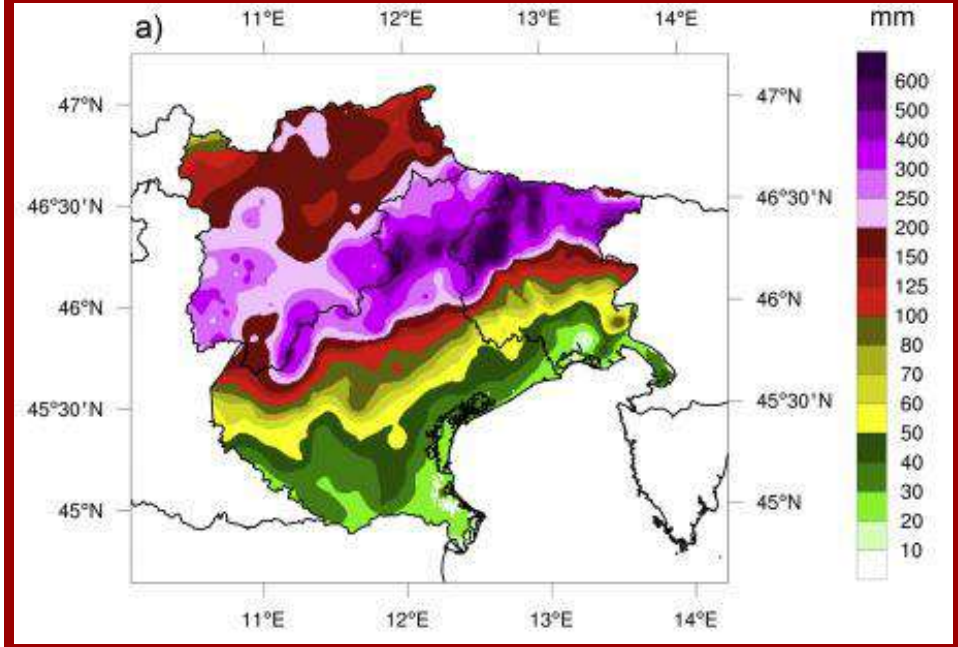


Giovannini et al. 2021

Striking events

Storm Vaia, 27-29 October 2018

Observed 72-h accumulated precipitation



Giovannini et al. 2021

Striking events

Storm Vaia, 27-29 October 2018

The compounding of extreme rainfall and winds can have unpredictable effects.

E.g., for Storm Vaia the management of river debris (forest wood).

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Storm Vaia, 27-29 October 2018

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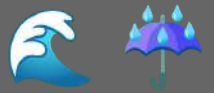
Rain and Wind → coastal flooding, building damage, emergency mng, clogging of sewers, ...

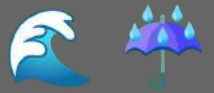


Waves and Rain → coastal flooding

Heat and Dust (PM10) → health risk

Other examples of impactful weather compounds

Waves and Wind → heavy seas impacting maritime transport and coasts



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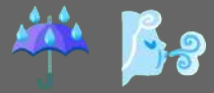
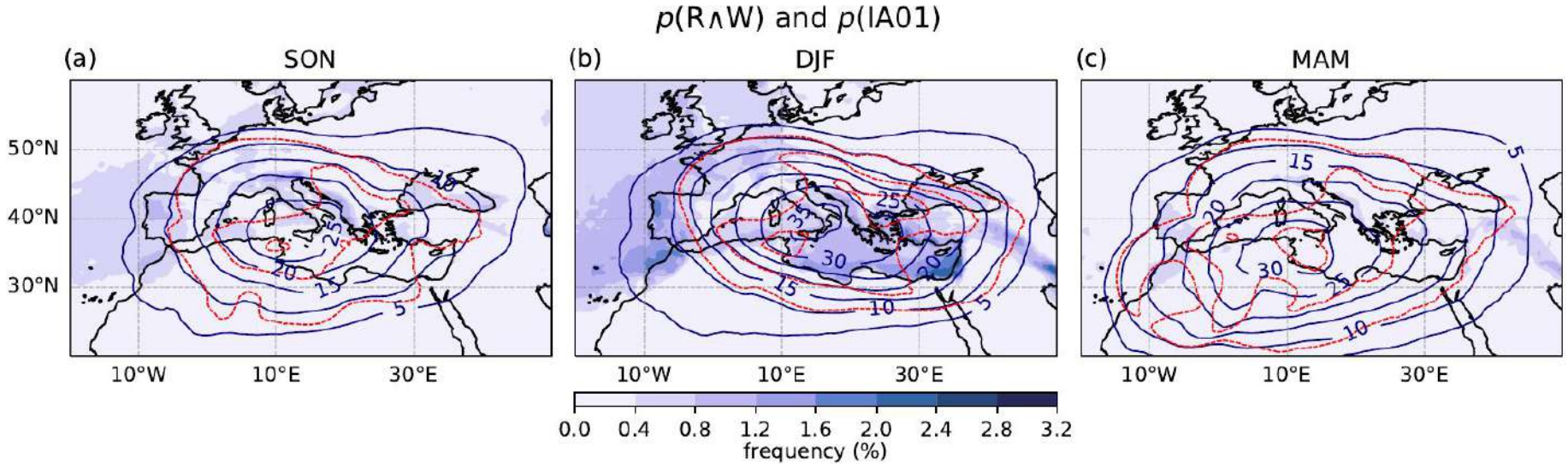


Rain and Wind → coastal flooding, …

Waves and Wind → heavy seas impacting maritime transport and coasts

Rain and Wind ☔ 🌬️: compound frequency

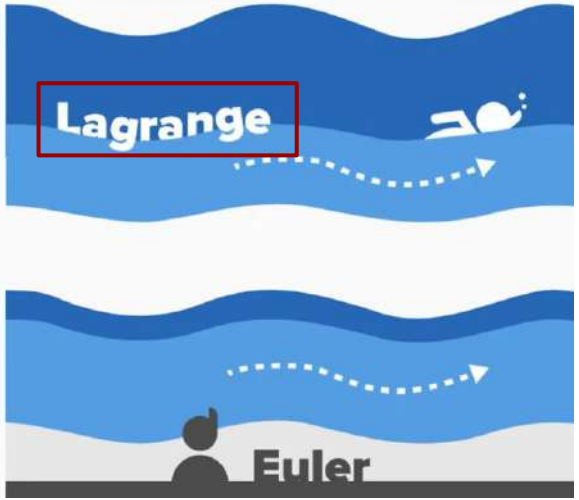


Uni-variate extremes from ERA5:

☔ total precipitation > max(pct, low_bound)

🌬️ 10-m wind / windgust > max(pct, low_bound)

Lagrangian viewpoint: how to treat Med-cyclones?

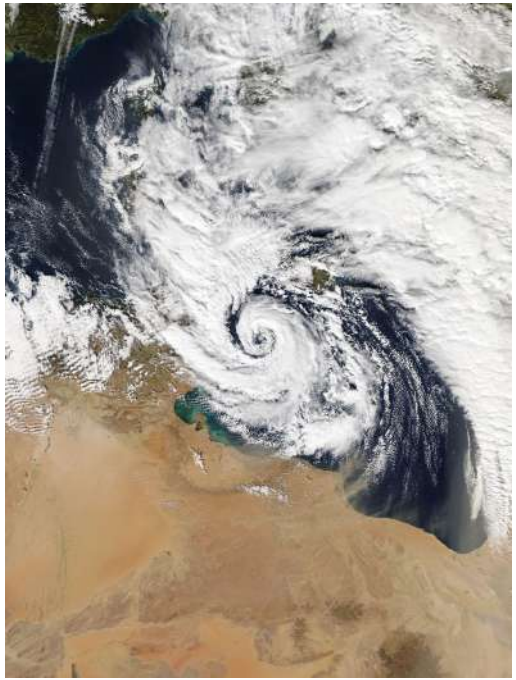


Med-cyclones from Flaounas et al. 2023 composite tracks (conf. level 5)

Lagrangian viewpoint: how to treat Med-cyclones?

Storm Xena, Nov 2018

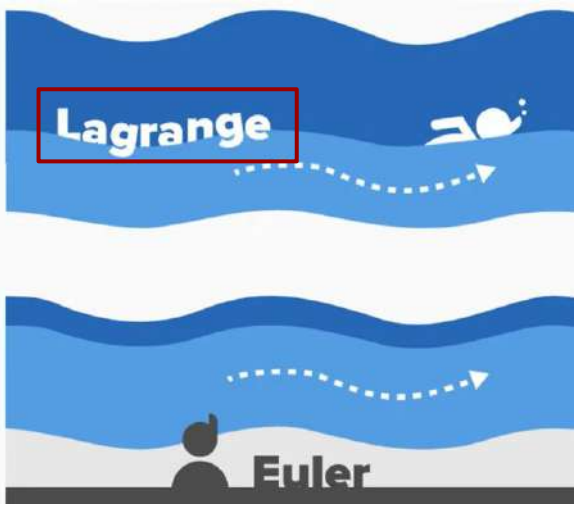
Medicane (?) Qendresa, Nov 2014



Saharan storm, Sep 2014

Medicane Ianos, Sep 2020

Lagrangian viewpoint: how to treat Med-cyclones?

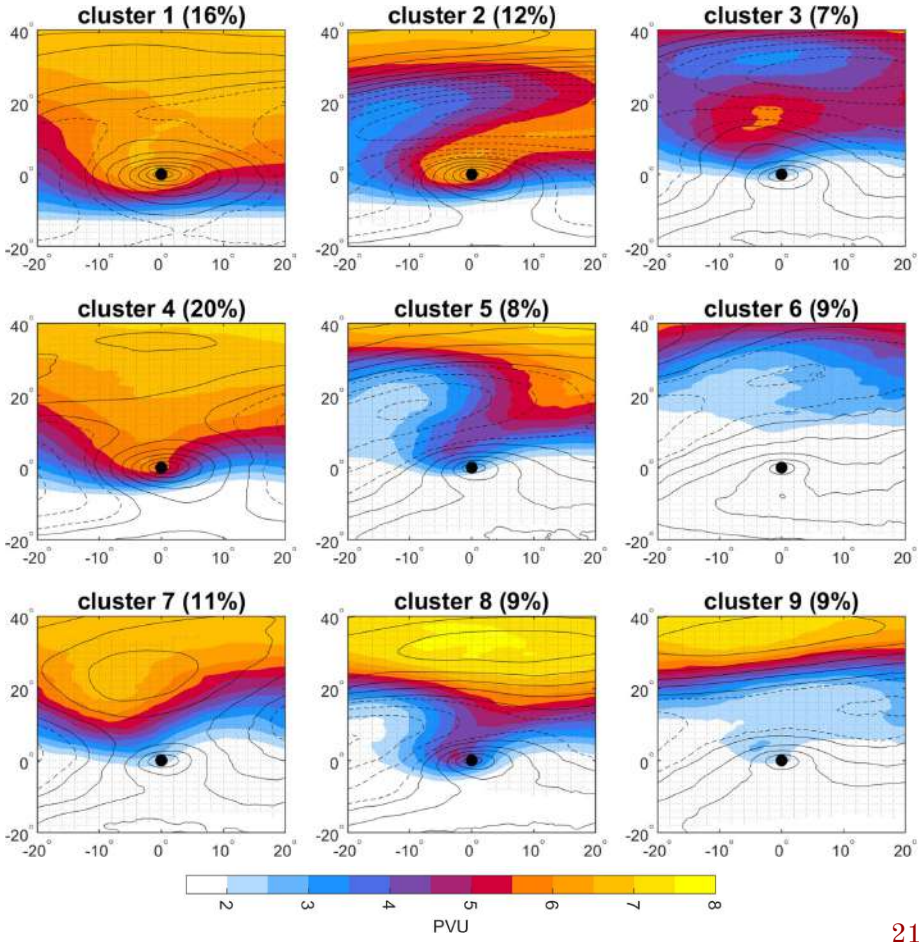






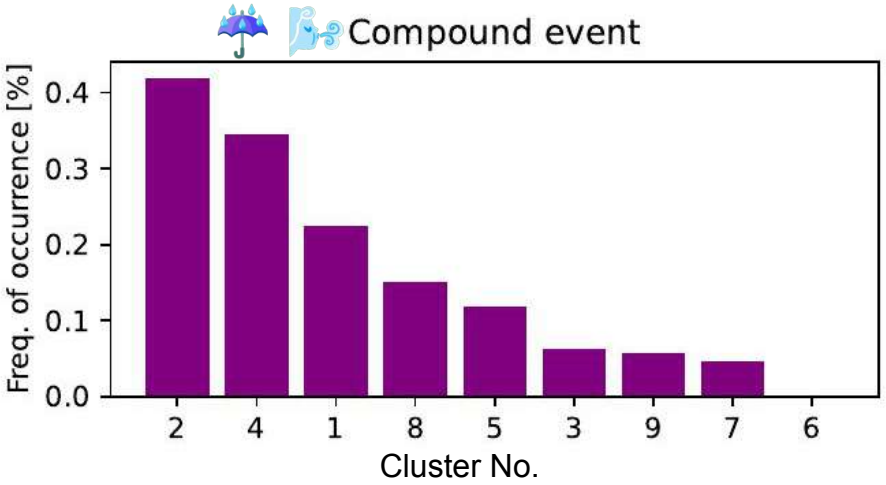
Givon et al. 2024

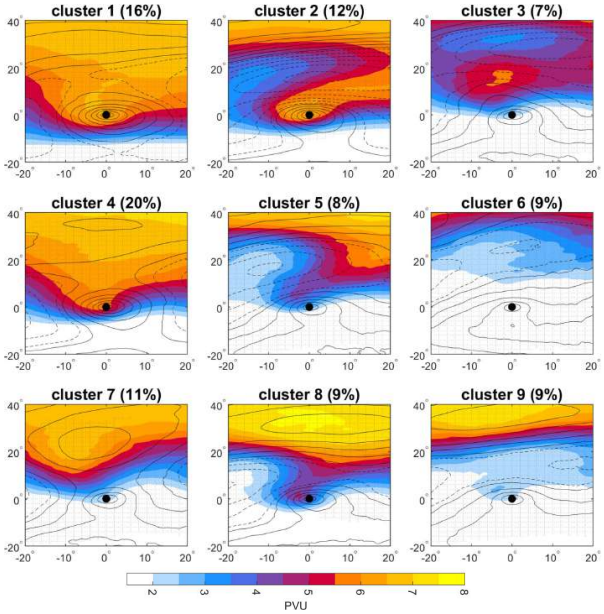
Lagrangian viewpoint: how to treat Med-cyclones?



Givon et al. 2024, Rousseau-Rizzi et al. 2024

Lagrangian viewpoint ☔ 🌬️: relevant clusters





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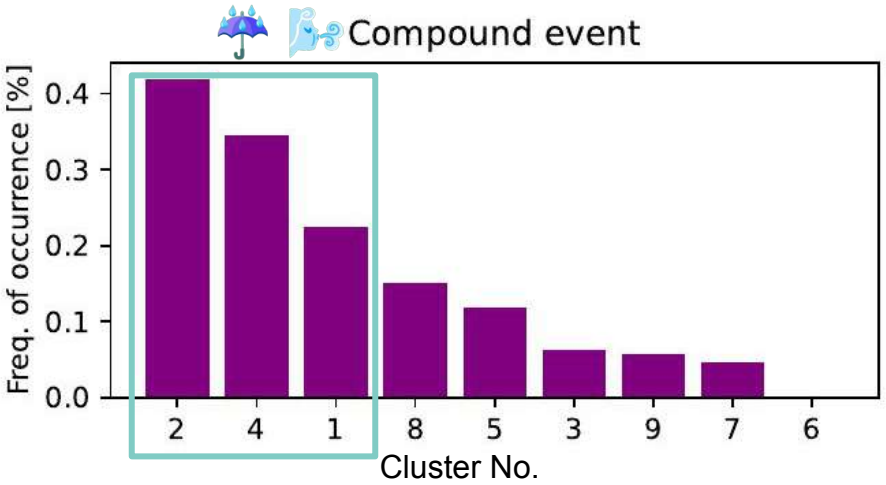
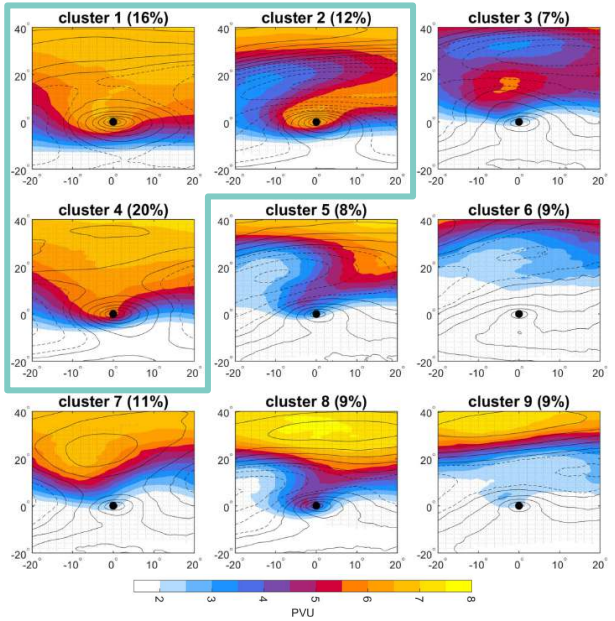
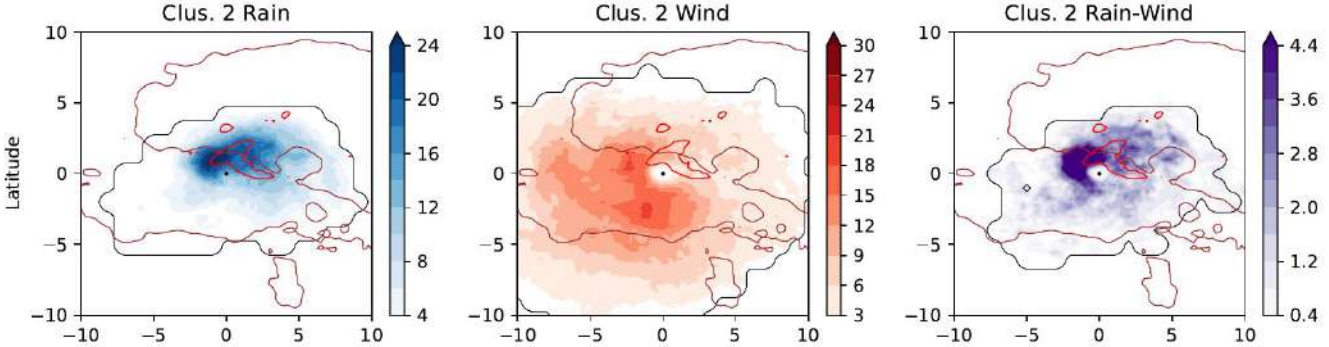




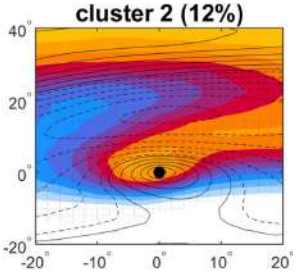
- Clusters 1,2,4 comprise lee-lows and Rossby-wave-breaking cyclones
- Peak season: winter
- Peak region: northern Mediterranean

Givon et al. 2024, Rousseau-Rizzi et al. 2024

Lagrangian viewpoint ☔ 🌬️: where are the compounds?



Rossby wave breaking low



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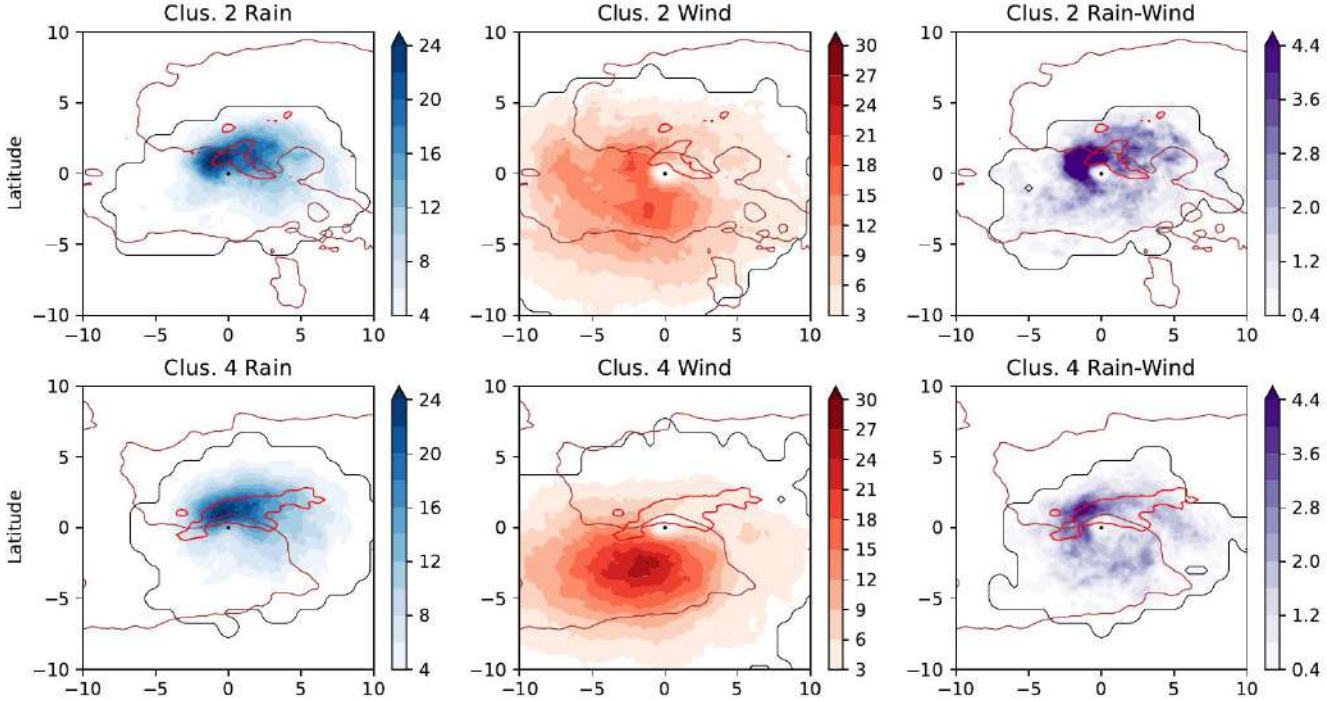
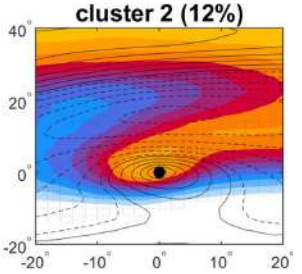
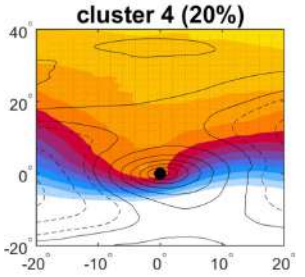


Rossby wave breaking low



(stage B) lee low

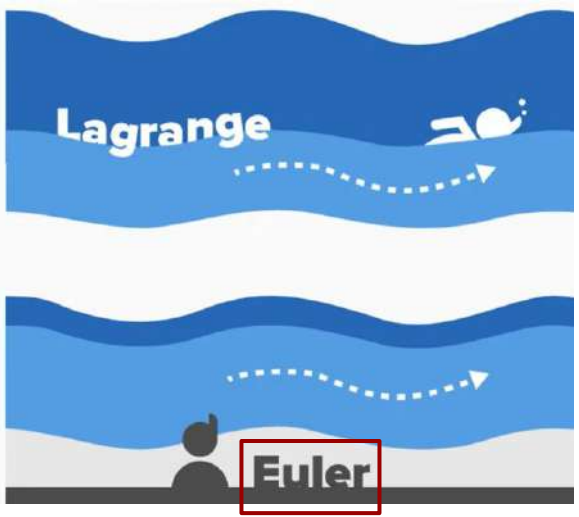


Summary (1)

- winter Med-cyclones have highest occurrence of compound ☔ 🌬️
- the cluster with maximum frequency is that with highest overlap between ☔ and 🌬️ footprints

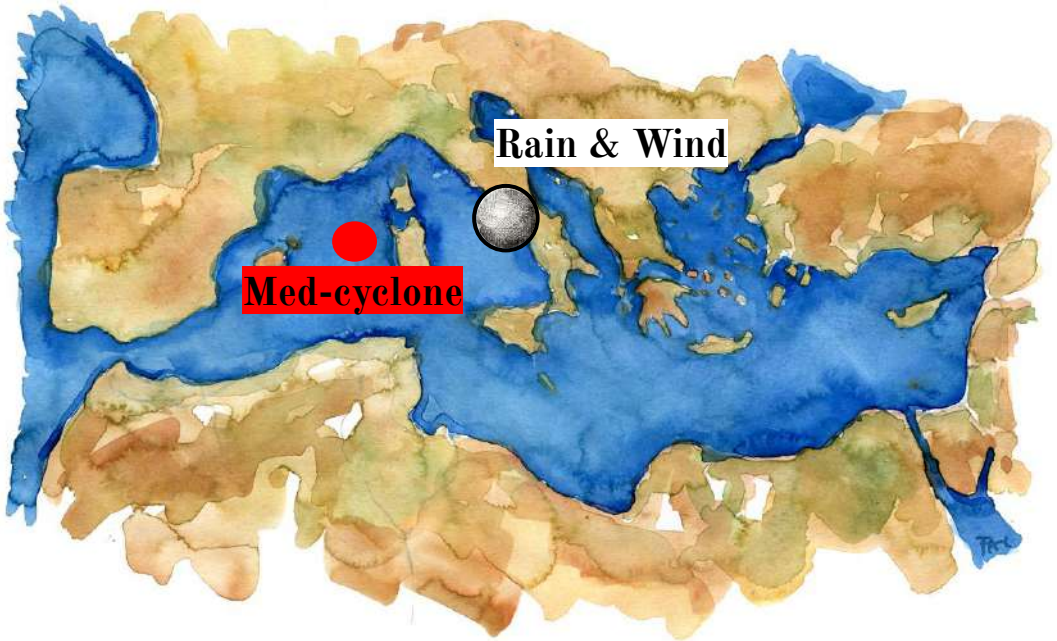
Details and results for 🌊 ☔ and 🔥 🧹 compounds in Rousseau-Rizzi et al. 2024

Eulerian viewpoint: how to treat Med-cyclones?



Eulerian viewpoint: how to treat Med-cyclones?

Rain & Wind
↕?
Med-cyclone



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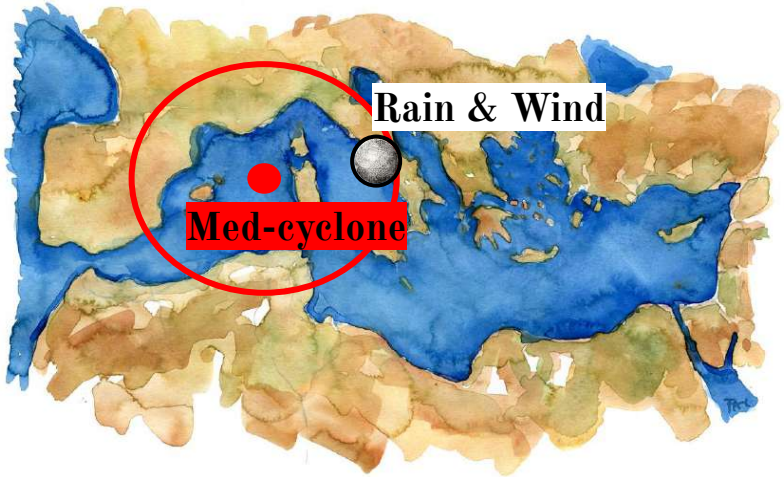
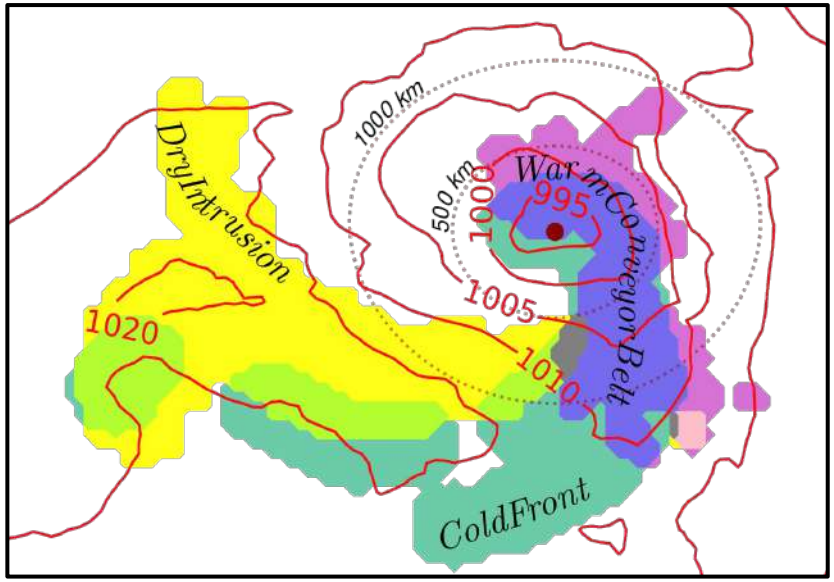
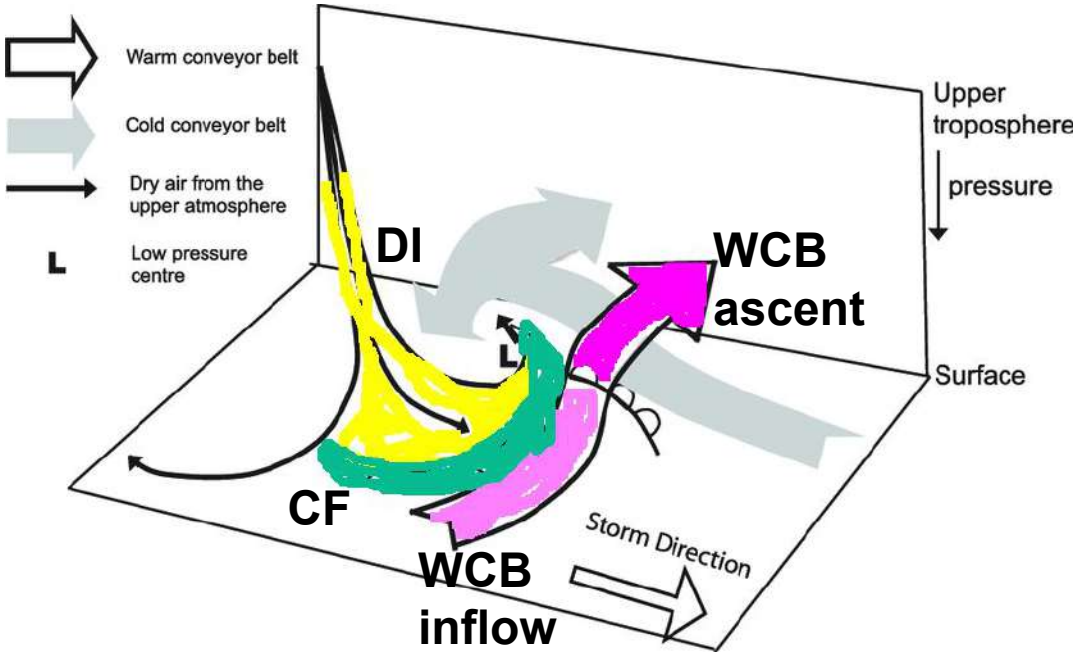




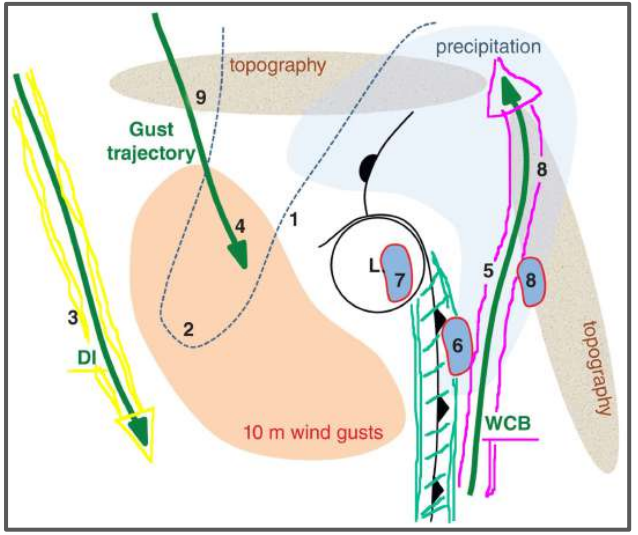
IMPACT AREA = **r1000km** + **WCB**(<500km) + **CF**(<500km) + **DI**(<1000km)

Eulerian viewpoint: why dynamical features?

Rain & Wind
↕?
Med-cyclone



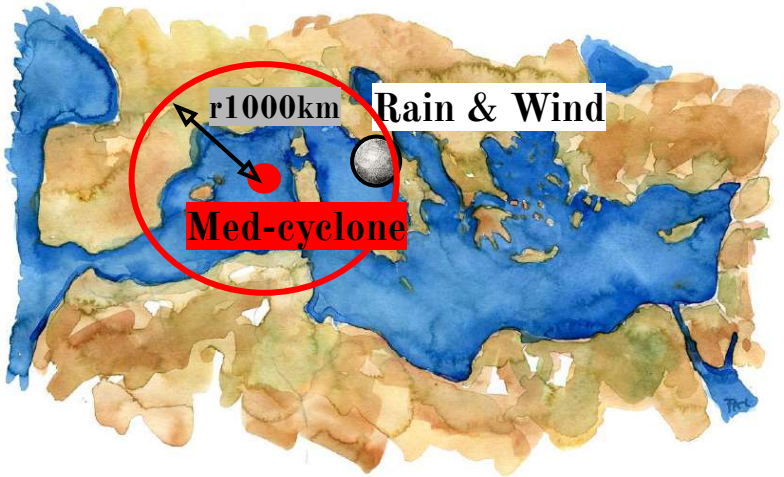
Catto 2013



Raveh-Rubin and Wernli 2016

Eulerian viewpoint: why such a large central area?

Rain & Wind
↕?
Med-cyclone



$$\textbf{IMPACT AREA} = \textbf{r1000km} + \textbf{WCB}(<500\text{km}) + \textbf{CF}(<500\text{km}) + \textbf{DI}(<1000\text{km})$$

Eulerian viewpoint: why such a large central area?

Rain & Wind
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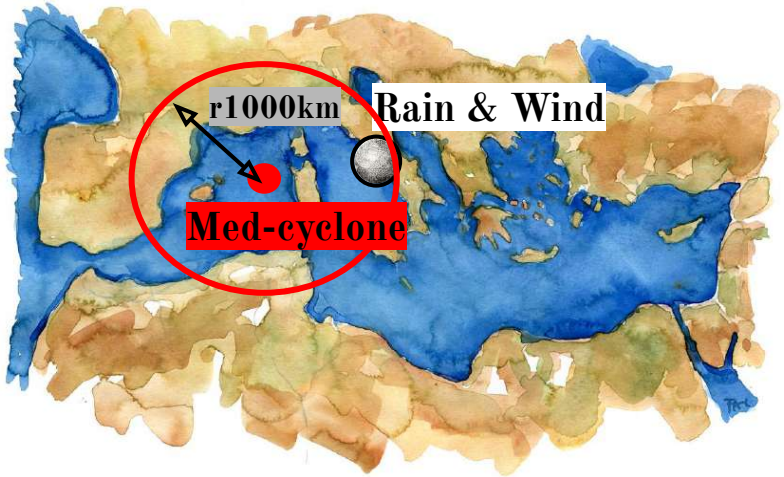

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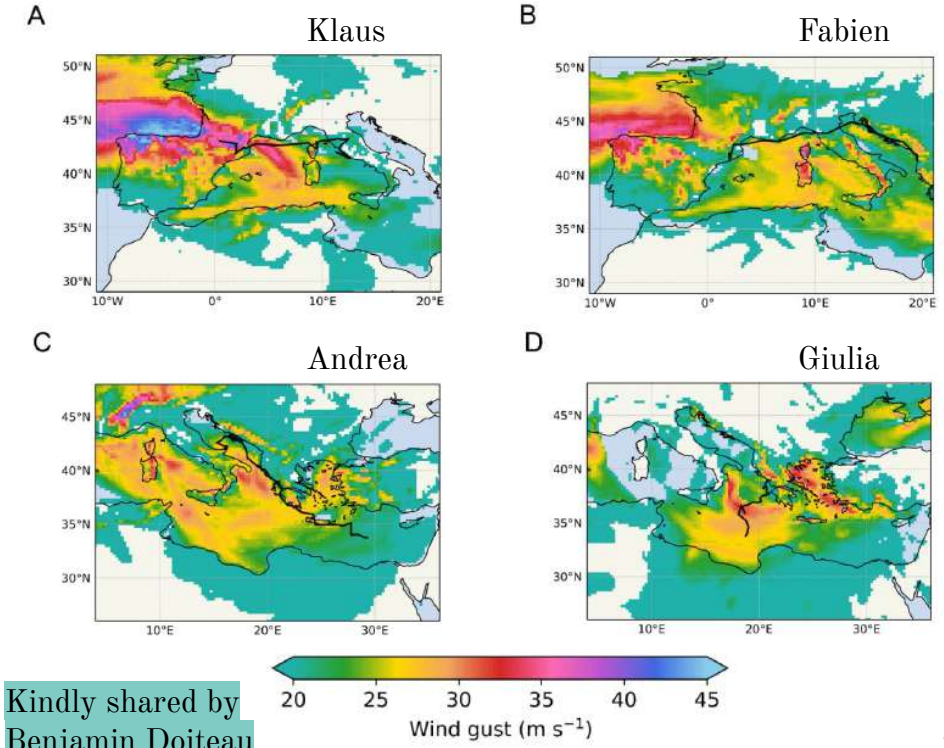


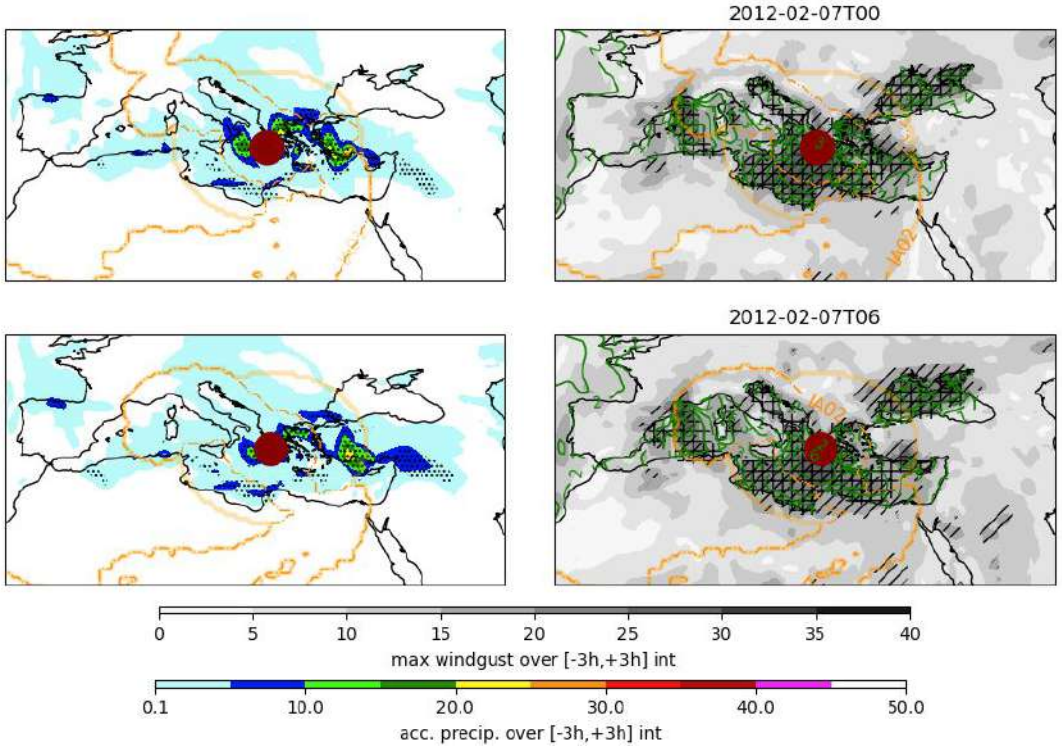
Kindly shared by Benjamin Doiteau

Eulerian viewpoint: why such a large central area?

Rain & Wind ↕? Med-cyclone

6h acc. precipitation

6h max. windgust (shaded), 6h max. wave height (contours)



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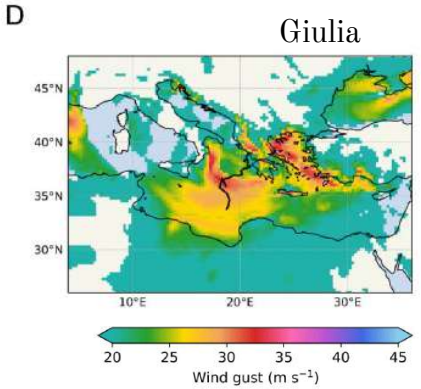
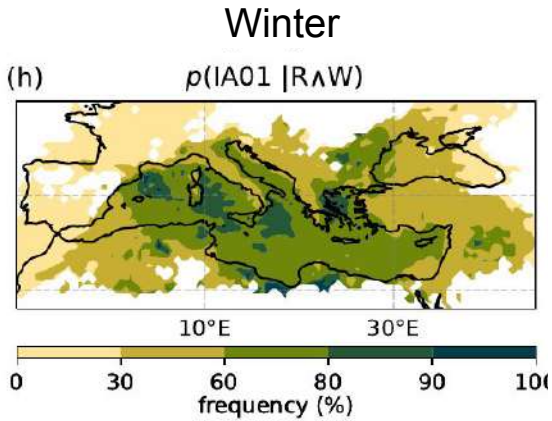


Eulerian viewpoint ☔ 🌬️: compound-cyclone association



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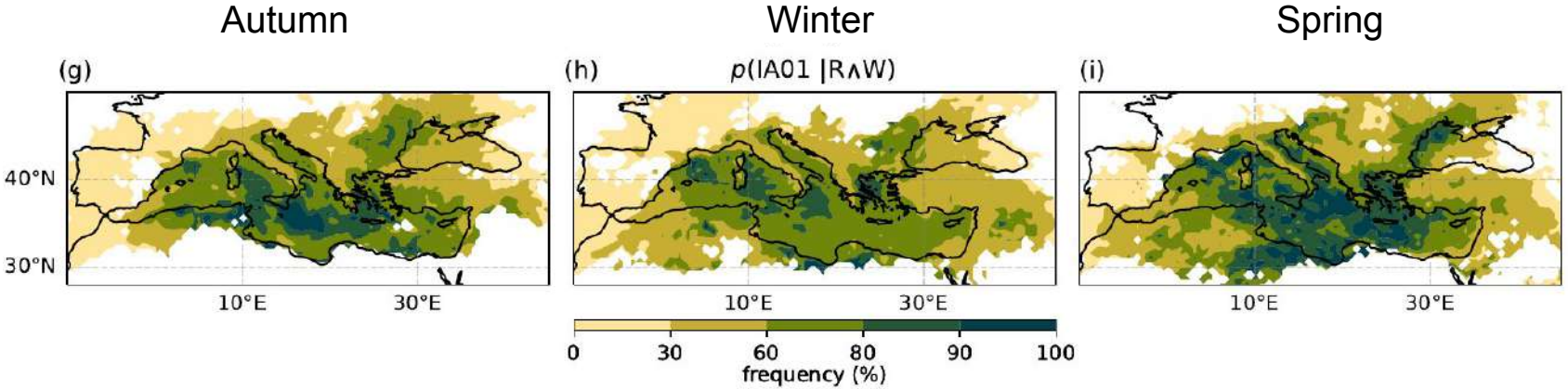
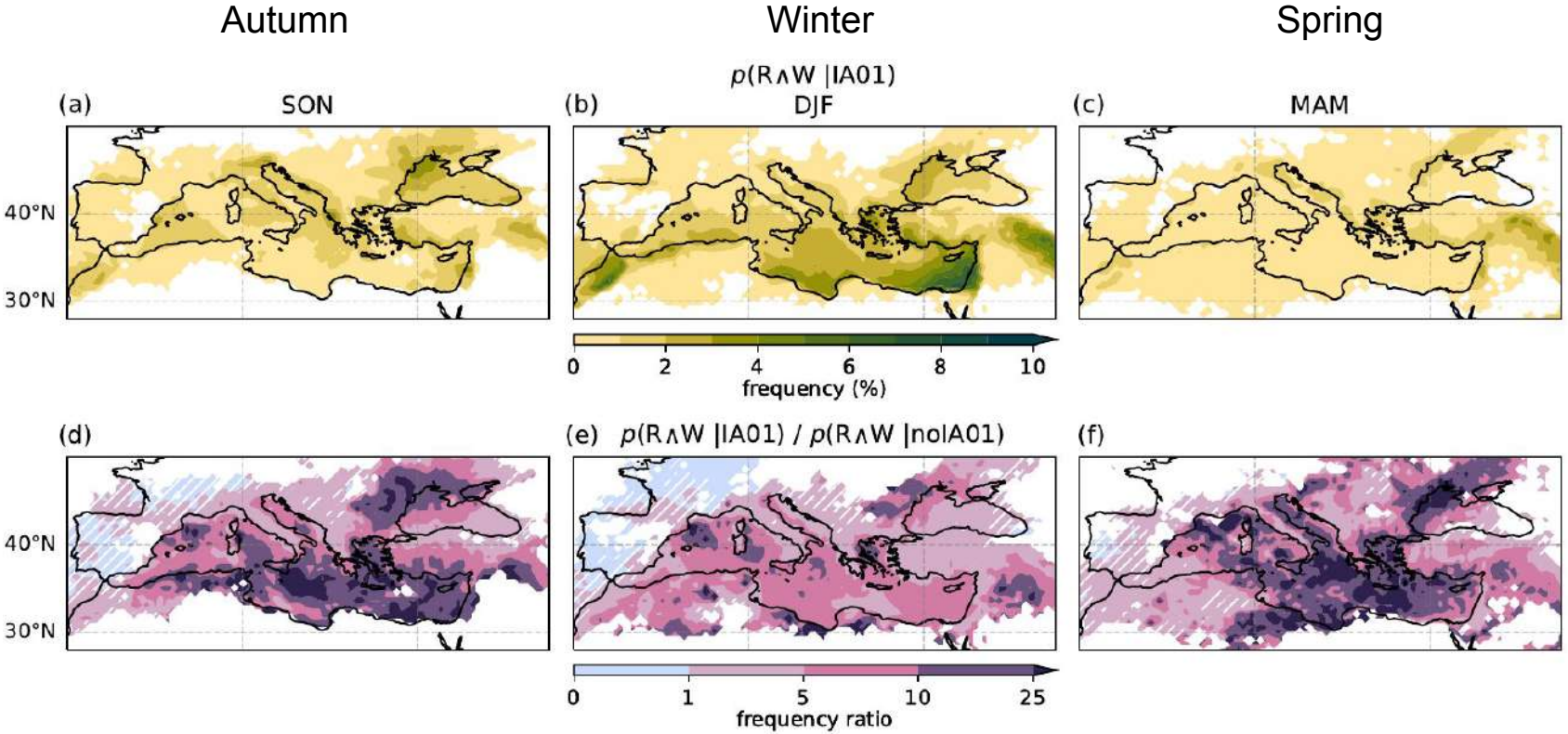
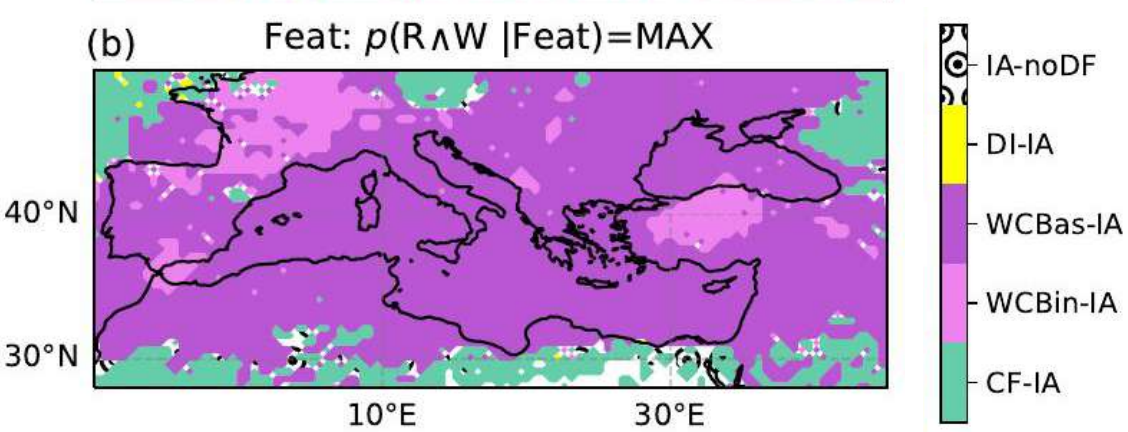


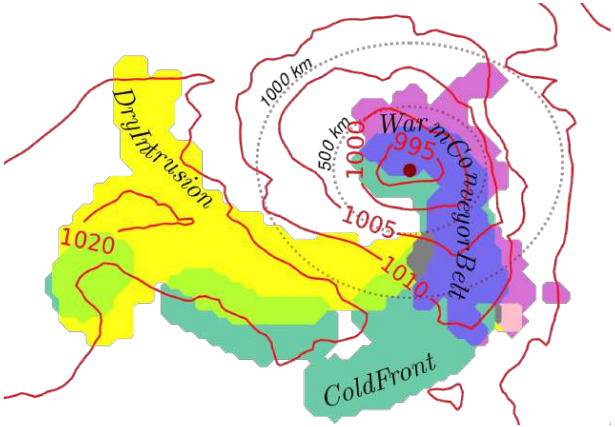
Eulerian viewpoint ☂️ 🌬️: compound frequency



IMPACT AREA $=$ **r1000km** $+$
WCB$(<500\text{km})$ $+$ **CF**$(<500\text{km})$ $+$
DI$(<1000\text{km})$

Eulerian viewpoint ☂ 🌬: which dynamical feature is most relevant?





Summary (2)

- winter Med-cyclones have highest occurrence of compound ☔ 🌬️
- the cluster with maximum frequency is that with highest overlap between extreme ☔ and 🌬️ footprints

- definition of an Impact Area
- 30-to-90 % of ☔ 🌬️ compounds are associated with a nearby Med-cyclone
- the presence of a Med-cyclone increases the likelihood of ☔ 🌬️ events
- WCBs maximise the occurrence of ☔ 🌬️ compounds

Details and results for 🌊 ☔ and 🔥 🧹 compounds in Rousseau-Rizzi et al. 2024

Details and results for 🌊 🌬️ compounds in Portal et al. 2024

Supplementary Material

SM: Definition of uni-variate extremes

Rousseau-Rizzi et al. 2024

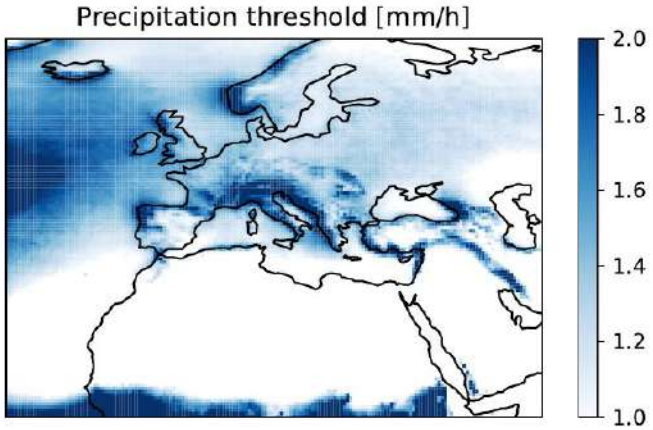
☔ 1h acc. prec > max(99th pct, 1 mm)

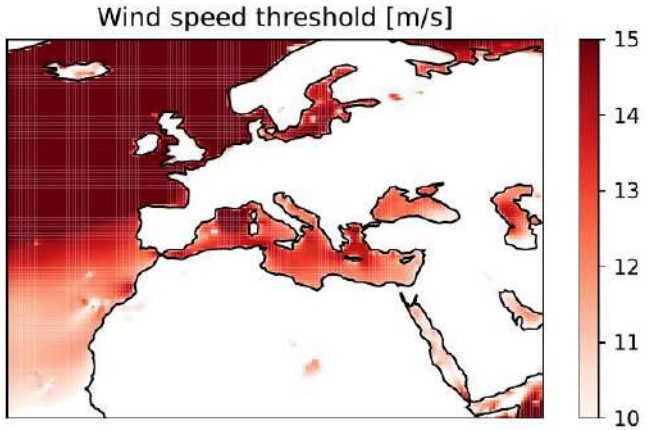
🌬️ 10-m wind > max(98th pct, 10 ms^{-1})

Portal et al. 2024

☔ 6h acc. prec > max(98th pct, 2 mm)

🌬️ 6h max windgust > max(98th pct, 10 ms^{-1})





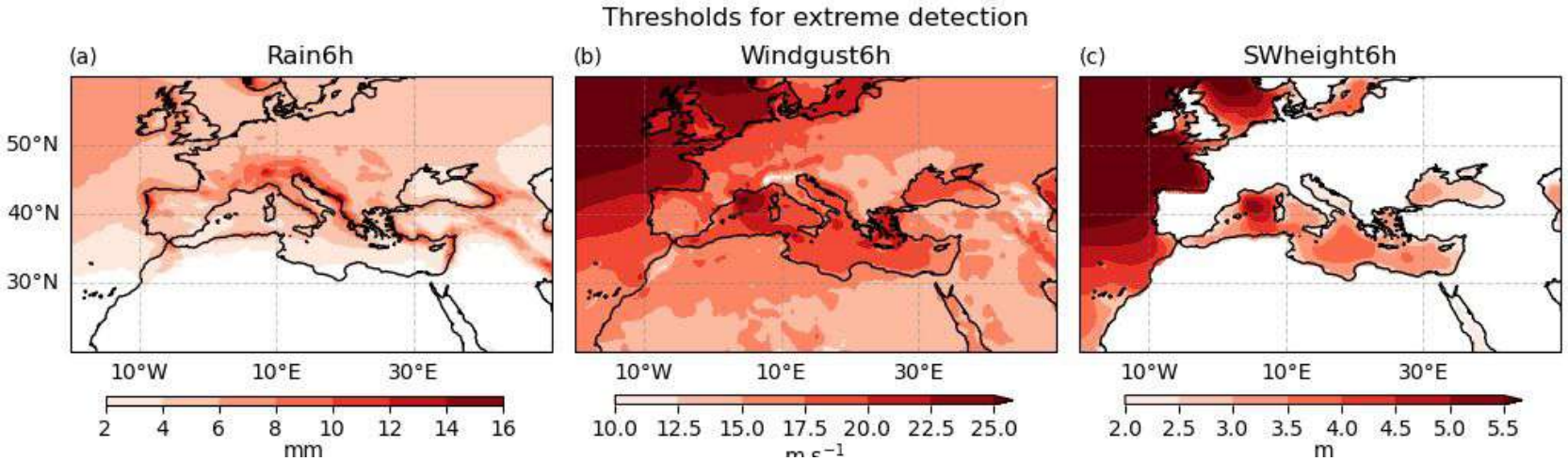
SM: Definition of uni-variate extremes

Rousseau-Rizzi et al. 2024

- 1h acc. prec > max(99th pct, 1 mm)
- 10-m wind > max(98th pct, 10 ms^{-1})

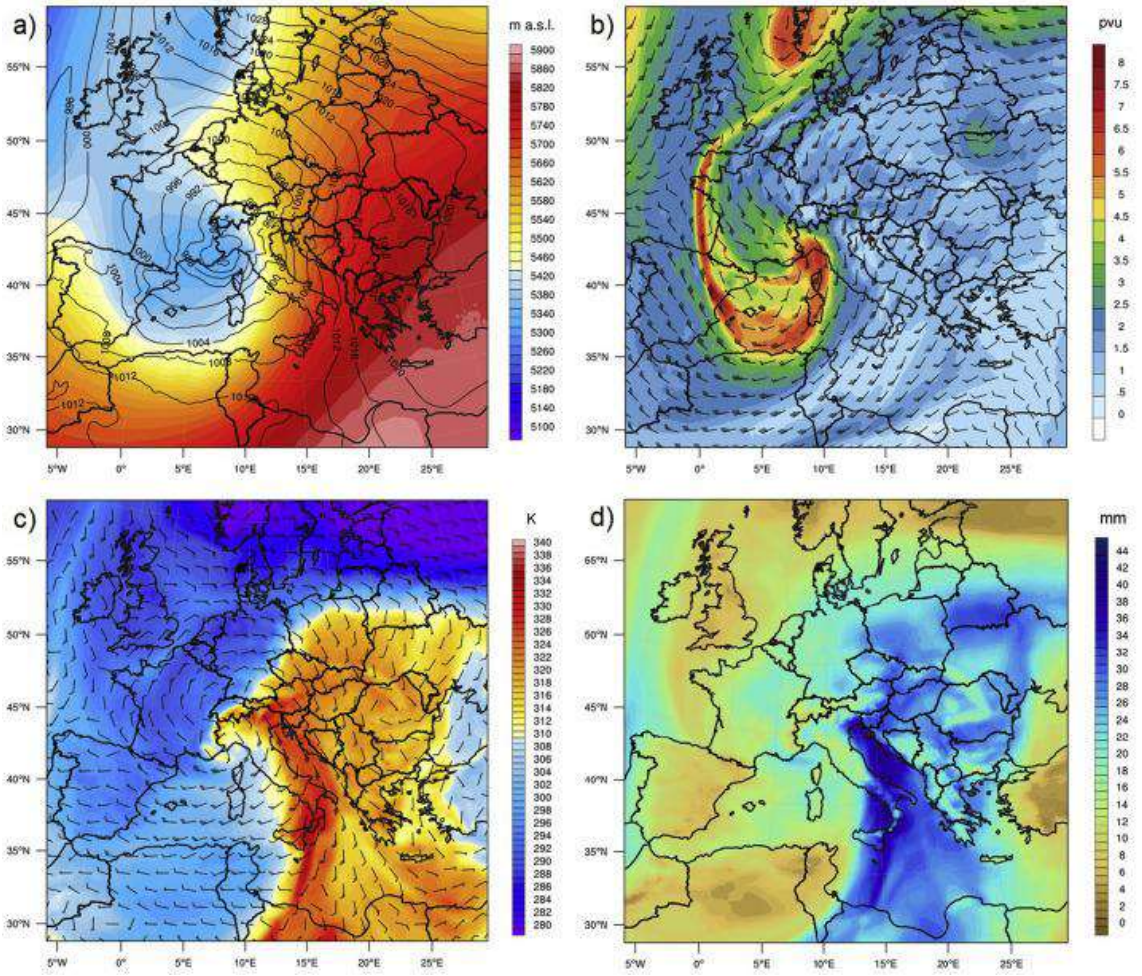
Portal et al. 2024

- 6h acc. prec > max(98th pct, 2 mm)
- 6h max windgust > max(98th pct, 10 ms^{-1})



SM: Storm Vaia, 29 October 2018 @ 18UTC

a) 500-hPa geopotential height and slp
b) 500–150 hPa potential vorticity and wind barbs at 300 hPa
c) 925 hPa equiv. pot. temperature and wind barbs at 925 hPa
d) precipitable water

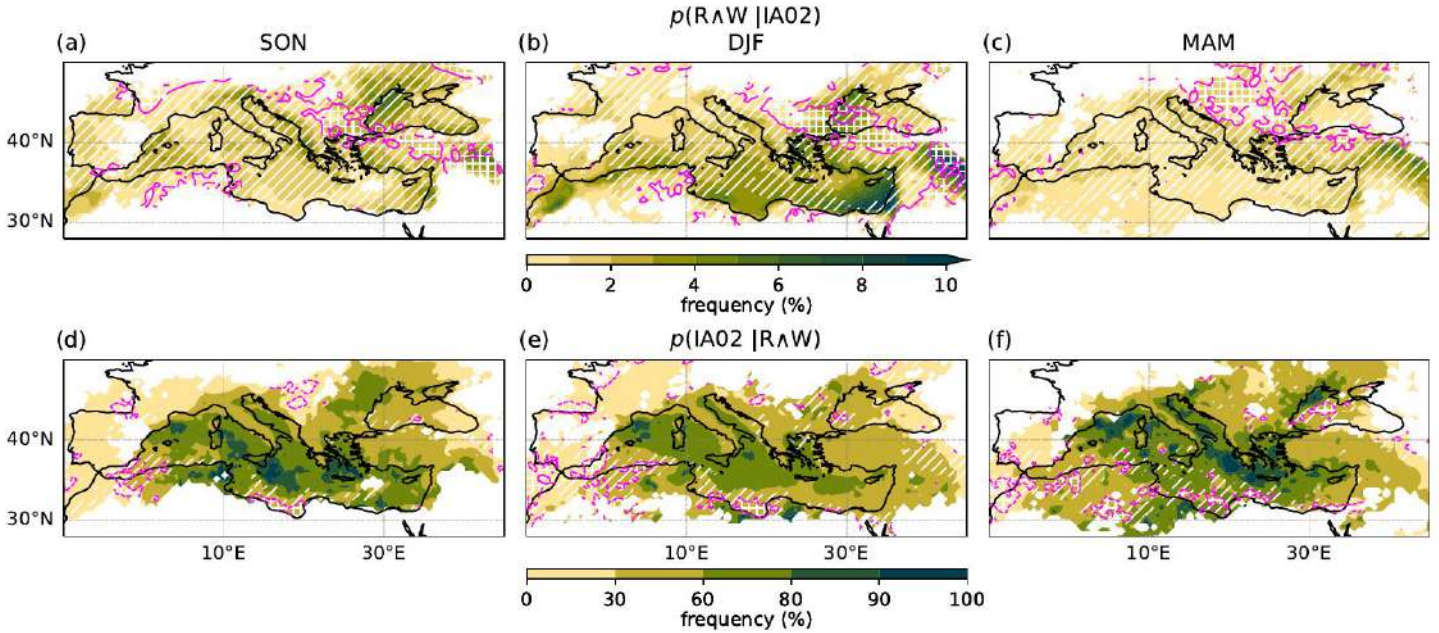


r(IA01)=1000 km

r(IA02)=500 km

SM: Comparison IA01 - IA02

If p(comp |IA01) = p(comp |IA02) and p(IA01 |comp) ≫ p(IA02 |comp) then:
comp is uniformly distributed within IA01.

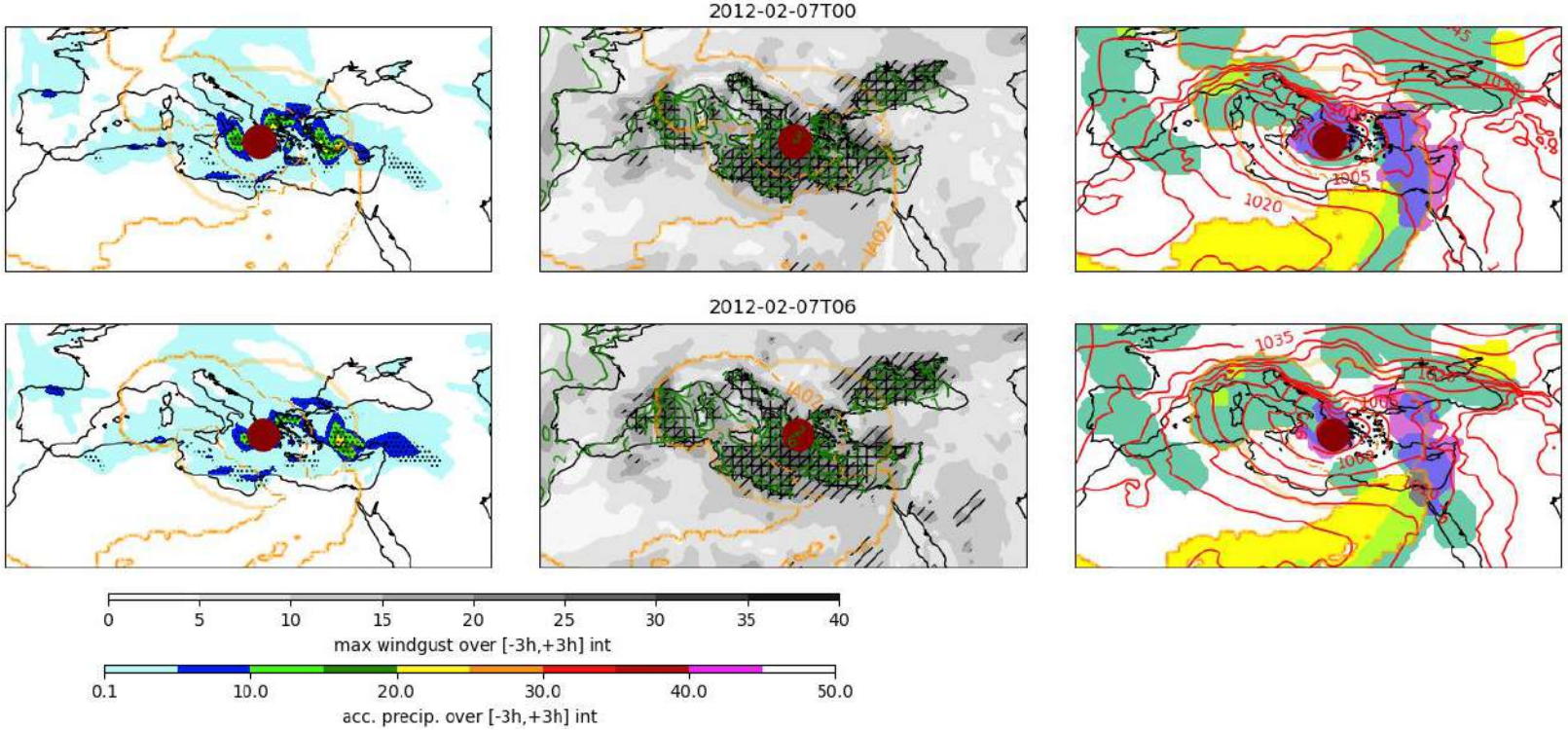


SM: Med-cyclone Giulia

6h acc. precipitation

6h max. windgust (shaded),
6h max. wave height (contours)

dynamical features



SM: Case studies Benjamin

Name	Date	Umax (m/s)	SLPmin (hPa)	SLPmin measured (hPa) - Station
Klaus	Jan 2009	46.5	979.1	979.7 - Cap Corse (France)
Fabien	Dec 2019	43.5	980.3	981.1 - Cap Corse (France)
Andrea	Jan 2012	45.0	980.7	981.3 - Kerkyra (Greece)
Julia	Feb 2012	35.5	982.2	987.3 - Methoni (Greece)
Torsten	Nov 2001	42.9	988.8	995.2 - Menorca (Spain)
Zorbas	Sep 2018	32.9	994.8	991.9 - Kalamata (Greece)
Rolf	Nov 2011	31.5	996.2	999.8 - Menorca (Spain)
Ianos	Sep 2020	27.2	1000.2	994.5 - Kefalhnia (Greece)

Table 3.1: List of the case studies, the maximal wind gusts inside a 1000 km circle from the cyclone centre and the minimum sea level pressure are retrieved from ERA5 reanalysis. The last column is the sea level pressure measured at the specified weather stations.

Objectively-identified dynamical features

WCB: *Lagrangian trajectories ascending of at least 600 hPa within 48 hours*, conditional to the presence of a nearby extratropical cyclone (Madonna et al., 2014), using ERA5 (Heitmann et al., 2023). Regions of low-level **inflow** (up to 800 hPa) and mid-level **ascent** (up to 400 hPa) are considered.

DI: *Lagrangian trajectories descending at least 400 hPa within 48 hours* (Raveh-Rubin, 2017). We consider the **lower-tropospheric DI outflow** at pressure values greater than 700 hPa (Catto and Raveh-Rubin, 2019).

CF: *Tracked lines of strong thermal gradients* following Hewson (1998); details on identification in ERA5 data in Sansom and Catto (2022). Frontal lines are **extended by a 2.5° distance** to obtain 2D objects (Catto and Pfahl, 2013).