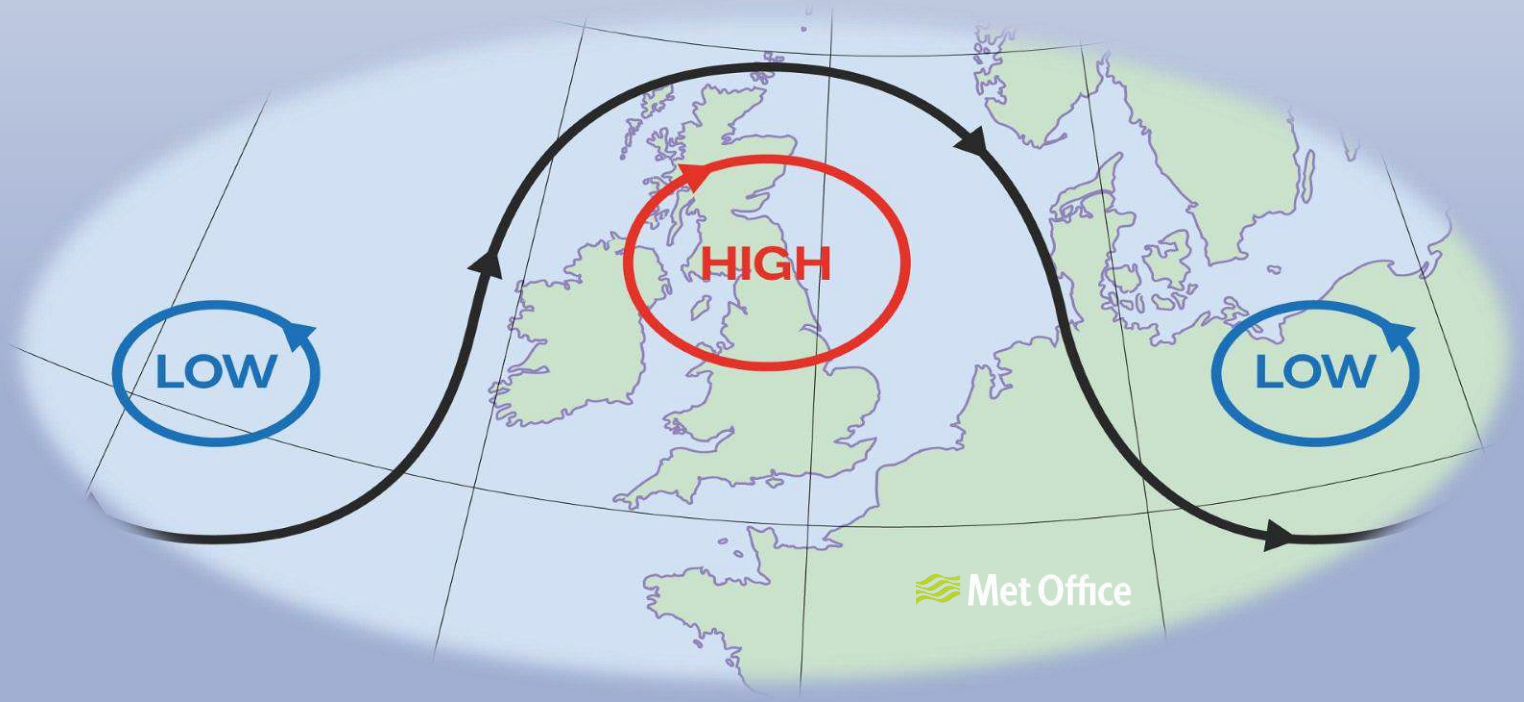


Atmospheric blocking and downstream Mediterranean cyclones

Dr. Pinelopi Loizou
Dr. Shira Raveh-Rubin

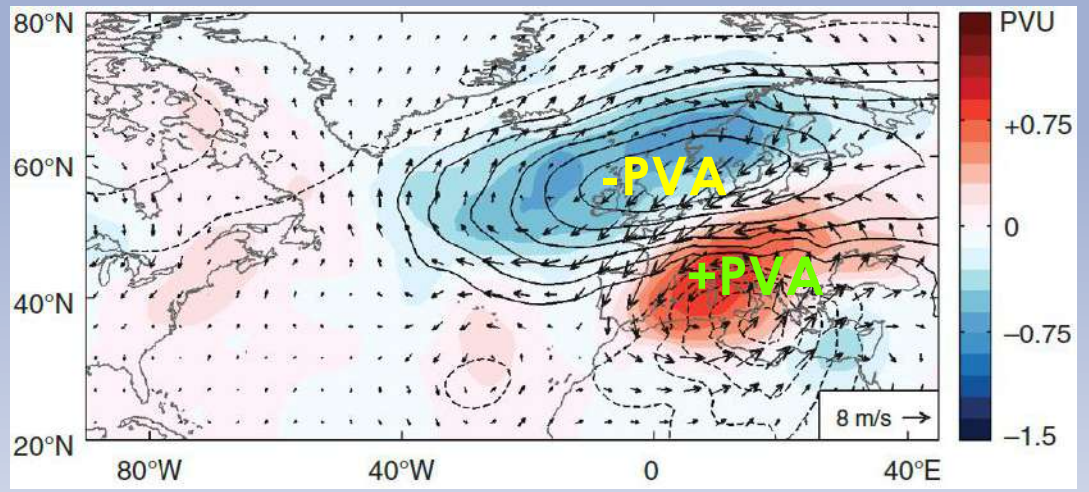
WEIZMANN INSTITUTE OF SCIENCE

MEDcyclones

Motivation

- Mediterranean Cyclones (MCs)
  - Associated with heavy rainfall
  - Upper-level PV streamers → precursors for cyclogenesis
- Atmospheric Blocking
  - Long-lasting, quasi stationary, self-sustaining anti-cyclonic system
  - Mostly connected to temperature extremes and droughts
  - Impact on the predictability of weather extremes
- The connection between blocking and MCs has not been examined systematically – addressing this can provide information on predictability

Impact of Storm Daniel (2023) and Storm Ianos (2020) in Greece



Raveh-Rubin and Flaounas (2017)

Aim: Systematic investigation of MC development downstream of Euro-Atlantic blocks and impact on cyclone-attributed precipitation.

Research Questions

1. How frequent is MC development downstream of atmospheric blocking events?

2. What is the impact on cyclone-attributed precipitation?

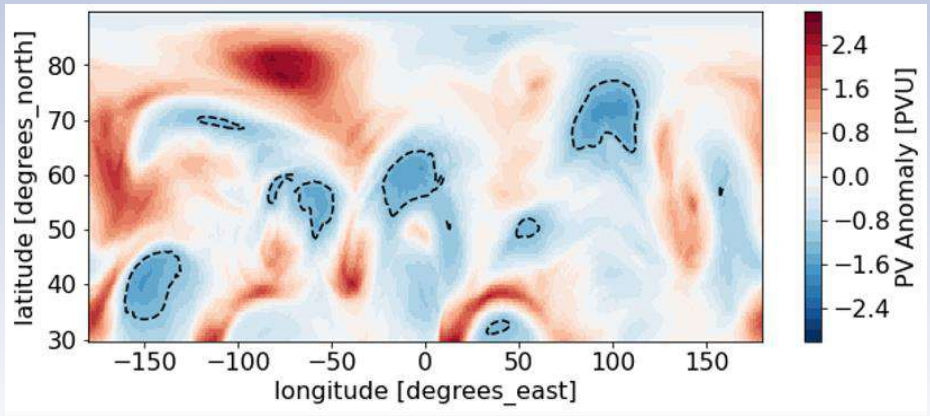
3. Does the impact vary between different types of MCs?

Methods & Data

Detecting Atmospheric Blocking

- **ERA5** data for 1979-2020, 3hourly intervals
- Vertically averaged **PV** between 500-150 hPa
- Track blocks as persistent negative PV anomaly
  - Closed contours below a threshold
- Ensure quasi-stationarity and persistence
  - 85% two-sided overlap between closed contours of successive time steps for at least **5 days**

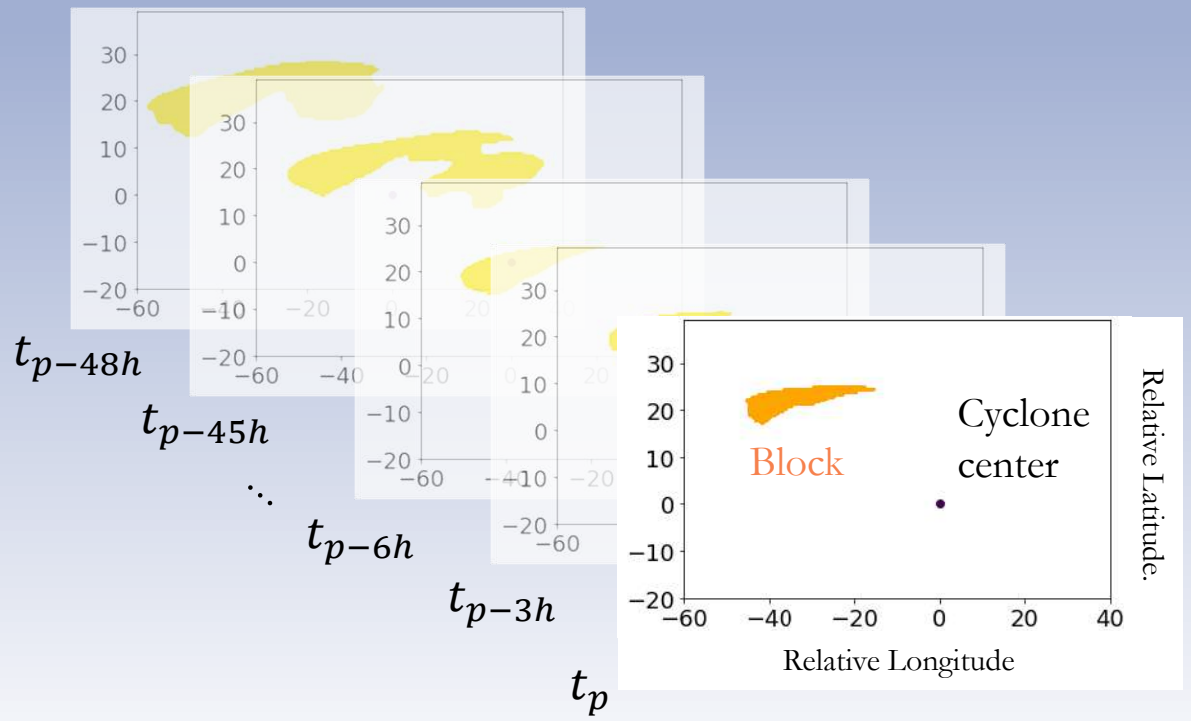
[Steinfeld, D., 2020: ConTrack - Contour Tracking. GitHub, adapted from the original index proposed by Schwierz, et al., 2004]



Mediterranean Cyclones (MCs)

3190 composite tracks of confidence level 5 [Flaounas et al., 2023]

Blocking & MCs



Methods & Data

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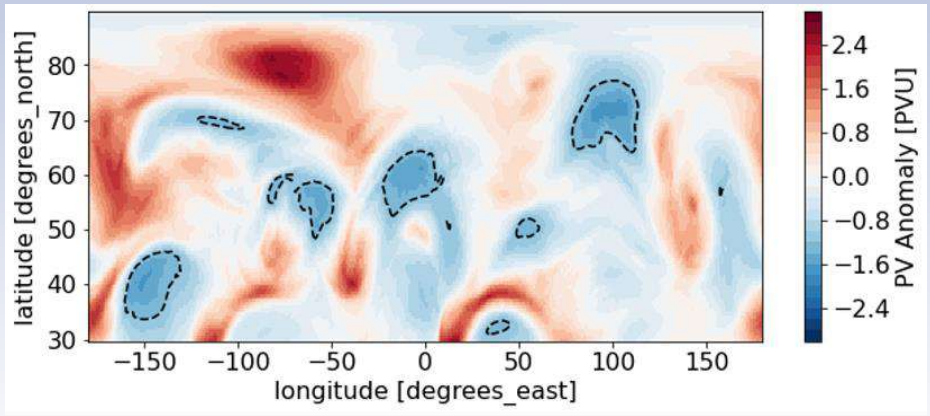
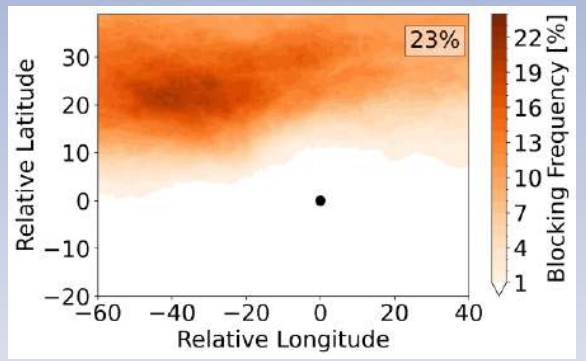


Mediterranean Cyclones (MCs)

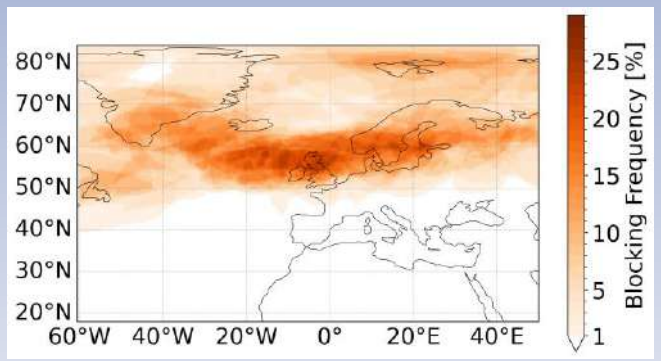
3190 composite tracks of confidence level 5 [Flaounas et al., 2023]

Blocking & MCs

Cyclone-relative perspective

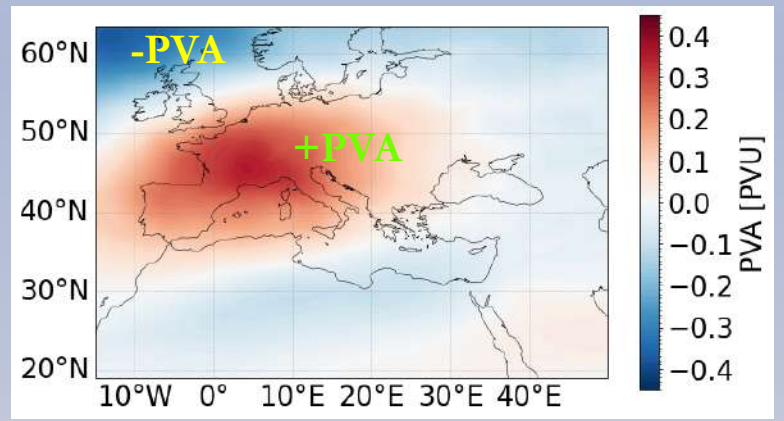


Geographically-fixed domain

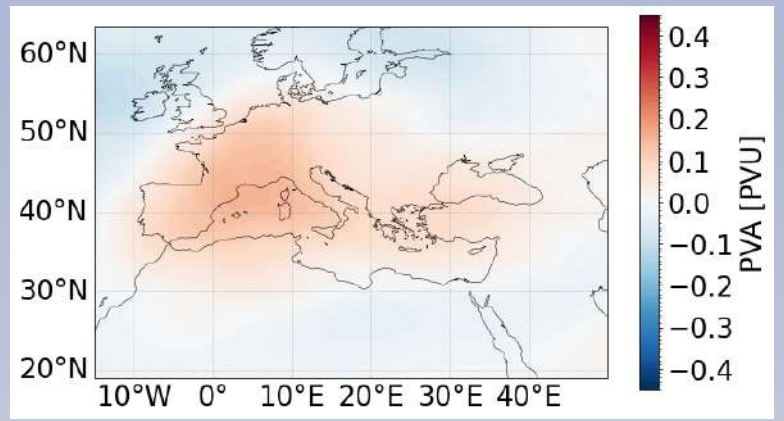


Dynamical impact

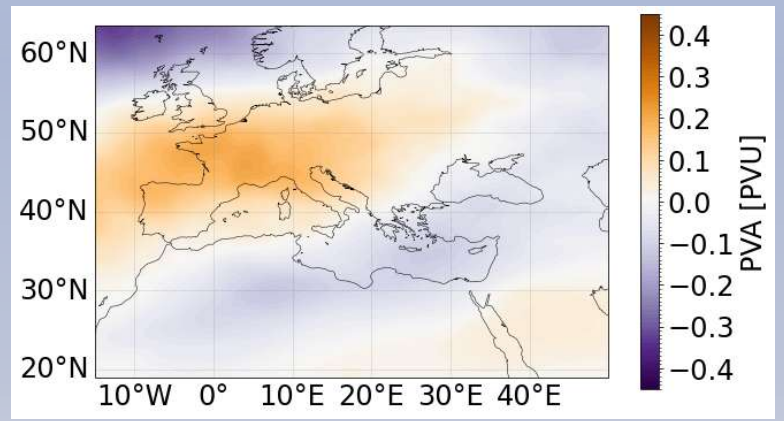
With Blocks (CB)

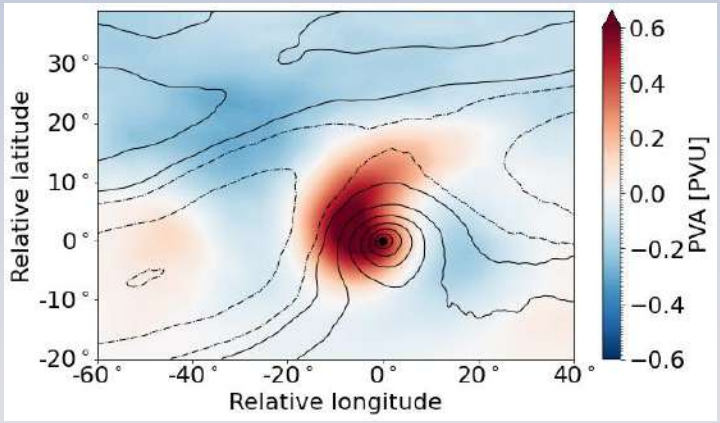


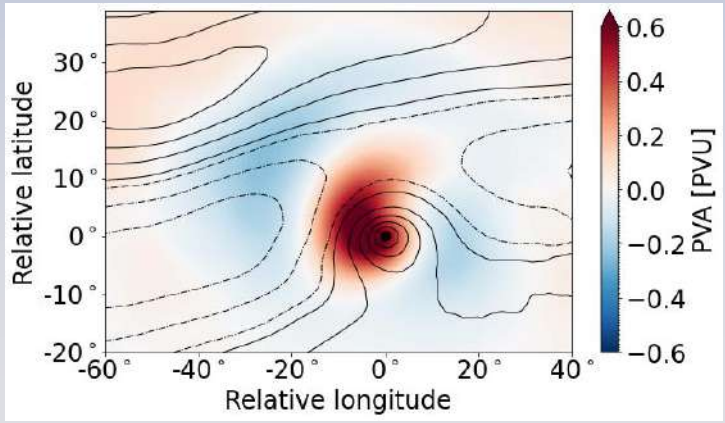
Without blocks (CNB)

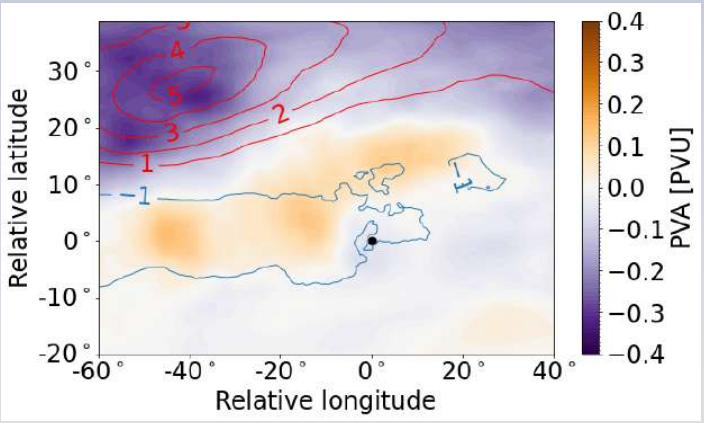


Difference in means:
CB - CNB







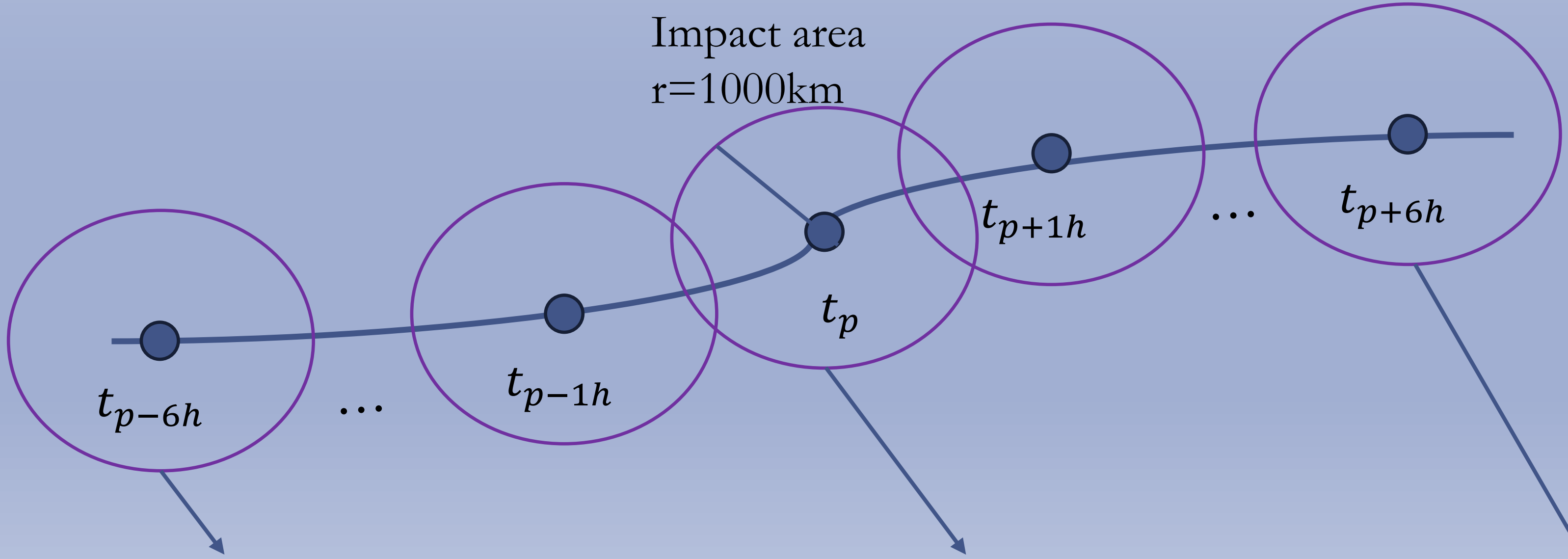


Contours: MSLP

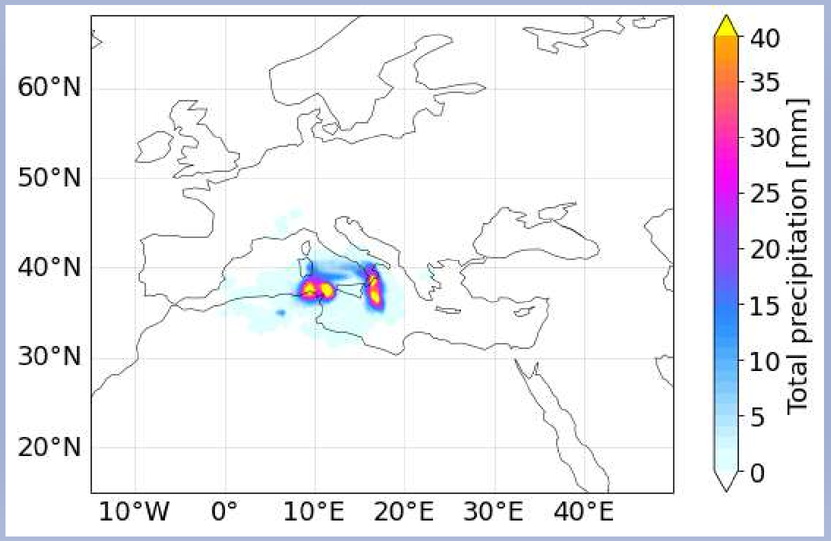
Positive MSLP difference
Negative MSLP difference

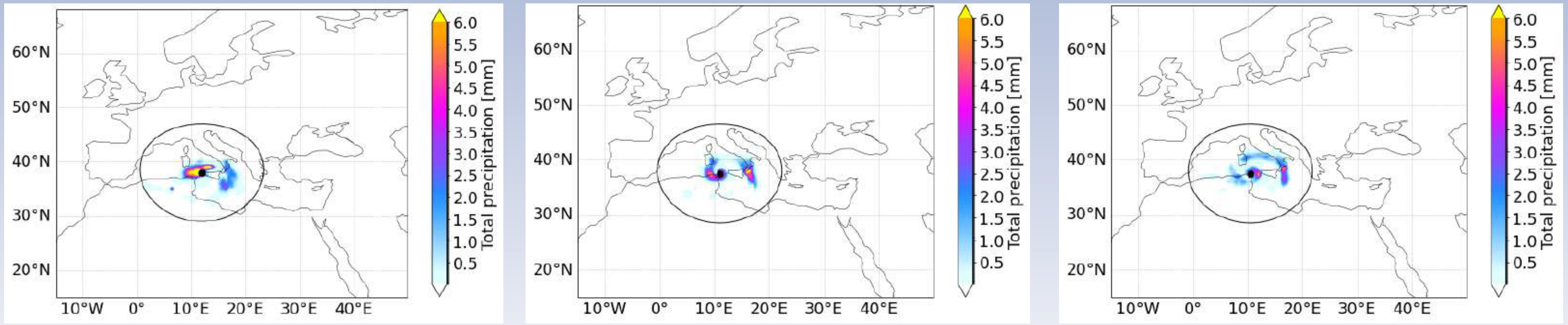
Stronger PV anomalies ➡ enhanced circulation ➡ deeper cyclones

Cyclone-attributed precipitation



12-hour accumulation

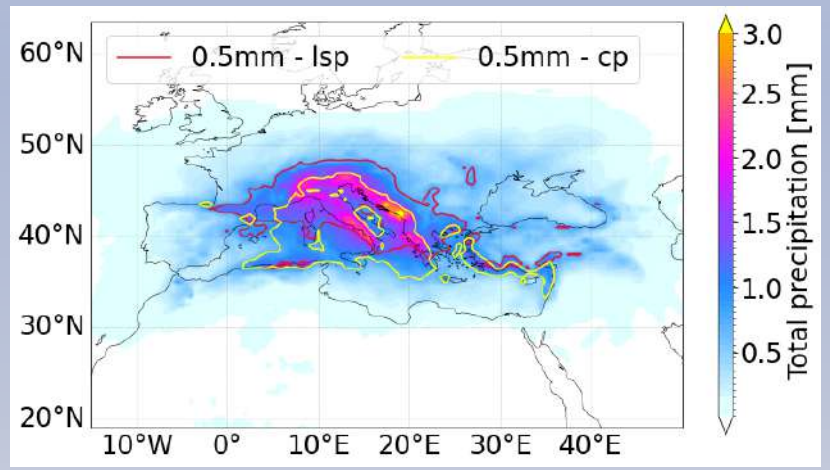




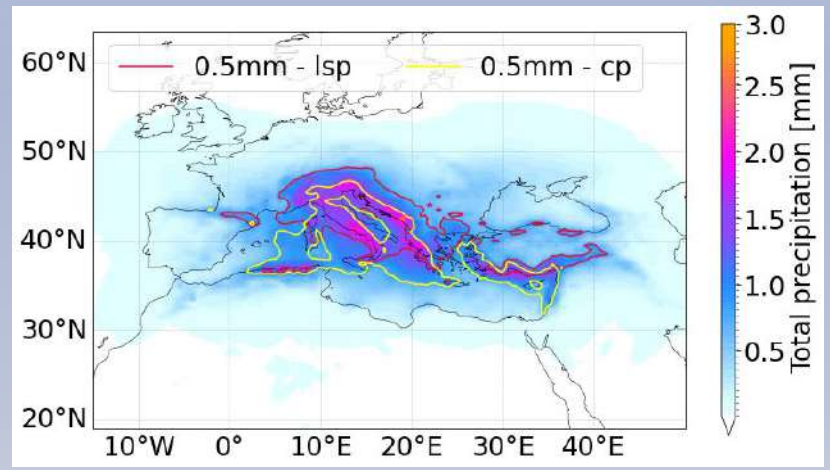
Cyclone-attributed precipitation

lsp: large-scale precipitation
cp: convective precipitation
total precipitation = lsp + cp

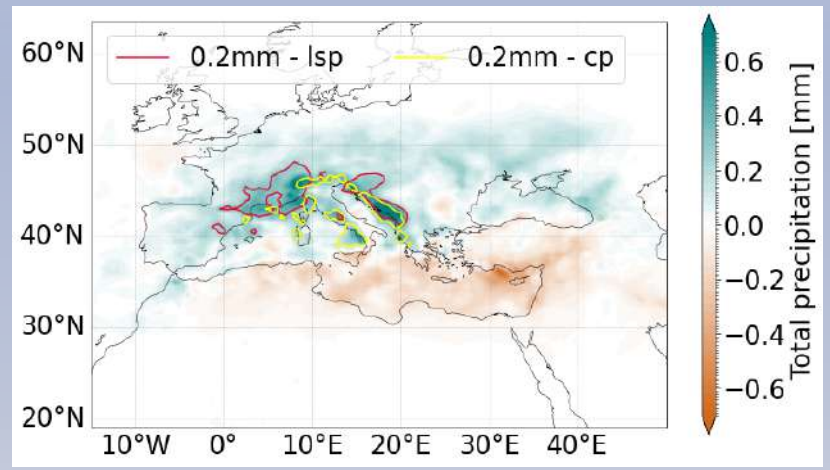
CB

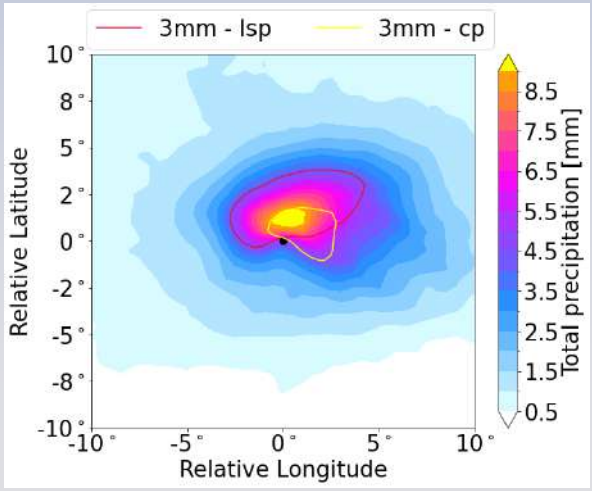


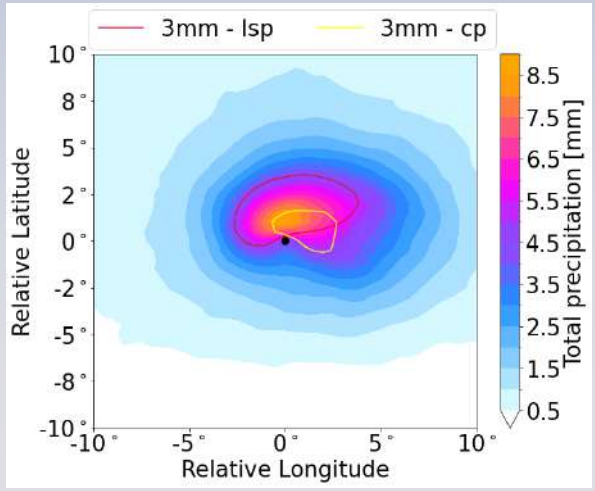
CNB

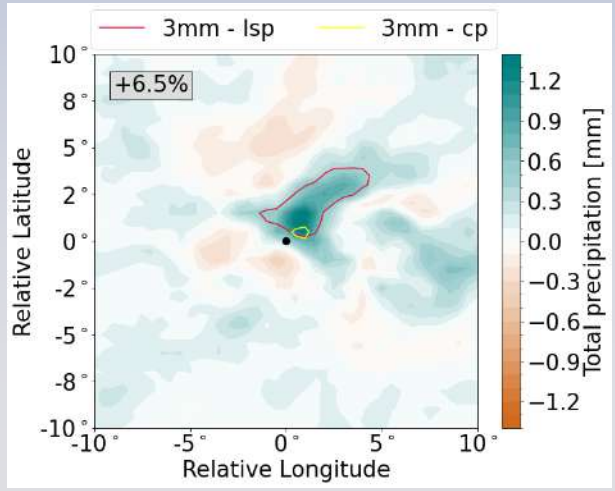


CB - CNB





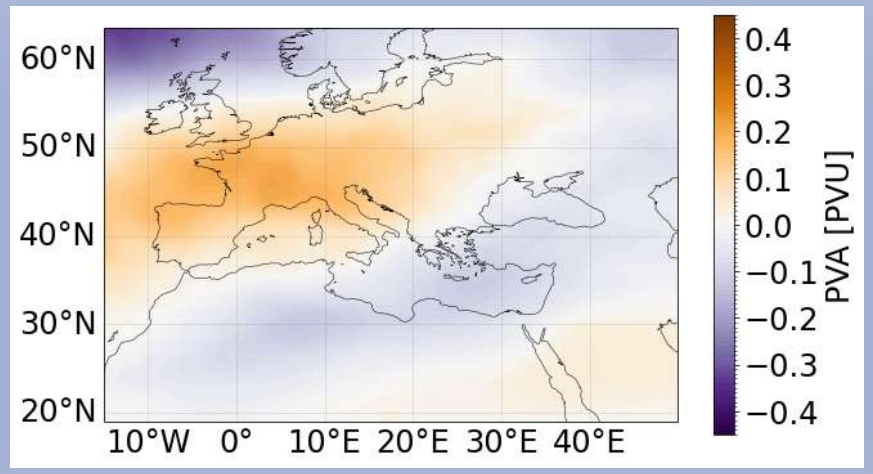




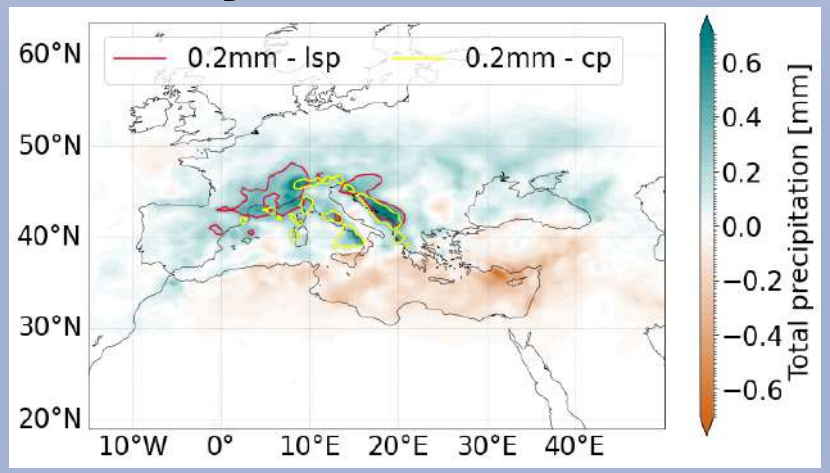
Split between northwestern and southeastern Europe/Mediterranean & more precipitation in the domain

Connecting PV, Precipitation and moisture

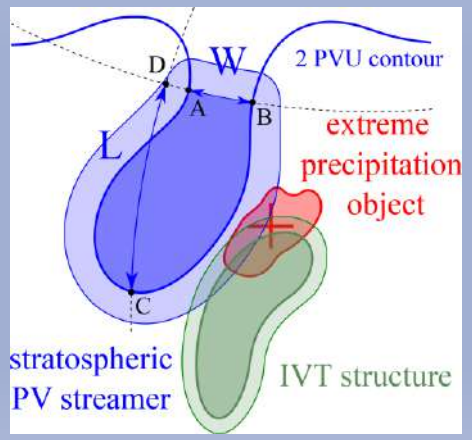
PV: CB – CNB



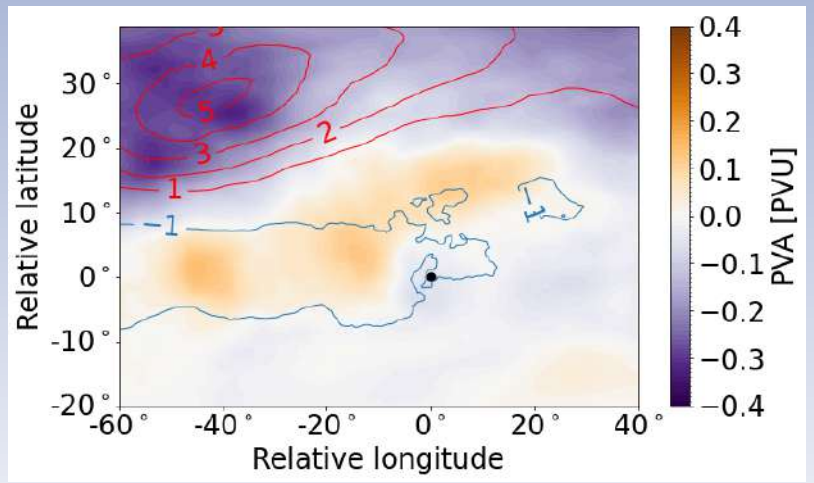
Precipitation: CB – CNB

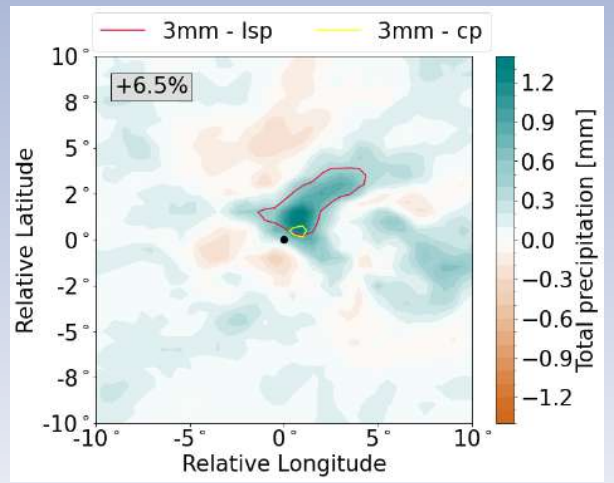


Integrated Vapour Transport (IVT)



[de Vries, 2021]





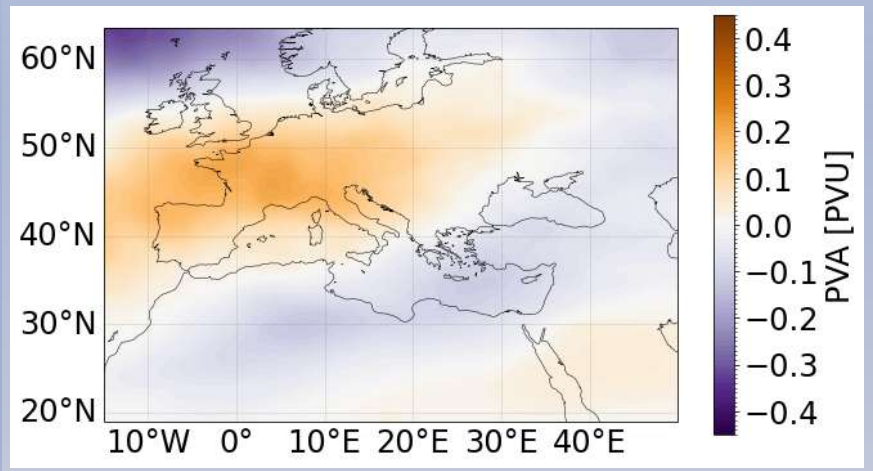
$$IVT = g^{-1} \int_{1000\,hPa}^{300\,hPa} q\boldsymbol{v} dp$$

v: horizontal wind — g: gravity

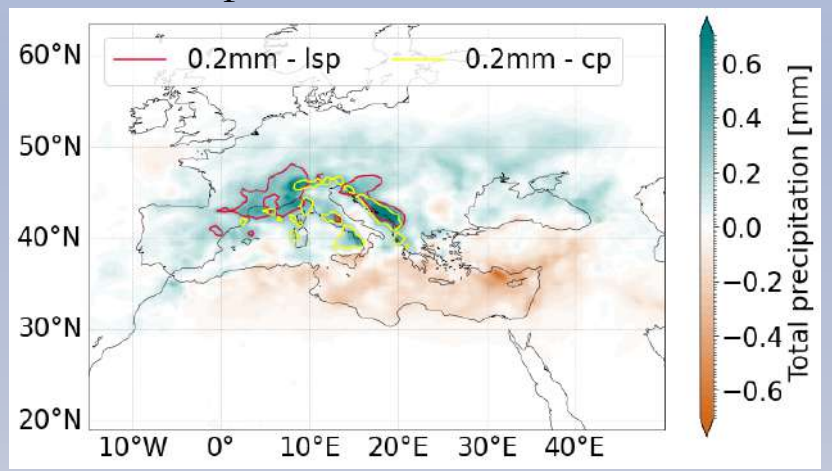
q: specific humidity — p: pressure

Connecting PV, Precipitation and moisture

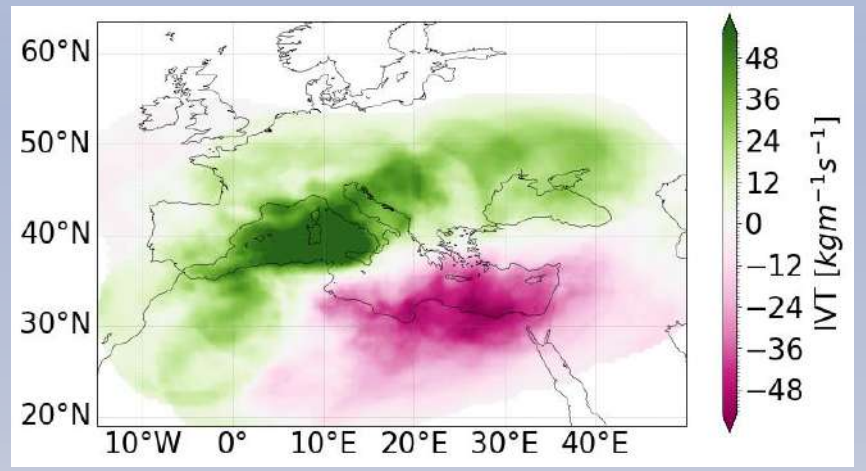
PV: CB – CNB

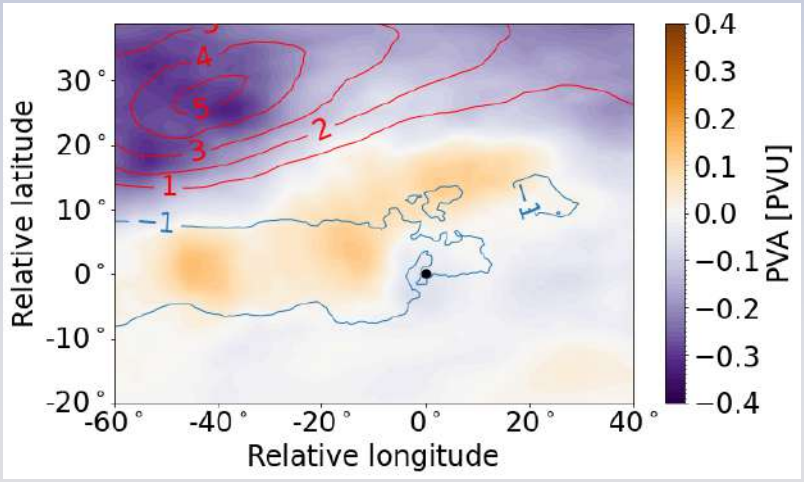


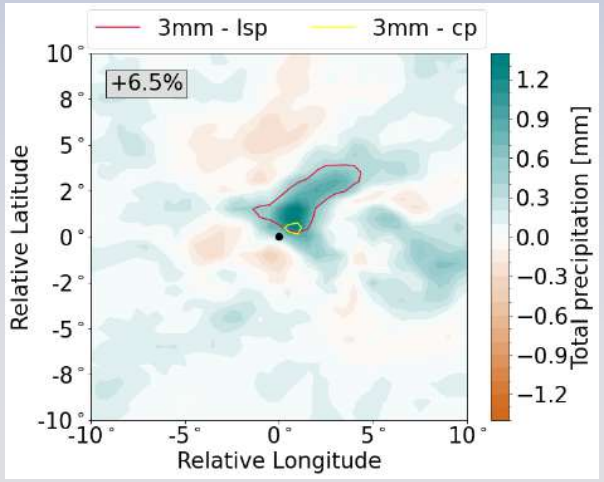
Precipitation: CB – CNB

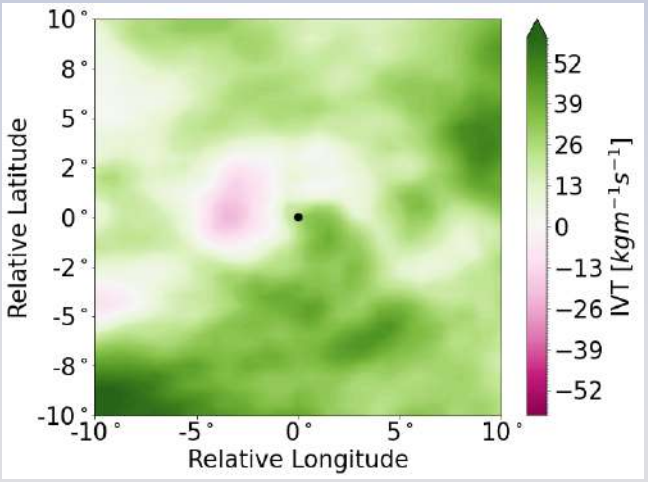


IVT: CB – CNB





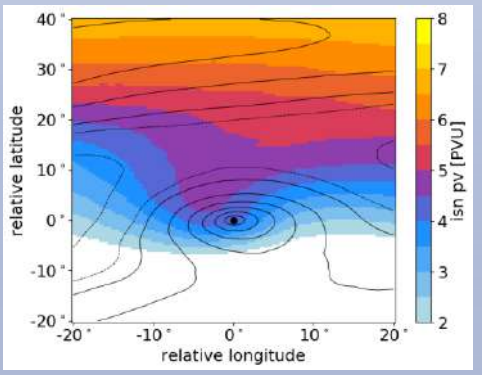




Distribution of moisture transport aligns with the distribution of precipitation

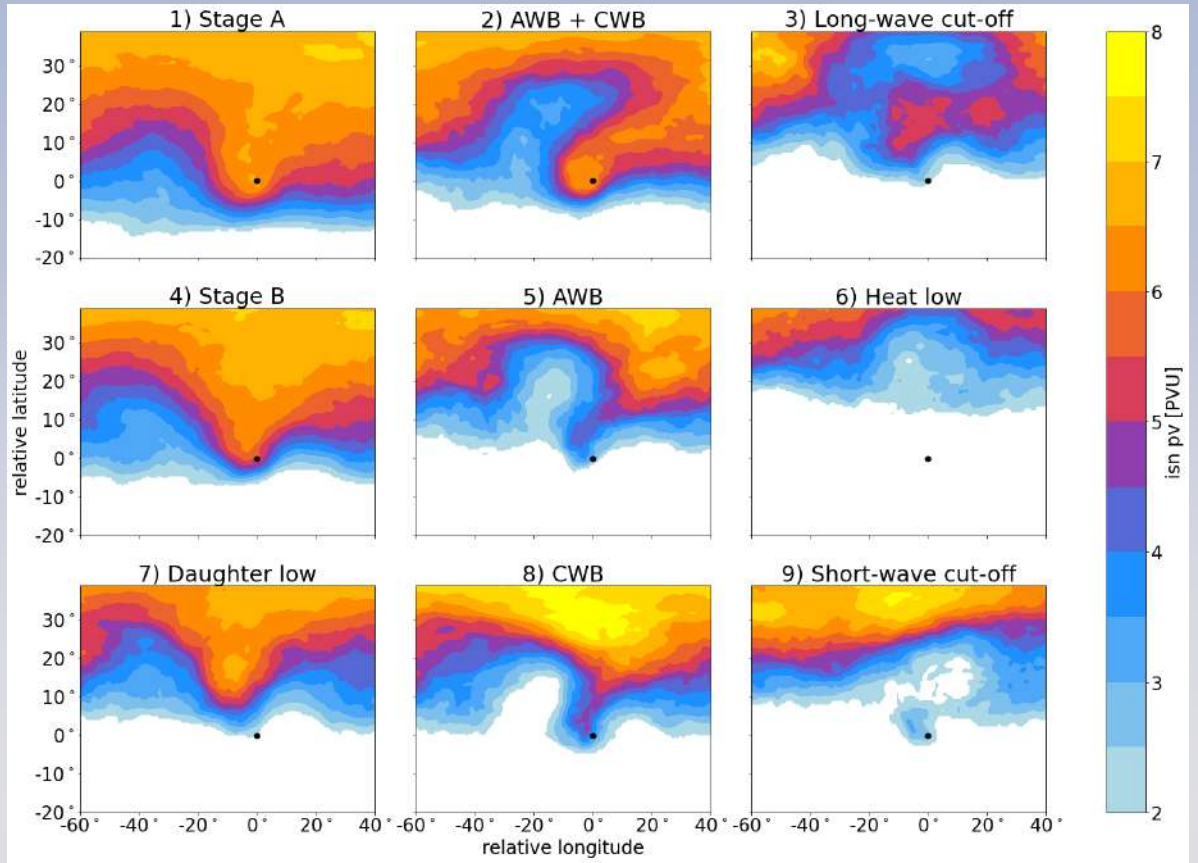
MC Classification

Shading: Isentropic PV (320-340K)
Lines: MSLP



- Classified 3190 cyclones into different clusters with distinct PV characteristics using a SOM algorithm [Givon et al., 2024]

1. Stage A Lee Cyclogenesis
2. Anti-cyclonic & cyclonic wave breaking (AWB + CWB)
3. Long-wave cut-off
4. Stage B Lee Cyclogenesis
5. Anti-cyclonic wave breaking (AWB)
6. Heat low (Sharav low)
7. Daughter cyclones
8. Cyclonic wave breaking (CWB)
9. Short-wave cut-off

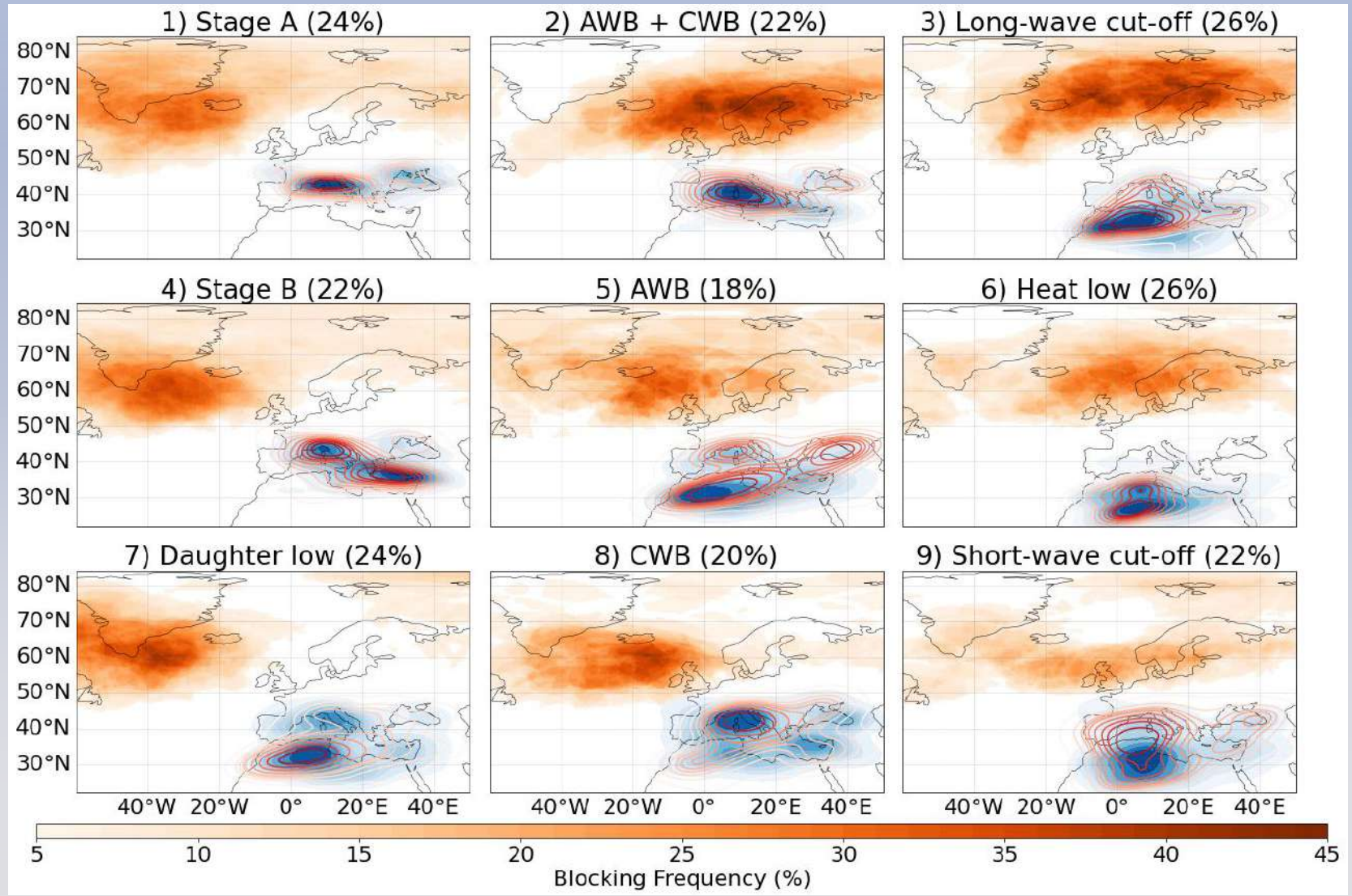


This classification improves our understanding of MC predictability

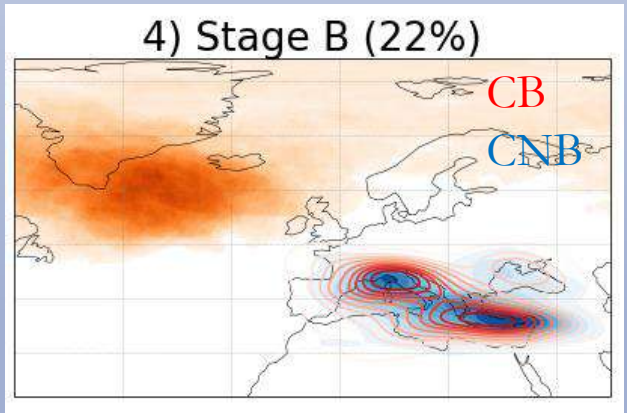
Geographical distribution per cluster

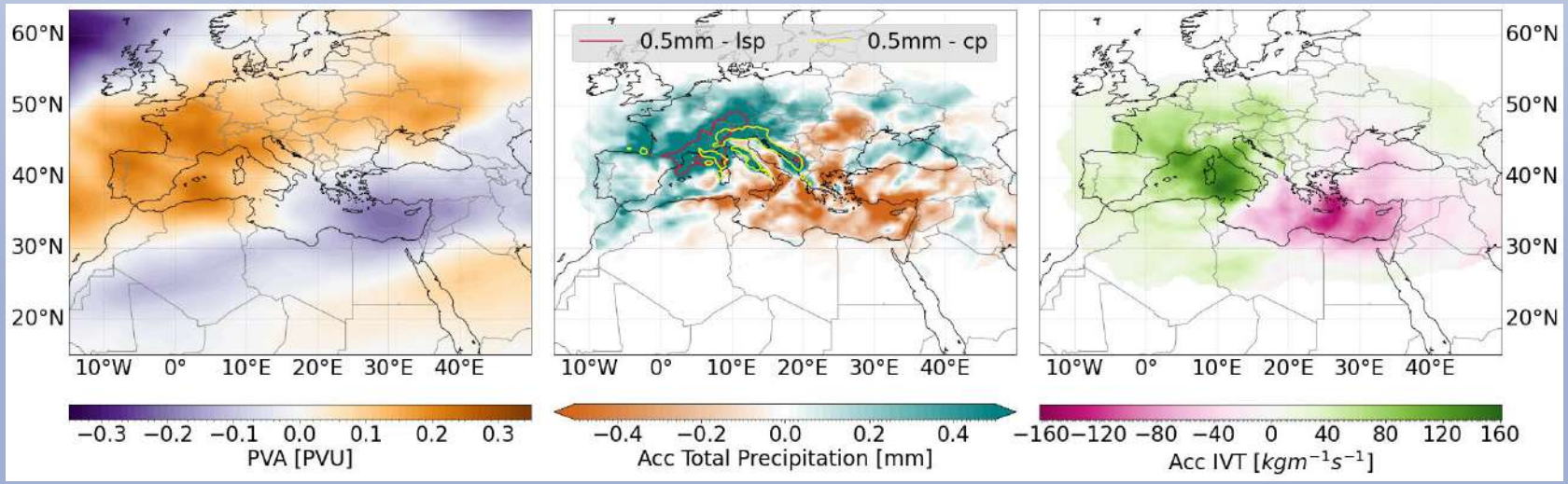
Blocking frequency for CB
Density of cyclone peak location for CB
Density of cyclone peak location for CNB

- 18-26% of MCs develop downstream of atmospheric block events
- The location of blocks varies geographically
- The location of peak intensity under CB can differ compared to CNB

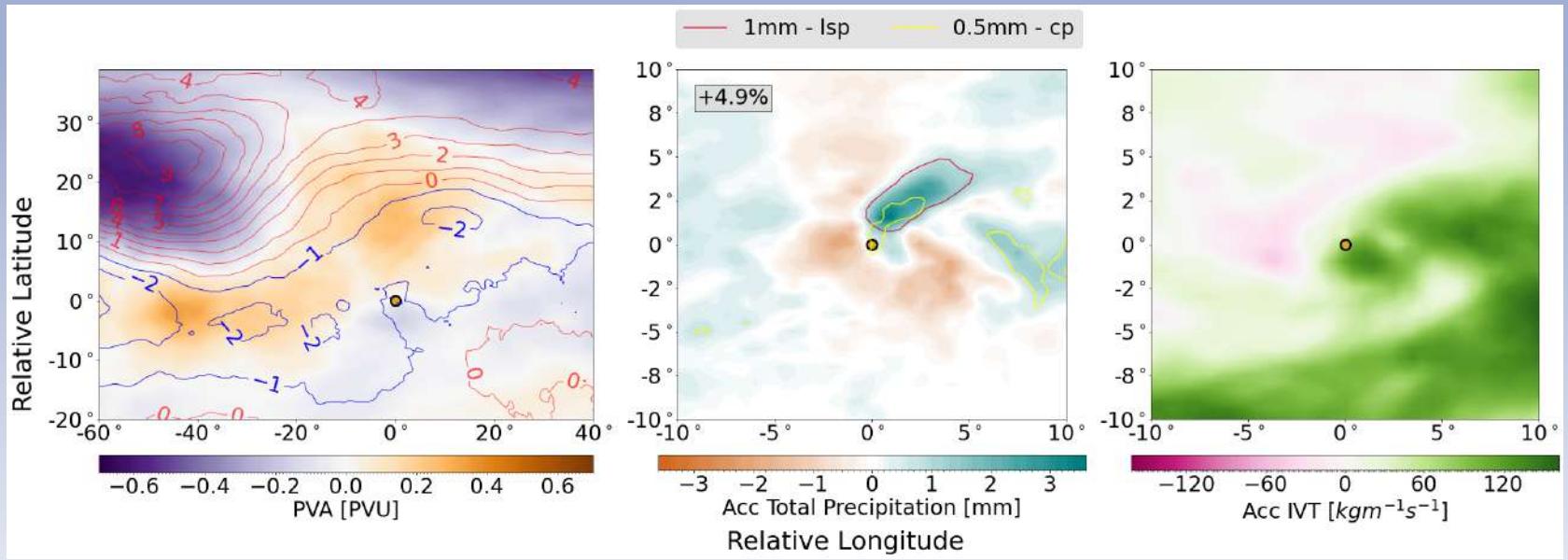


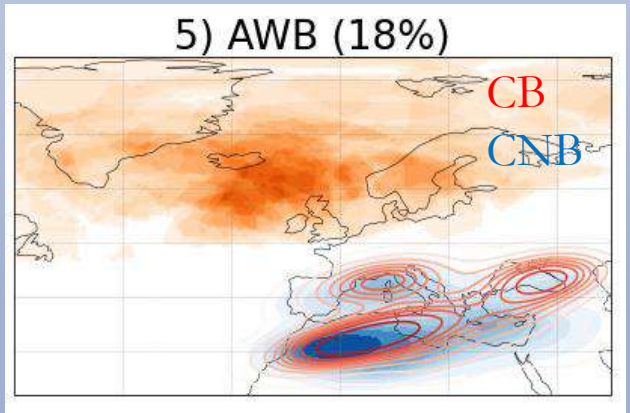
Large variability between different groups of MCs

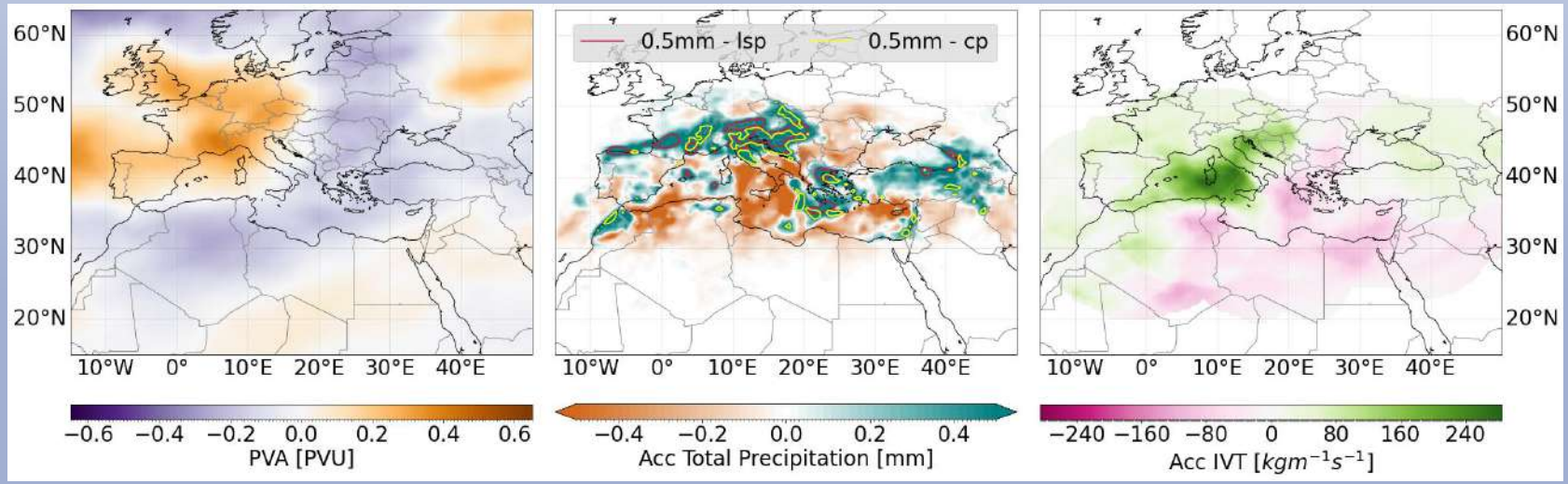




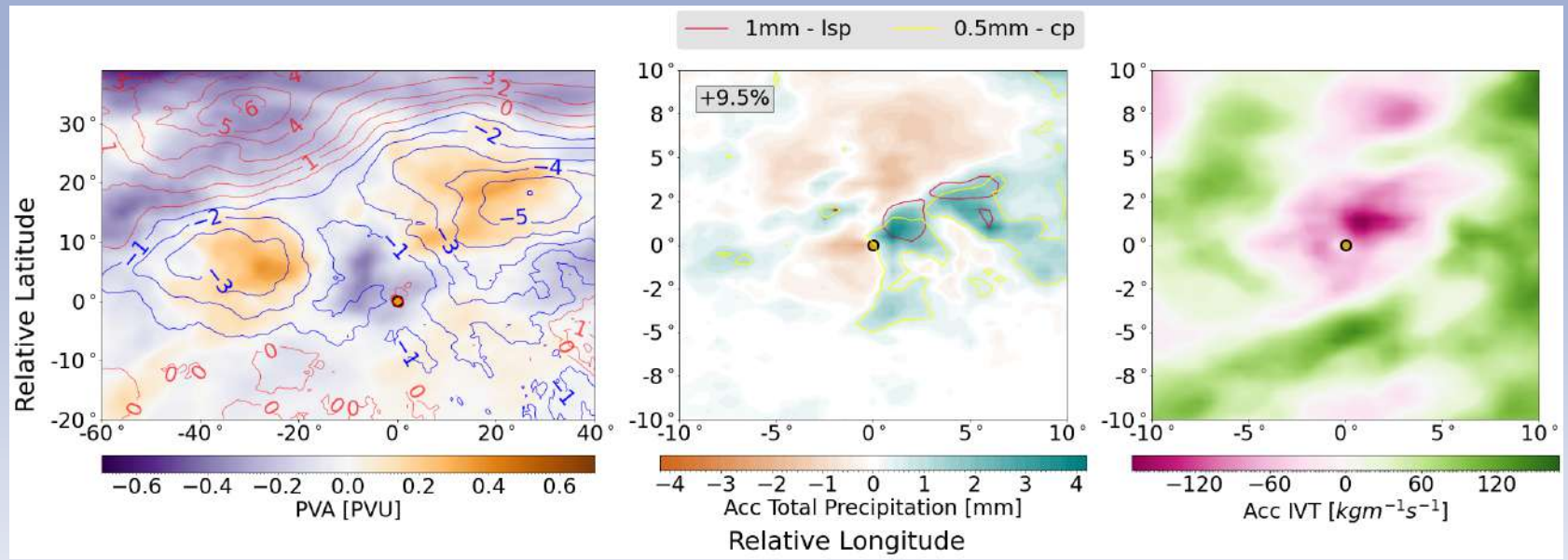
1. North Atlantic blocking
2. Similarity to overall means
3. Incresead precipitation
4. More moisture in lower part of domain

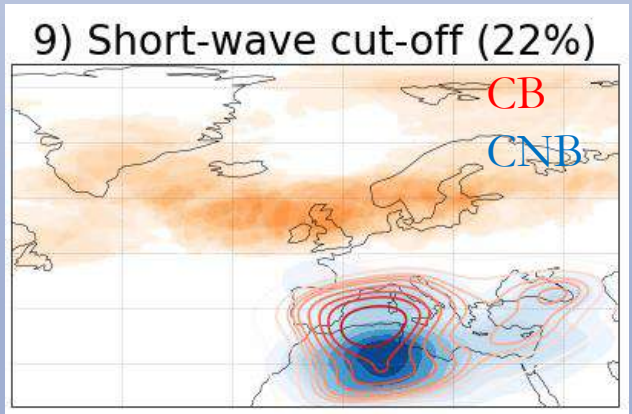


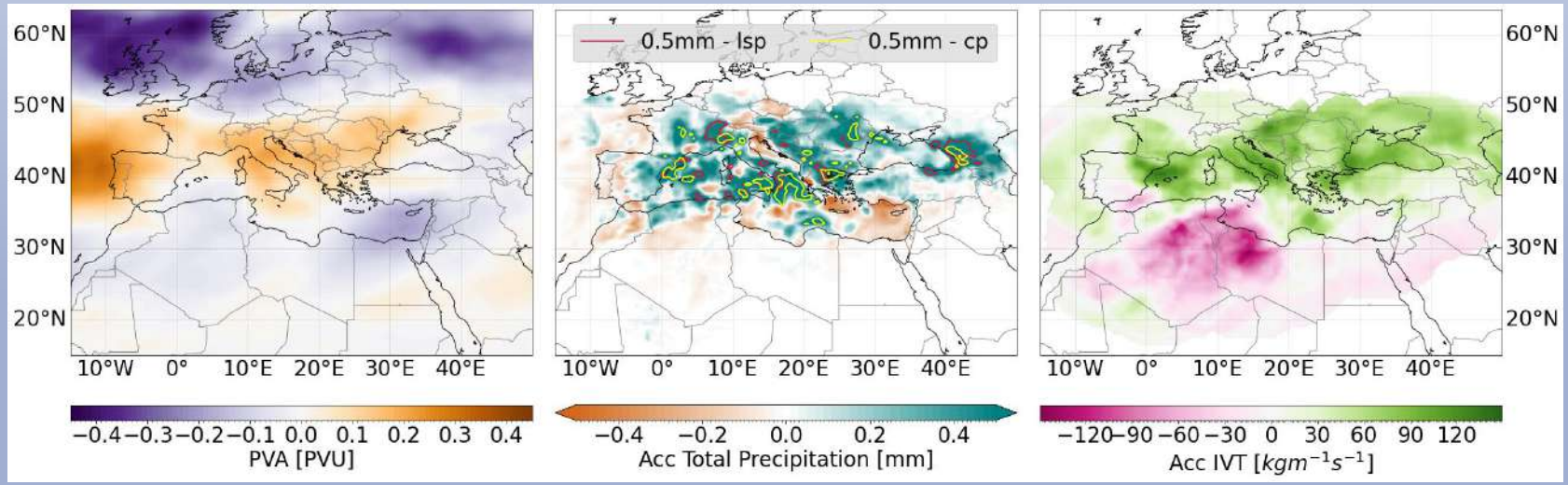




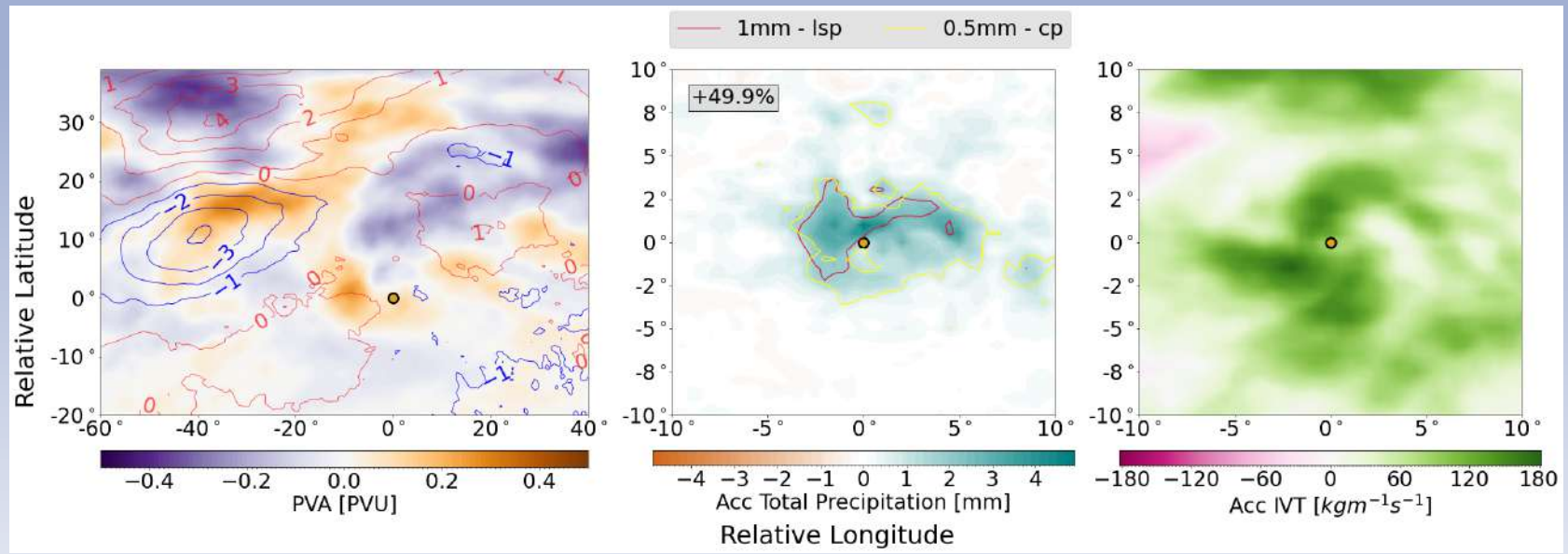
1. N. Atlantic/Scandinavian blocking
2. Increased precipitation at the eastern part of the domain
3. Long-range moisture transport





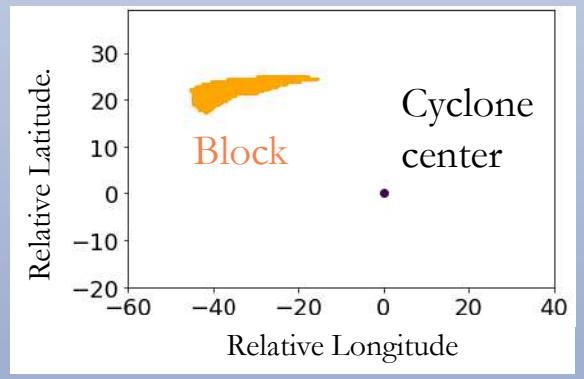


1. N. Atlantic/Scandinavian blocking (weak frequencies)
2. Increased sporadic/convective precipitation
3. 50% more precipitation in the domain



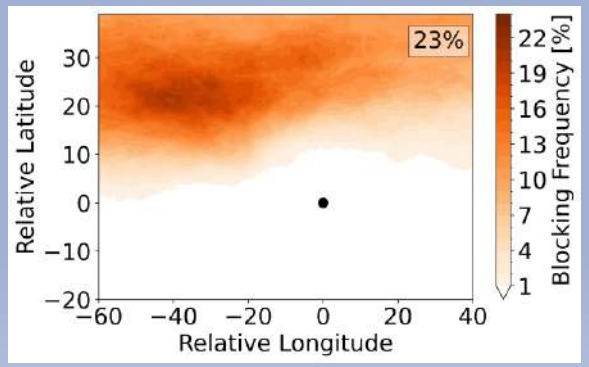
Summary

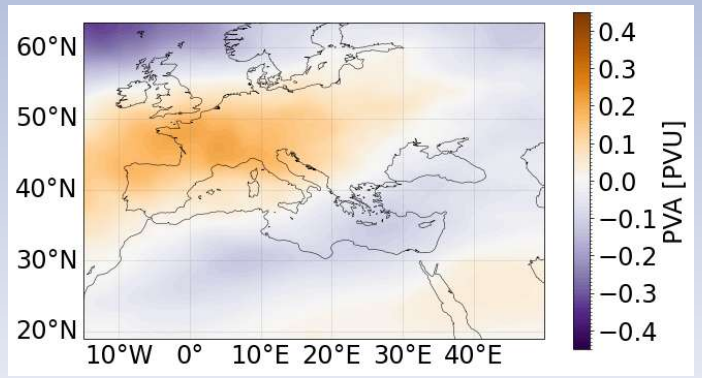
Systematic investigation of MC development downstream of Euro-Atlantic blocks and impact on cyclone-attributed precipitation.

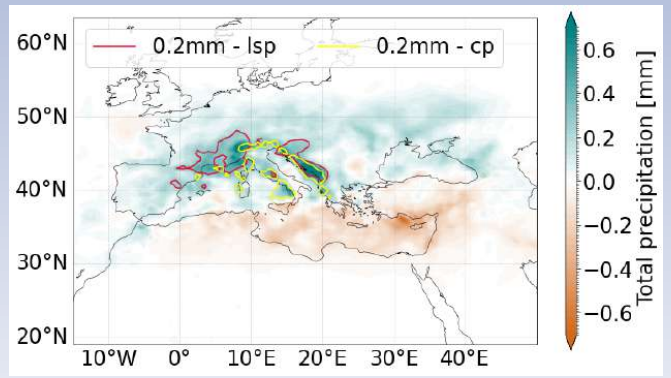


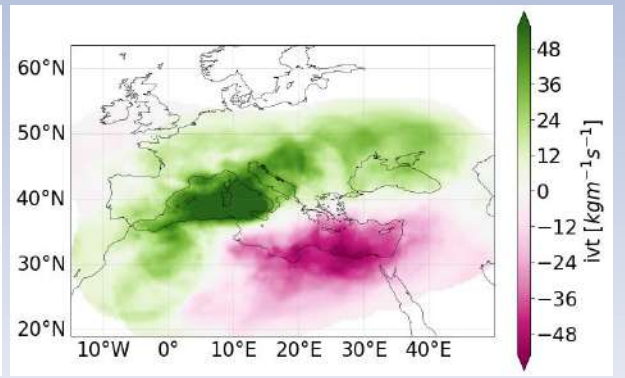
MCs under blocking conditions (23%):

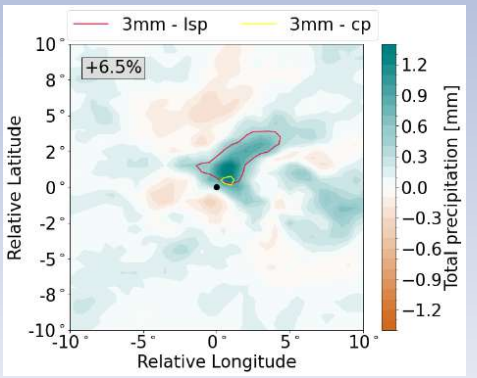
- Deeper cyclones (~1hPa)
- Increased precipitation around peak time
- Clear split between wetter northwest and drier southeast Mediterranean
- Relationship between PV, precipitation and moisture transport varies by cluster



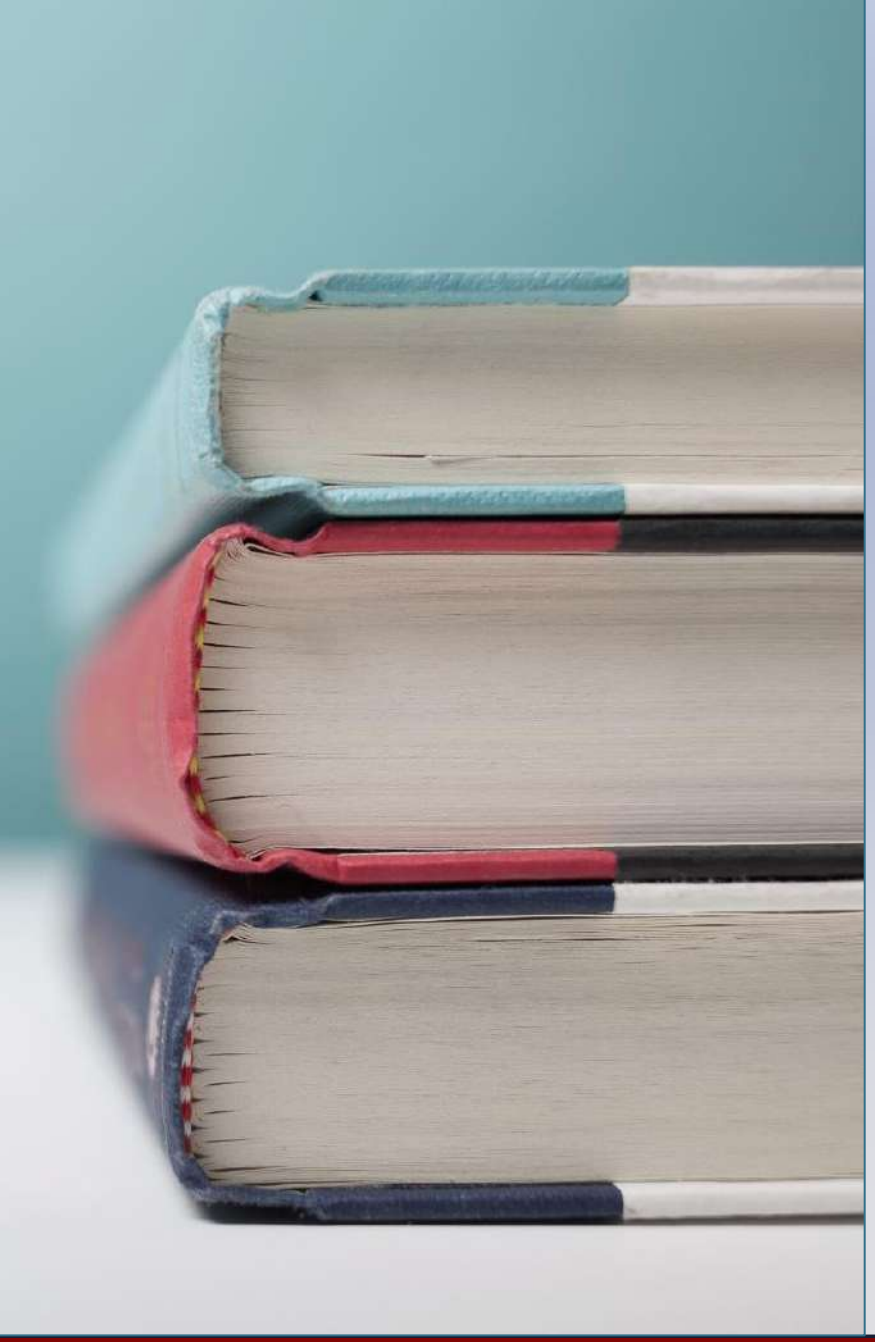








Important information on predictability



References

- Raveh-Rubin, S. and Flaounas, E. (2017), A dynamical link between deep Atlantic extratropical cyclones and intense Mediterranean cyclones. Atmos. Sci. Lett, 18: 215-221. https://doi.org/10.1002/asl.745
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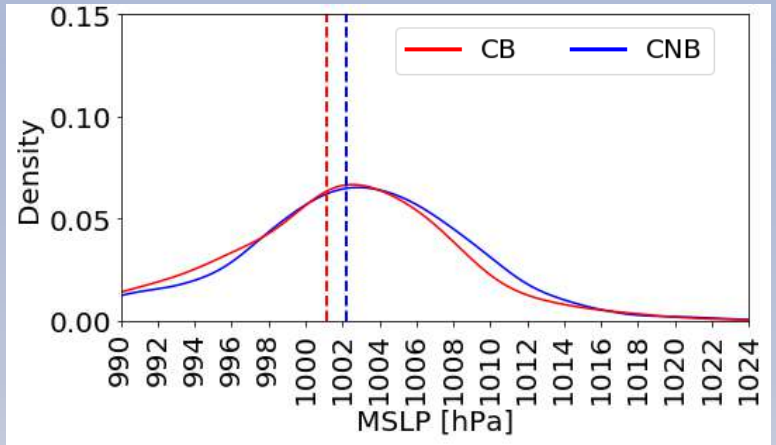
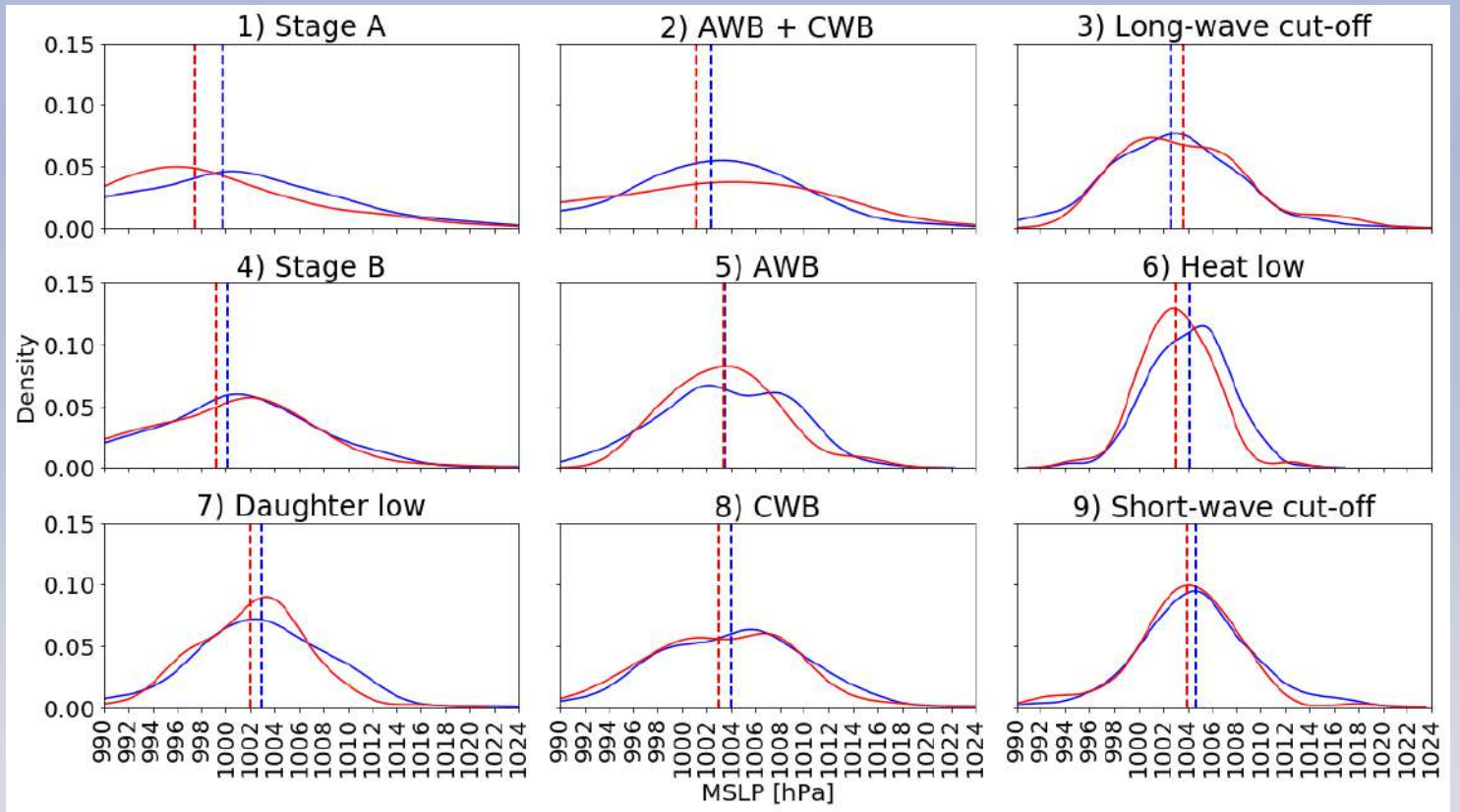
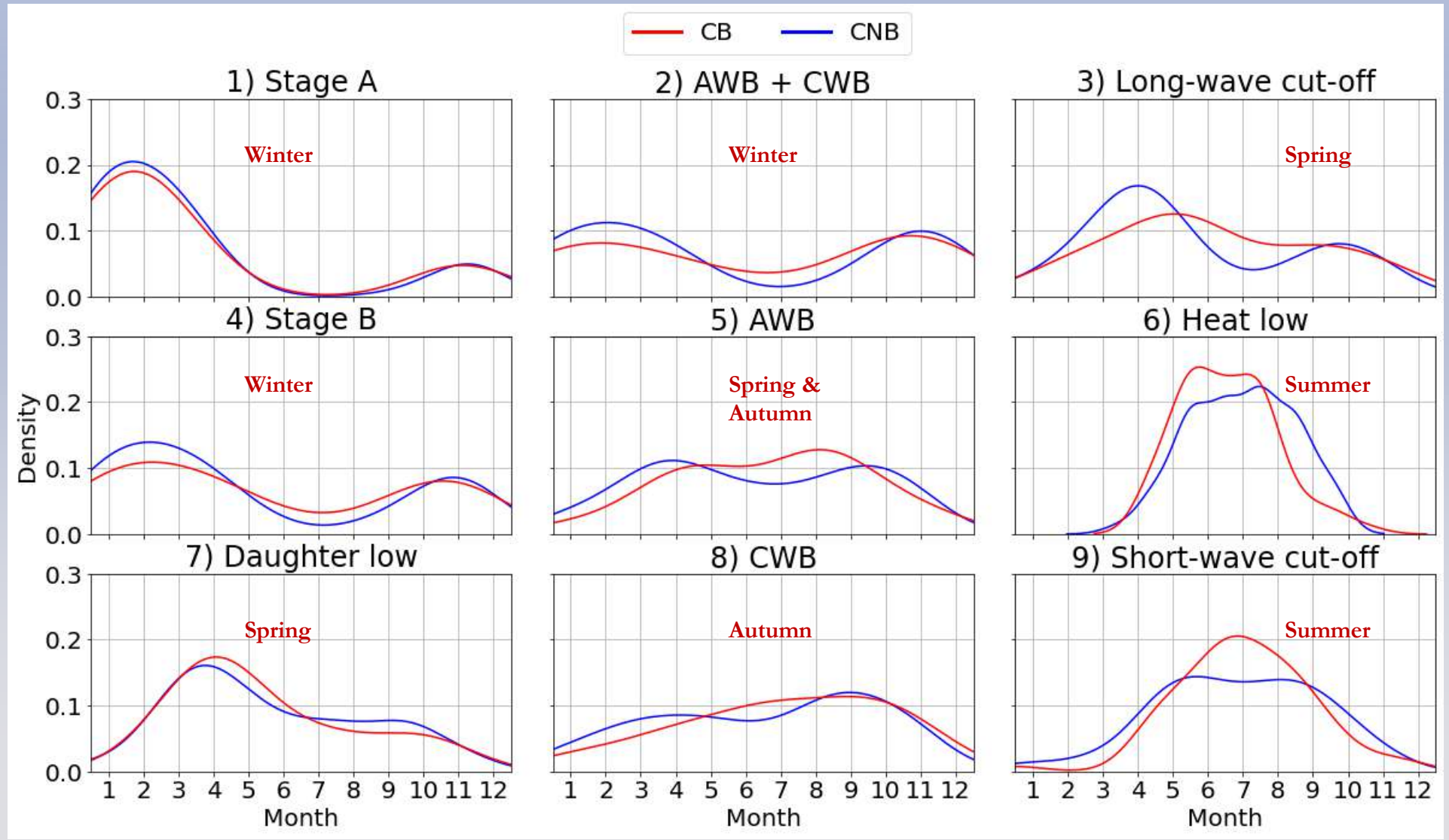
MSLP





Persistent blocking for 2 days prior peak ➡ deeper cyclone

Seasonality

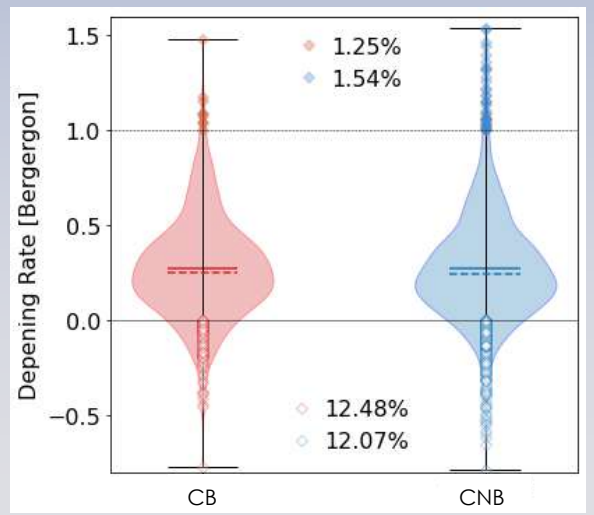


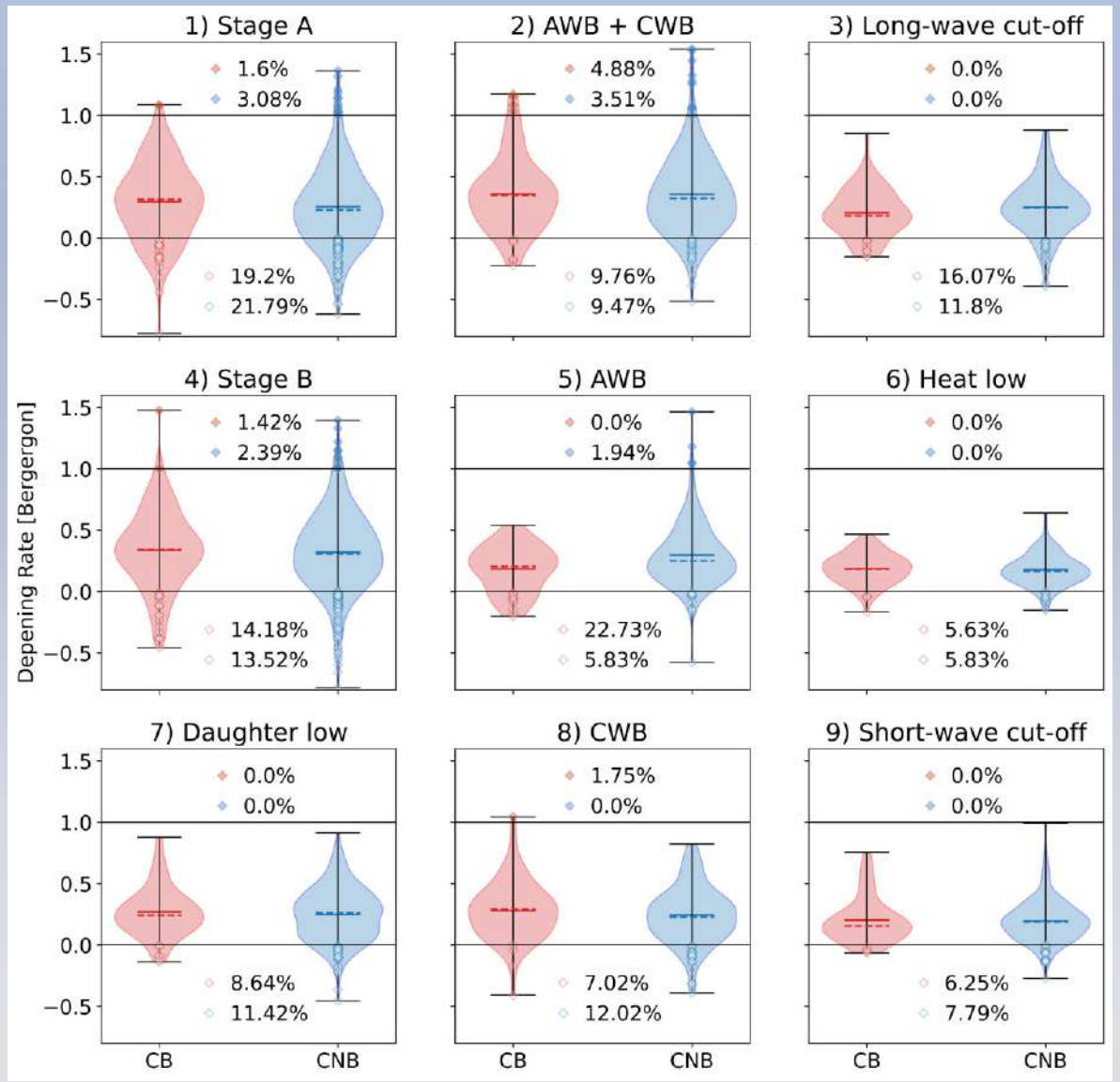
Varied seasonality

Cyclone Explosiveness

$$Bergeron = \frac{sin60}{sin\varphi_t}\frac{SLP_{t-12} - SLP_{t+12}}{24}$$

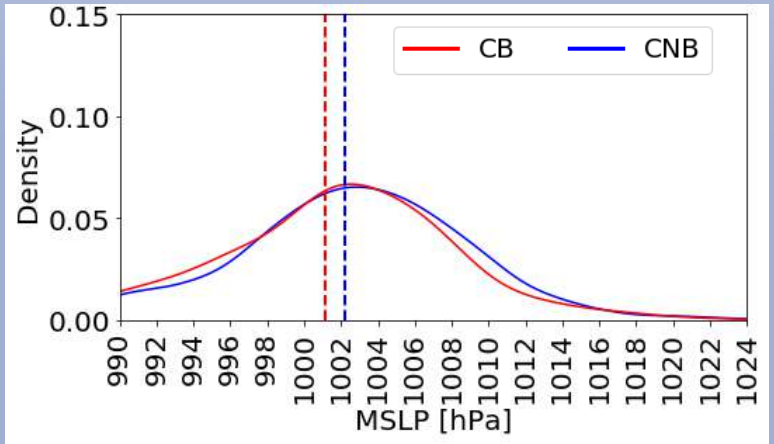
Bergeron > 1 ⇒ explosive cyclone





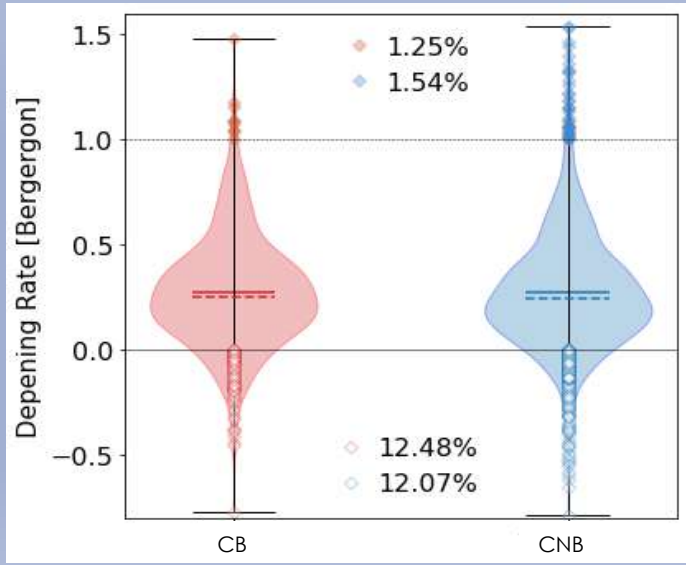
Persistent blocking for 2 days prior peak ⇏ explosive cyclone

Track characteristics



Persistent blocking ⇨ deeper cyclone

Explosiveness

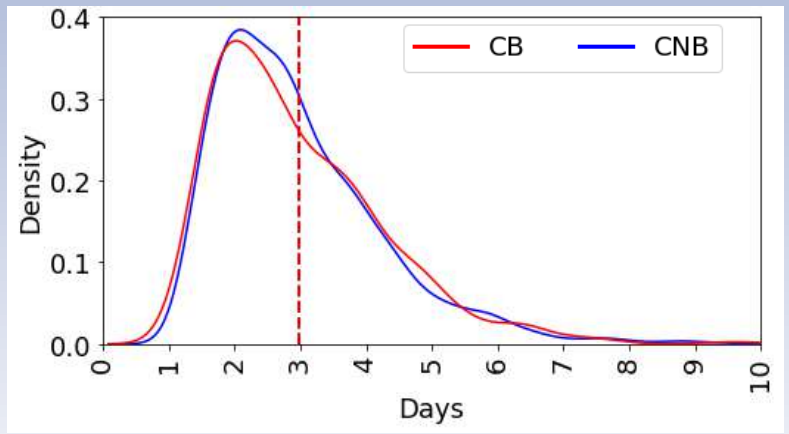


$$Bergeron = \frac{sin60}{sin\varphi_t}\frac{SLP_{t-12} - SLP_{t+12}}{24}$$

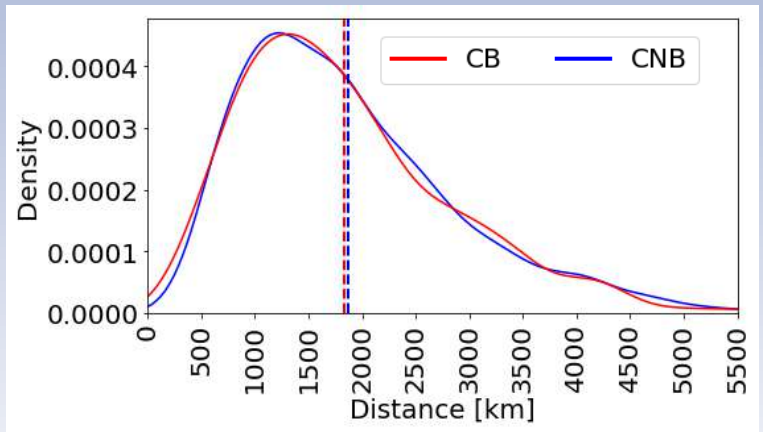
Bergeron > 1 ⇒ explosive cyclone

Deeper cyclone ⇏ explosive cyclone

Lifetime



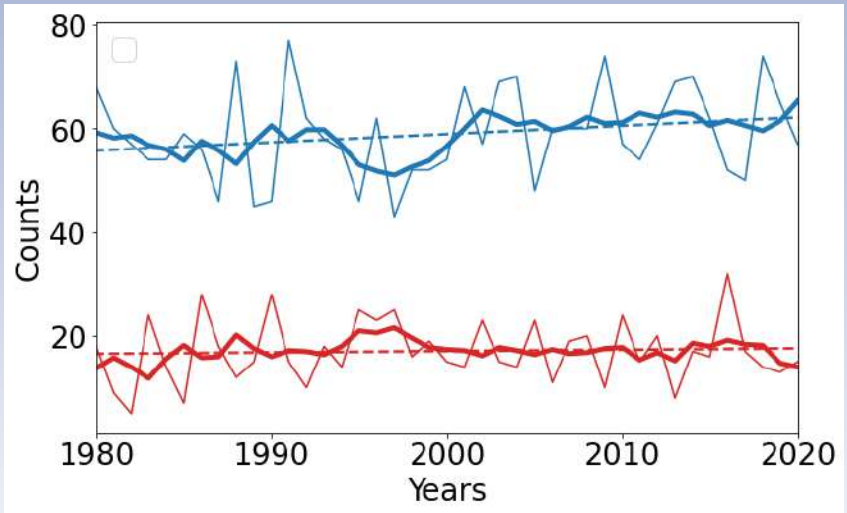
Distance travelled

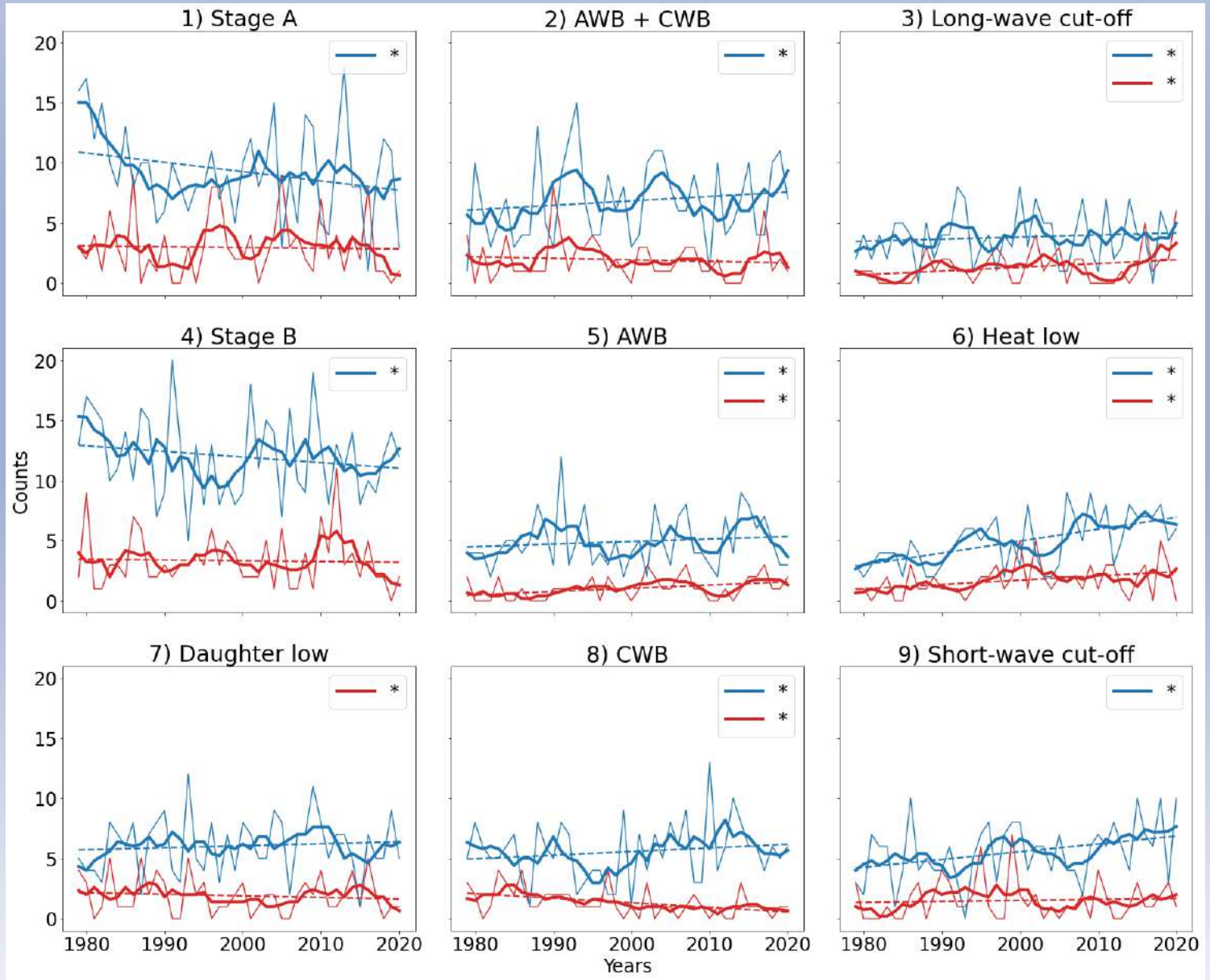


No major impact on lifetime and distance travelled

Trends

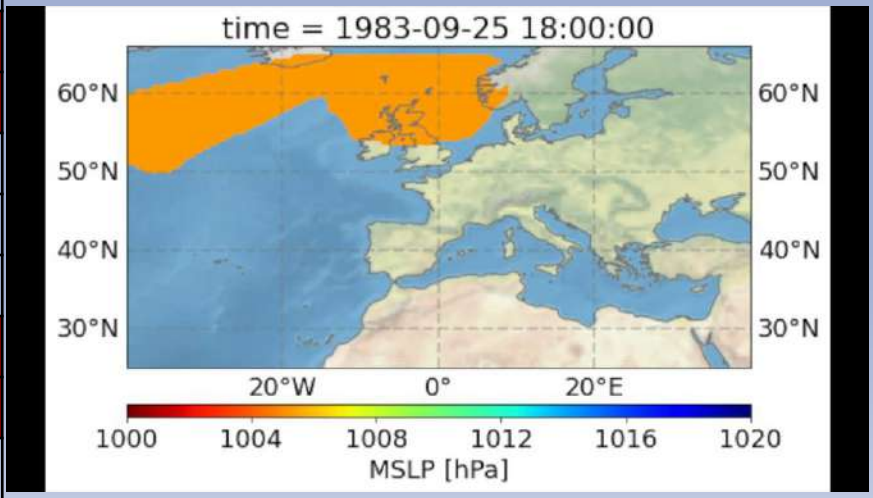
- Annual counts of cyclones in each scenario
- Thick line: 5-yr running mean
- Dashed line: linear fit on running mean
- Significance at 90 confidence level is indicated with *

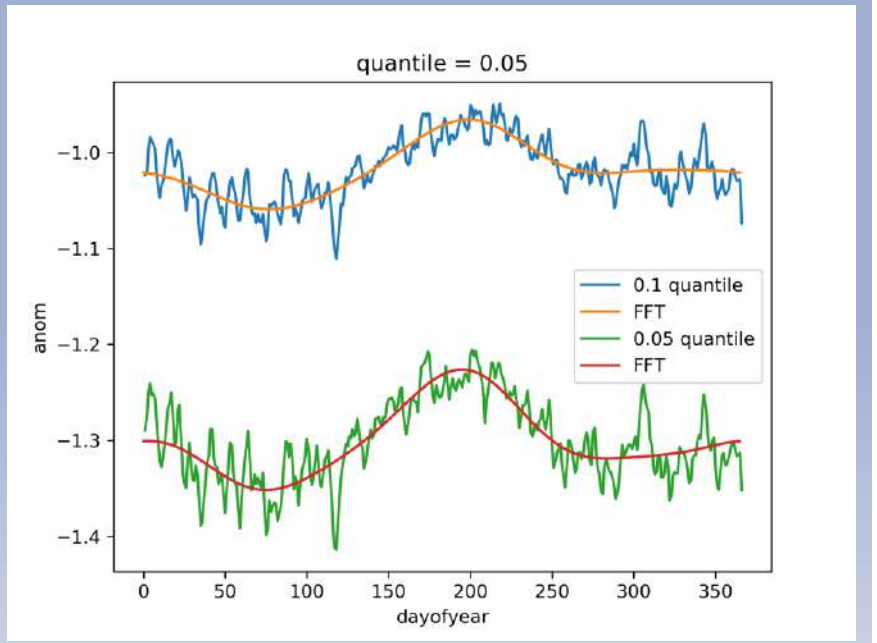




Medicanes

Date	ID	Name	CL	Block 2d	Block 1d	Block 18h	Block 15h	Block 12h	Block 9h	Block 6h	Block 3h
1982-01	274	Leucosia	2	No	No	No	No	No	No	No	No
1983-09	409	Callisto	9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
1995-01	1410	Celeno	2	No	No	No	No	Yes	Yes	Yes	Yes
1996-10	1580	Cornelia	5	No	No	No	No	No	No	No	No
2005-12	2409	Zeo	2	No	No	No	No	No	No	No	No
2006-09	2489	Maria	9	No	No	No	No	No	No	No	No
2011-11	2966	Rolf	4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2014-01	3164	Ilona	4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2014-11	3243	Qendresa	5	No	No	No	No	No	No	No	No
2017-11	3514	Numa	4	No	No	No	No	No	No	No	No
2018-09	3601	Zorbas	9	No	No	No	No	No	No	No	No
2020-09	3777	Ianos	6	No	No	No	No	No?	No?	No?	No?
2023-09	?	Daniel	?	?	?	?	?	?	?	?	?

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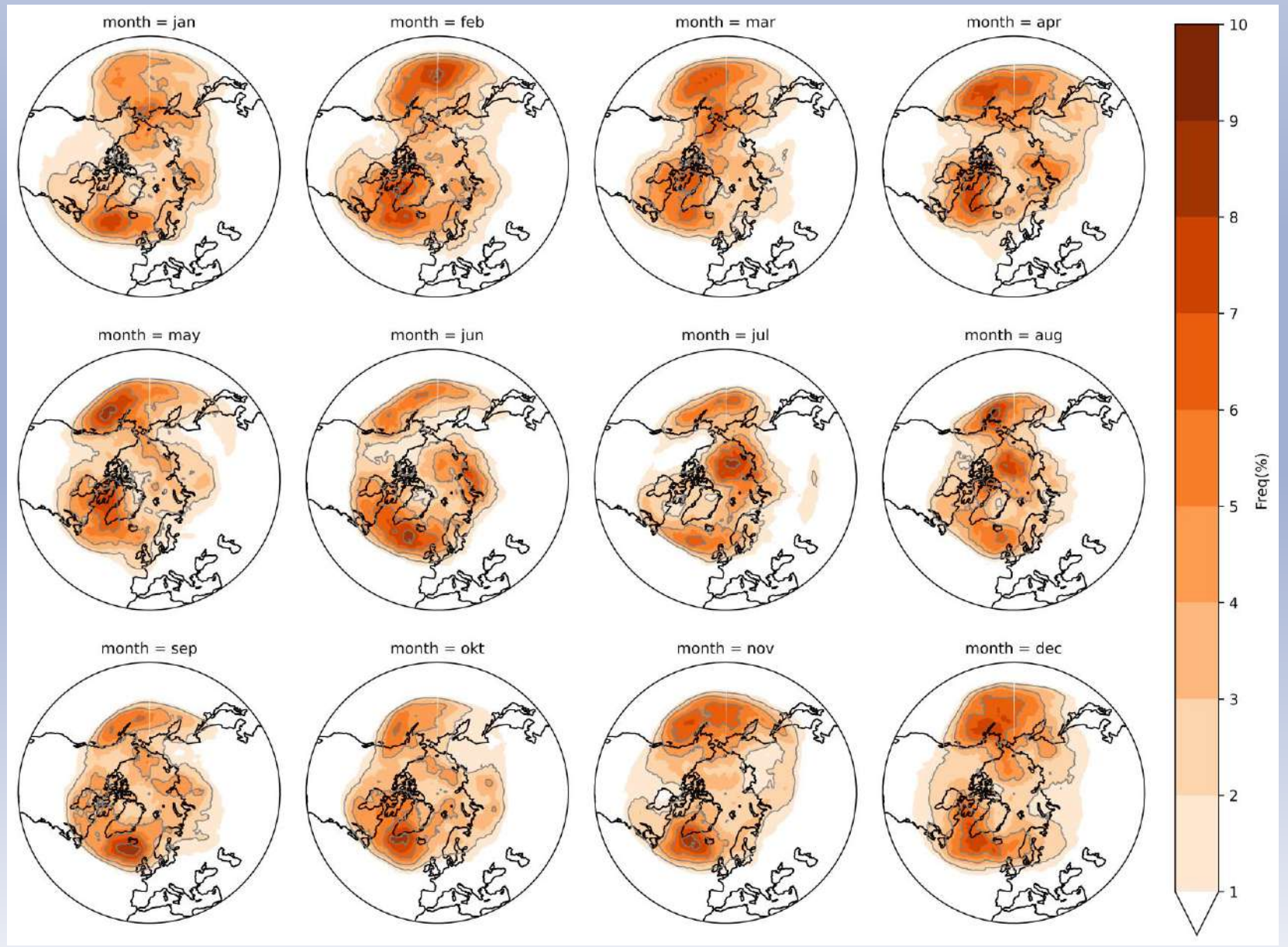
anom
−1.0
−1.1
−1.2
−1.3
−1.4
0
50
100
150
200
250
300
350
dayofyear
0.1 quantile
FFT
0.05 quantile
FFT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month = feb
month = mar
month = apr
month = may
month = jun
month = jul
month = aug
month = sep
month = okt
month = nov
month = dec
Freq(%)
10
9
8
7
6
5
4
3
2
1