Process-based classification of Mediterranean Cyclones: an Upper-Level PV perspective

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Contributions from Medcyclones COST-ACTION community

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MedCyclones
COST Action CA19109

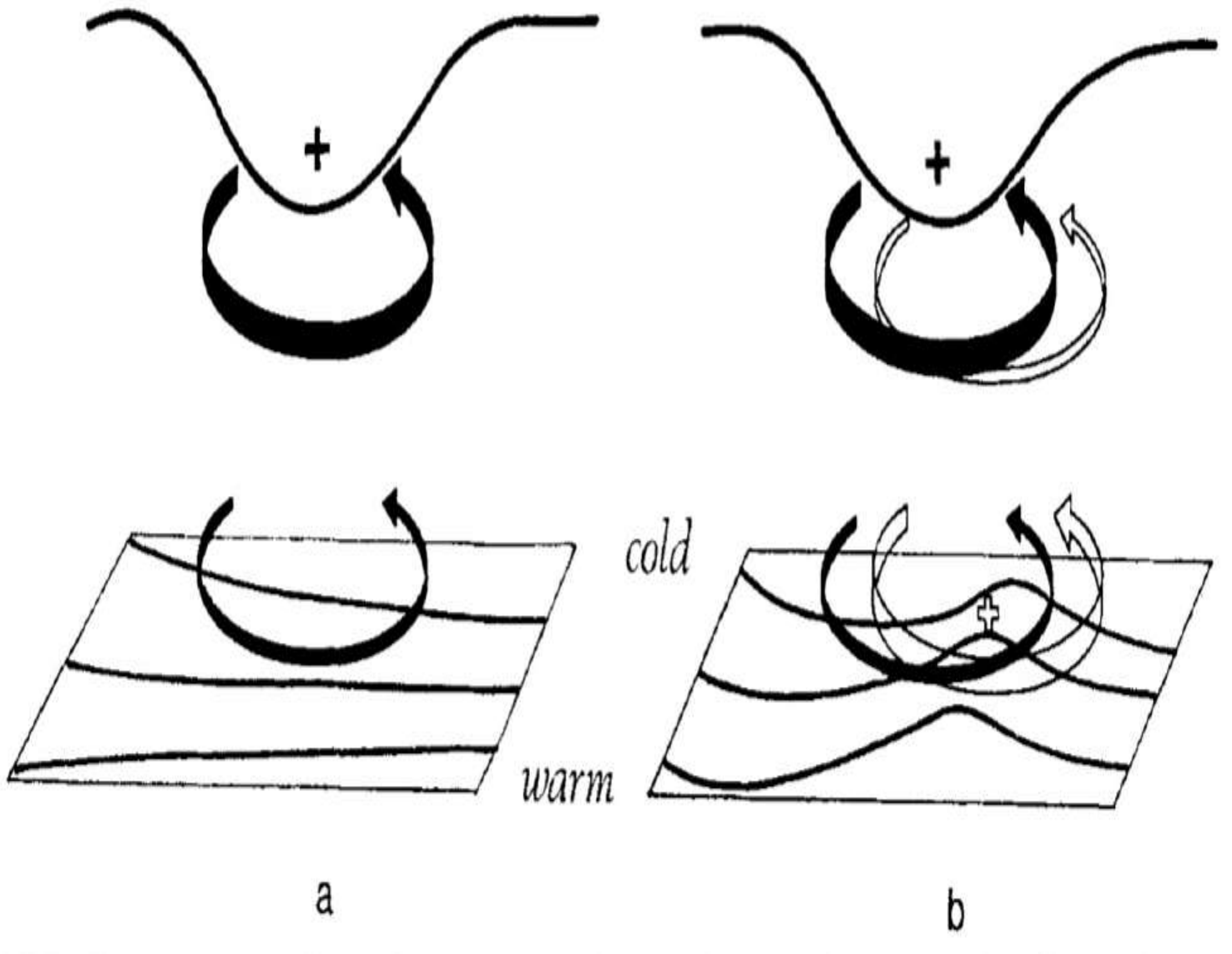
MCs deepening mechanisms

- Adiabatic processes (PV advection)
- Diabatic heat release (precipitation)
- Release of potential baroclinic instability
- Topography (geostrophic adjustment)
- Heat low (thermals)

Dynamic classification of MCs is absent

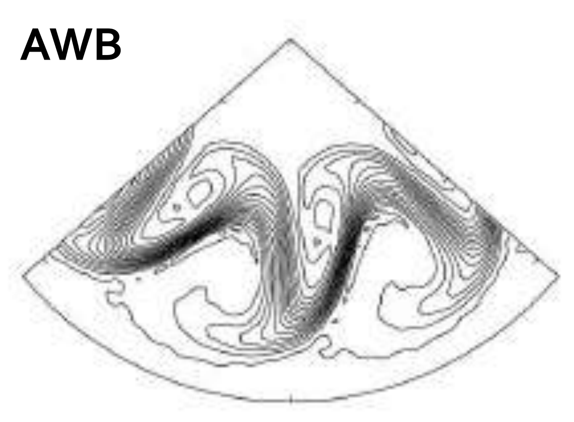
PV Perspective - Theory

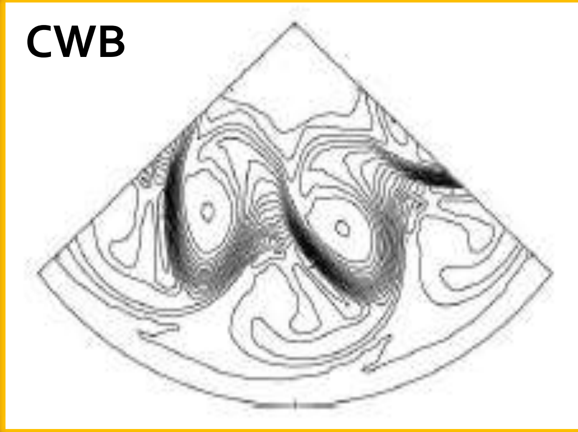
Hoskins et al., 1985



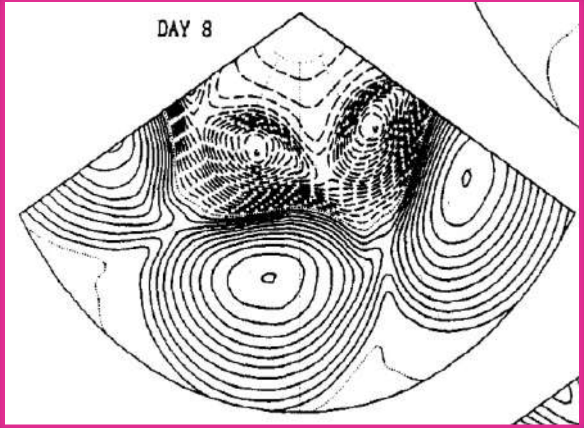
Thorncroft et al., 1993

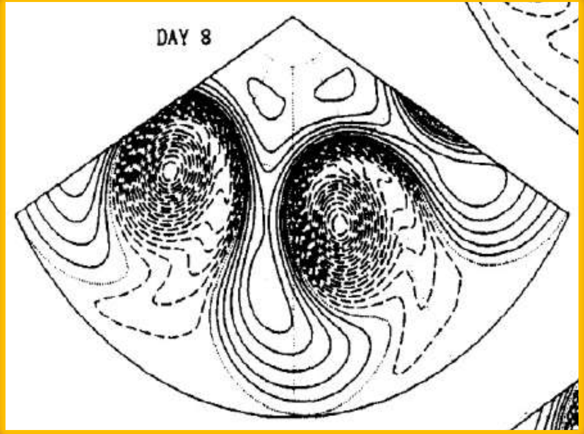
Potential temperature on 2 PVU surface





Sea level pressure

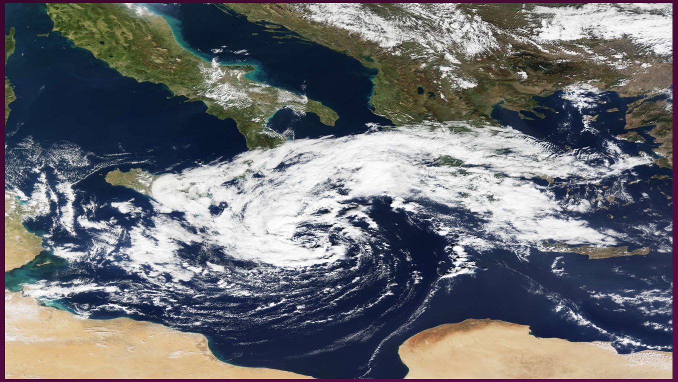




MCs are dominated by upper-level PV patterns

From an upper-level PV perspective, are there coherent "types" of MCs?

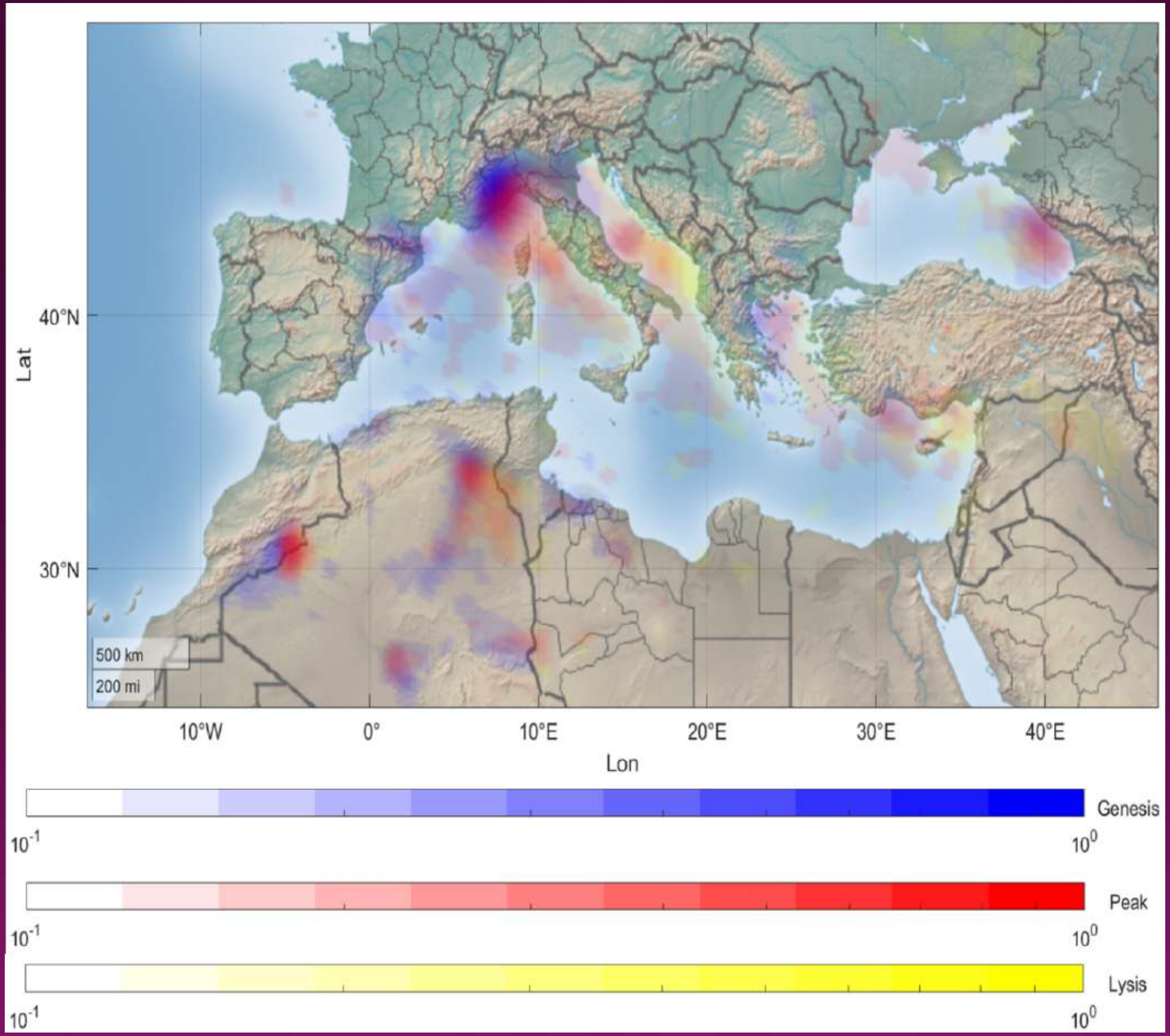
- Cyclone features?
- Surface impact?
- Long-term trends?
- Understand predictability



Dominant MC deepening mechanisms?

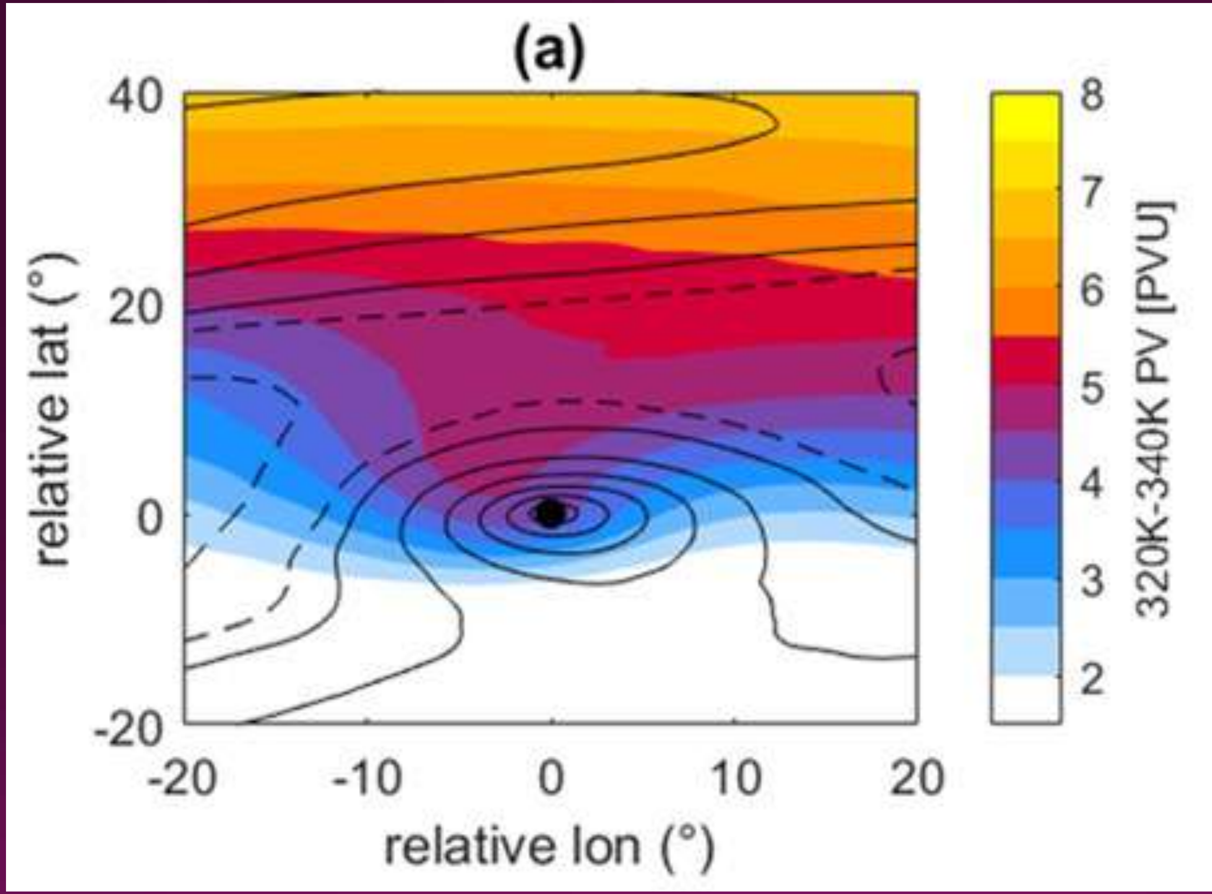
MCs Data

- Era5, 1979-2020
- Combined cyclone detection algorithm (Flaounas et al 2023)
- Confidence level 5
- 3190 cyclone tracks



PV Classification

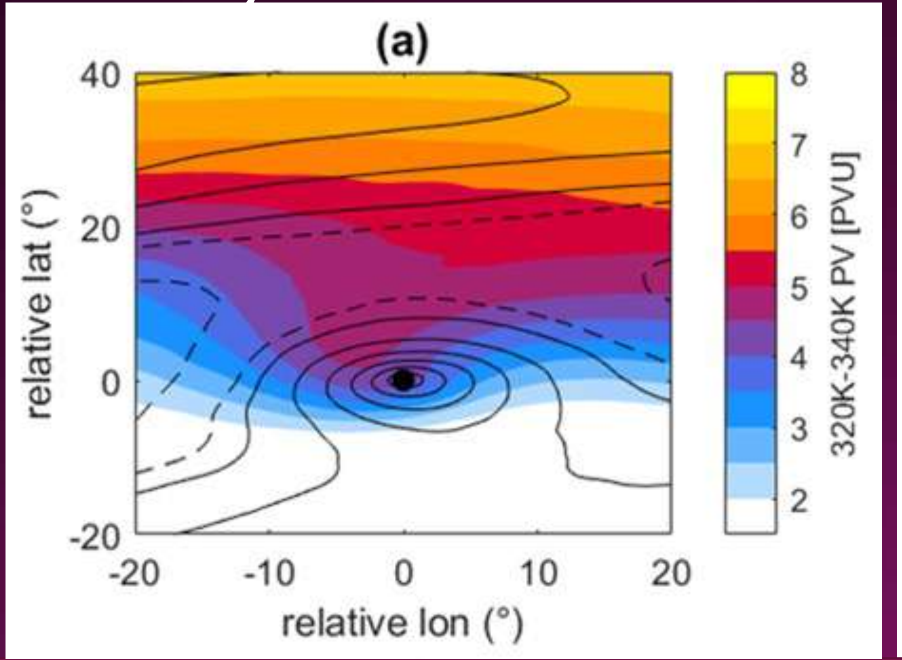
- Minimum SLP time
- Cyclone-centered
- Upper-level (320-340K) PV
- SOM classification
- 9 clusters



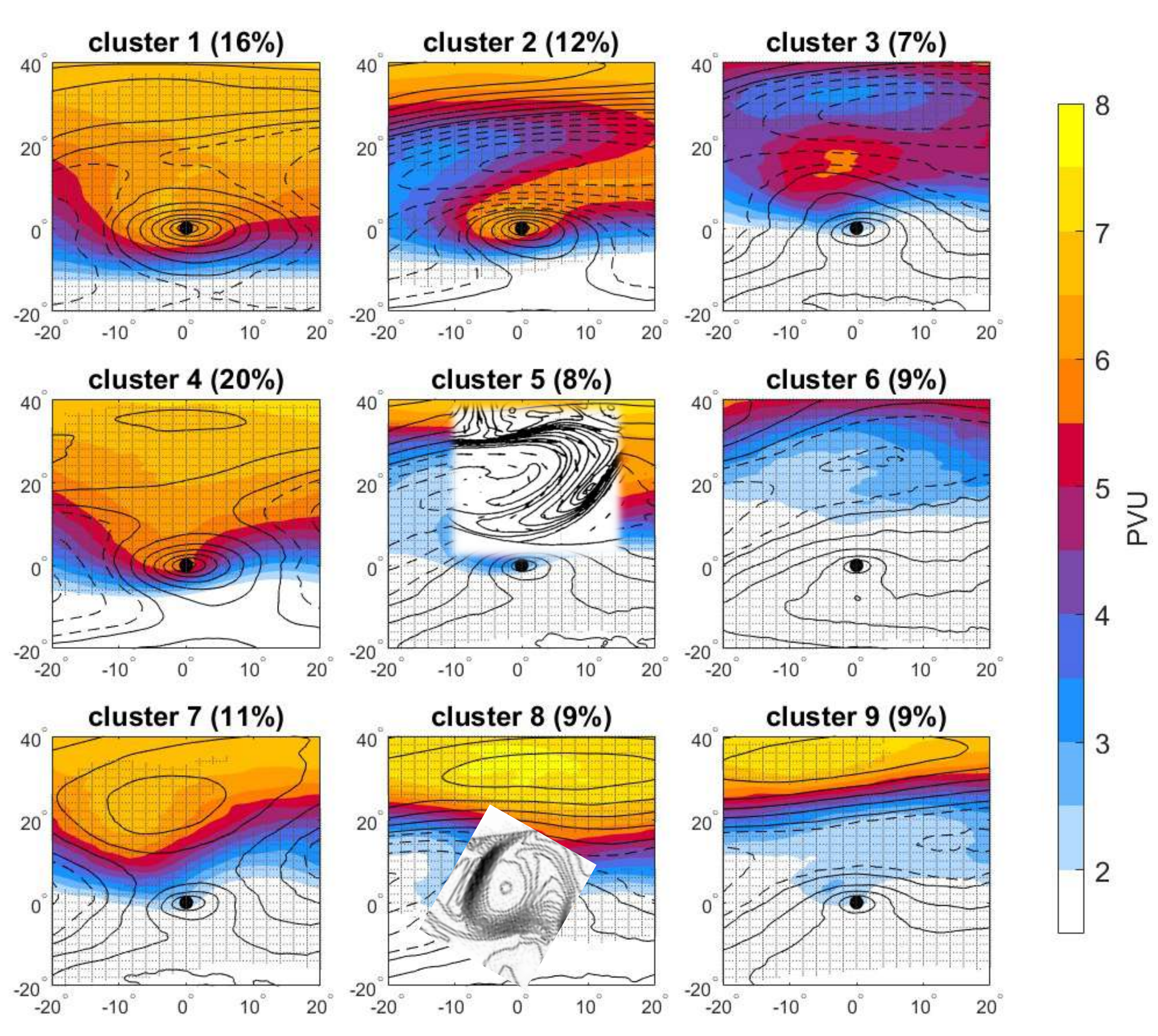
Results: PV SOM Classification

PV Clusters

1. Stage A lee-low
2. AWB+CWB low
3. Long-wave cut-off low
4. Stage B lee-low

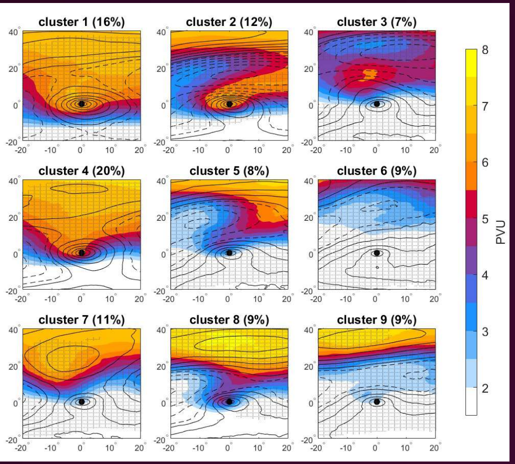


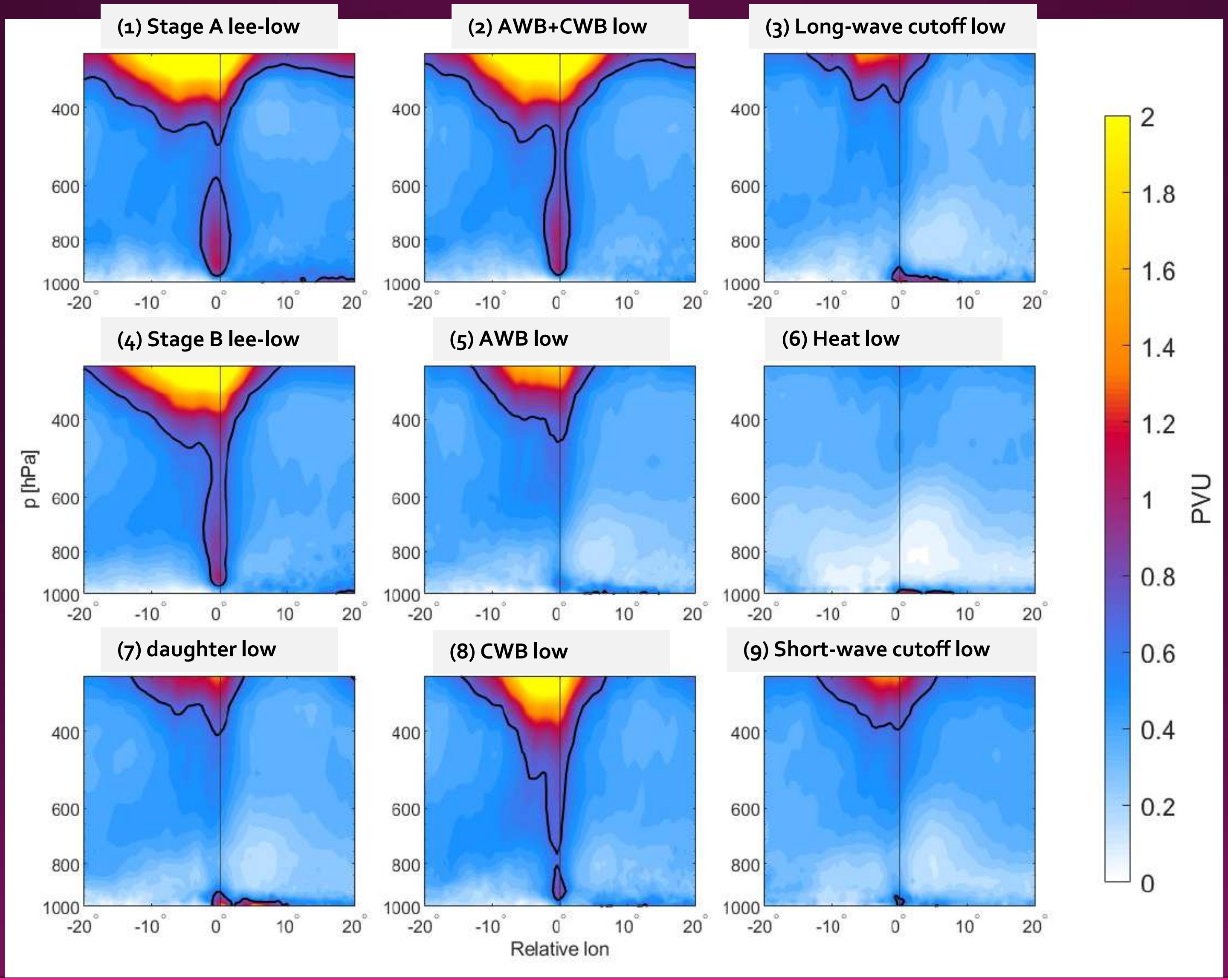
Upper-level PV and SLP



Distinct PV patterns of MCs do exist

PV Vertical Cross Section

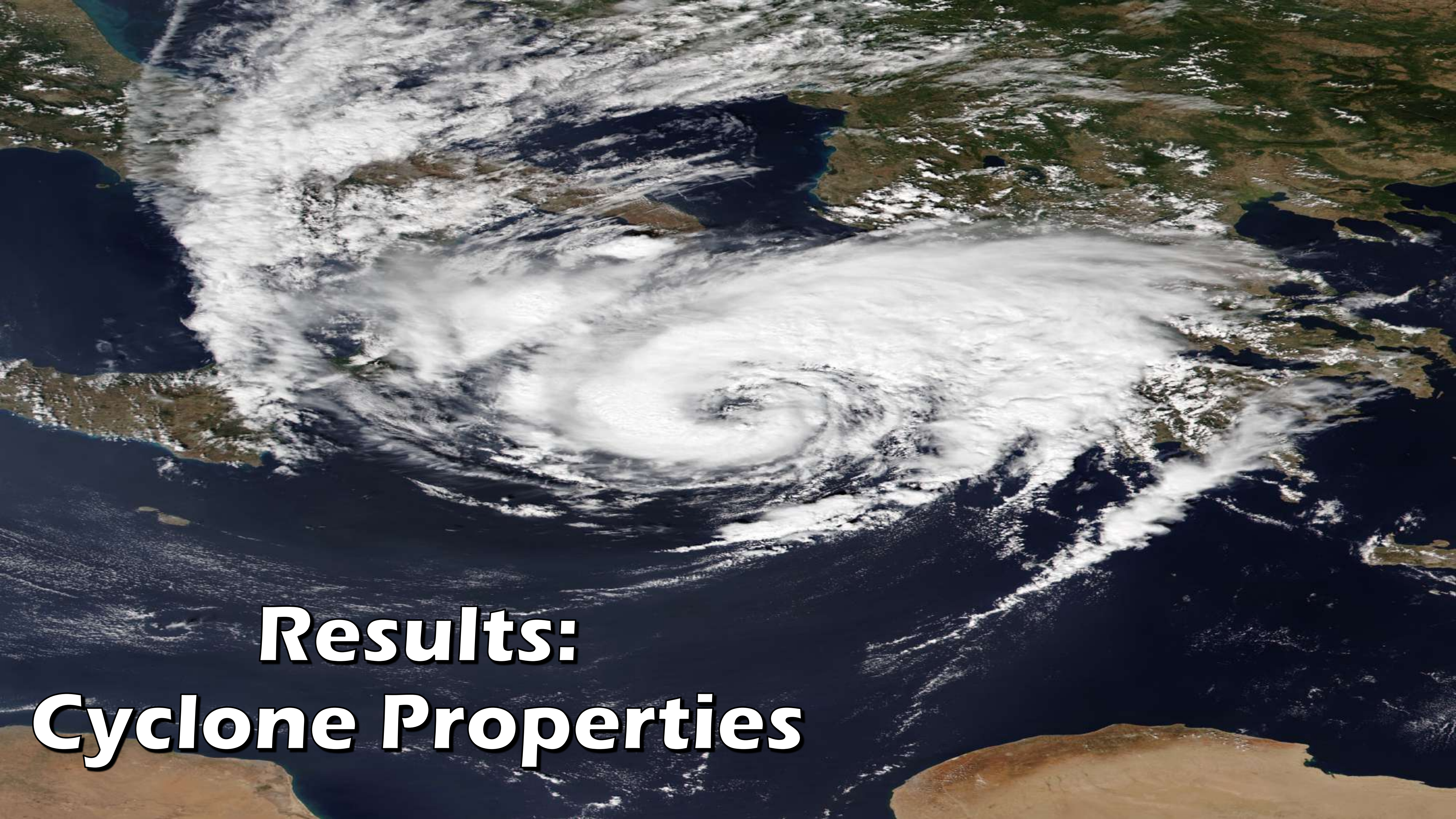




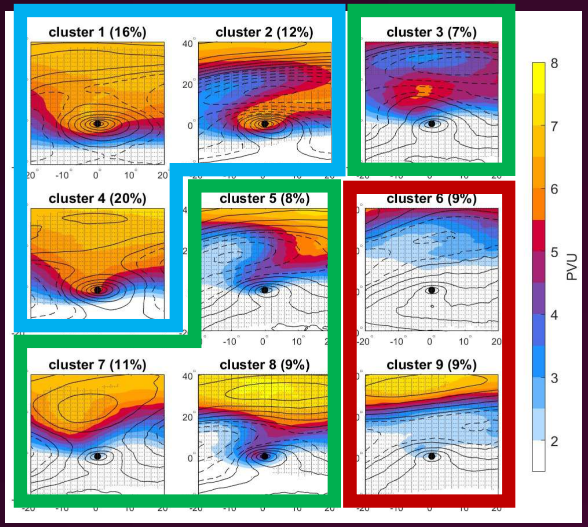
- Significant differences across the tropospheric column
- Diabatic
- Surface

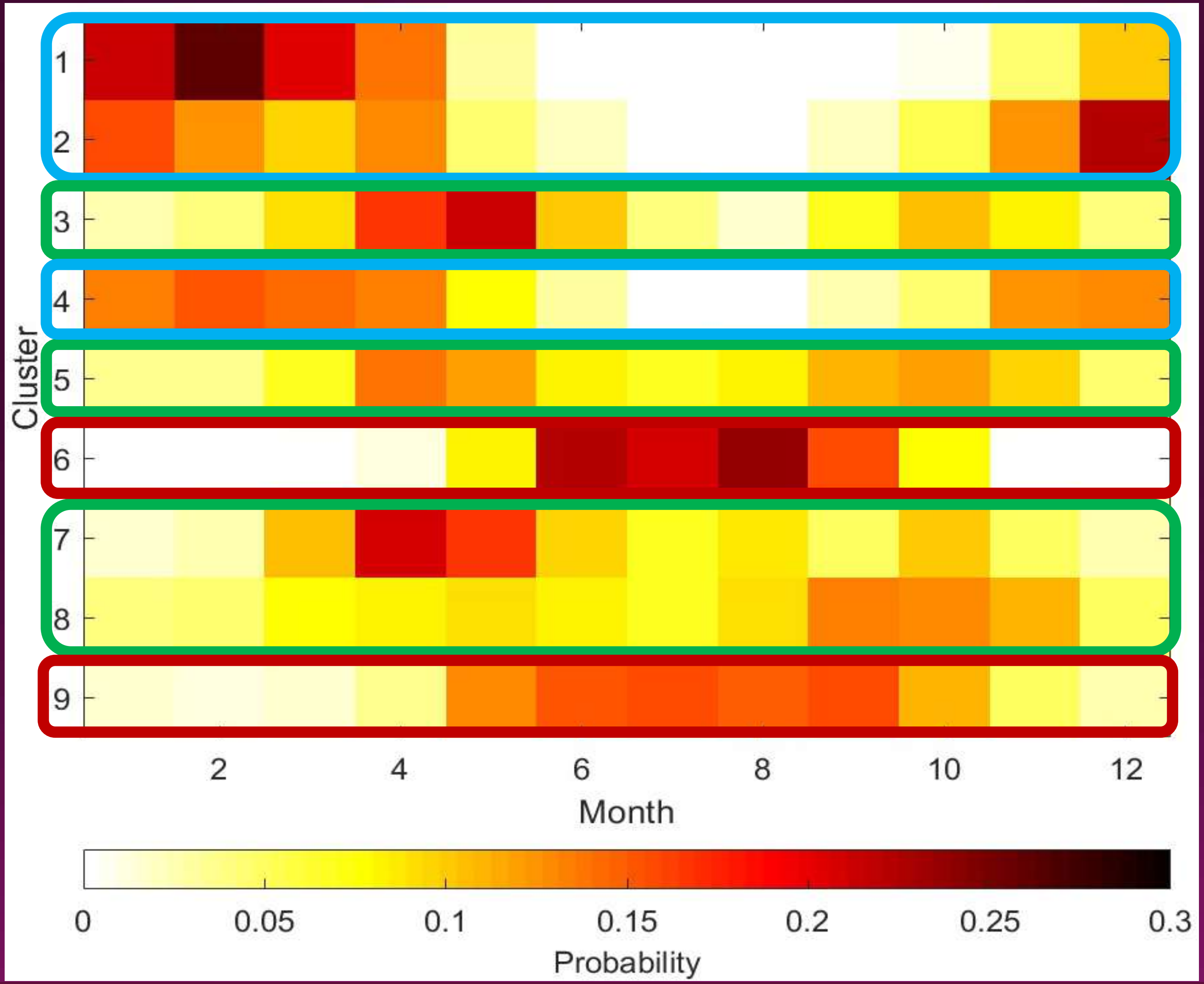
MC deepening processes are discernable

Results:
Cyclone Properties



Seasonal Distribution

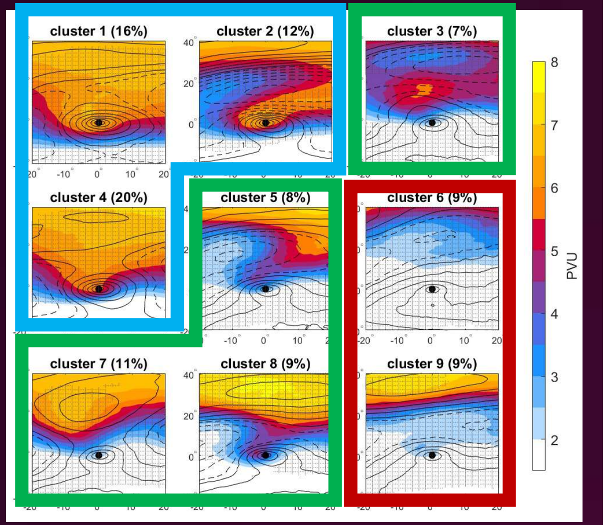


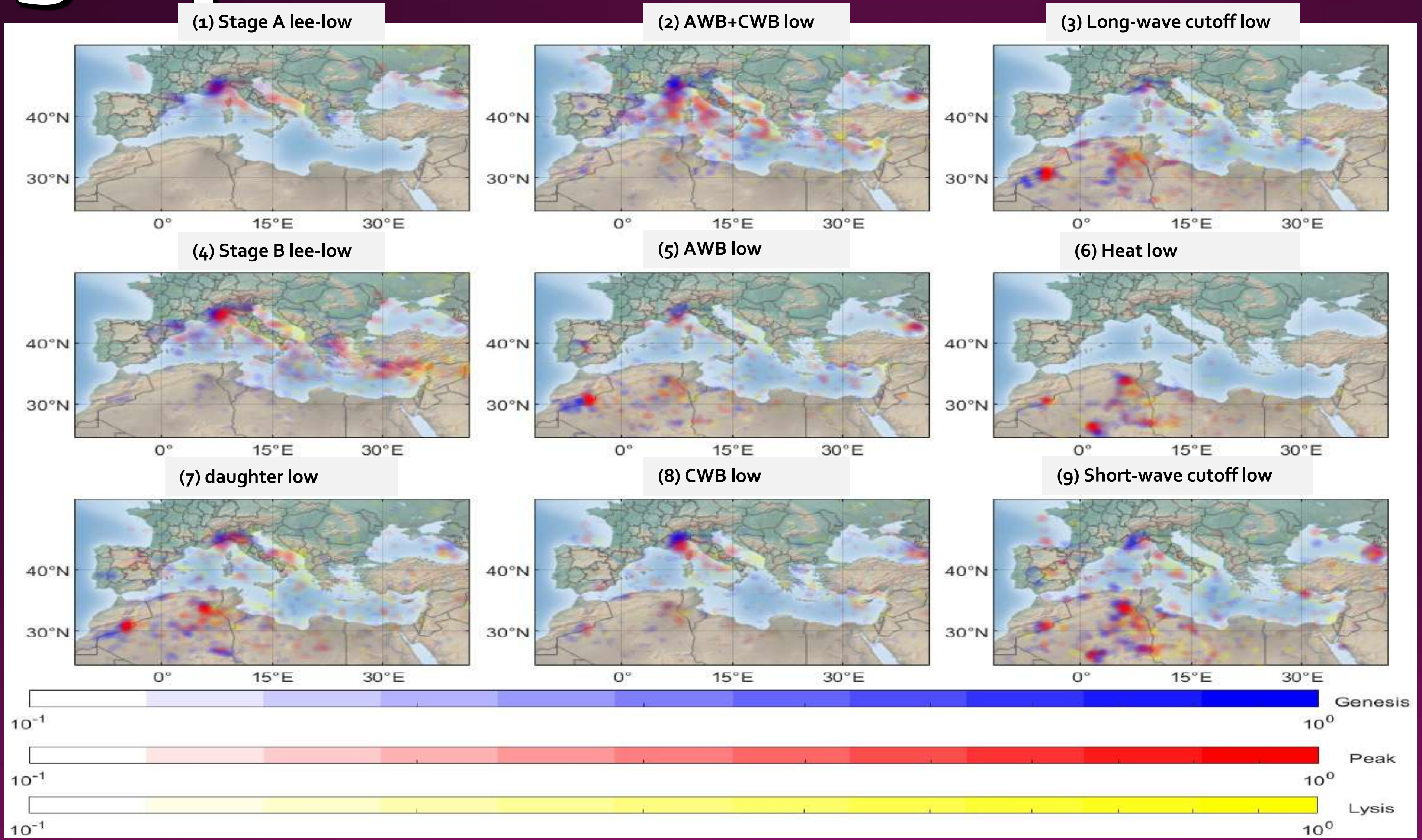


- The classification is not seasonally constrained
- *An artifact of absolute PV values (as opposed to PV anomalies)*

Most clusters show favorable seasons

Geographical Distribution



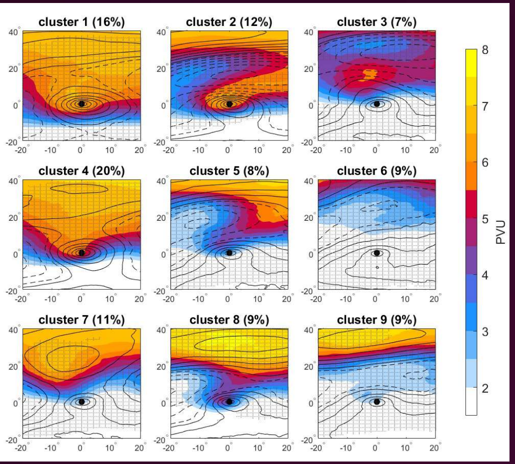


- The classification is not geographically constrained
- *An artifact of topographic influence on PV*

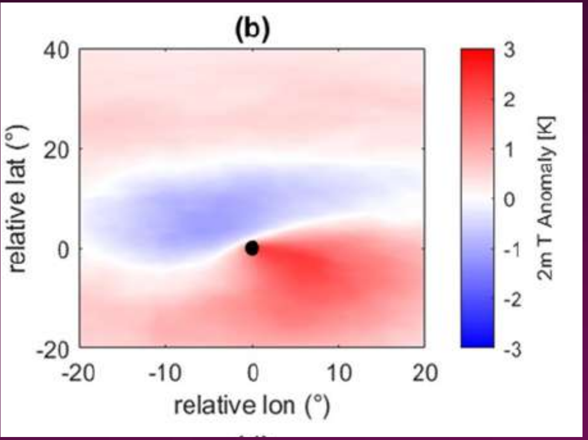
Most clusters show favorable regions

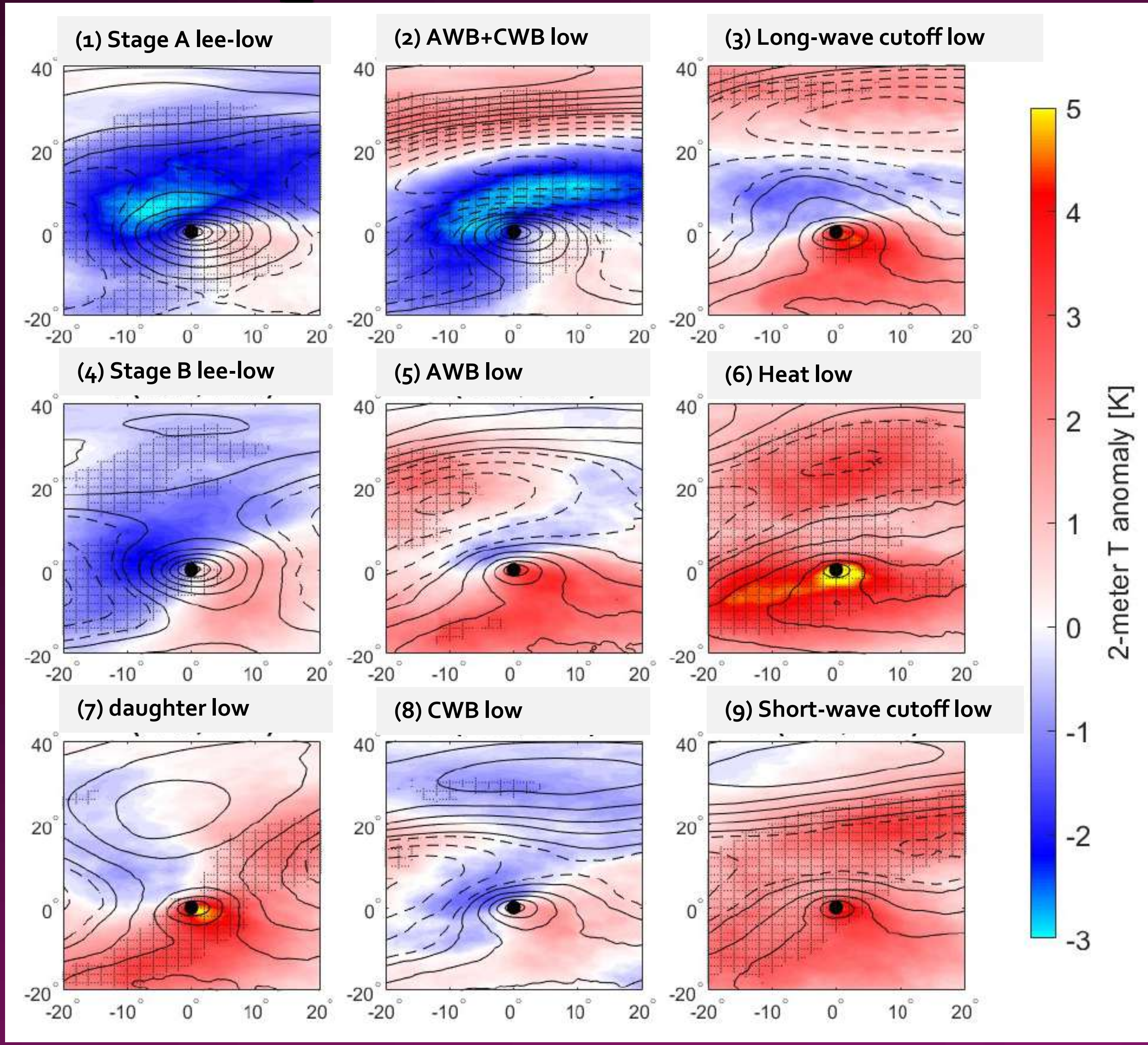

Results:
Surface Impact

2-meter Temperature Anomaly



Significance relative to total mean:

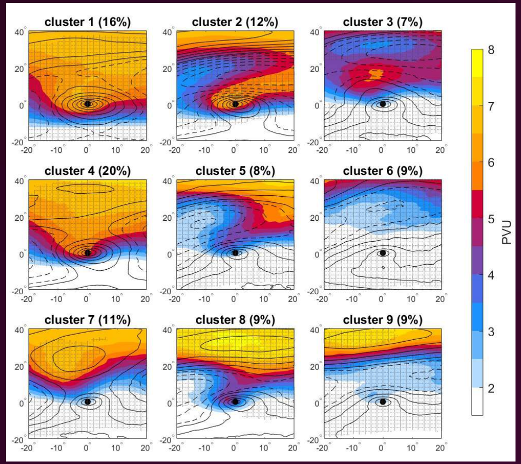




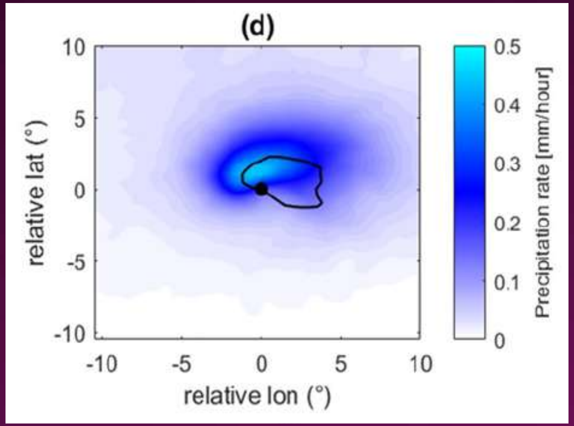
- Varying frontal structure

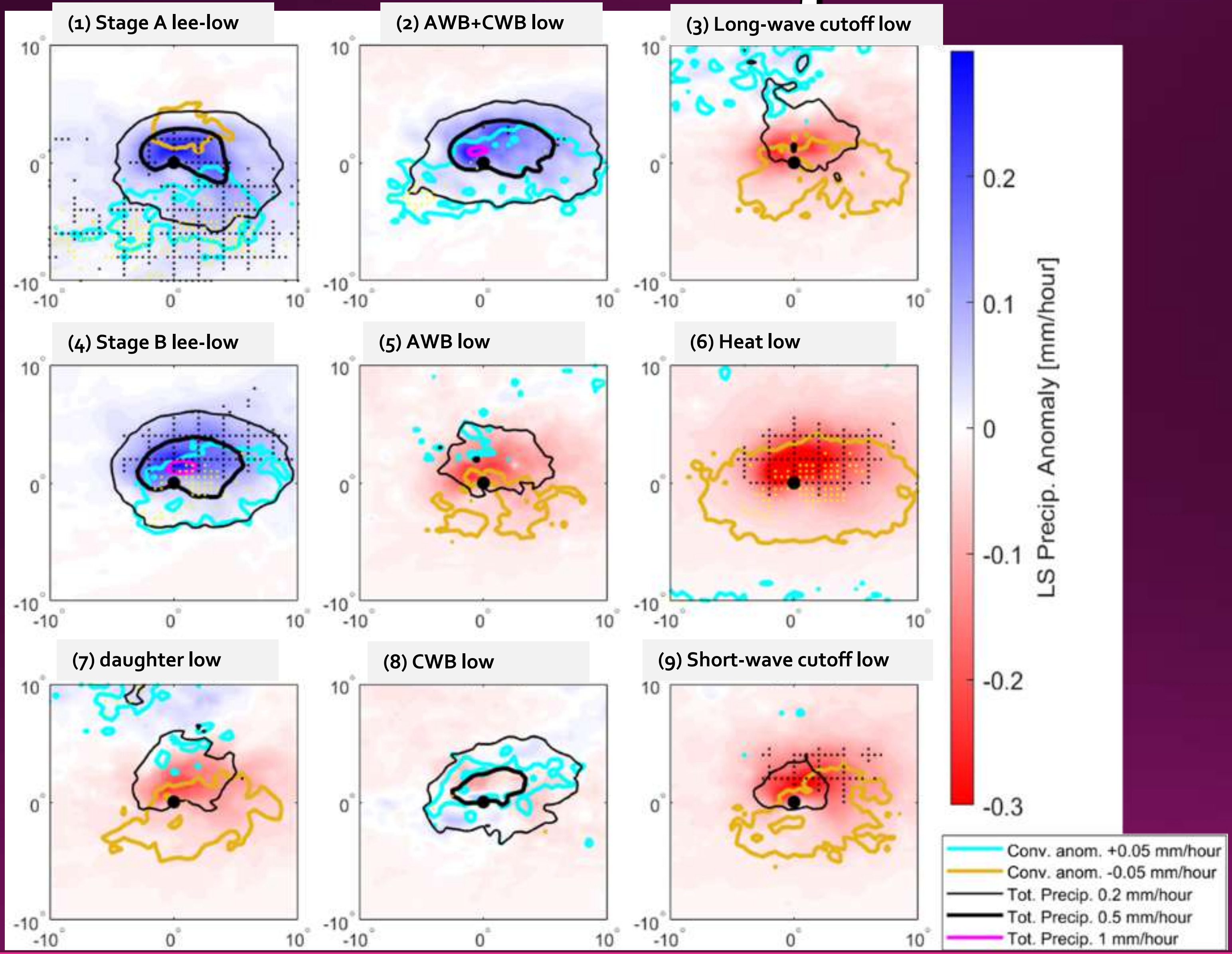
Different clusters are related to warm/cold anomalies

Large Scale & Convective Precipitation



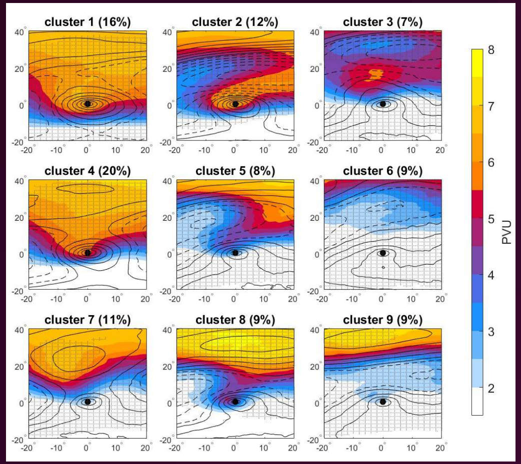
Deviations from total cyclone mean:



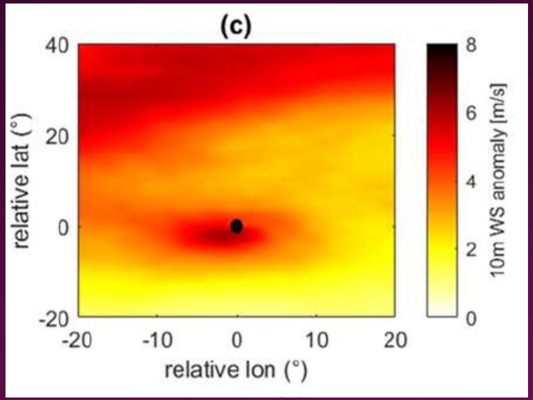


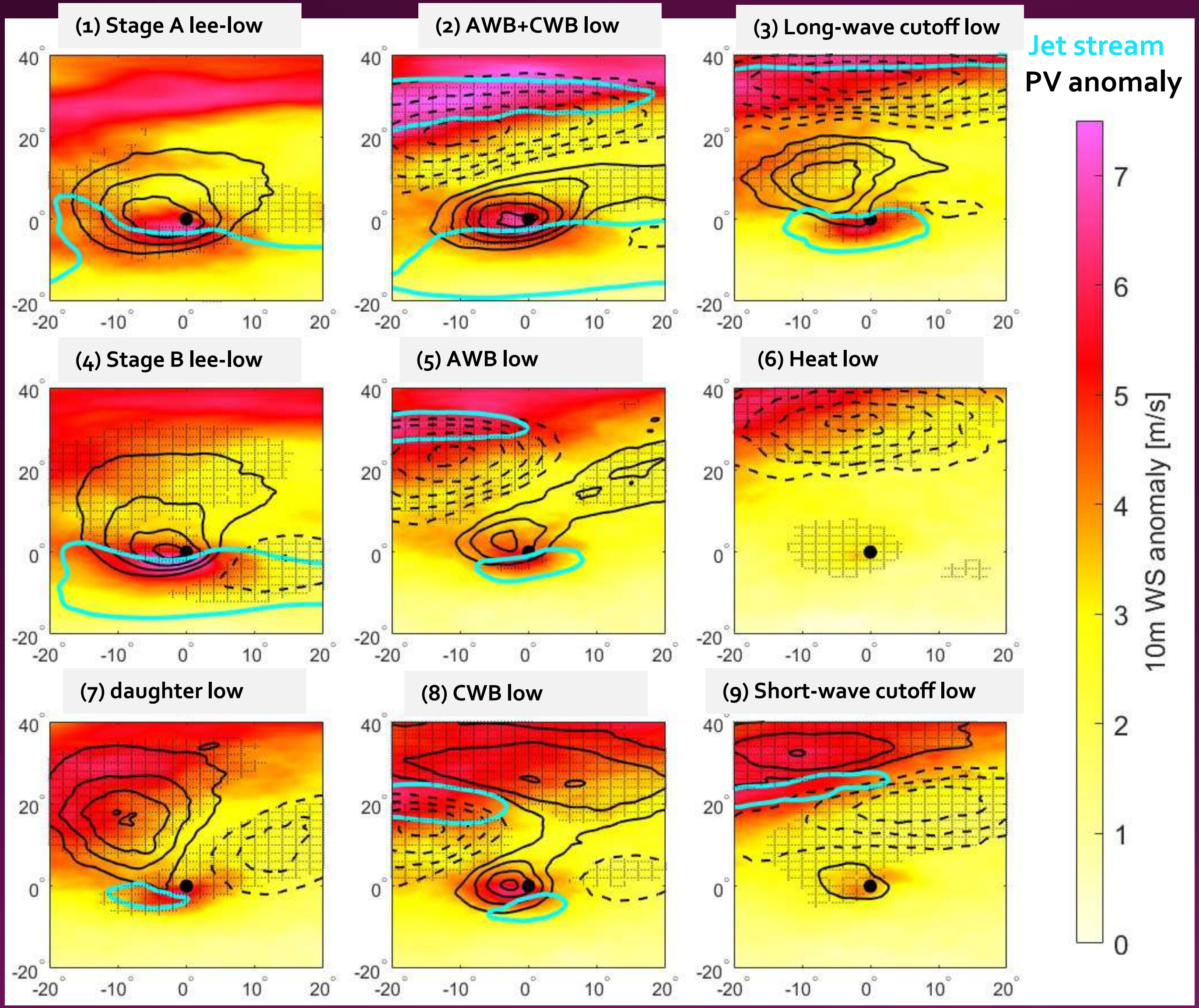
Precipitative response varies greatly between clusters

10-meter Wind anomalies



- Stormiest : 2, 4, 8
- Weakest: 6, 9

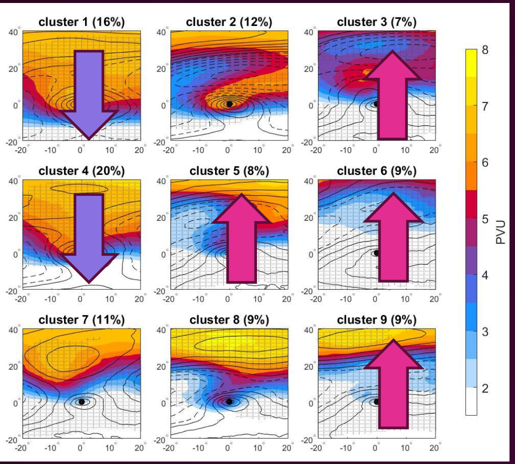


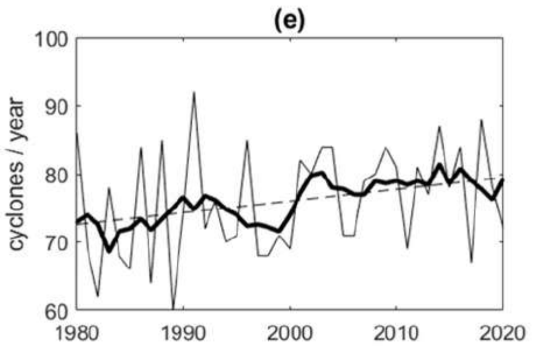


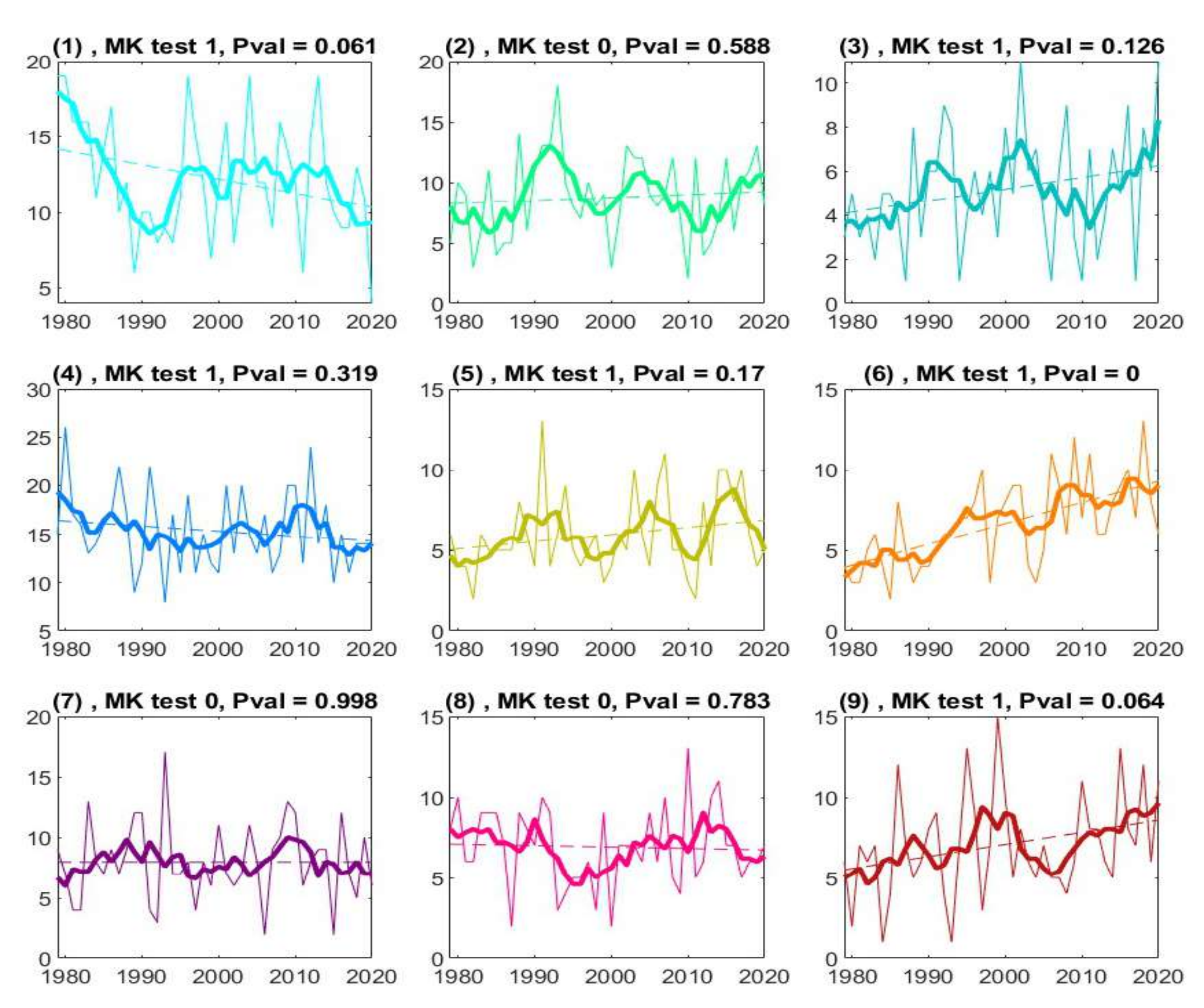
Winds vary greatly between clusters


Results:
Trends & Predictability

Climatological trends

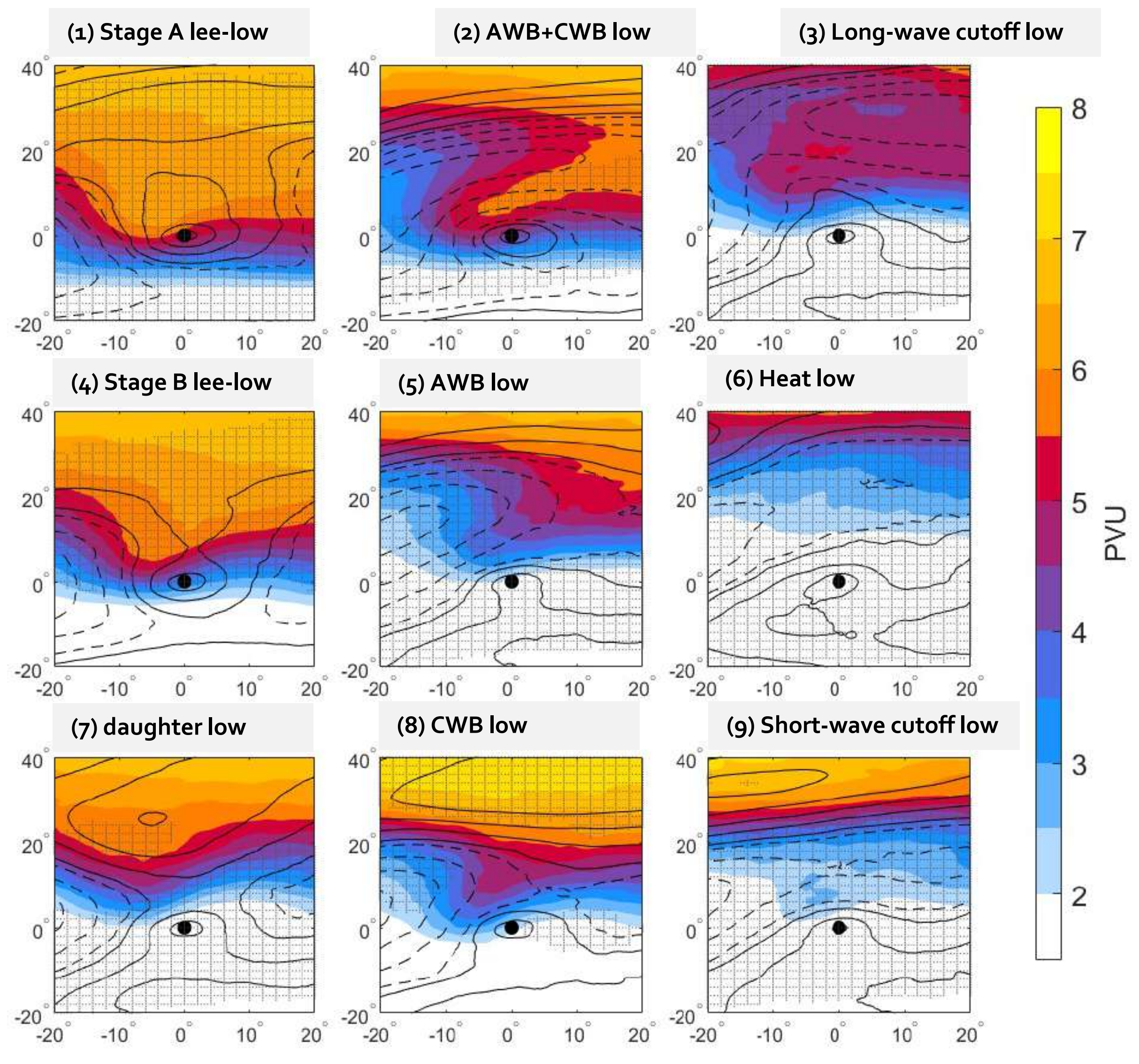




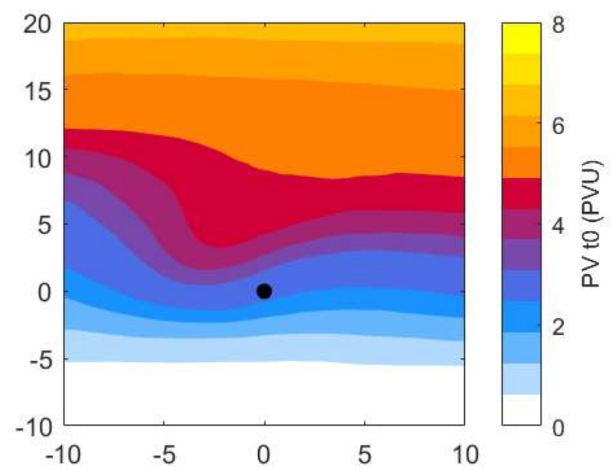


Decrease (increase) in winter (summer) cyclones

UPV at cyclogenesis



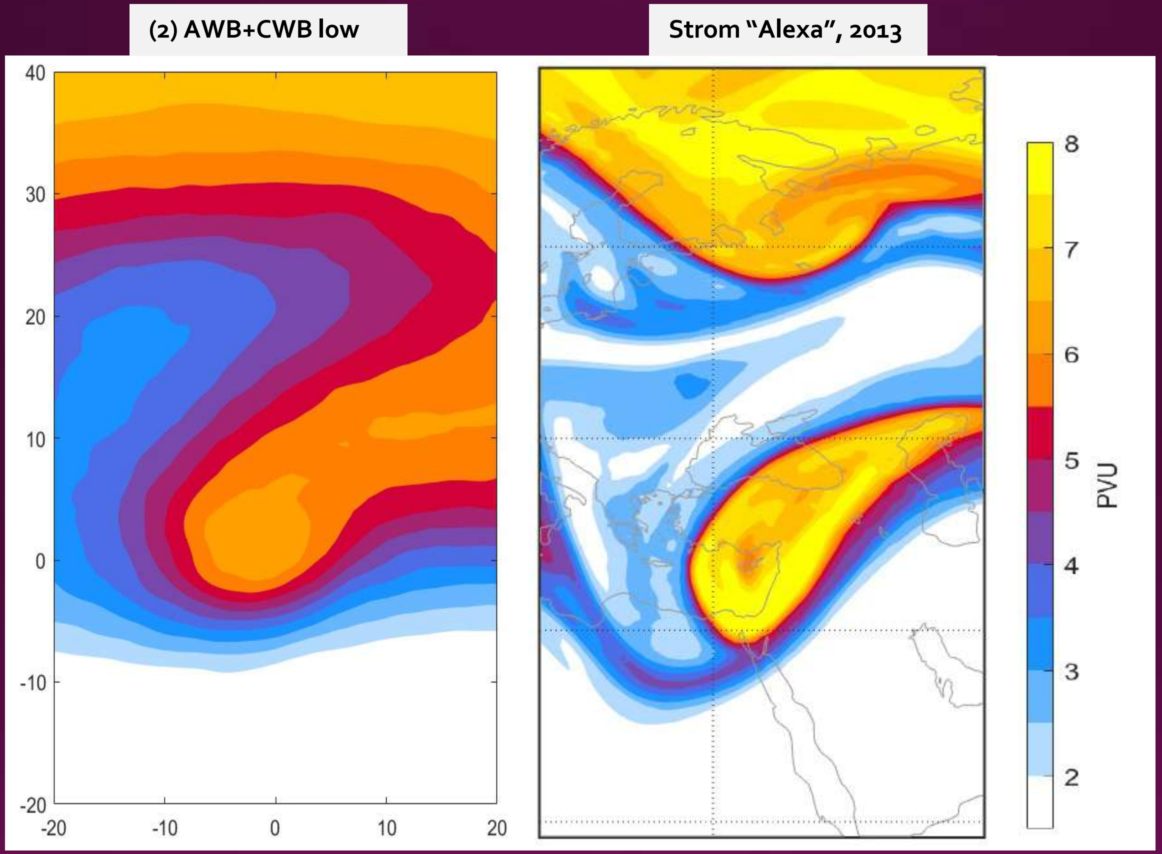
Significance relative to total cyclone mean:



Clusters can be determined already at cyclogenesis

Summary – dynamic PV classification of MCs

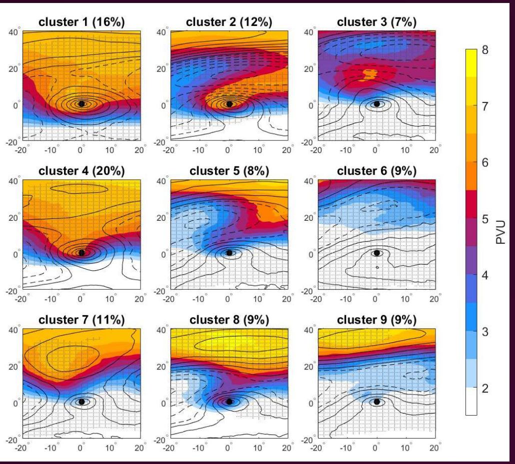
- 9 PV patterns
- Distinct geographic and seasonal distributions emerge
- Distinct surface response
- Indicative of dominant deepening mechanisms
- Opposing climatological trends



Givon, Y., Hess, O., Flaounas, E., Catto, J. L., Sprenger, M., and Raveh-Rubin, S.: Process-based classification of Mediterranean cyclones using potential vorticity, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2023-1247, 2023.

Enhanced understanding of MC predictability (on weather & climate scales)

Cluster overview



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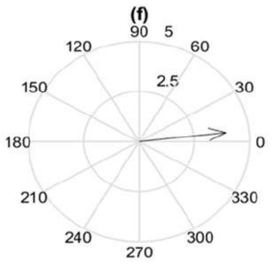
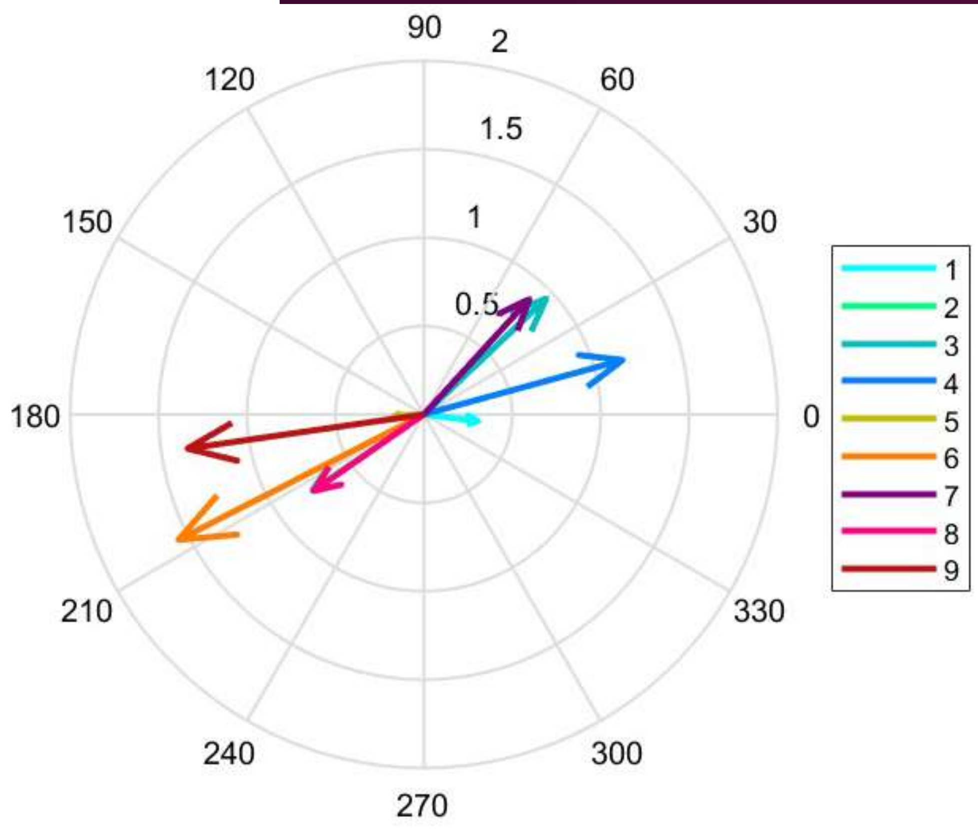
Cluster	(1) Stage A lee-low	(2) AWB+CWB low	(3) Long-wave cut-off low	(4) Stage B lee-low	(5) AWB low	(6) Heat low (Sharav)	(7) Daughter low	(8) CWB low	(9) Short-wave cut-off low
Season	winter	winter	spring	winter	spring/autumn	summer	spring	autumn	summer
Genesis	Alps	Alps	Atlas	Alps	Atlas	Atlas	diverse	Alps	diverse
Peak	Ligurian Sea	diverse	Atlas	diverse	Atlas	Sahara	diverse	Ligurian sea	diverse
Cold sector	extreme	extreme	weak	strong	mild	faint	weak	mild	faint
Warm sector	faint	Weak	strong	mild	strong	extreme	extreme	mild	strong
Precip.	heavy, LS+ C-	heavy, LS+ C+	mild, LS- C-	heavy, LS+ C+	mild, LS- C-	weak, LS- C-	mild, LS- C-	heavy, LS- C+	mild, LS- C-
Mobility	fast	slow	fast	fast	average	slow	fast	slow	slow
Trend	decrease	none	increase	decrease	increase	increase	none	none	increase

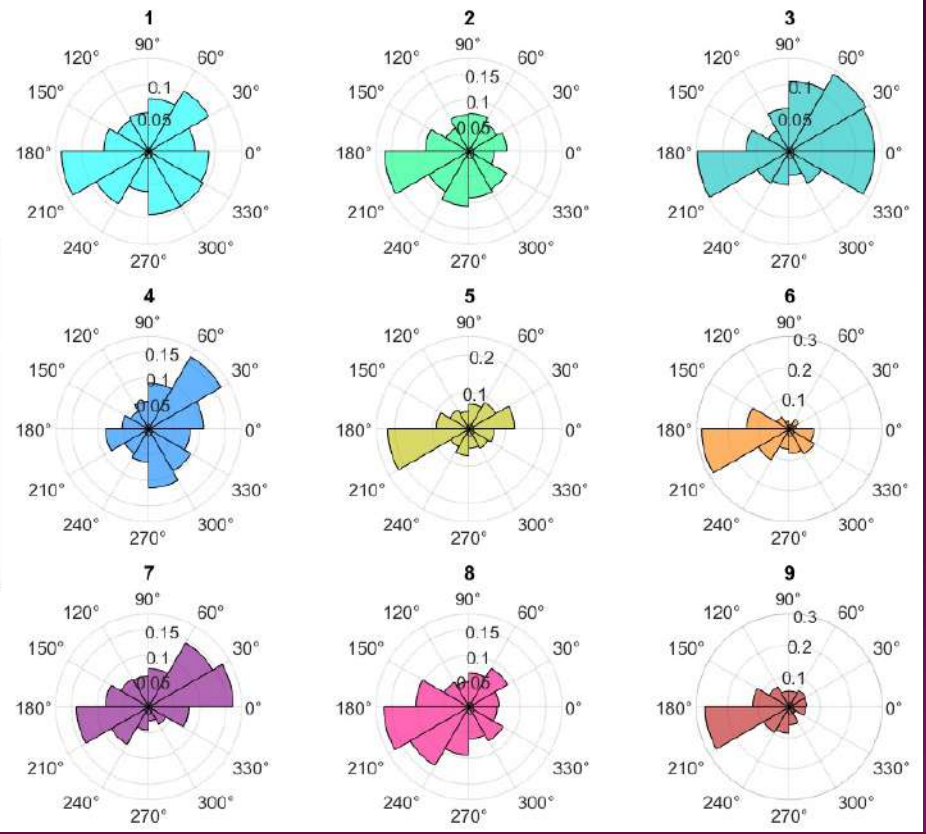
Cyclone Mobility

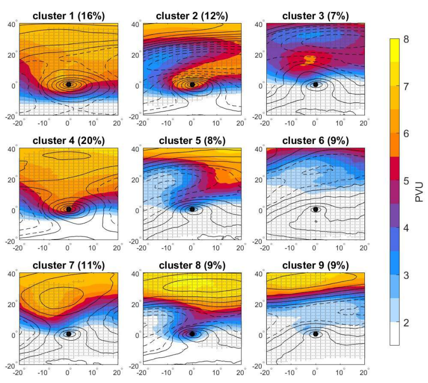
- Motion of cyclone centers
- Deviation from total average
- Averaged across cyclone lifetime



$$u_{cyclone} = \frac{2\pi r}{360} cos(\varphi) \frac{d\lambda_{cyclone}}{dt} \; ; \; v_{cyclone} = \frac{2\pi r}{360} \frac{d\varphi_{cyclone}}{dt}$$







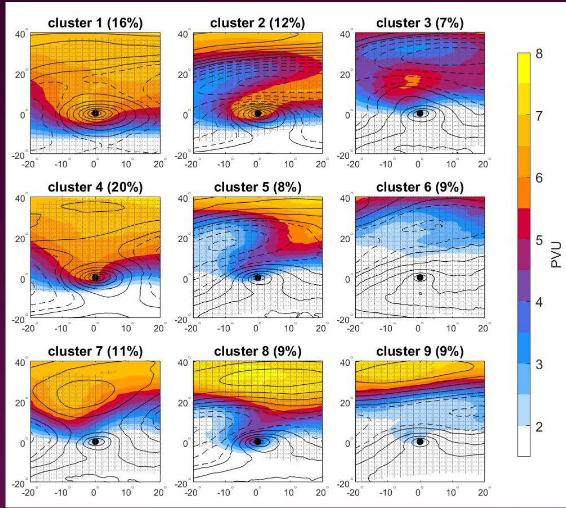
Some clusters tend to be more stationary

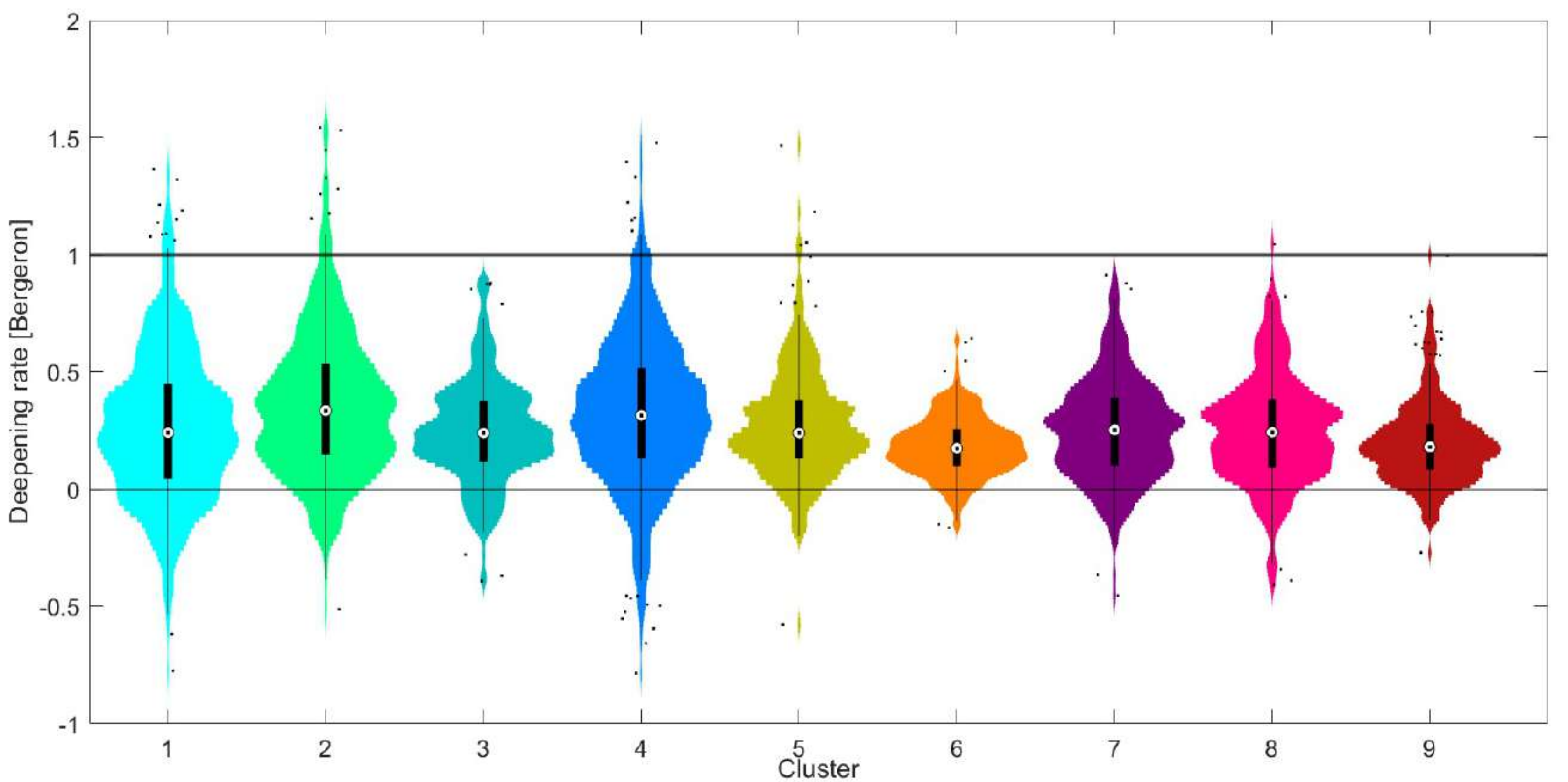
Cyclone explosiveness

$$Bergeron = -\frac{\sin 60}{\sin \phi_t}\frac{(SLP_{t+12} - SLP_{t-12})}{24}$$

- Maximum values for each track

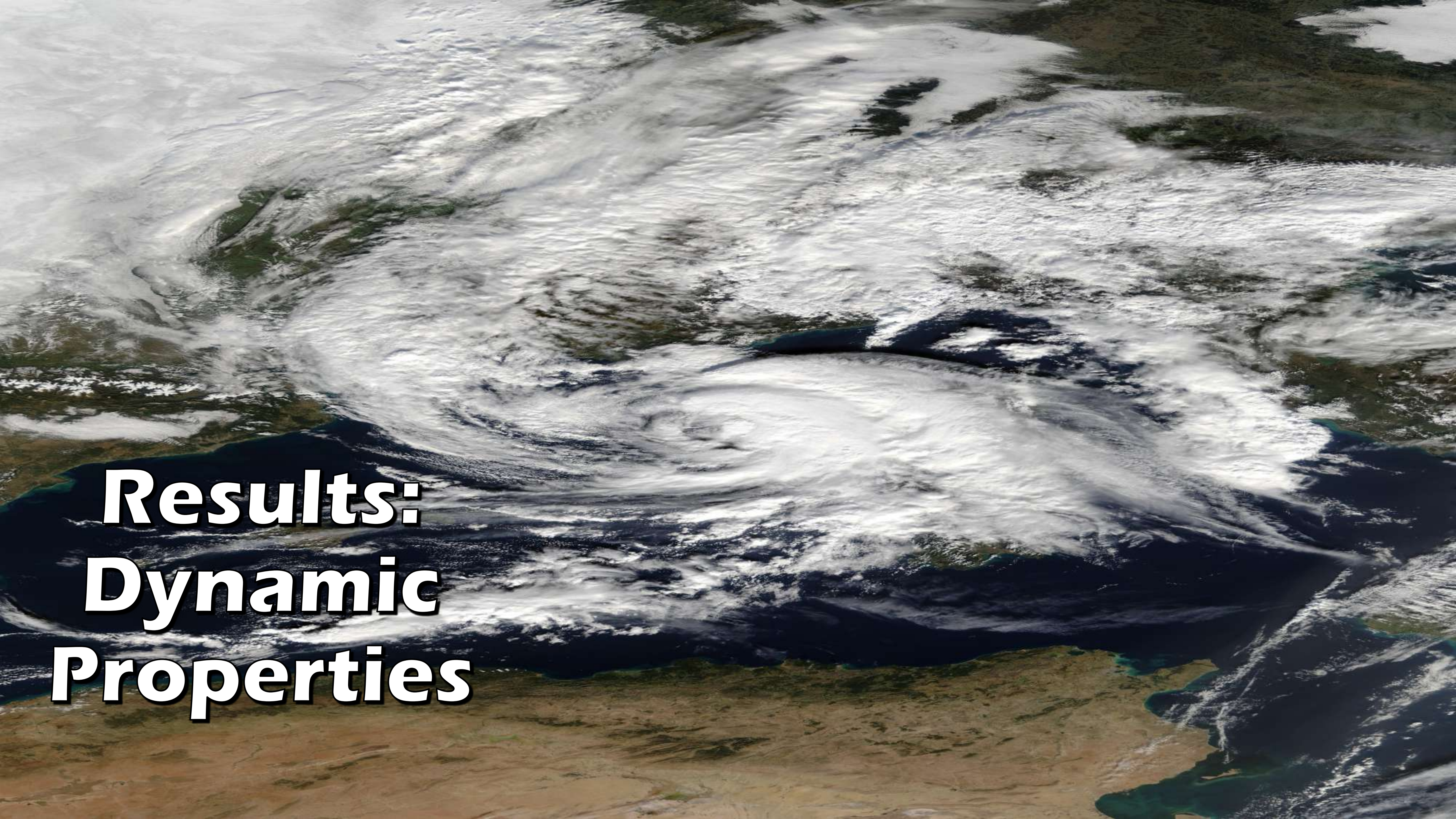
$Bergeron > 1$ → explosive cyclone



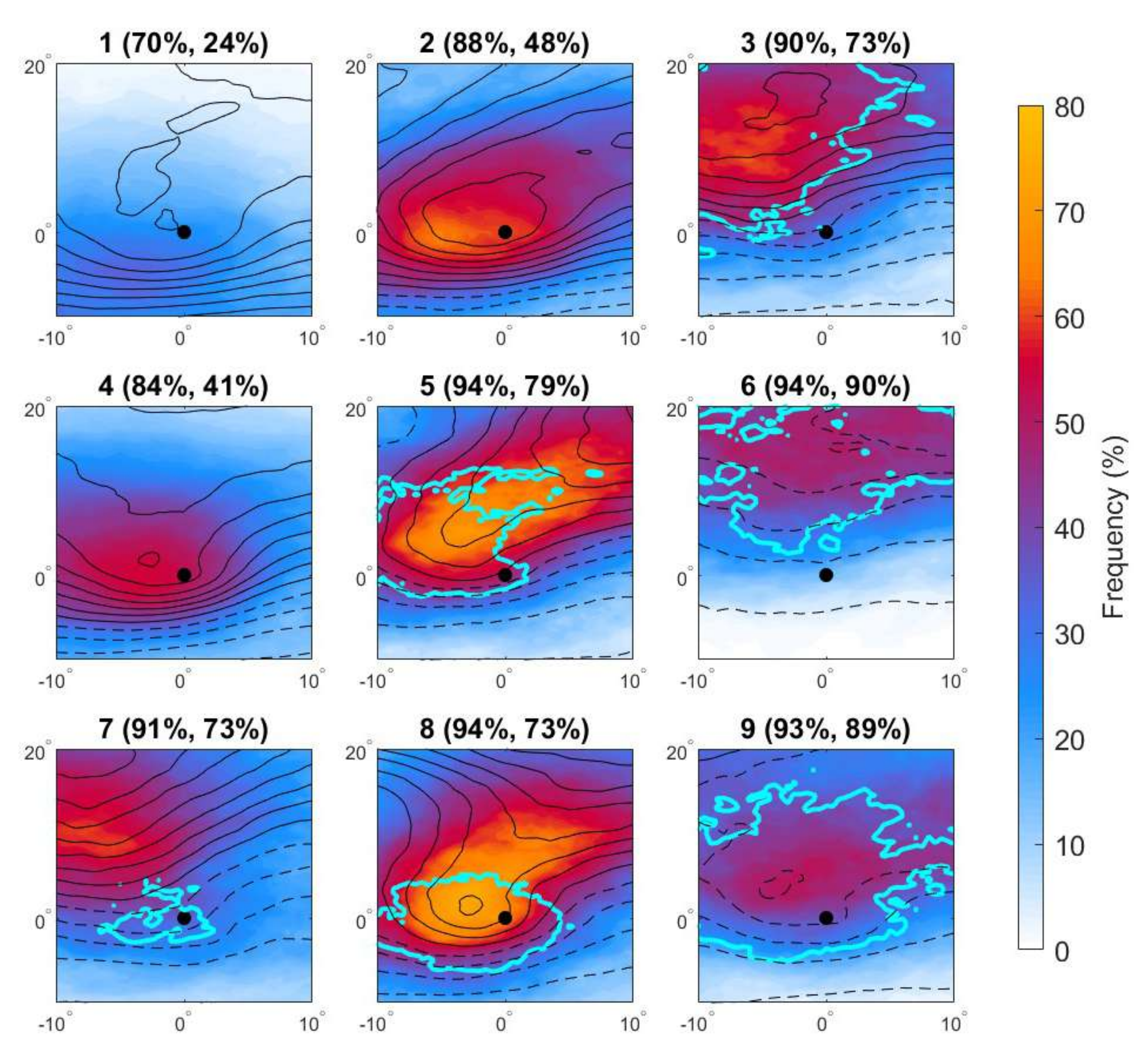


RWB clusters tend to be more explosive

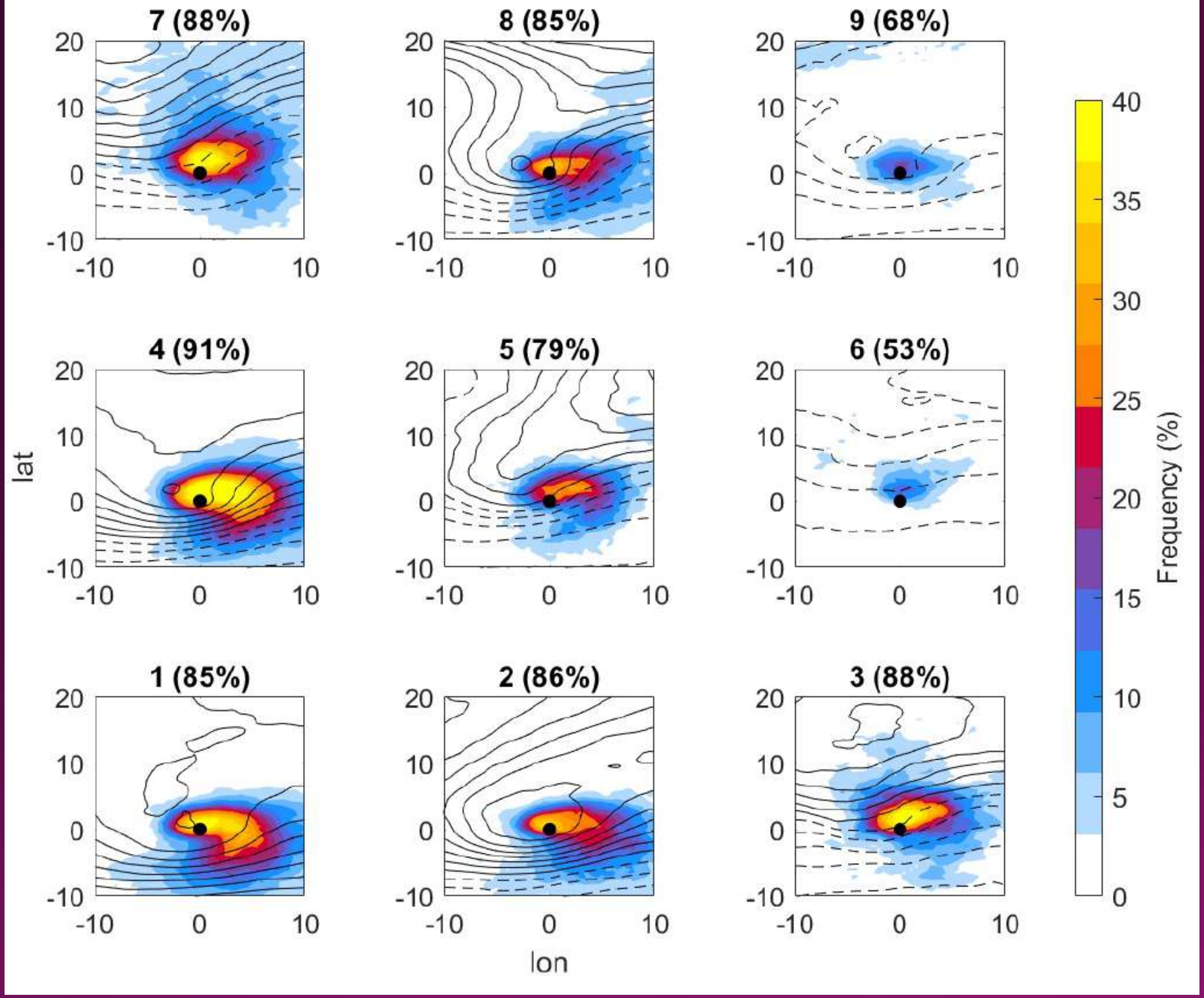
Results: Dynamic Properties



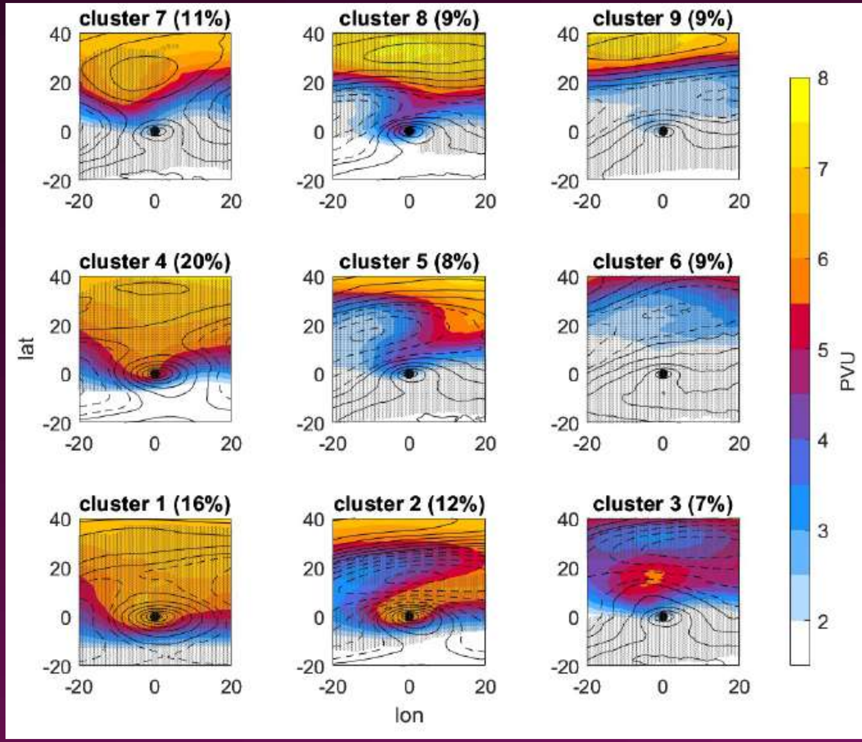
PV streamer & cutoff

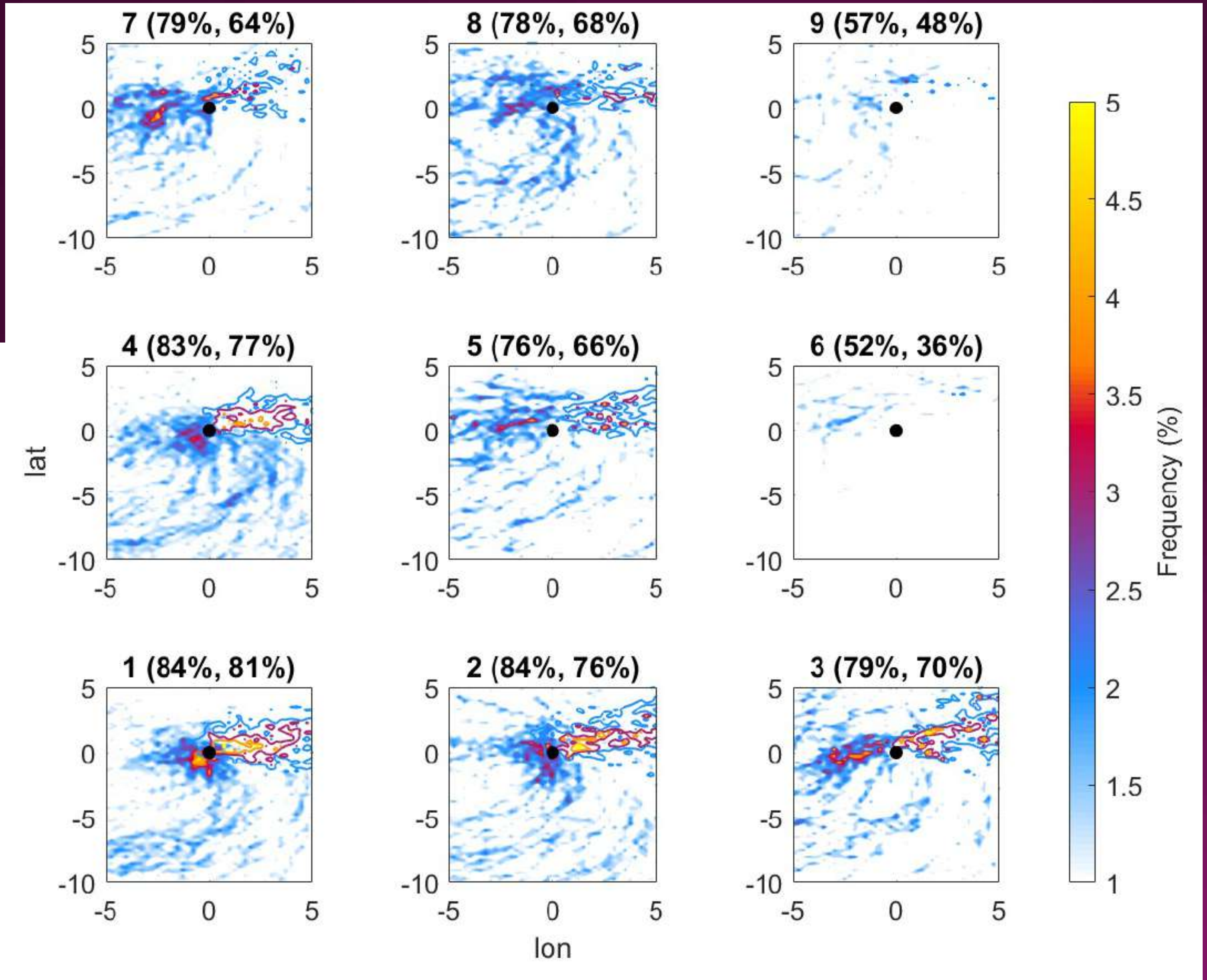


WCB – Mid. troposphere



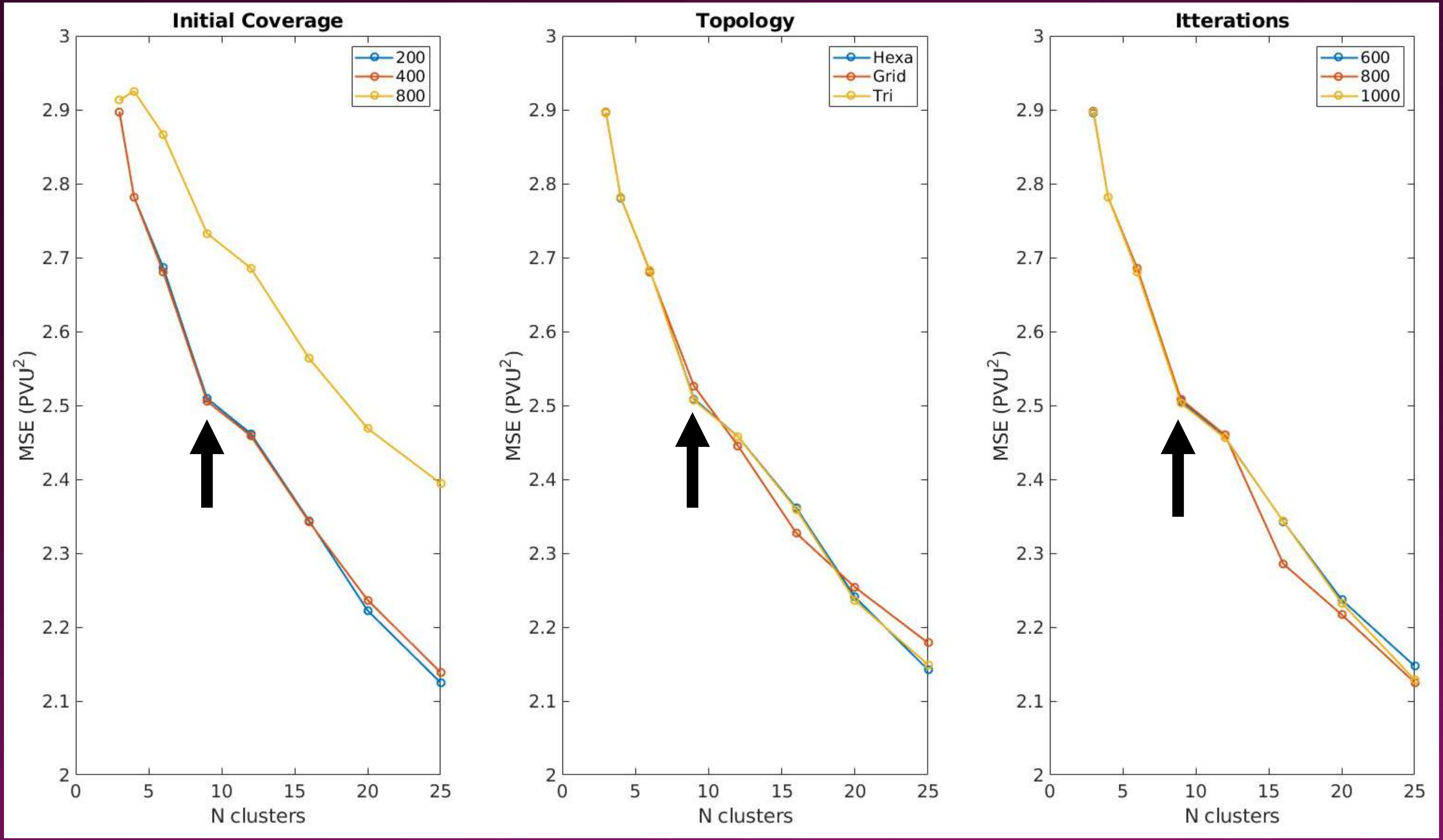
Front composites





SOM configuration

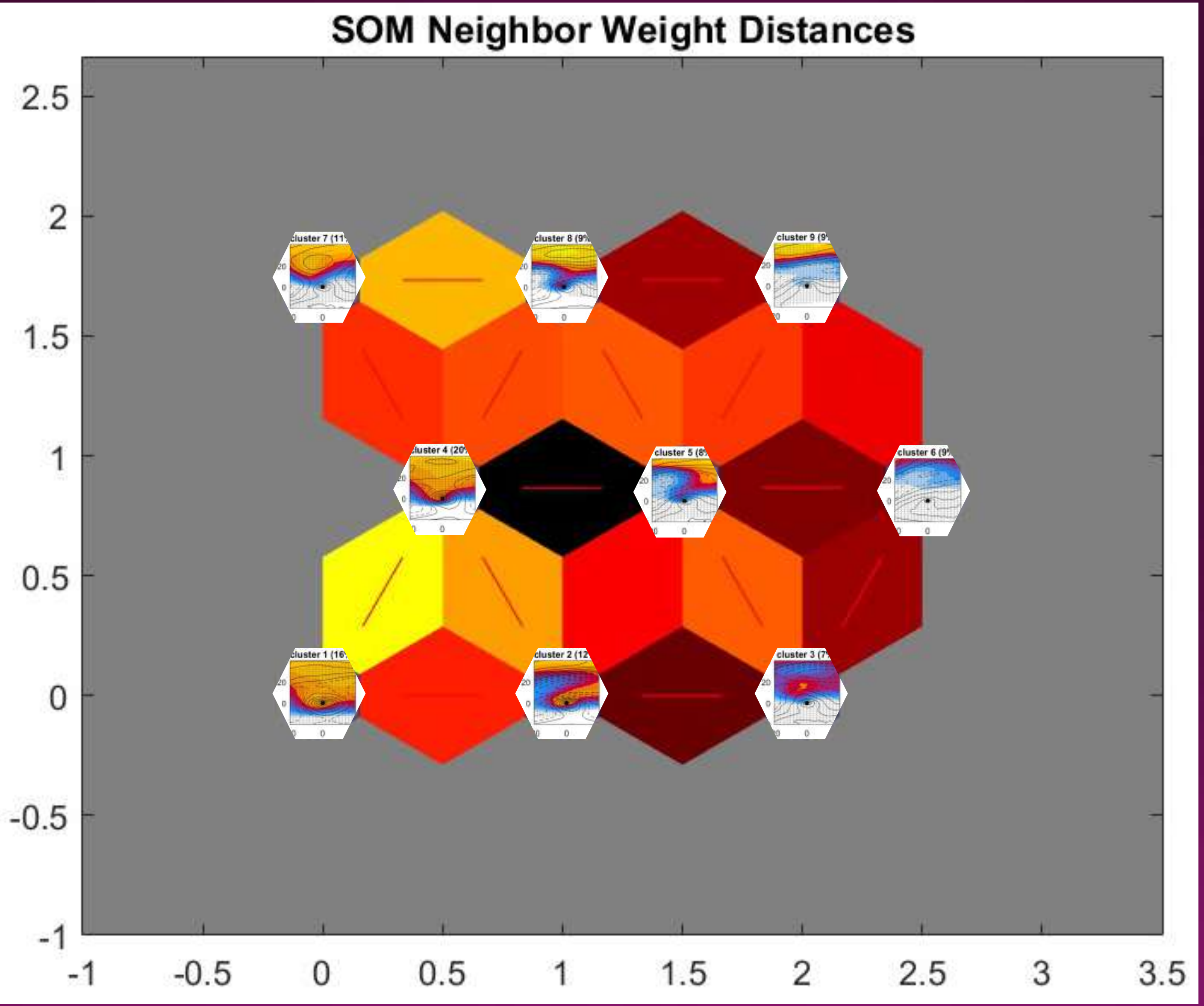
- Init. Cov.: 400
- Grid: Hexagon
- Iterations: 800
- N clusters: 9



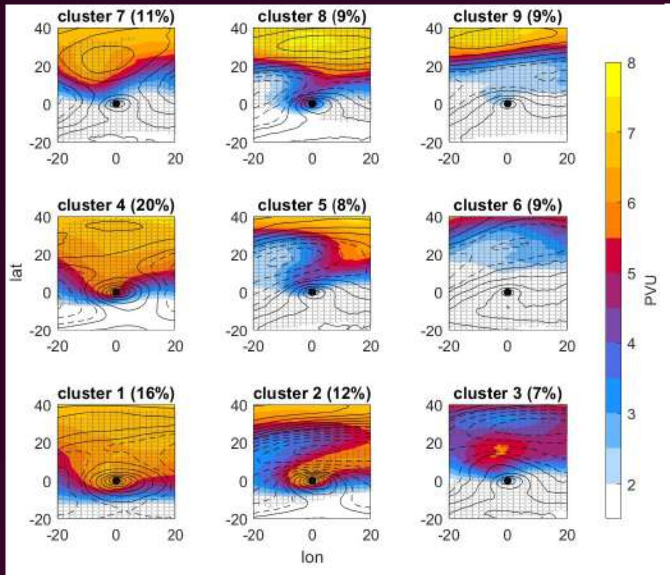
Self Organizing Map

- Nodes location corresponds to active regions and forms the SOM

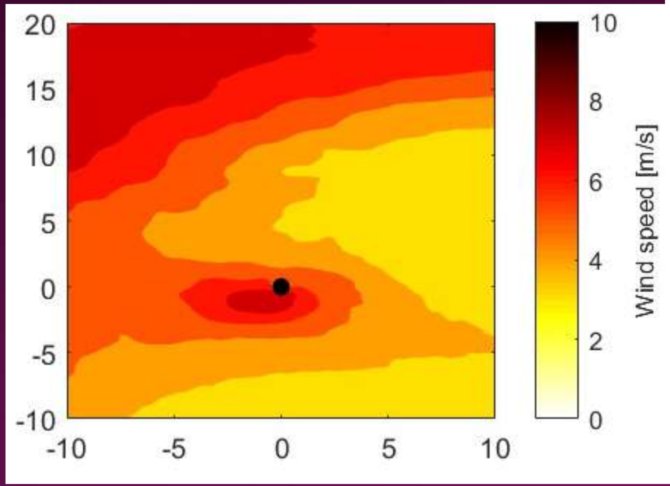
- Similarity ~ MSE

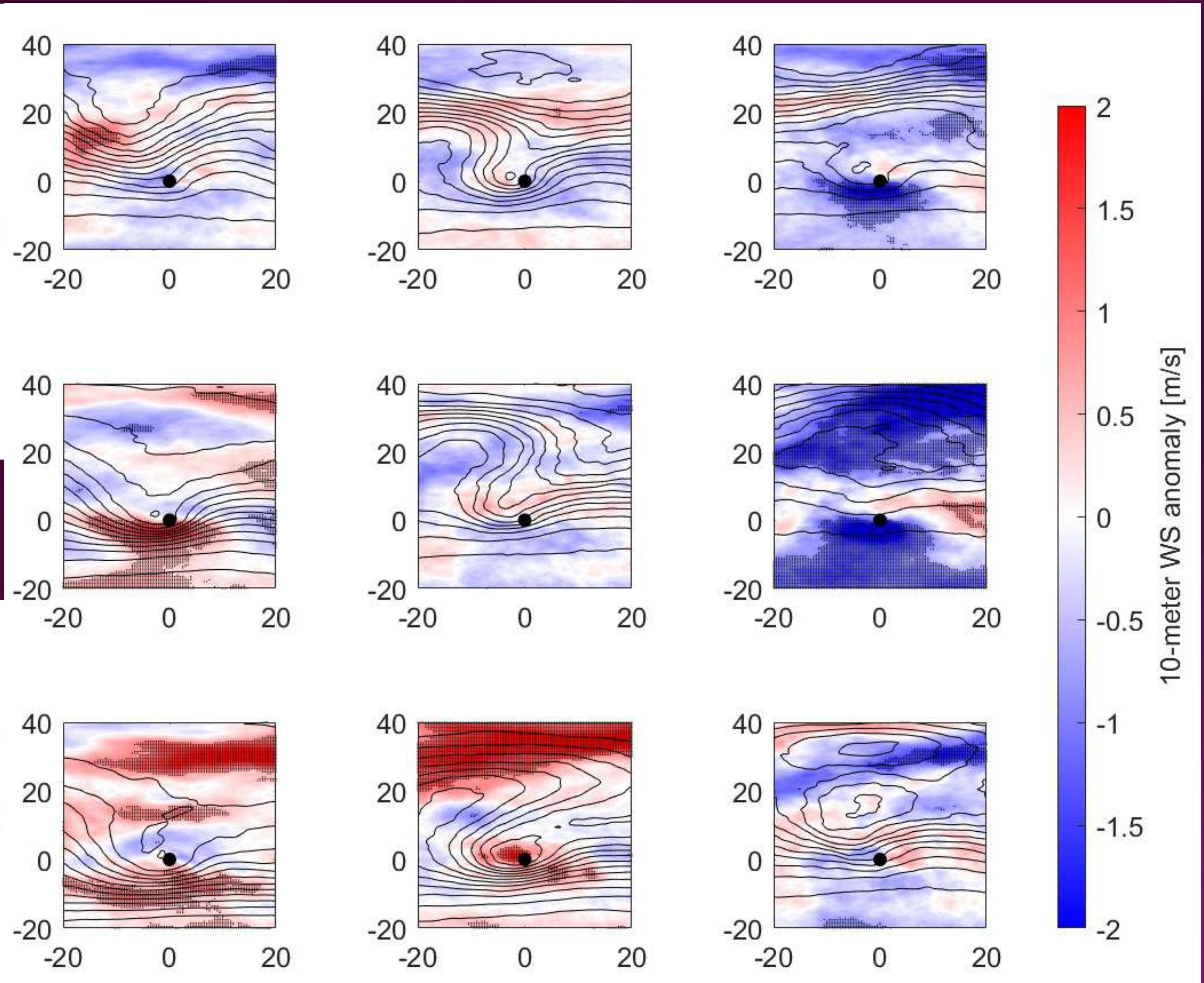


10-meter Wind Speed

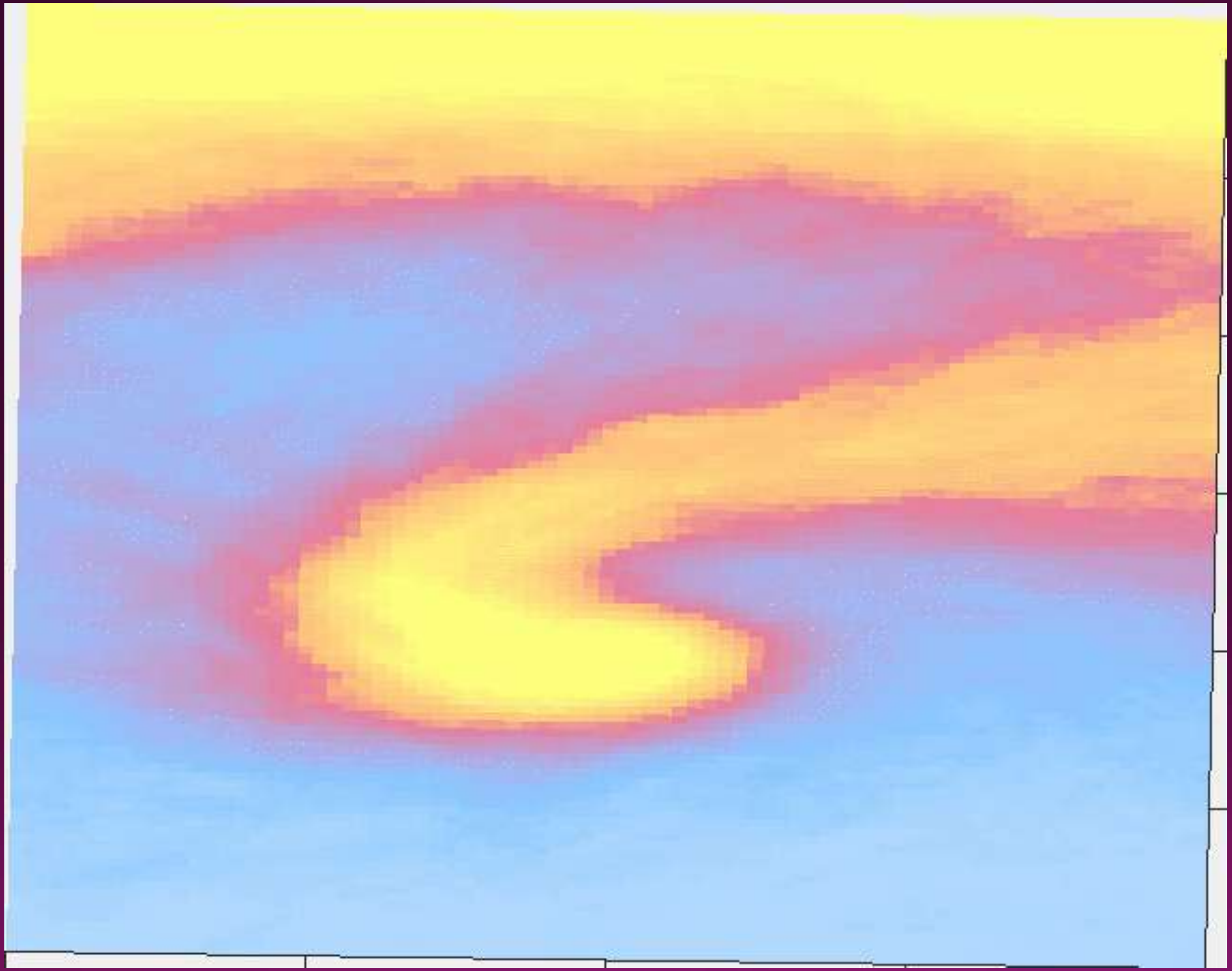


Anomalies relative to total cyclone mean:



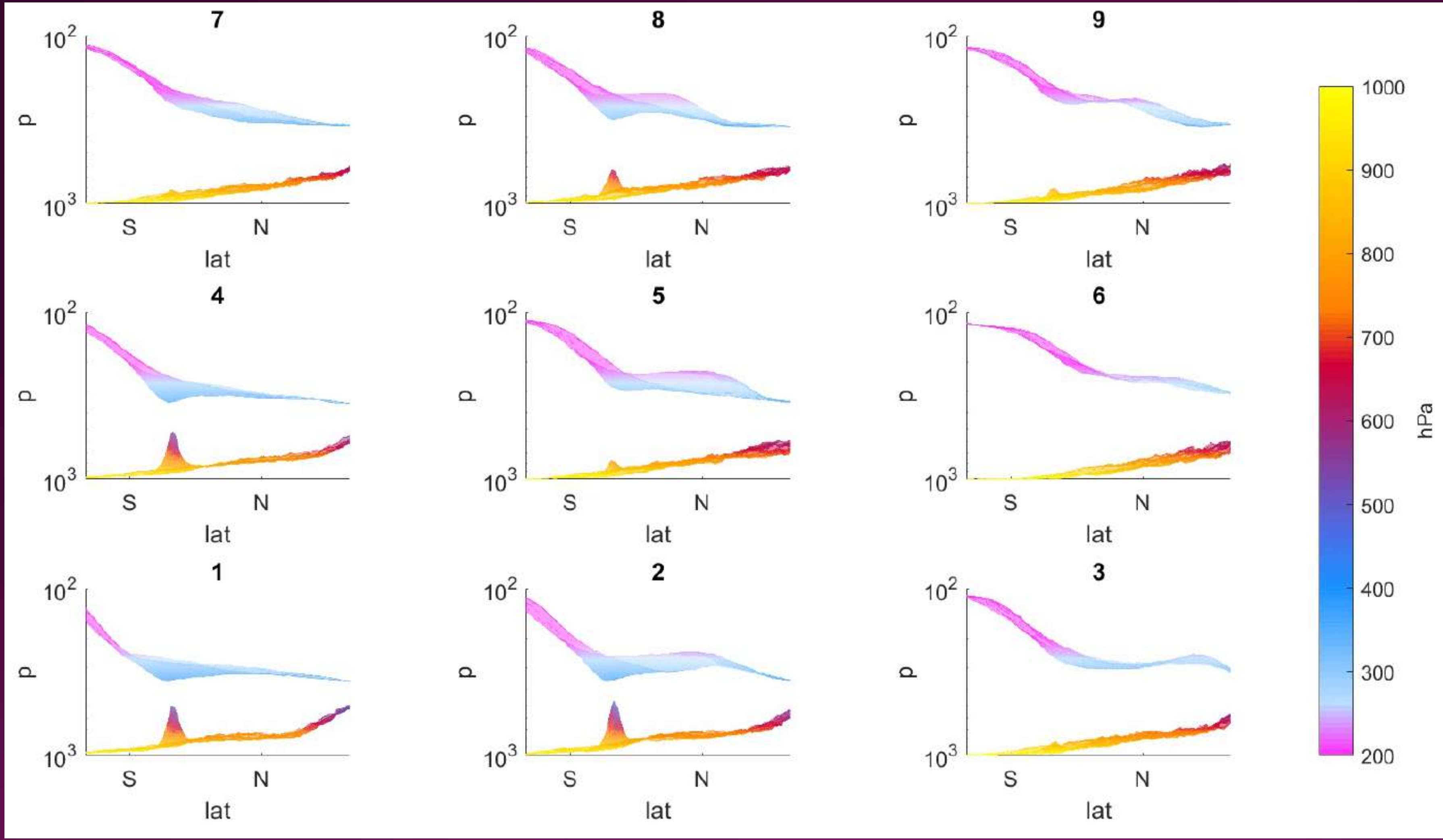


Results: 3D PV Structure



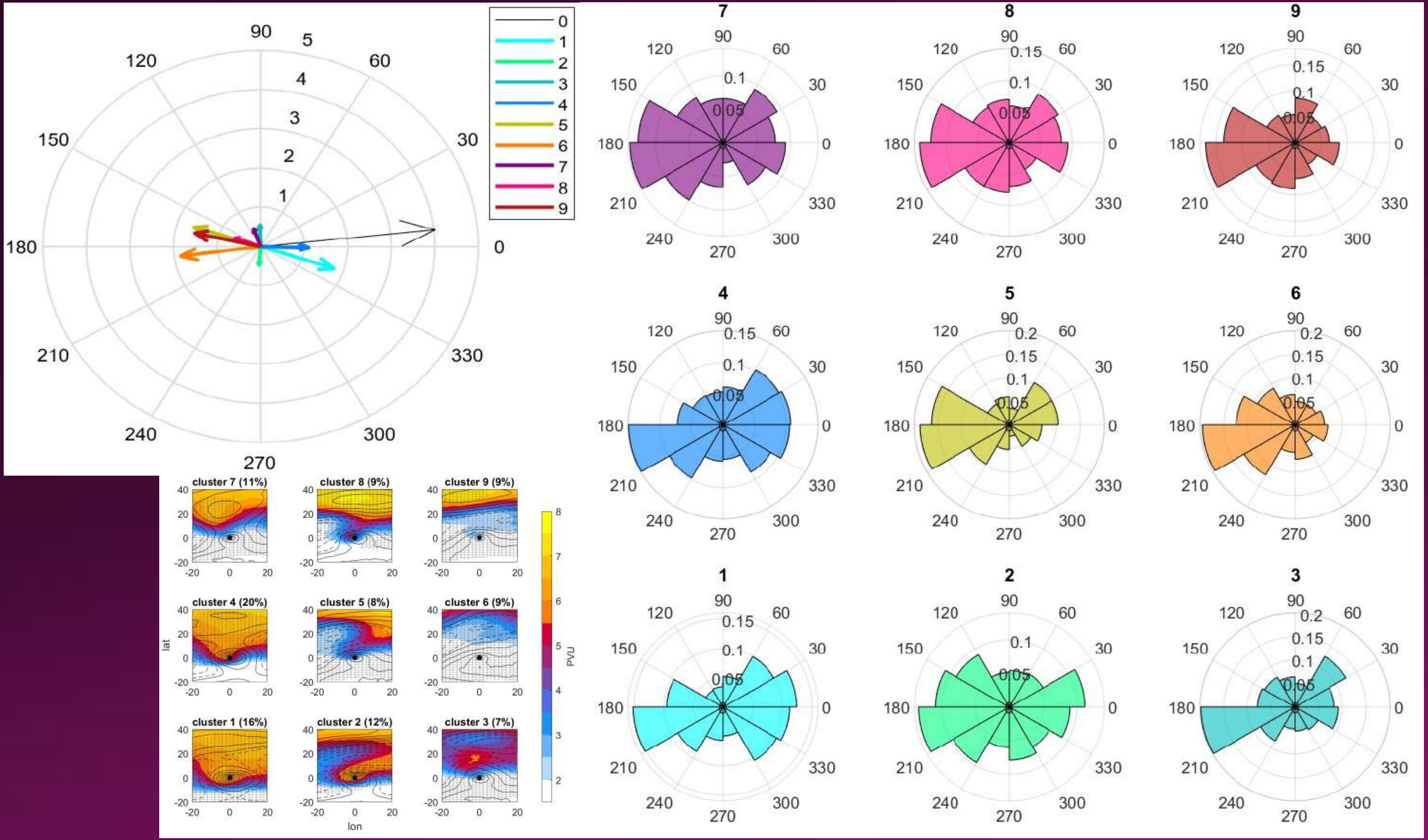
Tropopause-Surface coupling

- 2 PVU surface
- 0.5 PVU surface

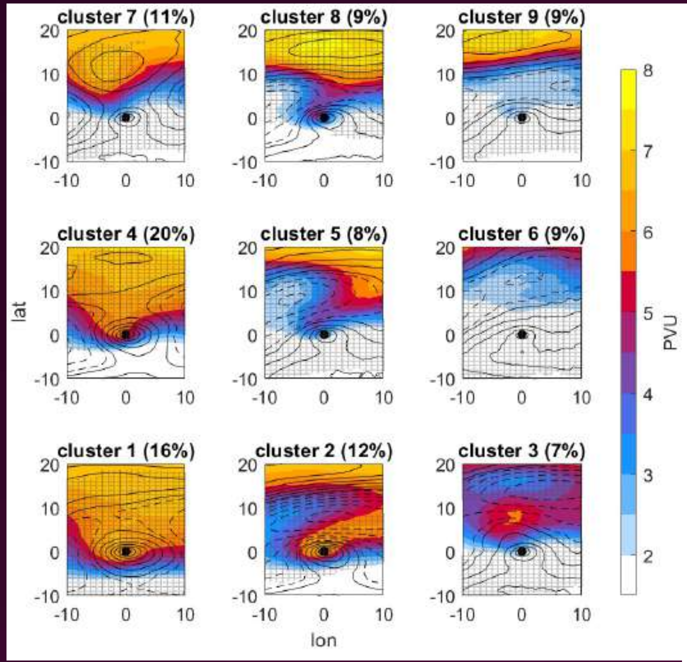


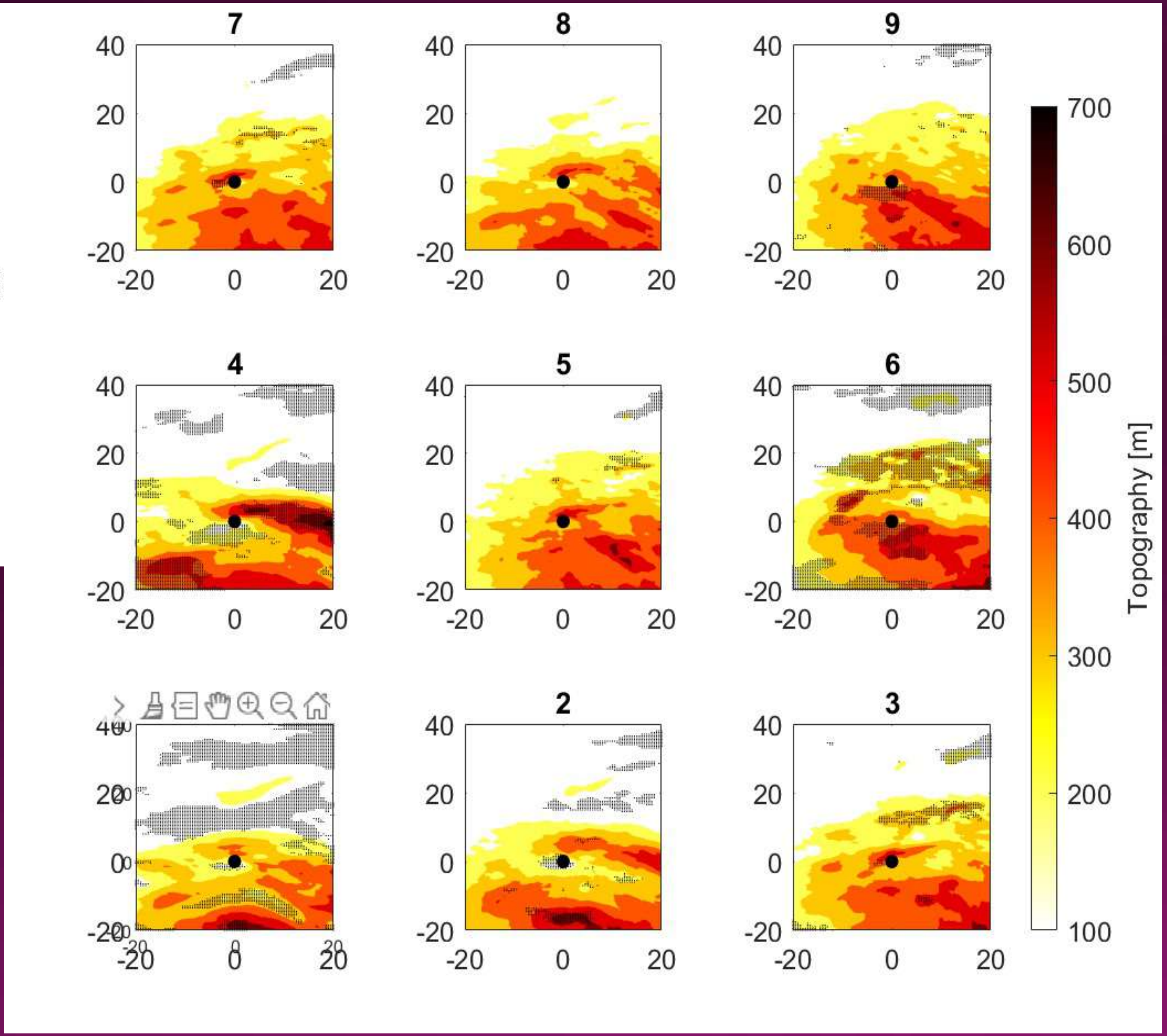
"PV towers" intensify surface winds

Mobility at cyclogenesis



Topography

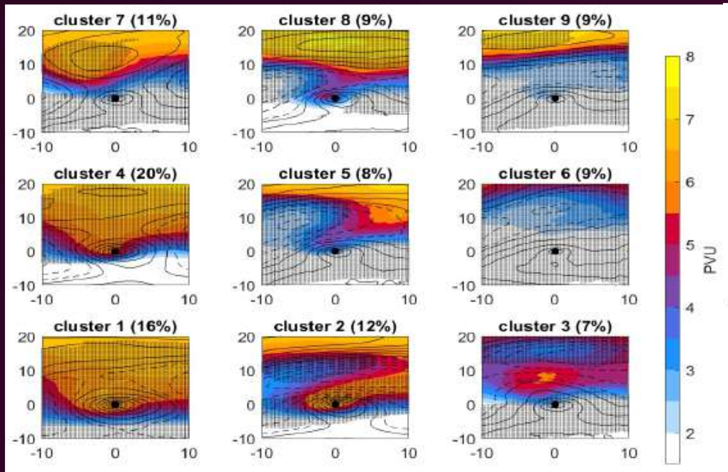




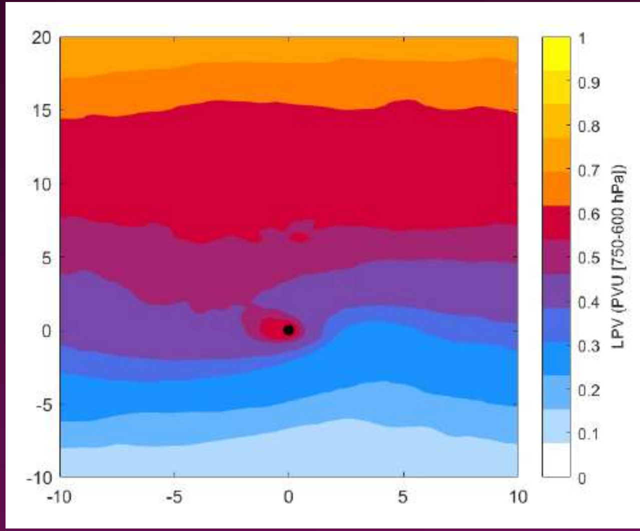
Topography at time 0

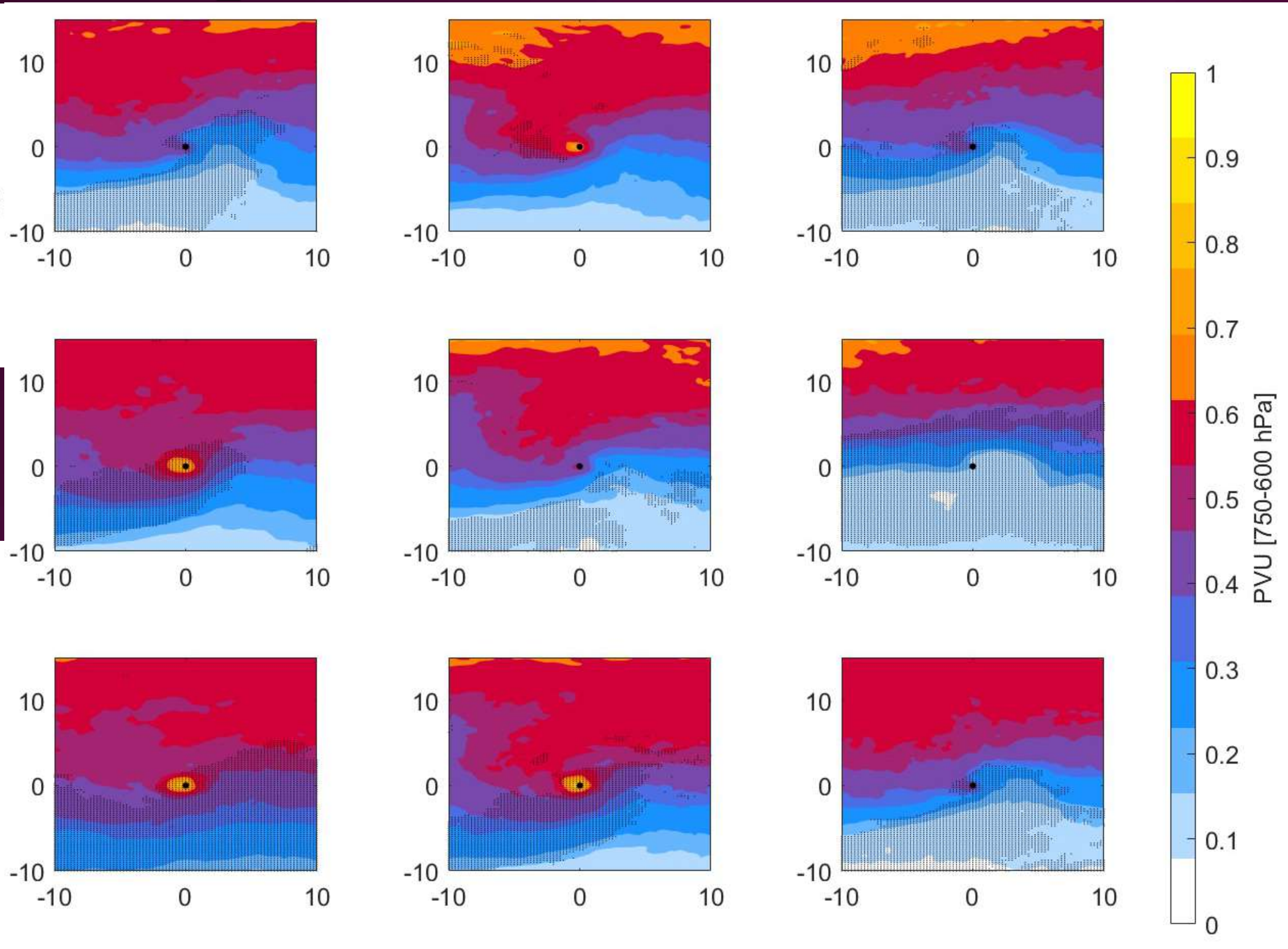
- Alps (1,2,4,8)
- Atlas (3,5,9)

LPV Response



Significance relative to total cyclone mean:





More Track Features