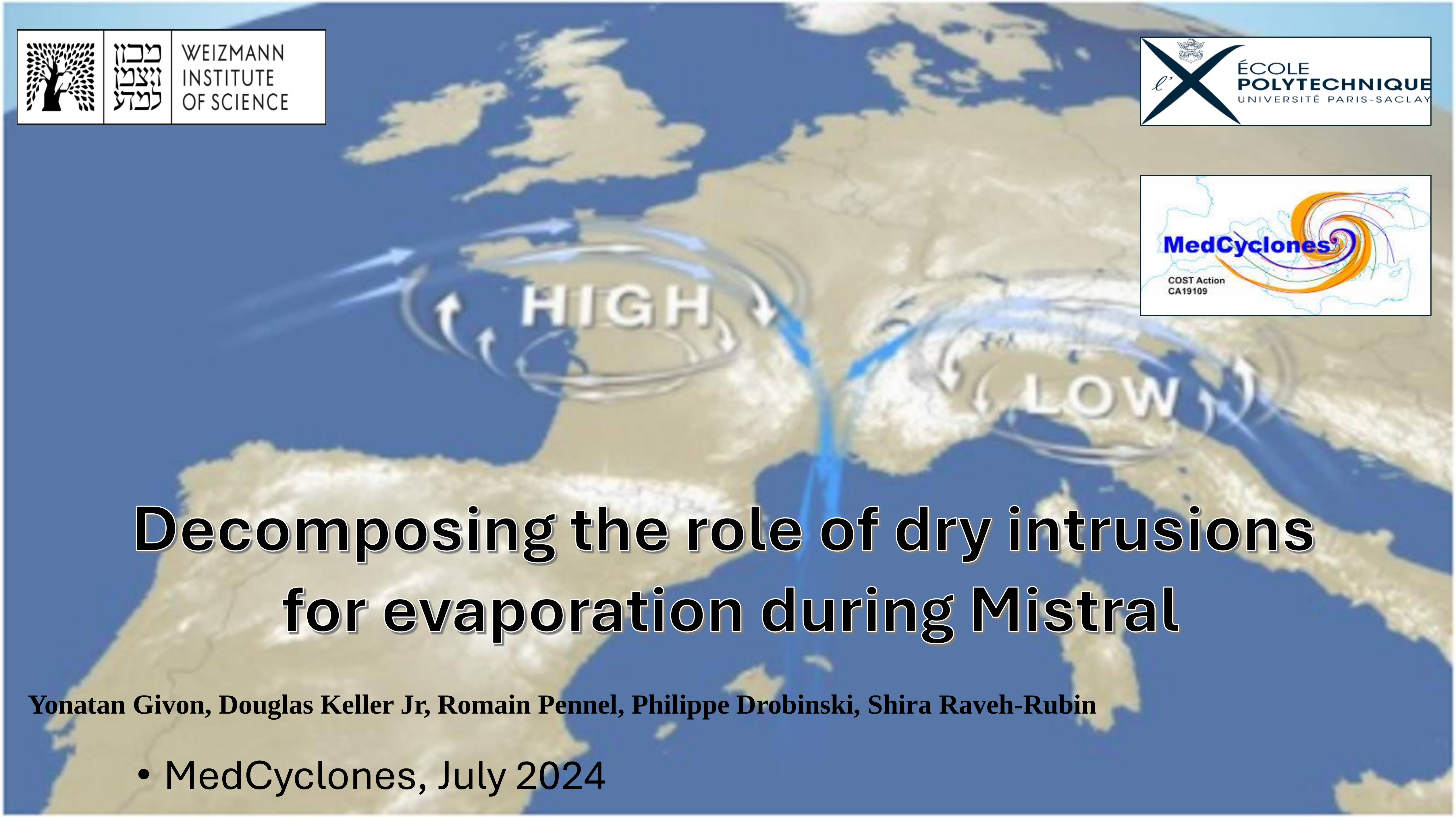

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Decomposing the role of dry intrusions for evaporation during Mistral

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- MedCyclones, July 2024

The Mistral Wind

- Northerly low-level **gap-wind** regime, centered at the Rhône Valley
- Dominant contributor to **Alpine lee-cyclogenesis** (Buzzi et al., 2020)
- A primary driver of **deep-water formation** in the Gulf of Lion (GOL) (Keller et al., 2022 & 2024)

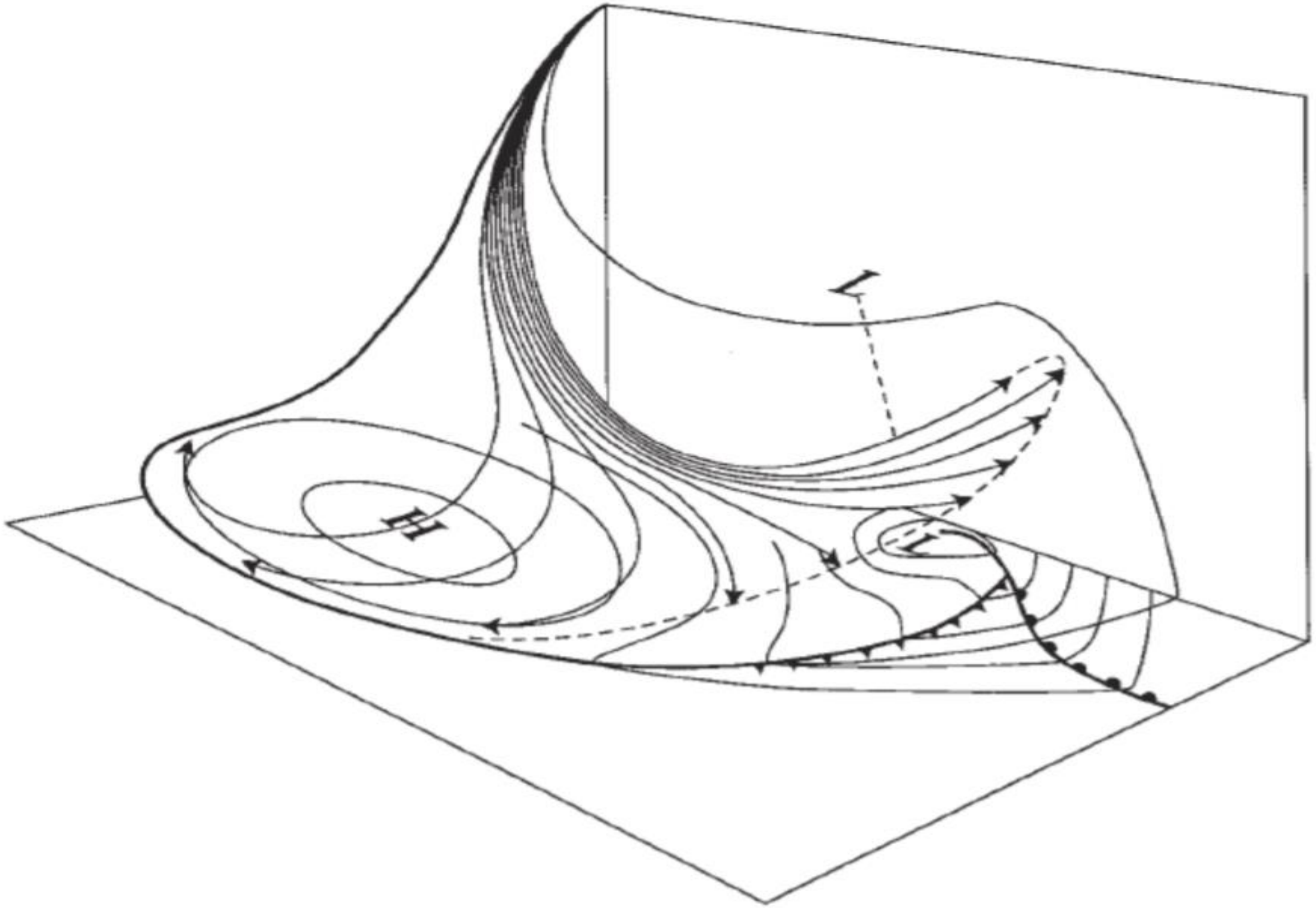
Descending motion

Mattocks & Bleck, 1986

DIs – Dry Intrusions

- **Descending** branches of extratropical cyclones
- **Dry and cold** anomalies (Raveh-Rubin & Catto, 2019 , Klaider and Raveh-Rubin, 2023)
- **Extreme** surface impact: gusts, dust, fires, and more (Ilotoviz et al., 2021; Fluck et al., 2022; Magaritz et al., 2023)

Evaporation hot spot

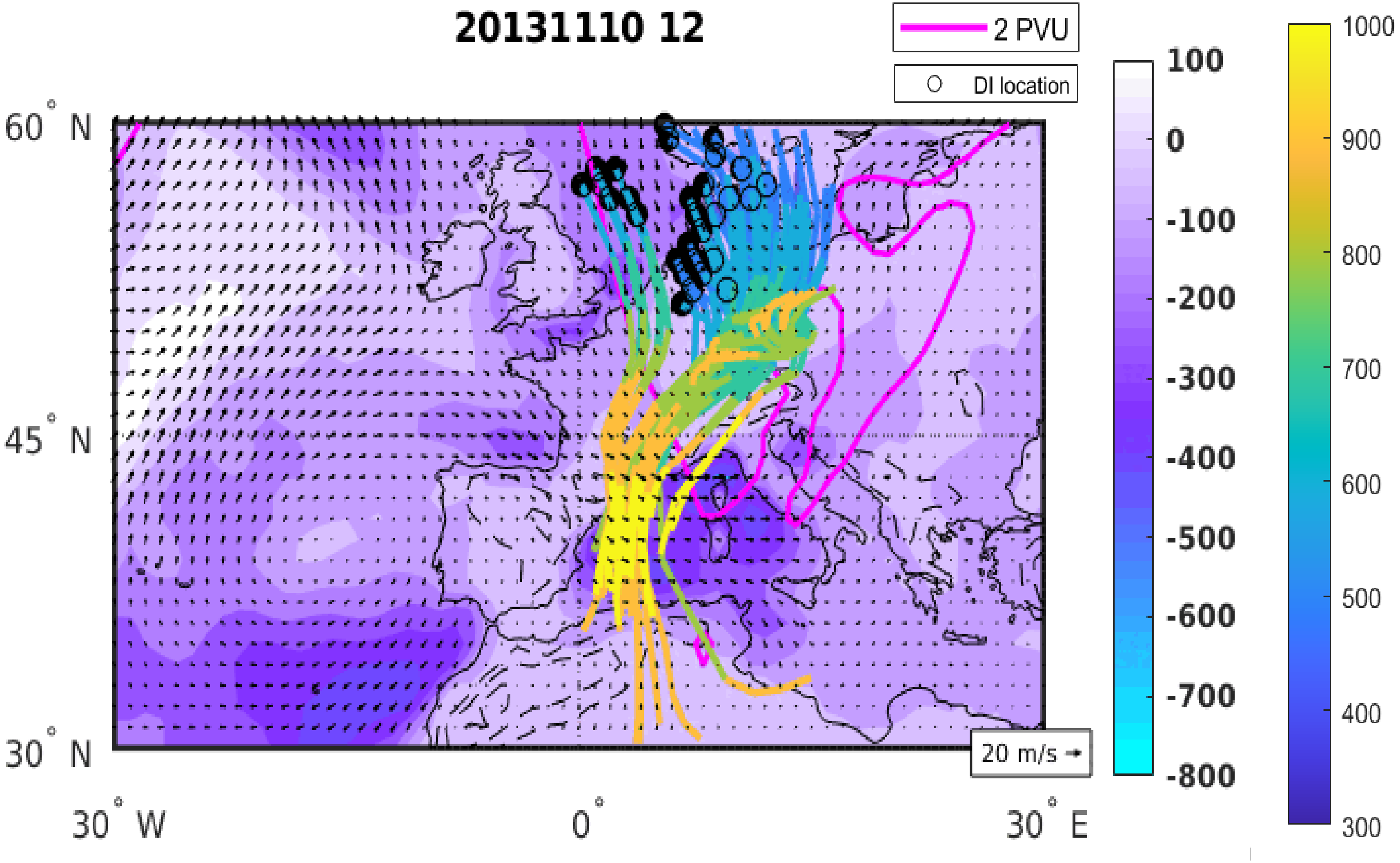


Browning, 1997; Danielsen, 1964

Linking DIs to Mistral

- At times, DIs appear **embedded in the Mistral** flow
- Stirred by the dynamical tropopause and **channeled by topography**

Extreme evaporation rates



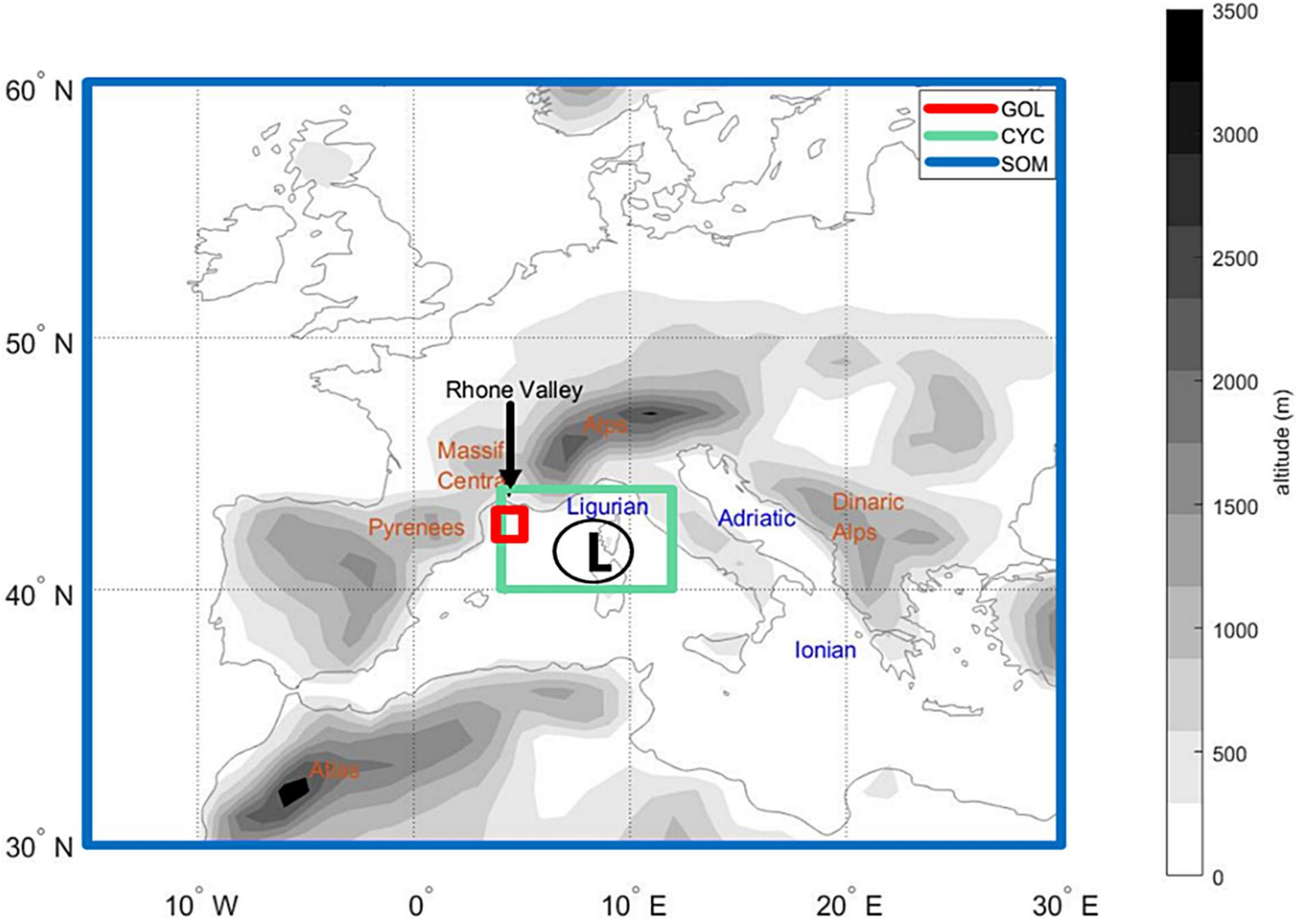
Objectives

- Isolate Mistral evaporation **drivers**
- Compare Mistral events with/without **DI**
- Quantify **DI contribution** to Mistral evaporation

Reveal underlying mechanisms

Mistral Detection

- **1981-2016** database of Mistral and DIs is compiled (ECMWF ERA-INTERIM reanalysis).
- 2734 Mistral days are captured, corresponding to **21% mean frequency** (Givon et al., 2021)



Dry Intrusion Detection

- Identified using Lagranto as trajectories with pressure Increase exceeding 400/48 [hPa/hour]

- Located within 1 ° of the GOL domain at pressure700 hPa during Mistral days

- Horizontal and vertical winds tracked along the DI trajectory

23% of Mistral days are co–located with DI trajectories

Mistral Evaporation Drivers

- Evaporation anomalies are **decomposed**

(Following Menezes et al., 2019):

WS= 10-meter wind speed

S= surface stability ($T_{2m} - SST$)

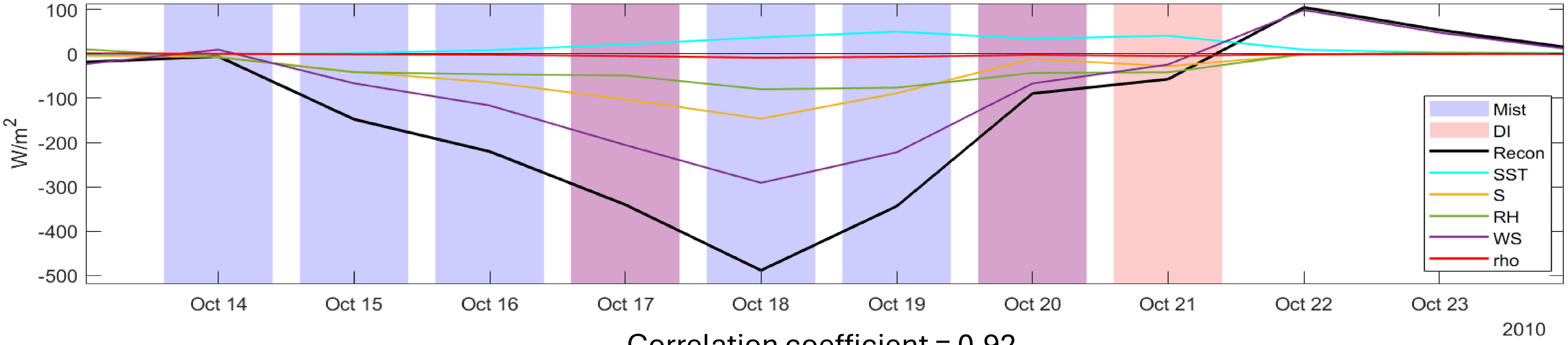
RH= relative humidity

SST= sea surface temperature

$\rho_a{}'$ = air density

$$\mathrm{SLHF} = L_v C_e WS(q_a - q_s)$$

$$SLHF' = \frac{\partial Q_l}{\partial WS}WS' + \frac{\partial Q_l}{\partial S}S' + \frac{\partial Q_l}{\partial RH}RH' + \frac{\partial Q_l}{\partial SST}SST' + \frac{\partial Q_l}{\partial \rho_a}\rho_a{}'$$

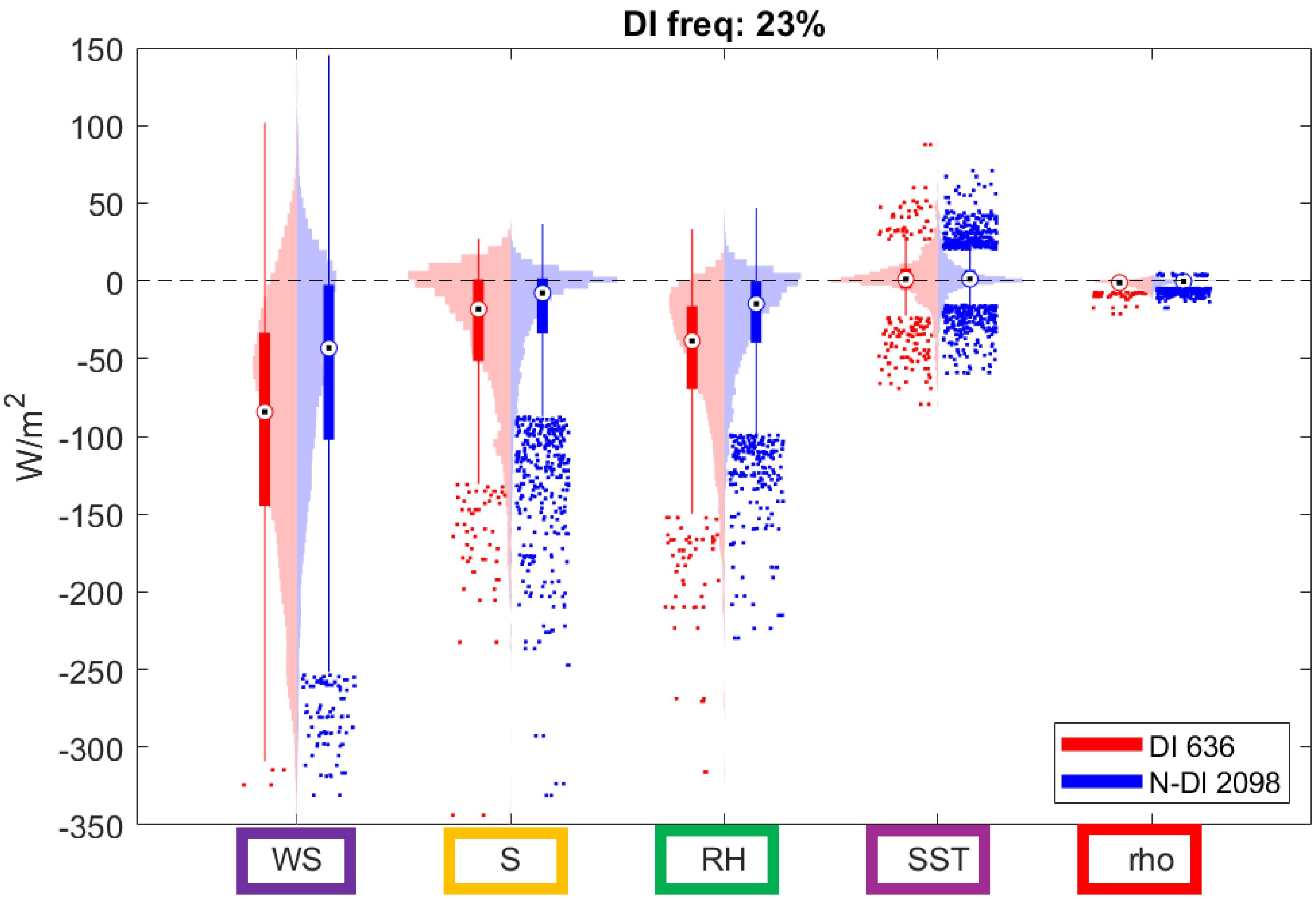


Correlation coefficient = 0.92

Evaporation Response to DI

- DIs **amplify** Mistral evaporation by ~100% on average
- Mistral evaporation dominated by **WS**

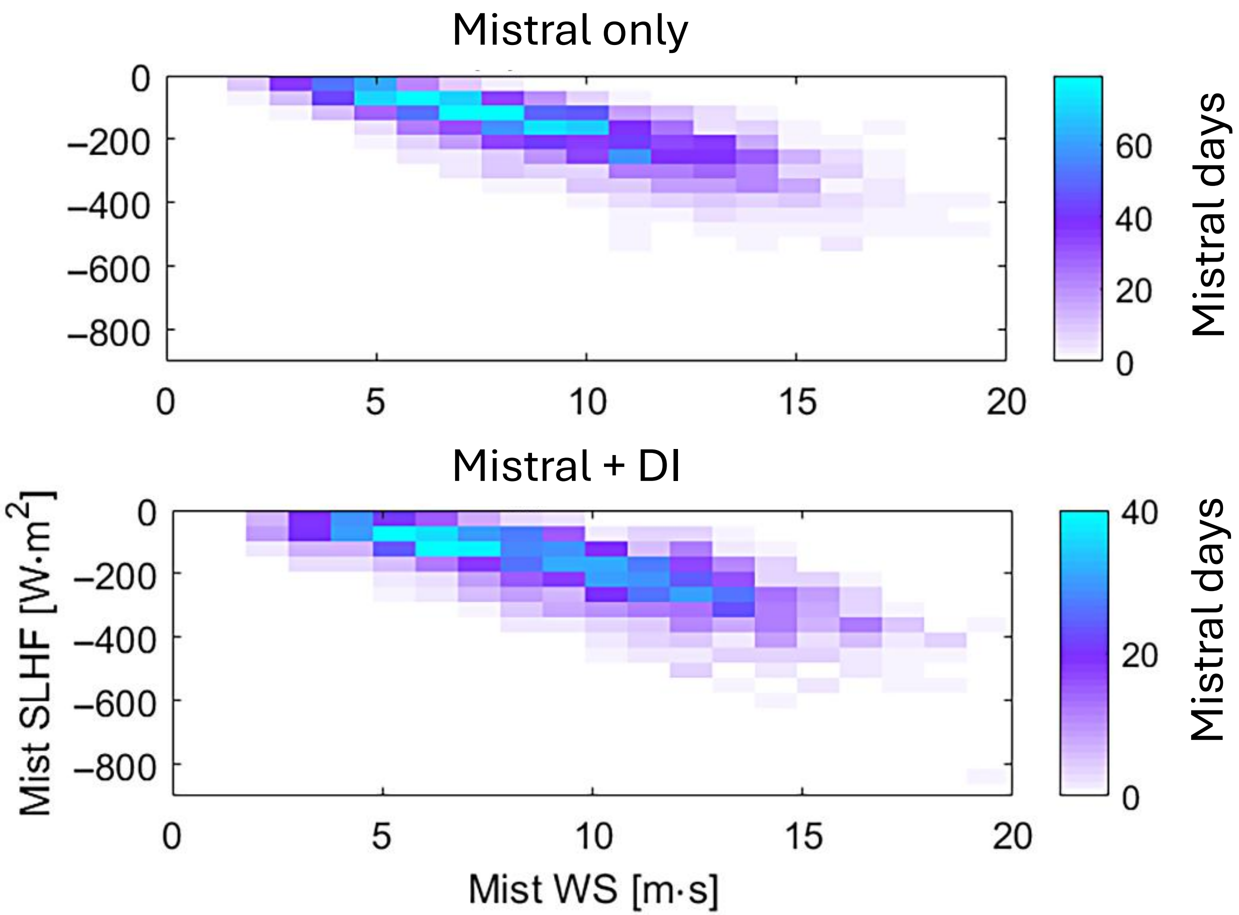
DIs amplify Mistral evaporation mainly by increased WS



Surface winds and SLHF

- Linear correlation suggests anomalies of ~7 m/s lead to $\sim 200\ W/m^2$ increase in SLHF
- DIs shift the density plot towards more extreme values

What is the source of momentum for DI-Mistral?



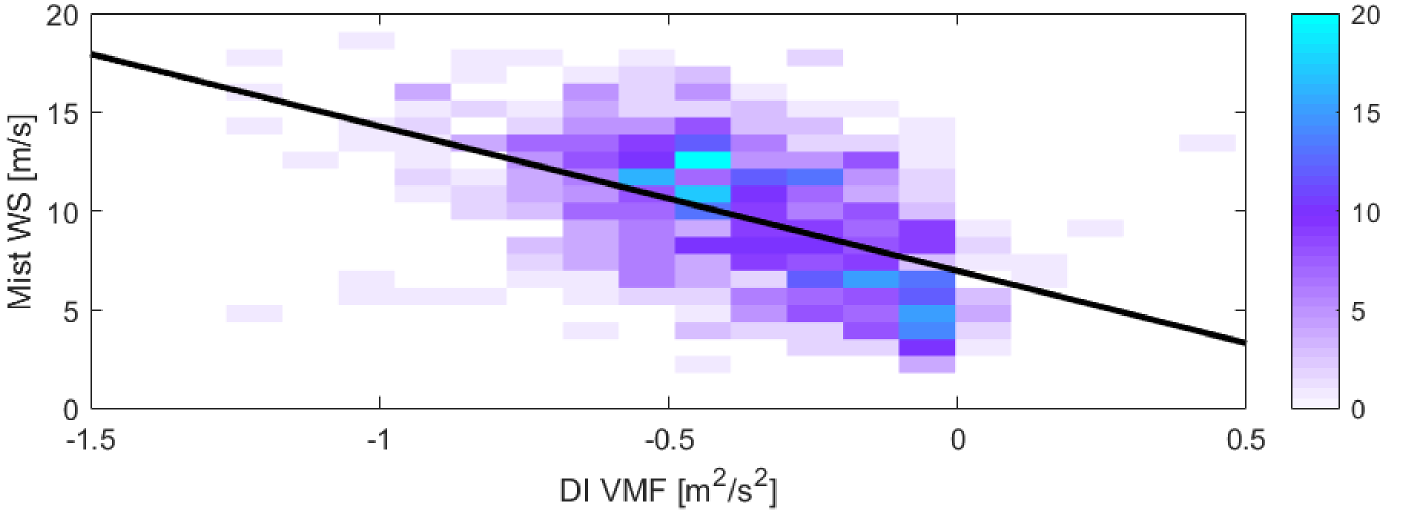
Vertical Momentum Flux (VMF)

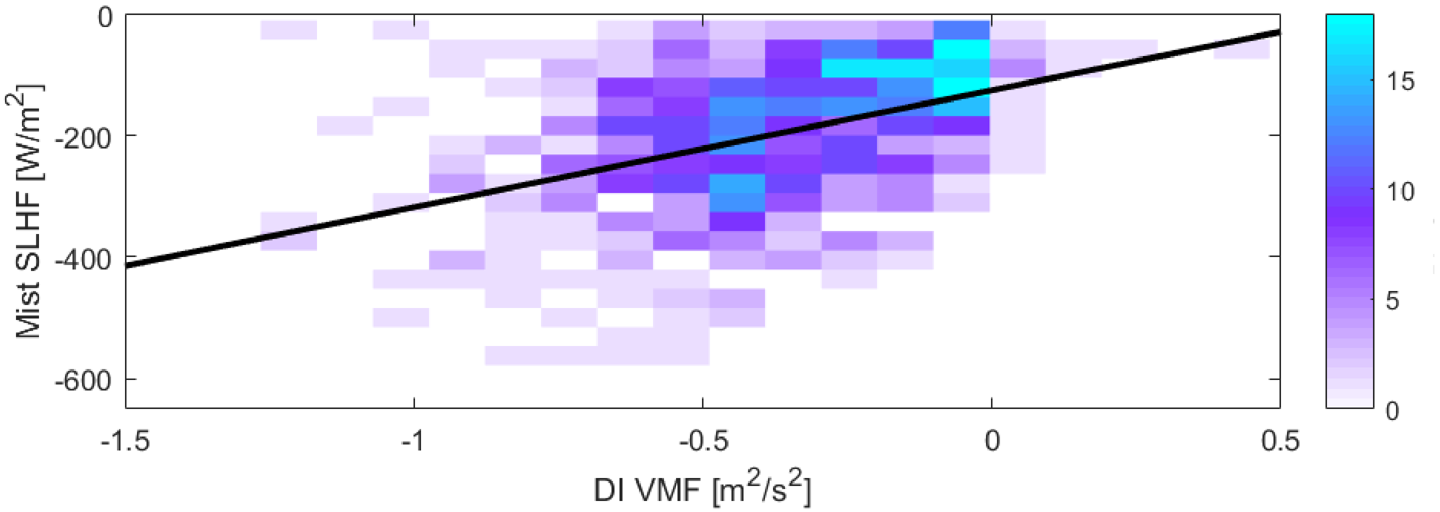
- Evaluated along DI trajectory:

$$VMF_{GOL} \equiv W_{DI@GOL}|V_{DI@GOL}|$$

- Correlate to Mistral WS at the GOL
- Increased WS is anti-correlated to VMF **delivered by DIs**

VMF anomalies of $-1[m^2/s^2]$ correspond to $\sim -200\ [W/m^2]$ SLHF anomalies

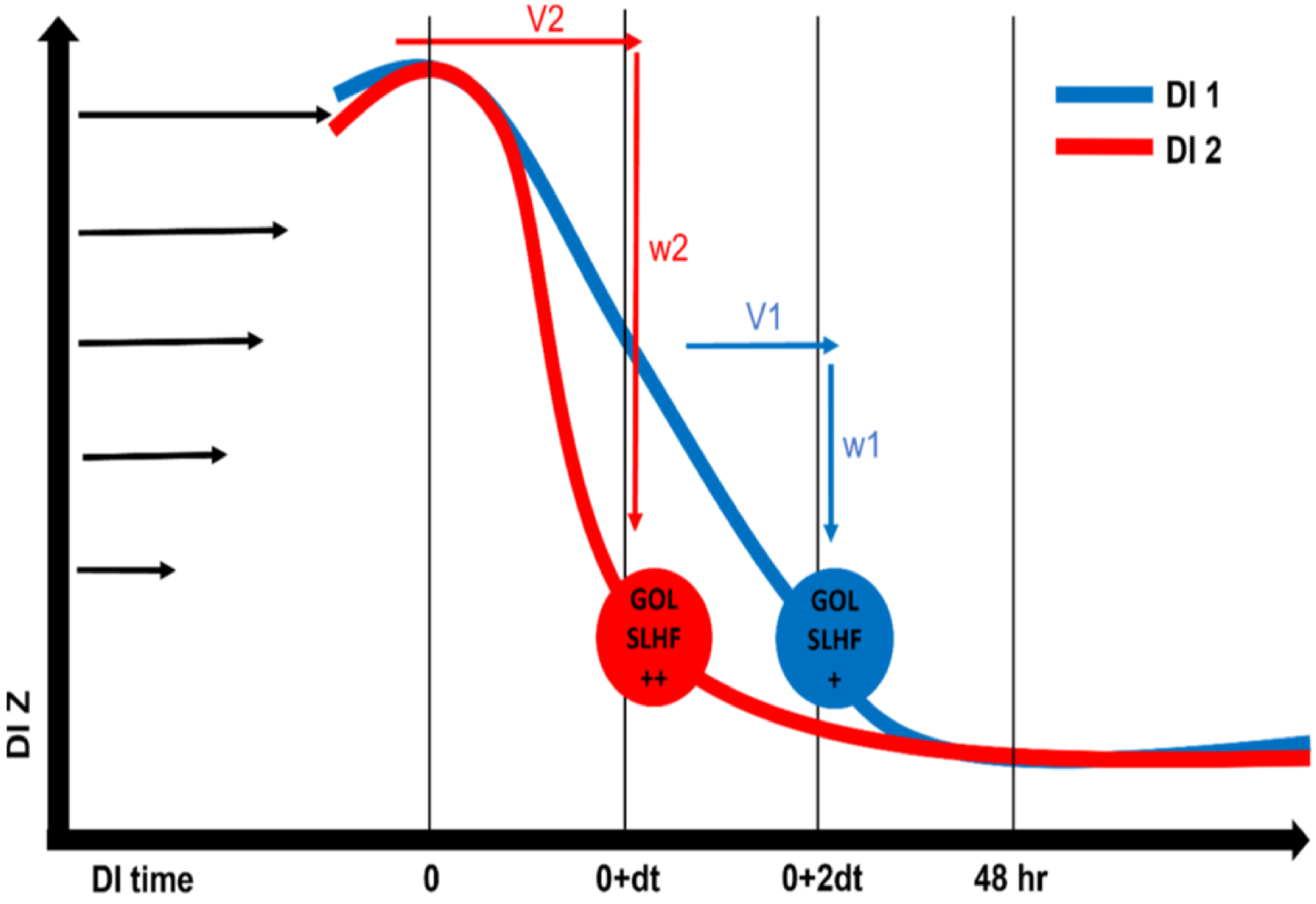




VMF and SLHF

- VMF is **decaying** along the DI trajectory
- DIs originating **closer** to the GOL merge with the Mistral at **earlier stages** of their lifetime, forming **steeper DIs**

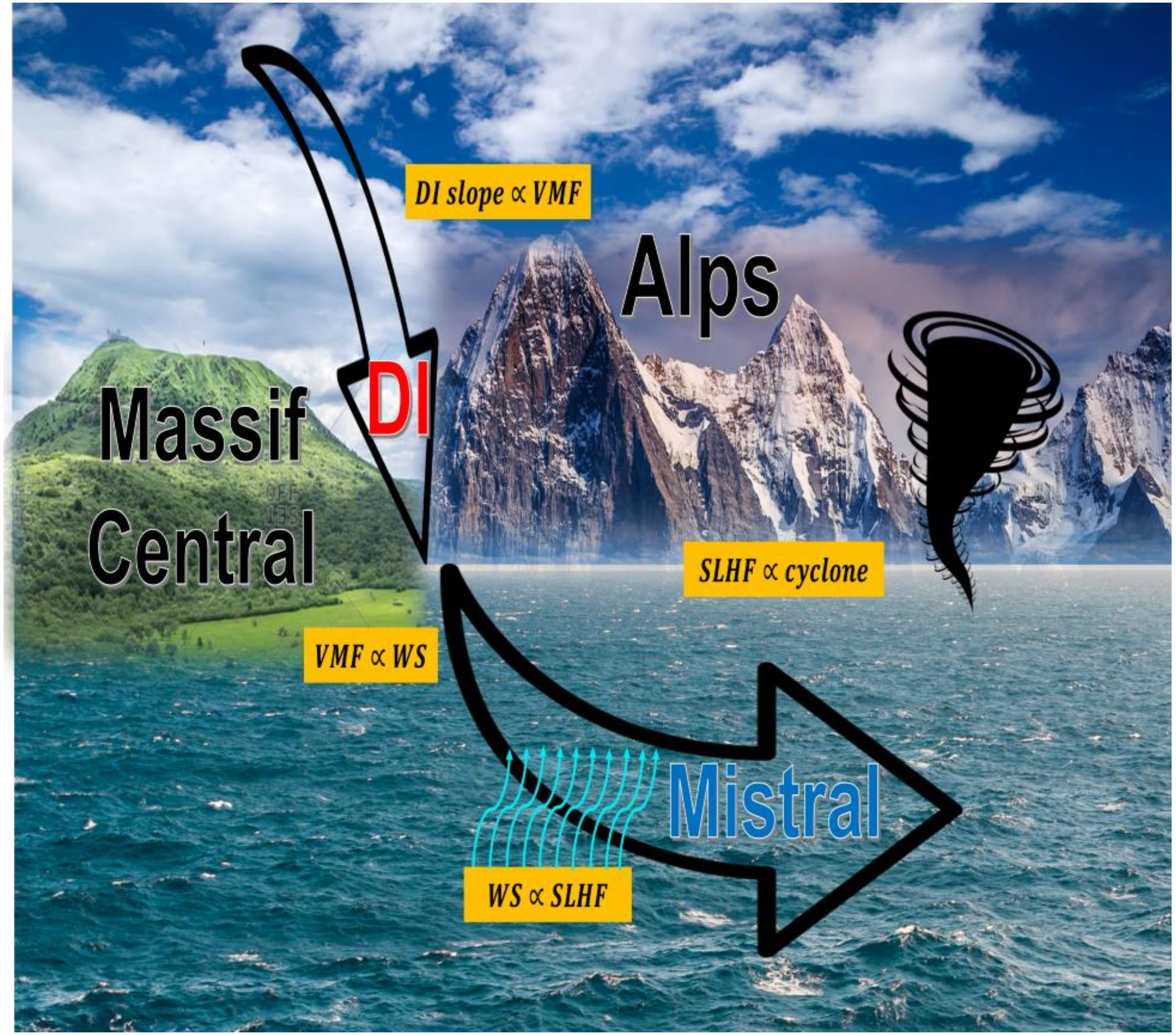
Steeper DIs charge the Mistral with maximum VMF, leading to extreme evaporation rates



Summary

- Mistral evaporation is dominated by **wind speed**
- DIs co-occur with Mistral on a **23% mean frequency**
- DIs enhance Mistral evaporation by over **100%**
- Even greater amplification for certain **PV clusters** (up to **300%**)
- VMF is critical for **extreme** SLHF

Givon, Y., Keller Jr, D., Pennel, R., Drobinski, P., & Raveh-Rubin, S. (2024). Decomposing the role of dry intrusions for ocean evaporation during mistral. QJRMS

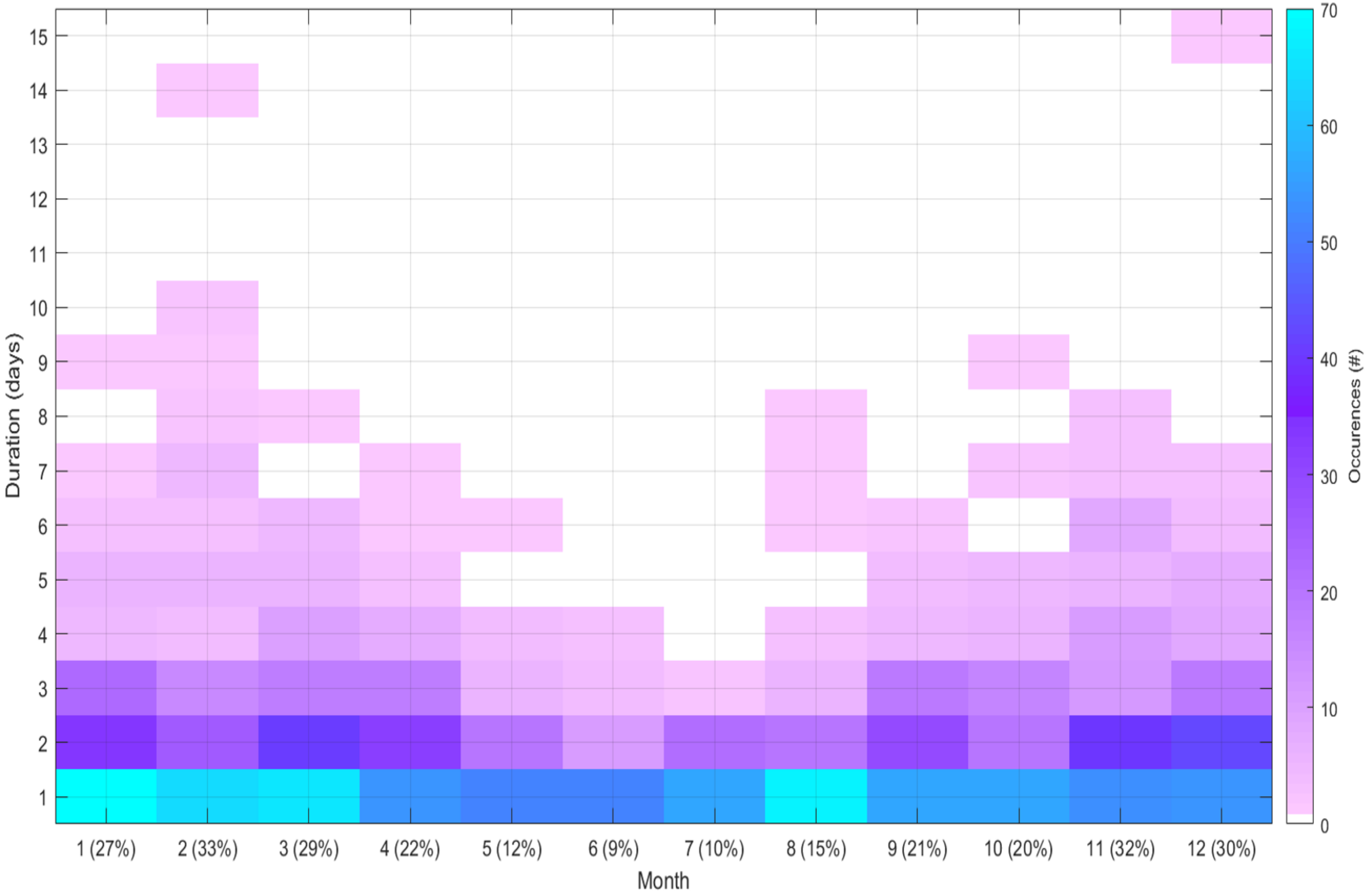


Enhanced DI-Mistral evaporation is driven by increased WS that stem from VMF, controlled by the DI slope.

Mistral Seasonality

- ERA-INTERIM data years 1981-2016 yields ~2700 Mistral days (21% annual mean frequency)

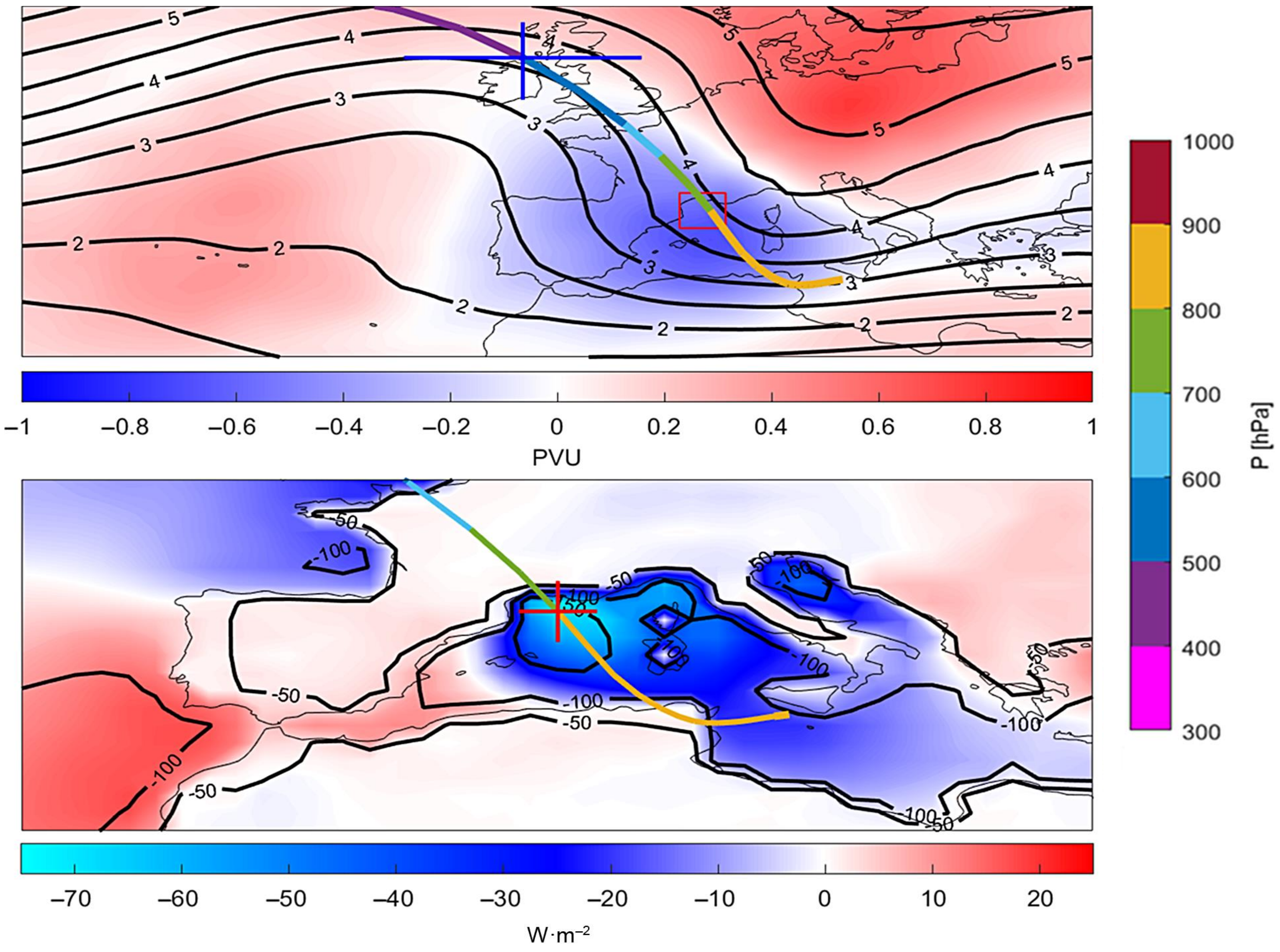
- Long events are more frequent in winter



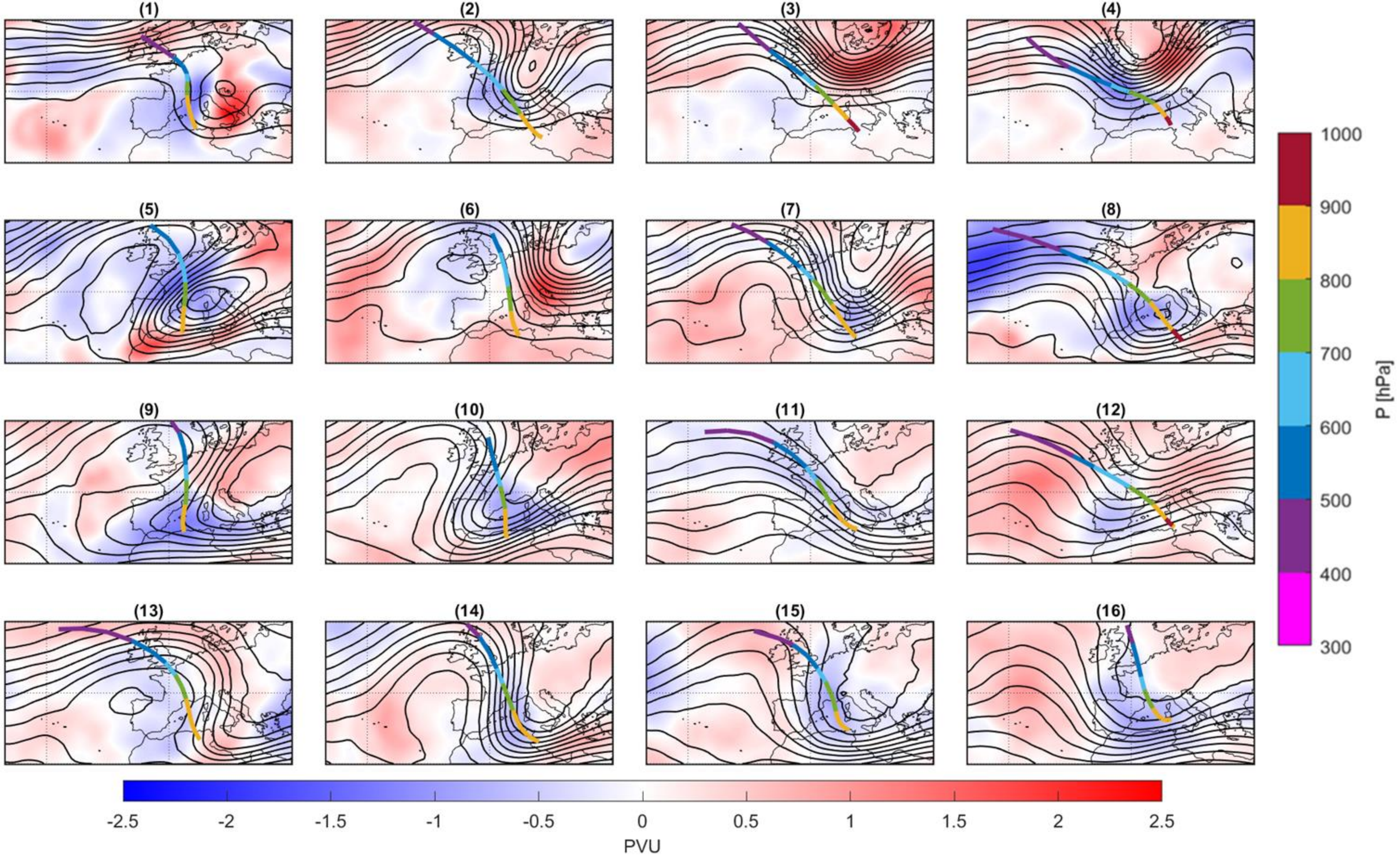
Mistral Response to DI

- Enhanced upper-level trough
- Eastward-shifted ridge
- Deeper cyclone
- Enhanced evaporation

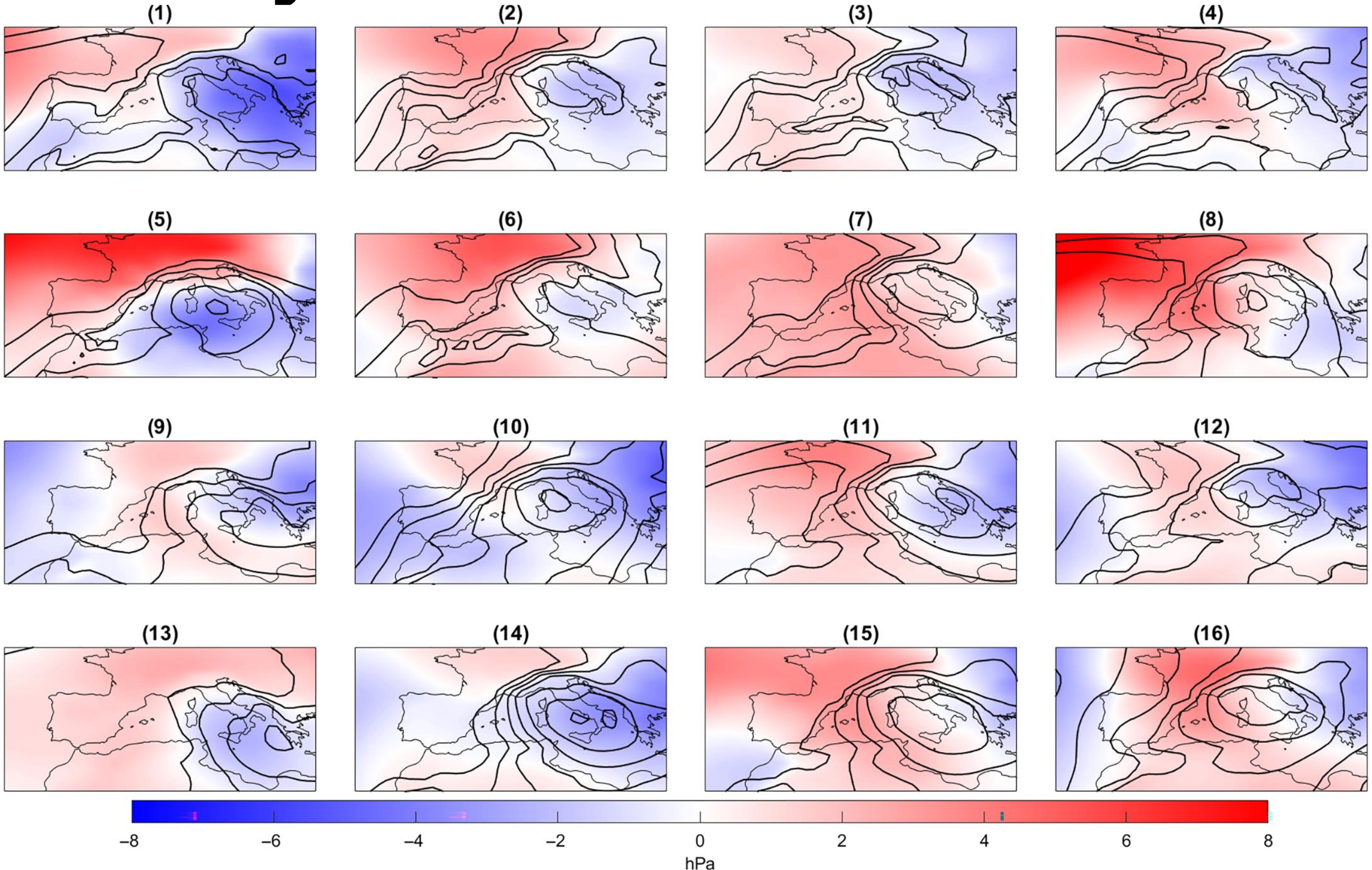
Evaporation impact extends well beyond the GOL



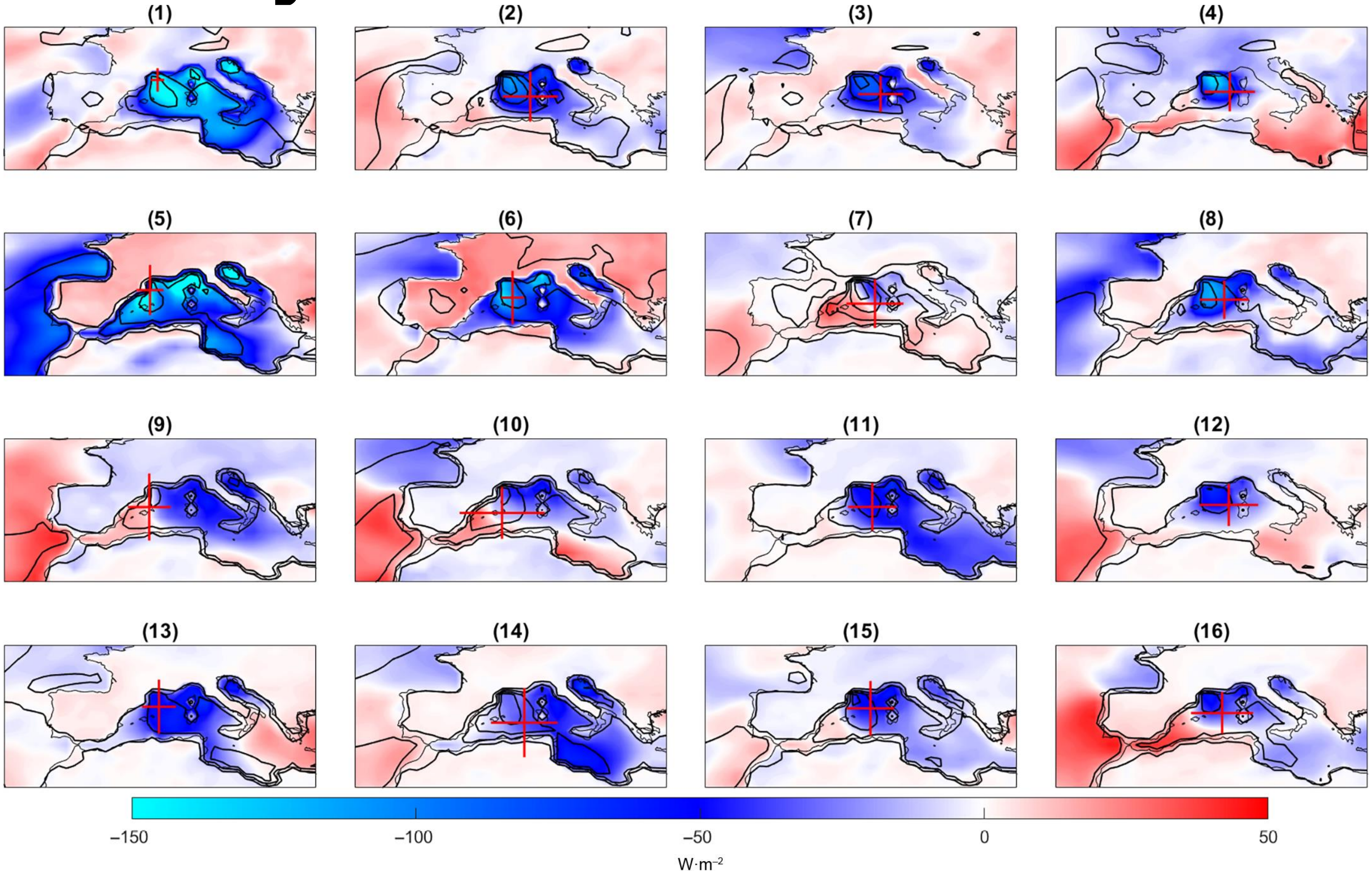
Cluster Analysis – PV



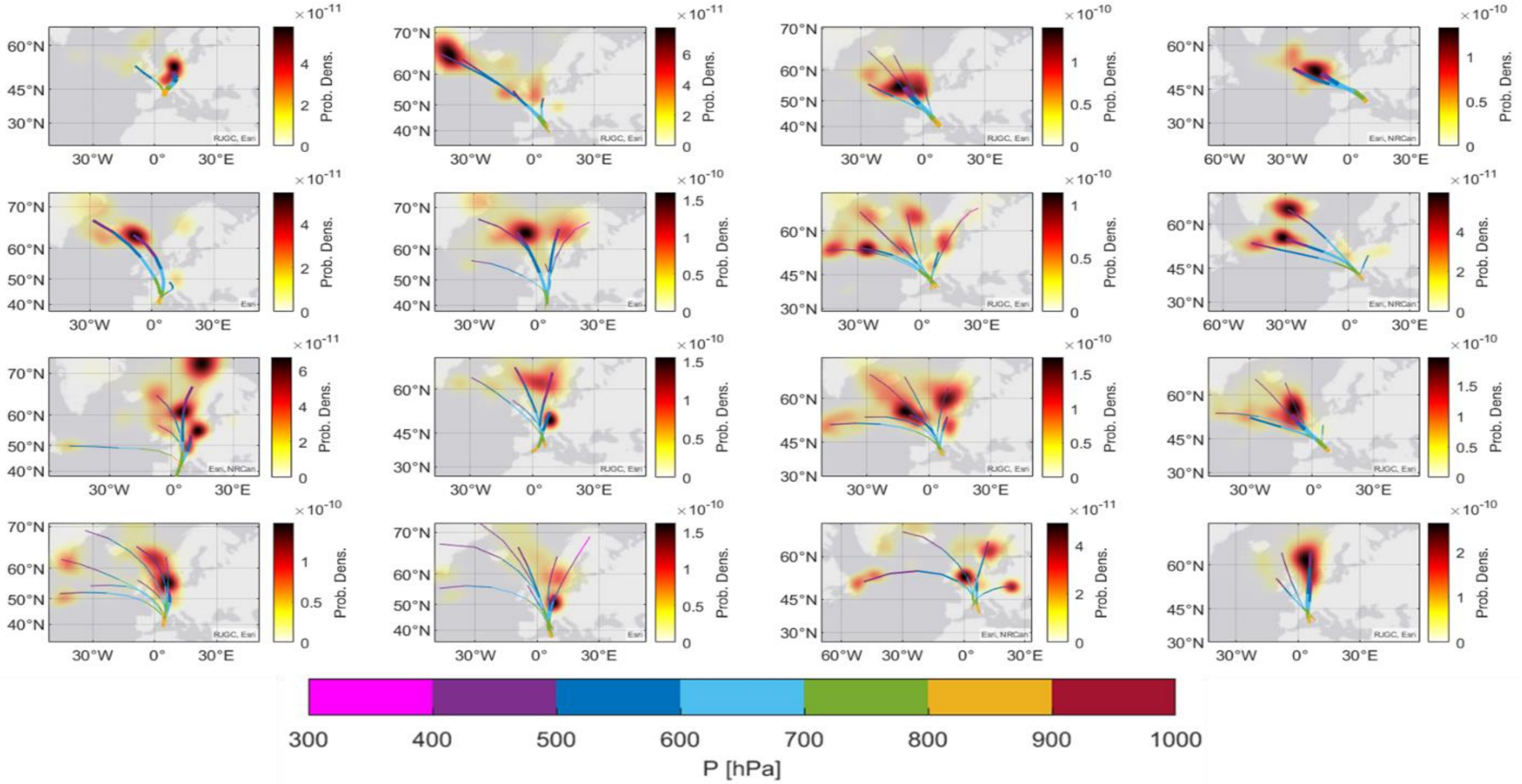
Cluster Analysis – SLP



Cluster Analysis – SLHF

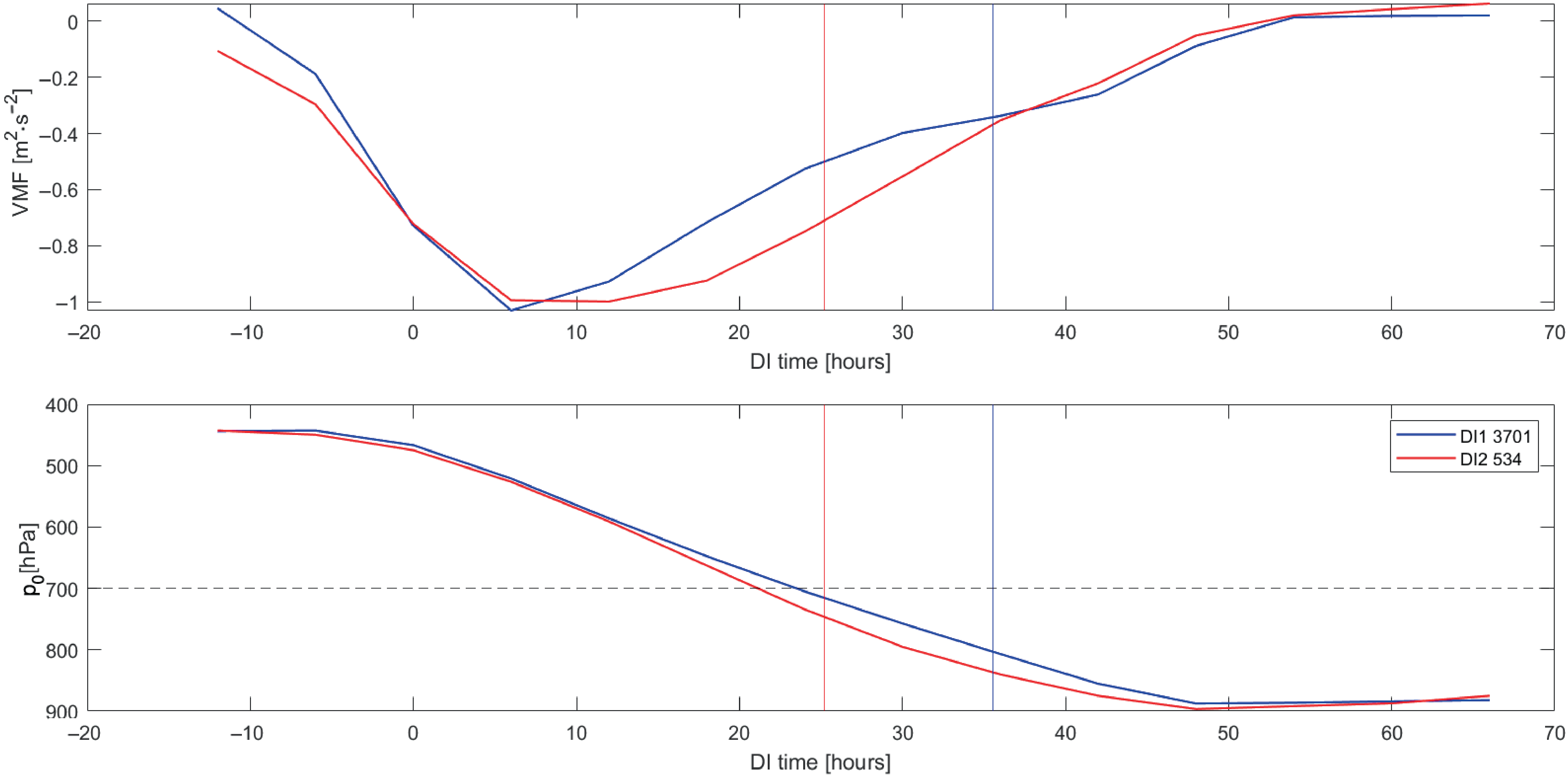


DI Origins



60°N
45°N
30°N
30°W
0°
30°E
×10-11
Prob. Dens.
RJGC, Esri
70°N
60°N
50°N
40°N
×10-10
Esri, NRCan
Esri
60°W
0
0.5
1
1.5
2
4
6
300
400
500
600
700
800
900
1000
P [hPa]

Schematic Revisited



Spatial Difference – DI1 vs DI2