A PHYSICALLY DESCRIPTIVE PHASE SPACE FOR MEDITERRANEAN CYCLONES

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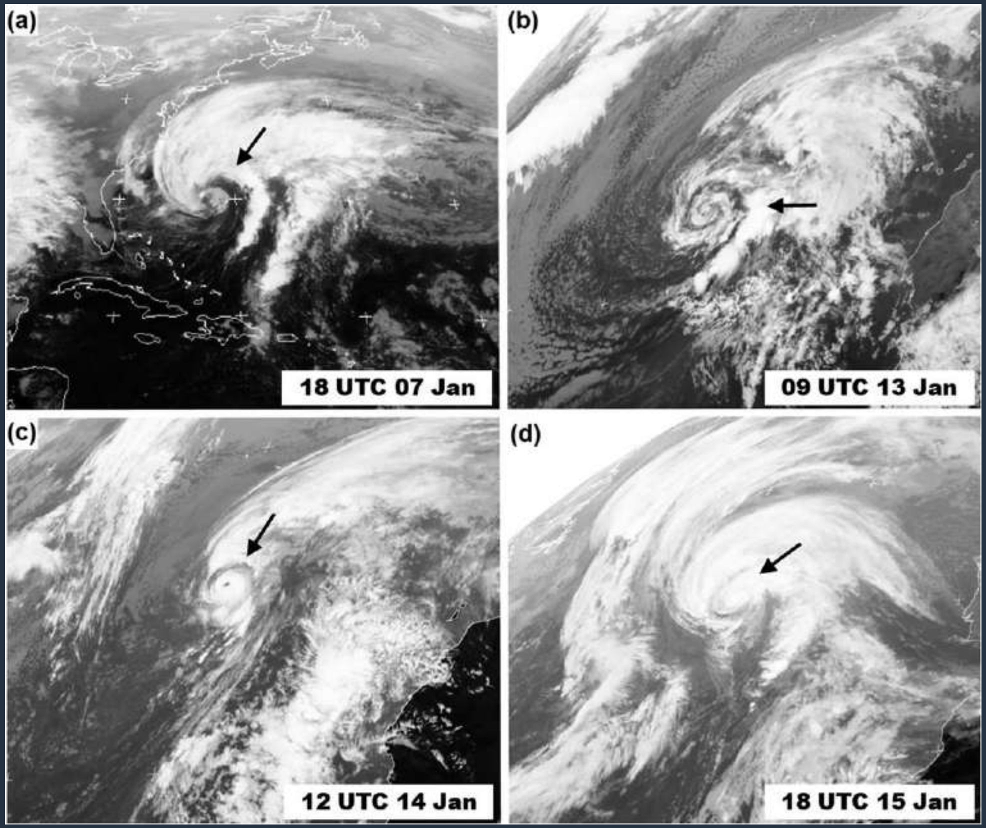
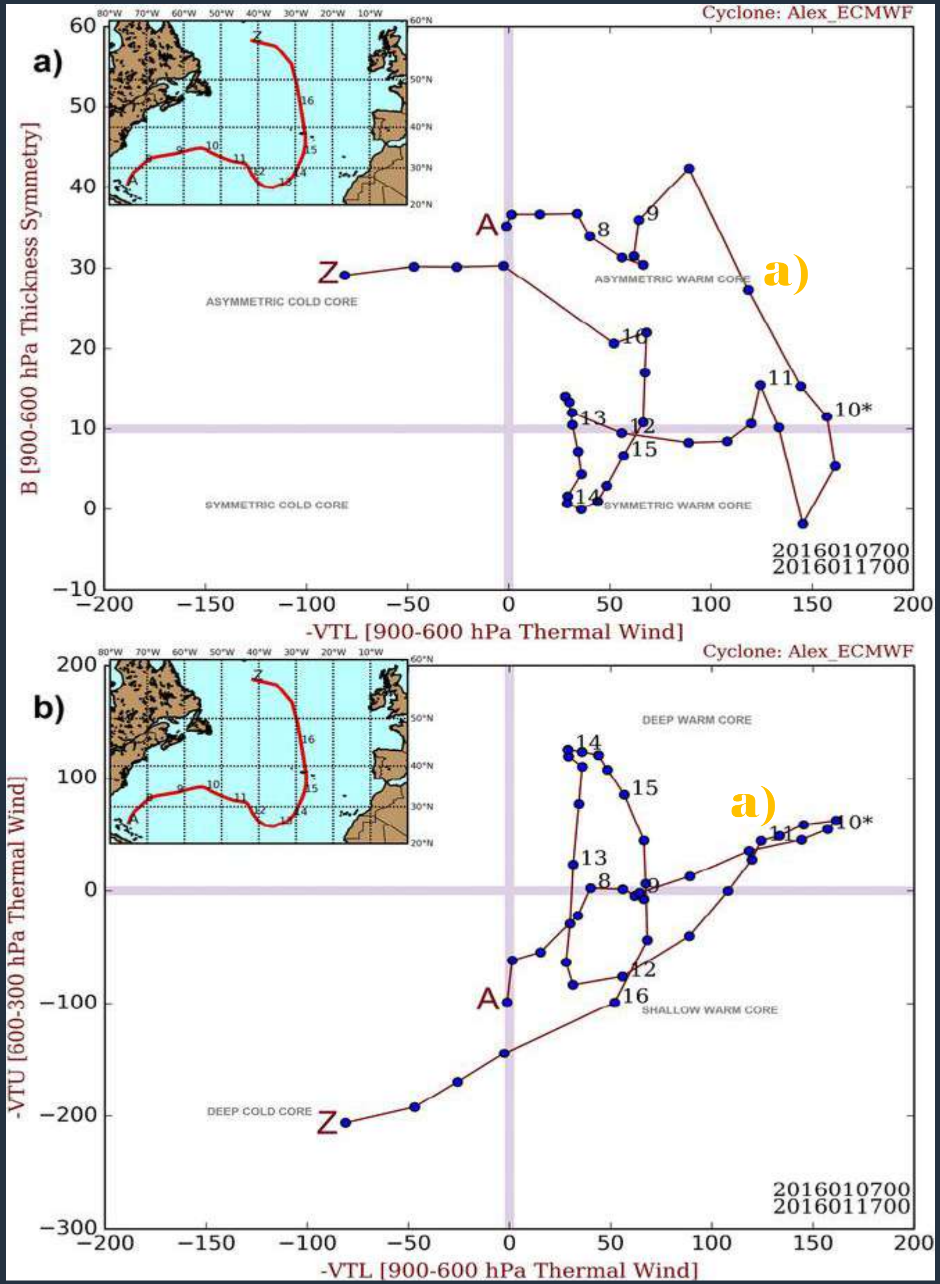
Introduction

- There is a continuum of cyclone types that, after 20 years since the advent of the cyclone phase space (CPS), it has not been clarified.
- The CPS is not a perfect tool as specific cyclone types in the continuum (e.g., hybrid cyclones) can be misclassified.
- One of the most common mis-identification is the confusion between warm seclusions and subtropical cyclones (STCs)/tropical cyclones (TCs)
  - *Examples of Zorbas (2018) or Hurricane Alex (2016)*

Introduction

- González-Alemán, J. J., J. L. Evans, and A. M. Kowaleski, 2018: *Use of Ensemble Forecasts to Investigate Synoptic Influences on the Structural Evolution and Predictability of Hurricane Alex (2016) in the Midlatitudes*. Mon. Wea. Rev., 146, 3143–3162, https://doi.org/10.1175/MWR-D-18-0015.1.





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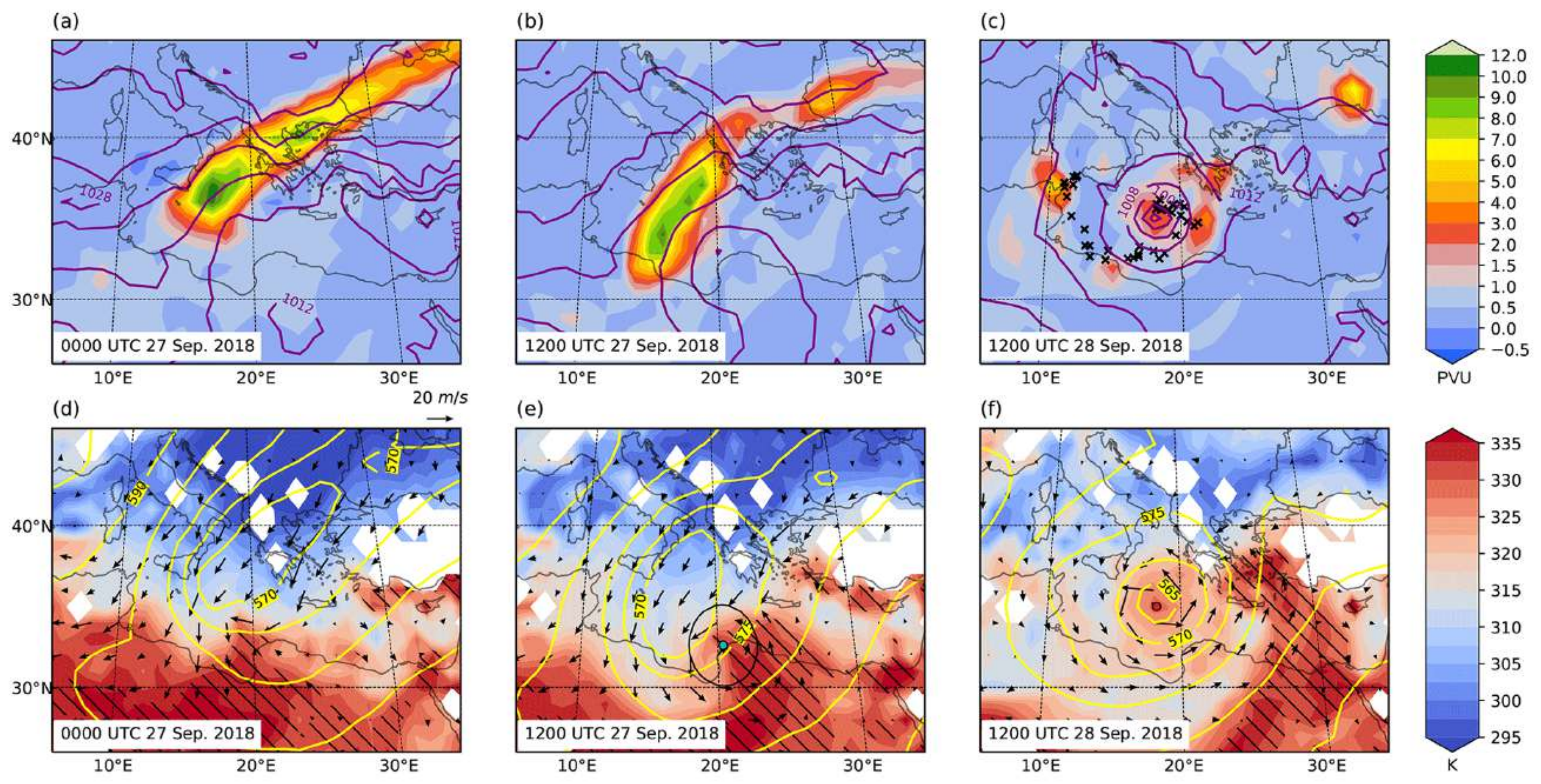
- Portmann, R., González-Alemán, J. J., Sprenger, M., and Wernli, H.: *How an uncertain short-wave perturbation on the North Atlantic wave guide affects the forecast of an intense Mediterranean cyclone (Medicane Zorbas)*. Weather Clim. Dynam., 1, 597–615, https://doi.org/10.5194/wcd-1-597-2020, 2020.



Introduction

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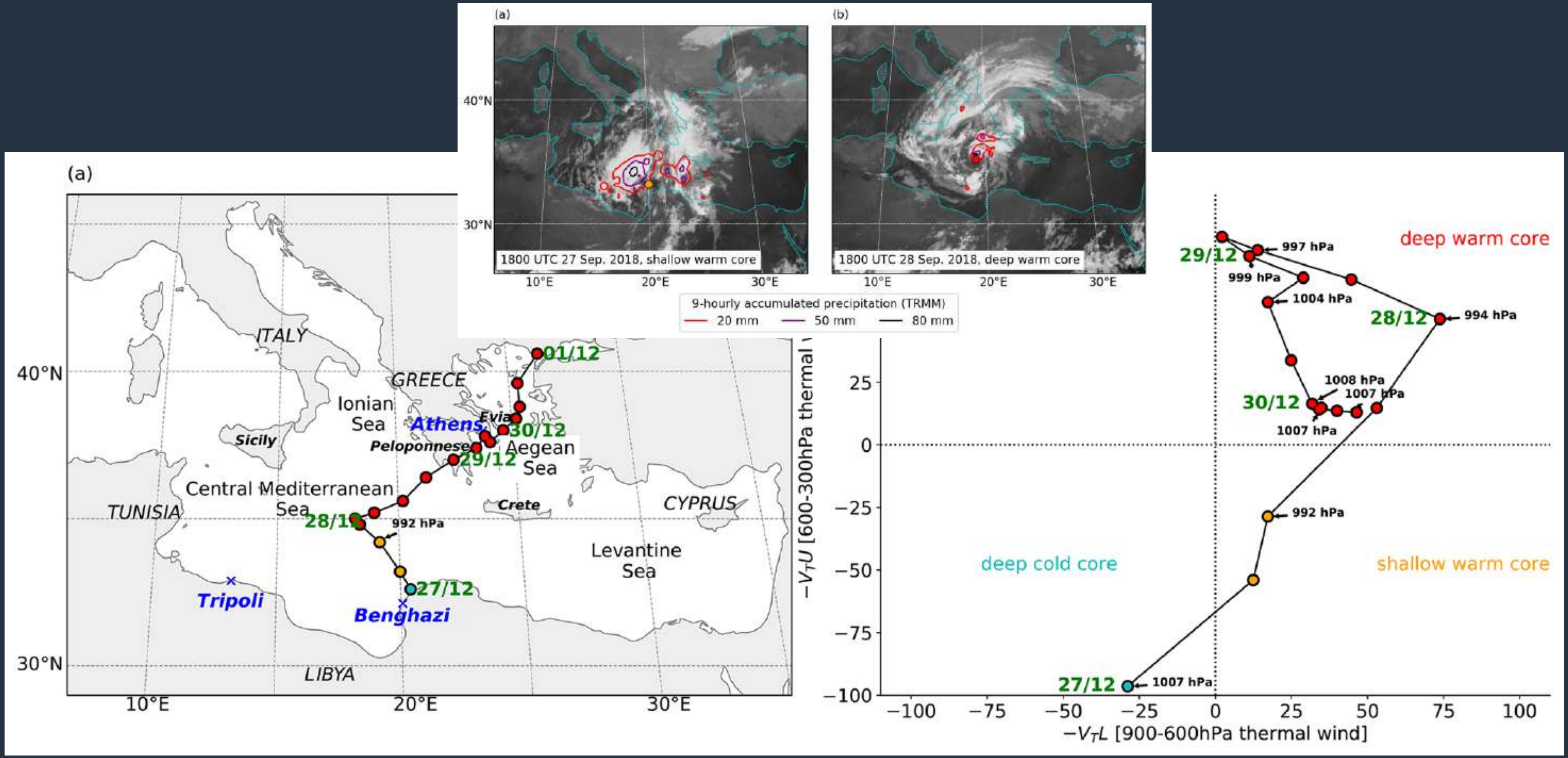
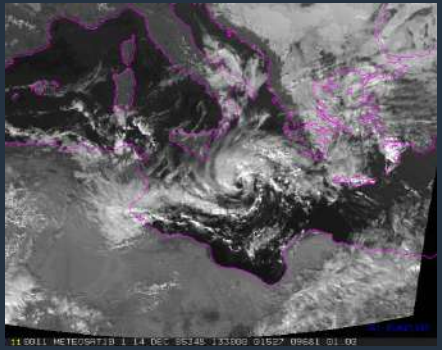
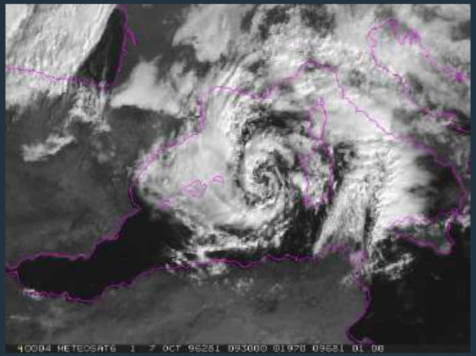


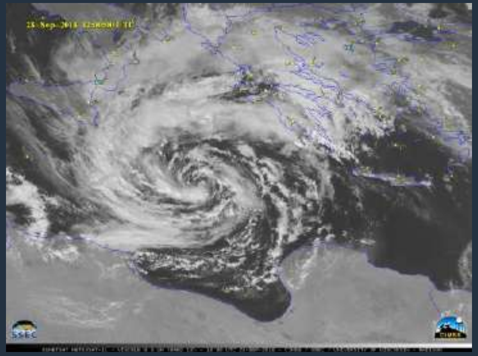
Introduction

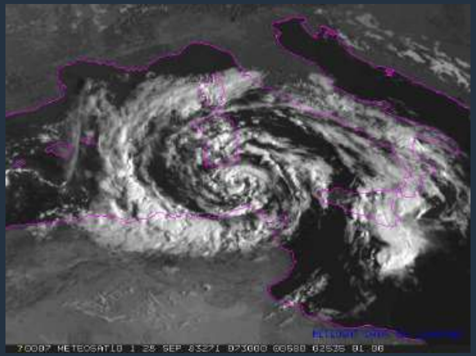
- Special confusion with the classification/identification of tropical-like and hybrid cyclones. Especially over the Mediterranean Sea.
- Warm seclusions potentially mis-classified as medicanes (tropical or tropical-like cyclones).

  See poster *"Characteristics of some of the most important medicanes in the last 40 years with ERA5 reanalysis data"* in poster session 1.



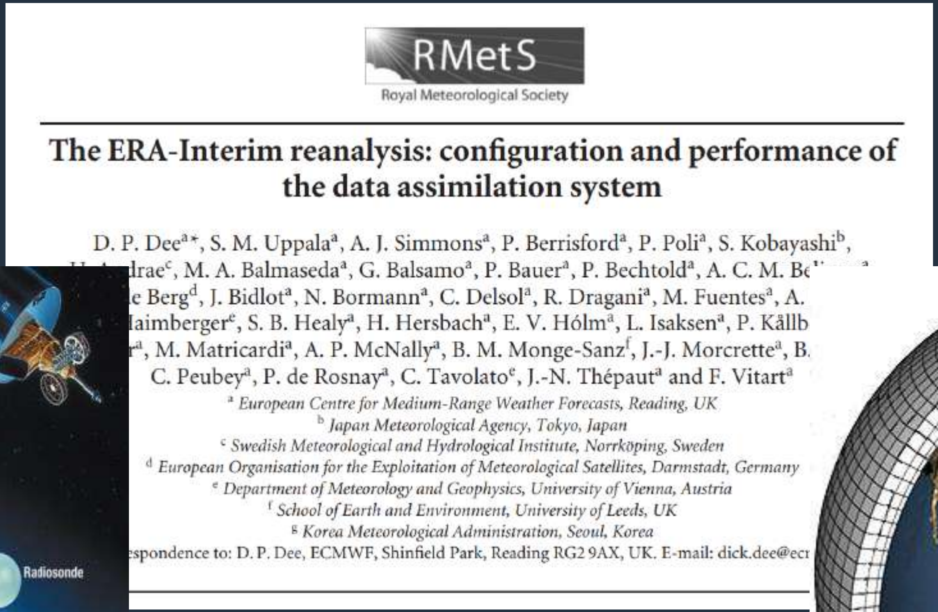






Data and Methods

ERA-Interim reanalysis is used, as part of the methodology derives from an article in 2017. But intentions to move to *ERA-5*.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The ERA-Interim reanalysis: configuration and performance of the data assimilation system

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...drae[c], M. A. Balmaseda[a], G. Balsamo[a], P. Bauer[a], P. Bechtold[a], A. C. M. Be...
...e Berg[d], J. Bidlot[a], N. Bormann[a], C. Delsol[a], R. Dragani[a], M. Fuentes[a], A.
...aimberger[e], S. B. Healy[a], H. Hersbach[a], E. V. Hólm[a], L. Isaksen[a], P. Kållb...
...r[a], M. Matricardi[a], A. P. McNally[a], B. M. Monge-Sanz[f], J.-J. Morcrette[a], B.
C. Peubey[a], P. de Rosnay[a], C. Tavolato[e], J.-N. Thépaut[a] and F. Vitart[a]

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[b] Japan Meteorological Agency, Tokyo, Japan
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[f] School of Earth and Environment, University of Leeds, UK
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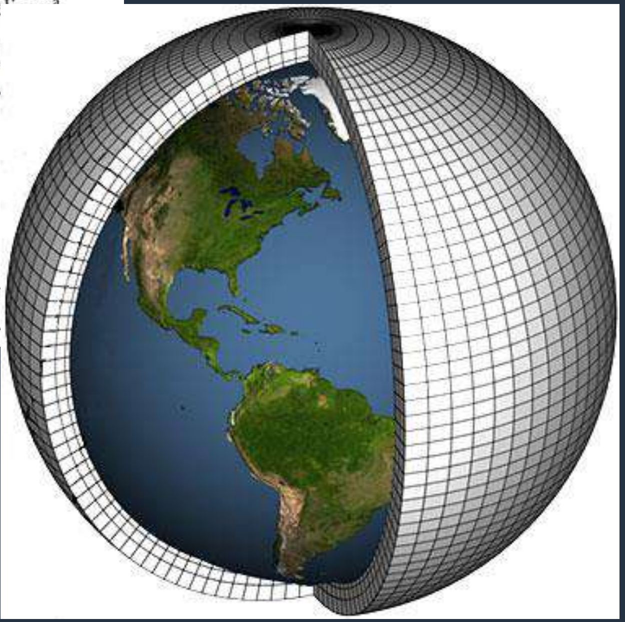
...espondence to: D. P. Dee, ECMWF, Shinfield Park, Reading RG2 9AX, UK. E-mail: dick.dee@ecr...

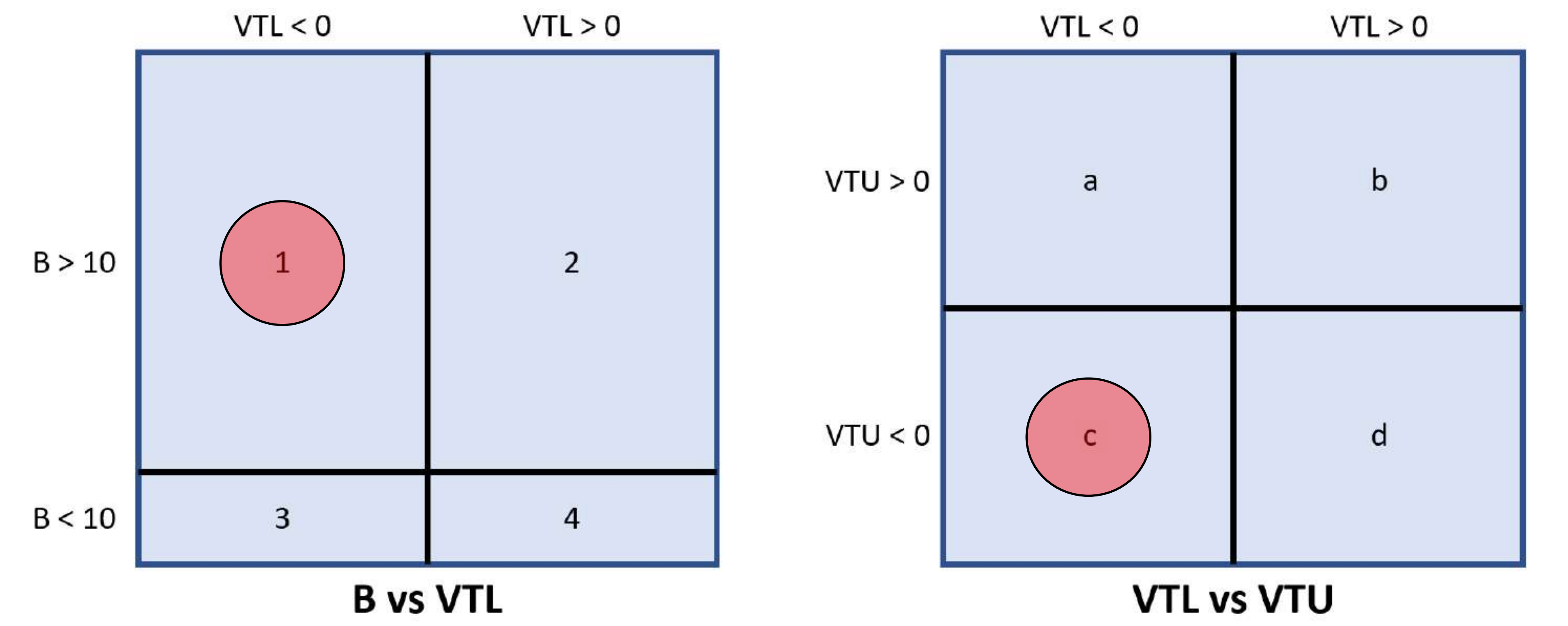


Data and Methods

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

Cyclone Phase Space:

1c Frontal Deep Cold Core (extratropical cyclone)

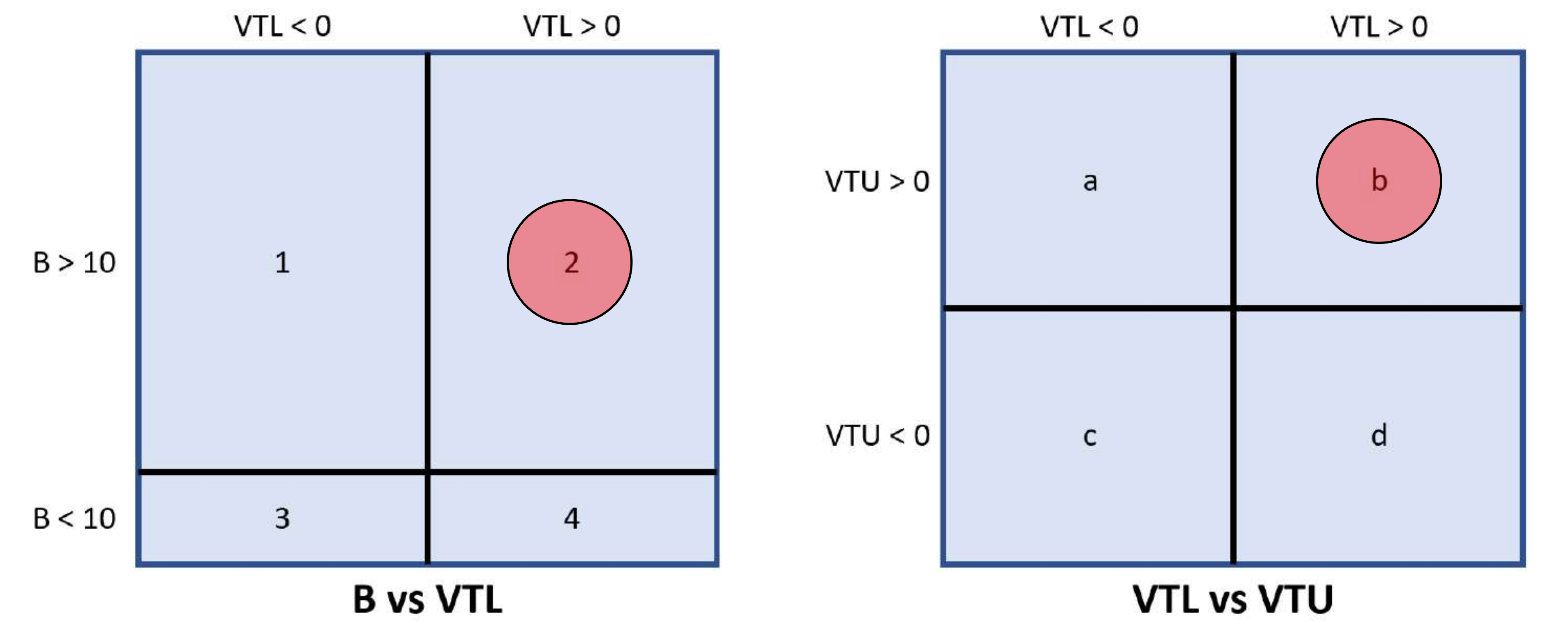


Data and Methods

Cyclone Phase Space:

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

2b Frontal Deep Warm Core (intense warm seclusion?)

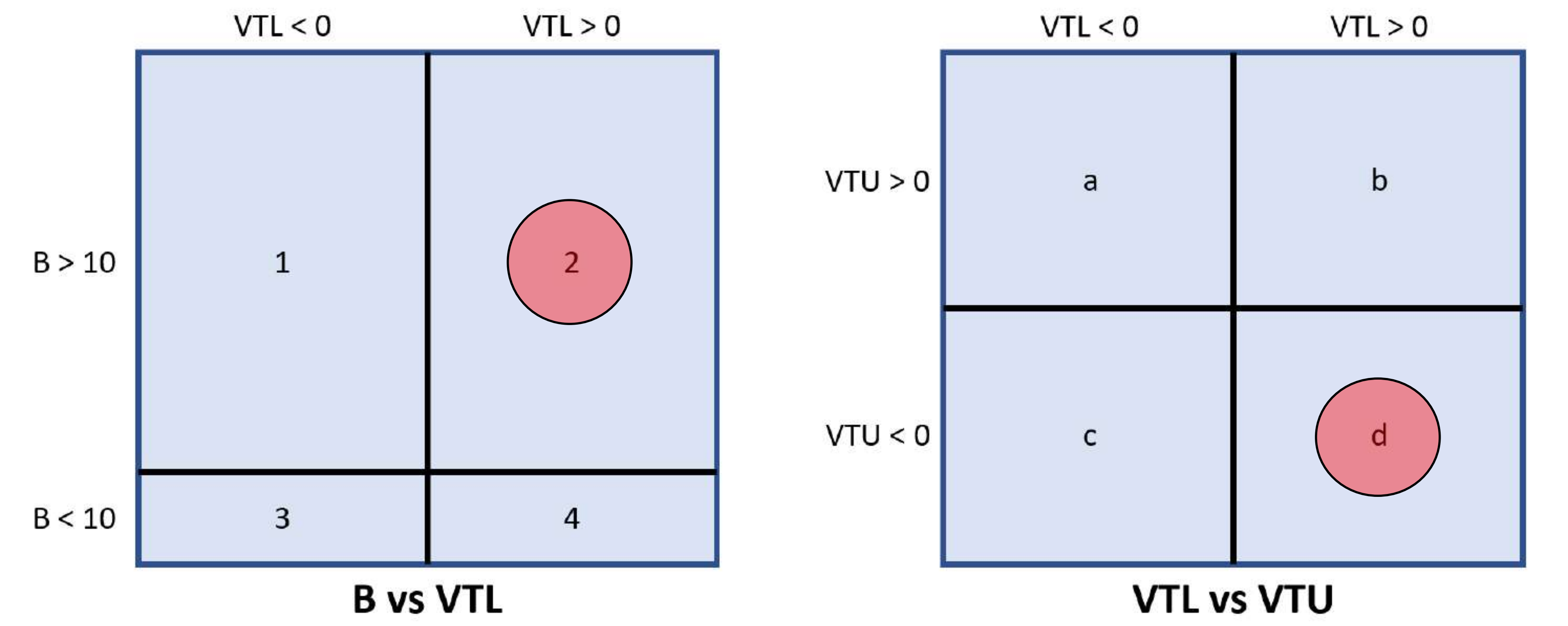


Data and Methods

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

Cyclone Phase Space:

2d Frontal Hybrid Core (warm seclusion)

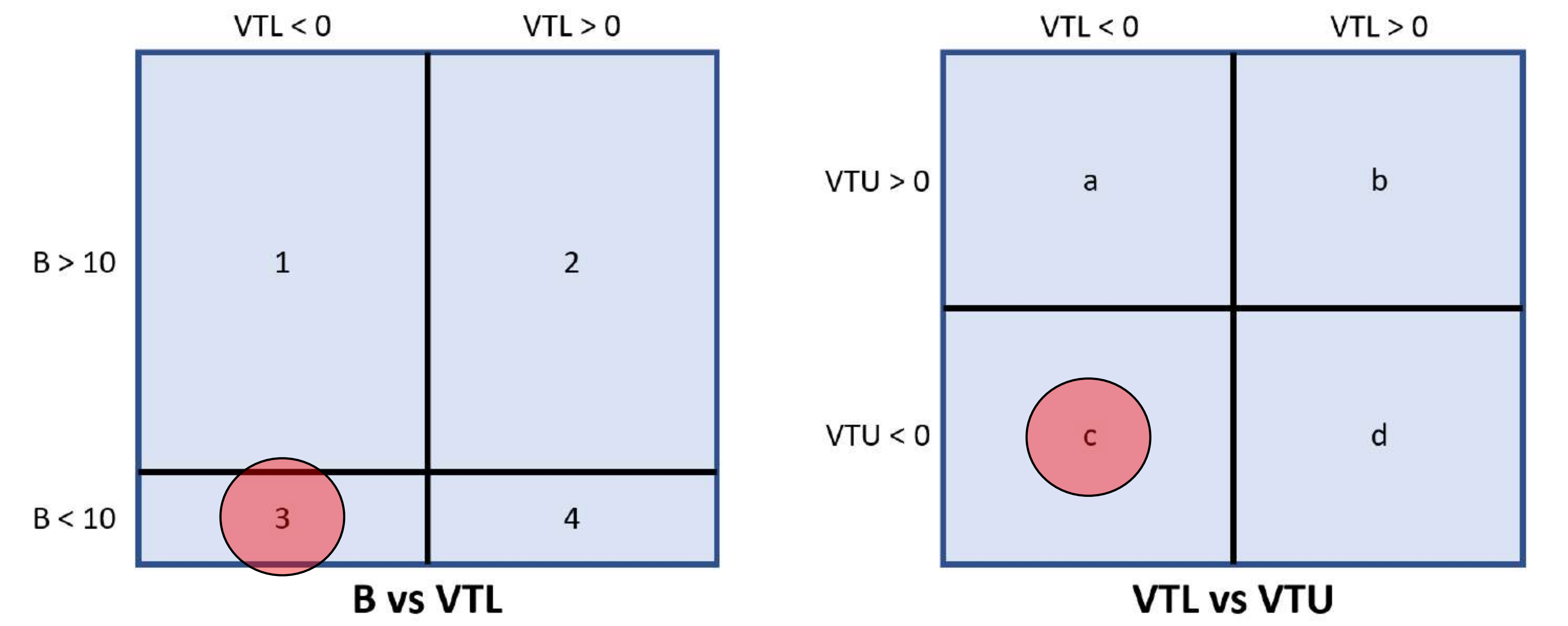


Data and Methods

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

Cyclone Phase Space:

3c Non-frontal Deep Cold Core (occluded extratropical cyclone)

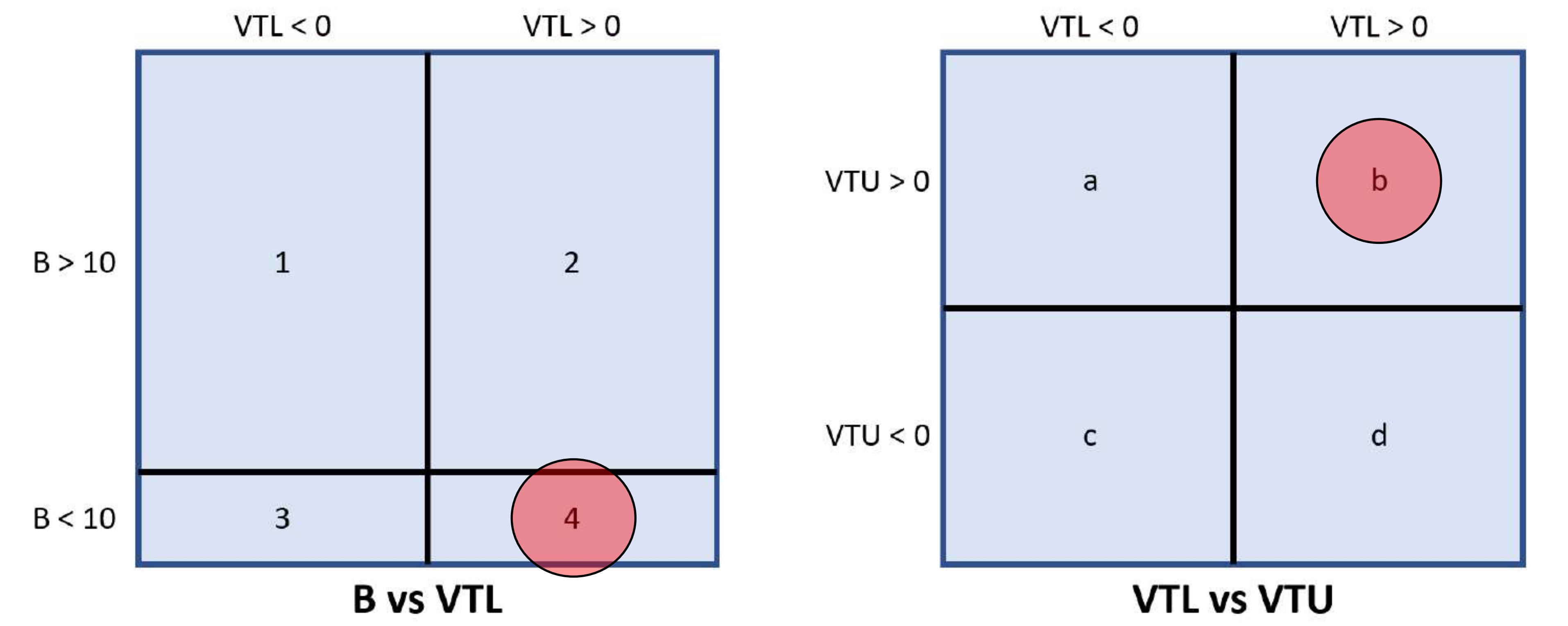


Data and Methods

Cyclone Phase Space:

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

4b Non-frontal Deep Warm Core (tropical cyclone)

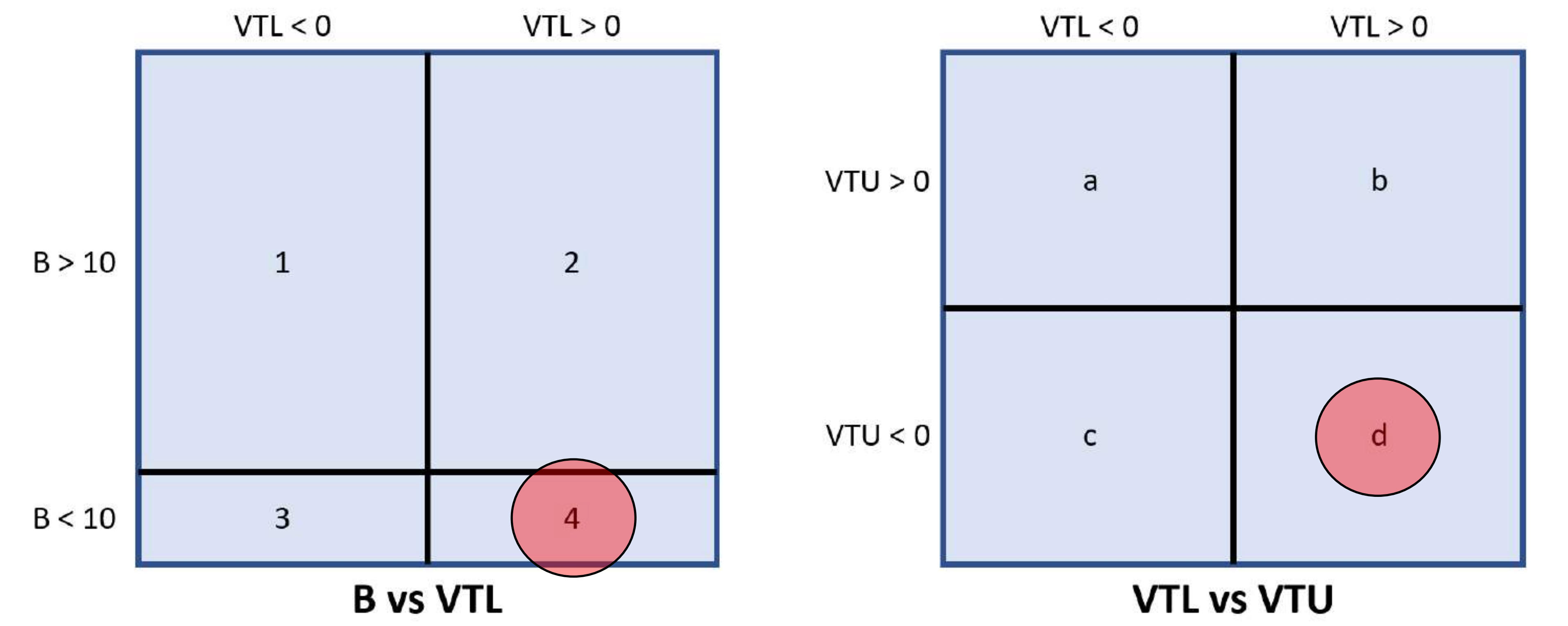


Data and Methods

1 and 2 : Frontal
3 and 4: Non-frontal
b: Deep Warm Core
c: Deep Cold Core
d: Hybrid (Shallow Warm Core)

Cyclone Phase Space:

4d Non-frontal Hybrid Core (subtropical cyclone)



Data and Methods

Principle Component Analysis:

Graf et al. (2017)

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Objective classification of extratropical cyclogenesis

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Extratropical cyclones experience vastly different genesis conditions at the first point of their tracks. A novel method is introduced to characterize this variability and classify genesis events by computing 30 diagnostic variables that describe the synoptic-scale environment of 16 029 genesis events in the Northern Hemisphere extratropics, using ERA-Interim reanalyses from 2000–2011. These variables are referred to as precursors and include parameters characterizing upper-level forcing, low-level baroclinicity, thermodynamic stability, surface fluxes and moist processes. The genesis events spread over a large portion of the 30-dimensional precursor phase space and no obvious clusters occur, which highlights the high variability of cyclogenesis processes and indicates that they form in a continuum rather than a few distinct categories. A projection of the genesis events to the first two principle components (PC) of the precursor phase space allows reduction of the dimensionality and introduction of a meaningful segmentation of the genesis events in five classes. The first two PCs are characterized by upper-level forcing (e.g. the amplitude of the upper-level potential vorticity (PV) anomaly) and low-tropospheric diabatic processes (e.g. precipitation and diabatically produced low-level PV), respectively. The first of the five classes identified constitutes the centre of the PC1–PC2 phase space and represents average conditions. Composites reveal that the four classes of events characterized by large positive or negative scores of PC1 and PC2 occur in distinct and strongly differing flow regimes, characterized by the strength of the upper-level forcing, the structure of the upper-level jet and the amplitude of low-level moist processes and baroclinicity. The four classes also have clearly differing geographical distributions. Many well-known cyclogenesis events fall within classes characterized by strong low-level moist processes with or without strong upper-level forcing. Also discussed are the robustness of the method and the linkage to classical concepts of cyclone classifications.

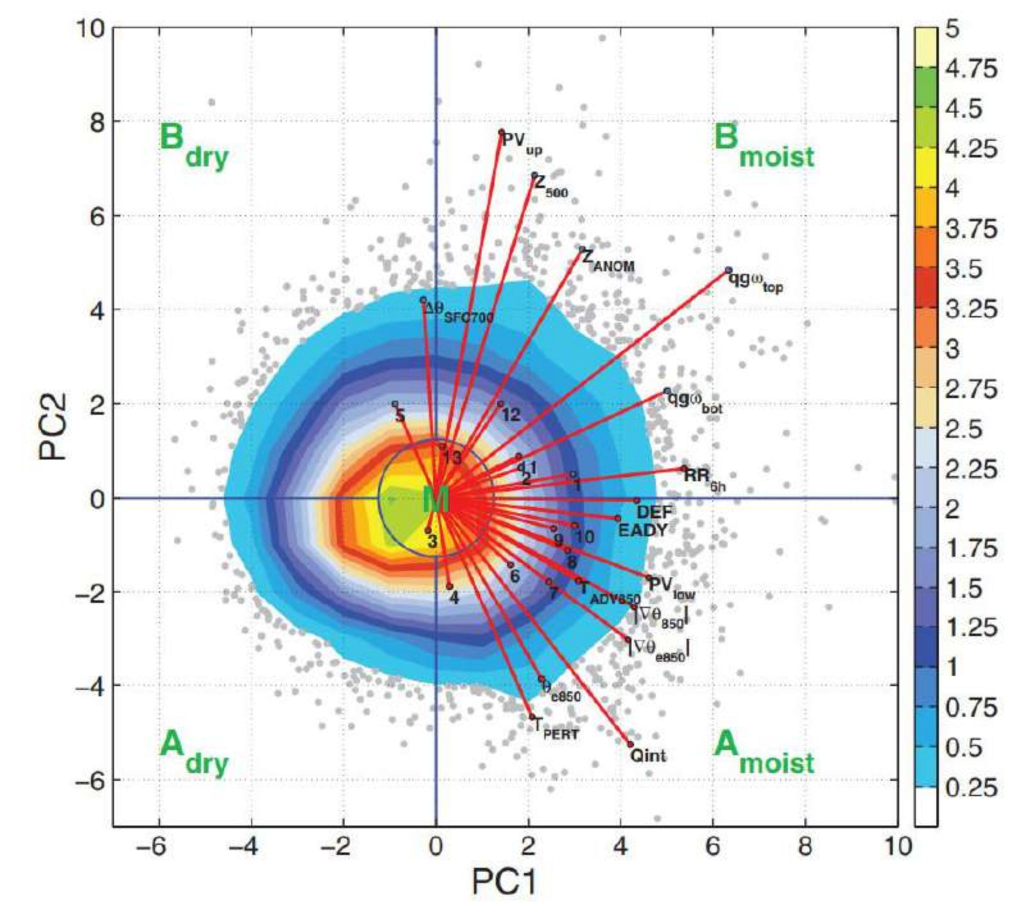
Data and Methods

Principle Component Analysis: Graf et al. (2017)

Short description of precursor	Abbrev.	Signal	Std	Mean	Skew
Upper-level PV (averaged between 600 and 200 hPa)	PV_{up}	+	**0.93** (5)	0.73	0.60
Geopotential height at 500 hPa	Z_{500}	−	0.90	−0.63	−0.03
Anomaly of geopotential height at 500 hPa	Z_{ANOM}	−	**0.94** (4)	−0.78	−0.66
Low-level contribution to QG vertical motion	$qg\omega_{bot}$	−	0.85	−**1.34** (2)	−1.21
Upper-level contribution to QG vertical motion	$qg\omega_{top}$	−	**1.07** (3)	−**1.37** (1)	−1.24
Wind speed averaged between 500 and 100 hPa	$VELJET$	+	0.88	0.57	0.44
Tropospheric static stability	N^2_{TROPO}	−	0.72	−0.82	0.11
Difference of pot. temperature between surface and 700 hPa	$\Delta\theta_{SFC700}$	−	0.74	−0.66	0.24
Mixed-layer CAPE	$CAPE$	+	**1.08** (2)	0.45	**4.42** (2)
Eady growth rate in lower troposphere	$EADY$	+	0.83	0.94	0.36
Eady growth rate in upper troposphere	$EADY_{up}$	+	0.78	0.64	0.51
Horizontal temperature gradient at 850 hPa	$\lvert\nabla\theta_{850}\rvert$	+	0.81	**1.08** (5)	0.55
Horizontal temperature advection at 850 hPa	T_{ADV850}	+	0.64	0.86	**1.32** (5)
Equivalent potential temperature at 850 hPa	θ_{e850}	+	0.76	0.86	−0.13
Horizontal gradient of equivalent pot. temperature at 850 hPa	$\lvert\nabla\theta_{e850}\rvert$	+	0.76	1.03	0.62
Environmental deformation at 850 hPa	DEF	+	0.84	**1.09** (4)	0.86
Petterssen frontogenesis function at 850 hPa	$FGEN_{850}$	+	0.87	1.02	**1.86** (3)
Anomaly of the 850 hPa temperature	T_{PERT}	+	0.81	0.88	0.13
Low-level PV (averaged between 1000 and 600 hPa)	PV_{low}	+	**0.93** (5)	0.99	0.19
Vertically integrated water vapour	$Qint$	+	0.92	0.98	0.37
Surface precipitation during 6 h before cyclogenesis	RR_{6h}	+	**1.53** (1)	**1.33** (3)	**1.64** (4)
Time period since moisture uptake	$UPTTIM$	+	0.52	0.66	−0.12
Difference of pot. temperature in 48 h back. trajectories	$TRAd\theta_{48}$	+	0.63	0.92	0.71
Pressure difference in 48 h back. trajectories	$TRAdP_{48}$	−	0.46	−0.99	0.95
Maximum change of pot. temperature in 48 h back. trajectories	$TRAd\theta_{MX}$	+	0.53	0.99	0.39
Maximum pressure difference in 48 h back. trajectories	$TRAdP_{MX}$	−	0.55	−1.06	0.43
Sensible heat flux at surface	$SSHF$	+	0.66	0.60	−0.17
Latent heat flux at surface	$SLHF$	+	0.58	0.62	−0.23
Skin temperature	SKT	+	0.78	0.54	−**4.68** (1)

Data and Methods

Principle Component Analysis: Graf et al. (2017)



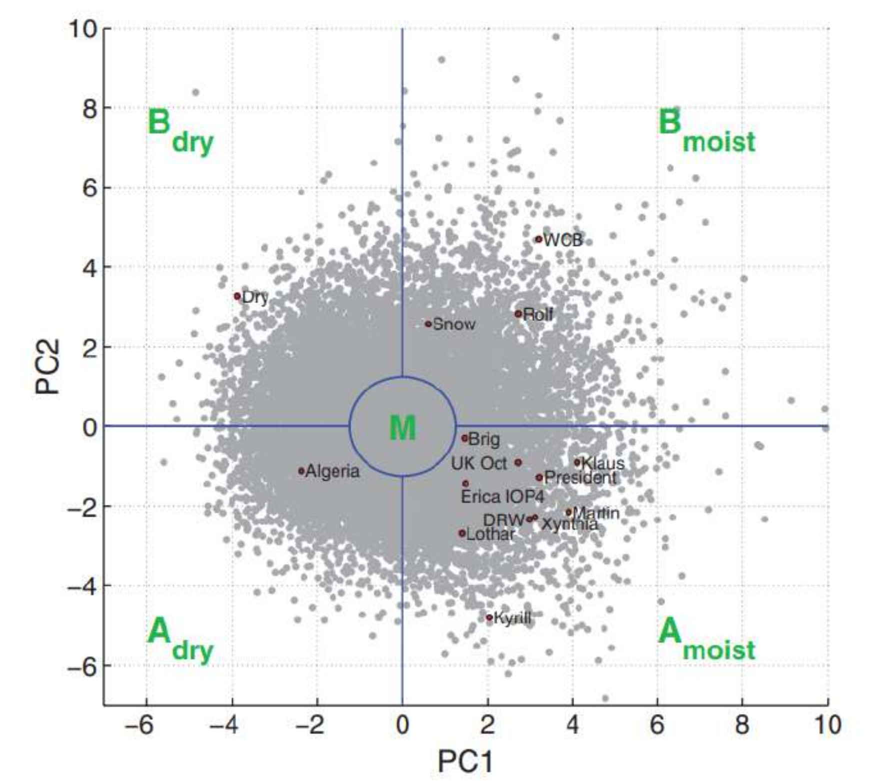
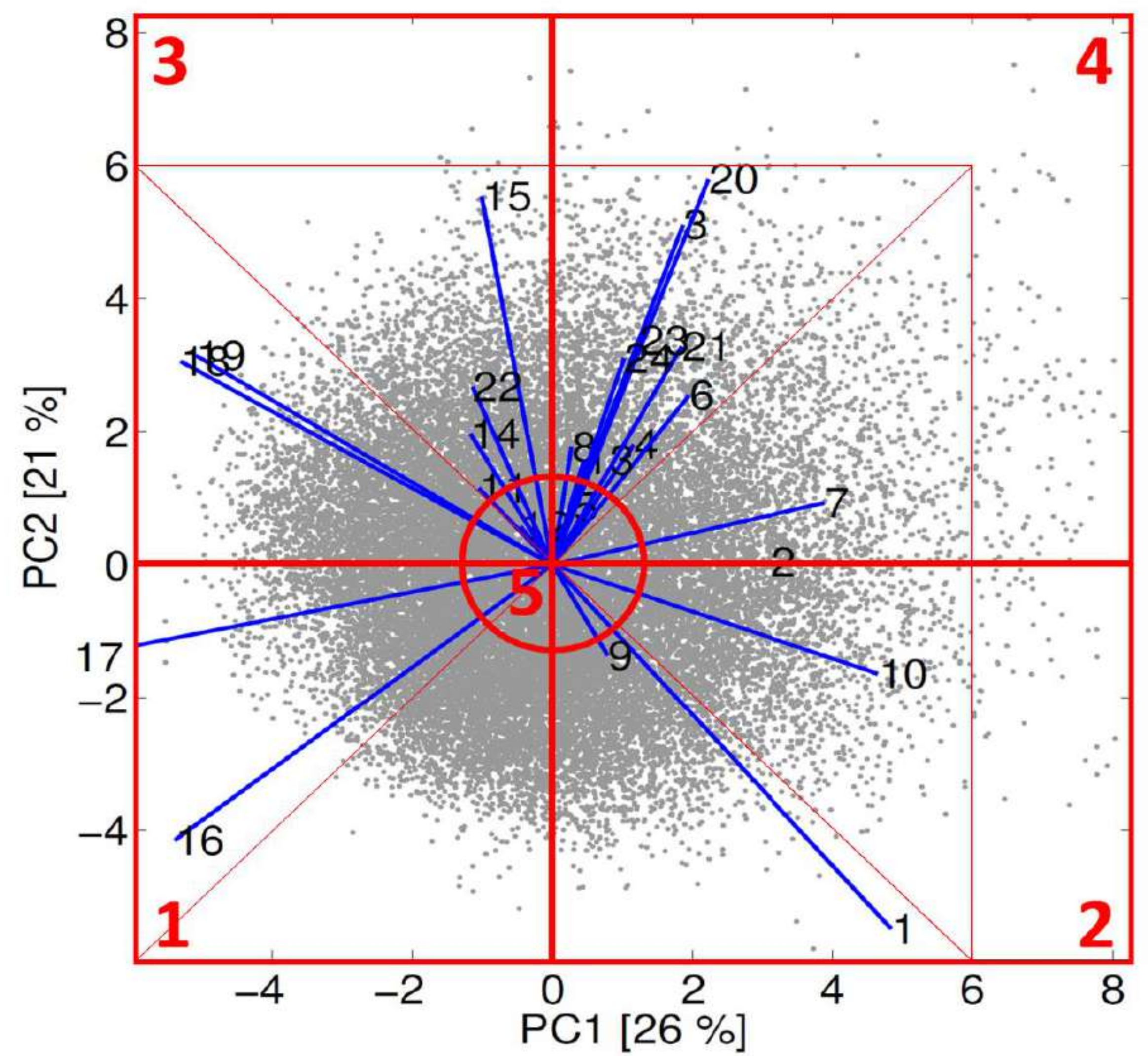


Figure 12. Biplot with selected cyclogenesis cases listed in Table 2 (red dots). The grey dots represent the scores of all cyclogenesis events. The blue solid lines define the class borders of the classification (as in Figure 4).

Results

PCA results:

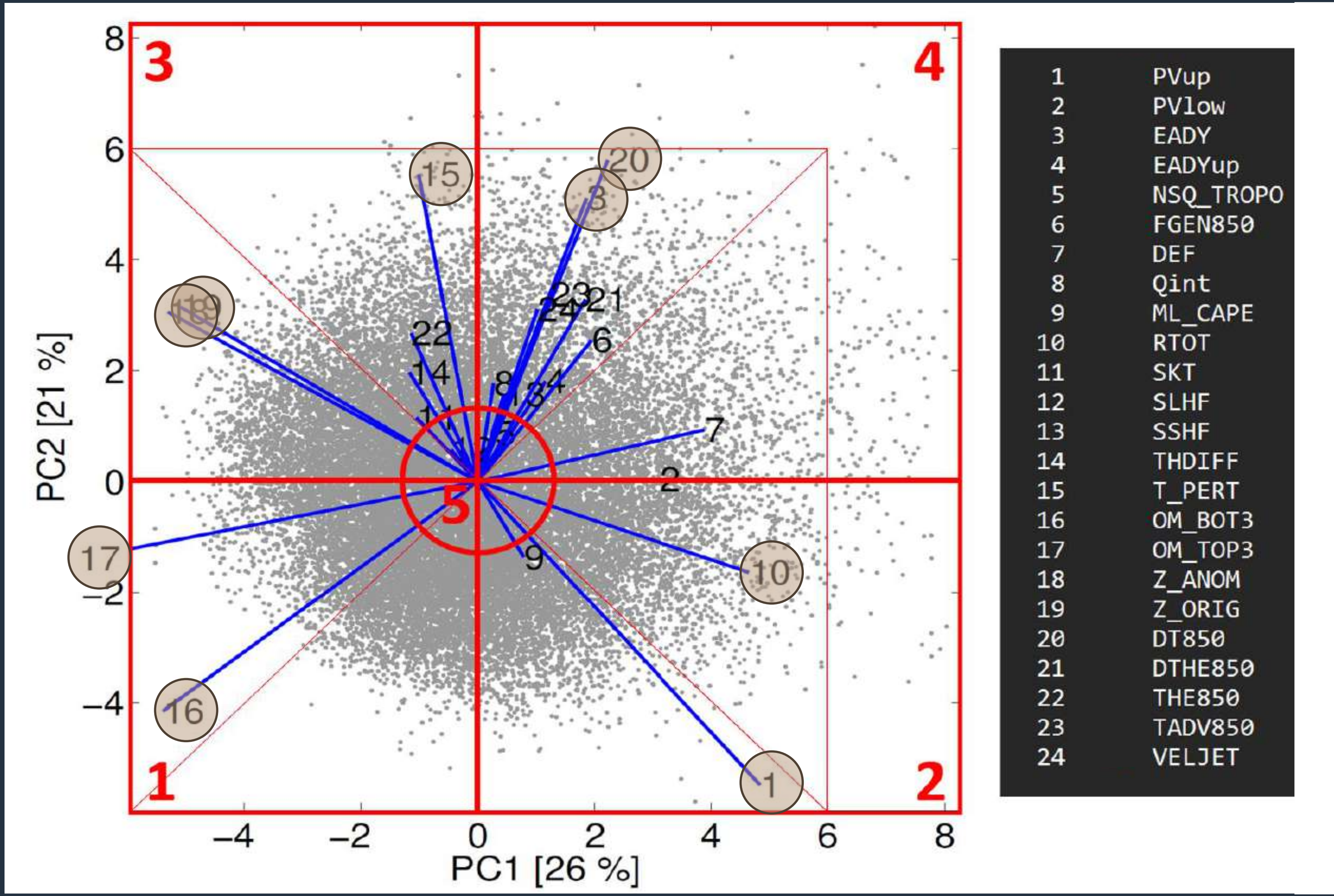


1	PVup
2	PVlow
3	EADY
4	EADYup
5	NSQ_TROPO
6	FGEN850
7	DEF
8	Qint
9	ML_CAPE
10	RTOT
11	SKT
12	SLHF
13	SSHF
14	THDIFF
15	T_PERT
16	OM_BOT3
17	OM_TOP3
18	Z_ANOM
19	Z_ORIG
20	DT850
21	DTHE850
22	THE850
23	TADV850
24	VELJET

Results

PCA results:

PC2: low-level, baroclinicity



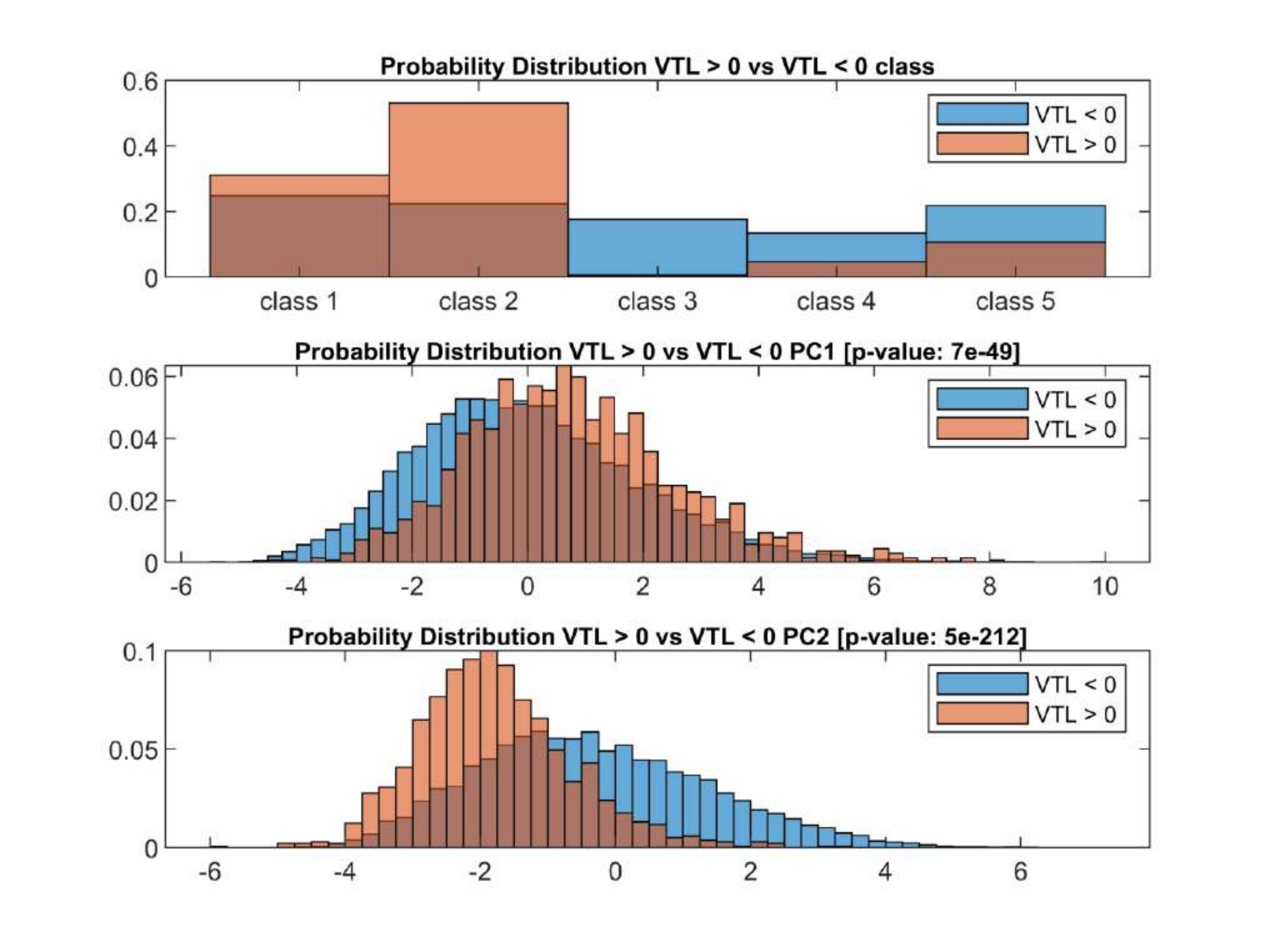
PC1: upper-level, QG omega

Results

Here we show the main results for specific initial questions that we initially wanted to address, but some other interesting results have been obtained and more are needed to be explored.

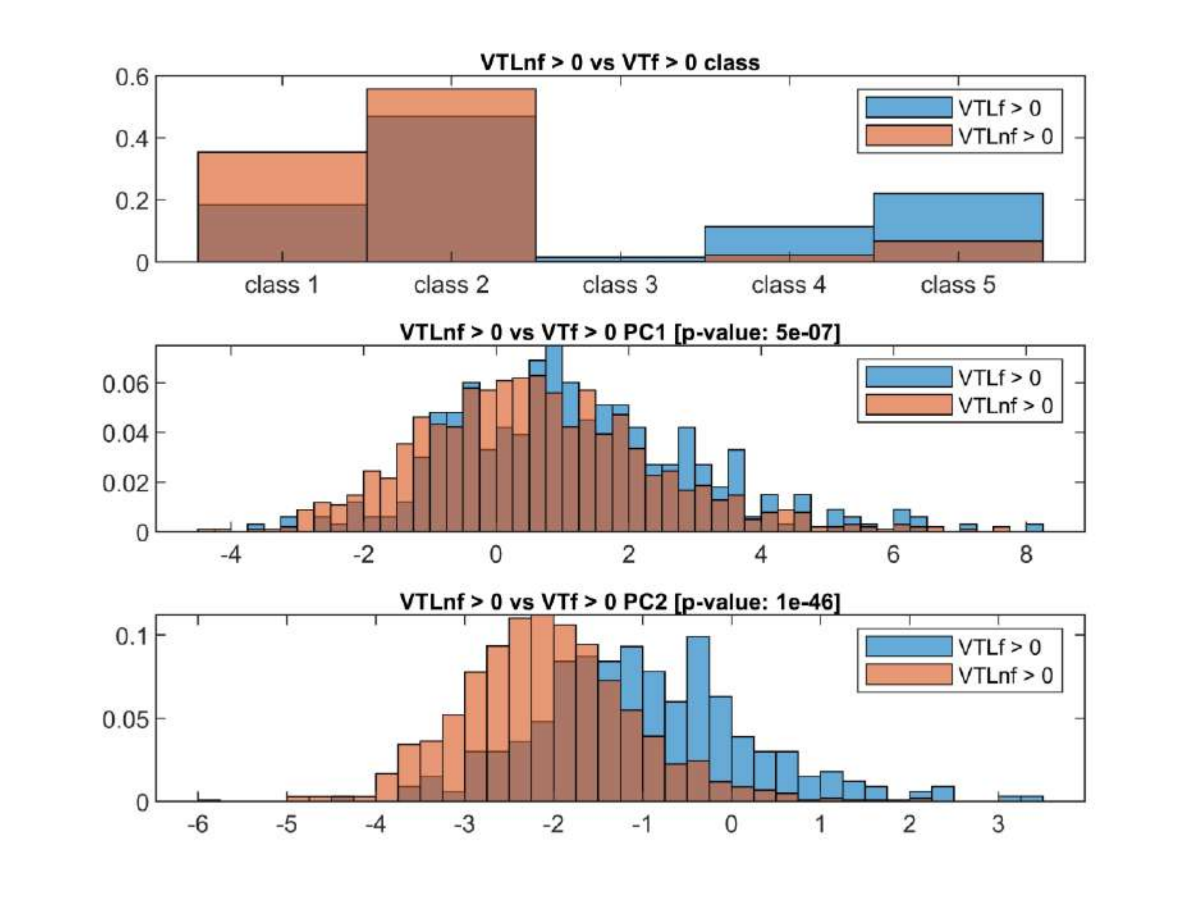
Results

Are CPS parameters related to PCA components?



Results

Can PCA components be used to physically distinguish between similar cyclones in the CPS (e.g., warm seclusions vs STCs/TCs)?

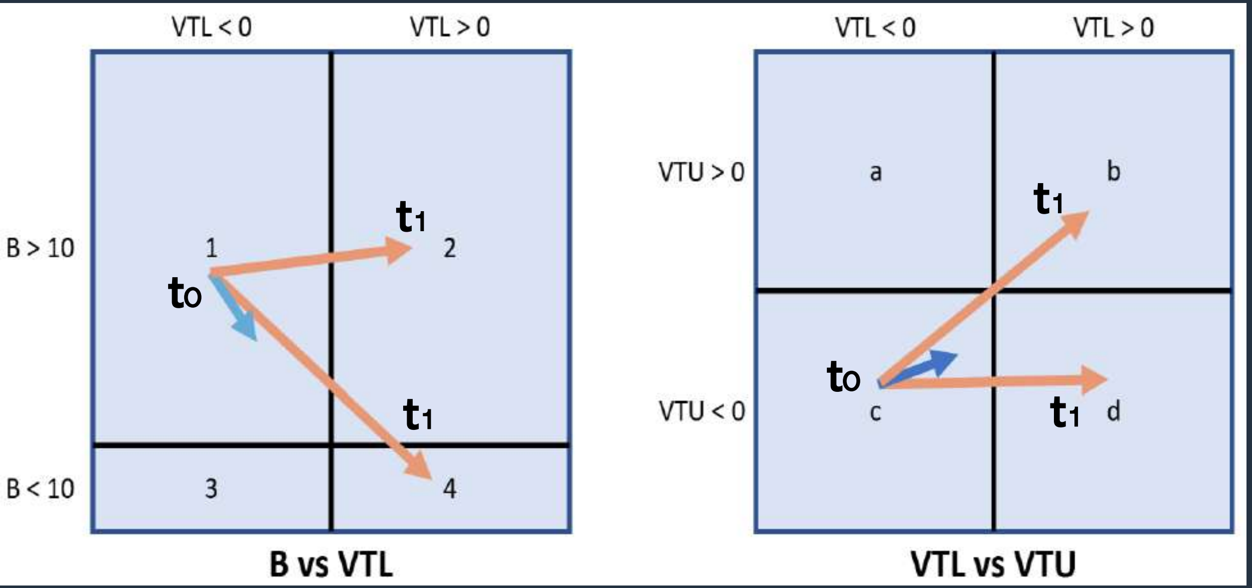


Warm seclusions:
VTLf > 0: Frontal shallow warm core

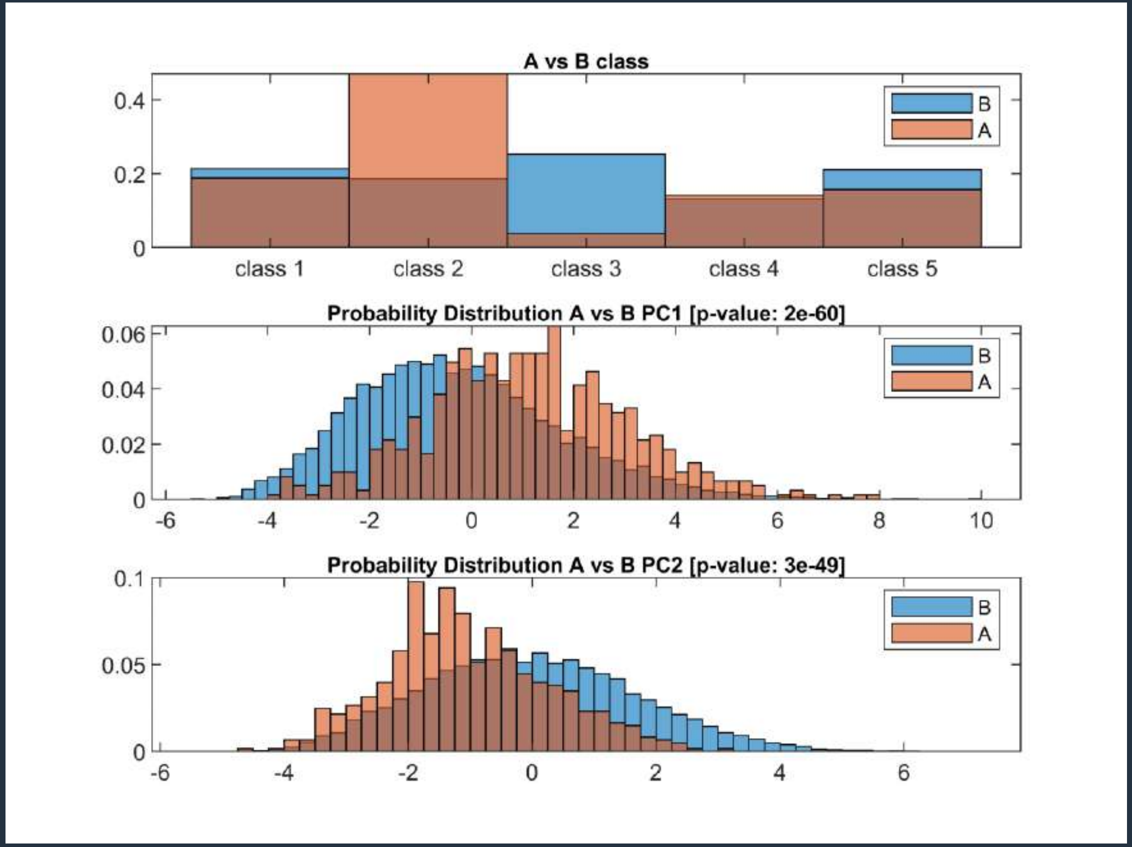
STCs:
VTLnf > 0: Non-frontal shallow warm core

Results

Can PCA parameters be used to help to physically interpret CPS transformations [t_0 --> t_1] ?

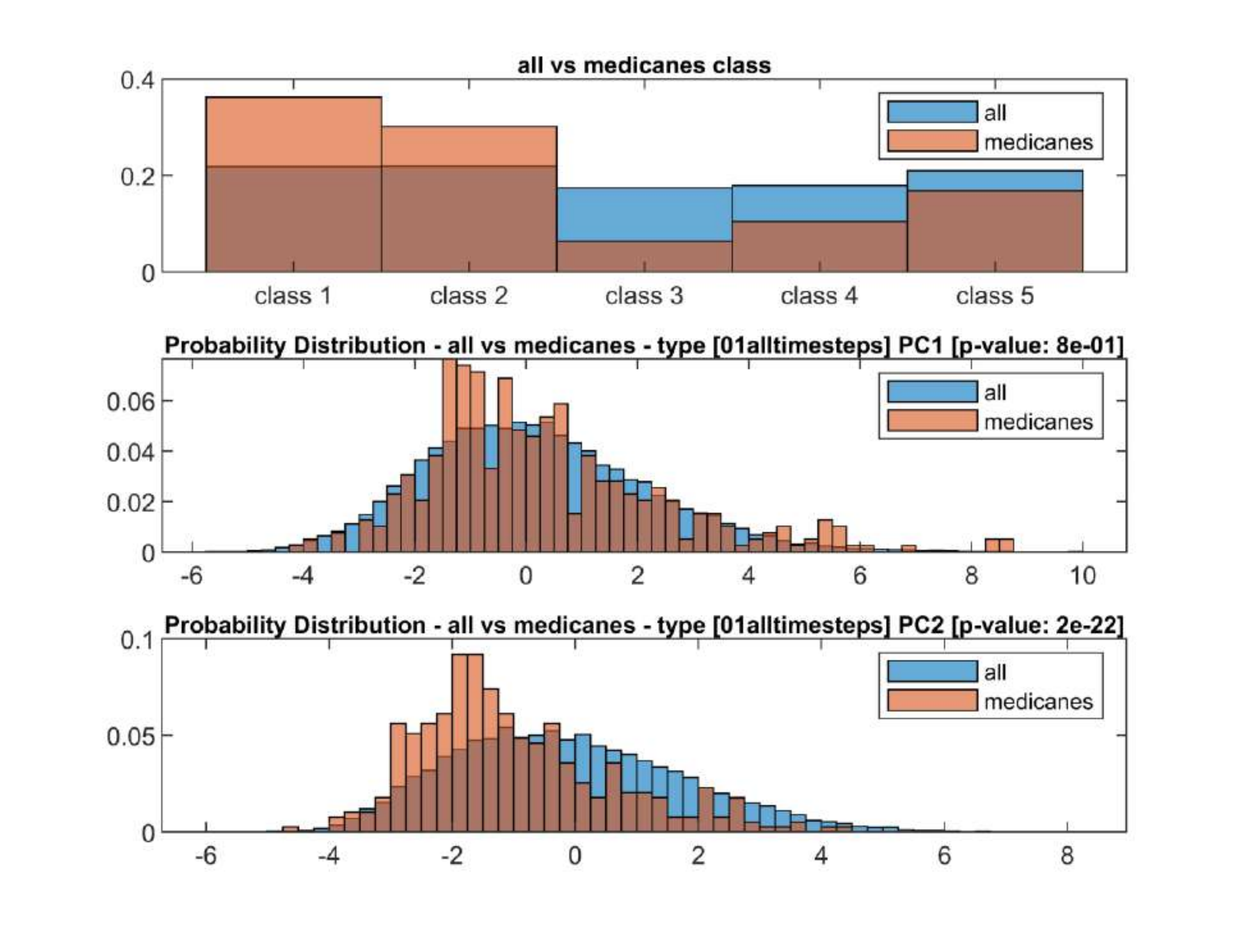


t_0



Results

Can PCA components be used to complement CPS and better classify Mediterranean tropical-like cyclones?



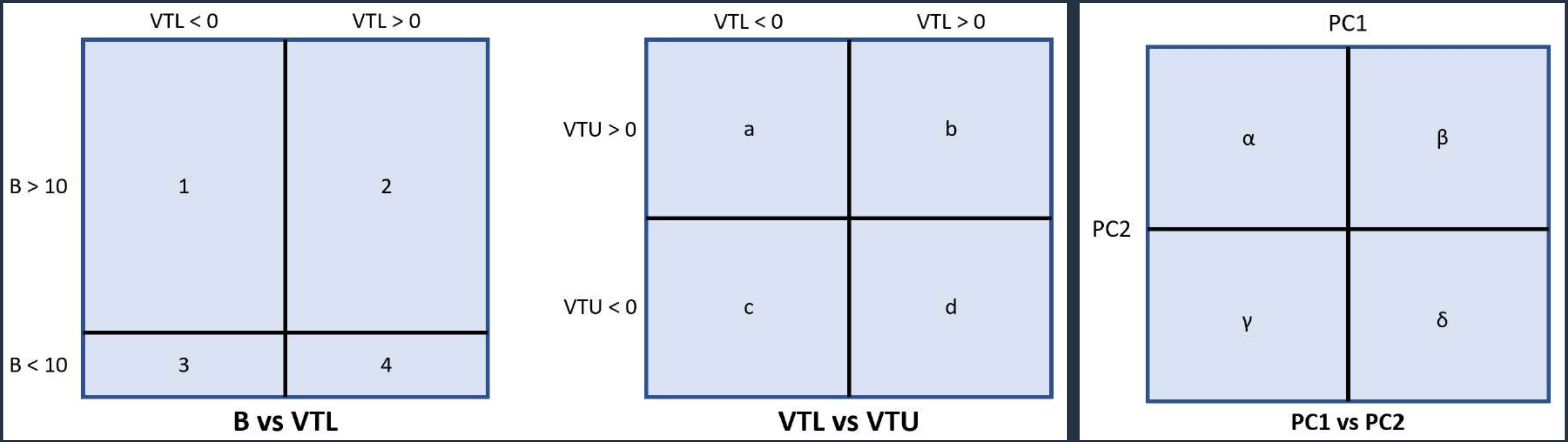
Conclusions

- CPS parameters **can** be related to PCA components.
- PCA parameters **can** be used to help to physically interpret CPS transformations.
- PCA **can** be used to physically distinguish between similar cyclones in the CPS (e.g., warm seclusions vs STCs/TCs)
- PCA components **could** be used to complement CPS and better classify Mediterranean tropical-like cyclones.
- Overall, PCA components merged with CPS **could** potentially contribute to better cyclone classification over the Mediterranean Sea and better explain their structure.

Future work

- Further work is needed, but potential future 5D phase space:

B, VTL, VTU, PC1, PC2 (1-4; a-d; α-δ):



Future work

- Move to ERA-5
- An operational tool to identify potential cyclone types transformation/cyclogenesis
- A research tool to effectively distinguish between cyclone types and respond questions on the environments/dynamics favouring development types
- Try to incorporate/improve with new potential parameters (*see Poster 8 in Poster Session 1*)
- Focus on cyclones with similar representation in the CPS

THANKS FOR YOUR ATTENTION!

QUESTIONS?

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