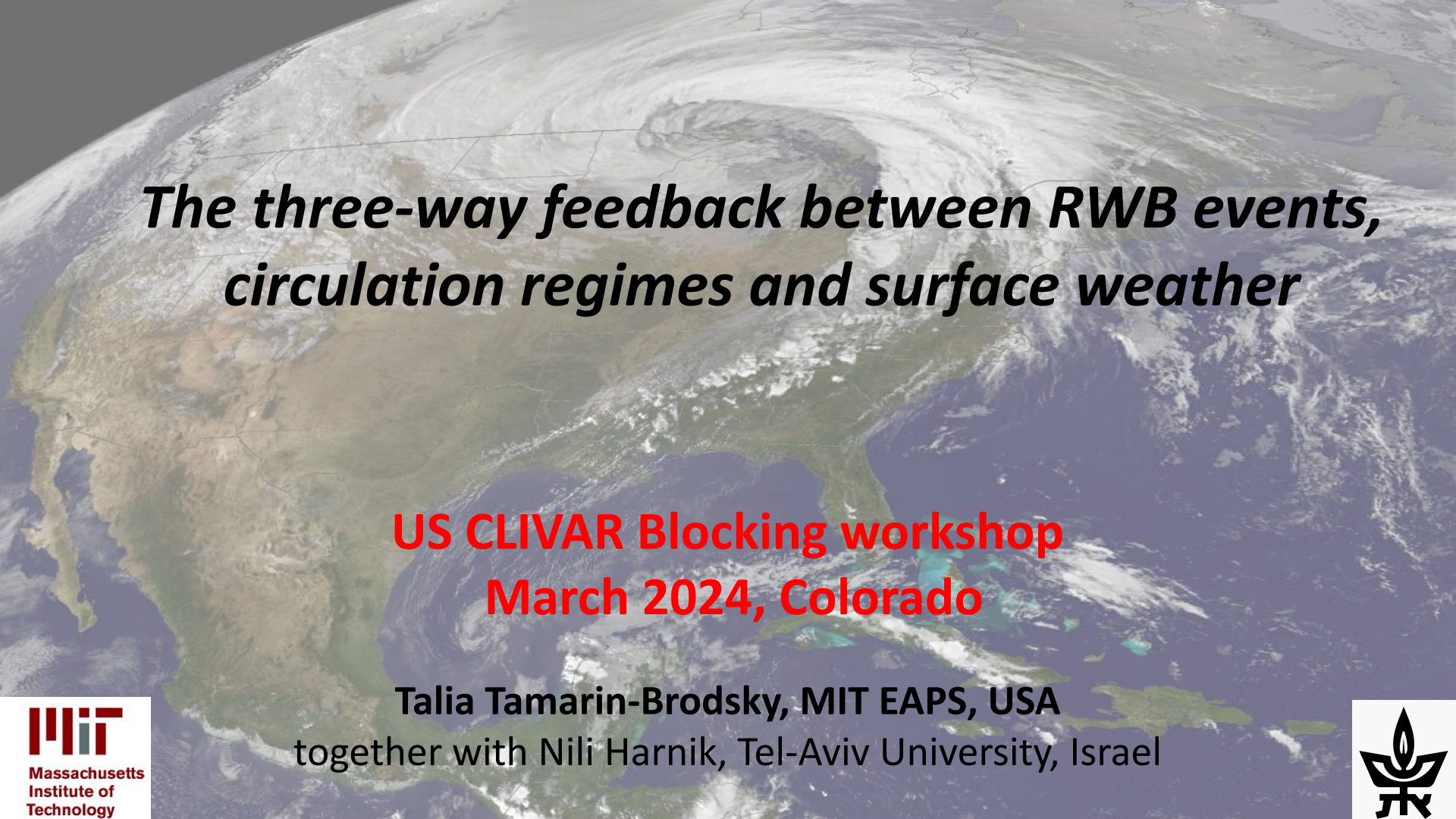


# *The three-way feedback between RWB events, circulation regimes and surface weather*

**US CLIVAR Blocking workshop**
**March 2024, Colorado**

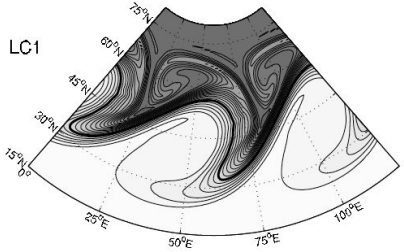
**Talia Tamarin-Brodsky, MIT EAPS, USA**
together with Nili Harnik, Tel-Aviv University, Israel

Massachusetts Institute of Technology

# Rossby Wave Breaking

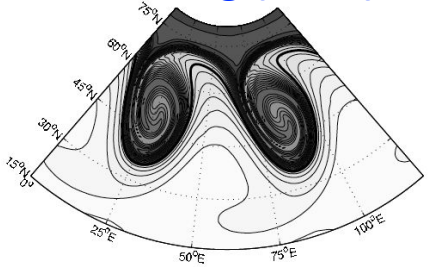
*Thorncroft et al. (1993): Two types RWB appearing at the end of baroclinic wave life cycles- LC1 (AWB) and LC2 (CWB)*

***Anticyclonic Wave Breaking (AWB)***




*southwest–northeast tilt*

***Cyclonic Wave Breaking (CWB)***




*southeast–northwest tilt*

*Polvani and Esler (2017)*

*In both cases, a reversal of the PV gradient- the ridge (block) is poleward of the trough*

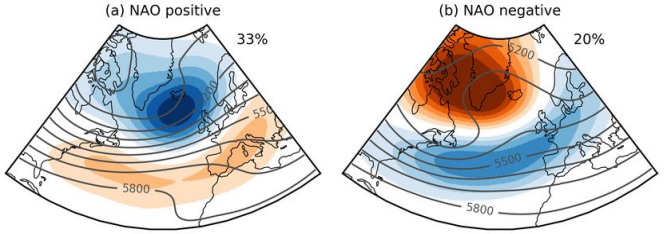
***Rossby Wave Breaking events are are closely related to Blocking events***

# RWB and weather regimes

RWB are more generally related to weather regimes, which are persistent and slowly varying states of the large-scale atmospheric circulation-

For example, previous studies suggested that-

- Positive NAO is associated with AWB □ a more tilted and northward jet regime
- Negative NAO is associated with CWBs□ a more zonal and southward jet regime



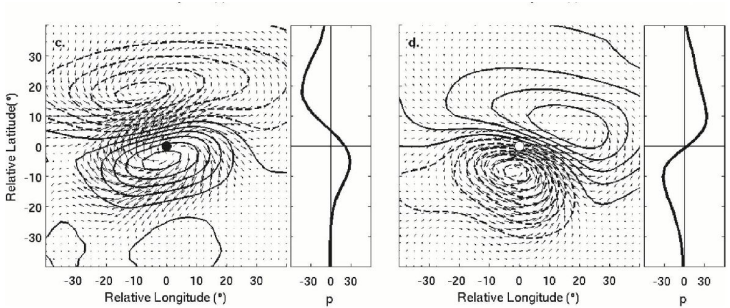

e.g., Woollings et al. 2007, Benedict et al. 2009, Franzke et al. 2011

Similarly, composites of SLP anomalies during AWB/CWB-

***AWB- Low/High SLP dipole***
***CWB- High/Low SLP dipole***

Strong and Magnusdottir, 2008

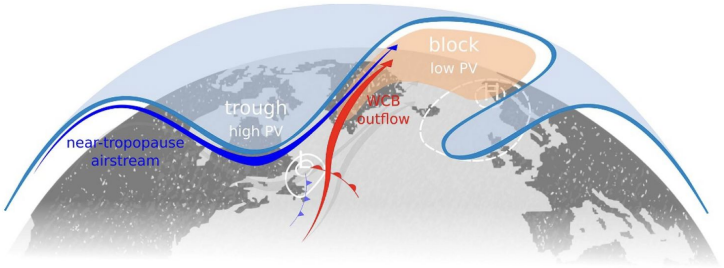
AWB CWB



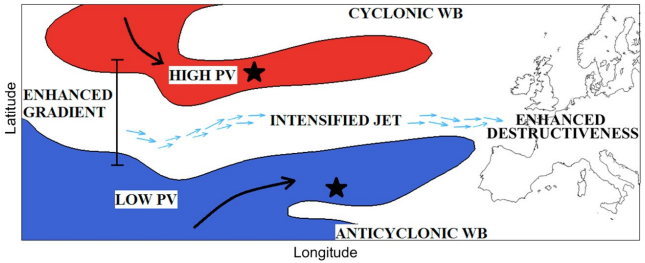
# RWB and weather systems

- Strong cyclones can, through latent heat release in the warm conveyer belt, significantly contribute to the downstream upper-level ridge/block, often terminating in wave breaking event (Steinfeld and Pfahl 2019, Grams et al. 2011, Steinfeld et al. 2022…)

Steinfeld et al. 2022,
Environ. Res. Lett.




- Wave breaking and/or circulation regimes influence the cyclone's track and intensity (e.g., Messori and Caballero 2015)



# Key questions

**What is the (three-way) interaction between the low-frequency flow (regimes), RWBs, and the surface weather systems?**

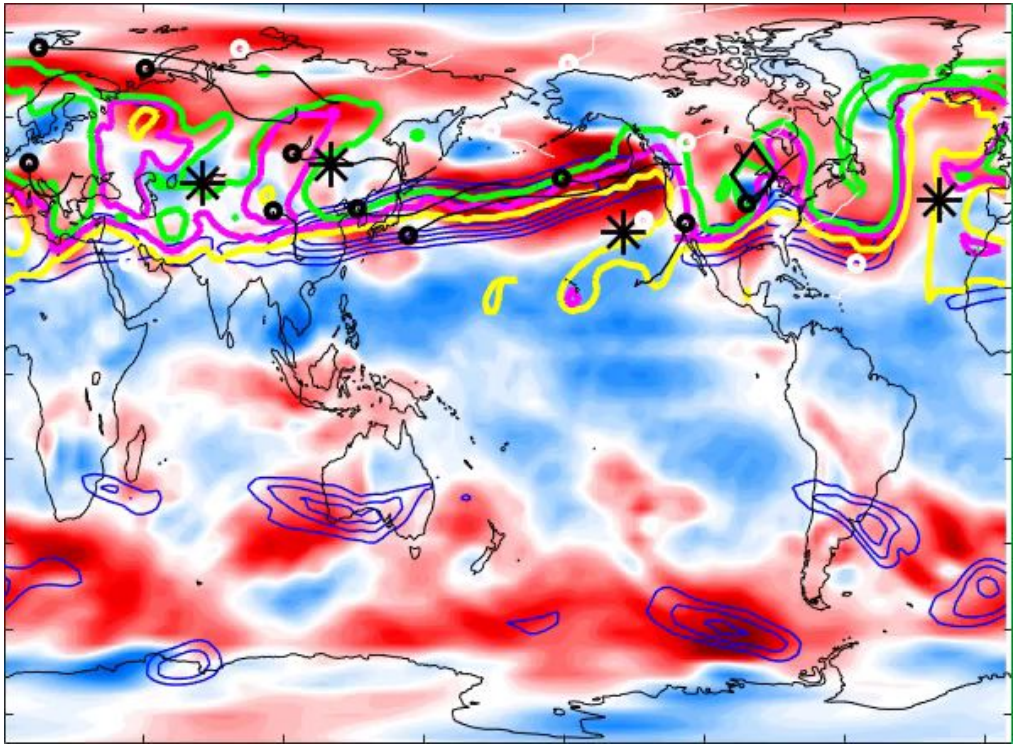
- ***What is the relation between the RWB events and surface weather systems?***
- ***How do slowly varying weather regimes influence this interaction?***
- ***How does that feed back to shape the slowly varying weather regime?***

# Identifying RWBs, weather systems & weather regimes

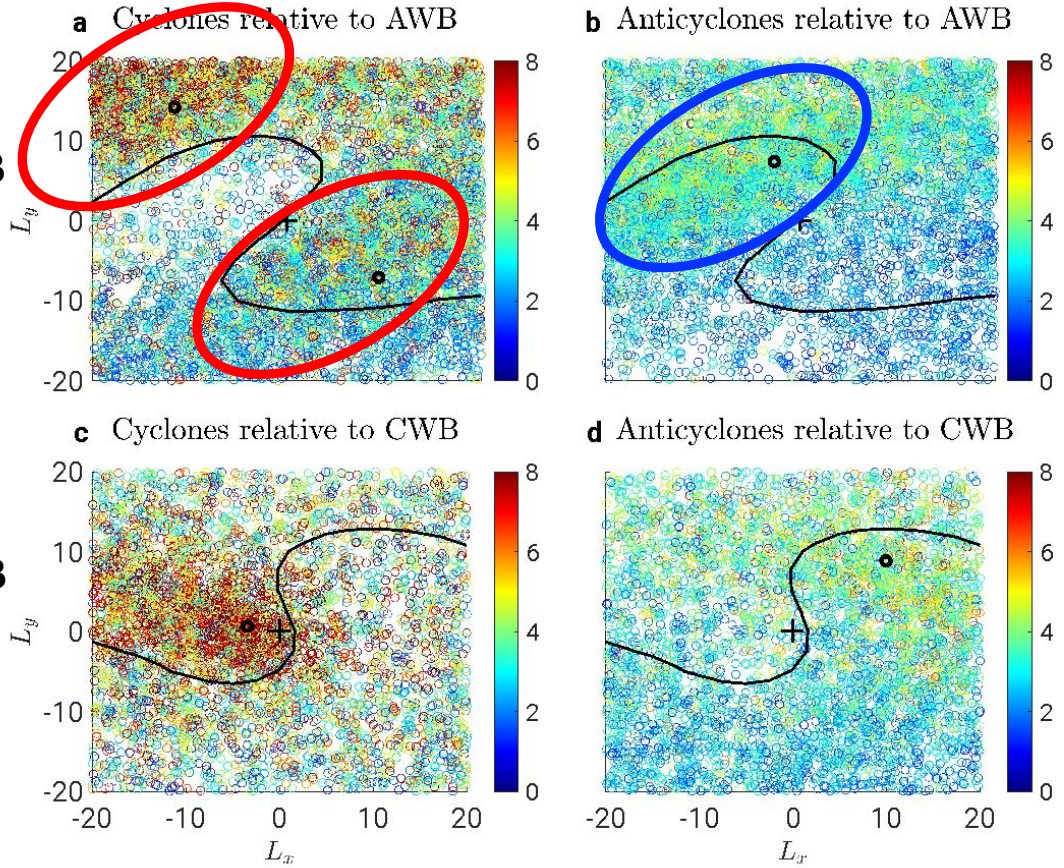
***We combine:***

- RWB detection algorithm, based an overturning of 250hPa PV
- A storm-tracking algorithm (TRACK)- based on 850 hPa vorticity field
- A k-means clustering technique (500hPa geopotential anomalies) for weather regimes in the North Atlantic

ERAI reanalysis data (DJF)



# Cyclones and Anticyclones relative to wave breaking



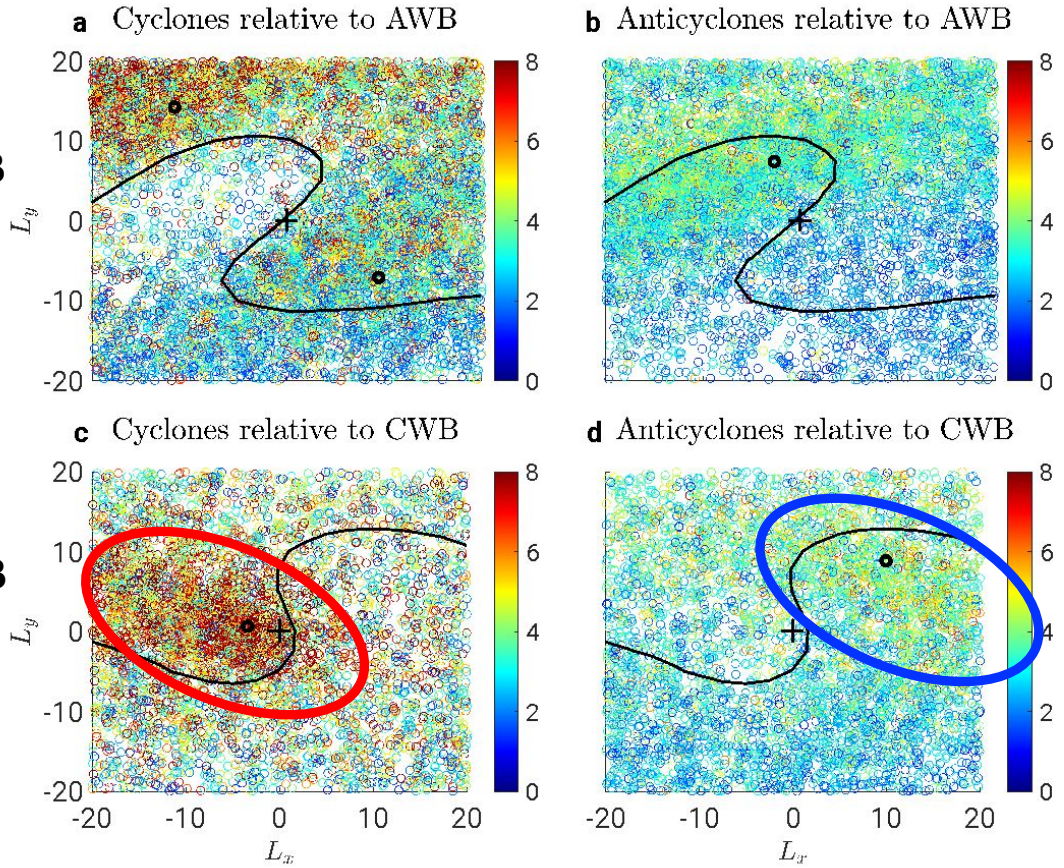

**AWB: two cyclones and one anticyclone between them. The cyclones to the NW of the anticyclones are stronger**

*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Cyclones and Anticyclones relative to wave breaking

**AWB**

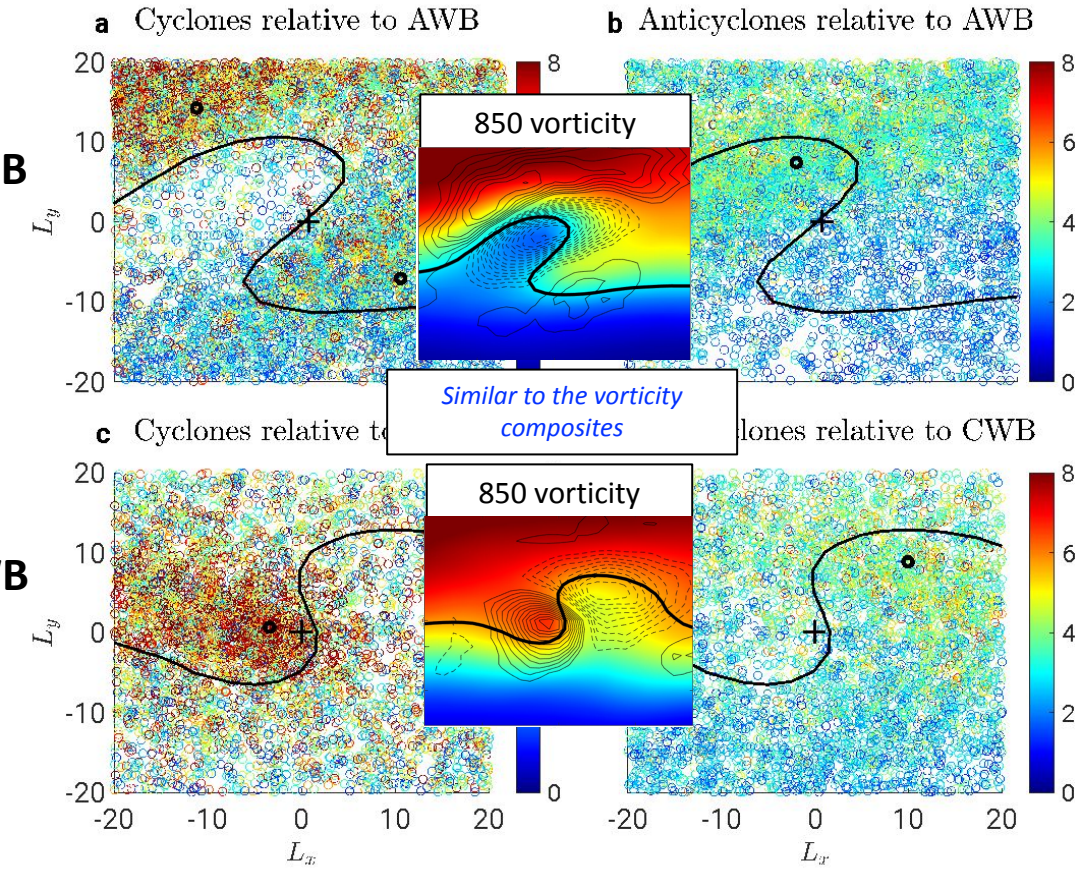
**CWB**




**CWB: one cyclone close to the breaking center and one anticyclone to its NE**

*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Cyclones and Anticyclones relative to wave breaking



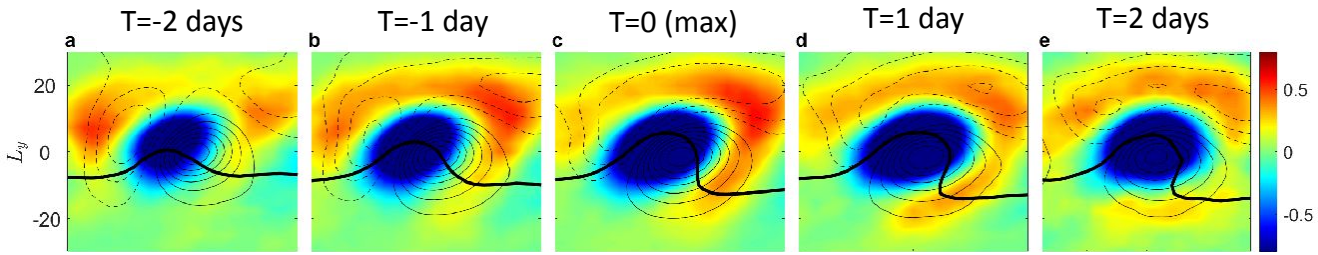

**AWB: two cyclones and one anticyclone between them. The cyclones to the NW of the anticyclones are stronger**

**CWB: one cyclone close to the breaking center and one anticyclone to its NE**

*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Anticyclones during AWB

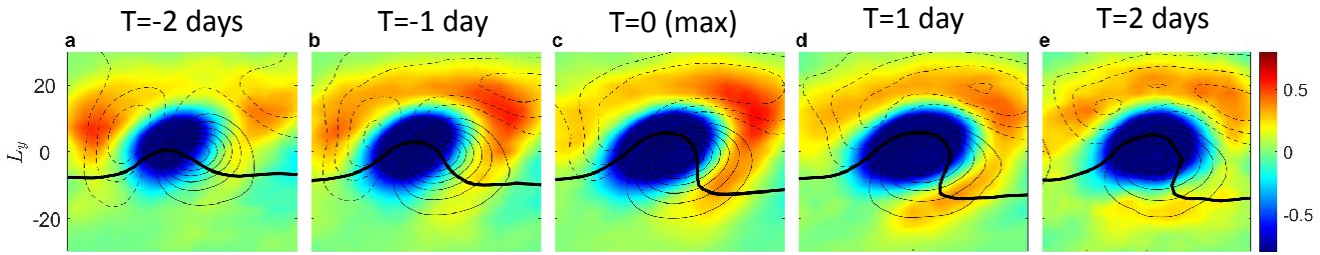
UPV anom
& SLP anom

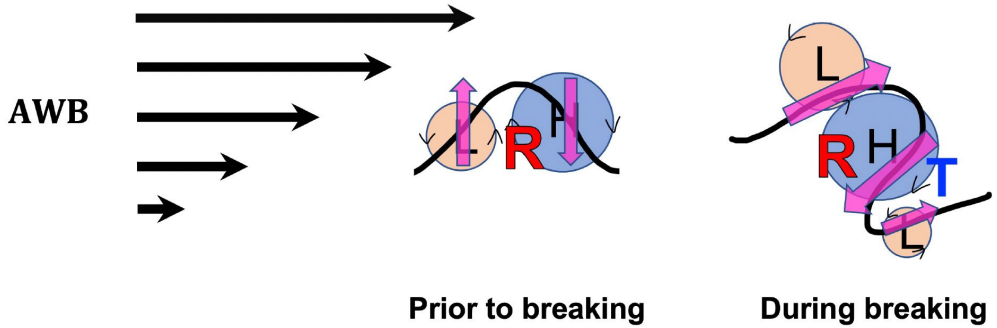



*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Anticyclones during AWB

UPV anom
& SLP anom



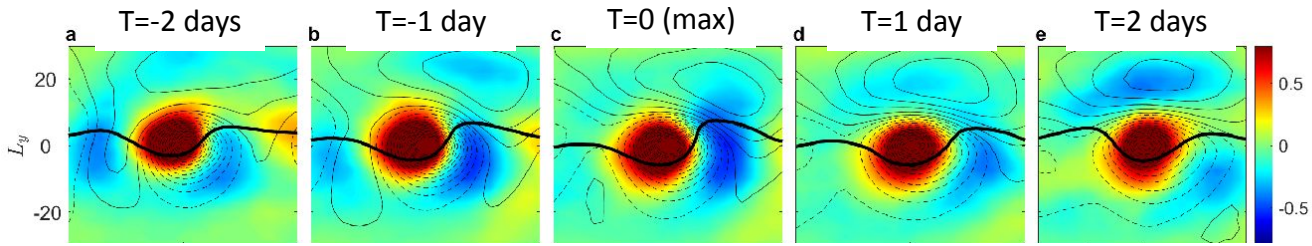




- *An anticyclone with a cyclone to its west in an anticyclonic shear*
- *Relative anticyclonic rotation*

*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Cyclones during CWB

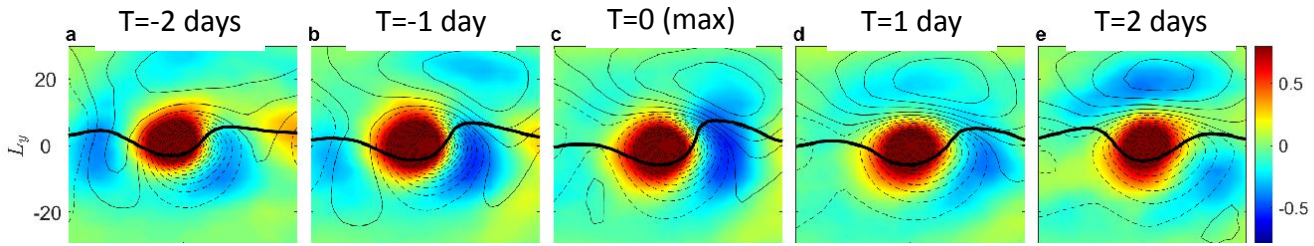
UPV anom
& SLP anom

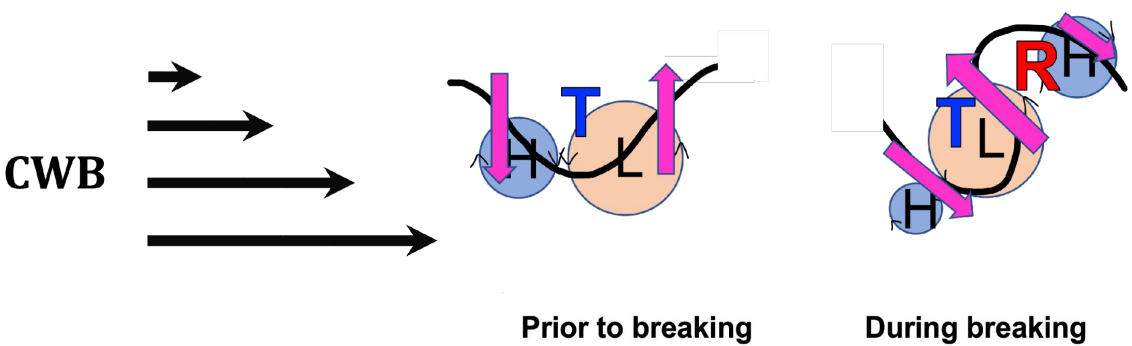



*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Cyclones during CWB

UPV anom
& SLP anom



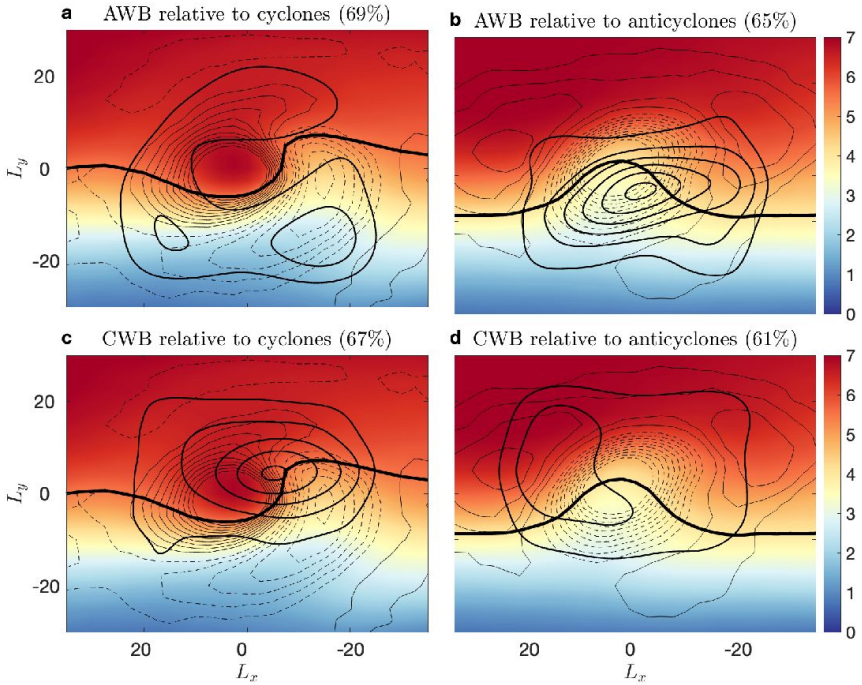




- *A cyclone with an anticyclone to its west in a cyclonic shear*
- *A relative cyclonic rotation*

*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# Composites over all cyclones & anticyclone in the NA

*Only few storms do not involve RWB during their lifetime (~ 15%)*




***Cyclones and CWB & anticyclones and AWB are more collocated, but all different pairing occur in similar frequencies***

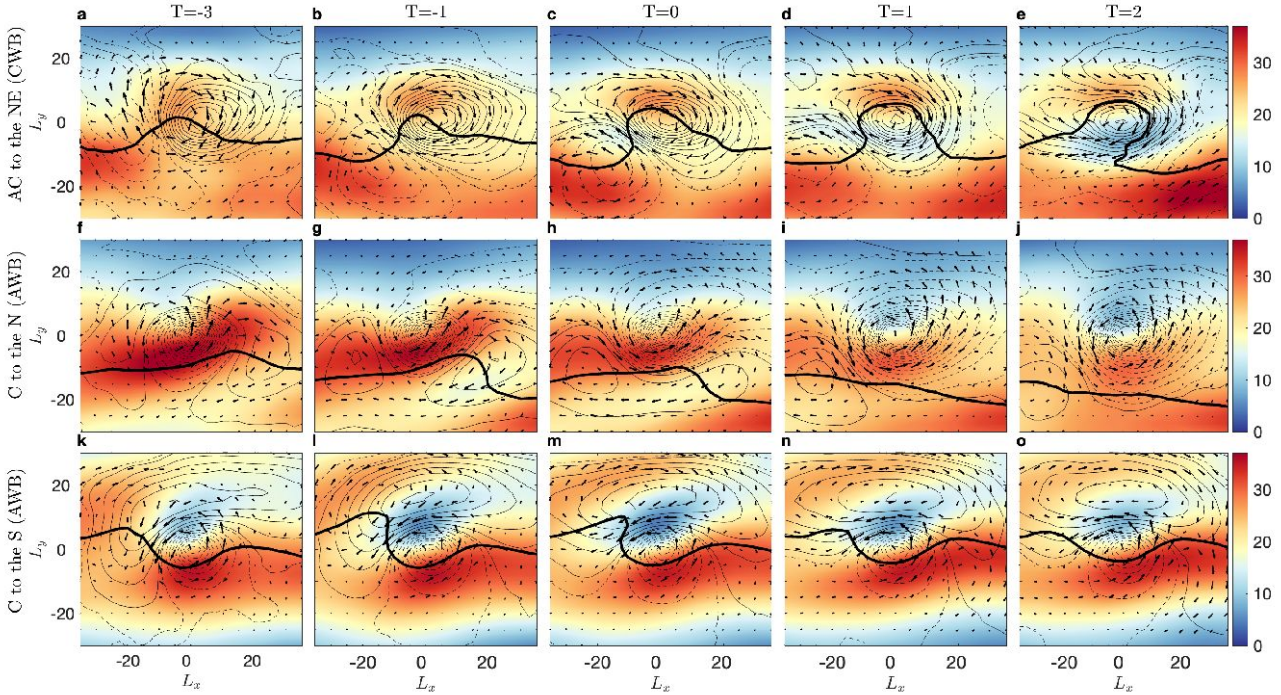
*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# “Opposite-sense” breaking and weather system type

**Anticyclones during CWB**

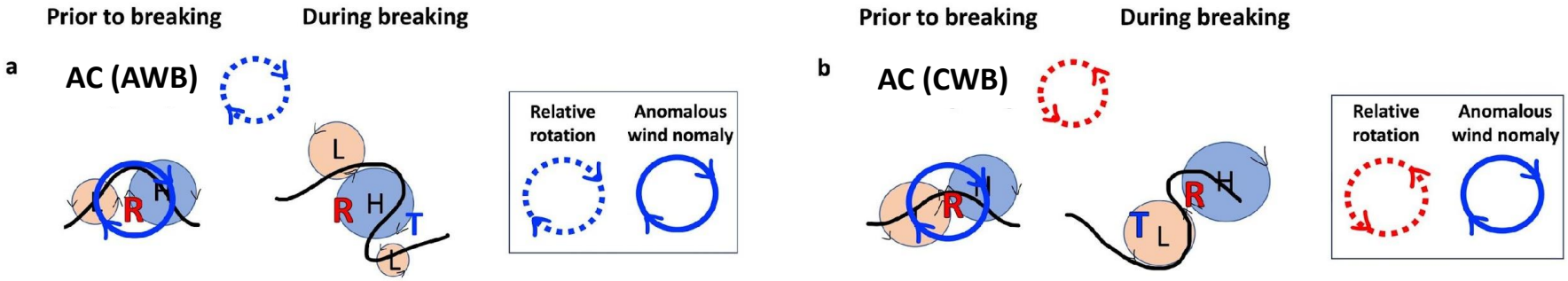
**Cyclones during AWB (NW)**

**Cyclones during AWB (SE)**




*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

# The life cycle of real-atmosphere weather system in different RWB types




*T. Tamarin-Brodsky and N. Harnik, WCD (2024)*

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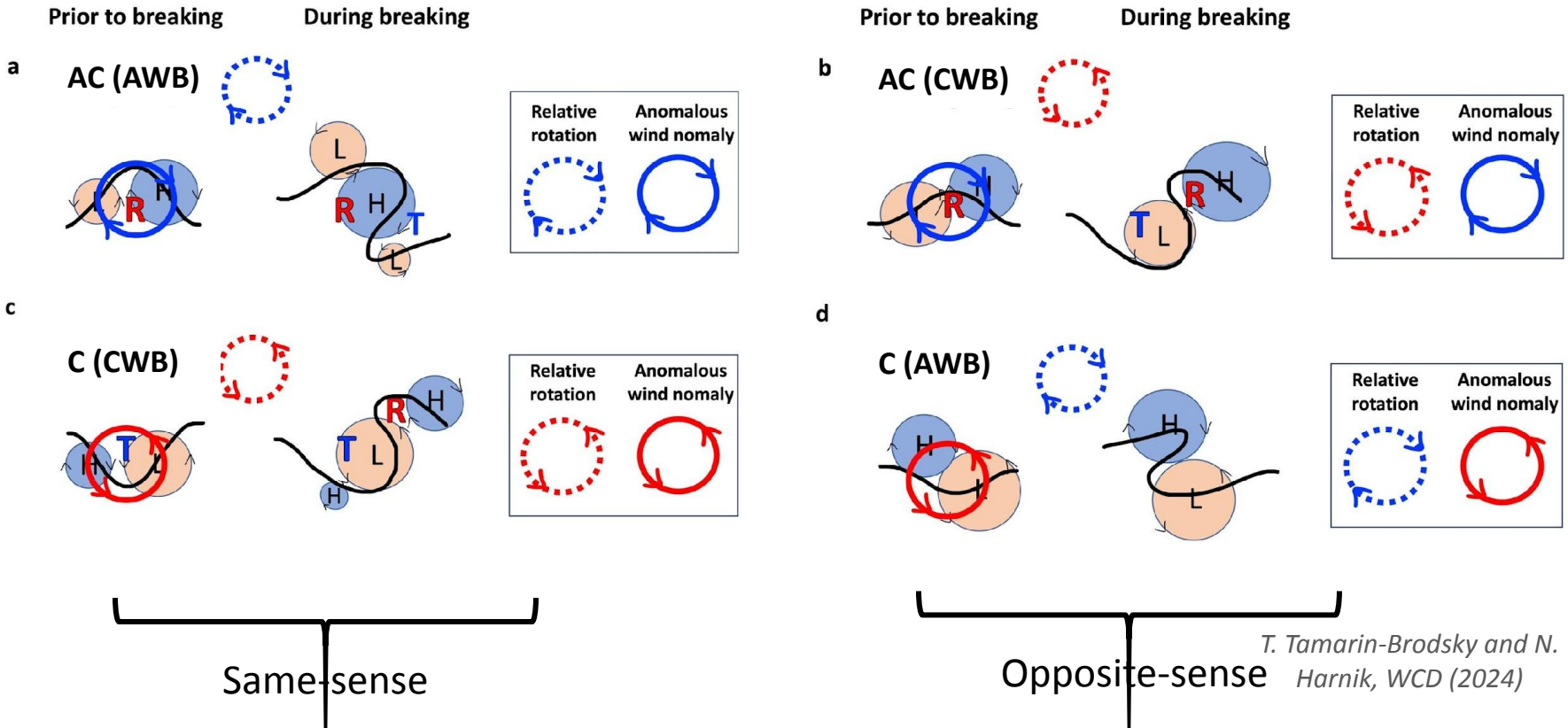


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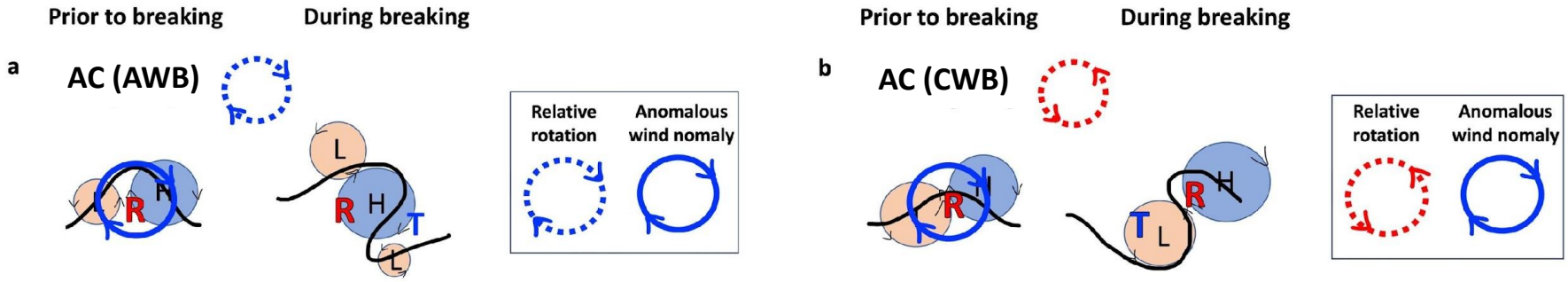
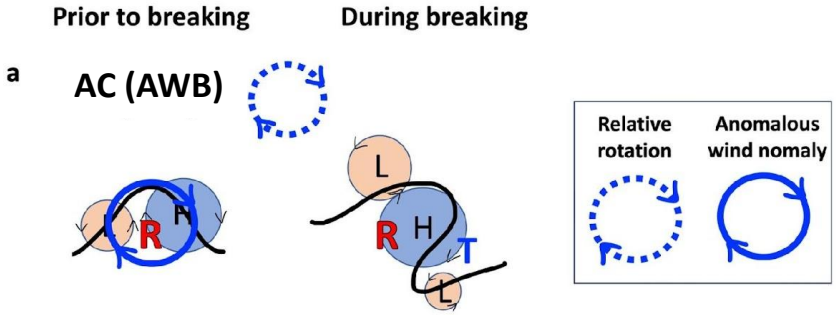
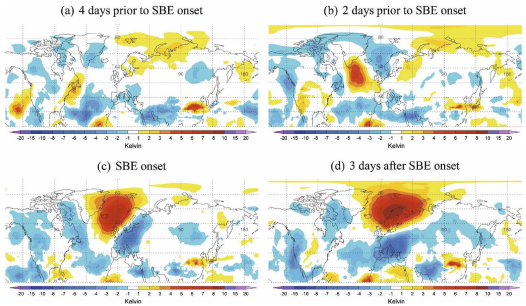


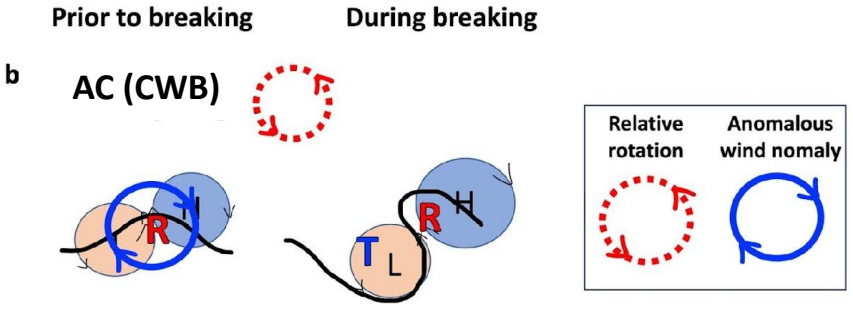

- The cyclone to the west is consistent with the ‘upstream cyclone theory’ suggested for blockings (Colucci, 1985; Lupo and Smith, 1995), and with studies about the role of the upstream warm conveyer belt. It was also shown important for the predictability of block onsets (Maddison et al., 2019, Steinfeld et al. 2020)
- May involve either a AWB or CWB, depending on the position relative to the jet, with the corresponding relative rotation in each case

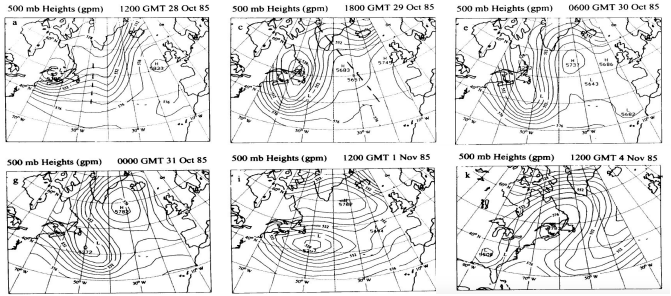
# The life cycle of real-atmosphere weather system in different RWB types




"The morphology of Northern Hemisphere Blocking", Tyrlis and Hoskins, 2008,JAS




A blocking eposide during October 28-Nov 4, 1985. Figure from Lupo and Smith, 1995

Composite of blocks over Europe□AWB

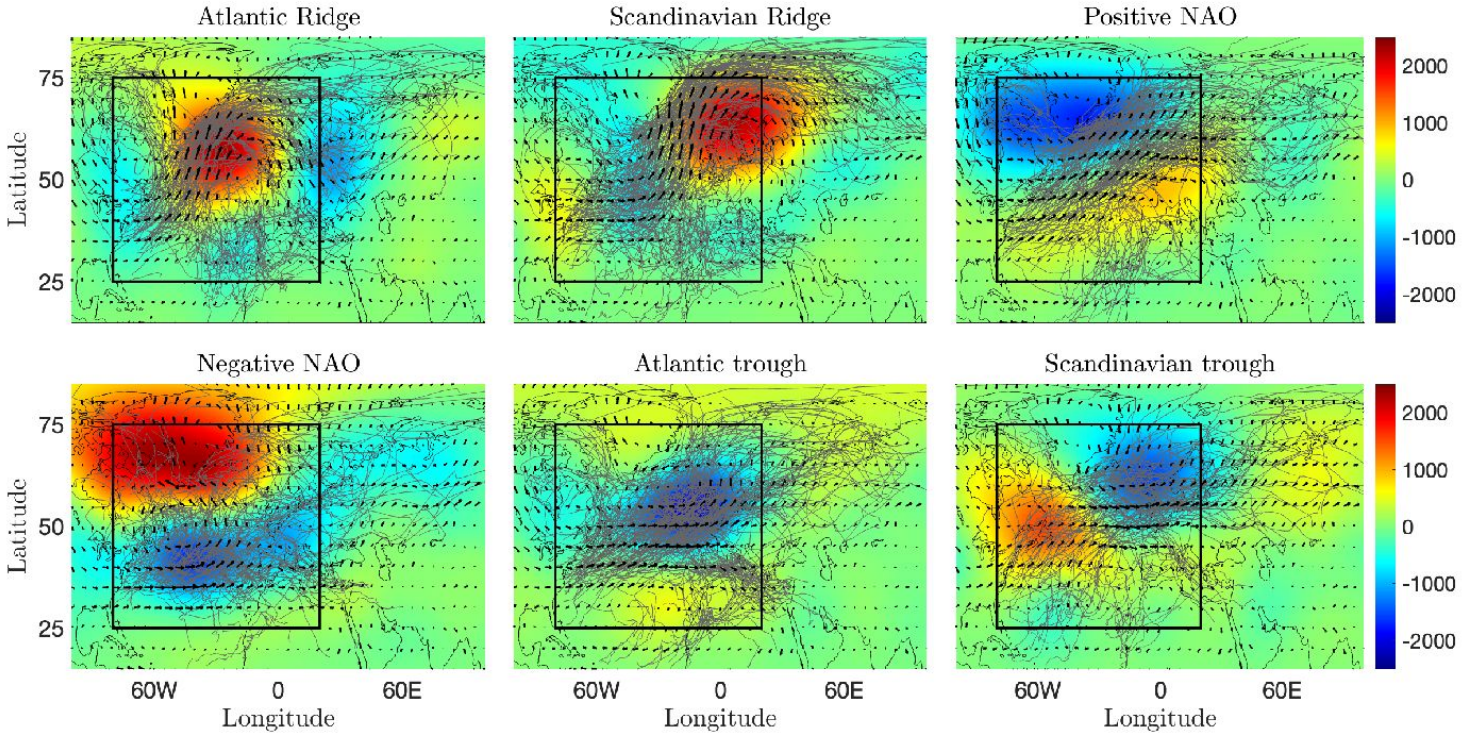
A blocking event in the upstream Atlantic□CWB

# Relation to weather regimes

***What is the (three-way) interaction between the low-frequency flow (regimes), RWBs, and the low-level cyclones and anticyclones?***

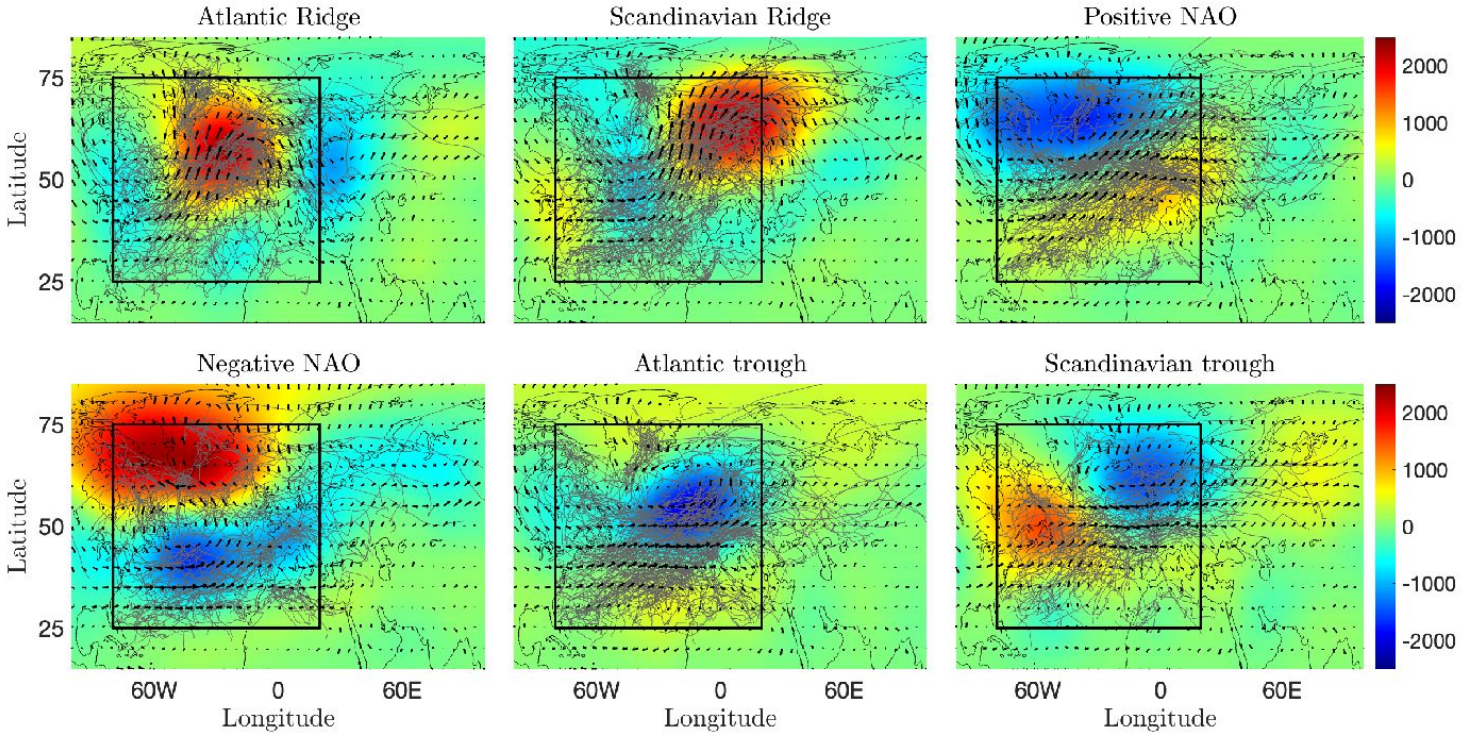
# Storm tracks in different North Atlantic weather regimes

## *Cyclone tracks* in different weather regimes



# Storm tracks in different North Atlantic weather regimes

## *Anticyclone tracks* in different weather regimes

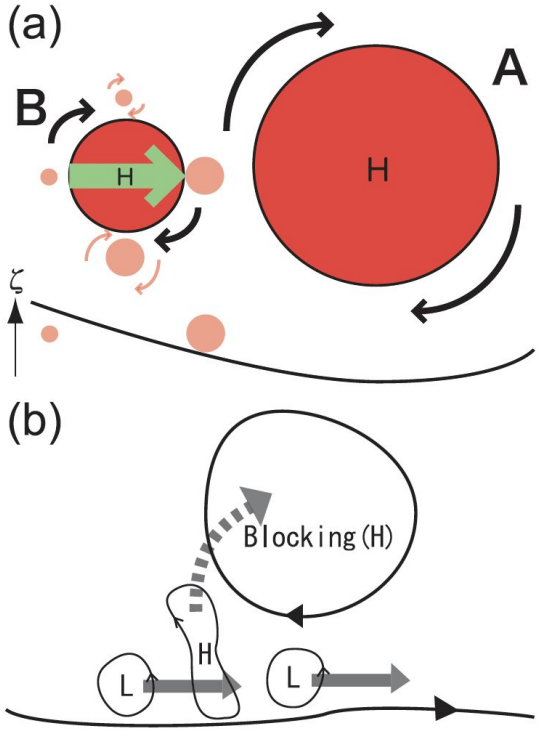


# The selective absorption mechanism

To first order, the tracks can be understood by the selective absorption mechanism (Yamazaki & Itoh, 2009 & 2012):

***Anticyclone travel through the low-frequency ridges, while cyclones are deflected by it***

***Cyclone travel through the low-frequency troughs, while anticyclones are deflected by it***



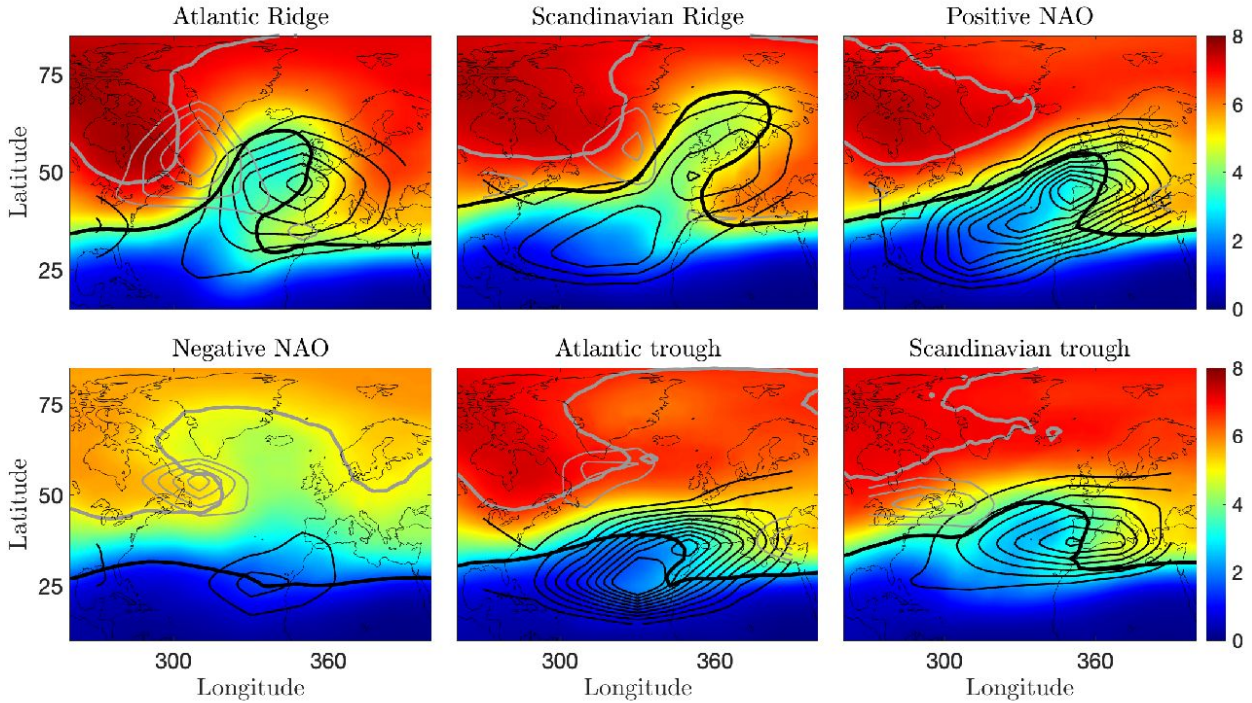

Akira Yamazaki and Hisanori Itoh, GRL 2009

# Cluster mean PV and RWB frequencies

**Black** contours- AWBs frequency

**Gray** contours- CWBs frequency

Colors=total UPV

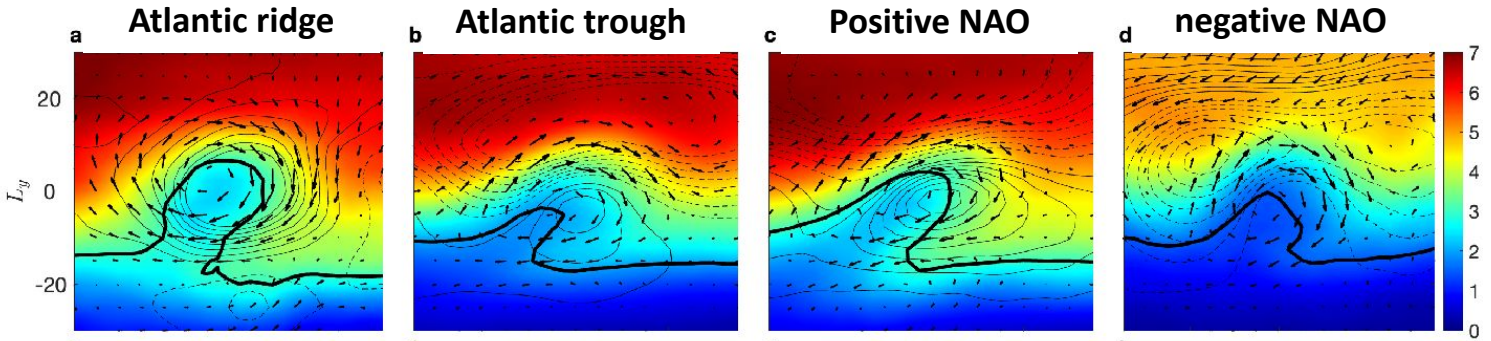



The slowly-varying flow (weather regimes) influences the storms' tracks, which in turn influence the location of the AWB/CWB events

# AC and C composites during RWB in different clusters

Total PV (color), SLP anomaly (contours) and anomalous U250

**Anticyclones** during **AWB**



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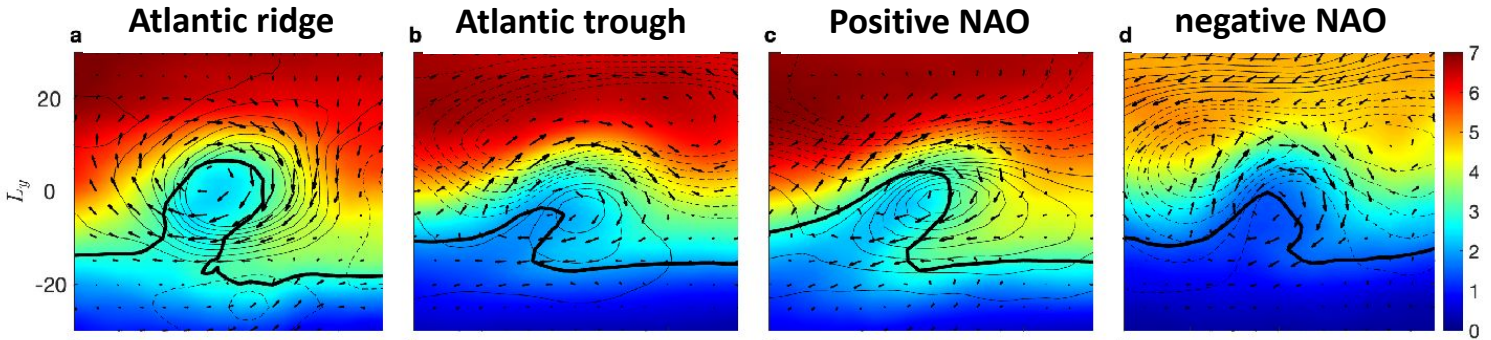
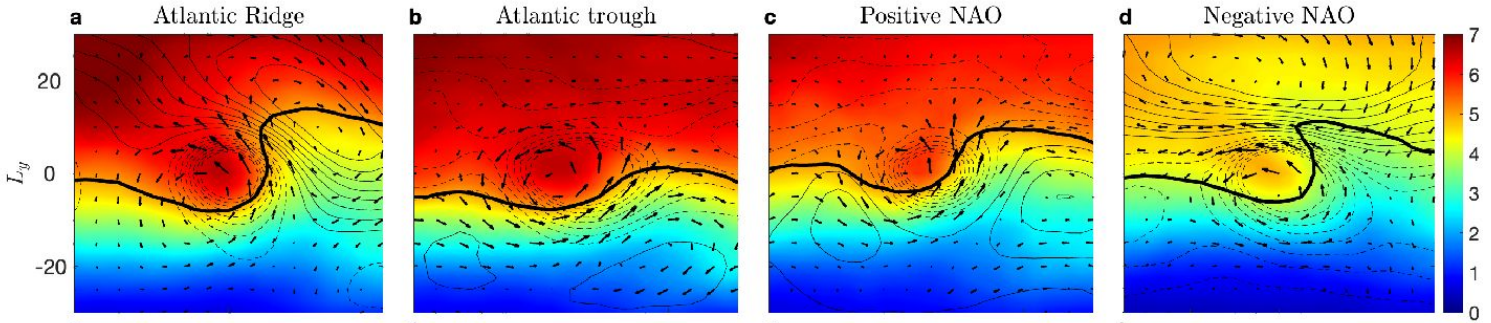



**Cyclones** during **CWB**

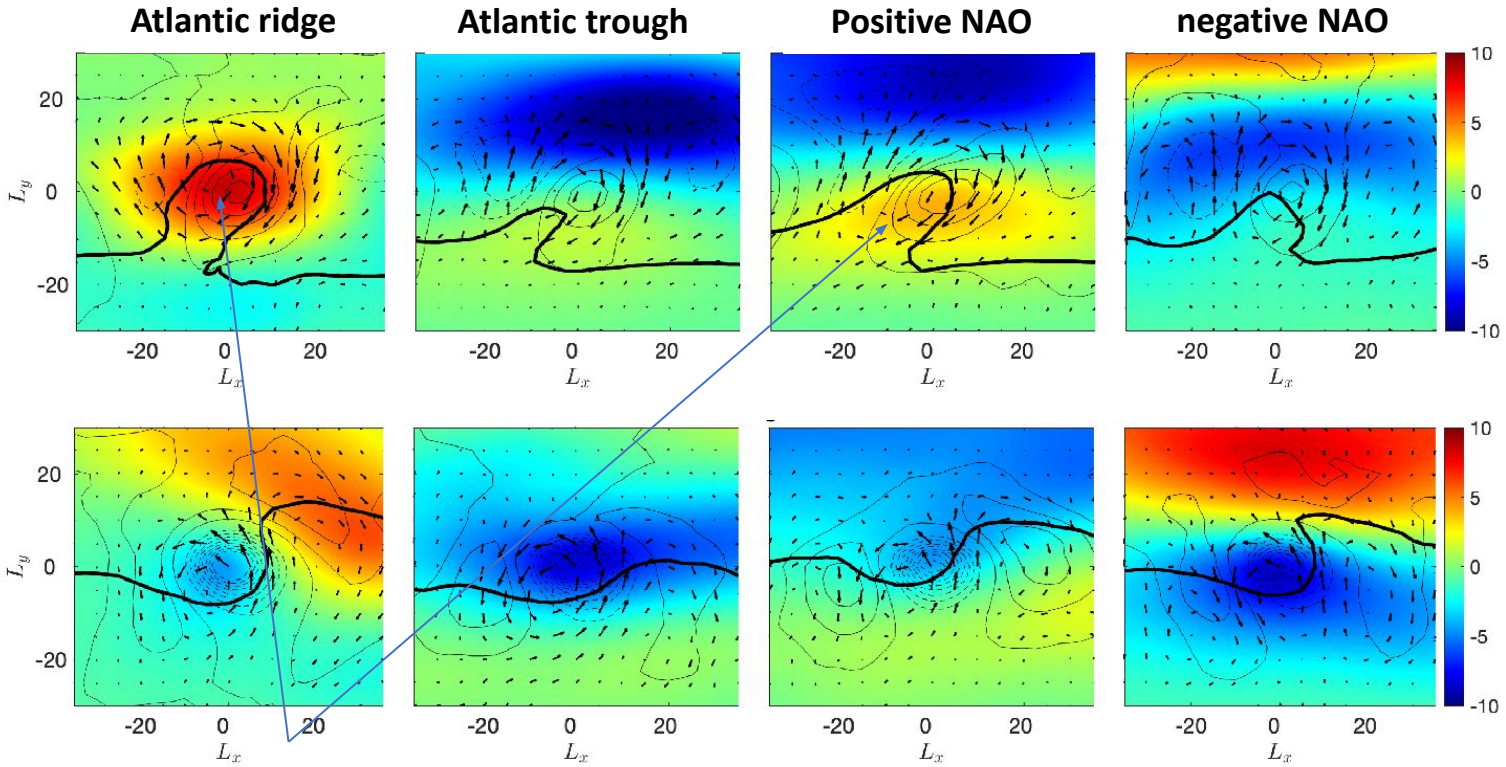


# AC and C composites during RWB in different clusters

LF (color) and HF (contours) SLP anomalies, and HF U250

**Anticyclones** during **AWB**

**Cyclones** during **CWB**



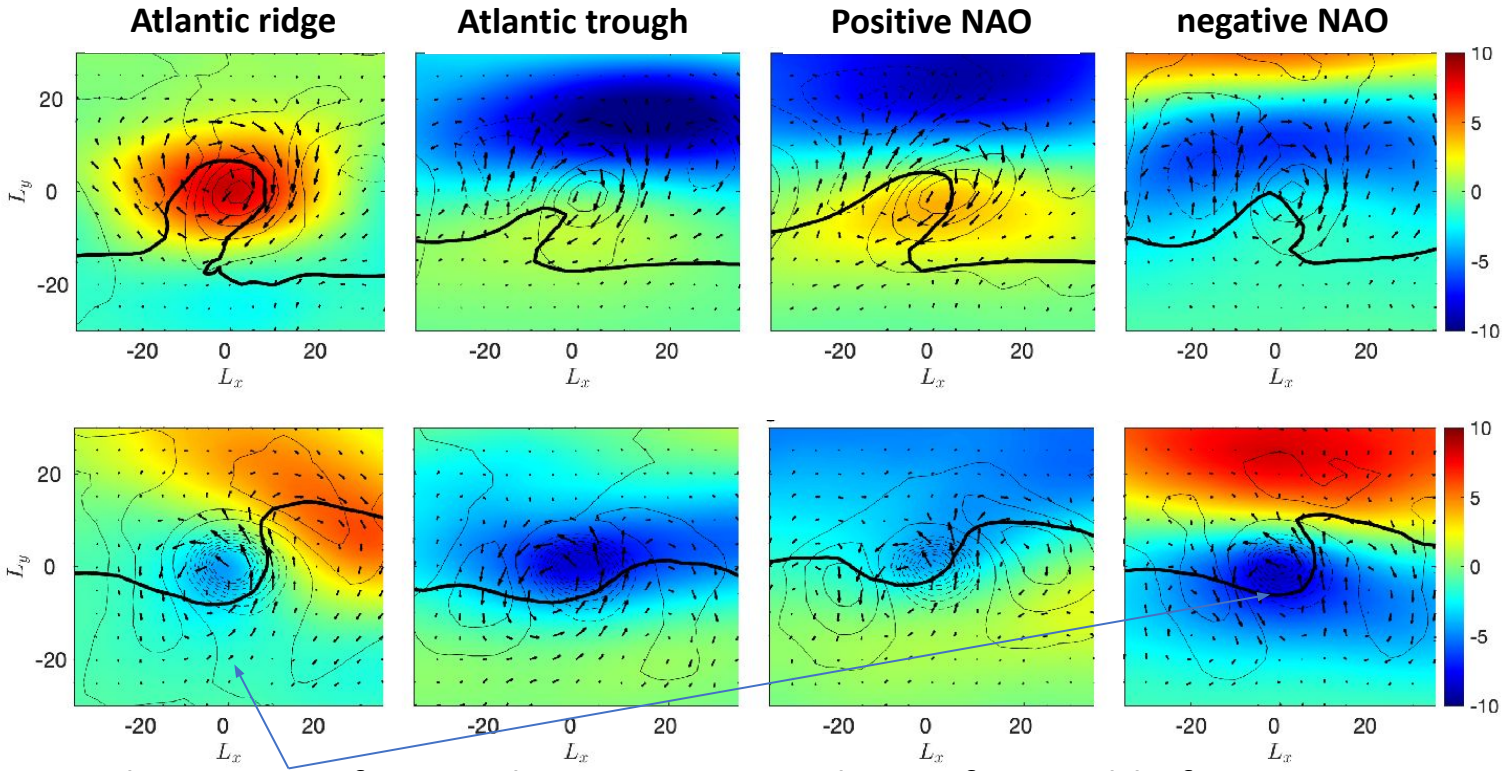

HF SLP anomalies are reinforcing the LF SLP anomalies □ favourable for AWB

# AC and C composites during RWB in different clusters

LF (color) and HF (contours) SLP anomalies, and HF U250

**Anticyclones** during **AWB**

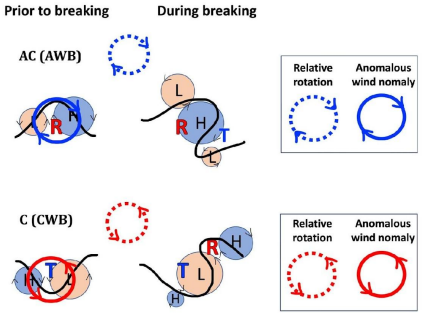
**Cyclones** during **CWB**



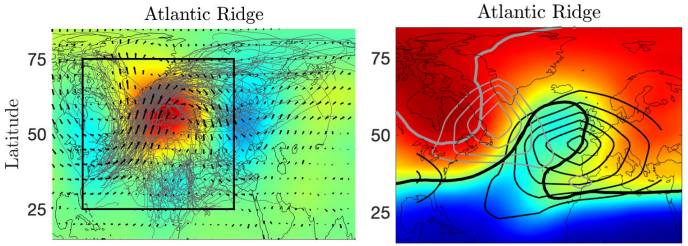

HF SLP anomalies are reinforcing the LF SLP anomalies □ favourable for CWB

# Summary

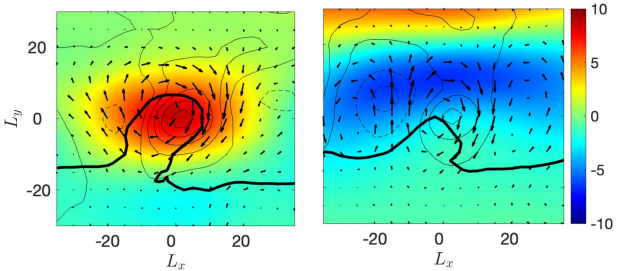
- *Low-level cyclones and anticyclones are intrinsically related to upper-level RWB events*




- *The slowly varying weather regimes influence the tracks of the low-level cyclones and anticyclones (selective absorption mechanism), which in turn influences where the wave breaking can occur*




- *Depending on where the breaking occurs with respect to the low-frequency (slowly varying) background flow, the AWB and CWB events can feed back either positively or negatively*




- *Open questions: How to better quantify these suggested relations? Can we prove causality? Can we show that the RWBs contribute to the persistence of the weather regimes?*

**Thank you** ☺