Dynamics of Different Blocking Types in the Northern Hemisphere from a Potential Vorticity Perspective

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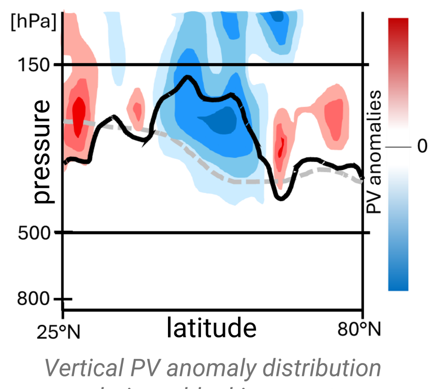
REFINEMENT OF SCHWIERZ ET AL (2004, GRL) BLOCKING ALGORITHM



Vertical PV anomaly distribution during a blocking event

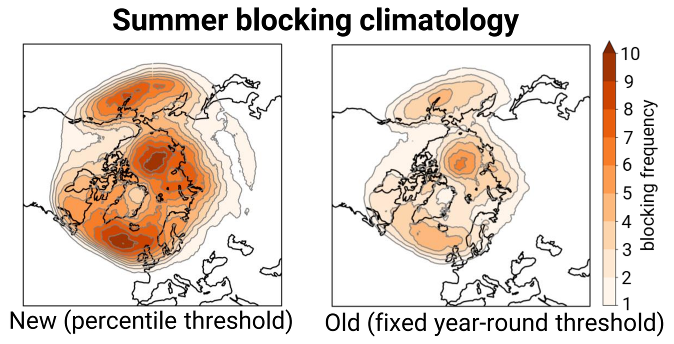
Blocks detected as negative anomalies of vertically-averaged potential vorticity (PV) (150-500hPa) with a lifetime of at least 5 days in ERA5 reanalysis (1979-2021)

MAJOR ADJUSTMENTS

Centered 30-day running-mean climatology, daily variable percentile threshold (low in summer, high in winter), two-sided spatial overlap criterion of 85%

Refinements of Schwierz et al. algorithm result in a more balanced climatology (more blocks in summer due to the lowered threshold, winter climatology hasn't changed

Summer blocking climatology



New (percentile threshold) Old (fixed year-round threshold)

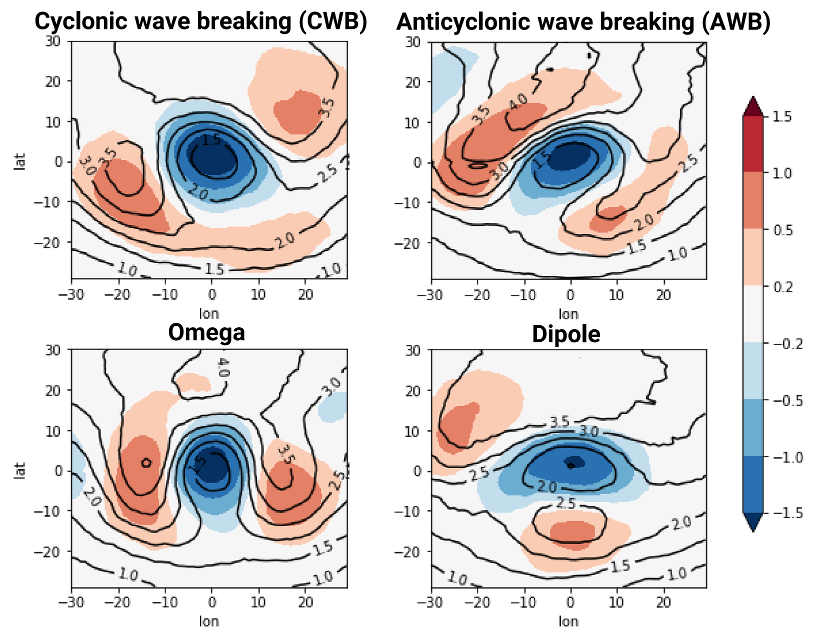
PARTITIONING INTO BLOCKING TYPES

Blocking-centered PV composites
(rotated pole grid)

Classify the types of blocking (during onset) based on *k*-means clustering in the phase space spanned by the leading 30 EOFs (explaining 75% of the variance)

The *k*-means algorithm (Lloyd 1982) with k=4 is used on the retained principal components and repeated 10 times with new initial cluster centroid positions. The average over each cluster is calculated to derive the **four blocking types.**

—— upper-tropospheric PV (in PVU)



Block-centered cluster means for the four blocking types

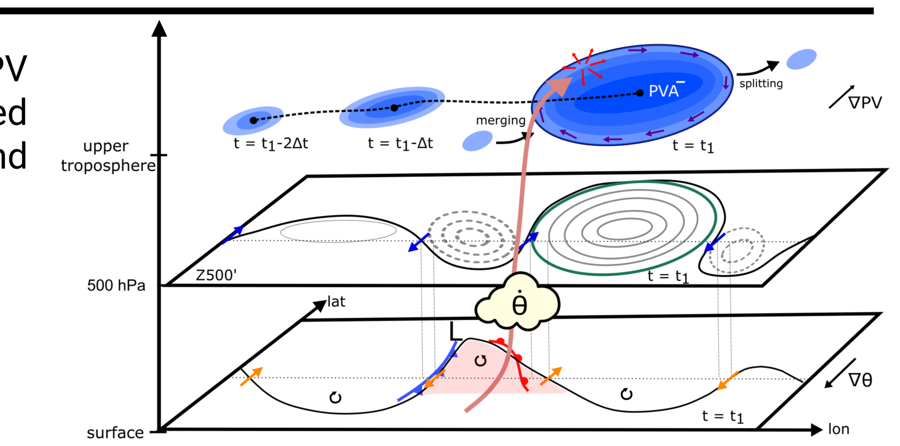
QUASI-LAGRANGIAN POTENTIAL VORTICITY FRAMEWORK

Following upper-tropospheric transient PV anomalies ($q' = q - q_0$; PVAs⁻) associated with blocks and quantify the role of dry and moist dynamics in its amplitude evolution (Hauser et al., 2023, WCD)

Integrated amplitude evolution
(Teubler and Riemer, 2021, WCD)

Helmholtz partitioning & piecewise PV inversion

full wind field: $\mathbf{v} = \mathbf{v}_0 + \mathbf{v}'_{div} + \mathbf{v}'_{up} + \mathbf{v}'_{low} + \mathbf{v}'_{res}$

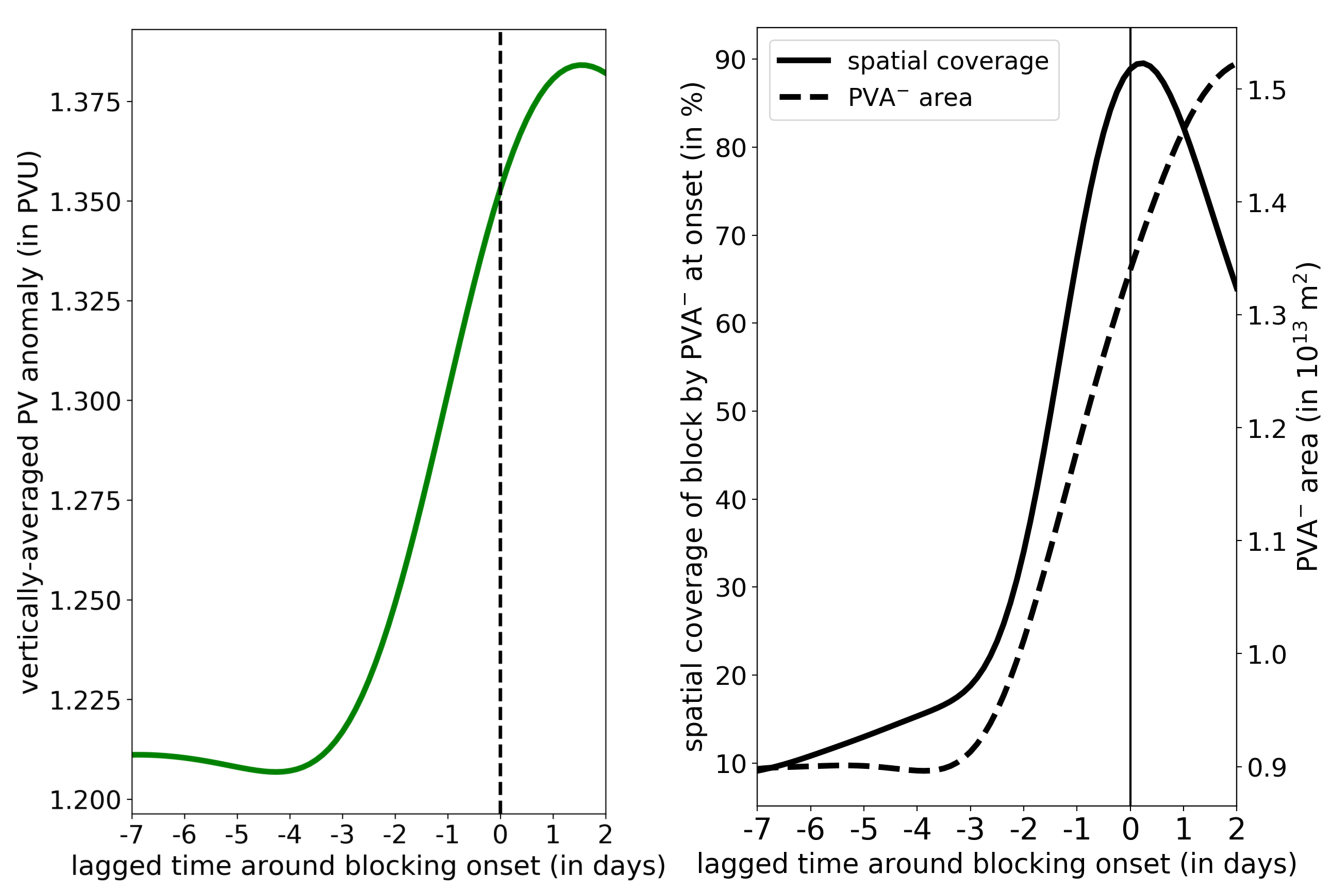


Schematic illustration of the quasi-Lagrangian PV framework

$$\underbrace{\frac{d}{dt}\int_{A(t)} q'\,dA}_{\text{DIAG}} = \int_{A(t)} [\underbrace{-\mathbf{v}'_{up}\cdot\nabla q_0}_{\text{UP}} \underbrace{- \mathbf{v}'_{low}\cdot\nabla q_0}_{\text{LOW}} \underbrace{- \mathbf{v}'_{div}\cdot\nabla q_0}_{\text{DIV}_{adv}} + \underbrace{q'(\nabla\cdot\mathbf{v}'_{div})}_{\text{DIV}_{div}} \underbrace{- \mathbf{v}'_{res}\cdot\nabla q_0}_{\text{RES}} + \underbrace{\mathcal{N}}_{\text{NON-CONS}}]\,dA + \underbrace{\oint_{S(t)} q'(\mathbf{v}_s - \mathbf{v})\,d\mathbf{S}}_{\text{BND}}$$

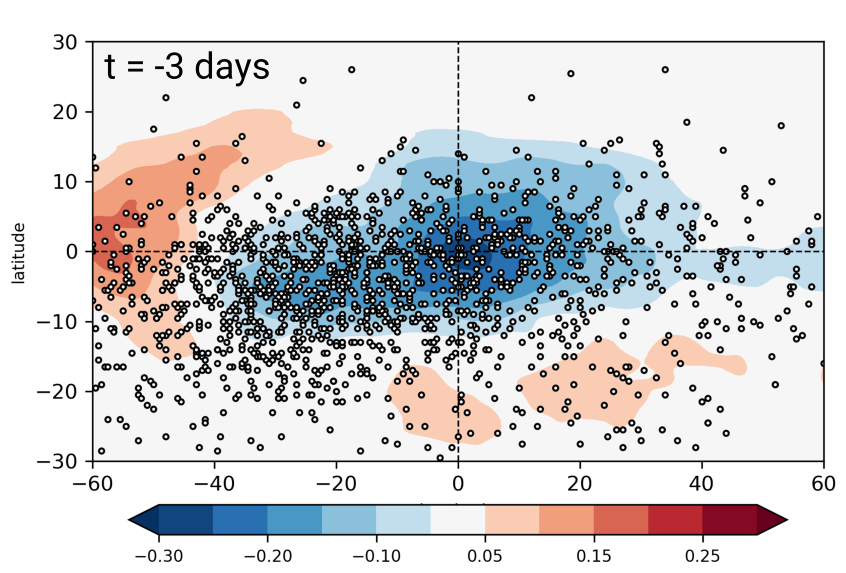
KEY AMPLIFICATION OCCURS BEFORE BLOCKING ONSET AND MOSTLY OUTSIDE OF THE BLOCKING AREA

We PVAs⁻ with the identified block at time of the onset and describe their characteristics around the onset:



Temporal evolution of the PVA⁻ amplitude (left, multiplied by -1!), PVA⁻ area (right, black solid) and spatial coverage of block by PVA⁻ (right, black dashed) around blocking onset.

PVAs⁻ linked to blocking show their strongest amplification within three days **before** the blocking onset (green line, left). This co-occurs with a rapid increase in PVA⁻ area (black dashed line, right) and the increase in the spatial coverage of the block by the PVA⁻ (black solid line, right) in the days prior to onset.



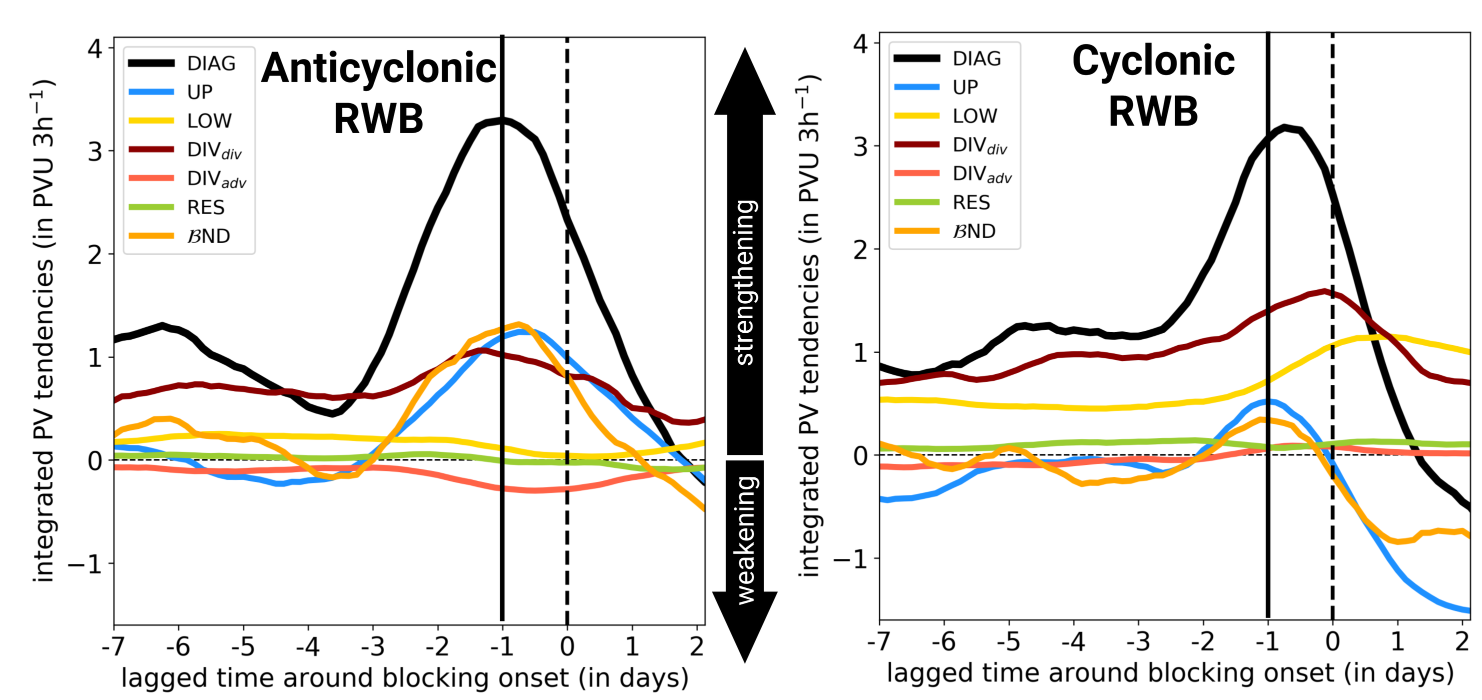
PV anomaly composite centered on blocks' center of mass position at onset and position of PVAs⁻ three days before.

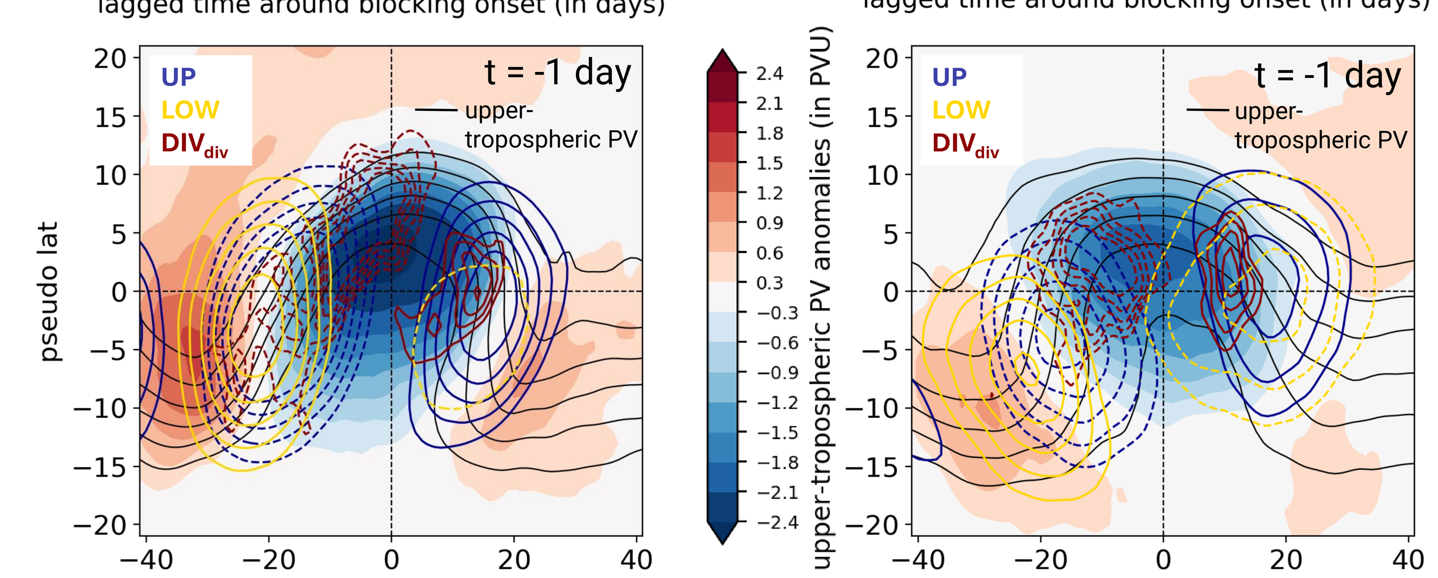
Tracing back those PVAs⁻ reveals that the amplification does not necessarily take place within the blocking region: PVAs⁻ often amplify during their propagation into the region where they become stationary and persistent.

This study is in preparation for the journal *Weather and Climate Dynamics* and submitted soon! ☺

STRONG DIFFERENCES IN PROCESS CONTRIBUTION TO AMPLIFICATION BETWEEN AWB AND CWB BLOCKING TYPES

Using the integrated amplitude evolution diagnostic and comparing the processes contributing to the PVA⁻ amplification to blocking onset between **anticyclonic** (left) and **cyclonic** (right) **RWB.** Independent of blocking type, divergent PV tendencies (**DIV_{div}**) are the leading contributions and point to the importance of moist processes. However, for anticyclonic RWB, quasi-barotropic dynamics (**UP**) make a larger contribution to PVA⁻ amplification while there's a remarkable contribution of baroclinic PV tendencies (**LOW**) for PVAs⁻ linked to cyclonic RWB.



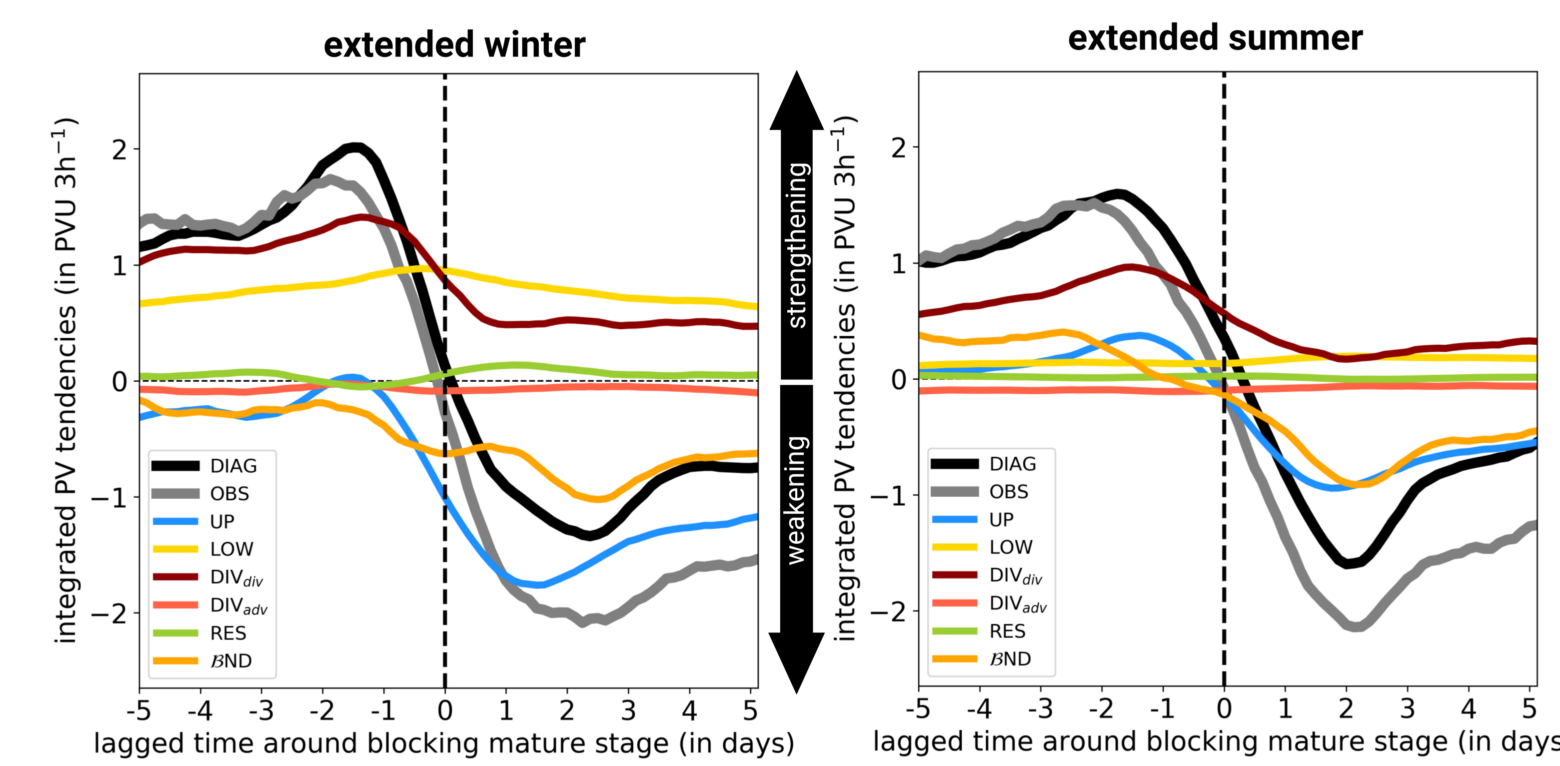


Upper: Integrated PV tendencies for the amplitude evolution of PVAs linked to blocking onset for the two different RWB types around blocking onset. Lower: Blocking-centered composites of PV anomalies (shading) and PV tendencies (positive: solid, negative: dashed).

Centered PVAs⁻ composites reveal the presence of a pronounced upstream trough linked to strong amplifying tendencies of **UP** along the upstream flank of the PVA⁻ linked to anticyclonic RWB. In contrast, tendencies of **LOW** are almost in phase with upper-tropospheric PV anomalies pointing to a favorable phase shift with the low-level temperature wave for PVAs⁻ linked to cyclonic RWB.

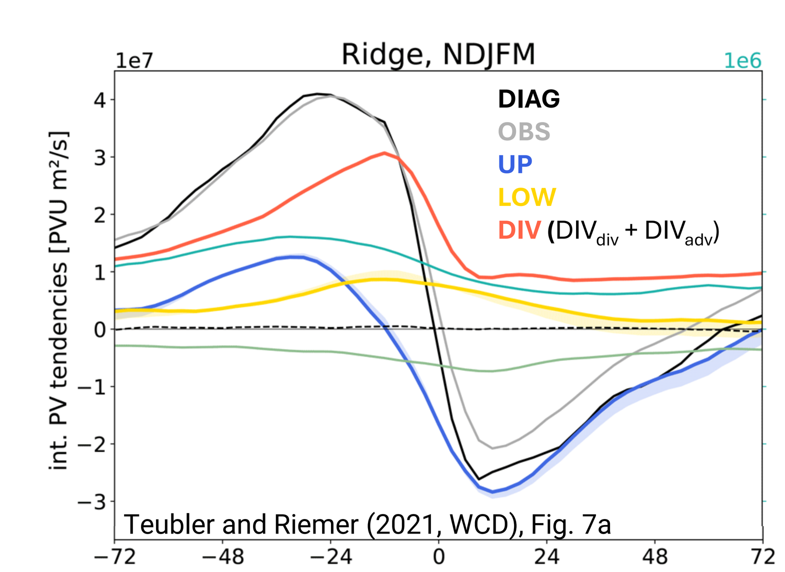
BLOCKS ARE LESS BAROTROPICALLY-DRIVEN THAN RIDGES AS PART OF RWPs AROUND MATURE STAGE

We here apply the framework to the blocking **mature stage** (and the PVAs⁻ linked to the block around mature stage) and partition into seasons to investigate if PVAs⁻ linked to blocks show a certain similarity in evolution as ridges in a Rossby wave packet (RWP) as in the study of Teubler and Riemer (2021, WCD).



Integrated PV tendencies for PVAs⁻ linked to blocks around the mature stage of in winter (left) and summer (right). OBS represents the observed PVA⁻ amplitude evolution.

Again, tendencies of **DIV_{div}** clearly lead the amplification of PVAs⁻ before the mature stage. Seasonal differences are mainly visible in contributions of **LOW** with lower contributions in summer due to decreased baroclinicity compared to winter.



Composite of RWP-ridges' amplitude change of in extended winter relative to maximum amplitude.

The relative importance of amplification by RW group propagation (**UP**) is of less importance for blocks. In contrast, ridges as part of RWPs develop following the concept on *downstream (moist-) baroclinic development* (Teubler and Riemer, 2021, WCD)

However, more similarities with ridge development arise for PVAs⁻ linked to cyclonic RWB around blocking onset.