Linkage Between Teleconnections and Rossby Wave Breaking Activity

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Objective & Background

- **Rossby wave breaking (RWB)** is a process by which Rossby waves become highly amplified and overturn in response to the background upper-tropospheric wind shear (typically in the vicinity of the jet stream)
  - **RWB** can be **cyclonic (CWB)** in cyclonic shear or **anticyclonic (AWB)** in anticyclonic shear
- RWB has been previously explored by several studies in relation to teleconnections:
  - Strong & Magnusdottir (2008) proved over 90% of the variability in the NAO can be explained by RWB, demonstrating the strong influence of Rossby Wave Breaks on NAO patterns
  - Hall et al. (2014) discussed the linkage between the NAO and changes in North Atlantic jet stream.
  - Bowley et al. (2019) explored seasonal and basin correlations to different teleconnections
- **Objective:** Analyze the frequency of **CWB and AWB across the Northern Hemisphere** and their relationship to teleconnections, particularly the **North Atlantic Oscillation (NAO)** and **Pacific North American (PNA)** patterns.

Methodology

Wave Break Identification

- Identifies overturning isentropes on the dynamical tropopause (DT) for December-January-February (DJF) 1980-2014.
  - Methodology aligns with the LaChat et al. (2024) application of Bowley et al. (2019) technique using ERA5 reanalysis data.
- ERA 5 data was used
  - 4 timesteps daily (00, 06, 12, and 18 UTC)
  - 0.25x0.25 degree grid spacing, regridded to 1.0x1.25 degrees.

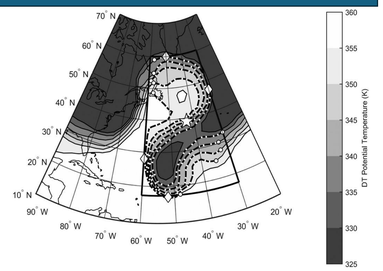


Figure [1]: Bowley et al. (2019) RWB identification method applied to an AWB. The star marks the centroid of the RWB, diamonds depict the Northward, Eastward, Southward, Westward extent of the RWB, and box represents the RWB region.

Grid-Based Frequency Approach

- Used discrete latitude and longitude indices (1° per latitude, 1.25° per longitude) to identify RWB events.
- Enclosed areas in figure [1] typed as a RWB event for compositing purposes.

Teleconnection Phase Analysis

- Climate Prediction Center daily teleconnection indices for the Pacific–North American (PNA) and North Atlantic Oscillation (NAO) patterns used to identify positive ($> 1\sigma$), negative ($< -1\sigma$), and neutral days.

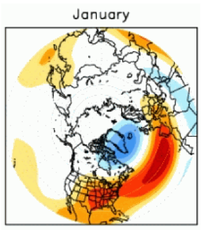


Figure [2a]: NAO pattern correlates height anomalies and teleconnection pattern (CPC)

A **positive PNA** occurs when there is high pressure over the western U.S. and low pressure over the eastern Pacific, amplifying the jet stream

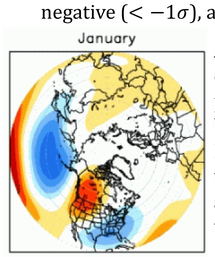


Figure [2b]: PNA pattern correlates height anomalies and teleconnection pattern (CPC)

A **positive NAO** occurs when the pressure difference between the Icelandic Low and the Azores High is strong, intensifying the jet stream.

Climatological Results

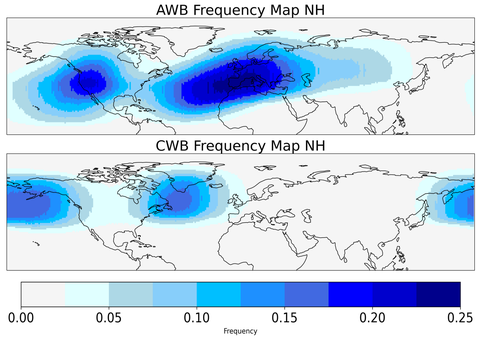
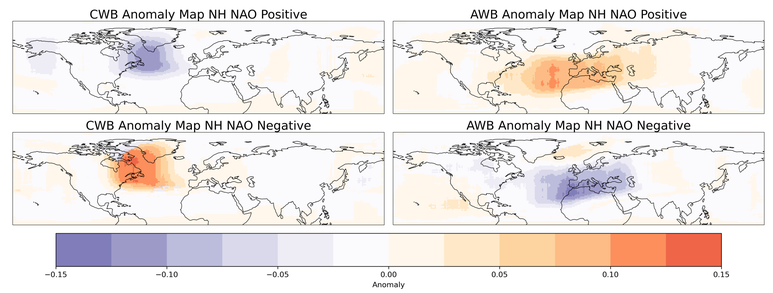


Figure [3]: Contours (2.5% interval) of DJF RWB frequencies across the Northern Hemisphere.

- Frequencies of AWB and CWB shows the climatological hotspots("surf zones") where wave breaking occurs.
- The Pacific and Atlantic surf zones are heavily favorable areas for wave breaks to occur.
- Overall, more waves break anti-cyclonically rather than cyclonically.

North Atlantic Oscillation



CWB Frequencies (NAO)

~80% decrease (increase) in CWB frequencies for the North Atlantic during a positive (negative) NAO.

During the positive (negative) phase, an anomalously weak (strong) Greenland blocking over the North Atlantic can lead to, or cause, higher (lower) frequency breaking in the North Atlantic.

CWB poleward heat transport develop the Greenland block (Michel & Rivière. 2011).

AWB Frequencies (NAO)

~50% increase (decrease) in AWB frequencies for the Mediterranean during a positive (negative) NAO.

Anomalously high AWB has previously been shown to trigger a positive NAO (Benedict et al. 2004).

A negative NAO is associated with a shortened, weaker, and more poleward jet, which can reduce the occurrence of AWB in the N. Atlantic surf zone.

Conclusion

RWB is critical in influencing regional weather and climate. Their occurrence are tied to the phases of the NAO and PNA. The NAO heavily shapes the North Atlantic jet stream strength and position, consequently modifying the spatial frequency distribution. The PNA pattern displayed significant anomalies through the United States and Atlantic Ocean. CWB anomalies had a much larger linkage to teleconnection throughout the spatiotemporal domain.

Teleconnection Correlations

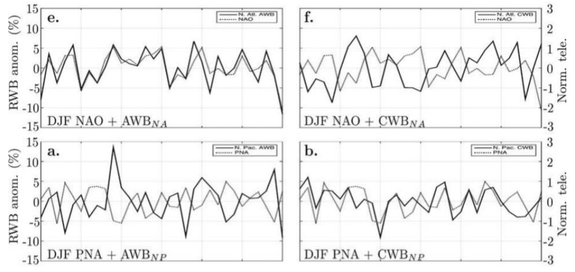
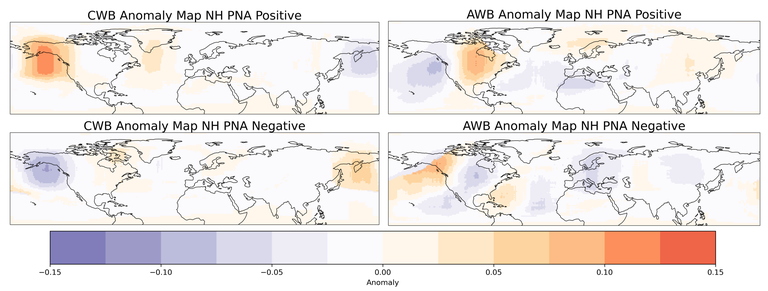


Figure [4]: 1980-2010 time series, RWB (solid) and seasonal DJF teleconnection indices (dashed) from Bowley et al. (2019) using NCEP-II dataset.

CWB regions: **CWB$_{NP}$** (40° – 80°N, 160°E – 140°W) and **CWB$_{NA}$** (40° – 80°N, 70° – 30°W).
AWB regions: **AWB$_{NP}$** (20° – 60°N, 150°– 90°W) and **AWB$_{NA}$** (20° – 60°N, 40°W – 20°E).

- NAO displays a strong correlation (anticorrelation) with AWB (CWB) in the North Atlantic.
- PNA displays a strong correlation (anticorrelation) with CWB (AWB) in the North Pacific.

Pacific North American



CWB Frequencies (PNA)

~80% increase (decrease) in CWB frequencies for the Aleutian Sea during a positive (negative) PNA.

The zonal movement in the Pacific surf zone likely linked to shifts in the jet stream.

Stronger and eastward elongated jet (+PNA) leads to anomalously strong (weak) cyclonic shear, causing higher (lower) frequency breaking in the Aleutian Sea (Franzke et al. 2011).

AWB Frequencies (PNA)

~50% increase (~ 30% decrease) in AWB frequencies for the central United States during a positive (negative) PNA.

The fluctuations in the Pacific jet stream influences the jet stream throughout North America and the North Atlantic.

Weaker and westward contracted jet (-PNA) leads to increase in AWB on northwest flank of N. Pacific surf zone, helping to establish ridging (Martius et al. 2007).

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