ON THE ROLE OF ROSSBY WAVE PHASE SPEED FOR PERSISTENT TEMPERATURE EXTREMES

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MOTIVATION

A persistent anticyclone is necessary for mid-latitude summer heatwaves (e.g. Pfahl & Wernli, 2012). Different mechanisms to produce such persistent anticyclones have been suggested.

- The phase speed of a circumglobal wave train with a synoptic-scale zonal wave number depends on the zonal-mean basic state (Petoukhov et al., 2013).
- Recurrent Rossby wave packets that develop or amplify repeatedly in the location increase the persistence of hot and cold temperature extremes (Röthlisberger et al., 2019).

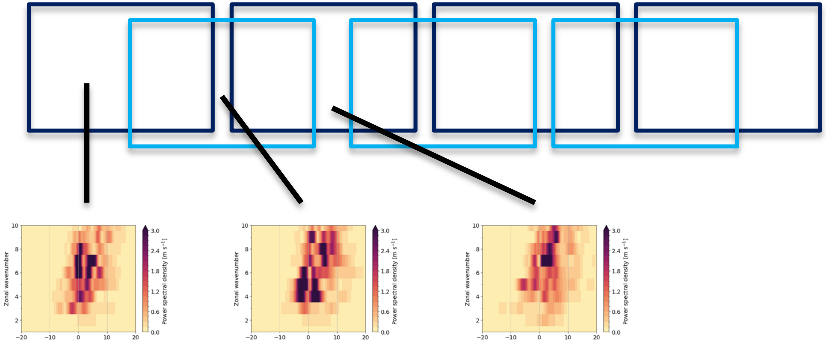
The first mechanism assumes that the persistence of the anticyclone implies the presence of a stationary wave. Here, we provide evidence that contradicts this assumption and, hence, advocate the second mechanism.

METHODS

1. The time series of 6-hourly meridional wind anomalies at 250hPa from ERA5 reanalysis (Hersbach et al., 2020) for boreal summer 1959-2021 is divided into overlapping 30-day windows.

2. For each window, the phase speed is estimated using space-time spectral analysis (Hayashi, 1979) following the methodology of Randel & Held (1991).

6-hourly data (JJA 1959-2021)
- divided into 30-day windows



one power spectrum for each window

METHODS

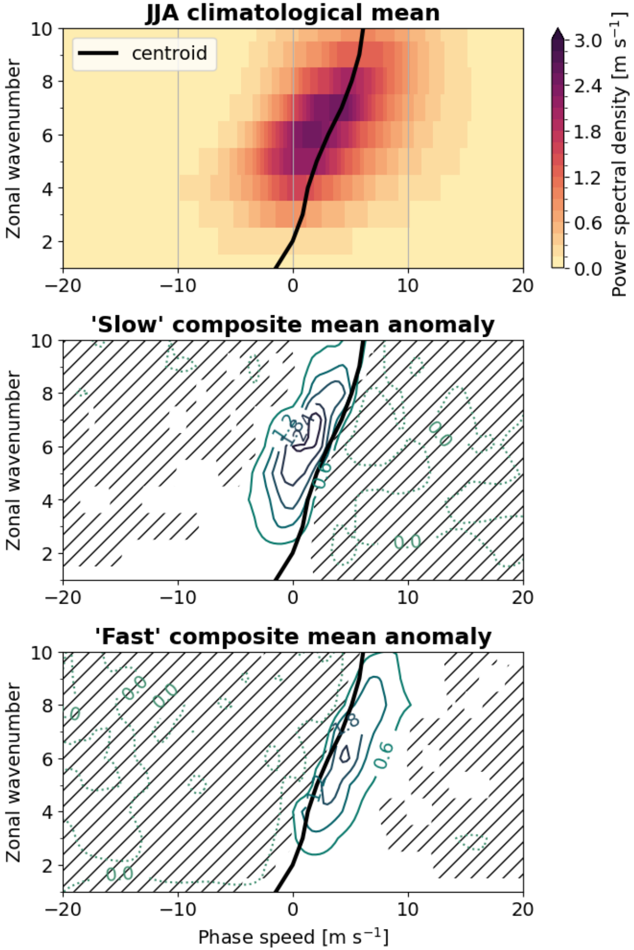
3. For each zonal wave number, the phase speed spectrum is divided into a "slow" and a "fast" phase speed bin at the centroid of the climatological-mean power spectrum.

4. Episodes during which the meridional-mean (35°N-65°N) meridional wind variance in the *"slow"* or *"fast"* phase speed bin exceeds its 90^{th} percentile are chosen to construct composites of 30-day mean meridional wind anomalies and heatwave frequency.

5. Heatwaves are defined as the set of days where the detrended daily-maximum 2m air temperature exceeds its 90^{th} percentile for at least three consecutive days. The heatwave frequency is defined as the number of heatwave onsets per 30-day window.

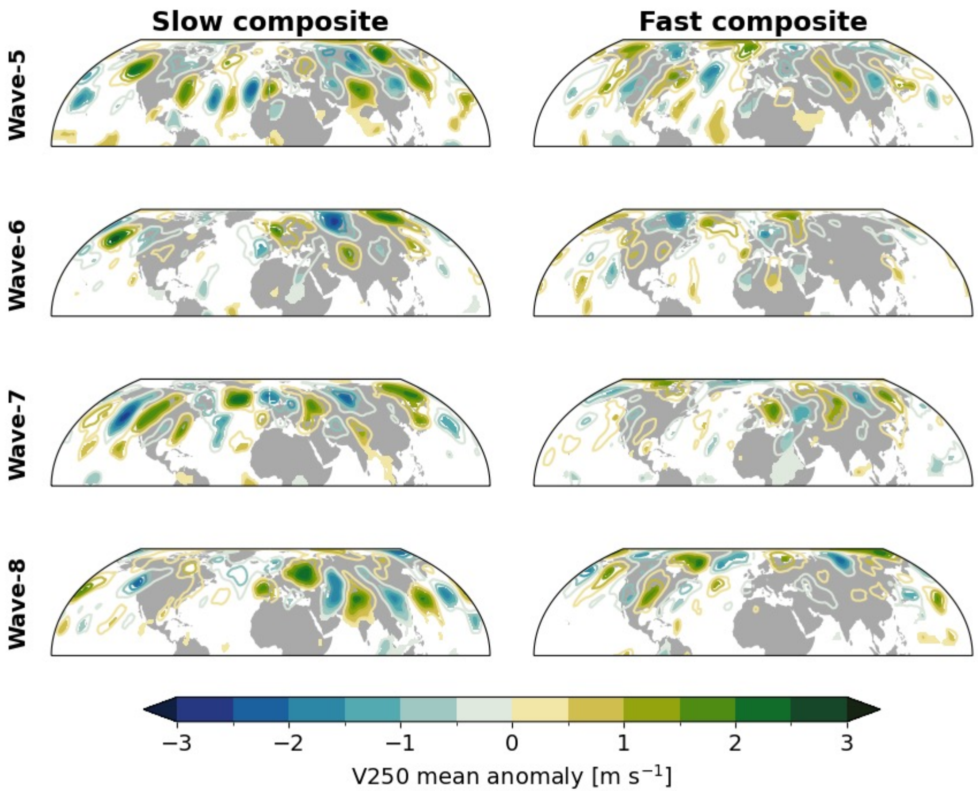
METHODS – SUMMARIZED

- The centroid of the climatological mean power spectrum of upper-tropospheric meridional wind is used as boundary between two separate phase speed bins.
- By integrating power spectral density over the phase speed dimension, we obtain time series of meridional wind variance for each wavenumber and each phase speed bin that are statistically independent.
- In the *"slow"* and *"fast"* composite, power spectral density is about twice the climatological value in the respective phase speed bin but unchanged in the opposite phase speed bin.



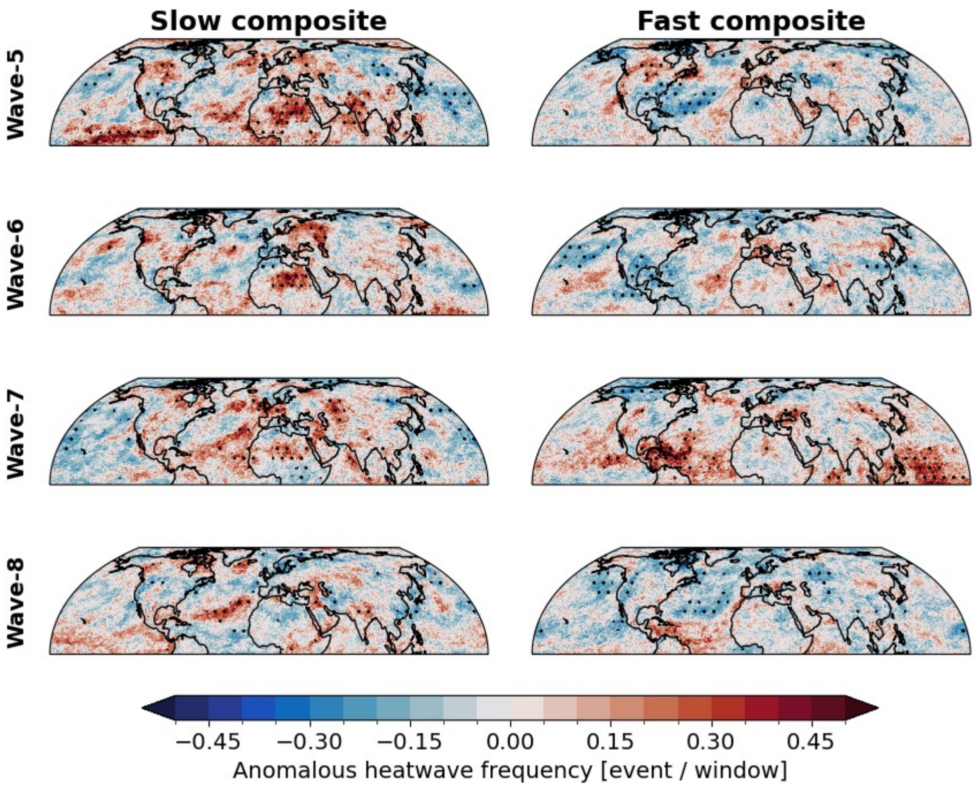
RESULTS I

- Composite-mean meridional wind anomalies at 250hPa for the *"slow"* and *"fast"* composite have a similar magnitude.
- Filled contours indicate a statistical significance at a two-sided 90% confidence level estimated by a t-test.
- The composite-mean signal constitutes a synoptic-scale wave train.



RESULTS II

- We find no evidence of a hemispheric signal of increased heatwave frequency during episodes of high synoptic-scale wave-energy with a low phase speed.
- Mid-latitude heatwave frequency is increased (decreased) in ridges (troughs) of composite-mean wave trains.
- (Sub-)tropical composite-mean anomalies might indicate teleconnections.



KEY POINTS

Episodes of strong meridional wind variance produce significant composite-mean wave trains regardless of the zonal phase speed estimated from 6-hourly data.

- Assuming a quasi-stationary, synoptic-scale Rossby wave that is periodic in time and longitude is not appropriate for explaining heatwaves.
- Localized Rossby wave packets that develop and amplify repeatedly in the same location are better suited.

The structure of 30-day mean meridional wind anomalies depends on characteristics of high-frequent variability, e.g., zonal wavenumber and phase speed.

EXPLAINING THE POSTER CONCLUSION

"Stationary Rossby wave dynamics are not suitable for explaining heatwaves"

- The common wave ansatz in a framework with a symmetric basic state assumes perfect periodicity, i.e., a wave amplitude that is constant in longitude and time. (Meridional wind) anomalies can be expressed as

$$\psi'(x, y, t) = \psi_0(y)e^{i(kx+\omega t)}$$

- This ansatz is not justified. If the wave amplitude was constant, then a fast phase propagation would eradicate any temporal-mean anomaly. If wave amplitude was constant, then a significant temporal-mean or composite-mean anomaly would require near-zero phase speed.

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FEEL FREE TO ASK QUESTIONS!

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