# Insights into circumglobal Rossby wave patterns from space-time spectral analysis

**Jacopo Riboldi*,** Efi Rousi★, Fabio D'Andrea, Gwendal Rivière and François Lott

*LABORATOIRE DE MÉTÉOROLOGIE DYNAMIQUE, PSL UNIVERSITÉ, PARIS, FRANCE*

**Now at Department of Earth Sciences, Uppsala University*

★ *Potsdam Institute for Climate Impact Research (PIK), Leibniz Association, Potsdam, Germany*

UPPSALA UNIVERSITET





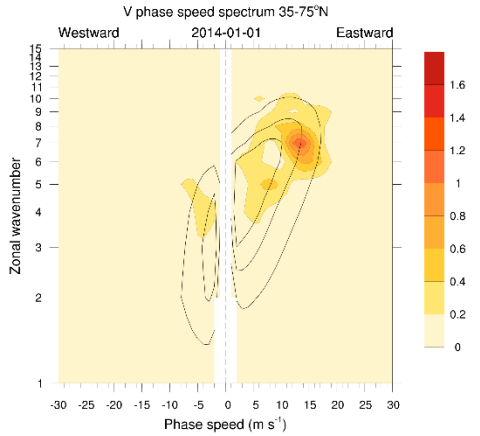
jacopo.riboldi@geo.uu.se

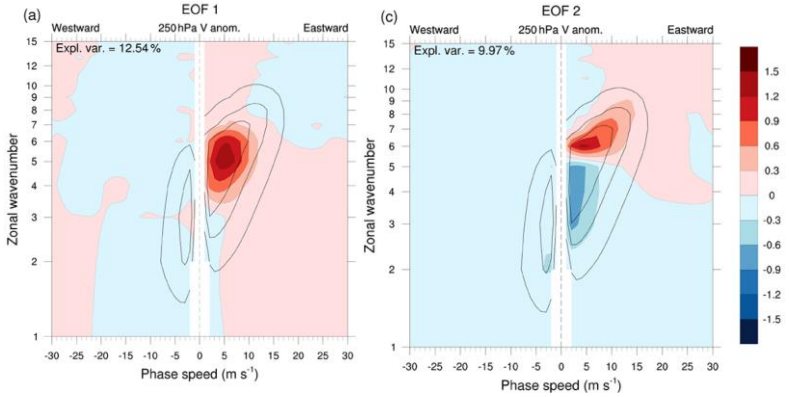
# Key points

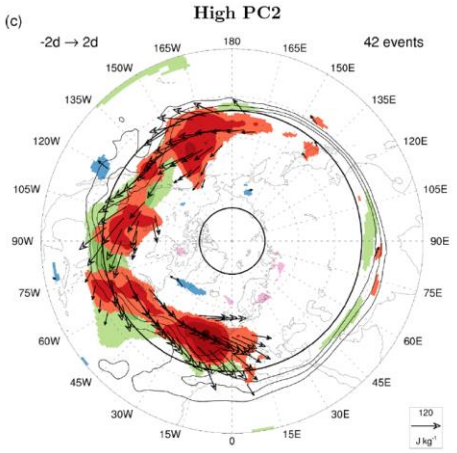
1. **Space-time spectral analysis:** a tool to analyze the complexity of Rossby waves at the hemispheric scale.

2. **Circumglobal Rossby wave patterns** project only on few wavenumbers and propagation speeds: potential for diagnostics.

3. **Insights:** Enhanced meridional geopotential gradient (waveguide) and eastward propagation of transient Rossby wave packets observed during CRWPs.



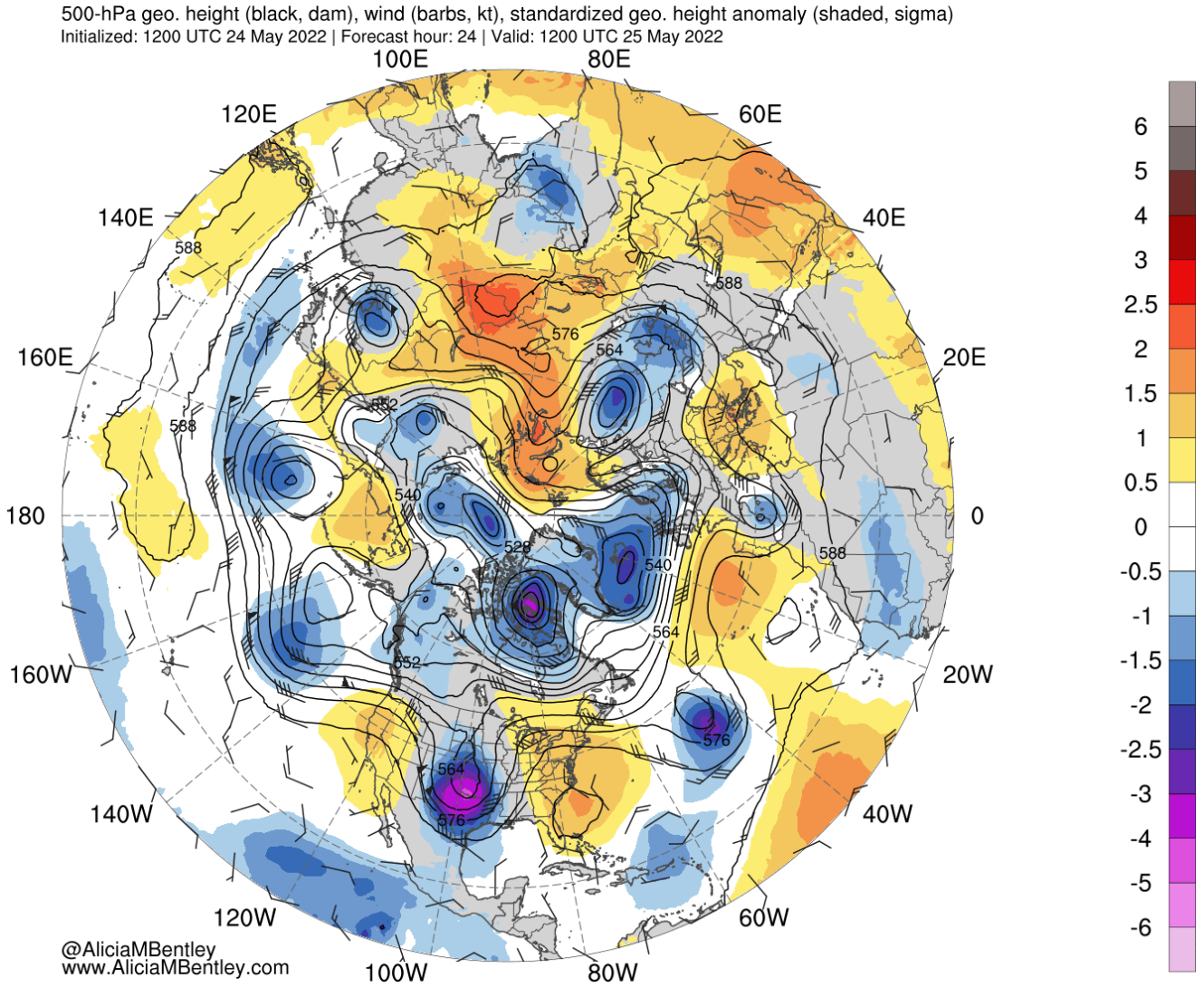




jacopo.riboldi@geo.uu.se

# Space-time spectral analysis

**Problem:**
Rossby waves span a big range of amplitudes, shapes and propagation speeds.

**How to get a compact representation of this complexity?**



# Space-time spectral analysis

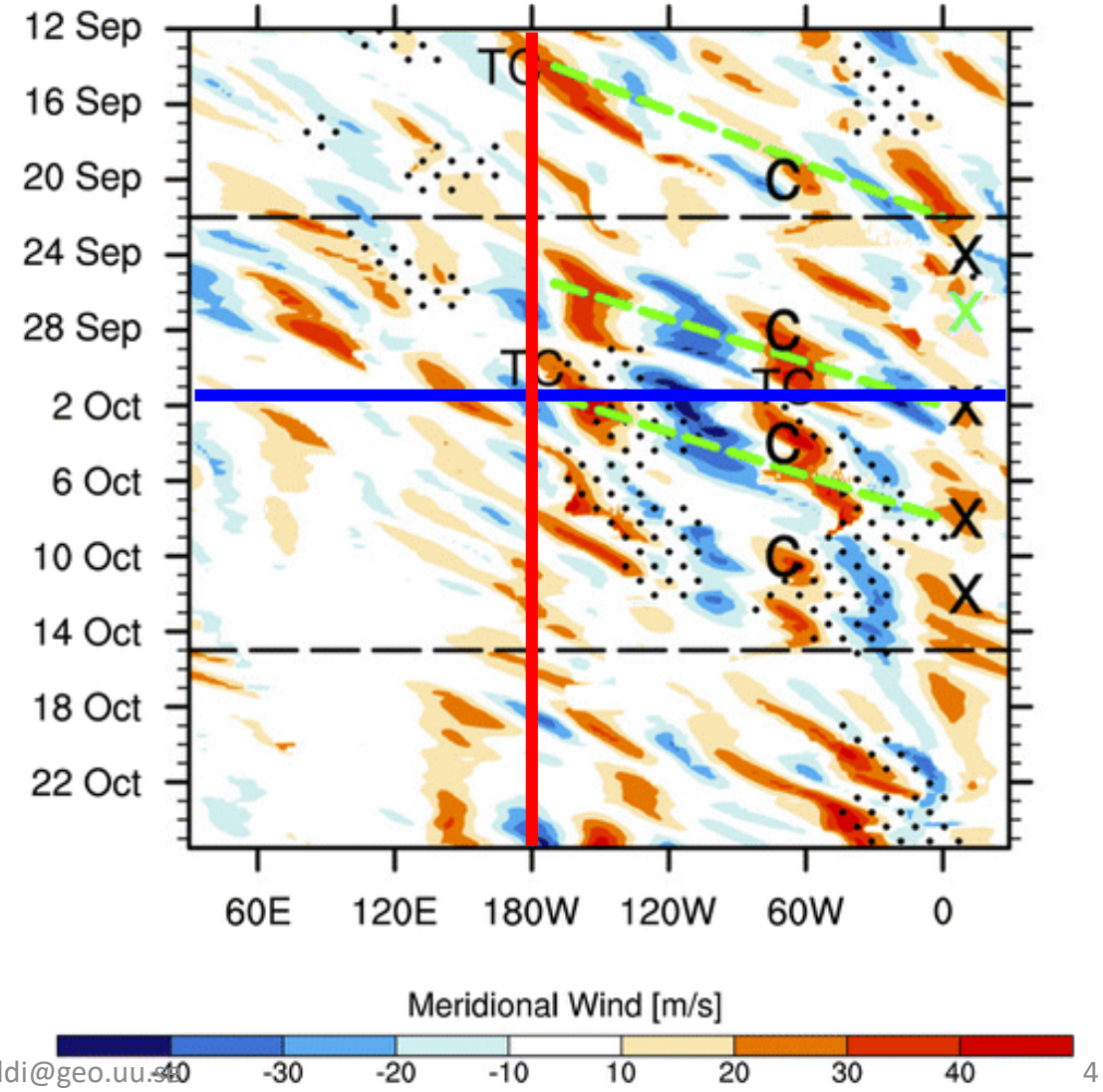
*(example: meridional wind at 250hPa in Autumn 1992, from Wirth et al. 2018).* ***Hoevmoller plot****.*

**Approach:**

**space/time (2D) Fourier analysis of 250hPa meridional wind V (ERA-Interim)**

**In space (latitude circle): spectrum of wavenumbers *n***

**In time (tapered 61d time window): spectrum of frequencies *ω***



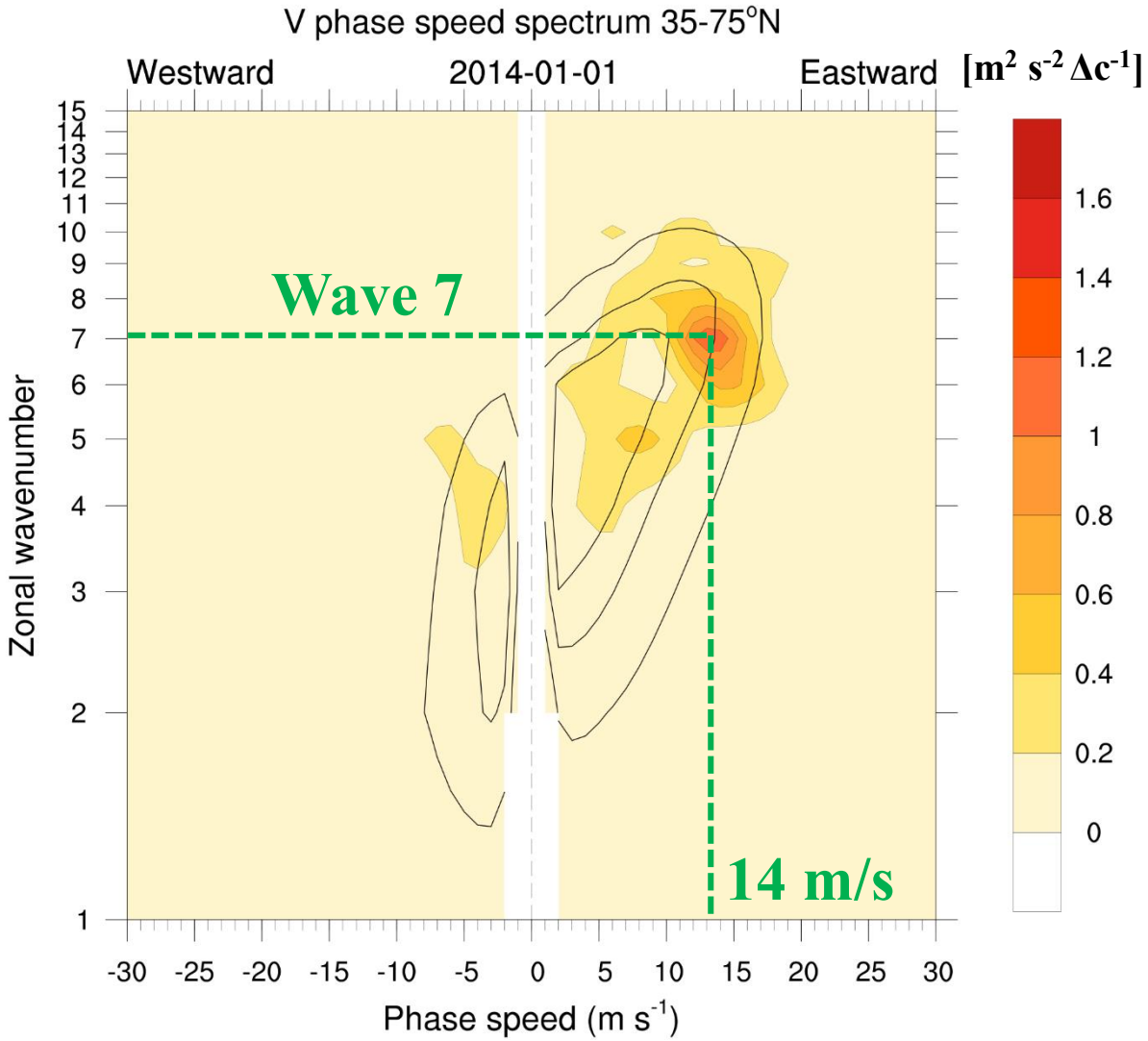
# Space-time spectral analysis

## Interpolation to phase speed and averaging across latitudes (Randel and Held 1991)

$$c_p = \frac{\omega}{k} = \frac{\omega a \cos(\phi)}{n}$$

**Example: 1st January 2014**

- Period period between **1st Dec 2013** and **31st Jan 2014 (inclusive 12-day tapering)**



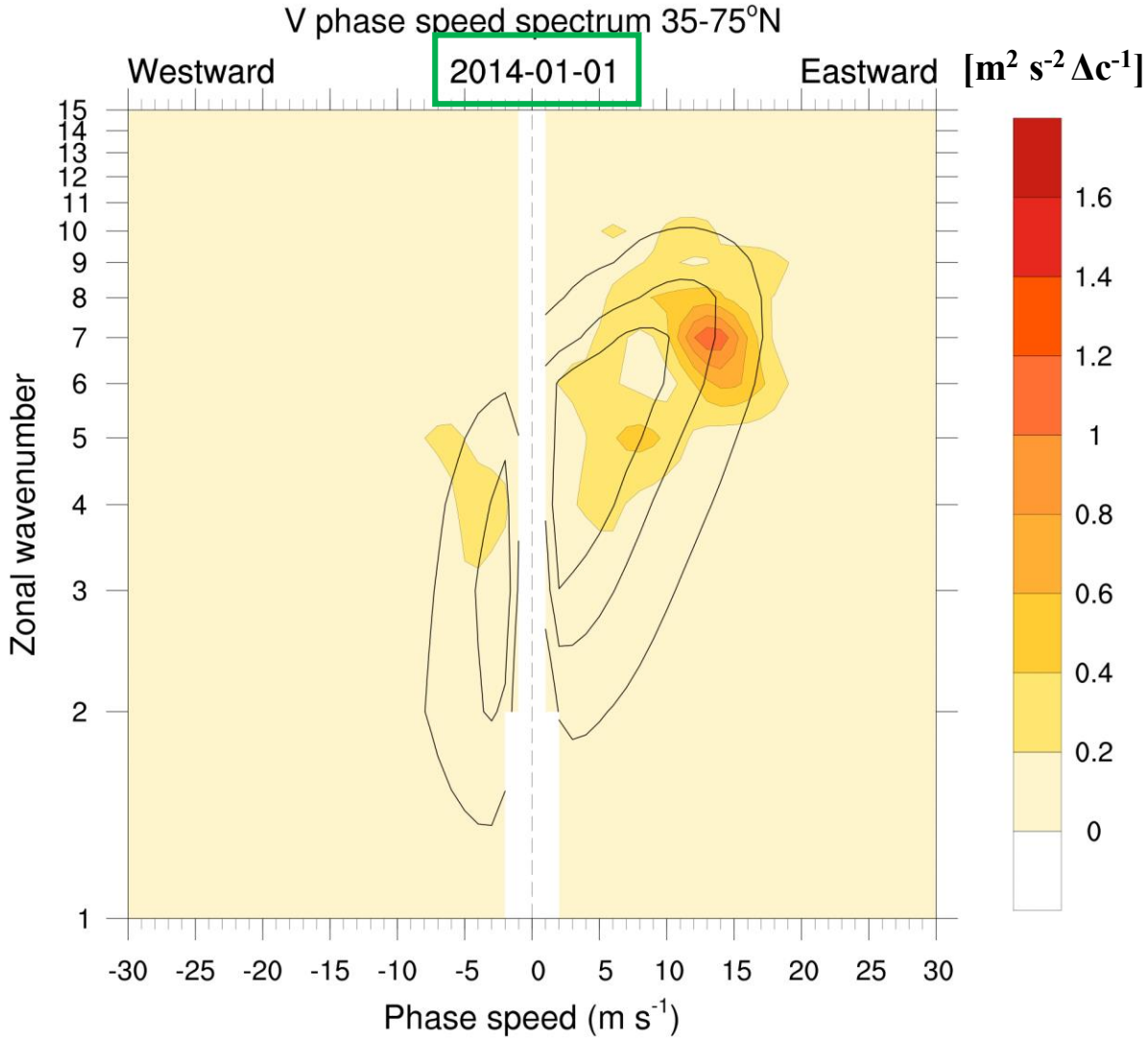

jacopo.riboldi@geo.uu.se

# Space-time spectral analysis

## Loop January 2014

1st part of month
High $(n, c_p)$ harmonics

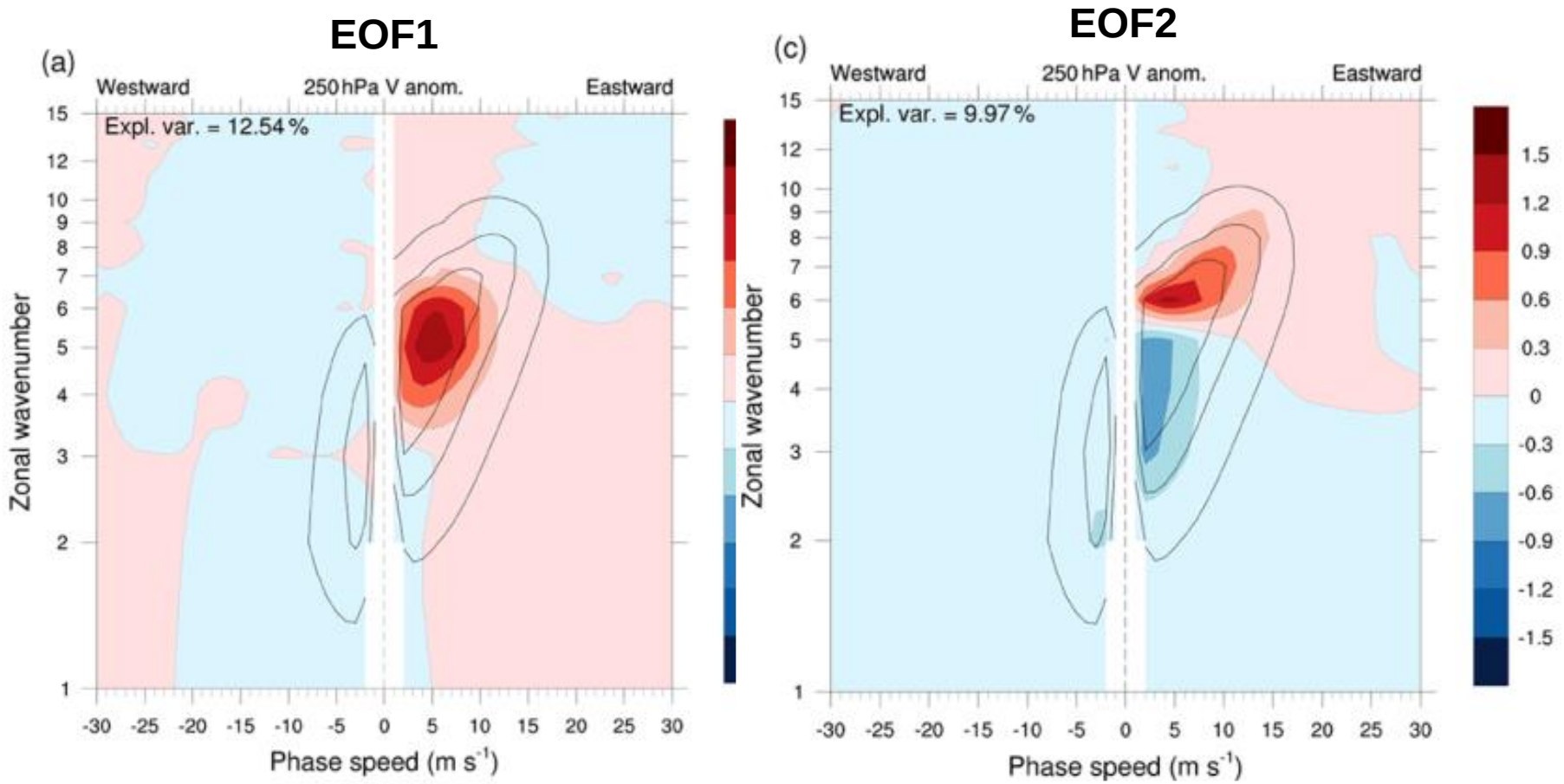
2nd part of month
Low $(n, c_p)$ harmonics




jacopo.riboldi@geo.uu.se

# Circumglobal Rossby wave patterns

**EOF analysis during DJF:** which wavenumber/phase speed harmonics co-vary together?






Riboldi et al. (2022, WCD)

# Circumglobal Rossby wave patterns

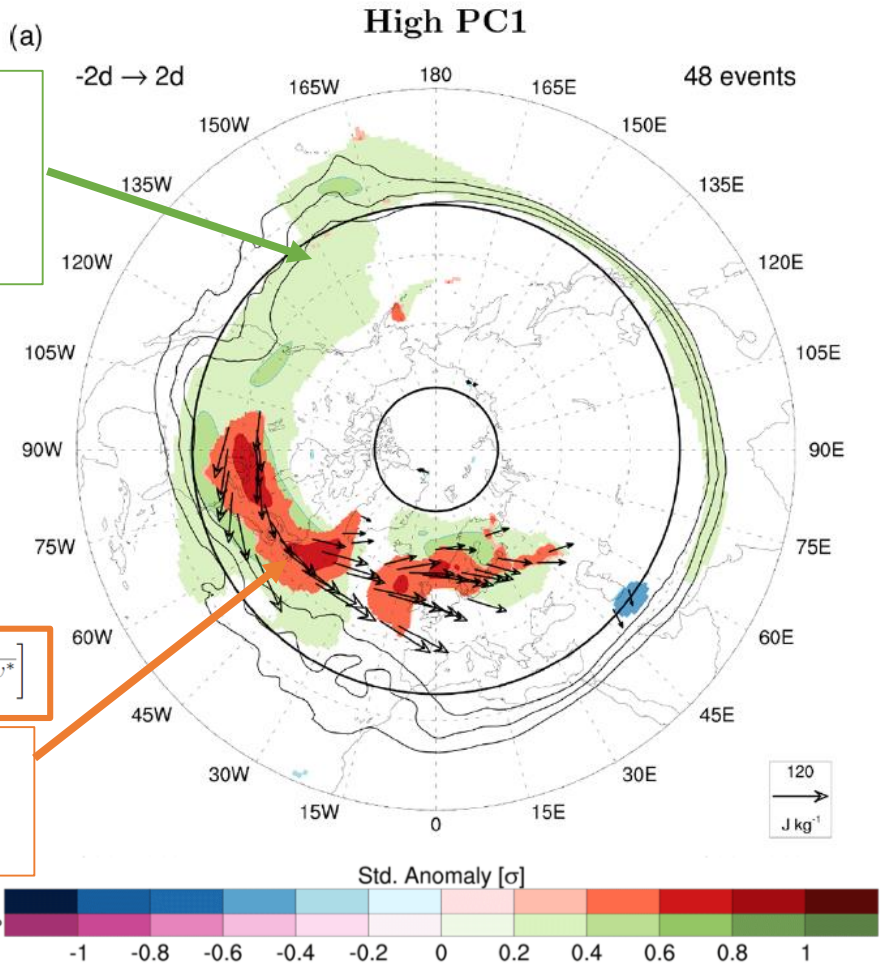
## Composite PC1 events

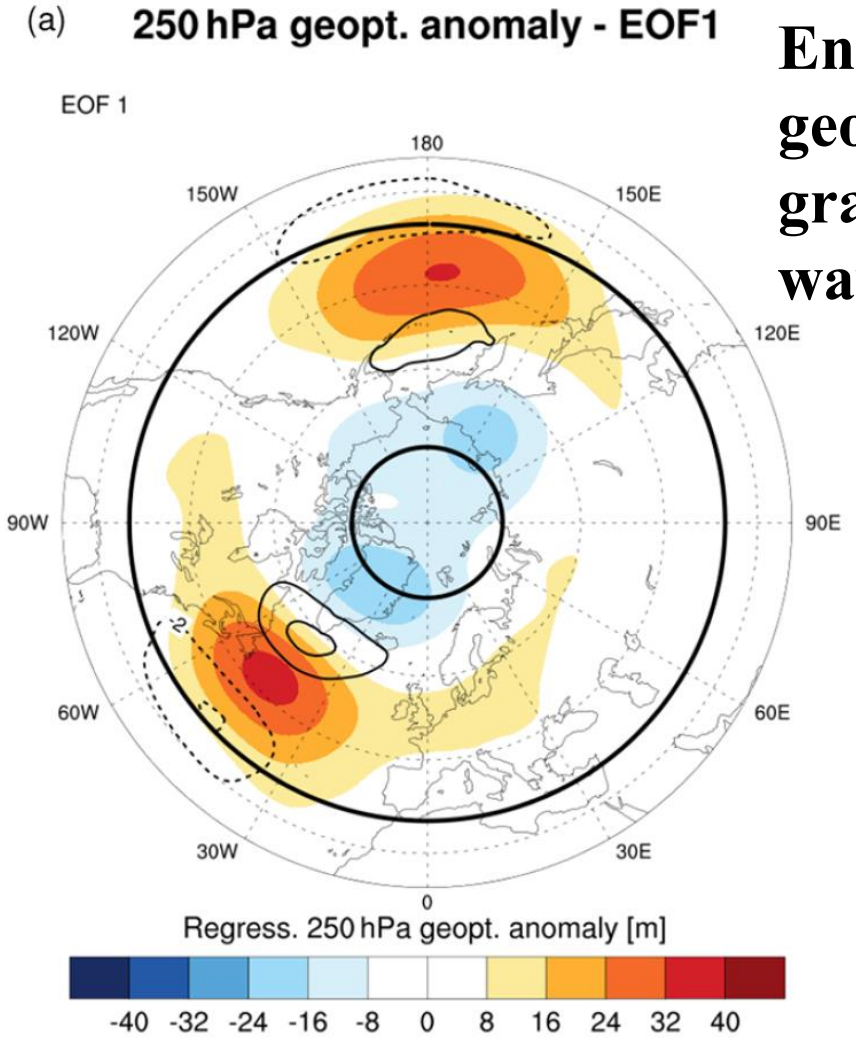
## Regression onto PC1

Anomalies in RWP amplitude

$$\mathbf{E} = (E_x, E_y) = \left[\frac{1}{2}\left(\overline{v^{*2} - u^{*2}}\right), -\overline{u^* v^*}\right]$$

Anomalies in zonal E-vector

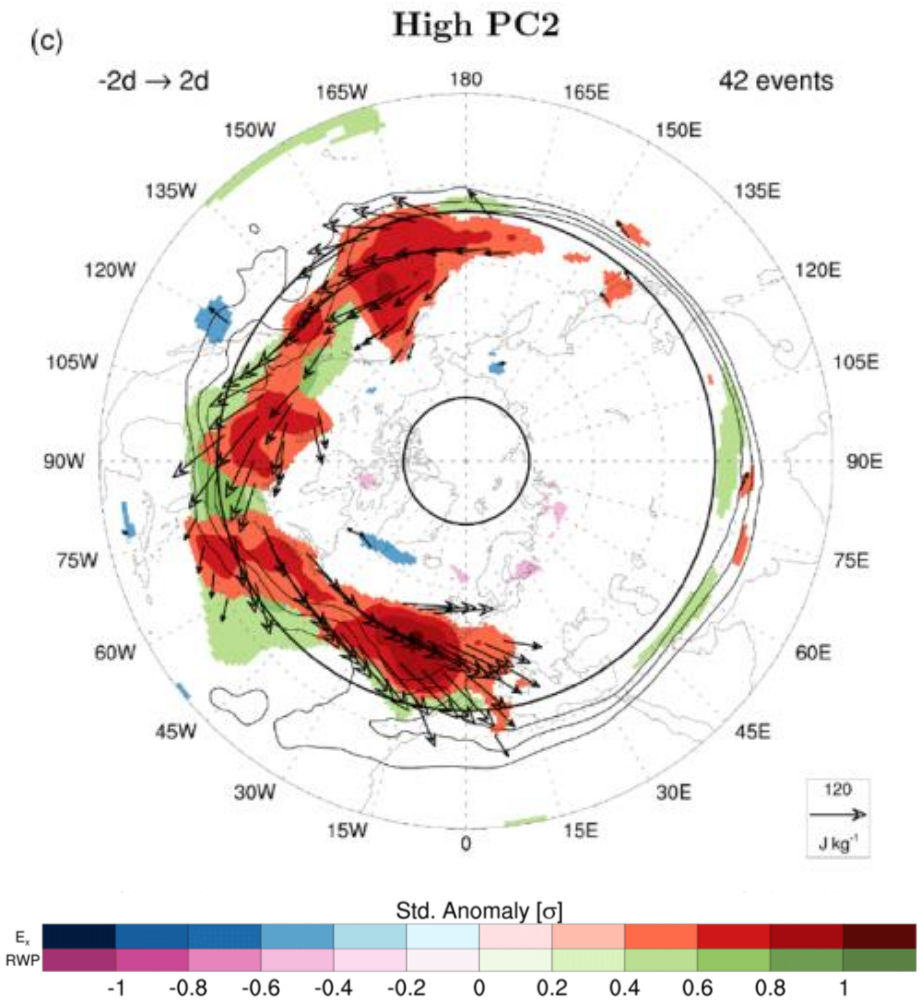


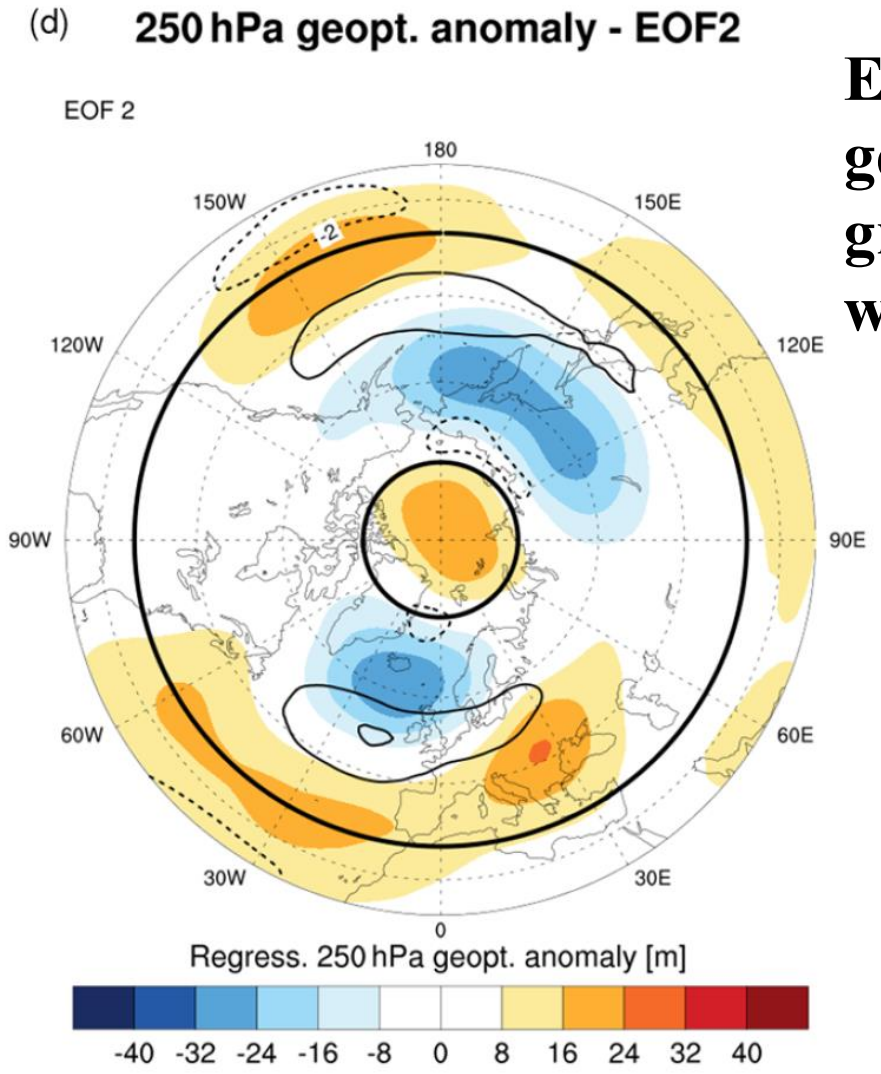

Enhanced geopotential gradient → waveguide

# Circumglobal Rossby wave patterns

## Composite PC2 events




## Regression onto PC2



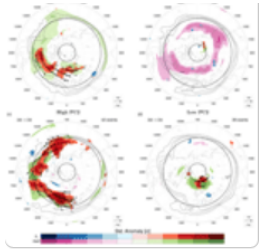

**Enhanced geopotential gradient → waveguide**

# Conclusions

- Circumglobal wave patterns **emerge spontaneously** from spectral variability as projecting onto a small set of wavenumber/phase speed harmonics.
- Results suggest that such patterns are caused by **circumglobal propagation of transient RWPs** with homogenous characteristics (at least during DJF).

**For more infos and discussion of results:**

Circumglobal Rossby wave patterns during boreal winter highlighted by space–time spectral analysis



Jacopo Riboldi[1,2], Efi Rousi[3], Fabio D'Andrea[1], Gwendal Rivière[1], and François Lott[1]

[1]Laboratoire de Météorologie Dynamique/IPSL, École Normale Supérieure, PSL Université, Sorbonne Université, École Polytechnique, IP Paris, CNRS, Paris, France

[2]Department of Earth Sciences, Uppsala University, Uppsala, Sweden

[3]Potsdam Institute for Climate Impact Research (PIK), Leibniz Association, Potsdam, Germany

**Correspondence**: Jacopo Riboldi (jacopo.riboldi@geo.uu.se)

# Supplementary infos (1)

## Event definition

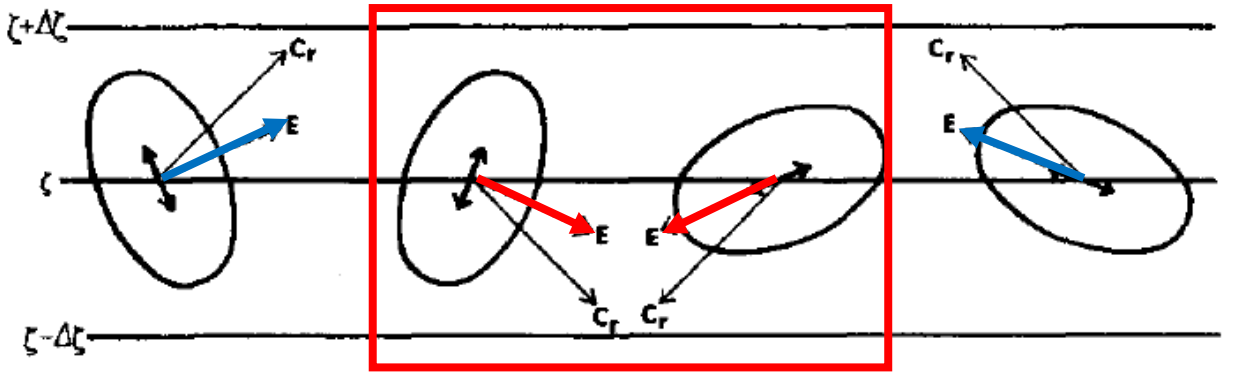
- Top 15% of each PC, minimal duration 5 days
- Minimum separation between events 10 days

## Diagnostics

- **E** vector (Hoskins et al. 1983)

$$\mathbf{E} = (E_x, E_y) = \left[\frac{1}{2}\left(\overline{v^{*2} - u^{*2}}\right), -\overline{u^* v^*}\right]$$

Proxy of the group speed and orientation of the eddies.



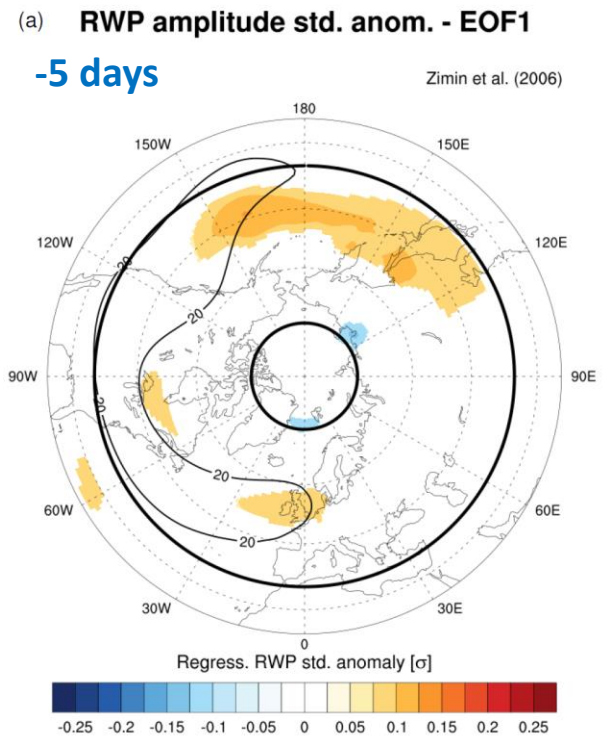

E-vector pointing upward: equatorward eddy momentum fluxes

E-vector pointing downward: poleward eddy momentum fluxes

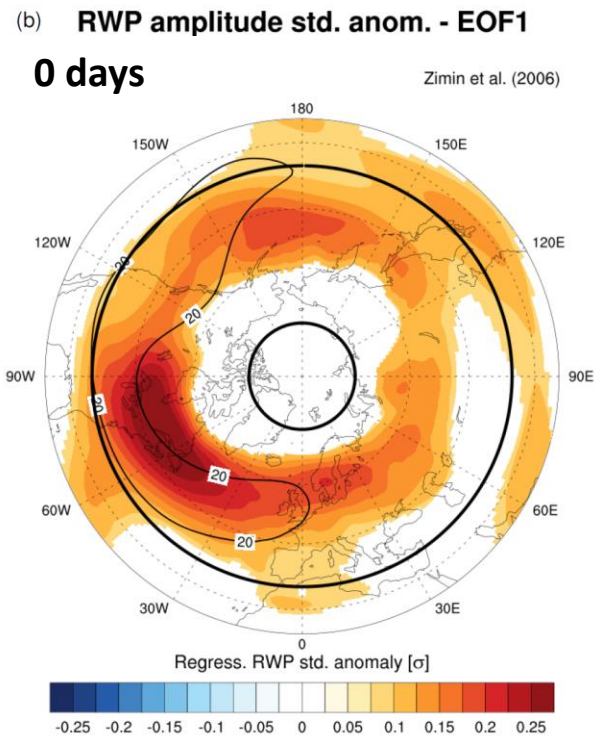
E-vector pointing upward: equatorward eddy momentum fluxes

# Supplementary infos (2)

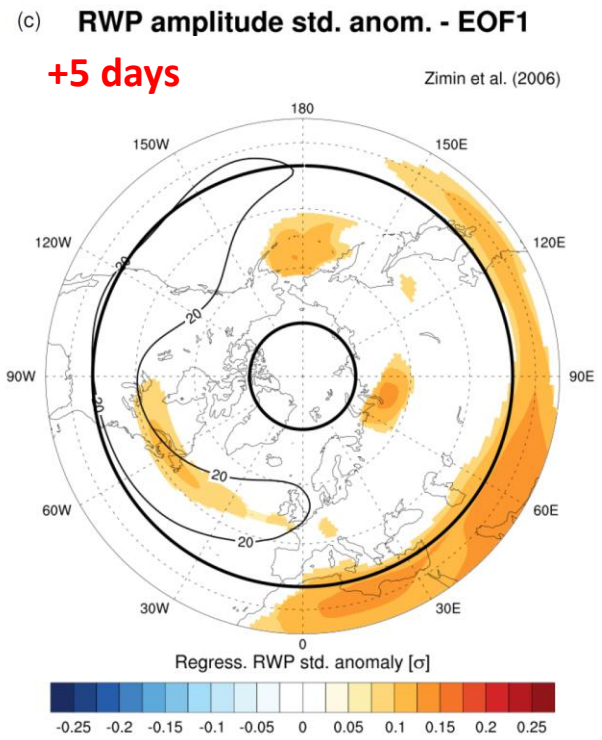
**Lagged regression** can be employed to visualize evolution of waves involved in a given pattern of variability. Here with EOF1:




**Lag -5 days: amplified Rossby waves over Pacific storm track**




**Lag 0: amplification over midlatitudes, maximum at North Atlantic storm track entrance.**




**Lag +5 days: propagation continues along the subtropical jet over North Africa-Middle East.**