Examining the Influence of Stratospheric Polar Vortex Variability and Tropopause Polar Vortices on Rossby Wave Breaking Regimes

UNIVERSITY AT ALBANY
STATE UNIVERSITY OF NEW YORK

Cameron R. Paquette and Andrea Lopez Lang

Department of Atmospheric and Environmental Science; University at Albany, SUNY, Albany, NY

Office of Naval Research – Science & Technology

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1. Introduction

Background:

- **Stratospheric Polar Vortex:** Planetary circulation defined by zonal-mean zonal wind at 60˚N and 10 hPa. Extreme vortex conditions can impact:
  - Arctic Oscillation phase (e.g., Lawrence et al. 2020), tropospheric Rossby wave guide (e.g. Wittman et al. 2007), extreme weather (Domeisen and Butler 2020)
- **Tropopause Polar Vortices** (TPVs): Long-lived (weeks) coherent tropopause-level vortices important in cyclogenesis, Rossby wave guide perturbations, and cold air outbreak occurrence (e.g., Hoskins et al. 1985)

Research Question:

➤ **Are changes in Rossby Wave Breaking (RWB) regimes between extreme stratospheric vortex states partially explained by changes in Tropopause Polar Vortices (TPVs)?**

2. Data & Methodology

Data:

- **ERA-Interim Reanalysis:**
  - Period: Dec–Feb 1979/1980–2016/2017

The Key Players:

- **Stratospheric Polar Vortex:**
  - *ZMW*: Zonal-mean wind @ 60˚N 10-hPa
    - > 90th % = **Strong** vortex (35 events)
    - < 10th % = **Weak** vortex (32 events)
- **TPV (n = 36064)**
  - **Detection** (Szapiro and Cavallo, 2018): *watershed basin* approach
  - Input fields: Tropopause level (2 PVU)
    - Zonal and meridional wind (m s^{-1})
    - Temperature (K)
- **Rossby Wave Breaking (RWB; n = 57621)**
  - **Detection** (Kalderi 2022) of three different types of RWB events:
    - Streamers, Overturns, Cutoffs
  - Input fields: Isentropic surfaces (310K, 330K, 350K)
    - Potential Vorticity
    - Zonal and meridional winds (m s^{-1})
  - Output data:
    - RWB Streamer dates, locations, extents, and magnitudes
    - Anticyclonic (**AWB**) and Cyclonic (**CWB**)
    - Including only top 50% of RWBs by size

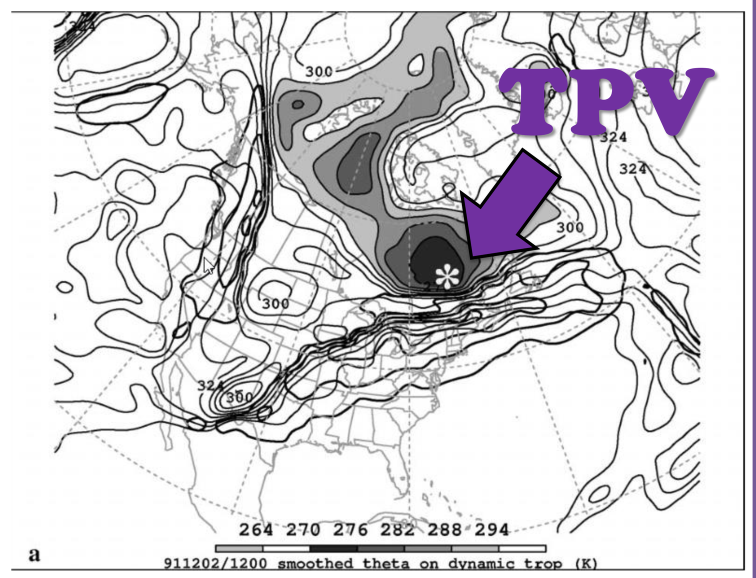


Fig. 1: 2 PVU potential temperature (thin solid, values at and below 342 K contoured at a 6-K interval, shaded as indicated for values below 294 K) and horizontal wind speed on the DT (thick solid; contour interval, 15 m/s; starting at 50 m/s). Star indicates TPV location. *Analysis valid at 0000 UTC 30 Nov 1991* (Pyle et al. 2004)

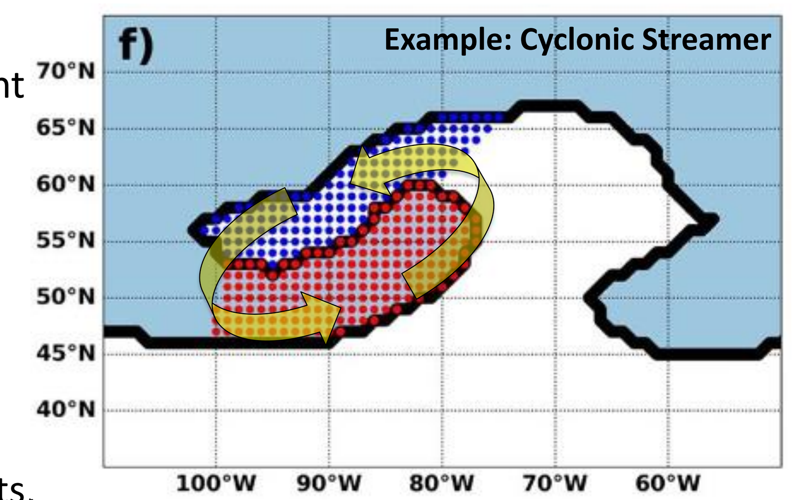


Fig. 2: Identification of a streamer-type Rossby wave break. Black line represents the dynamical tropopause. Shaded (unshaded) regions represent stratospheric (tropospheric) air. Dotted regions correspond to grid points associated with RWB (Blue = Tropospheric, Red = Stratospheric). *Data based on 330K day-averaged PV for 15 July 1979.* (Adapted from Kalderi 2022)

*Underlined indicate focus points for this poster

3. The Hypotheses

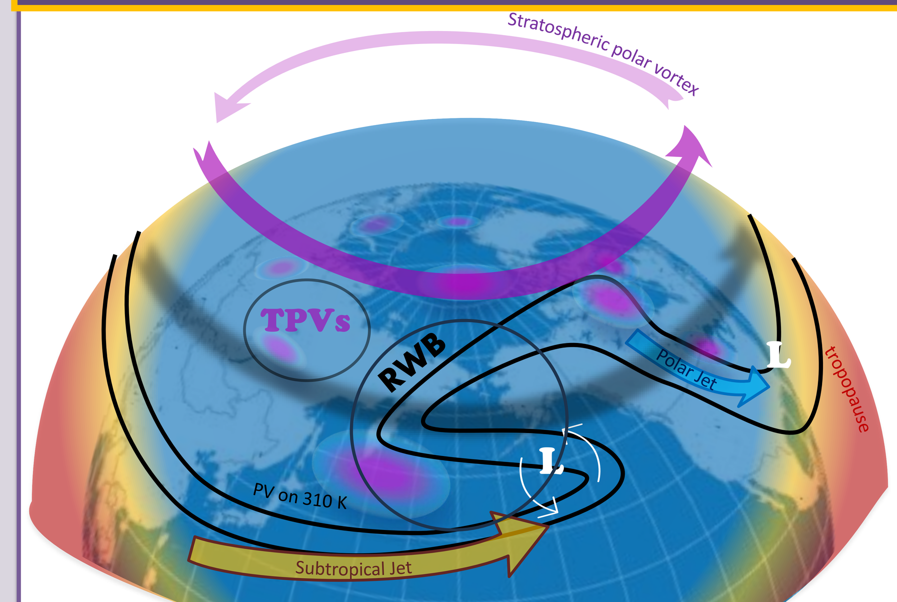


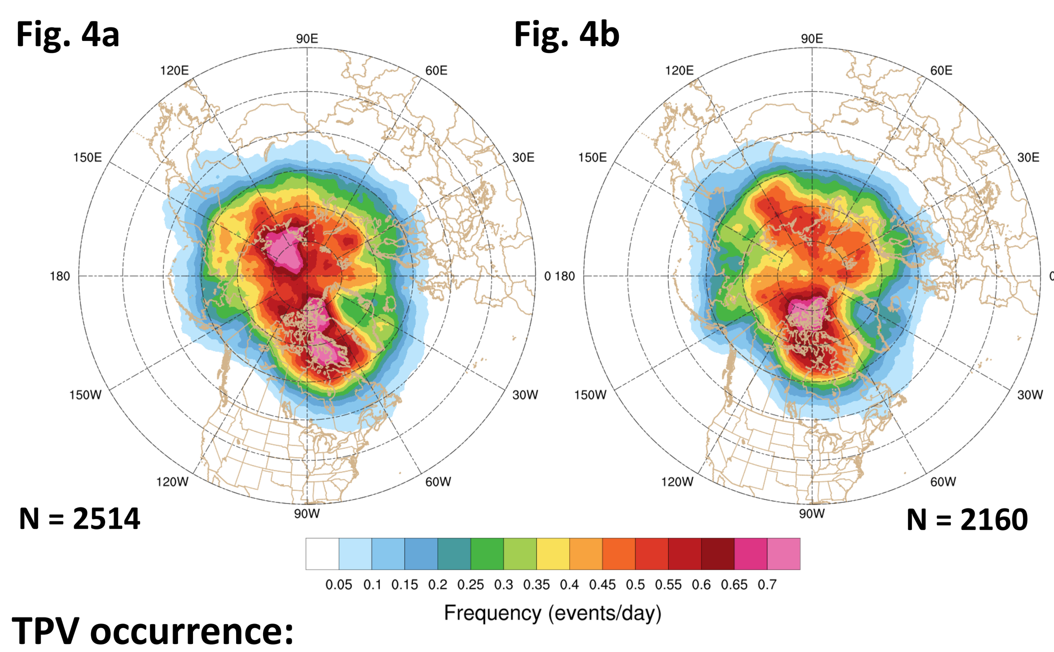
Fig. 3: A schematic representation of the joint effects of the stratospheric polar vortex and TPVs on the Rossby wave guide

General Hypotheses:

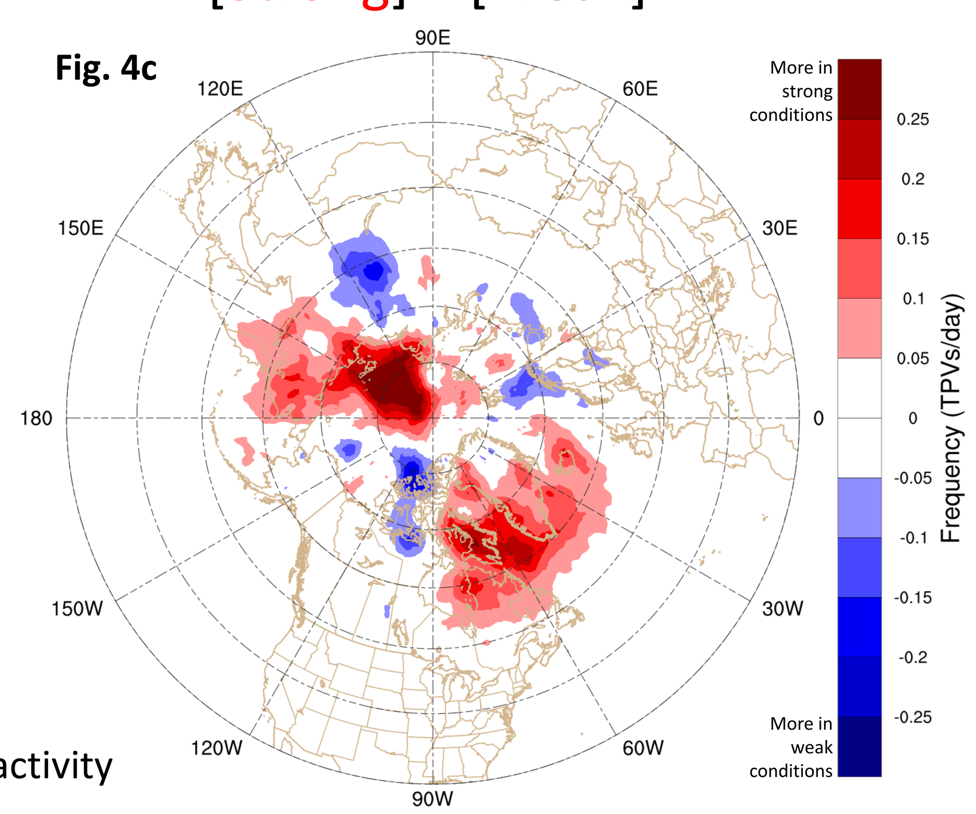
- Stratospheric polar vortex extremes alter background state of lower stratosphere and tropopause regions.
  - TPV characteristics, such as amplitude, location/track, and frequency are impacted by the stratospheric vortex state
  - RWB characteristics, such as location and type, are impacted by the stratospheric vortex state
- TPVs exported from the Arctic during stratospheric polar vortex extremes impact the occurrence of RWB.
  - TPVs and Rossby wave breaking promote long-term and large pattern changes (i.e., persistent blocking patterns)

4. Tropopause Polar Vortices (TPVs)

Weeks 2-4 after event onset



[Strong] – [Weak]



TPV occurrence:

- Strong vortex events: E. Siberian Seas/N. Atl see more TPV activity
- Weak vortex events: No significant increases

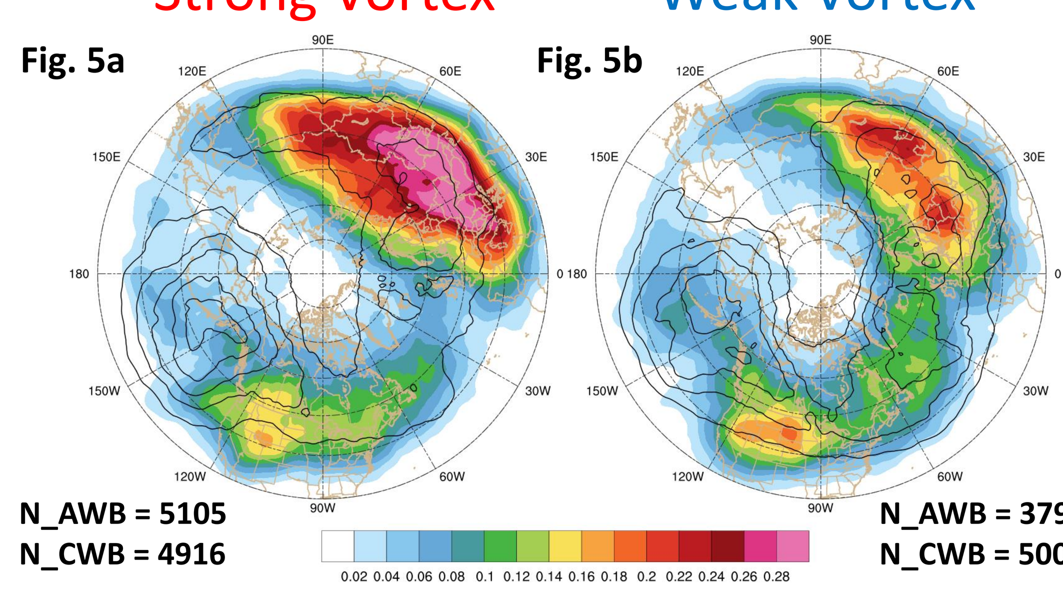
Key Takeaway:

Stratospheric variability may be connected to polar jet through TPV interactions

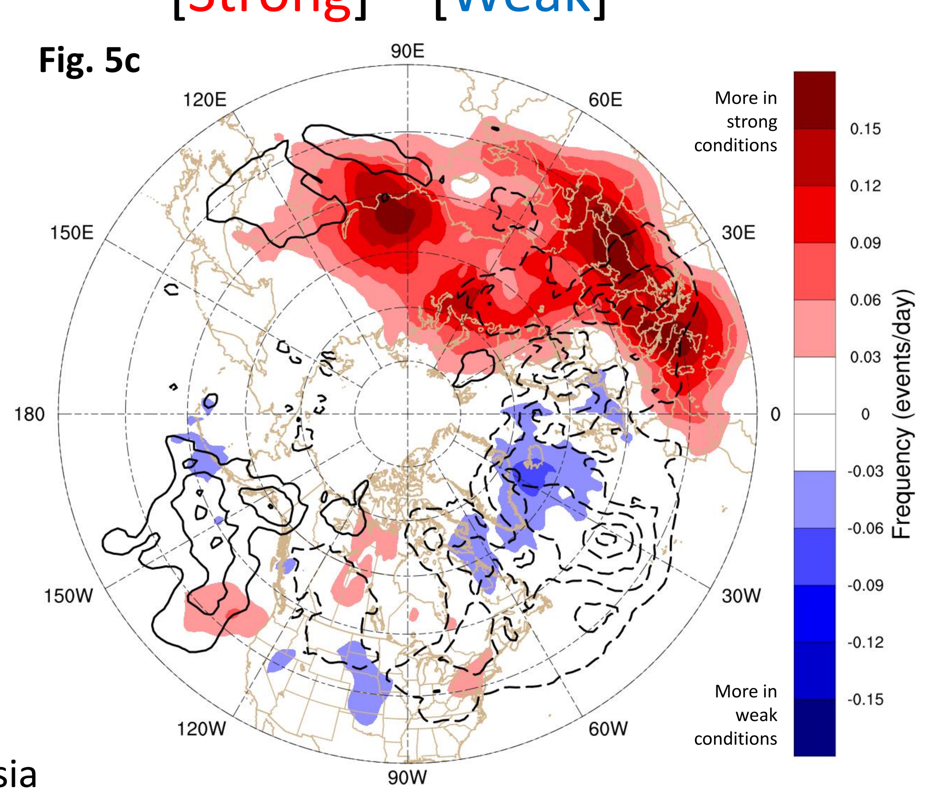
Fig. 4: TPV track densities during strong (Fig. 4a) and weak (Fig. 4b) stratospheric vortex extremes, and differences in TPV track densities between stratospheric vortex extremes, represented as strong - weak (Fig. 4c). Frequencies are calculated as number of TPVs per extreme vortex day.

5. Rossby Wave Breaking – Streamers on 310K

Weeks 2-4 after event onset



[Strong] – [Weak]



Anticyclonic Streamer (AWB) Locations (shading):

- Strong vortex events: Increase in Southern Europe, Central Asia

Cyclonic Streamer (CWB) Locations (contours):

- Weak vortex events (dashed): Increase in North Atlantic

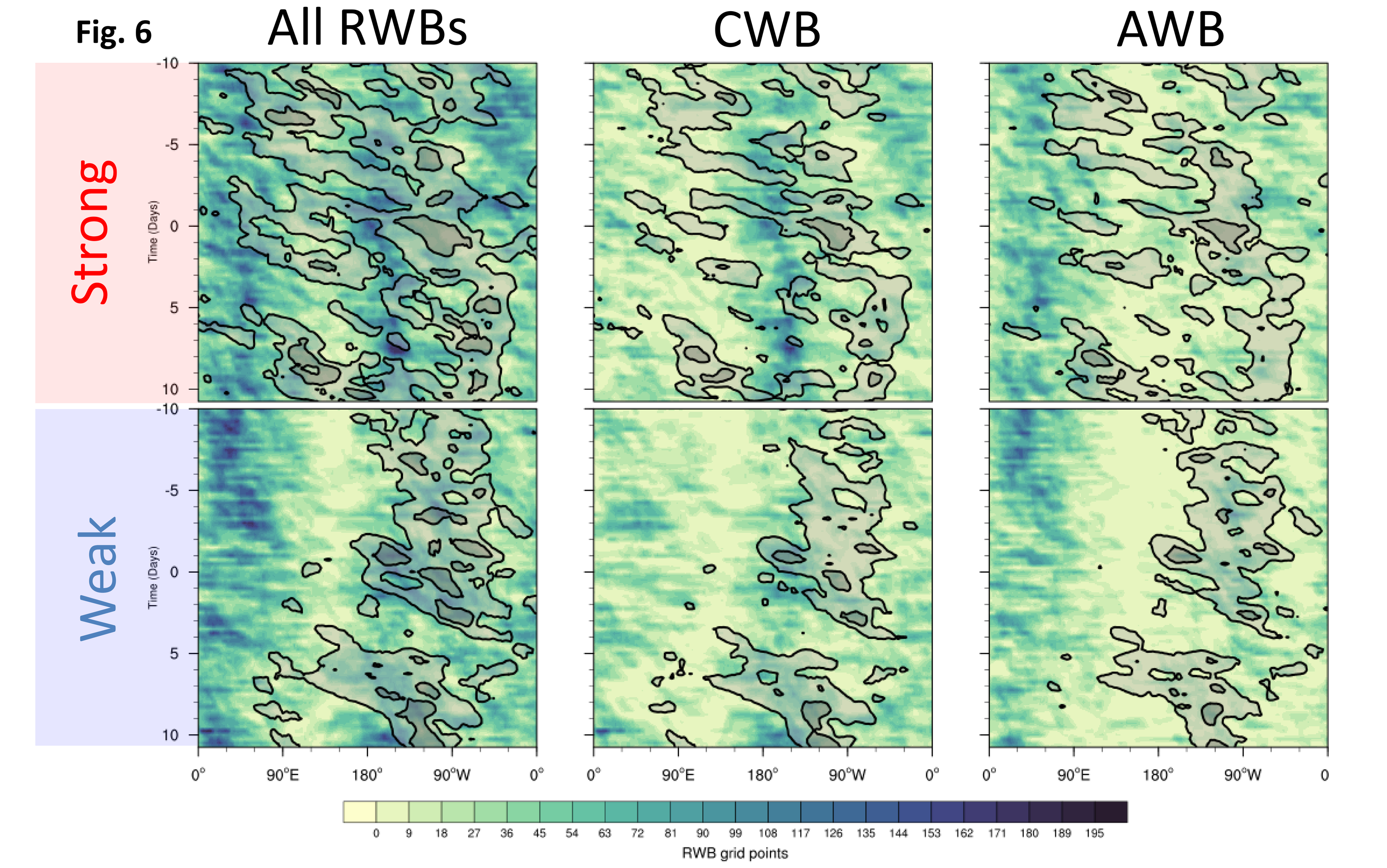
Key Takeaway:

Stratospheric variability linked to shifts in RWB location and type
~30% More AWBs on 310K sfc. during strong vortex conditions

Fig. 5: Streamer-type RWB frequency during strong (Fig. 5a) and weak (Fig. 5b) stratospheric vortex extremes. Shading (contours) represents AWB (CWB) streamers, contours plotted every 0.05 events per day. Differences in streamer-type track densities between stratospheric vortex extremes, represented as strong - weak (Fig. 5c). Shading (contours) represent differences in AWB (CWB) frequency. Contours plotted every 0.03 events per day. Dashed contours indicate negative frequency differences. Frequencies are calculated as number of RWB events per extreme vortex day.

6. Combined Analysis

Key Question: Do we observe differences in spatial or temporal overlap between TPVs and RWB Streamer events based on the stratospheric polar vortex state?



(Above) Fig. 6: Hovmoller plots centered on the 10 days before and after strong (top) and weak (bottom) stratospheric vortex conditions. The number of 35–75˚N grid points associated with all RWB streamers (left), CWB streamers (center), and AWB streamers (right) are shaded according to color bar, and the corresponding TPV are contoured every 50 TPVs (starting at 100) with grey shading. Only TPVs observed during same times as the corresponding RWB streamers are included for each column.

(Below) Fig. 7: Differences (strong – weak) in RWB Streamer events and TPVs shown in Fig. 6. Solid (dashed) contours represent increased TPV count during strong (weak) vortex events. Contour interval is every 50 TPVs.

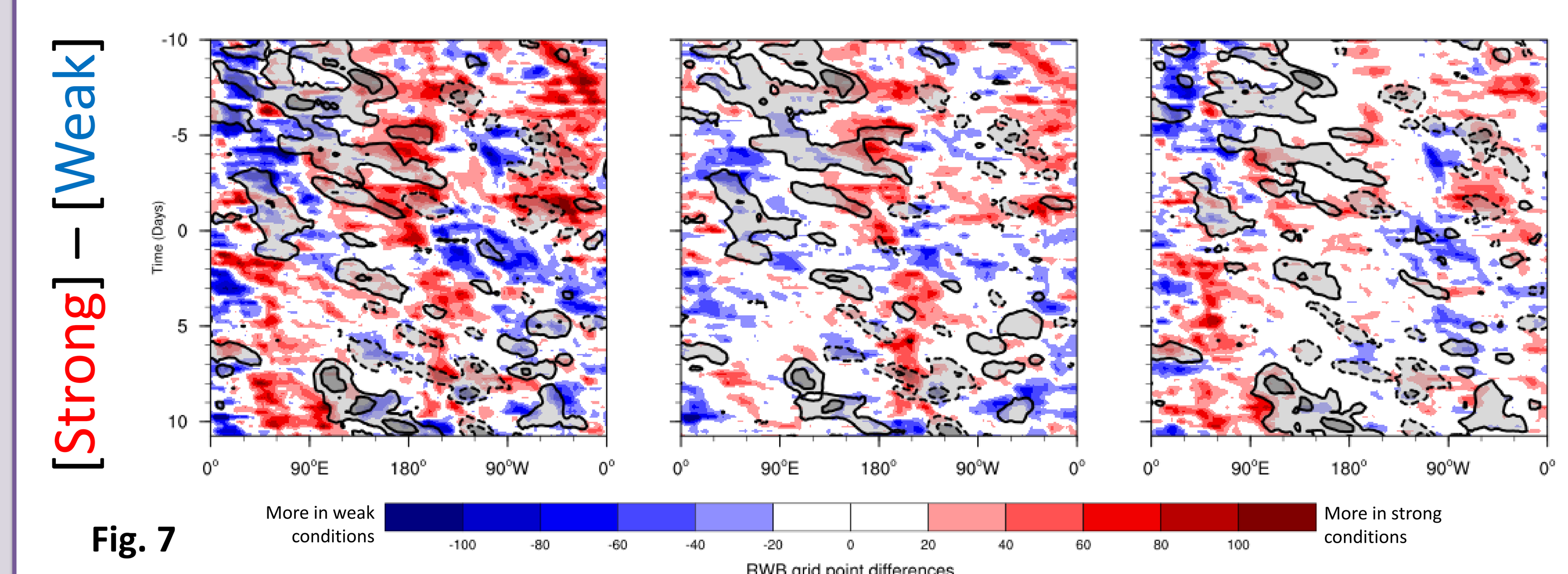


Fig. 7

Cyclonic Streamers (CWB):

- N. Pac jet exit regions have increased CWBs in strong vortex consistent with earlier analysis
- N. Atl jet transition at stratospheric event onset, more CWB after weak & more CWBs prior strong

Anticyclonic Streamers (AWB):

- European jet transitions at stratospheric event onset, more AWBs prior to weak & more AWBs after strong

TPV Questions:

- Increased propagation in midlatitude during strong vortex events?
- Are TPVs initiating CWB before onset of strong vortex event?

7. Conclusions and Future Work

Do we observe changes in TPVs and RWB Events during stratospheric vortex extremes?

➢ TPVs: Shifts in preferential jet interactions between extremes
➢ CWBs: North Atlantic during weak vortex | AWBs: Eurasia during strong vortex

Are there any potential connections between TPVs and RWBs?

➢ Some spatial overlap in TPV and RWB frequency (e.g. North Atlantic)
➢ TPV propagation speed increases during strong vortex events upstream of CWB events

Next Questions:

➢ **Does the absence of TPVs in N. Atl. during weak vortex events promote CWB?**
➢ **Dynamical implications of increased TPV frequency in the Siberian Arctic?**

8. References

Scan the QR code to view references!

Contact: Cameron Paquette
crpaquette@albany.edu

Thank You!