The Combined Influence of the MJO and the Stratospheric Polar Vortex on NH Winter Weather Patterns

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P-A8-03

MOTIVATION

- Two modes of climate variability that affect the Northern Hemisphere (NH) polar jet stream variability are the **Madden-Julian Oscillation** [MJO; *Madden and Julian*, 1971] and the **stratospheric polar vortex** [SPV; e.g., *Baldwin and Dunkerton*, 1999, 2001].
- Understanding how these modes interact with the Northern Hemisphere (NH) polar jet stream is a key to narrowing the subseasonal-to-seasonal (S2S) prediction gap [*Vitart et al.*, 2012].

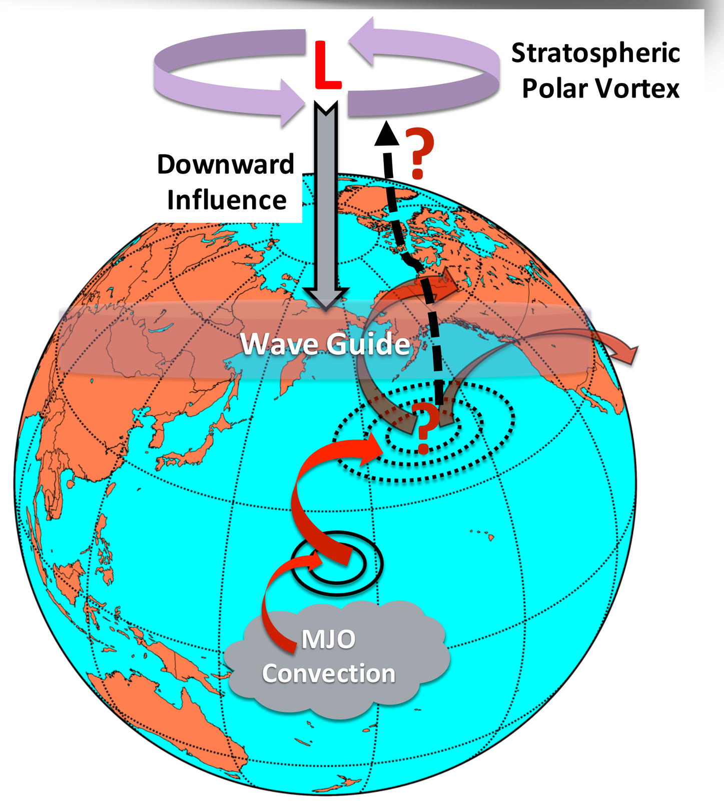


FIG. 1. Diagram of the central hypothesis for this project.

- Past works have considered the influences of these modes separately, but that does not have to be the case (*and likely is not*).
- **This work takes a novel approach and explores the importance of considering the strength of the SPV in understanding MJO interactions with the extratropical atmosphere (FIG. 1).**

DATA AND METHODS

- **Reanalysis:** ERA-Interim daily-mean fields from 1979–2018, with focus on October - March (i.e., the active season for MJO & SPV).
- The **MJO** (phase and amplitude) is defined using the *OLR MJO Index* [OMI; *Kiladis et al.,* 2014], as the excited wave patterns are more tied to the MJO-related convection than the wind pattern.
- The strength of the **SPV** is defined by the standardized Northern Annular Mode (NAM) index at 100 hPa [NAM_{100}; e.g., *Thompson and Wallace,* 2000]. This level captures stratospheric events that are most likely to propagate down into the troposphere.
- **Composite Criteria:**
  - An **MJO Event** is defined when the amplitude of the OMI Index is >1σ for a given phase. Cases when the amplitude is <1σ are considered **neutral**.
  - A **Strong (Weak) SPV Event** is defined when NAM_{100} is >1σ (<-1σ) for five consecutive days. When the NAM_{100} is between ±1σ , the SPV is considered **neutral.**

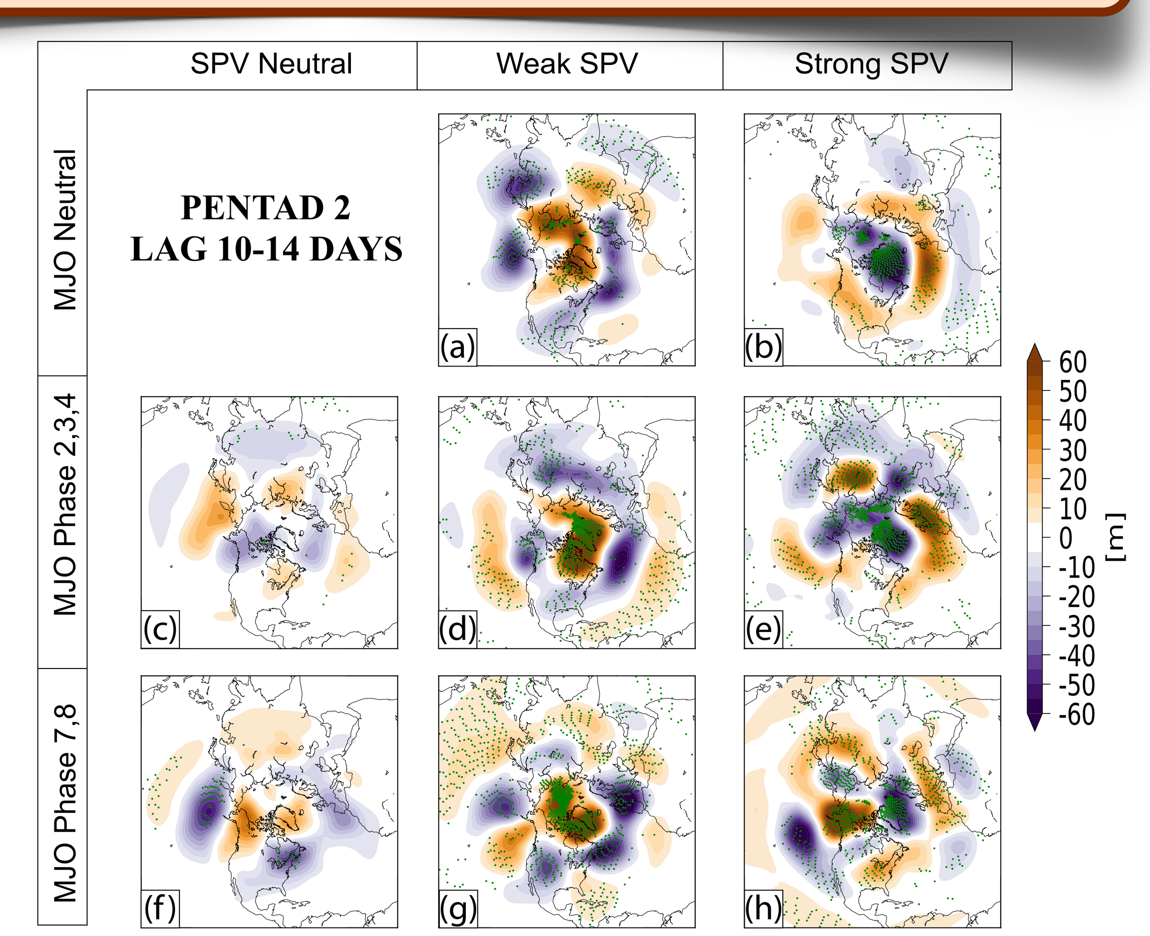
Phases 2,3,4 (Phases 7,8) are grouped together and chosen because they represent active (suppressed) convection over the Indian Ocean (Maritime Continent) – i.e., nearly opposite of each other.

	Neutral SPV	Weak SPV	Strong SPV
Neutral MJO		40	40
MJO 2,3,4	93	26	34
MJO 7,8	87	21	18

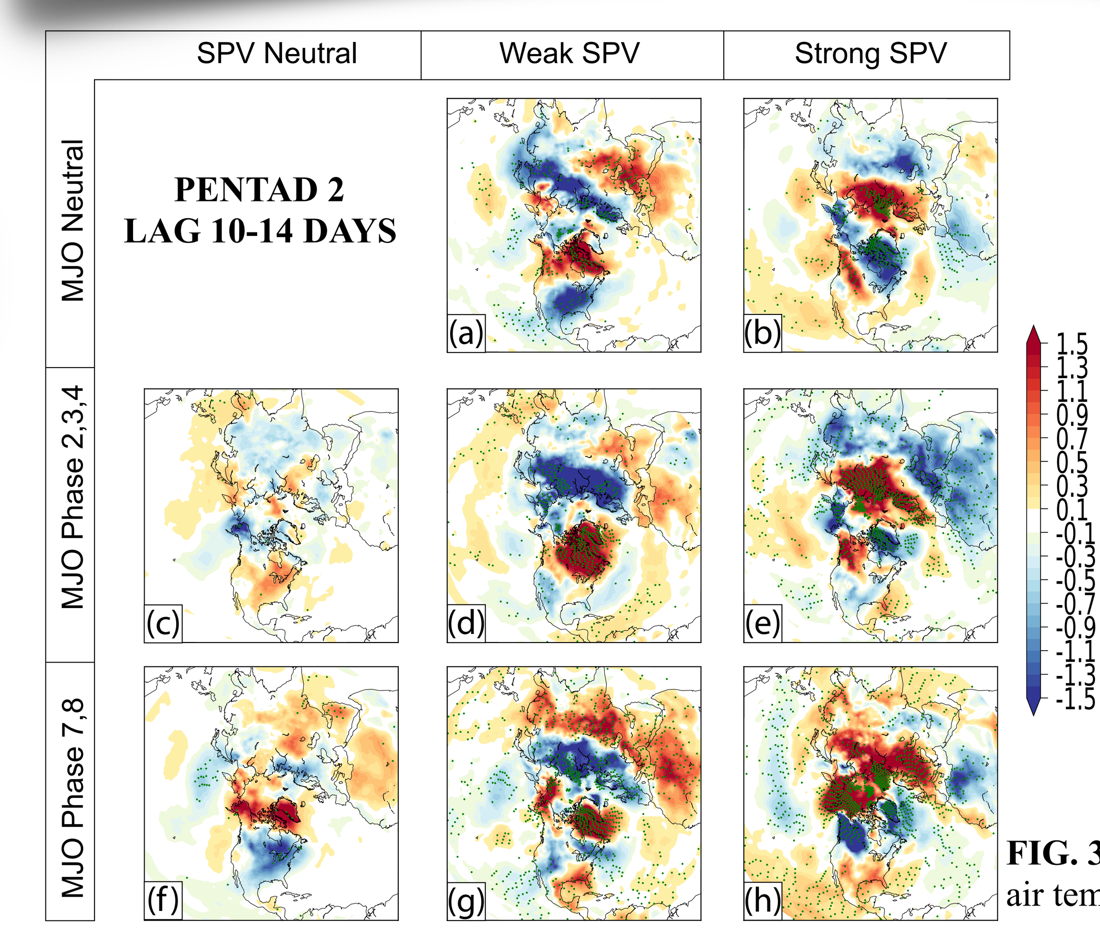
TABLE 1. Number of events per case explored in the study. Only days in October - March (i.e., the extended cold season) are considered.

RESULTS - 500 hPa GPH

FIG. 2. Lag composite of 500 hPa geopotential height anomalies (m) for the various conditional composite cases: **(a)** Weak SPV/MJO Neutral, **(b)** Strong SPV/MJO Neutral, **(c)** MJO 2,3,4/SPV Neutral, **(d)** MJO 2,3,4/Weak SPV, **(e)** MJO 2,3,4/Strong SPV, **(f)** MJO 7,8/SPV Neutral, **(g)** MJO 7,8/Weak SPV, and **(h)** MJO 7,8/Strong SPV. The lag imposed is 10-14 days after the start of the MJO event. Stippling indicates where anomalies are significant (i.e., 66% of the individual events have the same signed anomaly as the composite mean).



RESULTS - SURFACE TEMPERATURES

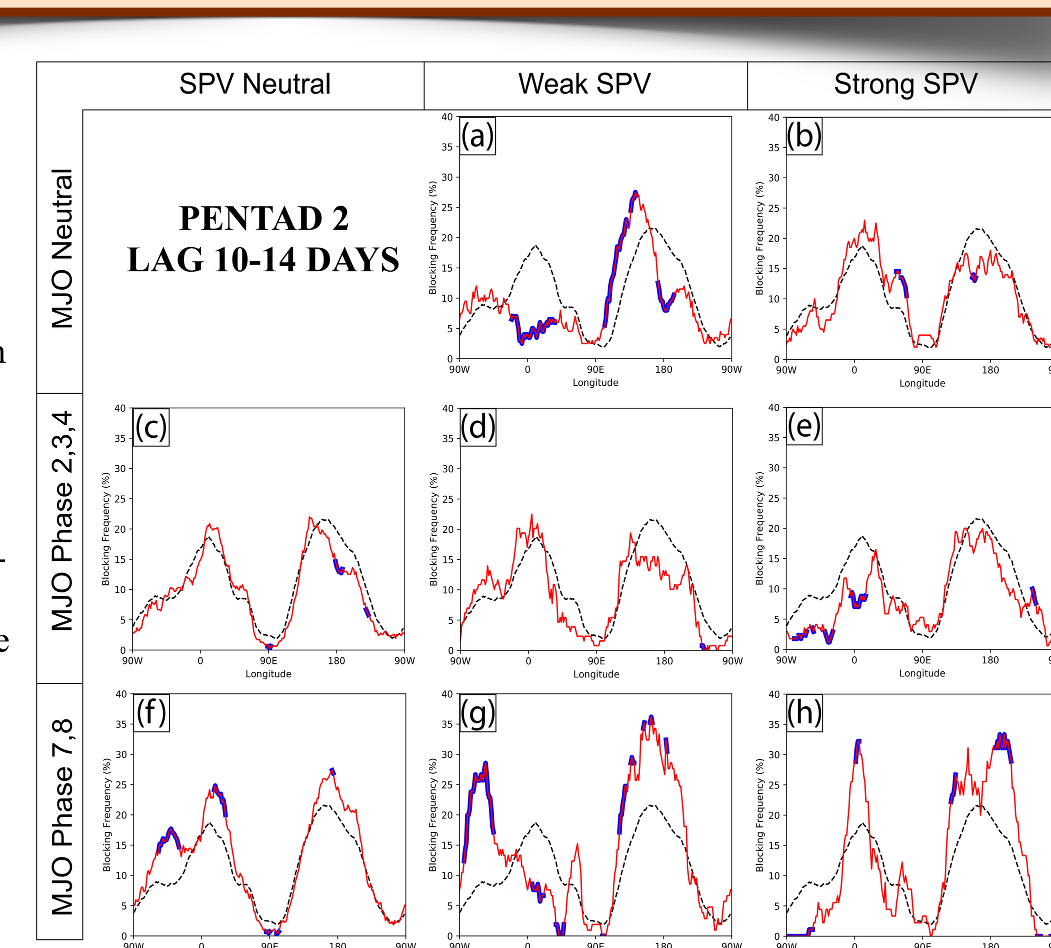


MJO / Neutral SPV composites have almost no consistency between amongst events, suggesting that the SPV might be an important discriminator.

FIG. 3. As in **FIG. 2** except for surface air temperature anomalies (K).

RESULTS - BLOCKING FREQUENCY

FIG. 4. (Red solid line) Lag composite (Days +10 to +14) mean blocking frequency between **40°N and 60°N** using the *Tibaldi and Molten* [1990] methodology for each conditional case during October - March (see headers). **(Black dashed line)** The October-March climatological blocking frequency. Blue dots denote where the difference between the composite mean and climatology is significant at the $p < 0.1$ level, according to a Monte Carlo test.



RESULTS - EP FLUX DIAGNOSTICS

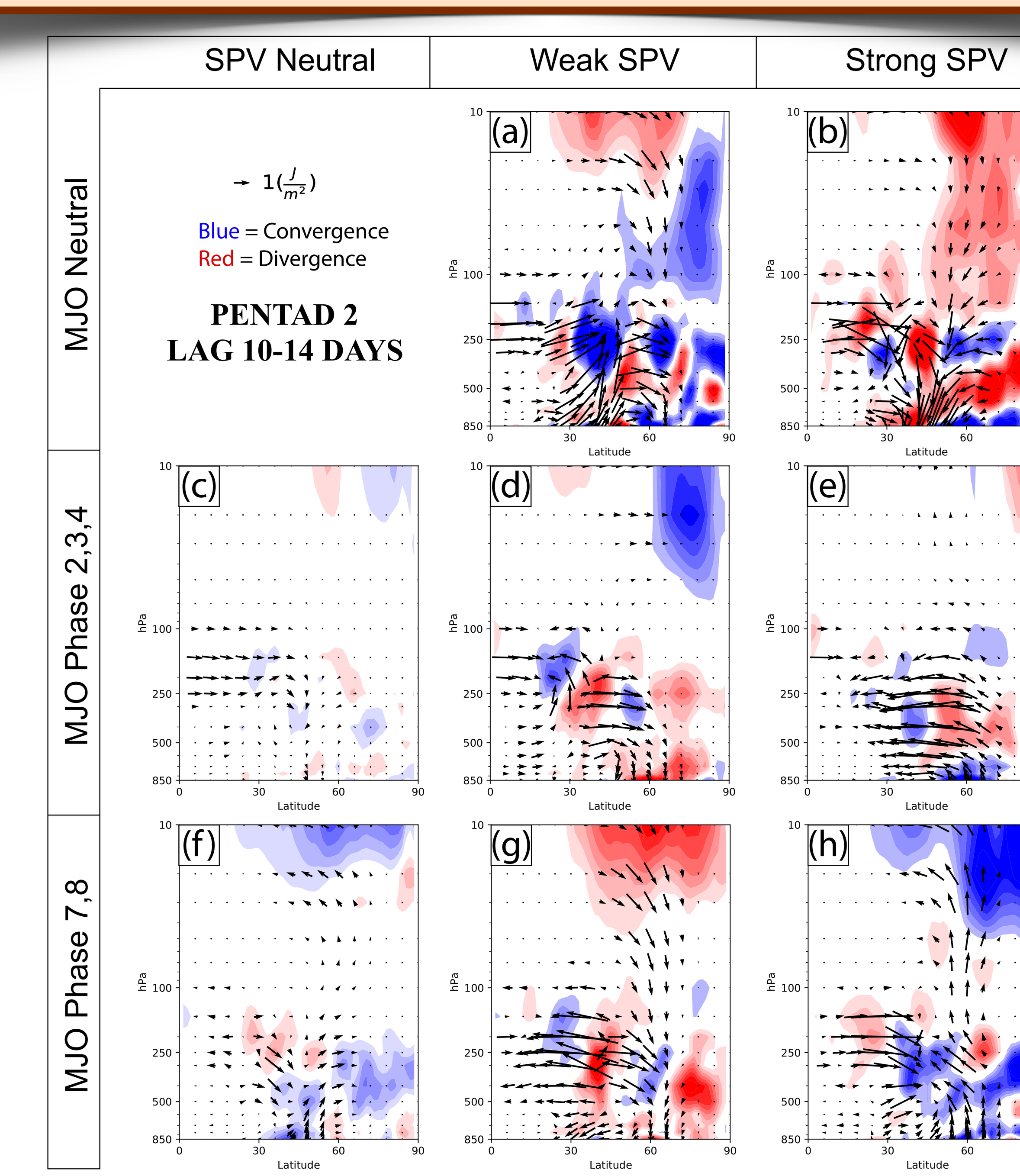


FIG. 5. Conditional lag (Days +10 to +14) composite of Eliassen-Palm (EP) flux anomalies (vectors; $J\ m^{-2}$) and EP flux convergence (shaded contours; m/s/day) for the same cases as **FIG. 2**. Blue (red) shading indicates EP flux convergence (divergence). Contour interval 0.25 m/s/day; zero contour omitted. Vectors are scaled similar to the methodology in *Edmon et al.* [1980].

CONCLUSIONS AND ONGOING WORK

- The MJO exerts a dominant control of the atmospheric patterns across the North Pacific, while the influences of the SPV dominates the tropospheric flow pattern over the North Atlantic and Europe.
- Significance of MJO-related teleconnections in tropospheric heights, surface temperatures, and jet stream winds (not shown) emerge when analyzing the *conditional* composites. This fact becomes important for S2S forecasts in areas like North America & Asia.
- MJO influences on the stratosphere may also be contingent on the state of the SPV, especially for MJO Phases 7/8. How these interactions may or may not feed back downward onto the troposphere and/or the MJO itself remains to be investigated.
- **ONGOING WORK:** (1) Are these interactions just linear? Analyses using linear regression instead of compositing indicate not entirely. (2) Examining these links in the S2S Model Database [*Ciasto et al.*, 2019, in prep]; (3) Investigating MJO / SPV interactions using **causal discovery** [*Barnes et al.*, 2019, in prep].

ACKNOWLEDGEMENTS

- This work is funded by the NOAA Modeling, Analysis, Prediction, and Projections (MAPP) Program (**Grant # NA16OAR4310090**) and is also part of work for the newly formed NOAA S2S Task Force.