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

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MOTIVATION

- Two climate modes that affect 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].
- Past studies have considered the influences of these modes separately on subseasonal-to-seasonal (S2S) weather regimes, but that does not have to be the case (*and likely is not*).
- This work takes a novel approach and explores the importance of the strength of the SPV **and** the MJO jointly on associated extratropical weather patterns **(FIG. 1).**

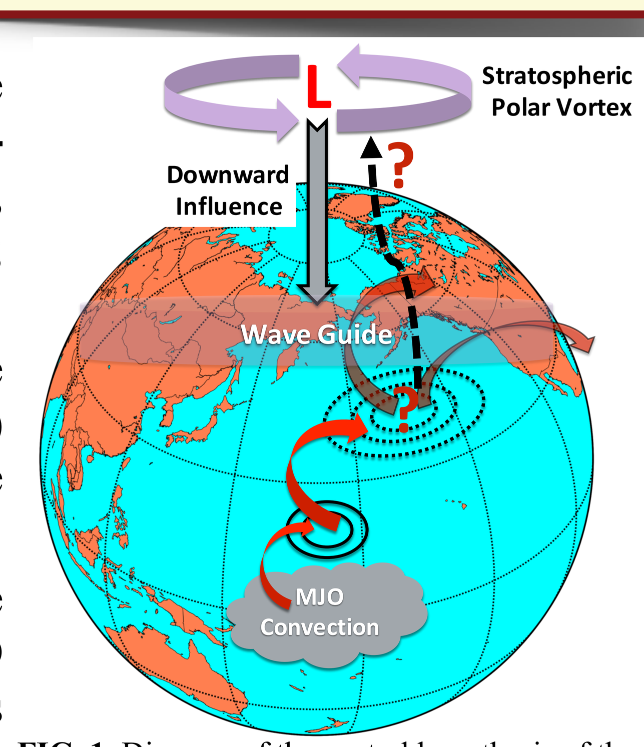


FIG. 1. Diagram of the central hypothesis of the project.

DATA AND METHODS

- **Reanalysis:** ERA-Interim daily-mean fields; October - March 1979–2018 (i.e., the active season for the MJO & SPV).
- **MJO Index (Phase and Amplitude):** OLR MJO Index [OMI; *Kiladis et al.,* 2014].
- **SPV Index:** Standardized Northern Annular Mode (NAM) index at 100 hPa [NAM_{100}; e.g., *Thompson and Wallace,* 2000].
  - Captures stratospheric events most likely to propagate into the troposphere.
- **Composite Criteria:**
  - ***MJO Event:*** |OMI| >1σ for a given phase for three (3) consecutive days. **Neutral MJO** events occur when |OMI| < 1σ.
  - ***Strong (Weak) SPV Event:*** NAM_{100} >1σ (<-1σ) for five (5) consecutive days. **Neutral SPV** events occur when $|NAM_{100}|$ < 1σ.

Phases 2,3 (Phases 7,8) are grouped together 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		37	43
MJO 2,3	68	23	21
MJO 7,8	69	18	18

TABLE 1. Number of events per case explored in the study.

RESULTS - 500 hPa HEIGHT ANOMALIES

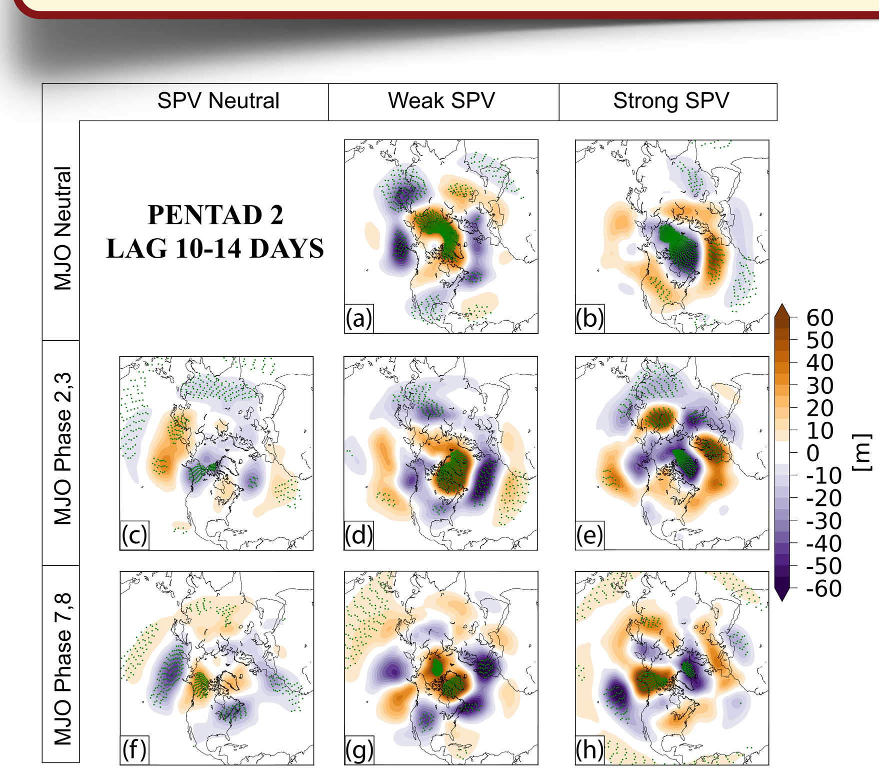


FIG. 2. Lag composite (+10 to +14 days) of 500 hPa geopotential height anomalies (m) for the various conditional MJO + SPV cases. Stippling indicates significant anomalies (p < 0.05) using a two-tailed bootstrapping test of N = 5000 samples with replacement.

Positive: Constructive Interference
Negative: Destructive Interference

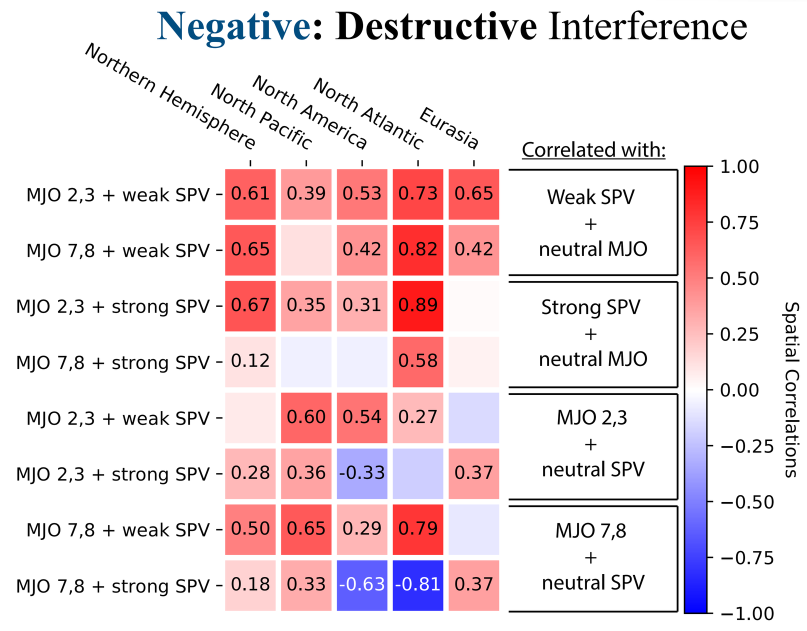


FIG. 3. Spatial correlation coefficients of MJO + SPV neutral composites against various conditional MJO + SPV events. Correlations done over the entire NH, the North Pacific (20°-60°N, 150°E-140°W), North America (20°-60°N, 60°-120°W), the North Atlantic (20°-75°N, 60°W-20°E), and Eurasia (20°-75°N, 30°-130°E). Significant correlation coefficients (p < 0.05) explicitly shown.

RESULTS - SURFACE TEMPERATURES ANOMALIES

FINDINGS FROM HEIGHT & TEMPERATURE COMPOSITES

- **The MJO** influences most strongly tropospheric circulation patterns ***across the North Pacific*** and parts of ***western North America***.
- **Variability in the SPV** strongly influences patterns over the ***North Atlantic and Europe***.

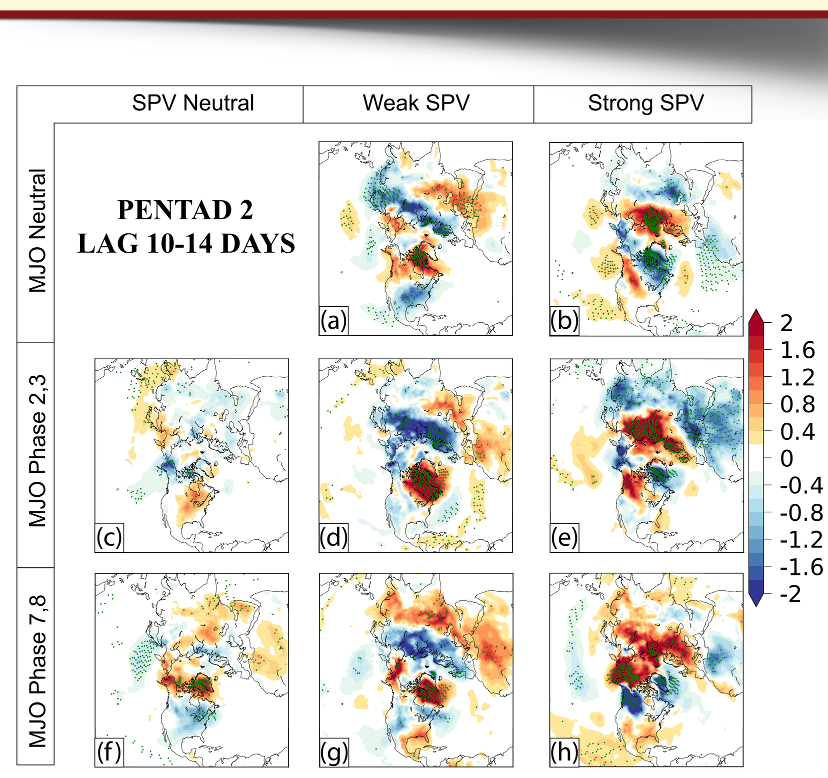
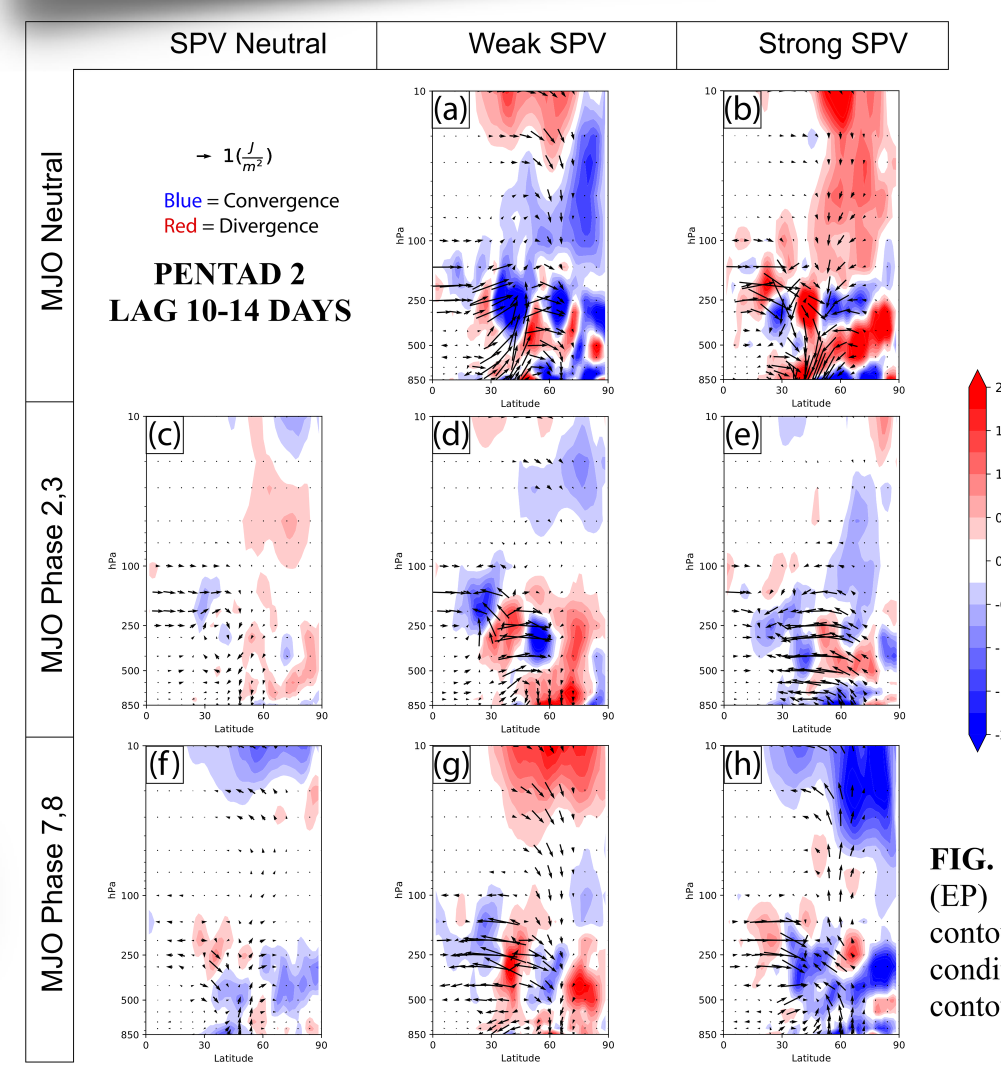


FIG. 4. As in **FIG. 2** but for surface temperature anomalies (K).

READ THE PAPER

Green, M. R. and **Furtado, J. C.** (2019), Evaluating the joint influence of the Madden-Julian Oscillation and the stratospheric polar vortex on weather patterns across the Northern Hemisphere. *Journal of Geophysical Research: Atmospheres*, 124, https://doi.org/10.1029/2019JD030771.

RESULTS - EP FLUXES AND S/T COUPLING



EP-FLUX COMPOSITE FINDINGS

- Anomalous wave propagation associated with MJO Phase 2,3 events is more confined to the troposphere with minimal (direct) influence on the stratosphere **(FIGS. 5c-e)** ⟹ *Tropospheric Pathway*
- Changes in tropospheric wave activity initiated by the MJO Phase 7,8 events could impact the stratosphere via enhanced upward wave fluxes (**FIGS. 5f-h**). ⟹ *Tropospheric & Stratospheric Pathway*

FIG. 5. Lag composites (+10 to +14 days) of Eliassen-Palm (EP) fluxes (vectors; J m^{-2}) and flux convergence (shaded contours; m/s/day) anomalies for the various MJO + SPV conditional cases. Shaded contour interval 0.25 m/s/day; zero contour omitted. Vectors scaled as in *Edmon et al.* [1980].

PRESSURE-TIME LAG COMPOSITE FINDINGS

- For *MJO Phase 2,3 + Neutral SPV* cases (**FIGS. 6a,b**), negative NAM conditions occur in the troposphere before Day 0. Then, a significant positive NAM tropospheric signature emerges, extending up into the stratosphere and strengthening the zonal winds.
- For *MJO Phase 7,8 + Neutral SPV* cases (**FIGS. 7a,b**), the trend after Day 0 is toward negative NAM in the *troposphere* (Days +8 to +12), with the stratospheric NAM turning negative *after* the troposphere, weakening the vortex (see green box).

MJO PHASE 2,3 + NEUTRAL SPV

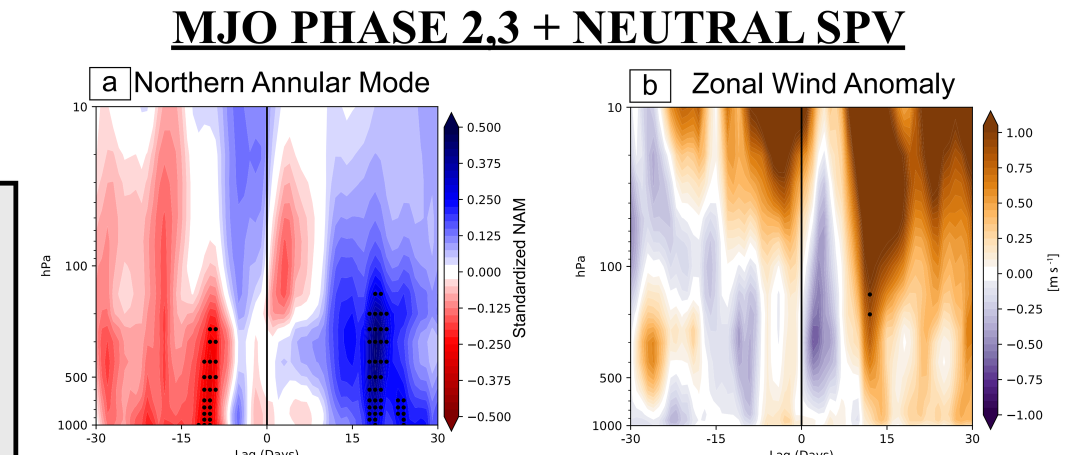


FIG. 6. Pressure-time lag composites of the (a) standardized NAM index and (b) area-averaged (60°N-80°N) zonal-mean u anomalies (m/s) for MJO Phase 2,3 + neutral SPV events. Day 0 represents start date of MJO event. Negative (positive) lags indicate the variable leads (lags) the start date of the MJO event. Black stippling indicates composite values significant at the p < 0.05 level.

MJO PHASE 7,8 + NEUTRAL SPV

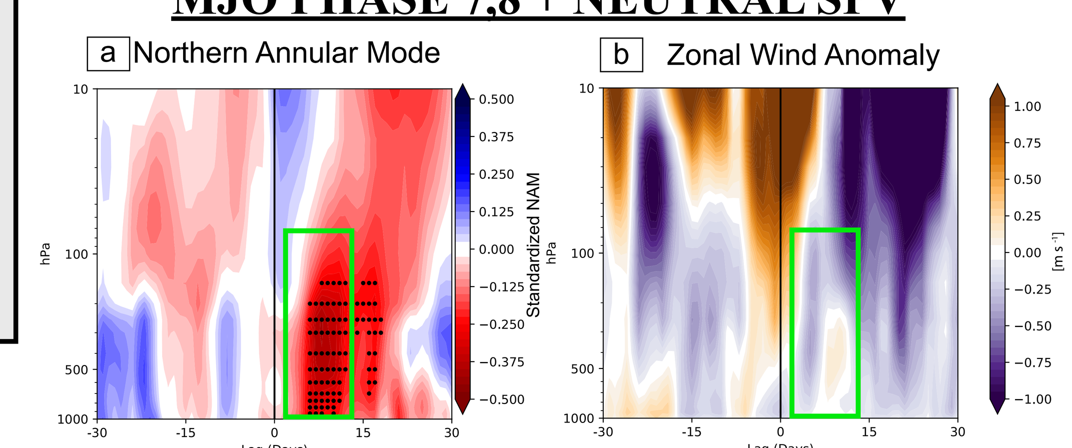


FIG. 7. As in **FIG. 6** but for MJO Phase 7,8 + neutral SPV. Green box shows the evolution of the standardized NAM and zonal-mean zonal wind values as they change from the troposphere to the stratosphere.

DISCUSSION & CONCLUSIONS

- The different composites based on different MJO + SPV joint conditions (**FIGS. 2 & 3**) illustrate that examining **both** modes together is important for skillful S2S forecasts, especially for areas like North America.
- MJO influences on the extratropical stratospheric circulation may be contingent on the state of the SPV, especially for MJO Phases 7,8. How these interactions may or may not feed back onto the troposphere and/or the MJO itself remains to be investigated.
- The joint influences of the MJO & SPV are not simply linear, as repeated analyses but with linear regression yield different patterns for the conditional cases (**not shown**).
- Two related studies bolster the findings in this work.
  - *Ciasto et al.* [2019, in prep.] examine associated MJO and SPV teleconnection patterns in the S2S Model Database. Results are similar to those shown here, though some stratospheric connections are model-dependent.
  - *Barnes et al.* [2019] use causal discovery methods and illustrate that the MJO can influence the NAO through a tropospheric and/or stratospheric pathway.
- A caveat of this work involves sample size, especially for the joint composites. Further modeling studies would thus be beneficial, particularly for testing specific mechanistic links associated with the MJO/SPV conditional cases.

ACKNOWLEDGEMENTS

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