Optimal North Pacific Blocking Precursors and Their Deterministic Subseasonal Evolution during Boreal Winter

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Teleconnections can modulate North Pacific blocking

- Slowly-evolving tropical heating patterns such as the El Niño-Southern Oscillation (ENSO) and Madden-Julian Oscillation (MJO; Figure 1) can modify the frequency and location of blocking.
- Given these teleconnections, there may be a **predictable component to blocking** on subseasonal timescales.
- A low order **linear inverse model (LIM)** has been found to reproduce subseasonal Northern Hemisphere variability, suggesting it may also be useful for studying North Pacific blocking.
- We find that a **LIM can reproduce the observed evolution of North Pacific blocking** and diagnose optimal precursors to this pattern.

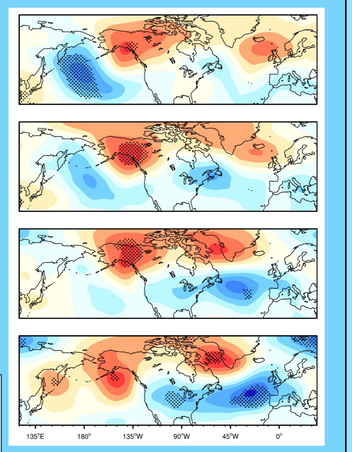


Figure 1: Composite 500-hPa height anomalies 0-3 (a-d) pentads following MJO phase 7. *Adapted from Henderson et al. 2016*

Research Questions

Q1. What are the *optimal initial conditions* associated with North Pacific blocks?

Q2. How do the *tropics* and *extratropics* influence block development?

Data, Blocking ID, Linear Inverse Model

- The NCEP/NCAR Reanalysis I dataset was used for all variables except OLR.
- Outgoing longwave radiation (OLR) from the NOAA Optimum Interpolated OLR dataset was also used.
- For all variables, we used daily mean data with a 7-day running mean applied and consider the period December-January-February (DJF), 1980-2014.
- **Blocks were identified** in the North Pacific using an approach motivated by Dole and Gordon (1983). A blocking event was identified if the area-averaged 200-hPa streamfunction anomaly between 46-56°N, 186-206°E was at least 1.25σ for at least five consecutive days. This resulted in the identification of **25 independent events during DJF 1980-2014.**

Variable	Domain
OLR	20°S-20°N 0-359°E
200-hPa streamfunction	0-90°N 0-359°E
850-hPa streamfunction	0-90°N 0-359°E

Table 1: Variables and domains used to create the LIM.

A LIM is an **empirical dynamical model** in which the dynamics are determined from the observed instantaneous and lagged covariance between a selected subset of climate anomalies (Penland and Sardeshmukh 1995; Eqns 1-3), in this case a subset relevant to North Pacific blocking (Table 1).

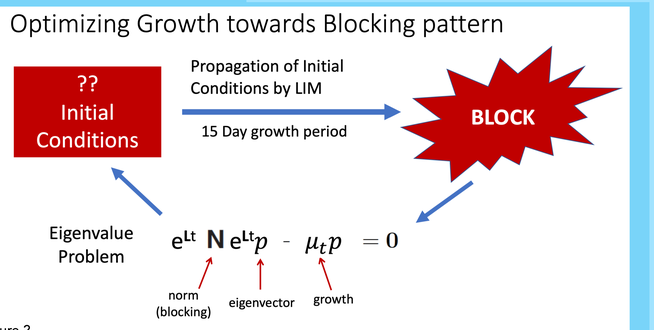


Figure 2

$$\mathbf{X} = \{\Psi_{200}, \Psi_{850}, \mathrm{OLR}_{\mathrm{trop}}\} \quad \text{Eqn 1}$$

$$\frac{d\mathbf{X}}{dt} = \mathbf{L}\mathbf{x} + \boldsymbol{F_S} \quad \text{Eqn 2}$$

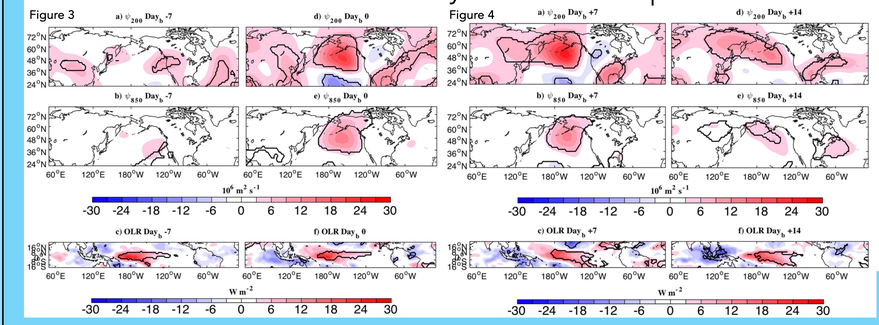
Evolution of system | Deterministic dynamics | White Noise

$$\mathbf{L} = ln(\mathbb{C}_5 * inv(\mathbb{C}_0))/5 \quad \text{Eqn 3}$$

Once the LIM operator is attained (Eqn 3), an optimization problem is set up to maximize amplifications towards a block over a selected time interval (e.g., 15 days; Figure 2).

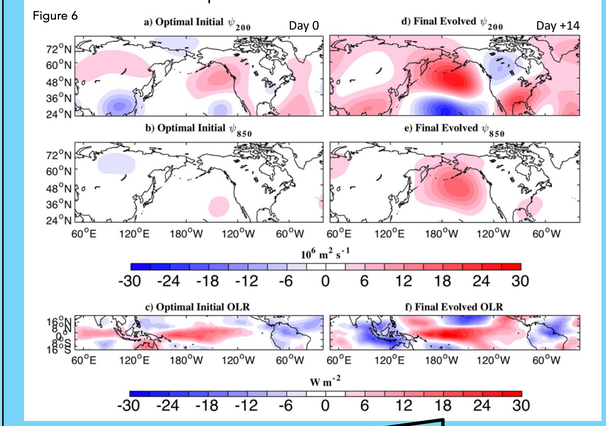
Optimal Precursors to North Pacific Blocking

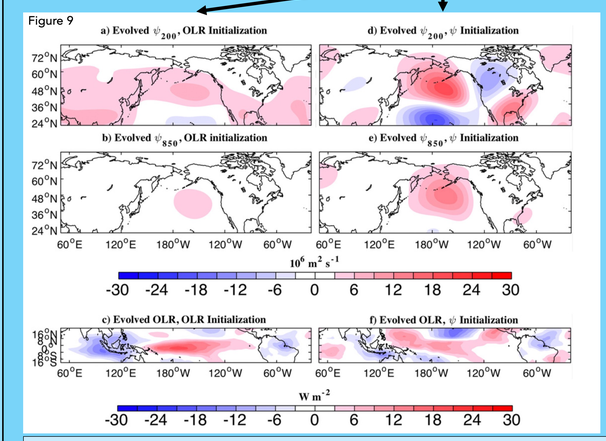
Reanalysis-Based Composite Block Evolution



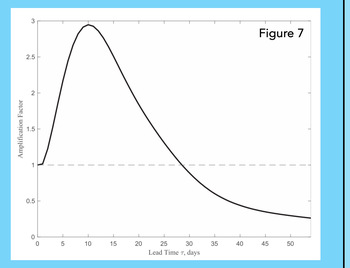
Figures 3-5: Composite evolution of blocking 7 days prior to 14 days following block onset.

LIM-derived Optimal Initial Pattern and Evolution



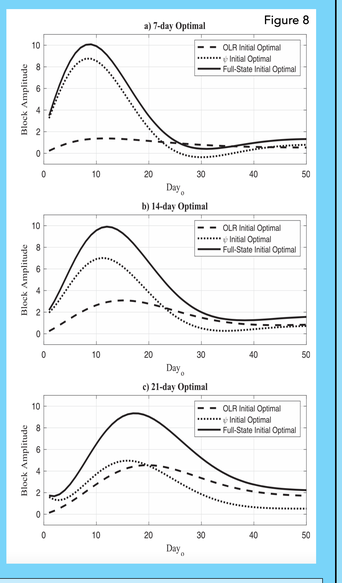


- The LIM can reproduce the observed subseasonal blocking evolution (Figure 6). **Optimal initial conditions** that maximize growth include an east Pacific ridge and suppressed tropical heating in the central Pacific.
- Peak system growth towards blocking occurs at a 10-day lead time, while some growth is possible up to 28 days in advance (Figure 7).



Tropical versus Extratropical Initial Conditions

- Tropical initial conditions contribute more strongly to blocking at longer growth intervals (Figure 8).
- Tropical and extratropical initial conditions both contribute to the dipole-type block in the central Pacific, and different circulation patterns elsewhere (Figure 9).



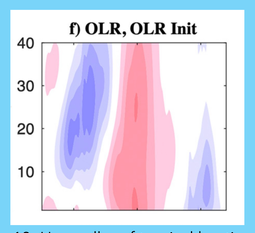


Figure 10: Hovmoller of tropical heating shows a stationary and propagating component.

Research Questions

A1. Optimal Initial conditions include suppressed central tropical Pacific heating (positive OLR) and antecedent east Pacific upper-level ridge.

A2: Both tropical and extratropical initial conditions contribute to blocking amplification, the former increasingly so at longer growth periods.

References

1. Henderson, S. A., E. D. Maloney, and E. A. Barnes, 2016: The influence of the Madden–Julian oscillation on Northern Hemisphere winter blocking. J. Climate, 29, 4597–4616, https://doi.org/10.1175/JCLI-D-15-0502.1.
2. Penland, C. and P. D. Sardeshmukh, 1995: The optimal growth of tropical sea surface temperature anomalies *J. Clim.* **8**, 1999–2024.
3. Breeden, M. L., B. T. Hoover, M. Newman, and D. J. Vimont, 2020: Optimal North Pacific Blocking Precursors and Their Deterministic Subseasonal Evolution during Boreal Winter. Mon. Wea. Rev., 148, 739–761, https://doi.org/10.1175/MWR-D-19-0273.1.