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.

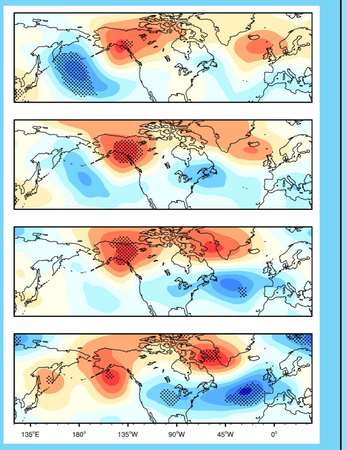


Figure 1: Composite 500-hPa height anomalies 0-3 (a-d) pentads following MJO phase 7. *Adapted from Henderson et al. 2016*

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).

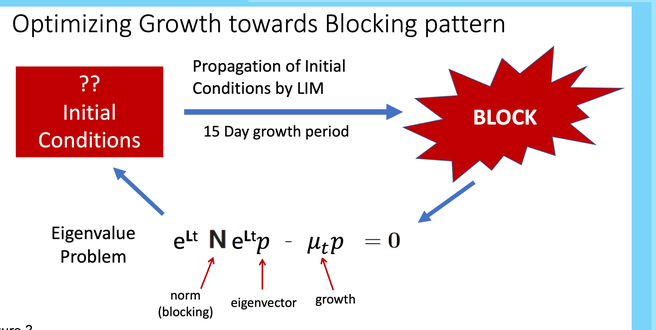


Figure 2

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

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

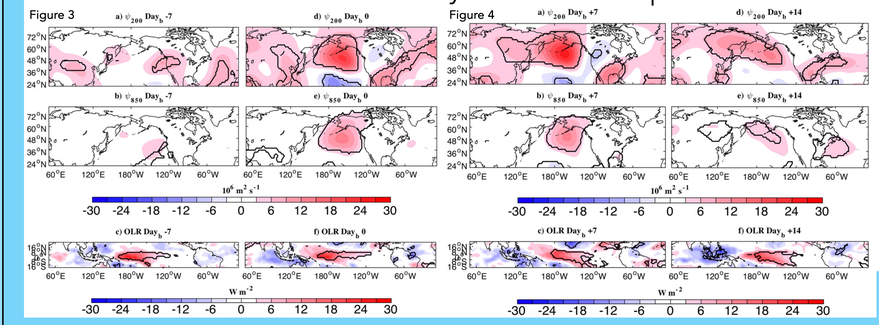
Evolution of system | Deterministic dynamics | White Noise

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

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).

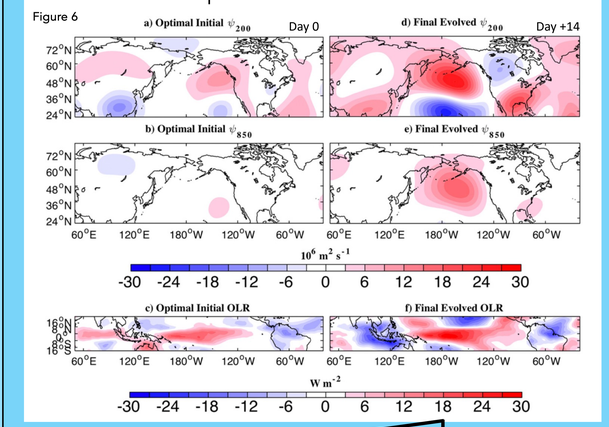
Optimal Precursors to North Pacific Blocking

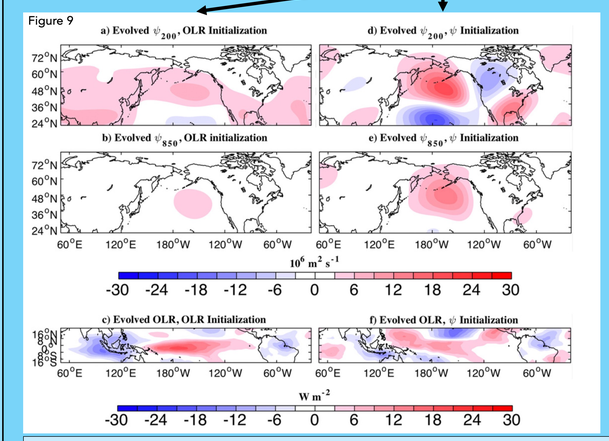
Reanalysis-Based Composite Block Evolution



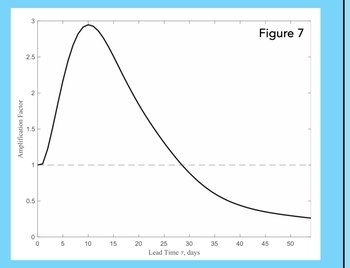
Figures 3-5: Composite evolution of blocking 7 days prior to 14 days following block onset.

LIM-derived Optimal Initial Pattern and Evolution



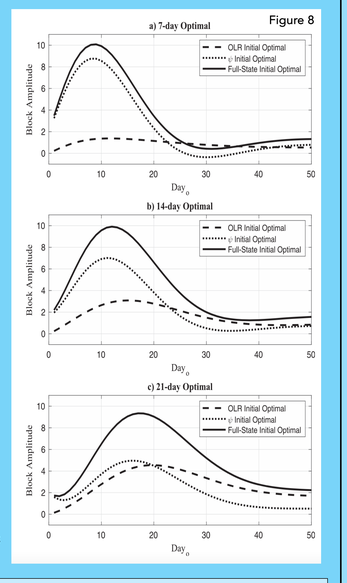


- The LIM can reproduce the observed subseasonal blocking evolution (Figure 6). **Optimal initial conditions** that maximize growth include an east Pacific ridge and suppressed tropical heating in the central Pacific.
- Peak system growth towards blocking occurs at a 10-day lead time, while some growth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



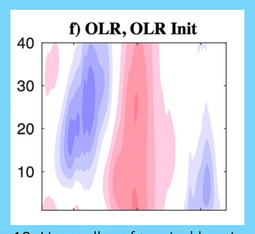


Figure 10: Hovmoller of tropical heating shows a stationary and propagating component.

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 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.