Forecasting North Pacific Height Anomalies with the MJO on S2S timescales

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Colorado State University
The traditional limits of model prediction skills
The traditional limits of model prediction skills

Synoptic wave theory

Adapted from: ici.columbia.edu/news/qa-subseasonal-prediction-project
Motivation

The traditional limits of model prediction skills

The S2S Prediction Gap

Prediction lead time

Annual cycle and interannual variability

Synoptic wave theory

Adapted from: li22.columbia.edu/news/qe-subseasonal-prediction-project
Motivation

The traditional limits of model prediction skills

The $S2S$ Prediction Gap

WEATHER EVENTS
Individual storm events; blizzards, rainstorms, hurricanes

$S2S$ EXTREMES
Tropical cyclone activity, heat waves, storm tracks, severe weather threats

SEASONAL OUTLOOKS
El Niño-Southern Oscillation, temperature and precipitation anomalies

Prediction desert?

Annual cycle and interannual variability

Synoptic wave theory

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Motivation II

Since 1980s
We already know the relationship between tropical forcing and extra-tropical teleconnected response.
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- Direct linear circulation response to diabatic heating or topography through poleward-propagating Rossby Waves.
- Internal growth of barotropic instability.
- Growth arising from the dynamical feedback of synoptic eddies.
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Heating and Teleconnected Response

Apparent heat source ($Q_1$, mm/day)

Geopotential Height Anomalies (m)

Cause and effect

Since Rossby waves take time to propagate into extra-tropical regions, the current geopotential height variations might result from previous phases of MJO.

Q1 is derived from ERA-Interim
Anomalous Z500 is derived from MERRA
Heating and Teleconnected Response

Apparent heat source ($Q$, mm/day)

Geopotential Height Anomalies (m)

<table>
<thead>
<tr>
<th>Phase</th>
<th>Lag 0-4 (day)</th>
<th>Lag 5-9 (day)</th>
<th>Lag 10-14 (day)</th>
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<tbody>
<tr>
<td>Phase 1</td>
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<td>Phase 8</td>
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Heating and Teleconnected Response

Apparent heat source ($Q_1$, mm/day)

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Quantifying the evolution and amplitude of teleconnection

By removing the first three harmonics of the annual cycle...
The second leading mode of the North Pacific height anomalies is related to MJO variations.
Quantifying the evolution and amplitude of teleconnection
Quantifying the evolution and amplitude of teleconnection

The averaged PC2 over different MJO phases and time lags shows two stair-like patterns.
The modulation on anomalous Z500 by teleconnections
The modulation on anomalous Z500 by teleconnections

Event 1
Event 2
Event 3
Event 4
...
Event N
The modulation on anomalous Z500 by teleconnections

Event 1

Event 2

Event 3

Event 4

... Event N
The modulation on anomalous Z500 by teleconnections

The color indicates the strength of teleconnection’s modulation on the variation of anomalous Z500.

Dark color -> robust modulation
Light color -> less robust modulation
Conclusions of the first part:

- Teleconnections are more robust over specific phases and lags.
- When teleconnections are robust, the modulation on anomalous Z500 are strong as well.

Question:

Does idea works for hindcast ensembles (and forecast)?
IF:
The teleconnections induced by MJO are only robust (consistently modulate anomalous Z500) over some phases and time lags.

Then:
The prediction skill is better over some phases and lags?
Composite sense

Two criteria:
- The first day of model initialization
- The first day of specific MJO phases
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Composite sense

Two criteria:
- The first day of model initialization
- The first day of specific MJO phases

Ensemble 1

Composite Event

Ensemble 2

Composite Event

Ensemble 10

Composite Event
Composite sense

Dots indicate all of the ensemble member agree with a positive sign(+) or negative sign(-) of Z500.
Composite sense

Dots indicate all of the ensemble member agree with a positive sign(+) or negative sign(-) of Z500.

Traditional Limit of model prediction skill (~10 days)
Conclusions – From Reanalysis ...

Shading = MJO phase 2 column integrated Q1 (mm/day)
Some phases of MJO can generate robust teleconnected response.
Robust teleconnected response can consistently modulate Z500 anomalies
Conclusions – From ensemble hindcasts

Robust teleconnections can also increase the agreement on Z500 over different ensemble members, which give us more confidence about the extended predictions.