Effect of Sudden Stratospheric Warmings on Subseasonal Prediction Skill in the NASA S2S Forecast System

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Sudden Stratospheric Warming (SSW)

- Rapid increase in temperature over the polar cap with coincident decrease and reversal of the circumpolar wind.
- Driven by planetary wave momentum forcing or “Eliassen-Palm flux divergence”

Limpasuvan et al [2004]
SSW Effects at the Surface

Average SLP anomaly in the month following an SSW

SSW associated with: enhanced Atlantic blocking, likelihood of extreme surface temperature and precipitation events, S2S forecast skill.

[Scaife et al. 2016]

[Kidston et al. 2015]
Previous work suggests forecast systems show some skill in predicting SSW events at 10 days, but poor skill at longer range.

Forecast initialization

- _______ 15 day
- . . . . . . 10 day
- --- --- 5 day

[Zonal Wind](#)

[10 Days]

[Westerly
Easterly]

[Tripathi et al. 2014]
### NASA’s GEOS Near Real-Time Sub/Seasonal Prediction Suite
(Molod et al. Poster A2-09)

<table>
<thead>
<tr>
<th></th>
<th>Subseasonal</th>
<th>Seasonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of Forecast</td>
<td>45 days</td>
<td>9-12 months</td>
</tr>
<tr>
<td>Frequency of forecasts</td>
<td>Every 5 days</td>
<td>Every 5 days</td>
</tr>
<tr>
<td>Number of Ensembles</td>
<td>4 per start date</td>
<td>Total of 10 per month</td>
</tr>
<tr>
<td>Frequency of submission</td>
<td>Once per week</td>
<td>Once per month</td>
</tr>
<tr>
<td>Initial Conditions from</td>
<td>GEOS S2S-2_1 ODAS</td>
<td>GEOS S2S-2_1 ODAS</td>
</tr>
<tr>
<td>Hindcasts</td>
<td>1999-2016</td>
<td>1980-2016/7</td>
</tr>
</tbody>
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- This study: SSW events as “forecasts of opportunity” to evaluate forecast skill in these periods and consider ways to improve the representation of the stratosphere for improvements skill.
- Using NASA GMAO’s 4-member ensembles of 45-day retrospective forecasts initialized every 5 days 1999-2016.
Forecast Stratospheric Winds vs MERRA-2

SSW Anomalies: Differences from Climatology

**Composite SSW Forecasts**

- Forecasts initialized 5-0 Days Before Warming
- MERRA-2 (Red) for Reference

**60 NH Winter Forecasts**

- Forecasts initialized +/-5 days of events show good long-term representation of the stratosphere and are used here to study effects on forecast skill at the surface.
Forecast Stratospheric Winds vs MERRA-2

SSW Anomalies: Differences from Climatology

Composite SSW Forecasts initialized 15-10 Days Before Warming

- 10-15-day forecasts still give reasonable representation of SSW events (similar to other S2S systems [Tripathi et al. 2014]).
- Some evidence that wave activity weakens 5-10 days after initialization compared to observations
MERRA-2 SSW Events 1999-present

- 15 events, 14 in the Retrospective Forecast set
- 30 initialization dates within +/-5 days of these events
- 30 x 4 ensemble members = 120 simulations, 30 ensemble means
Monthly Sea Level Pressure Anomalies following SSW Events 1999-2015

MERRA-2 Observations

Retrospective Forecasts

Mean Sea Level Pressure Anomaly
30 days following SSW events

Mean Sea Level Pressure Anomaly
10-40 days following SSW Events
SSW events show significantly more skill in the Atlantic sector
Ongoing Work: Reducing Bias with Gravity Wave Drag
NASA’s high-resolution (12km), short range (10-day) forecasts

- Tuning orographic gravity wave drag can reduce forecast bias and improve prediction skill

Seasonal Mean Stratospheric Forecast Errors

Stronger orographic gravity wave drag:
- reduced mean forecast bias
- improved forecast variability, including an accurate 10-day forecast of a very early final warming at season’s end.
Ongoing Work: Reducing Bias with Gravity Wave Drag

Observational Constraints: Moving beyond adhoc tuning

- Can observe gravity waves, but cannot observe gravity wave drag.
- Resolved gravity wave drag in validated high resolution models can constrain tuning for coarser resolution seasonal forecast models.
Summary & Conclusions

NASA’s GEOS S2S forecasts show good representation of SSW, and subseasonal surface effects when initialized within 5 days of SSW onset.

Forecasts show evidence for enhanced subseasonal forecast skill in Mean Sea Level Pressure in the North Atlantic sector following SSW events.

Extending the prediction range of SSW events themselves has associated potential to improve S2S skill: A pathway lies in the improved the representation of orographic gravity wave drag in the GEOS S2S model to reduce mean bias.