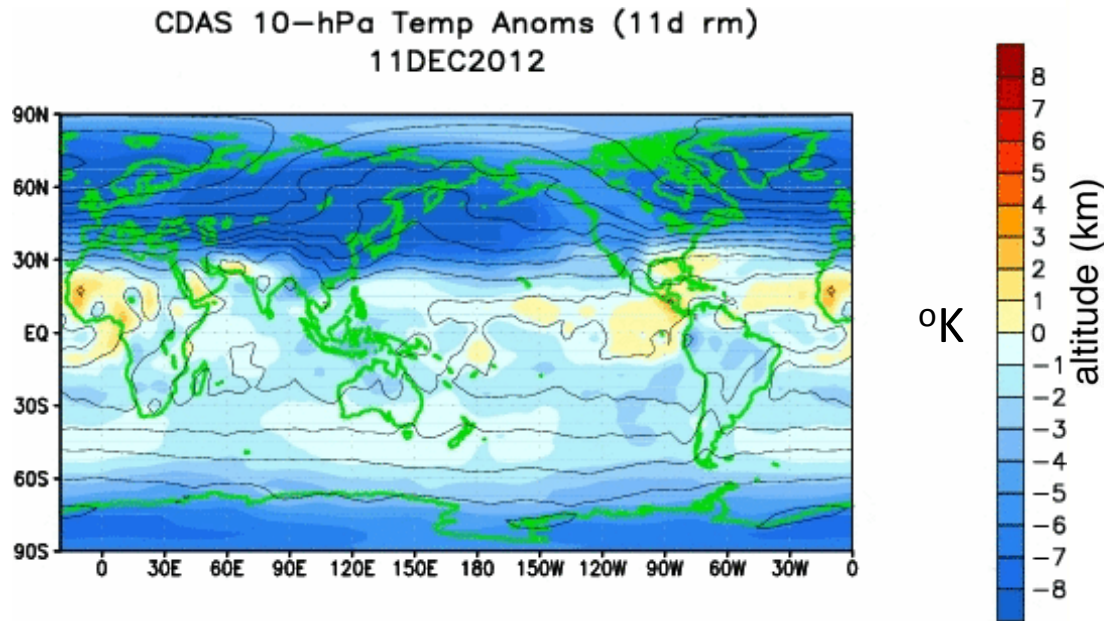# Effect of Sudden Stratospheric Warmings on Subseasonal Prediction Skill in the NASA S2S Forecast System

M. Joan Alexander[1], Lawrence Coy[2], Laura Holt[1], Zhao Li[3], Andrea Molod[3], and Steven Pawson[3]
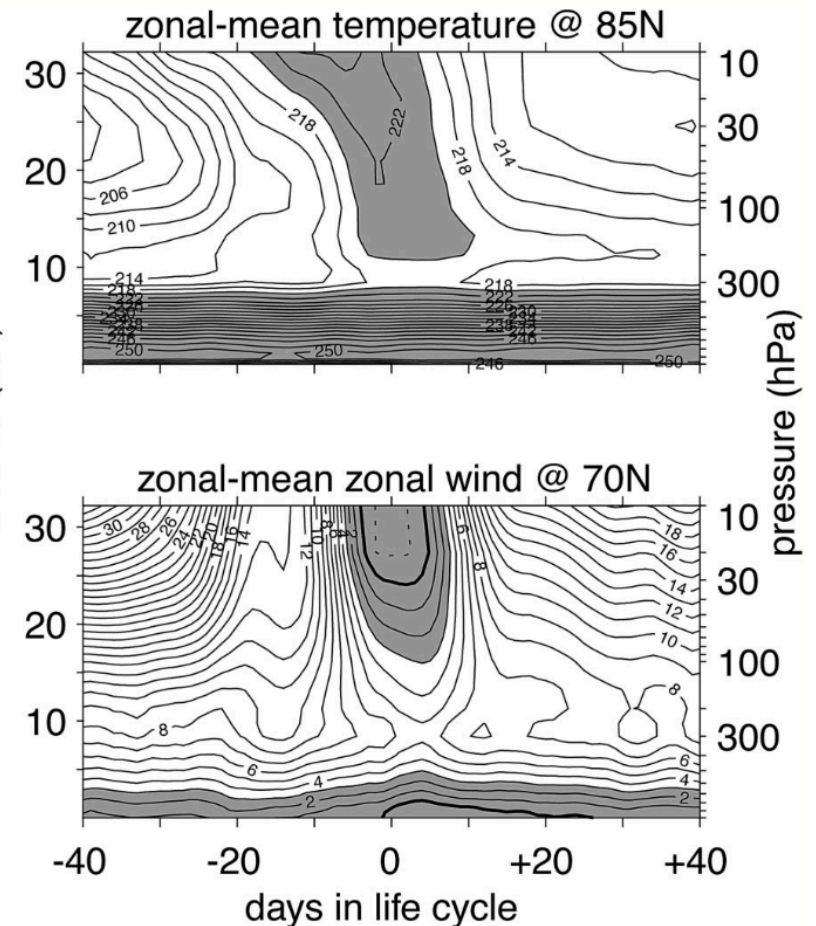
[1]NWRA, [2]SSAI/NASA, [3]NASA GMAO

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"
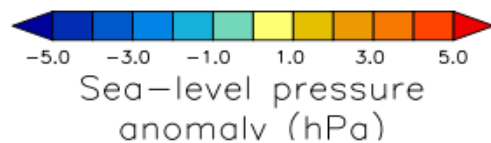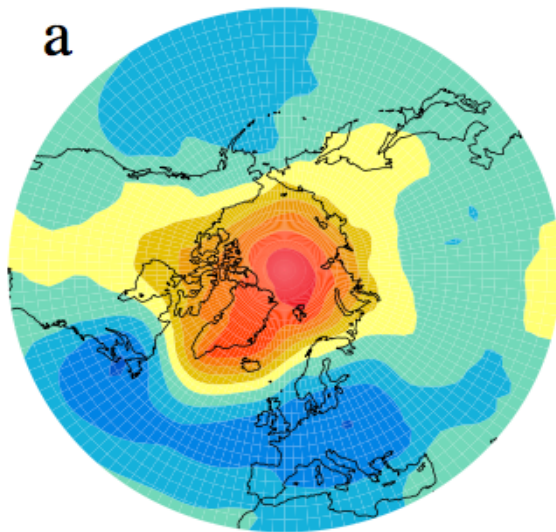
Limpasuvan et al [2004]

CDAS 10-hPa Temp Anoms (11d rm)
11DEC2012

°K

zonal-mean temperature @ 85N

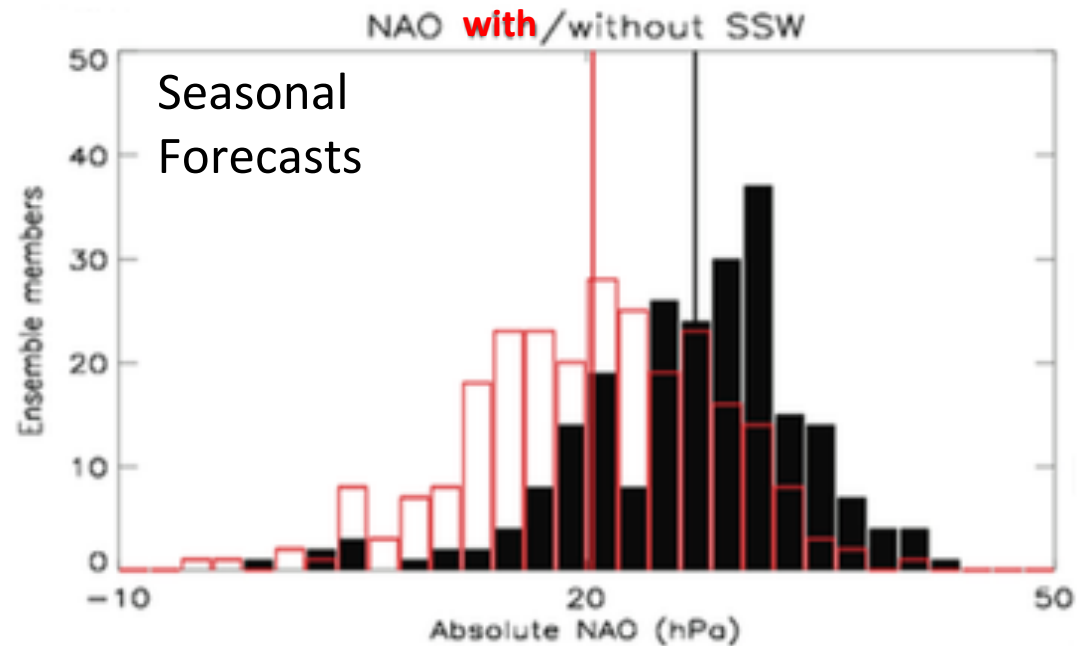zonal-mean zonal wind @ 70N

days in life cycle

Animation: 4/22/13 R. Gates

2

SSW Effects at the Surface

[Scaife et al. 2016]

Average SLP anomaly in the month following an SSW

[Kidston et al. 2015]

Seasonal Forecasts

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

Forecasting SSW

SPARC Project: SNAP (Stratospheric Network for the Assessment of Predictability)

Previous work suggests forecast systems show some skill in predicting SSW events at 10 days, but poor skill at longer range.
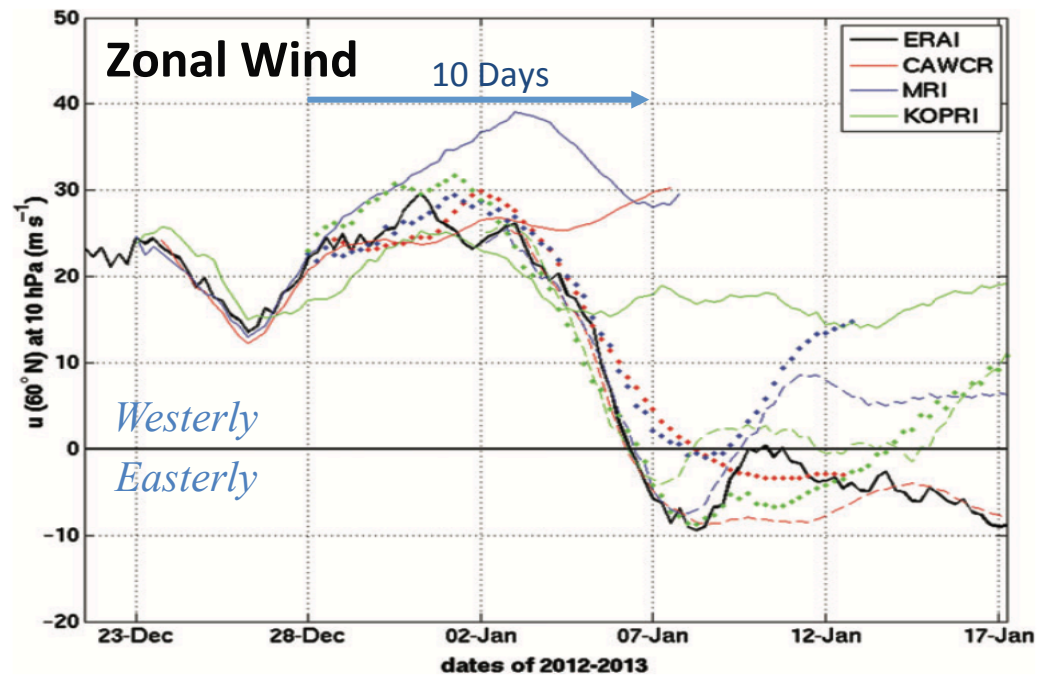
————— **Observed**

Forecast initilization

————— 15 day

· · · · · · · · 10 day

— — — — 5 day

[Tripathi et al. 2014]

NASA's GEOS Near Real-Time Sub/Seasonal Prediction Suite
(Molod et al. Poster A2-09)

	Subseasonal	Seasonal
Length of Forecast	45 days	9-12 months
Frequency of forecasts	Every 5 days	Every 5 days
Number of Ensembles	4 per start date	Total of 10 per month
Frequency of submission	Once per week	Once per month
Initial Conditions from	GEOS S2S-2_1 ODAS	GEOS S2S-2_1 ODAS
Hindcasts	1999-2016	1980-2016/7

- **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

Zonal Wind
Mean U−U$_c$

Temperature
Mean T−T$_c$

Wave Heat Flux
Mean v't'−v't'$_c$

60 NH Winter Forecasts
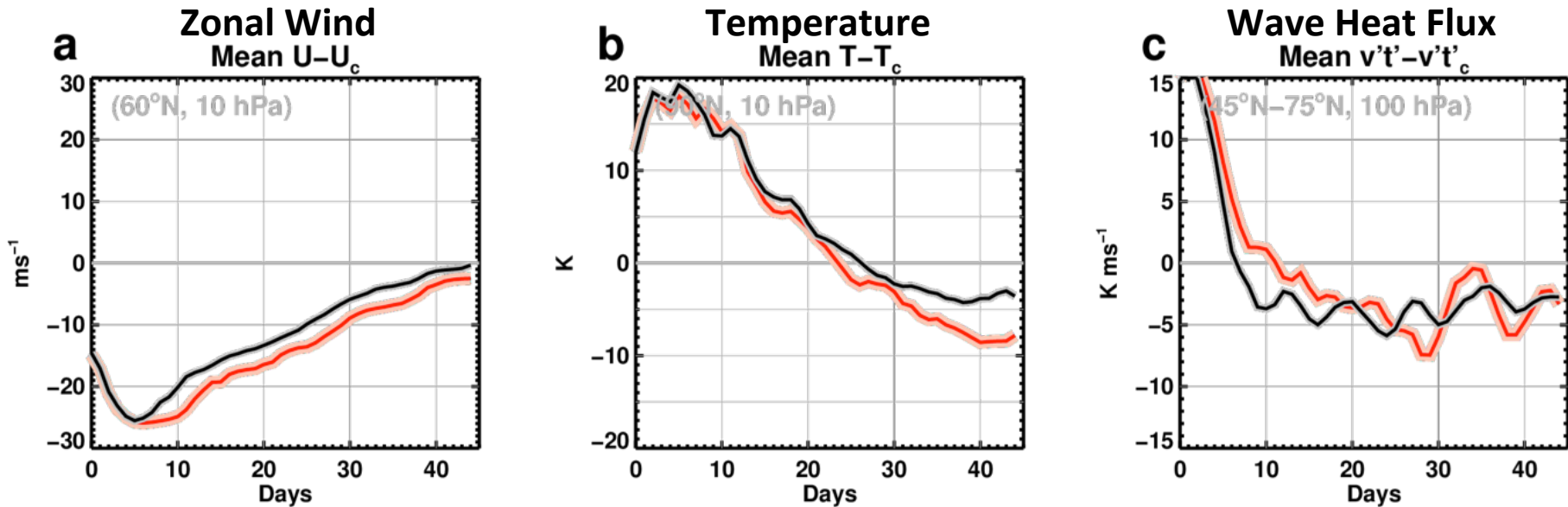
Composite SSW Forecasts
initialized **5-0 Days** Before Warming

MERRA-2 (Red) for Reference

- 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

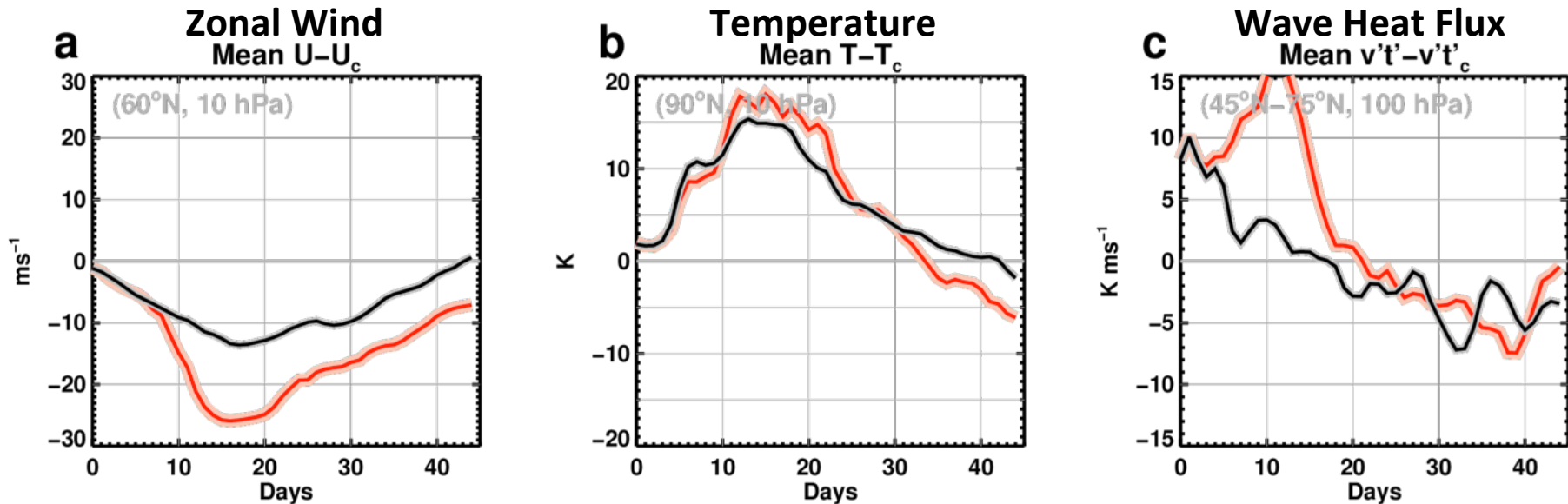**Composite SSW Forecasts** initialized **15-10 Days** Before Warming

MERRA-2 (Red)

- 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

| Event	SSW Date
1	26 Feb 1999
2	20 Mar 2000
3	11 Feb 2001
4	30 Dec 2001
5	17 Feb 2002
6	18 Jan 2003
7	5 Jan 2004
8	21 Jan 2006
9	24 Feb 2007
10	22 Feb 2008
11	24 Jan 2009
12	9 Feb 2010
13	24 Mar 2010
14	6 Jan 2013
15	12 Feb 2018

Zonal Wind (60° 10 hPa)
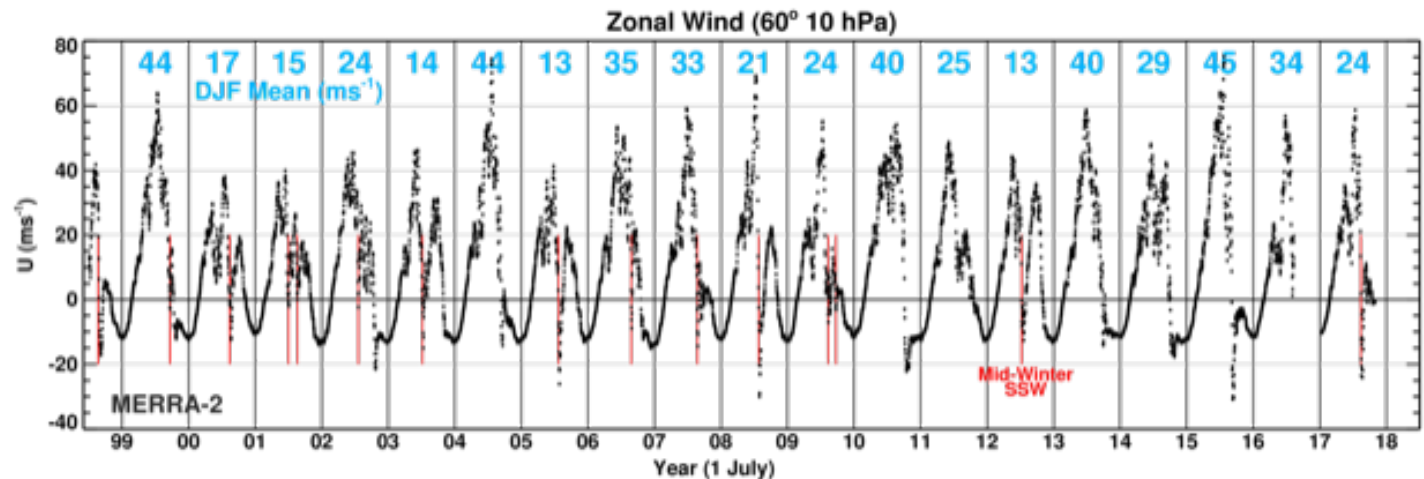
- 15 events, 14 in the Retrospective Forecast set
- 30 initialization dates within +/-5 days of these events
- 30 x 4 ensemble members = 120 simulations, 30 ensemble means

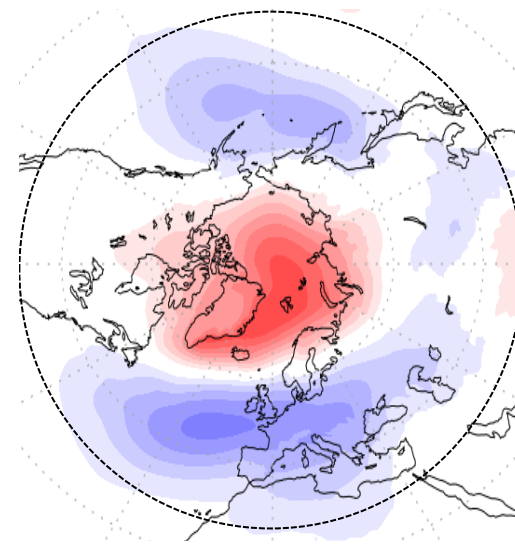# Monthly Sea Level Pressure Anomalies following SSW Events 1999-2015

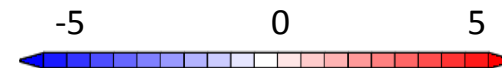**MERRA-2 Observations**

MSLP 30d Anomaly (hPa)
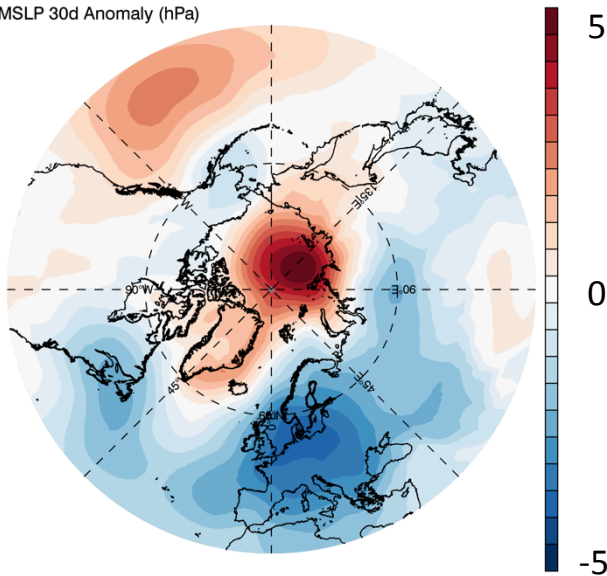
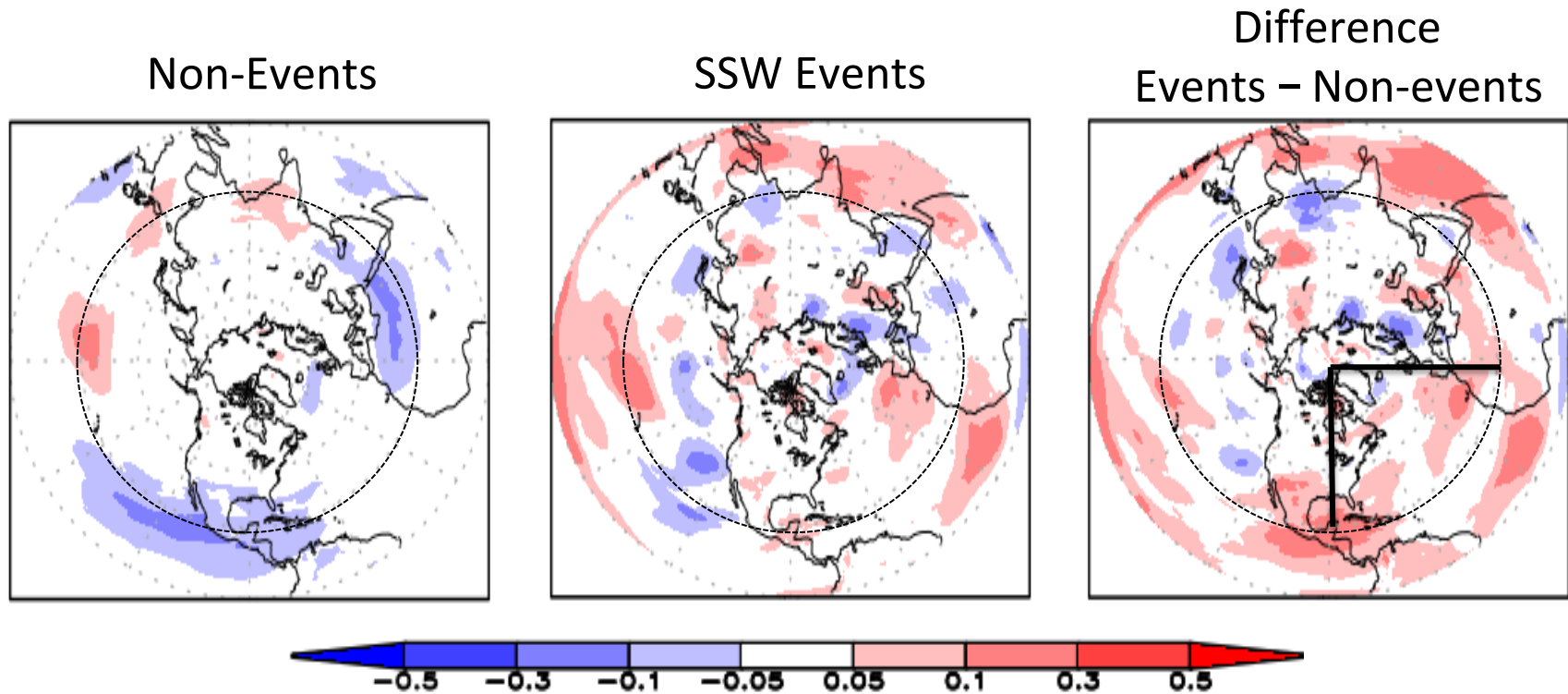**Mean Sea Level Pressure Anomaly 30 days following SSW events**

Retrospective Forecasts

Mean Sea Level Pressure Anomaly 10-40 days following SSW Events

GrADS/COLA

Mean Sea Level Pressure Forecast Skill

Non-Events   SSW Events   Difference
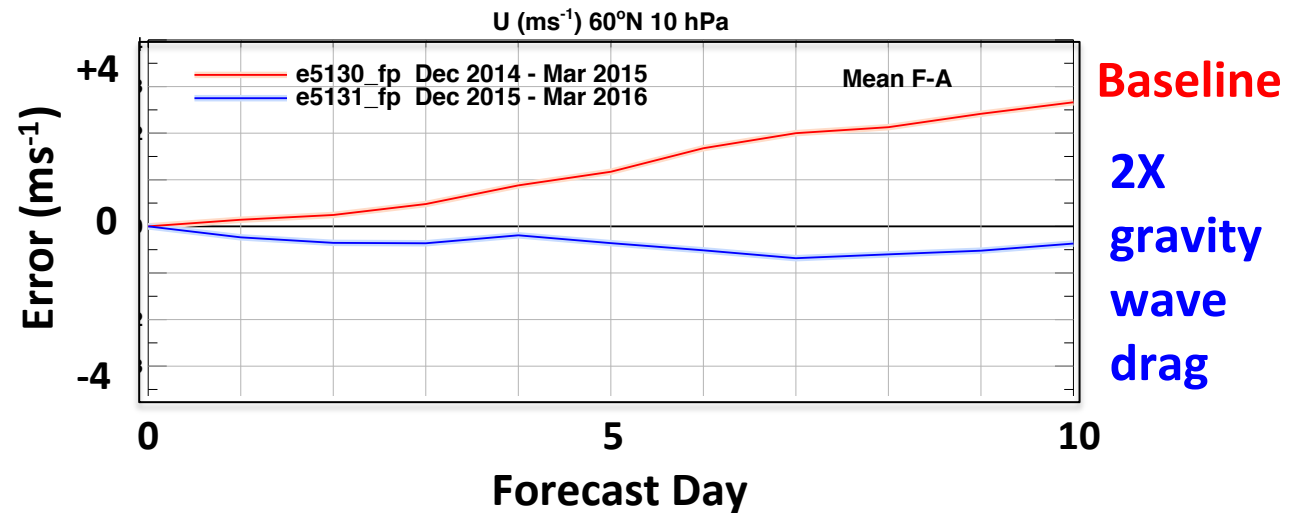   Events – Non-events

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

U (ms^{-1}) 60°N 10 hPa

e5130_fp Dec 2014 - Mar 2015 — Mean F-A
e5131_fp Dec 2015 - Mar 2016

Error (ms^{-1})
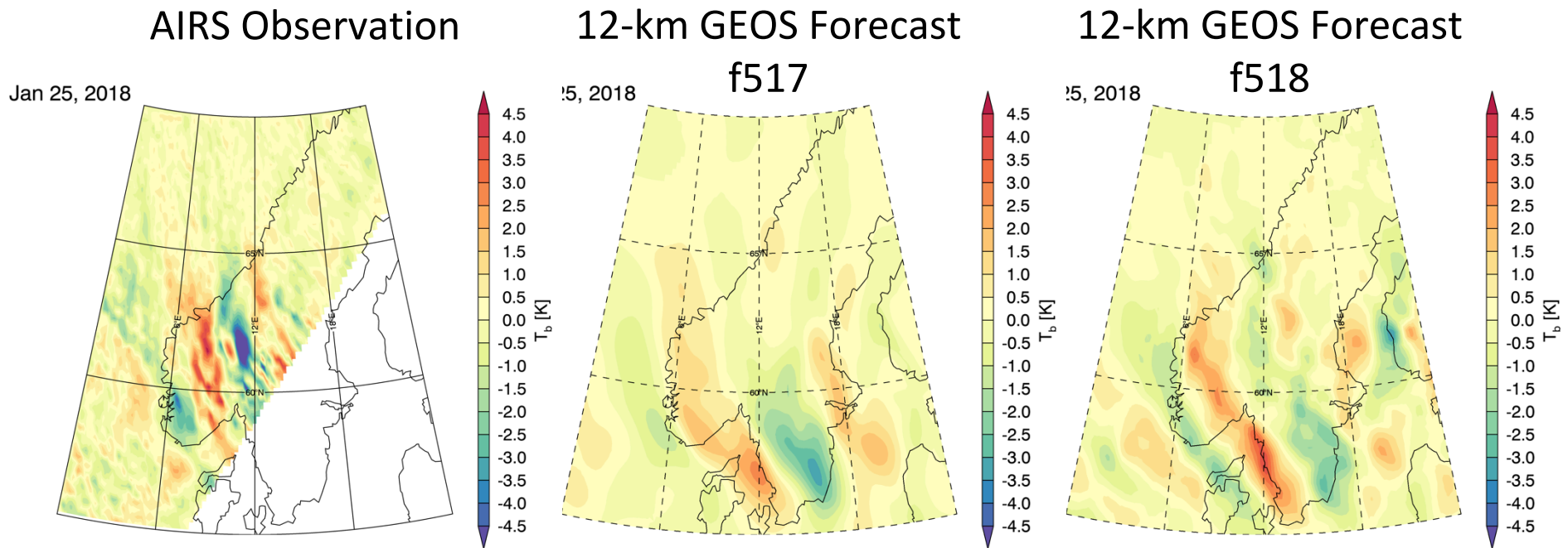
Forecast Day

Baseline

2X gravity wave drag

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

AIRS Observation

12-km GEOS Forecast f517

12-km GEOS Forecast f518

- 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.