

Sub-seasonal Forecasting of the Stratospheric Wave Events, Sudden Stratospheric Warmings, and their Influence on the Troposphere

L. Coy¹, P. A. Newman¹, J. Alexander², Z. Li¹, A. Molod¹, S. Pawson¹

¹ NASA Goddard Space Flight Center, Greenbelt, MD; ² Northwest Research Associates, Boulder, CO

Science Questions

Major Stratospheric Sudden Warming (SSW) events significantly disrupt the winter stratospheric circulation. However, SSWs occur over a broad vertical domain that includes not only the stratosphere but also the mesosphere, and in some cases, the troposphere.

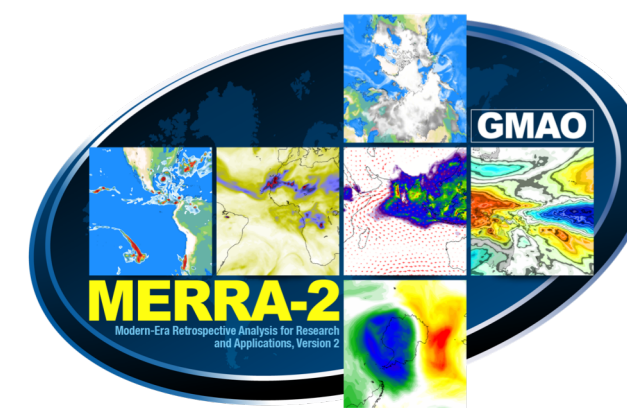
Here we investigate the possibility of forecasting SSW events on sub-seasonal time scales:

1. How far in advance can major SSW events be forecasted?
2. Can knowledge of SSW events improve tropospheric weather forecasts?

Global Analyses and Forecasts

NASA Global Modeling and Assimilation Office Products

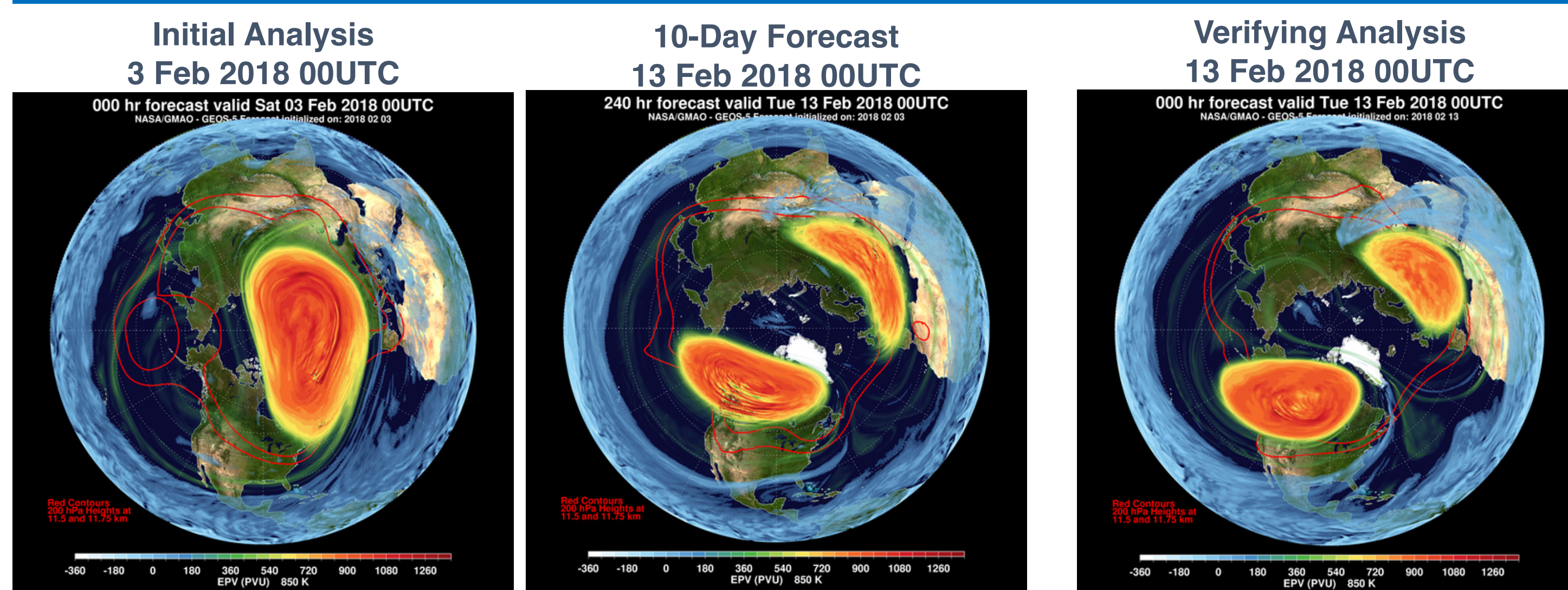
MERRA-2 Data Assimilation System (DAS): ongoing 50 km reanalyses starting from 1980



Forward Processing (GEOS FP) System: Near real time DAS with 12.5 km horizontal resolution and forecasts out to 10 days

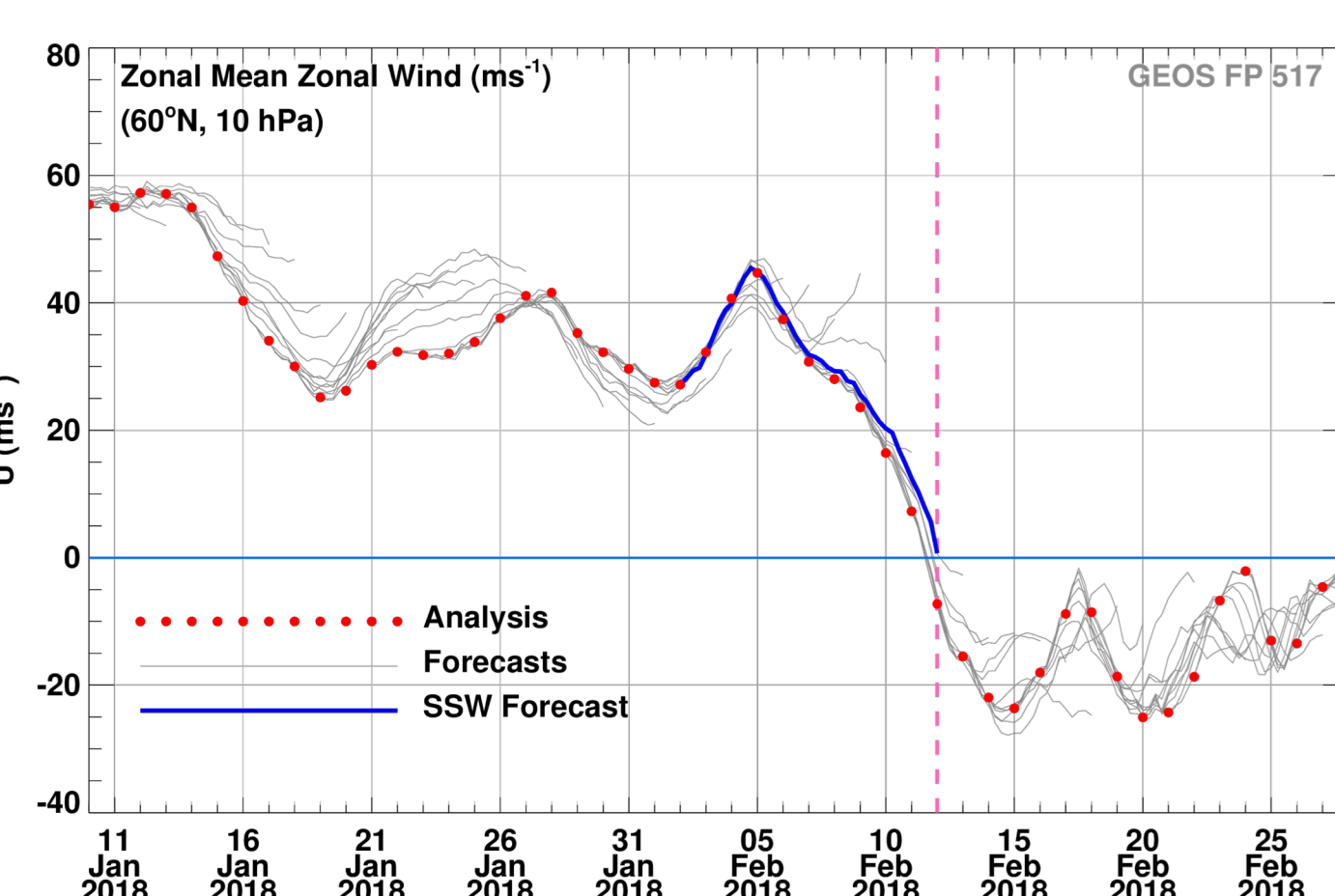
Seasonal to Subseasonal (GEOS S2S) System: Coupled atmosphere ocean forecasts out to 9 months with retrospective forecasts starting from 1980. Here we examine the 45 day sub-seasonal retrospective forecasts starting from 1999.

Forecast of Vortex Splitting Event of February 2018



EPV on the 850 K Potential Temperature Surface (~30 km)

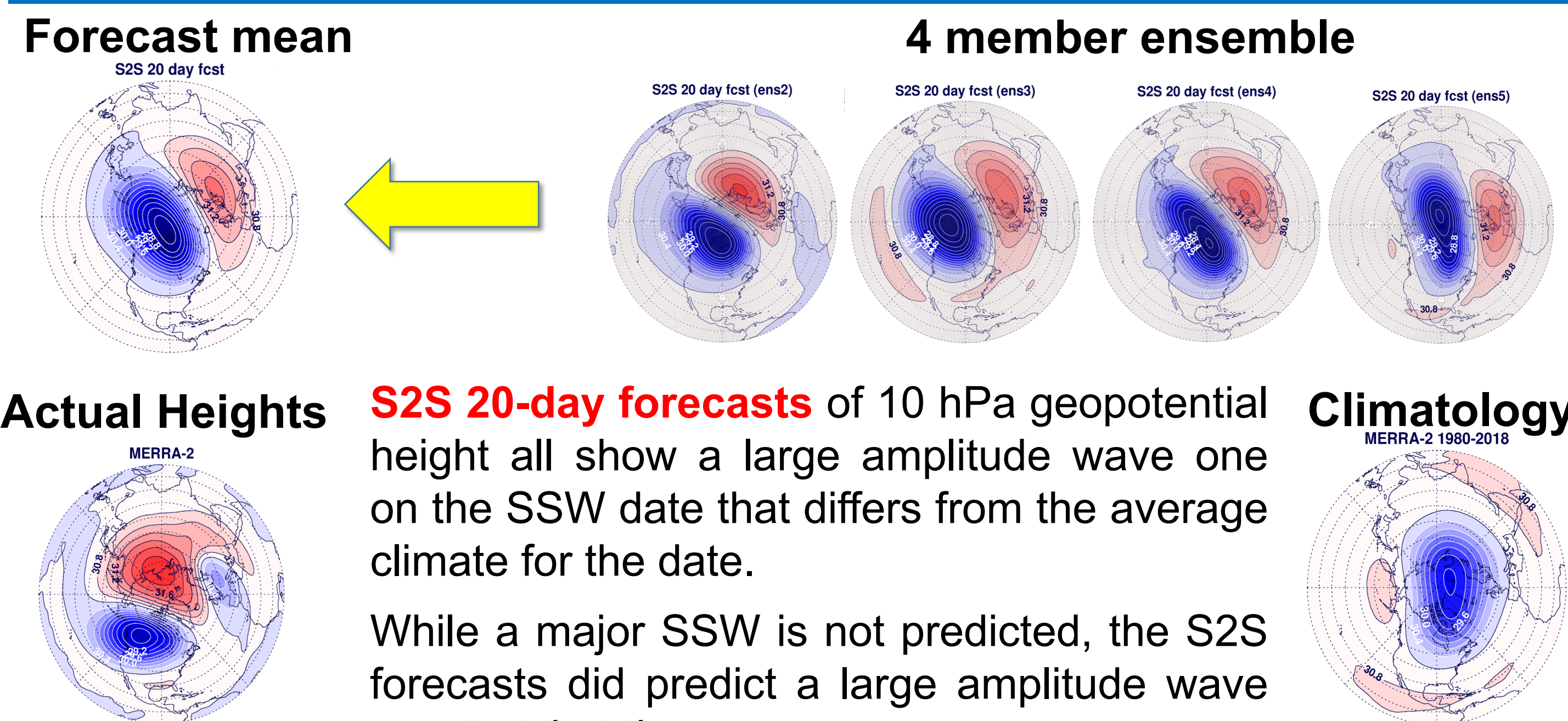
The FP **10-day forecasts** accurately capture the 1st Wave-2 SSW since 2009.



Zonal mean zonal wind 10-day FP forecast trajectories (light gray) with the 10-day forecast of the SSW wind reversal highlighted (blue). Red dots denote the verifying analyses.

2018 Forecasts showed excellent agreement with the analyses prior to the SSW.

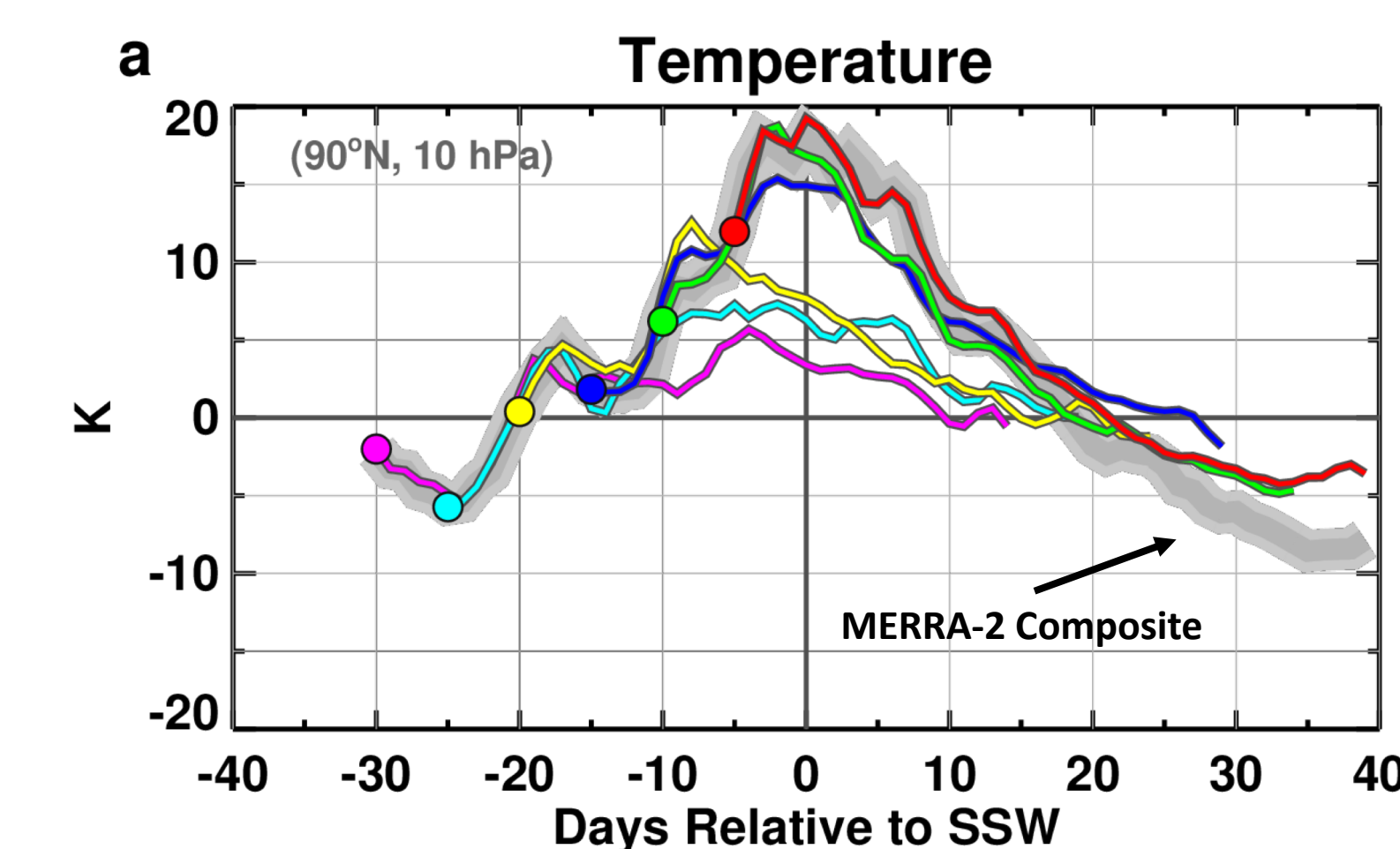
S2S Ensemble 20-Day Forecast of 2018 SSW (10 hPa)



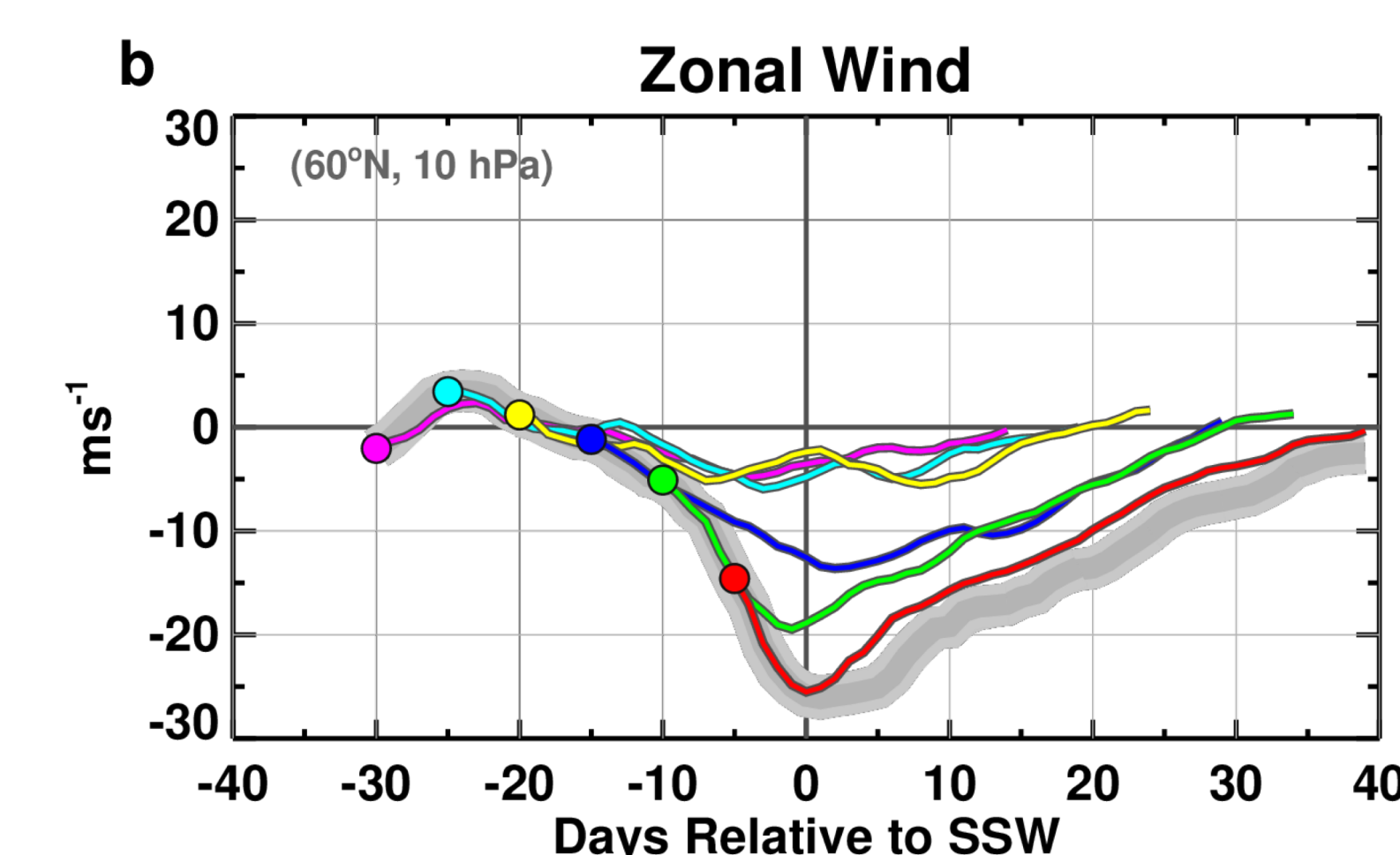
S2S 20-day forecasts of 10 hPa geopotential height all show a large amplitude wave one on the SSW date that differs from the average climate for the date.

While a major SSW is not predicted, the S2S forecasts did predict a large amplitude wave event at that time.

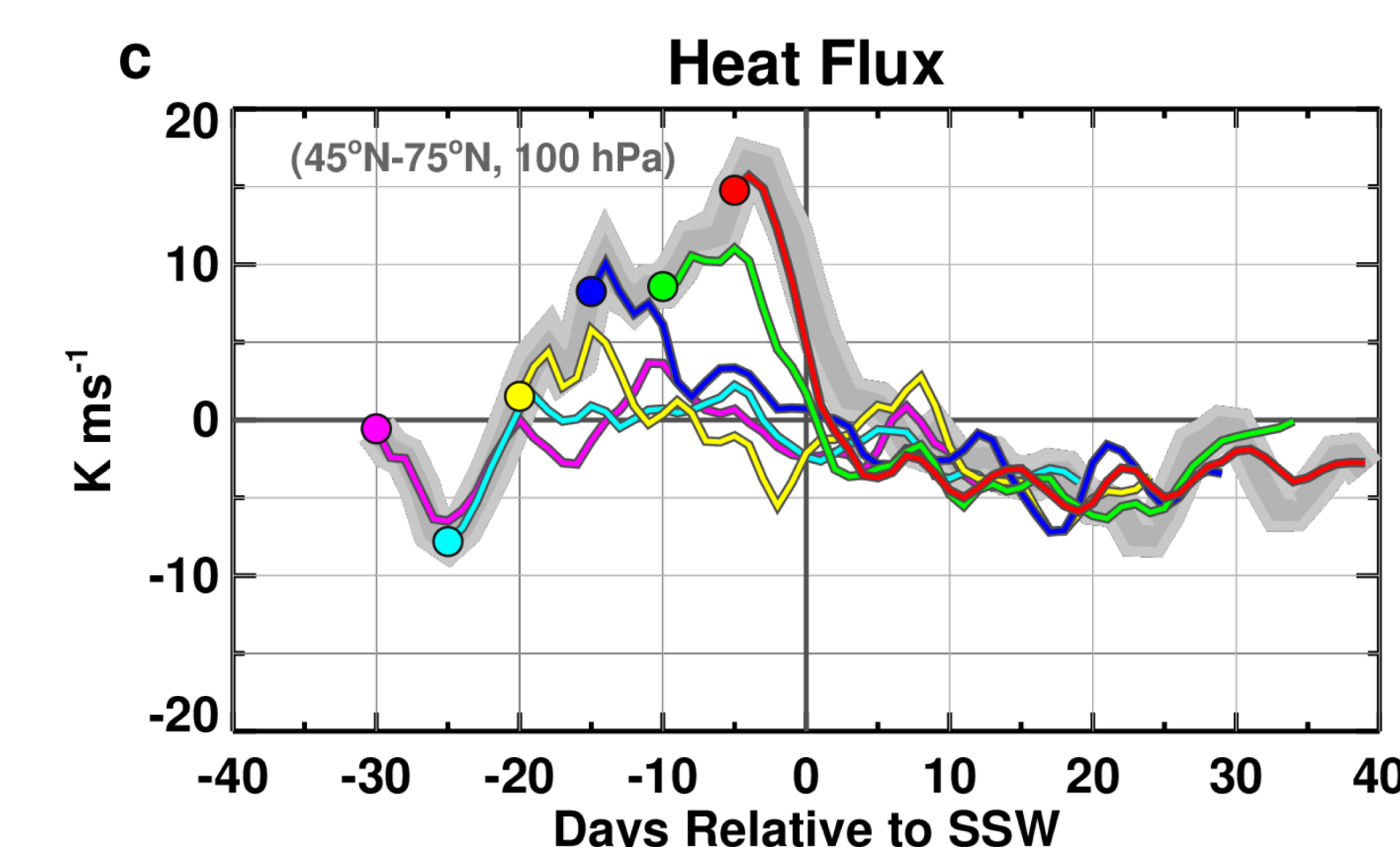
S2S Composite Forecast of 15 SSW Events



Polar Temperature (10 hPa): Rises during warming event. Forecasts initialized 5-15 days prior to the SSW accurately track the temperature response up to 40 days after the SSW date.



Zonal mean zonal wind (60°N, 10 hPa): Decreases during warming event. Even forecasts initialized 20-30 days before the event show some decrease in the wind.

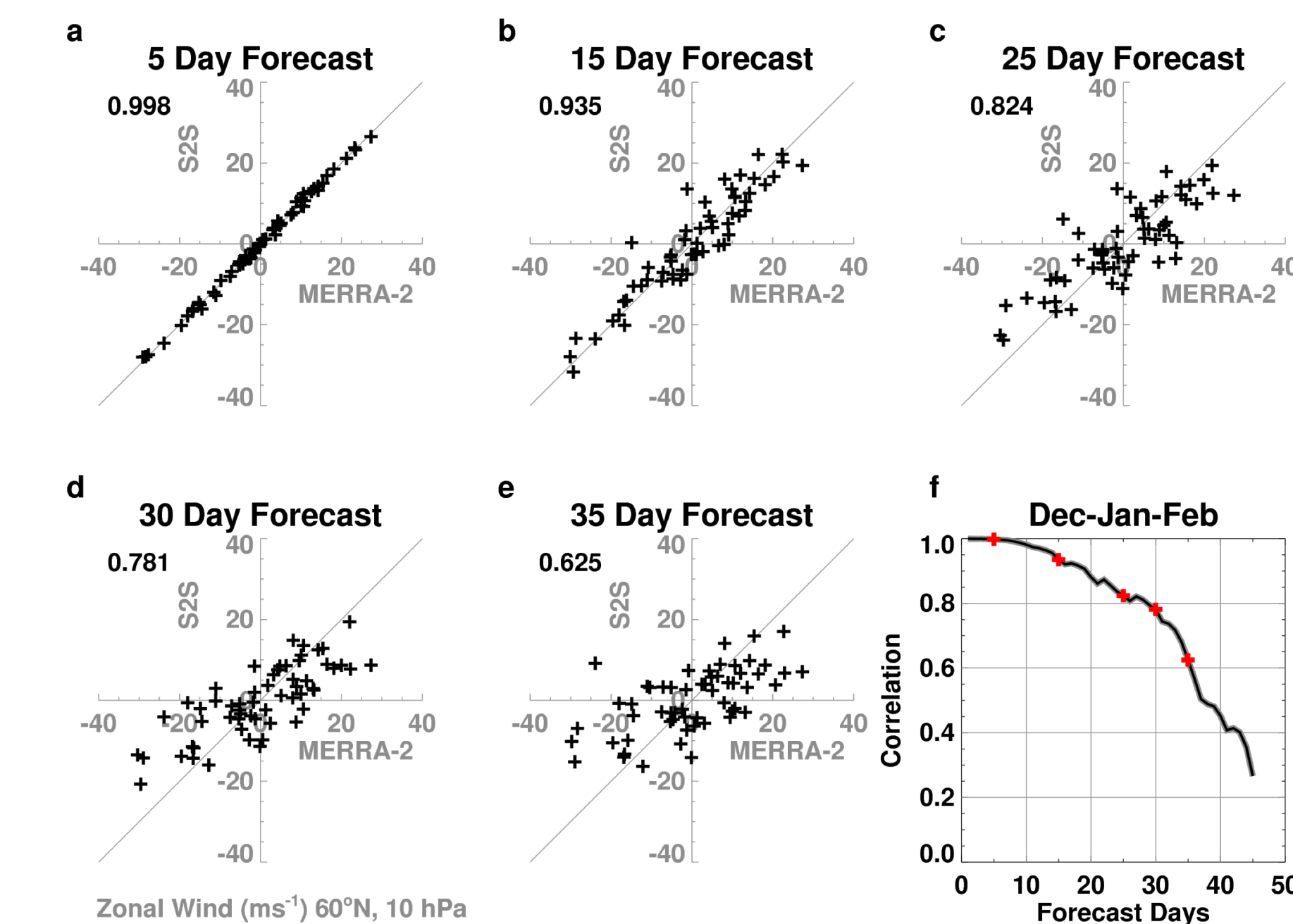


Zonal mean meridional heat flux (45-75°N, 100 hPa): Increases before the SSW events. S2S forecasts have difficulty capturing this increase in wave forcing from the troposphere.

- S2S Forecasts starting 5, 10, 15, 20, 25 and 30 days prior to the SSW dates.
- 60 S2S forecasts go into each composite forecast.
- The MERRA-2 composite of the 15 SSW events since 1999 is given by the thick gray curve.

S2S Forecasting Stratospheric Wave Activity

Stratospheric wave activity can be roughly approximated by monthly averaged zonal mean zonal wind (60°N, 10 hPa) (weaker winds imply stronger wave activity). Here the forecasted winds are compared with MERRA-2 values.



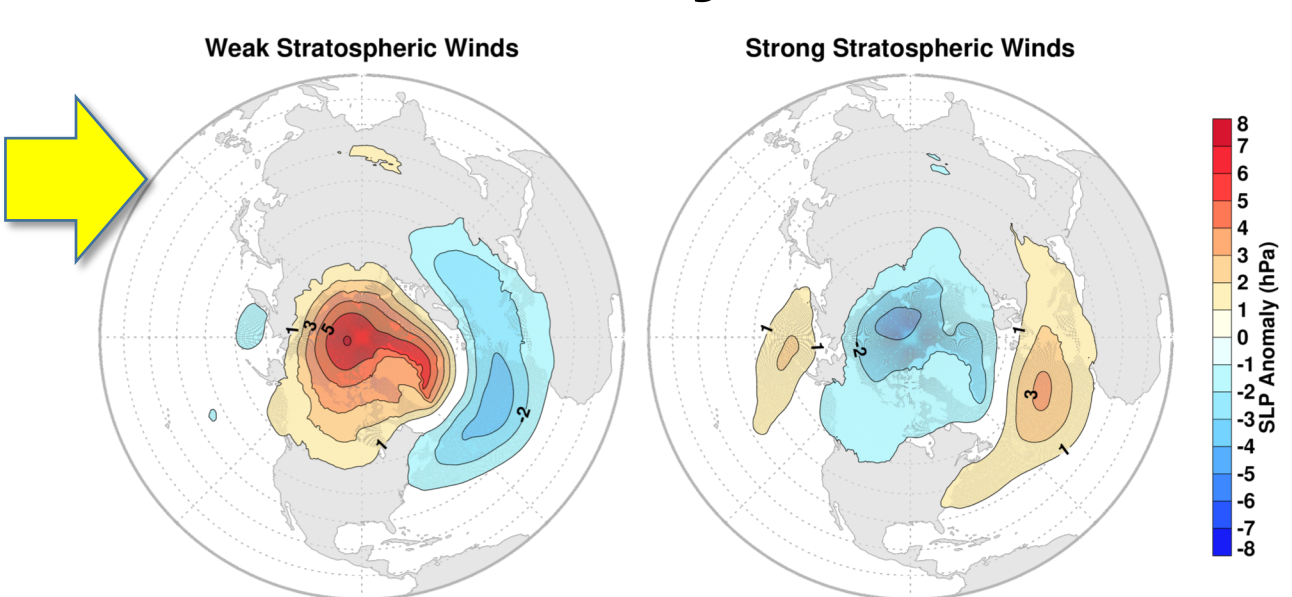
December, January, and February monthly averaged deviations from the mean.

Correlations suggest some skill out to 35 days. Red points mark the correlations shown in a-e.

Troposphere/Stratosphere Coupling

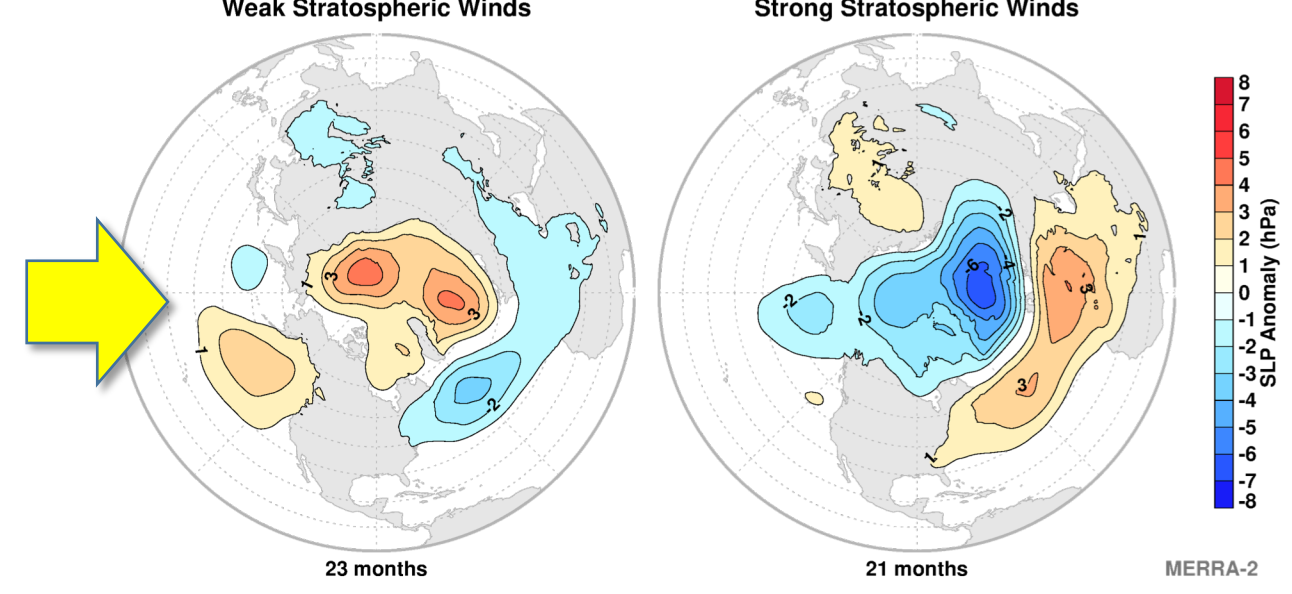
Connections between the stratosphere and troposphere are well studied. Here we show the DJF 25-30 day **S2S forecasted sea level pressure** (SLP) maps composited by the strength of the forecasted stratospheric wind (10 hPa, 60°N).

S2S 25-30 Day Forecasts



S2S forecasts show a typical first EOF pattern with higher polar SLP associated with weak stratospheric polar vortex.

MERRA-2 Assimilation



Corresponding MERRA-2 composite showing similar relation between the stratospheric winds and surface pressure

Conclusions

1. **FP system:** realistic forecasting of stratospheric wave activity and major SSW events out to 10 days.
2. **S2S system:** some information of major SSW events out to 20 days.
3. **S2S system:** some information about stratospheric wave activity out to 30 days.
4. **S2S system:** strong connection between stratospheric wave activity and SLP.

Future Directions

1. Develop routine **S2S 45-Day forecasting diagnostics** for the stratosphere and associated tropospheric changes.
2. Investigate longer, out to **9 month lead time**, S2S stratospheric forecasting skill and appropriate diagnostics.

