The Stratospheric Warming of 2018 in the Context of the Earth System

Steven Pawson, Lauren Andrews, Lawrence Coy, Richard Cullather, Young-Kwon Lim, and Andrea Molod
NASA Goddard Space Flight Center, Greenbelt, MD, USA

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 recent February 2018 major SSW and associated tropospheric effects to better understand:
1. How far in advance can major SSW events be forecasted?
2. Can knowledge of SSW events improve tropospheric weather, arctic sea ice, and surface 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 reanalyses starting from 1980

Forecast of Vortex Splitting Event of February 2018
The FP 10-day forecasts accurately capture the 1st Wave-2 SSW since 2009.

Sub-Seasonal Prediction February 2018
An ensemble member from an S2S forecast shows a similar pattern to the MERRA-2 Analysis

Vertical Coupling
Strong anomalies extend from the Stratosphere to the Troposphere after the SSW.

Tropospheric Response, SSW Plus 40 Days
The 40-day period after the SSW was characterized by anomalous high pressure over the Norwegian and Barents Seas and low pressure near the Azores. The Arctic high advected cold air down over central Europe, while warm subtropical Atlantic air was transported into the Arctic. The patterns reflect the historical SSW response but differ in magnitude (Smith et al., 2018, J. Clim. https://doi.org/10.1175/JCLI-D-17-0495.1).

Storm Track Changes in MERRA-2
Left: Typical day after SSW shows relation between stratospheric circulation and surface conditions, with stratospheric vortex and winds (white), upper tropospheric winds (red), and surface temperature change (GE OSS FP forecast).
Right: In SSW+40 days, the jet stream became more zonal and elongated over North America, leading to enhanced synoptic variability and severe weather over the central US, and more frequent cyclogenesis along the Atlantic seaboard.

Arctic Changes and Predictability
Top: The SSW and circulation changes led to an increase in sea ice cover in the Barents Sea in March 2018, while warm conditions and low sea ice cover resulted along the northeast Greenland coast.
Right: GEOS S2S sea-ice forecasts initialized in February 2018 demonstrate a similar, though diminished pattern in sea ice change in March.

Conclusions
- The SSW was associated with anomalous conditions that extended to the surface, with particularly enhanced effects in European surface temperatures, North Atlantic sea ice cover, and the North American jet stream and related storm track.
- Although circulation anomalies are consistent with canonical response patterns, the effects were particularly strong.
- Models accurately predicted SSW in 10-day lead forecasts with some S2S skill out to 20 days. S2S predictability also identified responses in sea ice field.