Prediction of the Eurasia/Siberian warm extreme events in 2020 in Version 2 of NASA's GEOS-S2S forecast system and the mechanism for their development and maintenance associated with Rossby-wave propagation

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There were unprecedently frequent and strong warm extreme events across Eurasia/Siberia over the first half of 2020. Specifically, the northeastern Siberia region experienced the record-breaking temperature that reached ~38° C in later period of June. To avoid risk that can adversely affect human life, reliable prediction of the warm extreme events and heatwaves is urgently required. In this study, we first examine predictions of the Siberian warm extreme events in Version 2 of NASA's Global Earth Observing System Subseasonal to Seasonal (GEOS-S2S) forecast system to identify the extent to which the model can reasonably anticipate these extreme events. We specifically focus on the forecasts at 10-15 day lead, which is beyond the weather forecast time scale.

To examine predictions of the individual warm extreme events, seven events, four of them that occurred in cold season (January and February) and three in warm season (April to June) are selected. Distribution of 2-meter air temperature anomalies forecasted by the GEOS-S2S model indicates that geographical location, spatial extent, and amplitude of the observed positive anomalies that reflect the warm extreme events is quite successfully forecasted at weather time scale lead. Forecasts at 10-15 day lead exhibit that, while the model captures the occurrence of the extreme events, it tends to underestimate the observed magnitude of warm anomalies. Model capability in regard to the prediction of geographical location of the events differ from case to case, either forecasting the location accurately or showing (zonal or meridional) shift of warm anomalies, compared to observed.

Following the examination of the model capability in forecasting the warm extreme events, dynamic mechanism that accounts for the cause and persistence of the extreme anomalies that lasts over multi-days is investigated. The investigation has a particular focus on the possible role of Rossby wave propagation in driving the warm extremes. Observed atmospheric structure at upper-troposphere (250hPa) evidences that the strong eddy height anomalies with alternate signs are distributed across the Atlantic and Eurasian mid-latitudes. This dominant structure is clearly in contrast to the structure during non-warm extreme periods that are characterized by less-well organized wave train-like distribution of eddy height anomalies. This difference in eddy height fields between extreme and non-extreme period indicates a significant role of the Rossby wave propagation in controlling the extreme weather events.

In order to find the Rossby wave source (RWS) region, the RWS is computed based on the quasi-geostrophic vorticity equation. Distribution of RWS over the mid-latitudes for the selected warm extreme events indicates that larger amplitude of RWS is generally found over the eastern North America near the storm track and the mid-latitude Atlantic. This estimated RWS is implemented into the global stationary wave model (SWM) to offer clear evidence on the importance of Rossby wave propagation originating from the eastern North America and the mid-latitude Atlantic in driving the warm extremes across Eurasia/Siberia. The results from SWM experiments reveal that the simulated eddy streamfunction anomalies match the observed extreme temperature anomaly distribution quite well, demonstrating that the extreme events are significantly controlled by the Rossby wave propagation originating from the eastern North America or the Atlantic.