

Separating and Quantifying Distinct Impacts of El Niño and Stratospheric Sudden Warmings on North Atlantic and Eurasian Wintertime Climate

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Introduction

- Stratospheric sudden warmings (SSWs) influence the troposphere, generally leading to a negative phase of the North Atlantic Oscillation (NAO).
- The winter North Atlantic surface climate signature of El Niño is also a negative NAO, but that signal is less clear.
- SSWs are more frequent in El Niño winters than neutral-ENSO winters by a factor of about 1.3, suggesting a stratospheric pathway of El Niño's influence on the North Atlantic.

To clarify the distinct impact and importance of El Niño and SSWs on the North Atlantic and Eurasia, we separate and quantify the wintertime surface climate effects of the two sources of variability.

Model Integrations

- Two ensembles of 200 one-year integrations of the Whole Atmosphere Community Climate Model (CESM1 WACCM) [1] initialized on June 1.
- Neutral-ENSO ensemble forced by observed 1950-2014 climatological SSTs from ERSSTv5 [2].
- El Niño ensemble forced by composite SSTs from years in the record with three consecutive fall or winter three-month seasons with Niño 3.4 anomalies above 1.0 K.

Forming Composites

- We composite winters with and without SSWs in each ensemble.
- We define SSWs using Charlton and Polvani 2007 [3] definition of Nov-Mar zonal mean zonal wind reversal at 60°N and 10 hPa.
- Composites with SSWs are averages of sixty-day periods following each winter's first SSW.
- Composites of winters without SSWs use central dates from Neutral-ENSO with SSW composite and randomly selected winters.
- Composites shown are anomalies with respect to the Neutral-ENSO without SSW composite.

SSW Frequency in Model Ensembles

	EN	Neutral
Total Winters	200	200
SSW events	174	85
Winters with SSWs	140	72
Winters with 2+ SSWs	32	12

- SSW frequency in El Niño winters is twice that in Neutral-ENSO winters in the model.
- The high ratio is likely due to strong El Niño forcing in the model.

Surface Climate Composites

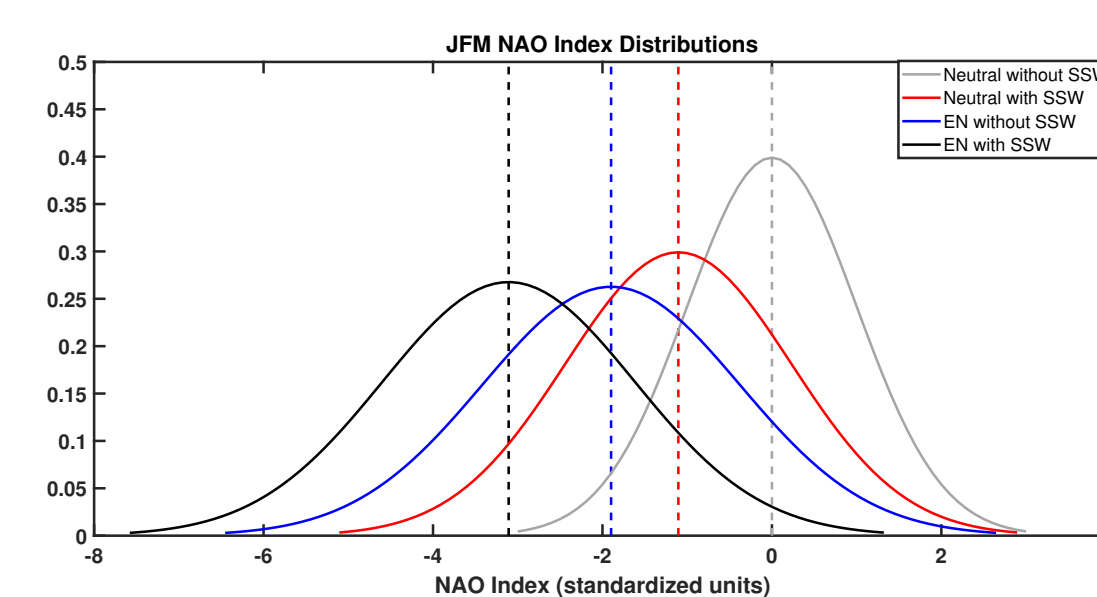


Figure 1: Fitted Gaussians of NAO indices normalized with respect to neutral-ENSO without SSW base state.

- Mean NAO indices:
SSW alone: -1.1. El Niño alone: -1.9. El Niño with SSW: -3.1.
- El Niño and SSWs individually result in similar negative effects on the NAO index.
- El Niño and SSW effects on the NAO are roughly additive.

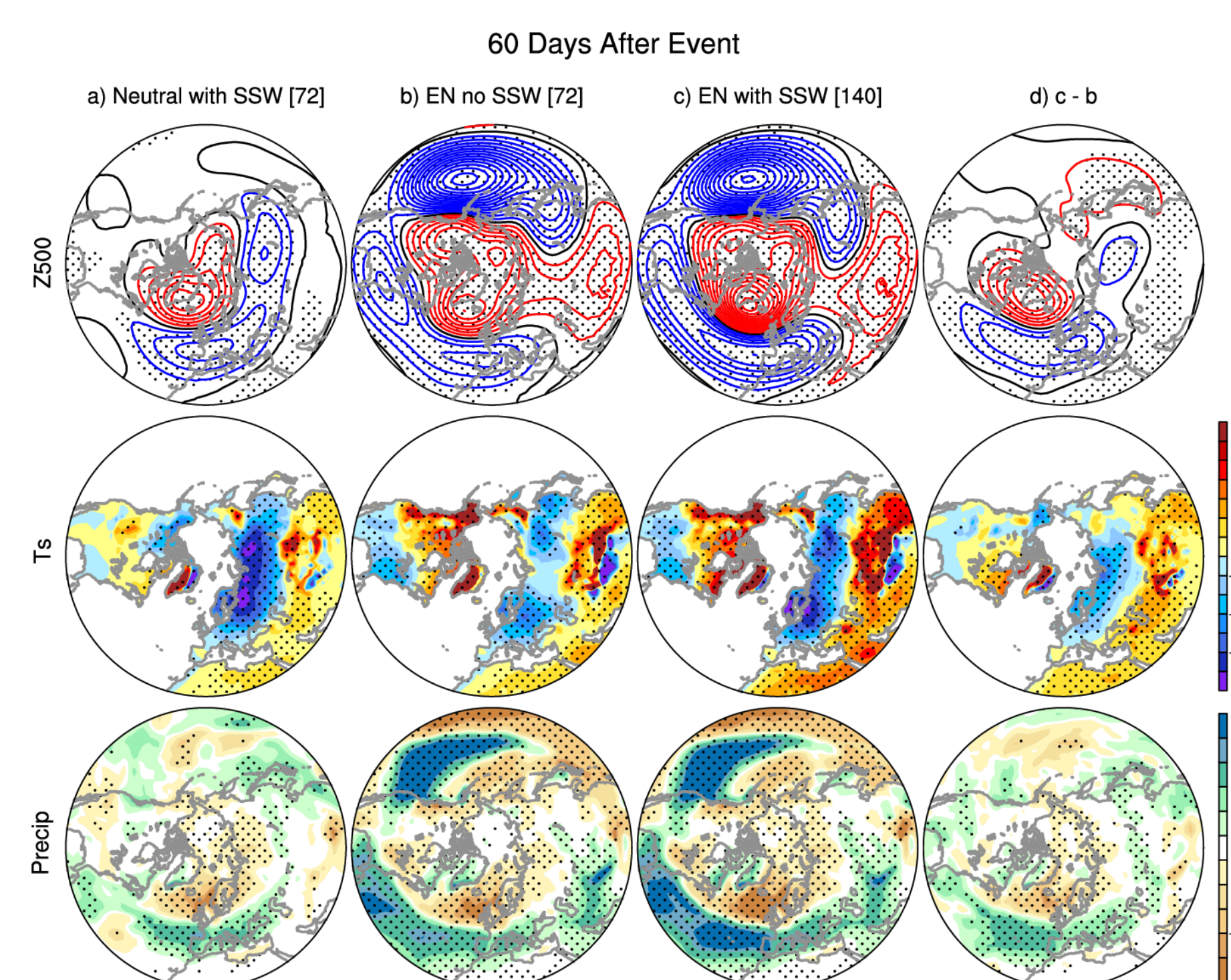


Figure 2: (Top) mean 500 hPa geopotential height anomalies. (Middle) mean 1000 hPa temperature anomalies (K). (Bottom) mean precipitation anomalies (mm/month).

- El Niño and SSWs alone lead to similar geopotential height and precipitation anomalies, and the effect of SSWs is similar in both El Niño and Neutral-ENSO states.
- All composites show Eurasian cooling, but SSWs contribute much more strongly to this effect, particularly in Siberia.

Regional and Local Impacts

Table 1: Eurasian (60°-75° N, 30°-120° E) surface temperature and Mediterranean (35° – 45° N, 10° – 25° E) precipitation anomalies.

	Neutral w/ SSW	EN no SSW	EN w/ SSW
Eurasian T (K)	-2.51	-0.59	-2.21
Med. precip (mm/mo)	+6.18	+6.91	+11.06

- SSWs result in about five times as much Eurasian cooling as El Niño.
- El Niño and SSWs have similar and roughly additive impacts on Mediterranean precipitation.

Table 2: Surface temperature anomalies (K) and precipitation rate anomalies (mm/month) for Paris, Stockholm, and Madrid.

	Neutral w/ SSW	EN w/o SSW	EN w/ SSW
Stockholm			
Surface T	-1.49	-1.34	-2.34
Precipitation	-25.58	-28.09	-44.24
Paris			
Surface T	-0.45	-0.57	-1.06
Precipitation	+7.81	-4.75	-1.44
Madrid			
Surface T	-0.20	-0.32	-0.42
Precipitation	+6.28	+11.83	+14.04

- Difference in relative impacts of El Niño and SSWs on precipitation is due to mismatch in the latitudinal centers of the dipoles.

Conclusion

- SSWs and strong El Niños have similar effects on the NAO and precipitation, but SSWs cause much more Eurasian cooling.
- SSW effect is similar regardless of EN/Neutral-ENSO conditions.
- Stratosphere must be well-resolved for accurate European wintertime forecasts.

References

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