# Distinct Impacts of El Niño and Stratospheric Sudden Warmings on Wintertime Climate

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# Subseasonal to Seasonal Climate Prediction

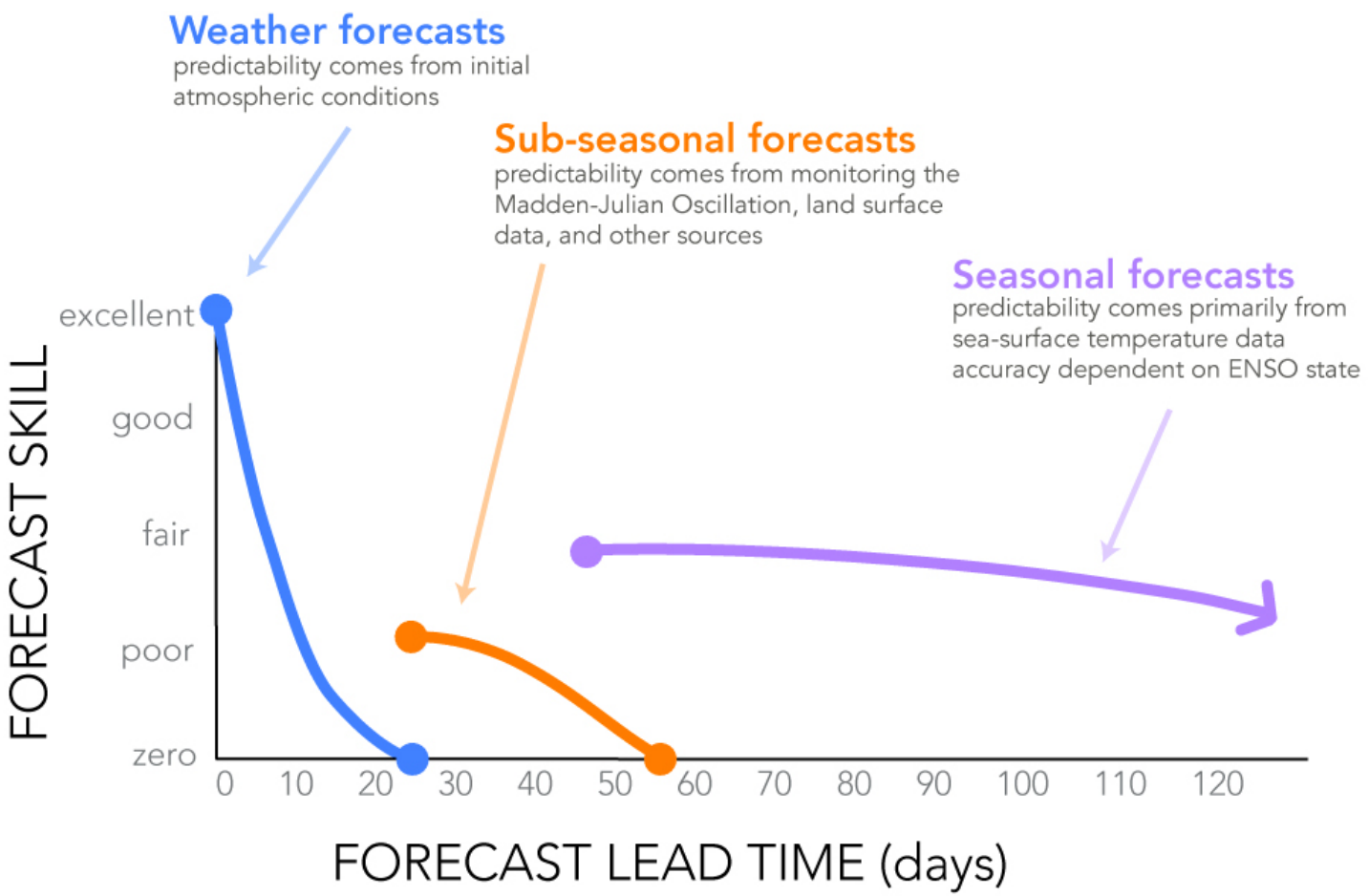


Figure: Forecast skill for various lead times, sources of predictability. Adapted by Elisabeth Gawthrop from figure by Tony Barnston.

# El Niño-Southern Oscillation (ENSO)

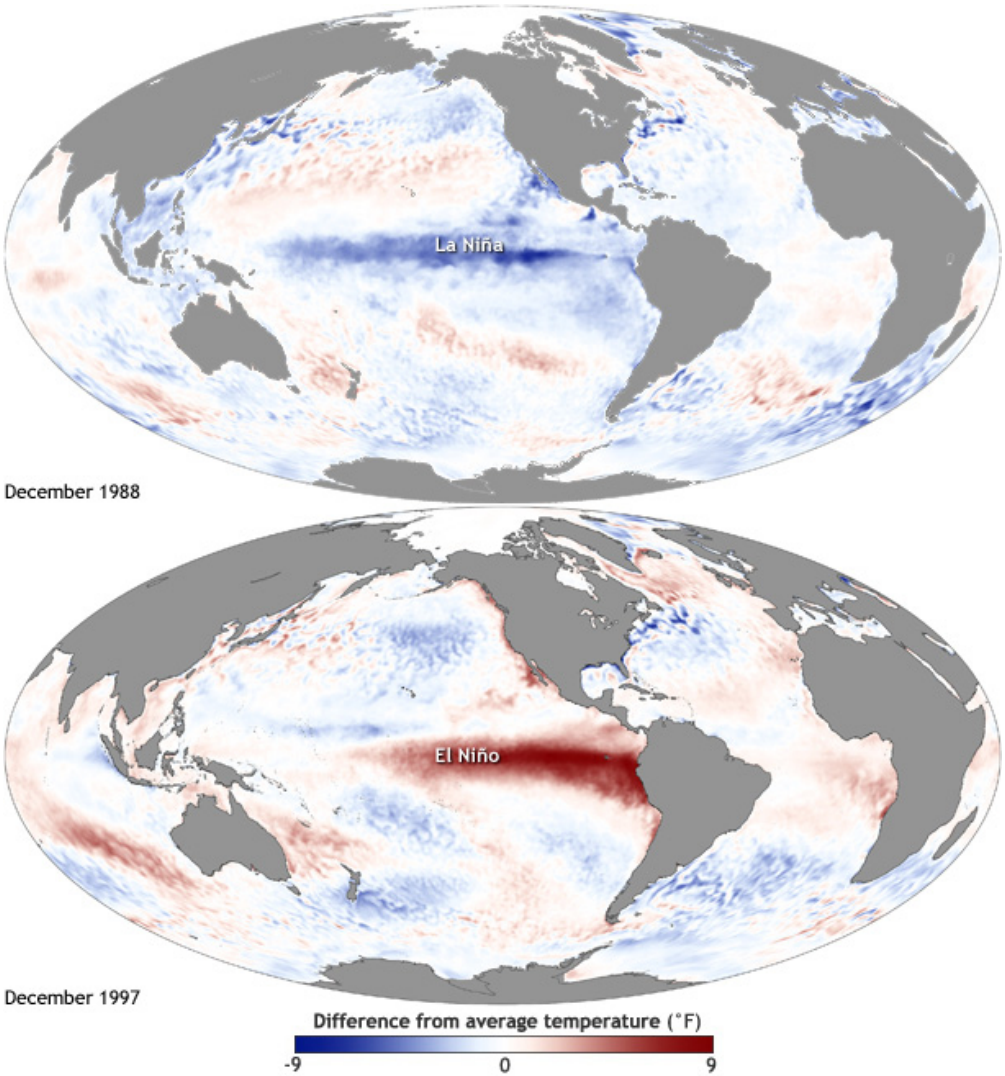


Figure: Maps by NOAA Climate.gov.

- ENSO associated with tropical temperature, pressure, precipitation anomalies
- Pressure and convection changes result in waves that propagate out of the tropics

# Typical North Atlantic Response to El Niño

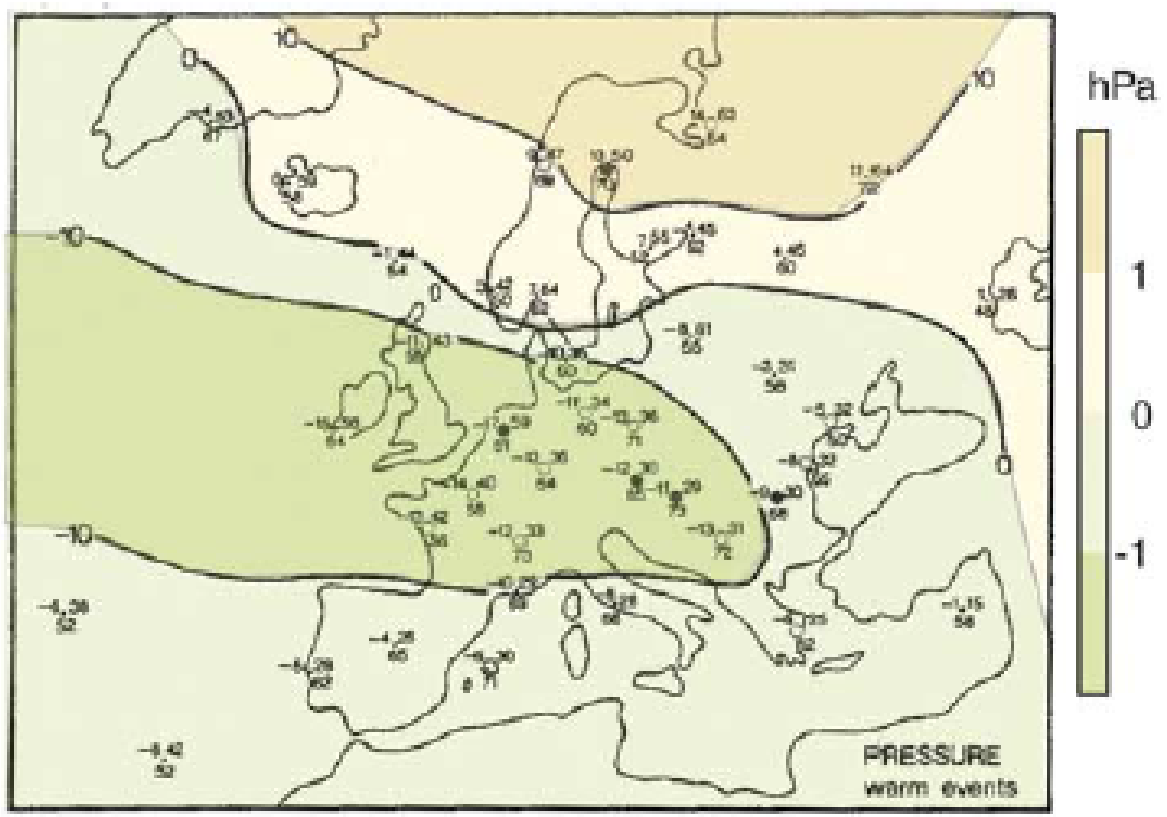


Figure: Sea level pressure anomaly composite for El Niño events 1880-1988. From Fraedrich and Müller 1992.

# Stratospheric Polar Vortex

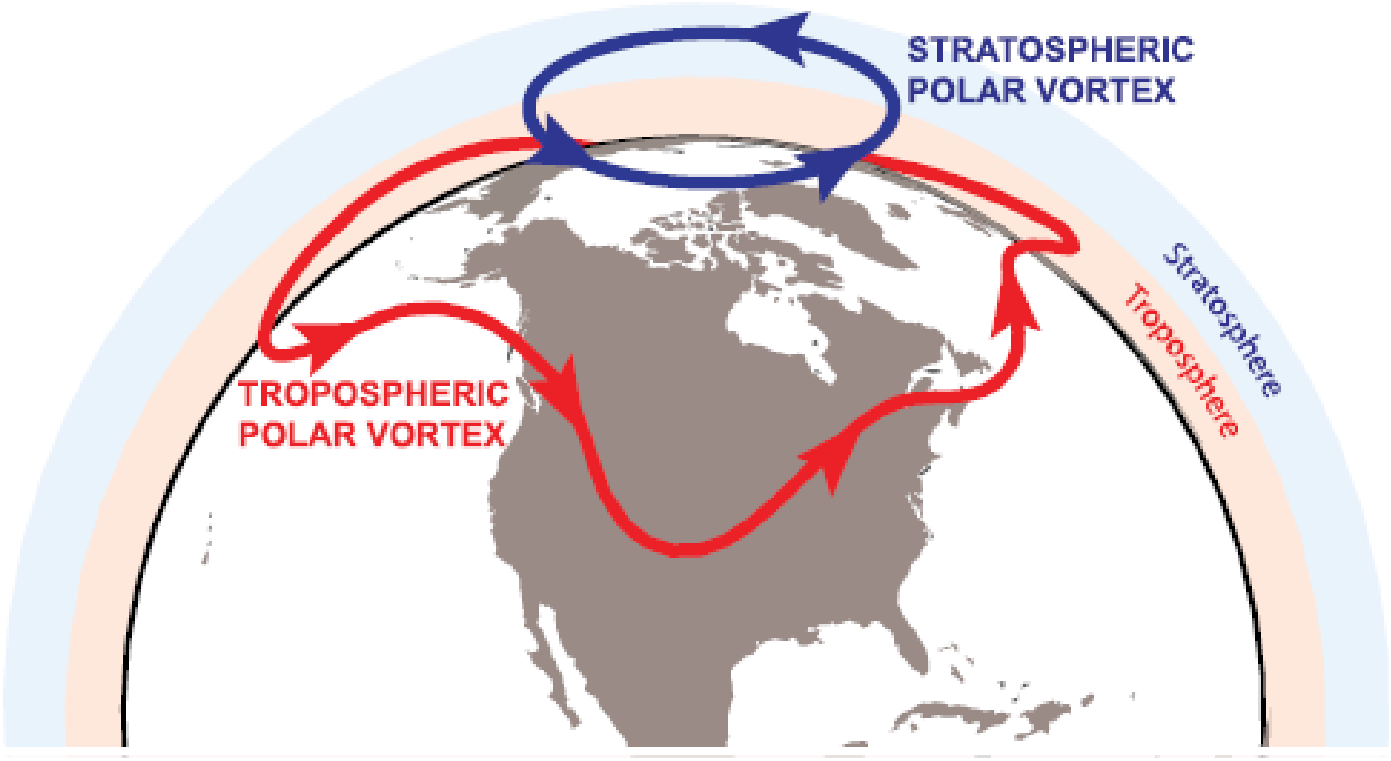


Figure: From Waugh, Sobel, Polvani 2017.

# Stratospheric Sudden Warming (SSW)

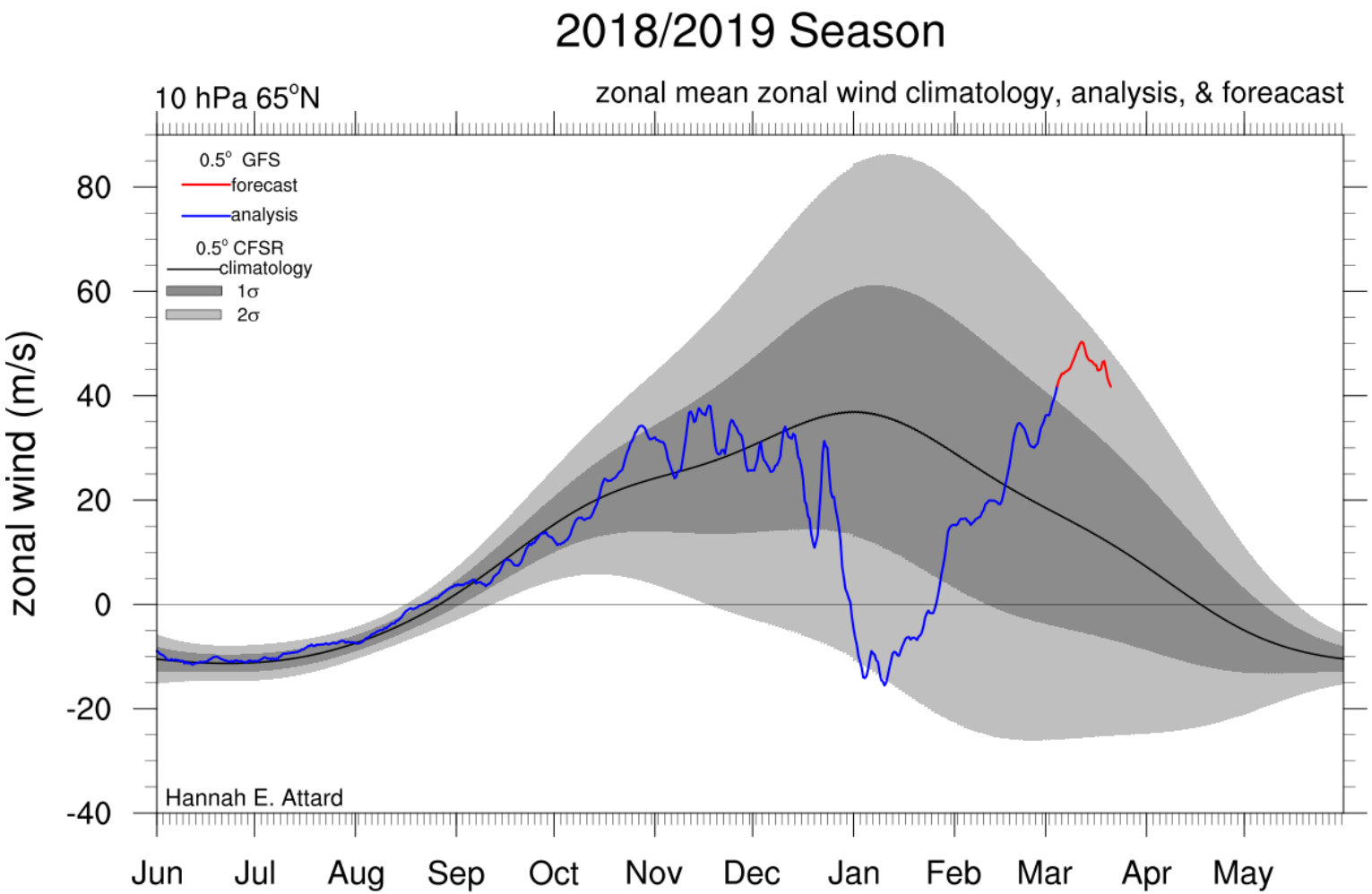


Figure: Stratospheric sudden warming at 2 Jan 2019. Plot from Hannah Attard.

# Typical Surface Response to SSWs

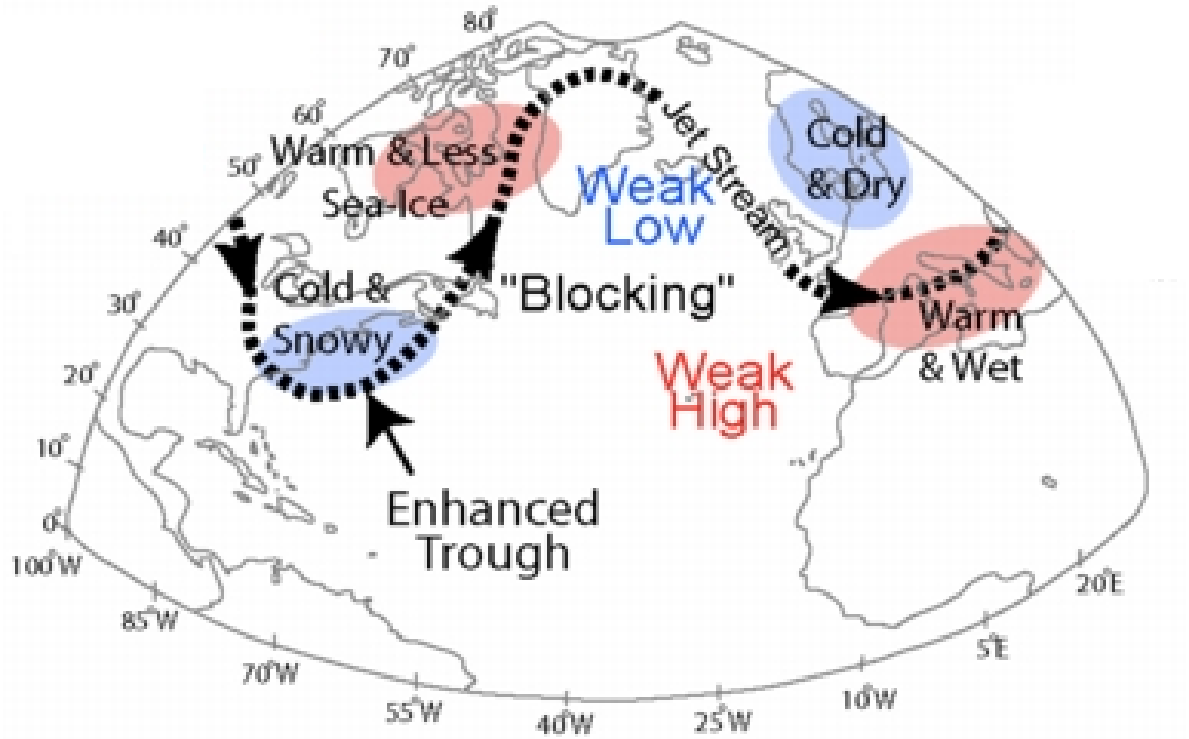


Figure: Features of the negative phase of the North Atlantic Oscillation. Figure from Wisconsin Weather.

# ENSO and SSW Frequency

El Niño increases SSW frequency by a factor of 1.3.

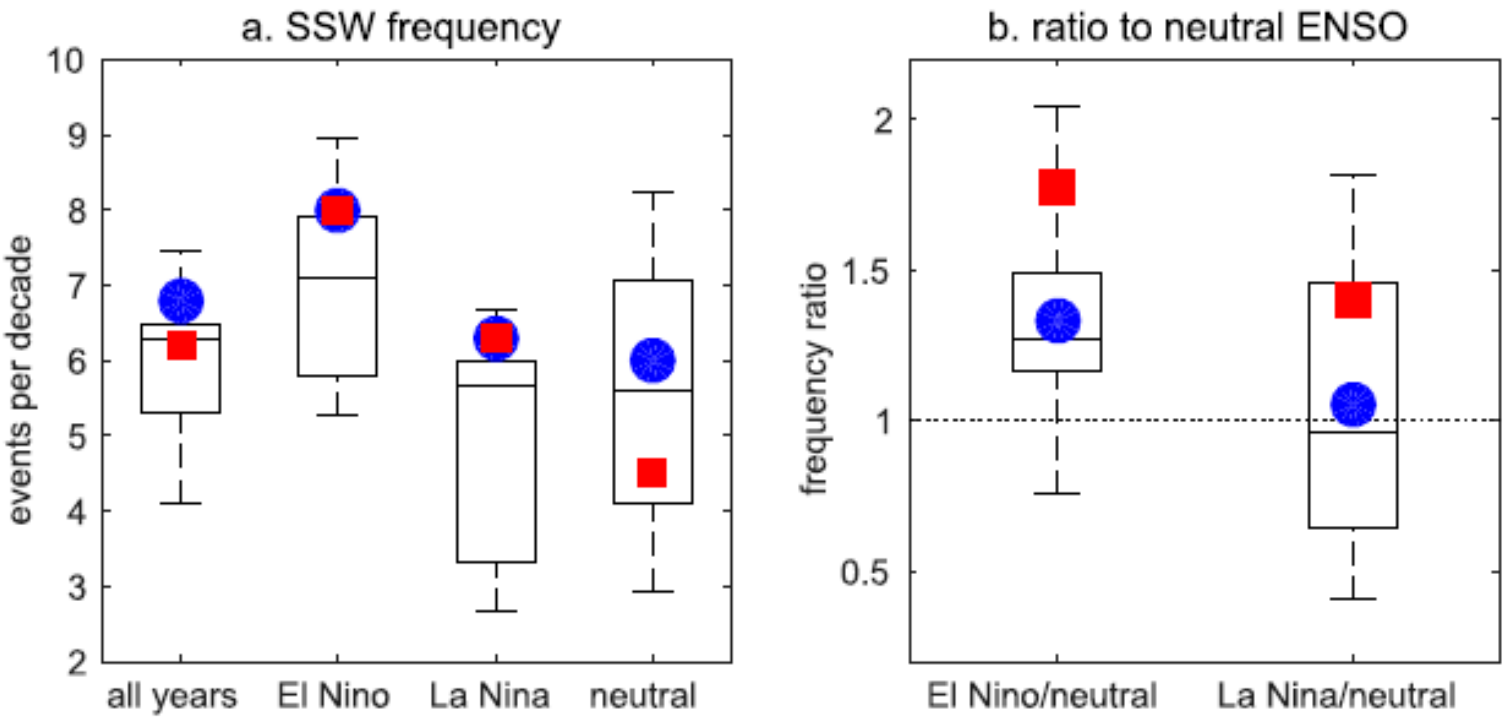


Figure: SSW frequency across ENSO phases. From Polvani et al 2017.

# Relative Impacts of El Niño and SSWs

- Observational (Butler et al. 2014) and modeling (Polvani et al. 2017) studies: **comparable differences due to SSWs, ENSO**
- Modeling studies (Ineson and Scaife 2009, Sigmund et al. 2013, Domeisen et al. 2015, Scaife et al. 2016): **anomalous mean European El Niño winter conditions only when SSWs occur**.
- Other modeling work (Bell et al. 2009, Li and Lau 2012): **negative NAO shift in El Niño winters in absence of active stratosphere**.

# Approach

- Do many one-year model integrations with slightly different initial conditions
- Use prescribed neutral-ENSO and strong El Niño sea surface temperatures
- Group into four sets of winters based on ENSO state and whether an SSW occurs
- Compare effects of El Niño and SSWs to basic state of neutral-ENSO without SSW

# Summary of Model Runs

- Whole Atmosphere Community Climate Model (WACCM)
- 200 one-year integrations for ENSO-neutral and El Niño
- Neutral-ENSO SSTs: 1950-2014 observed climatology
- El Niño SSTs: composite of strong El Niño events over 1950-2014

# SSW Frequency

Table: Summary of stratospheric sudden warming (SSW) events in EN and Neutral phases.

| | EN | Neutral |
|---|---|---|
| Total Winters | 200 | 200 |
| SSW events | 174 | 85 |
| SSW frequency/decade | 8.7 | 4.3 |
| Winters with SSWs | 140 | 72 |

# 60 Days After Event: Neutral-ENSO with SSW

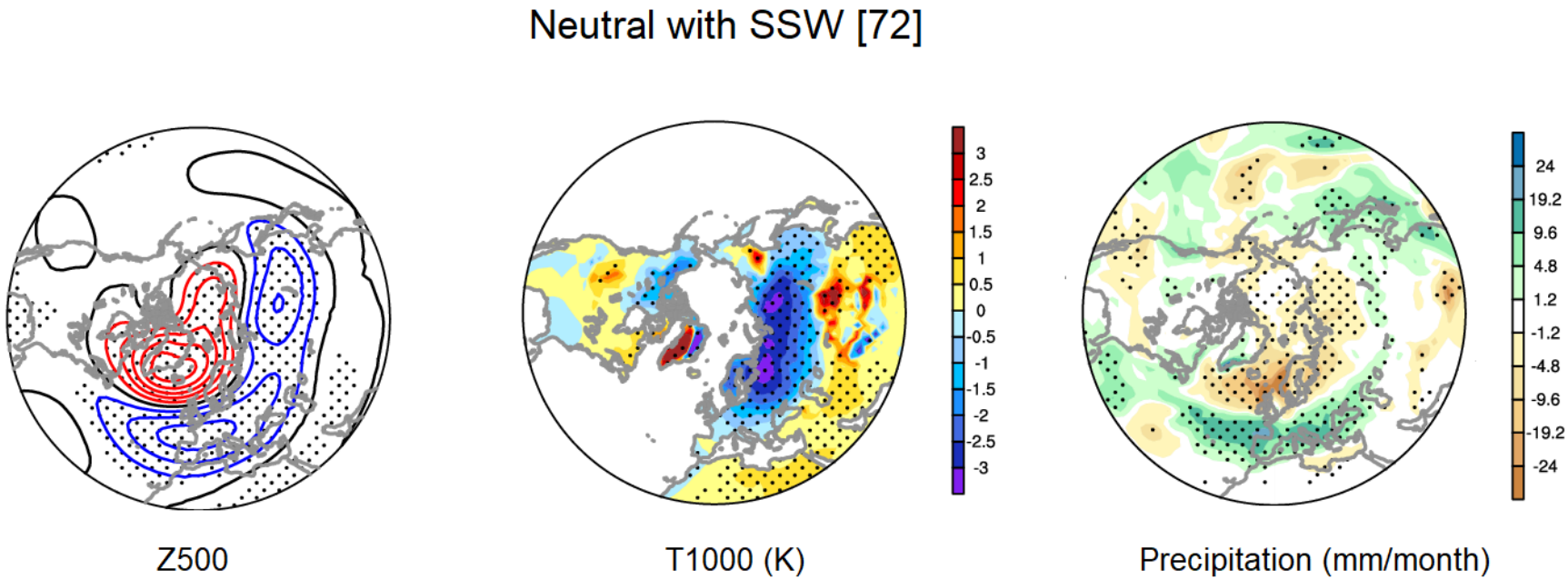


Figure: Surface climate response in the 60 days following an SSW in Neutral-ENSO conditions.

# 60 Days After Event: El Niño without SSW

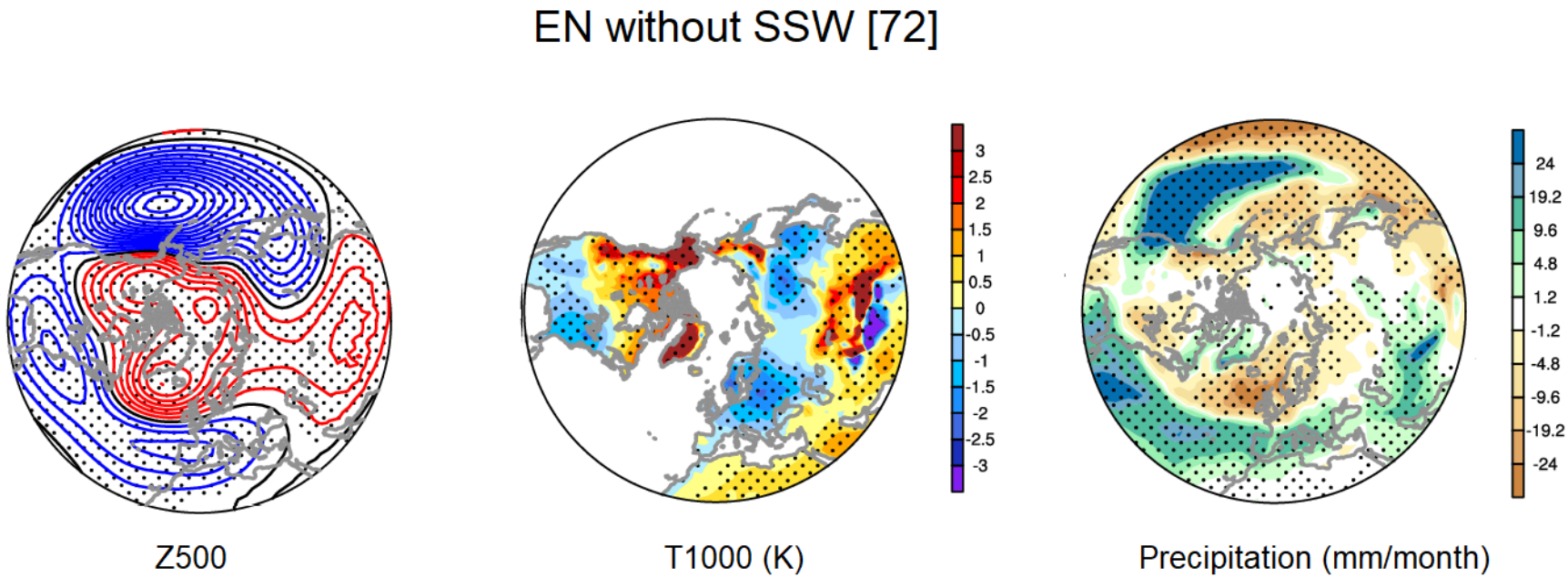


Figure: Surface climate response in 60-day periods during El Niño winters with a quiescent stratosphere.

# 60 Days After Event: El Niño with SSW

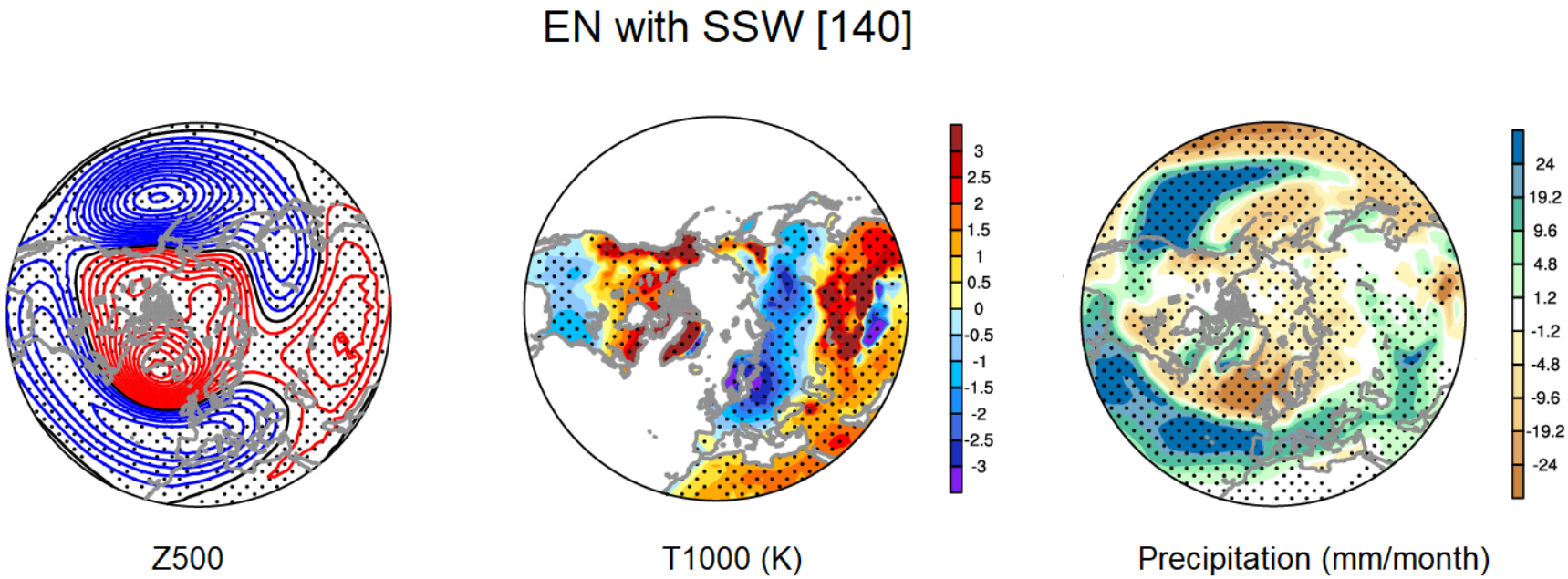


Figure: Surface climate response in the 60 days following an SSW in El Niño conditions.

# 60 Days After Event: Linear Additivity

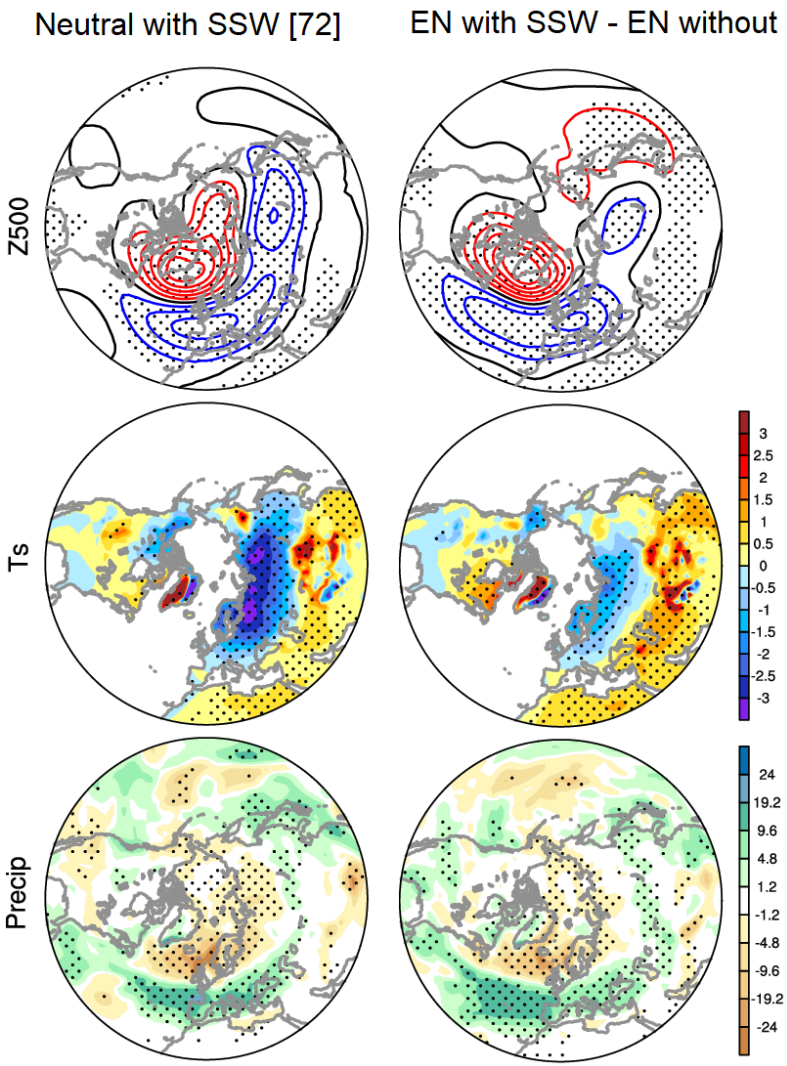


Figure: Surface climate response to SSWs in Neutral-ENSO and El Niño conditions.

# Regional Impacts

Table: 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 |

# Conclusions

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