ENSO-Driven Suppression of Interannual Atmospheric Variability Over North America

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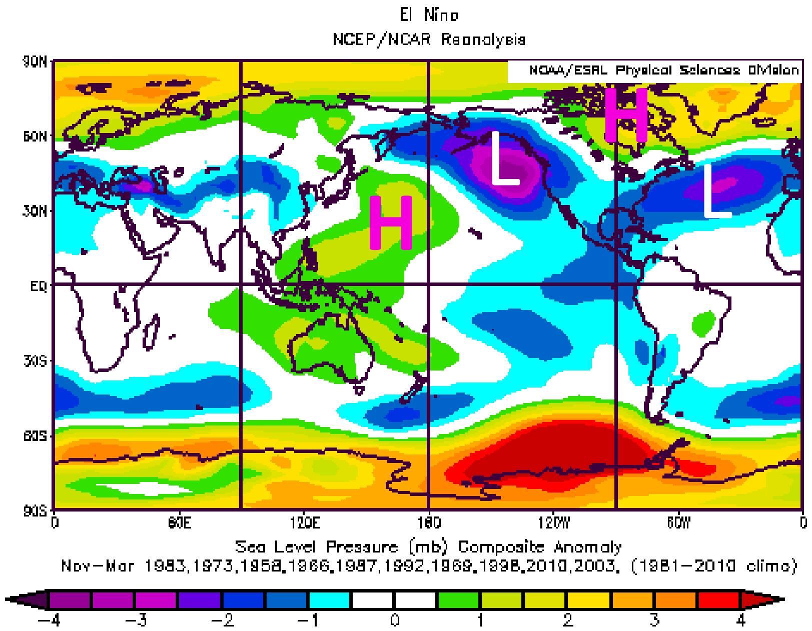
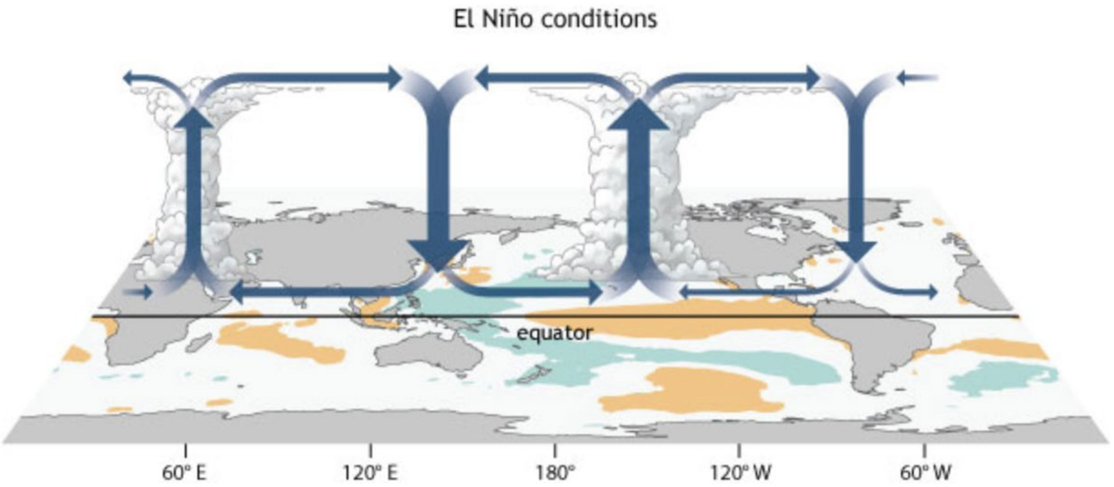
The Importance of ENSO teleconnections

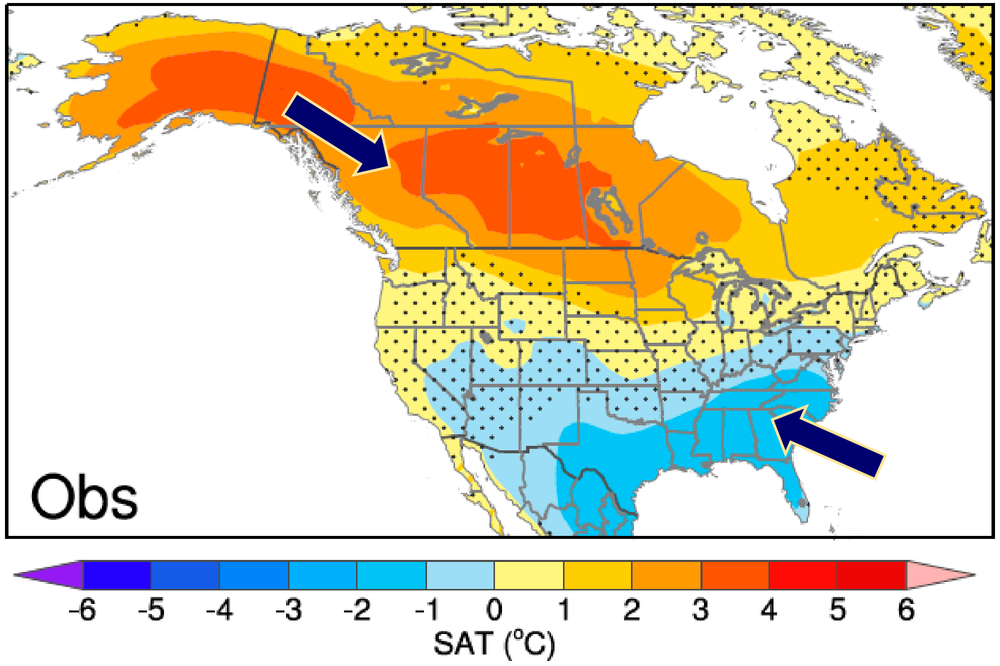
- Purpose is to show the atmospheric circulation and terrestrial impacts due to ENSO
- ENSO drives anomalous deep convection and latent heat release (Bjerknes, 1969)
- Perturbing global atmospheric circulation by Rossby wave train propagation (Ropelewski and Halpert, 1986)
- ENSO teleconnections effects temperature and precipitation globally (Barnston,2014)
- These impacts can enhance the risk of natural disasters and limit natural resources (Guimarães Nobre et al, 2019)
- It is important to understand climate without the presence of ENSO, in order to better understand ENSO's impacts

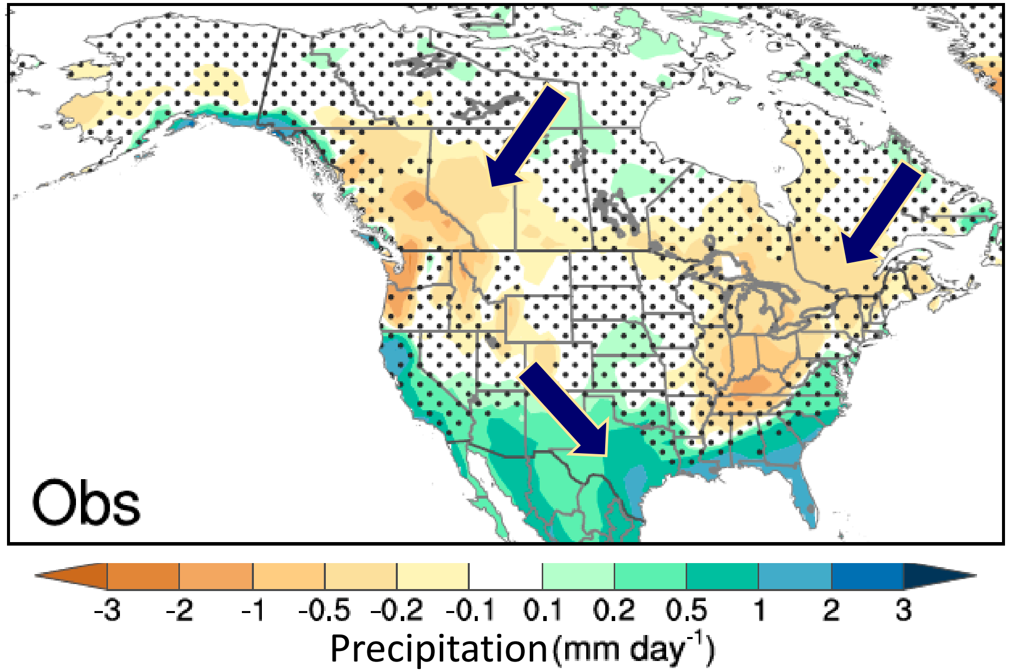




Current ENSO Teleconnections Over North America

- ENSO Composite anomalies (Deser et al., 2018)
  - 18 El Nino – 14 La Nina events during 1920-2013
  - 90% CI applied, Stippled regions are insignificant



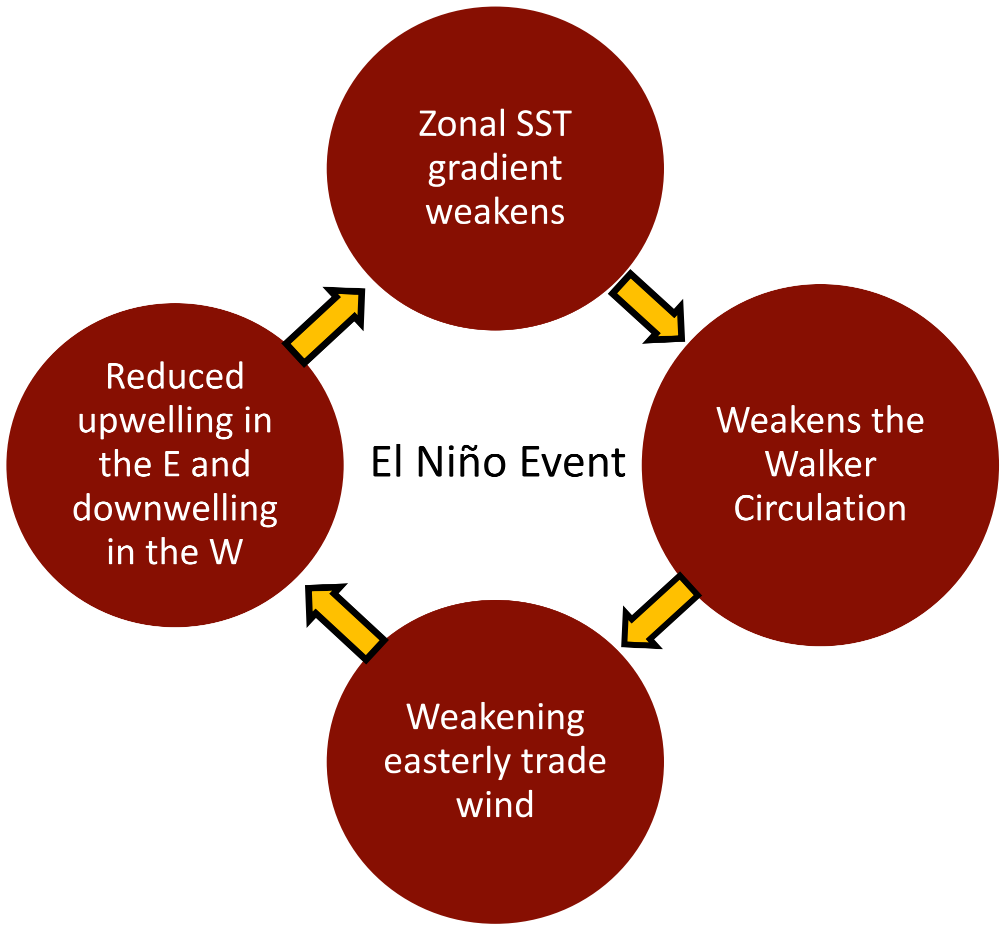


Common methods of removing ENSO

- Removing ENSO through linear regression
  - ENSO contains nonlinearities (Frauen et al., 2014)
- Removing the signal from the interannual (2-6 years) frequency band
  - ENSO potentially has a low frequency signal (Wittenberg, 2015)
- Assuming that the Nino3.4 SST index is strictly an ENSO signal
  - Tropical instability waves (Tian et al., 2018)
  - Subtropical influences (e.g., thermally coupled modes; Larson et al. 2018)
- Defining the first Principle Component and assuming this is encompasses all of ENSO variability.
  - Lagged response to ENSO (Compo and Sardeshmukh, 2010)

Method

- Suppression of the dynamical process that supports ENSO variability
- Bjerknes Feedback refers to the positive feedback loop between the ocean and atmosphere that reinforces the initial SST anomaly
- This experiment was done using a climate model due to the inability to remove the influence of the Bjerknes feedback in observational data



Method

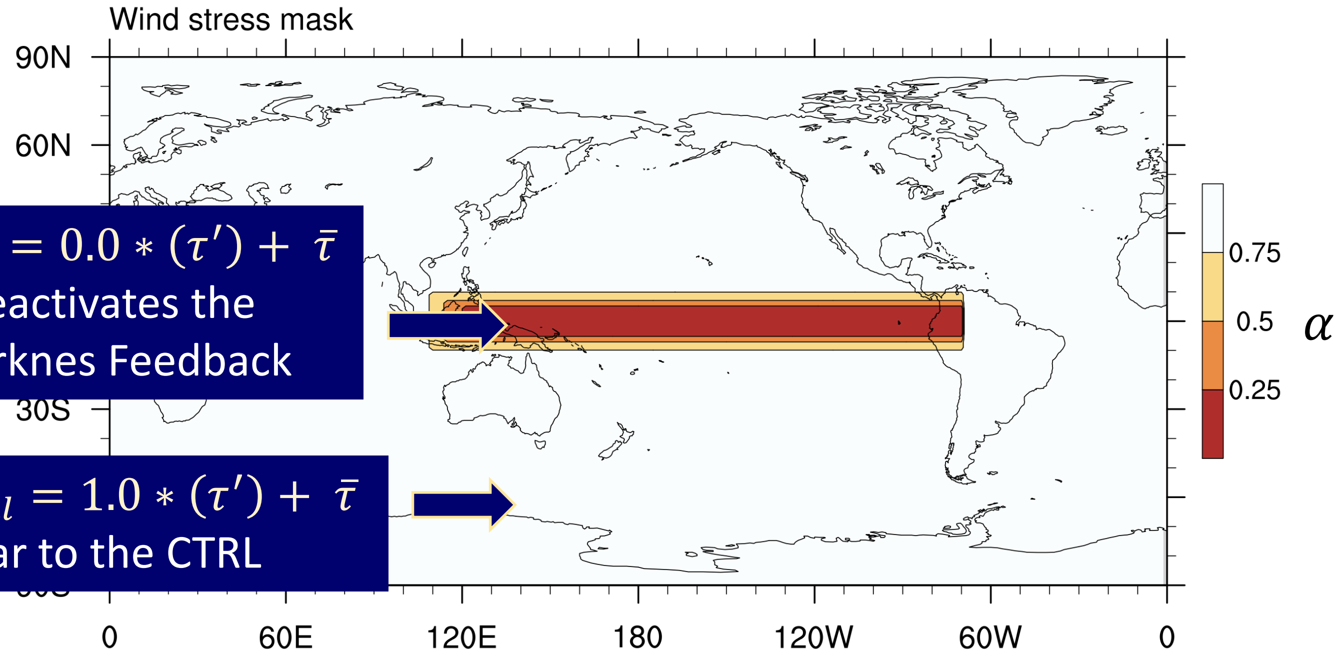
- NCAR CESM1-CAM4 is a fully coupled climate model
  - Present-day forcing, year 2000
  - Nominal 1° x 1° resolution

- CTRL: Control Experiment, simulates Earth's climate system

- NoENSO: Ocean is decoupled from anomalous wind stress in the tropical Pacific → short circuits the Bjerknes feedback
  → eliminates ENSO variability

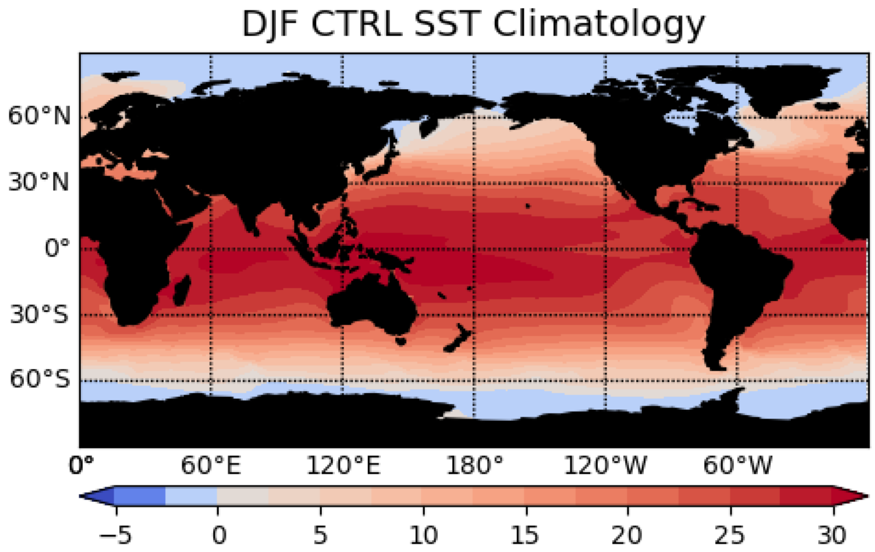
Method

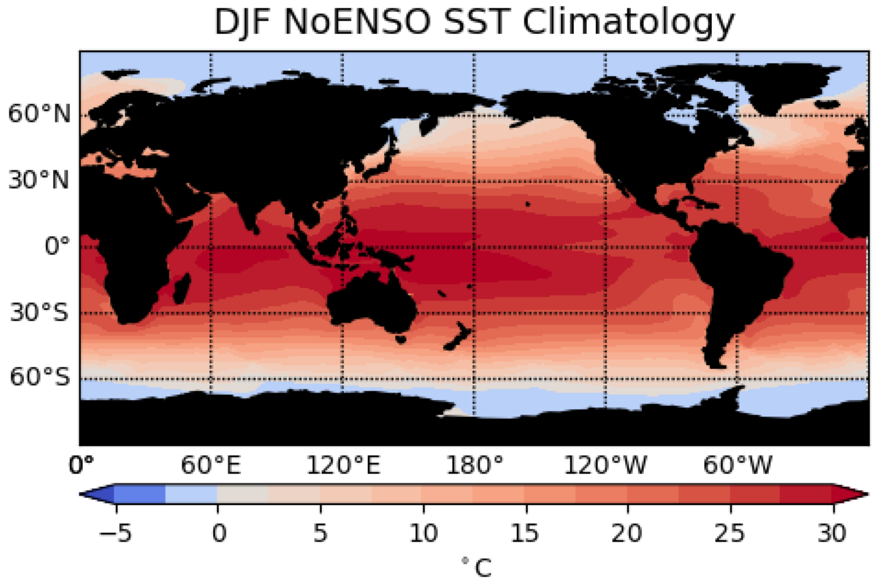
$$\tau_{total} = \alpha(\tau') + \bar{\tau}$$



$\tau_{total} = 0.0 * (\tau') + \bar{\tau}$
Deactivates the Bjerknes Feedback

$\tau_{total} = 1.0 * (\tau') + \bar{\tau}$
Similar to the CTRL

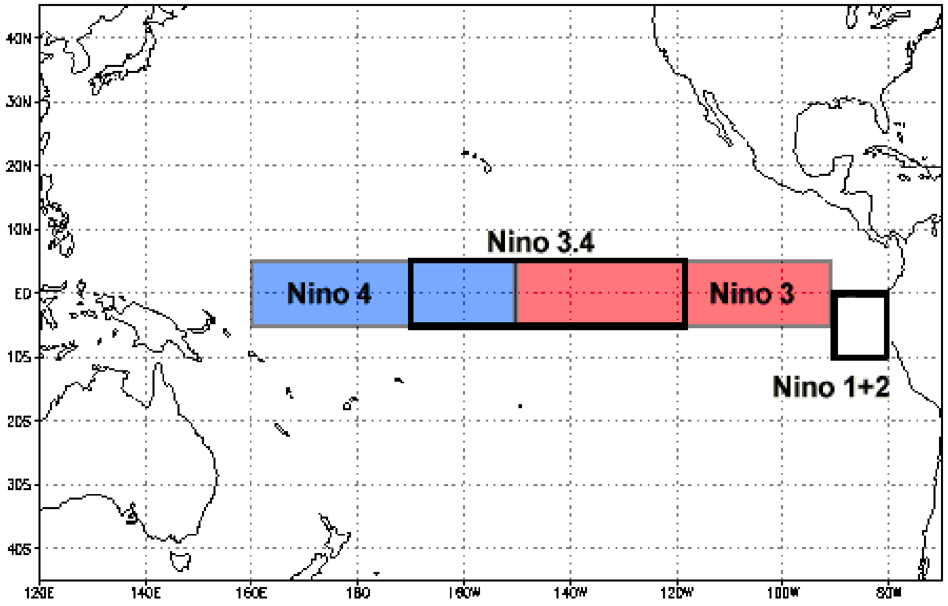




More Information: (e.g., Larson and Kirtman 2015, Larson et al. 2018)

Method

- The largest anomalies in the Equatorial Pacific are found during the December –January – February months
- Nino3.4 Region (5°N-5°S, 170°W-120°W)
- Niño3.4 Index is used to categorize ENSO events using a $\pm$0.5°C threshold



Provided by: NOAA

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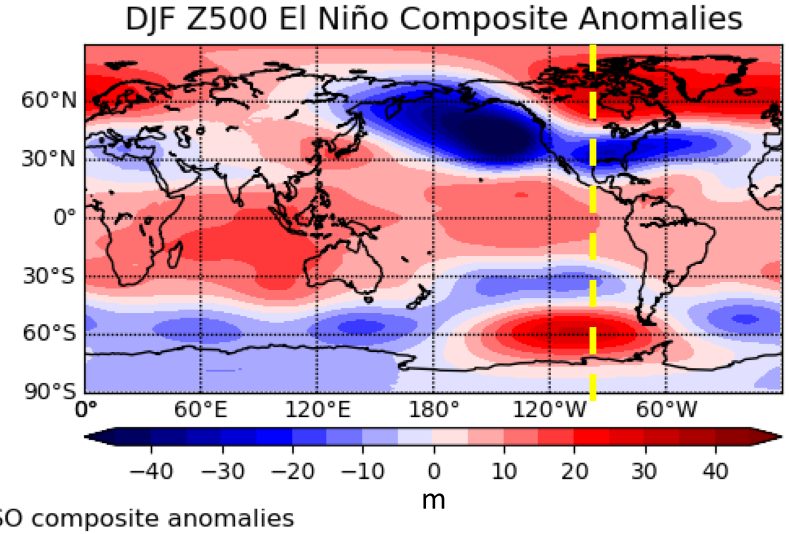
Method

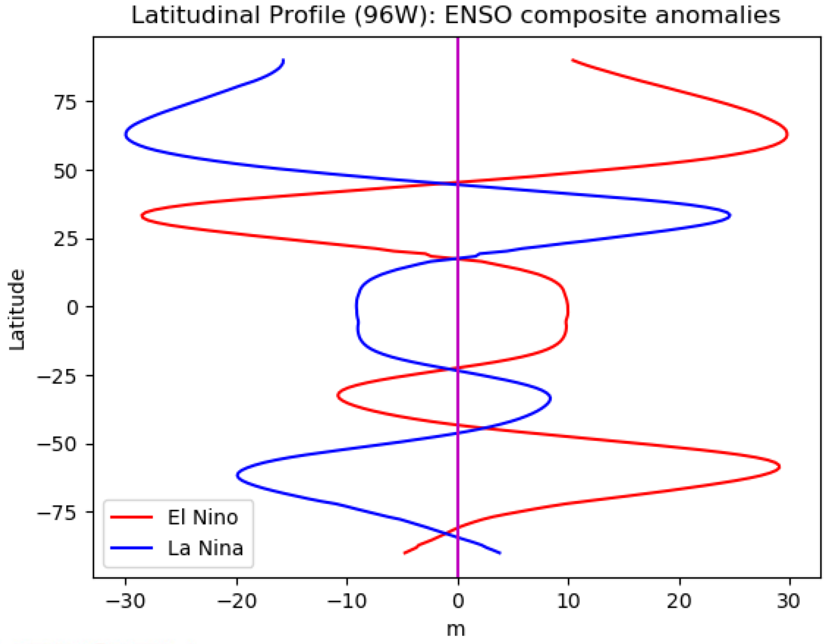
Monthly anomalies are calculated using:

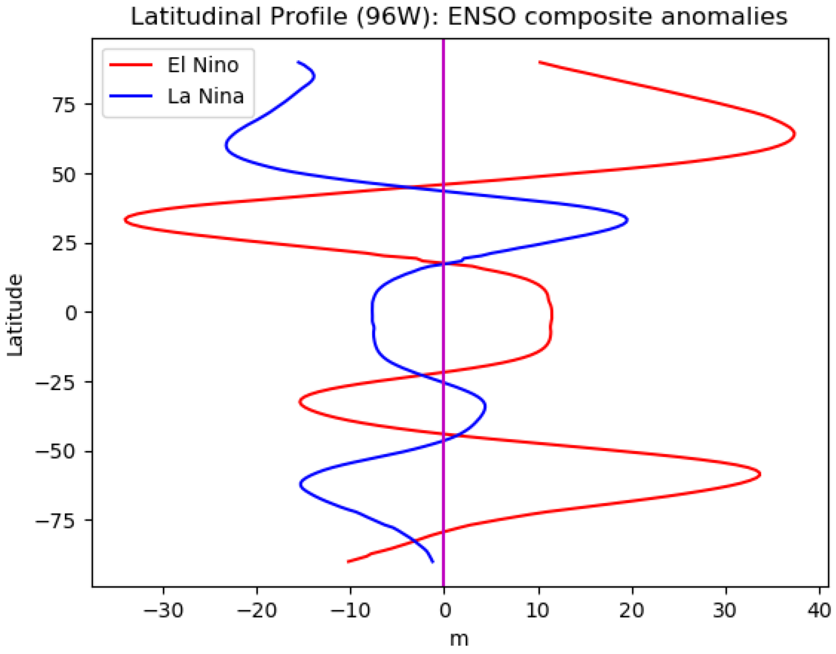
$$a'(x,y,t)_{CTRL} = a(x,y,t)_{CTRL} - \overline{a}(x,y,t)_{NoENSO}$$
$$a'(x,y,t)_{NoENSO} = a(x,y,t)_{NoENSO} - \overline{a}(x,y,t)_{NoENSO}$$

NoENSO reference climatology is used

- Asymmetries between ENSO events
- El Niño is stronger than La Niña; projects onto the mean-state

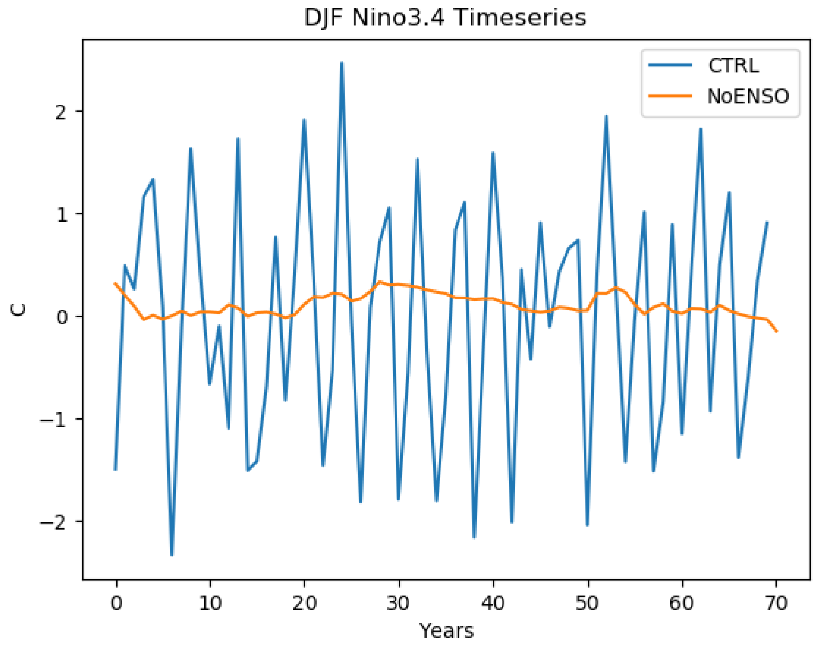


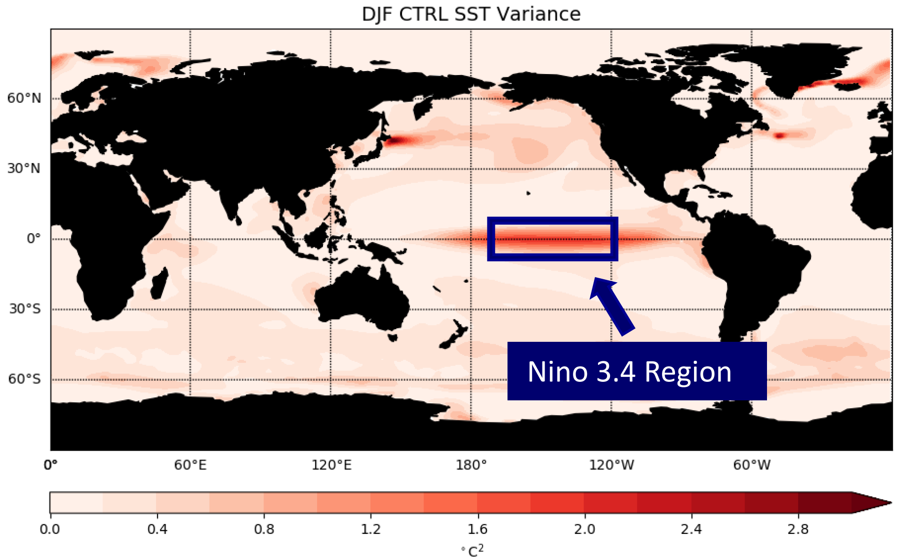


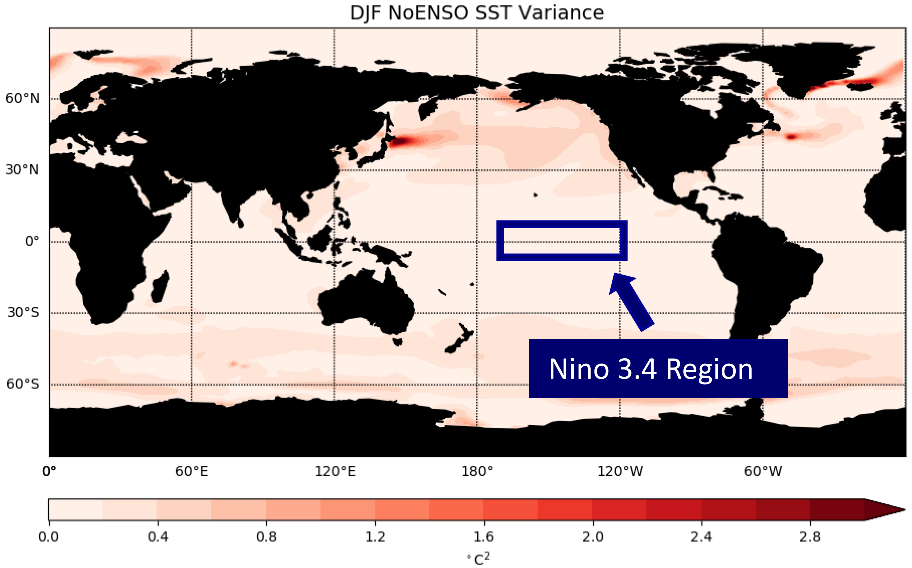


Sea Surface Temperature

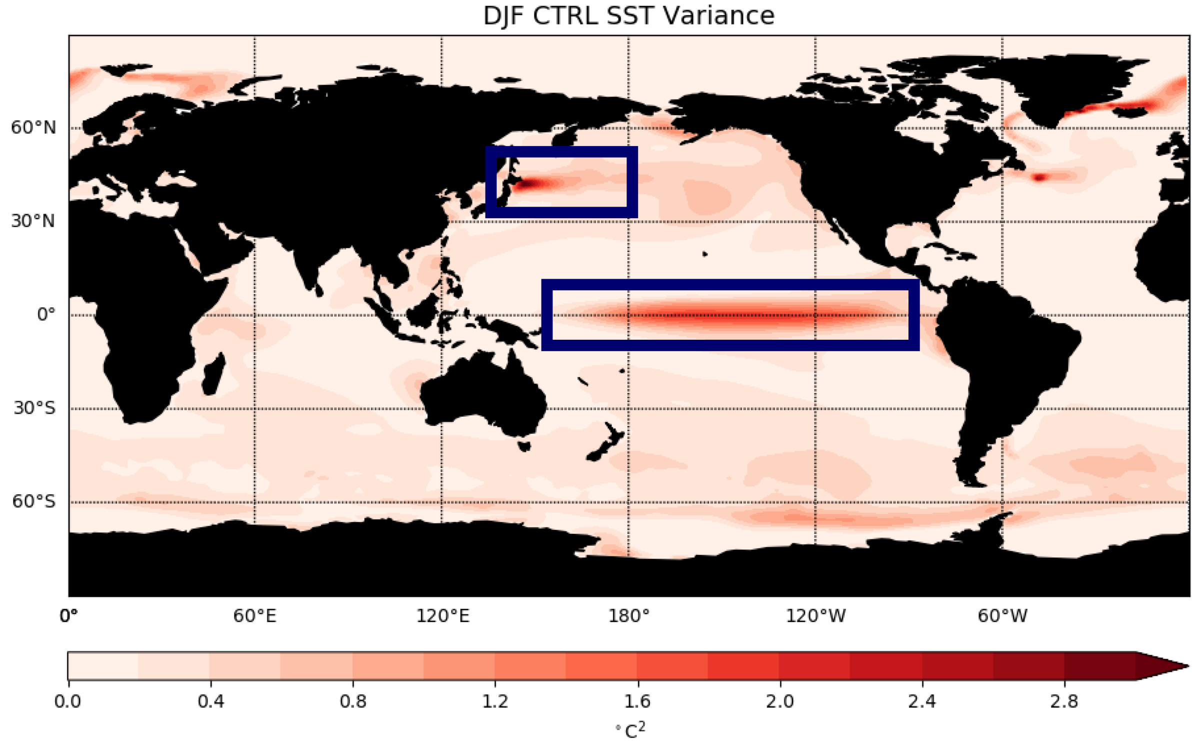
- CTRL run produces large anomalies in the Nino3.4 Index
- NoENSO run dampens the majority of the variability







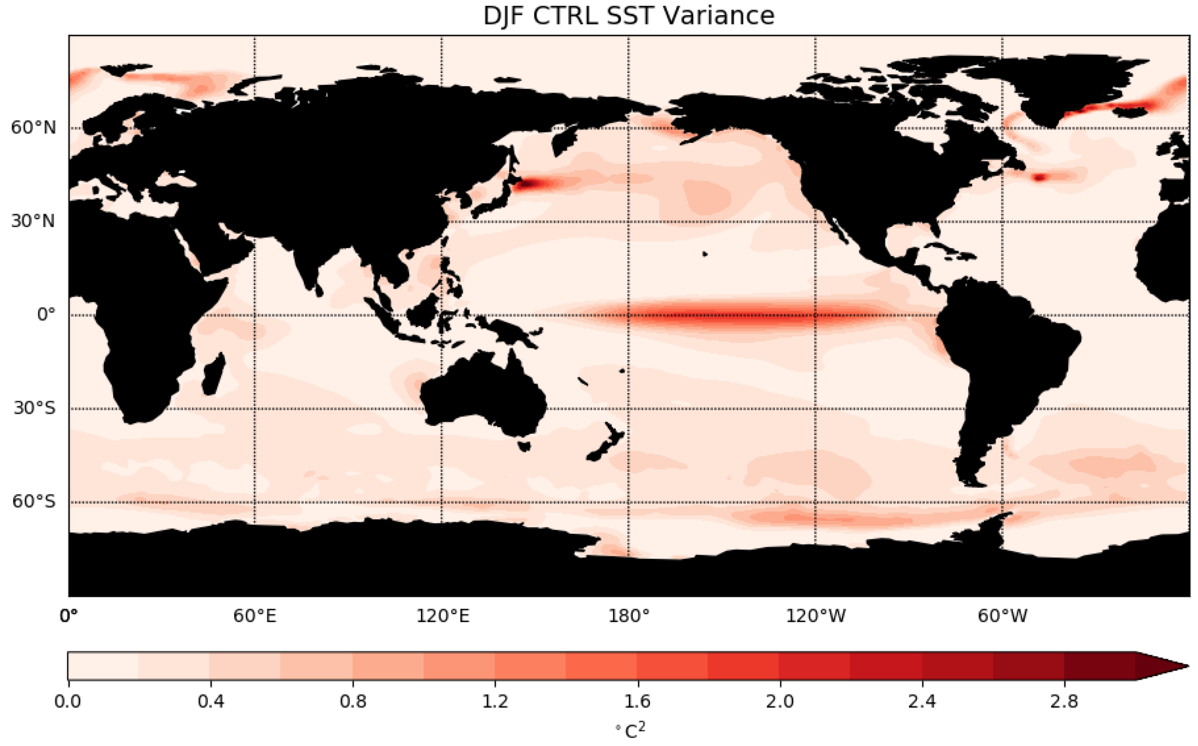
Sea Surface Temperature

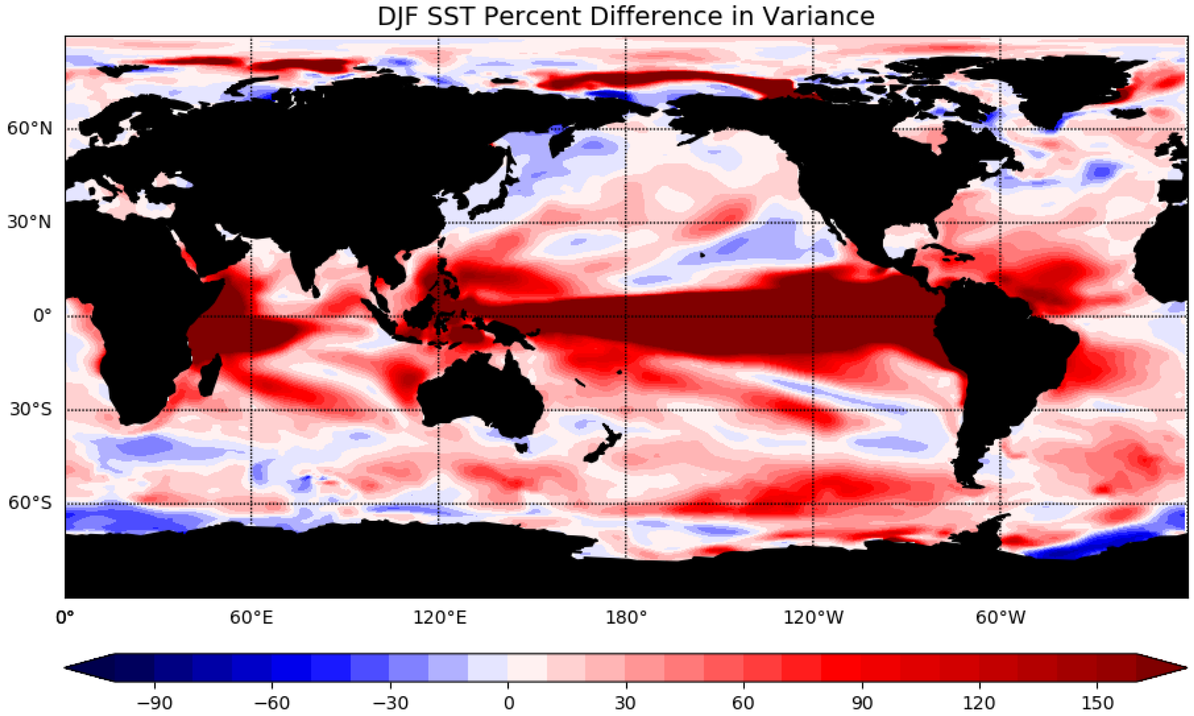


- Percent difference is used to compare the CTRL run with the NoENSO run
- Goal: ENSO-driven impacts on the atmospheric circulation

$$Percent\ Difference = \left(\frac{\sigma^2{}_{CTRL} - \sigma^2{}_{NoENSO}}{\sigma^2{}_{NoENSO}}\right) * 100$$

Sea Surface Temperature





ENSO suppresses variability where blue

ENSO enhances variability where red

- ENSO drives variability globally
- Particularly in the Equatorial Pacific and Indian Oceans

So, how does ENSO impact the Atmospheric Circulation?

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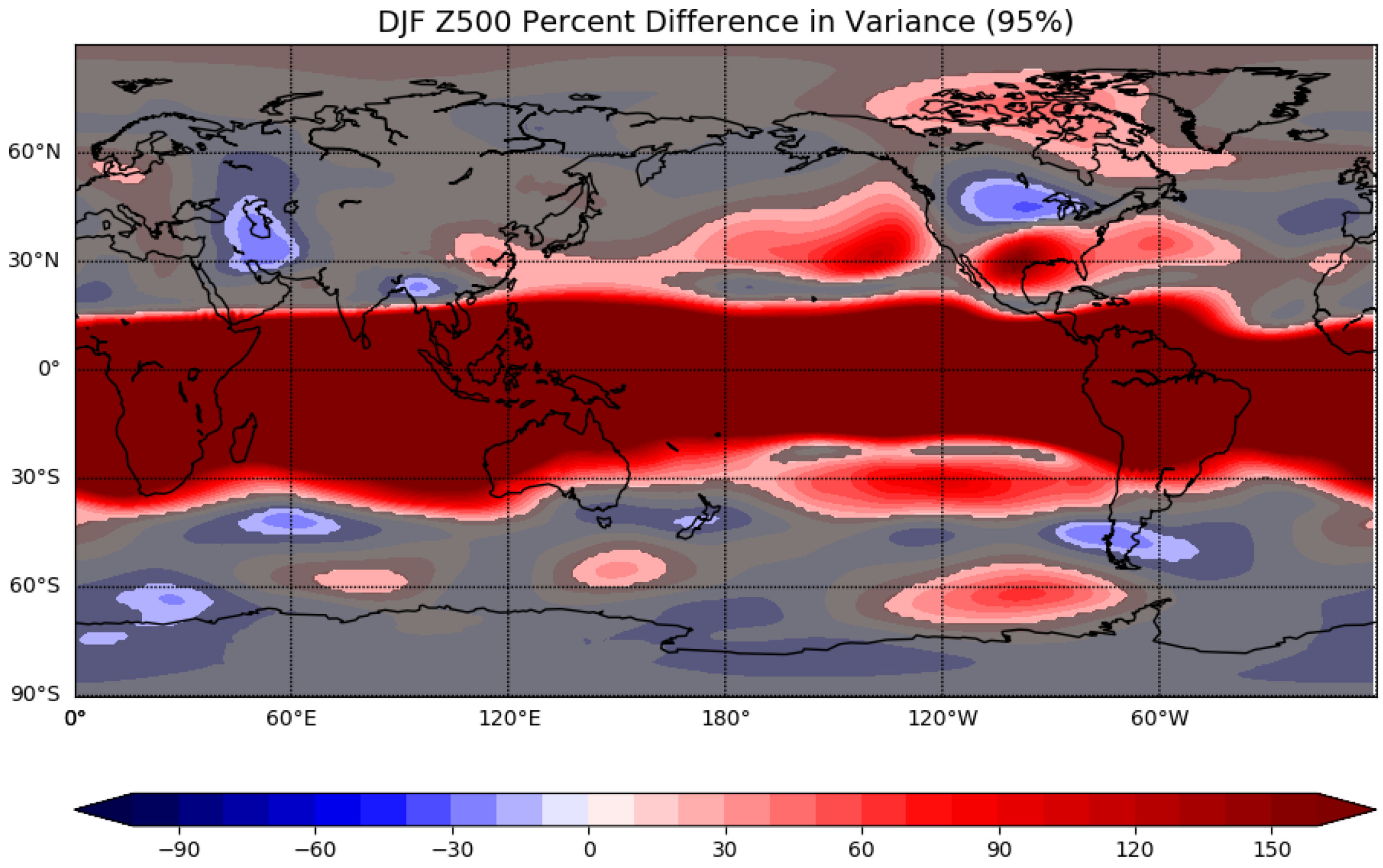
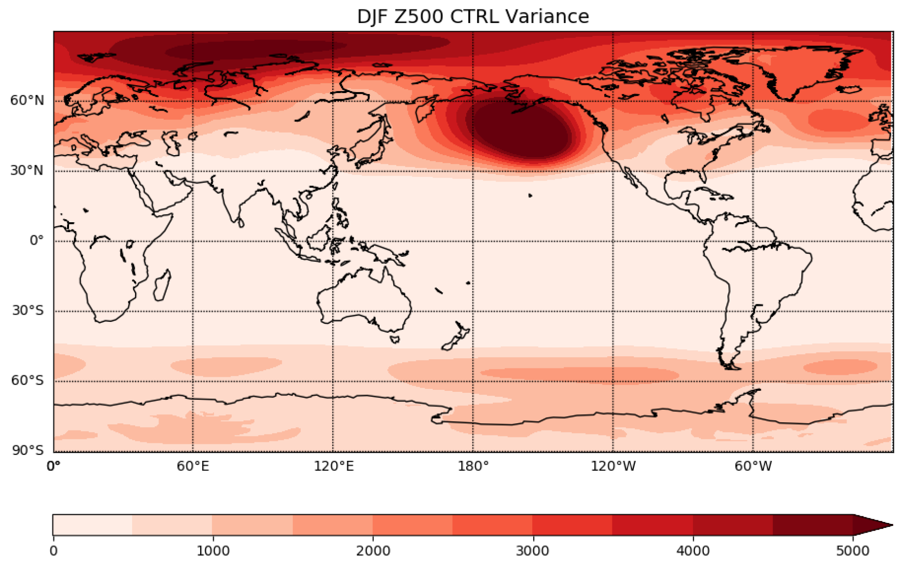
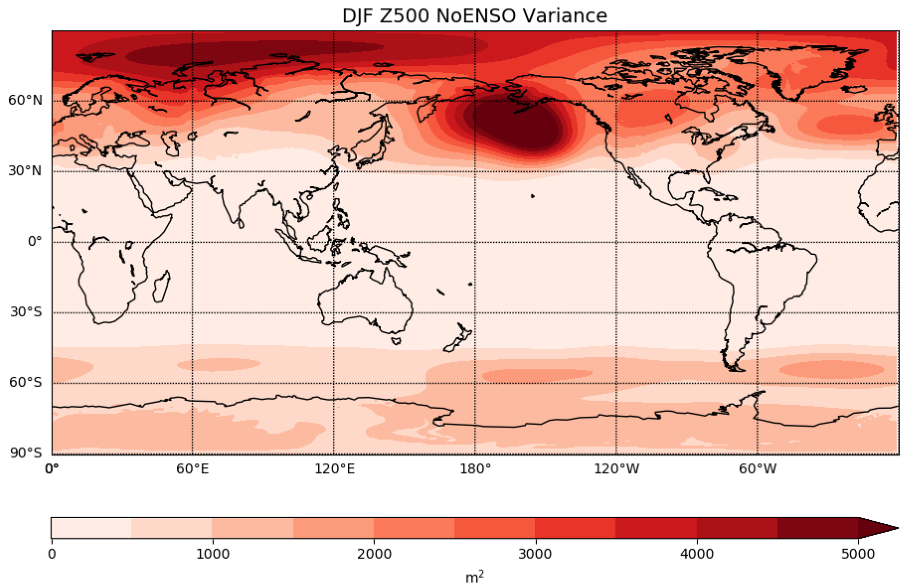
Significance of the Suppression Zone

- Similar spatial pattern
- Large variance over the US and near the Aleutian low







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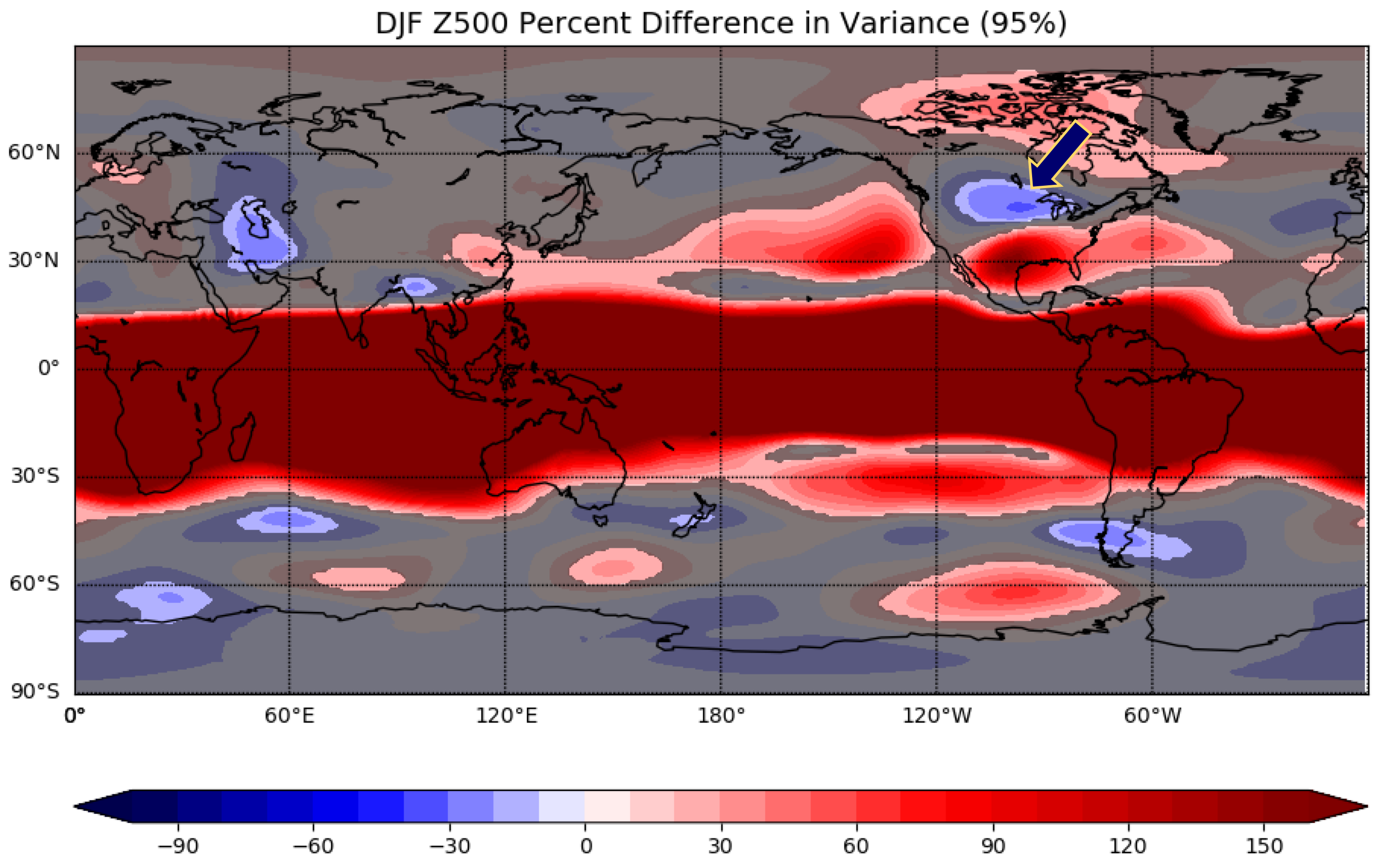
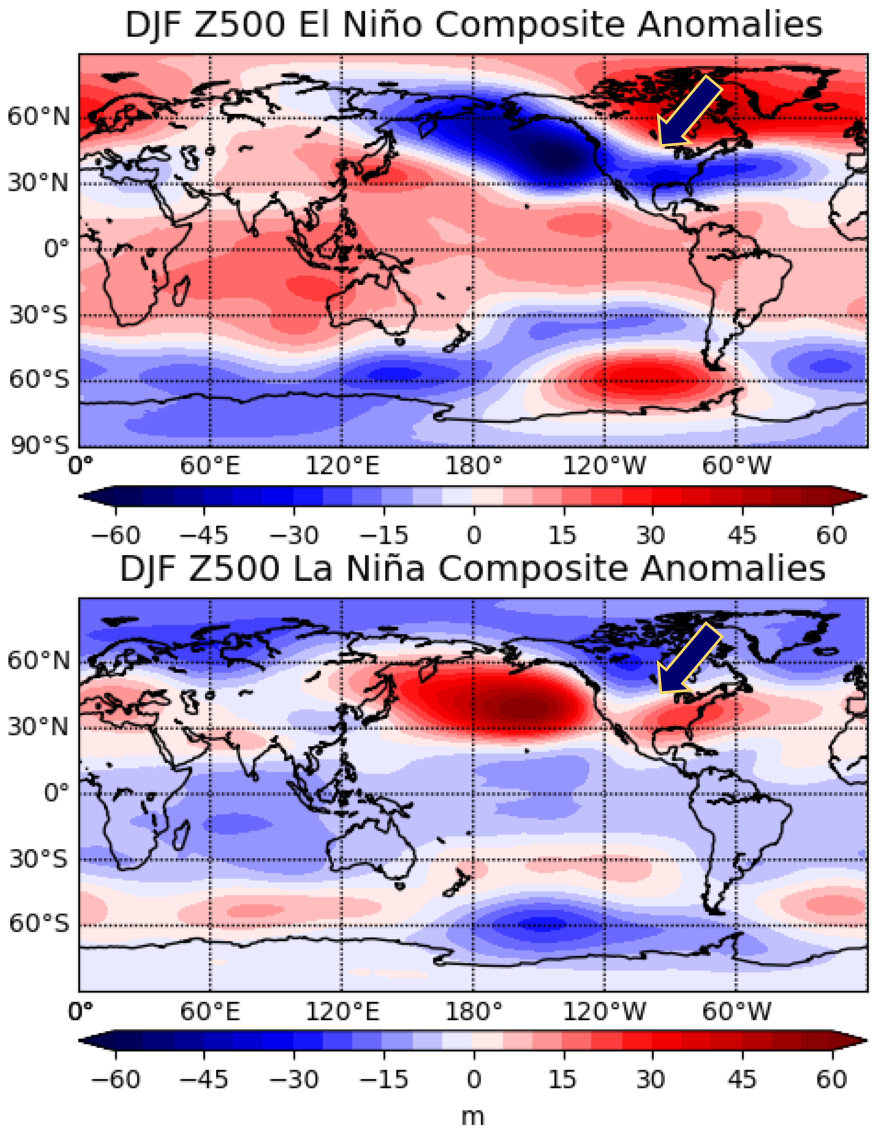
ENSO-Driven Suppression

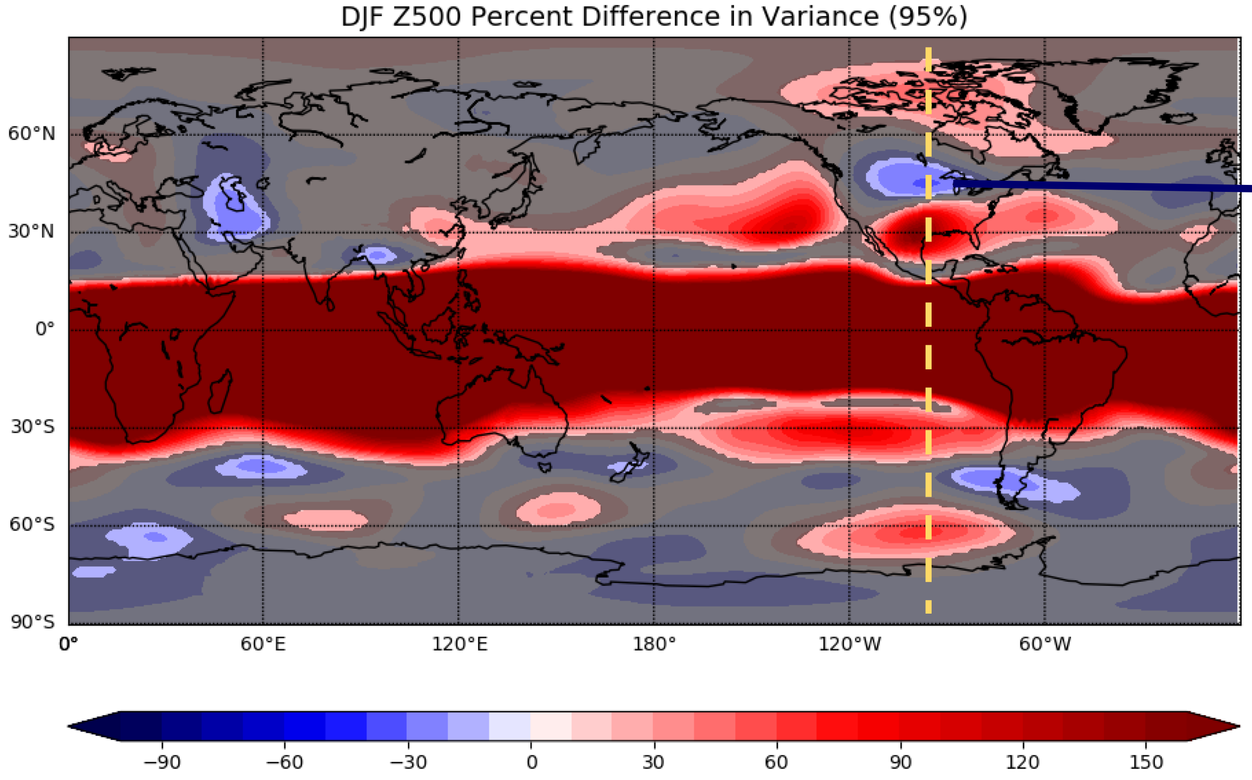
- The node between the ENSO-driven anomalous dipole results in reduced variability when ENSO is included

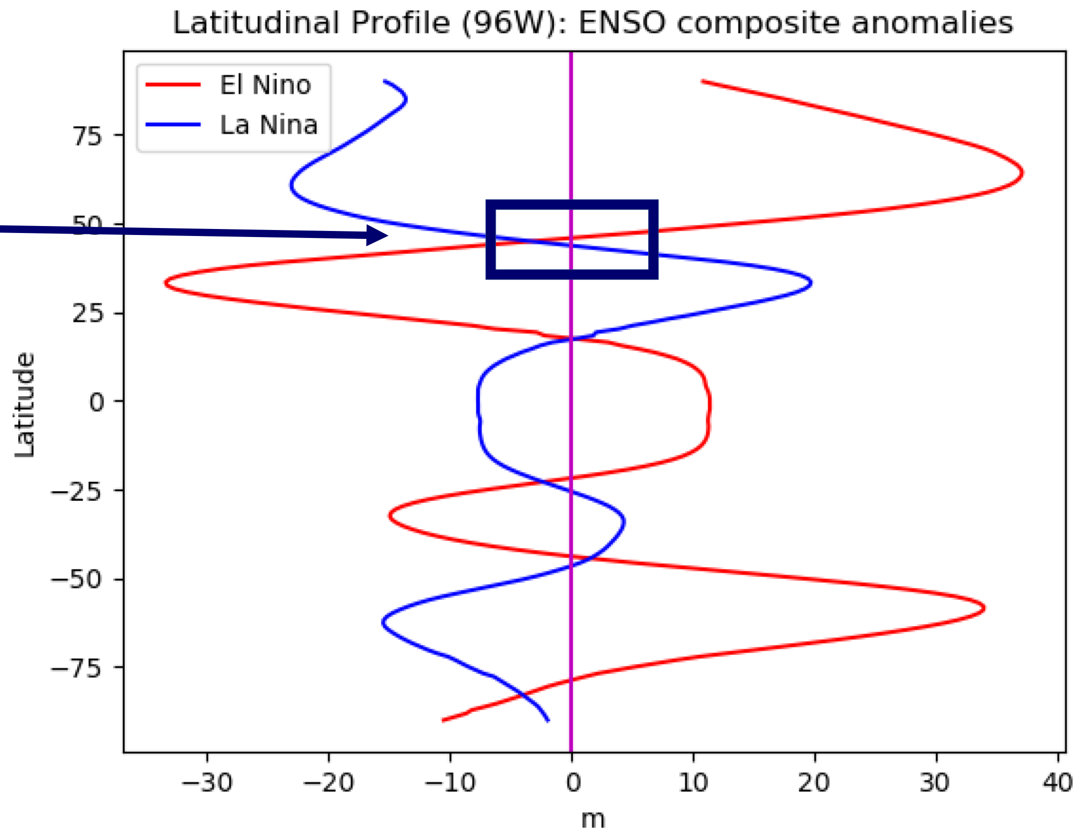




Latitudinal Profile

- Maximum of the Suppression zone is ~ 31% at 96°W





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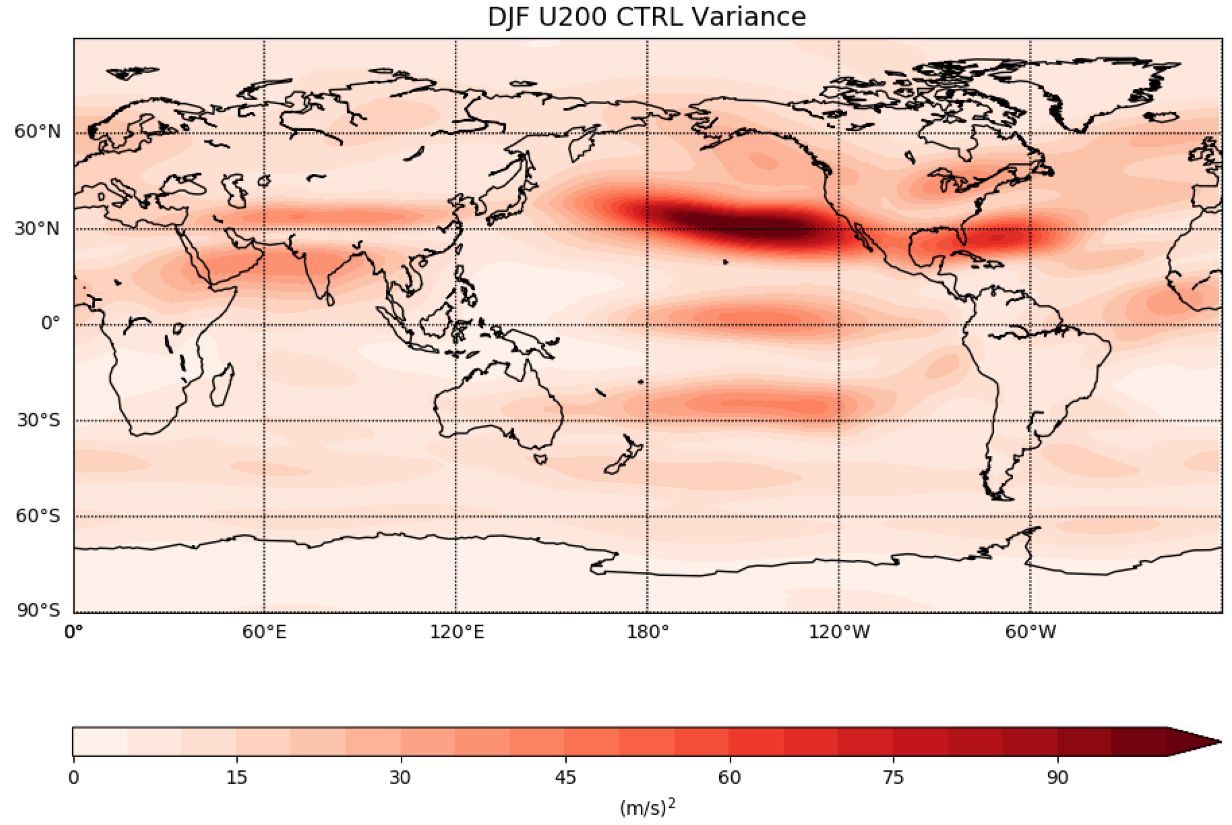
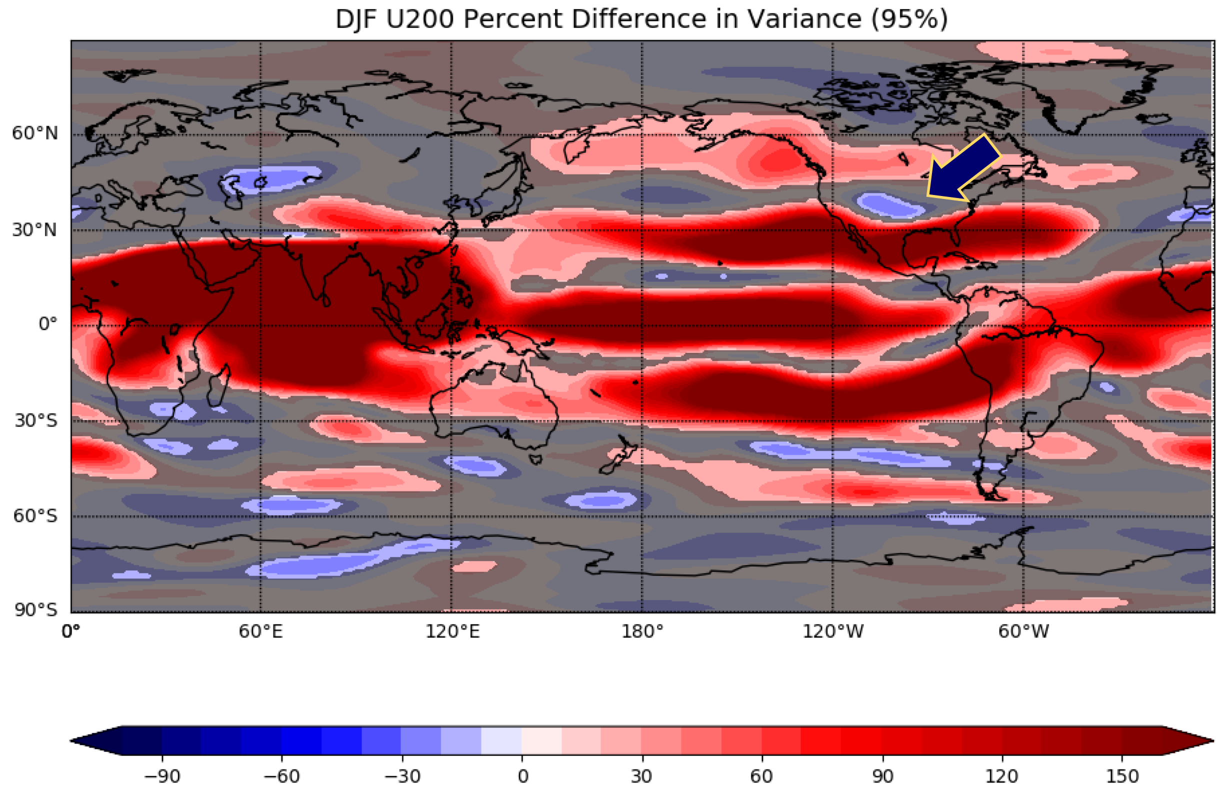
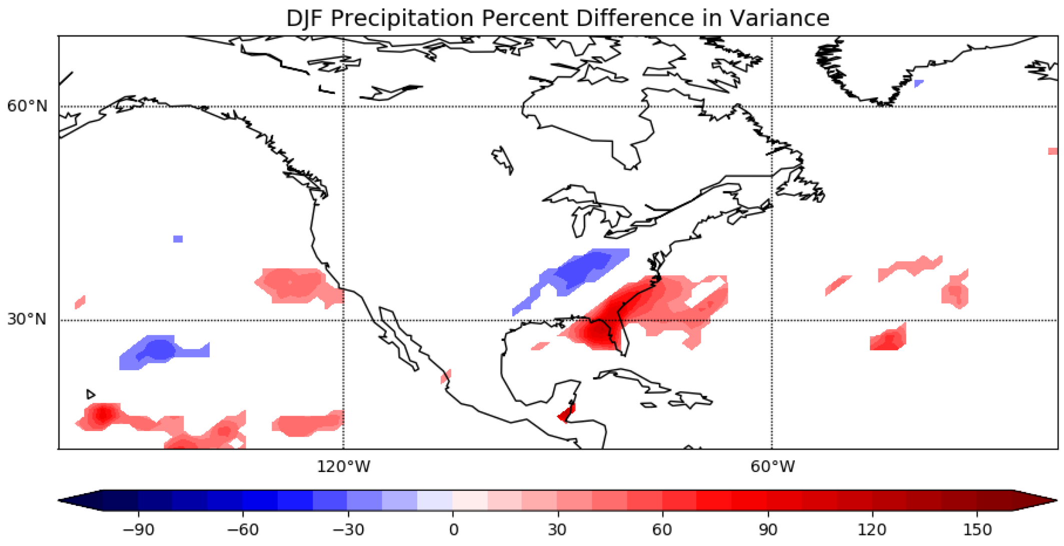
Jet level winds

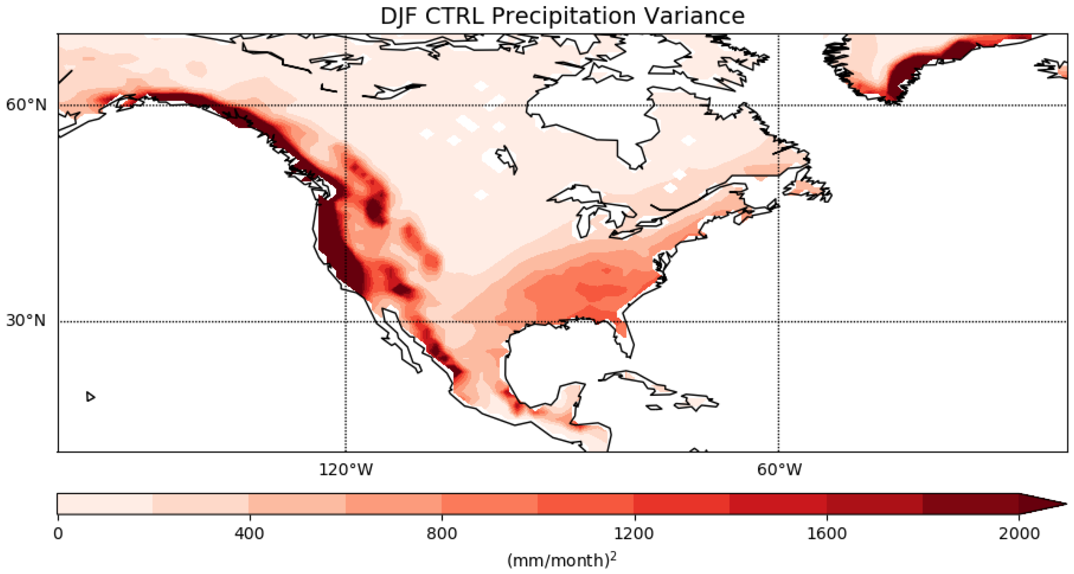




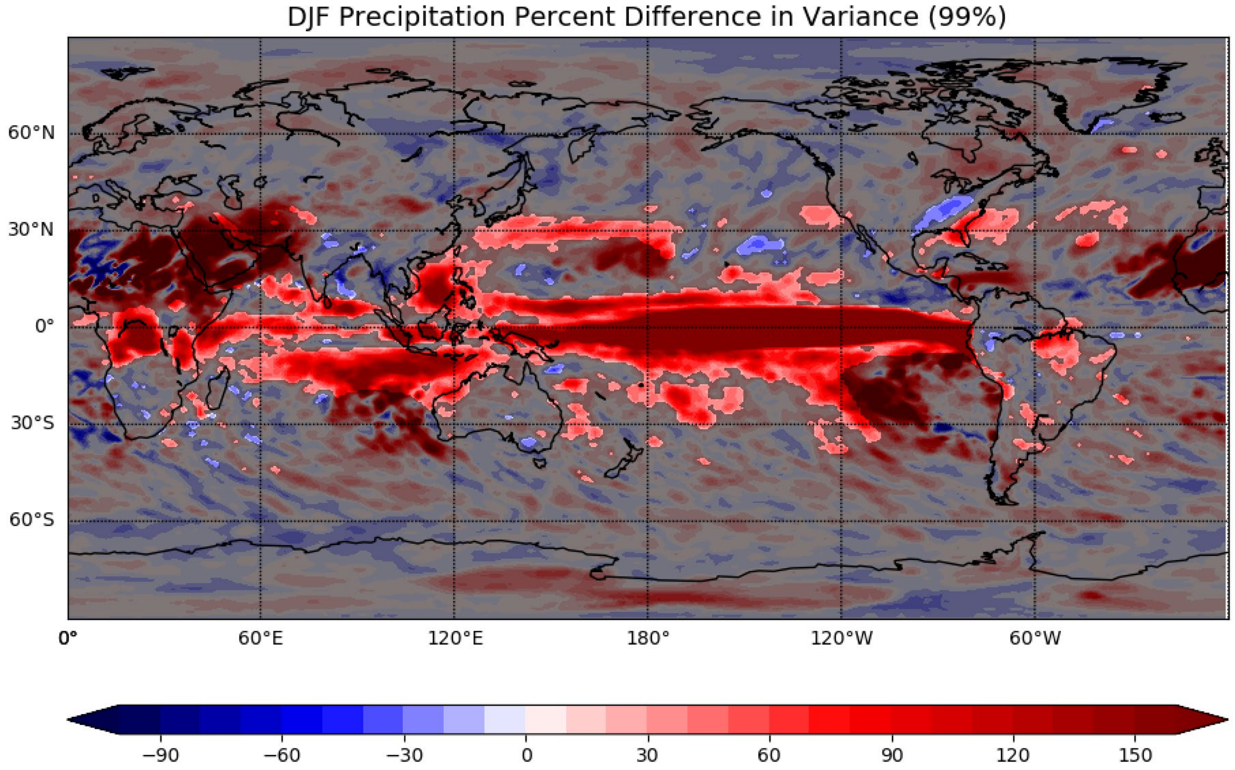
How does the suppressed upper level atmospheric circulation impact the surface?

ENSO-Driven Suppression of Precipitation Variability

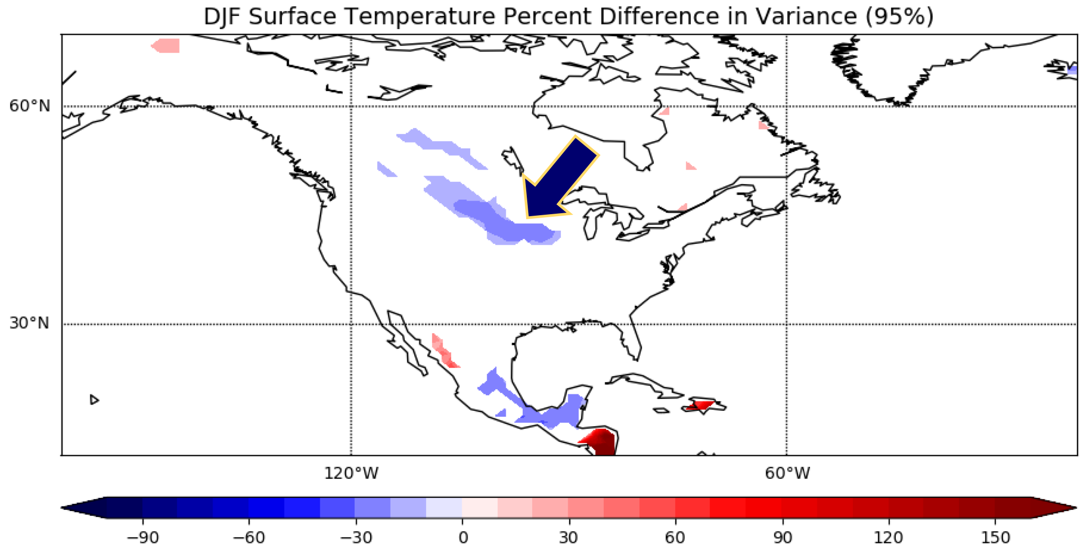


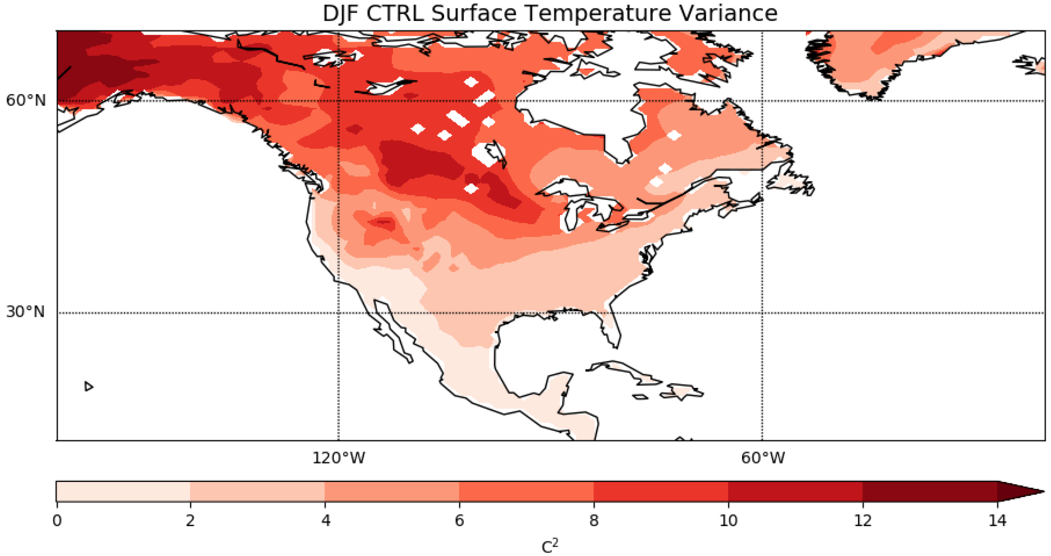


- ENSO increases variability in the southeast US by about 60%
- ENSO suppresses more than 30% of variability south of the Great Lakes
- Region of large interannual variability

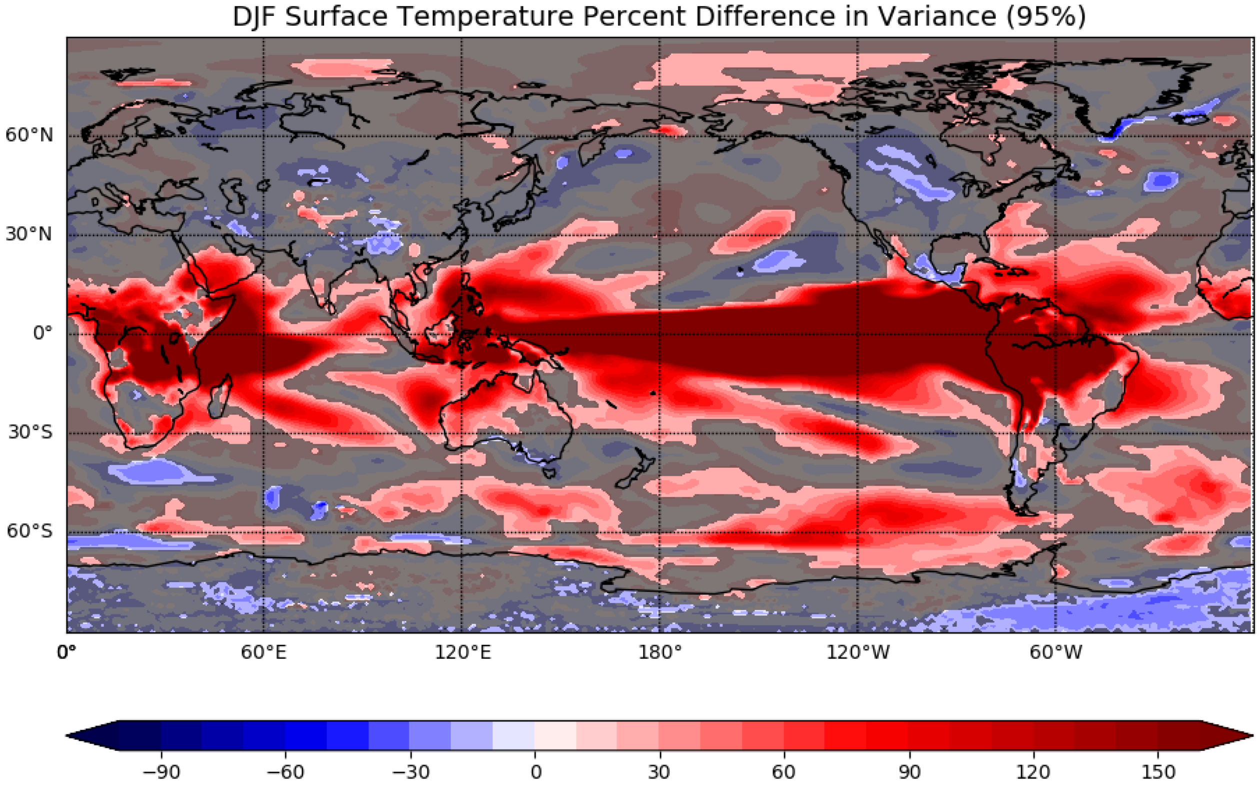


Surface Temperature





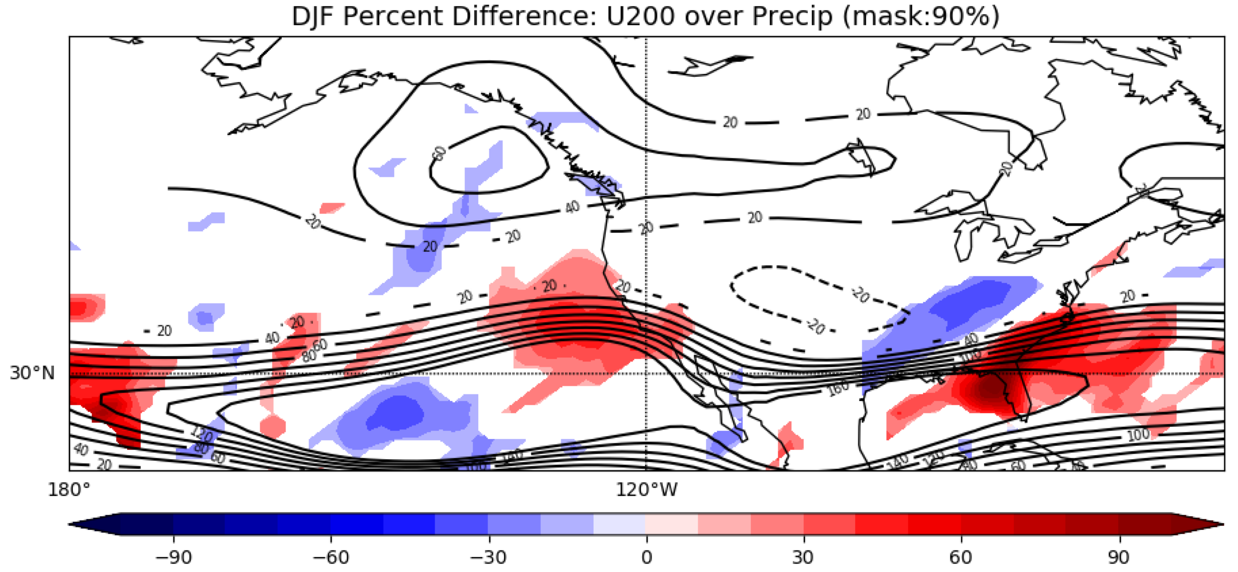
- Focusing on the Northern US region where surface temperature variability is large
- ENSO suppresses more than 20% of variability in the Northern US

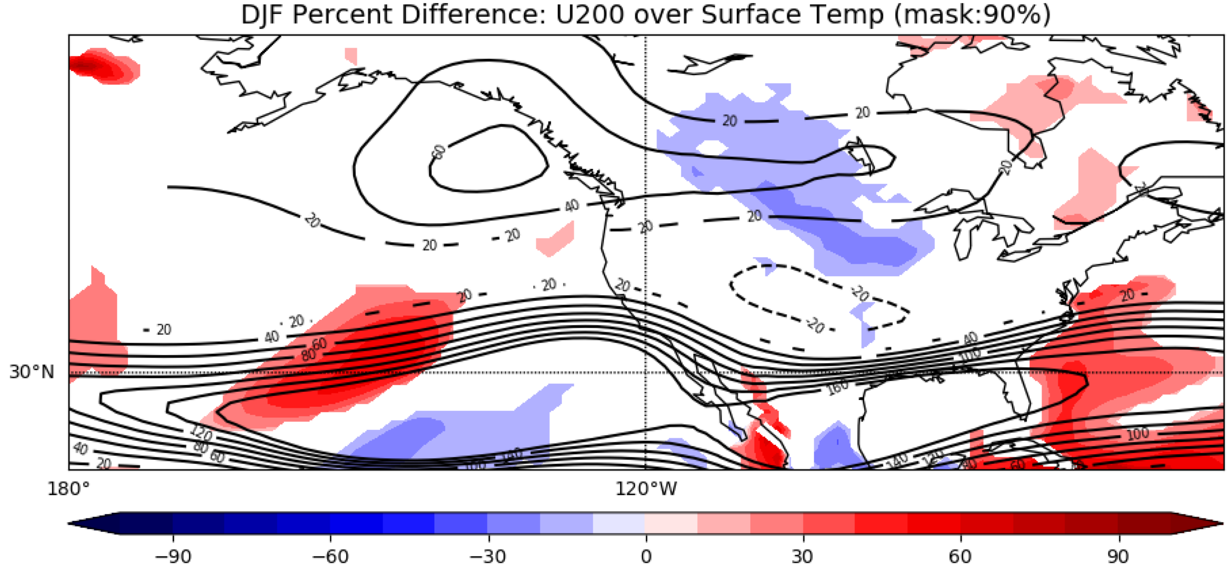


Suppressed Zones impact on the Surface

- Suppressed precipitation is to the east of the upper level suppression
- Suppressed surface temperature is to the north of the upper level suppression
- Future Work:

- Distinguishing which phase is contributing more to the suppressed regions
- Looking into the different flavors of ENSO to evaluate their contribution





Conclusion

- ENSO increases variability in the atmospheric circulation over the western and southern regions of the United States.
- ENSO suppresses variability in the atmospheric circulation over the Northern United States.
- ENSO forces an anomalous dipole over the North American Continent. The ”Suppression Zones” are located where ENSO anomalies are zero.
- The atmospheric suppression has terrestrial impacts through precipitation and temperature
- With a changing climate, ENSO events have been predicted to change in amplitude and frequency, which may impact the strength and frequency of ENSO teleconnections. (Liberto,2018) (Meehl and Teng, 2007)

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