Creation of an SST variability metric for E3SM

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Can we use sea surface temperature to predict patterns on land in E3SM?

Goal: create an SST variability metric for E3SM that tells us something about patterns on land.
SST variability
Variability is mostly seasonal
De-seasoned: dominated by ENSO processes

Other important oscillations:
- NAO
- PDO

Sea Surface Temperature Variability: Patterns and Mechanisms
Clara Deser, Michael A. Alexander, Shang-Ping Xie, and Adam S. Phillips

Deser et al. 2010

Understanding the role of sea surface temperature-forcing for variability in global temperature and precipitation extremes
Andrea J. Dittus, David J. Karoly, Markus G. Donat, Sophie C. Lewis, Lisa V. Alexander

Dittus et al. 2018

Tendencies, variability and persistence of sea surface temperature anomalies
Claire E. Bulgin, Christopher J. Merchant & David Ferreira

Bulgin et al. 2020

Metrics for understanding large-scale controls of multivariate temperature and precipitation variability

O’Brien et al. 2019
Ocean/ Land relationships

Understanding the role of sea surface temperature-forcing for variability in global temperature and precipitation extremes

Andrea J. Dittus, David J. Karoly, Markus G. Donat, Sophie C. Lewis, Lisa V. Alexander

1959-2013 Nino3.4 - R95p correlation coefficient

Dittus et al. 2018
Li et al (2016) looked at the relationship between salinity and precipitation

- High SSS over the northwestern subtropical Atlantic coincides with a local increase in moisture. The moisture is then directed toward and converges over the southern United States, which experiences increased precipitation and soil moisture.

**Approach:**

Do something similar for the U.S. in E3SM using SST.
Data Analysis

- Start with low res PI run, SST and precipitation

Precipitation
- Standardized precipitation index (SPI)
  - a widely used index to characterize meteorological drought on a range of timescales

\[ SPI = \frac{(P - P_*)}{\sigma P} \]

- Averaged over each HUC02 watershed
Standardized Precipitation Index

SPI for a typical year for each of the HU02 watersheds

What about SST?
SST variability

Mean of SST anomalies when precipitation is over the 95% percentile
Data Analysis

- SST (continued)
  - Seasonal cycles give spurious correlations (basically relating a seasonal cycle to itself)
  - Holtz-Winters decomposition avoids this

Holt-Winters decomposition on SST: seasonal, trend, residual, raw data
SST/SPI correlations

Correlated SST pointwise over much of the global ocean with SPI in each HUC02 watershed

Low resolution, de-seasoned SST (50 years)
Shading indicates significance

A positive correlation indicates that SST increases with SPI (a + SPI indicates more precipitation, a - indicates less). Overall, this means that warmer temperatures along the equator (e.g. an El Nino event) tended to produce significant increases in precipitation in many watersheds; PDO and NAO produce similar results.
SST/SPI correlations: Seasonal

Low resolution, March only (50 years)
Shading indicates significance
SST/SPI correlations: Seasonal

Low resolution, September only (50 years)
Shading indicates significance
Correlation of timeseries at 3 points, by watershed.
Instead of examining precipitation where it looks like ENSO is occurring, we can calculate ENSO itself and see how it relates to precipitation.

ENSO is calculated based on the NOAA Oceanic Nino Index - surface temperature anomaly for Nino 3.4 (5N to 5S, 170W to 120W).
ENSO

Typical January-March weather anomalies and atmospheric circulation during moderate to strong El Niño & La Niña.

- **El Niño**:
  - Persistent extended Pacific jet stream
  - Amplified storm track

- **La Niña**:
  - Variable Pacific jet stream
  - Blocking high pressure

Climate Prediction Center/NCEP/NWS
**NAO**

- NAO can be calculated as the normalized sea level pressure difference between Reykjavik and Lisbon
  - $+\text{NAO}=$ strengthening of the Icelandic low and the Azores high
  - $-\text{NAO}=$ weakening of both the Icelandic low and Azores high
Figure B. Phases of the North Atlantic Oscillation. (Image from NCEI).
Summary

- We can now pinpoint specific locations where SST affects drought/wetness across the U.S. in E3SM

- Most watersheds across the U.S. are influenced primarily by variability in decadal oscillations, especially ENSO and NAO

- NAO and ENSO affect precipitation patterns as expected across the U.S.
In progress

- Projection, high resolution run correlations
- Chlorophyll
- Other ideas?