ENSO Forecasts

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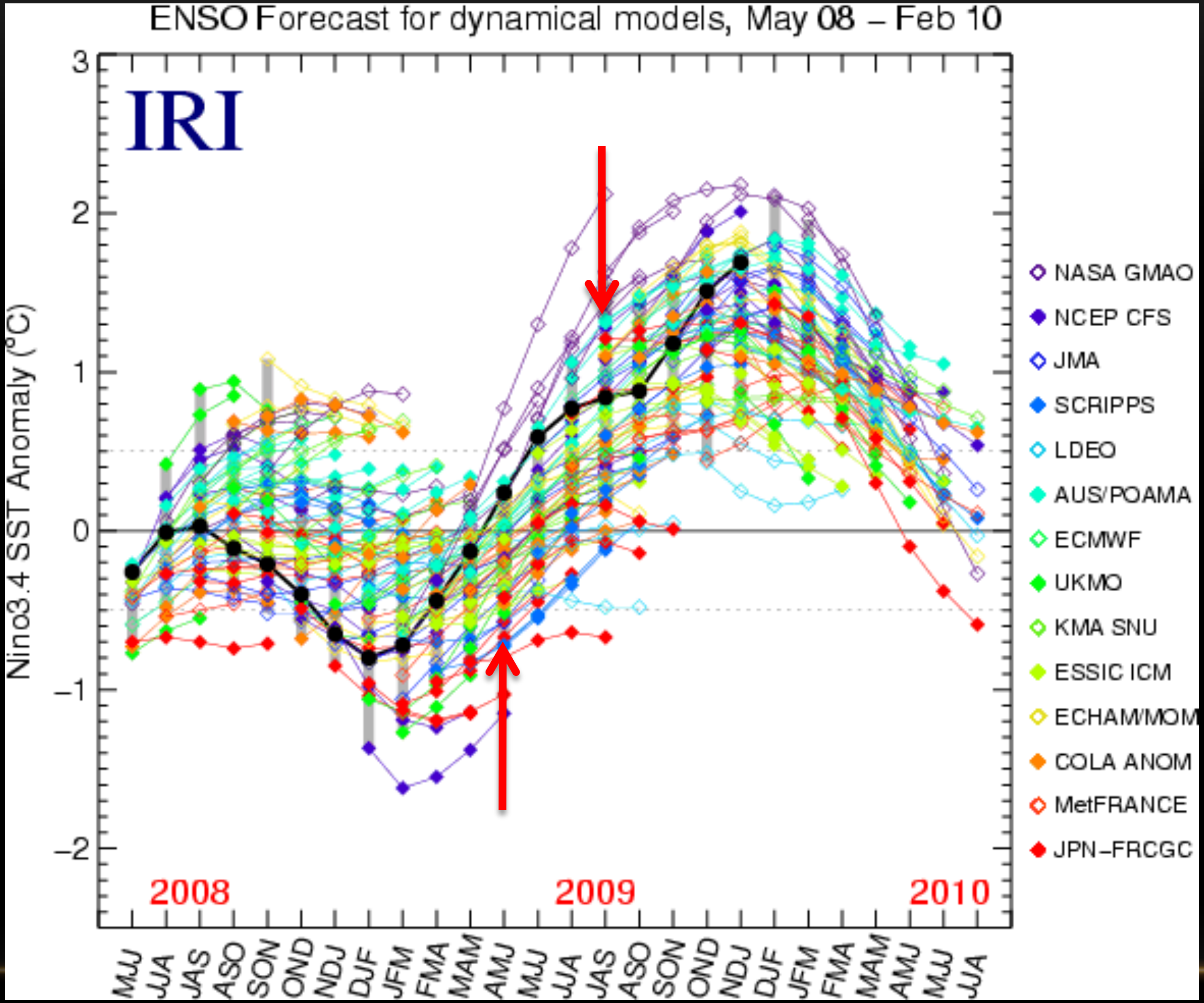
- Two types of prediction models:
  - Dynamical models: consist of a set of equations; initialized with current atmos. and oceanic conditions to predict their future state.
    - The Cane-Zebiak intermediate model in 1980s successful predicted the 1986–87 El Niño with lead times of 3 to 9 months; Coupled ocean-atmosphere models now give predictions of ENSO with a 1-year lead
  - Statistical models: developed based on past observations. A long period of record (30-50 years) is needed to construct ("train") a statistical model.
    - For example, a basic statistical model would be a simple regression of westerly wind anomalies and SSTs for different regions of the equatorial Pacific.

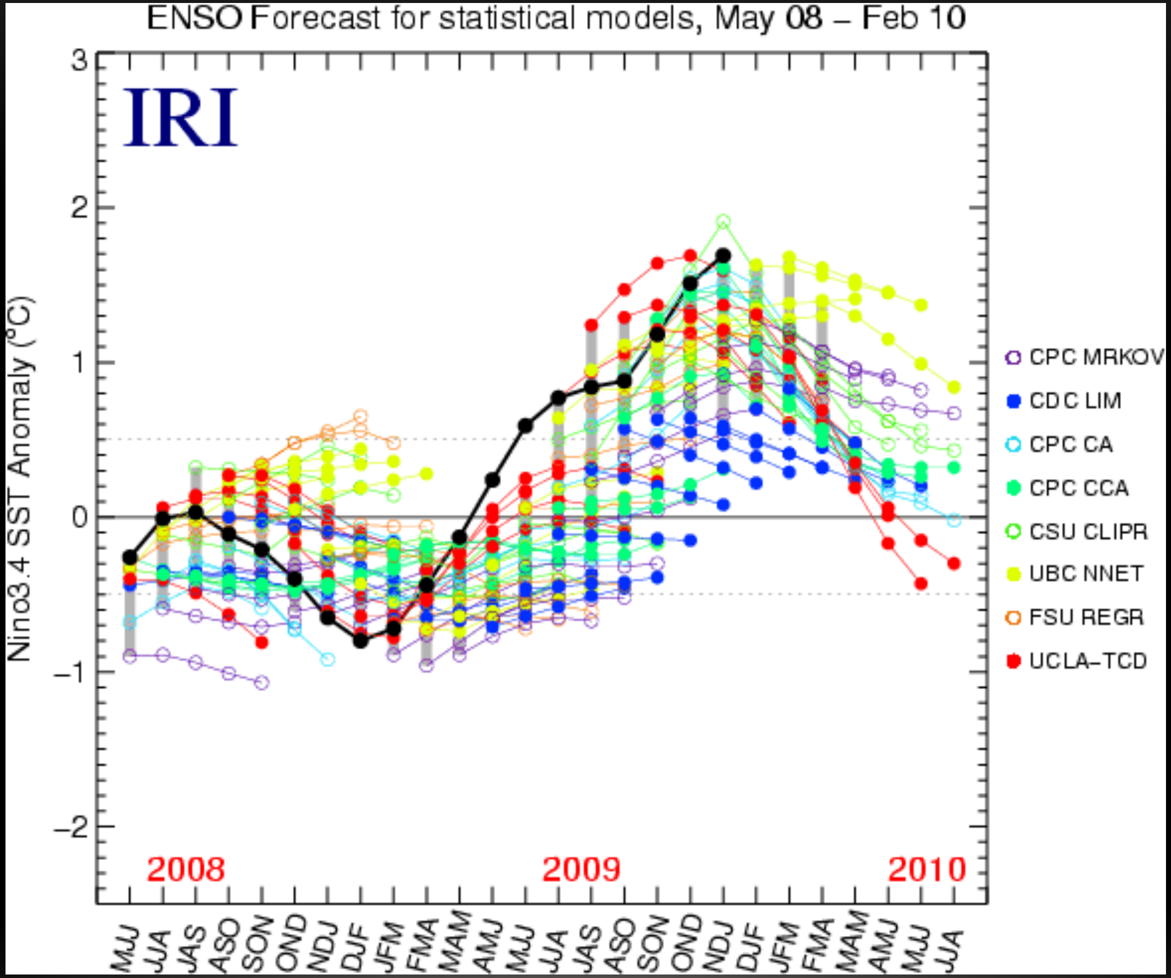
Dynamic Model Forecasts



- A wide spread of forecast values with roughly equal numbers having cold and warm biases

Figure from https://iri.columbia.edu/our-expertise/climate/enso/

Statistical Model Forecasts



- Statistical models have a smaller spread, they tend to have persistently warm or persistently cold biased forecasts; under-predict the intensity

Figure from https://iri.columbia.edu/our-expertise/climate/enso

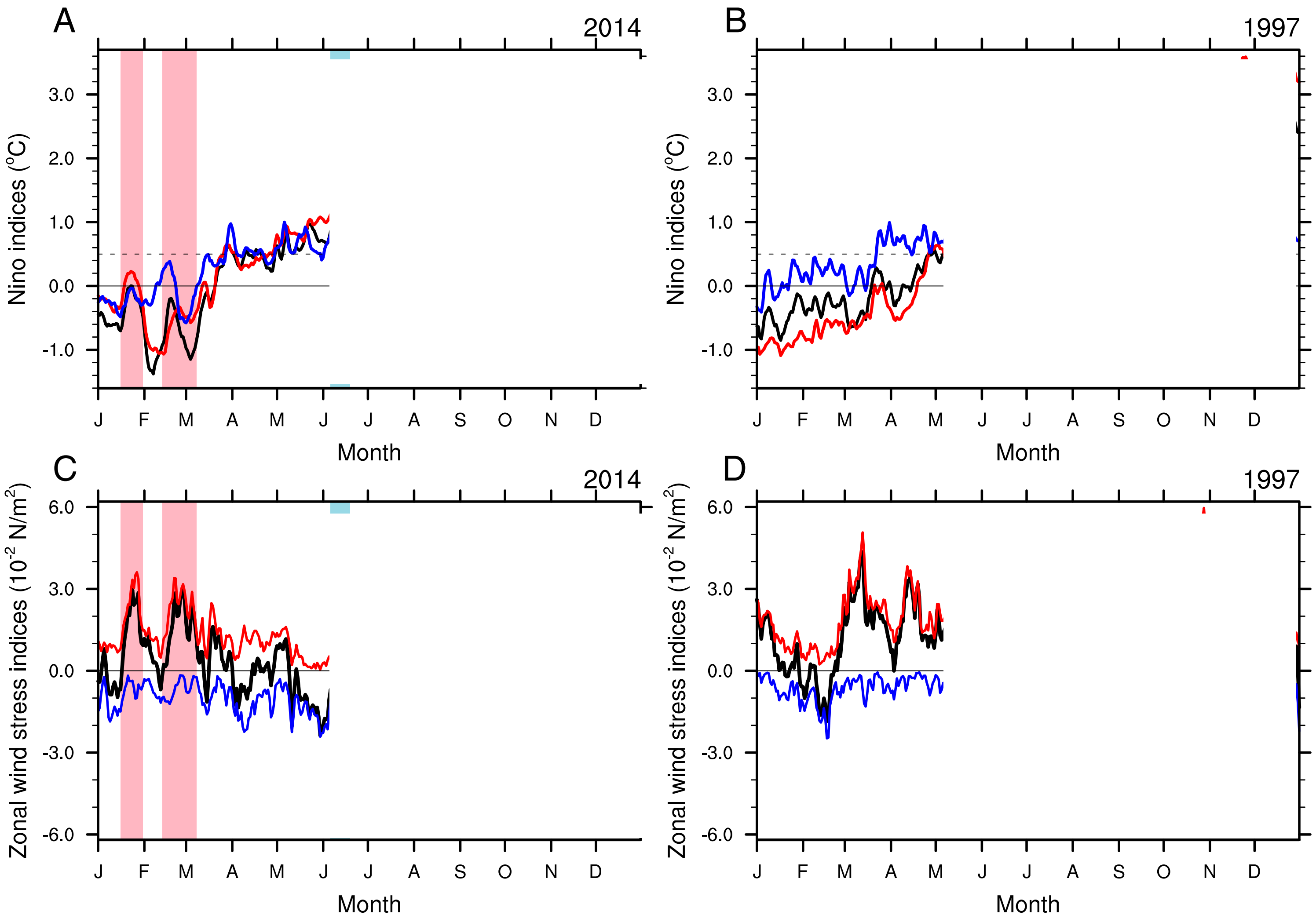
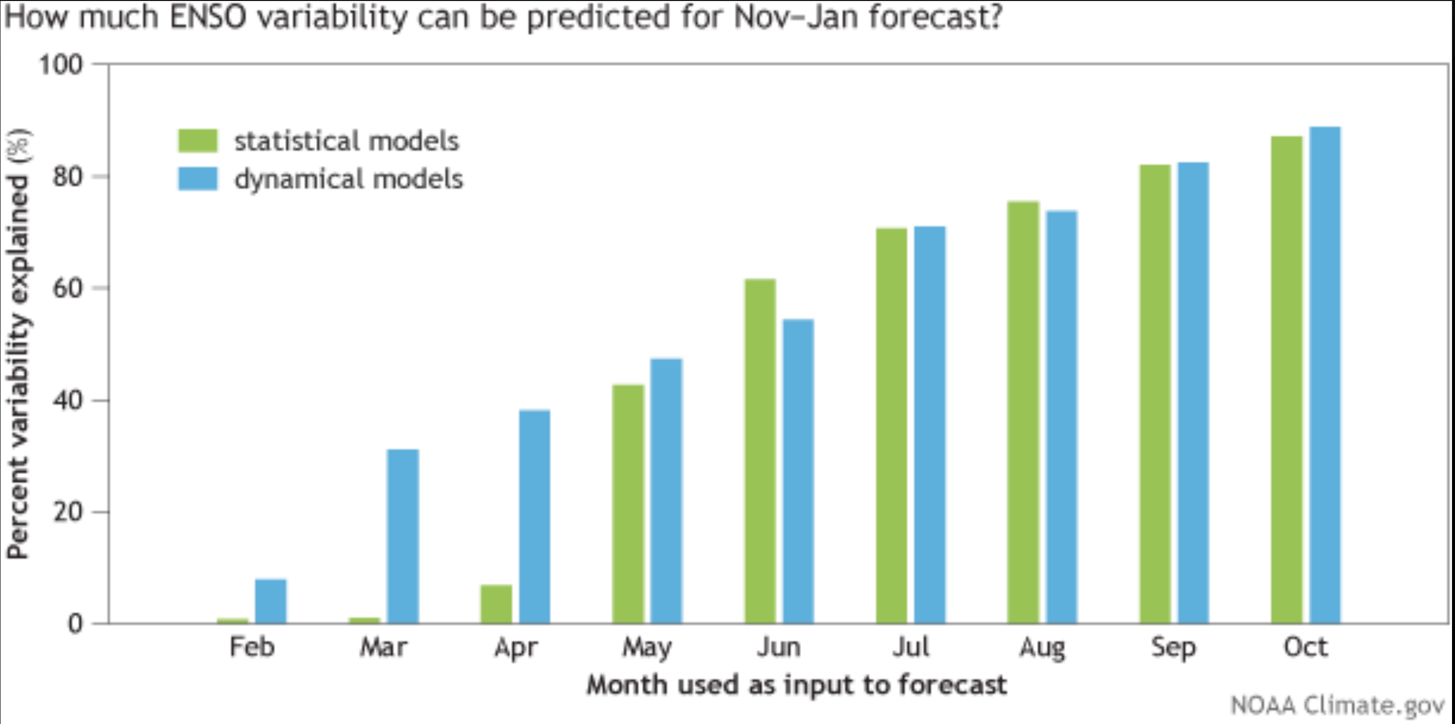


Fig. 1. El Niño development in (*A* and *C*) 2014 and (*B* and *D*) 1997. (*A* and *B*) Evolution of the Niño3, Niño4, and Niño3.4 indices; the first two indices describe SST anomalies (in degrees Celsius) in the eastern and central equatorial Pacific, respectively, whereas the last index covers the region in between. (*C* and *D*) Variation in the zonal wind stress indices. These indices are obtained by averaging wind stress anomalies (in 10^{-2} newtons per meter^2) in the equatorial Pacific zonally and between 5 °S and 5 °N and then selecting negative (blue; easterly anomalies), positive (red; westerly anomalies), or full values (black) (*Materials and Methods*). The spatial averaging is intended to take into account both the magnitude and the fetch of the wind bursts. During 2014, two early year WWBs were followed by an exceptional EWB in June (highlighted by pink and blue, respectively). This easterly burst apparently led to a rapid decrease of the Niño indices (*A*). In contrast, the 1997 El Niño exhibited persistent westerly wind activity throughout the year. The graphs start on January 1.

From Hu and Fedorov 2016, PNAS

Spring Predictability Barrier

Percent Variability Explained by Prediction



The skill of model runs based on February-October observations to predict the November-January (NDJ) average value in the Niño-3.4 SST region (ENSO).

- Prediction skill increases with decreasing forecast lead time.
- Prediction initialized in October captures about 90% of the winter ENSO fluctuations.
- Prediction initialized in June captures about 50% of the winter ENSO fluctuations.
- Statistical predictions have a similar performance to dynamical prediction for initialization after April.
- The skill of statistical models increases sharply from April to May

https://www.climate.gov/news-features/blogs/enso/spring-predictability-barrier-we%E2%80%99d-rather-be-spring-break

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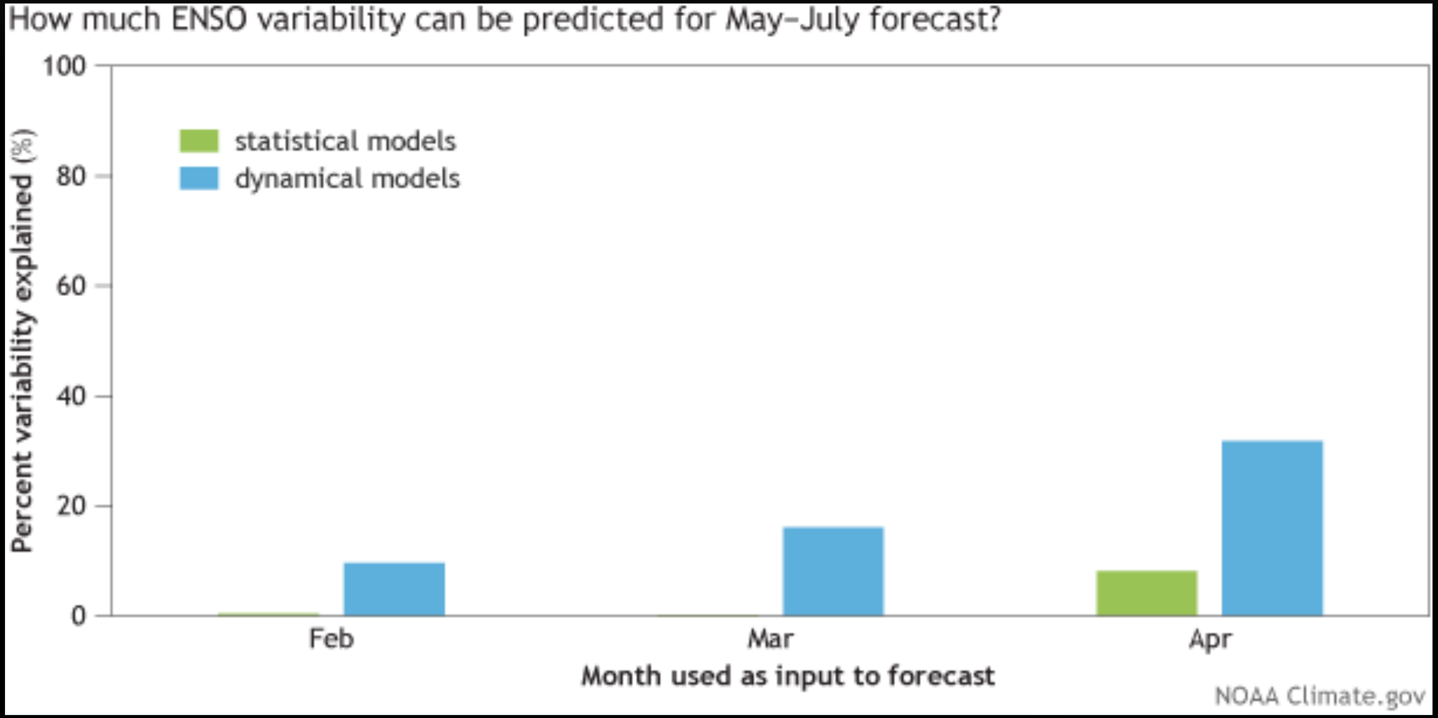
Percent Variability Explained by Prediction



The skill of model runs based on February, March, and April observations to predict the May-July (MJJ) average value in the Niño-3.4 SST region (ENSO).

- Predictions initialized in April explain less than 40% of the Nino3.4 variability in May-July (MJJ).
- Spring Predictability Barrier: a "valley" in ENSO forecasting accuracy
- Boreal spring is a transitional time for ENSO when signals are low and noise is high. Studies have also suggested that the ocean-atmosphere coupling is weaker in the spring due to weaker climatological SST gradients in the tropical Pacific Ocean.
- Dynamical models perform better than statistical models during the spring.

https://www.climate.gov/news-features/blogs/enso/spring-predictability-barrier-we%E2%80%99d-rather-be-spring-break

Challenges in ENSO prediction:

- CGCMs still have difficulty predicting the timing and strength of ENSO events accurately.
- Forecasts initialized in boreal spring are generally less skillful (“spring predictability barrier”)
- Simulations of ENSO in coupled GCMs are associated with the accuracy of the simulation of the climatological annual cycle, and many models have problems in simulating the mean annual cycle of SST.
- Multi-model ensemble (MME) forecasts have higher skills than the individual models.
- The forecast skill of individual models and the MME depends strongly on season, ENSO phase, and ENSO intensity. Generally speaking,
  - A stronger El Nino is better predicted.
  - The growth phases of both the warm and cold events are better predicted than the corresponding decaying phases. (spring barrier)
  - ENSO-neutral periods are far worse predicted than warm or cold events.

Summary

- ENSO is an atmospheric-ocean coupled mode.
  - Its oceanic component is characterized by SST anomalies over the tropical East and Central Pacific.
  - Its atmospheric component, the Southern Oscillation, involves a seesawing of surface pressure across the Equatorial Pacific.
- The warming and cooling episodes of ENSO usually last 9-12 months. They often begin to form during June-August, reach the peak strength during December-April, and then decay during May-July of the next year.
- ENSO is phase-locked to the annual cycle. Almost all the ENSO events peak during boreal winter (DJF).
- ENSO has an irregular, two to seven-year, cycle, with the average period around 4 years. El Nino tends to be stronger (in terms of SSTA) than La Nina.
- Some commonly used ENSO indices: Nino 3.4 measuring the SSTA over the East Central Pacific (5N-5S)(170-120W); SOI defined as the pressure difference between Darwin and Tahiti, a proxy of the trade wind strength or the Walker circ. intensity.

Summary (cont'd)

- Impacts of ENSO
  - Impacts in the tropics: coupled to the Walker circulation; the changes of precipitation over the tropical Pacific is broadly consistent with the local SST anomalies (warm-wet; cold-dry); the La Nina pattern a slight westward shift as precipitation responds to the total SST; ENSO also impacts tropical cyclone activity
  - Impacts of ENSO in extratropics: the PNA pattern, shift and intensity of the westerly jet, shift of the storm track
- ENSO theories:
  - Unstable mode of a coupled system: What are the positive feedback processes? What are the negative feedback processes? How are the simple model formulated to represent these processes?
  - Weakly damped mode sustained by high-frequency disturbances
- ENSO forecasts:
  - major approaches (statistical models vs. dynamic models) current status

Useful Links

- the ENSO outlook from the NOAA CPC https://www.cpc.ncep.noaa.gov/products/analysis_monitoring/lanina/enso_evolution-status-fcsts-web.pdf
- El Nino animations and graphics: http://www.elnino.noaa.gov/ani.html
- IRI ENSO model forecasts: http://iri.columbia.edu/climate/ENSO/currentinfo/SST_table.htm