El Niño 2015 Conference

Enhanced seasonal predictability of Asian Summer Monsoon rainfall following an El Niño event

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1. Objective

To identify ENSO contribution to the seasonal predictability of Asian summer monsoon (ASM) rainfall and investigate its mechanisms using the seasonal hindcasts for 1979-2008 by NCEP CFSv2 with a new multiple analyses ensemble (MAE) initialization strategy

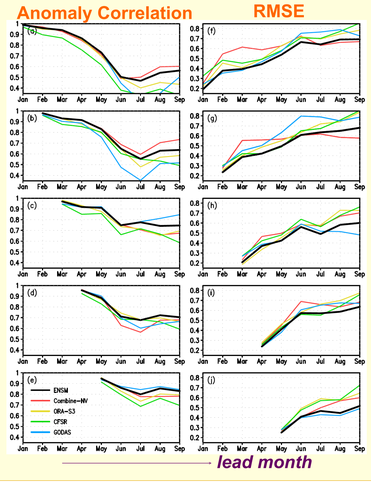
2. Multiple analyses ensemble (MAE) initialization

- CFSv2 hindcasts are initialized with an ensemble of **ocean initial conditions (OIC)** from four state-of-the-art ocean analyses
  - *NCEP Climate Forecast System Reanalysis (CFSR)*
  - *NCEP Global Ocean Data Assimilation System (GODAS)*
  - *ECMWF COMBINE-NEMOVAR Reanalysis (COMBINE-NV)*
  - *ECMWF Ocean Reanalysis System 3 (ORA-S3)*

  MAE initialization accounts for the ocean uncertainty efficiently and improves skill and reliability of the hindcasts.
- All reforecasts start at the beginning of each month from January to May and finish in September. Each OIC is matched with four instantaneous atmospheric and land initial states at 00Z of the first four days in each month. The MAE ensemble has 16 members.
- The leading modes of ASM rainfall during June-September in both observations (CMAP) and CFSv2 MAE hindcasts are identified using **Empirical orthogonal function (EOF) analysis**. A maximized signal-to-noise ratio EOF (MSN EOF) analysis of the MAE hindcasts confirms that the leading EOF modes are the most predictable modes.

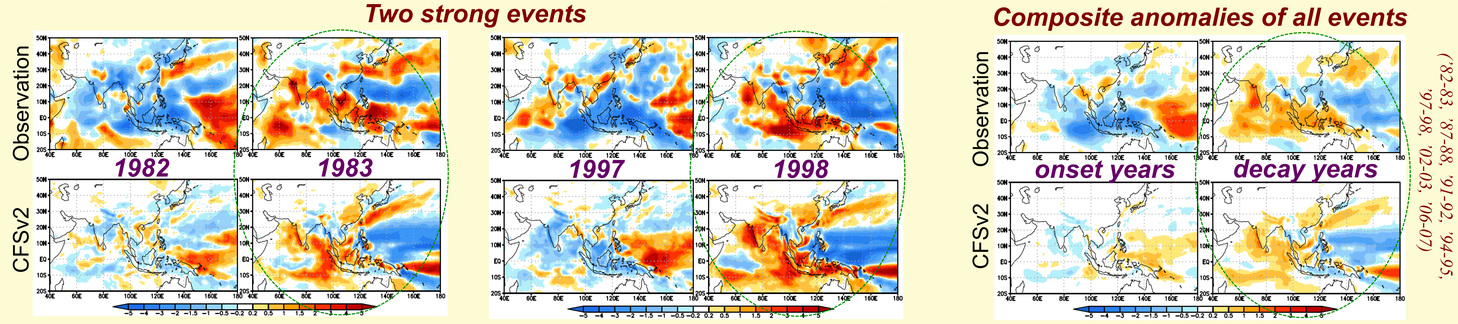
3. Seasonal Prediction of Niño-3.4 index

The skill of the MAE ensemble mean hindcast (black lines) initialized from the four different ocean analyses is always equivalent to the best hindcast initialized from any individual ocean analysis (colored lines), although the best performer varies with lead-time and starting calendar month. Therefore, **the MAE initialization yields better forecast skill and reliability than can be obtained in hindcasts initialized from individual ocean analyses**.



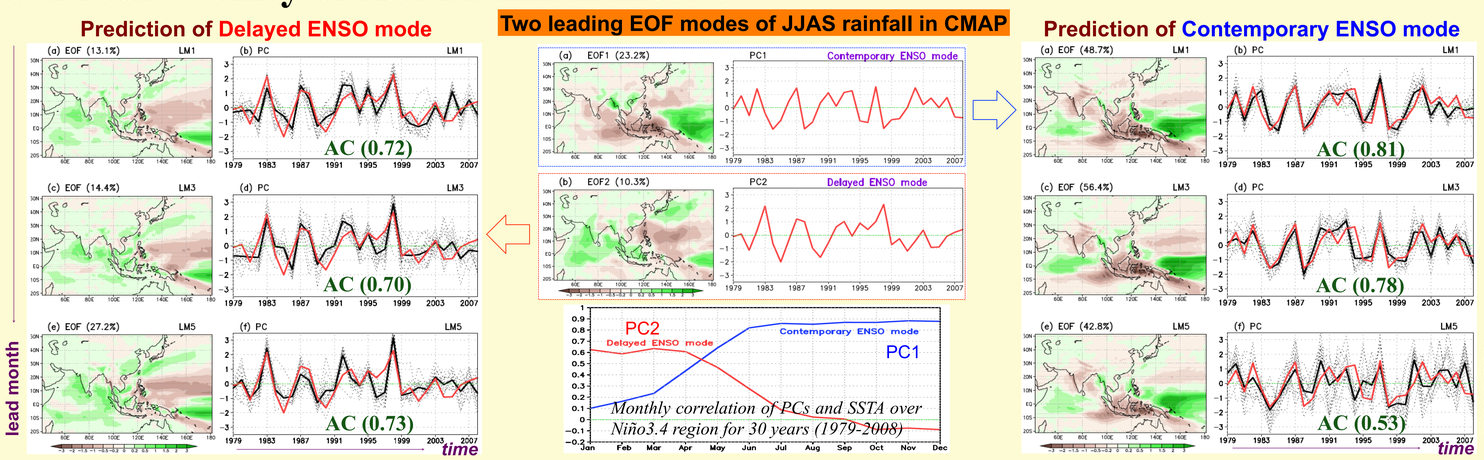
Acknowledgments *This research is supported by a grant from the Indian Institute of Tropical Meteorology and the Ministry of Earth Sciences, Government of India. This work used the Extreme Science and Engineering Discovery Environment (XSEDE), which is supported by National Science Foundation grant number ACI-1053575.*

4. Predicted ASM rainfall anomalies before/after the peak of El Niño events



- Predicted ASM anomalies from January IC for two strongest El Niño events and all-case composite.
- **ASM rainfall anomalies are more predictable after an El Niño event than preceding one**.

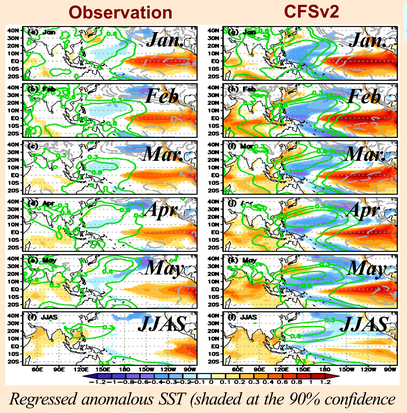
5. Predictability of ASM rainfall modes



- Two leading EOFs corresponding to the ASM rainfall anomalies during the summers when ENSO events are developing and decaying, designated as the contemporary and delayed ENSO modes.
- In MAE hindcasts, the delayed ENSO mode shows higher prediction skill and smaller ensemble spread than the contemporary mode as the lead-month increases, suggesting that the delayed ENSO mode has higher predictability.

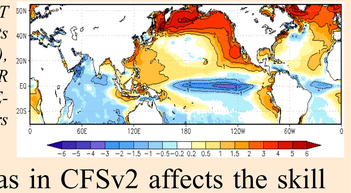
6. Potential mechanisms

The enhanced ASM predictability following an El Niño event results from **the warm SST anomalies in Indian Ocean during spring** and **the persistence of anomalous high sea level pressure over the western Pacific in the summer**. **The MAE hindcasts at long leads capture these features well**.



Regressed anomalous SST (shaded at the 90% confidence level, °C) and MSLP (green(+); grey(-) contours, hPa) associated with delayed ENSO mode.

Improving predictability by SST bias correction



27-yr (1982-2008) mean SST errors of the CFSv2 hindcasts in August (3-lead month), initialized with CFSR atmospheric and COMBINE-NV oceanic ICs. (4 members ensemble mean forecasts)

The systematic bias in CFSv2 affects the skill of its global monsoon rainfall prediction. We are examining the possible improvement of the monsoon prediction by correcting the large warm SST bias in northern oceans and cold bias in Indian Ocean and equatorial Pacific and Atlantic Oceans during boreal summer.