California Drought and the 2015-2016 El Niño

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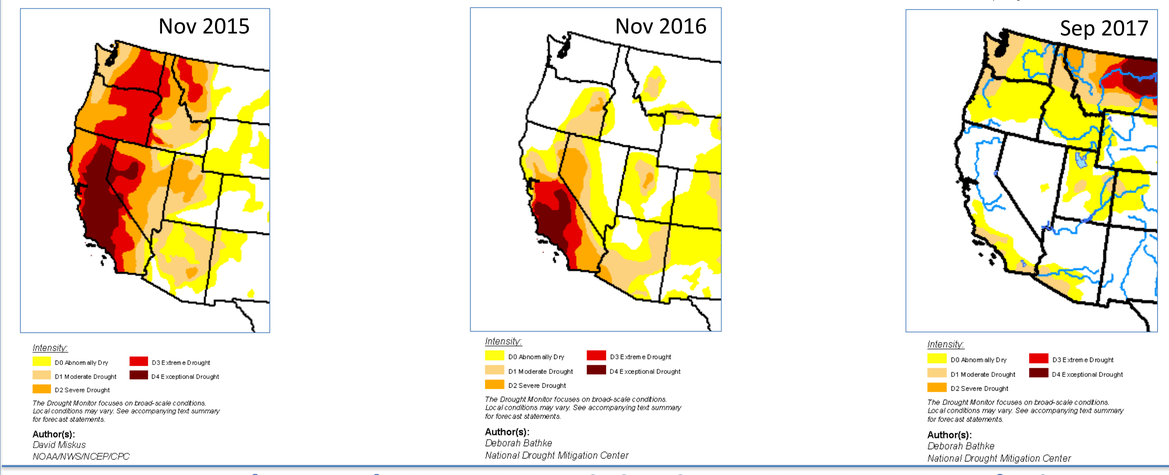
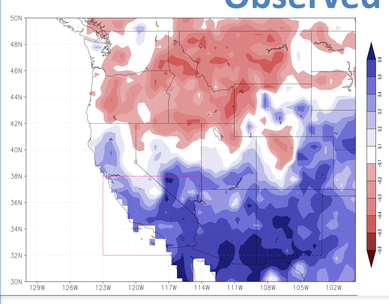
Background

- California experienced severe drought from 2011-2017
  - Mostly alleviated by record precipitation in winter 2016-2017
  - Followed multiple years of below-average rainy season precipitation

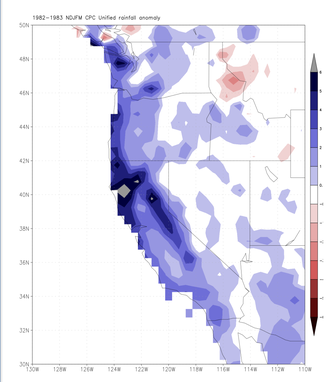


Observed NDJFM Precipitation – NINO34 Correlation



- Widespread hope that 2015-2016 El Niño event would end drought
  - Previous events associated with large rainfall anomalies
- Clear north-south dipole pattern, wet conditions in southern California
- Peak magnitudes between 0.5 and 0.6
- Significant amount of unexplained variance
- What other factors could be playing a role?

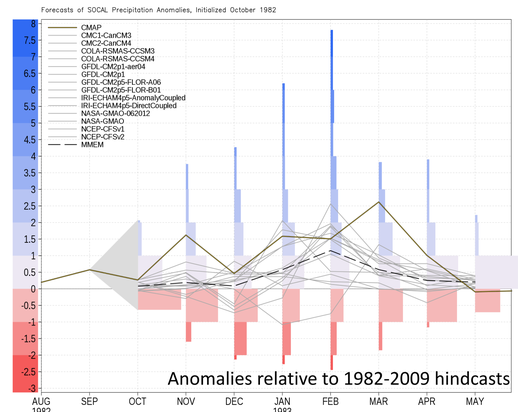
1982-1983 NDJFM Precipitation Anomalies



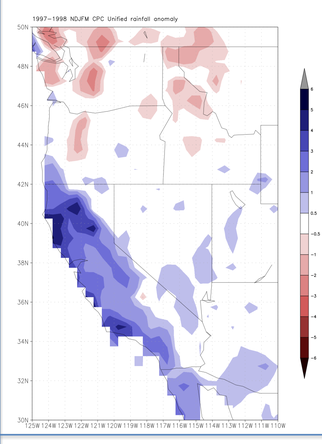
Positive rainfall anomalies for all of the west coast
(CPC Unified data)

Above average rainfall observed

Ensemble mean predicts above average rainfall



1997-1998 NDJFM Precipitation Anomalies

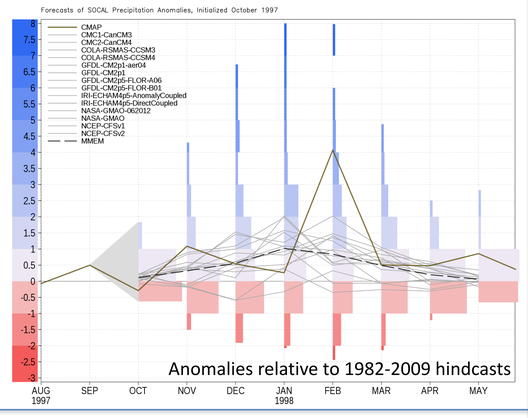


Positive rainfall confined to California

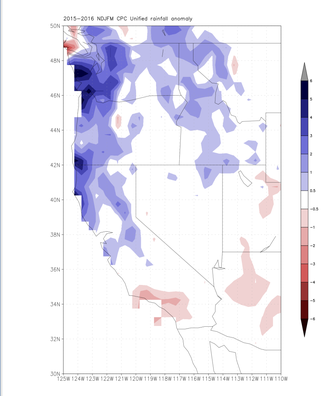
Very different event in Pacific NW

Above average rainfall observed

Ensemble mean predicts above average rainfall



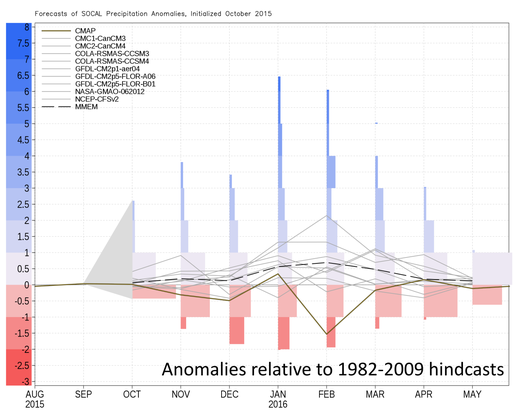
2015-2016 NDJFM Precipitation Anomalies



Positive rainfall anomalies for Pacific NW

Slightly below average rainfall observed for Southern California

Ensemble mean predicts above average rainfall



What Happened?

- Why did expected rainfall not materialize?
  - Variations between El Niño events?
    - Not all events are the same
  - Impact of other SST anomalies?
    - Could "the Blob" or other feature be playing a role?
  - Internal variability?
    - How strong is the forced signal?
    - How influential is atmospheric noise?
- Why did the models fail to capture the 2015/2016 response?
  - Models predicted above average rainfall for all three events
  - Correct for two out of the three

Ensemble Mean and Noise Correlation

- Let us decompose each model field into two components: $SST_{ij} = SST_i^E + SST_{ij}^N$

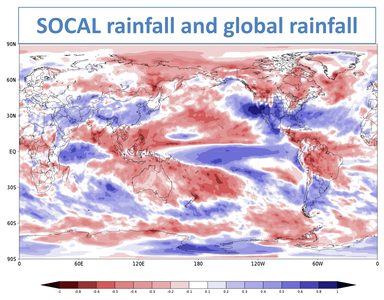
  where SST_i^E is the ensemble mean for year i, and SST_{ij}^N is the deviation from the ensemble mean (noise) for year i and member j

- We can then calculate correlations between different components
  - Predicted (ensemble mean) components, e.g.: $r_E = corr(SST_i^E, SOCAL_i^E)$
  - Unpredicted (noise) components, e.g: $r_N = corr(SST_{ij}^N, SOCAL_{ij}^N)$

- Ensemble mean is likely dominated by ENSO pattern
  - What is the structure of the noise patterns?
  - How do they influence southern California rainfall?

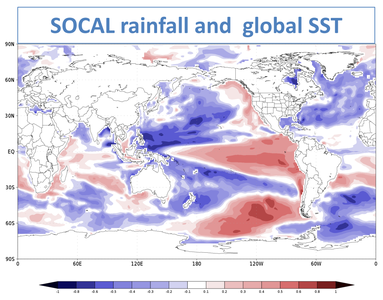
Ensemble Mean Correlations

SOCAL rainfall and global rainfall



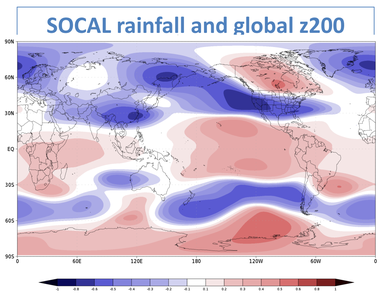
- High positive values over SOCAL region by construction
- Negative correlations over Pacific NW
- Local and tropical response consistent with response to ENSO

SOCAL rainfall and global SST



- Clear association between SOCAL rainfall and ENSO pattern
- Provides explanation for consistency of model rainfall response to ENSO events

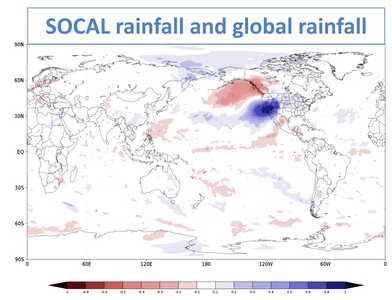
SOCAL rainfall and global z200



- High positive values in tropical eastern Pacific
- High negative values near US west coast
- Clear resemblance to El Niño teleconnection pattern

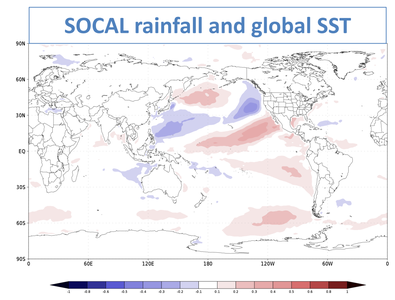
Noise Correlations

SOCAL rainfall and global rainfall



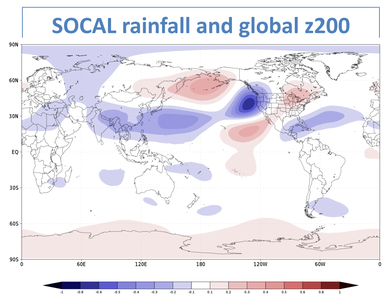
- High positive values over SOCAL region
- Negative correlations with Pacific NW
- Centers overlap with ensemble mean pattern
- Noise pattern is highly localized
- No apparent remote links

SOCAL rainfall and global SST



- Values generally not significant
- Weak correlation with ENSO region
- Tripole pattern in north Pacific
- Response to circulation anomaly?

SOCAL rainfall and global z200



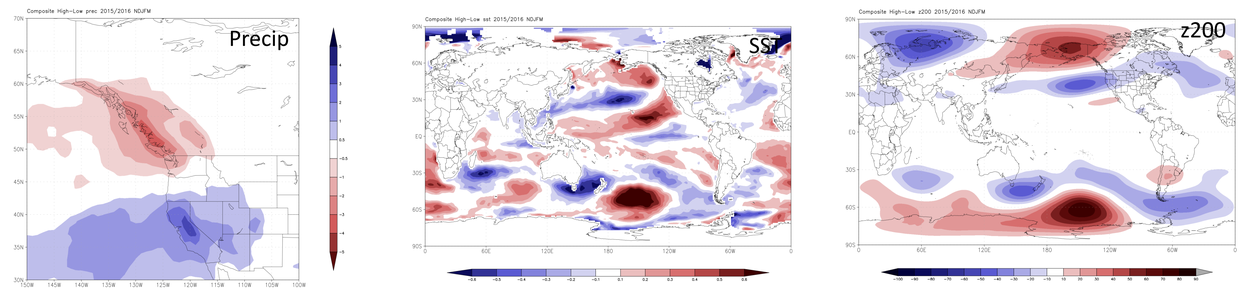
- Strong negative center off US West coast
- No correlation with increased heights in tropical Pacific
- Noise pattern is again relatively localized
- As with rainfall, overlap between ensemble mean and noise associations

Impact of Noise on 2015-2016 Event

- Does this analysis provide insight into the 2015/2016 event?

- Plume shows some members did produce below-average rainfall: How do these members differ?
  - 2 highest and 2 lowest SOCAL rainfall members selected from CMC4, CCSM4, FLOR-A, FLOR-B, NASA-062012
  - Important to note: Correlations taken from 1982-2009 hindcasts - 2015/2016 event not included in correlation analysis

Hypothesis: Differences between members in 2015/2016 forecasts will be consistent with noise patterns



Strong similarities for each composite to noise correlations

Conclusions

- Models – Noise Component
  - Similar rainfall pattern along west coast as for ENSO
  - Unpredicted (unpredictable?) variations in strength of west coast low strongly influence seasonal rainfall total
  - Minimal association with SST
    - Plausibly in response to circulation change
- 2015/2016 Event
  - Differences between high and low SOCAL rainfall members consistent with analysis of noise components
  - Suggests atmospheric noise plays a key role in intra-event variability
- Observations
  - Statistically significant correlation between NINO34 and California rainfall
  - Significant amount of unexplained variance
  - Straightforward explanation for intra-event variability
- Models – Ensemble Mean
  - Statistically significant correlation between NINO34 and California rainfall
  - Association should repeat from event to event
  - Ensemble mean forecasts will likely be for enhanced rainfall for every event