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science for a changing world

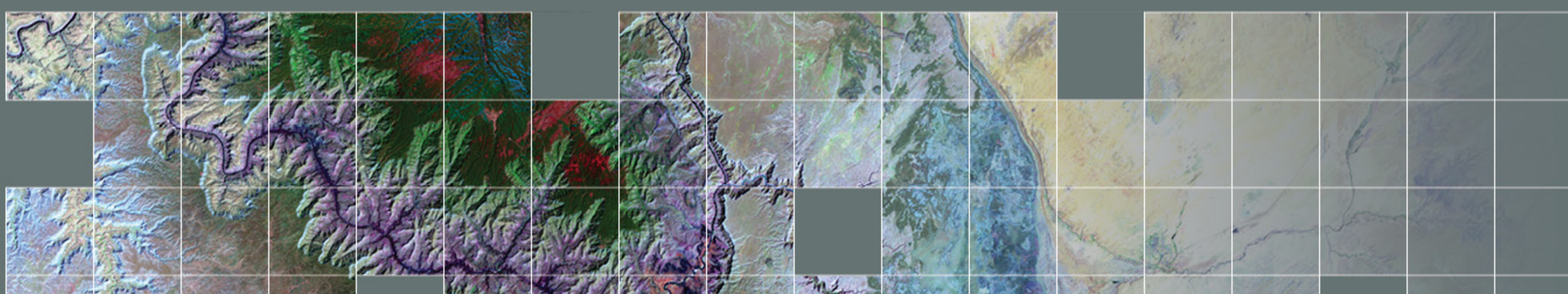
Climate Hazards Group
UC Santa Barbara

Climate and Land Use Change

Earth Resources Observation and Science (EROS) Center

A Climate Hazards Perspective on Attributing and Predicting ENSO-Related Droughts

Chris Funk, Shrad Shukla, Laura Harrison, Gregory Husak, Catherine Pomposi and Frank Davenport



Chris Funk, USGS/UCSB Climate Hazards Group

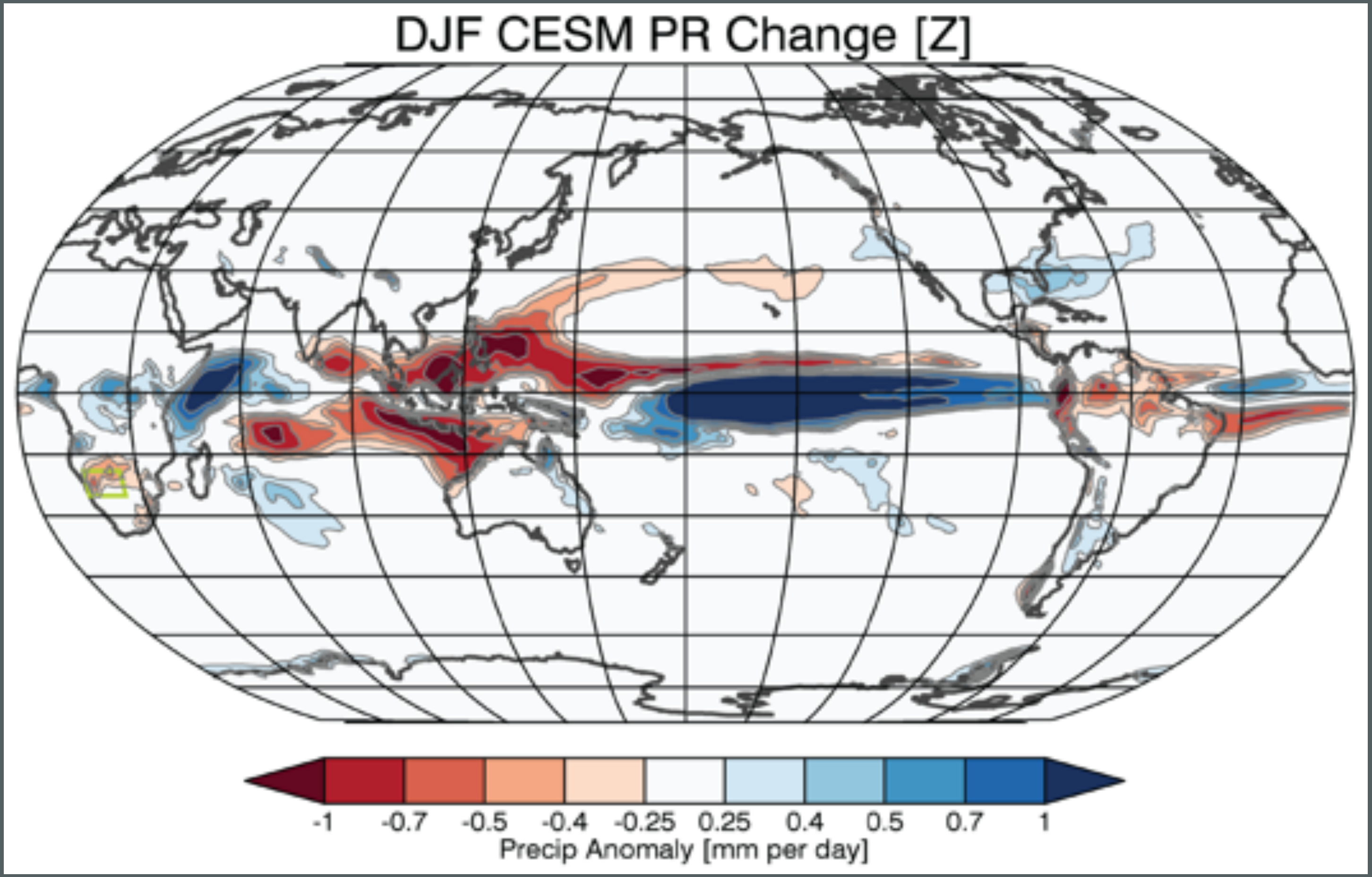
U.S. Department of the Interior
U.S. Geological Survey

FEWS NET
FAMINE EARLY WARNING SYSTEMS NETWORK

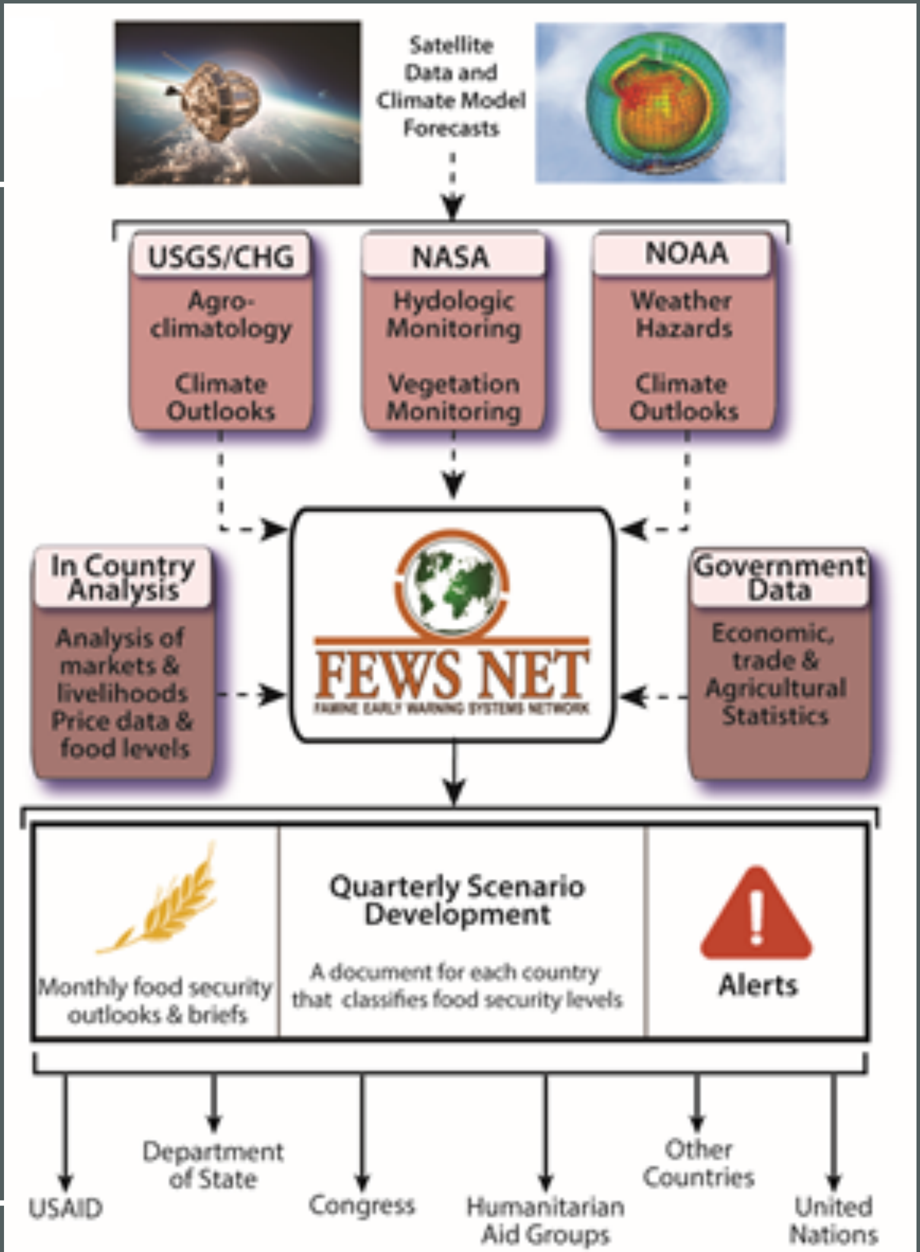
USAID
FROM THE AMERICAN PEOPLE

CHG | Climate Hazards Group

Twenty years supporting FEWS NET



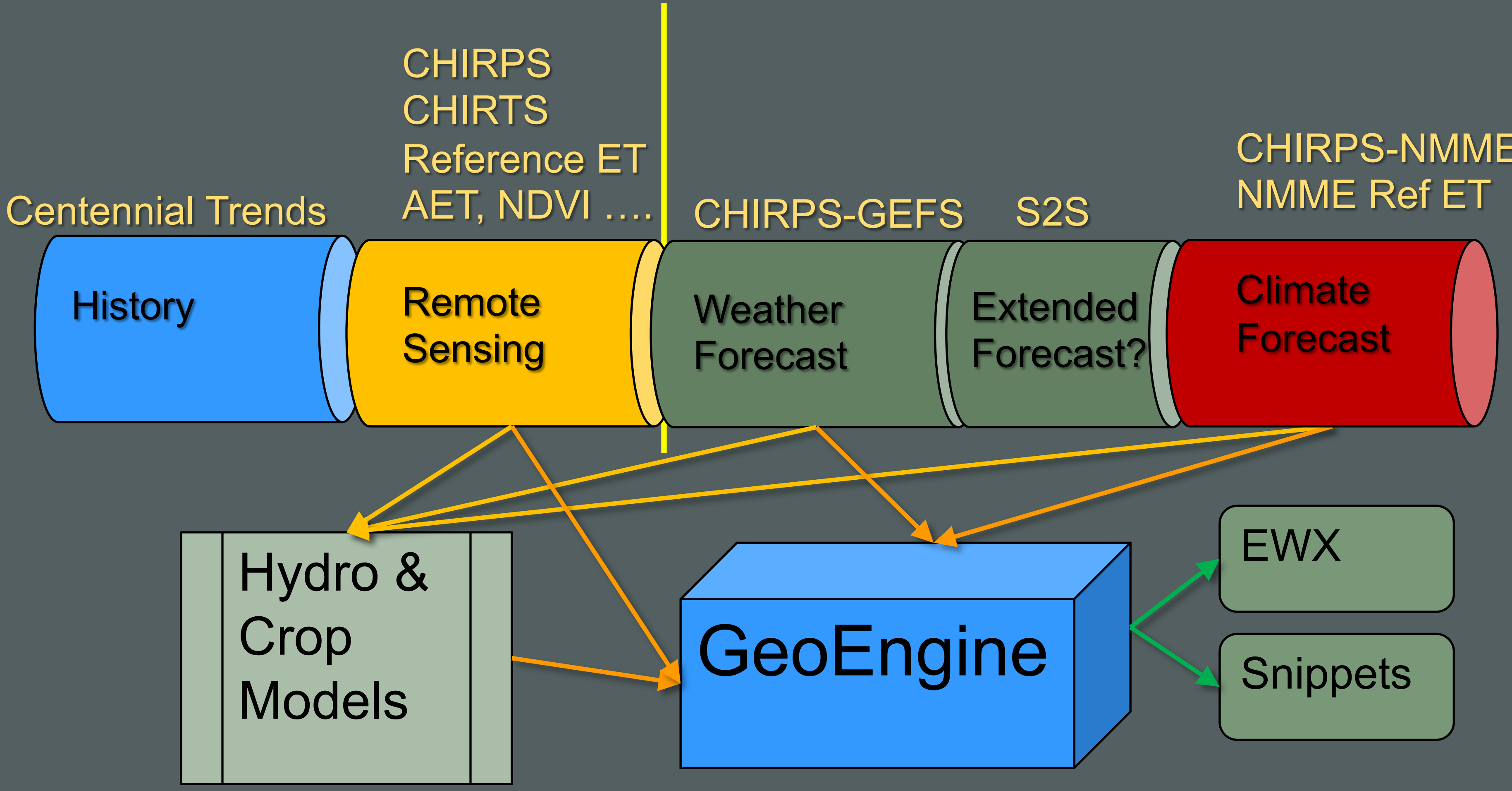
Famine Early Warning System Network



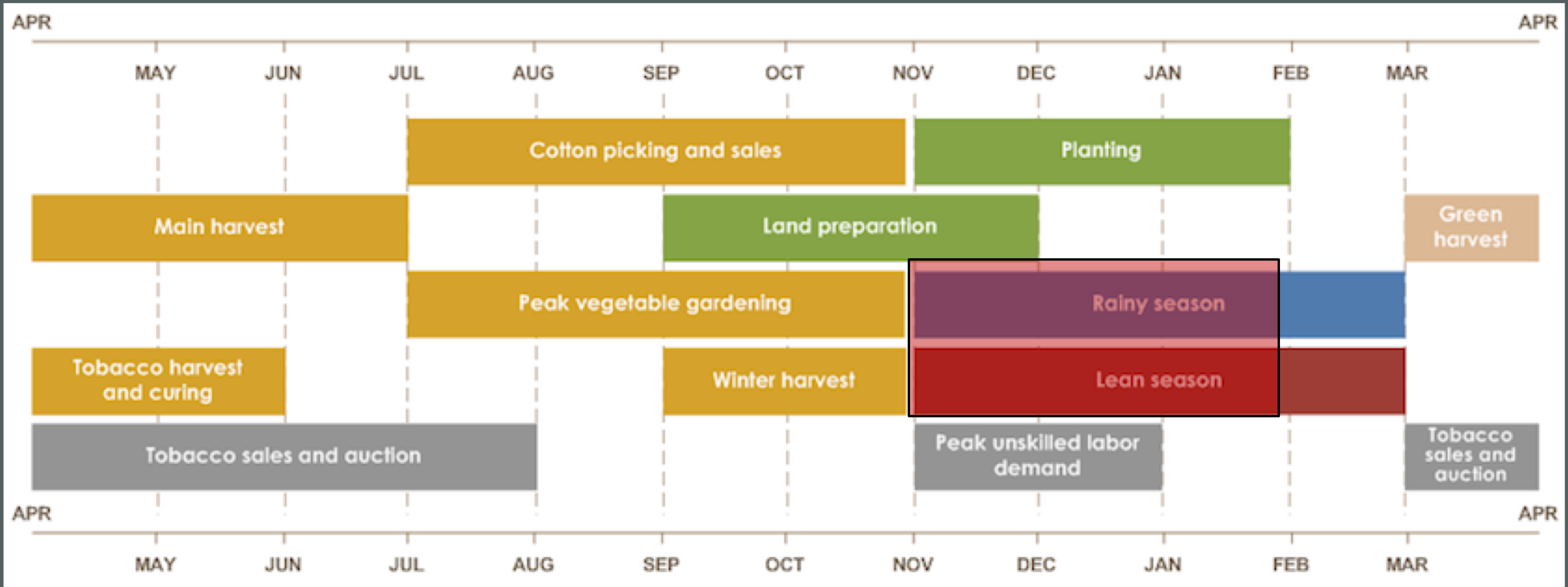
Improving Food Security Outlooks, BAMS, In Review

The Climate Hazards Center

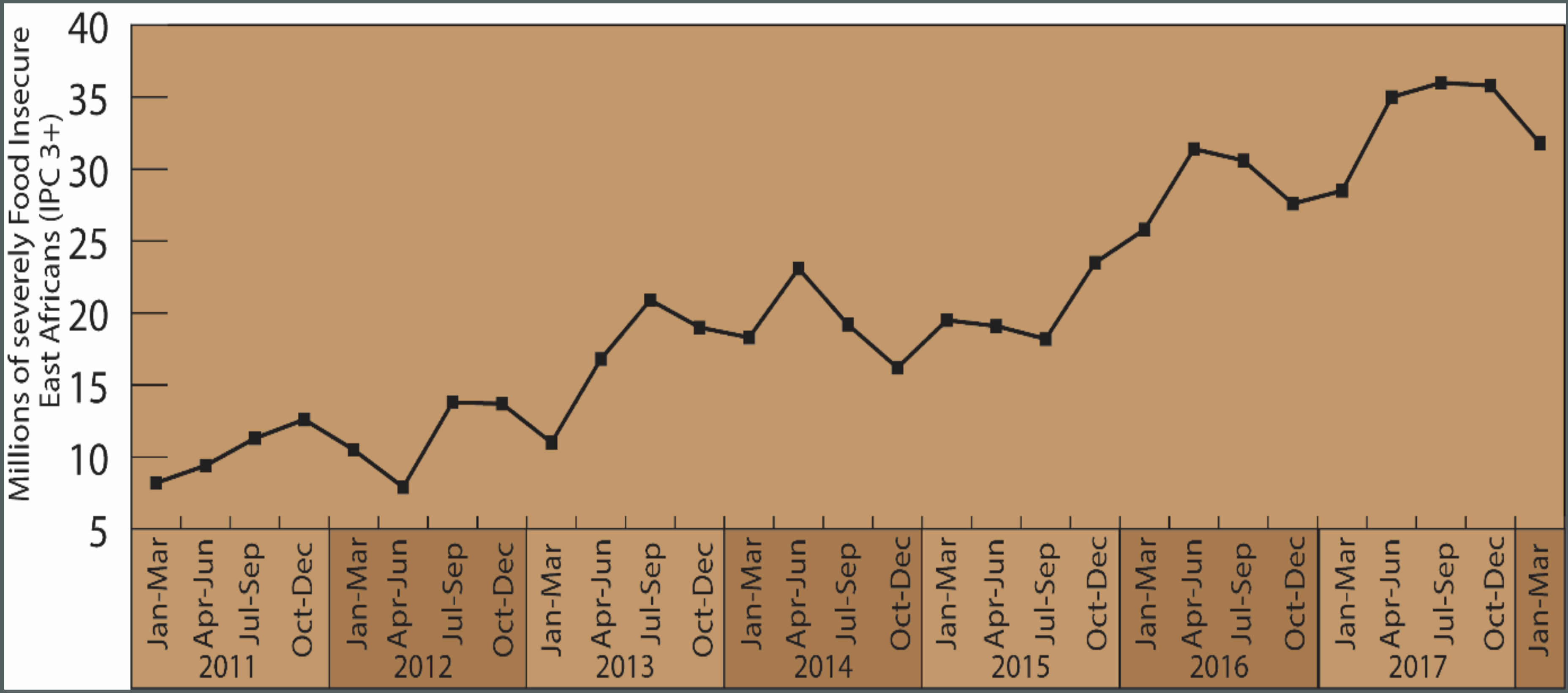
Integrated Early Warning System



Zimbabwe Seasonal Calendar

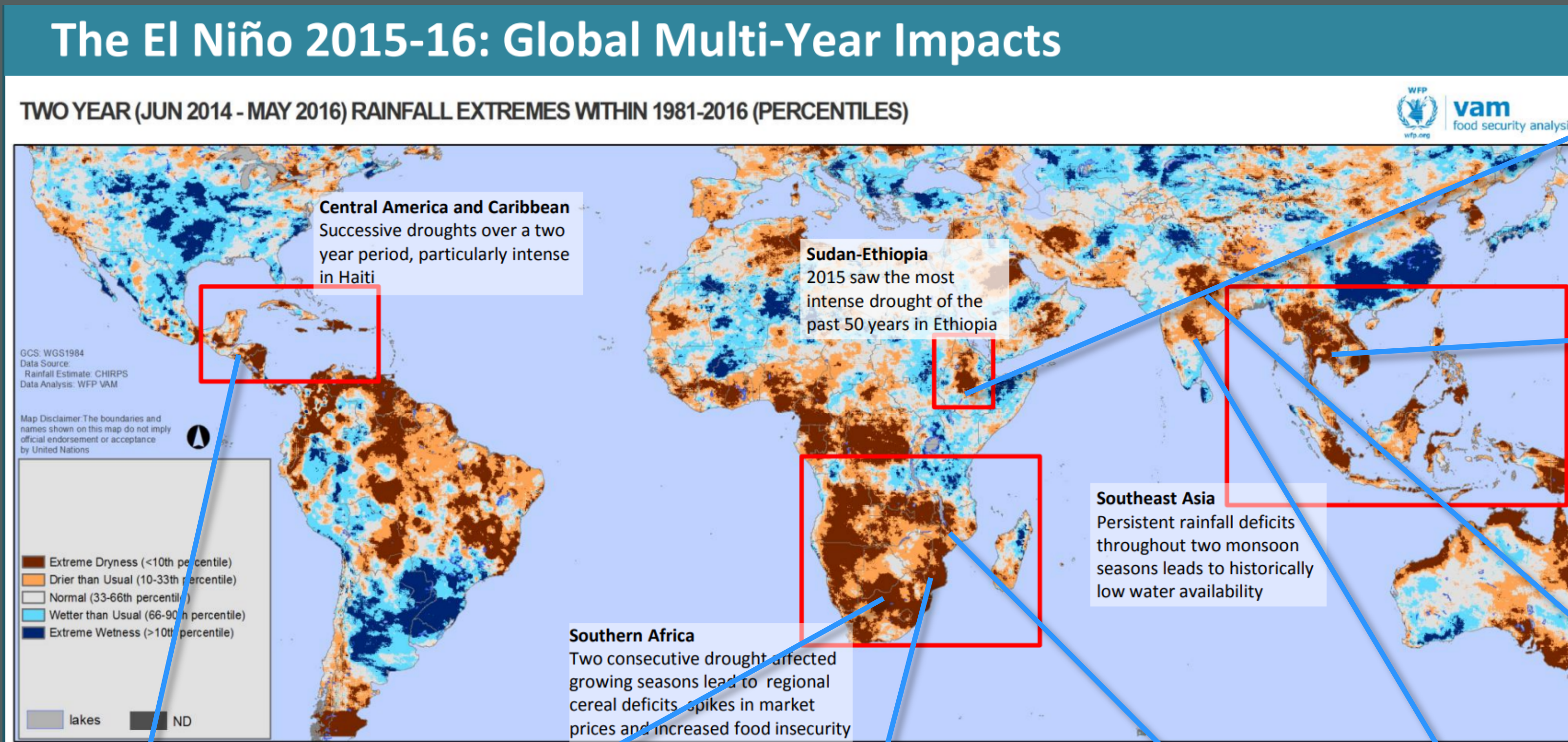


Context



Estimates of severely food insecure populations in the Greater Horn of Africa

The 2015-16 El Nino: Global Multi-Year Impacts



~11 million severely food insecure Ethiopians in 2016

$500 million dollar Ag Production loss (Christidis et al.)

2015 heat wave (>113°F) led to more than 2,500 deaths in India and Pakistan (Wehner et al. 2016)

330 million Indians affected by drought (Guha-Sapir et al. 2017)

Crisis levels of food insecurity in Central America and Haiti

Climate change increased intensity of drought (Yuan et al., Funk et al.)

~24 million people faced pre-famine conditions as a result of the 2015/2016 drought

Poor households in Malawi make ~$70 a year, spend 60-70% of their income on food. Food prices jumped by 45%

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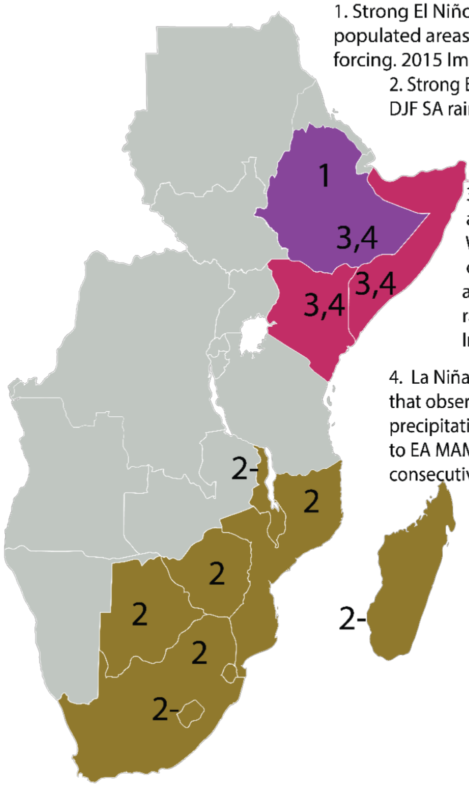
Schematic Figure of potential sequential droughts

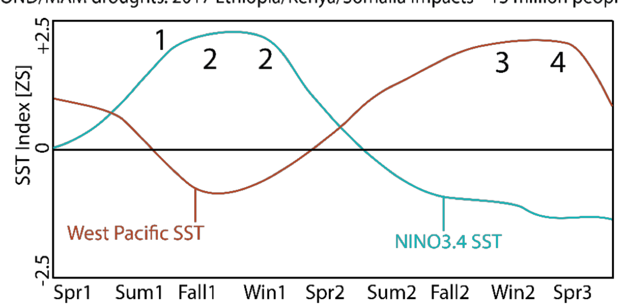


1. Strong El Niño forms during boreal summer of Year 1, disrupting Meher harvest in Ethiopia across densely populated areas of Ethiopia. Post-1980 JJAS East Pacific diabatic forcing ~70% greater than 1921-1980 diabatic forcing. 2015 Impact ~10 million people.

2. Strong El Niño continues through boreal fall and winter, disrupting rainfall across easterrn SA. Negative observed DJF SA rainfall/NINO3.4 SST relationship supported with CAM5 and CESM1 simulations. Strong El Niño events produce large circulation anomalies. CESM1 simulations indicate that strong ENSO events may be ~2.5 times more frequent now that in the 1920s. 2016 Impact ~10 million people. 2017 Impact ~16 million people.

3. La Niña-like conditions form in OND of Year 2. Since the late 1980s, this transition has often been accompanied by an upward jump in WEP and WNP SST. Strong and persistent warm SST anomalies in the West Pacific have been important for recent back to back OND and MAM EA droughts. During OND, observations, CAM5 and CESM1 simulations indicate a negative relationship between warmer WEP SST and EA OND rains on an interannual basis. Unlike in MAM, the OND response has not involved a decrease in rainfall through time. This may have to do with the comparatively limited influence of WEP warming on the Indian and Pacific branches of the Walker Circulation during OND.

4. La Niña-like conditions and warm WNP conditions tend to pesist into MAM of Year 3. Here we show that observations, CAM5 and CESM1 simulations all indicate that WNP SST plays an important role in modulating EA precipitation and the Indo-Pacific Walker Circulation. Increasing WNP SST and diabatic forcing are likely contributors to EA MAM rainfall declines. More frequent MAM droughts seem likely. Common West Pacific forcing may support consecutive OND/MAM droughts. 2017 Ethiopia/Kenya/Somalia Impacts ~13 million people.



Funk et al. QJRMS 2018

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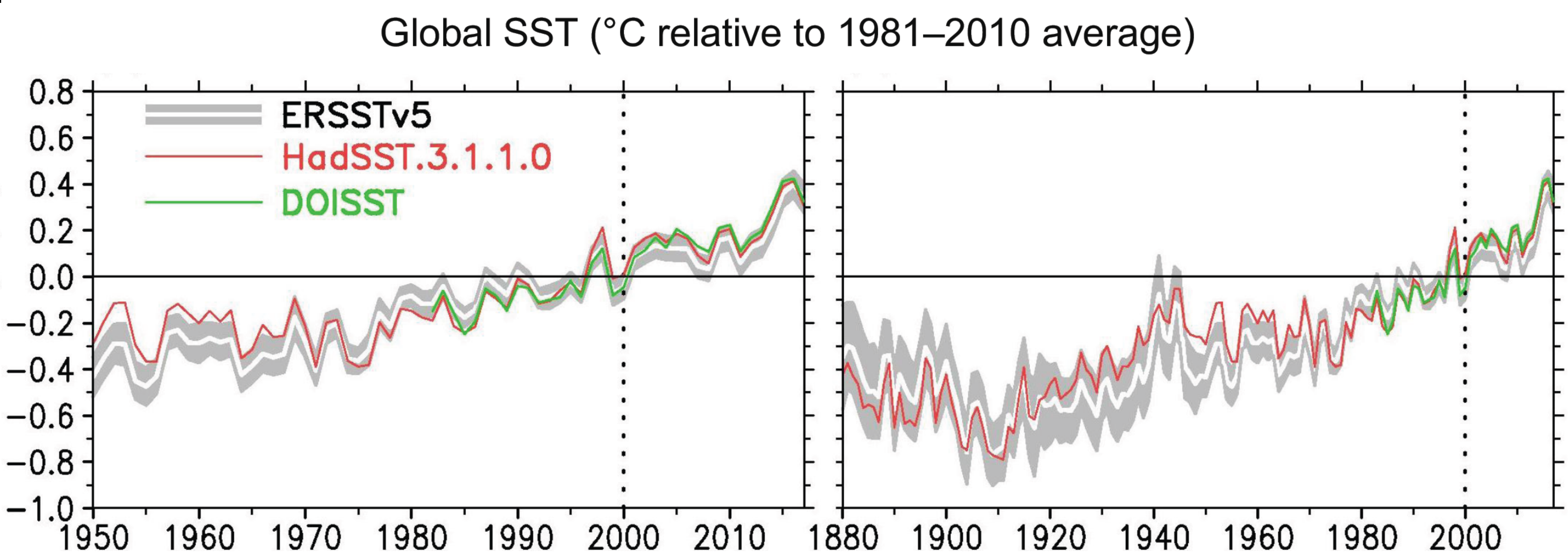
Big jump in SSTs beginning in 2015



NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION | State of the Climate in 2017

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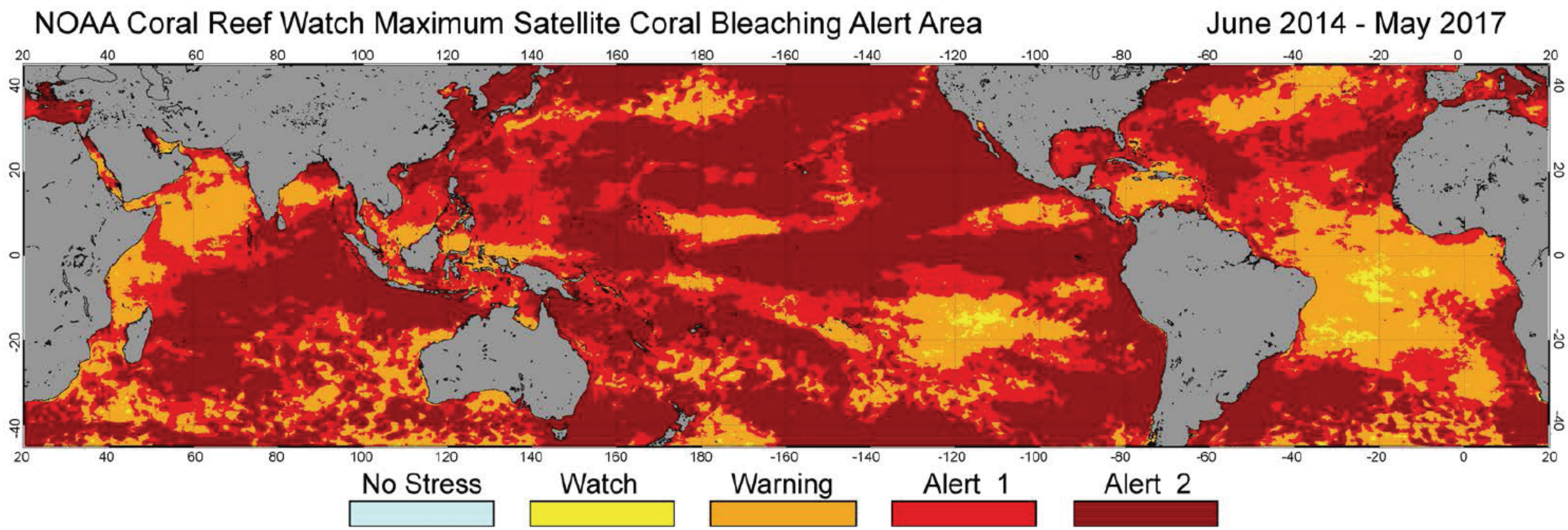
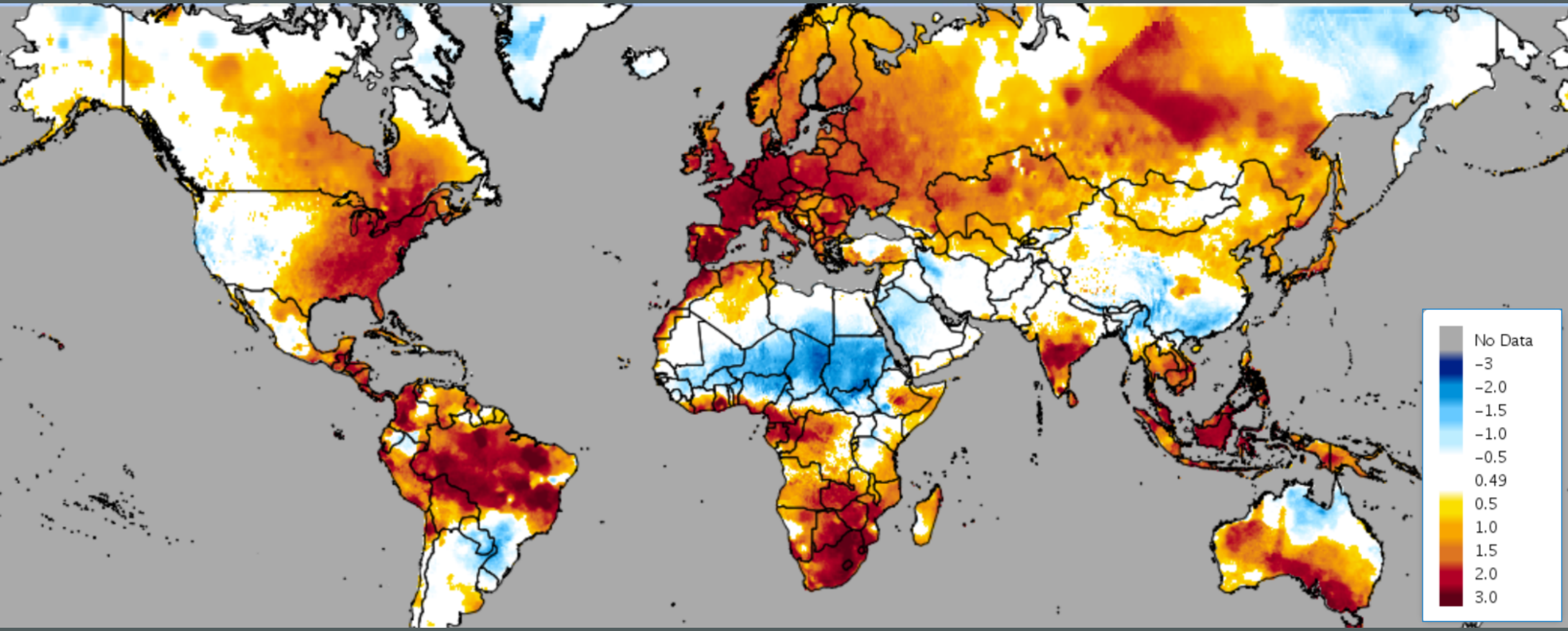
Marine Heat Waves pose grave risks to corals



- Warm Sea Surface Temperatures: **Unprecedented Three Years of Global Coral Reef Bleaching 2014–17** (pp. S74–S75)

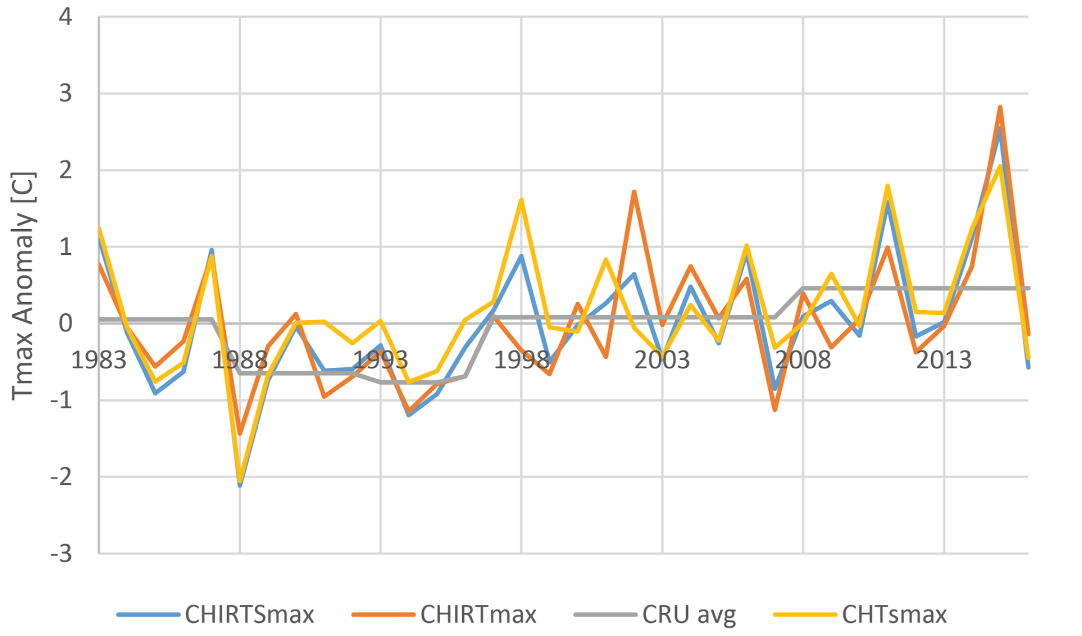
CHIRTSmax Temperatures Z-scores December 2015



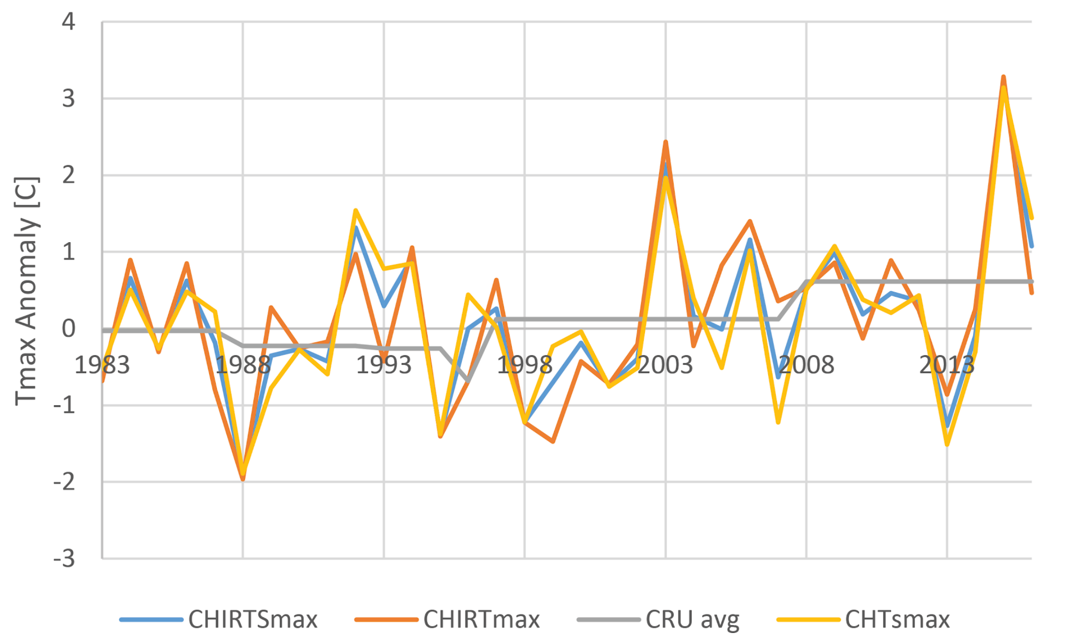
CHIRTS$_{max}$ Temperatures

Example time series for the Amhara region in Ethiopia (A) and the Mpumalanga Province in the Republic of South Africa (B).

A. July Tmax anomalies for Amhara Region of Ethiopia



B. December Tmax anomalies for Mpumalanga Province of South Africa



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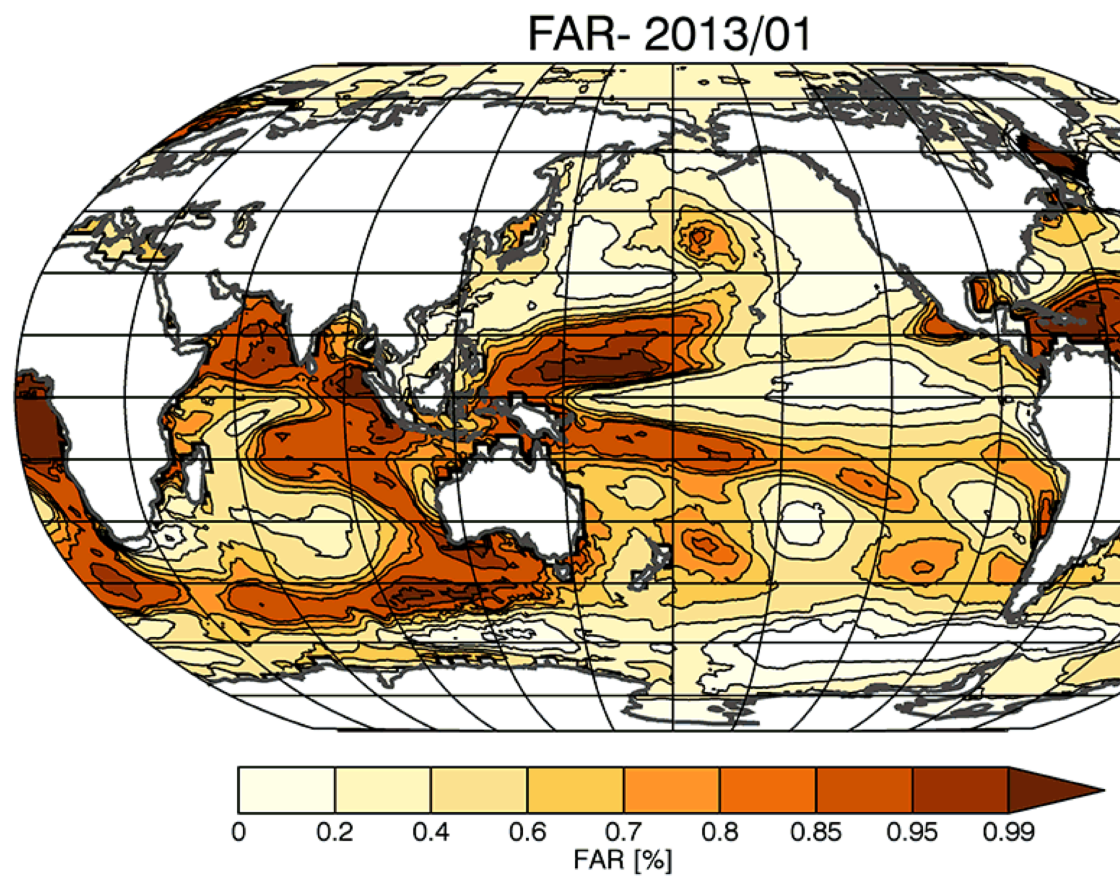
A climate hazards perspective – extremely warm SSTs produce droughts

FAR = 1 – *P0 / P1* (Allen, 2003)



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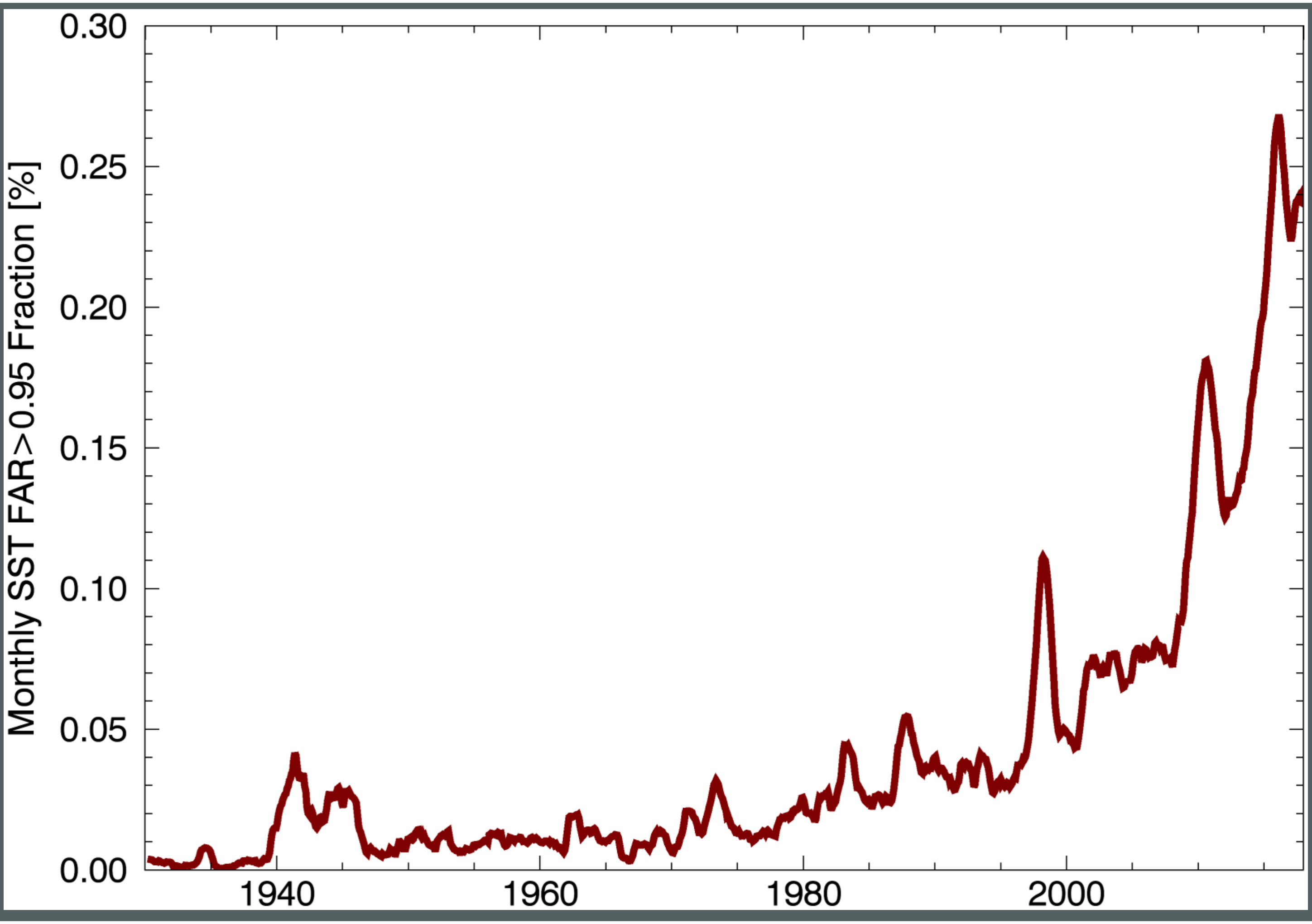
Time series of ocean area where FAR >0.95



Hovmoller Plots of equatorial Indo-Pacific SSTs

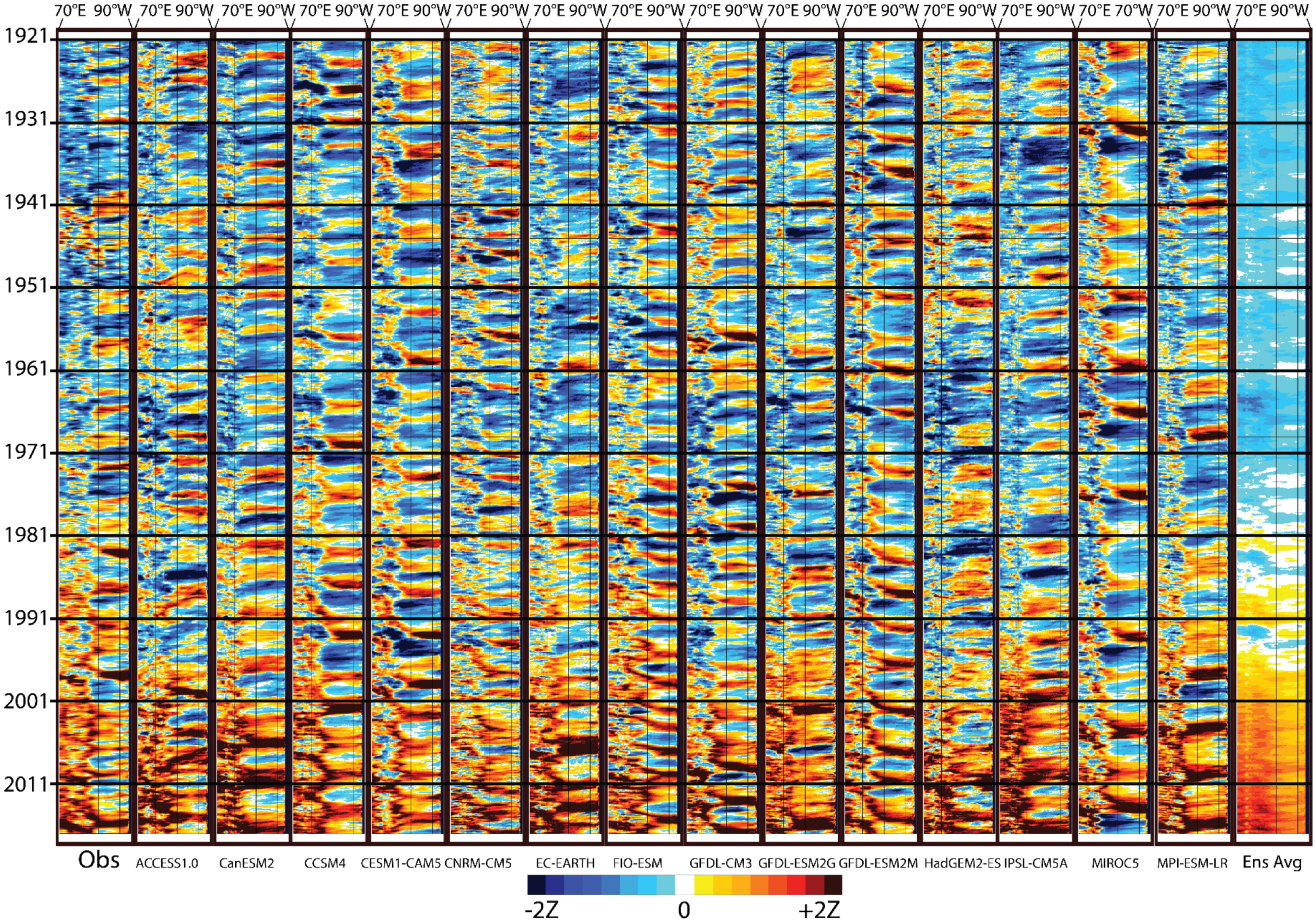
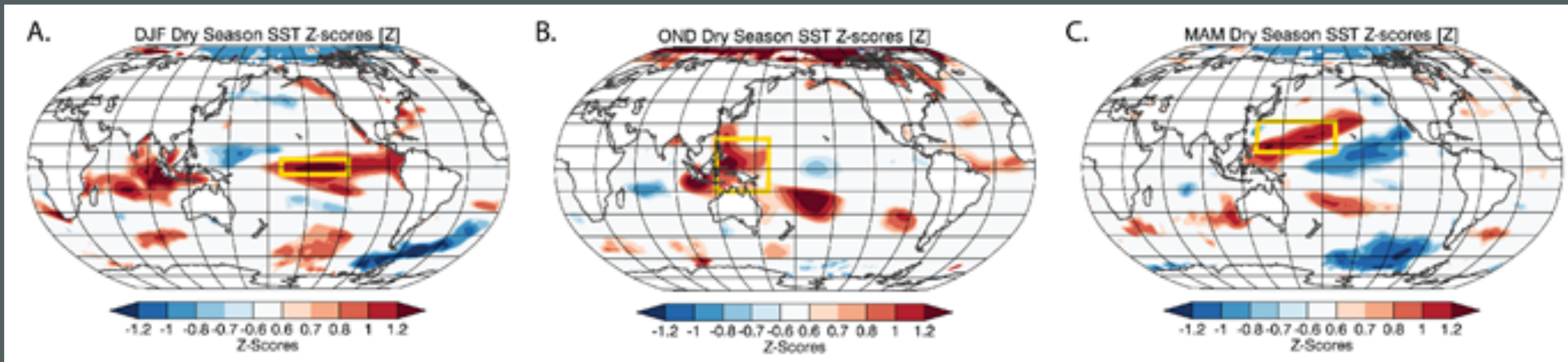


Figure 12. Hovmöller plots of standardized monthly SST anomalies. Each panel depicts equatorial SST from either observations, a single model simulation, or the ensemble average. Panels begin at 70°E and end at 90°W.

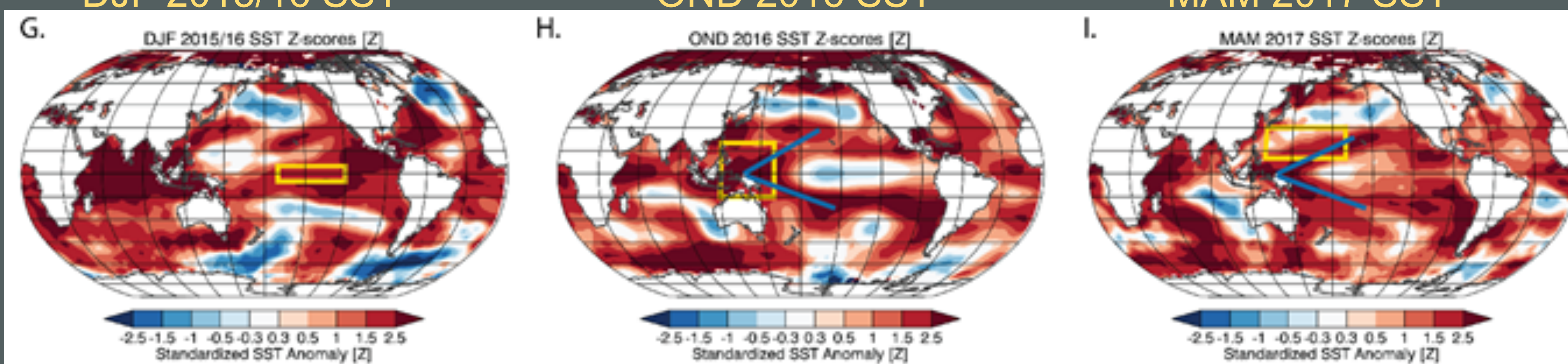
QJRMS, 2018

SST composites for recent EA/SA droughts

Southern Africa – DJF | East Africa – OND | East Africa - MAM



DJF 2015/16 SST | OND 2016 SST | MAM 2017 SST



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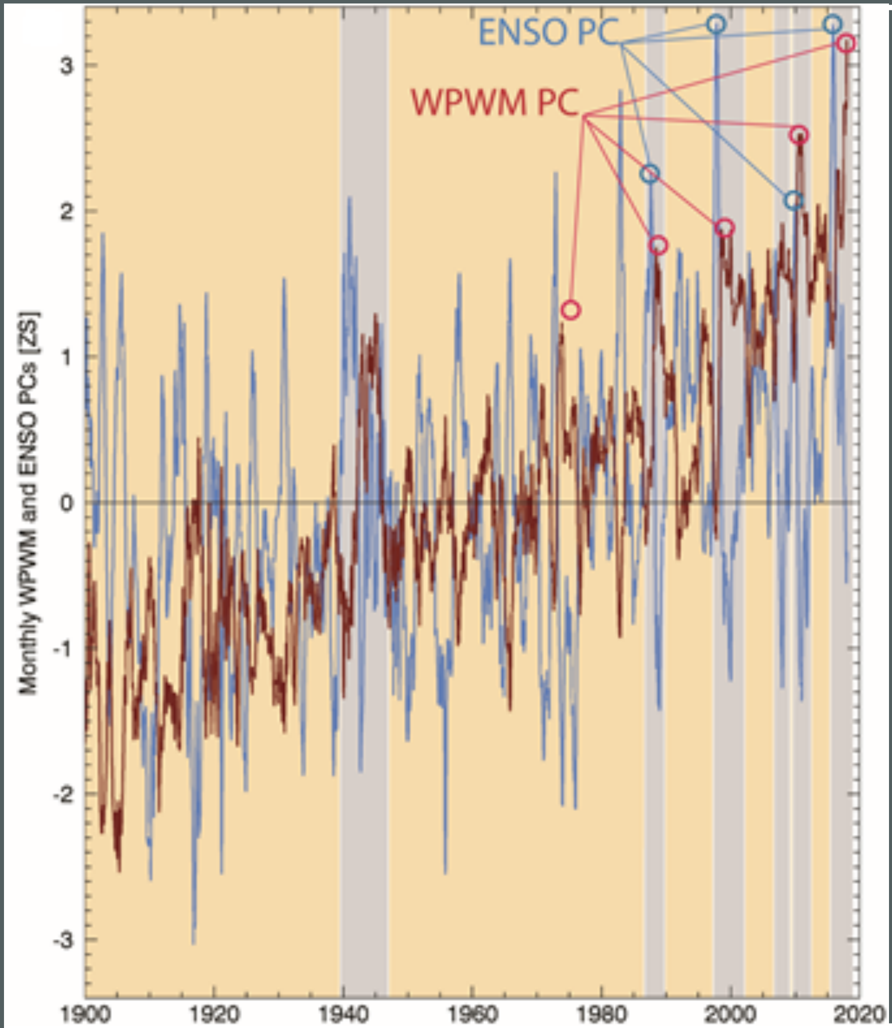
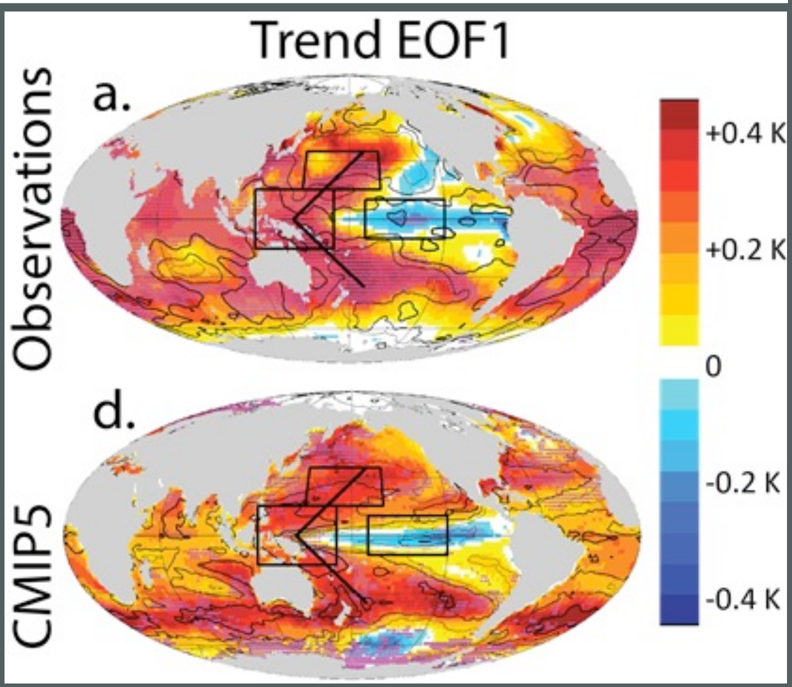
QJRMS, 2018

ENSO and West Pacific Warming Mode





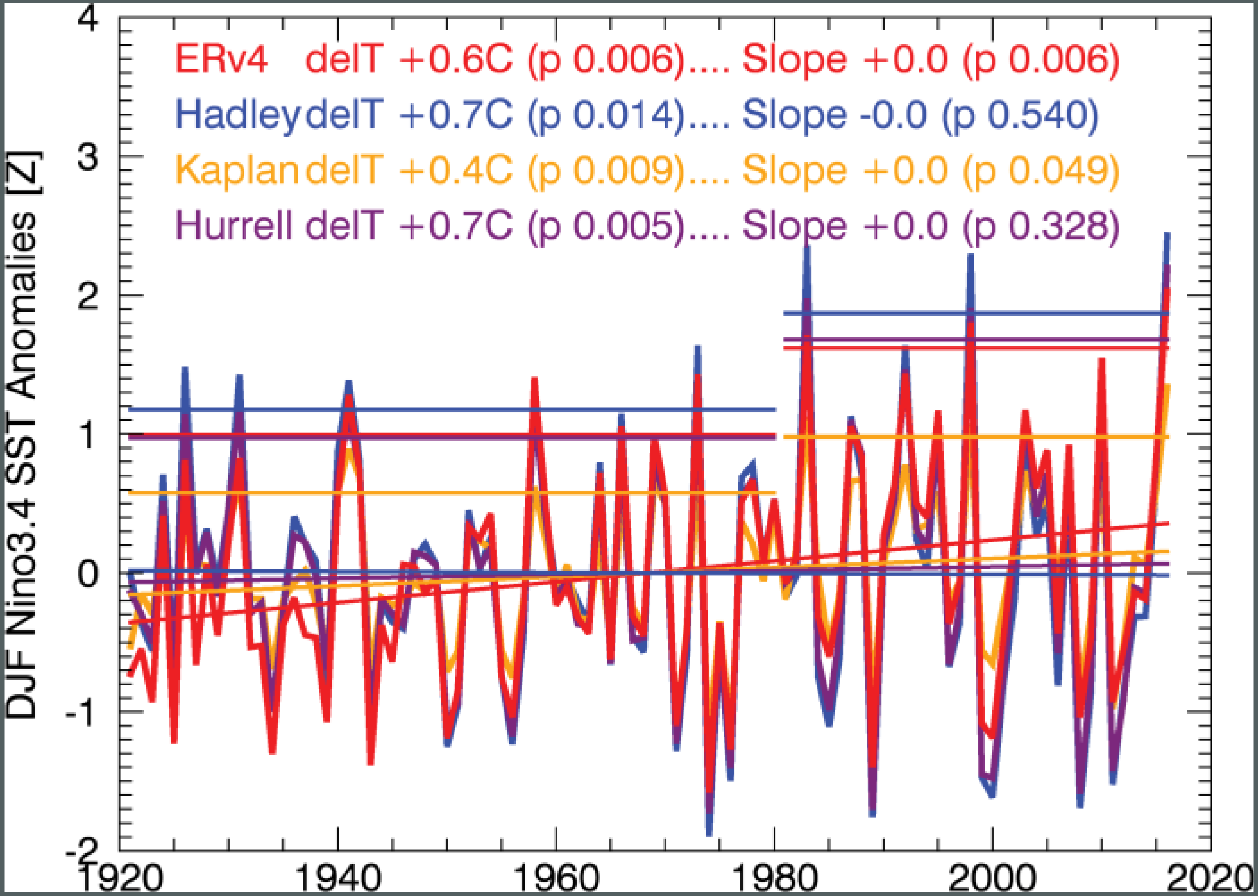
Funk & Hoell, 2015

Improving Food Security Outlooks, BAMS

One-in-six-year compositing

- **We can identify SST extreme states by**
  - Sorting SST indices over a given time period (say 1981-2016) and
  - Picking a set of ‘n’ extreme events
- **We can examine changes in extremes by repeating this process at two intervals,**
  - i.e. 1921-1980 and 1981-2016
  - And examining differences in composites
- **Null hypothesis:**
  - Uniformly warming SSTs, no change in precipitation
- **1-in-6 year time scale appropriate for Climate Outlook Fora**
- **Data: 53 CMIP5 simulations, 40 CESM1 simulations, 50 CanESM2 simulations, Observed SST, AMIP simulations**

We have observed more extreme El Nino events



The mean of 1-in-6 year Warm East Pacific NINO3.4 SSTs is increasing

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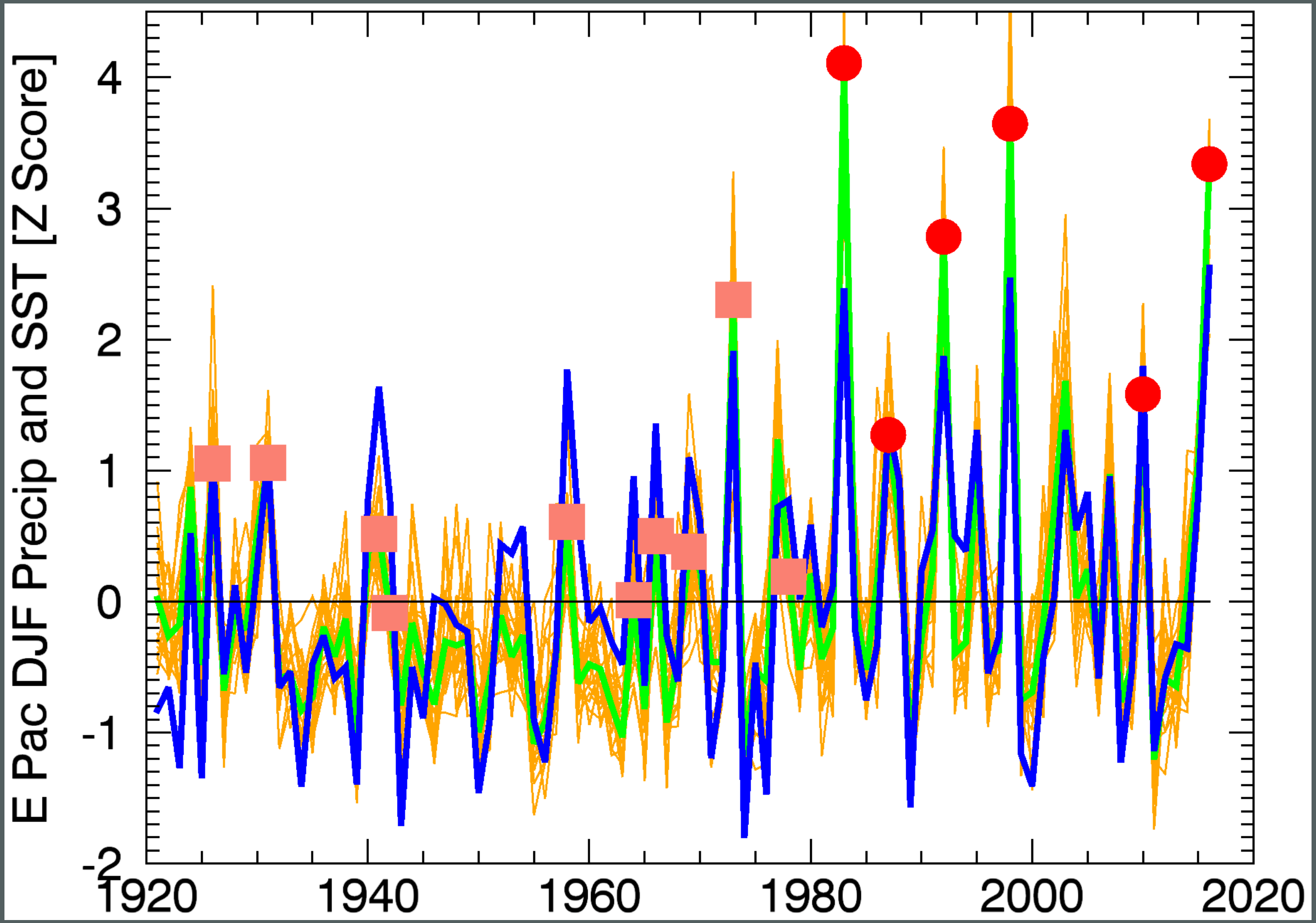
Funk et al. BAMS EEE 2017

NINO3.4 precipitation forcing associated with these events appears to be increasing



Standardized DJF CAM5 precipitation from the NINO3.4 region

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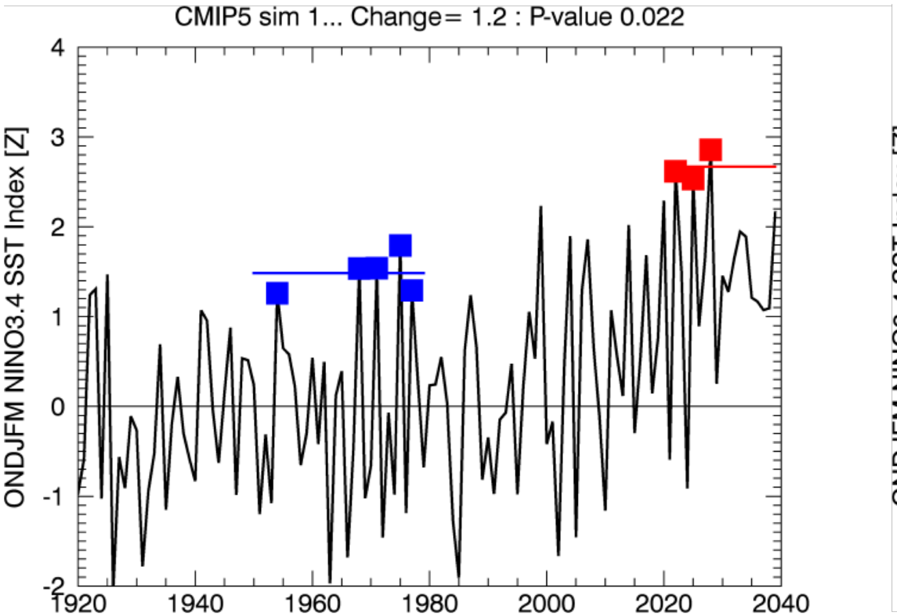
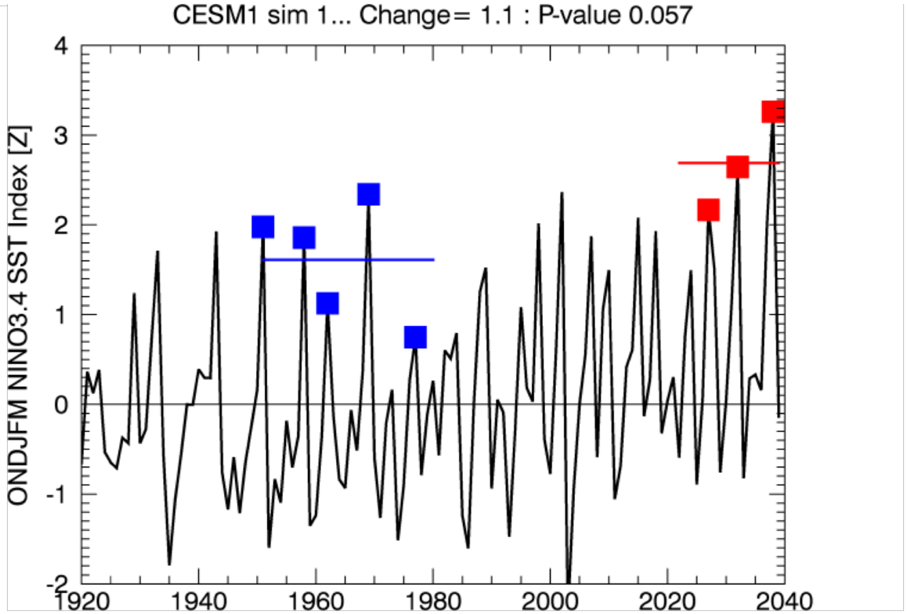
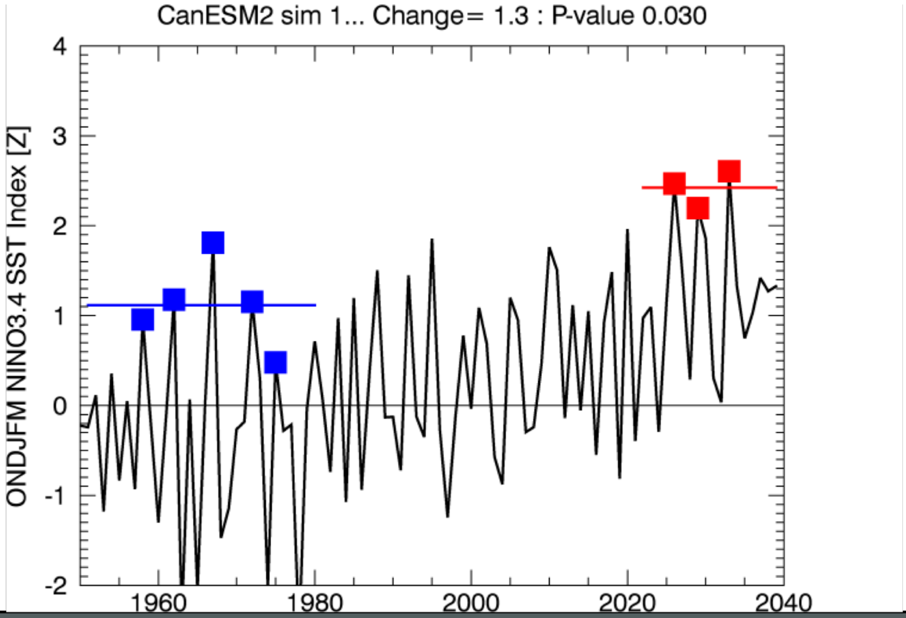
QJRMS, 2018

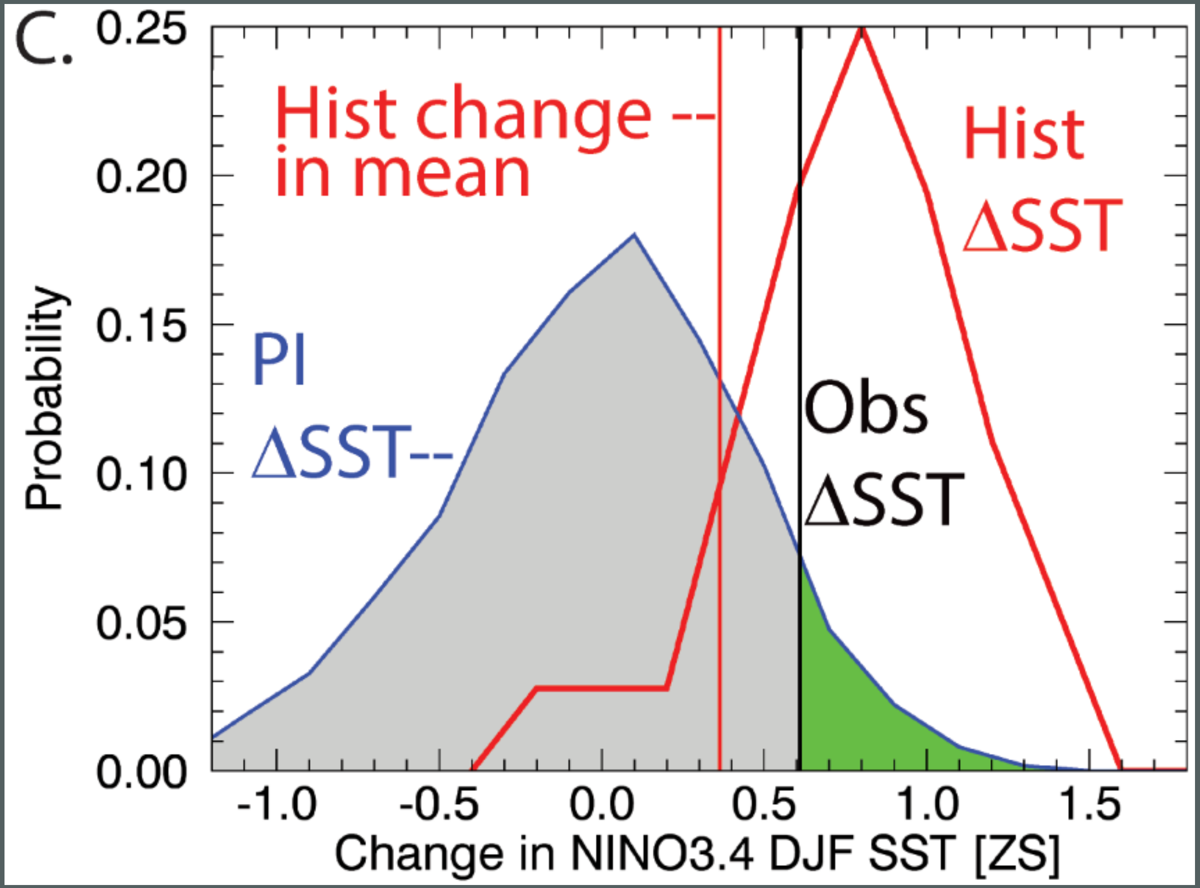
CMIP5, CESM1, CanESM2 NINO3.4 Time Series







CESM1 NINO3.4 DJF Attribution Analysis



~7% increase in NINO3.4 SSTs could arise in a world without climate change.

CESM1 predicts a ~+0.8Z increase, the change in the NINO3.4 mean is +0.4Z

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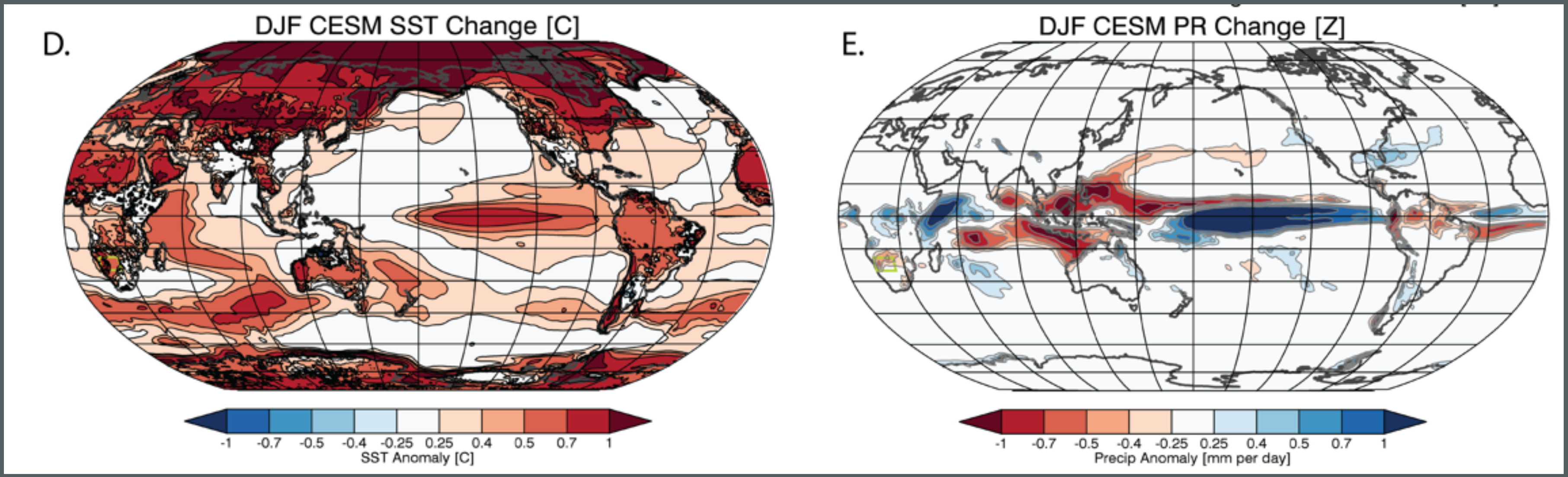
PI and Historic distributions of changes in 1-in-6 year maximum NINO3.4 SST. Gray/green shading denotes likelihood given PI conditions.

1-in-6 year composites of DJF climate change simulations from the CESM1 large ensemble show a shift towards substantially stronger El Ninos



Maps D and E show the change between 1981-2016 and 1921-1980 1-in-6 year El Nino events based on 40 CESM1 climate change simulations. D shows changes for DJF SSTs. E shows changes in DJF standardized precipitation.

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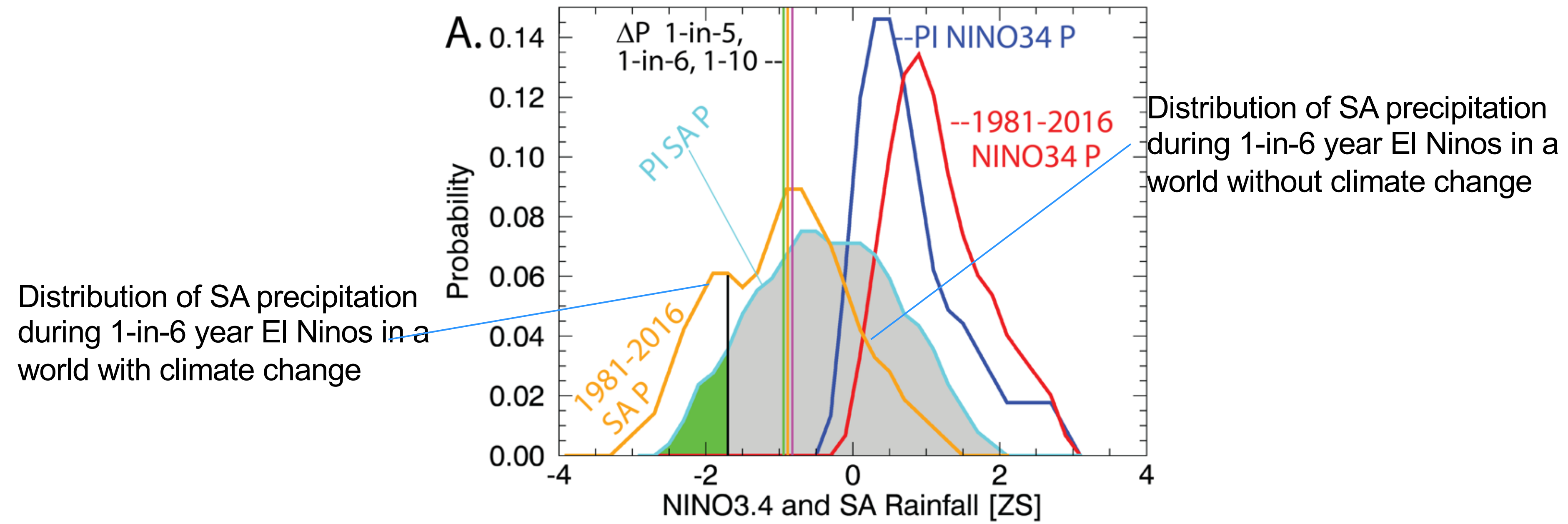
Funk et al. BAMS EEE 2017

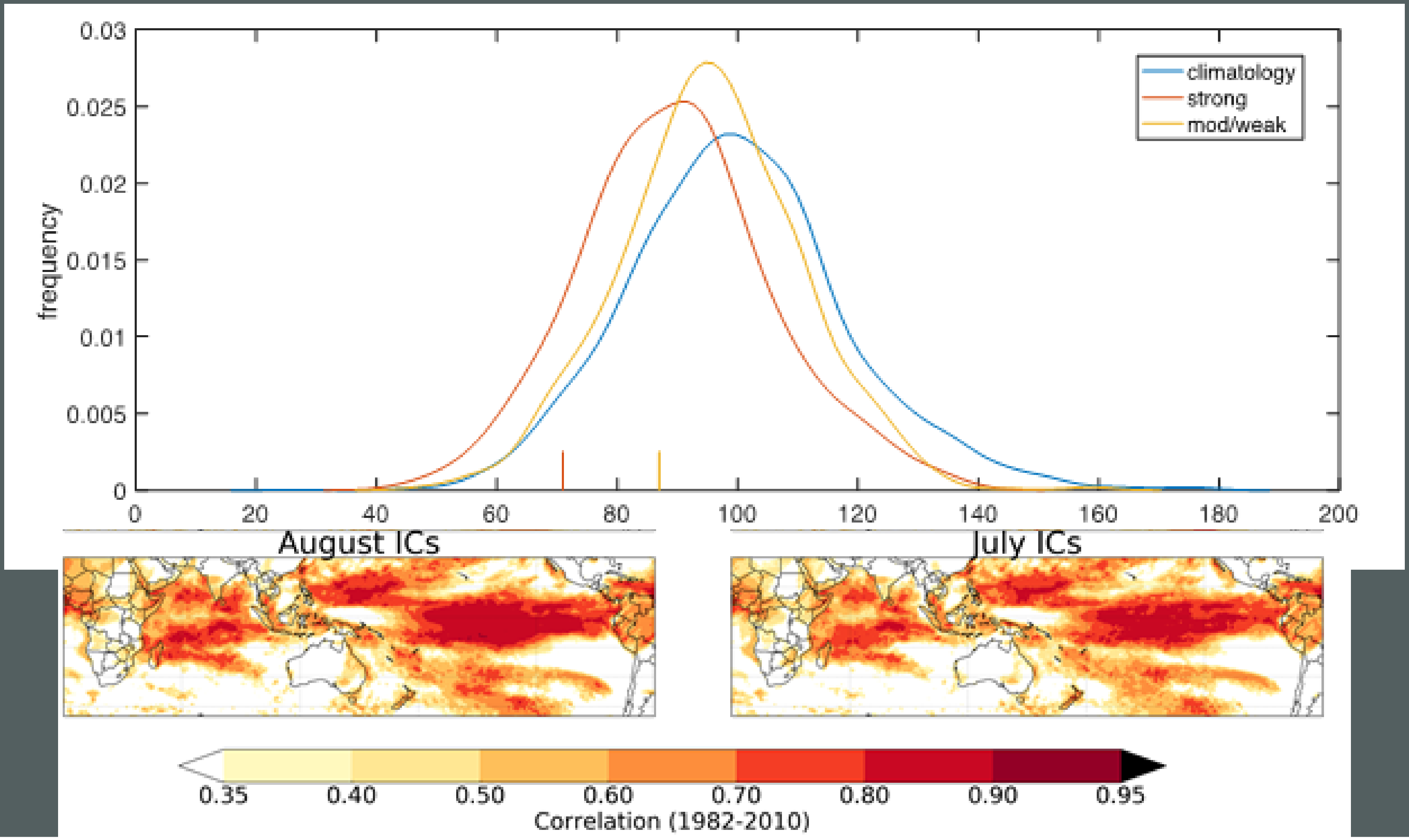
1-in-6 year composites of DJF climate change simulations from the CESM1 large ensemble show stronger drought impacts over Southern Africa



Precipitation attribution results. Standardized CESM SA and NINO3.4 El Nino precipitation PDFs for PI and 1981-2016 Historic ensembles. The historic MSENE ensemble was based on 15% of 40 simulations x 36 years = 216 El Niños). Also shown were results based on 10% and 20%. PI ensemble used 15% of 1680 years = 252 PI El Niños. Green and gray shading indicates the probability of the observed -1.7Z drought occurring within the PI distribution.

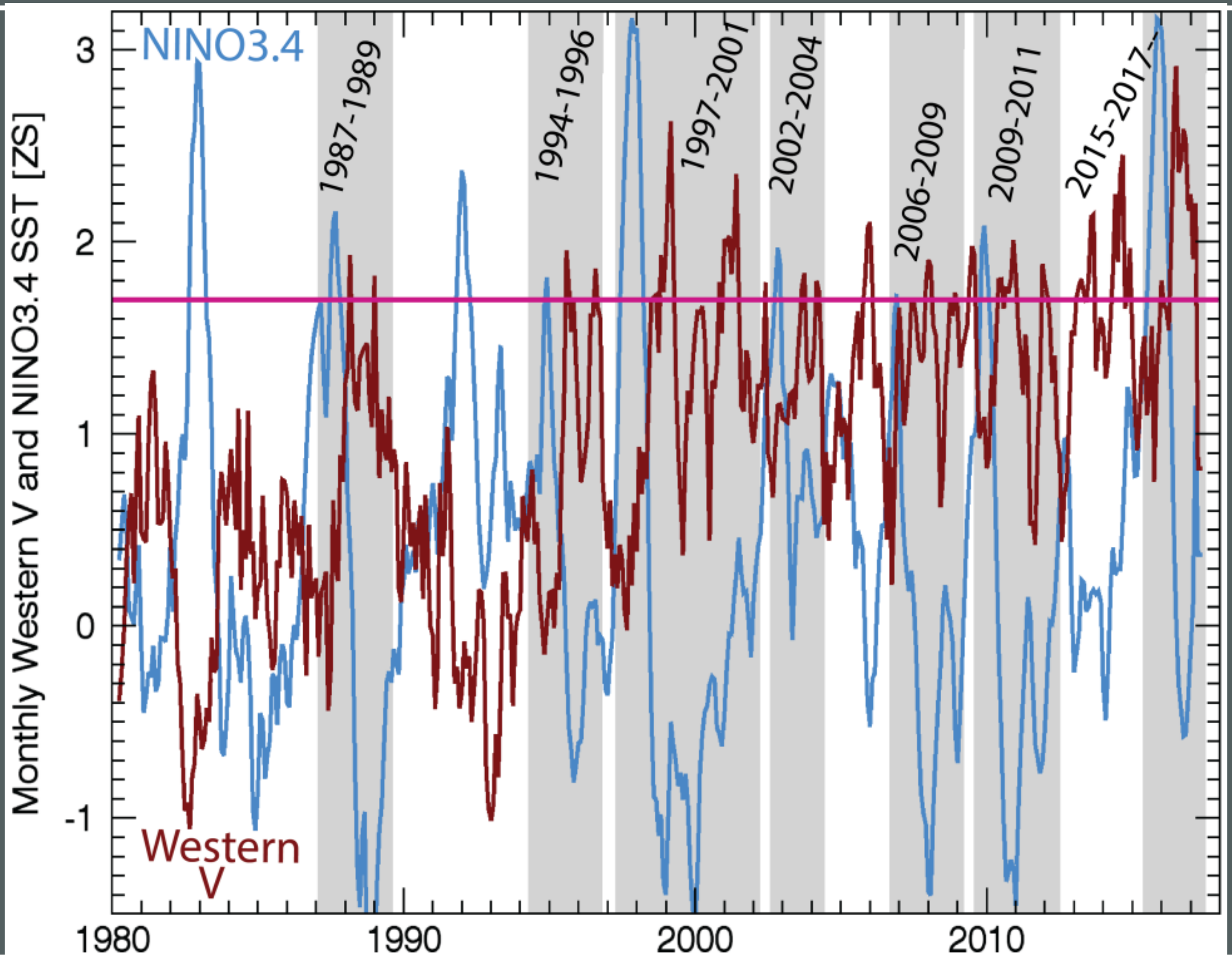
Funk et al. BAMS EEE 2017

CAM5, GFSv2, ECHAM5 AMIP Simulations suggest stronger El Ninos matter for Southern Africa



Pomposi et al. (2018) ERL

Switching to East Africa …



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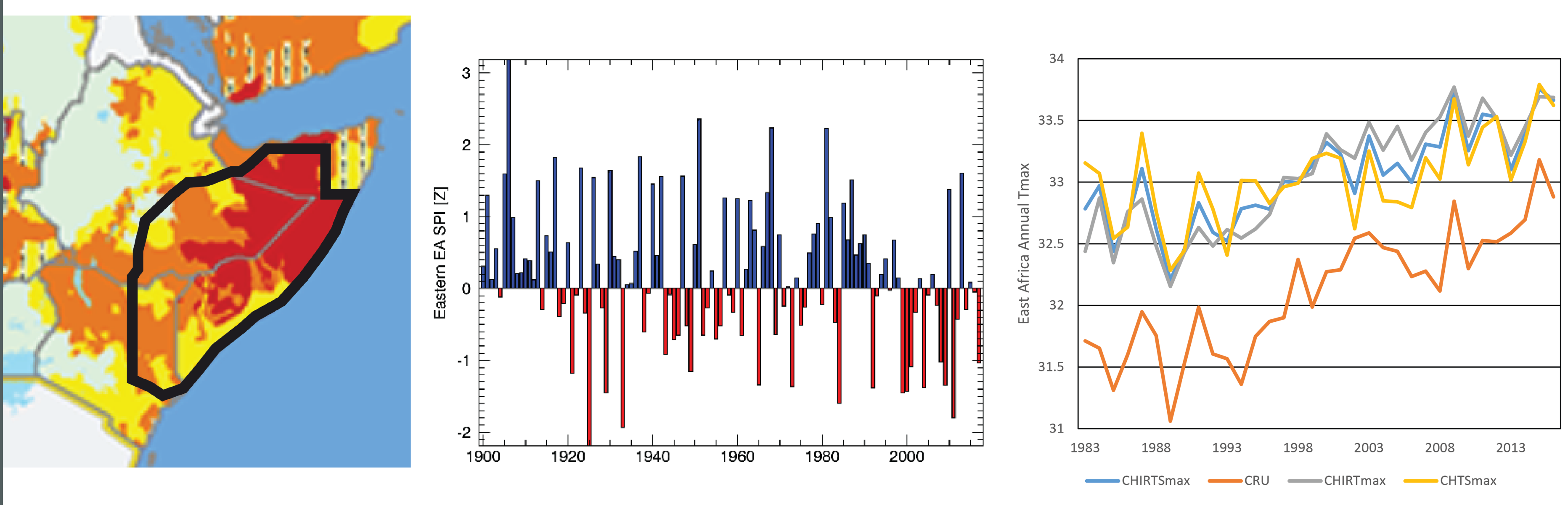
Food Insecure, drier, hotter …



October 2017 Integrated Phase Classification Food Security Outlook (left), March-May Standardized Precipitation Index time series (middle) and CHIRTSmax, CHIRTmax, CHTSmax and CRU TS 4.01 annual average Tmax for the region marked in the left panel (right).

CHIRTSmax paper …. In review at J. Climate

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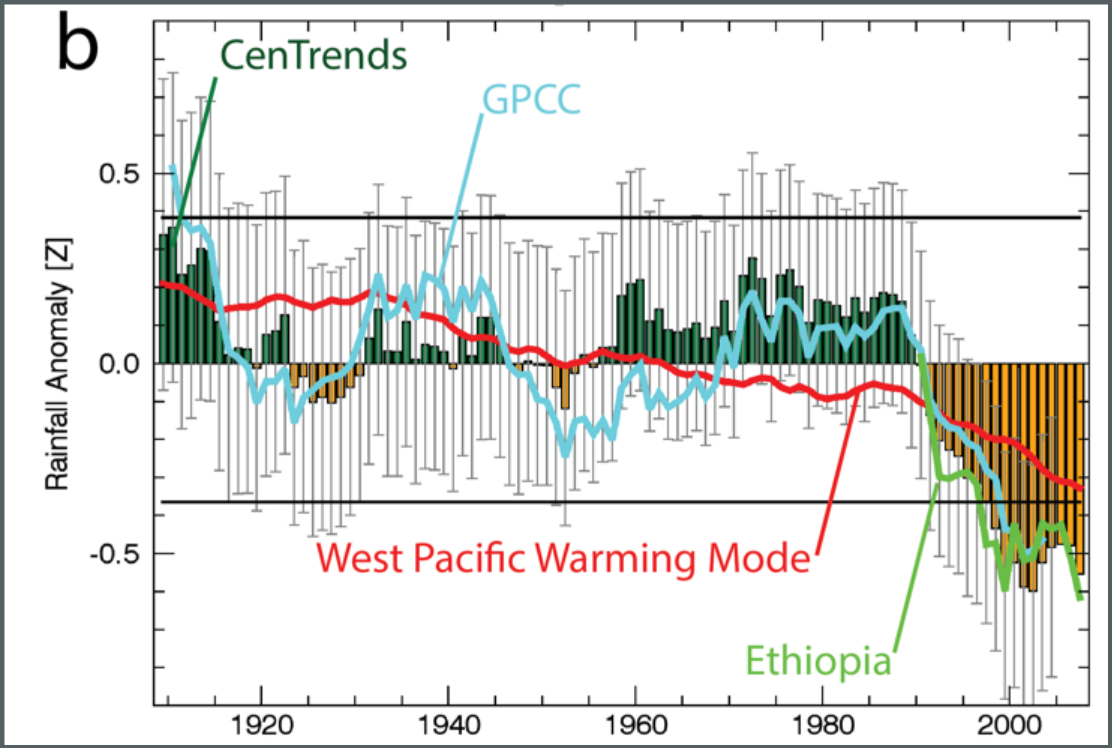
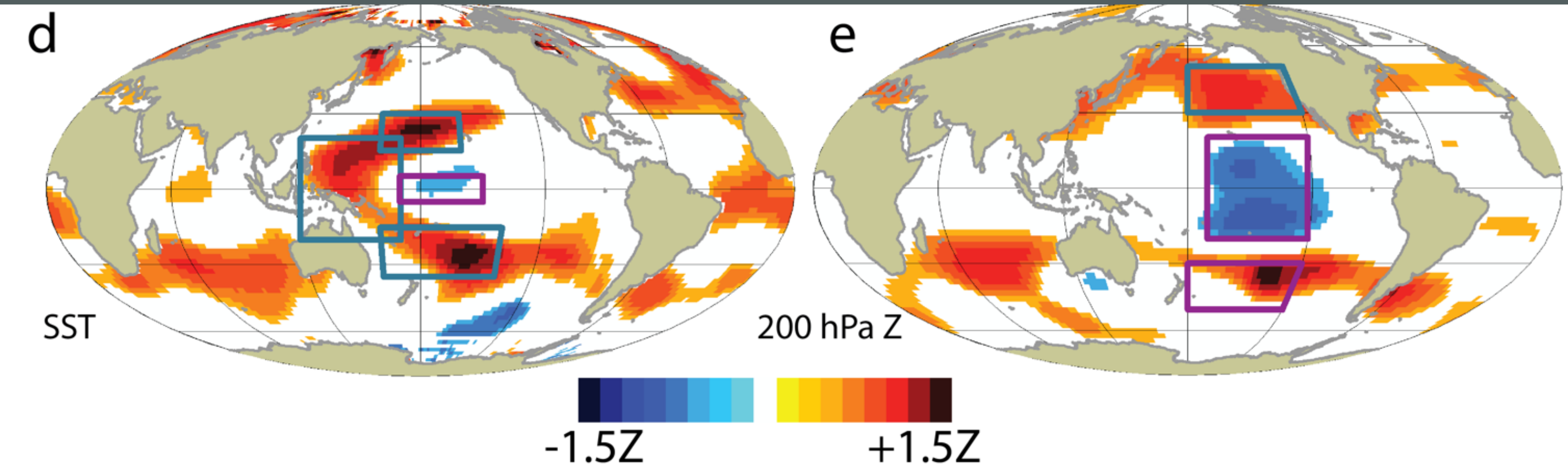
Analysis of long term changes in EA spring rains



20-yr EA rainfall with bootstrapped confidence intervals and standard errors. Vertical error bars denote CenTrends kriging standard errors. Horizontal lines indicate deviations significant at p=0.05, based on 10,000 bootstrapped samples. Red line indicates West Pacific Warming Mode regression estimates. Ethiopia time series averaged over Ethiopia southeast of 35°E, 9°N.

Composites of MAMJ SSTs and 200 hPa heights for recent EA MAMJ droughts



Funk et al. BAMS EEE 2018

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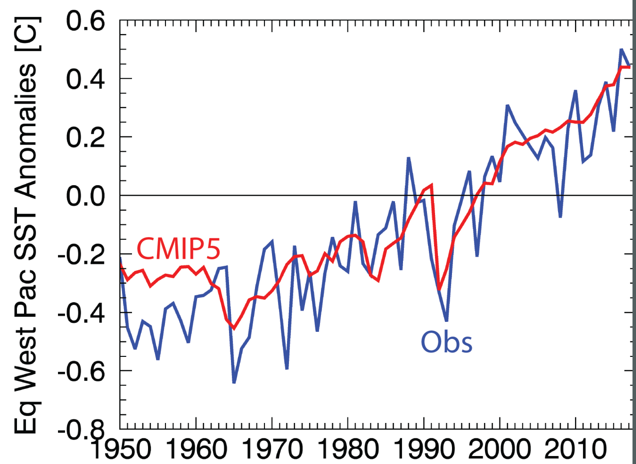
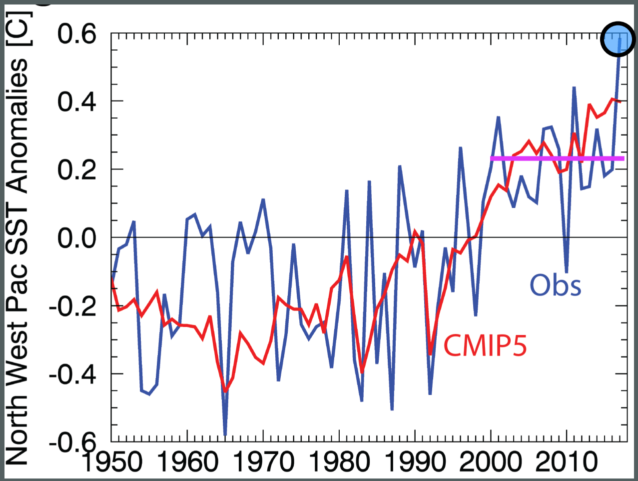
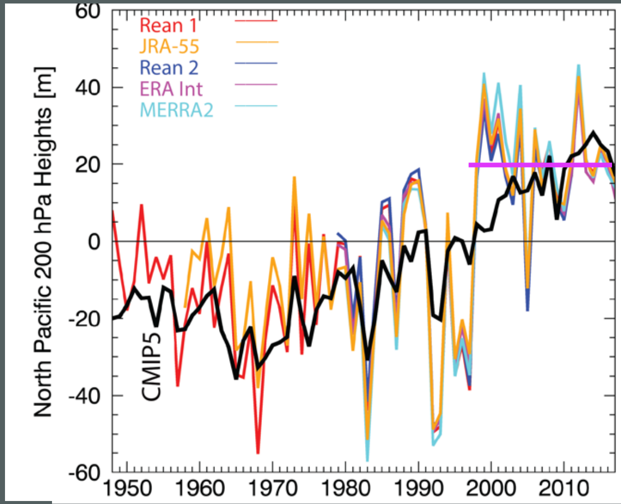
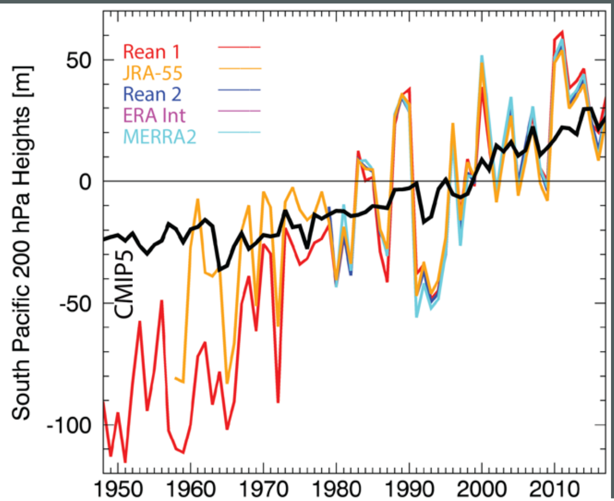
MAMJ Time series associated with Walker Circulation Intensification





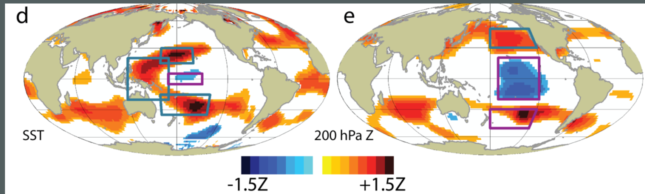
WNP SSTs combine trend and La Nina influences



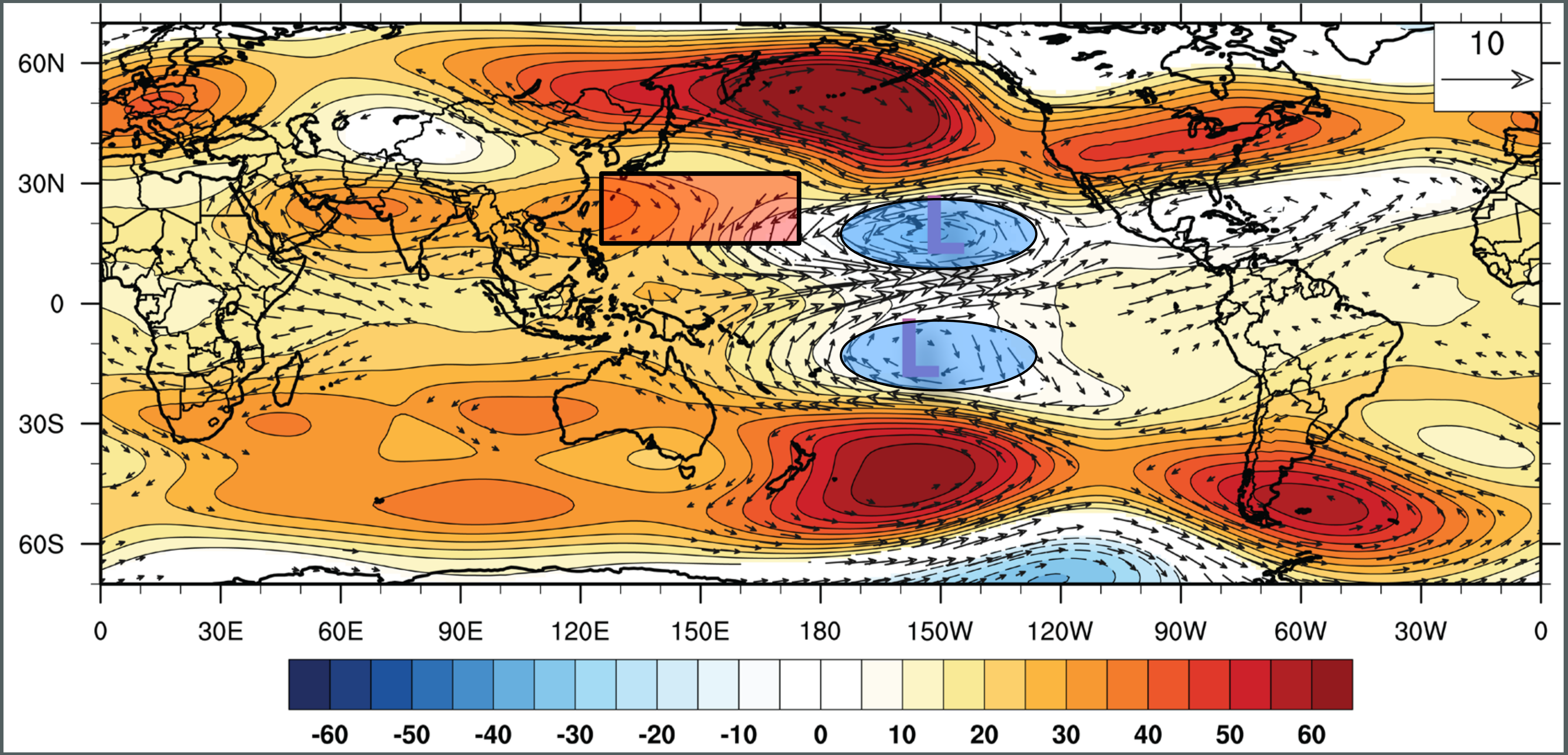


Reanalysis heights increasing, stronger meridional gradient during La Nina-like climate conditions

Funk et al. BAMS EEE 2018



Composites of MAM 200 hPa heights when western North Pacific is exceptionally warm



Funk et al. BAMS EEE 2018, QJRMS 2018

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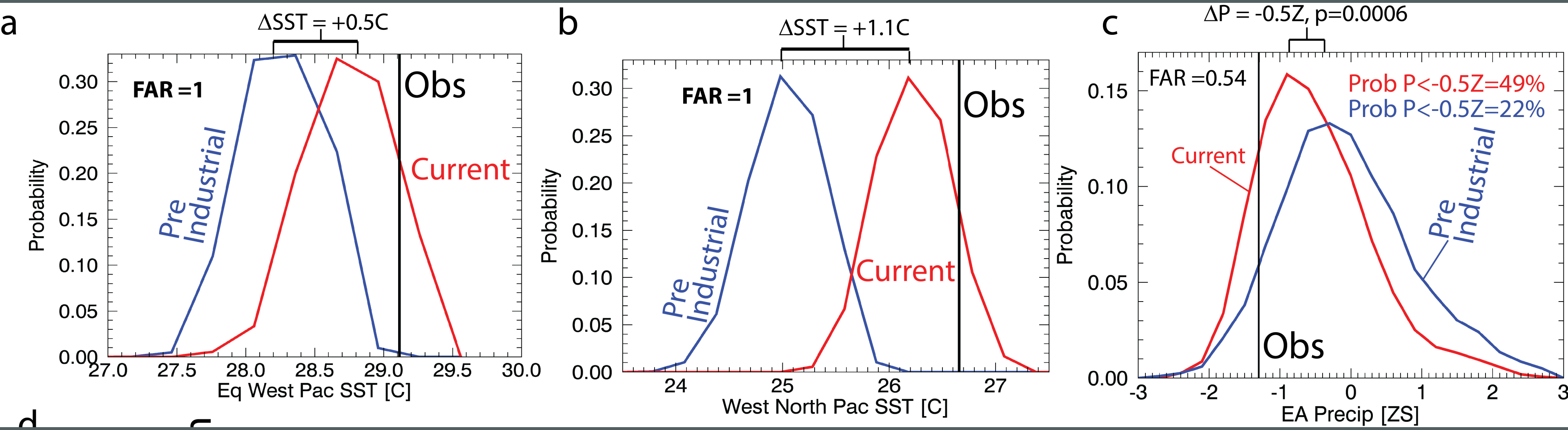
Formal Attribution Analyses (CESM1)



Attribution analyses for SST and East Africa precipitation. Precipitation PDFS contrast ENSO-neutral PI simulations with historical CESM1 simulations with ENSO neutral + warm 'Western V' SSTs

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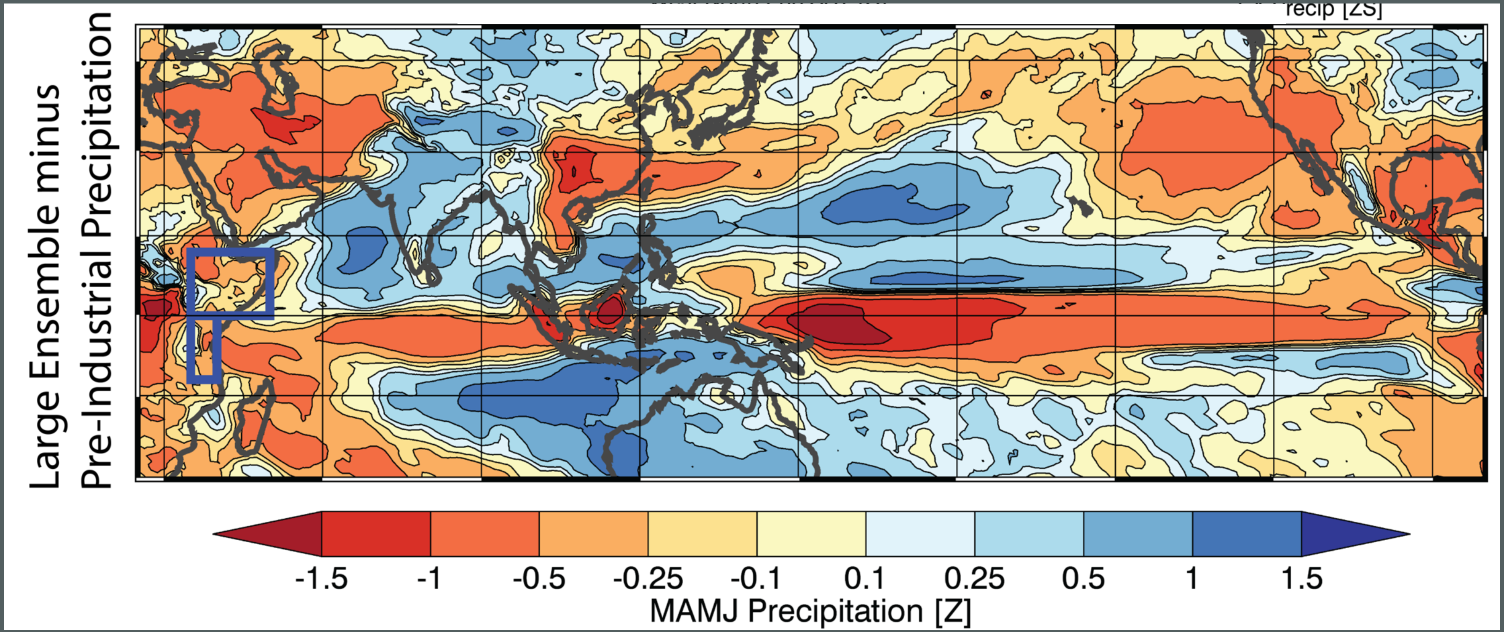
Funk et al. BAMS EEE 2018

MAMJ CESM1 Large Ensemble Attribution Analysis



A map of the difference in precipitation for the 43 LE analog seasons (Western V Gradient >1Z and NINO4 values between 0 and 1Z) and 674 Pre-Industrial analogs (NINO4 values between 0 and 1Z). When strong WVG conditions occur along with neutral-warm NINO4 SST, we find a La Niña-like response associated with dry EA conditions.

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BAMS EEE 2018

Conceptual Frameworks for ENSO-related climate change

CC = Trend + Natural Variability

How to separate Trend and Natural Var?

Very hard to know what the trend in the Walker Circulation will be.

$WC = A \pm U_A - B \pm U_B$

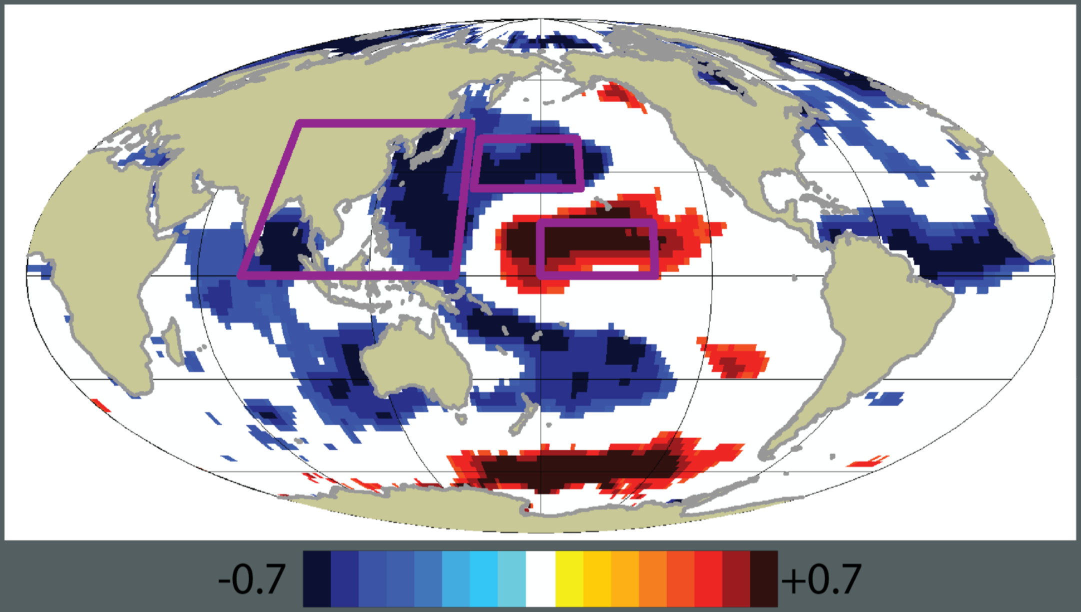
$(U_A - U_B) >?\ A-B$

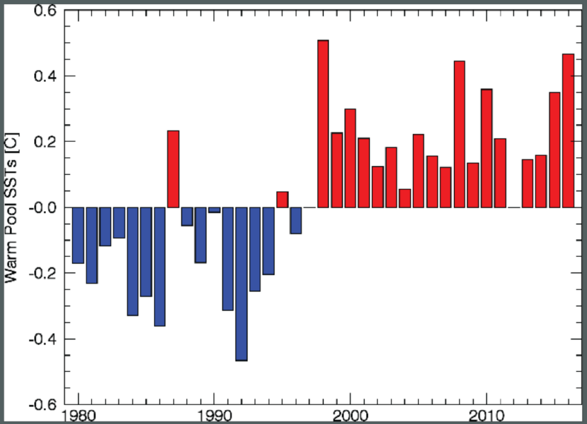
CC = Spatially varying pockets of extreme SSTs

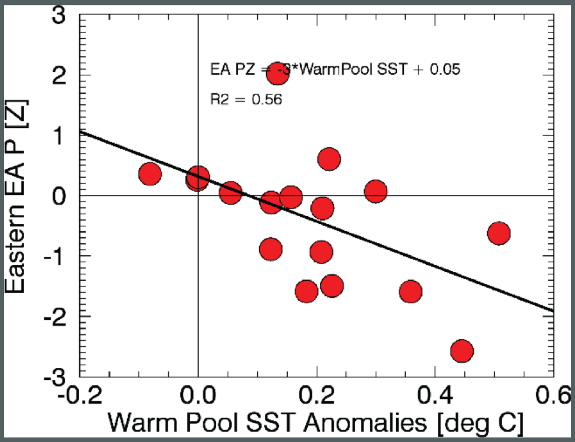
Opportunities for prediction

Stronger ENSO extremes

1981-2016 Correlation between October-November SSTs and March-June EA rainfall during Neutral and La Nina seasons

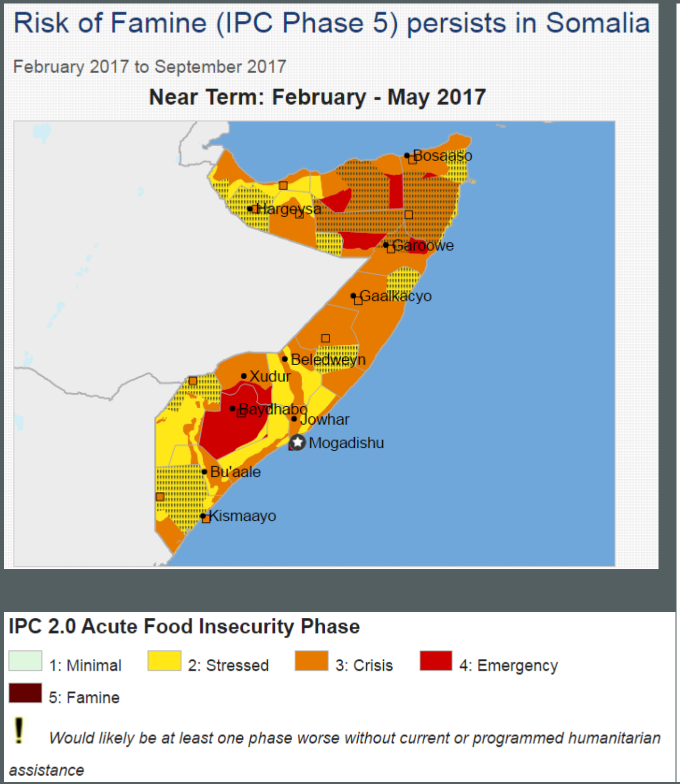


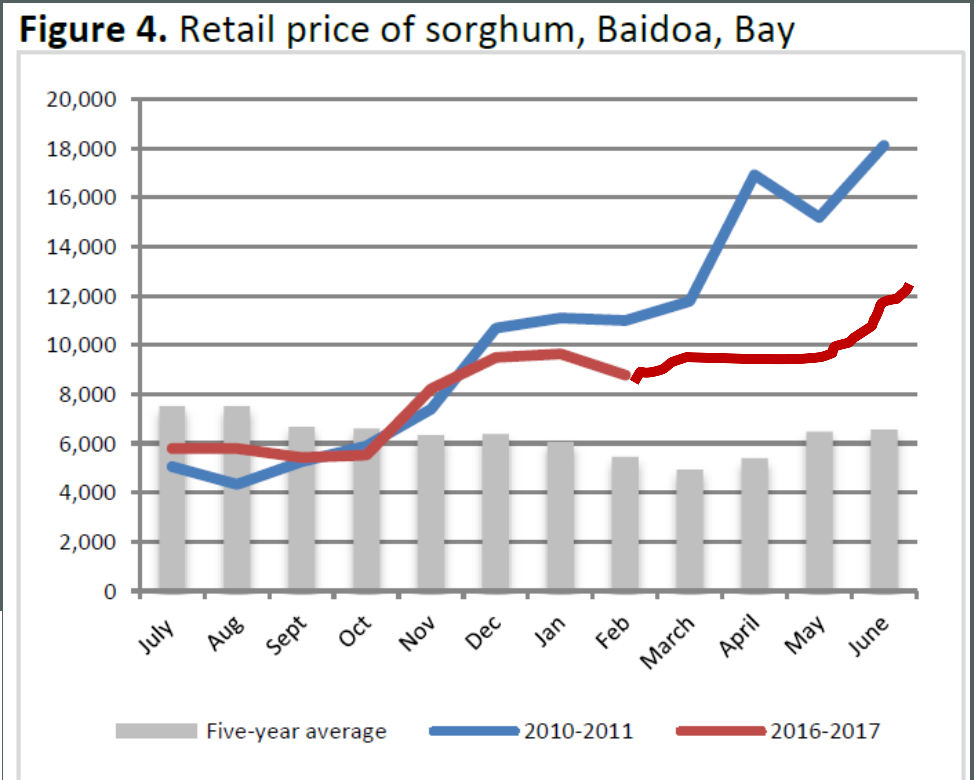




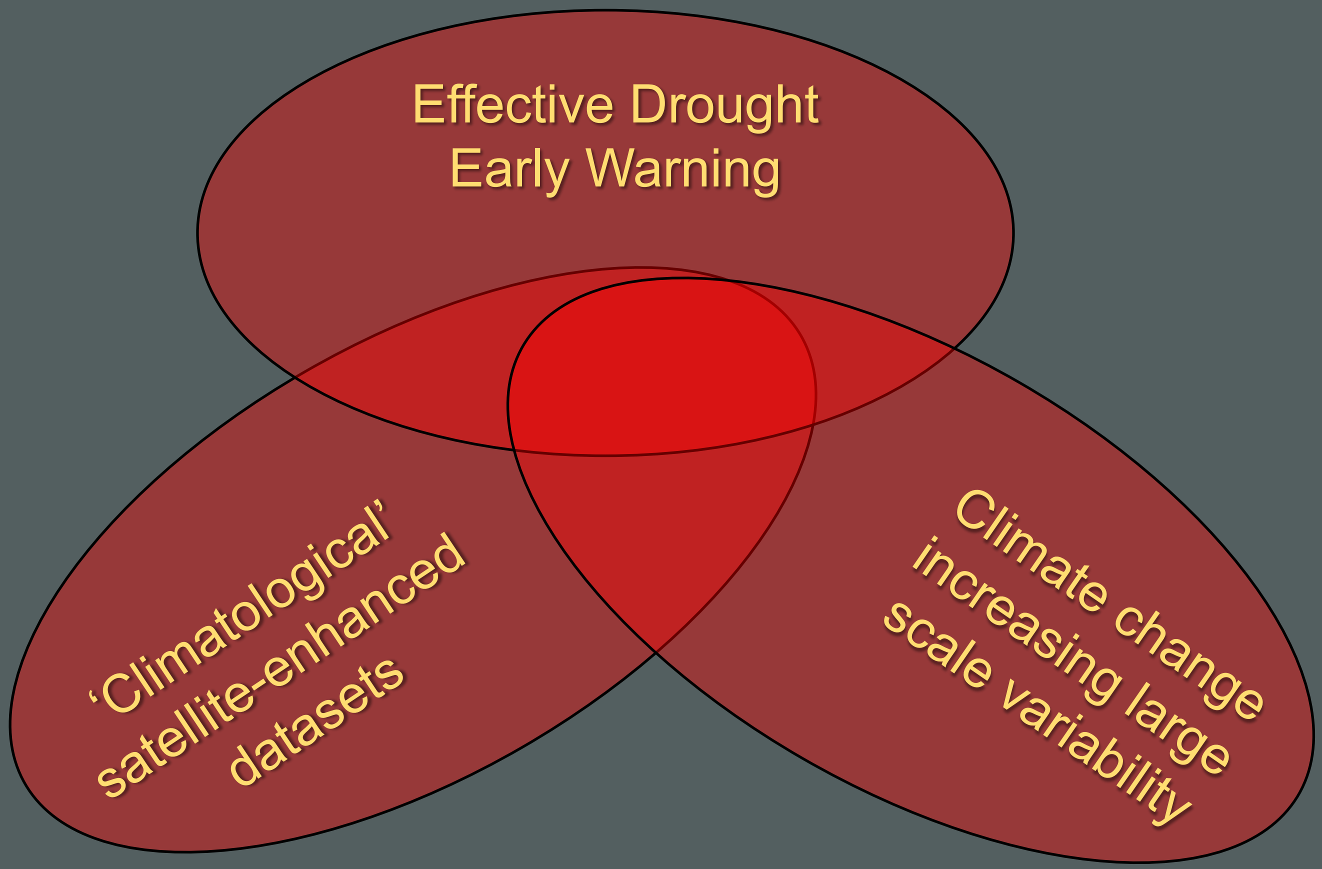
Since 2011: Hoell ~4 papers, Liebmann ~2 papers, Lyon/Yang/Vigaud ~5 papers, Shukla 2 papers, Funk ~2 papers…. Networking with WFP, FAO, EU, ICPAC, ….

Somalia Example:
Conclusion: Early Warning Helps





Thanks



Effective Drought Early Warning
'Climatological' satellite-enhanced datasets
Climate change increasing large scale variability