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# Subseasonal to Seasonal (S2S) Overview

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NOAA/NWS



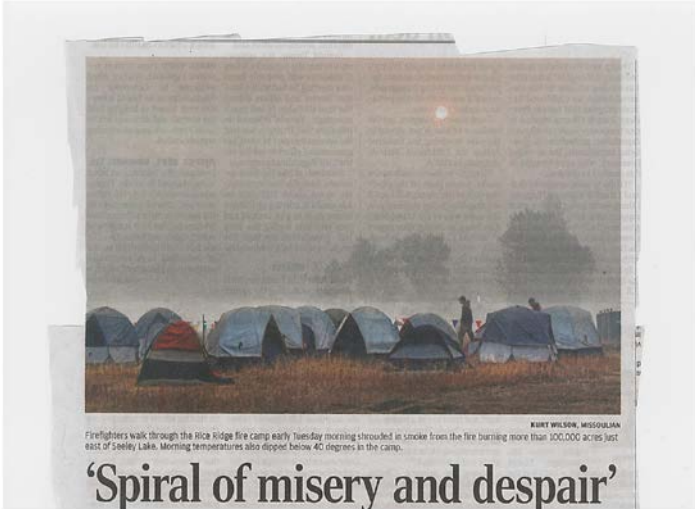
# Outline



- 
- Motivation/need for improved S2S model forecasts, especially for precipitation.
  - Drivers:
    - **CPC S2S prediction products that use ensembles with focus on first month.**
    - **CPC technical requirements for ensemble forecast systems.**
  - Success stories for S2S model predictions:
    - **EMC improved MJO forecast skill**
  - Science challenges limiting S2S forecast skill
  - Conclusions/Thoughts



# Why we need to keep pushing the skill envelope for improved S2S (precipitation) forecast skill

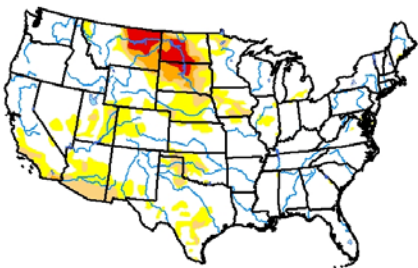


S2S predictions are characterized by a small signal and large noise.

Hence they are inherently probabilistic.

The key tool for informing forecasts are ensembles of dynamical models.

## U.S. Drought Monitor Continental U.S. (CONUS)



**July 11, 2017**  
(Released Thursday, Jul. 13, 2017)  
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	76.90	23.10	9.90	4.31	2.19	0.00
Last Week 07-04-2017	77.65	22.35	8.45	3.83	1.43	0.00
3 Months Ago 04-11-2017	73.01	26.99	8.17	1.44	0.09	0.00
Start of Calendar Year 01-01-2017	53.89	46.11	22.53	8.63	3.15	0.96
Start of Water Year 09-27-2016	53.60	46.40	18.96	8.10	3.20	1.16
One Year Ago 07-12-2016	55.60	44.40	17.68	8.19	2.57	1.11

**Intensity:**

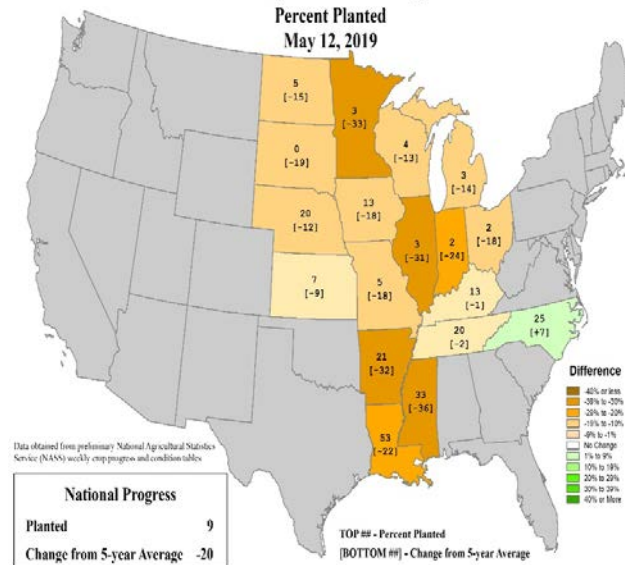
- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

**Author:**  
David Simeral  
Western Regional Climate Center

<http://droughtmonitor.unl.edu/>

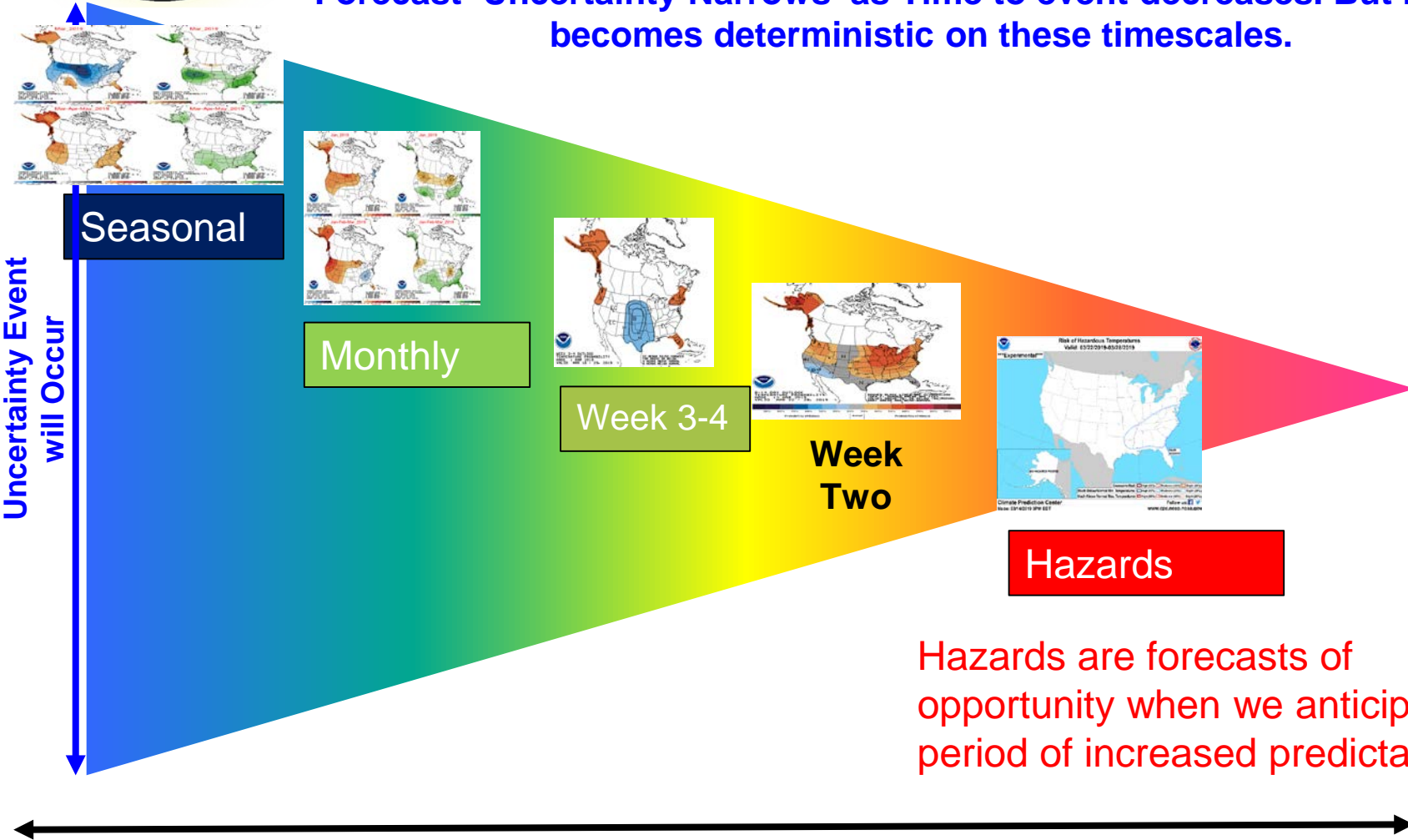
## U.S. Soybeans Progress





# The S2S Threat Vector

Forecast Uncertainty Narrows as Time to event decreases. But it never becomes deterministic on these timescales.



Hazards are forecasts of opportunity when we anticipate a period of increased predictability.



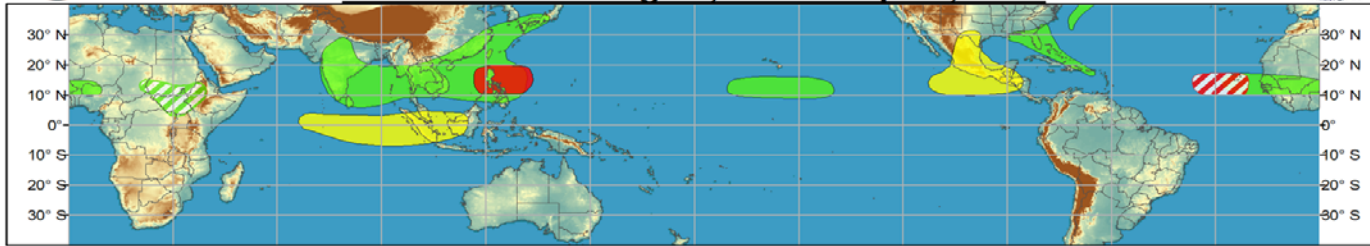
# Global Tropics Hazards and Benefits Outlook



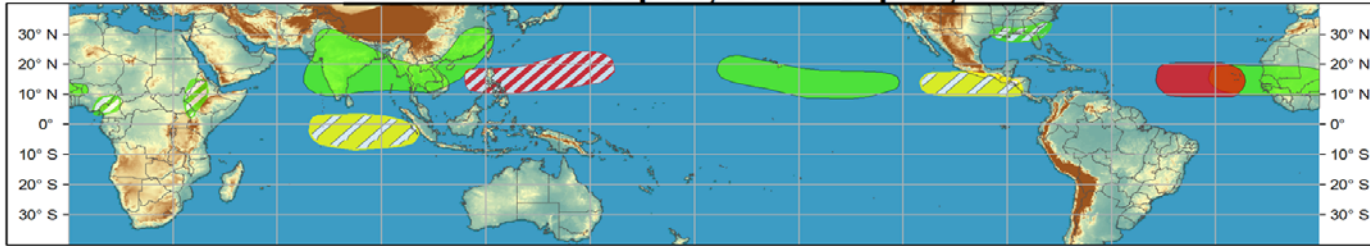
Global Tropics Hazards and Benefits Outlook - Climate Prediction Center



Week 1 - Valid: Aug 28, 2019 - Sep 03, 2019



Week 2 - Valid: Sep 04, 2019 - Sep 10, 2019



Confidence  
High Moderate

- Tropical Cyclone Formation** (High confidence: red, Moderate: red/white stripes) Development of a tropical cyclone (tropical depression - TD, or greater strength).
- Above-average rainfall** (High confidence: green, Moderate: green/white stripes) Weekly total rainfall in the upper third of the historical range.
- Below-average rainfall** (High confidence: yellow, Moderate: yellow/white stripes) Weekly total rainfall in the lower third of the historical range.
- Above-normal temperatures** (High confidence: orange, Moderate: orange/white stripes) 7-day mean temperatures in the upper third of the historical range.
- Below-normal temperatures** (High confidence: blue, Moderate: blue/white stripes) 7-day mean temperatures in the lower third of the historical range.

Produced: 08/27/2019

Forecaster: Pugh

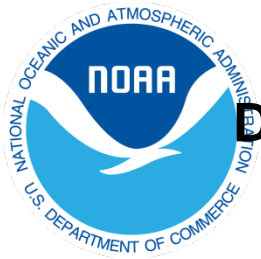
Forecasts of likelihood of:

Above or below average rainfall

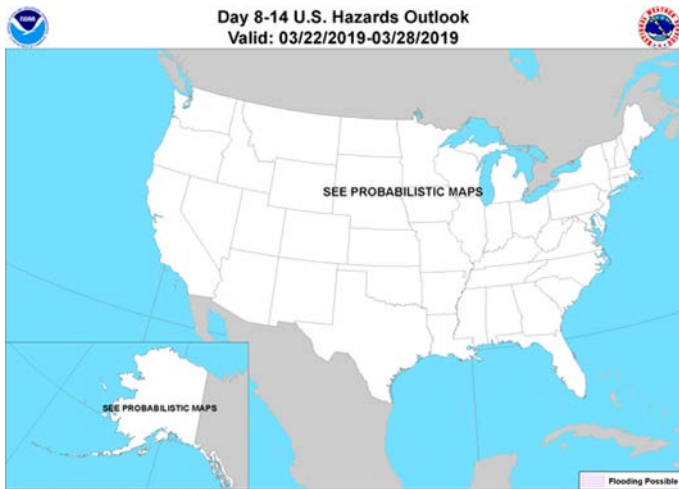
Above or below average temperature

Tropical cyclone development

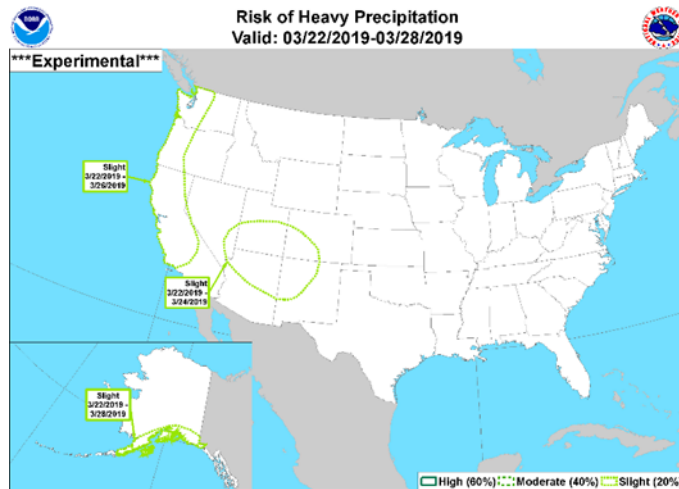




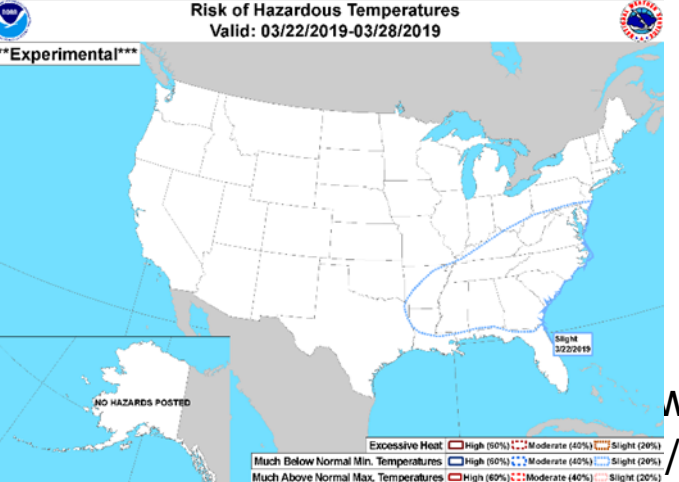
# Week Two Probabilistic Hazards Outlook Designed to Forecast Probability of Extreme Events



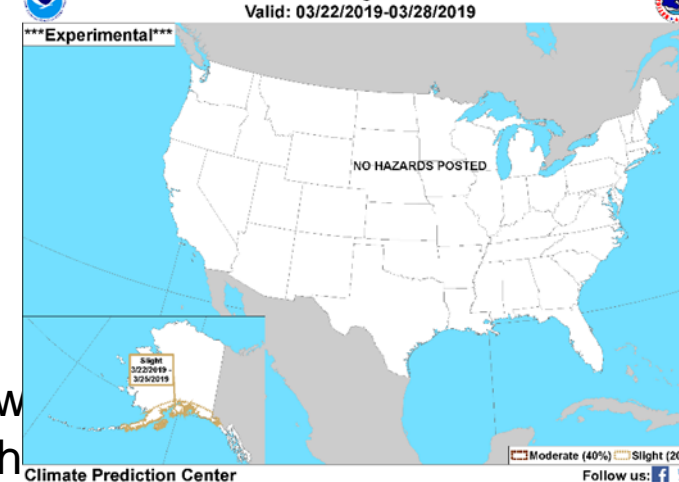
Climate Prediction Center  
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Slight (20-40%),  
Moderate (40-60%),  
Or High (GT 60%)  
Probability of:

Much below  
minimum or much  
above maximum  
temperature

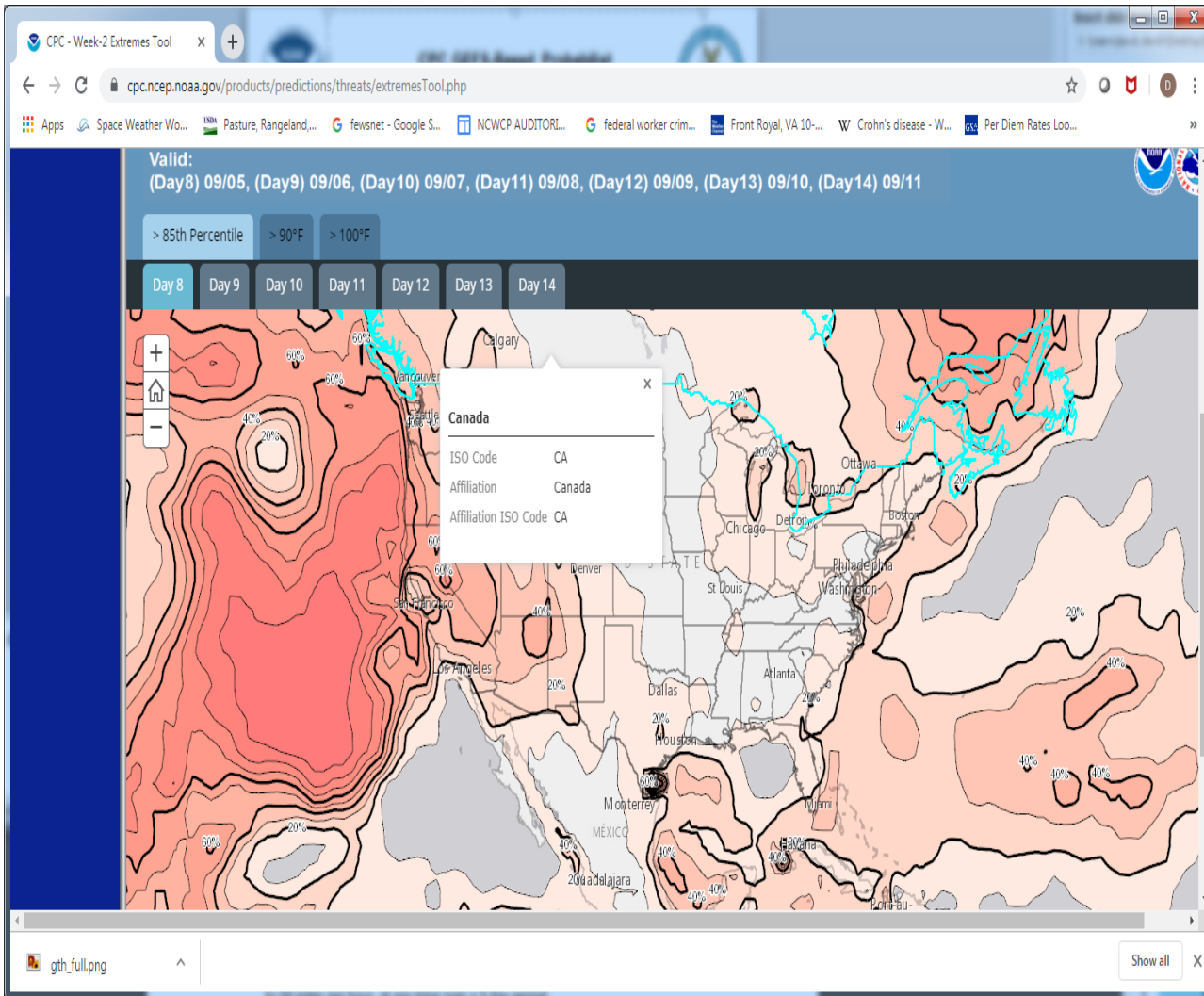
Heavy  
Precipitation

High Winds

ww  
/th



# CPC GEFS-Based Probabilities of Extremes Tool



GEFS-based daily day 8 to 14 global probabilities of:

Temperature:

- Upper or lower 15%
- Over 90 or 100F
- Less than 28, 32, or 40 F

Precipitation:

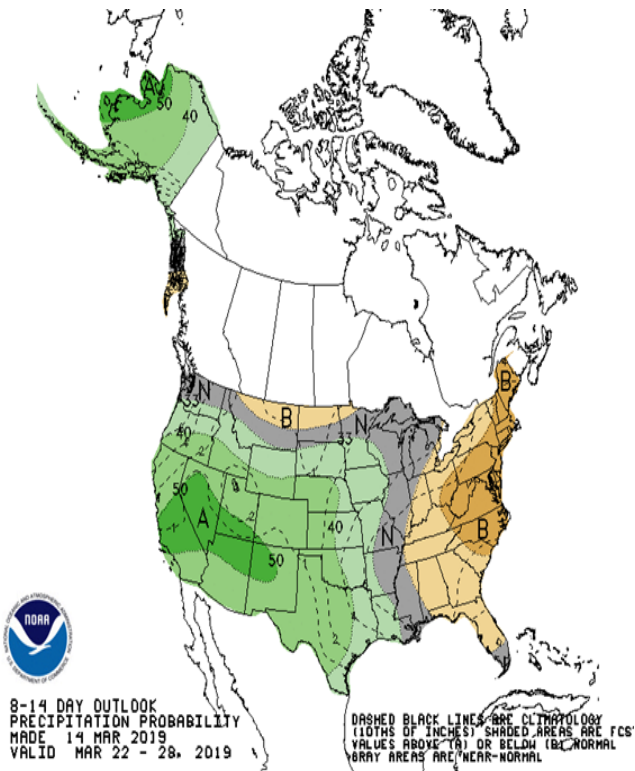
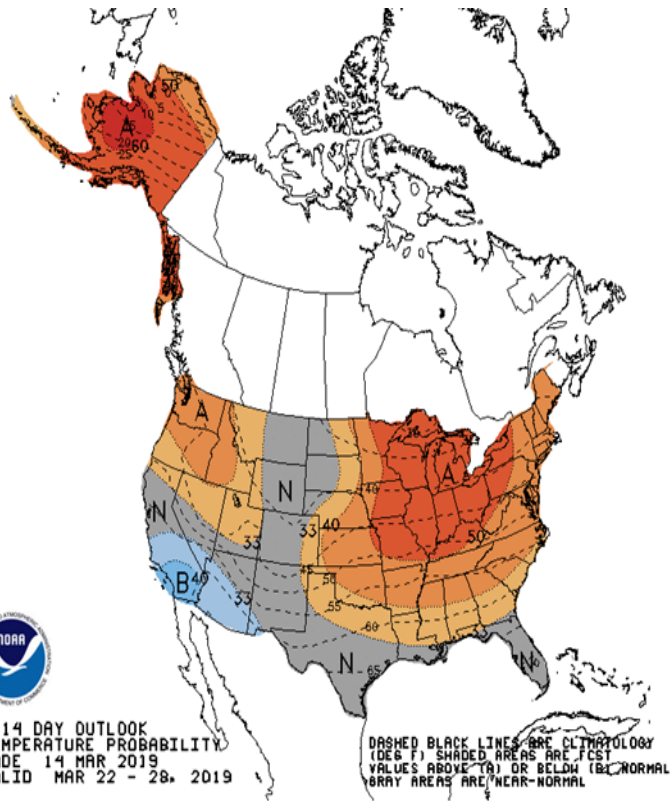
- Upper 15%
- Over 1, 2, or 4 inches

Winds:

- Upper 15%
- Over 25, 40, 50 MPH



# CPC Week Two Temperature and Precipitation Outlooks



Tercile Class Probabilities of Above, Near, or Below Normal

For temperature and precipitation

Issued daily.



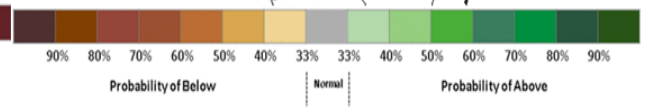
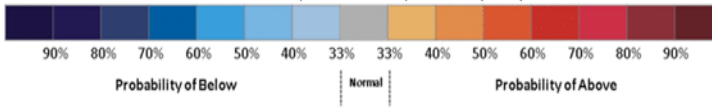
8-14 DAY OUTLOOK  
TEMPERATURE PROBABILITY  
MADE 14 MAR 2019  
VALID MAR 22 - 28, 2019

DASHED BLACK LINES ARE CLIMATOLOGY (DEG F) SHADED AREAS ARE FCST VALUES ABOVE (A) OR BELOW (B) NORMAL GRAY AREAS ARE NEAR-NORMAL



8-14 DAY OUTLOOK  
PRECIPITATION PROBABILITY  
MADE 14 MAR 2019  
VALID MAR 22 - 28, 2019

DASHED BLACK LINES ARE CLIMATOLOGY (TENTHS OF INCHES) SHADED AREAS ARE FCST VALUES ABOVE (A) OR BELOW (B) NORMAL GRAY AREAS ARE NEAR-NORMAL







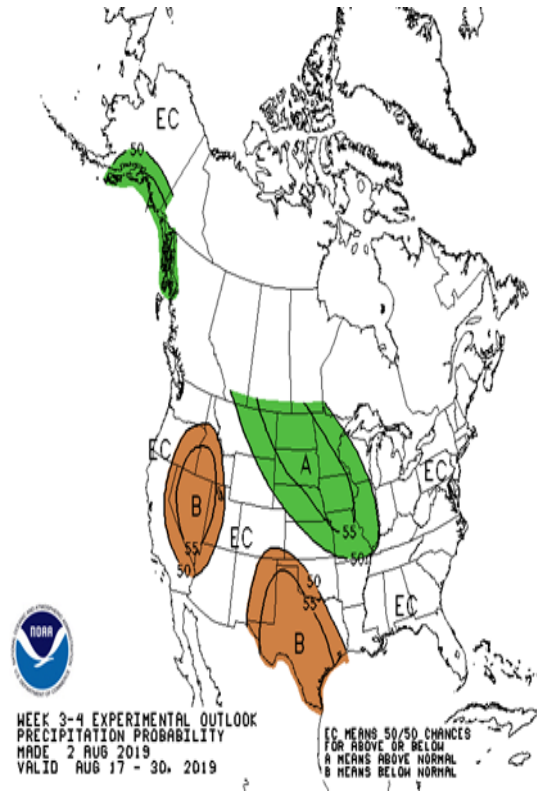
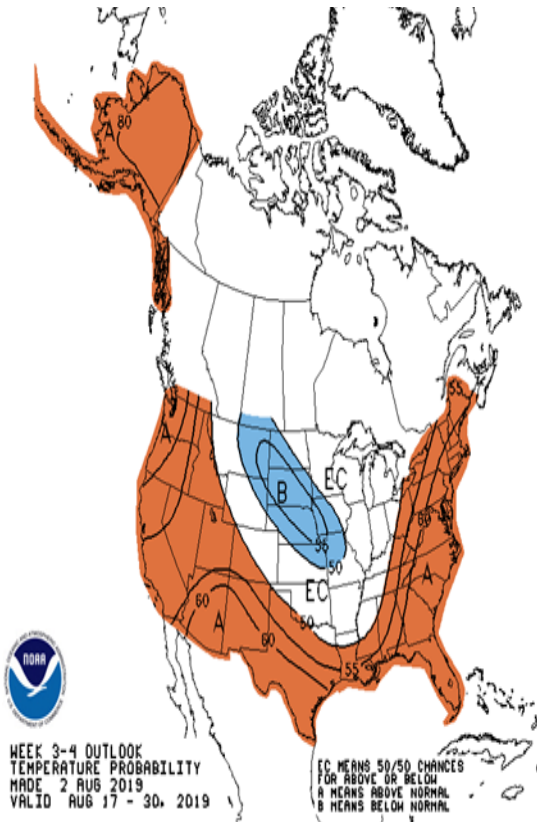
# CPC Week Three-Four Temperature and Precipitation Outlooks



Two Class Probabilities of  
Above or Below Normal

For temperature and  
precipitation

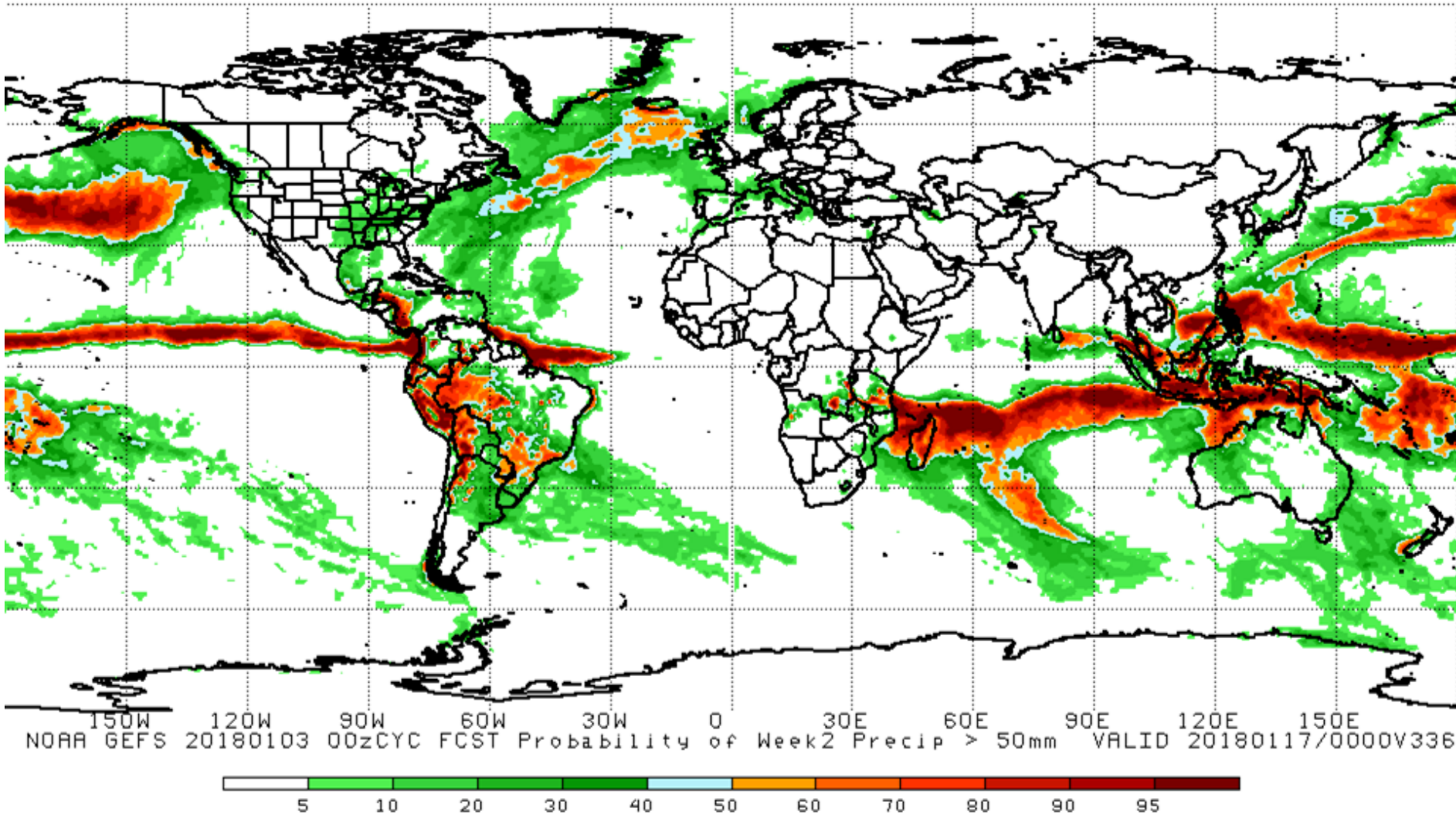
Issued Once per Week on  
Fridays

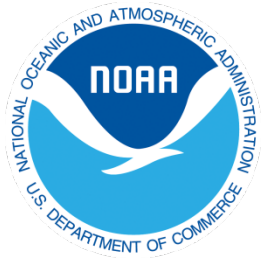




# CPC GEFS-Based Week-2 Precipitation Forecasts

## Probability of Exceedance of 50 mm Rainfall





# CPC Requirements for Day 6 to ~ Day 35 Ensemble Forecast System



- 
- Consistent reforecasts with each real-time upgrade:  
Length: At least 20 years, and 5 members.
  - Equilibrated boundary conditions in reforecasts and real-time, i.e. no discontinuities or non-physical trends (soil moisture, upper ocean temperature, and sea ice).
  - Metrics for evaluation of upgrades (including but not necessarily limited to):
    - Temperature and precipitation skill over same domain as CPC Outlooks.
    - Global skill for relevant fields for Global Tropics Hazards Outlook and International Desk products.
    - Fidelity of simulation of major modes of S2S variability and associated teleconnections: ENSO, MJO, AO, NAO, PNA, and SSW.



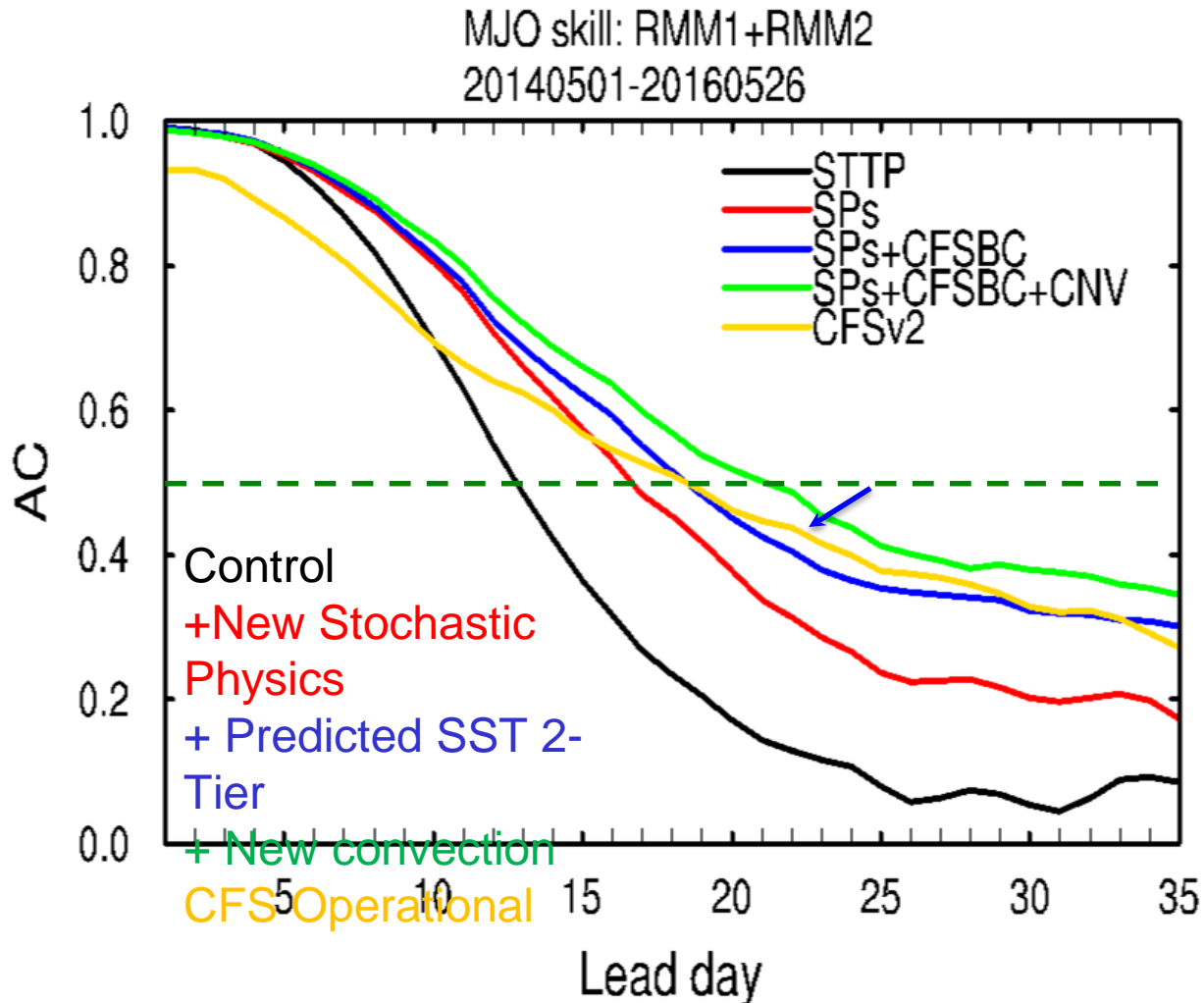
## CPC Wish List for Day 6 to ~ Day 35 Ensemble Forecast System



- 
- Reliable predictions of periods of enhanced versus suppressed predictability.
  - Improved precipitation forecasts on all timescales.
  - Reduction of persistent systematic errors in CGCMs.



# GEFS week 3&4 forecasts (May 2014-May 2016) (Zhu et al.)



Dramatically increased skill of MJO from improved physics! Need to continue to improve teleconnections from MJO, i.e. precipitation forecast skill over western US.

# Major Systematic Errors Limiting S2S Forecast Skill: El Nino False Alarms

## El Nino False alarms in CFSv2 (Wang)

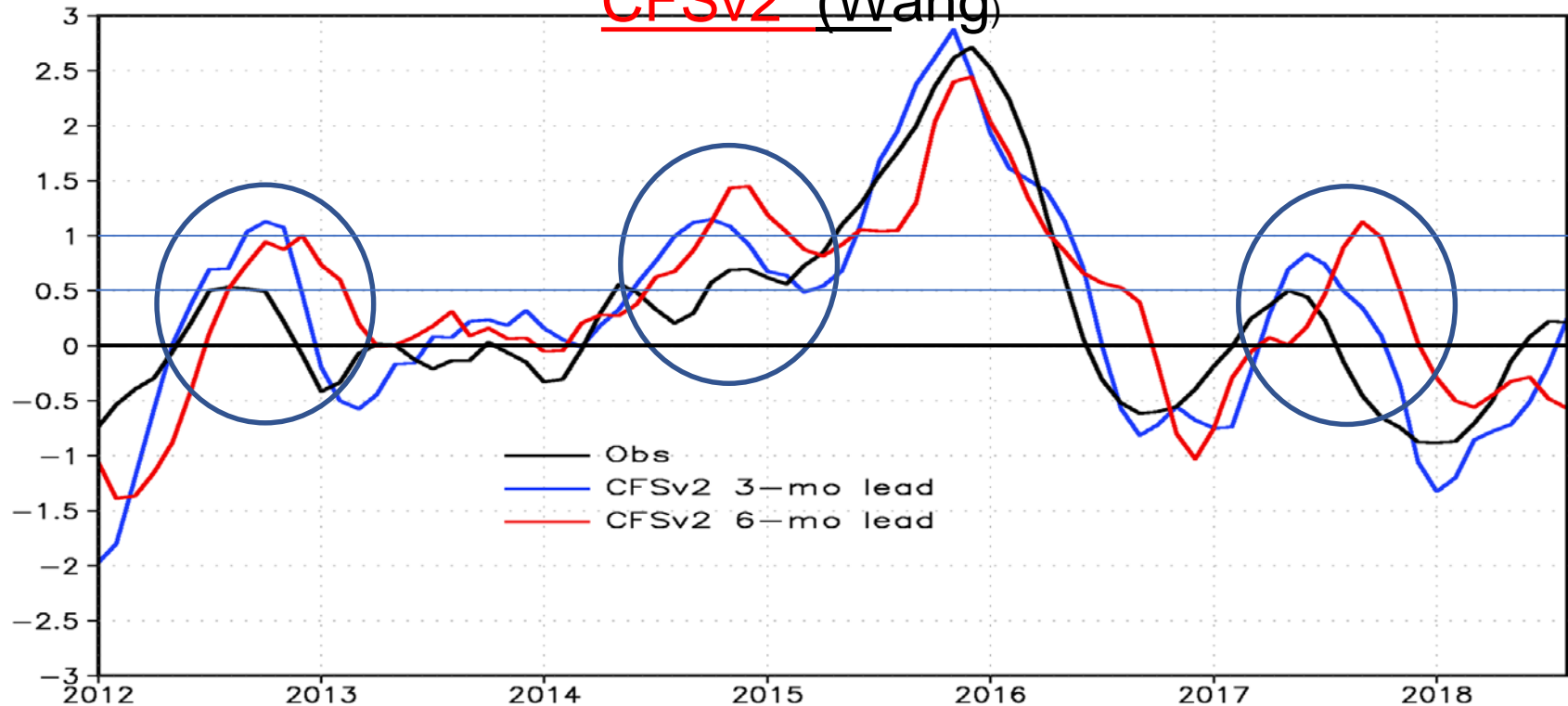


Figure shows forecasts for Nino3.4 SST at 3 month and 6 month lead from CFSV2. **This demonstrates that current generation coupled models have large errors in timing and amplitude of S2S equatorial Pacific SST anomalies.**

# State of the Art S2S Coupled Models Have Major Systematic Errors Forecasting Magnitude and Distribution of Average Precipitation in the Tropics (Even at First Month Lead)

Prec (mm/day) Monthly Forecast Anomaly Stdv (IC=Dec)

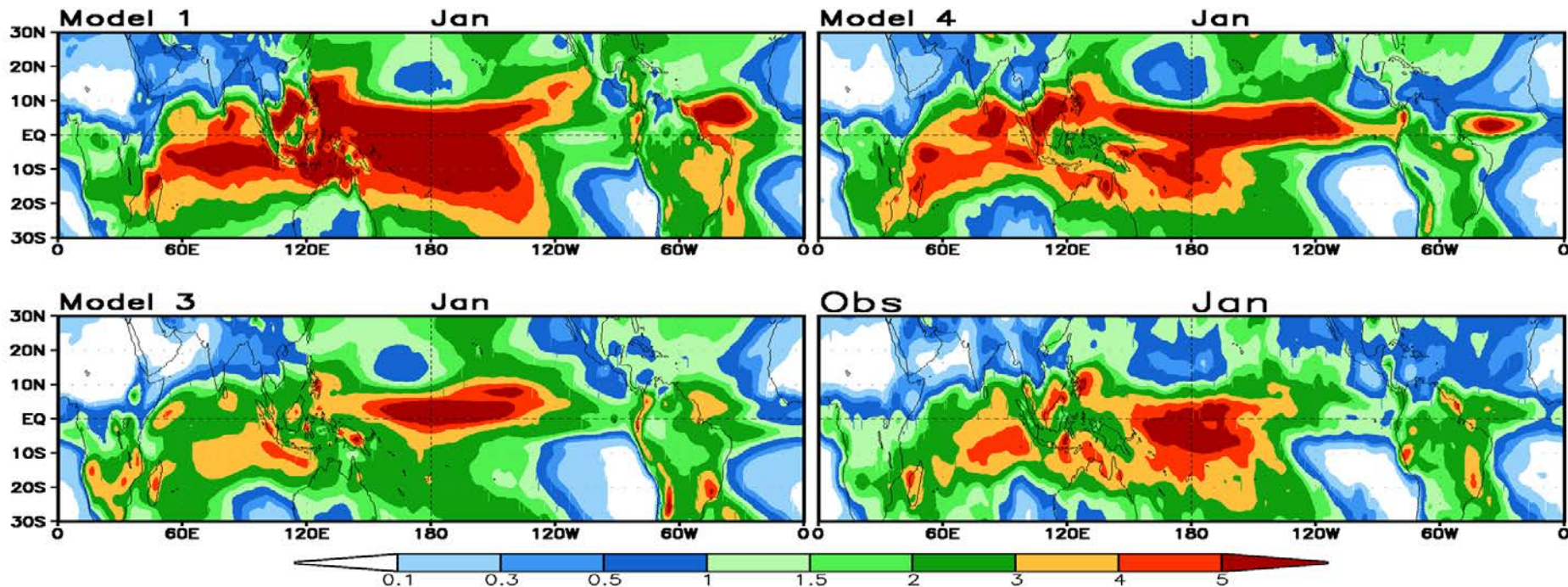
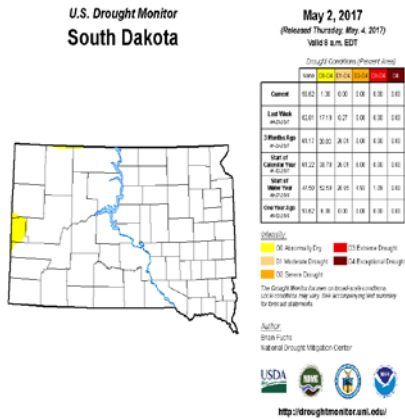
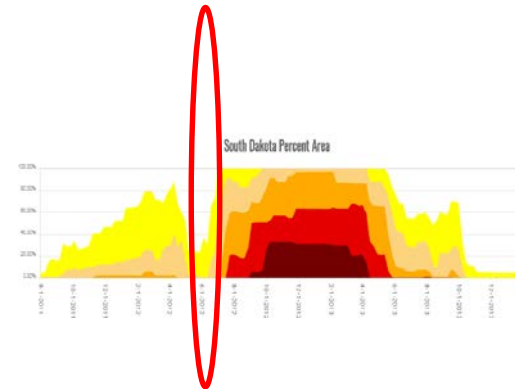
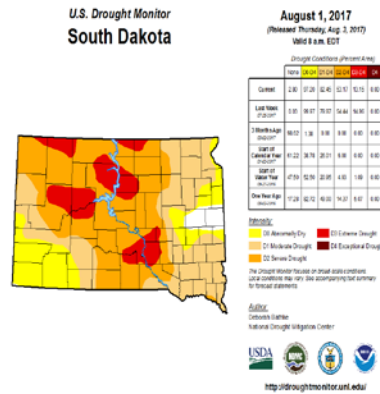


Figure compares standard deviation of precipitation from one month lead precipitation forecasts from 3 state of the art S2S models and observations. It demonstrates that models have errors of 100% or more in predicting mean statistics of tropical precipitation. Result is even worse if

# Science Challenge: Predicting Onset of the 2017 Northern Plains Flash Drought



Drought onset from May, 2017 to August, 2017



Drought onset occurred over about 60 day period.

Rapid onset of the 2017 Northern Plains occurred over a 2 to 3 month period. **All models failed to predict the onset of this drought beyond about two weeks lead.** The inability to predict the onset of this drought highlights several science challenges for improving spring and summer drought prediction skill:

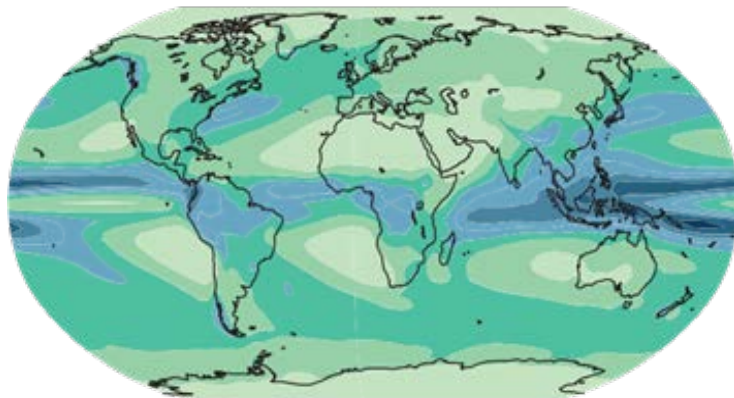
- Is there predictability for precipitation beyond week two for the Spring and Summer seasons when variability is controlled by convective as opposed to advective processes?
- Can land surface models accurately simulate the onset of flash drought conditions, which are at least partly due to enhanced evaporation?



# Systematic Precipitation Errors in CMIP5 Models (Figure 9.4 from Flato et al., 2013)

## Annual Mean Precipitation Rate (mm/day) for 1980 to 2005

(a) Multi Model Mean Precipitation

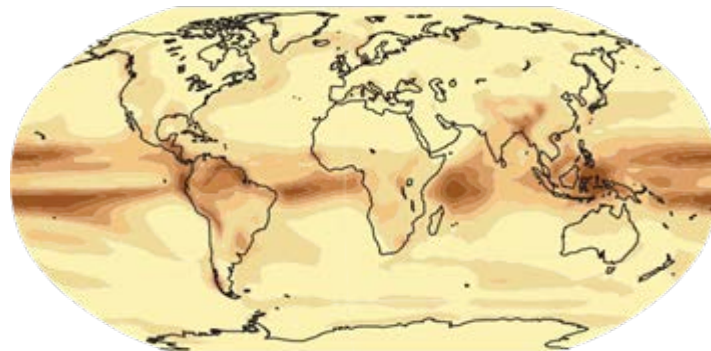


(mm day<sup>-1</sup>)



1 2.5 4 5.5 7 8.5 10

(c) Multi Model Mean of Absolute Error

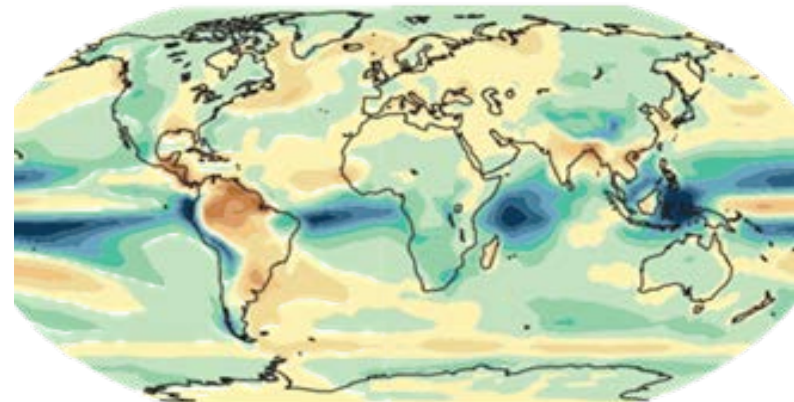


(mm day<sup>-1</sup>)



0.5 1 1.5 2 2.5 3

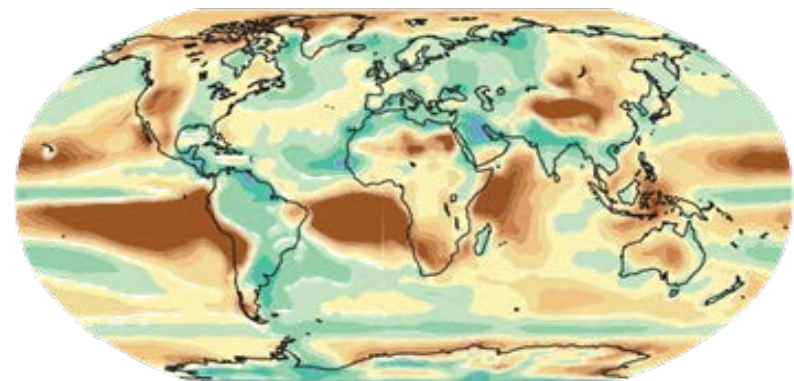
(b) Multi Model Mean Bias



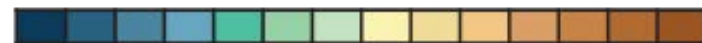
(mm day<sup>-1</sup>)



(d) Multi Model Mean of Relative Error



(%)



-90 -75 -60 -45 -30 -15 0 15 30 45 60 75 90

Figure shows that CMIP5 models have major errors in distribution of mean precipitation including the development of erroneous double ITCZ, that is not found in nature. Coupled models used for S2S



## Conclusions/Thoughts



- 
- Societal demand for S2S forecasts continues to grow.
  - S2S models are just starting to be run at resolutions where transient eddies are resolved. Hopefully, this leads to improvements in representation of their statistics from a forecasting perspective.
  - Persistent systematic errors in S2S (and climate change) models likely limit forecast skill. Reducing these errors should be a priority for the global S2S enterprise in order to meet societal demand for improved S2S forecast skill.

# Ability to Accurately Model Storms (and Hence Their Mean Statistics) is a Function of Resolution. Seasonal Forecast Models Currently use Resolution of 50 to 100 KM. Can We Expect Improved Forecast Skill As Seasonal Forecast Model Resolution Increases?

GFS Skill Improvement in 5-Day ACC Greater Than 0.9 Due to **Increased Resolution, Data Assimilation and Physics Upgrades**

