ENSO Impact on Extreme Heavy Rainfall in the U.S.

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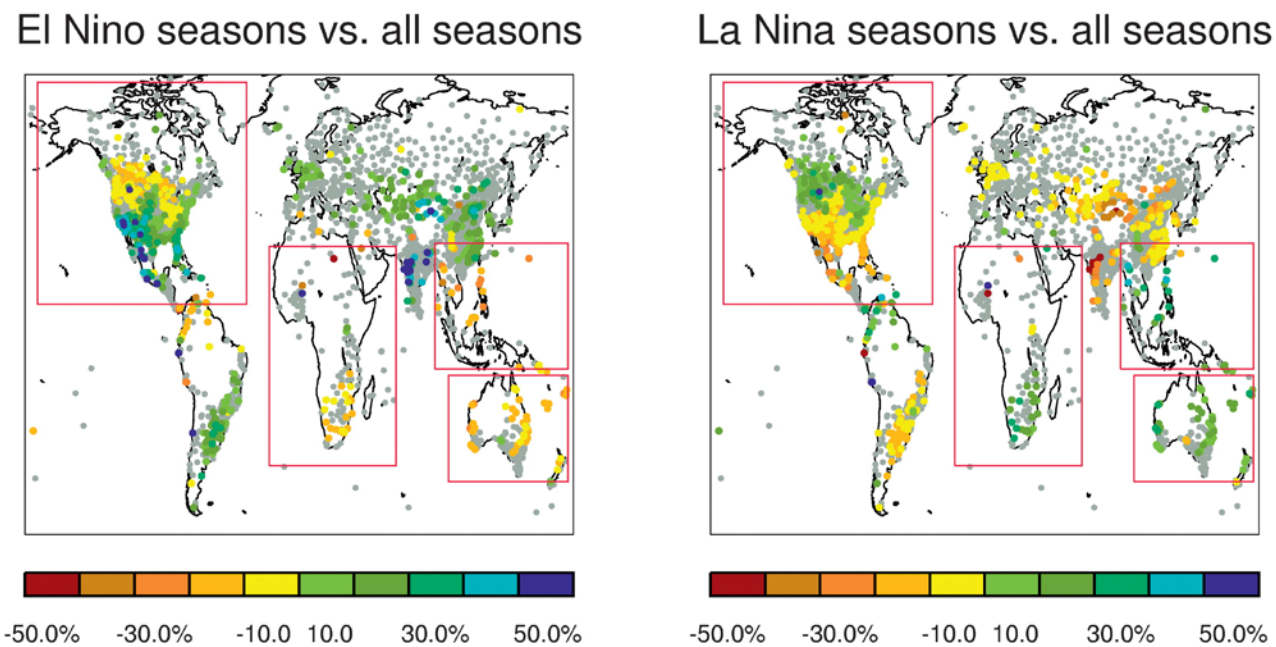
Introduction

- Significant ENSO influence was found on the frequency of extreme precipitation in North America (Cayan et al., 1999, Gershunov and Barnett, 1998, Higgins et al., 2011, Jones and Carvalho, 2012 and Schubert et al., 2008).

Difference (%) of intense precipitation
(5-day max precip, November to April months)



Kenyon and Hegerl, 2010

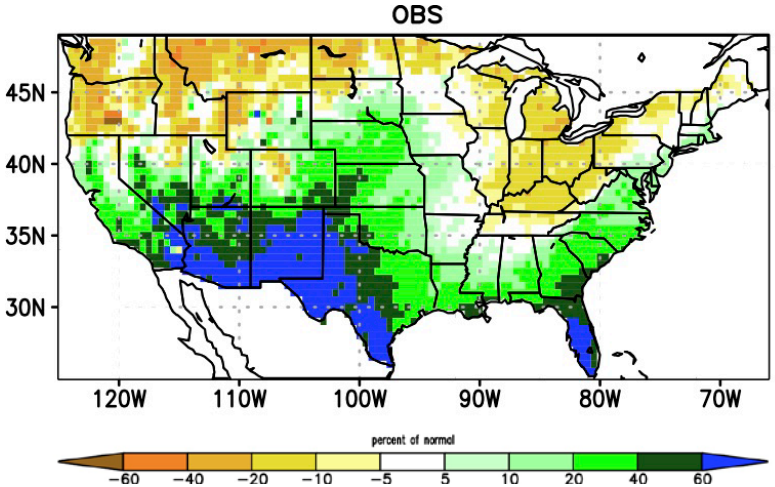
Introduction

- Estimating ENSO related “rarer” extreme precipitation events like a 1 in 10 year event or 1 in 100 year event that are relevant for flood-risk management is a challenge (e.g. Sun et al. 2015)
  - Influence difficult to detect
  - Small spatial scale events
  - Requires use of appropriate probabilistic models (e.g. extreme value distributions)
- Asymmetry in ENSO effect on regional rainfall extremes (Sun et al. 2015)

Questions

- How are the odds of extreme heavy daily precipitation conditioned by ENSO?
- How are changes in the odds of heavy daily precipitation related to the seasonal mean ENSO precipitation signal?

Cold Season (Nov-Apr) ENSO Signal
El Nino –La Nina
Relative to Normal Years (%)



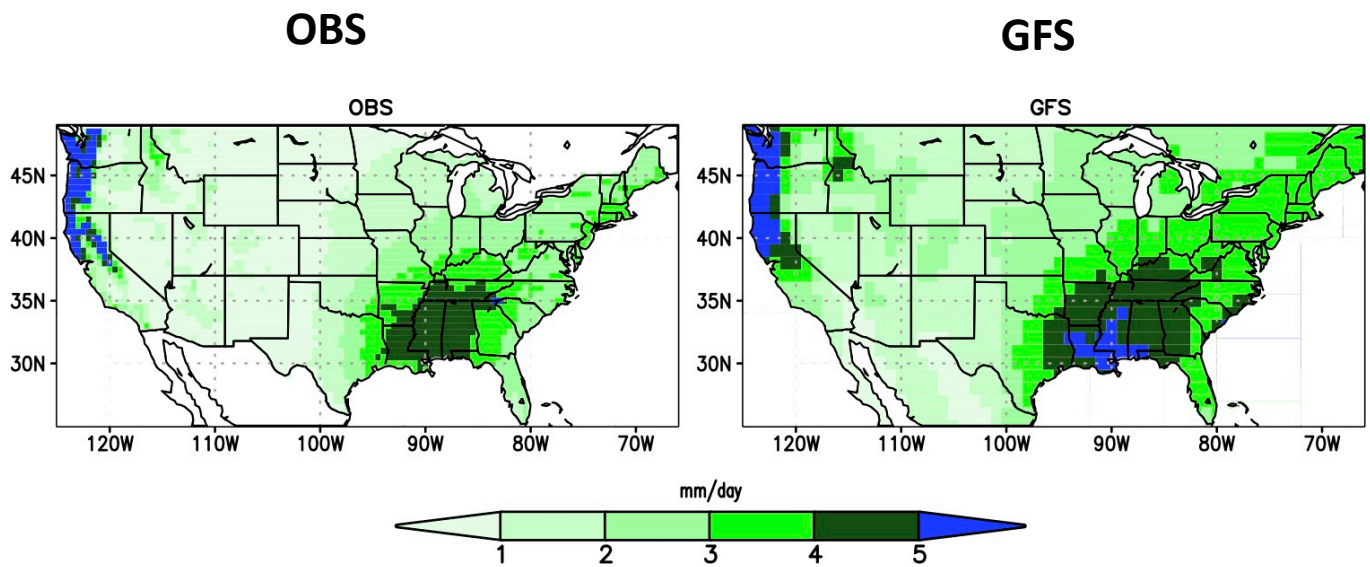
Based on Global Historical Climatology Network-Daily database (GHCN-D, Menne, et al. 2012) on a 0.5grid

Data and Analysis Approach

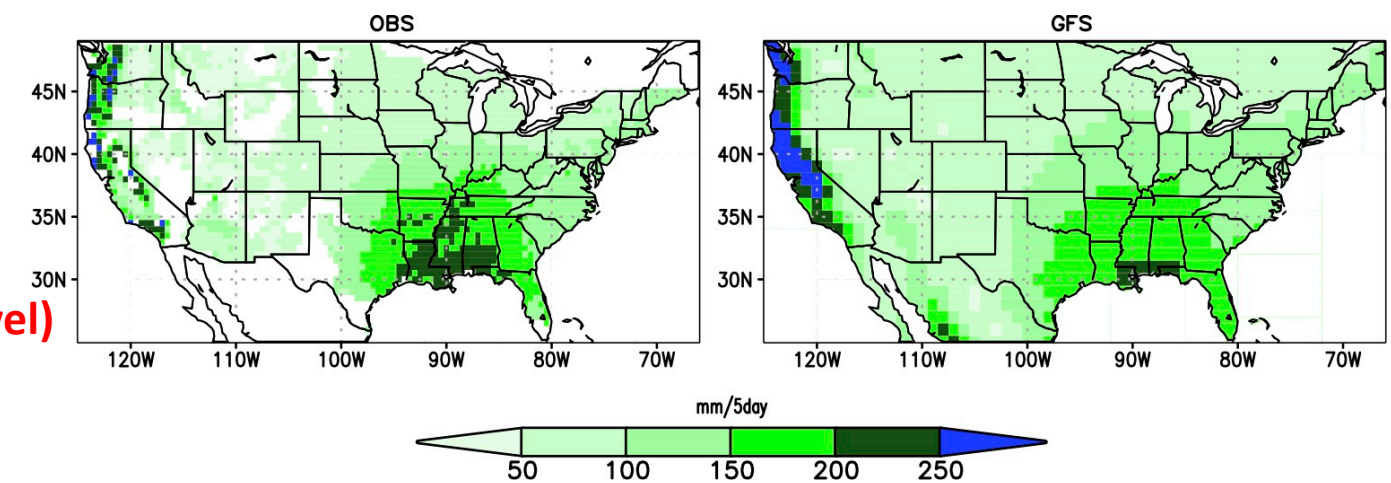
- Utilize (individual station observations Global Historical Climatology Network-Daily database (GHCN-D, Menne, et al. 2012) on a 0.5grid from 1900-2013.
- Diagnose 3 large-ensemble AMIP simulations for the period 1979-2014 (**GFS (50 runs)**, ECHAM5(30 runs), CAM5(50 runs))
- Study
  - November-April cold season mean (NDFJMA) and two-month means (ND,JF, MA)
  - Rainfall values of 1 in 20 year 5-day heavy precipitation events (20-year return level) for cold season and two-month seasons
  - Study changes relative toENSO neutral years
    - Seven El Nino years (DJF-Nino3.4 index >1.0^{o}C)
    - Seven La Nina (DJF-Nino3.4 index <-1.0^{o}C)
    - 21 ENSO neutral years

OBS-Model comparison for Nov-April season

Seasonal Mean Precipitation Climatology 1979-2013) [mm/day]



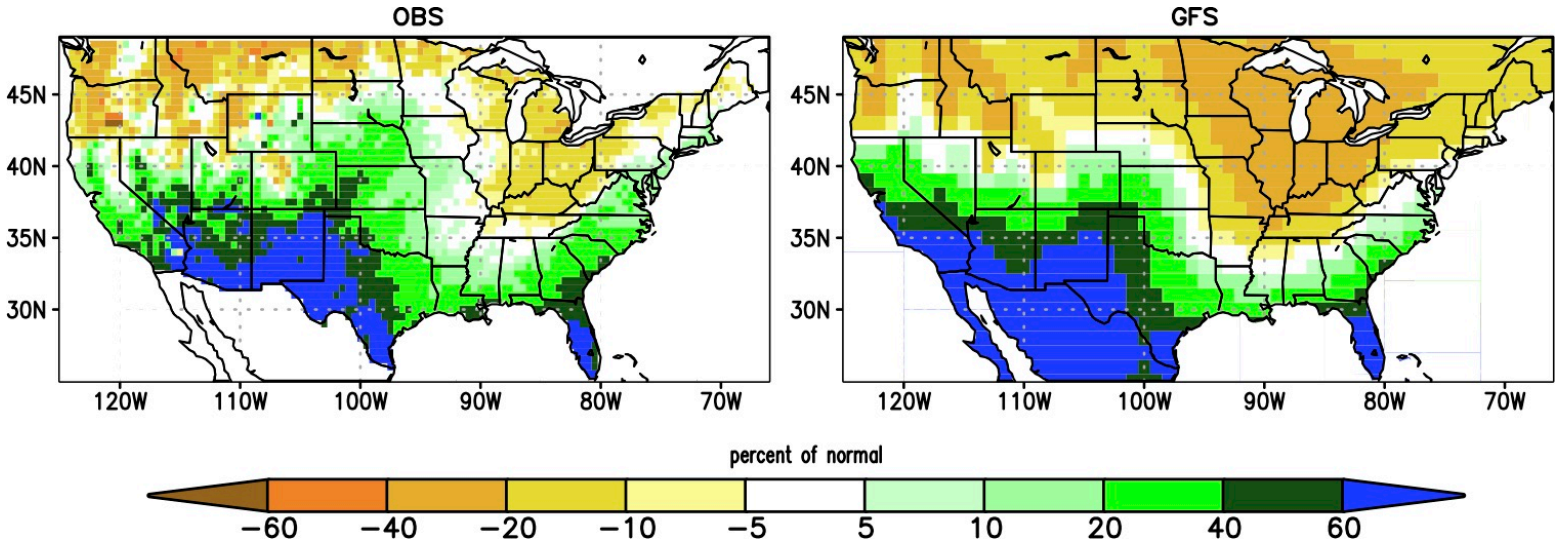
Rainfall Value of 1 in 20-year 5-day Event [mm/5day] (20 –year Return Level)



ENSO Precipitation Response
Nov-Apr Mean

OBS
(1900-2013)

GFS
(1979-2014)



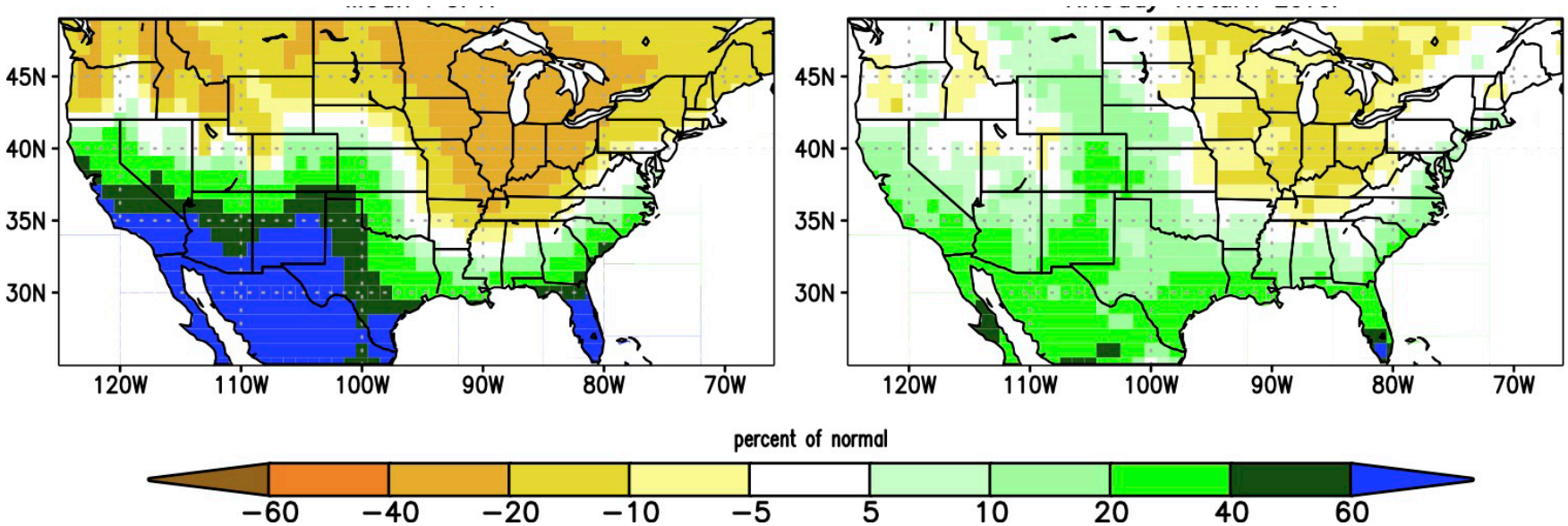
- Characteristic W-shape pattern is well reproduced in GFS
- Differences between OBS and GFS partly due to different ratio of very strong relative to moderate-strong events in composite

Comparison of canonical ENSO response between cold season mean and 20 year return level of 5-day extreme heavy rainfall events

ENSO Response (GFS)

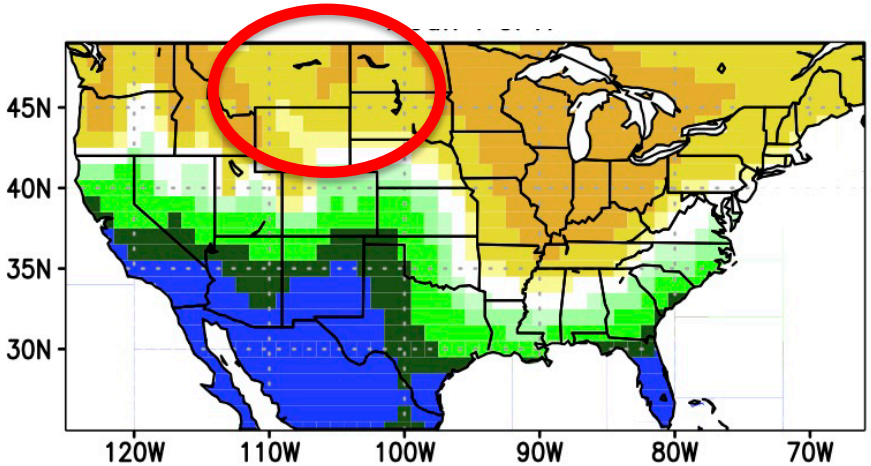
Cold Season
Mean Precipitation

20-year Return Level of
5-day Extreme Heavy Rainfall

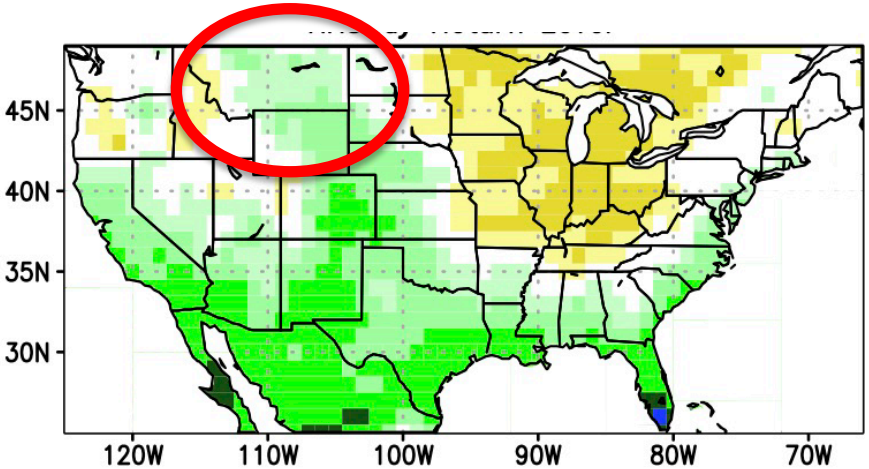


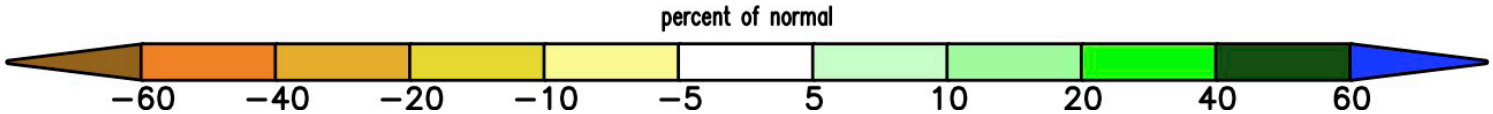
ENSO Response (GFS)

Cold Season
Mean Precipitation



20-year Return Level of
5-day Extreme Heavy Rainfall





El Nino and La Nina Response (GFS)

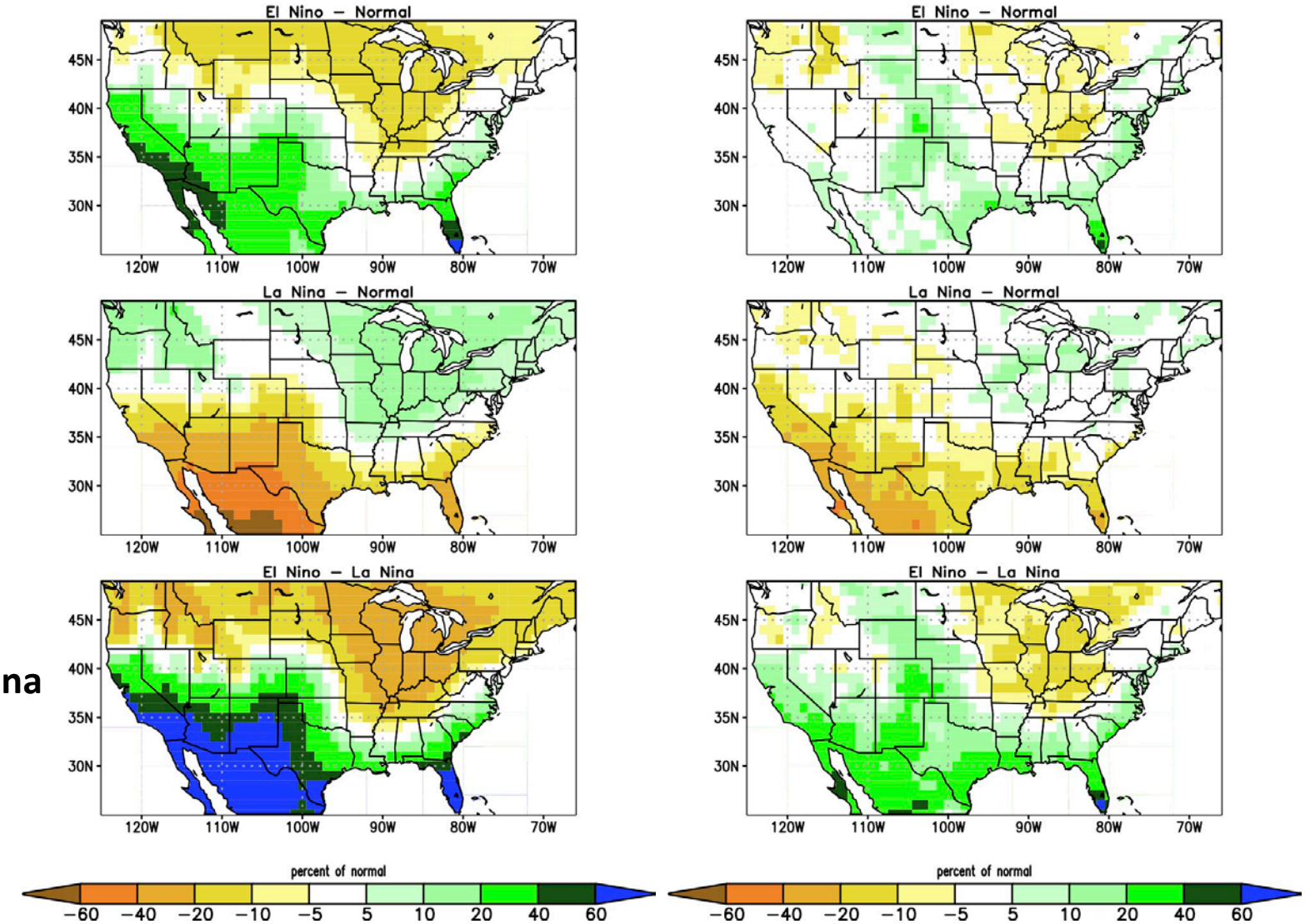
Cold Season Mean Precipitation

20-year Return Level of 5-day Extreme Heavy Rainfall

El Nino

La Nina

El Nino – La Nina



El Nino and La Nina Response (GFS)

Cold Season Mean Precipitation

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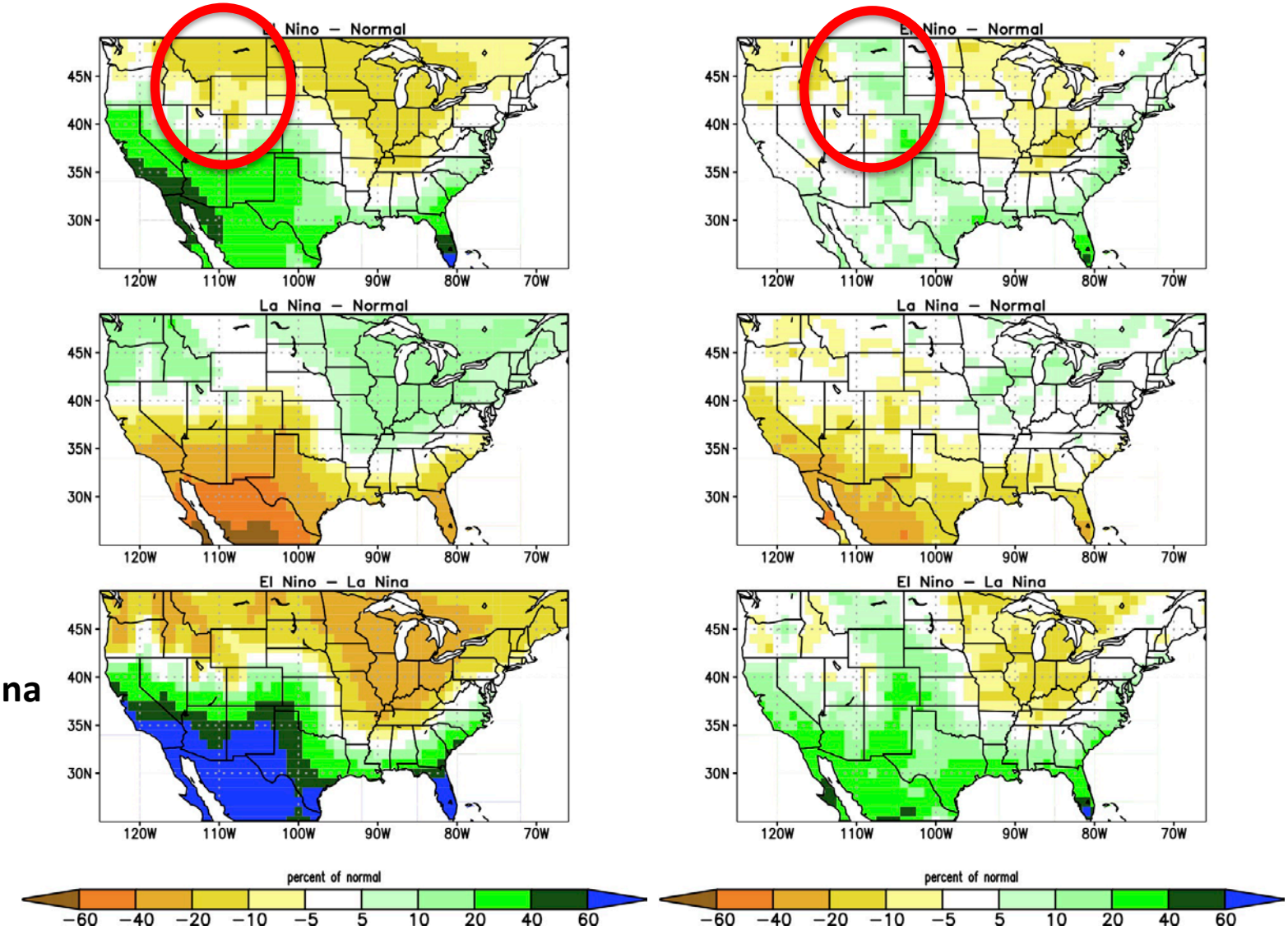

El Nino and La Nina Response (GFS)

Cold Season Mean Precipitation

20-year Return Level of 5-day Extreme Heavy Rainfall

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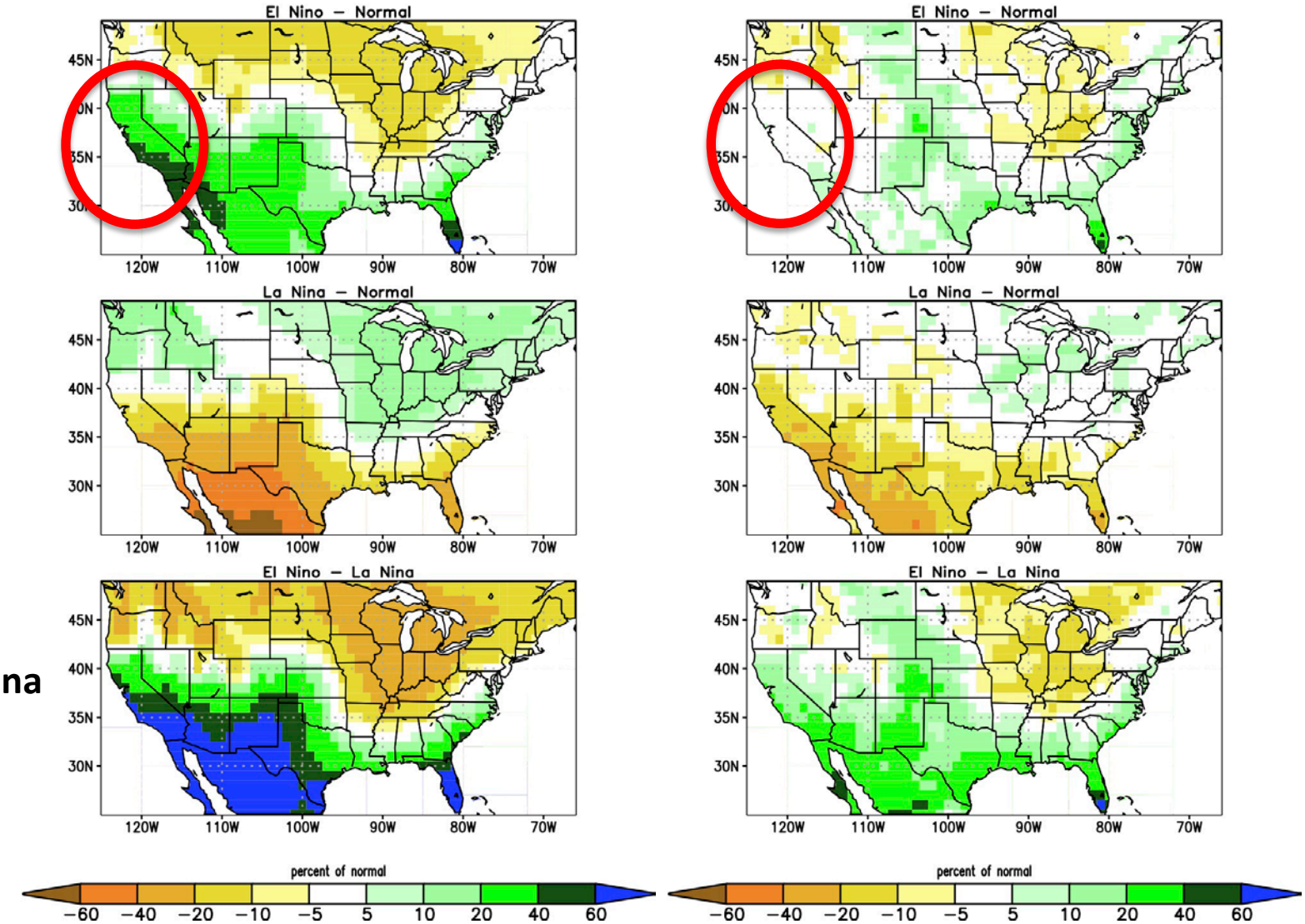
El Nino – La Nina

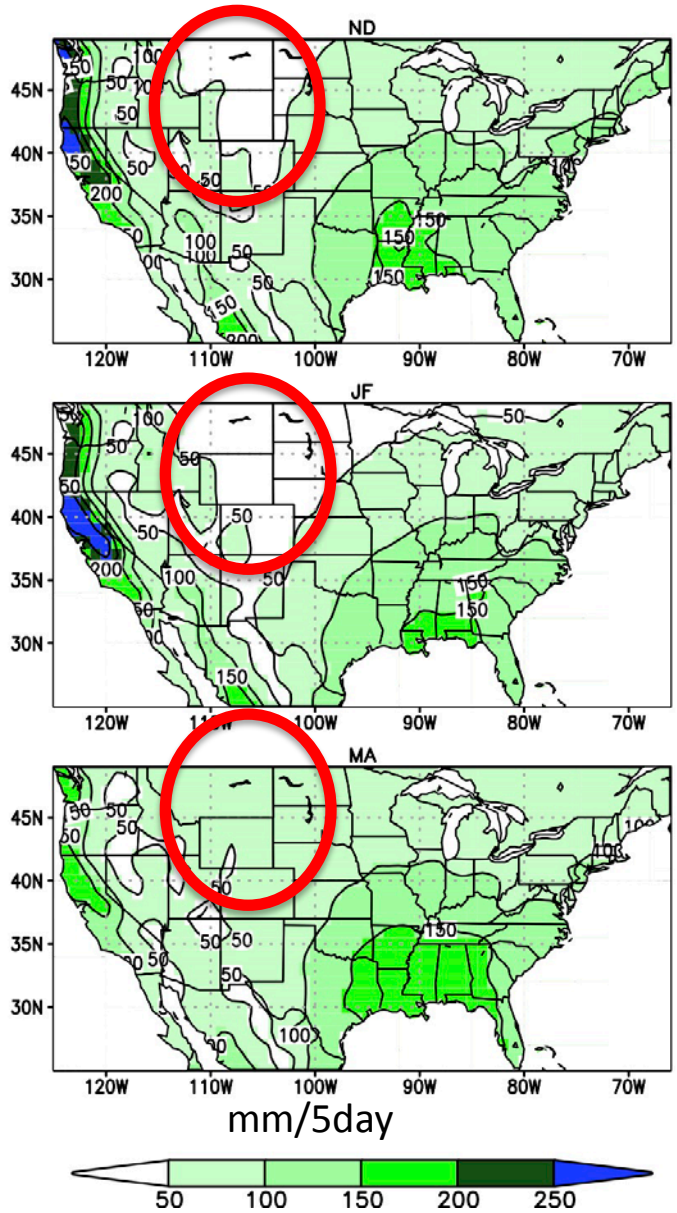


Seasonality of 20-year Return Levels

November/ December

January/ February

March/ April



Two-Month ENSO Response-GFS

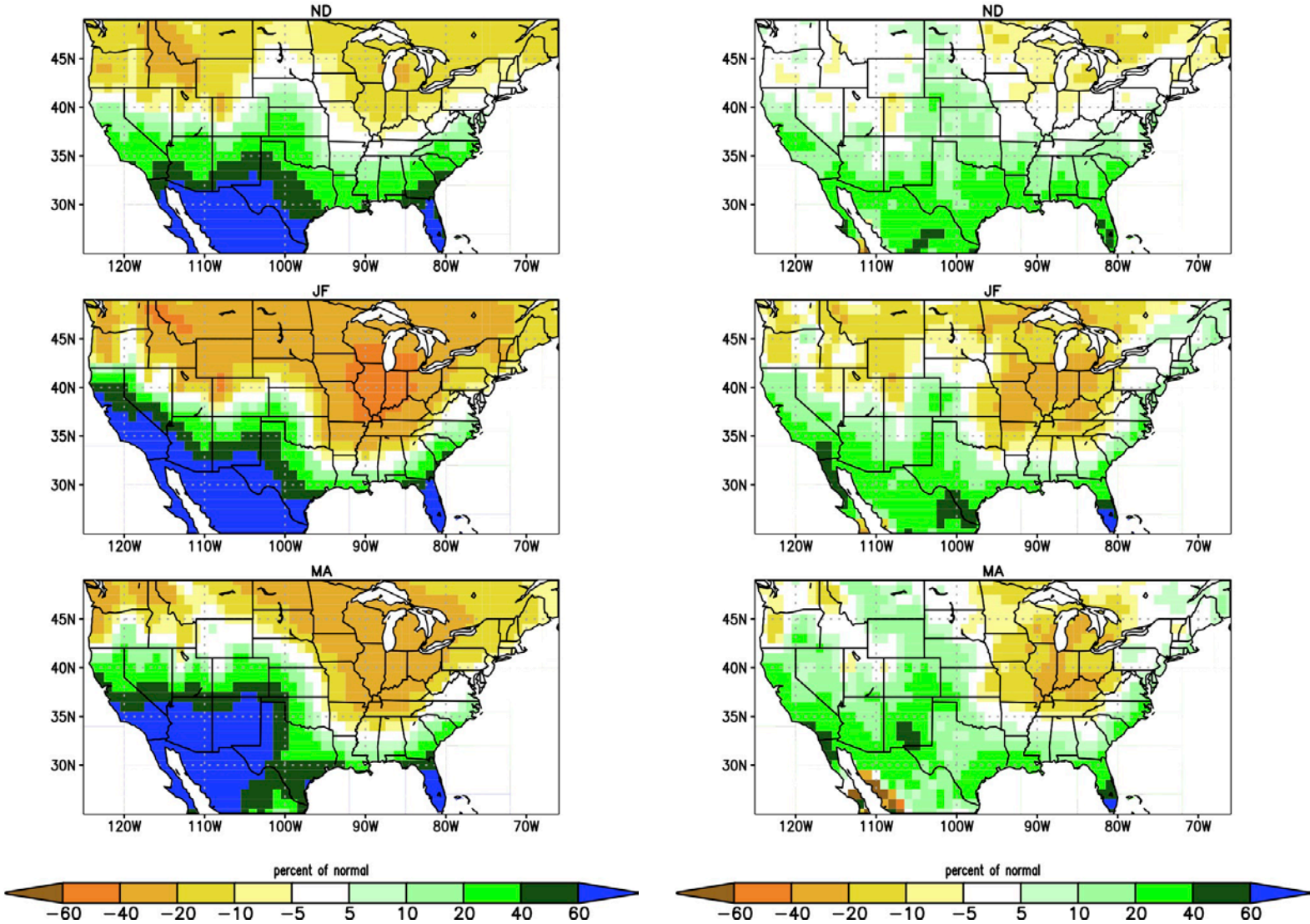
Mean Precipitation

20-year Return Level of 5-day Extreme Heavy Rainfall

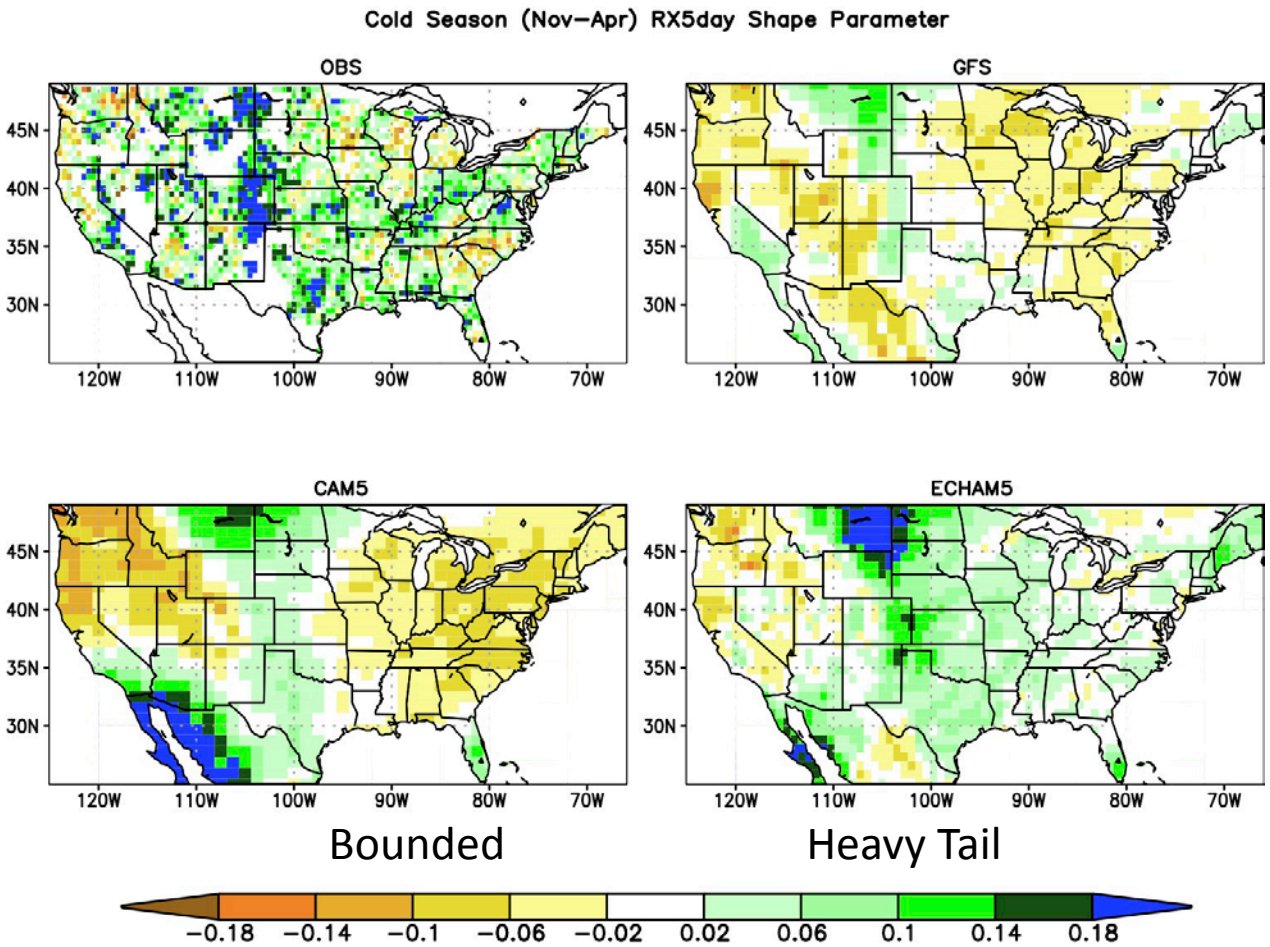
November/ December

January/ February

March/ April



Shape Parameter of extreme 5-day rainfall distributions



Proxy for the capacity of a probability distribution for having an extreme tail

Summary I

How are the odds of extreme heavy daily precipitation conditioned by ENSO?

- Based on GFS simulations and for cold season
  - During El Nino, the odds for extreme heavy 5-day rainfall events are increased in the central U.S. from the Northern Rockies to Texas and in the Southeast U.S.
  - During La Nina, they are strongly reduced in the West and Southwest U.S.

Summary II

How are changes in the odds of heavy daily precipitation related to the seasonal mean ENSO precipitation signal?

- Climate model simulations suggest that there are distinguished differences between seasonal mean and 20-year return level of 5-day extreme ENSO signal.
- Differences are most pronounced in Northern Rockies which exhibits an increase in extreme heavy 5-day rainfall amounts during El Nino especially in ND and MA.
- Pronounced asymmetry in extreme heavy rainfall ENSO response in regions like California.