# New Measure for NMME Forecast Uncertainty

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5. System Research Group

# NMME Forecast Uncertainty

- NMME deterministic forecast:

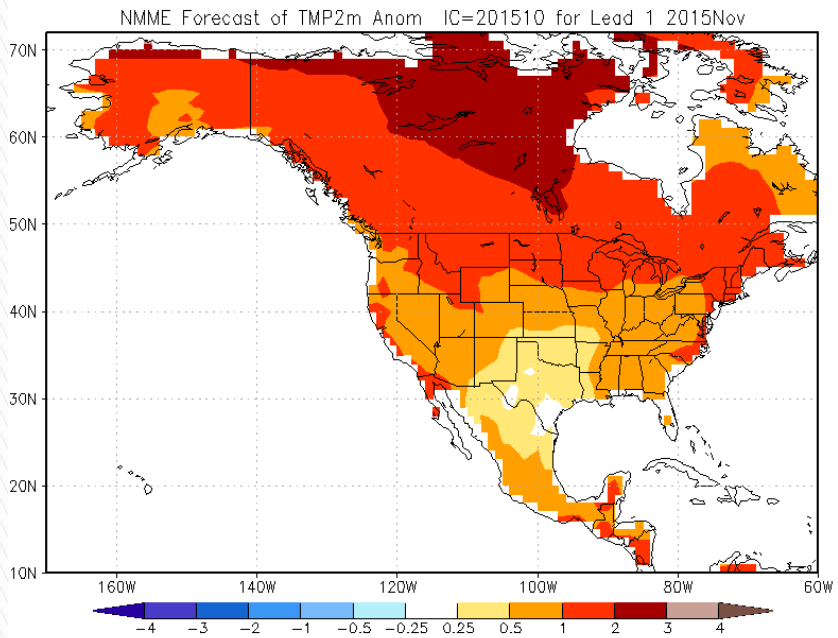
Anomalies of NMME are equal weight average for 7 models ensemble mean anomalies after bias correction :

$$F'(s,t,m,\tau) = \frac{1}{K}\sum_{k=1}^{K} F_k'(s,t,m,\tau)$$

- Users need more information about the model diversity or uncertainty of NMME ensemble mean forecast
- NMME probabilistic forecasts are for all members and all members are equally weighted.

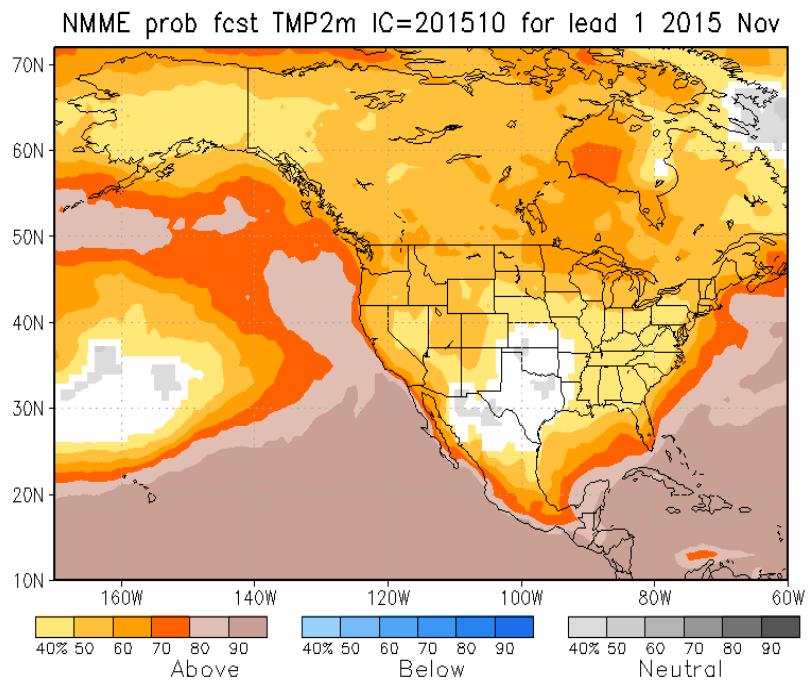
# Currently NMME Forecast with Oct. IC

## NMME Ensemble Mean Forecast (equal weight for 7 models)




The ensemble mean map is not complete if there is no uncertainty information

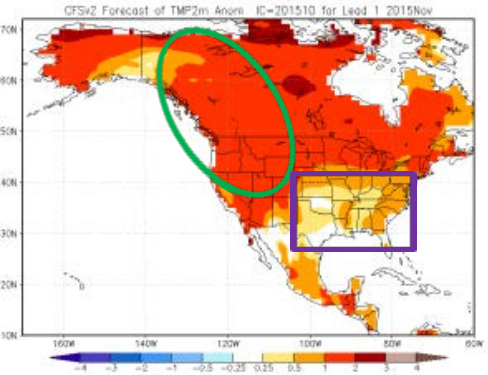
## NMME Probability Forecast (equal weight for 107 members)



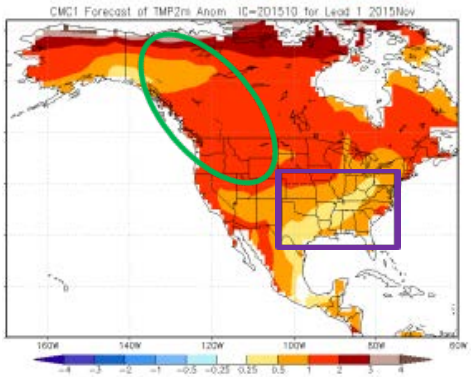

Probability forecast of three categories is a standard way of CPC expressing uncertainty. However, the weights are not consistent with the ensemble mean

# Uncertainty of NMME Forecast

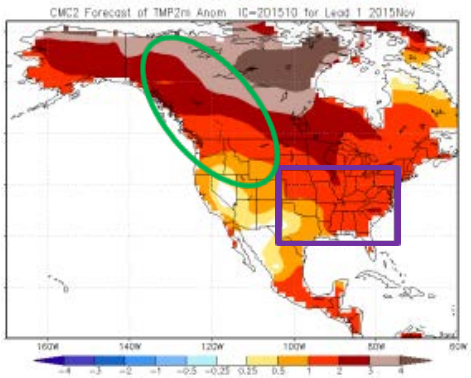
NCEP CFSv2



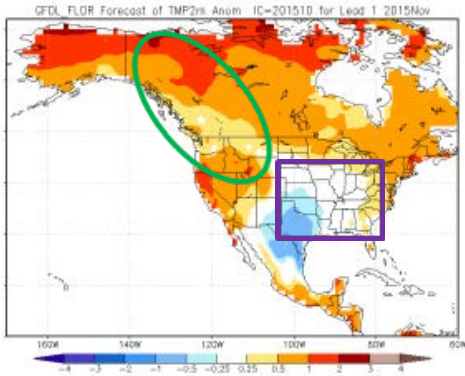

CanCM3



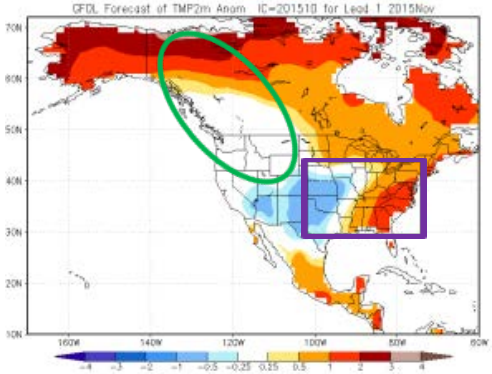

CanCM4



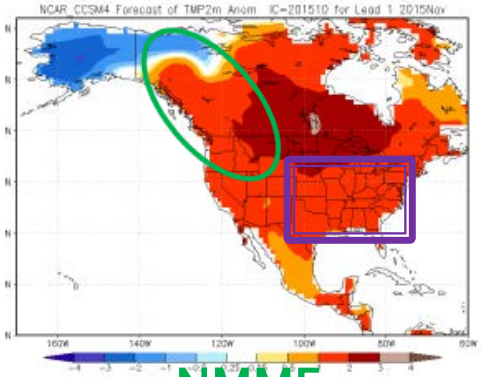

GFDL FLOR



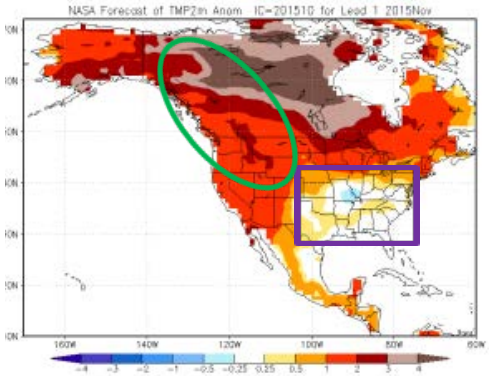

GFDL CM2.1



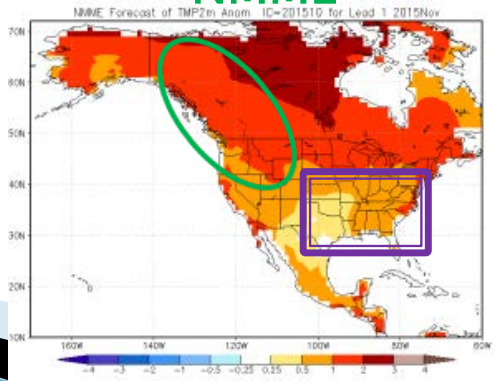

NCAR CCSM4




NASA GEOS5



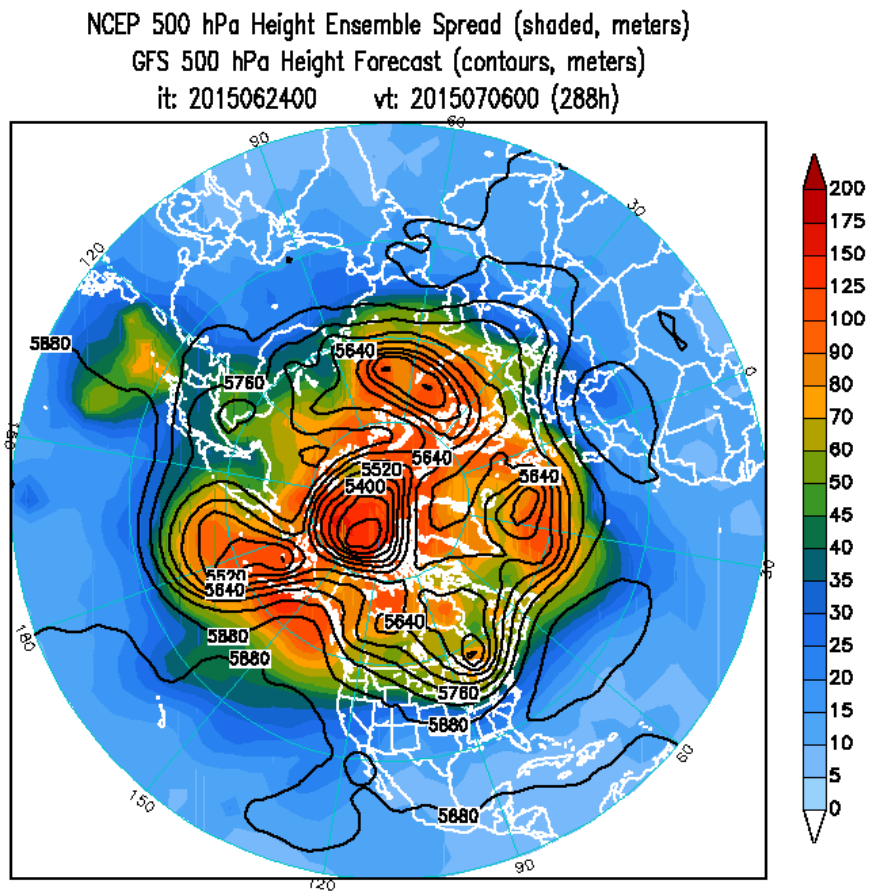

NMME

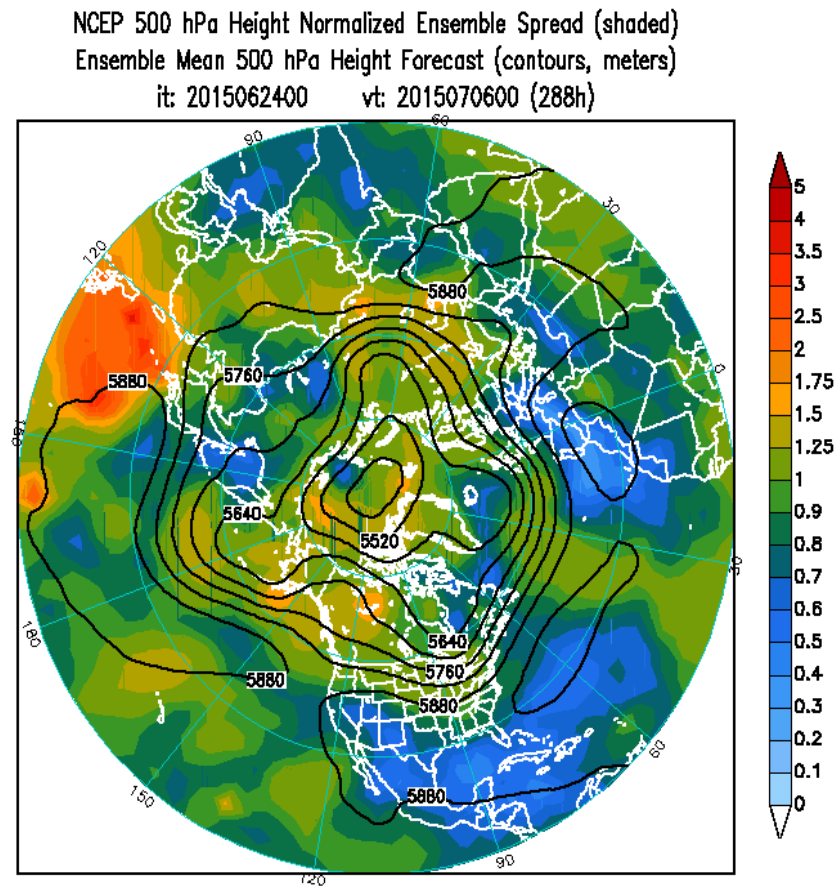



Model forecasts have good agreement on warm T2m anomalies over the northwestern of the North America

Model forecasts have less agreement on warm T2m anomalies over the southeastern CONUS

# Ensemble Mean and Ensemble Spread




## EMC Web Products

http://www.emc.ncep.noaa.gov/gmb/yluo/html_pqpf/rmop.html

Reference: Toth, Z., Y. Zhu, and T. Marchok, 2001: On the ability of ensembles to distinguish between forecasts with small and large uncertainty. Weather and Forecasting, 16, 436-477.

# Mutil-model Ensemble Variance

- We define mutil-model ensemble variance of space (s), lead (τ) and IC month (m) according to:

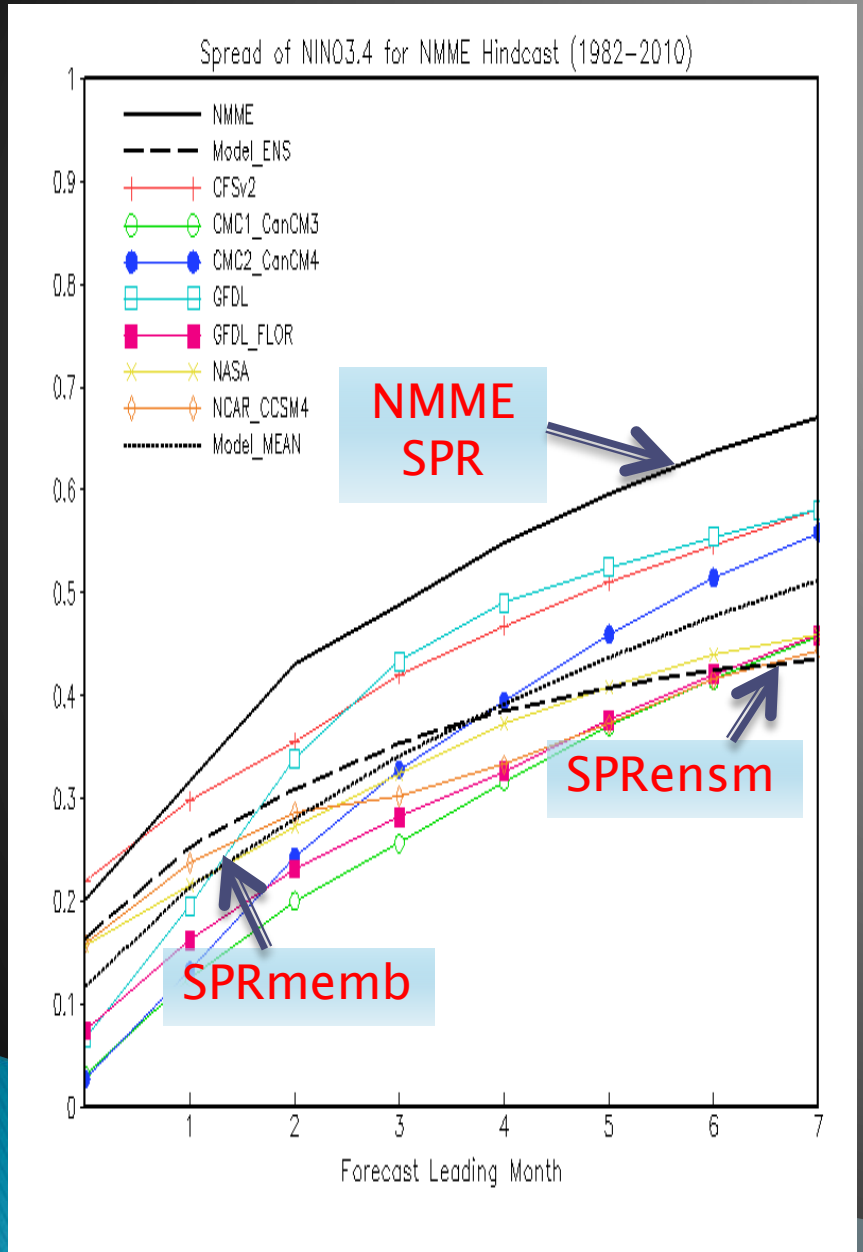
$$VAR = \underbrace{\frac{1}{K}\sum_{k=1}^{K}(F_k' - F')^2}_{\text{Between-model variance}} + \underbrace{\frac{1}{K}\sum_{k=1}^{K}\left(\frac{1}{N}\sum_{n=1}^{N}(f_{nk}' - F_k')^2\right)}_{\text{Within-model variance}}$$

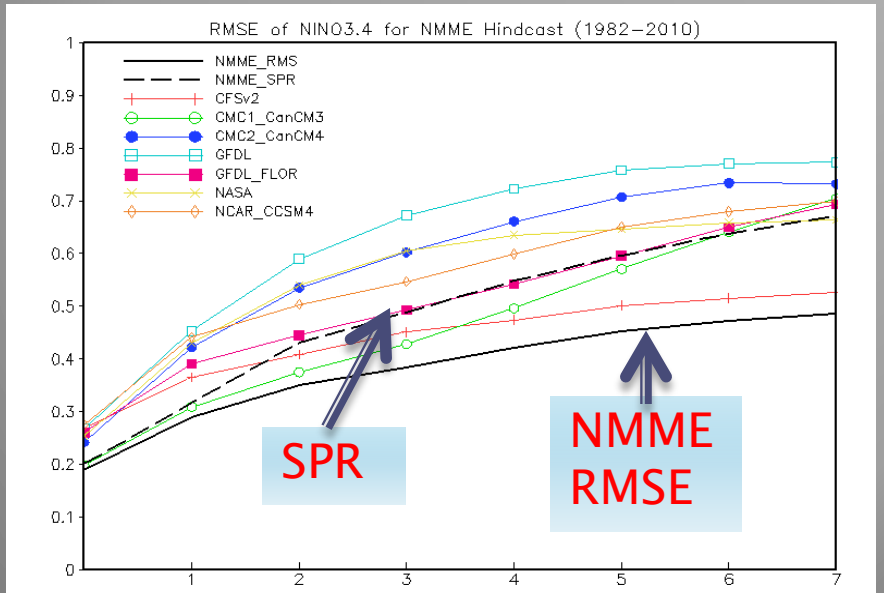
- Here the variance should be the sum of the two terms. Between-model variance is related to bias of forecast signal, within-model variance is linked to forecast noise.
- Therefore, define NMME Spread:

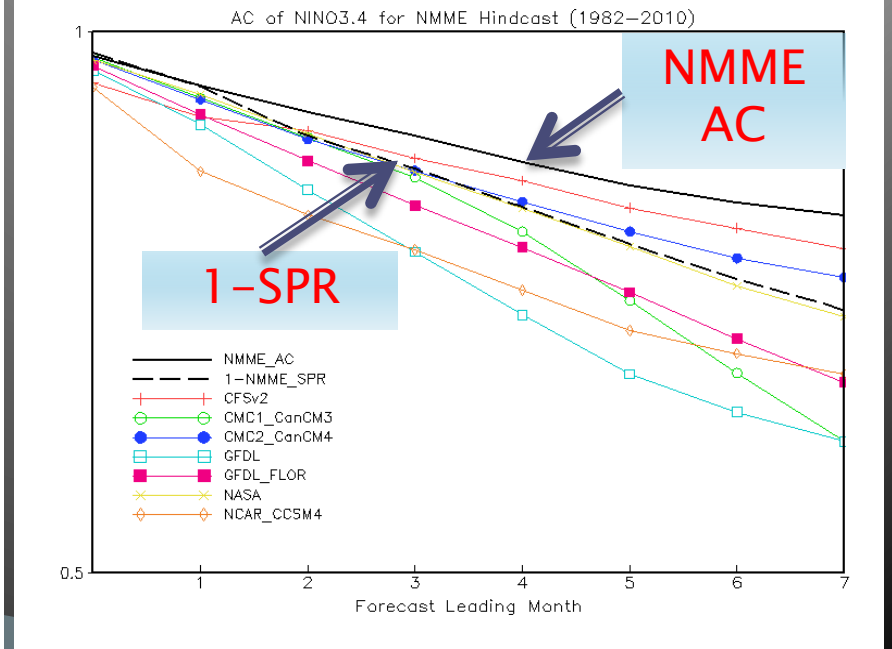
$$SPR^2 = SPRensm^2 + SPRmemb^2$$

Raftery, A. E., T. Gneiting, F. Balabdaoui, and M. Polakowski, 2005: Using Bayesian model averaging to calibrate forecast ensembles. Mon. Wea. Rev.,133,1155-1174."

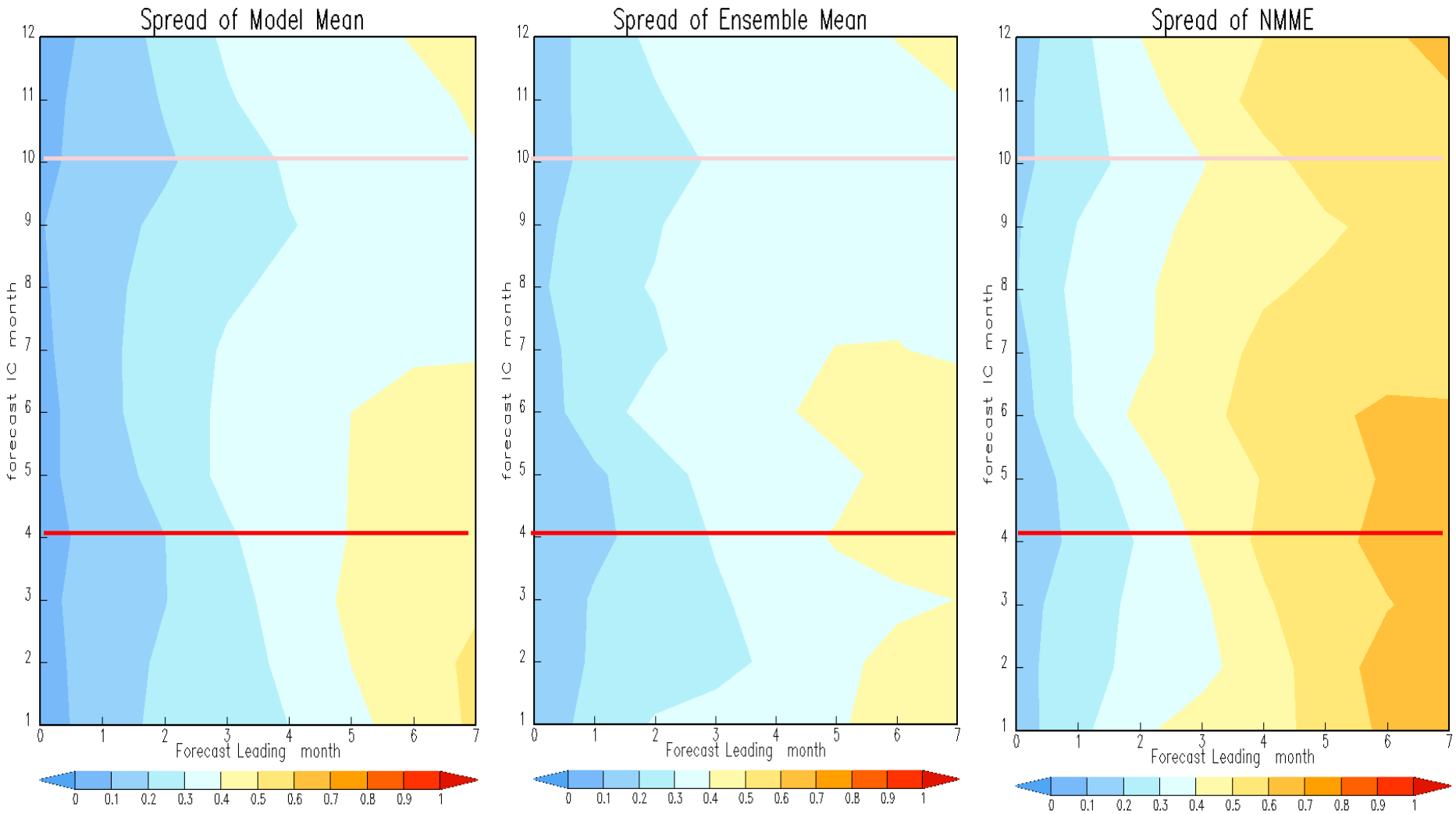
# Spread of Nino3.4 with RMSE and Skills



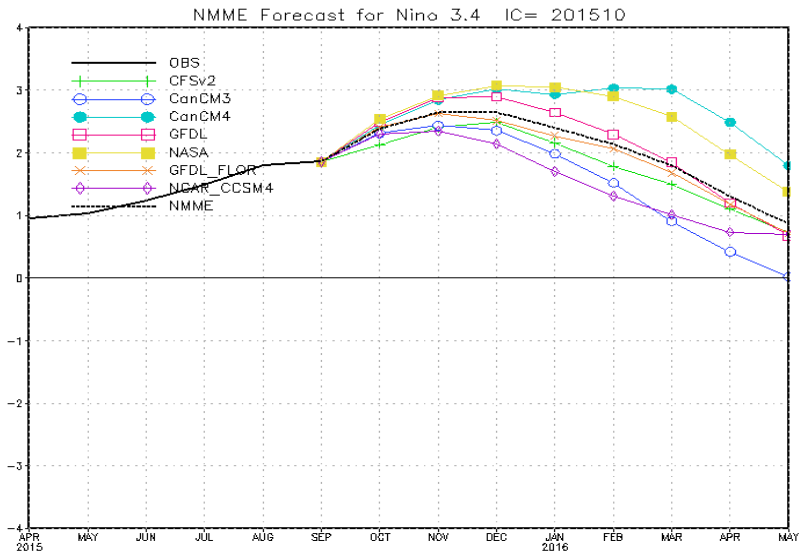



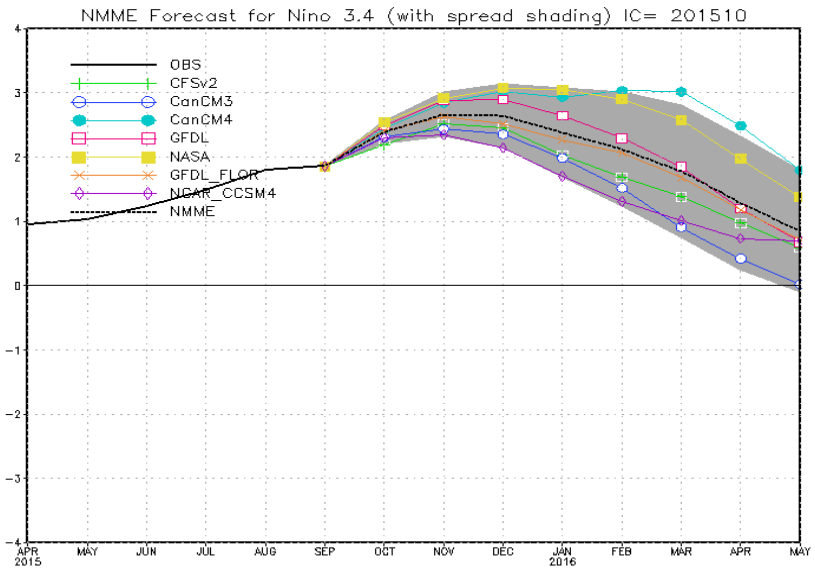



# Spread of NMME Nino3.4 (Hindcast for 1982-2010)

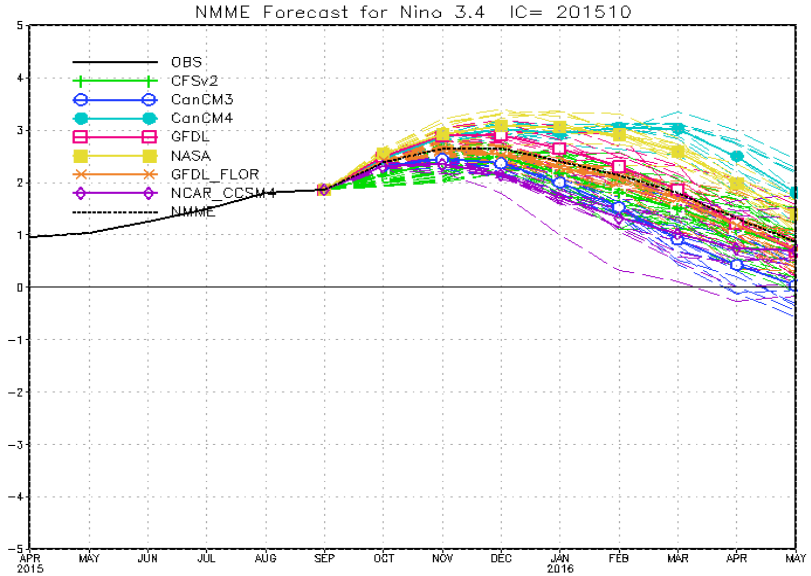


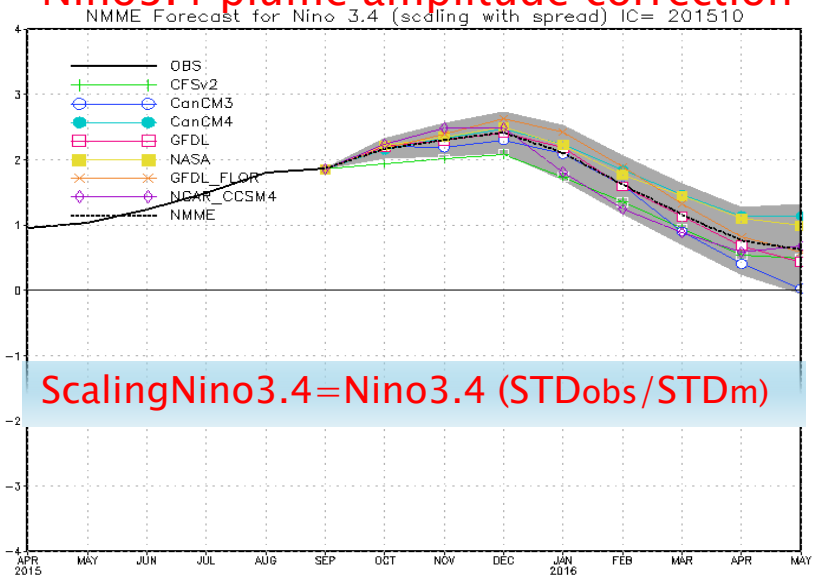
# Realtime Nino3.4 Plumes and Spread




Nino3.4 plume amplitude correction



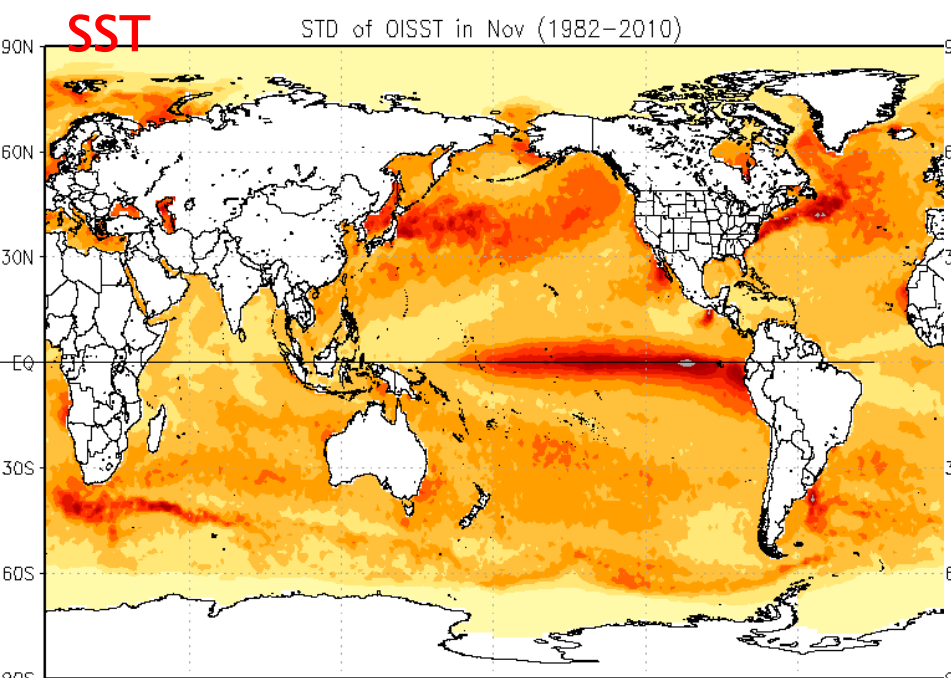

ScalingNino3.4=Nino3.4 (STDobs/STDm)

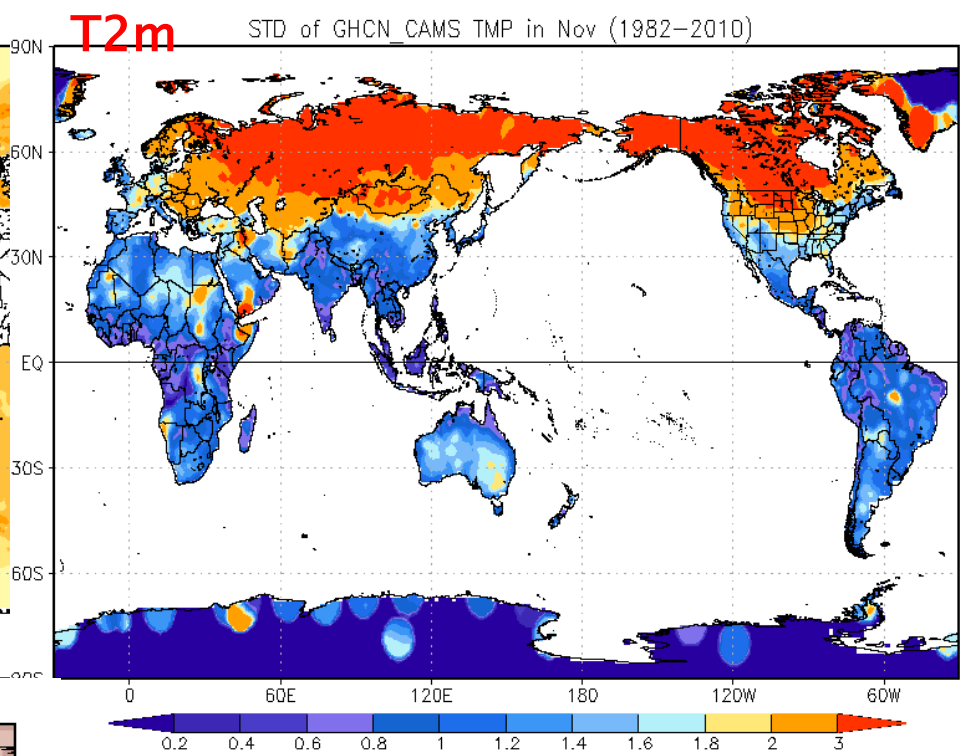
# NMME Forecast Uncertainty

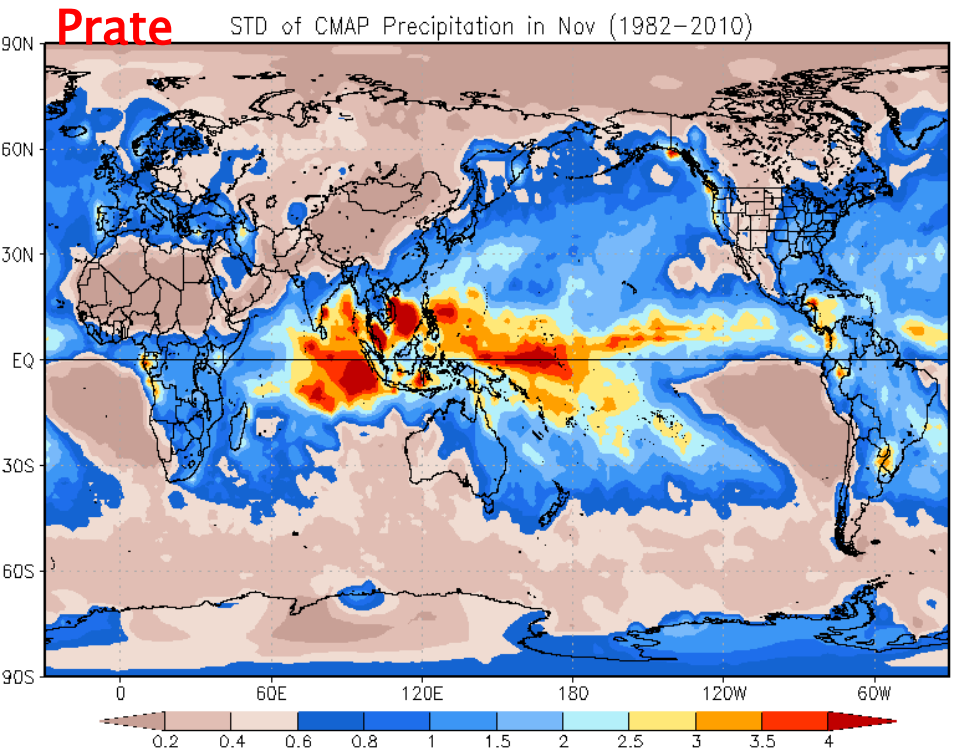
- We defined normalized spread to measure the uncertainty of NMME forecast:

$$SPRnor = (VAR)^{1/2} / STD_{obs}$$

- Here STDobs changes with monthly or seasonal as a normalizing factor for each lead time.
- SPRnor $\leq$ 1 means that model forecasts are in good agreement over the areas.
- SPRnor $\geq$1 indicates the NMME forecast uncertainty is bigger for higher diversity between models.




# Observation STD*obs*

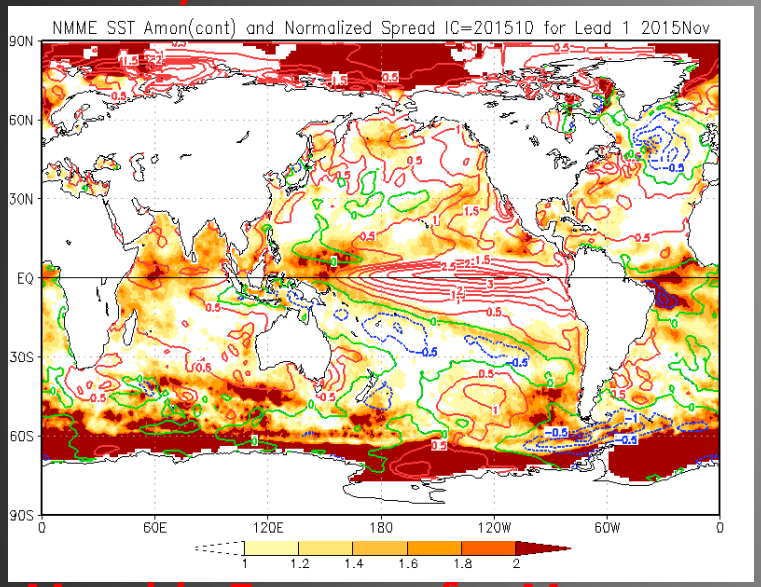
$$STD_{obs} = \frac{1}{T}\sum_{t}(VAR_{obs})^{1/2}$$

**SST: OISST-QD (1982-2010)**
**Prate.: CMAP (1982-2010)**
**T2m:GHCN_CAMS (1982-2010)**

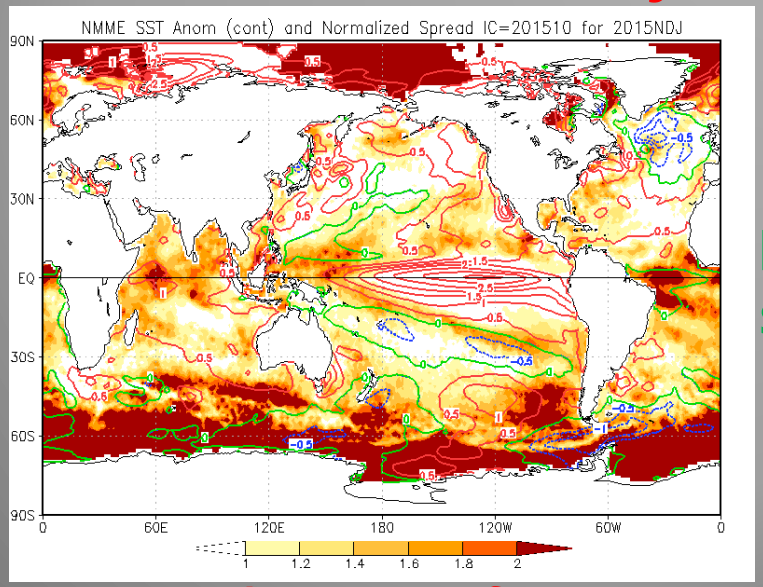
# SST Anomaly of NMME Forecast Uncertainty

Monthly Forecast for Nov

Lead 1 mon



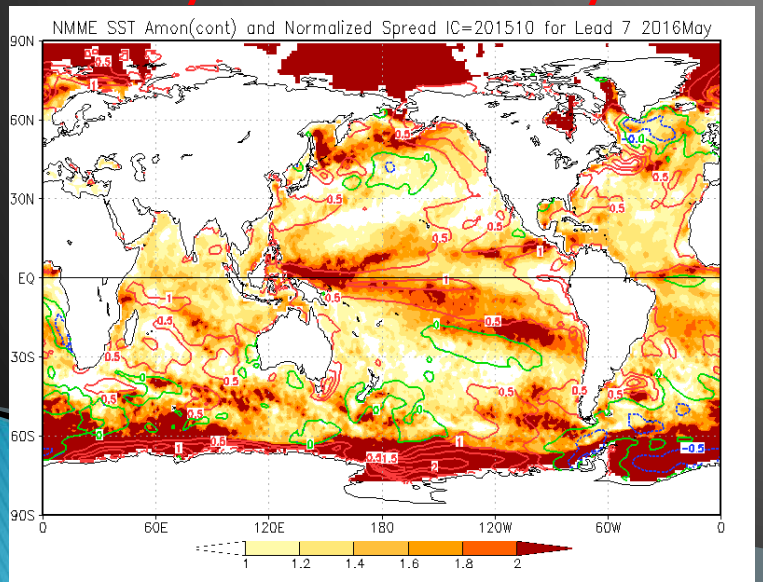

Seasonal Forecast for NDJ



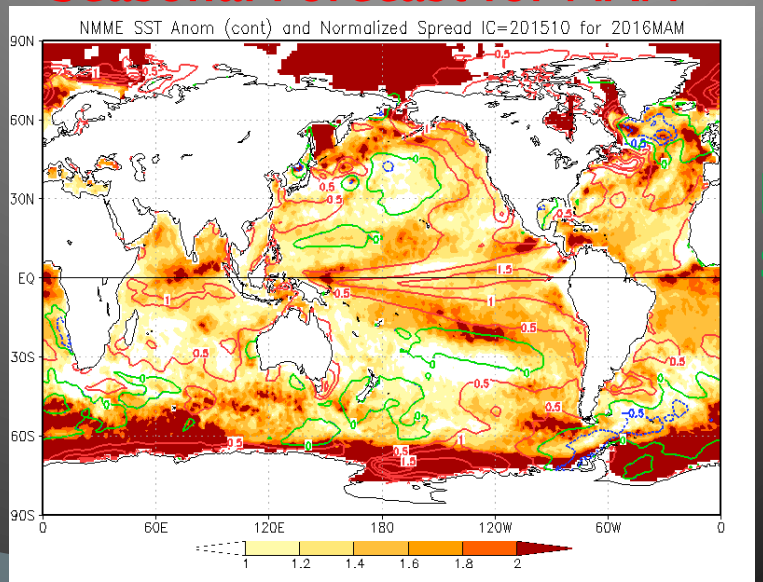

Lead 1 season

Monthly Forecast for May

Lead 7 mon




Seasonal Forecast for MAM

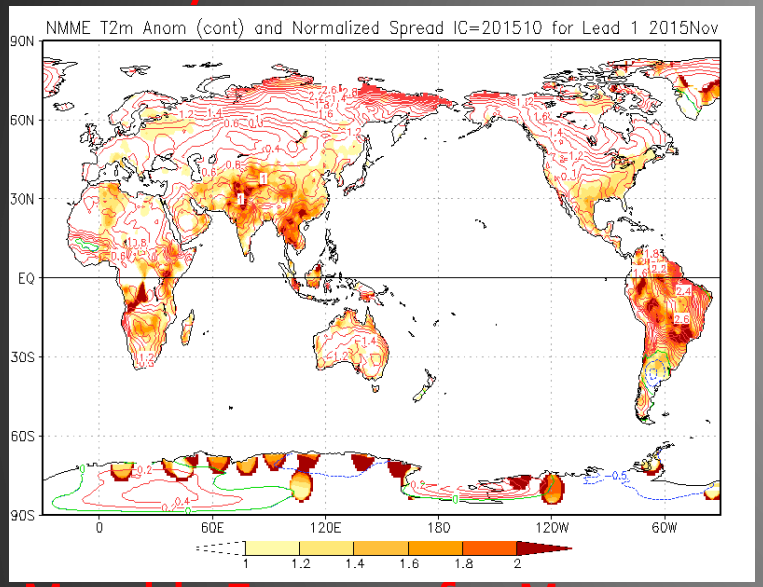



Lead 5 season

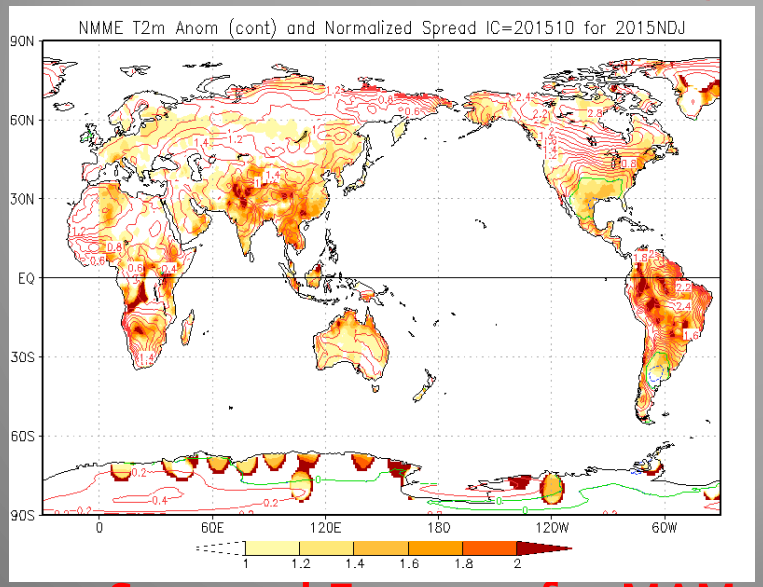
# T2m Anomaly of NMME Forecast Uncertainty

Monthly Forecast for November

Lead 1 mon



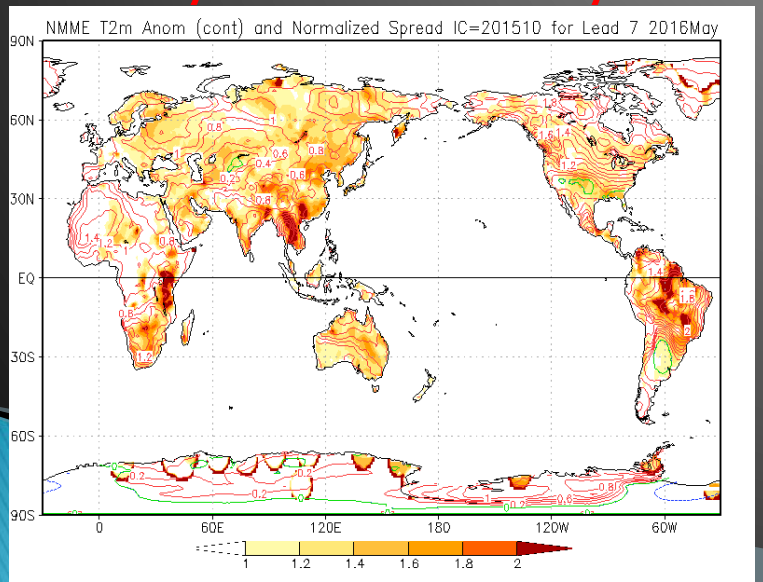

Seasonal Forecast for NDJ



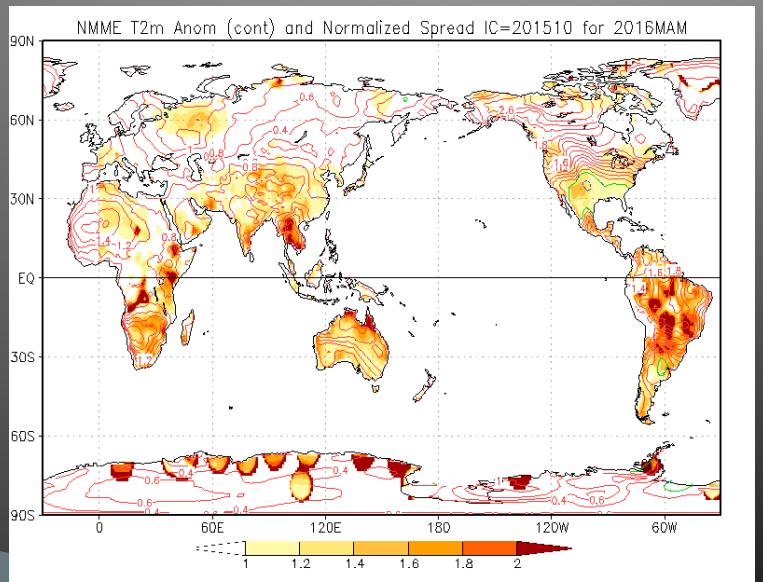

Lead 1 season

Monthly Forecast for May

Lead 7 mon




Seasonal Forecast for MAM



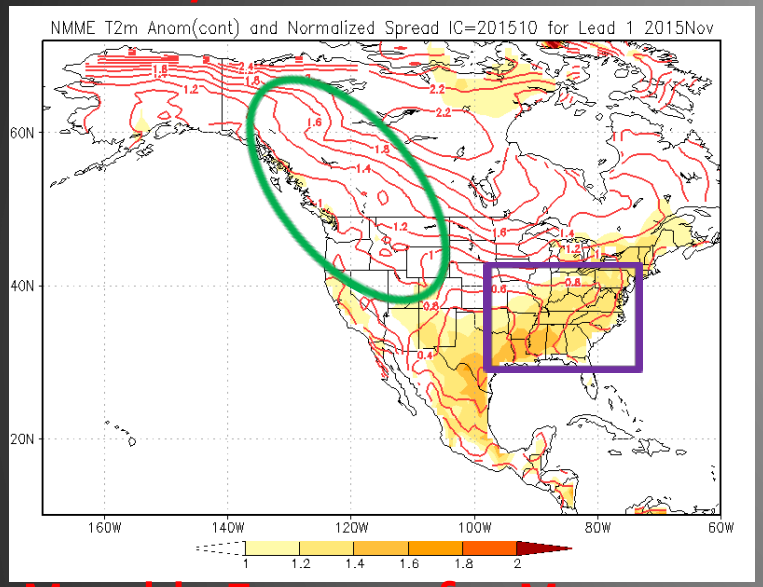

Lead 5 season

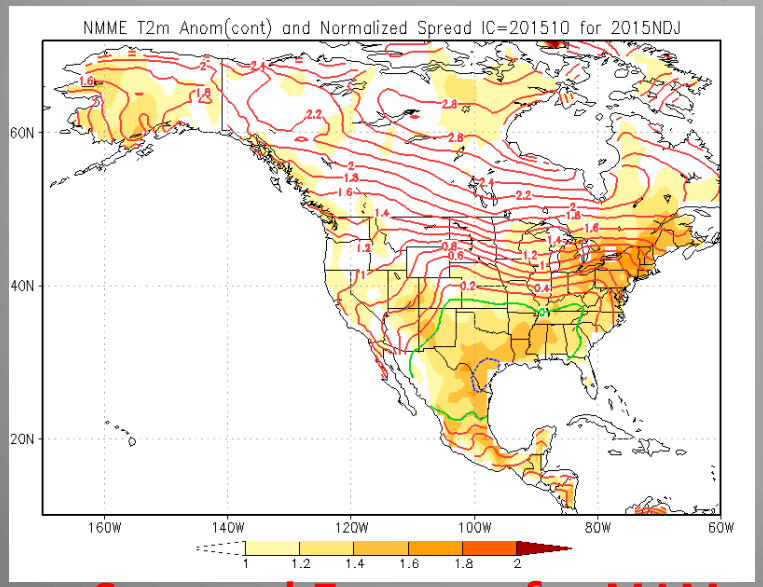
# T2m Anomaly of NMME Forecast Uncertainty

Monthly Forecast for Nov

Seasonal Forecast for NDJ

Lead 1 mon



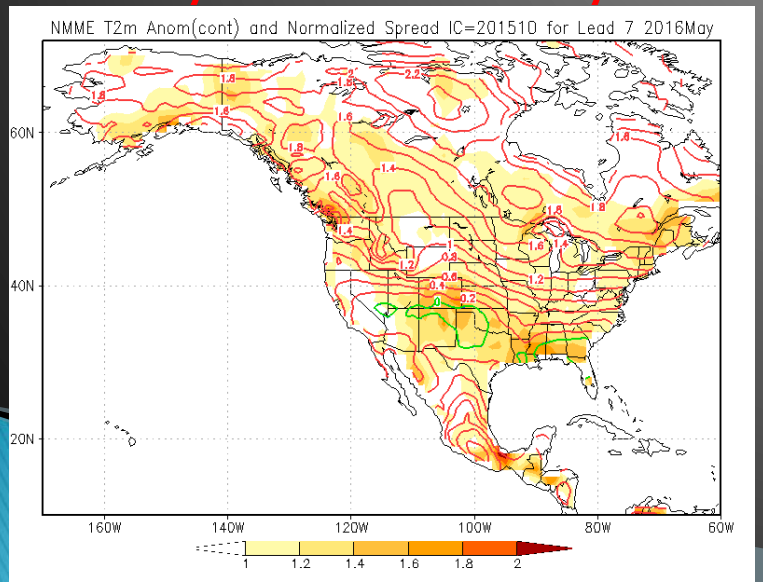



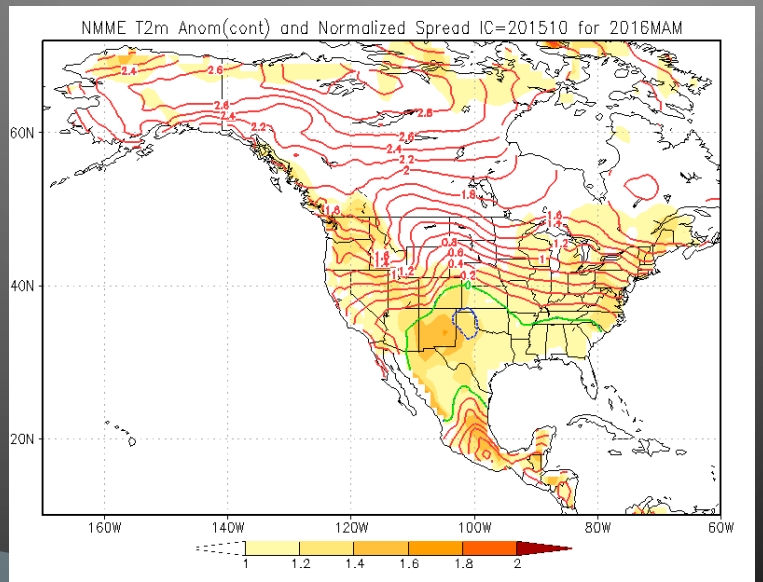

Lead 1 season

Monthly Forecast for May

Seasonal Forecast for MAM

Lead 7 mon



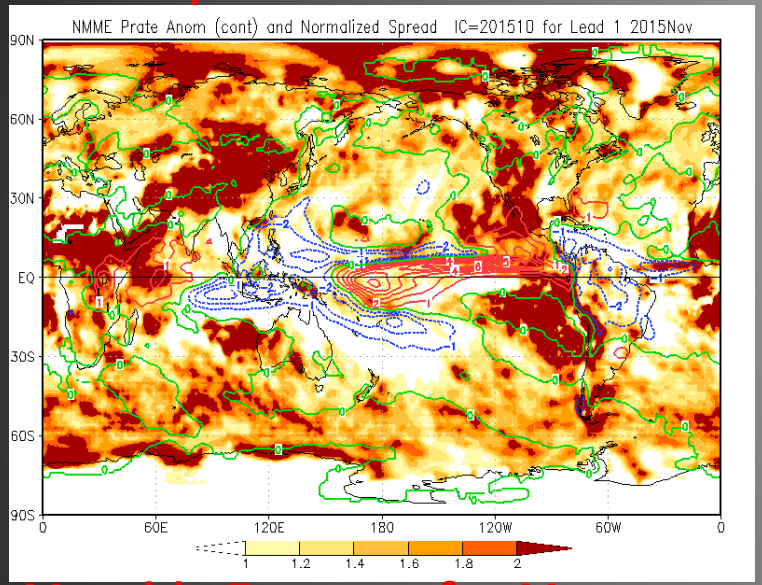




Lead 5 season

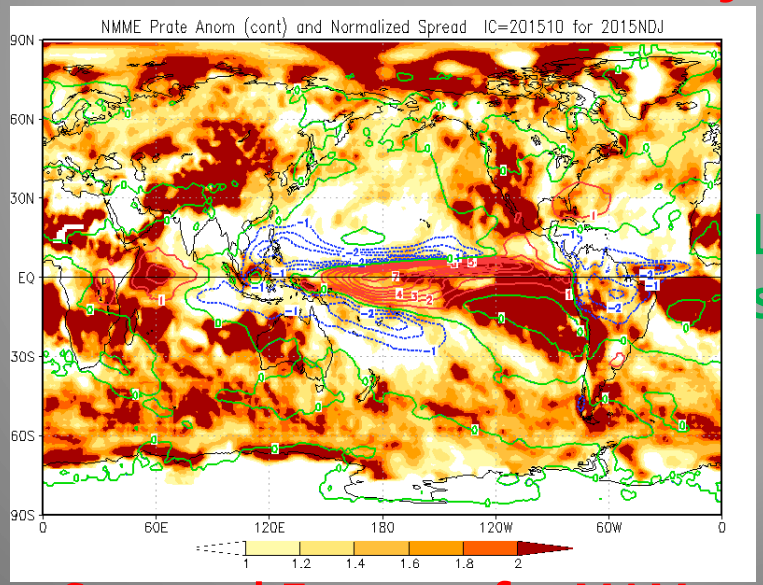
# Precipitation Anomaly of NMME Forecast Uncertainty

Monthly Forecast for Nov.

Lead 1 mon



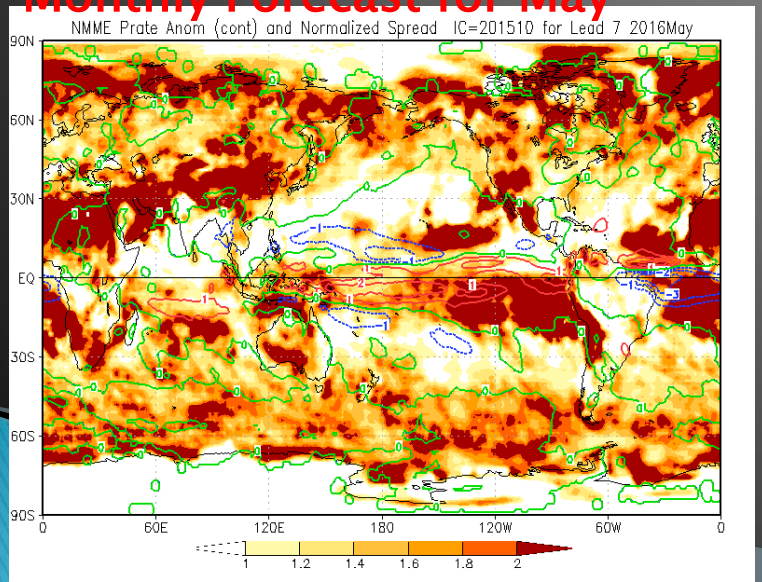

Seasonal Forecast for NDJ



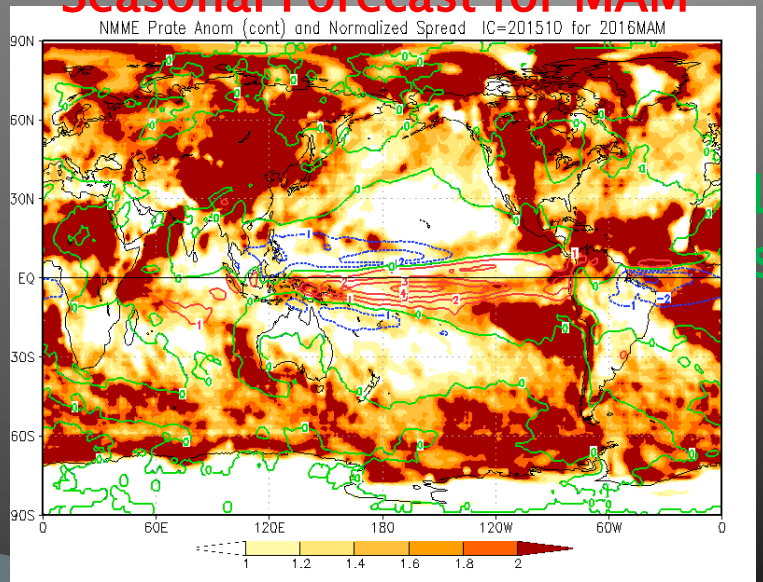

Lead 1 season

Monthly Forecast for May

Lead 7 mon




Seasonal Forecast for MAM



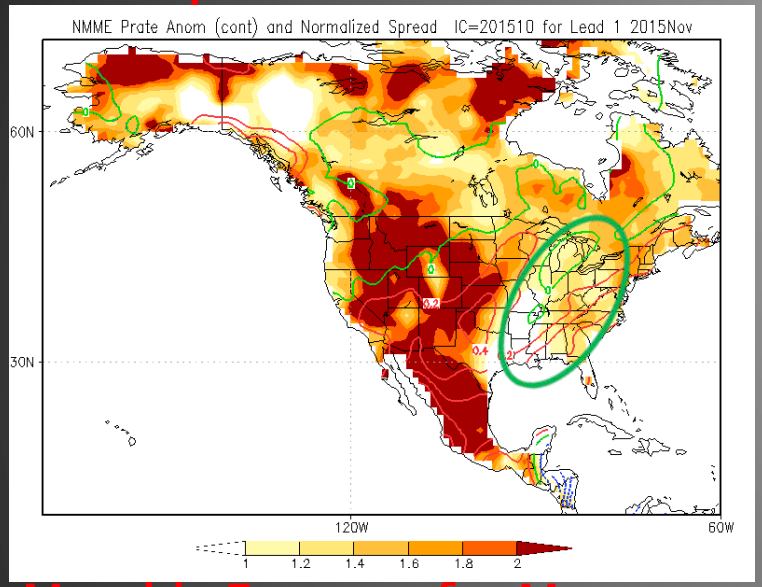

Lead 5 season

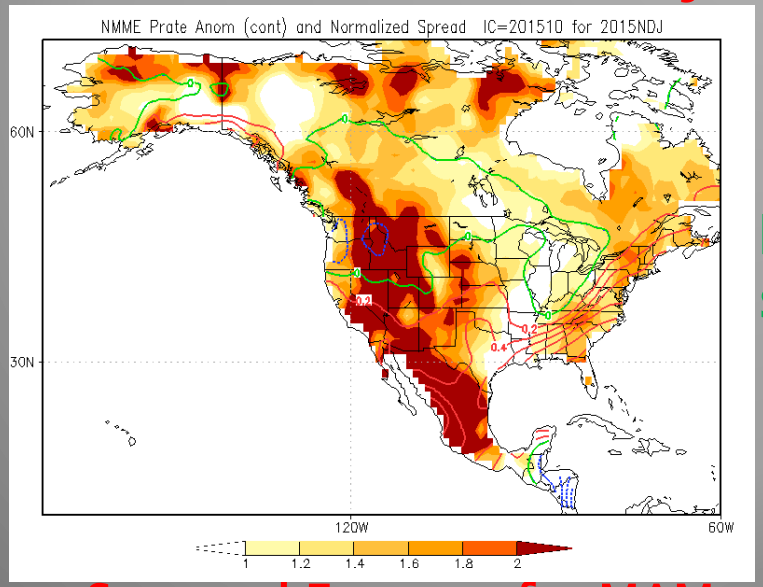
# Precipitation Anomaly of NMME Forecast Uncertainty

Monthly Forecast for Nov

Seasonal Forecast for NDJ

Lead 1 mon



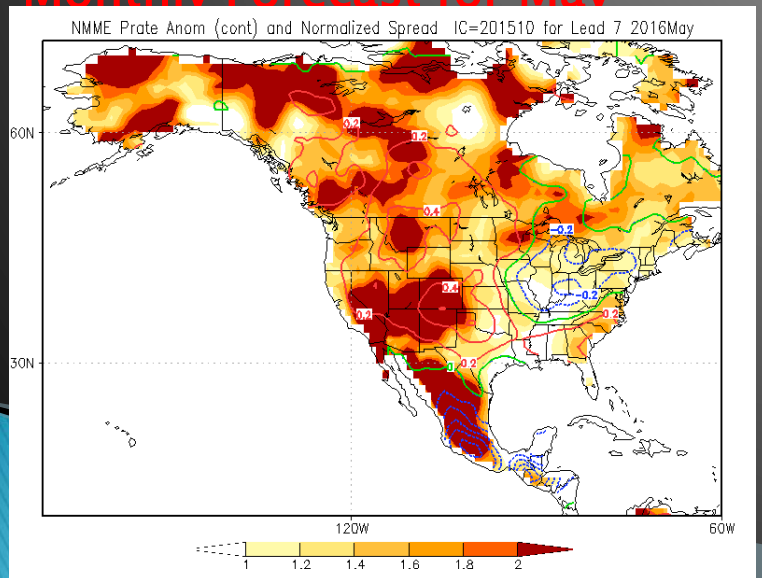



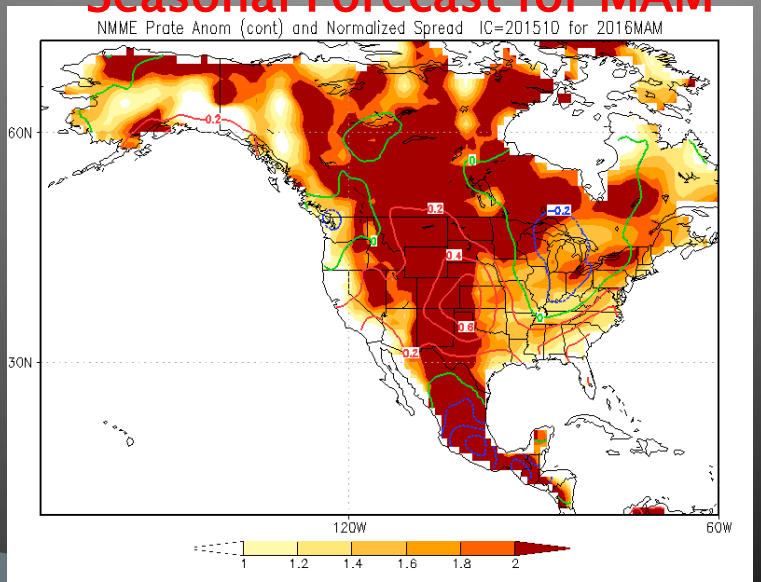

Lead 1 season

Monthly Forecast for May

Seasonal Forecast for MAM

Lead 7 mon

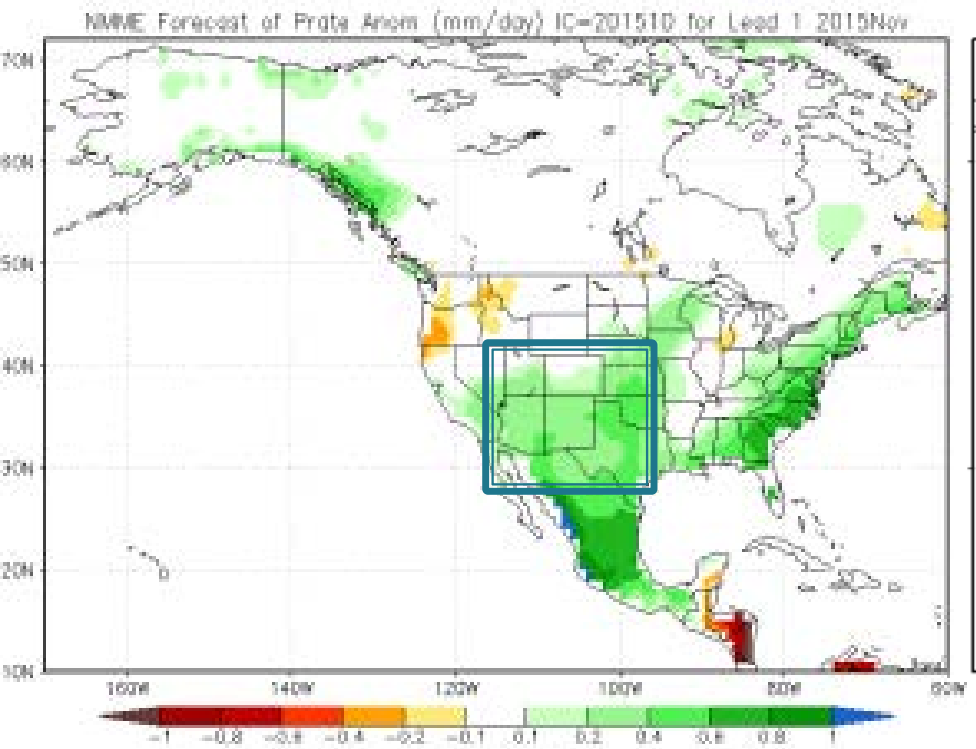


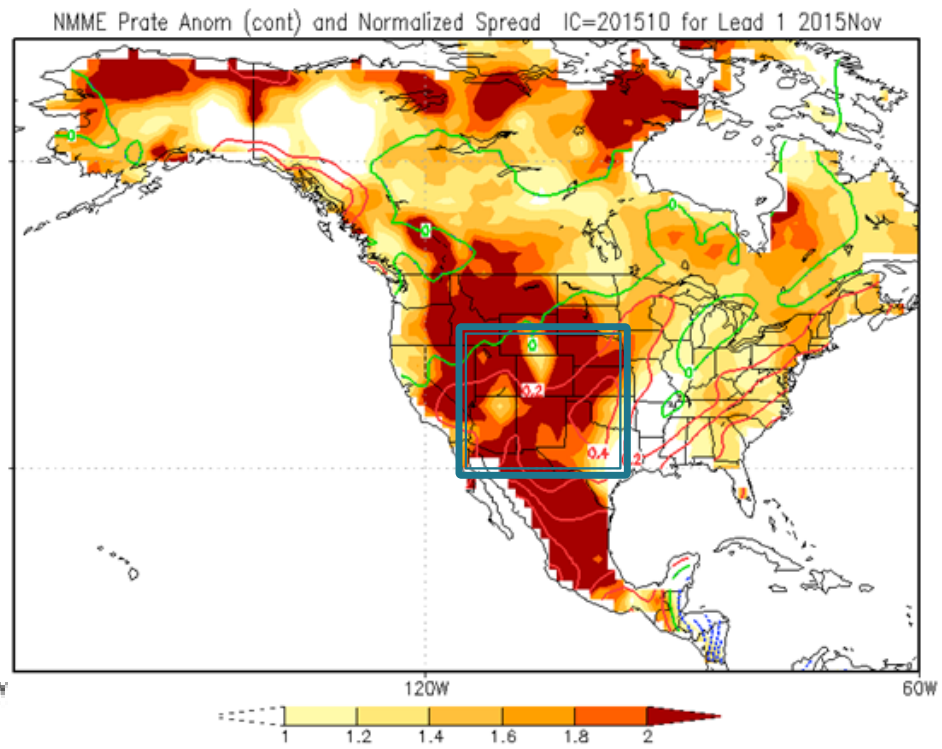

Lead 5 season

# Precipitation Anomaly of NMME for Nov 2015

## NMME Ensemble Mean




## NMME SPRnor



# Summary and Discussion

- NMME realtime spread is defined from multi-model ensemble variance, including between-model variance and within-model variance.
- Normalized ensemble spread is the new measurement for NMME forecast uncertainty, which is consistent with the NMME ensemble mean forecast.
- SPRnor $\leq 1$ indicates model forecasts in good agreement over the grid points. SPRnor $> 1$ means that model forecasts are more dispersed and have more uncertainty than observed inter-annual variability.
- Generally, realtime SPRnor increases with forecast leading time. However, some variables, such as precipitation, may be influenced by seasonal variance in certain regions.