# Probabilistic Drought Monitoring and Prediction

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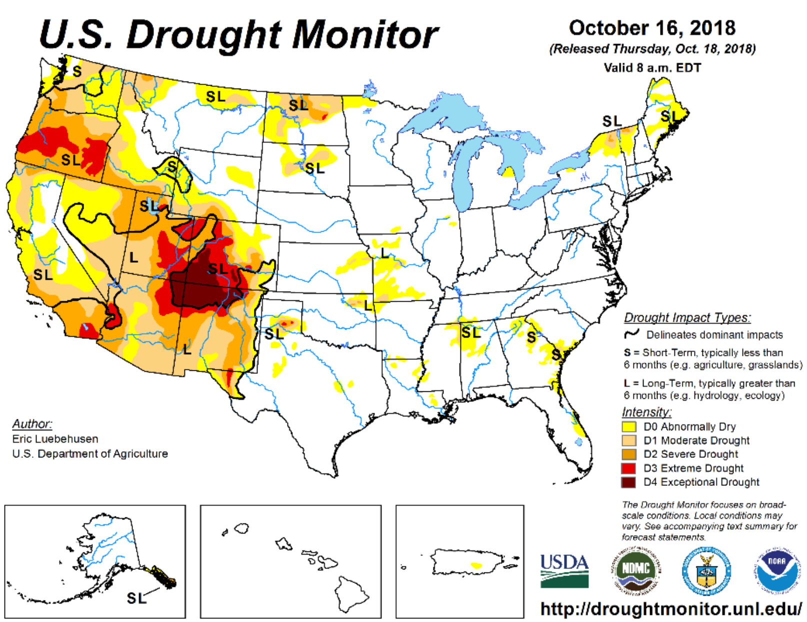
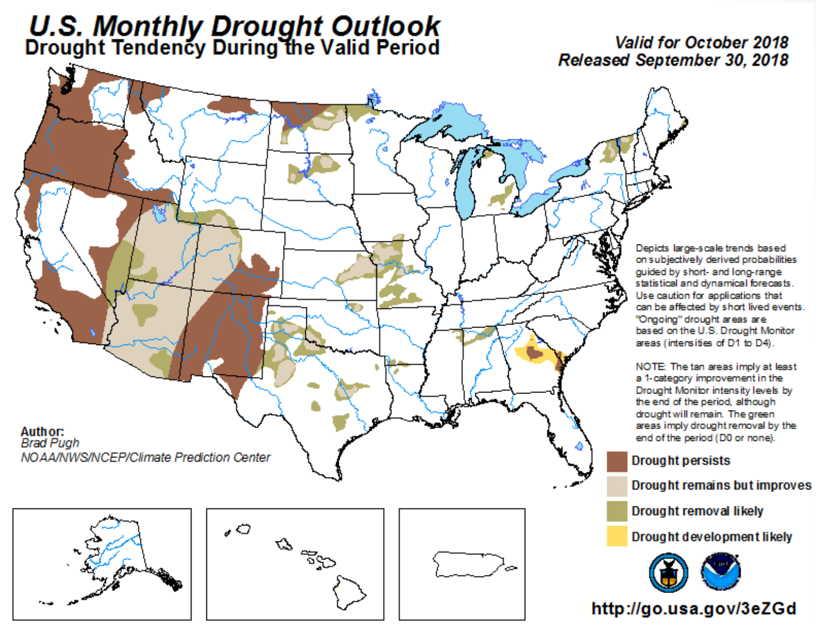
# Operational Drought Information




Current Drought Conditions

Changes from the Drought Monitor

- There is no information on uncertainties;
- For objective Drought Monitor and Drought Outlook, uncertainties can be estimated from members of ensemble

# a) Objective drought Monitor : One index to describe drought

Integrated Drought Index (IDI)

Grand mean : equally weighted mean of all members and mapped to a uniform distribution to indicate the mean state of drought

Members : Standardized Precipitation index (SPI6)

Soil Moisture Percentiles (SMP)

Standardized runoff index (SRI3)

from land surface models

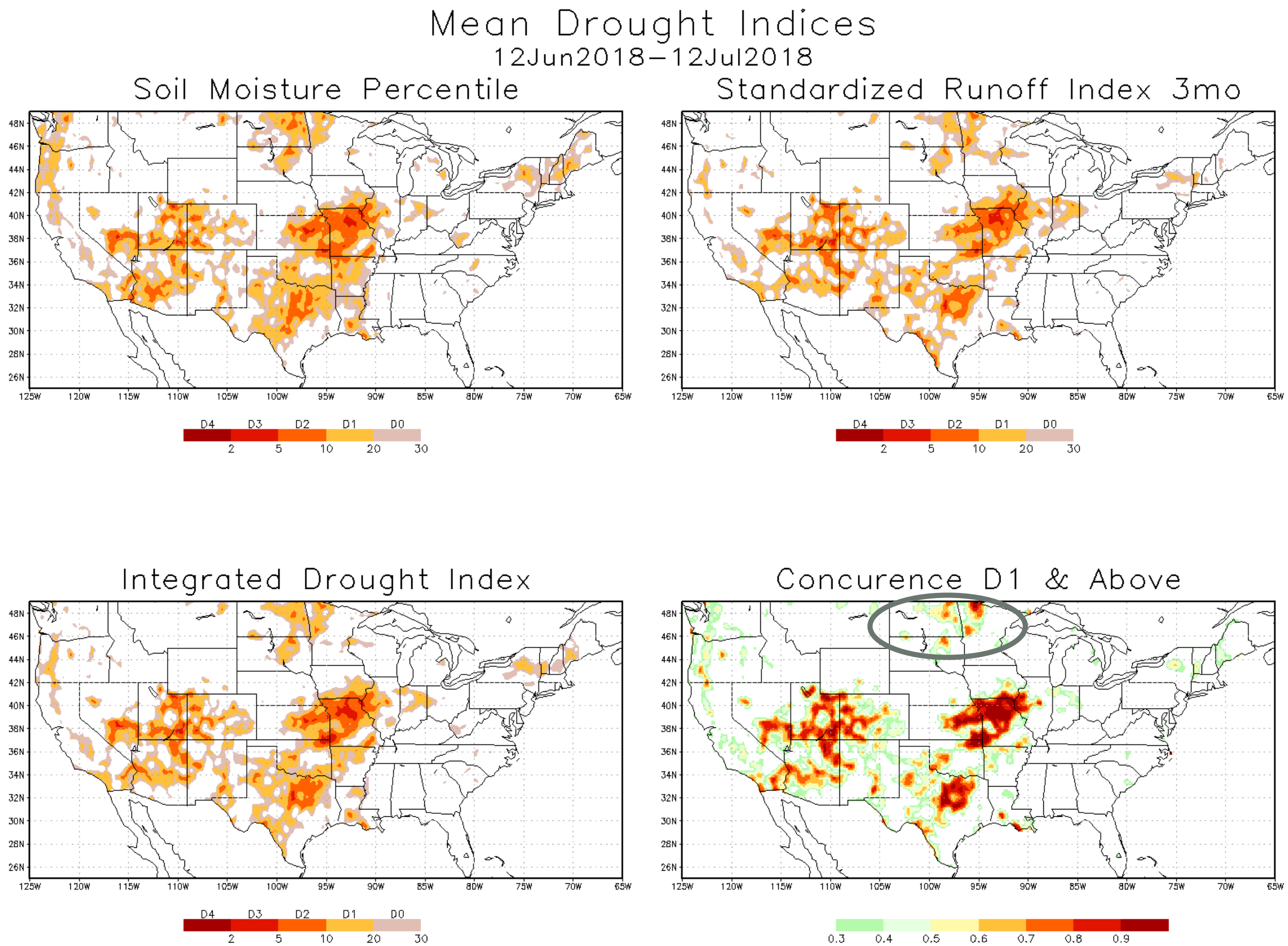
- Concurrence Measure– Uncertainties of the Grant mean:

  percentage of members agrees with the grand mean

Ref: Mo and Lettenmaier 2014)

# Operational drought monitoring

## Integrated drought index and Concurrence Measure based on the 4 NCEP/EMC models




Dr. Li Xu produces operational IDI daily

# b) Objective Drought Outlook

We have

- Variables : SRI3, SPI6 and SMP
- Models: CFSv2, CMC1, CMC2, GFDL and NASA and each model has 10 members (total 50 members)

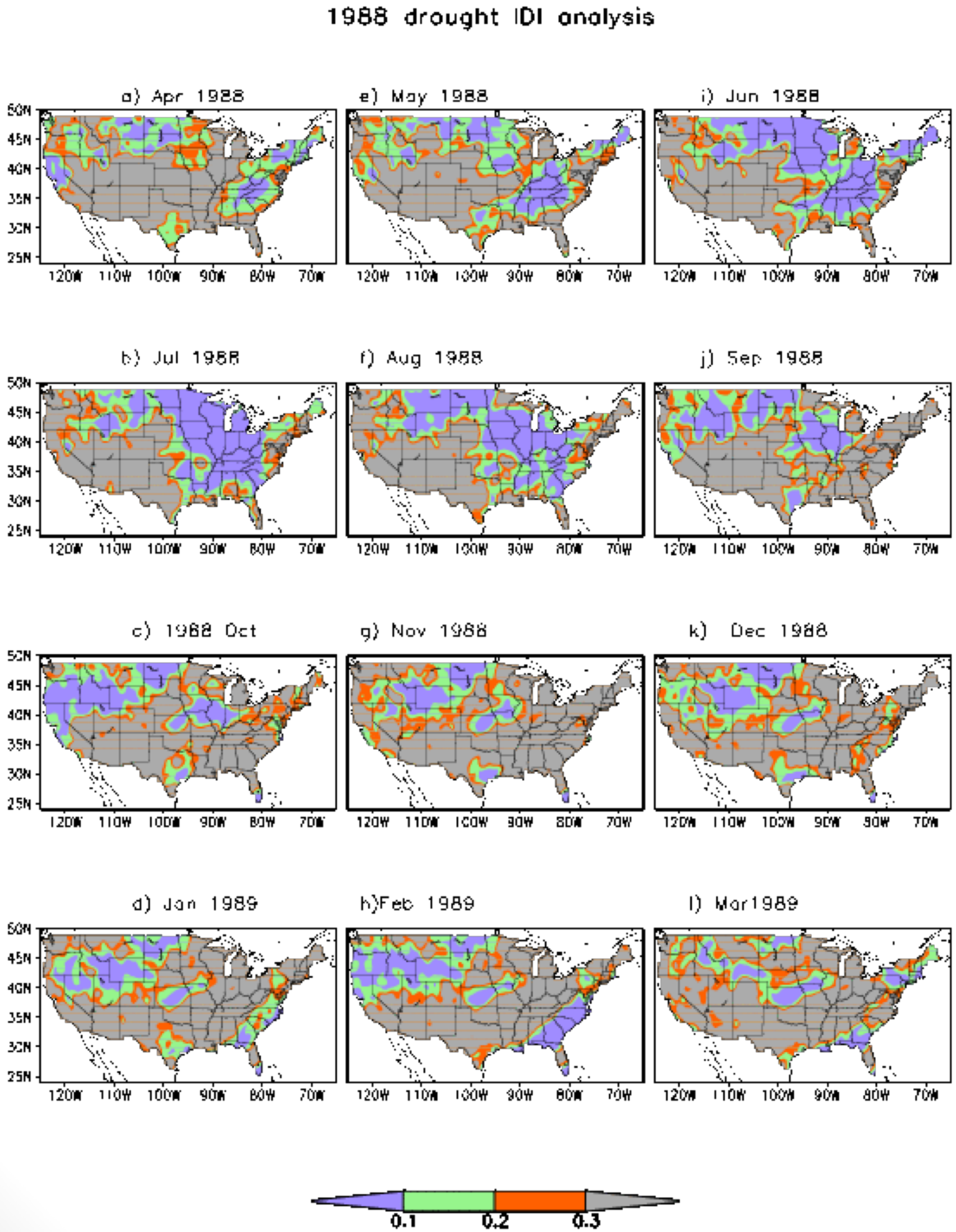
- Grand mean= the mean state of drought

= the mean of SPI6, SRI3 and SMP (in percentiles) from all 50 members and mapped onto a uniform distribution function (total 3x50 = 150 members)

- Probabilistic forecast: percentage of forecast members in D0-D4 and no drought categories

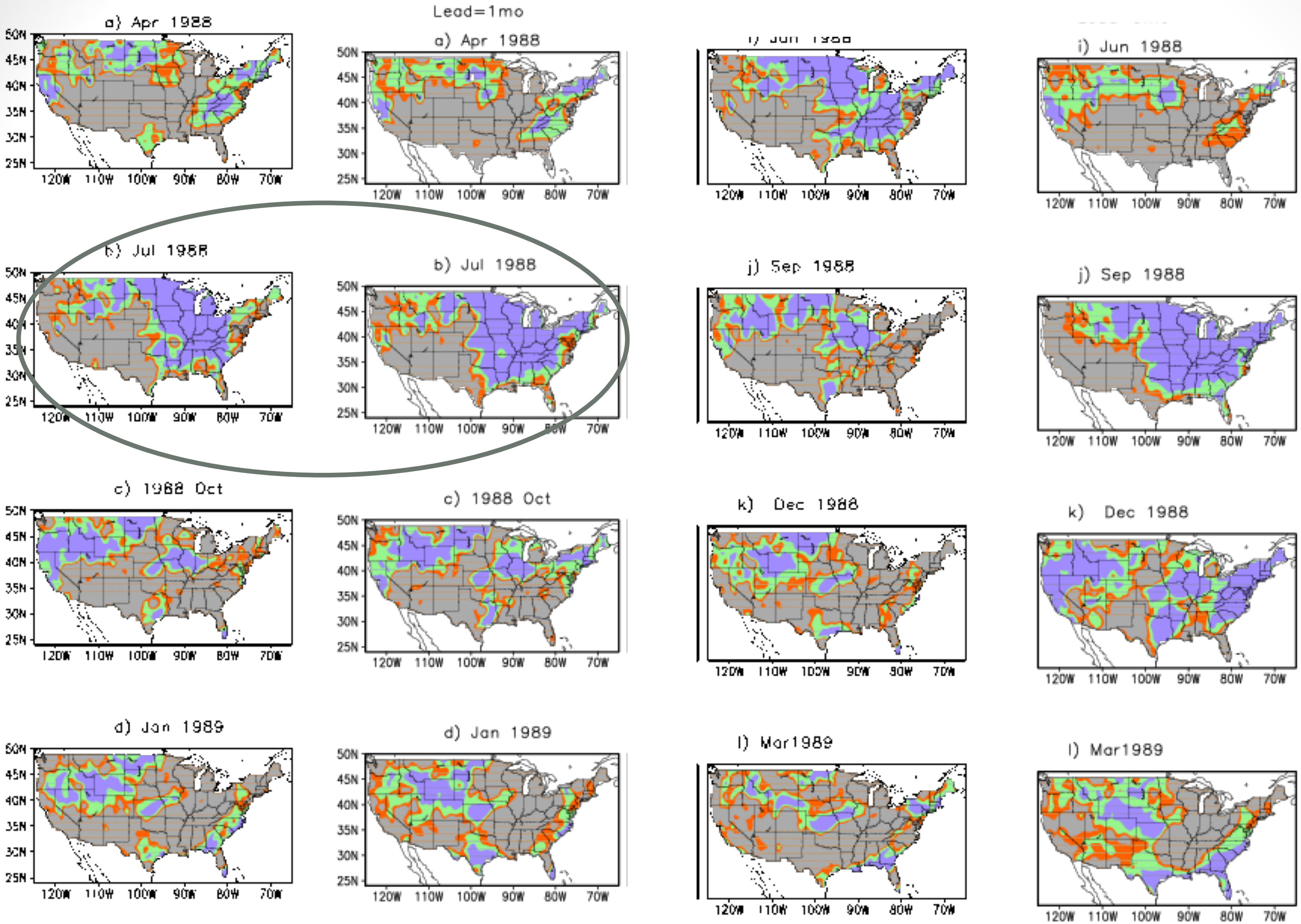
The same data used in Mo and Lettenmaier (2014)
Skill is high for SM and RO forecasts for lead 1 month due to initial conditions.

# An Example: 1988 drought depicted by the IDI (ana)




- The 1988 drought started from the eastern U.S. in April
- Expanded to the North and Northwest in June
- Drought in the eastern U.S. started to diminish in September while drought over the Northwest intensified
- Drought dissipated in 1989 winter

Verification IDI(ana) FCST lead1 Verification DI(ana) FCST lead3

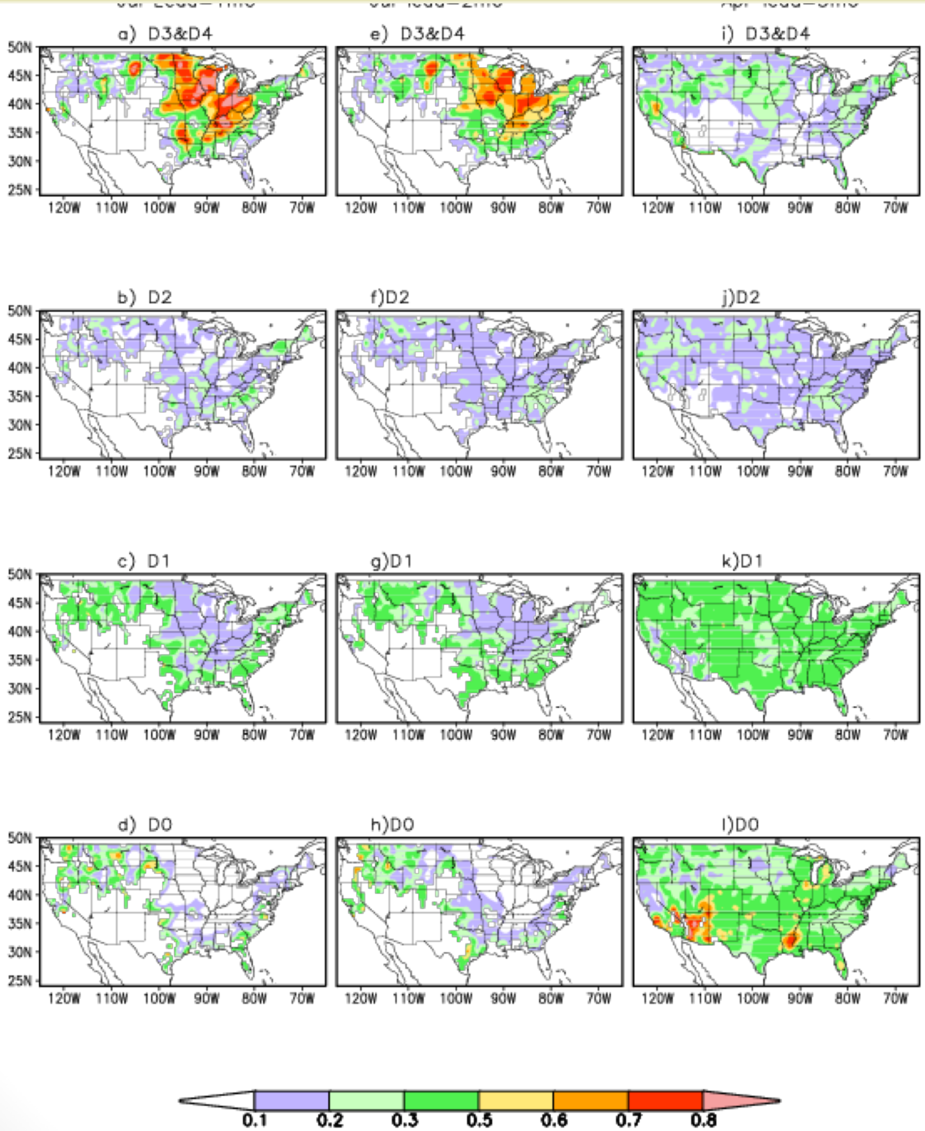



More persis -tent

- Verifying analysis :IDI from analysis

# Percentage of members in Dx (Dx=D0-D4) categories

| Ics | Lead=1mo July | Lead=2mo July | Lead=3mo April |
|---|---|---|---|




D3&D4

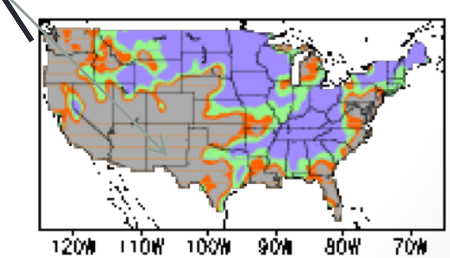
D2

D1

D0

- At lead=1mo,more than 70% members in D3 and D4
- At lead=3mo, percentage drops to less than 30%
- At Lead = 3 months ,drought strength decreases

Verification
1988 June

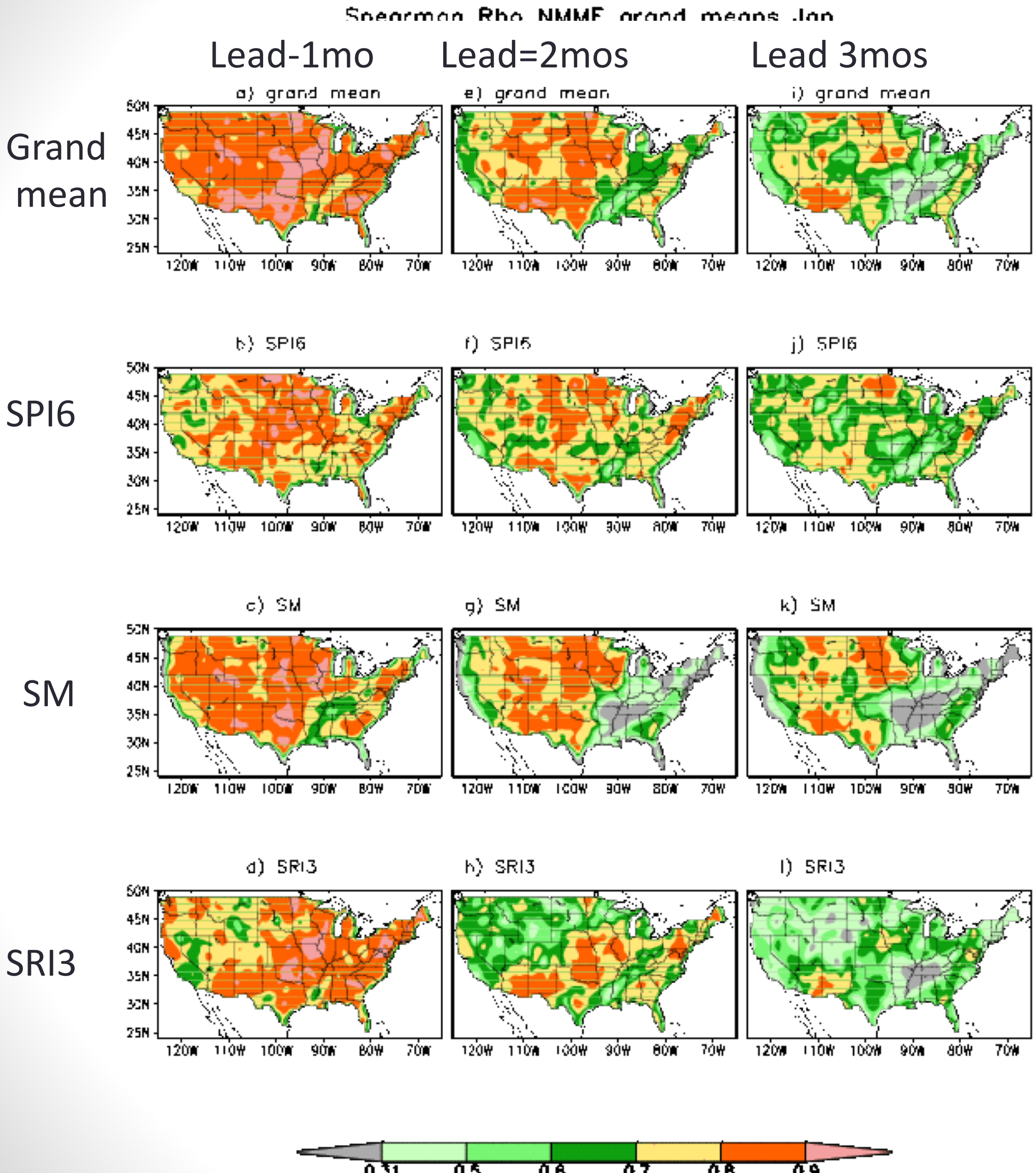


# Summary :the 1988 case

- For lead 1month, the NMME captures the evolution of drought.
- At lead=3 months, the grand mean forecast is more persistent than observations
- Forecasted drought is getting weaker as leads increase
- If this holds true, then the NMME at lead 1 month has good skill, but at lead 3 months, there is little skill

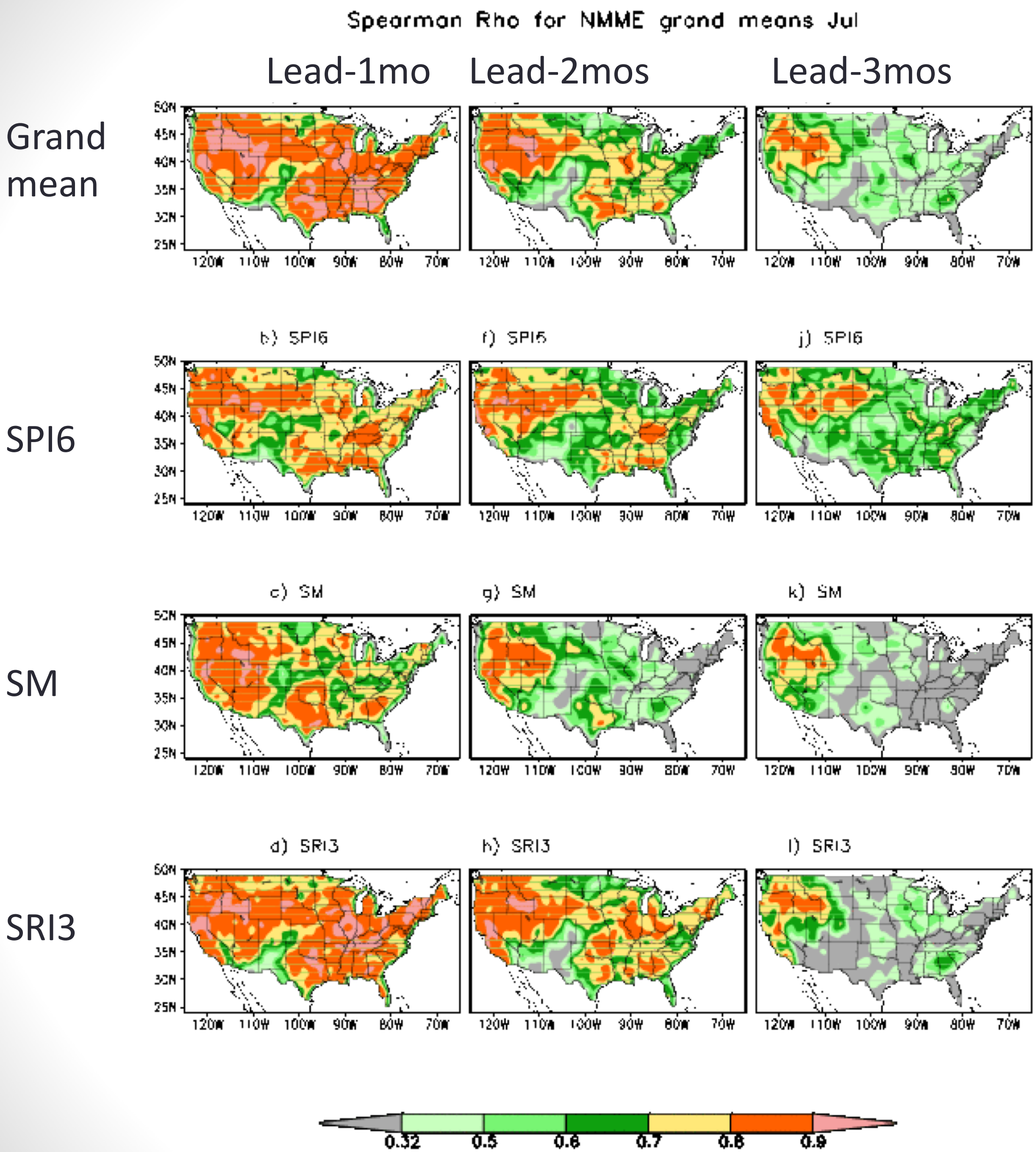
# verification

- We verify the forecasted grand mean against the IDI from analysis
- To verify the grand mean, we use  Spearman ranking correlation ( If we assume 29 degrees of freedom, then we need Rho to be above 0.37  to be statistically significant at the 5% level)
- For probabilistic forecasts, we use the  Equitable Threat Score (ETS to) measure the ability for the NMME to forecast drought




# January

1. Grand mean has higher or equal skill than the individual mean index;
2. Skill is higher over dryer areas and areas where correlations with P are low
3. Skill is low over dynamically active areas. e.g. along the path of the low level jet and the west coast



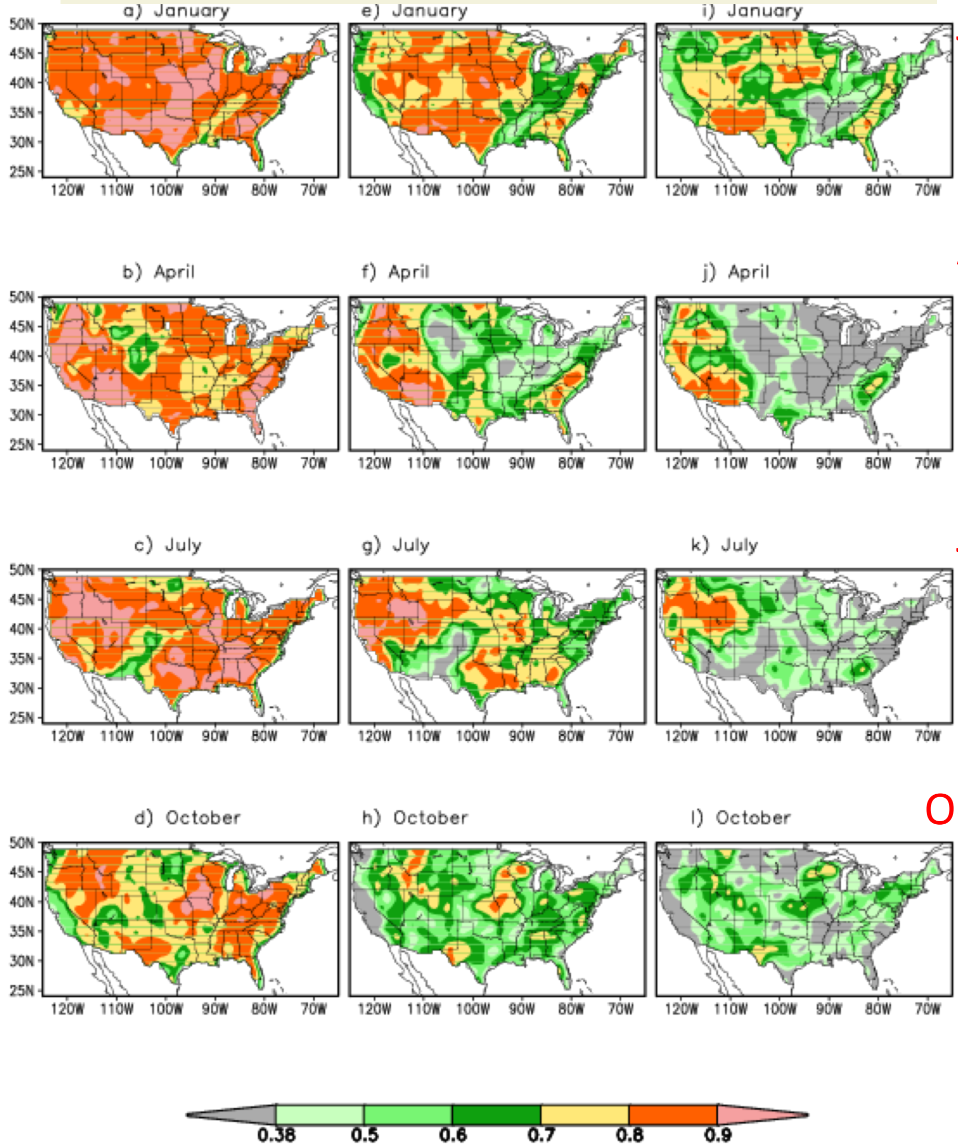

# July

- Grand mean still has higher or equal skill than individual mean index
- SM and runoff over the western region -> more persistence-> higher skill
- NMME P can not forecast monsoon and so skill is lower over the Southwest

## Skill of the grand mean

Spearman Rho for the IDI grand mean

Lead=1mo Lead=2mos Lead=3mos




Jan

April

July

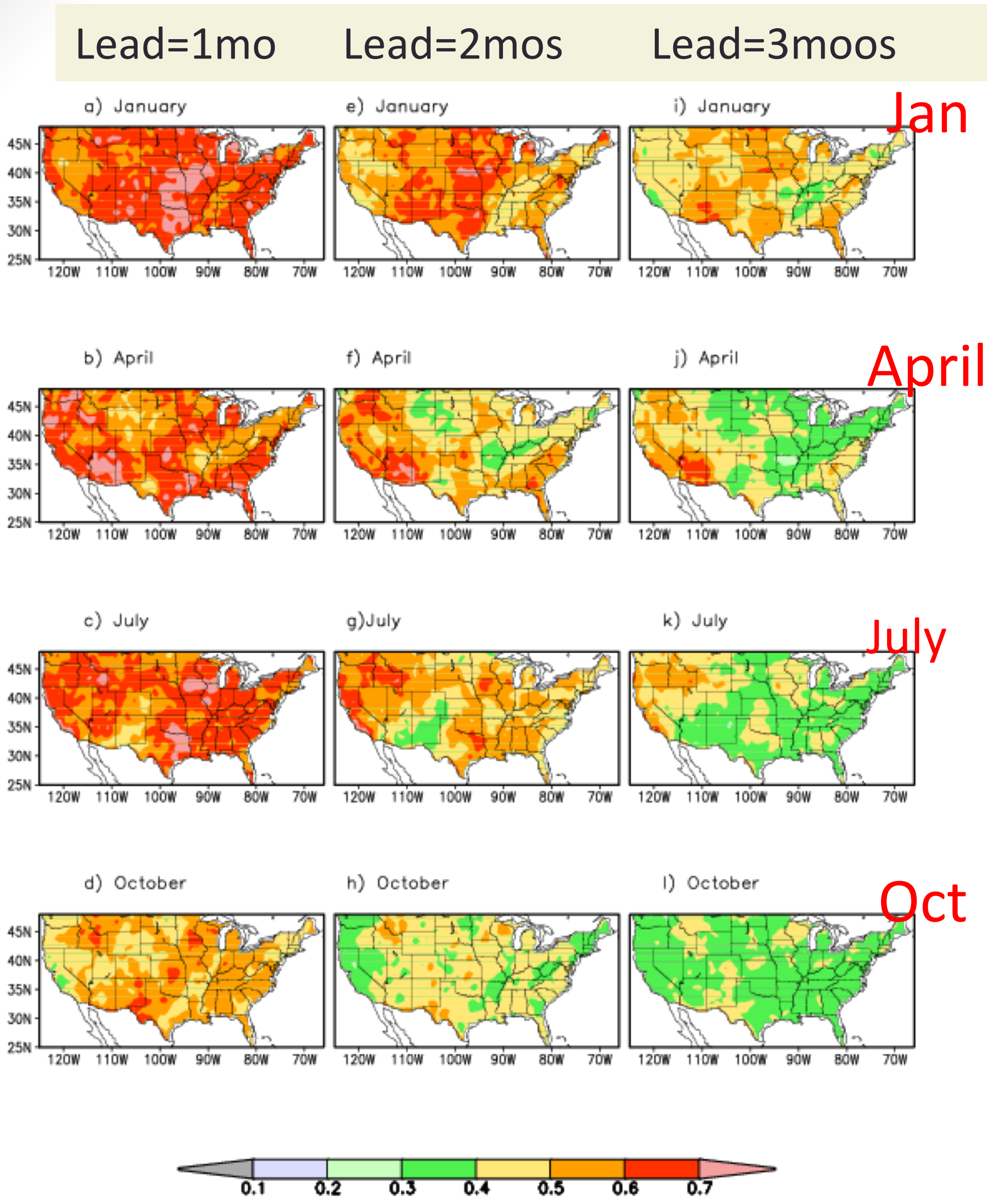
Oct

1.Winter fcsts have the highest skill over dry areas

2. In April, fcsts do not capture the snowmelt well

3. The fcsts do not capture the North American monsoon

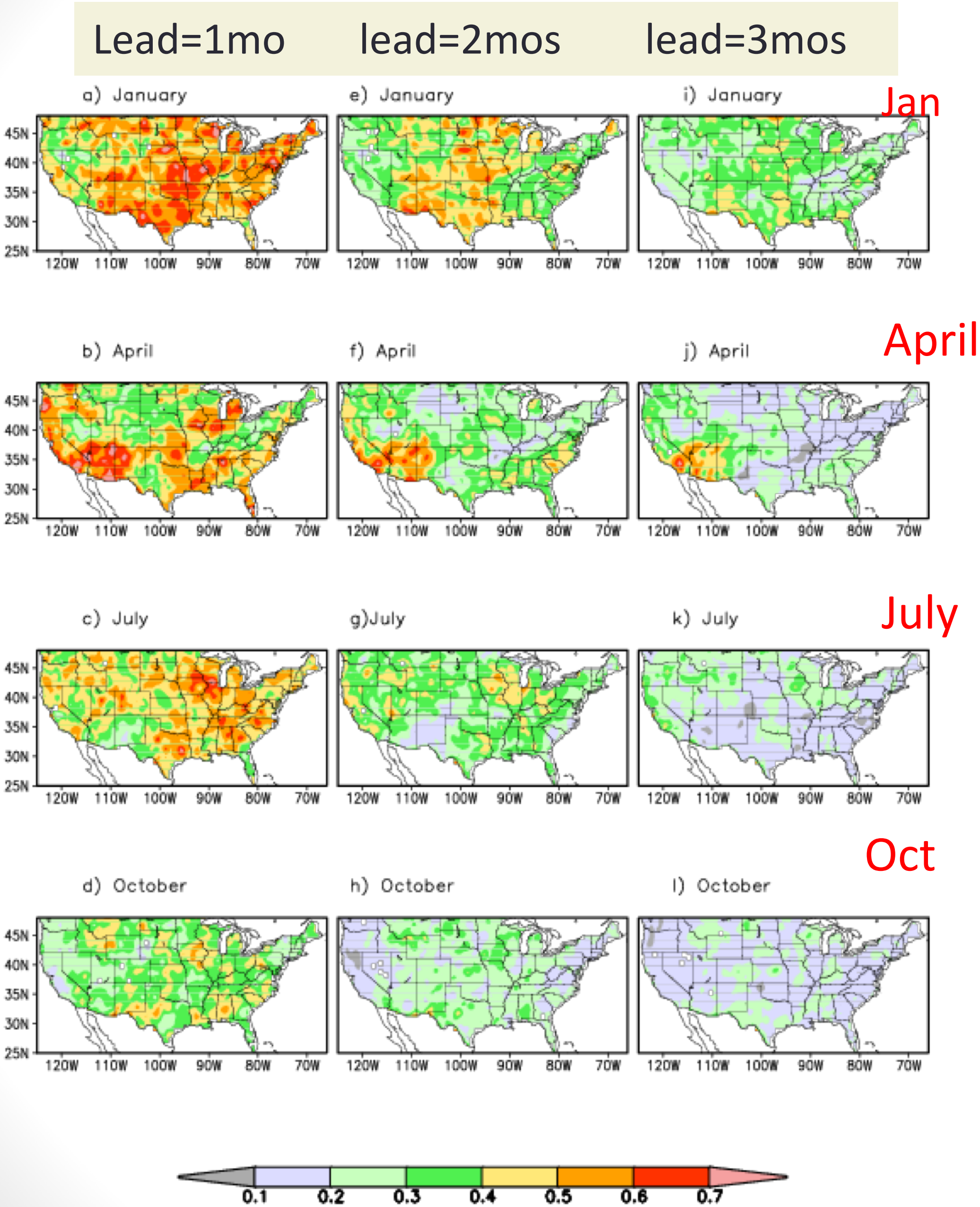
4. Skill is lower over dynamical active areas




# If observations indicate D0 or higher drought, percentage of members concurs

1, The concurrence is high for winter and for lead=1month

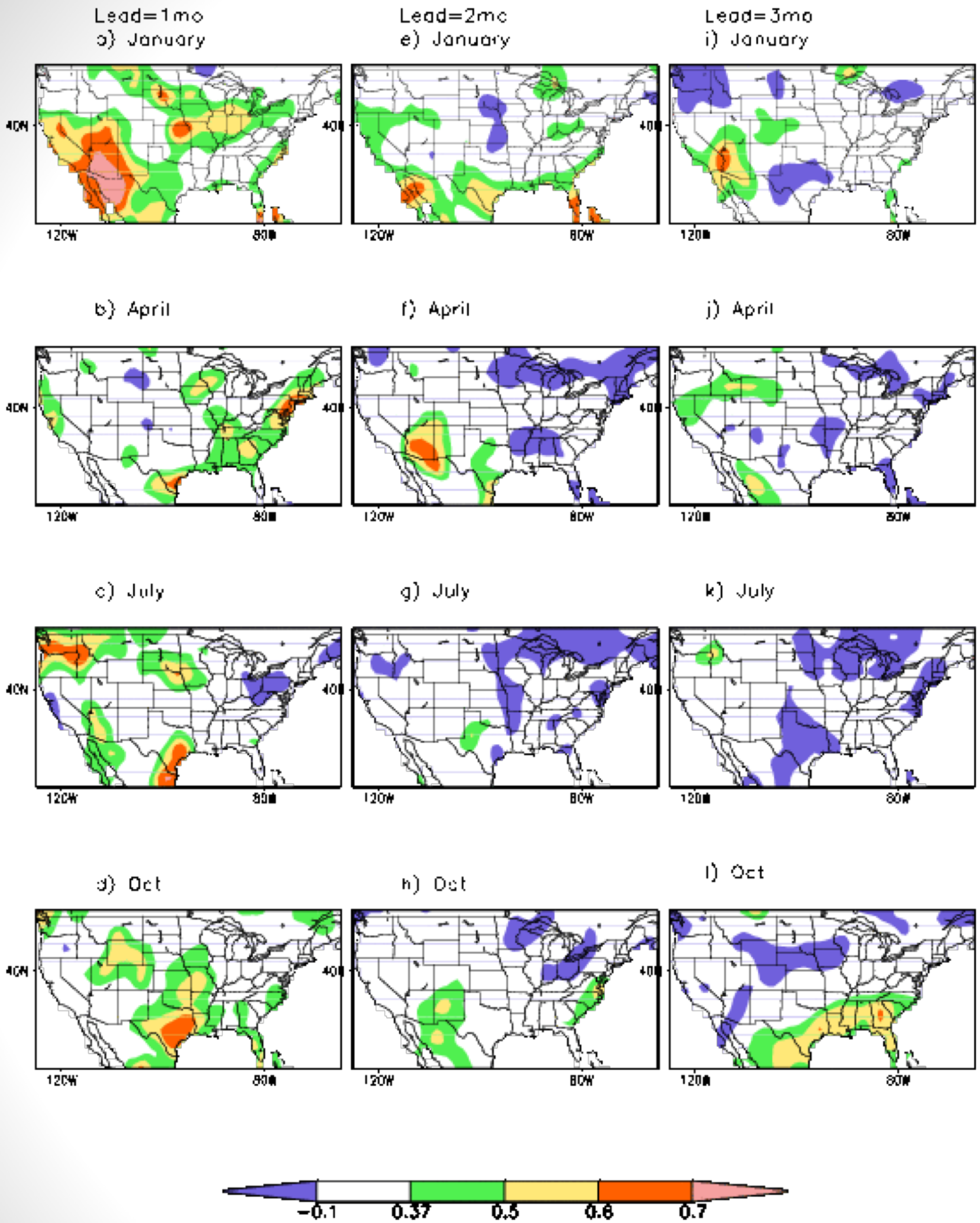
2. The concurrence for Lead=3months is low except for winter




If observations indicate D2 or higher drought, percentage of members concurs

For D2 and higher, the concurrence skill drops
It indicates that forecasts have large uncertainties
At lead=3mos, there are less than 40%members concur

This suggests that the NMME underestimates drought strength




# anomaly correlation for the ensemble P Forecasts

For hydroclimate forecasts

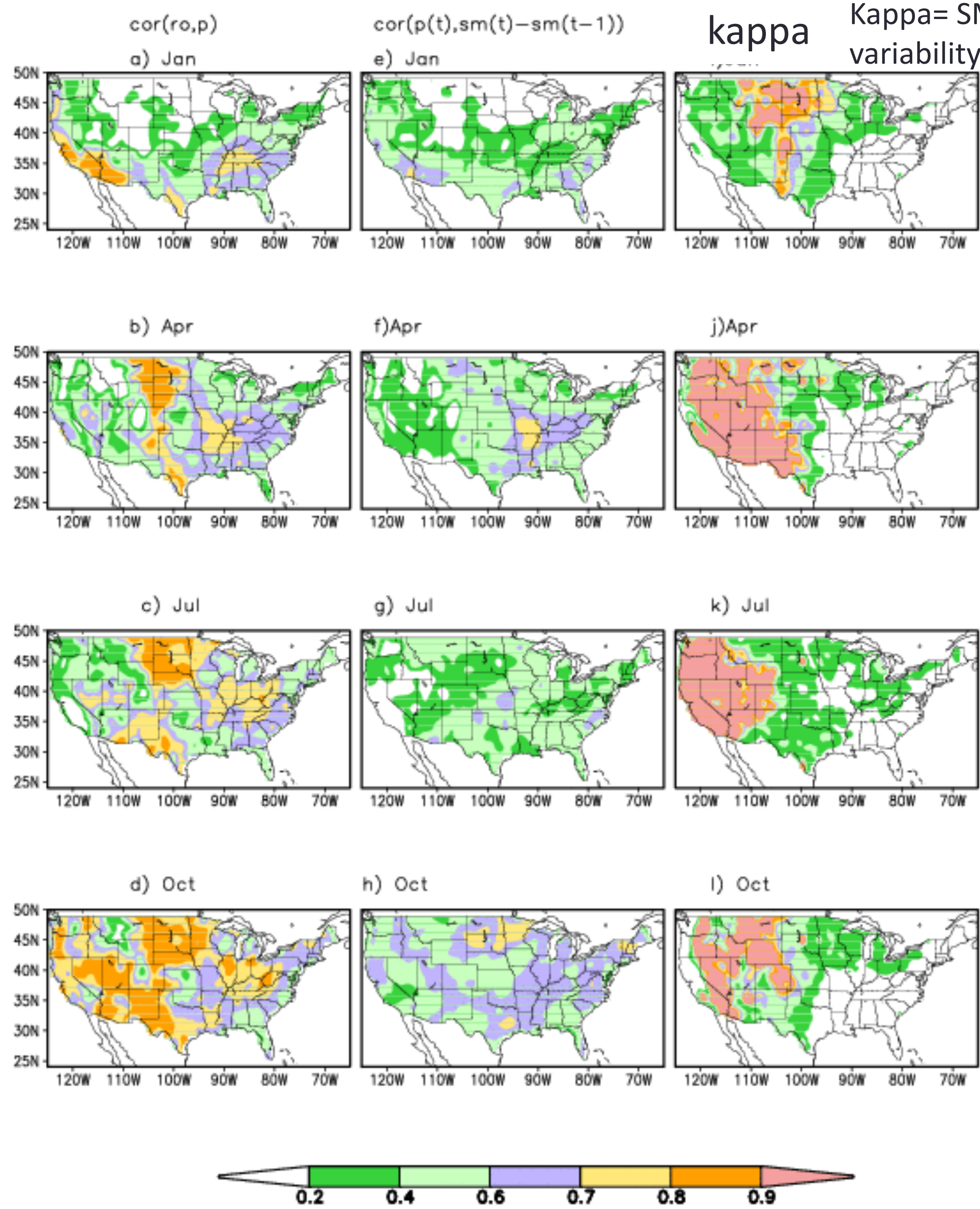
- IC s dominate the contributions to forecast skill at Lead-1
- When the CGCM forecasts start to contribute at Lead-2 or higher, the skill of P forecasts is so low, it does not make a difference

Purple means negative skill

No skill after Lead-1, Except the Southeast in Oct

Base period 1982-2010

Kappa= SM variability at IC/P variability




Where does skill come from?

Initial condition controlled regime: high skill

e.g. western interior region

More persistent

Smaller kappa

Less correlation with P

Dynamical forcing controlled regime : low skill

Model can not forecast that well

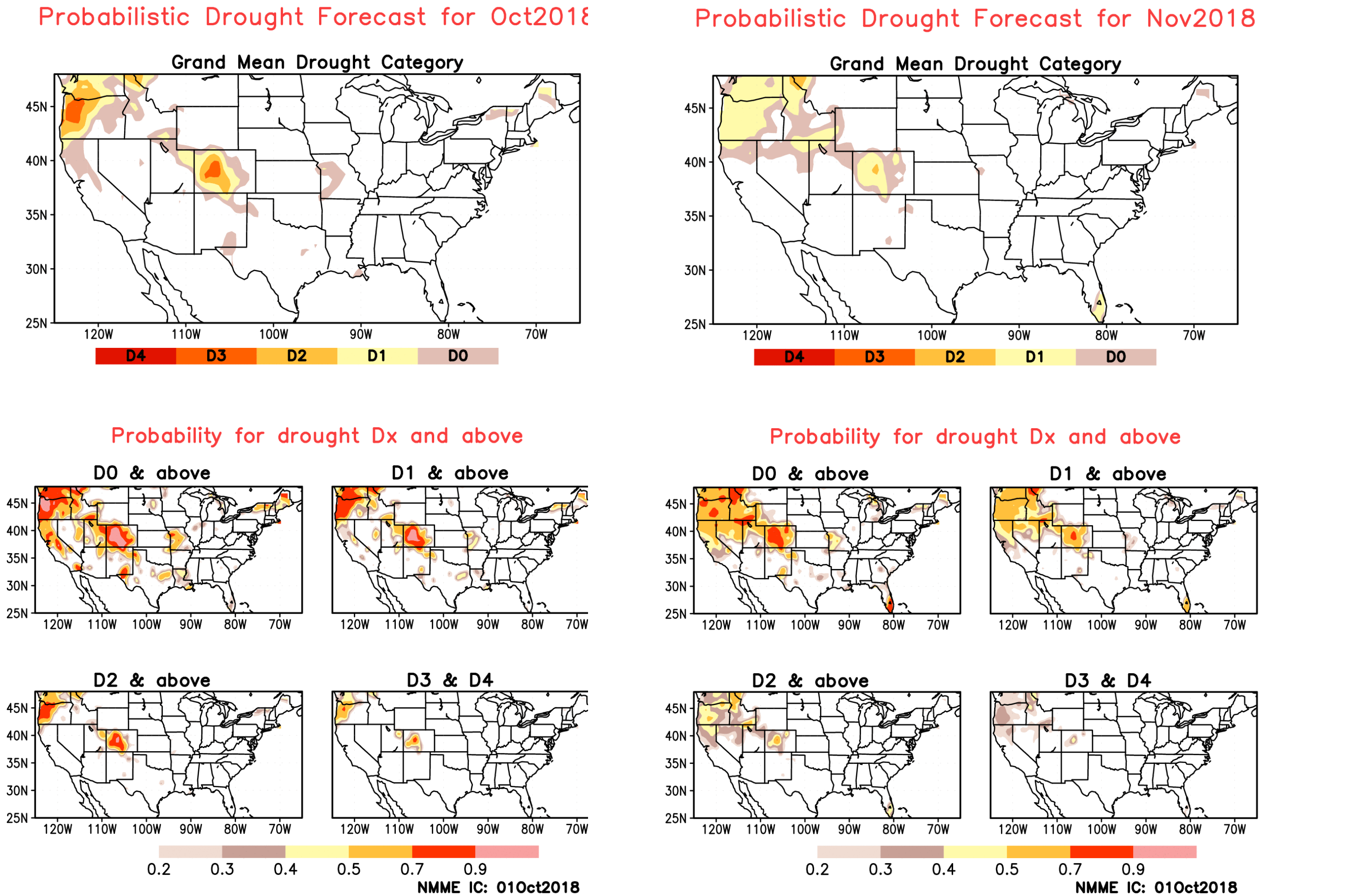
ref: Mo and Lettenmaier 2014

Shukla and Lettenmaier 2011

# Forecast skill

- Grand means have higher skill because ensemble mean SPI6, SRI3 and SMP have skill in different areas so the average ( grand mean) has higher skill
- The NMME P has some skill at lead 1 month. After that, skill drops quickly. This has large impact on SMP and SRI3 forecasts. After lead 1 month, skill decreases and uncertainties increases.
- The NMME hydroclimate forecasts are able to forecast the drought categories at lead=1 month due to the initial conditions. At lead= 2 months, the forecasts may recognize drought, but NOT able to capture the categories. At lead=3 months, lost cause.

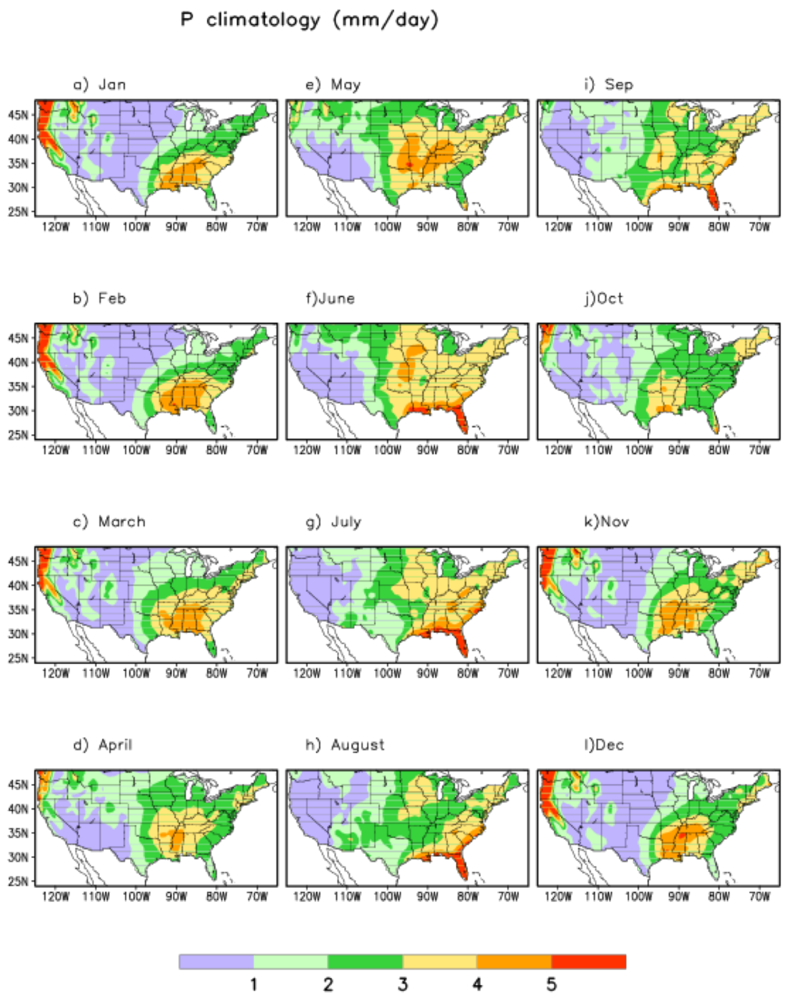
# Operational probabilistic meteorological drought SPI6 forecasts based on the P forecasts from the NMME (IC :1Oct 2018)




Dr. Li Xu products each month

# Future Improvement (dream?)

- 1. Drought monitoring is based on the NCEP EMC NLDAS only. It has four NLDAS models so It takes into consideration of diversity of land surface models, but they are all driven by the same forcing. It will be nice to include the UCLA NLDAS. Their forcing is differently from the EMC.
- 2. We only forecast SPIs. We consider to perform the hydroclimate forecast of SM and runoff. Then we can forecast the IDI (a more representative variable of drought status)
- 3. The hydroclimate forecasts are based on the VIC model. Will add more land models increase the skill of probabilistic forecasts?

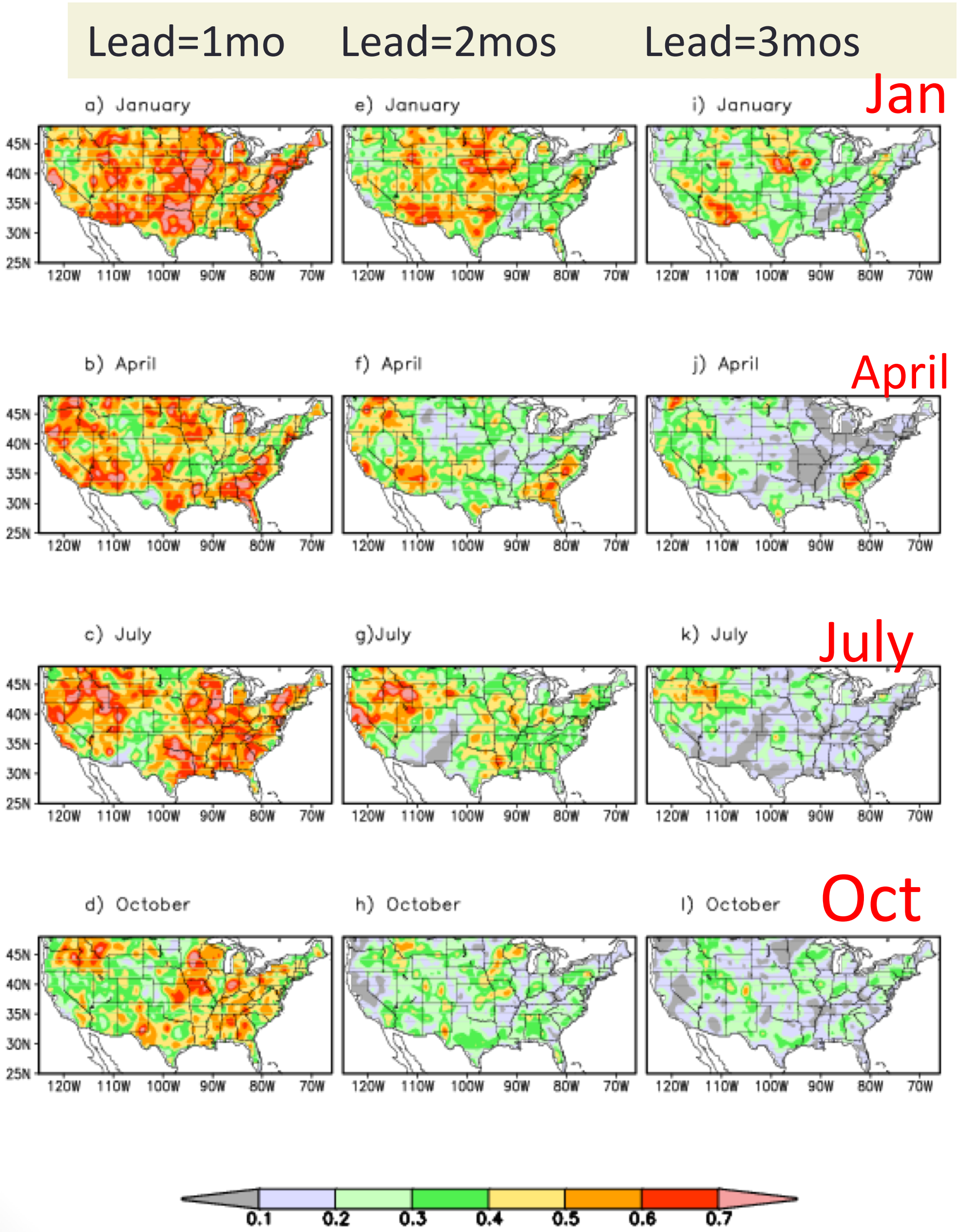

P climatology (mm/day)
a) Jan
e) May
i) Sep
b) Feb
f)June
j)Oct
c) March
g) July
k)Nov
d) April
h) August
l)Dec
45N
40N
35N
30N
25N
120W
110W
100W
90W
80W
70W
1
2
3
4
5

# Contingency Table : Equitable Threat Scores

- If both fcst and obs indicate drought: hit
- If fcst indicates drought, but not obs: false alarm
- If obs indicates drought, but not fcst: Miss
- The ETS score is for two category forecasts

ETS=$\frac{hIts - hits_{random}}{Hits + misses + false\ alarm - hits_{random}}$

- Where $hits_{random} = \frac{(hits+misses)(hits+false\ alarms)}{Total\ length}$
- The ETS score has the range from -1/3 to 1. Zero indicates no skill and perfect score is 1




# ETS for the grand mean

The ETS is similar to the concurrence
Skill is higher over winter and for lead=1