Drought Monitoring and Prediction over the United States: Current Status and challenges

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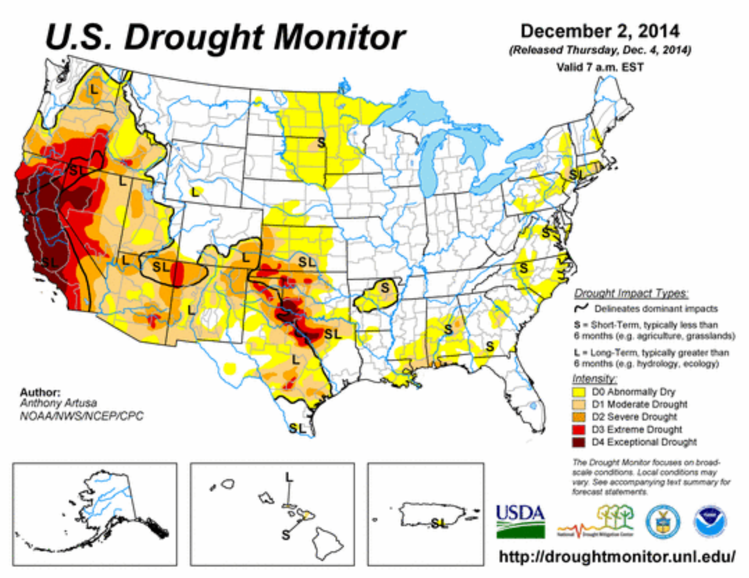
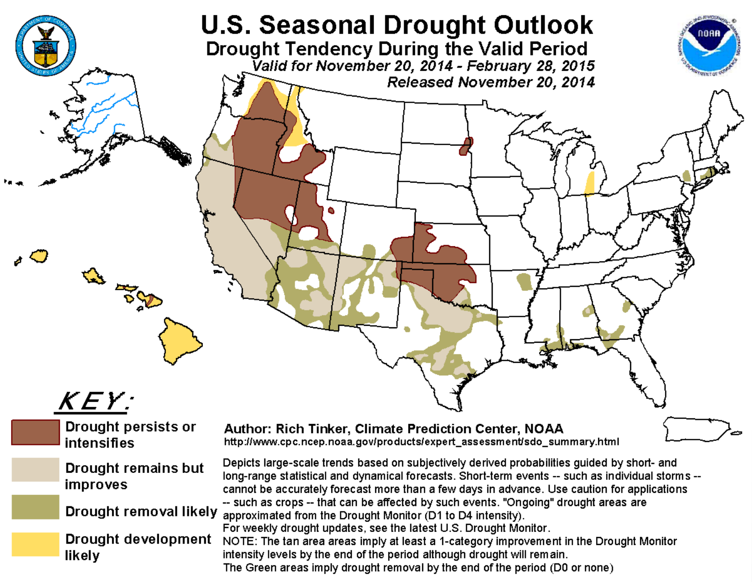
outline

- 1. How do we monitor drought over the U.S.?
- 2. How well can we forecast drought?
- 3. Challenges to expand to global domain.
- 4. Work together to advance

Mission

- CPC issues operational monthly and seasonal drought outlook and participates as U.S. Drought Monitor Authors.
- To support operational drought monitor and drought outlook, we give drought briefing each month to review the current drought conditions and drought forecasts



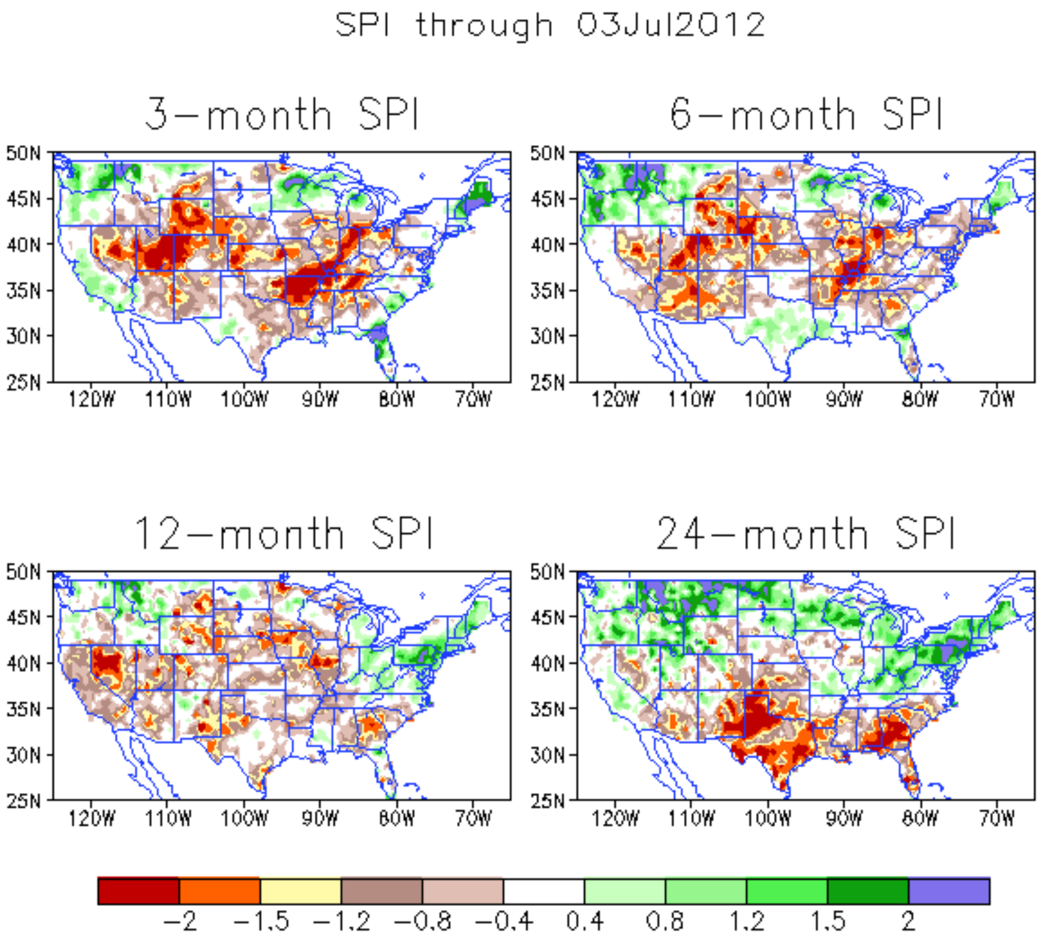


How do we currently monitor Drought ?

We use Drought indices

- Meteorological drought: Precipitation deficit. (Standardized precipitation Index: SPI index)
- Hydrological drought: Streamflow or runoff deficit (Standardized runoff index: SRI index)
- Agricultural drought: Total soil water storage deficit or soil moisture at the root zone deficit

(Total soil moisture percentile)



SPI

Advantages:

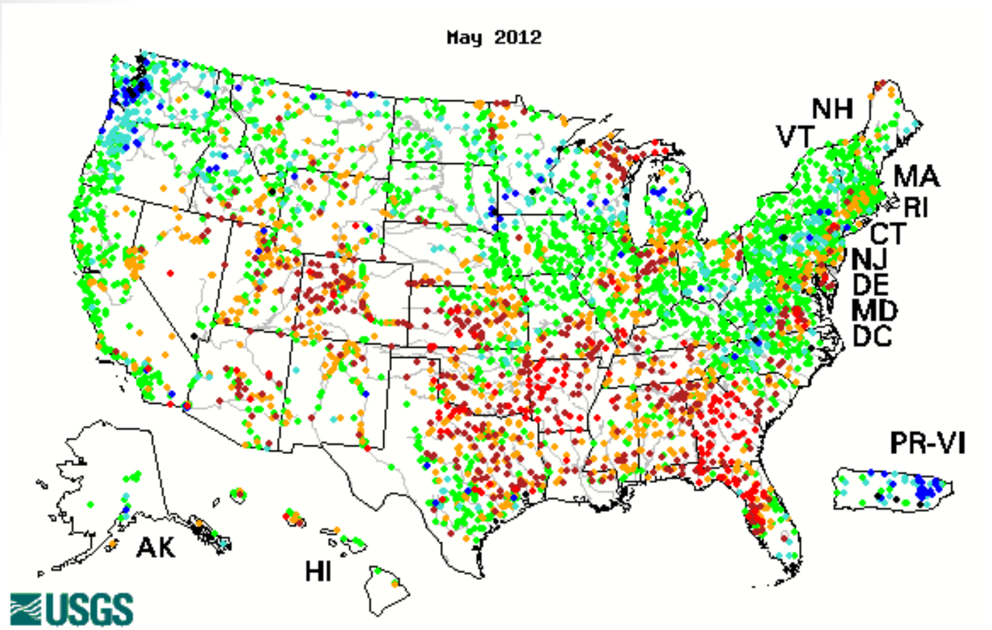
- Information on shorter and longer time scales
- Do not need models, we only need station data

Disadvantages

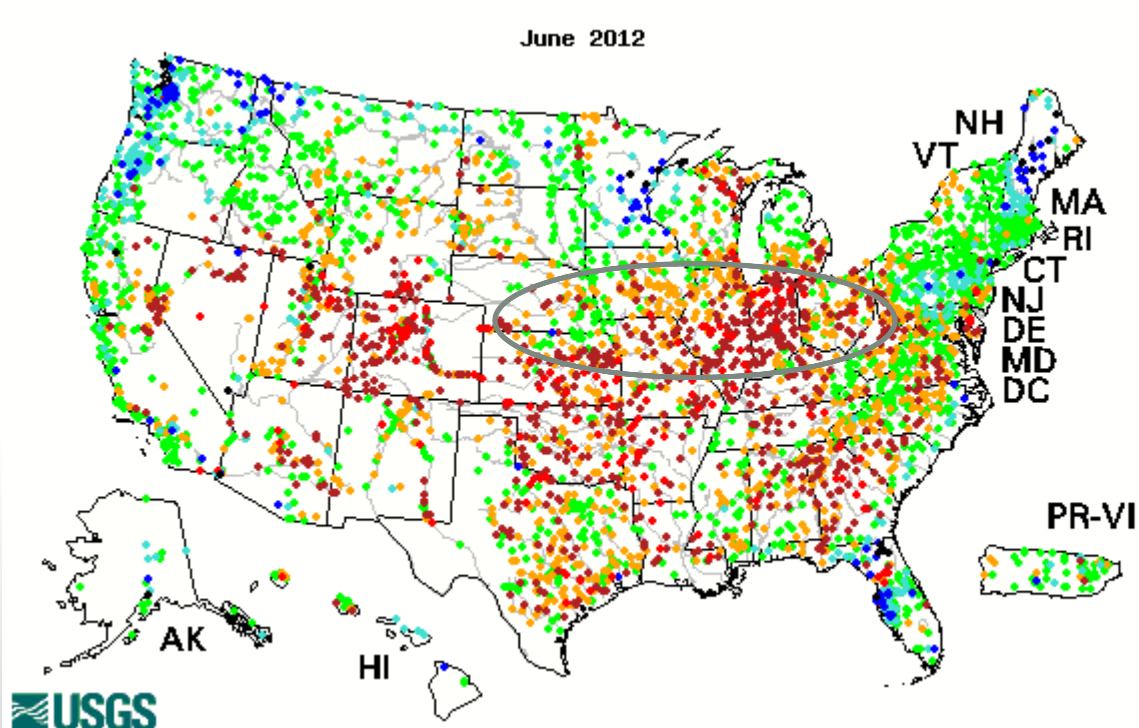
- No snow information
- Ares where E is large, it will not be representative

- *Dryness over the Northern Plains continues . It lasted for more than 6 months so they appeared in SPI3, SPI6 and even SPI12.*
- *For the Southeast, drought got some relieve*
- *For SPI3, areas east of 90W recovered from drought*

streamflow percentile (USGS)



Indicate river conditions – hydrological drought



In situ data for monitoring

ıation - Percentile classes					
0-24	25-75	76-90	>90	High	No Data
›elow ormal	Normal	Above normal	Much above normal		

North American Land Data Assimilation system

- Surface land model- Noah, SAC, VIC, Mosaic and Catchment model
- They are driven by forcing which consists of precipitation (P),   Max and min Tsurf and wind speed for a water balance model
- Some models have the energetics –radiation terms
- Outputs: Evaporation, Soil moisture, soil temperature, runoff , Snow water equivalent. And many others

The EMC NCEP system

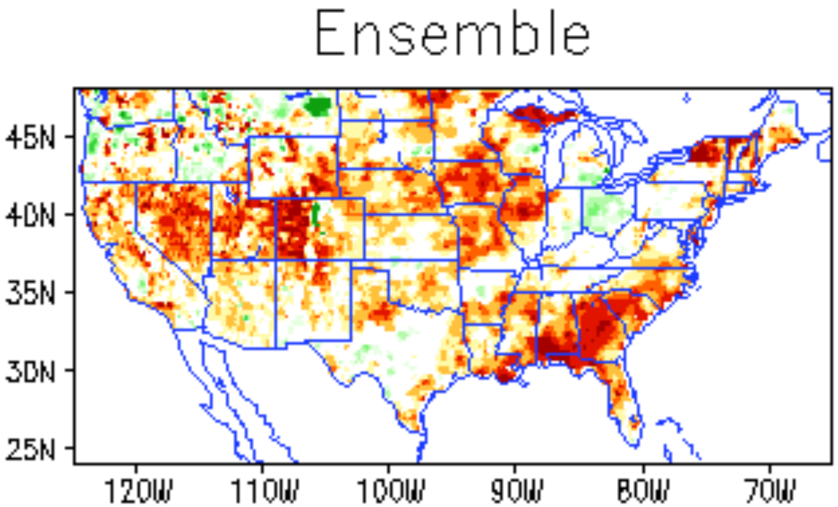
- Four models: Noah, VIC, Mosaic and SAC
- Climatology: 1979-2012
- On 0.125 degrees grid
- P forcing : From the CPC P analysis based on rain gauges with the PRISM correction.
- Other atmospheric forcing: From the NARR

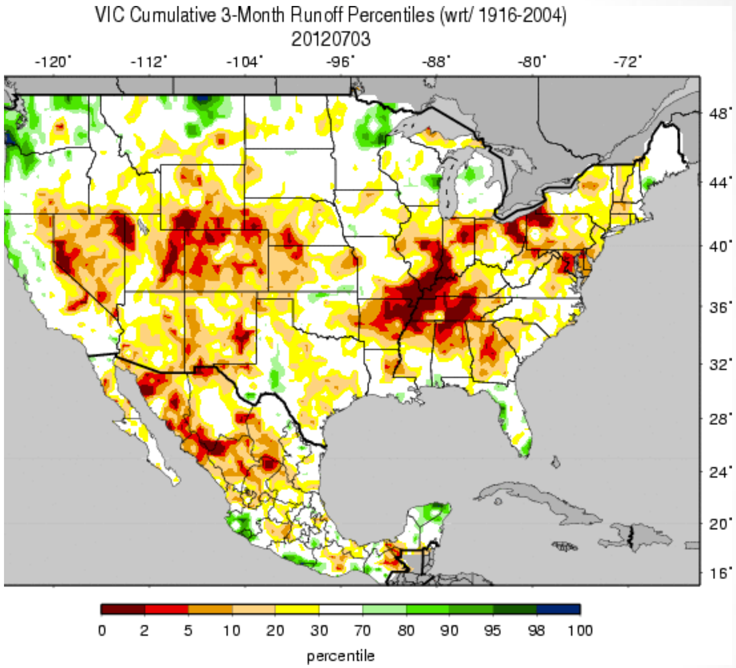
The UCLA/U Washington system

- Four models: Noah, VIC, SAC and CLM
- Climatology: 1915-2012
- On 0.5 degrees grid
- P, Tsurf and low level winds from NOAA/NCDC co-op stations
- P from index stations

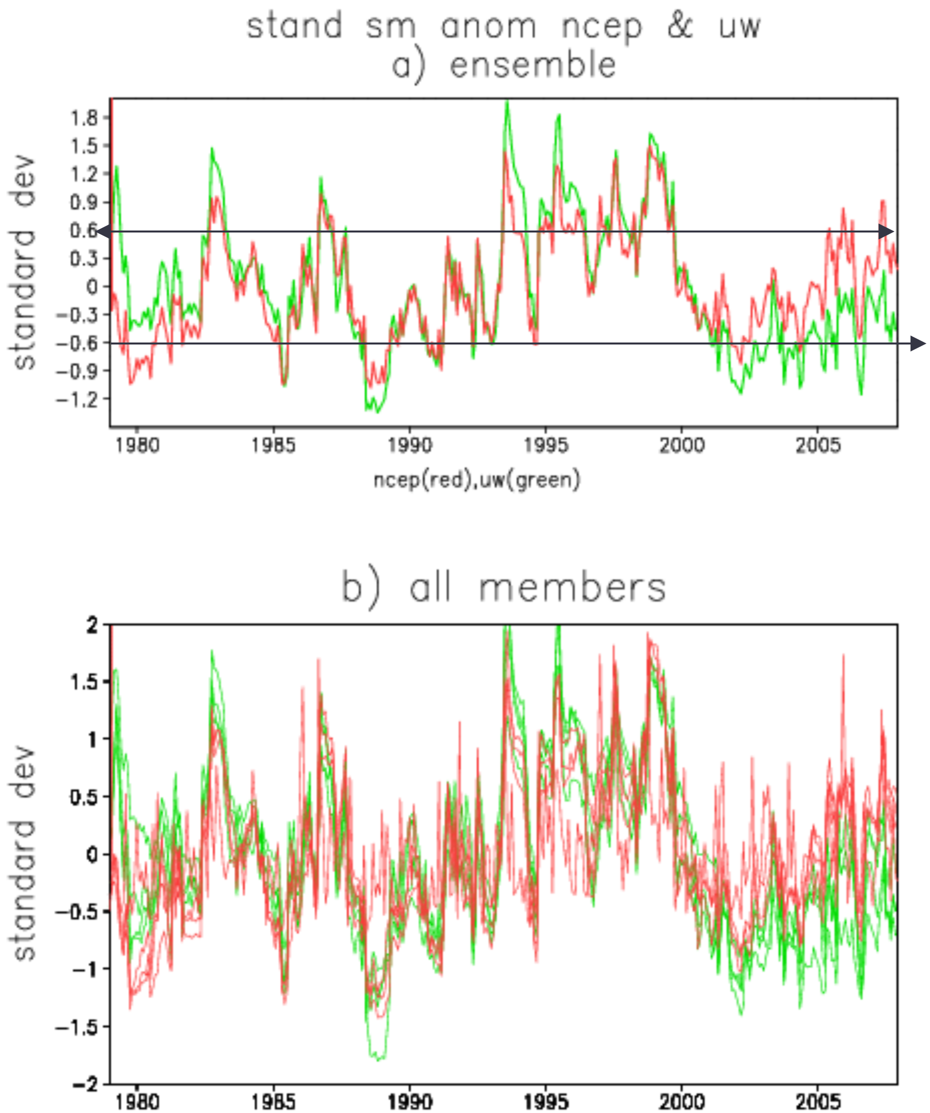
EMC/NCEP

UCLA/U Washington





Both total soil moisture percentiles show dryness over the North Central and New Mexico
But there are differences



standardized SM anomalies for area 38-42N,110-115W

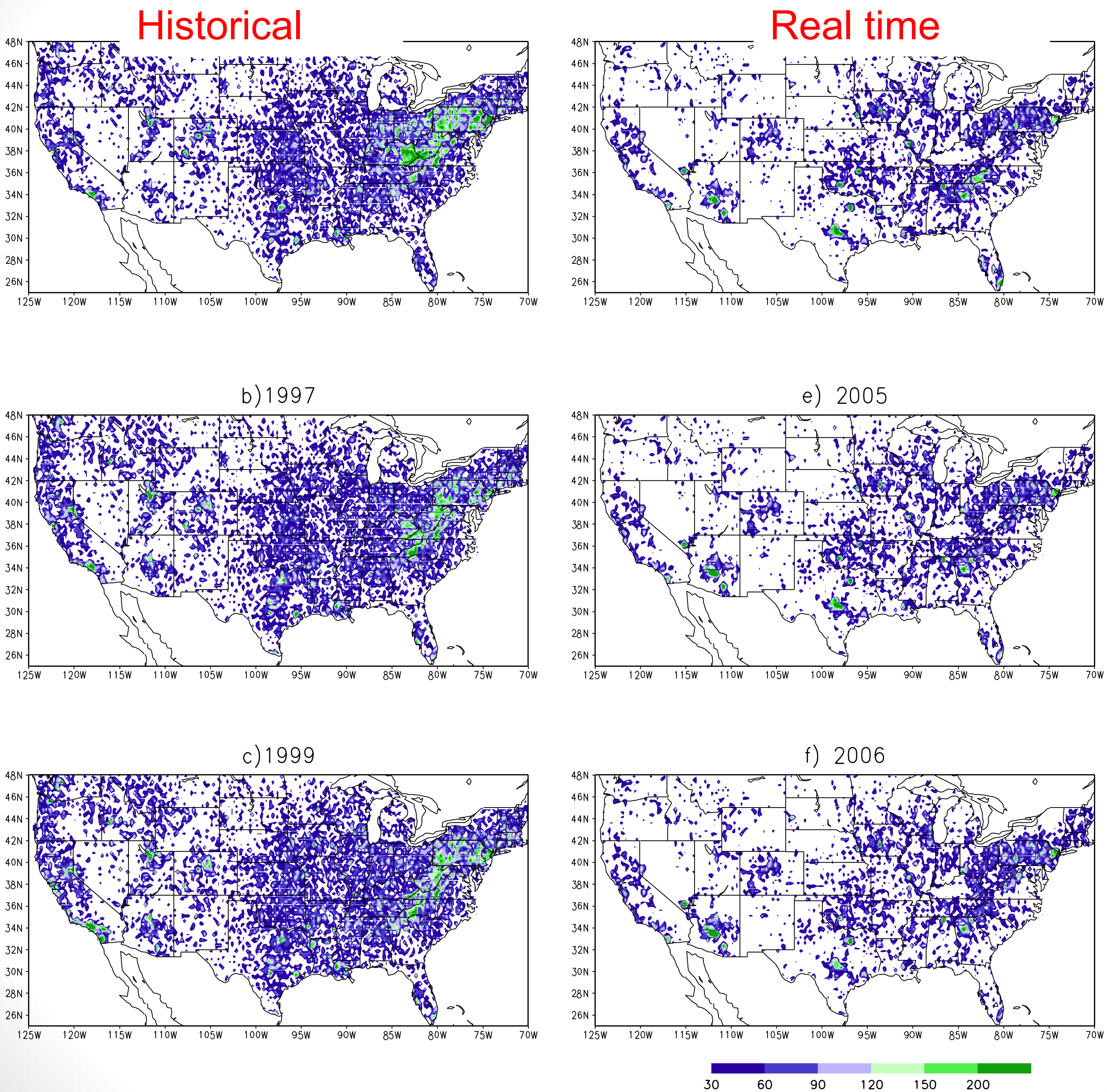
NCEP(red),UW(green)

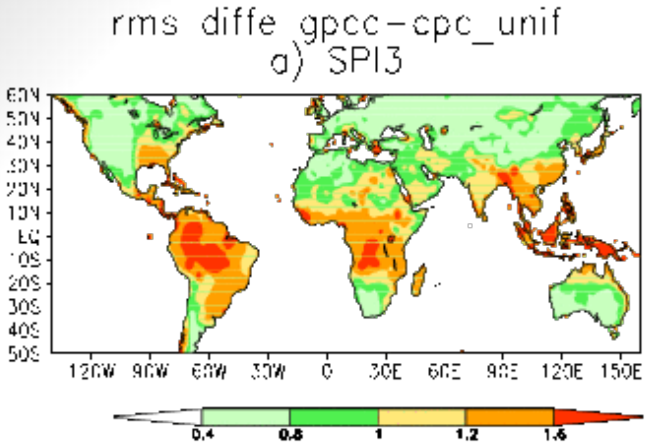
Uncertainties between systems

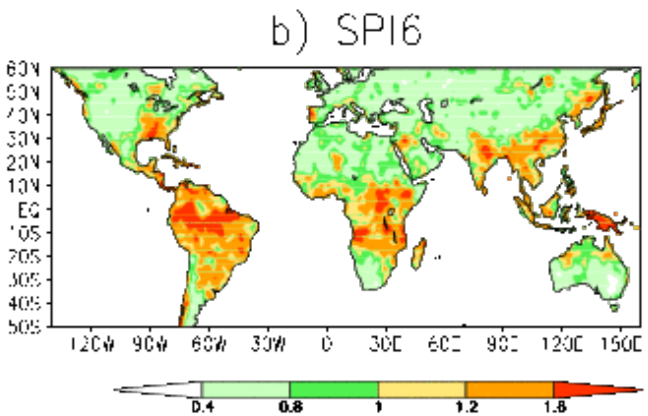
- Differences between two systems are larger than the spread among members of the same system
- The differences are not caused by one model. They are caused by forcing.
- In general, extreme values from the UW (Green) are larger than from the NCEP (red)

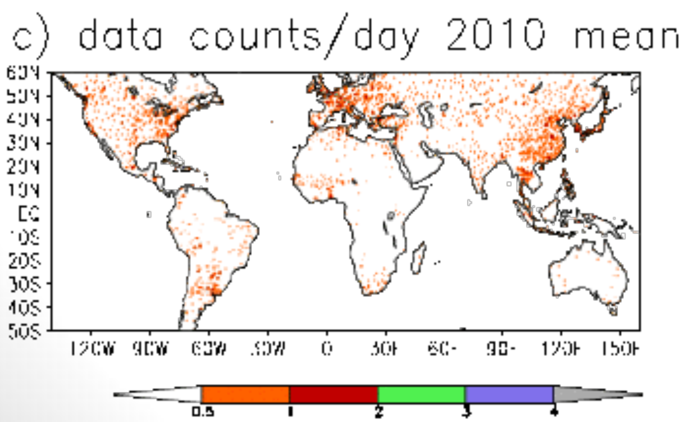
Ref: Mo et al 2012

Number of station reports averaged over a year









Global rms differences bet GPCC and CPC unified 1979-2010

Differences are larger than 1.2 for Tropics, South America and Africa

If -1.2 is the threshold for drought, then differences are too large for drought classification

The station counts indicate that there are so few stations in Africa, South America.
There is basically no input.

Ref: Mo and Lyon 2014

Problems

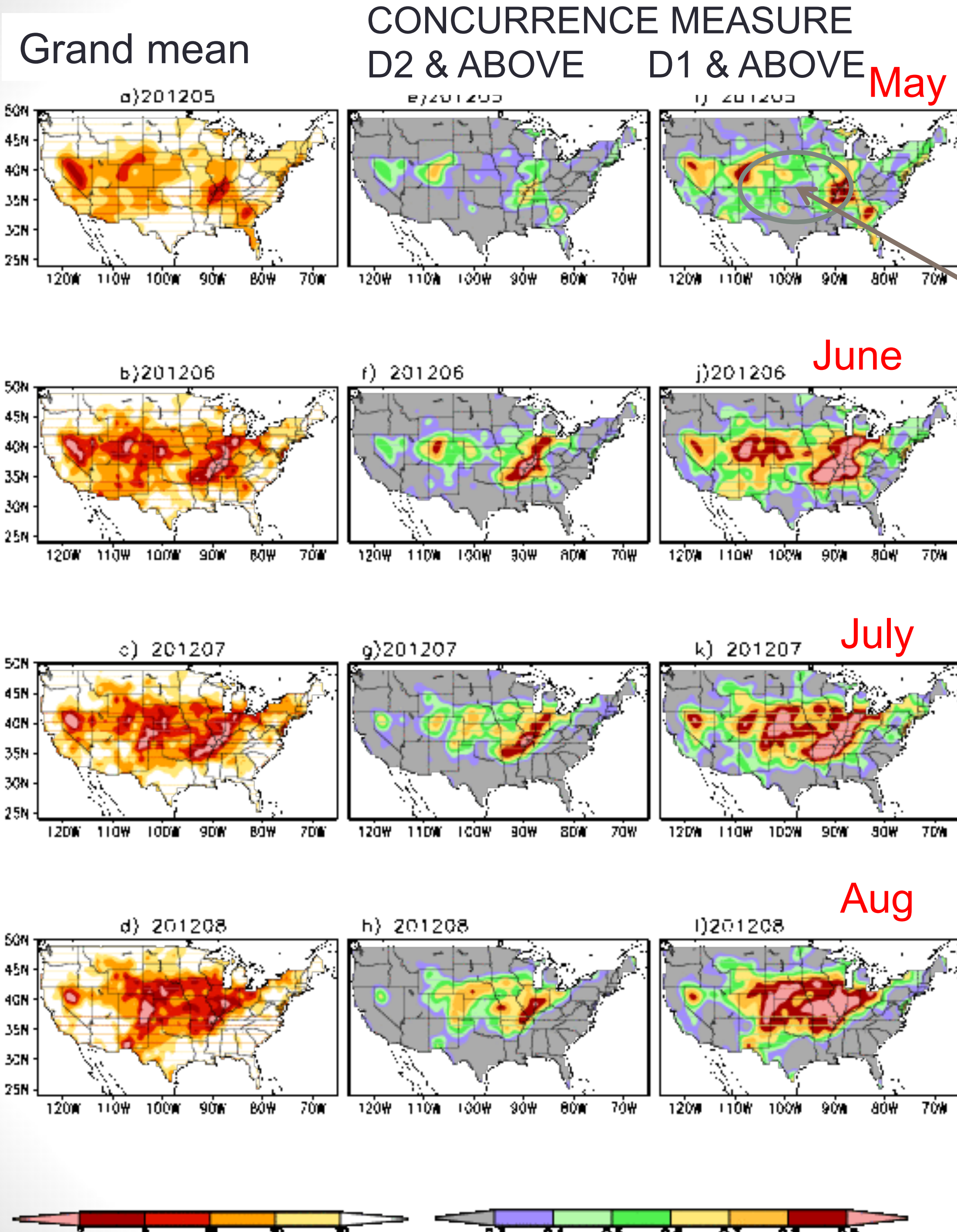
- All indices are able to select the same drought event, but uncertainties are too large to classify drought in the (D1, --- D4) categories.
- We are not able to give risk managers the best and worst scenarios and the occurrence probability.

Probabilistic approach

Grand mean index

- Calculate the drought index (SPI6, SMP and SRI3) from the corresponding monthly mean time series
- Put indices in percentiles
- grand mean index=> Equally weighted mean of SPI6(en), SMP(en) and SRI3(en) and transfer to a uniform distribution so they are btw 0 and 1
- Concurrence measure : % of indices that agree with the grand mean

Mo and Lettenmaier 2014



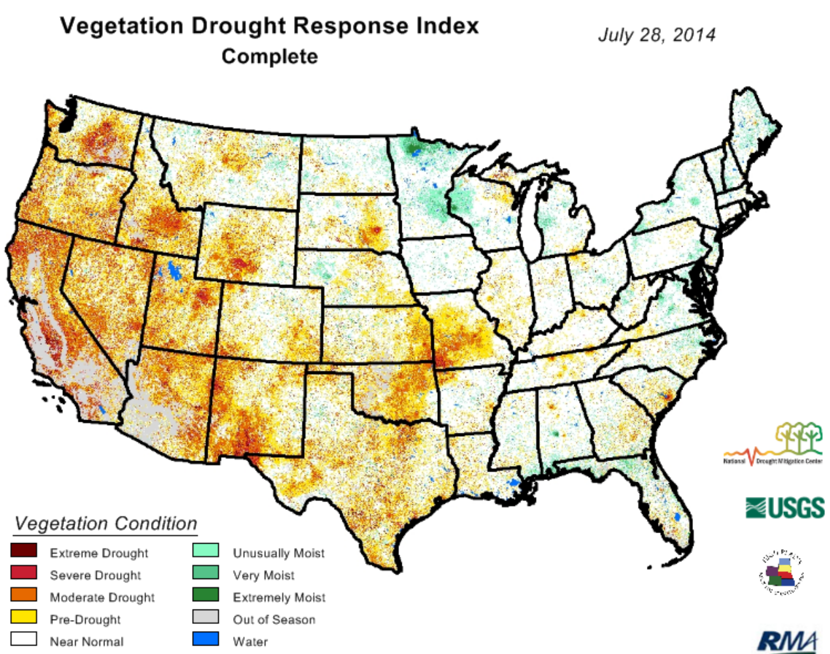
EXAMPLE 2012 Drought classification

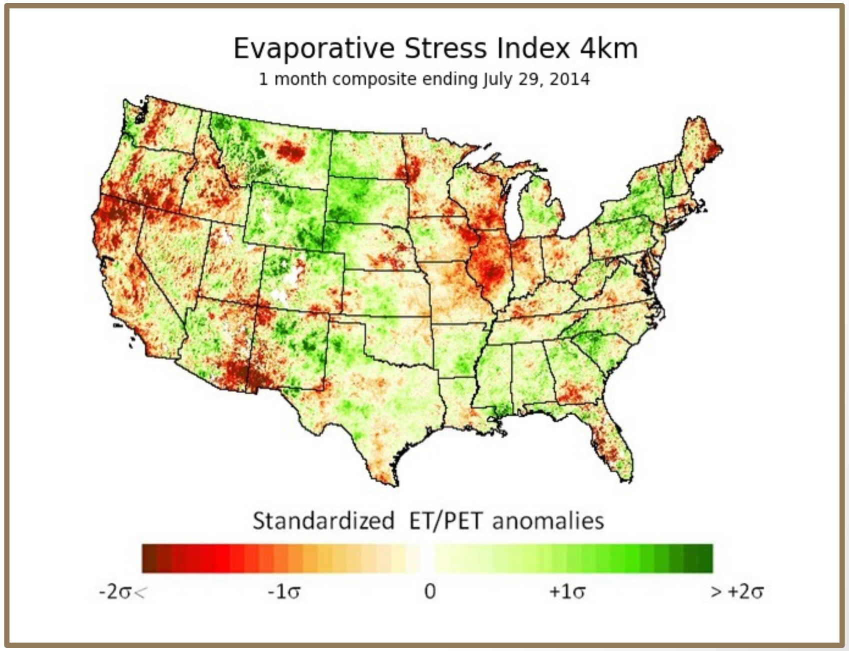
May: there were 50-60% cases indicate D1 drought or above

When drought deepened in June, more indices showed D1-D2 drought

Other indicators-satellite derived

1. Evaporative stress index – derived from the GOES satellite
2. GRACE ground water and simulated hydrological variables
3. VegDri
4. NVDI





Drought forecasts (NMME)

SPI

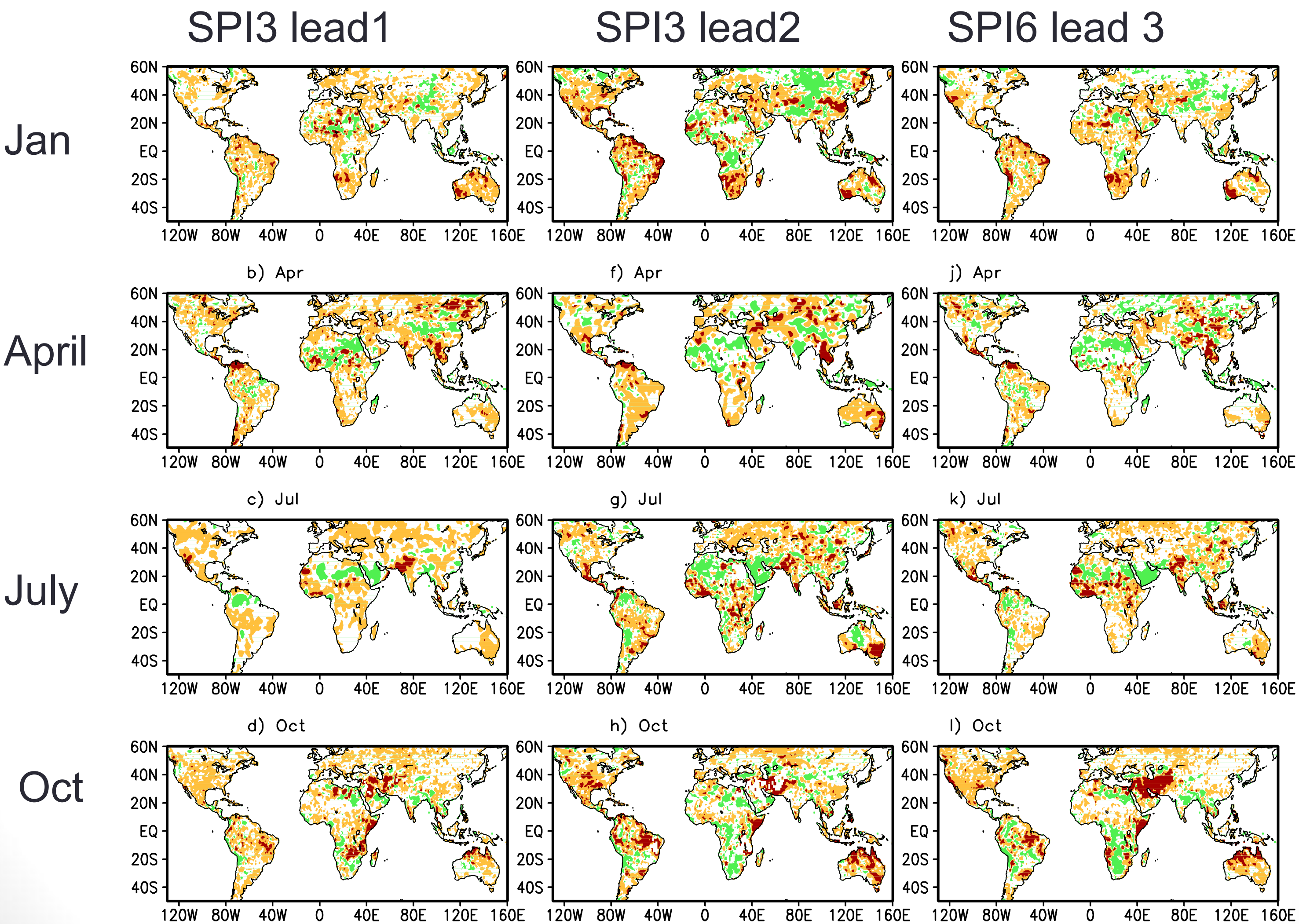
- Precipitation from the North American multi model ensemble (NMME) (Kirtman et al. 2013)
- From P, we can derive SPI

SM and runoff

- For hydrological forecasts, we used P and Tair forecasts from the global model to derive forcing
- We then drived a land surface model such as VIC which has better initial conditions to get SM and runoff
- Ref: Shukla and Lettenmaier(2011), Shukla et al. (2012)
- Wood and Lettenmaier (2006,2008)

Compare with persistence base line forecasts

(red: NMME is more skillful, dark red: stat sig at 10% level, Green : pers is more skillful)



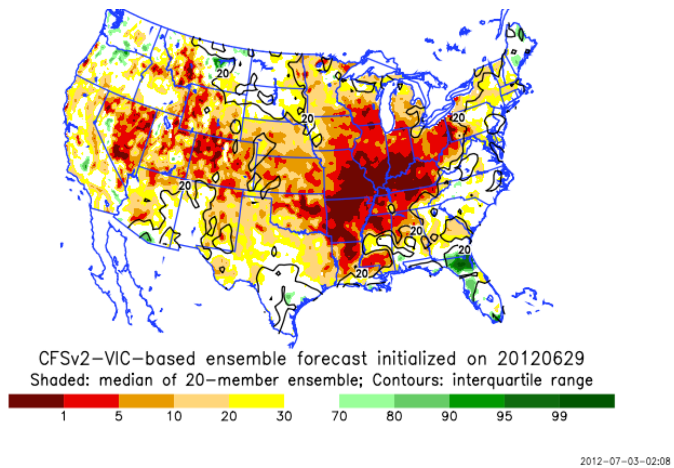
SPI forecasts

- For some areas, SPI6 forecasts at lead-1 to lead-3 have useful skill
- More skill comes from ENSO
- Over all, The forecasts for short leads are influenced strongly by the initial conditions.
- In general, the skill is slightly higher than persistence baseline , but not statistically significant at the 10% level

Ref: Dutra et al. 2014a, 2014b
Mo and Lyon 2014

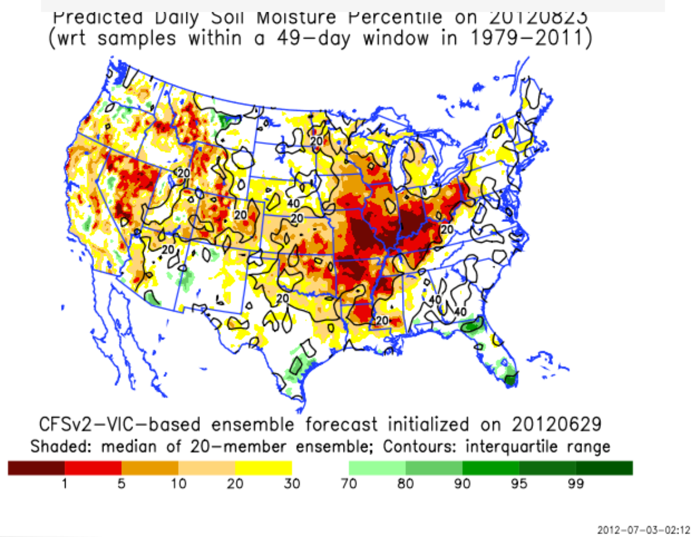
SM fcsts from MSU (Lifeng Luo) Ics 20120629

4 weeks

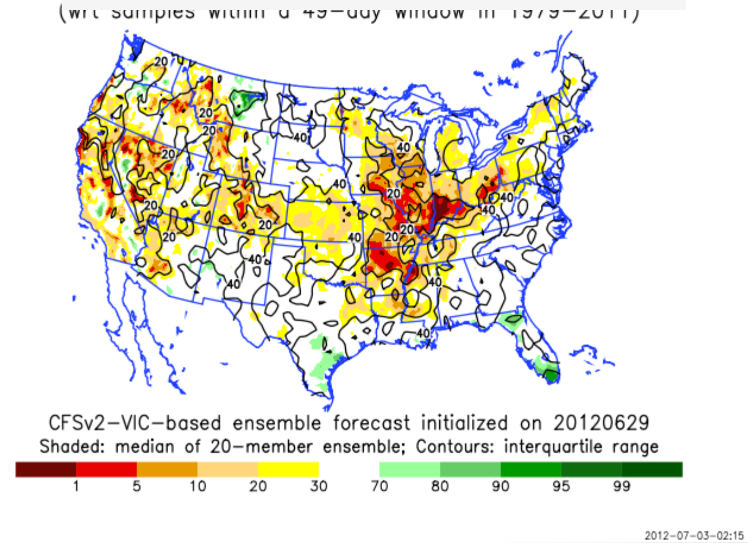


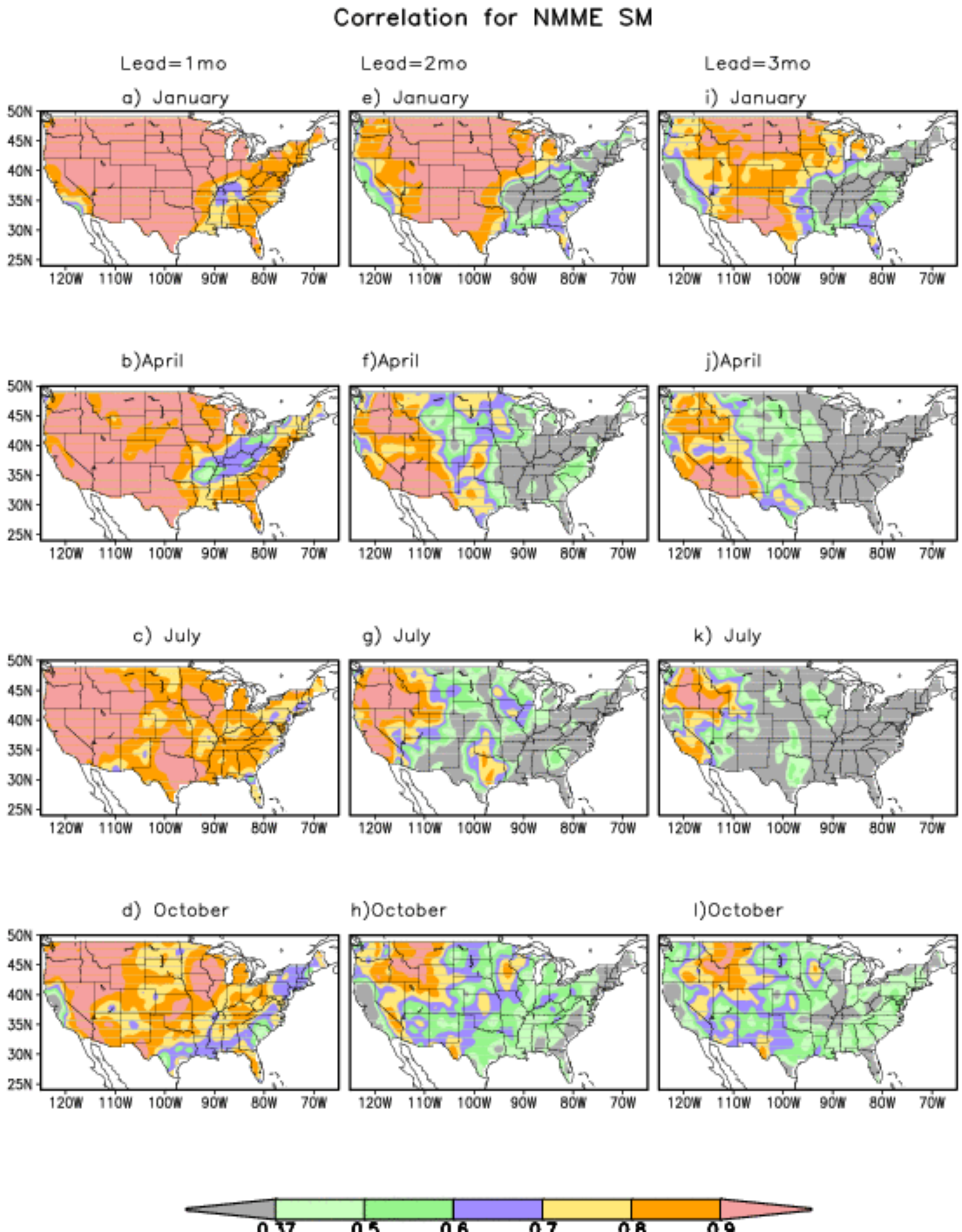
http://drought.geo.msu.edu/
research/forecast/drought.

8 weeks

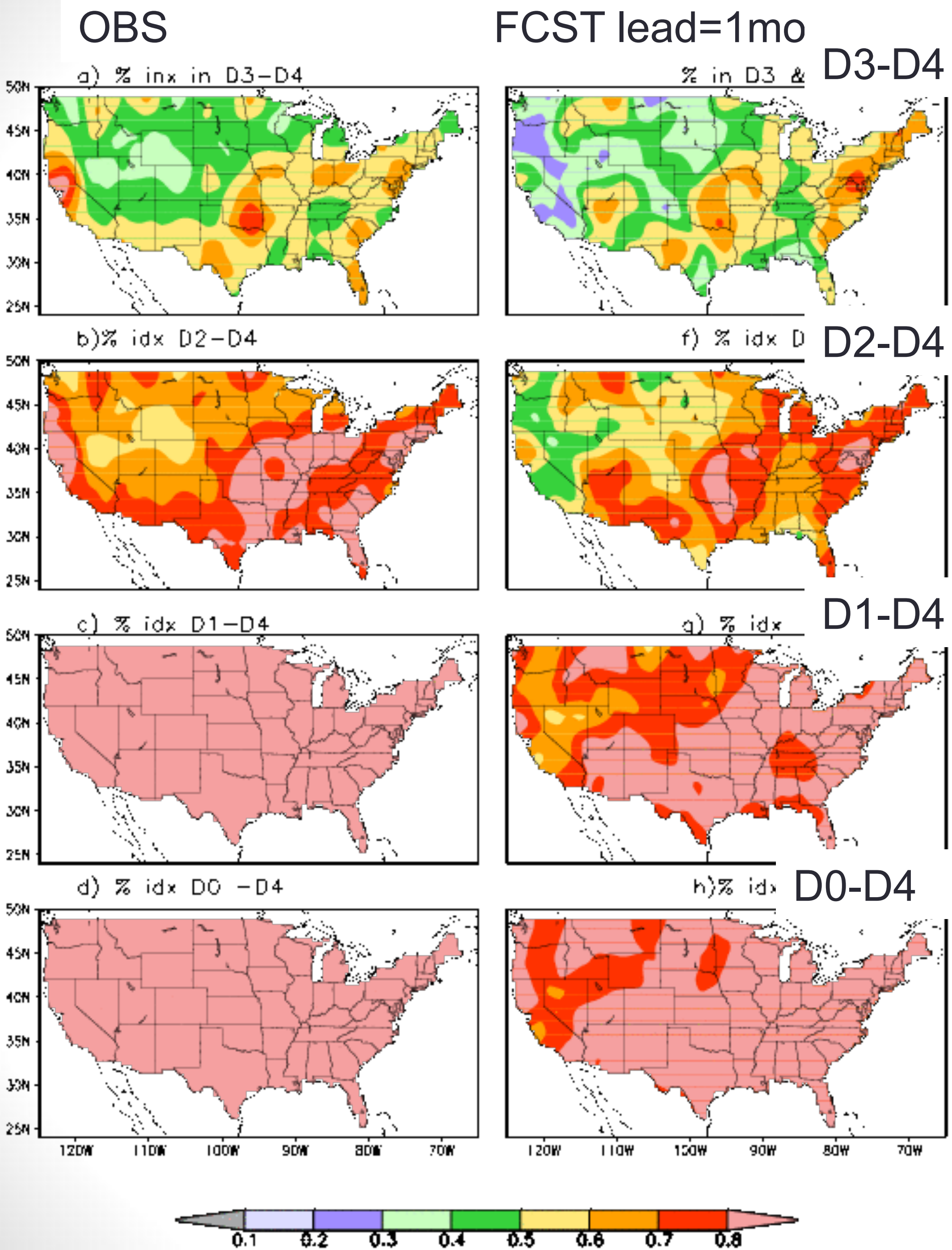


12 weeks





For lead 1 and lead 2 months, skill is high over the western dry region and low over dynamically active region
Still very good

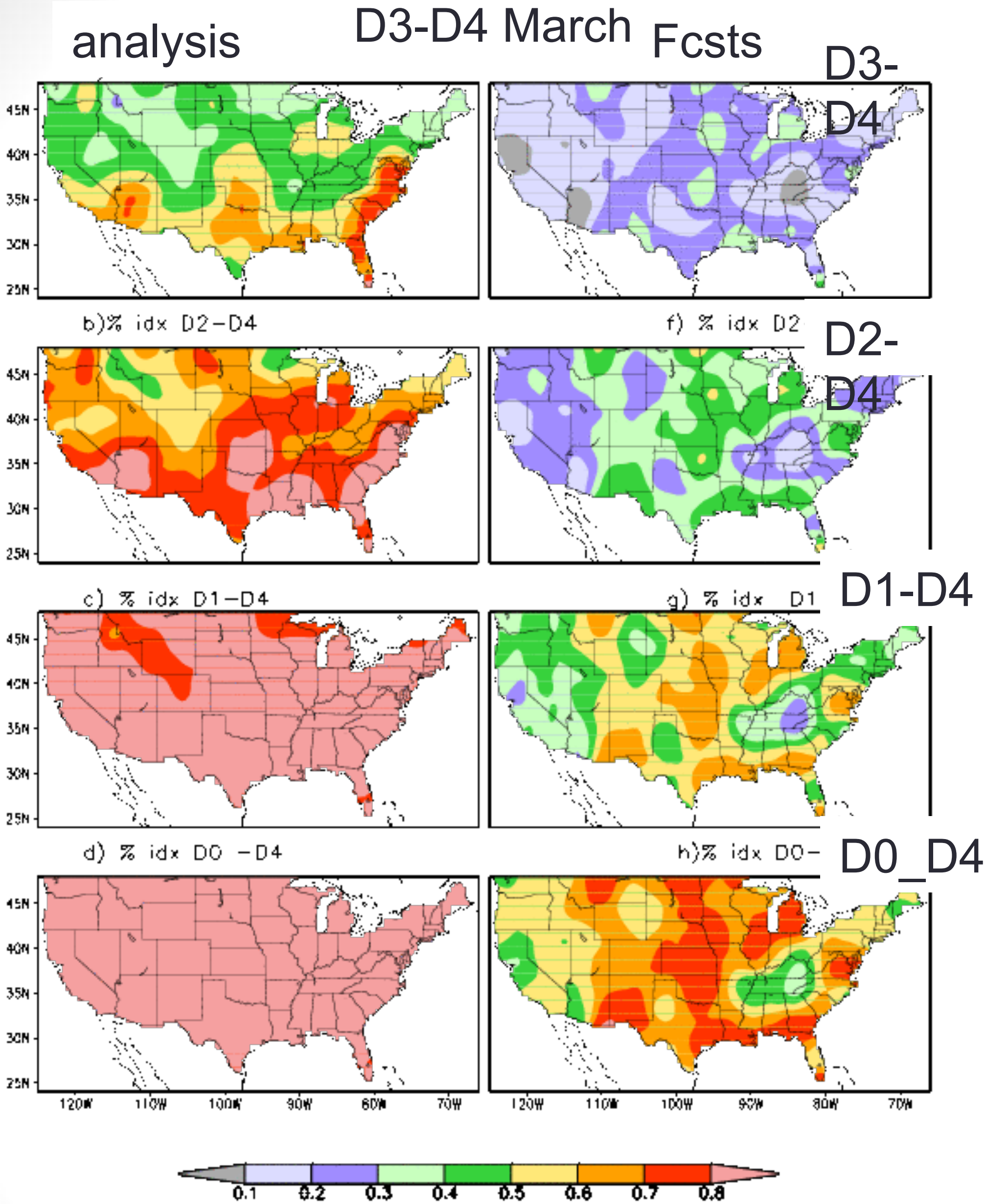


When the obs grand mean is in D3 & D4, % of members in

When Rho is above 0.7, fcsts are able to capture
Drought categories well

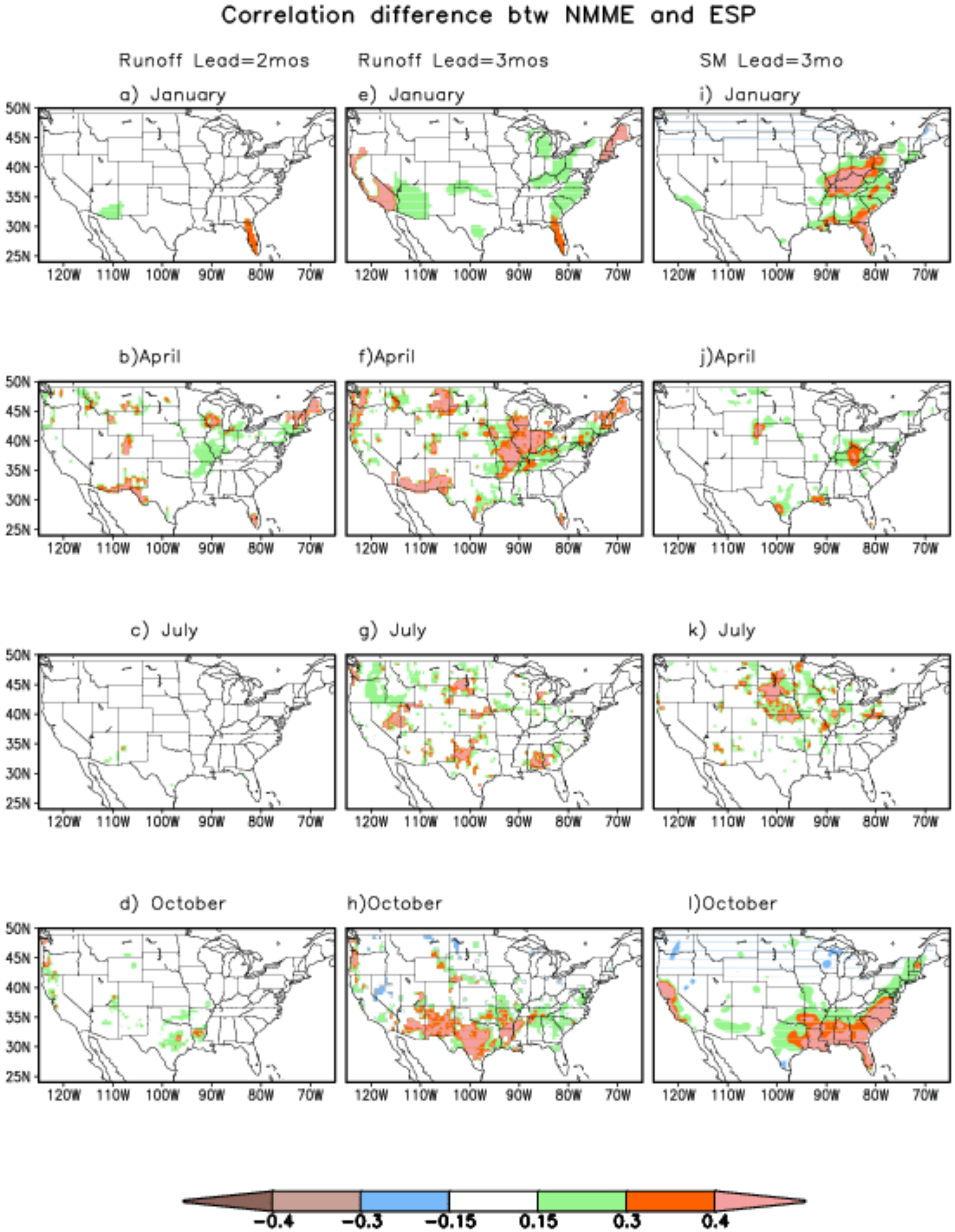
Forecasts lead=1mo
IC s=Jan

Jan forecast at lead=3 months



When the analyses indicate drought in the D3-D4 category:

Forecasts at lead=3 months indicate that forecasts are not able to capture the D3/D4 drought and less than 50% indicate D2 or higher drought Forecasts are wetter



Differences between the NMME & ESP

For lead-1 and lead-2 There are no statistically significant differences among the two (initial conditions dominant)

Please initial your land conditions properly because SM/runoff forecast skill for short leads come from initial conditions

Challenges: Improve drought forecasts

- INITIALIZE your land conditions properly for your global forecasts
- Improve global model climate P forecasts after lead=1 month
- Improve initial conditions of both global and regional/ hydrologic models

  Such as assimilate soil moisture, snow pack and ground water
- Better observations and data coverage
- **Understand** the strength and weakness of each prediction tool, so we can select the tools that will work well in a particular situation.
- Use multimodel, multi indices to develop probabilistic forecasts

How we can work together?

1. To improve drought or hydroclimate monitoring and forecasts, we need

A) Good precipitation data
B) Good snow pack and ground truth measurements
C) Ameriflux type flux towers or scan measurements to validate or calibrate surface land models
D) Initialize your global model land conditions properly so we do not have to use downscaling to obtain soil moisture or runoff

2. What can we provide?

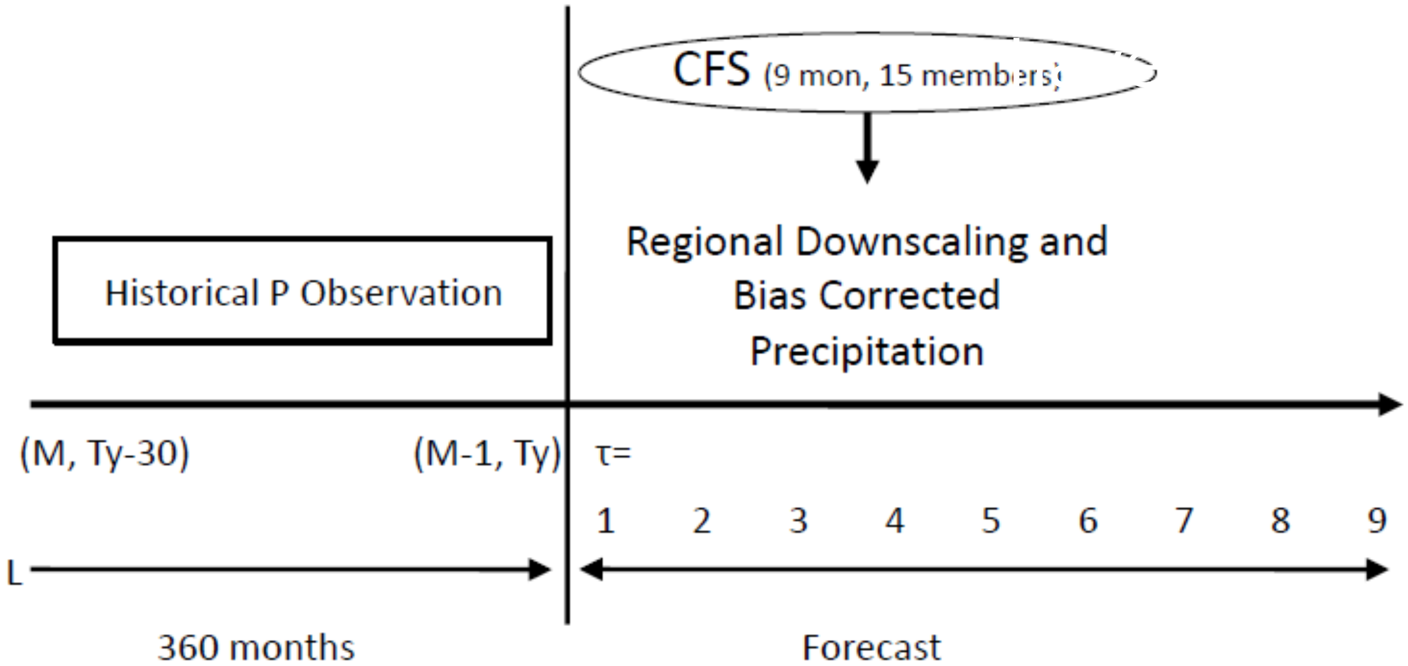
A) NLDAS or GLDAS to provide land conditions for you to study regional surface or atmospheric conditions
B) Better understanding of the extreme events

3. What do we like to have ?

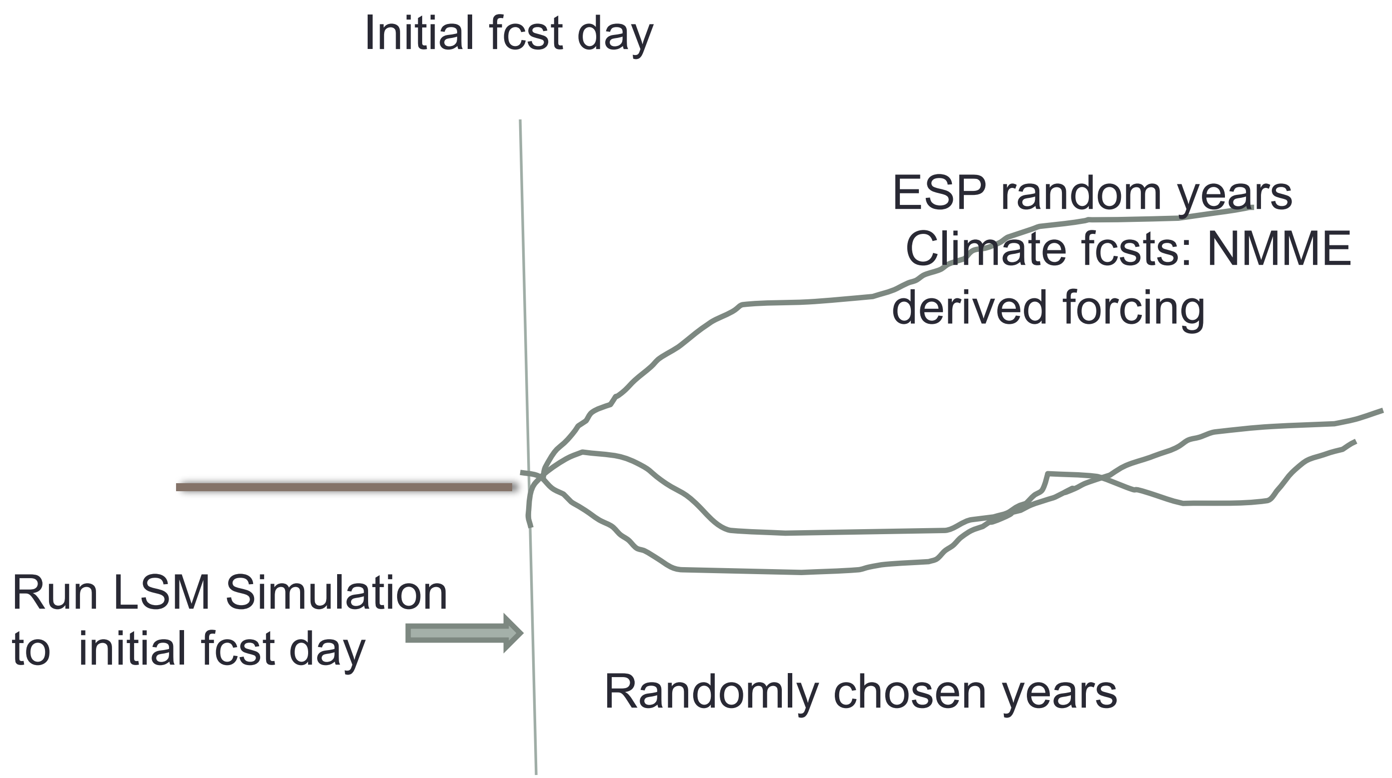
A)We like to have your feedback (positive or negative) of the quality of the GLDAS and regional information
B) Tell us what do we miss? Are these variables, or scales that you will need and we do not provide?

SPI forecast

Forecast Procedure



Ensemble Streamflow Forecasts (ESP) & NMME based forecasts

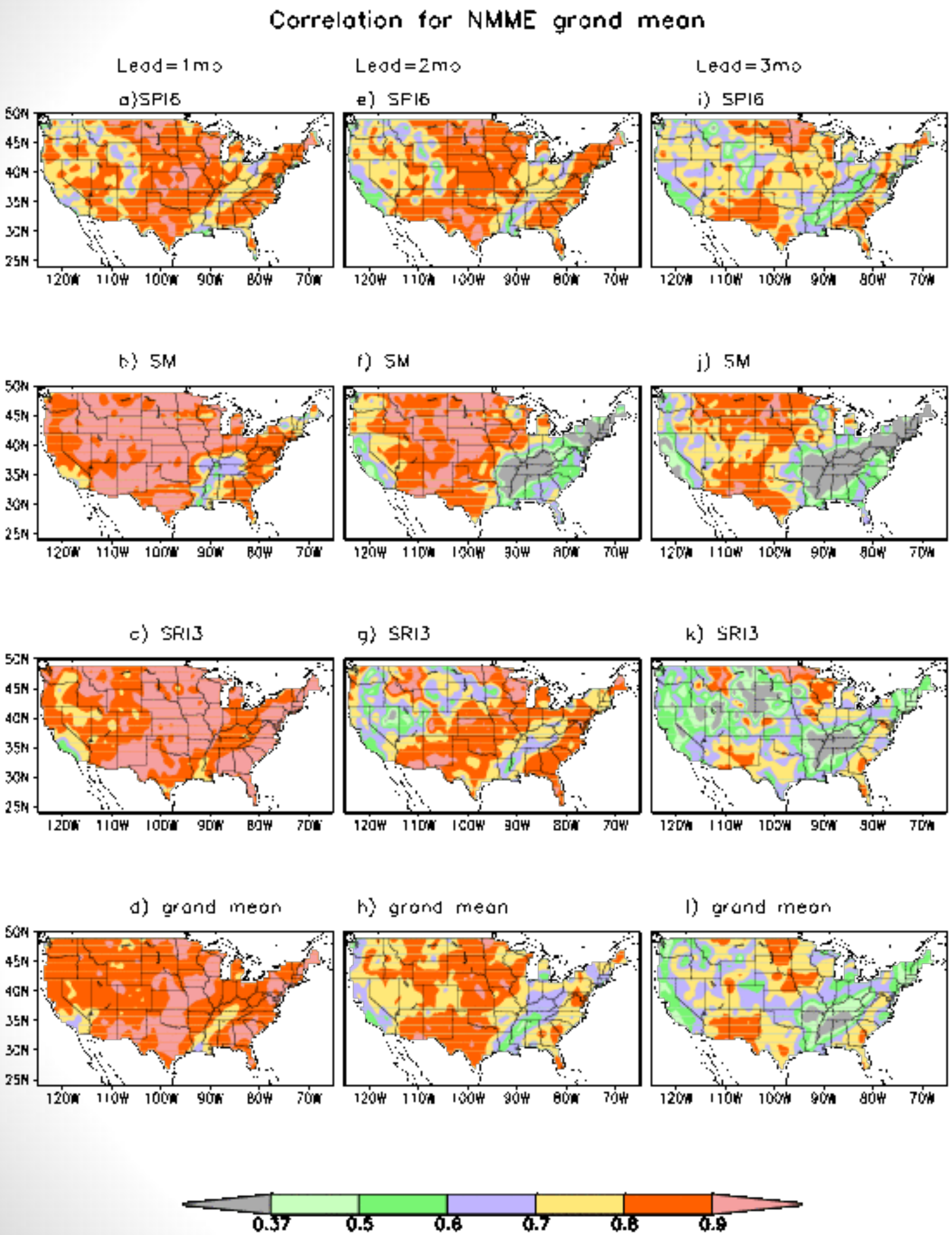


It has accurate initial conditions

ESP: knows seasonal cycle of forcing, but it does not have forecast information

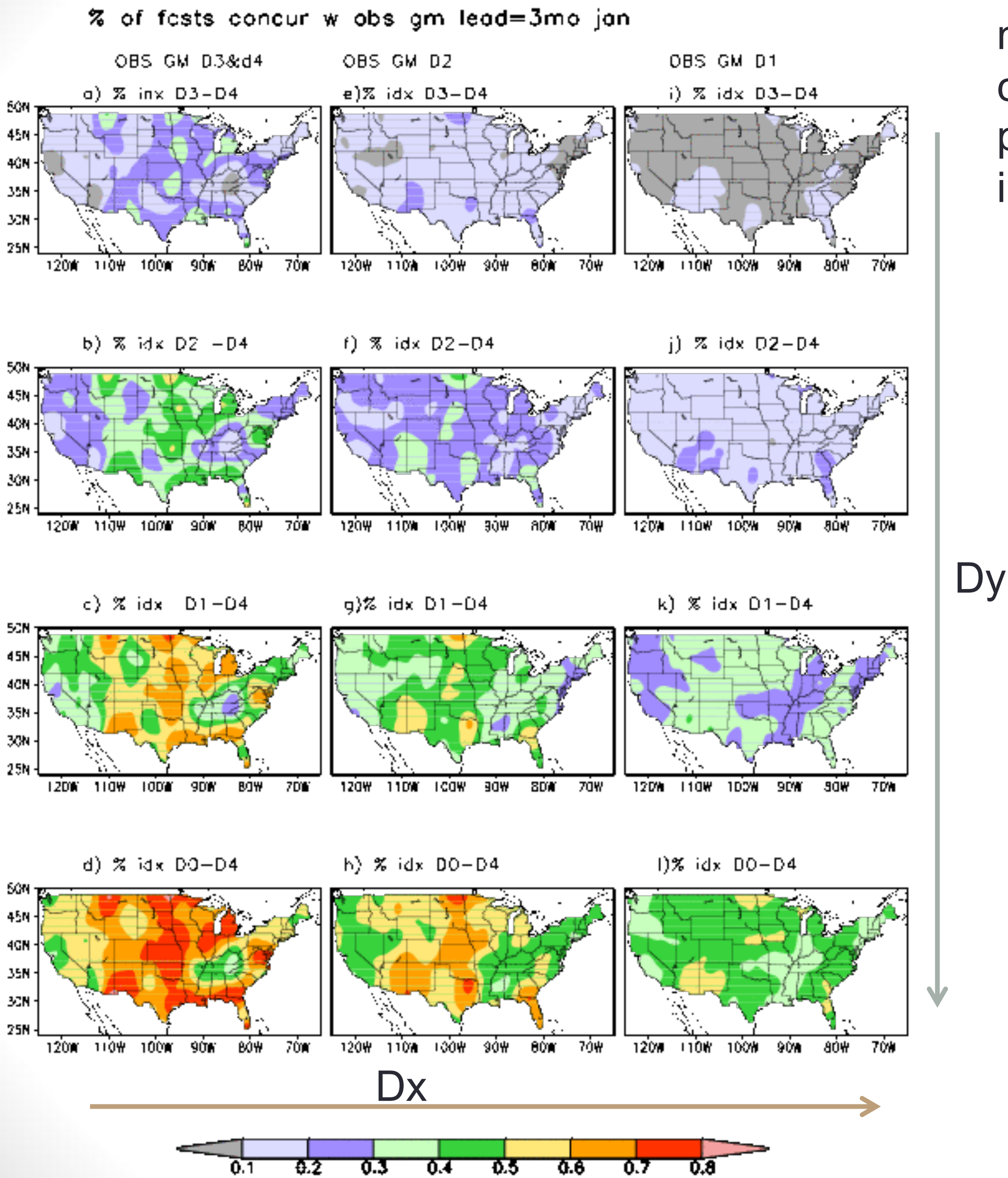
Climate hydro fcsts: have fcst information

Forcing derived from the NMME model fcsts



Based on the NMME forecasts
There are 56 members
And 3 indices, we are able to compute the grand mean and concurrence measure

Here is an example of the grand mean skill measured by the Spearman rank correlation



When the obs grand mean is in Dx category, the percentiles of fcsts in Dy

When the grand mean is in D3-D4, there are only less than 30% of fcsts in D3-D4 , but more than 50% of fcsts indicate drought

Lead= 3 months