# Multi-model seasonal forecasting of global drought onset

**Xing Yuan, and Eric F. Wood**

**Department of Civil and Environmental Engineering, Princeton University**

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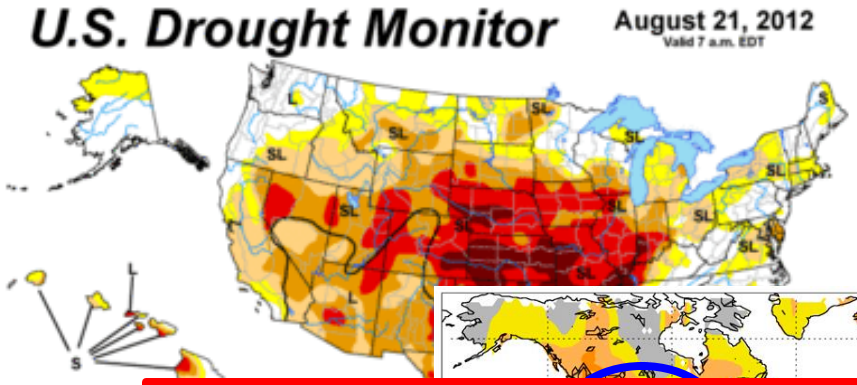
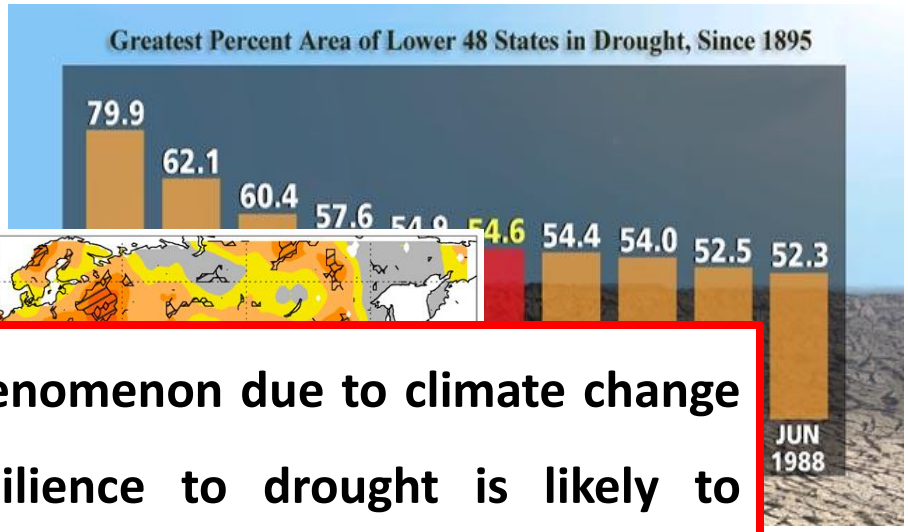
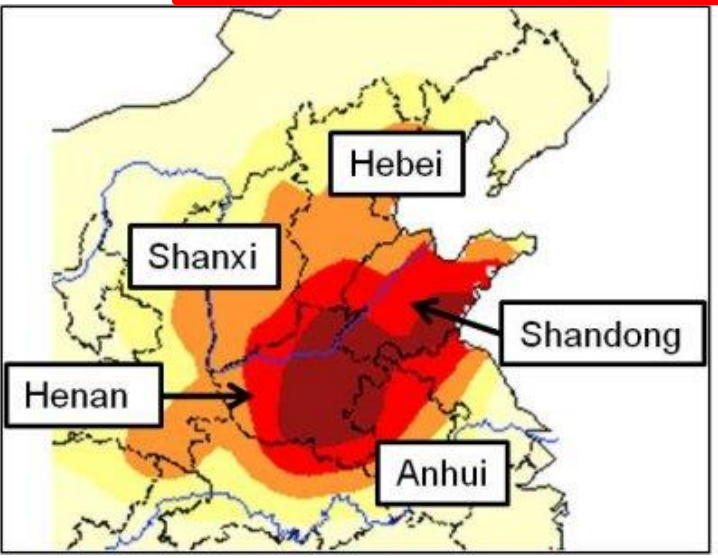
# Drought may cause heat wave, crop loss or even humanitarian crisis



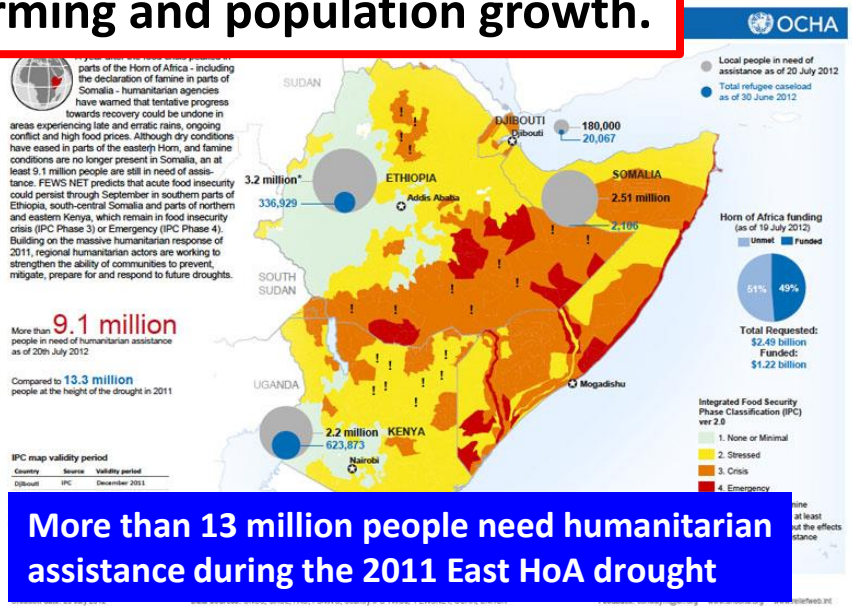

The associated heat wave killed more than 80 people.




**Although drought is a natural phenomenon due to climate change and climate variability, the resilience to drought is likely to decrease in the future with global warming and population growth.**

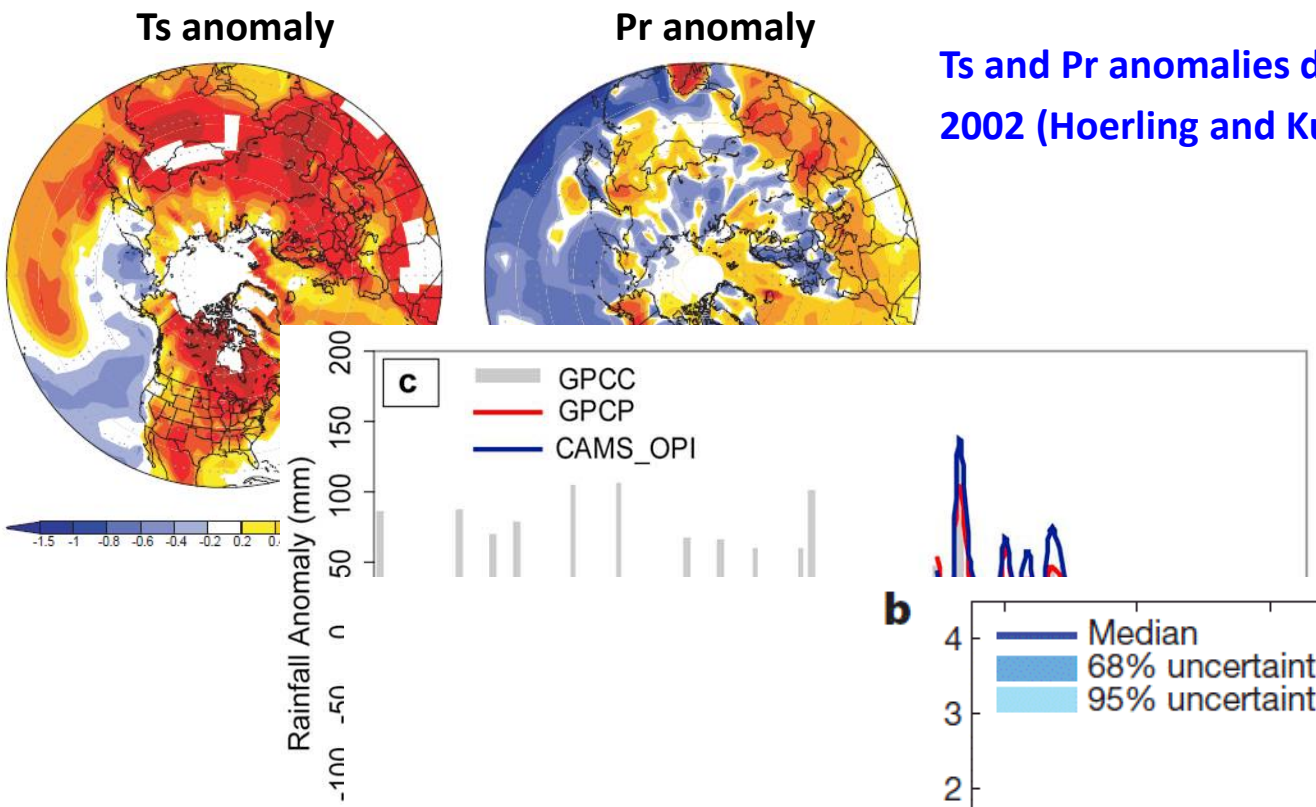




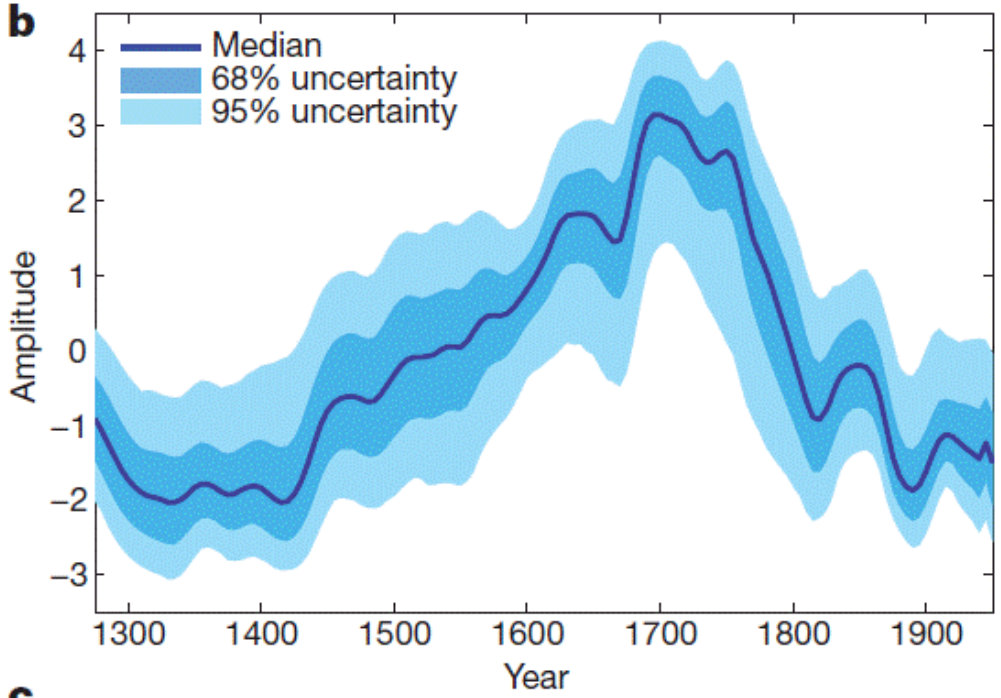



**More than 13 million people need humanitarian assistance during the 2011 East HoA drought**

# Drought may persist for years, decades, or even centuries

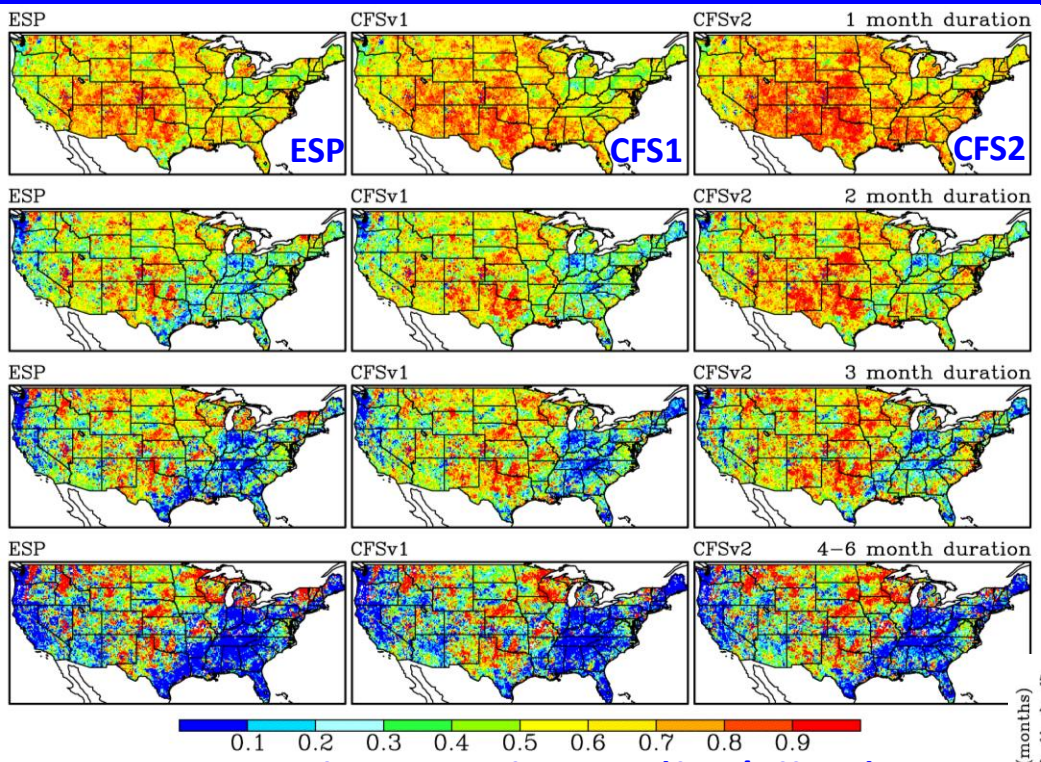



Ts and Pr anomalies during 1998-2002 (Hoerling and Kumar, 2003)




Moisture development of East Africa over past 700 years. (Tierney et al., 2013)

# Forecasting drought at seasonal scales (1-6 month)




Drought frequency forecast (fcst/offline)

1 month duration

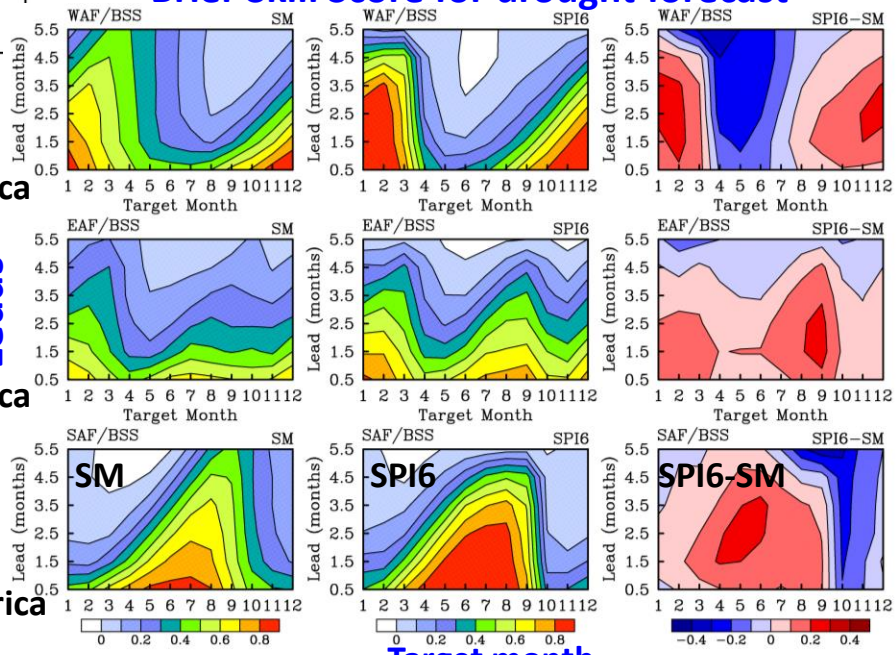
2 month duration

3 month duration

4-6 month duration

CFSv2-based seasonal hydroclimatic forecasts over conterminous United States (Yuan et al., JC, 2013, in press)

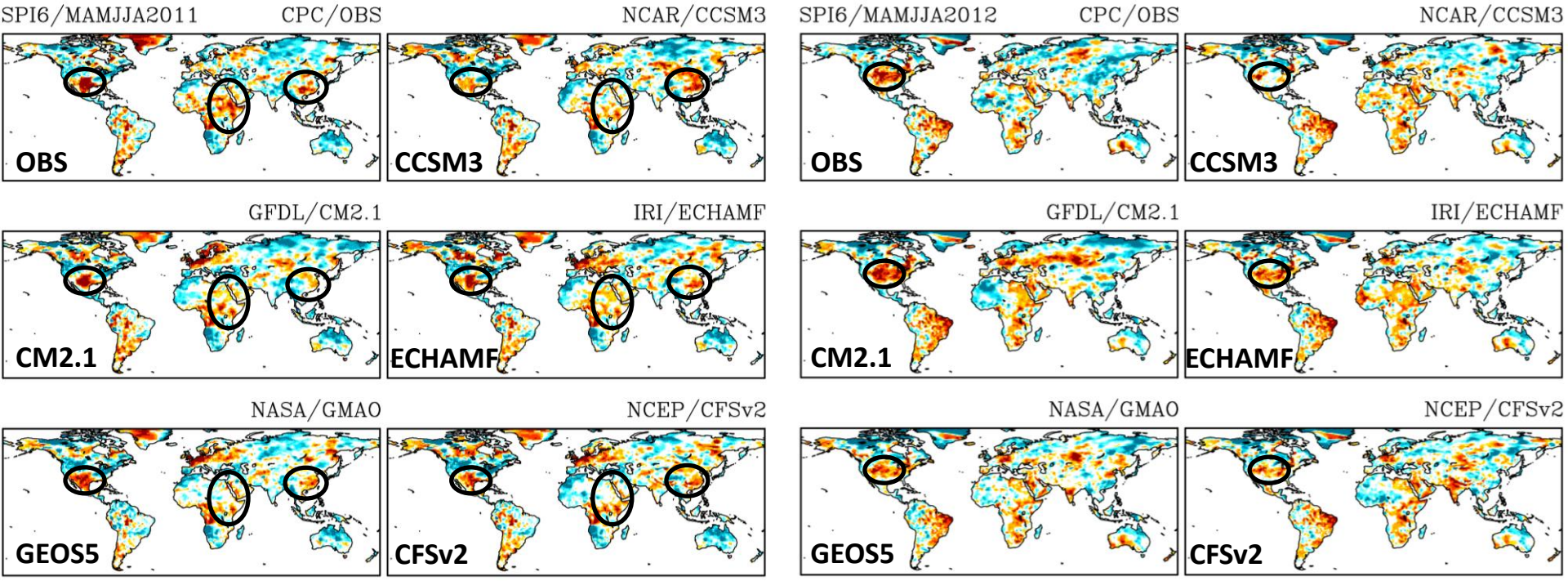
Brier Skill Score for drought forecast




Probabilistic Seasonal Forecasting of African Drought by Dynamical Models (Yuan et al., JHM, 2013, in review)

# Motivation for multi-model drought forecast

**SPI6 (blending MAM obs and JJA fcst) for drought forecast during 2011 and 2012**




SPI6/MAMJJA 2011 −2 −1.5 −1.2 −0.8 −0.5 0.5 0.8 1.2 1.5 2 SPI6/MAMJJA 2012

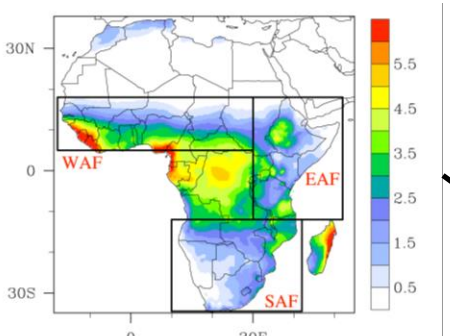
- Climate models do present different forecast skill for specific drought events.
- Can we take the advantages of different climate forecast models?
- Hindcast for comprehensive skill assessment.

# National Multi-Model Ensemble (NMME) project

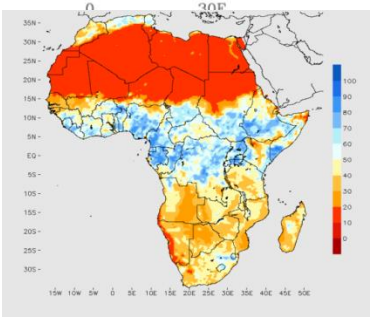
- The National Multi-Model Ensemble (NMME) is an experimental, multi-institutional prediction system to develop operational seasonal-to-interannual prediction.
- Phase-I NMME project consists of 7 coupled models from US, including NCAR/CCSM3, GFDL/CM2.1, IRI/ECHAM(A/F), NASA/GEOS5, and NCEP/CFSv1 & v2.
- Phase-II NMME project, two IRI models and one NCEP model (CFSv1) quit, and two CMC models (CanCM3 & 4) came in, resulting 6 models. Model update and initialization refinement.
- One of the measures of the success of NMME is to assess phenomenological skill, e.g., drought and MJO.
- Monthly hindcast data (Pr, T2) during 1982-2009 is available for all 9 models at one degree resolution, which is a very useful public resource for model comparison and combination research, and for targeted prediction such as drought onset forecast.

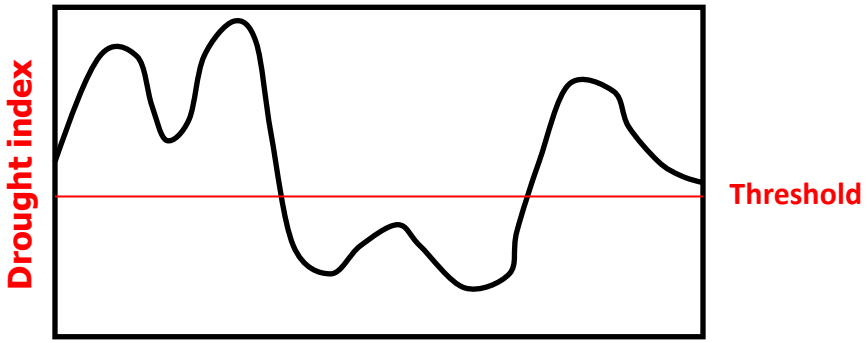
# Drought onset definition: 3 month continuous dry conditions

**Precipitation**

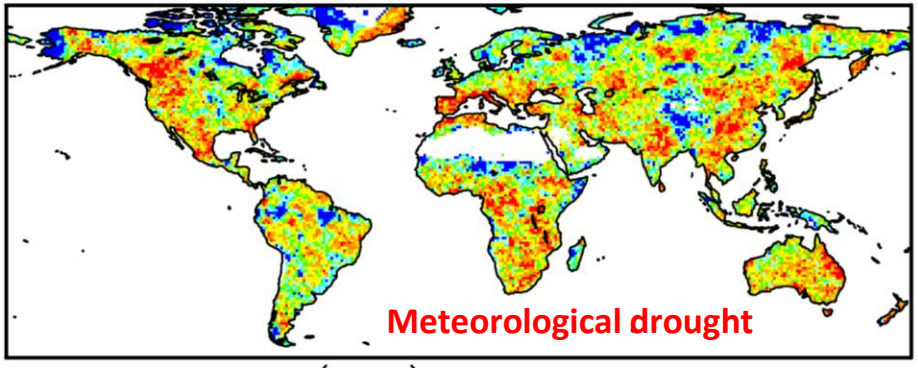



**Soil moisture**

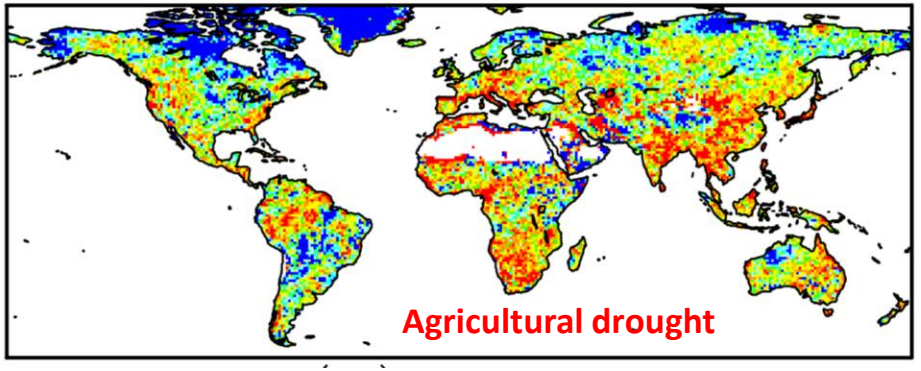





No. of Droughts (SPI6) at 1degree grids




No. of Droughts (SM) at 1degree grids

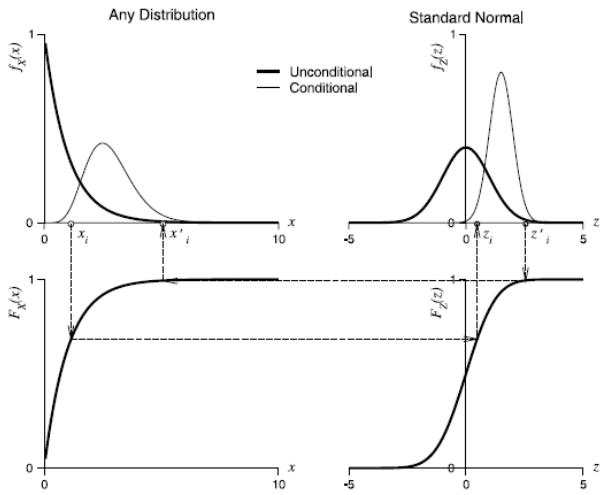


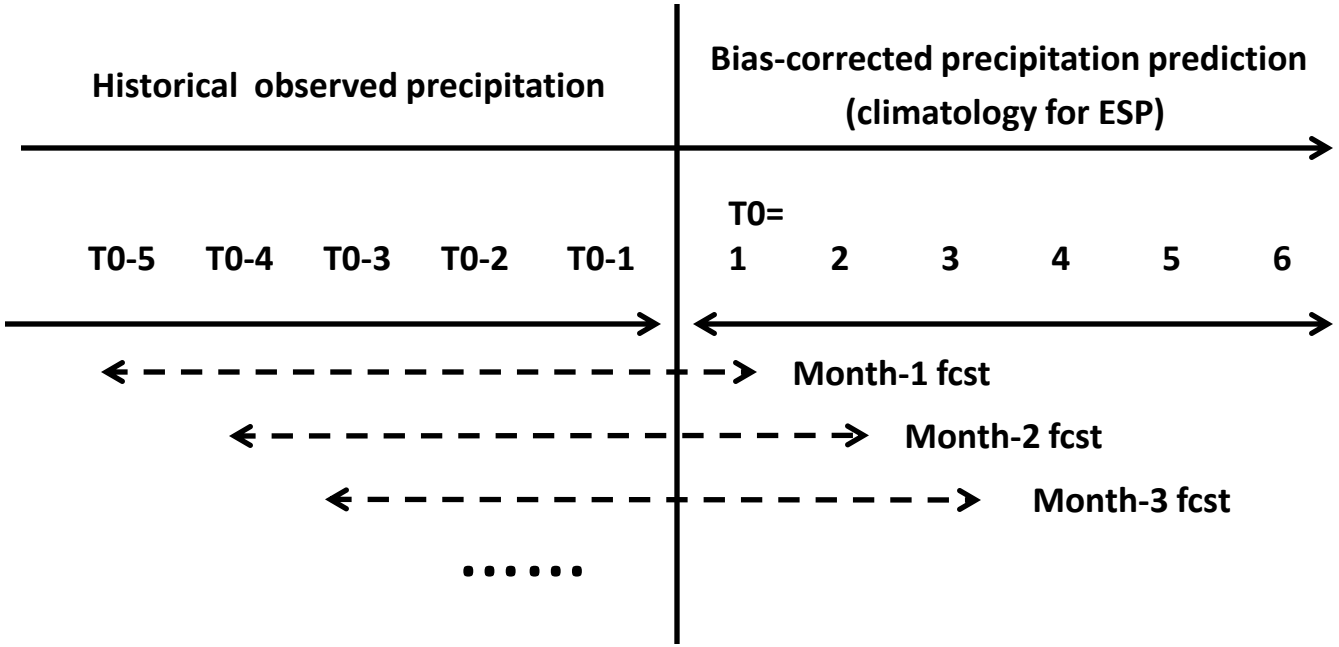


**1982-2009**

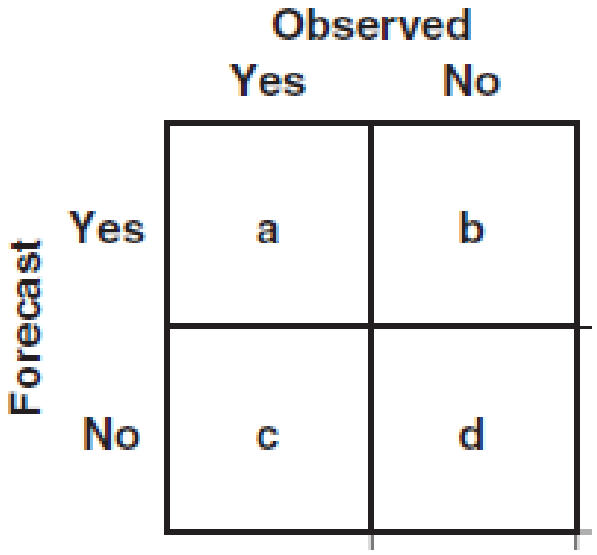
# Bias correcting precipitation for meteorological drought onset forecast

- Quantile-mapping for bias correction
- Blending historical observation and current bias-corrected prediction to obtain cumulative precipitation series
- Calculate SPI drought index



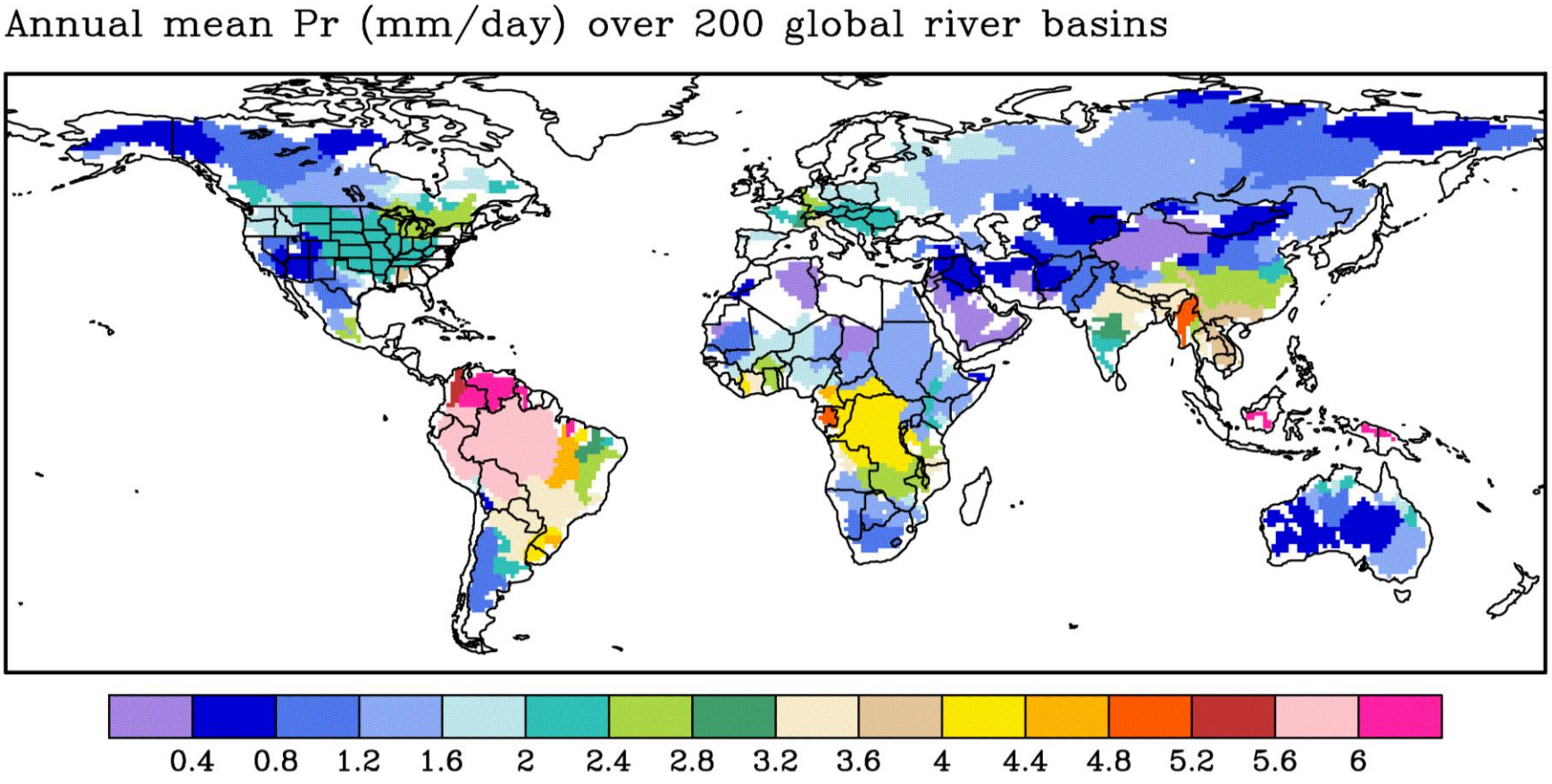
# Evaluation metrics



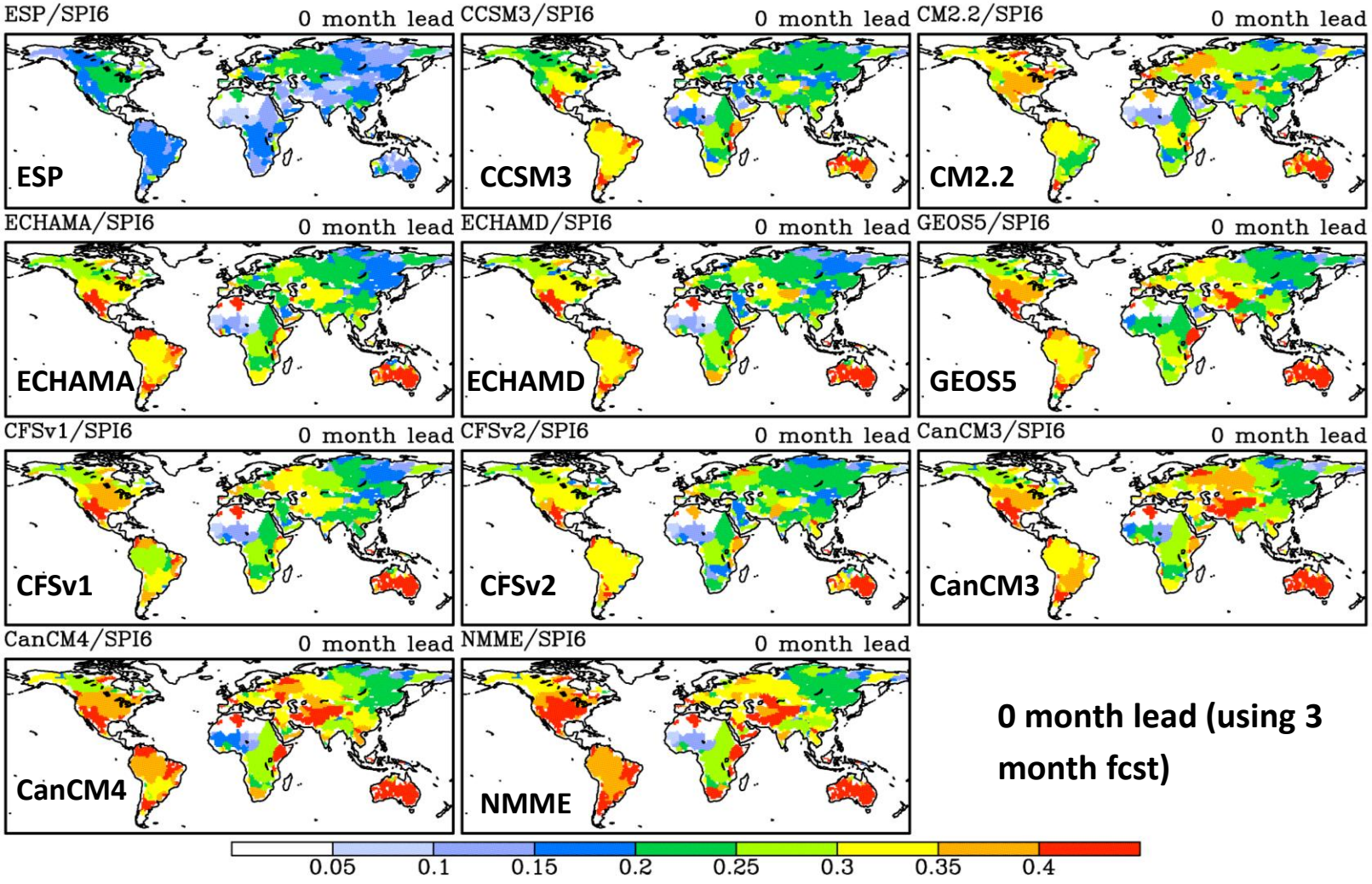

Probability of detection $p(y_1|o_1) = a/(a+c)$

Probability of false alarm $p(o_2|y_1) = b/(a+b)$

# Basin averaged precipitation climatology



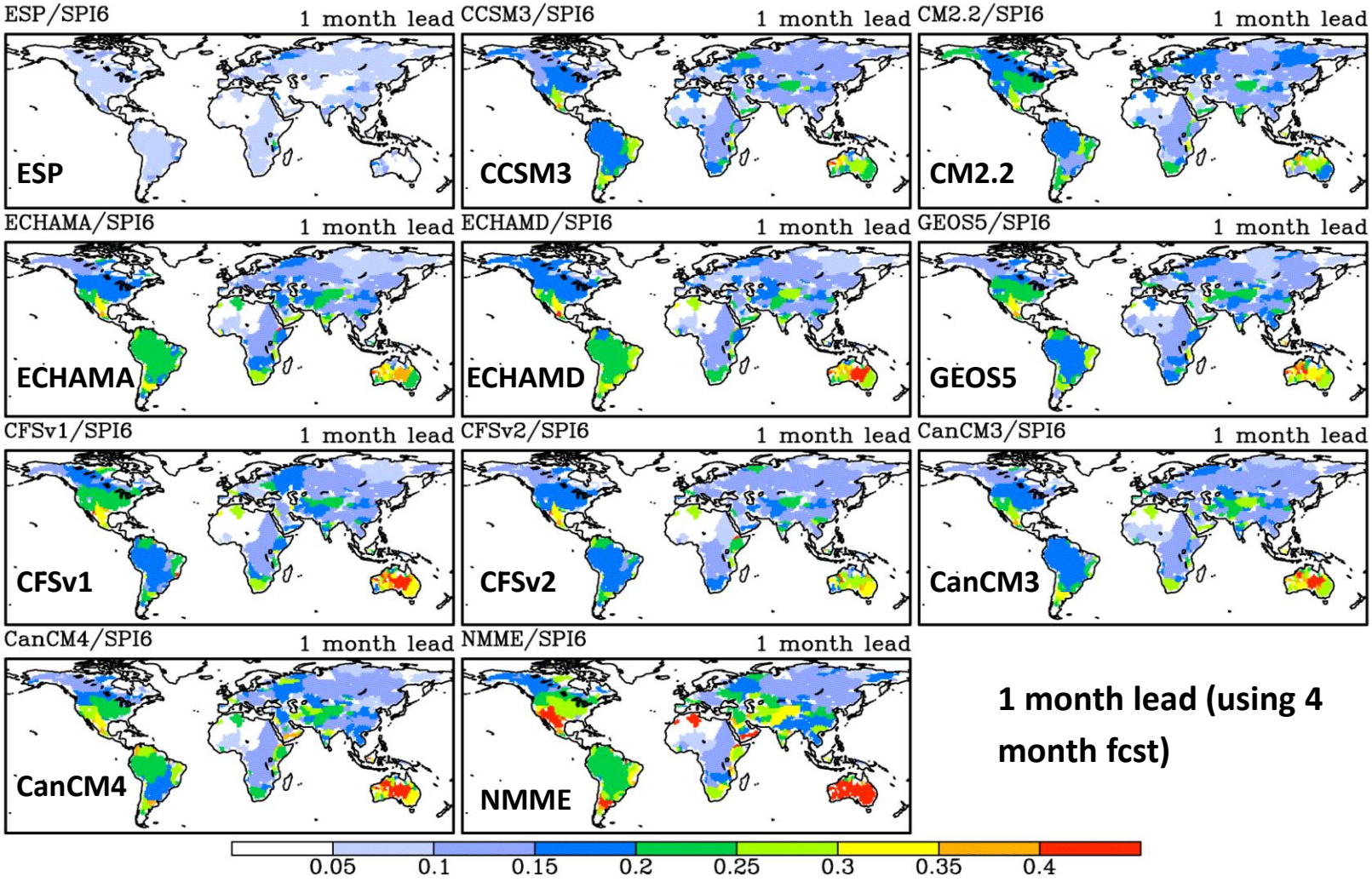
# Probability of detection for drought (SPI6) onset forecast




**0 month lead (using 3 month fcst)**

- **After bias correction, climate models produce better forecast than ESP (climatology)**
- **Higher skill over (N & S) America, Australia, Europe and C. Asia, lower over E. Asia and Africa**
- **Multi-model ensemble improves the forecast where individual models have high skill**

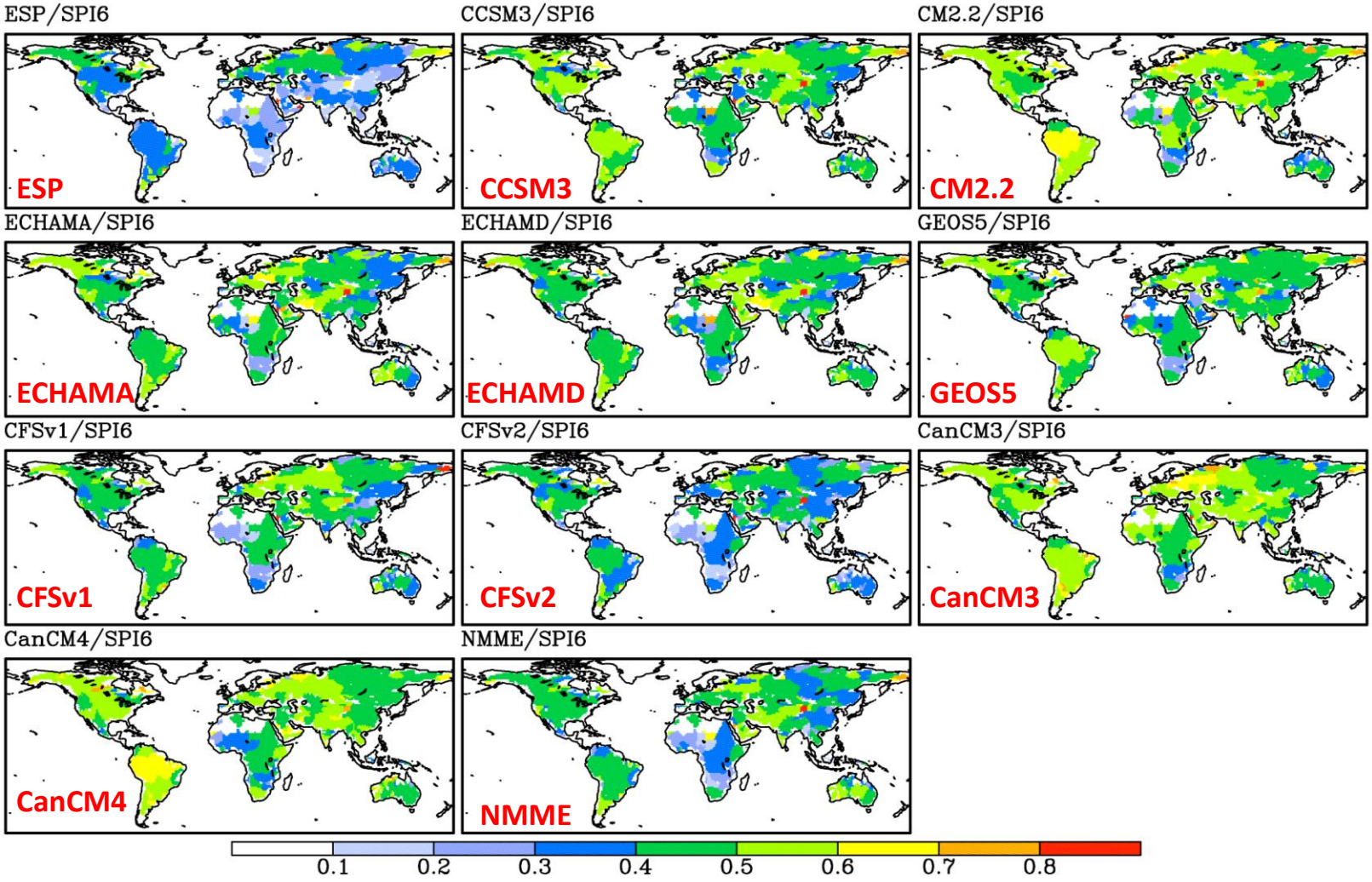
# Probability of detection for drought onset forecast




**1 month lead (using 4 month fcst)**

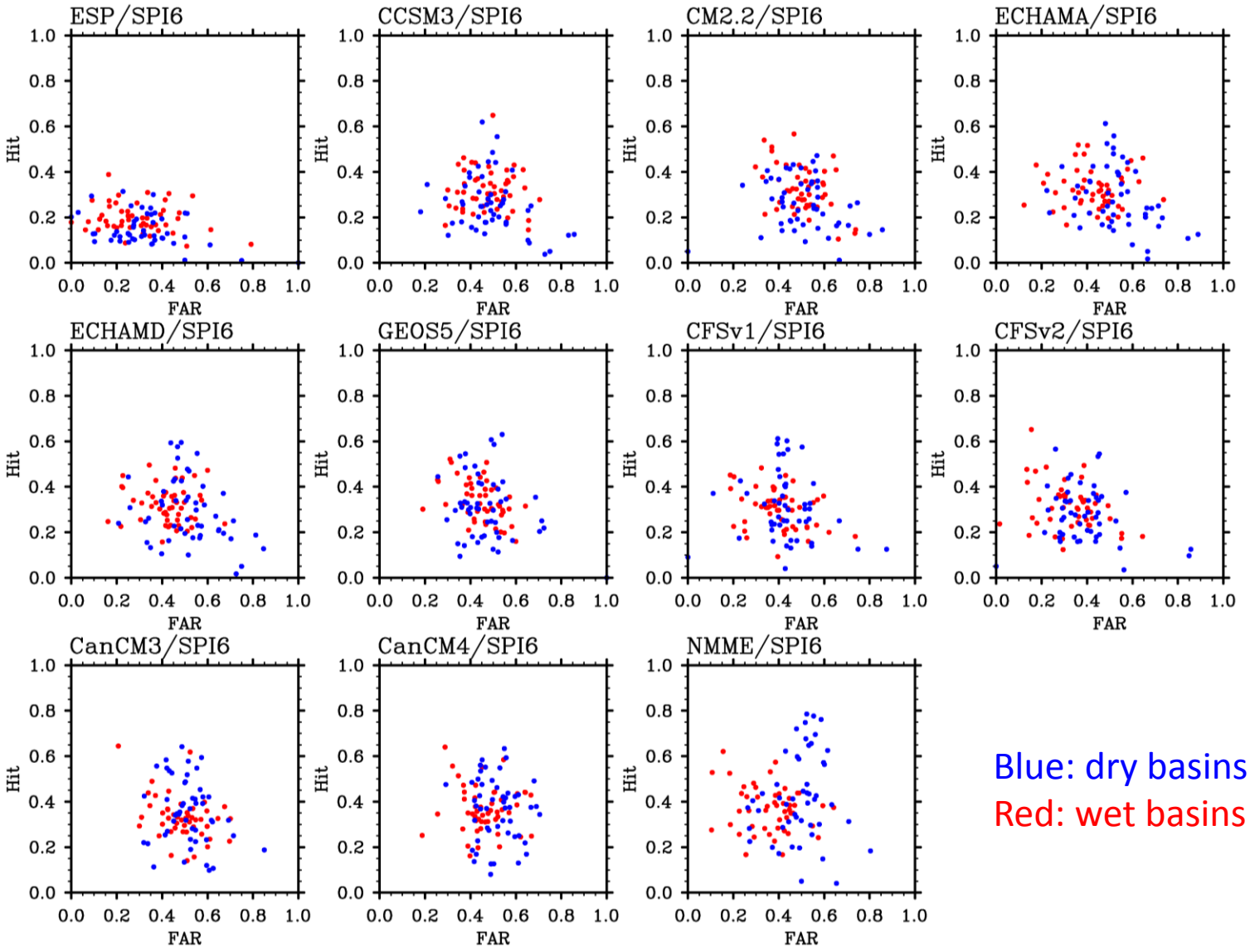
- **ESP has almost no skill for 1 month lead drought onset forecast**
- **NMME preserves high skill over N&C America, and Australia**

# Probability of false alarm




➢**False alarm ratio: ESP < NMME < Individual models**

# Scatter plots for hit rate and false alarm ratio for 200 basins

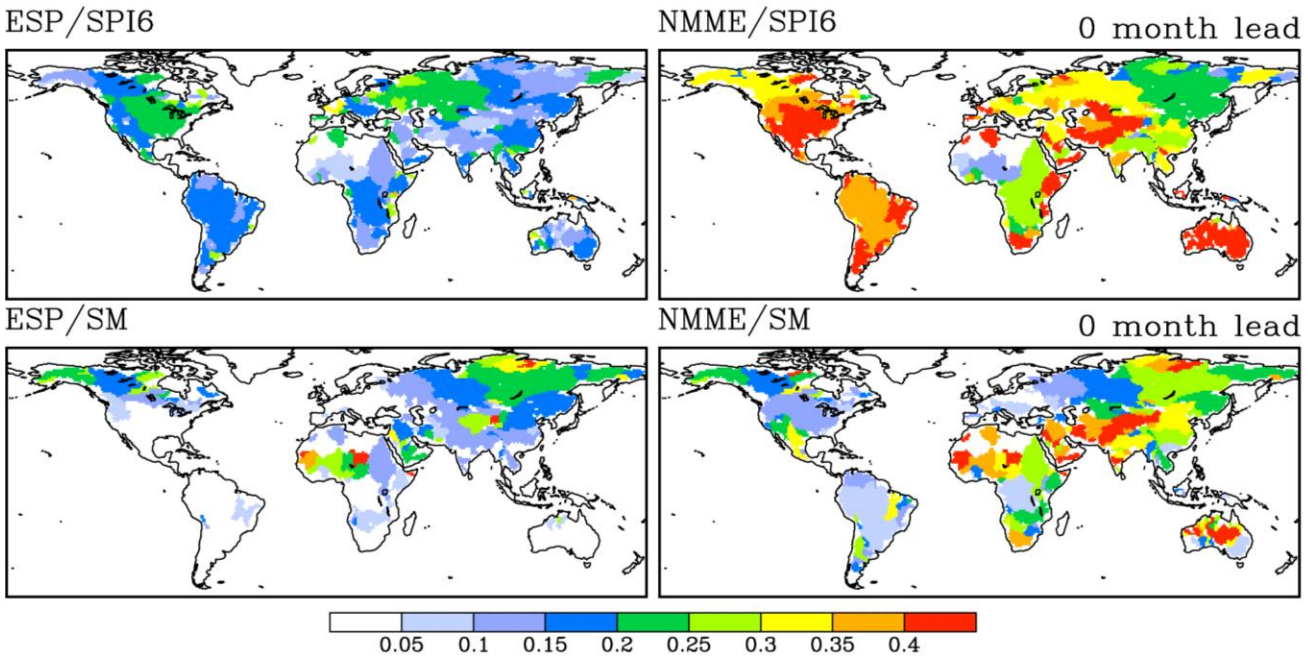



Blue: dry basins

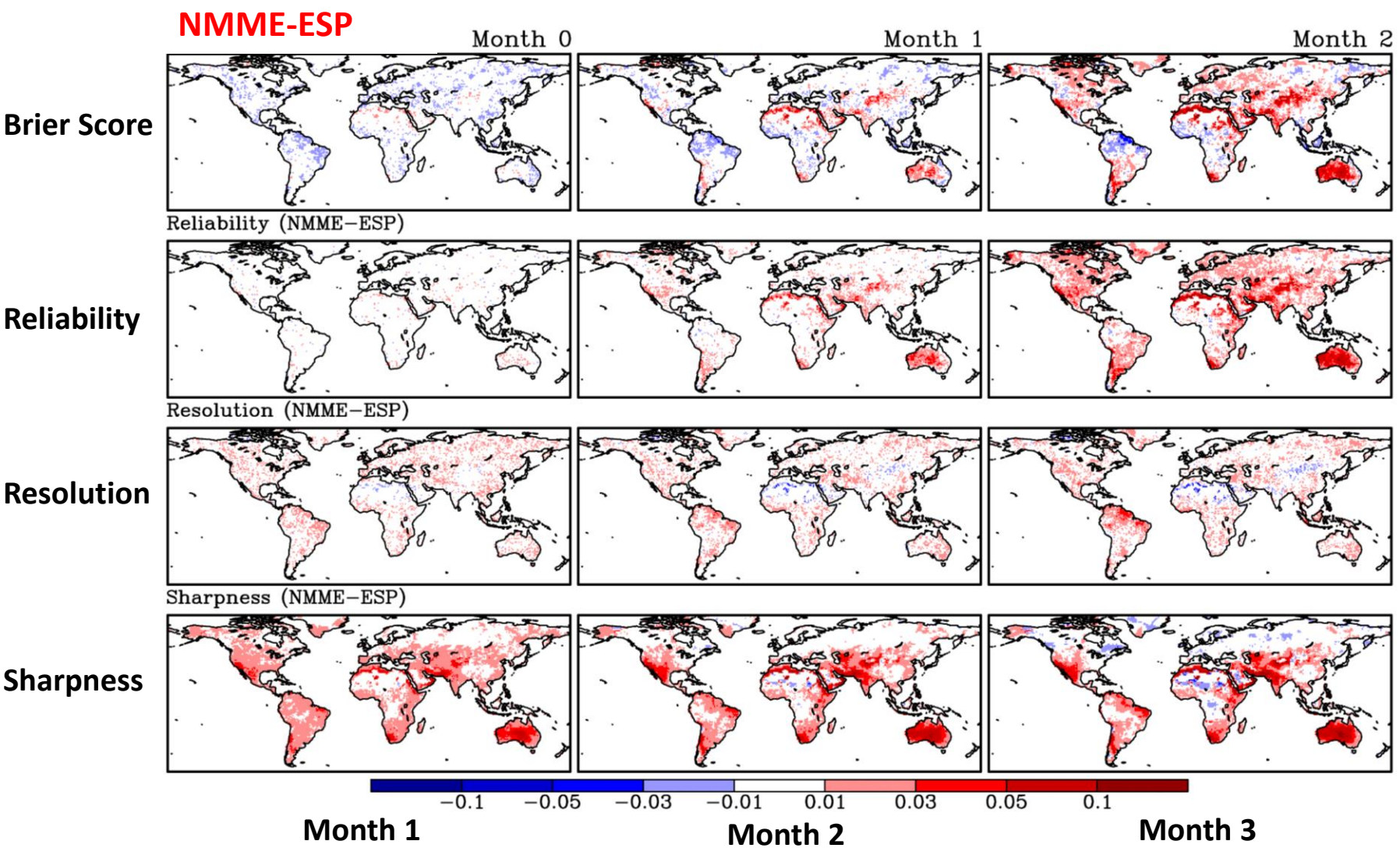
Red: wet basins

# Soil moisture drought onset forecast

- Bias correct monthly Pr and T2 and generate 20 ensemble, downscale them to daily series using climatology, and drive the VIC model to produce soil moisture ensemble forecast.
- Except for far east, northern China and west Africa, soil moisture drought onset forecast is much less skillful than SPI6. (It may be sensitive to the hydrological model)

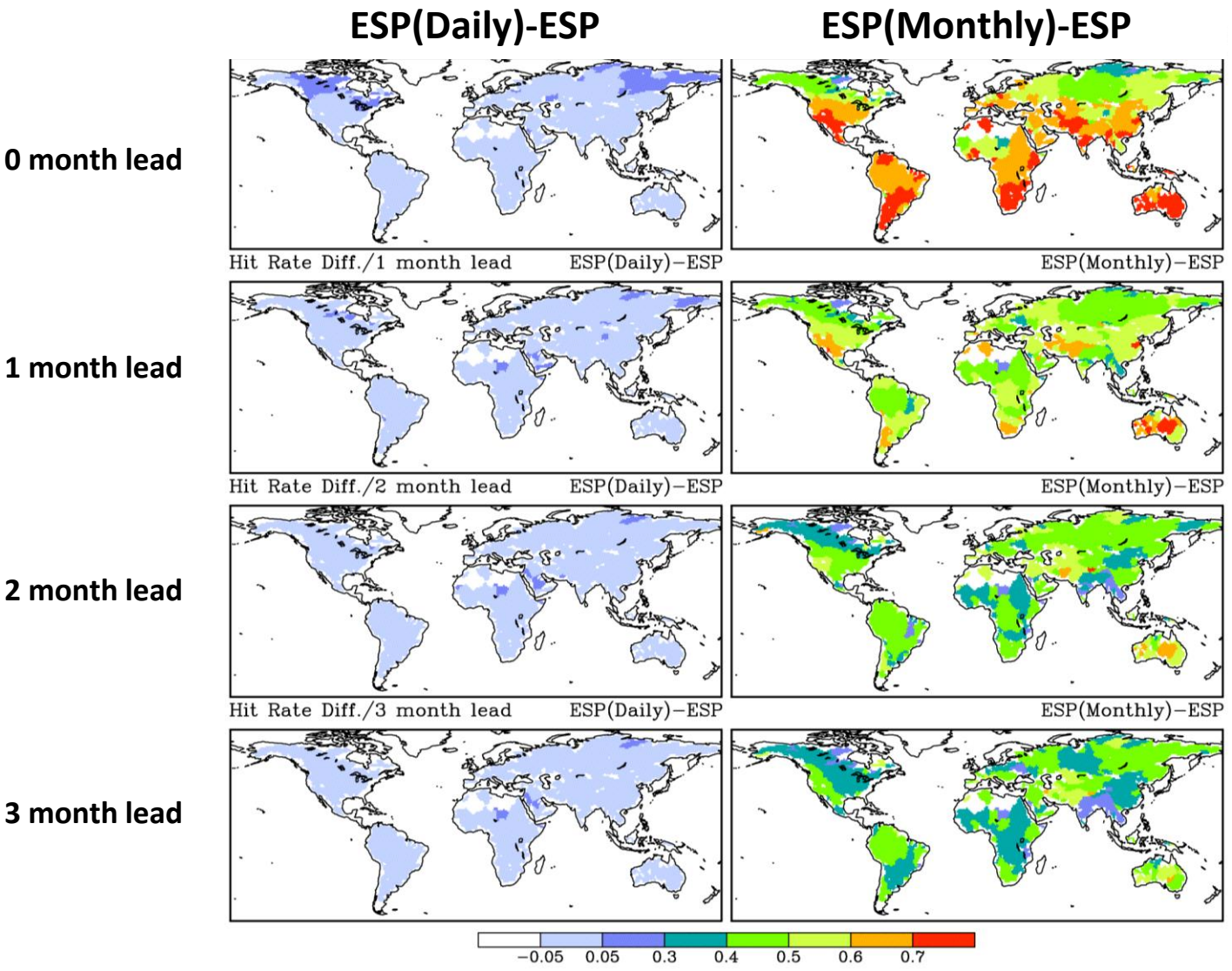


# Probabilistic quality of ensemble meteorological drought forecast




**Over-confident SPI6 forecast at long lead, current approach in reducing 109 NMME ensemble members to 20 members might not be reliable.**

# Sensitivity experiments for keeping daily or monthly information



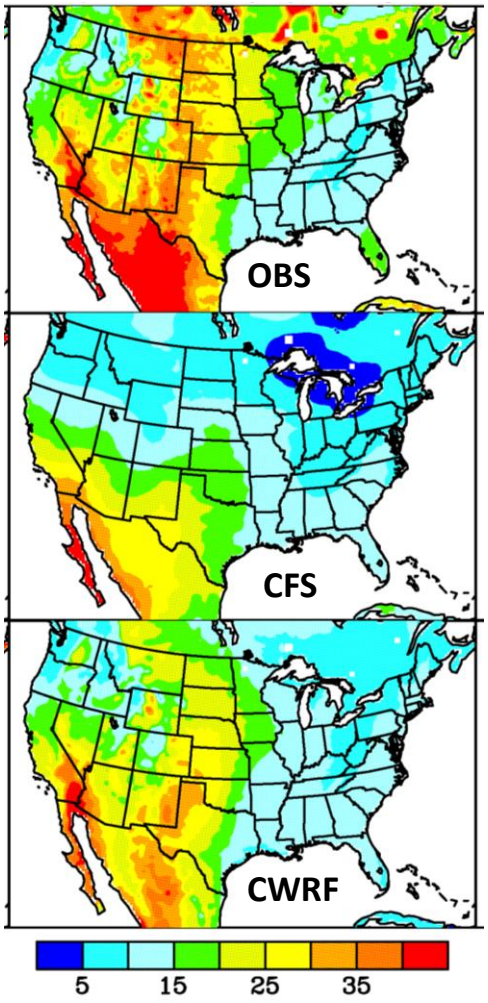

**Differences in hit rate of soil moisture drought forecast between sensitivity and CTL experiments**

# Summary

- Event-based drought forecast assessment: a rigorous (1 degree, 3 month duration) multi-model hindcast assessment has been done for predicting drought onset globally during 1982-2009 for both meteorological (SPI6) and agricultural (soil moisture) drought.
- It seems that there is a threshold (signal/noise) beyond which multi-model ensemble drought onset forecast can add value against single models (e.g., N. America, west Africa)
- While GCM-Hydro soil moisture drought forecast is more challenging than SPI6 due to their intrinsic characteristics or time scales, current downscaling approach might not be good enough due to over-confident errors and daily/monthly time series mismatch.

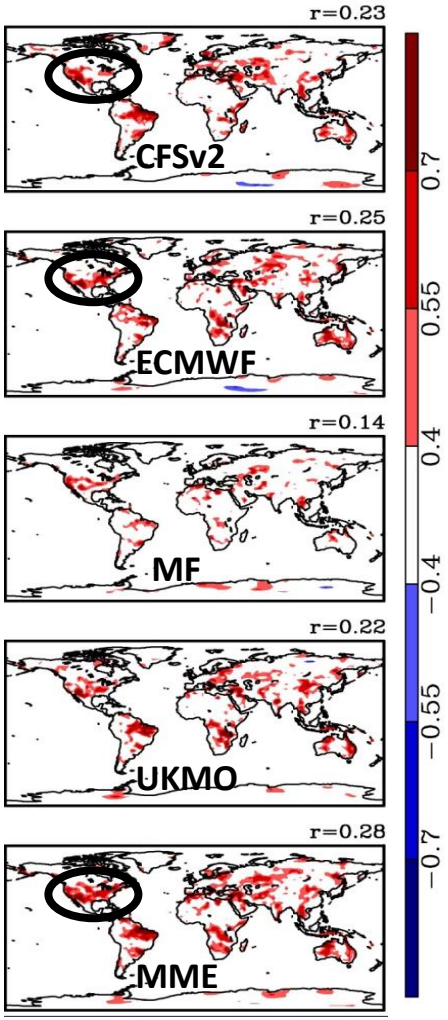
# Outlook for drought forecast: model improvement and independency

**Dynamical downscaling with CFS-CWRF**



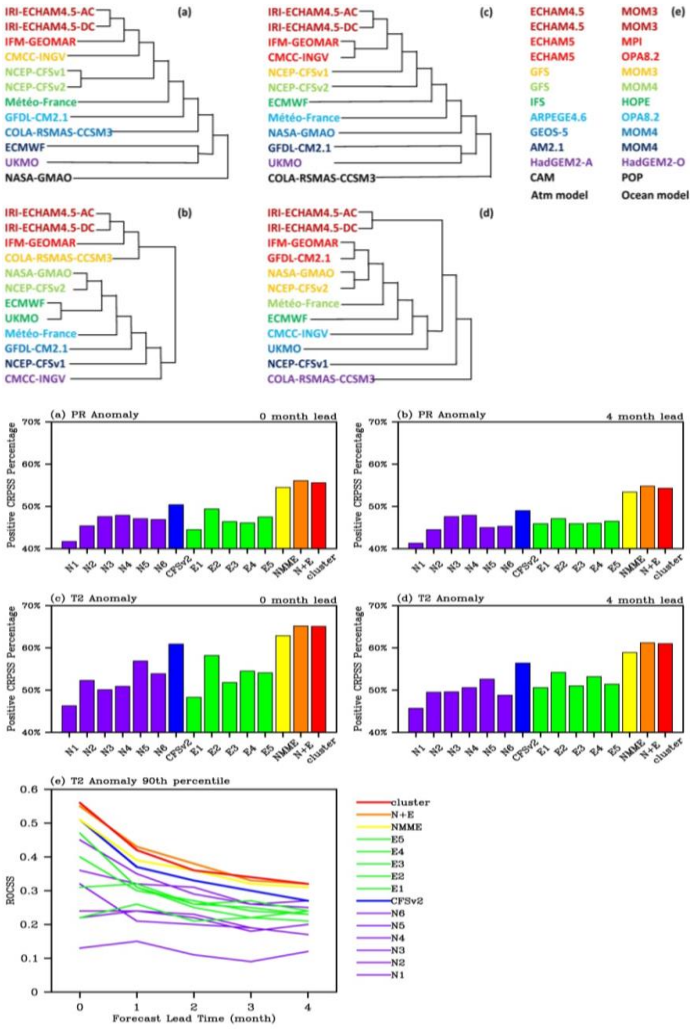

Yuan and Liang, GRL, 2011

**A first look at CFSv2**




Yuan et al., GRL, 2011

**Clustering of climate forecast models**




Yuan and Wood, GRL, 2012

Thank *everyone in the Land Surface Hydrology group* at Princeton

# *Thank you for your attention*!

**http://hydrology.princeton.edu/~xingy/**

**xingy@princeton.edu**