



A VIC-based Experimental Seasonal Hydrologic Forecast System over the Eastern US

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Background to the Eastern U.S. prediction activities

Three detailed scientific issues for the current project.

1. Forecast uncertainty

What are the statistical properties of seasonal climate forecasts, and how does these relate to hydrologic forecast uncertainty?

How does resulting forecasting skill depend on catchment size?

What is the relative role of seasonal climate forecasts versus initial hydrologic conditions as they affect hydrologic forecast skill in the eastern U.S.?

2. Removing seasonal climate model biases

Are there alternative methods to remove seasonal climate model biases in precipitation and temperature?

To what extent can **multi-model** forecasts lead to lower hydrologic forecast uncertainty?



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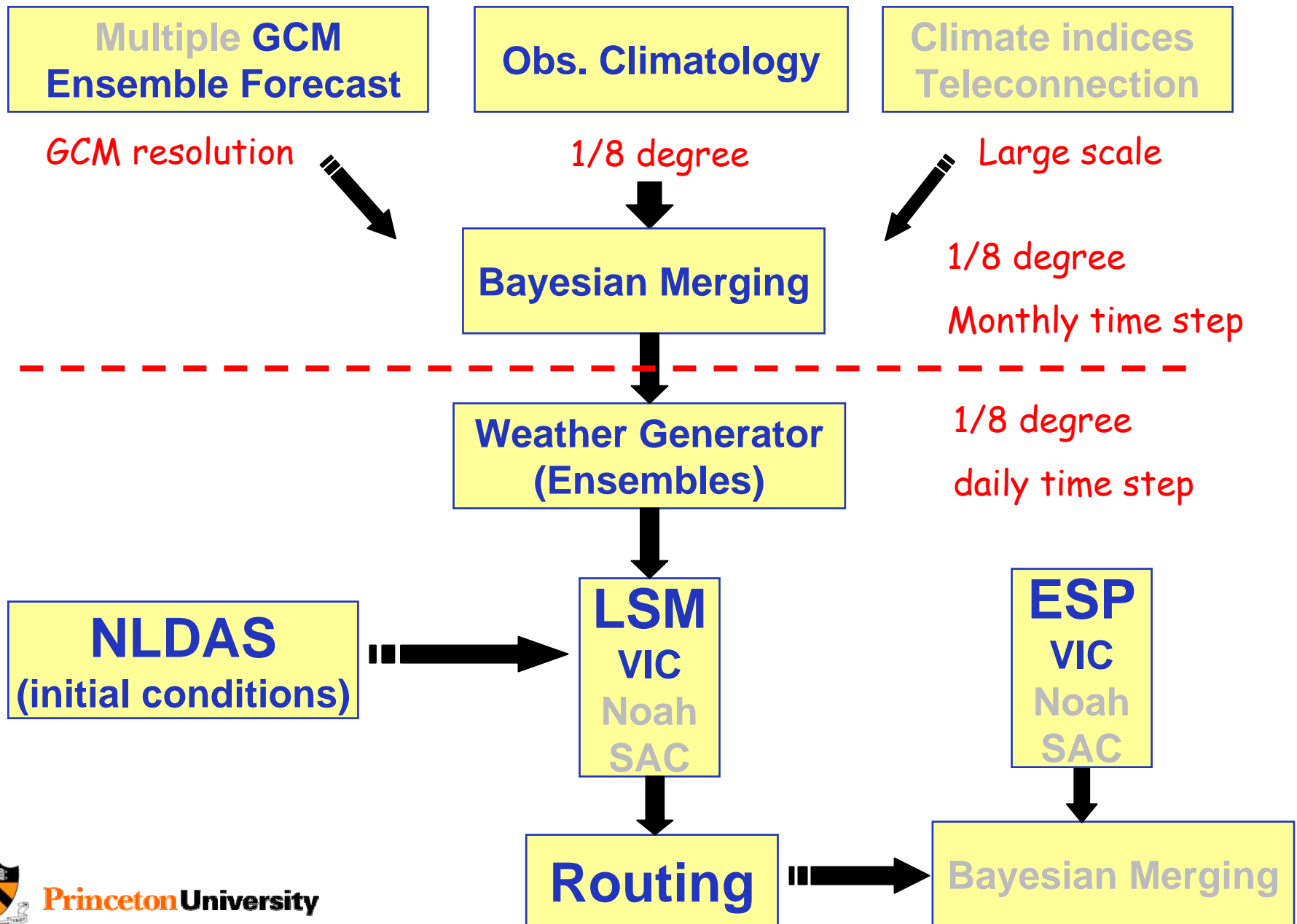
3. Generating hydrologic ensemble predictions

How can uncertainties in hydrologic models, model parameters and hydrologic initial conditions be best represented?

How can hydrologic ensemble forecasts be verified, and can the forecasts be used reliably and, if so, over what forecast periods?



Bayesian system under development



Bayesian merging of information

Bayes Theorem

$$p(\theta | y) = \frac{p(\theta, y)}{p(y)} = \frac{p(\theta) p(y | \theta)}{p(y)}$$

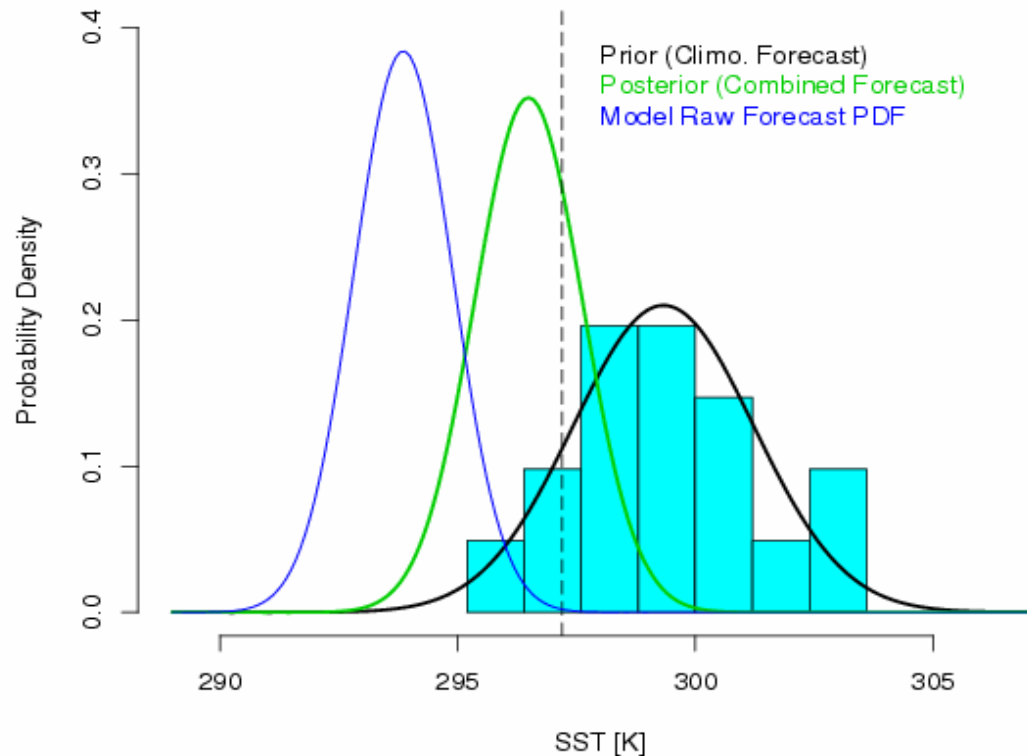
Posterior

1/8th degree
scale variable

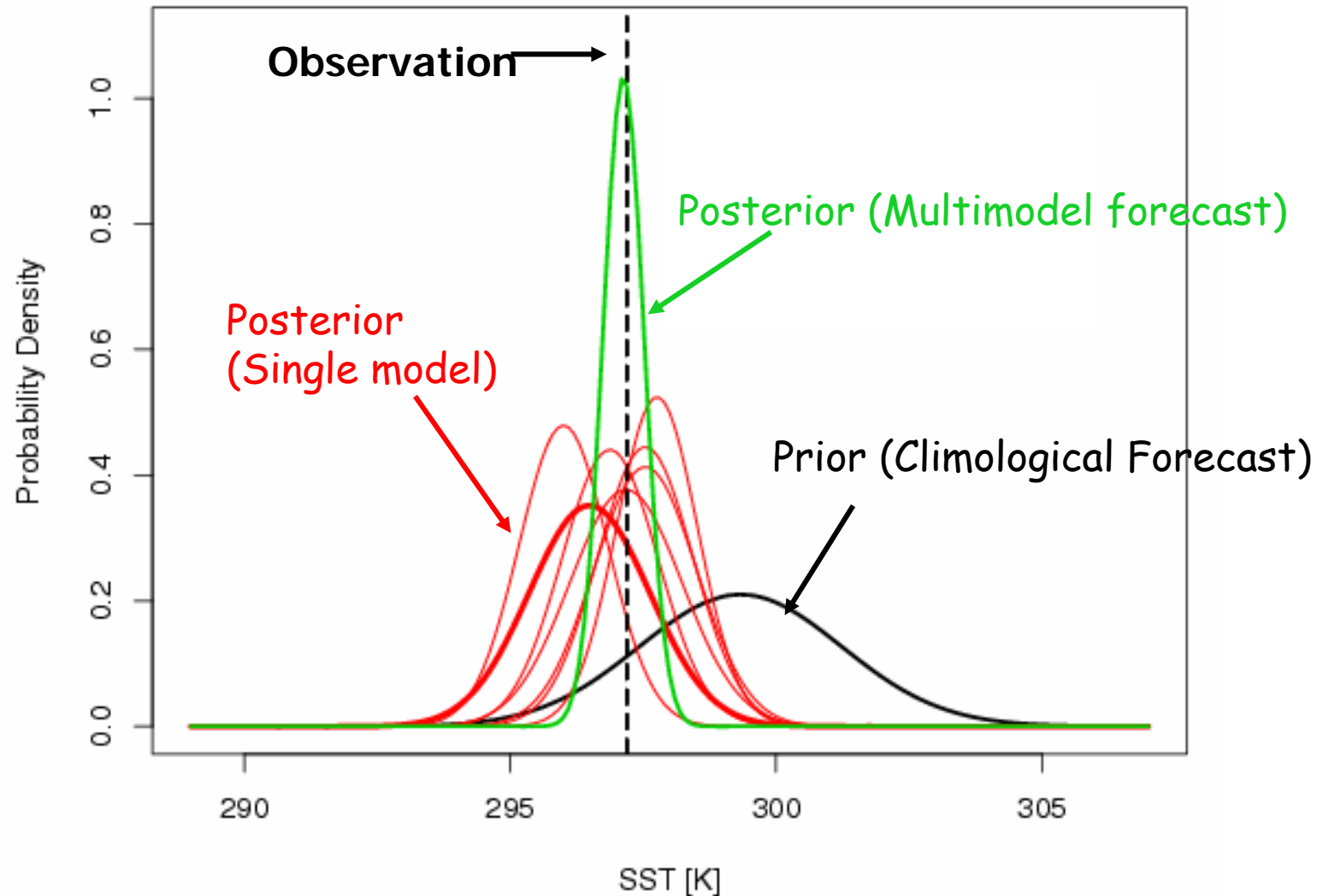
GCM-scale
variable

Prior
(local
climatology)

Likelihood function
(relates local scale
to GCM scale)



Merging multimodel forecast with climatology



Example: SST forecast

- Seasonal SST forecast from ECMWF DEMETER project

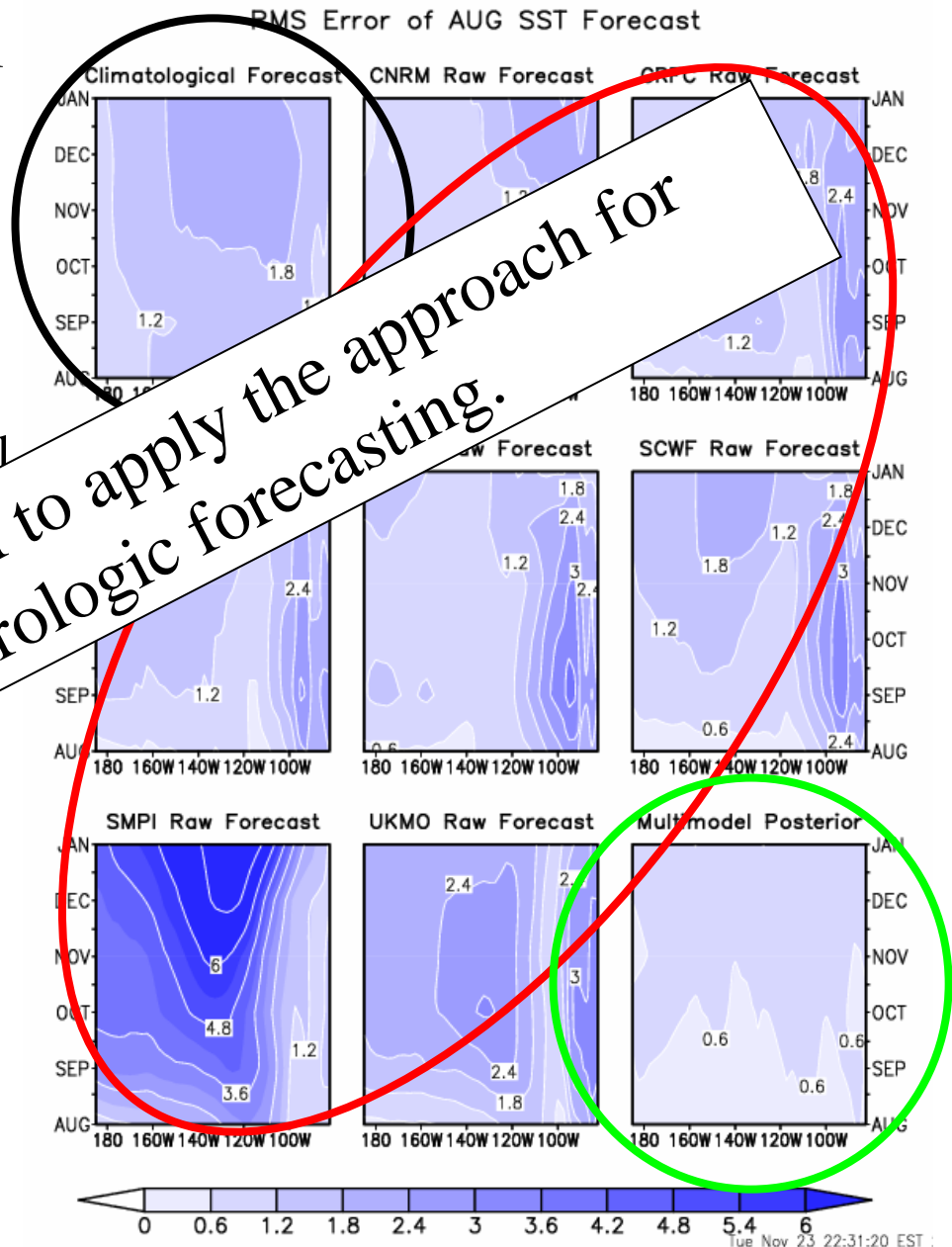
- 7 climate models
- 6 months forecast starting August
- 9 ensembles from each model
- 20 years (1980-1999)

- RMS error of all ensemble forecast initialized

- Forecast initialized with climatological SST

- Model posterior analysis has the smallest RMS error

There is great potential to apply the approach for seasonal hydrologic forecasting.



Bias-correction and downscaling approach

- Merge information from multiple sources instead of relying solely on a climate model forecast
 - Climatological distribution from in-situ observations
 - Seasonal forecast from multiple climate models
 - Climate indices (current and outlook)
- Compute directly at the spatial scale that is suitable for the hydrologic application ($1/8^{\text{th}}$ deg or smaller), which avoids spatial downscaling.
- The hydrological ensembles are generated from the merged GCM ensemble/s and in-situ information (posterior distribution) at the local spatial scale.



Generation of the daily (weather) sequences

- Randomly (**or conditionally**) select one month (the same month as the forecast period) from the historical dataset and use its day-to-day progression
- Adjust the monthly total precipitation and mean air temperature to match the posterior forecast
- Uniformly apply this adjustment to each day
- **Conditional selection**: find the closest 20 months in the historical record to the current month in terms of monthly total precipitation pattern over the entire basin. Using the time series of the same year over entire region keeps the spatial consistency and continuity.



Current status of our forecast system

- At the beginning of each month, we produce two experimental forecasts for the SE, one based on CPS **Climate Forecast System (CFS)** forecast and one based on conditional **ESP**.
- Each forecast has lead time up to 9 months and has 20 ensemble members.
- Forecast are posted on the Internet before the 10th of each month. (<http://hydrology.princeton.edu/forecast>)
- We are also working on ingesting multiple GCM seasonal forecasts into the system before making hydrologic ensembles.



Precipitation for 198504 (hindcast init:198504)

Climo

Obs

CFS-based Forecast

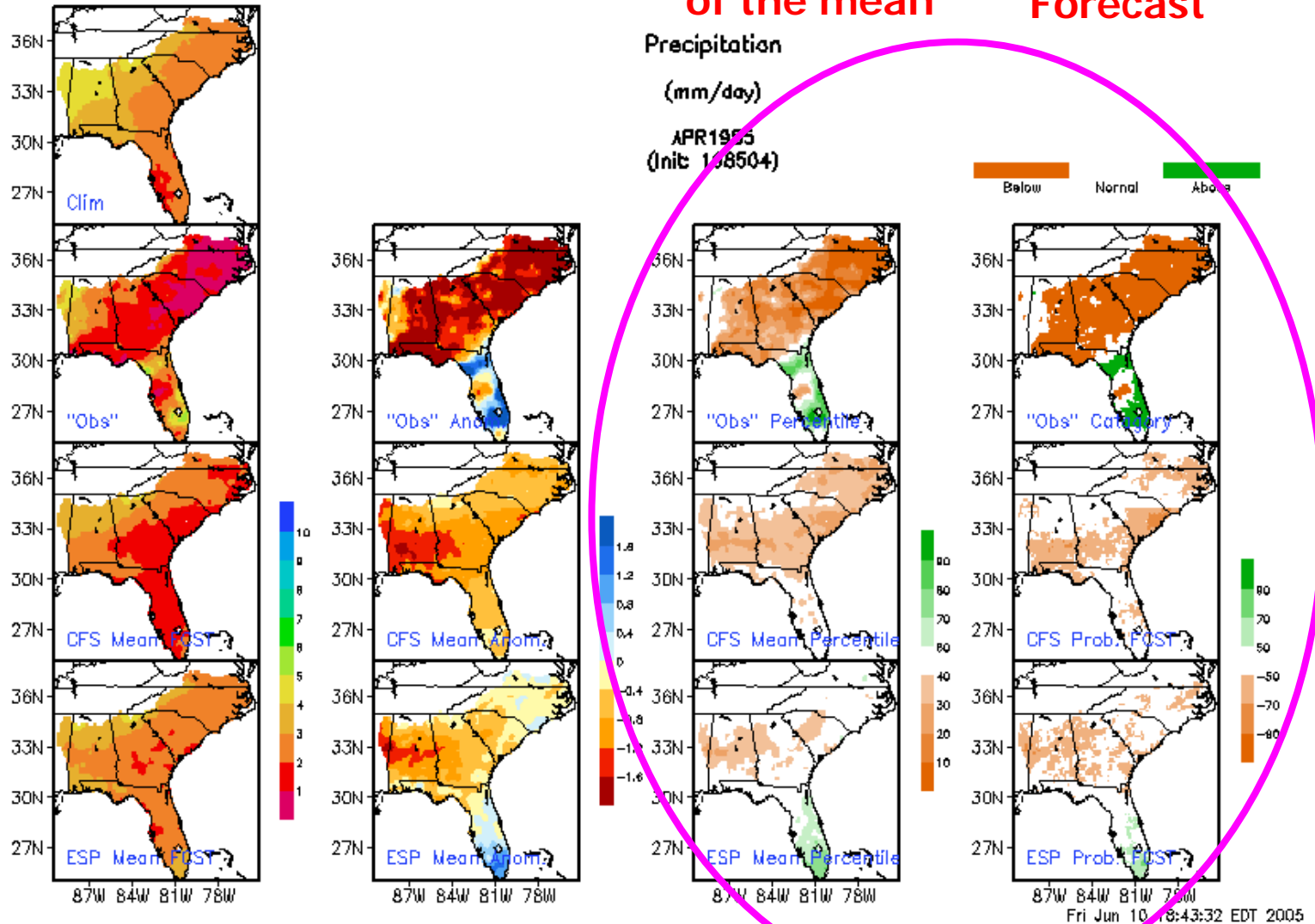
ESP-based Forecast

Mean

Anomaly

Percentile of the mean

Probabilistic Forecast



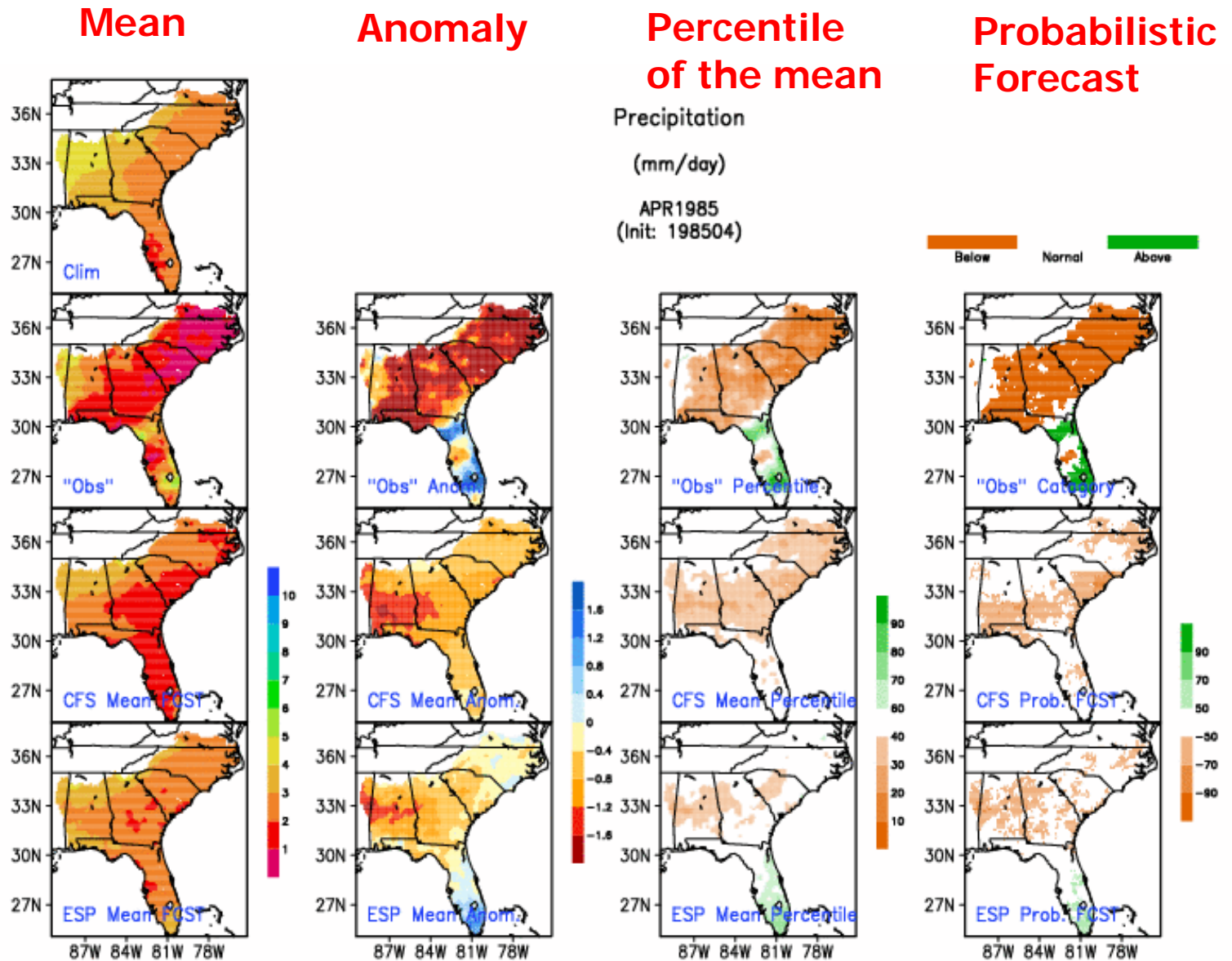
Precipitation time series (hindcast init:198504)

Climo

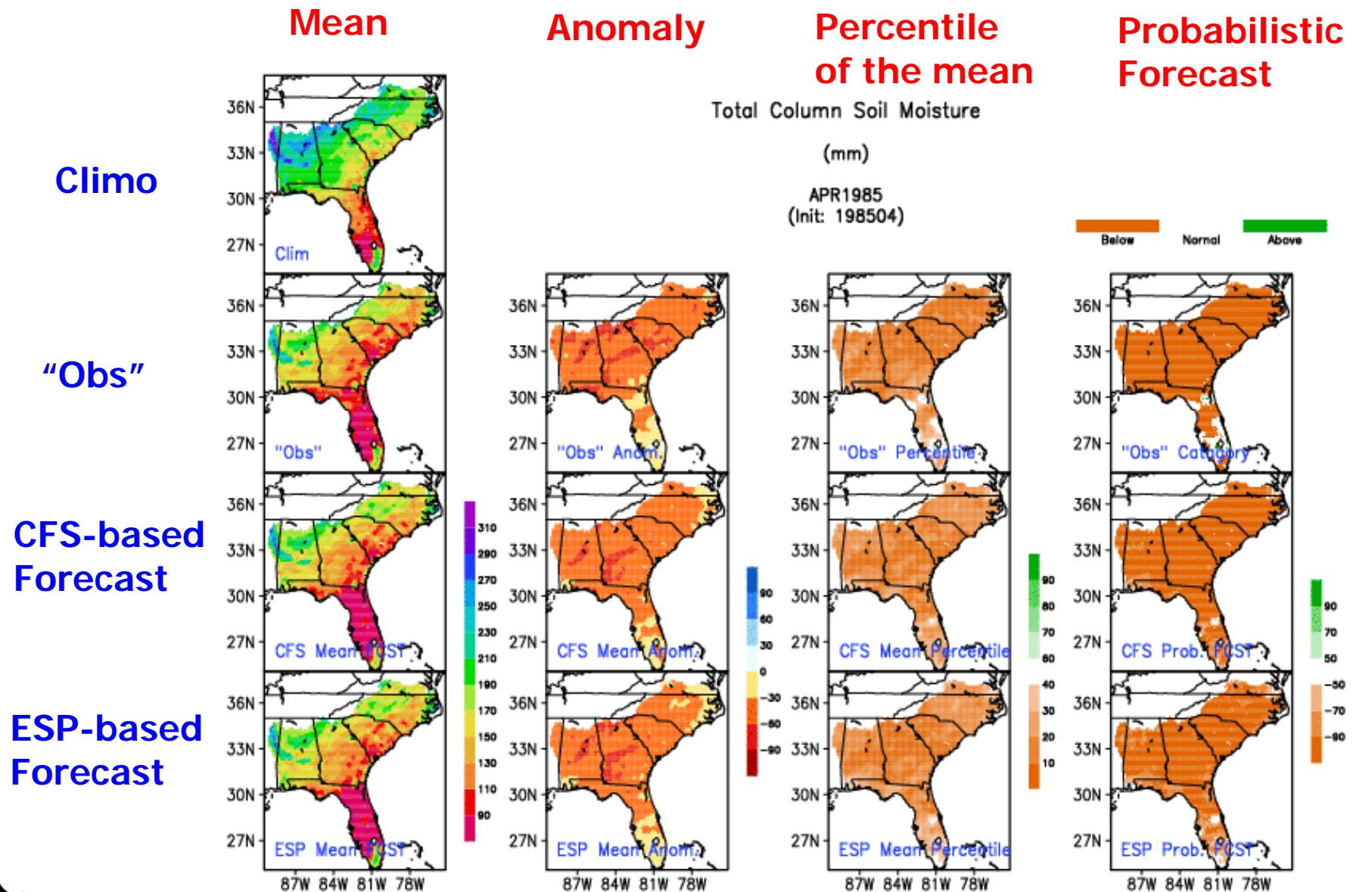
Obs

CFS-based Forecast

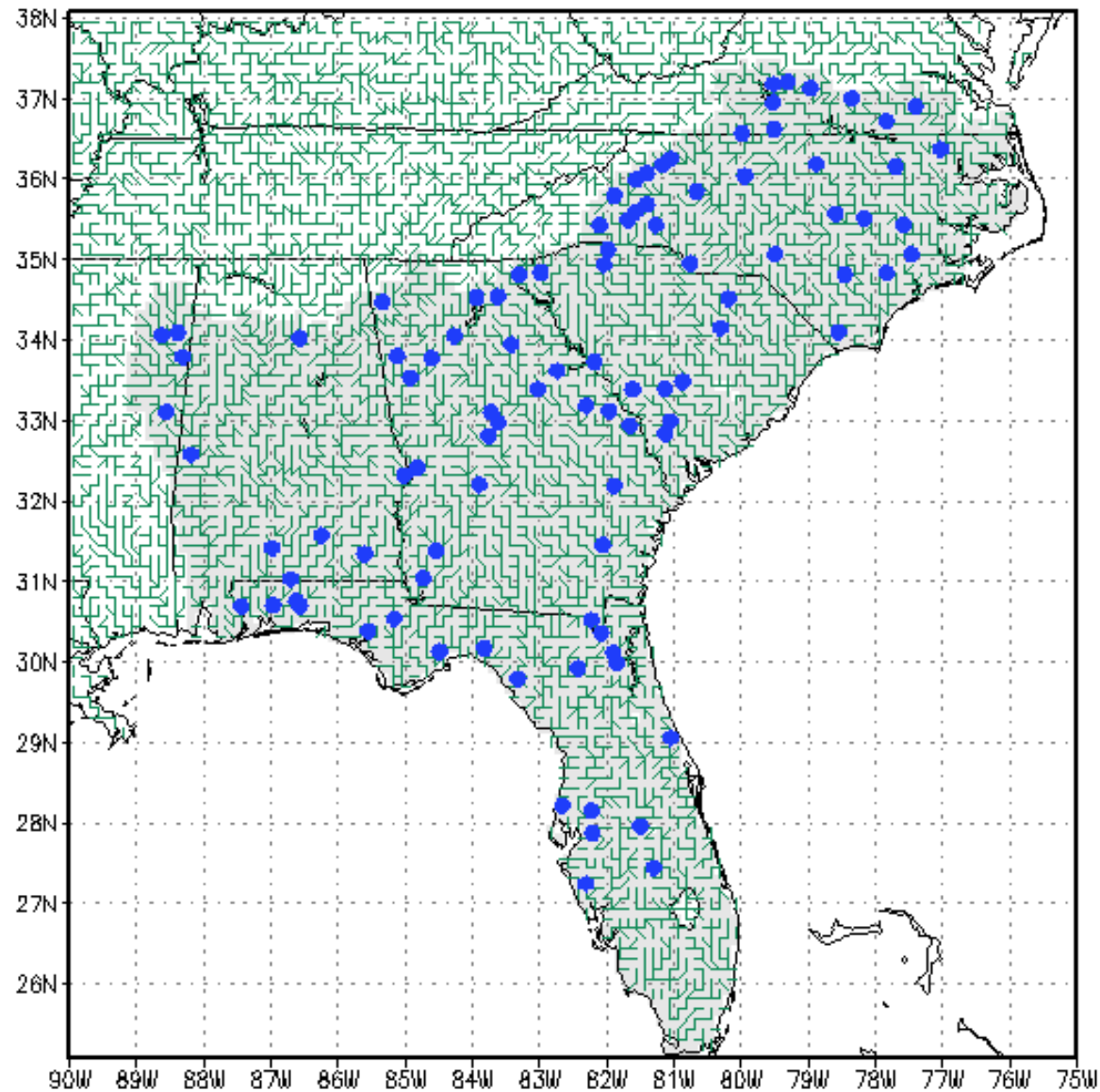
ESP-based Forecast



Soil Moisture time series (hindcast init:198504)



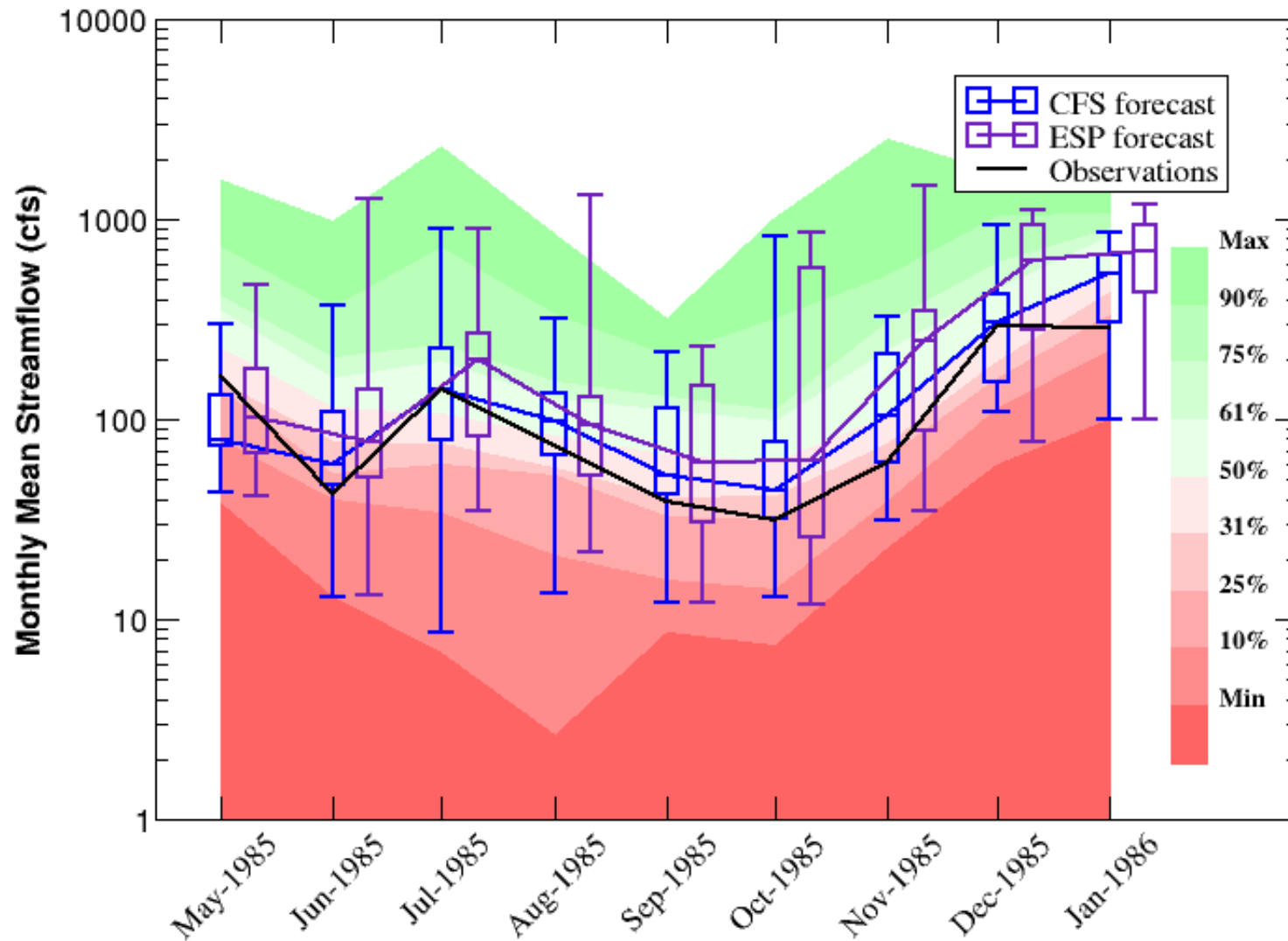
USGS streamflow gages in the SE



Streamflow hindcast verification (Init:198505)

Seasonal Streamflow Forecast (Init: 198505)

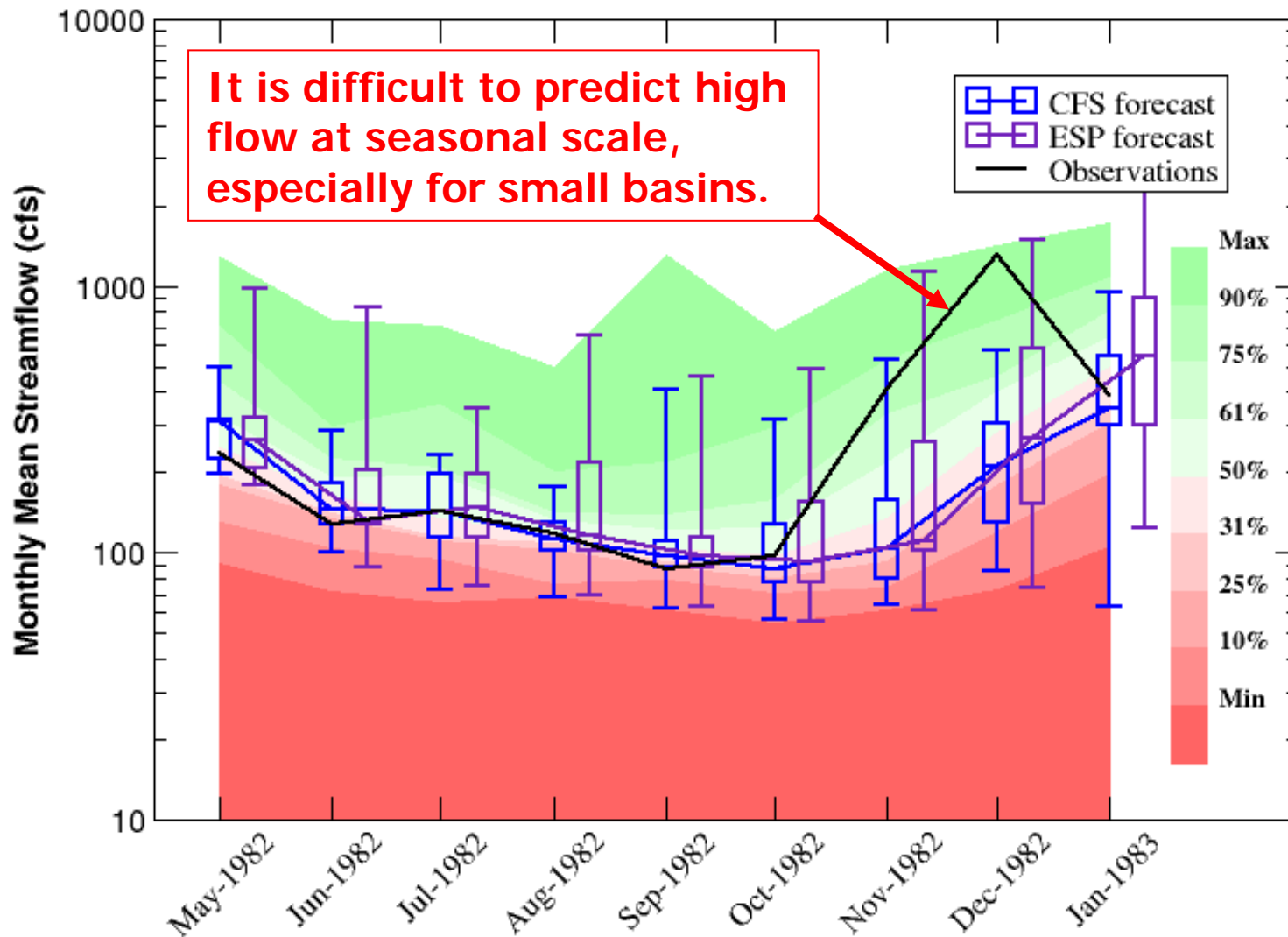
USGS 02342500 (32.3168°N, 85.0149°W), Drainage Area: 322.00 sq.miles



Streamflow hindcast verification (Init:198502)

Seasonal Streamflow Forecast (Init: 198205)

USGS 02398000 (34.4663°N, 85.3361°W), Drainage Area: 192 sq.miles

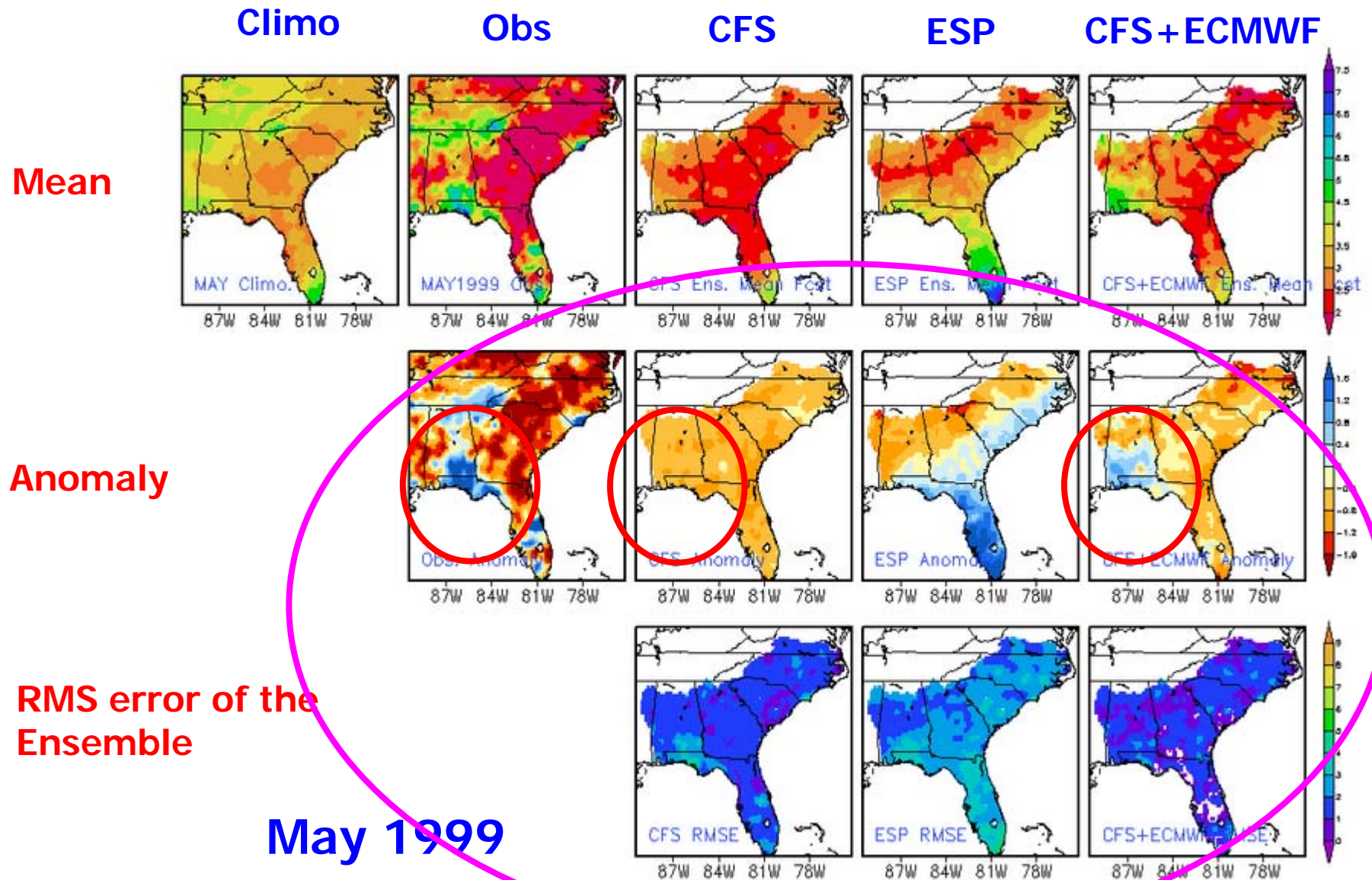


Multimodel hindcast with CFS & ECMWF DEMETER

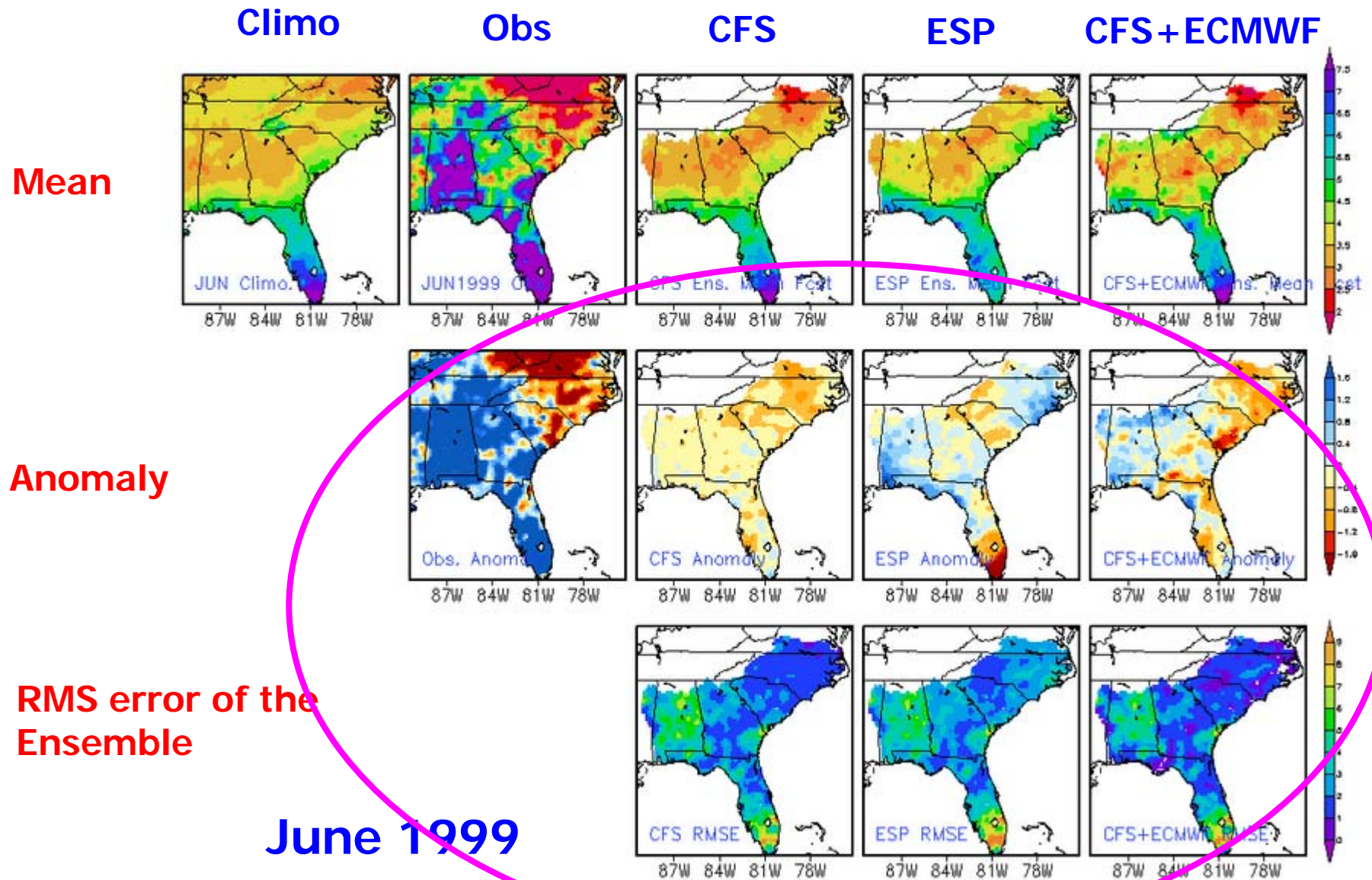
- Seasonal forecast from CPC CFS
 - 1 model
 - 9 months forecast
 - 15 ensemble members
 - 24 years (1981-2003)
- Seasonal forecast from ECMWF DEMETER project
 - 7 climate models
 - 6 months forecast starting Feb, May, Aug and Nov
 - 9 ensemble members from each model
 - 20 years (1980-1999)
- All information provided by the models is merged within the Bayesian framework.



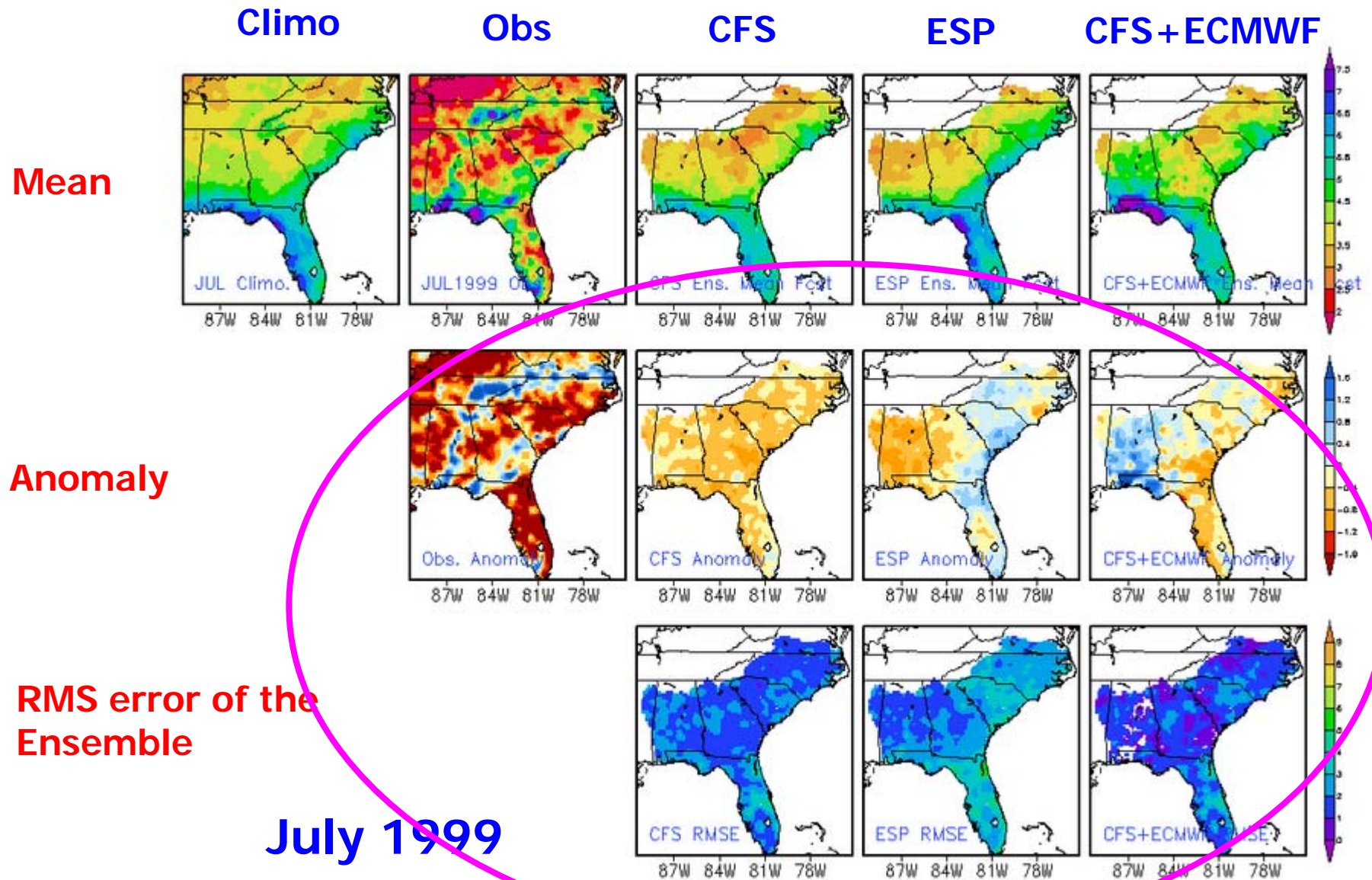
Multimodel **precipitation** hindcast (Init: 199905)



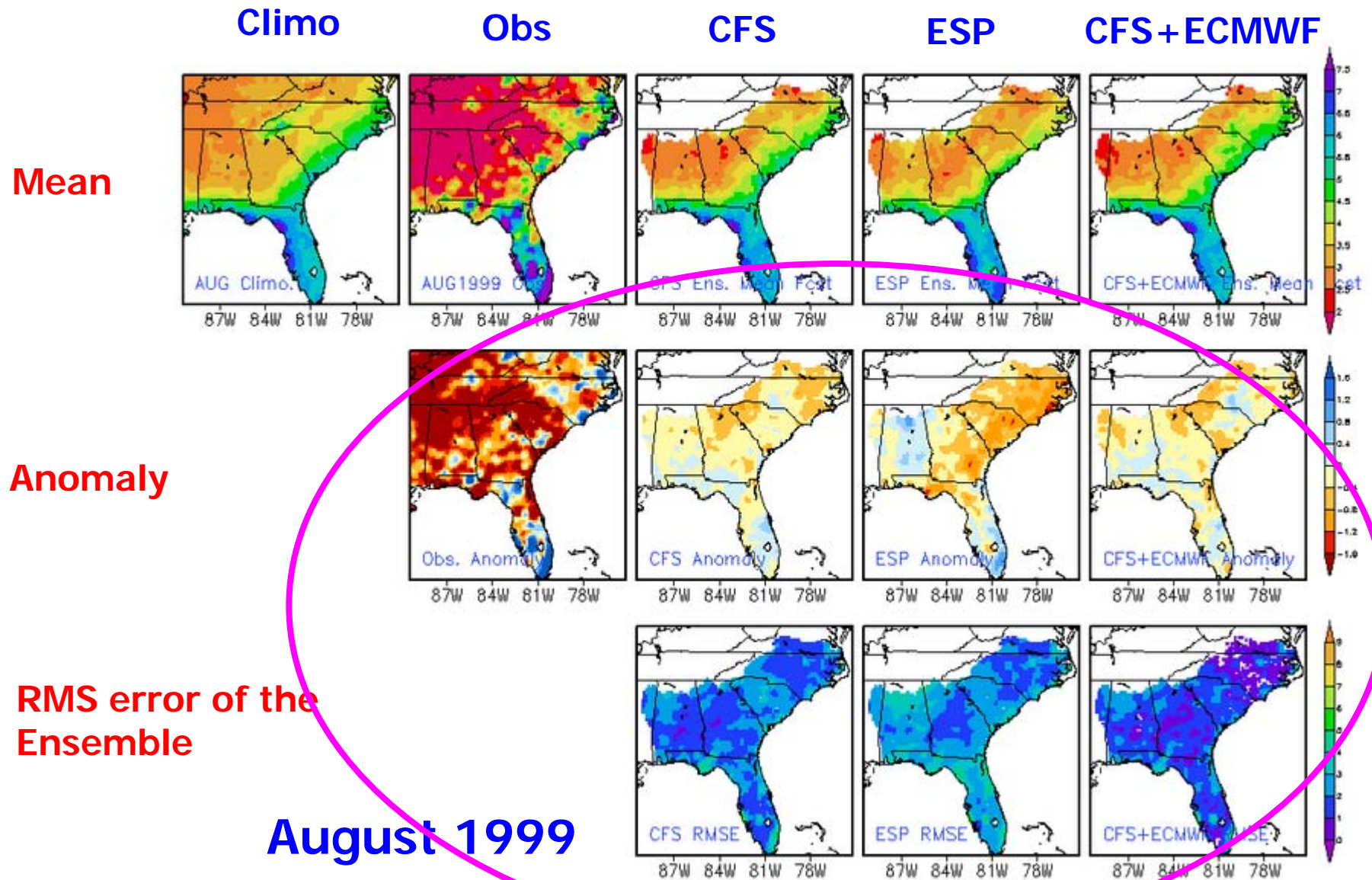
Multimodel **precipitation** hindcast (Init: 199905)



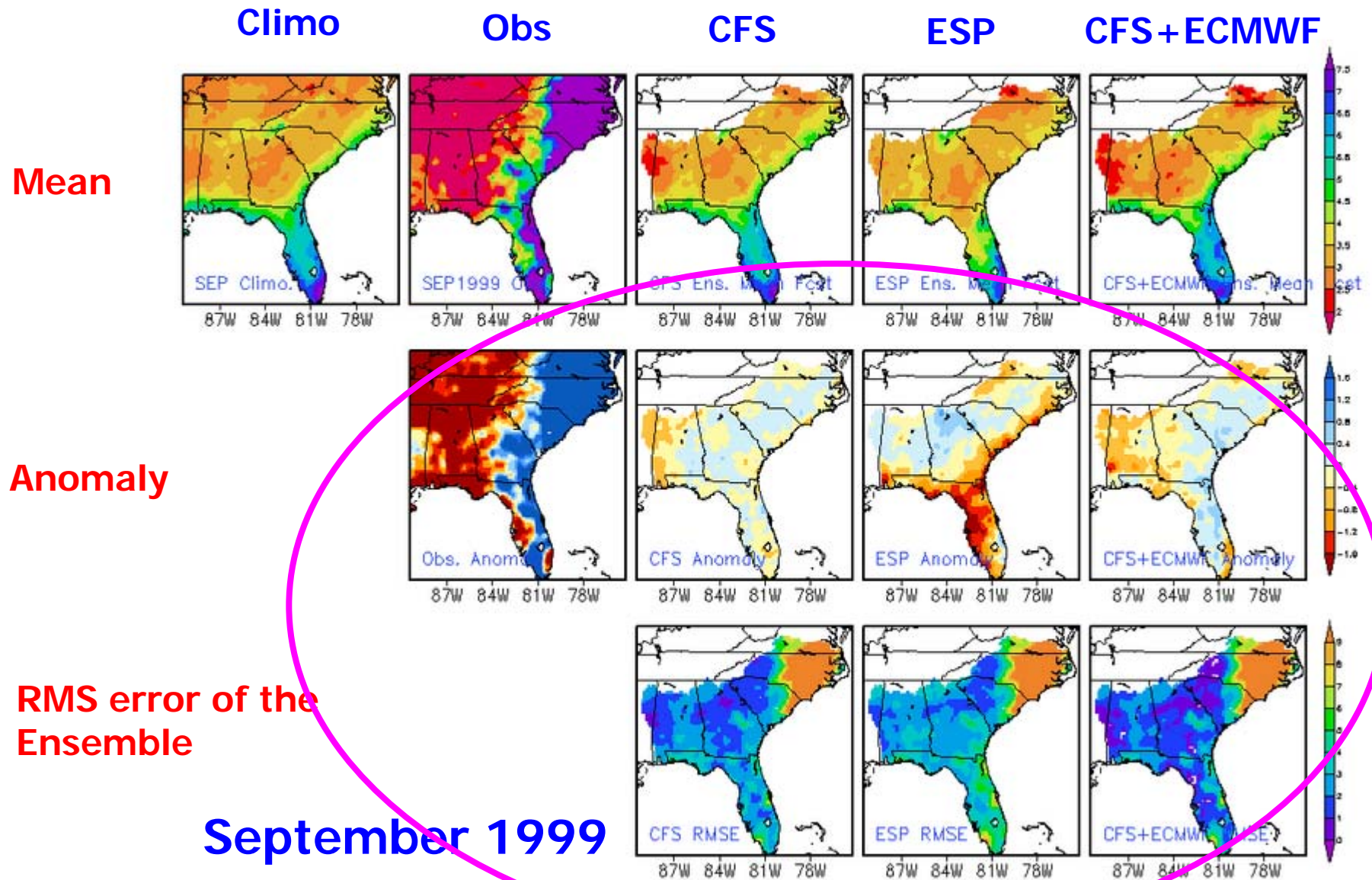
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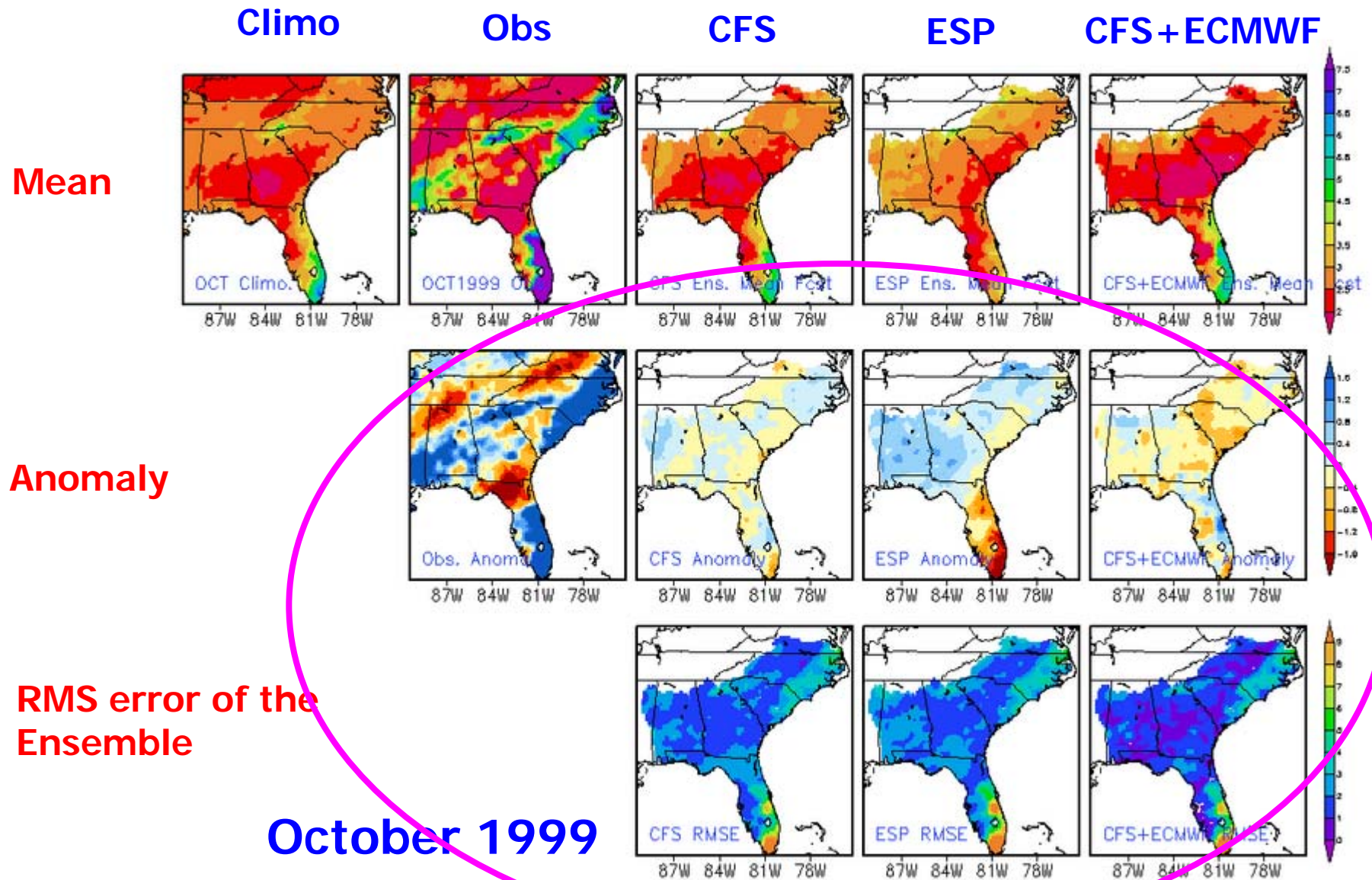
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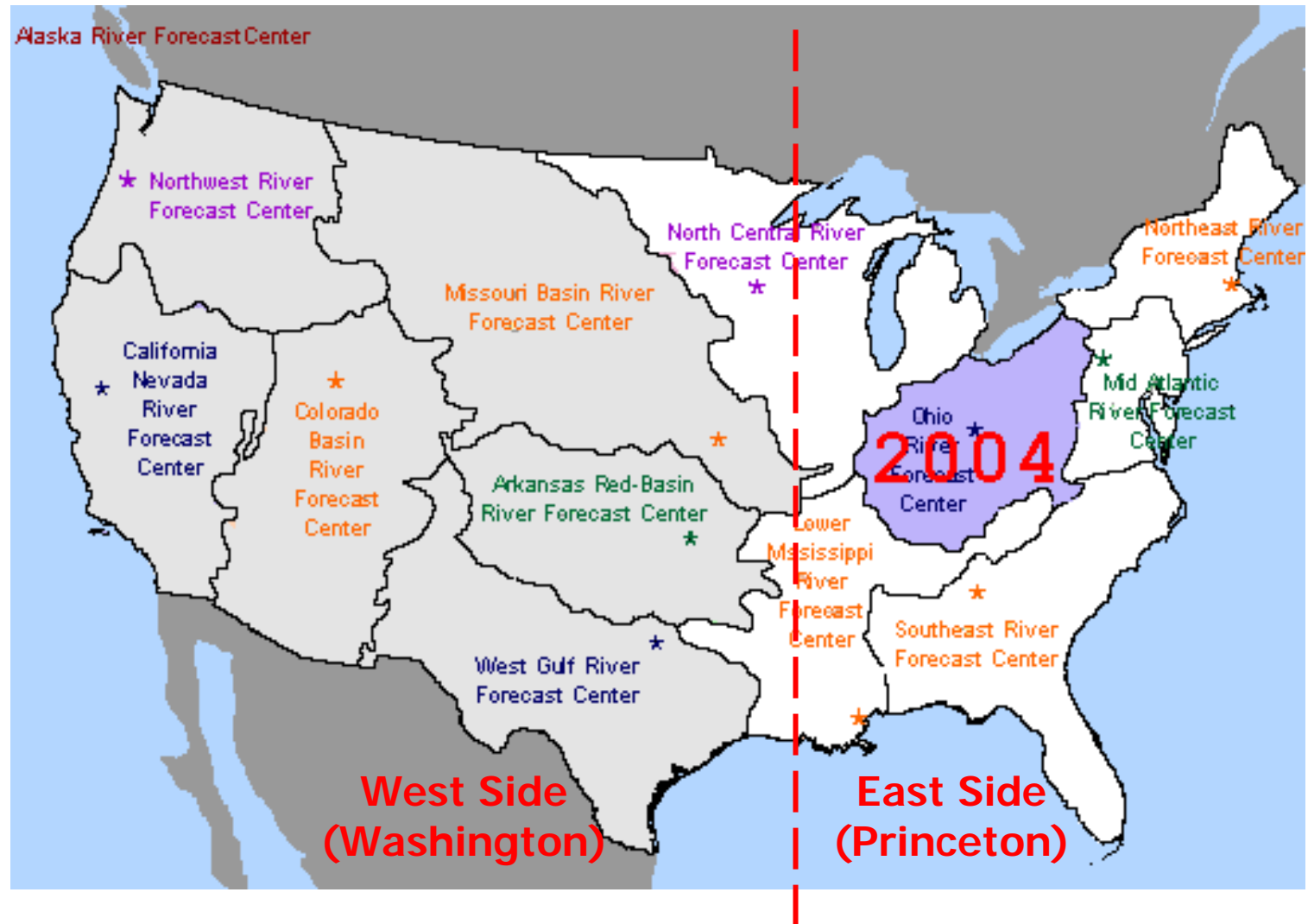
Planned activities for 2005-2007

1. Expansion of the forecast area
2. Developing a multi-model seasonal forecast ensemble system, which could include observations (as a prior).

This can be extended to the hydrological streamflow forecasting, using multi-model (LSM) Bayesian merged ensembles and multi-model, ESP-based ensembles as a prior.
3. Structuring the ensemble system within NLDAS and VIC for the southeastern U.S., and carrying out forecast evaluation.
4. Understanding the potential for seasonal predictability and forecast usefulness for the southeastern U.S.



US East-side hydrologic forecast system



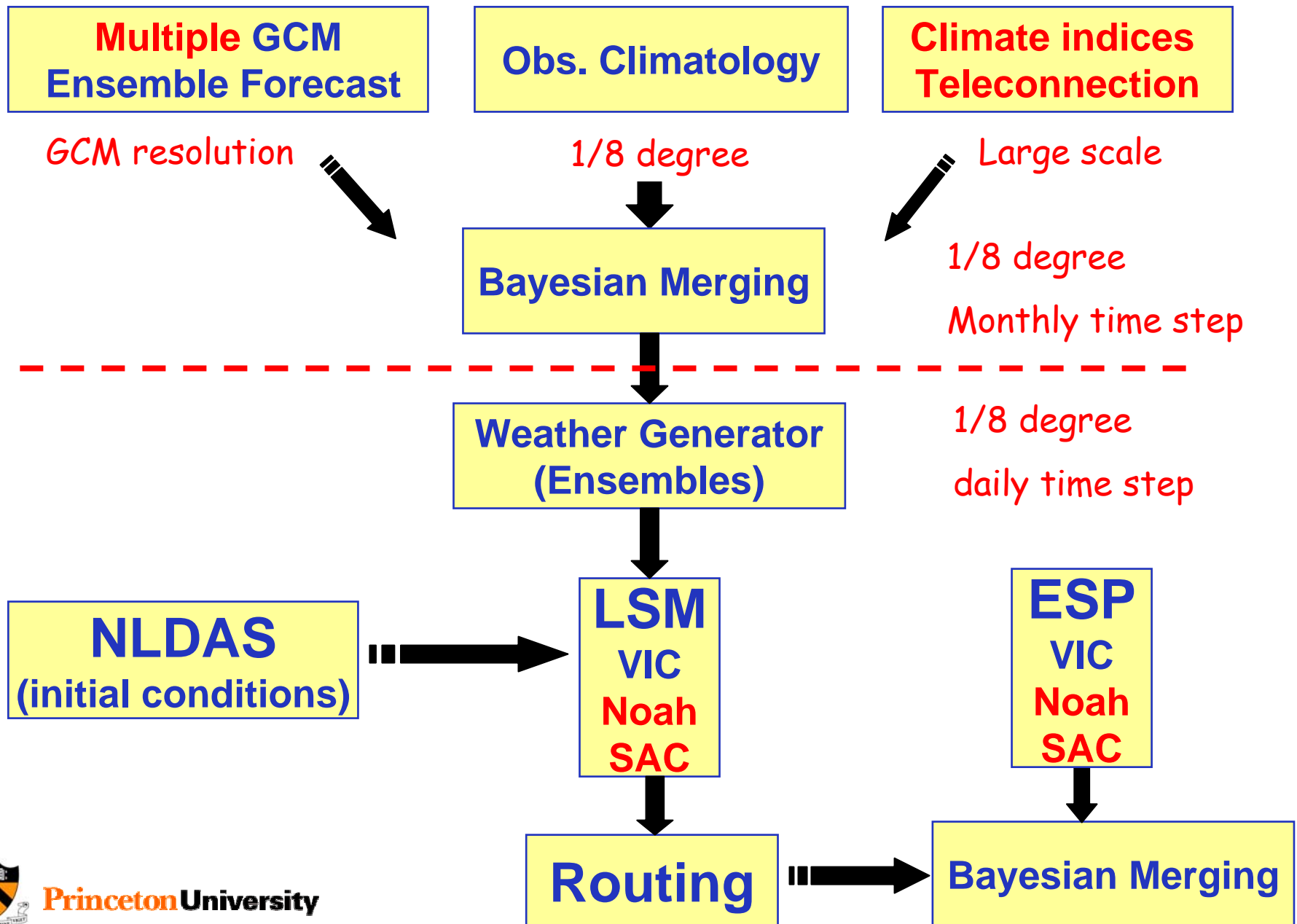
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3. Comprehensive evaluation of the skills of the forecast system.
4. Developing useful products based on NLDAS and the forecast system

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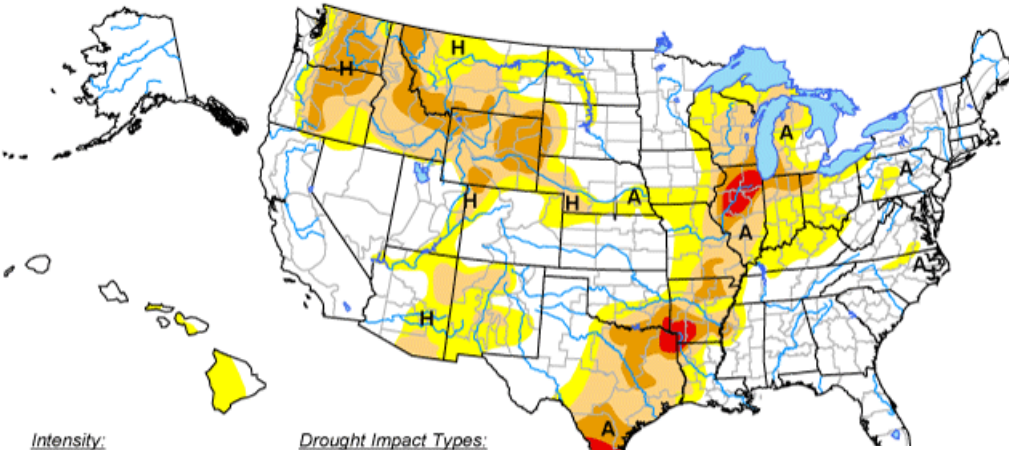
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Realtime drought monitoring with VIC and NLDAS

U.S. Drought Monitor

July 12, 2005
Valid 8 a.m. EDT



Intensity:

- D0 Abnormally Dry
- D1 Drought - Moderate
- D2 Drought - Severe
- D3 Drought - Extreme
- D4 Drought - Exceptional

Drought Impact Types:

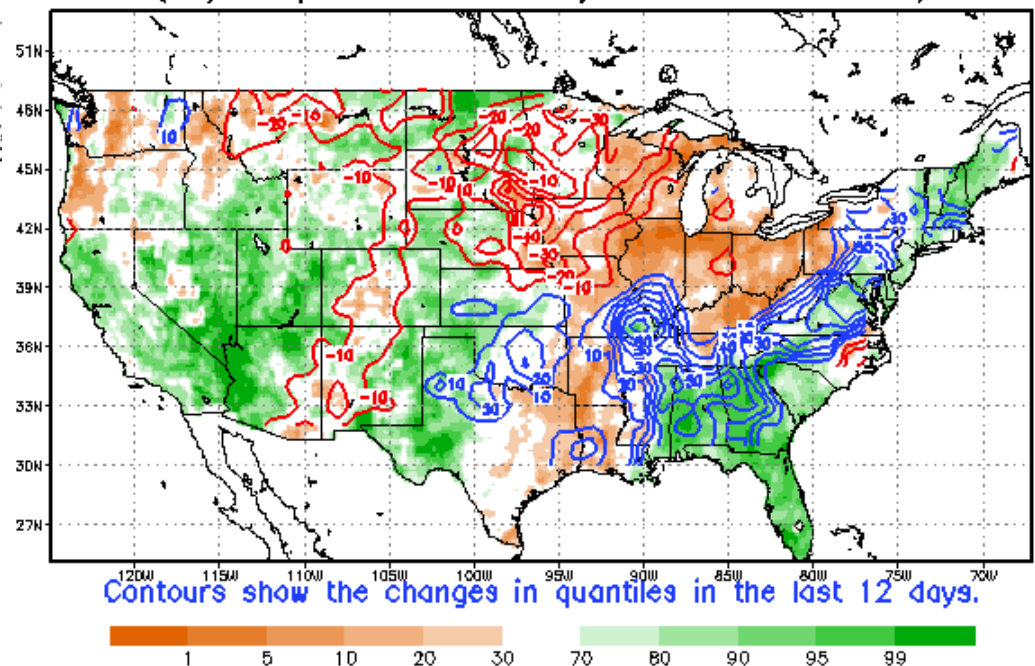
- Delineates dominant impacts
- A = Agricultural (crops, pastures, grasslands)
- H = Hydrological (water)
- (No type = Both impacts)

The Drought Monitor focuses on broad-scale conditions.
Local conditions may vary. See accompanying text summary
for forecast statements.

<http://drought.unl.edu/dm>

USDA
National Drought Mitigation Center
Released Thursday
Author: Richard Tinker, NC

Total Column Soil Moisture Percentiles on 20050712
(wrt/ samples within a 11-day window in 1951-2004)

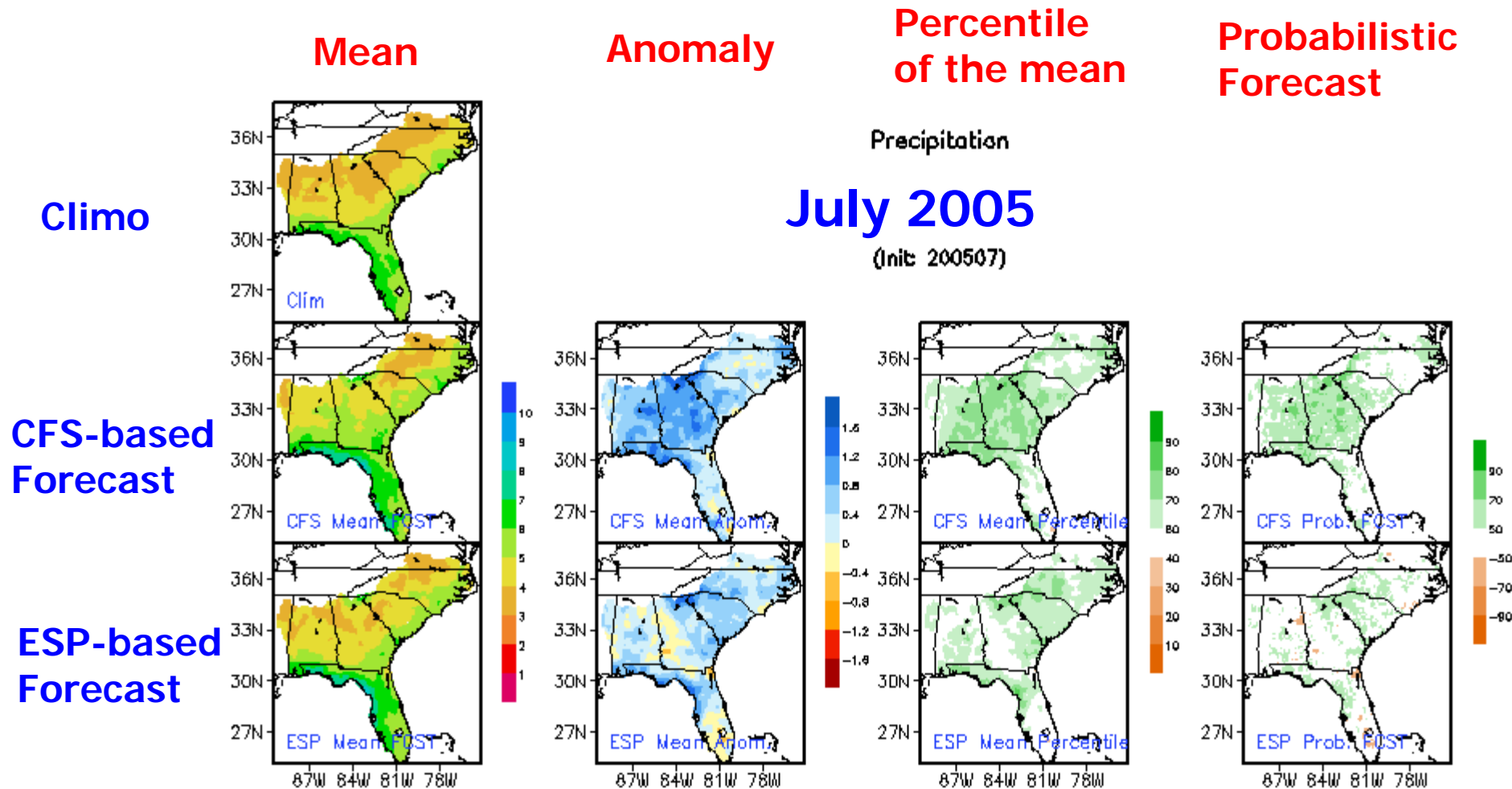


Contours show the changes in quantiles in the last 12 days.

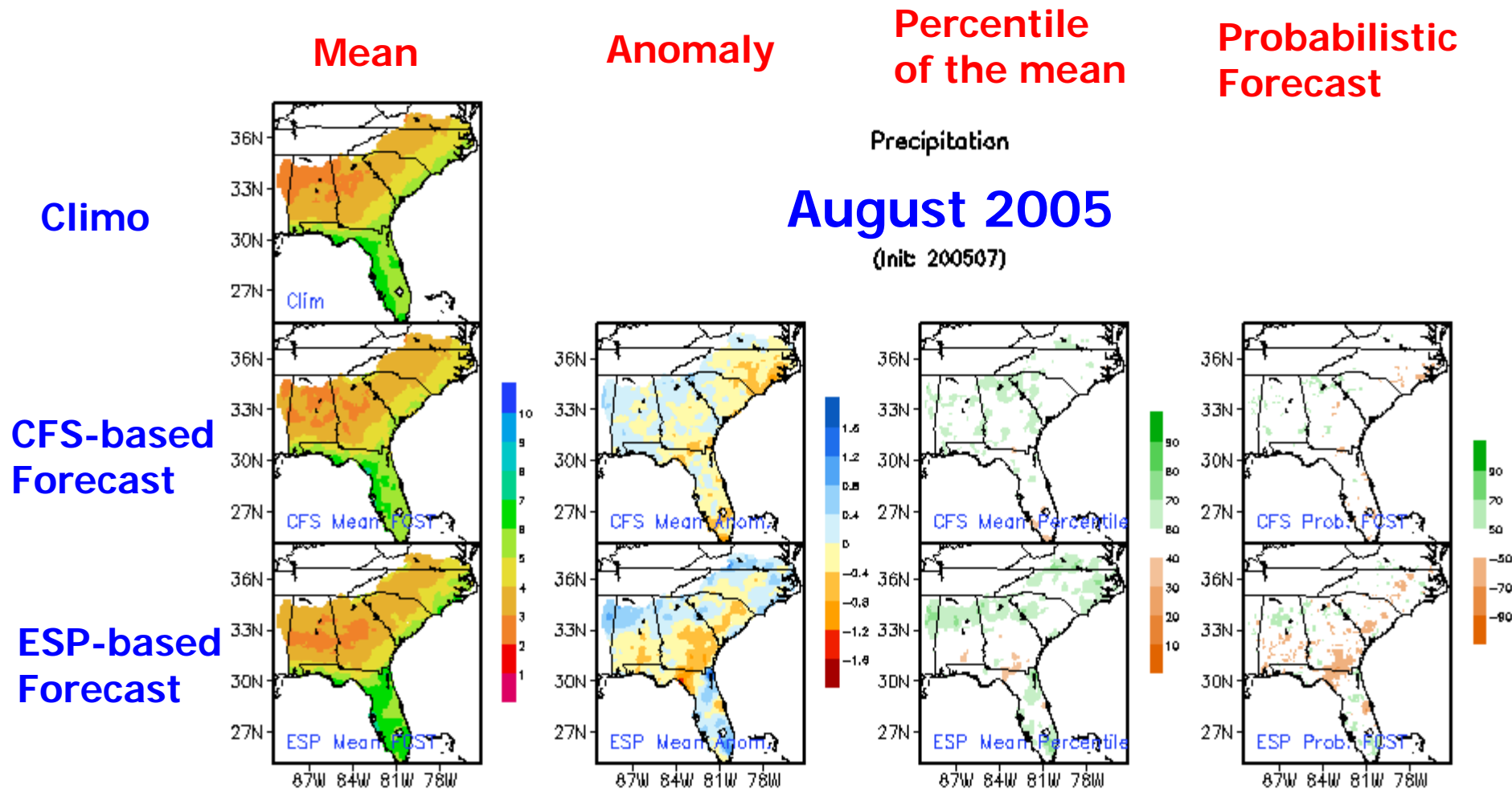


Princeton University

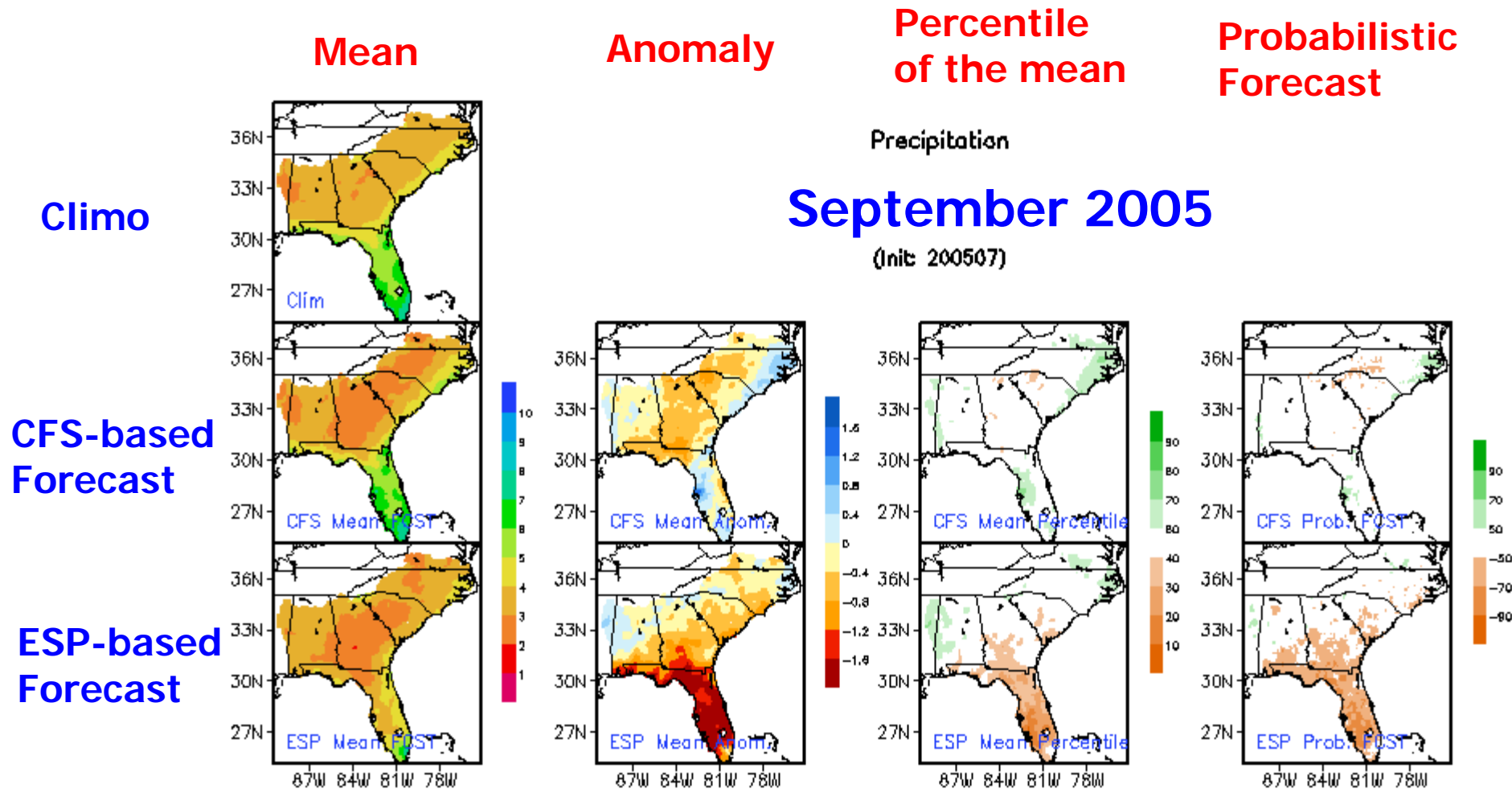
Latest precipitation forecast (Init: 200507)



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Climo

CFS-based Forecast

ESP-based Forecast

Mean

Anomaly

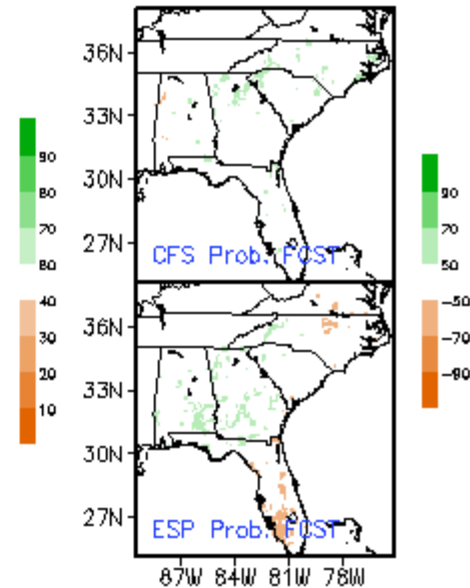
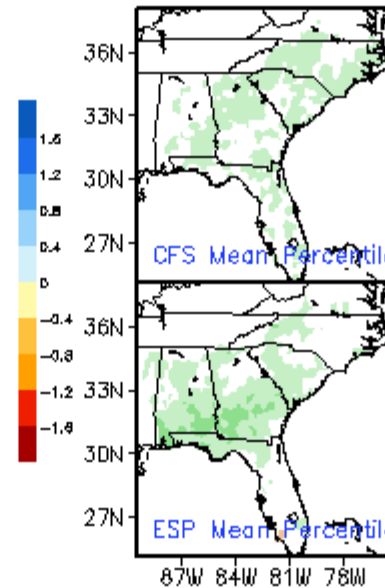
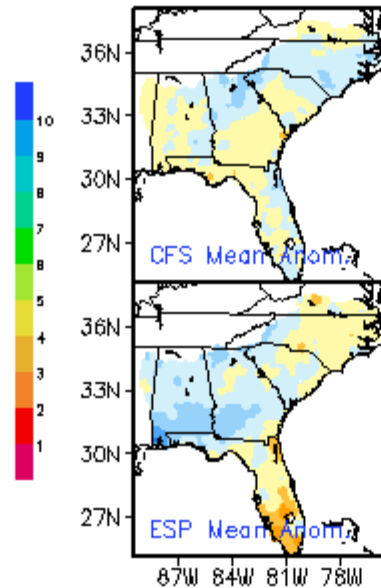
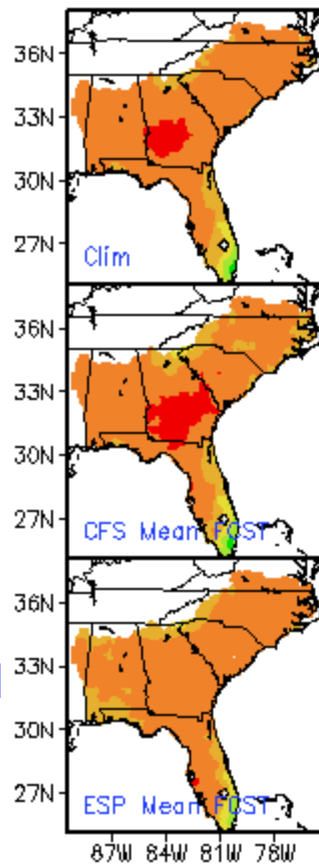
Percentile of the mean

Probabilistic Forecast

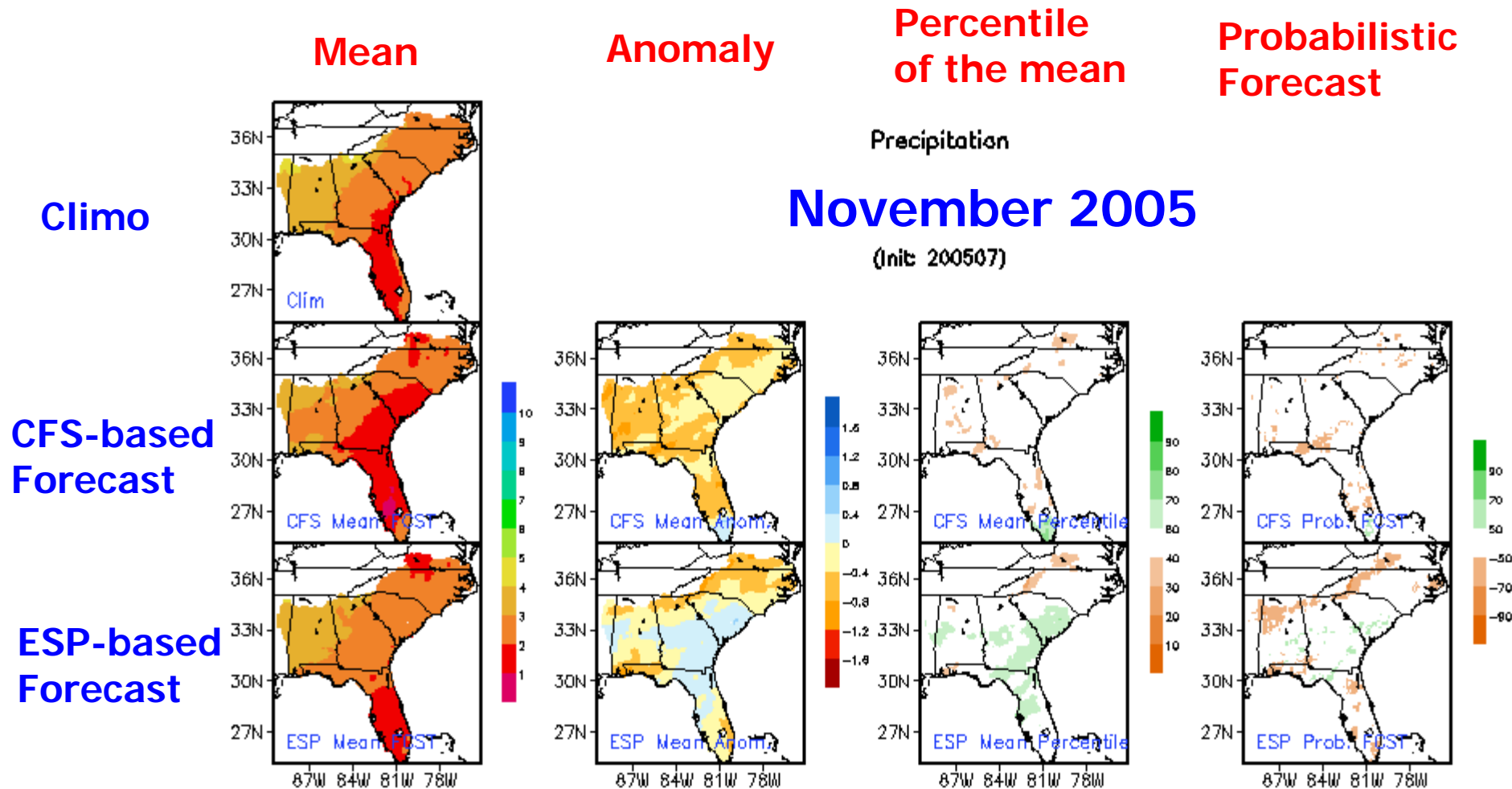
Precipitation

October 2005

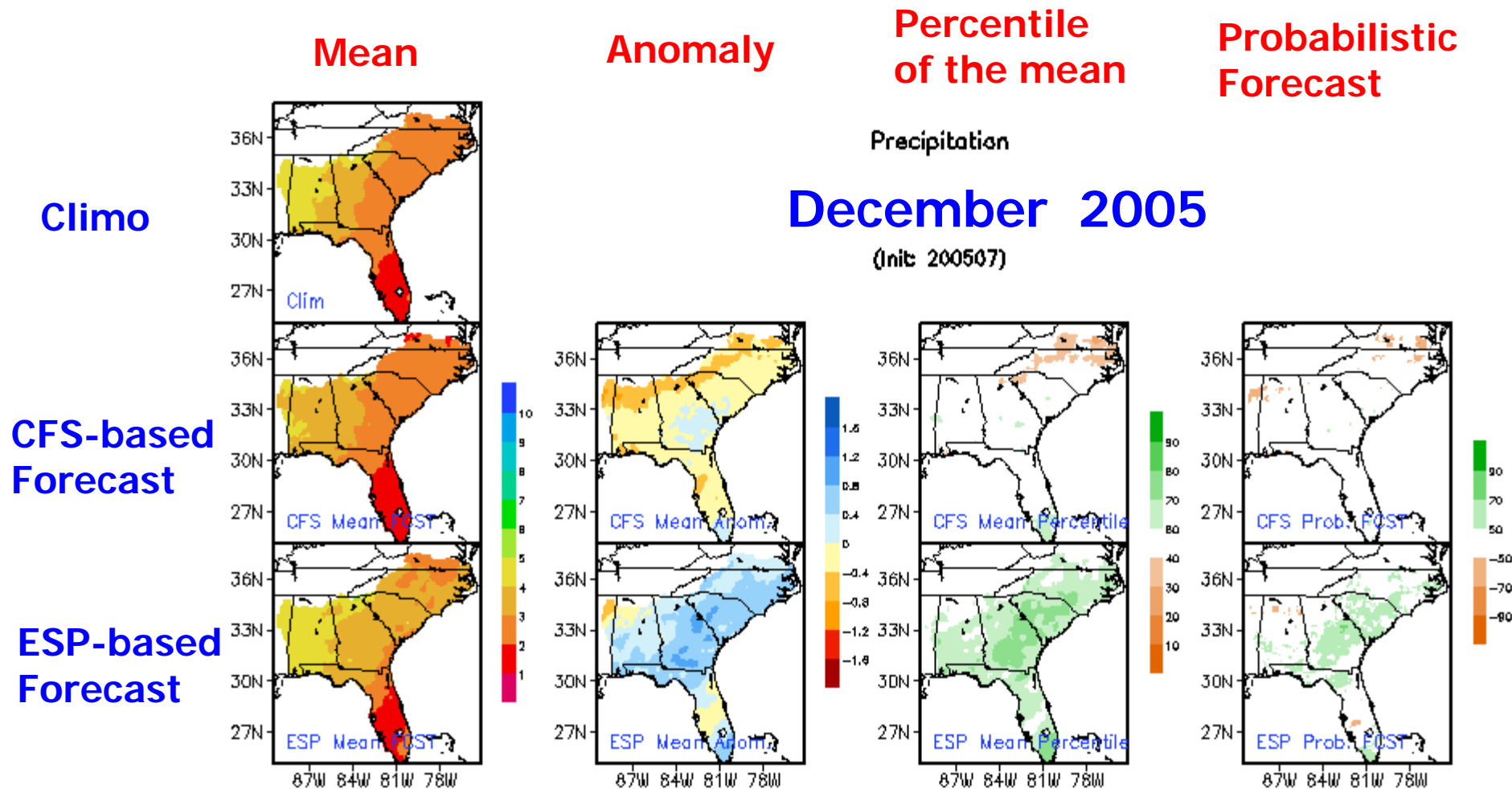
(init: 200507)



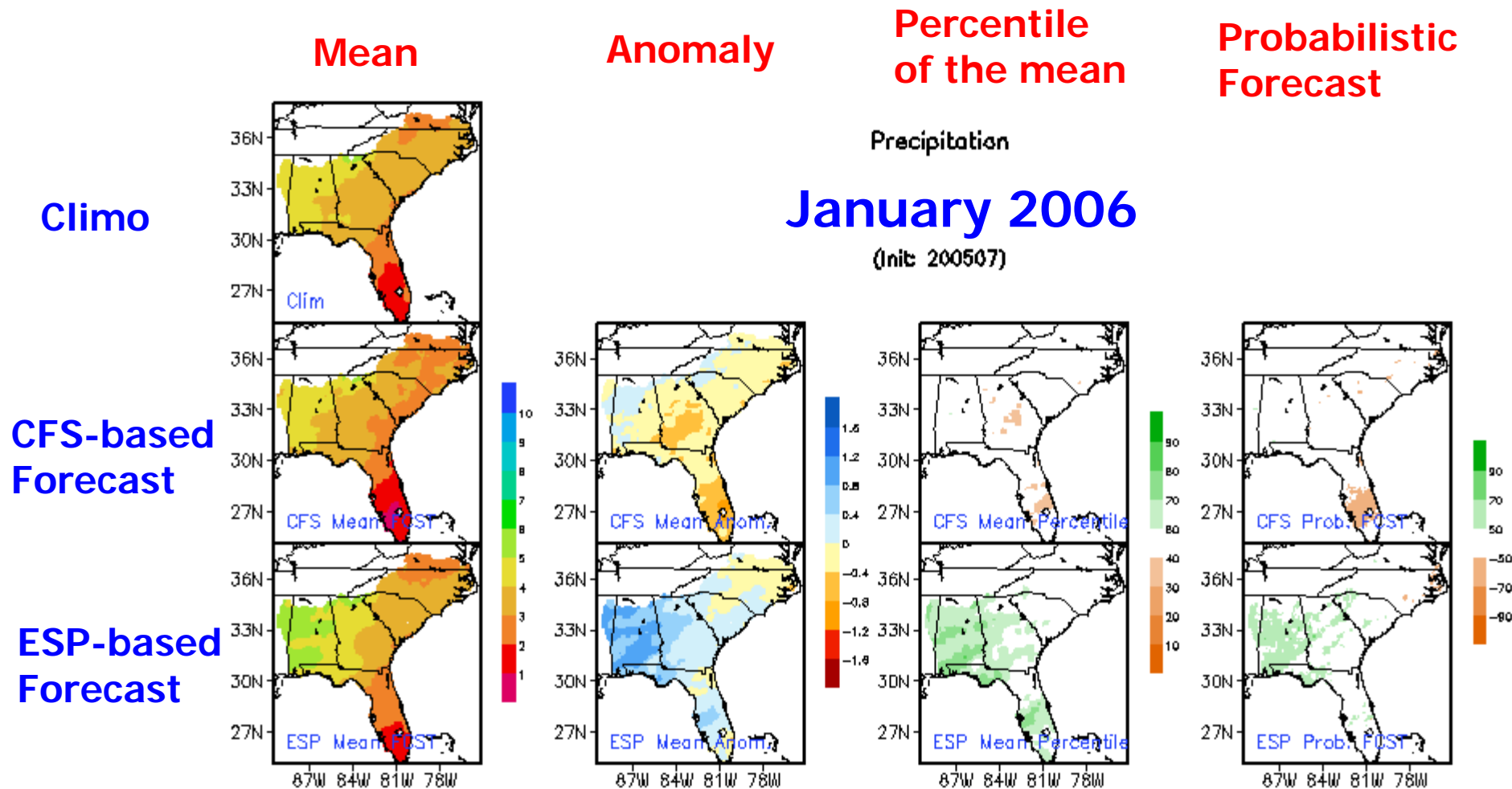
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Latest precipitation forecast (Init: 200507)



Climo

CFS-based Forecast

ESP-based Forecast

Mean

Anomaly

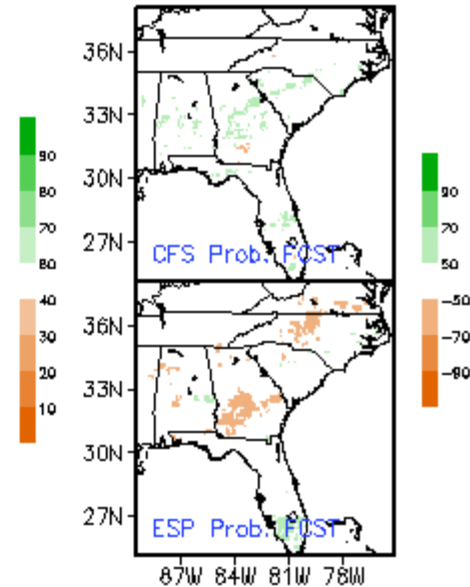
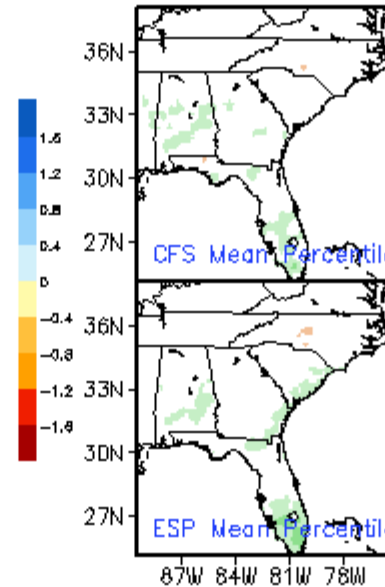
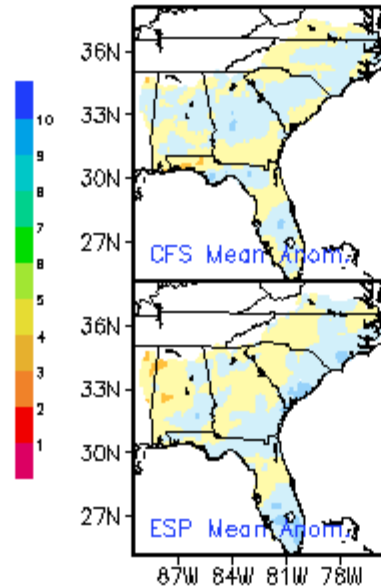
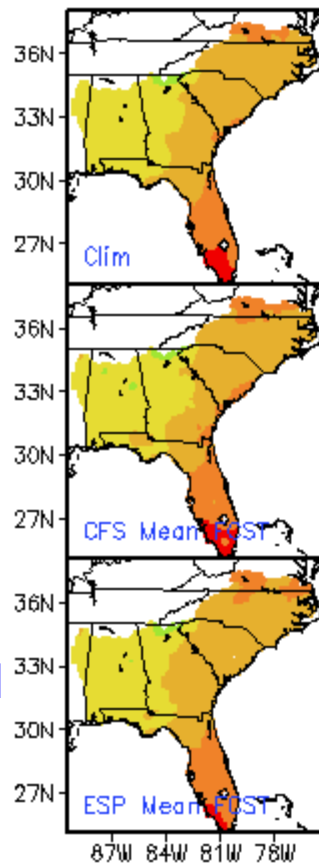
Percentile of the mean

Probabilistic Forecast

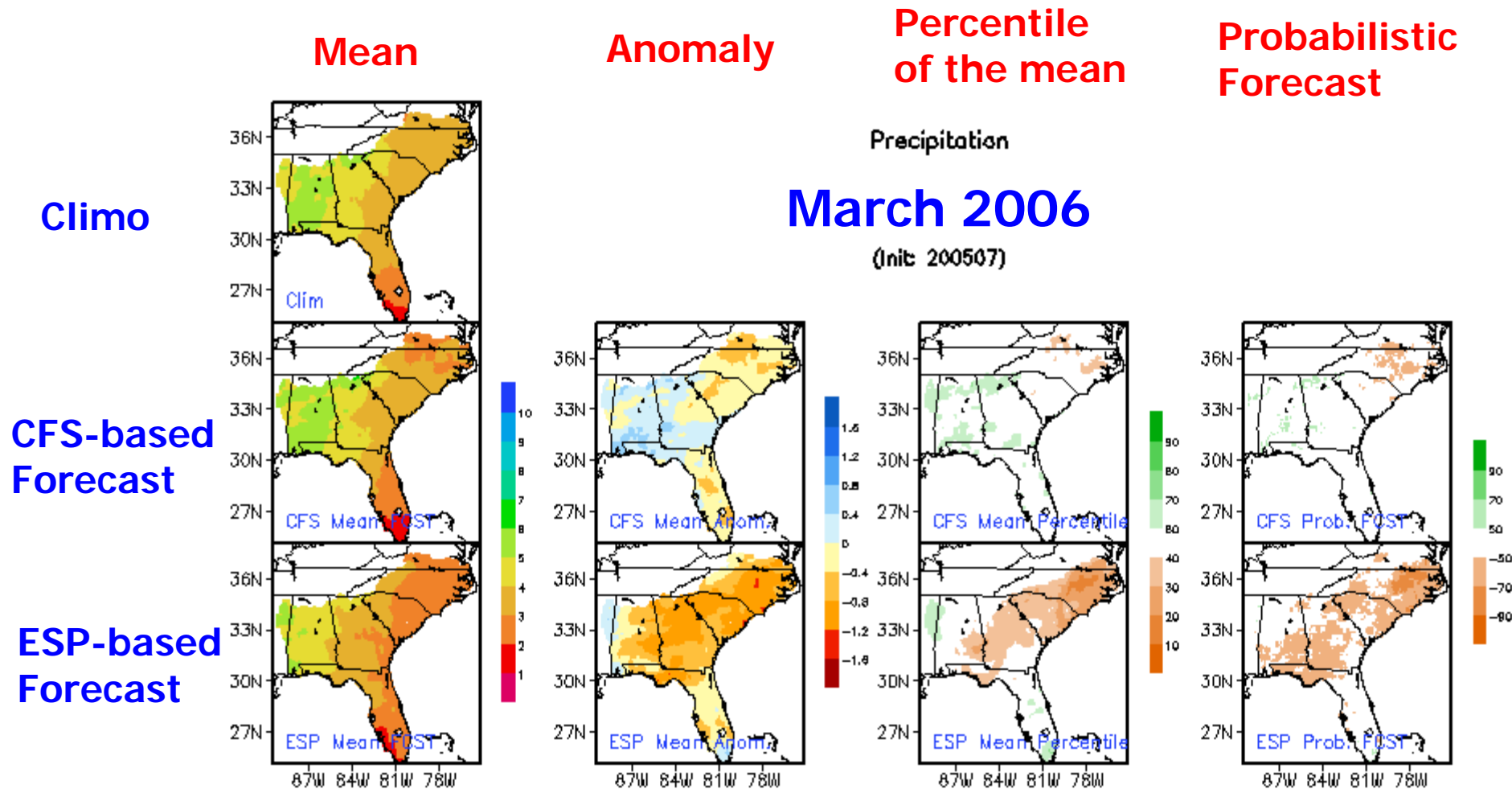
Precipitation

February 2006

(init: 200507)



Latest precipitation forecast (Init: 200507)



Thank you

