HEPEX
Hydrologic Ensemble Prediction EXperiment

Improving Precipitation Generation for Seasonal hydrologic Prediction

-- HEPEX Testbed Southeast US Activities

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Princeton University

June 27 to June 29, 2007
The 3rd HEPEX workshop
Stresa, Italy

WCRP
World Climate Research Programme

HAP GHP Hydrologic Application Project

Outline of the presentation

- Overview of GEWEX Hydrologic Application project (HAP) and the HEPEX SE-USA testbed.
- An example of seasonal hydrologic predictions activities in the U.S., Africa and Asia.
- Drought monitoring and recovery forecasting
- Future activities

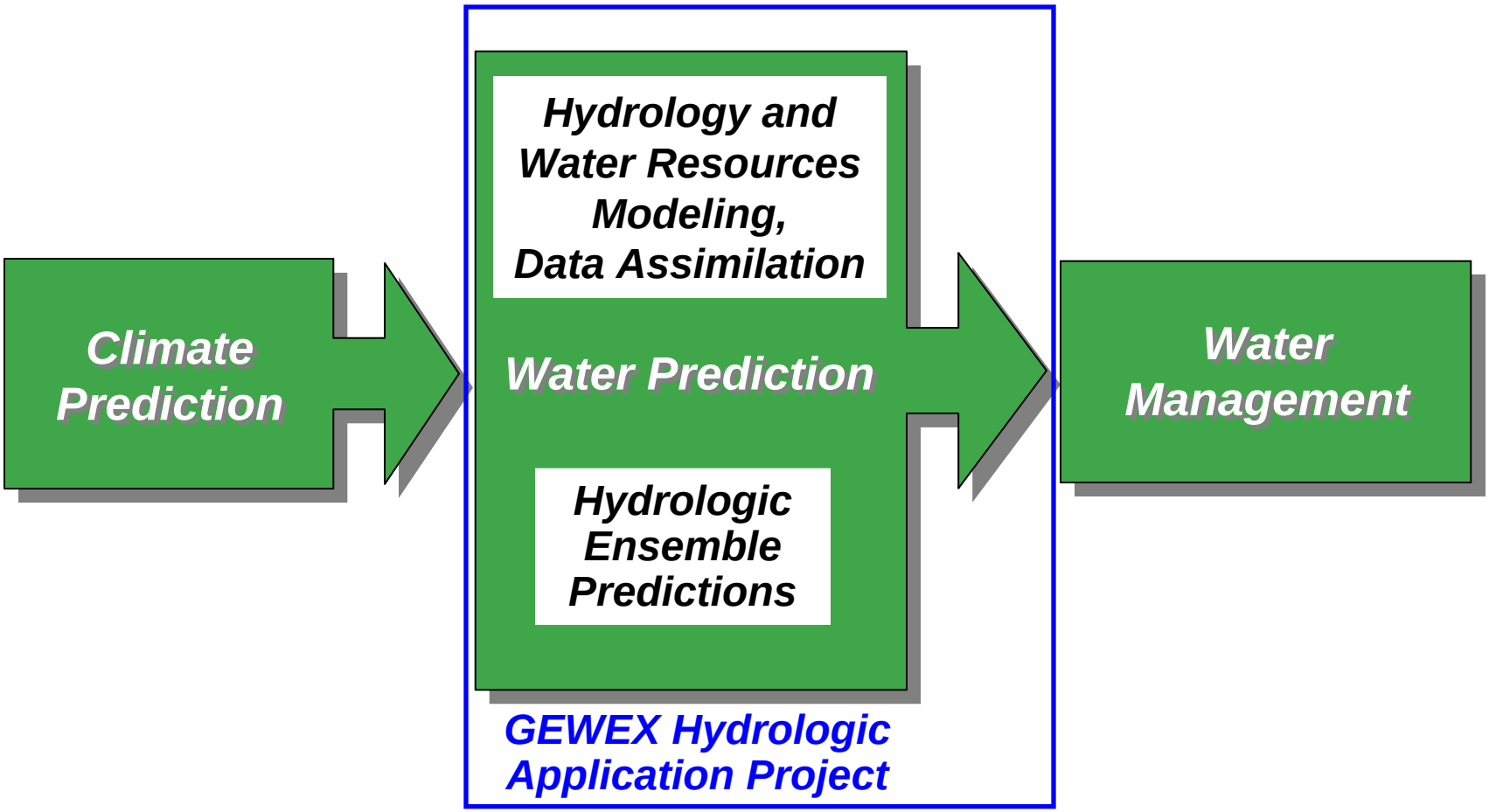
GEWEX Hydrologic Application Project (HAP)

Developing the science behind skillful ensemble hydrologic seasonal forecasts, and demonstrating their usefulness.

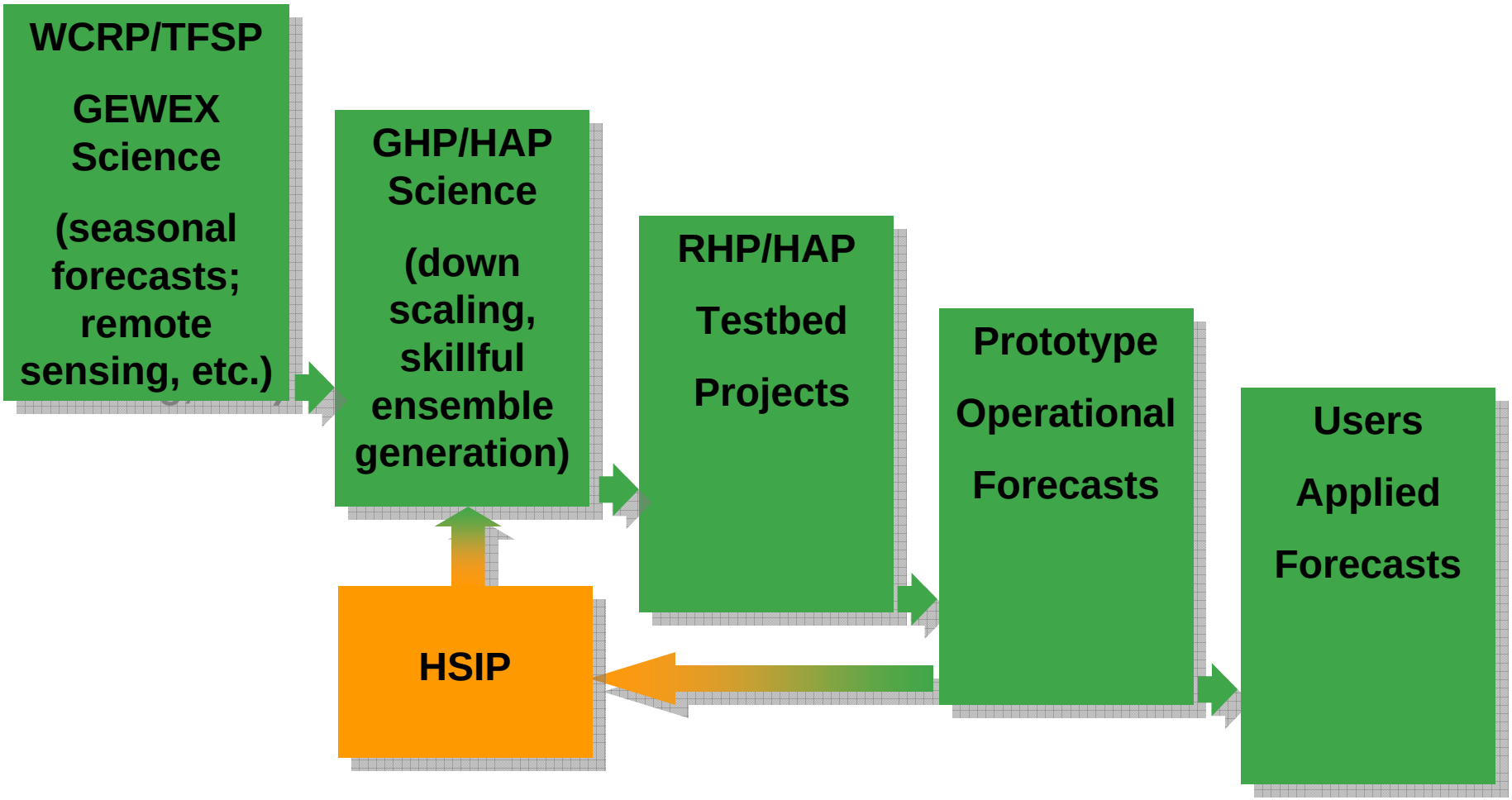
Hydrologic Application Project (HAP) goals:

1. Developing procedures for assessing current hydrologic conditions through application of GEWEX supported data products, including remote sensing;
2. Developing and testing of reliable, skillful hydrologic ensemble forecast procedures based on seasonal climate model forecasts;
3. Demonstrating that the procedures can be applied at scales useful for water resources through test-bed sites and demonstration projects;
4. Working with related projects, like GHP/WISE, HEPEX, Project for Ungauged Basins (PUB).

From Climate Prediction to Water Management



HAP Science Infusion Process (HSIP)



HEPEX Testbed in the Southeast U.S.

The purpose of the HEPEX testbed in the Southeast US is to address the following HEPEX science questions:

1) How can we generate skillful and reliable meteorological forcing for seasonal hydrologic forecasting?

2) How can we generate the hydrologic ensembles that reflect the total uncertainties?

3) How can climate information, such as teleconnections, be used reliably in seasonal hydrologic forecasting?

4) How do we validate hydrologic ensembles for extreme events?

HEPEX Testbed in the Southeast U.S.

Research Objectives

1) Understand the potential predictability of the climate system (more specifically precipitation and temperature) at seasonal time scales.
2) Identify regions where predictability exists in dynamic climate models
3) Develop methodology to process atmospheric information from dynamic climate models to meet the needs in hydrologic applications, including information merging, bias correction, spatial and temporal downscaling, etc.
4) Identify the ensemble size, initial conditions and models that are necessary to provide unbiased and reliable probabilistic forecast
5) Explore the possibility of multi-climate model and multi-hydrologic model approach in seasonal hydrologic prediction.
6) Share data and other software tools with the community so that we can move towards a community based hydrologic prediction system.

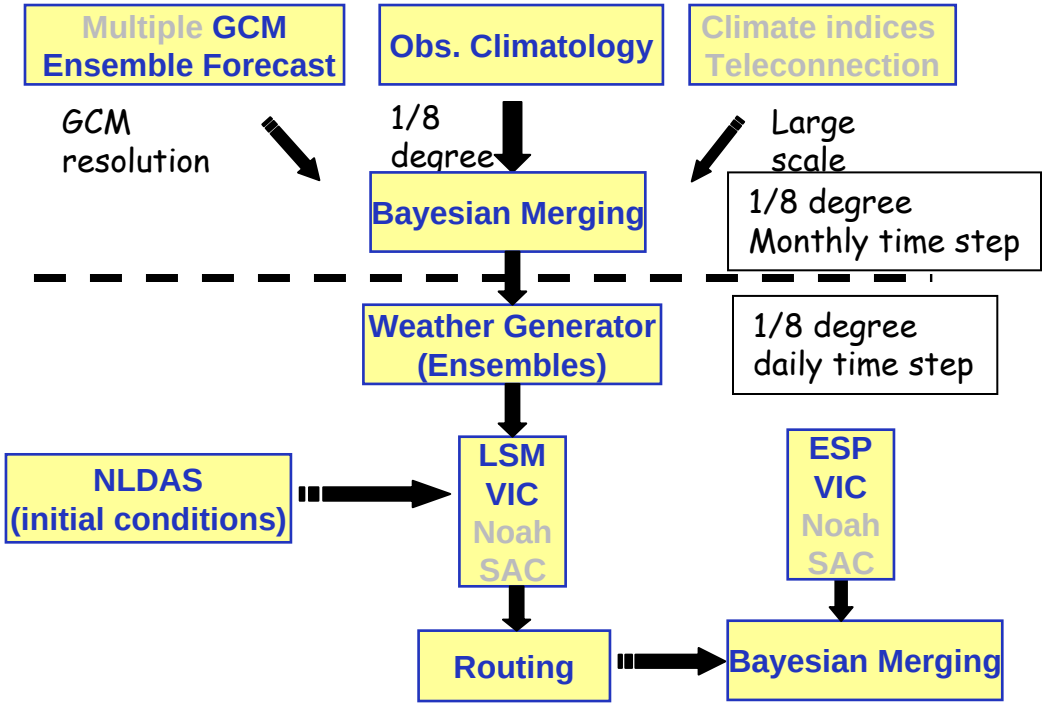
Exp. Seasonal Hydrologic Forecast System over US

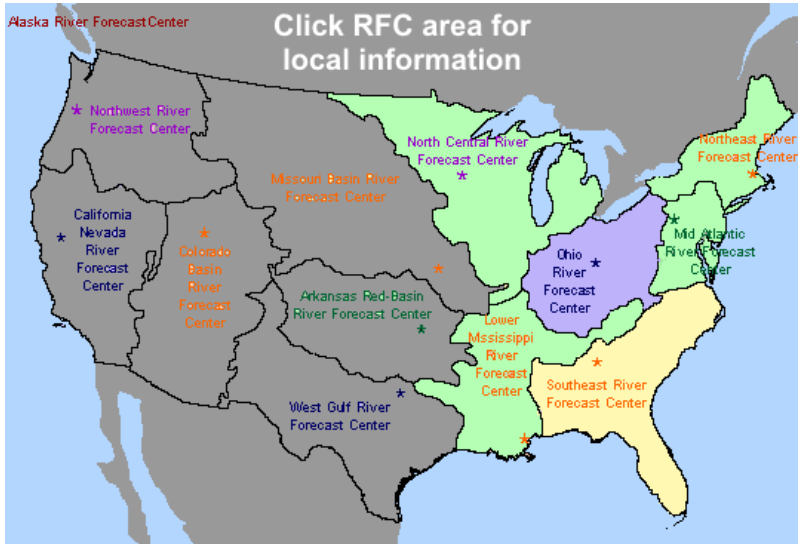
Current project objectives:

(i) develop a seasonal hydrologic forecasting system that utilizes NCEP dynamical Climate Forecast System (CFS),

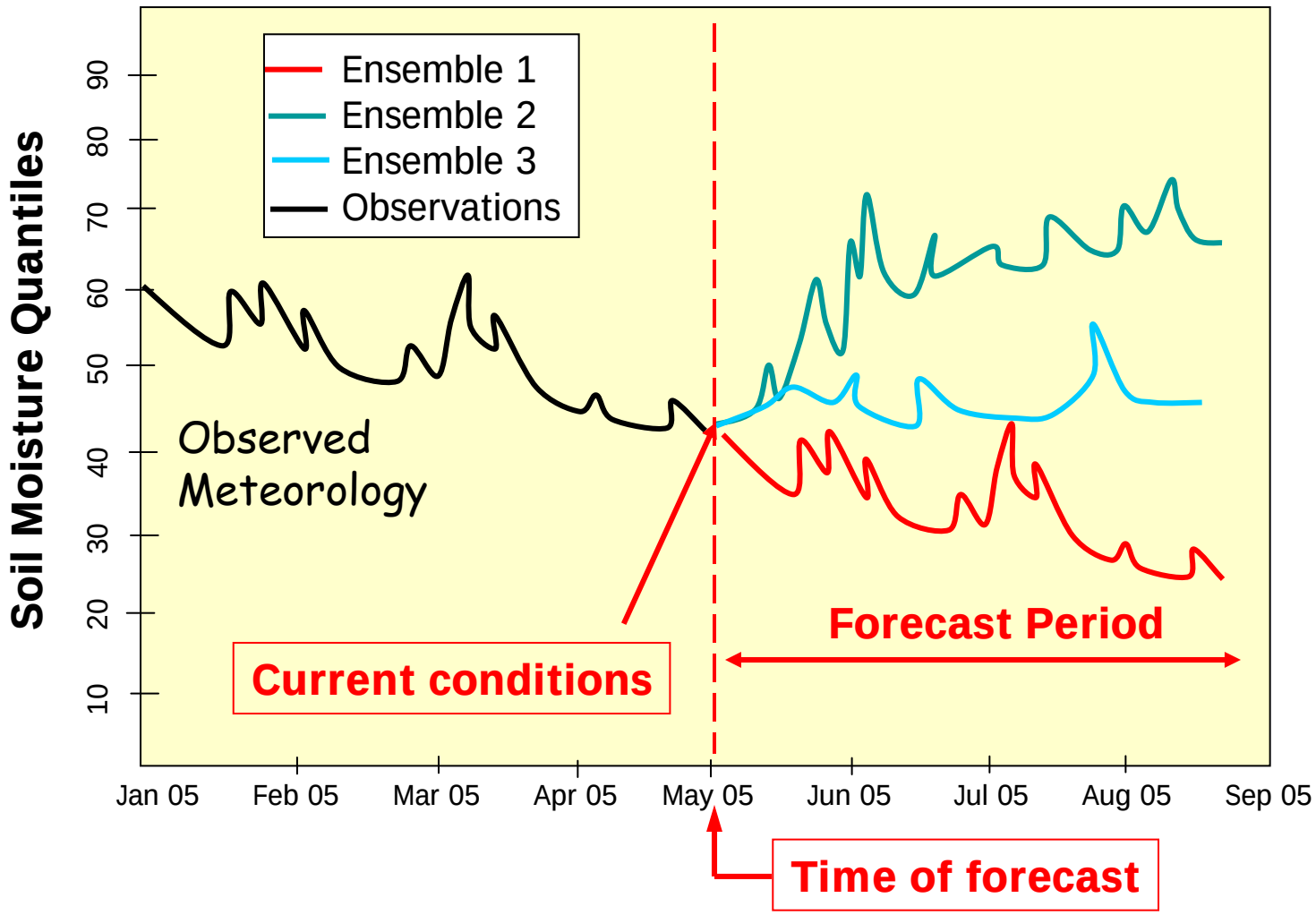
(ii) evaluate the hydrologic forecast uncertainty and skill over a range of basins and,

(iii) develop verification approaches for the generated hydrologic ensembles.

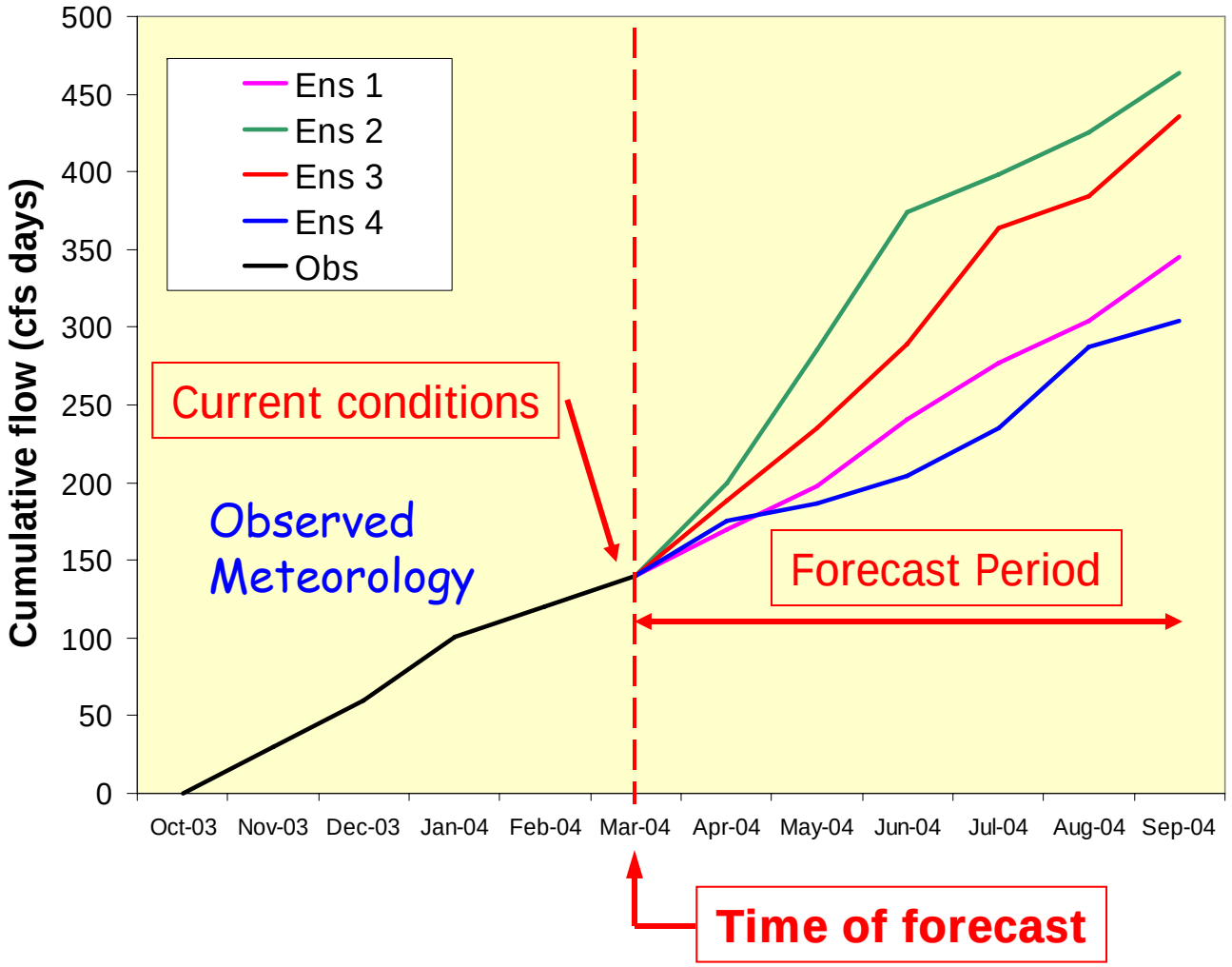




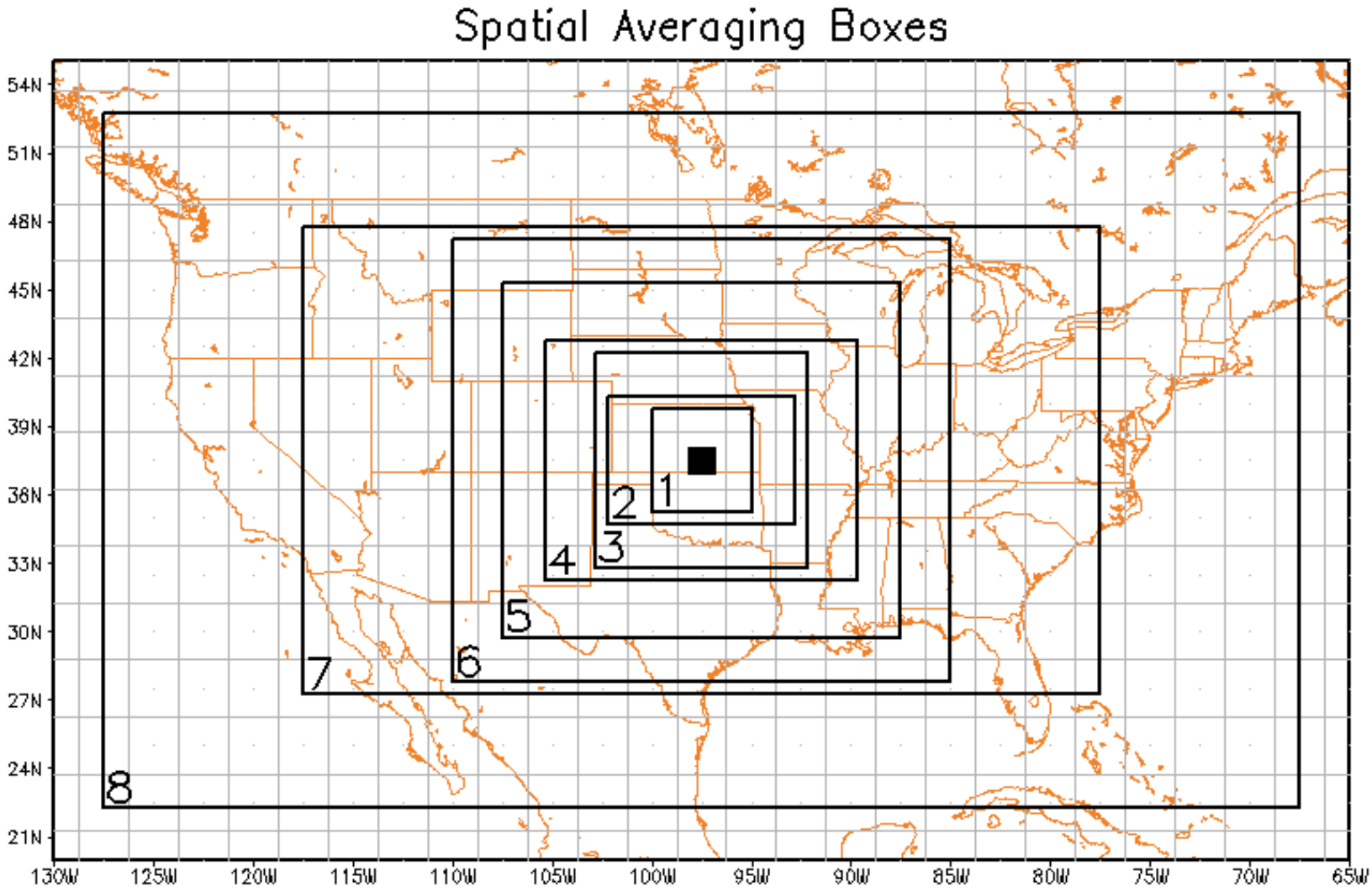
Hydrologic Ensembles

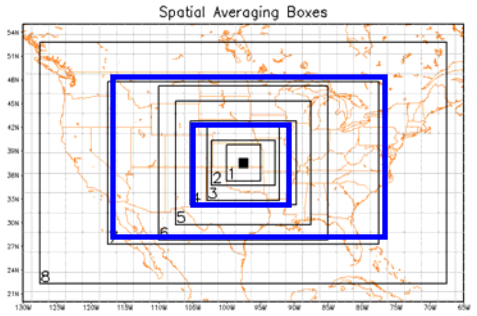


Hydrologic Ensembles



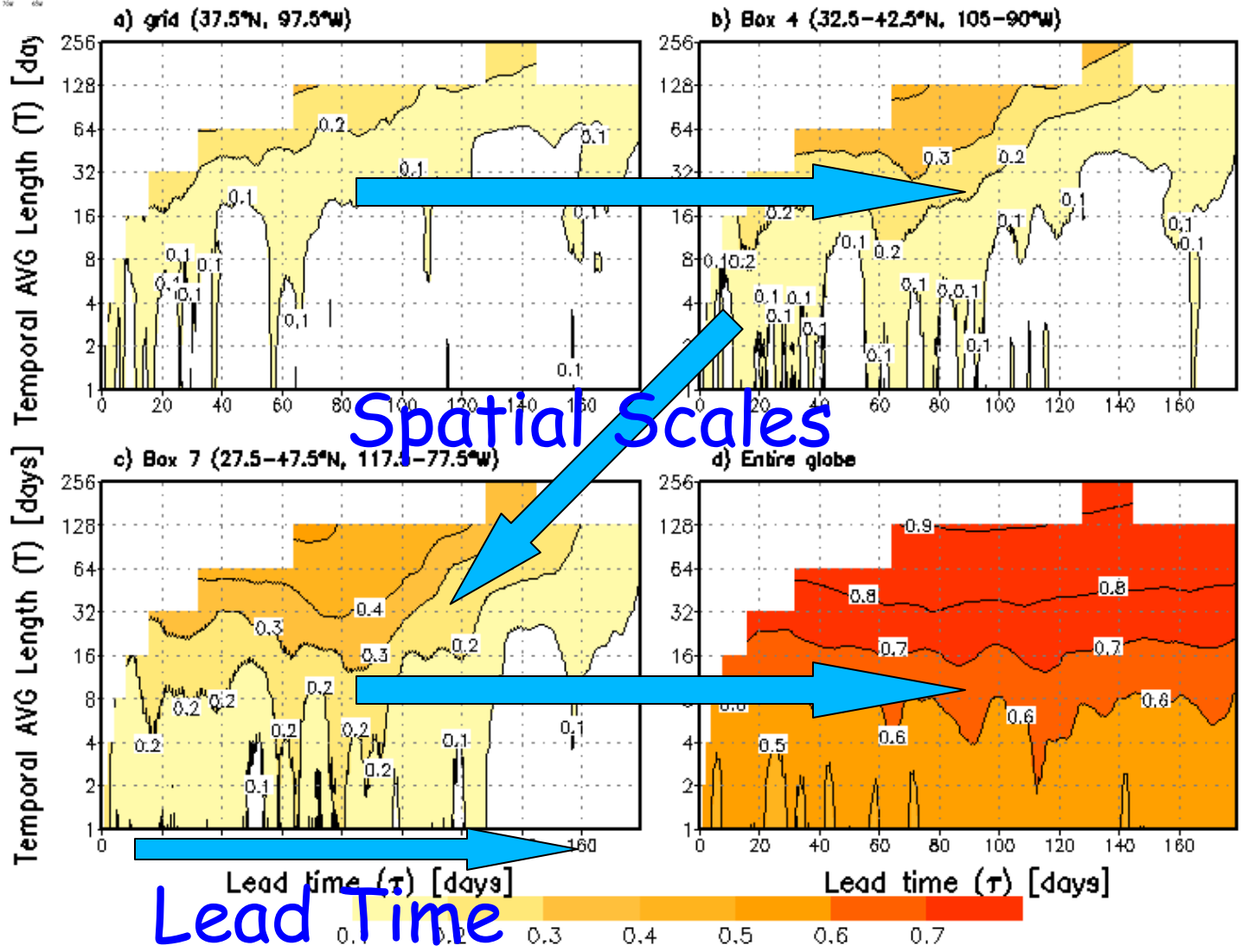
Idealized Predictability Studies (*Luo and Wood, GRL 2006*)

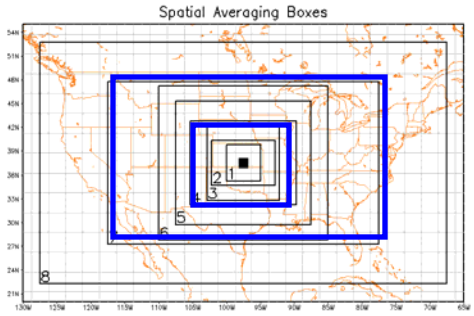




Variation of Idealized Predictability

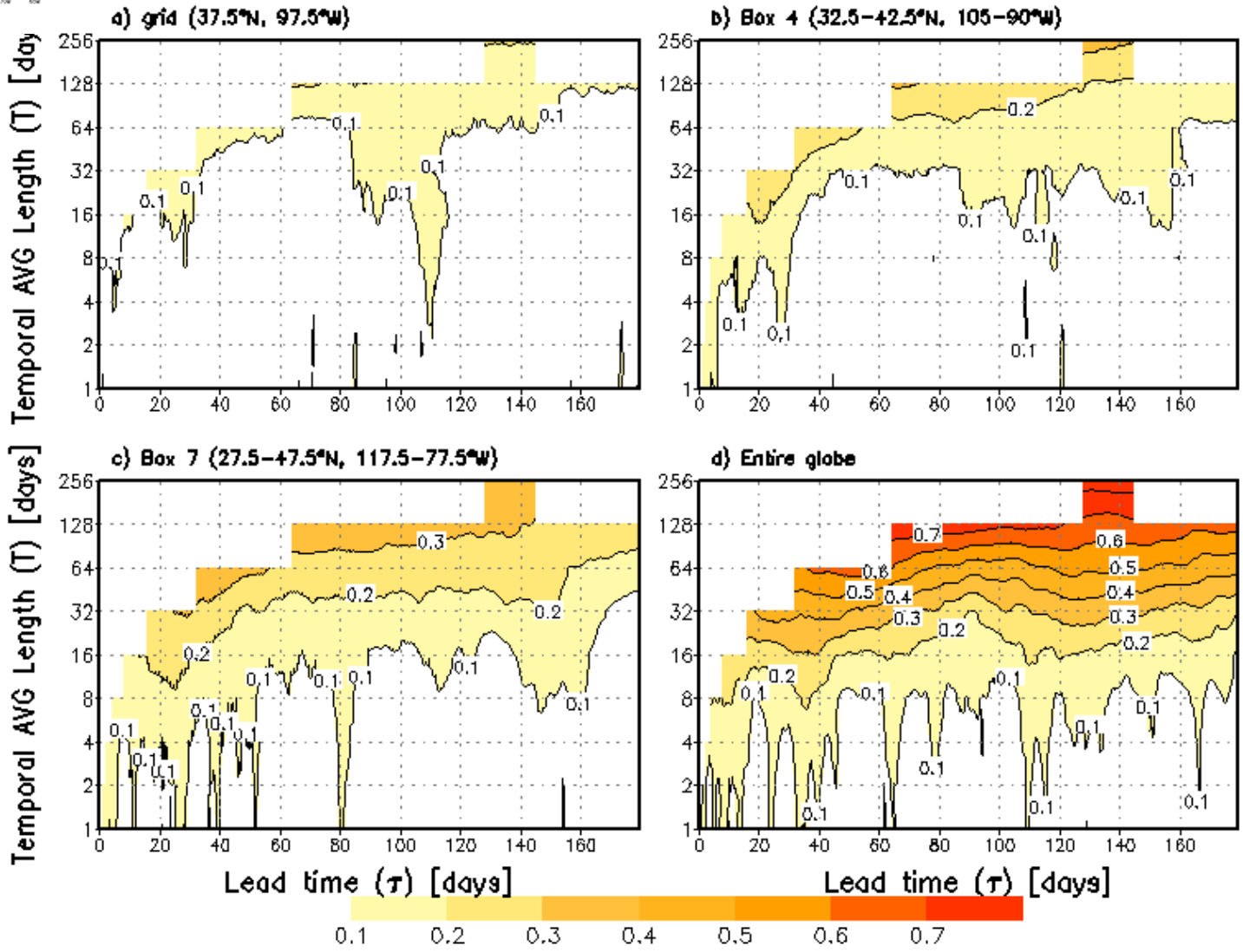
Idealized predictability of surface temperature in CFS





Variation of Idealized Predictability

Idealized predictability of precipitation in CFS



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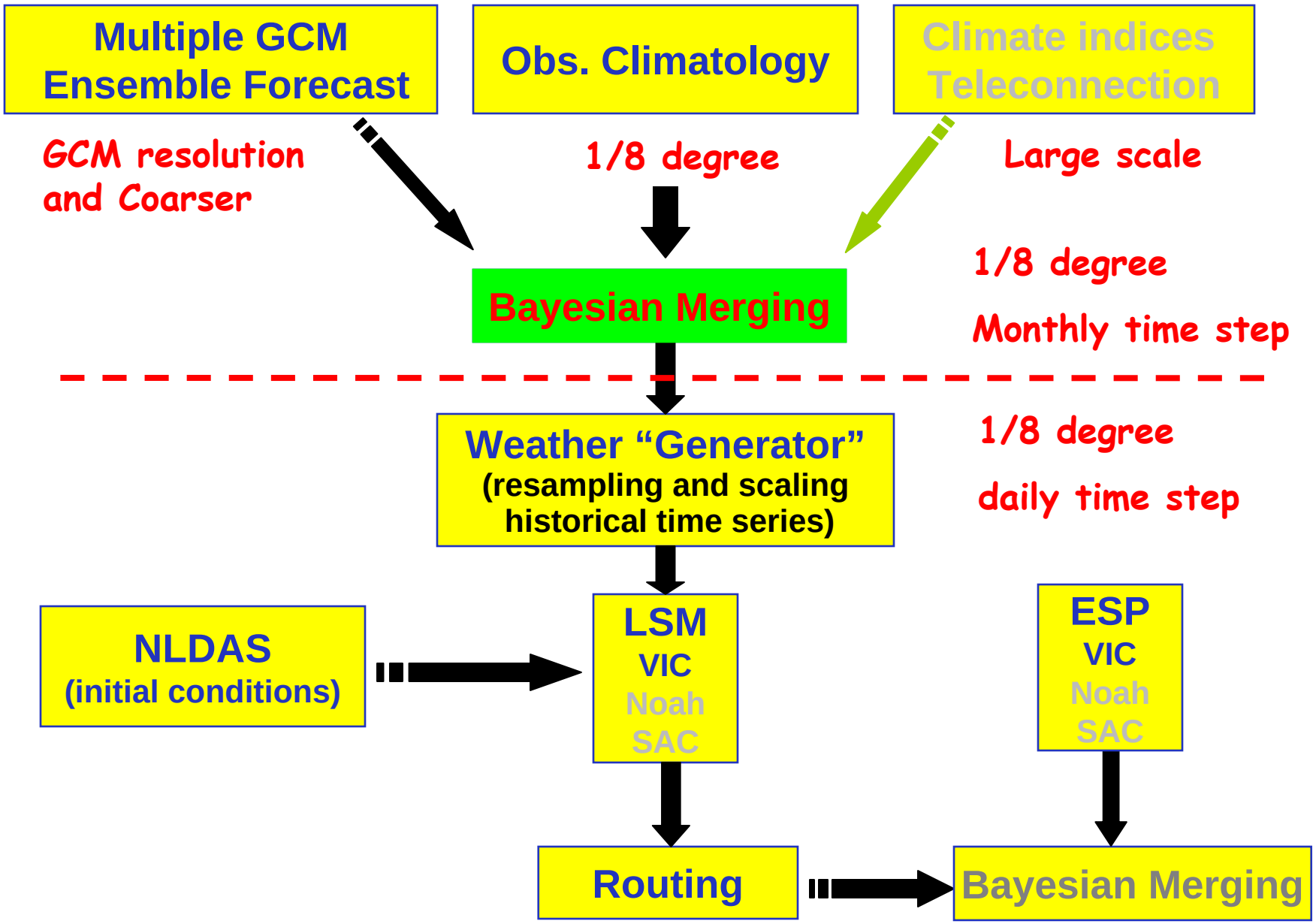
Hydrological Prediction System



Seasonal Hydrological Prediction System

- Bayesian Merging
  - Likelihood function builds the correlation between variables across different spatial scales.
  - GCM forecast information comes from larger spatial scales and longer temporal scales with increase in lead time to ensure that only useful (skillful) information is brought in.
- Spatial downscaling
  - Spatial downscaling is achieved via Bayesian merging and resampling of historical data.

Bayesian Merging of Information

Bayes Theorem

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

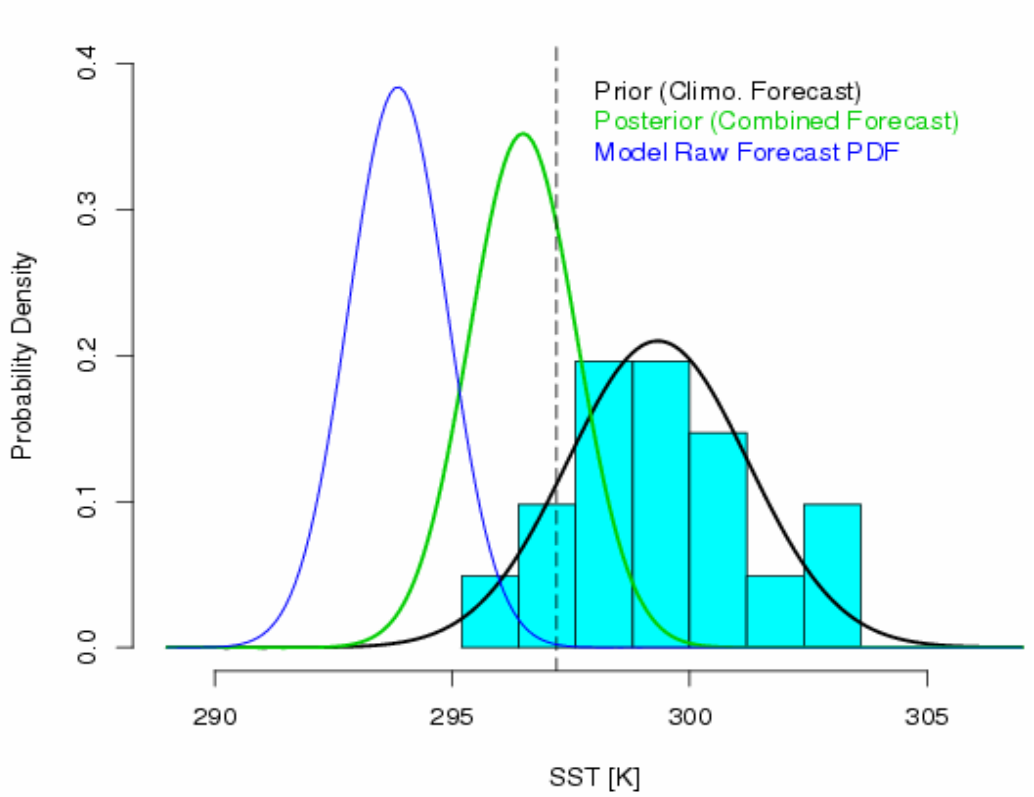
Posterior

1/8th degree scale variable

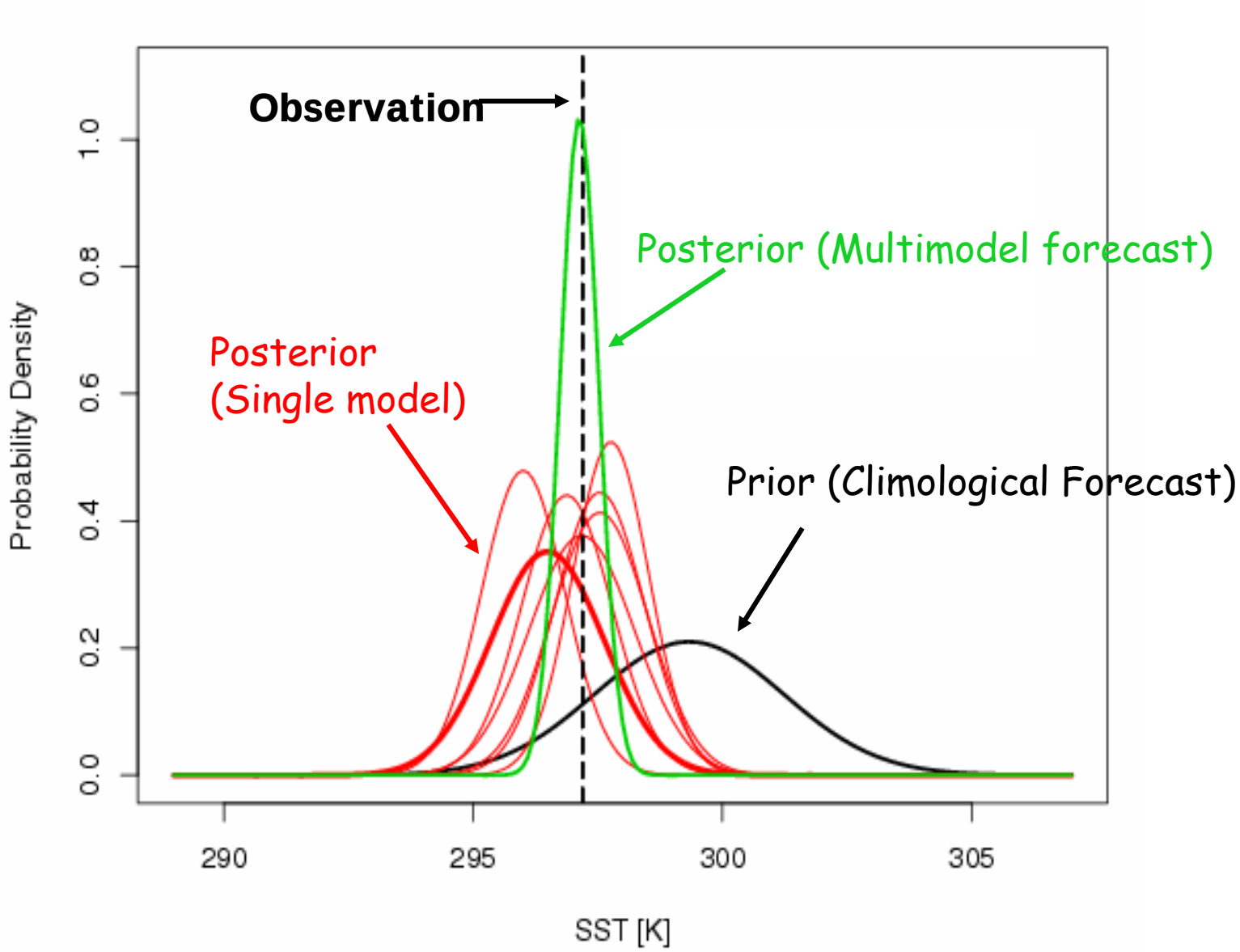
GCM-scale variable

Prior (local climatology)

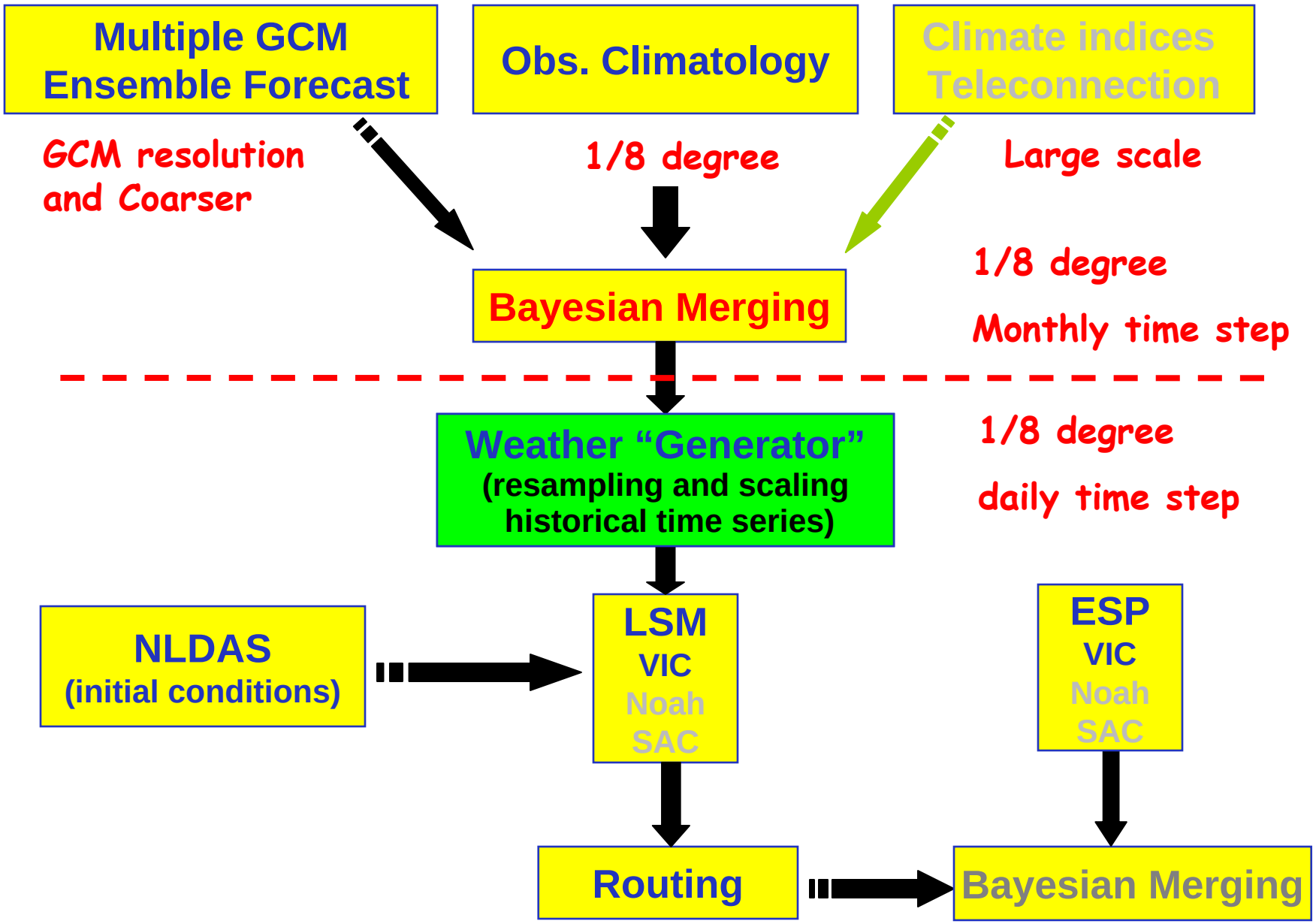
Likelihood function (relates local scale to GCM scale)



Merging Multi-model Forecast with Climatology



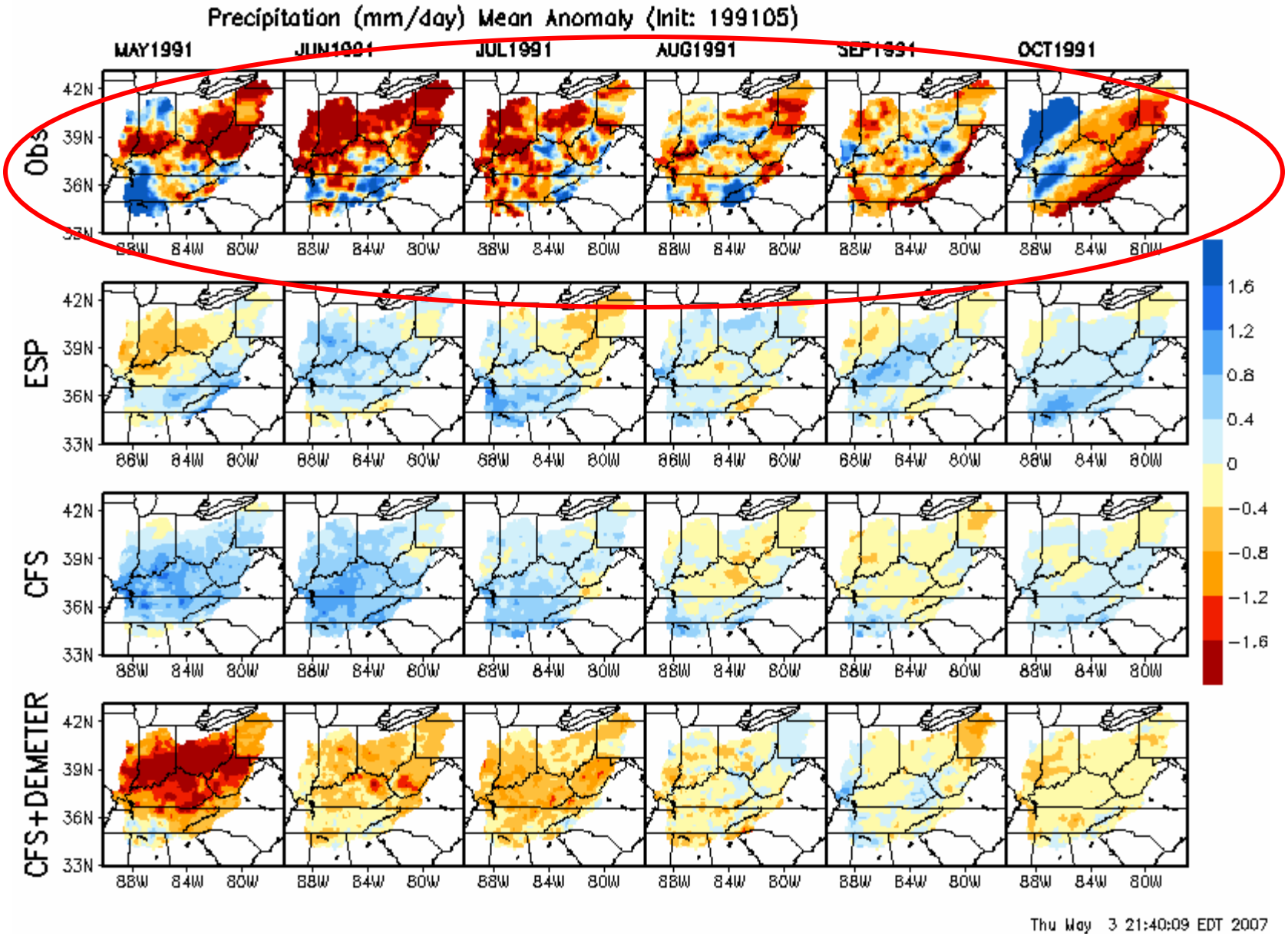
Hydrological Prediction System



Forcing Creation Method

- Temporal downscaling
  - Resampling and scaling daily atmospheric forcing from historical data to match the posterior distribution.
  - Conditional resampling based on similarity between the forecast field and the historical fields, so that dry years will tend to have high probabilities of being selected when the forecast condition is also dry.
  - The rank structure of the historical forcing is kept in space and time. The actual values are determined by the percentile values of the historical forcing and the current forecast distributions.
  - Forecast distributions are only available at monthly level at each individual grid.

Hindcast over Ohio River Basin



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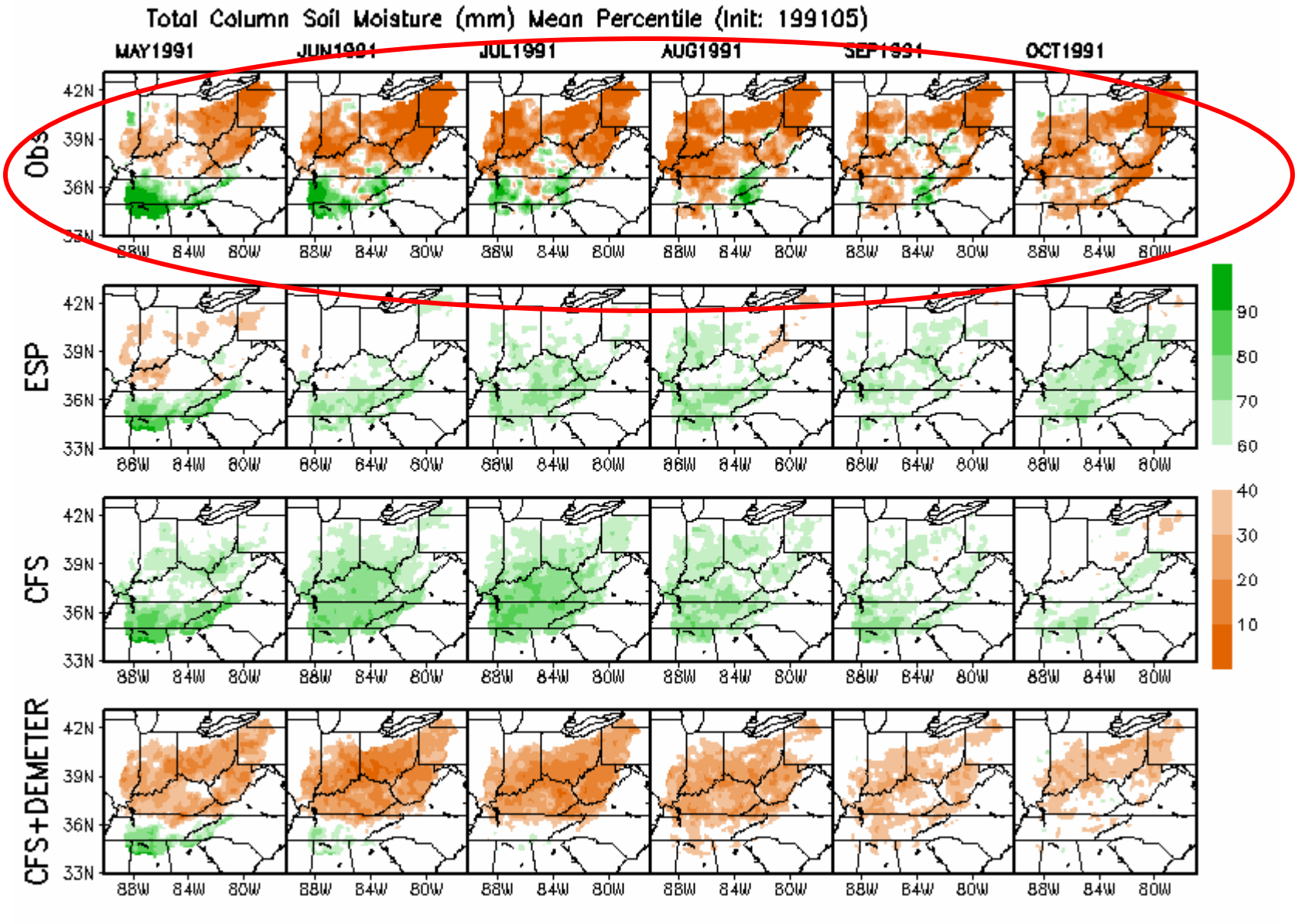
Hindcast Over Ohio River Basin



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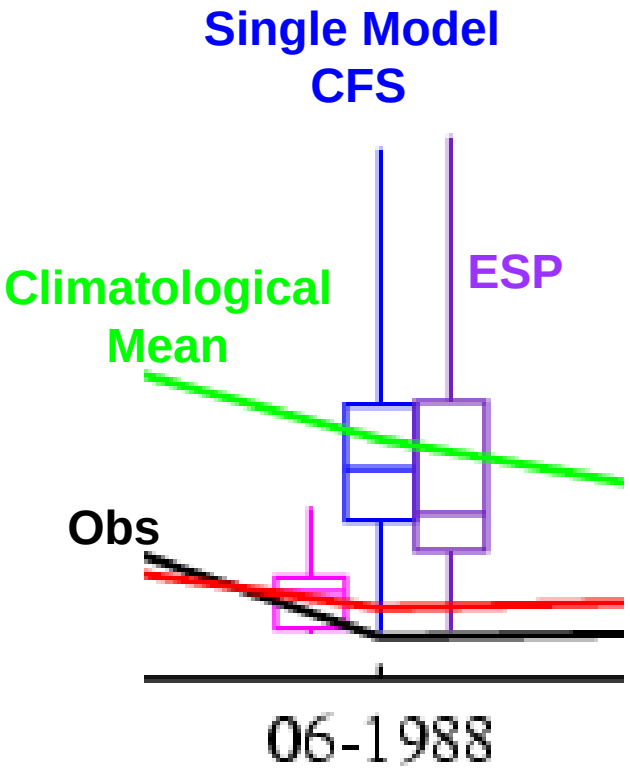
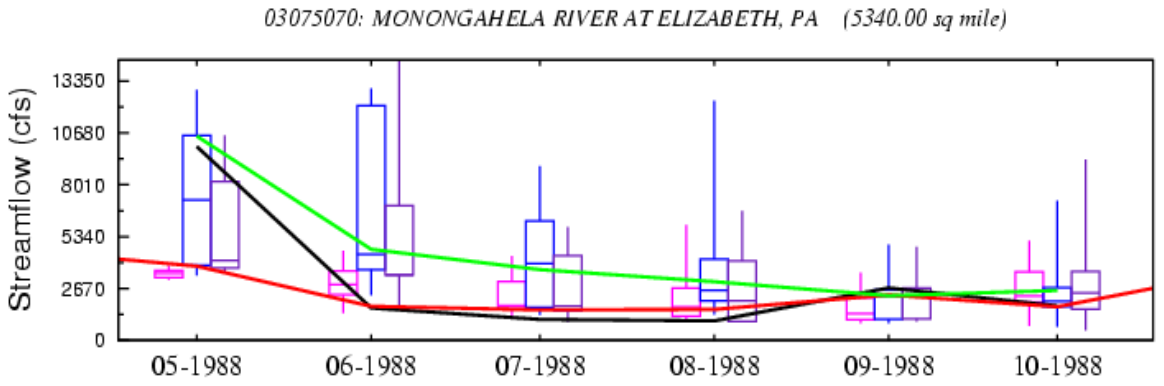
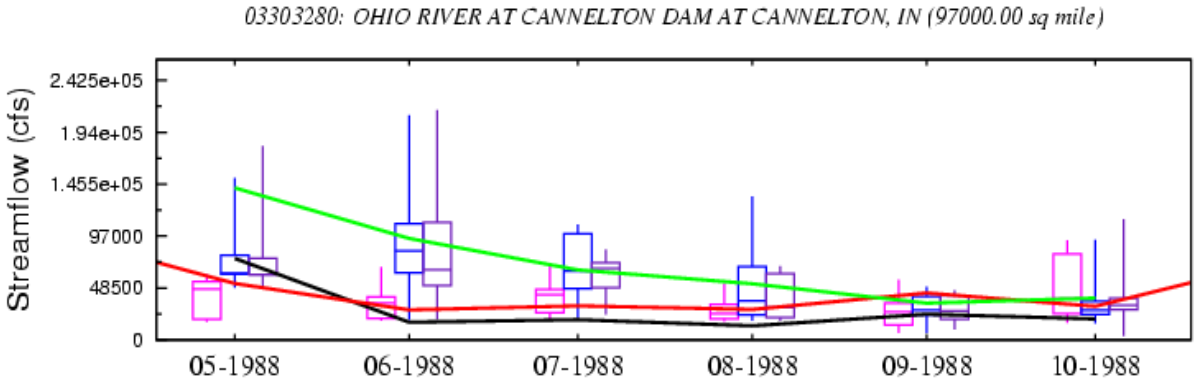
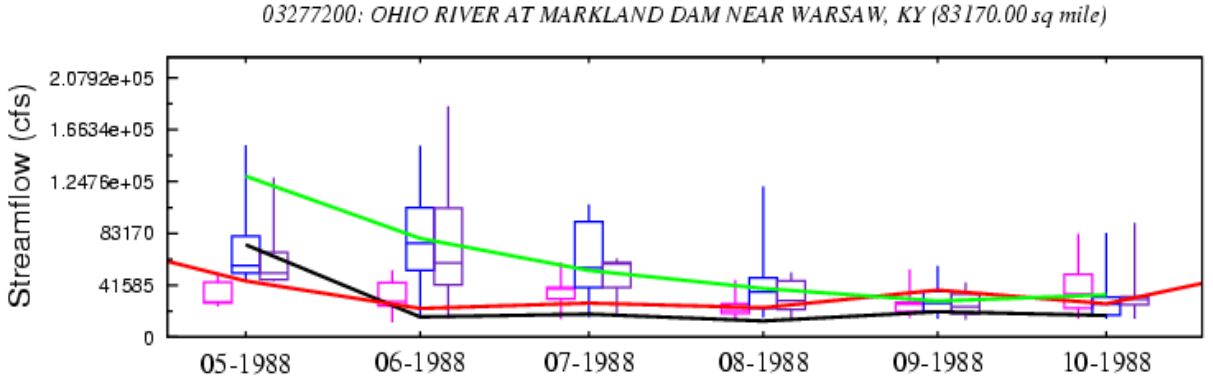
Hindcast Over Ohio River Basin



Multi-Model
CFS+DEMETER







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Streamflow: 198805 Forecast

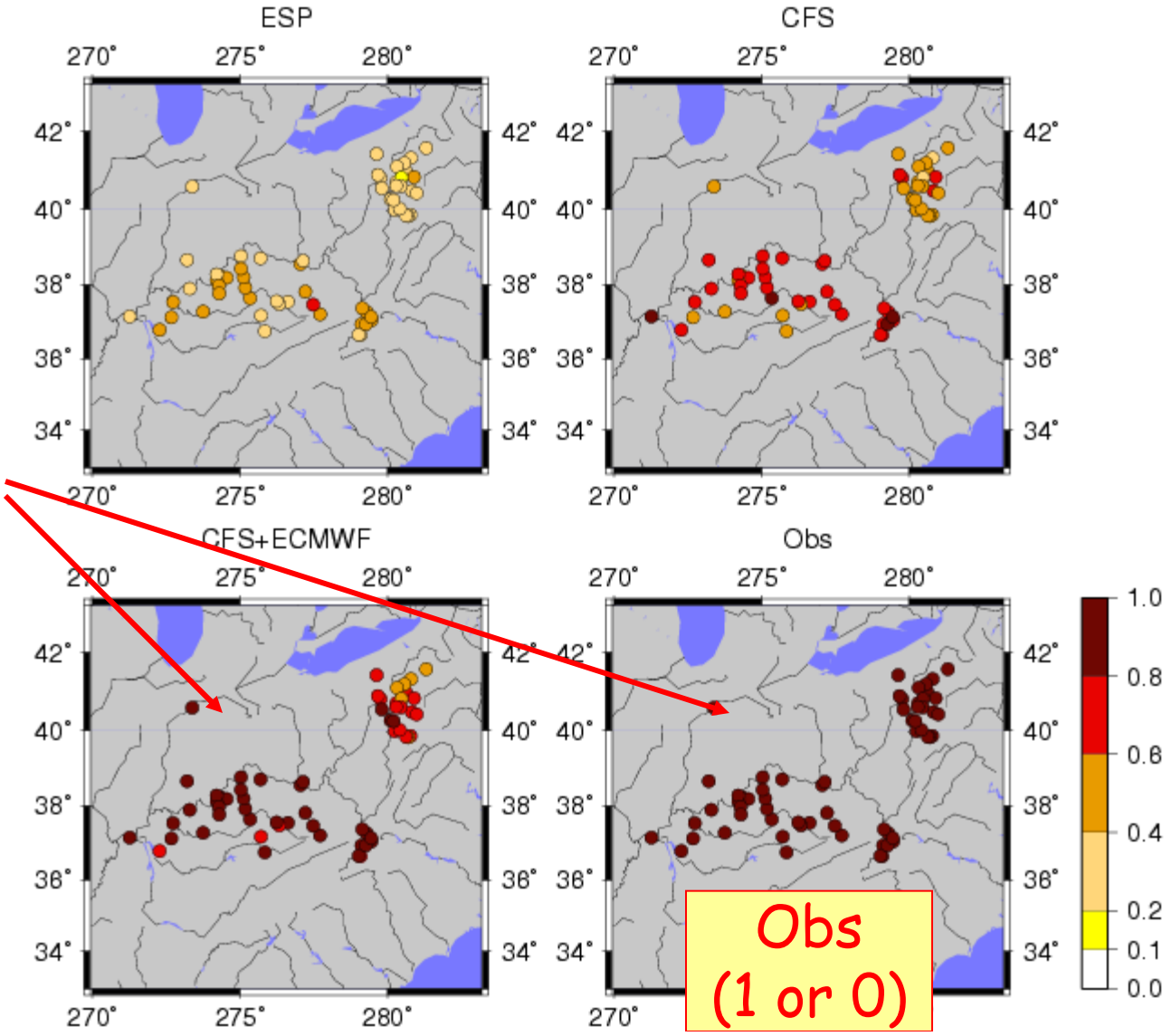
Probability of Jun88 Streamflow below 25% of Historical Distribution

Skilful forecast gives

higher probability for observed "1" events

and

lower probability for observed "0" events.



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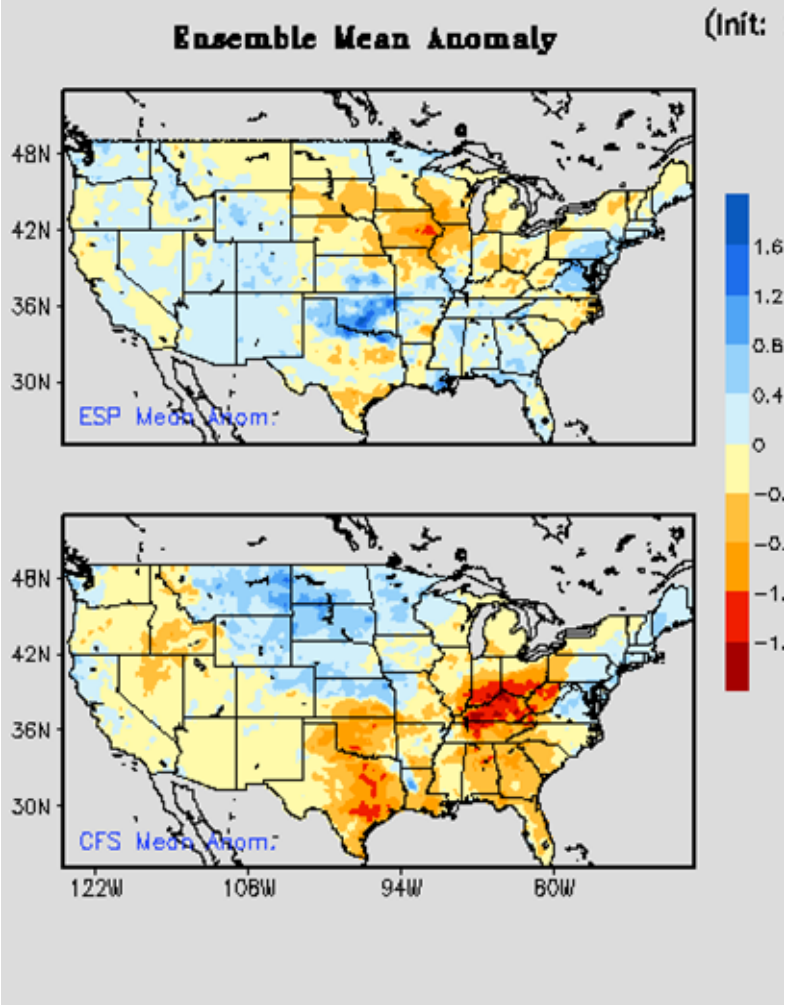
Realtime Forecast Over US

May 2007 forecast initialized May 2007

Precipitation Anomaly



Soil Moisture

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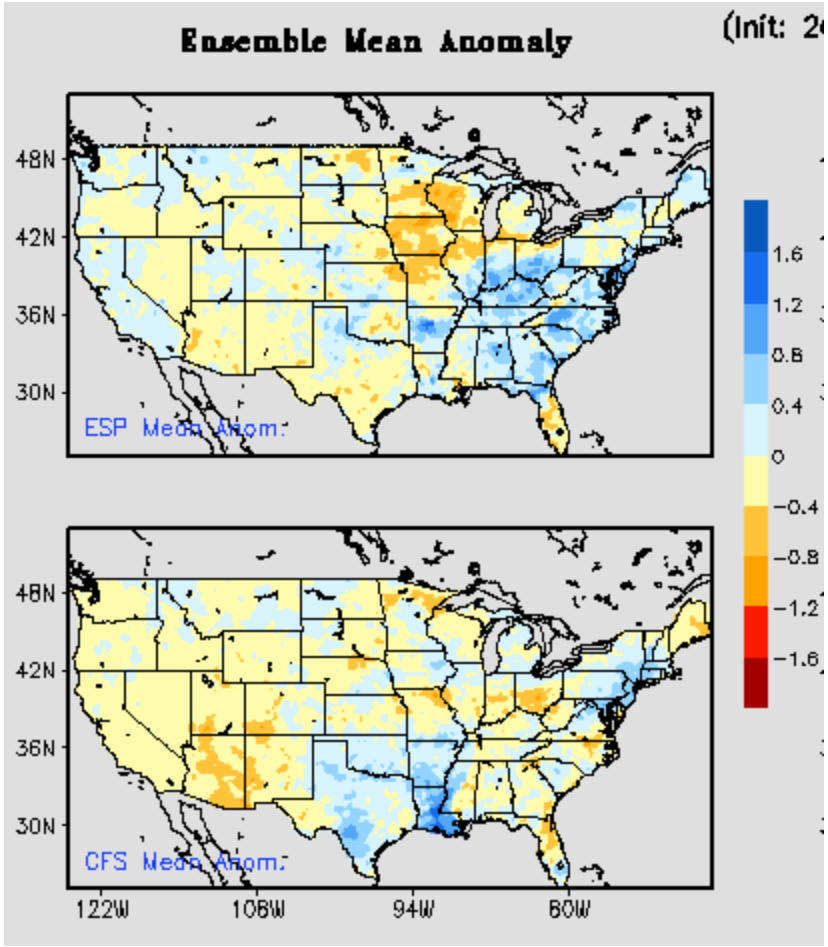
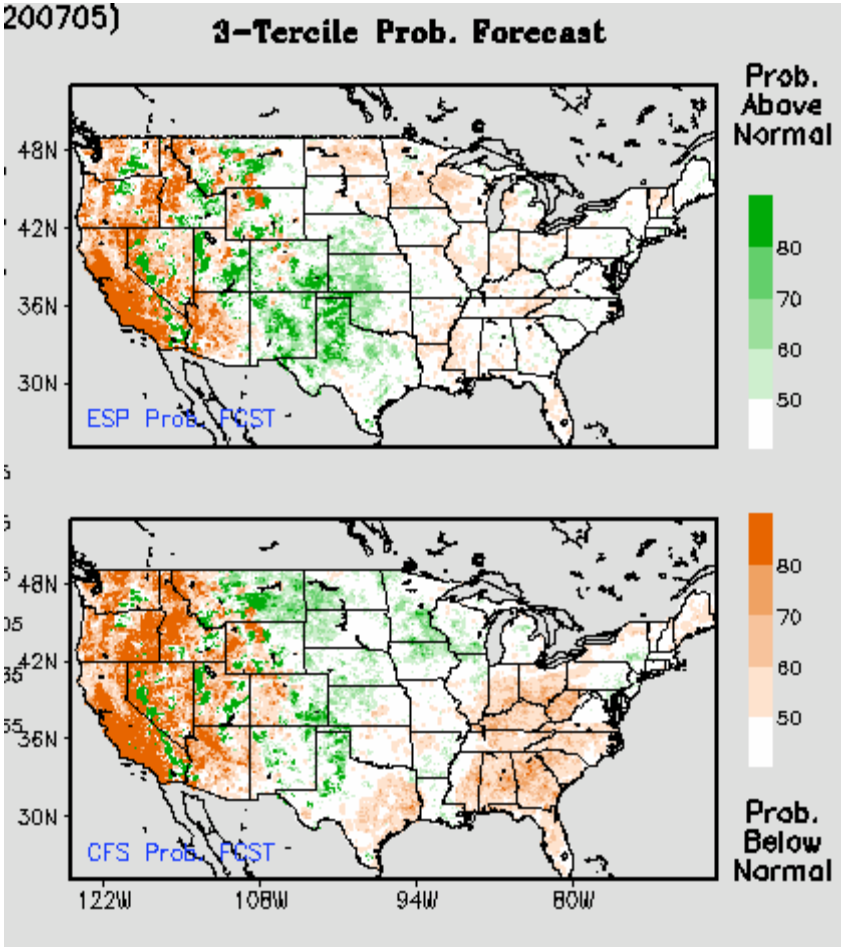
Realtime Forecast Over US

<u>August 2007</u> forecast initialized May 2007

Precipitation Anomaly



Soil Moisture



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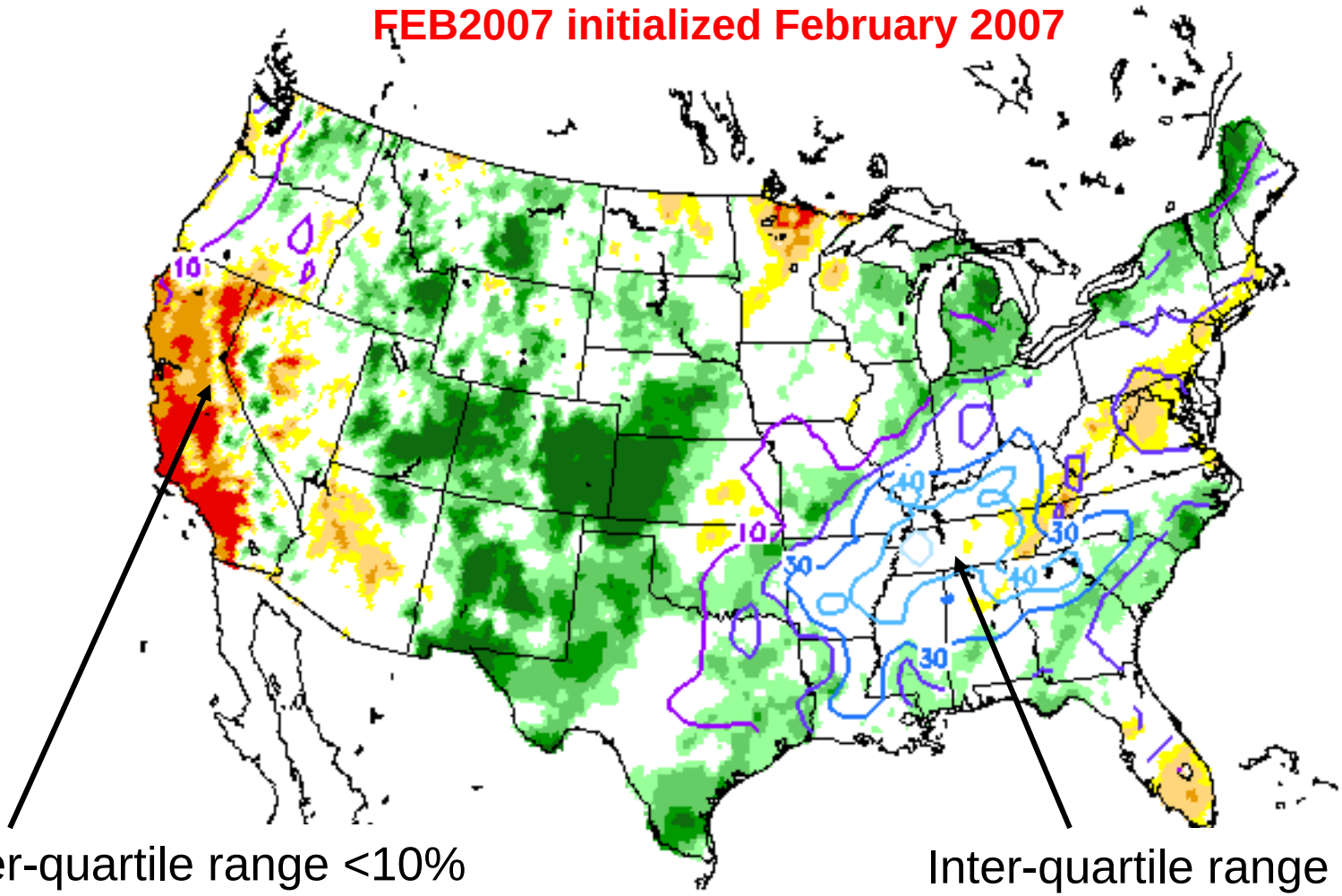
Drought Forecast and Recovery over U.S.

One month forecast:

FEB2007 initialized February 2007



Inter-quartile range <10%
(difference in percentile ranks)
(confidence high)

Inter-quartile range >40%
(difference in percentile ranks)
(confidence low)

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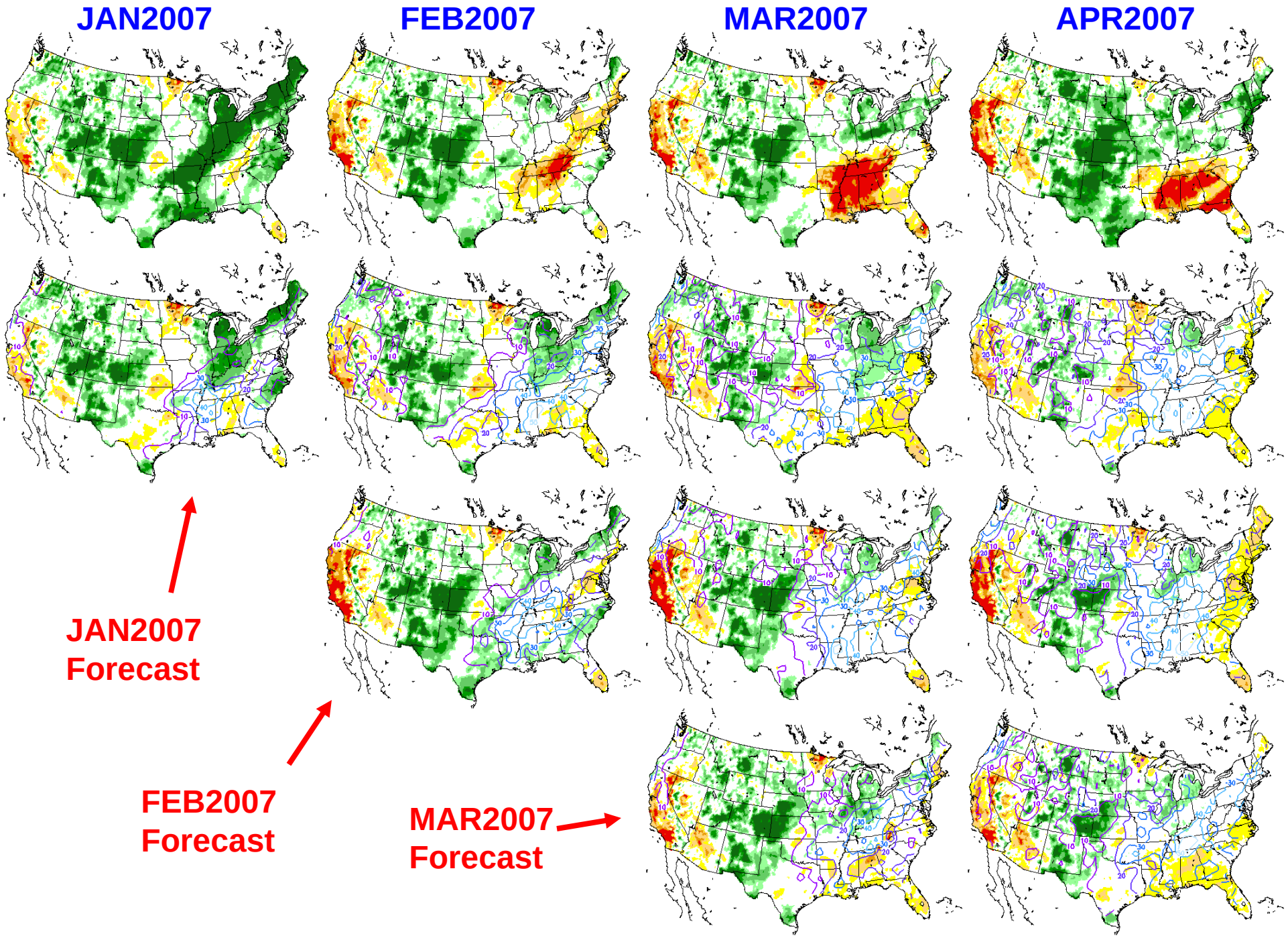
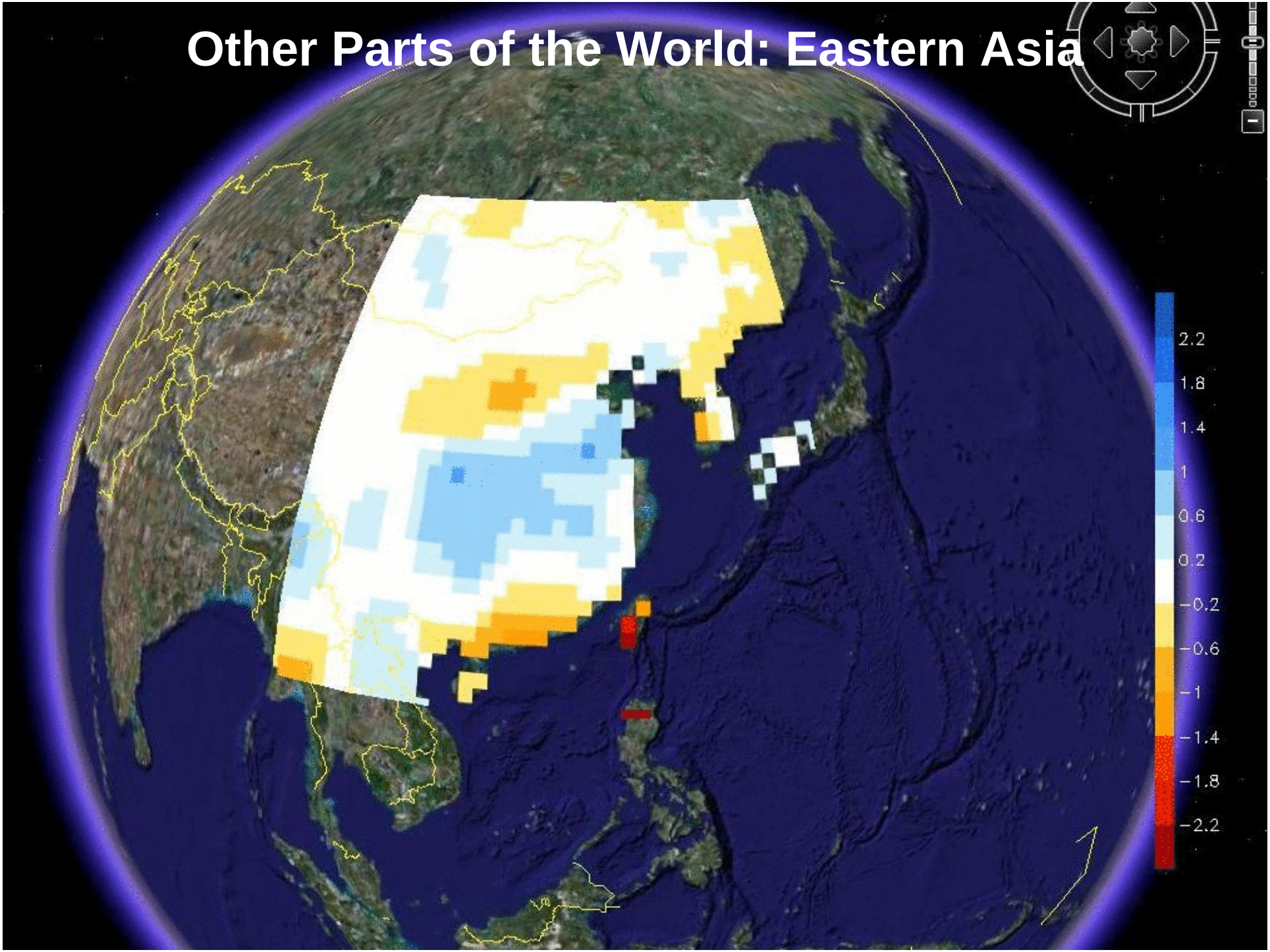
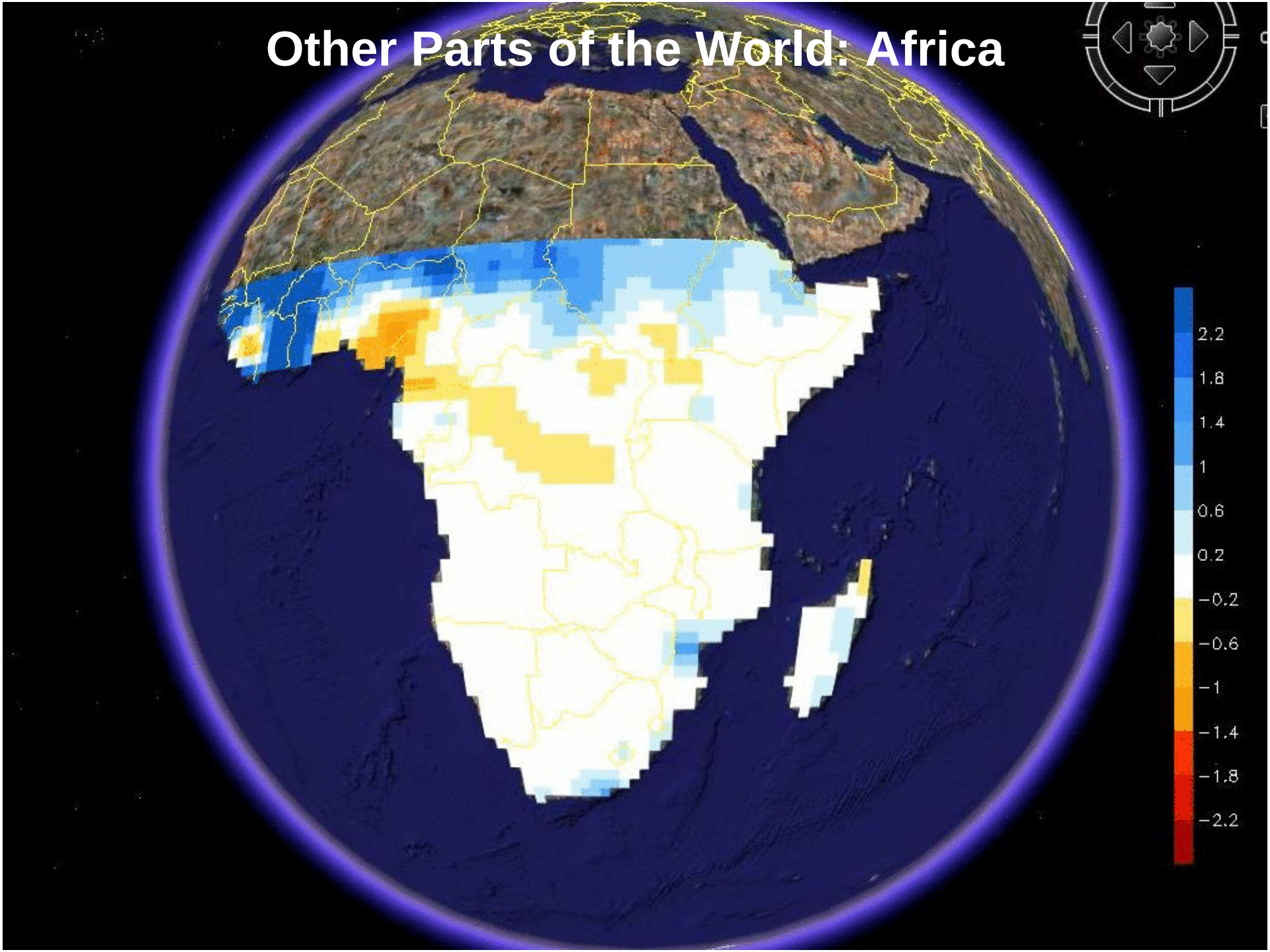

JAN2007
FEB2007
MAR2007
APR2007
JAN2007
Forecast
FEB2007
Forecast
MAR2007
Forecast

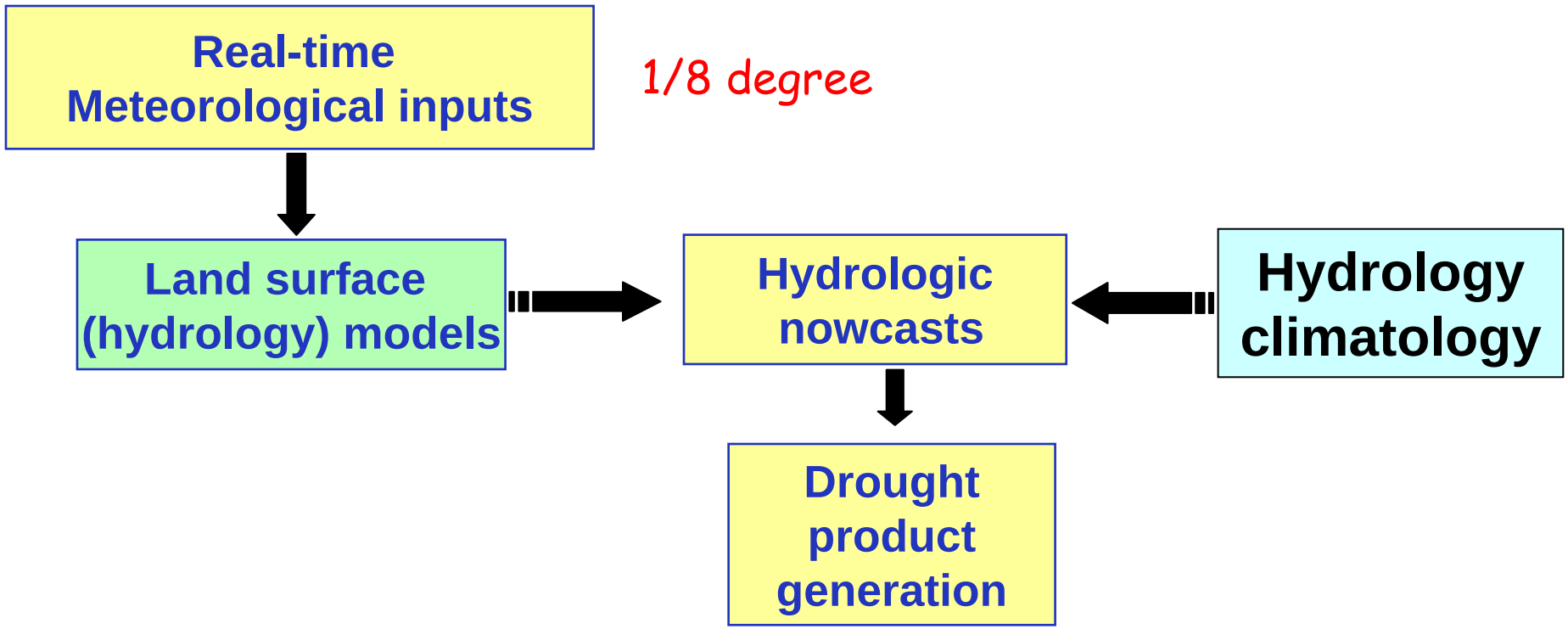
Other Parts of the World: Eastern Asia



Other Parts of the World: Africa

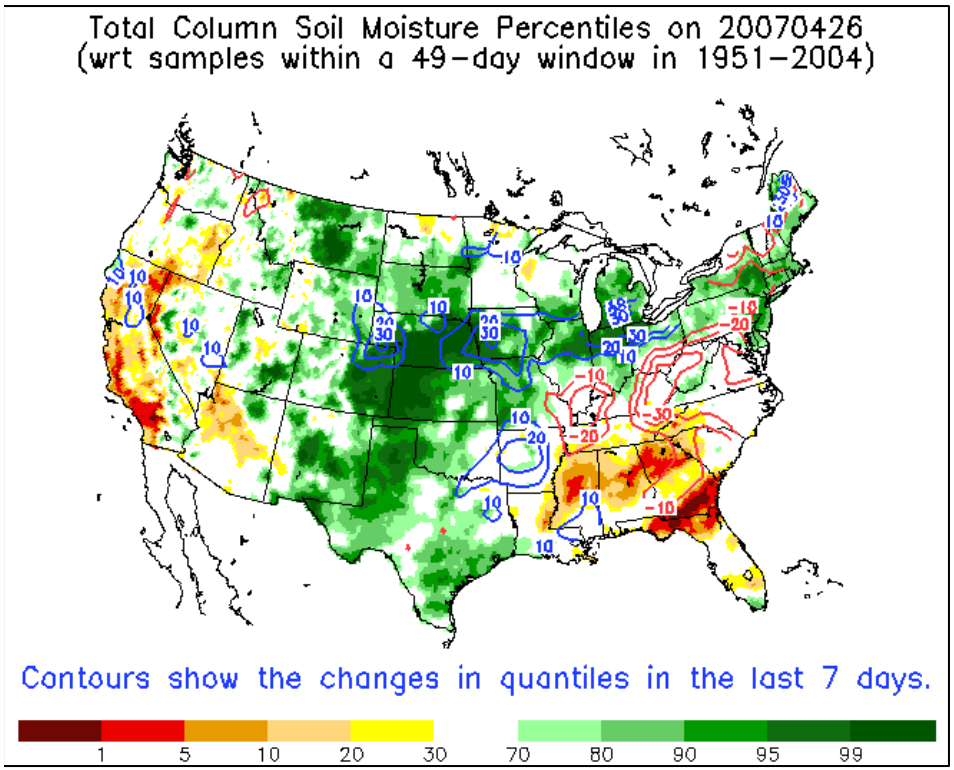


Drought Monitoring over the U.S.

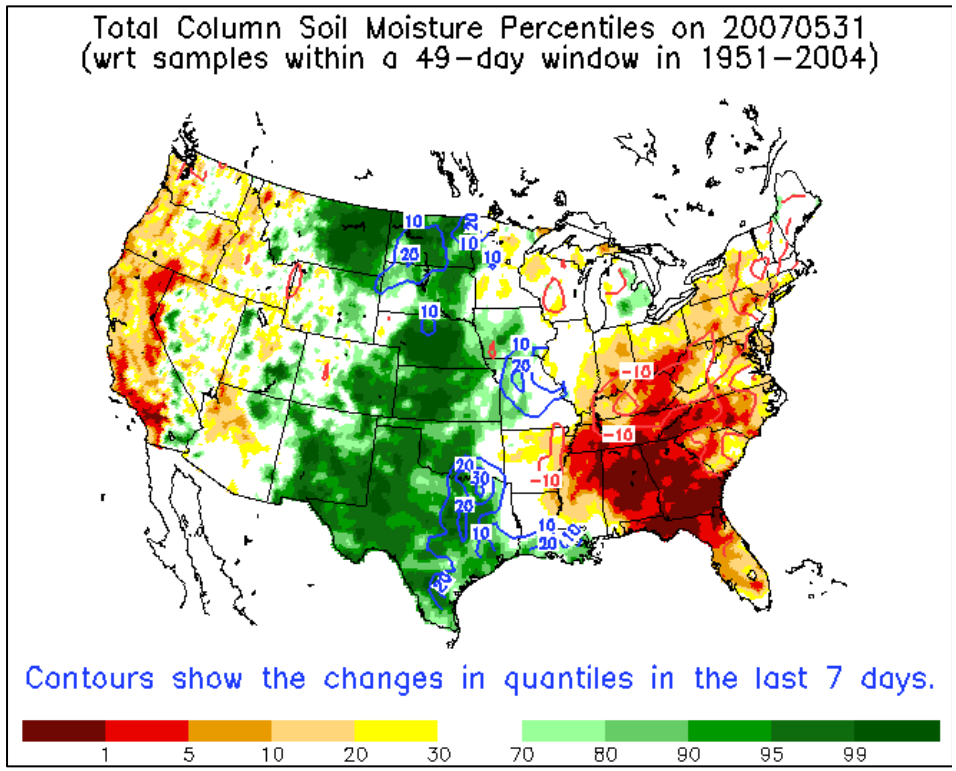


Nowcasts of soil moisture using NLDAS observations

April 26, 2007



May 31, 2007



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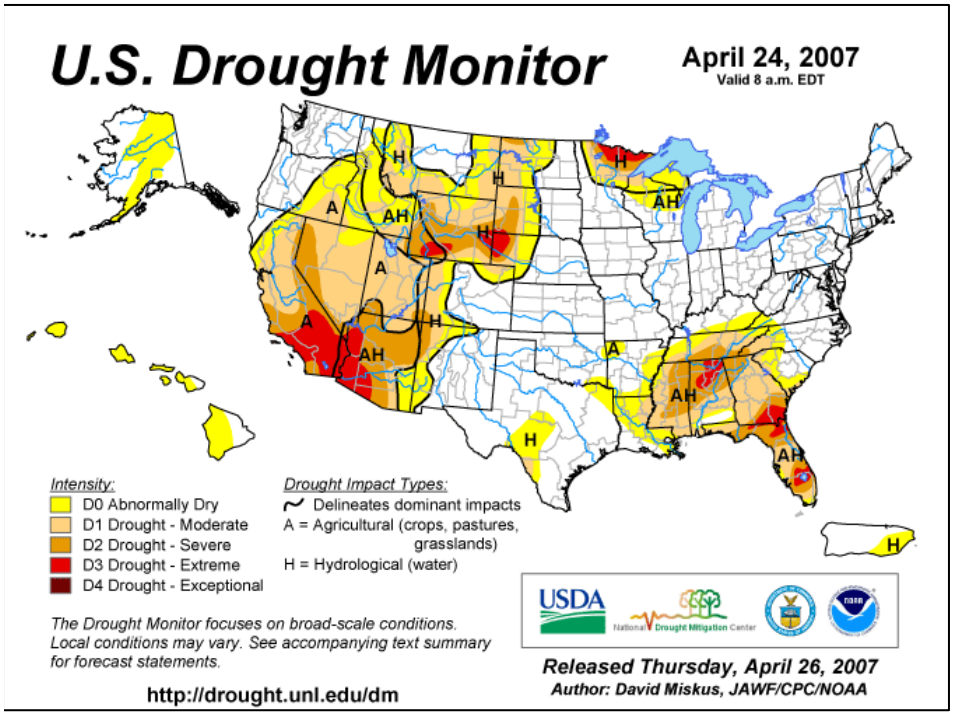
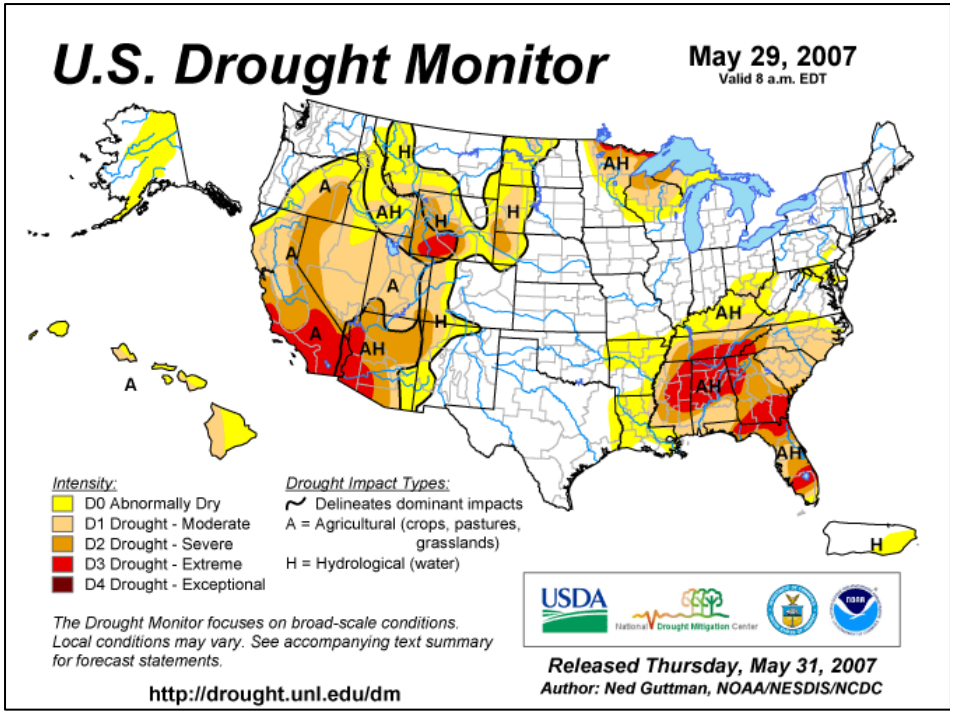
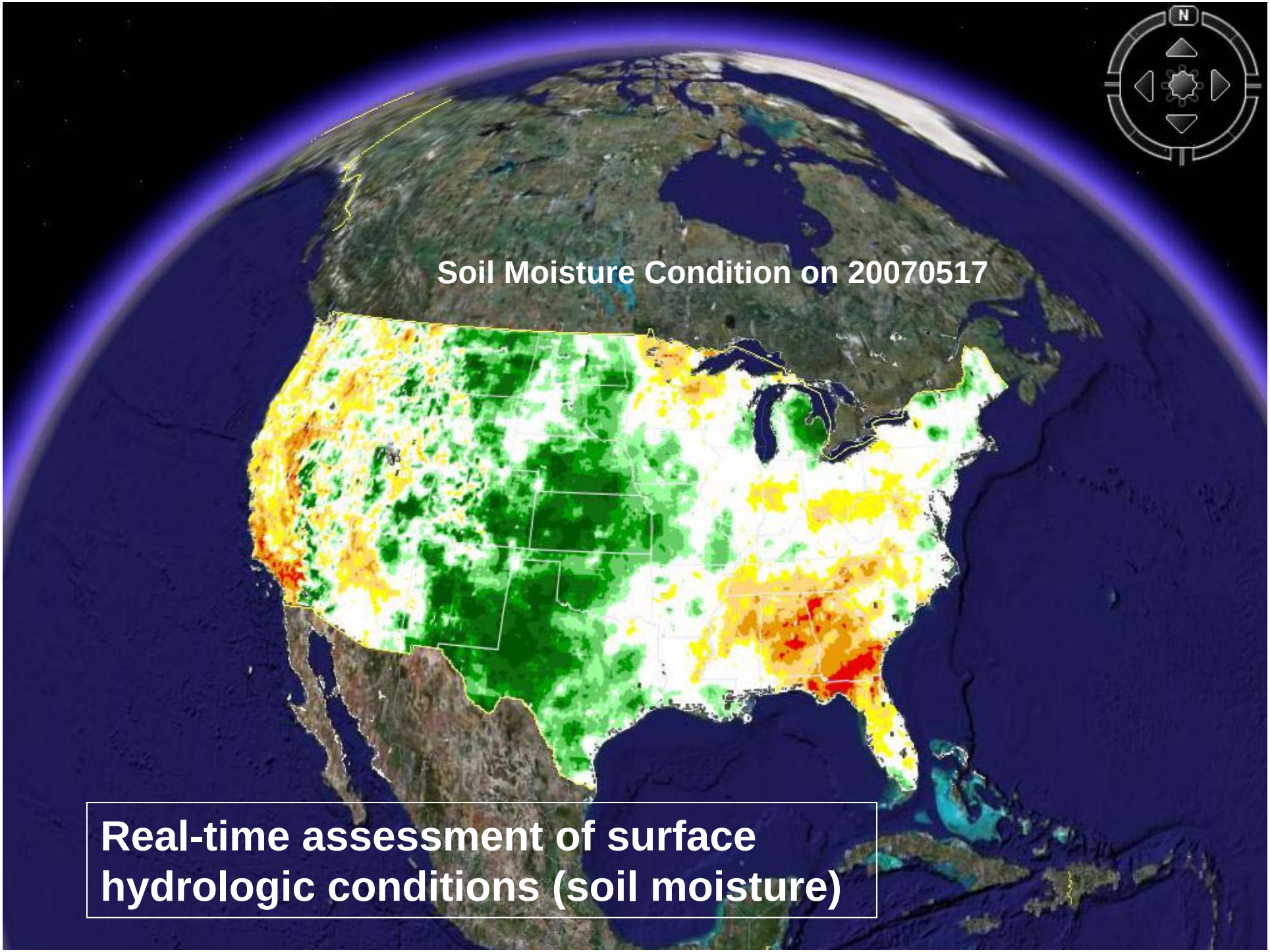
U.S. Drought Monitor

April 24, 2007



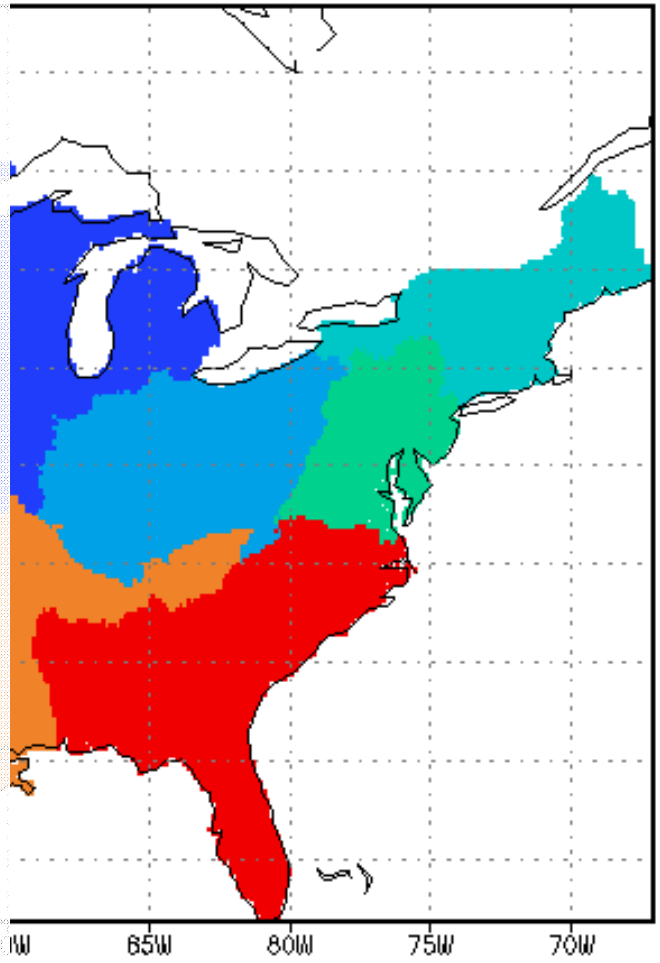
May 29, 2007




Soil Moisture Condition on 20070517
Real-time assessment of surface hydrologic conditions (soil moisture)

Testbed Data Availability

1. Land surface characteristics: including soil texture, topography, vegetation characteristics. These data are available for at 1/8-degree resolution. These data can be used to derive parameters used by individual model.
2. A 50-year daily 1/8-deg meteorological dataset is available. It contains daily precipitation and daily maximum and minimum temperature.
3. Long-term daily streamflow data are available from USGS for most of the streamflow gages.
4. Multiple climate model seasonal hindcasts (6-9 month) are available starting from 1978. These include NCEP CFS hindcast and ECMWF DEMETER hindcast.



Future Activities

- ***Seasonal Hydrologic Predictions*.**

  Generate a global (land) hydrologic re-forecasts (hindcasts) based on NOAA and DEMETER seasonal forecasts. Need to identify other testbed groups to evaluate the hydrologic ensemble forecasts.

  Utilize 7 models (CCM3.6, COLA, ECHAM4.5, ECPC, GFDL, NASA-NSIPP1, and NCEP-MRF9) from IRI)

- ***Continue to estimate current hydrologic conditions (snow, soil wetness)***
- ***Expand Water Resources Management Applications***

  Retrospective assessment of water resource management in GA through collaboration with people at GA Tech, and other groups (in HEPEX.)

More Information About This Work

Drought Monitoring and Hydrologic Forecasting with VIC

- About This Project
- Current Conditions
- Current Forecast
  - Max Temperature
  - Min Temperature
  - Precipitation
  - Forcing Posterior
  - Soil Moisture (L1)
  - Soil Moisture (L2)
  - Soil Moisture (L3)
  - Total Soil Moisture
  - Streamflow
  - From Others Ctrs
- Forecast Verification
- Multimodel Hindcast
- Hindcast Verification
- Documentations
  - Methodology
  - Bug Report
  - References
- Links
- Disclaimer
- Progress Report (Internal users only)

Drought Conditions On 20070607

Also available in google earth

The drought analysis is based on comparing the current soil moisture against the 54-yr retrospective climatology. The climatology is developed separately for each grid cell (> 55,000 cells in the USA) in the form of a pdf. The original drought analysis (Sheffield et al. 2004) fitted beta distributions to the soil moisture data. In this update we use empirical distributions based directly on the data. The plots shows the percentile of current soil moisture with respect to the 54-yr climatology defined as all values in a 11-day sampling window centered at 20070607.

View nowcast on: 20070607

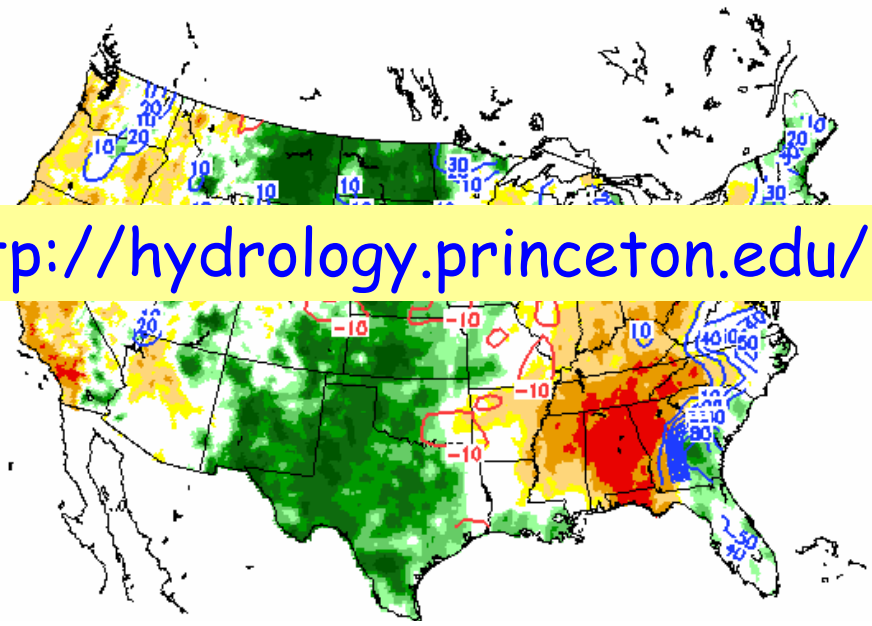
Most Current Drought Predictions

Current condition with changes in the last 7 days

News Update

May 9	The drought forecast verification page is added.
Feb 8	Due to disk failure, nowcast and forecast system currently are not running.
Dec 21	Seasonal forecast is now available for the entire US.

Total Column Soil Moisture Percentiles on 20070607
(wrt samples within a 49-day window in 1951-2004)



http://hydrology.princeton.edu/forecast

Thank You