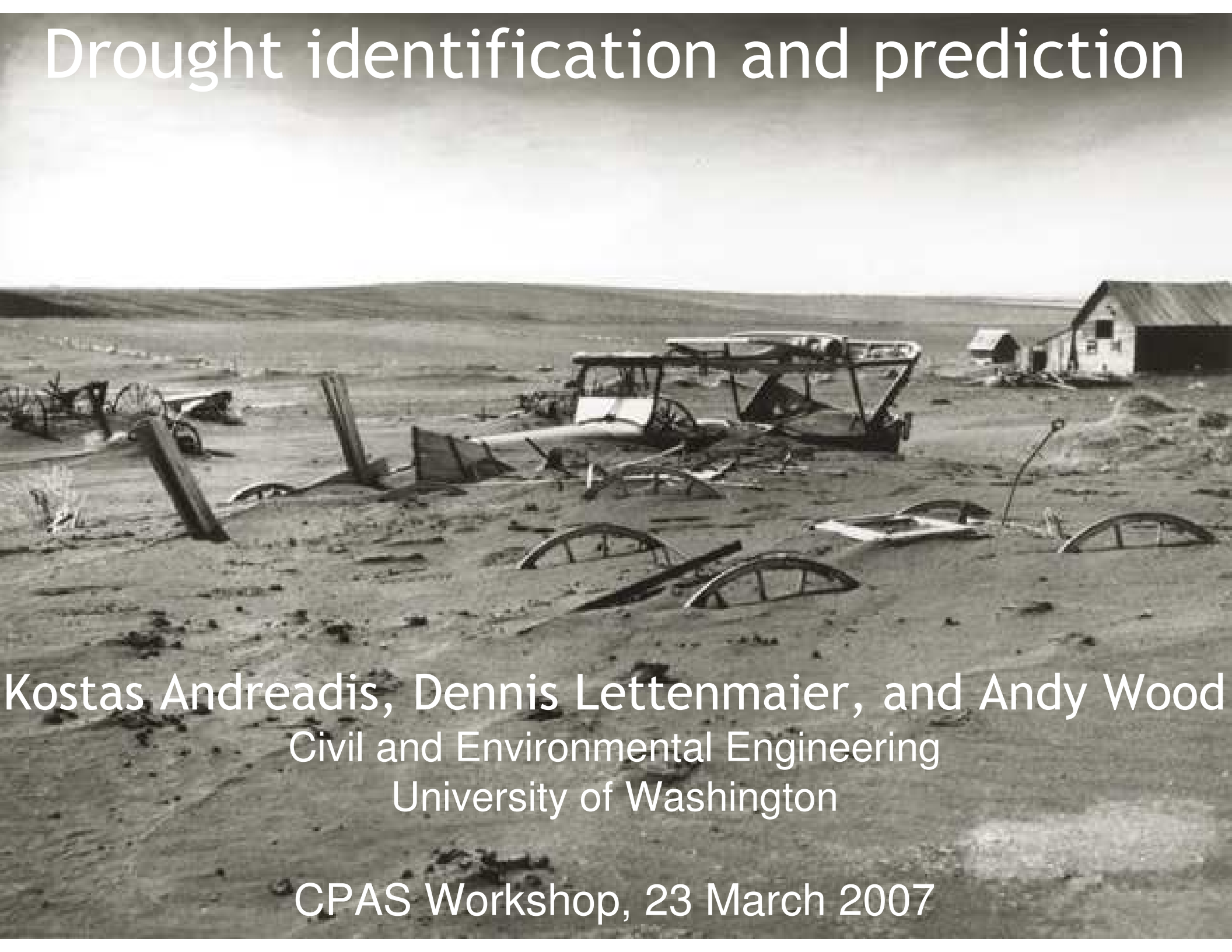
Drought identification and prediction



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CPAS Workshop, 23 March 2007

Motivation

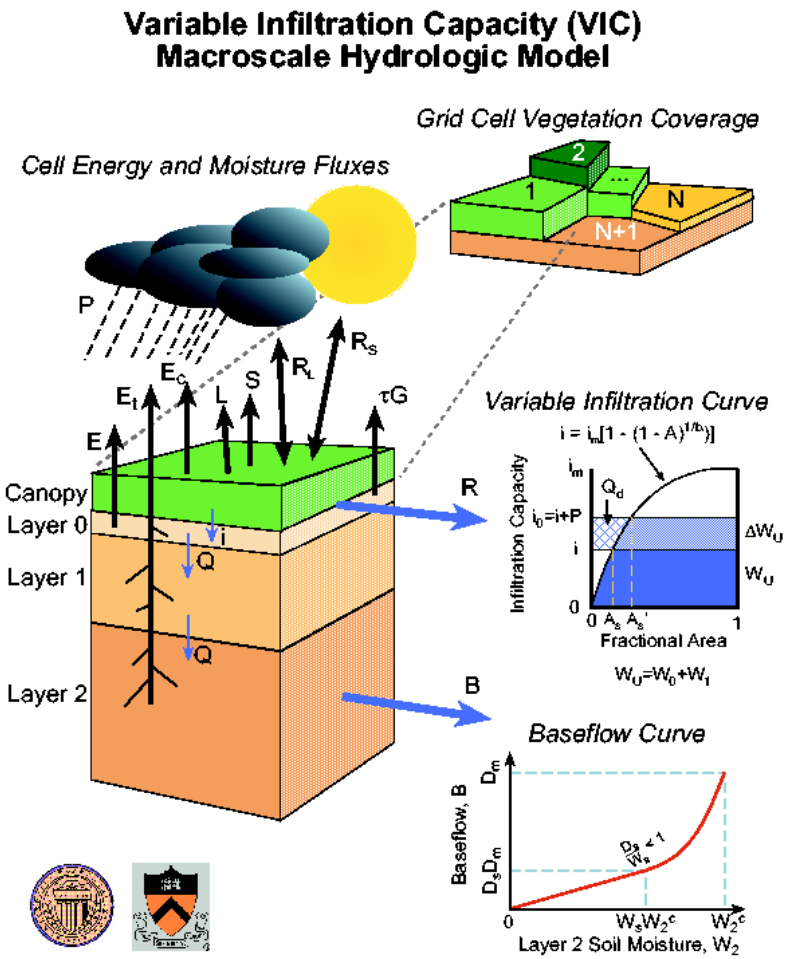
- Drought one of the most costly natural disasters
- Annual costs estimated at $6-8B (FEMA, 1995), with recent western US drought (2002) cost over $10B (NCDC, 2003)
- Drought monitoring and prediction
- Important to assess drought characteristics: severity, duration, frequency and areal extent
- PDSI most widely used
  - Offers simplicity and standardization
  - Not appropriate for high latitudes and during cold seasons

Motivation (cont'd)

- Alternative approach is to use hydrologic models to produce a spatially and temporally continuous dataset of more “direct” variables (soil moisture for agricultural and runoff for hydrological drought)
- Long-term and consistent precipitation and air temperature dataset from NCDC (1915-now)
- Need method for objective identification and estimation of drought characteristics
- Near real-time implementation and drought recovery prediction using hydrologic forecasting

Hydrologic model

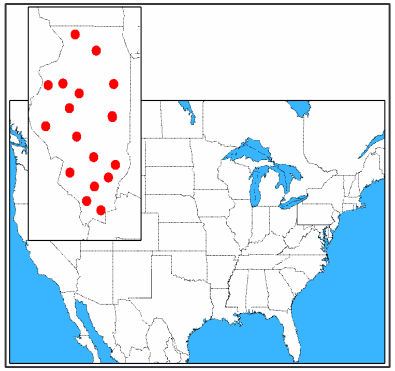
- Variable Infiltration Capacity (VIC) model
- Solves energy and water balance over gridded domain
- Accounts for subgrid variability in topography, land cover, soil moisture, and precipitation
- Streamflow estimated by routing runoff and baseflow through stream network
- Precipitation, air temperature and wind speed as input

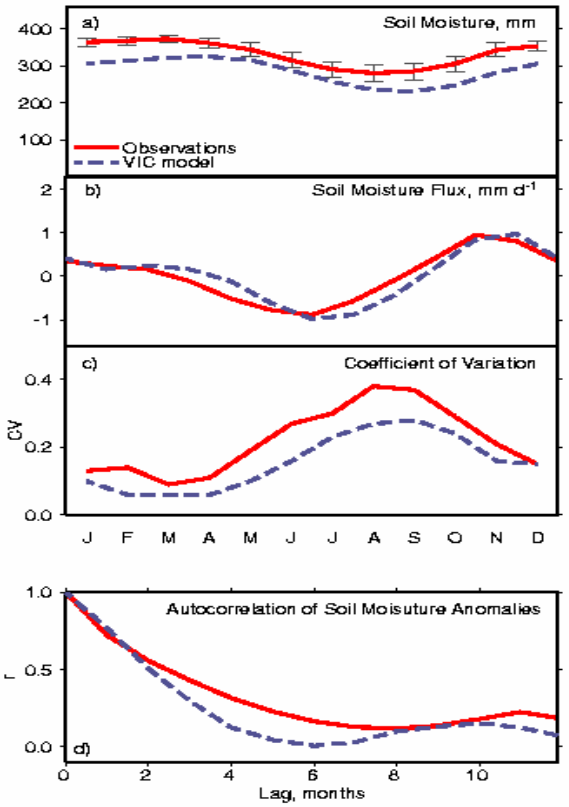


Model validation

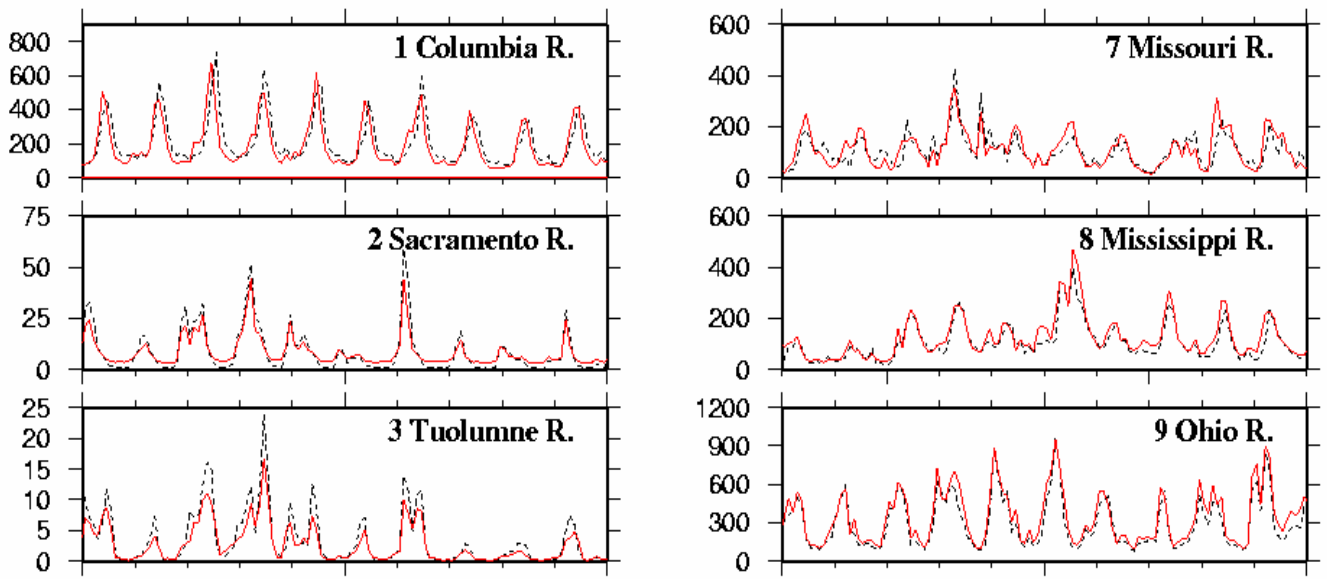
- VIC successfully applied in variety of climates and basins
- Good agreement for monthly streamflow compared with USGS observations
- Seasonal variability and temporal persistence of soil moisture flux well simulated when compared with point measurements

Soil Moisture Comparisons





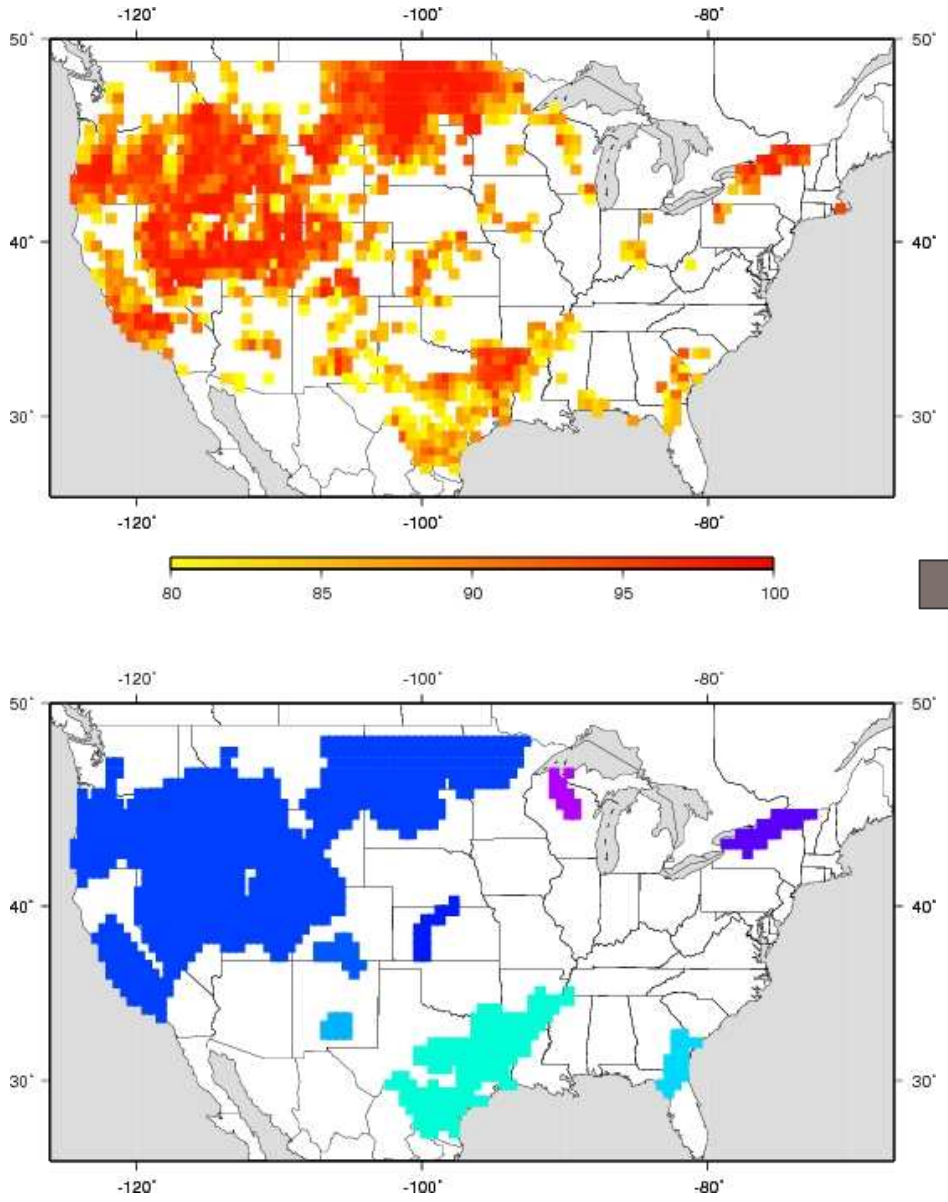
Streamflow Comparisons

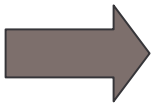


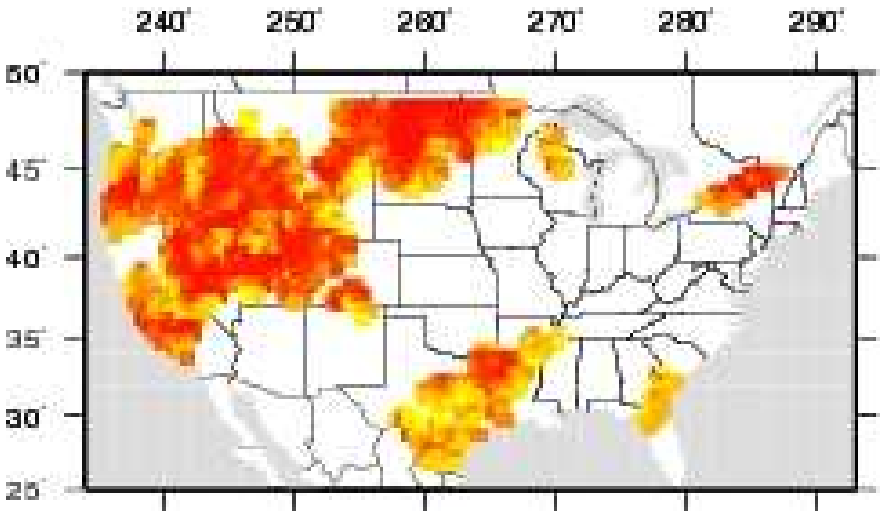
Drought identification

- Express soil moisture and runoff as percentiles relative to 1915-2003 climatology
- Threshold approach to identify drought at different levels (20^{th} percentile here)
- Spatial contiguity constraint for initial drought segmentation
- Drought classification using constraints on
  - Minimum area
  - Minimum distance between clusters
  - Neighborhood correlations
- Temporal continuity constraints
  - “Drought tracking” in retrospective analysis
  - Drought transition probability estimated from climatology

Drought identification maps

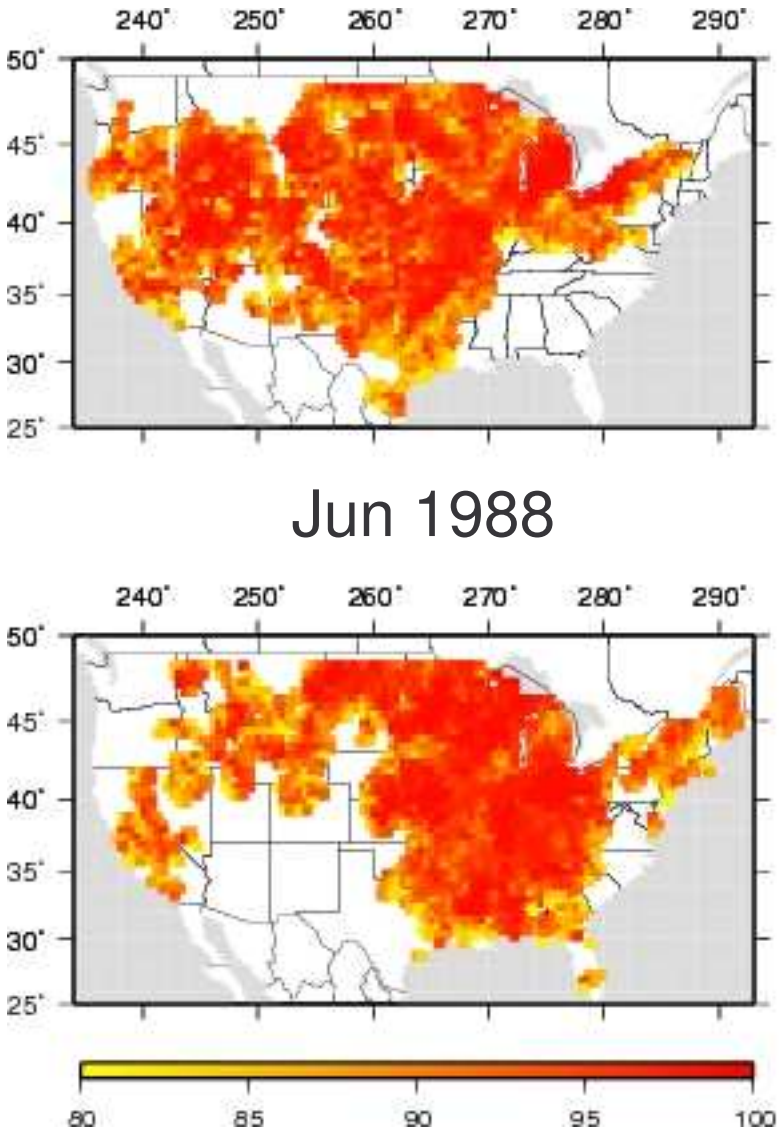




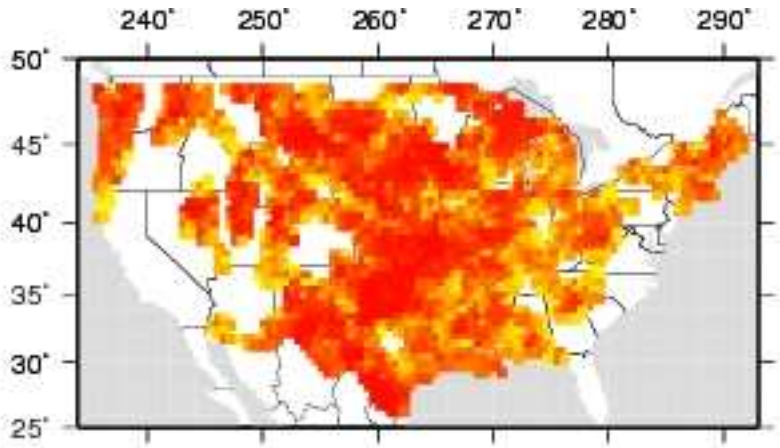


Spatial maps of drought

Jul 1934

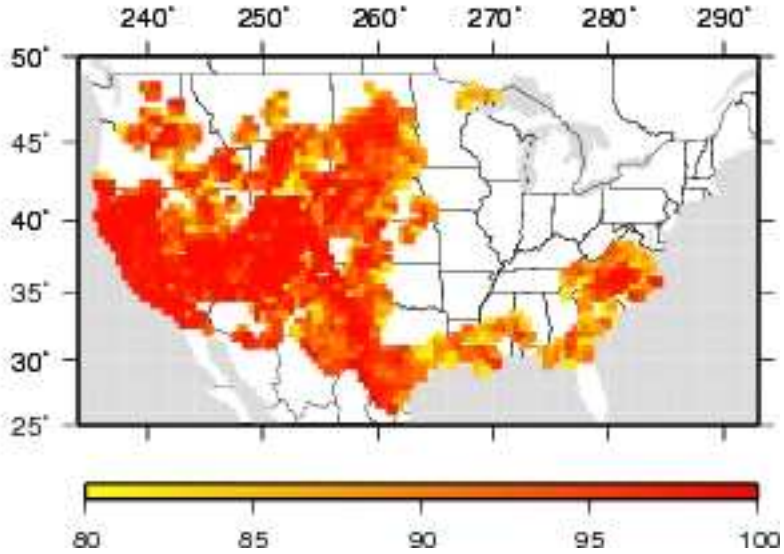


Nov 1952



Jun 1988

Jun 2002

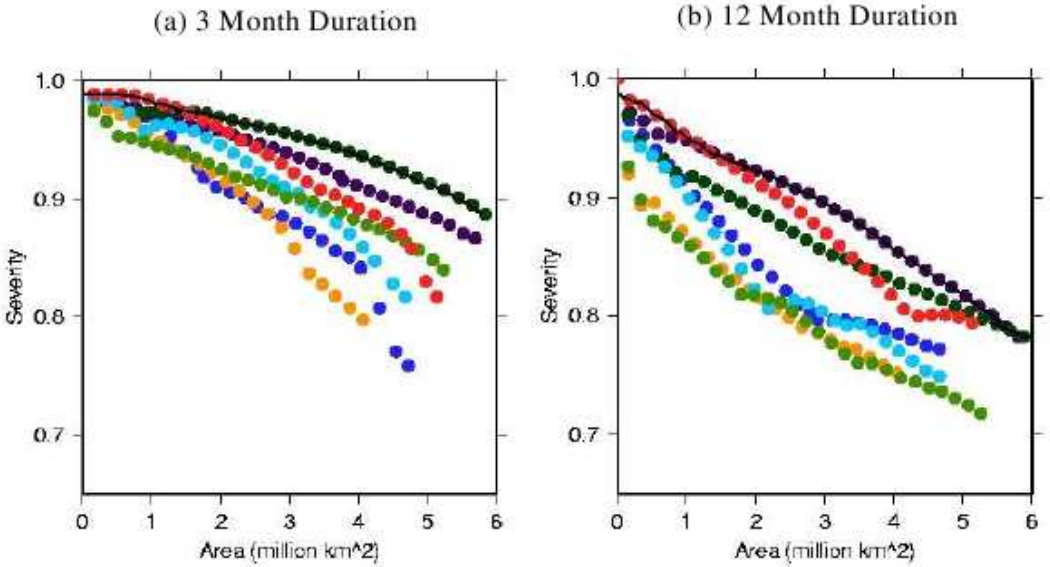


Severity-Area-Duration analysis

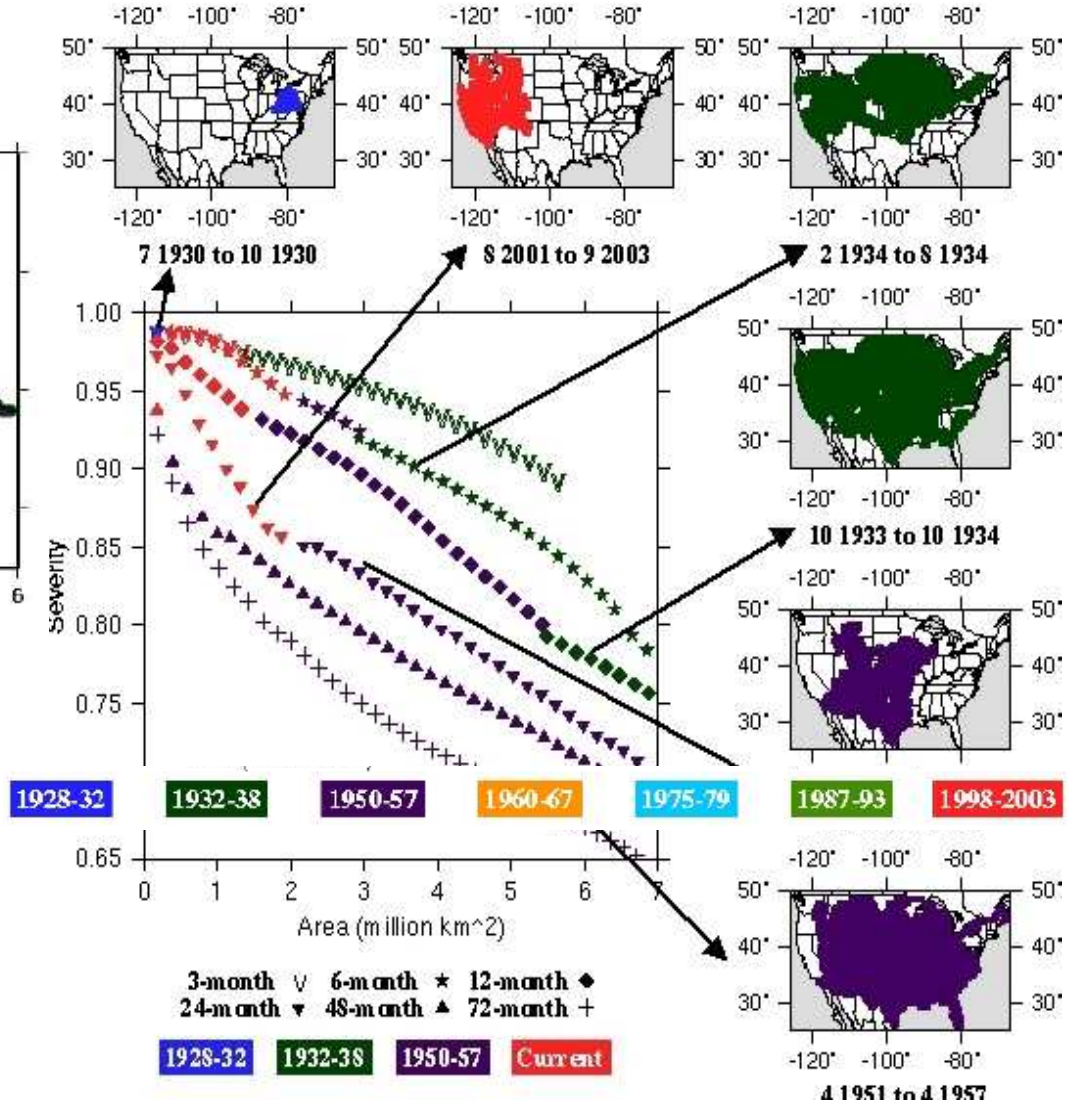
- At each time step
  - Identify drought events
  - Keep track of their duration, severity and areal extent
- Adapted Depth-Area-Duration analysis replacing rainfall depth with drought severity
- For different predefined areas and durations calculates average severity of each identified event
- Essentially a way to compare droughts in terms of severity, duration and areal extent

Severity-Area-Duration curves

Agricultural Drought (soil moisture)



Envelope Curves



Potential drought products

- Take advantage of UW Surface Water Monitor and West-wide forecasting system
- Drought severity map (directly derived from drought identification algorithm)
- Drought duration and frequency (temporally continuous dataset allows direct definition)
- Maps of trends in drought characteristics
- S-A-D curves for comparisons of current with historical droughts
- Maps of probabilities of recovery from drought at different lead times

Drought severity product

Week 1, 12/2005

Week 4, 1/2006

Week 1, 2/2006

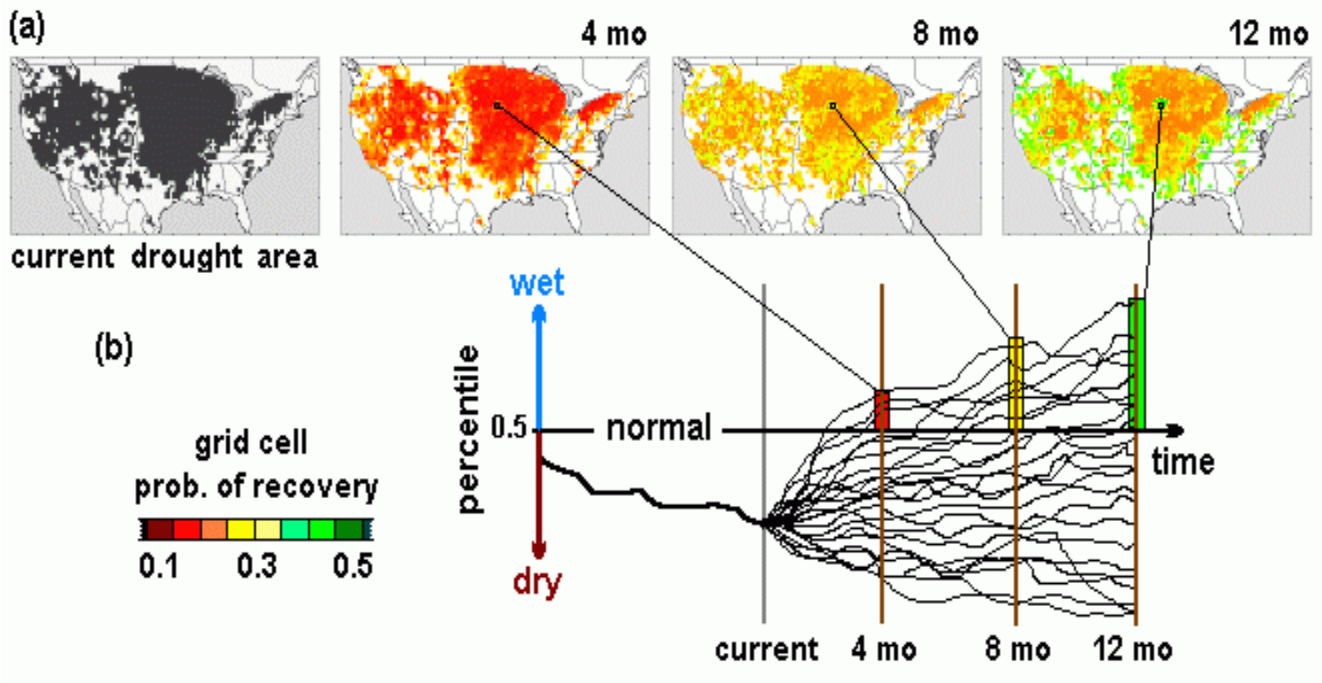
Week 4, 3/2006

Week 1, 4/2006

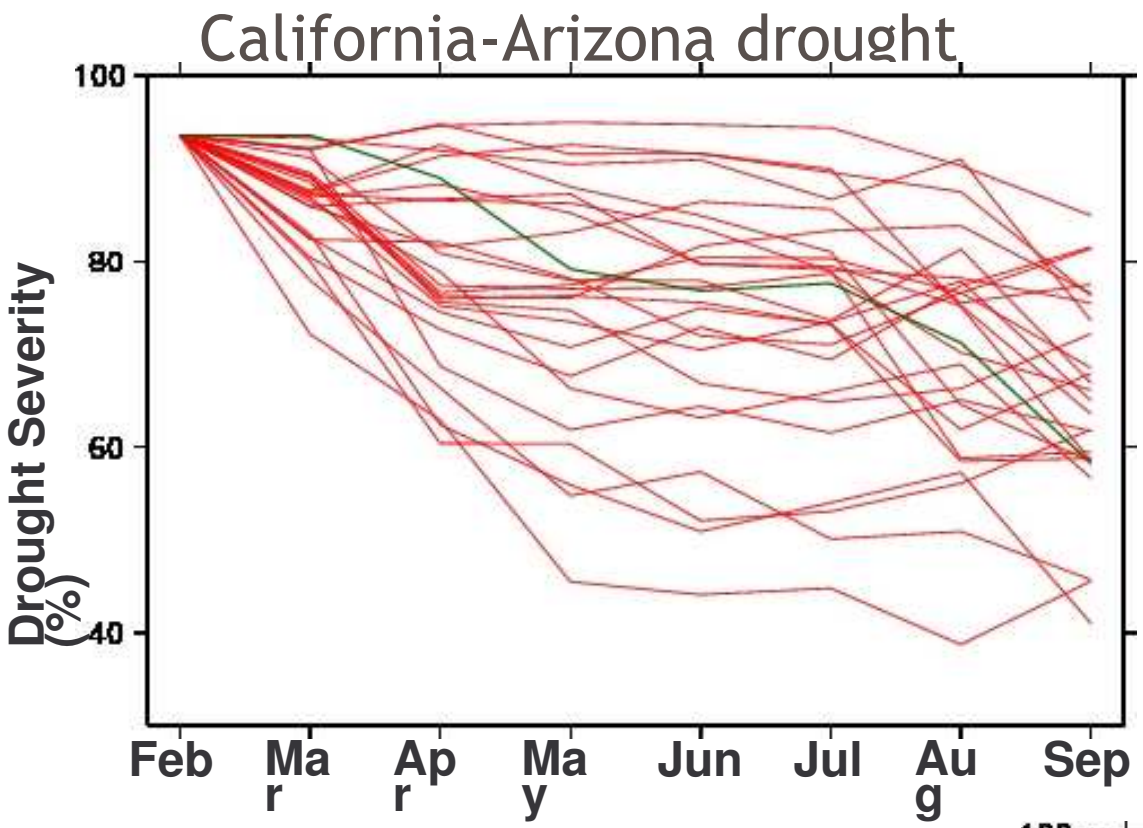
Week 4, 5/2006

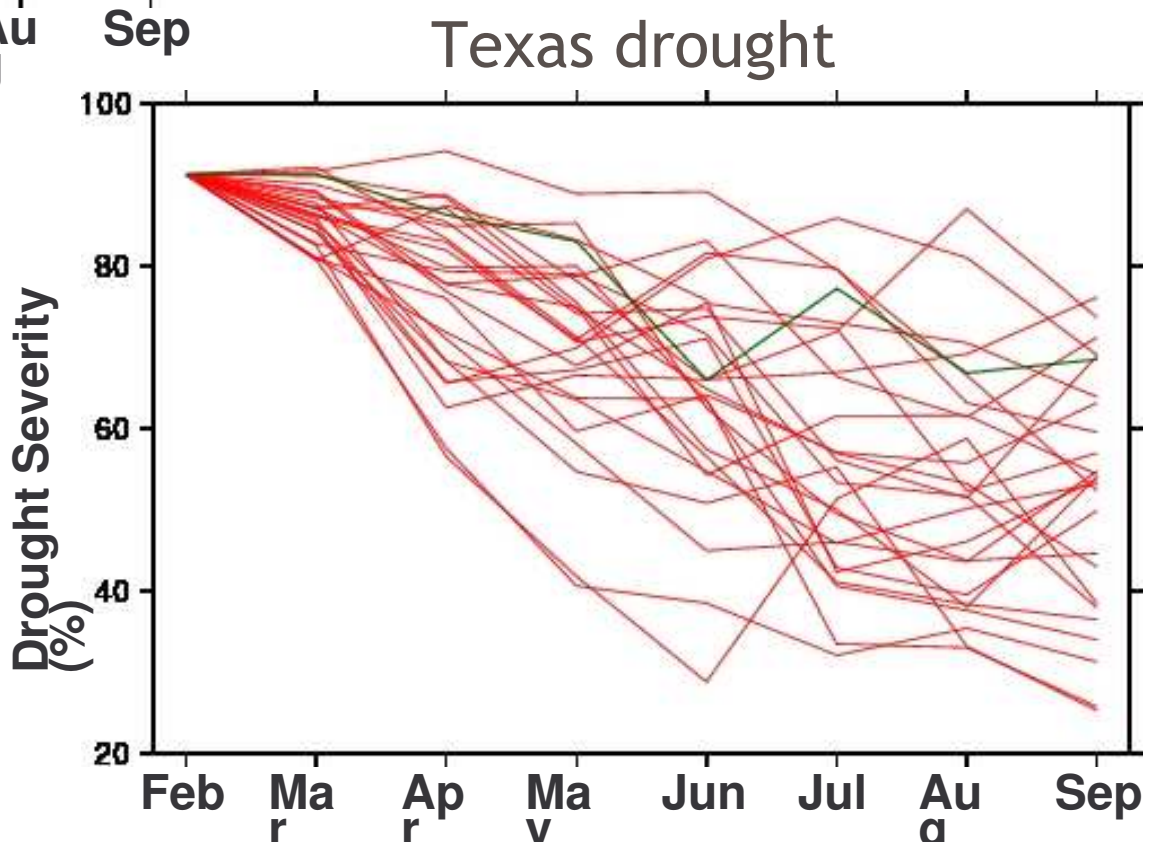
Drought recovery prediction methodology

- Use observed forcings to drive the model and produce “best knowledge” initial conditions for forecast
- Drive the model with precipitation and temperature forcings unconditionally sampled from climatology creating an ensemble of model trajectories
- At different lead times, estimate probability of soil moisture/runoff percentile exceeding threshold from ensemble = probability of recovery



Drought severity ESP forecast



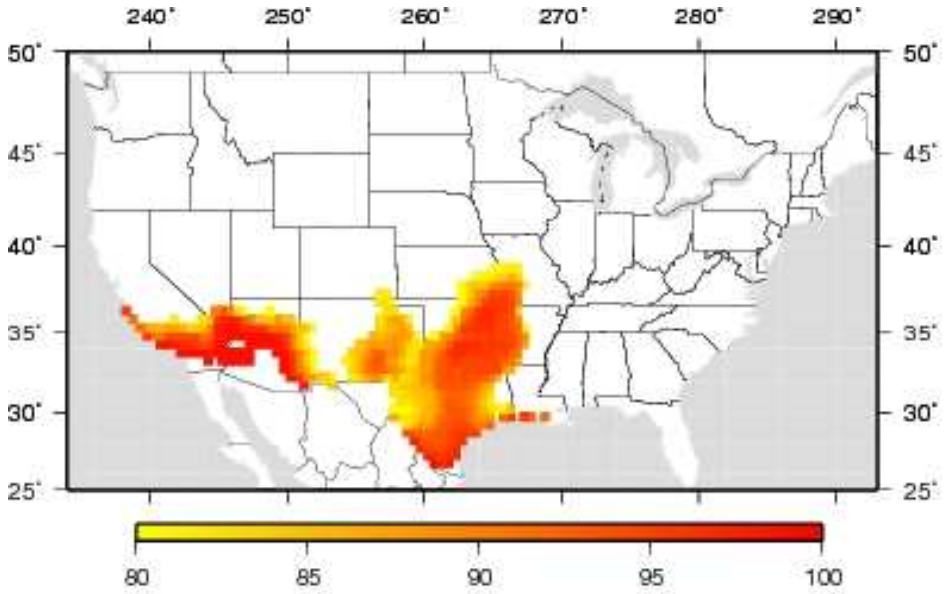


Ensemble

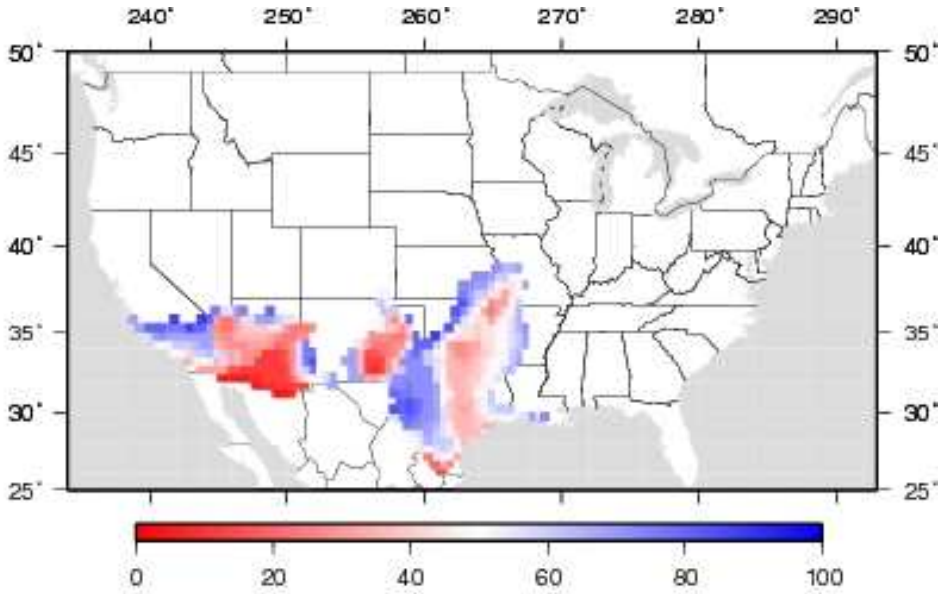
"Observed"

Probability of drought recovery

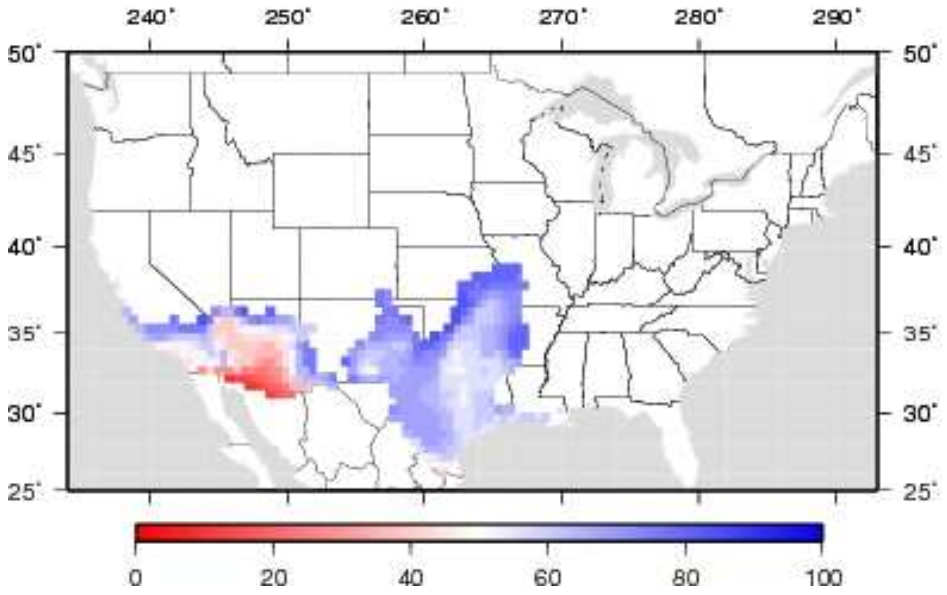
Initial Conditions (2/2006)



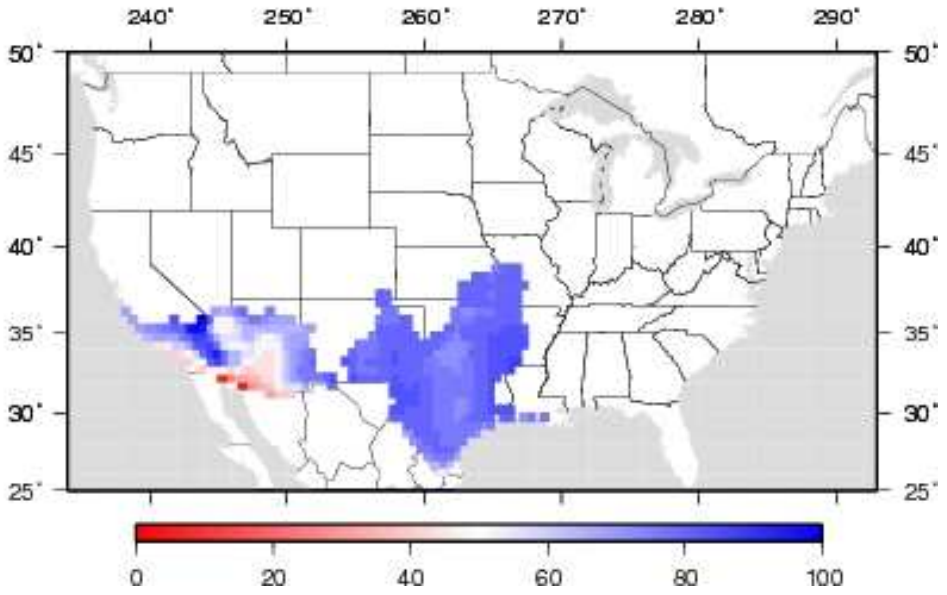
1-month lead forecast (3/2006)



3-month lead forecast (5/2006)



6-month lead forecast (8/2006)



Summary

- Algorithm for objective identification and delineation of drought
- Combination with hydrologic forecasting to estimate probability of drought recovery
- Importance of initial hydrologic state – Potential for merging of satellite and ground observations (data assimilation)
- Replace current ESP approach with ensemble version of CPC “official” forecast, perhaps others included in westwide system
- Provide suite of drought products through UW Surface Water Monitor, and add GIS functionality to the web-interface

Questions?