Climate Prediction Program for the Americas

Land-Atmosphere Interactions

Science and Implementation Plan

Samples of Progress

Synthesis and Integration

Outline of CPPA-SIP Chapter 4

CPPA vision: *improve operational intraseasonal to interannual climate prediction and hydrological applications.*

CPPA land-atmosphere interaction science objectives:

(1) improve understanding and simulation of coupled land-atmosphere processes through observation, data analysis, and modeling studies;

(2) determine the influence of land-atmosphere processes on intra-seasonal to interannual climate predictability; and

(3) use this knowledge to advance operational forecasts, monitoring, and analysis.

Discussion Topics:

1) *What are the main land-atmosphere priorities to improve climate forecasts over the Americas at SI timescales?*
2) *What are the primary implementation steps required given a $2-$3M per year budget.*
3) *What are the deliverables (short, mid, long term) or synthesis products?*

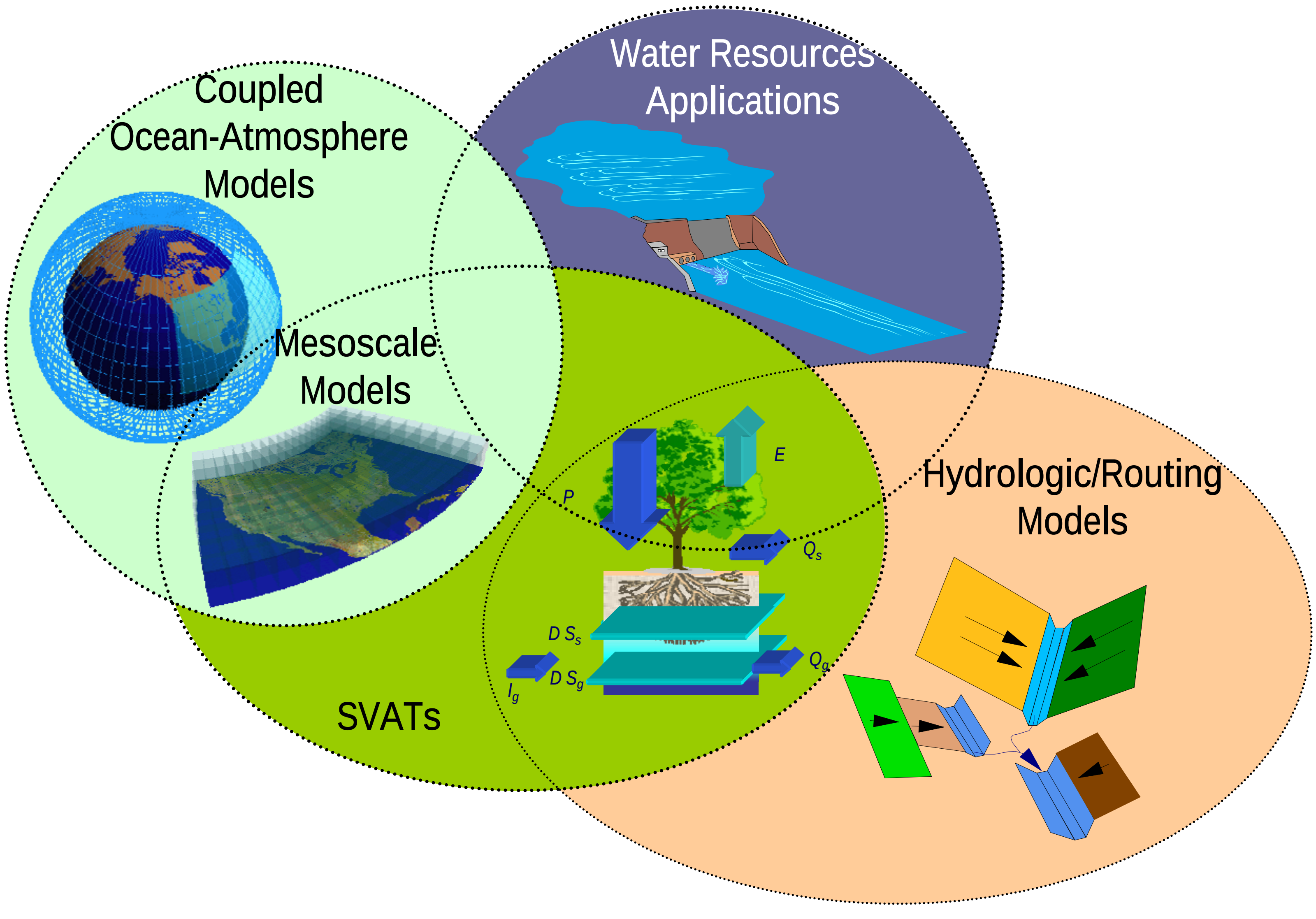
Other Questions:

A) *How should we integrate individual CPPA funded projects.*

B) *What are the interfaces between Chapter 4 and other chapters?*

Predictability chapter; hydrology and water management chapter

Complex scale and process interactions



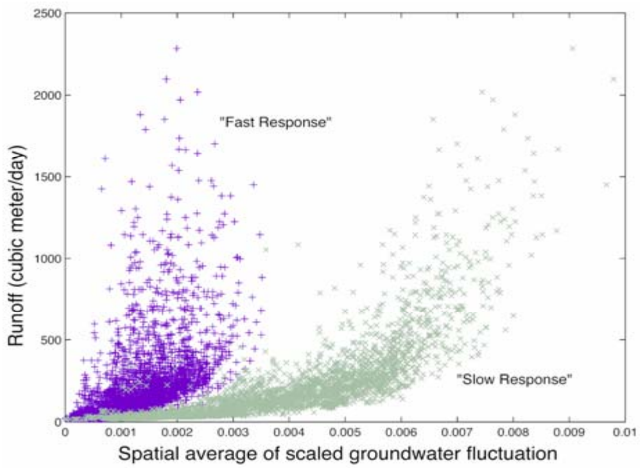
Objective 1: improve understanding and simulation of coupled land-atmosphere processes through observation, data analysis, and modeling studies.

- **Data Development:** Improve understanding of land-atmosphere interactions
  - **e.g. soil moisture, snow, vegetation, topography, field experiments**

- **Process and Modeling Studies:** Incorporate new understanding into climate prediction system (i.e. Core Projects)
  - **e.g. land surface models; regional climate models**

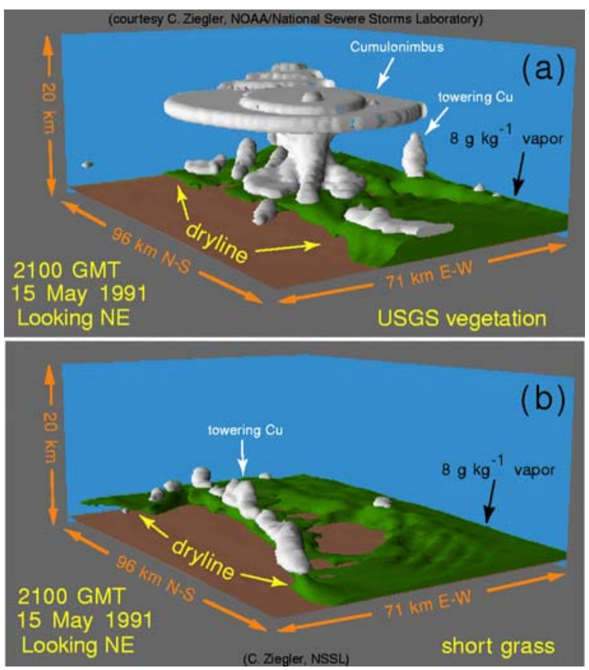
- **Orographic studies:** In regions with marked topography, climate conditions such as temperature, precipitation, and snow can be significantly modulated by orographic features.
  - **e.g. diagnostic studies of existing data, model experiments**

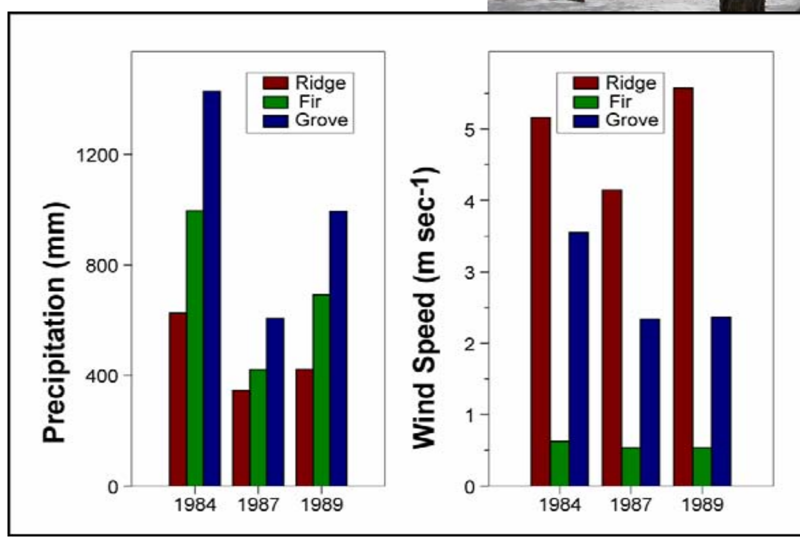
Analysis in support of model development



Analysis of subsurface flows for the Little Washita Indicates that two distinct flow regimes exit with different time scales. Hydrologic models should be able to reproduce these response features (Duffy).

Analysis of below canopy wind and snow shows the importance of topography and vegetation cover (Marks).



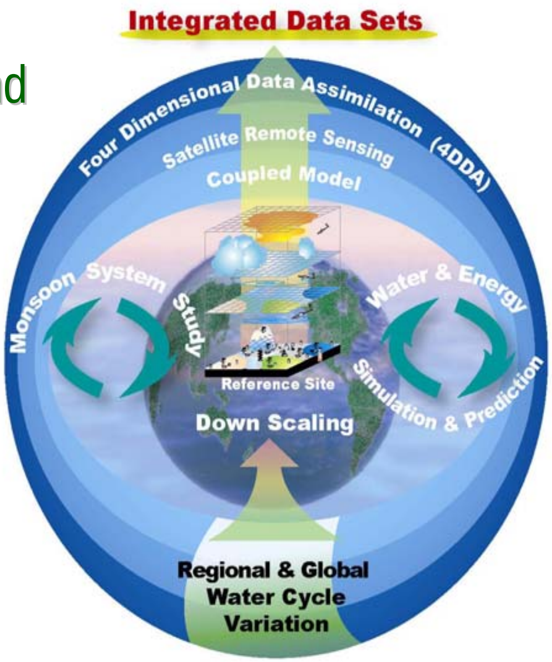


Heterogeneity of surface fluxes above different land cover types controls the intensity of summer convection (Pielke Sr).

Coordinated Enhanced Observing System

Scientific Rational

- Focused on the measurement, understanding, and modeling of water and energy cycles within the climate system.
- Motivated by the synchronism of the new generation of Earth observing satellites and GEWEX-CSEs.
- Primary goal to develop a consistent data set for 2001-2004 (and beyond with CEOP-2) to support research objectives in climate prediction and monsoon system studies.

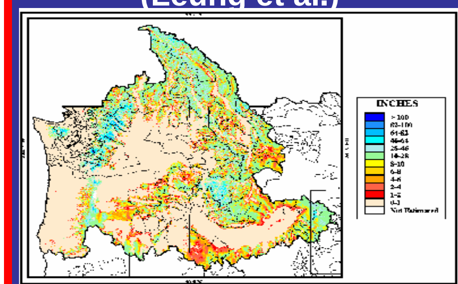


Activities:

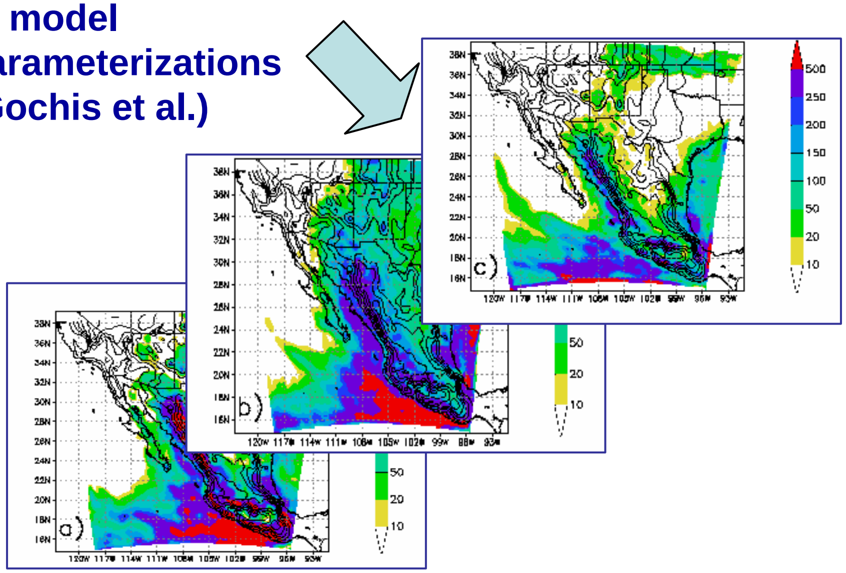
1. Provide data (in-situ, remote sensing, and model output) to CEOP and data management
2. Demonstrate the utility of satellite data in research and climate prediction
3. Evaluate the performance of global and regional models across climate regimes and time scales.
   - Water and Energy Simulation and Prediction (WESP)
   - Monsoon Studies

Hydrometeorology of Orographic Systems

Modeled snowpack and runoff improved with topographic Influences (Leung et al.)



Monsoon mountain rainfall very sensitive to model parameterizations (Gochis et al.)

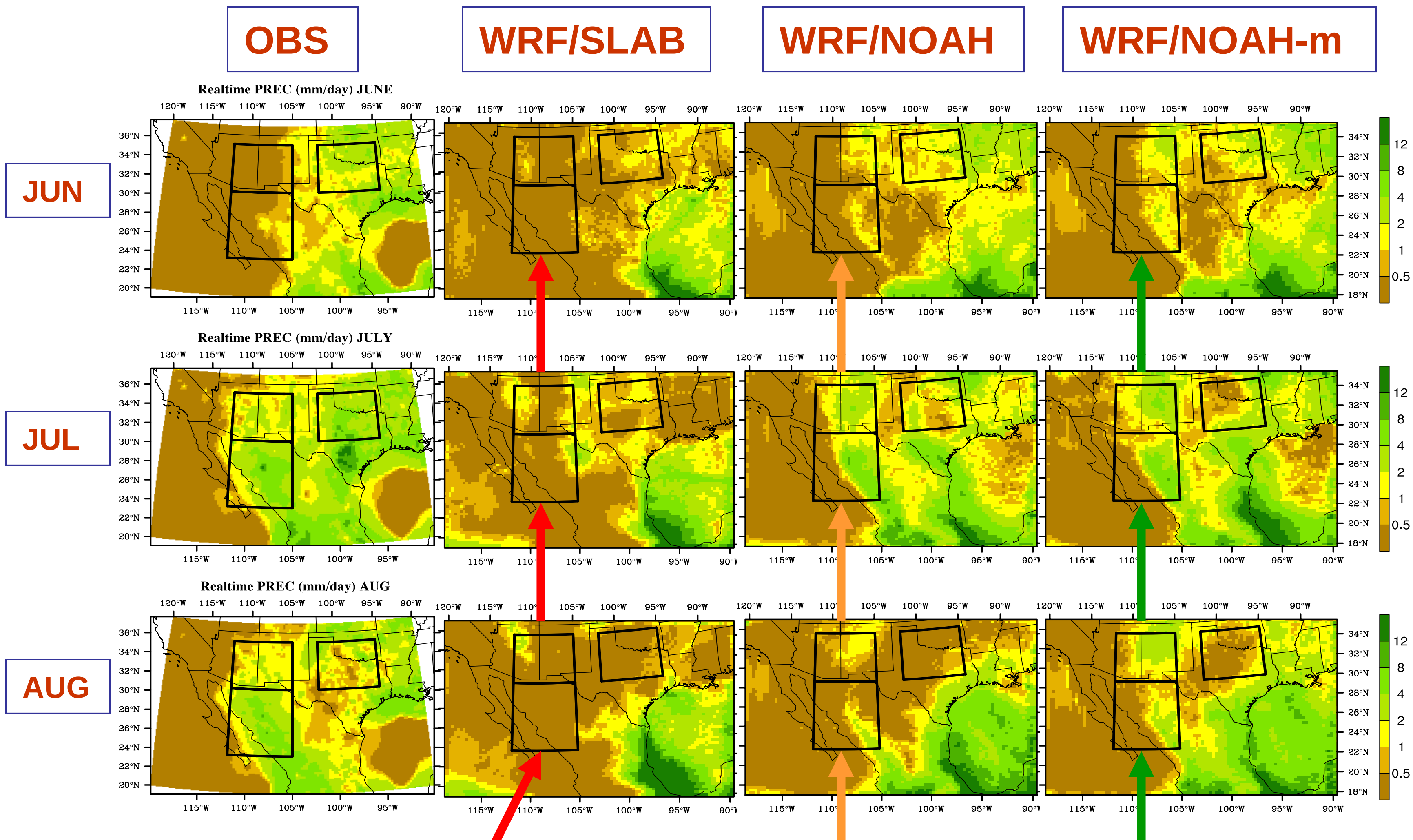


Challenge and future studies:

- **Observations and data analyses**
  - – orographic precipitation including assimilating satellite data
  - – hydroclimatic processes in the western mountains
- **Prediction**
  - – downscaling precipitation forecasts from large scale to sub-basin
  - – seasonal predictability in mountain regions (local and remote forcing)
  - – representation of subgrid variability of hydrologic variables (precipitation, snow, togography, vegetation) in climate models

Role of Land Surface Processes in Modulating NAMS Rainfall

(June 1, 2002 initialization, nested RCM 90/30km, NNRP Bdry. Forcing)

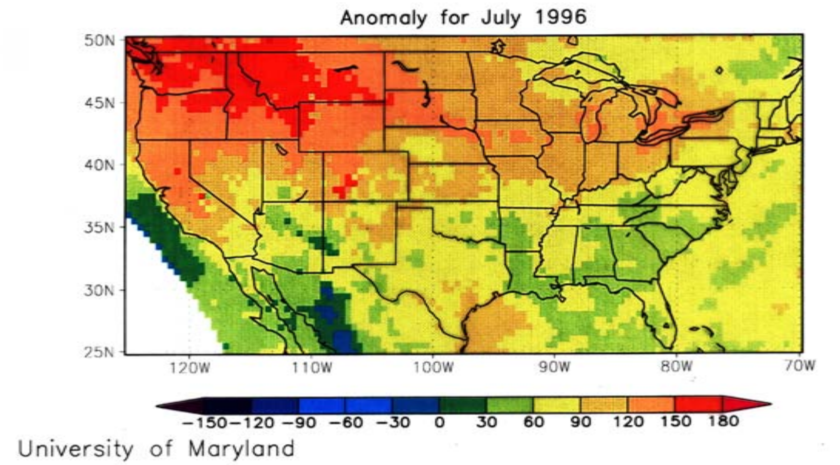


WRF/SLAB fails to produce rainfall for June – August.

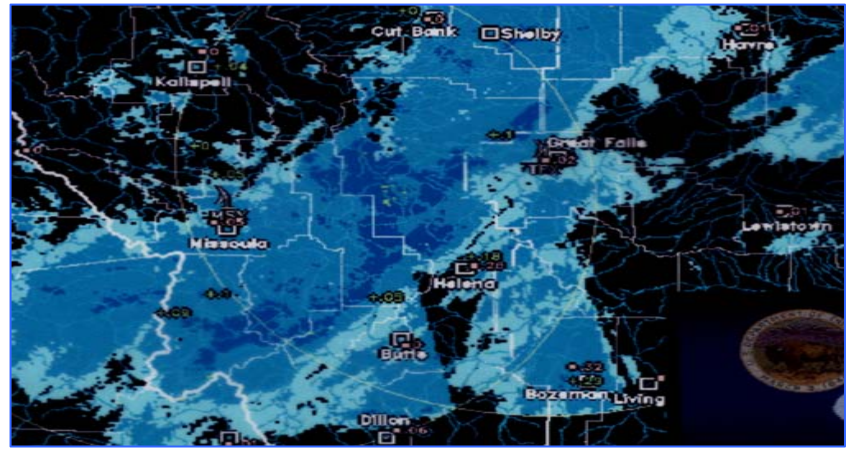
WRF/NOAH fails to capture rainfall in August.

WRF/NOAH-m best captures rainfall in August.

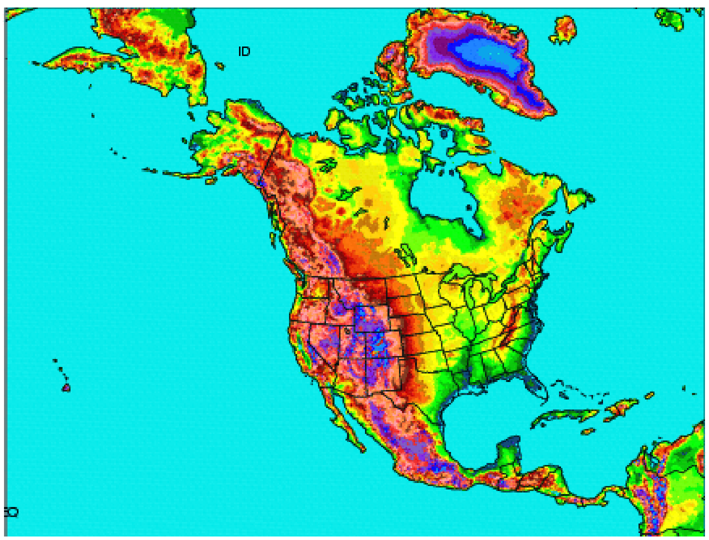
GAPP/CPPA: Examples of legacy data sets.



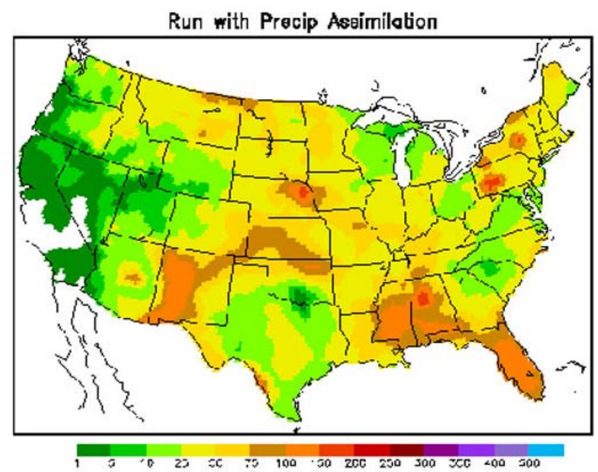
* Reanalysis of solar radiation products .(1996-2000)



* 5-year NEXRAD rain data set for the Mississippi Basin is complete.(1996-2000)



* Regional Reanalysis 25 - years of 32-km resolution products for North America.



* Soil Moisture Data sets from Oklahoma

Remote Sensing Applications

Scientific Rational

- Advances in continental and regional precipitation, surface soil-moisture, snow, surface soil freezing and thawing, surface inundation, river flow, and total terrestrial water-storage remote sensing provide the basis for a remote sensing research effort.
- Satellite data sets provide a valuable extension to conventional in-situ ground-based observations by providing continuous spatial coverage and repeat temporal coverage, which simplifies their use in modeling and assessment studies.

Activities:

1. Demonstrate the usefulness of remote sensing to provide forcing and parameters for land surface hydrological models, model state constraints for data assimilation and prediction systems, and validation data (fluxes and states such as surface temperature and soil moisture content)
2. Demonstrate of terrestrial hydrologic states and fluxes for improved forecasting, and seasonal climate prediction
3. Compare satellite derived land surface products with observations made during field experiments, including NAME (soil moisture) and enhanced data sets from the GEWEX Coordinated Enhanced Observation Period (CEOP) reference sites.

Objective 2: determine the influence of land-atmosphere processes on intra-seasonal to interannual climate predictability.

Scientific Rational

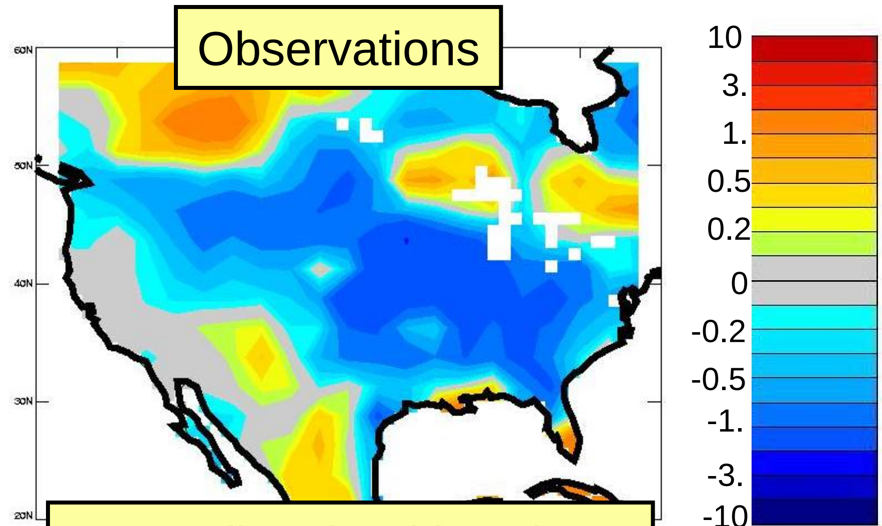
- Multi-month land-memory mechanisms: (i) the storage of water near the surface as soil moisture (ii) its storage on the surface as snow and ice, and (iii) nature and seasonal progression of growing vegetation.
- Understanding the strength of these relationships for different geographical regions and seasons, and their robustness over time and models remains a challenge

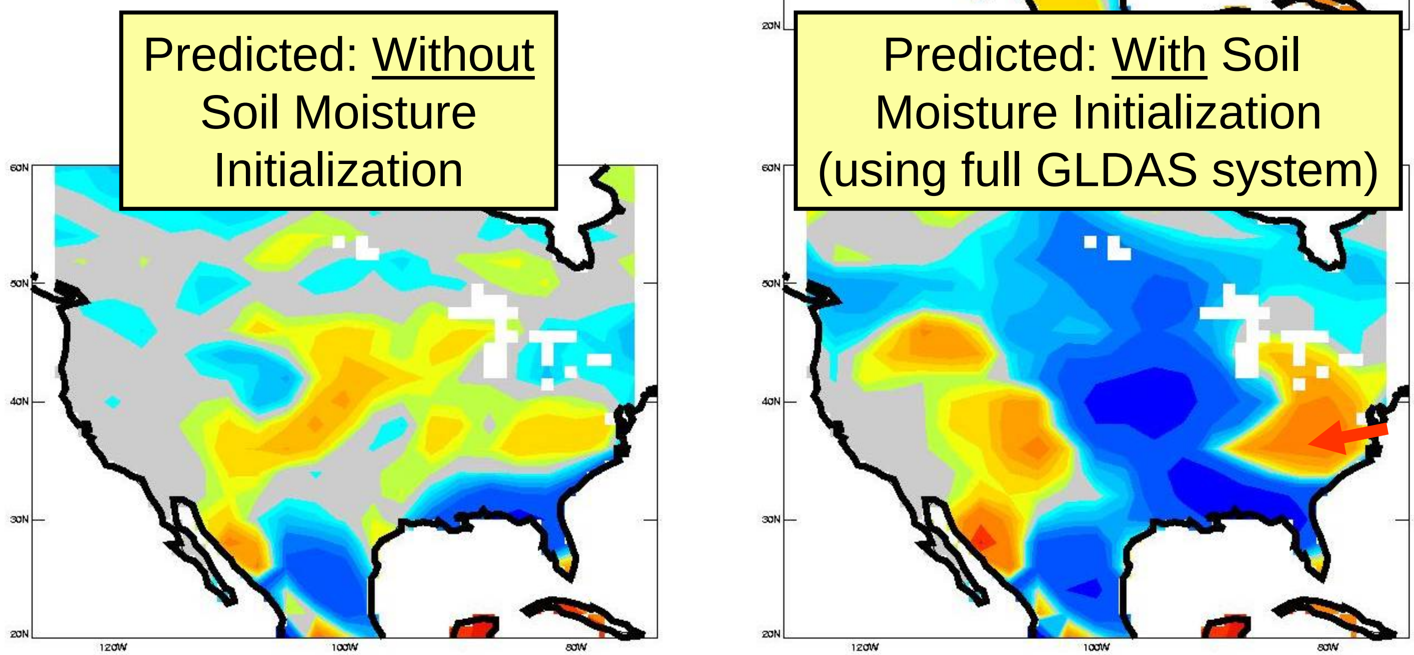
Activities:

1. Quantifying the strength of land memory processes
   - using existing data including NARR, Retroactive LDAS, satellite data
2. Understanding the spatial and temporal extent of the land memory signal
3. Quantifying the role of land memory in climate variability and prediction
4. Understanding land memory and variability across modeling scales

1988 U.S. Drought

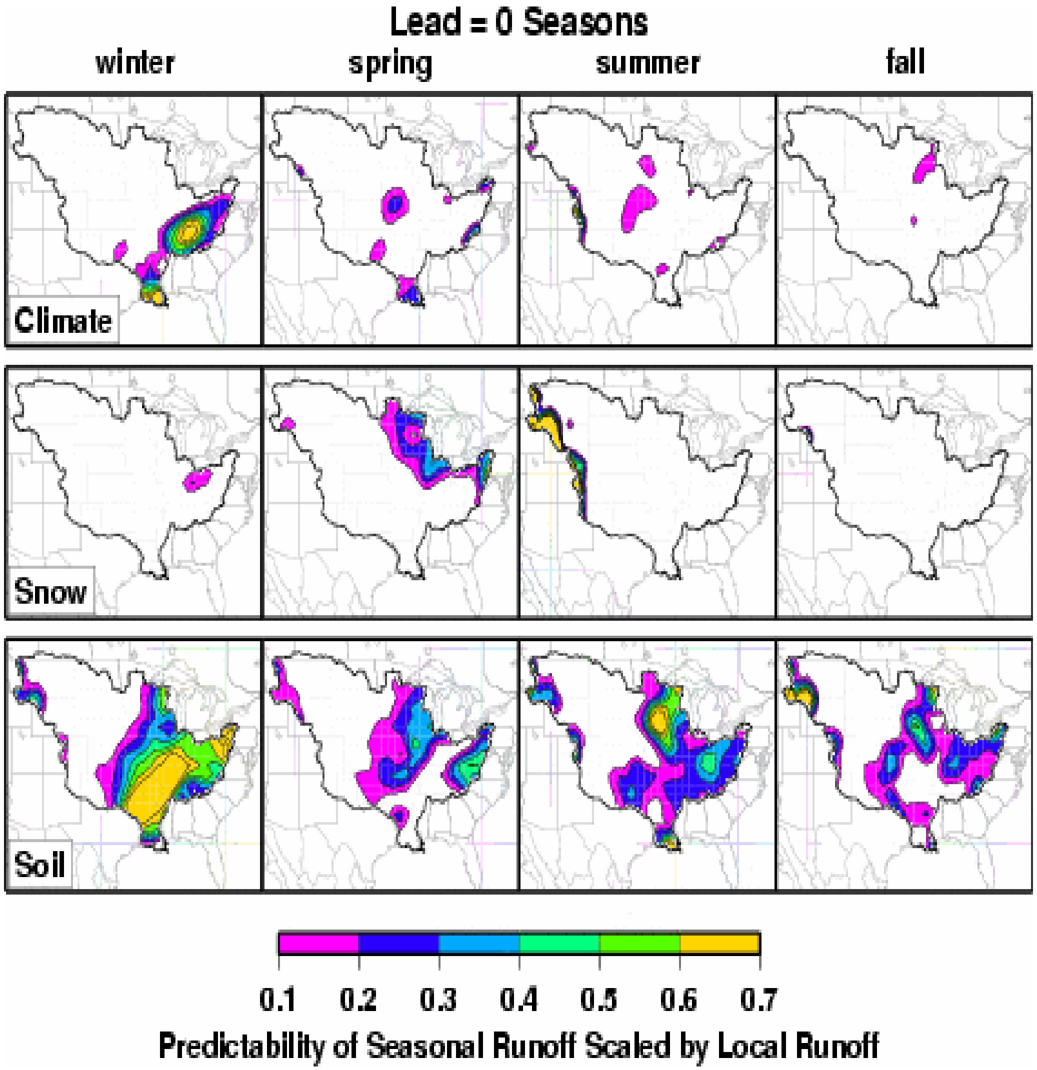
Prediction Improved by Soil Moisture Initial Condition





JJA precipitation anomalies (in mm/day, after R. Koster)

Hydrologic Predictability



Most of hydrological predictability comes from initial boundary conditions

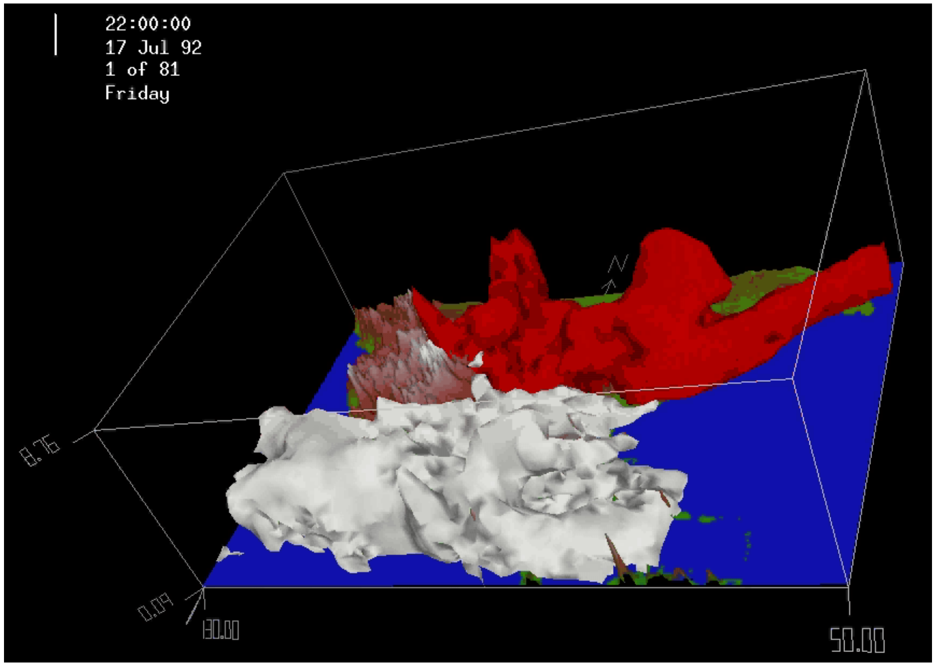
=> importance of LDAS

(Maurer and Lettenmaier)

- **soil moisture signal dominant;**
- **snow signal dominant in W in summer**
- **climate signal strong in SE in winter**

Water Cycling Research: coupling LDAS results

- Objective: To better understand the water cycle by quantifying geographic sources (local and remote) of precipitating water
- Soil water anomalies likely affect the local continental source of water for precipitation in the monsoon (e.g. Atlas et al. 1993)
- Controlled sensitivity experiments can be performed, using GLDAS initial conditions for the FVGCM
- Using realistic perturbations, what is the impact of wet and dry anomalies on the monsoon precipitation, and the relative sources of water



North America: Water evaporates from the Caribbean Sea moving westward (white isosurface) as the circulation changes this water is transported northward into the US. (The red isosurface shows water that has evaporated from the central US)

Bosilovich and Schubert, 2002; Bosilovich 2002

Objective 3: use improved understanding to advance operational forecasts, monitoring, and analysis.

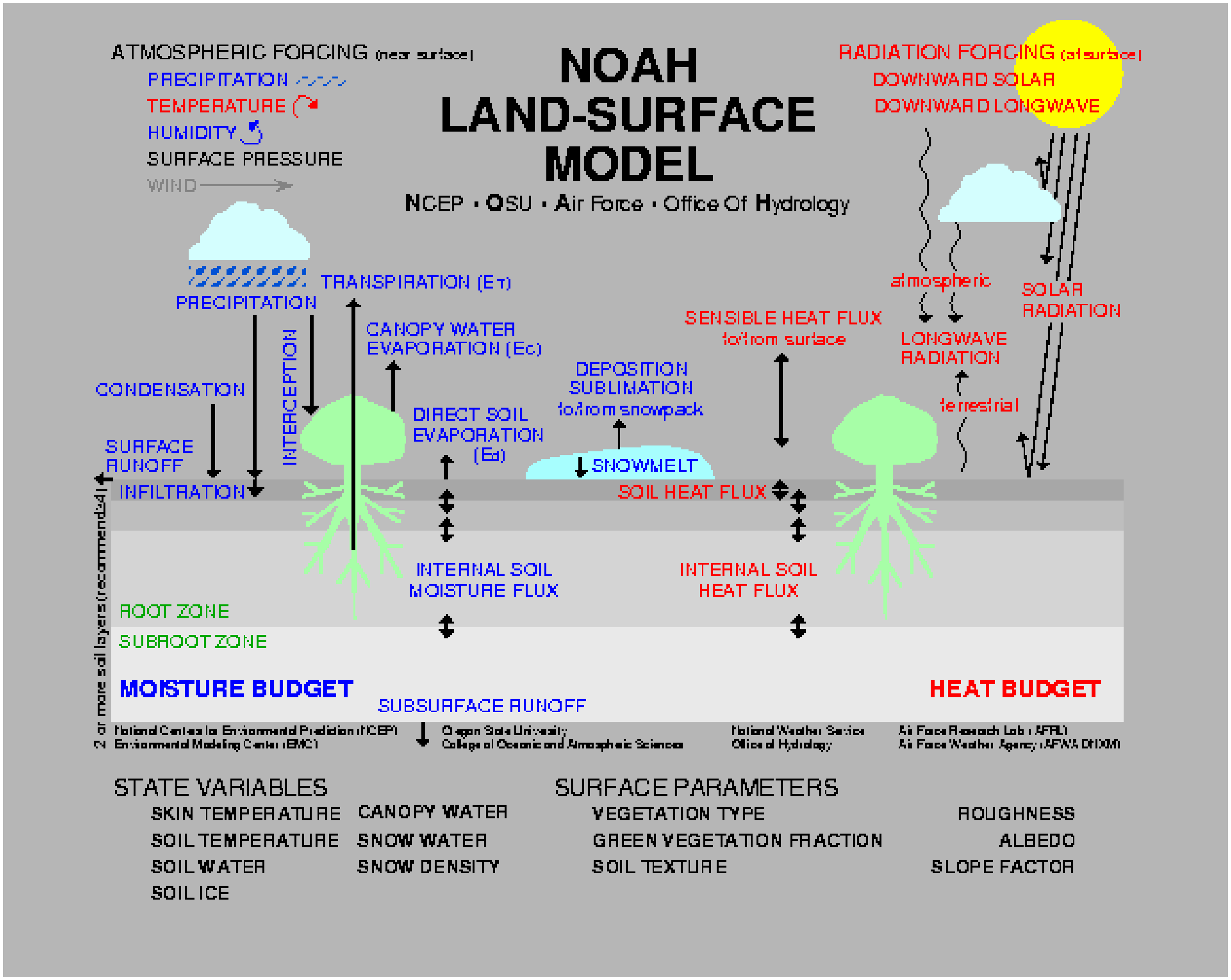
Scientific Rational

- Infrastructure is needed to construct and achieve a multi-scale, multi-model, end-to-end, ensemble seasonal prediction system – to be first demonstrated in hindcast mode and then secondly transitioned into operations.

Activities:

- Land surface model improvements: Providing improved land-model components for the coupled land/atmosphere prediction models
- Land Data Assimilation Systems: Developing and implementing global and regional land data assimilation systems
- Regional Climate Modeling: Developing, demonstrating and implementing regional climate models.
- Ensemble Hydrologic Prediction

Process and Modeling Studies



Core Project Approach:

Operational prediction improvements through research community engagement with operational NOAA-based "core" projects.

The ESP Process (OHD)

QPF, QTF

ESP Pre-Processor

Corrects bias, meteorological uncertainty

Ensemble traces of precipitation, temperature

Hydrologic model

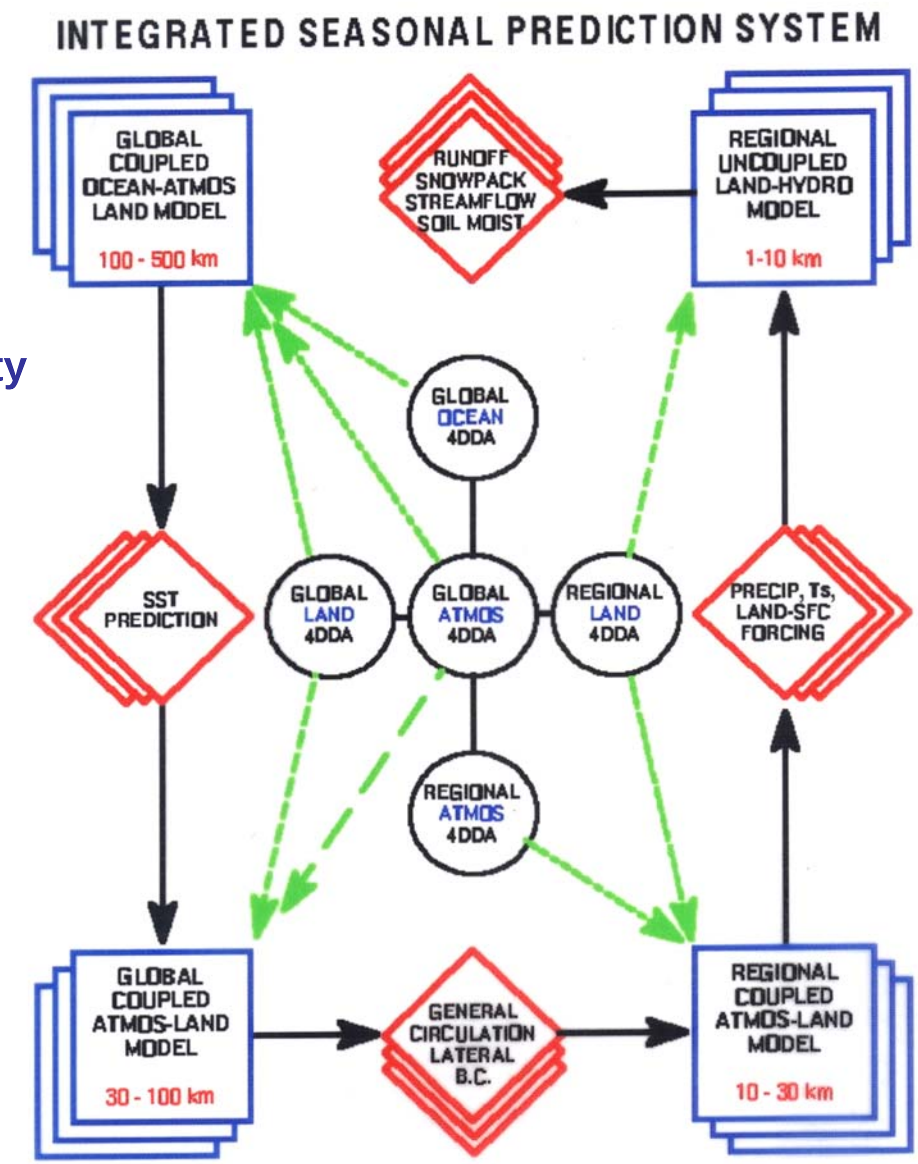
Ensemble traces of streamflow

ESP Post-Processor

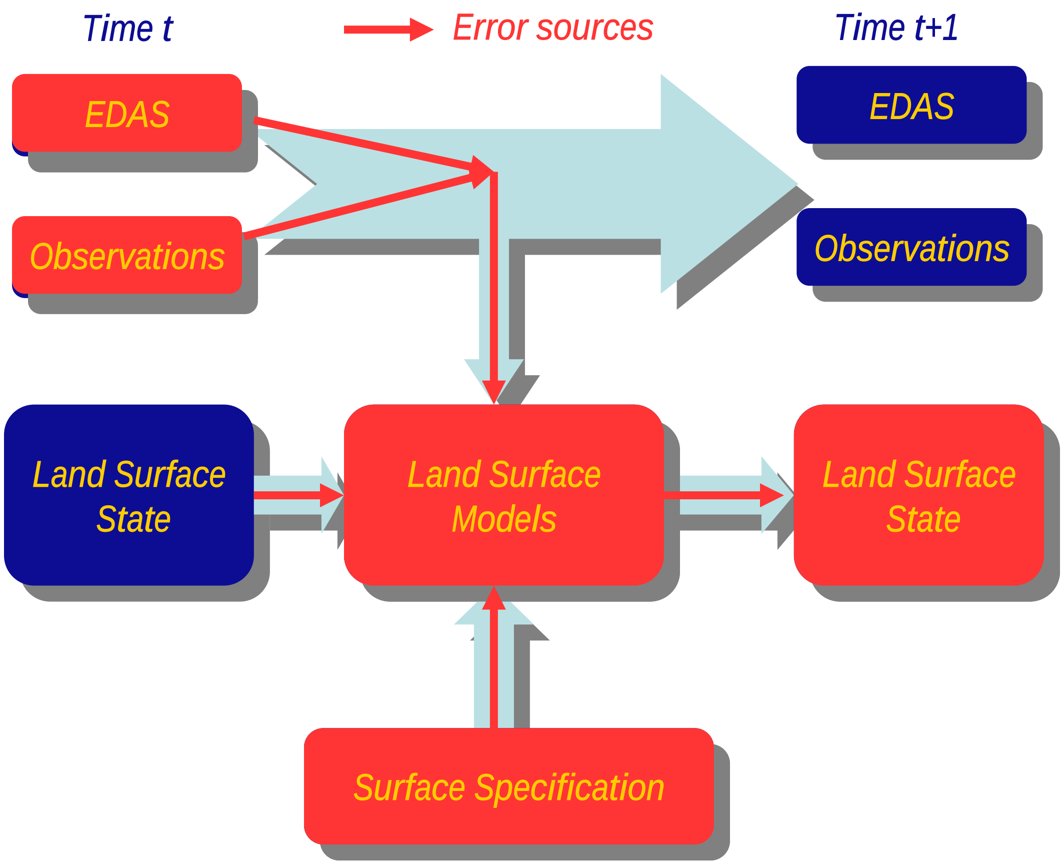
Corrects bias, hydrologic uncertainty

Ensemble traces of streamflow

Reflects both uncertainties



Land Data Assimilation System (LDAS)



Collaborators:
- **NOAA**
- **NASA**
- **Princeton U.,**
- **Rutgers U.**
- **U. Washington**
- **U. Maryland**

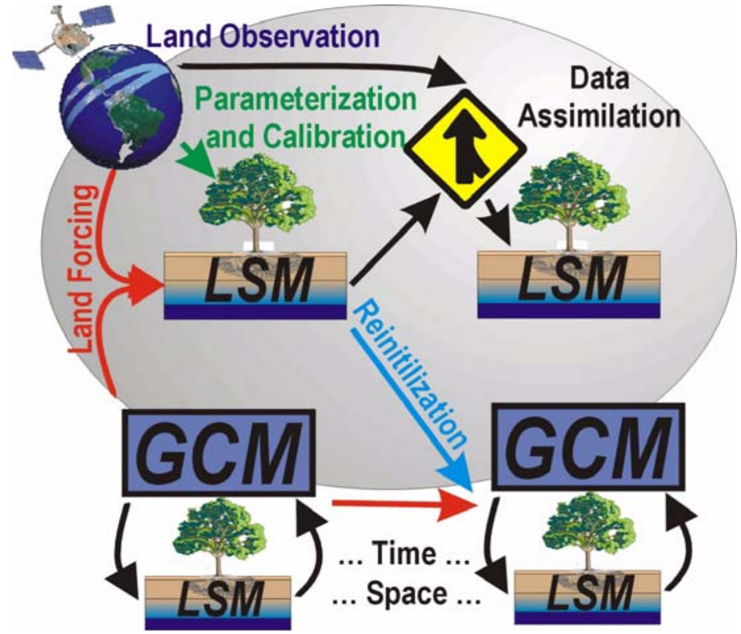
- **Real time LDAS provides *operationally* high quality land surface conditions and fluxes for NCEP climate prediction system.**
- **LDAS project is a good example of team work**
- **LDAS is working its phase II direction**

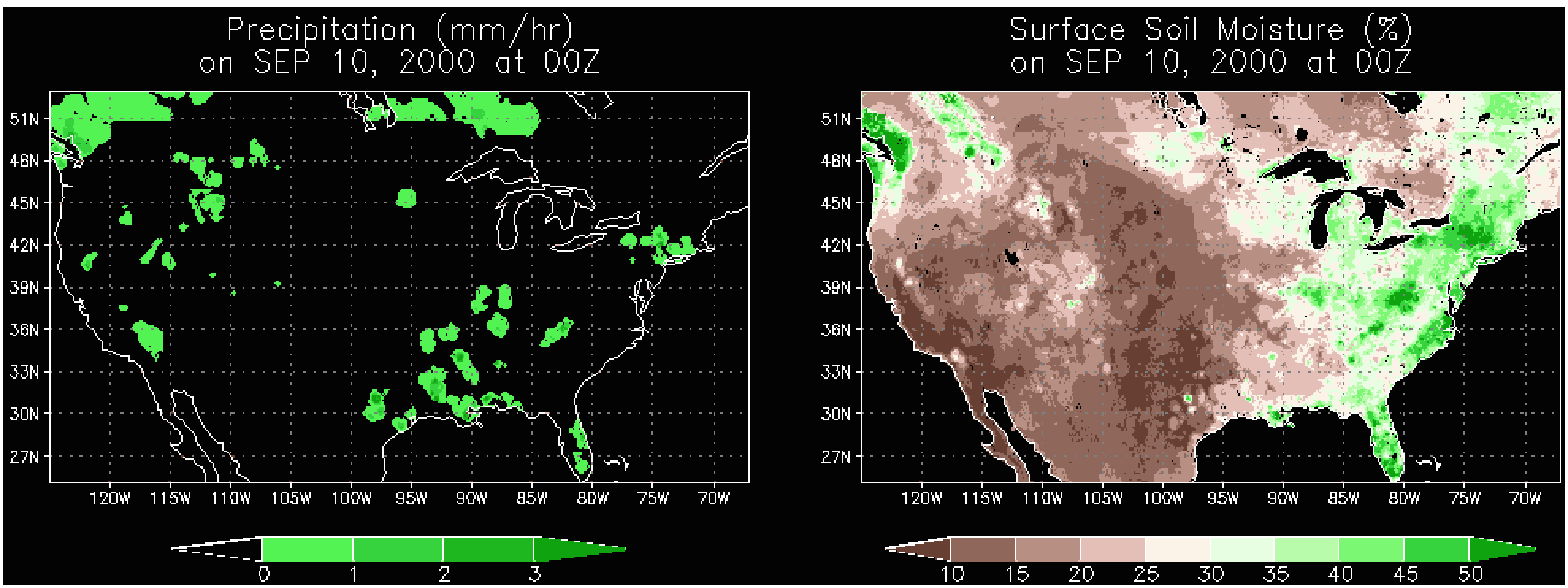
North American and Global Land Data Assimilation System

"LDAS" concept:

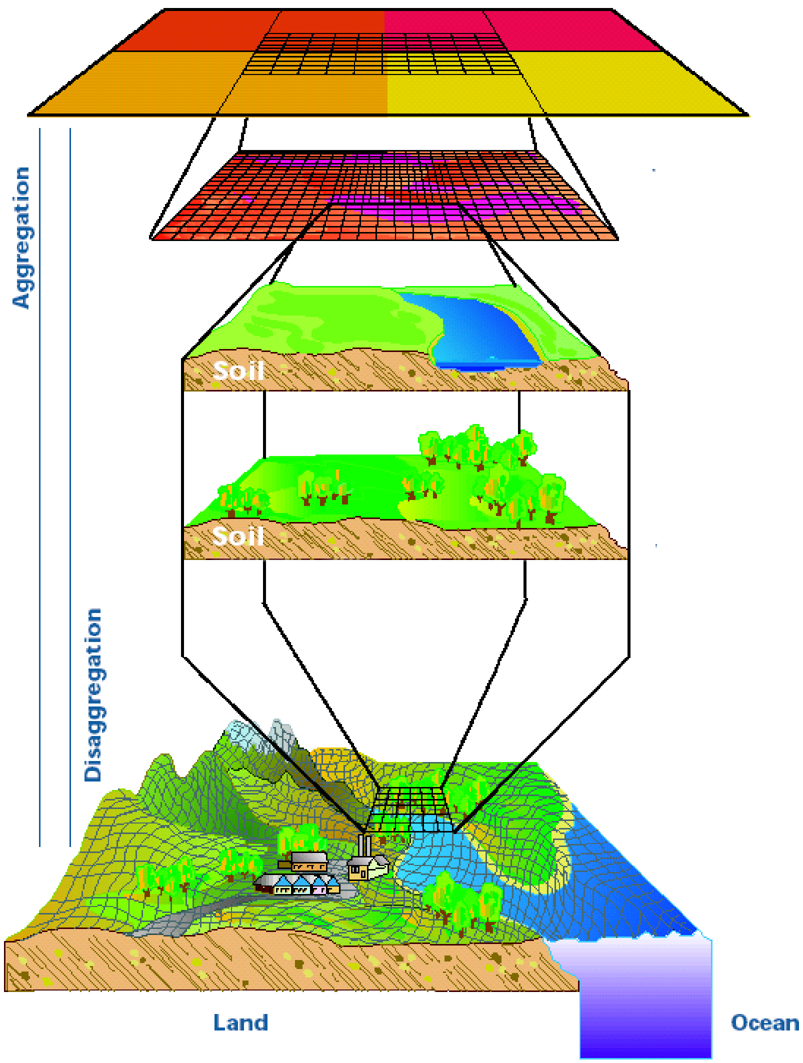
Optimal integration of land surface observations and models to *operationally* obtain high quality land surface conditions and fluxes.

Continuous in time&space; multiple scales; retrospective, realtime, and forecast





Regional Modeling: Dynamical Downscaling



Global climate model

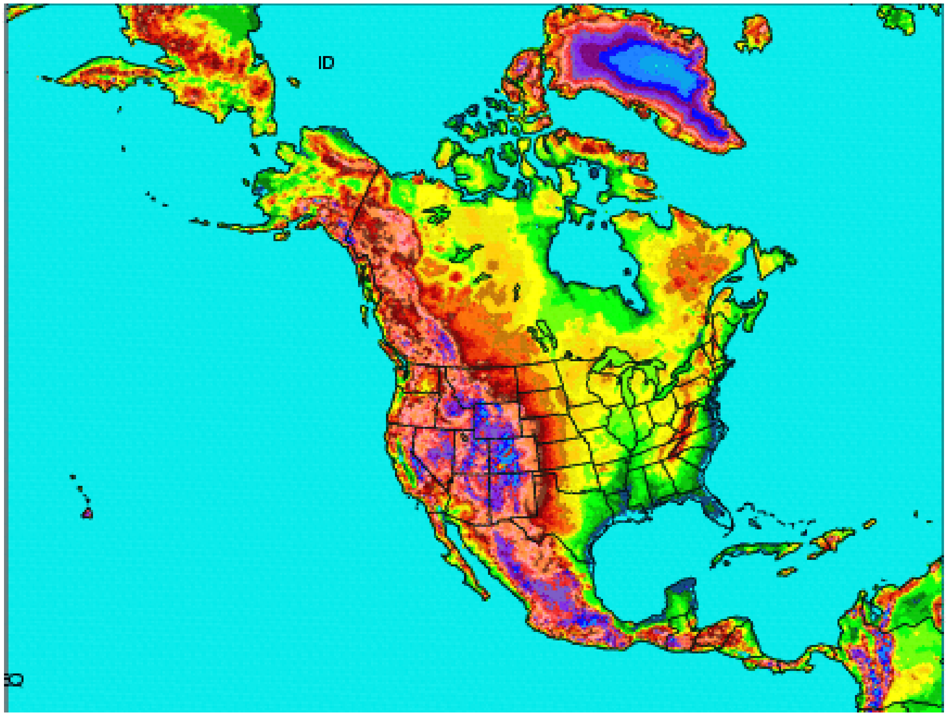
Regional climate model

Process models (e.g., hydrology, ecosystem)

Social systems

REGIONAL REANALYSIS

(REGIONAL REANALYSIS DOMAIN)



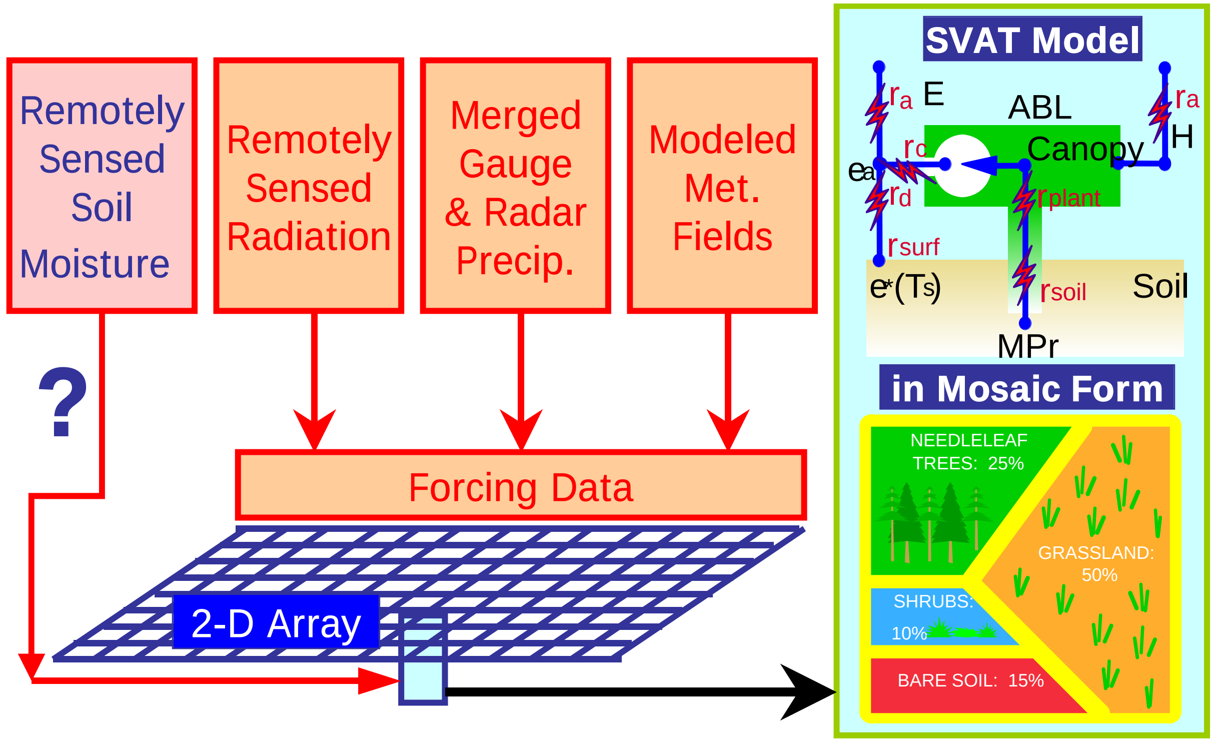
High resolution, dynamically consistent historical NA analysis

NCEP/ETA MODEL
32 KM Spatial Resolution;
3 Hourly Temporal Resolution

- **NCEP has completed Regional Reanalysis**
- **PIs are continuing to analyze the data**

Transition to NWS Operation

Example: Land Data Assimilation System (LDAS)

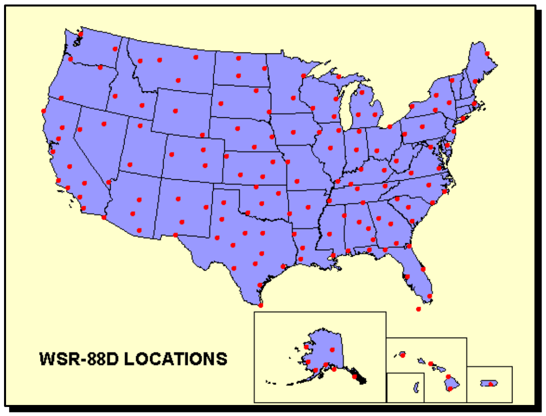


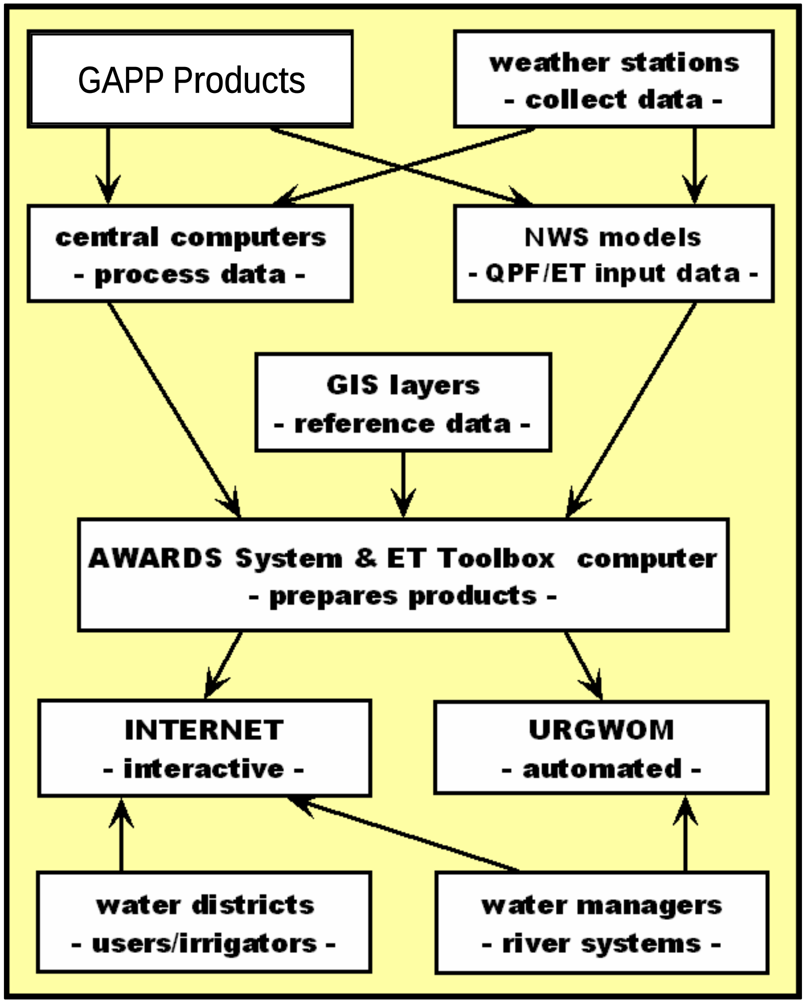
Accomplishment:

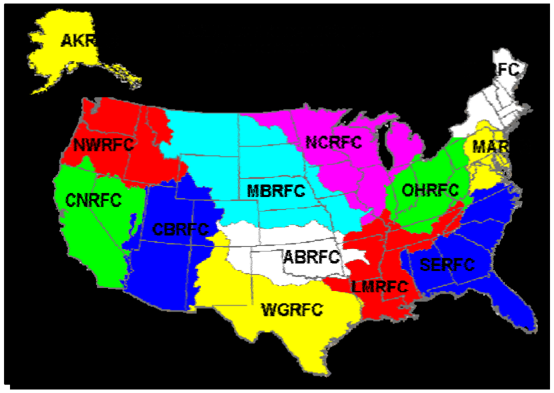
- Development of the LDAS system for the NCEP prediction system
- Real time LDAS to provide initial land boundary conditions for GCMs and RCMs
- Retroactive LDAS
- LDAS products validation

BoR DSS Environment for Interactive Web and River System Management

BoR AWARDS - ET Toolbox System







UW Experimental West-wide hydrologic prediction system

Department of Civil and Environmental Engineering

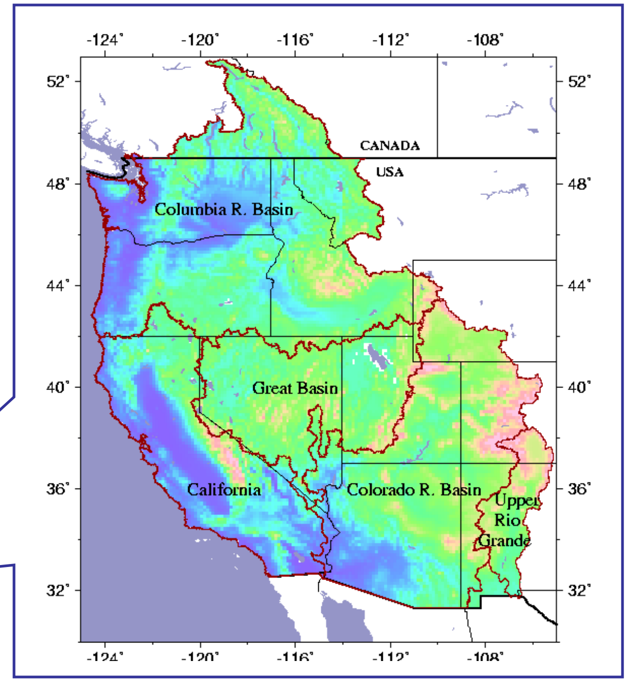
climate model output

CPC official forecasts

ESP as baseline fcst

Real-time Ensemble Forecasts

1. Downscaling
2. VIC hydrologic simulations



Ensemble Hindcasts (for bias-correction and preliminary skill assessment)

West-wide forecast products
- streamflow
- soil moisture, snowpack

tailored to application sectors
- fire, power, recreation

*** ESP extended streamflow prediction (unconditional climate forecasts run from current hydrologic state)**

(after Lettenmaier)

CPPA Land-Atmosphere Candidate Synthesis Products:

- *Quantify the influence of land states on the seasonal prediction skill of precipitation and temperature within the CPPA domain.*
- *Quantify the sensitivity of seasonal climate predictions to land states, including soil moisture, snow, orography and vegetation.*
- *Develop and test procedures to assimilate new data products (e.g. satellite data sets) and off-line model outputs (e.g., from LDAS systems) to provide improved weather and seasonal forecasts.*
- *Quantify seasonal climate forecast skill and accuracy requirements for water resources applications.*
- *Develop operational hydrologic forecasts incorporating the use of climate forecasts.*
- *Develop and evaluate the usefulness of seasonal hydrologic forecasts systems for water resources applications.*

CPPA Synthesis

CPPA has a broad vision and impressive research resources.

However, CPPA's breadth threatens to be diffusive, with the danger of resulting in a disparate group of unlinked projects.

To optimize progress toward its goals, CPPA research projects must be focused and their results synthesized to integrate their research results to address the CPPA vision.

- Coordinate CPPA working groups to bring CPPA PIs together with the Core Projects, Climate Testbed, and/or the Hydrology Testbed in research-to-operation transition.
- Synthesize CPPA land-atmosphere process modeling results.
- Coordinate an assessment of CPPA land-atmosphere observation products.
- End-user decision support and connections; document end-user requirements, develop pathways to connect DST's to CPPA capabilities.
- Produce synthesis products and reports based on existing funded projects
- Facilitate the transition of the research findings into model improvement and NWS operations
- Give recommendations for future research directions.

These synthesis efforts must be flexible enough to continuously reevaluate and respond to needs and gaps in the CPPA program to prevent bottlenecks that impede progress.

Synthesis Approach

How will we actually synthesize the CPPA research results?

Data discovery and database building: Develop an integrated database of CPPA land-atmosphere research results including results from CPPA investigators, core projects, NOAA labs, and affiliated partners.

Product integration and analysis: Provide a synthesis of available CPPA land-atmosphere research in a form that is accurate, unbiased, policy-relevant to the CPPA science community, CSSP agency partners, and a broad range of stakeholders.

-- Spatial and temporal rectification
-- Physical rectification or constraint
-- Communication

CPPA core project integration: Enable genuine improvements in our empirical quantification/detection, simulation and prediction of CPPA land-atmosphere synthesis products to be realized in operations.

Synthesis products: Develop synthesis products that show the progress the program is making towards its goals.

L-A Synthesis Product 1: Quantify the predictability of land states on seasonal precip and temp.

FY06: Dirmeyer, Nigam, Paegle, Serra, Wang, Wood, Webster, Xie, Zuidema
FY05: Huang, Maloney, Mechoso, Neelin, Xue
FY04: Berbery, Bosilovitch, Liebmann, Mo, Sorooshian, Stensrud
FY03: Berbery, Douglas, Enfield, Higgins, Liebmann, Shuttleworth, Zhang

L-A Synthesis Product 2: Quantify the sensitivity of seasonal climate predictions to land states.

FY06: Bras, Fu, Kumar, Leung, Paegle
FY05: Avissar, Famiglietti, Gong, Schemm
FY04: Avissar, Cotton, Douglas, Scott, Douglas, King, Lakshmi, Pielke, Ting, Van den Dool
FY03: Fu, Kim, Kumar, Lettenmaier, Marks, Wang, Yang, Yang

L-A Synthesis Product 3: Quantify seasonal climate forecast requirements for water applications.

FY06: Clark
FY05:
FY04:
FY03: Toth

L-A Synthesis Product 4: Develop operational hydrologic forecasts using climate forecasts

FY06: Cosgrove, Lettenmaier, Mo, Perica
FY05: Lettenmaier, Wood
FY04:
FY03:

L-A Synthesis Product 5: Develop seasonal hydrologic forecasts for water resources applications.

FY06: Clark, Sorooshian
FY05:
FY04: Duffy, Jain
FY03: Balaji