GEWEX Americas Prediction Project

GAPP Science and Implementation Plan
Overview

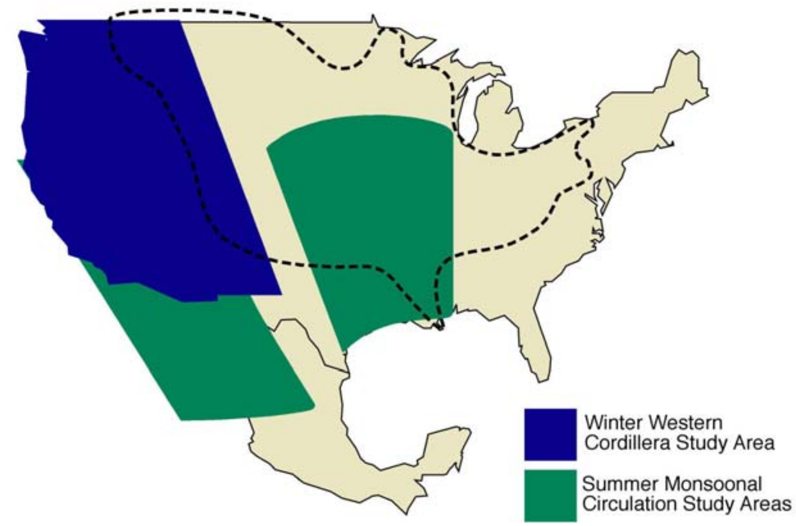
1. **Overview of GAPP**
- **Land Memory and Variability Studies**
- **Hydrometeorology of Orographic Systems**
- **Warm Season Precipitation**
- **CEOP**
- **Operational Seasonal Climate Prediction**
- **Hydrology and Water Resources Applications**
- **GAPP Remote Sensing Applications**
- **GAPP Data Management**
- **Organizational Elements**

1. GAPP Overview

A community based, international and interagency effort bringing hydrologists, land surface specialists, atmospheric scientists, and end-users together to advance climate prediction and improved resource management.

- **GAPP is a follow-on program to GCIP**
  - **extends from Mississippi river basin to the entire US**
  - **advances its focus from analysis to prediction**
- **GAPP is one of GEWEX Continental-Scale Experiments (CSEs)**
- **GAPP is sponsored by NOAA and NASA**
- **Organization elements:**
  - **Program manager**
  - **Science Advisory Group**
  - **Working groups**

GAPP Study Areas



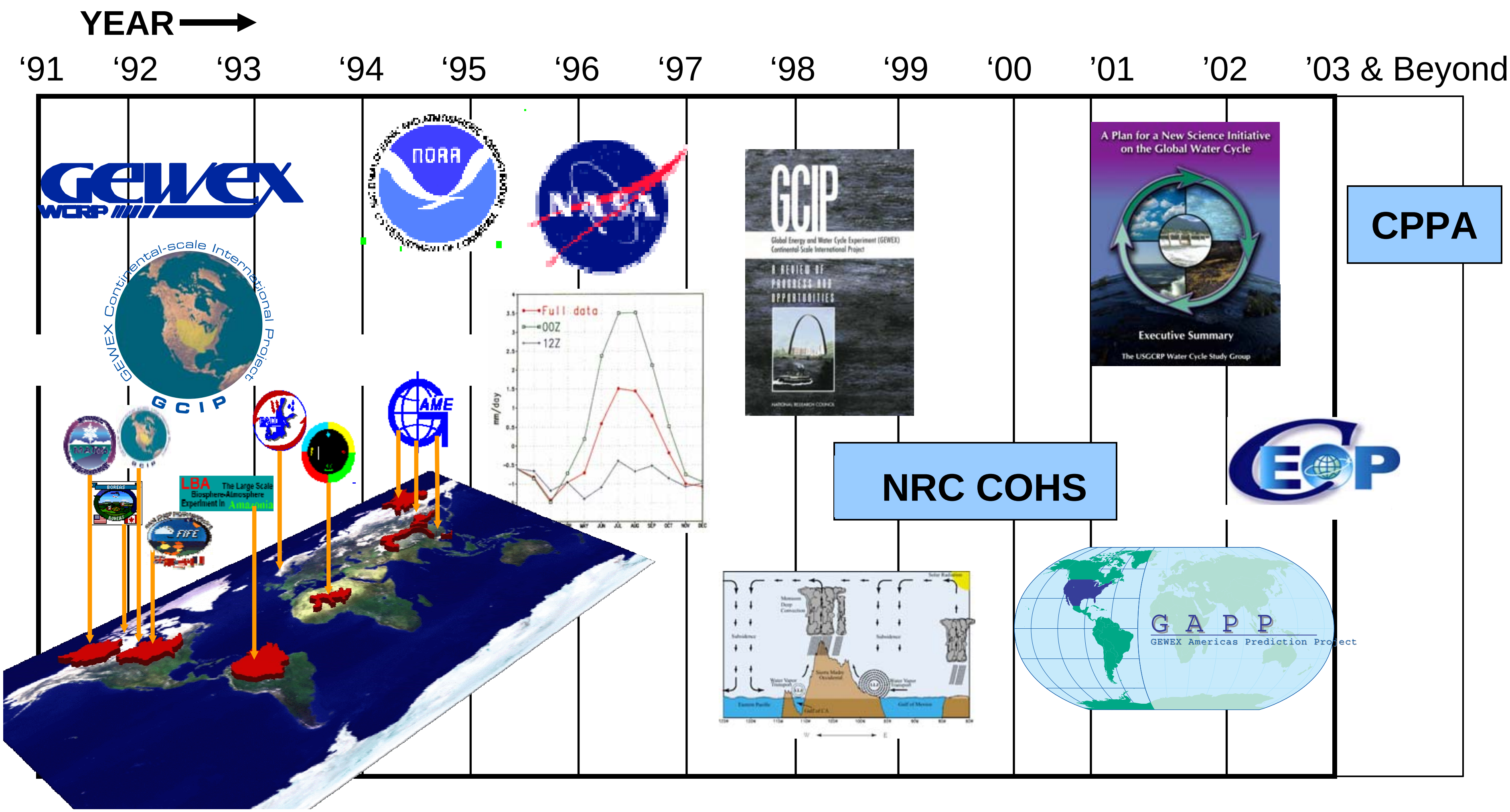
GAPP Background:

GAPP has a successful history rooted in international and interagency cooperation, scientific advisement, and operational relevance.

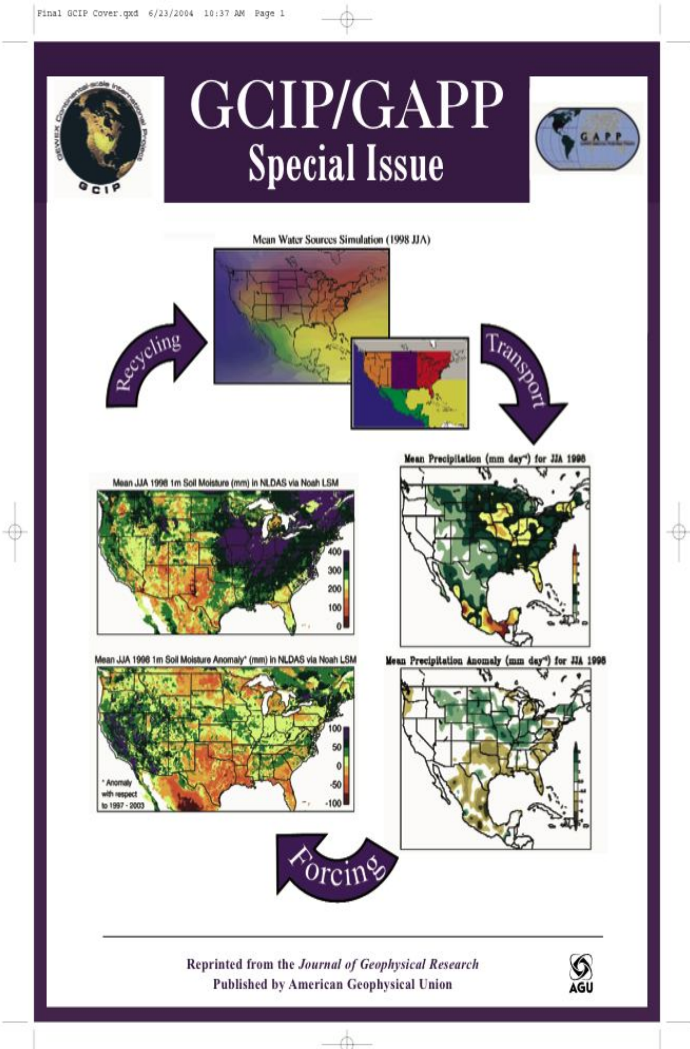
International: WCRP-UNESCO-IGOS-IAHS-IGBP

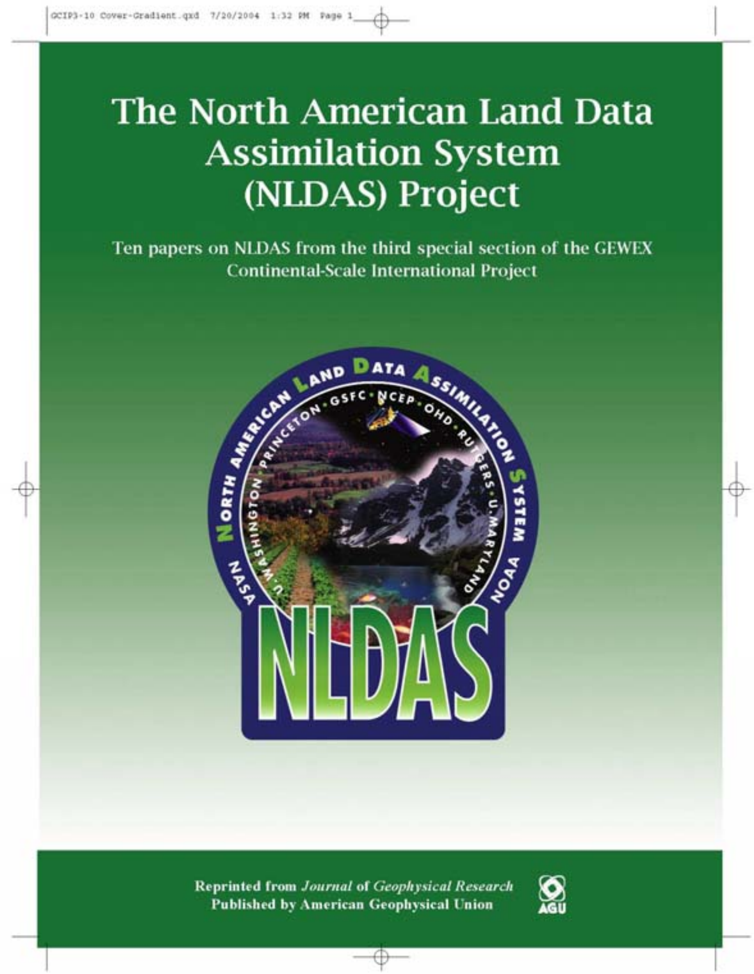
Interagency: NOAA-NASA-BoR-USGS-USDA-DOE-USACE

Research Community: ~50 university, federal, state, and private researchers



GCIP/GAPP JGR Special Issues





www.agu.org/journals/ss/GCIP3/

GEWEX Americas Prediction Project (GAPP)

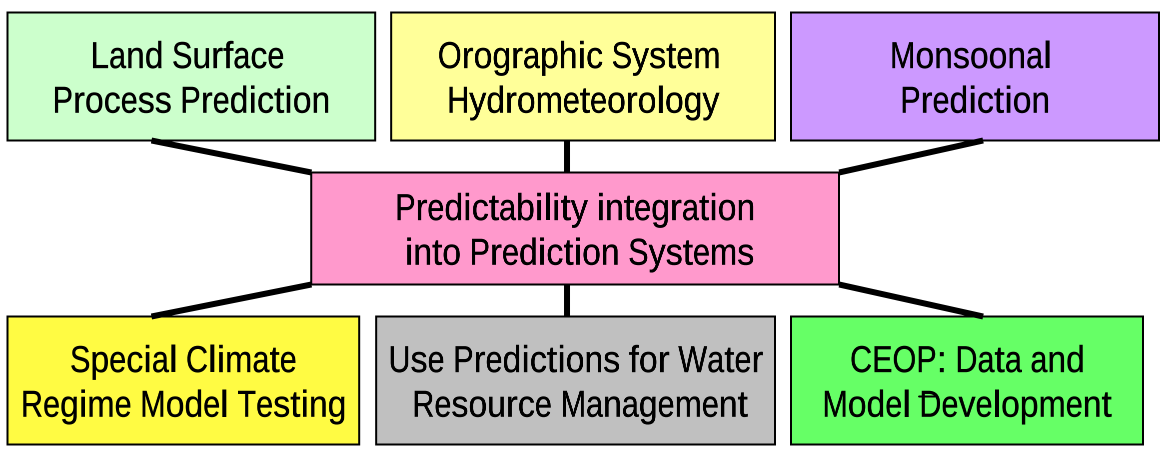
The **mission** of GAPP is to demonstrate skill in predicting changes in water resources over intraseasonal-to-interannual time scales, as an integral part of the climate system.

Science Objectives:

(i) Prediction: Develop and demonstrate a capability to make **reliable monthly to seasonal predictions of precipitation and land-surface hydrologic variables** through improved understanding and representation of land surface and related hydrometeorological and boundary layer processes in climate prediction models.

(ii) Decision support: **Develop application products for resource managers** by interpreting and transferring the results of improved climate predictions for the optimal management of water resources.

GAPP Components



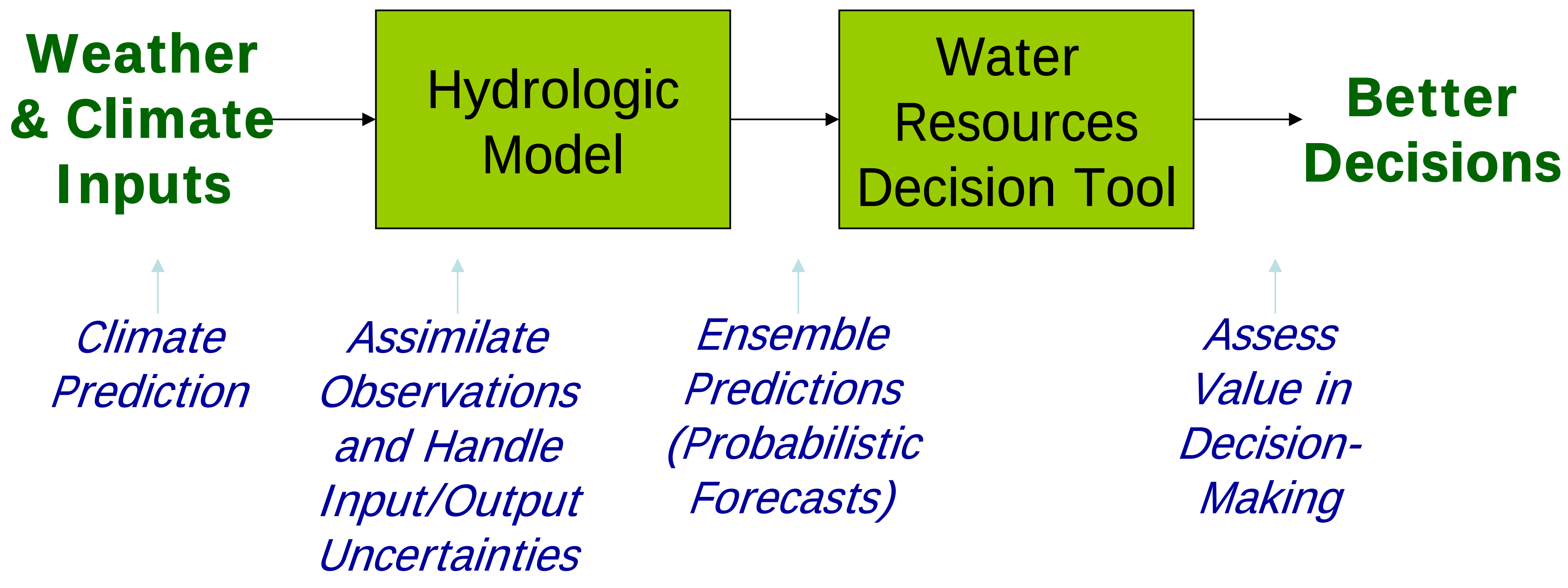
Objective 1: Improve intraseasonal to interannual climate prediction focused on improved understanding and modeling of land-atmosphere interactions.

- **Data Development:** Improve understanding of land-atmosphere interactions
  - **e.g. soil moisture, snow, vegetation, topography, NAME**
- **Process and Modeling Studies:** Incorporate new understanding into climate prediction system (thru GAPP NOAA Core Project)
  - **e.g. land surface models; LDAS; regional climate models**
- **Transition to Operations:** Provide hydrologic data sets for climate model development & validation and prediction research
  - **e.g. Regional Reanalysis, long-term and realtime precipitation data; CEOP; satellite observation applications**

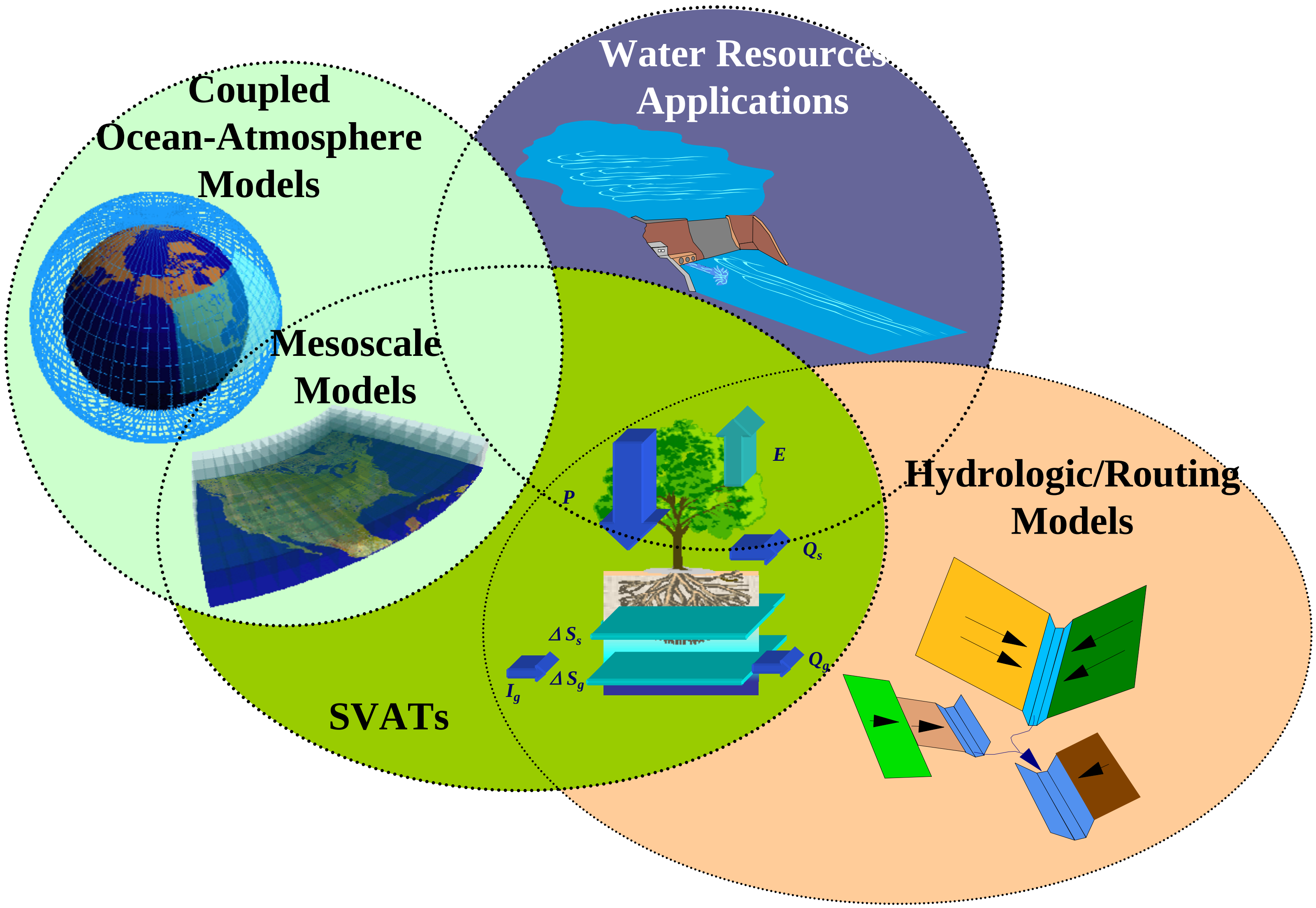
Objective 2 : Interpret and transfer climate forecasts for water resource management applications.

- Hydrologic predictability and prediction studies
  - Hydrologic predictability
  - Downscaling, biases correction, initialization,
  - Ensemble hydrologic prediction
  - Hydrologic model improvement

- Develop decision support tools for water resource applications
  - Build strong links with water users
  - Assessing forecast quality for decision making

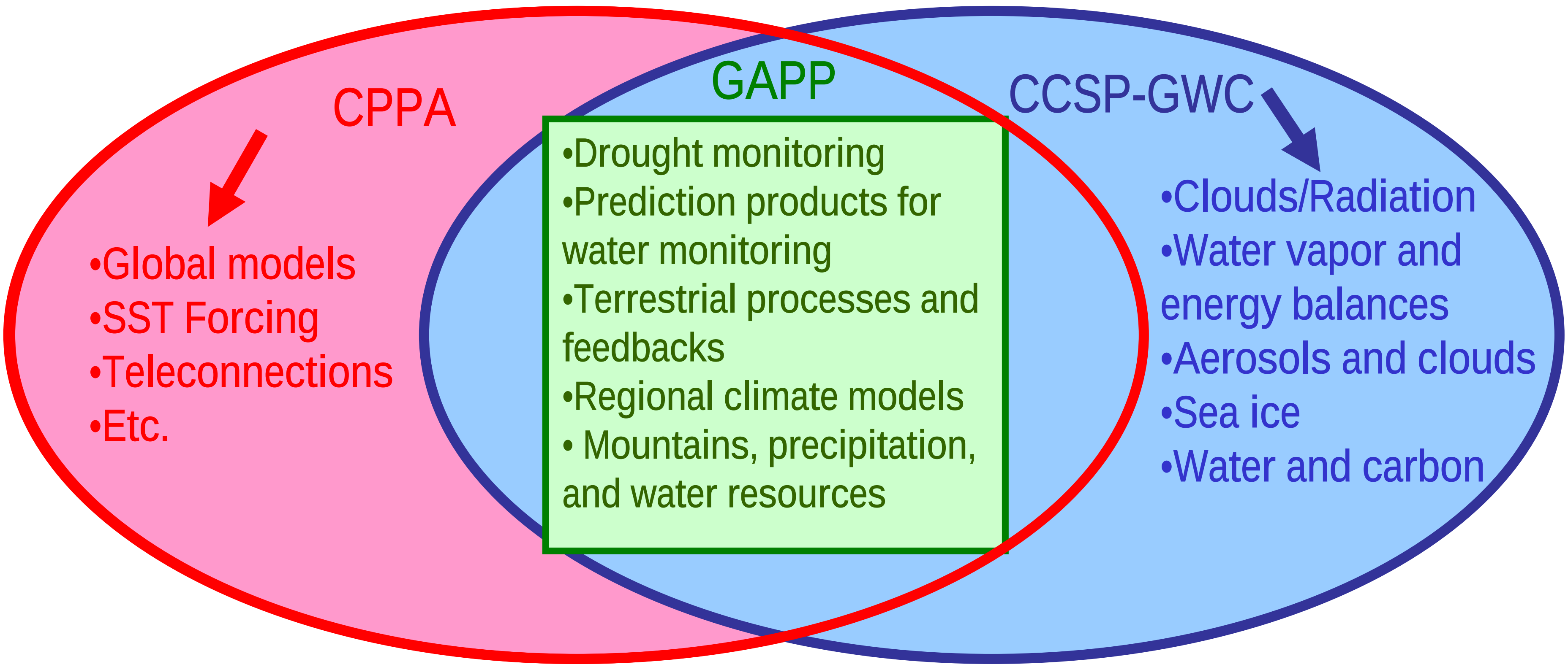


Model Coupling, Downscaling, and Hydrologic Applications



The *Climate Prediction Program for the Americas* (CPPA) merges NOAA's CLIVAR *Pan American Climate Studies* (PACS) and *GEWEX Americas Prediction Project* (GAPP) into a single integrated competitive research program to improve operational intraseasonal to interannual climate and hydrologic forecasting.

GAPP is ideally positioned to make significant contributions to CCSP-Global Water Cycle, Climate Prediction Program for the Americas (CPPA), and end-user goals.



2. Land Memory and Variability Studies

Scientific Rational

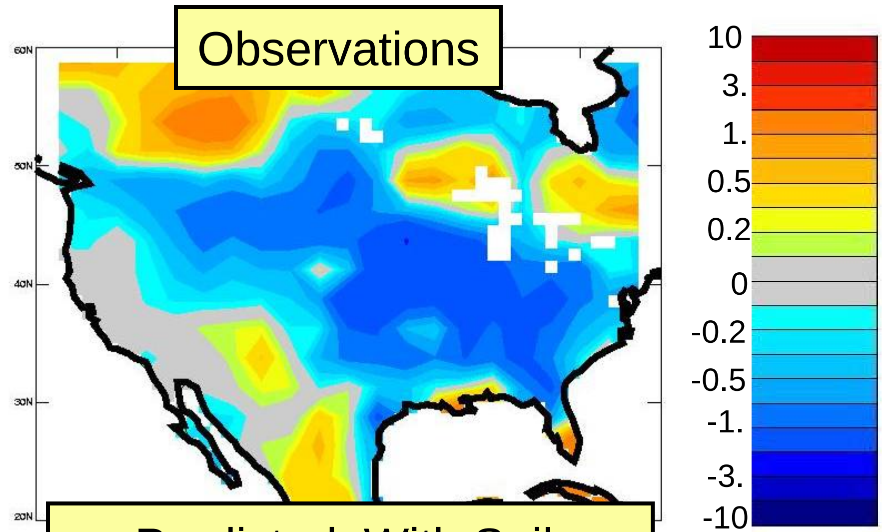
- Multi-month land-memory mechanisms: (i) the storage of water near the surface as soil moisture (ii) its storage on the surface as snow and ice, and (iii) nature and seasonal progression of growing vegetation.
- Understanding the strength of these relationships for different geographical regions and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

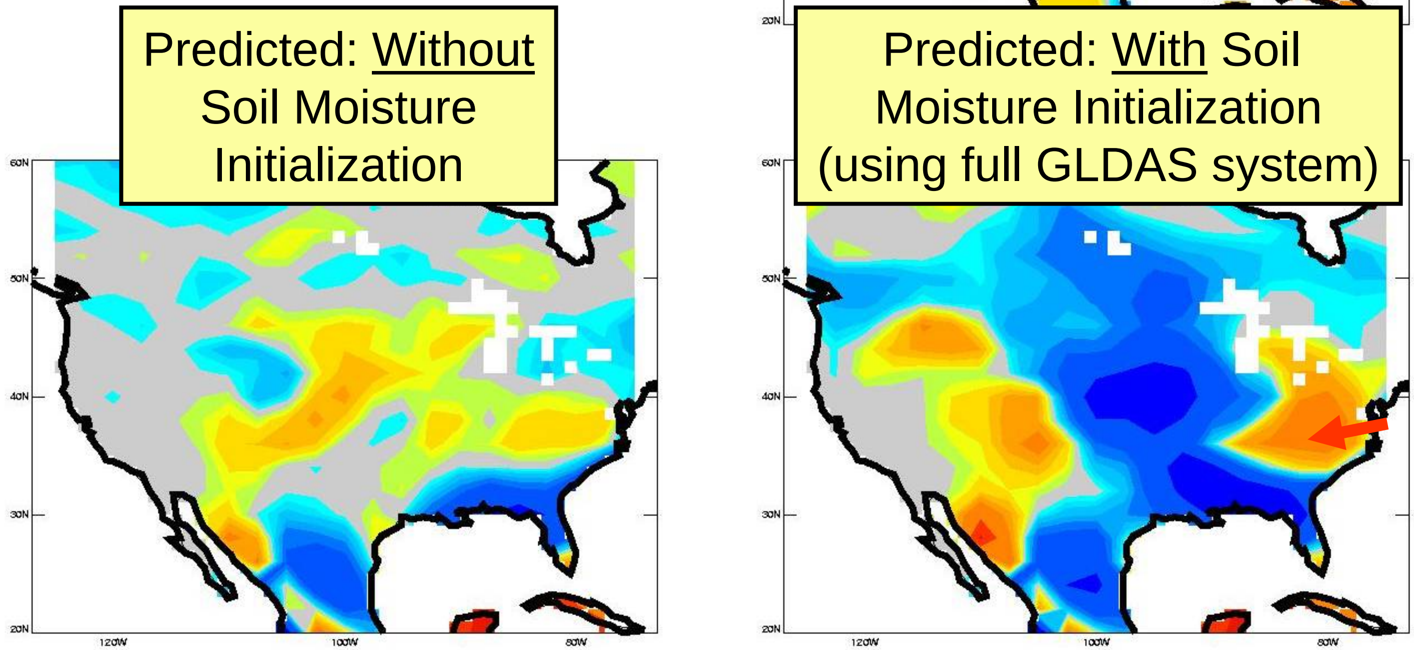
Activities:

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

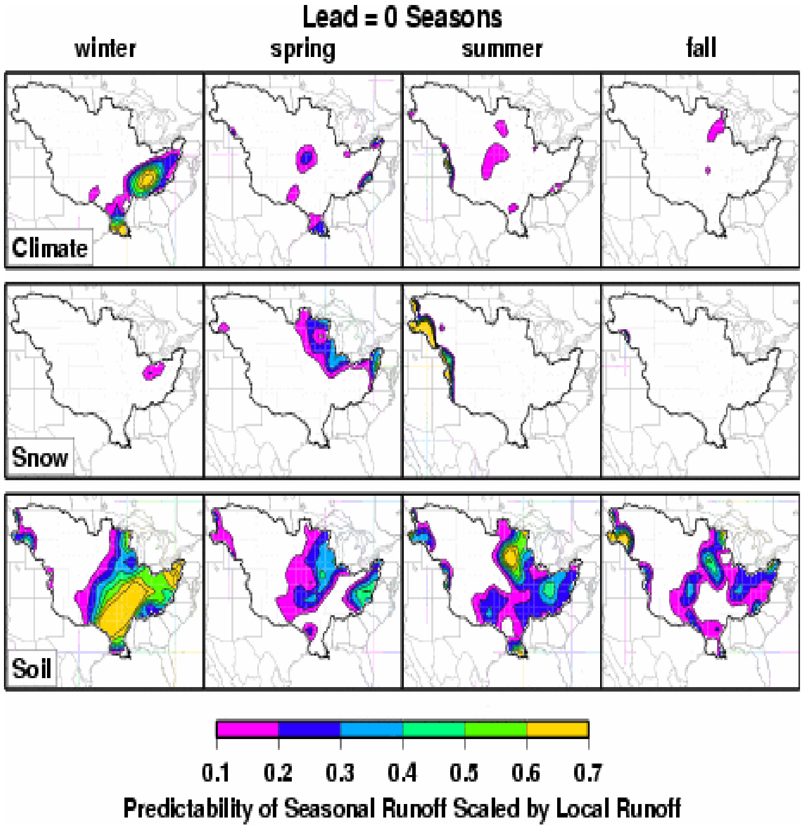
Prediction Improved by Soil Moisture Initial Condition





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**

3. Hydrometeorology of Orographic Systems

Scientific Rational

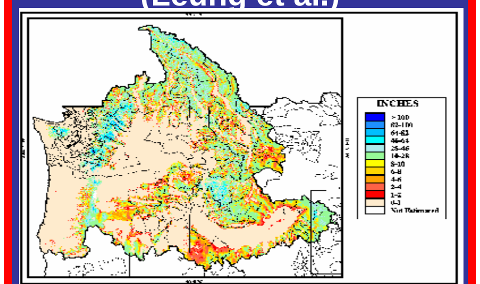
- In regions with marked topography, climate conditions such as temperature, precipitation, and snow can be significantly modulated by orographic features.
- Major gaps remain in our understanding of the natural evolution of clouds and precipitation in mountainous terrain, especially at horizontal scales less than 100 km.

Activities:

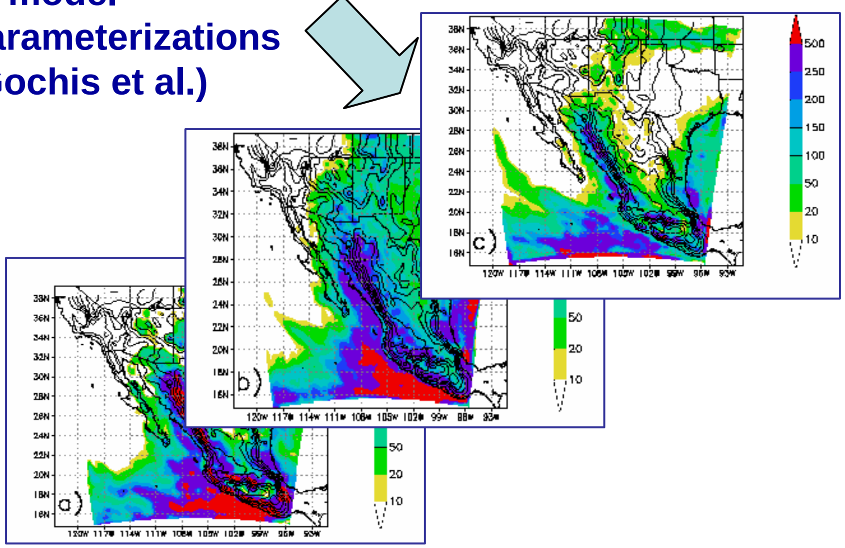
1. Diagnostic analyses of existing hydrometeorological data
2. Investigation of the mean seasonal cycle and predictability of its variability
3. Integrate atmospheric elements with surface hydrologic components
4. Carry out hydrometeorological model experiments
5. Apply climate and hydrologic models in seasonal climate forecasting for basins with complex terrain

3. Hydrometeorology of Orographic Systems

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



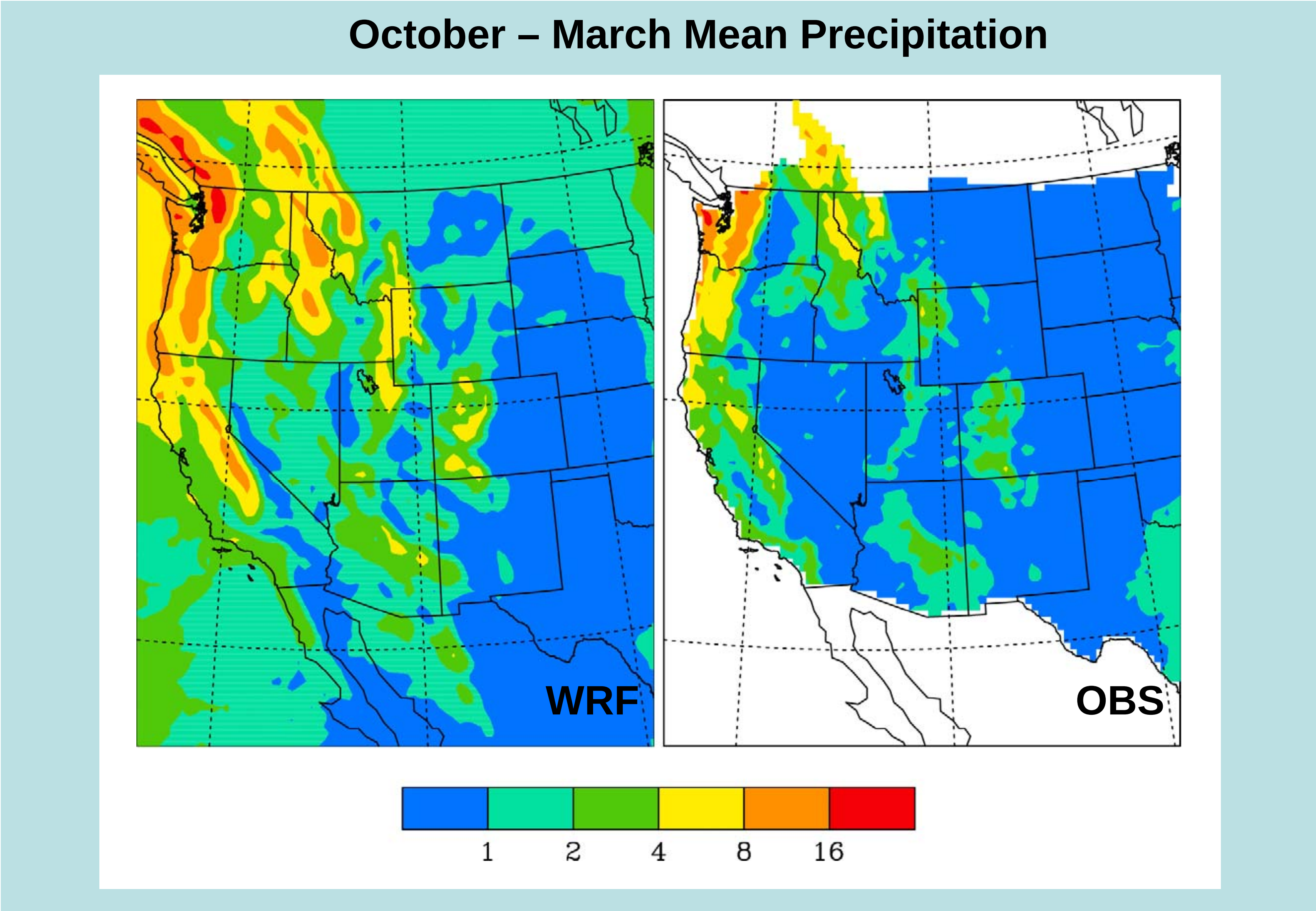
Monsoon mountain rainfall very sensitive to model parameterizations (Gochis et al.)



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

Results from WRF



4. Warm Season Precipitation

Scientific Rational

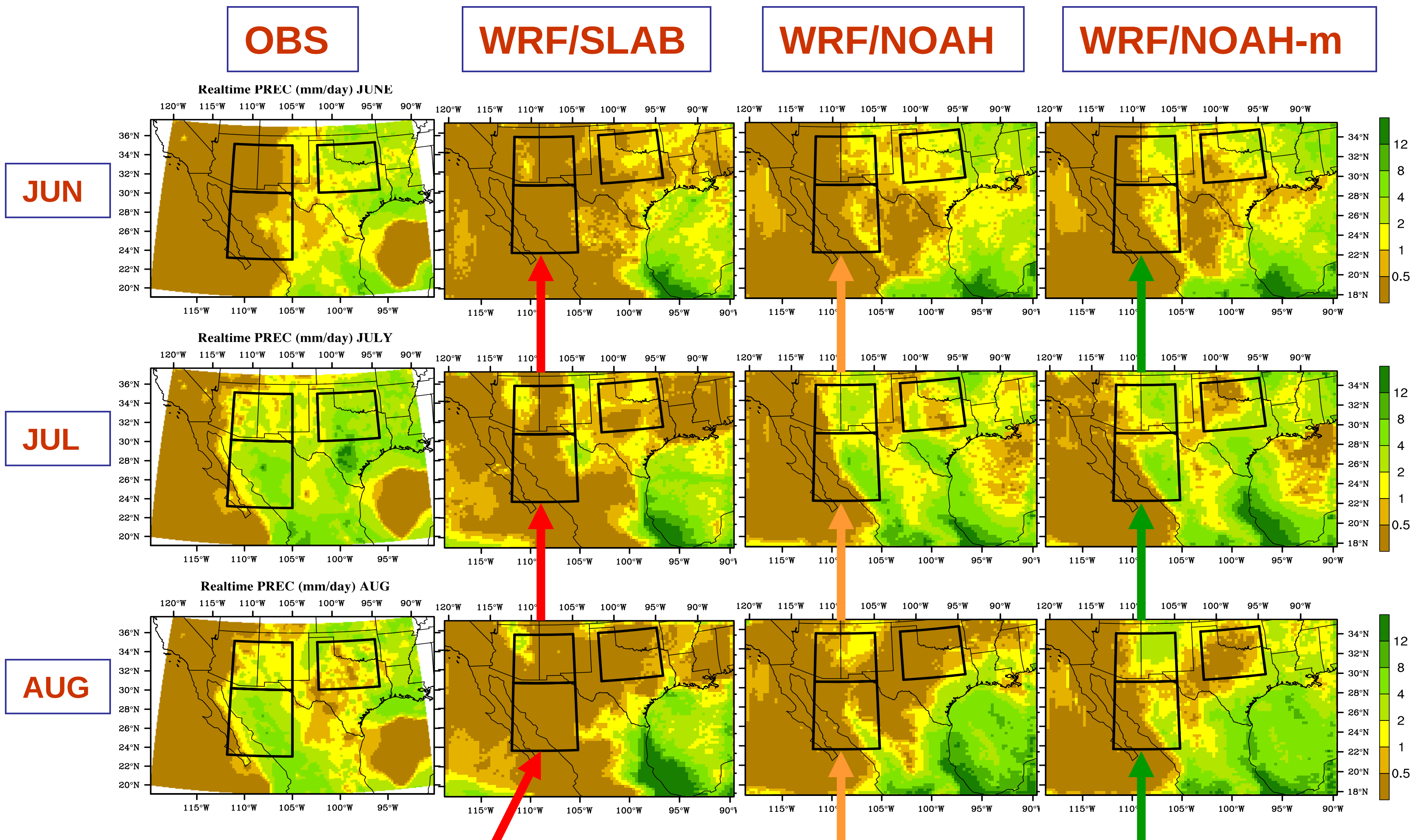
- Documenting the major elements of the NAMS regime and its variability, within the context of the evolving land surface-atmosphere-ocean annual cycle, is fundamental for improving warm season precipitation prediction
- The relative importance of land and ocean influences on North American precipitation changes with the seasons.
- The land surface has many memory mechanisms beyond soil moisture, such as snow extent, vegetation, and aerosols that must be understood.

Activities:

1. improved convective parameterization in climate/forecasting models
2. the North American monsoon system, with participation in NAME
3. utilizing GAPP research to enhance the operational skill in warm season precipitation forecasting.

Role of Land Surface Processes in Modulating NAMS Rainfall

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

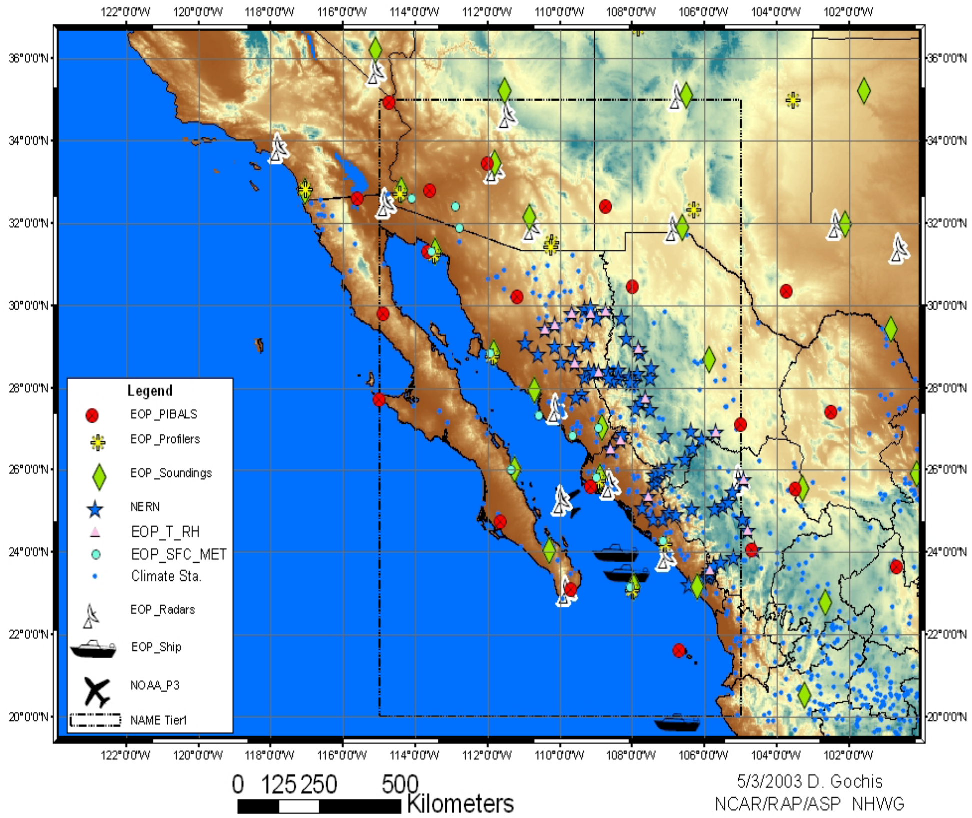


WRF/SLAB fails to produce rainfall for June – August.

WRF/NOAH fails to capture rainfall in August.

WRF/NOAH-m best captures rainfall in August.

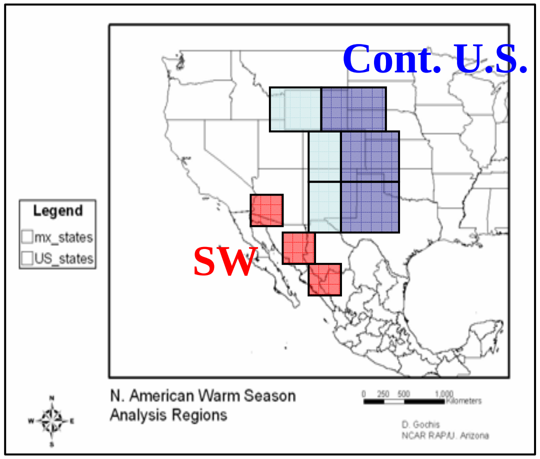
Predictability of Warm Season Precipitation

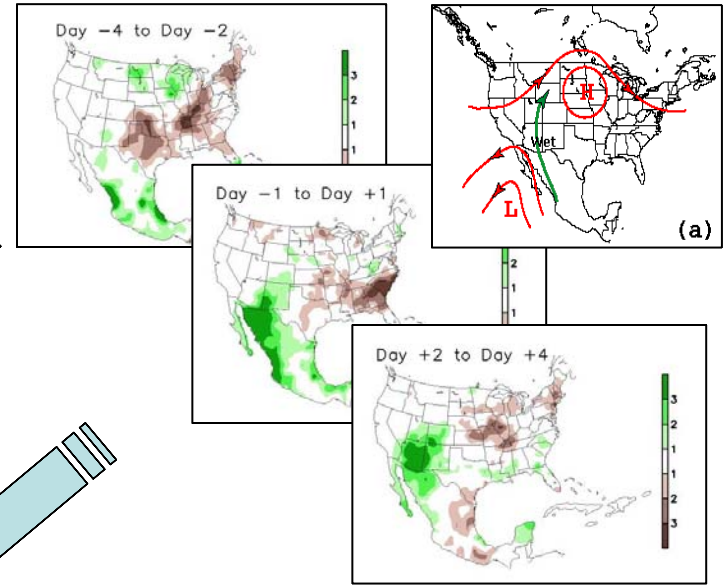


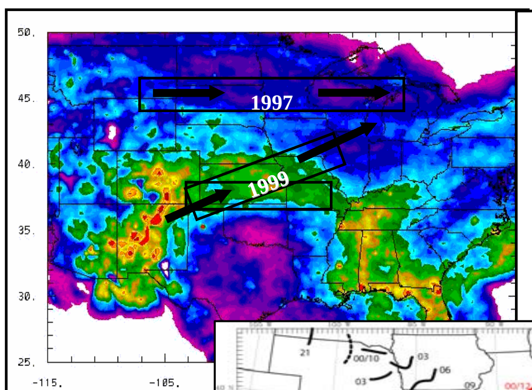
PACS and GAPP jointly support

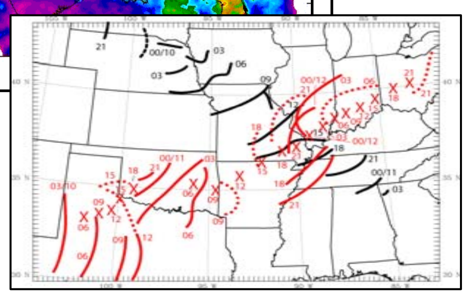
- **NAME 2004 Field Campaign in the core region of the North American Monsoon .**
- **pre-campaign and post-campaign diagnostic and modeling studies**

Covariance between core NAM and Continental U.S. Precipitation







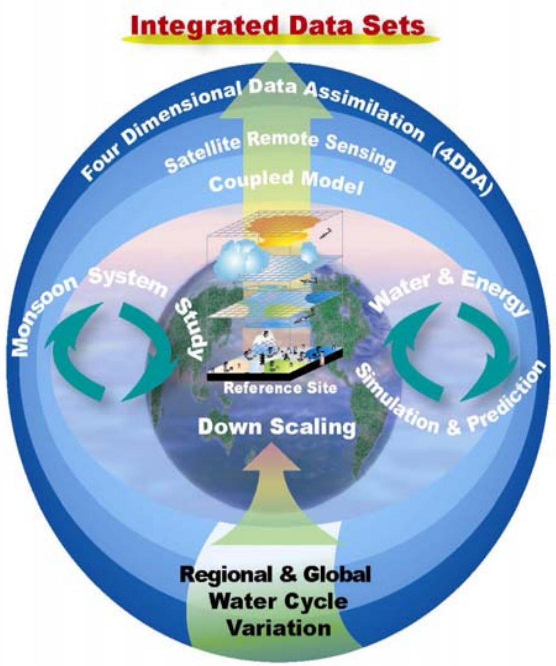


Improved Intra-seasonal Predictability

5. Coordinated Enhanced Observing System CEOP

Scientific Rational

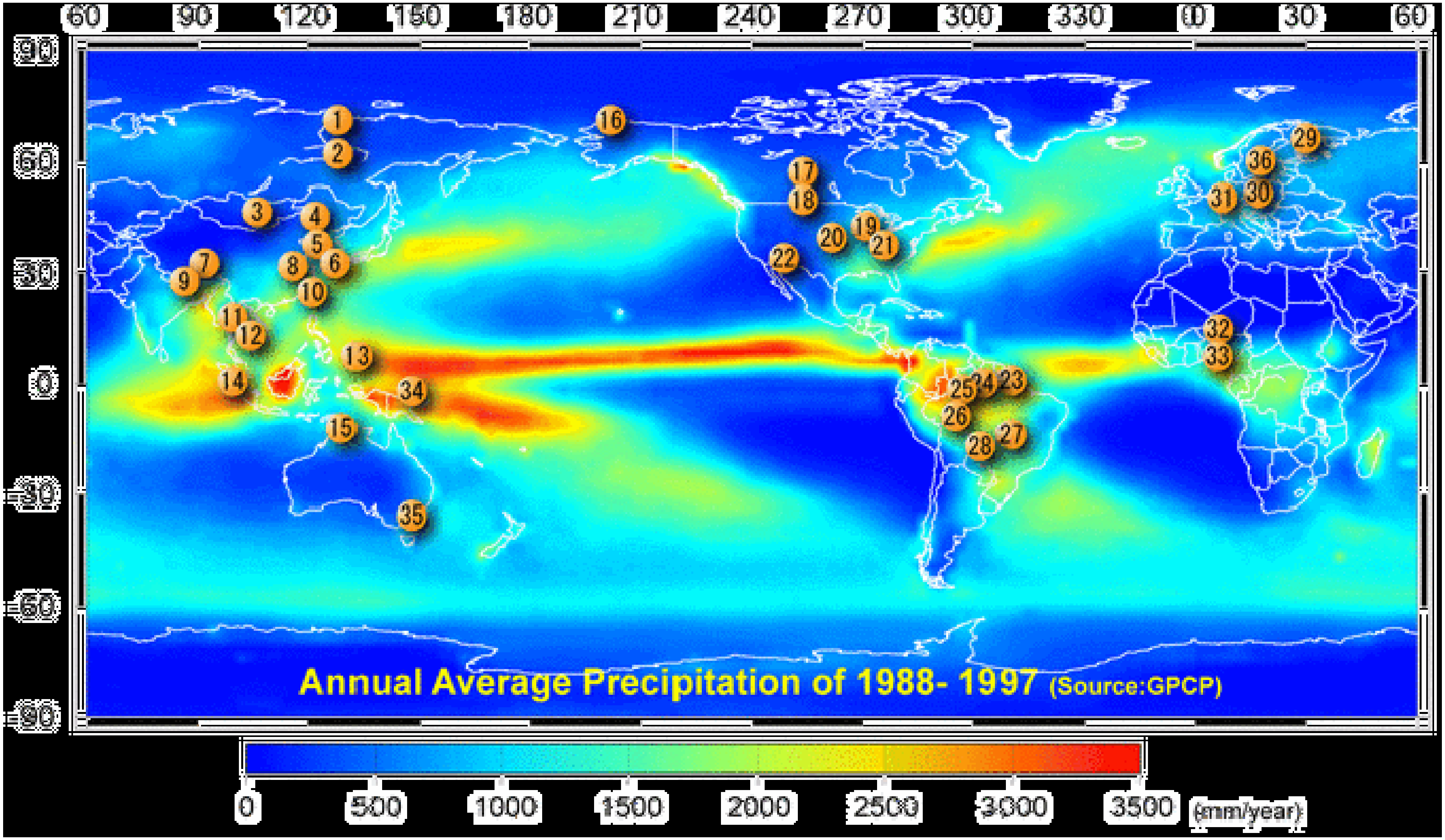
- Focused on the measurement, understanding, and modeling of water and energy cycles within the climate system.
- Motivated by the synchronism of the new generation of Earth observing satellites and GEWEX-CSEs.
- Primary goal to develop a consistent data set for 2001-2004 to support research objectives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

CEOP Reference Sites (now 41)



6. Operational Seasonal Climate Prediction: Components from GAPP

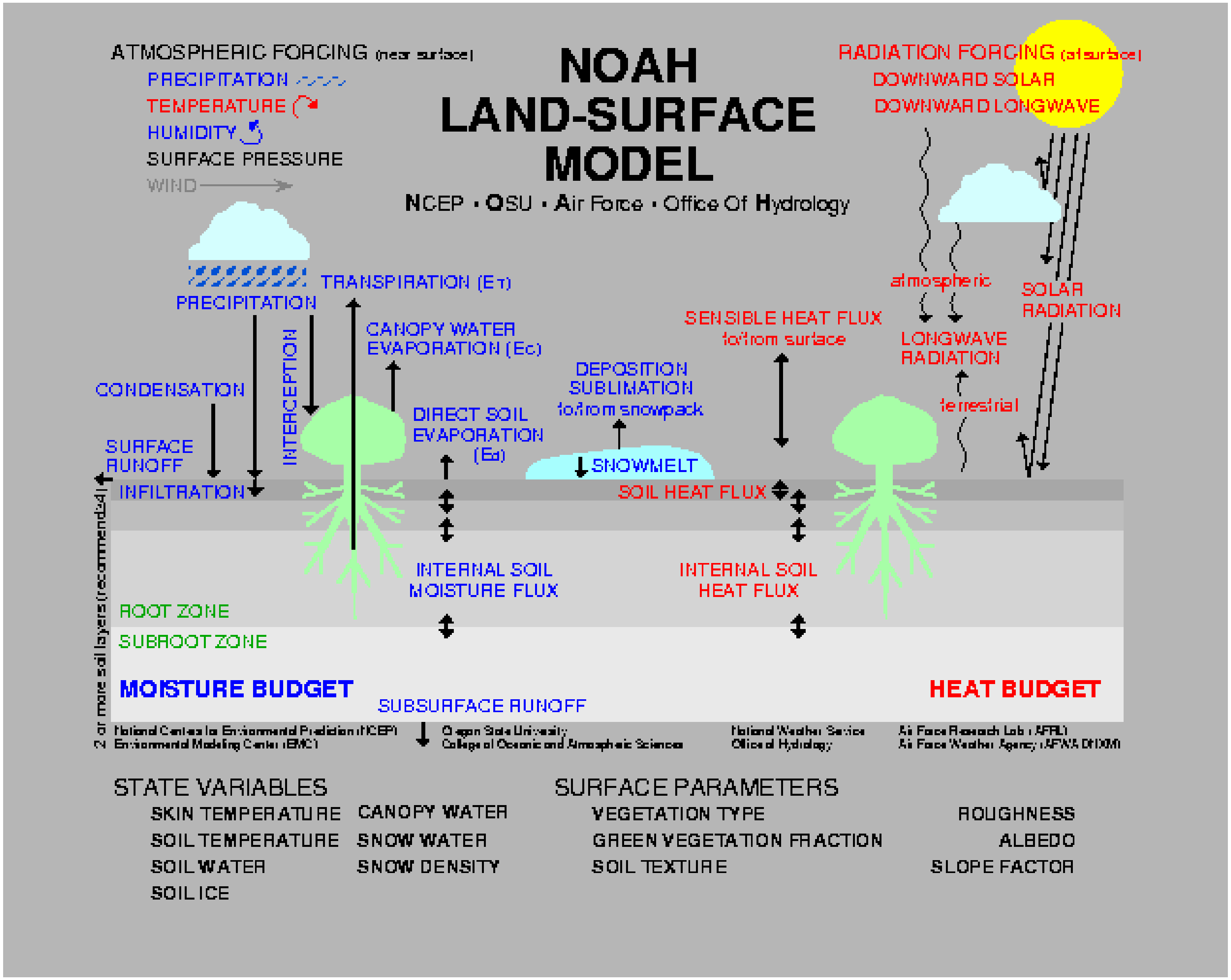
Scientific Rational

- This section describes the infrastructure for constructing and achieving 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:

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

Process and Modeling Studies



GAPP Approach:

Operational prediction improvements through research community engagement with operational NOAA-based GAPP “core” project.

The ESP Process (OHD)

QPF, QTF

ESP Pre-Processor

Corrects bias, meteorological uncertainty

Ensemble traces of precipitation, temperature

Hydrologic model

Ensemble traces of streamflow

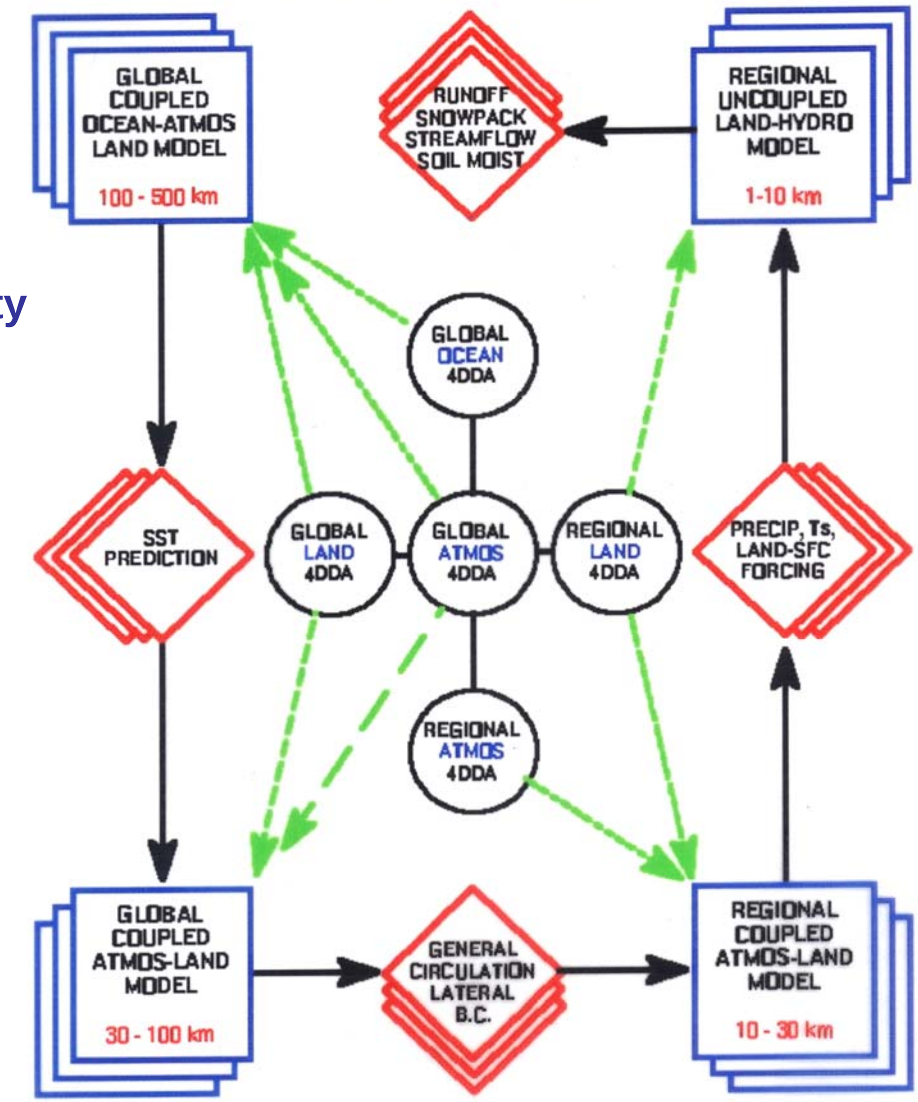
ESP Post-Processor

Corrects bias, hydrologic uncertainty

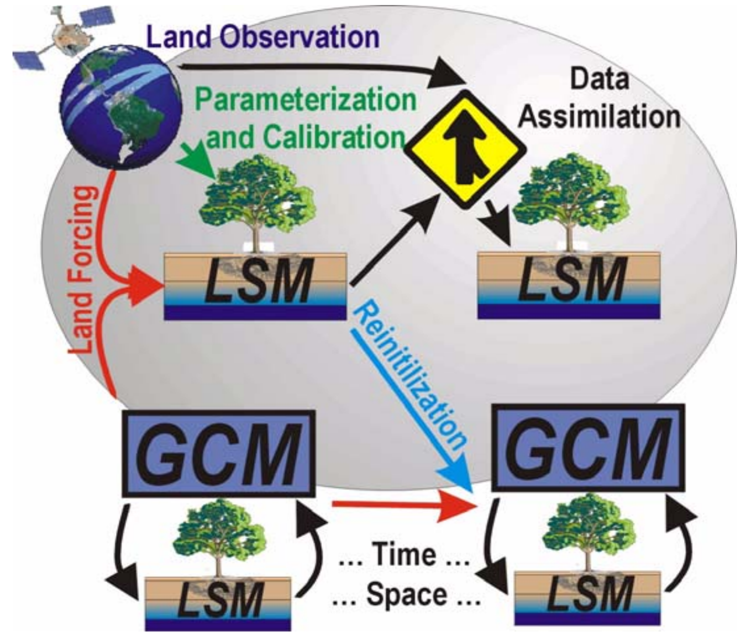
Ensemble traces of streamflow

Reflects both uncertainties

INTEGRATED SEASONAL PREDICTION SYSTEM



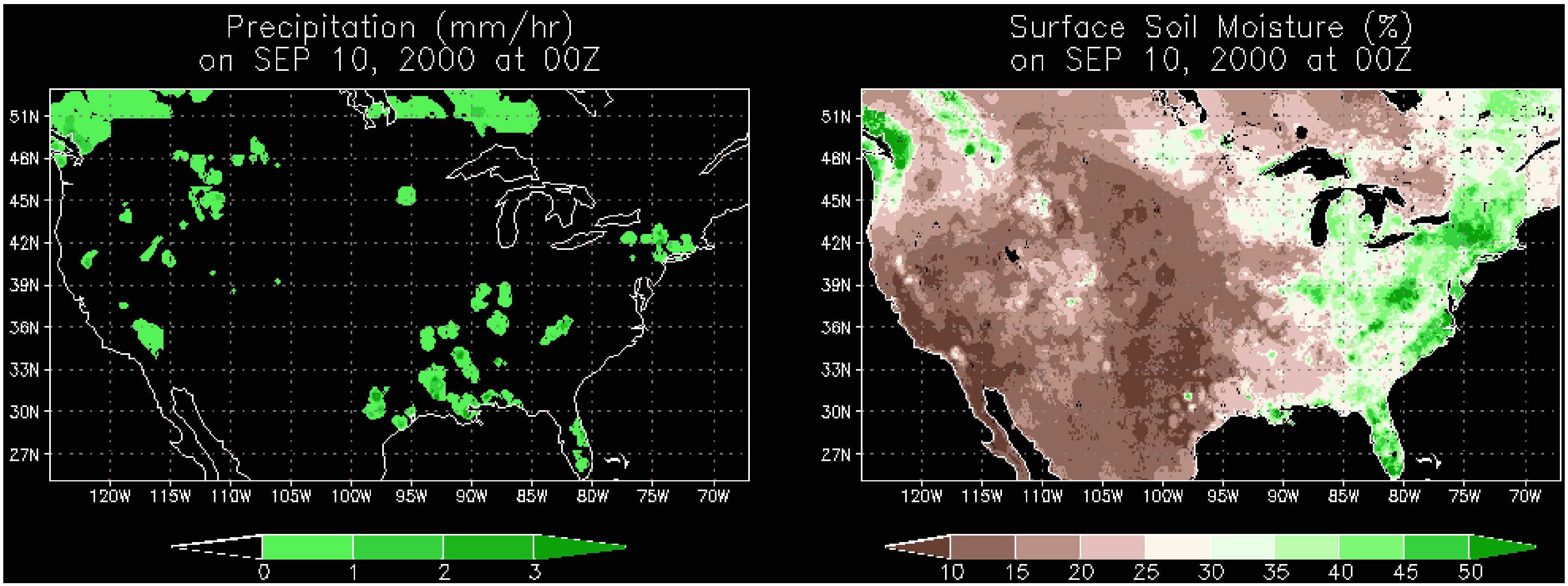
North American and Global Land Data Assimilation System



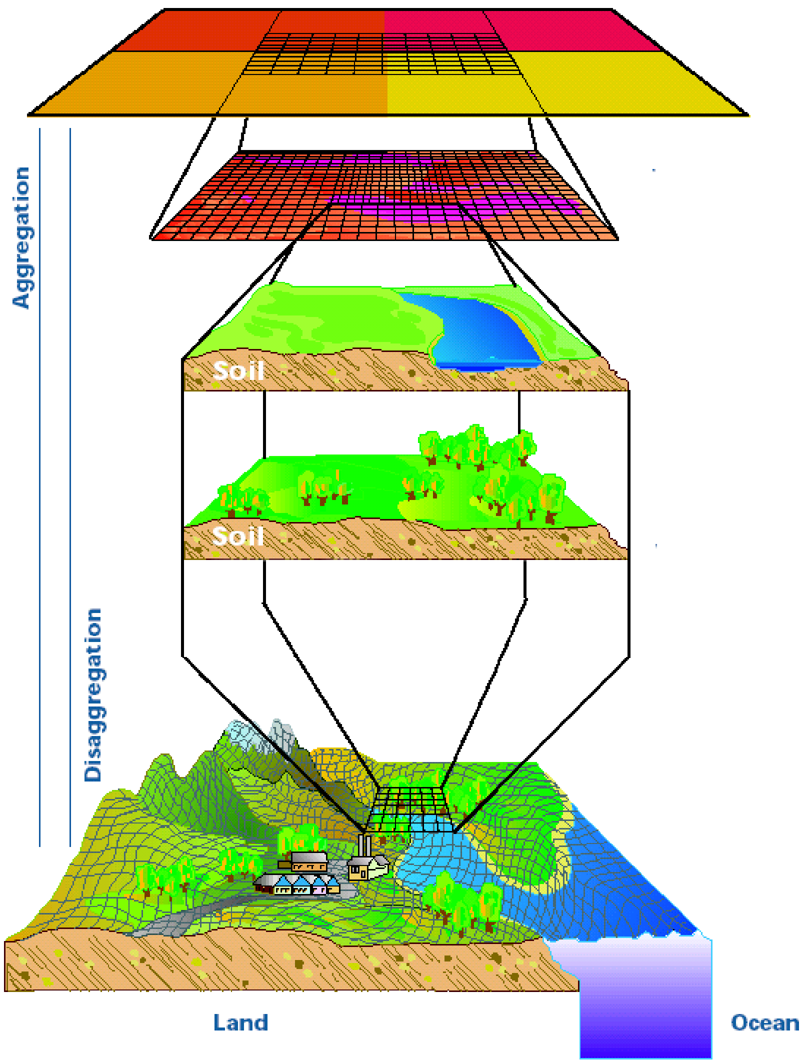
"LDAS" concept:

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

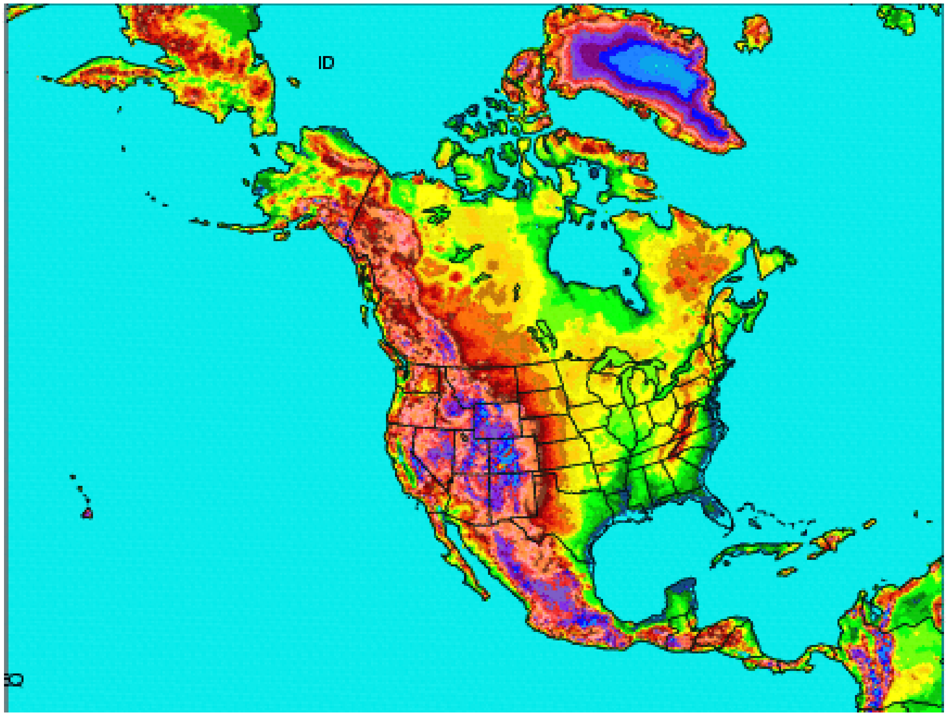
Regional climate model

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 (1979-2003)**
- **There will be a Regional Reanalysis Users Workshop next year**
- **PIs are encouraged to analyze the data**

7. Hydrology and Water Resource Applications

Scientific Rational

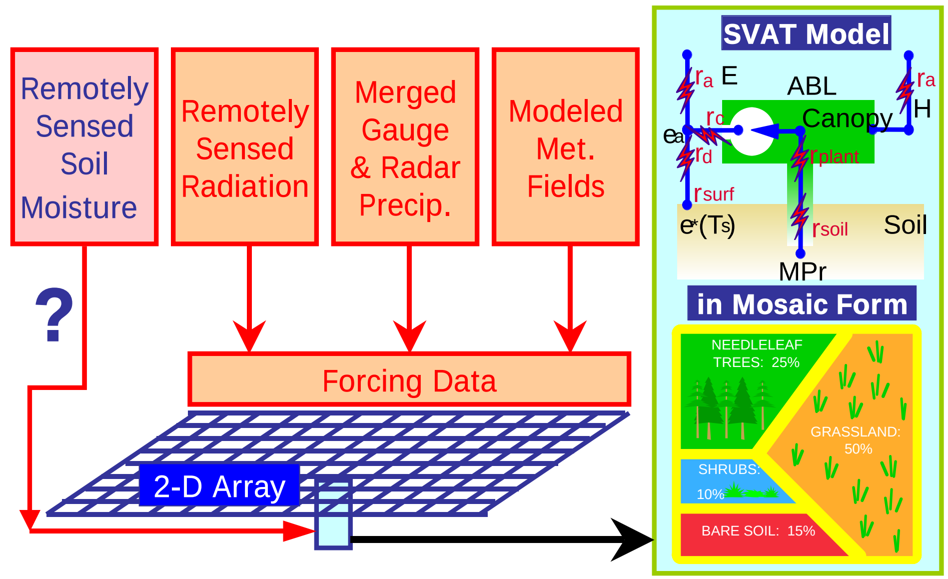
- Improvements in seasonal climate prediction obtained have the potential to improve management of water resources systems.
- Hydrologic forecast technologies are now emerging that can provide reliable forecasts with lead times of weeks or months.
- We must translate information on seasonal to interannual variations in climate into information on the probability of future streamflow conditions
- Water managers must understand the nature of probabilistic forecasts, and adapt management decision making for such information.

Activities:

1. Applications activities (demonstration projects) to evaluate and understand issues operational implementation of seasonal forecasting through partnering with NWS and other non-GAPP water users and agencies.

Transition to NWS Operation

Example: Land Data Assimilation System (LDAS)

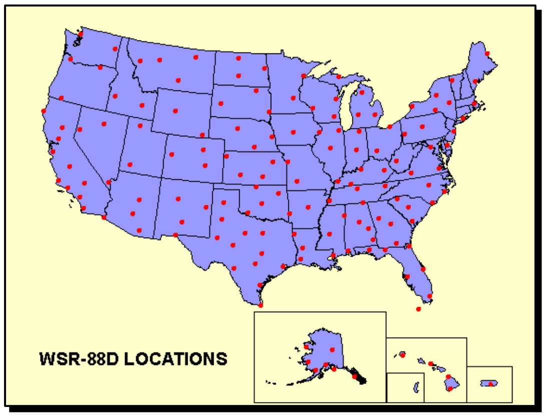


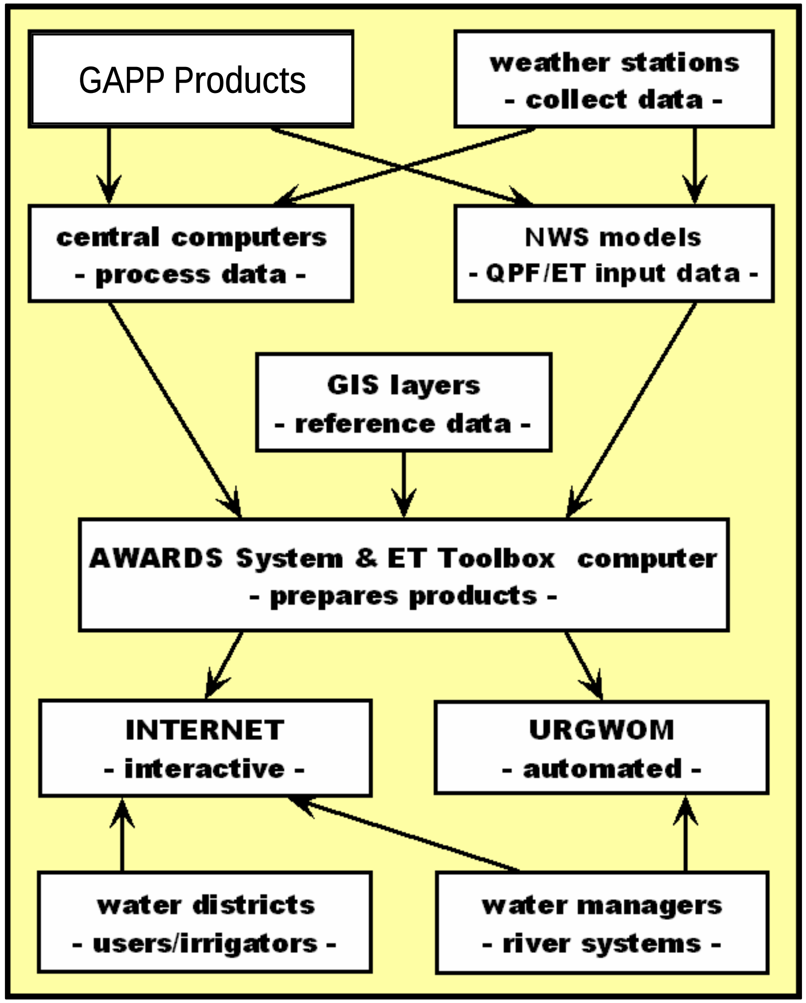
Accomplishment:

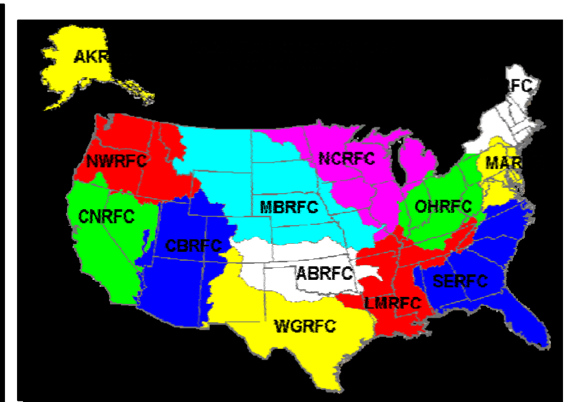
- Development of the LDAS system for the NCEP prediction system
- Real time LDAS to provide initial land boundary conditions for GCMs and RCMs
- Retroactive LDAS
- LDAS products validation

GAPP and 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

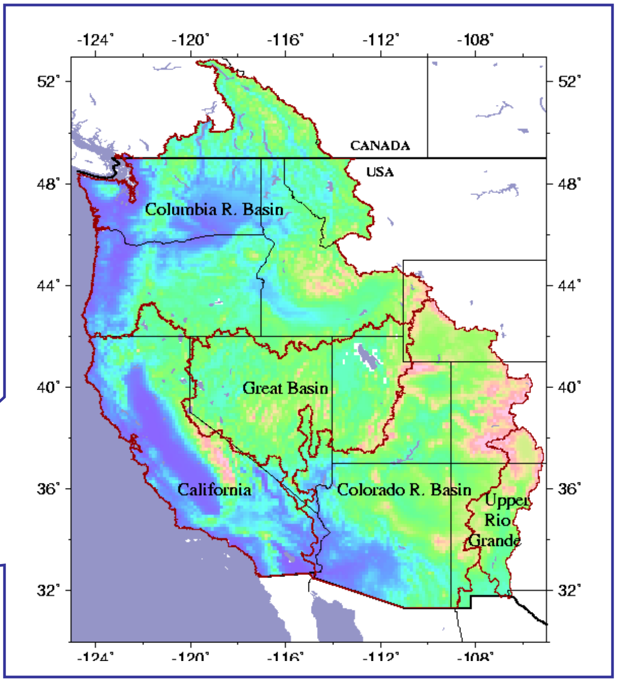
climate model output

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)

Lower Colorado River Authority Reservoir Decision Support System

Historical Streamflow Data

Predictor Variables

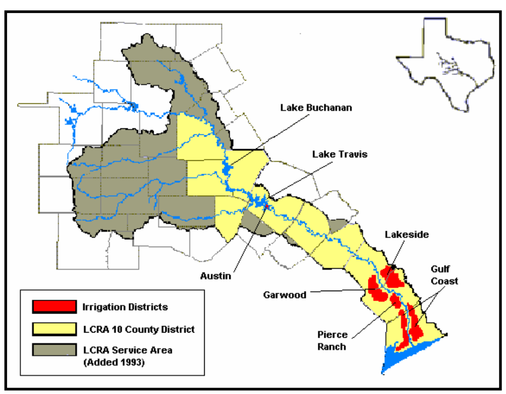
Streamflow Ensembles

Stochastic Reservoir System Model

User Interface

Reservoir Management Decisions

Use of climate forecasts in multi-purpose reservoir system operation (D. Watkins)



Predictors:
-ENSO
-PDO
-NAO
-SST

8. GAPP 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.

9. GAPP Data Management

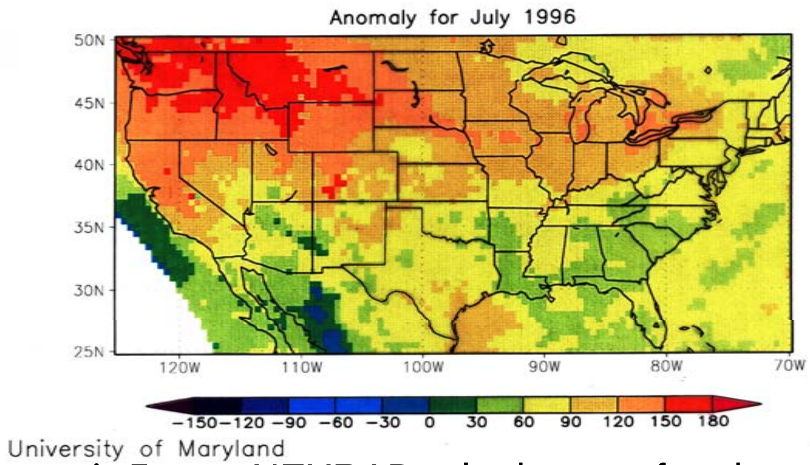
Rational

- GAPP must development of a comprehensive and accessible database for the Continental-scale GAPP study area and establish an evolving program of model development that will permit observations and analyses to be extended spatially within GAPP or applied globally with new observations.
- These data sets will consist primarily of relevant data from existing in-situ, remote sensing, and model output sources and will also include special (surface, upper air, and satellite) meteorological and hydrological observations with increased spatial and temporal resolution.

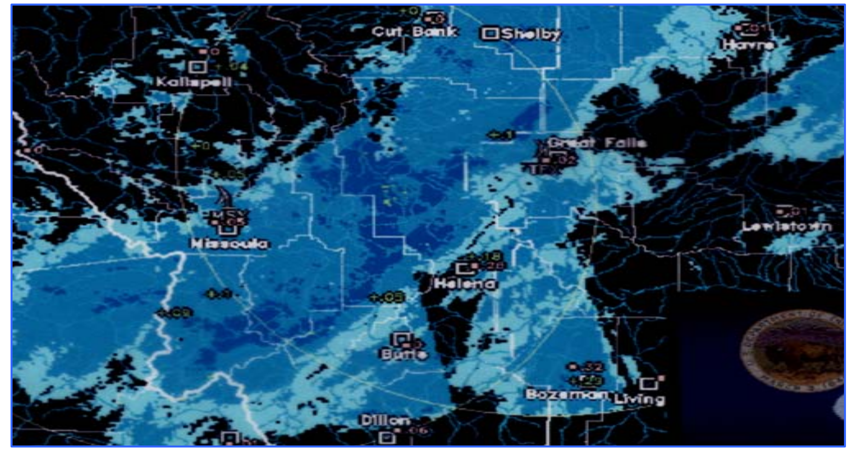
Activities:

1. Focus on the development of a comprehensive and accessible database for the Continental-scale GAPP study area that include data sets from existing in-situ, remote sensing, and model output sources, and includes special (surface, upper air, and satellite) meteorological and hydrological observations (e.g. CEOP).

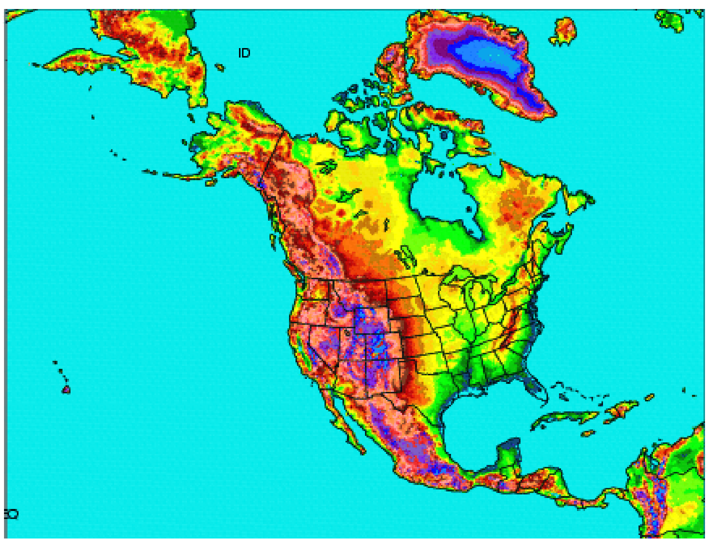
GAPP: Examples of legacy data sets.



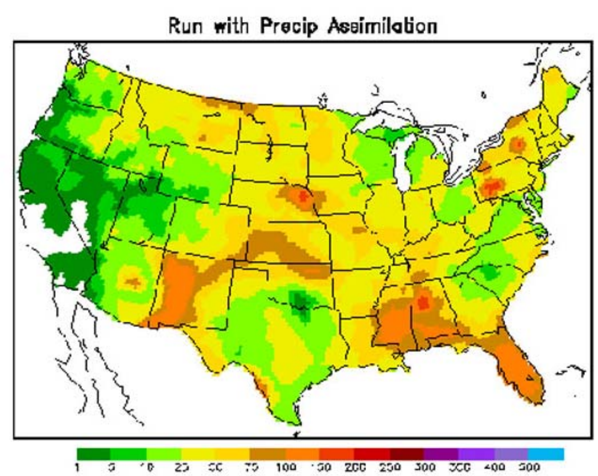
* 5-year NEXRAD rain data set for the Mississippi Basin is complete.(1996-2000)



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



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



* Soil Moisture Data sets from Oklahoma

10. GAPP Organizational Elements

Rational

- *NOAA and NASA program managers are responsible for overall implementation, but receive scientific guidance and advice from the GAPP Scientific Advisory Group.*
- *The GAPP Data Management Committee coordinates data-related activities*
- *The GAPP Working Groups (WG), coordinate the transfer of research results across the program elements and have the responsibility to produce the GAPP research synthesis products that document the progress of GAPP research to the research goals of CPPA and NTHP.*

Activities:

1. Science Advisory Group (SAG)
2. Data management committee
3. GAPP working groups
    - Predictability
    - Water Resources
    - Data and Observations
    - Joint GAPP-PACS NAME
4. 14 GAPP synthesis products

GAPP Synthesis Products:

What are the key factors governing hydrologic predictability, and in particular, the ability to predict streamflow, evapotranspiration, and soil moisture?

•Quantify the influence of land and ocean states on the seasonal prediction skill of precipitation and temperature within the GAPP domain. 2-4 years

What is the role of hydrologic prediction in coupled land atmosphere modeling?

•Quantify the sensitivity of seasonal climate predictions to land states, including soil moisture, snow, orography and vegetation. 2-4 years

•Assess and improve predictions of onset of the North American monsoon. 2-4 years

•Provide a regional reanalysis of the atmospheric and land surface states using state-of-the-science numerical modeling and data assimilation systems. 1-2 years

How can improved modeling strategies, including land data assimilation and ensemble forecasting, best be implemented in a hydrologic prediction framework?

•Quantify seasonal climate forecast skill and accuracy requirements for water resources applications. 2-4 years

•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. 1-3 years

•Quantify the value added to seasonal prediction skill from ensemble regional climate models relative to predictions from their parent global model within the GAPP domain. 2-4 years

GAPP Science Question*: How can the scientific contributions of GAPP, in areas such as coupled land-atmosphere modeling and seasonal forecasting, best be transferred to the operational hydrology and water resources community?*

•Develop and evaluate the usefulness of seasonal hydrologic forecasts systems for water resources applications.2-4 years

•Develop operational hydrologic forecasts incorporating the use of climate forecasts. 2-4 years

GEWEX-GAPP Science Question*: Can we understand and predict the variations in the regional and global hydrological regime and water resources and its response to changes in the environment?*

•Develop a historical understanding of the water and energy budget and its variability within the GAPP domain based on data and modeling, including

•Reanalysis-2. 2-4 years

•Develop an understanding of the GAPP water and energy budget, through data analysis and modeling studies, and its relationship to the global water and energy budget, with particular focus on GEWEX CSEs domains. 2-4 years

•Determine the transferability of climate and hydrologic models across different climate/hydrologic regimes. 1-3 years

•Carry out field experiments leading to improved understanding of the North American Monsoon system. 2 years

•Quantify surface fluxes and land-atmosphere climate feedbacks across the North American monsoon domain. 2-4 years

GEWEX Americas Prediction Project (GAPP)

The **mission** of GAPP is to demonstrate skill in predicting changes in water resources over intraseasonal-to-interannual time scales, as an integral part of the climate system.

Science Objectives:

(i) Prediction: Develop and demonstrate a capability to make **reliable monthly to seasonal predictions of precipitation and land-surface hydrologic variables** through improved understanding and representation of land surface and related hydrometeorological and boundary layer processes in climate prediction models.

(ii) Decision support: **Develop application products for resource managers** by interpreting and transferring the results of improved climate predictions for the optimal management of water resources.

GAPP Components