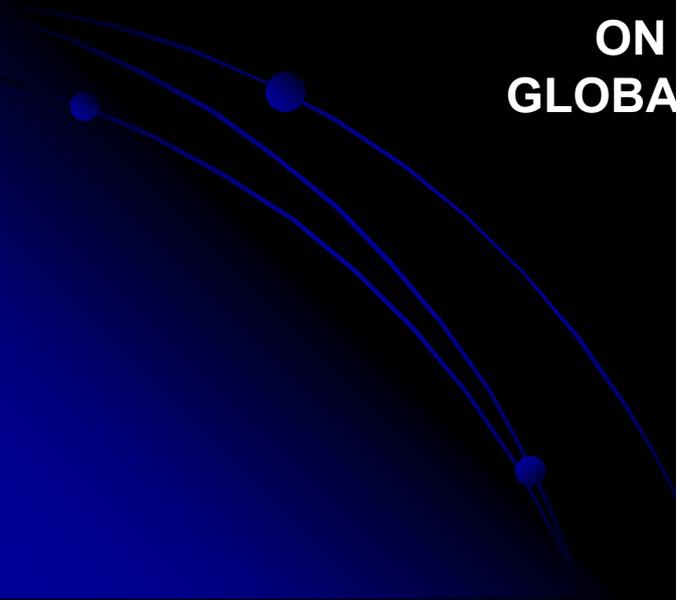


THE GLOBAL WATER CYCLE AND ITS ROLE IN CLIMATE AND GLOBAL CHANGE

**PRESENTED BY RICK LAWFORD
ON BEHALF OF THE INTERAGENCY
GLOBAL WATER CYCLE WORKING GROUP**



Purpose of “Water Cycle” Breakout Session

Opportunity for prepared comments by invited reviewers of the draft Plan
Opportunity for verbal questions, comments, and discussion from workshop attendees

IMPORTANT Reminder:

To be effective in improving the Strategic Plan, comments should be submitted electronically according to instructions on the website (www.climate-science.gov; follow links to Strategic Plan)

THE GLOBAL WATER CYCLE AND ITS ROLE IN CLIMATE AND GLOBAL CHANGE

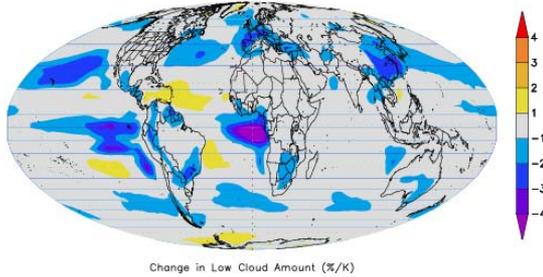
THE GLOBAL WATER CYCLE IS RESPONSIBLE FOR:

MAJOR UNCERTAINTIES IN CLIMATE CHANGE PROJECTIONS DUE TO CLOUD PARAMETERIZATIONS.

Diff T > 4°C

CLOUDS DECREASE

GFDL AM2-ML (2xCO₂ - CTRL)

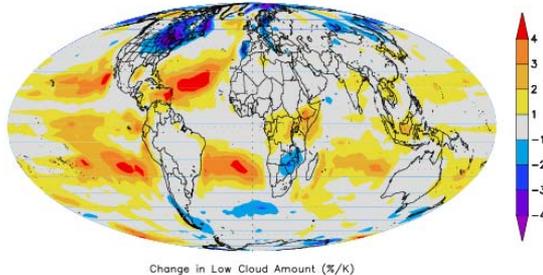


GFDL

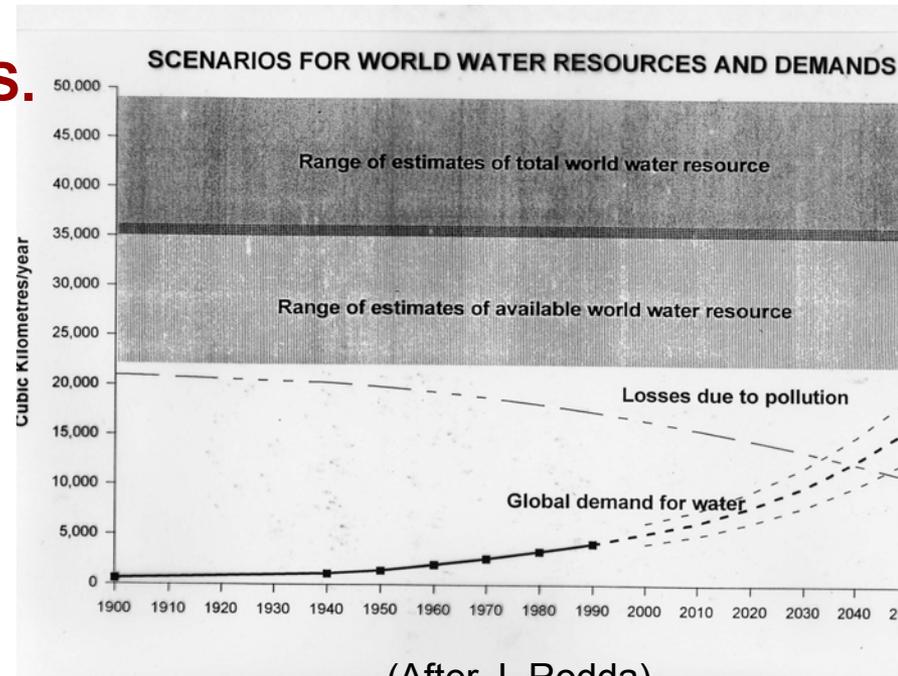
Diff T < 2°C

CLOUDS INCREASE

NCAR CAM2 (Year70 @1%CO₂/yr - CTRL)



NCAR

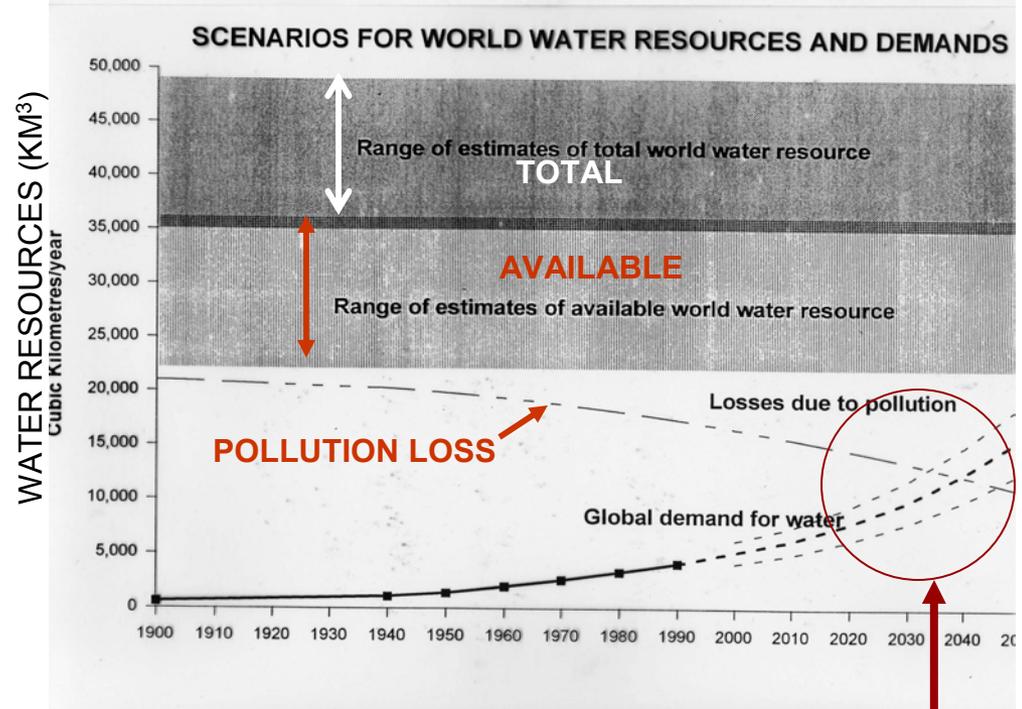
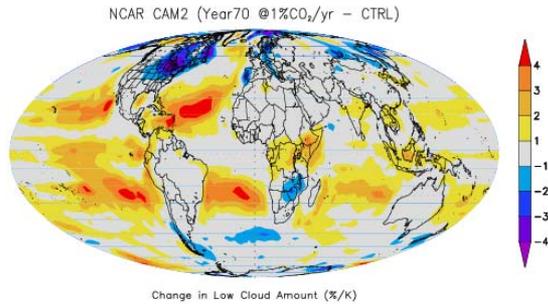
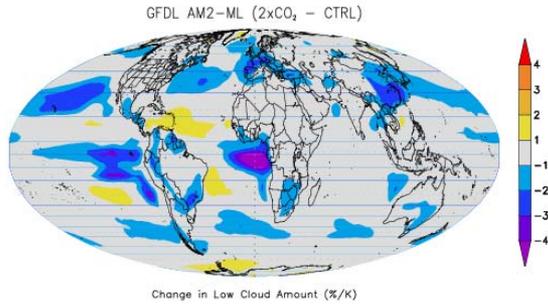


MAJOR REGIONAL AND GLOBAL ISSUES RELATED TO SECURITY, STABILITY AND SUSTAINABILITY.

THE GLOBAL WATER CYCLE AND ITS ROLE IN CLIMATE AND GLOBAL CHANGE

THE GLOBAL WATER CYCLE IS RESPONSIBLE FOR:

MAJOR REGIONAL AND GLOBAL ISSUES RELATED TO SECURITY, STABILITY AND SUSTAINABILITY.

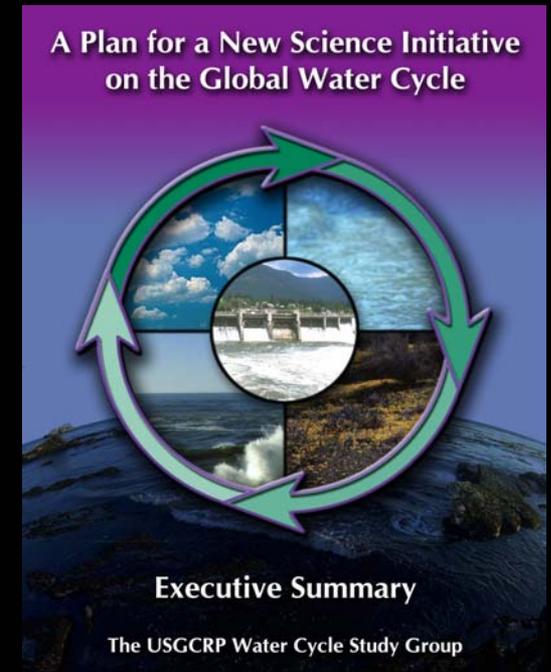
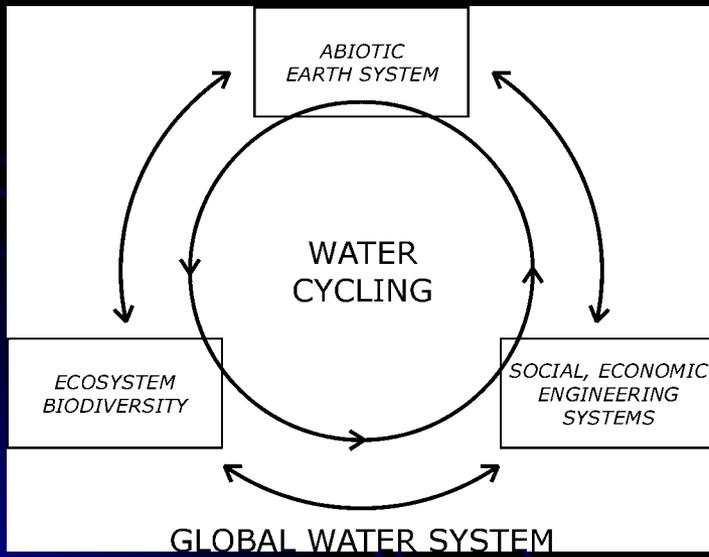


MAJOR UNCERTAINTIES IN CLIMATE CHANGE PROJECTIONS DUE TO CLOUD PARAMETERIZATIONS (After J. Rodda)

DEMAND WILL EXCEED SUPPLY OVER MANY AREAS BY 2030 - 2050.

DEFINING THE GLOBAL WATER CYCLE

THE GLOBAL WATER CYCLE (GWC) ENCOMPASSES THE **MOVEMENTS, TRANSFORMATIONS AND RESERVOIRS OF WATER, ENERGY AND WATER-BORNE MATERIALS** THROUGHOUT THE EARTH SYSTEM AND THEIR **INTERACTIONS WITH ECOSYSTEMS AND THE GLOBAL WATER SYSTEM**. THE GWC OPERATES ON THE FULL CONTINUUM OF SPACE AND TIME SCALES AND INVOLVES PHASE CHANGES AND ENERGY EXCHANGES.



WATER CYCLE RESEARCH AIDS WATER RESOURCE DECISION MAKING

KNOWLEDGE OF THE WATER CYCLE:

- CONTRIBUTES TO THE ALLOCATION OF WATER RESOURCES IN THE CONTEXT OF MANAGEMENT CONSTRAINTS.
- PROVIDES BASIS FOR BETTER FLOOD CONTROL STANDARDS.
- HELPS MAINTAIN HYDROPOWER PRODUCTION
- HELPS MEET IRRIGATION, URBAN AND INDUSTRIAL DEMAND.
- IS A BASIS FOR FORMULATING FEDERAL AND STATE WATER QUALITY REGULATIONS.
- CONTRIBUTES TO ADDRESSING RECREATIONAL AND ENVIRONMENTAL DEMANDS.

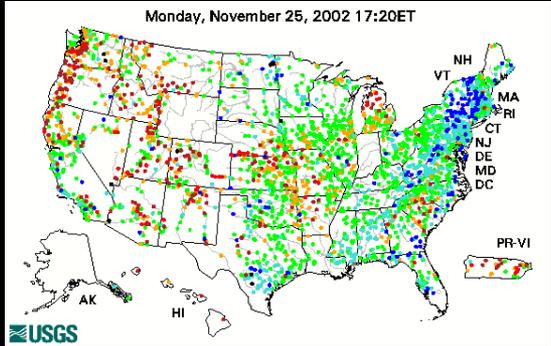


ROLES OF AGENCIES IN THE WATER CYCLE PROGRAM

Watershed and River Systems Management Program



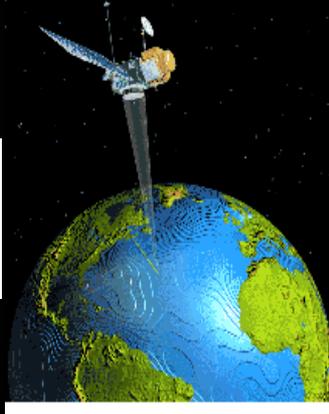
UNDERSTANDING
NSF (NASA, DOE)



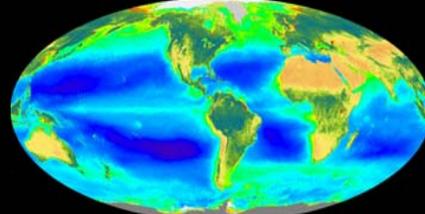
USDA
USGS
APPLICATIONS
EPA BoR
USACE

PREDICTION
NOAA (DOE, NASA)

OBSERVATIONS
NASA, NOAA (DOE,
USGS, USDA)



TOPEX/Poseidon Satellite Over the earth



Hydropower

Research and development of decision support systems and their application to achieve an equitable balance among water resource issues.

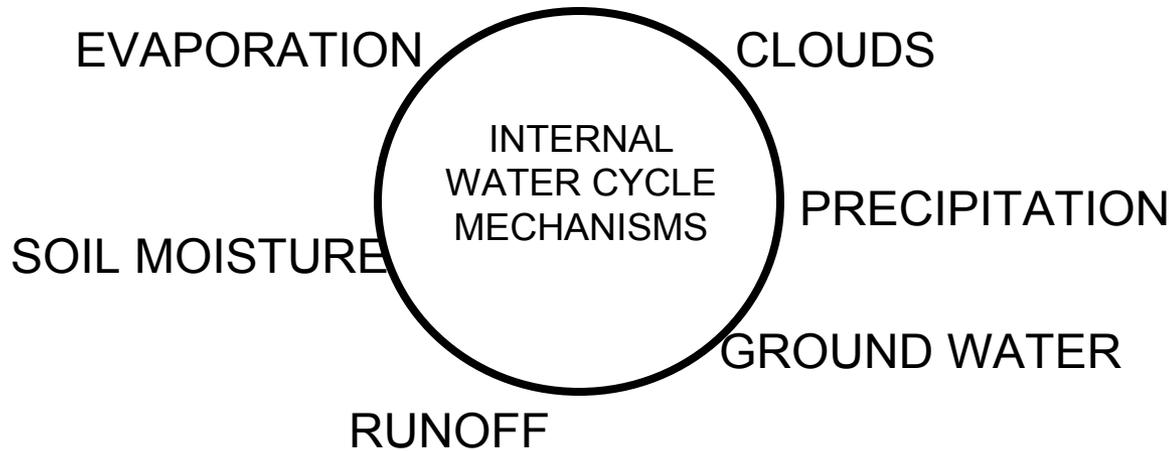
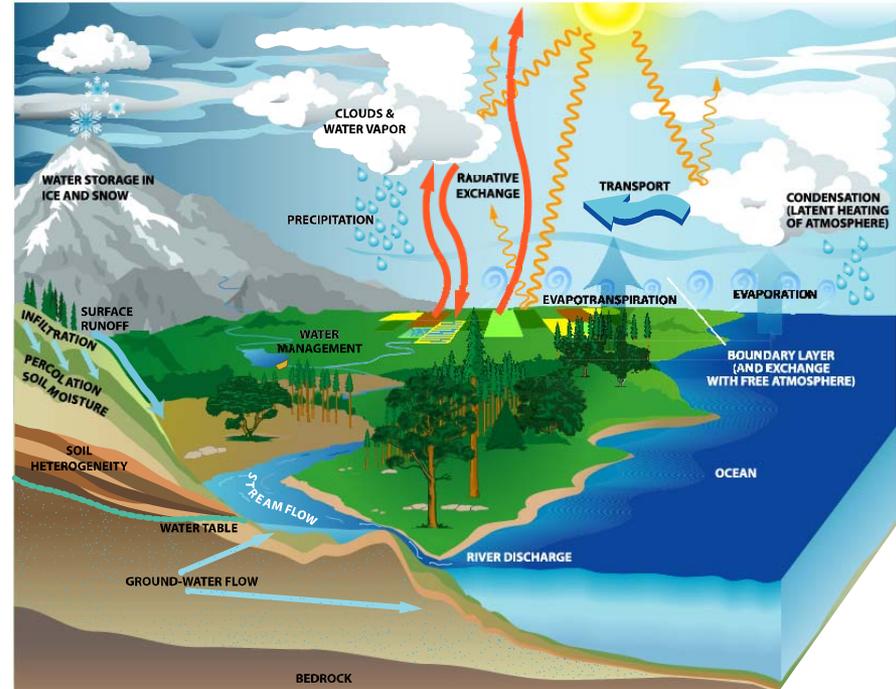
Bureau of Reclamation
Managing Water for The American West

Riparian Habitat Endangered Species

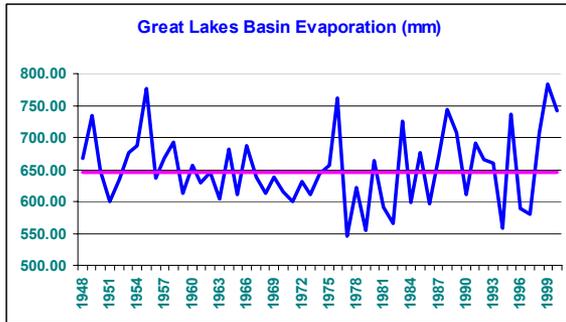


INTERNAL WATER CYCLE MECHANISMS

QUESTION #1: WHAT ARE THE UNDERLYING MECHANISMS AND PROCESSES RESPONSIBLE FOR THE MAINTENANCE AND VARIABILITY OF THE WATER CYCLE; ARE THE CHARACTERISTICS OF THE CYCLE CHANGING AND, IF SO, TO WHAT EXTENT ARE HUMAN ACTIVITIES RESPONSIBLE FOR THESE CHANGES?



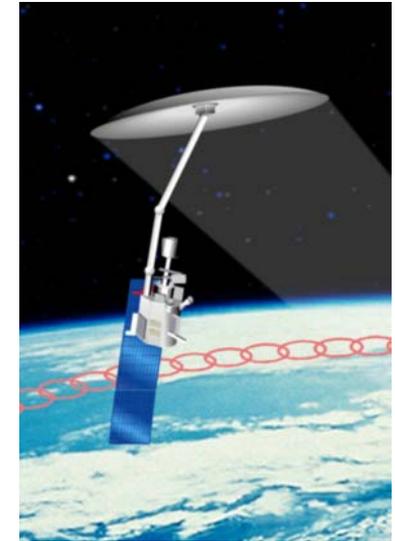
THRUST: IDENTIFYING GWC TRENDS AND THEIR CAUSES



GLERL: INCREASED LAKE EVAPORATION FROM WARMER TEMPERATURES.

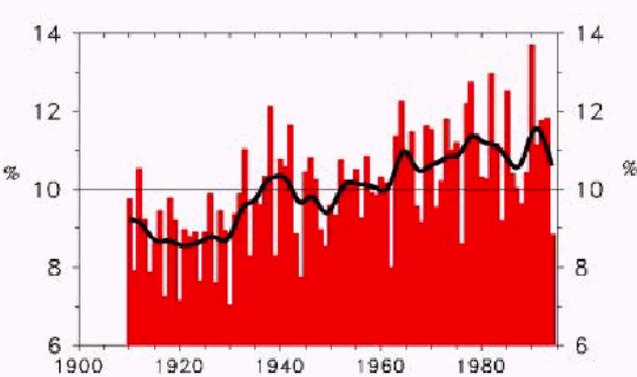
PRIORITIES:

- 1) ASSEMBLE NEW DATA SETS.
- 2) ANALYZE AND ATTRIBUTE TRENDS.
- 3) DEVELOP NEW SENSORS FOR FUTURE GLOBAL MAPPING.



NASA: **GRACE** MEASURES GROUND WATER AND **HYDROS** PLANS TO MEASURE SOIL MOISTURE.

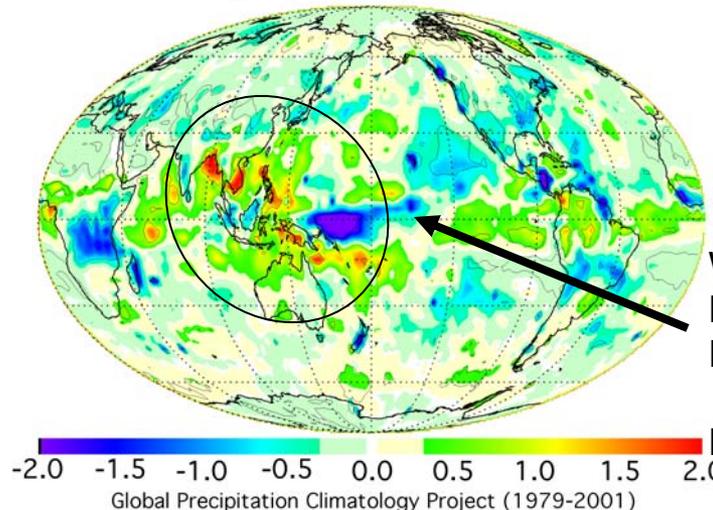
Percent of United States with Extreme Precipitation Events



Source: <http://www.ncdc.noaa.gov/ol/climate/research/gcps/papers/amsbull/amsbull.html>

NCDC: AREA OF INTENSE RAIN IS INCREASING (IS THE WATER CYCLE ACCELERATING?)

23 Year Change in Global Precipitation Anomalies
January 1979 to September 2001

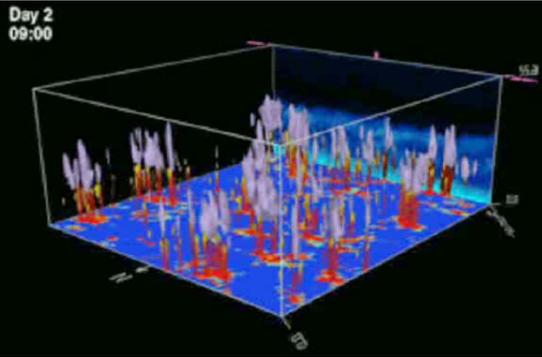


WHILE GLOBAL TRENDS DO NOT APPEAR TO EXIST FOR PRECIPITATION, REGIONAL TRENDS DO OCCUR.

THRUST: DETERMINING THE MAGNITUDES AND CONSEQUENCES OF WATER CYCLE FEEDBACKS IN THE CLIMATE SYSTEM,

PRIORITIES:

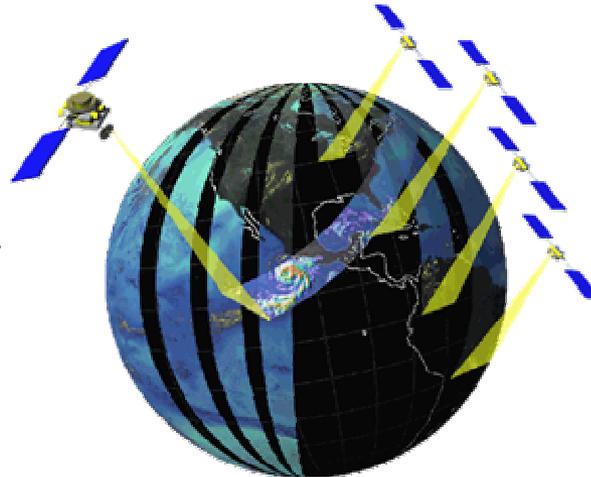
- GLOBAL PRECIPITATION MEASUREMENT (GPM) MISSION.
- NEW CLOUD FEEDBACK PARAMETERIZATIONS.
- MELTING PERMAFROST AREAS: ASSESS CHANGES IN FRESHWATER FLUXES TO THE ARCTIC OCEAN AND RELEASE OF GREENHOUSE GASES (CH₄).



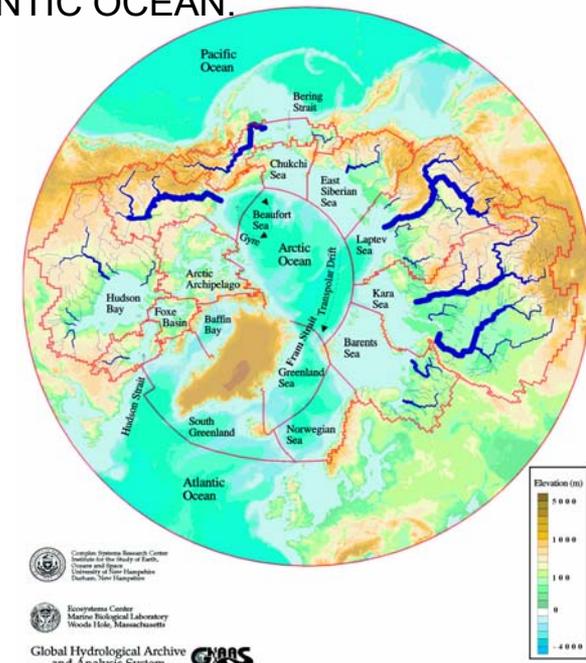
ASSESSING THE ROLE OF CLOUDS REQUIRES MODELS WITH BETTER PHYSICS AND HIGHER MODEL RESOLUTION (APPROX. 1 KM)
(aft. Moncrieff)

VARIABILITY IN RUNOFF TO THE ARCTIC OCEAN MAY BE LINKED TO THE STRENGTH OF THE THERMOHALINE CIRCULATION IN THE ATLANTIC OCEAN.

(after Vorosmarty, 2000)

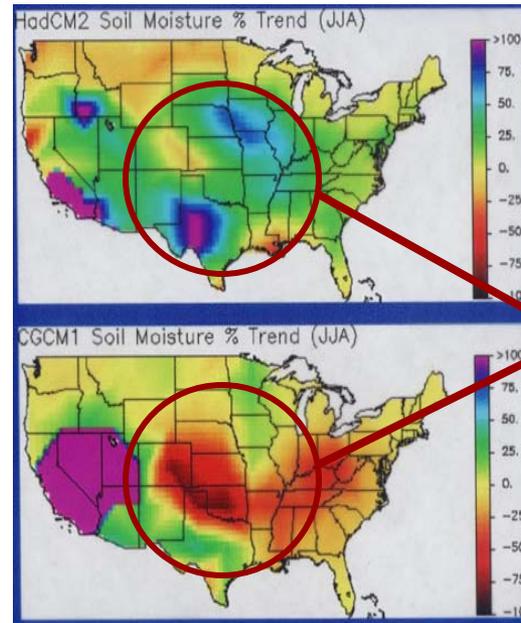


GLOBAL AND REGIONAL WATER BUDGETS AND GLOBAL HYDROLOGIC FORECASTS REQUIRE ROUTINE GLOBAL RAIN MEASUREMENTS.



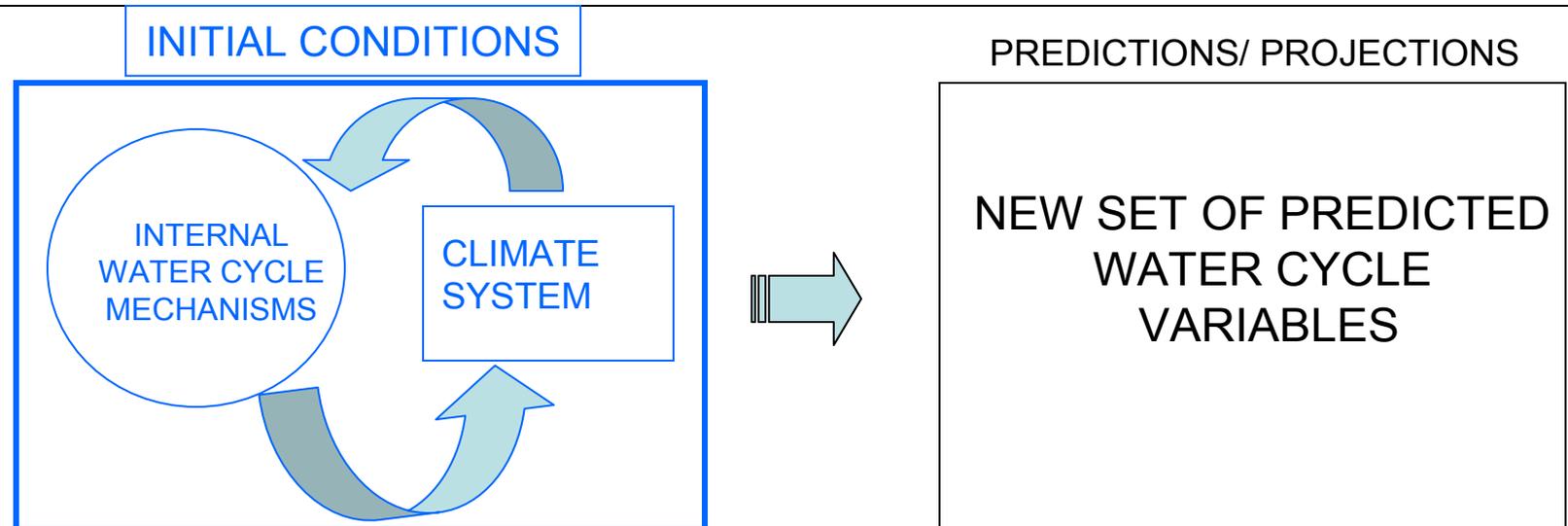
PREDICTING WATER CYCLE VARIABILITY AND CHANGE

QUESTION #3: WHAT ARE THE KEY UNCERTAINTIES IN SEASONAL TO INTERANNUAL PREDICTIONS AND LONG TERM PROJECTIONS OF WATER CYCLE VARIABLES, AND WHAT IMPROVEMENTS ARE NEEDED IN GLOBAL AND REGIONAL MODELS TO REDUCE THESE UNCERTAINTIES?



One model shows drying and the other shows moistening over critical areas of the USA.

Soil moisture in 2100

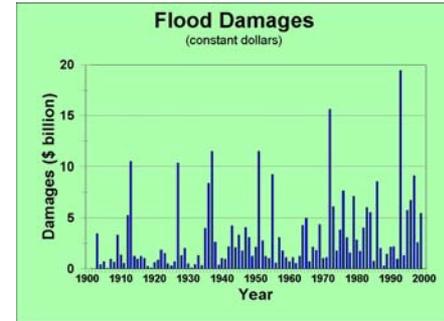


THRUST: IMPROVE PREDICTIONS OF WATER CYCLE VARIABLES AT SEASONAL TO INTERANNUAL (SI) AND LONGER TIME SCALES

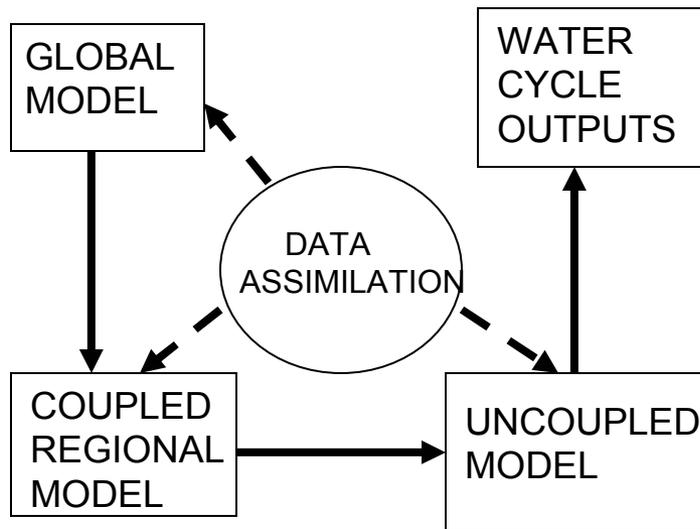
PRIORITIES:

- SEASONAL PREDICTION OF PRECIPITATION.
- PREDICTION OF HYDROLOGIC EXTREMES.
- IMPROVED REPRESENTATION OF WATER CYCLE PROCESSES IN CLIMATE MODELS.

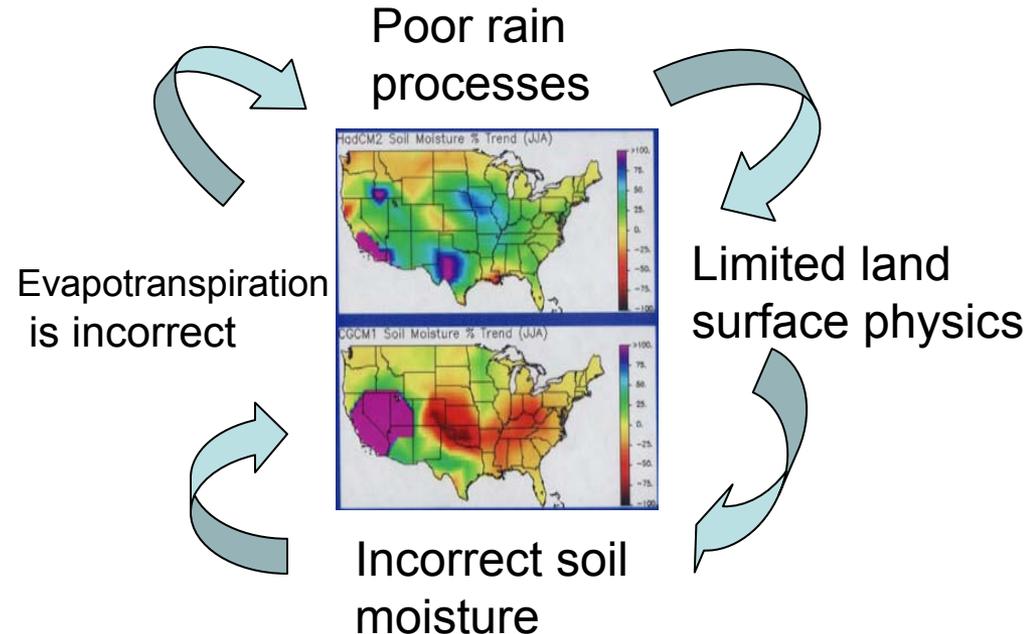
ACCURATE SI PREDICITON OF EXTREMES COULD RESULT IN \$BILLIONS OF SAVINGS



FORECAST IMPROVEMENTS CAN BE OBTAINED BY BETTER PARAMETERIZATIONS, MODEL INITIALIZATION AND DATA ASSIMILATION

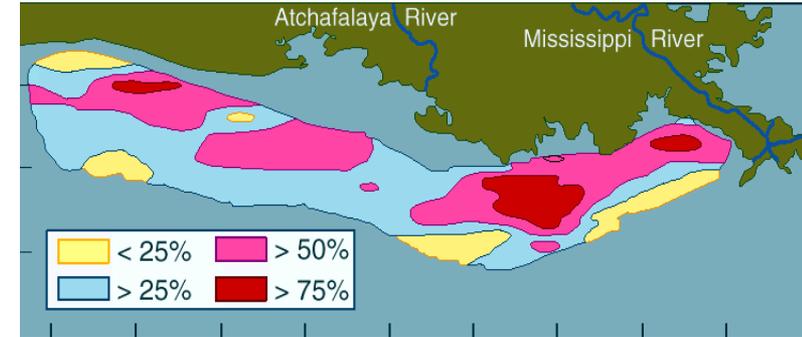


GWC PROCESS REPRESENTATION IN CLIMATE MODELS: HOW CAN WE BREAK THE CYCLE OF MEDIOCRITY?

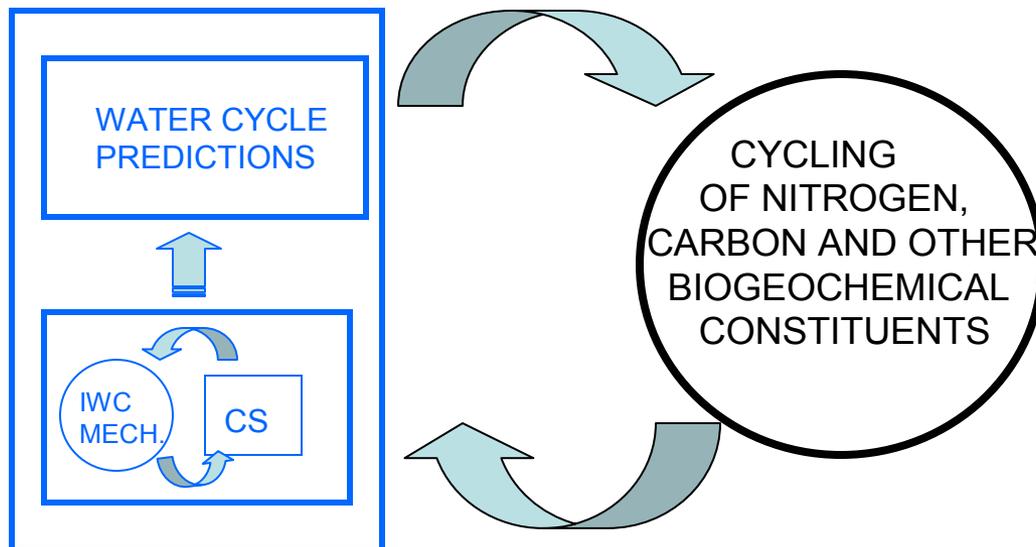


LINKS WITH BIOGEOCHEMICAL CYCLES

QUESTION #4: HOW DOES THE WATER CYCLE AND ITS VARIABILITY AFFECT THE QUALITY OF AVAILABLE WATER FOR HUMAN CONSUMPTION, ECONOMIC ACTIVITY, AGRICULTURE AND NATURAL ECOSYSTEMS; AND HOW DO THE VARIABILITY AND INTERACTIONS WITHIN THE WATER CYCLE AND BETWEEN OTHER BIOGEOCHEMICAL CYCLES AFFECT SEDIMENT AND NUTRIENT TRANSPORT, AND MOVEMENTS OF TOXIC CHEMICALS AND OTHER BIOGEOCHEMICAL SUBSTANCES?



Areas of hypoxia in the Gulf of Mexico due to nitrogen transport in the Mississippi River. (after Scavia)

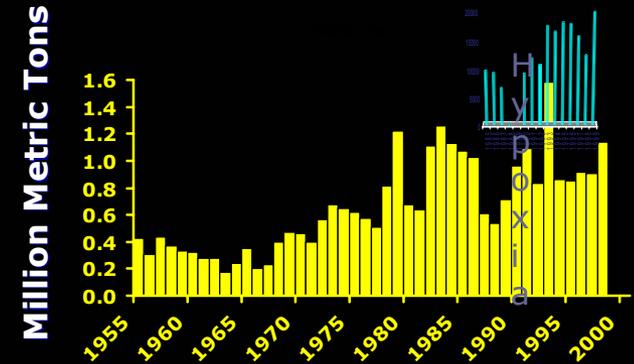


THRUST: WATER'S ROLE IN CYCLING BIOGEOCHEMICAL CONSTITUENTS

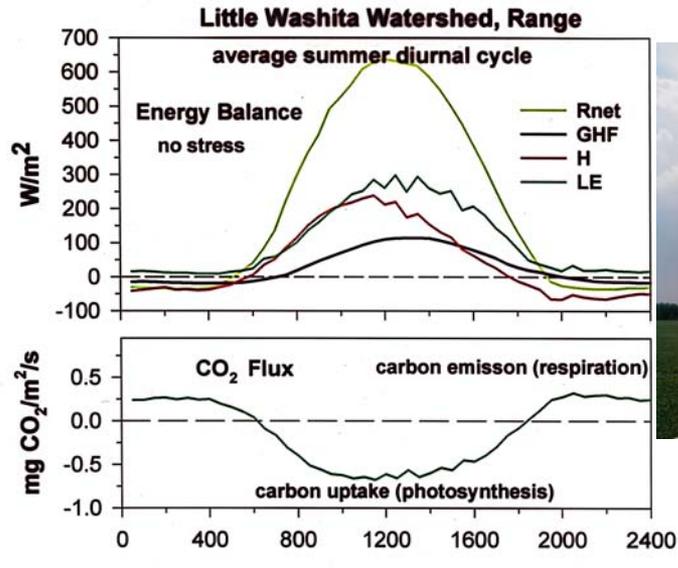
PRIORITIES:

- CLIMATE VARIABILITY AND FEEDBACKS TO WATER QUALITY.
- LAND USE CHANGE IMPACTS ON THE REGIONAL WATER CYCLE.
- TECHNOLOGIES, MANAGEMENT PRACTICES THAT ALLEVIATE CLIMATE IMPACTS.

Nitrate Flux to the Gulf of Mexico

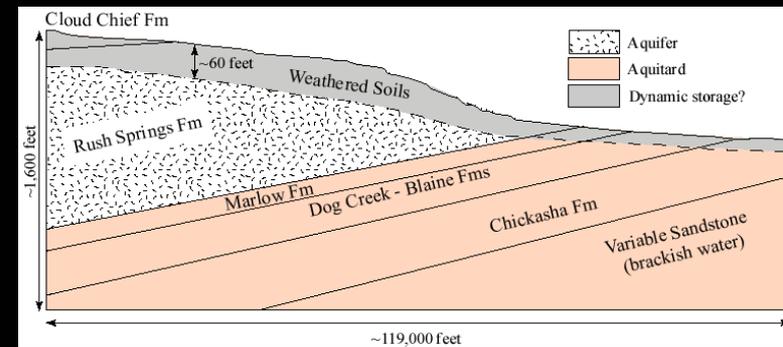


NON-POINT NITROGEN EMISSIONS HAVE BEEN INCREASING OVER THE LAST TWO DECADES. (after Scavia)



(after Meyers)

SURFACE WATER FLUXES AND CARBON FLUXES ARE HIGHLY CORRELATED – DEMONSTRATING THE NEED FOR DYNAMIC VEGETATION MODELS FOR CLIMATE PREDICTION AND CARBON SEQUESTRATION STUDIES.



UNDERSTANDING NEEDED OF SUB-SURFACE PHYSICAL AND BIOLOGICAL PROCESSES THAT GOVERN WATER QUALITY. (after Duffy)

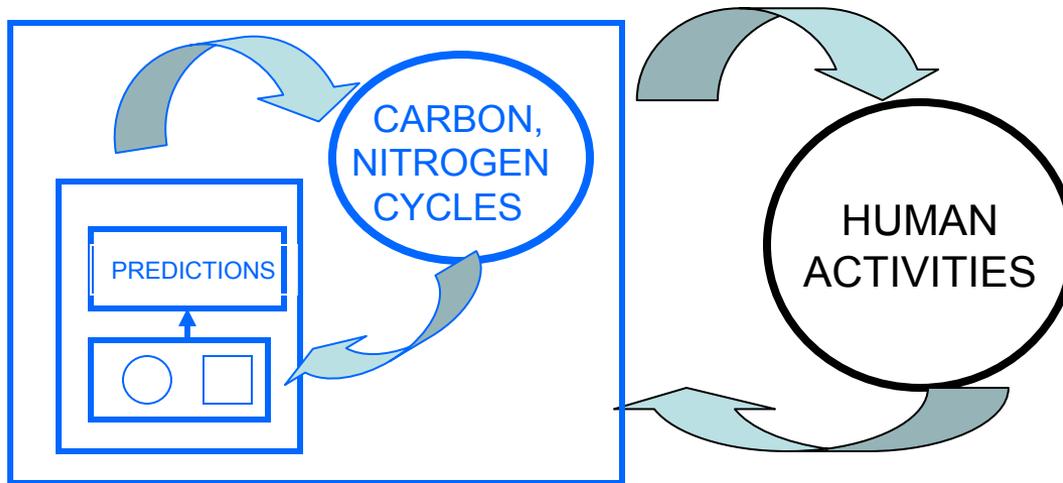
WATER MANAGEMENT AND WATER CYCLE SCIENCE

QUESTION # 5: WHAT ARE THE CONSEQUENCES, AT A RANGE OF TEMPORAL AND SPATIAL SCALES, FOR HUMAN SOCIETIES AND ECOSYSTEMS OF GLOBAL WATER CYCLE VARIABILITY AND CHANGE? HOW CAN THE RESULTS OF GLOBAL WATER CYCLE RESEARCH BE USED TO INFORM WATER RESOURCE POLICY AND MANAGEMENT DECISION PROCESSES?



PEOPLE::

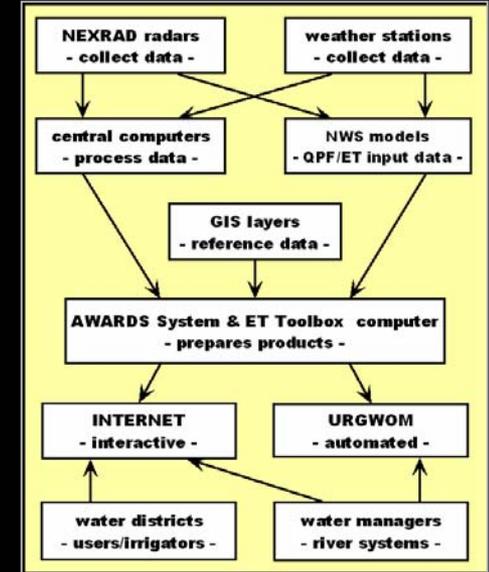
- CREATE DEMAND
- ALTER SUPPLY AND STORAGE.
- INFLUENCE CLIMATE
- ADAPT TO CHANGE!



THRUST: WATER CYCLE INFORMATION AND IMPROVED DECISIONS

PRIORITIES:

- DEVELOP BETTER MECHANISMS FOR MAKING KNOWLEDGE AVAILABLE TO USERS.
- DEVELOP MORE RELEVANT INFORMATION FOR USERS.
- ASSESS IMPLICATIONS OF WATER MANAGEMENT PRACTICES FOR CLIMATE FEEDBACKS, LONG-TERM WATER SUPPLIES, AND STRATEGIES FOR ADAPTING TO CLIMATE VARIABILITY AND CHANGE.

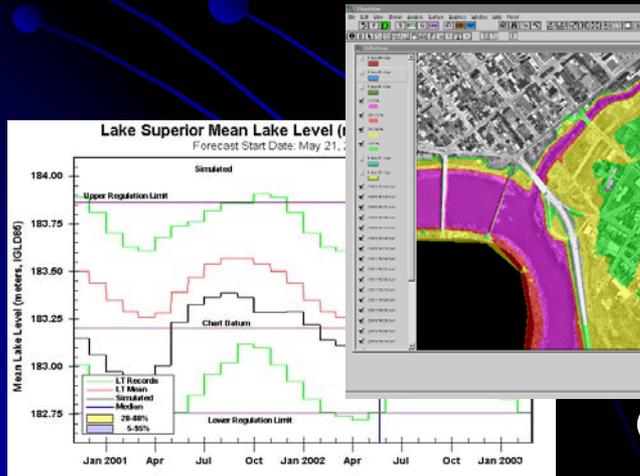


INTERNET RIVER SYSTEM MODELS AND TOOLS.



OTHER EXAMPLES:

DECISION SUPPORT CALENDARS



(A. Ray)

SEASONAL PRODUCTS FROM THE ADVANCED HYDROLOGIC PREDICTION SYSTEM (AHPS)

(OHD)

SPECIALIZED FORECAST SYSTEMS

(GLERL)

SOME KEY PRODUCTS AND PAYOFFS (2-5 YEARS)

- **INTEGRATED** LONG-TERM GLOBAL AND REGIONAL **DATA SETS** OF CRITICAL WATER CYCLE VARIABLES **FOR ANALYZING TRENDS**.
- **PROCESS STUDIES OVER REGIONAL TESTBEDS** TO IMPROVE MODEL PARAMETERIZATIONS (E.G. CLOUDS, SOIL MOISTURE).
- **ANALYSES** OF CLOUD AND RADIATION FIELDS UNDER DIFFERENT ATMOSPHERIC CONDITIONS **TO SUPPORT CLOUD FEEDBACK RESEARCH**.
- NEW **MONITORING PRODUCTS AND EARLY WARNING TOOLS FOR DROUGHT**, BASED ON OBSERVATIONS AND ASSIMILATED FIELDS OF SOIL MOISTURE, PRECIPITATION AND RUNOFF.
- LONG-TERM **MONITORING AND ANALYSIS OF REGIONAL FLOWS AND WATER QUALITY** IN 1) BASINS WITH “NATURAL” FLOWS, 2) AGRICULTURAL WATERSHEDS, AND 3) LARGE DEVELOPED BASINS.
- **PROTOCOLS** FOR ESTABLISHING **BENCHMARK HYDROLOGIC DATA** AT WATERSHED AND BASIN SCALES FOR INTERDISCIPLINARY STUDIES.
- **DECISION SUPPORT TOOLS** FOR INTEGRATING HISTORIC DATA, SATELLITE DATA, DATA ASSIMILATION PRODUCTS, PREDICTIONS AND SOCIO-ECONOMIC ANALYSES **TO SUPPORT WATER MANAGEMENT**.
- **ASSESSMENTS OF THE STATUS AND TRENDS IN US RIVER FLOWS, STORAGE CHANGES AND WATER USE**.

READINESS AND FEASIBILITY

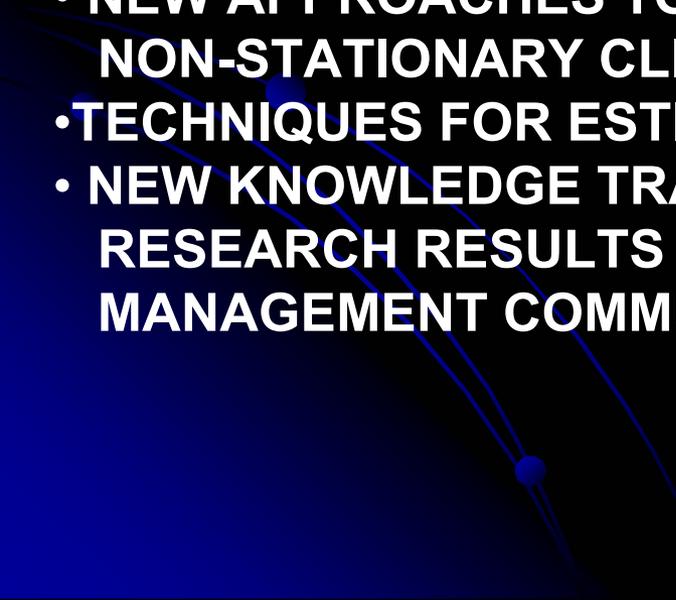
US WATER CYCLE AGENCIES HAVE A NUMBER OF PROGRAMS IN PLACE THAT ARE ADDRESSING MANY IMPORTANT WATER CYCLE ISSUES. THESE INCLUDE RESEARCH INITIATIVES SUCH GWC (NASA, NSF), GAPP (NOAA, NASA), ARM (DOE), CUASHI (NSF) AND AGENCY PROGRAMS AND INFRASTRUCTURE (NSF, NASA, USGS, USDA, NOAA, DOE, USBR). SOME PROGRAM ENHANCEMENTS ARE NEEDED TO ADDRESS SCIENCE GAPS.

THE WATER CYCLE COMMUNITY HAS NEW TOOLS AVAILABLE THAT CAN HELP WITH MAKING WATER CYCLE RESEARCH AND KNOWLEDGE AVAILABLE TO THE USER COMMUNITY. THESE TOOLS INCLUDE:

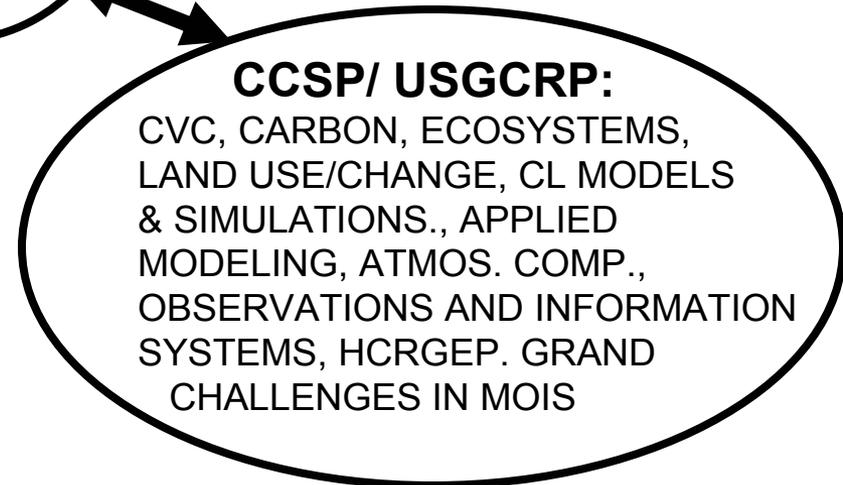
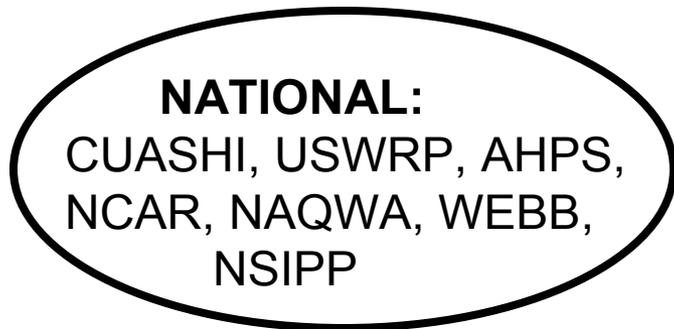
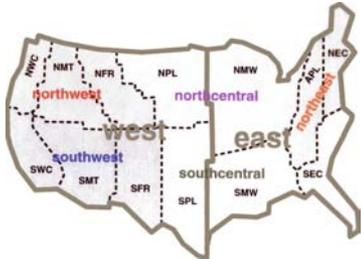
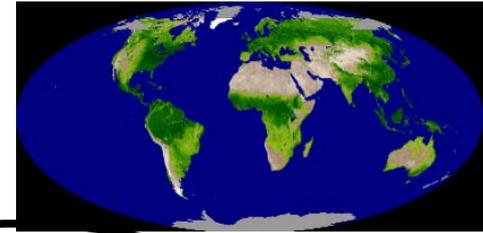
- EXTENSIVE DATA SYSTEMS (NCDC, NAWQA, ETC).
- LAND DATA ASSIMILATION CAPABILITIES.
- SEASONAL TO INTERANNUAL PREDICTION CAPABILITIES.
- DATA FROM NEW SATELLITE SYSTEMS (AQUA, TERRA, GPM PLANS)
- REGIONAL TESTBEDS (RISA PROJECTS, CART/ARM SITE, AMERIFLUX SITES, RESEARCH WATERSHEDS, TO NAME A FEW).

THE PROGRAM ENHANCEMENTS OUTLINED IN THIS REPORT WOULD MAKE MORE OF WATER CYCLE INFORMATION AVAILABLE TO USERS IN MORE USER-FRIENDLY FORMATS AND IN INTERACTIVE RESEARCHER/ USER DIALOGUES.

SOME RESEARCH NEEDS

- **EXPANDED OBSERVATIONAL CAPABILITIES (NEW SENSORS, REGIONAL TESTBEDS AND NETWORK ENHANCEMENTS).**
 - **NEW SATELLITE MISSIONS SUCH AS MISSIONS FOR PRECIPITATION AND SOIL MOISTURE.**
 - **ENHANCED DATA ASSIMILATION CAPABILITIES.**
 - **PROCESS STUDIES LEADING TO NEW MODEL PARAMETERIZATIONS.**
 - **SENSITIVITY TESTS AND MODEL INTERCOMPARISONS TO ASSESS NEW MODEL DEVELOPMENTS.**
 - **PREDICTABILITY STUDIES.**
 - **NEW APPROACHES TO DESIGN STATISTICS BASED ON NON-STATIONARY CLIMATE DATA.**
 - **TECHNIQUES FOR ESTIMATING AND PREDICTING WATER DEMAND.**
 - **NEW KNOWLEDGE TRANSFER FRAMEWORKS TO DISSEMINATE RESEARCH RESULTS AND PREDICTIONS TO THE WATER MANAGEMENT COMMUNITY.**
- 

GLOBAL WATER CYCLE LINKAGES



**“THE GLOBAL WATER CYCLE IS
ESSENTIAL KNOWLEDGE THAT LINKS
ALL OF THE ELEMENTS OF THE CCSP.”**

SUMMARY AND THE PATH FORWARD

GLOBAL WATER CYCLE KNOWLEDGE AND RESEARCH IS AVAILABLE TO MAKE SUBSTANTIAL CONTRIBUTIONS TO THE CCSP. IN ADDITION, MODEST ENHANCEMENTS OF RESOURCES AND BETTER INTERAGENCY COORDINATION COULD INCREASE THESE CONTRIBUTIONS.

PRIORITIES (TENTATIVE) FOR THE PROGRAM ARE:

- ACTIVITIES THAT SUPPORT THE INFORMATION SERVICES OF CCSP.
- NEW RESEARCH INITIATIVES ON 1) GWC FEEDBACKS (CLOUDS AND LAND) TO THE CLIMATE, 2) PREDICTION OF HYDROLOGIC EXTREMES, AND 3) THE CONSEQUENCES OF WATER CYCLE VARIABILITY FOR WATER QUALITY AND THE SOURCES, SINKS AND TRANSPORT OF NITROGEN AND CARBON.
- DEVELOPMENT OF INTERAGENCY INITIATIVES.

YOUR ADVICE IS NEEDED ON GWC PROGRAM CONTENT AND PRIORITIES.

YOUR SUPPORT IS NEEDED TO ENSURE THAT AGENCIES MOVE THIS AGENDA FORWARD WITH BETTER COORDINATION AND STRONGER INITIATIVES OVER THE NEXT 2 TO 4 YEARS,

YOUR INVOLVEMENT AND OWNERSHIP OF THE PROGRAM ARE NEEDED TO MAXIMIZE ITS POTENTIAL TO SUCCEED.

PERSONAL OBSERVATIONS:

- * THE WATER CYCLE SESSION WAS ATTENDED BY A NUMBER OF PEOPLE WHO HAD SPECIFIC ISSUES WITH THE GWC CHAPTER: VEGETATION PROCESSES, OCEANS, ETC. SOME PEOPLE ATTENDED BECAUSE THEY VIEWED THE WATER CYCLE AS A CRITICAL ISSUE.
- * THE CROSS-DISCIPLINARY WORKING GROUPS RECOGNIZED WATER AS AN IMPORTANT ISSUE AND AS A POTENTIAL INTEGRATING THEME.
- * WHILE THE IMPORTANCE OF WATER WAS RECOGNIZED AT THE WORKSHOP IT IS UNCLEAR THAT:
 - THERE WILL BE A STRATEGY TO MAKE THE WATER CYCLE A PRIORITY.
 - THE REASON WHY WATER OR WATER CYCLE SHOULD BE A PRIORITY HAS BEEN NOT BEEN WELL ARTICULATED NOR COMMUNICATED TO CCSP MANAGEMENT BY AN INDEPENDENT SOURCE.
 - THE SSG'S VIEWS OF PRIORITIES AND SUPPORT FOR THE GWC HAS BEEN COMMUNICATED TO THE CCSP.
 - GWC WILL BE ADOPTED AS A CCRI PRIORITY.