NASA ENERGY AND WATER CYCLE STUDY

NEWS

Project Scientist: P. Houser (GMU/CREW)
Program Manager: J. Entin (NASA-HQ)

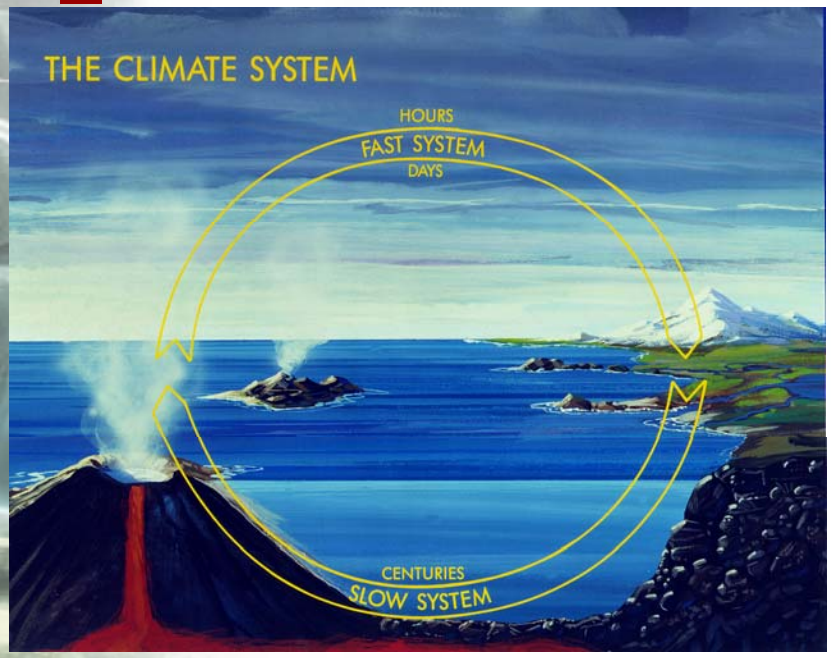
NEWS Integration Team: *W. Rossow (GISS), W. Lapenta (MSFC), B. Lin (LaRC), E.. Njoku (JPL), C. Schlosser (MIT), R. Schiffer (UMBC)*

NEWS Challenge:

Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

The Water and Energy Cycle

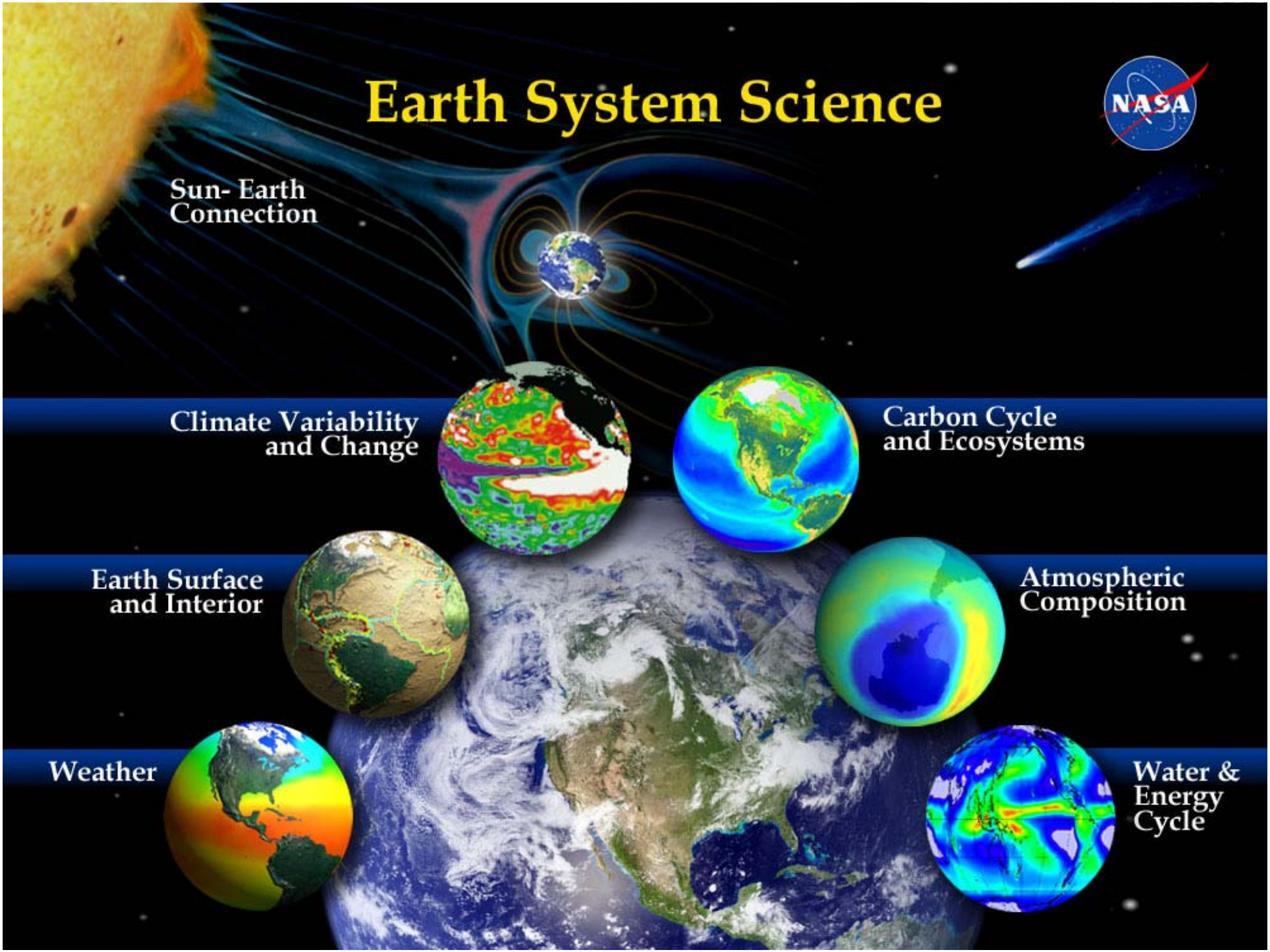
Water in the climate system functions on <u>all</u> time scales: From hours to centuries



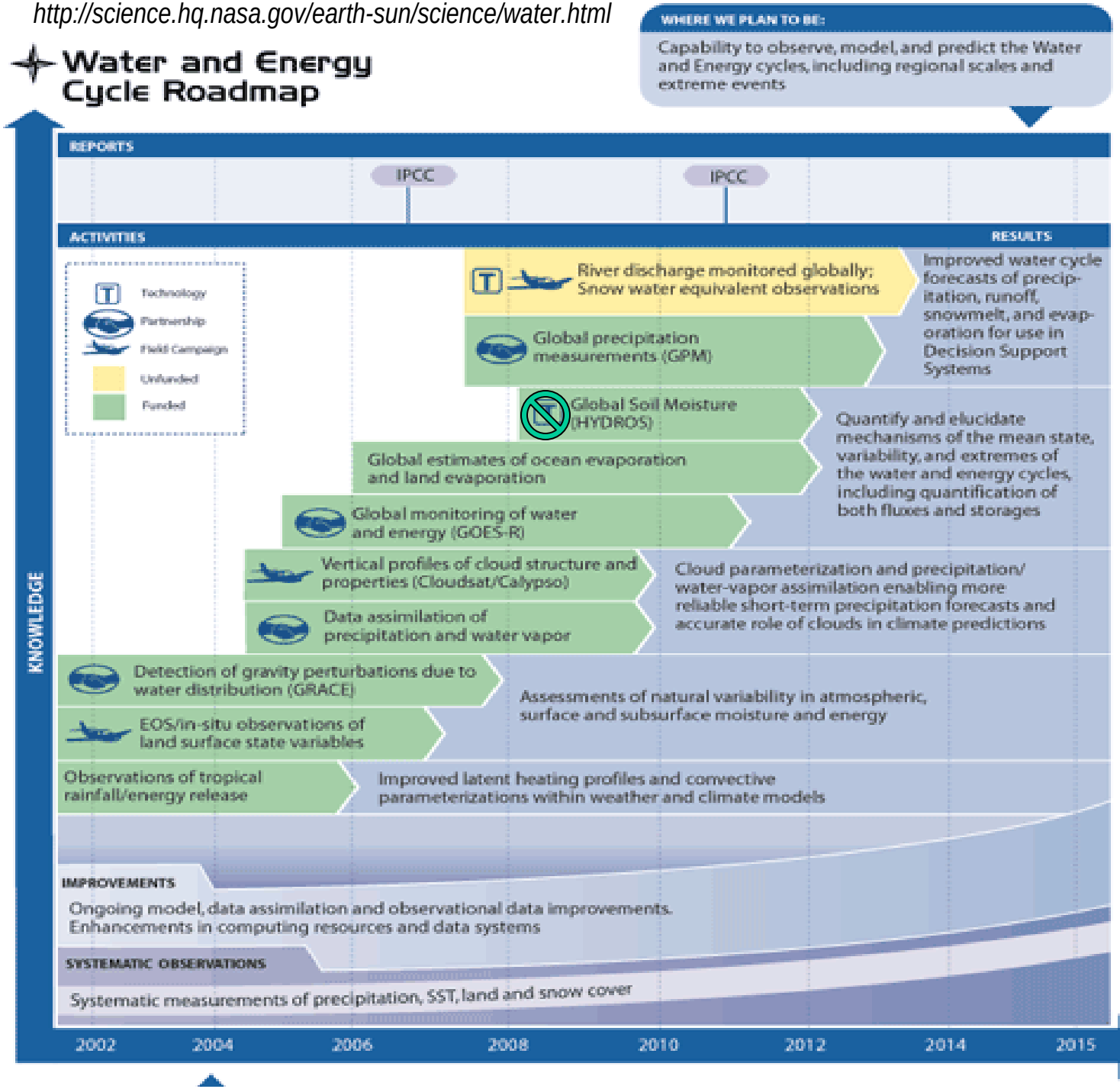
The Energy and Water Cycles are *<u>tightly intertwined</u>* – Solar radiation drives and feedbacks with the water cycle, and energy is transferred through water movement and phase change.

Why study the water & Energy cycle?

1. ***Water exists in all three phases in the climate system and the phase transitions are a significant factor in the regulation of the global and regional energy balances***
2. ***Water vapor in the atmosphere is the principal greenhouse gas and clouds at various levels and composition in the atmosphere represent both positive and negative feedback in climate system response***
3. ***Water is the ultimate solvent and global biogeochemical and element cycles are mediated by the dynamics of the water cycle***
4. ***Water is the element of the Earth system that most directly impacts and constraint human society and its well-being.***


Earth System Science
NASA
Sun- Earth Connection
Climate Variability and Change
Carbon Cycle and Ecosystems
Earth Surface and Interior
Atmospheric Composition
Weather
Water & Energy Cycle

http://science.hq.nasa.gov/earth-sun/science/water.html

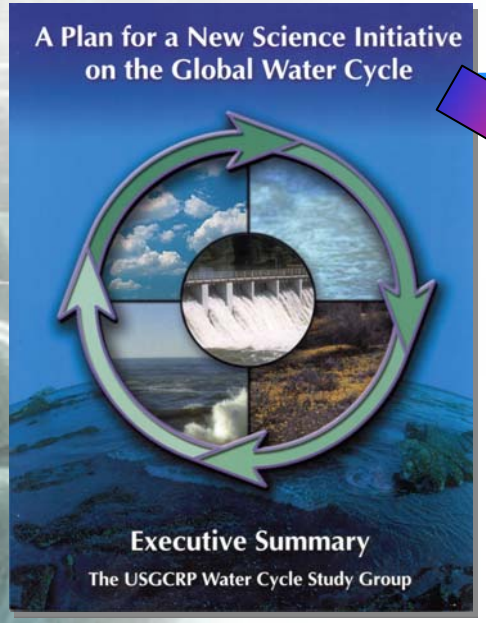


Related Programs:

+ Terrestrial Hydrology
+ Precipitation Sciences
+ LCLUC
+ NEWS
+ Modeling (MAP)
+ Cloud Modeling
+ Water Management

Related Missions:

+ ACRIMSAT
+ Aqua
+ Aquarius
+ ERBS
+ GPM
+ GRACE
+ ICESat
+ Jason-1
+ OSTM
+ SORCE
+ Terra
+ TOPEX-Poseidon
+ TRMM
+ Cloudsat & CALISPO



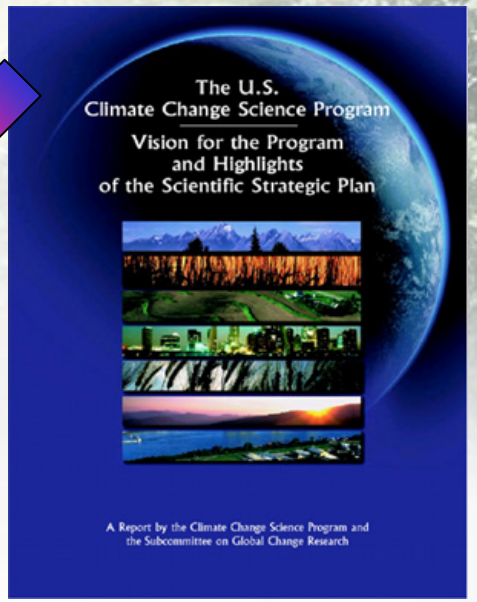
NASA ENERGY AND WATER CYCLE STUDY

NEWS

What are the causes of water cycle variations?

Are variations in the global and regional water cycle predictable?

How are water and nutrient cycles linked?



NASA Earth Science Program Water & Energy Cycle Science Questions (7 of 24 questions):

- How are global precipitation, evaporation and the cycling of water changing?
- What are the effects of clouds and surface hydrologic processes on Earth's climate?
- How are variations in local weather, precipitation and water resources related to climate variation?
- What are the consequences of climate change and increased human activities for coastal regions?
- How can weather forecast duration and reliability be improved?
- How can predictions of climate variability and change be improved?
- How will water cycle dynamics change in the future?

NASA Water and Energy cycle Study (NEWS) Challenge:

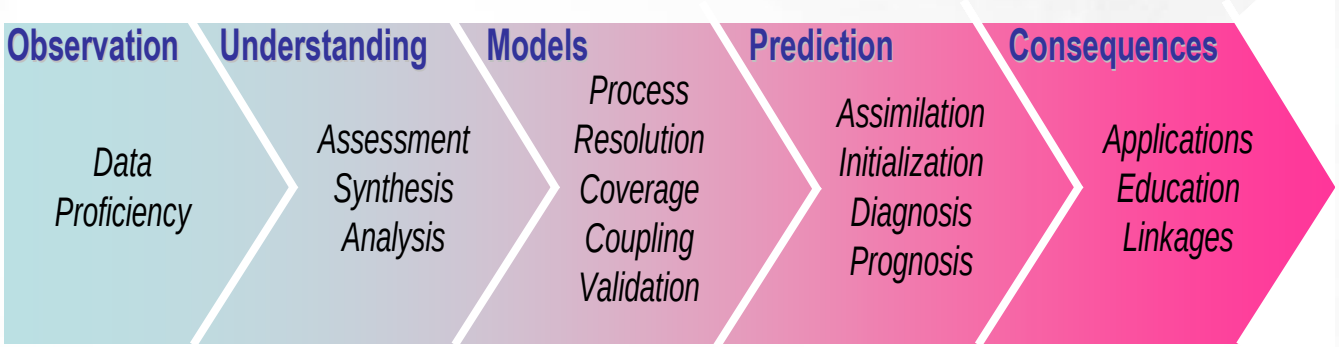
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

NASA ENERGY AND WATER CYCLE STUDY NEWS

NEWS Integrated Water and Energy Cycle Research Challenge:

Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

The NEWS challenge is **global** in scale and requires the integration of NASA **system components** to **make decisive progress toward the NEWS challenge** in an **end-to-end program**

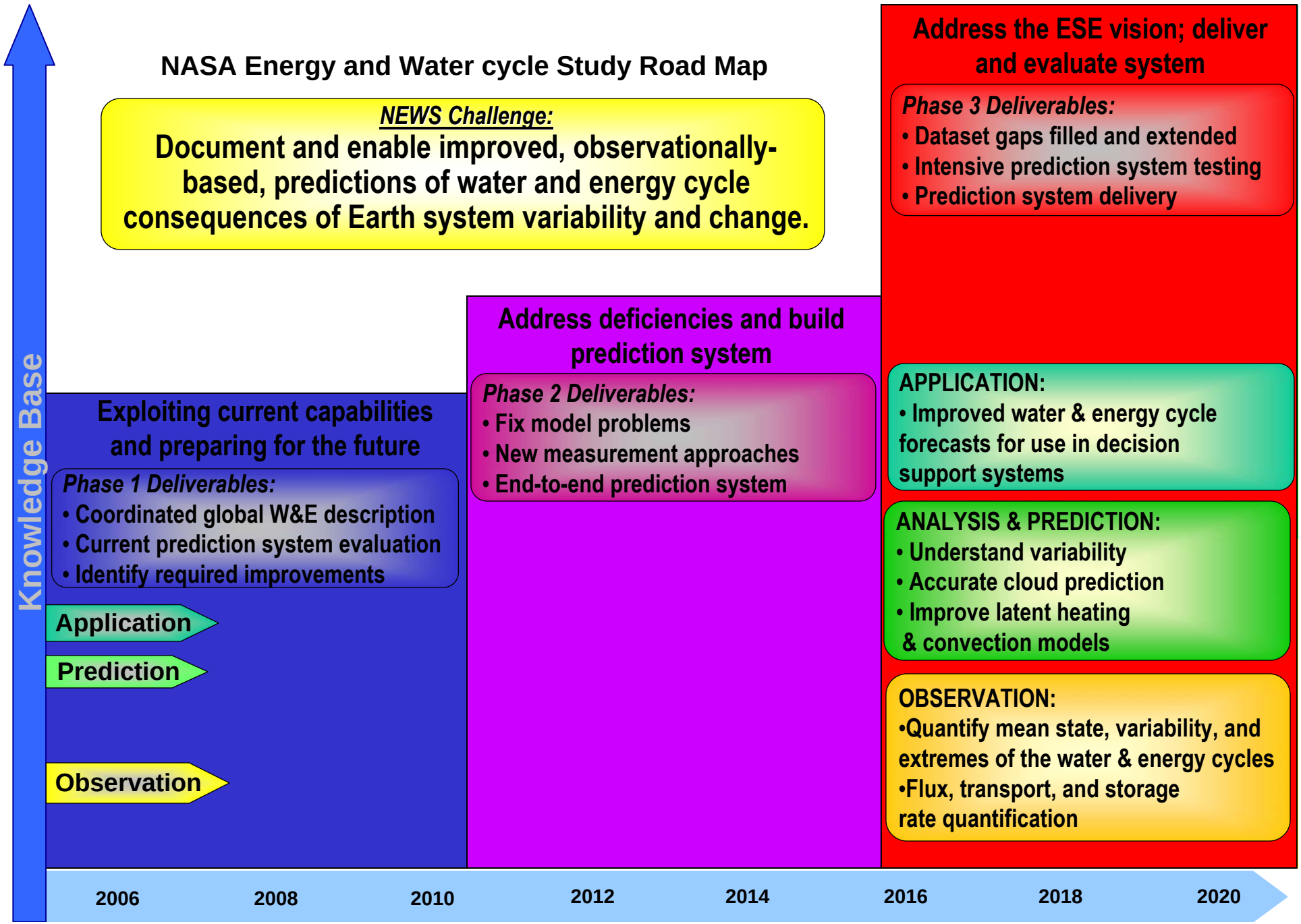


Product-driven investigations: cooperate to produce a cross-discipline comprehensive science solution.

Discovery-driven investigations carried out by individuals or small groups of scientists to make advances in our understanding of key Earth-science processes.

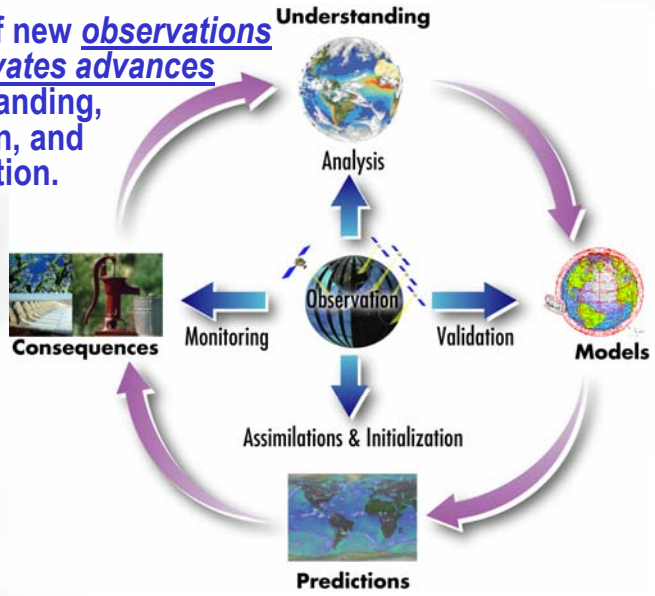
Interdisciplinary program: Discipline-based research not a focus of NEWS.

NEWS Science Integration Team: Support NEWS investigations and integrate their research results to address NASA-ESE science questions. The NEWS integration group will work with NEWS investigations to implement their results into a larger coordinated product, such as a NASA model, data system, etc.


NASA Energy and Water cycle Study Road Map
NEWS Challenge:
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.
Knowledge Base
Exploiting current capabilities and preparing for the future
Phase 1 Deliverables:
• Coordinated global W&E description
• Current prediction system evaluation
• Identify required improvements
Application
Prediction
Observation
Address deficiencies and build prediction system
Phase 2 Deliverables:
• Fix model problems
• New measurement approaches
• End-to-end prediction system
Address the ESE vision; deliver and evaluate system
Phase 3 Deliverables:
• Dataset gaps filled and extended
• Intensive prediction system testing
• Prediction system delivery
APPLICATION:
• Improved water & energy cycle forecasts for use in decision support systems
ANALYSIS & PREDICTION:
• Understand variability
• Accurate cloud prediction
• Improve latent heating & convection models
OBSERVATION:
•Quantify mean state, variability, and extremes of the water & energy cycles
•Flux, transport, and storage rate quantification
2006
2008
2010
2012
2014
2016
2018
2020

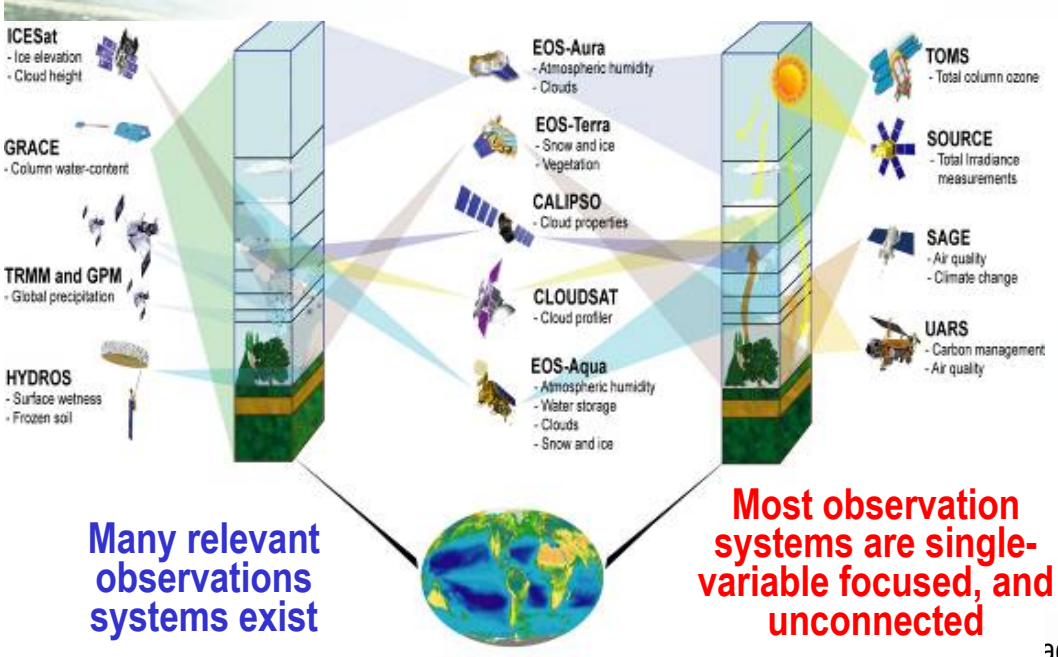
NEWS Observation Strategy

The availability of new ***observations strongly motivates advances*** in understanding, prediction, and application.



Input - Output = Storage Change

Transport + Evaporation - Precipitation – Runoff - P = ΔLand Storage + ΔWater Vapor



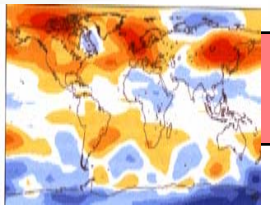
Many relevant observations systems exist

Most observation systems are single-variable focused, and unconnected

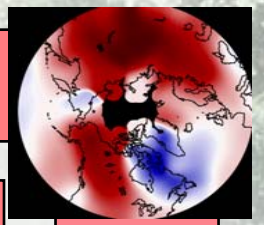
We must define and develop an integrated user-focused water observation system that can not only detect climate trends but also local variation of extremes

We must preserve critical *in-situ* benchmark observations that enable us to detect trends & extremes.

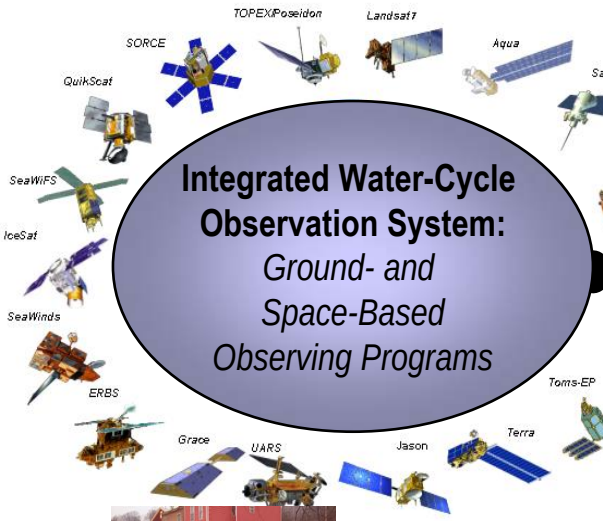
NEWS Water & Energy Cycle Prediction Strategy



Global Warming Scenarios



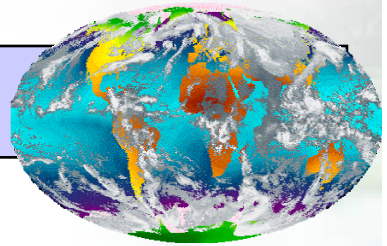
Operational Climate Models (MAP,GMAO,WRF,etc.)

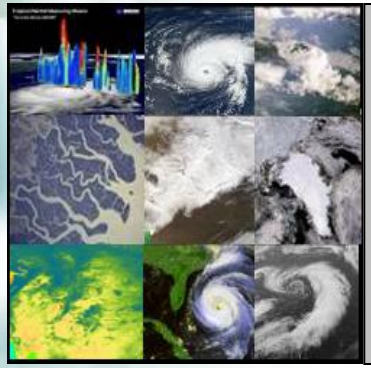


- Advance Understanding and Model Physics
- Improve Initialization & Assimilation
- Diagnose and Identify Predictable Changes

Next-generation Water& Energy Cycle Prediction System

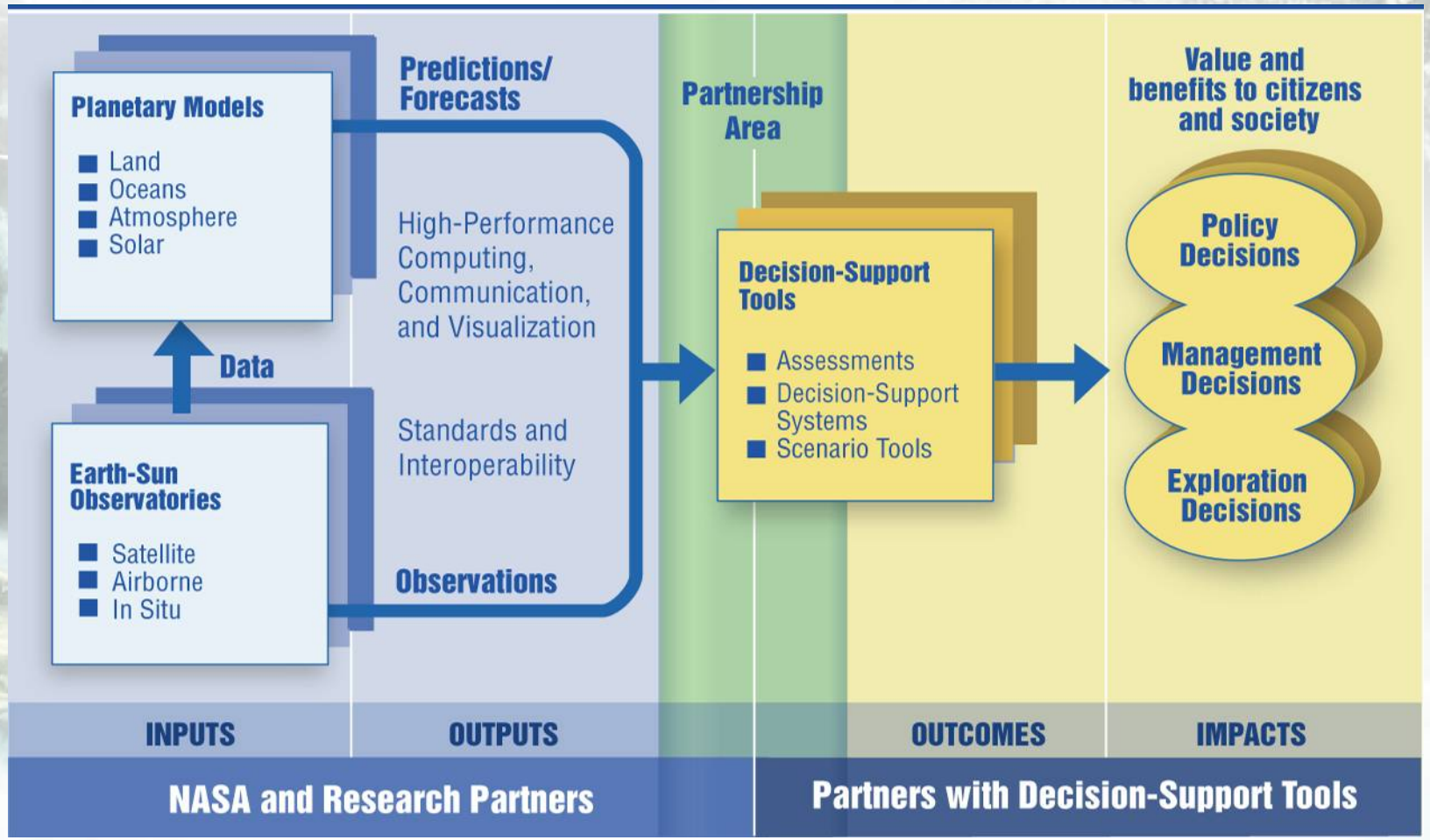
Water & Energy Cycle Prediction





- Useful prediction is critical – it is the link to stakeholders.
- Need a new paradigm of climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes.
- More fully constrain climate models with observations, to improve their realism and believability.

NASA: Linking Science to Consequences

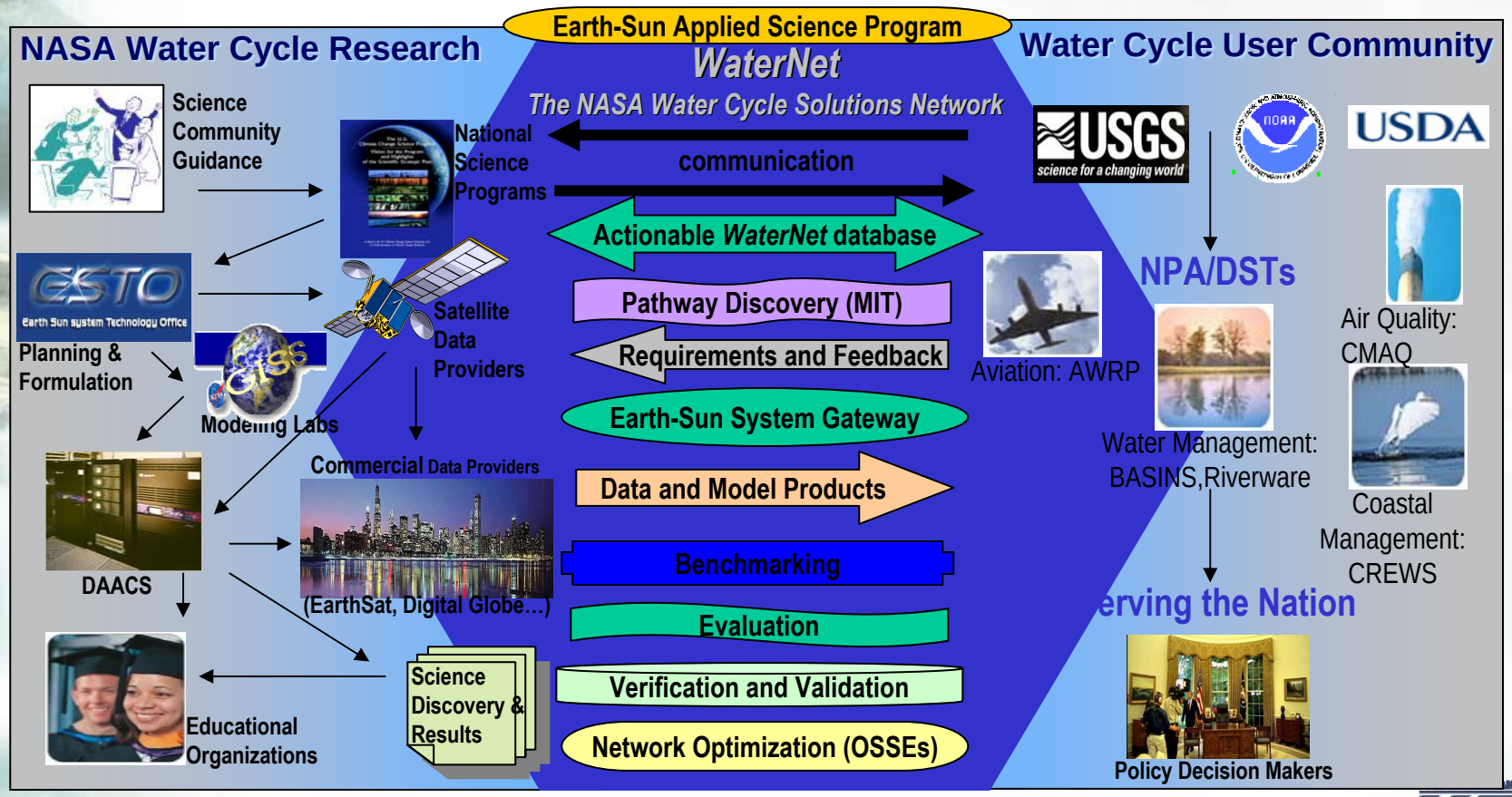


To deliver social, economic and environmental benefit to stakeholders through sustainable and appropriate use of water by directing towards improved integrated water system management

WaterNet: The NASA Water Cycle Solutions Network

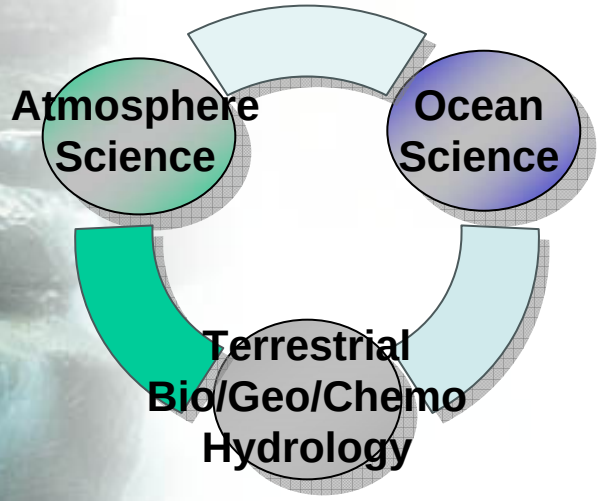
Improve and optimize the sustained ability of water cycle researchers, stakeholders, organizations and networks to interact, identify, harness, and extend NASA research results to augment decision support tools.

1. ***Evolve a network of partners:*** identify and analyze partner organizations to define collaboration pathways.
2. ***Routinely identify, prioritize, mine and communicate relevant research products and results.***
3. ***Optimize water cycle partner access*** to research results and products to create a self-sustaining network.
4. ***Analyze and document*** the network effectiveness through metrics, resource estimates and documentation.
5. ***Education and outreach*** is important to help society understand and use the research in every-day application.



NEWS Linkages

Interdisciplinary Research



NEWS can't solve these problems alone – must partner:

- World Climate Research Program (WCRP)
  - Global Energy and Water Experiment (GEWEX)
  - Climate Variability (CLIVAR)
  - Climate and Cryosphere (CLIC)
- IGOS-Partners Water Cycle Theme
- Global Observing system (GCOS)
- Global Earth Observation (GEO and IWGEO)
- International Geosphere-Biosphere Programme (IGBP)
- Hydrology for Environment, Life, and Policy (HELP)
- Global Water System Project (GWSP)

Researchers must work in close partnership with end-users, and define their research priorities based on user needs.

•Observations:

→Define an integrated water & energy observation system that can detect global mean trends and local variation of extremes

→Preserve critical *in-situ* observations that enable trends & extreme detection.

•Research:

→Develop climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes.

→More fully constrain climate models with observations, to improve their realism.

Improved prediction of consequences is a key to meet user needs.

State of the Water & Energy Cycle

Evaluate our ability to detect, analyze, and understand global water cycle change, variability, prediction and predictability.

Water and Energy Cycle Data Integration

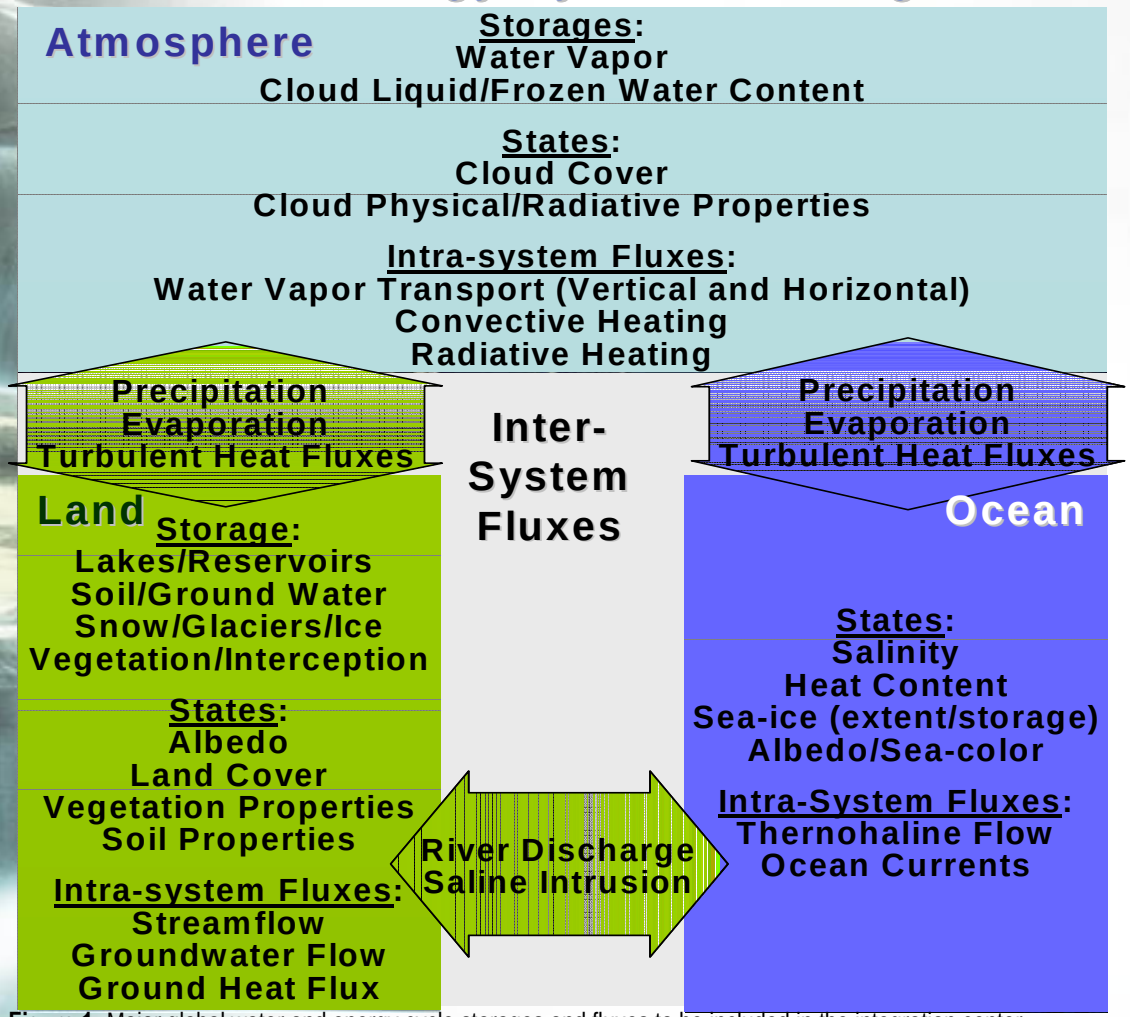


Figure 1: Major global water and energy cycle storages and fluxes to be included in the integration center.

Global Satellite Water Balance Study:

Schlosser & Houser, 2006

$$\frac{d\langle Q \rangle}{dt} = \langle E \rangle - \langle P \rangle$$

Precipitation (1979-1999):

- Global Precipitation Climatology Project (GPCP): Adler et al., (2003)
- CPC Merged Analysis of Precipitation (CMAP): Xie and Arkin (1997)

Ocean Evaporation (1987-1999):

- Goddard Satellite-based Surface Turbulent Fluxes Version 2 (GSSTF2): Chou et al., (2003)
- Hamburg Ocean Atmosphere Parameters and Fluxes from Satellites: Bentamy et al. (2003)

Land Evaporation:

- Global Offline Land Dataset (GOLD) (1959-2002): Dirmeyer et al., (2005):
- ***Global Soil Wetness Project Phase 2 (GSWP2): 1986-1995***

Precipitable Water: NASA Global Water Vapor Project (NVAP)

Model Output: Climate of 20th Century

Annual Mean Statistics (1988-1999)

NEWS (Schlosser&Houser)

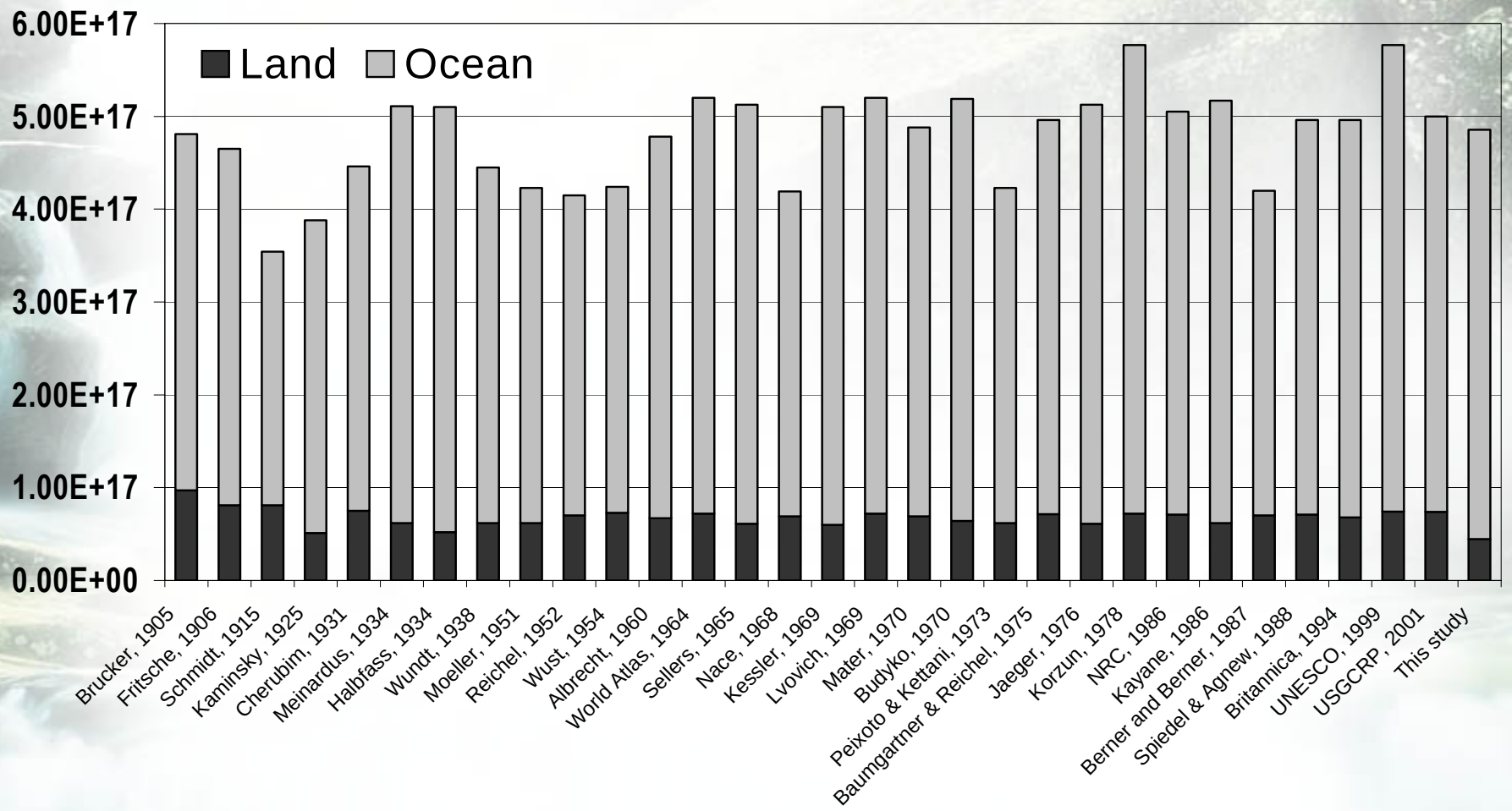
	Precipitation	Evaporation	| P-E |
Land (Units in kg/yr)	1.05E+17 ± 0.02E+17	GOLD1: 0.64E+17	~4.0E+16
	1.02E+17 ± 0.02E+17	GOLD2: 0.62E+17	~4.2E+16
Ocean	3.80E+17 ± 0.06E+17	4.41E+17	6.5E+16
	3.72E+17 ± 0.04E+17	3.93E+17	1.7E+16
Global	GPCP 4.85E+17 ± 0.06E+17	GSSTF2+GOLD 5.03E+17	~ 2.4E+16
	CMAP 4.74E+17 ± 0.04E+17	HOAPS+GOLD 4.56E+17	

Note: Total atmospheric water storage ~ 10^{16} kg, annual change ~10^{14} kg

Adapted from Schlosser and Houser (2006,)

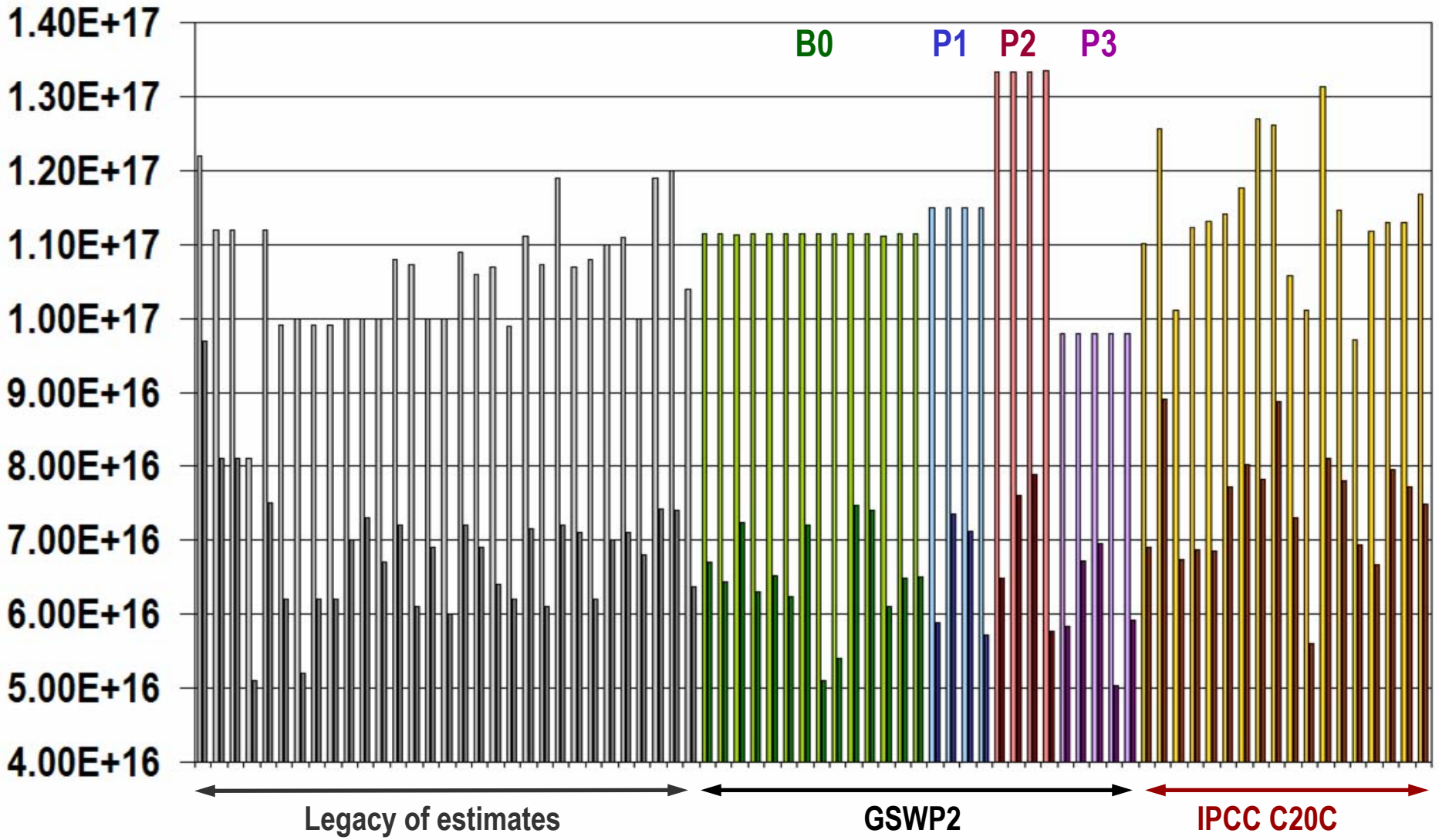
- Global annual mean precipitation and evaporation balance to ~5% or 24,000 (metric) gigatons of water.
- Imbalance exceeds global estimate of annual precipitation error.

Comparison of Global Evaporation Fluxes to Previous Estimates



- Global fluxes of precipitation and evaporation are comparable to previous century of estimates.
- No discernable trend is seen in both compilations of the flux estimates.
- The notable disparity with this study is the lower values of both precipitation (not shown) and evaporation flux estimates over land.

Mean Annual Global Land Precipitation and Evaporation (kg/yr)

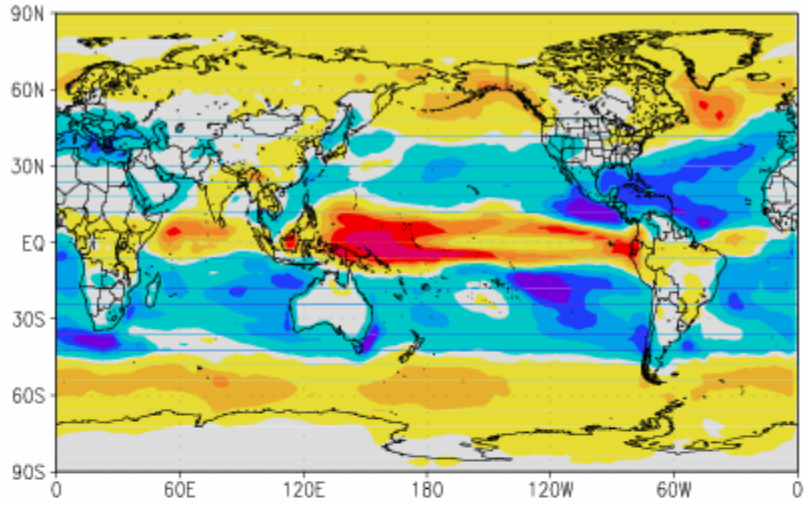


- **Model-based (offline and coupled) scatter of estimates marginally higher than compilation of "modern" observationally-based estimates.**

Multi-model ensemble mean change from IPCC GCMs

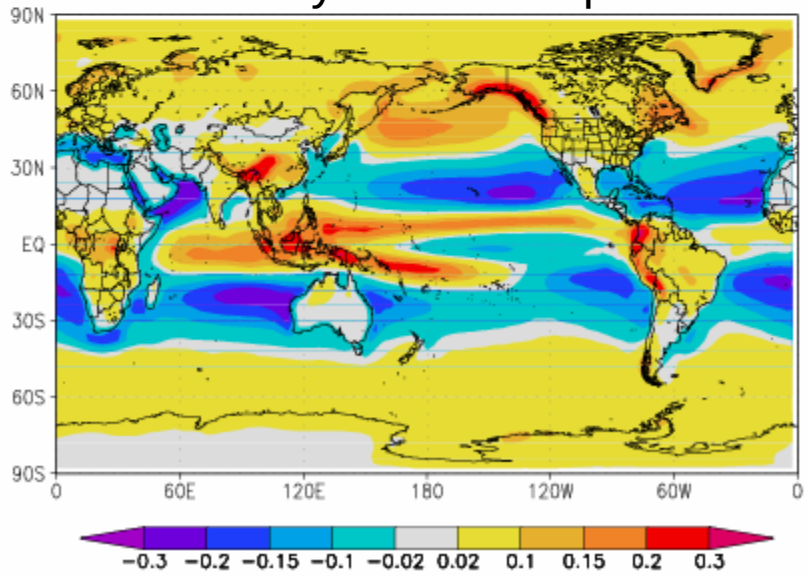
Change in (P-E) for 2100 minus 2000

"Dry regions get drier, wet regions get wetter"

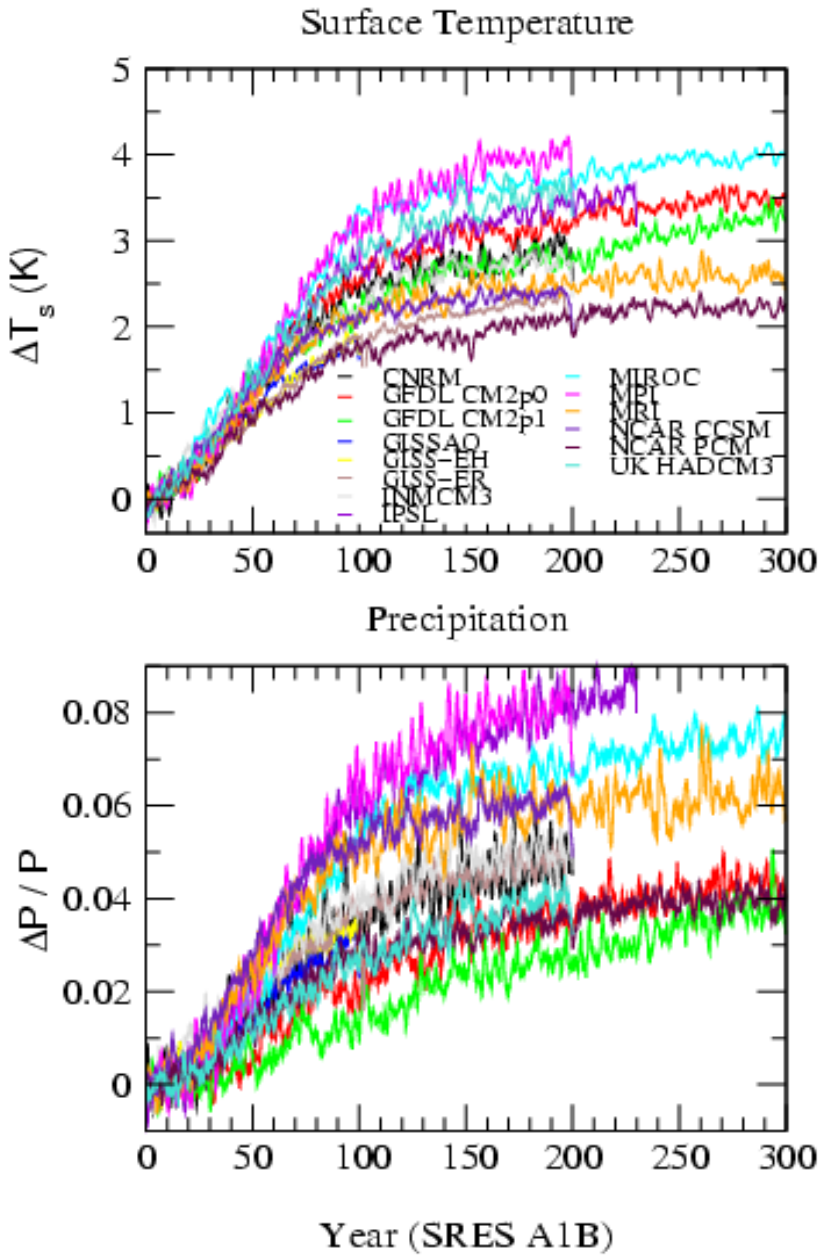


Held and Soden (2006)

"Thermodynamic" component

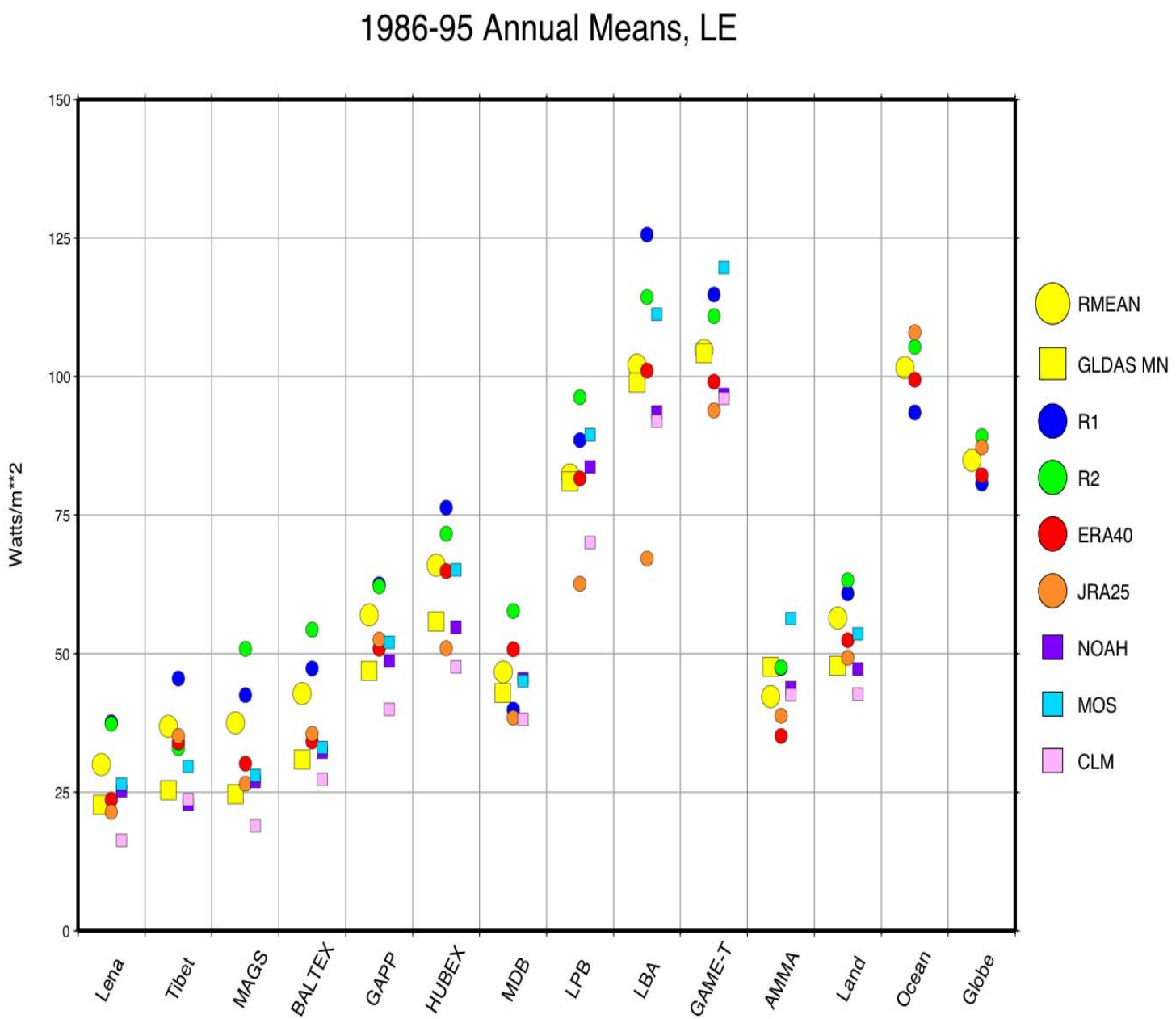


Δ(P-E) mm/da



Vecchi and Soden (2007)

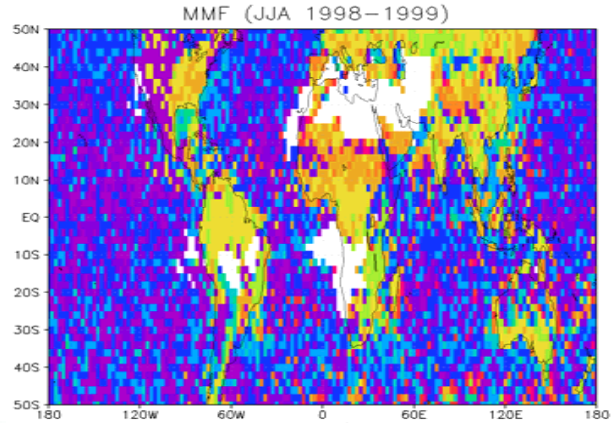
Model Estimates of Evaporation Over the GEWEX CSEs



Annual mean latent heat flux (W/m^2) from R1, R2, ERA40, JRA, Noah, CLM, Mosaic and ensemble means for GHP CSE regions as well as for the Global Land (-60 to + 60), Ocean (-90 to 90), and the entire Globe. The areas are ordered from left to right by their annual mean surface air temperatures in the R1. Note the dry MDB and AMMA areas bracketing the wetter tropical areas.

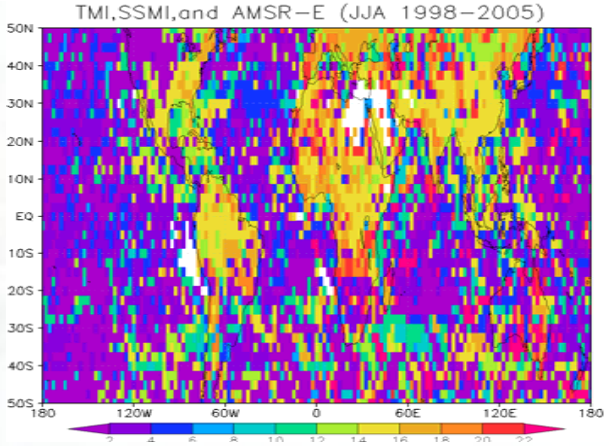
MMF Precipitation Analysis
Local Time of Maximum Precipitation Frequency (Summer)

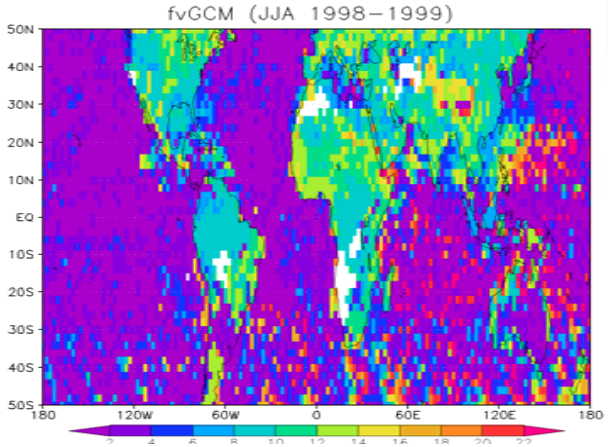
MMF JJA 1998-1999



	Land	Ocean
MW	1600-1800	0200-0600
MMF	1600-1800	0200-0600
fvGCM	0800-1000	0000-0400

Merged MW JJA 1998-2005





fvGCM JJA 1998-1999

The geographical distribution of the local solar time (LST) of summer (JJA) precipitation frequency maximum from 2-year (1998-1999) simulations with the Goddard MMF and the fvGCM and the 8-year (1998-2005) merged satellite microwave only observation. **The MMF reproduces the correct timing of diurnal cycle maximum over the land (1600-1800 LST) and over the oceans (0200-0600) while the diurnal cycle of the fvGCM simulation peaks too early.**

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Status:

- Revised implementation plan posted: http://wec.gsfc.nasa.gov
- 2nd annual NEWS PI meeting – September 2006
- 20+ Investigations underway, results being produced

- Now it is time to start integrating, and addressing the NEWS implementation steps!