NASA ENERGY AND WATER CYCLE STUDY

NEWS

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Outline:

- Define water and energy cycle
- Why water & energy cycle?
- Outstanding issues
- NEWS Strategy & Plan
- Partnerships

NEWS Challenge:

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

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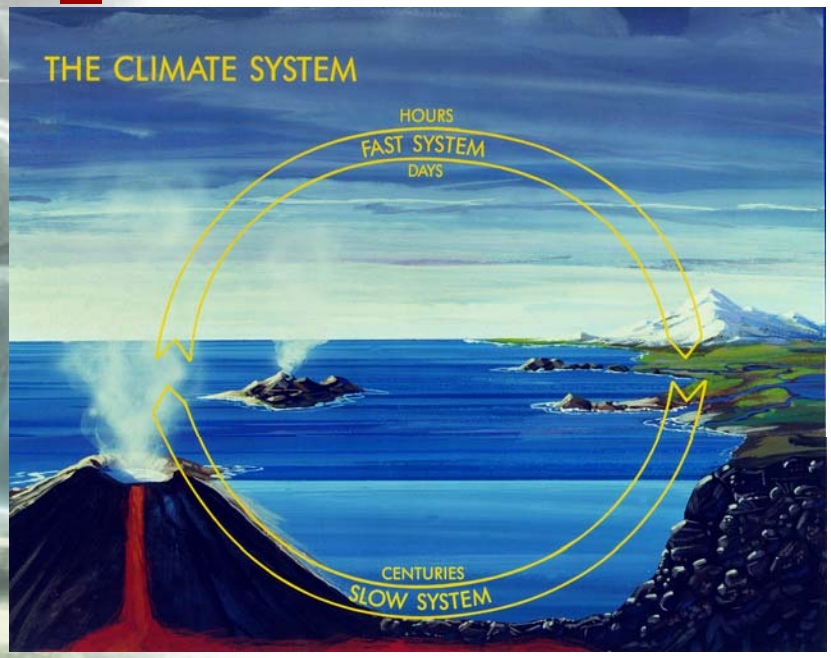
The global water and energy cycle encompasses the movements, transformations, and reservoirs of water, energy, and water-borne materials throughout the Earth system and their interactions with ecosystems and the global water system. The global water and energy cycle operates on the full continuum of space and time scales and involves phase changes and energy exchanges.

The Water and Energy Cycle

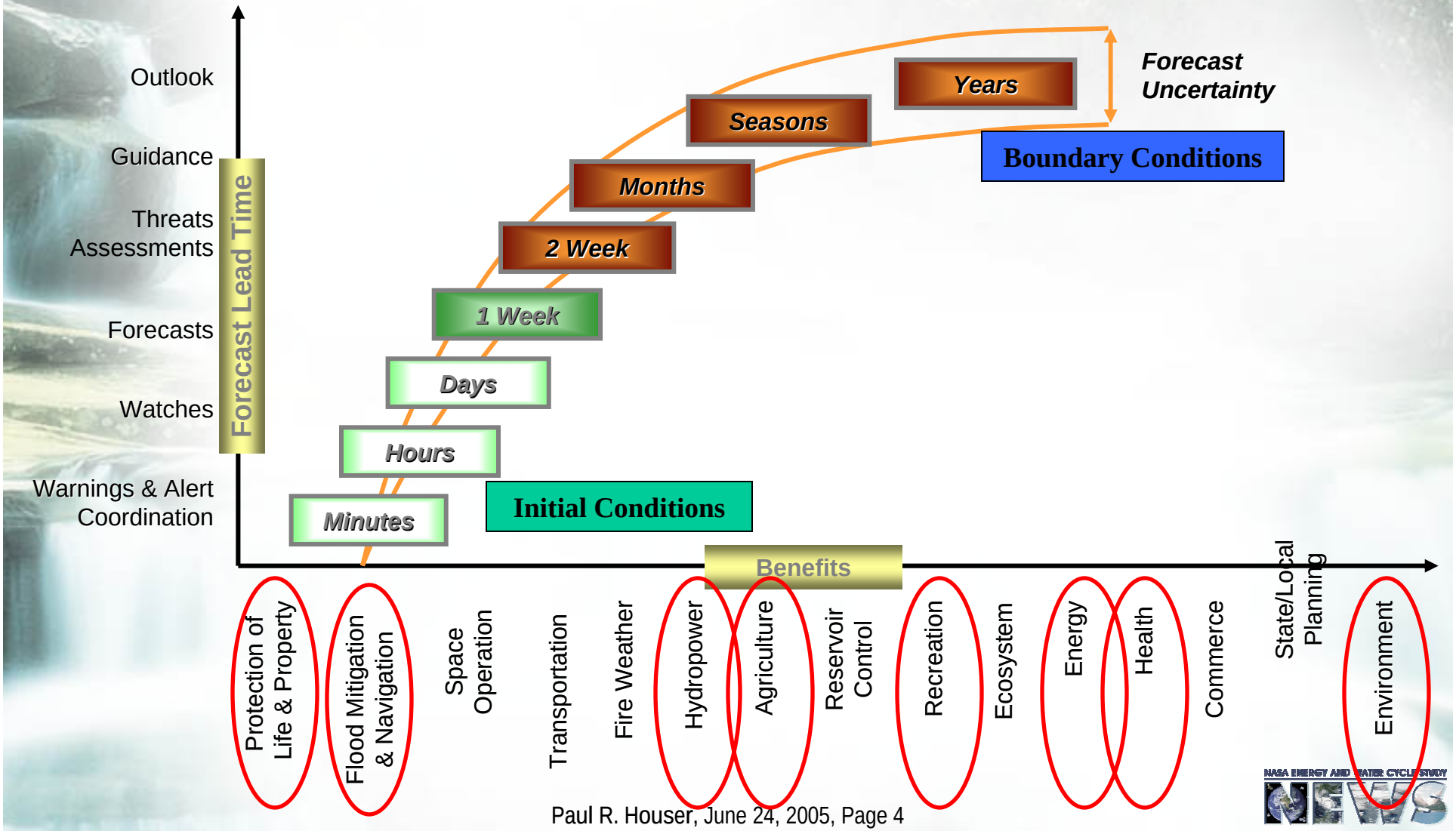
Water in the climate system functions on <u>all</u> time scales: From hours to centuries



- *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*
- *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*
- *Water is the ultimate solvent and global biogeochemical and element cycles are mediated by the dynamics of the water cycle*
- *Water is the element of the Earth system that most directly impacts and constraint human society and its well-being.*

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.

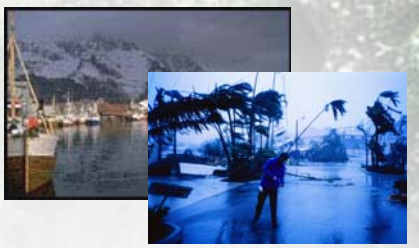
Seamless Suite of Forecasts to meet W&E cycle needs



Why study the water and energy cycle?...

Variations in greenhouse gases, aerosols, and solar activity force changes in climate...

...but, consequences of climate change are realized through the water cycle.



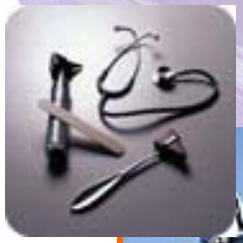
Thus, we must *characterize*, *understand*, and *predict* variations in the global water cycle.

Water and Energy is linked to all 12 Science Application Themes.

Carbon Management

Water Management

Agricultural Competitiveness



Public Health

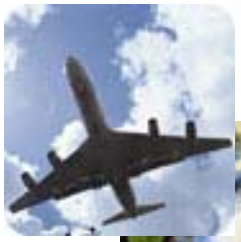
Homeland Security

Invasive Species

Energy Forecasting

Coastal Management

Community Growth



Aviation Safety

Disaster Preparedness

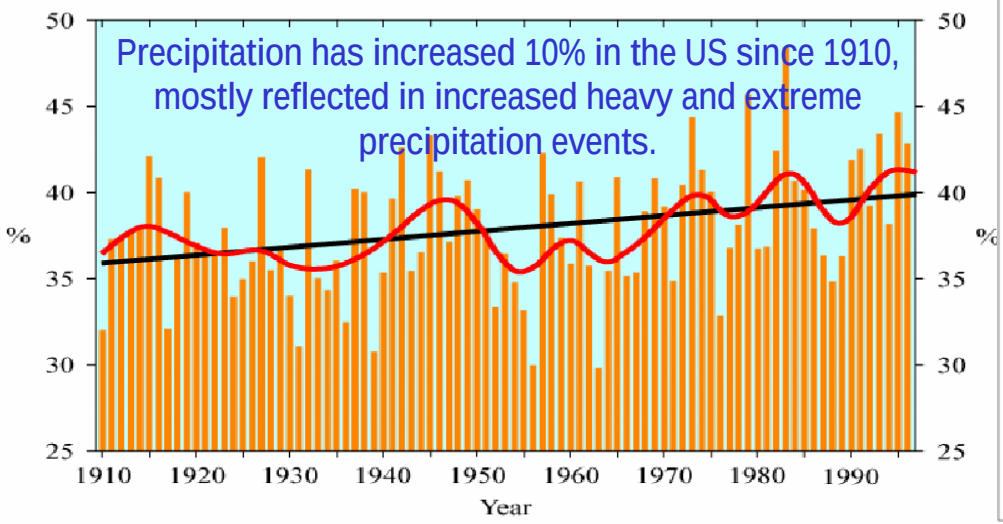
Air Quality

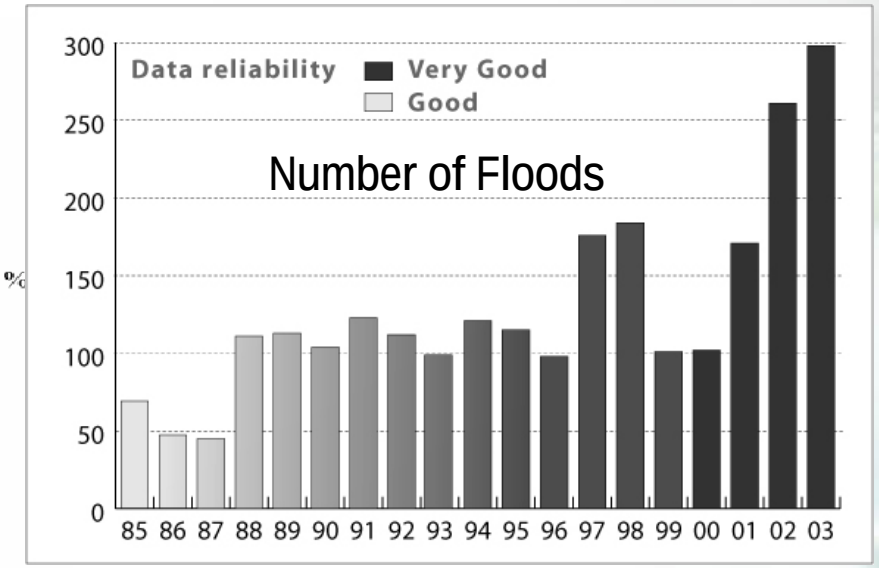
A generally accepted hypothesis regarding global water cycle changes:

"According to model predictions, the *most significant manifestation of climate change would be an acceleration of the global water cycle, leading to ... a general exacerbation of extreme hydrologic regimes, floods and droughts*" (NASA-GWEC, 2000).

"*There is evidence that suggests that the global hydrologic cycle may be intensifying, leading to an increase in the frequency of extremes*" (USGCRP water cycle science plan)

Climate models generally project an acceleration in the rate of global water cycling and an increase in global precipitation … (Morel, GEWEX News, 2001)





From Dartmouth

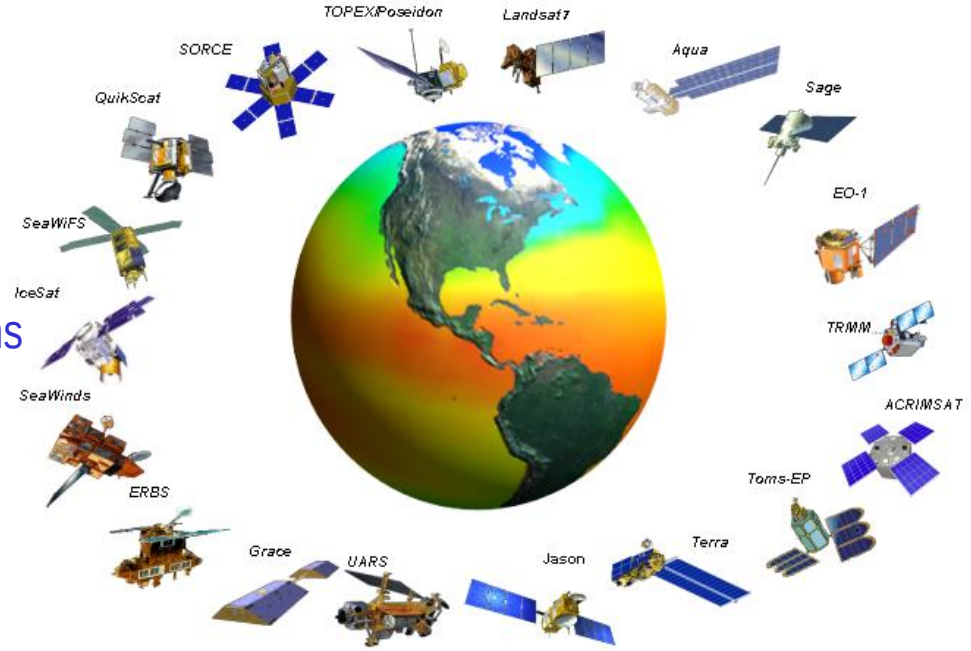
Current Knowledge and Major Uncertainties

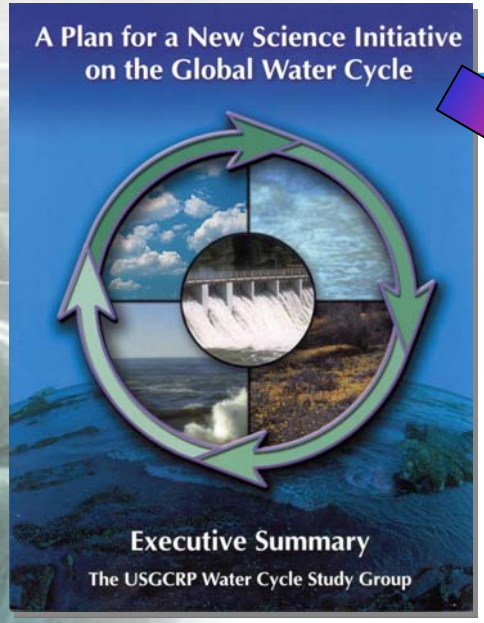
What we know

•global atmospheric and surface temperature distributions
•top-of-the-atmosphere radiation fluxes
•point processes

What we need to know

•global precipitation and water vapor distributions
•cloud radiation absorption and scattering properties
•global soil moisture, snow cover/depth distributions
•surface runoff
•evaporation
•land surface/atmosphere feedbacks
•uncertainties in integrated E&WC processes





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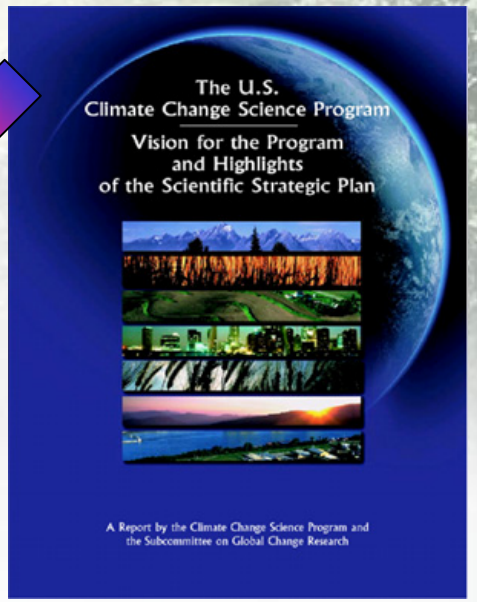
What are the causes of water cycle variations?

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:

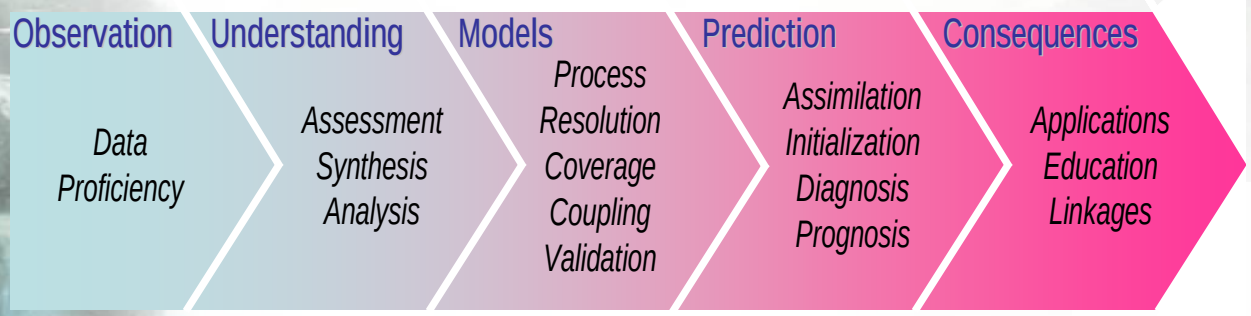
Document and enable improved, observationally-based, predictions of water and energy cycle consequences of Earth system variability and change.

NASA ENERGY AND WATER CYCLE STUDY NEWS

NEWS Integrated Water and Energy Cycle Research

From Observations to Consequences

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

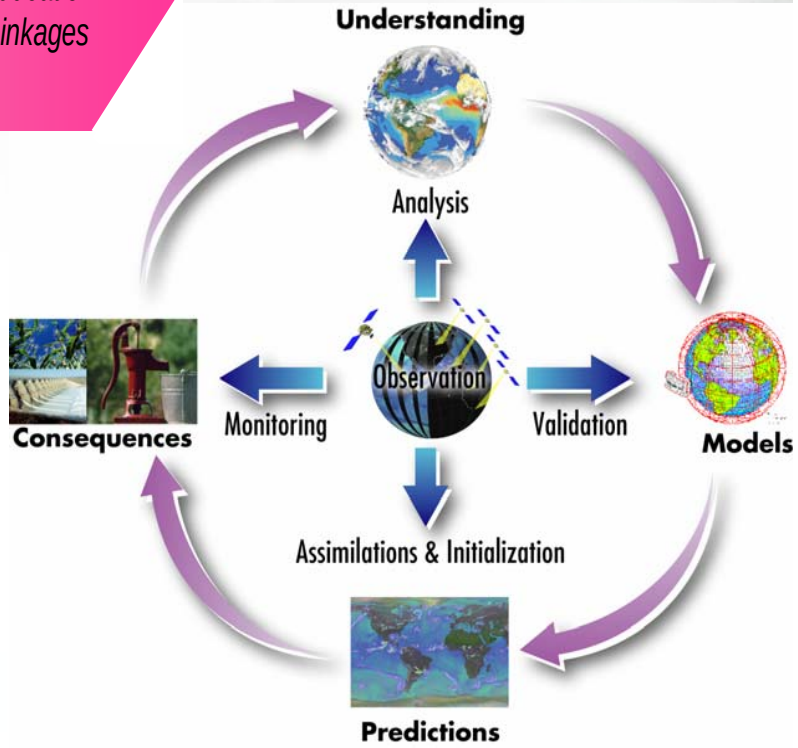


Product-driven NEWS investigations directly cooperate with NASA to produce a coordinated cross-discipline comprehensive solution.

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

NEWS is a interdisciplinary program: Discipline-based research will be performed by existing NASA discplinary programs.

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

DRAFT Unofficial Version (4.22.2004)

Focus Area Linkages
- C = Carbon
- V = Climate variability
- A = Atmospheric composition
- W = Weather
- S = Surface & interior

- T = Technology development
- ✈ = Field campaign
- = Funded
- = Unfunded

Knowledge Base

NEWS Challenge:

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

Exploiting current capabilities and preparing for the future

Phase 1 Deliverables:
- First coordinated global W&E description
- Current prediction system evaluation
- Identify required system improvements

Application
- Selected demonstrations
- Climatology baselines V
- Establish requirements T

Prediction
- Land-cloud model C V A W ✈
- Multi-platform analysis T
- Physics-based modeling T
- New climate datasets V
- OSSEs ✈

Observation
- Advanced Analysis T
- TRMM TERRA AQUA GRACE ICESAT S C W A V
- AURA CloudSAT CALIPSO V A W

Address deficiencies and build prediction system

Phase 2 Deliverables:
- Fix model problems with new observations
- New measurement approaches developed
- End-to-end prediction system developed

- Observations used in planning
- Test prediction of extremes W V
- Develop application metrics

- Enhanced RT models T V W ✈
- Improved physics C V W ✈
- Model convergence T W V
- Super-parameterization T
- Multi-platform analysis T

- Advanced multi-platform retrievals T ✈
- Experimental W&E observation system T ✈
- First Coordinated W&E Obs W V C
- Cold seasons T ✈
- GPM AQUARIUS HYDROS T
- Surface water T ✈

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

- Predict consequences of climate change
- Global hydrologic warning system T
- Demonstrate useful predictions T W V

ANALYSIS & PREDICTION:
- Understand variability in stores and fluxes
- Accurate cloud prediction
- Improve latent heating & convection models

- Reprocess combined observation record V
- Demonstrate prediction capacity W V
- Full end-to-end system test T

- Comprehensive W&E cycle data management and retrieval system T ✈
- Coordinated W & E system T

OBSERVATION:
- Quantify mean state, variability, and extremes of the water & energy cycles
- Flux, transport, and storage rate quantification

2004 IPCC Report 2006 2008 IPCC Report 2010 2012 IPCC Report 2014 2016 IPCC Report 2018

NEWS Components

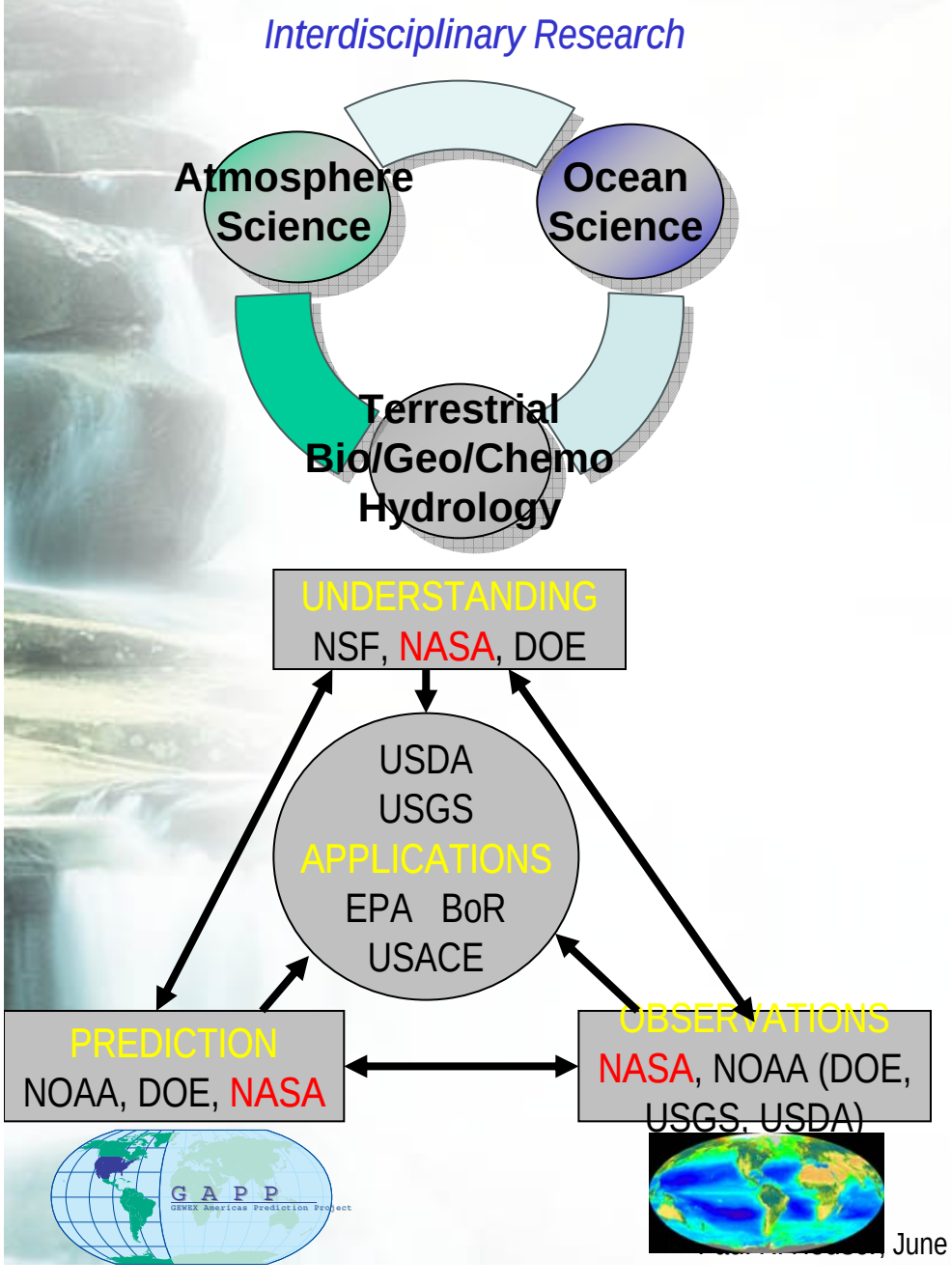
NEWS Constraints

- Focus on water and energy processes and dynamics in the climate system.
- The NEWS challenge is a global scale objective
- Integrate water and energy cycle system components (observations and predictions)
- NEWS elements: Observation, Understanding, Models, Prediction and Consequences
- Make decisive progress toward NEWS challenge
- NASA administers the water and energy cycle focus area as an end-to-end program
- DSS development is not supported by NEWS

NEWS Objectives:

- Develop and deploy experimental E&WC global observing system
- Document the global E&WC by obtaining complete observational record of all associated relevant geophysical properties
- Build fully interactive global climate model that encompasses process-level E&WC forcings and feedbacks – *Climate models that can predict weather-scale extremes*
- Create global surface and atmosphere data assimilation system for E&WC variables
- Assess variability of the global E&WC on time scales ranging from seasonal to decadal, and space scales ranging from regional to continental to global
- Support the application of climate prediction capabilities for estimating the impact of climate variability and change on water resources

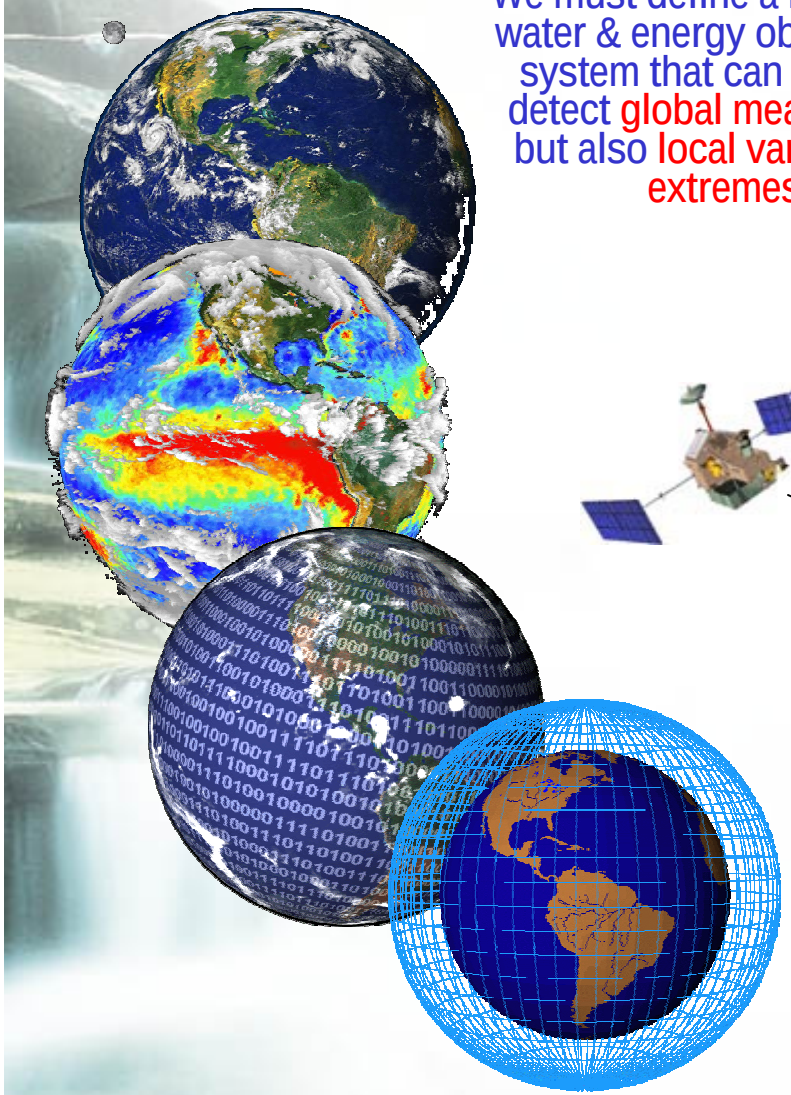
NEWS Linkages



- Formal – CCSP
  - Water Cycle sub-group
    - Basic research (NSF, NOAA, DOE)
    - Applied research (EPA, BoR, USDA, USGS)
  - Climate Variability and Change group
  - Others (Atm. Comp., International, Human Dimensions, e
- Informal
  - NCAR - explicit water cycle program
  - GFDL
  - GAPP – small scale end to end / focused on prediction
  - CUASHI – land observation inspired research
- 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)
- And many more….!

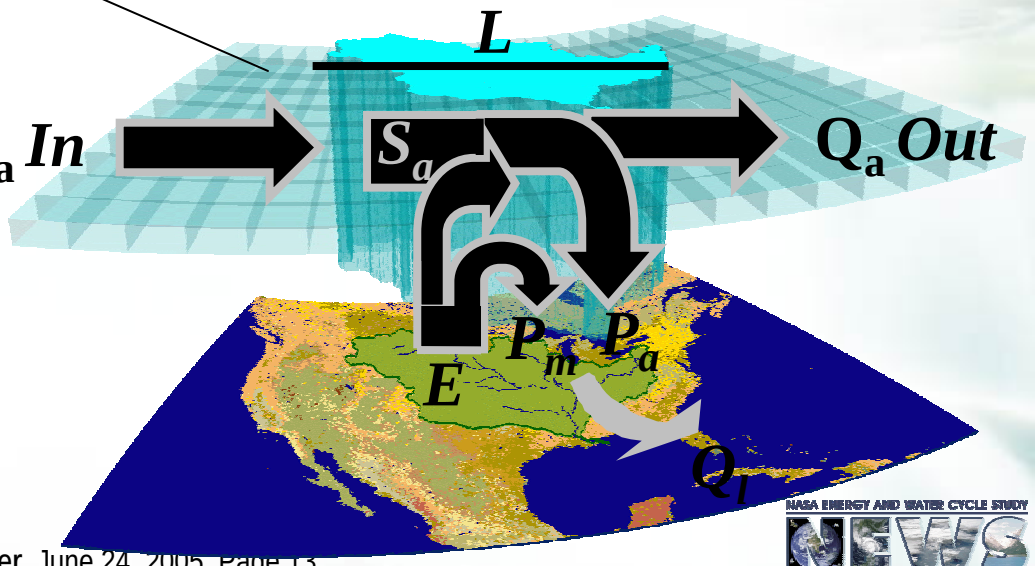
NEWS Observation

We must define a integrated water & energy observation system that can not only detect global mean trends but also local variation of extremes



Input - Output = Storage Change

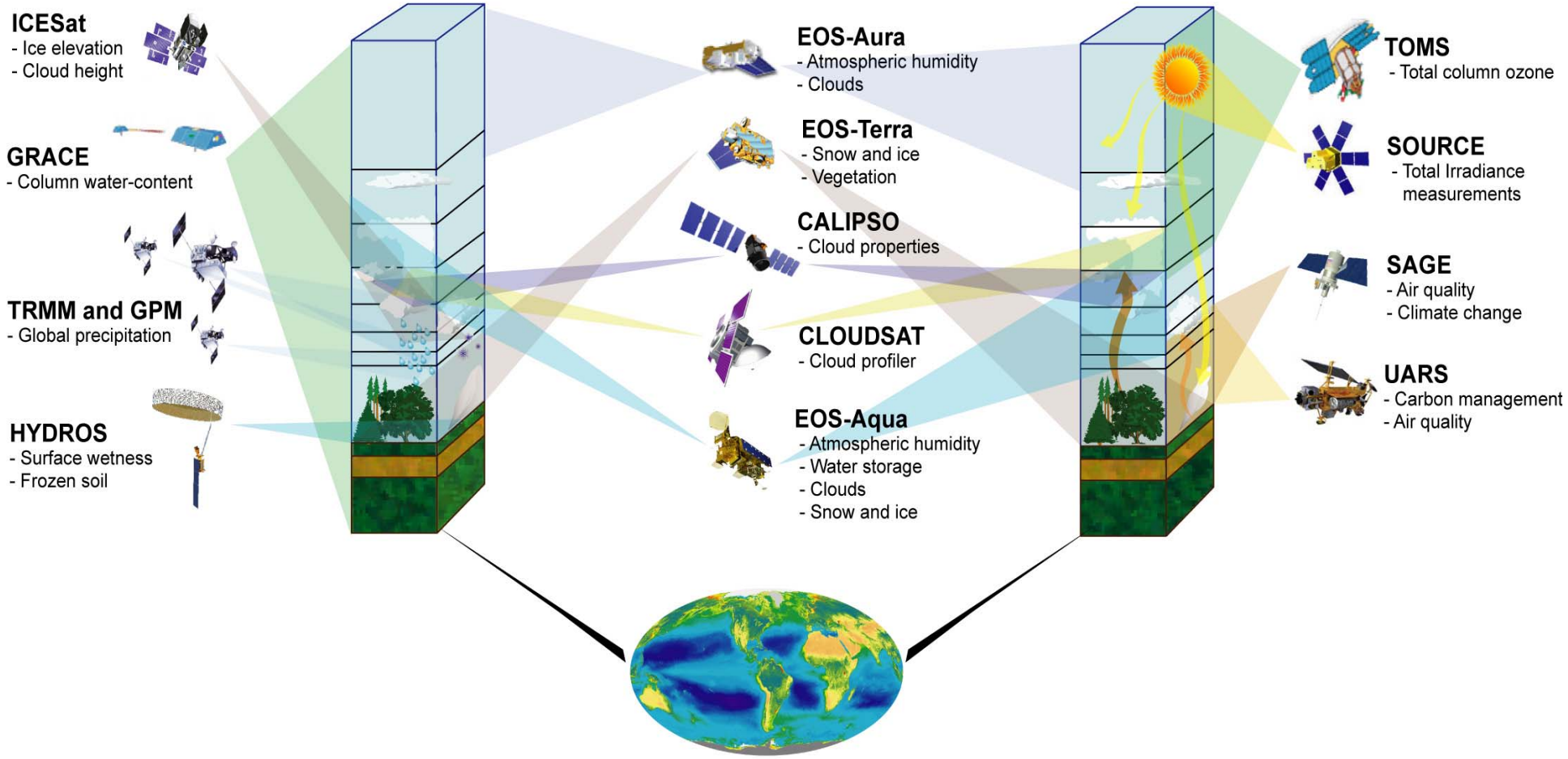
Transport + Evaporation - Precipitation – Runoff - P = ΔLand Storage + ΔWater Vapor



Water Cycle Missions

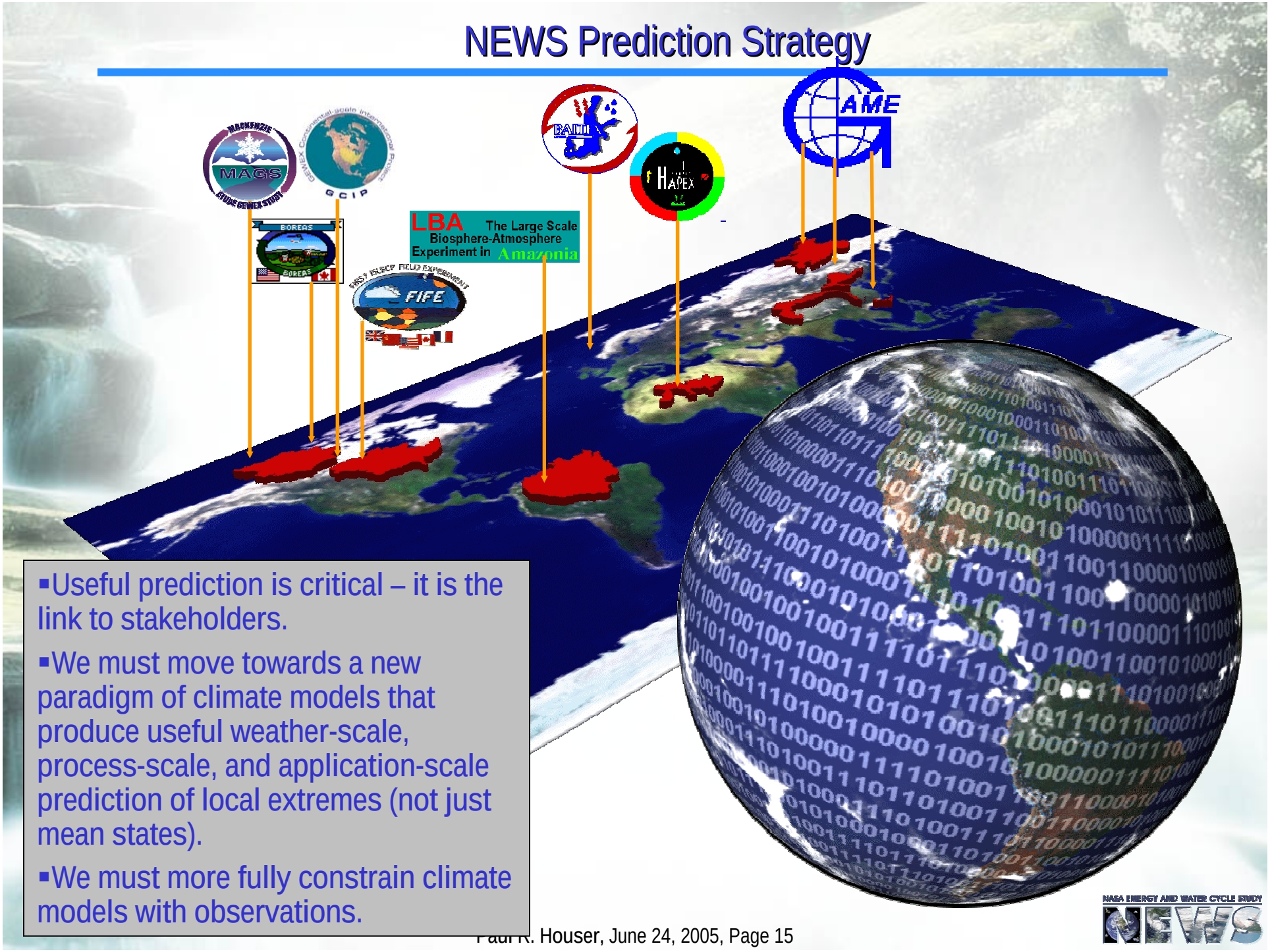
Water and Energy Cycle Missions

Energy Cycle Missions



Complementary Water and Energy Cycle Missions

NEWS Prediction Strategy



- Useful prediction is critical – it is the link to stakeholders.
- We must move towards a new paradigm of climate models that produce useful weather-scale, process-scale, and application-scale prediction of local extremes (not just mean states).
- We must more fully constrain climate models with observations.

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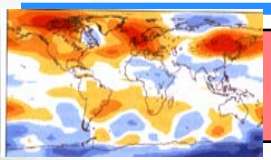
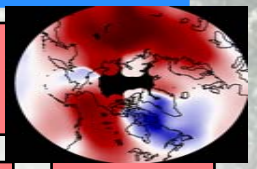
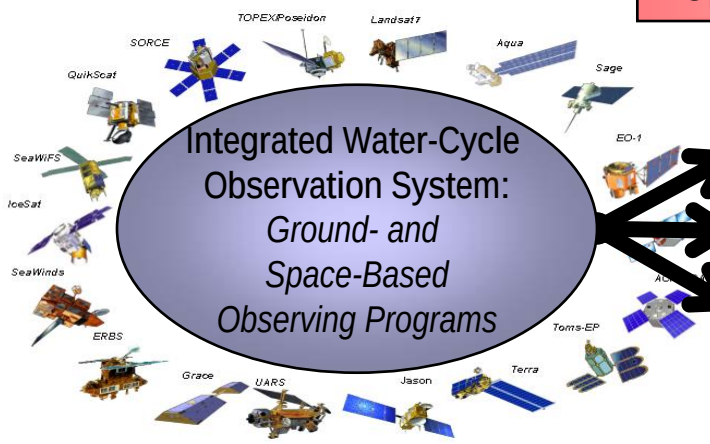
Water & Energy Cycle Prediction Strategy



Global Warming Scenarios



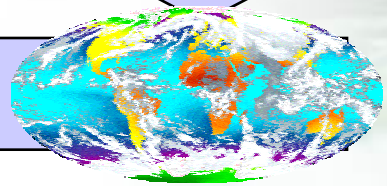
Operational Climate Models (GFDL, NCAR, NCEP)



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

Next-generation Global Water& Energy Cycle Prediction System

Water & Energy Cycle Prediction



What is science/model/data integration (coordinate, synthesis, enhance, link, interface, etc)?

- •Quantification: Intercomparison, geolocation, balance assessment, error assessment, validation, super-ensembles, predictability assessment
- •Unification: Data assimilation, calibration, time/space continuity, etc.
- •Collaboration: Encouraging groups to team towards grand-challenge solutions.

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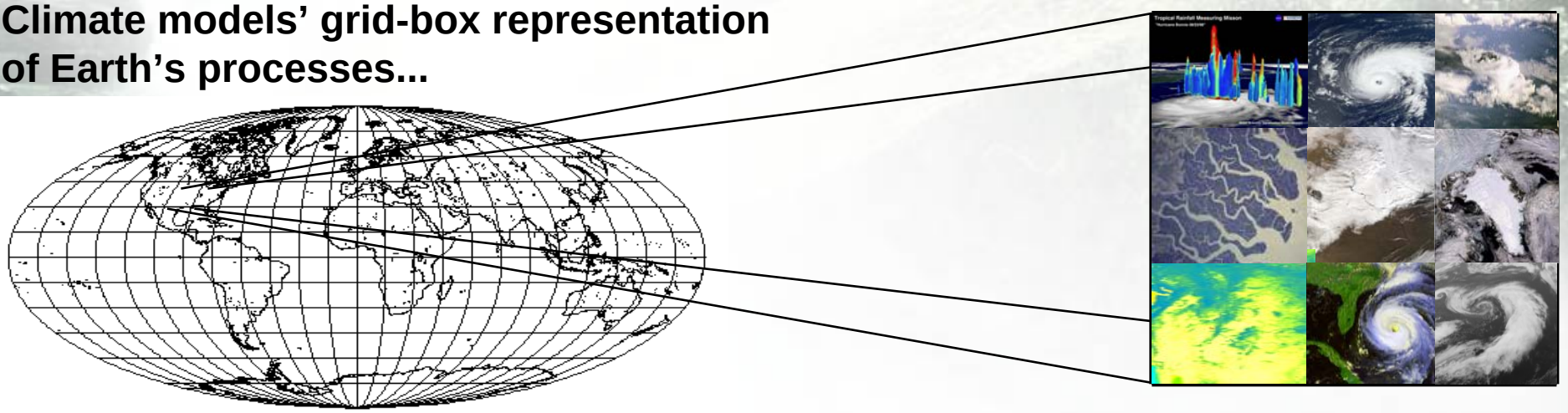
Global Water & Energy Cycle: Advance Understanding and Model Physics

Climate models' grid-box representation of Earth's processes...



Each grid-box can only represent the "average" conditions of its area.

However, controlling processes of the water cycle (e.g. precipitation) vary over much smaller areas.

How can climate models effectively represent the controlling processes of the global water cycle?

"Conventional" approach: make the model grid-boxes smaller (increase resolution)

- Slow progress: may take ~50 years to be computationally feasible

Breakthrough approach: *Simulate a sample* of the small-scale physics and dynamics using high resolution *process-resolving models* within each climate model grid-box

- "Short-cut" the conventional approach (~10 years to implement)

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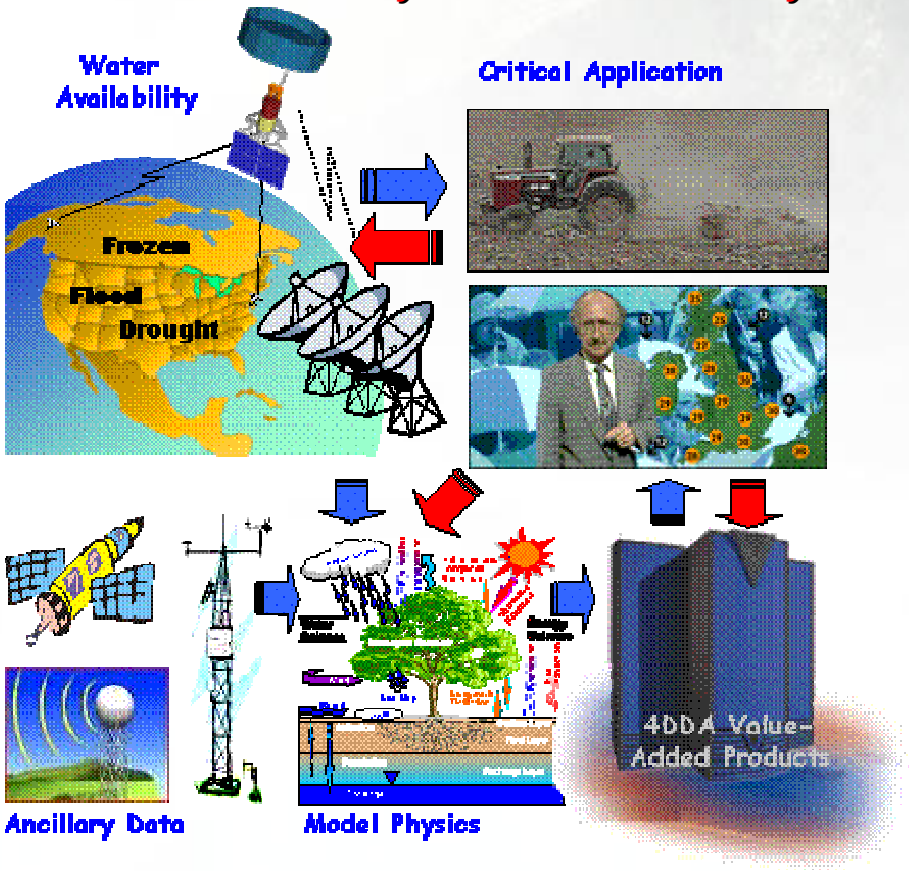
NEWS: Linking Science to Consequences

End-to-end coordination enabling understanding and prediction of the Earth system:

Research driven by the needs of society



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

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NEWS Challenge:

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

Status:

- NEWS NRA: Written, Reviewed, and <almost> announced
- NEWS – Draft Implementation Plan: http://wec.gsfc.nasa.gov
- NEWS – NSIT: 7-member NEWS science integration team formed
- NEWS – Kick off meeting: Sept 7-9, 2005 New York (GISS)
- NEWS - ROSES: Gap-filling amendment to be released in early July