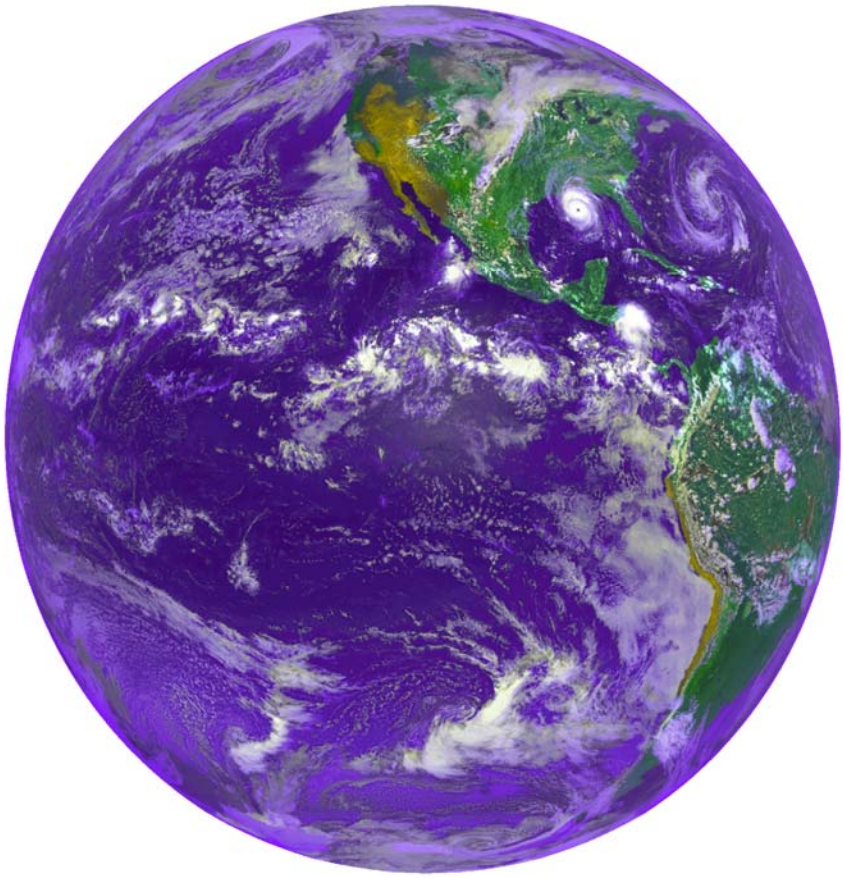
The NASA Energy and Water cycle Study (NEWS) Implementation Plan

Executive Summary



"Predicting Energy and Water Cycle Consequences of Earth System Variability and Change"

Prepared by the NASA Energy- and Water-Cycle Study (NEWS) Science Team

January 2007

Executive Summary

Life on Earth is dependent on water. Our economic, political and social systems will be greatly affected by alterations in the global energy and water cycle, particularly regional precipitation shifts, and extreme hydrologic events, such as floods and droughts. We know, for a fact, that climate variability and change has occurred throughout history, and these changes have had direct impacts on water availability. The key science questions that need to be addressed are *to what extent expected climate changes are related to changes in the rate of the Earth's energy and water cycles*, and *can future water and energy cycling changes be predicted*.

The energy and water cycle is driven by a multiplicity of complex processes and interactions at all time and space scales, many of which are inadequately understood and poorly represented in climate models. There are several distinct reasons to quantify and predict the global water cycle:

- 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 represent both positive and negative feedback in climate system response.
- Water is the ultimate solvent; so global biogeochemical cycles are mediated by the dynamics of the water cycle.
- Water directly impacts and constrains humans and their well-being.

The scientific framework for the *Water and Energy Cycle Focus Area (WECFA)* is outlined in the NASA Earth Science Enterprise Strategy document, issued in October 2003. It is one of six focus areas that define the scientific content of the NASA Earth Science Program, and includes both research and technology components. Integration amongst its disciplinary sub-components is planned and implemented through the NASA Energy and Water cycle Study (NEWS) research program whose central challenge is "***to document and enable improved, observationally-based, predictions of energy and water cycle consequences of Earth system variability and change.***"

The scientific priorities adopted by WECFA and NEWS reflect the issues outlined in the Strategic Plan for the U.S. Climate Change Science Program (July 2003). These are:

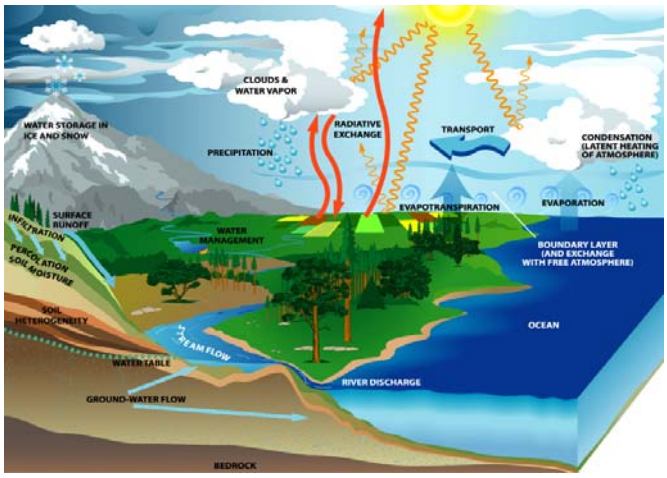


Figure 1: Energy and water cycle conceptualization.

- Understand the mechanisms and processes responsible for the maintenance and variability of the energy and water cycle, including the extent of human interaction.
- Determine how feedback processes control the interactions between the global energy and water cycle and other climate system components, and how these feedbacks are changing.
- Assess the key uncertainties in seasonal-to-annual and longer term energy and water cycle predictions, and outline model improvements needed to reduce these uncertainties.
- Evaluate the consequences, over a range of space and time scales, of energy and water cycle variability and change to human societies and ecosystems, and their affect on nutrient and biogeochemical cycles.
- Provide a scientific basis to support informed decision processes in light of changing water resource conditions and policies.

When fully implemented, the NEWS research program will yield significant advances and breakthroughs in water and energy cycle climate science. Progress in achieving its objectives will be

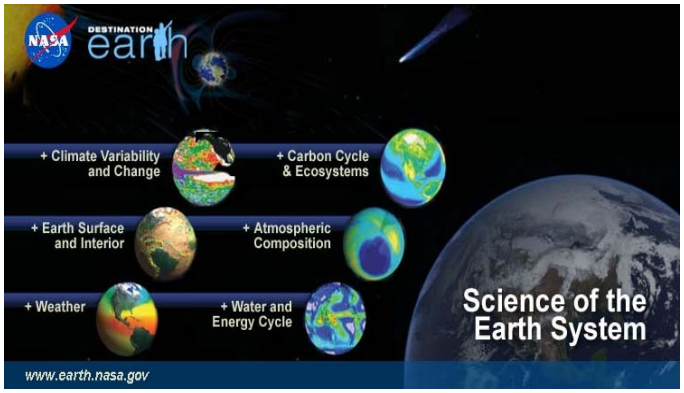


Figure 2: NASA's six Earth science focus areas.

measured against its success in identifying gaps and making significant advances in:

- Promoting the development of an experimental energy and water cycle observing system.
- Assessing global energy and water cycling through an observational record that includes all associated geophysical parameters.
- Building a fully interactive experimental global climate model that encompasses the process-level forcings on and feedbacks within the global energy and water cycle.
- Creating a global land and atmosphere data assimilation system for energy and water variables.
- Assessing the variability of the global energy and water cycle on time scales ranging from seasonal to decadal, and space scales ranging from regional to continental to global.
- Supporting the application of climate prediction capabilities for estimating the societal impact of climate variability and climate changes on water resources over a variety of time and space scales.

The broad national objectives of energy and water related climate research extend well beyond the purview of any single agency or program, and call for the support of many activities that are matched to each agency's respective roles and missions. NASA has the experience and expertise to support the full range of investigations, from global-remote sensing to point-scale field observations, global data acquisition, and the development of prediction systems that can assimilate these measurements.

Advanced Global Observations

Global observations of energy and water cycle variables are needed for three very different purposes. First, long term records of significant climate and hydrologic indicators are needed to characterize the variability and explore the predictability of the global energy and water cycle, based on observed characteristic time scales (frequency spectrum) and apparent responses to quasi-instantaneous disturbances. Second, comprehensive observations of (ideally) all aspects of the complex processes involved in the global energy and water cycle are required to explore the interactions between these processes and conduct penetrating tests of their numerical representations. Finally, complete observation-based determinations of relevant state parameters are needed (ideally) to initialize model predictions. It is expected that observation requirements for process studies and energy and water cycle predictions will be further refined in the course of NEWS implementation.

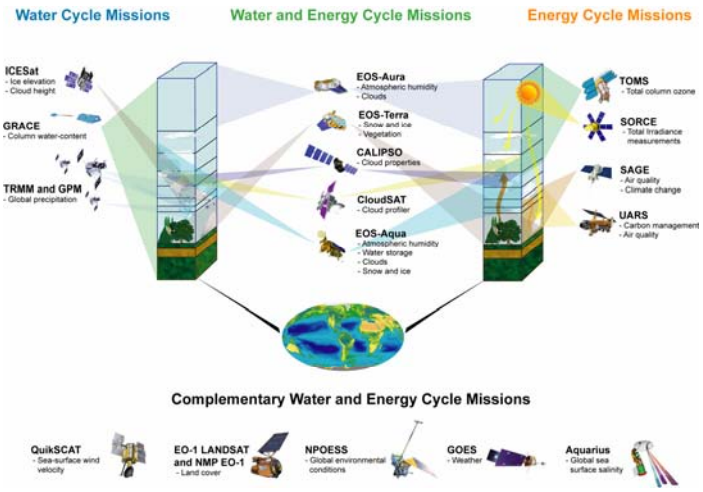


Figure 3: Energy and water cycle satellites.

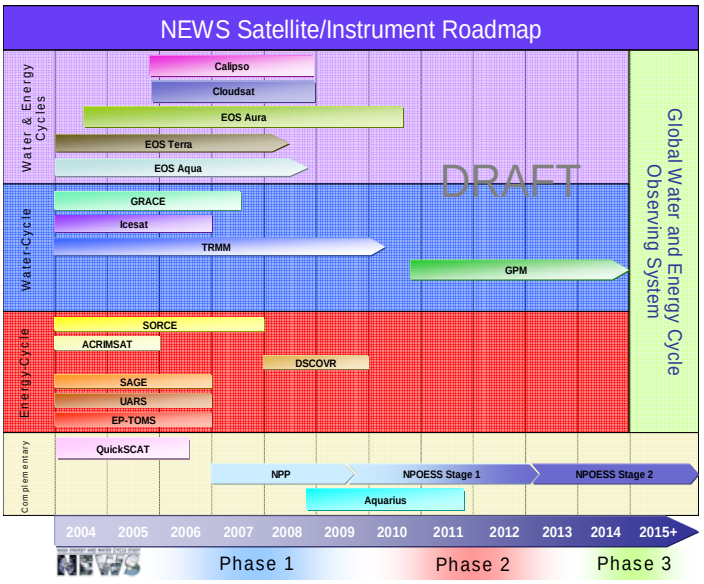


Figure 4: Energy and water cycle satellite timeline.

In terms of the more existing, current and pending missions, the orbiting fleet of NASA research satellites that provide relevant energy and water-cycle observations include: the TRMM precipitation measurement satellite and the Global Precipitation Measurement (GPM) constellation; the EOS Terra, Aqua and Aura satellites that pave the way to the next-generation NPOESS operational satellites; the GRACE Earth gravity measurement mission; the ICESat global topography mission; Landsat and EO-1 Earth surface imaging; QuikSCAT ocean surface wind measurements; CloudSAT and Calipso to measure the horizontal and vertical structure of cloud, snowfall and aerosol optical properties; SORCE satellite to observe solar radiation, and the other relevant energy and water-cycle missions (i.e. TOPEX-POSIDEON, JASON, QuikSCAT, EO-1, NPOESS, GOES, Aquarius, etc.) which are

described on the NASA website (www.earth.nasa.gov).

These experimental/research satellites are typically aimed at measuring specific components and/or processes of the global energy and water cycles, over a relatively short period of time – in a climatological perspective.

While measurement systems scheduled for the near future will fill in critical observational gaps or improve current observational capabilities, only incomplete provisions are being made for high quality measurements of some essential climate variables; notably ocean surface winds and soil moisture. This may require collecting data from an ad-hoc succession of diverse satellite measurements and appropriate data analysis methods to ensure long-term consistency. Inferring reliable climatological records of variables and trends in the global energy and water cycle from multiple space and surface based observing systems remains a research challenge, even for basic quantities such as rainfall. Thus, a substantial long-term effort is required to periodically reanalyze the complete collection of satellite data with improved retrieval algorithms, and to develop the means for satellite sensor inter-calibrations. A recent WCRP Report on Satellite Observations calls for the following action: *"Space agencies should consider an international effort in order to meet the GCOS and WCRP needs for cross-calibration, overlap, and continuity for operational satellites. Meeting these objectives within budgetary constraints will likely require innovative approaches. Such approaches may wish to consider a cooperative mission using a subset of common passive frequencies in the visible, infrared, and microwave spectrum and optimum orbital configuration to serve as a common radiance transfer standard."*

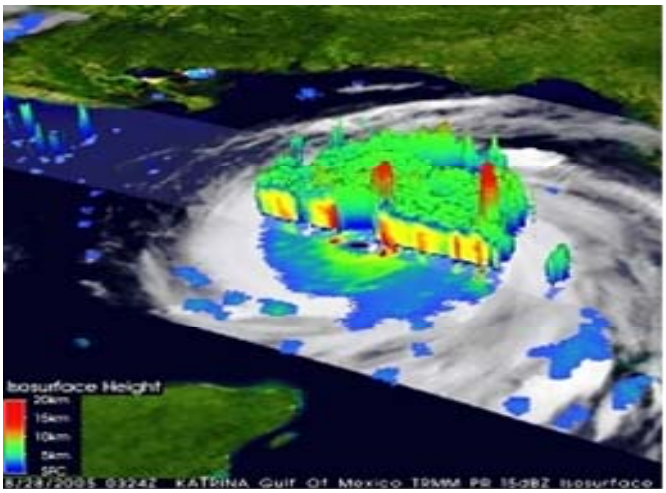


Figure 5: NASA hurricane modeling.

Modeling and Data Assimilation

Modeling and analysis are a key means of making predictions and of integrating the NASA Earth Science focus area results into a comprehensive understanding of the Earth system. Modeling and analysis requirements are diverse, encompass a multiplicity of spatial and temporal scales, and involve a hierarchy of models from comprehensive, global, Earth system models to local, more process-oriented models. Computational models of the climate system play a central role in any effort to understand, simulate, and predict variability and changes in the Earth geophysical, chemical and biological environment. An important goal of the NASA Energy and Water cycle Study is to develop coupled interactive Earth system models that link the atmosphere, oceans, land masses and biosphere into a comprehensive whole. Model-assimilated data sets provide an improved description of much of the global system and its interacting components, and can be invaluable for addressing the major NEWS challenge of tracking global and regional variability in the energy and water cycle. The production and evaluation of analysis of the Earth system are necessary steps in the development of accurate and useful coupled land, ocean and atmosphere data assimilation and prediction systems for the global energy and water cycle. The scales resolved by this analysis must include diurnal to centennial time scales, and individual catchment basins to global spatial scales. The full spectrum of energy and water processes in the system must cover cold and warm season, high and middle latitude, subtropical, and tropical regions, and atmosphere, land and ocean from the subsurface to the top of the stratosphere. To enable application to water resources, streamflow, soil moisture, evaporation and precipitation must be realistically represented.

The ultimate demonstration of NEWS scientific advances is to be found in the development of a new generation of climate models that account for all significant physical parameters in the climate system and testing decadal or longer model predictions against past and current climatological records. The NEWS implementation plan calls for the cooperation of interested modeling teams to develop and test potentially revolutionary model formulations that resolve - at least statistically - the characteristic space- and time-scales of atmospheric energy and water processes and explicitly represent relevant basic parameters. Advances in computing technology now make it possible to implement such process-scale resolving representations that have the potential for more closely reproducing the highly non-linear behavior of atmospheric processes and

delivering much improved approximations of energy and water fluxes.

To achieve the ultimate goal of operational global change predictions and applications across all significant scales NASA has developed collaborations with other Federal agencies, in particular the National Oceanic and Atmospheric Administration (NOAA), National Science Foundation (NSF), Department of Energy (DoE), U.S. Geological Survey (USGS), Department of the Interior (DoI), the Department of Agriculture (DoA), the scientific community-at-large and private industry. Such interagency collaborations reflect NASA contributions to the overall Climate Change Science Program (CCSP) Global Water Cycle (GWC) initiative, and include experimental and operational observations and analysis tools for characterizing air/sea fluxes, ocean circulation, atmospheric state, land surface vegetation, sub-surface hydrology, snow and ice among others; as well as support for the development of new general circulation models and end-to-end prediction systems. In some cases, NASA investments may be required to supplement these activities to ensure that they meet specific needs, for example, *in situ* measurements of parameters that are essential to validating space based remote sensing, as well as quantities needed but not otherwise measured or derived.

Implementation Phases

Implementation of the NEWS program is planned in three phases, each successive phase being focused on a range of research activities, and represents advances beyond the current status of observations, modeling and applications. The next-generation prediction system will be based on a global observing and assimilation system to determine the initial state of climate (especially external and internal forcings) and a modeling system to make the forecast, neither of which currently exist in complete or accurate form. Developing the prediction capability requires progressing through an iterative cycle of research elements: observations, analysis, model development and testing, evaluation, and demonstration, in parallel with the program's research efforts to further develop prediction models and applications. The development of observing/data analysis system capabilities evolves applications.

The emphasis during **phase-1** is to exploit current capabilities and prepare for future developments of NEWS program elements. **Phase-2** focuses on addressing deficiencies and building a viable "prediction" system. **Phase-3**, focuses on the delivery of an end-to-end system to address the NASA Earth Science vision, namely: comprehensive observations to accurately quantify the state and variability of the global water cycle, including time series data sets with no major gaps; routine analysis of variability in storage, transports and fluxes of water; routine prediction of key water cycle parameters (including clouds, precipitation, radiation interactions, energy budgets, and surface hydrological variables), and improved forecasts for use in water management and decision making.

Specifically, the **first phase** focuses on the first coordinated attempt to describe the complete global energy and water cycle using existing and forthcoming satellite and ground based observations, and laying the scientific foundation for essential NEWS developments in model representations of atmospheric energy and water exchange processes. This comprehensive energy and water data analysis program must exploit crucial datasets, some still requiring complete re-processing, as well as new satellite measurements. These data products will then be evaluated for accuracy and consistency, in part by using them in the first diagnosis of the weather-scale (space and time) variations of the global energy and water cycle over the past one-two decades**.** The primary objective is to ensure that results of this analysis effort serve as a recognized data basis with which to compare with corresponding climate statistics produced by existing climate models, quantify systematic deficiencies, and identify needed improvements. The data records to be produced through these efforts are mandatory for developing and validating models that meet NEWS scientific requirements.

	Summary of Key Phase 1 Milestones
Observations and Retrieval	• Continue and enhance global measurements of clouds and aerosols, radiation vertical profiles • Assess methods for quantifying snowfall and mixed precipitation • Evaluate and invest in technology for observing land/water storage • Evaluate global dataset adequacy and quality • Develop improved multi-sensor multivariate geophysical retrieval methods • Quantify NEWS data requirements
Analysis	• Reduce uncertainties in describing the global water/energy budget components • Improve accuracy of precipitation and evaporation estimates • Develop new climate data products (e.g., latent and radiative heating profiles) • Quantify predictability of energy and water cycle variations (all spatial scales) • Develop diagnostic techniques for investigating how multiple feedback processes affect climate responses to forcings
Modeling and Prediction	• Improve current parameterizations of clouds and precipitation, land surface hydrology, atmospheric boundary layer and ocean mixed layer • Develop stand-alone ultra-high resolution cloud process and land hydrology models with atmospheric coupling for water/energy fluxes, soil moisture, runoff • Develop high resolution models for coupled clouds, radiation and hydrology • Test embedded process models in general circulation models • Develop and test advanced energy and water data assimilation methods • Quantify/evaluate causes/differences in precipitation predictions between global precipitation prediction models • Establish performance metrics for energy and water predictions
Applications	• Identify currently available data and analysis products useful for applications • Conduct selective demonstrations of usefulness of current data • Link weather & climate predictions to demonstrate their use in assessments of examples of representative consequences (e.g., extreme events) • Identify observation and prediction system requirements for water management applications

The second phase will focus on correcting the deficiencies identified in the first phase, exploiting and evaluating the newer measurements from recently deployed satellites (especially GPM), advancing multivariate analysis procedures to exploit the full range of observations, and developing new measurement approaches for future flight missions.

Simultaneously, the second phase includes implementing new process-resolving or otherwise improved representations of energy and water exchange processes in general circulation models (GCM), assembling a complete end-to-end data assimilation and prediction system for seasonal and shorter-range forecasts, and testing the predictions against observed transient variations or changes in climate statistics. This will involve reprocessing of legacy data as required. An important objective of the second phase is to deliver useful seasonal predictions that can be applied to, and evaluated for their value to optimize water management decision-making.

	Summary of Key Phase 2 Milestones
Observations and Retrieval	• Facilitate the delivery of an experimental energy and water cycle observation system to acquire comprehensive observations of cloud structure & optical properties, radiation fluxes, precipitation, atmospheric circulation, and aerosols, for testing CRM's, GCM's and CCM's (A-Train and other continuing observations) • Exploit Phase 1 findings in developing advanced retrieval techniques for rain/snow, water vapor, wind etc., w/sampling density to directly determine transport, divergence terms, and soil moisture, water storage and freeze/thaw events • Identify and develop innovative remote sensing methods • Compare new remote sensing capabilities with in situ data from experimental sites and/or field campaigns • Form partnerships with operational agencies
Analysis	• Apply multi-variate analysis techniques in retrospective analysis of climate variability to investigate causes of natural variability and fast feedback processes, and discriminate between forced and unforced responses • Assess climate variability (short time scales) and forcing (longer time scales) • Assess the predictability of energy and water variations on an expanded range of space and time scales
Modeling and Prediction	• Develop simplified process resolving representations of precipitation and land hydrology for GCM simulations • Evaluate conventional parametric representations of clouds, precipitation, boundary layer, land hydrology in climate models compared with weather events and observed seasonal/interannual variations • Assess similarities and differences between model climate variability on short time scales and forced responses of models on longer time scales • Improve representation of slow feedback processes • Determine most informative model products for predicting water supply • Assemble experimental end-to-end energy and water cycle prediction system from observations to data assimilation, model initialization and prediction, to assessments of hydrological consequences and decision support systems
Applications	• Test ability to predict consequences of extreme hydrological events • Develop prediction skill metrics aiding decision making procedures

The third phase will focus on facilitating the development of a capability for short term, and annual to decadal-scale climate predictions, in cooperation with the climate modeling community. The implementation plan calls for delivery of advanced atmospheric GCM formulations that can demonstrably predict changes in the energy and water cycle up to at least several seasons. An objective of the third phase will be testing against observations and decadal predictions produced by fully interactive models of the complete climate system and/or simpler configurations involving the partial replacement of active components by observed boundary conditions. The third phase will also aim to deliver more penetrating tests of model performances using extended analyses of the widest possible range of observations, including some of the new global observing systems evaluated in the second phase.

	Summary of Key Phase 3 Milestones
Observations and Retrieval	• Complete assembly and deployment of a full experimental energy and water cycle observing system • Further development of a comprehensive data management and retrieval system • Reprocess the combined record of energy and water global observations using advanced retrieval methods
Analysis	• Characterize the slower feedback processes that effect the energy and water cycles
Modeling and Prediction	• Produce a fully interactive global climate system model that characterizes the complete energy and water cycle • Construct a comprehensive energy and water data assimilation and prediction system • Conduct a full end-to-end prediction system test against the past 30-50 year observational record
Applications	• Test the accuracy of energy and water cycle prediction products for applications to water resource management. • Demonstrate ability to predict consequences of climate change and hydrologic extremes • Demonstrate feasibility of a global hydrologic warning system

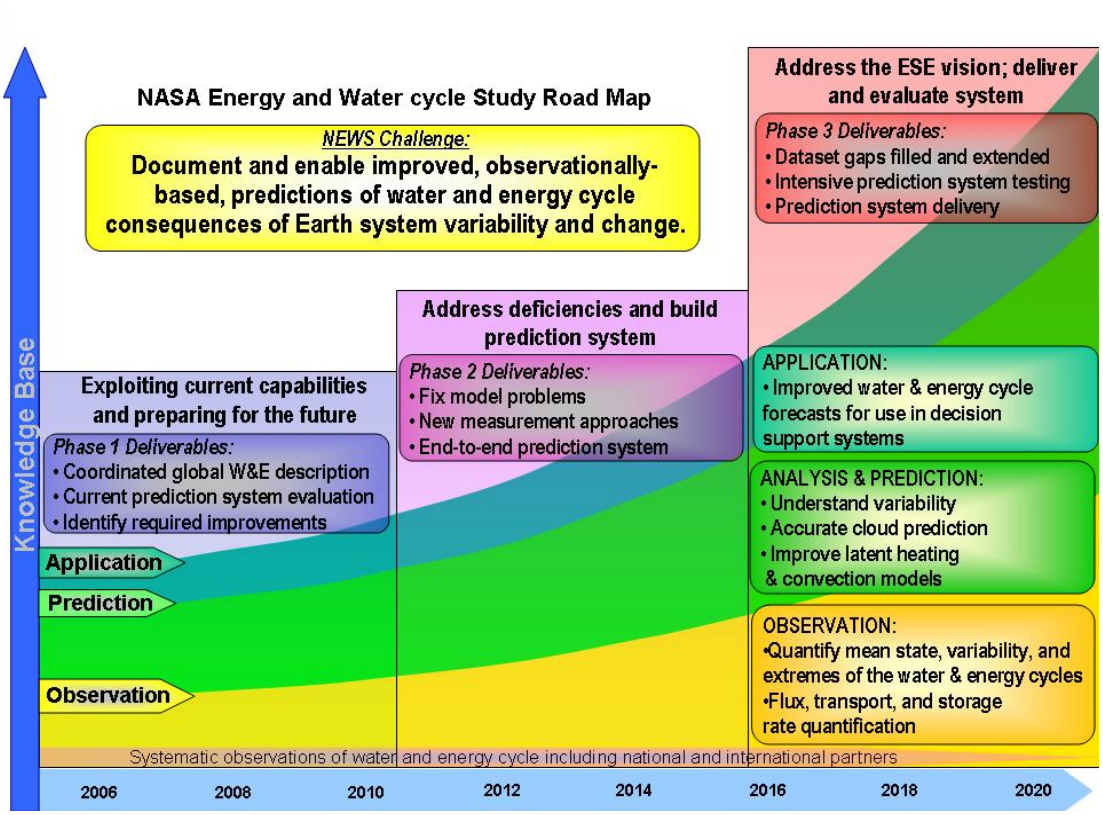


Figure 6: NASA Energy and Water cycle Study roadmap.

It is envisioned that the NEWS program will build upon existing NASA-supported basic research in atmospheric physics and dynamics, radiation, climate modeling, and terrestrial hydrology. While these NASA programs fund research activities that address individual aspects of the global energy and water cycle, they are not specifically designed to generate a coordinated result. The implementation concept for NEWS is specifically intended to promote innovative mechanisms to work across these programmatic boundaries.

The NEWS activity will be comprised principally of product-driven investigations, exploration-driven investigations and integrative effort studies. NEWS will include:

- *Product-Driven Investigations:* Systematic research investigations intended to combine and interpret past and current observations, derive global analysis and prediction tools and products and identify technological and observational requirements to guide future NASA investments.

- *Discovery-Driven Investigations:* Fundamental investigations to identify key missing elements and explore new scientific frontiers to improve capabilities and knowledge of the energy and water components of the Earth system.
- *Integration-Investigations:* Integration of the WECFA and NEWS science activities by acting as an interface with other Earth Science research foci and activities, coordinating the conduct of NEWS investigations, and leading specific studies needed for integration of the results of independent product-driven or discovery-driven investigations.

Exchanges of energy and water within the Earth system involve a multiplicity of interactive processes. Understanding and predicting these processes require a complex multi-disciplinary research program, innovative observing tools, and advanced model developments. Organizing these complex activities calls for dedicated management and oversight approaches to ensure that both financial and human resources are efficiently applied to serve NASA Earth Science priorities. Clearly, the broad national objectives of energy and water related climate research extend well beyond the purview of any single agency or program, and involve the support of activities that are essentially matched to each agency's respective roles and mission. Accordingly, NEWS will focus its priorities on scientific activities that are consistent with NASA's primary responsibilities in this area of research. In principle, NEWS does not plan to undertake significant research on all program elements, but looks to other NASA programs, other Federal agency programs, and the international community, as sources of essential data and knowledge. Examples include experimental and operational observations of air/sea fluxes, ocean circulation, atmospheric state, snow and ice; as well as support for the development of new general circulation models. In some cases, NEWS investments may be required to supplement these activities to ensure that they meet NASA needs, for example, *in situ* measurements of parameters that are essential to validating space based remote sensing, as well as quantities needed but not otherwise measured or derived.

Solution Support

With respect to application spin-offs, NASA has identified twelve theme areas to exploit the Earth Science technologies (see Figure 8). For each of the theme areas a systems engineering approach is used to incorporate remote sensing observations and modeling predictions to decision support tools.

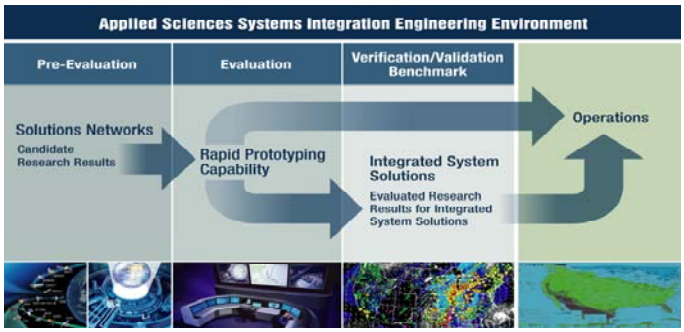


Figure 7: NASA's applied Earth sciences system engineering integration environment.

In this approach NASA data are evaluated verified/validated and benchmarked to study possible improvements. The primary emphasis of the program is to supply NASA data and information that may yield improvements to other groups, emphasizing US Federal agencies having broad or national applications. The number of potential NASA partners for these application areas is large. NOAA, DoD, EPA, USDA, USBR, USGS, NMFS, NOAA-NESDIS, NIH, CDC, USFWS, BLM, FEMA, in addition to state and local agencies (DEQ, etc.) are all potential users of a wide variety of information concerning the management of the Earth, and forecasts for future variability and change.

NEWS is also a major contributor to the interagency coordinated efforts planned under the National Climate Change Science Program (CCSP) which incorporates the US Global Change Research Program (USGCRP) and the Presidential Climate Change Research Initiative (CCRI). The primary NEWS interface with the NASA Applied Science Program, as well as with the array of energy and water related applications, will be through the recently approved NASA Water Cycle Solutions Network (WaterNet).

Figure 8: NASA's national priority applications.

NASA's principal energy and water research connection to the international science community is through the World Climate Research Programme (WCRP), especially the Global Energy and Water Experiment (GEWEX), but including aspects of CLIVAR and CLiC. GEWEX has overall international WCRP responsibility for providing an interface with all the national space agencies with respect to energy and water cycle related global climate research requirements, instruments, data, and science support. NEWS and GEWEX share emphasis on improved coupled land-surface and atmosphere representations in prediction models at all scales, illustrated the direct links to the water cycle, and has provided increased importance of both existing and future satellite sensing of the land and near surface parameters. Other international connections include those with the International Geosphere-Biosphere Program (IGBP), the International Human Dimensions Program (IHDP), and the Group on Earth Observations (GEO).

Program Integration

The NEWS program recognizes the need for a comprehensive effort to integrate model, satellite and in-situ datasets that are required to quantify the rate and variation of water and energy cycling throughout our global environment. Emerging data collection, integration, modeling, management, distribution and analysis technologies provide a unique opportunity for provision of integrated water and energy cycle datasets to various user communities. In order to address the NEWS challenge, NEWS will require integration and interpretation of global water and energy cycle changes in the vertical fluxes, the amount of storage, and lateral fluxes.

As a first-order science integration task, steps have been taken to establish a NEWS Data Integration Center (NDIC), whose purpose is to serve the overall NEWS team and its partners by compiling, integrating, diagnosing and disseminating water and related energy cycle observations and predictions that are required to pursue the NEWS challenge. Data integration is multifaceted: and encompasses (a) spatial-temporal rectification allowing inter-comparison and quality evaluation of disparate data; (b) physical data and error constraints using four dimensional data assimilation techniques, and (c) interconnection of disparate NEWS research teams. A key NDIC task is enable the quantification of global water cycling rates, which requires global data integration for vertical water fluxes, land water storages, and lateral land water fluxes. These observations will provide the basis for the NEWS team to develop: diagnostic trend studies, transient variability and predictability; model validation; and initialization. Essentially, the NDIC will integrate and interpret past, current and future global space-based and in-situ water and energy cycle observations and model predictions to instill improved water and energy cycle understanding and information into global prediction, application, and education systems. The NDIC will primarily serve the NEWS team, but will also be open for collaboration with a large number of scientists, educators, managers, and research organizations to quantify the rate of global water and energy cycling through integration and interpretation of information on global changes in the vertical fluxes, storages, and lateral fluxes.

In summary, NEWS integrates the NASA Water and Energy Focus Area science activities, acts as an interface with other Earth Science research foci, and leads specific studies needed for integration of the results of independent investigations. Exchanges of energy and water within the Earth system involve a multiplicity of interactive processes. Understanding and predicting these processes require a multi-disciplinary research program, innovative observing tools, and advanced model developments. Organizing these activities has been assigned to a dedicated NEWS Science Integration Team (NSIT) to ensure that needed integration of various NEWS projects and linkages with partners and NASA system components are efficiently applied to serve NASA Earth Science priorities.

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Acronyms:

Aquarius	Satellite mission to measure global sea surface salinity
BLM	Bureau of Land Management
CCNY	City College of New York
CCRI	Climate Change Research Initiative
CCSP	Climate Change Science Program
CDC	Climate Diagnostic Center
CIMAS	Cooperative Institute for Marine and Atmospheric Studies
CLiC	Climate and Cryosphere
CLIVAR	Climate Variability and Predictability
CREW	Center for Research on Environment and Water
CSU	Colorado State University
DEQ	Department of Environmental Quality
DoA	Department of Agriculture
DoD	Departments of Defense
DoE	Departments of Energy
DoI	Department of the Interior
EOS Terra	Satellite mission for atmosphere, land, and oceans
EPA	Environmental Protection Agency
FEMA	Federal Emergency Management Agency
GCM	General Circulation Model
GCOS	Global Climate Observing System
GEO	Group on Earth Observations
GEWEX	Global Energy and Water Experiment
GISS	Goddard Institute for Space Studies
GMU	George Mason University
GOES	Geostationary Operational Environmental Satellite
GPM	Global Precipitation Measurement
GRACE	Gravity Recovery and Climate Experiment
GSFC	Goddard Space Flight Center
GWC	Global Water Cycle
ICESat	Ice, Cloud, and land Elevation Satellite
IHDP	International Human Dimensions Program
JASON	Oceanography Mission Satellite
JPL	Jet Propulsion Laboratory
Landsat	Land satellite Earth surface imaging
MIT	Massachusetts Institute of Technology
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NDIC	NEWS Data Integration Center
NESDIS	National Environmental Satellite and Data Information Service
NEWS	NASA Energy and Water cycle Study
NIH	National Institutes of Health
NMFS	National Marine Fisheries Services
NOAA	National Oceanographic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSF	National Science Foundation
NSIT	NEWS Science Integration Team
PNNL	Pacific Northwest National Laboratory
QuikSCAT	Satellite mission for ocean surface wind measurements
RSS	Remote Sensing Systems
TOPEX-POSIDEON	Satellite to map ocean surface topography
TRMM	Tropical Rainfall Measuring Mission
UCI	University of California, Irvine
UMBC	University of Maryland Baltimore County
USBR	US Bureau of Reclamation
USDA	United States Department of Agriculture
USFWS	US Fish and Wildlife Services
USGCRP	US Global Change Research Programme
USGS	US Geological Survey
WCRP	World Climate Research Programme
WECFA	Water and Energy Cycle Focus Area

The full version of the NEWS Implementation Plan, a living document, may be found at
http://www.nasa-news.org/implementation_plan/