NASA Energy and Water Cycle Study
Abstracts of selected proposals.
(NNH07ZDA001N-NEWS)

This synopsis is for the NASA Energy and Water Cycle Study (NEWS) solicitation of the NASA Research Announcement (NRA) ROSES-2007 NN-H-07-Z-DA-001-N. The NRA offered opportunities for research to contribute to the goals of the NEWS program by performing studies to address one of two goals. The first goal was to examine the dynamics of the water and energy cycles in the context of extreme events, such as floods, droughts, etc. The second goal was to generate estimates of the global evaporation flux, i.e. the movement of water from the land or ocean surface into the atmosphere. Evaporation projects were to use information from each the water cycle and the energy cycle, in hopes that juxtaposing the two distinct sources would allow for improved understanding of the environment. All projects will work to collaborate with existing NEWS projects in an effort to integrate different projects to allow research results to answer larger questions that confront society, such as "Is the Global Water Cycle accelerating?", which single projects are unable to comprehensively address.

NASA selected 10 proposals for funding out of 48 submitted proposals. The NRA had forecasted that available funding levels would be approximately $1,000,000 per year, for four years. It is currently estimated that total funding for the selected investigations will be approximately $6,600,000 over the four programmatic years of research activity. Selected proposals offer a course of research for either a three or four year period. The Principal Investigator, institution, and investigation title are provided for the selected projects. Other co-investigators are not listed here. In the future, please see the NEWS web-site, http://nasa-news.org, where information on these projects will be available once they have commenced.

Robert Adler/University of Maryland College Park
Global Precipitation Variations and Extremes

This proposal focuses on the science question: How are the characteristics of global precipitation changing in terms of means, variations and extremes, and what is the confidence in our conclusions? Important characteristics of global precipitation (including global and regional means, extremes, variations and trends, and the confidence limits thereof) will be determined by extending, improving and analyzing the 29+ year standard merged precipitation analyses of the Global Precipitation Climatology Project (GPCP) of the WCRP/GEWEX and other shorter, high quality data sets such as from TRMM.

Specifically, this project will: 1) establish the climatology of global precipitation, the mean spatial and seasonal variations, and inter-annual variations, and the uncertainty of these estimates; 2) examine inter-decadal changes and recent (30-year) trends in precipitation (global and regional) and relate these to large-scale forcing (e.g., ENSO, NAO and volcano/aerosol impacts) and variations and trends in surface temperature; 3) develop a climatology of precipitation extremes (and time history of such); and 4) continue to produce, monitor, validate and improve the monthly global, merged GPCP analyses.

This project will also actively contribute to the integrated NEWS effort to analyze the full global water cycle as a whole, examining all the relevant observational global data sets (e.g., ocean evaporation, clouds, water vapor, etc.), in conjunction with other investigators, to identify inconsistencies, artifacts and limitations in the data sets and better understand both the means and variations in all the water cycle components. As part of this effort we will derive best estimates of precipitation and confidence limits so that overall water (and energy) balances can be derived.

John Albertson/Duke University
Identifying Controls and Predictability of Extreme Drought Persistence from Remote Sensing Data.

The scale and frequency of water-related disasters is increasing. In the 1990s alone there were an estimated 280,000 deaths worldwide due to drought. In fact, nearly 90% of the total deaths due to natural disasters in the 1990s came from hydrometeorological events. It is expected that by 2025 up to 20% of the world's population is likely to be found in water-scarce countries. Beyond death and human suffering these droughts have large economic impacts. For example, the drought in Zimbabwe of the 1990's has been tied to a change in GDP of -11%.

Important feedbacks and interactions exist between surface moisture and convective precipitation during summer months and these feedbacks have the potential to increase the persistence of droughts. Hence, for a given set of synoptic conditions, the integrated time history of surface water and energy fluxes controls the timing and onset of summertime convective precipitation. NASA has contributed to the understanding of these feedbacks predominately through large-scale climate modeling studies. However, the generality of these results is limited by the coarse resolution of the land-atmosphere dynamics and the highly simplified model formulations. The proposed project seeks to identify the controls and predictability of persistence in extreme droughts from the use of existing remotely sensed data of land surface and cloud conditions. Through the use of distributed data sets, this project will be able to consider the effects of spatial information at potentially important length scales and avoid model-injected-bias.

The project will focus on two contrasting geographical regions: 1) the great plains of the US, and 2) the southeastern US. While these regions have very different land cover and average rainfall patterns, they share a susceptibility to persistent droughts and a large economic vulnerability to these events.

Mark Bourassa/ Florida State University
Improved Fields of Satellite-Derived Ocean Surface Turbulent Fluxes of Energy and Moisture

Surface turbulent heat fluxes will be derived from a combination of satellite observations. These fluxes will be gridded to more accurately calculate surface turbulent fluxes of energy (sensible and latent heat fluxes) and moisture (evaporation) over water. Many NEWS projects would benefit from more accurate oceanic turbulent fluxes of heat and moisture. The unique aspects of this proposal are (1) a new approach for satellite-based retrieval of near surface (10m height) air temperature and atmospheric humidity on a 3 hourly to 24 hourly scale; (2) calculation of surface turbulent fluxes on these scales from non-NWP data; and (3) an investigation of the strengths and weaknesses of gridding that will be optimized to minimize regional and global biases in the fluxes. Recent SEAFLUX comparisons of NWP flux products (and flux related variables) have found large regional biases. We have also compared fluxes based on monthly averaged wind, temperature, and humidity to the average of fluxes determined from six hourly data: biases exceeding 5Wm-2 cover approximately half the global ocean, and that biases exceeding 100Wm-2 routinely occur near western boundary currents during winter months. Our goals are to more accurately determine the input data for flux models, to work with that data on a time scale that greatly reduces the large biases found in monthly products, and to grid these fluxes in a manner that is relatively effective in reducing biases and random errors.

Yi Deng/Georgia Institute of Technology, School of Earth and Atmospheric Sciences
Investigating the Dynamical Control of the Pacific Storm Track on the Occurrence of Extreme Hydrological Events in the Western United States Using NASA Observations and Models

Midlatitude storm tracks play a key role in the Earth's climate system through their transport of momentum, heat and moisture in the troposphere. A better understanding of storm tracks' response to changing radiative forcing and the impact of this response on regional/global energy and hydrological cycle is essential for the evaluation and improvement of climate models and ultimately the success of climate prediction. Among the physical processes that are least understood is the dynamical control of the Pacific storm track on the occurrence of extreme hydrological events in the western United States. During the Northern Hemisphere winter, landfalling cyclones that are responsible for most flooding events in the Pacific Northwest and northern California originate from the Pacific storm track. In the southwest United States, mountain snowpack that accounts for the majority of the regional spring and summer water supply is highly correlated with winter snowfall brought in, or triggered by, cyclones exiting the Pacific storm track.

How is climate change going to affect this picture? In the future, will there be more flooding events in the Pacific Northwest and more severe droughts in the Southwest? Can the latest NASA GISS and GSFC general circulation models (GCMs) correctly predict such potential changes? In particular, have the models accurately represented the mechanisms through which the Pacific storm track controls the occurrence of extreme hydrological events in the western United States? Fundamentally, how does the environmental moisture affect the overall activity of the Pacific storm track and how does the storm track anomalies lead to anomalous downstream eddy moisture transport and cyclone landfall at the west coast of the United States?

This proposal will address the above questions through a combination of observational data diagnosis and numerical modeling. Specific research goals are to 1) identify the coupled modes between the Pacific storm track and environmental moisture using NASA Modern Era Retrospective-analysis for Research and Applications (MERRA) data and satellite products; 2) investigate using MERRA the mechanisms through which the Pacific storm track influences the winter cyclone landfall and precipitation, as well as the occurrence of extreme hydrological events in the western United States; 3) examine the ability of NASA GCMs in simulating the various aspects of the storm-track-moisture interaction focusing on the predictability of extreme precipitation events related to cyclone landfall; and 4) diagnose the coupled-model output of NASA GCMs to infer the potential impacts of global-warming on both water resources and the characteristics of extreme hydrological events in the western United States.

This project responds to the requested research topic - "the role of water and energy cycle in extreme events". It will investigate both water cycle observations and model simulations, evaluate the ability of climate models to capture the occurrence and intensity of extreme events, draw connections between the dynamics of the climate system and the predictability of extreme events and will ultimately contribute substantially to the NEWS program objective of "documenting and enabling improved, observationally based, predictions of water and energy cycle consequences of Earth system variability and change".

Dara Entekhabi/Massachusetts Institute of Technology
Shifts in Extreme Precipitation Events Based on Resolved Atmospheric Changes

The proposed project addresses element 2 of the NEWS call titled: Role of Water and Energy Cycle in Extreme Events. The proposed project will combine remotely sensed and in situ measurements with reanalyses and climate model projections to quantify the changes in the frequency of extreme events. The projections will be based on multi-model IPCC AR4 data archives in order to assess model structure differences. The project addresses both extreme high precipitation amounts and persistent low precipitation amounts. We recognize that model projections and atmospheric models in general do not resolve moist processes well. The simulations of moist processes cannot be relied upon for neither climatology nor extremes. However the models do resolve large-scale (hemispheric) general circulation features that result from the interactions of radiative and dynamical processes. At the same time extreme high precipitation is generally a local phenomenon that is not resolved in atmospheric models. We will use statistical conditioning (also known as composites) to find the large-scale dynamical conditions that lead to extremes at local scales. This is done by first conditioning atmospheric reanalysis primitive states on the occurrence of extreme precipitation (as percentile of historical record). These composites provide the large-scale (resolved in models) conditions that lead to local scale extreme precipitation. This approach has been successfully demonstrated (published results) for Italian Alps region and ECMWF reanalysis by the principal investigator and students. Then, the frequency of the appearance of this pattern in an AR4 model with current climate is estimated. Finally the changes in the frequency of this atmospheric pattern in a greenhouse-gas forced AR4 model will be estimated. A mapping of model-to-reanalysis primitive states fields has to be placed in between the steps. At the other end of extremes, i.e. droughts, the conditioning is no longer on point precipitation gages because droughts are often seasonal in duration and cover large areas. For the droughts we will use merged satellite-based precipitation products as well as merged satellite vegetation index products to define the conditioning state or composite index. The same analysis of the frequency of the large-scale atmospheric conditions in atmospheric reanalysis and then AR4 model projections will be performed. Again a mapping of reanalysis and climate model is necessary since the two may have biases relative to one-another. The deliverable and ultimate results of the proposed project are robust estimates of extreme low and high precipitation in a changed climate that uses only the resolved processes of the climate models.

James Famiglietti/University of California, Irvine
Mass Changes in Earth's Global Water Reservoirs

Water storage changes in Earth’s land, ocean, atmosphere and ice reservoirs vary on time scales ranging from instantaneous to geologic. As such they represent a fundamental and interactive component of the climate system. Until recently, the lack of a consistent, single monitoring framework has hampered efforts to track shorter-term, human time scale variations (e.g. monthly, seasonal-interannual and decadal-scale) of these storage changes, which are essential for enhanced weather and climate prediction, and for monitoring global change impacts on the hydrologic cycle. The recent launch of the Gravity Recovery and Climate Experiment (GRACE) satellite mission in 2002 now offers a tremendous opportunity to monitor water storage changes in Earth’s major reservoirs: it is now possible to perform comprehensive assessment and analysis of mass movements in the global water cycle using one observing system. Here we propose to continue and expand our first NEWS project which used GRACE observations of time-variable gravity to provide a first global, comprehensive assessment of monthly water storage changes in Earth’s ocean, ice, and land reservoirs. Expansions of our previous work will include: production and comparison of GRACE-based estimates of oceanic evaporation and terrestrial evapotranspiration; understanding the occurrence and persistence of terrestrial water storage anomalies during extreme hydrological events; using sea level rise estimates as a constraint on global water cycle variability; participation in the NEWS Water Cycle Integration and Assessment project; and collaboration with the several members of the NEWS team on water balance and related studies.. Because or work will characterize storage changes in Earth’s major water reservoirs, it should provide an important constraint on NEWS team flux estimates between reservoirs, as well as on other NEWS team terrestrial storage estimates (e.g. snow, surface water, soil moisture and/or groundwater).

Alan Lipton/Atmospheric and Environmental Research, Inc.
Toward Assimilation of Satellite Data in Modeling Water Vapor Fluxes over Land

This project applies microwave and infrared satellite data to improve model estimations of evaporation over land. These satellite data contain information about near-surface soil

and vegetative moisture. The relationships of the measurements to the fluxes is indirect, so analysis of fluxes depends on mathematical or statistical models, which integrate information from other sources. For fluxes over global land areas, bulk formulations for the fluxes are problematic because there are essential parameters for which reliable information is not available, and because the results are highly sensitive to errors in these parameters and to errors in the satellite-provided variables. Data assimilation systems are an attractive option because they have the potential to optimally account for the information content and the error characteristics of all the data sources, while introducing physical constraints with a numerical model. Successful assimilation requires that the model parameterizations and variables are compatible with the satellite measurement sensitivities. When they are incompatible, the satellite information is effectively rejected or misguides the analysis.
In this project, we will identify environments and regions where current land surface models are inconsistent with satellite-derived parameters related to evaporation, and hence where modeled evaporative fluxes are likely to be erroneous. This identification will be done employing simple physical and statistical models of expected relationships. For selected environments where inconsistencies are prominent, we will characterize the discrepancies by performing detailed analyses of model variables and satellite and in-situ measurements. The analyses will focus on the surface transfer processes for moisture and energy, and remote sensing phenomenology. The results are intended to provide direction toward improving surface models and their assimilation of data for water vapor flux modeling. This improvement is an essential step toward monitoring and predicting variability of water and energy cycles as manifestations of global change.

Gavin Schmidt/ NASA Goddard Space Flight Center
Satellite and Model Constraints on Water Cycling Responses to ENSO and Tropical Variability Using Water Isotopes

The advent of water isotope-enabled atmospheric circulation models and the validated and ongoing monitoring of water isotopes from the Tropospheric Emission Spectrometer (TES) on board Aura, means that there is an unprecedented opportunity to integrate this new hydrologic tracer into more traditional studies of water cycling in the atmosphere. This work exploits the key feature that the water vapor isotope ratio (HDO/H2O) is sensitive to the history of moist processes acting during transport from the source region to the observation point and is therefore orthogonal to traditional water metrics. As such, closing water budgets with an incorrect balance of contributing fluxes (evaporation, precipitation, air mass mixing) gives rise to an observable isotope error, and gives guidance as to which fluxes deserve greater scrutiny.

Our objective is to use TES observations of tropospheric water vapor and its isotopes along with two atmospheric general circulation models that include isotopic physics to help constrain atmospheric water budgets. We aim to establish which components of the water budgets are most influential to tropospheric moisture variability caused by the El Nino-Southern Oscillation (ENSO), the intra-seasonal Madden Julian Oscillation (MJO) and tropical cyclones (TCs).

To complement the data analysis, the water isotope-enabled versions of NASA GISS ModelE and NCAR Community Atmosphere Model (CAM) will be used to evaluate how well the observed data can be simulated in an AMIP-style mode (using observed changes in SST) and with wind nudging from the NCEP reanalysis. The comparisons will serve to validate the model physics, the isotope retrievals and provide quantitative measures of changes in water vapor budgets in the subtropics and tropics.

Eric A. Smith/ NASA Goddard Space Flight Center
Historical Rendition of Mediterranean Water Cycle based on Earth Satellite Measurements

The Mediterranean Sea is noted for behaving as a "concentration basin:", meaning that it exhibits positive evaporation minus surface precipitation (E - P) properties throughout the four seasons and from one year to the next (where the brackets indicate some type of space-time average). Nonetheless, according to the ECMWF Era-40 48-year (1958-2005) climate reanalysis dataset, for various phases of the North Atlantic Oscillation (NAO) when the pressure gradient between Portugal and Iceland becomes either very relaxed (large negative NAO-Index) or in transition (small positive or negative NAO-Index), the atmospheric moisture source properties of the basin become weak, at times even reversed for several months. These conditions denote negative (E - P) behavior, thus the conditions for a more conventional "dilution basin". Such behavior poses numerous questions concerning how and why these events occur. Moreover, it begs the question of what it would take for the basin to reach its tipping point in which (P) would exceed (E) throughout the rainy season (some six months) on an annually persistent basis -- and the Mediterranean Sea would transform to a recurring "dilution basin".

This proposal investigates some of these questions by: (1) establishing over a period from 1979 to present, based on detailed analyses of satellite retrieved data products from a combination of Earth observing satellite platforms, plus additional specialized data products, (2) diagnosing the salient physical and meteorological mechanisms that lead to the weaker E - P events, (3) determining the climate state under which meteorological background conditions could maintain the Mediterranean Sea as a "dilution basin" throughout the rainy season on an annually recurring basis, and (4) investigating how such conditions might modify important internal and external climatic processes known to be closely related to the dynamic, thermodynamic, and hydrologic properties of the Mediterranean basin, for example (a) drought frequency over Iberian peninsula, (b) rainfall accumulation within African Sahel, (c) alteration of the Levantine branch of the east-west aligned open thermohaline cell, and (d) modification of warm and salty intermediate flow through Gibraltar straight.

Eric Wood/Princeton University
Development and Diagnostic Analysis of a Multi-Decadal Global Evaporation Product for NEWS

Documenting the global water and energy cycle through observations is fundamental to achieve the goals of GEWEX and NASA's Earth Science Research Strategy to obtain a quantitative description of the variations in the global energy and water cycle. Such documentation is needed to enable NASA and its supported NEWS investigators to acquire enhanced knowledge of Earth's climate, including characterizing the memories, pathways and feedbacks between key water, energy and biogeochemical cycles. Amongst the various climate cycle variables, surface evapotranspiration (ET) or latent heat flux is often considered the climate linchpin variable because it plays a central role in the water, energy and carbon cycles, and is common to all three. It is unique in providing the link between the energy and water budgets at the land surface; the link between the terrestrial water and carbon cycle through vegetation transpiration, plays a central role in coupling the land and ocean surfaces to the atmosphere, and operates over fast (diurnal) and slow (seasonal) time scales. Much of our understanding of the complex feedback mechanisms between the Earth surface and the surrounding atmosphere is focused on quantifying this process, as well as to determine the biological environment and its water use efficiency. The GEWEX Radiation Panel (GRP), in collaboration with the GEWEX Land Surface Study (GLASS), has launched an activity called LandFlux with the goal of fostering the needed capabilities to produce and diagnose a global, multi-decadal surface turbulent flux data product. The GRP has already supported the development of an ocean surface heat flux activity (SeaFlux). A LandFlux product, coordinated with the SeaFlux product would contribute to the efforts of the NASA NEWS team in their collective effort to further our understanding of the global energy and water cycles.
