ROSES 2011: Selected NEWS Projects

Joel Norris

Observed Tropical Expansion: Impact on the Hydrological and Energy Cycles

Recent observational analyses show the tropical belt has widened over the last several decades. Estimates range from 2-5 degrees latitude since 1979 and are based on several metrics, including satellite observations of ozone concentrations, microwave sounding unit atmospheric temperatures, and radiosonde observations of the tropopause. These dynamical/temperature changes imply similar displacement of the hydrological and energy cycles, including the subtropical dry zones and mid-latitude storm tracks. Although such precipitation pattern shifts are more relevant to society, impacting ecosystems, agriculture and water resources, they have not been previously investigated.

Climate models also show widening of the tropical belt over the last few decades. This includes poleward displacement of the atmospheric circulation, in addition to the dry zones and storm tracks. Model estimates of tropical expansion, however, are significantly smaller than observations. In fact, 21st century model projections are less than the observed rate of recent expansion. This suggests the hydrological cycle is changing much faster than models predict.

We will use multiple datasets previously developed by NASA NEWS to quantify the hydrological consequences of recent tropical expansion, focusing on zonal displacement of the subtropical dry zones and mid-latitude storm tracks. In addition to mean trends, hydrological extremes will also be investigated, such as increased drought frequency/severity on the equatorward flank of the storm tracks. The GPCP precipitation data set will be combined with ISCCP and NOAA's PATMOS-x cloud observations to determine if the tropical expansion reported by dynamical/thermodynamical parameters is associated with a change in the location of the storm track and the size of the subtropical dry zone. Although satellite cloud data sets suffer from heterogeneities, we have recently performed rigorous statistical procedures on both ISCCP and PATMOS-x to detect and remove non-climate artifacts. In addition to bringing together cloud and precipitation data, we will investigate the corresponding radiative impacts using CERES and ERBE. The Modern Era Retrospective-Analysis for Research and Applications (MERRA) will be used to further quantify poleward displacement of the hydrological and energy cycles, and to investigate the important dynamical processes. Finally, we will employ the Global Land Data Assimilation System (GLDAS) models to determine if land surface components of the water and energy cycles, like soil moisture and evapotranspiration, also exhibit a tropical expansion signature.

There is no universally accepted mechanism for the cause of the recent poleward shift of the tropics. We will therefore investigate possible mechanisms, and the processes likely responsible for faster than modeled expansion. This includes the role of natural variability (e.g., ENSO) and anthropogenic forcings, like ozone and absorbing aerosols. Attribution will be facilitated by evaluation of the regional and seasonal characteristics of the widening. We will use the output from recently conducted modeling experiments to quantify such seasonal and spatial dependencies.

Our results will provide the first, comprehensive picture of the hydrological impacts associated with tropical expansion, improve understanding of the mechanisms involved, and provide an assessment of what changes will likely occur in future decades. By using several independent data sets, we will be able to quantify the uncertainties, while improving confidence in our results.

Ralf Bennartz

The Role of Boundary Layer Clouds in the Global Energy and Water Cycle: An Integrated Assessment Using Satellite Observations

This proposal seeks funding to globally study an important aspect of the energy and water cycle, namely stratiform boundary layer clouds and their relation to cloud albedo and precipitation formation. The study will be performed using the suite of different NASA instruments. One key component of the proposed study is that it will make use of innovative techniques that allow to remotely sense cloud microphysical and radiative properties synergistically using visible/near-infrared and microwave sensors. These techniques allow discriminating cloud microphysical effects from cloud dynamics better than traditional approaches and are thus are excellently suited to address issues of cloud microphysics, and its impact on the energy and water cycle via cloud albedo and latent heating due to precipitation. In particular, the following issues will be addressed and are discussed in more detail in the full proposal:

The combination of visible/near-infrared and passive microwave will allow to quantify the variability of cloud droplet number concentration, cloud geometrical thickness, cloud liquid water, and rain water path, as well as their impact on shortwave albedo and precipitation generation. These variables are of high scientific relevance by themselves, but will also establish a global reference dataset for validation of global climate models (GCMs). We will create a unified dataset spanning the entire Aqua lifetime using MODIS and AMSR-E.

Regional and global studies of the variability of the aforementioned parameters will be performed. These studies will allow estimating the impact of e.g. biomass burning events on cloud albedo and precipitation generation. Changes in retrieved geophysical variables will be related to anthropogenic sources based on aerosol and other auxiliary observations. Each step will be accompanied by an extensive error analysis of all components within the process leading to uncertainty estimates for all derived parameters.

We are planning to evaluate the entire Aqua-MODIS and AMSR-E dataset starting at level 2. To achieve this, the study will make use of the Atmosphere Product and Evaluation Test Element (PEATE) located at the University of Wisconsin¿s Space Science and Engineering Center (SSEC). We have already successfully transferred research code to run quasi-operationally within the PEATE. We are thus confident that the proposed data processing work can leverage the existing infrastructure at SSEC to a maximum extend.

William Olson

Characterizing Uncertainties in Large-Scale Atmospheric Heating Distributions Derived from TRMM Observations and Reanalysis Datasets

During the previous NEWS funding cycle, estimates of latent, eddy sensible, and radiative heating in the atmosphere based upon Tropical Rainfall Measuring Mission (TRMM) observations were developed and partially validated using available ground-based and satellite reference data. These heating estimates were then combined to yield the large-scale atmospheric apparent heat source, or Q1, and an 11-year TRMM record of Q1 (1998-2008) was derived.

Recently, long-term mean Q1 distributions were compared to reanalysis estimates from the Climate Forecast System-Reanalysis, (CFS-R), the Modern Era Retrospective-Analysis for Research and Applications (MERRA), and the ECMWF Re-Analysis Interim (ERA-Interim). These comparisons revealed systematic differences between the TRMM and reanalysis Q1 estimates, as well as differences in the contributing latent, eddy sensible, and radiative components of heating. However, before it is possible to attribute these systematic differences to "errors" in either the TRMM or reanalysis datasets, a better understanding of the potential uncertainties in both sources of data must be acquired. In the proposed investigation, we will make a step toward understanding the discrepancies of TRMM and reanalysis heating estimates by first examining the uncertainties in TRMM estimates of the latent and eddy sensible heating contributions (Q1-QR) to Q1. In brief, we will (a) quantify the sensitivity of TRMM large-scale heating estimates to uncertainties in heating algorithm assumptions and a priori information, characterizing the uncertainties of heating estimates in relation to these underlying algorithm uncertainties, (b) re-examine the TRMM vs. reanalysis differences in light of algorithm uncertainties for several large-scale heating products, such as long-term global zonal- and meridional-mean distributions, the mean seasonal cycle of heating, ENSO heating anomalies, and the composite anomalous heating structure of the MJO, and (c) study composites of TRMM vs. reanalysis heating differences stratified by rain intensity, convective/stratiform proportion, mean precipitation depth, and other parameters in order to better understand the dependence of these differences on atmospheric state.

The proposed investigation dovetails with a tandem investigation proposed by our collaborator, Dr. L'Ecuyer. The emphasis of his study will be the quantification of uncertainties in TRMM radiative heating rate (QR) estimates. As an outcome of these related investigations, the nature of uncertainties in TRMM and reanalysis Q1 distributions will be better understood, and eventually this should lead to improved descriptions of atmospheric diabatic heating, a critical component of the earth's energy budget.

Rachael Pinker

Integration of satellite radiative fluxes in support of hydrological modeling

The goal of NNH10ZDA001N-NEWS is to integrate Earth Science Research Program components towards progress in NEWS objectives: enabling improved, observationally based, predictions of water and energy cycle consequences of Earth system variability and change. The investigations should integrate and interpret past, current, and future space based and in situ observations into assimilation and prediction products and models that are global in scope and of sufficient length to address extremes and abrupt changes. Earth's climate depends on its radiative balance controlled by solar input, surface properties, and distribution of radiatively active gases, clouds, and aerosols in the atmosphere.

To advance the understanding of the climate system and of the hydrological cycle, the best possible information on radiative fluxes is needed at several scales; it is also needed for advancing existing NEWS projects and goals, namely: 1. The Drought and Flood Extremes group aims to understand the mechanisms responsible for regional water and energy extremes - changes in radiative fluxes during these extremes are of interest. 2. The Evaporation and Latent Heating group tries to understand the role of latent heat fluxes in the climate system which requires the best latent heat flux data for scales that include the smaller ones of individual extreme events - this necessitates the understanding of radiative forcing variability. 3. The Water and Energy Cycle Climatology group aims to develop state of the global water cycle and state of the global energy cycle assessments, to be based on recent, high quality ground and space observations and data integrating models. Many of the needed datasets have gaps in challenging regions. Understanding the quality of the radiative fluxes in these problematic regions is of basic necessity. 4. The Modeling group, is charged with the development of connections with observations and process related projects. Radiative fluxes are needed both for model evaluation and for forcing.

We contribute to efforts to derive radiative fluxes from satellites at global and regional scales and work closely with the scientific community to meet their needs. The emphasis has been on shortwave model development; evaluation/calibration of results; and use of information in climate related studies. Recently, capabilities have been developed to infer longwave fluxes. It is imperative to have a better understanding of the differences between available products. We propose to perform an in depth evaluation of current NASA sponsored satellite based estimates of radiative fluxes (shortwave and longwave) as well as numerical model outputs to identify problems. Understanding scale issues of the validation process is important for generating informative error metrics which should result from this project.

Xun Jiang

Investigation of the Recycling Rate of Moisture in the Atmosphere From Observation and Model

The recycling rate of atmospheric moisture, which is defined as the ratio of precipitation to column water vapor, is an important indicator of climate change. Numerical models predict that the recycling rate of atmospheric moisture decreases with time at the global scale [Allen and Ingram, 2002; Held and Soden, 2006; Stephens and Ellis, 2008] in response to the global warming. A recent observational study [Wentz et al., 2007] did not agree with the result of numerical models. Based on the latest data sets of precipitation and water vapor (GPCP V2.1 and SSM/I V6), we have conducted a preliminary examination of global precipitation and column water vapor, which suggests a consistent view of recycling rate of atmospheric moisture at the global scale between numerical models and observations. Our preliminary analyses further reveal that precipitation increased ~ 3.0% per decade and decreased ~ 4.7% per decade in the high-precipitation area and low-precipitation area, respectively. The opposite trends of precipitation between the high-precipitation and low-precipitation areas are also qualitatively consistent with the "rich-get-richer" mechanisms suggested by numerical models [Chou and Neelin, 2004; Held and Soden, 2006; Neelin et al., 2006; Chou et al., 2009].

Our preliminary analyses have already generated some important results. However, these preliminary results need more validation. The physics and dynamics behind these observational results need more study. We propose to validate these preliminary results with more observational data sets (SSM/I, GPCP, GPCC, TRMM, NVAP, AIRS, and AMSR). We will also conduct more investigations of the temporal variations and spatial patterns of precipitation, column water vapor, and recycling rate of atmospheric moisture with multiple observation data sets. We also propose to conduct new diagnostic studies, which are based on reanalysis data sets (NCEP2, ECMWF, ECMWF-Interim), to study the underlying physics and dynamics seen in the observations. GISS-HYCOM will be used in this proposal to investigate the variations in the precipitation, water vapor, and large-scale circulations in the model as a result of global warming.

Judith Curry

Integrated analysis of atmospheric water cycle in intense marine storms

This project focuses on characterizing and understanding the coupled roles of surface latent heat flux, atmospheric latent heating, and precipitation in intense storms that are characterized by high surface wind speeds.

Evaporation and latent heating

This project builds upon the success of our previous NEWS grant: ¿Global analysis of ocean surface fluxes of heat and freshwater: satellite products, NWP analyses, and CMIP simulations.¿ A key accomplishment of our previous NEWS research was the development of a method to determine surface latent flux under high wind conditions using satellite data. A satellite-derived dataset was created and applied to analyzing surface latent heat flux in selected North Atlantic hurricanes, for which in situ data were available. We have also begun using this ocean latent heat flux data set to examine the role of the hydrological cycle in the Southern Ocean that has contributed to an increase in the extent of Antarctic sea ice. The proposed project builds on our earlier research and focuses on evaporation, latent heating, and on tropical cyclones (hurricanes) and storms in the Southern Ocean. The proposed research will target the following two research questions: 1) What is the role of the surface evaporative flux and atmospheric latent heating in the life cycle of the integrated kinetic energy, precipitation, and intensification of hurricanes?

The analysis will use the satellite-derived latent heat flux, sea surface temperature, atmospheric latent heating and rainfall, combined with analyses from the North Atlantic Extended Best Tracks hurricane data set. Time series analysis over the lifecycle of individual hurricanes (4 times per day) of water budget values integrated over the storm area will provide the basis for an observationally based water and latent heating budget and its interaction with the evolution of hurricanes. This unprecedented analysis will support theoretical understanding of hurricanes as well as provide test cases for hurricane forecast model evaluation. 2) How does the hydrological cycle in the high latitudes of the Southern Ocean influence the variability of Antarctic sea ice?

Our recent PNAS paper identified (from reanalysis and climate model simulations) an enhanced hydrological cycle in the Southern Ocean that has resulted in an increase of the Antarctic sea ice extent over the last three decades. The mechanism that we identified for this increase in sea ice extent is through the reduced upward ocean heat transport (associated with surface warming and freshening) and increased snowfall. We propose to examine the variability of these processes using the satellite data sets of latent heat flux, sea surface temperature, rainfall, and snowfall in combination with reanalysis data sets (e.g. NASA MERRA).

Joseph Santanello

Investigating the Impact of Land-PBL Coupling on the Water and Energy Cycle in NASA Model and Observation Products

Motivation:

The impact of the land on the water and energy cycle is modulated by its coupling to the planetary boundary layer (PBL), and begins at the local scale. In NEWS Phase-1, model capabilities and diagnostics were developed to quantify and evaluate local land-atmosphere coupling (LoCo) at the process-level. To date, broader (i.e. global) application of LoCo diagnostics has been limited by observational data requirements of land-PBL fluxes and states that are typically only found in localized, short-term field campaigns. Consequently, the strength and accuracy of LoCo in NEWS model and observation products remains undiagnosed to date. Significant uncertainty and spread remain in NEWS estimates of global/continental/regional evaporation (ET) and water and energy cycles as a result of imperfect and diverse estimation techniques, models, and observations employed at disparate temporal and spatial scales (e.g. LIS-WRF, MERRA, GLDAS, and satellite-derived products). However, satellite remote sounders such as AIRS employ high-spectral resolution measurements that are sensitive to land-PBL thermal and moisture properties at scales comparable to NEWS products. To this end, we hypothesize that AIRS radiance signatures can be used to evaluate, intercompare, and constrain the representation of land-PBL coupling and its influence on the water and energy cycle in NEWS model and observation products. This proposed research will therefore work towards bridging the gaps in local/regional scale process-focused models with large-scale, global and climate models by employing radiances as an intermediary and benchmark to evaluate a range of NEWS and community products against.

Prior Accomplishments

Under NEWS Phase-1, the PI has led the recent GEWEX-GLASS LoCo initiative and has developed a coupled modeling system (LIS-WRF) and diagnostics of land-PBL behavior that can be applied to any model or observation set. In addition, the PI has led an investigation into LoCo processes as measured by the AIRS instrument which indicates that AIRS radiances are sensitive to and can be correlated with land-PBL properties over an extended period.

Methodology

This research will be conducted using existing products from local/regional (LIS-WRF, 1-40km) and continental/global (e.g. GLDAS, 25km; MERRA, 50km; ERA-Interim, 150km NARR/CFSR, 32/50 km) scale models, in-situ and AIRS observations, a satellite data simulator unit (G-SDSU), and a model verification

system (LVT). Specifically, the tasks outlined for this proposal are as follows:
1. Evaluate the accuracy, variability, and limitations of land-PBL coupling in of an array of NASA and community model and observation products using a suite of LoCo diagnostics at global 'hotspots' of L-A interactions. 2. Compare the radiance spectra measured from AIRS against those from each of the model and observation products as generated from a satellite data simulator, for a range of land-PBL regimes and conditions (e.g. extremes) and as a function of their sensitivity to LoCo processes. 3. Determine how errors in components of LoCo (e.g. evaporation, PBL depth) translate into differences in radiance signatures using statistical techniques, and extend analysis to the global coverage of AIRS. Overall, this proposed research will work towards bridging the gaps in local/regional scale process-focused models with large-scale, global and climate models by employing AIRS as an intermediary and benchmark to evaluate against in the context of the processes governing LoCo. The long data record of AIRS will also enable seasonal and inter-annual evaluation to be conducted amongst the products.

Dennis Lettenmaier

Assessment of the role of surface water storage in the terrestrial water budget

Space-time variations in surface water storage (in lakes, reservoirs, wetlands, and river channels) are not well observed by present in situ or satellite sensors. Nonetheless, these variations are potentially large. For instance, estimates based on statistical extrapolations of the global distribution of lake storage variations imply a mean seasonal variation in surface water storage globally which is order of 5 cm distributed over the global land areas. Changes in manmade reservoir storage could add another one third to one half to this number. Based on model inferences, total seasonal surface water variations on a global basis could therefore be about half of the equivalent value for soil moisture. The launch of the Surface Water and Ocean Topography (SWOT) swath altimetry mission (currently projected for 2019) will provide direct estimates of surface water storage interseasonal and interannual variations over almost all of the global land areas. We propose here to construct pre-SWOT estimates of global surface water variations retrospectively at 0.25 degree latitude-longitude spatial resolution a and monthly time step from 1950 to 2010, using a combination of modeling (for all global surface water) and direct estimates for large lakes and reservoirs from existing track altimetry data where and when available for the largest inland water bodies. We will also use GRACE data to infer, in combination with model-based estimates of soil moisture variations, the residual that might be attributable to lake, reservoir, and wetland storage variations, as a second independent estimate.

The overarching science question to be addressed by this proposal is: What are the magnitudes of seasonal and interannual variations in surface water storage over the continents and major river basins relative to similar variations in other terms in the land surface water budget? Subsidiary science questions are: a) What are the relative magnitudes of seasonal and interannual variations in lake and wetland storage relative to those in manmade reservoirs? b) How do the magnitudes of surface water storage variations at seasonal and interannual time scales vary over the continents relative to other terms in the land surface water budget? c) Is there evidence of changes in surface water storage variations over the last half century, and if so, where?

This proposal directly addresses area 5 of the NEWS Implementation Plan (assessing the variability of the global energy and water cycle) and (for those aspects of the project based directly on observational records) area 2 (assessing global energy and water cycling through an observational record. In addition, the proposal responds directly to area 2.3 of the call (accounting of the state of the global water and energy cycles, based on data from the most advanced space and ground based measurements systems and output from observation-integrating models). It also responds to area 2.4 (modeling and water cycle prediction). The proposed data set will be a contribution to the NEWS water and energy cycle climatology working group, of which the PI is a member (current project ends later this year). Given the PIs ongoing participation in the NEWS science team, he and his group have an understanding of the overall NEWS strategy, and more specifically, protocols for preparation of NEWS data products, with which the proposed activity will conform.

Hui Su

Using NEWS Water and Energy Cycle Products to Investigate Processes that Control Cloud Feedback

Clouds play an important role in the Earth's energy budget and water cycle. Cloud feedback constitutes one of greatest uncertainties in climate change predictions. We propose to integrate data products developed under the NASA NEWS program with other satellite and reanalysis data to investigate the physical processes that control cloud feedback. The observational data analysis results will be compared with the CMIP5 model simulations. Instead of analyzing cloud-related water and energy fluxes in isolation, we propose to employ the "conditional sampling" approach to analyze the clouds and related fluxes sorted by collocated large-scale dynamic and
thermodynamic parameters. We will use data from CCCM-CERES, GEWEX SRB, SEAFLUX, ISCCP, and TRMM, in combination with A-Train (Aqua AIRS/MODIS, CloudSat/CALIPSO, Aura MLS) products and reanalysis data from ECMWF and MERRA. Four specific tasks will be conducted to provide a comprehensive view of the spatial distribution and temporal variations of clouds and related processes, with a focus on the tropical oceanic regions in the past decade.

The four proposed tasks are:
1. Analyzing spatial variability;
2. Examining interannual anomalies;
3. Investigating decadal changes;
4. Comparing with the CMIP5 model simulations.

The uncertainties in the observational flux products will be assessed. The proposed project leverages on-going efforts led by members of the proposed team, including multi-satellite data analysis, evaluation of the CMIP5 model simulations using A-Train data and the error-analysis of NEWS water and energy cycle products. Moving a step further from documenting the changes of cloud-related water and energy fluxes, our study identifies the relationships between the cloud-related fluxes and their large-scale environmental conditions, including the atmospheric circulation pattern, in order to understand the mechanisms that drive the cloud changes. The proposed work directly addresses the NEWS challenge to document and enable improved predictions of water and energy cycles in response to natural and anthropogenic climate changes. Our project goals align with and support the NEWS "Water and Energy Cycle Climatology" Working Group. The proposed work will improve our understanding of the physical processes that govern cloud feedback and potentially lead to improvements in the representation of these processes in the climate models. Our model-data comparison results will be a timely NEWS contribution to the upcoming IPCC Fifth Assessment Report (AR5).

Siegfried Schubert

Warm-Season Short-term Climate Extremes in the Northern Hemisphere in a Changing Climate: The Role of Stationary Rossby Waves

Climate extremes, including droughts, floods and heat waves, have profound impacts on human society and the natural environment, and constitute an important component of the Earth¿s energy and water cycle. The key physical processes that produce such extreme events and how they might change in a changing climate are not yet well understood. Recent research highlights the important role of stationary Rossby waves in determining warm season subseasonal surface temperature and precipitation variability including extreme events such as heat waves and droughts in a number of regions throughout the Northern Hemisphere. This proposal seeks to further investigate the role of stationary Rossby waves in warm-season short-term climate extremes including how that role might change in a changing climate. The specific objectives of the proposal are to 1) quantify the physical and dynamical mechanisms linking stationary Rossby waves to short-term climate variability and extremes in precipitation and surface temperature; 2) quantify the nature of the forcing of the stationary Rossby waves. This includes an assessment of the nature of the transient eddies associated with the stationary waves both in terms of their effect on those waves and the extreme weather events those transients produce; and 3) investigate the potential impacts of Pacific Decadal Variability (PDV), Atlantic Multi-decadal Variability (AMV) and global warming, on the stationary Rossby waves and associated short-term climate extremes.

The proposed study will leverage NASA NEWS datasets, NASA MERRA, and the output of various AGCM experiments that are carried out with the NASA GEOS-5 AGCM and the NCAR CAM3. Specifically, precipitation, water vapor and atmospheric radiative flux products from NASA NEWS as well as the comprehensive MERRA dataset will be used to better characterize the temporal and spatial distribution of the past climate extremes and investigate their mechanisms. The output of century-long AMIP runs with the GEOS-5 AGCM, and a 12000-year SST climatology run with the NCAR CAM3 will be used to further quantify the maintenance and the nature of the forcing of the stationary Rossby waves. In addition, a set of idealized SST runs and an ensemble of future time-slice runs with the GEOS-5 AGCM will be used to investigate the potential impacts of PDV, AMV and global warming. The focus will be on their impacts on the processes that affect Rossby wave propagations, such as changes in the mean jets and sub-monthly transients, and how that may impact the occurrence of short-term climate extremes.

The proposal is aligned with and supports the NEWS integration working group on Drought and flood extremes¿ in that it is an integrative and synergistic study of the physical and dynamical processes responsible for the development of some of the most socio-economically-relevant components of the energy and water cycle.

Michael Bosilovich

Quantifying observation influence on regional water budgets in reanalyses

Statement of the Problem: NASA¿s latest reanalysis, the Modern-Era Retrospective analysis for Research and Applications (MERRA), has shown significant improvement over previous reanalyses and is equivalent in skill to the ECMWF-Interim reanalysis in terms of global, continental and basin scale climatological precipitation. However, details of regional water cycles still exhibit biases that result from model physics uncertainties interacting with an observation suite that varies in space and time. The proposed work investigates biases at the regional scale to provide understanding that better informs the NEWS science community on how best to use MERRA data.

The extent of regional biases can be deduced from the magnitude and behavior of the non-physical increment terms of the conservation equations which provide a wealth of information as to the biases in model physics as well as the utility and veracity of the observations being assimilated. A new data set just now being released is called the MERRA Gridded Innovations and Observations (GIO). MERRA-GIO includes not only the observations assimilated in MERRA, but also the forecast and analysis error compared to each observing system, in a straightforward data format. Using this data, we can ascertain the degree to which the reanalysis agrees with each observing system and how the observations influence the increments. Ultimately, we can identify the major observing system controls on the moisture, heat and radiative fluxes and transports.

Methodology: The initial focus of the project will be evaluating the observations assimilated in MERRA over North America, where a strong dipole structure in the vertically-integrated moisture increments during the warm season signifies a discrepancy between E-P from the model physics compared to that derived by moisture transport. In this conventional data rich region, we will use the MERRA-GIO data set to determine the relative constraining roles of various observations and to examine the systematic forcing from model physics (or lack thereof) that requires correction. We will use the North American evaluation with GIO as a template for the diagnostic development to then address biases in hydrometeorological fluxes in other key regional anomalies in MERRA, among them the Amazon basin, the central African region, the Indo-Pacific warm pool / tropical ITCZ, and the subtropical oceanic ridges. Far fewer conventional data characterize these regions and so the ability of remotely-sensed data to correct model physics will be a prime focus.

Significance / Relevance to NASA / NEWS: In addition to quantifying how observations are interacting with the GEOS5 model physics, this study will inform the NEWS MERRA user community on the physical basis for biases and will provide practical examples of how to use the GIO data in analyzing and evaluating MERRA reanalysis results. Finally, the results of this analysis will guide improvement of model physics and satellite bias correction strategies in preparation for future NASA reanalysis efforts. Deeper physical explanations will be addressed through collaboration with other NEWS projects, capitalizing on the NEWS integration working groups.

Shih-Yu Wang

Identifying extreme precipitation "hotspots" in the changing tropical-midlatitude interaction using MERRA and satellite data

This project will conduct a focused data analysis in the study of extreme precipitation threat and identify vulnerable regions in a changing climate. Extreme precipitation events are tied closely to the occurrence of intense mesoscale convective systems (MCSs). Intense MCSs tend to occur where instability, moisture, and lift are enhanced by frequent interactions between tropical and midlatitude weather systems, such as the low-level jet (LLJ) and propagating synoptic disturbances. In the subtropics and midlatitudes, these weather systems are modulated considerably by the circumglobal teleconnection (CGT)-i.e. Rossby short waves excited in the jet stream "waveguide". Our analysis of some recent extreme precipitation events (e.g., the 2008 Iowa floods, the 2010 Pakistan and the Australian floods) have revealed synoptic couplings between the LLJ, propagating disturbances, and the CGT.

Post-1970, climate change has modified the general circulation in two basic ways: 1) a weakening of, and a poleward shift of the jet streams, and 2) a widening of the tropical belt. Given the CGT¿s underlying waveguide mechanism, any long-term changes in the jet streams are likely to modify the CGT in a permanent way. Our preliminary analysis has found a long-term change in the CGT that coincides with the event-related CGT patterns. Meanwhile, the widened tropical belt indicates a strengthening of the LLJ. It is therefore hypothesized that the changing interaction between the CGT and the LLJ may have modified the characteristics of extreme precipitation in various regions. The proposed study aims to quantify this modification and identify the affected regions.

We propose a diagnostics-based approach to investigate extreme precipitation threats through the combination of climate dynamics and weather forecasting methods. We will (1) construct the frequency and the "best predictors" of intense MCSs, (2) characterize the CGT and LLJ features through a set of circulation criteria, (3) define extreme precipitation threat using logistic regression to connect the MCS predictors with the CGT and LLJ dynamics, and (4) examine the distribution and variability of extreme precipitation threats. We will utilize the Modern Era Retrospective-analysis for Research and Applications (MERRA) data and verify our findings with Tropical Rainfall Measuring Mission (TRMM) data. Climate change impacts on extreme precipitation threat will be assessed through the Goddard Institute for Space Studies (GISS) general circulation model.

This proposal addresses the NEWS Integration Working Groups (1) Drought & Flood Extremes by conducting a statistical and dynamical characterization of the precipitation extremes and by investigating the physical processes responsible for these extremes. The proposed work is also relevant to Water and Energy Cycle Climatology, since we intend to evaluate water cycle consequences of climate change, and to Modeling and Water Cycle Prediction, as the expected results will help improve weather, seasonal, and climate
predictions.

Robert Brakenridge

Accelerating Changes in Arctic Ocean River Discharge Using Coupled Satellite- and Ground-based Measurements, 2002-Present

Instrumental streamflow records (Overeem and Syvitski, 2010) indicate a 9.8% increased discharge (1977-2007) for 19 large Arctic rivers in Canada and Eurasia. There is also a shift of maximum discharge to earlier in the summer, most likely due to earlier snowmelt. The rate of increase accelerates in the latter part of these records. These recent results can be tested and extended into the present and expanded to ungauged rivers by utilizing ongoing NASA AMSR E-based river discharge measurements (Brakenridge et al., 2007). We address 3 science questions related to NEWS program objectives: 1) changes in the timing of spring river ice break-up in relation to changing temperature regimes, 2) changes in total annual freshwater discharge into the ocean, and 3) the causes and predictability of the runoff/discharge changes. There are 128 AMSR-E river measurement sites above 65 deg N: once successfully calibrated to discharge values and ice response thresholds, each site can be used to measure time of spring ice breakup, duration of thaw season flow, and total seasonal discharge after ice breakup. The records extend from mid-2002 to present, cover the important inflowing rivers, and can thus complement, overlap, and test the published in situ station-based analysis, temporally and spatially. Our study will incorporate NASA sensor-based discharge and ice-cover measurements into the ongoing intensive study of Arctic warming and rates and its cause-and-effect relations to the global hydrological cycle.

Anita Rapp

Quantifying the water and energy budgets of marine subsidence regions

Because of their large spatial extent and tenuous but persistent cloud cover, marine subsidence regions are a critical modulator of the global water and energy balance, yet remain one of the most difficult regions to adequately observe and simulate. These regions appear as virtual deserts in global precipitation climatologies such as the Global Precipitation Climatology Project (GPCP) due the inherent inability of conventional spaceborne sensors to measure light precipitation from shallow liquid clouds. The proposed work is motivated by recent convergent estimates of the global surface radiation from the Global Energy and Water Cycle Experiment (GEWEX) Surface Radiation Budget (SRB) and A-train based estimates that suggest a more vigorous cycling of water and thus latent heat from the surface to the atmosphere than is currently estimated by GPCP. Further analysis is necessary to identify what regions and modes of precipitation may play into the apparent incongruity in global scale radiation and water cycle estimates. The approach of the proposed work is to improve the global closure of the water and energy budgets by focusing on closure within a specific regime (marine subsidence regions) where the conventional precipitation sensors have known shortcomings and in situ observations confirm that light precipitation is a common occurrence. This proposal will support the Water and Energy Cycle Climatology (2.3) working group by exploring the regional closure of the water and energy cycle and will link to other elements of the NEWS program by leveraging both observational and model-reanalysis estimates of surface and atmospheric fluxes of heat and moisture that will include new regional precipitation climatologies in marine subsidence regions.

Specific deliverables of the proposal include (1) a characterization of water and energy cycles in marine subsidence regions, (2) development of a climatology of surface precipitation from CloudSat observations, and (3) an evaluation of the moisture and energy fluxes in NASA¿s Modern Era Retrospective-Analysis for Research and Applications (MERRA) project. Analysis of the regional water and energy budget requires estimates of (a) the surface sensible and latent heat fluxes, (b) the surface and atmospheric component of the radiation budget, and (c) the atmospheric flux divergence of energy and moisture. Surface sensible and latent heat estimates will be used from the forthcoming Goddard Satellite-Based Surface Turbulent Fluxes version 3 (GSSTF-3) product. Radiation products will include estimates from the Clouds and Earth¿s Radiant Energy System (CERES) instrument, the CloudSat Fluxes and Heating Rates product, and the GEWEX SRB. Water vapor divergence will be estimated from the observational product of Hilburn (2009). The unique observations of light precipitation from CloudSat will be used to quantify the precipitation in the subsidence regions. CloudSat is ideally suited to compliment the existing precipitation climatology in these regions where the distribution of precipitation is dominated by light warm rain events. Relevant to the objectives of the NEWS program, this precipitation dataset will be compared against that of GPCP and CMAP in order to refine our understanding of the established global climatology. In addition, the observational water and energy fluxes will be used to evaluate MERRA in these subsidence regions to determine how well modern reanalysis products capture the regional water and energy budget

Carol Anne Clayson

Characteristics of and Relationships between Surface Heat and Moisture Fluxes and Ocean-Atmosphere Variability

In order to understand how the climate responds to variations in forcing, one necessary component is to understand the full distribution of variability of exchanges of heat and moisture between the atmosphere and ocean. A number of studies recognize the important role of surface heat and moisture fluxes in the generation and decay of important coupled air-sea phenomena. These mechanisms operate across a number of scales and contain significant contributions from interactions between the anomalous (i.e. non-mean), often extreme-valued, flux components. It is important to have a characterization and understanding of these processes for the development of accurate modeling efforts. We propose an integrated approach towards determining the interaction of the atmosphere and the ocean through the surface fluxes of heat and moisture, combined with other weather properties, on a variety of spatial and temporal scales. In particular, we are seeking to understand the variability and extremes in air-sea fluxes of heat and moisture in the context of the water and energy cycle, and how the entire distribution of fluxes varies over time, with location, and with differing weather and climate states.

A number of satellite-derived products are currently available for addressing these issues, and the increased resolution and quality of many of these products allow for more accurate resolution of sub-daily variability. It is thus timely to use these products and companion model reanalysis data to evaluate more than the means and trends of the heat and moisture fluxes between the ocean and atmosphere. This project will use the full spectrum of variability in these fluxes and associated parameters (such as cloud properties, rainfall, profiles of latent heating, and vertical velocity estimates) to document their distributions with associated weather states, explore the driving oceanic and atmospheric factors producing the distributions, and evaluate to what extent the distributions (including the extremes) are affected by larger-scale coupled phenomena such as phases of ENSO and the NAO.

The key questions to be addressed by this study are: (1) How do the distributions of the heat and moisture fluxes over the global oceans vary in space and time? Howdo these distributions relate to the associated near-surface atmospheric properties, sea surface temperature, and cloud processes? (2) What local weather states as evidenced by cloud and surface properties are associated with the surface heat and moisture flux distributions? Do changes over time to the distributions occur because of changes in frequencies of weather states or because of changes in the weather states themselves? (3) How do these distributions and weather states vary within the larger-scale climate variability? To what extent can this be determined given the changing sampling characteristics over a 20 year period? Our study is relevant to two NEWS working groups: most directly Evaporation and Latent Heating, and secondarily Water and Energy Cycle Climatology. Documentation of the distribution of surface fluxes, their means and extremes, and an elucidation of the physical linkage of the various surface heat and moisture fluxes to their related atmospheric weather states and their variability under various climate regimes lies directly at the heart of the NEWS program.

Robert Oglesby
Quantifying the Relative Roles of Local Versus Remote Effects on North American Summertime Drought
Considerable attention has been paid to the remote effects of sea surface temperature anomalies on North American summertime drought. The ENSO, PDO, and AMO have all been implicated; furthermore their joint, nonlinear interactions are also important, and add considerable complexity to the problem. Much attention has also been paid to local effects, especially those due to changes in soil moisture, snow cover, and land use. Such changes can strongly impact land surface-atmosphere interactions, at the time they occur, and, in the case of snow cover, during subsequent warm seasons. Importantly, these surface changes can be affected by both natural influences and human activities.

Current thinking is that the remote effects are likely responsible for initiating drought, while the local effects help to prolong and enhance it. But this is largely conjecture - while each of these effects has been separately well-studied, much less attention has been paid to understanding and quantifying how the remote and local effects actually interplay to account for summertime precipitation regimes over North America. The time is now ripe for such a study. We propose to build on our ongoing and previous research and quantify the relative roles of the local and remote forcings. Our focus will be on the central US, though attention will also be paid to the southwestern monsoon region. Both observational and modeling analyses will be conducted. Two key aspects will be addressed: 1) Quantifying the relative roles of the remote and local effects. 2) Alleviating the most important current weakness in understanding and predicting the role of local effects, which is poor knowledge of the spatial and temporal distribution of ET fluxes from the land to the atmosphere.

Specific project tasks include: 1) Use of global (NCAR and NASA) models, and regional (WRF) models to evaluate the combined effects of SST anomalies and reduced soil moisture). This task will build on our ongoing NOAA CPPA project which is examining just the role of the SST anomalies on North American precipitation and drought, as well as our previous NASA THP projects aimed at evaluating the roles of soil moisture (directly) and snow cover (seasonally-lagged) on summertime precipitation over the western half of the U.S. Now we will develop a research strategy, similar to the previous, that uses select global and regional climate model simulations to evaluate how the physical mechanisms actually responsible for the precipitation respond to the separate and combined remote and local influences. Observations (actually, NOAA and ECMWF global and regional reanalyses) will be used to constrain the model analyses. That is, are the model results reflected in what really has happened, while also recognizing that the observations also reflect every possible climate factor, not just the specific ones that we consider. 2) Use of new integrated ET observational datasets to provide the constraints on ET (and its effects) that has been sorely lacking in previous studies. The flux of moisture from the land surface to the atmosphere is one of the most crucial, yet least understood, aspects of the climate system. Until we fully understand its role, we cannot expect to properly quantify the relative roles of remote and local effects. We have ongoing studies aimed at evaluation of ET fluxes from space-based (MODIS) platforms, and from surface-based Bowen ratio tower measurements. For this project, the two new observational datasets will be merged into one that has comprehensive spatial and temporal coverage over the central and western US. This new dataset will be used to constrain the model results investigating the relative role of local effects. It will also prove invaluable to our other ongoing efforts aimed at improving the representation of land surface effects into regional climate models.

Seiji Kato

Investigation of Earth radiation budget variability by cloud object analysis

Using the NASA Energy and Water Cycle Study (NEWS) A-train product that have been produced in our previous NEWS investigation (CCCM) and existing Clouds and the Earth¿s Radiant System (CERES) data sets, this proposed investigation focuses on understanding the variability of top-of-atmosphere (TOA) and surface radiation budget. We will quantify the variability of both TOA and surface monthly mean irradiances using more than 10 years of CERES data sets. Once irradiance variabilies are computed, we will investigate processes that affect TOA radiation budget by investigating cloud variability using a cloud object analysis approach. Cloud objects are contiguous cloud structure defined using satellite derived cloud properties. The objective is to identify processes that affect TOA radiation budget by investigating cloud types (cloud objects) frequency of occurrence change and cloud property change within a cloud type. Using more than 3 years of the merged CALIPSO and CloudSat data product (CCCM), we refine and extend cloud object definitions used in earlier studies to all cloud types (low-, mid-, and high-level clouds). Accurate cloud height included in the merged CALIPSO and CloudSat data product allows us to accurately classify clouds by their cloud top height. In addition, CloudSat¿s ability to detect precipitation and drizzle in particular can be used to further separate non-precipitating clouds from precipitating clouds within a cloud object.

The identified cloud variability from this proposed investigation is essential for climate models to simulate the global TOA irradiance variability and their validations. The result of our investigation offers a direct path to test climate models. Our investigation also sets requirements for climate models to properly model energy flows.

Patrick Taylor

Towards an Improved Understanding of the Diurnal Cycle Influence on Earth's Energy and Water Cycle Variability and Prediction

Energy and Water Cycle (E&WC) prediction is a difficult problem involving complex atmosphere-ocean-land interactions. Accurate E&WC prediction is critical for future planning in the agriculture and energy sectors, and will become more important in a warming, more crowded world. The key to better predictive capabilities is a better understanding of system variability. E&WC prediction progress has proved difficult, since it exhibits variability on a wide range of time scales from short-term, intra-diurnal to long-term, decadal. To improve E&WC prediction, the solution must focus on understanding physical interactions causing variability on critical time scales that feed variability.

Improving seasonal-to-annual E&WC prediction is an adopted NASA Energy and Water Cycle Studies (NEWS) science priority, outlined in the NEWS Implementation Guide. The critical physical processes feeding seasonal-to-annual E&WC variability must be identified and understood. Cloud and precipitation diurnal cycles are driven by physical processes critical to longer term E&WC prediction. For example, a common flaw of global models, including MERRA, is a consistent generation of convective precipitation and clouds too early in the day. As a result, convective precipitation rates and cloud top heights are often misrepresented. Incorrect timing of convective clouds will lead to an overestimate of reflected solar radiation, because model clouds will occur when the sun is most intense instead of later in the day. Biases in precipitation timing and intensity will unrealistically force the surface water budget, leading to errors in surface runoff and evaporation. Also, a misrepresentation of convective height will change vertical energy transport, leading to unrealistic feedbacks with large-scale meteorology. These diurnal cycle biases change the character of model physical processes and their interactions leading to an erroneous representation of E&WC variability and reduce model predictive skill. It is imperative to understand diurnal cycle influence on monthly, seasonal, and annual E&WC variability to improve prediction. Proposed herein is a set of studies designed to illuminate the controls on monthly, tropical diurnal cycle amplitude and phase and the physical mechanisms linking the diurnal cycle to E&WC variability. These studies focus around answering a simple science question: what are the consequences of misrepresenting cloud, precipitation, and radiation diurnal cycles for seasonal-to-annual E&WC prediction? Addressing this question, we propose to integrate NEWS and NASA sponsored data and model products including TRMM, CERES, and MERRA. Ancillary ECMWF and NCEP reanalysis, geostationary satellite cloud retrievals, and HOAPS surface turbulent fluxes will be used to enhance the project. We propose three critical steps toward improving the understanding of the diurnal cycle influence on the E&WC. First, we must understand the character of precipitation, cloud, and radiation diurnal cycles and how other processes influence these characteristics. Regionally, the meteorological state and surface turbulent heat fluxes influence on monthly precipitation, clouds, and radiation diurnal cycles will be investigated using MERRA and HOAPS. Second, we must exploit the understanding gained from observational studies to test model diurnal cycle simulations, identifying key deficiencies. Preliminary results show that MERRA produces diurnal cycle biases in climatologically important convective and marine stratocumulus regions. If models do not reproduce key relationships, atmospheric state will be misrepresented and E&WC predictive capabilities compromised. Third, a combined model-data approach must be used to investigate how diurnal cycle biases influence the model E&WC, leading to a deeper understanding of the critical physical processes and how to improve E&WC prediction.