EARTH SCIENCE DIVISION

Strategic Goal 2: Expand scientific understanding of the Earth and the universe in which we live

Outcome 2.1: Advance Earth system science to meet the challenges of climate and environmental change

Objective 2.1.1: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate system.

NASA established the NASA Energy and Water cycle Study NEWS), whose long-term grand challenge is *to document and enable improved, observationally based, predictions of water and energy cycle consequences of Earth system variability and change*. The NEWS program builds 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 cycles, 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 and disciplinary boundaries.

The cycling of energy and water has obvious and significant implications for the health and prosperity of society. The availability and quantity of water is vital to life on earth and helps to tie together the Earth's lands, oceans and atmosphere into an integrated physical system. The NASA Energy and Water Cycle Study aims to:

- Derive satellite-based energy and water cycle climatologies, including monthly, continental and oceanic averages of the Earth's radiation balance, as well as precipitation, evaporation, and water vapor.
- Evaluate uncertainties to add a believability measure for application for this data and help guide future satellite technology decisions. The new integrated global water and energy assessment will be used in conjunction with NASA's Modern Era Retrospective Analysis for Research and Applications (MERRA) reanalysis, to study and improve predictions of weather and climate variability. These integrated water and energy satellite studies will provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, which will help mitigate future damage caused by these extremes.
- Benefit from NASA-sponsored research using satellite observations to improve or create new estimates of water cycle variables, both fluxes and reservoirs, including their relationship with other important environmental processes. MODIS data from the Terra and Aqua satellites has been used in multiple ways to better understand snow and in-land water dynamics, especially the climatechange affected regions of the northern latitudes. Additional satellite data from Aqua (AMSR-E instrument) and QuikScat have been combined with

MODIS to better assess snow melt timing and dynamics. Multiple satellite data streams and hydrologic models have been used to better understand agriculture areas and drought dynamics. Satellite data has also been used to

- better understand and estimate the movement of water in the atmosphere, with some particular emphasis on the water flux from the world's oceans.
- In many cases these advances represent a strong contribution towards improving climate model representation of water cycle attributes

NEWS integrates NASA results into a state-of-the-art synthesis of the global water and energy cycles. As a team, we are the group that is looking across the NASA satellite missions to see if together, the picture that emerges is consistent/makes sense; and has allowed us to learn new things about how the planet (and the human population) moves water and energy around, including how the water cycle is

NASA compiled the first-ever satellite-based energy and water cycle climatology, including monthly, continental and oceanic averages of the Earth's radiation balance, as well as precipitation, evaporation, and water vapor. The accompanying uncertainty evaluation adds a believability measure for application for this data and is helping to guide future satellite technology decisions. This new integrated global water and energy assessment is being used in conjunction with NASA's Modern Era Retrospective-Analysis for Research and Applications (MERRA) reanalysis, to study and improve predictions of weather and climate variability. These integrated water and energy satellite studies have also provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, which will help mitigate future damage caused by these extremes.

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NEWS Supported research also allows the first independent assessment of the range (or uncertainty) in global ET estimates from remote sensing-driven models where the models were driven by common forcing data, based on EOS AQUA and TERRA sensor (MODIS, AIRS, CERES) data. Continued work using 1984-2008 ISCCP and SRB radiation data sets is on-going.

At the same time, NEWS has fostered the development of radically new model representations of energy and water exchange processes that resolve significant

process scales and spatial variability in ground boundary conditions. Such process-resolving models may be first constructed as independent stand-alone modules that can be tested against ad hoc field measurements and systematic observations at

selected experimental sites. The codes may be simplified through statistical sampling of process-scale variables or otherwise reduced to generate integrated fluxes representative of each grid-element in a climate model.

This is supported by a broad exploration of potential new observing techniques concerning all aspects of the energy and water cycle, and initiating relevant technical feasibility and scientific benefit studies.

NEWS has produced very good results from individual PIs, but the big payoff has been the major integrated science results resulting from collaborations or teams within NEWS. For example, the NEWS Climatology Working Group, involving about 20 NEWS PIs and Co-Is has taken on a very large project of integrating numerous satellite data sets to estimate the global and continental-scale means and variations of both the water and energy cycles. All fields have associated errors attached and these are used to adjust the fields to achieve balance, if appropriate. This activity alone makes NEWS worthwhile and unique. Individual instrument science teams do algorithms and analyze results from their instrument, MEASURES produces CDRs, IDS does non-global studies of important interdisciplinary processes. But the NEWS activity is attempting to integrate all our (primarily satellite-based) observations into a complete picture of the energy and water cycles, not just the means, but also seasonal and inter-annual variations and trends—and using the water/energy cycle conservation equations as an additional constraint. This is a big undertaking and requires significant resources over a sustained period.

The NEWS Energy and Water Cycle Climatology working group has established the first objectively-balanced estimates of the joint water cycle and energy budget based primarily on the recent golden era of NASA Earth observation. Combining the available datasets that cover the first decade of the twenty-first century reveals that annual mean estimates of the net radiative flux into the Earth's surface exceed corresponding turbulent heat flux estimates by 13-24 Wm^{-2}, more than an order of magnitude larger than our best estimates of the current forcing by increased greenhouse gas concentrations in the atmosphere. The largest imbalances occur over the global oceans where component flux algorithms operate independently in the absence of closure constraints. Unlike previous studies that have sought to correct these imbalances through primarily ad hoc adjustments to specific fluxes, the NEWS team has pioneered a novel approach to reintroduce energy and water cycle closure information into independently-derived flux datasets, that explicitly accounts for uncertainties in all component fluxes. The technique embraces the NEWS paradigm of integrating a broad spectrum of expertise in the component energy flux datasets to ultimately improve the predictive capabilities of climate models. It has been applied to a ten-year record of satellite observations to estimate all atmospheric and surface energy fluxes and their seasonal cycles globally and for each of 7 continents and 9 ocean basins. These new benchmarks of global and continental energy budgets and their seasonal variability will be critical for evaluating the energetic forcings and water cycle consequences of climate change and evaluating their representation in climate prediction models.

FY 2011 Annual Performance Goal	FY 09	FY10	FY11	FY12
2.1.4.1: ES-11-9: Demonstrate planned progress in quantifying the key reservoirs and fluxes in the global water cycle and assessing water cycle change and water quality. Progress relative to the objectives in NASA's 2010 Science Plan will be evaluated by external expert review	Green	Green	Green	

FY 2014 ES-14-9: Demonstrate planned progress in improving the ability to predict climate changes by better understanding the roles and interactions of the ocean, atmosphere, land, and ice in the climate.

Objective 2.1.4: Progress in quantifying the key reservoirs and fluxes in the global water cycle and assessing water cycle change and water quality.

The cycling of energy and water has obvious and significant implications for the health and prosperity of society. The availability and quantity of water is vital to life on earth and helps to tie together the Earth's lands, oceans and atmosphere into an integrated physical system.

NASA has continued progress toward improving its description of the water and energy cycle, including the size and movement between its stores. Coincident use of multiple satellite and model data sources have led to improvement both in the quantification of the water and energy cycle and the uncertainty estimates of its terms, with both groundwater and total storage two newly provided variables provided by the GRACE satellite. GRACE data has been used to provide large area estimates of the change in total water storage, with estimates of groundwater overabstraction in the Middle-East and California. The state of the global water and energy balance has been derived from NASA satellite data globally and regionally, and on annual and monthly time scales. Shorter term remote sensing data sets (EOS era~10 years) have been combined with longer term satellite records (e.g. snow covered area) and land surface model simulations to provide assessment capability to determine if, where, and how the water cycle might be changing. Progress is being made to observe water quality over oceans, lakes and rivers as highlighted at a NASA water quality workshop and in the creation of a new NASA water quality remote sensing science team.

The NASA Energy and Water cycle Study (NEWS) has compiled a satellite-based energy and water cycle climatology, including monthly, continental and oceanic averages of the Earth’s radiation balance, as well as precipitation, evaporation and water vapor. The accompanying uncertainty evaluation adds a believability measure for application of this data and is helping to guide future satellite technology decisions and helping to improve climate model predictions using advanced diagnostics. These integrated water and energy satellite studies have also provided insights to the mechanisms and severity of mid-western U.S. floods and droughts, which will help mitigate future damage caused by these extremes. NEWS initiated a new science team with innovative integration projects focused on the role of clouds in the climate system, the origins and dynamics of the 2012 midwestern drought, and the ~2002 global climate shift.

Appendix 4: Supporting Material for Objective 2.1.4

Prime Accomplishments

1) Rodell et.al. The Observed State of the Water Cycle in the Early 21st Century

The most noticeable consequences of climate change will be impacts on the water cycle journey through ocean, atmosphere, land, and back again - whose vagaries determine the distribution of humanity, agriculture, and all life on land, and also control circulation of the oceans and atmosphere. A robust, global inventory of current hydrologic flux rates is essential to the assessment and prediction of climate change. This hydrologic article and its energetic companion (L'Ecuyer et al., this issue) attempt to quantify the current state of the water and energy cycles, which is an important first step towards the NASA Energy and Water Cycle Study (NEWS) program goal of evaluating water and energy cycle consequences of climate change (NSIT, 2007).

Reference: **Rodell, M., H.K. Beaudoing, T. L'Ecuyer, W. Olson, J.S. Famiglietti, P.R. Houser, R. Adler, M. Bosilovich, C.A. Clayson, D. Chambers, E. Clark, E. Fetzer, X. Gao, G. Gu, K. Hilburn, G. Huffman, D.P. Lettenmaier, W.T. Liu, F.R. Robertson, C.A. Schlosser, J. Sheffield, and E.F. Wood, The State of the Global Water Cycle at the Start of the 21st Century, *,Submitted to J. Climate,* 2014.**

2) Reference: L'Ecuyer et.al The Observed State of the Energy Budget in the Early 21s Century

This study documents new observational benchmarks of global and continental energy budgets and their seasonal variability from the recent golden era of Earth-observing satellites. Combining available datasets spanning the first decade of the twenty-first century reveals that the net radiative flux into the Earth's surface exceeds turbulent heat flux estimates by 13-24 Wm^{-2}. The largest imbalances occur over oceanic regions where the component algorithms operate independent of closure constraints. Rigorous assessment of the uncertainties in each dataset suggests that these surface energy imbalances fall within anticipated error bounds but the systematic nature of the required adjustments across different regions and the fact that their magnitudes often approach acceptable limits suggests that biases may be present in one or more datasets.

Reference: **L'Ecuyer, T., H.K. Beaudoing, M. Rodell, W. Olson, B. Lin, S. Kato, C.A. Clayson, E. Wood, E. Clark, R. Adler, G. Huffman, M. Bosilovich, F. Robertson, J.S. Famiglietti, P.R. Houser, D. Chambers, E. Fetzer, X. Gao, G. Gu, K. Hilburn, D.P. Lettenmaier, W.T. Liu, C.A. Schlosser, and J. Sheffield, The observed state of the energy balance in the early 21st century, *Submitted to J. Climate,* 2014**
Website

3) **NEWS 10 Year Progress Report**

Implementation of the NEWS program was initially planned in three phases, each successive phase being focused on a range of research activities, as described in the NEWS Implementation Plan, 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 a iterative cycle of research elements: observations, analysis, model development and testing, evaluation, and demonstration of applications. The development of observing/data analysis system capabilities evolves in parallel with the program's research efforts to further develop prediction models and applications.

It was 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 cycles, 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. Based on the NEWS Implementation Plan central issue of assessing the key uncertainties in seasonal-to-annual and longer-term energy and water cycle predictions, and outline model improvements needed to reduce these uncertainties, the following milestones were adopted for each NEWS phase. To date NEWS members have published 193 publications

Reference: Document
Website: http://www.nasa-news.org (July 20, 2014)

4) **Conference served to focus important progress in understanding the Global Water and Energy Cycle**

The increasing demand for fresh water and the impacts of climate change on water availability and extreme events highlight why water is a current major global concern and is "Trending Now." The 7th International Scientific Conference on the Global Water and Energy Cycle celebrated 25 years of GEWEX research and set the stage for the next phase of research addressing the World Climate Research Programme Grand Challenges on water resources, extremes, and climate sensitivity through observations and data sets, their analyses, process studies, model development and exploitation, applications, technology transfer to operational results, and research capacity development and training for the next generation of scientists.

Reference: GEWEX
Website: http://gewex.org

5) **NASA NEWS Press Release**

Researchers Offer an Explanation for Expansion of Tropical Belts: A multi-decadal climate cycle is influencing the trend that expands deserts and pushes storm tracks closer to the poles

A team of researchers led by a former Scripps postdoctoral researcher offered a new explanation for why Earth's tropical belt, bounded by the tropics of Cancer and Capricorn, has progressively expanded since the late 1970s. Robert J. Allen, now an assistant professor at the University of California, Riverside, led a NASA-funded study

that found the recent widening of the tropical belt is primarily caused by multi-decadal sea surface temperature variability in the Pacific Ocean. This variability includes the Pacific Decadal Oscillation (PDO), a pattern of Pacific climate variability that switches roughly every 30 years between two different circulation patterns in the North Pacific Ocean. The researchers say anthropogenic pollutants are another influence that modifies the PDO. The result is an expansion of the range of subtropical deserts that stay dry year-round tropical deserts and the pushing of storm tracks closer to the poles. / (March 2014

Reference: Press Release
https://scripps.ucsd.edu/news/researchers-offer-explanation-expansion-tropical-belts
Website: http://www.nasa-news.org

6) **NASA-JAXA's New Precipitation Satellite Sees First Atlantic Hurricane**

The five GPM passes over Arthur are the first time a precipitation-measuring satellite has been able to follow a hurricane through its full life cycle with high-resolution measurements of rain/ice.

Webiste:http://www.nasa.gov/content/goddard/nasa-jaxas-new-precipitation-satellite-sees-first-atlantic-hurricane/ - .U76krRZbnoYhttp://www.nasa.gov/content/goddard/nasa-jaxas-new-precipitation-satellite-sees-first-atlantic-hurricane/#.U76krRZbnoY
Reference:

Additional Highlights

NASA Aircraft Concludes Six-Week Ground Validation and Hydrology Campaign

A NASA high-altitude ER-2 aircraft concluded its participation June 16 in a study aimed at gaining a better understanding of precipitation over mountainous terrain.

The Integrated Precipitation and Hydrology Experiment, or IPHEx, field campaign is part of the ground validation effort for the Global Precipitation Measurement (GPM) mission, an international satellite mission led by NASA and the Japan Aerospace Exploration Agency. GPM's Core Observatory launched Feb. 27, 2014, to provide next-generation observations of rain and snow worldwide every three hours. But to get accurate measurements from space, scientists have to understand what is happening on the ground.

For the six-week field campaign over the southern Appalachian mountains, the NASA team and their partners at Duke University and NOAA's Hydrometeorological Test Bed set up ground stations with rain gauges and ground radar throughout western North Carolina. In addition to the ground sites, they also collected data sets from satellites and two aircraft.

The NASA ER-2 aircraft that deployed to Robins Air Force Base in Warner Robins, Georgia, May 3 was able to fly when rain was in the air. The ER-2's cruising altitude of 65,000 feet kept it well above the storm systems it was observing, allowing it to act as a proxy-satellite. The aircraft carried a suite of instruments, including three that took measurements similar to those taken by GPM's Core Observatory.

The second aircraft participating in the research was the University of North Dakota's Citation. The Citation flew at altitudes between 10,000 and 25,000 feet and measured raindrops and where ice particles formed. The ER-2 joined the Citation on several occasions, flying above the other aircraft to get the full profile of rainfall in the atmosphere.

When it returned to the NASA Armstrong Flight Research facility in Palmdale, California, the ER-2 had flown 18 IPHEx science missions totaling more than 95 flight hours over the southeastern United States, including North and South Carolina, Florida, Georgia and Tennessee.

NASA and its partners monitor Earth's vital signs from land, air and space with a fleet of satellites and ambitious airborne and ground-based observation campaigns. The agency shares this unique knowledge with the global community and works with institutions in the United States and around the world that contribute to understanding and protecting our home planet.

Reference:

http://www.nasa.gov/topics/earth/features/arctic-seaicemax-2013.html.Website:
http://neptune.gsfc.nasa.gov/csb/

2014 Ocean Sciences Meeting

Held at the Ocean Sciences Meeting in February 2014, the Ocean Salinity and Water Cycle Variability and Change Session (073) highlighted a wide range of current research investigating ocean variability and change related to ocean salinity, an important driver of ocean circulation and a key indicator of the global water cycle. Content was focused on observing platforms that provide comprehensive salinity data while extending the scope of ocean and climate research such as the SMOS (Soil Moisture and Ocean Salinity) satellite (launched in November 2009) and the Aquarius/SAC-D satellite (launched in June 2011). These satellite observations are complemented by in-situ observations from the Argo array, which measures sub-surface salinity (and temperature) and the process-oriented field experiment SPURS (Salinity Processes in the Upper Ocean Regional Study, 2012-2013) in the salinity maximum of the North Atlantic

These recent observations, along with historical measurements, are revolutionizing the view of the ocean on short (hourly, daily to seasonal) and longer (climate, >30-year) timescales. The session involved studies on oceanic variability and change, using observational and model-based approaches, over all timescales and with a key focus on salinity along with temperature and other ocean-state variables. (Feb. 2014)

Satellite Rain-On-Snow Detection to Help Reindeer Herders

The objective is to develop a satellite algorithm using the Advanced Microwave Scanning Radiometers (AMSR-E and AMSR2) for detecting rain-on-snow events daily over the subarctic regions. This will provide a new indicator for wintertime climate change monitoring, and it will help communities of native Arctic reindeer herders with climate adaptation to improve herd management. The algorithm will be validated using satellite rainfall data from the new Global Precipitation Measurement mission, and in-situ measurements in Northern Canada. Some ground-based observations as well as efficient dissemination of satellite ROS product to reindeer herders and managers across the Arctic will be implemented through the U Arctic EALAT Institute on Circumpolar Reindeer Husbandry, the International Centre for Reindeer Husbandry, the Reindeer Portal, and the Arctic Portal.

NASA's Aquarius Returns Global Maps of Soil Moisture

Scientists working with data from NASA's Aquarius instrument have released worldwide maps of soil moisture, showing how the wetness of the land fluctuates with the seasons and weather phenomena.

Soil moisture, the water contained within soil particles, is an important player in Earth's water cycle. It is essential for plant life and influences weather and climate. Satellite readings of soil moisture will help scientists better understand the climate system and have potential for a wide range of applications, from advancing climate models, weather forecasts, drought monitoring and flood prediction to informing water management decisions and aiding in predictions of agricultural productivity.

SMAP Handbook Soil Moisture Active Passive

The SMAP Handbook is a compendium of information on the project near its time of launch (scheduled for November 5, 2014). The SMAP Science Definition Team and Project personnel wrote this 180-pages volume together to provide the community with comprehensive information on programmatic, technological, and scientific aspects of the mission

The SMAP Handbook includes a mission overview that introduces and traces the science goals and requirements to the measurement approach and to the data systems. The technological approaches to the instrument are also outlined and unique technical capabilities of the mission such as radio frequency interference detection and mitigation are highlighted.

The SMAP science products are introduced in three sections: 1) Soil Moisture, 2) Value-Added Data Assimilation, and 3) Carbon Cycle. Calibration and validation (Cal/Val) is outlined in a dedicated section.

The SMAP Project and the SMAP Science Definition Team developed formal plans to engage application users from a diversity of settings and institutions. The SMAP applied science and engagement with applications users are also described in the SMAP Handbook.

The final section of the SMAP Handbook is a bibliography of papers in peer-reviewed

science journals that are either about SMAP or produced in response to the development of the SMAP mission.

The citation for the volume is: Entekhabi, D., S. Yueh, P. O'Neill, K. Kellogg et al., SMAP Handbook, JPL Publication JPL 400-1567, Jet Propulsion Laboratory, Pasadena, California, 182 pages, 2014.

GPM

An international satellite mission launched by NASA and JAXA on Feb. 27, 2014, will set new standards for precipitation measurements worldwide using a network of satellites united by the GPM Core Observatory.

The first set of data from the Global Precipitation Measurement mission is now available to the public.

The data set consists of GPM Microwave Imager instrument observations, called brightness temperatures. Brightness temperatures are a measurement of naturally occurring energy radiated, in this case, by precipitation particles like raindrops or snowflakes. Other data sets, like the rain rate information, will be released later this summer. By themselves, however, the brightness temperatures convey valuable data on the location and structure of storm systems – including tropical cyclones and hurricanes. The earlier-than-expected data release is part of an effort to give forecasters the best possible data for the full summer Atlantic hurricane season.

All GPM data products will be released to the public by September 2. Current and future data sets are available to registered users from NASA Goddard's Precipitation Processing Center website at: http://pps.gsfc.nasa.gov/

The Global Precipitation Measurement (GPM) is an international satellite mission that will set a new standard for precipitation measurements from space, providing the next-generation observations of rain and snow worldwide every three hours. The GPM mission data will advance our understanding of the water and energy cycles and extend the use of precipitation data to directly benefit society.

NASA and the French space agency Centre National d'Études Spatiales (CNES) have agreed to jointly build, launch, and operate a spacecraft to conduct the first-ever global survey of Earth's surface water and to map ocean surface height with unprecedented detail.

Air SWOT

NASA takes to the air to measure the world's water.

The AirSWOT program will help to map fresh water resources and explore how the oceans impact climate change. NASA knows that access to fresh water and the impacts of climate change will be two of this century's biggest challenges. The ongoing AirSWOT mission, a partnership with the French and Canadian space agencies, will help to improve our understanding in both of those areas.

IceBridge Begins 2014 Arctic Campaign

Researchers from Operation IceBridge left NASA's Wallops Flight Facility in Wallops Island, Va., on March 10 for Greenland to begin a new season of collecting data on Arctic land and sea ice. Flights will run through May 23 from Thule Air Base and Kangerlussuaq, Greenland, with a weeklong deployment to Fairbanks, Alaska. The first part of the campaign will focus on sea ice in the Arctic Ocean north of Greenland and in the Beaufort and Chukchi seas north of Alaska. The remainder of the campaign will turn to measuring ice surface elevation and thickness at many of the Greenland Ice Sheet's outlet glaciers. (March 2014)

MERRA-Land Surface Diagnostics Product Release

A supplemental and improved set of land surface hydrological fields ("MERRA-Land") was generated by re-running a revised version of the land component of the MERRA system (Reichle, 2012). Specifically, the MERRA-Land estimates benefit from corrections to the precipitation forcing with the global gauge-based NOAA Climate Prediction Center "Unified" (CPCU) precipitation product and from revised parameter values in the rainfall interception model, changes that effectively correct for known limitations in the MERRA surface meteorological forcings.

With a few exceptions, the MERRA-Land data appear more accurate than the original MERRA estimates and are thus recommended for those interested in using MERRA output for land surface hydrological studies. As an example, Figure 2 examines the drought conditions experienced across the western United States and along the East Coast during August 2002. The MERRA and MERRA-Land drought indicator shown in the figure is derived by ranking, separately for each grid cell, the normalized, monthly mean root zone soil moisture anomalies for June, July, and August of 1980 through 2011 and converting the rank for August 2002 into percentile units. For comparison, the drought severity assessed independently by U.S. Drought Monitor is also shown. The figure clearly demonstrates that MERRA-Land data are more consistent with the Drought Monitor than MERRA data.

You can access the data through the various available download and visualization services provided at the GES DISC by going to: http://disc.sci.gsfc.nasa.gov/daac-bin/DataHoldings.pl?LOOKUPID_List=MST1NXMLD.

Publications

Modeling

Shi, J. J., T. Matsui, W.-K., Tao, Q. Tan, C. Peters-Lidard, M. Chin, K. Pickering, N. Guy, S. Lang and E. M. Kemp, 2014: Implementation of an aerosol–cloud-microphysics–radiation coupling into the NASA unified WRF: Simulation results for the 6–7 August 2006 AMMA special observing period. ***Quarterly Journal of the Royal Meteorological Society*****. doi: 10.1002/qj.2286**

Aerosols affect the Earth's radiation balance directly nd cloud microphysical processes indirectly via the activation of cloud condensation and ice nuclei. These two effects have

often been considered separately and independently, hence the need to assess their combined impact given the differing nature of their effects on convective clouds. To study both effects, an aerosol–microphysics–radiation coupling, including Goddard microphysics and radiation schemes, was implemented into the NASA Unified Weather Research and Forecasting model (NU-WRF). Fully coupled NU-WRF simulations were conducted for a mesoscale convective system (MCS) that passed through the Niamey, Niger area on 6–7 August 2006 during an AMMA special observing period. The results suggest that rainfall is reduced when aerosol indirect effects are included, regardless of the aerosol direct effect. Daily mean radiation heating profiles in the area traversed by the MCS showed the aerosol (mainly mineral dust) direct effect had the largest impact near cloud tops just above 200 hPa where short-wave heating increased by about 0.8 K day^{-1}; the weakest long-wave cooling was at around 250 hPa. It was also found that more condensation and ice nuclei as a result of higher aerosol/dust concentrations led to increased amounts of all cloud hydrometeors because of the microphysical indirect effect, and the radiation direct effect acts to reduce precipitating cloud particles (rain, snow and graupel) in the middle and lower cloud layers while increasing the non-precipitating particles (ice) in the cirrus anvil. However, when the aerosol direct effect was activated, regardless of the indirect effect, the onset of MCS precipitation was delayed about 2 h, in conjunction with the delay in the activation of cloud condensation and ice nuclei. Overall, for this particular environment, model set-up and physics configuration, the effect of aerosol radiative heating due to mineral dust overwhelmed the effect of the aerosols on microphysics. (Feb 2014)

Bosilovich, Michael G., 2013: Regional Climate and Variability of NASA MERRA and Recent Reanalyses: U.S. Summertime Precipitation and Temperature. J. Appl. Meteor. Climatol., 52, 1939–1951.doi: http://dx.doi.org/10.1175/JAMC-D-12-0291.1

Reanalyses have increasingly improved resolution and physical representation of regional climate and so may provide useful data in many regional applications. These data are not observations, however, and their limitations and uncertainties need to be closely investigated. The ability of reanalyses to reproduce the seasonal variations of precipitation and temperature over the United States during summer, when model forecasts have characteristically weak forecast skill, is assessed. Precipitation variations are reproduced well over much of the United States, especially in the Northwest, where ENSO contributes to the large-scale circulation. Some significant biases in the seasonal mean do exist. The weakest regions are the Midwest and Southeast, where land–atmosphere interactions strongly affect the physical parameterizations in the forecast model. In particular, the variance of the Modern-Era Retrospective Analysis for Research and Applications (MERRA) is too low (extreme seasonal averages are weak), and the variability of the Interim ECMWF Re-Analysis (ERA-Interim) is affected by spurious low-frequency trends. Surface temperature is generally robust among the reanalyses examined, though; reanalyses that assimilate near-surface observations have distinct advantages. Observations and forecast error from MERRA are used to assess the reanalysis uncertainty across U.S. regions. These data help to show where the reanalysis is realistically replicating physical processes, and they provide guidance on the quality of the data and needs for further development. (Aug 2013)

Wang, H., and S. Schubert, 2014. The precipitation response over the continental United States to cold tropical Pacific sea surface temperatures. *J. Climate*, 27, 5036-5055. doi: 10.1175/JCLI-D-13-00453.1. Link to Published Version

The dominant pattern of SST variability in the Pacific during its cold phase produces pronounced precipitation deficits over the continental United States throughout the annual cycle. This study investigates the observed physical and dynamical processes through which the cold Pacific pattern affects U.S. precipitation, particularly the causes for the peak dry impacts in fall, as well as the nature of the differences between the summer and fall responses.

Results show that the peak precipitation deficit over the United States during fall is primarily due to reduced atmospheric moisture transport from the Gulf of Mexico into the central and eastern United States and secondarily a reduction in local evaporation from land–atmosphere feedback. The former is associated with a strong and systematic low-level northeasterly flow anomaly over the southeastern United States that counteracts the northwest branch of the climatological North Atlantic subtropical high. The above northeasterly anomaly is maintained by both diabatic heating anomalies in the nearby intra-American seas and diabatic cooling anomalies in the tropical Pacific. In contrast, the modest summertime precipitation deficit over the central United States is mainly an intensification of the local dry anomaly in the preceding spring from local land–atmosphere feedback; the rather weak and disorganized atmospheric circulation anomalies over and to the south of the United States make little contribution. An evaluation of the NASA Seasonal-to-Interannual Prediction Project (NSIPP-1) AGCM simulations shows it to be deficient in simulating the warm season tropical convection responses over the intra-American seas to the cold Pacific pattern and thereby the precipitation responses over the United States, a problem that appears to be common to many AGCMs. (July 2014)

Wang, H., S. Schubert, R. Koster, Y.-G. Ham, and M. Suarez, 2014. On the role of SST forcing in the 2011 and 2012 extreme U.S. heat and drought: A study in contrasts. *J. Hydrometeor*, 15, 1255-1273. doi: 10.1175/JHM-D-13-069.1. Link to Published Version

This study compares the extreme heat and drought that developed over the United States in 2011 and 2012 with a focus on the role of sea surface temperature (SST) forcing. Experiments with the NASA Goddard Earth Observing System, version 5 (GEOS-5), atmospheric general circulation model show that the winter/spring response over the United States to the Pacific SST is remarkably similar for the two years despite substantial differences in the tropical Pacific SST. As such, the pronounced winter and early spring temperature differences between the two years (warmth confined to the south in 2011 and covering much of the continent in 2012) primarily reflect differences in the contributions from the Atlantic and Indian Oceans, with both acting to cool the east and upper Midwest during 2011, while during 2012 the Indian Ocean reinforced the Pacific-driven, continental-wide warming and the Atlantic played a less important role. During late spring and summer of 2011, the tropical Pacific SST forced a continued warming and drying over the southern United States, though considerably weaker than observed. Nevertheless, the observed 2011 anomalies fall well within the model's intraensemble spread. In contrast, the observed rapid development of intense heat and drying over the central United States during June and July 2012 falls on the margins of the model's intraensemble spread, with the response to the SST giving little indication that 2012 would produce record-breaking precipitation deficits and heat. A diagnosis of the 2012 observed circulation anomalies shows that the most extreme heat and drought was tied to the development of a stationary Rossby wave and an associated anomalous upper-tropospheric high maintained by weather transients.(June 2014)

Schubert, S. D., H. Wang, R. Koster, M. Suarez, and P. Groisman, 2014. Northern Eurasian heat waves and droughts. *J. Climate – Special Drought Edition*, 27, 3169-3207. 10.1175/JCLI-D-13-00360.1. Link to Published Version

This article reviews the understanding of the characteristics and causes of northern Eurasian summertime heat waves and droughts. Additional insights into the nature of temperature and precipitation variability in Eurasia on monthly to decadal time scales and into the causes and predictability of the most extreme events are gained from the latest generation of reanalyses and from supplemental simulations with the NASA Goddard Earth Observing System model, version 5 (GEOS-5). Key new results are 1) the identification of the important role of summertime stationary Rossby waves in the development of the leading patterns of monthly Eurasian surface temperature and precipitation variability (including the development of extreme events such as the 2010 Russian heat wave); 2) an assessment of the mean temperature and precipitation changes that have occurred over northern Eurasia in the last three decades and their connections to decadal variability and global trends in SST; and 3) the quantification (via a case study) of the predictability of the most extreme simulated heat wave/drought events, with some focus on the role of soil moisture in the development and maintenance of such events. A literature survey indicates a general consensus that the future holds an enhanced probability of heat waves across northern Eurasia, while there is less agreement regarding future drought, reflecting a greater uncertainty in soil moisture and precipitation projections. Substantial uncertainties remain in the understanding of heat waves and drought, including the nature of the interactions between the short-term atmospheric variability associated with such extremes and the longer-term variability and trends associated with soil moisture feedbacks, SST anomalies, and an overall warming world.(May 2014)

Reichle, R. H., R. H., G. J. M. De Lannoy, B. A. Forman, C. S. Draper, and Q. Liu, 2014. Connecting Satellite Observations with Water Cycle Variables through Land Data Assimilation: Examples Using the NASA GEOS-5 LDAS. *Surv. Geophys.*, 35, 577-606. doi:10.1007/s10712-013-9220-8. Link to Published Version

A land data assimilation system (LDAS) can merge satellite observations (or retrievals) of land surface hydrological conditions, including soil moisture, snow, and terrestrial water storage (TWS), into a numerical model of land surface processes. In theory, the output from such a system is superior to estimates based on the observations or the model alone, thereby enhancing our ability to understand, monitor, and predict key elements of the terrestrial water cycle. In practice, however, satellite observations do not correspond directly to the water cycle variables of interest. The present paper addresses various aspects of this seeming mismatch using examples drawn from recent research with the ensemble-based NASA GEOS-5 LDAS. These aspects include (1) the assimilation of coarse-scale observations into higher-resolution land surface models, (2) the partitioning of satellite observations (such as TWS retrievals) into their constituent water cycle components, (3) the forward modeling of microwave brightness temperatures over land for radiance-based soil moisture and snow assimilation, and (4) the selection of the most relevant types of observations for the analysis of a specific water cycle variable that is not observed (such as root zone soil moisture). The solution to these challenges involves the careful construction of an observation operator that maps from the land surface model variables of interest to the space of the assimilated observations.(May 2014)

Cullather, R., S. M. J. Nowicki, B. Zhao, and M. J. Suarez. (2014). Evaluation of the surface representation of the Greenland ice sheet in a general circulation model J. Climate. 10.1175/JCLI-D-13-00635.1

Simulated surface conditions of the Goddard Earth Observing System model, version 5 (GEOS-5), atmospheric general circulation model (AGCM) are examined for the contemporary Greenland Ice Sheet (GrIS). A surface parameterization that explicitly models surface processes including snow compaction, meltwater percolation and refreezing, and surface albedo is found to remedy an erroneous deficit in the annual net surface energy flux and provide an adequate representation of surface mass balance (SMB) in an evaluation using simulations at two spatial resolutions. The simulated 1980–2008 GrIS SMB average is 24.7 ± 4.5 cm yr^{-1} water-equivalent (w.e.) at ½° model grid spacing, and 18.2 ± 3.3 cm yr^{-1} w.e. for 2° grid spacing. The spatial variability and seasonal cycle of the ½° simulation compare favorably to recent studies using regional climate models, while results from 2° integrations reproduce the primary features of the SMB field. In comparison to historical glaciological observations, the coarser-resolution model overestimates accumulation in the southern areas of the GrIS, while the overall SMB is underestimated. These changes relate to the sensitivity of accumulation and melt to the resolution of topography. The GEOS-5 SMB fields contrast with available corresponding atmospheric models simulations from phase 5 of the Coupled Model Intercomparison Project (CMIP5). It is found that only a few of the CMIP5 AGCMs examined provide significant summertime runoff, a dominant feature of the GrIS seasonal cycle. This is a condition that will need to be remedied if potential contributions to future eustatic change from polar ice sheets are to be examined with GCMs. (July 2014)

Meehl, G. A., L. Goddard, G. Boer, R. Burgman, G. Branstator, C. Cassou, S. Corti, G. Danabasoglu, F. Doblas-Reyes, E. Hawkins, A. Karspeck, M. Kimoto, A. Kumar, D. Matei, J. Mignot, R. Msadek, H. Pohlmann, M. Rienecker, T. Rosati, E. Schneider, D. Smith, R. Sutton, H. Teng, G. J. Van Oldenborgh, G. Vecchi, and S. Yeager, 2014. Decadal climate prediction: An update from the trenches. *B. Am. Meteorol. Soc*, 95, 243-267. doi: 10.1175/BAMS-D-12-00241.1. Link to Published Version

This paper provides an update on research in the relatively new and fast-moving field of decadal climate prediction, and addresses the use of decadal climate predictions not only for potential users of such information but also for improving our understanding of processes in the climate system. External forcing influences the predictions throughout, but their contributions to predictive skill become dominant after most of the improved skill from initialization with observations vanishes after about 6–9 years. Recent multimodel results suggest that there is relatively more decadal predictive skill in the North Atlantic, western Pacific, and Indian Oceans than in other regions of the world oceans. Aspects of decadal variability of SSTs, like the mid-1970s shift in the Pacific, the mid-1990s shift in the northern North Atlantic and western Pacific, and the early-2000s hiatus, are better represented in initialized hindcasts compared to uninitialized simulations. There is evidence of higher skill in initialized multimodel ensemble decadal hindcasts than in single model results, with multimodel initialized predictions for near-term climate showing somewhat less global warming than uninitialized simulations. Some decadal hindcasts have shown statistically reliable predictions of surface temperature over various land and ocean regions for lead times of up to 6–9 years, but this needs to be investigated in a wider set of models. As in the early days of El Niño–

Southern Oscillation (ENSO) prediction, improvements to models will reduce the need for bias adjustment, and increase the reliability, and thus usefulness, of decadal climate predictions in the future. (Feb 2014)

Wang, A., M. Barlage, X. Zeng, and C. Draper, 2014. **Comparison of land skin temperature from a land model, remote sensing, and in-situ measurement**. *J. Geophy. Res*, **119**, 3093-3106. doi: 10.1002/2013JD021026. Link to Published Version

Land skin temperature (Ts) is an important parameter in the energy exchange between the land surface and atmosphere. Here hourly Ts from the Community Land Model version 4.0, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite observations, and in situ observations from the Coordinated Energy and Water Cycle Observation Project in 2003 were compared. Both modeled and MODIS Ts were interpolated to the 12 station locations, and comparisons were performed under MODIS clear-sky condition. Over four semiarid stations, both MODIS and modeled Ts show negative biases compared to in situ data, but MODIS shows an overall better performance. Global distribution of differences between MODIS and modeled Ts shows diurnal, seasonal, and spatial variations. Over sparsely vegetated areas, the model Ts is generally lower than the MODIS-observed Ts during the daytime, while the situation is opposite at nighttime. The revision of roughness length for heat and the constraint of minimum friction velocity from Zeng et al. (2012) bring the modeled Ts closer to MODIS during the day and have little effect on Ts at night. Five factors contributing to the Ts differences between the model and MODIS are identified, including the difficulty in properly accounting for cloud cover information at the appropriate temporal and spatial resolutions, and uncertainties in surface energy balance computation, atmospheric forcing data, surface emissivity, and MODIS Ts data. These findings have implications for the cross evaluation of modeled and remotely sensed Ts, as well as the data assimilation of Ts observations into Earth system models.(March 2014)

Noble, E., L. M. Druyan, M. Fulakeza, 2014: The Sensitivity of WRF Daily Summertime Simulations over West Africa to Alternative Parameterizations. Part I: African Wave Circulation. Mon. Wea. Rev., 142, 1588–1608. doi: http://dx.doi.org/10.1175/MWR-D-13-00194.1 LinMERRAk

The performance of the NCAR Weather Research and Forecasting Model (WRF) as a West African regional-atmospheric model is evaluated. The study tests the sensitivity of WRF-simulated vorticity maxima associated with African easterly waves to 64 combinations of alternative parameterizations in a series of simulations in September. In all, 104 simulations of 12-day duration during 11 consecutive years are examined. The 64 combinations combine WRF parameterizations of cumulus convection, radiation transfer, surface hydrology, and PBL physics. Simulated daily and mean circulation results are validated against NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA) and NCEP/Department of Energy Global Reanalysis 2. Precipitation is considered in a second part of this two-part paper. A wide range of 700-hPa vorticity validation scores demonstrates the influence of alternative parameterizations. The best WRF performers achieve correlations against reanalysis of 0.40–0.60 and realistic amplitudes of spatiotemporal variability for the 2006 focus year while a parallel-benchmark simulation by the NASA Regional Model-3 (RM3) achieves higher correlations, but less realistic spatiotemporal variability. The largest favorable impact on WRF-vorticity validation is achieved by selecting the Grell–Devenyi cumulus convection scheme, resulting in higher correlations against reanalysis than simulations

using the Kain–Fritch convection. Other parameterizations have less-obvious impact, although WRF configurations incorporating one surface model and PBL scheme consistently performed poorly. A comparison of reanalysis circulation against two NASA radiosonde stations confirms that both reanalyses represent observations well enough to validate the WRF results. Validation statistics for optimized WRF configurations simulating the parallel period during 10 additional years are less favorable than for 2006.

Lindsay, R., M. Wensnahan, A. Schweiger, J. Zhang, 2014: Evaluation of Seven Different Atmospheric Reanalysis Products in the Arctic*. J. Climate, 27, 2588–2606. doi: http://dx.doi.org/10.1175/JCLI-D-13-00014.1 Link

Atmospheric reanalyses depend on a mix of observations and model forecasts. In data-sparse regions such as the Arctic, the reanalysis solution is more dependent on the model structure, assumptions, and data assimilation methods than in data-rich regions. Applications such as the forcing of ice–ocean models are sensitive to the errors in reanalyses. Seven reanalysis datasets for the Arctic region are compared over the 30-yr period 1981–2010: National Centers for Environmental Prediction (NCEP)–National Center for Atmospheric Research Reanalysis 1 (NCEP-R1) and NCEP–U.S. Department of Energy Reanalysis 2 (NCEP-R2), Climate Forecast System Reanalysis (CFSR), Twentieth-Century Reanalysis (20CR), Modern-Era Retrospective Analysis for Research and Applications (MERRA), ECMWF Interim Re-Analysis (ERA-Interim), and Japanese 25-year Reanalysis Project (JRA-25). Emphasis is placed on variables not observed directly including surface fluxes and precipitation and their trends. The monthly averaged surface temperatures, radiative fluxes, precipitation, and wind speed are compared to observed values to assess how well the reanalysis data solutions capture the seasonal cycles. Three models stand out as being more consistent with independent observations: CFSR, MERRA, and ERA-Interim. A coupled ice–ocean model is forced with four of the datasets to determine how estimates of the ice thickness compare to observed values for each forcing and how the total ice volume differs among the simulations. Significant differences in the correlation of the simulated ice thickness with submarine measurements were found, with the MERRA products giving the best correlation ($R = 0.82$). The trend in the total ice volume in September is greatest with MERRA (-4.1×10^3 km^3 decade^{-1}) and least with CFSR (-2.7×10^3 km^3 decade^{-1}).(April 2014)

Lindsay , R., M. Wensnahan, A. Schweiger, J. Zhang, 2014: Evaluation of Seven Different Atmospheric Reanalysis Products in the Arctic*. J. Climate, 27, 2588–2606. doi: http://dx.doi.org/10.1175/JCLI-D-13-00014.1 Link

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SNOW and ICE

Comiso, J.C. (2014). Sea ice concentration and extent . In Encyclopedia of Remote Sensing. Berlin Heidelberg: SpringerPublishing. 10.1007/Springer Reference_327226

Among the most seasonal and most dynamic parameters on the surface of the Earth is sea ice which at any one time covers about 3–6 % of the planet. In the Northern Hemisphere, sea ice grows in extent from about 6 × 10$_6$ km$_2$ to 16 × 10$_6$ km$_2$, while in the Southern Hemisphere, it grows from about 3 × 10$_6$ km$_2$ to about 19 × 10$_6$ km$_2$ (Comiso, 2010; Gloersen et al., 1992). Sea ice is up to about 2–3 m thick in the Northern Hemisphere and about 1 m thick in the Southern Hemisphere (May 2014)

Comiso Josefino C., Hall Dorothy K.. Climate trends in the Arctic as observed from space. *WIREs Clim Change* 2014, 5: 389-409. doi: 10.1002/wcc.277

The Arctic is a region in transformation. Warming in the region has been amplified, as expected from ice-albedo feedback effects, with the rate of warming observed to be ~0.60 ± 0.07°C/decade in the Arctic (>64°N) compared to ~0.17°C/decade globally during the last three decades. This increase in surface temperature is manifested in all components of the cryosphere. In particular, the sea ice extent has been declining at the rate of ~3.8%/decade, whereas the perennial ice (represented by summer ice minimum) is declining at a much greater rate of ~11.5%/decade. Spring snow cover has also been observed to be declining by −2.12%/decade for the period 1967–2012. The Greenland ice sheet has been losing mass at the rate of ~34.0 Gt/year (sea level equivalence of 0.09 mm/year) during the period from 1992 to 2011, but for the period 2002–2011, a higher rate of mass loss of ~215 Gt/year has been observed. Also, the mass of glaciers worldwide declined at the rate of 226 Gt/year from 1971 to 2009 and 275 Gt/year from 1993 to 2009. Increases in permafrost temperature have also been measured in many parts of the Northern Hemisphere while a thickening of the active layer that overlies permafrost and a thinning of seasonally frozen ground has also been reported. To gain insight into these changes, comparative analysis with trends in clouds, albedo, and the Arctic Oscillation is also presented. (March 2014)

Nghiem, S., Hall D. K, Foster J. L., and Neumann G. (2014). Terrestrial Snow. In Njoku E. (Ed.), Encyclopedia of Remote Sensing. Berlin Heidelberg: Springer-Verlag. 10.1007/SpringerReference_327235

Among key parameters characterizing seasonal snow cover in cold land regions are snow

area, extent, depth, water equivalent, accumulation onset, melt onset, ice layer, melt duration, and season length. Within an area p(i,j) that has a fractional snow cover of fS(i,j), the actual area that is fully covered by snow is sA(i,j) = fS(i,j) · p(i,j) at a location determined by indices i and j on the Earth's surface. Then, the total snow area SA is the summation of all sA(i,j). Depending on the sensitivity, accuracy, and resolution of a satellite sensor, the existence of snow cover in p(ij) can be detected when sA(i,j) is sufficiently large. The composition of all areas p(i,j) where snow is detectable constitutes the snow extent SE, which is smaller than SA unless snow fully covers all snow area.

Wang, Xianwei, Xiao Cheng, Peng Gong, C.K. Shum, David M. Holland, and Xiaowen Li. 2014. Freeboard and Mass Extraction of the Disintegrated Mertz Ice Tongue with Remote Sensing and Altimetry Data. Remote Sensing of Environment, 144:1-10.

In February 2010, the Mertz Ice Tongue (MIT) collapsed and generated a giant iceberg. However, parameters about this iceberg have not been calculated and published in detail. In this study, the freeboard map of this iceberg was generated for the first time using a time-series ICESat/GLAS data. Methods for producing the freeboard map of this iceberg are suggested. Field data for ice velocity were used to relocate the footprints collected by different campaigns. Cross-validation was conducted with freeboards extracted from crossovers observed within 30 days of each other. The precision of the freeboard extraction is approximately ± 0.50 m, when taking one standard deviation as the precision. The freeboard varied from 23 m to 59 m with the mean of 41 m.

With assumption of hydrostatic equilibrium (assuming a snow layer depth of 1 m, a snow density of 360 kg/m3, an ice density of 915 kg/m3 and a sea water density of 1024 kg/m3), the minimum, maximum and average ice thickness were calculated as 210 m, 550 m and 383 m respectively. The total ice loss is approximately 8.96 × 1011 tons over an area, 34 km in width and 75 km in length, or approximately 2560 ± 5 km2. These parameters extracted from remote sensing and altimetry data will provide additional information for studies of the evolution of iceberg, especially in iceberg tracking system (Jan 2014)

Borsa, A., G. Moholdt, H.A. Fricker, and K.M. Brunt (2014). A range correction for ICESat and its potential impact on ice-sheet mass balance studies *The Cryosphere*, *8*, 345–357 10.5194/tc-8-345-2014

We report on a previously undocumented range error in NASA's Ice, Cloud and land Elevation Satellite (ICESat) that degrades elevation precision and introduces a small but significant elevation trend over the ICESat mission period. This range error (the Gaussian-Centroid or "G-C" offset) varies on a shot-to-shot basis and exhibits increasing scatter when laser transmit energies fall below 20 mJ. Although the G-C offset is uncorrelated over periods ≤ 1 day, it evolves over the life of each of ICESat's three lasers in a series of ramps and jumps that give rise to spurious elevation trends of −0.92 to −1.90 cm yr^{-1}, depending on the time period considered. Using ICESat data over the Ross and Filchner–Ronne ice shelves we show that (1) the G-C offset introduces significant biases in ice-shelf mass balance estimates, and (2) the mass balance bias can vary between regions because of different temporal samplings of ICESat. We can reproduce the effect of the G-C offset over these two ice shelves by fitting trends to sample-weighted mean G-C offsets for each campaign, suggesting that it may not be

necessary to fully repeat earlier ICESat studies to determine the impact of the G-C offset on ice-sheet mass balance estimates.(2014)

Brucker, L., D.J. Cavalieri, T. Markus, and A. Ivanoff (2014). NASA Team 2 Sea Ice Concentration Algorithm Retrieval Uncertainty *IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING*. 10.1109/TGRS.2014.2311376

Satellite microwave radiometers are widely used to estimate sea ice cover properties (concentration, extent, and area) through the use of sea ice concentration (IC) algorithms. Rare are the algorithms providing associated IC uncertainty estimates. Algorithm uncertainty estimates are needed to assess accurately global and regional trends in IC (and thus extent and area), and to improve sea ice predictions on seasonal to interannual timescales using data assimilation approaches. This paper presents a method to provide relative IC uncertainty estimates using the enhanced NASA Team (NT2) IC algorithm. The proposed approach takes advantage of the NT2 calculations and solely relies on the brightness temperatures (TBs) used as input. NT2 IC and its associated relative uncertainty are obtained for both the Northern and Southern Hemispheres using the Advanced Microwave Scanning Radiometer for the Earth Observing System (AMSR-E) TB. NT2 IC relative uncertainties estimated on a footprint-by-footprint swath-by-swath basis were averaged daily over each 12.5-km grid cell of the polar stereographic grid. For both hemispheres and throughout the year, the NT2 relative uncertainty is <;5%. In the Southern Hemisphere, it is low in the interior ice pack, and it increases in the marginal ice zone up to 5%. In the Northern Hemisphere, areas with high uncertainties are also found in the high IC area of the Central Arctic. Retrieval uncertainties are greater in areas corresponding to NT2 ice types associated with deep snow and new ice. Seasonal variations in uncertainty show larger values in summer as a result of melt conditions and greater atmospheric contributions. Our analysis also includes an evaluation of the NT2 algorithm sensitivity to AMSR-E sensor noise. There is a 60% probability that the IC does not change (to within the computed retrieval precision of 1%) due to sensor noise, and the cumulated probability shows that there is a 90% chance that the IC varies by less than &#- 00B1;3%. We also examined the daily IC variability, which is dominated by sea ice drift and ice formation/melt. Daily IC variability is the highest, year round, in the MIZ (often up to 20%, locally 30%). The temporal and spatial distributions of the retrieval uncertainties and the daily IC variability is expected to be useful for algorithm intercomparisons, climate trend assessments, and possibly IC assimilation in models.(April 2014)

Land

Justice, C. O., et al. (2013), Land and cryosphere products from Suomi NPP VIIRS: Overview and status, *J. Geophys. Res. Atmos*., 118, 9753–9765, doi:10.1002/jgrd.50771.

The Visible Infrared Imaging Radiometer Suite (VIIRS) instrument was launched in October 2011 as part of the Suomi National Polar-Orbiting Partnership (S-NPP). The VIIRS instrument was designed to improve upon the capabilities of the operational Advanced Very High Resolution Radiometer and provide observation continuity with NASA's Earth Observing System's Moderate Resolution Imaging Spectroradiometer (MODIS). Since the VIIRS first-light images were received in November 2011, NASA- and NOAA-funded scientists have been working to evaluate the instrument performance and generate land and cryosphere products to meet the needs of the NOAA operational

users and the NASA science community. NOAA's focus has been on refining a suite of operational products known as Environmental Data Records (EDRs), which were developed according to project specifications under the National Polar-Orbiting Environmental Satellite System. The NASA S-NPP Science Team has focused on evaluating the EDRs for science use, developing and testing additional products to meet science data needs, and providing MODIS data product continuity. This paper presents to-date findings of the NASA Science Team's evaluation of the VIIRS land and cryosphere EDRs, specifically Surface Reflectance, Land Surface Temperature, SurfaceAlbedo, Vegetation Indices, Surface Type, Active Fires, Snow Cover, Ice SurfaceTemperature, and Sea Ice Characterization. The study concludes that, for MODIS data product continuity and earth system science, an enhanced suite of land and cryosphere products and associated data system capabilities are needed beyond the EDRs currently available from the VIIRS. (Sept 2013)

Zhang X., Tang, Q., Zhang X., and Lettenmaier, D. P., 2014: Runoff sensitivity to global mean temperature change in the CMIP5 models. *Geophysical Research Letters*, doi: 10.1002/2014GL060382

We estimated runoff sensitivities to global mean temperature (GMT) change using climate experiments archived in the Coupled Model Intercomparison Project Phase 5 (CMIP5) and compared with the similar CMIP3 results. We also evaluated differences in runoff sensitivity for the Earth System Models (ESMs) and Climate System Models (CSMs), which were separately identified in CMIP5 for the first time. Our results show that runoff sensitivity is relatively independent of emission scenarios in CMIP5, as in CMIP3 results. Global mean runoff would increase about 2.9% per °C of global warming in CMIP5, as contrasted with 1.9% in CMIP3. Although global runoff sensitivity patterns for CMIP5 and CMIP3 are roughly similar, CMIP5 suggests significant declines (increases) in runoff sensitivity over 17% (25%) of the global land area relative to CMIP3. Globally, the ESMs and CSMs have about the same model spread in runoff change projections.

Bohn, T. J., and D. P. Lettenmaier, 2013: Exploring the response of West Siberian wetland methane emissions to future changes in climate, vegetation, and soil microbial communities, *Biogeosciences Discuss.*, 10, 16329-16369, doi:10.5194/bgd-10-16329-2013.

We ran the VIC land surface model over the West Siberian Lowland (WSL), forced with outputs from 32 CMIP5 models for the RCP4.5 scenario, and compared the effects of changes in climate and vegetation (leaf area index in particular) on predicted wetland CH_4 emissions and other fluxes for the period 2071–2100, relative to the period 1981–2010. We also explored possible responses of soil microbial communities to these changes. Our results suggest that, if soil microbial communities acclimatize to elevated temperatures without changes in species abundances, end-of-century CH_4 emissions from the WSL will only rise to 3.6 Tg CH_4 yr^{-1} (6% above historical emissions). In contrast, if microbial species abundances in the north additionally shift to resemble those in the south, CH_4 emissions will more than double, to 7.3 Tg CH_4 yr^{-1}. Crucially, while historical emissions were concentrated in the southern half of the domain, acclimatization plus microbial population shifts concentrate almost 3/4 of future emissions in the northern half of the domain, where the possible release of carbon with permafrost thaw is a concern. In addition, microbial population shifts disproportionately increase microbial activity in the period during and immediately following snowmelt, when highly labile

carbon is first thought to be released from the soil. This work indicates the importance of better constraining the responses of soil microbial communities to changes in climate and vegetation as they are critical determinants of the region's future methane emissions. (Oct. 2013)

Nijssen, B., S. Shukla, C. Lin, H. Gao, T. Zhou, J. Sheffield, E. F. Wood, D. P. Lettenmaier, 2013: A prototype Global Drought Information System based on multiple land surface models, *J. Hydrometeorol.*, , doi: http://dx.doi.org/10.1175/JHM-D-13-090.1

The implementation of a multimodel drought monitoring system is described, which provides near-real-time estimates of surface moisture storage for the global land areas between 50°S and 50°N with a time lag of about 1 day. Near-real-time forcings are derived from satellite-based precipitation estimates and modeled air temperatures.

The system distinguishes itself from other operational systems in that it uses multiple land surface models (Variable Infiltration Capacity, Noah, and Sacramento) to simulate surface moisture storage, which are then combined to derive a multimodel estimate of drought. A comparison of the results with other historic and current drought estimates demonstrates that near-real-time nowcasting of global drought conditions based on satellite and model forcings is entirely feasible. However, challenges remain because hydrological droughts are inherently defined in the context of a long-term climatology. Changes in observing platforms can be misinterpreted as droughts (or as excessively wet periods). This problem cannot simply be addressed through the addition of more observations or through the development of new observing platforms. Instead, it will require careful (re)construction of long-term records that are updated in near–real time in a consistent manner so that changes in surface meteorological forcings reflect actual conditions rather than changes in methods or sources. (Aug 2014)

Kumar, S., Lawrence, D. M., Dirmeyer, P. A. and Sheffield, J. (2014), Less reliable water availability in the 21st century climate projections. *Earth's Future*, 2: 152–160. doi: 10.1002/2013EF000159

The temporal variability of river and soil water affects society at time scales ranging from hourly to decadal. The available water (AW), i.e., precipitation minus evapotranspiration, represents the total water available for runoff, soil water storage change, and ground water recharge. The reliability of AW is defined as the annual range of AW between local wet and dry seasons. A smaller annual range represents greater reliability and a larger range denotes less reliability. Here we assess the reliability of AW in the 21st century climate projections by 20 climate models from phase 5 of the Coupled Model Intercomparison Project (CMIP5). The multimodel consensus suggests less reliable AW in the 21st century than in the 20th century with generally decreasing AW in local dry seasons and increasing AW in local wet seasons. In addition to the canonical perspective from climate models that wet regions will get wetter, this study suggests greater dryness during dry seasons even in regions where the mean climate becomes wetter. Lower emission scenarios show significant advantages in terms of minimizing impacts on AW but do not eliminate these impacts altogether. (March 2014)

Xia, Y., M. B. Ek, C. D. Peters-Lidard, D. Mocko, M. Svoboda, J. Sheffield, and E. F. Wood (2014), Application of USDM statistics in NLDAS-2: Optimal blended NLDAS drought index over the continental United States, *J. Geophys. Res. Atmos*., 119, 2947–2965, doi:10.1002/2013JD020994.

This study performs three experiments to calibrate the drought area percentages in the continental United States (CONUS), six U.S. Drought Monitor (USDM) regions, and 48 states downloaded from the USDM archive website. The corresponding three experiments are named CONUS, Region, and State, respectively. The data sets used in these experiments are from the North American Land Data Assimilation System Phase 2 (NLDAS-2). The main purpose is to develop an automated USDM-based approach to objectively generate and reconstruct USDM-style drought maps using NLDAS-2 data by mimicking 10 year (2000–2009) USDM statistics. The results show that State and Region have larger correlation coefficients and smaller root-mean-square error (RMSE) and bias than CONUS when compared to the drought area percentages derived from the USDM, indicating that State and Region perform better than CONUS. In general, State marginally outperforms Region in terms of RMSE, bias, and correlation.

Analysis of normalized optimal weight coefficients shows that soil moisture percentiles (top 1 m and total column) play the dominant role in most of the 48 states. The optimal blended NLDAS drought index (OBNDI) has higher simulation skills (correlation coefficient and Nash-Sutcliffe efficiency) in the South, Southeast, High Plains, and Midwest regions when compared to those in the West and Northeast. The highest simulation skills appear in TX and OK. By using optimal equations, we can reconstruct the long-term drought area percentages and OBNDI over the continental United States for the entire period of the NLDAS-2 data sets (January 1979 to present). (March 2014)

Kam, J, J. Sheffield, and E. F. Wood, 2014: A Multi-Scale Analysis of Drought and Pluvial Mechanisms for the Southeastern United States, J. Geophys. Res.-Atmos.,doi:10.1002/2014JD021453.

The Southeast (SE) U.S. has experienced several severe droughts over the past 30 years, with the most recent drought during 2006–2008 causing agricultural impacts of $1 billion. However, the mechanisms that lead to droughts over the region and their persistence have been poorly understood due to the region's humid coastal environment and its complex climate. In this study, we carry out a multiscale analysis of drought mechanisms for the SE U.S. over 1979–2008 using the North American Regional Reanalysis (NARR) to identify conditions associated with drought and contrast with those associated with pluvials. These conditions include land surface drought propagation, land-atmosphere feedbacks, regional moisture sources, persistent atmospheric patterns, and larger-scale oceanic conditions. Typical conditions for SE U.S. droughts (pluvials) are identified as follows: (1) weaker (stronger) southerly meridional fluxes and weaker (stronger) westerly zonal fluxes, (2) strong moisture flux divergence (convergence) by transient eddies, and (3) strong (weak) coupling between the land surface and atmosphere. The NARR demonstrates that historic SE droughts are mainly derived from a combination of a strong North Atlantic subtropical high (NASH) and Icelandic Low (IL) during summer and winter, respectively, which peak 1 month earlier than the onset of the drought. The land surface plays a moderate role in drought occurrence over the SE via recycling of precipitation, and the oceans show an asymmetric influence on droughts and pluvials depending on the season. This study suggests that the

NASH and IL can be used as a predictor for SE droughts at 1 month lead despite the overall that it represents an atmospheric forcing. (June 2014)

Chaney, Nathaniel W., Justin Sheffield, Gabriele Villarini, Eric F. Wood, 2014: Development of a High-Resolution Gridded Daily Meteorological Dataset over Sub-Saharan Africa: Spatial Analysis of Trends in Climate Extremes. *J. Climate*, 27, 5815–5835.doi: http://dx.doi.org/10.1175/JCLI-D-13-00423.1

Assessing changes in the frequency and intensity of extreme meteorological events and their impact on water resources, agriculture, and infrastructure is necessary to adequately prepare and adapt to future change. This is a challenge in data-sparse regions such as sub-Saharan Africa, where a lack of high-density and temporally consistent long-term in situ measurements complicates the analysis. To address this, a temporally homogenous and high-temporal- and high-spatial-resolution meteorological dataset is developed over sub-Saharan Africa (5°S–25°N), covering the time period between 1979 and 2005. It is developed by spatially downscaling the National Centers for Environmental Prediction–National Center for Atmospheric Research (NCEP–NCAR) reanalysis to a 0.1° spatial resolution, detecting and correcting for temporal inhomogeneities, and by removing random errors and biases by assimilating quality-controlled and gap-filled Global Summary of the Day (GSOD) in situ measurements. The dataset is then used to determine the statistical significance and magnitude of changes in climate extremes between 1979 and 2005. The results suggest a shift in the distribution of daily maximum and minimum temperatures toward a warmer mean with a faster increase in warm than cold events. Changes in the mean annual precipitation and heavy rainfall events are significant only in regions affected by the Sahel droughts of the 1970s and 1980s. (Aug 2014

Ershadi, A., M. F. McCabe, J. P. Evans, N. W. Chanet, E. F. Wood, 2014, Multi-site evaluation of terrestrial evaporation models using FLUXNET data, *Agricultural and Forest Meteorlogy*, 187, 46-61.

We evaluated the performance of four commonly applied land surface evaporation models using a high-quality dataset of selected FLUXNET towers. The models that were examined include an energy balance approach (Surface Energy Balance System; SEBS), a combination-type technique (single-source Penman–Monteith; PM), a complementary method (advection-aridity; AA) and a radiation based approach (modified Priestley–Taylor; PT-JPL). Twenty FLUXNET towers were selected based upon sat- isfying stringent forcing data requirements and representing a wide range of biomes. These towers encompassed a number of grassland, cropland, shrubland, evergreen needleleaf forest and deciduous broadleaf forest sites. Based on the mean value of the Nash–Sutcliffe efficiency (NSE) and the root mean squared difference (RMSD), the order of overall performance of the models from best to worst were: ensemble mean of models (0.61, 64), PT-JPL (0.59, 66), SEBS (0.42, 84), PM (0.26, 105) and AA (0.18, 105) [statistics stated as (NSE, RMSD in Wm^{-2})]. Although PT-JPL uses a relatively simple and largely empirical formulation of the evaporative process, the technique showed improved performance com- pared to PM, possibly due to its partitioning of total evaporation (canopy transpiration, soil evaporation, wet canopy evaporation) and lower uncertainties in the required forcing data. The SEBS model showed low performance over tall and heterogeneous canopies, which was likely a consequence of the effects of the roughness sub-layer parameterization employed in this scheme. However, SEBS performed well overall. Relative to PT-JPL and SEBS, the PM and AA showed low

performance over the majority of sites, due to their sensitivity to the parameterization of resistances. Importantly, it should be noted that no single model was consistently best across all biomes. Indeed, this outcome highlights the need for further evaluation of each model's structure and parameterizations to identify sensitivities and their appropriate application to different surface types and conditions. It is expected that the results of this study can be used to inform decisions regarding model choice for water resources and agricultural management, as well as providing insight into model selection for global flux monitoring efforts. (April 2014)

Aizhong, Y., Q. Duan, X. Yuan, E. F. Wood, J. Schaake, 2014, Hydrologic post-processing of MOPEX streamflow simulations, *J. of Hydrol*., 508, 147-156.

There are many approaches to improve hydrologic model predictions, including pre-processing to deal with input uncertainty, data assimilation to treat initial and boundary condition uncertainty, model calibration to reduce parametric uncertainty. Hydrologic post-processing is an approach for treating uncertainties from hydrologic model outputs propagated from all upstream sources. It works by relating model outputs (e.g., streamflow) to corresponding observations through a statistical model. This paper compares the effect of post-processing and model calibration in improving hydrologic forecasts under different hydroclimatic conditions and across different models. Observed and simulated daily streamflow data from the Second Workshop on Model Parameter Estimation Experiment (MOPEX) were used for the comparisons described above. The results from 7 hydrologic models showed that post-processing alone was better than the results from hydrologic model calibrations for 12 basins in the eastern United States. The predictive QQ plot indicates that the predictive distributions of post-processed ensemble streamflow simulations are reliable. Post-processed results were similar for different hydrologic models, but were quite different for different basins. In terms of ensemble prediction, post-processing results tended to be over-confident. In general, post-processing can improve hydrological forecasts and reduce uncertainty in wet basins, but caution should be taken when applying post-processing to dry basins where there are many zeros values in the data. (Nov.2014)

Leroux, D. J., Y. H. Kerr, E. F. Wood, A. K. Sahoo, R. Bindlish, T. J. Jackson, 2014, An Approach to Constructing a Homogeneous Time Series of Soil Moisture Using SMOS, IEEE Transactions on *Geoscience and Remote Sensing*, 52, 393-405.

Overlapping soil moisture time series derived from two satellite microwave radiometers (the Soil Moisture and Ocean Salinity (SMOS) and the Advanced Microwave Scanning Radiometer-Earth Observing System) are used to generate a soil moisture time series from 2003 to 2010. Two statistical methodologies for generating long homogeneous time series of soil moisture are considered. Generated soil moisture time series using only morning satellite overpasses are compared to ground measurements from four watersheds in the U.S. with different climatologies. The two methods, cumulative density function (CDF) matching and copulas, are based on the same statistical theory, but the first makes the assumption that the two data sets are ordered the same way, which is not needed by the second. Both methods are calibrated in 2010, and the calibrated parameters are applied to the soil moisture data from 2003 to 2009. Results from these two methods compare well with ground measurements. However, CDF matching improves the correlation, whereas copulas improve the root-mean-square error. (Jan 2014)

Maloney, E. D., S. J. Camargo, E. Chang, B. Colle, R. Fu, K. L. Geilw, Q. Hu, X. Jiang, N. Johnson, K. B. Karnauskas, J. Kinter, B. Kirtman, S. Kumar, B. Langenbrunner, K. Lombardo, L. Long, A. Mariotti, J. E. Meyerson, K. Mo, J. D. Neelin, Z. Pan, R. Seager, Y. Serraw, A. Seth, J. Sheffield, J. Thibeault, S.-P. Xie, C. Wang, B. Wyman, and M. Zhao, 2011: North American Climate in CMIP5 Experiments: Part III: Assessment of 21st Century Projections. *J. Climate*, 27, 2230-2270.

In part III of a three-part study on North American climate in phase 5 of the Coupled Model Intercomparison Project (CMIP5) models, the authors examine projections of twenty-first-century climate in the representative concentration pathway 8.5 (RCP8.5) emission experiments. This paper summarizes and synthesizes results from several coordinated studies by the authors. Aspects of North American climate change that are examined include changes in continental-scale temperature and the hydrologic cycle, extremes events, and storm tracks, as well as regional manifestations of these climate variables. The authors also examine changes in the eastern North Pacific and North Atlantic tropical cyclone activity and North American intraseasonal to decadal variability, including changes in teleconnections to other regions of the globe. Projected changes are generally consistent with those previously published for CMIP3, although CMIP5 model projections differ importantly from those of CMIP3 in some aspects, including CMIP5 model agreement on increased central California precipitation. The paper also highlights uncertainties and limitations based on current results as priorities for further research. Although many projected changes in North American climate are consistent across CMIP5 models, substantial intermodel disagreement exists in other aspects. Areas of disagreement include projections of changes in snow water equivalent on a regional basis, summer Arctic sea ice extent, the magnitude and sign of regional precipitation changes, extreme heat events across the northern United States, and Atlantic and east Pacific tropical cyclone activity. (March 2014)

Kam, J., J. Sheffield, X. Yuan, and E.F. Wood, 2014: Did a skillful prediction of sea surface temperatures help or hinder forecasting of the 2012 Midwestern US drought?, *Environ. Res. Lett.*, 9, 034005, doi:10.1088/1748-9326/9/3/034005.

The latest drought to hit the Midwestern (MW) US region, in 2012, was driven by the least summer precipitation for the last three decades with $20 billion in agriculture losses. For 2012, the summer forecast skill for Pacific and Atlantic sea surface temperature (SST) anomalies and low MW precipitation is remarkably good for some National Multi-Model Ensemble (NMME) models, but this is not generally repeated for other drought years, with some models predicting extreme wet anomalies, despite skill in predicting Pacific and Atlantic SST anomalies. In order to diagnose the origins of the limited skill of the NMME models, we use singular value decomposition (SVD) for global SSTs and continental US (CONUS) precipitation from observational data and NMME hindcasts (1982–2012). Observational data indicate that there is an insignificant coupling between global SSTs and MW precipitation during summer over the last 30 years. However, the NMME climate forecast models show strong coupling and therefore predicted the 2012 drought fortuitously for the wrong reason (a strong pan-Pacific El Nino–Southern Oscillation (ENSO)-like pattern). The observational data indicate that the strength of ENSO teleconnections with CONUS precipitation has weakened and the precipitation footprint has shifted over the past decades, suggesting that the transient nature of teleconnections may play a role in poor model skill. (March 2014)

Sheffield, J., E. F. Wood, N. Chaney, K. Guan, S. Sadri, X. Yuan, L. Olang, A. Amani, A. Ali, and S. Demuth, 2013; A Drought Monitoring and Forecasting System for Sub-Sahara African Water Resources and Food Security. *Bull. Am. Met.* Soc.e-View, doi: http://dx.doi.org/10.1175/BAMS-D-12-00124.1

Drought is one of the leading impediments to development in Africa. Much of the continent is dependent on rain-fed agriculture, which makes it particularly susceptible to climate variability. Monitoring drought and providing timely seasonal forecasts are essential for integrated drought risk reduction. Current approaches in developing regions have generally been limited, however, in part because of unreliable monitoring networks. Operational seasonal climate forecasts are also deficient and often reliant on statistical regressions, which are unable to provide detailed information relevant for drought assessment. However, the wealth of data from satellites and recent advancements in large-scale hydrological modeling and seasonal climate model predictions have enabled the development of state-of-the-art monitoring and prediction systems that can help address many of the problems inherent to developing regions. An experimental drought monitoring and forecast system for sub-Saharan Africa is described that is based on advanced land surface modeling driven by satellite and atmospheric model data. Key elements of the system are the provision of near-real-time evaluations of the terrestrial water cycle and an assessment of drought conditions. The predictive element takes downscaled ensemble dynamical climate forecasts and provides, when merged with the hydrological modeling, ensemble hydrological forecasts. We evaluate the overall skill of the system for monitoring and predicting the development of drought and illustrate the use of the system for the 2010/11 Horn of Africa drought. A key element is the transition and testing of the technology for operational usage by African collaborators and we discuss this for two implementations in West and East Africa. (June, 2014)

Lichstein, J. L., N.-Z. Golaz, S. Malyshev, E. Shevliakova, T. Zhang, J. Sheffield, R. A. Birdsey, J. L. Sarmiento, and S. W. Pacala, 2013: Confronting terrestrial biosphere models with forest inventory data. *Ecological Applications*, http://dx.doi.org/10.1890/13-0600.1

Efforts to test and improve terrestrial biosphere models (TBMs) using a variety of data sources have become increasingly common. Yet, geographically extensive forest inventories have been under-exploited in previous model–data fusion efforts. Inventory observations of forest growth, mortality, and biomass integrate processes across a range of timescales, including slow timescale processes such as species turnover, that are likely to have important effects on ecosystem responses to environmental variation. However, the large number (thousands) of inventory plots precludes detailed measurements at each location, so that uncertainty in climate, soil properties, and other environmental drivers may be large. Errors in driver variables, if ignored, introduce bias into model–data fusion. We estimated errors in climate and soil drivers at U.S. Forest Inventory and Analysis (FIA) plots, and we explored the effects of these errors on model–data fusion with the Geophysical Fluid Dynamics Laboratory LM3V dynamic global vegetation model. When driver errors were ignored or assumed small at FIA plots, responses of biomass production in LM3V to precipitation and soil available water capacity appeared steeper than the corresponding responses estimated from FIA data. These differences became nonsignificant if driver errors at FIA plots were assumed to be large. Ignoring driver errors when optimizing LM3V parameter values yielded estimates for fine-root allocation that were larger than biometric estimates, which is consistent with the expected direction of bias. To explore whether complications posed by driver errors could be circumvented

by relying on intensive study sites where driver errors are small, we performed a power analysis. To accurately quantify the response of biomass production to spatial variation in mean annual precipitation within the eastern United States would require at least 40 intensive study sites, which is larger than the number of sites typically available for individual biomes in existing plot networks. Driver errors may be accommodated by several existing model–data fusion approaches, including hierarchical Bayesian methods and ensemble filtering methods; however, these methods are computationally expensive. We propose a new approach, in which the TBM functional response is fit directly to the river-error-corrected functional response estimated from data, rather than to the raw observations. (June 2014)

Wuebbles, D., G. Meehl, K. Hayhoe, T. R. Karl, K. Kunkel, B. Santer, M. Wehner, B. Colle, E. M. Fischer, R. Fu, A. Goodman, E. Janssen, H. Lee, W. Li, L. N. Long, S. Olsen, A. Seth, J. Sheffield, and L. Sun, 2012: CMIP5 Climate Model Analyses: Climate Extremes in the United States. *Bull. Amer. Meteor. Soc.*, doi: http://dx.doi.org/10.1175/BAMS-D-12-00172.1.

This is the fourth in a series of four articles on historical and projected climate extremes in the United States. Here, we examine the results of historical and future climate model experiments from the phase 5 of the Coupled Model Intercomparison Project (CMIP5) based on work presented at the World Climate Research Programme (WCRP) Workshop on CMIP5 Climate Model Analyses held in March 2012. Our analyses assess the ability of CMIP5 models to capture observed trends, and we also evaluate the projected future changes in extreme events over the contiguous Unites States. Consistent with the previous articles, here we focus on model-simulated historical trends and projections for temperature extremes, heavy precipitation, large-scale drivers of precipitation variability and drought, and extratropical storms. Comparing new CMIP5 model results with earlier CMIP3 simulations shows that in general CMIP5 simulations give similar patterns and magnitudes of future temperature and precipitation extremes in the United States relative to the projections from the earlier phase 3 of the Coupled Model Intercomparison Project (CMIP3) models. Specifically, projections presented here show significant changes in hot and cold temperature extremes, heavy precipitation, droughts, atmospheric patterns such as the North American monsoon and the North Atlantic subtropical high that affect interannual precipitation, and in extratropical storms over the twenty-first century. Most of these trends are consistent with, although in some cases (such as heavy precipitation) underestimate, observed trends. (April 2014)

Manfreda, S., L. Brocca, T. Moramarco, F. Melone, and J. Sheffield, 2014: A physically based approach for the estimation of root-zone soil moisture from surface measurements, *Hydrol. Earth Syst. Sci.* , 18, 1199-1212.

In the present work, we developed a new formulation for the estimation of the soil moisture in the root zone based on the measured value of soil moisture at the surface. It was derived from a simplified soil water balance equation for semiarid environments that provides a closed form of the relationship between the root zone and the surface soil moisture with a limited number of physically consistent parameters. The method sheds lights on the mentioned relationship with possible applications in the use of satellite remote sensing retrievals of soil moisture. The proposed approach was used on soil moisture measurements taken from the African Monsoon Multidisciplinary Analysis (AMMA) and the Soil Climate Analysis Network (SCAN) databases. The AMMA

network was designed with the aim to monitor three so-called mesoscale sites (super sites) located in Benin, Mali, and Niger using point measurements at different locations.

Thereafter the new formulation was tested on three additional stations of SCAN in the state of New Mexico (US). Both databases are ideal for the application of such method, because they provide a good description of the soil moisture dynamics at the surface and the root zone using probes installed at different depths. The model was first applied with parameters assigned based on the physical characteristics of several sites. These results highlighted the potential of the methodology, providing a good description of the root-zone soil moisture. In the second part of the paper, the model performances were compared with those of the well-known exponential filter. Results show that this new approach provides good performances after calibration with a set of parameters consistent with the physical characteristics of the investigated areas. The limited number of parameters and their physical interpretation makes the procedure appealing for further applications to other regions. (May 2014)

Xia, Y., J. Sheffield, M. B. Ek, J. Dong, N. Chaney, H. Wei, J. Meng, E. F. Wood, 2014: Evaluation of multi-model simulated soil moisture in NLDAS-2. *J. Hydrology*, 512, 107-125, doi:10.1016/j.jhydrol.2014.02.027

The North American Land Data Assimilation System (NLDAS) phase 2 (NLDAS-2) has generated 31-years (1979–2008) of water and energy products from four state-of-the-art land surface models (Noah, Mosaic, SAC, VIC). The soil moisture data from these models have been used for operational drought monitoring activities, but so far have not yet been comprehensively evaluated. In this study, three available in situ soil moisture observation data sets in the United States were used to evaluate the model-simulated soil moisture for different time scales varying from daily to annual. First, we used the observed multiple layer monthly and annual mean soil moisture from the Illinois Climate Network to evaluate 20-years (January 1985–December 2004) of model-simulated soil moisture in terms of skill and analysis of error statistics. Second, we utilized 6-years (1 January 1997–31 December 2002) of daily soil moisture observed from 72 sites over the Oklahoma Mesonet network to assess daily and monthly simulation skill and errors for 3 model soil layers (0–10 cm, 10–40 cm, 40–100 cm). Third, we extended the daily assessment to sites over the continental United States using 8-years (1 January 2002–31 December 2009) of observations for 121 sites from the Soil Climate Analysis Network (SCAN). Overall, all models are able to capture wet and dry events and show high skill (in most cases, anomaly correlation is larger than 0.7), but display large biases when compared to in situ observations. These errors may come from model errors (i.e., model structure error, model parameter error), forcing data errors, and in situ soil moisture measurement errors. For example, all models simulate less soil moisture due to lack of modeled irrigation and ground water processes in Illinois, Oklahoma, and the other Midwest states. (May 2014)

Wang, S., J. Huang, J. Li, A. Rivera, D. W. McKenney, and J. Sheffield, 2014: Assessment of water budget for sixteen large drainage basins in Canada. *J. Hydrol.*.
DOI: 10.1016/j.jhydrol.2014.02.058

This study represents the first attempt to examine the spatial and seasonal variations of the surface water budget by using state-of-the-art datasets for sixteen large Canadian drainage basins with a total area of 3.2 million km^2. The datasets used include two precipitation grids produced using measurements and reanalysis models, land surface

evapotranspiration and water surface evaporation estimated using the EALCO model, streamflow measured at hydrometric stations, and total water storage change derived from GRACE satellite observations. The monthly water imbalance resulted from these datasets varied from 7.0 mm month^{-1} to 21 mm month^{-1} among the studied basins, which was 30% on average of the corresponding monthly precipitation. The accumulated water budget imbalance over the 7 years of 2002–2008 varied from close to zero to ±10 mm month^{-1}. The positive and negative imbalances among the sixteen basins were largely offset and the all-basin imbalance was very close to 0. The uncertainties in precipitation, streamflow, evapotranspiration and total water storage change all contributed to the water budget imbalance and their relative magnitudes were found to vary with basin and season. In most cases, precipitation showed the largest uncertainties, which had similar magnitudes to the water budget imbalances. While improvements are noted in comparison with previous water budget studies over the regions, the water imbalance obtained for some basins is quite large, suggesting that considerable improvements in both the observation networks and models are necessary before the water budget closure can be substantially improved over this region (May 2014)

Guan, K., D. Medvigy, E.F. Wood, K.K. Caylor, S. Li, and S.J. Jeong, 2014: Deriving Vegetation Phenological Time and Trajectory Information Over Africa Using SEVIRI Daily LAI. IEEE Trans. *Geosci. Remote Sensing*, 52, 1113-1130, doi:10.1109/TGRS.2013.2247611

Vegetation phenology is closely connected to the terrestrial carbon budget, and interacts with the atmosphere through surface water and energy exchange. A comprehensive and detailed characterization of the spatio-temporal pattern of vegetation phenology can be used to improve the understanding of interactions between vegetation and climate in Africa. This research provides an approach to derive phenology time and trajectory parameters by optimally fitting a double-logistic curve to daily remotely sensed leaf area index (LAI) from the spinning enhanced visible and infrared imager. The proposed algorithm can reconstruct the temporal LAI trajectory based on the optimized parameters with a high accuracy, and provides user-defined phenological timing information (e.g., start/end of the growing season) and trajectory information (e.g., leaf emergence/senescence rate and length) using these fitted parameters. Both single and double growing-season cases have been considered with a spatial classification scheme implemented over Africa. The newly derived vegetation phenology of Africa exhibits emerging spatial patterns in growing season length, asymmetric green-up and green-off length/rate, and distinctive phenological features of cropland and natural vegetation. This approach has the potential to be applied globally, and the derived vegetation phenological information will improve dynamic vegetation modeling and climate prediction.

Pan, M., A. K. Sahoo, and E. F. Wood, 2014: Improving soil moisture retrievals from a physically-based radiative transfer model. *Remote Sens. Env.*, 140, 130-140, doi:10.1016/j.rse.2013.08.02

Near surface soil moisture is being estimated from space-borne passive microwave observations through inverting a physically-based radiative transfer model (RTM), the land surface microwave emission model (LSMEM) at Princeton University for the past several years. The existing retrieval scheme utilizes only the horizontal (H) polarization measurement from a single channel (10.65 GHz). This physically-based approach requires a relatively large number of parameters, and it generally suffers from large biases/errors due to the difficulty in determining the correct parameters. This study

characterizes these errors in order to improve the retrieval performance. Through model sensitivity analysis, this study finds that a dual polarization approach (using both horizontal and vertical polarizations) is needed to infer the correct vegetation opacity and correct polarization mixing measured by the space-borne sensor. Revisions are then made to the LSMEM formulations and soil moisture retrieval algorithm by 1) combining two vegetation parameters and one roughness parameter into one effective vegetation optical depth (VOD) value; and 2) providing an additional model equation that estimates the effective VOD from both polarizations and an initial guess of soil moisture value. The new retrieval algorithm is implemented to produce a daily 0.25° gridded soil moisture dataset based on observations from the Advanced Microwave Scanning Radiometer-EOS (AMSR-E). Validations are performed globally against land surface model simulations and at local/point scale against in-situ data within the continental United States. The new retrievals are shown to have good and robust performance over most parts of the world in terms of reproducing the spatial and temporal dynamics of soil moisture. (Jan 2014)

SWOT

Durand, Michael, Jeffrey Neal, Ernesto Rodríguez, Konstantinos M. Andreadis, Laurence C. Smith, Yeosang Yoon, "Estimating reach-averaged discharge for the River Severn from measurements of river water surface elevation and slope." ***Journal of Hydrology*****, Volume 511, 16 Pages 92–104**.

An algorithm is presented that calculates a best estimate of river bathymetry, roughness coefficient, and discharge based on input measurements of river water surface elevation (h) and slope (S) using the Metropolis algorithm in a Bayesian Markov Chain Monte Carlo scheme, providing an inverse solution to the diffusive approximation to the shallow water equations. This algorithm has potential application to river h and S measurements from the forthcoming Surface Water and Ocean Topography (SWOT) satellite mission. These results suggest that it should be possible to estimate river discharge via SWOT observations of river water surface elevation, slope and width. (April 2014)

Gleason, C.J., and Smith, L.C., "Toward global mapping of river discharge using satellite images and at-many-stations hydraulic geometry." ***PNAS Early Edition*****, Feb. 2014. (Link)Sept. 2013)**

Rivers provide critical water supply for many human societies and ecosystems, yet global knowledge of their flow rates is poor. We show that useful estimates of absolute river discharge (in cubic meters per second) may be derived solely from satellite images, with no ground-based or a priori information whatsoever. The approach works owing to discovery of a characteristic scaling law uniquely fundamental to natural rivers, here termed a river's at-many-stations hydraulic geometry. A first demonstration using Landsat Thematic Mapper images over three rivers in the United States, Canada, and China yields absolute discharges agreeing to within 20–30% of tra- ditional in situ gauging station measurements and good tracking of flow changes over time. Within such accuracies, the door appears open for quantifying river resources globally with repeat imaging, both retroactively and henceforth into the future, with strong impli- cations for water resource management, food security, ecosystem studies, flood forecasting, and geopolitics. (Link)Sept. 2013)

NASA LIS

Kumar, S.V., K.W. Harrison, C.D. Peters-Lidard, J.A.Santanello, D. Kirschbaum: 2014 Assessing the impact of L-band observations on drought and flood risk estimation: A decision theoretic approach in an OSSE environment. ***Journal of Hydrometeorology****,*

Observing System Simulation Experiments (OSSEs) are often conducted to evaluate the worth of existing data and data yet to be collected from proposed new missions. As missions increasingly require a broader "Earth systems" focus, it is important that the OSSEs capture the potential benefits of the observations on end-use applications. Towards this end, the results from the OSSEs must also be evaluated with a suite of metrics that capture the value, uncertainty, and information content of the observations while factoring in both science and societal impacts. In this article, we present a soil moisture OSSE that employs simulated L-band measurements and assess their utility towards improving drought and flood risk estimates, using the NASA Land Information System (LIS). A decision-theory based analysis is conducted to assess the economic utility of the observations towards improving these applications. The results suggest that the improvements in surface soil moisture, root zone soil moisture and total runoff fields obtained through the assimilation of L-band measurements are effective in providing improvements in the drought and flood risk assessments as well. The decision theory analysis not only demonstrates the economic utility of observations, but also shows that the use of probabilistic information from the model simulations is more beneficial compared to the use of corresponding deterministic estimates. The experiment also demonstrates the value of a comprehensive modeling environment such as LIS for conducting end-to-end OSSEs by linking satellite observations, physical models, data assimilation algorithms and end-use application models in a single integrated framework.

Arsenault, K. R., Houser, P. R. and De Lannoy, G. J. M. (2014), Evaluation of the MODIS snow cover fraction product. ***Hydrol. Process.,*** **28: 980–998. doi: 10.1002/hyp.9636**

Eleven years of daily 500 m gridded Terra Moderate Resolution Imaging Spectroradiometer (MODIS) (MOD10A1) snow cover fraction (SCF) data are evaluated in terms of snow presence detection in Colorado and Washington states. The SCF detection validation study is performed using in-situ measurements and expressed in terms of snow and land detection and misclassification frequencies. A major aspect addressed in this study involves the shifting of pixel values in time due to sensor viewing angles and gridding artifacts of MODIS sensor products. To account for this error, 500 m gridded pixels are grouped and aggregated to different-sized areas to incorporate neighboring pixel information. With pixel aggregation, both the probability of detection (POD) and the false alarm ratios increase for almost all cases. Of the false negative (FN) and false positive values (referred to as the total error when combined), FN estimates dominate most of the total error and are greatly reduced with aggregation. The greatest POD increases and total errorreductions occur with going from a single 500 m pixel to 3×3-pixel averaged areas. Since the MODIS SCF algorithm was developed under ideal conditions, SCF detection is also evaluated for varying conditions of vegetation, elevation, cloud cover and air temperature. Finally, using a direct insertion data assimilation approach, pixel averaged MODIS SCF observations are shown to improve modeled snowpack conditions over the single pixel observations due to the smoothing of more error-prone observations and more accurately snow-classified pixels. (Jan. 2014)

F. R. Robertson, M. G. Bosilovich, J. B. Roberts, R. H. Reichle, R. Adler, L. Ricciardulli, W. Berg, and G. J. Huffman, 2014: Consistency of Estimated Global Water Cycle Variations over the Satellite Era. *J. Climate*, 27, 6135–6154.doi: http://dx.doi.org/10.1175/JCLI-D-13-00384.1

Motivated by the question of whether recent interannual to decadal climate variability and a possible "climate shift" may have affected the global water balance, we examine precipitation minus evaporation ($P - E$) variability integrated over the global oceans and global land for the period 1979–2010 from three points of view—remotely sensed retrievals and syntheses over the oceans, reanalysis vertically integrated moisture flux convergence (VMFC) over land, and land surface models (LSMs) forced with observations-based precipitation, radiation, and near-surface meteorology.

Over land, reanalysis VMFC and P − evapotranspiration (ET) from observationally forced LSMs agree on interannual variations (e.g., El Niño/La Niña events); however, reanalyses exhibit upward VMFC trends 3–4 times larger than P − ET trends of the LSMs. Experiments with other reanalyses using reduced observations show that upward VMFC trends in the full reanalyses are due largely to observing system changes interacting with assimilation model physics. The much smaller P − ET trend in the LSMs appears due to changes in frequency and amplitude of warm events after the 1997/98 El Niño, a result consistent with coolness in the eastern tropical Pacific sea surface temperature (SST) after that date. When integrated over the global oceans, E and especially P variations show consistent signals of El Niño/La Niña events. However, at scales longer than interannual there is considerable uncertainty especially in E. This results from differences among datasets in near-surface atmospheric specific humidity and wind speed used in bulk aerodynamic retrievals. The P variations, all relying substantially on passive microwave retrievals over ocean, also have uncertainties in decadal variability, but to a smaller degree.(Aug 2014)

Rodell, M., H.K. Beaudoing, T. L'Ecuyer, W. Olson, J.S. Famiglietti, P.R. Houser, R. Adler, M. Bosilovich, C.A. Clayson, D. Chambers, E. Clark, E. Fetzer, X. Gao, G. Gu, K. Hilburn, G. Huffman, D.P. Lettenmaier, W.T. Liu, F.R. Robertson, C.A. Schlosser, J. Sheffield, and E.F. Wood, The state of the global water cycle at the start of the 21st century, Submitted to *J. Climate*, 2014.

This study quantifies mean annual and monthly fluxes of Earth's water cycle over continents and ocean basins during the first decade of the millennium. To the extent possible, the flux estimates are based on satellite measurements first and data-integrating models second. A careful accounting of uncertainty in the estimates is included. It is applied within a routine that enforces multiple water and energy budget constraints simultaneously in a variational framework, in order to produce objectively-determined, optimized flux estimates. In the majority of cases, the observed annual, surface and atmospheric water budgets over the continents and oceans close with much less than 10% residual. Observed residuals and optimized uncertainty estimates are considerably larger for monthly surface and atmospheric water budget closure, often nearing or exceeding 20% in North America, Eurasia, Australia and neighboring islands, and the Arctic and South Atlantic Oceans. The residuals in South America and Africa tend to be smaller, possibly because cold land processes are a non-issue. Fluxes were poorly observed over the Arctic Ocean, certain seas, Antarctica, and the Australasian and Indonesian Islands, leading to reliance on atmospheric analysis estimates. Many of the satellite systems that

contributed data have been or will soon be replaced. Observation integrating models will be critical for ameliorating gaps and discontinuities in the data records caused by these transitions. Continued development of such models is essential for maximizing the value of remote sensing observations. Next generation observing systems are the best hope for significantly improving global water budget accounting.

L'Ecuyer, T., H.K. Beaudoing, M. Rodell, W. Olson, B. Lin, S. Kato, C.A. Clayson, E. Wood, E. Clark, R. Adler, G. Huffman, M. Bosilovich, F. Robertson, J.S. Famiglietti, P.R. Houser, D. Chambers, E. Fetzer, X. Gao, G. Gu, K. Hilburn, D.P. Lettenmaier, W.T. Liu, C.A. Schlosser, and J. Sheffield, The observed state of the energy balance in the early 21st century, Submitted to *J. Climate*, 2014.

This study documents new observational benchmarks of global and continental energy bud gets and their seasonal variability from the recent golden era of Earth-observing satellites. Combining available datasets spanning the first decade of the twenty-first century reveals that the net radiative flux into the Earth's surface exceeds turbulent heat flux estimates by 13-24 Wm^{-2}. The largest imbalances occur over oceanic regions where the component algorithms operate independent of closure constraints. Rigorous assessment of the uncertainties in each dataset suggests that these surface energy imbalances fall within anticipated error bounds but the systematic nature of the required adjustments across different regions and the fact that their magnitudes often approach acceptable limits suggests that biases may be present in one or more datasets. To reintroduce energy and water cycle closure into independently-derived flux datasets,a novel variational method for objectively imposing balance constraints is introduced that explicitly accounts for uncertainties in all component fluxes. Applying the analysis to a ten-year record of satellite observations suggests that globally, 180 Wm^{-2} of atmospheric longwave cooling is balanced by 74 Wm^{-2} of shortwave absorption and 106 Wm^{-2} of latent and sensible heating. At the surface, 527 Wm^{-2} of downwelling radiation is balanced by 399 Wm^{-2} of thermal emission, 22 Wm^{-2} of shortwave reflection, and 106 Wm^{-2} of turbulent heat transfer. The resulting implied residual heat flux into the oceans (0.45 Wm^{-2}) is consistent with recent observations of changes in ocean heat content. Budgets are also presented for each of 7 continents and 9 ocean basins on annual and monthly scales. This study documents new observational benchmarks of global and continental energy bud gets and their seasonal variability from the recent golden era of Earth-observing satellites. Combining available datasets spanning the first decade of the twenty-first century reveals that the net radiative flux into the Earth's surface exceeds turbulent heat flux estimates by 13-24 Wm^{-2}. The largest imbalances occur over oceanic regions where the component algo rithms operate independent of closure constraints. Rigorous assessment of the uncertainties in each dataset suggests that these surface energy imbalances fall within anticipated error bounds but the systematic nature of the required adjustments across different regions and the fact that their magnitudes often approach acceptable limits suggests that biases may be present in one or more datasets. To reintroduce energy and water cycle closure into independently-derived flux datasets, a novel variational method for objectively imposing balance constraints is introduced that explicitly accounts for uncertainties in all component fluxes. Applying the analysis to a ten-year record of satellite observations suggests that globally, 180 Wm^{-2} of atmospheric longwave cooling is balanced by 74 Wm^{-2} of shortwave absorption and 106 Wm^{-2} of latent and

sensible heating. At the surface, 527 Wm^{-2} of downwelling radiation is balanced by 399 Wm^{-2} of thermal emission, 22 Wm^{-2} of shortwave reflection, and 106 Wm^{-2} of turbulent heat transfer. The resulting implied residual heat flux into the oceans (0.45 Wm^{-2}) is consistent with recent observations of changes in ocean heat content. Budgets are also presented for each of 7 continents and 9 ocean basins on annual and monthly scales. (July 2014)

Wang, J. J., R. F. Adler, G. J. Huffman, and D. F. Bolvin (2014). An Updated TRMM Composite Climatology of Tropical Rainfall and Its Validation *Journal of Climate*, *27*(1), 273-284 10.1175/JCLI-D-13-00331.1

An updated 15-yr Tropical Rainfall Measuring Mission (TRMM) composite climatology (TCC) is presented and evaluated. This climatology is based on a combination of individual rainfall estimates made with data from the primary TRMM instruments: the TRMM Microwave Imager (TMI) and the precipitation radar (PR). This combination climatology of passive microwave retrievals, radar-based retrievals, and an algorithm using both instruments simultaneously provides a consensus TRMM-based estimate of mean precipitation. The dispersion of the three estimates, as indicated by the standard deviation σ among the estimates, is presented as a measure of confidence in the final estimate and as an estimate of the uncertainty thereof. The procedures utilized by the compositing technique, including adjustments and quality-control measures, are described. The results give a mean value of the TCC of 4.3 mm day^{-1} for the deep tropical ocean belt between 10°N and 10°S, with lower values outside that band. In general, the TCC values confirm ocean estimates from the Global Precipitation Climatology Project (GPCP) analysis, which is based on passive microwave results adjusted for sampling by infrared-based estimates. The pattern of uncertainty estimates shown by σ is seen to be useful to indicate variations in confidence. Examples include differences between the eastern and western portions of the Pacific Ocean and high values in coastal and mountainous areas. Comparison of the TCC values (and the input products) to gauge analyses over land indicates the value of the radar-based estimates (small biases) and the limitations of the passive microwave algorithm (relatively large biases). Comparison with surface gauge information from western Pacific Ocean atolls shows a negative bias (~16%) for all the TRMM products, although the representativeness of the atoll gauges of open-ocean rainfall is still in question. (Jan 2014)

J. S. Famiglietti, M. Rodell. Water in the Balance. *Science*, 2013: 340 (6138): 1300 DOI: 10.1126/science.1236460

Earth's climate is changing, and so is its hydrologic cycle. Recent decades have witnessed rising rates of global precipitation, evaporation, and freshwater discharge (1). Extreme flooding is occurring with greater intensity and frequency in some regions; in others, extreme drought is becoming more common (2). Most climate models indicate that by the end of this century, the dry regions of the world will become drier, whereas the wet areas will become wetter (3). Meanwhile, groundwater reserves, the traditional backup for water supplies during extended periods of drought, are in decline globally (4–6). GRACE (the Gravity Recovery and Climate Experiment, a joint U.S.-German satellite mission) monitors these variations on monthly to decadal time scales, providing detailed data on the water cycle that are an essential prerequisite for contemporary water management.(June 2013)

Buckley, B.M., R. Fletcher, S.-Y. Wang, B. Zpttoli, and C. Pottier, 2014: Monsoon extremes and society over the past millennium on mainland Southeast Asia. *Quarterly Science Reviews*. 95, Pages 1-19

The early 21st century has seen vigorous scientific interest in the Asian monsoon and significant development of paleo-proxies of monsoon strength. These include the Monsoon Asian Drought Atlas – a 700-year, gridded reconstruction of hydroclimate derived from 327 tree ring records – and several long speleothem records from China and India. Similar progress has been made on the study of monsoon climate dynamics through re-analysis data products and General Circulation Model diagnostics. The story has emerged of a variable monsoon over the latter Holocene, with extended droughts and anomalously wet episodes that occasionally and profoundly influenced the course of human history. We focus on Southeast Asia where an anomalous period of unstable climate coincided with the demise of the capital of the Khmer Empire at Angkor between the 14th and the 16th centuries, and we suggest that protracted periods of drought and deluge rain events, the latter of which damaged Angkor's extensive water management systems, may have been a significant factor in the subsequent transfer of the political capital away from Angkor. The late 16th and early 17th century experienced climate instability and the collapse of the Ming Dynasty in China under a period of drought, while Tonkin experienced floods and droughts throughout the 17th century. The 18th century was a period of great turmoil across Southeast Asia, when all of the region's polities saw great unrest and rapid realignment during one of the most extended periods of drought of the past millennium. New paleo-proxy records and the incorporation of historical documentation will improve future analyses of the interaction between climate extremes, social behavior and the collapse or disruption of regional societies, a subject of increasing concern given the uncertainties surrounding projections for future climate. (July 2014)

Wang, S.-Y., J.-H. Yoon, R. R. Gillies, and C. Cho, 2013: What caused the winter drought in western Nepal during recent years? *J. Climate*, doi: 10.1175/JCLI-D-12-00800.1

Western Nepal has experienced consecutive and worsening winter drought conditions since 2000, culminating in a severe drought episode during 2008/09. In this study, the meteorological conditions and a historical perspective of the winter droughts in western Nepal were analyzed using instrumental records, satellite observations, and climate model simulations. Meteorological diagnosis using atmospheric reanalysis revealed that 1) winter drought in western Nepal is linked to the Arctic Oscillation and its decadal variability, which initiates a tropospheric short-wave train across Eurasia and South Asia; and that 2) the persistent warming of the Indian Ocean likely contributes to the suppression of rainfall through enhanced local Hadley circulation. Simulations from the phase 5 of the Coupled Model Intercomparison Project (CMIP5) sets of historical single-forcing experiments indicated that the increased loading of anthropogenic aerosols is also a compounding factor in the precipitation decline during the later decades. It is therefore conceivable that the recent spells of decadal drought in Nepal are symptomatic of both natural variability and anthropogenic influences. Given the observations that winter precipitation has declined to near zero while groundwater has hardly been replenished, appropriate management of western Nepal's water resources is both critical and necessary. (Nov 2013)

Getirana, A. C. V. and Peters-Lidard, C., 2013: Estimating water discharge from arge radar altimetry datasets, *Hydrol. Earth Syst. Sci*., 17, 923-933, doi:10.5194/hess-17-923-2013

The objective of this study is to evaluate the potential of large altimetry datasets as a complementary gauging network capable of providing water discharge in ungauged regions. A rating curve-based methodology is adopted to derive water discharge from altimetric data provided by the Envisat satellite at 475 virtual stations (VS) within the Amazon basin. From a global-scale perspective, the stage–discharge relations at VS are built based on radar altimetry and outputs from a modeling system composed of a land surface model and a global river routing scheme. In order to quantify the impact of model uncertainties on rating-curve based discharges, a second experiment is performed using outputs from a simulation where daily observed discharges at 135 gauging stations are introduced in the modeling system. Discharge estimates at 90 VS are evaluated against observations during the curve fitting calibration (2002–2005) and evaluation (2006–2008) periods, resulting in mean normalized RMS errors as high as 39 and 15% for experiments without and with direct insertion of data, respectively. Without direct insertion, uncertainty of discharge estimates can be mostly attributed to forcing errors at smaller scales, generating a positive correlation between performance and drainage area. Mean relative streamflow volume errors (RE) of altimetry-based discharges varied from 15 to 84% for large and small drainage areas, respectively. Rating curves produced a mean RE of 51% versus 68% from model outputs. Inserting discharge data into the modeling system decreases the mean RE from 51 to 18%, and mean NRMSE from 24 to 9%. These results demonstrate the feasibility of applying the proposed methodology to the continental or global scales

Takahashi, H., H. Su, J. H. Jiang, Z. J. Luo, S.-P. Xie, and J. Hafner 2013: Tropical water vapor variations during the 2006–2007 and 2009–2010 El Niños: Satellite observation and GFDL AM2.1 simulation, *J. Geophys. Res. Atmos*., 118, 8910–8920, doi:10.1002/jgrd.50684.

Water vapor measurements from Aura Microwave Limb Sounder (MLS, above 300 hPa) and Aqua Atmospheric Infrared Sounder (AIRS, below 300 hPa) are analyzed to study the variations of moisture during the 2006–2007 and 2009–2010 El Niños. The 2006–2007 El Niño is an East Pacific (EP) El Niño, while the 2009–2010 El Niño is a Central Pacific (CP) El Niño or El Niño *Modoki*. Results show that these two types of El Niño events produce different patterns of water vapor anomalies over the tropical ocean, approximately resembling the cloud anomalies shown in Su and Jiang (2013). Regression of water vapor anomalies sonto the Niño-3.4 SST for the A-Train period shows a clear "upper tropospheric amplification" of the fractional water vapor change, i.e., the ratio of the change in specific humidity to the layer-averaged specific humidity. Furthermore, tropical water vapor anomalies in different circulation regimes are examined. It is shown that the variations of water vapor during the 2006–2007 El Niño are mainly controlled by the thermodynamic component, whereas both dynamic and thermodynamic components control the water vapor anomalies during the 2009–2010 El Niño. GFDL AM2.1 model simulations of water vapor and cloud anomalies for the two El Niños are compared with the satellite observations. In general, the model approximately reproduces the water vapor anomalies on both zonal and meridional planes but it produces too strong a cloud response in the mid- and lower troposphere. The model fails to capture the dynamic component of water vapor anomalies, particularly over the Indian Ocean. (Aug 2013)

Jiang, X., et al., 2013: Influence of El Nino on Mid-tropospheric CO2 from Atmospheric Infrared Sounder and Model. *J.Atmos. Sci*., 223-230.

Midtropospheric CO_2 retrievals from the Atmospheric Infrared Sounder (AIRS) were used to explore the influence of stratospheric sudden warming (SSW) on CO_2 in the middle to upper troposphere. To choose the SSW events that had strong coupling between the stratosphere and troposphere, the authors applied a principal component analysis to the NCEP/Department of Energy Global Reanalysis 2 (NCEP-2) geopotential height data at 17 pressure levels. Two events (April 2003 and March 2005) that have strong couplings between the stratosphere and troposphere were chosen to investigate the influence of SSW on AIRS midtropospheric CO_2. The authors investigated the temporal and spatial variations of AIRS midtropospheric CO_2 before and after the SSW events and found that the midtropospheric CO_2 concentrations increased by 2–3 ppm within a few days after the SSW events. These results can be used to better understand how the chemical tracers respond to the large-scale dynamics in the high latitudes. (August 2013)

Tao, Z., Santanello, J. A., Chin, M., Zhou, S., Tan, Q., Kemp, E. M., and Peters-Lidard, C. D. 2013: Effect of land cover on atmospheric processes and air quality over the continental United States – a NASA unified WRF (NU-WRF) model study, *Atmos. Chem. Phys. Discuss*., 13, 5429-5475, doi:10.5194/acpd-13-5429-2013, 2013.

The land surface plays a crucial role in regulating water and energy fluxes at the land–atmosphere (L–A) interface and controls many processes and feedbacks in the climate system. Land cover and vegetation type remains one key determinant of soil moisture content that impacts air temperature, planetary boundary layer (PBL) evolution, and precipitation through soil-moisture–evapotranspiration coupling. In turn, it will affect atmospheric chemistry and air quality. This paper presents the results of a modeling study of the effect of land cover on some key L–A processes with a focus on air quality. The newly developed NASA Unified Weather Research and Forecast (NU-WRF) modeling system couples NASA's Land Information System (LIS) with the community WRF model and allows users to explore the L– A processes and feedbacks. Three commonly used satellite- derived land cover datasets – i.e., from the US Geological Survey(USGS)and University of Maryland(UMD),which are based on the Advanced Very High Resolution Radiometer (AVHRR), and from the Moderate Resolution Imaging Spectroradiometer (MODIS) – bear large differences in agriculture, forest, grassland, and urban spatial distributions in the continental United States, and thus provide an excellent case to investigate how land cover change would impact atmospheric processes and air quality. The weeklong simulations demonstrate the noticeable differences in soil mois- ture/temperature, latent/sensible heat flux, PBL height, wind, NO /ozone, and PM air quality. These discrepancies can 2 2.5 be traced to associate with the land cover properties, e.g. stomatal resistance, albedo and emissivity, and roughness (July 2013)

Wang, S.-Y., L. Hipps, R. R. Gillies, and J.-H. Yoon (2014), Probable causes of the abnormal ridge accompanying the 2013–2014 California drought: ENSO precursor and anthropogenic warming footprint, *Geophys. Res. Lett*., 41, 3220–3226, doi:10.1002/2014GL059748.

The 2013–2014 California drought was initiated by an anomalous high-amplitude ridge system. The anomalous ridge was investigated using reanalysis data and the Community Earth System Model (CESM). It was found that the ridge emerged from continual sources

of Rossby wave energy in the western North Pacific starting in late summer and subsequently intensified into winter. The ridge generated a surge of wave energy downwind and deepened further the trough over the northeast U.S., forming a dipole. The dipole and associated circulation pattern is not linked directly with either El Niño–Southern Oscillation (ENSO) or Pacific Decadal Oscillation; instead, it is correlated with a type of ENSO precursor. The connection between the dipole and ENSO precursor has become stronger since the 1970s, and this is attributed to increased greenhouse gas loading as simulated by the CESM. Therefore, there is a traceable anthropogenic warming footprint in the enormous intensity of the anomalous ridge during winter 2013–2014 and the associated drought.(May 2014)

Wang, Shih-Yu, Michelle L'Heureux, Jin-Ho Yoon, 2013: Are Greenhouse Gases Changing ENSO Precursors in the Western North Pacific?. *J. Climate,* 26, 6309–6322.

Multiple global reanalysis and precipitation datasets were analyzed in order to explain the dynamic mechanisms that lead to an observed intensification of the monsoon trough and associated tropical cyclone activity over the Bay of Bengal (BOB) during the pre-monsoon month of May. We find that post-1979 increases in both pre-monsoon precipitation and tropical cyclone intensity are a result of enhanced large-scale monsoon circulation, characterized by lower-level cyclonic and upper-level anti-cyclonic anomalies. Such circulation anomalies are manifest of the tropospheric expansion that is caused by regional warming. The deepened monsoon trough in the BOB not only affects tropical cyclone frequency and timing, but also acts to direct more cyclones towards Myanmar. We propose that increasing sea surface temperature in the BOB has contributed to an increase in cyclone intensity. Our analyses of the Community Earth System Model single-forcing experiments suggest that tropospheric warming and a deepening of the monsoon trough can be explained by two discreet anthropogenic causes an increase in absorption due to aerosol loading, and an increase in the land-ocean thermal contrast that results from increased greenhouse gases. The ensuing circulation changes provide favorable conditions for tropical cyclones to grow and to track eastward towards Myanmar (Sept. 2013)

Wang, S.-Y., K. Hakala, R. R. Gillies, and W. J. Capehart, 2014: The Pacific Quasi-Decadal Oscillation (QDO) - An important precursor towards anticipating major flood events in the Missouri River Basin? *Geophysical Research Letters*,41. 41, 991–997, doi:10.1002/2013GL059042

Measurements taken by the Gravity Recovery and Climate Experiment satellites indicated a continued water storage increase over the Missouri River Basin (MRB) prior to the 2011 flood event. An analysis of the major hydrologic variables in the MRB, i.e.,those of soil moisture, streamflow, groundwater storage, and precipitation, show a marked variability at the 10–15 year time scale coincident with the water storage increase. A climate diagnostic analysis was conducted to determine what climate forcing conditions preceded the long-term changes in these variables. It was found that precipitation over the MRB undergoes a profound modulation during the transition points of the Pacific quasi-decadal oscillation and associated teleconnections. The results infer a prominent teleconnection forcing in driving the wet/dry spells in the MRB, and this connection implies persistence of dry conditions for the next 2 to 3 years. **(Feb 2014)**

Buckley, B. M., R. Fletcher, S.-Y. Wang, B. Zottoli, and C. Pottier, 2014: Monsoon extremes and society over the past millennium on mainland Southeast Asia. *Quaternary Science Reviews*

The early 21st century has seen vigorous scientific interest in the Asian monsoon and significant development of paleo-proxies of monsoon strength. These include the Monsoon Asian Drought Atlas e a 700-year, gridded reconstruction of hydroclimate derived from 327 tree ring records e and several long speleothem records from China and India. Similar progress has been made on the study of monsoon climate dynamics through re-analysis data products and General Circulation Model diagnostics. The story has emerged of a variable monsoon over the latter Holocene, with extended droughts and anomalously wet episodes that occasionally and profoundly influenced the course of human history. We focus on Southeast Asia where an anomalous period of unstable climate coincided with the demise of the capital of the Khmer Empire at Angkor between the 14th and the 16th centuries, and we suggest that protracted periods of drought and deluge rain events, the latter of which damaged Angkor's extensive water management systems, may have been a significant factor in the subsequent transfer of the political capital away from Angkor. The late 16th and early 17th century experienced climate instability and the collapse of the Ming Dynasty in China under a period of drought, while Tonkin experienced floods and droughts throughout the 17th century. The 18th century was a period of great turmoil across Southeast Asia, when all of the region's polities saw great unrest and rapid realignment during one of the most extended periods of drought of the past millennium. New paleo-proxy records and the incorporation of historical documentation will improve future analyses of the interaction between climate extremes, social behavior and the collapse or disruption of regional societies, a subject of increasing concern given the uncertainties surrounding projections for future climate. (July 2014)

Schubert, S. D., H. Wang, R. D. Koster, and M. J. Suarez. 2014. "Northern Eurasian Heat Waves and Droughts." *J. Climate* 27 3169-3207 [Journal Article/Letter] [10.1175/JCLI-D-13-00360.1]

This article reviews the understanding of the characteristics and causes of northern Eurasian summertime heat waves and droughts. Additional insights into the nature of temperature and precipitation variability in Eurasia on monthly to decadal time scales and into the causes and predictability of the most extreme events are gained from the latest generation of reanalyses and from supplemental simulations with the NASA Goddard Earth Observing System model, version 5 (GEOS-5). Key new results are 1) the identification of the important role of summertime stationary Rossby waves in the development of the leading patterns of monthly Eurasian surface temperature and precipitation variability (including the development of extreme events such as the 2010 Russian heat wave); 2) an assessment of the mean temperature and precipitation changes that have occurred over northern Eurasia in the last three decades and their connections to decadal variability and global trends in SST; and 3) the quantification (via a case study) of the predictability of the most extreme simulated heat wave/drought events, with some focus on the role of soil moisture in the development and maintenance of such events. A literature survey indicates a general consensus that the future holds an enhanced probability of heat waves across northern Eurasia, while there is less agreement regarding future drought, reflecting a greater uncertainty in soil moisture and precipitation projections. Substantial uncertainties remain in the understanding of heat waves and drought, including the nature of the interactions between the short-term atmospheric

variability associated with such extremes and the longer-term variability and trends associated with soil moisture feedbacks, SST anomalies, and an overall warming world. (May 2014

Zhao, L., Wang, S.-Y., Jin, J. and Clark, A. J. (2014), Weather Research and Forecasting model simulations of a rare springtime bow echo near the Great Salt Lake, USA. *Met. Apps*. doi: 10.1002/met.145

The semiarid climate and rugged terrain in the interior west of the United States do not favour the development of bow echoes, a type of convective storm associated with intense, damaging winds. However, on 21 April 2011, a bow echo associated with a fast-moving midtropospheric perturbation formed across the Great Salt Lake (GSL) in Utah,producing damaging winds along its path. Intrigued by the rarity of this bow echo and the inability of the North American Mesoscale model (NAM) to forecast it, this event was studied by using available observations and conducted simulations with the Advanced Research Weather Research and Forecasting (WRF) model. Sensitivity to the microphysics schemes (MPSs), horizontal grid spacing, intensity of moisture content, and a physical lake model in the WRF model were examined. It was found that: (a) reduction in grid spacing from 12 and 4 km to 1 km along with improved depiction of low-level moisture substantially improved the bow echo simulation, (b) the presence of GSL did not impact bow echo development, and (c) the WRF model appeared to inherit a phase error in the passage of the midtropospheric perturbation from the NAM initial and lateral boundary conditions. The phase error resulted in a 1–2 h delay in the bow echo passage. These results highlight the difficulties in simulating such a bow echo event, and suggest similar challenges future faced by subsequent regional climate downscaling studies on future extreme weather in the western United States.(May 2014

Donglian Sun; Pinker, R., Factors Contributing to the Spatial Variability of Satellite Estimates of Diurnal Temperature Range in the United States, *Geoscience and Remote Sensing Letters, IEEE* , vol.11, no.9, pp.1524,1528, Sept. 2014doi: 10.1109/LGRS.2014.2298371

Diurnal temperature range (DTR) is an important index of climate change that can be affected by many environmental factors. The impact of each of these factors on DTR is still much debated. We show that the cooling effect due to transpiration from dense vegetation on land surface temperature (LST) is more evident during daytime than nighttime, which makes the difference between daily maximum and minimum LSTs (LSTmax - LSTmin) or DTR decrease with vegetation; this is seen only during the growing season. DTR drops with soil moisture (SM) for all seasons. The effect of water vapor (WV) radiative forcing makes DTRs decrease during the warm seasons (summer and fall) and may have affected most significantly the dip of DTR during summer over the southern two-thirds of the eastern United States. During summer, the effects of vegetation and WV on the decrease in DTR are more significant than other factors such as SM and aerosols.keywords: {atmospheric boundary layer; atmospheric humidity; atmospheric techniques;la nd surface temperature;remote sensing;transpiration;vegetation;DTR estimate spatial variability;LST;United States;climate change index;cooling effect;dense vegetation;diurnal temperature range;land surface temperature;satellite DTR estimates;transpiration;water vapor radiative forcing;Land surface temperature;Meteorology;Ocean temperature;Sun;Temperature distribution;Vegetation;Vegetation mapping;Aerosols;Diurnal temperature range (DTR);WV;evapotranspiration

(ET);precipitation;radiative forcing effect of water vapor (WV);soil moisture (Sept. 2014)

Taylor, Patrick C., 2014: Variability of Monthly Diurnal Cycle Composites of TOA Radiative Fluxes in the Tropics. *J. Atmos. Sci.,* 71, 754–766. doi: http://dx.doi.org/10.1175/JAS-D-13-0112.1

Earth system variability is generated by a number of different sources and time scales. Understanding sources of atmospheric variability is critical to reducing the uncertainty in climate models and to understanding the impacts of sampling on observational datasets. The diurnal cycle is a fundamental variability evident in many geophysical variables—including top-of-the-atmosphere (TOA) radiative fluxes. This study considers aspects of the TOA flux diurnal cycle not previously analyzed: namely, deseasonalized variations in the monthly diurnal cycle composites, termed monthly diurnal cycle variability. Significant variability in the monthly diurnal cycle composites is found in both outgoing longwave radiation (OLR) and reflected shortwave (RSW). OLR and RSW monthly diurnal cycle variability exhibits a regional structure that follows traditional, climatological diurnal cycle categorization by prevailing cloud and surface types. The results attribute monthly TOA flux diurnal cycle variability to variations in the diurnal cloud evolution, which is sensitive to monthly atmospheric dynamic- and thermodynamic-state anomalies. The results also suggest that monthly diurnal cycle variability can amplify or buffer monthly TOA flux anomalies, depending on the region. Considering the impact of monthly diurnal cycle variability on monthly TOA flux anomalies, the results suggest that monthly TOA flux diurnal cycle variability must be considered when constructing a TOA flux dataset from sun-synchronous orbit. The magnitude of monthly diurnal composite variability in OLR and RSW is regionally dependent—1–7 W m^{-2} and 10%–80% relative to interannual TOA flux variability. The largest (4–7 W m^{-2}; 40%–80%) and smallest (1–3 W m^{-2}; 10%–30%) TOA flux uncertainties occur in convective and nonconvective regions, respectively, over both land and ocean. (Feb. 2014)

Su, H., J.H. Jiang, C. Zhai, T.J. Shen, J.D. Neelin, G.L. Stephens, and L.Y. Yung, 2014: Weakening and Strengthening Structures in the Hadley Circulation Change under Global Warming and Implications for Cloud Response and Climate Sensitivity, *J. Geophys. Res*, doi:10.1002/2014JD021642

It has long been recognized that differences in climate model-simulated cloud feedbacks are a primary source of uncertainties for the model-predicted surface temperature change induced by increasing greenhouse gases such as CO_2. Large-scale circulation broadly determines when and where clouds form and how they evolve. However, the linkage between large-scale circulation change and cloud radiative effect (CRE) change under global warming has not been thoroughly studied. By analyzing 15 climate models, we show that the change of the Hadley Circulation exhibits meridionally varying weakening and strengthening structures, physically consistent with the cloud changes in distinct cloud regimes. The regions that experience a weakening (strengthening) of the zonal-mean circulation account for 54% (46%) of the multimodel-mean top-of-atmosphere (TOA) CRE change integrated over 45°S–40°N. The simulated Hadley Circulation structure changes per degree of surface warming differ greatly between the models, and the intermodel spread in the Hadley Circulation change is well correlated with the intermodel spread in the TOA CRE change. This correlation underscores the close interactions between large-scale circulation and clouds and suggests that the uncertainties of cloud feedbacks and climate sensitivity reside in the intimate coupling between large-scale circulation and clouds. New model performance metrics proposed in this work,

which emphasize how models reproduce satellite-observed spatial variations of zonal-mean cloud fraction and relative humidity associated with the Hadley Circulation, indicate that the models closer to the satellite observations tend to have equilibrium climate sensitivity higher than the multimodel mean. (May 2014)

Kress, B. T., M. K. Hudson, and J. Paral (2014), Rebuilding of the Earth's outer electron belt during 8–10 October 2012, *Geophys. Res. Lett.*, 41, 749–754, doi:10.1002/2013GL058588

Geomagnetic storms often include strong magnetospheric convection caused by sustained periods of southward interplanetary magnetic field. During periods of strong convection, the Alfvén layer, which separates the region of sunward convection from closed drift shells, is displaced earthward allowing plasma sheet particles with energies in the hundreds of keV direct access inside of geosynchronous. Subsequent outward motion of the Alfvén boundary and adiabatic energization during storm recovery traps plasma sheet electrons on closed drift shells providing a seed population for the outer radiation belts. In situ observations of the 8–10 October 2012 geomagnetic storm and MHD test particle simulations illustrate the morphology of this process. Data and modeling results support the conclusion that recovery (Feb 2014)

Jiang, X., et al., 2014: Influence of Stratospheric Sudden Warming on AIRS Mid-tropospheric CO2. *Journal of the Atmospheric Sciences*, doi:10.1175/JAS-D-13-064.1.

Midtropospheric CO_2 retrievals from the Atmospheric Infrared Sounder (AIRS) were used to explore the influence of stratospheric sudden warming (SSW) on CO_2 in the middle to upper troposphere. To choose the SSW events that had strong coupling between the stratosphere and troposphere, the authors applied a principal component analysis to the NCEP/Department of Energy Global Reanalysis 2 (NCEP-2) geopotential height data at 17 pressure levels. Two events (April 2003 and March 2005) that have strong couplings between the stratosphere and troposphere were chosen to investigate the influence of SSW on AIRS midtropospheric CO_2. The authors investigated the temporal and spatial variations of AIRS midtropospheric CO_2 before and after the SSW events and found that the midtropospheric CO_2 concentrations increased by 2–3 ppm within a few days after the SSW events. These results can be used to better understand how the chemical tracers respond to the large-scale dynamics in the high latitudes. (Aug 2013)

Zhao, L., Wang, S.-Y., Jin, J. and Clark, A. J. (2014), Weather Research and Forecasting model simulations of a rare springtime bow echo near the Great Salt Lake, *USA. Met. Apps*. doi: 10.1002/met.1455

The semiarid climate and rugged terrain in the interior west of the United States do not favour the development of bow echoes, a type of convective storm associated with intense, damaging winds. However, on 21 April 2011, a bow echo associated with a fast-moving midtropospheric perturbation formed across the Great Salt Lake (GSL) in Utah, producing damaging winds along its path. Intrigued by the rarity of this bow echo and the inability of the North American Mesoscale model (NAM) to forecast it, this event was studied by using available observations and conducted simulations with the Advanced Research Weather Research and Forecasting (WRF) model. Sensitivity to the microphysics schemes (MPSs), horizontal grid spacing, intensity of moisture content, and a physical lake model in the WRF model were examined. It was found that: (a) reduction

in grid spacing from 12 and 4 km to 1 km along with improved depiction of low-level moisture substantially improved the bow echo simulation, (b) the presence of GSL did not impact bow echo development, and (c) the WRF model appeared to inherit a phase error in the passage of the midtropospheric perturbation from the NAM initial and lateral boundary conditions. The phase error resulted in a 1–2 h delay in the bow echo passage. These results highlight the difficulties in simulating such a bow echo event, and suggest similar challenges future faced by subsequent regional climate downscaling studies on future extreme weather in the western United States.(May 2014)

Barandiaran, D., S.-Y. Wang, and K. Hilburn (2013), Observed trends in the Great Plains low-level jet and associated precipitation changes in relation to recent droughts, *Geophys. Res. Lett.*, 40, 6247–6251, doi:10.1002/2013GL058296

Recent drought over the Great Plains has had significant impacts on agriculture and the economy, highlighting the need for better understanding of any ongoing changes in the regional hydroclimate. Trends in the Great Plains low-level jet (GPLLJ) during the months April–June and associated precipitation are analyzed using the North American Regional Reanalysis (NARR) for the period 1979–2012. Linear trends computed for meridional winds and precipitation intensity, frequency, and total across the Great Plains show that (1) the GPLLJ has strengthened and expanded northward and (2) precipitation has decreased substantially in the Southern Plains while increasing in the Northern Plains. Particularly in May, the rainy season in the Oklahoma-Texas region, precipitation has migrated northward in correspondence to the shifted northern edge of the GPLLJ, leading to near 50% declines in precipitation since 1979. These observed changes are discussed in the context of recent droughts and projected climate for the region. (Dec 2013)

Hearty, T. J., A. Savtchenko, B. Tian, E. Fetzer, Y. L. Yung, M. Theobald, B. Vollmer, E. Fishbein, and Y.-I. Won (2014), Estimating sampling biases and measurement uncertainties of AIRS/AMSU-A temperature and water vapor observations using MERRA reanalysis, *J. Geophys. Res. Atmos.,* 119, 2725–2741, doi:10.1002/2013JD021205.

We use MERRA (Modern Era Retrospective-Analysis for Research Applications) temperature and water vapor data to estimate the sampling biases of climatologies derived from the AIRS/AMSU-A (Atmospheric Infrared Sounder/Advanced Microwave Sounding Unit-A) suite of instruments. We separate the total sampling bias into temporal and instrumental components. The temporal component is caused by the AIRS/AMSU-A orbit and swath that are not able to sample all of time and space.

The instrumental component is caused by scenes that prevent successful retrievals. The temporal sampling biases are generally smaller than the instrumental sampling biases except in regions with large diurnal variations, such as the boundary layer, where the temporal sampling biases of temperature can be ± 2 K and water vapor can be 10% wet. The instrumental sampling biases are the main contributor to the total sampling biases and are mainly caused by clouds. They are up to 2 K cold and > 30% dry over midlatitude storm tracks and tropical deep convective cloudy regions and up to 20% wet over stratus regions. However, other factors such as surface emissivity and temperature can also influence the instrumental sampling bias over deserts where the biases can be up to 1 K cold and 10% wet. Some instrumental sampling biases can vary seasonally and/or diurnally. We also estimate the combined measurement uncertainties of temperature and water vapor from AIRS/AMSU-A and MERRA by comparing similarly sampled

climatologies from both data sets. The measurement differences are often larger than the sampling biases and have longitudinal variations. (March 2014)

Wang, S.-Y., K. Hakala, R. R. Gillies, and W. J. Capehart (2014), The Pacific quasi-decadal oscillation (QDO): An important precursor toward anticipating major flood events in the Missouri River Basin?, *Geophys. Res. Lett.*, 41, 991–997, doi:10.1002/2013GL059042..

Measurements taken by the Gravity Recovery and Climate Experiment satellites indicated a continued water storage increase over the Missouri River Basin (MRB) prior to the 2011 flood event. An analysis of the major hydrologic variables in the MRB, i.e., those of soil moisture, streamflow, groundwater storage, and precipitation, show a marked variability at the 10–15 year time scale coincident with the water storage increase. A climate diagnostic analysis was conducted to determine what climate forcing conditions preceded the long-term changes in these variables. It was found that precipitation over the MRB undergoes a profound modulation during the transition points of the Pacific quasi-decadal oscillation and associated teleconnections. The results infer a prominent teleconnection forcing in driving the wet/dry spells in the MRB, and this connection implies persistence of dry conditions for the next 2 to 3 years.(Feb. 2014

Barandiaran, D. and S.-Y. Wang, 2014: The Missing Teleconnection Between the North Atlantic and Sahel Precipitation in CFSv2. ***Atmospheric Science Letter***

This study presents new findings on the link between interannual variabilities of atmospheric circulations over the North Atlantic and precipitation over the African Sahel (P_S). Our analysis shows a meridionally stratified circulation wave train resembling the East Atlantic (EA) mode, apparently connected to P_S through Rossby wave dispersion in the middle troposphere originating from the North Atlantic. However, the Climate Forecast System version 2 fails to depict the EA and its P_S impact. Because the EA explains 29% of variance of P_S, this portion of P_S variability is either missing in the seasonal forecast, or being made up by an alternative process. (March 2014)

Wong, S.,T. S. L'Ecuyer, W. S. Olson, X. Jiang, and E. J. Fetzer, 2013: Local balance and variability of atmospheric heat budget over oceans: Observation and reanalysis- based estimates.*J. Climate*, 27, 893-913

The authors quantify systematic differences between modern observation- and reanalysis-based estimates of atmospheric heating rates and identify dominant variability modes over tropical oceans. Convergence of heat fluxes between the top of the atmosphere and the surface are calculated over the oceans using satellite-based radiative and sensible heat fluxes and latent heating from precipitation estimates. The convergence is then compared with column-integrated atmospheric heating based on Tropical Rainfall Measuring

Mission data as well as the heating calculated using temperatures from the Atmospheric Infrared Sounder and wind fields from the Modern-Era Retrospective Analysis for Research and Applications (MERRA). Corresponding calculations using MERRA and the European Centre for Medium-Range Weather Forecasts Interim Re-Analysis heating rates and heat fluxes are also performed. The geographical patterns of atmospheric heating rates show heating regimes over the intertropical convergence zone and

summertime monsoons and cooling regimes over subsidence areas in the subtropical oceans. Compared to observation-based datasets, the reanalyses have larger atmospheric heating rates in heating regimes and smaller cooling rates in cooling regimes. For the averaged heating rates over the oceans in 40°S–40°N, the observation-based datasets have net atmospheric cooling rates (from −15 to −22 W m^{-2}) compared to the reanalyses net warming rates (5.0–5.2 W m^{-2}). This discrepancy implies different pictures of atmospheric heat transport. Wavelet spectra of atmospheric heating rates show distinct maxima of variability in annual, semiannual, and/or intraseasonal time scales. In regimes where deep convection frequently occurs, variability is mainly driven by latent heating. In the subtropical subsidence areas, variability in radiative heating is comparable to that in latent heating. (Jan. 2014)

Schubert, Siegfried D., Hailan Wang, Randal D. Koster, Max J. Suarez, Pavel Ya. Groisman, 2014: Northern Eurasian Heat Waves and Droughts. *J. Climate*, 27, 3169–3207.doi: http://dx.doi.org/10.1175/JCLI-D-13-00360.1

This article reviews the understanding of the characteristics and causes of northern Eurasian summertime heat waves and droughts. Additional insights into the nature of temperature and precipitation variability in Eurasia on monthly to decadal time scales and into the causes and predictability of the most extreme events are gained from the latest generation of reanalyses and from supplemental simulations with the NASA Goddard Earth Observing System model, version 5 (GEOS-5). Key new results are 1) the identification of the important role of summertime stationary Rossby waves in the development of the leading patterns of monthly Eurasian surface temperature and precipitation variability (including the development of extreme events such as the 2010 Russian heat wave); 2) an assessment of the mean temperature and precipitation changes that have occurred over northern Eurasia in the last three decades and their connections to decadal variability and global trends in SST; and 3) the quantification (via a case study) of the predictability of the most extreme simulated heat wave/drought events, with some focus on the role of soil moisture in the development and maintenance of such events. A literature survey indicates a general consensus that the future holds an enhanced probability of heat waves across northern Eurasia, while there is less agreement regarding future drought, reflecting a greater uncertainty in soil moisture and precipitation projections. Substantial uncertainties remain in the understanding of heat waves and drought, including the nature of the interactions between the short-term atmospheric variability associated with such extremes and the longer-term variability and trends associated with soil moisture feedbacks, SST anomalies, and an overall warming world.(May 2014)

Kumar, Anil, Robert A. Houze, Kristen L. Rasmussen, Christa Peters-Lidard, 2014: Simulation of a Flash Flooding Storm at the Steep Edge of the Himalayas*. J. Hydrometeor, 15, 212–228. doi: http://dx.doi.org/10.1175/JHM-D-12-0155.1

A flash flood and landslide in the Leh region of the Indus Valley in the Indian state of Jammu and Kashmir on 5–6 August 2010 resulted in hundreds of deaths and great property damage. Observations have led to the hypothesis that the storm, which formed over the Tibetan Plateau, was steered over the steep edge of the plateau by 500-hPa winds and then energized by the ingestion of lower-level moist air, which was approaching from the Arabian Sea and Bay of Bengal and rose up the Himalayan barrier. A coupled land surface and atmospheric model simulation validates this hypothesized storm scenario, with the model storm taking the form of a traveling mesoscale squall line with a leading

convective line, trailing stratiform region, and midlevel inflow jet. In this region, the development of a mesoscale storm over high terrain is highly unusual, especially one in the form of a propagating squall line system. This unusual storm occurrence and behavior could serve as a warning sign in flash flood prediction. The coupled atmosphere and land surface model showed that the excessive runoff leading to the flood and landslide were favored by the occurrence of this unusual meteorological event coinciding temporally and spatially with favorable hydrologic conditions. Additionally, the model simulations showed that previous rainstorms had moistened the soil during the entire season and especially over the few days leading up to the Leh flood, so the normally arid mountainsides were likely not able to rapidly absorb the additional rainfall of the sudden 5 August squall line.(Feb 2014)

Land Use Change

• **Andrew J. Hansen, Nathan Piekielek, Cory Davis, Jessica Haas, David M. Theobald, John E. Gross, William B. Monahan, Tom Olliff, and Steven W. Running 2014. Exposure of U.S. National Parks to land use and climate change 1900–2100. Ecological Applications 24:484–502. http://dx.doi.org/10.1890/13-0905.1**

Many protected areas may not be adequately safeguarding biodiversity from human activities on surrounding lands and global change. The magnitude of such change agents and the sensitivity of ecosystems to these agents vary among protected areas. Thus, there is a need to assess vulnerability across networks of protected areas to determine those most at risk and to lay the basis for developing effective adaptation strategies. We conducted an assessment of exposure of U.S. National Parks to climate and land use change and consequences for vegetation communities. We first defined park protected-area centered ecosystems (PACEs) based on ecological principles. We then drew on existing land use, invasive species, climate, and biome data sets and models to quantify exposure of PACEs from 1900 through 2100. Most PACEs experienced substantial change over the 20th century (>740% average increase in housing density since 1940, 13% of vascular plants are presently nonnative, temperature increase of 1°C/100 yr since 1895 in 80% of PACEs), and projections suggest that many of these trends will continue at similar or increasingly greater rates (255% increase in housing density by 2100, temperature increase of 2.5°–4.5°C/100 yr, 30% of PACE areas may lose their current biomes by 2030). In the coming century, housing densities are projected to increase in PACEs at about 82% of the rate of since 1940. The rate of climate warming in the coming century is projected to be 2.5–5.8 times higher than that measured in the past century. Underlying these averages, exposure of individual park PACEs to change agents differ in important ways. For example, parks such as Great Smoky Mountains exhibit high land use and low climate exposure, others such as Great Sand Dunes exhibit low land use and high climate exposure, and a few such as Point Reyes exhibit high exposure on both axes. The cumulative and synergistic effects of such changes in land use, invasives, and climate are expected to dramatically impact ecosystem function and biodiversity in national parks. These results are foundational to developing effective adaptation strategies and suggest policies to better safeguard parks under broad-scale environmental change. (April 2014)

Applications

Arsenault, K., Houser P., and De Lannoy G (2014). Evaluation of the MODIS snow cover fraction product *Hydrol. Process*, *28*, 980 - 998 10.1002/hyp.9636

Eleven years of daily 500 m gridded Terra Moderate Resolution Imaging Spectroradiometer (MODIS) (MOD10A1) snow cover fraction (SCF) data are evaluated in terms of snow presence detection in Colorado and Washington states. The SCF detection validation study is performed using in-situ measurements and expressed in terms of snow and land detection and misclassification frequencies. A major aspect addressed in this study involves the shifting of pixel values in time due to sensor viewing angles and gridding artifacts of MODIS sensor products. To account for this error, 500 m gridded pixels are grouped and aggregated to different-sized areas to incorporate neighboring pixel information. With pixel aggregation, both the probability of detection (POD) and the false alarm ratios increase for almost all cases. Of the false negative (FN) and false positive values (referred to as the total error when combined), FN estimates dominate most of the total error and are greatly reduced with aggregation. The greatest POD increases and total error reductions occur with going from a single 500 m pixel to 3×3-pixel averaged areas. Since the MODIS SCF algorithm was developed under ideal conditions, SCF detection is also evaluated for varying conditions of vegetation, elevation, cloud cover and air temperature. Finally, using a direct insertion data assimilation approach, pixel averaged MODIS SCF observations are shown to improve modeled snowpack conditions over the single pixel observations due to the smoothing of more error-prone observations and more accurately snow-classified pixels (Jan 2014)

Cai, X., Z. Yang, C. David, G. Niu, and M. Rodell (2014). Hydrological evaluation of the Noah-MP land surface model for the Mississippi River Basin Journal of Geophysical Research: Atmospheres *Journal of Geophysical Research*: Atmospheres, 119, 1-16 10.1002/2013JD020792

This study evaluates regional-scale hydrological simulations of the newly developed community Noah land surface model (LSM) with multiparameterization options (Noah-MP). The model is configured for the Mississippi River Basin and driven by the North American Land Data Assimilation System Phase 2 atmospheric forcing at 1/8° resolution. The simulations are compared with various observational data sets, including the U.S. Geological Survey streamflow and groundwater data, the AmeriFlux tower micrometeorological evapotranspiration (ET) measurements, the Soil Climate Analysis Network (SCAN)-observed soil moisture data, and the Gravity Recovery and Climate Experiment satellite-derived terrestrial water storage (TWS) anomaly data. Compared with these observations and to the baseline Noah LSM simulations, Noah-MP shows significant improvement in hydrological modeling for major hydrological variables (runoff, groundwater, ET, soil moisture, and TWS), which is very likely due to the incorporation of some major improvements into Noah-MP, particularly an unconfined aquifer storage layer for groundwater dynamics and an interactive vegetation canopy for dynamic leaf phenology. Noah-MP produces soil moisture values consistent with the SCAN observations for the top two soil layers (0–10 cm and 10–40 cm), indicating its great potential to be used in studying land-atmosphere coupling. In addition, the simulated groundwater spatial patterns are comparable to observations; however, the inclusion of groundwater in Noah-MP requires a longer spin-up time (34 years for the entire study domain). Runoff simulation is highly sensitive to three parameters: the surface dryness factor (α), the saturated hydraulic conductivity (k), and the saturated soil (Jan 2014)

Dirmeyer, P.A, J. Wei, M. G. Bosilovich, and D. Mocko (2014). Comparing Evaporative Sources of Terrestrial Precipitation and Their Extremes in MERRA Using Relative Entropy *Journal of Hydrometeor*, 15, 102-116 10.1175/JHM-D-13-053.1

A quasi-isentropic, back-trajectory scheme is applied to output from the Modern-Era Retrospective Analysis for Research and Applications (MERRA) and a land-only replay with corrected precipitation to estimate surface evaporative sources of moisture supplying precipitation over every ice-free land location for the period 1979–2005. The evaporative source patterns for any location and time period are effectively two-dimensional probability distributions. As such, the evaporative sources for extreme situations like droughts or wet intervals can be compared to the corresponding climatological distributions using the method of relative entropy. Significant differences are found to be common and widespread for droughts, but not wet periods, when monthly data are examined. At pentad temporal resolution, which is more able to isolate floods and situations of atmospheric rivers, values of relative entropy over North America are typically 50%–400% larger than at monthly time scales. Significant differences suggest that moisture transport may be a key factor in precipitation extremes. Where evaporative sources do not change significantly, it implies other local causes may underlie the extreme events (Feb 2014)

Gupta, H. V., and G. S. Nearing (2014), Debates—The future of hydrological sciences: A (common) path forward? Using models and data to learn: A systems theoretic perspective on the future of hydrological science, *Water Resour*. Res., 50, 5351–5359, doi:10.1002/2013WR015096.

Hirsch, A., J. Kala, A.J. Pitman, C. Carouge, J.P. Evans, V. Haverd, and D. Mocko (2014). Impact of Land Surface Initialization Approach on Subseasonal Forecast Skill: A Regional Analysis in the Southern Hemisphere *Journal of Hydrometeor*, 15, 300-319 10.1175/JHM-D-13-05.1

The authors use a sophisticated coupled land–atmosphere modeling system for a Southern Hemisphere subdomain centered over southeastern Australia to evaluate differences in simulation skill from two different land surface initialization approaches. The first approach uses equilibrated land surface states obtained from offline simulations of the land surface model, and the second uses land surface states obtained from reanalyses. The authors find that land surface initialization using prior offline simulations contribute to relative gains in subseasonal forecast skill. In particular, relative gains in forecast skill for temperature of 10%–20% within the first 30 days of the forecast can be attributed to the land surface initialization method using offline states. For precipitation there is no distinct preference for the land surface initialization method, with limited gains in forecast skill irrespective of the lead time. The authors evaluated the asymmetry between maximum and minimum temperatures and found that maximum temperatures had the largest gains in relative forecast skill, exceeding 20% in some regions. These results were statistically significant at the 98% confidence level at up to 60 days into the forecast period. For minimum temperature, using reanalyses to initialize the land surface contributed to relative gains in forecast skill, reaching 40% in parts of the domain that were statistically significant at the 98% confidence level. The contrasting impact of the land surface initialization method between maximum and minimum temperature was associated with different soil moisture coupling mechanisms. Therefore, land surface initialization from prior offline simulations does improve predictability for temperature,

particularly maximum temperature, but with less obvious improvements for precipitation and minimum temperature over southeastern Australia (Feb 2014)

Kala, J., M. Decker, J.-F. Exbrayat, A.J. Pitman, C. Carouge, J.P. Evans, G. Abramowitz, and D. Mocko (2014). Influence of Leaf Area Index Prescriptions on Simulations of Heat, Moisture, and Carbon Fluxes *Journal of Hydrometeor*, 15, 489-503 10.1175/JHM-D-13-063.1

Leaf area index (LAI), the total one-sided surface area of leaf per ground surface area, is a key component of land surface models. The authors investigate the influence of differing, plausible LAI prescriptions on heat, moisture, and carbon fluxes simulated by the Community Atmosphere Biosphere Land Exchange version 1.4b (CABLEv1.4b) model over the Australian continent. A 15-member ensemble monthly LAI dataset is generated using the Moderate Resolution Imaging Spectroradiometer (MODIS) LAI product and gridded observations of temperature and precipitation. Offline simulations lasting 29 years (1980–2008) are carried out at 25-km resolution with the composite monthly means from the MODIS LAI product (control simulation) and compared with simulations using each of the 15-member ensemble monthly varying LAI datasets generated. The imposed changes in LAI did not strongly influence the sensible and latent fluxes, but the carbon fluxes were more strongly affected. Croplands showed the largest sensitivity in gross primary production with differences ranging from −90% to 60%. Plant function types (PFTs) with high absolute LAI and low interannual variability, such as evergreen broadleaf trees, showed the least response to the different LAI prescriptions, while those with lower absolute LAI and higher interannual variability, such as croplands, were more sensitive. The authors show that reliance on a single LAI prescription may not accurately reflect the uncertainty in the simulation of terrestrial carbon fluxes, especially for PFTs with high interannual variability. The study highlights that accurate representation of LAI in land surface models is key to the simulation of the terrestrial carbon cycle. Hence, this will become critical in quantifying the uncertainty in future changes in primary production.

Thomas, A., J. Reager, J. Famiglietti, and M. Rodell (2014). A GRACE-based water storage deficit approach for hydrological drought characterization *Geophysical Research Letters*.

We present a quantitative approach for measuring hydrological drought occurrence and severity based on terrestrial water storage observations from NASA's Gravity Recovery and Climate Experiment (GRACE) satellite mission. GRACE measurements are applied by calculating the magnitude of the deviation of regional, monthly terrestrial water storage anomalies from the time series' monthly climatology, where negative deviations represent storage deficits. Monthly deficits explicitly quantify the volume of water required to return to normal water storage conditions. We combine storage deficits with event duration to calculate drought severity. Drought databases are referenced to identify meteorological drought events in the Amazon and Zambezi River basins and the southeastern United States and Texas regions. This storage deficit method clearly identifies hydrological drought onset, end, and duration; quantifies instantaneous severity and peak drought magnitude; and compares well with the meteorological drought databases. It also reveals information about the hydrological effects of meteorological drought on regional water storage. (March 2014)

Wang, S.-Y., J.-H. Yoon, R. R. Gillies, and C. Cho, 2013: What caused the winter drought in western Nepal during recent years? *Journal of Climate*, doi: 10.1175/JCLI-D-12-00800.1 (2013)

Western Nepal has experienced consecutive and worsened winter drought conditions since 2000 culminating in a severe drought episode during 2008-2009. In this study, the meteorological conditions and a historical perspective of the winter droughts in western Nepal were analyzed using respectively instrumental records, satellite observations and climate model simulations. Meteorological diagnosis using atmospheric reanalysis revealed that (1) winter drought in western Nepal is linked to the Arctic Oscillation an its decadal variability, which initiates a tropospheric short-wave train across Eurasia and South Asia, and that (2) the persistent warming of the Indian Ocean likely contributes to the suppression of rainfall through enhanced local Hadley circulation. Simulations from the CMIP5 sets of historical single-forcing experiments indicated that increased loading of anthropogenic aerosols is also a compounding factor in the precipitation decline during the later decades. It is therefore conceivable that the recent spells of decadal drought in Nepal drought are symptomatic of both natural variability and anthropogenic influences. Given the observations that winter precipitation has declined to near zero while groundwater has hardly been replenished, appropriate management of western Nepal's water resources is both critical and necessary.(Nov 2013)

Wang, S.-Y., R. R. Gillies, and H. van den Dool, 2013: On the yearly phase delay of winter intraseasonal mode in the western United States. *Climate Dynamics*, DOI: 10.1007/s00382-013-1784-y

In the western United States, persistent and recurrent flow patterns not only modulate precipitation events but also result in prolonged surface inversion episodes. In this region, the frequency of persistent ridge/trough events ranges between 20 and 40 days, well within the intraseasonal timescale. Based on NCEP reanalysis data starting at 1949, with a focus on the interior West, we observed that episodes of prolonged ridge/trough events appear to occur about a week later every year and resets every 5–7 years—a previously undocumented phenomenon examined herein. Diagnostic analyses indicate that the interplay between regional intraseasonal flow patterns and the North Atlantic Oscillation (NAO) alternates the preferred timeframe for the persistent ridge/trough events to occur. This may result from different phases of the NAO shifting the winter mean ridge and such shifts modulate the occurrence and timing of persistent ridge/trough events. When the timing changes evolve around the quasi-6 years cycle of the NAO, the resultant evolution forms what appears to be a steady phase delay in the ridge/trough events year after year. These results are a further step in disclosing the multiple-scale interaction between intraseasonal and interannual modes and its regional climate/weather impact.(March 2014

Gu, G., R.F. Adler, 2013: Interdecadal variability/long-term changes in global precipitation patterns during the past three decades: global warming and/or pacific decadal variability? *Clim. Dyn*.

This study explores how global precipitation and tropospheric water vapor content vary on the interdecadal/long-term time scale during past three decades (1988–2010 for water vapor), in particular to what extent the spatial structures of their variations relate to changes in surface temperature. EOF analyses of satellite-based products indicate that the first two modes of global precipitation and columnar water vapor content anomalies are

in general related to the El Niño-Southern oscillation. The spatial patterns of their third modes resemble the corresponding linear fits/trends estimated at each grid point, which roughly represent the interdecadal/long-term changes happening during the same time period. Global mean sea surface temperature (SST) and land surface temperature have increased during the past three decades. However, the water vapor and precipitation patterns of change do not reflect the pattern of warming, in particular in the tropical Pacific basin. Therefore, other mechanisms in addition to global warming likely exist to account for the spatial structures of global precipitation changes during this time period.

An EOF analysis of longer-record (1949–2010) SST anomalies within the Pacific basin (60oN–60oS) indicates the existence of a strong climate regime shift around 1998/1999, which might be associated with the Pacific decadal variability (PDV) as suggested in past studies. Analyses indicate that the observed linear changes/trends in both precipitation and tropospheric water vapor during 1988–2010 seem to result from a combined impact of global mean surface warming and the PDV shift. In particular, in the tropical central-eastern Pacific, a band of increases along the equator in both precipitation and water vapor sandwiched by strong decreases south and north of it are likely caused by the opposite effects from global-mean surface warming and PDV-related, La Niña-like cooling in the tropical central-eastern Pacific. This narrow band of precipitation increase could also be considered an evidence for the influence of global mean surface warming.(June 2013)

Brown, M. E., V. Escobar, S. Moran , D. Entekhabi , P. E. O'Neill , E. G. Njoku , B. Doorn , and J. K. Entin (2013) NASA's Soil Moisture Active Passive (SMAP) Mission and Opportunities For Applications Users, *Bulletin of American Meteorological Society 10.1175/BAMS-D-11-00049*

Water in the soil, both its amount (soil moisture) and its state (freeze/thaw) plays a key role in water and energy cycles, in weather and climate, and in the carbon cycle. Additionally, soil moisture touches upon human lives in a number of ways from the ravages of flooding to the needs for monitoring agricultural and hydrologic droughts. Because of their relevance to weather, climate, science, and society, accurate and timely measurements of soil moisture and freeze/thaw state with global coverage are critically important.

The SMAP Applications program is ground-breaking and serves as an example for other NASA missions to expand their focus to include user communities' needs in the early phases of mission development. Through a team that includes an applications lead on the Science Definition Team (SDT), leadership from the mission, and an applications coordinator, the applications program works to characterize the community of mission data users through workshops and applied research. We have also initiated a program of Early Adopters to promote application research in the pre-launch stages of the mission, in order to provide a better understanding of how SMAP data products can be scaled and integrated onto organizations' policy, business, and management activities. These efforts will expand the use of the data after launch, and increase the societal benefit of the mission. (Aug 2013)

Young, A. H., J. J. Bates, and J. A. Curry (2013), Application of cloud vertical structure from CloudSat to investigate MODIS-derived cloud properties of cirriform, anvil, and deep convective clouds, *J. Geophys. Res. Atmos*., 118, 4689–4699, doi:10.1002/jgrd.50306.

CloudSat cloud vertical structure is combined with the CALIPSO Lidar and Collection-5 Level 2 cloud data from Aqua's Moderate Resolution Imaging Spectroradiometer (MODIS) to investigate the mean properties of high/cirriform, anvil, and deep convective (DC) clouds. Cloud properties are sampled over 30°S–30°N for 1 year and compared to existing results of Collection-4 Aqua MODIS high-level cloud observations where cloud types were categorized using the International Satellite Cloud Climatology Project (ISCCP) cloud classification scheme. Results show high/cirriform sampled in this study have high biases in cloud top pressure and temperature due to CloudSat's sensitivity to thin high clouds. Mean cloud properties of DC show reasonable agreement with existing DC results notwithstanding mean cloud optical thickness which is ~23% higher due to the exclusion of thick cirrus and anvil clouds. Anvil cloud properties are a mix between high/cirriform and DC according to ISCCP cloud optical thickness thresholds whereby ~80% are associated with high/cirriform and the other 20% are associated with DC. The variability of cloud effective particle radii was also evaluated using DC with ≥5 dBZ echoes at and above 10 km. No evidence of larger cloud effective particle radii are given despite considering higher reaching echoes. Using ISCCP cloud optical thickness thresholds, ~25% of DC would be classified as cirrostratus clouds. These results provide a basis to evaluate the uncertainty of the ISCCP cloud classification scheme and MODIS-derived cloud properties using active satellite observations. (May 2013)

Stephens, G L., J. Li, M. Wild, C. A. Clayson, N. Loeb, S. Kato, T. L'Ecuyer, P. W. Stackhouse Jr, M. Lebsock and T. Andrews, (2013) An update on Earth's energy balance in light of the latest global observations ***Nature Geoscience Progress Article***.

Climate change is governed by changes to the global energy balance. At the top of the atmosphere, this balance is monitored globally by satellite sensors that provide measurements of energy flowing to and from Earth. By contrast, observations at the surface are limited mostly to land areas. As a result, the global balance of energy fluxes within the atmosphere or at Earth's surface cannot be derived directly from measured fluxes, and is therefore uncertain. This lack of precise knowledge of surface energy fluxes profoundly affects our ability to understand how Earth's climate responds to increasing concentrations of greenhouse gases. In light of compilations of up-to-date surface and satellite data, the surface energy balance needs to be revised. Specifically, the longwave radiation received at the surface is estimated to be significantly larger, by between 10 and 17 Wm^{-2}, than earlier model-based estimates. Moreover, the latest satellite observations of global precipitation indicate that more precipitation is generated than previously thought. This additional precipitation is sustained by more energy leaving the surface by evaporation — that is, in the form of latent heat flux — and thereby offsets much of the increase in longwave flux to the surface. (Sept.2013)

Getirana, A. C. V. and Peters-Lidard, C.: Estimating water discharge from large radar altimetry datasets, ***Hydrol. Earth Syst. Sci.,*** **17, 923-933, doi:10.5194/hess-17-923-2013, 2013**

The objective of this study is to evaluate the potential of large altimetry datasets as a complementary gauging network capable of providing water discharge in ungauged regions. A rating curve-based methodology is adopted to derive water discharge from altimetric data provided by the Envisat satellite at 475 virtual stations (VS) within the Amazon basin. From a global-scale perspective, the stage–discharge relations at VS are built based on radar altimetry and outputs from a modeling system composed of a land surface model and a global river routing scheme. In order to quantify the impact of model

uncertainties on rating-curve based discharges, a second experiment is performed using outputs from a simulation where daily observed discharges at 135 gauging stations are introduced in the modeling system. Discharge estimates at 90 VS are evaluated against observations during the curve fitting calibration (2002–2005) and evaluation (2006–2008) periods, resulting in mean normalized RMS errors as high as 39 and 15% for experiments without and with direct insertion of data, respectively. Without direct insertion, uncertainty of discharge estimates can be mostly attributed to forcing errors at smaller scales, generating a positive correlation between performance and drainage area. Mean relative streamflow volume errors (RE) of altimetry-based discharges varied from 15 to 84% for large and small drainage areas, respectively. Rating curves produced a mean RE of 51% versus 68% from model outputs. Inserting discharge data into the modeling system decreases the mean RE from 51 to 18%, and mean NRMSE from 24 to 9%. These results demonstrate the feasibility of applying the proposed methodology to the continental or global scales. (2013)

Meetings

SMAP

SMAP will provide a capability for global mapping of soil moisture and freeze/thaw state with unprecedented accuracy, resolution, and coverage. SMAP science objectives are to acquire space-based hydrosphere state measurements over a three-year period to:

Understand processes that link the terrestrial water, energy and carbon cycles, Estimate global water and energy fluxes at the land surface, Quantify net carbon flux in boreal landscapes, Enhance weather and climate forecast skill and Develop improved flood prediction and drought monitoring capabilities

SMAP Meetings/Workshops:

January 7, 2014 SMAP Focus Session on Health and Disease Exposure, Atlanta, GA**: A** unique opportunity to collect and distribute information about different user needs while discussing how SMAP soil moisture and surface freeze/thaw state data products can be used to address needs of the CDC and the broader public health community

Enabling the Evolution of Land Imaging with New Approaches and Products

April 8, 2014 SMAP Applications Workshop #3 and SMOS/SMAP Short Course, Boulder, CO. The goal of the SMOS/SMAP Short Course is to provide background on SMOS and SMAP data products and formats in order to foster use in atmospheric modeling and forecast applications.

June 2 3, 2014 SMAP Science Team (ST) Meeting #2, Pasadena, CA ,June 3, 2014

The NASA SMAP Applications Focus Session on Health and Disease Exposure is a unique opportunity to collect and distribute information about different user needs while discussing how SMAP soil moisture and surface freeze/thaw state data products can be used to address needs of the CDC and the broader public health community.

June 2014 HyspIRI Data Product Symposium (June 2014)

August 2914 PMM Science Team Meeting

SMAP Highlights

- **Landbou High School teams up with NASA (May 22, 2014)**

Recently, Landbouu High School hosted two NASA scientists, including SMAP's Dr. Erika Podest, to learn about the

- **SMAP Focus Session on Health and Disease Exposure, Atlanta, GA, January 7-8, 2014** The NASA SMAP Applications Focus Session on Health and Disease Exposure is a unique opportunity to collect and distribute information about different user needs while discussing how SMAP soil moisture and surface freeze/thaw state data products can be used to address needs of the CDC and the broader public health community.

Improved seasonal soil moisture forecasts using SMAP data will directly benefit famine early warning systems particularly in sub-Saharan Africa and South Asia, where hunger remains a major human health factor and the population harvests its food from rain-fed agriculture in highly monsoonal (seasonal) conditions. Indirect benefits will also be realized as SMAP data will enable better weather forecasts that lead to improved predictions of heat stress and virus spreading rates. Better flood forecasts will lead to improved disaster preparation and response. SMAP will also benefit the emerging field of landscape epidemiology (aimed at identifying and mapping vector habitats for human diseases such as malaria) where direct observations of soil moisture can provide valuable information on vector population dynamics.

- **A satellite launched to study the salinity of the ocean is proving helpful in understanding the land.**

- **NASA's Aquarius instrument, which is aboard the Argentinian Satélite de Aplicaciones Científicas, captured the data used to make this image showing soil moisture around the globe.** This soil moisture map is useful for researchers monitoring soil conditions for agriculture, as well as scientists trying to understand the global water cycle, according to NASA's Earth Observatory

- **SMAP Satellite Soil Moisture Validation and Application Workshop**

The objective of the workshop was to discuss and reconcile recent methodological advances in the validation and application of global satellite soil moisture data. The workshop focused on soil moisture products derived from current and future active and passive microwave sensors operating in the low frequency range from 1 to 10 GHz, including but not limited to ASCAT, SMOS, AMSR-E, ASAR, SMAP, Sentinel-1 and any combination thereof.

- **SMAP is implementing a strategy that promotes applications research and engages a broad community of users in SMAP applications**. This responds to recommendations of the NRC Decadal Survey report *(Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, Space Studies Board, National Academies Press, 2007)*. **The goals of the SMAP applications program include**:
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- Promote the use of SMAP products to a community of end-users and decision makers that understand SMAP capabilities and are interested in using SMAP products in their application
- Facilitate feedback between SMAP user communities and the SMAP mission

Provide information on and documentation of collaboration with different classes of users and communities, and design communication strategies to reach out to these new communities including those of precipitation, drought detection, agriculture, ecosystem modeling, among others**Applications Workshops and Tutorials** provides a list of SMAP applications workshops and tutorials.

Other Meetings and Field Campaigns

- **Trending Now: Water: The 7th International Conference on the Global Water and Energy Cycle, July 14-17, 2014, The Hague, The Netherlands**

The 7th International Scientific Conference on the Global Water and Energy Cycle was held in TheHague on 14-17 July 2014. The Conference celebrated 25 years of GEWEX research and set the stage for the next phase of research addressing the World Climate Research Programme Grand Challenges on water resources, extremes, and climate sensitivity through observations and data sets, their analyses, process studies, model development and exploitation, applications, technology transfer to operational results, and research capacity development and training for the next generation of scientists.

• **The 2014 Annual NEWS (NASA Energy and Water cycle Study) Science Team Meeting** was held May 29-30, 2014, at NASA Goddard. Presentations from PIs showed much progress from their funded projects and a robust discussion centered on the 'way forward for NEWS' with connections to other programs.

- **2014 PMM Science Team Meeting, August 8, 2014**
- The meeting consisted of general oral and poster sessions covering mission/program status, partner reports, science activities, field campaign results, and other science team business. There will also be Radar, Combined, Radiometer, and Multi-Satellite algorithm team meetings, which all participants are encouraged to attend. As part of the PMM program review process, each funded Principal Investigator is required to present a poster and to provide a poster title on the meeting registration form. Other attendees are welcome to contribute posters on a space available basis

- **Ice Sheet and Glacier Modelers Meet at Goddard**

Lab researcher Sophie Nowicki was one of the organizers of the Ice Sheet MIP for CMIP6 meeting, a meeting of ice sheet and glacier modelers that gathered about 35 participants from 10 countries on July 16-18 at the Goddard campus. The sea-level projections made by the glaciological community as part of the Intergovernmental Panel on Climate Change process have often been out of phase with the projections considered by the Coupled Model Intercomparison Project community. A primary focus of this meeting was to develop a plan that will allow ice sheet and glacier models to be better integrated, in order to improve both sea level projections due to changes in the cryosphere and our understanding of the cryosphere in a changing climate.

- **MABEL's Alaskan Campaign**

Starting this month, scientists from the cryospheric laboratory, together with other researchers, engineers and pilots are going to Fairbanks, Alaska, to fly an airborne test instrument called the Multiple Altimeter Beam Experimental Lidar, or MABEL. MABEL collects data in the same way that the upcoming Ice, Cloud and land Elevation Satellite-2 (ICESat-2)'s instrument will – with lasers and photon-detectors. Between July 12 and

August 1, MABEL will fly aboard NASA's high-altitude ER-2 aircraft as the Arctic sea ice and glaciers are melting. The data from the Alaskan campaign will allow researchers to develop computer programs, or algorithms, to analyze the information ICESat-2 will collect on Arctic summer conditions.

2014 HyspIRI Data Product Symposium, June 4-5,2014:

HyspIRI: Enabling the Evolution of Sustainable Land & Aquatic Imaging with New Approaches and Products*

The HyspIRI Airborne Campaign; * Calibration Approaches; * The Intelligent Payload Module (IPM), Data Management Approaches and Tools; *

- **NASA's HyspIRI: Seeing the Forest and the Trees and More!** Scientists have used the technique, called imaging spectroscopy, to learn about water on the moon, minerals on Mars and the composition of exoplanets. Green's favorite place to apply the technique, however, is right here on the chemically rich Earth, which is just what he and colleagues achieved this spring during NASA's Hyperspectral Infrared Imager (HyspIRI) airborne campaign.

"We have ideas about what makes up Earth's ecosystems and how they function," said Green, of NASA's Jet Propulsion Laboratory in Pasadena, Calif., and principal investigator of the campaign's Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) instrument. "But a comprehensive understanding requires us to directly measure these things and how they change over landscapes and from season to season."

NASA IceBridge Concludes Artic Field Campaign (May 2014)

Researchers with NASA's Operation IceBridge have completed another successful Arctic field campaign. On May 23, NASA's P-3 research aircraft left Thule Air Base, Greenland, and returned to Wallops Flight Facility in Virginia marking the end of 11 weeks of polar research.

During this campaign, researchers collected data on Arctic sea and land ice – both repeating measurements on rapidly changing areas and expanding coverage into new, unsurveyed regions. The mission also released two sea ice data products and provided a professional development opportunity for three science teachers.

IceBridge's sea ice measurements help researchers understand how Arctic ice is changing, particularly those forecasting how sea ice coverage will change over the summer. To meet the need for timely ice thickness measurements IceBridge releases a quick look data product before the end of the campaign that gives an almost real-time look at sea ice.

This quick look product first debuted in 2012 and is joined this year by a new data product that uses IceBridge data together with measurements from the European Space Agency's satellite, CryoSat-2, to show ice thickness across the entire Arctic Ocean.