

Program and Abstracts Book

**NASA GLOBAL DROUGHT
MONITORING WORKSHOP**

**April 11 and 12, 2011
Silver Spring, MD**

NASA Global Drought Monitoring Workshop
April 11 and 12, 2011

Hilton Washington DC/Silver Spring, MD
8727 Colesville Road,
Silver Spring, Maryland, USA, 20910.

Agenda

Version: April 10, 2011

Workshop Objectives

- 1) To review the information requirements for global-scale, drought monitoring products for global and regional applications.
- 2) To evaluate the information value of NASA capabilities and explore ways in which these capabilities can be used more effectively to inform water security/management concerns at global to sub-continent scales.
- 3) To assess the specific requirements for monitoring agricultural and hydrological droughts and the capabilities of the current suite of NASA data products to provide that information.
- 4) To develop a set of actions that would enable NASA, either separately or in collaboration with other organizations, to more effectively impact drought information for decision making.

08:00 – 08:30: Registration

April 11

08:30 -10:00: **Session 1: Introduction and Background** (Chair: Dave Toll, NASA)

08:30 – 08:35: Welcome and Introduction (Dave Toll, NASA)

08:35 – 09:00: Overview of the objectives of the workshop and introduction to the NASA Water Resources Program (Bradley Doorn, NASA)

09:00 – 09:15: Introduction to the NASA Water Science Program (Jared Entin, NASA)

09:15 – 09:40: INVITED KEYNOTE: Global Drought Monitoring: Lessons from NIDIS and the Drought Monitor Process (Kelly Redmond, DRI)

09:40 – 09:55: The Development of the Global Drought Monitor Portal and Summaries of the April 2010 Global Drought Assessment and associated Workshops (Richard Heim, NOAA)

09:55 – 10:00: Discussion

10:00 - 10:15: Break

10:15 – 11:00: **Session 2: Existing national and international drought services: services, opportunities and gaps** (Chair: Brad Doorn)

10:15 – 10:30: NDMC and USDM Activities (Mike Hayes, University of Nebraska, NDMC)

10:30 – 10:40: NASA contributions to global drought monitoring (Dave Toll, NASA)

10:40 – 10:55: USAID's international water and drought related activities (S. Tokar, US AID)

10:55- 11:00: Discussion

11:00 – 12:40: **Session 3: Special requirements for drought monitoring in the fields of agriculture and hydrology** (Chair: Jared Entin, NASA)

11:00 – 11:15: Global Operational Systems that Monitor Drought Impacts on Global Crop Production (Curt Reynolds, USDA)

11:15 – 11:30: GEOSS Agriculture activities and drought (Chris Justice, UMD, College Park)

11:30 – 11:45: Meeting regional needs for drought information through SERVIR (Ashutosh Limaye, NASA)

11:45 – 12:00: Drought, food security and FEWSNET (Jim Verdin, USGS)

12:00 – 12:15: Monitoring Many Faces of Drought over the United States (Kingste Mo, NOAA)

12:15 – 12:30: Issues in drought monitoring: Canadian experiences (Rick Lawford, UMBC)

12:30 – 12:40: Discussion

12:40 – 13:45: Lunch

13:45 – 16:00: **Session 4: Current and potential use of NASA and other remote sensing products in monitoring and analysis of drought.** (Chair: Jim Verdin, USGS)

13:45 – 14:00: Examples of the use of NASA and other Remote Sensing and data assimilation products and information platforms in drought monitoring and prediction. (Shawana Johnson, Global Marketing Insights)

14:00 – 14:15: Soil Moisture Active Passive (SMAP) observations for identifying drought (Molly Brown, NASA)

14:15 – 14:30: A Satellite-based drought product using thermal remote sensing of evapotranspiration (Martha Anderson, USDA)

14:30 – 14:45: Examining the role of evaporative demand in drought monitoring (Mike Hobbins, NOAA)

14:45 – 15:00: Integrated data and model needs for drought monitoring (Dennis Lettenmaier, Univ. of Washington)

15:00 – 15:15: Enhancement of Drought Monitoring with NASA Satellite Data (Son Nghiem, JPL/NASA)

15:15 - 15:30: Vegetation Drought Response Index (VegDRI) - A Tool for Agricultural Drought Monitoring (Brian Wardlow, University of Nebraska, NDMC)

15:30 – 15:50: Break and Poster Viewing

- 15:50 – 16:05: Application of Assimilated GRACE Data for Drought Monitoring (Matthew Rodell, NASA)
- 16:05 – 16:20: Downscaling and drought predictions (Xin-Zhong Liang, UMD-CP)
- 16:20 – 16:35: Group on Earth Observations (GEO) Global Drought Early Warning Information Service (Richard Heim (NOAA) for Will Pozzi)

16:35 – 17:30: **Session 5: Contributions of data assimilation products and models in monitoring and predicting drought** (Chair: Ted Engman, SAIC-Goddard)

- 16:35 – 16:50: Quantitative Drought Monitoring based on Land Surface modeling and Remote Sensing Products (Alok Sahoo, Princeton)
- 16:50 – 17:05: Global Drought Monitoring Using PERSIANN and SPI (Peyman Daneshkar Arasteh, UCI)
- 17:05 – 17:20: Enhancing the Famine Early Warning Systems Network (FEWS NET) over Africa by tracking agricultural drought using the NASA product-based FEWSNET Land Data Assimilation System (FLDAS) (Soni Yatheendradas, NASA and UMD-ESSIC)
- 17:20 – 17:30: Discussion

Poster Presentations:

- Wenhong Li (Duke): Changes of the North Atlantic Subtropical High and its impacts on summer droughts/floods in the Southeastern United States
- Peyman Daneshkar Arasteh (UCI): Global Precipitation Trend Analysis Using PERSIANN
- Jason Giovannettone (Institute for Water Resources): The Institute for Water Resources Drought Atlas Software (IWR-DAS)
- Alys Thomas (UCI): Distinguishing Regional Drought Characteristics Using GRACE Terrestrial Water Storage Datasets
- Zhong Liu (NASA): Maps, Tools and Services at NASA GES DISC for Supporting Global Drought Monitoring Activities
- Clement Alo: Drought in the Nile Basin: characterizing variability and studying processes with the Nile Land Data Assimilation System
- John Bolten (NASA): The Middle East and North Africa Land Data Assimilation System
- Lisa Darby (NOAA): The National Integrated Drought Information System (NIDIS)

April 12:

- 08:30 – 09:30: **Session 5: Contributions of data assimilation products and models in monitoring and predicting drought (Continued)** (Chair: Brian Wardlow University of Nebraska, NDMC)

08:30 – 08:45: NLDAS and Drought Monitoring over the Continental United States (Mike Ek, NOAA)

08:45 – 09:00: The Use of Earth Observations in the North American Land Data Assimilation System (NLDAS) for Drought Monitoring and Prediction (David Mocko, NASA)

09:00 – 09:15: Evaluation of long-term, high-resolution NLDAS products using in-situ observations, and application of these products to the U.S. Drought Monitor (Youlong Xia, NOAA)

09:15- 0930: The Seasonal Prediction of Hydrological Drought (Randy Koster, NASA)

09:30 - 10:30: **Session 6: Drought monitoring in the framework of global programs** (Chair: Ashutosh Limaye, NASA)

09:30 – 09:45: GEO and Drought monitoring activities (Rick Lawford, UMBC)

09:45 – 10:00: Report on the recent WCRP drought workshop in Barcelona (Siegfried Shubert, NOAA)

10:00 – 10:15: A Remote Sensing-based Global Agricultural Drought Monitoring and Forecasting System for Supporting GEOSS (Liping Di, GMU)

10:15 – 10:30: MENA Water Information System Platform (WISP) drought activities (Ben Zaitchik, John Hopkins University)

10:30 -10:45: Break and Poster Viewing

10:45 – 12:00: **Session 7: Short reports (10 minutes) on drought programs in other departments** (Chair: Brad Doorn, NASA)

NOAA: Climate and drought activities (Nancy Beller-Simms, NOAA)

USGS drought related activities (Jerad Bales, USGS)

US BOR drought related activities (Ken Nowak, US BOR)

USEPA drought related activities (Audrey Levine, US EPA)

NASA: Maps, Tools and Services at NASA GES DISC for Supporting Global Drought Monitoring Activities (Zhong Liu, NASA)

NIDIS and drought monitoring and update on the IEEE Drought Workshop (Chad McNutt, NOAA)

Discussion

12:00 – 13:00: Lunch

13:00 – 15:00: **Session 8: Breakout Groups** (Chair: Rick Lawford, UMBC)

13:00 – 13:10: Introduction to Breakout Groups (See details below)

13:10 – 15:00: Breakout Groups meet for discussions

15:00 – 15:20: Break

15:20 – 17:00: **Session 9: Plenary summary session** (Chair: Chad McNutt, NOAA)

15:20 – 15:50: Reports from breakout groups and discussion

15:50 – 16:20: Discussion on Next Steps and writing assignments for developing an action plan.

16:20 – 17:00: Workshop Summary (Rick Lawford (UMBC), Brad Doorn (NASA), Jared Entin (NASA), David Toll (NASA))

Breakout groups. Three working groups will be formed from attendees at the workshop.

Working Group #1: (Christa Peters-Lidard, Kelly Redmond, Dave Toll)

Global drought monitoring strategies: This working group will consider strategic issues such as maximizing the use of global products in a regional context, data policies, NASA's role in US drought monitoring, and NASA's role in international drought monitoring projects. The group will be expected to identify partners for NASA to advance its new applications paradigm in the drought area (ref. B Doorn's presentation) and help clarify how NASA should position itself to effectively implement that paradigm. It should also provide a clear role for NASA among the many agencies and international organizations that have drought programs of different types.

Working Group #2: (Chris Justice, Ashutosh Limaye, Ted Engman)

Scientific and technical issues that must be considered in the development of Global Drought monitoring systems. This group will examine the limitations of science, sensor technology, and the adequacy of current and planned missions to support a Global Drought Monitoring System. These discussions will address meteorological, agricultural and hydrologic drought. It will also look at the scientific impediments to applying these global products to regional droughts and to ensuring the products are useful to regional drought centers. Current sensor capabilities and information systems will also be discussed in this context.

Working Group #3: (Mike Hayes, Jim Verdin, Brad Doorn)

Institutionalizing developments in global drought monitoring services. While NASA and its collaborators have many assets that contribute to global drought monitoring and they have stimulated a number of studies and experimental products very few, if any of them are being effectively adapted and mobilized by other institutions. This working group is asked to consider how NASA and its partners can determine that a product is ready for transfer, what factors should be considered in preparing for its transfer (by NASA, by the receiving institution and by the researchers involved), and the steps that should be taken in encouraging such a transfer to occur. In order to make the discussion more concrete the group will be encouraged to identify several NASA drought-related products and technologies that are currently ready for institutionalization and will work through a

scenario to show how other services may adopt them and incorporate them into an operational service.

ABSTRACTS (Oral)

Name: Richard Heim, Mike Brewer, and Will Pozzi

Email: Richard.Heim@noaa.gov

Title: The Development of the Global Drought Monitor Portal and Summary of the April 2010 Global Drought Assessment Workshop

Abstract: International workshops and conferences have, for many years, noted the importance of drought monitoring and have called for the creation of drought early warning systems (the 2007 GEO Ministerial Summit in Cape Town, South Africa, the 2009 WMO-sponsored Inter-Regional Workshop on Indices and Early Warning Systems for Drought in Lincoln, Nebraska, USA, and the 2010 Global Drought Assessment Workshop [GDAW] in Asheville, North Carolina, USA, are recent examples). Drought monitoring, assessment, response, mitigation, adaptation, and early warning systems have been created in a number of countries around the world, and some regional and continental efforts have been successful, but a global drought early warning system (GDEWS) remains elusive. The National Integrated Drought Information System (NIDIS) portal is a web-based information system created to address drought services and early warning in the United States, including drought monitoring, forecasting, impacts, mitigation, research, and education. The geographic scope of the NIDIS portal is being expanded with data and web services capabilities to support the North American Drought Monitor (NADM). The robust services of the NIDIS portal could serve as the foundation for an even broader international drought Clearinghouse, or Global Drought Monitor Portal (GDMP). This paper will summarize results of the GDAW, describe the technical capabilities of the GDMP, and discuss the creation of the GDMP in the context of a GDEWS. This paper is being presented in conjunction with the paper, "Global and Regional Drought Monitoring Implementation through the Global Earth Observation System of Systems (GEOSS)," which was submitted by Will Pozzi.

Name: Curt Reynolds

Email: curt.reynolds@fas.usda.gov

Title: Global Operational Systems that Monitor Drought Impacts on Global Crop Production

Abstract: The recent food price crisis of 2008 and 2011 has placed global droughts and its impact on global crop production on the forefront. However, there are few operational systems that monitor global droughts or the impacts of droughts on global crop production. Most current drought monitoring systems tend to focus on national or regional coverage, although many of these monitoring systems utilize satellites and geospatial tools that have the potential for global coverage with global applications. Current needs for monitoring global droughts are to expand existing regional systems with global coverage whenever possible; apply drought indices over major grain belts and during crop growing seasons; and better utilize surface energy balance models with the thermal band for estimating actual evapotranspiration and crop-water use over both irrigated and rainfed croplands.

Name: Kingtse Mo
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Title: Monitoring Many Faces of Drought over the United States

Abstract: Drought indices derived from the North American Land data Assimilation Systems (NLDAS) from 1979 to the present are used to monitor drought over the United States. For meteorological drought, the Standardized Precipitation Index (SPI) is used to measure precipitation deficits. The Standardized Runoff Index (SRI) similar to the SPI is used to classify hydrological drought. Agricultural drought is measured by monthly mean soil moisture (SM) anomaly percentiles.

One important aspect of drought monitoring is to communicate uncertainties in the system to users. Indices from the NCEP system were compared to those from the University of Washington. While the indices derived from different models within the same system are similar, the differences between the ensemble mean indices from two different systems are large. The largest differences occurred after 2002 when both systems went to real time operation. Uncertainties were also found in the snow melt and snow accumulation which have large impact on spring time runoff.

The NASA satellite derived data can serve as independent sources for developing better precipitation forcing and for verification. The drought forecasts based on the NSIPP GMAO model have been used as one realization of forecast ensemble that drought forecasters use for guidance. These products are very useful to the drought operations at CPC.

Name: Dr. Shawana Johnson, GISP
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Title: Example of the use of NASA and other Remote Sensing and data assimilation products and information platforms in drought monitoring and prediction.

Abstract: 2011 NASA Global Drought Monitoring, April 11-12, 2011

ABSTRACT OVERVIEW:

Utilizing NASA, NOAA and private sector data the Rocky Mountain Supercomputing Centers, Inc. (RMSC), GCS Research and Global Marketing Insights, Inc. are focused on:

Using a high performance computing cloud (HPC Cloud) to perform project work which requires extremely difficult computational analytics necessary for hosting and managing multiple satellite sensor datasets needed for (near) real-time data assimilation products.

The development of this information platform on in a high performance environment addresses multiple sensor integration problems which include:

- Problems of Scale
- Simulation and Modeling
- Difficult or "Hard" Problems
- Non-Deterministic (NP)
- Adaptive Systems (Artificial and Natural)

And demonstrating sustainability improvements in modeling with the datasets all in one database (keeping their native resolutions) in order to look at responses to all variables and see what signals the data provides in order to view entire regions of the world at one time and make quicker, more accurate land use predictions such as, global food security, while working with multiple data sources for rainfall, temperature, etc. and working with multiple agencies.

This on-going project fully demonstrates (with RMSC's HPC Cloud) government-to-government interagency programs and government-to-business collaboration. The following datasets (raster and vector of 100's of gigabytes per country) have been placed in a secure, interoperable cloud running Microsoft HPC Server 2008 and SQL Server Enterprise with the latest edition of ESRI ArcGIS.

The scalable solution is being used to complete high-fidelity analytics: time series analysis, change detection, correlation analyze for geoprocessing and geostatistics. RMSC is capturing all metrics on system performance and utilization against data volumes in order to better understand processing benchmarks, efficiency and scalability for workflow optimizations. Scalability and flexibility are the project's strengths.

MODIS (NASA - Moderate Resolution Imaging Spectroradiometer)/ TERRA/AQUA Satellites TRMM (NOAA- The Tropical Rainfall Measuring Mission)-Precipitation Radar/ GOES-8/10, METEOSAT-7/5 NCEP (The National Center for Environmental Prediction)-NCEP/NCAR Reanalysis 1 AFWA-LIS (Air Force Weather Agency-Land Information System) SPOT-Veg NDVI (Satellite Pour l'Observation de la Terre, France) AWIFS (Advanced Wide Field Sensor)/ IRS (RESOURCESAT-1 - India) PET (Global Potential Evapotranspiration)

The project is a follow on to a successful interagency project with National Geospatial-Intelligence Agency, NASA, and USDA which developed applications observing drought and agricultural production in Iraq and was expanded to four additional countries from 2007-2010. This current effort is focused on Drought Monitoring and Agriculture Crop Yield specifically in certain areas of the United States utilizing real-time management of multiple input variables to build predictive models which can be utilized for a variety of private sector applications. This specific project, once expanded across the globe, would demand a PetaScale Cloud to deliver the computations and data volumes required to ingest, manipulate and analyze these earth observations.

This project enables next-generation discoveries, advancements and solutions for commercial, academic, tribal and governmental stakeholders utilizing high performance computing applications and services. Users of these HPC services can have immediate access to multiple sensors, analytics and 3D visualizations of any monitored region. For example, where there is little or inaccurate ground information about that country's water management and vegetative condition, this capability can provide actionable insight for any decision support process. In a nutshell, the paradigm shifting vision of this project integrates a secure HPC cyberinfrastructure, cloud computing capabilities and a new on demand, pay-as-you-go business model maximizing human capital and minimizing physical investments.

Name: Molly Brown
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Title: Soil Moisture Active Passive (SMAP) observations for identifying drought

Abstract: The Soil Moisture Active Passive (SMAP) mission is one of the first-tier projects recommended by the U.S. National Research Council Committee on Earth Science and Applications from Space. The SMAP mission is under development and it is scheduled for launch in 2014. The SMAP mission is designed to produce high-resolution and accurate global mapping of soil moisture and its freeze/thaw state using an instrument architecture that incorporates an L-band (1.26 GHz) radar and an L-band (1.41 GHz) radiometer. The project science goals address several topics in water, energy and carbon cycle science as well as provide improved capabilities in several hydrometeorological and hydroclimatological (natural hazards) applications. The preliminary baseline algorithms are undergoing tests and evaluations using airborne field experiment observations. Additional tests are made using the end-to-end SMAP Algorithm Testbed simulation environment. Data characteristics and their use after launch for monitoring drought will be the focus of this talk.

Name: Martha Anderson
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Title: A SATELLITE-BASED DROUGHT PRODUCT USING THERMAL REMOTE SENSING OF EVAPOTRANSPIRATION

Abstract: Thermal infrared (TIR) remote sensing of land-surface temperature (LST) provides valuable information about the sub-surface moisture status: soil surface temperature increases with decreasing water content, while moisture depletion in the plant root zone leads to stomatal closure, reduced transpiration, and elevated canopy temperatures. In this paper, a satellite-based methodology for routine drought monitoring will be described using continental-scale maps of evapotranspiration (ET) obtained with a TIR-based surface energy balance model. In this approach, moisture stress is quantified in terms of the reduction of ET from the potential rate (PET) expected under non-moisture limiting conditions.

The Atmosphere-Land Exchange Inverse (ALEXI) model is used to map land-surface water and energy fluxes across the continental U.S. at 5-10km resolution using TIR imagery from the Geostationary Operational Environmental Satellites (GOES). A derived Evaporative Stress Index (ESI), given by anomalies in ET/PET, shows good correspondence with standard drought metrics and with patterns of antecedent precipitation, but at significantly higher spatial resolution due to limited reliance on ground observations. The ALEXI ESI algorithm does not require precipitation or soil texture information, unlike the Palmer Drought Index, the Standardized Precipitation Index, and other drought indices based on rainfall or soil water balance. Being an independent means for assessing drought conditions, the ESI has significant potential for enhancing the existing suite of drought monitoring products. Work is underway to further evaluate multi-scale ESI implementations over the U.S. and other continents with geostationary satellite coverage.

Name: Mike Hobbins
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Title: Examining the role of evaporative demand in drought monitoring

Abstract: Drought monitors rely heavily on precipitation and temperature data to derive moisture fluxes at the surface, often using estimates of evaporative demand (E_o , also known as potential evaporation) based on temperature alone to derive actual evapotranspiration (ET_a) fluxes from bucket models. However, the choice of E_o -driver for bucket models significantly affects both the magnitude and direction of trends in estimated ET_a and soil moisture, particularly in energy-limited areas (in water-limited areas, ET_a and soil moisture trends are driven by $Prcp$ trends). All else equal, temperature-based E_o measures will always result in long-term ET_a declining (i.e., drying) as temperature rises, whereas physically based E_o estimates (i.e., that combine radiative and advective drivers by also including data on short- and long-wave radiation, wind speed, and vapor pressure) will more accurately reflect observations of both wetting and drying under warming.

We contend that using a physically based observed E_o driver that is available on a daily basis with limited latency (i) as a drought metric in itself, and (ii) to drive drought monitors' bucket models, will enhance characterization of the evaporative dynamics of ongoing drought. Combining near-real-time E_o observations with short-term E_o forecasts will permit more accurate predictions of drought development.

We test this first contention by deriving E_o from (amongst others) the Penman-Monteith formulation for reference crop evapotranspiration (ET_{rc}). From a 30+ year reanalysis of daily CONUS-wide E_o driven by North American Land Data Assimilation System data, we have implemented a simple drought metric "the Evaporative Demand Drought Index (EDDI)" based on accumulating ET_{rc} anomalies. The basic premise is that ET_{rc} increases under dry conditions at the land surface-atmosphere interface, due to the complementarity of E_o with ET_a at a regional scale and a mixture of decreases in vapor pressure, and increases in temperature, wind speed, and solar radiation. Extensive periods of positive accumulated ET_{rc} anomalies (i.e., positive EDDI) then register as periods of drought; negative as wet periods. We present these results and compare them to established drought measures across CONUS from 1979 to the present. In reanalyses of drought over CONUS the EDDI metric shows great promise, and the system is easily extensible to a global scale by driving the ET_{rc} formulation with Global Data Assimilation System data.

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5National Oceanic and Atmospheric Administration, Climate Prediction Center,
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6National Aeronautics and Space Administration, Washington DC

Title: Enhancement of Drought Monitoring with NASA Satellite Data

Abstract: Drought monitoring effectively and consistently is difficult because of its subtle arrival and departure, large spatial and temporal variability from drought to drought, and varying impacts in different sectors (e.g., agriculture, water supply). The U.S. Drought Monitor (USDM) is an operational drought monitoring system and the primary national scale tool for current drought decision support (<http://drought.unl.edu/dm/monitor.html>), which is being transitioned in to the National Integrated Drought Information System (NIDIS).

Two major limitations in the current U.S. drought monitoring effort have been identified: (1) the coarse level of spatial detail at which analyses are performed and results delivered, and (2) lack of detailed, accurate, and objective data especially where current networks of weather stations are sparse, such as in the public lands of the West. These factors represent the largest impediments to early detection of drought and its impacts at the county level, where key drought decisions are made. To address these issues, hydrologic and ecologic observations from NASA Earth satellite sensors, including the Advanced Microwave Scanning Radiometer Earth Observing System (AMSR-E), the QuikSCAT/SeaWinds Scatterometer (QSCAT), and the Moderate Resolution Imaging Spectroradiometer (MODIS), are assimilated to enhance USDM.

False rains due to anomalous propagation (AP) problems in radar meteorology or due to virga (dry rain, dry thunderstorms, etc.), especially in the western U.S., may prematurely decrease drought severity level or inappropriately terminate drought conditions in drought monitoring assessments. The Jet Propulsion Laboratory develops a unique product of soil moisture change (SMC) from QSCAT satellite scatterometer data. SMC represents rainwater that actually reaches to land surface and makes the soil wet. Therefore, SMC is directly relevant to drought monitoring, circumventing problems of virga and serious AP errors. From the collaboration among the Jet Propulsion Laboratory, NOAA Physical Science Division, NOAA Climate Prediction Center, and NDMC, we developed a number of specific products and derivatives from SMC data for enhancing drought monitoring and forecasting. Moreover, in collaboration with NIDIS personnel, a transition into NIDIS is carried out to demonstrate the utility of SMC in the operational environment, in view of the up-coming Oceansat-2 scatterometer data and the future SMAP (Soil Moisture Active and Passive) data.

The USGS EROS Center, in collaboration with NDMC, has developed a hybrid drought indicator known as the Vegetation Drought Response Index (VegDRI) that incorporates NASA satellite observations, climate data, and biophysical indicators. In 2009, the VegDRI (incorporating MODIS imagery) was tested by USDM authors. They found the VegDRI to meet the finer resolution needs of the USDM along with the potential for addressing the regional scale needs of NIDIS. SMC is more representative of hydrological conditions while VegDRI accounts more for the ecological component. Therefore, these products provide a synergistic characterization and thus better assessments for drought monitoring than does each single product as a stand-alone parameter. Moreover, since the satellite data are collected globally, we can built

on the experiences and results obtained for U.S. to enhance systems for global drought monitoring, for which some initial examples will be presented.

Acknowledgments

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Name: Matthew Rodell

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Title: Application of Assimilated GRACE Data for Drought Monitoring

Abstract: A unique aspect of the Gravity Recovery and Climate Experiment (GRACE) with respect to hydrological remote sensing is its ability to sense changes in water stored in all levels of soil column, including groundwater. Thus GRACE is well suited for identifying hydrological droughts, when total water storage is low. The U.S. and North American Drought Monitor products are two of the premier decision support tools for drought, but they have previously depended heavily on precipitation indices and subjective assessments, due to a lack of widespread and systematic groundwater and soil moisture observations. GRACE has the potential to fill that void, but its spatial and temporal resolutions and data latency limit its direct applicability for operational drought assessment. We overcome these issues by synthesizing GRACE data with other ground and space based meteorological observations within a sophisticated numerical model of land surface water and energy processes. The resulting high resolution, near real-time fields of soil moisture and groundwater storage variations are then used to generate drought indicator maps, which are now being passed to our partners at NOAA's National Climatic Data Center (NCDC), the National Drought Mitigation Center (NDMC) of the University of Nebraska, Lincoln, NOAA's Climate Prediction Center (CPC).

Name: Will Pozzi (Given by Richard Heim)

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Title: Global and Regional Drought Monitoring Implementation through the Global Earth Observation System of Systems (GEOSS)

Abstract: During the last year, two GEO drought initiatives, the Global Drought Monitoring Initiative and the GEO Architectural Implementation Pilot Water and Drought Working Group have coalesced with the 2010 NOAA Global Drought Assessment Workshop in beginning a Global Drought Community of Practice and a Global Drought Monitor Portal, housed through the NIDIS portal. The North American Drought Monitor, the European Drought Observatory, the University College London Global Drought Monitor, and the Princeton Experimental African Drought Monitor were linked through installation of map server software and OGC Web Mapping Services. Argentina and the Commonwealth of Australia are also members, who are being integrated into the global drought monitoring portal (and community). Arrangements are also being made to extend coverage to East Asia, as well. Given the

difficulty of reliably detecting the slow onset conditions of drought, the global drought community of practice provides a necessary adjunct effort to achieve scientific consensus on drought indices based upon multiple budget components of water (besides precipitation), drought vulnerability assessment, and complementation with Land Surface Model and Hydrologic Model soil moisture with satellite-derived soil moisture and evapotranspiration. Future cooperative opportunities exist for multiple model ensemble and intercomparison experiments over Africa and South America, as currently exists with the NLDAS drought monitor. (Drought monitoring workshop)

Name: Alok Sahoo for Eric Wood
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Title: QUANTITATIVE DROUGHT MONITORING BASED ON LAND SURFACE MODELING AND REMOTE SENSING PRODUCTS

Eric F. Wood, Justin Sheffield, Alok Sahoo Princeton University, Princeton, NJ 08544

Abstract: Drought monitoring for agriculture and water resources applications is increasingly relying on objective, quantitative indices to provide large-scale and often high resolution (field scale) assessments of water availability, water use and crop productivity. Such drought indices are needed to provide consistent measures for seasonal forecast systems, where historical drought assessments are used to measure forecast model skill. Additionally, drought forecasts are a critical component of famine early warning systems and related agricultural management. Outside the United States, agricultural extension service personnel who can assess local drought conditions are often unavailable. At Princeton in collaboration with the University of Washington, a quantitative drought index has been developed, initially over the United States based on 1/8th degree VIC land surface modeling with meteorological forcings from the North American Land Data Assimilation System (NLDAS). Comparisons with the National Drought Monitor shows very good agreement with the extent and severity of drought. This initial system has been expanded to a multi-model system as part of the NCEP EMC NLDAS activities and at the University of Washington as part of their drought research. The VIC LSM component has been implemented globally using a suite of weather model analysis and remote sensing datasets as inputs to the model, including an experimental drought monitoring system for Africa in collaboration with UNESCO.

More recently, a drought index based on remote sensing data sets has been developed and compared to our model based. Remote sensing datasets are now available at large scales for all components of the water cycle, including evapotranspiration, precipitation, soil moisture and total water storage. Importantly for drought assessment, these datasets are becoming available for several years to decades, which allows for the construction of climatologies against which current conditions can be compared. In this presentation, we show remote sensing based estimates for evapotranspiration and soil moisture derived from different combinations of remote sensing data sources and algorithms. These datasets are potentially well suited for quantifying vegetative and moisture stress and for understanding how drought is linked through the surface energy balance. Additional research is needed to determine whether they are sufficiently sensitive and robust for detecting drought and its temporal and spatial characteristics.

Name: Peyman Daneshkar Arasteh
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Title: Global Drought Monitoring Using PERSIANN and SPI

Abstract: Drought as the most insidious cause of human misery has serious implications not only on the socio-economic stability of the affected regions but also the world economy will be affected from its impacts. To manage drought, it must be recognized and monitored globally, preparedness must be done regionally and action locally.

In this research, global drought occurrence in the past decade (2000-2009) were studied using PERSIANN 0.25 degree monthly data set and SPI with 1 and 3 months time scales was used to investigate drought characteristics. Maps of drought severity were developed and showed spatial extent of drought affected areas. The study showed that developing countries were affected more than developed countries during the past decade. Potentials of PERSIANN were also shown in drought monitoring the global scale.

Name: Soni Yatheendradas
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Title: Enhancing the Famine Early Warning Systems Network (FEWS NET) over Africa by tracking agricultural drought using the NASA product-based FEWSNET Land Data Assimilation System (FLDAS)

Soni Yatheendradas, Christa Peters-Lidard, Amy McNally, Chris Funk, Jim Verdin

Abstract: The Famine Early Warning Systems Network (FEWS NET) is the US Agency for International Development's (USAID) decision support system for high priority international food aid programs. These programs safeguard the lives and livelihoods of tens of millions of the world's poorest and most vulnerable people. We are currently enhancing FEWS NET by configuring a custom instance of NASA's Land Information System (LIS) for the relevant domains, data streams, and monitoring/forecast requirements associated with food security assessment. In the same manner as the NLDAS drought monitor this FEWS NET Land Data Assimilation System (FLDAS) will have the capability to provide soil moisture anomalies from various land surface models in LIS (e.g., Noah, Mosaic, SAC and eventually VIC). Unique features of the FLDAS will be its coverage over continental Africa and the standard Water Requirement Satisfaction Index (WRSI) method for characterizing drought stress. Initial testing of this system over continental Africa with the Noah LSM illustrates several critical issues related to agricultural drought assessment that prohibit direct translation of the NLDAS drought monitor approach to a new region: First, sparse data availability necessitates the use of satellite based rainfall estimates with climatological corrections; and second, the standard landcover classes used in land surface modeling do not include representations of agricultural crops. Instead, actual crop types and rooting depths will need to be used in order to provide meaningful agricultural drought assessment. We will present results of our case studies illustrating these critical considerations for regional and global agricultural drought monitoring.

Name: Michael Ek, Youlong Xia, Eric Wood, and the NLDAS team
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Title: NLDAS and Drought Monitoring over the Continental United States

Abstract: The North American Land Data Assimilation System (NLDAS) is a multi-model land modeling and assimilation system that is run in uncoupled mode (driven by atmospheric forcing). NLDAS provides retrospective and real-time high-resolution water and energy cycle products such as surface fluxes, soil moisture, snow cover, and runoff/streamflow, along with the surface meteorology and precipitation data sets used as forcing for the NLDAS land models. These products support e.g. drought monitoring, seasonal hydrological prediction, weather and climate forecasting, model evaluation, and land-hydrology research within the GAPP (GEWEX Americas Prediction Project) and CPPA (Climate Prediction Program for the Americas) as well as in other communities. In particular, these products have been applied to support the National Integrated Drought Information System (NIDIS) activities such as the U.S. drought monitor, NCEP/CPC monthly drought briefing, and NCEP/CPC seasonal outlooks. NLDAS has become a mature system and will be implemented in NCEP operations in the near future.

Name: David Mocko
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Title: The Use of Earth Observations in the North American Land Data Assimilation System (NLDAS) for Drought Monitoring and Prediction

Abstract: The North American Land Data Assimilation System (NLDAS) is a collaboration project among several groups: NOAA/NCEP's Environmental Modeling Center (EMC), NASA's Goddard Space Flight Center (GSFC), Princeton University, the University of Washington, the NOAA/NWS Office of Hydrological Development (OHD), and the NOAA/NCEP Climate Prediction Center (CPC). The NLDAS participants have produced quality-controlled and spatially and temporally consistent hourly datasets from the best available observations and land-surface model (LSM) output; datasets available include precipitation, soil moisture, snow cover, and runoff/streamflow. The NLDAS system is currently running in near real-time on a 1/8th-degree grid over central North America; retrospective NLDAS datasets and simulations also extend back to January 1979. The NLDAS webpage provides a near real-time drought monitor, and NLDAS products are used as part of the National Integrated Drought Information System (NIDIS) U.S. Drought Monitor as well as a seasonal experimental forecast system at NOAA/CPC. The use of Earth observations in the generation of NLDAS data products will be presented, including how these observations contribute to drought monitoring and prediction. Future plans of the NLDAS project to include satellite retrievals of soil moisture and snow cover in a data assimilation mode to improve drought monitoring and prediction will also be discussed.

Name: Youlong Xia, Mike Ek, and the NLDAS team
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Title: Evaluation of long-term, high-resolution NLDAS products using in-situ observations, and application of these products to the U.S. Drought Monitor

Abstract: The North American Land Data Assimilation System (NLDAS) has a long successful history of producing surface meteorology and precipitation data sets used as forcing for land-surface models (LSMs) to produce soil moisture, snow cover, and runoff/streamflow products. These products have been used in numerous applications for researchers both within GAPP (GEWEX Americas Prediction Project) and CPPA (Climate Prediction Program for the Americas) as well as in other communities. In particular, these products have been applied to support the National Integrated Drought Information System (NIDIS) activities such as U.S. drought monitor, NCEP/CPC monthly drought briefing, and NCEP/CPC seasonal outlook. NLDAS has become mature for NCEP operational implementation; therefore, it will be implemented in NCEP operations in the near future.

However, until now these products have not been comprehensively evaluated using all available in-situ measurements and/or remotely-sensed data. Therefore, the community and users do not have a broad picture on the reliability and accuracy of these products. We evaluate the long-term (1979-present) NLDAS streamflow/total runoff (and soil moisture, which are usually applied for hydrological and agricultural drought monitoring, using as many short and long-term in-situ observations as possible over the United States. This assessment is based on simulation skill (anomaly correlation) and mean bias between simulation and observation for different time scales varied from hourly to annual, different models, different soil depths, different seasons, and different variables. The results show that reliability and accuracy of NLDAS products depend on variables, seasons, time scales, and soil depths. They can indeed be used for drought analysis and monitoring in spite of substantial model differences. Also presented is how the NLDAS products are directly used in the U.S. Drought Monitor (USDM) through collaboration with the USDM author group.

Name: Randal Koster

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Title: The Seasonal Prediction of Hydrological Drought

Abstract: The prediction of hydrological (water resources) drought is examined here in the more general context of the prediction of streamflow at seasonal time scales. We examine in particular the ability of a realistic initialization of land moisture states to contribute to streamflow forecast skill. One multi-model study suggests that realistic land initialization will have significant impact on air temperature forecasts but only limited useful impact on precipitation forecasts during a subseasonal forecast period, except when the initial water anomalies are particularly extreme; the net impact on streamflow prediction from this facet of initialization is accordingly small. A more relevant facet of the initialization, however, examined with a different multi-model study, involves the memory of the initial land water into the forecast period. A series of forecast experiments shows that while snowpack information by itself provides a dominant contribution to streamflow prediction skill during the melt season in mountainous areas, the isolated contribution of initial soil moisture information is large and significant in many areas, in all seasons. A comparison of the relative variances of total initial water in a region and the total precipitation falling in that region during the forecast period is

found to be a useful indicator of where streamflows (and their deficits) may be forecasted accurately.

Name: Liping Di
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Title: A Remote Sensing-based Global Agricultural Drought Monitoring and Forecasting System for Supporting GEOSS

Abstract: As one of the important technical contributors to Global Earth Observation System of Systems (GEOSS), the Center for Spatial Information Science and Systems (CSISS), George Mason University, is implementing a remote sensing-based global agricultural drought monitoring and forecasting system (GADMFS) as a GEOSS societal benefit areas (agriculture and water) prototype. The goals of the project are 1) to establish a system as a component of GEOSS for providing global on-demand and systematic agriculture drought information to users worldwide, and 2) to support decision-making with improved monitoring, forecasting, and analyses of agriculture drought. GADMFS has adopted the service-oriented architecture and is based on standard-compliant interoperable geospatial Web services to provide online on-demand drought conditions and forecasting at ~1 km spatial and daily and weekly temporal resolutions for any part of the world to world-wide users through the Internet. Applicable GEOSS recommended open standards are followed in the system implementation. The system's drought monitoring relies on drought-related parameters, such as surface and root-zone soil moisture and NDVI time series derived from remote sensing data, to provide the current conditions of agricultural drought. The system links to near real-time satellite remote sensing data sources from NASA and NOAA for the monitoring purpose. For drought forecasting, the system utilizes a neural-network based modeling algorithm. The algorithm is trained with inputs of current and historic vegetation-based and climate-based drought index data, biophysical characteristics of the environment, and time-series weather data. The trained algorithm will establish per-pixel model for drought forecasting. The model will produce on-demand drought prediction in ~1km or higher spatial resolution, covering whole world by using weather forecasting data as the input. The system will be implemented in multiple phases. Phase I is concentrated only on NDVI-based drought monitoring to demonstrate the concept and feasibility. In phase I, 30-year calibrated global weekly NDVI composites from AVHRR and MODIS are used to establish the baseline and dynamics of vegetation conditions for each co-registered pixel. Multiple NDVI based agricultural drought indices will be computed (e.g., normalized agriculture drought index (NADI), SVI, VegDRI) against the baseline and dynamics of 30-year global NDVI time series for global drought monitoring.

Name: Zhong Liu
Email: zhong.liu@nasa.gov

Title: Maps, Tools and Services at NASA GES DISC for Supporting Global Drought Monitoring Activities

Zhong Liu, William Teng, Steven Kempler and Dana Ostrenga

Abstract: Drought events happen every year around the world. Severe and prolonged droughts could cause heavy damages on agriculture food production

and affect people's daily lives. Dry conditions could create fuels for wild fires. Monitoring droughts can be a challenging task, especially in data sparse regions. Data from satellite observations provide additional information in those regions.

This poster will describe services provided by the NASA Goddard Earth Sciences (GES) Data and Information Services Center (DISC) to support global drought monitoring activities. The services consist of two parts, maps and tools. All maps (URL: http://disc.gsfc.nasa.gov/agriculture/ais_sup/current_conditions.shtml) are derived from the Experimental Near-Real-Time TRMM Multi-Satellite Precipitation Analysis (TMPA or 3B42RT). There are three types of maps, accumulated rainfall, rainfall anomaly and percent of normal rainfall for past 3 hours, 24 hours, 10 days, 30 days, 60 days and 90 days, respectively (Note: no anomaly and percent of normal maps for 3 hours and 24 hours). There are 16 global and regional maps, updated daily, for each of the past conditions. The daily climatology was derived from the 3-hourly TRMM Multi-Satellite Precipitation Analysis (3B42 V6) between 1998 and 2009. These maps provide a convenient way to monitor global droughts, without data downloading, processing and maintenance.

The tools are provided by the TRMM Online Visualization and Analysis System (TOVAS, URL: <http://disc2.nascom.nasa.gov/Giovanni/tovas/>). Advanced users could use TOVAS to do customized rainfall analysis and visualization tasks, as well as to obtain data outputs for use in other applications.

The GES DISC also provides services to support global monitoring activities in other federal agencies. For example, we have been providing a machine-to-machine service to support the USDA Crop Explorer (http://www.pecad.fas.usda.gov/cropexplorer/mpa_maps.cfm) allowing to obtain the latest precipitation information around the world.

More details and examples will be presented in the poster along with existing issues and future plans.

ABSTRACTS (Posters)

Name: Wenhong Li
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Title: Changes of the North Atlantic Subtropical High and its impacts on summer droughts/floods in the Southeastern United States

Abstract: The Southeast United States (SE US) is one of the fastest growing regions of the country. Water supplies in this area are increasingly stressed, especially in summer. In recent decades, summer droughts and floods repeatedly struck the SE US, causing devastating socioeconomic impacts on the region. What caused such enhanced summer rainfall variability has been investigated in the study. Our results demonstrated that the

enhancement of rainfall variability is closely related to a more intense and westward movement of the North Atlantic Subtropical High (NASH) in recent decades. Our attribution analysis suggested that the changes of the NASH are mainly due to anthropogenic warming. In the 21st century, with an increase of the atmospheric CO2 concentration, the center of the NASH would further intensify, and the western ridge of the NASH would shift further westward. These changes would increase the likelihood of both strong anomalously wet and dry summers over the SE US in future as suggested by the IPCC AR4 models.

Name: Peyman Daneshkar Arasteh

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Title: Global Precipitation Trend Analysis Using PERSIANN

Abstract: Climate change affects hydrologic status of the Earth and leads a series of changes in precipitation, evaporation, drought and flood. So, it affects the socio-economic stability of most societies. Precipitation spatial-temporal variations as a consequence of climate change affect water balance in basin scale. So, analysis and study of precipitation temporal trend and spatial pattern helps to manage basin water resources.

In this research, global precipitation trend in the past decade (2000-2009) were studied using PERSIANN 0.25 degree monthly data set and Mann-Kendall test. Maps of Mann-Kendall statistics were developed and showed spatial extend of significant trends. A comparison with the results of a parallel work on global drought monitoring showed that significant trends lies on drought affected areas where mostly are developing countries. Therefore, climate change and its consequences precipitation trend and drought caused more poverty and more economic fragility in developing countries during the past decade.

Name: Jason Giovannettone

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Title: The Institute for Water Resources Drought Atlas Software (IWR-DAS)

Abstract: The USACE Institute for Water Resources is developing a non-proprietary software that allows the creation of a drought atlas using L-moments and regional rainfall frequency analysis according as the method is presented in Hosking and Wallis (1997). The method of L-moments is preferred over using regular moments due to the fact that L-moment statistics are more robust in terms of accommodating extreme values and L-moments have the ability to characterize a greater number of frequency distributions than conventional moments. An additional advantage is that L-moments are less susceptible to bias in their estimation than regular moments. Regional frequency analysis is used on the assumption that if the frequencies of rainfall events are similar at several nearby locations within a region, a statistical analysis of all observations at all sites within the region will result in a more accurate frequency distribution at each site compared to limiting the analysis to only the at-site data for each site. Due to this fact, using L-moments allows the development of a drought atlas in arid and semi-arid regions where data is sparse spatially and may be available only over a limited time period at individual sites. The end result will depend

on three pieces of input: storm duration, time period for the analysis (beginning month and number of months), and the frequency of the event, and will consist of a series of digital maps that answer questions such as, "What is the probability that the current drought will end in X months?", "How long a drought should we prepare for, and "What is the frequency of maximum drought intensity observed?"

Name: Alys Thomas
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Title: Distinguishing Regional Drought Characteristics Using GRACE
Terrestrial Water Storage Datasets

Abstract: This research attempts to delineate and quantify seasonal to annual regional hydrologic drought signals in terrestrial water storage (TWS) datasets measured by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites. The objective is to specify the degree and time frame drought can be identified within the terrestrial hydrologic system for the purpose of broadening the drought monitoring capabilities of the GRACE satellites. This will serve as groundwork for unprecedented, global drought monitoring by way of remote sensing. GRACE TWS anomalies (TWSA) not only have information about the mass change of water storage over time but the dataset inherently contains information about climate change, water use, surface water, and groundwater; all linked to drought. Probability distribution analysis was applied to TWS data to identify (1) abnormally low values that can be considered drought; and (2) the likelihood of water storage reaching these low values based on a GRACE period from June 2002 to September 2009. The probability and magnitude of a drought event based on probability distribution functions allows us to more simply express drought severity for basin averages, much like the methodology used in calculating the Standardized Precipitation Index (SPI). TWS and precipitation joint-probability distributions may also contain valuable information about the propagation of drought over time. Future investigations include: exploring the spatial distribution of water storage and drought, determining human contributions to groundwater depletion during drought, and investigating relationships between water storage variation, drought, and climate oscillations like the El Nino Southern Oscillation and monsoon activity. Multivariate Regression and Principle Component analyses with GRACE and precipitation, soil moisture, and temperature datasets will emphasize climate and watershed conditions associated with GRACE-identified drought. Water resource managers will directly benefit from this alternate view of the variation of water stores in the presence of drought conditions via GRACE satellite data.

Name: Zhong Liu
Email: zhong.liu@nasa.gov

Title: Maps, Tools and Services at NASA GES DISC for Supporting Global
Drought Monitoring Activities

Abstract: Drought events happen every year around the world. Severe and prolonged droughts could cause heavy damages on agriculture food production and affect people's daily lives. Dry conditions could create fuels for wild

fires. Monitoring droughts can be a challenging task, especially in data sparse regions. Data from satellite observations provide additional information in those regions.

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More details and examples will be presented in the poster along with existing issues and future plans.

Name: John Bolten

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Title: The Middle East and North Africa Land Data Assimilation System

Abstract: The Arab region of the Middle East and North Africa (MENA) is dominated by dry, warm deserts, areas of dense population, and inefficient use of fresh water resources. Many areas are prone to hydroclimatic extremes that are realized by devastating floods and extended times of drought. Still, the dynamics of the water cycle in the MENA remain relatively poorly monitored due in part to the shortage of meteorological observations and the lack of data sharing between nations. This presentation will cover early results from the Land Data Assimilation System for the MENA region (MENA LDAS) designed to provide regional, gridded fields of hydrological states and fluxes relevant for water resources assessments. The MENA LDAS is envisaged to aid in the identification and evaluation of regional hydrological anomalies by synergistically combining the physically-based Catchment Land Surface Model (CLSM) with observations from several independent data products including soil-water storage variations from the Gravity Recovery and Climate Experiment (GRACE) and irrigation intensity derived from the Moderate Resolution Imaging Spectroradiometer (MODIS).

Name: Clement Alo
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Title: Drought in the Nile Basin: characterizing variability and studying processes with the Nile Land Data Assimilation System

Clement A. Alo, Benjamin F. Zaitchik, Shahid Habib, Martha Anderson, Mutlu Ozdogan

Abstract: The NASA Nile Land Data Assimilation System (Nile LDAS) is being developed to support studies of hydrologic variability, land cover patterns, and climate change impacts in the countries that share the Nile basin. The Princeton University reanalysis dataset is one of several meteorological forcing datasets currently applied to Nile LDAS, which provides estimates of hydrological states and fluxes across the basin at 5km to 25km resolution. Here we examine the spatial and temporal patterns of rainy season precipitation amount and consecutive dry days based on 3-hourly precipitation fields from the Princeton dataset, and explore possible association of the variability in these variables with the El Nino Southern Oscillation (ENSO). Empirical orthogonal function (EOF) analysis of data for the period 1979-2008 shows that variability in consecutive dry days is strongest over northern Tanzania and northwestern Kenya. Consecutive dry days anomalies appear to be associated with ENSO, suggesting that ENSO conditions play an important role in the occurrence of drought in the Nile Basin. Follow-on studies are in progress to merge, compare, and improve Nile LDAS datasets in order to provide optimal estimates of hydrological states and fluxes in the Nile basin, with the ultimate objective of improving drought analysis and response in an evolving climate.

Name: Lisa Darby
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Title: The National Integrated Drought Information System (NIDIS)

Abstract: The National Integrated Drought Information System Act of 2006 (NIDIS Act PL 109-430) prescribes an interagency approach, led by NOAA, for the development and coordination of drought risk information to support proactive decision-making. The NIDIS goal as stated in the Act is to "Enable the Nation to move from a reactive to a more proactive approach to managing drought risks and impacts". NIDIS was developed in partnership with the Western Governors Association, but is national in scope. NIDIS has three general tasks under its authorization: (I) Provide an effective drought early warning system that: (a) collects and integrates information on the key indicators of drought and drought severity; and (b) provides timely information that reflect state and regional differences in drought conditions; (II) Coordinate Federal research in support of a drought early warning system; and, (III) Build upon existing forecasting and assessment programs and partnerships.

NIDIS: Structure and Governance At the national level the multi-agency NIDIS Executive Council, co-chaired by the directors of the NOAA Climate Program Office and the National Drought Mitigation Center, oversees the NIDIS Program Office. The NIDIS Program Office coordinates the multi-agency and multi-state NIDIS Program Implementation Team (NPIT) and is chaired by the NIDIS Program

Office. The Executive Council also acts as the interagency recipient of feedback from the NPIT on drought-related monitoring and research priorities and gaps. To fulfill the goals of the Act, NOAA supports four components at the national level under NIDIS: "Coping With Drought: Grants to assess impacts of drought on agriculture, ecosystems, and water resources and develop decision support prototypes (RISA, SARP, TRACS Programs)"

Climate Test-beds: Projects to improve predictions and links between climate forecasts and streamflow projections for particular basins (MAPP, CPC).

The US Drought Portal: A clearinghouse for drought-related information and products. (NCDC and National Drought Mitigation Center) Regional Drought Early Warning Information Systems: Early warning system development and implementation. Building on the above activities and in partnership with other agencies, tribes and states, NIDIS develops basin-specific drought indicators, management triggers, monitors and portals. It facilitates ongoing discussion of existing and potential drought conditions and impacts among resource managers through webinars and workshops; and develops user guidance and decision support tools to support drought plans (NIDIS Program Implementation Team). The NIDIS Program Implementation Team (NPIT) is composed of representatives from, at present, over fifty federal, state and tribal agencies, and academic and private entities, across the country. These teams support five critical activities that are the bases for early warning information systems:

- (1) Communication and Education,
- (2) Integrated monitoring and forecasting products,
- (3) Impacts assessments and decision support tool development,
- (4) Drought information portal development (incl. sub-regional portals), and
- (5) Engaging preparedness communities-Embedding information from (1) through (4) into planning and adaptation.

These components were identified from well-established literatures and experience on the nature of effective early warning systems in disaster management, technological forecasting, health systems and others, and are discussed further in the NIDIS Implementation Plan (www.drought.gov). At the regional level, NPIT members already engaged in selected locations (see below) convene and coordinate multi-agency and multi-state teams, including institutions and individuals from affected communities, to develop the regional drought early warning information systems. These activities are directly supported by and designed in collaboration with the NIDIS Program Office.