Progress Report

National Drought Monitoring System for Drought Early Warning Using Hydrologic and Ecologic Observations from NASA Satellite Data

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Background

The objective of this project is to assimilate 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), into a national drought monitoring system, specifically the United States Drought Monitor (USDM), an existing national decision support tool used for drought monitoring and drought early warning.

Several 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) the lack of detailed, accurate, and objective data sources especially where current networks of weather stations are sparse in the public lands of the West. These represent the two largest impediments to early detection of drought and its impacts at the county level, which is where key drought decision making takes place.

JPL has the lead in the development of drought monitoring products from QSCAT and AMSR-E. The role of USGS/EROS is the development of systems for production of time-series vegetation index (VI) imagery from MODIS data, and delivery of VI products to USDM authors and the drought community in general. The NDMC plays the role of lead integrator for an improved operational USDM system. NOAA Physical Science Division (PSD) is responsible to develop engineering prototypes of NASA products with the zoom-in capability for use in drought monitor and to validate and benchmark the results. NDMC is responsible for ingesting NASA results from JPL and USGS into the existing USDM system for drought decision support, and performing benchmark analyses.

Summary of this year accomplishment highlight

Drought is among the most difficult of all natural hazards to monitor effectively and consistently because it has varying impacts in different sectors (e.g., agriculture, water supply), a subtle arrival and departure, and large spatial and temporal variability from drought to drought. The U.S. Drought Monitor (USDM) is an operational drought monitoring system and the primary national scale tool for current drought decision support.

The Jet Propulsion Laboratory develops a unique product of soil moisture change (SMC) from 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 (dry rain, dry thunderstorms, etc.) and serious anomalous propagation (AP) errors in radar meteorology. JPL produces and provides daily and weekly SMC data for the entire coterminous United States (CONUS). SMC date files are automatically uploaded to NOAA Physical Science Division (PSD) using an automated processor developed at JPL. At NOAA PSD, SMC data are used to make numerous products and derivatives with various color protocols and drought contour overlay. Then, the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln can use these products to evaluation the enhancement of drought monitoring, and NOAA Climate Prediction Center (CPC) can potentially use them to help with drought forecast/outlook. In addition, SMC products are found useful for wildfires applications, especially in the process of issuing Red Flag Warning, which is critical to wildfire prevention and mitigation.

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, including Mark Svoboda, a climatologist at the NDMC. They found the VegDRI to meet the finer resolution needs of the USDM along with the potential for addressing the regional scale needs of the National Integrated Drought Information System (NIDIS). The VegDRI was used to both confirm existing areas of drought and for potentially identifying new areas of drought that were not currently being depicted via traditional drought indicators at coarser resolutions. This project is modernizing drought monitoring techniques to take advantage of today's improved computing power and the synoptic repetitive imaging capacity of NASA's modern satellite-borne sensors.

Progress for 2009

JPL:

- Providing QuikSCAT soil moisture change (SMC) data for drought applications: data for entire CONUS, daily data production, nearly daily of CONUS, and automated routine upload processor is ready. Procedure for PSD to get AMSR-E soil moisture data.
- Resolution benchmarking: SMC data gridded at ¼ degree in latitude and longitude, resolving county scale per Nyquist scale requirement estimated at 27 km.
- Prototyping: Working with the team to develop SMC prototypes with different color protocols, file format, and drought contour overlay options.
- Demonstration of improvement (all) – JPL automated SMC data upload to NOAA Physical Science Division.
- Incorporating latest satellite algorithm improvements and advanced NASA products/results for drought monitoring: Improving SMC algorithms and products, initiating and testing new QS products for drought monitoring/forecast.

USGS:

- MODIS Vegetation Indices ingested into a drought model called the Vegetation Drought Response Index (VegDRI) were produced in an operational fashion during 2009 at USGS EROS.

- Evaluation of those vegetation products is ongoing. One evaluation method focused on a data intercomparison involving several different drought indicators including the U.S. Drought Monitor.
- Highest correlations were found between the VegDRI and the Palmer Drought Severity Index.
- Results were then presented at the Fall 2009 American Geophysical Union. Full operational delivery of VegDRI will occur early in 2010.

NDMC:

- Worked with JPL and NOAA-PSD on feedback of the QuikSCAT derived SMC product (e.g., legend, incorporation of DM vector overlays, cartographic color scheme, and temporal updating) for presentation of case study results (by Son Nghiem) at the U.S. Drought Monitor (USDM) Forum in Austin, TX on Oct. 7-8, 2009.
- Obtained results for VegDRI and the enhanced DM/DSS mock-up.
- Research efforts with regards to U.S. and North American drought monitoring and its potential ties to the NIDIS, Global Earth Observation System of Systems (GEOSS), and the North American Drought Monitor, which lack sufficient observed observations and is ready to evaluate new remotely sensed data and derivative products.
- Provided guidance/feedback on initial JPL and NOAA PSD derivative products involving the QuikSCAT SMC. Provided information on DM ranking percentile criteria, color scheme, and USDM operational methods, color scheme, delta maps, and temporal production needs that will be applied to the SMC product.
- Work being done between the NDMC, PSD, and NIDIS Portal Team for setting up operational integration of the Soil Moisture Change (SMC) product into the NIDIS Drought Monitor Author Community and/or GIS Map Viewer on the Portal (drought.gov).

NOAA PSD:

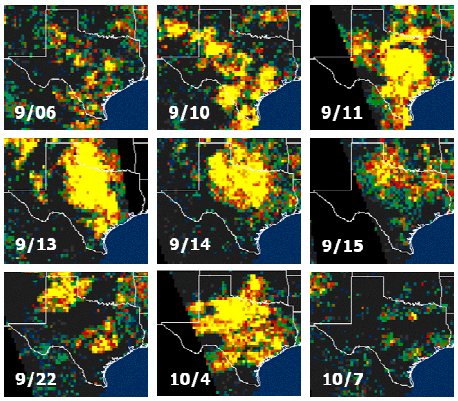
- Acquiring and assembling NASA QuikSCAT/SMC data set Obtained results for VegDRI and the enhanced DM/DSS mock-up.
- Acquiring and assembling AWDN Nebraska in-situ soil moisture data set.
- Establishing semi-automatic daily updates for SMC data stream.
- Establish weekly updates of SMC consumer imagery, including SMC weekly derivatives.
- Developing software for detail correlation of high resolution satellite data with in-situ data.

DFO:

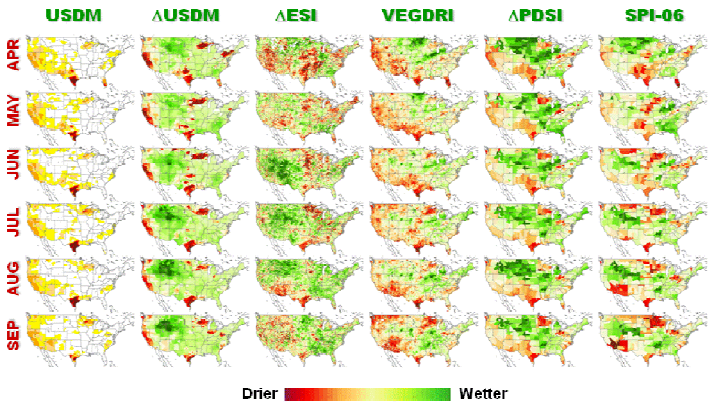
- Testing MODIS Rapid Response Subset-based water classification algorithms (mainly using the band 1,2,7 geotiff files).
- Implemented test drought displays, 10 deg x 10 deg land areas for 48 states and Alaska. Basic approach involves comparison of MODIS-imaged normal surface water conditions to present MODIS-imaged surface water.
- acquisition of imagery, processing water classification, GIS vectorization, and quality control of “normal surface water” (mean conditions) map layers, based on MODIS Subset data, 2007-present. First area to be completed includes California and Nevada.
- Development of HTML displays importing the latest Drought Monitor display, thence allowing directed, clickable access to MODIS-based Surface Water Drought displays, and also AMSR-E surface water sites.

NOAA CPC (non-cost collaborator):

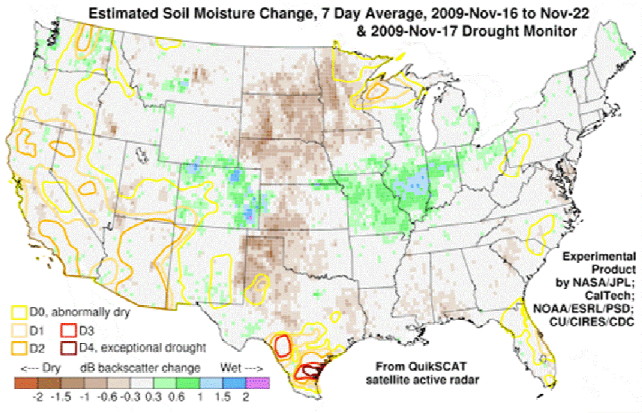
- Review of current procedures for production of Drought Outlooks, including principal inputs for short-term and long-term forecasts.
- Identifying candidates for drought monitor and forecast: multi-model LDAS, soil moisture anomaly, historical PDI data, etc.
- Potential utilization of soil moisture change data to identify recent trends (non-stationary) for applications to drought forecast.
- Advising the team on drought forecast/outlook issues.



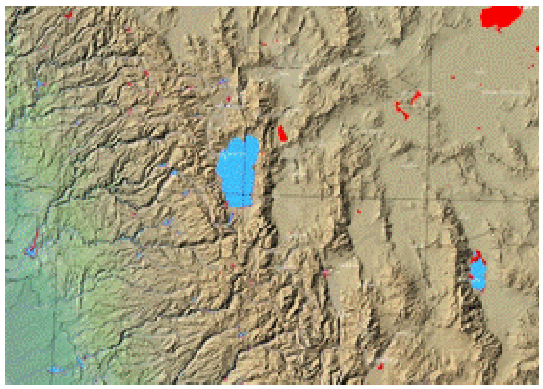
(a) Soil moisture change in Texas in 2009



(b) VEGDRI intercomparison with drought monitor products



(c) SMC prototype with drought contour overlay



(d) MODIS surface water display for drought (red)

Figure 1. Examples of results for enhancing national drought monitoring system using hydrologic and ecologic observations from NASA satellite data.

Publications and Presentations in 2009

Brown, J.F., Miura, T., Gu, Y., Jenkerson, C., and Wardlow, B., ”Utilizing a multi-sensor satellite time series in real-time drought monitoring across the United States”, *In* Proceedings of the 2009 Joint Assembly of the American Geophysical Union, May, 2009, Toronto, Canada. [Presentation].

Gu, Y., Brown, J.F., van Leewen, W., Reed, B.C., and Miura, T., “Phenologic classification of the United States: a framework for extending a multi-sensor time series for vegetation

drought monitoring," *In* Proceedings of the Annual Meeting of the Association of American Geographers, March, 2009, Las Vegas, Nevada. [Presentation].

Gu, Y., Brown, J.F., Miura, T., van Leewen, W., and Reed, B.C., "Phenological classification of the United States: a geographic framework for extending multi-sensor time series data," manuscript in preparation.

JPL Photo Journal, "Rapid Dry-Up of Rainwater on Land Surface Leading to the Santa Barbara Wildfire," *Internet article* http://photojournal.jpl.nasa.gov/catalog/PIA12006, Jet Propulsion Laboratory, Pasadena, California, 8 May 2009.

NDMC et al., Initial stage of preparing individual book chapters for VegDRI and SMC approaches for a new book entitled 'Remote Sensing of Drought: Innovative Monitoring Approaches' being prepared for CRC Press (May – Sept., 2009 – Wardlow).

NDMC presented VegDRI and the enhanced DM/DSS mock-up at the North American Drought Monitor Forum in Ottawa, Canada. Another NDMC presentation discussed research efforts with regards to U.S. and North American drought monitoring and its potential ties to the NIDIS, Global Earth Observation System of Systems (GEOSS), and the North American Drought Monitor, which lack sufficient observed observations and is ready to evaluate new remotely sensed data and derivative products (Oct. 2008 – Wardlow, Fuchs, and Svoboda).

NDMC presented VegDRI at the US/Canada Bi-lateral GEO Workshop hosted by the National Science Foundation (NSF) in Arlington, VA. (Oct. 2008 – Wardlow).

Nghiem, S. V., D. Balk, E. Rodriguez, G. Neumann, A. Sorichetta, C. Small, and C. D. Elvidge, "Observations of Urban and Suburban Environments with Global Satellite Scatterometer Data," *ISPRS Journal of Photogrammetry and Remote Sensing*, 64, 367-380, doi:10.1016/j.isprsjprs.2009.01.004, 2009.

Nghiem, et al. (authors from JPL, USGS, NDMC, NOAA PSD, DFO, and others), "Pattern and Frequency of Soil Moisture Variability over the Continental United States," *manuscript* in revision, 52 pp., 2009.

Nghiem, S. V., "NASA Satellite Data for Applications to Early Warning of Droughts across the World – Examples for Africa," *Inter-Regional Workshop on Indices and Early Warning Systems for Drought*, Lincoln, Nebraska, 8-11 December 2010.

Nghiem, S. V., "Satellite Observation of Soil Moisture Change and Applications to Drought Monitoring," *6th U.S. Drought Monitor Forum*, Lower Colorado River Authority, Redbud Center, Austin, Texas, 7-8 October 2009.

Nghiem, S. V., "Geophysical Information from NASA Satellite Scatterometry – Western U.S. and California," *ESRI International User Conference*, San Diego Convention Center, San Diego, California, 13-17 July 2009.