

Solutions Network Formulation Report

Visible/Infrared Imager/Radiometer Suite and Advanced Microwave Scanning Radiometer Data Products for National Drought Monitor Decision Support

February 1, 2007

1. Candidate Solution Constituents

- a. Title: Visible/Infrared Imager/Radiometer Suite and Advanced Microwave Scanning Radiometer Data Products for National Drought Monitor Decision Support
- b. Author: Leland Estep, Science Systems and Applications, Inc., John C. Stennis Space Center
- c. Identified Partners: National Drought Mitigation Center, U.S. Department of Agriculture Risk Management Agency, National Oceanic and Atmospheric Administration, and U.S. Geological Survey
- d. Specific DSS/DST: VegDRI and VegOUT; Drought Monitor Decision Support System
- e. Alignment with National Application: Agricultural Efficiency
- f. NASA Research Results – Table 1:

| Missions | Sensors/Models | Data Product |
|-------------------|---------------------------------|------------------------------------|
| NPP ¹ | VIIRS ² | Terrestrial (e.g., Land Cover) |
| Aqua | AMSR-E ³ | Soil Moisture |
| GSFC ⁴ | Multiple (e.g.6S ⁵) | Atmospherically corrected products |

¹NPP: NPOESS (National Polar-orbiting Operational Environmental Satellite System) Preparatory Project; ²VIIRS: Visible/Infrared Imager/Radiometer Suite; ³AMSR-E: Advanced Microwave Scanning Radiometer; ⁴GSFC: Goddard Space Flight Center; ⁵6S: Second Simulation of the Satellite Signal in the Solar Spectrum

- g. Benefit to Society: Monitoring of climate, soils, and other biophysical parameters to project drought possibility

2. Abstract

Drought effects are either direct or indirect depending on location, population, and regional economic vitality. Common direct effects of drought are reduced crop, rangeland, and forest productivity; increased fire hazard; reduced water levels; increased livestock and wildlife mortality rates; and damage to wildlife and fish habitat. Indirect impacts follow on the heels of direct impacts. For example, a reduction in crop, rangeland, and forest productivity may result in reduced income for farmers and agribusiness, increased prices for food and timber, unemployment, reduced tax revenues, increased crime, foreclosures on bank loans to farmers and businesses, migration, and disaster relief programs.

In the United States alone, drought is estimated to result in annual losses of between \$6–8 billion. Recent sustained drought in the United States has made decision-makers aware of the impacts of climate change on society and environment. The eight major droughts that occurred in the United States between 1980 and 1999 accounted for the largest percentage of weather-related monetary losses.

Monitoring drought and its impact that occurs at a variety of scales is an important government activity – not only nationally but internationally as well. The NDMC (National Drought Mitigation Center) and the

USDA (U.S. Department of Agriculture) RMA (Risk Management Agency) have partnered together to develop a DM-DSS (Drought Monitoring Decision Support System). This monitoring system will be an interactive portal that will provide users the ability to visualize and assess drought at all levels.

This candidate solution incorporates atmospherically corrected VIIRS data products, such as NDVI (Normalized Difference Vegetation Index) and Ocean SST (sea surface temperature), and AMSR-E soil moisture data products into two NDMC vegetation indices—VegDRI (Vegetation Drought Response Index) and VegOUT (Vegetation Outlook)—which are then input into the DM-DSS.

3. Detailed Description of Candidate Solution

a. Purpose/Scope

Drought impacts on water supplies, agriculture, and forests demonstrate society's susceptibility to climate change. Congress enacted the Agricultural Risk Protection Act of 2000 to encourage the USDA RMA and farmers to be more proactive in managing drought risk. Several programs have been developed to enhance drought monitoring on both a national and international scale by integrating observing systems and local and regional input. A few years later, Congress enacted the National Integrated Drought Information System Act of 2006, which instituted a drought early-warning system. The bill established a NIDIS (National Integrated Drought Information System) within NOAA (the National Oceanic and Atmospheric Administration) to strengthen and coordinate federal efforts to accurately monitor and predict droughts. The DM-DSS falls within the objectives of the NISDIS (NDMC, 2006b).

In general, drought monitoring is difficult because of variance in such parameters as duration, intensity, extent, etc. among individual drought events. Climate and weather data have historically been used to monitor drought, but this information has not been spatially detailed enough to be of value to those making decisions regarding conditions. These issues have led the NDMC to partner with the USDA RMA to develop vegetation indexing tools, visualization tools to display this information, Web-based packages to access this information, and archives databases for trending and further analysis. These two groups began working on developing a Drought Monitor Decision Support System in 2006 (NDMC, 2006b).

Data products required for drought monitoring include observations of precipitation, soil moisture, snow water content and snow depth, soil and air temperatures, humidity, wind speed and direction, and solar radiation (WGA, 2004). NASA satellite products have already been used in support of some of the drought monitoring tools that have been developed. Presently, VegDRI and VegOUT use AVHRR (Advanced Very High Resolution Radiometer) data at 1 km² spatial resolution: AVHRR Ocean SST data and AVHRR NDVI imagery are important input data layers (Brown and Verdin, 2006). These tools could be further enhanced by supplanting the AVHRR data layers with those generated by the higher spatial resolution VIIRS.

Presently, NDMC relies on the placement of field-collected soil temperature and soil moisture measurements, which has been too sparse and has been absent in many areas (WGA, 2004). Use of synoptic AMSR-E data on soil moisture levels over a scene would provide higher-resolution information.

b. Identified Partners

The National Drought Mitigation Center was established in 1995 to help develop and implement services to reduce societal vulnerability to drought (NDMC, 2006a). The NDMC is located at the School of Natural Resources at the University of Nebraska–Lincoln. The NDMC is a relatively small group that receives information by NOAA, the USDA, and the USGS (U.S. Geological Survey) to inform, educate, and produce drought forecasts. The center works closely with the USDA RMA on

several partnership agreement projects, including the development of the Drought Monitor Decision Support System.

The NDMC is also collaborating with the USGS and other researchers at the University of Nebraska–Lincoln to develop two vegetation index tools used monitor drought: VegDRI and VegOUT. VegDRI maps drought effects’ spatial patterns using current vegetation conditions. VegOUT produces a longer forecast on vegetation conditions – for a period of several weeks. Presently, VegOUT is planned to produce forecasts at 4- and 6-week projections. Both tools produce regional maps at 1 km² spatial resolution that are updated every 2 weeks.

VegDRI is calculated using data-mining techniques that integrate complex information from satellite imagery, climate-based drought indices, land cover types, soil characteristics, and additional environmental factors. VegOUT builds on VegDRI, incorporating data such as Pacific Ocean SST maps to produce 2-, 4-, and 6-week outlooks for vegetation conditions.

VegOUT and VegDRI are currently used to provide input to the U.S. Drought Monitor, a Web-based drought assessment map. The Monitor provides a depiction of national drought conditions based on a combination of drought indicators and field reports. Drought assessments through the U.S. Drought Monitor are issued by a group of Federal agencies, including The Climate Prediction Center (DOC (U.S. Department of Commerce)/NOAA/National Weather Service), the Joint Agricultural Weather Facility (USDA/DOC/NOAA), and NOAA’s National Climatic Data Center. It is currently envisioned that the DM-DSS will eventually replace the U.S. Drought Monitor.

c. NASA Earth-science Research Results

The launch of the NPP (National Polar Orbiting Environmental Sensor Suite (NPOESS) Preparatory Project) in about 2011 will have onboard VIIRS. The NPP satellite will be at an altitude of 824 km in a sun-synchronous orbit with 1030 local equator crossing time. Through the follow-on NPOESS program, VIIRS data will be a primary source of systematic remote sensing imagery until about 2022 (Yu and Privette, 2005).

VIIRS has 22 spectral bands, including 16 moderate-resolution (750-m pixels) and 5 imagery resolution (375-m pixels) bands, plus 1 panchromatic band. The central wavelengths of the VIIRS thermal infrared bands (10.8 and 12.0 m), used in land surface temperature retrievals, are similar to those of the Moderate Resolution Imaging Spectroradiometer (11.0 and 12.0 m) and AVHRR (10.8 and 12.0 m). VIIRS features a rotating telescope design to minimize stray light and includes onboard calibration sources for solar and thermal bands. Specifically, VIIRS SST-derived imagery and computed NDVI image data will be of value to the target DSTs.

The AMSR-E onboard the Aqua platform is a conically scanning, total power, passive microwave radiometer sensing microwave radiation (brightness temperatures) at 12 channels and 6 frequencies that vary from 6.9 to 89.0 GHz. Horizontally and vertically polarized radiation are measured independently at each frequency. AMSR-E produces an “AE_Land” data product. This product is a global swath surface of soil moisture mapping plus other parameters including surface type, vegetation water content, surface temperature, and quality control parameters. These data are spatially resampled to a nominal 25-km equal area Earth grid. Soil moisture maps produced using AMSR-E data could supplement the field-collected soil moisture data.

d. NASA Earth-science Models

Satellite instruments provide global coverage at nearly constant solar times, but the observations measure reflected radiance and transmission information that must be determined using radiative transfer models to account for reflectance and atmospheric variables. NASA-funded atmospheric correction codes, such as the 6S (Verote et al., 1997), remove the effects of the atmosphere and

produce reflectance maps that can be used in Earth-application algorithms to produce useful products, such as NDVI maps.

e. Proposed Configuration's Measurements and Models

In this candidate solution, biophysical and oceanic information data sets including NDVI and SST will be generated based on VIIRS acquisitions. The acquired data will be atmospherically corrected using NASA-funded atmospheric correction tools such as 6S. In addition, soil moisture levels (and perhaps vegetation moisture content data) over a scene would be acquired through AMSR-E. The data mining algorithms currently used on the data layers to aid in producing present status as well as forecasts (Agrawal et al., 1993; Harms et al., 2001; Li et al., 2003) will likely also be required.

These satellite-acquired datasets would be incorporated into the NDMC VegOUT tool to map drought effects' spatial patterns using current vegetation conditions and the VegDRI tool to produce a longer-period forecast on vegetation conditions.

Outputs from these tool sets would be fed into the DM-DSS currently being developed as an NDMC – RMA partnership agreement project.

4. Programmatic and Societal Benefits

Drought, unlike hurricanes or tornadoes, is a slowly evolving phenomenon. Predicting drought conditions far enough in advance allows an opportunity to take steps to mitigate drought effects. Hence, given adequate warning, farmers, ranchers, and various levels of governmental officials can plan to deal with drought onset. For example, using drought prediction maps, certain areas have “banked” water supplies to offset reduced precipitation associated with drought onset. Drought prediction therefore provides varied societal benefits that cut across economic and ecological lines. With water supplies and food sources threatened, it is crucial that an early warning system be developed. This candidate solution supports the Agricultural Efficiency National Application.

5. References

- Agrawal, R., T. Imielinski, and A. Swami, 1993. Mining association rules between sets of items in large databases. In *Proceedings of the ACM SIGMOD 1993 International Conference on Management of Data*, Washington DC, USA.
- Brown, J., and J. Verdin, 2006. Remote sensing tools for improving drought decision support. In *Proceedings Managing Drought and Water Scarcity in Vulnerable Environments: Creating a Roadmap for Change in the United States*, 18–20 September 2006, Longmont, CO (Geological Society of America, Boulder, CO).
- Harms, S., J. Deogun, J. Saquer, and T. Tadesse, 2001. Discovering representative episodal association rules from event sequences using frequent closed episode sets and event constraints. In *Proceedings of the 2001 IEEE International Conference on Data Mining*, San Jose, CA, USA.
- Li, D., S. Harms, S. Goddard, W. Waltman, and J. Deogun, 2003. Time-series data mining in a geospatial decision support system. In *Proceedings of The National Conference on Digital Government Research*, 18–21 May, Boston, MA, USA, <http://www.digitalgovernment.org/dgrc/dgo2003/cdrom/POSTERS/li.pdf> (accessed December 12, 2006).
- NDMC [National Drought Mitigation Center], 2006a. *About the NDMC*. University of Nebraska–Lincoln, <http://drought.unl.edu/about.htm> (accessed January 27, 2006).
- NDMC, 2006b. *What's New: VegDRI and VegOUT/Drought Monitor Decision Support System*. University of Nebraska–Lincoln, <http://www.drought.unl.edu/news/currentresearch.html> (accessed December 12, 2006).

- Vermote, E., D. Tanre, J. Deuze, M. Herman, and J. Morcrette, 1997. Second Simulation of the Satellite Signal in the Solar Spectrum. *IEEE Transactions on Geoscience and Remote Sensing* 35(3):675–686, [http://modis-atmos.gsfc.nasa.gov/docs/Vermote%20et%20al.%20\(1997b\).pdf](http://modis-atmos.gsfc.nasa.gov/docs/Vermote%20et%20al.%20(1997b).pdf) (accessed January 22, 2007).
- WGA [Western Governors Association], 2004. *Creating a Drought Early Warning System for the 21st Century*. <http://www.westgov.org/wga/publicat/nidis.pdf> (accessed December 12, 2006).
- Yu, Y., and J. Privette, 2005. Analysis of the NPOESS VIIRS land surface temperature algorithm using MODIS data. *IEEE Transactions on Geoscience and Remote Sensing*, 4: 1123–1126.