NIDIS Remote Sensing Workshop: Showcase of Products & Technologies

By Christina Alvord of WWA

Three knowledge assessment workshops are scheduled for 2008 by the National Integrated Drought Information System (NIDIS). These workshops are intended to foster collaboration and partnerships between the scientific community and decision makers, in order to better monitor, manage, and prepare for drought on local, regional, and national scales. Each workshop addresses a different element of monitoring and planning for drought, providing user groups and decision makers with a valuable review of selected drought science, products, and research topics. Information about all three NIDIS workshops is available at: http://www.drought.gov.

Introduction

The NIDIS workshop, "Contributions of Satellite Remote Sensing to Drought Monitoring," was held on February 6-7, 2008 in Boulder, Colorado for over thirty researchers, scientists, and natural resource managers representing a variety of universities and federal, state, and local agencies. The workshop provided participants with an overview of available satellite remote sensing technologies and products for cross-sector applications in drought monitoring, management, and planning in the United States. In turn, participants provided recommendations regarding the utility and presentation of remote sensing technologies, including input for near-term modifications to operational products and ideas for future development and research. User groups were represented by local water managers from Denver Water, City of Aurora, Colorado Water Conservation Board, and the Upper Colorado Water Conservancy District. Three state climatologists served as lead panelists to facilitate discussion between producers and users. This article responds to a workshop recommendation to better inform user groups about remote sensing products and applications. This article introduces several technologies and products for monitoring vegetation health, snow and precipitation extent and cover, and soil moisture and ET conditions. These products have cross-sector applications for monitoring emerging and ongoing drought conditions.

Satellite Remote Sensing

Satellite remote sensing generally refers to the process of observing and recording the transmission of electromagnetic energy that radiates and reflects from terrestrial and atmospheric surfaces. These transmissions correspond to specific portions of the electromagnetic spectrum (EMS). Observations (or data) collected from different wavelengths in the EMS reveal information about surface characteristics and processes. Data from the visible, infrared and microwave portions of the EMS are used for monitoring various aspects of drought, including vegetation health and cover, evapotranspiration, precipitation amount and locale, soil moisture, snow cover extent, snow water equivalent (SWE), and snowpack temperature (Figure 1a). Although observations from certain parts of the spectrum lend themselves better to specific surface properties, some drought indicators are hybrids of data collected from multiple areas. Observations collected by satellites are integrated into standardized indices (e.g., Normalized Difference Vegetation Index (NDVI), Palmer Drought Severity Index, (PDSI), Standardized Precipitation Index (SPI), or assimilated into land, water, or energy balance models (Figure 1b). In addition, satellite remote sensing observations are increasingly used in conjunction with ground and/or airborne measurements. Data produced from satellite observations are typically presented in map form to show the spatial variation of a drought-related index.

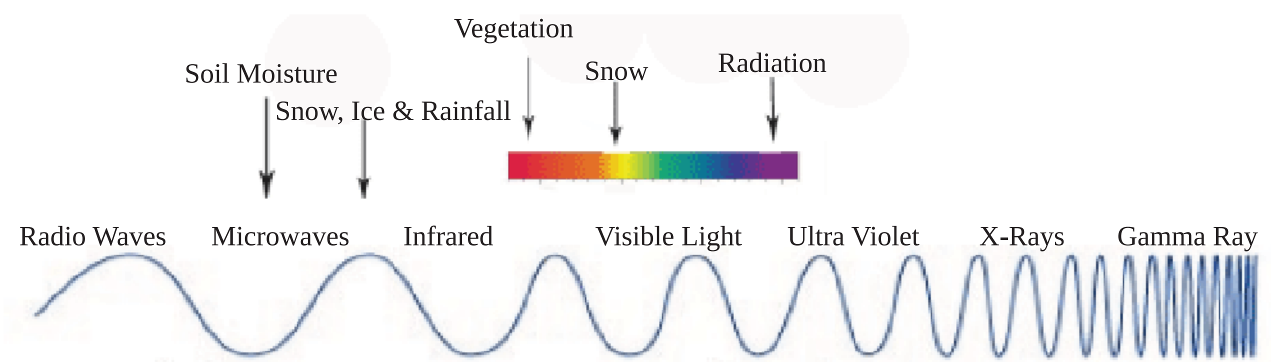

Figure 1a: Visual representation of the electromagnetic spectrum (EMS) and the observed parameters that best respond to different wavelengths.

Remote sensing-based systems augment information available from conventional data sources, (i.e. instrument stations) and provide consistent continuous coverage at frequent intervals. Disadvantages of satellite remote sensing include the inability to obtain data through cloud cover (with the exception of microwave sensors), the need to correct for extraneous atmospheric effects that can complicate spatial and temporal extrapolation, and the need for long-standing financial commitment to operate and maintain satellites and ground data reception and processing systems. Finally, confidence in data and trends using satellite remote sensing is related to the level of maturity and length of historical data streams collected by satellites. For example, datasets and corresponding products and technologies used to monitor vegetation health and snow extent have longer records than those used to monitor evapotranspiration (ET) and soil moisture.

Precipitation and Snow Cover Products

Precipitation and snow cover products provide estimates of precipitation amount, timing, location, and the extent of snow cover. Approaches to monitoring precipitation and snow using satellite based observations are inherently different. Precipitation is detected while it is still carried in the atmosphere (microwave and thermal infrared), and snow properties are detected by monitoring conditions at the ground surface (visible, infrared, and microwave). Snow and ice are highly reflective surfaces and have distinct signals in the visible, infrared, and microwave portions of the EMS, and thus these wavelengths are well-suited to monitoring snow characteristics (Figure 1a). Observed and modeled snowpack characteristics derived using remote sensing observations include snow water equivalent (SWE), snow depth, surface and profile snowpack temperatures, snowmelt, surface and blowing snow sublimation, and snow-surface energy exchanges.

Remote sensing measurements of precipitation are indirect and they rely on relating either thermal infrared cloud top temperatures and/or microwave scattering to rain rates using empirical methods. Thermal infrared images are acquired every 15-30 minutes by geostationary satellites, while microwave images are acquired every few hours by polar orbiting satellites. Though acquired less frequently microwave observations are imperically superior since scattering is a direct response to the presence of raindrops in the atmosphere. Precipitation may or may not be occurring below cold clouds, so thermal infrared estimates of cloud top temperatures are less reliable than microwave observations.

Precipitation Analysis, daily 4 km, 24 hr totals for the continental U.S. from the NWS

The NWS River Forecast Centers (RFCs) integrate precipitation station observations with the NWS Surveillance Doppler Radar to generate daily 4x4 km gridded precipitation estimates for the U.S and Puerto Rico. These gridded rainfall estimates integrate satellite observations where radar coverage is missing. Visualization options allow users to generate products for different time frames (i.e. precipitation estimates in the last 7, 30, or 60 days), zoom into desired RFC region or state, and overlay major river systems and RFC, state, city, and county boundaries.

Product URL:

Precipitation analysis: http://water.weather.gov/

Contact: Victor Murphy, NWS, Victor.Murphy@noaa.gov

Snow Data Assimilation System (SNODAS) from NOAA National Operational Hydrologic Remote Sensing Center (NOHRSC)

NOHRSC integrates satellite remote sensing of snow cover, airborne data, and in situ (snow depth and water equivalent) measurements into the SNODAS model. SNODAS integrates all snowpack observations (e.g. SWE, snowpack temperature,

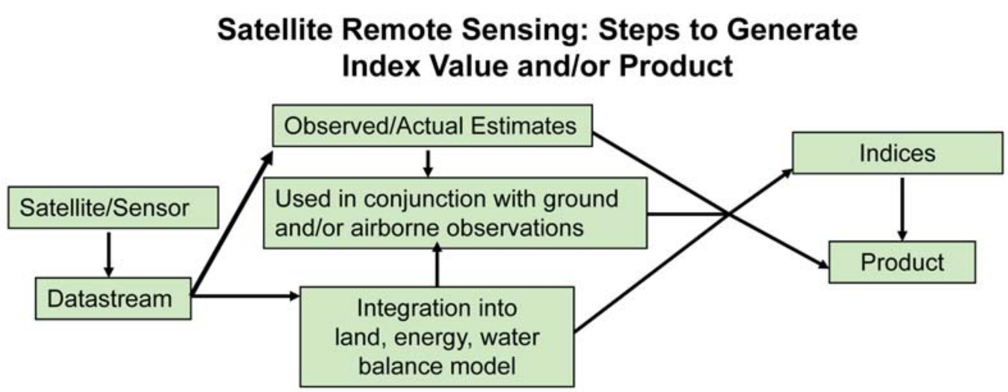

Figure 1b: Schematic depicting steps to generate index value and/or product using remote sensing data. Observations collected from one or multiple satellites or sensors are processed into datastreams. Datastreams are used to derive actual conditions, integrated in a land, energy, or water balance model or combined with ground and/or airborne observations to generate an index value and/or product for use in drought management.

snowmelt, etc) with corresponding topographic observations (e.g. elevation, vegetation cover) and atmospheric observations (e.g. air temperature) for a given area. SNODAS then models surrounding snowpack conditions based on what is known about the snowpack, topography, and atmospheric conditions for the observed area. Multiple snowpack products are extrapolated from SNODAS, including daily 1-km grids of snowpack characteristics (e.g. SWE, snow depth, surface and profile snowpack temperatures, snowmelt, and surface and blowing snow sublimation; Figure 1c).

Product URLs:

SNODAS products are housed at the National Snow and Ice Data Center, URL: http://nsidc.org/data/docs/noaa/g02158_snodas_snow_cover_model/index.html

The National Snow Analysis (NSA) website (www.nohrsc.noaa.gov/nsa) at NOHRSC provides maps and text descriptions of multiple snowpack characteristics based on SNODAS. NSA options include customization features, allowing users to tailor products by region, parameter observed (e.g., SWE, snow depth, snowpack temperature), with corresponding topographic observations (e.g. elevation, vegetation cover) and atmospheric observations (e.g. air temperature) for a given area.

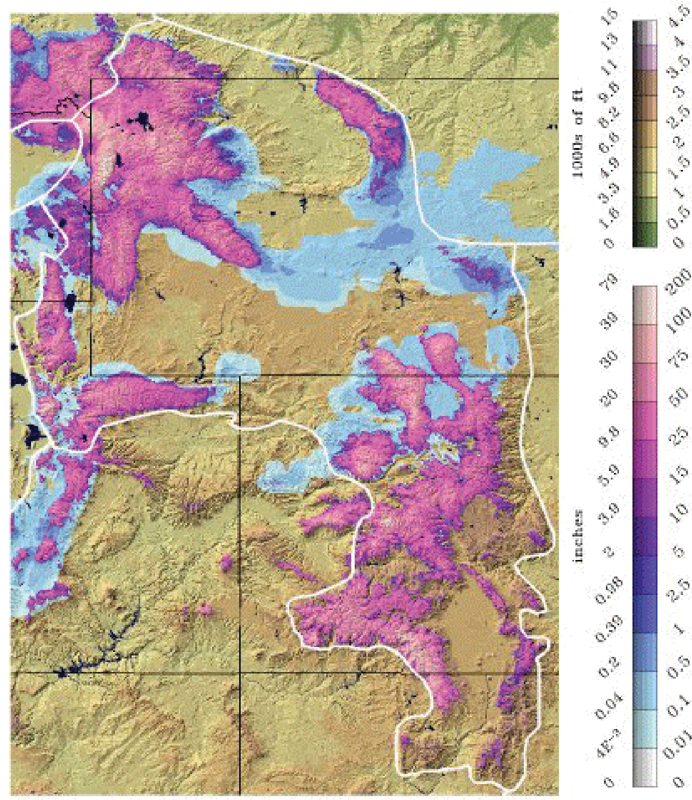

Figure 1c: SWE estimates (inches) for the Central Rockies on May 1, 2008. The National Operational Hydrologic Remote Sensing Center's (NOHRSC) SNODAS model integrates daily ground based, airborne, and satellite snow observations to generate estimates of snowpack characteristics for the continental U.S.. The National Snow Analysis (NSA) products (http://www.nohrsc.noaa.gov/nsa/) extrapolate estimates for individual snowpack characteristics based on SNODAS output and allow users to customize products by parameter, region, or time frame.

Evapotranspiration (ET) and Soil Moisture Products

ET is the combination of transpiration of water into the atmosphere by plants and direct evaporation from the soil surface. ET rates are depressed during drought due to reduced availability of moisture. Low ET rates are associated with higher than normal land surface temperatures. Remote sensing of land-surface temperature (LST) derived from thermal-infrared (TIR) data can be used to indirectly monitor changes in ET and detect drought conditions.

Estimates of moisture content of the upper soil layer using satellite remote sensing are made from direct processing of microwave image data as well as by land data assimilation models. This is especially valuable in areas that lack sufficient ground-based soil moisture observations. Passive microwave data are sensitive to changes in soil moisture in the first few centimeters of the soil column, while active microwave systems are most sensitive to changes in wetness at the surface itself. In both instances results are optimal in landscapes with sparse vegetative cover because bare ground provides the clearest signal for measuring soil moisture, while the water content of plant leaves can obscure that signal. As a result, direct remote sensing of soil moisture is better suited for arid landscapes such as the western U.S.

Evaporative Stress Index (ESI) using ALEXI surface energy balance model from the U.S. Department of Agriculture (USDA)

ESI equals 1 minus the ratio of actual ET to potential ET, and values range from 0 (ample moisture) to 1 (stressed). Data for ESI is generated by synthesizing land surface temperature (LST) observations using thermal-infrared band data with surface energy balance model (ALEXI). ESI values show good spatiotemporal correspondence with other precipitation based drought indices, but at a higher spatial resolution. Hourly and daily maps of ESI will be available on the web in fall 2008 for continental U.S. at the 5-10 km spatial scale.

Contact: Martha Anderson, USDA, martha.anderson@ars.usda.gov

ET Mapping from Riverside Technology (RTI)

RTI produces maps of ET using thermal observations from two satellites (MODIS and Landsat). These are integrated into a surface energy balance model **(**METRIC). Customized ET maps using METRIC range from 120 m to 1 km spatial scale with 4 to 16 day composites. ET maps are used to develop multi-temporal and spatial scale products, which are integrated into water management decision support systems, such as the South Platte Decision Support System (SPDSS) in Colorado. This should improve forecasts of potential water demands for reservoir operations irrigation scheduling, and well augmentation.

Product URL:

ET Mapping: http://snake.riverside.com/waterdss/.
Contact: Graeme Aggett, Riverside Technology, gra@riverside.com

Vegetation Health (Crops, Rangeland, Forest) Products

Vegetation products are used for monitoring cropland, rangeland, and forest health for evaluating agricultural production, fire danger, and land cover change. Vegetation stress is caused by precipitation and soil moisture deficit and this leads to a decrease in plant photosynthetic capacity and moisture content. Thus, information about vegetation stress acquired by remote sensing can help monitor agricultural and rangeland drought.

Plant canopies under stress are drier and contain less chlorophyll than leafy, green, robust canopies. Plant photosynthetic capacity and moisture content can be detected and quantified using visible and infrared satellite observations. Satellite observations are aggregated to produce vegetation indices or products for multiple vegetation stress indicators, including leaf area index (total leaf surface of vegetation divided per unit area of ground), plant growth (vigor), vegetation cover, and biomass production (kg of plant matter/square meter).Vegetation indices are analyzed to target or highlight anomalous departures from an expected "normal" level of plant health. Infrared and visible satellite observations are integrated into a number of vegetation or drought indices, including, but not limited to, the Normalized Difference Vegetation Index (NDVI), the Vegetation Health Index (VHI), and the Vegetation Drought Response Index (VegDRI), a proxy for the Palmer Drought Severity Index (PDSI). Products range from 250-m to16-km spatial resolution with 7 to 16 day temporal frequency.

Normalized Difference Vegetation Index (NDVI) products from NOAA, NASA, and U.S. Geological Survey (USGS)

NDVI is an indicator of vegetation canopy photosynthesis, and it has been widely used to monitor vegetation at regional and global scales (1km^2-16 km^2). NDVI correlates well with Standardized Precipitation Index (SPI) during the growing season in the central Great Plains and has strongest correlation in areas with low soil water holding capacity. NDVI is a numerical transform of visible red (absorbed by chlorophyll) and near infrared (reflected by the spongy mesophyll layer of leaves) response in spectral bands that are sensitive to changes in plant growth. NDVI typically ranges from 0.1 up to 0.8, with higher values associated with greater density and greenness of the plant canopy. Surrounding soil and rock values are close to zero.

Product URLs:

United States/1 km NDVI from AVHRR satellite dataset: http://ivm.cr.usgs.gov/viewer/viewer.htm (for recent maps) and http://edcsns17.cr.usgs.gov/Earth Explorer/ (to order 1 km AVHRR data products).
Contact: Jeffrey Eidenshink, USGS, jeidenshink@usgs.gov

United States/250 m-500 m-1 km NDVI from NASA: MODIS satellite dataset: ftp://elpdl02.cr.usgs.gov/eMODIS/ (for historical and expedited data).
Contact: Calli Jenkerson, ADNET, contractor for USGS, jenkerson@usgs.gov

Global/4 km AVHRR NDVI and Vegetation Health Indices: http://www.orbit.nesdis.noaa.gov/smcd/emb/vci/VH/index.html(for historical and current maps).
Contact: Felix Kogan, NOAA, felix.kogan@noaa.gov

VegDRI produced by the National Drought Mitigation Center (NDMC) and the USGS

The Vegetation Drought Response Index (VegDRI) is a hybrid drought indicator, integrating satellite remote sensing and surface observations to characterize the intensity and spatial pattern of drought-induced vegetation stress (Figure 1d). VegDRI generates 1 km resolution maps by integrating two satellite-based observations (percent average seasonal greenness[1] and start of season anomaly[2], two climate-based indices: PDSI and SPI, and five

[1]Percent average season greenness is the percent of green vegetation for a given period from the start of the growing season in comparison to historic average.
[2]Start of season anomaly is the difference in the date when photosynthetic production surpasses base or winter photosynthetic production as compared to a historical normal, typically expressed in terms of an early, average, or late start of growing season.

biophysical characteristics) land cover type, soil available water capacity, ecological setting, percent irrigated agriculture, and elevation. VegDRI is available for 22 states in the central and western U.S. and will expand across the eastern U.S. in 2009.

Product URL:

VegDRI http://www.drought.unl.edu/vegdri/VegDRI_Main.htm. Contact: Brain Wardlow, NDMC, bwardlow2@unlnotes.unl.edu and Jesslyn Brown, USGS, jfbrown@usgs.gov

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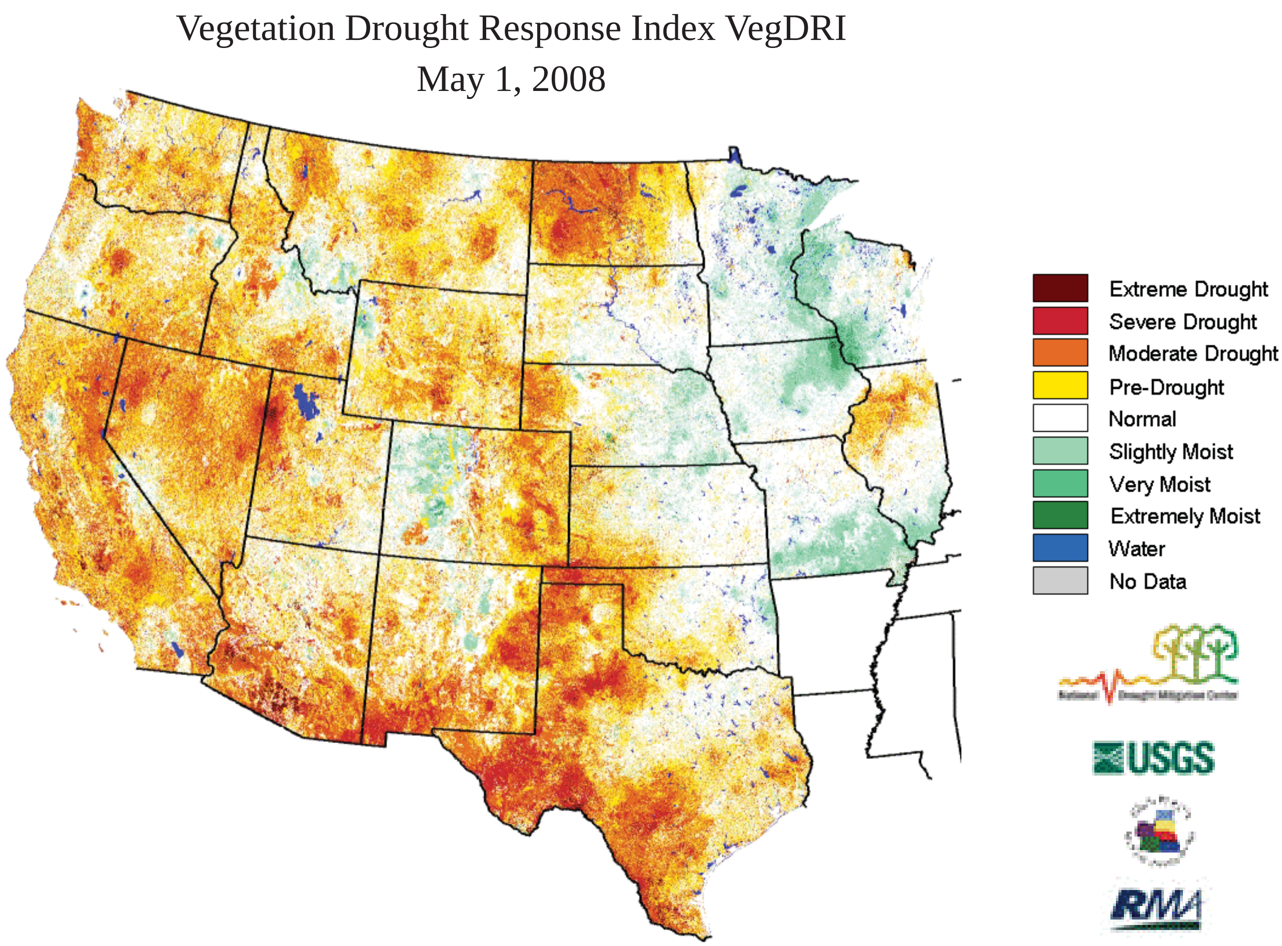

Figure 1d. The VegDRI calculations integrate satellite-based observations of vegetation conditions, climate data, and other biophysical information such as land cover/land use type, soil characteristics, and ecological setting. VegDRI maps have with a 1-km^2 spatial resolution and are produced every two weeks. The coverage of VegDRI will expand across the eastern U.S. in May 2009.

On the Web

-For information on NIDIS, including data resources, visit: www.drought.gov.

-Remote sensing product explanations including extended abstracts, workshop presentations, and other information are currently available at: http://wwa.colorado.edu/current_projects/nidis_remote_sensing_workshop.html.