1) Project Information

A GOES Thermal-Based Drought Early Warning Index for NIDIS
NA09OAR4310179

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Collaborator: Jason Otkin, SSEC, U-Wisconsin

Third Progress Report for the period of 1 June 2011 – 31 May 2012

2) Results and Accomplishments

The objective of this project was to develop a suite of satellite-based evapotranspiration (ET) and related soil moisture and drought products over the continental U.S. (CONUS) and North America in direct support of the NCEP/CPC North American Drought Briefing (NADB) and the National Integrated Drought Information System (NIDIS). Products are delivered in near real-time directly to users Mo (NCEP/CPC) and Svoboda (National Drought Mitigation Center; NDMC) and will be distributed publically through the NIDIS U.S. Drought Portal. The remote sensing products are generated with a regional-scale Atmosphere-Land Exchange Inverse (ALEXI) model, which diagnoses the surface energy balance using a time-differential land-surface temperature (LST) rise signal derived from GOES thermal infrared (TIR) imagery. The ALEXI-based Evaporative Stress Index (ESI), representing standardized anomalies in the ratio of actual to potential ET (f_{PET}), shows good spatiotemporal correspondence with standard precipitation-based drought indices.

At present, realtime ALEXI processing is conducted at NOAA-NESDIS, then output is pushed to USDA-ARS for final ESI production and web dissemination. We anticipate consolidating all steps at NOAA-NESDIS when the project is completed.

In Year 3 of this project, the primary accomplishments were to a) automate realtime data production with the ALEXI CONUS processing infrastructure; b) commence realtime delivery to NCEP/CPC for use in the NADB; c) assess ESI performance in comparison with crop condition and soil moisture datasets provided by the National Agricultural Statistics Service (NASS), with special attention to identification of flash drought signals; d) evaluate an ALEXI-derived TIR soil moisture indicator in comparison with microwave retrievals and hydrologic model output from the Land Data Assimilation System (LDAS); e) generate a data archive with a second ALEXI domain over North America (NA); and f) refine the web interface for data distribution and visualization in response to user feedback from CPC and NDMC.

Realtime generation and delivery of ALEXI products

ALEXI over the CONUS domain uses LST data from the GOES sounder and meteorological inputs from the North American Regional Reanalysis (NARR). The following tasks were accomplished during YR3:

- Completed development of automated routines to run the ALEXI CONUS domain in real-time. ALEXI executes at NOAA-NESDIS at 6AM each day, processing results from the preceding day.
- Developed automated routines to ingest and mosaic new MODIS Leaf Area Index (LAI) composites in real-time, and interpolate to the ALEXI CONUS domain.
- Developed routines to temporally project real-time MODIS LAI composites forward in time to address data latency issues (e.g., MODIS LAI composites are generated with a 10 to 17 day lag).
- Developed strategy for addressing NARR production latency (typically 4 days), using RUC analyses (and more recently Rapid Refresh (RAP) datasets) to drive realtime ALEXI runs, then reprocessing retrospectively as NARR becomes available
- Reprocessed and archived the ALEXI climatology (2000 to current).
- Developed routines to automatically "push" ALEXI output to a NOAA FTP server. A cron job at USDA picks up the data daily, computes anomalies, and processes output for web distribution.
- Solicited and incorporated feedback from users Svoboda and Mo re. website improvements.

Note that differences between RUC/RAP and NARR lead at some times to significant anomalies in the realtime ESI. Improvement in NARR production timescale (1 day lag) would greatly benefit timeliness of drought information from both ESI and NLDAS, and would simplify the ESI production stream.

Integration of ESI products into the North American Drought Briefing

The ESI concept was introduced by Co-I K. Mo in the NADB in April, and realtime ESI was included in the May briefing. Also in May, Co-I Svoboda introduced the ESI to the USDM listerver, with positive response.

Evaluation of ESI performance in comparison with NASS crop condition and soil moisture data

The USDA National Agricultural Statistics Service (NASS) generates weekly reports on soil moisture (SM) and crop condition (CC) at the county level based on data supplied by observers on the ground. While the data are qualitative

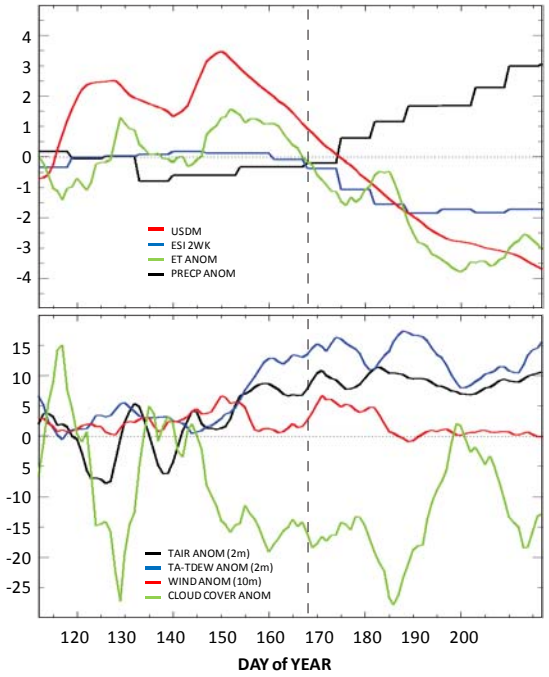

Figure 1: Analysis of flash drought indicators, OK 2011.

(categorical), they provide a unique spatially dense validation dataset for assessing spatiotemporal impacts of drought, particularly affects on vegetation heath. Archived monthly CC/SM data provided by NASS at the county scale for 2000-2008 have been mapped and preliminary comparisons show good spatiotemporal correlation with ESI products.

Under funding through this project, collaborator Otkin is investigating ESI utility for identifying timing (early warning) and severity of crop stress conditions during the growing season. The focus is on a series of "flash drought" events that occurred in the past decade in the Cornbelt and Great Plains, where rapid stress onset was induced by persistently hot, dry and windy conditions. The expected signature is a period of anomalously high ET followed by steady degradation into negative anomalies (Fig 1). Because flash drought is more directly related to rate of consumptive water use rather than precipitation deficits, an ET-based drought indicator like ESI is uniquely well-suited to identifying such events.

Assessment of an ALEXI-derived TIR soil moisture indicator

- A series of analyses were performed to study relationships between ALEXI f_{PET} and SM products from a passive microwave (MW) retrieval (AMSR-E) and a land surface model (Noah) over the contiguous US.
- An analysis of spatial anomaly correlations on a seasonal time scale showed that seasonal composites were spatially consistent between the three datasets, except for the degradation in AMSR-E anomaly detection over moderate to dense vegetation, mainly occurring over the eastern half of the CONUS.
- The ALEXI SM maps showed better spatial correspondence with Noah SM than did the MW SM retrievals over the period studied here (2003-2008).
- A temporal correlation analysis showed that Noah and AMSR-E time-series were better correlated in sparsely vegetated ($f_c < 0.5$) regions (western and central CONUS), while ALEXI was better correlated with the Noah reference under moderate to dense vegetation ($f_c > 0.5$), primarily in eastern CONUS.
- A Triple Collocation (TC) study over CONUS, evaluating relative errors between Noah, ALEXI, and AMSR-E SM estimates yielded similar results (Yilmaz, et al., 2012).
- An analogous TC study over the Nile River Basin (using ALEXI results generated from Meteosat LST) confirmed ALEXI's added value in SM retrieval for densely vegetated areas in the Sahel and Ethiopian Highlands (Anderson, et al., 2012).
- ALEXI SM was compared to observations collected at 23 SM sites in Spain and France, along with AMSR-E and ASCAT products. Of these ALEXI showed the best overall agreement with in situ observations (Fig 2).

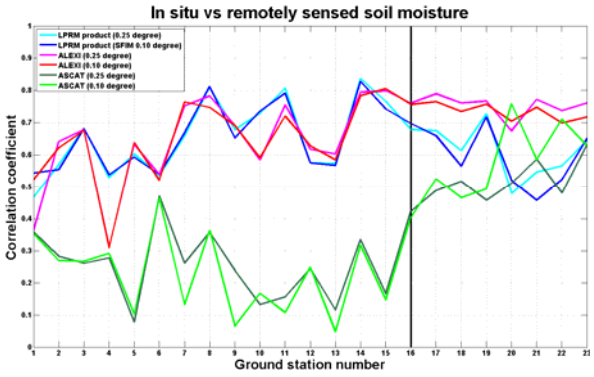

Figure 2: Temporal correlation between SM indicators from ALEXI, AMSR-E (LPRM) and ASCAT and in situ measurements at 23 SM sites in Spain (stations 1-15) and France (16-23) (Parniussa et al., 2012)

Development of ESI products for the North American domain

The North American (NA) domain uses LST data from GSIP and meteorological inputs from NARR.

- Developed scripts to retrieve and archive GSIP LST and insolation in realtime.
- Reprocessed and archived the ALEXI NA domain climatology (2009 to current).
- Generated ESI products for 2009-present. Despite short baseline for determining normals (3 years), there is good qualitative agreement with drought events recorded in the NA Drought Monitor (see Fig 3). Agreement will improve as the baseline is extended.

Funds will be sought to extend the GSIP dataset back to 2000, to generate NA ESI record comparable to CONUS.

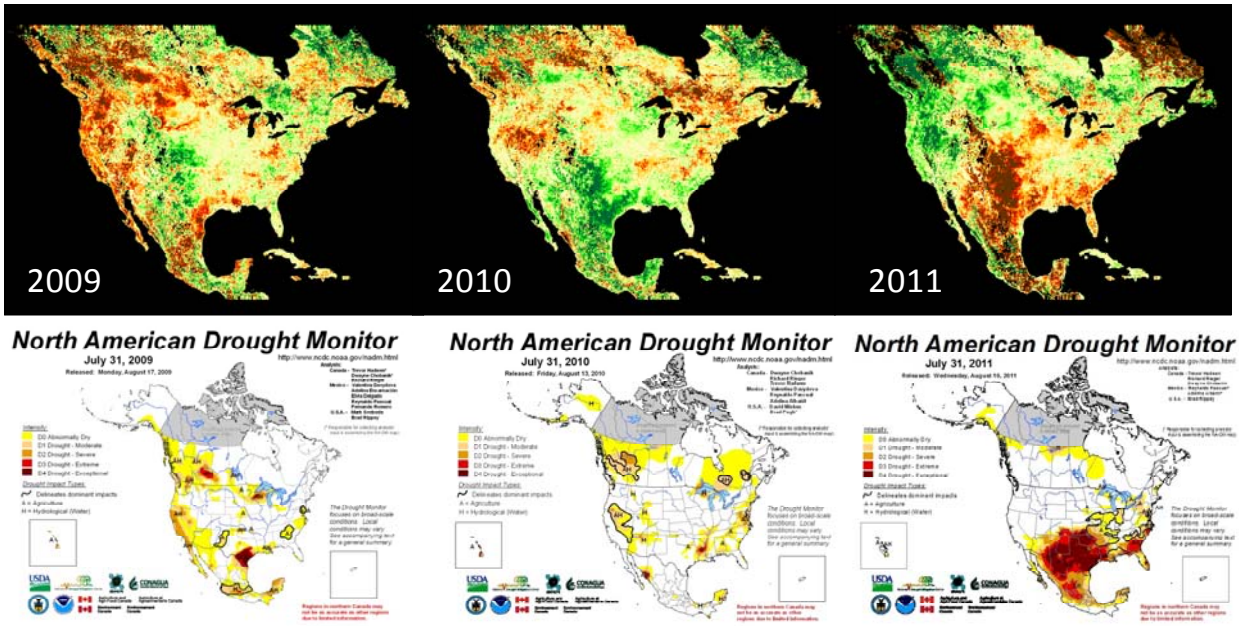

Figure 3: Comparison of preliminary ESI (July) over NA domain (3 year baseline only) with drought events recorded in the North American Drought Monitor. In top panel, red indicates negative ET/PET anomalies.

Refinement of the ESI website

A website has been developed at HRSL to visualize ESI products side-by-side in comparison with USDM drought classifications and other drought indicators, both in real-time and retrospectively. End-user feedback and associated web page modifications are being recorded using a SharePoint collaboration web page, which can be accessed by the PI and web developers. Feedback provided by users Svoboda and Mo regarding access speed, annotation, and documentation has been used to improve web delivery. The site is currently password protected during a beta testing period involving end-users at NDMC and CPC. We anticipate opening the site to public access within a few months. We will work with NCDC to implement a link to this website within the US Drought Portal at drought.gov.

3) Highlights of Accomplishments

- Developed realtime ALEXI CONUS ESI processing and data delivery infrastructure.
- ESI products introduced into NADB and USDM listserv.
- Developed archive of ALEXI ESI products at 12-km resolution over North America (2009-present).
- Evaluated ALEXI ESI in comparison with NASS SM/CC datasets, and conducting assessment of flash drought signals.
- Evaluated ALEXI SM products in comparison with AMSR-E, Noah, and in situ datasets over the US, and in Europe and Africa.
- Refined web site for CONUS ESI data visualization and dissemination – public release planned for Summer 2012. NA ESI will be added when available.

4) Publications

Wardlow, B. D., M. C. Anderson, and J. P. Verdin (Eds.) (2012), *Remote sensing of drought - innovative monitoring approaches*, 422 pp., CRC Press/Taylor and Francis, Boca Raton, FL.

Hayes, M. J., M. D. Svoboda, B. D. Wardlow, M. C. Anderson, and F. N. Kogan (2012), Drought monitoring - Historical and current perspectives, in *Remote Sensing of Drought*, edited by B. D. Wardlow, M. C. Anderson and J. P. Verdin, pp. 1-19, CRC Press/Taylor and Francis, Boca Raton, FL.

Anderson, M. C., C. R. Hain, B. Wardlow, A. Pimstein, J. R. Mecikalski, and W. P. Kustas (2012), A thermal-based Evaporative Stress Index for monitoring surface moisture depletion, in *Remote Sensing for Drought: Innovative Monitoring Approaches*, edited by B. Wardlow and M. C. Anderson, pp. 145-167, CRC Press/Taylor & Francis Boca Raton, FL.

Wardlow, B. D., M. C. Anderson, J. Sheffield, B. D. Doorn, J. P. Verdin, X. Zhan, and M. Rodell (2012), Future opportunities and challenges in remote sensing of drought, in *Remote Sensing for Drought: Innovative Monitoring Approaches*, edited by C. P. T. a. Francis, pp. 389-409, Boca Raton, FL.

Anderson, W. B., B. F. Zaitchik, C. R. Hain, M. C. Anderson, M. T. Yilmaz, J. R. Mecikalski, and L. Schultz (2012), Towards an integrated soil moisture drought monitor for East Africa, *Hydrol. Earth Syst. Sci.*

Yilmaz, M. T., W. T. Crow, M. C. Anderson, and C. R. Hain (2012), An objective methodology for merging satellite and model-based soil moisture products, *Water Resources Res.*

Hain, C. R., W. T. Crow, M. C. Anderson, and J. R. Mecikalski (2012), An EnKF dual assimilation of thermal-infrared and microwave satellite observations of soil moisture into the Noah land surface model, *Water Resources Res.*

5) PI Contact Information

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6) Budget for Coming Year

A one-year extension (through June 2013) was requested and approved for funds remaining at USDA. These funds are supporting collaborator J. Otkin in completing the flash drought study.