A SATELLITE-BASED DROUGHT PRODUCT USING THERMAL REMOTE SENSING OF EVAPOTRANSPIRATION

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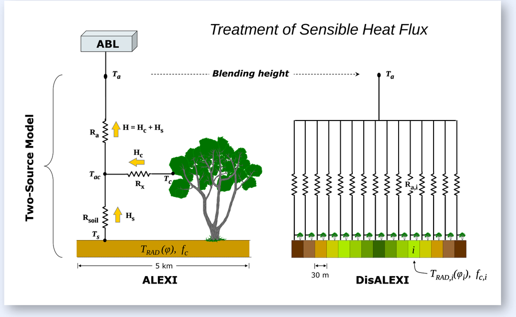
Abstract

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. This paper describes a satellite-based methodology for routine drought monitoring using 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.

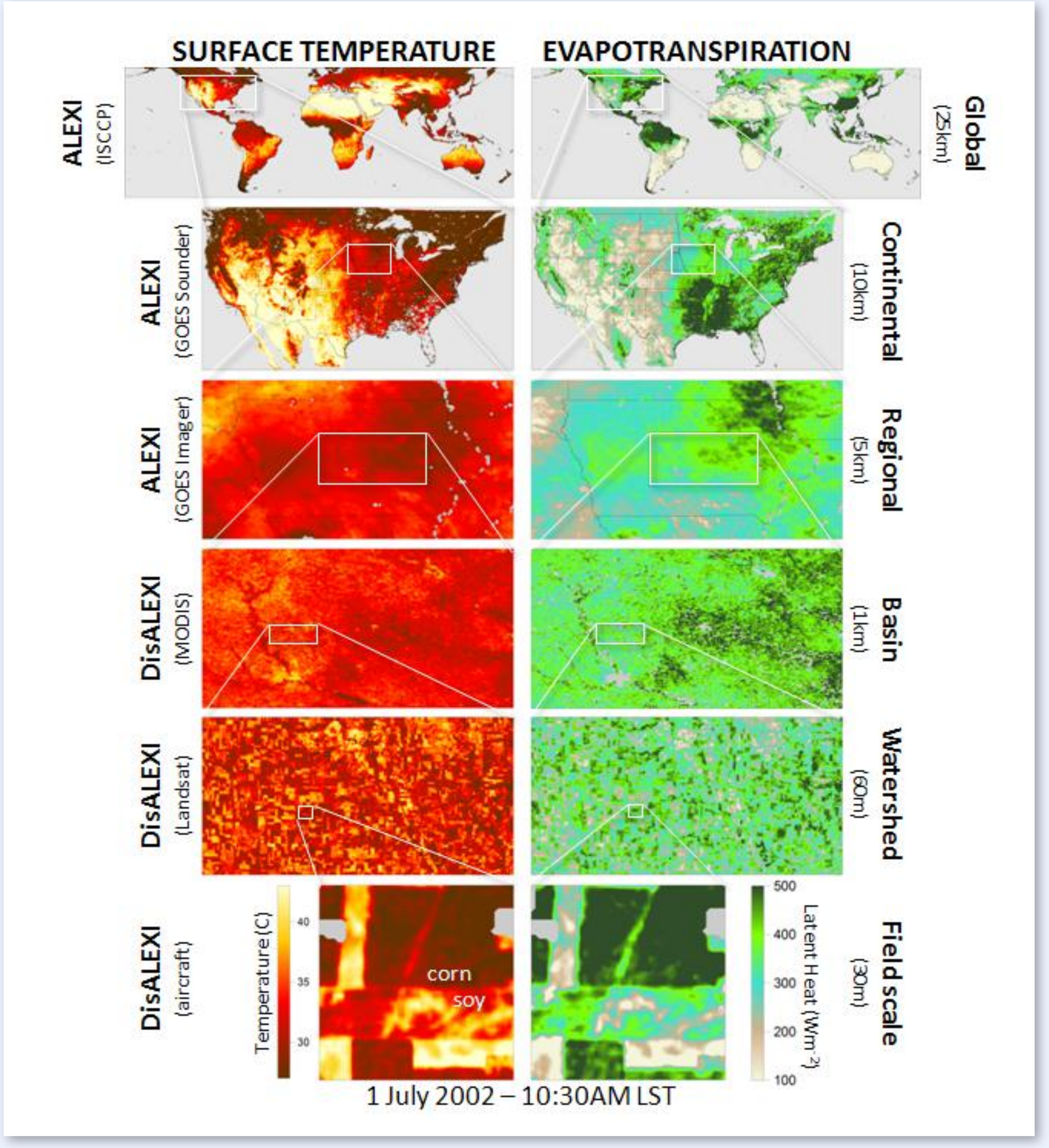
The Atmosphere-Land Exchange Inverse (ALEXI) model is used to map land-surface water and energy fluxes across the continental U.S. at 100m to 10km resolution using TIR imagery from polar orbiting and geostationary satellites. A derived Evaporative Stress Index (ESI), describing standardized anomalies in the ET/PET ratio, 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 standard drought indices based on rainfall or soil water balance. Being an independent means for assessing drought conditions, the ESI has 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.

Mapping ET with GOES

The Atmosphere-Land Exchange Inverse (ALEXI) model (Anderson et al., 2007a,b) was designed to minimize the need for ancillary meteorological data while maintaining a physically realistic representation of land-atmosphere exchange over a range in vegetation cover conditions.



A two-source (soil+vegetation) energy balance model is applied in a time differential mode, coupled with an atmospheric boundary layer (ABL) model to internally simulate land-atmosphere feedback on near-surface air temperature and surface fluxes. This reduces sensitivity to LST retrieval errors.



In combination with a flux disaggregation algorithm, DisALEXI (Norman 2003), the ALEXI modeling system creates self-consistent flux maps from field to global scales.

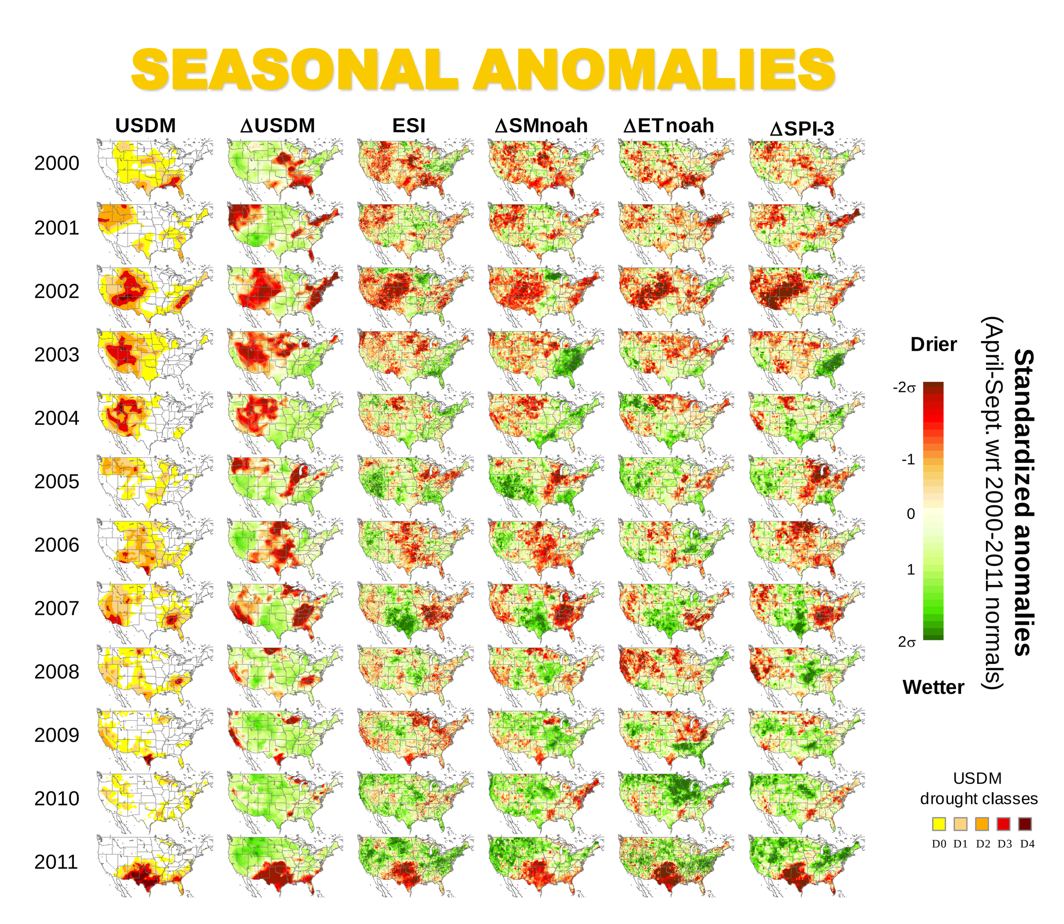
Evaporative Stress Index (ESI)

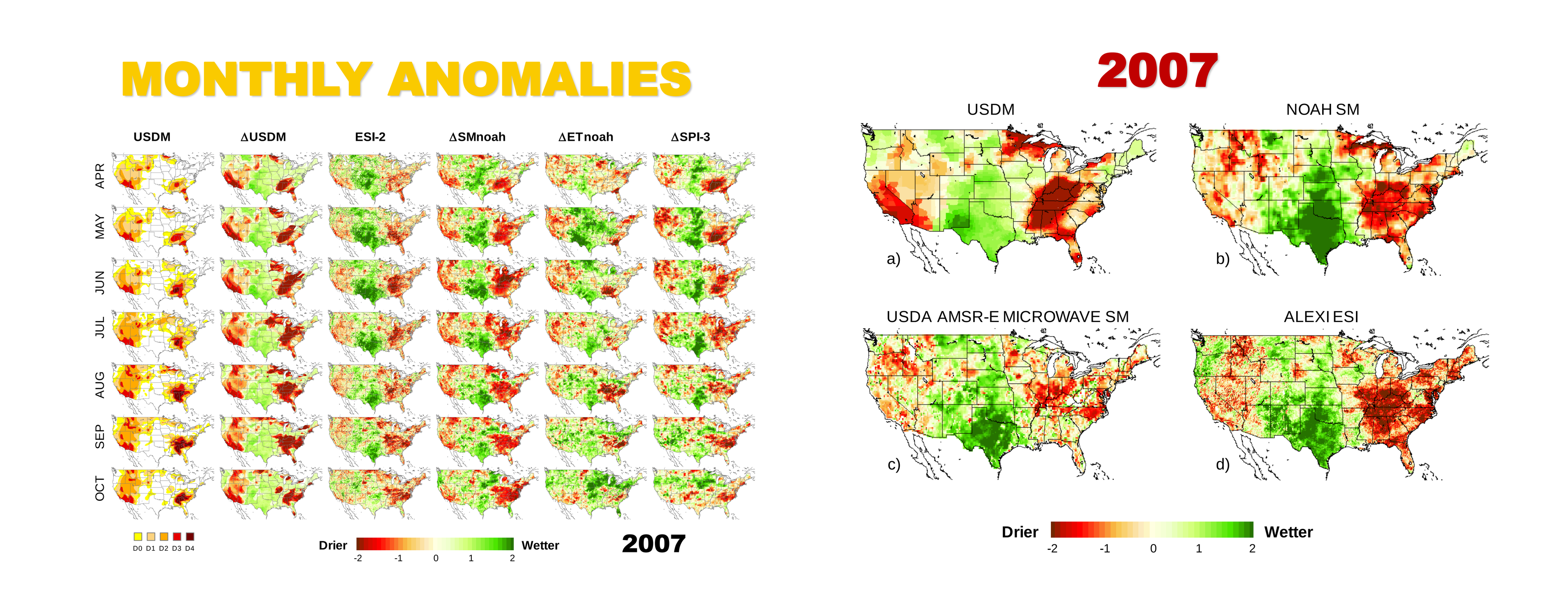
Using hourly skin temperature and insolation data from GOES East and West, along with Leaf Area Index and albedo from MODIS, the ALEXI algorithm has been executed over a 10-km resolution grid covering the continental U.S. for 2000-present. ALEXI climatologies can be extended back to 1979 using GOES imagery archived at NCDC through the ISCCP B1 Data Rescue project.

"Moisture stress" is often quantified in terms of the reduction of ET from the potential rate (PET) expected under non-moisture limiting conditions.

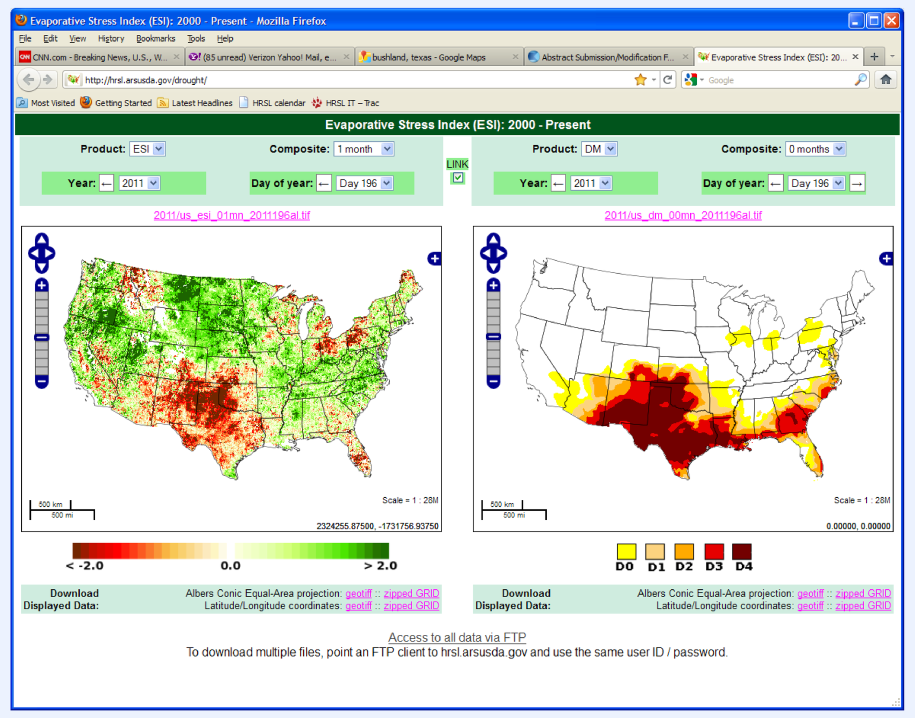
These plots shows seasonal (April-Sept) composites of an **Evaporative Stress Index (ESI), given by standardized anomalies in the ratio ET/PET**, where ET is the actual evapotranspiration determined by ALEXI. Also shown are anomalies in soil moisture and ET outputs from the Noah land-surface model and the 3-month Standardized Precipitation Index (SPI-3), along with anomalies in drought classifications in the U.S. Drought Monitor (USDM). All anomalies are computed with respect to 12-year normal conditions (2000-2011).

Because precipitation is not used as an input to ALEXI, the ESI provides an independent assessment of drought conditions. The ESI reflects anomalous water use, and incorporates non-precipitation related moisture inputs to the system (e.g., irrigation, shallow water table extraction).





Monthly ESI comparisons for 2007 show good agreement with evolving drought patterns. The TIR inputs to ALEXI detect drought conditions even under the dense forest cover in the southeast where AMSR-E microwave soil moisture retrievals lose sensitivity.

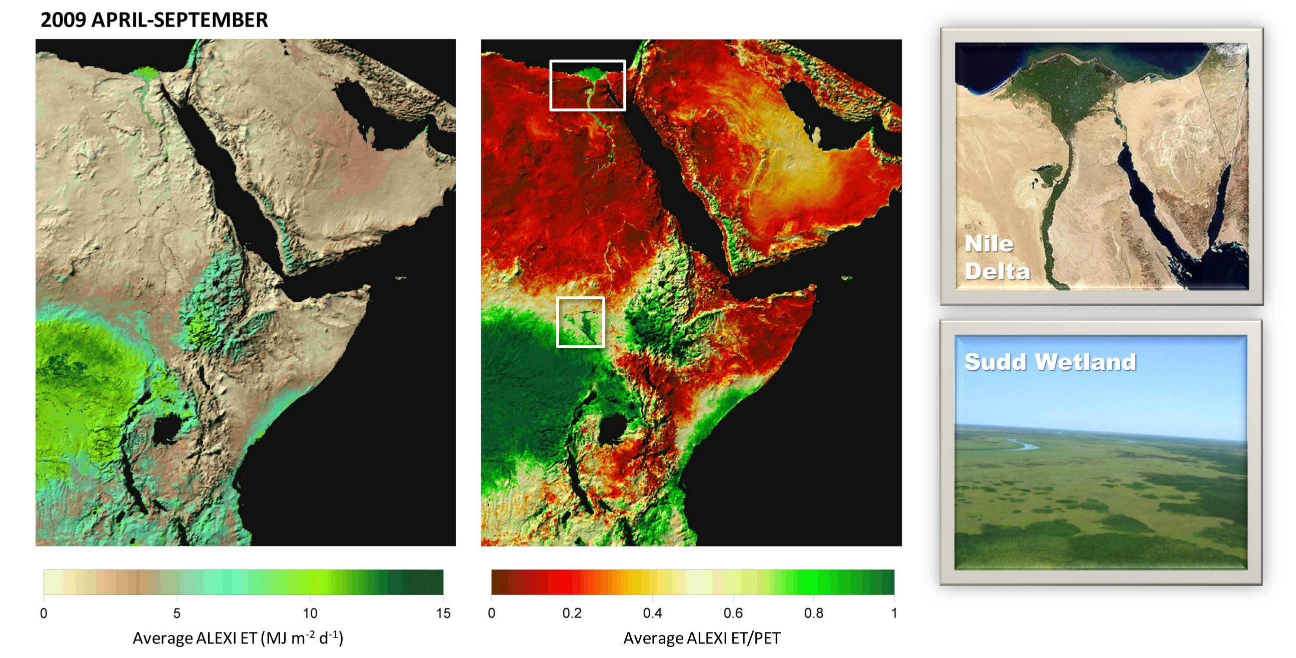


Through a grant from the NOAA Climate Dynamics and Experimental Prediction program, a suite of ALEXI drought products are being developed on a 1/8° grid over the contiguous U.S., Canada, and Mexico, with the intent of transition to operations within NESDIS/NCEP in FY12. These products will be disseminated to the North American drought community through the National Integrated Drought Information System (NIDIS) web portal. The CONUS product is shown to the left.

Multiple independent drought indicators support the "convergence of evidence" approach used to develop the U.S. Drought Monitor.

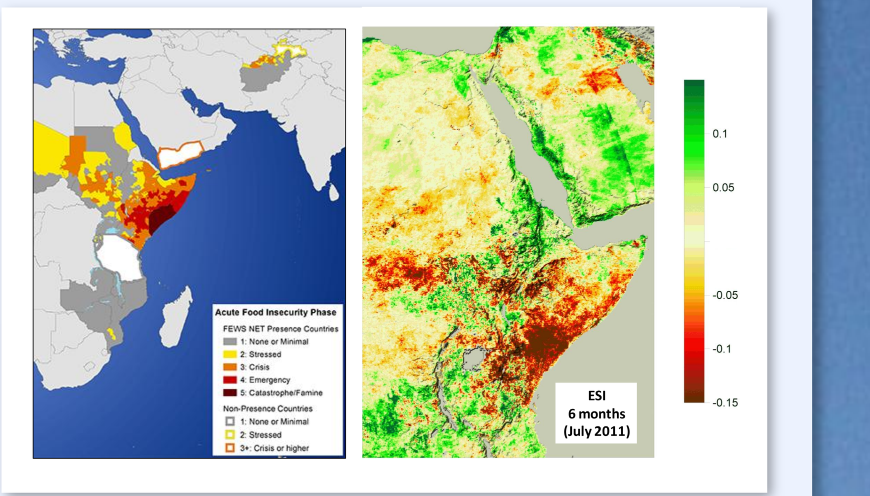
Mapping with Meteosat

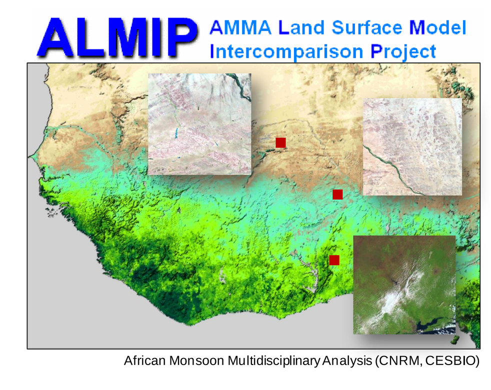
The ALEXI system has recently been ported to routine land-surface products derived from Meteosat Second Generation (MSG) geostationary satellite data (LSA SAF - landsaf.meteo.pt). This system is being used to map ET and drought over Europe, Africa and the Middle East.



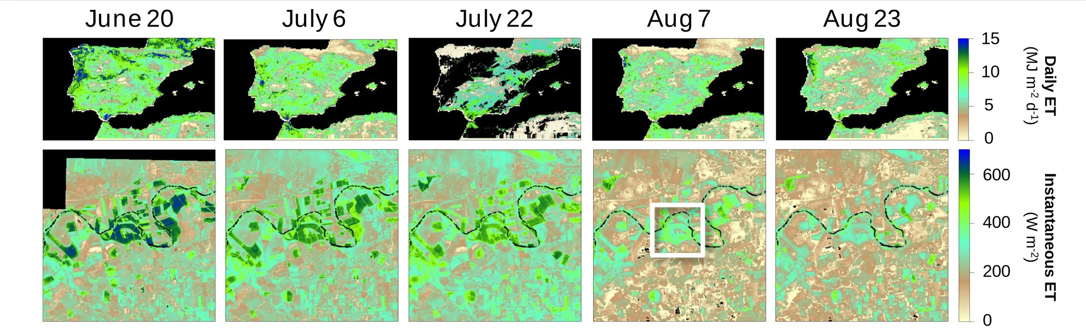
These maps provide diagnostic estimates of water loss over the irrigated Nile Delta and the Sudd Wetland in southern Soudan. These ET features are spatially unrelated to patterns in rainfall, and are not easily captured within prognostic modeling systems like Noah, which are based on water balance.

The 6-month ESI composite over the Horn of Africa (right) shows strong ET deficits in the region of hardest hit in Somalia by the 2011 famine.





ALEXI ET time-series maps are also being used in the ALMIP model intercomparison over west Africa, studying impacts of moisture gradients on development of the African Monsoon (left).



Application of ALEXI/DisALEXI over an irrigated agricultural area along the Guadalquivir River in southern Spain during the 2009 growing season. White box indicates the 3-km MSG pixel size.

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