This article will demonstrate the utility of a thermal-based remote sensing technique for monitoring evapotranspiration (ET), vegetation health/stress, and soil moisture status at local to continental scales. The paper is intended for researchers in a broad range of scientific disciplines – from the biosciences, atmospheric sciences, and hydrology – and also for policy makers in environmental and water regulatory agencies.

Across the U.S. there are ever increasing and competing demands for freshwater resources for use in agriculture, ecosystems sustainability and urban development. Recent extended droughts in the Western and Southeastern U.S. have further exacerbated ongoing “water wars”. To facilitate wise water management, and to better identify and mitigate the impacts of drought, there is a critical need for robust, operational assessments of ET and water stress at the field, county, watershed, state and continental scales. Just as a thermometer is used to diagnose stress in the human body, land-surface temperature (LST) derived from thermal remote sensing is a valuable diagnostic of the surface moisture status – dry soil and stressed vegetation both lead to elevated LST.

Related Eos articles have focused on using remote sensing for estimating continental-scale carbon budgets [1] or determining representativeness of the tower-based carbon/water vapor AmeriFlux network [2]. A very simple and empirical thermal Vegetation Health Index is currently used in national drought assessments [3], but can provide false signals under certain energy constraints [4].

In this article we will present a more robust and physically-based methodology for integrating thermal remote sensing from multiple satellite platforms to diagnose ET, vegetation stress, and soil moisture status at spatiotemporal resolutions relevant to management applications [5]. This multi-scale surface energy balance modeling system (Atmosphere-Land Exchange Inverse; ALEXI) has been validated under a range of climate and vegetation conditions, showing good agreement with ground-based flux and moisture observations. An associated flux disaggregation technique (DisALEXI) facilitates scale-appropriate comparisons between model and measurements and is critical for resolving moisture features at the management scale [5].

ALEXI is run daily over a 10km grid covering the contiguous US using thermal data from the GOES satellites, providing coarse-resolution ET/stress at hourly timesteps [6]. A derived Evaporative Stress Index shows good spatial correlation with antecedent precipitation, and is being assessed for utility in operational drought monitoring at the continental scale [7; Fig. 1]. High-resolution stress assessments using ~monthly Landsat thermal data (60-120m resolution) are essential for tying these coarse stress signatures to the observation and application scale, facilitating connections with activities occurring on the ground. For operational monitoring, MODIS, at 1km resolution and daily timesteps, effectively bridges the spatiotemporal gap between GOES and Landsat (Fig. 2).
This article will be timely in that NASA is currently considering eliminating high-resolution thermal imaging capabilities on future Landsat missions. The 100m scale is critical for resolving individual fields and waterways, and this move will effectively derail active water management programs in western states using Landsat imagery to monitor regional consumptive use (http://landsat.gsfc.nasa.gov/news/news-archive/soc_0011.html). It is important that the value of thermal remote sensing be brought to the attention of the scientific community at this time.

Figure 1: Anomalies in the ALEXI Evaporative Stress Index compared to anomalies in gridded precipitation from the Climate Prediction Center, both averaged over the growing season (April to September). The ALEXI model does not use precipitation as an input – moisture stress is diagnosed from GOES derived land-surface temperatures. While perfect agreement is not expected, the strong spatial correlations indicate that the thermal band does carry useful information about moisture status – even under the dense forest cover in the Eastern US where microwave soil moisture mapping techniques are unreliable.
Figure 2: Maps of evaporative stress over Southern Florida derived from GOES, MODIS and Landsat 7 thermal imagery for Feb 2003, showing stress in the agricultural area south of Lake Okeechobee and parts of Miami. Maps of this type can be used for monitoring the health of hydrologically sensitive ecosystems like the Florida Everglades.