STUDY OF WATER USE IN AGRICULTURAL LANDSCAPES AT HIGH SPATIOTEMPORAL RESULOTION

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ABSTRACT

A detailed spatially explicit evapotranspiration (ET) mapping at daily basis is of substantial benefit for agricultural water management. An integrated multi-sensor approach that combines the benefits of the high spatial resolution of Landsat and the high temporal resolution of MODIS and geostationary satellites to provide daily field-scale ET estimates is evaluated over two different agricultural landscapes. The ET data fusion methodology described here can provide detailed information about daily and seasonal water use patterns. This information can be of utility for irrigation managers at the scale of individual fields as well as for regional monitoring of water use toward allocation and conservation efforts.

Index Terms— Evapotranspiration, thermal infrared, data fusion, irrigation, mead, the central sand

1. INTRODUCTION

Accurate monitoring of water use over agricultural landscapes is essential in improving regional water management. In the past two decades, remote sensing algorithms based on surface energy balance have greatly advanced our ability to estimate of actual evapotranspiration (ET) [1-4]. The land-surface temperature derived from derived from thermal infrared (TIR) imagery plays a key role in the surface energy partitioning, which governs the land-surface water loss to the atmosphere [1, 2]. However, no single TIR satellite system currently operating is capable of capturing daily ET dynamics at field scales, given tradeoffs between spatial and temporal resolution inherent in satellite imaging systems [5]. An integrated multi-sensor approach that combines the benefits of the high spatial resolution (30 m) of Landsat and the high temporal resolution (daily) of MODIS and geostationary satellites to provide daily field-scale ET estimates will be of substantial benefit for agricultural water management [6].

In this paper we apply an ET fusion model at two test sites in the US. Midwest: a typical corn/soybean rotation site, and a region where intensive groundwater has led to a significant impacts on local water tables and streamflow. The goal of this work is to evaluate the performance of this ET data fusion approach at different agricultural sites as well as to investigate how crop water stress and spatial patterns in evaporative fluxes corresponds to a wide combination of management practices and meteorological conditions to provide better water management practices.

2. METHODOLOGY

The ET fusion procedure used in this study combines multi-scale surface energy balance evaluations (ALEXI) and a data fusion methodology (STARFM). Remotely sensed land surface temperature derived from various thermal imaging sensors over a range of different spatial and temporal resolutions drive a multi-scale surface energy balance algorithm [7]. To support regional applications, ALEXI couples The Two-Source Energy Balance (TSEB) model [4] with an atmospheric boundary layer (ABL) model to simulate changes in near surface air temperature (Ta) that are consistent with TSEB modeled surface fluxes[2,3]. For this study, GOES observations are used to determine surface radiometric temperature at a 4-km spatial resolution. To map flux distributions at higher spatial resolution than can be supported by geostationary satellite data, an ALEXI flux disaggregation scheme known as DisALEXI is implemented [8, 9]. This disaggregation approach uses higher resolution TIR imagery from sensors like Landsat, MODIS and even airborne sensors [7, 9] to spatially disaggregate the coarser resolution ALEXI flux estimates. The Spatial and Temporal Adaptive Reflectance Fusion Model (STARFM), developed by Gao et al. [10], is used to combine temporally sparse

Landsat and daily MODIS ET maps in order to retrieve Landsat-like images at daily time steps.

3. STUDY SITES

The goal of this work is to evaluate the performance of this ET data fusion approach over agricultural landscapes as well as to provide information for regional monitoring of water use. With this aim, two study sites are selected: (1) the Mead, NE study area (MEAD), located east of Wahoo, NE, and mainly occupied by corn and soybean fields. Mead is a typical corn/soybean rotation system in the Midwestern U.S (Figure 1 and 2). In these experiments both irrigated undrained fields were monitored using flux towers, representing two cases of mixed irrigated/unirrigated landscape. (2) the Central Sand, WI study area (Central Sand), located east of the Central Sand Plains, and is a mosaic of cropland, managed grasslands and scattered woodlots of pine, oak, and aspen (Figure 1 and 3). The Central Sands region have been affected by intensive irrigation, resulted in drops in groundwater levels and streamflows in recent years.

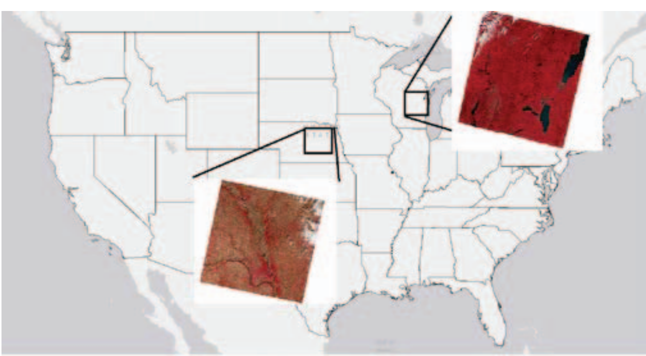

Figure 1. Location of the study fields within the continental U.S.

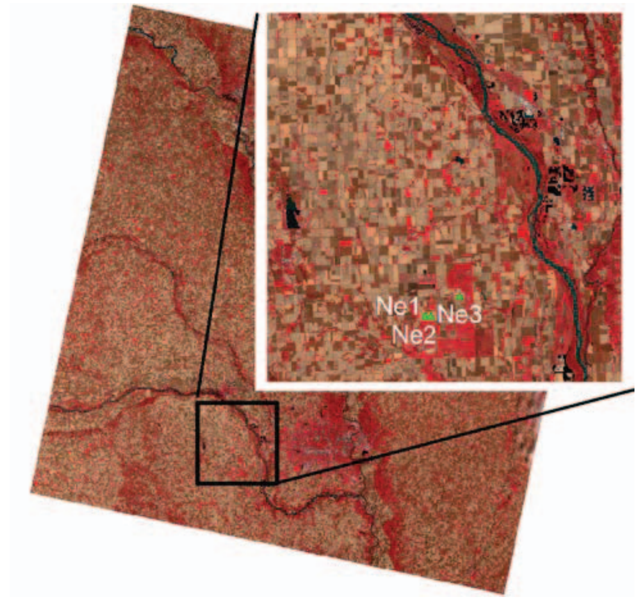

Figure 2. Location of the study fields in the MEAD study area (Landsat false color composite, October 2013). Triangles demarcate the location of the eddy covariance flux towers. This site is mainly occupied by corn and soybean fields

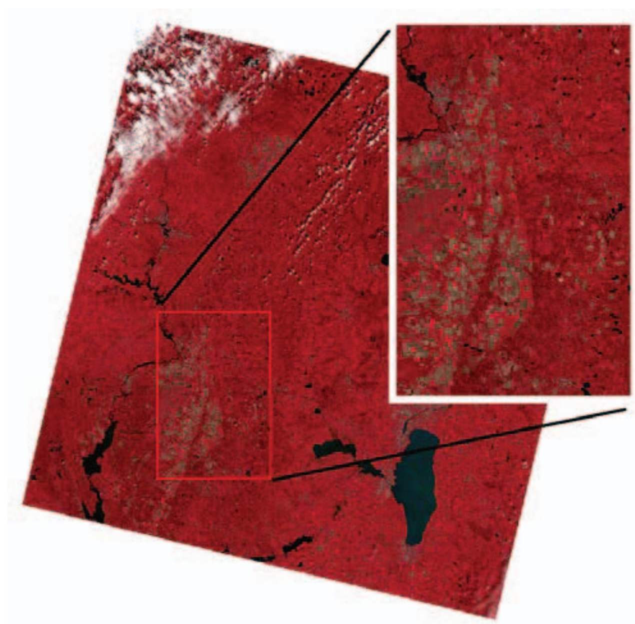

Figure 3. Location of the study fields in the Central Sand study area (Landsat false color composite, September 2014). It's in the eastern portion of the Central Sand Plains, where the land cover is a mosaic of cropland, managed grasslands and scattered woodlots of pine, oak, and aspen.

4. PRELIMINARY RESULTS

A continuous stream of daily Landsat-like ET maps has been produced for each experiment using STARFM and compared with observations from eddy covariance systems. Figure 4 is an example of the comparison in flux tower NE3 in a rainfed corn field.

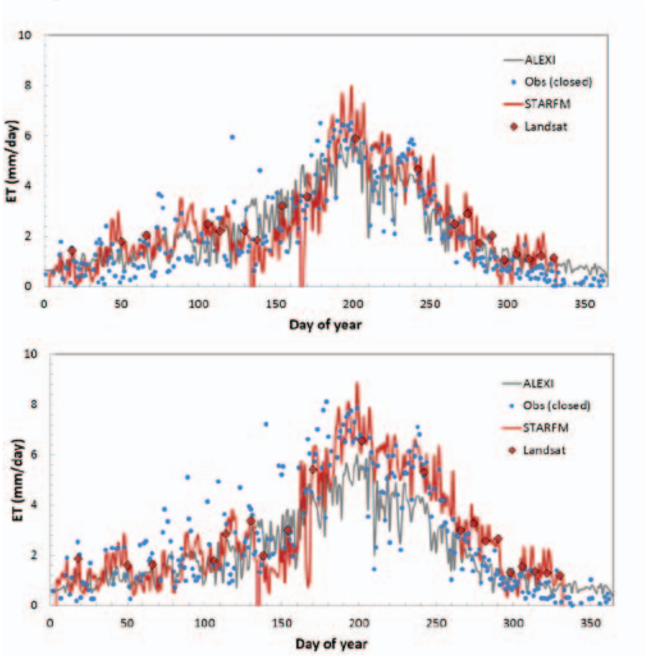

Figure 4. Comparison of STARFM modeled (red line, Fusion) and flux tower observed (blue dots, Obs) time-series of daily ET for the MEAD rainfed site. Grey line is ET estimated from ALEXI at 4 km resolution. Red diamonds (Landsat) represent DisALEXI estimates at Landsat overpass dates. The above plot is rainfed corn fields. The below plot is irrigated corn fields.

In the plot, the observed fluxes represent the average tower observations in the fields, while the modeled values represent a spatial average over all 30-m pixels within the given fields. In comparison with the observations, the fusion model seems to reproduce the general ET trends reasonably well in the rainfed fields. For the irrigated field, the overall envelope captures the general ET trends, though the STARFM ET prediction misses to predict some of the high observed ET value. These spikes in ET observations is probably resulted from irrigation events. Similarly, the daily ET generated from 4km ALEXI flux is reasonably consistent with fluxes in rainfed field. A statistical performance metrics shows that the ET dynamics in the rainfed fields are reproduced on a day-to-day basis with an error of about 1.3 mm d^{-1} in the rainfed fields and 1.6 mm d^{-1} in the irrigated fields respectively. Seasonal variations in spatial patterns of ET around the MEAD site are demonstrated in Figure 5.

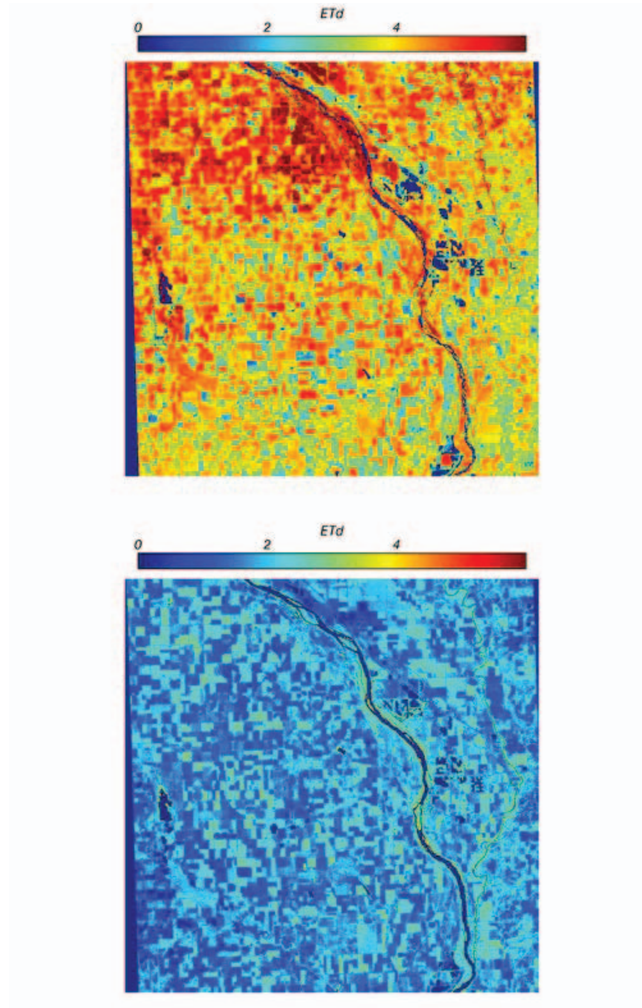

Figure 5. Spatial pattern of daily ET (mm d^{-1}) at the MEAD site at two times during the growing season (DOY183 (above) and DOY283 (below)) in 2013.

High spatiotemporal ET map timeseries for both Mead and the Central Sands will be accumulated over the growing season to provide an accounting of water use by crop type and land-use/water management. In the Mead study, the focus is on integrating moisture stress information – conveyed by maps of the actual-to-potential ET ratio – with crop modeling systems to improved predictions of at-harvest yield. Moisture deficiencies occurring at sensitive times during the crop development cycle will result in reductions from potential yield estimates.

For the Central Sands study, the goal is to associate multi-year field-scale ET estimates with patterns in groundwater decline observed. Lake levels, groundwater levels, and streamflows in the Wisconsin Central Sands have been depressed since 2005.

However, the amount of groundwater pumped for irrigation, applied to fields, and consumptively used (i.e. evapotranspired) is somewhat uncertain [11]. This study aims to provide a detailed ET pattern at daily basis for a better groundwater resource management at the Central Sand.

5. CONCLUSIONS

Continuous monitoring of daily ET at field scale can be achieved by combining thermal infrared remote sensing data information from multiple satellite platforms. Performance of multi-sensor and -scale data fusion approach to mapping ET using GOES, MODIS and Landsat TIR imagery was assessed in application over agricultural fields. The ET data fusion methodology described here can provide detailed information about daily and seasonal water use patterns and can be of utility for irrigation managers at the scale of individual fields as well as for regional monitoring of water use.

6. REFERENCES

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