J2.2 UTILITY OF SATELLITE THERMAL REMOTE SENSING FOR MAPPING RIPARIAN AND UPLAND DESERT WATER USE

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1. INTRODUCTION

Remote sensing data combined with land surface models can provide spatially distributed fluxes over large areas. However, capturing the full range of variability in the fluxes is dependent on the resolution of the remote sensing data. For example, in a relatively homogeneous cropping region in Iowa where over 90% of vegetation cover is either corn or soybean, Kustas et al. (2004) found that when the resolution is > 500 m fluxes from the two crops were not easily distinguished. Clearly, for landscapes with patchy vegetation and dissected topography, the resolution is crucial for discriminating fluxes for the different land covers and for interpreting tower-based flux observations.

In this paper, a high resolution Landsat 5 TM scene collected during the 2004 Soil Moisture Experiment (SMEX04) conducted in southern Arizona and Mexico was combined with local meteorological measurements in a land surface model at high (30 m) and low (960 m) resolution for investigating the impact of resolution on variability in land surface fluxes. This analysis will focus on in a semiarid rangeland watershed, Walnut Gulch.

2. THE MODEL

The model used in this study is Two-Source-Model (TSM) developed by Norman et al. (1995). A detailed description of the original TSM formulations can be found in Norman et al. (1995). Since then, several revisions have been made in order to accommodate a wider range of land cover and environmental conditions. The modifications included replacing the Beer's law type expression used to derive net radiation for soil and canopy components with a more physically-based algorithm developed by Campbell and Norman (Campbell and Norman, 1998), introducing a clumping factor into the model since over many landscapes the vegetation is clumped, and applying a revised soil resistance formulation. The revised models are described in Kustas and Norman (1999, 2000) and most recently in Li et al. (2005). The modeling approach evaluates the temperature contribution of the vegetated canopy layer and soil/substrate to the radiometric surface temperature observation, and the resulting turbulent heat flux contributions driven by surface-air temperature differences with aerodynamic resistance parameterizations from the vegetation and soil components.

3. DATA AND SITE DESCRIPTION

A summary of the SMEX04 project conducted during July-August 2004, typically the "monsoon season" (see http://www.ars.usda.gov/Research/docs.htm?docid=8995). During the field campaign, several Landsat TM scenes were collected. One scene was acquired soon after a precipitation event on July 29, 2004, providing much needed rainfall in the Walnut Gulch Watershed (WGW), the focus of this study. In the WGW and surrounding region, nearly 70% of vegetation, which was once grassland, is now classified as shrub land. During the experiment, two eddy flux towers were installed, one in a shrub land subwatershed (Lucky Hills) and the other in a grassland subwatershed (Kendall). The eddy flux towers also provided measurements of local meteorological conditions, including solar radiation, air temperature, vapor pressure and wind speed, all used as input for the TSM model. The Landsat image provided the land use classification, NDVI

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which is used to estimate fractional vegetation cover, and radiometric surface temperature (T_R). The procedure for processing the Landsat data follows Li et al. (2004). Figure 1 is the Landsat false color image over the watershed area with the two eddy flux tower locations noted.

Figure 1. Landsat false color image over watershed study area. Yellow stars are the approximate locations of the flux tower in the Lucky Hills (LH) and the Kendall (KE) subwatershed. The Walnut Gulch Watershed boundary is denoted in yellow.

4. RESULTS

The model was run at different resolutions using the Landsat data combined with the local meteorological data. For Landsat 5, the derived NDVI and land surface temperature pixel resolution are 30 and 120 m, respectively. The meteorological data from the flux tower observations were distributed over the WGW region adjusted for elevation since the elevation over watershed changes from 1200 m to over 2000 m.

The model output of the latent heat flux (LE) for the WGW area is illustrated in Figure 2. In Figure 2 the high LE values (>200 W m^{-2}) for the watershed and surrounding region come from the riparian, and higher elevation areas whereas the low LE values (<100 W m^{-2}) are mostly within the WGW boundary. The riparian area along the San Pedro River is easily observed having relatively large LE > 300 W m^{-2}. The high LE patterns in the southwest and northeast of WGW boundary are higher elevation forested areas having relatively high vegetation cover. For the Lucky Hills (LH) site, LE ~ 50 W m^{-2} while the Kendall (KE) site has LE ~ 150 W m^{-2} . Preliminary LE measurements from the eddy flux towers gave LE ~30 W m^{-2} for the LH site and ~100 W m^{-2} for KE, in reasonable agreement with TSM-derived values.

The TSM was also run at 960 m resolution, representative of the MODIS land surface temperature resolution (~1 km). To produce 960 m resolution NDVI and T_R, the Landsat 5 red and near-infrared and thermal-infrared radiance data were aggregated to 960 m and then NDVI and T_R were generated.

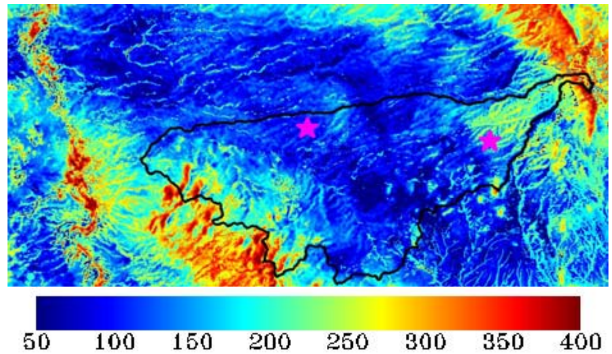

Figure 2. Map of the latent heat fllux (LE) over the WGW region at high resolution (W m^{-2}). The flux tower locations (magenta stars) and WGW boundary (black line) are provided.

In Figure 3 the 960 m resolution map of LE generated by the TSM is displayed. At 960 m resolution, much of the spatial pattern in LE particularly the high values distinguishing the riparian area along the San Pedro river at the west end of the WGW boundary is virtually lost.

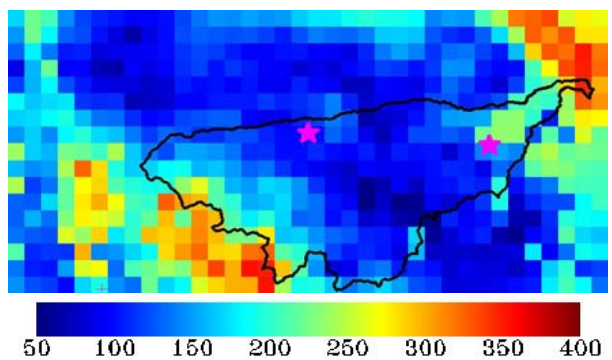

Figure 3. Map of the latent heat flux (LE) over the WGW region at 960 m resolution (W m^{-2}). The flux tower locations (magenta stars) and WGW boundary (black line) are provided.

The high resolution image is also very useful for interpreting the eddy flux tower measurements, especially for the Kendall site which had highly dissected topography from ephemeral stream channels containing riparian vegetation. For the Kendall area, there is significant spatial variation in the TSM-derived LE (Figure 4) and H (Figure 5). A 2 X 2 km area surrounding the Kendall flux tower shows LE varying from 50 to 300 W m^{-2} and H varying from 100 to 350 W m^{-2}. The wind direction during overpass time (Figure 4) indicates that depending on the measurement height and stability, eddy flux instruments could be affected by very different heat/water vapor sources. At the Kendall site, there were two eddy flux instruments positioned at 2 and 10 m above local terrain. Preliminary processing of the flux data indicated a tendency for differences to exist in H and LE measurements at the two observation heights.

At 960 m resolution, such detail in the spatial patterns of the fluxes is lost. Therefore, at the MODIS resolution, there is likely to be significant errors due to a lack of interpretation in both the model output and the flux observations.

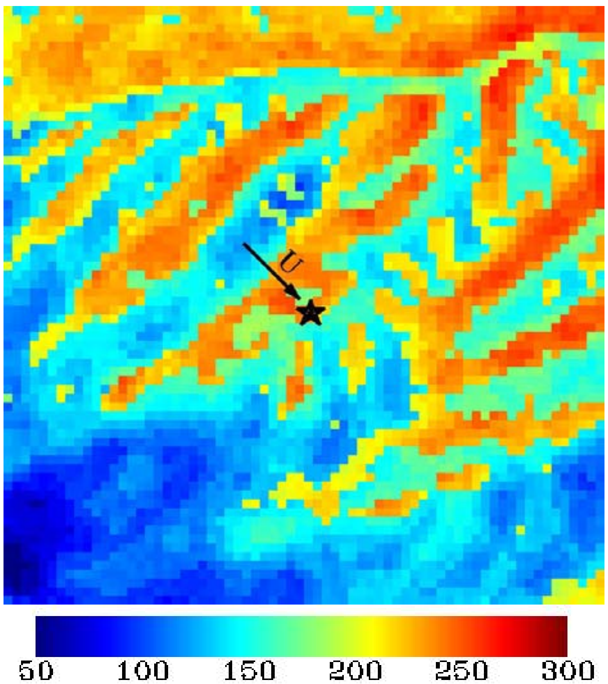

Figure 4. Map of latent heat flux LE around the Kendall site (2km x 2km). The black star denotes the flux tower location and arrow labeled U indicates wind direction during the Landsat overpass.

5. CONCLUSION

A two-source energy balance model was applied to Landsat TM imagery collected over south of Arizona. The model was run at Landsat and MODIS resolutions. The results show that at Landsat resolution, a full range in the spatial variation in LE is possible, discriminating water use for riparian areas from upland desert shrub lands. However, at the MODIS resolution, the range in LE and hence spatial distribution in water use is much narrower with the riparian area not discernable. The high resolution imagery is also be useful for interpreting eddy flux tower observations. At Landsat resolutions, flux-footprint models can be applied in order to estimate more accurately the source area of the model output that is likely to affect the flux measurements. An example of this for the Kendall subwatershed is illustrated where TSM-derived LE and H vary spatially by more than 100 W m^{-2} within several hundred meters of the flux tower.

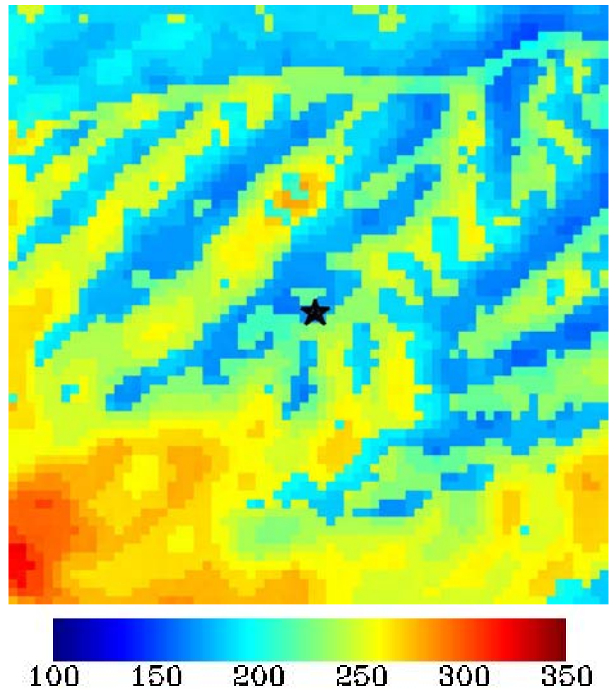

Figure 5. Map of sensible heat flux H around Kendall site (2km x 2km). The black star denotes the location of the flux tower.

6. ACKNOWLEDGEMENT

Financial and logistical support for the SMEX04 project from NASA and USDA-ARS made this study possible.

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