The Incorporation of Land Use and Multiple Measurement Sites into the PASS Modeling System for Surface Energy Budget Estimates

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Introduction

The PAramaterization of Subgrid Scale (PASS) surface fluxes modeling system originally described by Gao et al. (1998) has been enhanced to include 1) the effects of land use differences across the regime of interest, 2) stability corrections to parameter critical to flux estimates, and 3) the ability to distribute meteorological data from multiple sites within the modeled area to each grid element. More reasonable stability corrections can now be incorporated on a pixel-by-pixel basis determined by both land use categories and meteorological conditions more closely associated with the location.

Model Operation Sequence

The description of site-wide fluxes is created by running the PASS twice using as input Normalized Differential Vegetation Index (NDVI) and surface temperature estimates calculated from Advanced Very High Resolution Radiometer (AVHRR) satellite data and LOWTRAN7 to calculate atmospheric corrections at approximately 1-km resolution (Figure 1). The first run, PASS1, calculates the relative soil moisture as described by Song et al (1999b). Here, the surface roughness is dependent on the land use category that is determined in turn from a 200-m resolution land use U.S. Geological Survey (USGS) data set. Thirty-seven land use categories are combined into five (urban, crop, rangeland, water, and forest); the percentage of each category within each satellite pixel is determined and used to modify estimates of surface roughness and effective measurement height of the meteorological variables (Figure 2). The critical estimate in this pass is the estimate of surface-sensible heat flux that is controlled principally by the air (site-wide mean from measurements)-surface (from satellite) temperature difference. The latent heat is then derived from an energy balance equation and then used with an aerodynamic relationship to estimate surface conductance and relative soil moisture shown in Figure 3 (Song et al. 1999a; Gao et al. 1998; Kim and Verma 1991).

The second run (PASS2) again uses the satellite data and land use data, now with the previously calculated soil moisture estimates at each grid element (Song et al. 1999a) and local air temperature, moisture, and wind speed derived from a distribution function that uses all available measurements within the modeled area. Presently, a geometrical distribution ($1/r^2$) is used to distribute values to each grid element. The critical element in this pass is the calculation of latent heat flux from an aerodynamic equation using water vapor deficit and a calculated surface and aerodynamic resistance (Song et al. 1999a). The sensible heat flux is then estimated as a residual from the surface energy balance equation.

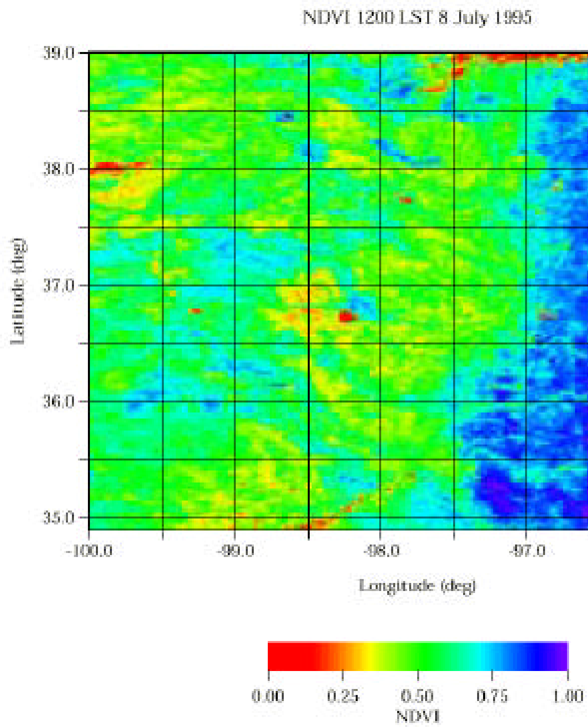

Figure 1a. AVHRR-derived NDVI inputs to the PASS.

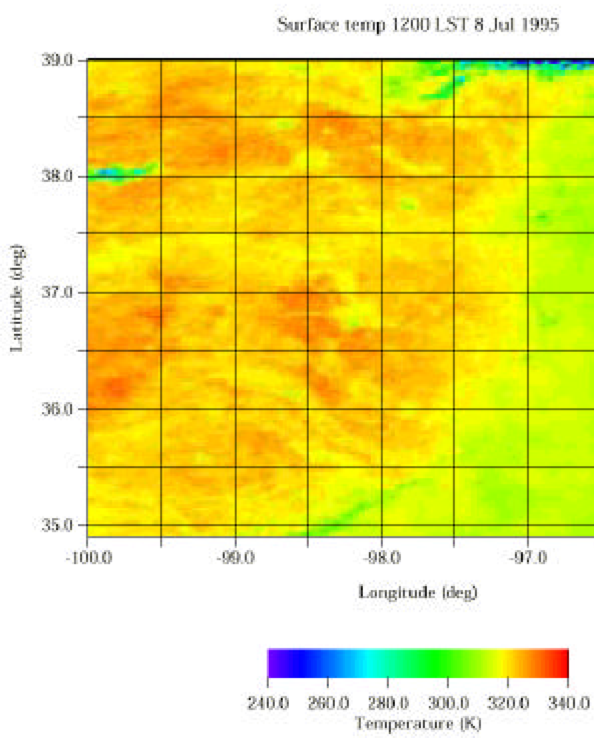

Figure 1b. AVHRR-derived temperature inputs to the PASS.

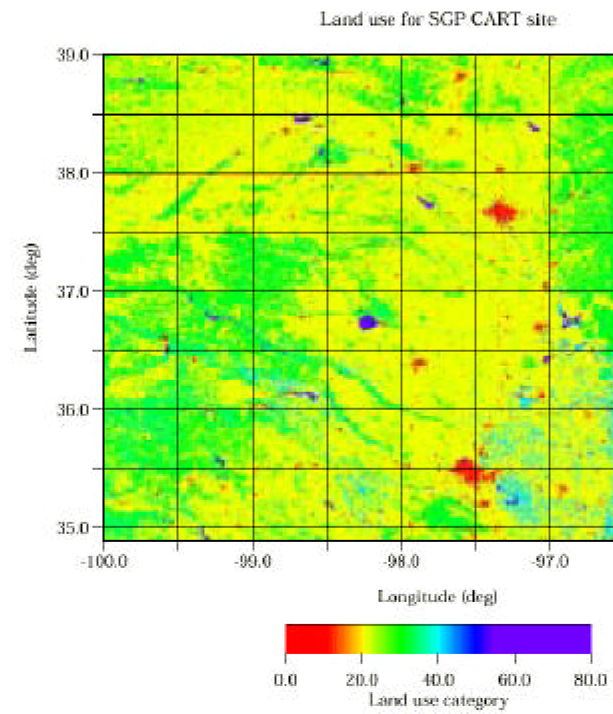

Figure 2. Land use data across the Cloud and Radiation Testbed (CART) site at the 200-m x 200-m resolution used as source for five land use categories.

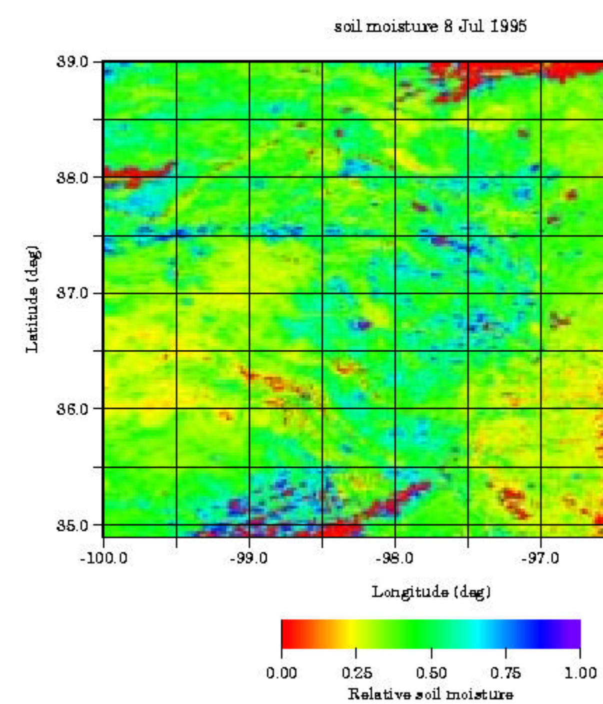

Figure 3. Soil moisture across the CART site at 1-km resolution derived from NDVI, sfc temp and a single statin average meteorological data.

Effects

The dependence of the meteorological variables on the multiple sites on July 8, 1995, indicates warmer, dryer conditions over the western CART site The calculated latent heat flux (Figure 4) reflects these conditions. A comparison of the effects of land use data is illustrated in Figure 4b, where PASS2 was run with only a single land use category (range land) for the entire CART site. Note that the definition of urban regions (Wichita, Kansas; Norman, Oklahoma; and Tulsa, Oklahoma; defined by land use values less than 20 in Figure 2 or small LE in Figure 4a) essentially disappears when only the single land use category is used. When only a single met station is used rather than the ten available Energy Balance Bowen Ratio (EBBR) sites, the distribution of fluxes across the site (Figure 5) varies by more than 10% across the CART site (the single station was chosen to be in the west). Net radiation differences are smaller, usually less than 5%.

The cumulative effects of multiple meteorology sites and land use categorization across the site are shown in Figure 6. Average latent and sensible heat fluxes are observed to decrease (increase) by about 10% monotonically as the number of meteorology sites changes from one to ten for July 8, 1995. Average latent and sensible heat fluxes differ by more than 60% among land use categories while the net radiation differs by less than 10%.

The agreement between modeled fluxes and EBBR values within the same grid element is not surprisingly quite variable; the mean difference between modeled and measured latent heat flux is 29% and between modeled and measured sensible heat flux is 46%. These differences are not surprising given the scale of the EBBR estimates (100 m) versus the modeled values (1 km). Consider also that the central facility estimates are made above the equivalent of rangeland even though the land use category for that pixel is 100% cropland.

References

Gao, W., R. L. Coulter, B. M. Lesht, J. Qiu, and M. L. Wesely, 1998: Estimating clear-sky regional surface fluxes in the Southern Great Plains atmospheric radiation measurement site with ground measurements and satellite observations. *J. Appl. Meteorol.*, **37**, 5-22.

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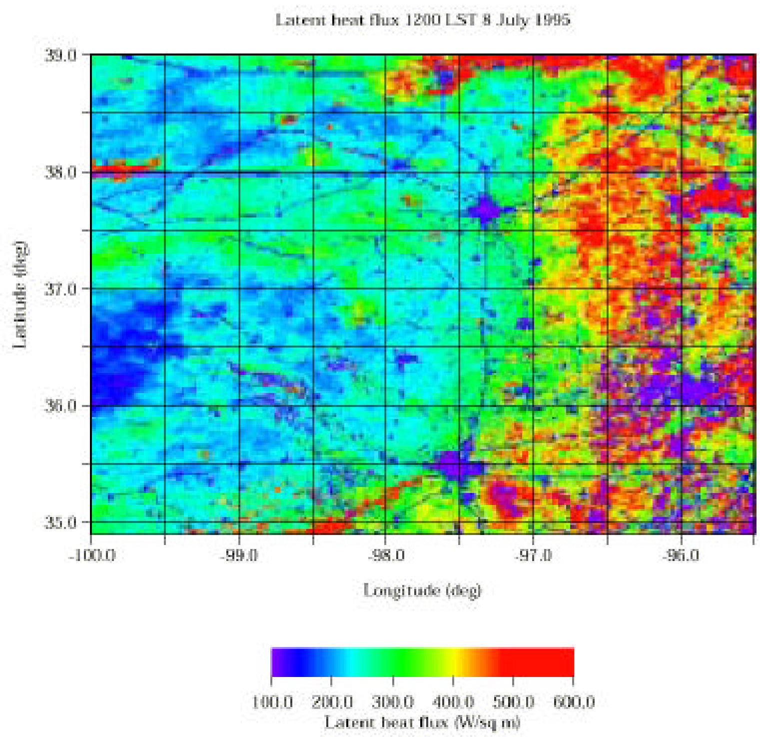

Figure 4a. Calculated latent heat flux from PASS across the Southern Great Plains (SGP) CART site.

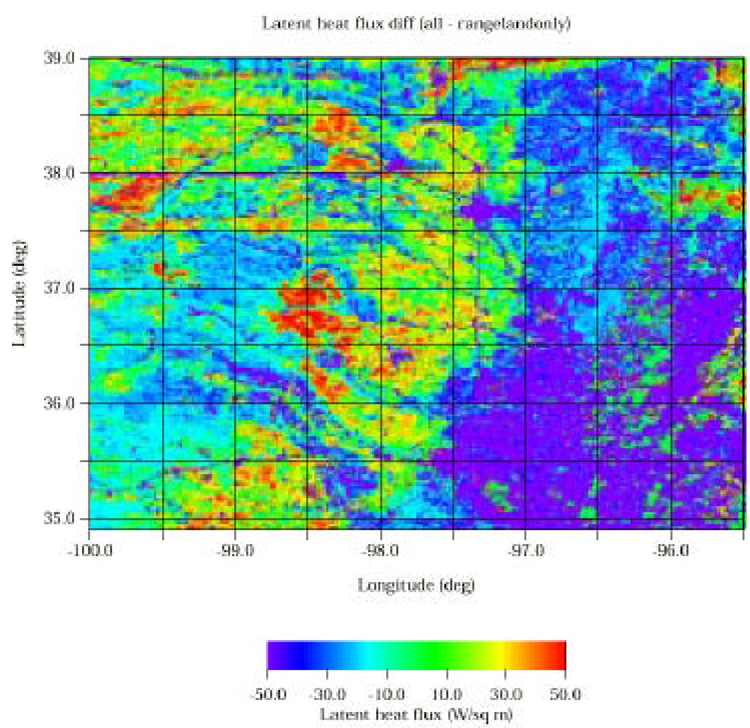

Figure 4b. Difference in latent heat flux between all land use and assuming rangeland only.

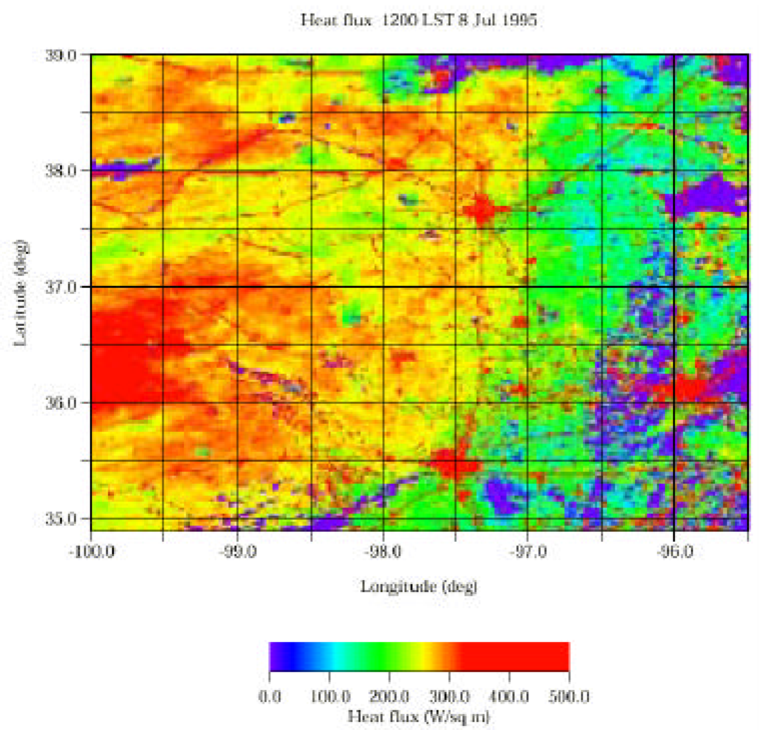

Figure 5a. Sensible heat flux from PASS across the SGP CART site.

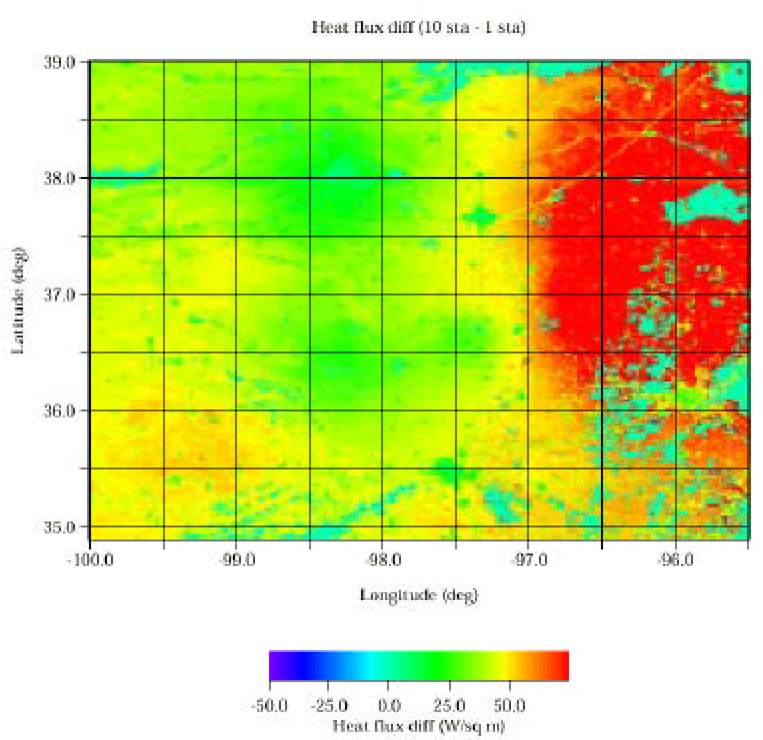

Figure 5b. Heat flux difference between using ten met stations and one met station.

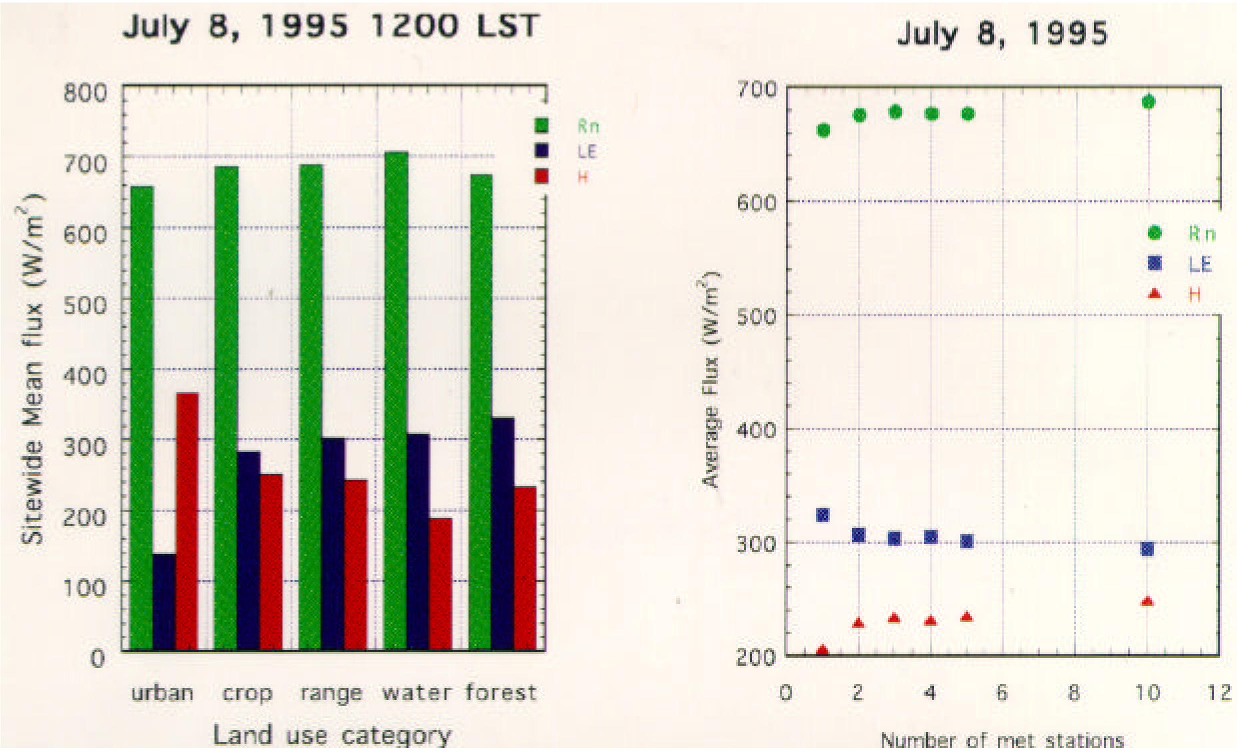

Figure 6. PASS fluxes averaged across the CART site as function of (left) land use category and (right) number of met stations.

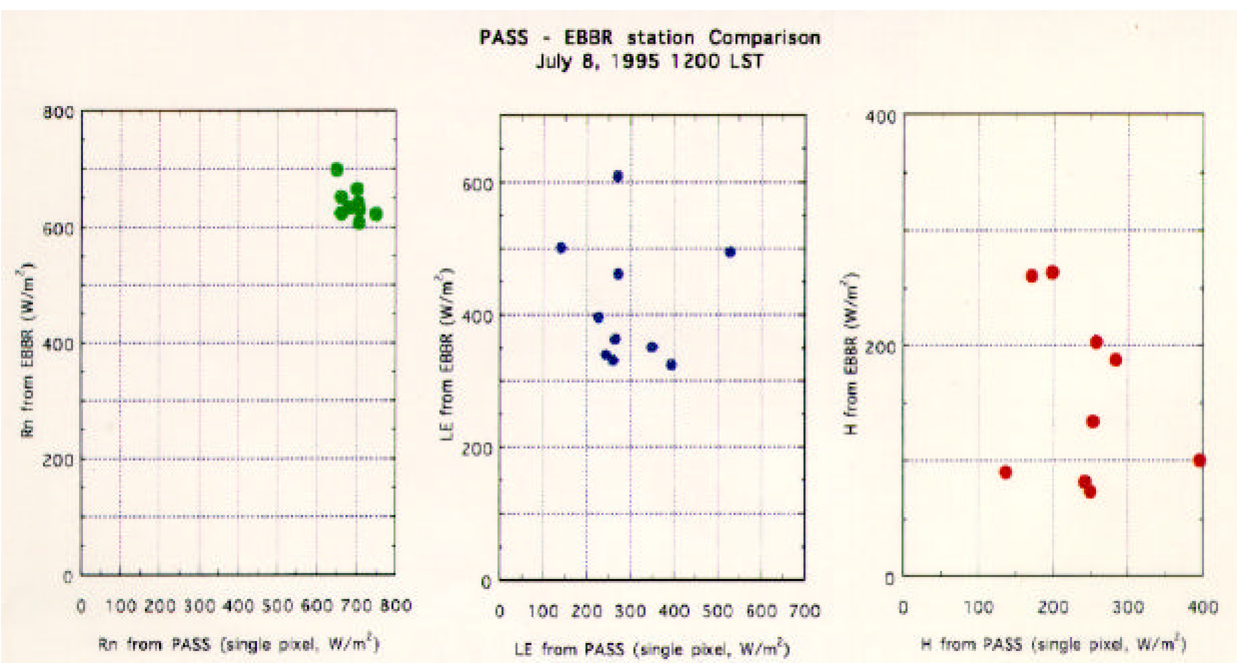

Figure 7. Local fluxes from EBBR measurements compared with PASS estimates from coincident pixel.