Heterogeneous Surface Fluxes and Their Effects on the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) Site

J. C. Doran, Q. Hu, J. M. Hubbe, J. C. Liljegren, W. J. Shaw, and S. Zhong
Pacific Northwest National Laboratory
Richland, Washington

G. J. Collatz
NASA Goddard Space Flight Center
Greenbelt, Maryland

Introduction

The treatment of subgrid-scale variations of surface properties and the resultant spatial variations of sensible and latent heat fluxes have received increasing attention in recent years. Mesoscale numerical simulations of highly idealized conditions, in which strong flux contrasts exist between adjacent surfaces, have shown that under some circumstances the secondary circulations induced by land-use differences can significantly affect the properties of the planetary boundary layer (PBL) and the region of the atmosphere above the PBL. At the Southern Great Plains (SGP) Cloud and Radiation Testbed (CART) site, the fluxes from different land-surface types are not expected to differ as dramatically as those found in idealized simulations. Although the corresponding effects on the atmosphere should thus be less dramatic, they are still potentially important. From an Atmospheric Radiation Measurement (ARM) perspective, in tests of single column models (SCMs) it would be useful to understand the effects of the lower boundary conditions on model performance. We describe here our initial efforts to characterize the variable surface fluxes over the CART site and to assess their effects on the PBL that are important for the performance of SCMs.

Fluxes Over the CART Site

The SiB2 model (Sellers et al. 1986) was chosen to help produce a flux map of the CART site. The SiB2 model makes use of soil, plant, and meteorological data to calculate the sensible and latent heat fluxes over vegetated or bare surfaces. Estimates of leaf area index for vegetation are obtained from satellite-derived Normalized Difference Vegetation Index values, while meteorological fields are computed using data from the Oklahoma

Mesonet, National Weather Service stations, the Kansas State University Mesonet, and the CART central and extended sites. The multiquadric basis function interpolation scheme of Nuss and Titley (1994) is used to obtain values for precipitation, temperature, humidity, incoming solar radiation, and wind speeds over the CART domain, and these variables are then mapped onto an array of 50 x 58 grid cells, each 6.25 km on a side. A new set of fields is computed every 30 minutes for the time periods of interest.

Initial soil moisture values are computed using the approach of Liston et al. (1993). The SiB2 model is then run for each grid cell in the array to obtain the sensible and latent heat fluxes at each grid point. If there are several principal vegetation types found in a given grid cell, SiB2 can be run for each vegetation type, and the net fluxes are then computed from a weighted average of the contributions from each type. An example of the fluxes computed by this methodology is shown in Figure 1. The gridded flux values are then used to obtain a time series of spatially averaged fluxes over the domain, at resolutions ranging from $(6.25 \text{ km})^2$ on up to domain-wide averages.

Such flux calculations are subject to several sources of uncertainty. The largest appears to be the difficulty in specifying the soil moisture profiles accurately for the whole site. At this time, soil moisture measurements are quite limited. Although this situation will improve over the next two years with the addition of soil moisture probes at the extended sites, soil moisture descriptions are expected to remain problematic. A second difficulty is determining the accuracy of the interpolated fields, particularly for variables such as solar radiation, which can change rapidly and irregularly under partly cloudy conditions. A third problem is the specification of the
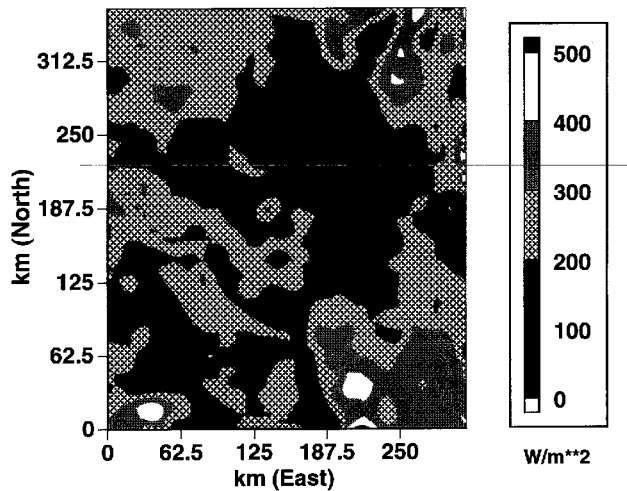
Figure 1. SGP CART sensible heat fluxes derived from the SiB2 model for July 28, 1994.

plant characteristics on a fine enough scale, and with sufficient differentiation among the various plant types, to allow SiB2 methods to compute fluxes accurately.

Some degree of tuning is possible by comparing modeled flux values with fluxes measured at the extended sites and making some adjustments in the plant parameters or soil moisture values to obtain improved agreement. This procedure must be used with care, however, to avoid forcing agreement between modeled and measured flux values for the wrong reason. To date, flux measurements have not been available from wheat fields, which constitute a major crop in the CART site, but this situation is also expected to improve substantially by late 1995.

Mesoscale Modeling

Using data from the 1992 Boardman experiment (Doran et al. 1995) and applying the RAMS (Regional Atmospheric Modeling System [Pielke et al. 1992]) mesoscale model as an analysis tool, it has been shown that spatially varying surface heat fluxes can result in varying mixed-layer depths over the domain (Doran and Zhong 1995). A similar result is anticipated for the CART region. In addition, differences in column-integrated moisture, temperature, and the probability of cloud formation are also expected to be found. To

examine these features, the RAMS model is being used to simulate conditions over the SGP CART site for a number of selected cases.

Initial tests of the RAMS model for this domain do show effects in the PBL arising from spatially varying heat fluxes caused by differences in soil moisture. However, the parameterizations used in Version 3a of RAMS show a sensitivity of sensible and latent heat fluxes to soil moisture that appears to be greater than that actually found from CART data. As a result, the soil moisture in RAMS must currently be treated as a tuning parameter that can be adjusted to produce flux fields similar to those obtained from the SiB2 modeling exercise described above. Figure 2 shows the variations in mixed-layer depth computed for a flux distribution similar but not identical to that given in Figure 1. The variations across the domain are significant and are not currently accounted for in SCMs.
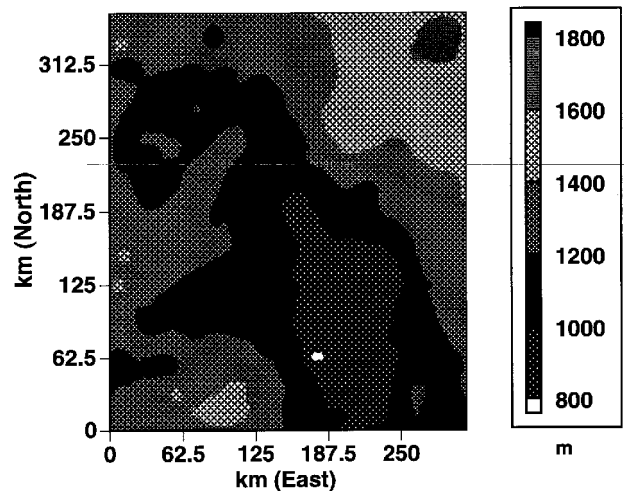
Acknowledgment

Figure 2. Mixing heights derived from the RAMS model for fluxes similar to those in Figure 1.

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