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Sensitivity of surface climate to land surface parameters: A case study using the simple biosphere model SiB2

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[1] Significant uncertainties may result from numerical models if fed with inappropriate input data. Biosphere-atmosphere transfer models are sensitive to input vegetation parameters, and the degree to which parameter estimates rely on the definition of the land cover type varies with models. In this study we use the simple biosphere model (SiB2) to evaluate uncertainties associated with misclassification of the land cover type and how they propagate to surface climate variables. We estimate that in regions with heterogeneous landscapes, the aggregation of land cover types from 1 × 1 km to 100 × 100 km horizontal resolution overestimates the area of the dominant type by up to 70%. The largest uncertainties associated with land cover misclassification are found in leaf area index and roughness length both of which have significant impact on the fluxes of carbon, water and energy at the earth surface. Other important uncertainties occur when the misclassification confuses plants with different carbon pathways. An assessment of the uncertainties is obtained comparing outcomes resulting from a choice of a dominant type in a 100 × 100 km area to those obtained using a mosaic of land cover composition weighted by its fractional cover. The difference shows the choice of the dominant type to be cooler by 0.6°C than the average of the mosaic at local noon, while at night it is warmer by 1.7°C. Our results indicate that the diurnal temperature range (dtr) varies from 13°C for the dominant type to 15°C for the weighted average. The difference in the dtr is due to higher minimum temperature simulated with the dominant type. The choice of a dominant type also results in a daily carbon assimilation loss of 28,000 gC compared to the average.

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1. Introduction

[2] Land surface models such as the Biosphere-Atmosphere Transfer Scheme-BATS [*Dickinson*, 1984] or the simple biosphere model SiB2 [*Sellers et al.*, 1996a] simulate the exchange of energy, water and momentum between the soil, vegetation and the atmosphere. These land surface models are coupled to atmospheric General Circulation Models (GCMs) and often operate at the same spatial resolution as the host GCM. The grid cell used in current GCMs is rather coarse (e.g., 2° × 2°) compared to the resolution of most satellite-derived land cover products. On the other hand the land cover within the grid is represented either by one biome in the case of "dominant" type or several biomes when "mosaics" are used [*Koster and Suarez*, 1996]. The biomes are used to prescribe many land surface parameters to describe optical, morphological and physiological characteristics.

[3] There are obvious problems associated with prescribing the dominant land cover type within a coarse resolution grid cell. In areas of heterogeneous landscapes, the most common (modal) land cover type may represent a relatively small proportion of the total cell area. For example, comparing the 1 km MODIS land cover classification for North America with a 1° resolution version, the 1° version overestimates the proportion of the dominant type within each cell, sometimes by as much as 70% (Figure 1). As a result, outputs from models using coarse resolution may carry significant uncertainties at regional and local scales. In addition, these errors do not necessarily "cancel out" when considered across the continent as a whole (Table 1). Some subsidiary classes (e.g., urban land cover) disappear completely from the landscape when using the dominant type aggregation.

[4] The implication of these errors for modeling depends in part on the type of model under consideration. Climate models typically compute grid-size fluxes of water and energy at the land surface. The dominant biome concept used by most climate models is not representative of the mix of ecosystems coexisting within the same grid. However, it is a reasonable compromise between high computational overhead and simple description of the physics. For land surface models that incorporate a carbon cycle such as SiB2, the dominant biome classification is even more problematic, especially in the tropics where it may misclassify plants species with different carbon pathways. These "third generations" land surface models [*Sellers et al.*, 1997] have a coupled photosynthesis-stomatal conductance module [*Collatz et al.*, 1991, 1992; *Farquhar et al.*, 1980]

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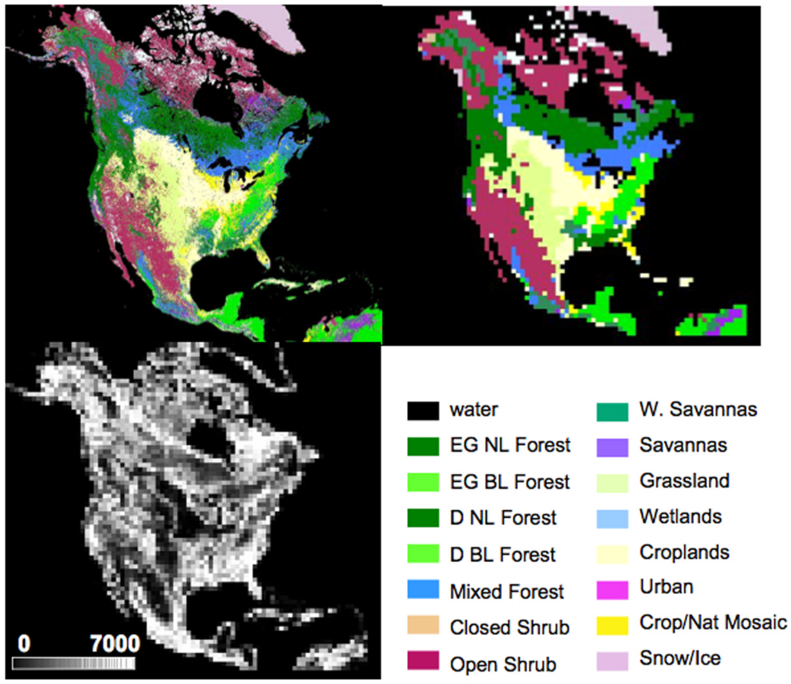

Figure 1. Differences between 1 km and 100 km (~1°) land cover representations for North America. (top left) MODIS 1 km IGBP land cover classification, (top right) MODIS land cover map aggregated to 1° resolution using dominant type, and (bottom left) the difference between the area of the dominant type in the 1° cell (e.g., 10,000 km^2) and the actual area of that type within the cell from the 1 km representation. In heterogeneous landscapes, the area of the dominant type is overestimated by up to 7000 km^2, or 70% of the cell area.

that allows the simultaneous computation of carbon assimilation while regulating the water loss through the stomates to the atmosphere [*Cowan*, 1977]. C4 plants, dominant in tropical and subtropical herbaceous vegetation [*Collatz et al.*, 1998] are much more water use efficient than their C3 counterparts occurring in all woody and temperate herbaceous plants and for given environmental conditions, they are capable of higher photosynthetic rates [*Collatz et al.*, 1992].

5. Concluding Remarks

[28] The results from this study illustrate the uncertainties encountered by a numerical model if fed with inappropriate input data. Results are also affected to some extent by the quality of the climate input data. Development of data sets such as those produced by the International Satellite Land Surface Climatology Project Initiative II (ISLSCP II) is of central importance for improving model inputs or to validate their outputs. Most current land surface models are complex and require a large set of internally consistent input data that is not readily available from a single uniform source. Therefore sources of uncertainties are large.

[29] The problem of scaling land cover type to models resolution is typical and all modelers face it. This study shows that scaling data up from fine to coarse resolution for modeling use can produce significant uncertainties in model's simulations. The degree to which parameter estimate rely on the definition of the land cover type varies with models. The simple biosphere model assessed in this study uses satellite data in addition to land cover type to determine some of its biophysical parameters and therefore has a reduced reliance on land cover type because satellite data carry much of the spatial heterogeneity of the surface characteristics. Other land surface models that do not use satellite data may be more sensitive to misclassification errors and their implications in the computation of surface fluxes. Our study also shows that modeling uncertainties associated with land cover misclassification are more important in heterogeneous regions.

[30] There are many other parameters within SiB2 and other land surface models that rely on land cover type. Our study is an example illustrating land cover misclassification errors and how they propagate down to the surface climate variables. It raises the need to develop global data sets to characterize the vegetation morphological, optical and physiological parameters necessary for current surface vegetation transfer schemes common to most climate models. Some of these properties such as canopy top and base height as well as canopy shape could probably be developed from radar or lidar data, but other algorithms depicting vegetation health, temperature and water stress levels from remotely sensed data are highly desirable. This problem will become more acute in the near future as high-resolution satellite vegetation data such as MODIS data at 250 m horizontal resolution will be more accessible. However, if this fine resolution data set is not accompanied by vegetation morphological, optical and physiological characteristics at an appropriate spatial scale, the modeling of surface water and energy transfers at the land surface-atmosphere interface will suffer and will hamper our ability to improve climate predictability. Not only will surface characteristics ensure that major model's components are appropriately parameterized, but they will also and most importantly help solve some problems associated with scaling of vegetation data and the loss of information contained in the spatial heterogeneity. Projects such as ISLSCP II should be encouraged and should be oriented toward collection, formatting and distribution of specific sets of data that are most needed.