Comparison of Four Different Stomatal Resistance Schemes Using FIFE Data. Part II: Analysis of Terrestrial Biospheric–Atmospheric Interactions

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ABSTRACT

Stomatal resistance (R_s) forms a pivotal component of the surface energy budget and of the terrestrial biosphere–atmosphere interactions. Using a statistical–graphical technique, the R_s-related interactions between different atmospheric and physiological variables are resolved explicitly from observations made during the First ISLSCP (International Satellite Land Surface Climatology Project) Field Experiment (FIFE). A similar analysis was undertaken for the R_s parameterization schemes, as used in the present models. Three physiological schemes (the Ball–Woodrow–Berry, Kim and Verma, and Jacobs) and one operational Jarvis-type scheme were evaluated in terms of their ability to replicate the terrestrial biosphere–atmosphere interactions.

It was found that all of the R_s parameterization schemes have similar qualitative behavior for routine meteorological applications (without carbon assimilation). Compared to the observations, there was no significant difference found in employing either the relative humidity or the vapor pressure deficit as the humidity descriptor in the analysis. Overall, the relative humidity–based interactions were more linear than the vapor pressure deficit and hence could be considered more convenient in the scaling exercises. It was found that with high photosynthesis rates, all of the schemes had similar behavior. It was found with low assimilation rates, however, that the discrepancies and nonlinearity in the interactions, as well as the uncertainties, were exaggerated.

Introduction of CO_2 into the analysis created a different dimension to the problem. It was found that for CO_2-based studies, the outcome had high uncertainty, as the interactions were nonlinear and the schemes could not converge onto a single interpretive scenario. This study highlights the secondary or indirect effects, and the interactions are crucial prior to evaluation of the climate and terrestrial biosphere–related changes even in the boundary layer perspective. Overall, it was found that direct and indirect effects could lead the system convergence toward different scenarios and have to be explicitly considered for atmospheric applications at all scales.

1. Introduction

Experiments such as HAPEX-MOBILHY (Hydrological Atmospheric Pilot Experiment-Mobilisation du Bilan Hydrique) (André et al. 1986), FIFE (Sellers et al. 1988), EFEDA (ECHIVAL Field Experiment in a Desertification-threatened Area) (Bollé et al. 1993), and the Vegetation and Energy Balance Experiment (Niyogi et al. 1995; Raman et al. 1998) have asserted the significant impact that surface features, such as vegetation and soil moisture, have on the planetary boundary layer (PBL) structure. PBL processes are initiated (and modulated) through alterations in the surface thermohydraulic parameters. Hence, modeling efforts at all scales—micro (Su et al. 1996), meso (Alapaty et al. 1997), and global (Sellers et al. 1996; Randall et al. 1996)—attempt to realistically represent the responses of surface-induced changes (Jarvis 1976; Deardorff 1978; Avissar et al. 1985; Dickinson et al. 1986; Sellers et al. 1986, 1996; Wetzel and Chang 1988; Noilhan and Planton 1989; Xue et al. 1991; Acs 1994; Bosilovich and Sun 1995; Viterbo and Beljaars 1995; Alapaty et al. 1997; Niyogi et al. 1997a, among others). In addition to the meteorological applications for terrestrial biosphere–atmosphere interaction studies, physiologically intensive efforts are under way (Farquhar et al. 1980; Ball 1987; Finnigan and Raupach 1987; Meyers and Paw U 1987; Goudriaan 1988; Lynn and Carlson 1990; Grantz and Meinzer 1990; Raupach 1991; Collatz et al. 1991, 1992; Kim and Verma 1991; Baldocchi 1992, 1994; Dougherty et al. 1994; Jacobs 1994; Nikolov et al. 1995; Su et al. 1996; Sellers et al. 1996; Randall et al. 1996; Cox et al. 1996; Foley et al. 1996).

The meteorological and physiological treatments of the terrestrial biosphere–atmosphere interactions have certain subtle differences that need to be addressed. As shown in Fig. 1a, the generic pathway for the com-

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