THE COMMON LAND MODEL

BY YONGJIU DAI, XUBIN ZENG, ROBERT E. DICKINSON, IAN BAKER, GORDON B. BONAN, MICHAEL G. BOSILOVICH, A. SCOTT DENNING, PAUL A. DIRMEYER, PAUL R. HOUSER, GUOYUE NIU, KEITH W. OLESON, C. ADAM SCHLOSSER, AND ZONG-LIANG YANG

Scientists from several institutions and with different research backgrounds have worked together to develop a prototype modular land model for weather forecasting and climate studies. This model is now available for public use and further development.

Climate and weather forecasting models require the energy, water, and momentum fluxes across the land–atmosphere interface to be specified. Various land surface parameterizations (LSPs), ranging from the simple bucket-type LSP in the 1960s to the current soil–vegetation–atmosphere interactive LSP, have been developed in the past four decades to calculate these fluxes. The Project for Intercomparison of Land Surface Parameterization Schemes (PILPS) has demonstrated that, even with the same atmospheric forcing data and similar land surface parameters, different LSPs still give significantly different surface fluxes and soil wetness, partly because of the differences in the formulations of individual processes and coding architectures in participant models (Henderson-Sellers et al. 1995). On the other hand, most LSPs share many common components, suggesting the need to develop a publicly available common land model with a modular structure that could facilitate the exploration of new issues, less repetition of past efforts, and sharing of improvements and refinements contributed by different groups.

The Common Land Model (CLM) effort dates back to the mid-1990s and has evolved through various workshops and e-mail correspondence. The initial motivation was to provide a framework for a truly community-developed land component of the National Center for Atmospheric Research (NCAR) Community Climate System Model (CCSM). Interest in applying CLM came from the Goddard Space Flight Center (GSFC) Data Assimilation Office (DAO), which was implementing the Mosaic model (Koster and Suarez 1992), and the Center for Ocean–Land–Atmosphere Studies (COLA) scientists, who were revising their Simplified Simple Biosphere Model (SSiB) (Xue et al. 1991). We also established ties to groups performing carbon cycle and ecological modeling.

In developing CLM, we attempted to combine the best features of three existing successful and relatively

AFFILIATIONS: DAI AND DICKINSON—School of Earth and Atmospheric Sciences, Georgia Institute of Technology, Atlanta, Georgia; ZENG—Department of Atmospheric Sciences, University of Arizona, Tucson, Arizona; BAKER AND DENNING—Department of Atmospheric Sciences, Colorado State University, Fort Collins, Colorado; BONAN AND OLESON—National Center for Atmospheric Research, Boulder, Colorado; BOSSILOVICH AND HOUSER—NASA GSFC, Greenbelt, Maryland; DIRMEYER AND SCHLOSSER—Center for Ocean–Land–Atmosphere Studies, Calverton, Maryland; NIU AND YANG—Department of Geological Sciences, University of Texas at Austin, Austin, Texas
CORRESPONDING AUTHOR: Dr. Yongjiu Dai, School of Earth and Atmospheric Sciences, Georgia Institute of Technology, 311 Ferst Dr., Atlanta, GA 30332
E-mail: dai@eas.gatech.edu
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well documented and modular land models; the Land Surface Model (LSM) of Bonan (1996), the Biosphere–Atmosphere Transfer Scheme (BATS) of Dickinson et al. (1993), and the 1994 version of the Chinese Academy of Sciences Institute of Atmospheric Physics LSM (IAP94) (Dai and Zeng 1997). However, CLM is designed in such a way that model components from other LSPs can be incorporated into it very easily. Since the initial CLM code was completed in late 1998, the FORTRAN90 program has gone through four iterations of improvements. Since then CLM has also gone through four rigorous beta tests. We have used very comprehensive observational data: a variety of multiyear point observational data over different regions of the world, regional data over the U.S. Red–Arkansas River basin, and the Global Soil Wetness Project (GSWP) (Dirmeyer et al. 1999) data. These data include all data in PILPS. CLM has also been tested in the multiagency Land Data Assimilation System (LDAS). Results from these extensive tests will be published elsewhere by CLM participants. In addition, CLM has been coupled with the NCAR Community Climate Model (CCM3) (Zeng et al. 2002). The results of this coupled run have shown that CLM simulates surface air temperature, the annual cycle of runoff, and snow mass significantly better than the LSM.

The overall structure of CLM includes three elements: 1) the core single-column soil–snow–vegetation biophysical code, 2) the land boundary data, and 3) the scaling procedures within a climate model required to interface atmospheric model grid-square inputs to land single-column processes. The interface routines that isolate the land model from the needed data structures are also important. Such separation of functionality allows the best science to be used for each of these elements, and, in particular, ensures that the core model can be tested with single-point field data, that the latest satellite remote sensing and global field survey datasets can be incorporated, and that the latest scaling procedures can be adopted. This paper primarily documents the single-column model treatment and some of the offline testing results. Two initial versions of land boundary data have been documented in Zeng et al. (2002) and Bonan et al. (2002).

CLM has added complexity in order to satisfy a wide variety of applications. For example, the multilayer soil and snow structure provides accurate simulations over a wide variety of timescales and hence is useful for such disparate applications as model data assimilation of surface properties, and determining soil temperatures beneath snow for matching measurements of soil respiration. Managing such complexity is not easy. However, we anticipate that good documentation and the open scrutiny of many scientists will eliminate any serious errors. Simplified versions for specific applications would not be difficult to develop. However, further improvements in the parameterization of runoff, and better integration into models of vegetation dynamics and soil biogeochemistry, are likely to further increase the code complexity.

In this article, we will first describe in brief the model initialization needs and physical parameterizations and then report some encouraging offline model testing results using two observational datasets.

SUMMARY. More than 30 land surface models have been published so far, and this number increases every year. This emphasis reflects the general recognition of the importance of land surface processes in weather forecasting and climate studies. These models share many common components with each other. However, even with the same atmospheric forcing data and similar land surface parameters, these models still give significantly different surface fluxes and soil wetness.

While individual land model development (particularly with innovation) should be always encouraged, scientists from several institutions also recognized a few years ago that some synergy and model convergence are also needed. The Common Land Model (CLM), presented in this paper, represents our efforts in this direction. Offline studies presented here demonstrate that CLM can realistically simulate the key state variables and fluxes. Confirmation of the results using other observational datasets will be reported elsewhere. Furthermore, when CLM is coupled with the NCAR CCM3, it is found to significantly improve the climate simulation of surface air temperature, runoff, and snow mass, with little impact on other aspects (Zeng et al. 2002). Therefore, CLM is now ready for public release (Dai et al. 2001).

Some of the components in CLM need to be further improved. For instance, the runoff parameterization follows the ideas of TOPMODEL, but subgrid topographic data have not been used. The interaction of underground water with the surface water has not been considered either. Primarily as a biophysical model, the biogeochemical cycle and dynamic vegetation components also need to be added to CLM. The modular code structure of CLM would help facilitate these improvements and further developments by the larger community.