JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 116, D12110, doi:10.1029/2010JD015140, 2011

The community Noah land surface model with multiparameterization options (Noah-MP): 2. Evaluation over global river basins

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Received 4 October 2010; revised 4 February 2011; accepted 25 March 2011; published 24 June 2011.

[1] The augmented Noah land surface model described in the first part of the two-part series was evaluated here over global river basins. Across various climate zones, global-scale tests can reveal a model's weaknesses and strengths that a local-scale testing cannot. In addition, global-scale tests are more challenging than local- and catchment-scale tests. Given constant model parameters (e. g., runoff parameters) across global river basins, global-scale tests are more stringent. We assessed model performance against various satellite and ground-based observations over global river basins through six experiments that mimic a transition from the original Noah LSM to the fully augmented version. The model shows transitional improvements in modeling runoff, soil moisture, snow, and skin temperature, despite considerable increase in computational time by the fully augmented Noah-MP version compared to the original Noah LSM. The dynamic vegetation model favorably captures seasonal and spatial variability of leaf area index and green vegetation fraction. We also conducted 36 ensemble experiments with 36 combinations of optional schemes for runoff, leaf dynamics, stomatal resistance, and the β factor. Runoff schemes play a dominant and different role in controlling soil moisture and its relationship with evapotranspiration compared to ecological processes such as the β factor, vegetation dynamics, and stomatal resistance. The 36-member ensemble mean of runoff performs better than any single member over the world's 50 largest river basins, suggesting a great potential of land-based ensemble simulations for climate prediction.

Citation: Yang, Z.-L., G.-Y. Niu, K. E. Mitchell, F. Chen, M. B. Ek, M. Barlage, L. Longuevergne, K. Manning, D. Niyogi, M. Tewari, and Y. Xia (2011), The community Noah land surface model with multiparameterization options (Noah-MP): 2. Evaluation over global river basins, *J. Geophys. Res.*, *116*, D12110, doi:10.1029/2010JD015140.

1. Introduction

[2] The Noah land surface model (LSM) has been used not only in short-term weather forecasting, but also in intraseasonal to interannual climate predictions and downscaling of global climate model (GCM) projections. Its coupling with Global Forecast System (GFS) for operational weather and climate predictions by the National Centers for Environmental Prediction (NCEP) requires testing the Noah LSM at a global scale and a longer time scale. Most of previous Noah testing efforts have been focused at local scales [e.g., *Chen et al.*, 1997] (hereinafter Chen97) or continental U.S. at a shorter time scale [*Ek et al.*, 2003; *Mitchell et al.*, 2004]. While *Niu et al.* [2011] describe the augmented Noah LSM with multiple parameterization options (Noah-MP) and the testing results at local scales and a shorter time scale, this second paper focuses on testing Noah-MP and a recent version of the Noah LSM (Noah V3) at a global scale. Across various climate zones, global-scale testing can reveal models' weaknesses and strengths that a local-scale testing cannot. For instance, many previous local- and regional-scale studies revealed that Noah V3 produces a shallower snowpack [*Ek et al.*, 2003; *Pan et al.*, 2003; *Mitchell et al.*, 2004; *Livneh et al.*, 2010]. But as we will show in section 3.4, Noah V3 does not always produce shallower snow everywhere. It simulates too much snow in high-latitude river basins from forming excessive frost on the snow surface. In addition, global-scale tests are more challenging than local- and regional-scale tests. Given constant model parameters (e.g.,

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0148-0227/11/2010JD015140