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SOIL SURFACE RUNOFF SCHEME FOR IMPROVING LAND-HYDROLOGY AND SURFACE FLUXES IN SIMPLE SiB (SSiB)

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1. INTRODUCTION

Evapotranspiration on land is hard to measure and difficult to simulate. On the scale of a GCM grid, there is large subgrid-scale variability of orography, soil moisture, and vegetation. Our hope is to be able to tune the biophysical constants of vegetation and soil parameters to get the most realistic space-averaged diurnal cycle of evaporation and its climatology. Field experiments such as FIFE, BOREAS, and LBA help a great deal in improving our evapotranspiration schemes. However, these improvements have to be matched with, and coupled to, consistent improvement in land-hydrology; otherwise, the runoff problems will intrinsically reflect on the soil moisture and evapotranspiration errors. Indeed, a realistic runoff simulation also ensures a reasonable evapotranspiration simulation provided the precipitation forcing is reliable.

We have been working on all of the above problems to improve the simulated hydrologic cycle. Through our participation in the evaluation and intercomparison of land-models under the behest of Global Soil Wetness Project (GSWP), we identified a few problems with Simple SiB (SSiB; Xue *et al.*, 1991) hydrology in regions of significant snowmelt. Sud and Mocko (1999) show that inclusion of a separate snowpack model, with its own energy budget and fluxes with the atmosphere aloft and soil beneath, helps to ameliorate some of the deficiencies of delayed snowmelt and excessive spring season runoff. Thus, much more realistic timing of meltwater generation was simulated with the new snowpack model in the subsequent GSWP re-evaluations using 2 years of ISLSCP Initiative I forcing data for 1987 and 1988. However, we noted an overcorrection of the low meltwater infiltration of SSiB. While the improvement in snowmelt timing was found everywhere, the snowmelt infiltration has became excessive in some regions, e.g., Lena river basin. This leads to much reduced runoff in many basins as compared to observations. We believe this is a consequence of neglect of the influence of subgrid-scale variations in orography that affects the production of surface runoff. We attempt to address the problem as follows.

2. RUNOFF AND OROGRAPHY

To solve the aforestated problem, we modified the SSiB model to allow for the influence of horizontal variations in orography on runoff. This is instituted by analyzing observations on river basins and at several latitude bands to determine how the lateral runoff varies as a function of subgrid-scale orography. We produced a global map of subgrid-scale variation of orography (Fig. 1) and immediately realized that regions of large variations of subgrid-scale orography had large runoff deficits. Consequently, we determined the hydrologic basin-scale runoff error as a function of variance of subgrid-scale

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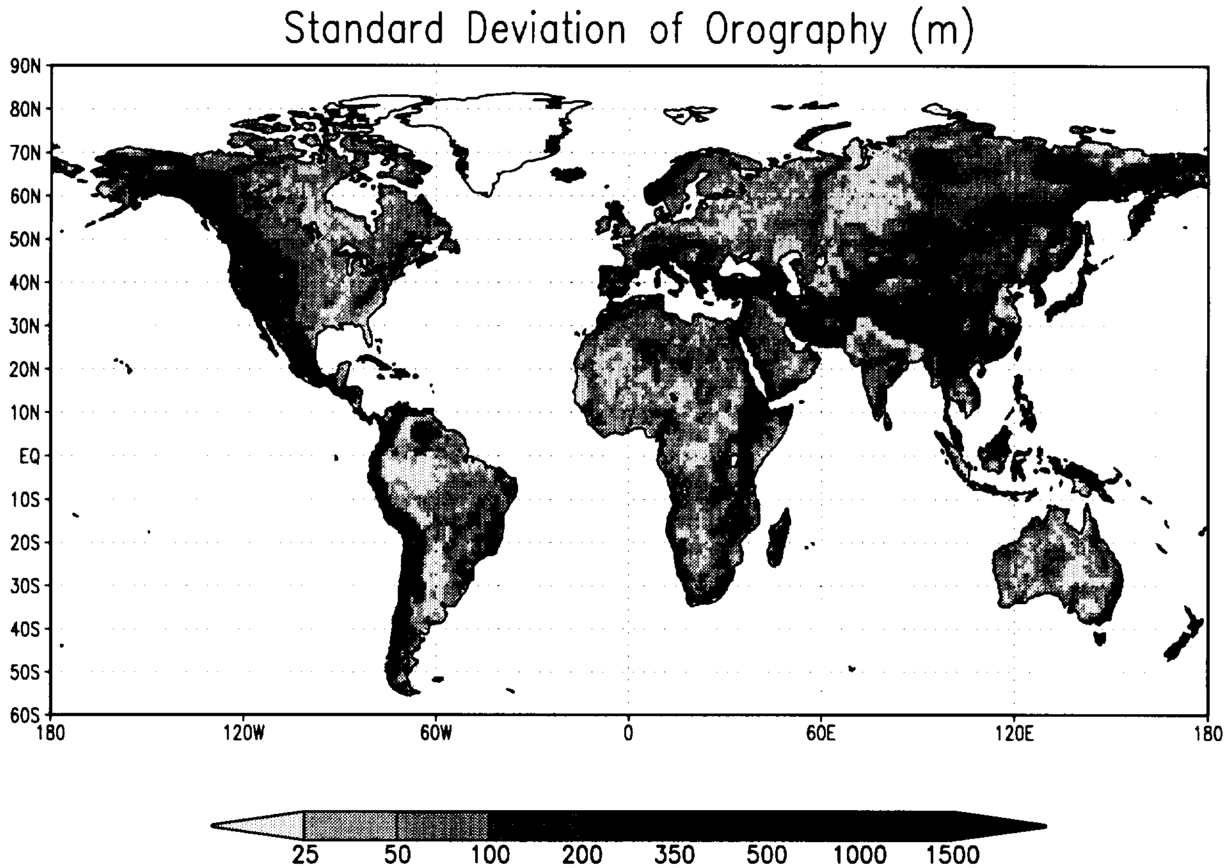

Figure 1: Standard Deviation of orography (m) on 1 deg. grid from Global 30 Arc Second Elevation Data produced by USGS.

orography on a 1^{O} x 1^{O} grid, and came up with an empirical relationship between orography and annual mean runoff errors (Fig. 2). We parameterize pre-infiltration runoff, R_o, by a simple relationship:

$$R_o = (\text{Snowmelt} + \text{Rain})\ \chi\ \left(\frac{\sigma}{\sigma_{max}}\right), \quad (1)$$

where functional χ represents runoff fraction of the available surface infiltration flux (Snowmelt + Rain) and σ is the standard deviation of orography within the cell. Clearly, χ is a function of normalized subgrid-scale variance of orography. A linear fit to the annual basin-scale runoff errors as a function of subgrid-scale orography and available infiltration gave an average slope of 2.197.

3. RESULTS

The new runoff scheme with the influence of orography was evaluated in GSWP. Fig. 3 shows that the modification increases the runoff in most of the basins of high-variance of orography (such as the Lena river basin, bottom panel), while its effect is minimal in regions with flat orography (such as the Volga river basin, top panel). The annual runoff amount in the Lena river basin has greatly increased, and additional flow is produced in the late summer and fall. For a true evaluation of flow timing, however, both the new snow model and old snow model with the effects of orography must be evaluated with a robust river routing model in conjunction with TRIP (Oki and Sud, 1998).

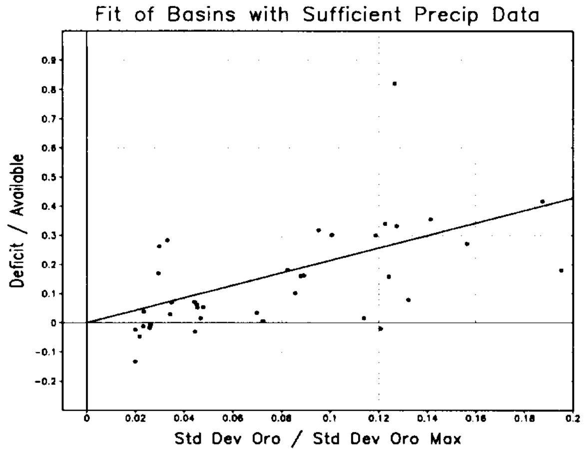

Figure 2: Least-squares fit of runoff deficit (observed minus modelled) to standard deviation of orography on an annual basis for river basins in 1987 and 1988.

Such a surface runoff scheme is currently being evaluated for implementation in SSiB with the new snow model. Further evaluation of the scheme will be conducted with the GSWP dataset for 1987-1988 as well as in the GEOS II GCM with SSiB. Preliminary results show that modified SSiB is expected to resolve the problem of too little runoff in regions of strong orography.

4. CONCLUSION

As evident from first principles, a suitable scheme for orographic runoff is likely to increase and hence improve the annual mean runoff in several basins, but there are intraseasonal runoff errors which are related to the physics of river flow and routing schemes. Those issues can only be resolved by combined improvement of river routing schemes and land hydrology. The question of better representation of variance of orography is also being examined. In the present context, we note that influence of subgrid-scale orography has beneficial effect on the annual mean runoff in a GCM.

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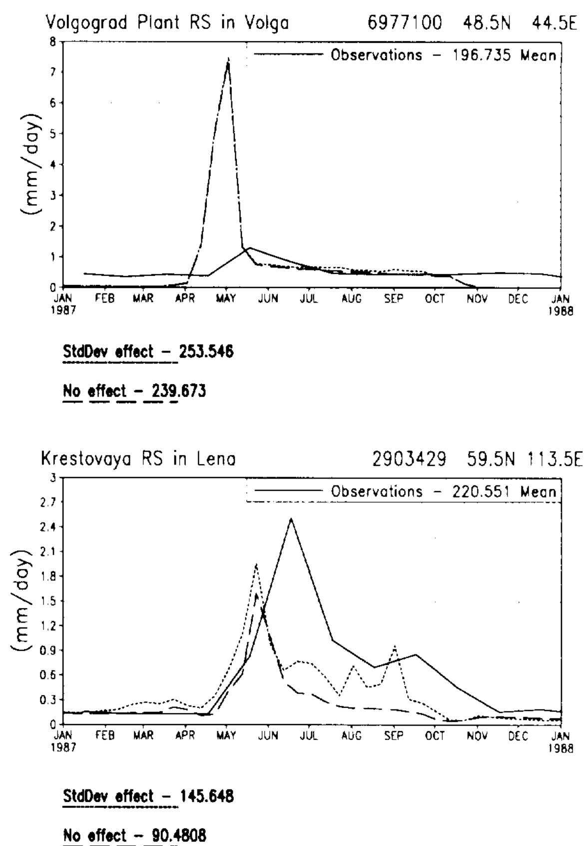

Figure 3: Runoff produced in the a] Volga river basin (top) and b] Lena river basin (bottom) for both the new snow model in SSiB (long dash) and the new snow model with effects of standard deviation of orography (short dash), along with observations (solid) of river flow taken at the locations indicated in the titles. Numbers are annual runoff in (mm/year).