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EXPLORE PARAMETER SENSITIVITIES AND MODEL CALIBRATION IN A LOCALLY COUPLED ENVIRONMENT

Yuqiong Liu[1]*, H. V. Gupta[1], S. Sorooshian[2], and L. A. Bastidas[3]
[1] University of Arizona, Tucson, Arizona
[2] University of California, Irvine, Irvine, California
[3] Utah State University, Logan, Utah

1. INTRODUCTION

As land surface modeling is moving from the offline mode to the coupled mode, it is also highly desirable to extend the offline calibration of land surface models to coupled applications. Sen et al. (2001) showed that the simulation of precipitation and air temperature with CCM3-BATS2 was significantly affected by applying optimal land-surface parameters from the offline calibration of the land surface model. However, to fully address the influence of the lack of land surface-atmosphere interactions on the results of PILPS-like offline calibration and evaluation experiments, it is necessary to extend parameter estimation for land surface models from offline modes to coupled modes. A desirable intermediate step could be the local-scale coupled action as proposed by the Global Land-Atmosphere Systems Study (GLASS) panel. A locally coupled Single Column Model (SCM) can serve this purpose and was chosen for sensitivity analysis and model calibration in this study.

2. MODELS AND DATA

In this study, we have been using the NCAR Single-column Community Climate Model (SCCM), which is a single grid column separated from the global model-Community Climate Model version 3(CCM3) and the land surface model coupled to it is the NCAR LSM. For comparison purposes, the offline LSM was also used to conduct some sensitivity analysis and calibration experiments.

Data used to drive the NCAR-SCCM are from an IOP (Intensive Operation Period) data set over the Southern Great Plains (SGP) site of the DOE's Atmospheric Radiation Measurement (ARM) program. This IOP data set extends from July 18, 1995 to August 4, 1995 at 20-min intervals and experiences various summer weather conditions, including several intensive precipitation periods.

3. METHODOLOGY

In this study, the simple one-at-a-time sensitivity analysis approach was first used to identify 32 land-surface parameters (information available upon request), which appeared to be more or less sensitive in the locally coupled environment. Then, a multi-objective approach based on MOGSA (Bastidas et al. 1998) was used to explore the parameter sensitivities from both multi- and single-objective point of views, with eight atmospheric parameters (Table 1) also involved. The Root Mean Square (RMS) error function was used as the objective function for land surface fluxes or variables (latent heat LH, sensible heat SH, ground temperature T_g) and atmospheric forcing variables (precipitation, net downward radiation R_{net}, air temperature T_{air}). The multi-objective sensitivity analysis experiment allowed to further filter out some parameters which are not sufficiently sensitive and were thus omitted in the subsequent model calibration experiments.

Table 1 Atmospheric parameters for sensitivity analysis

No	Name	Description
1	capelmt	Threshold value of CAPE for deep convection [J/kg]
2	tau	Adjustment time scale for CAPE consumption [sec]
3	fmax	Maximum fractional entrainment rate of updrafts
4	alfa	Proportionality factor for downdraft mass flux profile
5	rhminl	Minimum relative humidity for low cloud formation
6	rhminh	Minimum relative humidity for mid-level and high cloud formation
7	Cconv	Coefficient for calculating column convective cloud
8	rhccn	Reduction on "rhminl" over CCN rich land areas

Different calibration cases (Table 2) were designed to examine how the land surface-atmosphere interactions affect model calibrations in a locally coupled environment.

Table 2 A comparison of different calibration cases

Case	Objectives	Land par. (θ)	Atmo. Par. (ϕ)
DEF	N/A	Default	Default
Single-step, coupled calibration cases			
A1	Land only	Calibrated	Default
A2	Land only	Default	Calibrated
A3	Land only	Calibrated	Calibrated
B3	Atmo. only		
C3	Both		
Step-wise calibration cases			
A4	Land only	$\theta^{lsm}_{offline}$ **	Calibrated
B4	Atmo. only		
C4	Both		

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* *Corresponding author address*: Yuqiong Liu, Univ. of Arizona, Dept. of Hydrology and Water Resources, Tucson, AZ 85721; e-mail: yqliu@hwr.arizona.edu

** An optimum land parameter set from offline calibration

In Table 2, "*single-step, coupled calibration cases*" refer to those cases where land surface and atmospheric parameters are optimized simultaneously in the locally coupled environment, while "*step-wise, calibration cases*" refer to cases where land surface parameters and atmospheric parameters are successively optimized in offline and coupled modes, respectively. In addition, to explore the importance of precipitation and net downward surface radiation in the coupled environment, cases A3, B3, C3, were re-conducted in a partially decoupled environment, where observations of these two quantities instead of model simulations were used to drive the land surface part of the model. These cases are referred to as partially decoupled cases (A5, B5, C5) in this paper.

4. RESULTS FROM SENSITIVITY ANALYSIS

The purpose of sensitivity analysis is two-fold: 1) to obtain a better understanding of model parameter sensitivities in a locally coupled environment; and 2) to reduce the dimensionality of the parameter space for subsequent calibration experiments. Figure 4.1 shows the global and single-objective sensitivities of the 12 vegetation parameters and 4 initial soil moisture conditions for 3 different cases: 1) off-line LSM with 32 land-surface parameters; 2) coupled SCCM with 32 land-surface parameters; and 3) coupled SCCM with 32 land-surface parameters and 8 atmospheric parameters, while the sensitivities of the 16 soil parameters are shown in Fig. 4.2. For case 3, the sensitivities of atmospheric parameters are shown in Figure 4.3. In these figures, if a bar corresponding to a parameter is above the solid line (i.e., the KS probability is less than 0.5), we consider the parameter to be sensitive.

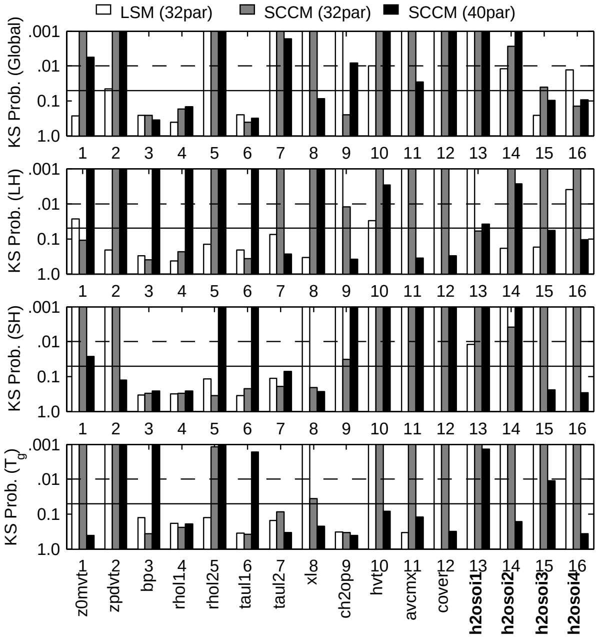

Fig. 4.1 Sensitivities of vegetation parameters and initial soil moisture conditions

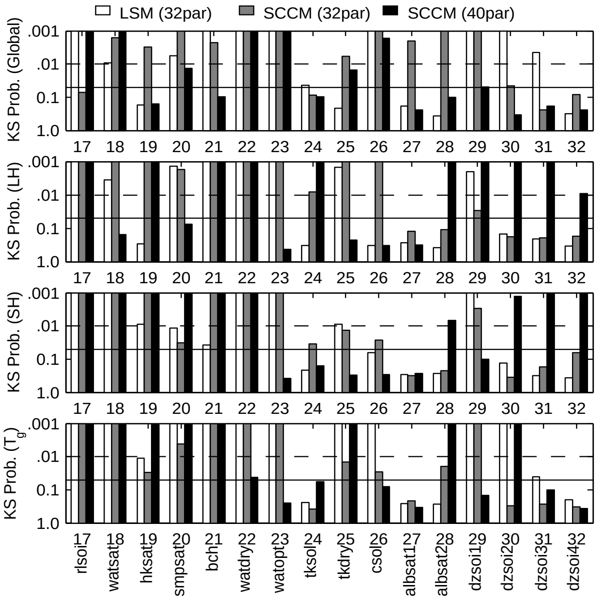

Fig. 4.2 Sensitivities of soil parameters

As can be noted from Figs 4.1 and 4.2, the sensitivities of parameters differ from case to case. A comparison of case 1 with cases 2 and 3 can infer the influences of the land-atmosphere interactions on the parameter sensitivities, while the implications of the interactions between land and atmospheric parameters can be inferred by comparing cases 1 and 2 with case 3. From the multi-objective point of view, there are 22, 23, and 18 sensitive land-surface parameters in cases 1, 2, and 3, respectively. In addition, Fig 4.3 shows that most of the 8 atmospheric parameters are globally sensitive; LH is sensitive to all the 8 atmospheric parameters; and SH only has three sensitive atmospheric parameters.

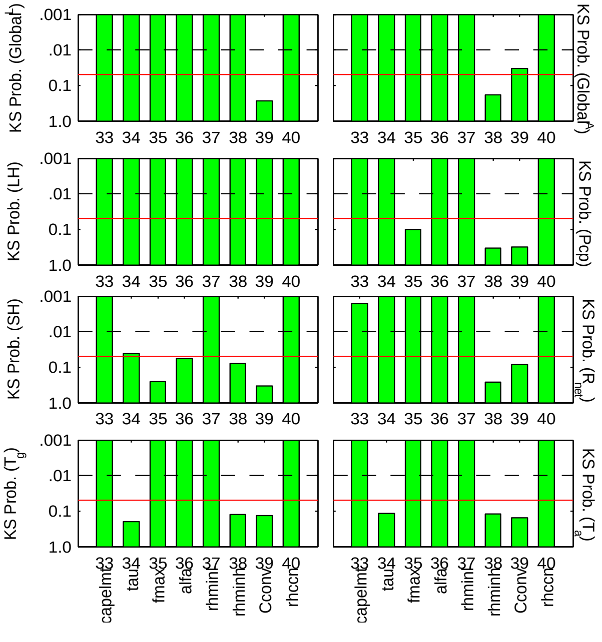

Fig. 4.3 Sensitivities of atmospheric parameters

5. RESULTS FROM MODEL CALIBRATION

Shown in Fig. 5.1 are the objective function values (normalized by the default RMS errors) from different calibration cases as described in Section 3.

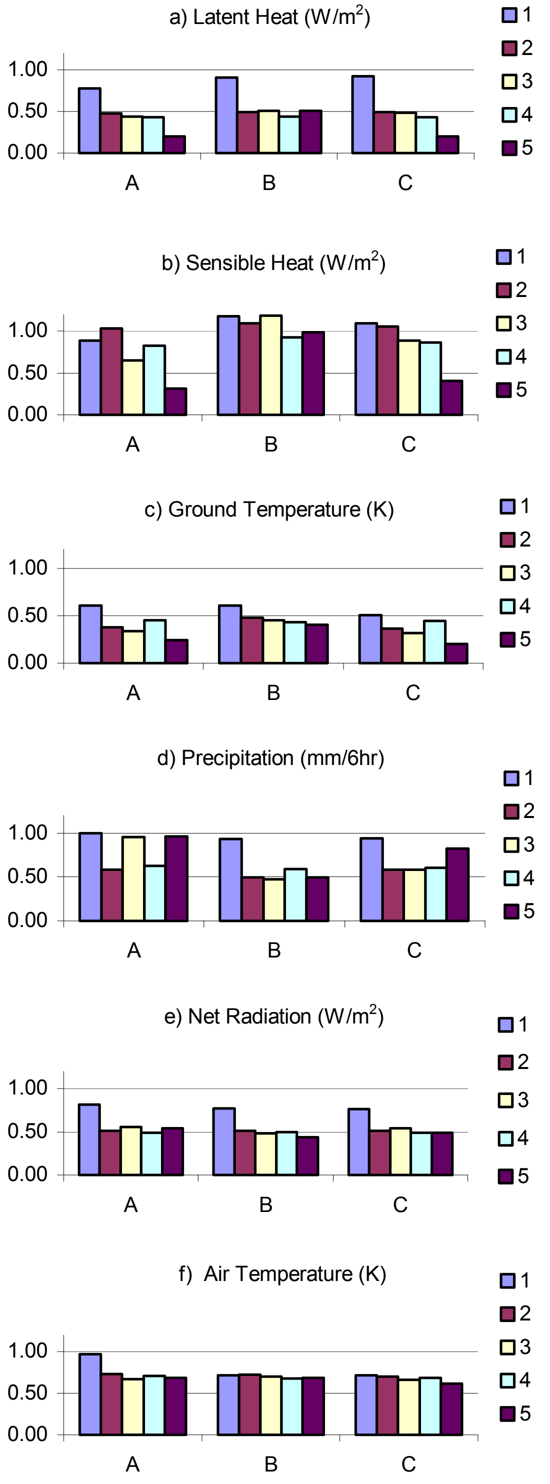

Fig. 5.1 RMSE of different variables (LH, SH, T_g, Precip., R_{net}, and T_{air}) for different cases

Generally speaking, the objective function values have been effectively reduced in almost all cases, except for a few cases (A2, B1-3, C1, and C2) where the error of sensible heat appears to be higher than in the default case. Cases A1, B1, and C1, where only land-surface parameters are involved in the calibration process, generally have the highest error for all the 6 fluxes/variables, indicating the importance of including atmospheric parameters into the calibration process in the coupled environment. For latent heat, ground temperature, and net radiation, the errors have been reduced by 50% or more (except in cases A1, B1, and C1), while the calibration effects for the other three variables (sensible heat, precipitation, and air temperature) appear to be less encouraging, especially for sensible heat. The step-wise cases (A4, B4, and C4) have achieved equivalent results, if not better than, as in the corresponding single-step cases, thus more desirable in that computational resources can be significantly reduced in step-wise cases. In addition, in the partially decoupled environment (cases A5, B5, and C5), the best calibration results have been achieved for the three land-surface fluxes/variables (latent heat, sensible heat, and ground temperature); even for the two decoupled variables (precipitation and net radiation), the errors are greatly reduced compared to the default case. This indicates the significant role that precipitation and net radiation play in the two-way interactions between the land surface and the atmosphere.

6. DISCUSSION AND CONCLUSIONS

This study sheds new lights on the importance of including the land surface-atmosphere interactions in parameter estimation for land surface models. The multi-objective sensitivity analysis shows that, as expected, the land surface-atmosphere interactions could have significant influences on the model parameter sensitivities, thus greatly affecting parameter estimation in the locally coupled environment. The calibration results obtained in this study indicate that it is crucial to include both land-surface and atmospheric parameters in the calibration of a coupled land surface model and precipitation and radiation are two important atmospheric forcing variables which dominate the two-way interactions within the coupled system.

REFERENCES

Bastidas, L. A., H. V. Gupta, S. Sorooshian, W. J. Shuttleworth, and Z. L. Yang, 1999: Sensitivity analysis of a land surface scheme using mutli-criteria methods. *J. Geophys. Res.*, **104**(D16), 19,481-19,490.

Sen, O. L., L. A. Bastidas, W. J. Shuttleworth, Z. L. Yang, H. V. Gupta, and S. Sorooshian, 2001: Impact of field calibrated vegetation parameters on GCM climate simulations, *Quart. J. Roy. Meteor. Soc.*, 127(574), 1,199-1,224.

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