Principal Investigator: Yang, Zong-Liang
Organization: U of Arizona
Title: SGER: Parameterization of the Topographic Control on the Runoff Production Coupled to the CCSM Core Single-Column Land Model

Project Participants

Senior Personnel

Name: Yang, Zong-Liang
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Niu, Guo-Yue
Worked for more than 160 Hours: Yes
Contribution to Project:
Dr. Niu was involved in the experimental design, the execution of experiments, and the plotting of results. He was provided with three months support from this project.

Graduate Student

Undergraduate Student

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

We have been working closely with the CLM group, especially, Gordon Bonan and his group members in NCAR, and Robert E. Dickinson and his group members in GaTech.

Activities and Findings

Research and Education Activities: (See PDF version submitted by PI at the end of the report)

Findings: (See PDF version submitted by PI at the end of the report)

Training and Development:
This project helped Dr. Niu gain invaluable experience understanding TOPMODEL concepts and using DEMS dataset. Although the runoff model developed at this stage has proved successful in improving the simulations, we hope to write a new NSF proposal that will specifically address the problems that has been identified in this exploring project.
**Outreach Activities:**
In addition to publications and presentations of our results, we have documented our model both in the code and in the users' guide. These will be provided to a broad community that uses CLM.

---

**Journal Publications**


---

**Books or Other One-time Publications**

---

**Web/Internet Site**

---

**Other Specific Products**

---

**Contributions within Discipline:**
The runoff model that we have developed has been linked to the NCAR CCSM which will be used by the climate community all over the world.

---

**Contributions to Other Disciplines:**

---

**Contributions to Human Resource Development:**

---

**Contributions to Resources for Research and Education:**

---

**Contributions Beyond Science and Engineering:**

---

**Categories for which nothing is reported:**

Organizational Partners
Any Book
Any Web/Internet Site
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Human Resource Development
Contributions: To Any Resources for Research and Education
Contributions: To Any Beyond Science and Engineering
The goal of this project is to develop a new runoff parameterization scheme accounting for the topographic control on the subgrid soil moisture distribution and runoff generation for the NCAR Community Land Model (CLM).

This goal has been successfully achieved. A highly simplified version of the topography-based runoff model (TOPMODEL) was tested with the Red Arkansas River dataset (Yang et al., 2000), and was then coupled into CCM3/CLM (Zeng et al., 2001; Bonan et al., 2001). At an experimental mode, we have also tested a full version of the TOPMODEL with the Red Arkansas River dataset and the Torne/Kalix River Basin dataset (Yang et al., 2000; Yang and Niu, 2002; Niu and Yang, 2002).

In the first stage, the highly simplified version incorporates an important concept of TOPMODEL that assumes the exponential decay of the saturated hydraulic conductivity. The saturated fraction of a GCM grid box is parameterized as a function of water table depth. This version has been tested with the Red Arkansas River dataset (Yang et al., 2000). The results have shown a significant improvement, especially in the total amount of runoff, upon the former versions of CLM. This version was coupled with CCM3 and the results were analyzed by Zeng et al. (2001) and Bonan et al. (2001). The results showed that it significantly improved the simulation of the annual cycle of runoff compared to the NCAR LSM version 1.0.

In the second stage, the full version of TOPMODEL has been tested with the Red Arkansas River Basin and the Torne/Kalix River Basin Datasets, which were used in PILPS 2c and 2e, respectively. In addition, we have tested sensitivities of this version to some key parameters such as saturated hydraulic conductivity decay factor, anisotropic factor that differentiates saturated hydraulic conductivity in lateral and vertical directions, topographic index computed from different resolution of DEMs, and the parameterization of frozen soil and lakes (surface water storage). Three new findings are in order:

(1) The effects of frozen soil (Yang and Niu, 2002)

The frozen soil can reduce the soil permeability and hence the timing and intensity of runoff. The default version of the CLM assumes the freezing point at 0°C. This assumption may not be valid because the dissolved salts in the soil water can make the freezing point lower than 0°C. The streamflow is more accurately simulated when the freezing point is changed from 0°C to -2°C.
(2) The effects of the saturated hydraulic conductivity decaying factor (Niu and Yang, 2002a)

The decaying factor is crucial for simulating the baseflow, i.e., the recession curve of a hydrograph. It affects significantly the vertical distribution of saturated hydraulic conductivity and soil moisture. A larger decaying factor leads to a faster decay of hydraulic conductivity with depth and hence a smaller bottom drainage, which, in turn, produces a shallower water table and faster response of surface runoff.

(3) The effects of topographic index computed from different resolution of DEMs (Niu and Yang, 2002b)

The topographic indexes $\ln(a / \tan \beta)$ computed from coarser resolution of DEMs are larger than those from finer resolution due to the larger contribution area ($\ln(a)$) and smaller slope values ($\ln(\tan \beta)$) in the coarser resolution. This leads to a reduced topographic control on baseflow productions which are proportional to $e^{-\lambda}$, where $\lambda$ is the mean value of the topographic index of a grid box. This reduction is mainly due to the underestimates of slope values.

This work was funded by NSF fund ATM-0095094.

References:


The goal of this project is to develop a new runoff parameterization scheme accounting for the topographic control on the subgrid soil moisture distribution and runoff generation for the NCAR Community Land Model (CLM).

This goal has been successfully achieved. A highly simplified version of the topography-based runoff model (TOPMODEL) was developed and incorporated into CLM. The new CLM model was tested with the Red Arkansas River dataset (Yang et al., 2000), and was then coupled into the NCAR CCM3 (Zeng et al., 2001; Bonan et al., 2001). At an experimental mode, we have also tested a full version of the TOPMODEL with the Red Arkansas River dataset and the Torne/Kalix River Basin dataset (Yang et al., 2000; Yang and Niu, 2002; Niu and Yang, 2002).

In the first stage, the highly simplified version incorporates an important concept of TOPMODEL that assumes the exponential decay of the saturated hydraulic conductivity. The saturated fraction of a GCM grid box is parameterized as a function of water table depth. This version has been tested with the Red Arkansas River dataset (Yang et al., 2000). The results have shown a significant improvement, especially in the total amount of runoff, upon the former versions of CLM. This version was coupled with CCM3 and the results were analyzed by Zeng et al. (2001) and Bonan et al. (2001). The results showed that it significantly improved the simulation of the annual cycle of runoff compared to the NCAR LSM version 1.0.

In the second stage, the full version of TOPMODEL has been tested with the Red Arkansas River Basin and the Torne/Kalix River Basin Datasets, which were used in PILPS 2c and 2e, respectively. In addition, we have tested sensitivities of this version to some key parameters such as saturated hydraulic conductivity decay factor, anisotropic factor that differentiates saturated hydraulic conductivity in lateral and vertical directions, topographic index computed from different resolution of DEMs, and the parameterization of frozen soil and lakes (surface water storage).
The new runoff scheme has been incorporated into the version 2 of CLM, hereafter CLM2. This new land surface parameterization has been linked with the NCAR CCM3. Bonan et al. (2001) have compared the results from CCM3/CLM2 with CCM3/LSM1, where LSM1 is an earlier land surface module for CCM3. The annual cycle of runoff is greatly improved in CCM3/CLM2, especially in arctic and boreal regions where the model has low runoff in cold seasons when the soil is frozen and high runoff during the snow melt season.

In addition, an exploratory study was carried out in the off-line mode in order to understand the sensitivities of CLM to selected key parameters. Three new findings are in order:

(1) The effects of frozen soil (Yang and Niu, 2002)

The frozen soil can reduce the soil permeability and hence the timing and intensity of runoff. The default version of the CLM assumes the freezing point at 0°C. This assumption may not be valid because the dissolved salts in the soil water can make the freezing point lower than 0°C. The streamflow is more accurately simulated when the freezing point is changed from 0°C to -2°C.

(2) The effects of the saturated hydraulic conductivity decaying factor (Niu and Yang, 2002a)

The decaying factor is crucial for simulating the baseflow, i.e., the recession curve of a hydrograph. It affects significantly the vertical distribution of saturated hydraulic conductivity and soil moisture. A larger decaying factor leads to a faster decay of hydraulic conductivity with depth and hence a smaller bottom drainage, which, in turn, produces a shallower water table and faster response of surface runoff.

(3) The effects of topographic index computed from different resolution of DEMs (Niu and Yang, 2002b)

The topographic indexes \( \ln(a/\tan \beta) \) computed from coarser resolution of DEMs are greater than those from finer resolution due to the larger contribution area \( \ln(a) \) and smaller slope values \( \ln(\tan \beta) \) in the coarser resolution. This leads to a reduced topographic control on baseflow productions which are proportional to \( e^{-\lambda} \), where \( \lambda \) is the mean value of the topographic index of a grid box. This reduction is mainly due to the underestimates of slope values.