Global testing and sensitivity analyses of VIC hydrologic parameterizations in CLM

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Methodology

Model
- CLM4.5 Science Branch Tag: VIC
- VIC hydrology has been implemented into the Tag

Methodology
- Three VIC parameters were selected for sensitivity analyses:
  - $b$, $D_{\text{max}}$, $W_s$
- The uncertainty quantification framework for CLM developed in Hou et al. (2012) were used for a global sensitivity analysis
- GRDC annual runoff (climatology) were used as the benchmark dataset
- CLM was run globally at 0.9x1.25 degree using the I2000 case
Merging of CLM4 and VIC
Comparison between runoff parameterizations

CLM4

- Physically based

- Assumptions from TOPMODEL:
  - High-resolution topographic data are available;
  - Subsurface flow is topographic driven.
  - A quasi-steady state to approximate saturated zone dynamics;
  - Recharge to ground water is spatially uniform;

These assumptions are invalid, e.g., over flat terrain or arid regions

VIC

- Conceptual

- Limited assumptions:
  - land surface, and therefore surface runoff generation, is heterogeneous;
  - Subsurface flow is a nonlinear function of deep-layer water availability

- Calibration of parameters are recommended
UQ framework designed for CLM

Parameterization - candidate parameters of interest

Prior information (mean, variance, bounds)

Entropy method
Minimum Relative Entropy (MRE)

Closed-form Prior probability density functions (pdfs)

Quasi Monte Carlo sampling

Realizations of parameter sets

CLM forward modeling

Output responses:
Total runoff

Output statistics:
1. Natural variability of output responses
2. Propagation of uncertainty of input parameters

Multi-variate generalized linear model analysis and significance statistical tests:
1. Rank of significance of input parameters
2. Relationships between outputs and inputs

Selected parameters

Hou et al., 2012
Huang et al., 2013
VIC parameter values from GLDAS

\[ \begin{align*}
D_{\text{max}} & \quad b & \quad W_s \\
\text{Mean} & \quad 25.14 & \quad 0.13 & \quad 0.75 \\
\text{Max} & \quad 49.94 & \quad 0.99 & \quad 1.00 \\
\text{Min} & \quad 0.11 & \quad 0.00 & \quad 0.50 \\
\text{STD} & \quad 12.44 & \quad 0.13 & \quad ----- \\
\end{align*} \]
Generating samples of VIC parameters

- Probability density functions of the three selected parameters

- 64 samples for CLM global simulations

![Probability space and Parameter space diagrams](image-url)
Calibration against the GRDC total runoff field (climatology)
Calibrated VIC parameter values
Seasonal differences in runoff

(a) CLM - GRDC

(b) CLMVIC$_{opt}$ - GRDC

(c) CLM - GRDC

(d) CLMVIC$_{opt}$ - GRDC
Simulations outside of the calibration period
Beyond water: GPP simulations from NASA-MsTMIP

Relative difference: -20.4% (CLM4VIC – CLM4)

MODIS: 112 Pg C/year
CLMVIC: 114 Pg C/year
CLM4.0: 143 Pg C/year

Poster:
Impacts of hydrologic parameterizations on global terrestrial carbon cycle dynamics in the Community Land Model
Summary and future work

- VIC runoff parameterizations have been implemented into the CLM4.5 science branch; Selected VIC parameters were calibrated under a UQ framework against GRDC total runoff field;
- In general, calibration could reduce biases in annual runoff simulations for both the calibration and simulation periods.
- However, the calibration strategy presented here is oversimplified. We will investigated parameter uncertainties, transferability, and UQ strategy separately in the near future;
- Both structural and parameter uncertainties in the runoff generation schemes can lead to large uncertainty in carbon modeling, highlighting the significant interactions among the water, energy, and carbon cycles and the need for improving hydrologic parameterizations in land surface models.
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