Impact of the hard-coded parameters on the hydrologic and atmospheric fluxes of the land surface model Noah-MP

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1. Motivation

Land surface models incorporate a large number of processes containing a number of parameters that can be specified by the user. Land surface models may have, however, process descriptions that contain fixed, hard-coded numbers in the computer code. We identified 139 hard-coded values in all Noah-MP process options, which restrict the model's agility during parameter estimation. We performed a Sobol' global sensitivity analysis of Noah-MP for a specific set of process options with 42 standard parameters and 75 hard-coded parameters. The sensitivities of the hydrologic and atmospheric output fluxes were evaluated [2].

2. Methods

We quantified parameter sensitivies of Noah-MP in three steps.

All parameters (139 + 71) → 1. → Active & inform. para. (75 + 42) → 2. → Sobol' index $S_i(x, y, t)$ → 3. → Av. Sobol' index $< S_i >_{x,y,t}$

1. **Identification of active and informative parameters**
   We applied the sequential screening approach introduced by Cuntz et al. [1] to identify non-informative parameters (based on elementary effects).
   Computational costs: $10N_{\text{all}} \approx 2100$ model runs
2. **Sensitivity of active and informative parameters**
   The main and total Sobol' index were determined using the method described by Cuntz et al. [1].
   Computational costs: $2000N_{\text{inf}} \approx 80,000$ model runs
3. **Aggregating spatio-temporal sensitivities**
   The time and space dependent Sobol' indexes were arithmetically averaged (discharge outputs) [2],

$$\overline{S_i} = \frac{1}{T}\sum_{t=1}^{T} S_i(t) = \frac{1}{T}\sum_{t=1}^{T} \frac{V_i(t)}{V(t)},$$

   or variance weighted averaged (atmospheric fluxes) [2],

$$\overline{S_i} = \frac{\sum_{t=1}^{T} V(t)S_i(t)}{\sum_{t=1}^{T} V(t)} = \frac{\sum_{t=1}^{T} V_i(t)}{\sum_{t=1}^{T} V(t)}.$$

   Computational costs: 0 model runs

3. Experimental Setup

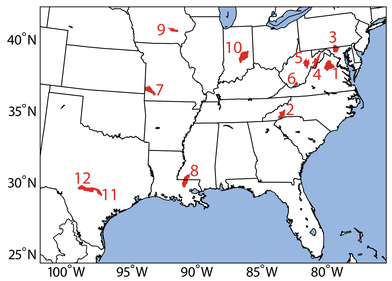

Fig. 1: Location of 12 considered MOPEX catchments within continental United States

These sensitivities were evaluated at twelve catchments of the Eastern United States with very different hydro-meteorological regimes.

- Meteorological forcings: NLDAS-2
- Static data: LDAS
- Spatial resolution: 0.125°
- Simulation period: 1979 to 1999 (first five years are spin-up)

4. Sensitivities for South Branch Potomac

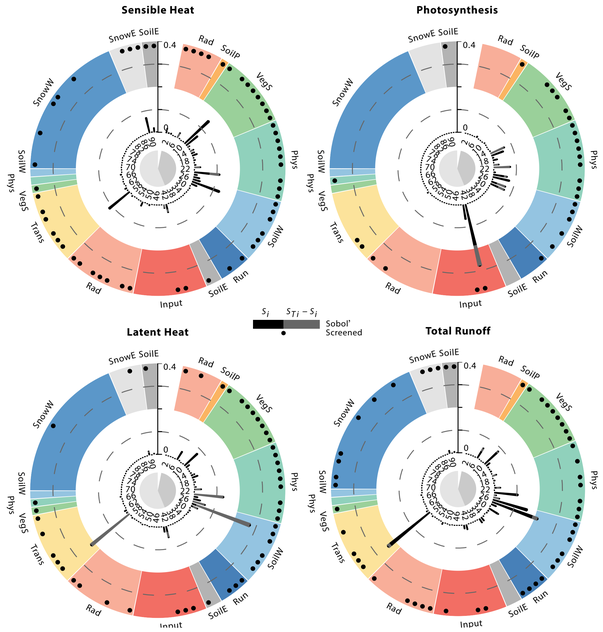

Fig. 2: Stacked bar charts of mean first-order and total-order Sobol' indexes Si and STi of standard and hard-coded parameters of the output fluxes sensible heat, photosynthesis, latent heat, and total runoff at the catchment South Branch Potomac. The lower gray bars of the stacks are Si and total stacks are STi. Only parameters with a filled square on top of the radius have Sobol' indexes. Colored sections are parameter categories.

Noah-MP's hydrologic output fluxes are sensitive to two thirds of its standard parameters. The most sensitive parameter is, however, a hard-coded value in the formulation of soil surface resistance for evaporation.

5. Sensitivities for all Catchments

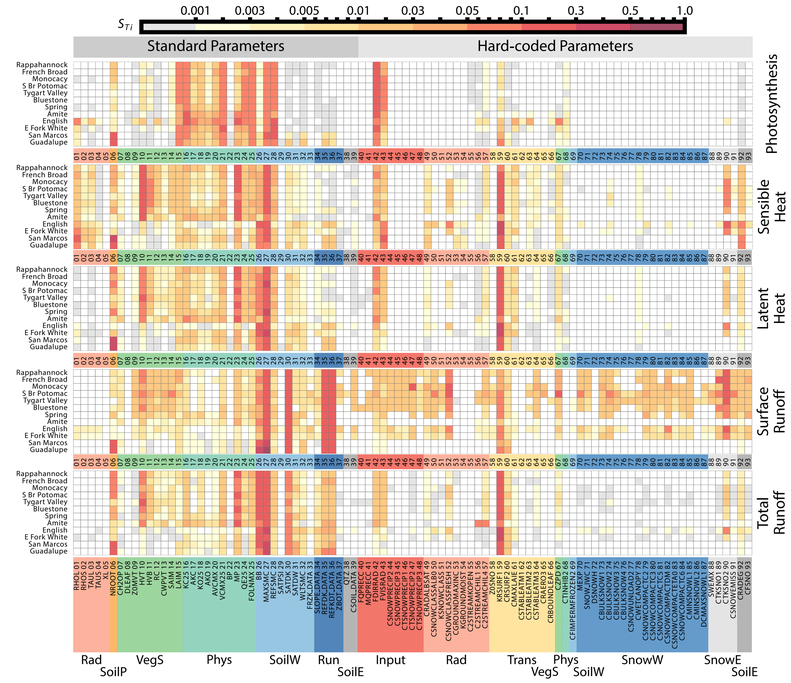

Fig. 3: Total-order Sobol' indexes STi of standard and hard-coded parameters of the output fluxes photosynthesis, sensible heat, latent heat, surface runoff, and total runoff at all 12 MOPEX catchments. Sobol' indexes are variance-weighted averages in time for photosynthesis, sensible heat, and latent heat, and plain averages for surface runoff, and total runoff. Empty cells are parameters that were filtered out during initial parameter screening and no Sobol' index was calculated. Colored sections underlying parameter numbers and names are parameter categories.

- Latent heat and total runoff show very similar sensitivities because of their tight coupling via the water balance.
- Latent heat and total runoff are sensitive to both, plant and soil parameters. Calibrating only soil parameters, for example, limits the ability to derive realistic model parameters.
- Sensible and latent heat exhibit almost the same sensitivities.
- Sensitivities of photosynthesis are different from those of latent heat (more similar to transpiration).
- Surface runoff is sensitive to almost all hard-coded parameters, but total runoff is not. Hydrologic signatures might be needed to extract the signal of surface runoff from total runoff.
- The formulation of evaporation seems to be oversensitive to a single parameter (KRSURF1 - 59).

Overall, we recommend to include the most sensitive hard-coded model parameters that were exposed in this study when calibrating Noah-MP [2].

[1] Cuntz, M., Mai, J., Zink, M., Thober, S., Kumar, R., Schäfer, D., et al. (2015). Computationally inexpensive identification of noninformative model parameters by sequential screening. WRR, 51(8), 6417–6441.

[2] Cuntz, M., Mai, J., Samaniego, L., Clark, M. P., Wulfmeyer, V., Branch, O., et al. (2016). The impact of standard and hard-coded parameters on the hydrologic fluxes in the Noah-MP land surface model. JGR: Atmospheres, 1–25.

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