Sensitivity Analysis of the Land Surface Model Noah-MP for Different Output Fluxes in 12 Distinct Catchments

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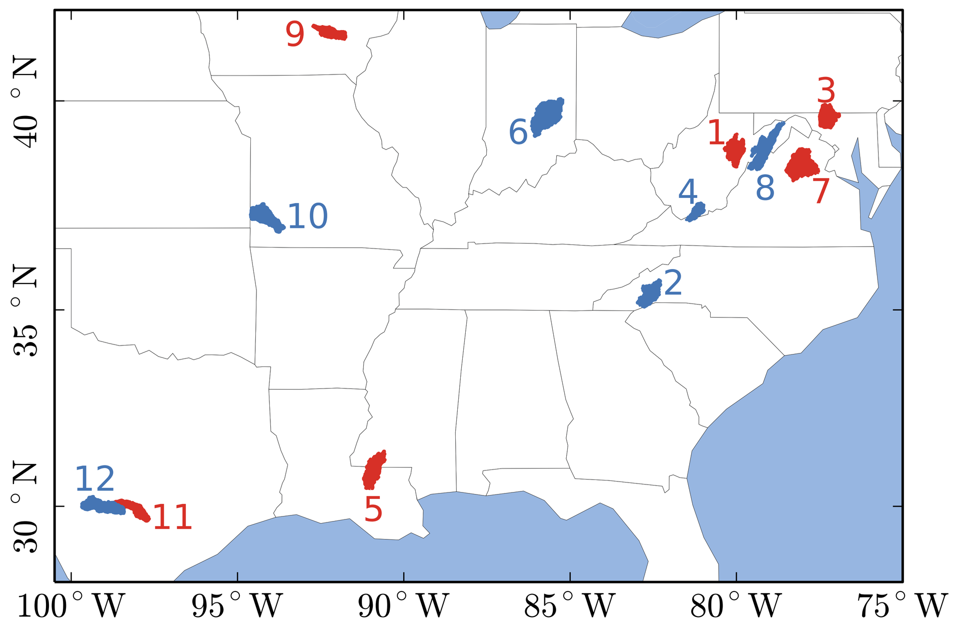
1. Motivation

Land Surface Models (LSMs) use a plenitude of process descriptions to represent the carbon, energy and water cycles. They are highly complex and computationally expensive. Practitioners, however, are often only interested in specific parts of the model such as latent heat or surface runoff. In model applications like parameter estimation, the most important parameters are then chosen by experience or expert knowledge. Hydrologists interested in surface runoff therefore choose mostly soil parameters while biogeochemists focus on carbon fluxes and hence on vegetation parameters. However, this might neglect parameters that are important, for example, through strong interactions with the parameters chosen. Additionally, supposedly unimportant parameters are often fixed (i.e., hard-coded) during model development. However, these might be highly relevant during model calibration but remain normally undetected.

2. Study Area

Noah-MP is applied in 12 MOPEX catchments. Meterological forcings are obtained from NLDAS-2 and static data from LDAS. The spatial resolution is 0.125° and the simulation period is from 1979 to 1999 with the first years as spin-up. Additional catchment characteristics are given in the following table.



No	Name	Mean Rainfall [mm]	Mean Runoff [mm]	Runoff Coefficient [-]	Mean Snow [mm]	Mean Winter Temperature [°C]	Dominant Land Cover [-]
1	Tygart Valley River	1198	735	0.61	1901	-0.3	Dec BdLf For
2	French Broad	1413	800	0.56	902	3.6	Mixed Forest
3	Monocacy River	1050	420	0.40	1737	1.3	Dec BdLf For
4	Bluestone River	1036	416	0.40	798	2.0	Dec BdLf For
5	Amite River	1563	609	0.38	25	11.2	Evg NdLf For
6	East Fork White River	1013	377	0.37	679	-0.5	Grassland
7	Rappahannock River	1037	377	0.36	733	3.0	Mixed Forest
8	**South Branch Pot.**	**1055**	**341**	**0.32**	**2582**	**0.3**	**Dec BdLf For**
9	**English River**	**900**	**269**	**0.29**	**1776**	**-2.9**	**Grassland**
10	Spring River	1075	298	0.27	377	3.0	Dec BdLf For
11	San Marcos River	825	179	0.21	4	11.2	Grassland
12	**Guadalupe**	**763**	**116**	**0.15**	**7**	**10.1**	**Veg Mosaic**

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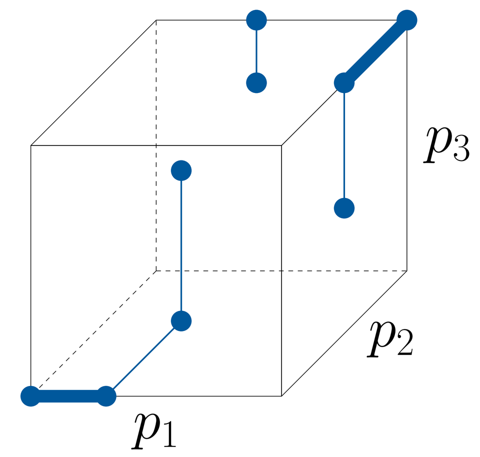
[1] M. Cuntz, J. Mai *et al.*, "Computationally inexpensive identification of non-informative model parameters by sequential screening," Jan 2015, submitted to WRR.

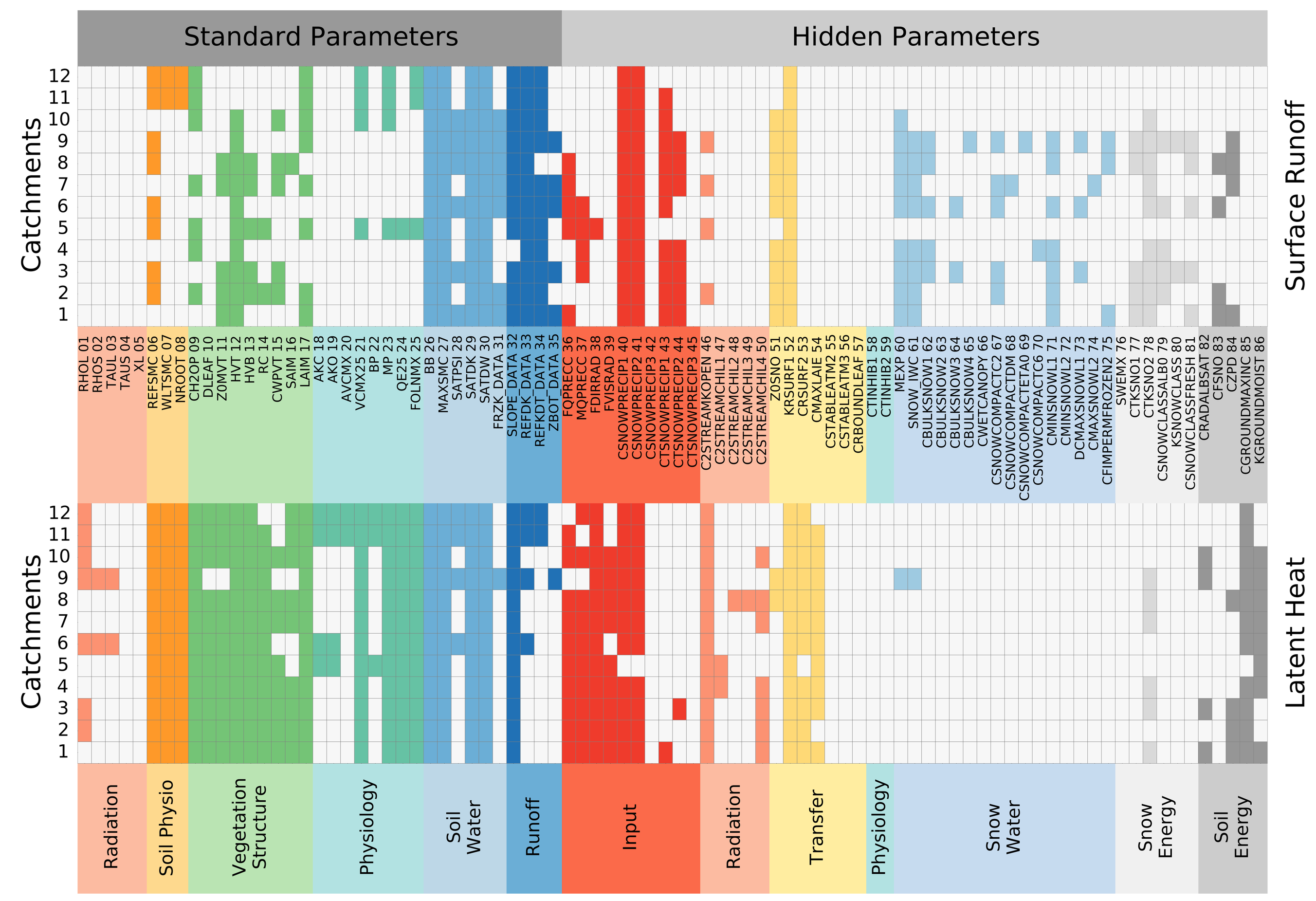
[2] M. Göhler, J. Mai, and M. Cuntz, "Use of eigendecomposition in a parameter sensitivity analysis of the Community Land Model," *JGR*, vol. 118, pp. 904–921, 2013.

3. Methods

The code was scanned for hard-coded values that are termed hidden parameters. 146 such numbers were found in all processes of Noah-MP but independent of vegetation or soil type. These parameters are in addition to the 93 standard parameters of Noah-MP. 38 standard and 80 hidden parameters remained in the analysis when the specific options of Noah-MP were chosen. Informative parameters were screened for different model outputs[1]: surface runoff, underground runoff, latent heat, and transpiration. Sobol' sensitivity analyses were performed on the parameters identified. Per basin and output flux on average 1,300 model runs for the screening and 75,000 model runs for the Sobol' analysis were required.



4. Parameter Screening

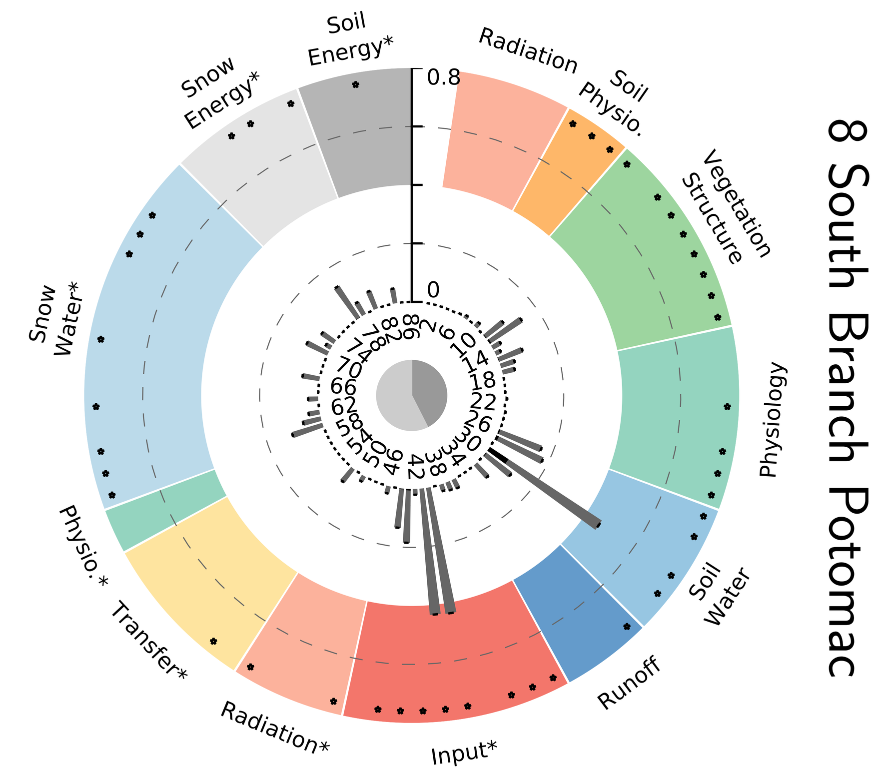


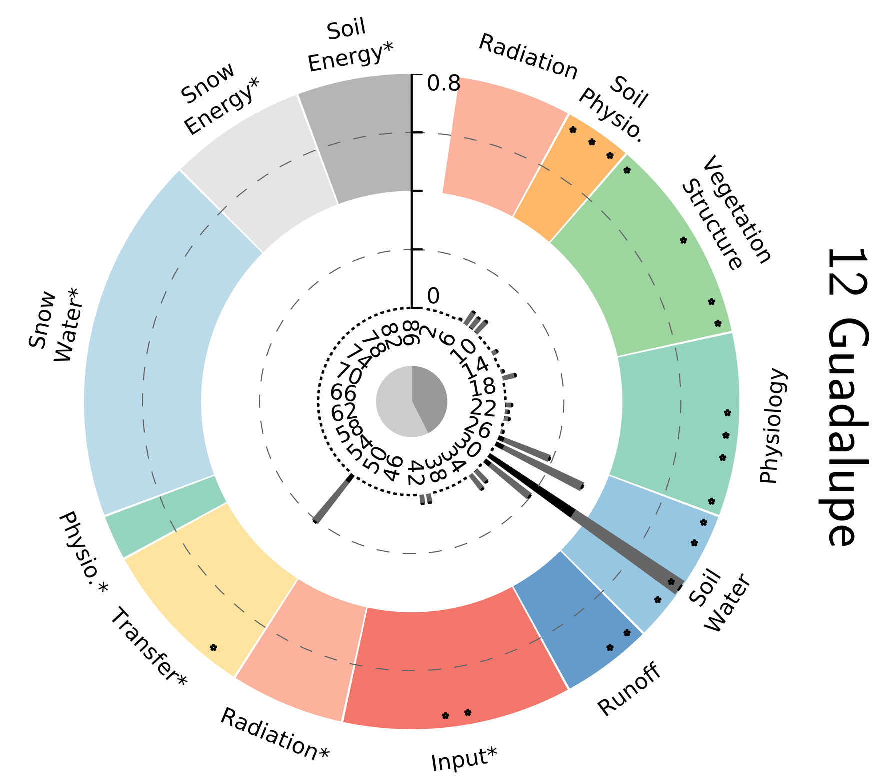
- Informative parameters depend more on model output than on catchment characteristics
- On average 29% of in total 118 parameters are informative
- On average 38% of informative parameters are hidden
- Snow parameters are highlighted in surface runoff
- Parameters for vegetation, i.e. plant-soil interface, structure and physiology, are highlighted in latent heat

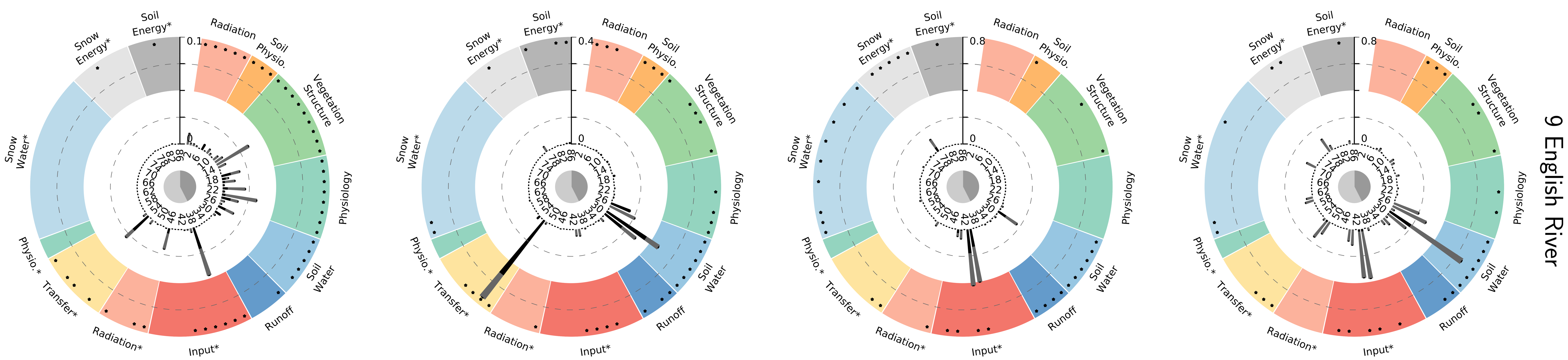
5. Sensitivity Analysis

- Few informative parameters show high sensitivity
- Large number of snow parameters important in snowy catchments and these are all hidden
- Runoff in snowy catchments sensitive to hidden separation of rain and snow
- Saturated hydraulic conductivity very important for runoff processes
- Influence of vegetation parameters depends on land cover type

- Sensitivities of underground runoff are more similar to those of latent heat than to those of surface runoff
- Sensitivities of latent heat dominated by evaporation processes
- Hidden parameter in formulation of surface resistance for evaporation is oversensitive, similar to findings for CLM v3.5[2]







Transpiration Latent Heat Surface Runoff Underground Runoff