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DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
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# Alternative spatial configurations to reflect landscape structure in a hydrological model: SUMMA applications to the Reynolds Creek Watershed and the Columbia River Basin


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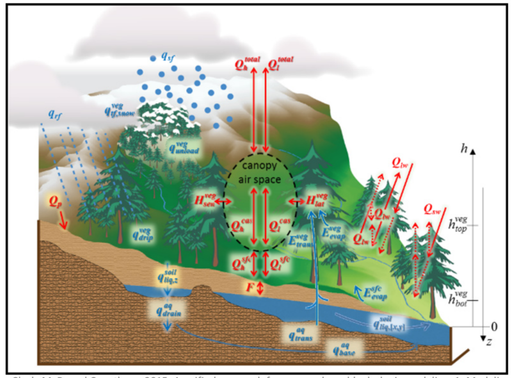
EGU2016-10413


## 1 SUMMA: Structure for Unifying Multiple Modeling Alternatives

Most hydrologic modelers share a common general understanding of how the dominant fluxes of energy and water affect the time evolution of thermodynamic and hydrologic states.

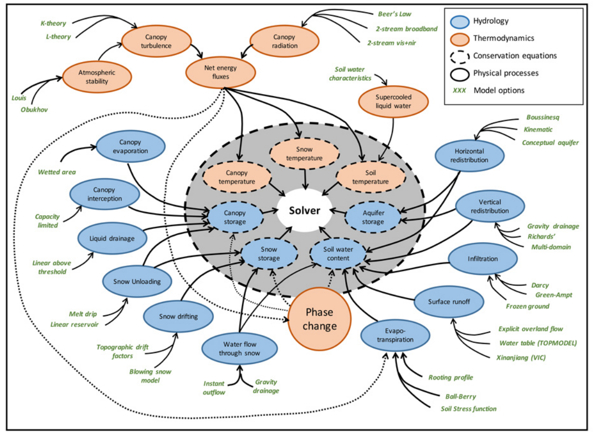
The major scientific issues in hydrologic model development are (a) representing spatial variability and hydrologic connectivity throughout the model domain (b) parameterizing the fluxes of water and energy at the spatial scale(s) of the model discretization.

SUMMA provides a unifying modeling framework by defining a general set of conservation equations for mass and energy, with the capability to incorporate multiple choices for spatial discretizations and flux parameterizations.




Clark, M. P., and Coauthors, 2015: A unified approach for process-based hydrologic modeling: 1. Modeling concept. *Water Resour Res*, **51**, 2498-2514, 10.1002/2015wr017198.

## Alternative process representations




The SUMMA "horrendogram": A conceptual diagram illustrating how SUMMA supports multiple alternative model options for a range of physical processes, integrated as part of a common numerical solver.

Clark, M. P., and Coauthors, 2015: A unified approach for process-based hydrologic modeling: 1. Modeling concept. *Water Resour Res*, **51**, 2498-2514, 10.1002/2015wr017198.

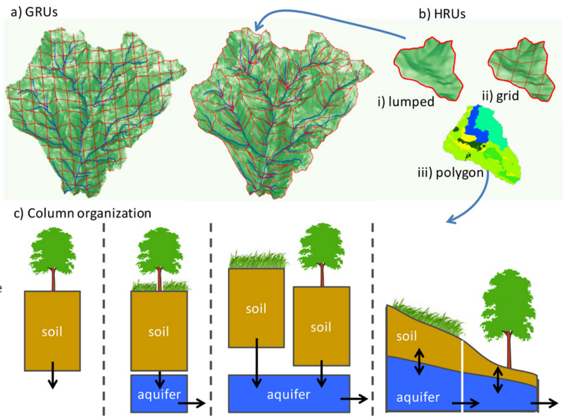
## 2 Alternative spatial representations

Spatial organization of SUMMA, showing:

(a) GRUs (grid or polygon)
(b) HRUs (single unit, grid, polygon), and
(c) the connection among soil columns and the aquifer.

The horizontal footprint of each vertical soil column corresponds to a single HRU, and there can be multiple soil columns (HRUs) embedded within a GRU.

Multiple configurations of GRUs and HRUs are possible, which may be optionally connected or disconnected, representing spatial variability across a hierarchy of scales.



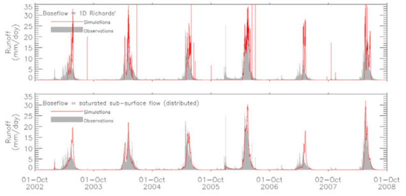

Clark, M. P., and Coauthors, 2015: A unified approach for process-based hydrologic modeling: 2. Modeling implementation and case studies. *Water Resour Res*, **51**, 2515-2542, 10.1002/2015wr017200.

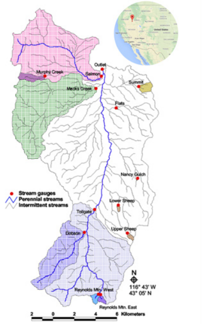
## 3 Small scale simulations

### Reynolds Creek Experimental Watershed

Impact of different lateral flux parameterizations on simulations of runoff (red lines) for the Reynolds Mountain East basin (right), showing (top) the 1-d Richards parameterization and (bottom) the spatially distributed saturated subsurface flow parameterization. The runoff observations (shading) are described by Reba et al. [2011]

Clark, M. P., and Coauthors, 2015: A unified approach for process-based hydrologic modeling: 2. Modeling implementation and case studies. *Water Resour Res*, **51**, 2515-2542, 10.1002/2015wr017200.




Courtesy: 199.133.140.121/rcew/watersheds/start

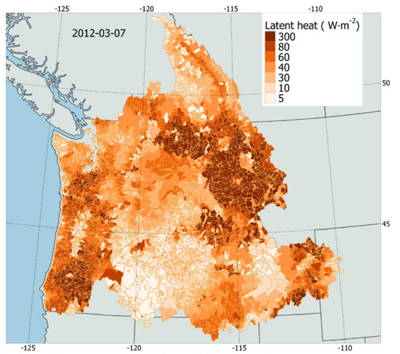
Basin-wide runoff strongly depend on the model representation of lateral flow. Simulations based on the 1D Richards equation exhibit too many "spikes" in the hydrograph (top plot). This approach lacks an explicit representation of lateral flow and vertical drainage from the bottom of the soil profile is delivered immediately to the stream.

The spatially distributed simulations, including lateral flow among soil columns, represent the observations better (bottom). In these simulations, multiple hillslope soil columns contribute inflow to the riparian zone, resulting in the persistence of partially saturated soils in the riparian zone and less spiky runoff dynamics.

Reba, M. L., D. Marks, M. Seyfried, A. Winstral, M. Kumar, and G. Flerchinger (2011), A long-term data set for hydrologic modeling in a snow-dominated mountain catchment, *Water Resour. Res.*, **47**, 10.1029/2010WR010030.

## 4 Large scale simulations

### Columbia River Basin


We are now developing the infrastructure to run SUMMA over much larger spatial domains. In this ***proof-of-concept*** simulation, SUMMA is configured for the Columbia River Basin (CRB) in the northwestern United States and Canada (left panel). Here, the CRB is discretized into 11,723 hydrologic response units (HRUs) according to the Geospatial Fabric (Viger and Bock, 2014). The soil parameters are derived from the Soil Survey Geographic (SSURGO) Database (Soil Survey Staff, 2012). The land cover parameters are based on the National Land Cover Database from the year 2001 (Homer and others, 2007). The forcing data, including hourly air pressure, temperature, specific humidity, wind speed, precipitation, shortwave and longwave radiations, are based on Phase 2 of the North American Land Data Assimilation System (NLDAS-2; Mitchell et al., 2004) and averaged for each HRU. The right panel shows the latent heat flux at the end of a brief simulation (one week with an hourly time step).


Homer, C., and Coauthors, 2007: Completion of the 2001 National Land Cover Database for the Conterminous United States. *Photogrammetric Engineering and Remote Sensing*, **73**(4), 337-341.

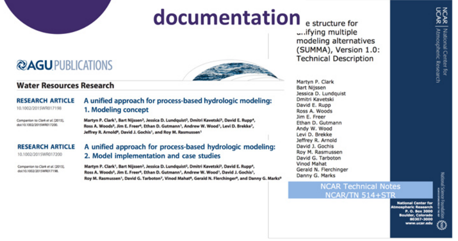
Mitchell, K.E., and Coauthors, 2004: The multi-institution North American Land Data Assimilation System (NLDAS): Utilizing multiple GCIP products and partners in a continental distributed hydrological modeling system. *J Geophys Res*, **109**, D07S90.

Soil Survey Staff, Natural Resources Conservation Service, 2012: Soil Survey Geographic (SSURGO) Database, United States Department of Agriculture: http://sdmdataaccess.nrcs.usda.gov/.

Viger, R. J. and Bock, Andrew, 2014: GIS Features of the Geospatial Fabric for National Hydrologic Modeling, US Geological Survey, 10.5066/F7542KMD.


## 5 SUMMA: Resources

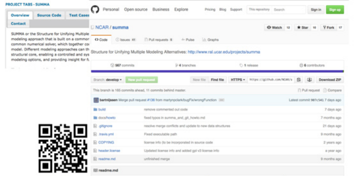
### Publications and documentation




### SUMMA web site with test data sets

www.ral.ucar.edu/projects/summa

### Github source code repository



www.github.com/ncar/summa


This work was made possible in part by funding from NASA's Advanced Information Systems Technology Program and the US Army Corps of Engineers