Modeling Dry Creek Experimental Watershed as an integrated hydrologic system

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Overview

A significant limitation in many efforts to use physically based distributed hydrologic models, particularly in regions of complex terrain, is the complete lack of meteorologic forcing data at sufficiently fine spatial resolution approaching the correlation scales of meteorologic phenomena. Observational weather and climate data in mountainous regions are typically sparse, temporally discontinuous, and often poorly representative of the domain of interest. An alternative is to use a numerical weather prediction model to generate meteorologic forcing data for hydrologic models. This approach, while computationally intensive, leads to internally and physically consistent environmental forcing variables distributed over the landscape at remote and ungauged areas. These data can then be used to feed sophisticated models of surface-subsurface hydrology. We describe the application of such a system for the Dry Creek Experimental Watershed (DCEW) in southwest Idaho as well as some of the associated challenges.

Modeling Framework

The Weather Research and Forecasting (WRF) model (Skamarock et al., 2008) is a sophisticated community regional weather and climate model that simulates the environmental forcings (precipitation, temperature, pressure, humidity, radiation, and wind) required as input to the ParFlow-CLM model (Maxwell and Miller, 2005). These forcings are generated first via a regional WRF model, then regridded and reformatted as input to the ParFlow-CLM modeling system. CLM, the Community Land Model, is a column land surface model that describes the fluxes of water and energy at the land surface. CLM has been previously coupled to ParFlow, a parallelized, 3-dimensional, variably saturated surface and subsurface flow model. The ParFlow-CLM modeling system is applied over the Dry Creek Experimental Watershed located in the Boise foothills.

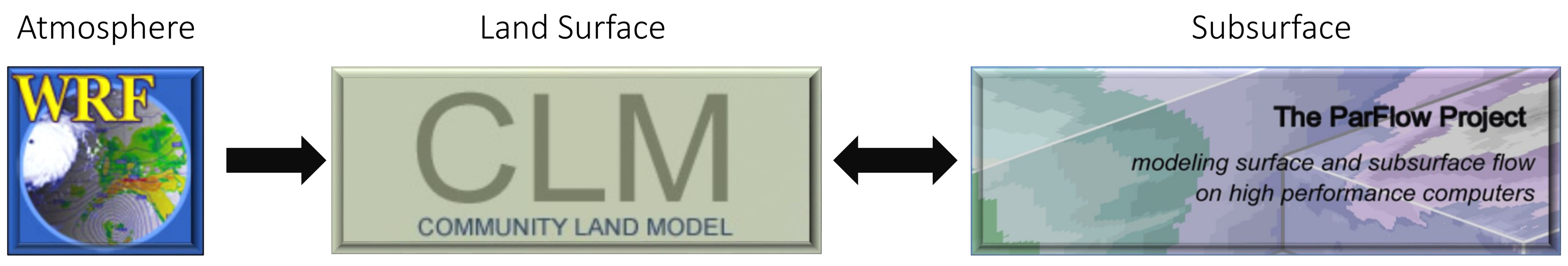

Figure 1. Diagram illustrating the flow of information between models.

WRF Modeling

The Weather Research and Forecasting (WRF) Model is used to dynamically downscale the North American Regional Reanalysis (NARR) over southern Idaho for a period extending from October 1, 2008 to June 1, 2009. The model is run using a set of three nested domains (d01, d02, and d03) of 9, 3, and 1 km horizontal resolution respectively (Figure 3). WRF physics parameterizations were selected based upon the results of the NCAR Colorado Headwaters project (Liu et al., 2011). Near surface temperature, winds, humidity, and pressure as well as incoming shortwave and longwave radiation and precipitation are output at hourly intervals then regridded and reformatted as input files for ParFlow-CLM.

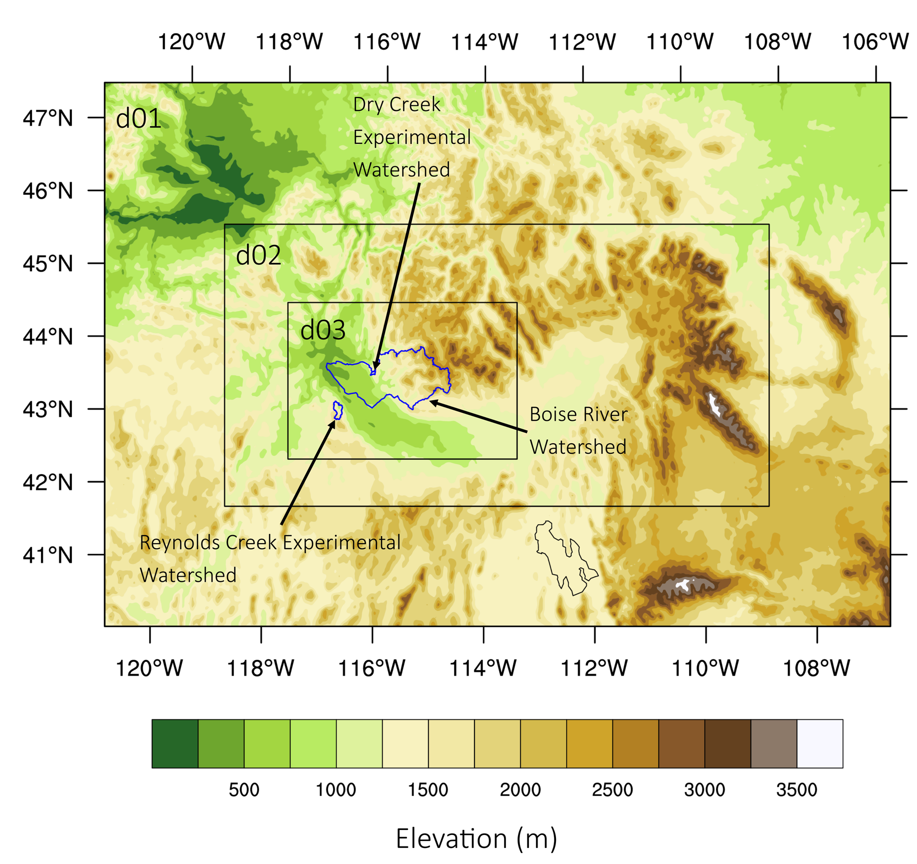

Figure 2. Map of nested WRF model domains and model terrain.

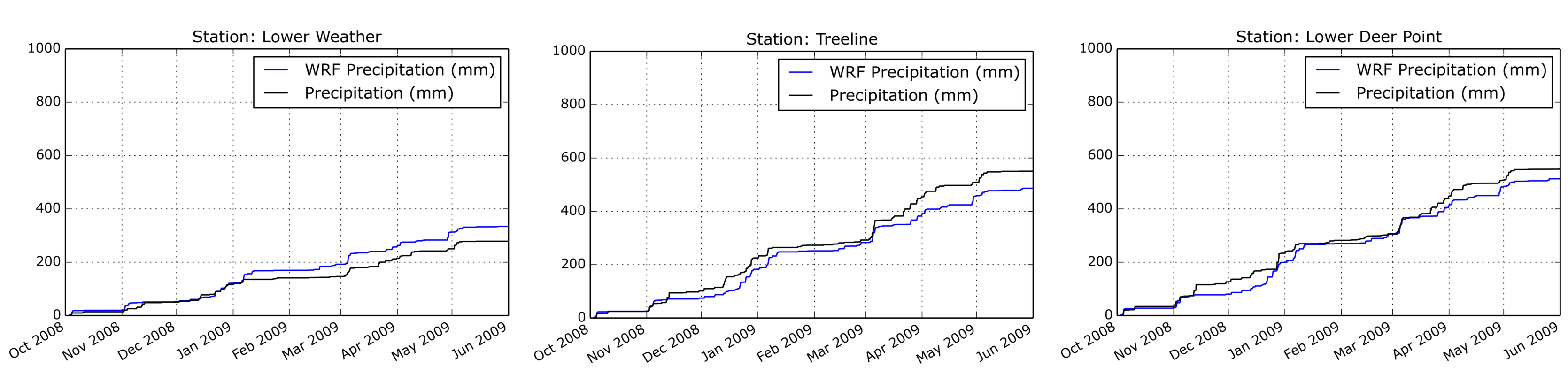

Figure 3. Plots of cumulative modeled (d03: 1km) and observed precipitation for 3 weather stations in Dry Creek Experimental Watershed.

ParFlow-CLM Modeling

The ParFlow-CLM model describes the partitioning of energy and water at the land surface and the movement of water over and through the watershed. The resolution of the model grid and associated parameters is 30m. The terrain information is from the National Elevation Database, land cover information from LANDFIRE, and soils information from the SSURGO database. Soils are modeled as 1.0 m deep with bedrock below using 20 vertical layers. A drainage experiment was used to generate the initial conditions. Meteorologic forcing information is applied at hourly time steps and at varying grid resolutions (9, 3, and 1km). Initial simulations start at 0Z on October 1, 2008 and extend for approximately 750 hours.

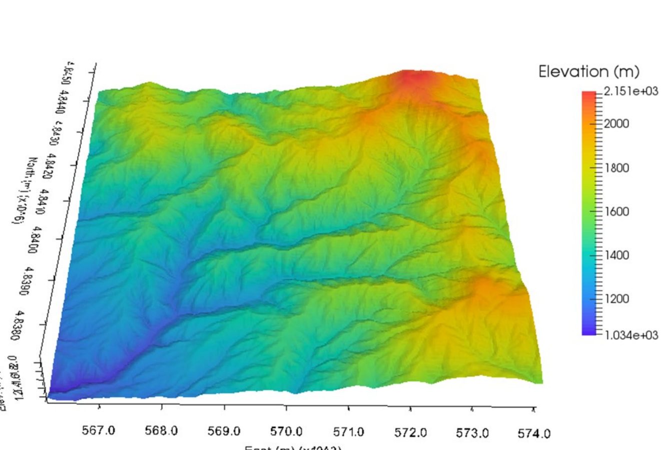

Figure 4. ParFlow-CLM model terrain.

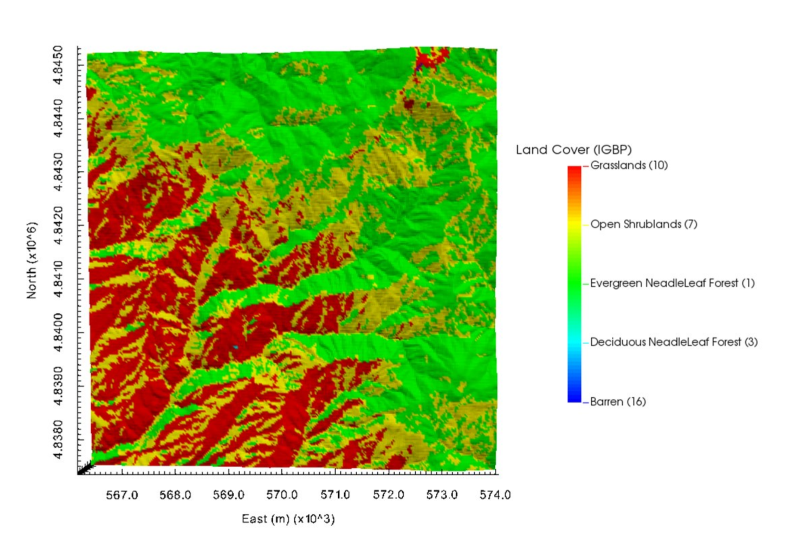

Figure 5. ParFlow-CLM land cover type.

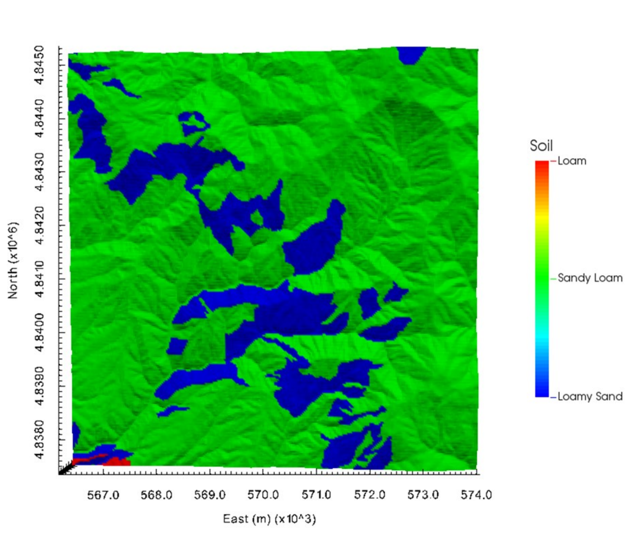

Figure 6. ParFlow-CLM soil type.

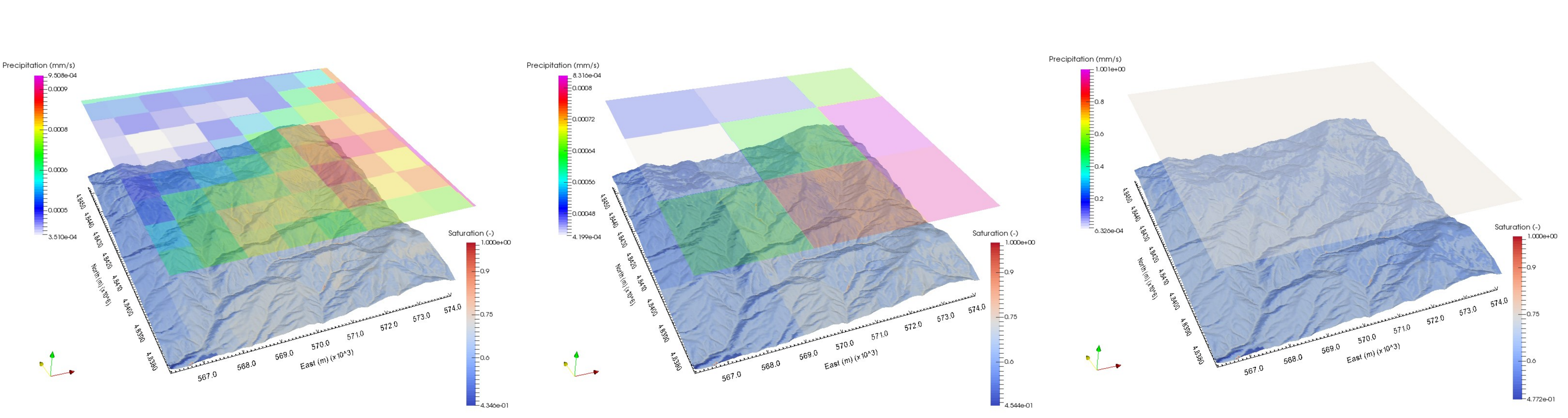

Figure 7. Visualizations showing precipitation forcing information of varying resolution from the 3 WRF model grids over the ParFlow-CLM model domain.

Saturation

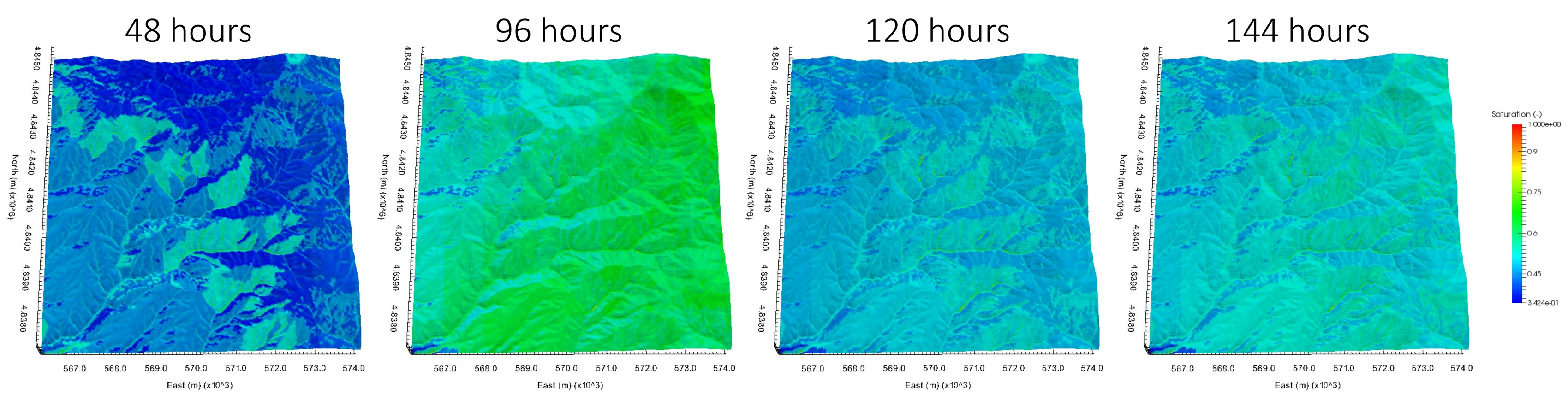

Figure 8. Maps showing saturation values at a specified number of hours into the simulation (d03:1km forcings).

Soil Moisture

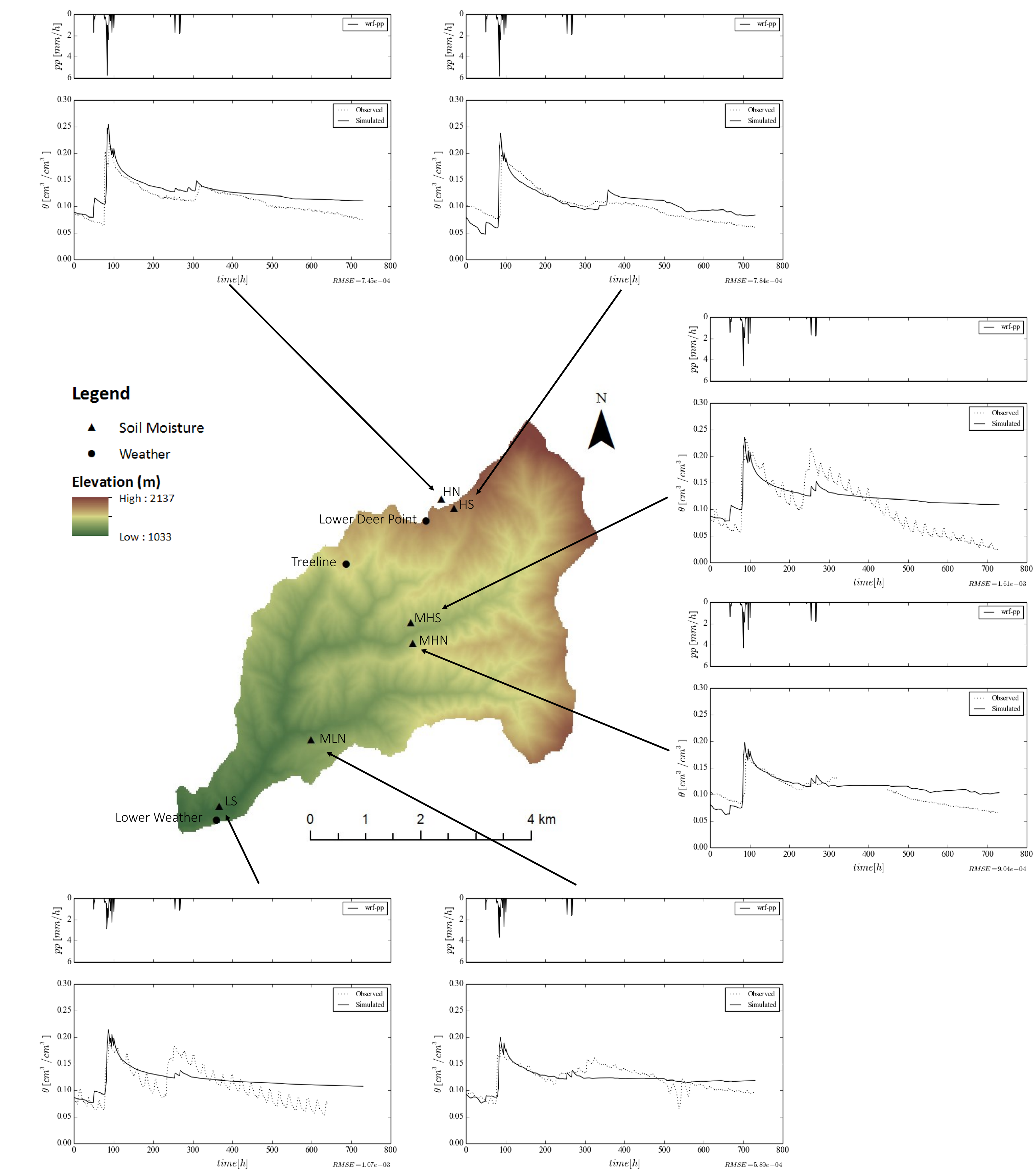

Figure 9. Comparisons of simulated vs observed soil moisture (d03: 1km-interpolated forcings). Precipitation rate is shown on the top subplots.

- Observed diel signal in the LS and MHS records is not simulated
- The soil moisture signal from the first precipitation event is simulated well for all locations
- The response from the second precipitation event at LS and MHS is larger than at other sites and not well simulated
- Simulated timing of soil moisture response appears correct in Figure 9
- The simulated response to the first precipitation event does not appear to be sensitive to the varying resolution forcing information
- The timing of soil moisture response to the second precipitation event changes significantly depending upon the forcing information

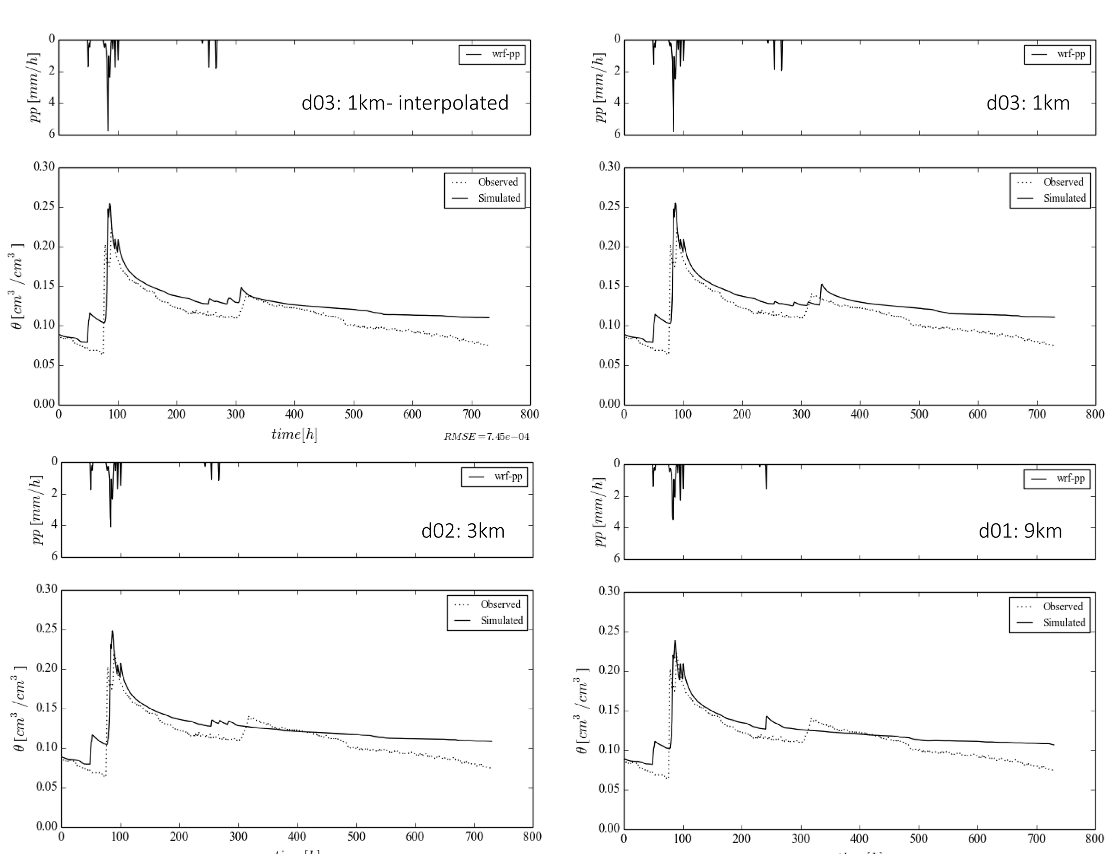

Figure 10. Comparison of observed vs simulated soil moisture at site HN showing simulations with varying resolution forcing information.

Conclusions

- WRF simulates precipitation reasonably well for the 8 month period from 10/08 - 6/09 with some notable exceptions
- Depending upon the nature of the precipitation event the resolution of the forcing information is more or less important for simulating soil moisture
- Discrepancies between soil moisture simulations and observations require further investigation

Acknowledgements

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