Evaluating Full Physics and Conceptual Hydrological Model Soil Moisture Simulations with Observations

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Overview

- The NOAA Earth System Research Laboratory Physical Sciences Division (NOAA/ESRL/PSD) has deployed soil moisture observing stations in the Russian River and American river basins located in northern California (Zamora et al. 2011), and the Babocomari river basin located in Southeastern, AZ (Zamora et al., 2014).
- The soil moisture observations have been compared with soil moisture gridded fields simulated using the National Weather Service Office of Water Prediction (NWS/OWP) Research Distributed Hydrological Model (HL-RDHM) and the National Center for Atmospheric Research (NCAR) WRF-Hydro modeling system
- The NWS/OWP National Water Model (NWM) was implemented operationally by the NWS in 2016 and is based on the NCAR WRF-Hydro modeling system

Objectives

- Compare the PSD Observations with NWS/OWP/NWM soil moisture simulations annually, seasonally, and during flood events in an effort to improve the model physics.
- Develop and test soil moisture data assimilation strategies using PSD observations that can be implemented operationally in the National Water Model

- What good are soil moisture observations?

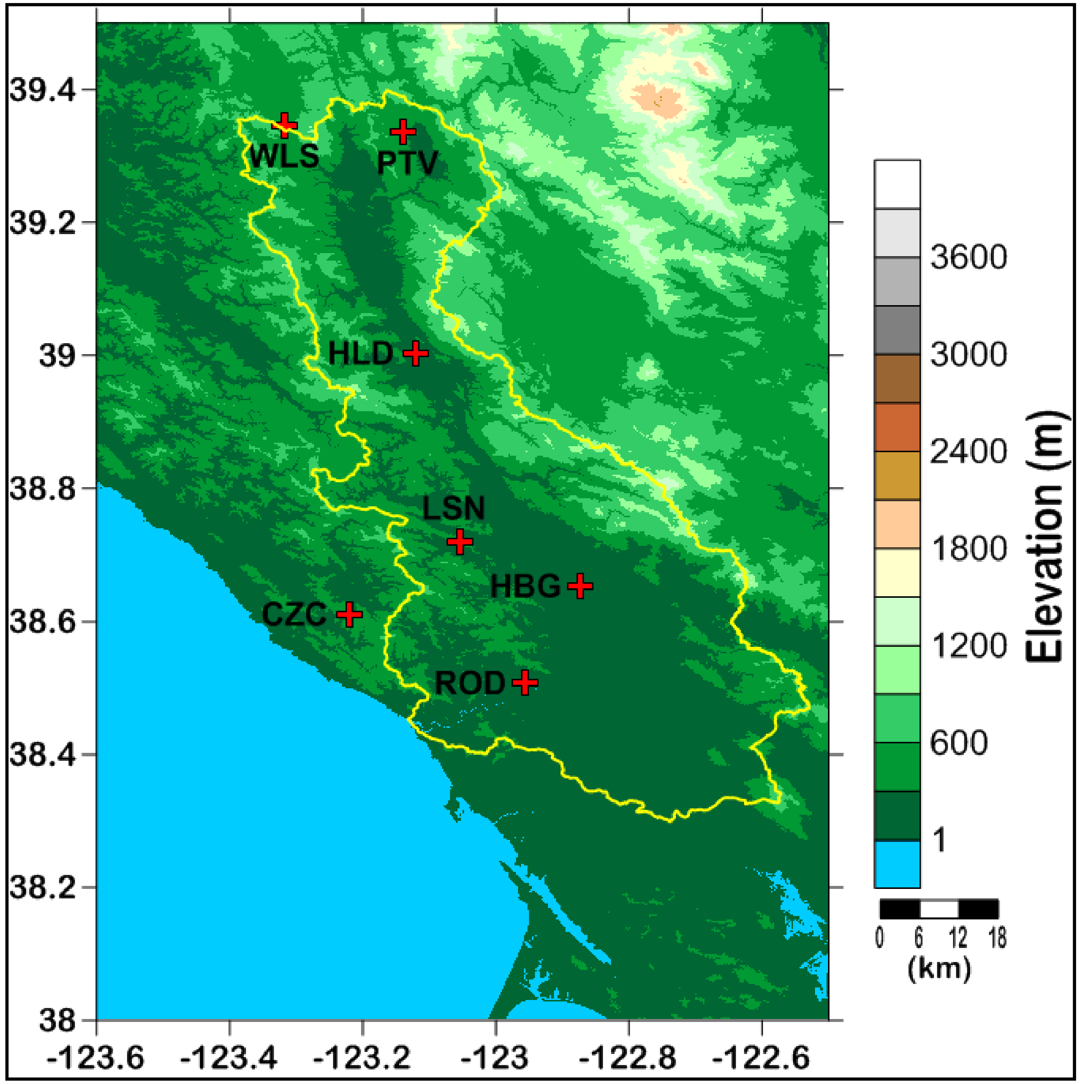
SAC-SMA *Sacramento Soil Moisture Accounting*

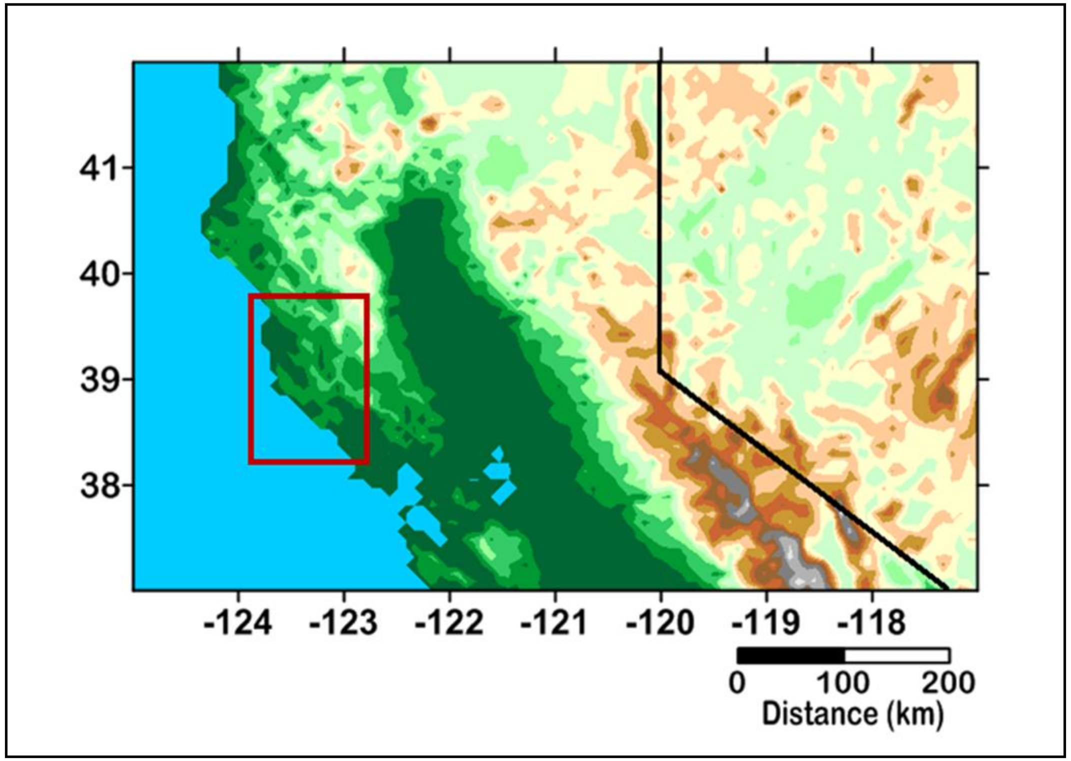
Models need to get the right answer for the right reason with a minimum of tuning.

- Why bother with the NWS HL-RDHM Conceptual Model?

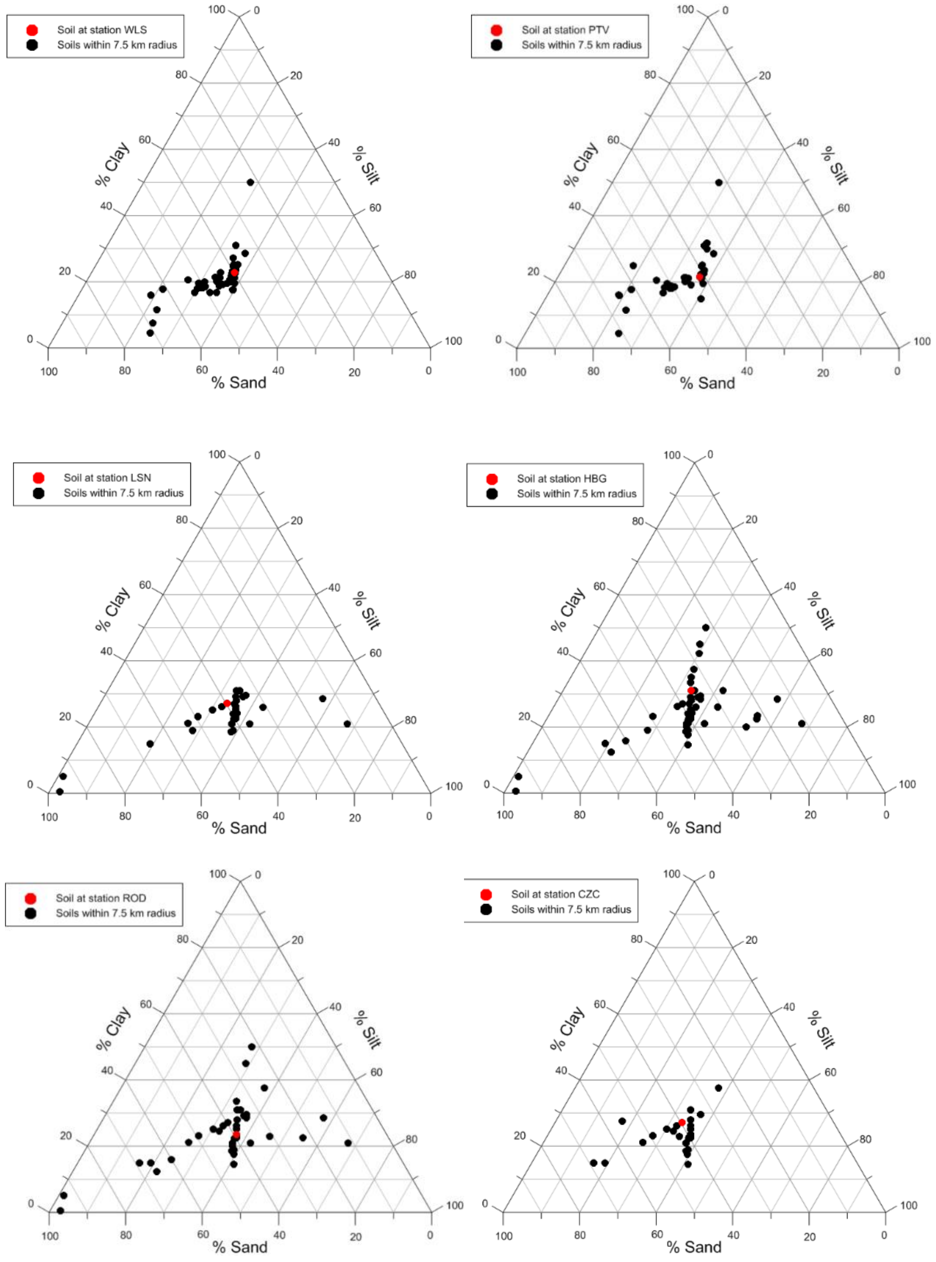
Complexity does not always give you a better meteorological or streamflow forecast

Russian River Basin Soil Moisture Observing Network





Red crosses show the locations of the soil moisture observing stations at Cazadero, (CZC) Rio Nido (ROD), Lake Sonoma (LSN), Healdsburg (HBG), Hopland (HLD), Potter Valley (PTV), and Willits (WLS).



Soil at station WLS
Soils within 7.5 km radius
Soil at station PTV
Soils within 7.5 km radius
Soil at station LSN
Soils within 7.5 km radius
Soil at station HBG
Soils within 7.5 km radius
Soil at station ROD
Soils within 7.5 km radius
Soil at station CZC
Soils within 7.5 km radius
% Clay
% Silt
% Sand
0
20
40
60
80
100

Hydrological Model Configurations

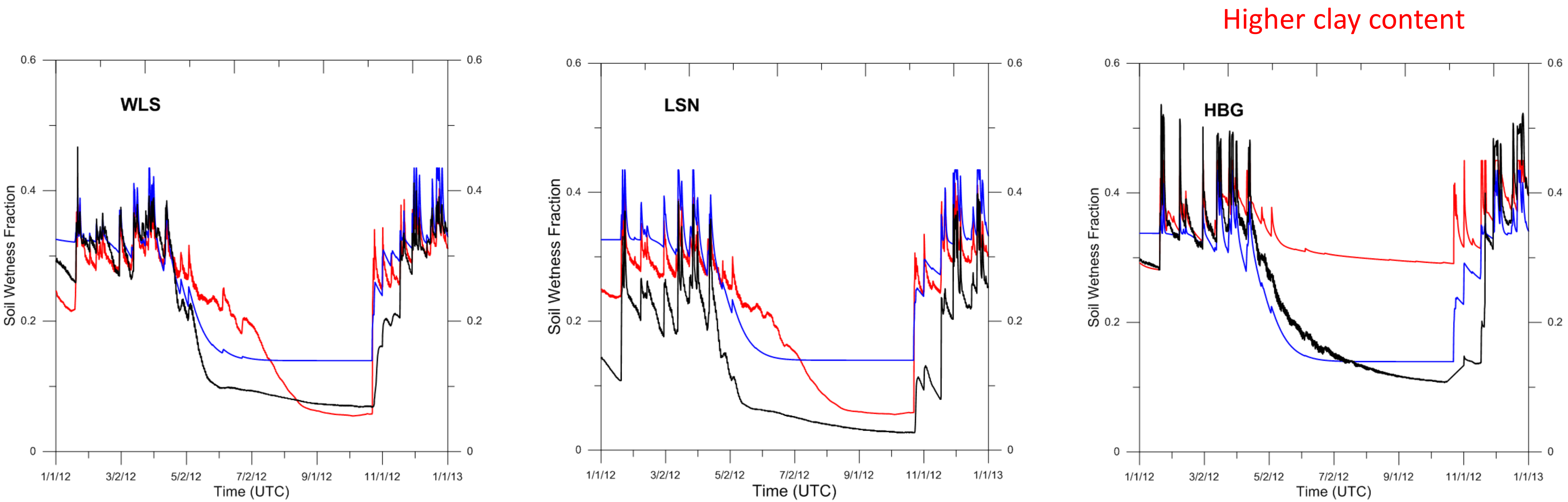
HL-RDHM Configuration

- Sacramento Model Heat Transfer version (Koren el al. 2007)
- HRAP 4-km grid, OWP routing
- OWP a-priori parameters (Out of the box)
- NWS California Nevada River Forecast Center Forcing
- 6-h time step
- Simulation period: 1 January 2012 – December 2012

WRF-Hydro Configuration

- WRF-Hydro version 3.0 (Gochis et al. 2013)
- Noah MP LSM 1-km grid, 250 m routing
- NCAR a-priori parameters (Out of the box)
- NLDAS Forcing
- 1-h LSM time step
- Simulation period: 1 January 2012 – December 2012

Observational Intercomparison (three of six locations shown)



Observed soil moisture (solid black), WRF-Hydro simulated soil moisture (solid red), and HL-RDHM (solid blue) simulated soil moisture for the period 1 January, 2012 – 31 December 2012.

Statistical Results

Site	Bias RDHM	Corr RDHM	RMSE RDHM	NSE RDHM
HBG	-0.0219	0.9077	0.0517	0.8129
HLD	0.6180	0.9333	0.0939	-0.7644
LSN	0.8351	0.9413	0.1152	-0.4115
PTV	-0.1456	0.9745	0.0459	0.7758
ROD	0.0166	0.9407	0.0508	0.8196
WLS	0.2148	0.9678	0.0508	0.7720

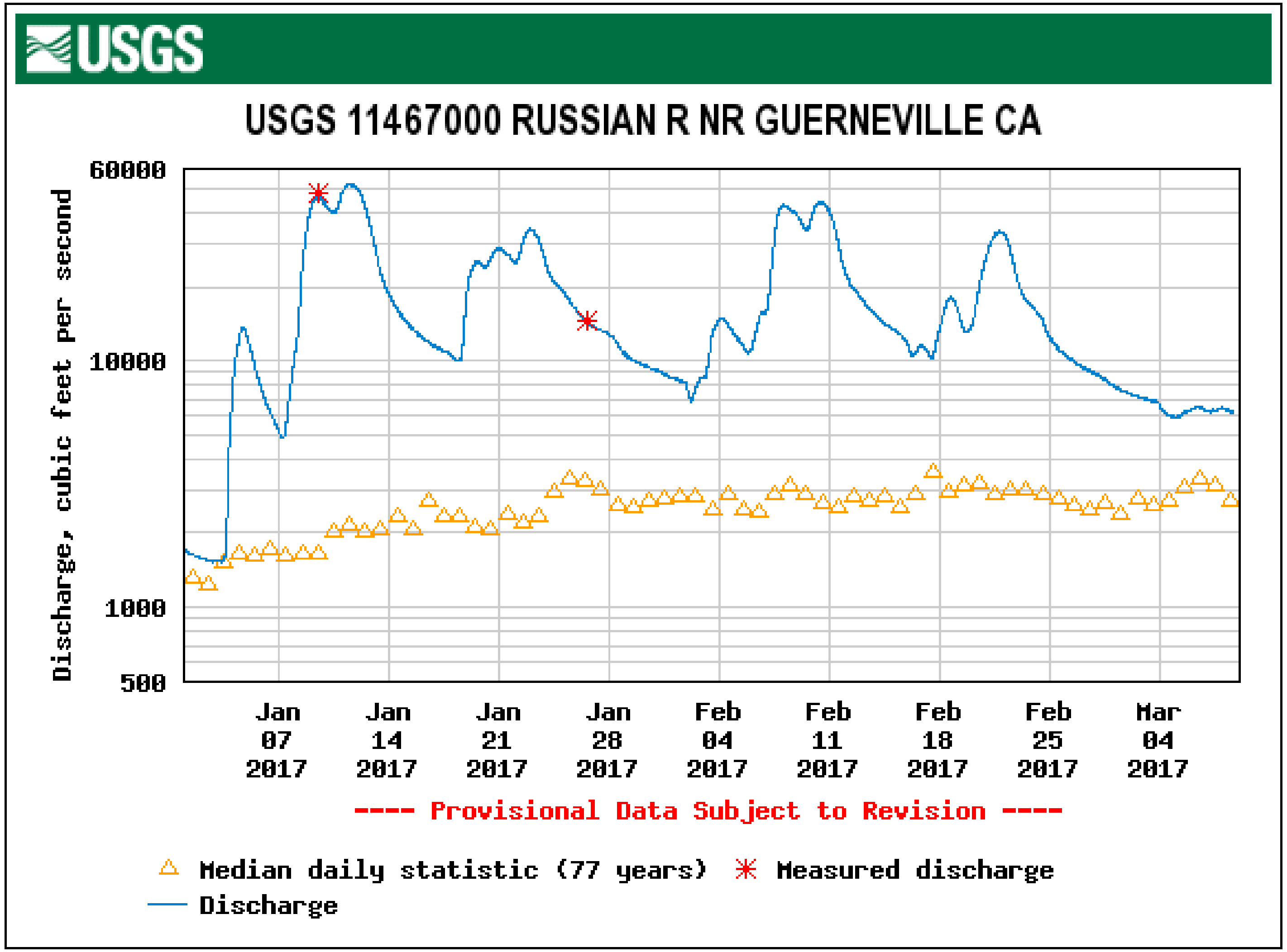
Site	Bias WRF-H	Corr WRF-H	RMSE WRF-H	NSE WRF-H
HBG	0.3513	0.8487	0.2111	-0.0258
HLD	0.5410	0.8893	0.0964	-0.8587
LSN	0.6082	0.8814	0.0939	0.0623
PTV	-0.2169	0.9342	0.0714	0.4574
ROD	0.1293	0.9441	0.0634	0.7189
WLS	0.1160	0.8735	0.0592	0.7197

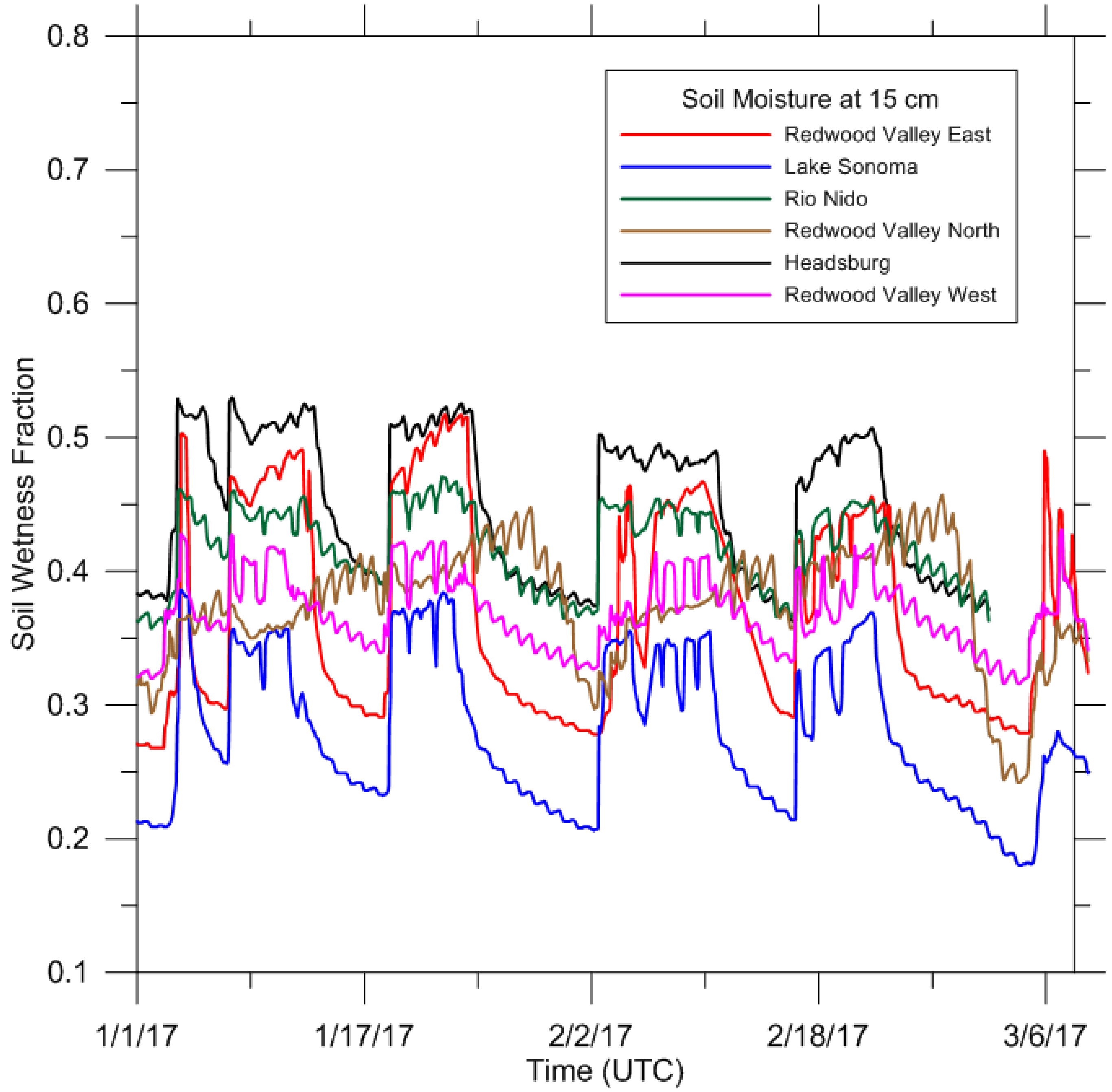
* Corr = Correlation Coefficient, NSE = Nash Sutcliffe Efficiency

Summary

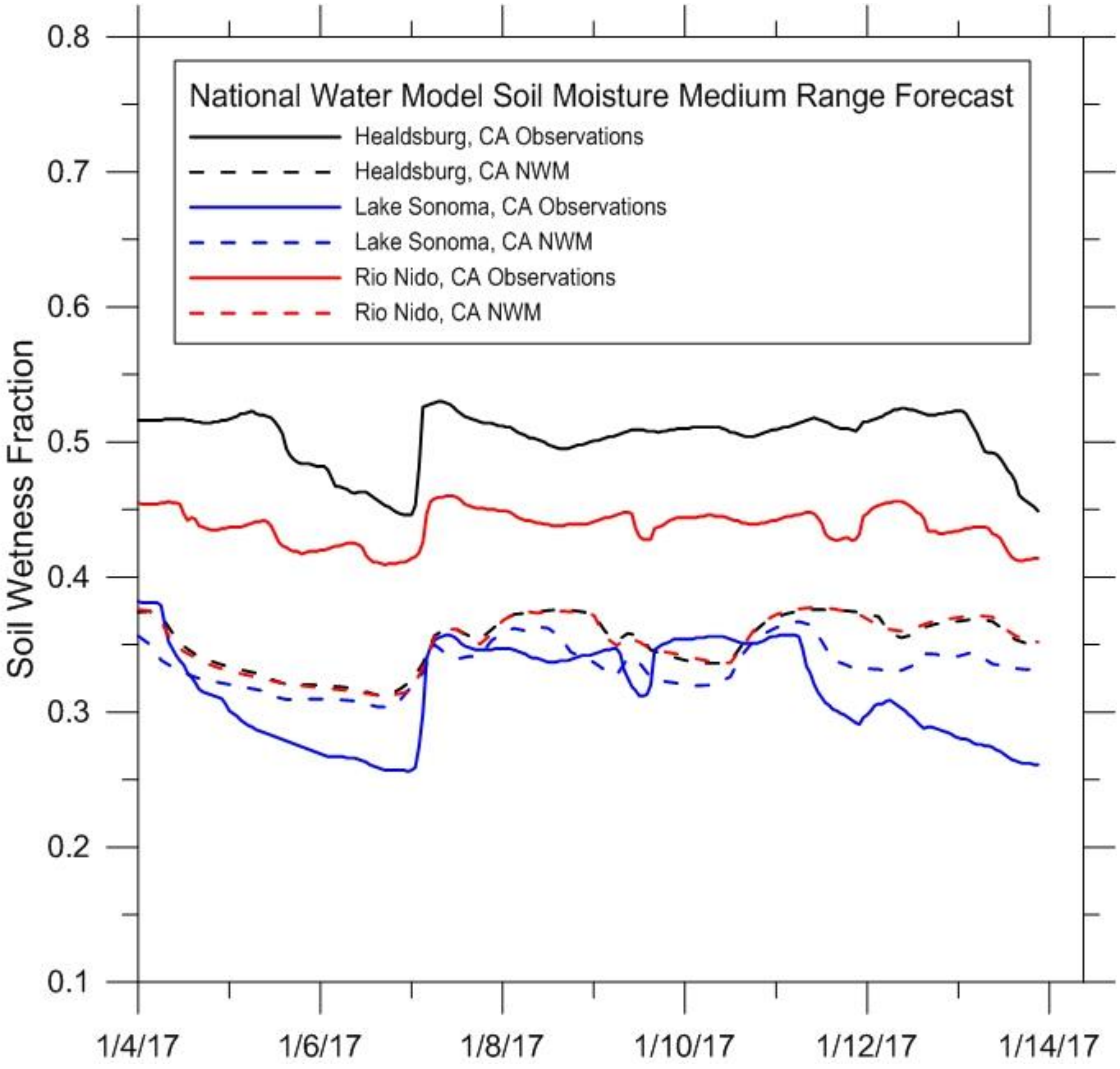
- The preliminary results shown here indicate that both uncalibrated modeling systems can reproduce the observed soil volumetric water content in the Russian River Basin
- The statistical differences between the models should be discounted given that the models were not driven using the same precipitation and temperature forcing
- Future PSD work will focus on running both models using the same forcing fields and evaluating not only the soil moisture grids but also the outlet hydrographs
- Currently the NWM uses the observed hydrographs in the data assimilation stage. Future PSD work will also focus data assimilation strategies that utilize the hydrographs and the soil moisture observations

New Results From the Record Wet Winter





Soil Moisture at 15 cm
Redwood Valley East
Lake Sonoma
Rio Nido
Redwood Valley North
Headsburg
Redwood Valley West
Soil Wetness Fraction
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1/1/17
1/17/17
2/2/17
2/18/17
3/6/17
Time (UTC)



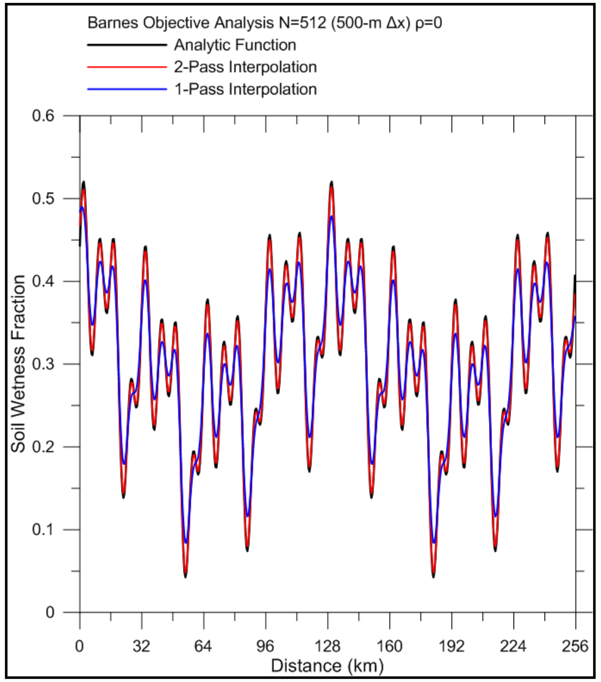
Forcing

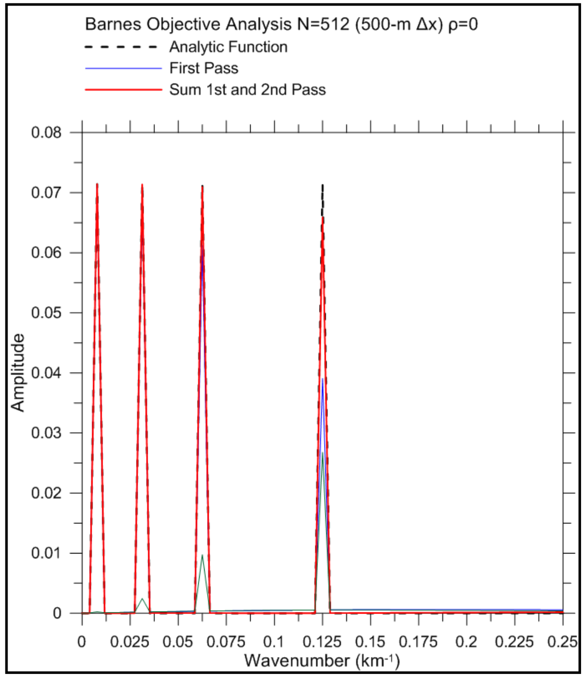
Analysis and Assimilation: MRMS blend/HRRR/RAP

Short-Range (0-18 h) : Downscaled HRRR/RAP

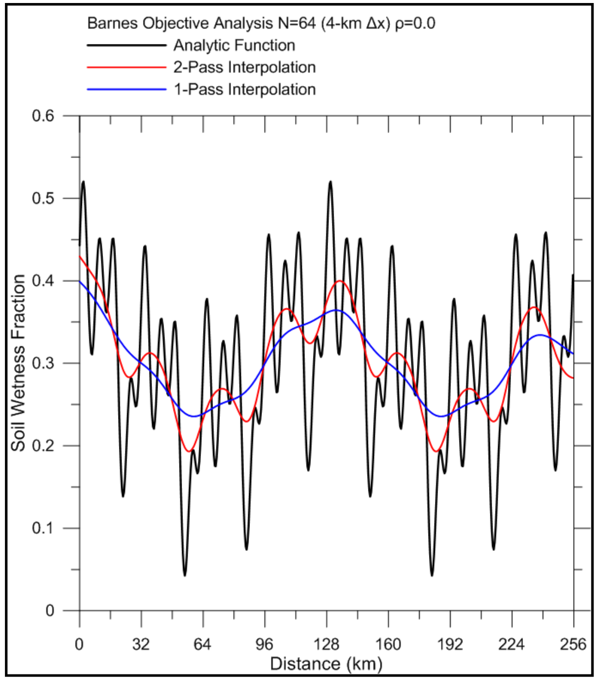
Medium-Range (0-10 day) : Downscaled GFS

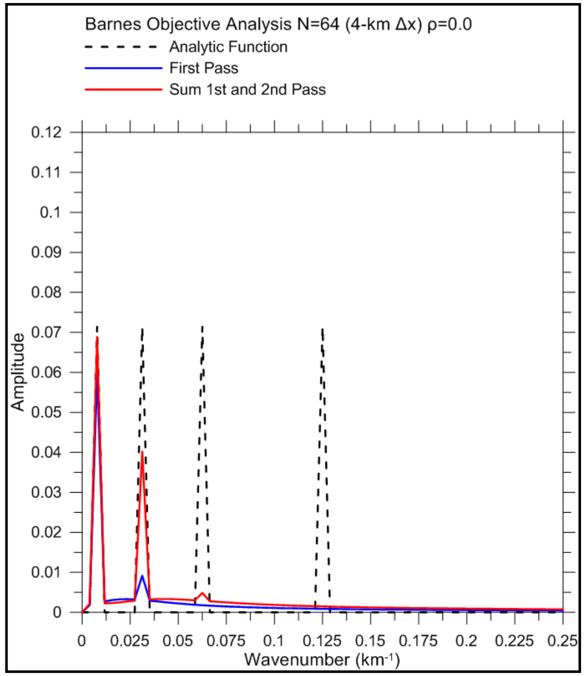
Long-Range (0-30 day) : Downscaled CFS





- Linear superposition of 128, 64, 16, and 8-km horizontal scales/waves (8-km scale is the Nyquist scale when the HRAP grid is utilized)
- Objectively analyzed the field using a 2-pass Barnes OA
- Fourier decomposition used to show how the OA method performs in wavenumber space





Results of the 1-D Tests

- When the field is well sampled the OA method recovers the phase and amplitude of all scales
- When the field is under-sampled the OA method correctly damps the Nyquist scale (However, this aliased scale amplitude appears at low wavenumbers)
- Under optimal conditions (regular sampling in space) only soil moisture variability on scales longer than 32 km can be resolved with any confidence using the observations alone.
- Gridding the HMT soil moisture observations by themselves using any inverse distance weighting (IDW) method could lead to large errors.