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Data Assimilation of COSMOS measurements

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With acknowledgments to: Jim Shuttleworth, Ave Arellano, Marek Zreda, Tim Hoar, Mike Barlage, Jeff Anderson, Shirley Papuga, Trenton Franz

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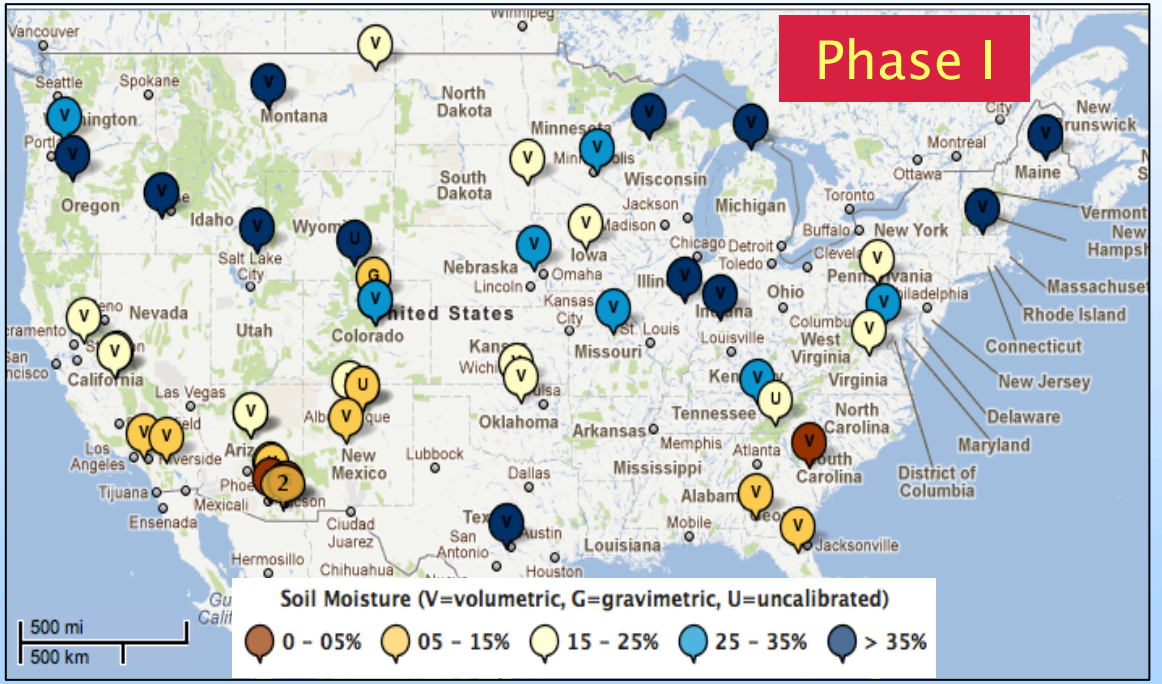
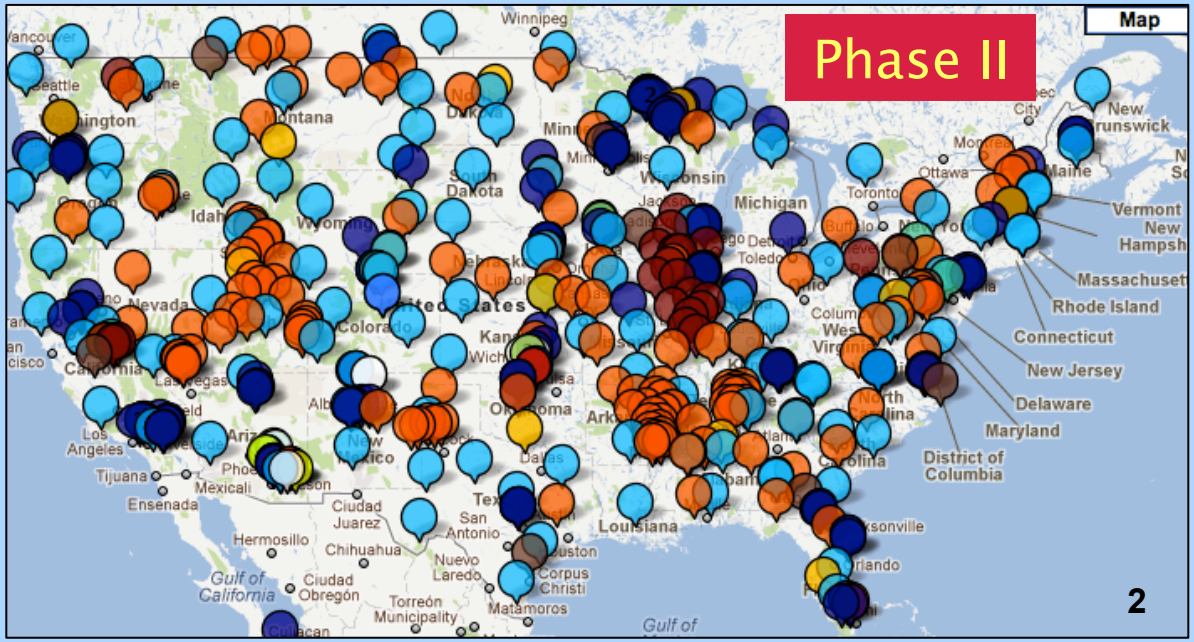
COsmic-ray Soil Moisture Observing System

http://cosmos.hwr.arizona.edu

Goals:

- Improve weather and short-term climate forecast across CONUS
- Provide calibration/ validation of satellite remote sensing soil moisture products



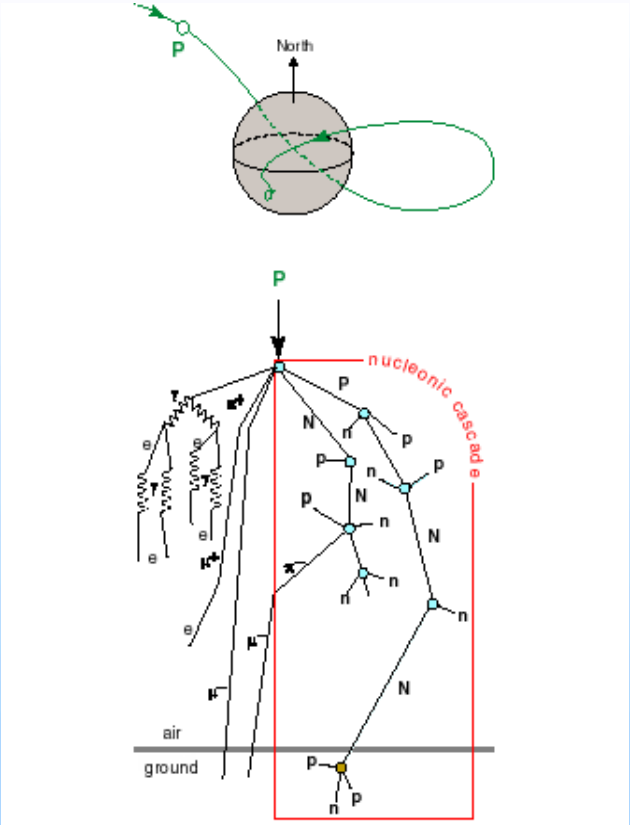


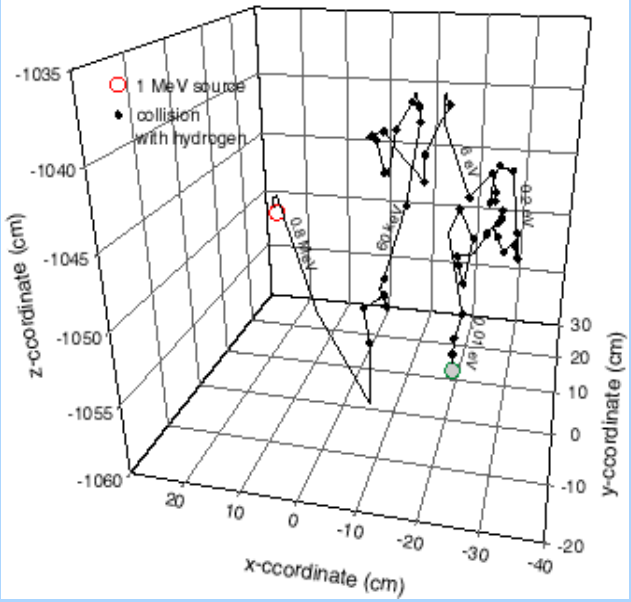
Data: Real-time, hourly, publicly available

Cosmic-Rays on Earth

- Primary - mostly protons and alphas
- Interact with magnetic field
  - *intensity depends on geomagnetic latitude*
- Interact with atmospheric nuclei
- Produce secondary particles - cascade
  - *intensity depends on barometric pressure*
- Produce fast neutrons
  - slowing down by elastic collisions
  - leads to thermalization
  - and then absorption

The last three processes depend on the chemical composition of the medium, in particular on its hydrogen content





Space:

incoming high-energy cosmic-ray proton

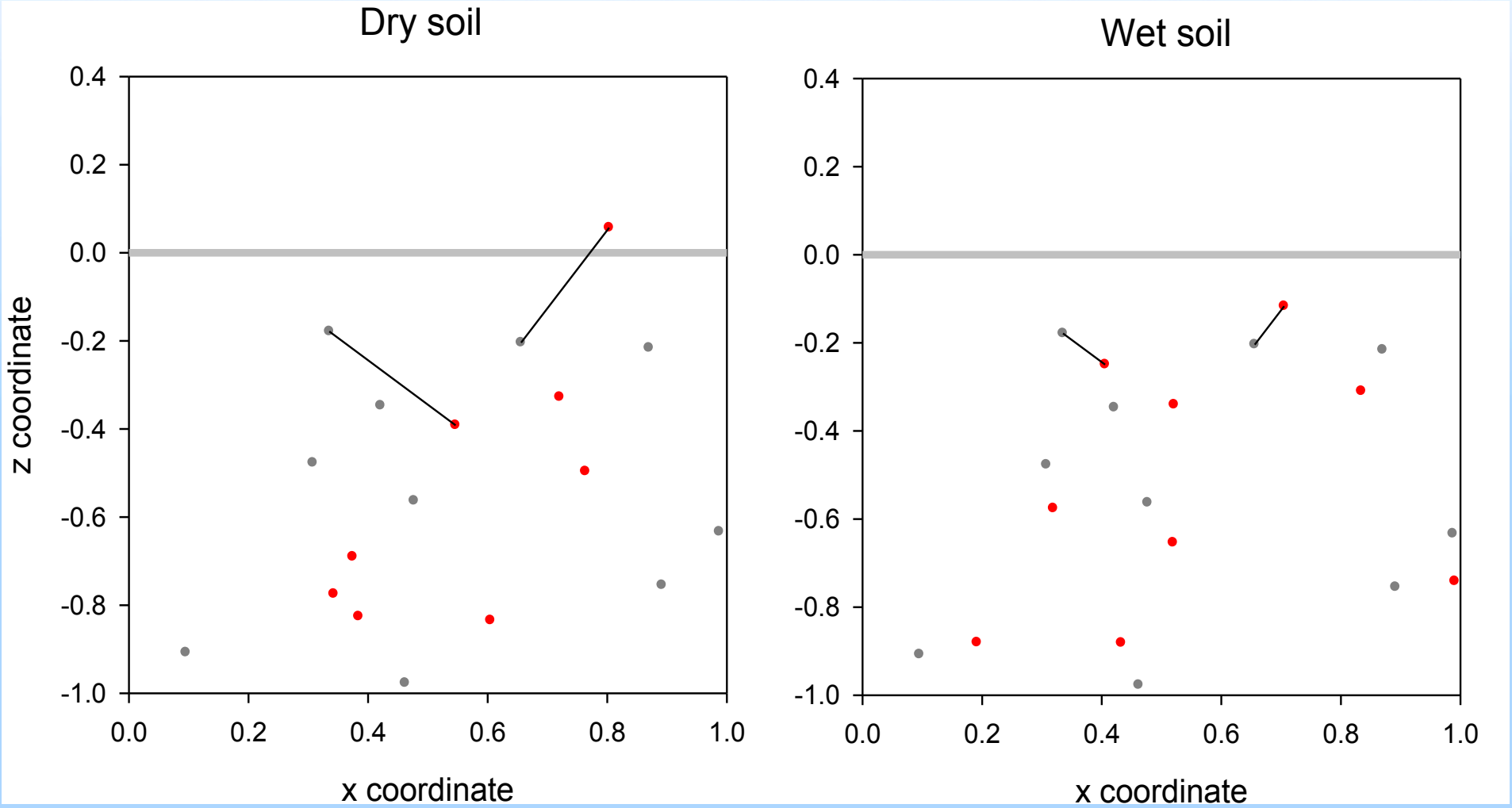
Atmosphere:

generation of secondary cosmic rays

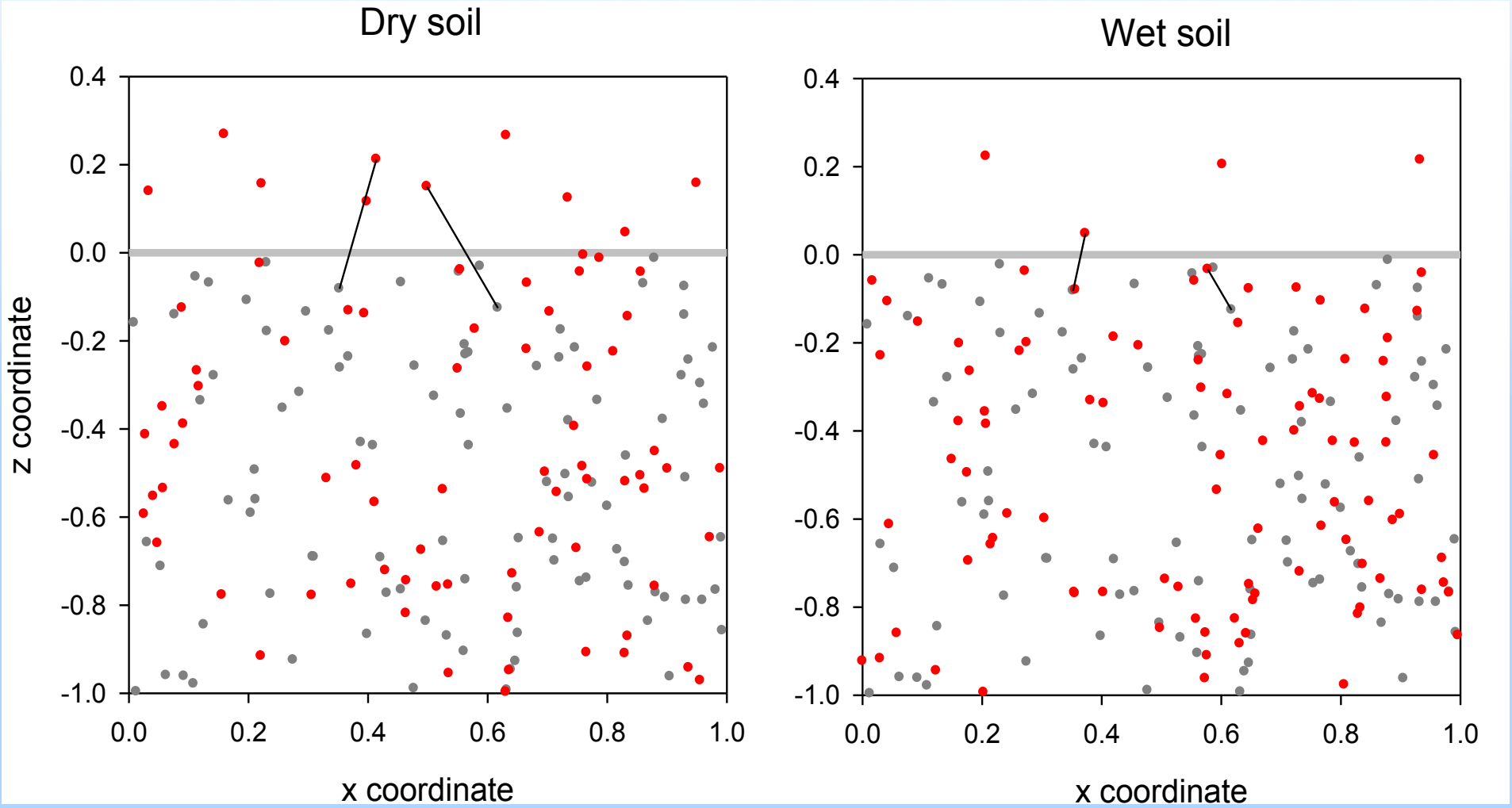
Ground:

scattering
thermalization
absorption

A simple experiment…



Effect of Hydrogen on Slowing Fast Neutrons



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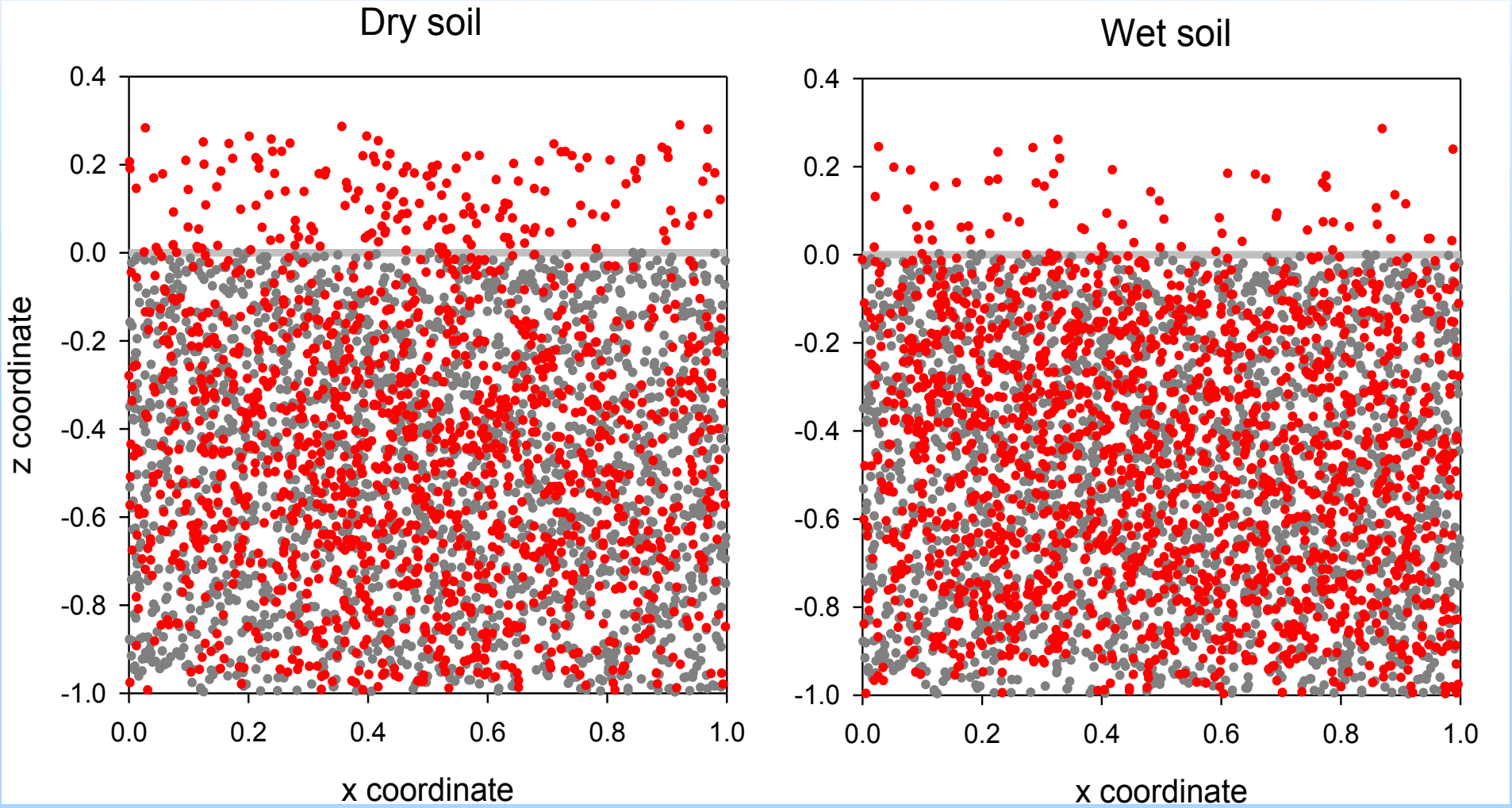
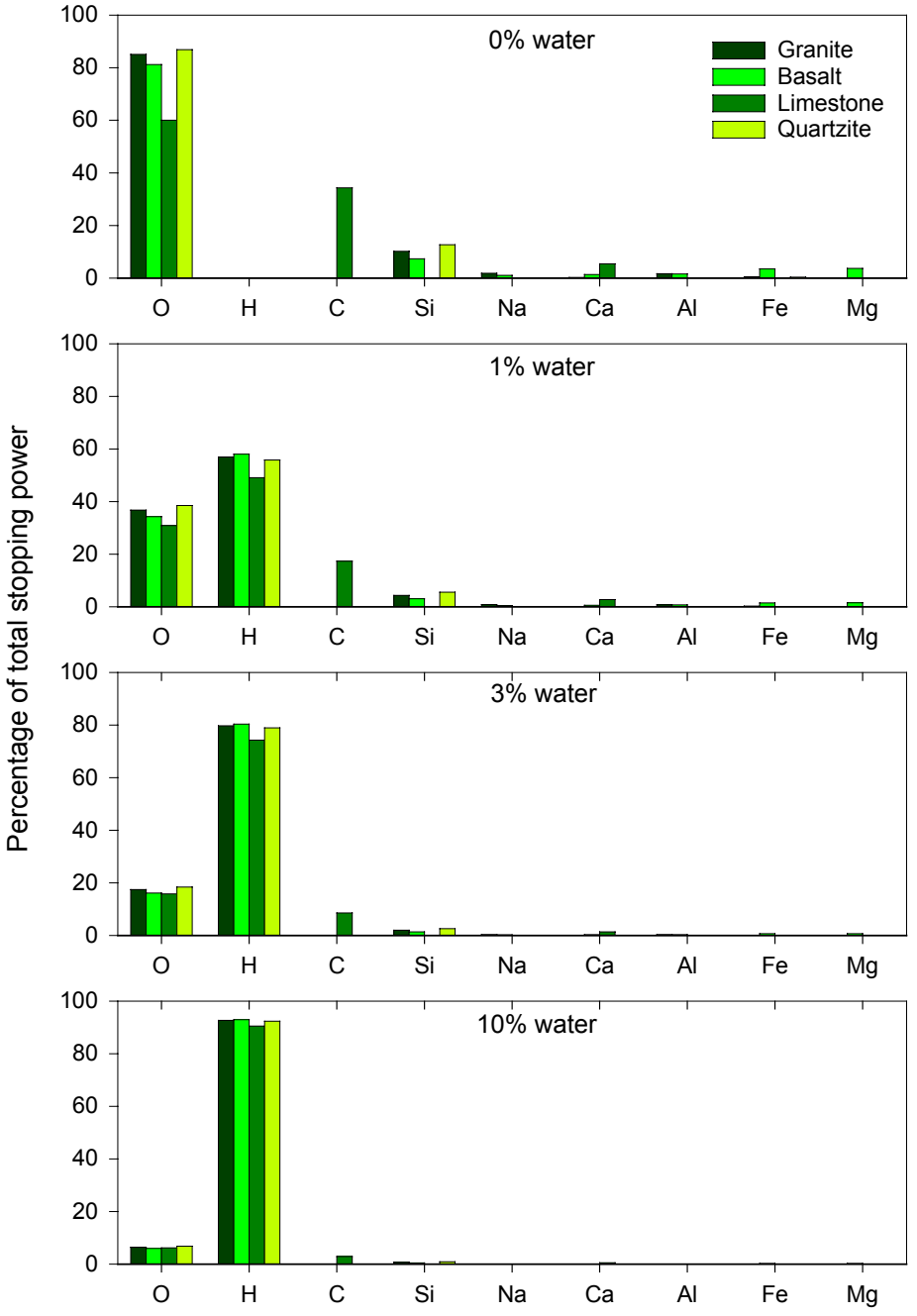
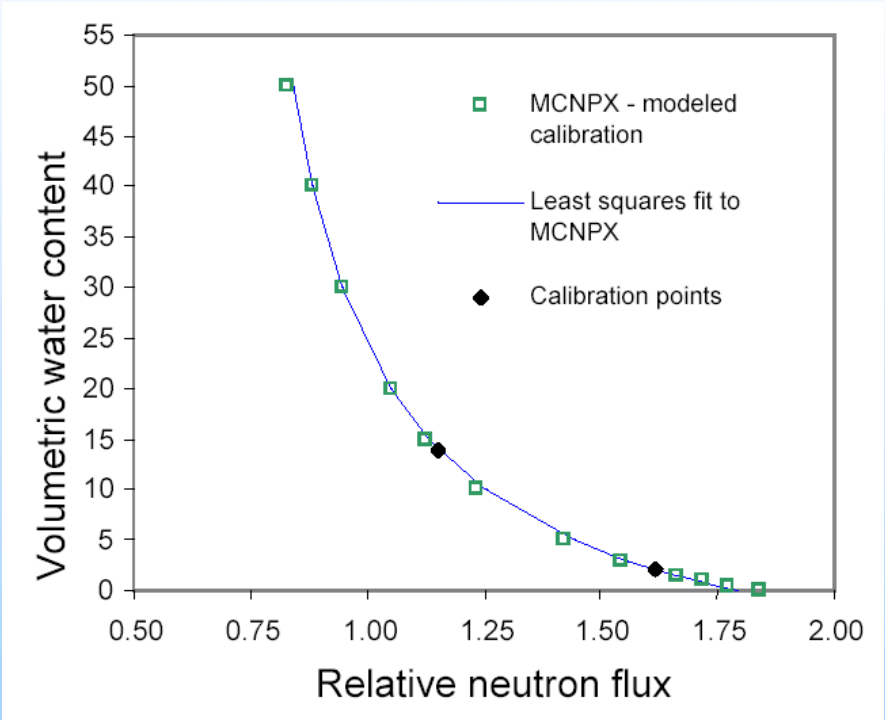
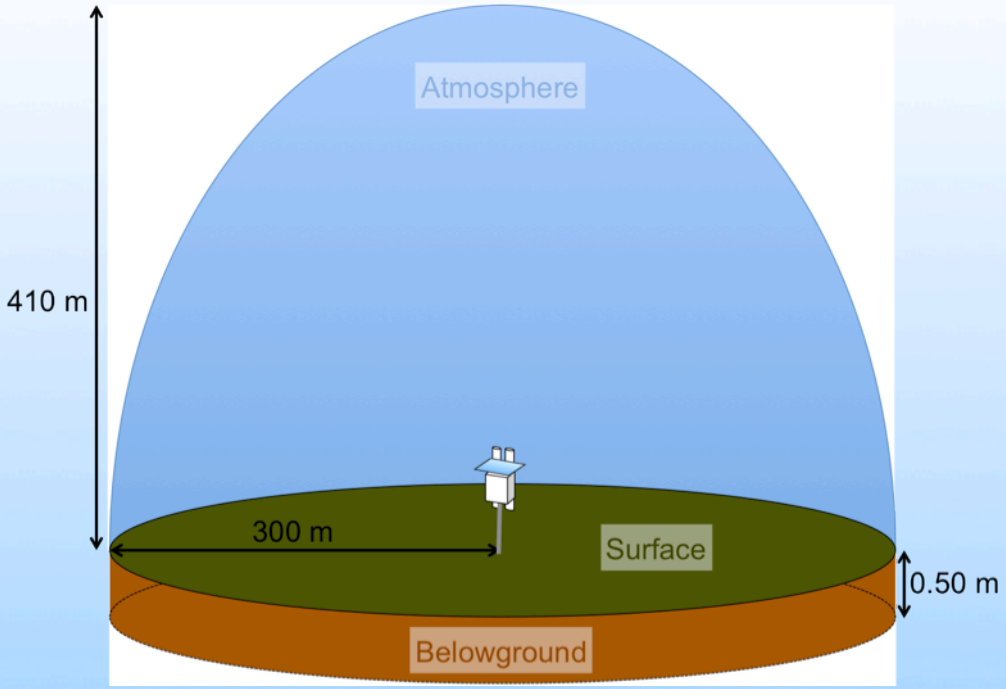


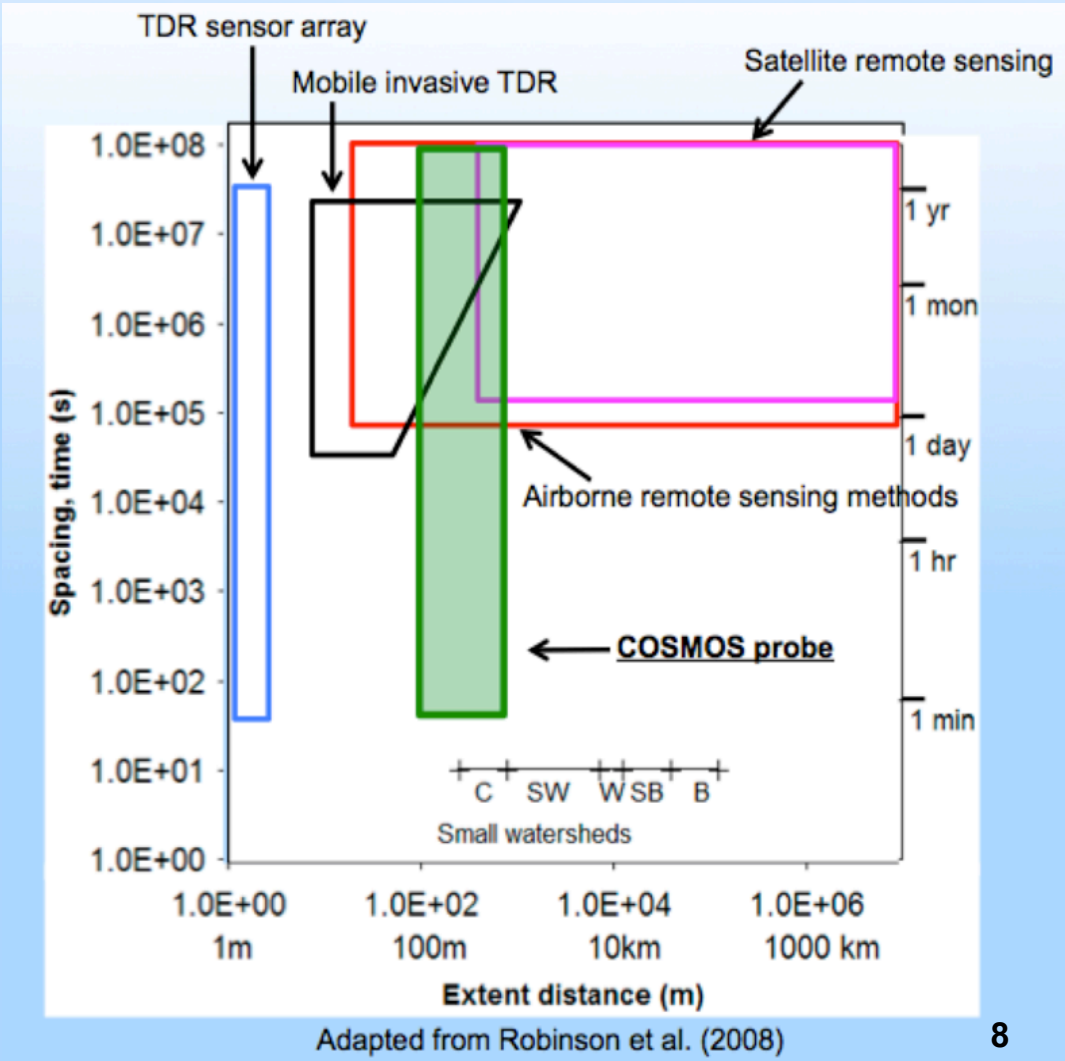
Hydrogen ('H_2O') and Stopping Power





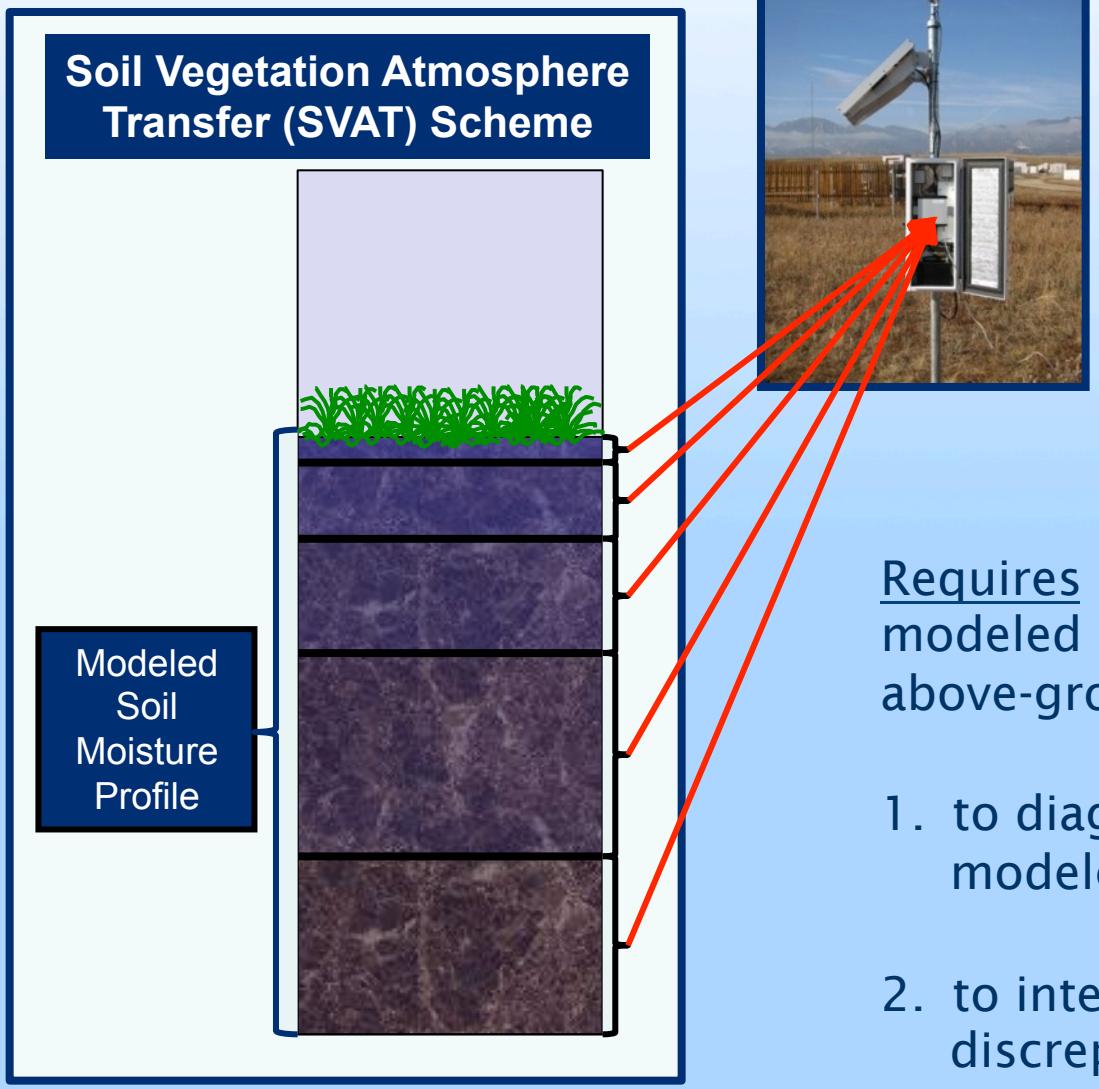
COSMOS Sensor Footprint





Adapted from Robinson et al. (2008)

COsmic-ray Soil Moisture Interaction Code (COSMIC)



GOAL

to update LSM-derived soil moisture profiles by assimilating the cosmic-ray fast neutron count

Requires an accurate model to interpret modeled soil moisture profiles in terms of the above-ground fast neutron count:

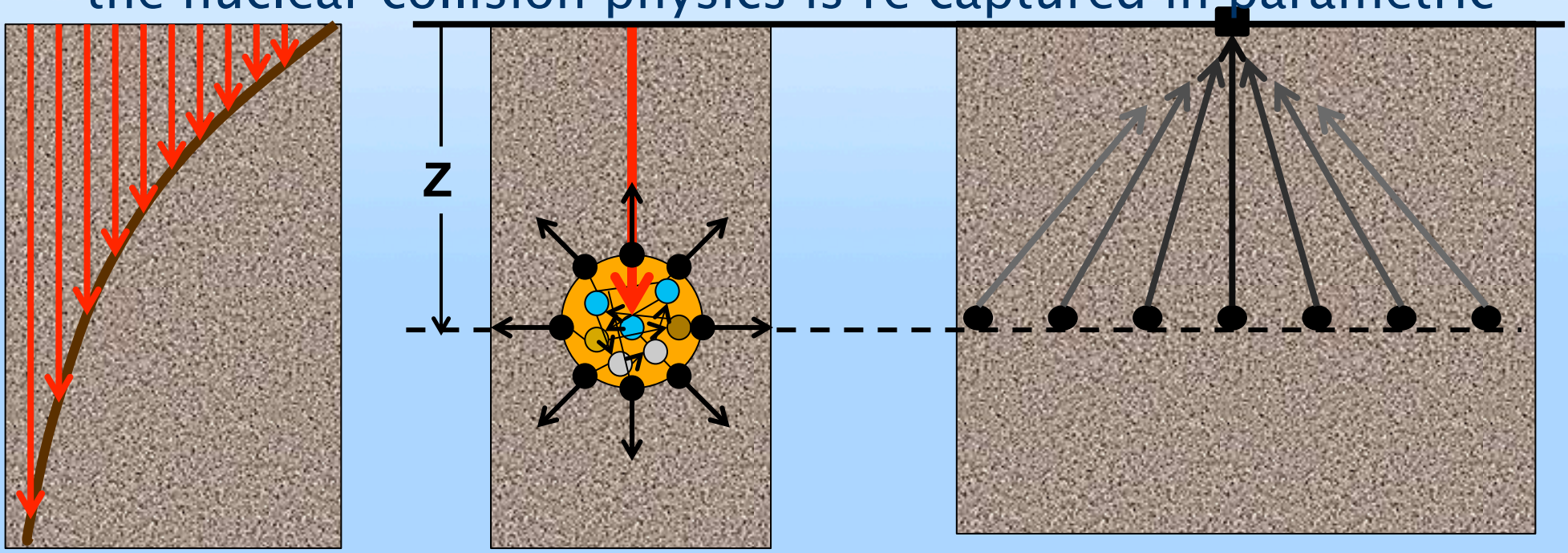
1. to diagnose if there is a discrepancy in the modeled soil moisture status

2. to interpret knowledge of the extent of that discrepancy back into the LSM, with weighting between layers reflecting their relative influence on the fast neutron count

COSMIC: Conceptual Model

COSMIC is a simple analytic model which:

- captures the essential below-ground physics that MCNPX represents
- can be calibrated by optimization against MCNPX so that the nuclear collision physics is re-captured in parametric



Exponential reduction in the number of high energy neutrons with depth

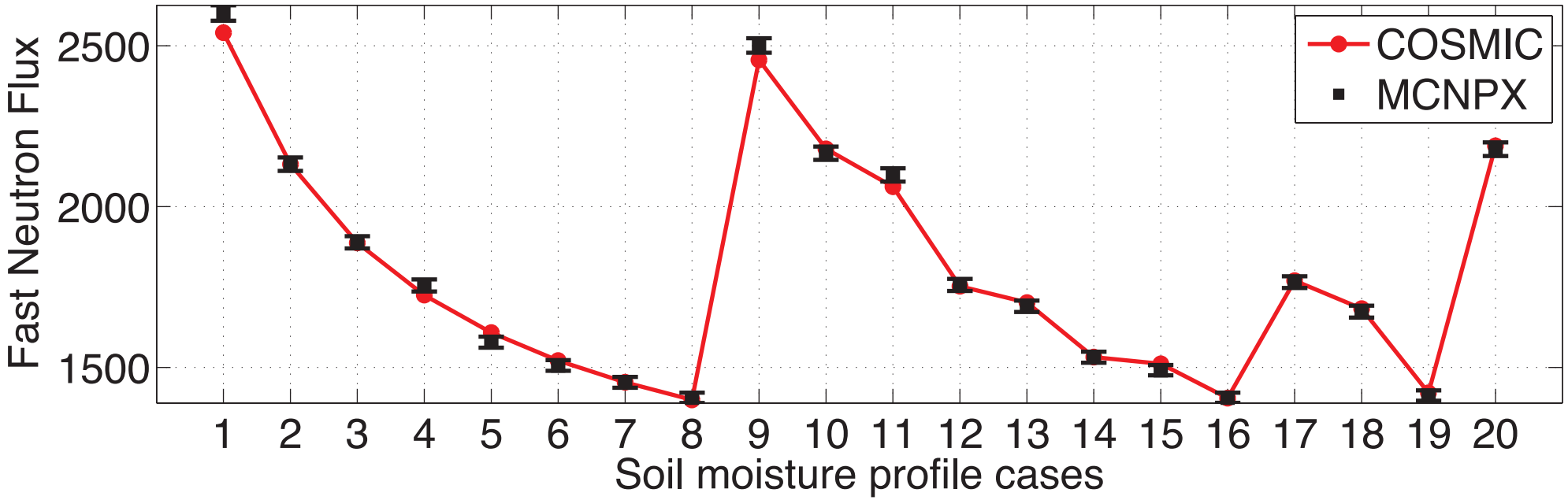
Isotropic creation of fast neutrons from high energy neutrons at level "*z*"

Exponential reduction in the number of the fast neutrons created at level "*z*" before their surface measurement

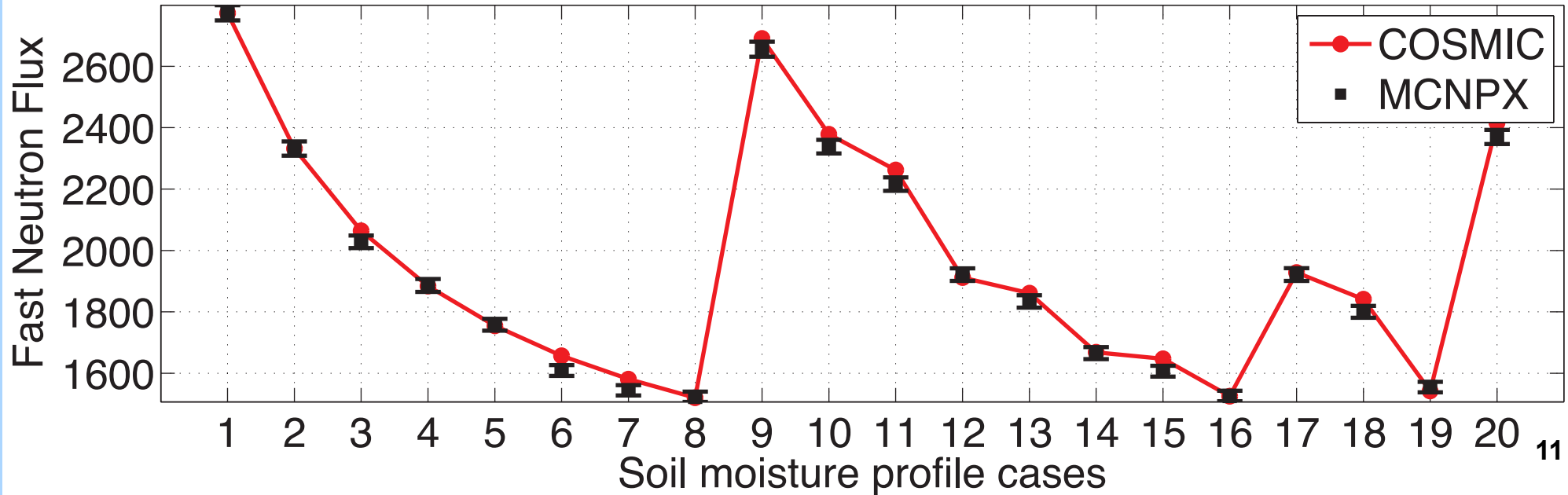
high energy neutrons → fast neutrons

COSMIC: Calibration

Manitou Forest (Colorado)



Santa Rita (Arizona)



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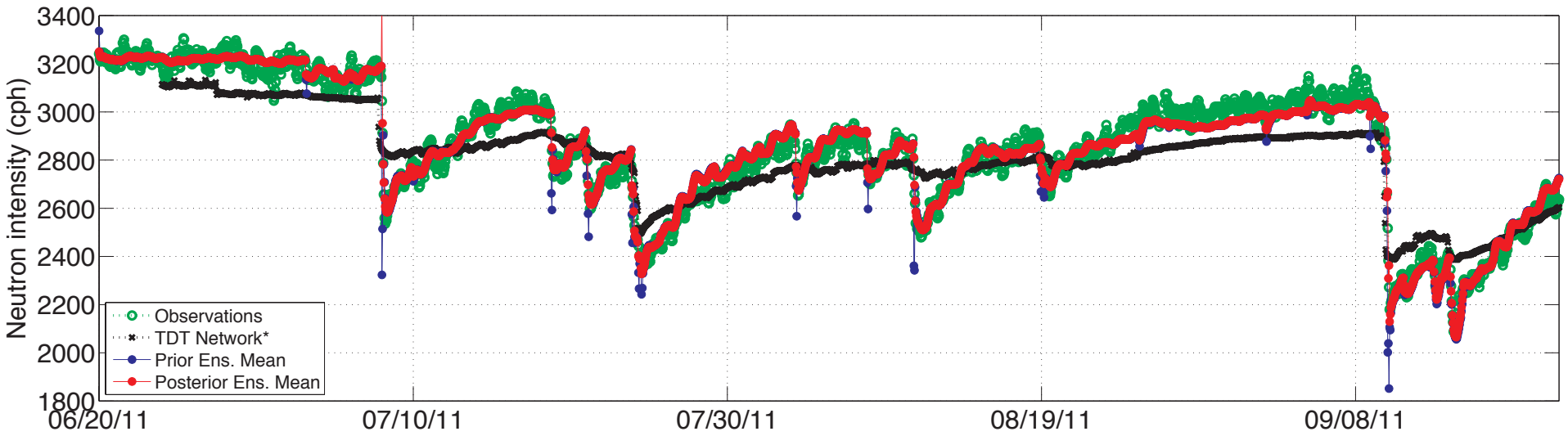
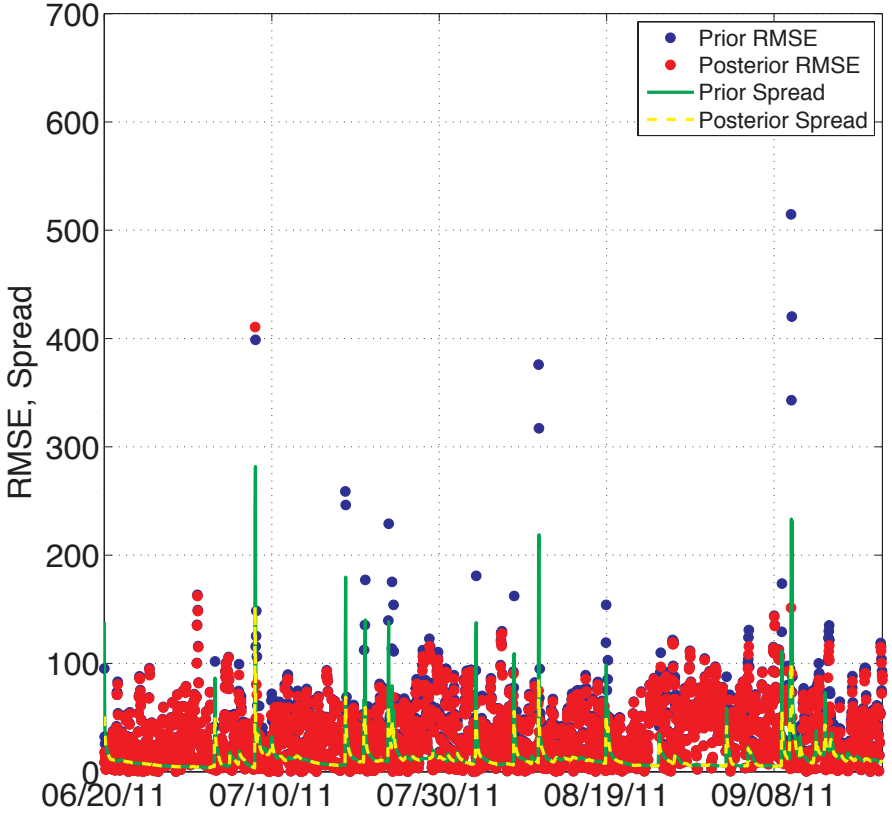
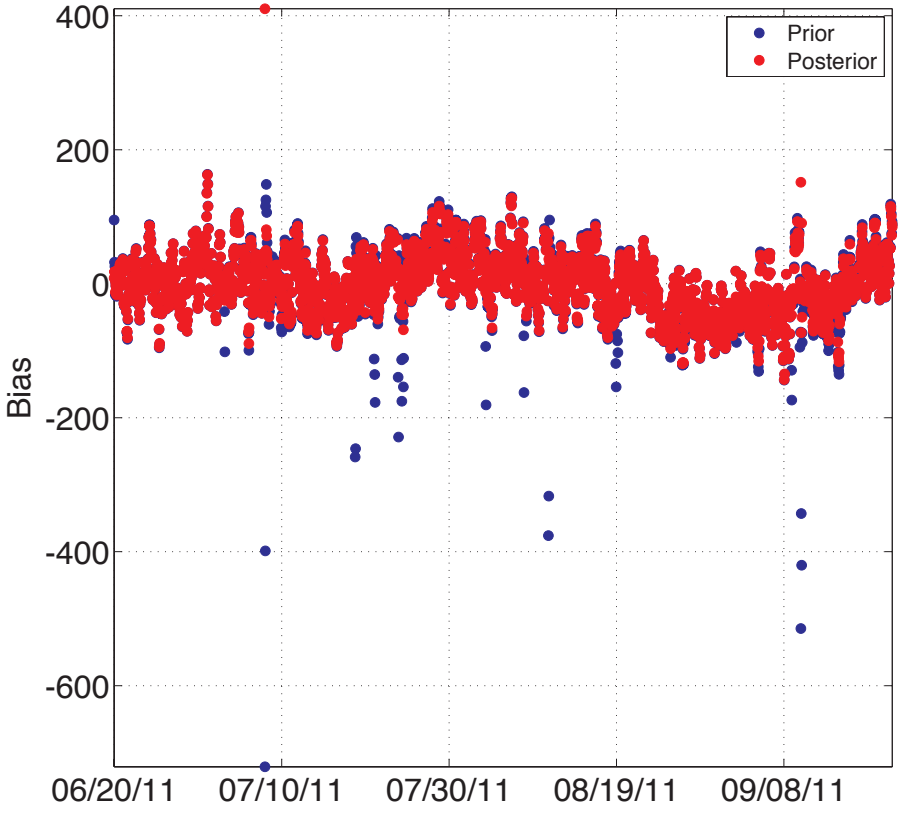
Previous DA Results

- NOAH-MP + DART
- Changes in DART's csh scripts (very rudimentary!!!!)
- Santa Rita Ameriflux site (near Tucson)
- 3 months of simulation (06/20/2011 through 09/20/2011)
- 40 ensemble members
- Perturbed meteorological forcing
- Assimilate neutron intensity every hour (model never runs free!!!)
- Update NOAH-MP 'state' variables
- Comparison with average soil moisture from network of point-scale sensors place around the COSMOS footprint (18 profiles, 5 depths)
- Comparison with flux tower measurements

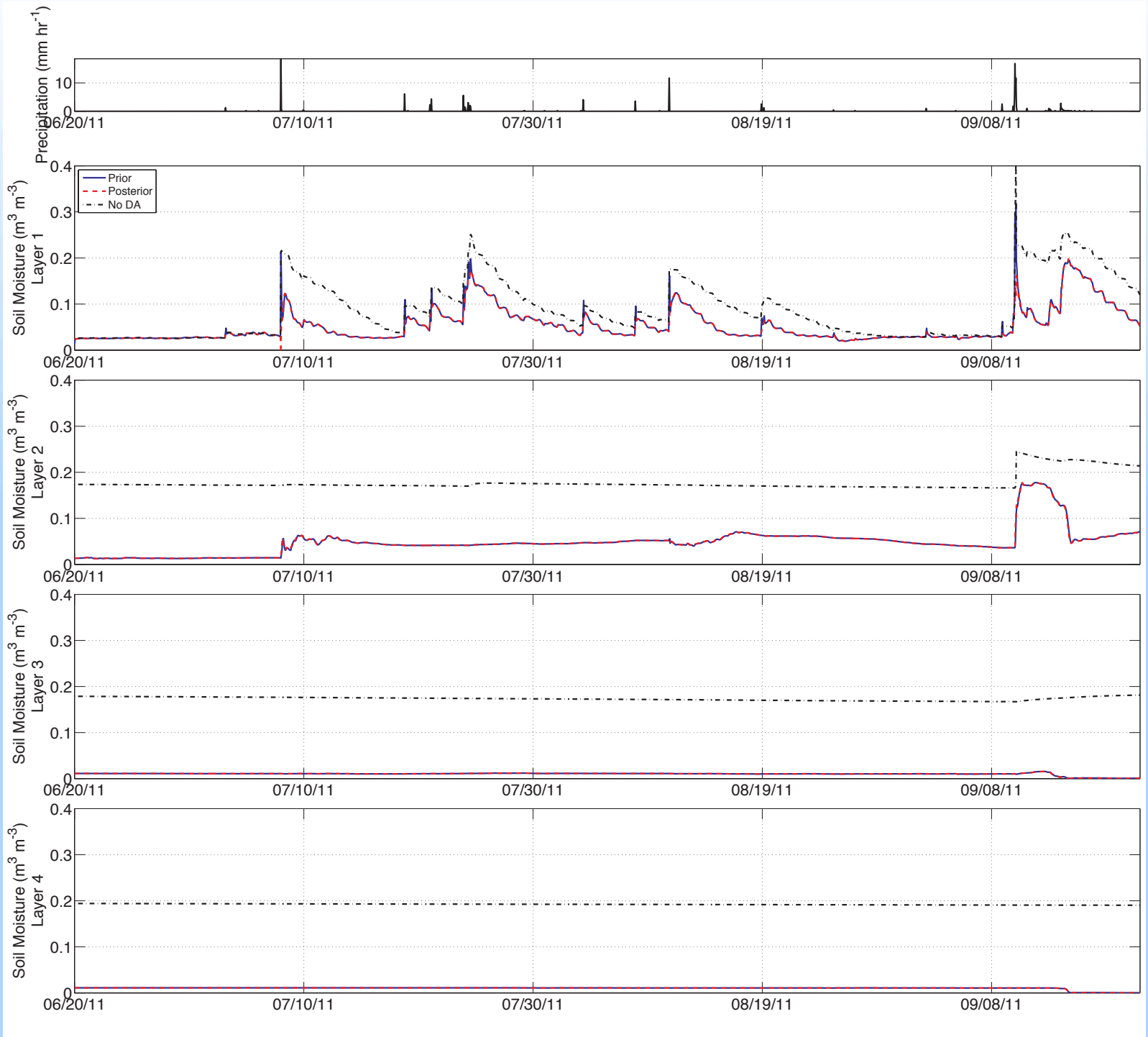
Neutron Intensity and Integrated Soil Moisture







NOAH-MP Soil Moisture: DA versus Free Run



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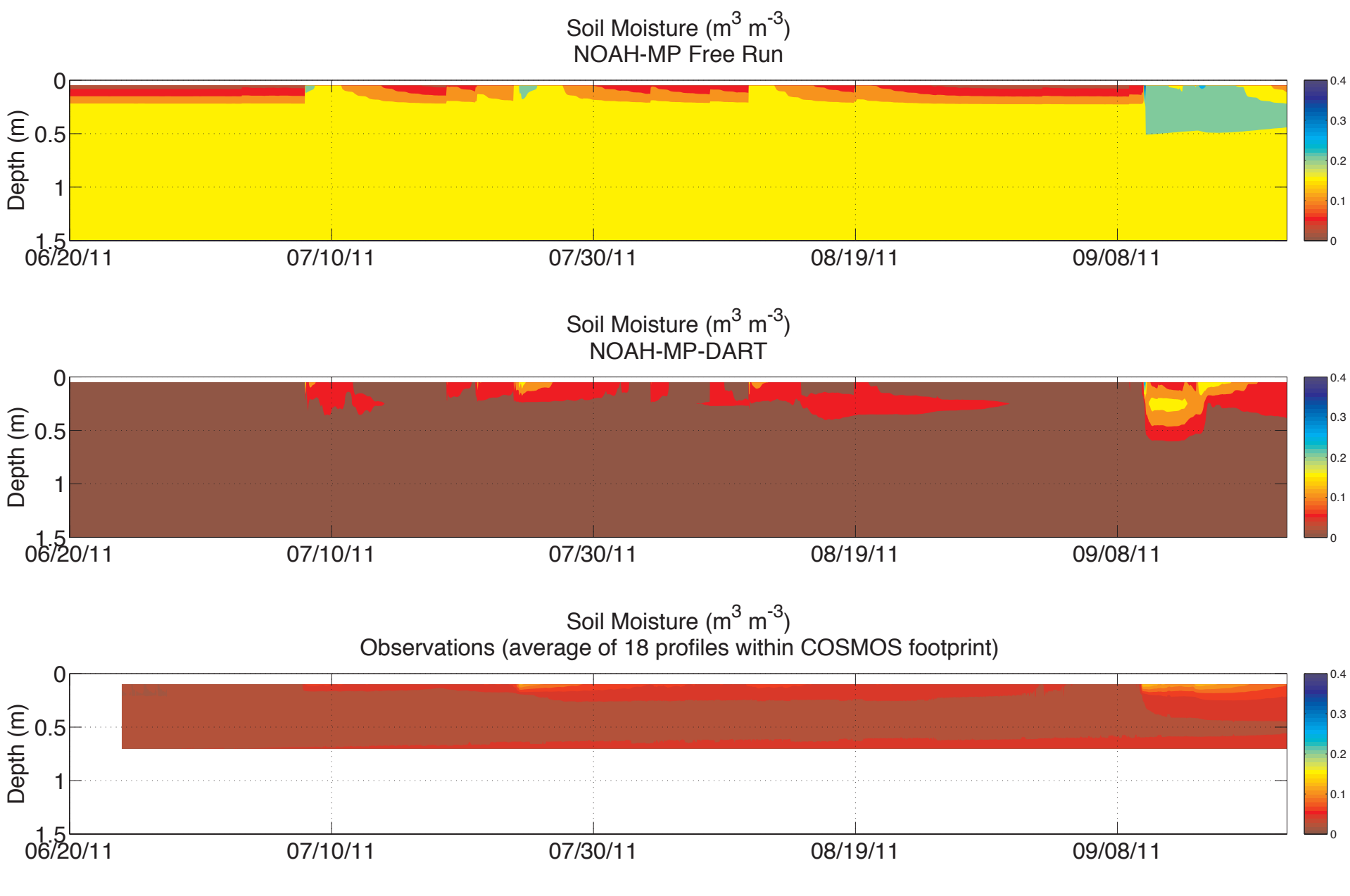

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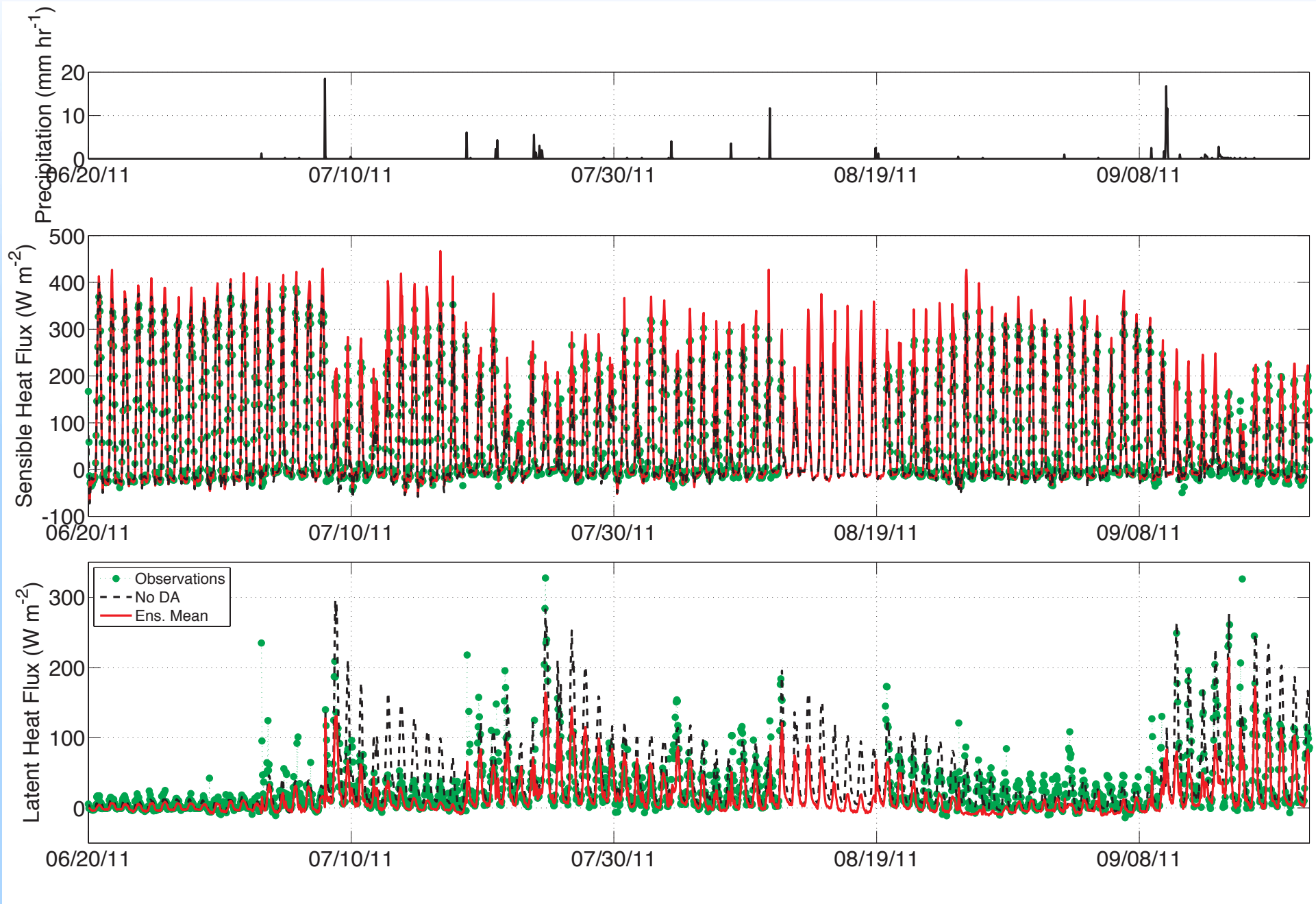
Surface Energy Fluxes



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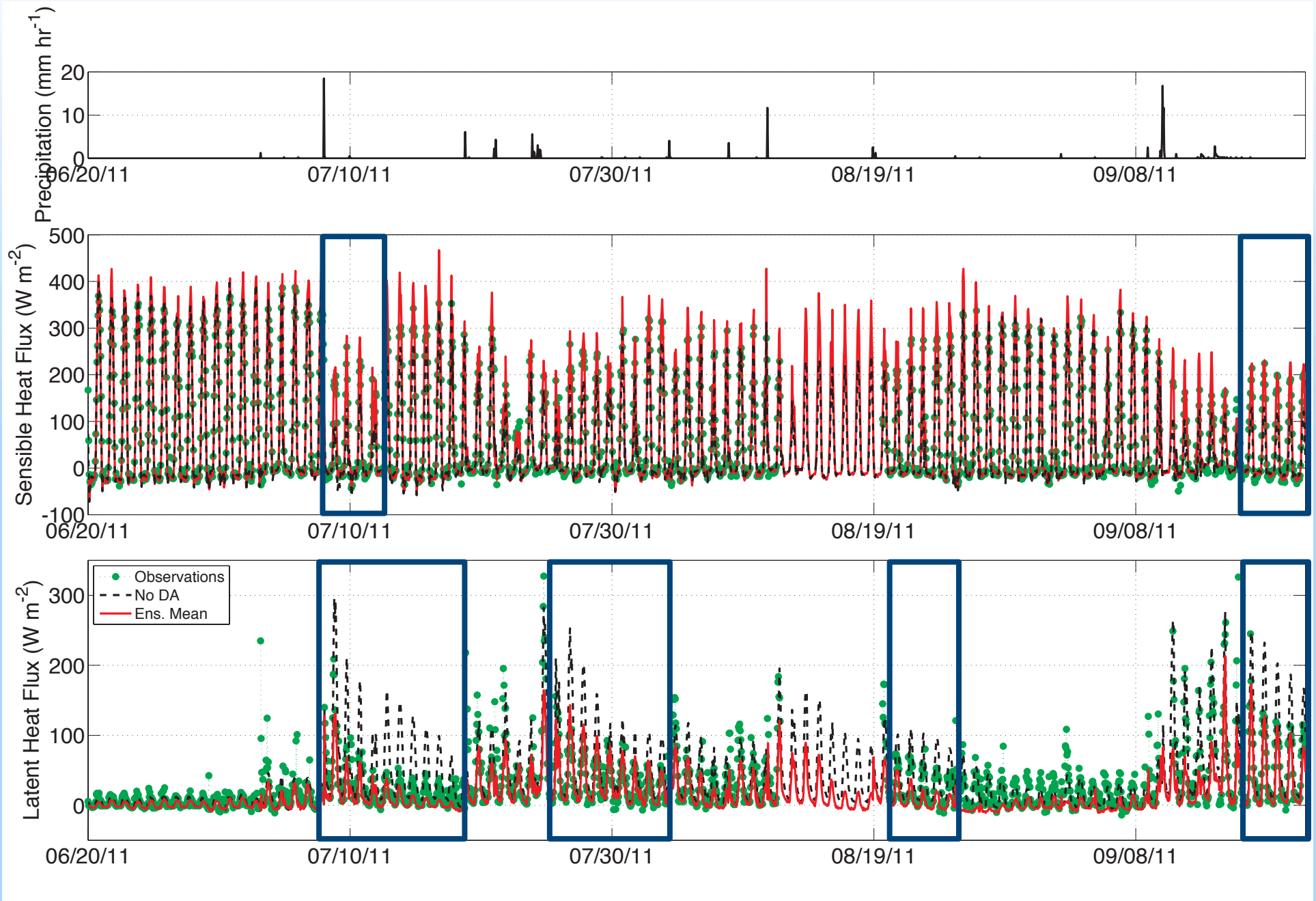

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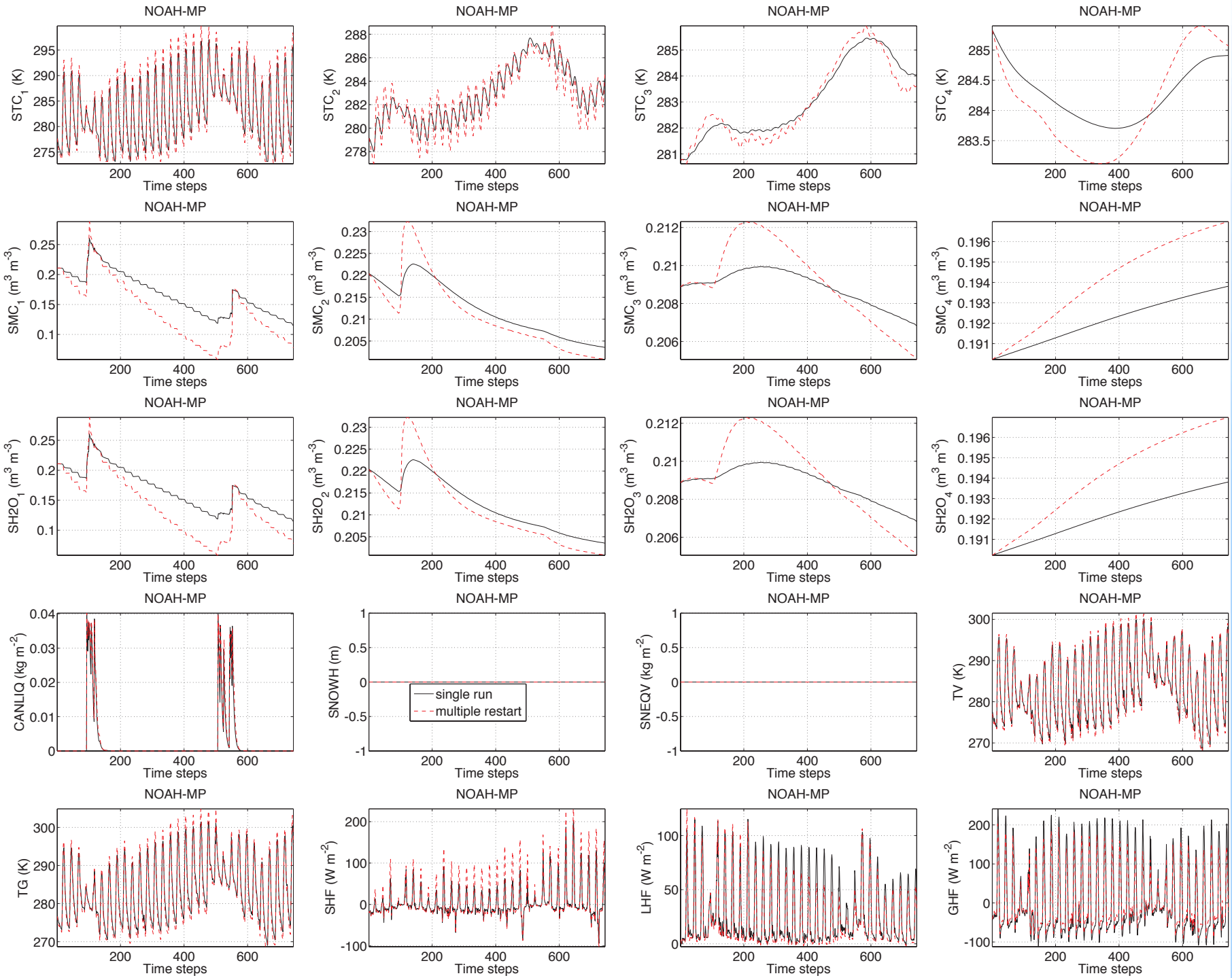
NOAH-MP: Restart Issues!!!



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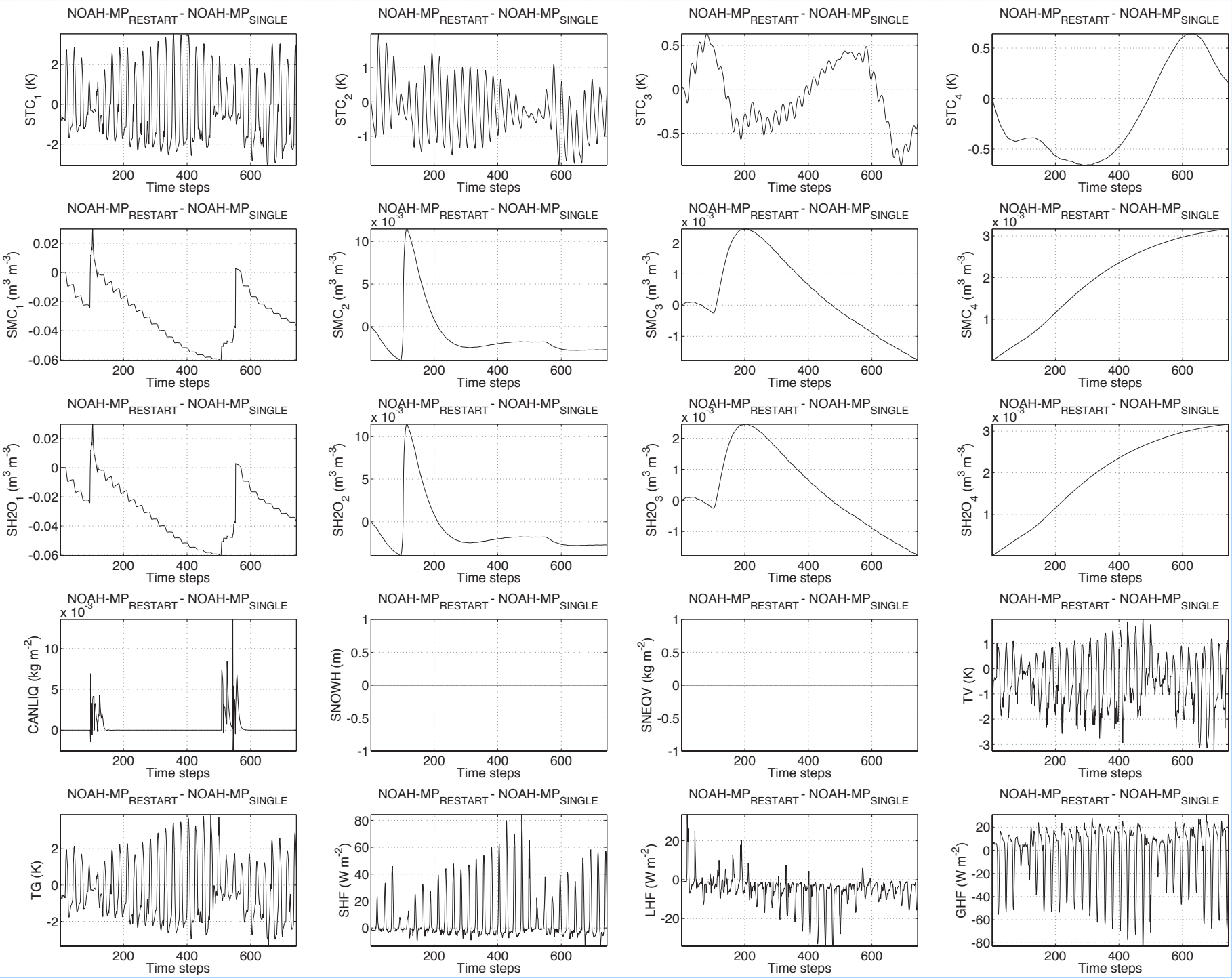
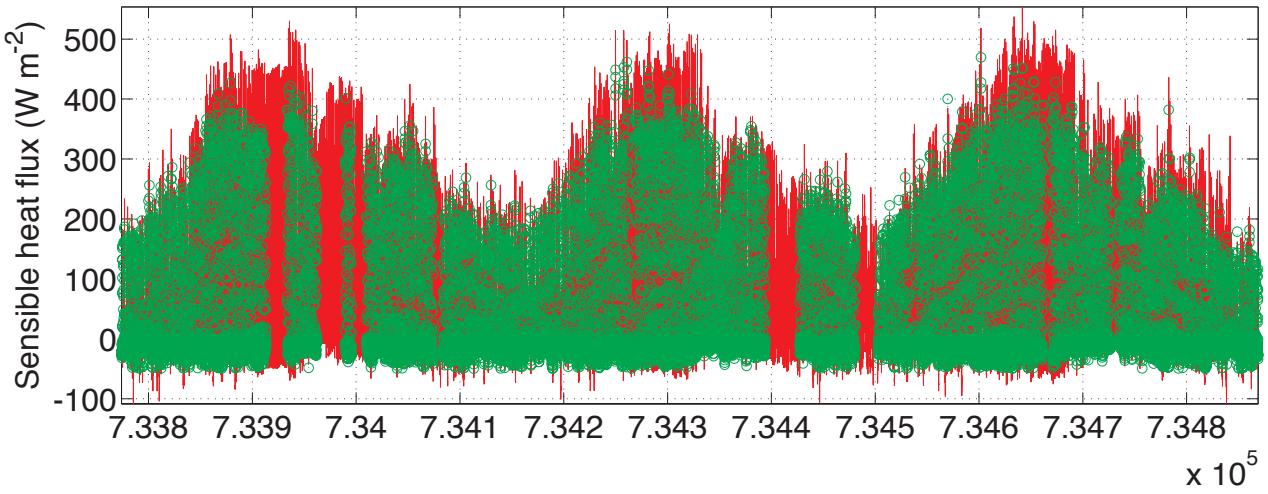
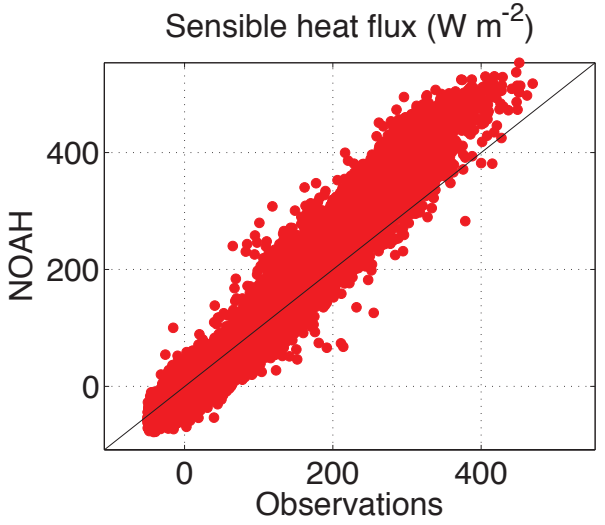


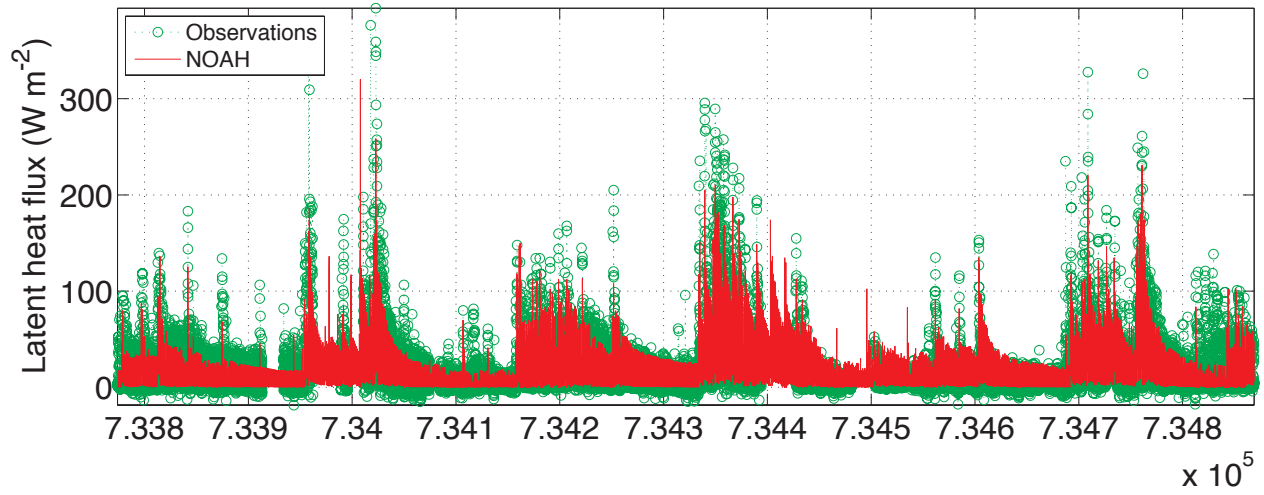
Current Status: NOAH HRLDAS

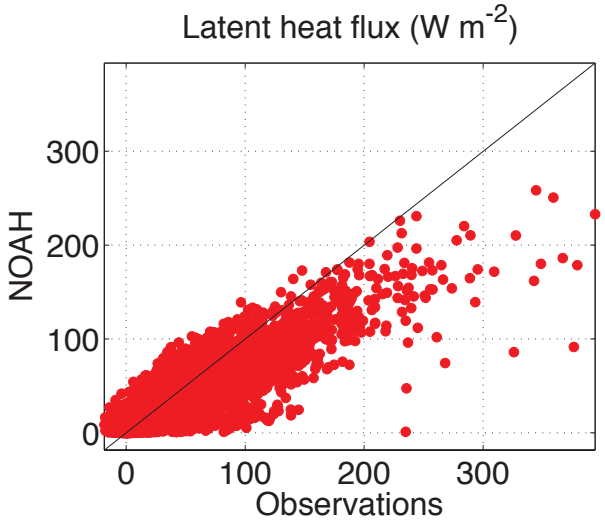
- NOAH "2D" set up for single-point simulations only (at the moment)
- Bottom interface of WRF model (easy to expand to coupled simulations in the future!!!)
- Much 'cleaner' set of scripts in DART
- Choice to include variables to be assimilated or evaluated
- Handles namelist, restart and forcing files quite differently from NOAH-MP (1D model)
- So far… implementation using standard forcing data that came with model (from Michael Barlage)
- Currently working on script to extract only needed forcing files from a master NetCDF data (to avoid manipulating tens of thousands of files at each DART update)
- Set of template files to facilitate user-specified site and parameters

Santa Rita NOAH stand-alone simulation









Goals: Before returning to Tucson

- Clean and working version of NOAH-DART
- Generate perturbed meteorological forcing and implement into scripts
- Need to fix some minor interpolation issues (Tim mentioned right before he left)
- Run and test *perfect_obs* experiment
- Run and test simple *filter* experiment
- Cleaner version of COSMIC in *obs_def_COSMOS.f90* (at the moment, there are some hardwired parameters specific to Santa Rita site) → make *obs_def_COSMOS.f90* read from standard look-up table for other sites
- Create a *obs_seq.in* and *obs_seq.out* file with actual COSMOS measurements
- Copy new DART version to UA computers and implement parallel processing