Data Assimilation of Cosmic-ray Derived Soil Moisture

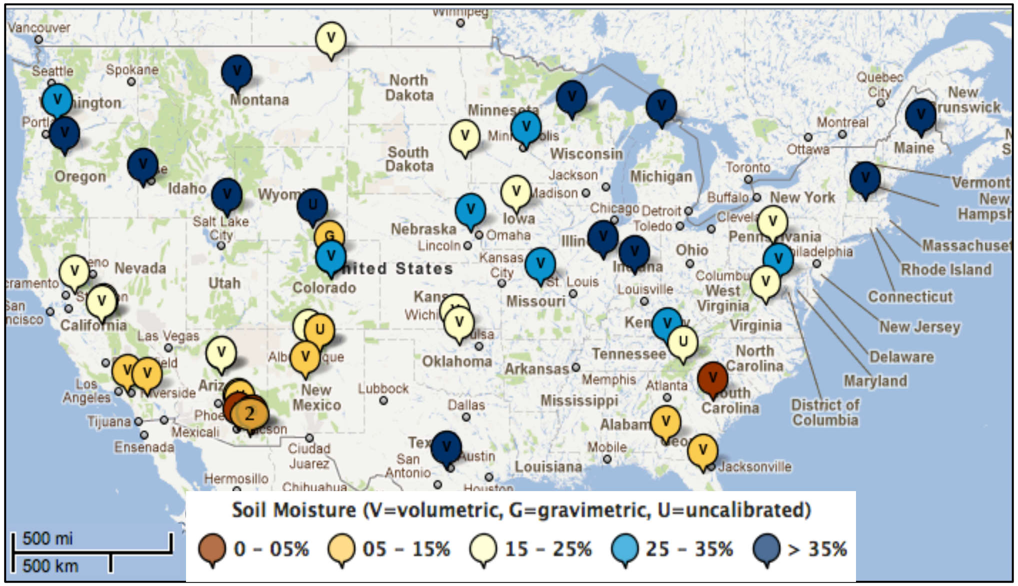
Rafael Rosolem

With acknowledgments to W. J. Shuttleworth, M. Zreda, X. Zeng, A. Arellano, T. Hoar, J. Anderson, T. Franz, S. A. K. Papuga, M. Barlage, C. Zweck, D. Desilets, G. Womack, J. Broermann, R. Chrisman, A. M. Karczynski

THE UNIVERSITY OF ARIZONA®

AGU Fall Meeting
December 04, 2012

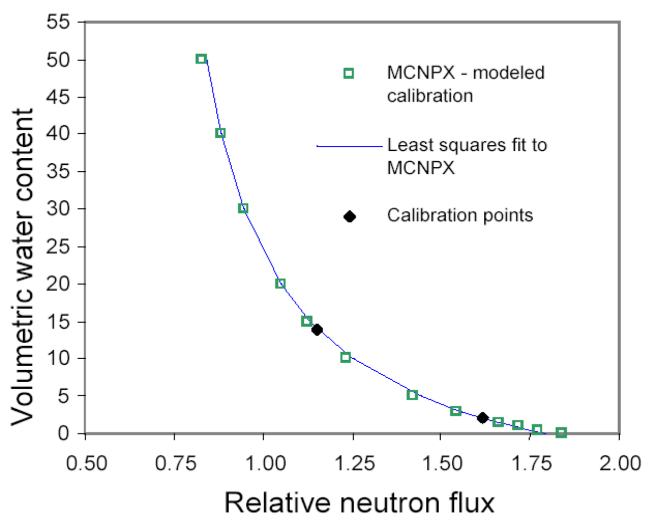
COsmic-ray Soil Moisture Observing System

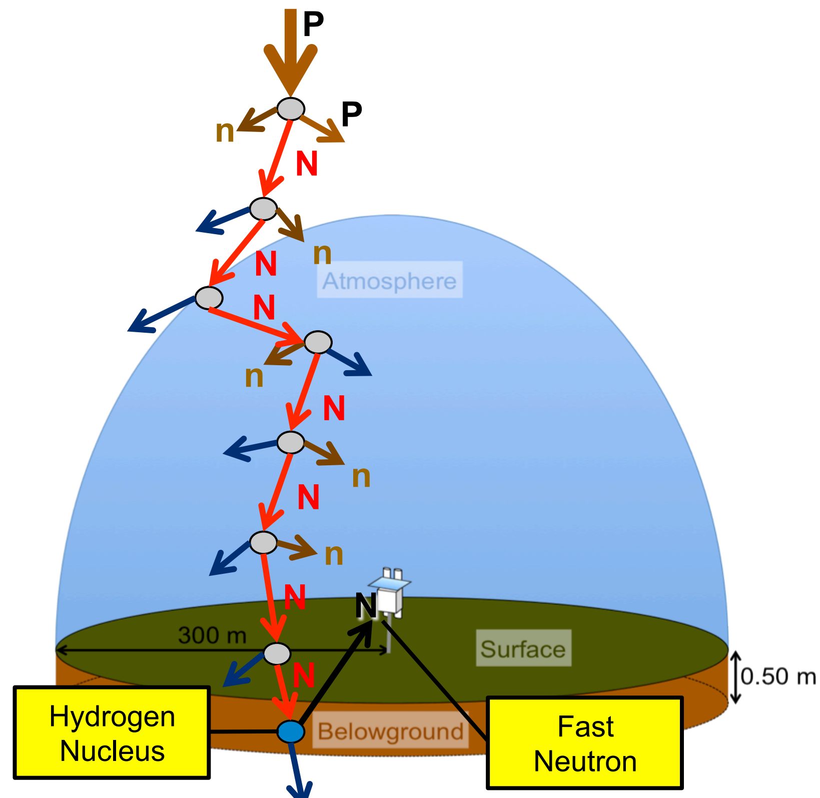


COSMOS

Cosmic-ray Soil Moisture Observing System

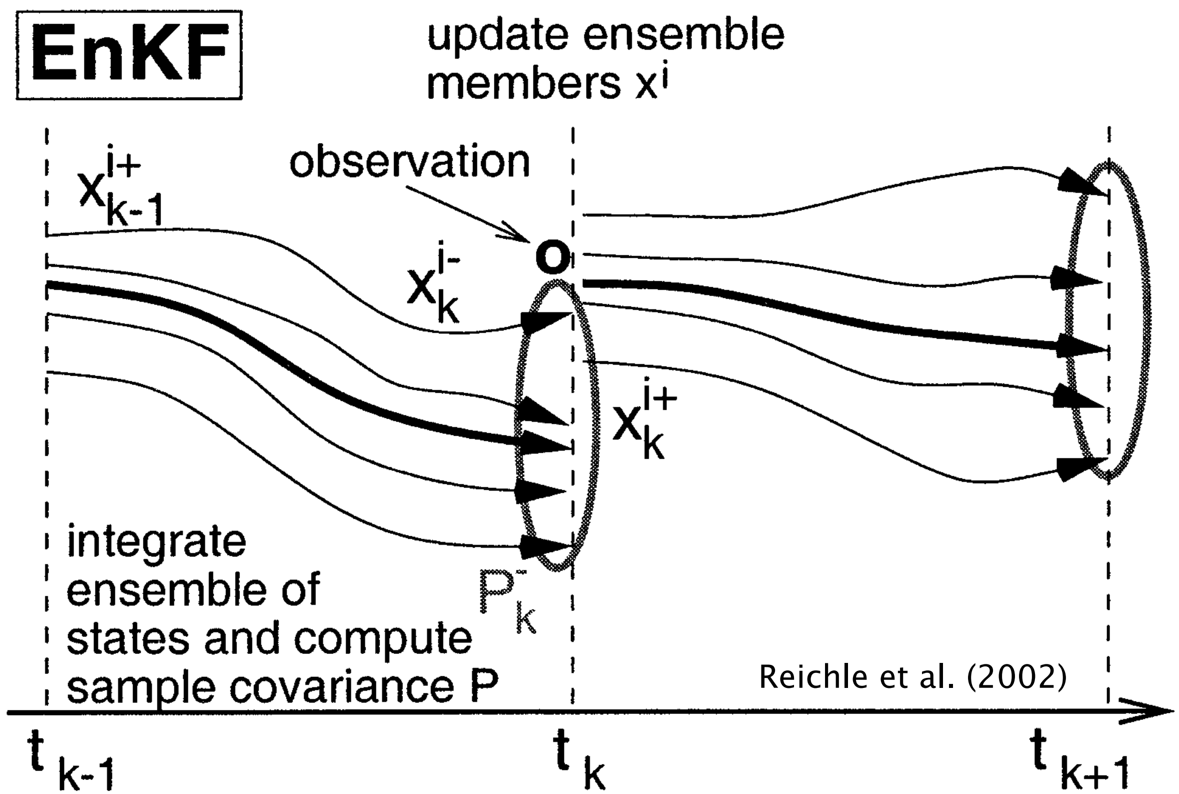
http://cosmos.hwr.arizona.edu





Data Assimilation

$$P(X \mid OBS) = \frac{P(OBS \mid X).P(X)}{\text{normalization factor}}$$



X = state variable (e.g., soil moisture)

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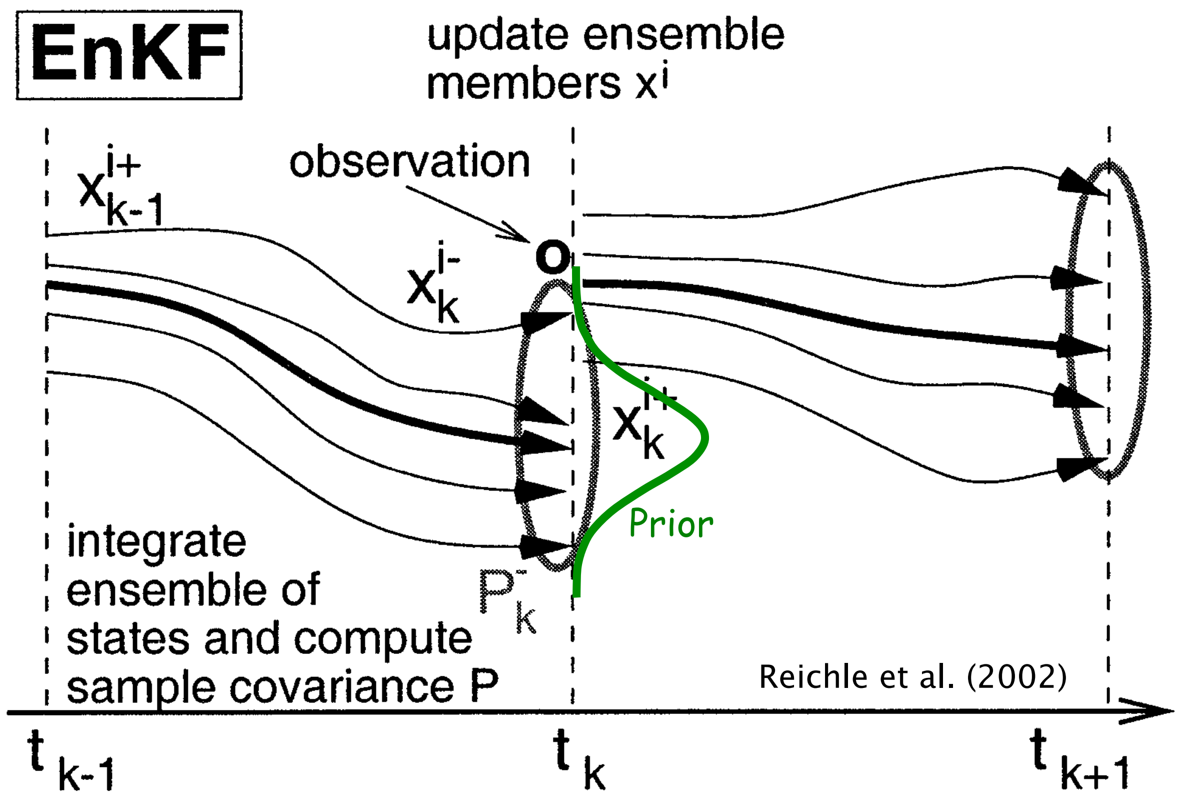

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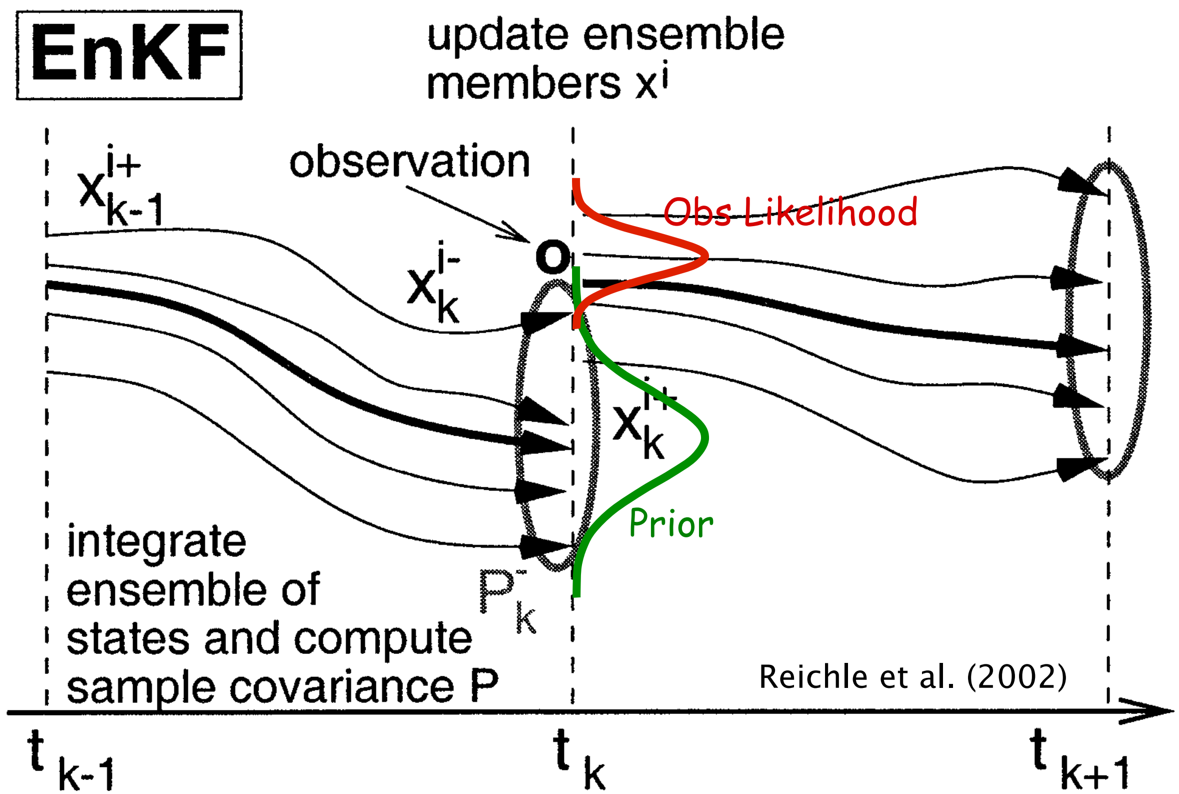

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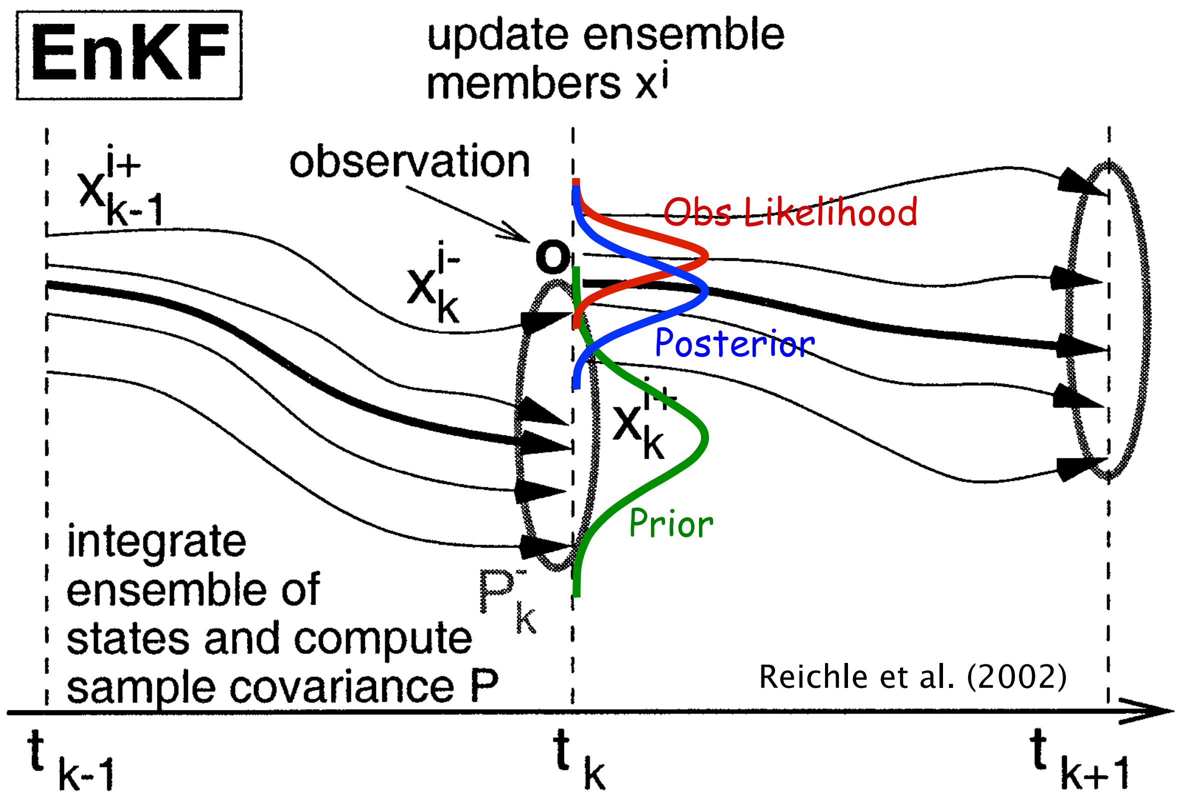

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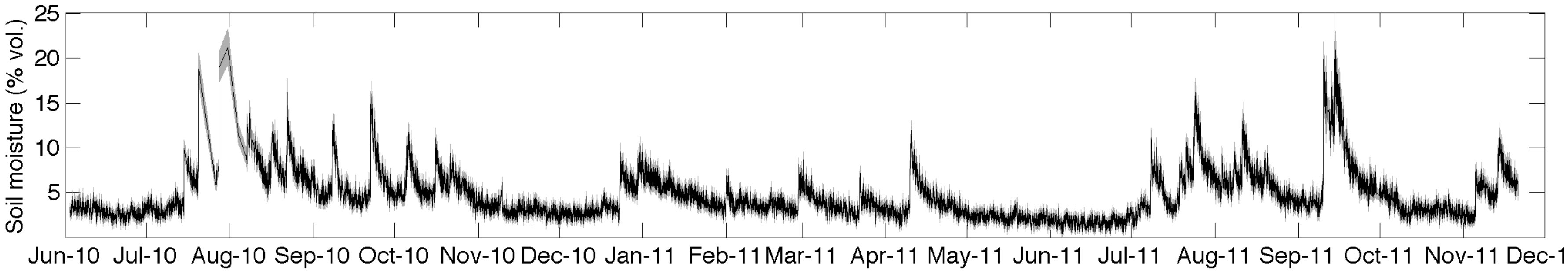
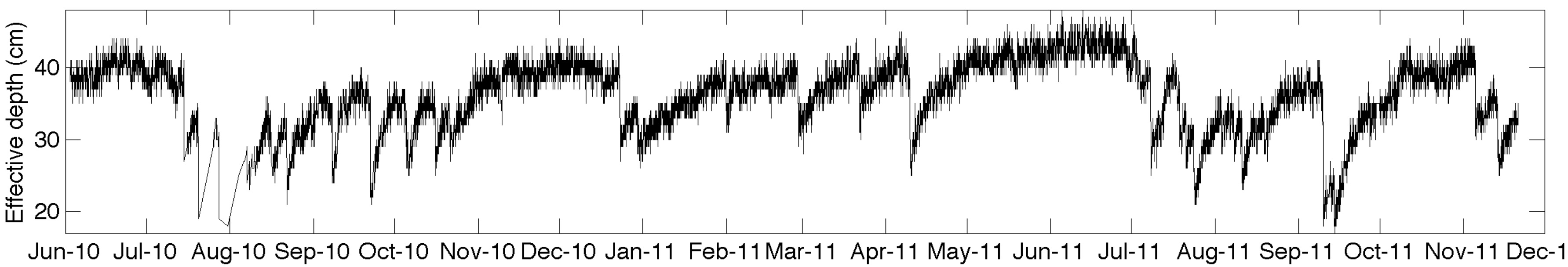
Soil Moisture and Measurement Depth

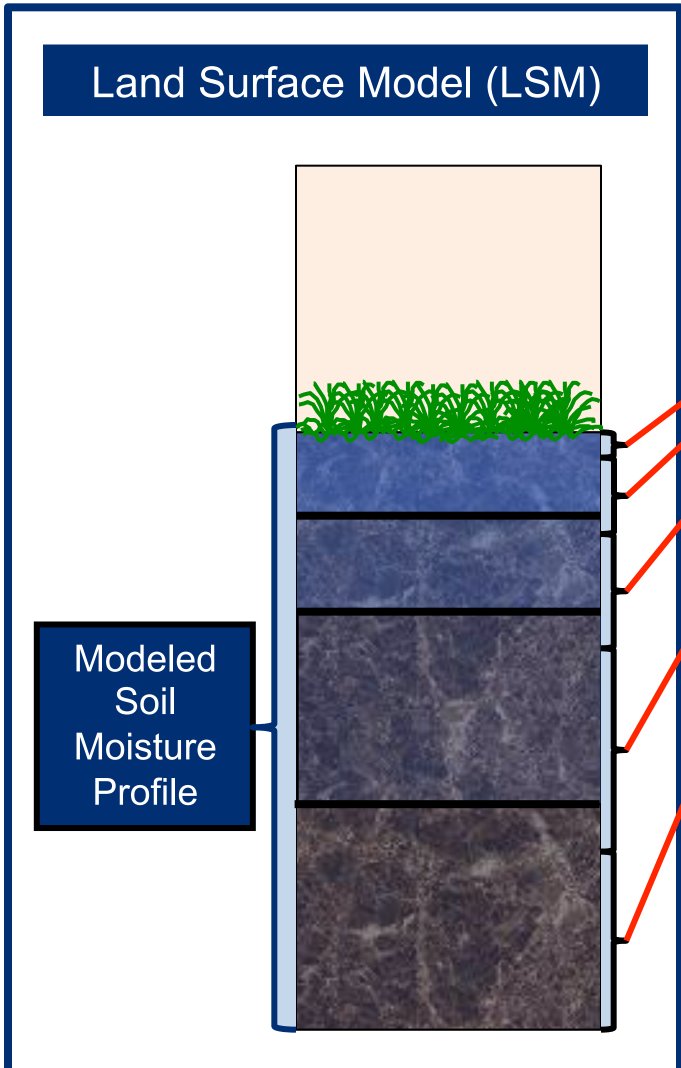
- "Effective" measurement depth depends on soil moisture
- Can reach several individual layers of a typical land surface model





Therefore, **direct assimilation of neutron intensity** is more **desirable**!!!

Can We Assimilate Neutron Counts?



GOAL

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

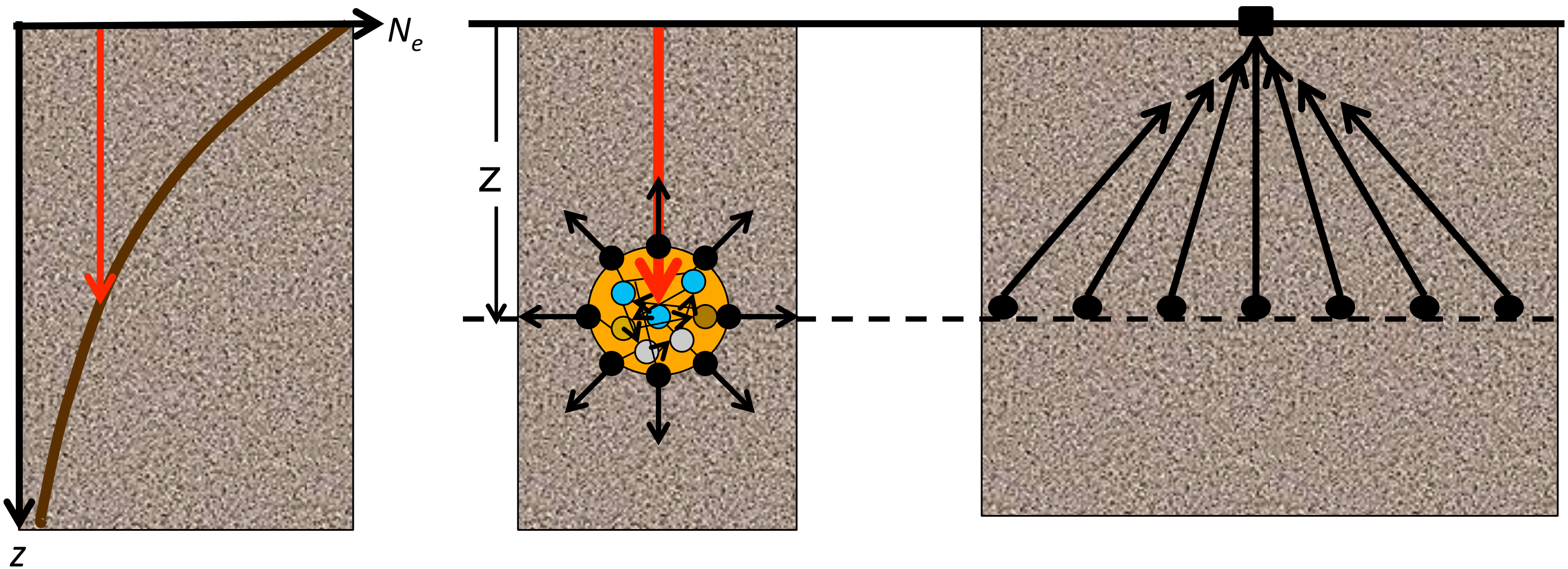
Requires an accurate model to interpret modeled soil moisture profiles in terms of the above-ground fast neutron count

Monte Carlo Neutron Particle model (**MCNPx**) does that but it is **too slow** for use in **data assimilation**

COsmic-ray Soil Moisture Interaction Code (COSMIC)

COSMIC is a simple analytic model which:

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



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

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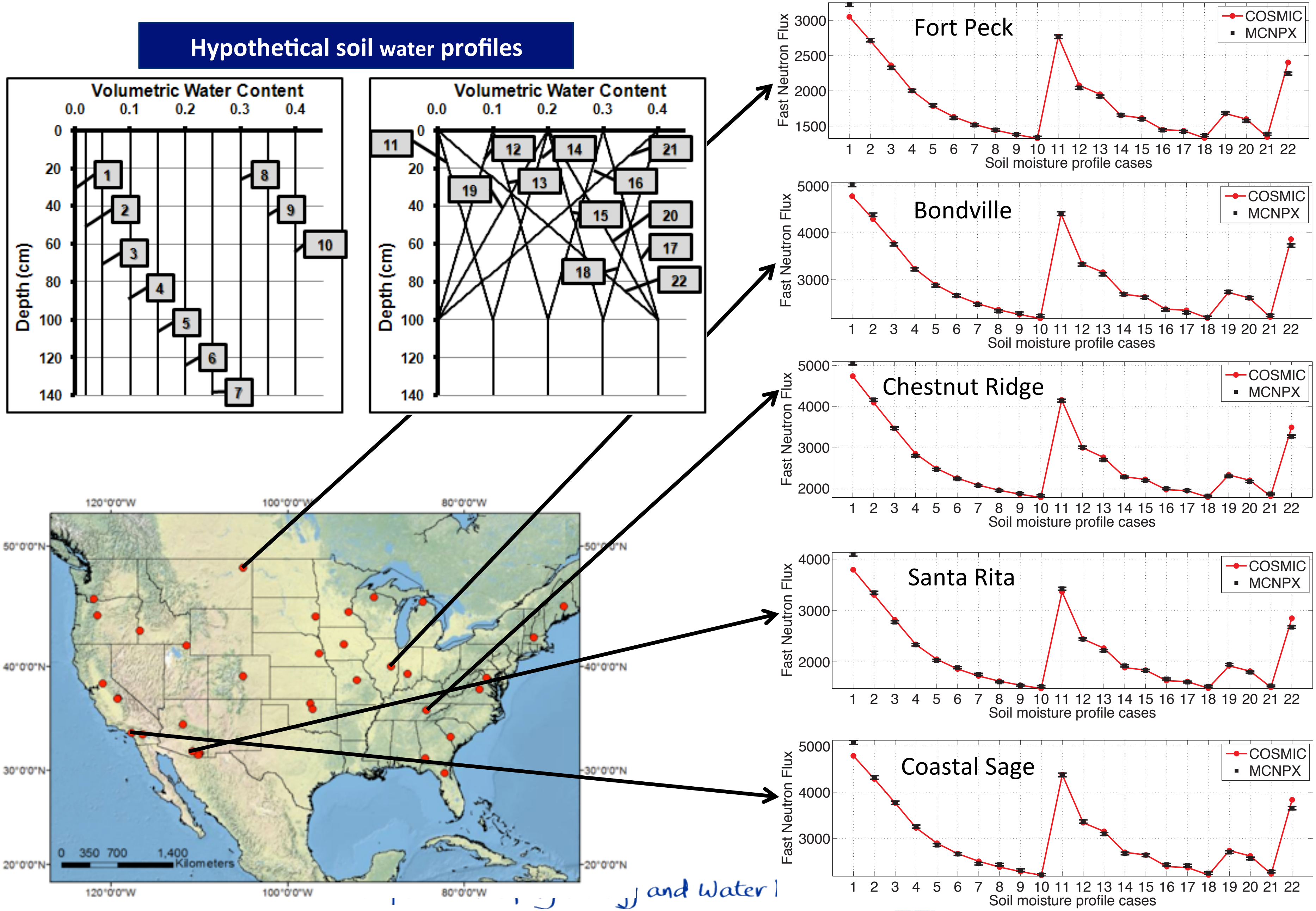
$$N_{COSMOS} = N \int_0^{\infty} \left[\underbrace{\exp\left(-\left[\frac{m_s(z)}{L_1} + \frac{m_w(z)}{L_2} \right] \right)} \cdot \underbrace{\left[\alpha \rho_s(z) + \rho_w(z) \right]} \cdot \underbrace{\left(\frac{2}{\pi} \right) \int_0^{\pi/2} \exp\left(\frac{-1}{\cos(\theta)} \left[\frac{m_s(z)}{L_3} + \frac{m_w(z)}{L_4} \right] \right) .d\theta} \right] .dz$$

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

Calibrating COSMIC



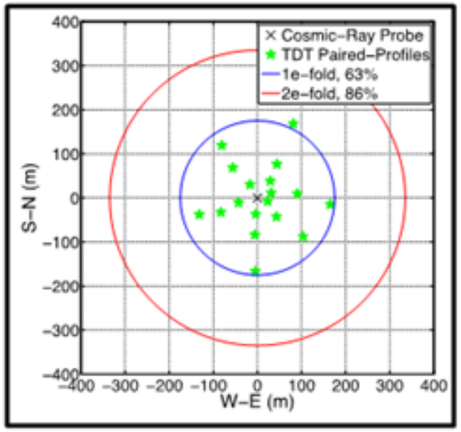
and Water

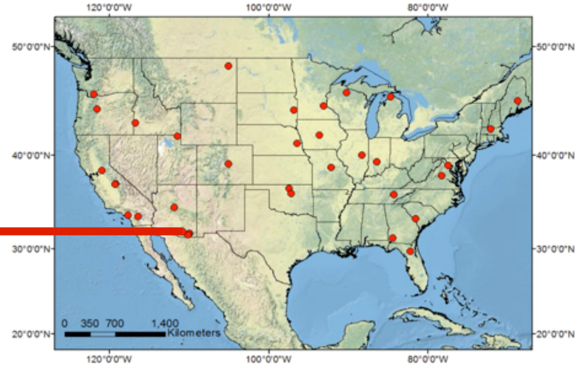
COSMIC Performance at Santa Rita (AZ)

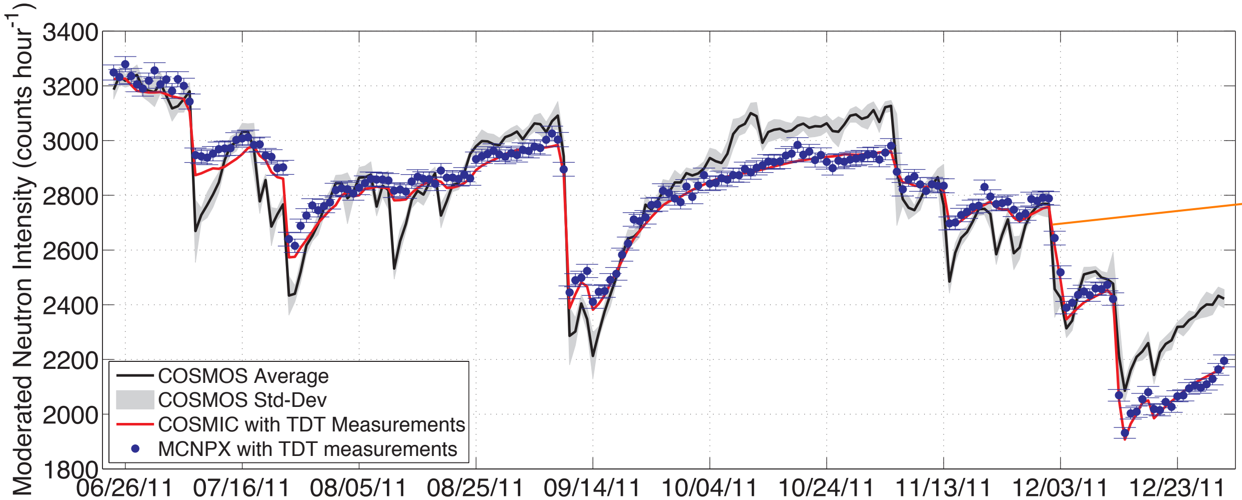
Using COSMIC to estimate COSMOS counts from measured soil moisture profiles (TDT sensors)

(a)

(b)

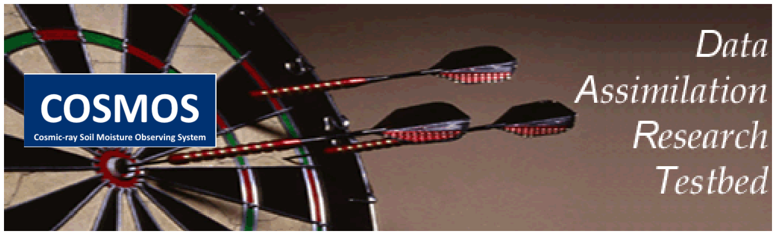




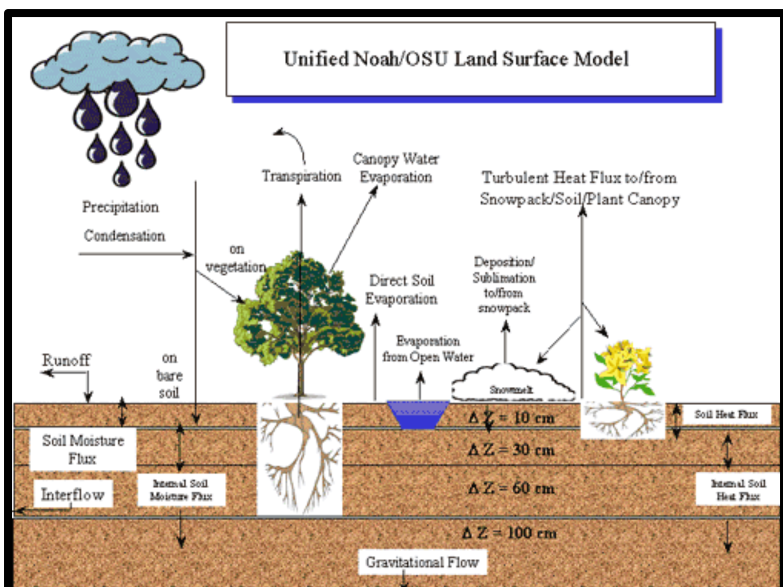


The area-average soil moisture from the TDT sensors doesn't sample the near-surface soil moisture (0-10 cm), so the COSMIC calculation based on it doesn't recognize the faster rate of drying of surface soil moisture

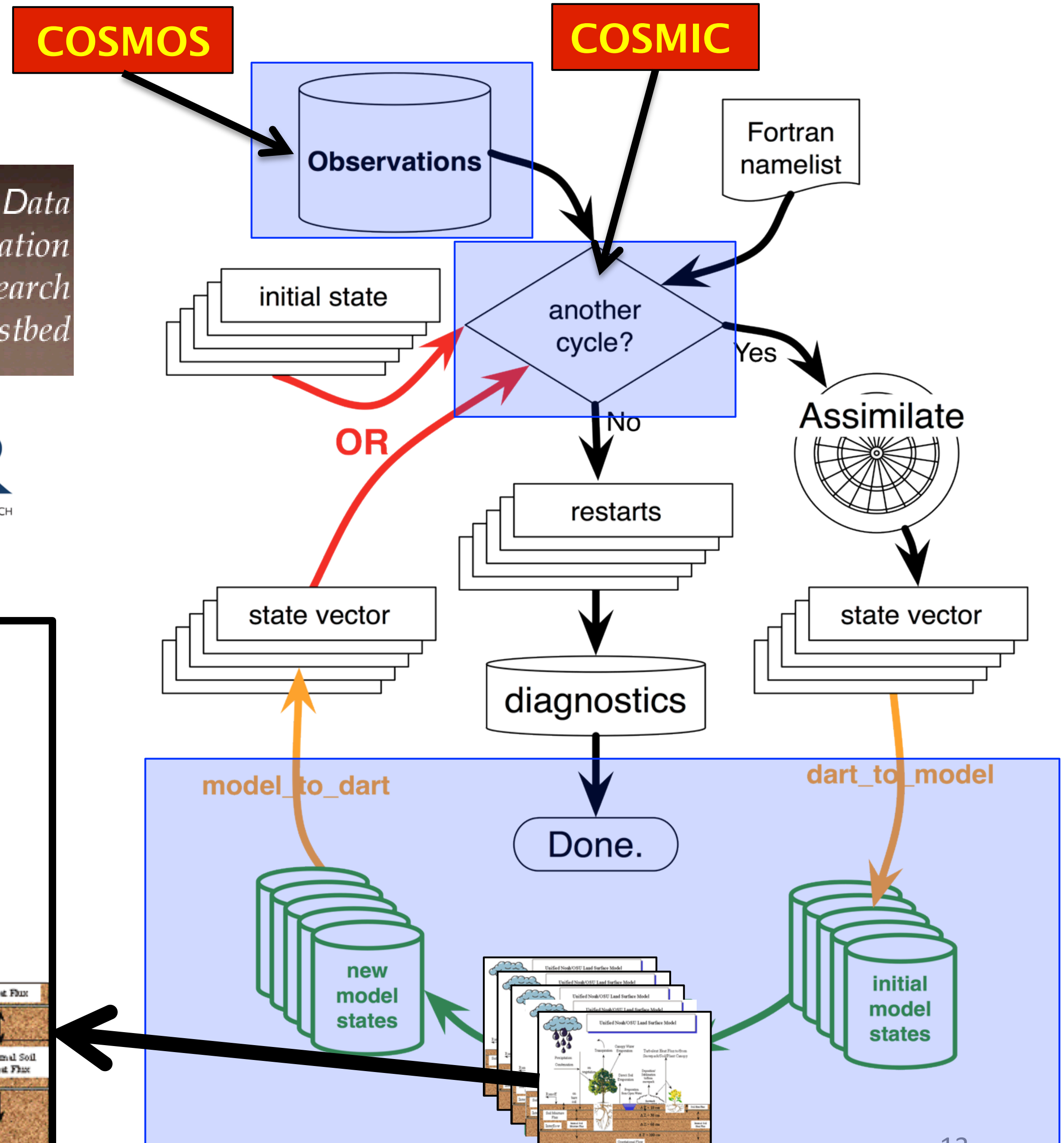
Data Assimilation Framework



NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

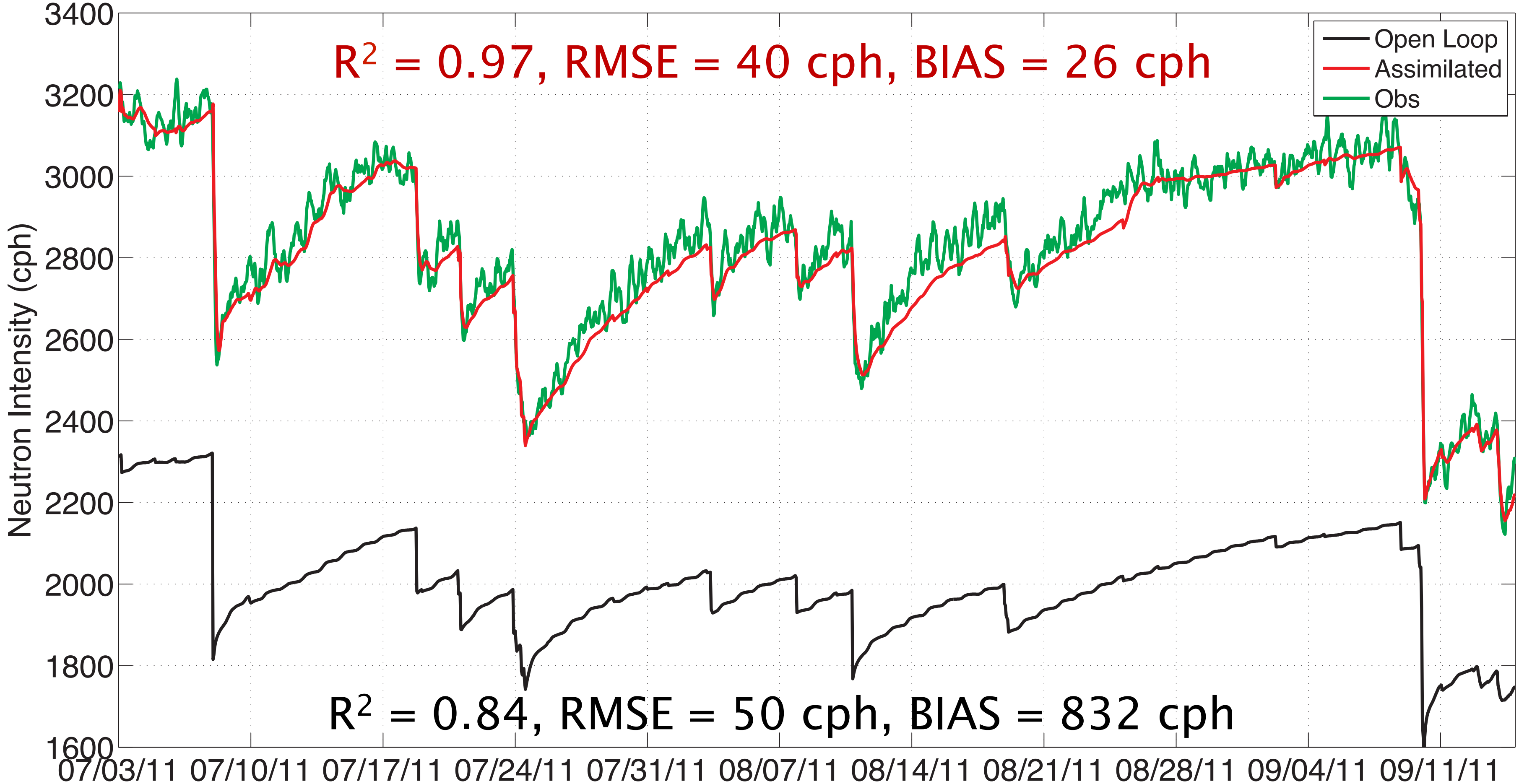


http://www.ral.ucar.edu/research/land/technology/lsm.php

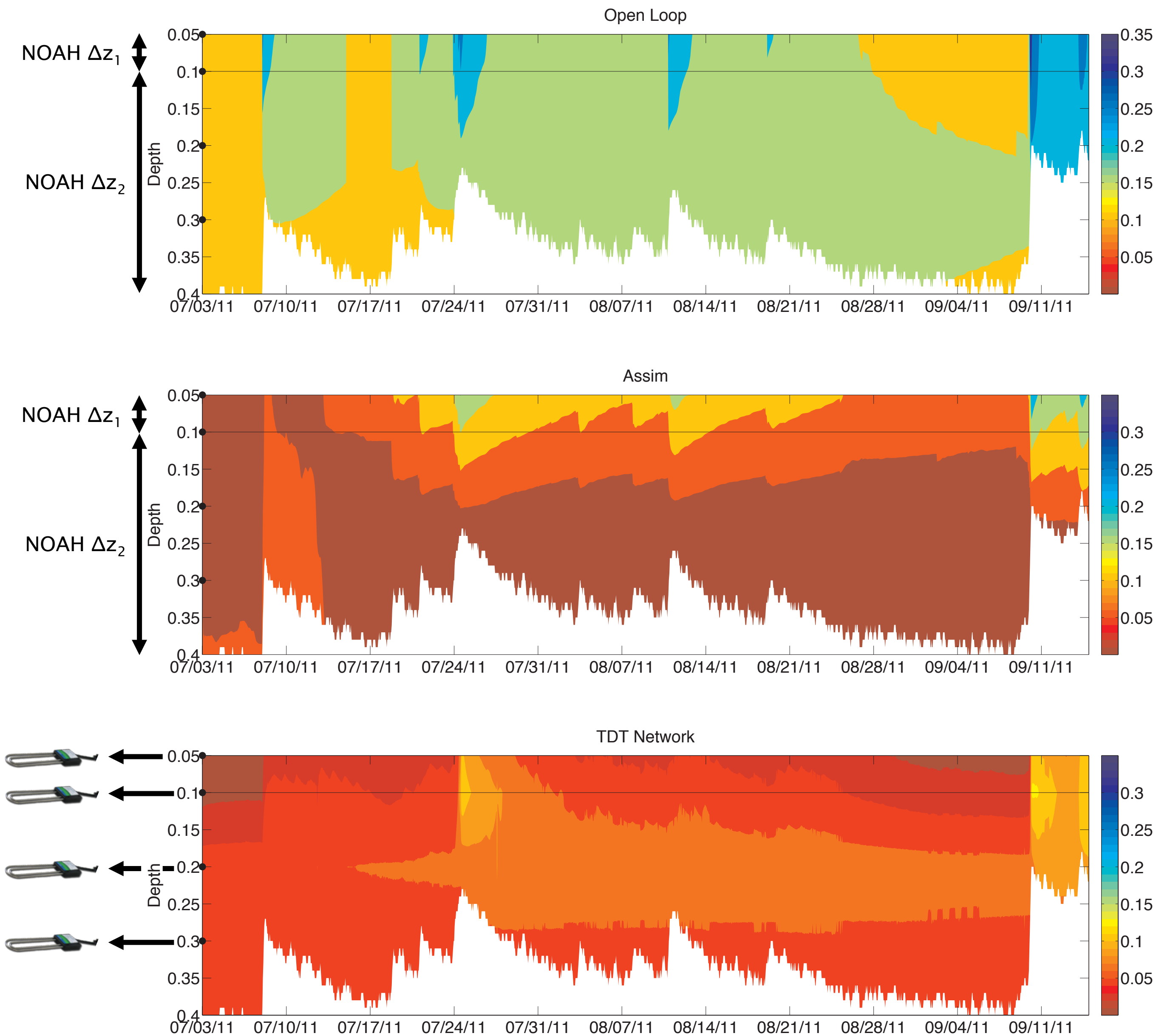


http://www.image.ucar.edu/DAReS/DART/

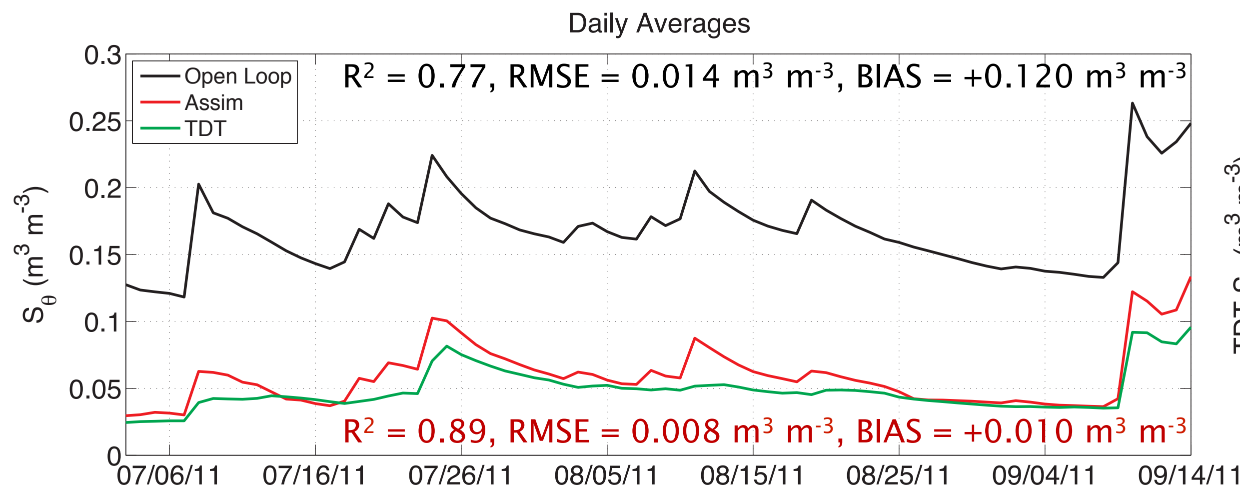
NOAH-DART: Neutron Intensity Assimilation

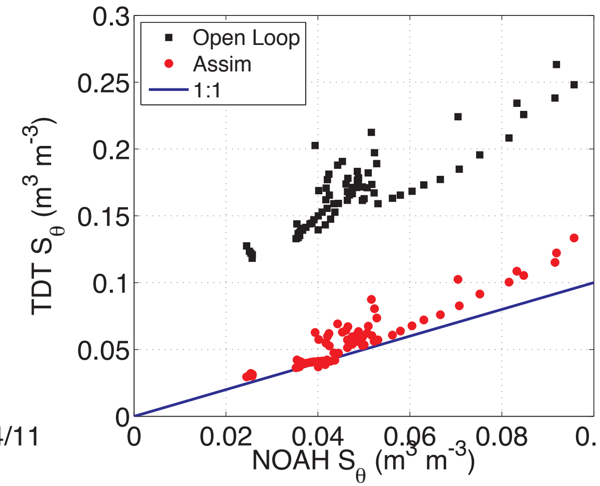


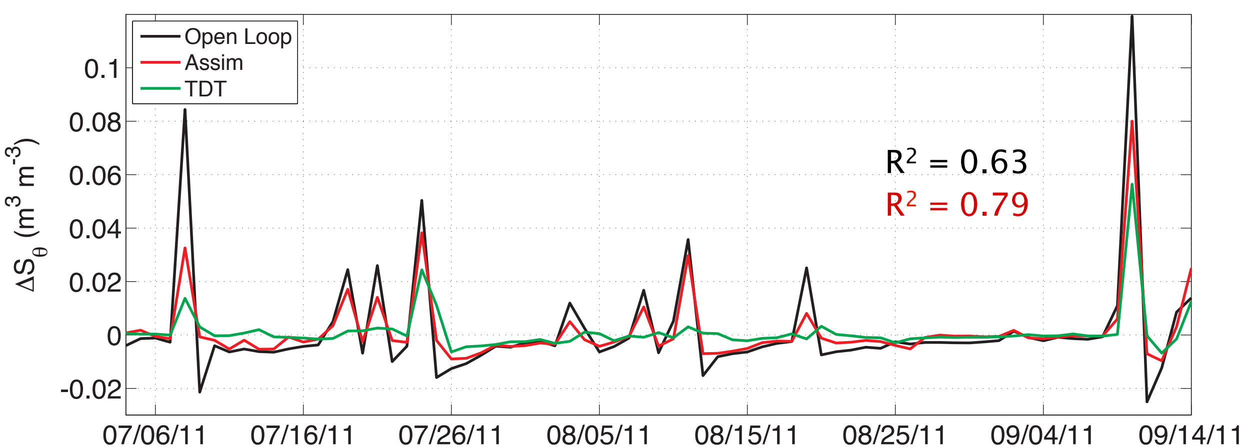
NOAH-DART: Soil Moisture Profiles



NOAH-DART: Integrated Soil Moisture







Concluding Remarks

- **COSMIC** accurately **simulates** the equivalent **number of neutrons given** model-derived **soil moisture profile**

- **NOAH soil moisture** (surface + root zone) **improved** after assimilating COSMOS neutron counts

- Updated **soil moisture rate of change** could potentially be **used to constrain parameters** in **NOAH** (under investigation)

E-mail: rosolem@email.arizona.edu

H31G-1194. Measuring Total Surface Moisture with the COSMOS Rover by Bobby Chrisman
12.05.2012 (Wed), Poster, Moscone South

H52A-02. Estimates of near surface water flux at intermediate spatial scales using a cosmic-ray neutron probe by Trenton Franz
12.07.2012 (Fri) @ 10:35am, Moscone West 3014