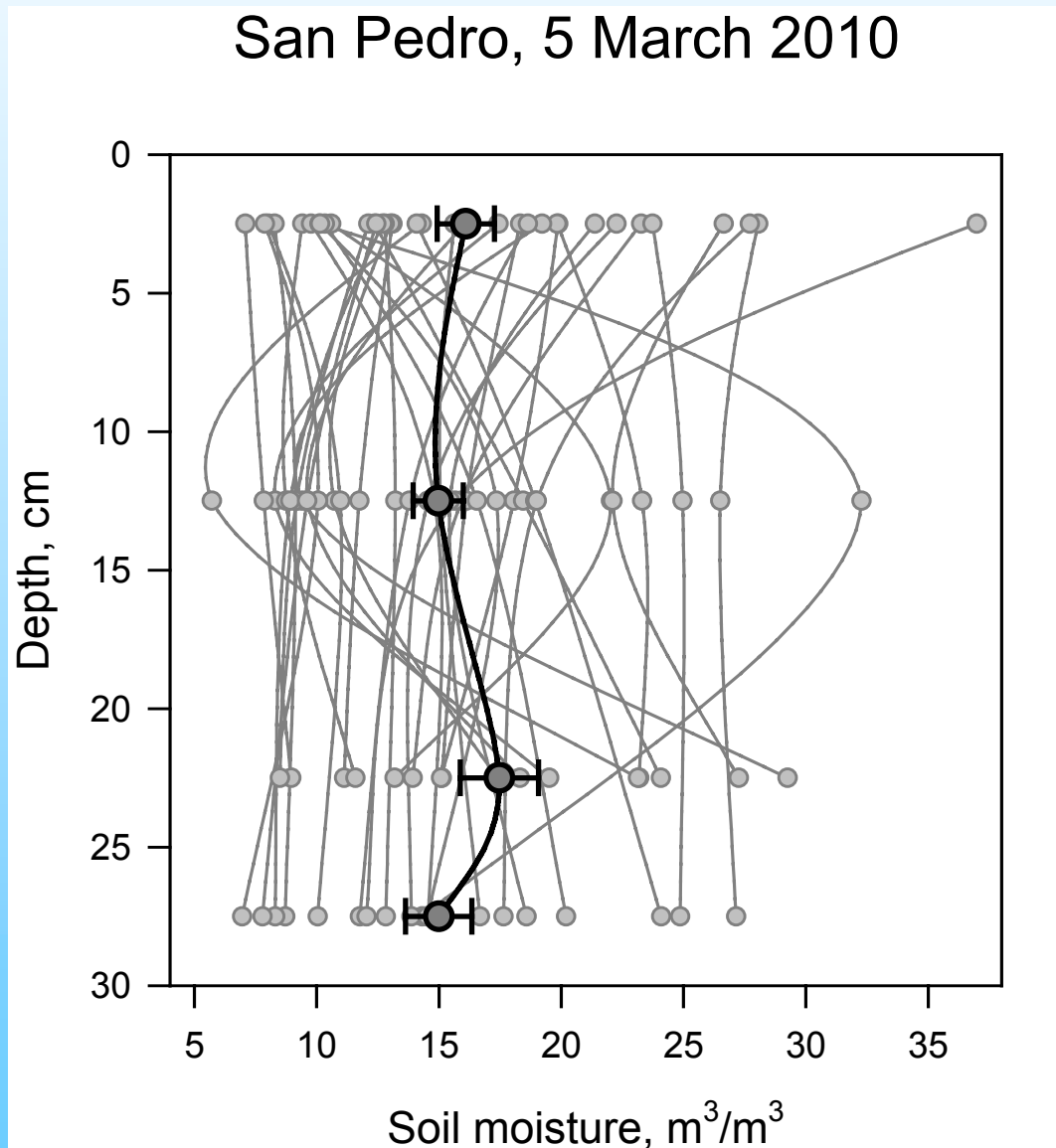
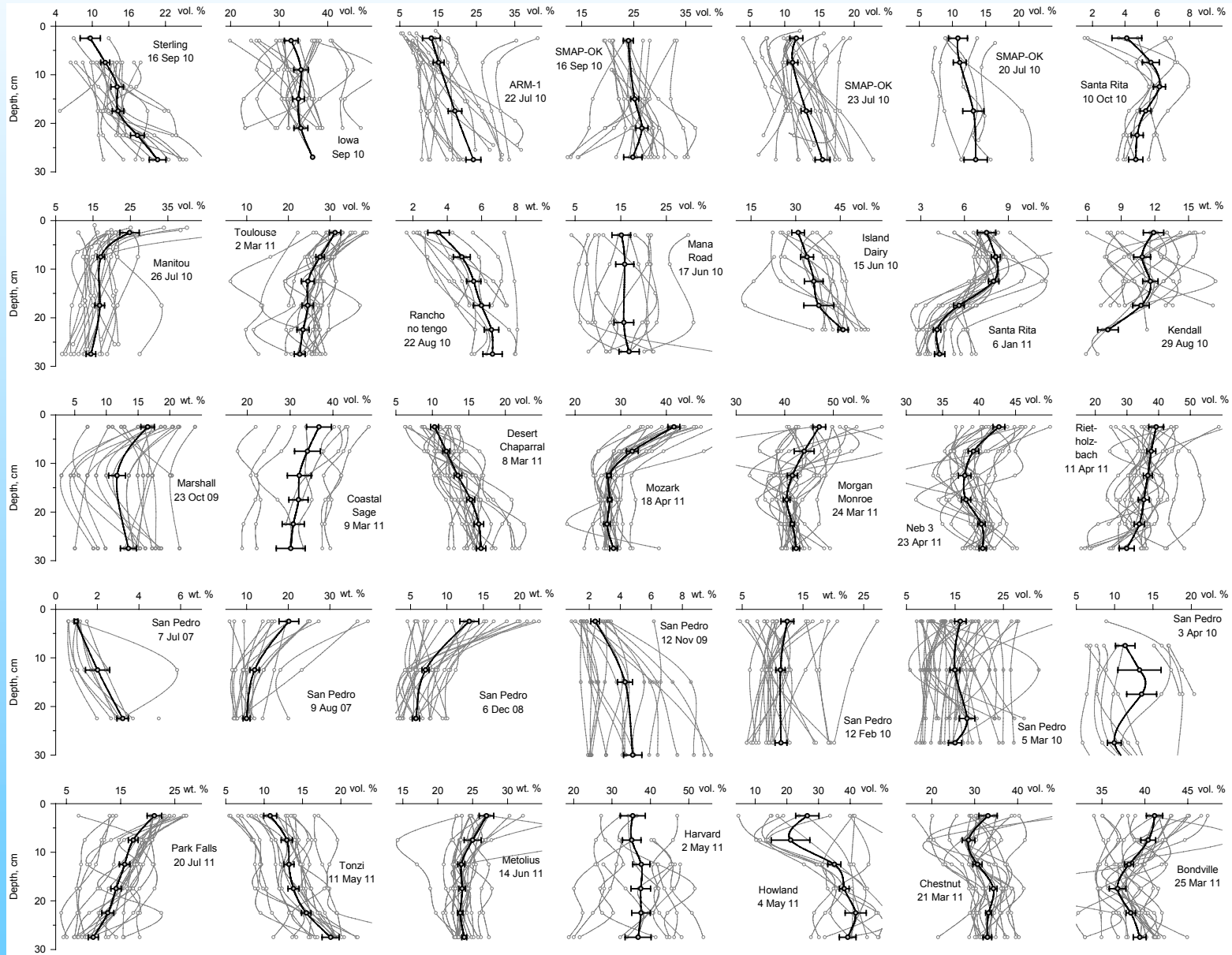


# Variations in soil moisture: circle, 200 m radius



# Variations in soil moisture: 25 sites

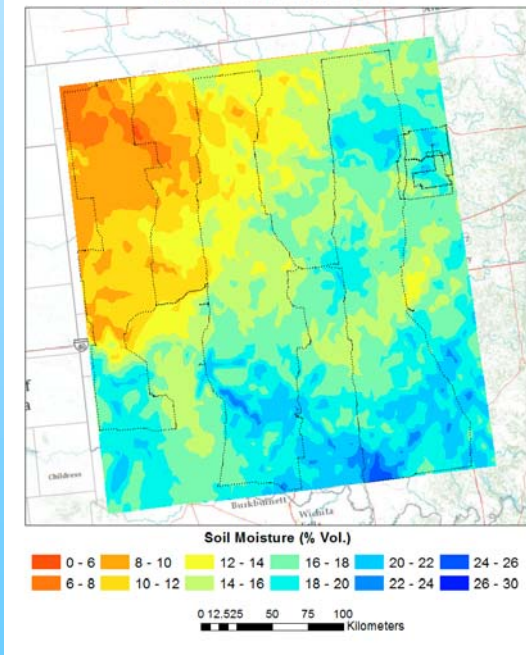
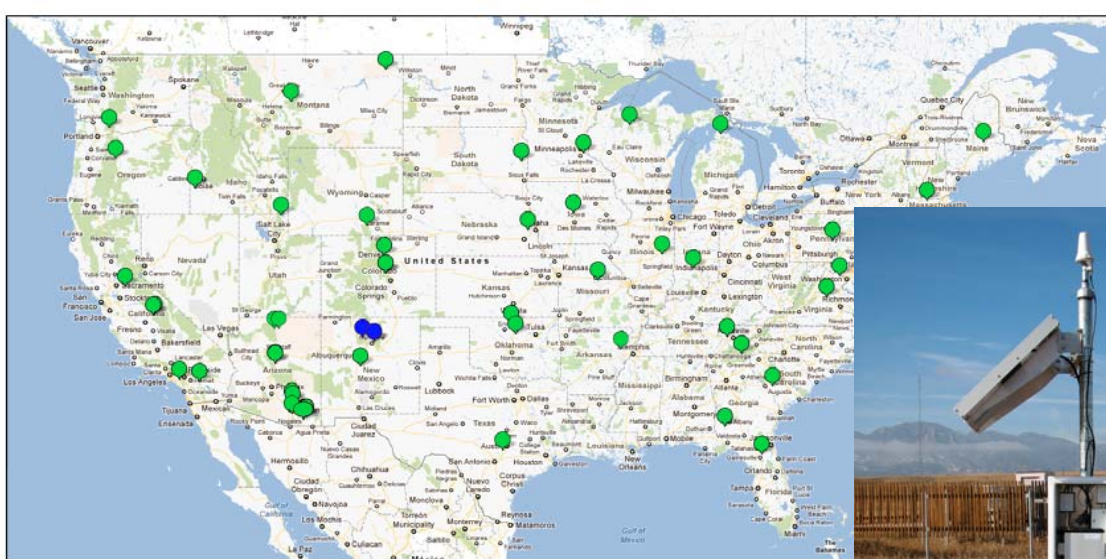


*Soil moisture profiles paper: GRL, readied for submission in June 2012.*

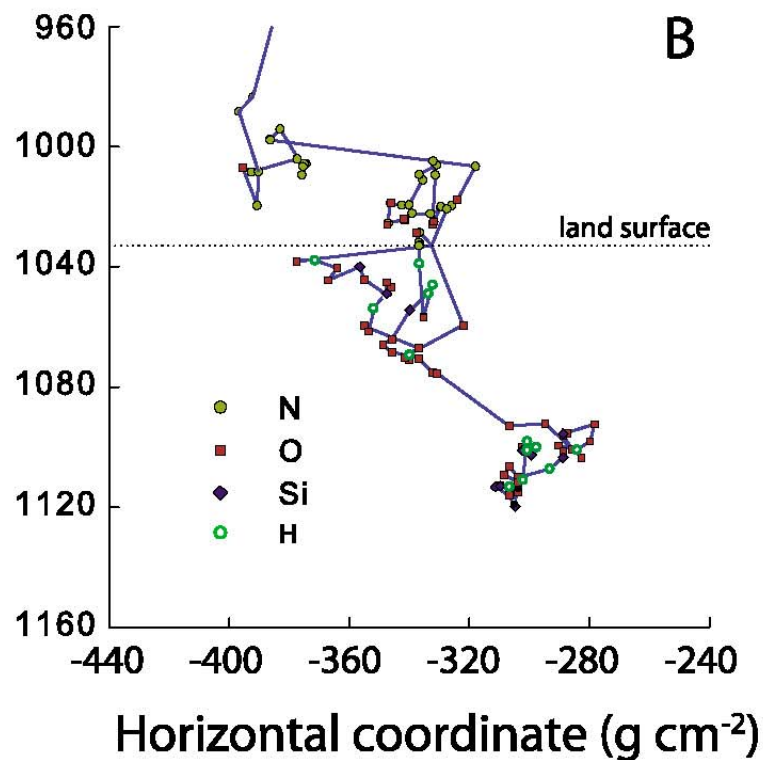
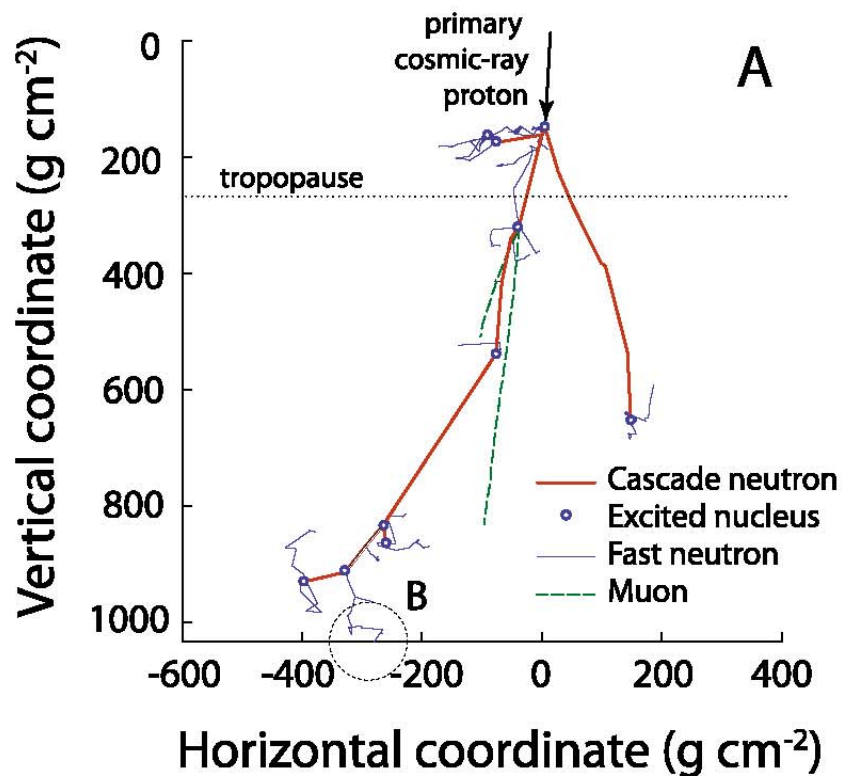
# Measuring area-average soil moisture using stationary and roving cosmic-ray (COSMOS) probes

M. Zreda, X. Zeng, J. Shuttleworth, T. Franz, R. Rosolem, C. Zweck and T. Ferre

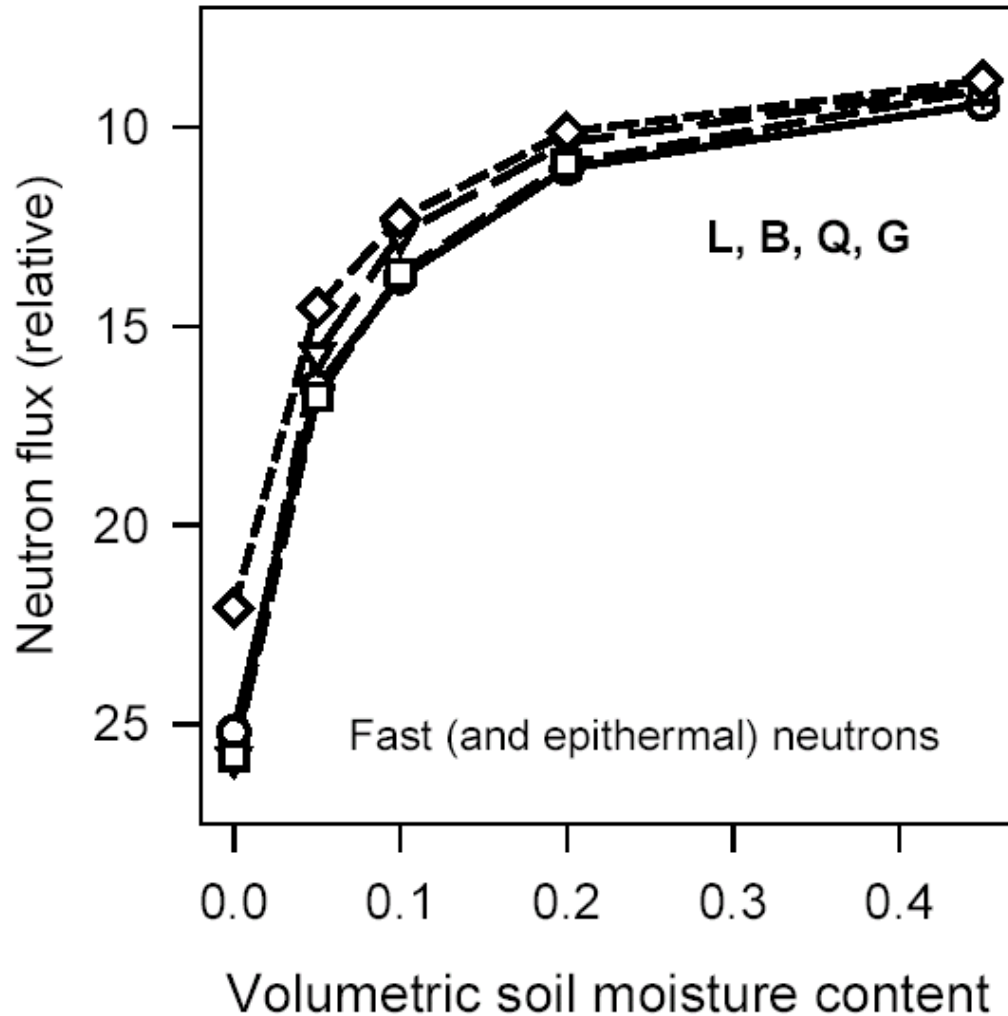
*University of Arizona*



# Slowing fast neutrons



# Fast neutron response to soil moisture



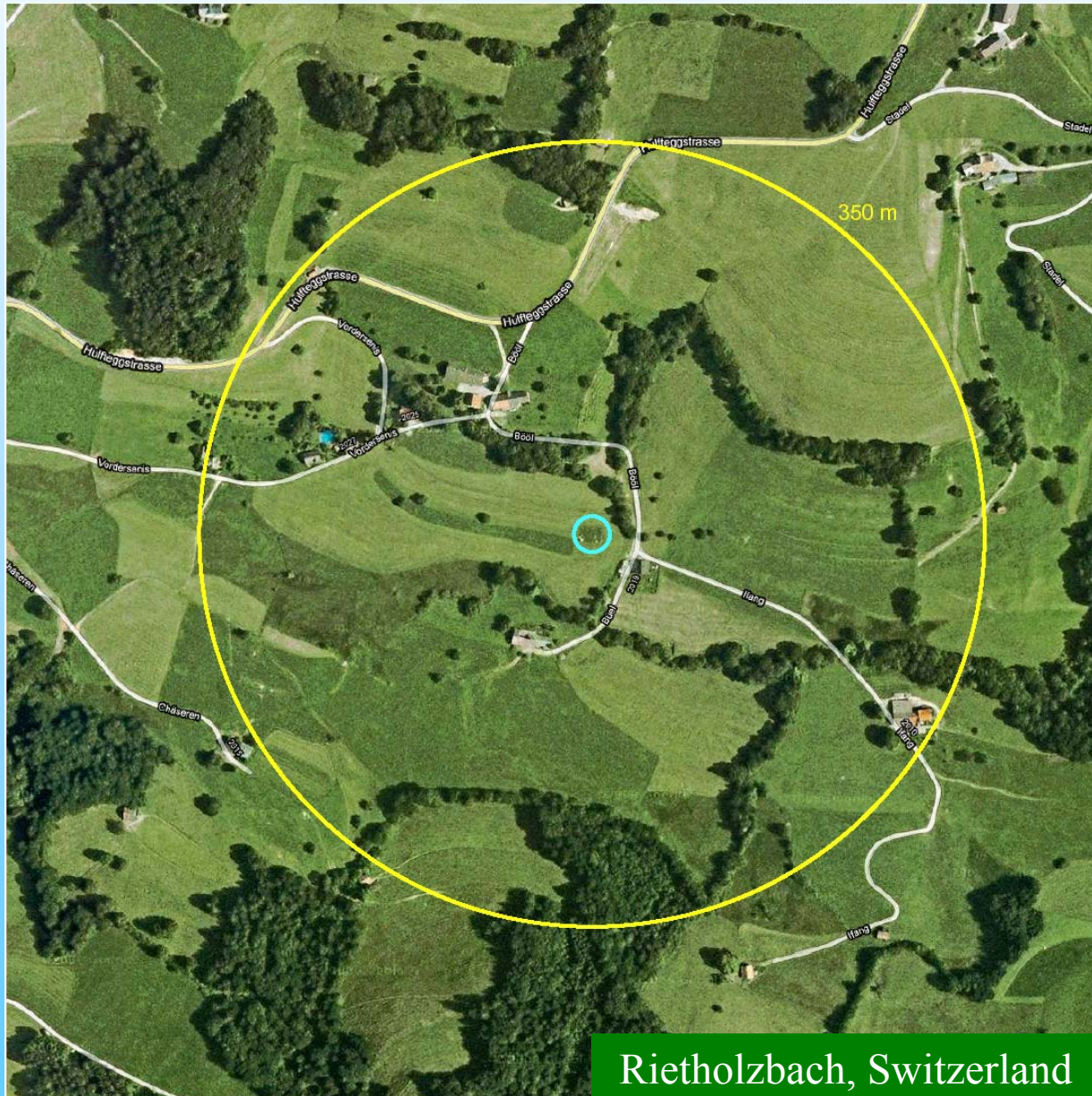
$$\theta_m = \frac{a_0}{\left(\frac{N}{N_0}\right)^{-a_1}} - a_2$$

## Notes:

- (1) Valid for neutrons with energies between 10 eV and 1 MeV.
- (2) Valid for water content >2% by volume.
- (3) Factors other than soil moisture affect the shape of this function.



# Horizontal footprint: 660 m diameter



- (1) 86% of neutrons within radius of 350 m.
- (2) Independent of soil moisture.
- (3) Increases with increasing altitude (decreasing air density).
- (4) Decreases with increasing atmospheric water vapor pressure.

# Measurement thickness: 10 cm - 70 cm

- (1) 86% of neutrons within measurement thickness
- (2) Strongly dependent on soil moisture
- (3) Minimum depth: 10 cm in saturated soils
- (4) Maximum depth: 70 cm in completely dry soils
  - Practical maximum: <70 cm (-> lattice water)
- (5) Independent of altitude
- (6) Independent of atmospheric water vapor pressure

# Computations/corrections

$$\theta_m = \frac{a_0}{\left(\frac{N}{N_0}\right)^{-a_1}} - a_2$$

## Corrections to N (or $N_0$ ) or $\Theta_m$ :

### Standard:

Barometric pressure variations (N)

### Implemented recently:

Secular variations in the incoming neutron intensity (N)

### Worked out and being implemented now:

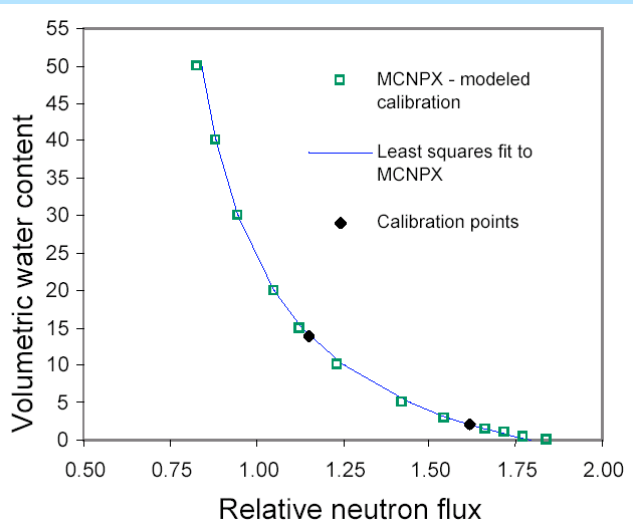
Lattice water ( $\Theta_m$ )

Atmospheric water vapor (N; alternatively  $\Theta_m$ )

### In progress:

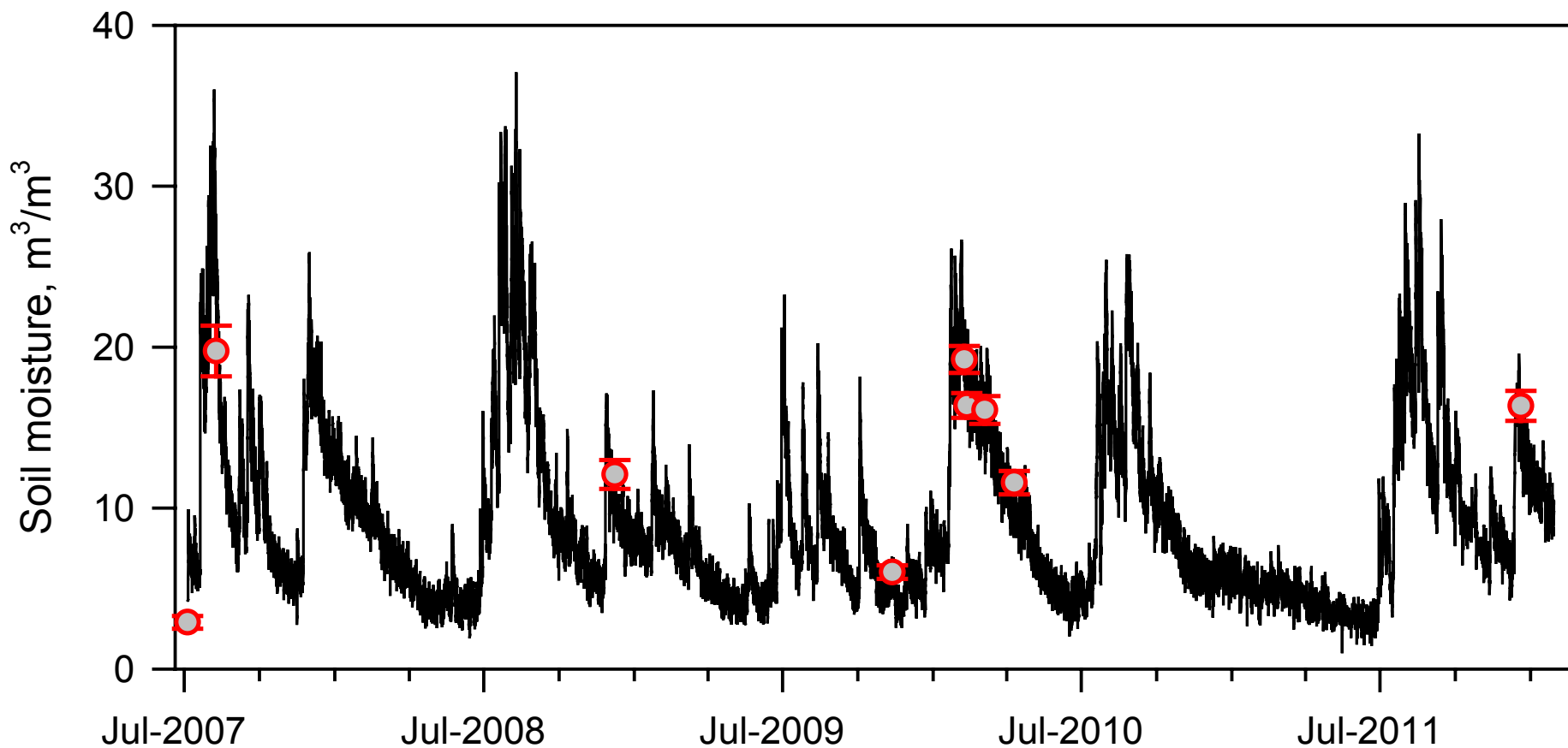
Vegetation (possibly large effect)( $\Theta_m$  or N)

Snow and other water at the surface (large effect) ( $\Theta_m$  or N)





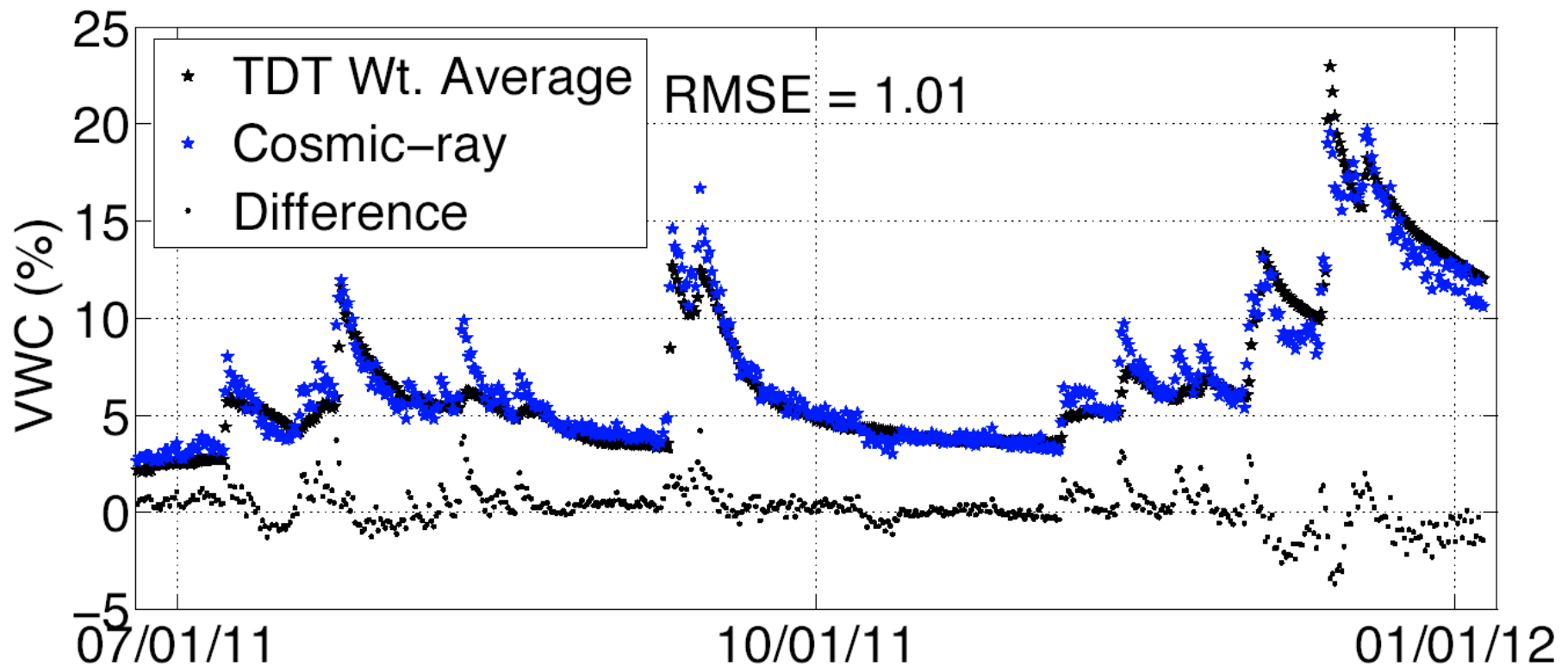
# Comparison with gravimetric data



Neutron data corrected for temporal variations in:

- atmospheric pressure;
- incoming cosmic-ray intensity;
- atmospheric water vapor;

# Comparison with 180 TDT sensors



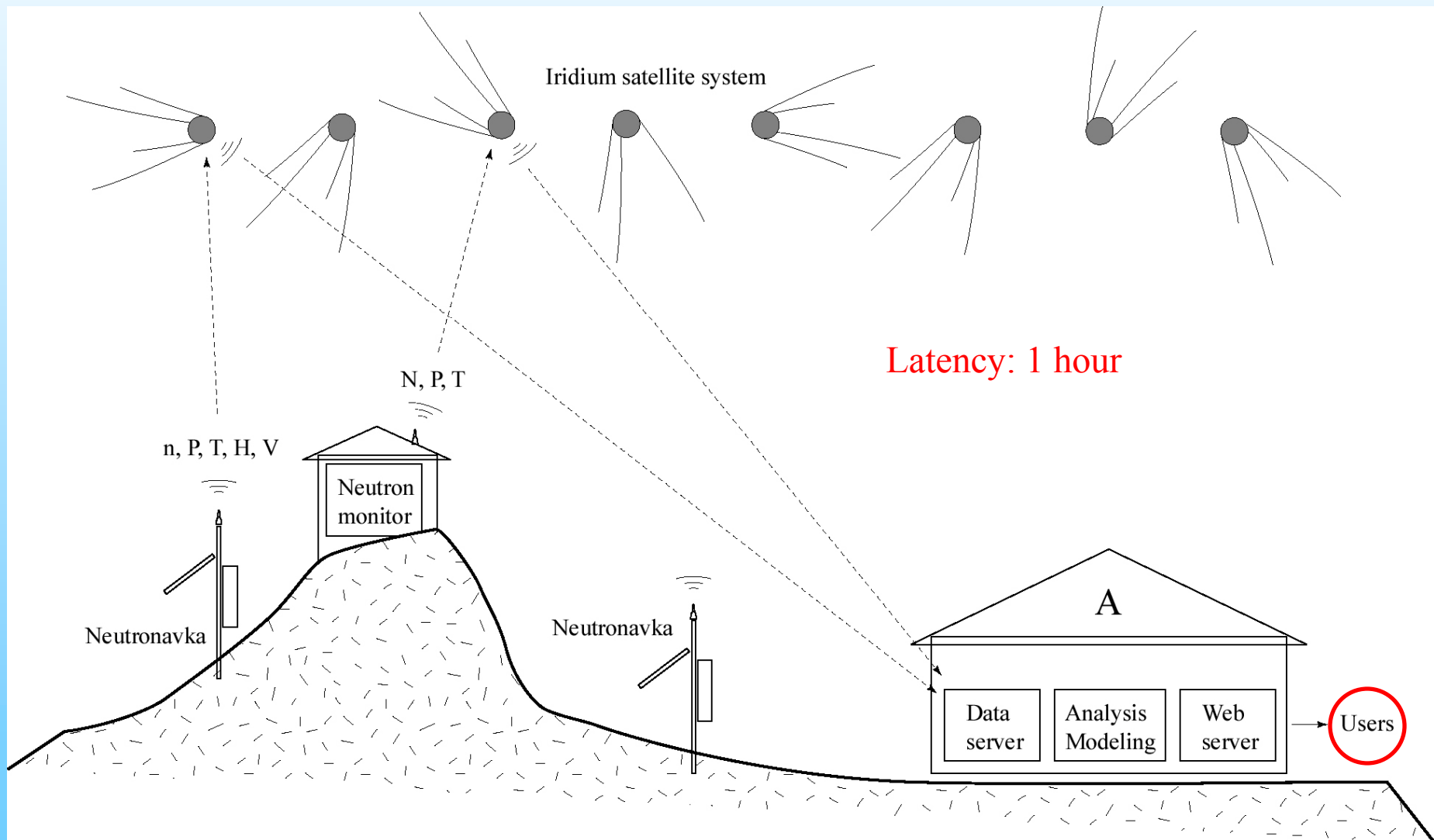
Neutron data corrected for temporal variations in:

- atmospheric pressure;
- incoming cosmic-ray intensity;
- atmospheric water vapor;

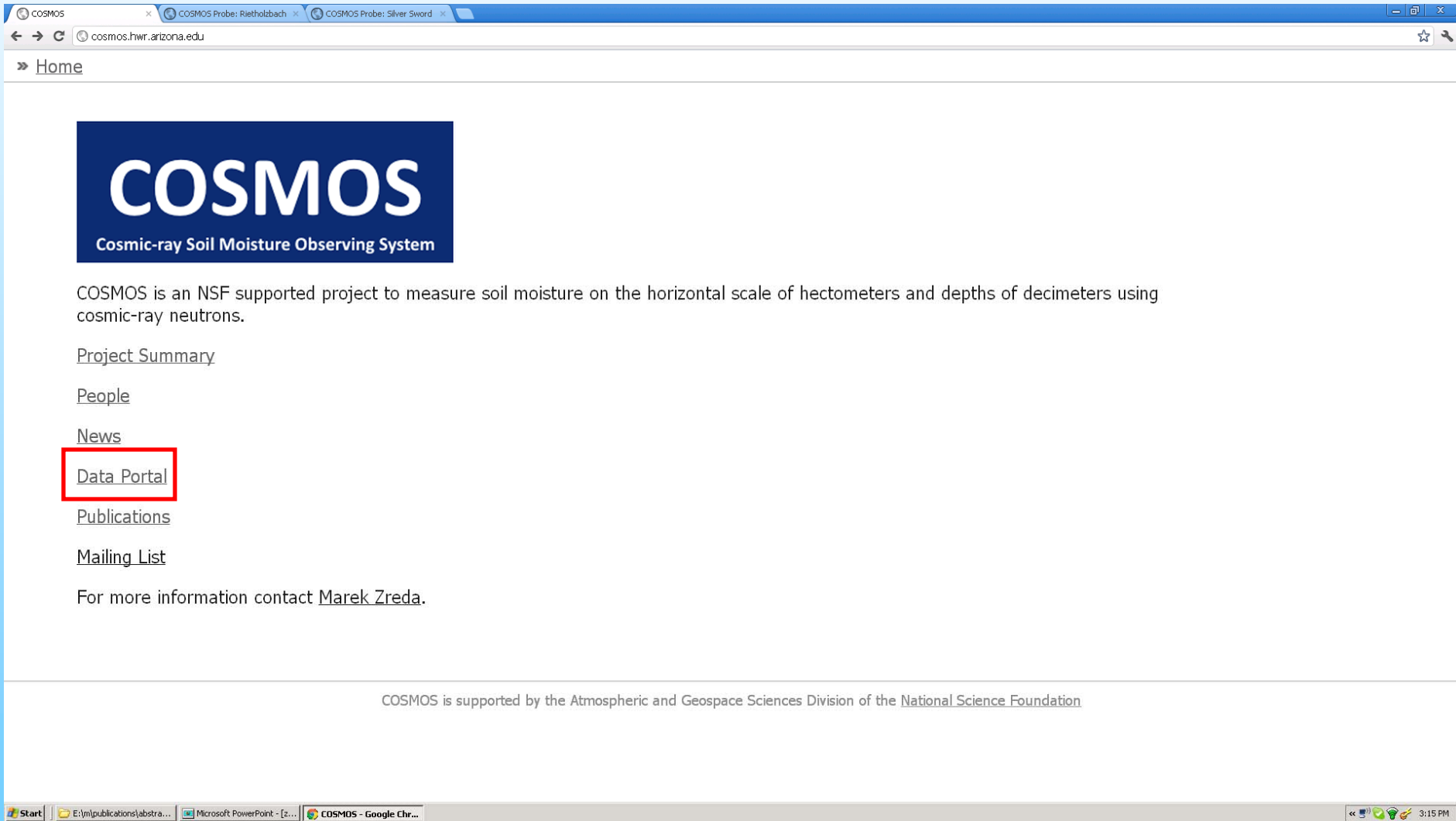
TDT sensors calibrated in the field.

Frantz et al., 2012, Vadose Zone Journal (in review).

# COsmic-ray Soil Moisture Observing System (COSMOS)



# COSMOS web site

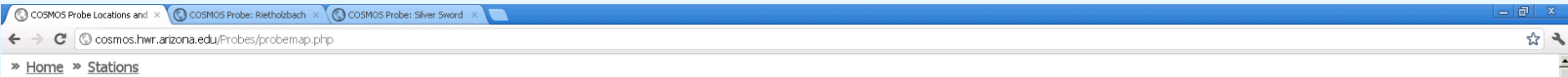


The screenshot shows a web browser window with the URL [cosmos.hwr.arizona.edu](http://cosmos.hwr.arizona.edu). The page features a blue header with the COSMOS logo and the text "Cosmic-ray Soil Moisture Observing System". Below the logo, there is a paragraph describing the project: "COSMOS is an NSF supported project to measure soil moisture on the horizontal scale of hectometers and depths of decimeters using cosmic-ray neutrons." A list of navigation links is provided: [Project Summary](#), [People](#), [News](#), [Data Portal](#) (highlighted with a red box), [Publications](#), and [Mailing List](#). At the bottom of the page, it states "COSMOS is supported by the Atmospheric and Geospace Sciences Division of the [National Science Foundation](#)". The browser's taskbar at the bottom shows the Start button, several open applications, and the system tray with the time 3:15 PM.

COSMOS public server: [cosmos.hwr.arizona.edu](http://cosmos.hwr.arizona.edu)



# COSMOS web site: probe locations - USA



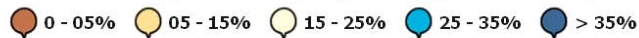
## Location of COSMOS Probes

Click on balloons for site descriptions and data access.

[Probe\\_Status](#) (map)



Soil Moisture (V=volumetric, G=gravimetric, U=uncalibrated)



COSMOS public server: [cosmos.hwr.arizona.edu](http://cosmos.hwr.arizona.edu)

# Global COSMOS

COSMOS Probe Locations and

cosmos.hwr.arizona.edu/Probes/probemap.php

Home » Stations

## Location of COSMOS Probes

Click on balloons for site descriptions and data access. [Station List](#) [Diagnostics](#) [Utilities](#)

Map | Satellite | Hybrid

Soil Moisture (V=Volumetric, G=Gravimetric, U=Uncalibrated)

- 0 - 05%
- 05 - 15%
- 15 - 25%
- 25 - 35%
- > 35%

COSMOS is supported by the Atmospheric and Geospace Sciences Division of the National Science Foundation

Start | E:\m\proposals\current\... | Microsoft Word | usda ars - Google Search... | COSMOS Probe Location... | 5:15 PM

# COSMOS web site: probe data

**Silver Sword**

The site is co-located with the USDA National Resources Conservation Service 'Silver Sword' site. More information regarding the USDA site can be found at <http://www.wcc.nrcs.usda.gov/nwcc/site?sitenum=2101&state=HI>

Installation Date:	2010-06-15
Timezone (UTC):	-10
Cutoff Rigidity (GV):	12.87
Mean Pressure (mb):	725
Mean Bulk Density (g/cm <sup>3</sup> ):	0.78
Mean Lattice Water (% weight):	9.57
Max. Count Rate (/hr):	2633

Soil Moisture (% Volumetric), [Calibration Data](#)

Effective Measurement Depth (cm)

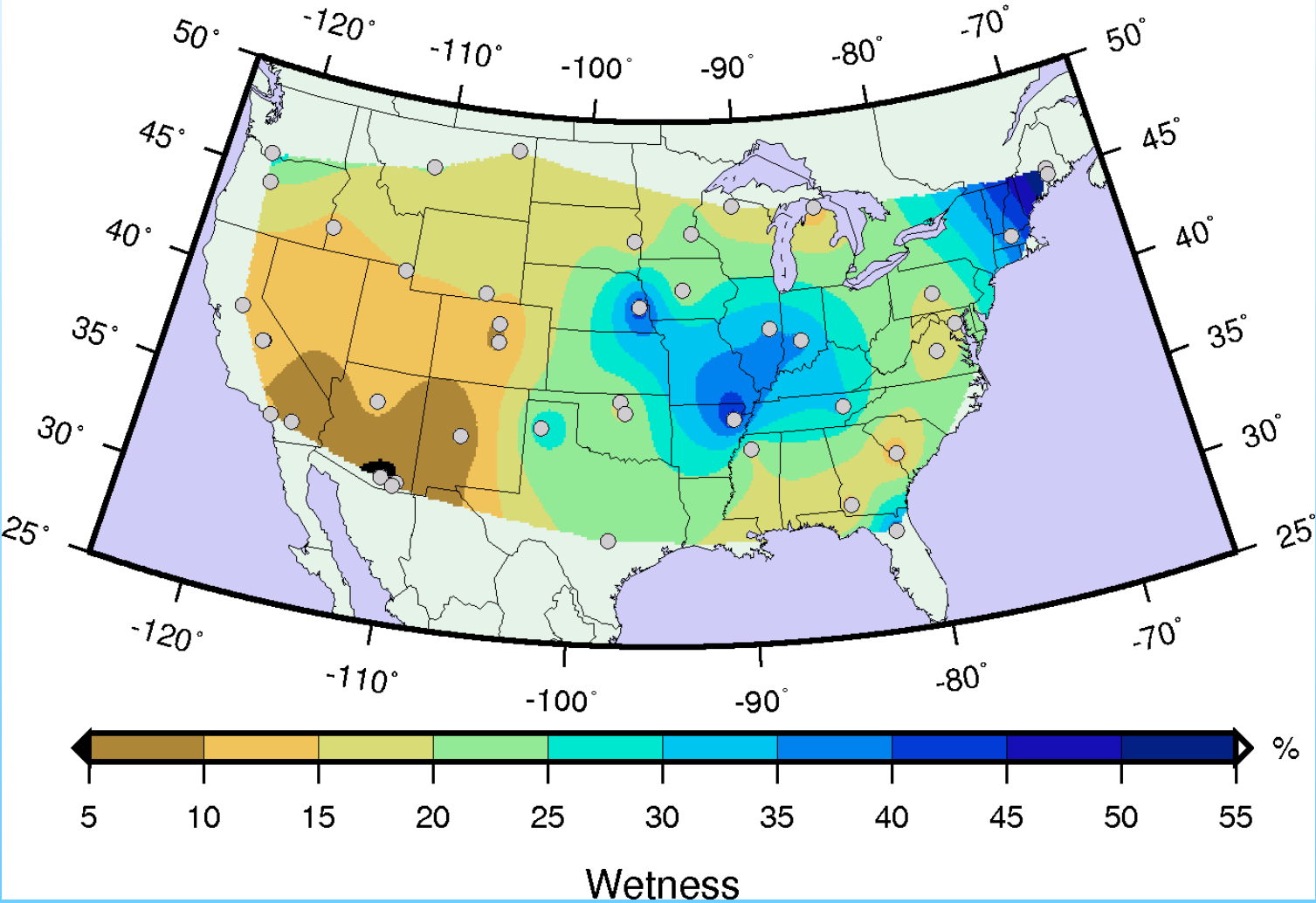
[Level 1 Data \(Plots\)](#) [Level 2 Data](#) [Level 3 Data](#) [Data Levels](#) [Excel \(.xls\)](#) [Matlab \(.mat\)](#) [Python \(.pkl\)](#)

COSMOS data is research level and subject to change.

COSMOS is supported by the Atmospheric and Geospace Sciences Division of the [National Science Foundation](#)

# COSMOS data: contour map of the US

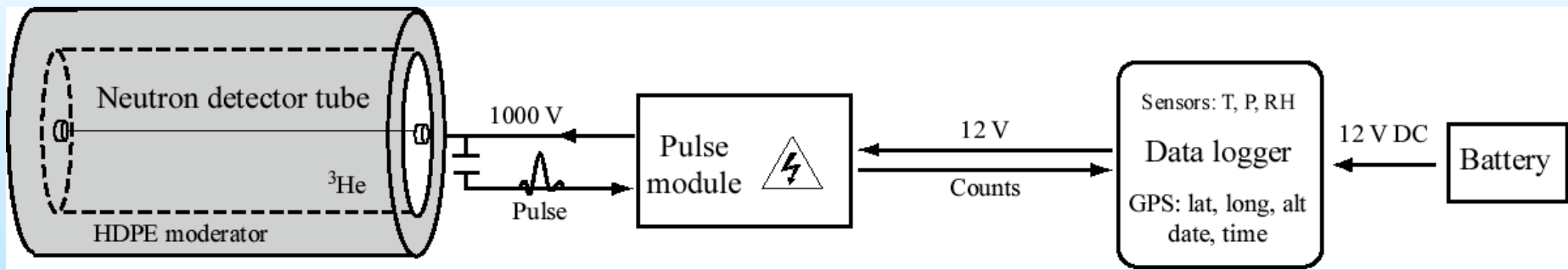
COSMOS interpolated wetness for 2012-06-15



COSMOS public server: [cosmos.hwr.arizona.edu](http://cosmos.hwr.arizona.edu)



# Mobile measurements using COSMOS rover



## Two modes:

- (1) stop and measure (SAM);
- (2) drive and measure (DAM).

## Can do:

- (1) 1-D transects.
- (2) 2-D maps.

Current



New



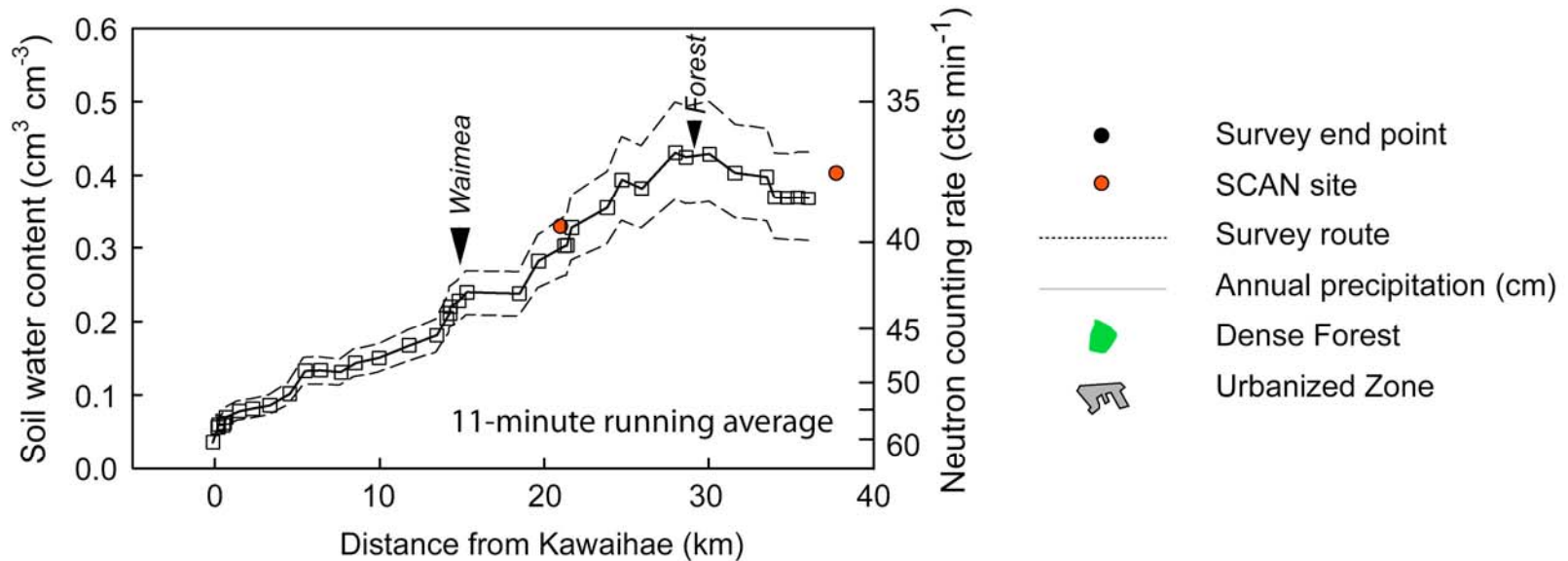
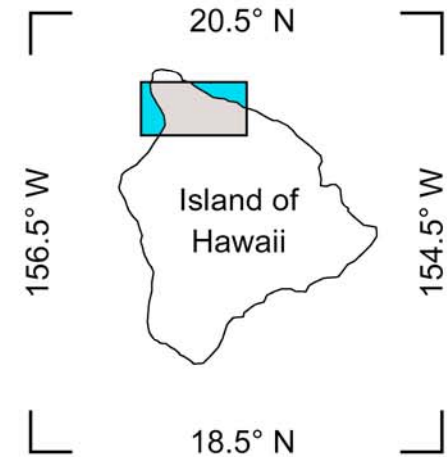
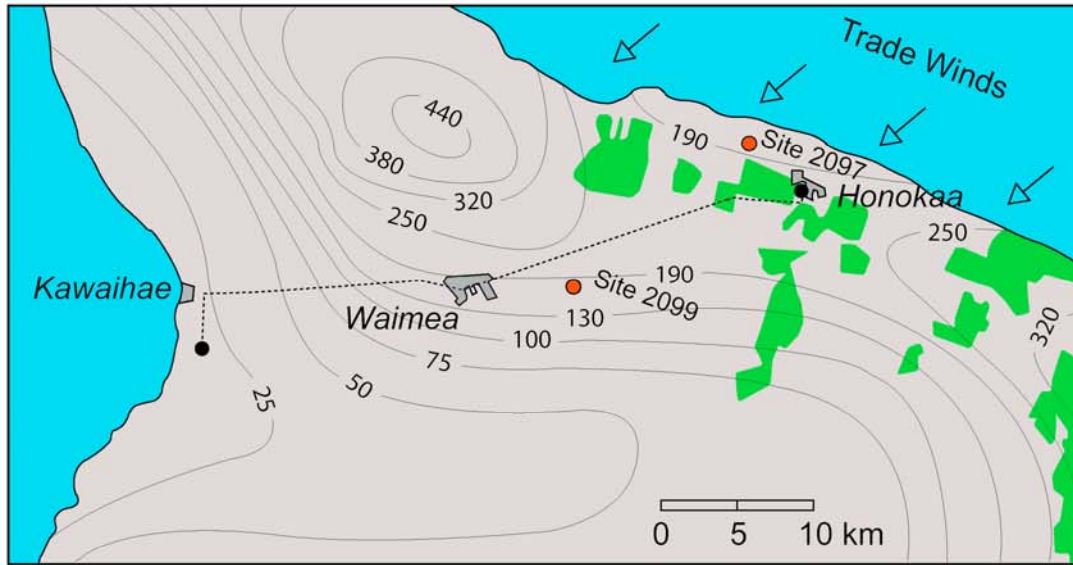
Standard (US) version



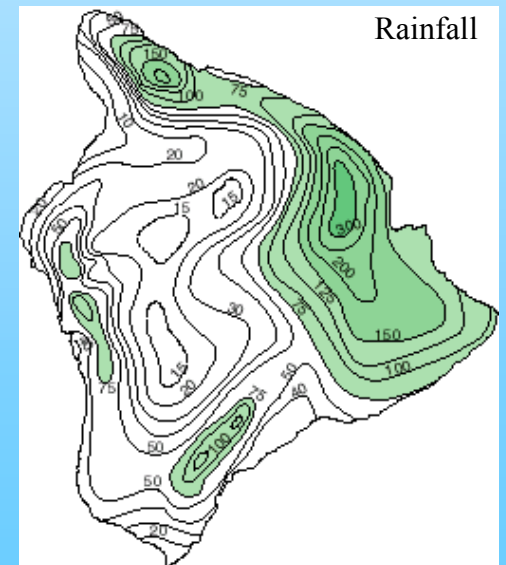
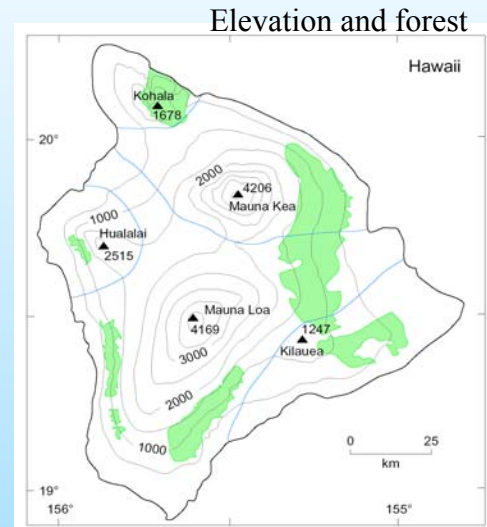
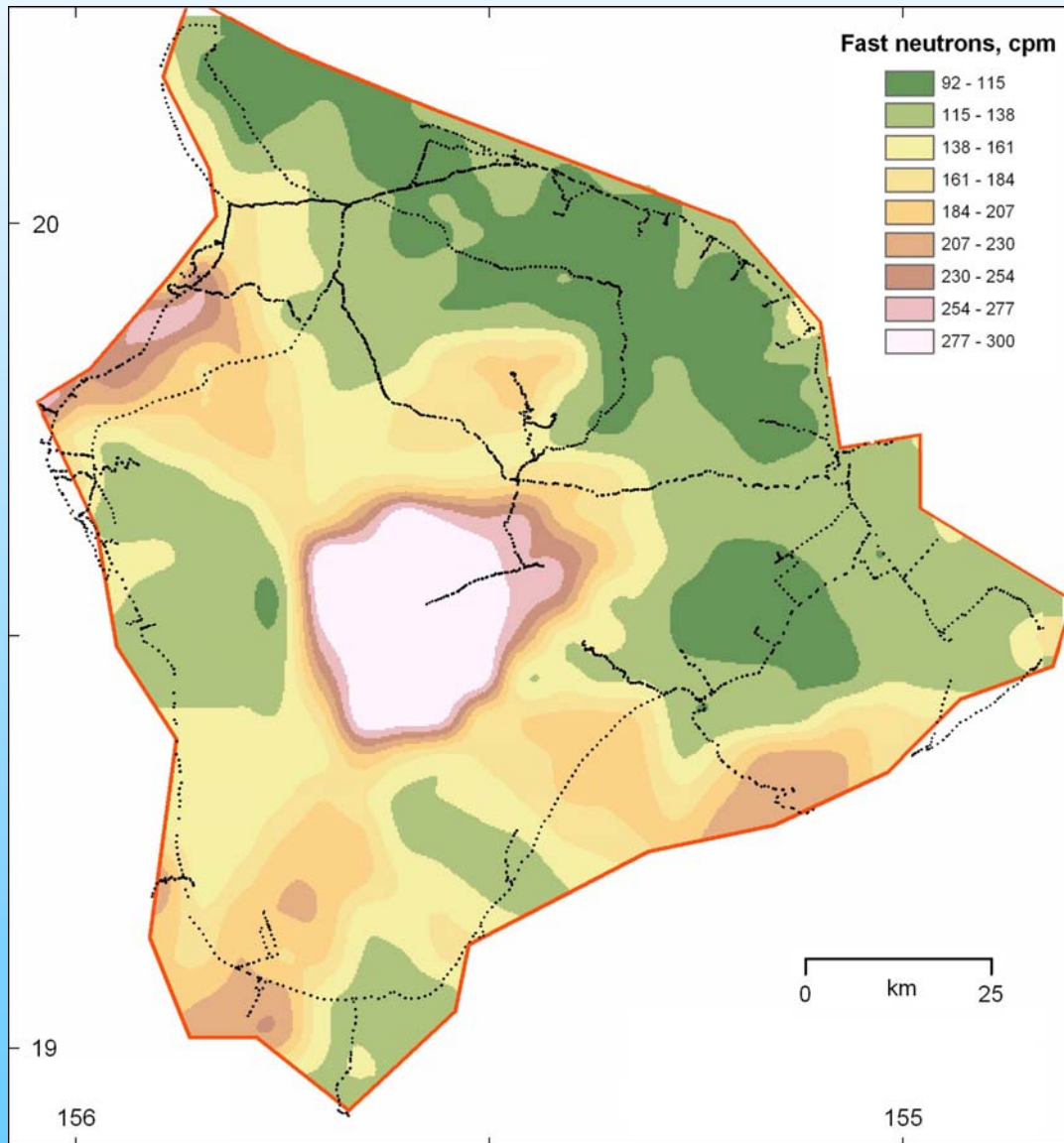
European version



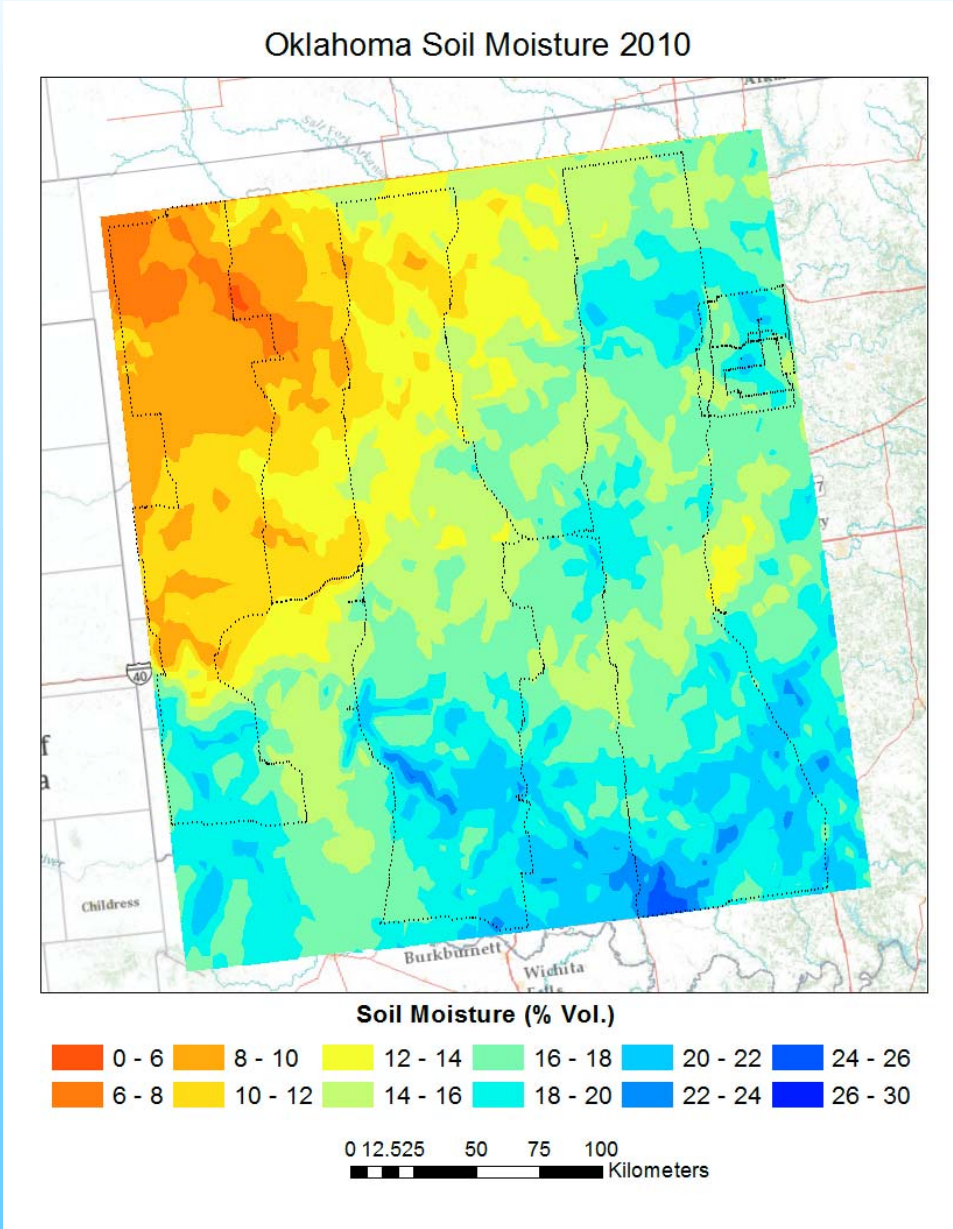
# COSMOS rover: transect, Hawaii



# COSMOS rover: map, Hawaii



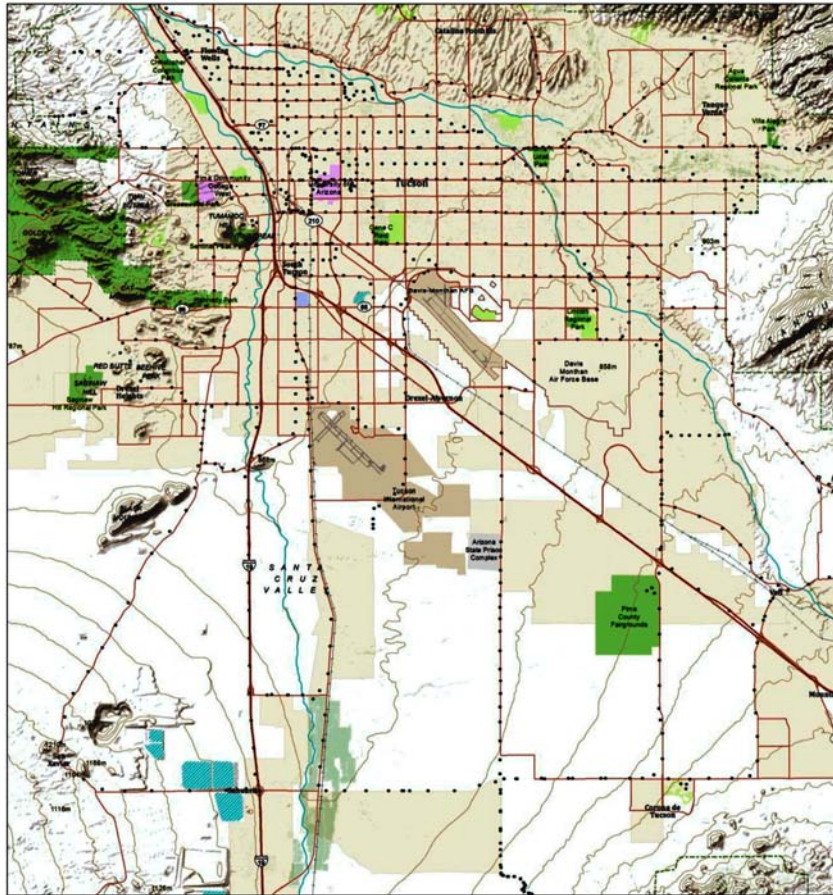
# COSMOS rover: soil moisture map of Oklahoma, Sept. 2010





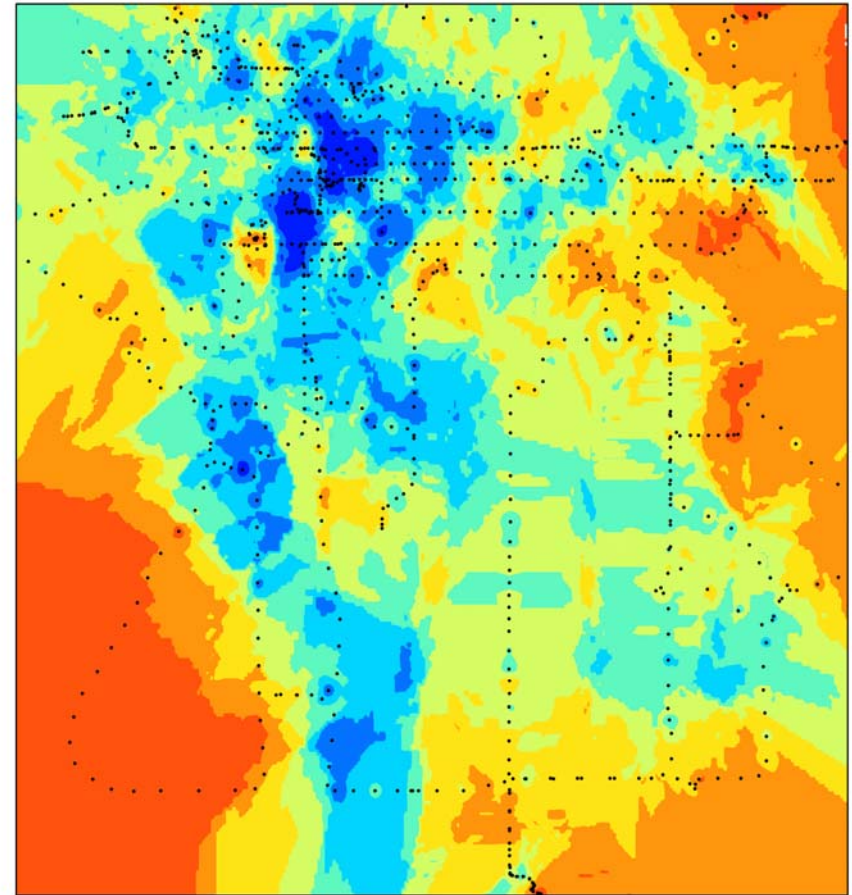
# COSMOS rover: periodic maps of the Tucson Basin

Tucson Basin Topography and Survey Locations



0 3 6 9 12  
Kilometers

Jan.29.2012 Soil Moisture (% Vol.)



0 3 6 9 12  
Kilometers

Monthly maps, except during summer monsoon - weekly. Calibrated at a stationary COSMOS site.