Variations in soil moisture: circle, 200 m radius

San Pedro, 5 March 2010

Zreda et al., 2012, HESS Disc. 9, 4505-4551.
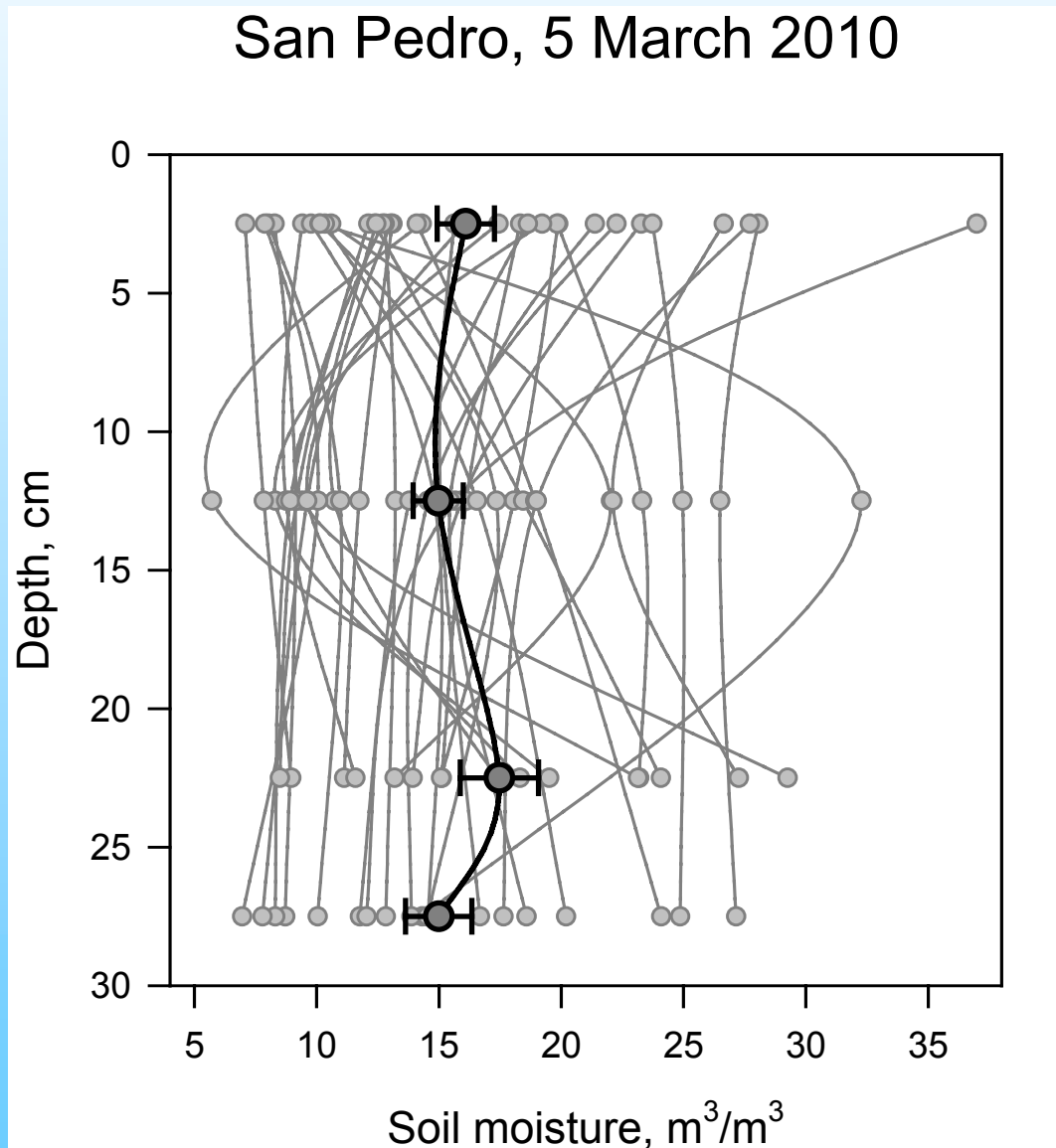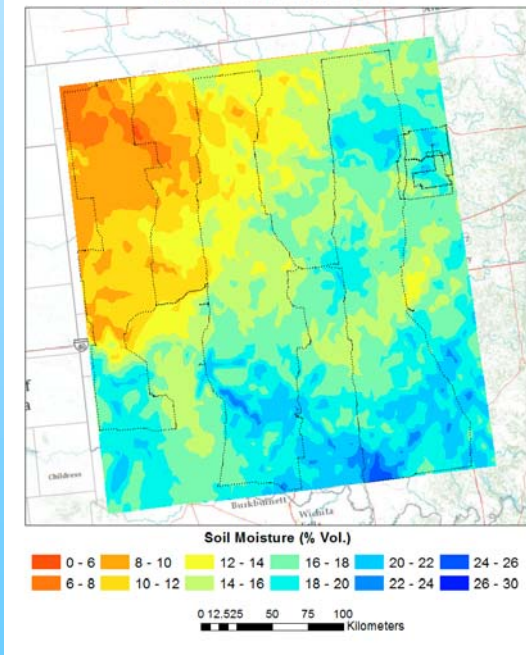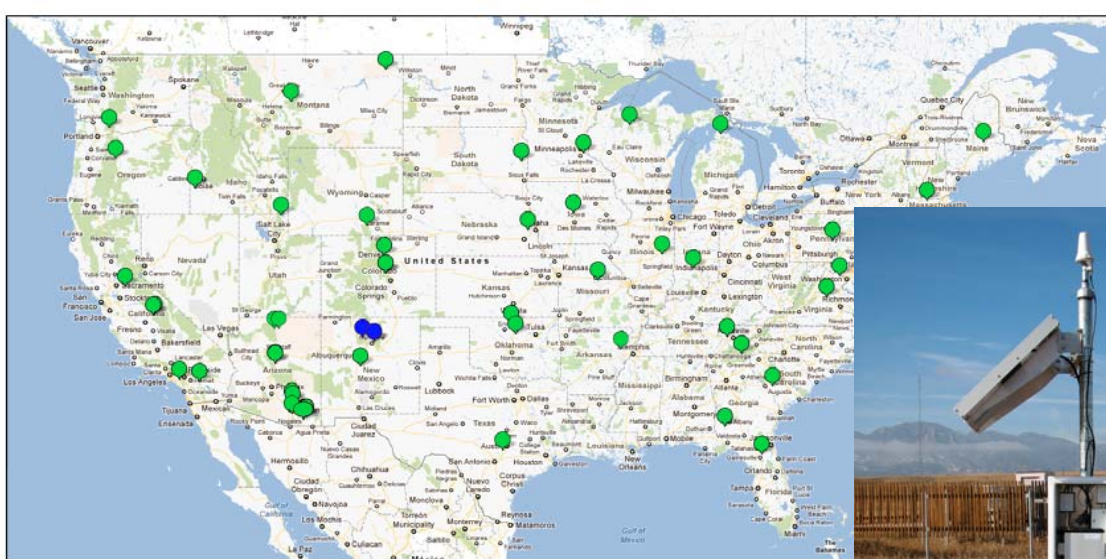
Variations in soil moisture: 25 sites
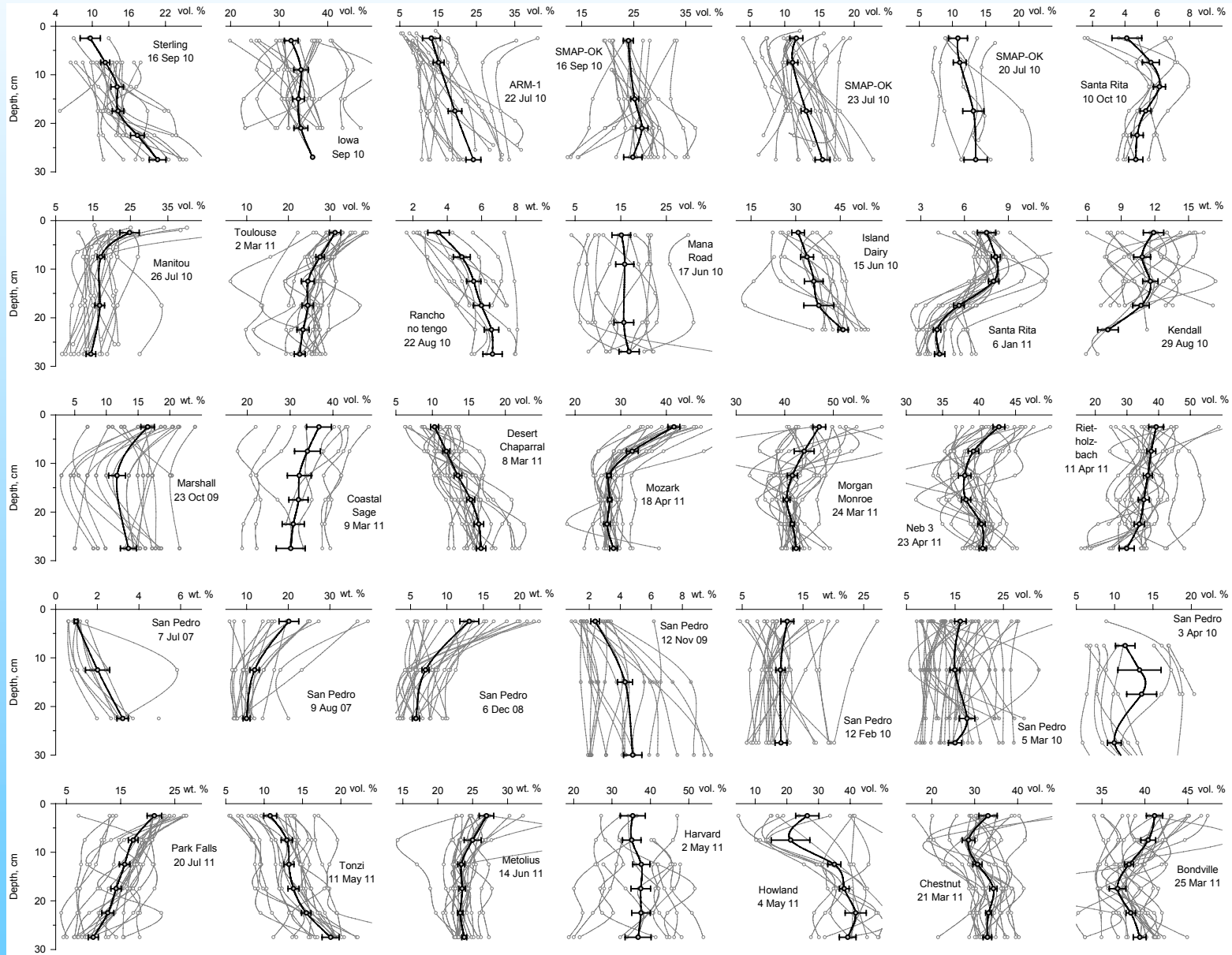
Soil moisture profiles paper: GRL, readied for submission in June 2012.
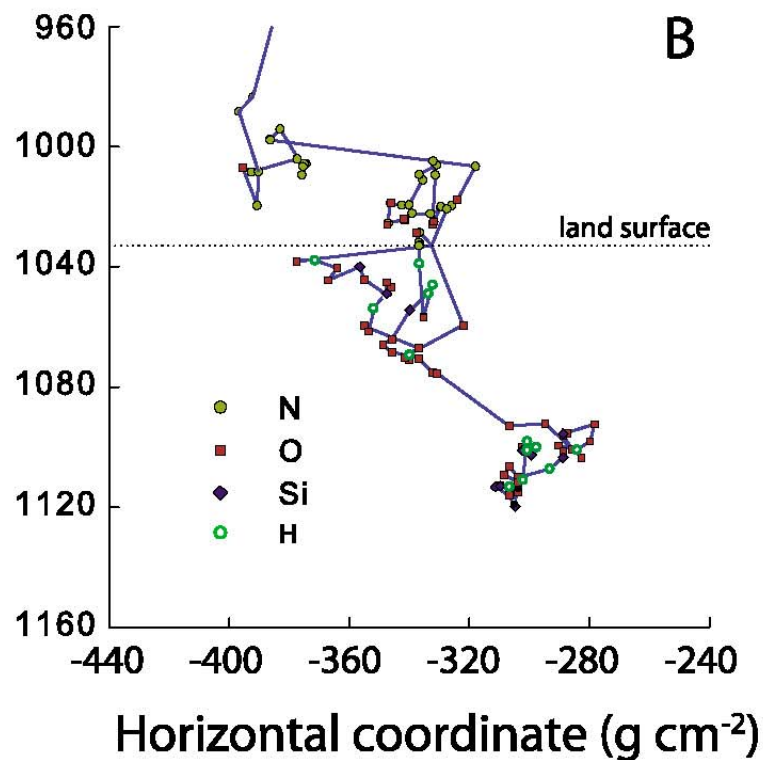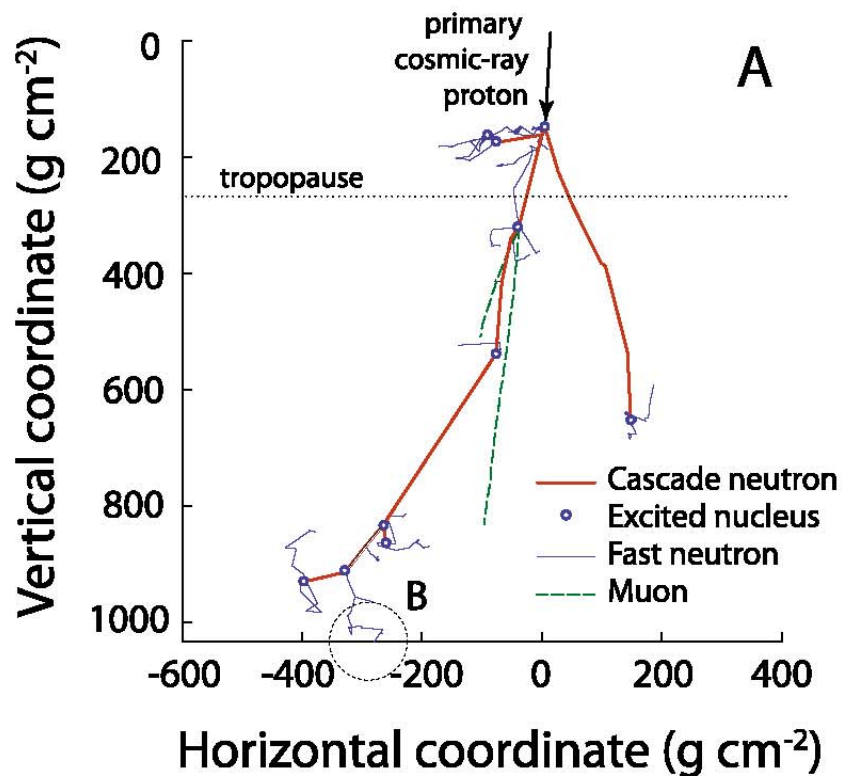
Measuring area-average soil moisture using stationary and roving cosmic-ray (COSMOS) probes

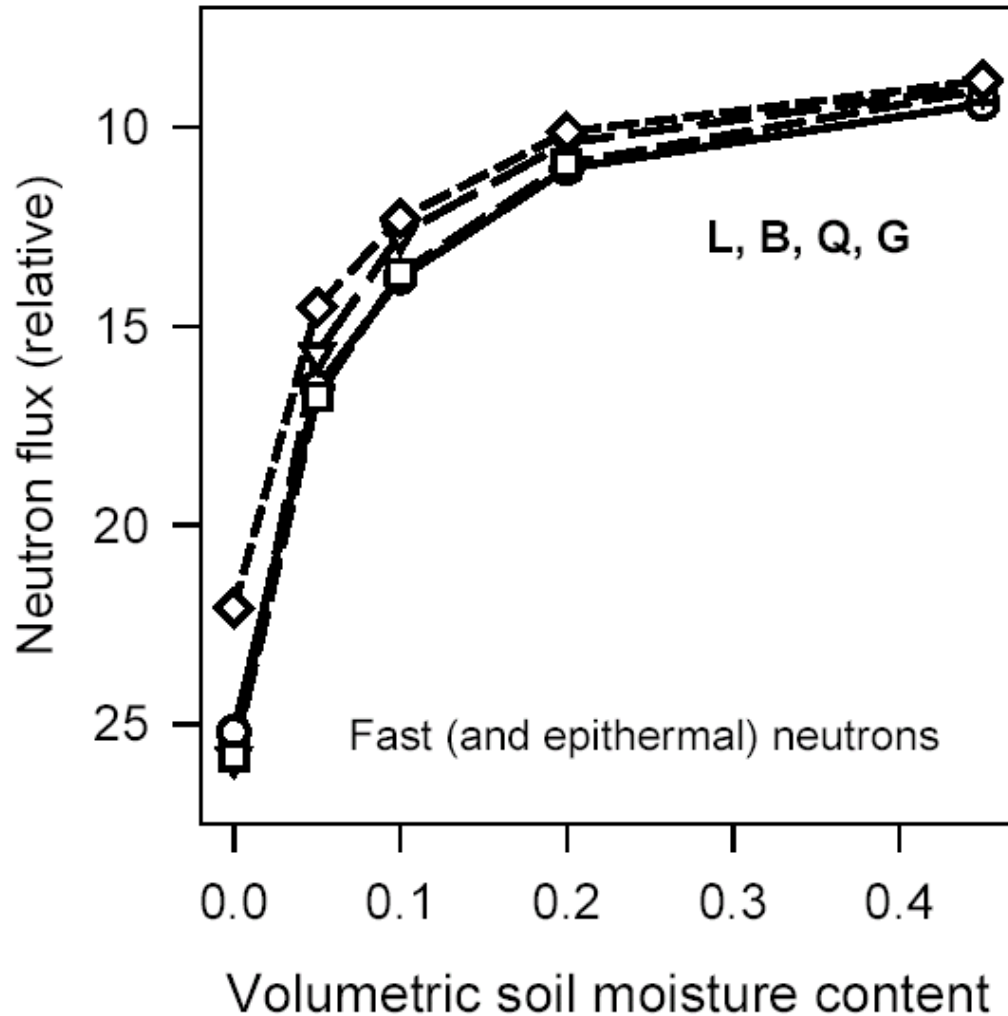M. Zreda, X. Zeng, J. Shuttleworth, T. Franz, R. Rosolem, C. Zweck and T. Ferre

University of Arizona

Soil Moisture (% Vol.)

| 0 - 6 | 8 - 10 | 12 - 14 | 16 - 18 | 20 - 22 | 24 - 26 |
| 6 - 8 | 10 - 12 | 14 - 16 | 18 - 20 | 22 - 24 | 26 - 30 |

0 12.5 25   50   75   100
Kilometers

Slowing fast neutrons

Desilets et al., 2010, Water Resour. Res. 46, W11505.
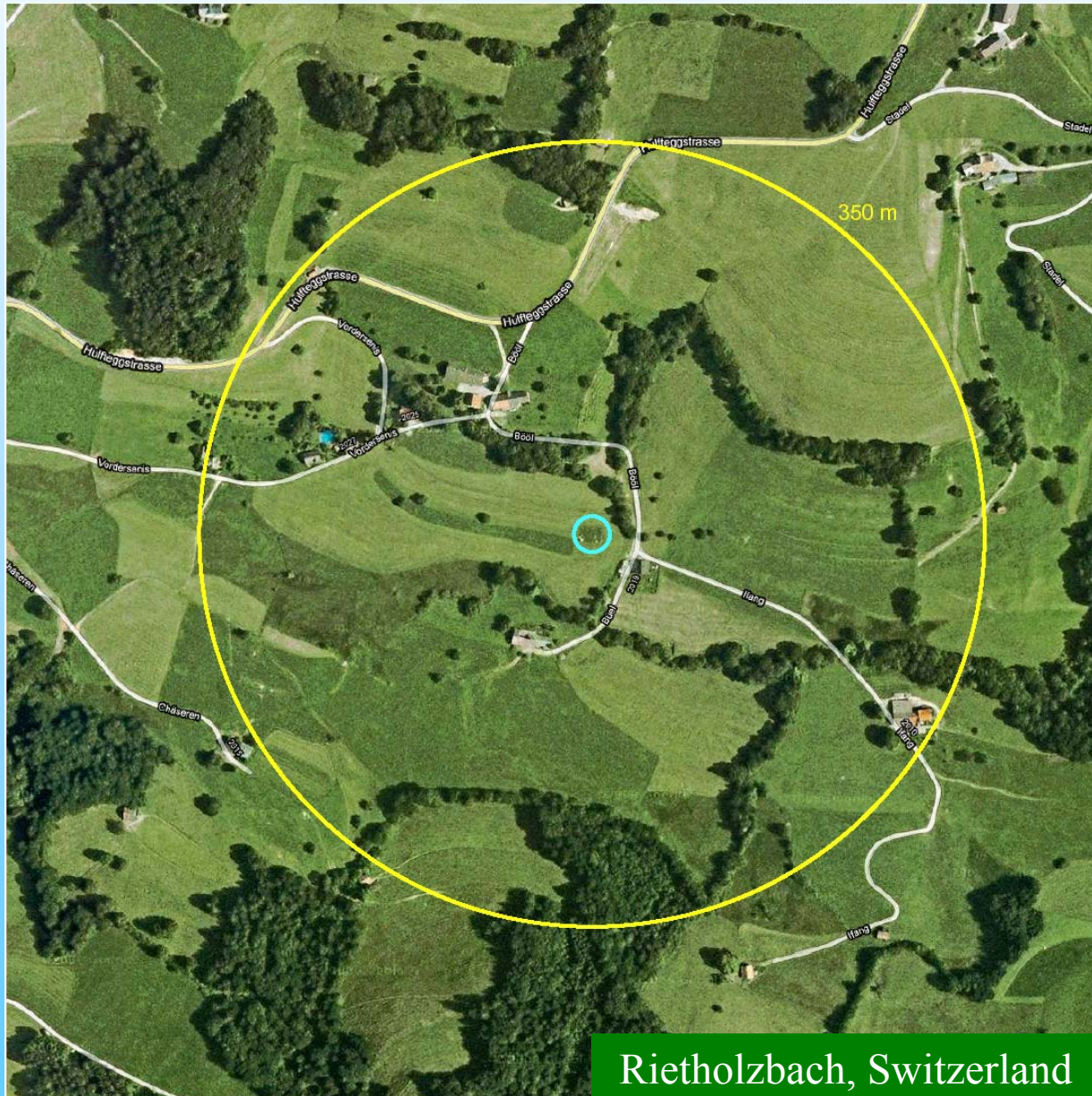
Fast neutron response to soil moisture

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

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.

Zreda et al., 2008, Geophys. Res. Lett. 35, L21402.

Horizontal footprint: 660 m diameter

350 m

Rietholzbach, Switzerland

(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.

Zreda et al., 2008, Geophys. Res. Lett. 35, L21402.

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

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

Corrections to N (or N_0) or Θ_m:

Standard:

Barometric pressure variations (N)

Implemented recently:

Secular variations in the incoming neutron intensity (N)

Worked out and being implemented now:

Lattice water (Θ_m)

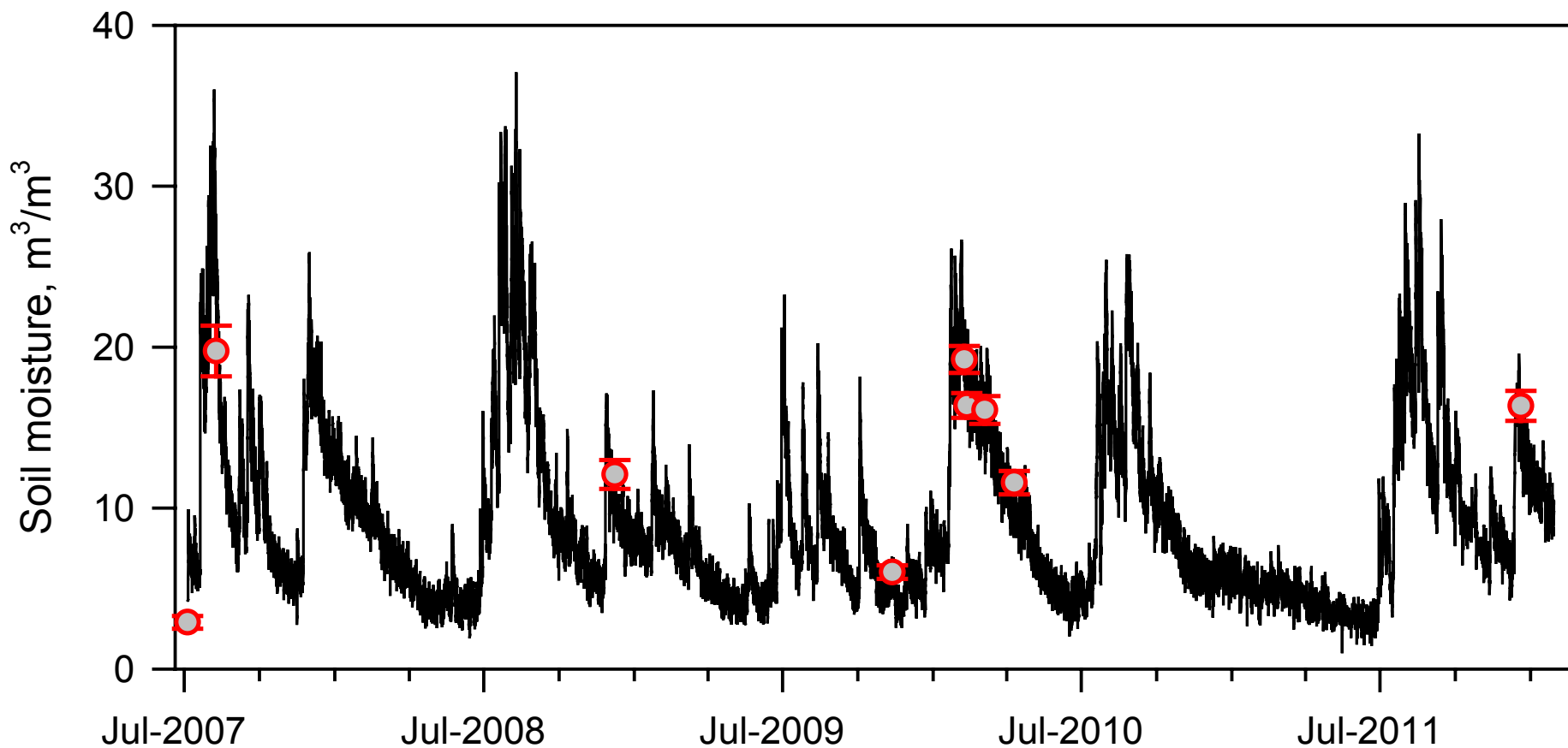Atmospheric water vapor (N; alternatively Θ_m)

In progress:

Vegetation (possibly large effect)(Θ_m or N)

Snow and other water at the surface (large effect) (Θ_m or N)
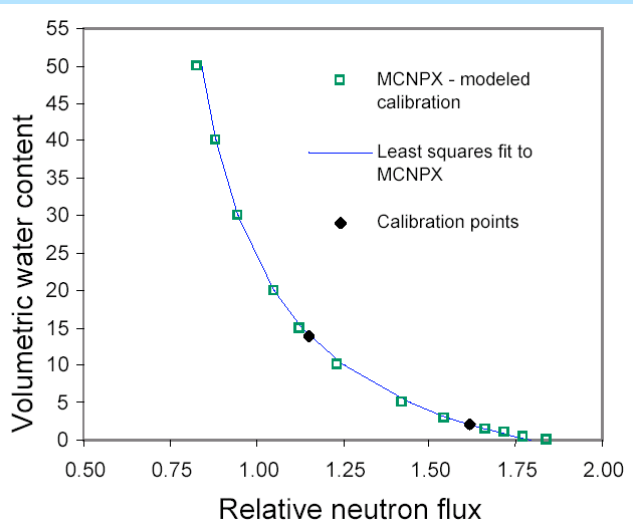
Comparison with gravimetric data

Neutron data corrected for temporal variations in:
- atmospheric pressure;
- incoming cosmic-ray intensity;
- atmospheric water vapor;

Zreda et al., 2012, Hydrol. Earth System Sci. Disc. 9, 4505-4551.
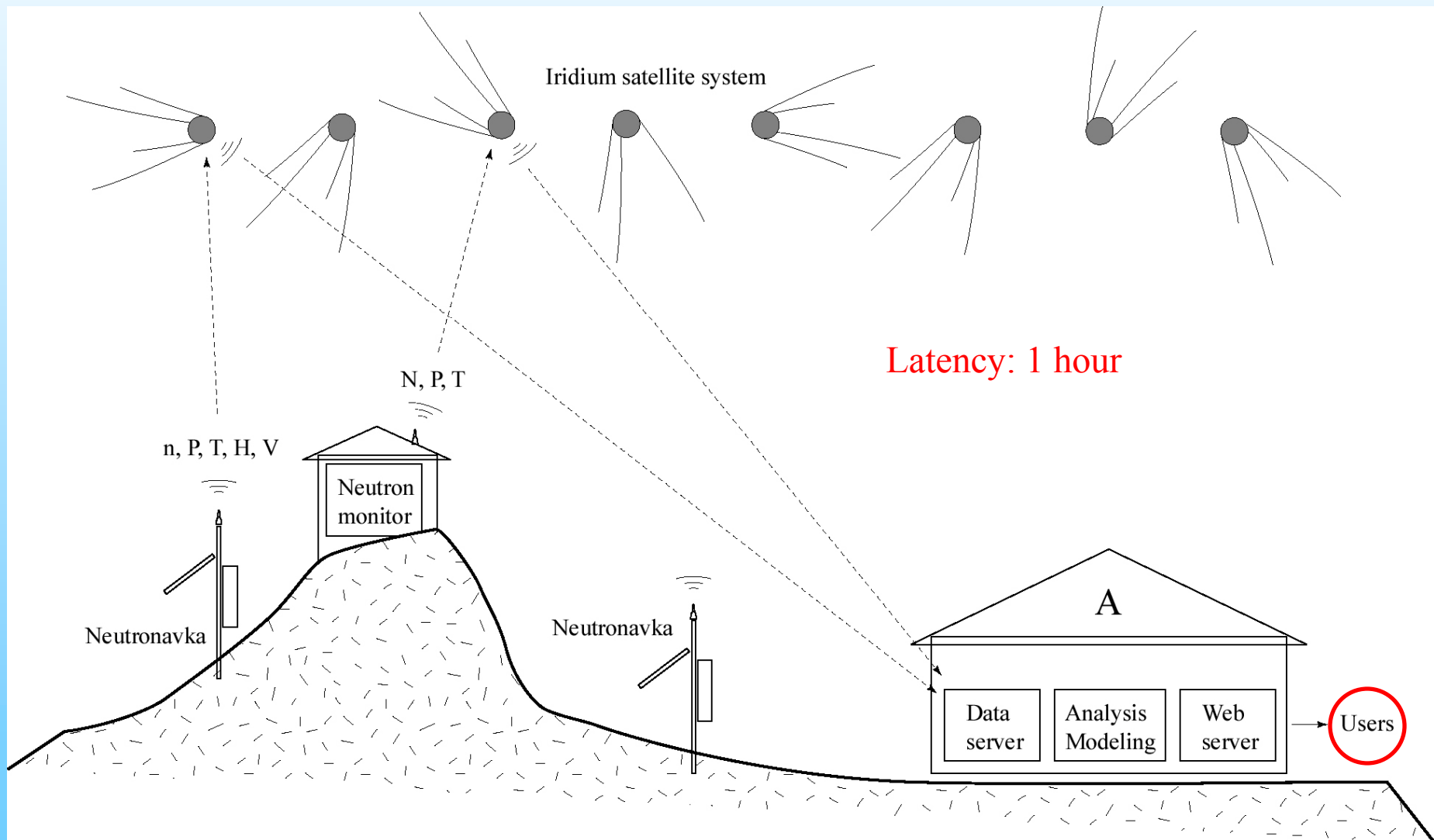
Comparison with 180 TDT sensors
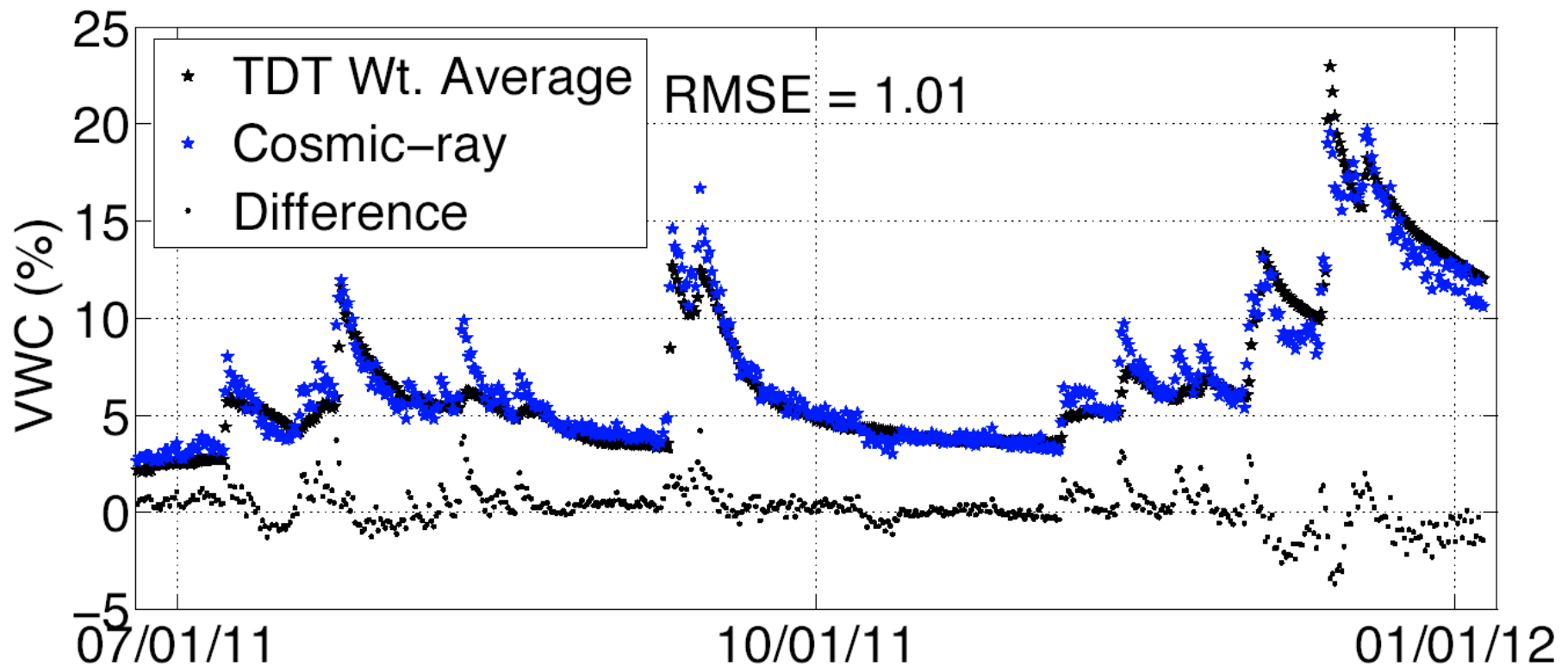
Neutron data corrected for temporal variations in:
- atmospheric pressure;
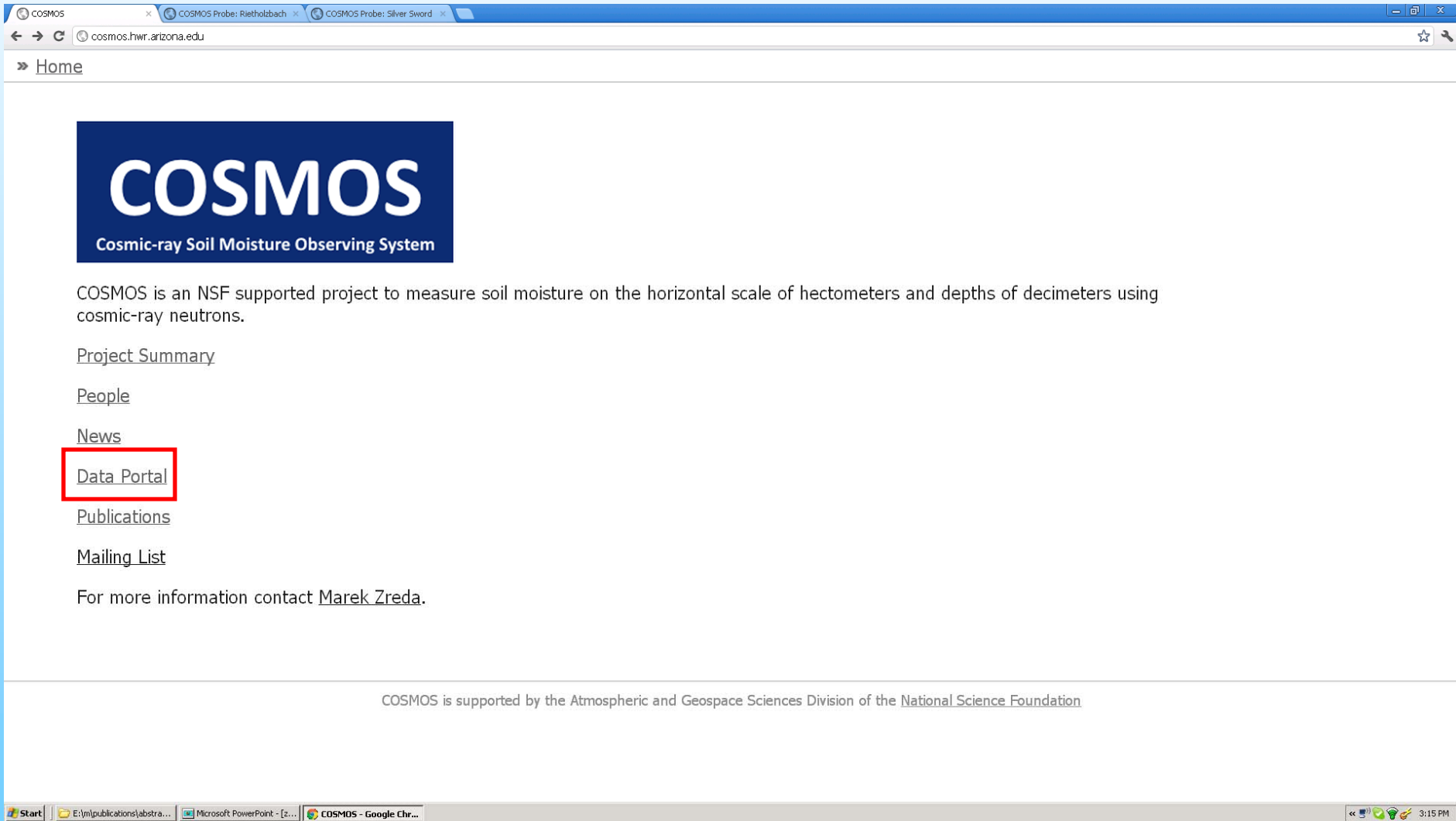- incoming cosmic-ray intensity;
- atmospheric water vapor;

TDT sensors calibrated in the field.

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

COsmic-ray Soil Moisture Observing System (COSMOS)

Iridium satellite system

Latency: 1 hour

N, P, T

n, P, T, H, V

Neutron monitor

Neutronavka

Neutronavka

A

| Data server | Analysis Modeling | Web server | Users |

Zreda et al., 2012, Hydrol. Earth System Sci. Disc. 9, 4505-4551.

COSMOS web site

COSMOS public server: cosmos.hwr.arizona.edu

COSMOS web site: probe locations - USA
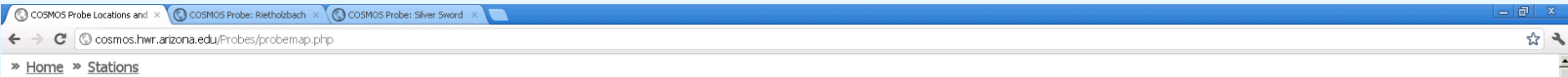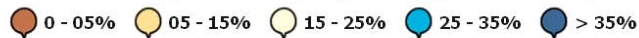
COSMOS public server: cosmos.hwr.arizona.edu

Global COSMOS

COSMOS public server: cosmos.hwr.arizona.edu

COSMOS web site: probe data

COSMOS public server: cosmos.hwr.arizona.edu

COSMOS data: contour map of the US

COSMOS interpolated wetness for 2012-06-15

Wetness
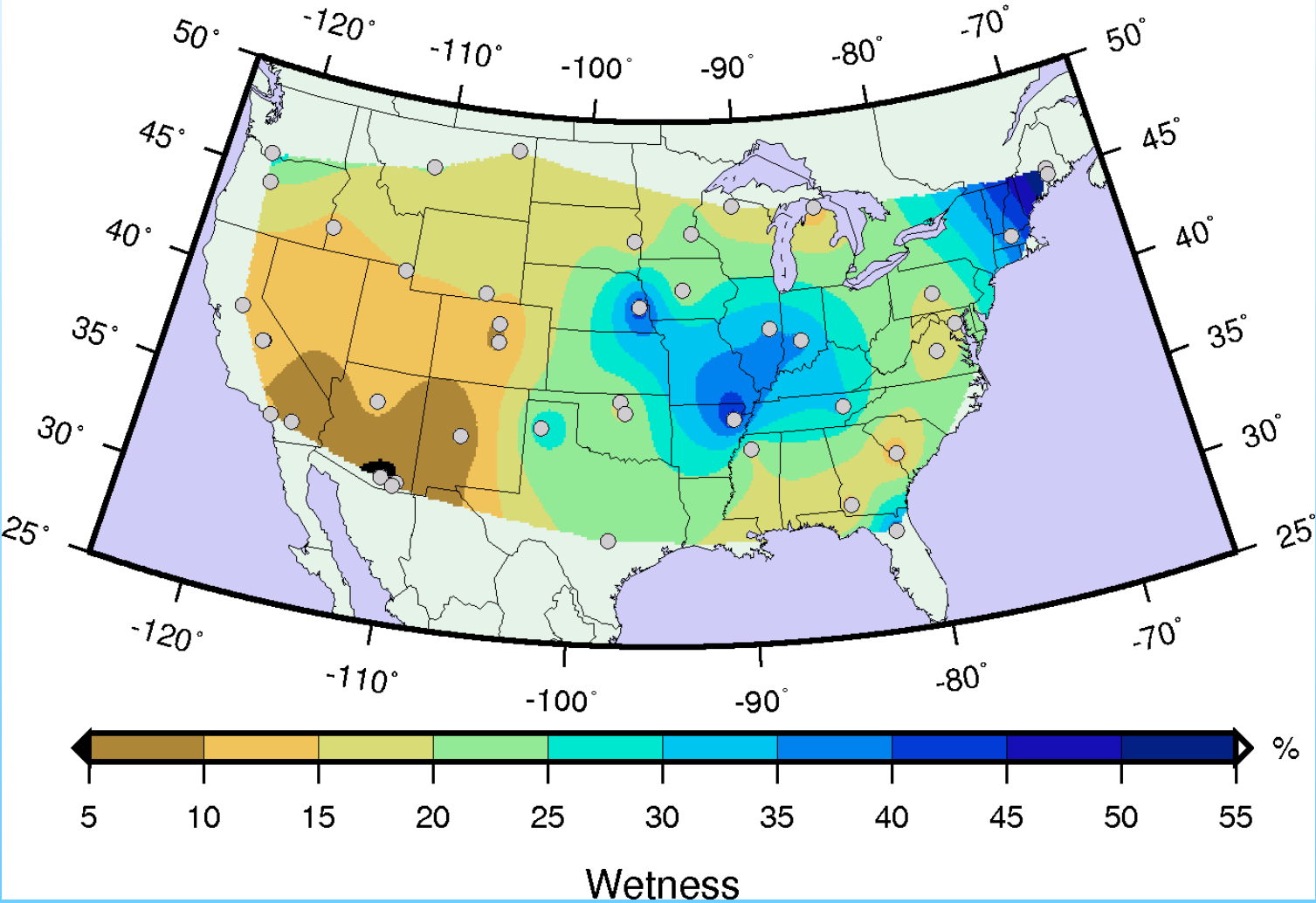
Mobile measurements using COSMOS rover
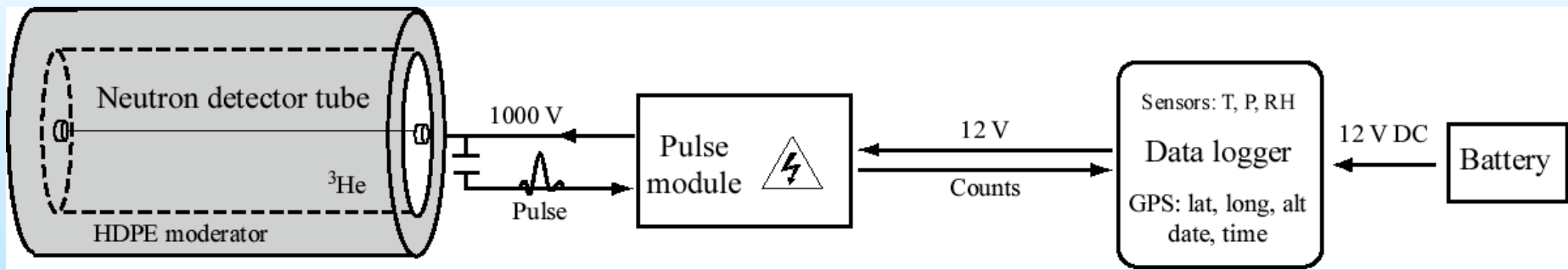
Two modes:

(1) stop and measure (SAM);

(2) drive and measure (DAM).

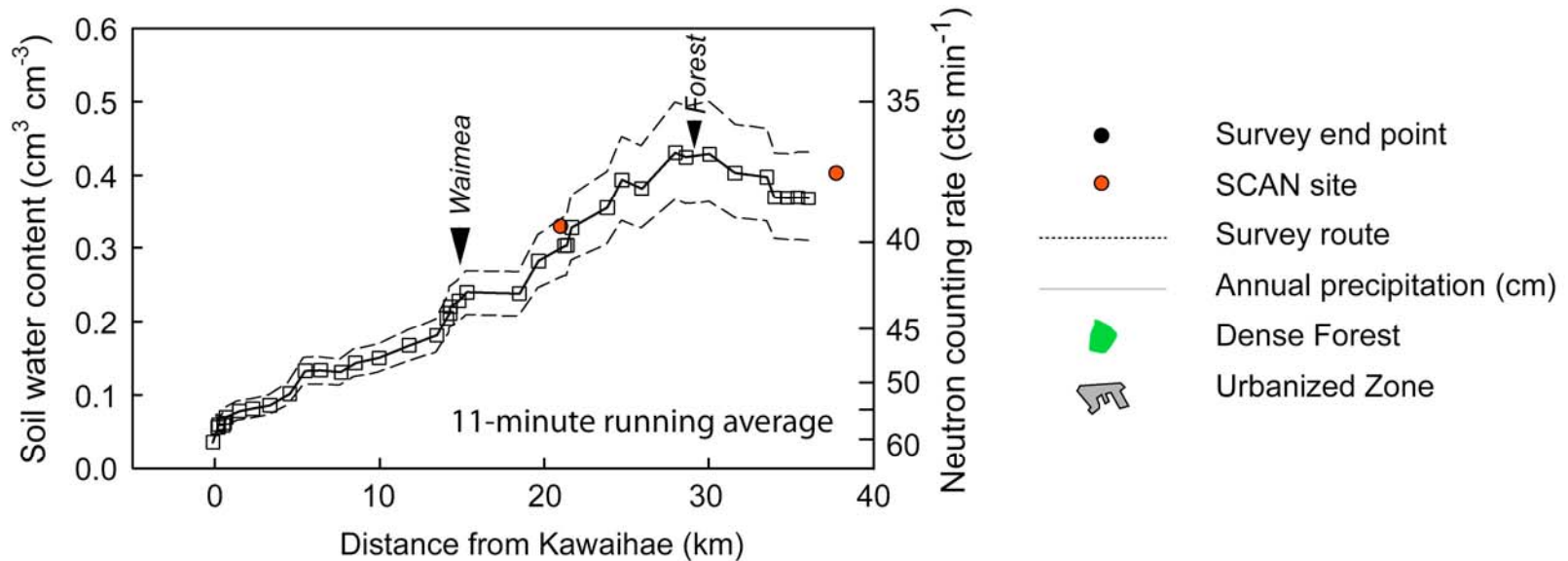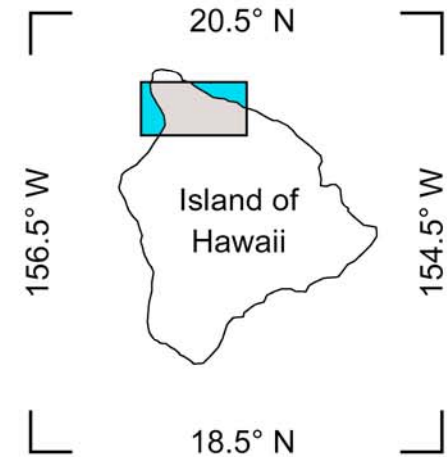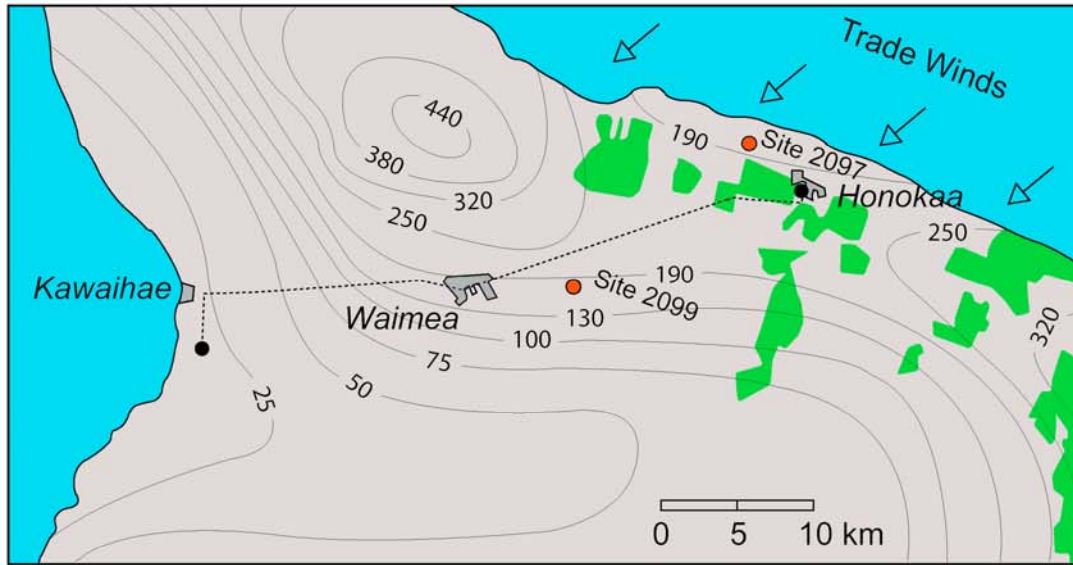**Can do:**

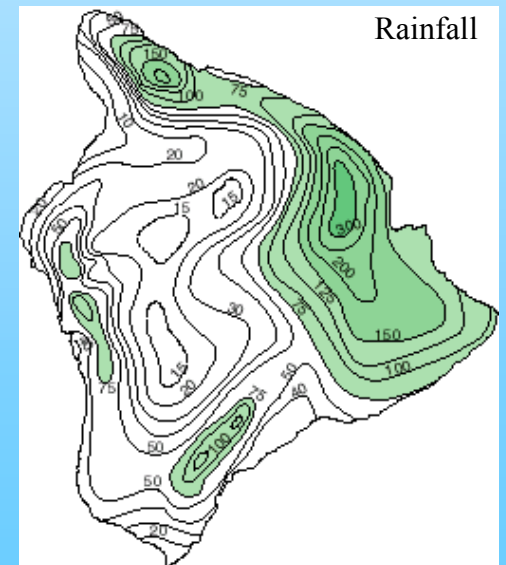(1) 1-D transects.

(2) 2-D maps.

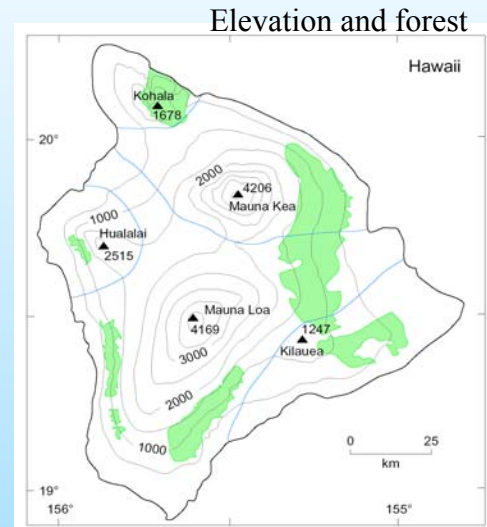Current

New

Standard (US) version

European version

COSMOS rover: transect, Hawaii

COSMOS rover: map, Hawaii

Fast neutrons, cpm

- 92 - 115
- 115 - 138
- 138 - 161
- 161 - 184
- 184 - 207
- 207 - 230
- 230 - 254
- 254 - 277
- 277 - 300

Elevation and forest

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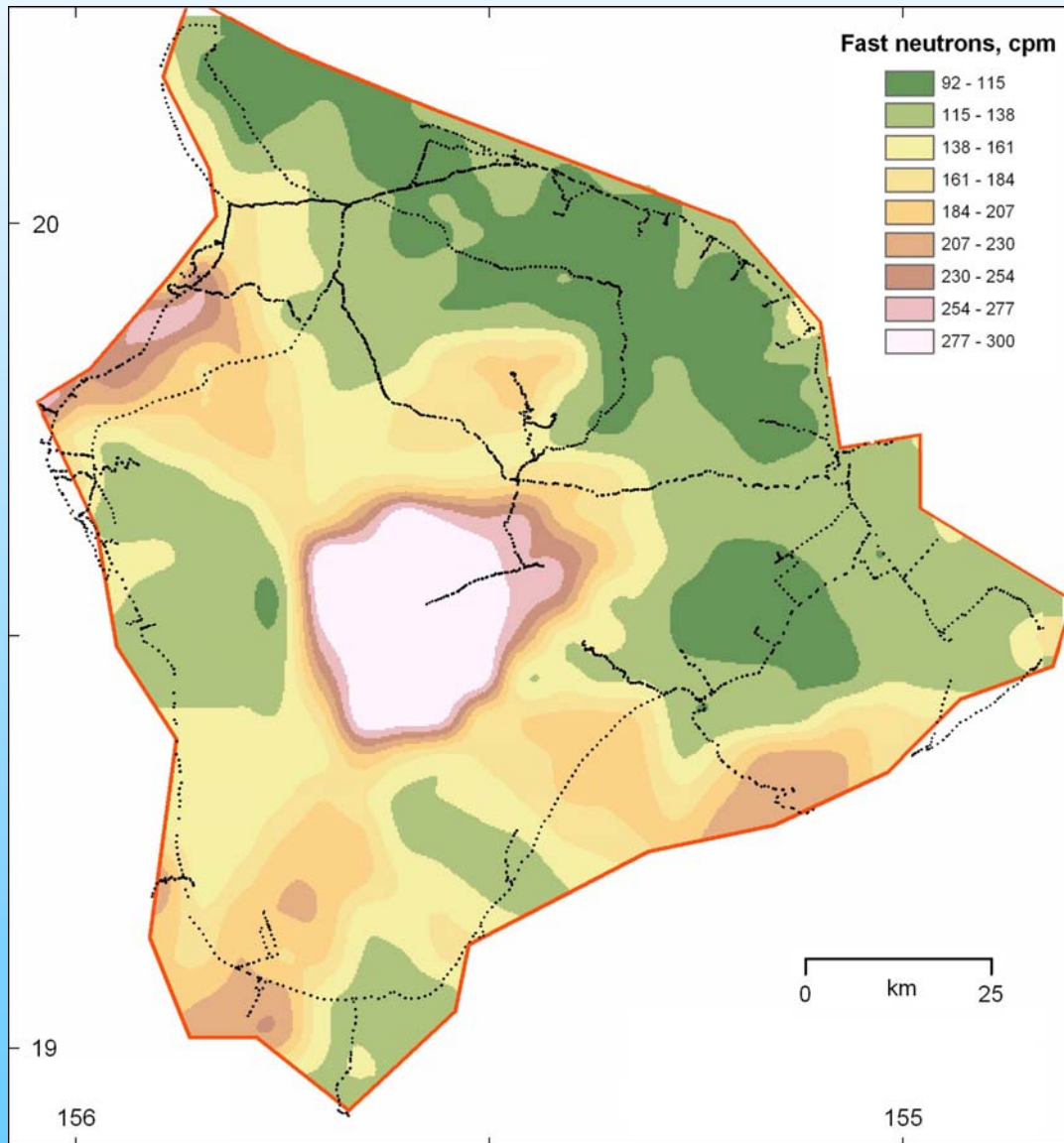
COSMOS rover: soil moisture map of Oklahoma, Sept. 2010

Oklahoma Soil Moisture 2010

Soil Moisture (% Vol.)

0 - 6   8 - 10   12 - 14   16 - 18   20 - 22   24 - 26
6 - 8   10 - 12   14 - 16   18 - 20   22 - 24   26 - 30

0 12.5 25   50   75   100
Kilometers
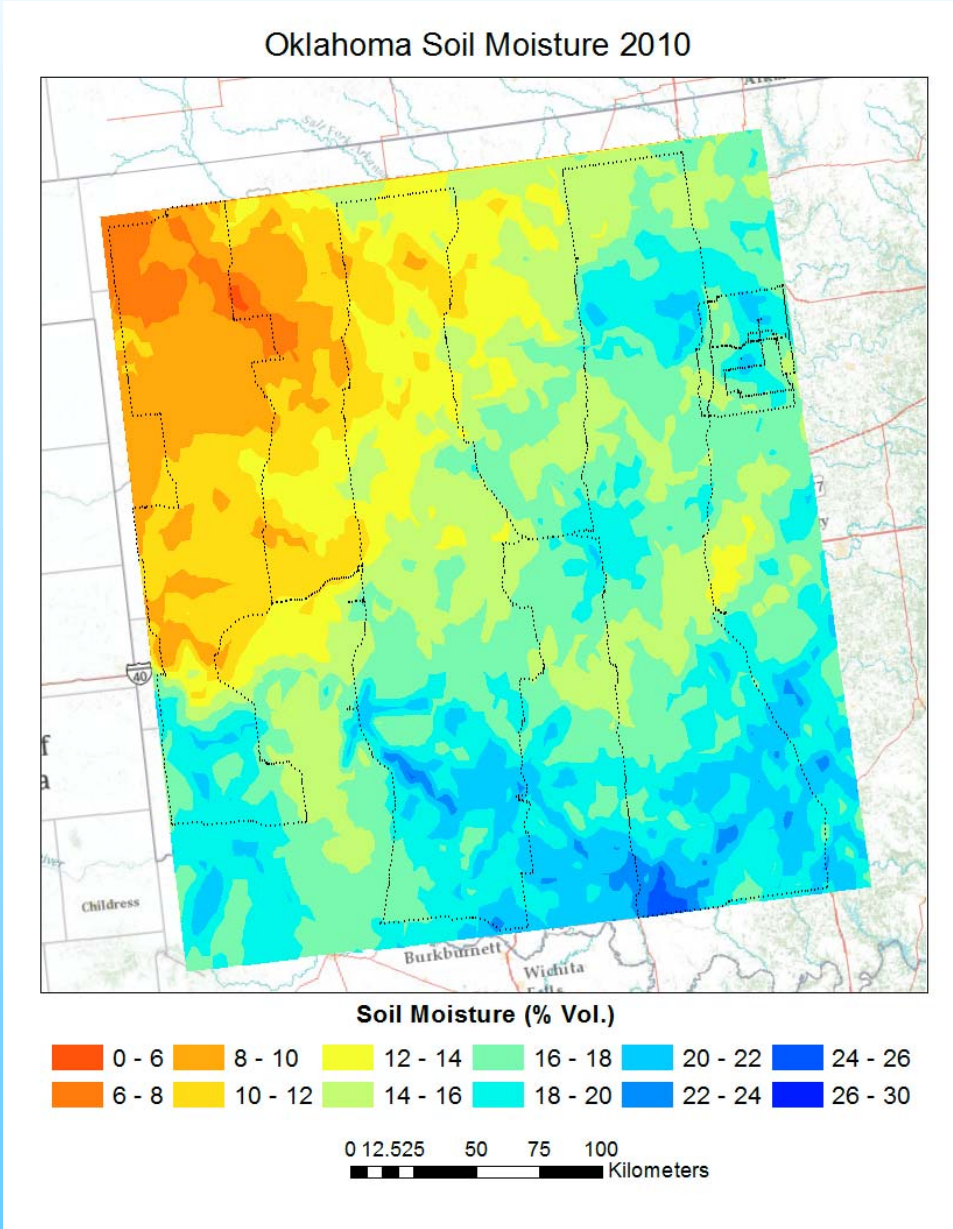
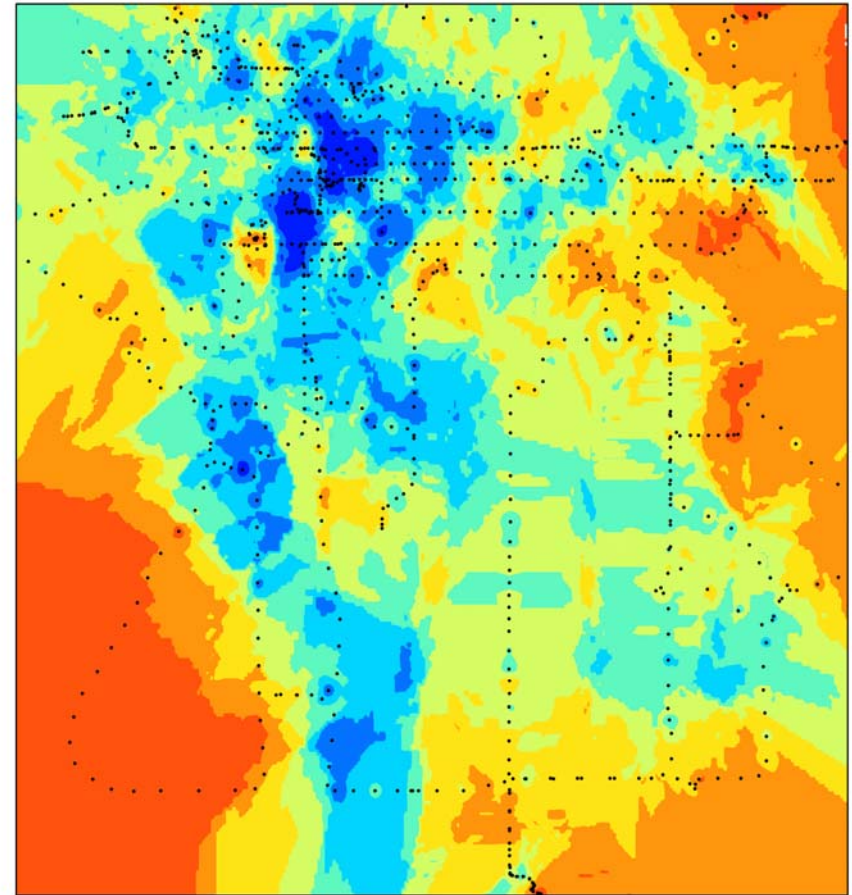# COSMOS rover: periodic maps of the Tucson Basin

Tucson Basin Topography and Survey Locations
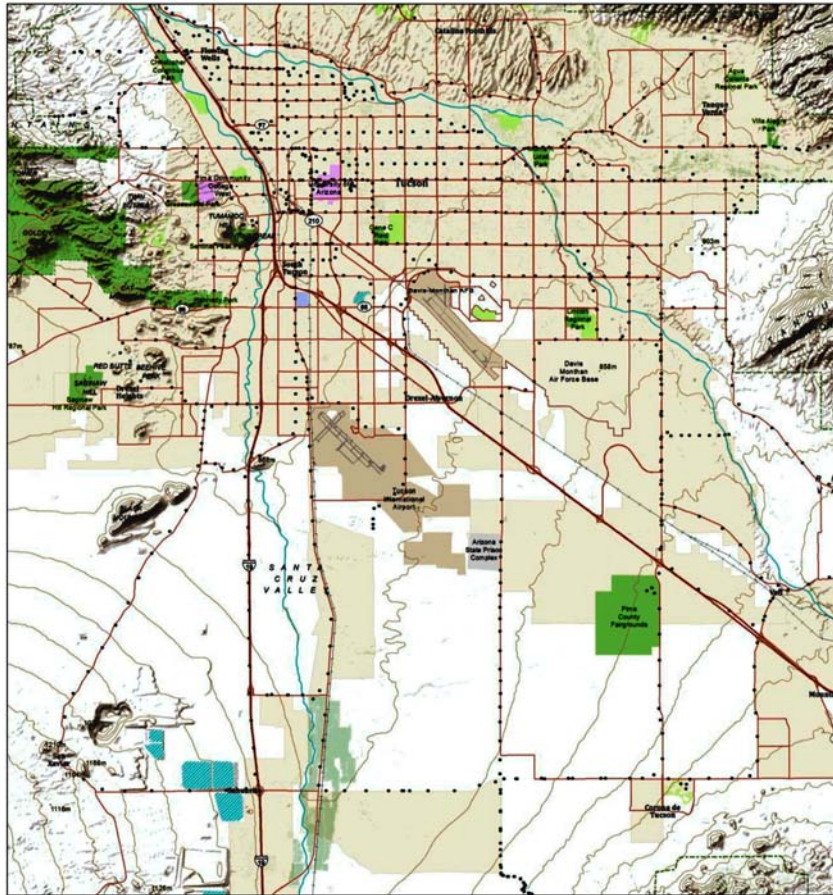
0   3   6   9   12
Kilometers

Jan.29.2012   Soil Moisture (% Vol.)

4.0 - 6.5	7.8 - 8.8	9.7 - 10.6	11.6 - 13.5
6.5 - 7.8	8.8 - 9.7	10.6 - 11.6	13.5 - 19.5

0   3   6   9   12
Kilometers

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