HOW WELL COSMIC RAY PROBES MEASURE THE WIDE AREA SNOW WATER EQUIVALENT?

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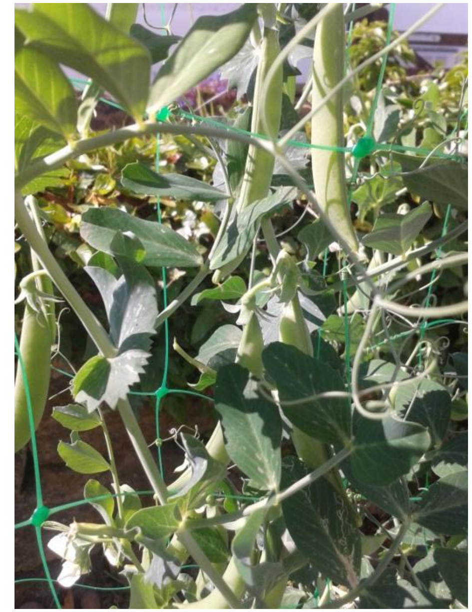
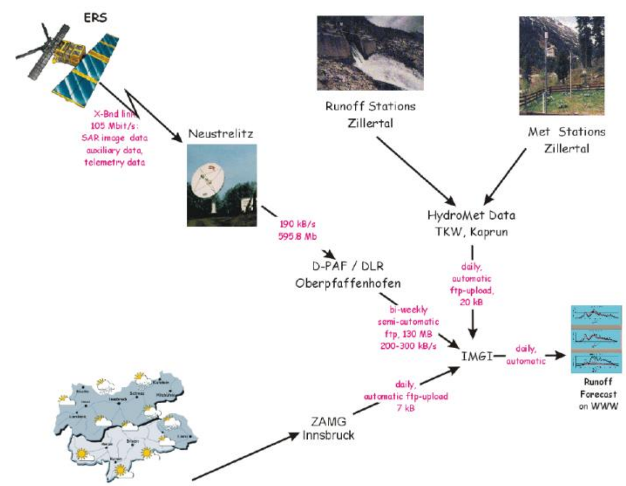
METU

SNOW ; AN ECOLOGICAL PHENOMENA
19 -21 September 2017 Smolenice-SK

Summary

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bi-weekly
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ftp, 130 MB
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Runoff Stations
Zillertal
Met Stations
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HydroMet Data
TKW, Kaprun
daily,
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Runoff
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Numerical Weather Forecast
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ZAMG-Vienna

Summary

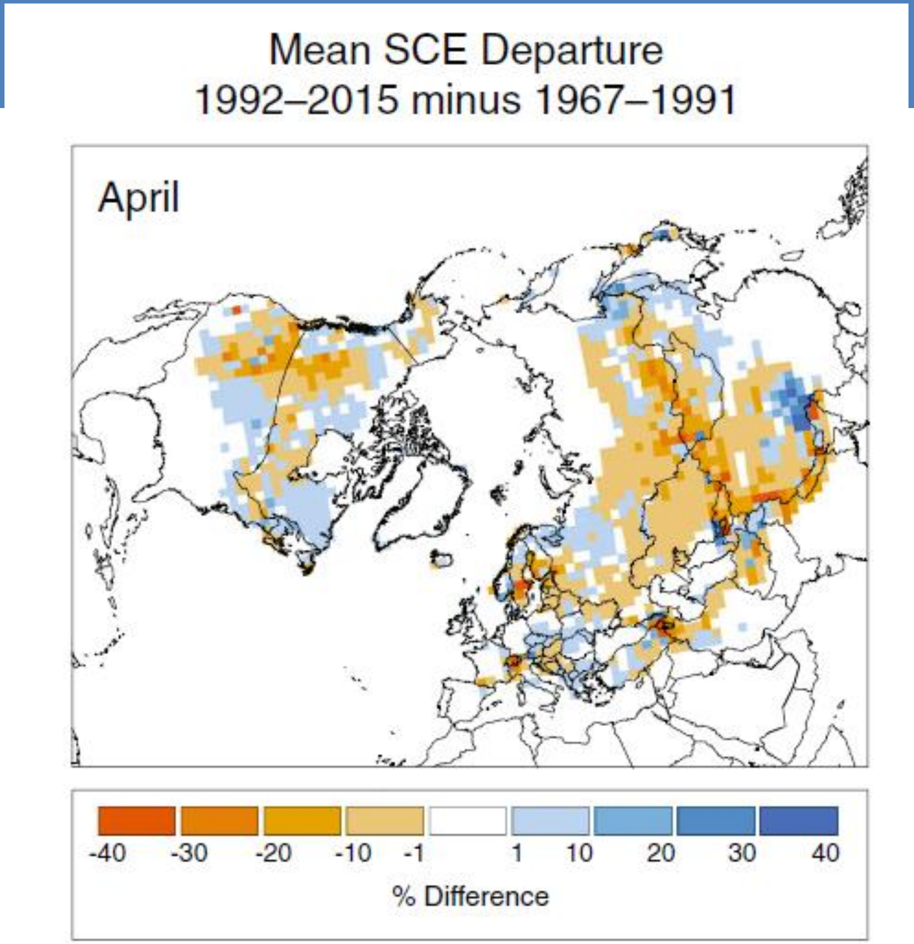


Figure 1 Comparison of April snow cover extent over Northern Hemisphere lands between the first (1967–1991) and second (1992–2015) half of the satellite data record. Locations where snow cover is less extensive in the second half of the period are shown in brown shades, and where the second half had more extensive cover in blue shades. SCE is from the NOAA satellite series and based on analyses of the climate data record product generated at Rutgers University

Kunkel et al., 2016 «Trends and Extremes in Northern Hemisphere Snow Characteristics»
DOI 10.1007/s40641-016-0036-8

Summary

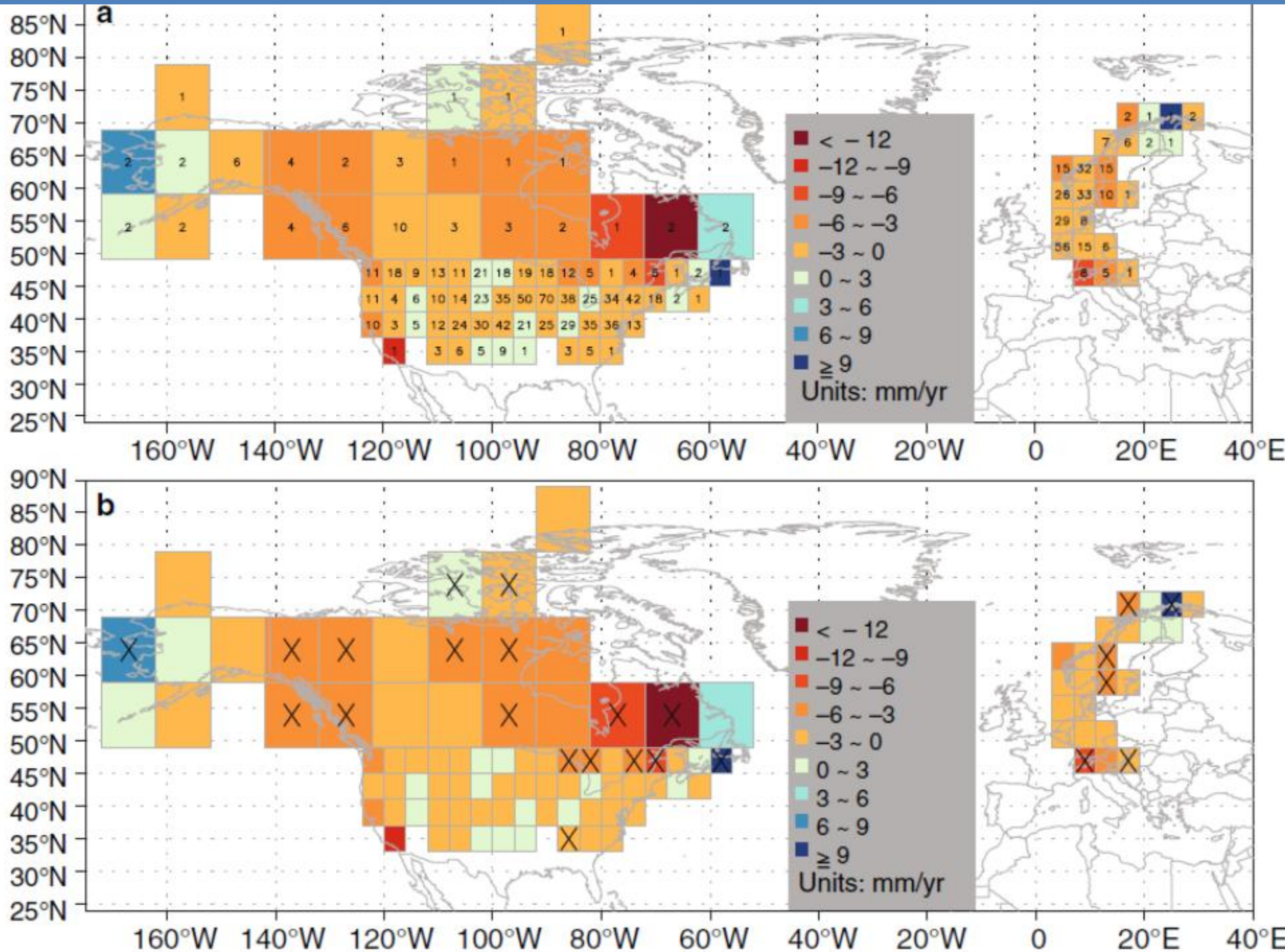
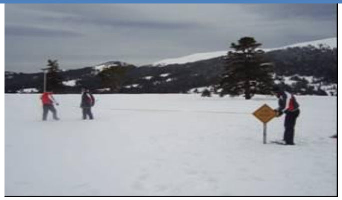


Figure 5 Grid box trends (%/decade) in annual maximum snow depth for cold season periods of 1960/1961–2014/2015. **a** *Numbers* indicate number of stations available in that grid box. **b** *Boxes with* "x" indicate statistically significant trends at the $p < 0.05$ level of significance

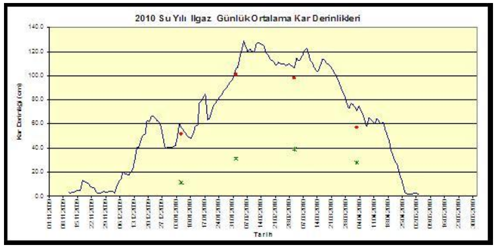
«Evaluation of overall trends in snowfall extremes is a challenge Because most studies are regional in nature and the ready availability of station data is quite limited for Eurasia and at high latitudes over North America.»

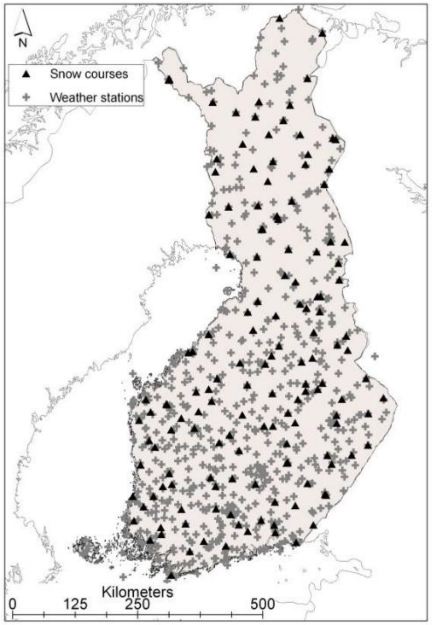
Measurement of Snow

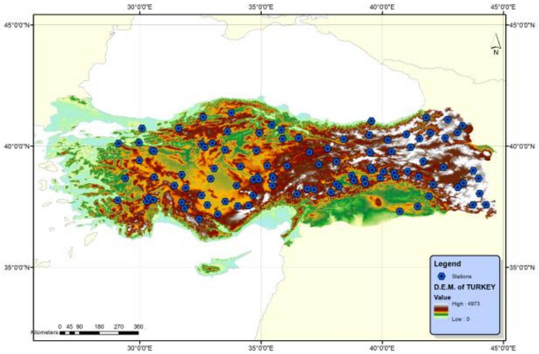




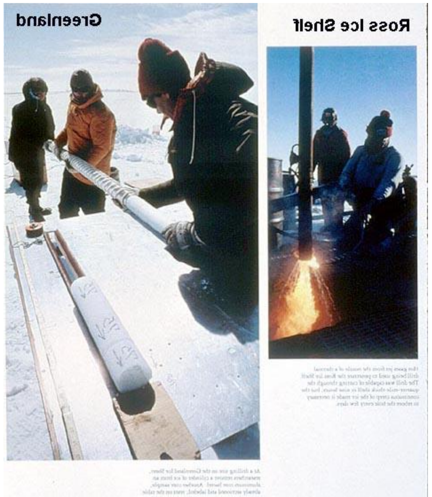










IN-SITU SNOW MEASUREMENTS

SAMPLING WITH SNOW TUBES, DIGGING SNOW PITS AND MEASURING MANUALLY THE DENSITY, TEMPERATURE, HARDNESS, AND OTHER QUANTITIES.

1st Field campaign of ES104 COST action Erzurum-Turkey March 2016

IN-SITU SNOW MEASUREMENTS

COSMIC RAY SENSORS

- The first neutron probe is known to be developed after World War II (Evett, 2001).
- The first appearance of the relation between neutron counts and soil moisture in literature was in 1952 (Gardner & Kirkham, 1952)

How a conventional neutron probe works?

- Fast neutrons generated by a neutron source are decelerated by soil moisture and then counted by a neutron probe.
- In a previously prepared calibration curve, the amount of soil moisture corresponding to the number of decelerated neutrons can be obtained directly.

The main problem with conventional neutron probes:

- Radioactive materials are used as a fast neutron source.
- The radioactive material has to be suspended to the depth at which the moisture will be measured.
- The difficulty and risk of controlling the radioactive substances by means of environmental aspects limit the use of these devices.

How to solve this problem:

- By using **cosmic rays** as the neutron source.

COSMIC RAY SENSORS

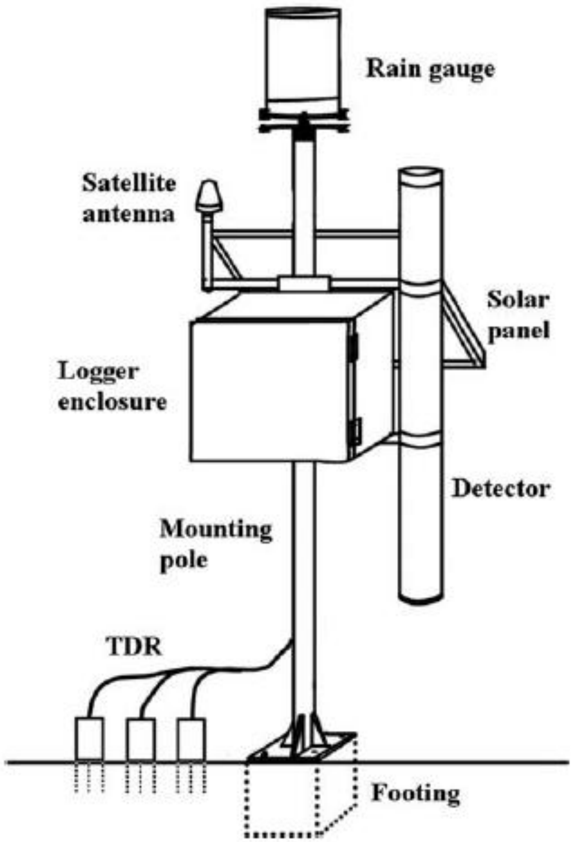
- As an environmentally friendly alternative to conventional neutron probes CRP uses cosmic rays as the neutron source (Zreda, et al., 2008).

- Soil moisture content can be inferred from the measurements of low-energy cosmic ray neutrons that are generated within soil, moderated mainly by hydrogen atoms, and diffused back to the atmosphere.

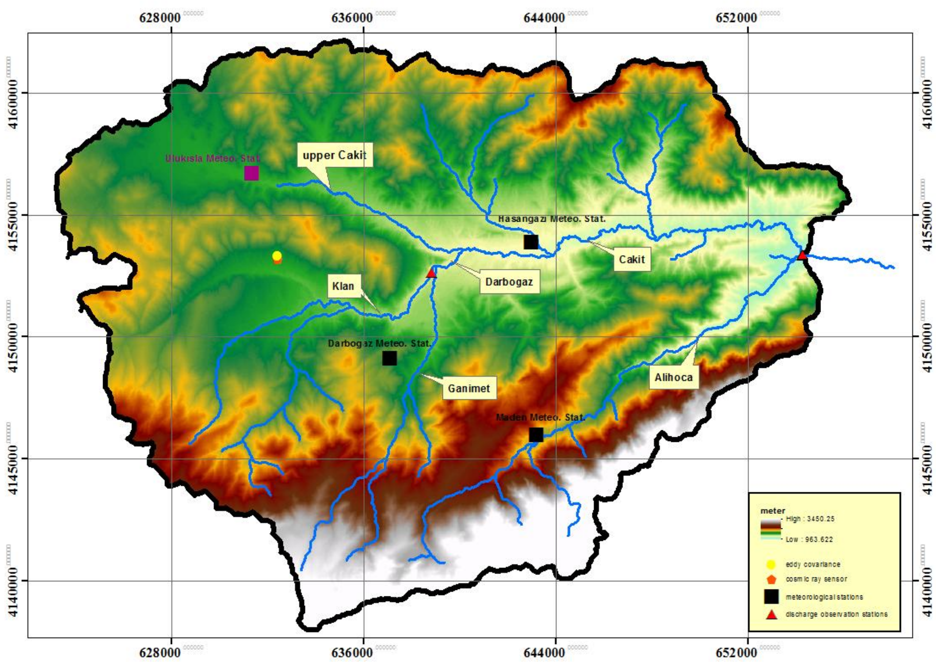
- Neutron intensity above the surface is inversely correlated with the hydrogen content of the soil and hydrogen content is a good indicator of water (H_2O) availability.

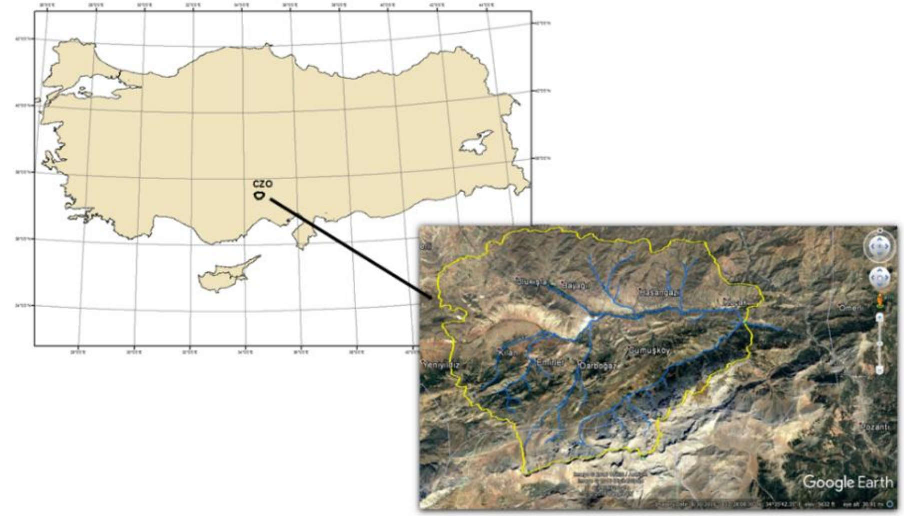
COSMIC RAY SENSORS

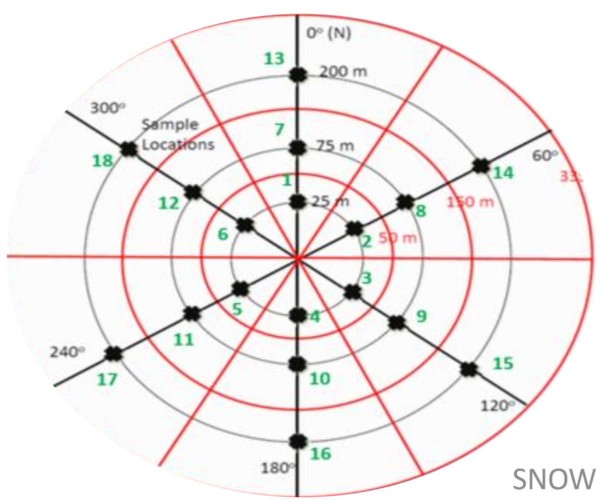
A CRS200B soil moisture probe (Hydroinnova, NM, USA) is installed at 1459 m in a basin which is located in the south part of Turkey.

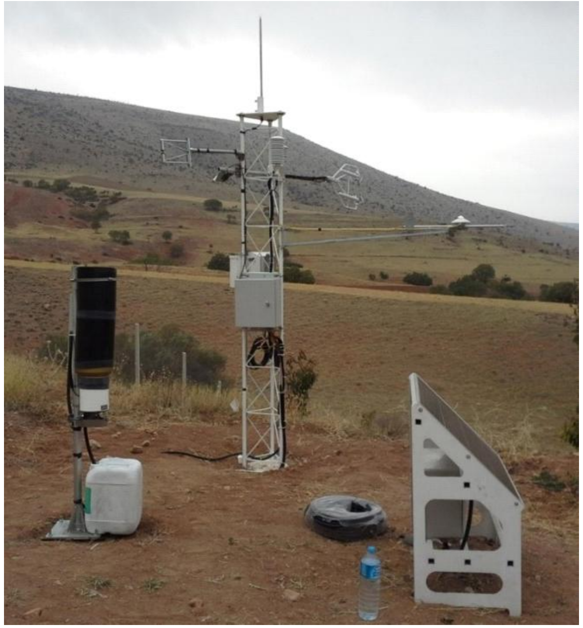


SOIL MOISTURE MONITORING



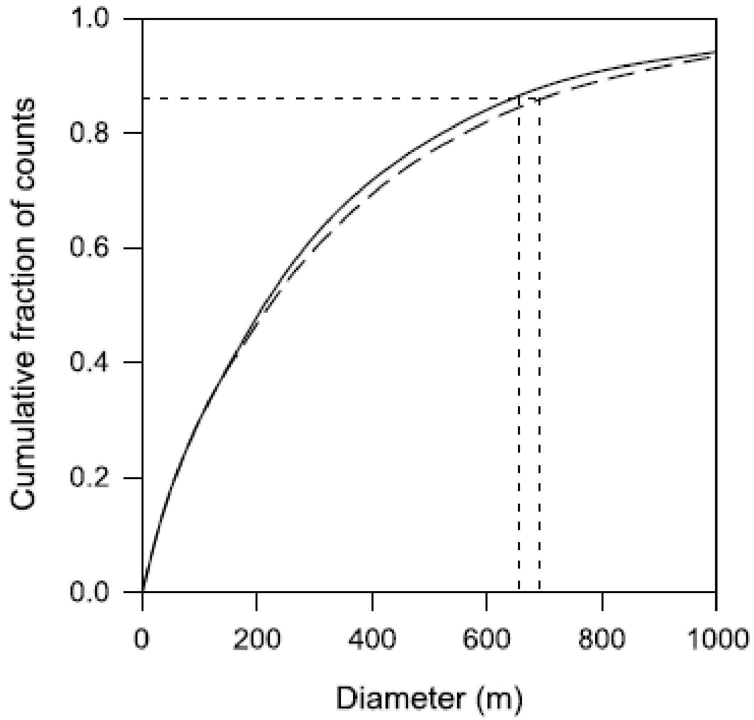




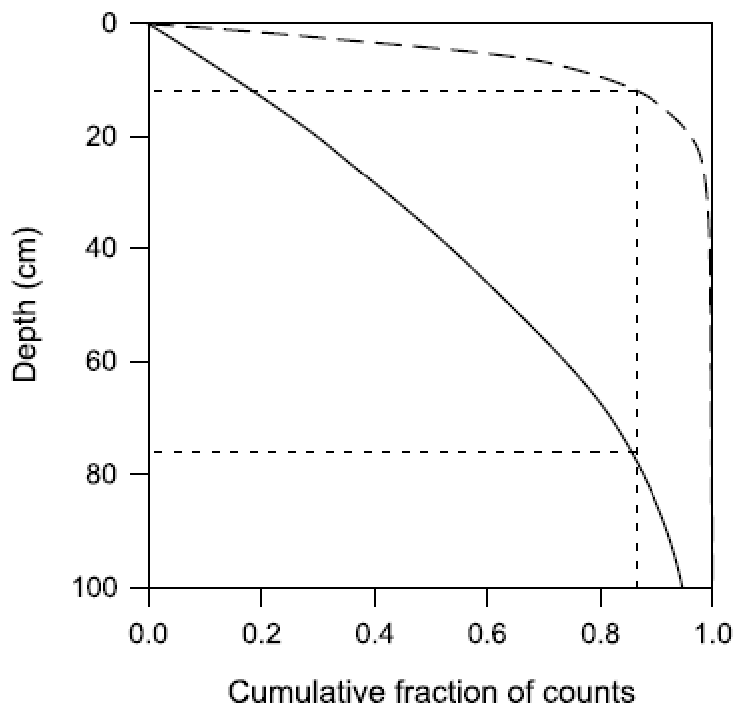


COSMIC RAY SENSORS

- Footprint of a neutron detector placed at the surface (Zreda, et al., 2008):
  - Solid line is dry soil (0% moisture)
  - Dashed line is saturated soil (40% water by volume)



- Measurement depth of a neutron detector placed at the surface. (Zreda, et al., 2008)
  - Solid line is dry soil (0% moisture)
  - Dashed line is saturated soil (40% water by volume)



CORRECTION OF NEUTRON COUNTS

In order to infer the soil moisture amount using CRPs, variations due to environmental factors have to be considered. These factors include

- Atmospheric pressure,
- Atmospheric water vapor and
- Intensity of the incoming neutron flux.

(Hawdon, et al., 2013)

$$N = N_{raw}\left(\frac{f_P f_{wv}}{f_i}\right)$$ **(Eq. 1)**

Where;

N : Corrected neutron flux

N_{raw} : Uncorrected neutron count from the CRP

f_p : Correction factor for Atmospheric Pressure Variation

f_{wv} : Correction factor for changes in atmospheric water vapor

f_i : Correction factor for incoming neutron intensity

CORRECTION FOR ATMOSPHERIC PRESSURE VARIATION

Neutron flux is measured by CRPs for elevation and air pressure above the sensor. For this reason, neutron counts are corrected for a reference pressure condition.

(Desilets, et al., 2006)

$$f_P = \exp\left[\beta\left(P - P_{ref}\right)\right] \qquad \textbf{(Eq. 2)}$$

Where;

P :Atmospheric pressure (mb)

P_{ref} :Reference atmospheric pressure (mb) (atmospheric pressure at sea level (1013.25 hPa) is generally used.)

β :Atmospheric attenuation coefficient (cm2 g-1 or mb-1)

CORRECTION FOR ATMOSPHERIC WATER VAPOR VARIATION

Atmospheric water vapor also moderates neutrons which will eventually influence the neutron counts.

(Rosolem, et al., 2013).

$$f_{wv} = 1 + 0.0054\left(\rho_{v0} - \rho_{v0}^{ref}\right) \quad \textbf{(Eq. 3)}$$

Where;

P_{vo}^{ref} :Reference absolute humidity (g m^{-3})

P_{vo} :Near-surface absolute humidity (g m^{-3})

CORRECTION FOR INCOMING NEUTRON FLUX INTENSITY

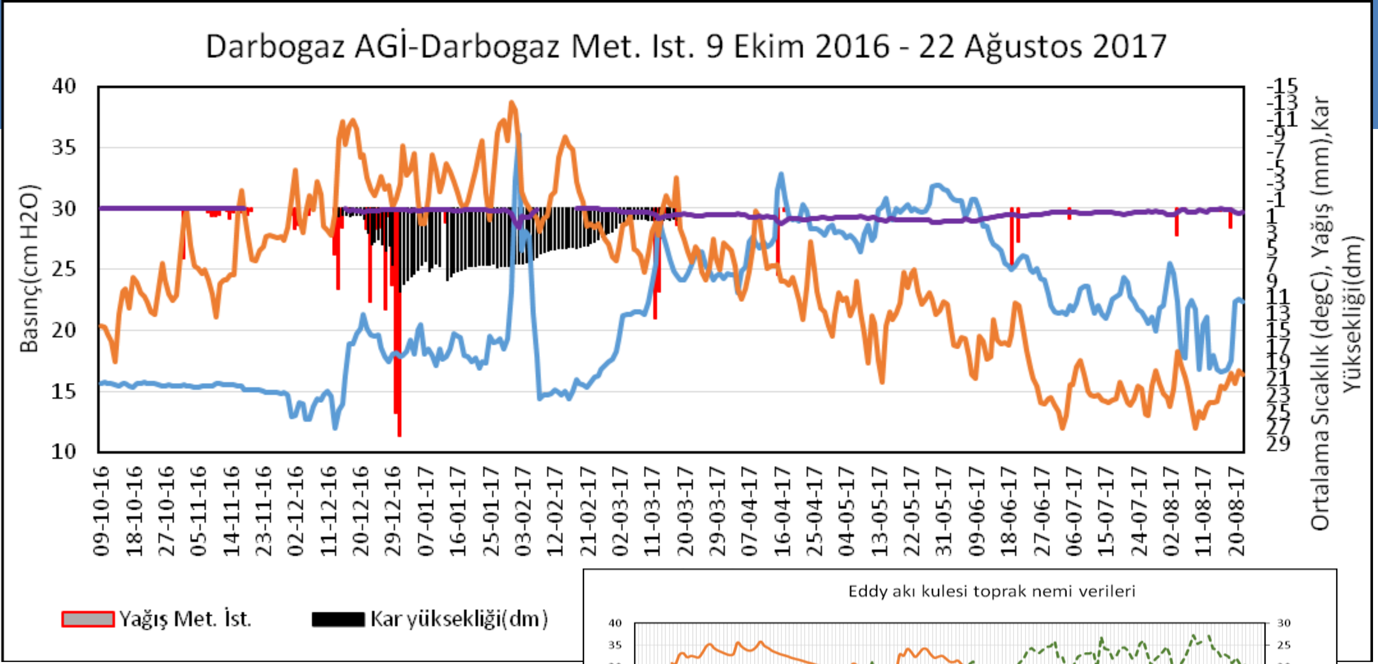
- The intensity of incoming primary cosmic ray particles affects the flux of neutrons that reach the Earth's surface.
- There are neutron monitors measuring the flux of high-energy secondary neutrons around the globe. (e.g. NMDB Network www.nmdb.eu)
- Flux of high-energy secondary neutrons is not influenced by water availability, thus it is possible to use these measurements to correct CRP data. (Zreda, et al., 2012)

$$f_i = \frac{I_m}{I_{ref}} \quad \textbf{(Eq. 4)}$$

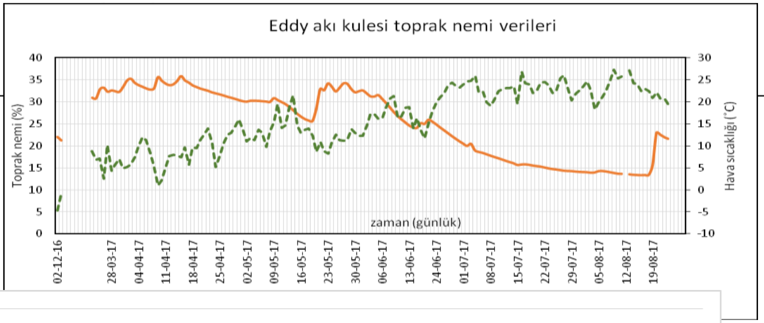
Where;

I_m :Selected neutron monitor counting rate at any particular point in time

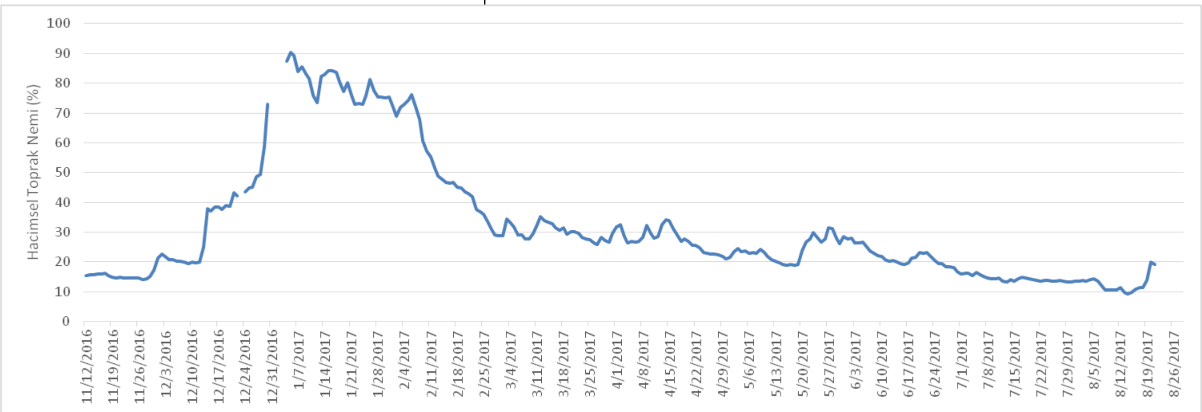
I_{ref} :Reference counting rate for the same neutron monitor from an arbitrary fixed point in time.



Meteorological Station

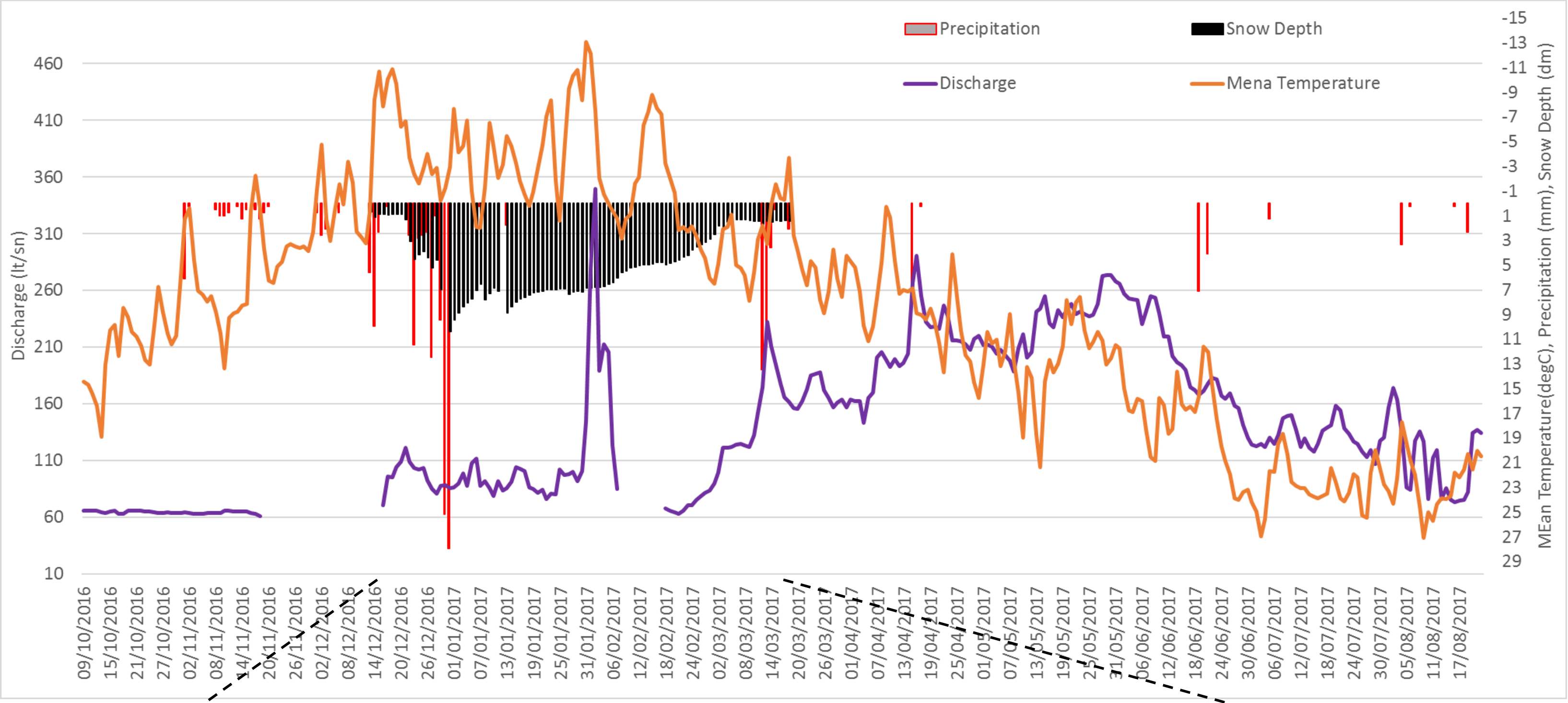


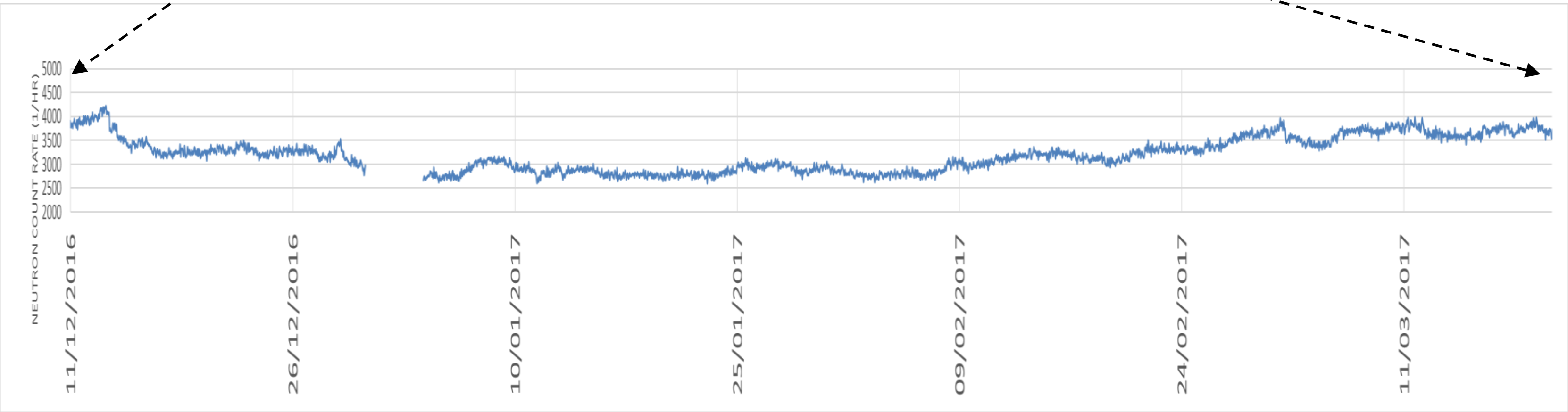
TDR measurements



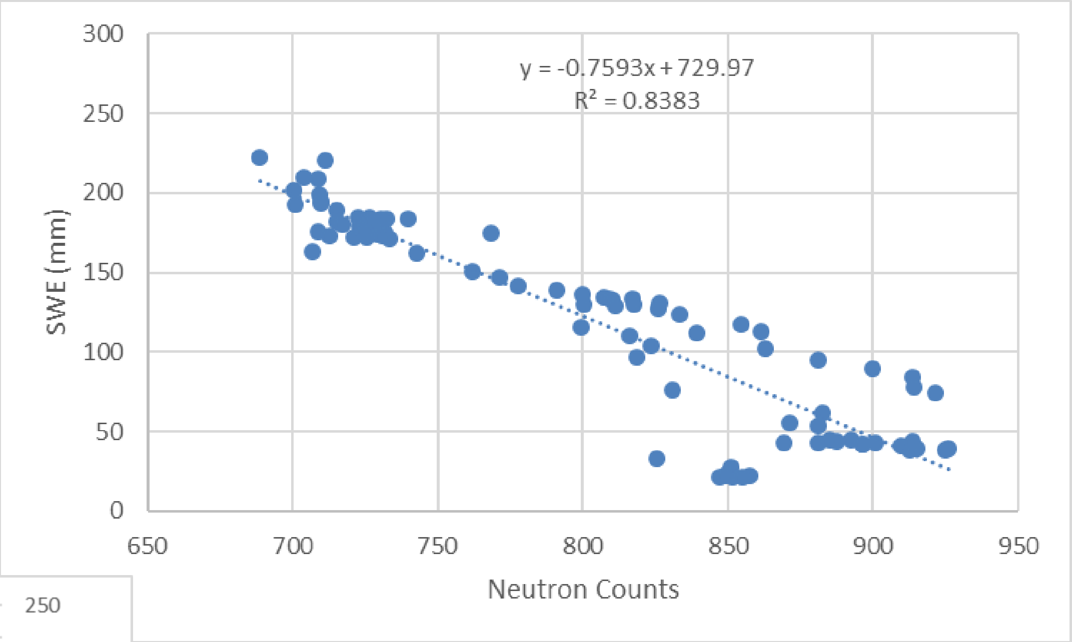
Cosmic Ray Sensor measurements

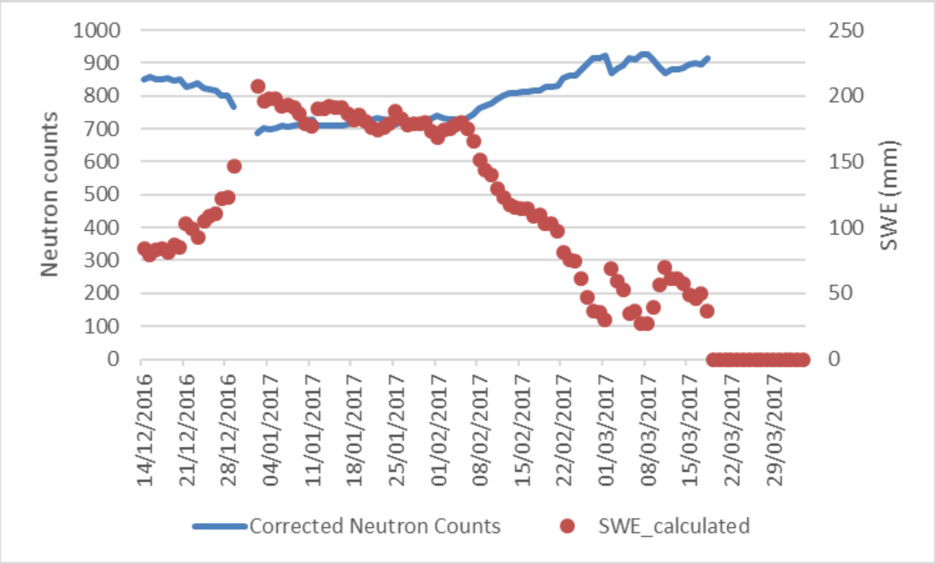
SWE MONITORING





SWE MONITORING





Discussion

- Snow depth values observed at meteorological station were converted to SWE values. In general, moderated neutron intensity shows an expected negative relationship with SWE
- Methodology of calibration of the volumetric soil moisture is presented in the guide by Franz T. (2012). For the SWE calibration a similar approach must be followed. With an assumed footprint of 300 m, snow samples along 25, 75, and 200m radials around the CRP are included in Sigoin and Si (2016).
- A detailed snow depth and SWE measurements within the footprint of CRP could lead more accurate calibration.
- The CRP measurement is also influenced by the soil water storage in the top of the soil profile beneath the snowpack being measured. It is stated by Niu and Yang (2006) and Sigouin and Si (2016) that CRPs may overestimate SWE by measuring water in soil just below the snow cover.

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TÜBİTAK

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cost

European Cooperation in Science and Technology