



Cosmic-ray soil water monitoring: the development, status & potential of the COSMOS-India network

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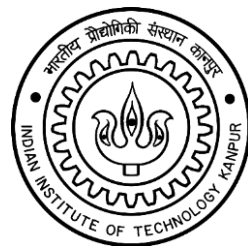


COSMOS-India: outline

- Background & rationale
- Basics of measurement principle
- COSMOS-India network & sites
- Selected results
- Future work

COSMOS-India: objectives

- Collaborative development of soil moisture (SM) network in India using cosmic ray (COSMOS) sensors
- Deliver high temporal frequency SM observations at the intermediate spatial scale in near real-time
- Development of national COSMOS-India data system & near real time data portal
- Integrate with Earth Observation datasets for validated SM maps of India
- Empower many other applications...



Acknowledgment: other COSMOS networks



Soil Moisture (V=Volumetric, G=Gravimetric, U=Uncalibrated)
 ● 0 - 05% ● 05 - 15% ● 15 - 25% ● 25 - 35% ● > 35%



cosmos.hwr.arizona.edu



cosmos.ceh.ac.uk

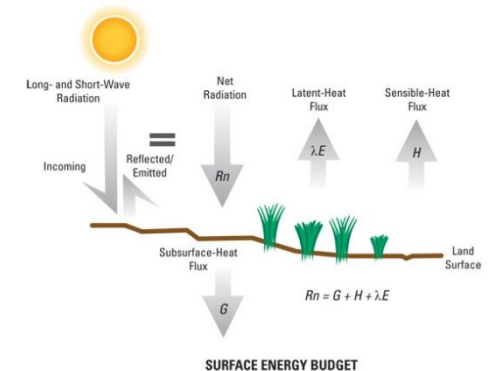
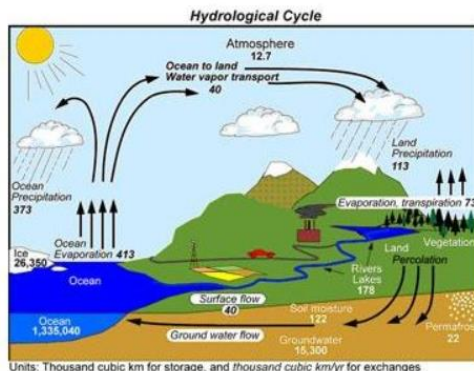
Key

● COSMOS-UK sites



Why measure soil moisture (SM)?

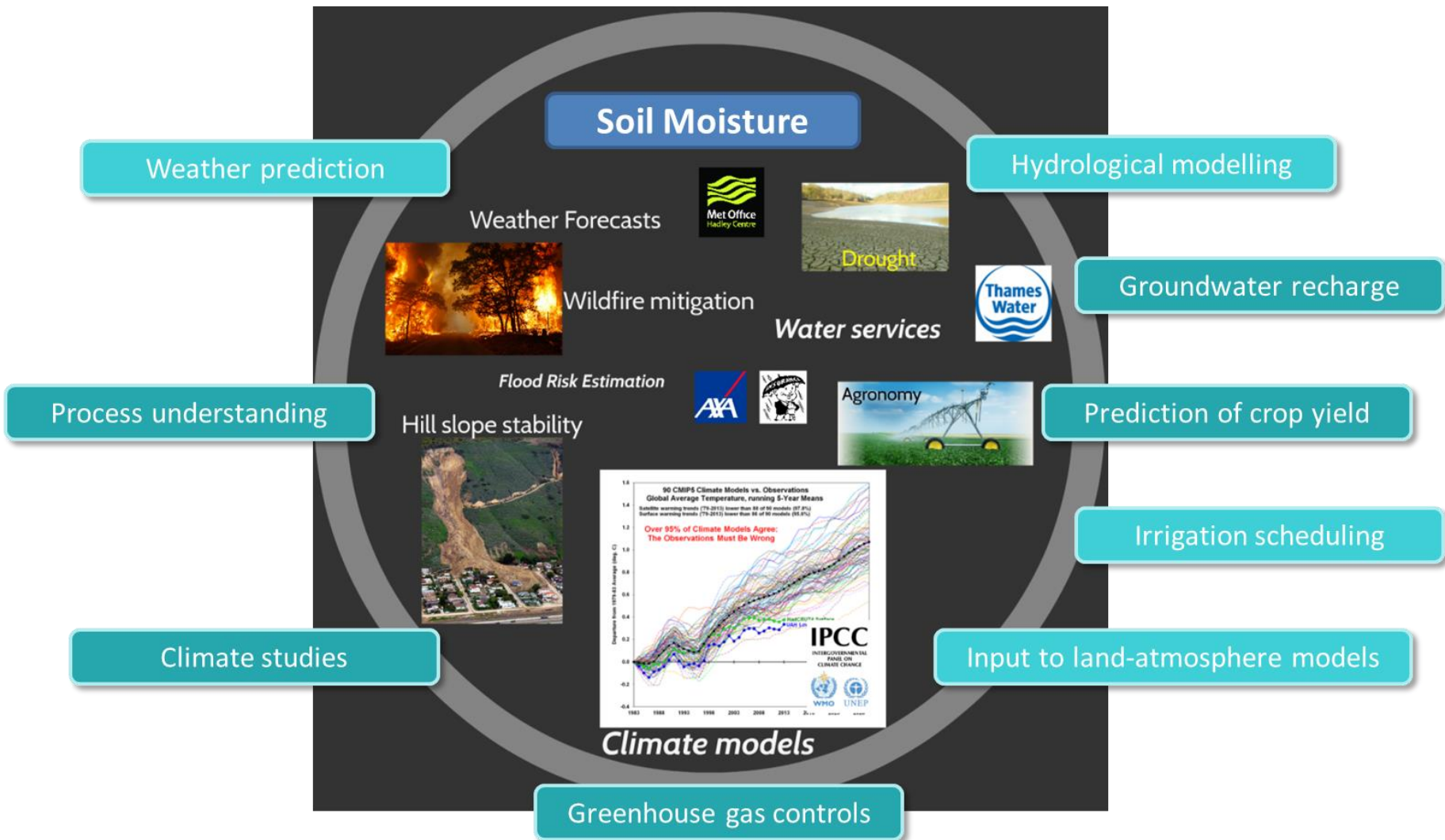
- Controls exchanges of energy & mass between land surface & atmosphere
- Hydrology: controls evapotranspiration, partitioning between runoff & infiltration, groundwater recharge
- Meteorology: partitioning solar energy into sensible, latent & soil heat fluxes, surface-boundary layer interactions
- Plant growth & soil biogeochemistry



<https://www2.ucar.edu/atmosnews/people/aiguo-dai>

<https://nevada.usgs.gov/water/et/measured.htm>

Applications of soil moisture data



SM observation techniques

- **Challenge:** SM observations at spatial & temporal resolution relevant to applications (e.g. gridded models, field scale)
- **Point scale:** high temporal resolution & low cost
- Issues - spatial heterogeneity & sensor placement (e.g. tilled fields)
- Scale gap between hydrological models & satellite products
- **Satellite remote sensing:** near-surface soil moisture over large areas
- Issues - discontinuous, coarse, limited penetration depth, sensitive to surface conditions, high cost
- **COSMOS:** spatially averaged, intermediate scale, continuous
- More relevant to models, eddy covariance, satellite data products



<http://www.acclima.com/>



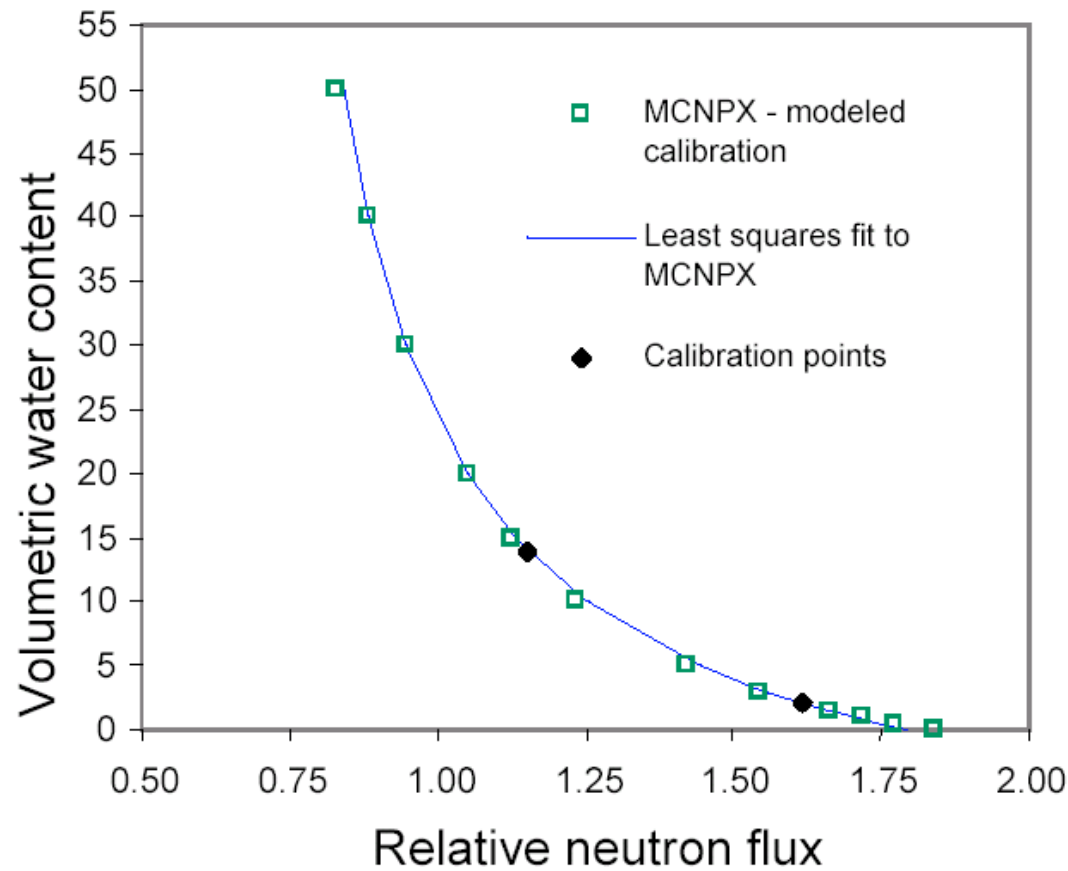
<https://cosmos.ceh.ac.uk/>



<http://www.esa.int/spaceinimages/Images/>

COsmic-ray Soil Moisture Observing System

- Exploits inverse relationship between fast neutron intensity & near-surface water content (specifically hydrogen)



COSMIC-ray Soil Moisture Observing System

- Exploits inverse relationship between fast neutron intensity & near-surface water content (specifically hydrogen)
- Near-surface neutron intensity (count) is a function of production by cosmic rays & their moderation (thermalisation) by surrounding H atoms
- Gas (He^3 or BF_3) discharge tube (CRS) detects reduction (increase) in fast neutrons as SM (H) increases (decreases)
- CRS calibrated *in situ* to convert from neutron intensity to volumetric soil water content ($\text{m}^3 \text{m}^{-3}$)

COsmic-ray Soil Moisture Observing System

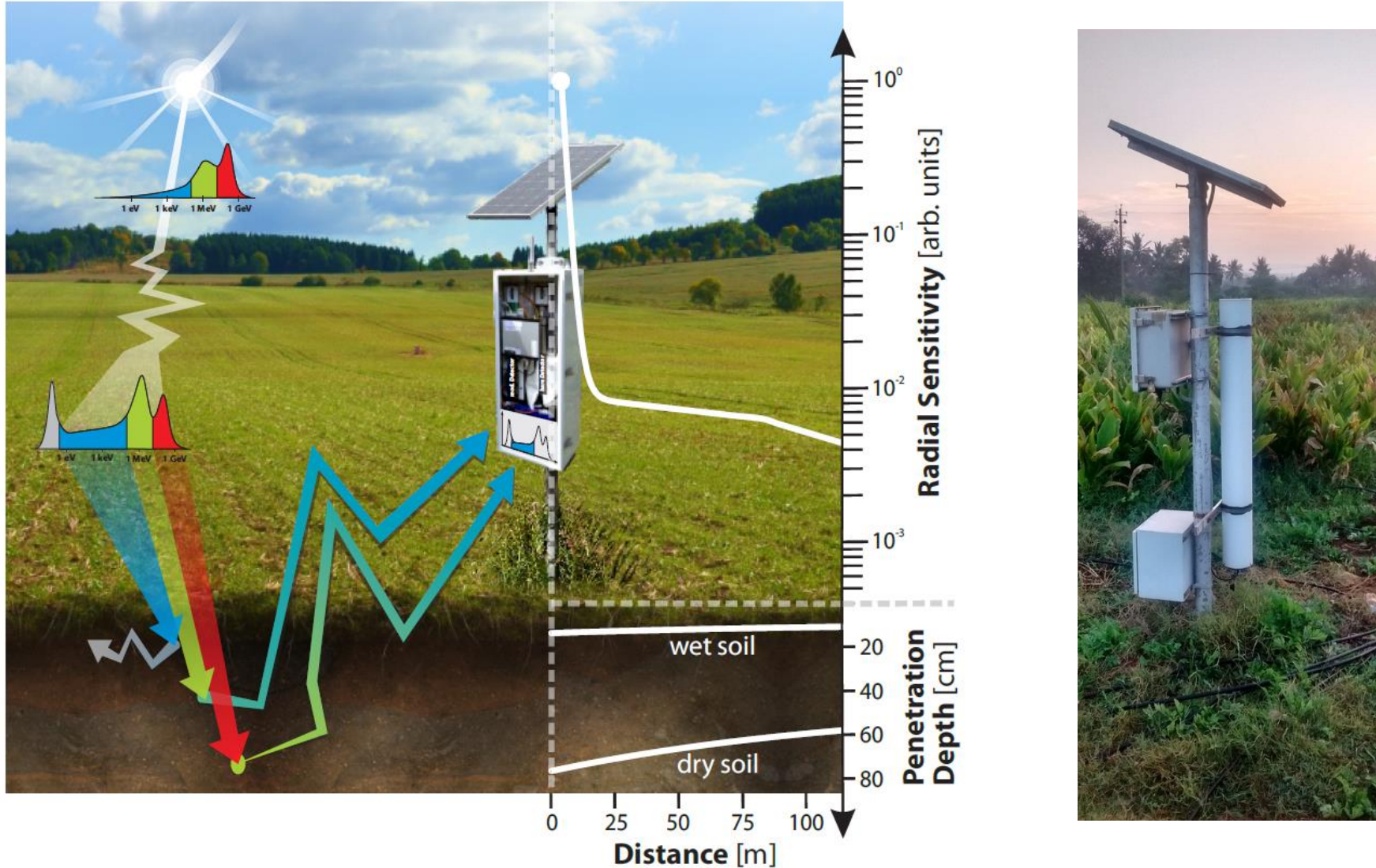
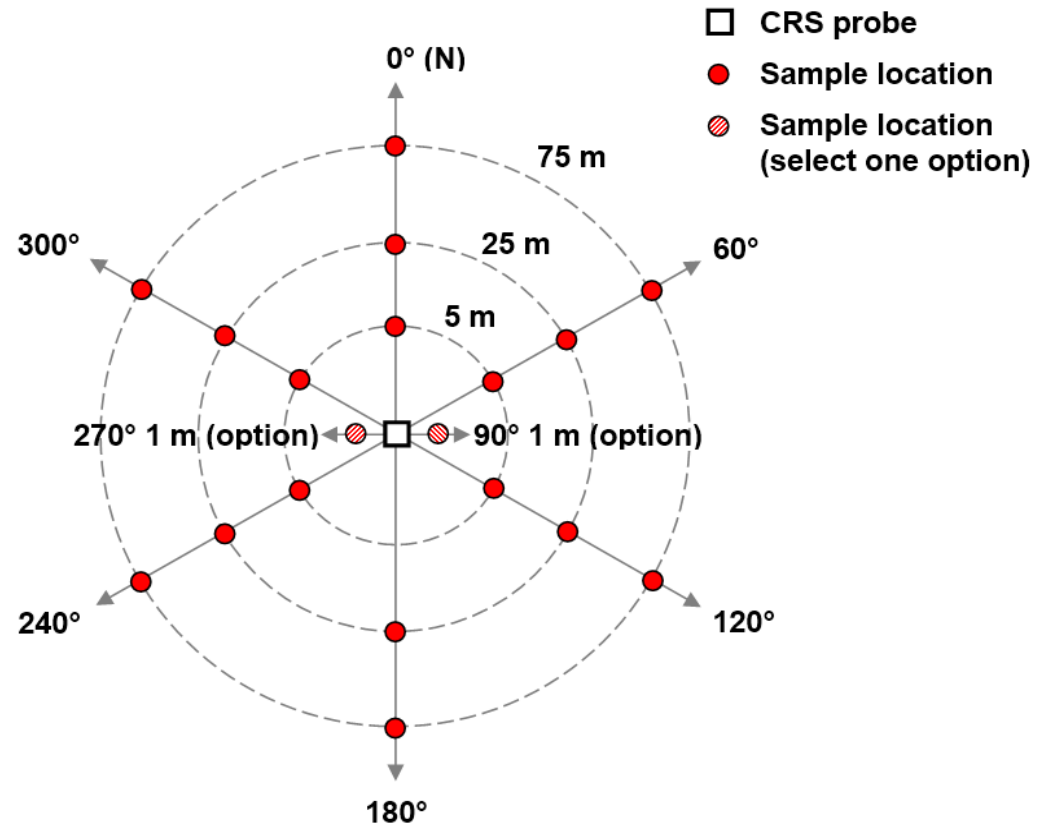


Image source: Schron et al.(2015). Monitoring environmental Water with Ground albedo Neutrons and Correction fro Incoming COSMOS Rays with Neutron Monitor Data. The 34th International Cosmic Ray Conference, 30th July to 6th August 215. The Hague, The Netherlands

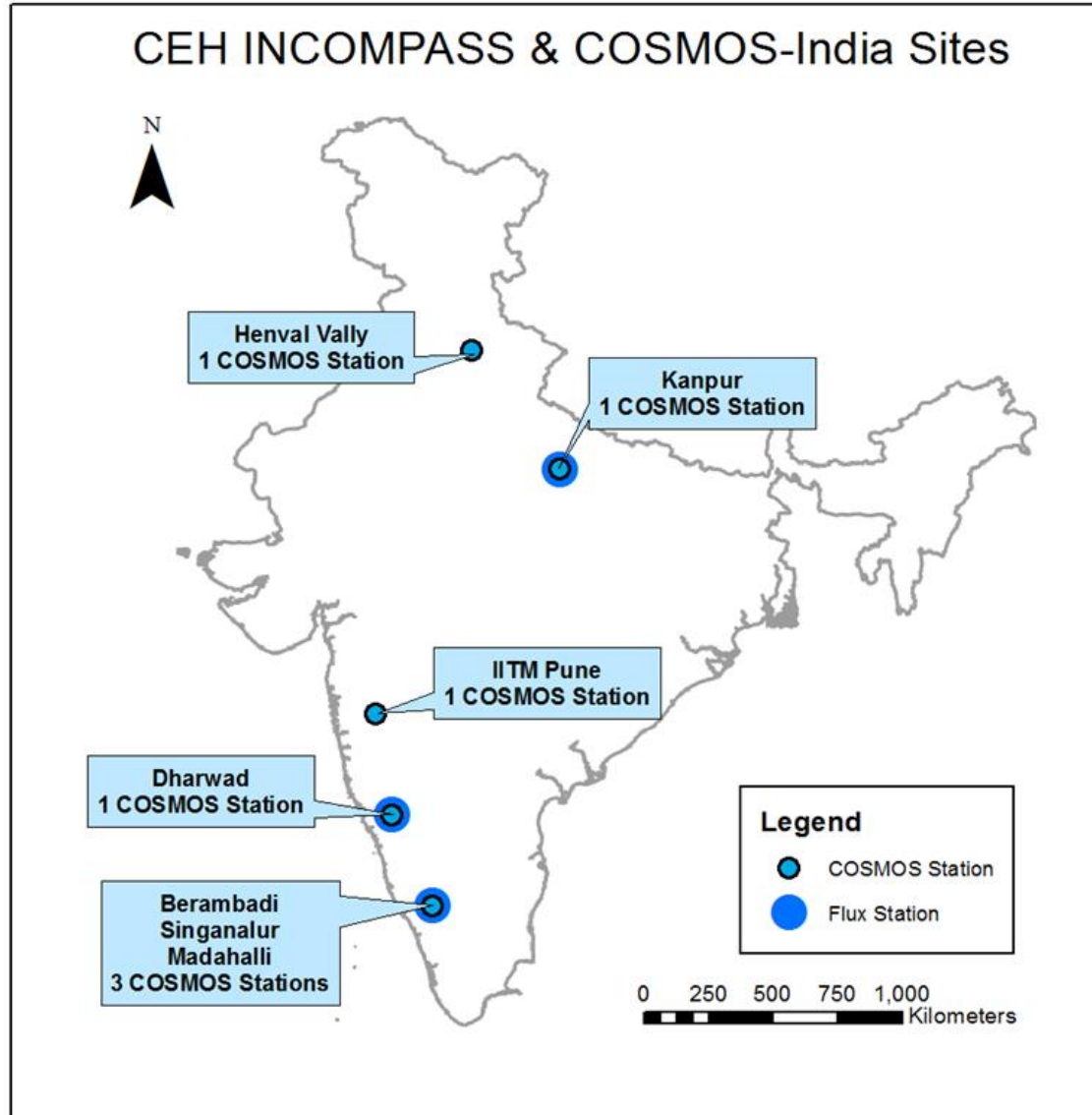
Calibration: Soil Sampling & analysis

- 108 soil samples from 18 locations from 6 depths
- Volumetric soil water (& bulk density) by oven drying at 105 ° C for 36 hours
- Lattice & bound water (incinerated at 1000 ° C)
- SOM & SOC by loss-on-ignition



Acknowledgement: Dr James Blake, CEH

The COSMOS-India network



Acknowledgement: Hollie Cooper, CEH.

Standalone COSMOS-India stations



Singanallur, Alfisol
September 2015



Madahalli, Alfisol
February 2016



IITM Pune, Vertisol
February 2017



Henvall Valley, Fluvisol
June 2017

- Neutron counts, pressure, temperature, humidity, precipitation
- Email based telemetry system

COSMOS & INCOMPASS flux towers



Berambadi, Alfisol
September 2015



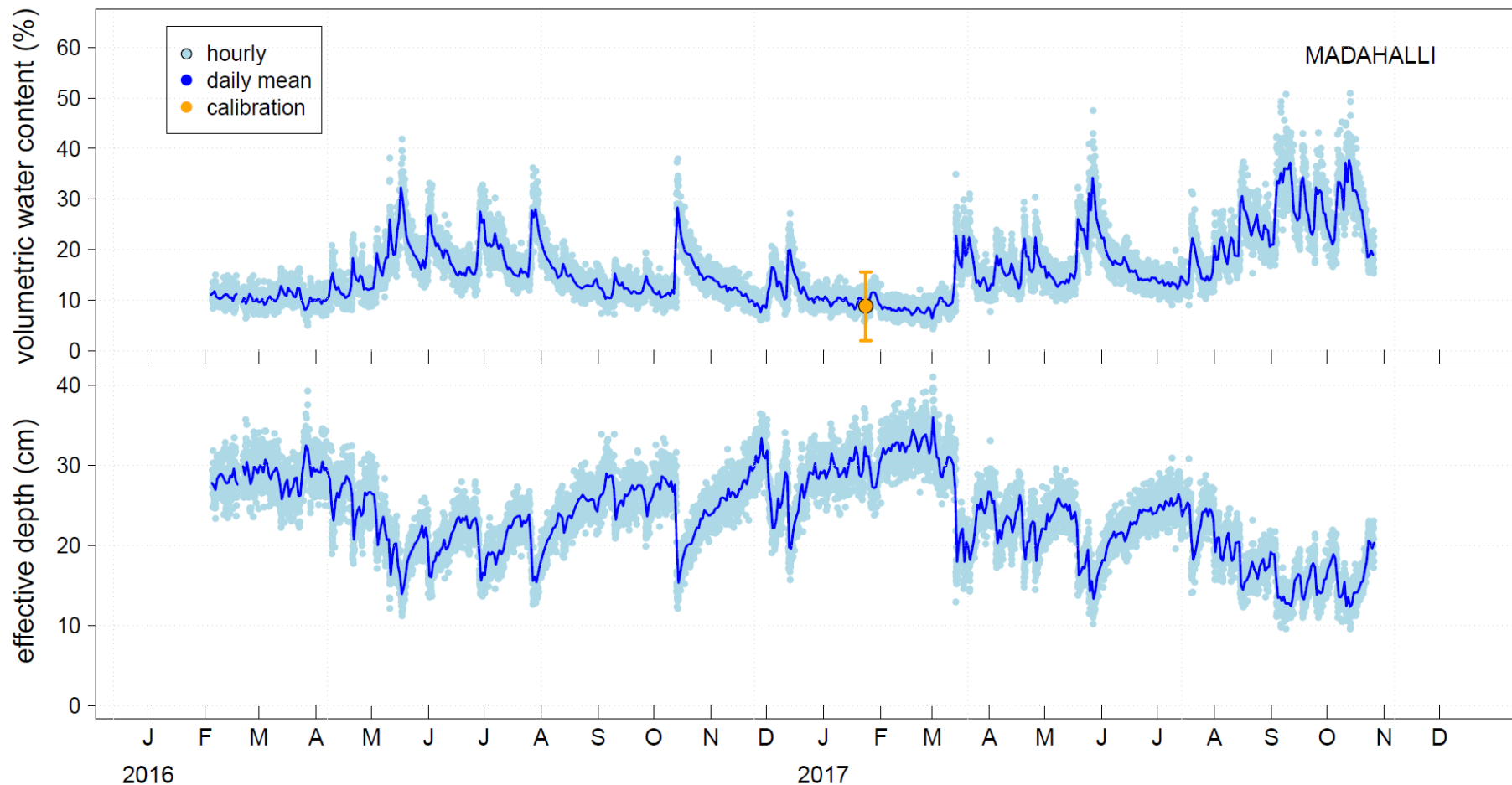
IIT Kanpur, Fluvisol
February 2016



UAS Dharwad, Vertisol
January 2017

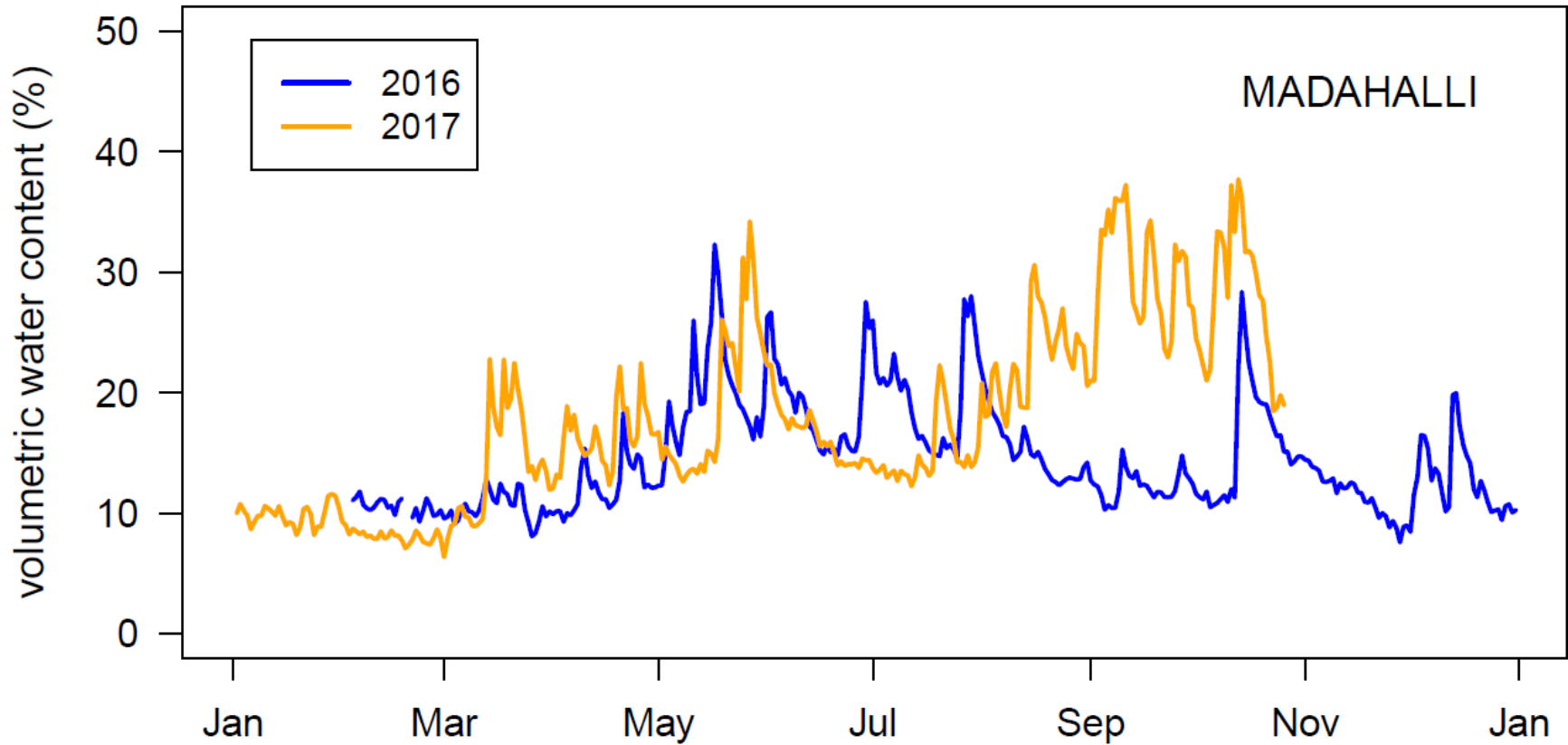
- Eddy covariance, meteorology & soil physics, COSMOS
- 3G telemetry system

COSMOS soil moisture ($\text{m}^3 \text{m}^{-3}$)

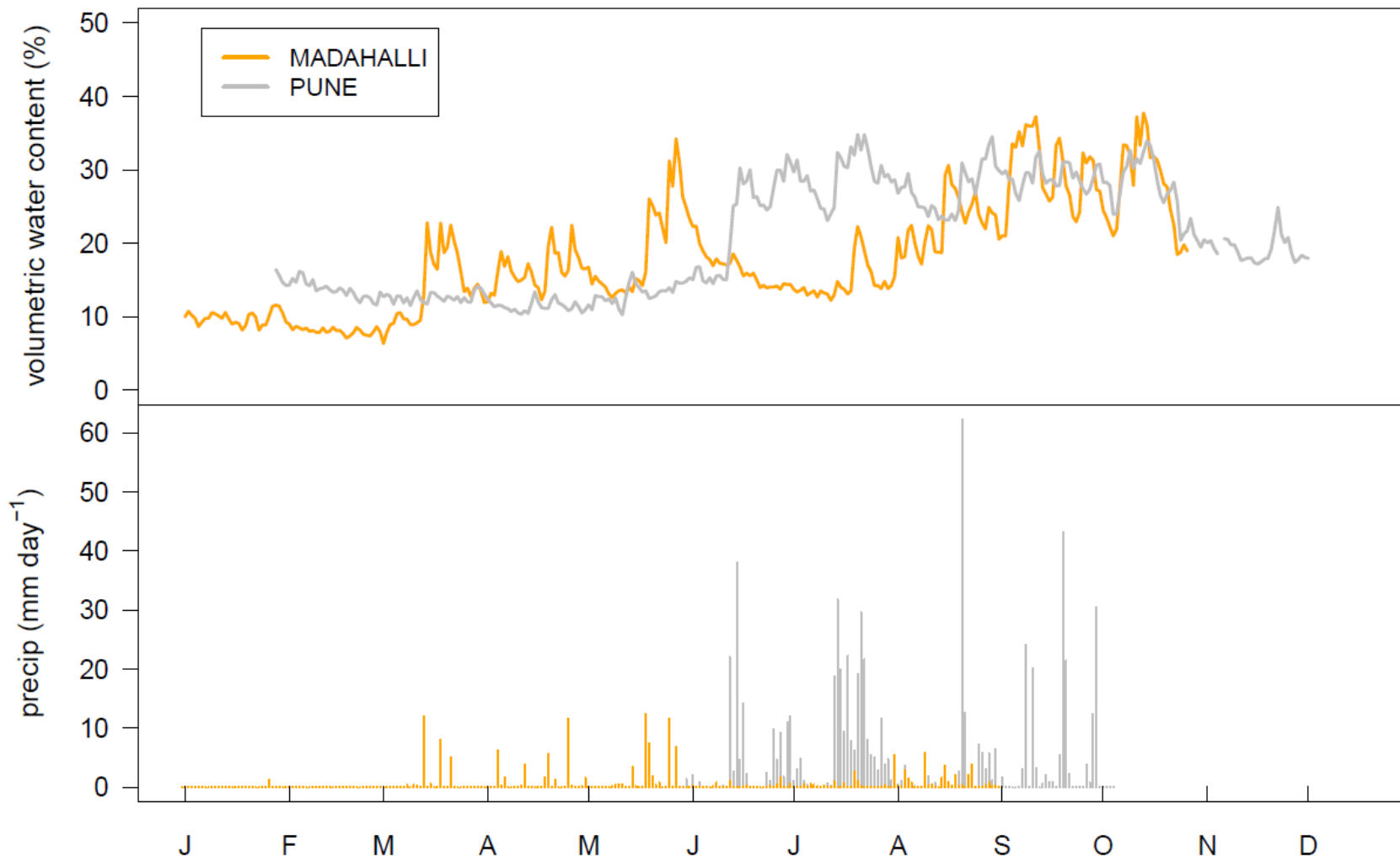


Hourly (points) & daily means (lines) of COSMOS volumetric soil water content (VWC; $\text{m}^3 \text{m}^{-3}$) & modelled effective measurement depth

COSMOS soil moisture ($\text{m}^3 \text{m}^{-3}$)



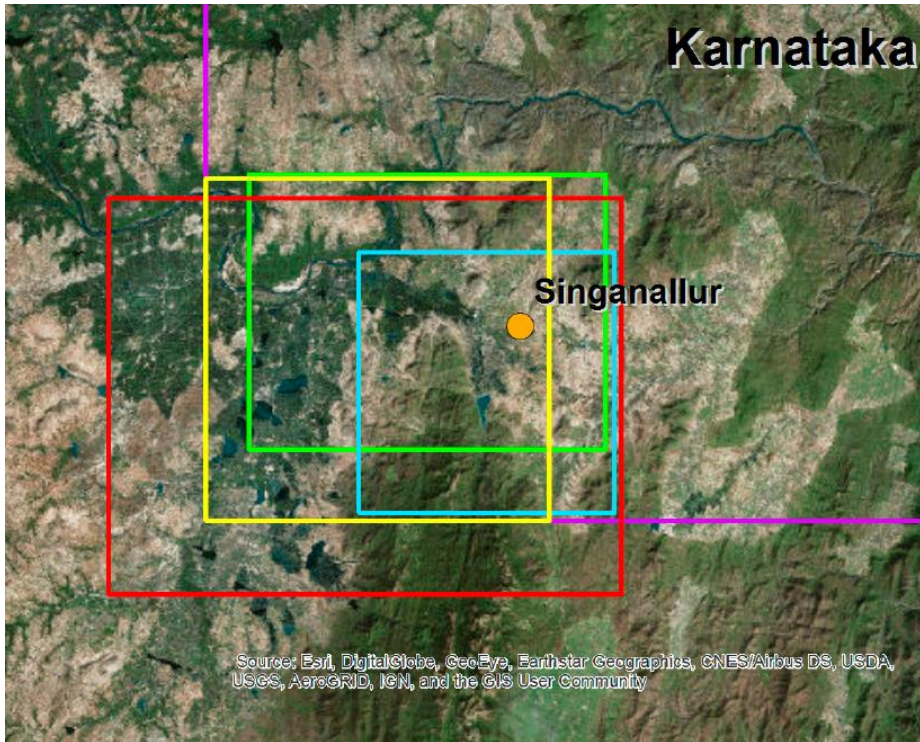
COSMOS soil moisture ($\text{m}^3 \text{m}^{-3}$)



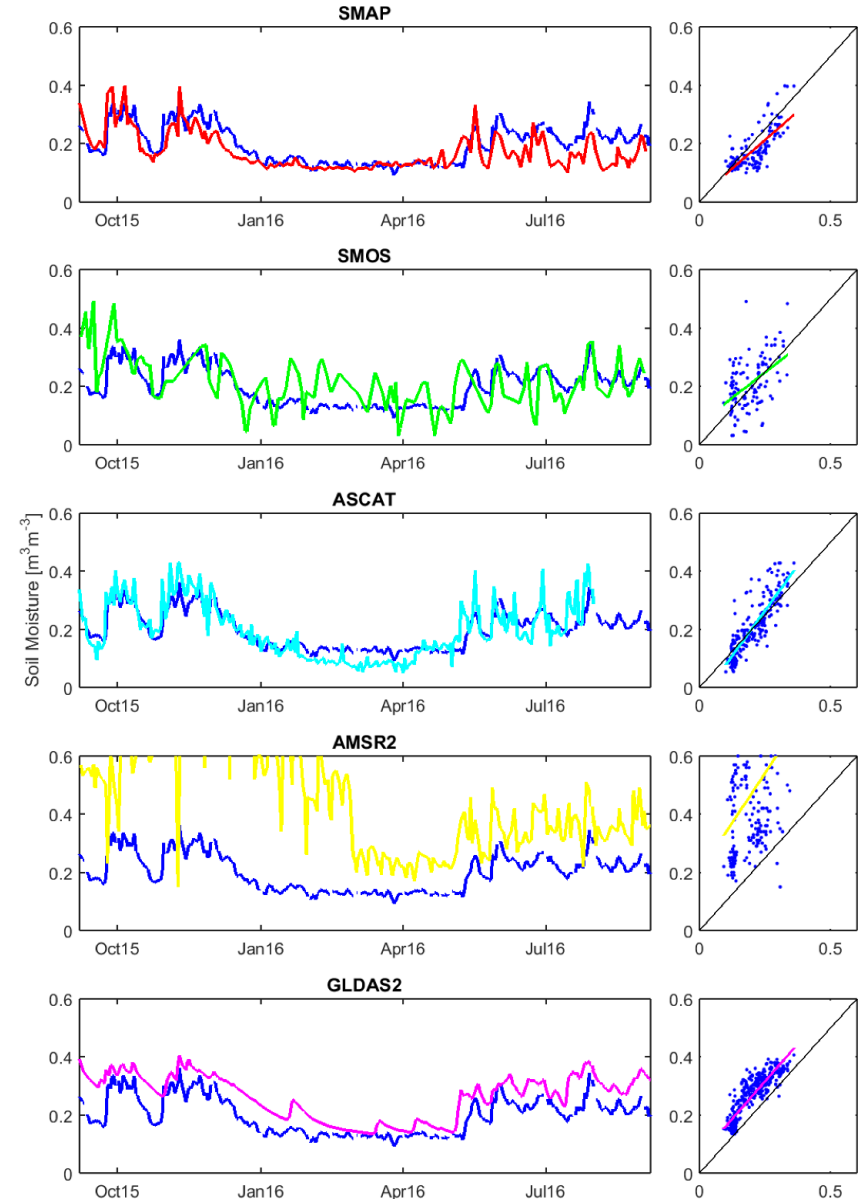
COSMOS-India: future plans

- COSMOS-India data centre ~ February 2018
- Expanding the COSMOS-India network
- Validation & calibration of EO datasets
- Integration of COSMOS-India data with hydrological, land surface & meteorological models
- Example: UPSCAPE Project, Sustaining Water Resources (SWR) Programme

Example: Validation of EO datasets



Montzka, Carsten; Bogena, Heye R.; Zreda, Marek; Monerris, Alessandra; Morrison, Ross; Muddu, Sekhar; Vereecken, Harry. 2017, *Remote Sensing*, 9, 103. 30



COSMOS-India Data Centre

- Securely managed & centralised data centre based on COSMOS-UK (<https://cosmos.ceh.ac.uk/>)
- Single authoritative source for COSMOS-India data
- Automated & consistent processing of COSMOS SM
- Automated QC, daily plots for data checking & analysis
- New COSMOS-India website with real-time graphs



The Centre for Ecology & Hydrology has established, and continues to grow, a long-term network of soil moisture monitoring stations for the United Kingdom, with funding from the [Natural Environment Research Council](#). The network provides near-real time soil moisture data for use in a variety of applications including farming, water resources, flood forecasting and land-surface modelling. Each station is equipped with an instrument that uses cosmic-rays to sense soil moisture over an area of about 20 hectares (about 50 acres). Data from the network have the potential to transform the way that we understand and model the natural environment.

Resources are provided on this website to enable you to:

Summary

- Overview of COSMOS-India network
- Seven sites across India providing intermediate scale SM observations in near real-time
- Empower applications across meteorology, hydrology, agronomy...
- COSMOS-India Data Centre
- cosmos.ceh.ac.uk