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THE PROVISION OF DATA FROM THE COSMOS-UK SOIL MOISTURE MONITORING NETWORK

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This paper describes the data available from COSMOS-UK, a new soil moisture monitoring network for the UK based on passive cosmic-ray moisture probes which are capable of measuring average soil water content over a circular footprint of around 350m in radius and depths of up to 0.5 m. Around 35 probes, with an associated array of meteorological and point soil moisture sensors, will be deployed across the UK in a network designed to best represent a range of soil and land cover types, complement existing scientific monitoring over a wide range of subject areas, and capture the variability in soil moisture over the country. Data will be automatically quality controlled and data streams will be openly and freely accessible via services and formats that conform to existing international standards, enabling integration with forecasting and data assimilation systems.

Background

Soil moisture has a major influence in many areas of environmental science. It is the major factor in determining how catchments respond to rainfall and therefore accurate knowledge of soil moisture can assist in estimating flood risk, including for forecasting. It is key to understanding drought stress to plants and wildlife. In agriculture, improved estimates could help target planting times and improve yields. Soil moisture is a factor influencing our weather, soil chemistry, soil microbial activity and greenhouse gas exchange. However it is difficult and expensive to measure at the field or catchment scale [1]. Remote sensing methods generally capture information about the top few cm of soil, on a grid of 10 km or more [2], [3]. Traditional in-situ point soil moisture measurements, though able to measure soil moisture over a depth profile, generally only represent the area local to the probe.

The COSMOS-UK network

The Centre for Ecology and Hydrology (CEH) is installing the first UK nationwide network to systematically measure soil moisture and other environmental variables such as weather, soil temperature, and solar radiation using state-of-the-art technology. Each COSMOS-UK station is equipped with a cosmic ray soil moisture probe providing spatially integrated soil water content representative of near-surface conditions across a large area (of approximately a 350 m radius and to a depth of about 0.5 m, although the sampling volume changes with soil moisture). The

sensor detects naturally occurring neutrons, which have been generated from cosmic rays, and which are slowed by water in the soil and diffused back to the atmosphere [4].

Approximately 35 sites (figure 1) have been selected for the COSMOS-UK network representing a broad range of land cover and soil types, including agricultural land and woodland. Sites are being installed in two operational phases, with an initial 4 sites installed from October 2013 to verify instrumentation and soil calibration methods, followed by a further 30 sites installed over several months from April 2014. The COSMOS-UK instruments are generally being co-located with existing scientific environmental monitoring to enhance utilization across a variety of science areas and are installed with a range of research-quality meteorological and soil monitoring sensors to enable detailed understanding of processes affecting soil moisture at the site. Phenological cameras provide almost 360º coverage on a sub-daily basis to enable understanding of local vegetation and atmospheric conditions.

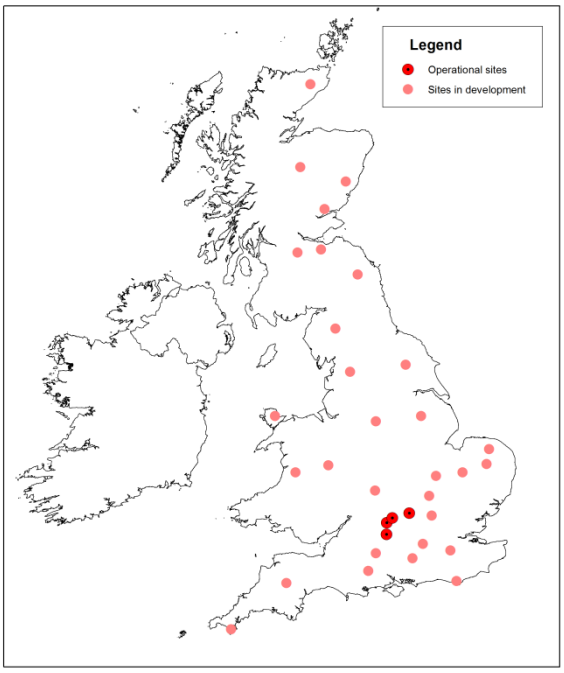

Figure 1. Map of COSMOS-UK sites at time of publication.

Data processing for the COSMOS-UK network

Measurements are accessed via standard telemetry technology using the mobile phone network. Data are logged, received and processed at half-hourly intervals. Processing involves loading all data to a relational database, creating a “level 1” dataset of all raw values, and applying automatic quality control rules, removing erroneous values and flagging suspect data, to create a “level 2” dataset of validated values together with the soil moisture data calculated from the COSMOS neutron counts. A third level dataset, within which missing periods of data will be infilled using information from alternative sources, is being considered. A list of sensors deployed and parameters measured can be seen in table 1.

Table 1. List of sensors deployed within the COSMOS-UK network and the parameters measured

Sensor name	Measured feature	Parameters measured
COSMOS probe	Soil, footprint ~300m radius	Raw neutron counts, spatially aggregated soil moisture
Automatic Weather Station	Air at ~2m	Air temperature, pressure, absolute and relative humidity
Anemometer	Air at ~2m	Wind speed and direction
OTT weighing raingauge	Land surface	Precipitation intensity and volume
4-component radiometer	Land surface	Incoming and outgoing long and short wave radiation
Self calibrating soil heat flux plates	Soil at depth of 3cm	Heat flux
Soil moisture profile	Soil at depths of 15, 40 and 65cm	Electrical conductivity and moisture content
Time Domain Transmissometry soil moisture probe	Soil at 10cm	Electrical conductivity, temperature and moisture content
Soil temperature profile	Soil at depths of 2, 5, 10, 20, 50cm	Temperature

Potential use of COSMOS-UK data

COSMOS-UK data has potential to be used within hydro-meteorological modelling by providing real-time data for model validation and forecasting. There is also potential for data assimilation techniques to combine the data with gridded physically based model estimates to produce improved spatially extensive national estimates of soil moisture across the UK. The COSMOS-UK data will also significantly increase the number of real-time soil moisture measurements globally and are therefore likely to be of interest at a global level. To enable these and other potential uses, the network will generate live streams of data for modellers, forecasters, researchers and data portals. Whilst the COSMOS probe soil moisture will undoubtedly be of most interest, the range of measured parameters available is likely to be of interest to scientific and other users across a range of disciplines, and provision of detailed information about the precise nature of measurements and the instrumentation used is seen as important.

Data streams

A dedicated data portal for the COSMOS-UK network has already been created, providing direct access to graphs of the data and contextual maps (www.ceh.ac.uk/cosmos). Wider discovery of the data resource represented by COSMOS-UK for the wide range of potential users will be enabled through provision of standards-based metadata (ISO19115) and services (CS-W) registered within widely accessed portals such as the UK government data portal (data.gov.uk). At the global level the same services will be provided via GEOSS (Global Earth Observation System of Systems, www.earthobservations.org/geoss.shtml), which aims to use standards to link environmental observing systems to provide data useful across a range of societal benefit areas.

Data standards are essential for machine-to-machine communication of data. As well as commonly agreed formatting these should employ accepted terminology and usage in describing the exact nature of data being communicated. Observations and Measurements (O&M) [5] is an international standard of the Open Geospatial Consortium (OGC) and the International Standards Organisation (ISO). It provides a schema for the description of observations within which a property of a real-world feature is estimated by some procedure, which can be an instrument or process. As well as enabling interoperability, the availability within the standard of fine-grained procedure information supports detailed understanding of data quality, which is particularly important for scientific datasets such as those available from COSMOS-UK. O&M is the response model (i.e. it is format of the returned data) for queries based on another OGC standard, the Sensor Observation Service (SOS) [6]. SOS enables networks of sensors to be queried remotely to provide information on what is being measured within a network, and where and when it is measured, thus enabling the discovery of datasets at a more fine-grained level than standard (e.g. CS-W) metadata searches. A further OGC standard of use in this area is WaterML2 [7], an information model based on O&M for the representation and exchange of hydrological data. It includes explicit representation of time series observations and is already in use including by organizations such as USGS for dissemination of its water data.

As the second phase of COSMOS-UK stations are installed, data for all of the 50+ parameters measured, both raw and quality controlled series, will be made available, in real-time via the above standards, enabling simple discovery for a wide range of users, and providing comprehensive information on the processes used in the creation of the data series.

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