

Copernicus In Situ

COSMOS-UK

Matt Fry

(on behalf of the whole
COSMOS-UK team)

JNCC soil moisture
workshop

15th July 2020

Copernicus In Situ : Hydrology

The **Copernicus In Situ Component** maps the landscape of in situ data availability, **identifies data access gaps or bottlenecks**, **supports the provision** of cross-cutting data and **manages partnerships** with data providers to improve access and use conditions.

End of first contract complete, hydrology project running since 2018, new 4-year period due to start

Hydrology addresses river flows, river / lake levels, river / lake water quality, soil moisture

Aim to:

- Highlight need for hydrological in situ data for Copernicus
- Improve access to in situ data for / across Copernicus services
- Identify avenues to improve availability of in situ data



Implemented by



Copernicus In Situ : Soil moisture

- Soil moisture data is fundamentally limited by lack of measurements, which limits validation of products
- Available data is well used by Copernicus services
- ISMN largely contains all globally available data
- No issues with data sharing across Copernicus services
- Highlight sustainability and need for more measurements
- Field-scale measurements in particular would be beneficial



Implemented by



UKCEH and the COSMOS-UK network

Aim: to establish a real-time, field-scale soil moisture monitoring network for the UK, using the COSMOS Cosmic Ray Soil Moisture Sensor

Established 2013 (initially 3 sites, currently 49 sites)

Funded through NERC research funding and UKCEH national capability



Applications for COSMOS-UK data

Soil Moisture

Hydrological Outlooks

Process understanding

Weather Forecasts



Weather prediction



Wildfire mitigation

Water services



Hydrological modelling

Flood forecasting

Flood Risk Estimation



Agronomy

Groundwater recharge

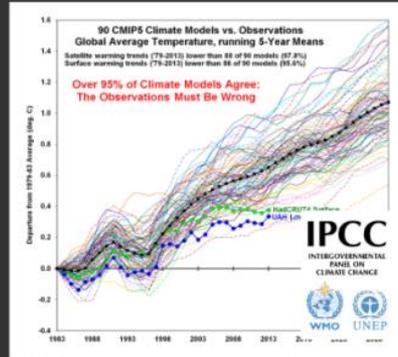
Drought monitoring

Hill slope stability



Prediction of crop yield

Climate studies



Irrigation scheduling

Climate models

Input to land-atmosphere models

Greenhouse gas controls

Cosmic-ray soil moisture sensor: COSMOS

- Sits above ground (non-intrusive, non-destructive).
- Functions automatically.
- Footprint ~200m in diameter.
- Looks up to 80cm into soil.
- Provides field/landscape scale soil moisture data in (near) real-time that are highly relevant for hydrological and other applications.



How does the CRNS work?

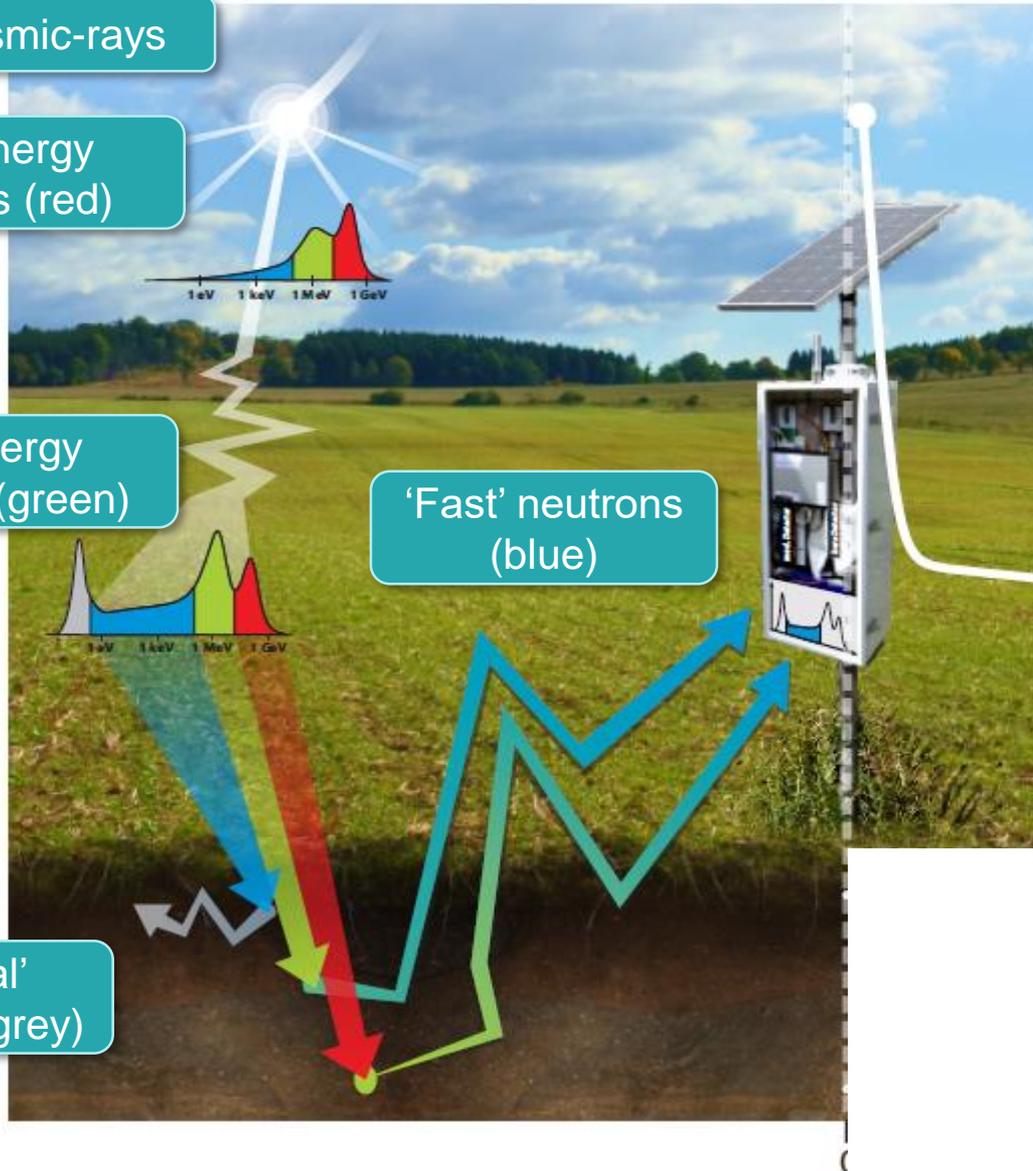
Cosmic-rays

High energy neutrons (red)

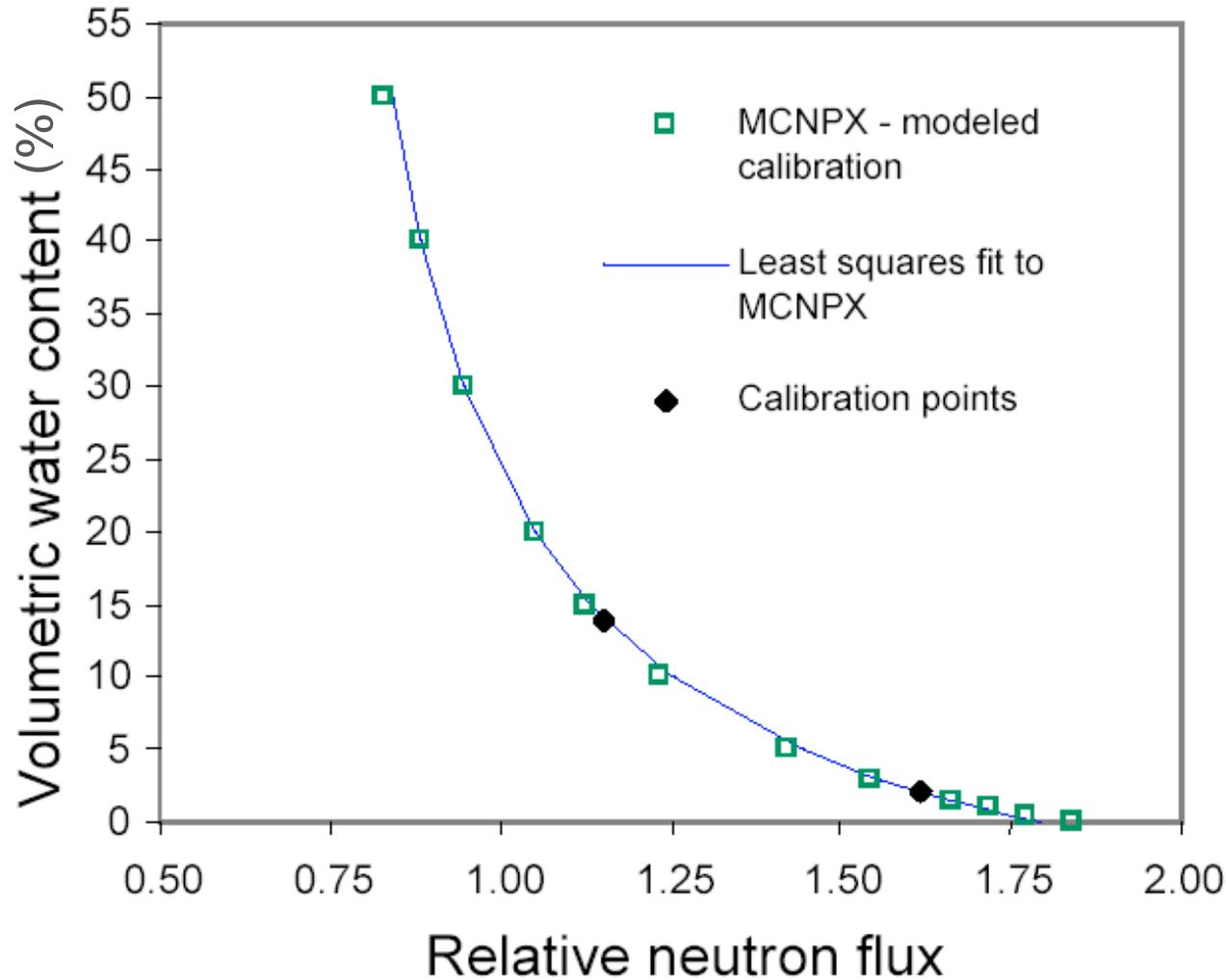
Low energy neutrons (green)

'Fast' neutrons (blue)

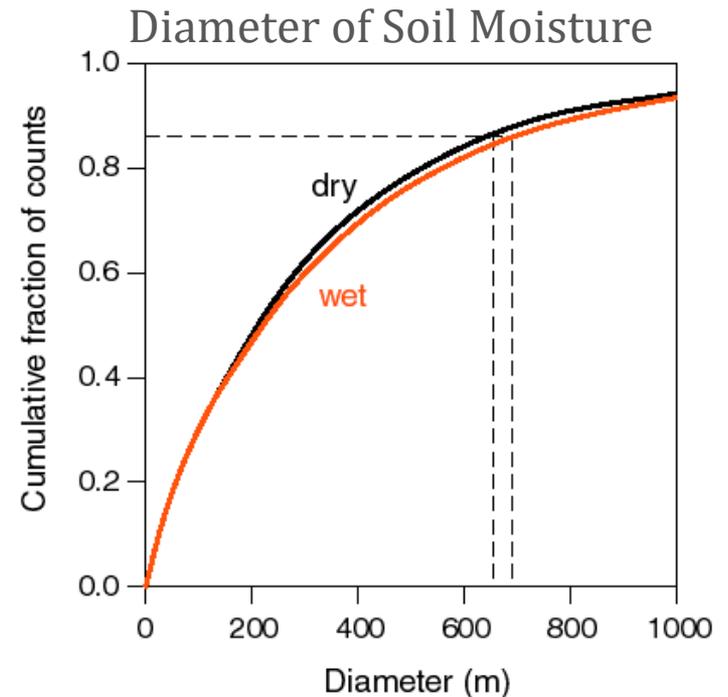
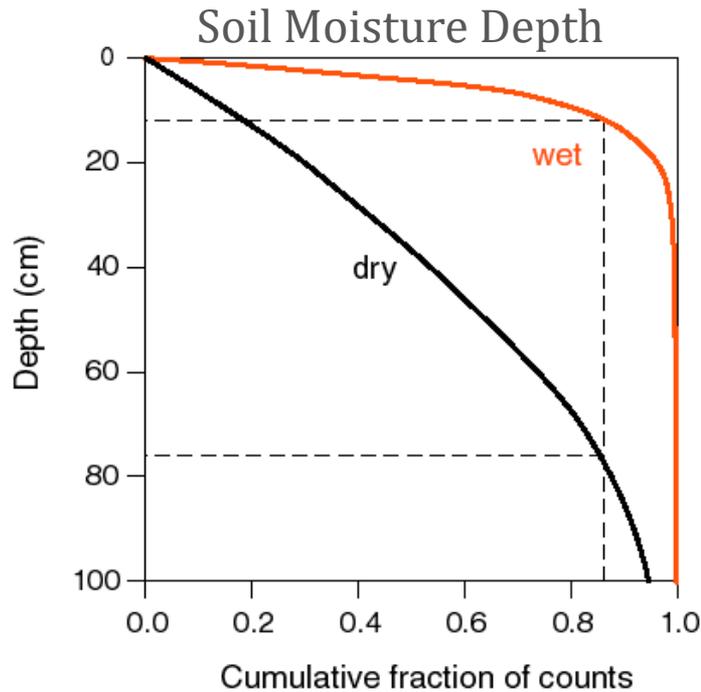
'Thermal' neutrons (grey)



From neutron counts to soil moisture



Sampling volume of CRS



Neutron scattering theory and models estimate the measurement footprint diameter and depth. Since more neutrons reaching the sensor come from interactions with water close to the sensor, the derived soil moisture reflects a weighted average of the sampling volume. The depth of this volume is sensitive to wetness as indicated by the figure on the left.

Corrections, calibration and calculations

Observed neutron counts corrected for varying:

- atmospheric pressure
- humidity
- background neutron intensity

(from Jungfrauoch monitoring station)

Relationship between corrected counts and soil moisture established through calibration

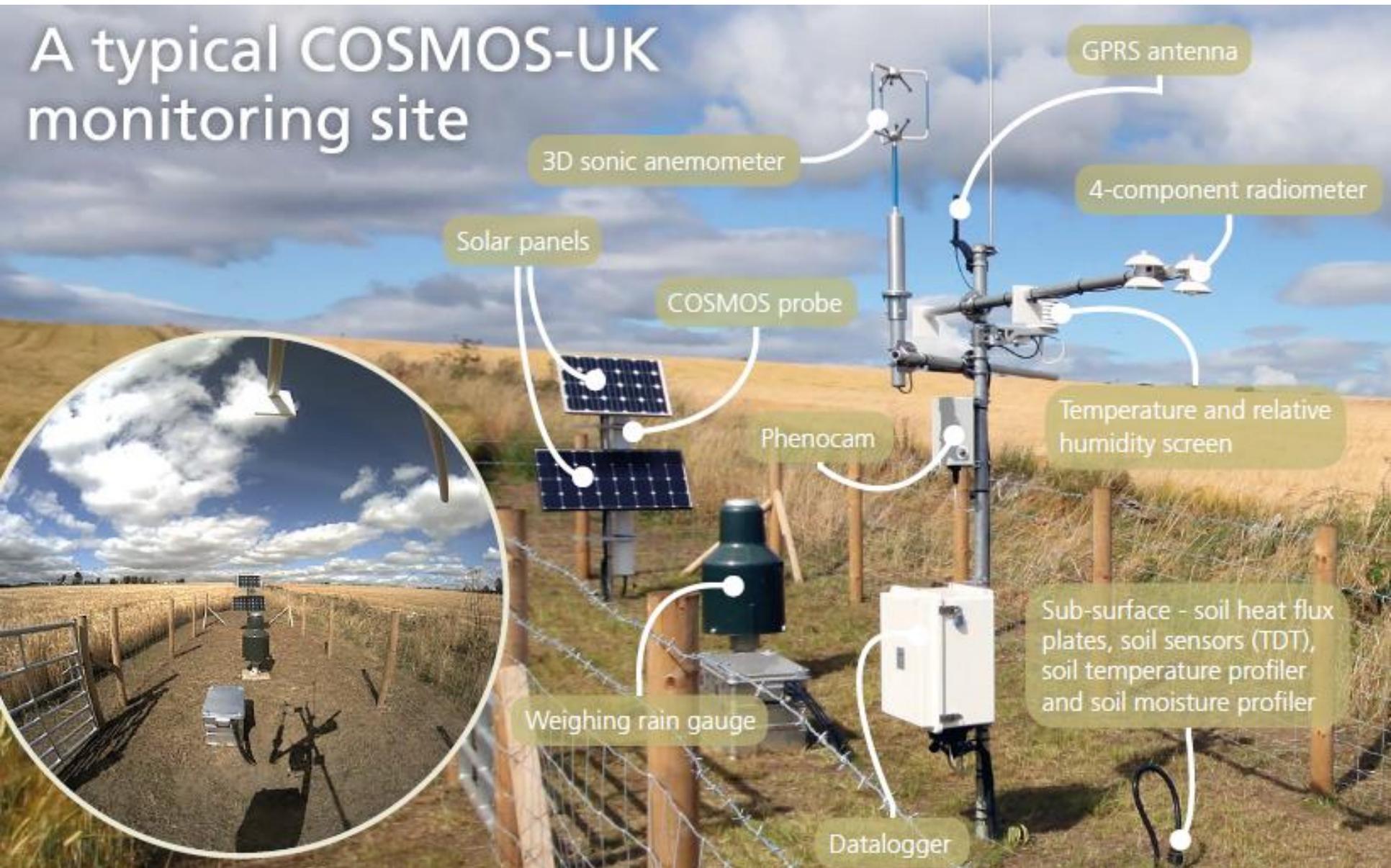
Calibration soil sampling:

- volumetric water content and dry bulk density
- soil organic matter
- lattice & bound water



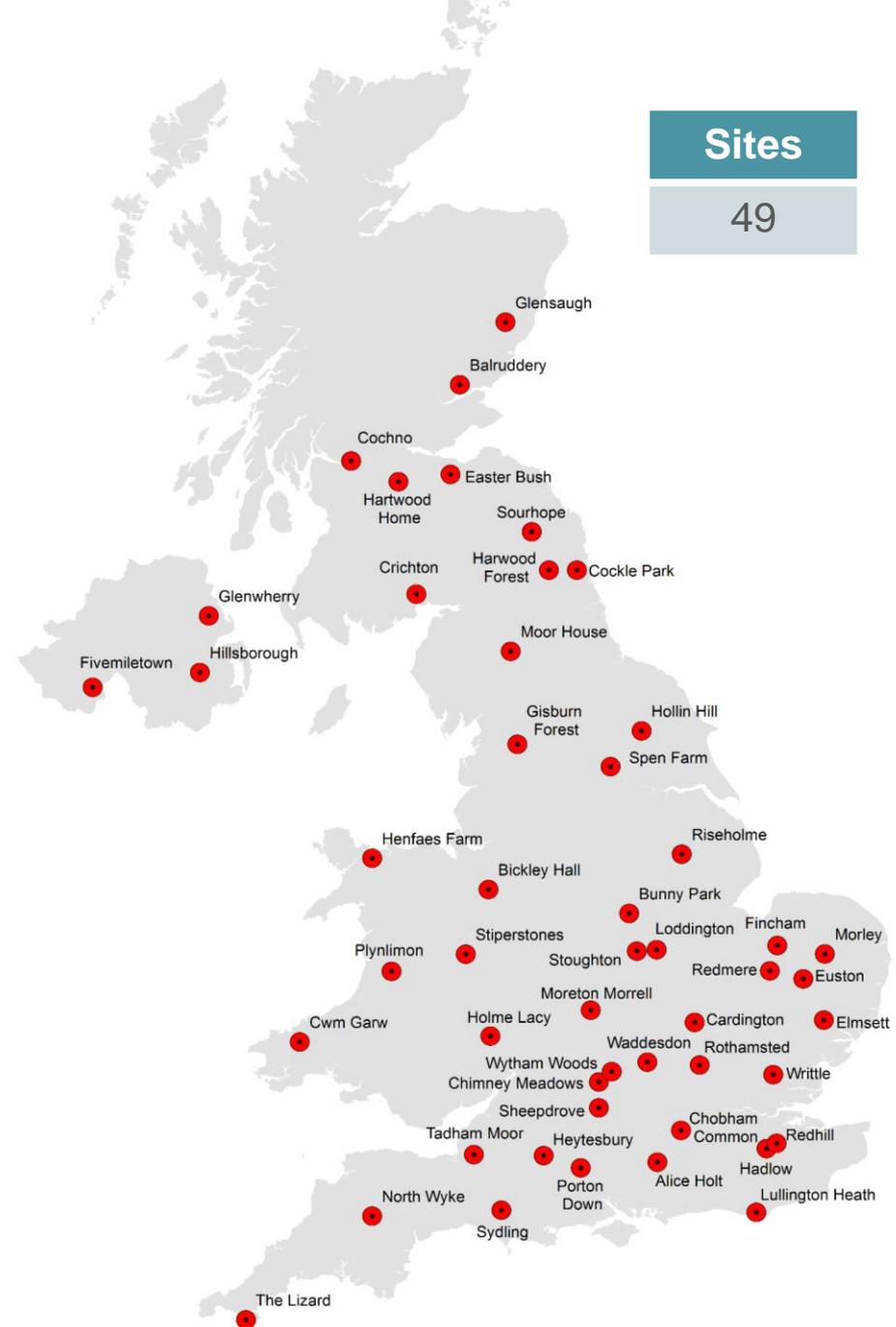
COSMOS-UK site instrumentation

A typical COSMOS-UK monitoring site

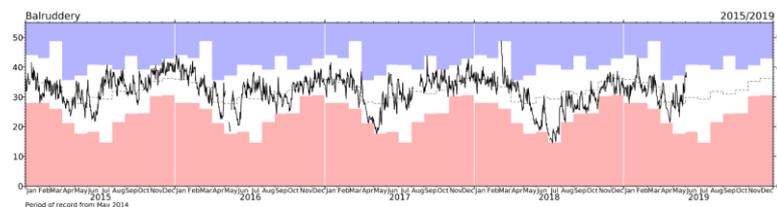


Current network

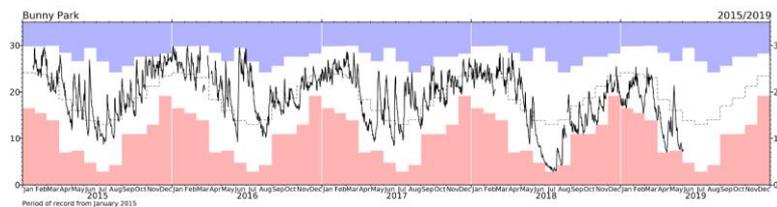
- UK wide coverage (more sites planned)
- Varying spatial density
- Sampling wide range of climate, land cover, soils, geology and topography
- Co-located with existing research / monitoring where possible
- Meeting site requirements
- Current aim ~ 50 sites



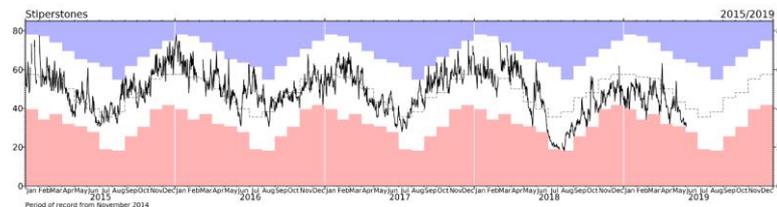
Balruddery Farm, Scotland



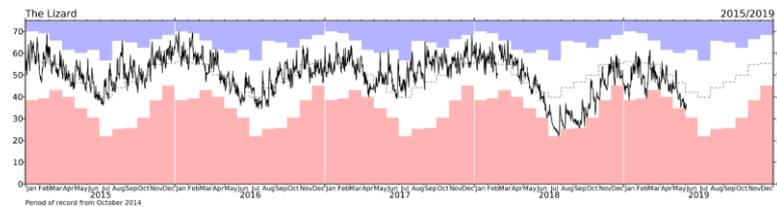
Bunny Park, East Midlands



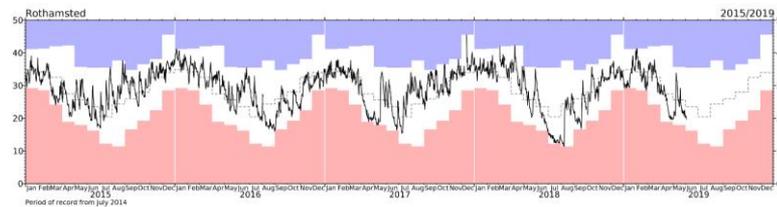
Stiperstones, West Midlands



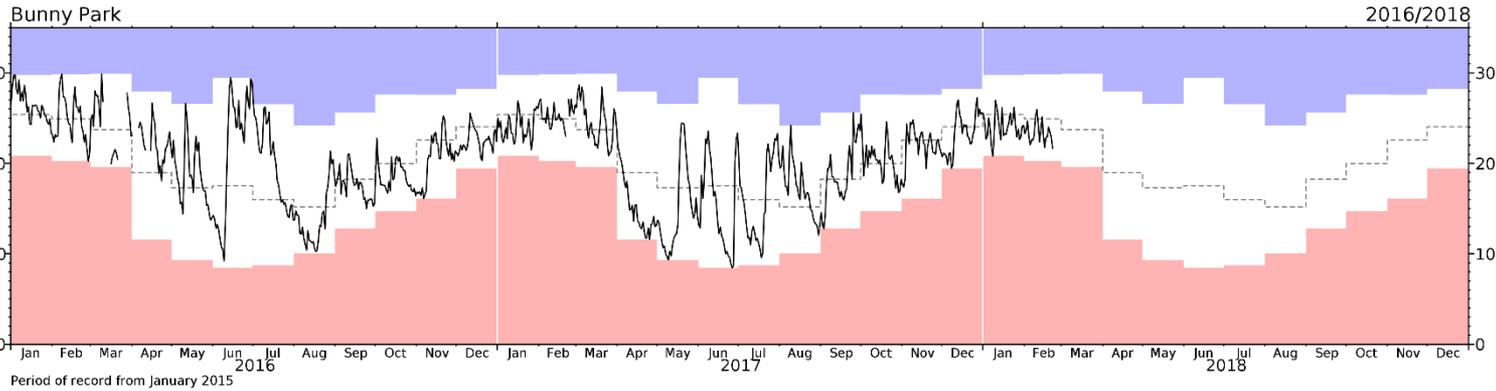
The Lizard, South West England



Rothamsted, East of England

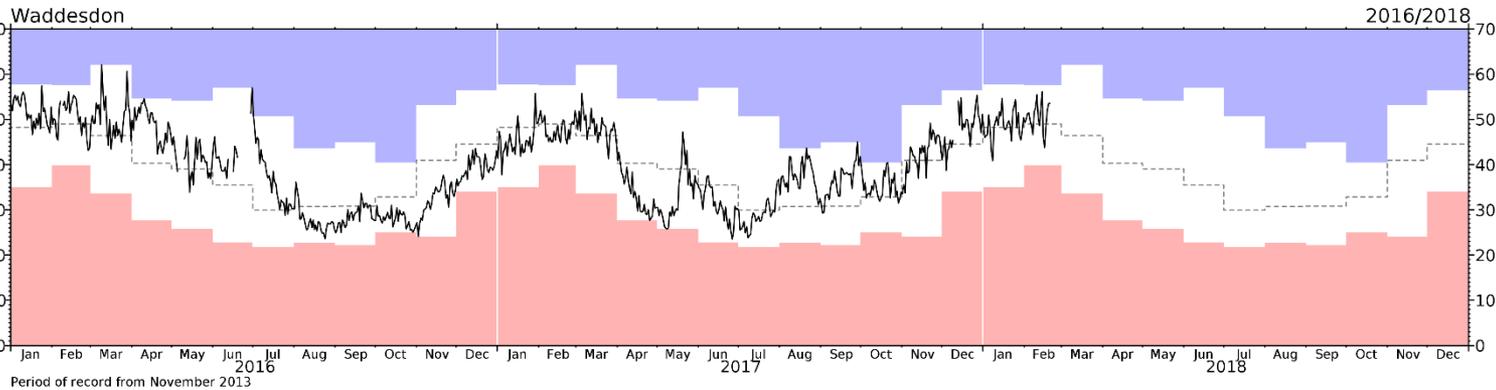


The derived data

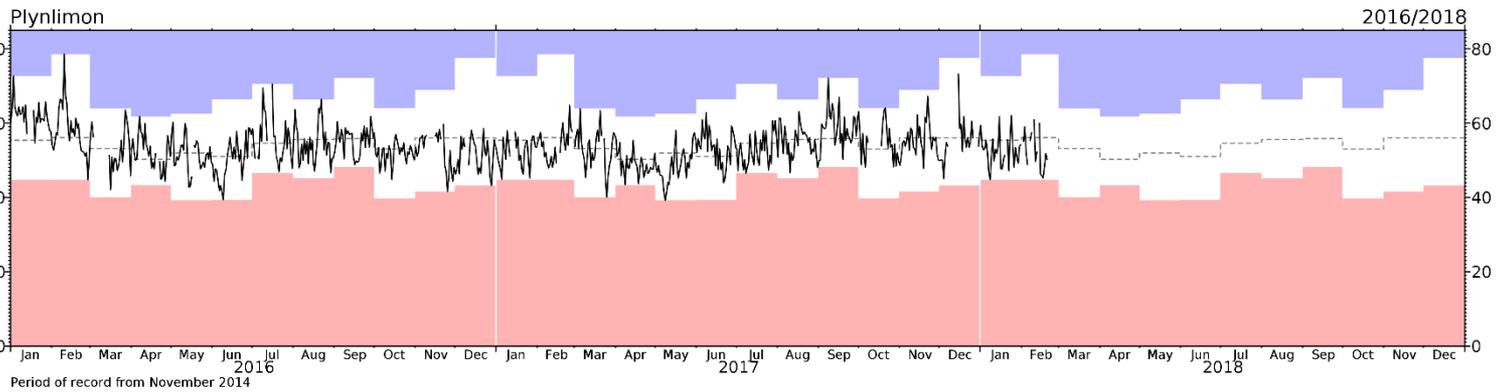


The figures show volumetric water content (%).

Bunny Park is typical of a good agricultural soil.



Waddesdon is a heavier soil suitable for grazing.



Plynlimon is an upland/peat site

Comparison of COSMOS and point sensors



Data from Rothamsted since installation in July 2014

Black: Cosmic ray sensor Red and Green: TDT point sensors at 10cm depth



Automated data processing

- Data processing fully automated
- Automated QA/ QC including range / spike checks
- Production of plots, “dashboard” overviews for manual / visual QC
- Calculation of derived products (e.g. Potential Evaporation, Snow Water Equivalent)

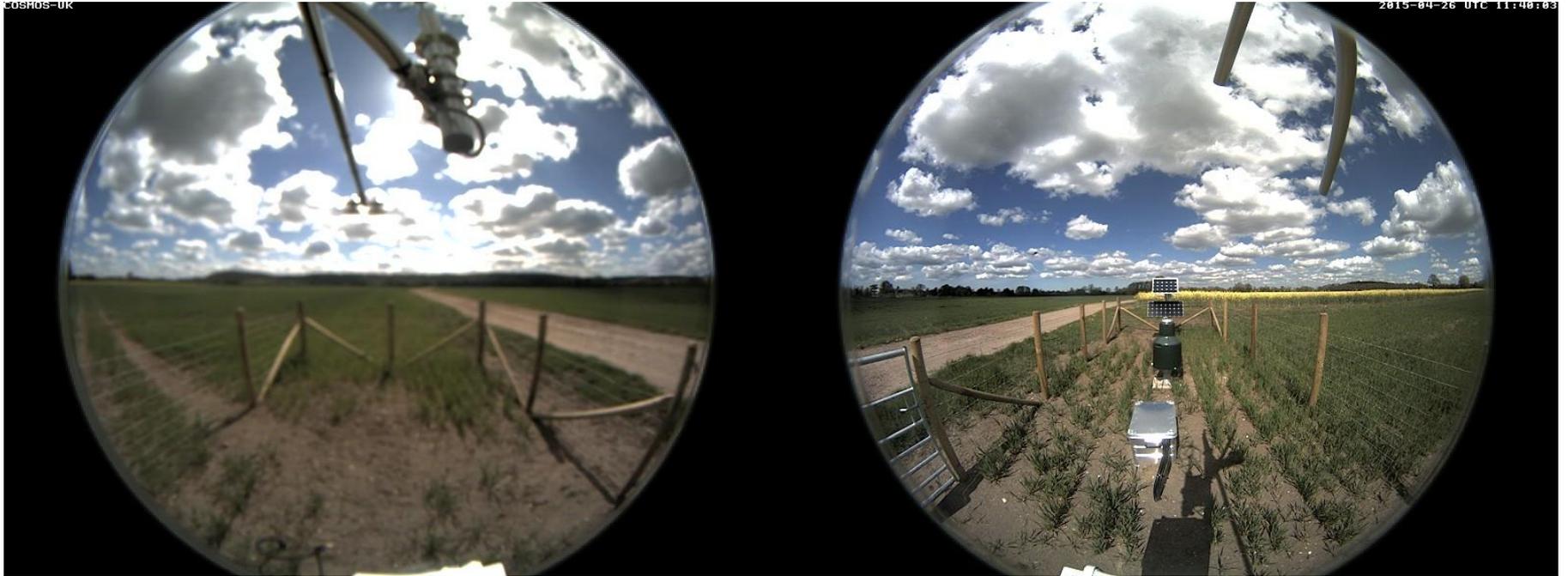
Monitored data

| VARIABLES | UNIT | INTERVAL |
|---|-----------------|----------|
| Precipitation | Mm | 1 min |
| Absolute humidity | gm^{-3} | 30 min |
| Relative humidity | % | 30 min |
| Air temperature | $^{\circ}C$ | 30 min |
| Atmospheric pressure | hPa | 30 min |
| Incoming longwave radiation | Wm^{-2} | 30 min |
| Incoming shortwave radiation | Wm^{-2} | 30 min |
| Outgoing longwave radiation | Wm^{-2} | 30 min |
| Outgoing shortwave radiation | Wm^{-2} | 30 min |
| Wind direction | <i>degrees</i> | 30 min |
| Wind speed | ms^{-1} | 30 min |
| 3D wind speed data (x3) | ms^{-1} | 30 min |
| Volumetric water content at 3 depths (15cm, 40cm, 65cm) (IMKO Profile) | % | 30 min |
| Soil heat flux (x2) | Wm^{-2} | 30 min |
| Soil temperature at five depths (2cm, 5cm, 10cm, 20cm, 50cm) | $^{\circ}C$ | 30 min |
| Soil temperature and volumetric water content (10cm, and up to 4 other depths x2) (TDT) | $^{\circ}C$ & % | 30 min |

Derived data

| VARIABLES | UNIT | INTERVAL |
|--------------------------------------|------------|--------------|
| Volumetric water content (CRNS) | % | Hourly/daily |
| Soil moisture index | - | Daily |
| Typical sensing depth of CRNS (D86) | mm | Hourly/daily |
| Neutron counts from CRNS (corrected) | counts | Hourly |
| Potential evaporation | mm | Daily |
| Net radiation | Wm^{-2} | 30 min |
| Mean sea level pressure | hPa | 30 min |
| Albedo | - | 30 min/daily |
| Snow day | True/False | Daily |
| Snow water equivalent | mm | Hourly/daily |

PhenoCam



North and south facing cameras generate a time series of photographs that provide qualitative information about the changing vegetation (phenology) around each site.

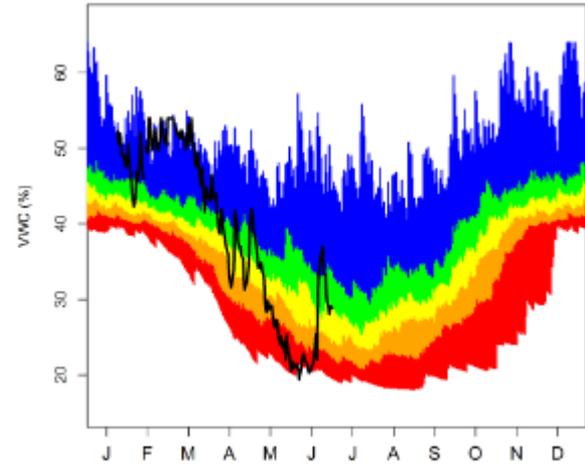
In process : RGB time series from the field area

Ongoing work

Flux data, actual evaporation



Modelling to develop understanding of soil moisture “climatology”



Developing further QC and gap filling with AI



Website - content

COSMOS-UK

HOME THE NETWORK DATA SCIENCE SOIL & WATER RESOURCES ABOUT

Site details Time-series data

Site name: Lullington Heath
Installation date: 2014-12-16
Easting, northing: 554365, 101634

Time period: 1 week 1 month 3 months 6 months 1 year 2 years 3 years
End date: 2018-10-04
Sites: South East England

Map Time-series data

Dataset key:
Uncalibrated: ● ~ 30%
No data: ● ~ 40%
<0.3: ● ~ 50%
0.3-0.6: ● ~ 60%
0.6-0.9: ● ~ 70%
0.9-1.1: ●
1.1-1.5: ●
> 1.5: ●

Map symbols:
~ 30%: ■
~ 40%: ▲
~ 50%: ◆
~ 60%: ●
~ 70%: ●

The Soil Moisture Index, SMI, rescales Volumetric Water Content, VWC, using likely minimum and maximum water content for each site. On this scale a value of one represent represents field-capacity which is a typical water content in late autumn and early spring. SMI will generally be lower than this in the summer, perhaps reaching zero in a particularly dry summer, and higher than this in the winter.

A simple five-class categorisation of soils based on typical maximum water content is used in this map with different symbols representing each class as indicated above. Being in different classes can explain why neighbouring sites have different SMI values, although especially in the summer, this can also be caused by very local variation in rainfall.

Volumetric water content (%)

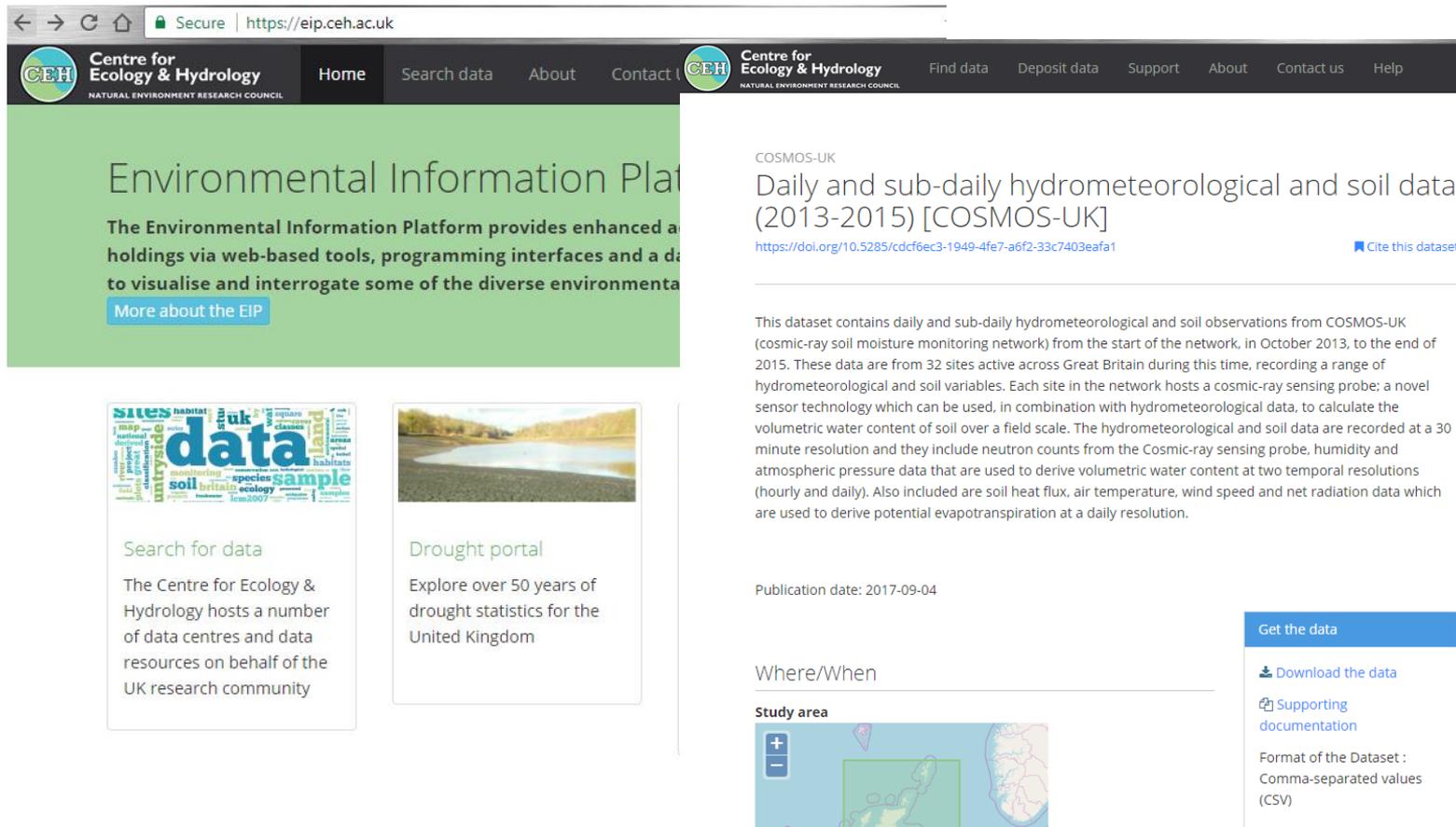
Chimney Meadows COSMOS sensor VWC

Chobham Common COSMOS sensor VWC

Lullington Heath COSMOS sensor VWC

Redhill COSMOS sensor VWC

Data and information: data downloadable



Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

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Environmental Information Platform

The Environmental Information Platform provides enhanced access to environmental data holdings via web-based tools, programming interfaces and data visualisation tools to visualise and interrogate some of the diverse environmental data held by CEH.

[More about the EIP](#)

Search for data

The Centre for Ecology & Hydrology hosts a number of data centres and data resources on behalf of the UK research community

Drought portal

Explore over 50 years of drought statistics for the United Kingdom

COSMOS-UK

Daily and sub-daily hydrometeorological and soil data (2013-2015) [COSMOS-UK]

<https://doi.org/10.5285/cdcf6ec3-1949-4fe7-a6f2-33c7403eafa1> [Cite this dataset](#)

This dataset contains daily and sub-daily hydrometeorological and soil observations from COSMOS-UK (cosmic-ray soil moisture monitoring network) from the start of the network, in October 2013, to the end of 2015. These data are from 32 sites active across Great Britain during this time, recording a range of hydrometeorological and soil variables. Each site in the network hosts a cosmic-ray sensing probe; a novel sensor technology which can be used, in combination with hydrometeorological data, to calculate the volumetric water content of soil over a field scale. The hydrometeorological and soil data are recorded at a 30 minute resolution and they include neutron counts from the Cosmic-ray sensing probe, humidity and atmospheric pressure data that are used to derive volumetric water content at two temporal resolutions (hourly and daily). Also included are soil heat flux, air temperature, wind speed and net radiation data which are used to derive potential evapotranspiration at a daily resolution.

Publication date: 2017-09-04

Where/When

Study area

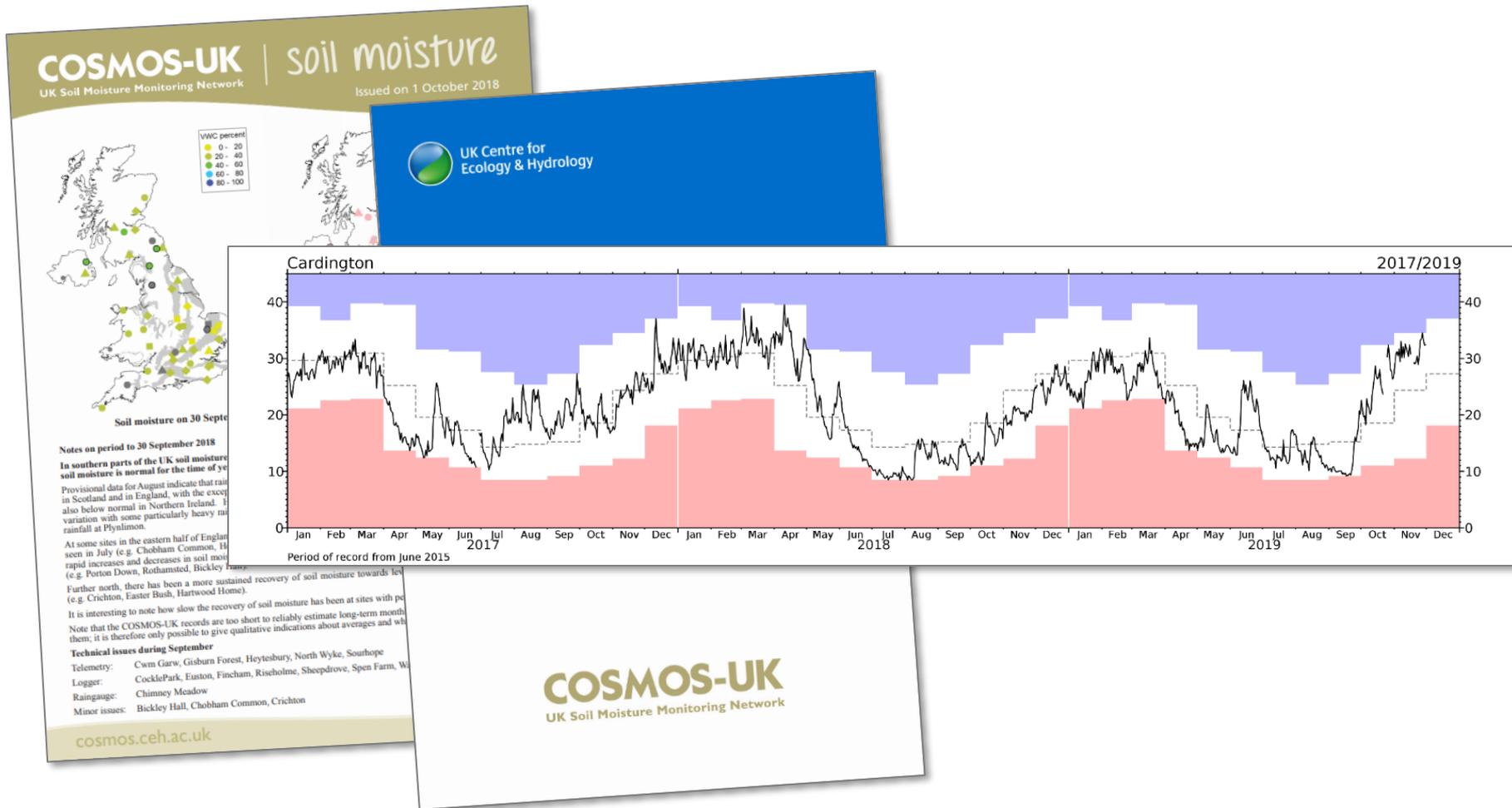
[Get the data](#)

- [Download the data](#)
- [Supporting documentation](#)

Format of the Dataset :
Comma-separated values (CSV)

Data to 2017: <https://doi.org/10.5285/a6012796-291c-4fd6-a7ef-6f6ed0a6cfa5>
2018 update in process.

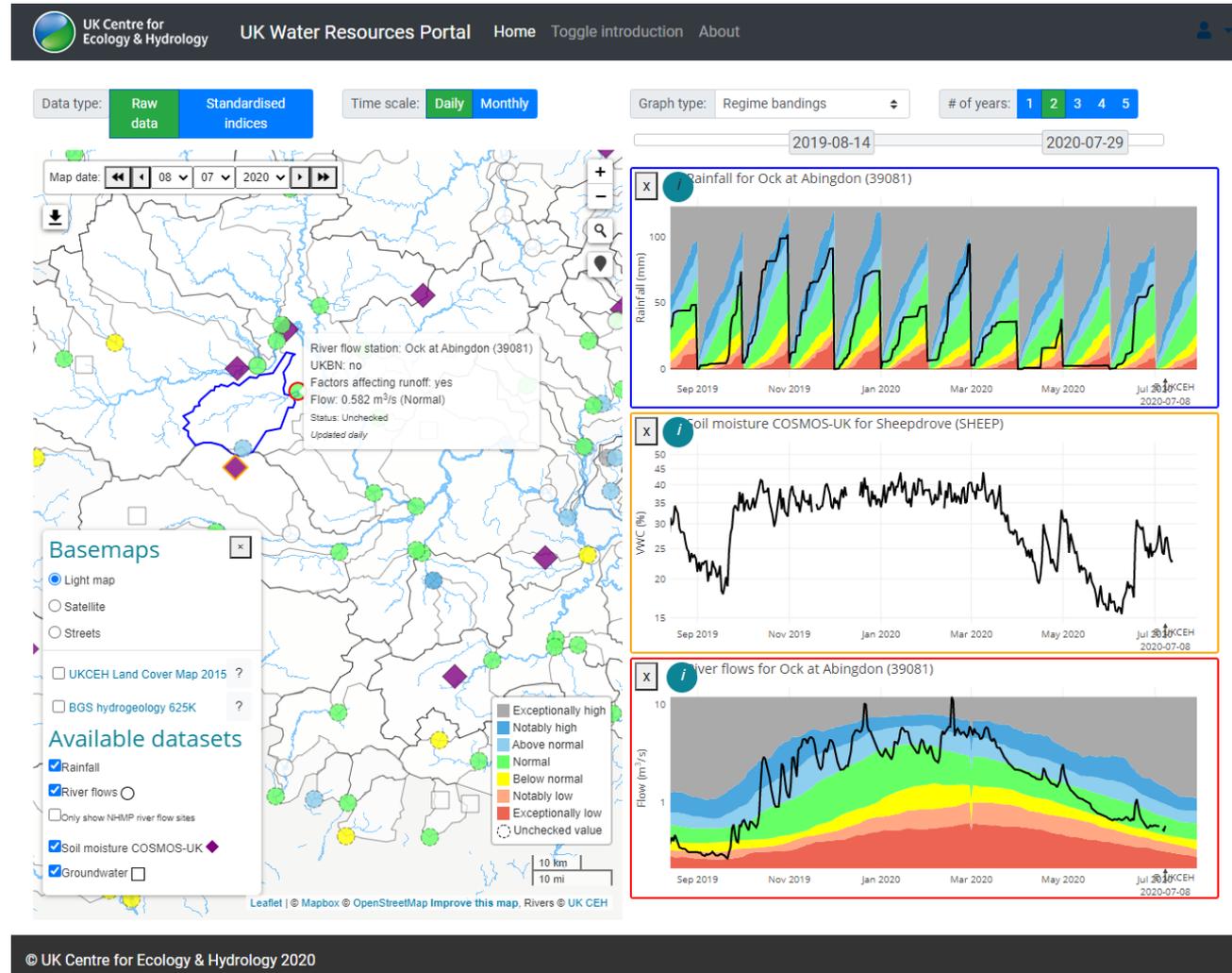
Other data products



Sign up to receive monthly summaries here: <https://cosmos.ceh.ac.uk/>

Real time water resources assessment

COSMOS-UK data integrated within the UKCEH Water Resources Portal alongside rainfall, river flow, groundwater level information



<https://eip.ceh.ac.uk/hydrology/water-resources/>

Acknowledgements – site hosts



EUSTON
ESTATE



SRUC



SWEETLAMB
COMPLEX



The James
Hutton
Institute



PRIFYSGOL
BANGOR
UNIVERSITY



Cheshire
Wildlife Trust



Game & Wildlife
CONSERVATION TRUST
The Allerton Project



The University of
Nottingham

UNITED KINGDOM • CHINA • MALAYSIA



FARMCARE



ROTHAMSTED
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MORLEY
AGRICULTURAL FOUNDATION



Forest Research



Met Office



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UNIVERSITY OF
LINCOLN



Mr. Hugh's

Acknowledgements – UKCEH staff

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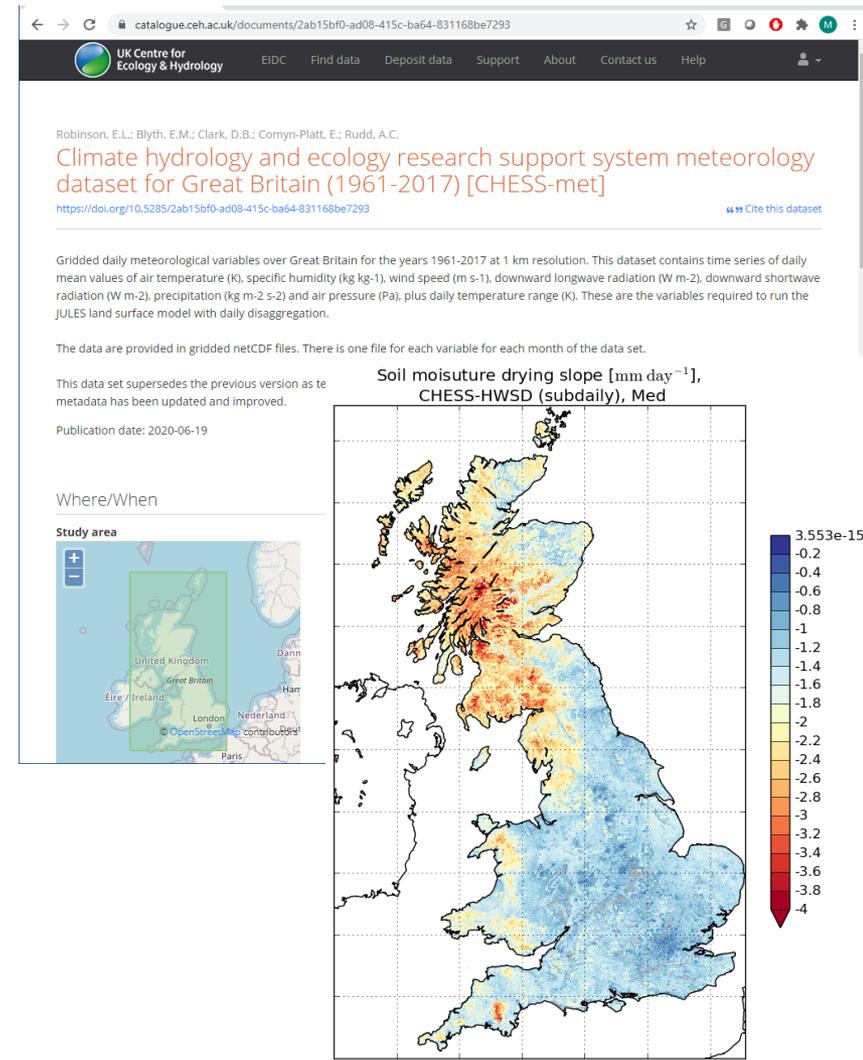
Related projects and COSMOS-UK applications

- Currently a huge amount of work on inter-comparisons for various applications / geographical areas
- Finding the “sweet spot” between:
 - Observations: high temporal, low spatial resolution, accurate (?)
 - Models: high temporal and spatial resolution
 - EO: high spatial resolution, real-time
- Recent EGU session is a great overview, many have posters online:

<https://meetingorganizer.copernicus.org/EGU2020/displays/35547>

CHESS: 1km modelled data across the UK

- Meteorological data suitable for driving the JULES land surface model at 1km (downscaled from other data sources)
- Daily data 1961 - 2017
- JULES model run to 2015 available, including soil moisture
- Currently in use within the Hydro-JULES project



Martinez-de la Torre, A.; Blyth, E.M.; Robinson, E.L. (2018). Water, carbon and energy fluxes simulation for Great Britain using the JULES Land Surface Model and the Climate Hydrology and Ecology research Support System meteorology dataset (1961-2015) [CHESS-land]. NERC Environmental Information Data Centre. <https://doi.org/10.5285/c76096d6-45d4-4a69-a310-4c67f8dcf096>

Inter-comparison

SMOS, SMAP, Sentinel data and JULES-CHESS soil moisture compared to COSMOS-UK data

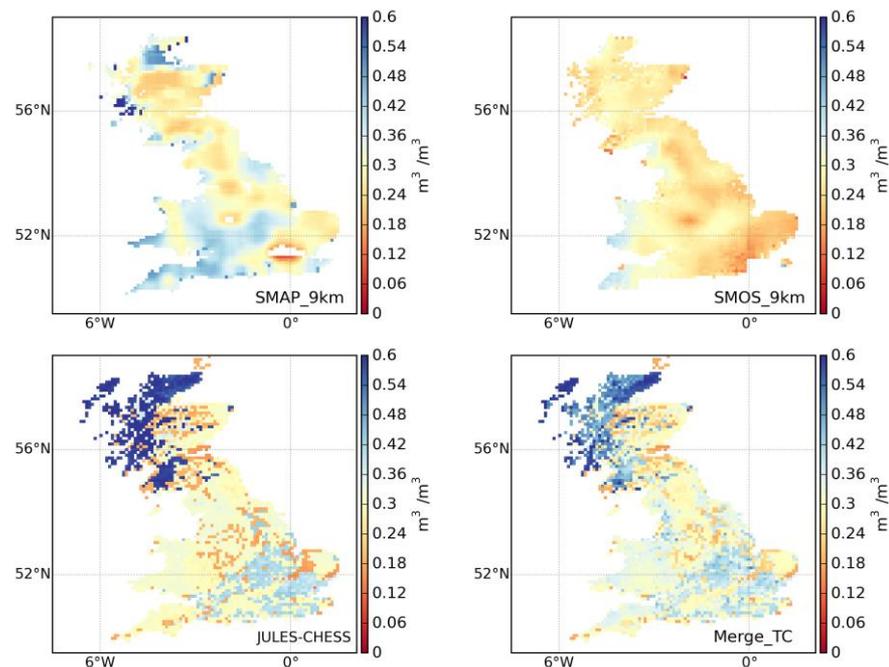
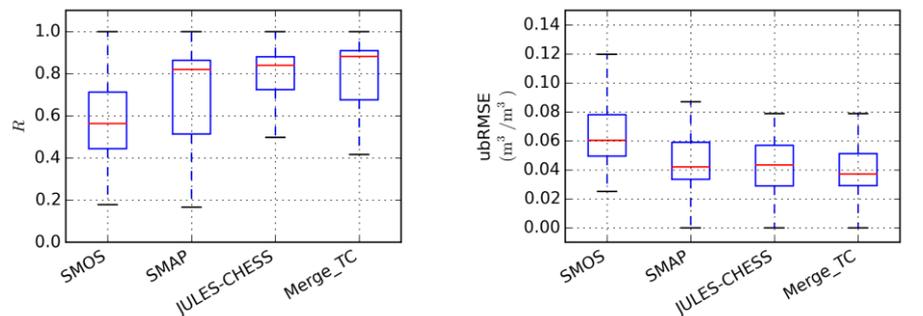
Triple-collocation method used to produce merged product

Jian Peng¹, Tristan Quaife³, Ewan Pinnington³, Jonathan Evans², Phil Harris², Emma Robinson², Eleanor Blyth², and Simon Dadson^{1,2}

¹University of Oxford, ²UK Centre for Ecology & Hydrology, ³National Centre for Earth Observation,

<https://doi.org/10.5194/egusphere-egu2020-18099>

Direct comparison



Improving modelled soil moisture with observations

JULES output + COSMOS-UK obs

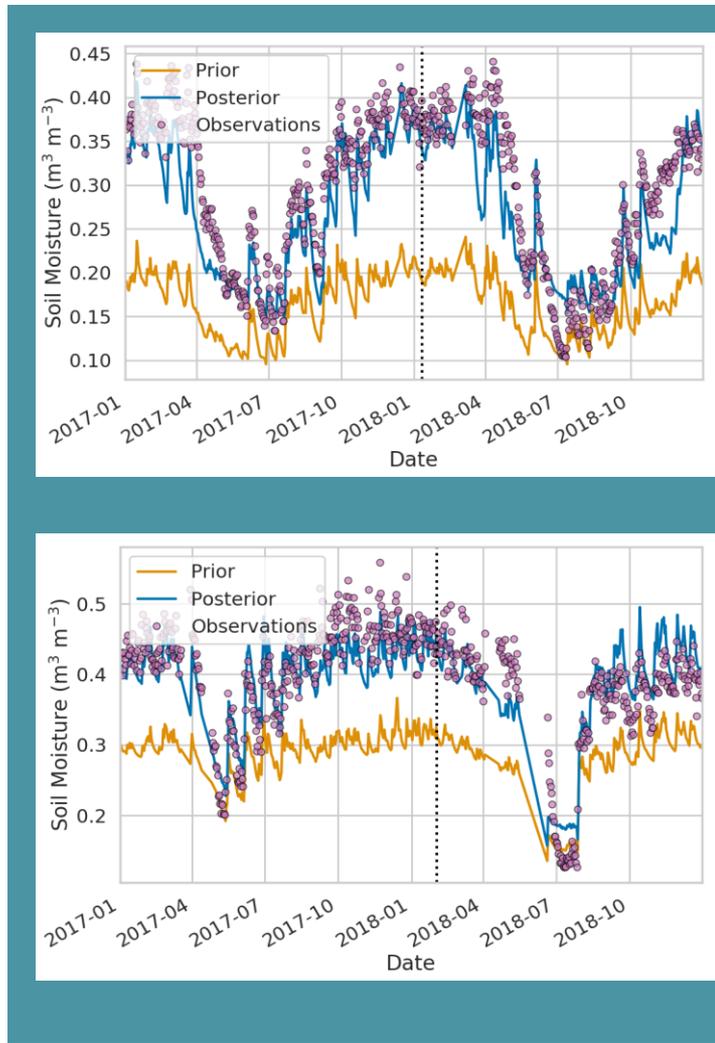


Updated soil physics constants
(via optimised underlying pt function)



Better JULES OUTPUT

Comparison of original (prior) and new (posterior) soil physics parameters also gives insight into **how** the data assimilation is able to improve the fit (interesting questions about scale, geographical location, model process representation....)



E. Cooper,¹ E. Pinnington², R. Ellis¹, E. Blyth¹, S. Dadson¹, H. Cooper¹

¹ UKCEH, Wallingford, UK

² NCEO, University of Reading, UK

See other COSMOS-UK applications:

[A performance assessment method for SAR satellite-derived surface soil moisture data using a soil-water balance model, meteorological observations, and soil pedotransfer functions.](#)

John Beale, Toby Waine, Ronald Corstanje, and Jonathan Evans

<https://doi.org/10.5194/egusphere-egu2020-3387>

[Progress in evaluating satellite soil moisture products in Great Britain against COSMOS-UK and in-situ soil moisture measurements](#)

Nevil Wyndham Quinn, Chris Newton, David Boorman, Michael Horswell, and Harry West

<https://doi.org/10.5194/egusphere-egu2020-15831>

In summary

- Globally, soil moisture measurements are hugely lacking, limiting validation of EO products
- COSMOS-UK is a relatively dense network providing near real-time, field scale (~200m) soil moisture measurements at ~10-70cm depth
- Range of other data products providing full met variables, PE, snow, phenocam data, etc.
- Lots of work underway to bring combined benefits of observations, modelling, and EO
- Data freely downloadable
- Get in touch for collaborations cosmosuk@ceh.ac.uk

Thanks

Matt Fry

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