Copernicus In Situ

COSMOS-UK

Matt Fry

(on behalf of the whole COSMOS-UK team)

JNCC soil moisture workshop

15th July 2020

UK Centre for Ecology & Hydrology

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

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

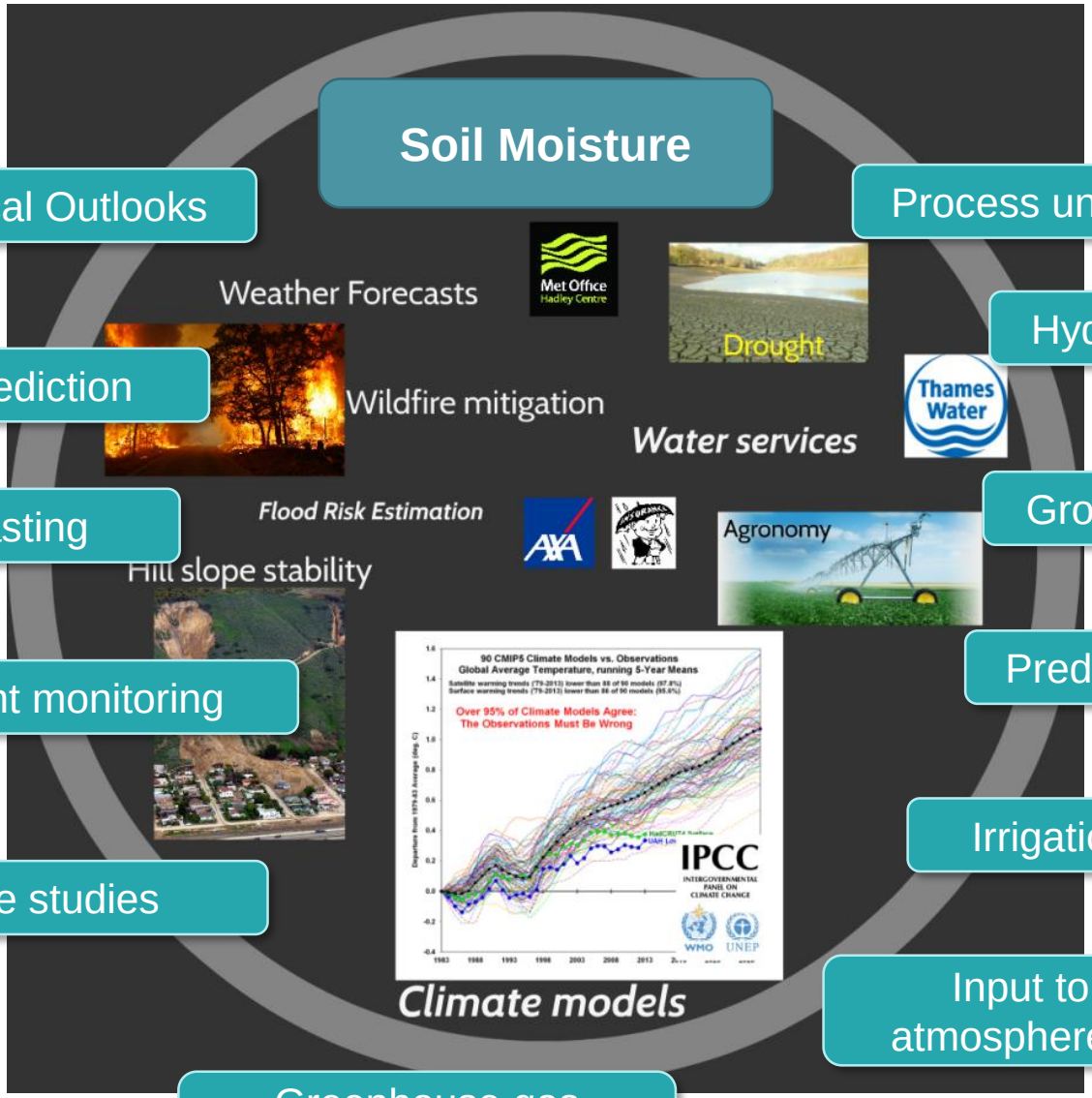
UKCEH and the COSMOS-UK network

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



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?

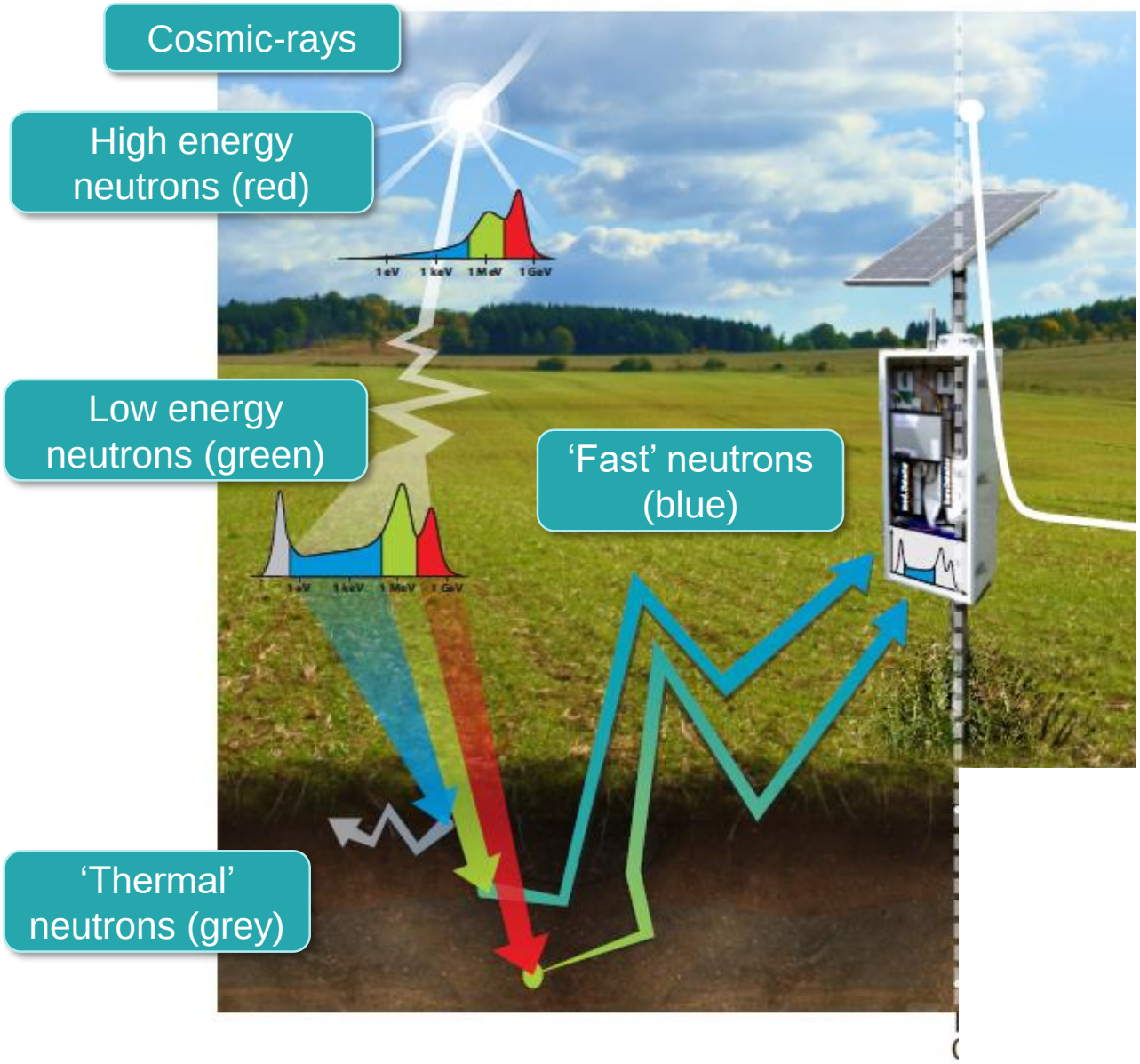


Figure from Schrön *et al.* (2015) https://pos.sissa.it/236/231/pdf

From neutron counts to soil moisture

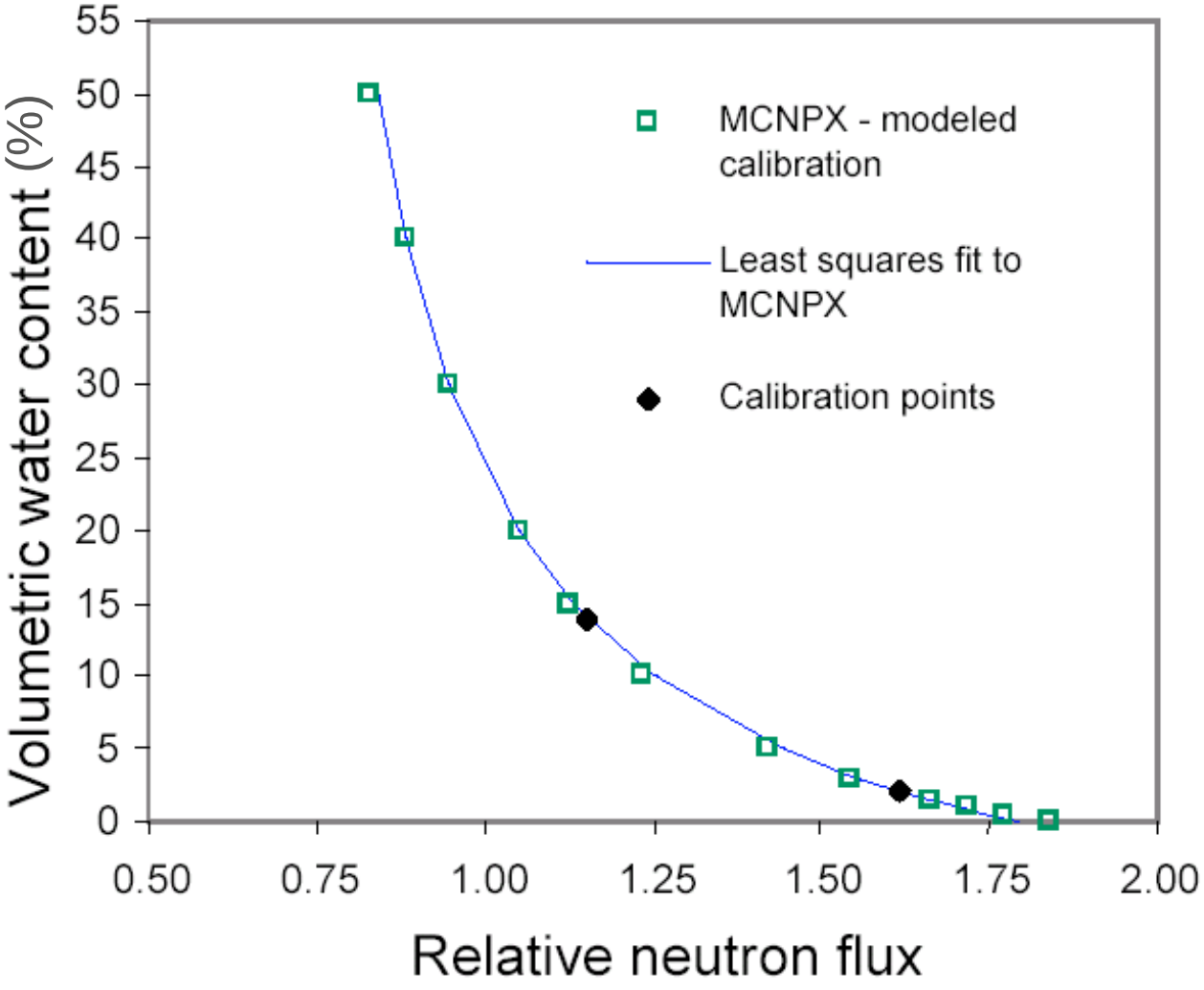
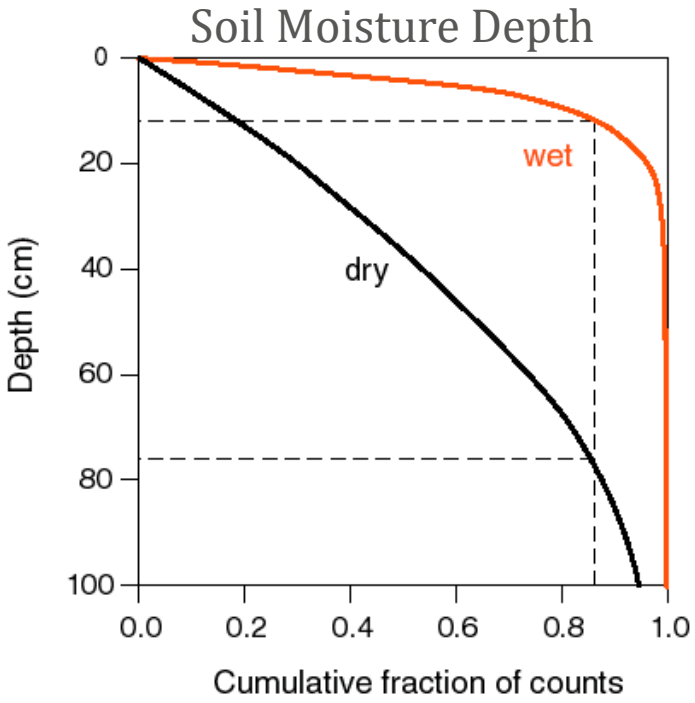
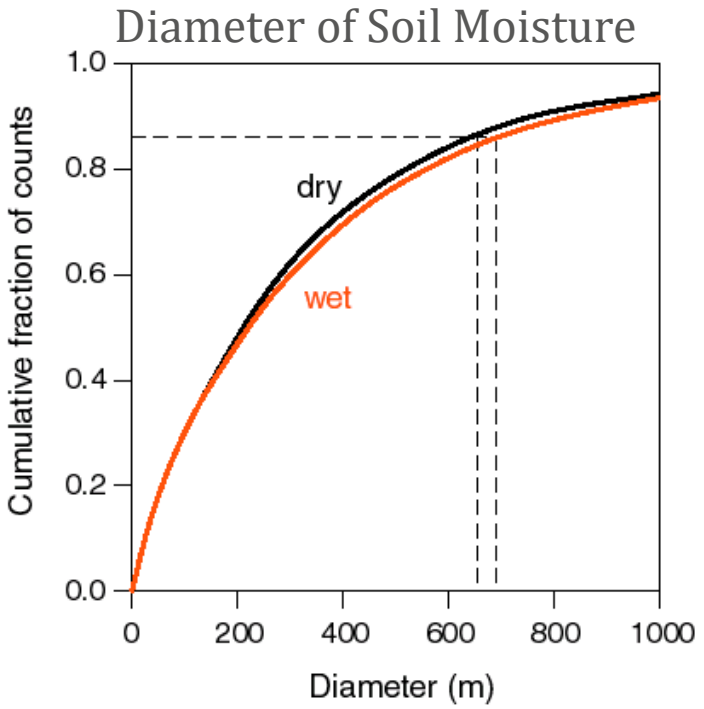


Figure courtesy of: M. Zreda, J. Shuttleworth, X. Zeng, C. Zweck and T. Ferre

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

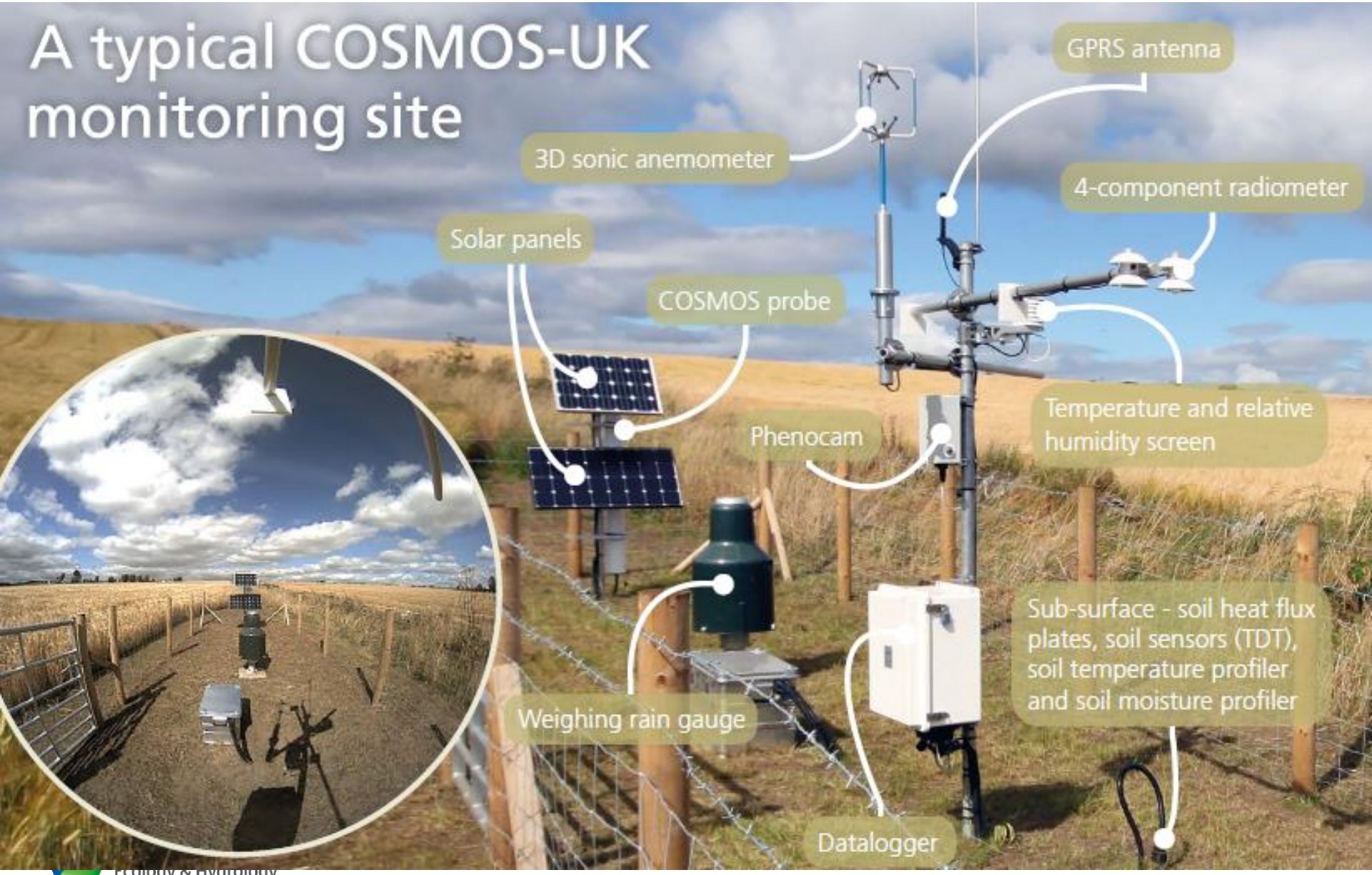
(from Jungfraujoch monitoring station)

Relationship between corrected counts and soil moisture established through calibration

Calibration soil sampling:

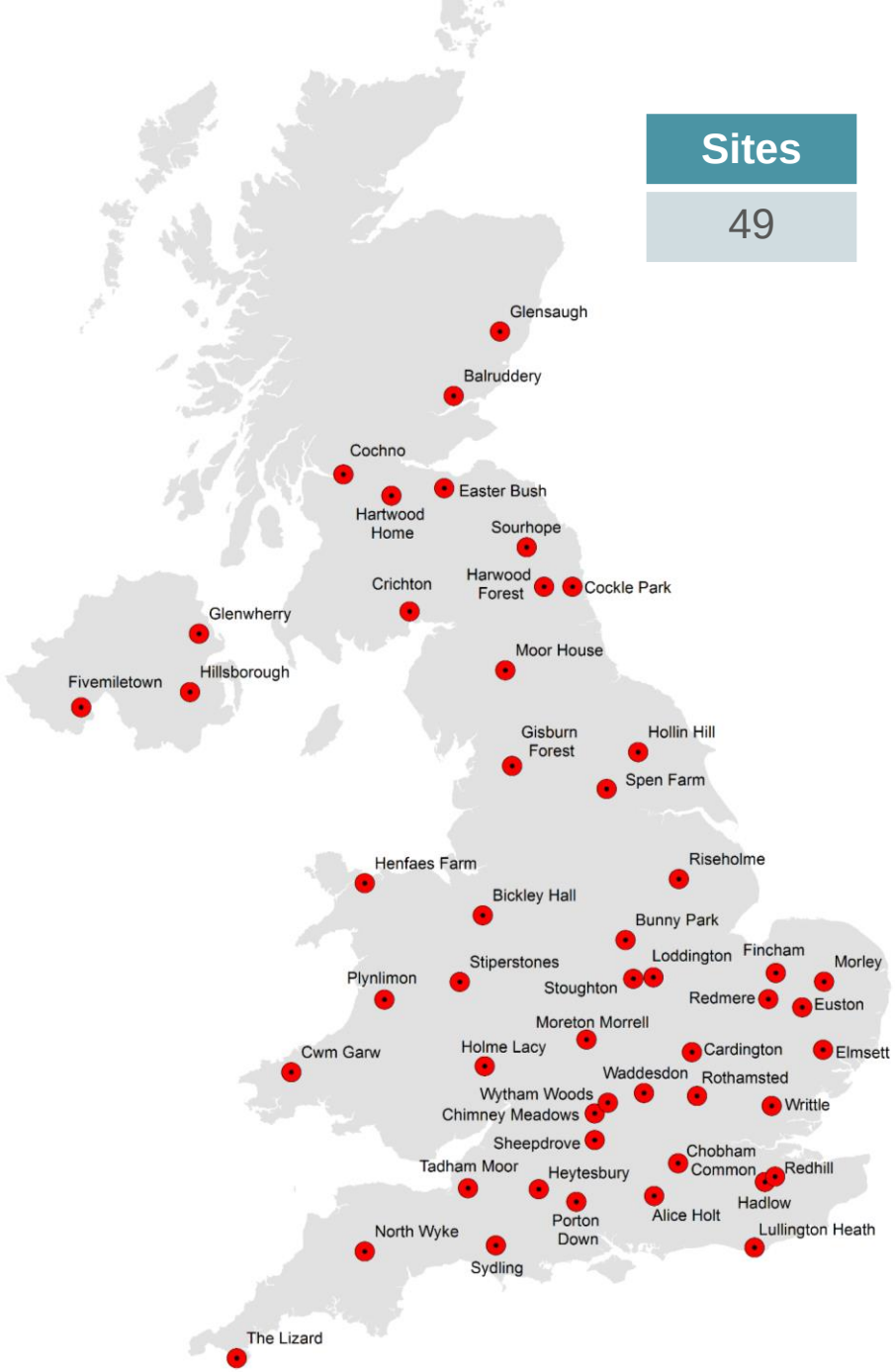
- volumetric water content and dry bulk density
- soil organic matter
- lattice & bound water

COSMOS-UK site instrumentation



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



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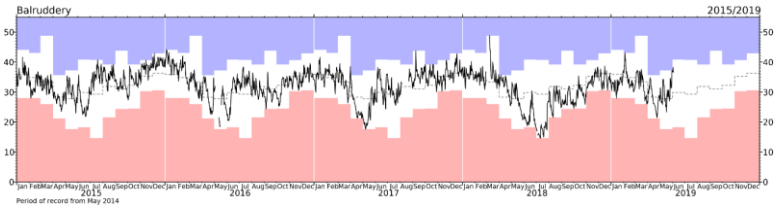
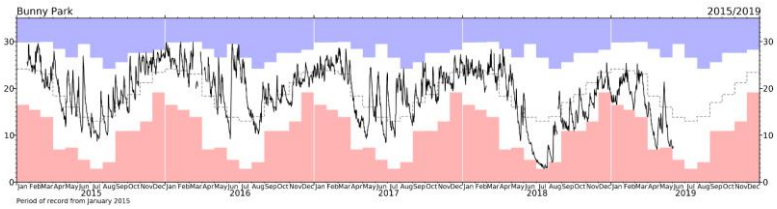
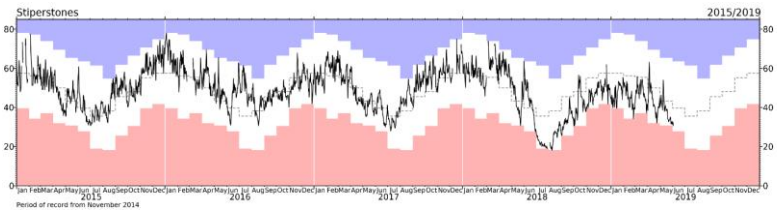
Balruddery Farm, Scotland



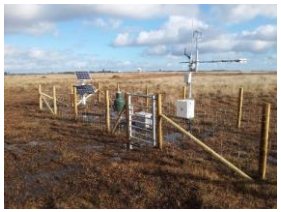
Bunny Park, East Midlands

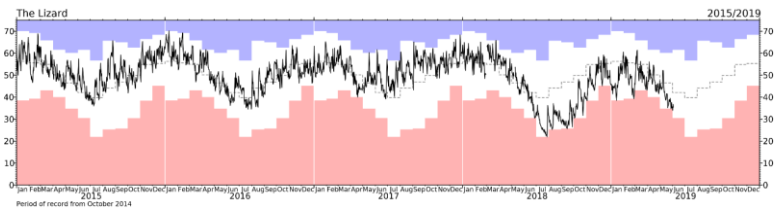


Stiperstones, West Midlands

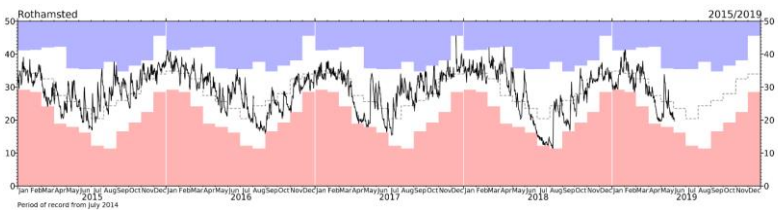


The Lizard, South West England

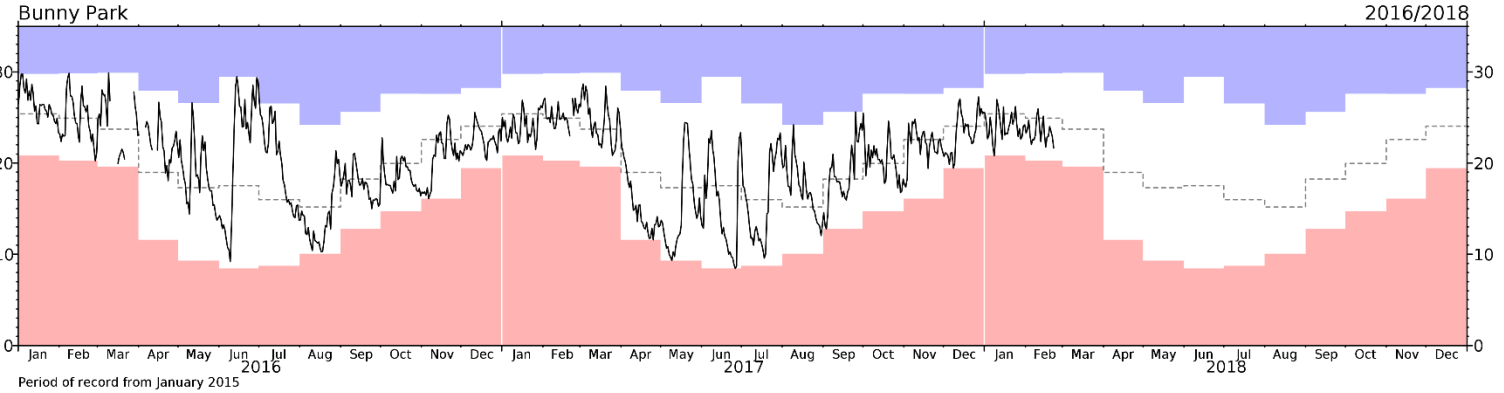


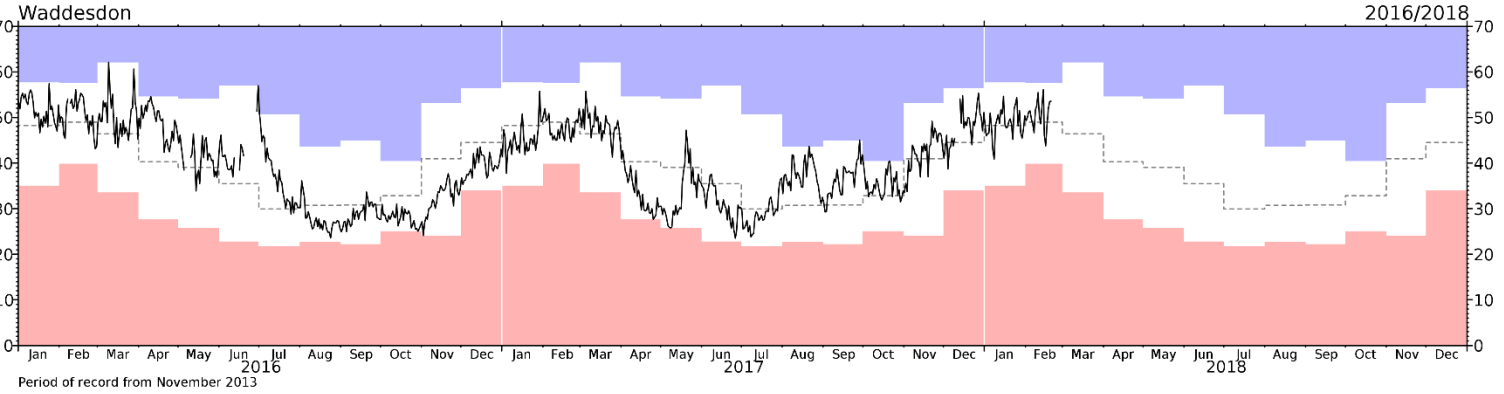


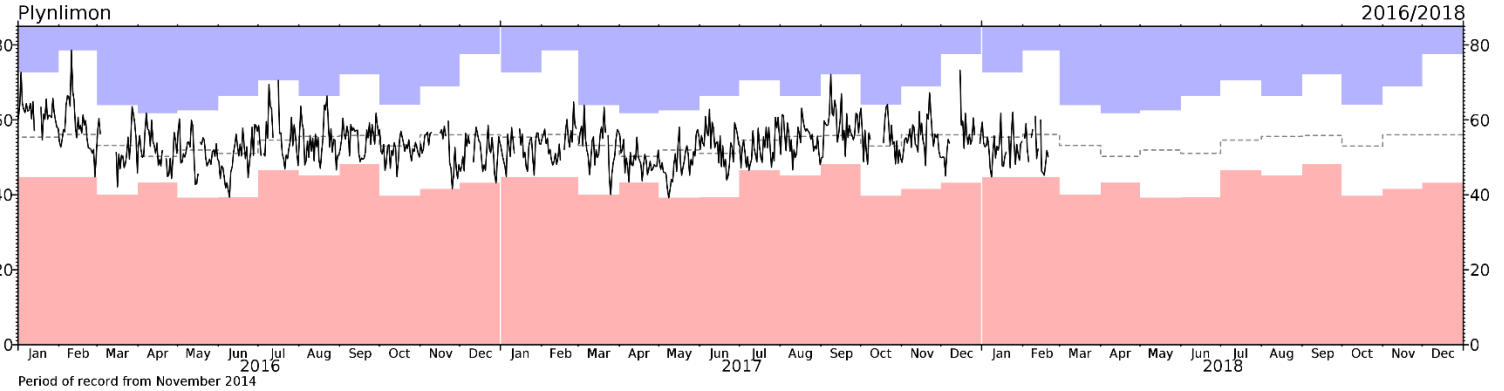
Rothamsted, East of England



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 depth

Red and Green: TDT point sensors at 10cm

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)

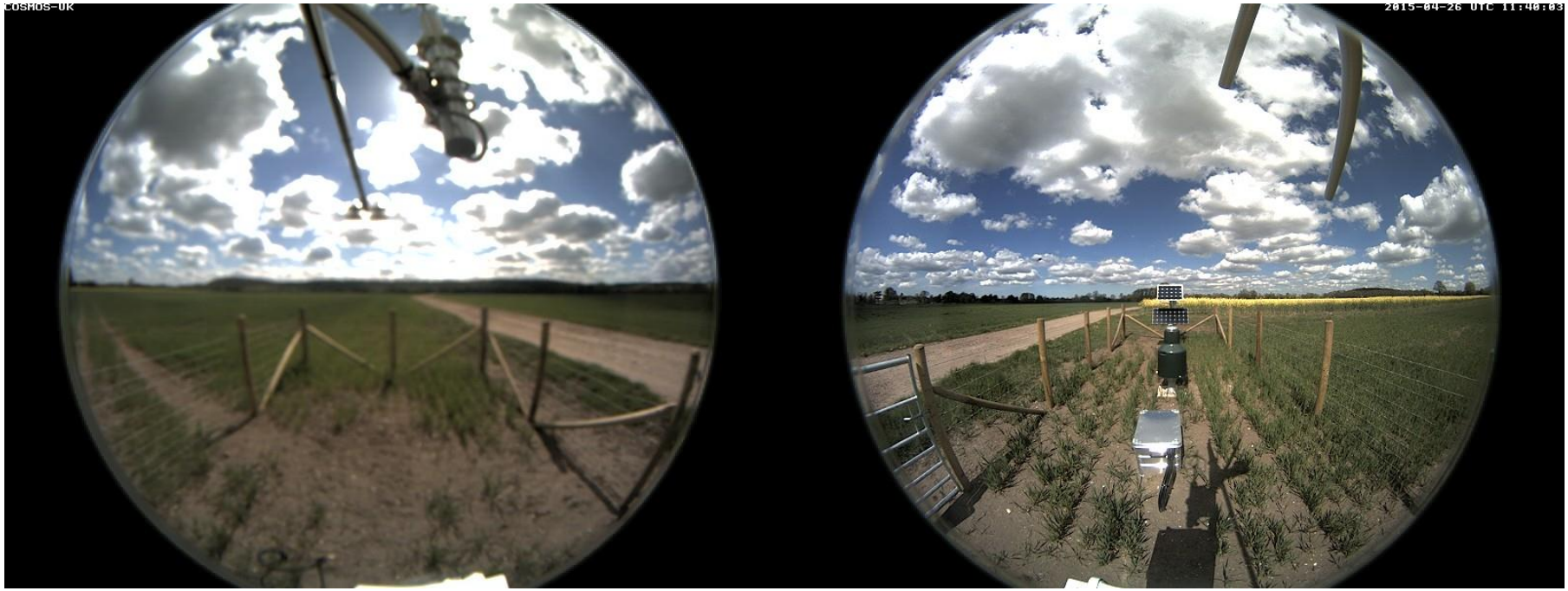
Monitored data

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	$degrees$	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



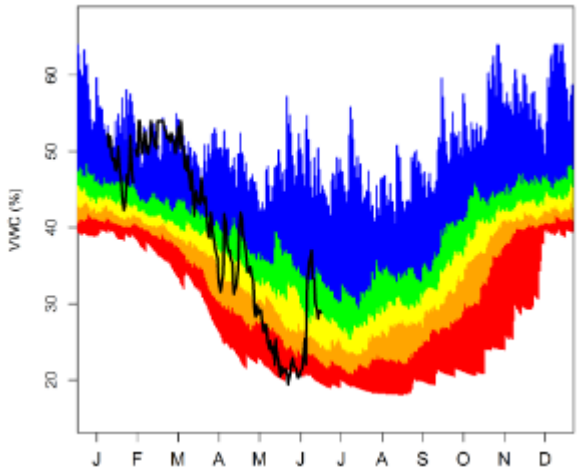
North and south facing cameras generate a time series of photographs that provide qualitative information about the changing vegetation (phenology) around each site.

In process : RGB time series from the field area

Ongoing work

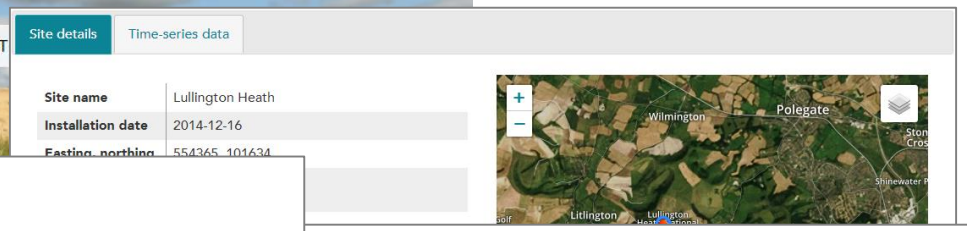
Flux data, actual evaporation

Modelling to develop understanding of soil moisture “climatology”



Developing further QC and gap filling with AI

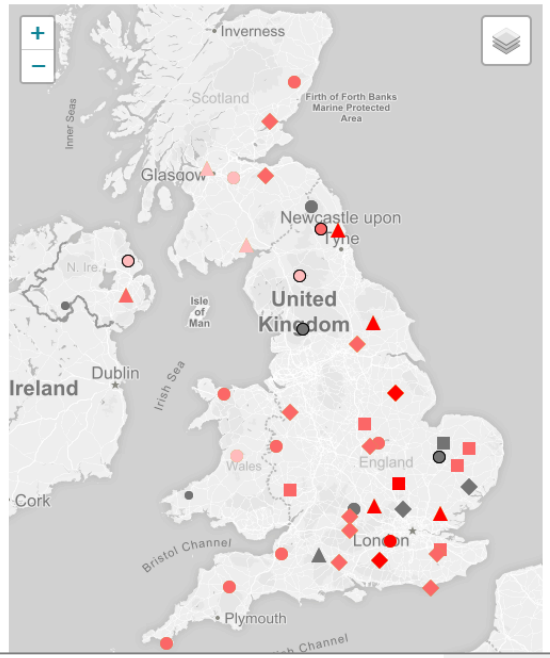
Website - content



Home

Data

Map | Time-series data



Daily dataset: Soil moisture index (SMI)

Date: 2018-10-03

Dataset key

Uncalibrated:	
No data:	
<0.3:	
0.3-0.6:	
0.6-0.9:	
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.

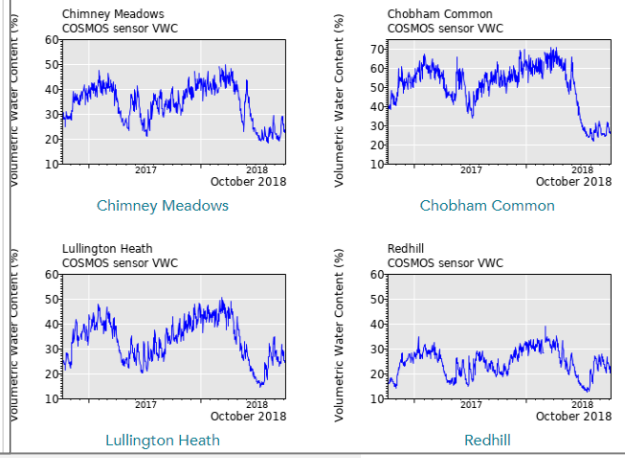
Time period

1 week | 1 month | 3 months | 6 months | 1 year | 2 years | 3 years

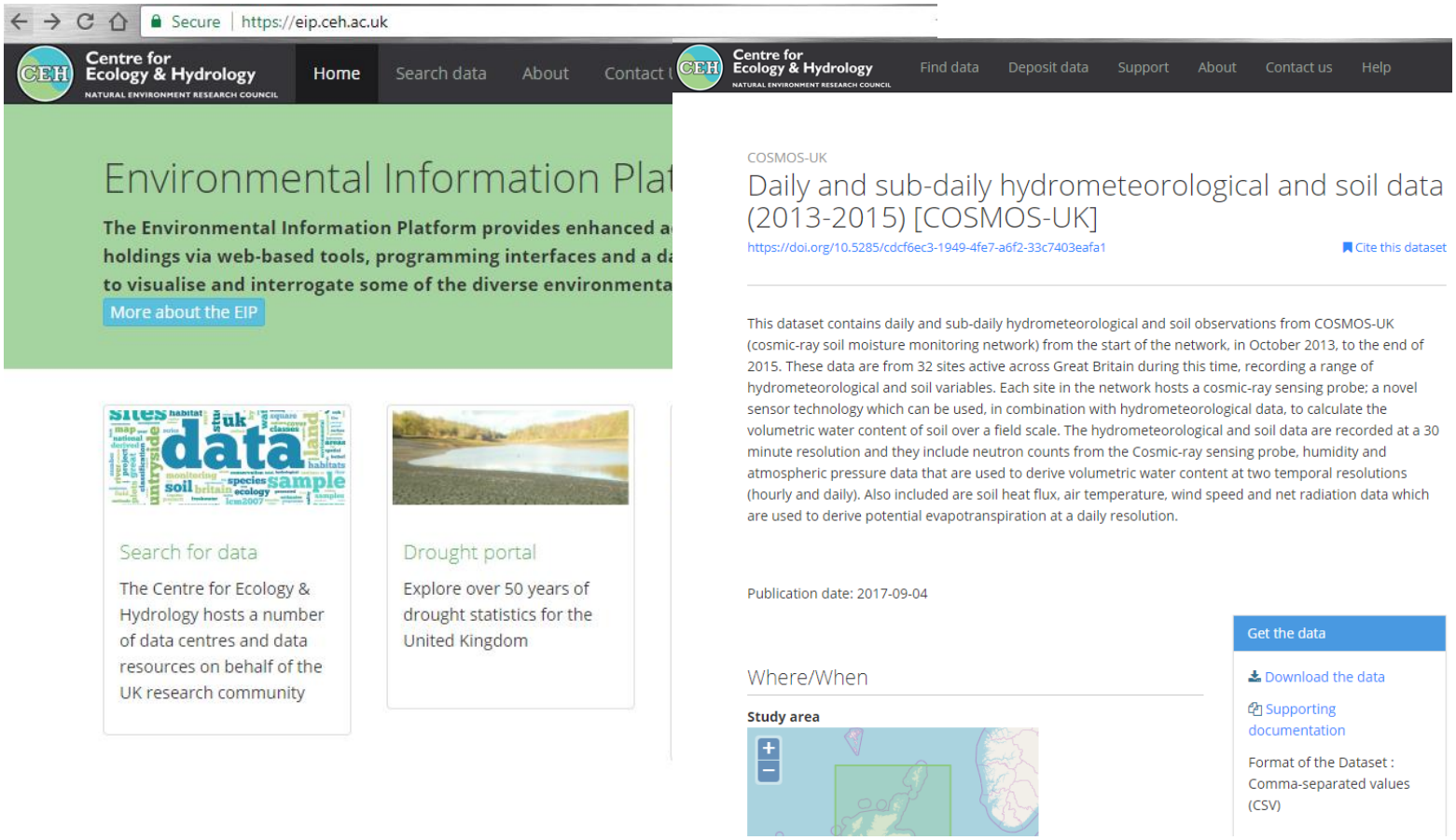
End date 2018-10-04

(VWC) (daily) Sites: South East England

(daily)

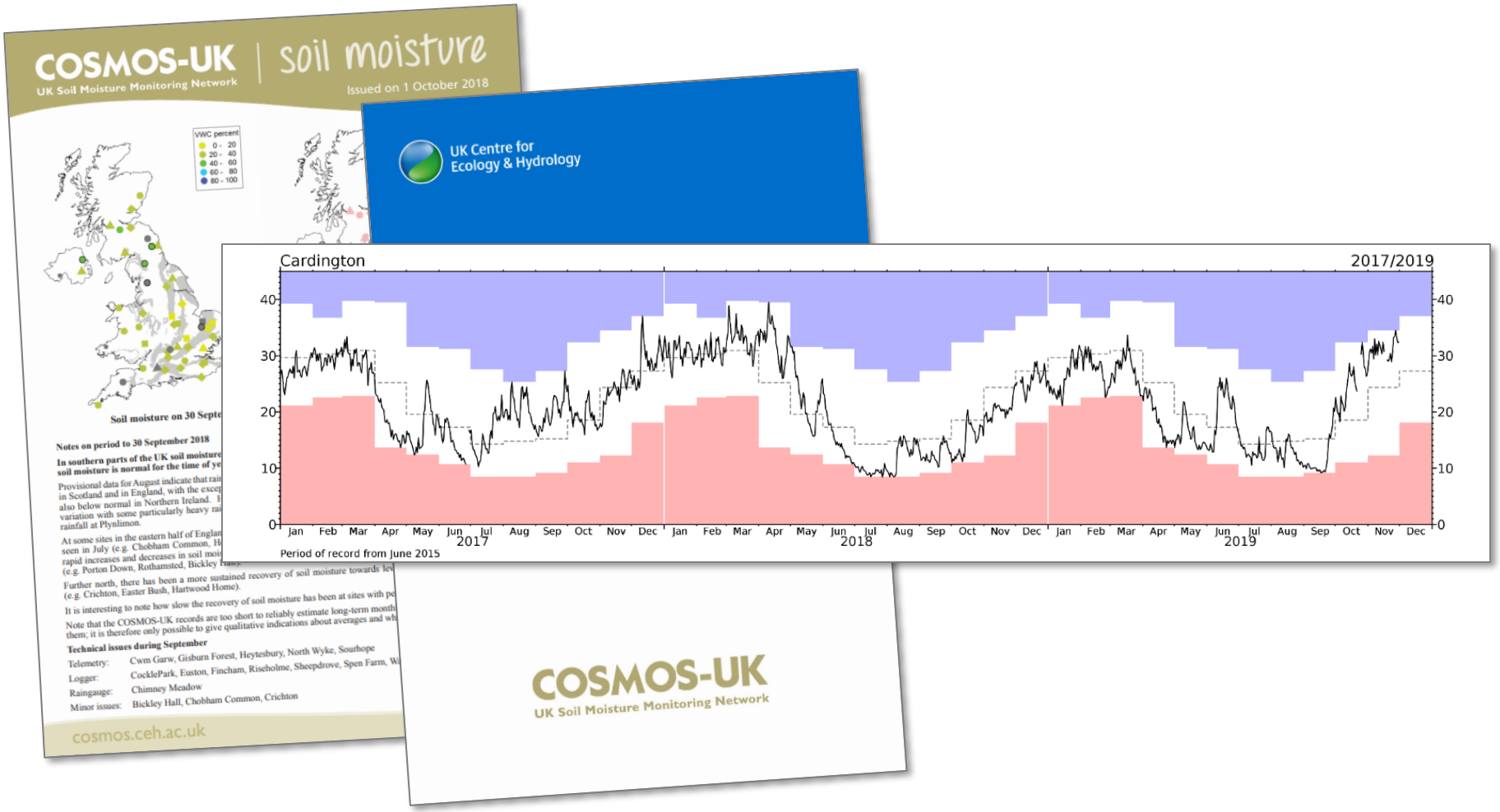


Data and information: data downloadable



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

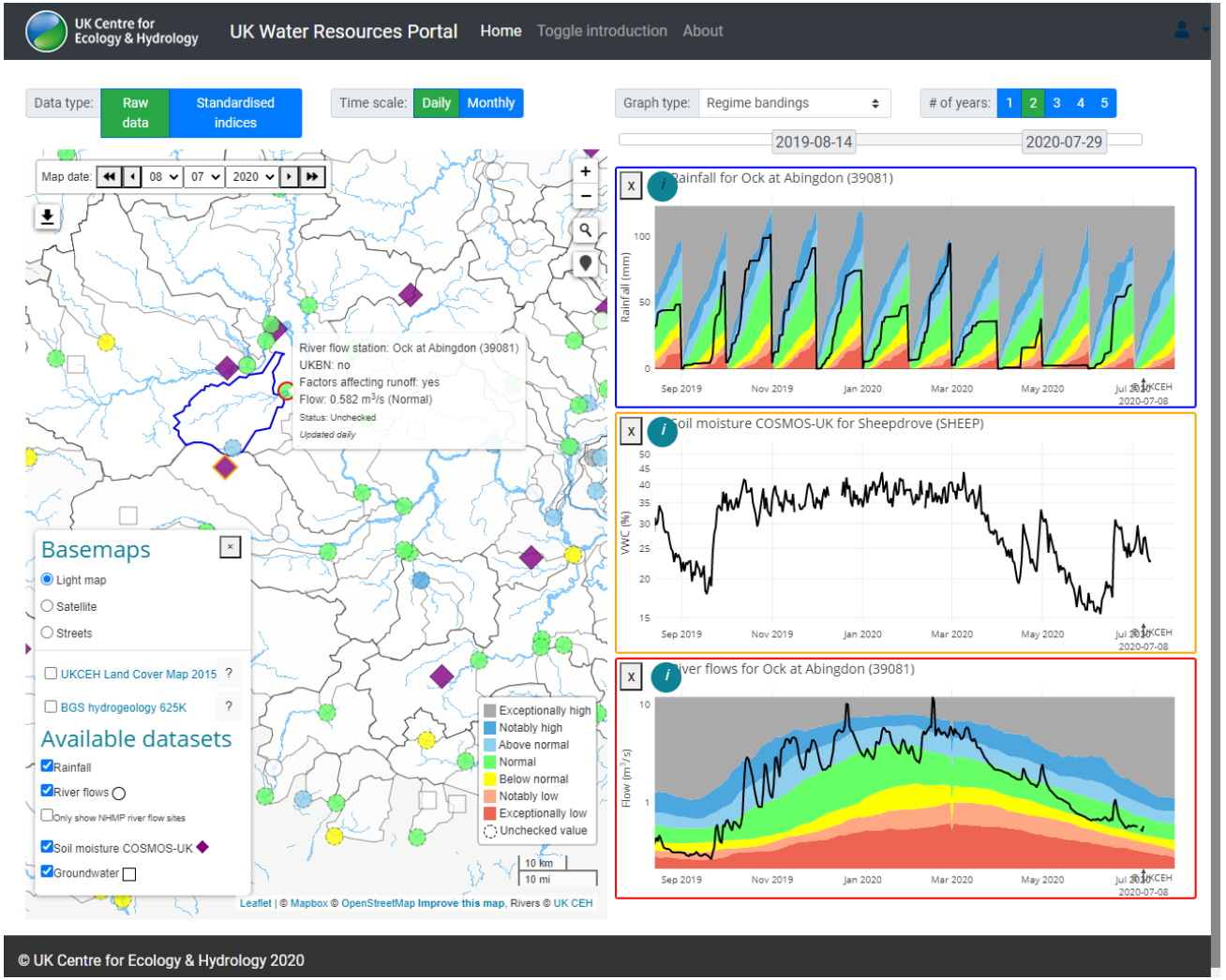
Other data products



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

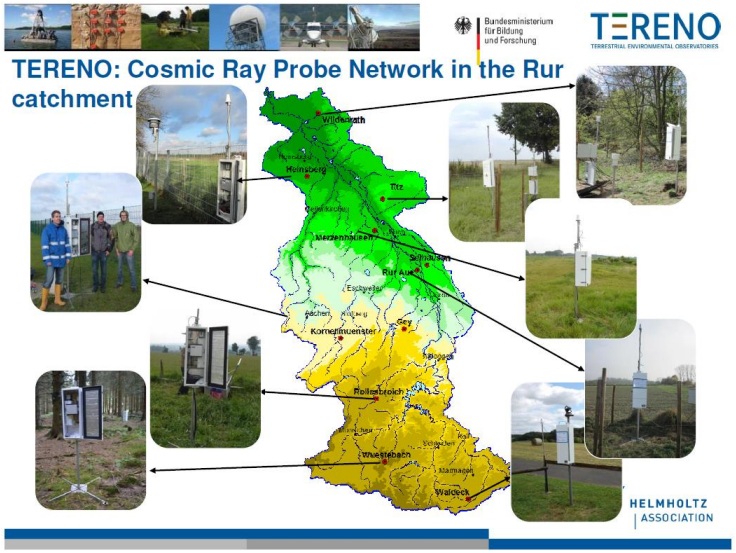
Real time water resources assessment

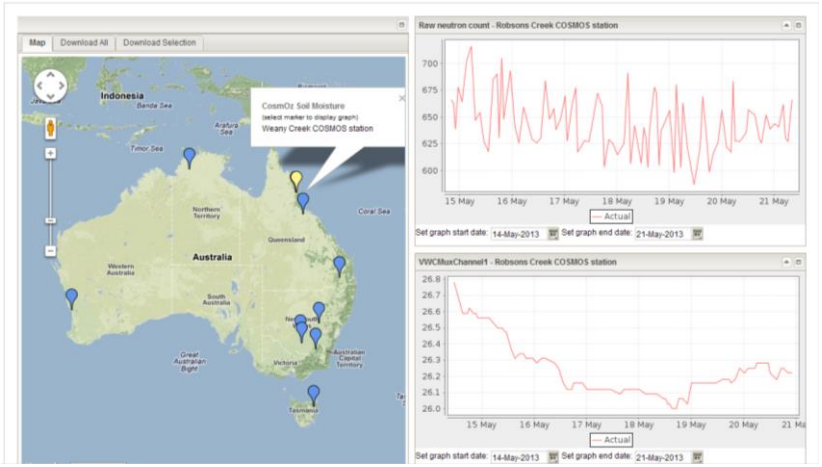
COSMOS-UK data integrated within the UKCEH Water Resources Portal alongside rainfall, river flow, groundwater level information

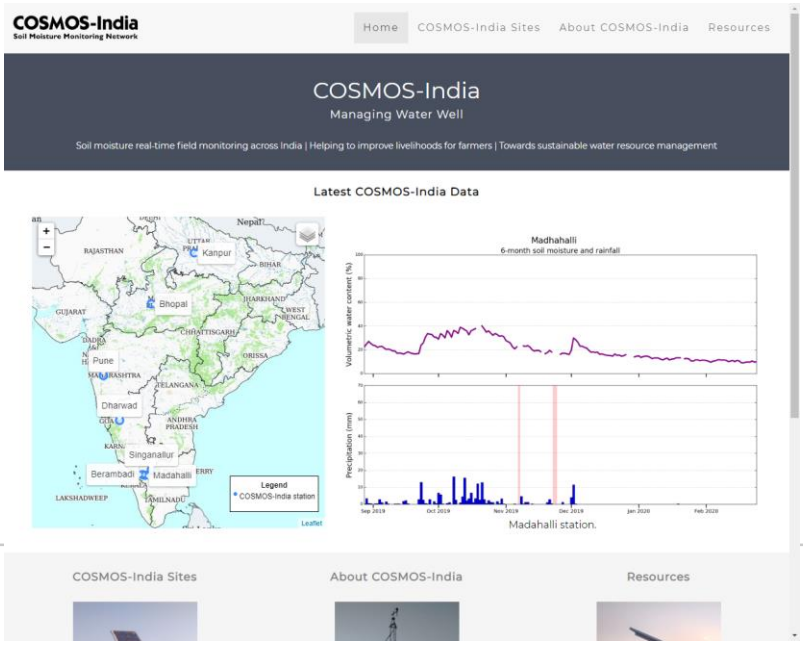


https://eip.ceh.ac.uk/hydrology/water-resources/

Outside the UK...







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Acknowledgements – site hosts

Acknowledgements – UKCEH staff

Vasileios Antoniou, Anne Askquith-Ellis, Sarah Bagnoli, Lucy Ball, Emma Bennett James Blake, David Boorman, Milo Brooks, Michael Clarke, Nick Cowan, Hollie Cooper, Liz Cooper, Alex Cumming, Louisa Doughty, Jonathan Evans, Phil Farrand, Matthew Fry, Ned Hewitt, Olivia Hitt, Alan Jenkins, Filip Kral, Jeremy Libre, William Lord, Colin Roberts, Ross Morrison, Gemma Nash, Matthew Parkes, Jo Newcomb, Dan Rylett, Peter Scarlett, Andrew Singer, Simon Stanley, Oliver Swain, Jenna Thornton, Emily Trill, Helen Vincent, John Wallbank, Helen Ward, Alan Warwick, Ben Winterbourne and George Wright.

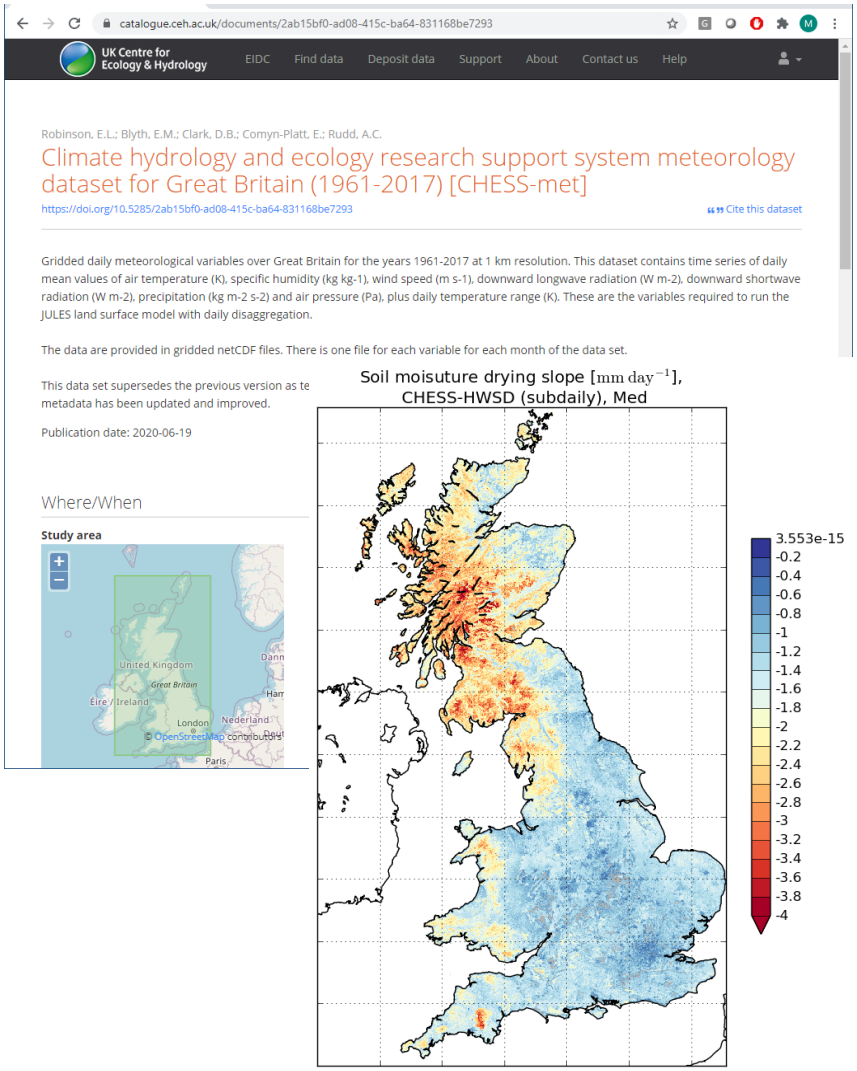
Related projects and COSMOS-UK applications

- 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

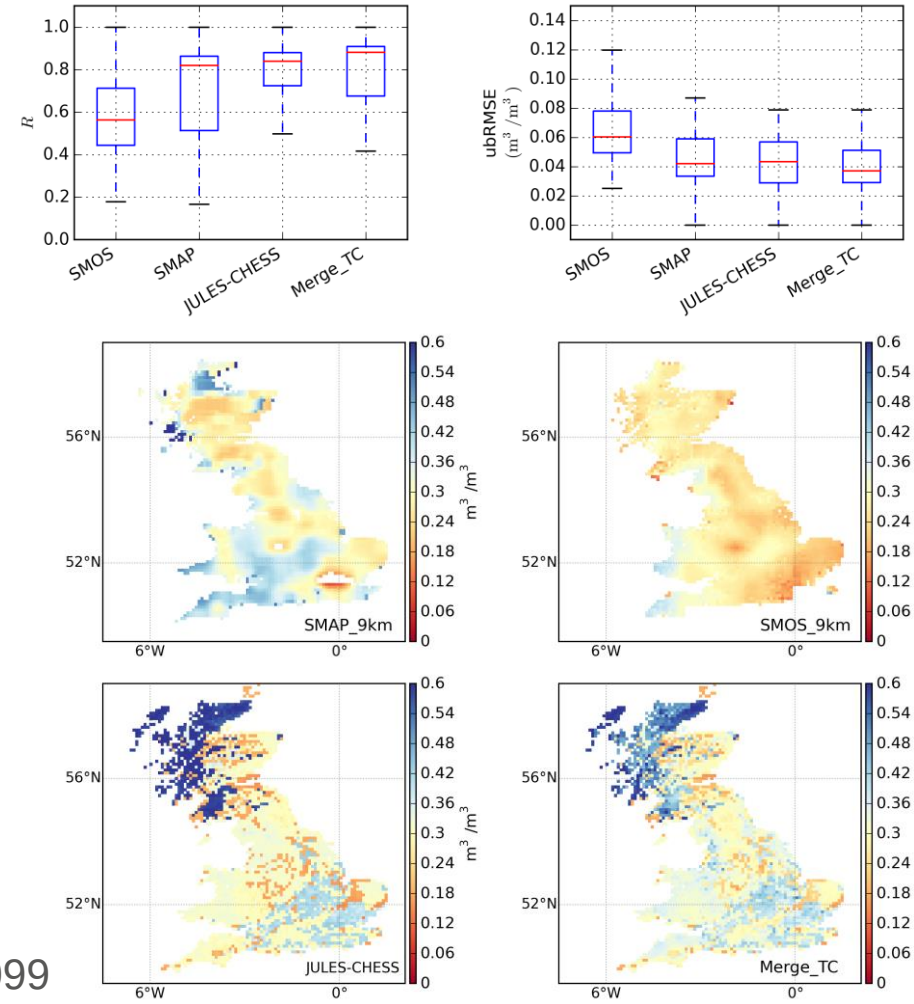
Triple-colocation method used to produce merged product

Jian Peng[1], Tristan Quaife[3], Ewan Pinnington[3], Jonathan Evans[2], Phil Harris[2], Emma Robinson[2], Eleanor Blyth[2], and Simon Dadson[1,2]

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

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

Direct comparison

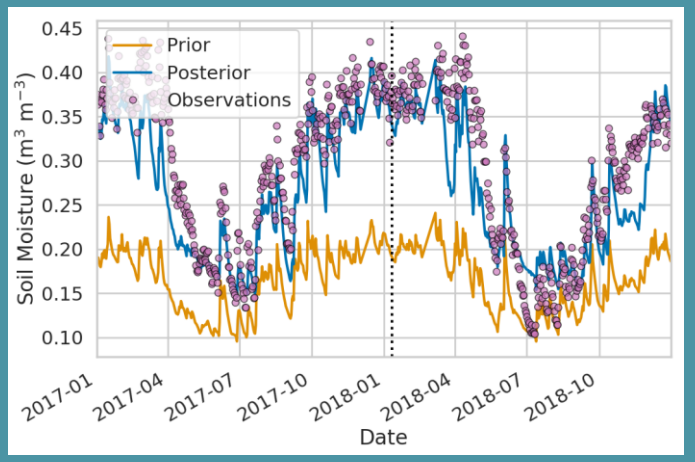


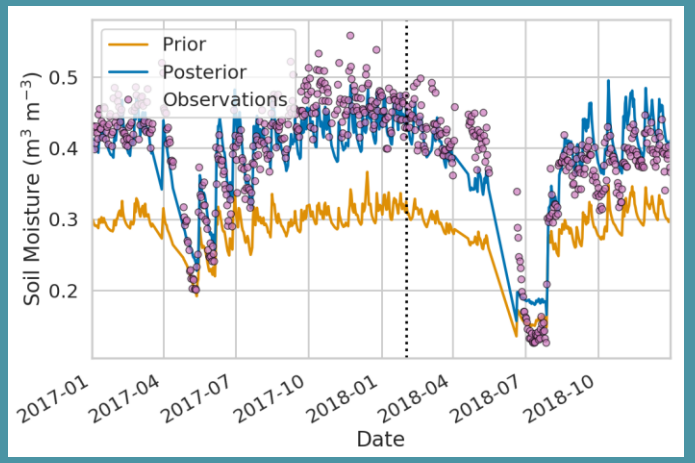
Improving modelled soil moisture with observations

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. Pinnington[2], R. Ellis[1], E. Blyth[1], S. Dadson[1], H. Cooper[1]

[1] UKCEH, Wallingford, UK

[2] NCEO, University of Reading, UK

Hydro-JULES

UK Centre for Ecology & Hydrology

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

COSMOS-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

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