

The COSMOS-UK Network and Floods and Droughts Research Infrastructure (FDRI)

Dr Jonathan G. Evans, and the whole
COSMOS-UK Team

11th June 2025

Current Status and Future Directions of Soil
Moisture Observations – ISMON Workshop



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Overview - Introduction

- 1) COSMOS-UK national soil moisture monitoring network.
- 2) Brief look at UKCEH Greenhouse Gas (GHG) Flux Network.
- 3) What's coming: Floods and Droughts Research Infrastructure (FDRI)



COSMOS-UK



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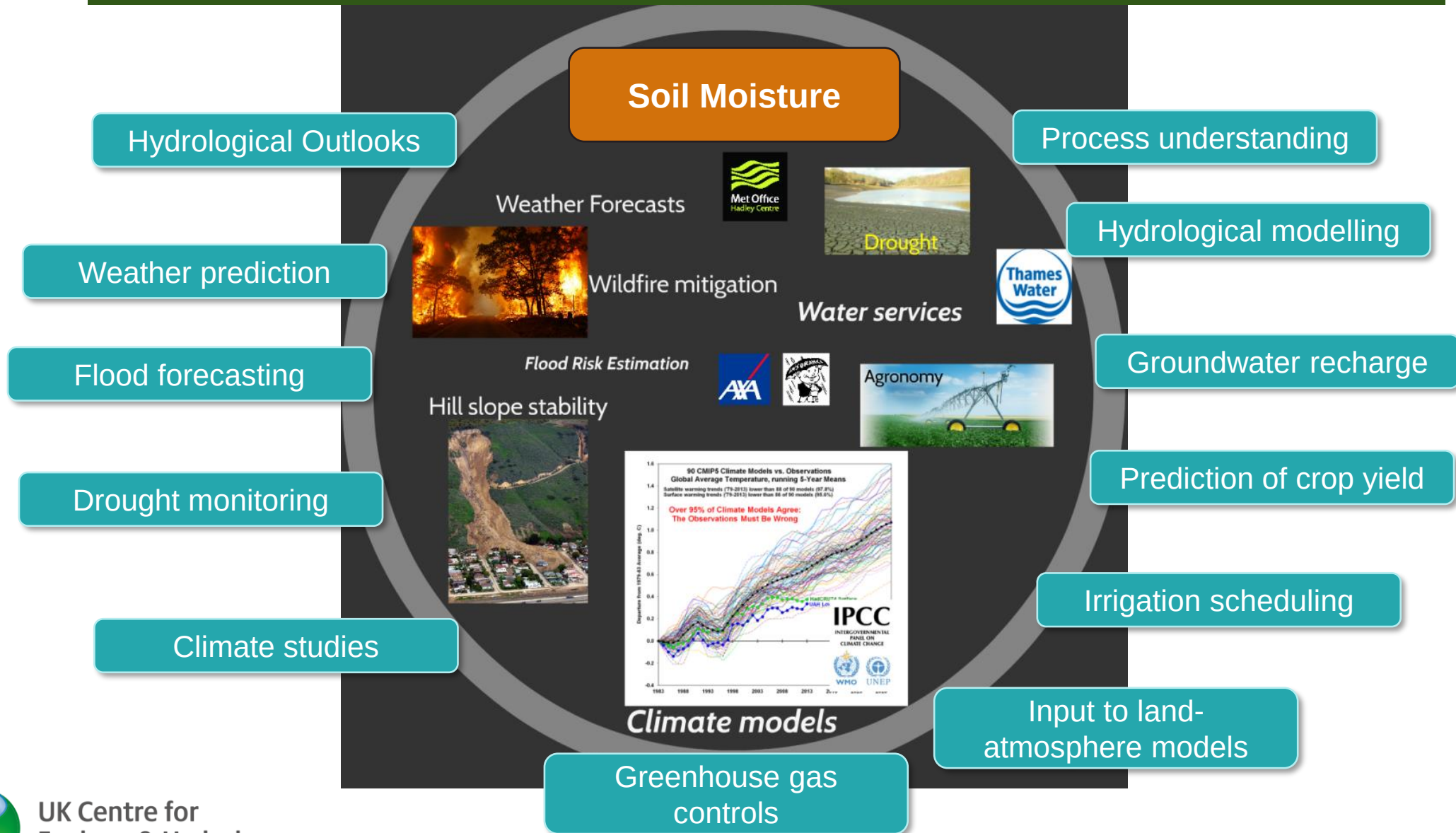
COSMOS-UK: Introduction

Aim: Delivering UK wide soil moisture and weather data using cosmic-ray neutron sensors (CRNS)

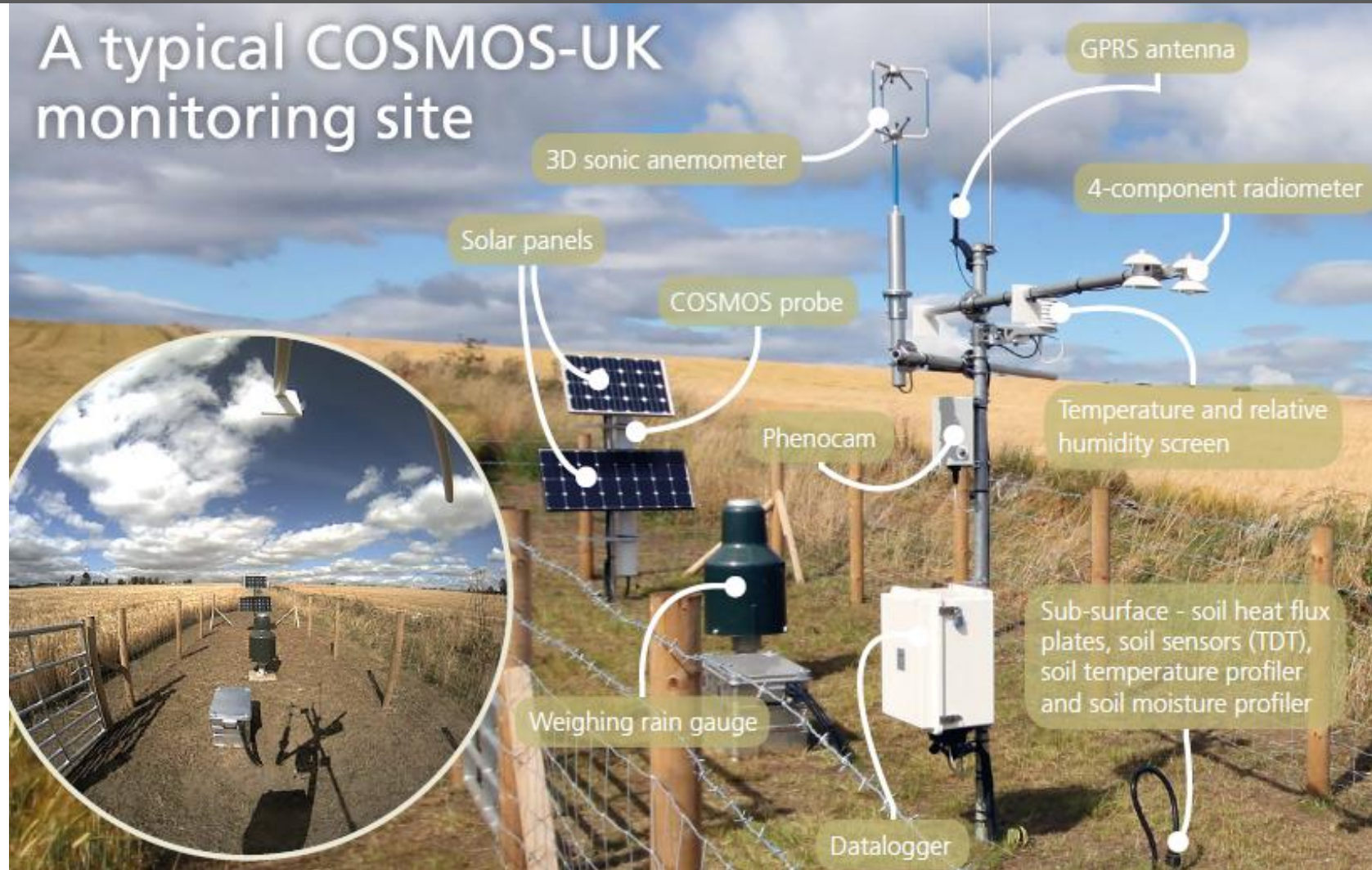
- 1) CRNS technology enables an **integrated measure of field-scale soil moisture** (up to 200 m footprint radius), averaging out soil heterogeneity.
- 2) CRNS **bridges the scale gap** between point and satellite measurements.
- 3) CRNS enabled the deployment of a **low-maintenance near real-time telemetered network**.



Applications for COSMOS-UK Data



COSMOS-UK: Site Instrumentation



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From: Cooper, H. M., et. al.(2021) "[COSMOS-UK: national soil moisture and hydrometeorology data for environmental science research](#)". Earth Syst. Sci. Data, 13, 1737–1757, doi: 10.5194/essd-13-1737-2021

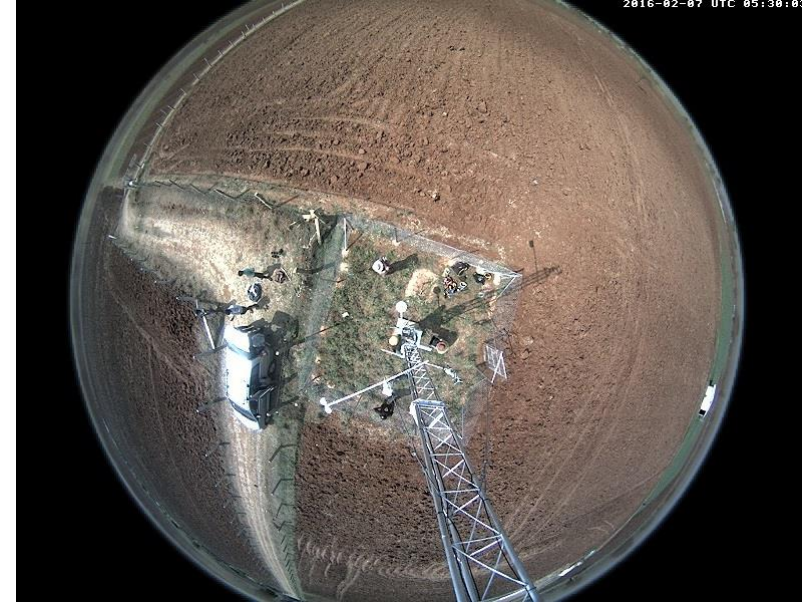
Point Sensor to Field Scale Soil Moisture



Acclima Time Domain Transmissometry (TDT) point soil moisture sensor (bottom left) & Soil heat flux plate (top right)

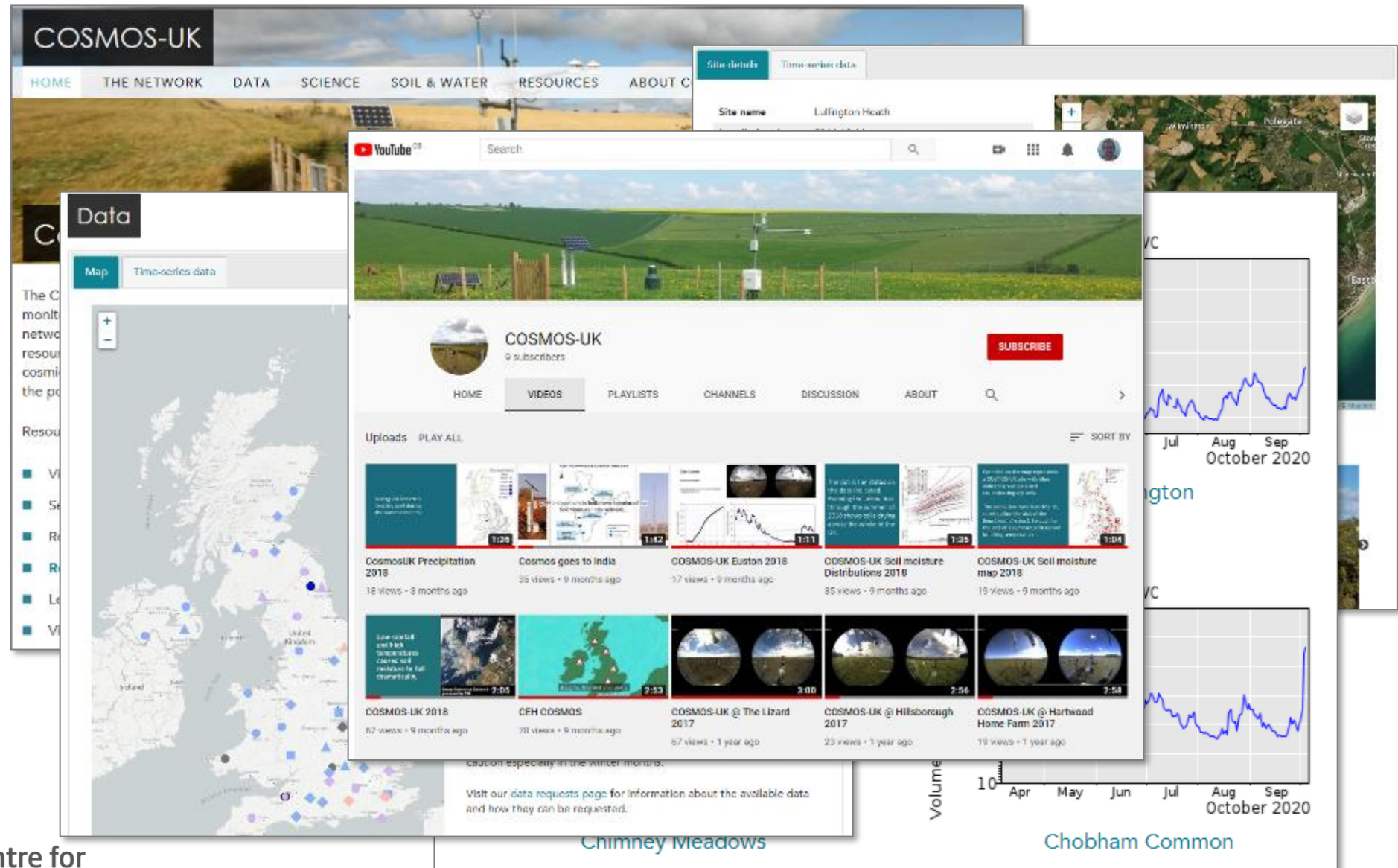


Cosmic Ray Neutron soil moisture Sensor (CRNS) or 'COSMOS' Probe – field scale measurement



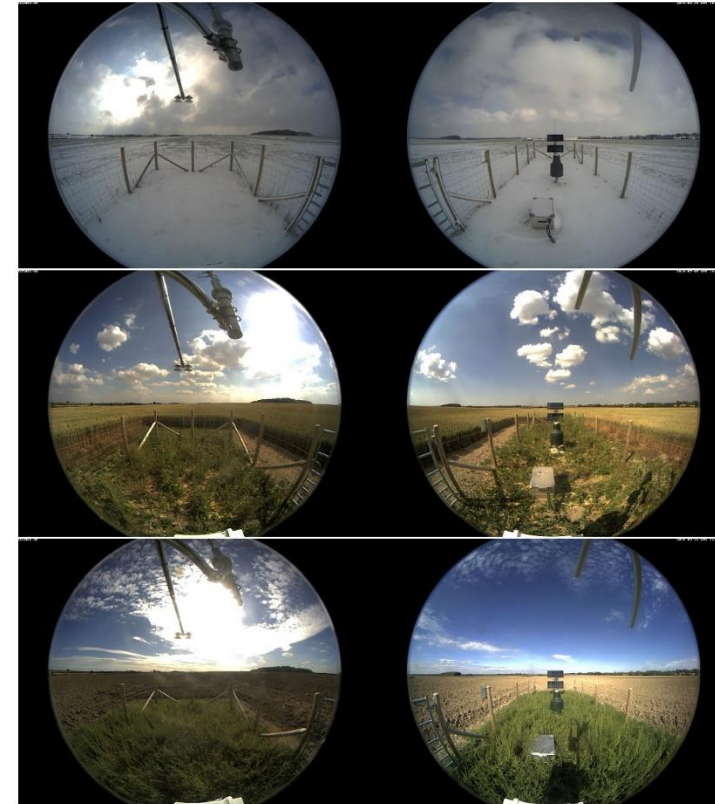
Above: Phenocam photo from Berambadi Eddy Covariance flux tower & COSMOS site, Karnataka, India
Shows approximate COSMOS 'footprint' or measurement area

COSMOS-UK website



COSMOS-UK: Hydrological Applications

- Several studies (e.g. Peng et.al. 2021) have compared JULES model and EO soil moisture with COSMOS-UK data.
 - Data Assimilation (DA)
 - Full model driving data available
 - Evaporation (PE & ET_a,) for water balance studies.
 - Land cover changes
 - Snow Water Equivalent
2021. Wallbank, J.R. et.al., 2021
Hydrological Processes, 35, e14048,
DOI: 10.1002/hyp.14048



Fincham COSMOS-UK PhenoCam, East Anglia.
Snow February 2018, rapeseed oil crop
July 2018, bare field in September 2018. From
Cooper et. al. 2021, Earth Syst. Sci. Data, 13,
1737–1757



Improved Pedo-transfer Functions via DA

Combining JULES with observations to improve soil moisture estimates

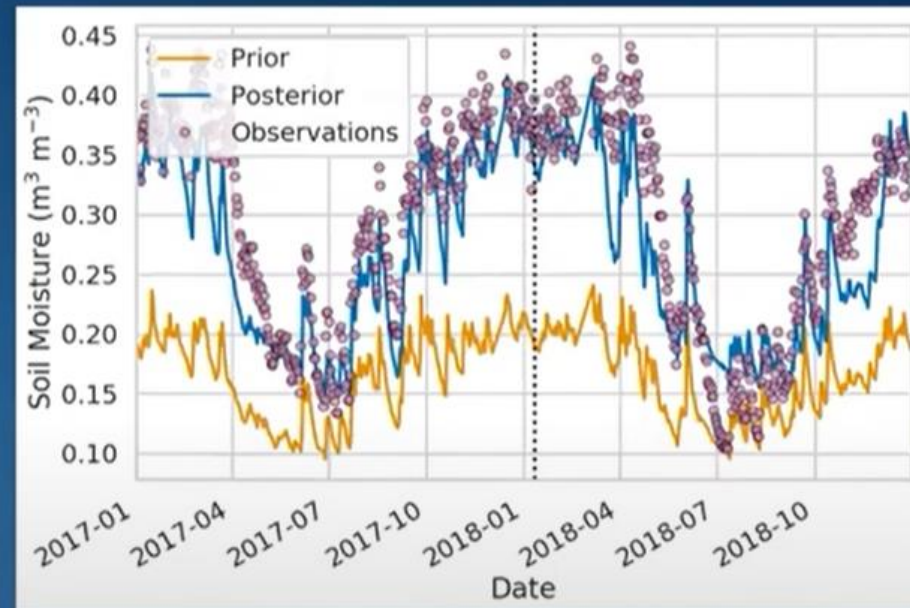
<https://www.youtube.com/watch?v=mxD0enCHq6E>

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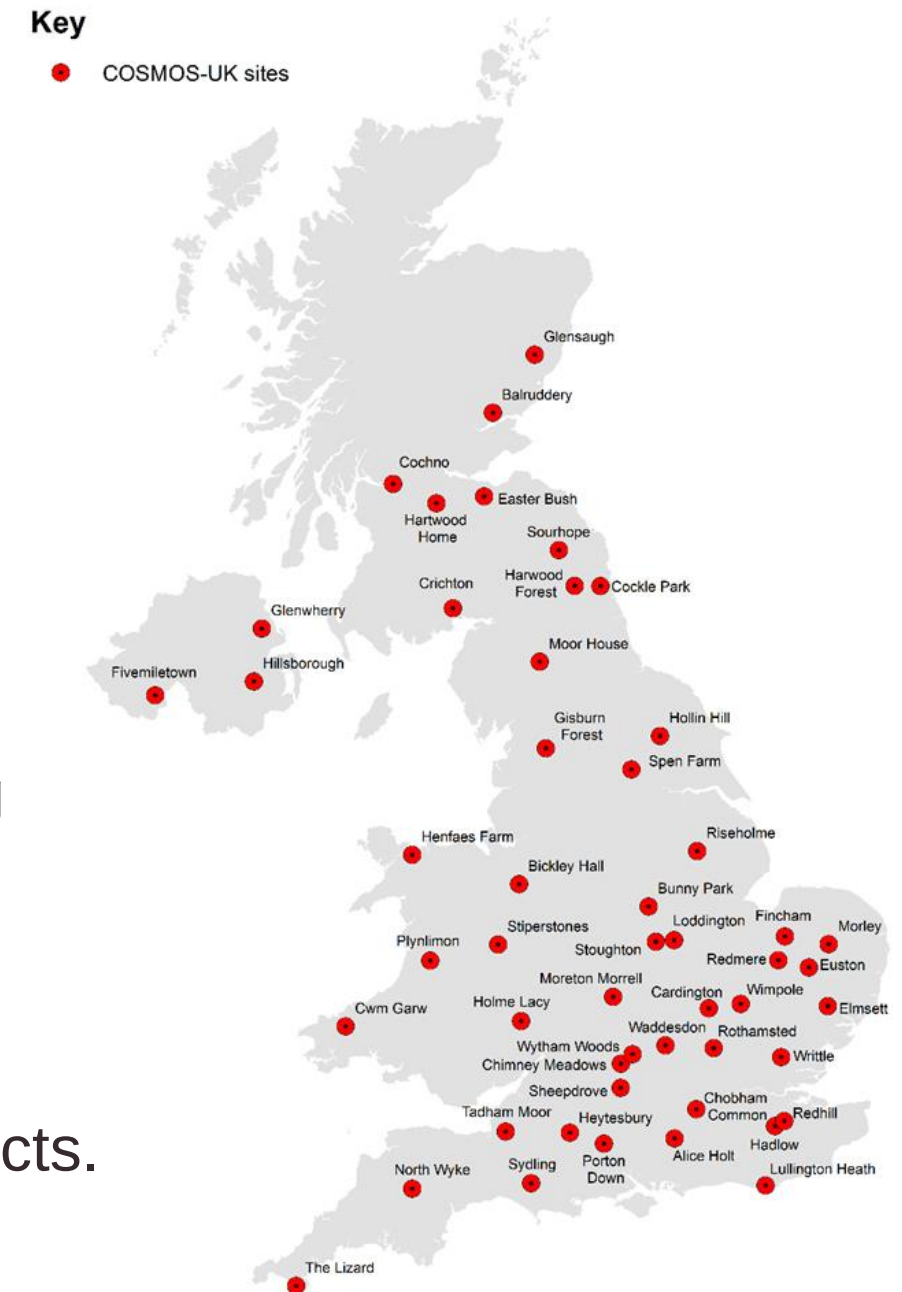


COSMOS-UK

2021. Cooper, E., Blyth, E., Cooper, H., Ellis, R., Pinnington, E., and Dadson, S. J., "[Using data assimilation to optimize pedotransfer functions using field-scale in situ soil moisture observations](#)". Hydrol. Earth Syst. Sci., 25, 2445–2458, doi: 10.5194/hess-25-2445-2021

Scalable Information

- UK wide coverage
Varying spatial density
- Sampling wide range
of climate, land cover, soils, geology and
topography
- Co-located with existing research / monitoring
where possible
- Calibration, validation, data assimilation &
machine learning are keys tools to leverage
COSMOS-UK data to improve gridded products.



Achieving Impact in Water, Climate, Space Weather...

- New insights and actionable information from observations.
- Policy & practitioner relevant operational soil moisture products.
- Attracts sustained funding supporting long-term networks.
- In turn drives innovation in water science & measurement technology

Future increases in soil moisture drought frequency at UK monitoring sites: merging the JULES land model with observations and convection-permitting UK climate projections

Magdalena Szczykulska* , Chris Huntingford , Elizabeth Cooper  and Jonathan G Evans 

Published 5 September 2024 • © 2024 The Author(s). Published by IOP Publishing Ltd

[Environmental Research Letters](#), Volume 19, Number 10

Land-Atmosphere Interactions Exacerbated the Drought and Heatwave Over Northern Europe During Summer 2018

Paul A. Dirmeyer , Gianpaolo Balsamo, Eleanor M. Blyth, Ross Morrison, Hollie M. Cooper

First published: 15 April 2021 | <https://doi.org/10.1029/2020AV000283> | Citations: 52

Detecting Ground Level Enhancements Using Soil Moisture Sensor Networks

A. D. P. Hands , F. Baird, K. A. Ryden, C. S. Dyer, F. Lei, J. G. Evans, J. R. Wallbank, M. Szczykulska, D. Rylett, R. Rosolem, S. Fowler, D. Power, E. M. Henley

First published: 14 July 2021 | <https://doi.org/10.1029/2021SW002800> | Citations: 4

Comparison of Met Office regional model soil moisture with COSMOS-UK field-scale in situ observations

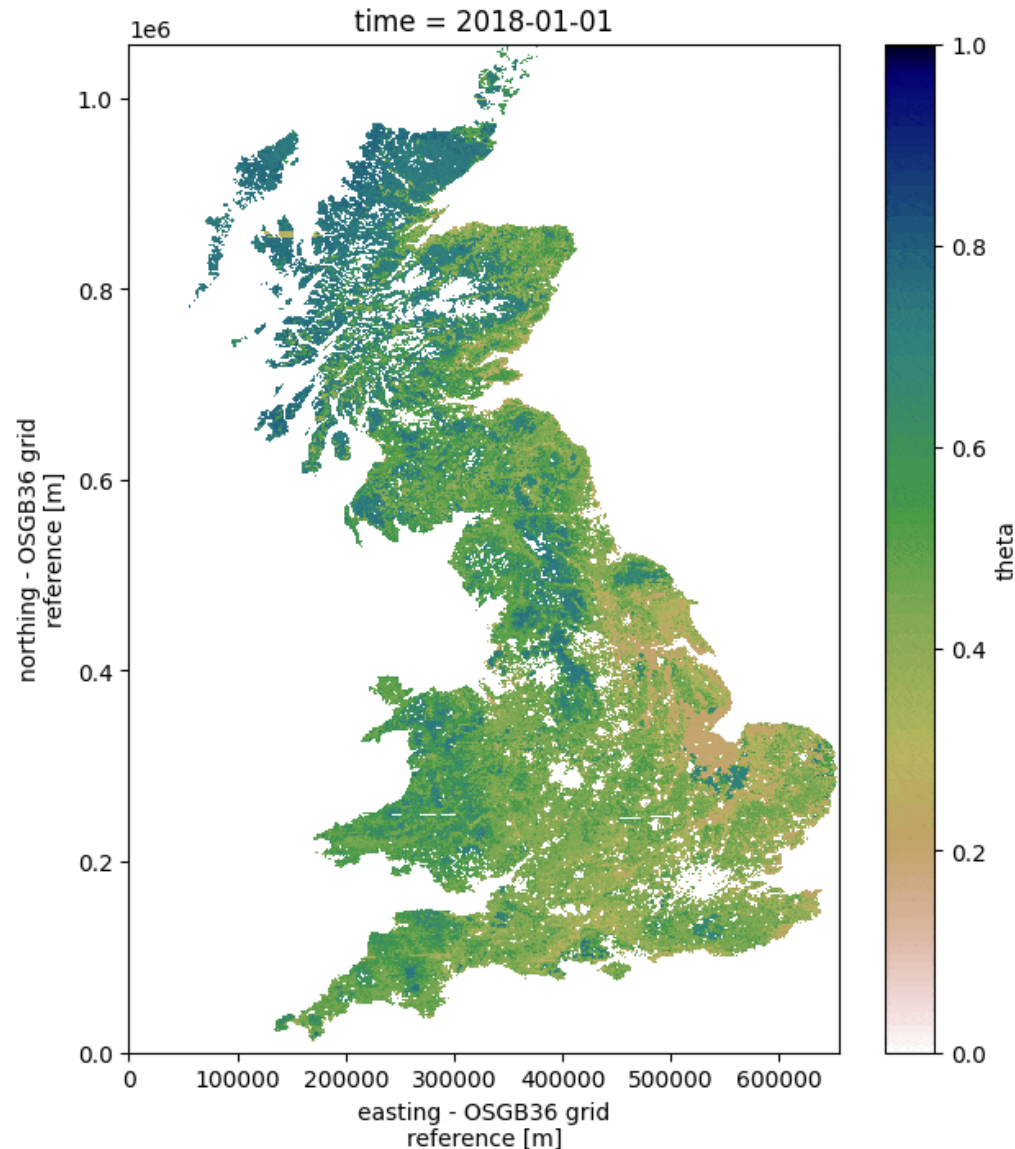
Elizabeth Cooper , Cristina Charlton-Perez, Rich Ellis

First published: 11 April 2024 | <https://doi.org/10.1002/asl.1236>

Daily 1 km Soil Moisture: 2018 Drought

Machine Learning Daily
Soil Moisture Map

Using many data inputs
including COSMOS-UK



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COSMOS-UK – Exemplary Accessible Data

1. COSMOS-UK website – view live data now:
<https://cosmos.ceh.ac.uk/data> & Use API



COSMOS-UK



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2. Download complete datasets from EIDC (data available from 2013 to end of 2023): <https://doi.org/10.5285/5060cc27-0b5b-471b-86eb-71f96da0c80f>



3. International Soil Moisture Network

Data is fully described and can be referenced via: "[COSMOS-UK: national soil moisture and hydrometeorology data for environmental science research](#)". Earth Syst. Sci. Data, 13, 1737–1757



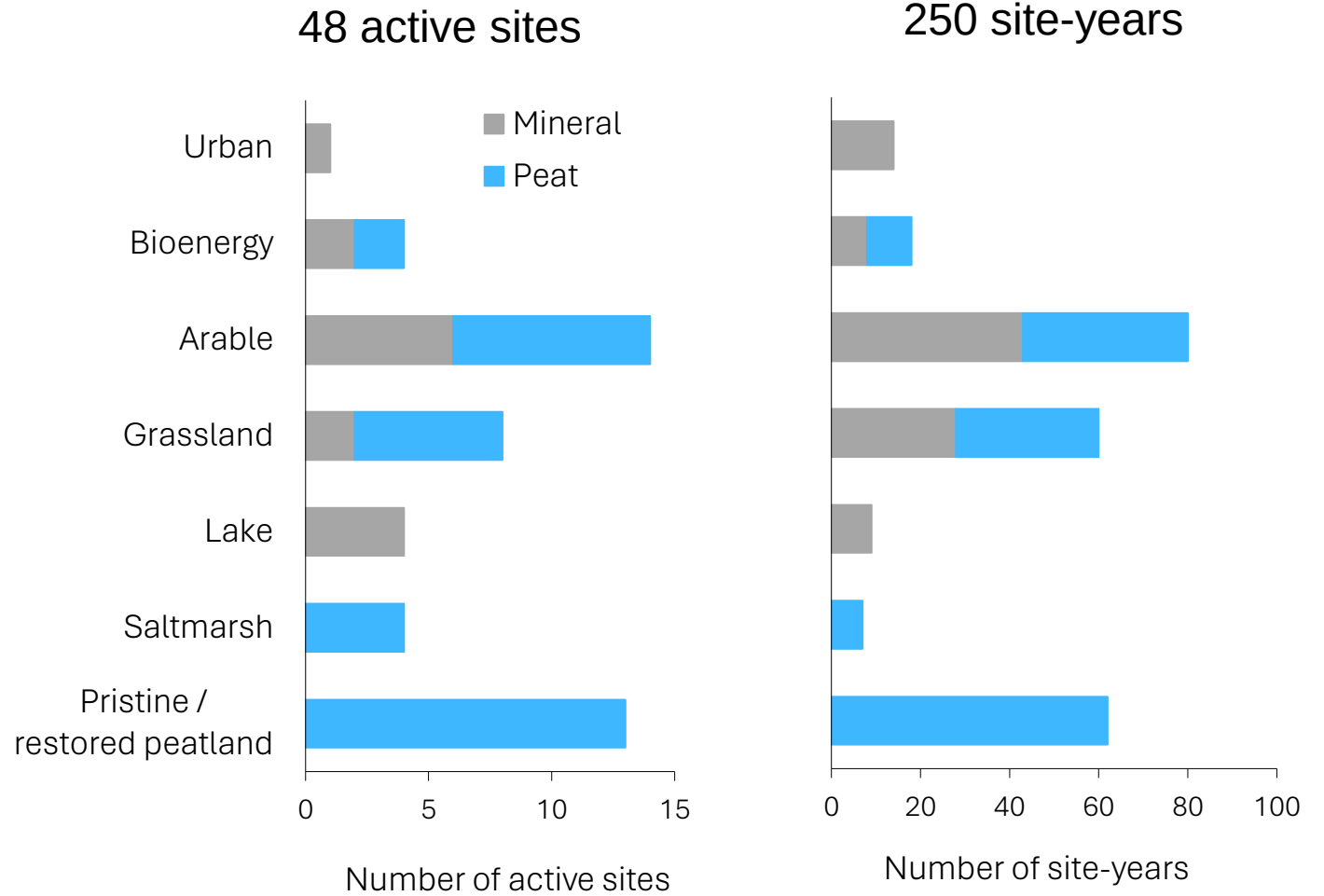
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NATIONAL CAPABILITY
FOR UK CHALLENGES

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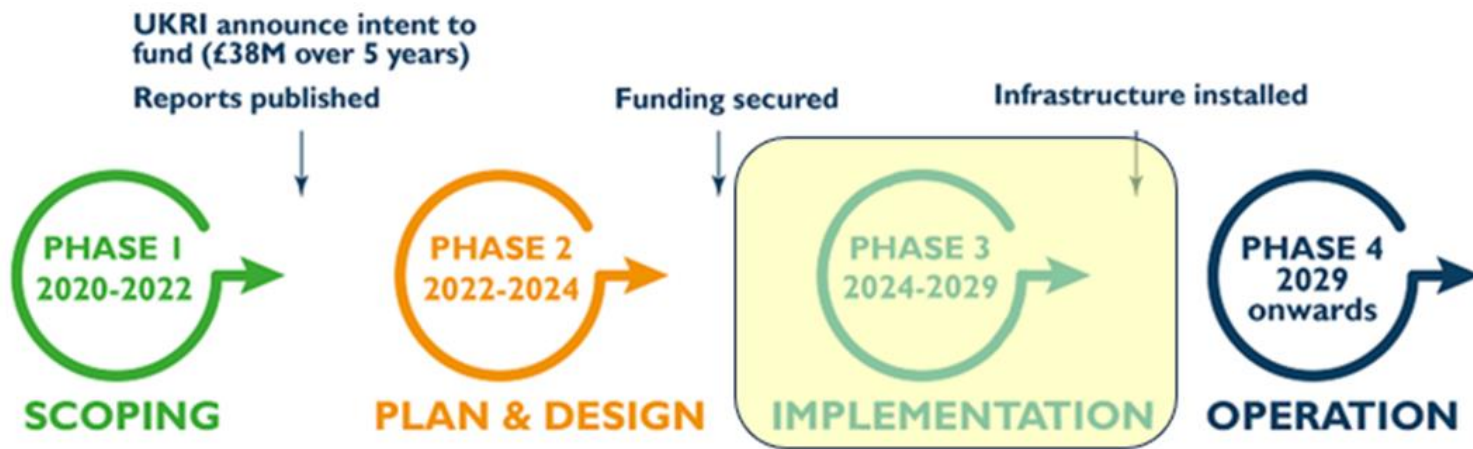


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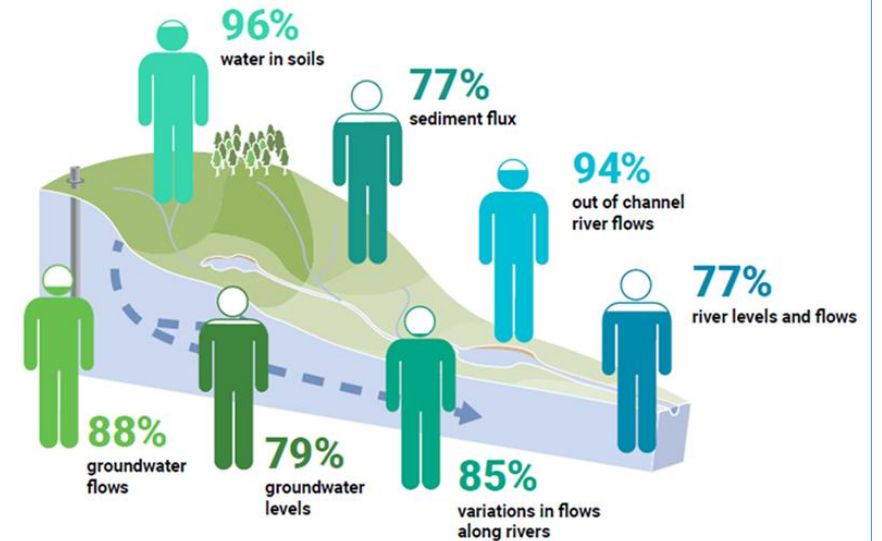
What is the Floods and Droughts Research Infrastructure (FDRI)?

The NERC-funded FDRI facility will provide open access to field- and digital-infrastructure for floods and droughts research.

An innovative whole system approach to catchment monitoring & landscape-scale investigations.

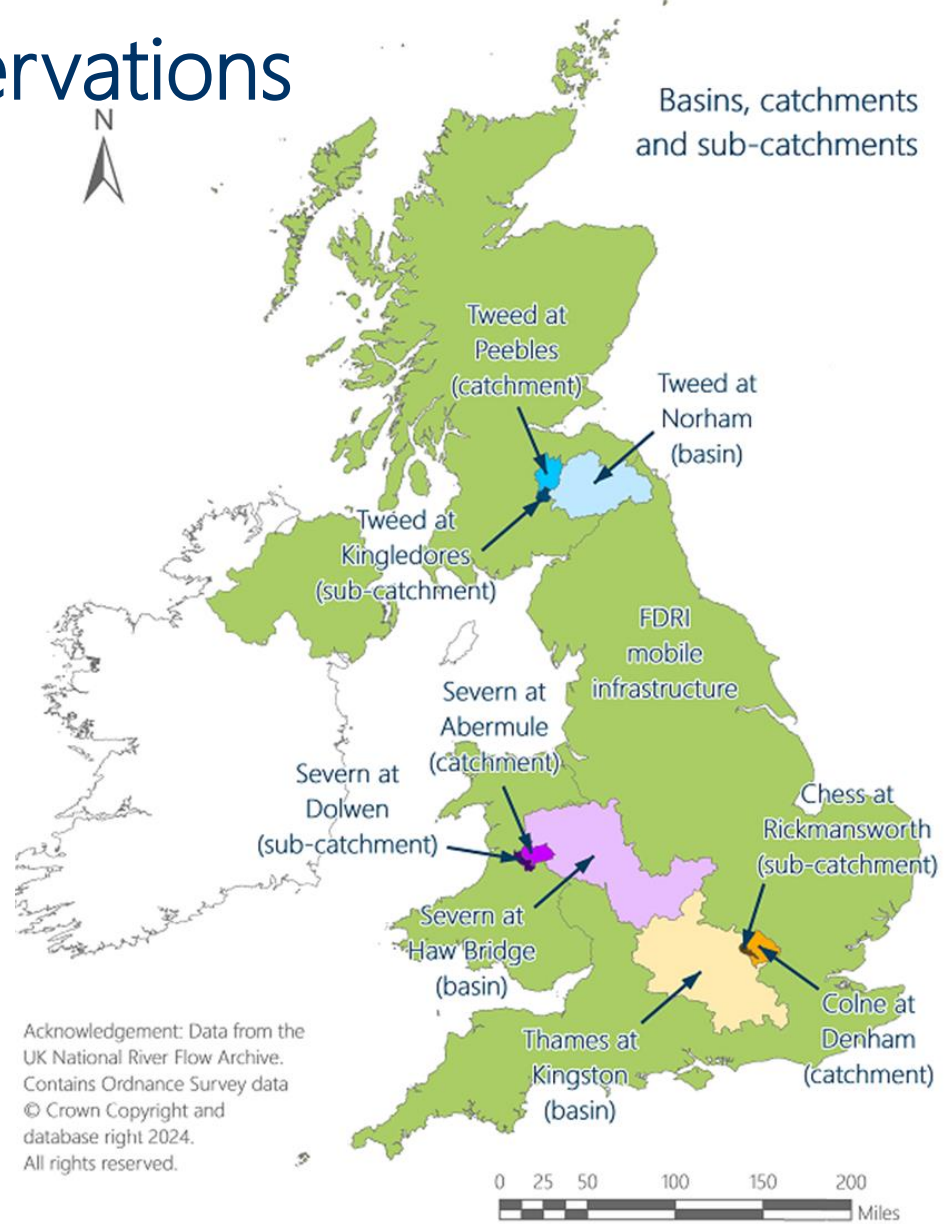
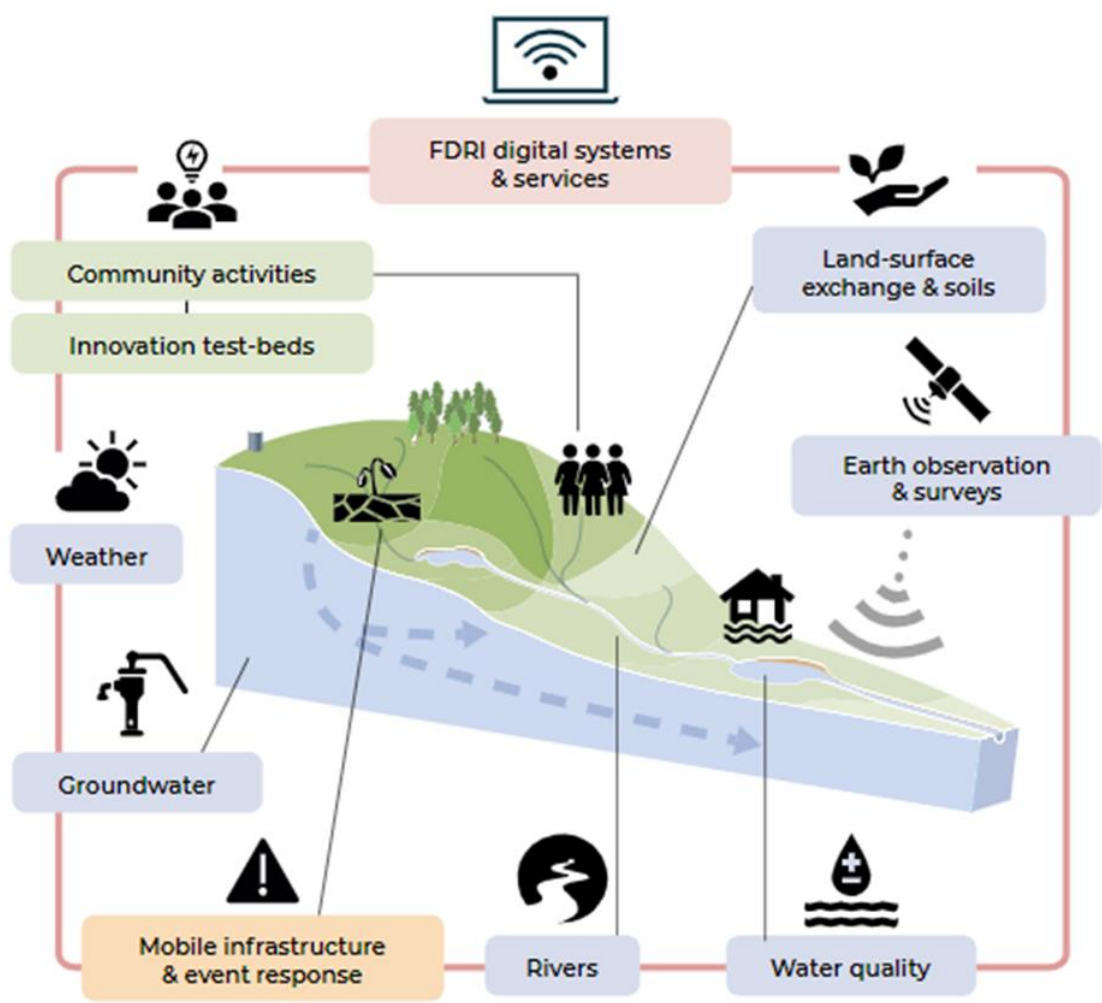


Request for more observations



- Full hydrological observations
- Large catchment monitoring
- > 100 km²
- Three catchments representative of the UK
- Open access data streams
- Open-air labs & testbeds

Need for new integrated observations



DIGITAL

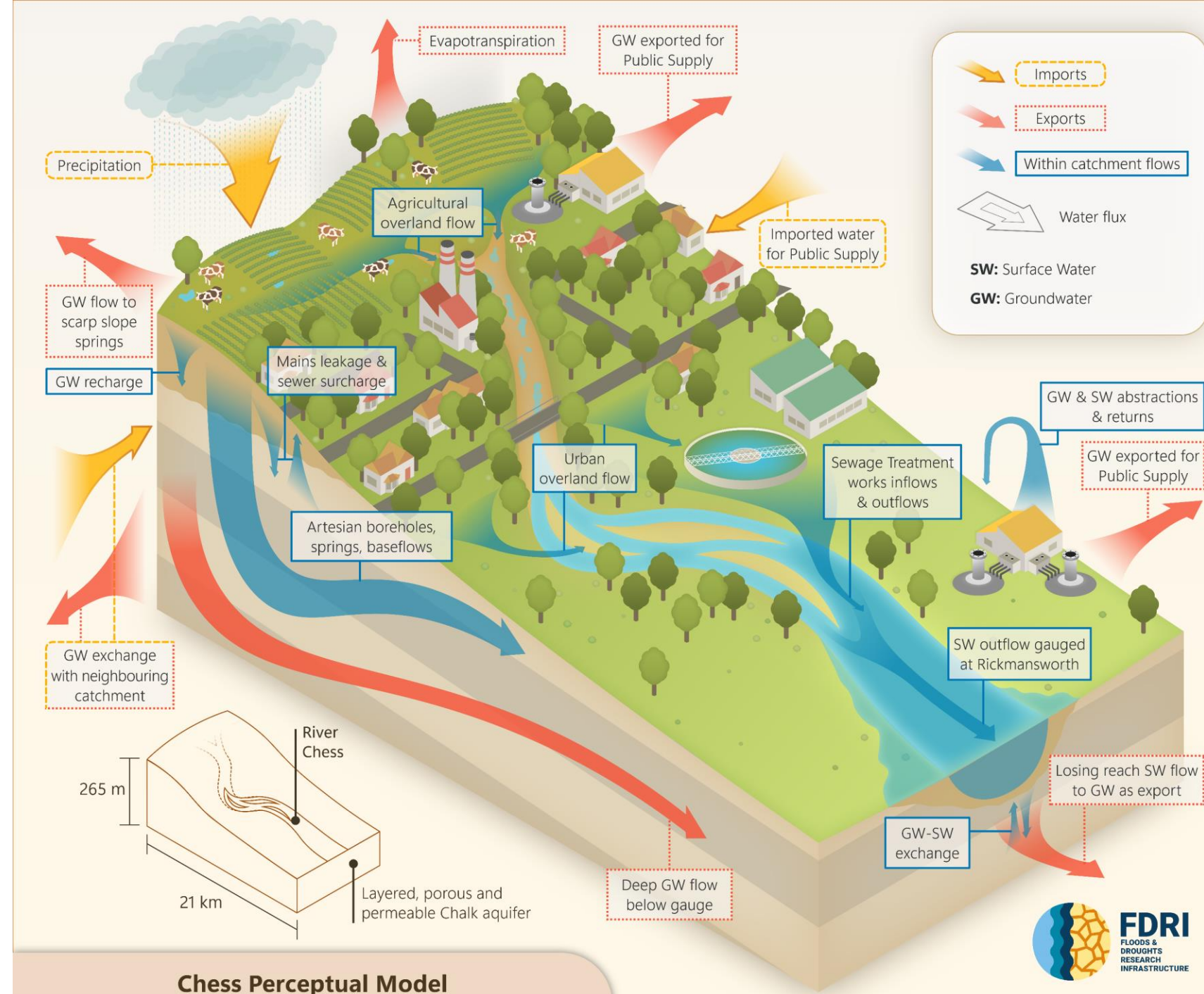
CAPACITY BUILDING

INNOVATION

Perceptual Model of Catchment – The River Chess

- Informs Catchment Monitoring Design
- New soil moisture and soil water tension sensors into deep chalk.
- New CRNS stations
- Full hydrological cycle monitoring including evapotranspiration.

Illustration created by Miranta Kouvari from Science Graphic Design



New tools for flood flow measurements

To measure flood flows with a drone....

Drone-readable gauge-boards in field?

Floodplain topography mapped with drone-mounted LiDAR

River bathymetry mapped with ADCP

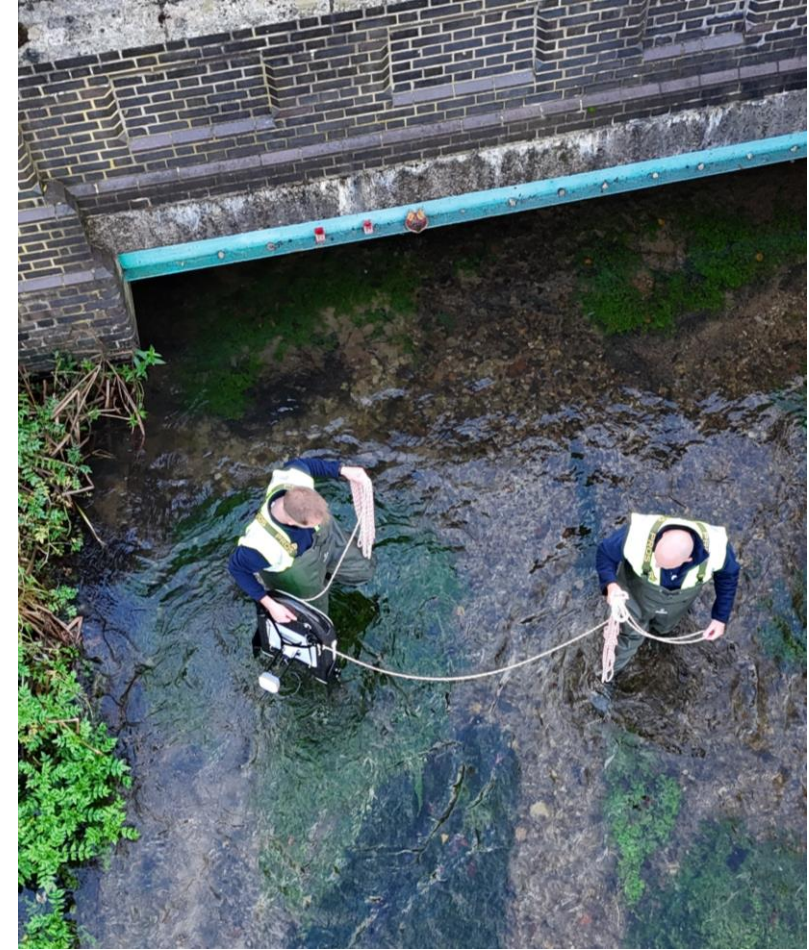


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The FDRI Vision

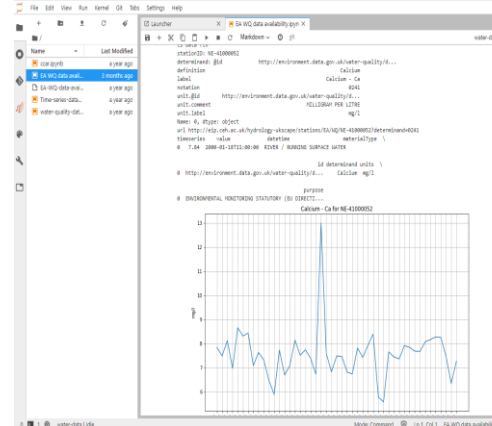
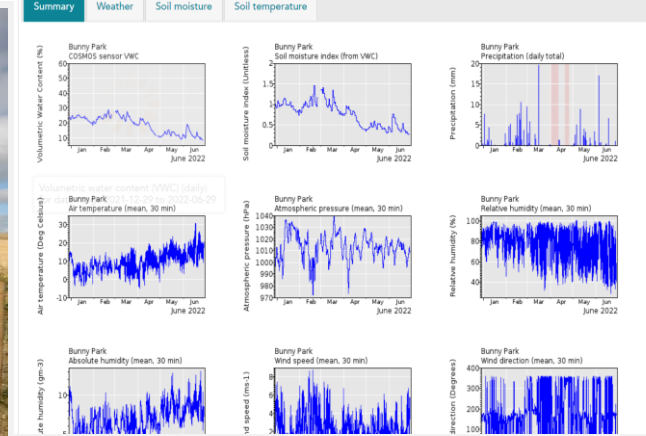
The FDRI facility will address contemporary issues in the water environment, such as:

- Solutions to mitigate the effects of climate change on flooding & water shortage.
- Water pollution problems and viable solutions.
- Valuing Blue-Green infrastructure.
- Improving flood forecasts.
- Water solutions for food, energy and nature.
- Maximising digital systems to manage water.



FDRI Digital Objectives

- Delivering new FDRI monitoring data
 - Exemplar of gold standard sensor data management
- Enhancing access to existing hydrological data
 - Exemplar of community data commons, providing new research opportunities
- Providing platforms for data-driven hydrological research
 - Infrastructure to change the way data-driven research is undertaken
- Supporting the community
 - Creating the next generation of digital-first hydrologists



Acknowledgements – UKCEH staff past and present

Josh Alton, Vasileios Antoniou, Anne Askquith-Ellis, Sarah Bagnoli, Lucy Ball, Emma Bennett, James Blake, David Boorman, Milo Brooks, Sandie Clemas, Michael Clarke, Nick Cowan, Hollie Cooper, Liz Cooper, Alex Cumming, Louisa Doughty, Jonathan Evans, Phil Farrand, Matthew Fry, Jane Gilbert, Susie Griffin, Duncan Harvey, Ned Hewitt, Olivia Hitt, Tom Holburn, Helen Houghton-Carr, Tim Howson, Chris Hutchinson, Alan Jenkins, Guillermo Jiménez Arranz, Yvonne Keen, Doran Khamis, Ezra Kitson, Filip Kral, Jeremy Libre, William Lord, Colin Roberts, Ross Morrison, Gemma Nash, Felicity O'Callaghan, Matthew Parkes, Jo Newcomb, Gwyn Rees, Nick Reynard, Dan Rylett, Peter Scarlett, Andrew Singer, Richard Smith, Phil St Quintin, Simon Stanley, Oliver Swain, Magdalena Szczykulska, Simon Teagle, Jenna Thornton, Emily Trill, Helen Vincent, Phil Vincent, John Wallbank, Helen Ward, Alan Warwick, Ben Winterbourn, George Wright.



Thank You

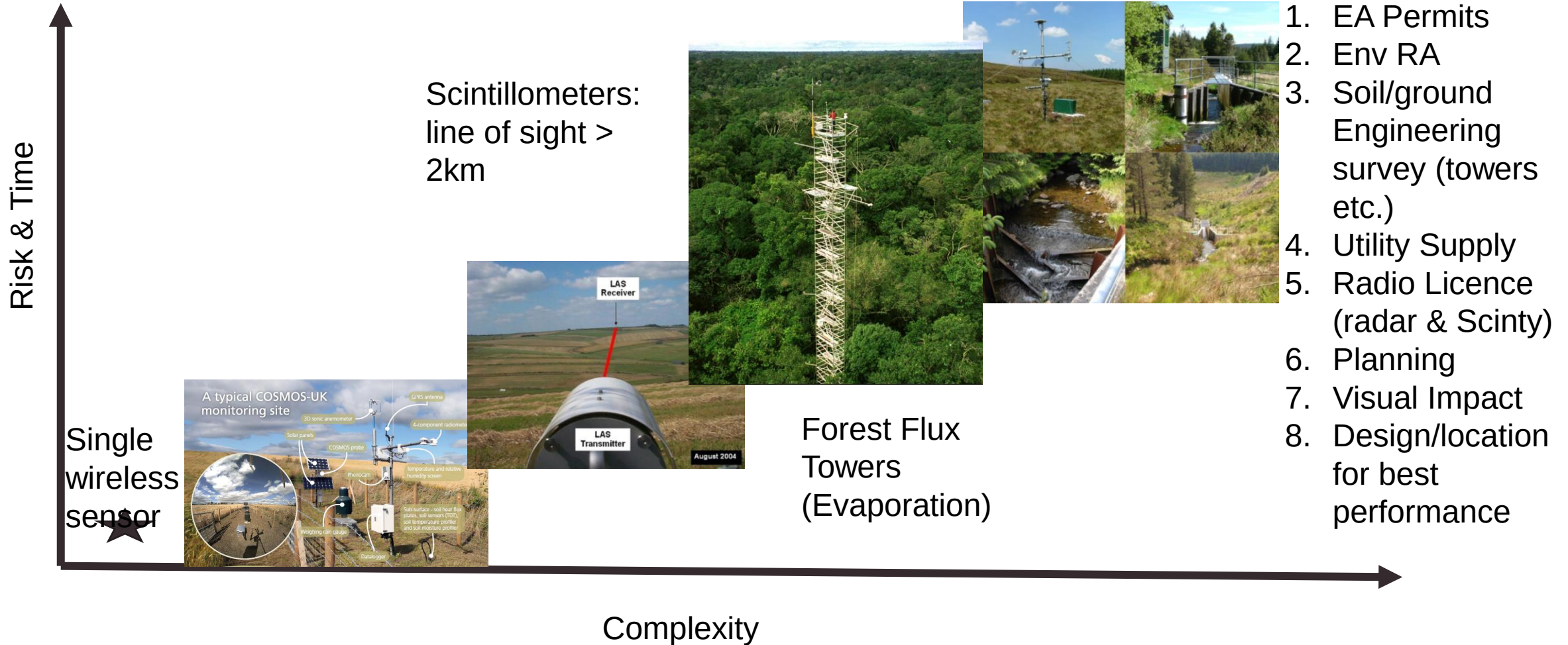
Any questions?



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Site Types for FDRI



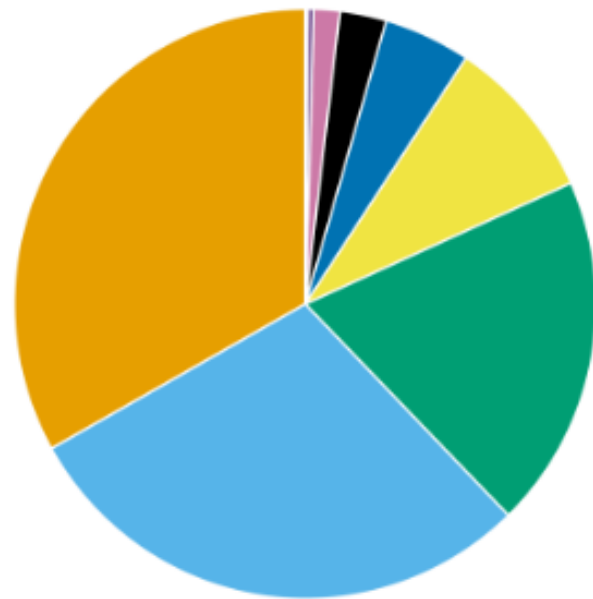
ISMN COSMOS-UK Download Statistics for July to December 2024



COSMOS-UK download requests for the last 6 months = **1,478**

Download requests for all time (beginning 2023) = **4,547**

Percentages of download requests by area of GEO societal benefit (July 01, 2024 - December 31, 2024)



Orange	Agriculture (33.2 %)
Light Blue	Water (29.1 %)
Green	Climate (19.4 %)
Yellow	Ecosystems (9.0 %)
Dark Blue	Disasters (4.8 %)
Black	Weather (2.6 %)
Pink	Biodiversity (1.4 %)
Purple	Energy (0.3 %)
Dark Purple	Health (0.1 %)



EO & Gridded Model Applications

Triple co-location to evaluate and merge soil moisture products.

Essentially operating in *comparison mode*, for example:
Validation of Spaceborne and Modelled Surface Soil
Moisture Products with Cosmic-Ray Neutron Probes

Carsten Montzka, Heye Bogena, Marek Zreda, Alessandra Monerris, Ross Morrison, Sekhar Muddu and Harry Vereecken
Remote Sensing. **2017**, 9(2), 103; doi:[10.3390/rs9020103](https://doi.org/10.3390/rs9020103)

“the Rur catchment in Germany, the COSMOS sites in Arizona and California (USA), and Kenya, one CosmOz site in New South Wales (Australia), and a site in Karnataka (India).”

Peng J. et. al. 2021, Estimation and evaluation of high-resolution soil moisture from merged model and Earth observation data in the Great Britain. *Remote Sensing of Environment*, 264

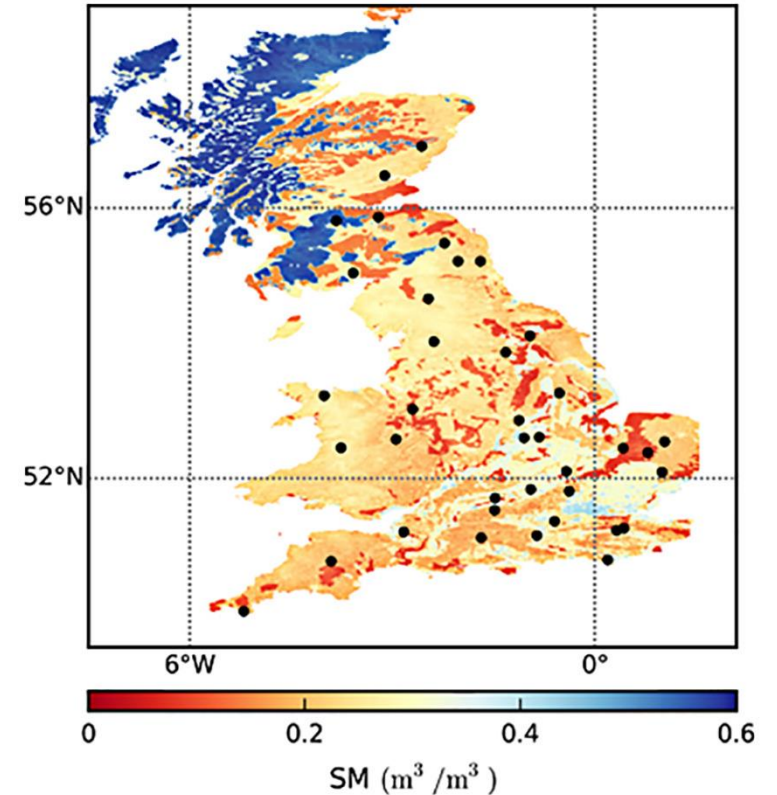


Fig. 1. Distributions of 38 COSMOS-UK stations used in this study. The base map is the spatial pattern of simulated soil moisture from JULES-CHESS on 2015.04.22.

The Scale Matching Issue

Need for measurement standards and traceability in soil moisture observations: Euramet Project Soil Moisture Metrology (SoMMet)

<https://www.sommet-project.eu/home>

Harmonisation of measurement scales both spatial and temporal.

For EO shallow satellite observations can be better matched via modelling – Beale *et al.* 2021

Modelling top 2 to 5cm of soil moisture gives faster response time and appropriate depth matching for EO comparison.

- Current research on horizontal scale matching / harmonisation in SoMMet.



Acclima Time Domain Transmissometry (TDT) point soil moisture sensor (bottom left) & Soil heat flux plate (top right)

J. Beale, T. Waine, J. Evans and R. Corstanje, "A Method to Assess the Performance of SAR-Derived Surface Soil Moisture Products," in IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 14, pp. 4504-4516, 2021, doi: [10.1109/JSTARS.2021.3071380](https://doi.org/10.1109/JSTARS.2021.3071380)