NFM Webinar 15/04/21

University of Reading

LANDWISE NFM

# Improving Soil Moisture Estimation Using Space Radar

Dr. Will Maslanka, Prof. Keith Morrison, Dr. Kevin White

UKRI Natural Environment Research Council

## Presentation Outline

LANDWISE Project: Place of Remote Sensing

Space Based Radar Remote Sensing

Space Based Soil Moisture Observations

Linking back to NFM

# LANDWISE Project

LANDWISE: **LAND** management in lo**W**land catchments for **I**ntegrated flood ri**S**k r**E**duction

*Overarching Research Questions*

a) How effective are different land-based NFM measures at increasing infiltration, evaporative losses and below-groundwater storage in different locations across lowland catchments?

b) How does the effectiveness of land-based measures vary seasonally and between years with respect to antecedent conditions, precipitation magnitude and duration?

c) How effective are land-based measures at delivering catchment-wide water storage and infiltration, and thereby reducing runoff rates, compared to targeted approaches to reduce downstream flood (and drought) risk across different catchment scales (<100-8000km$^2$)?

# LANDWISE Project

LANDWISE: **LAND** management in lo**W**land catchments for **I**ntegrated flood ri**S**k r**E**duction

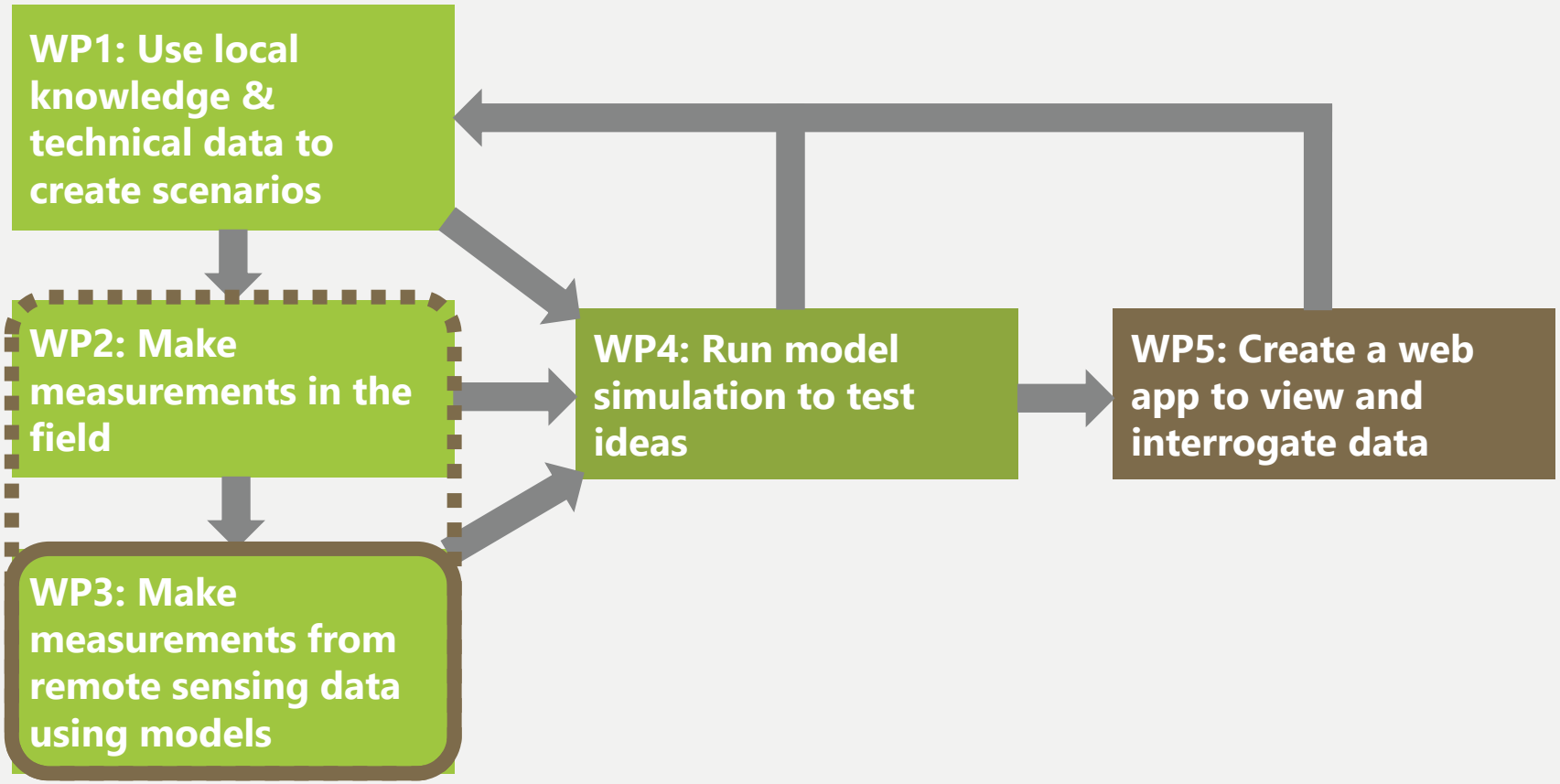
*Overarching Research Questions (Simplified)*

a) How effective are different land-based NFM measures at keeping water out of the river?

b) How does that effectiveness vary?

c) How effective are they at reducing flood risk across different catchment scales?

# LANDWISE Project




WP6: Project management and sharing knowledge

# Remote Sensing - Radar

WP3 uses RADAR as it's primary remote sensing method


RADAR echo (or **backscatter, σ°**) is a measure of returned signal.

Can be used to obtain information about an object.

- Speed of a moving car.
- Detecting aircraft.
- Amount of rain falling.
- In the case of LANDWISE, the soil moisture of the ground.

# Remote Sensing - Radar

Water in the soil affects the dielectric constant of the soil

- Dielectric constant effectively determines the electrical properties of soil and strongly influences the intensity of the Radar backscatter coefficient, σ°.

By measuring σ° over a time period, we can estimate **relative soil moisture**, if we have a "wet" and "dry" reference σ°.

- Taken by finding the largest and smallest σ° values in the time series.

By measuring σ° AND surface roughness for a single observations, we can estimate the **absolute soil moisture**.

- By using RADAR backscatter models.

# Space Based RADAR

Sentinel 1 Constellation
- Sentinel 1A launched 2014
- Sentinel 1B launched 2016

Strict 6 day repeat cycle
- 175 orbits per cycle

Dependable viewing geometry and spatial coverage

Frequency: 5.405 GHz

Resolution: 20 x 22m

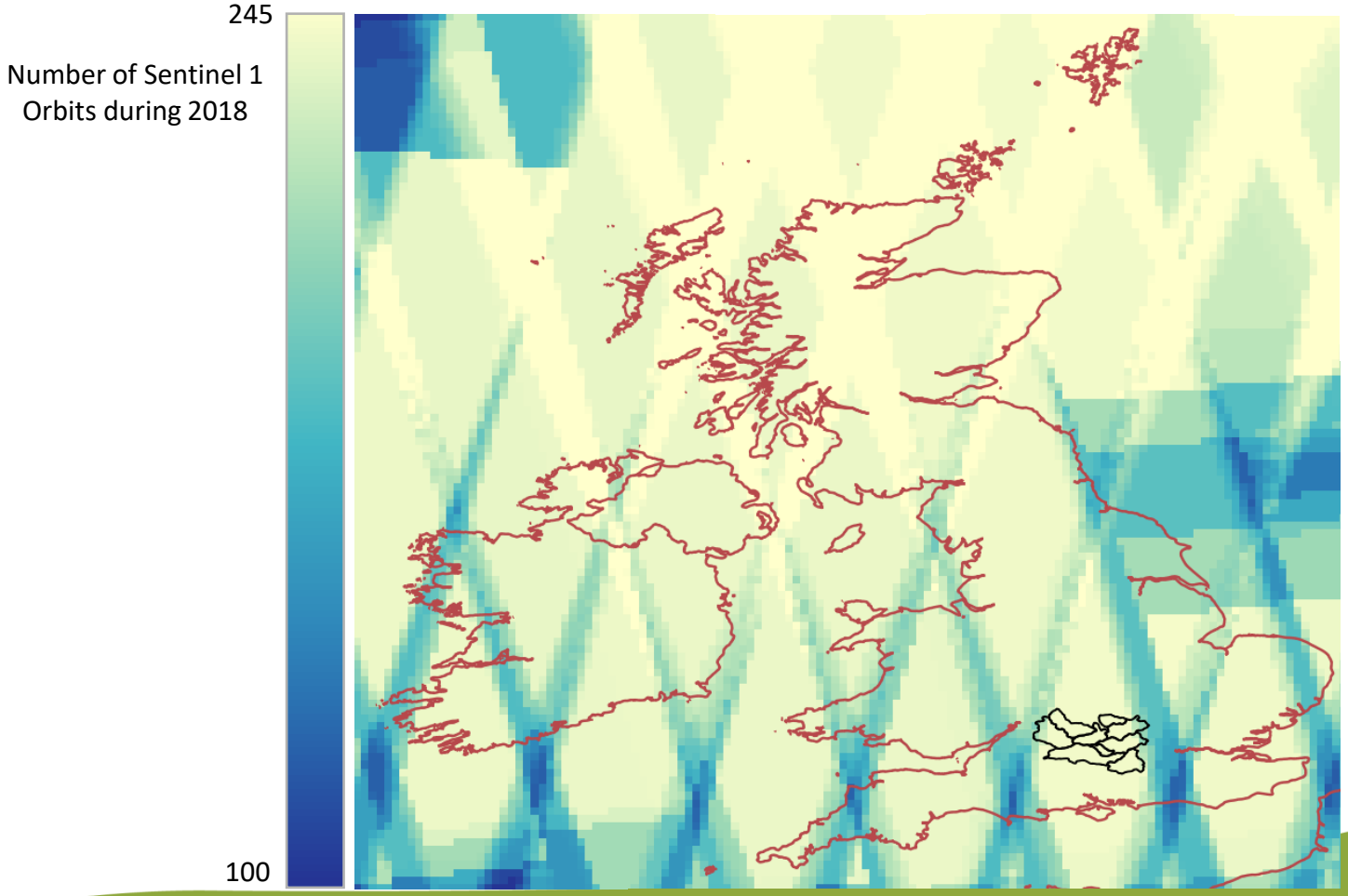

Artists Rendition of Sentinel 1 Satellite in orbit.

Image courtesy of ESA.

More information about Sentinel 1 at www.sentinels.copernicus.eu

# Space Based RADAR

## Coverage over the Thames Basin



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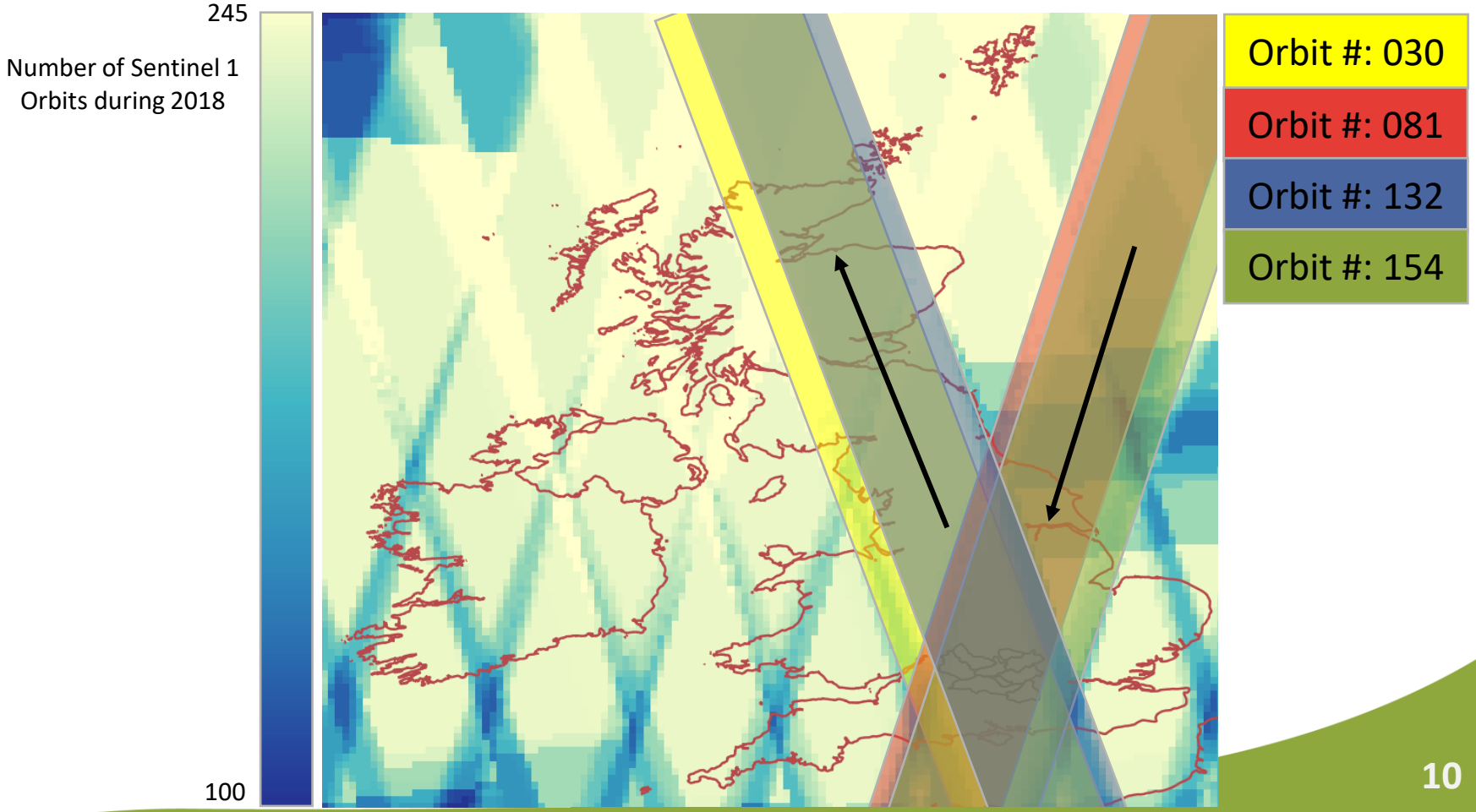

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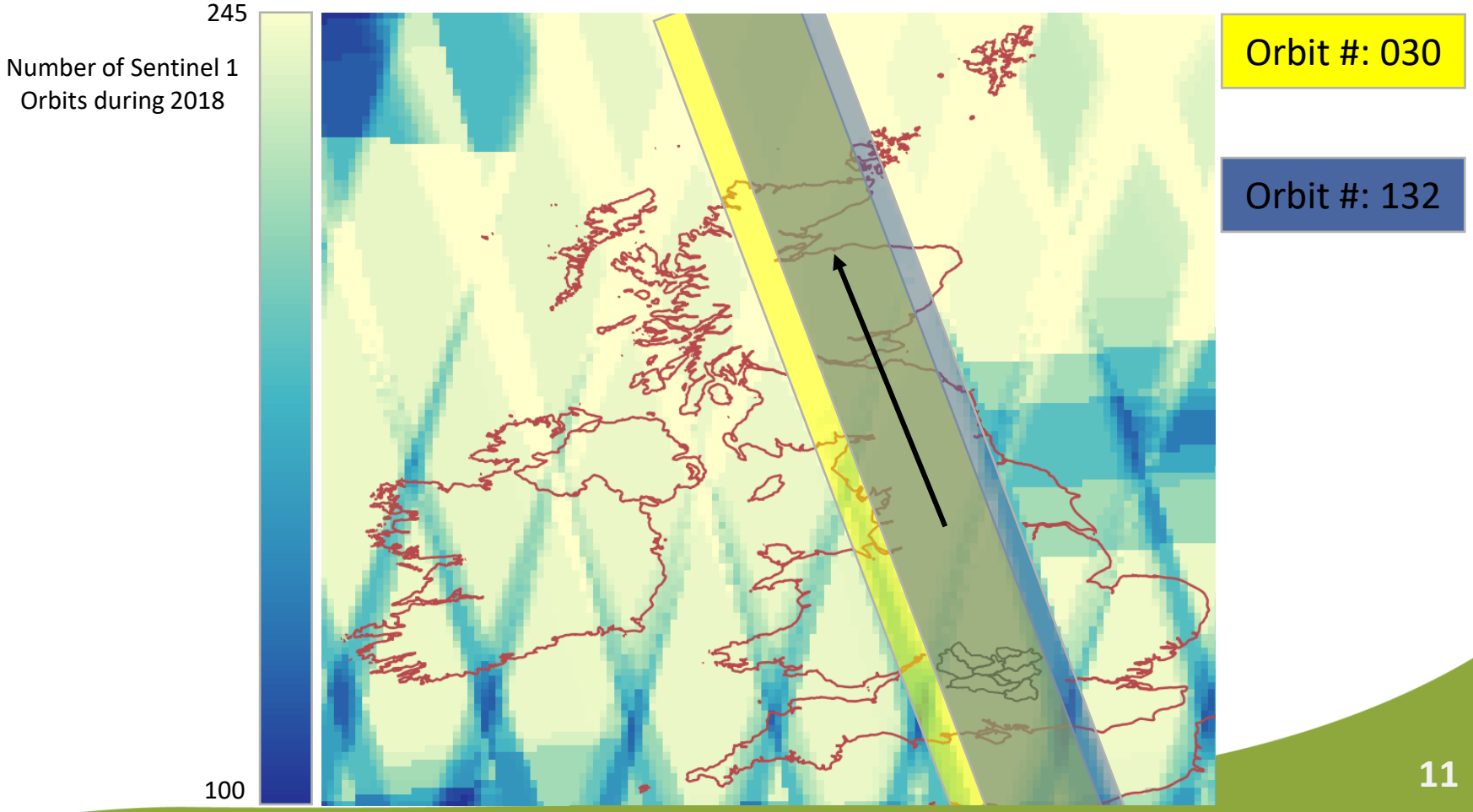

# Space Based RADAR

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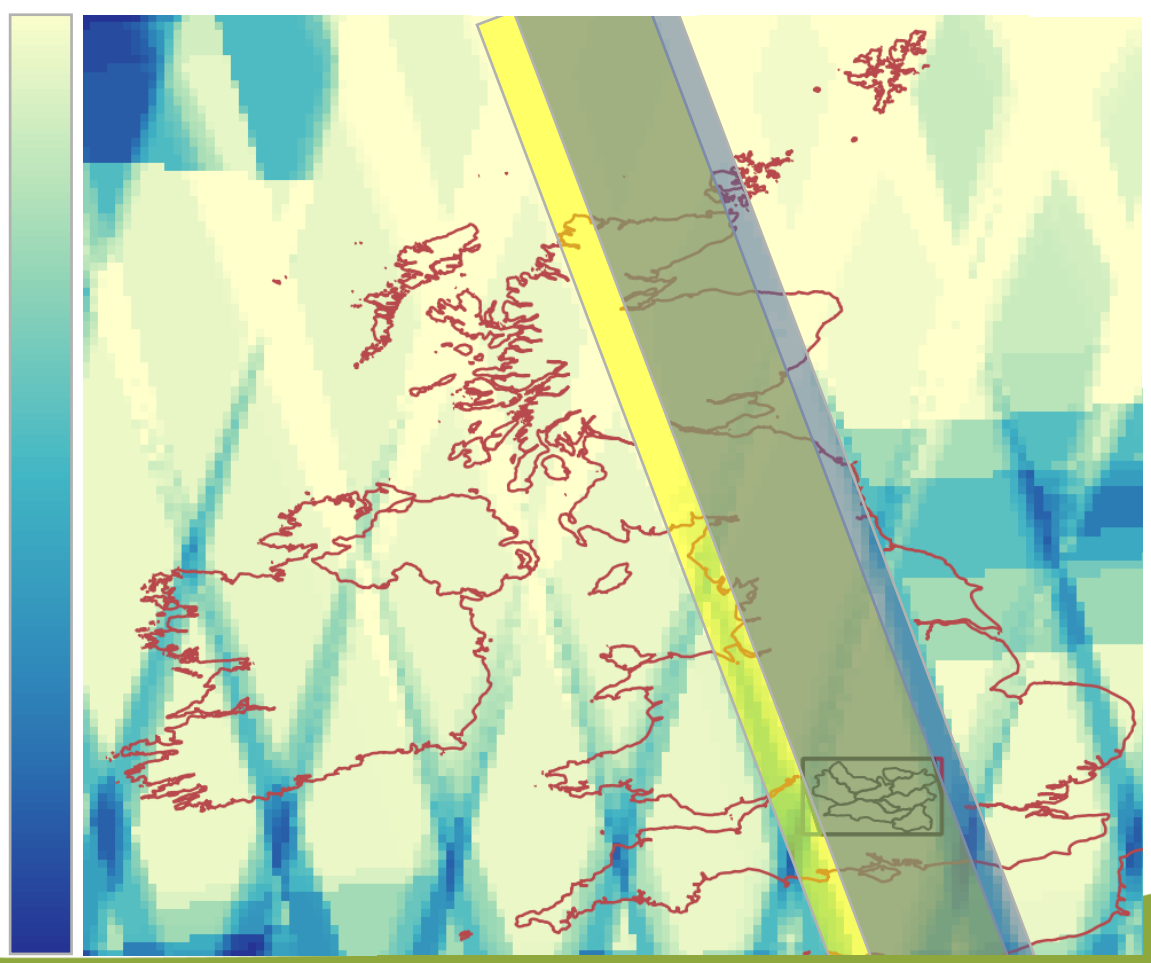
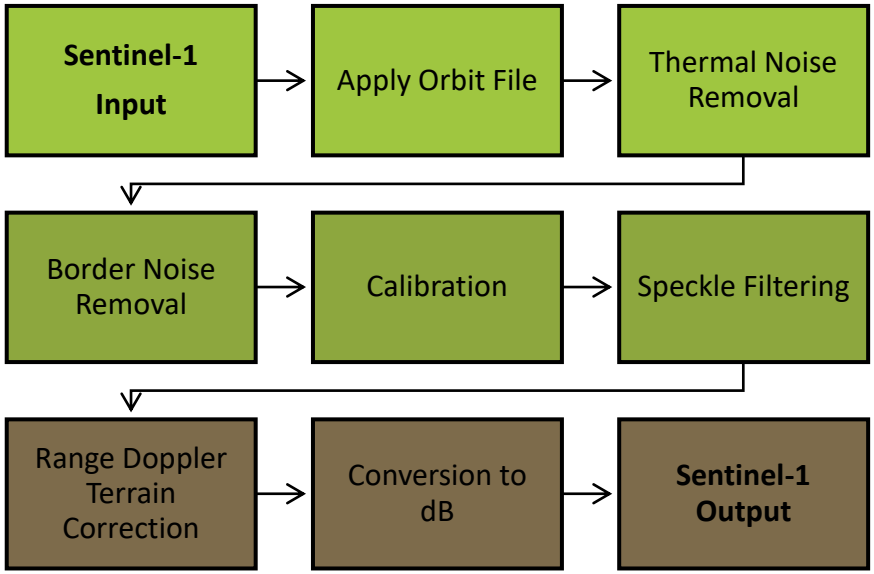


# Space Based RADAR

Not a matter of just looking at the raw data from the Satellite.

Data needs to be processed to remove a number of artifacts.

Processing follows the layout proposed by Filipponi (2019).

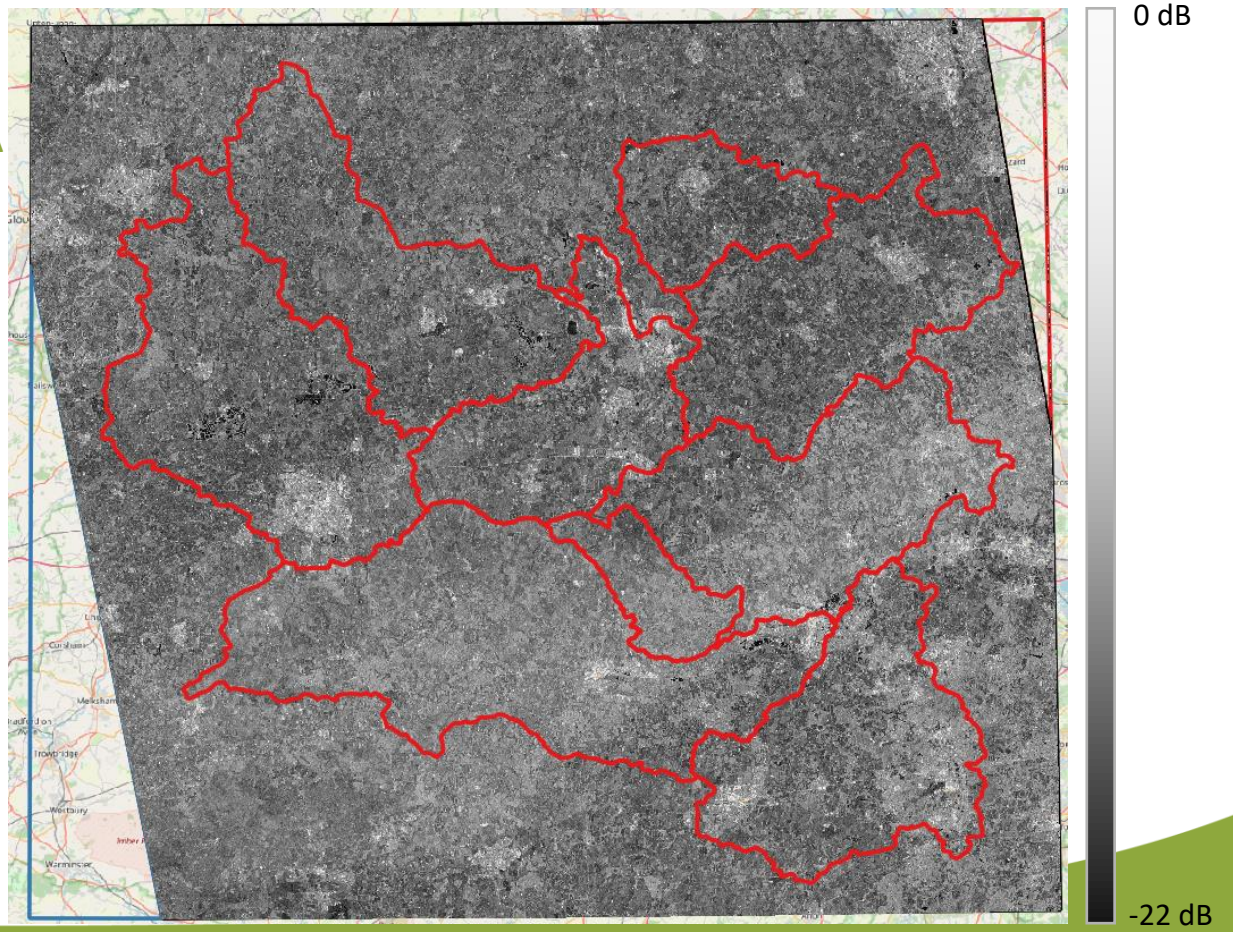



F. Filipponi., "*Sentinel 1 GRD Preprocessing workflow*" in *Proceedings*, vol., 18 iss. 11, pp. 1-4, Jun. 2019.

# Space Based RADAR

Once processing is complete, creates images like this…

11/09/18
17:50
Sentinel 1A
Orbit 132
VV



# Space Based Soil Moisture Observations

Having repeat measurements of $\sigma^o$, we can compare a single scene against the largest* and smallest* backscatter values, assuming that they correspond to the driest and wettest soil values.

*don't actually use the largest and smallest, but use a statistical method to remove outliers.

Use simple formula to estimate relative surface soil moisture

TU Wien backscatter model for Sentinel 1 (Hornacek et al. 2012)

- Adapted from original model (ERS scatterometer – Wagner et al. 1999)

$$m_s(t) = \frac{\left(\sigma^o(40,t) - \sigma_d^o(40)\right)}{\left(\sigma_d^o(40) - \sigma_w^o(40)\right)}$$

M. Hornacek *et al.*, "Potential for High Resolution Systematic Global Surface Soil Moisture Retrieval via Change Detection Using Sentinel-1," in *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, vol. 5, no. 4, pp. 1303-1311, Aug. 2012.

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$$m_s(t) = \frac{(Snapshot\ \sigma^o - Dry\ \sigma^o)}{(Dry\ \sigma^o - Wet\ \sigma^o)}$$

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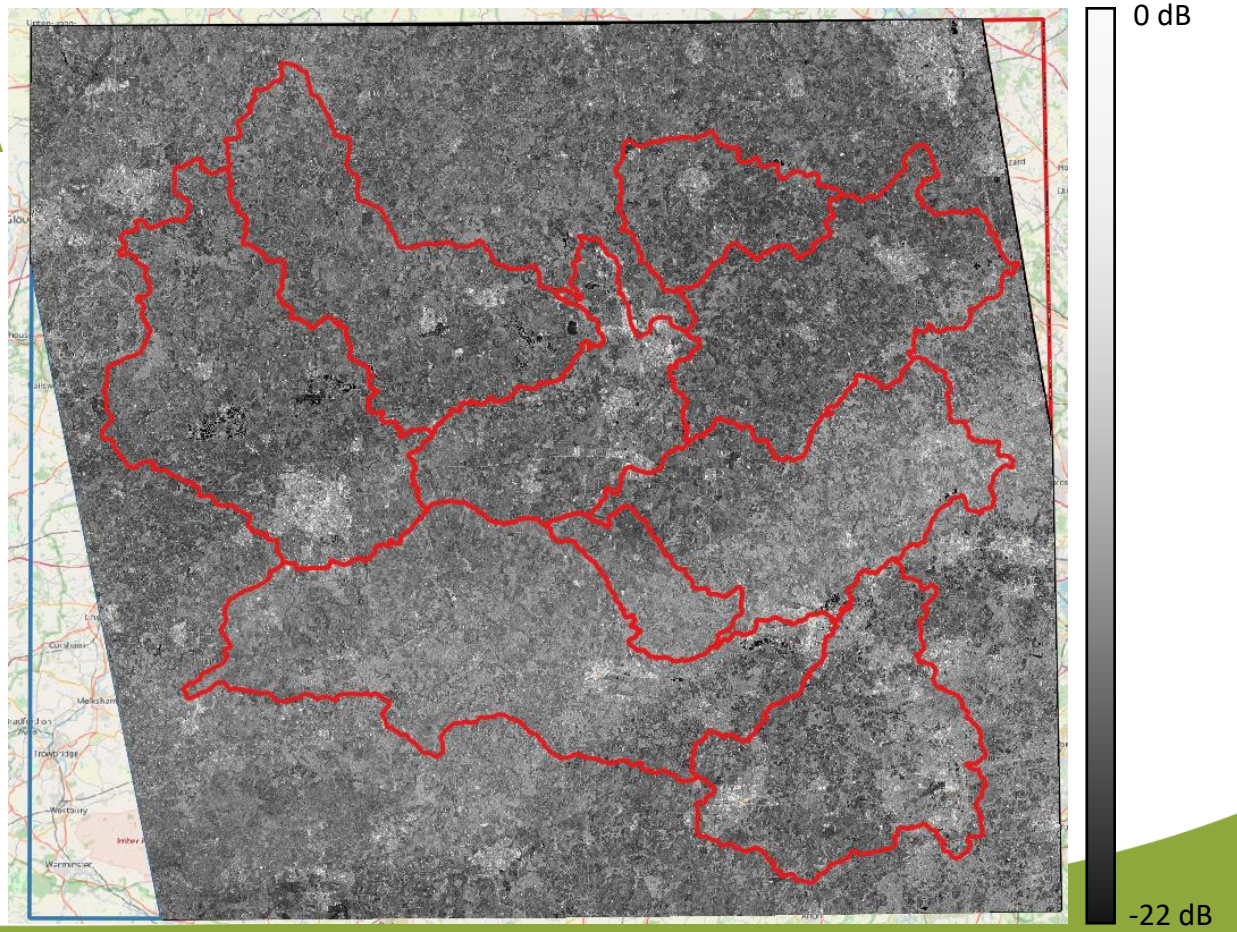
# Space Based Soil Moisture Observations

Turns backscatter images from this…

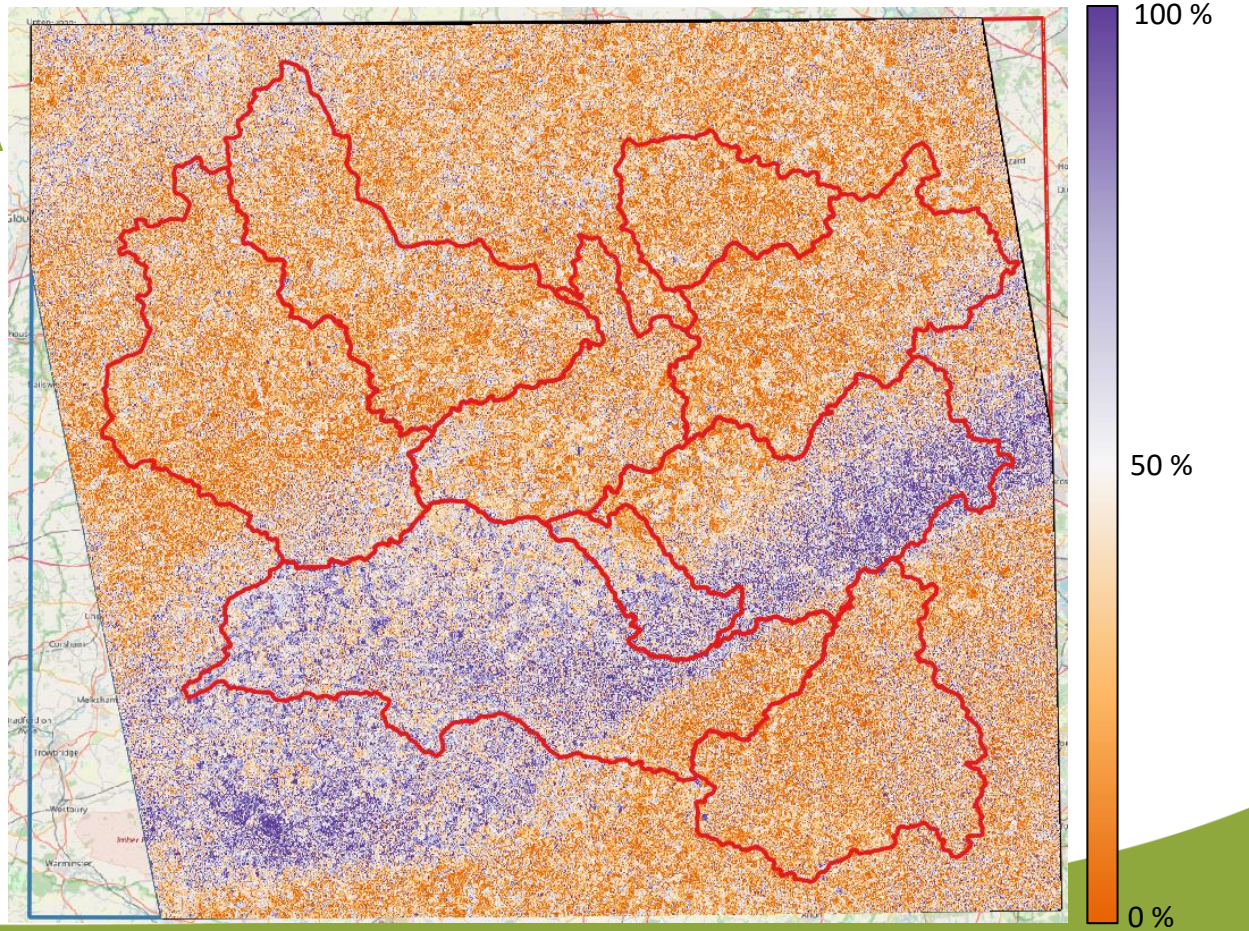
11/09/18
17:50
Sentinel 1A
Orbit 132
VV



# Space Based Soil Moisture Observations

… to this (original resolution)

11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

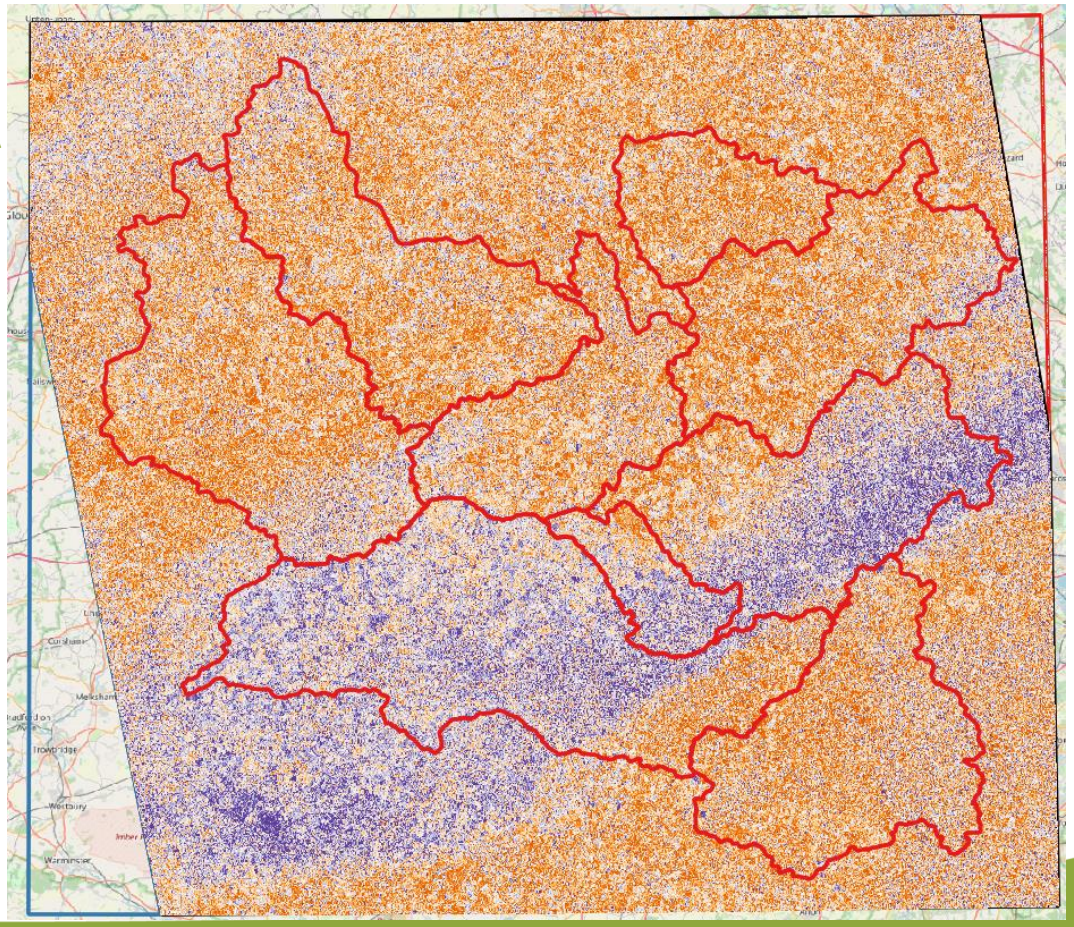
Shouldn't use original resolution, as backscatter is impacted by numerous other variables.

| Concerning Vegetation | Concerning Soils |
|---|---|
| Water Content | Roughness |
| Crop Row Orientation | Tillage |
| Size | Soil Moisture |
| Crop Density | |
| Wind Bending | |

# Space Based Soil Moisture Observations

… to this (original resolution)

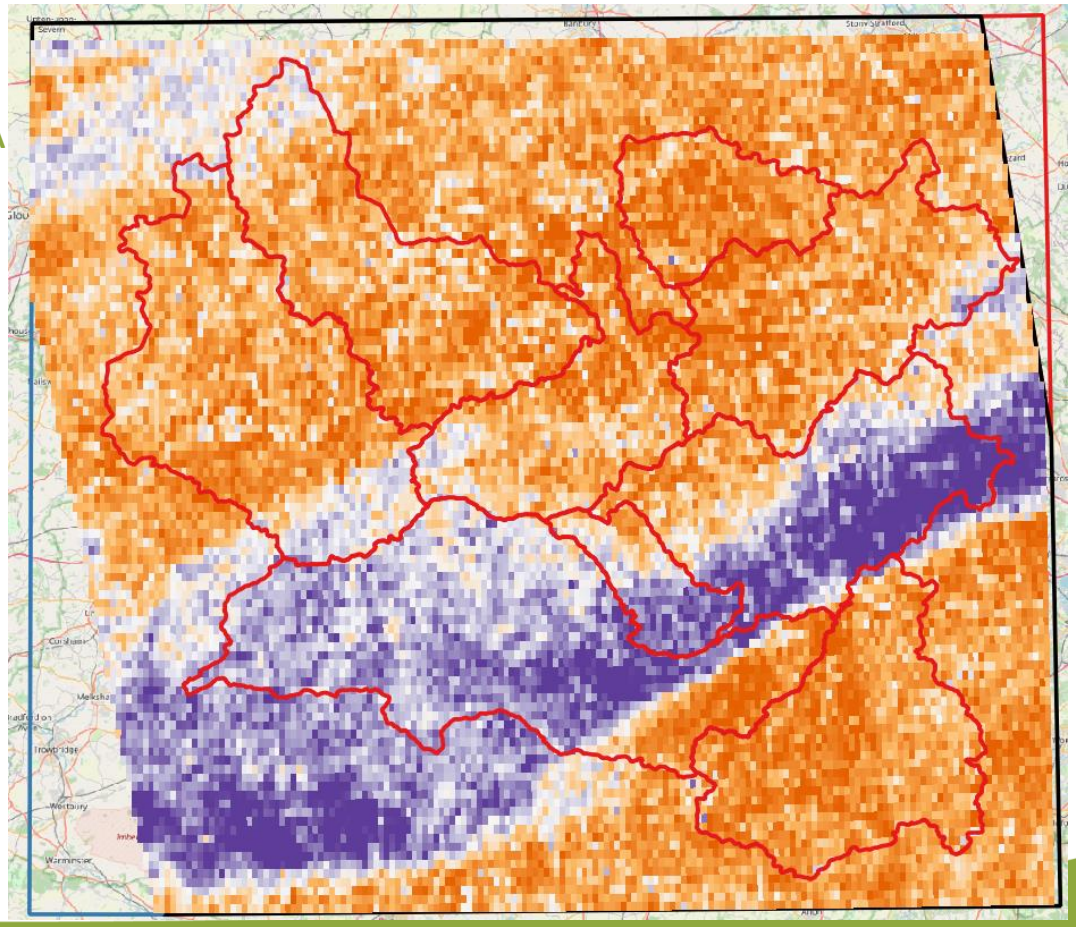
11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

… to this (1km averaging)

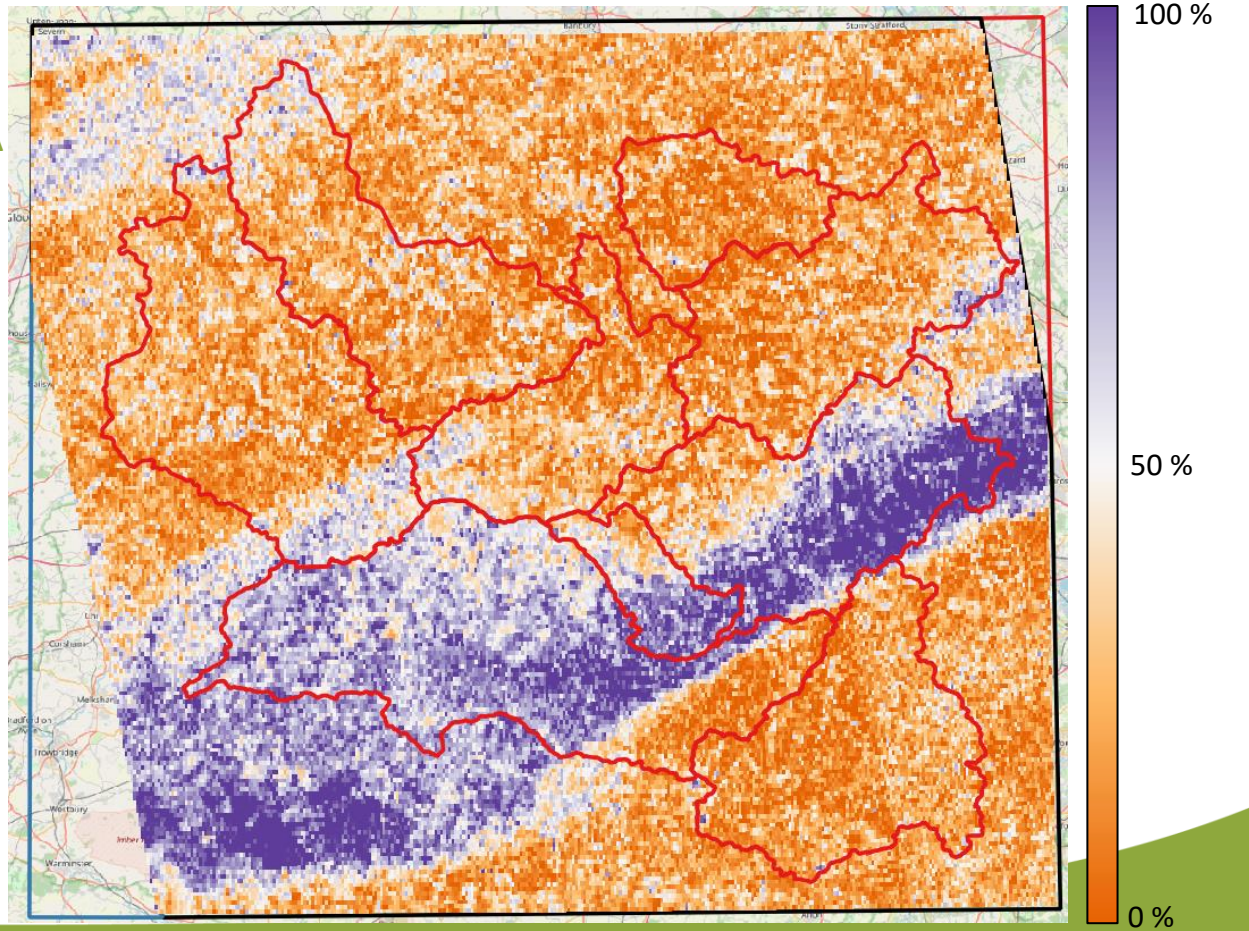
11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

… to this (500m averaging)

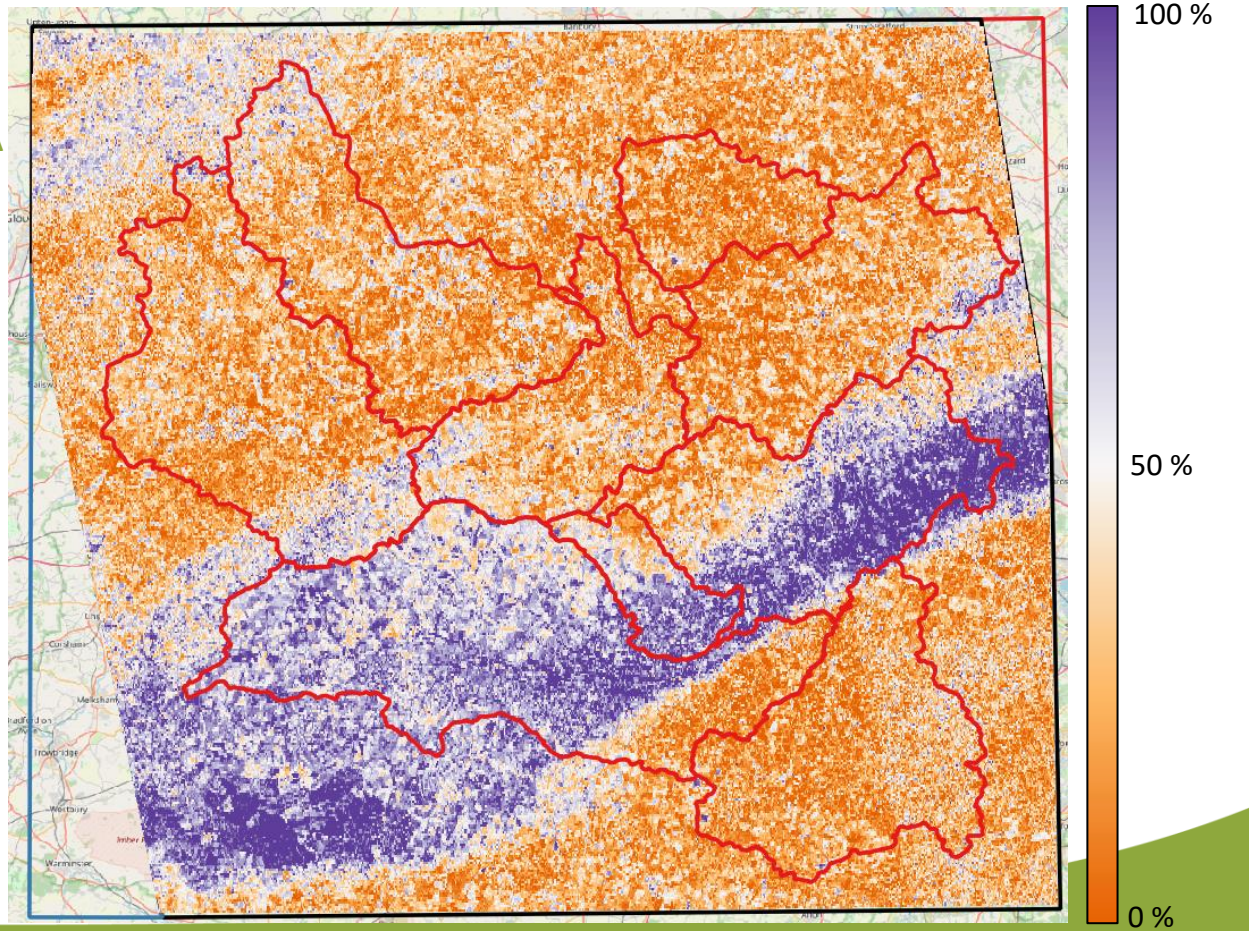
11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

… to this (250m averaging)

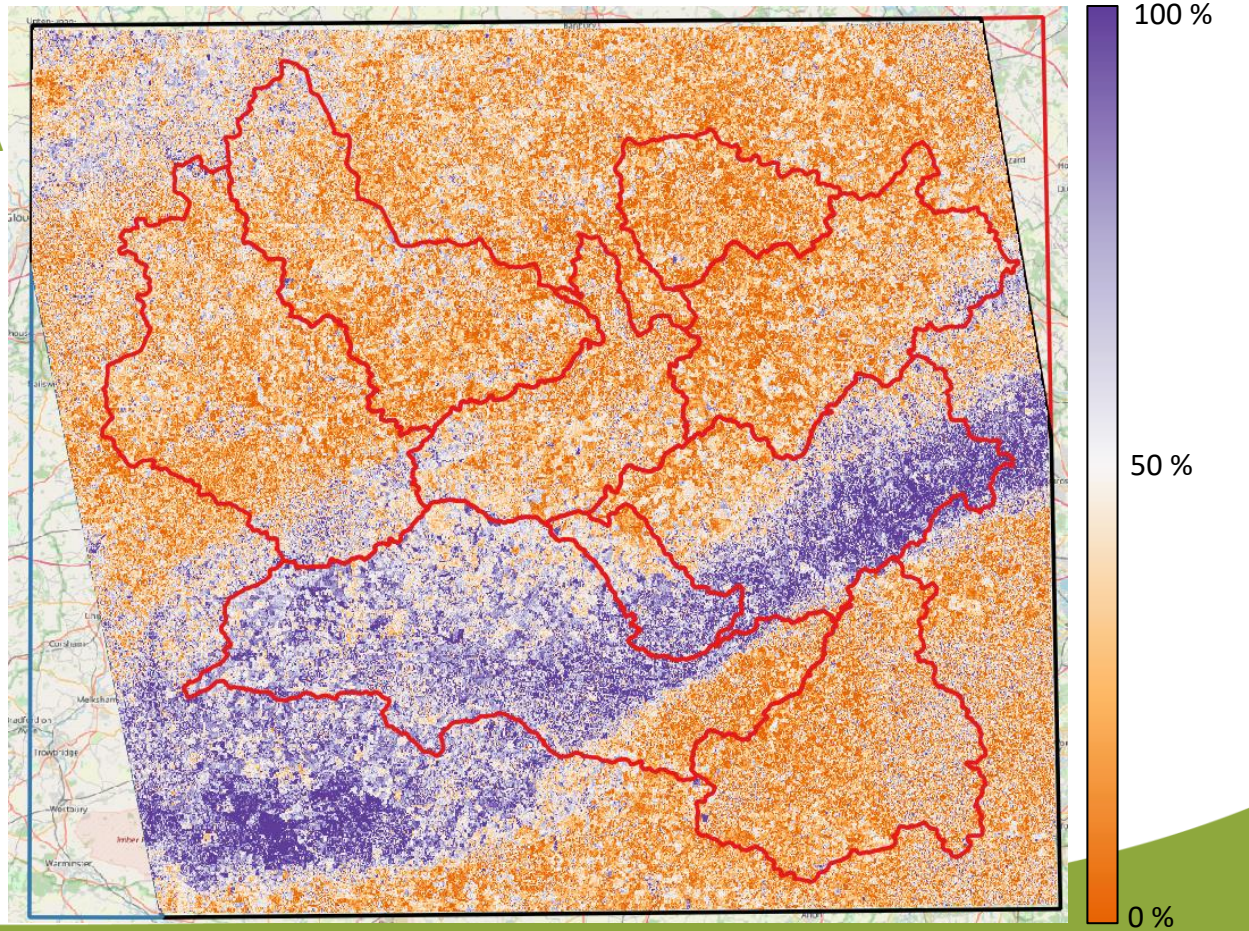
11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

… to this (100m averaging)

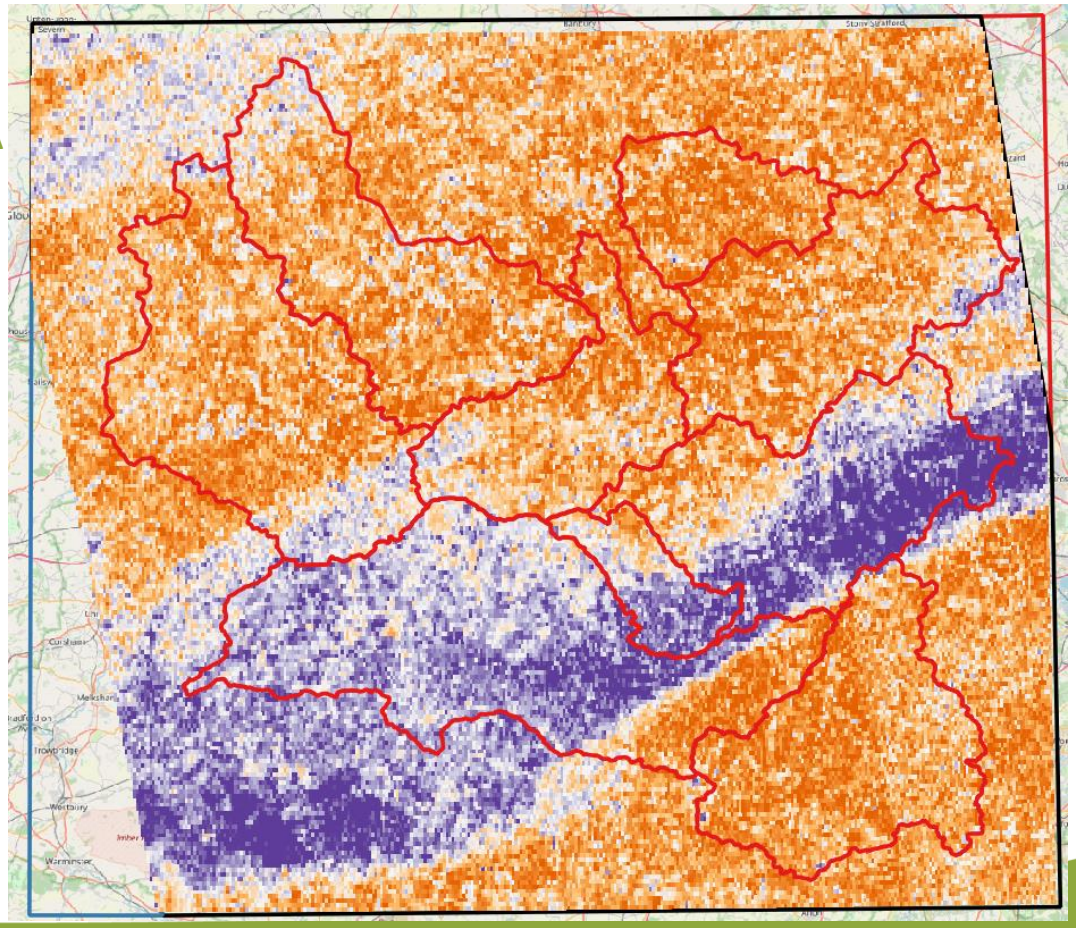
11/09/18
17:50
Sentinel 1A
Orbit 132



# Space Based Soil Moisture Observations

## But why the spatial pattern? Localised Shower

11/09/18
17:50
Sentinel 1A
Orbit 132
500 m




11/09/18
14:50 – 17:50
rainfall
accumulation

# Space Based Soil Moisture Observations

## But why the spatial pattern? Localised Shower

11/09/18
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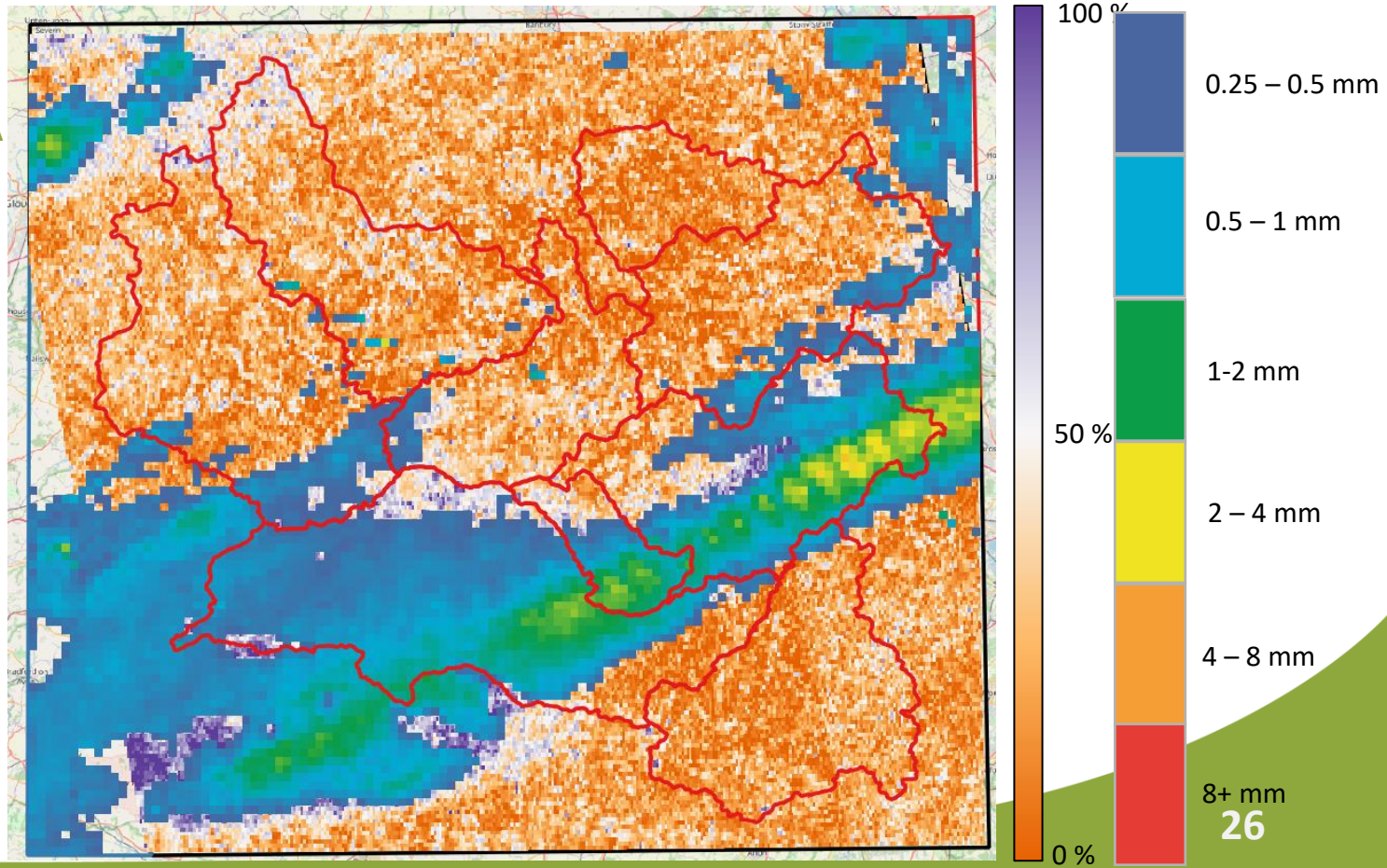
Sentinel 1A
Orbit 132
500 m

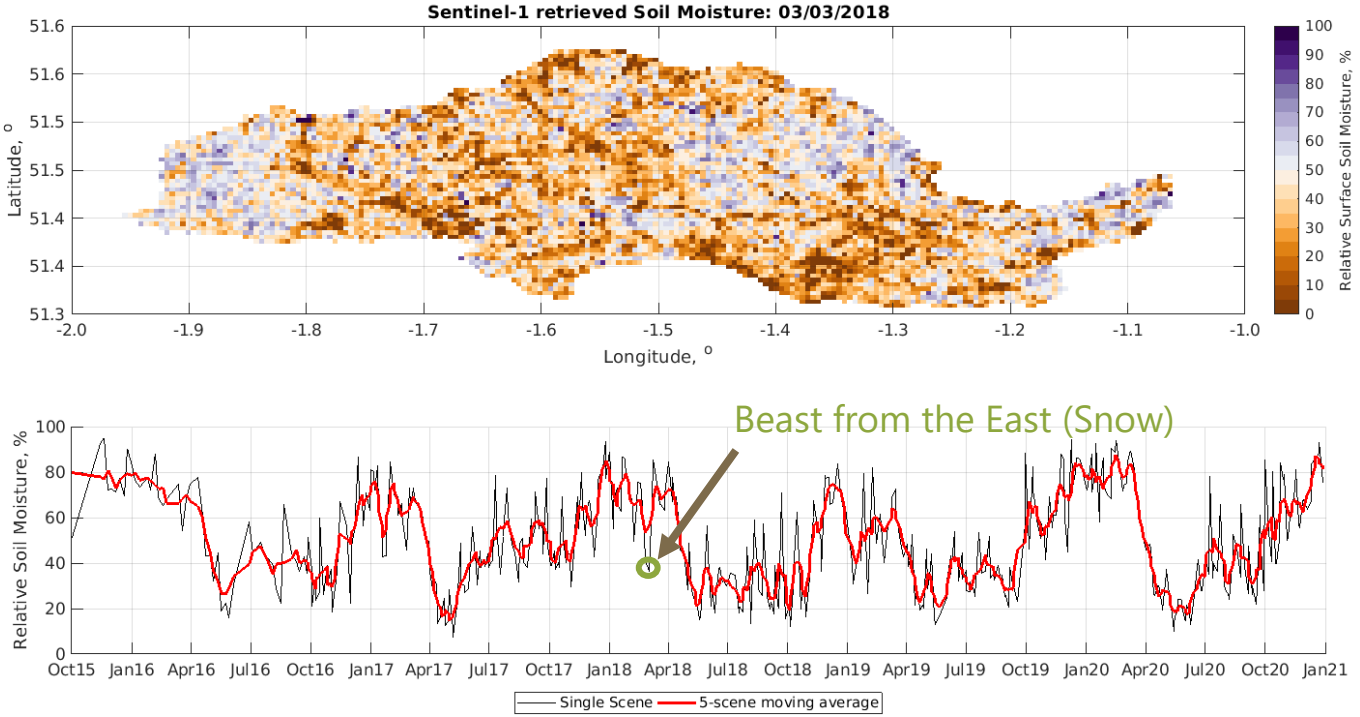



11/09/18
14:50 – 17:50
rainfall
accumulation

# Space Based Soil Moisture Observations

## Ability to Produce Timeseries

### Kennet Catchment

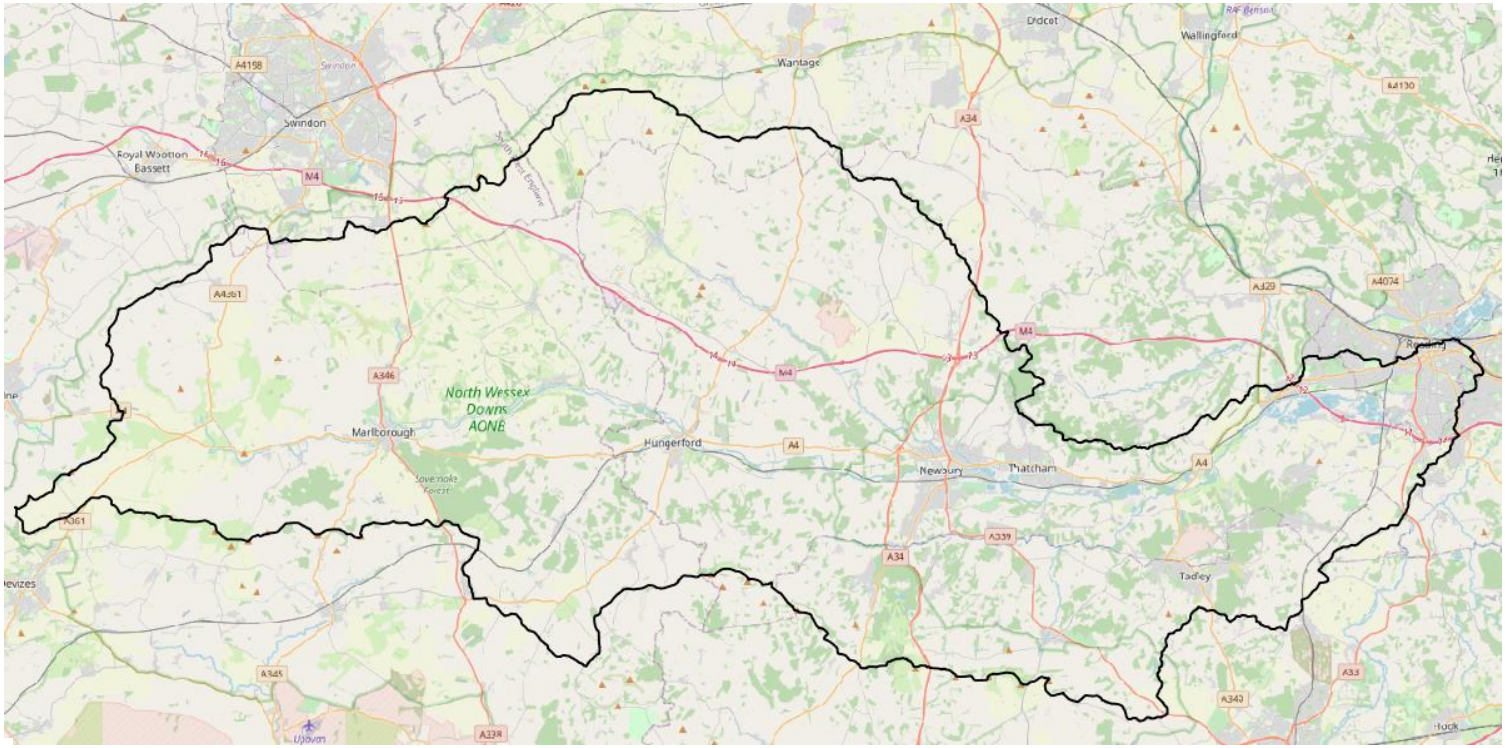


# Space Based Soil Moisture Observations

## Catchment wide comparisons

Kennet Catchment

Sentinel 1A
11/09/18 Orbit 132
17:50 500 m



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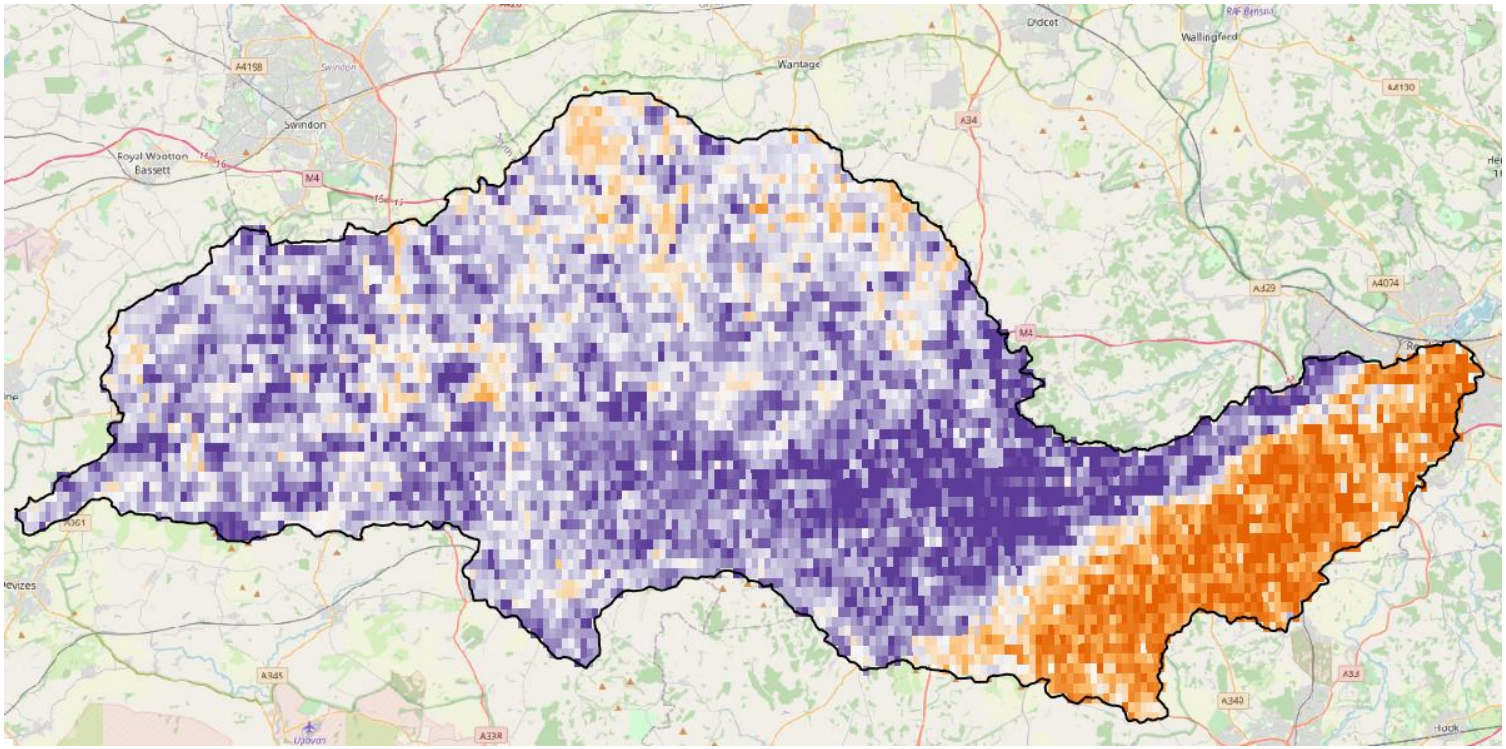
## Catchment wide comparisons

### Kennet Catchment



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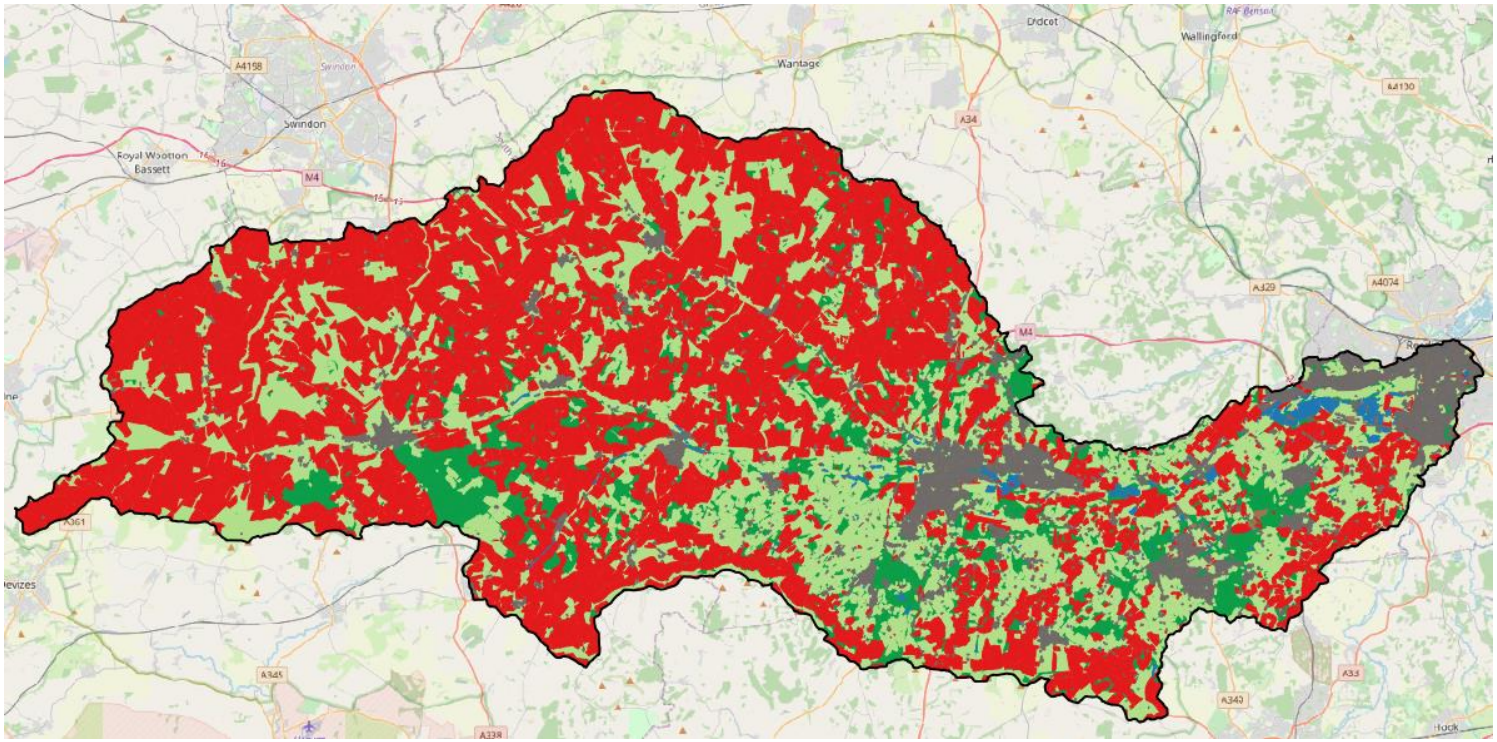
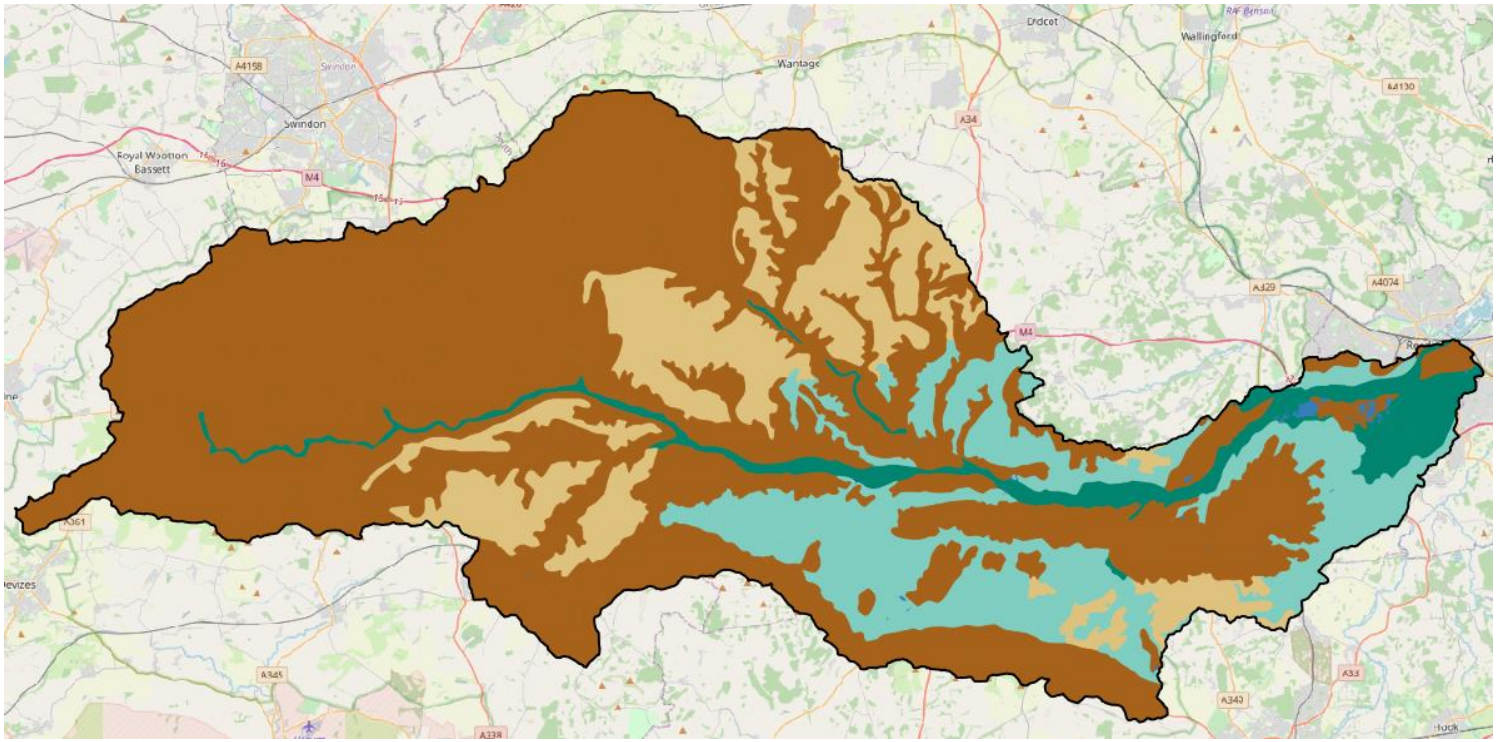



***CEH LCM 2015***

# Space Based Soil Moisture Observations

## Catchment wide comparisons

### Kennet Catchment




***Soilscapes Cranfield***

- Freely Draining
- Slightly Impeded Drainage
- Impeded Drainage
- Naturally Wet
- Water

# Linking back to NFM

*Overarching Research Questions (Simplified)*

a) How effective are different land-based NFM measures at keeping water out of the river?

b) How does that effectiveness vary?

## Detailed Field Survey

- Aim to better characterise field scale heterogeneity for different practices and soil parameters.
  - Take Soil Moisture observations via ground-based RADAR unit.
  - Linked with detailed field survey
    - Hand held soil moisture probes (Theta Probe)
    - Comparison with Electrical Resistivity Tomography (ERT)
    - Soil parameters via Centre of Ecology and Hydrology observations in WP2

# Linking back to NFM

Rig-mounted RADAR observations

- 4 – 8 GHz
- 1m footprint
- High resolution scans (~mm)

Soil moisture transects across fields, aligned with ERT and Theta probe observations, as well as CEH Soil property observations

Look at soil moisture change across tram lines

# Linking back to NFM

Assess how different types of land/soil properties effect soil moisture

- Floodplain Grassland vs Woodland
- Controlled Traffic vs Conventional on Chalk and Clay
- Herbal Lays vs Rye Grass

Coincide with Sentinel 1 passes

- Look to scale up field scale RADAR observations to compare with catchment scale RADAR observations.

Impacted by COVID-19, but watch this space!

## Presentation Summary

Introduction to LANDWISE Project

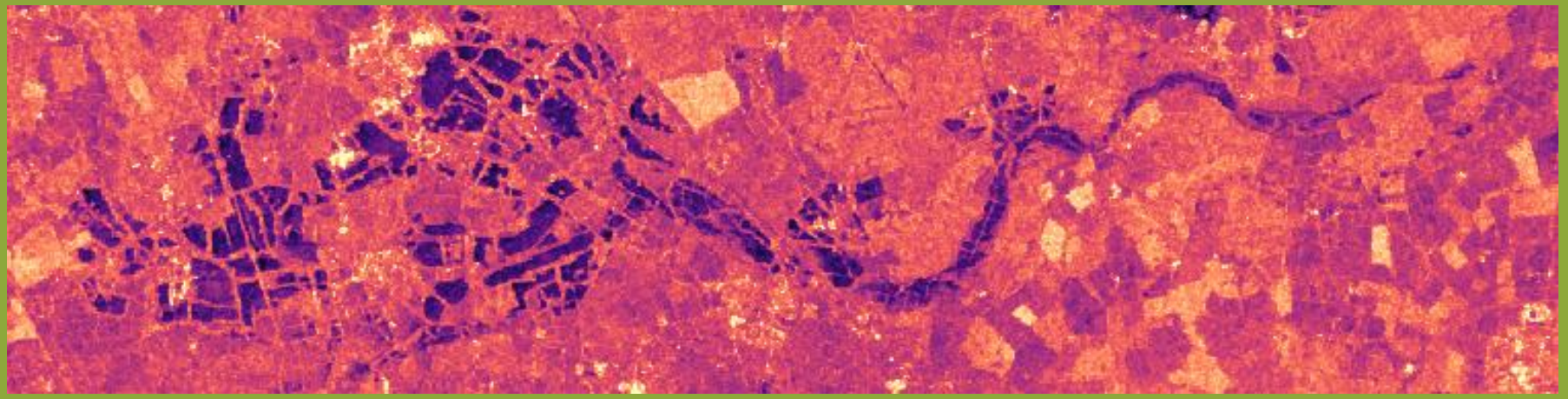
Space Based Radar Remote Sensing

Space Based Soil Moisture Observations of the Thames Basin

Briefly touched upon the WP3 elements of the long-awaited Landwise detailed fieldwork

LANDWISE NFM

## Any Questions?



False Colour σ° of Cotswold's Water Park @ Cricklade