

Understanding soil moisture dynamics through cosmic rays: a global analysis

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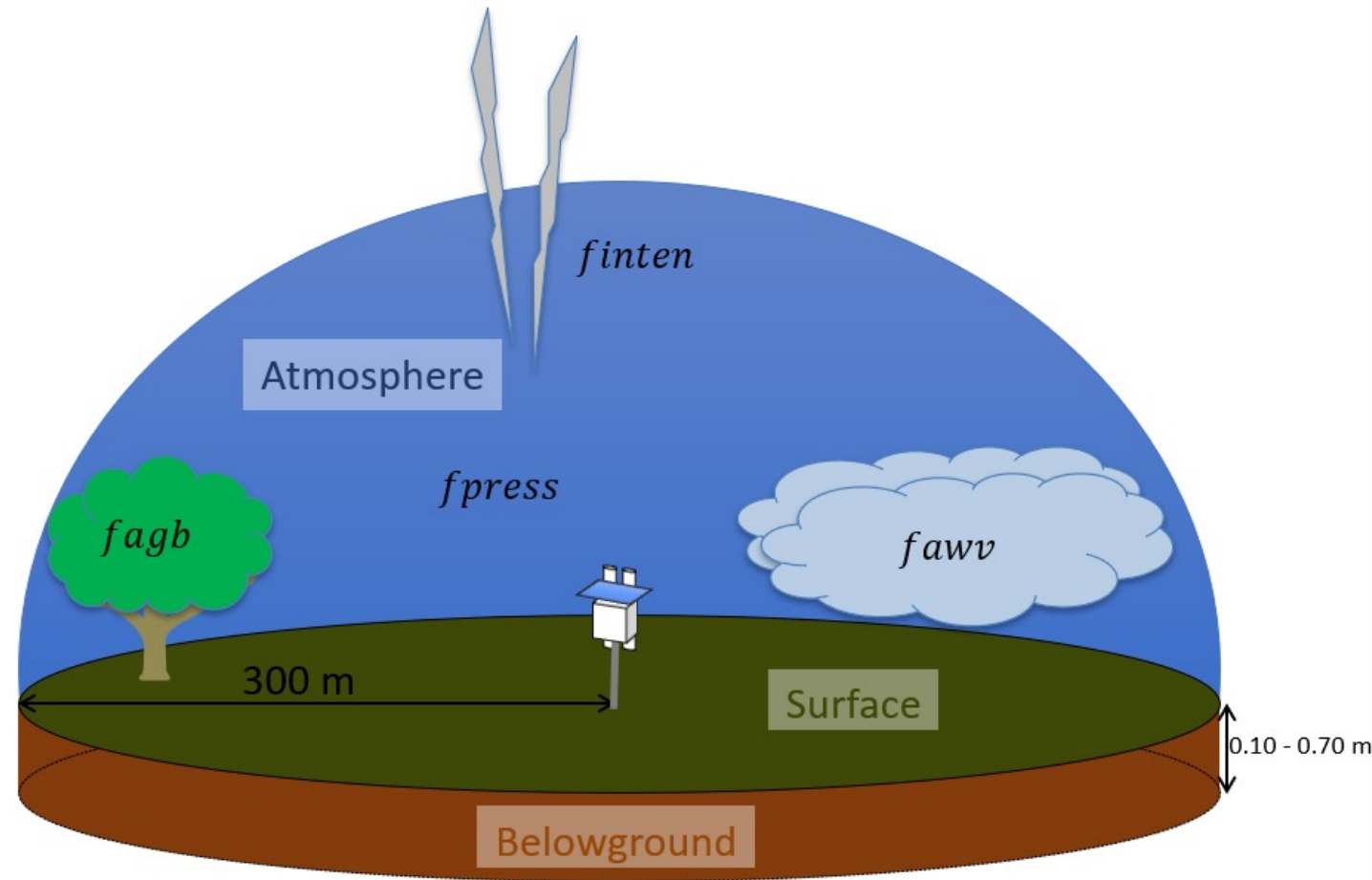


With thanks:

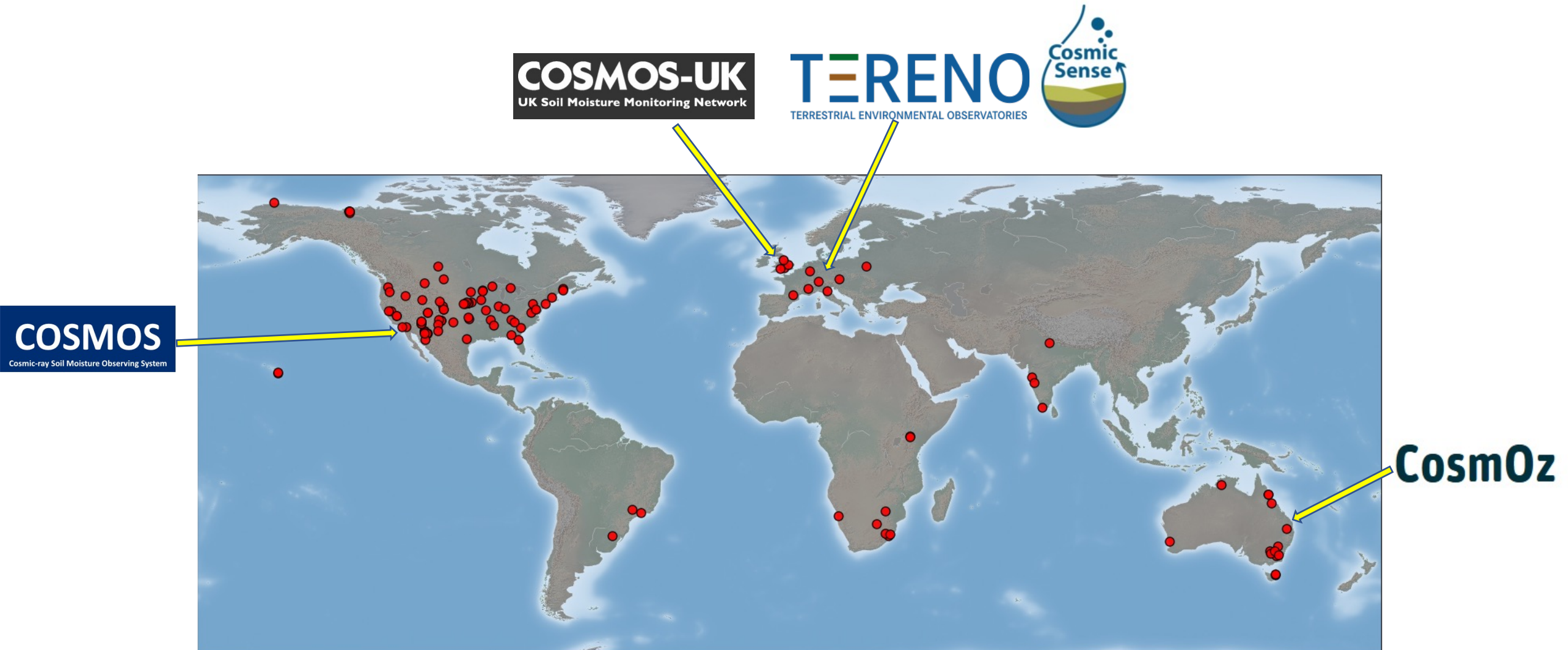
Cosmic-Ray Neutron Sensor (CRNS)

The CRNS can give estimates of field scale, root-zone soil moisture at hourly intervals. The technique is possible due to the influence hydrogen atoms have on fast neutrons (which come from cosmic-rays). Put simply, higher neutron counts means lower soil moisture.

Additional corrections are required to remove the influence on the neutron signals that come from sources besides soil moisture. These are generally considered to be; incoming neutron intensity (f_{inten}), atmospheric water vapour (f_{awv}), atmospheric pressure (f_{press}) and above ground biomass (f_{agb}).



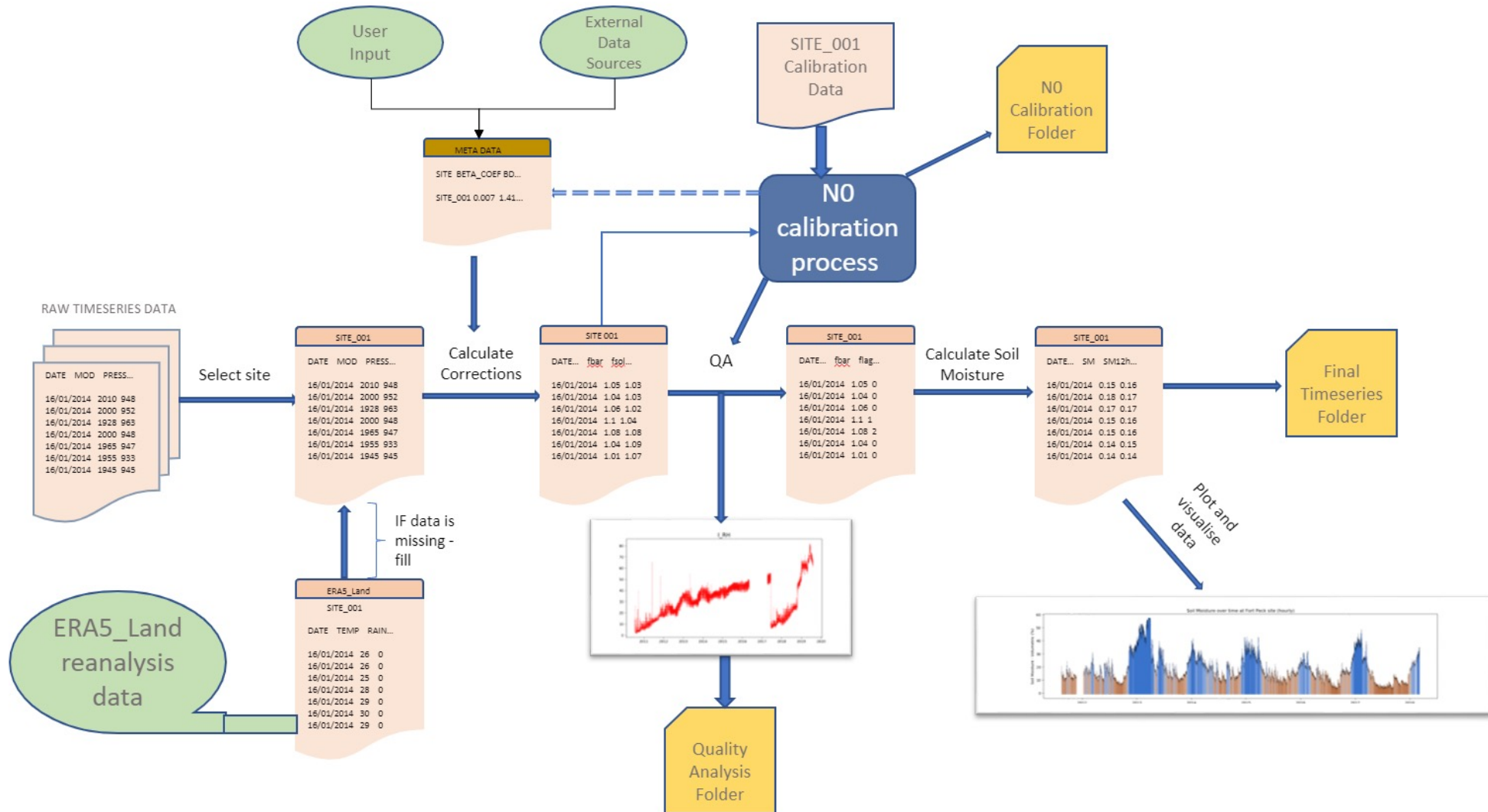
Large networks of sensors have been employed around the world, as well as individual sensors. Some of these sensors have been running for >10 years.



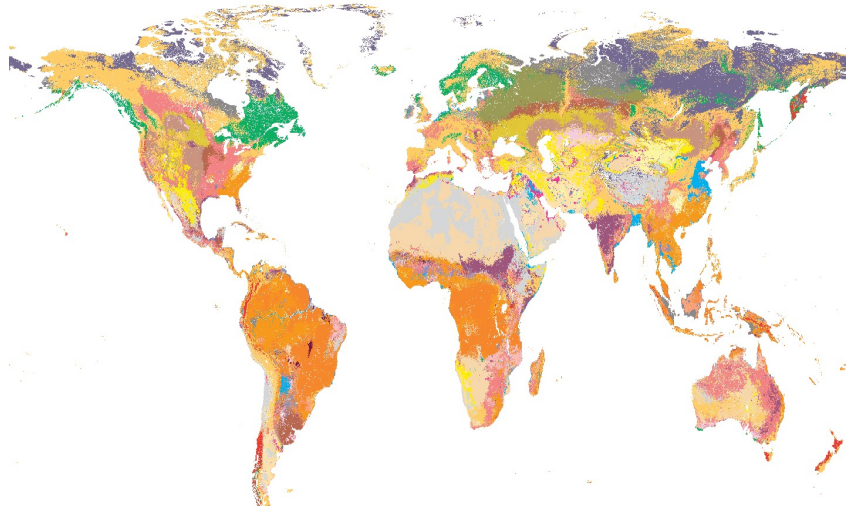
Unfortunately, there is currently no standardisation of the processing methods between different networks and sensors (see steps highlighted in bold below). These differences can lead to changes in estimates. We believe this ultimately leads to a reduced ability to compare sites in different networks.

Data processing steps			
Atmospheric pressure correction	Yes	Yes	Yes
High-energy neutron intensity correction	Jungfraujoch reference site with no local correction	Neutron monitor site with closest cutoff rigidity value to site	Jungfraujoch reference site with local correction (Hawdon et al. 2014; WRR)
Atmospheric water vapor correction	No	Yes	Yes
Aboveground biomass correction	No	No	No
Lattice water and soil organic carbon correction	No	Yes	Yes

We developed **crspy**, an open-source python tool, designed to process raw CRNS data from any sensor. This ensures soil moisture data is produced using a harmonized methodology, better facilitating global analysis.



With harmonized datasets available we also wished to collect informative meta data describing the sites we have. We designed functions to collect meta data for each site. This information is a mixture of global data products and computed metrics from site sensor data (such as local meteorological variables).



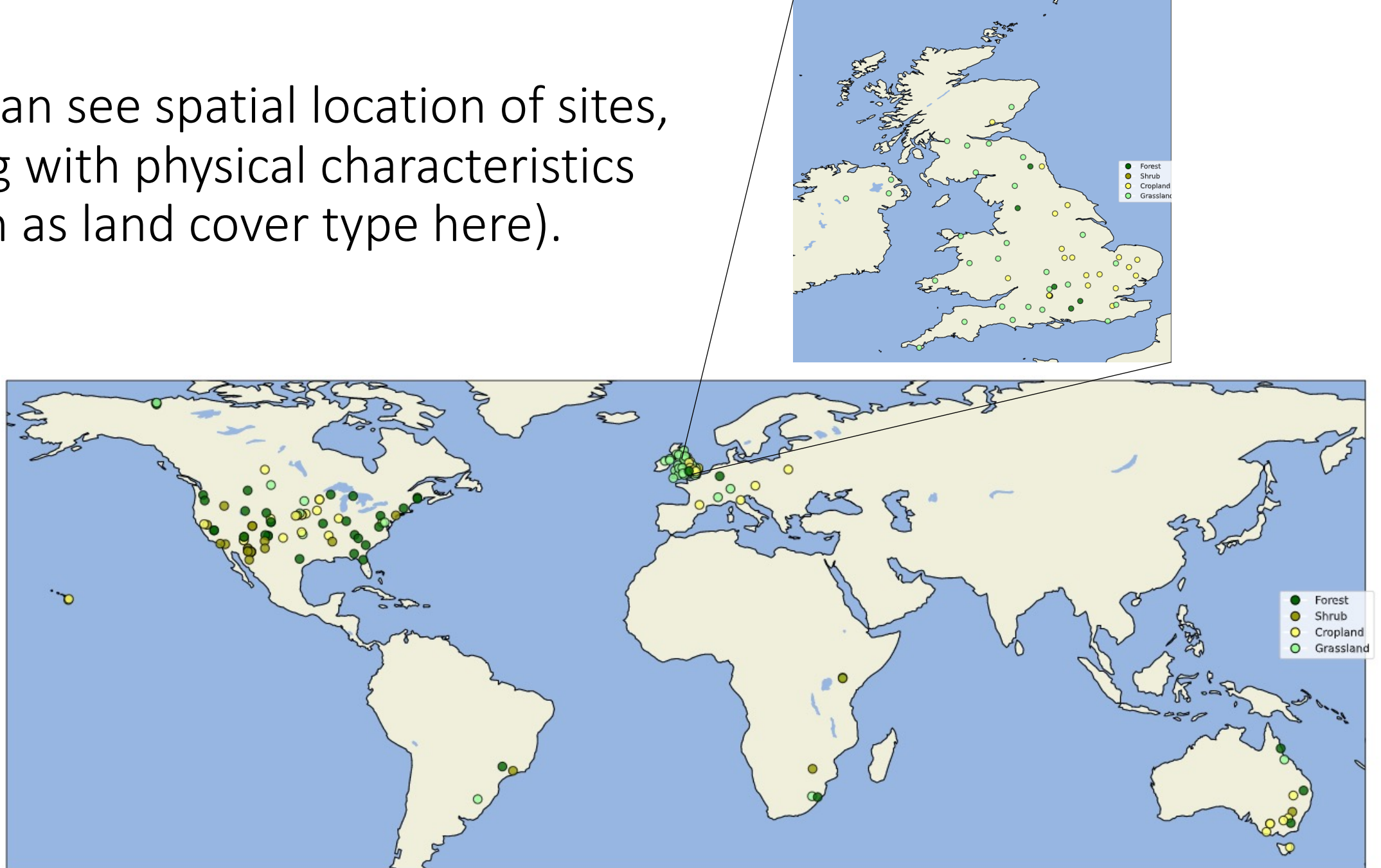
International Soil Reference and Information Centre

- Bulk density, particle distribution
- www.soilgrids.org

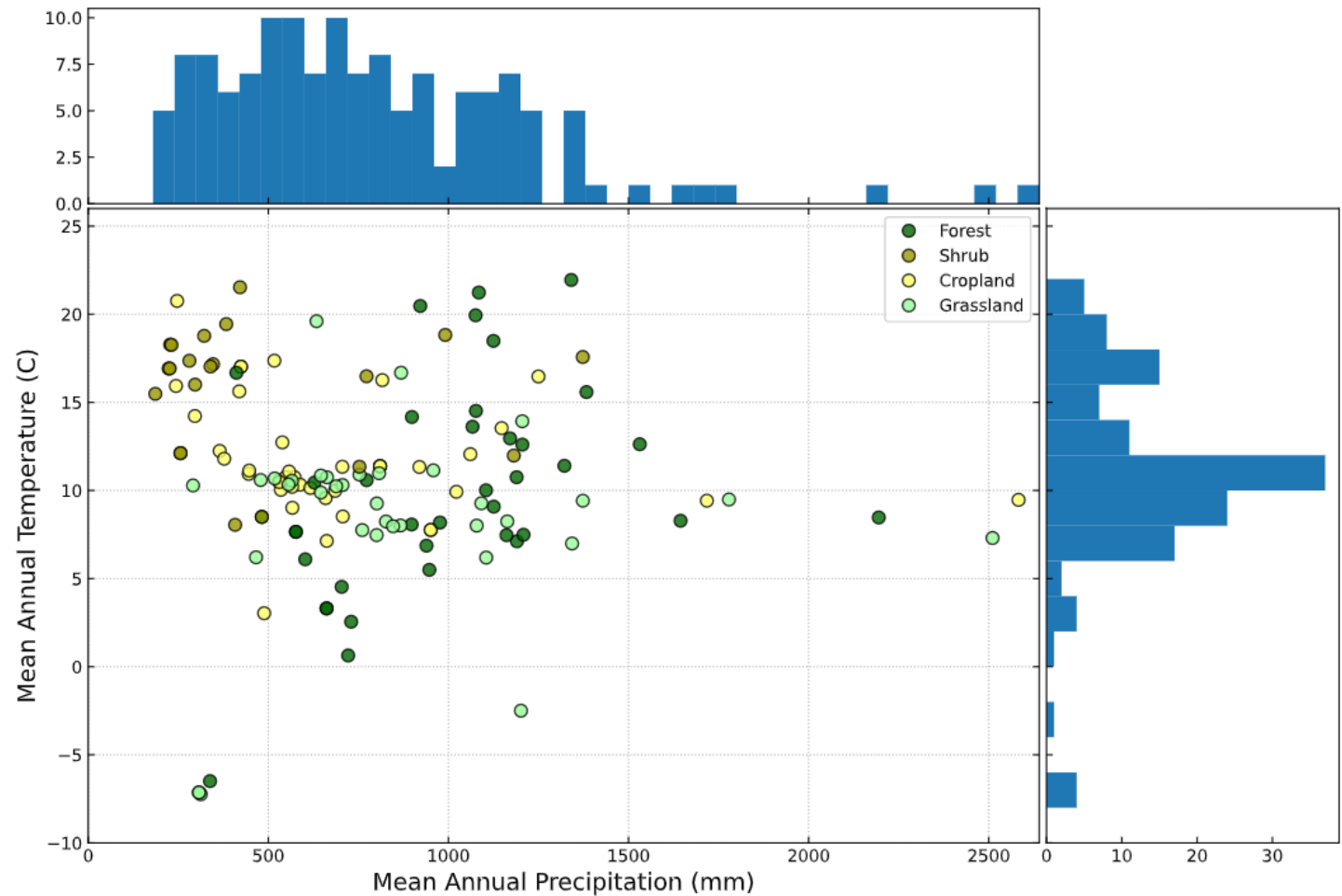
European Space Agency – Climate Change Initiative

- Land cover and above ground biomass data
- www.climate.esa.int

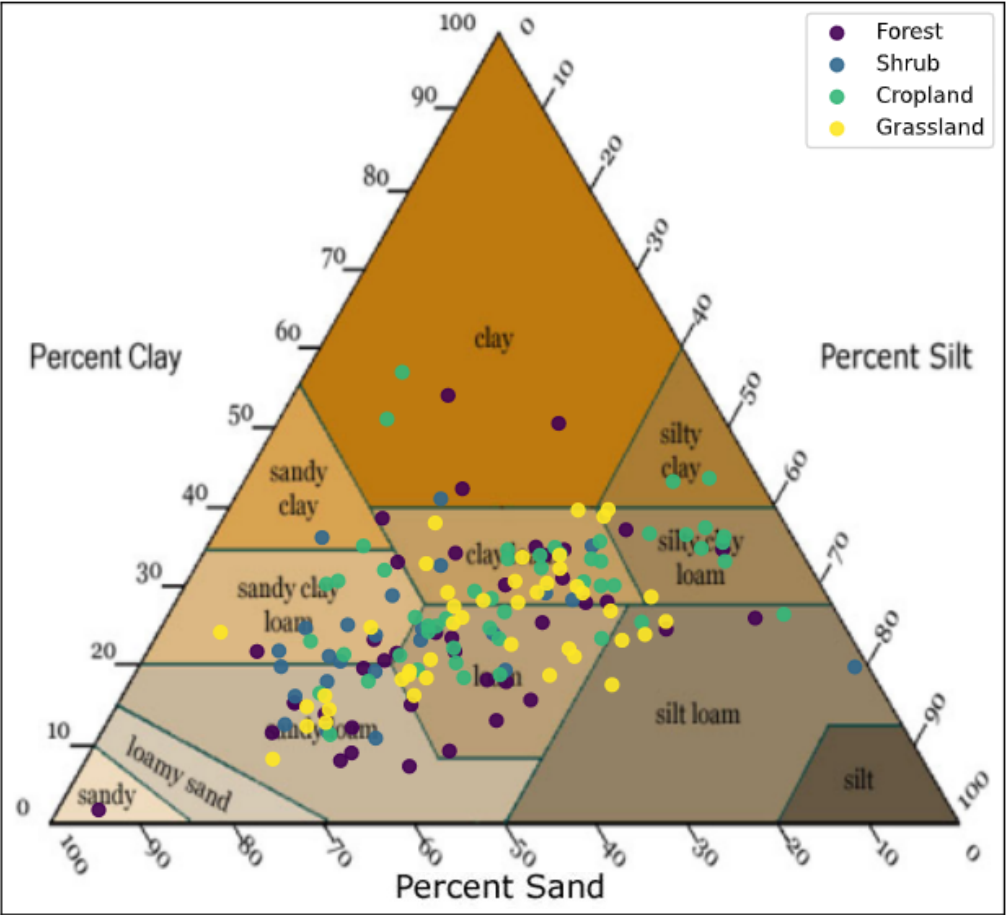
We can see spatial location of sites, along with physical characteristics (such as land cover type here).



Meta data can help us when clustering sites. Each point represents one site. We demonstrate here that using multiple networks provides a greater spread of sites with different soil types and meteorological conditions.



Scatter-histogram across global sites, colours represent land cover types (derived from ESA CCI data).



Soil types of selected CRNS sites. Colour represents the land cover type (ESA CCI data) of the site. Soil types derived from SoilGridsv2 data.

Summary

1. Cosmic-Ray Neutron Sensors (CRNS) are a valuable tool for understanding field scale soil moisture dynamics at sub-daily time scales
2. Global networks of these sensors can be incredibly valuable, but without a consensus on processing methodology, big data global studies can be limited
3. We have developed **crspy** an open-source python tool for the processing of CRNS data using up to date methods based on recent literature
4. An additional routine in **crspy** is the collection of informative meta data for each site, using global data products as well as in-situ measurements.
5. GMD paper currently in review, will shortly be available in GMD discussions.



Available at <https://www.github.com/danpower101/crspy>