Evaporation and Soil Moisture

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Evaporation Data

- **Actual evapotranspiration** measured by Eddy Covariance (EC) stations.

Eddy Covariance is a technique to observe the turbulent flux of water vapour as it leaves the earth's surface. The words explain the method: the very small changes in vertical air movement and changes in water vapour are 'correlated' so that the net vertical flux is measured.

Another option is to weigh the soil (lysimeter).

- **Estimated evapotranspiration** can be derived from the energy balance
- **Potential/reference evapotranspiration** calculated/modelled from meteorological data – either at a site or across a large area.

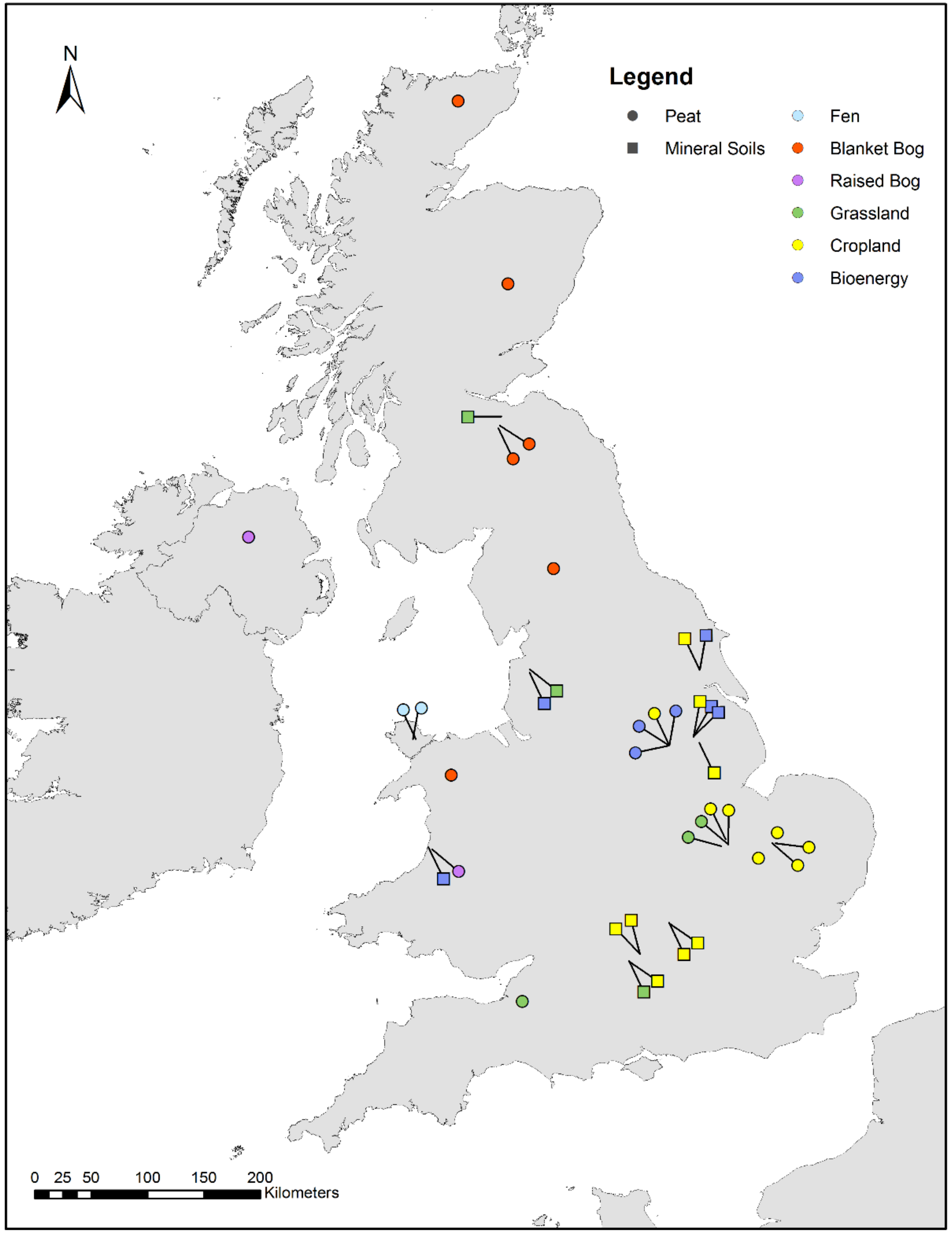
Soil Moisture Data

- Measured at fine scale and different depths using point observations. These observations are often hard to use as soil moisture varies over very fine spatial scales due to soil moisture structures.

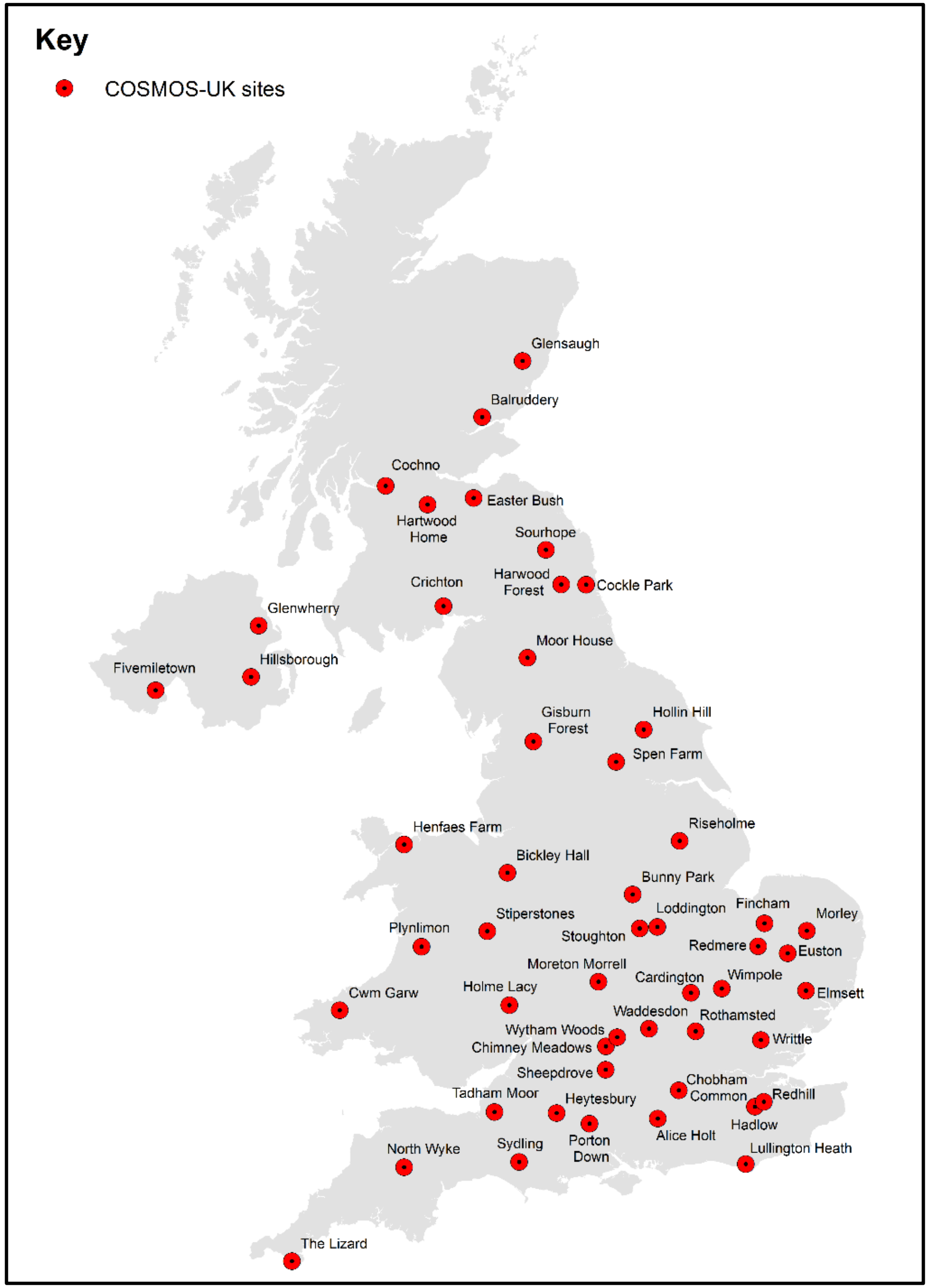
- Measure at broader scale (~100m) using COSMOS stations. These measure the impact of water on Cosmic rays arriving from space. Only available for the top soil (~10cm).

- Measure at large scale from satellite. These measure the impact of surface water (1cm) on the radiation from the land (reflected and emitted).

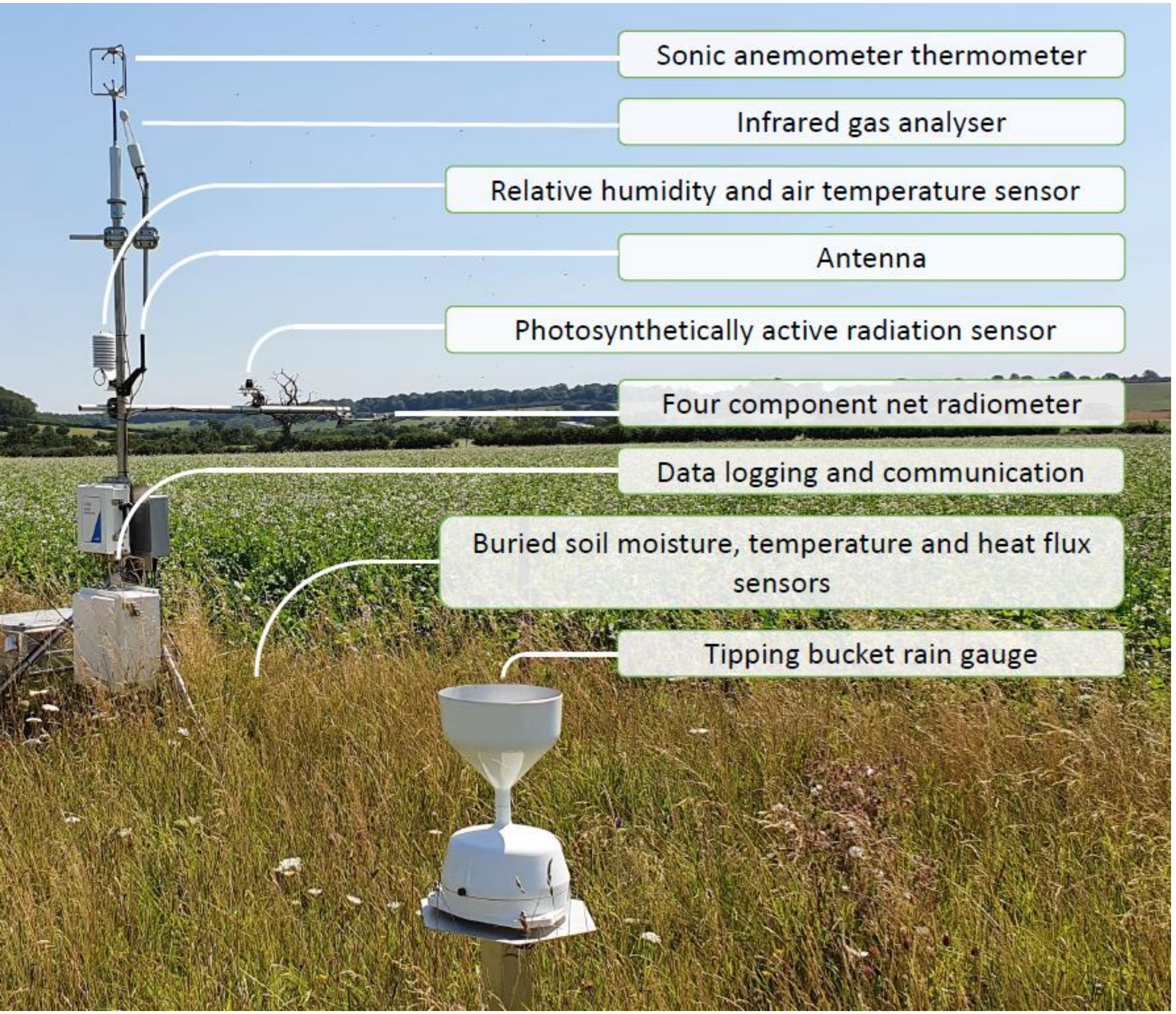
Active, decommissioned and proposed UKCEH EC sites



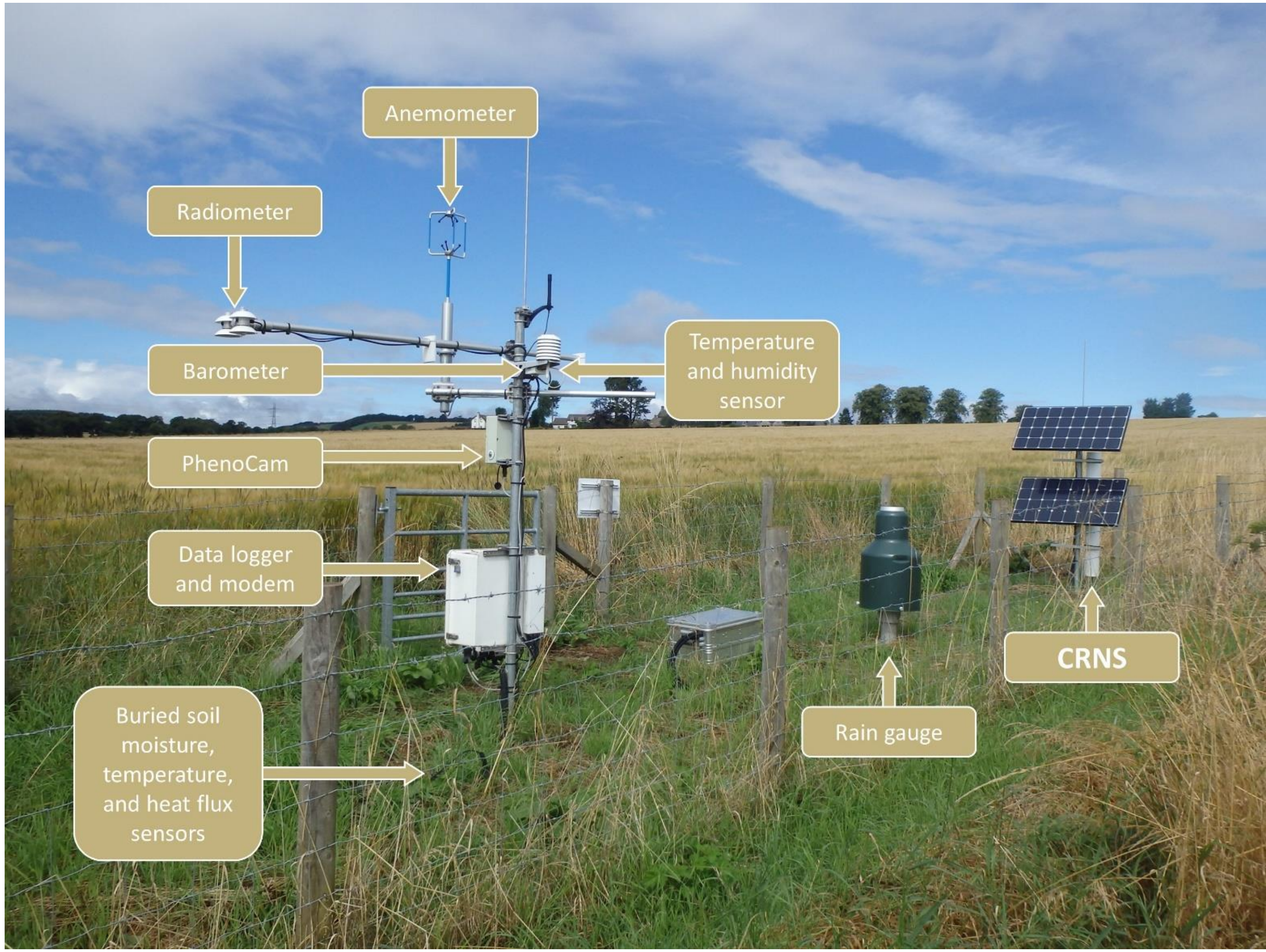
Active and decommissioned UKCEH COSMOS-UK sites



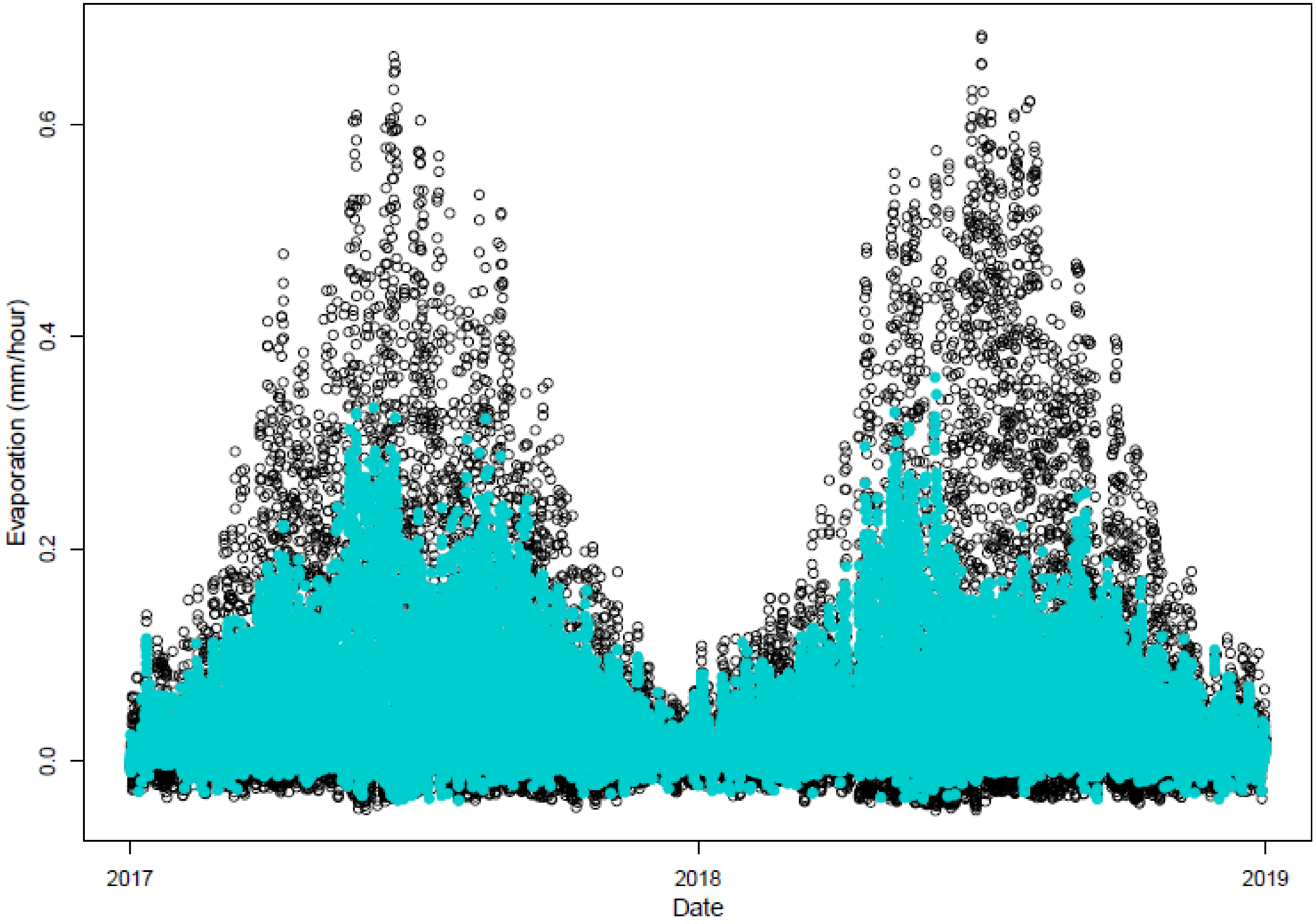
UKCEH EC flux station



UKCEH COSMOS-UK station



Modelled PE (black) compared to actual ET (blue) for a UK Land Flux site



Equations for Evaporation

Black: known, Red: unknown

$H = \rho c_p (T_s - T_a)/r_a$

$\lambda E = \rho\lambda\,(Q_s - Q_a)/r_a$

$\lambda E = \rho\lambda(Qsat(T_s) - Q_a)/(r_a + r_s)$

$A = \lambda E + H$

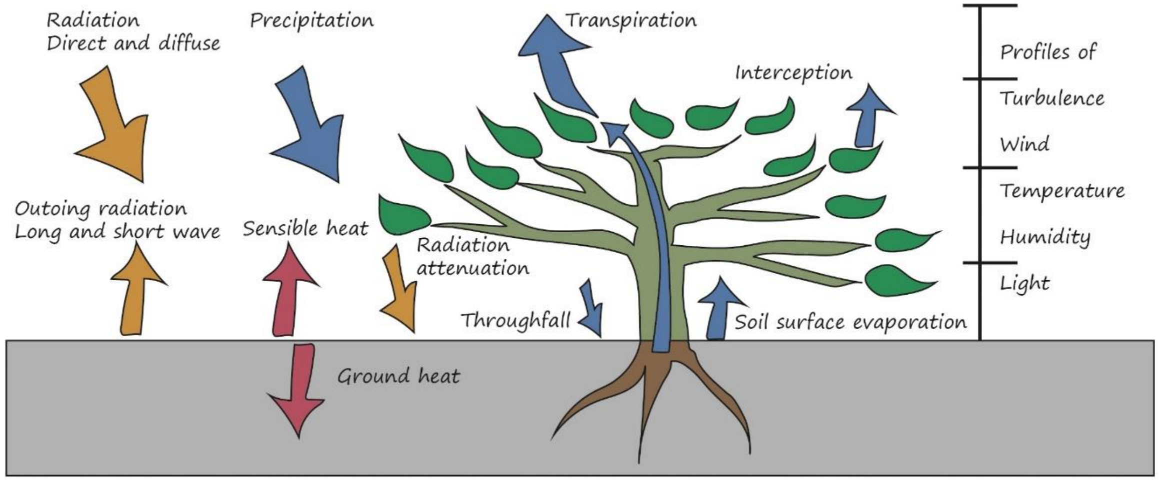
Introducing Δ: less sensitive to *T. So assume* Δ(Ta)= Δ((Ts+Ta)/2)

$dQsat(T)/_{dT} = \Delta$

$Qsat(T_s) - Qsat(T_a) = \Delta(T_s - T_a)$

Sub into top equations..

$$\lambda E = \frac{\Delta A + \rho c_p\,(Qsat(T_a) - Q_a)/r_a}{\Delta + c_p/\lambda(1 + \frac{r_s}{r_a})}$$



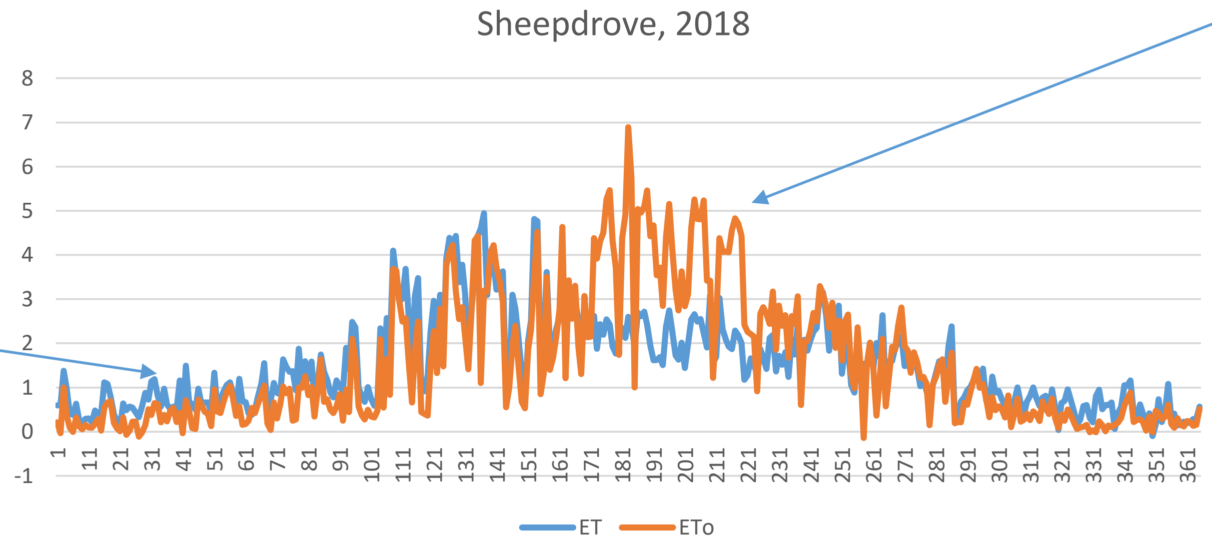
r_s: surface resistance: a very important parameter

Potential Evaporation (PE): r_s is 60 s/m: unstressed vegetation

Interception/open water/ice/snow: r_s is set to 0.

Transpiration: r_s is a function of the vegetation and soil moisture

AE>PE
Because vegetation is wet. Therefore Rs=0 s/m for some of the time.

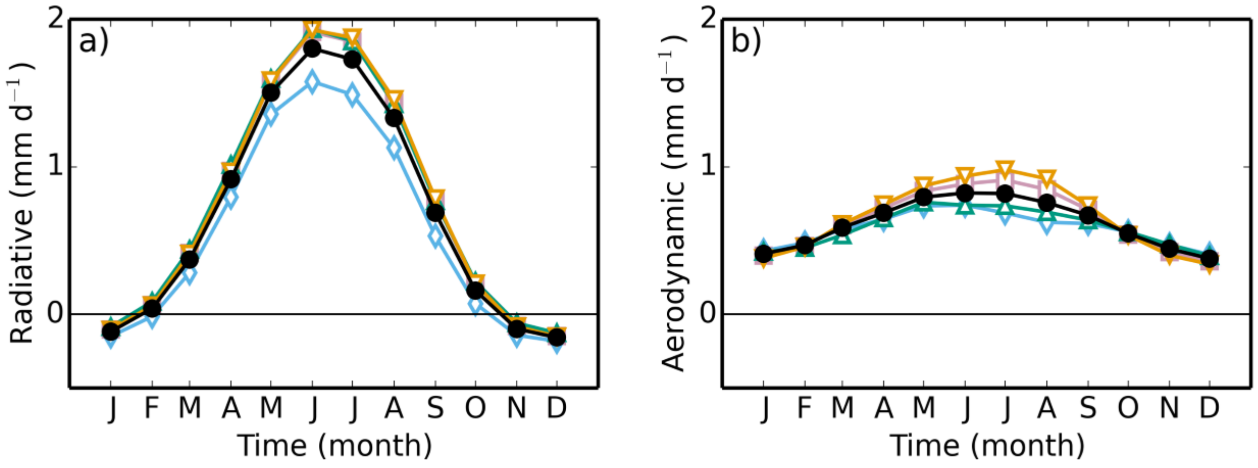


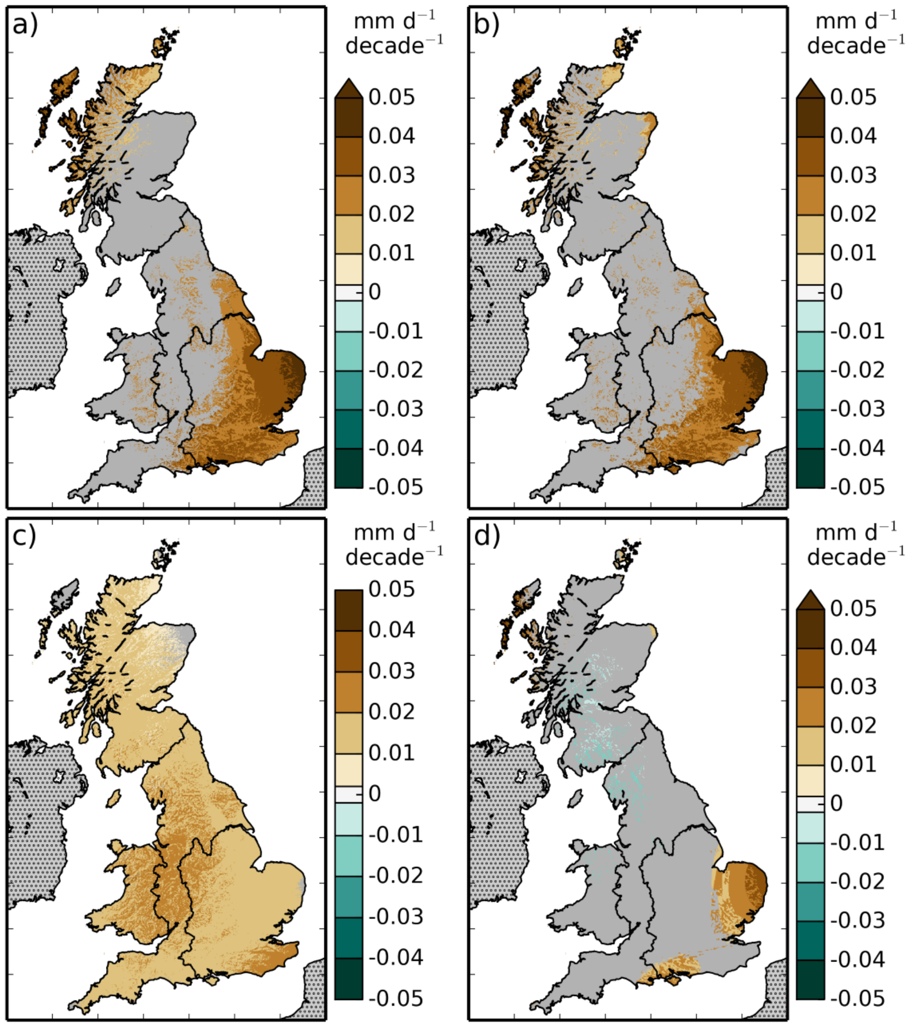
Summer dry conditions
PE>AE
Because soil moisture deficit is reducing the transpiration.
Rs>60s/m

Where change in the Air or Sun affects PE

Look at how Radiation and Wind affect PE.

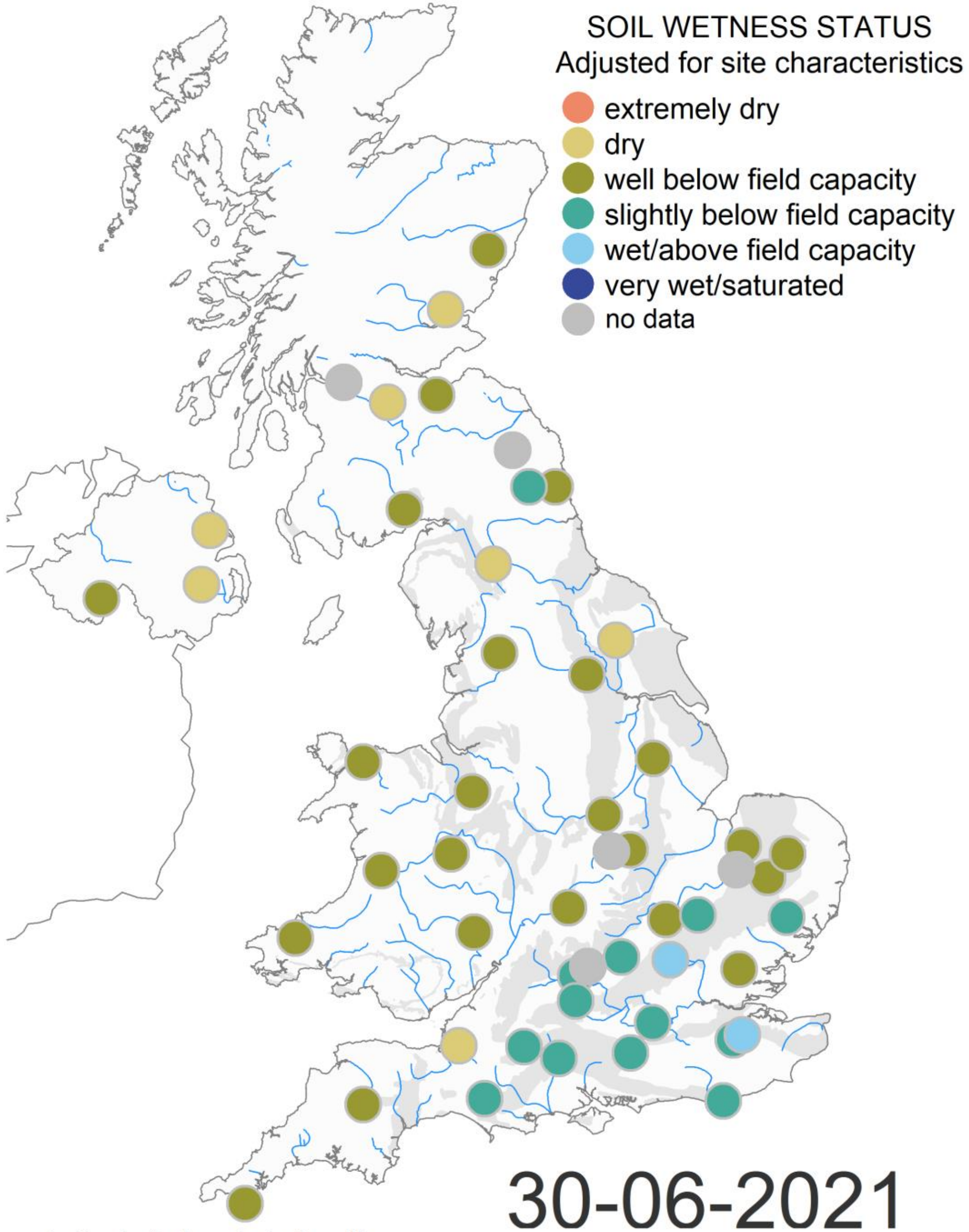
$$\color{red}{\lambda E} = \frac{\Delta A + \rho c_p \left(Qsat(T_a) - Q_a\right)/r_a}{\Delta + c_p/\lambda(1 + \frac{r_s}{r_a})}$$





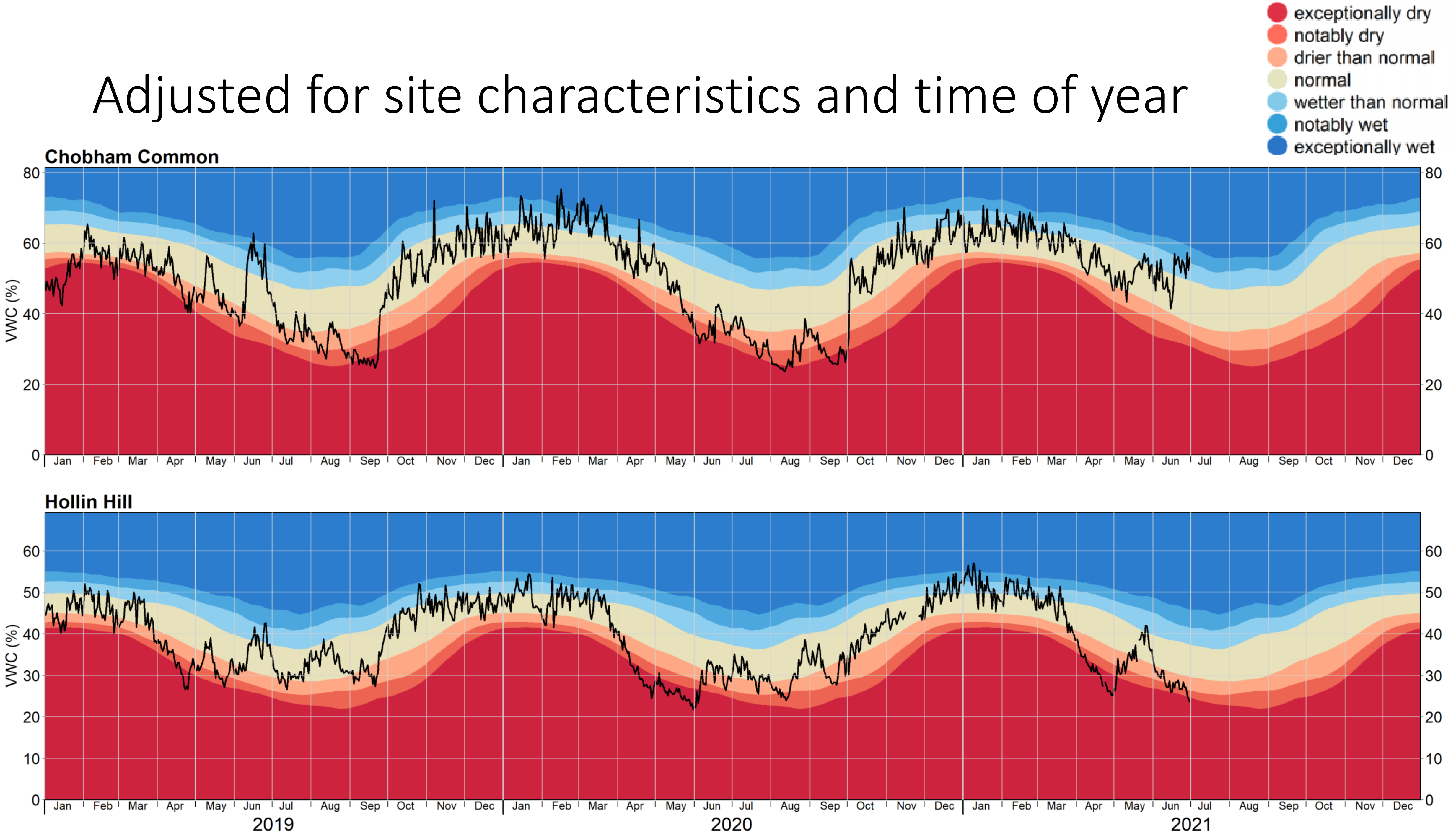
Soil Moisture Data

- Field scale soil moisture data are available at ~50 sites across the UK
- Sub-daily and daily Volumetric Water Content (VWC) plus meteorological data
- Soil moisture indices present data adjusted for site characteristics and/or time of year



Grey shading indicates principal aquifers.

Adjusted for site characteristics and time of year



Equations for Soil Moisture

Soils can be modelled as a porous material through which water flows.

Flow=K x ($\frac{d\Psi}{dz}$+1)

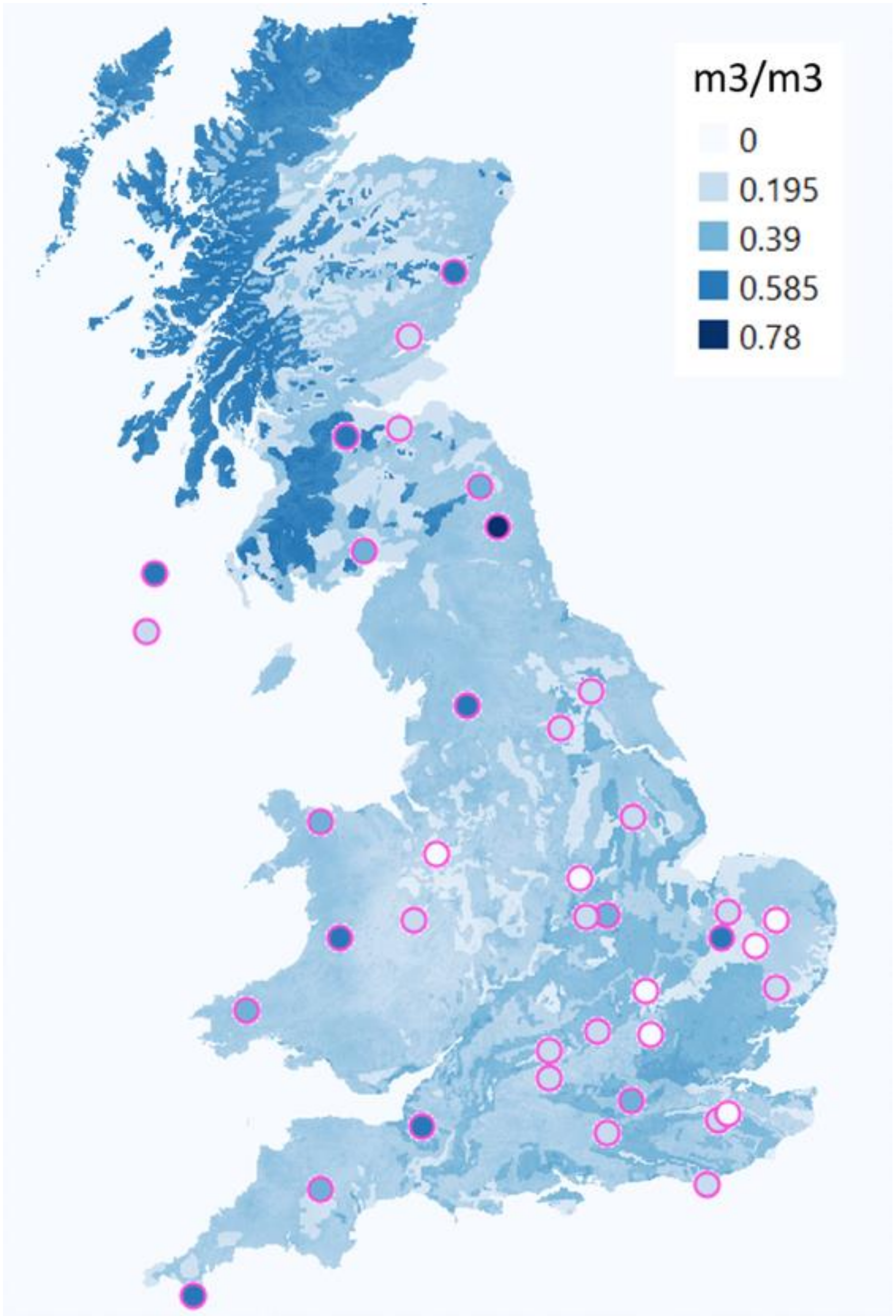
K is the conductivity of the soil, and varies massively with moisture

Ψ is the suction or tension of the soil, and also varies with moisture

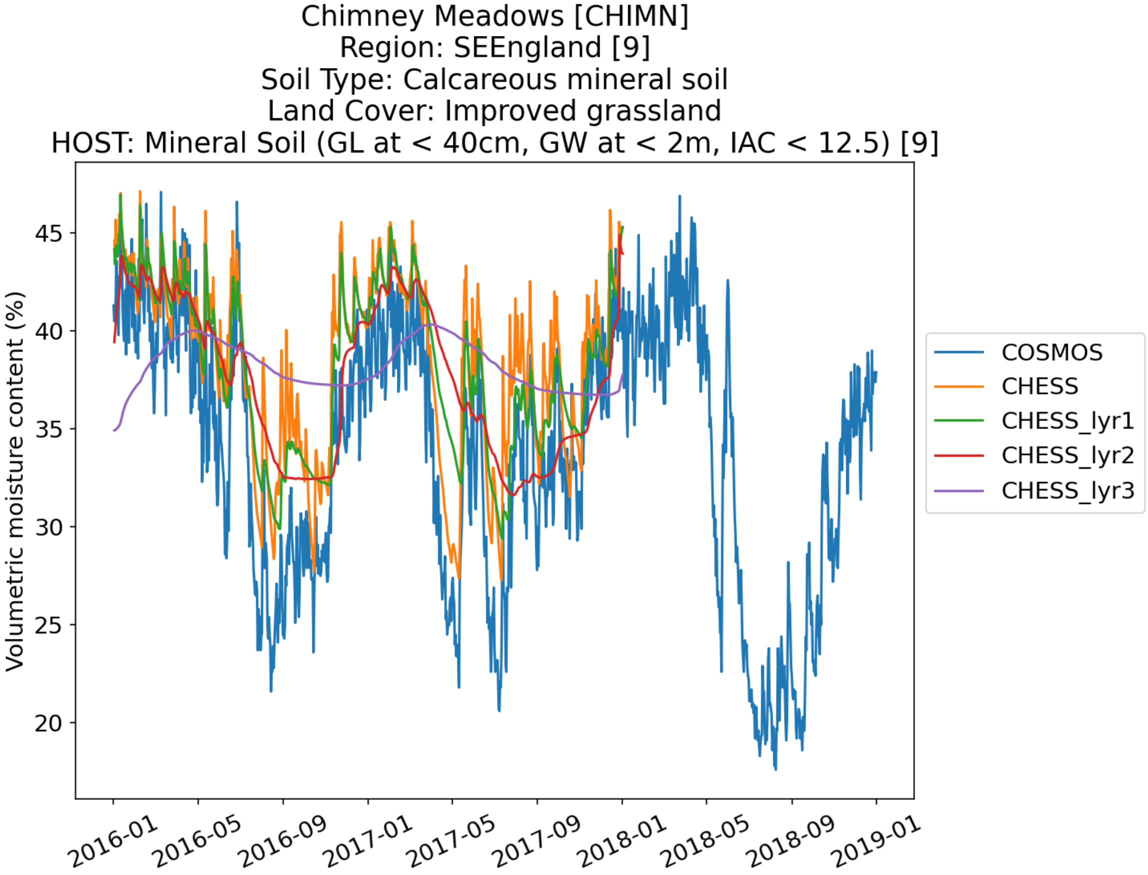
OR

Soils can be modelled as a leaky bucket of water.

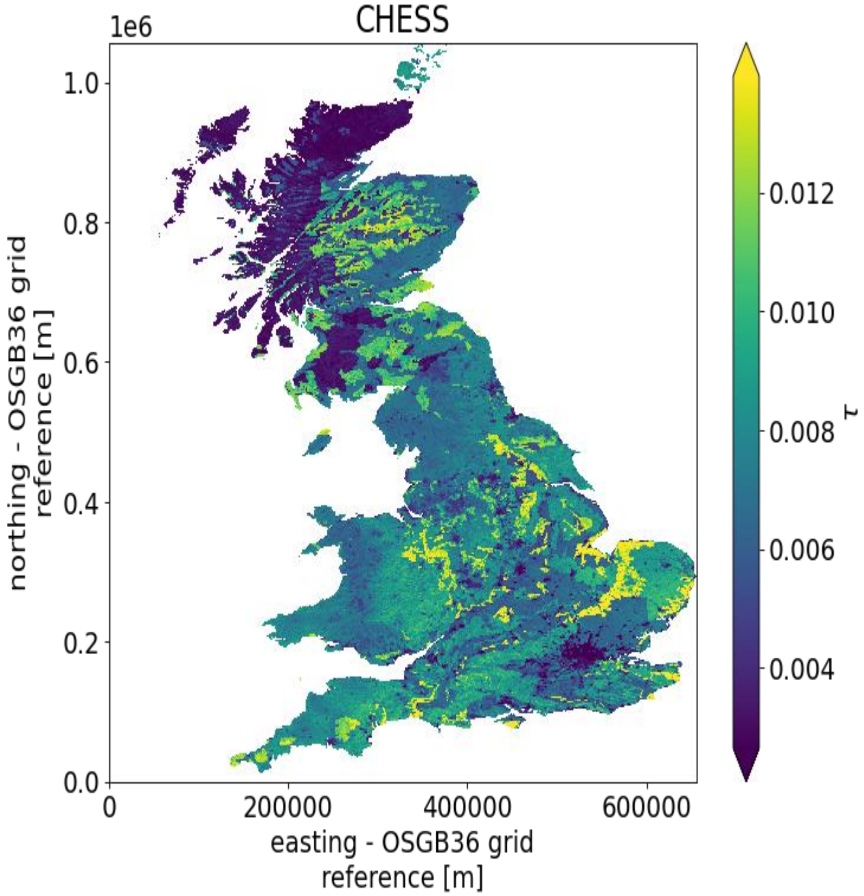
In both – the evaporation is controlled by the amount of water in the soil relative to its full or saturated value.



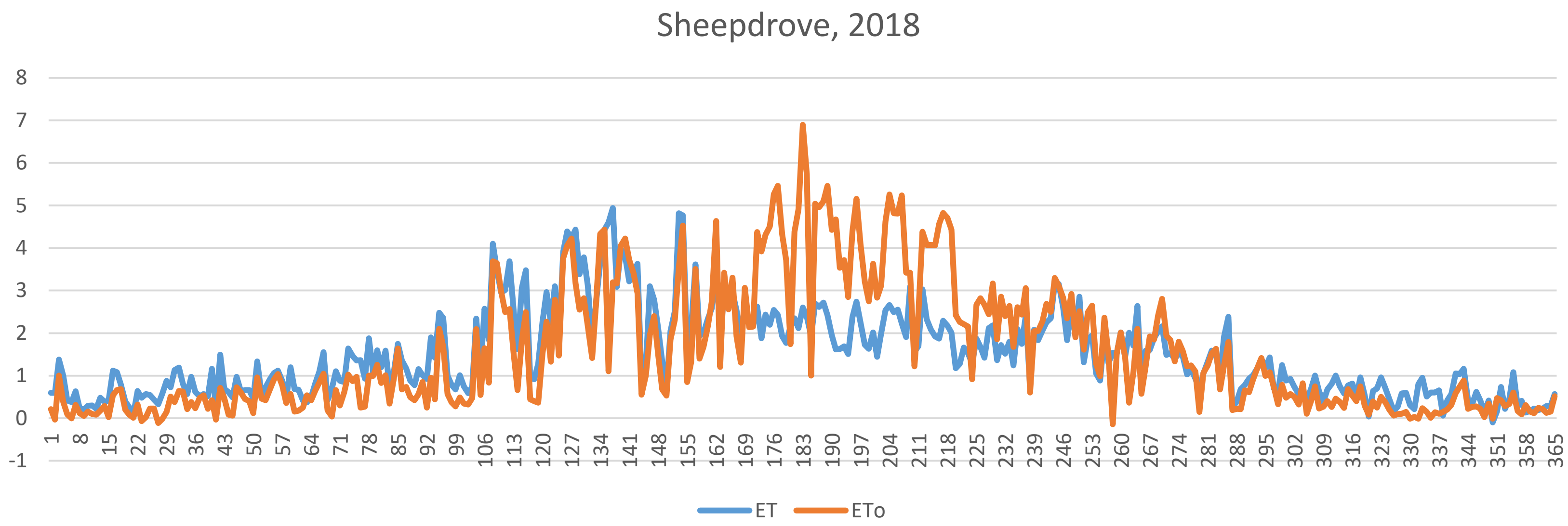
How does soil moisture dynamics vary with soil type and soil depth?

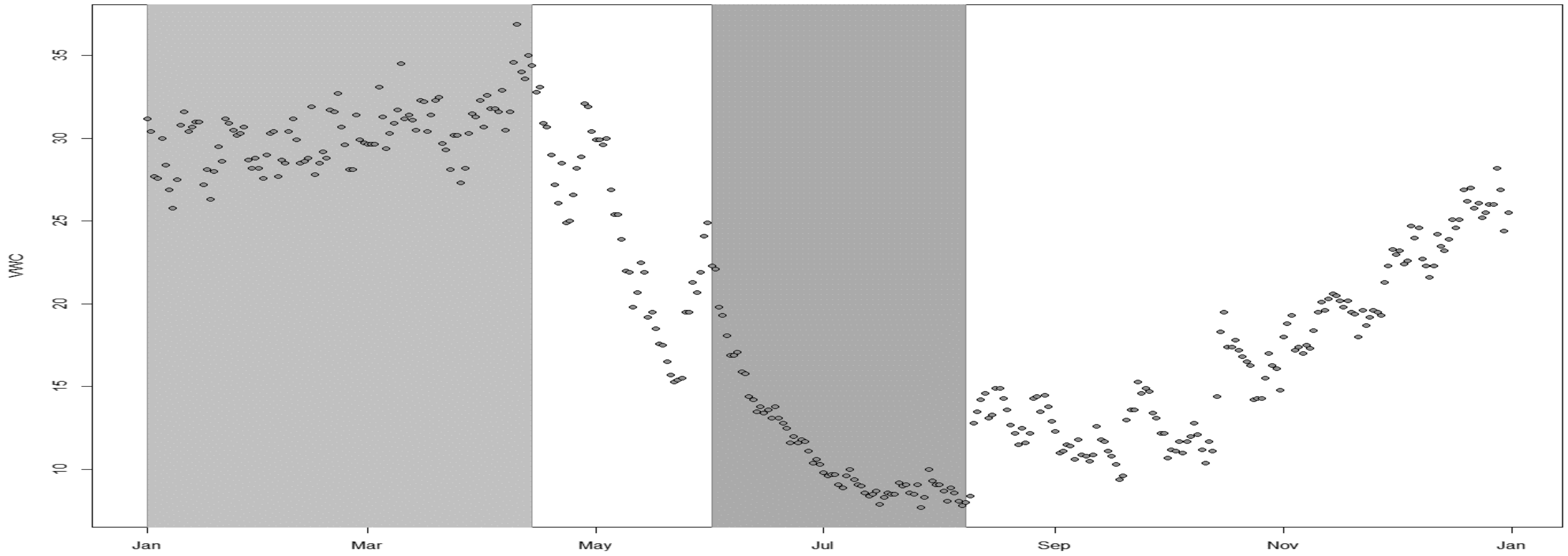


<u>Rate of change of soil moisture/soil moisture</u>



Modelling using extreme soil moisture and ET

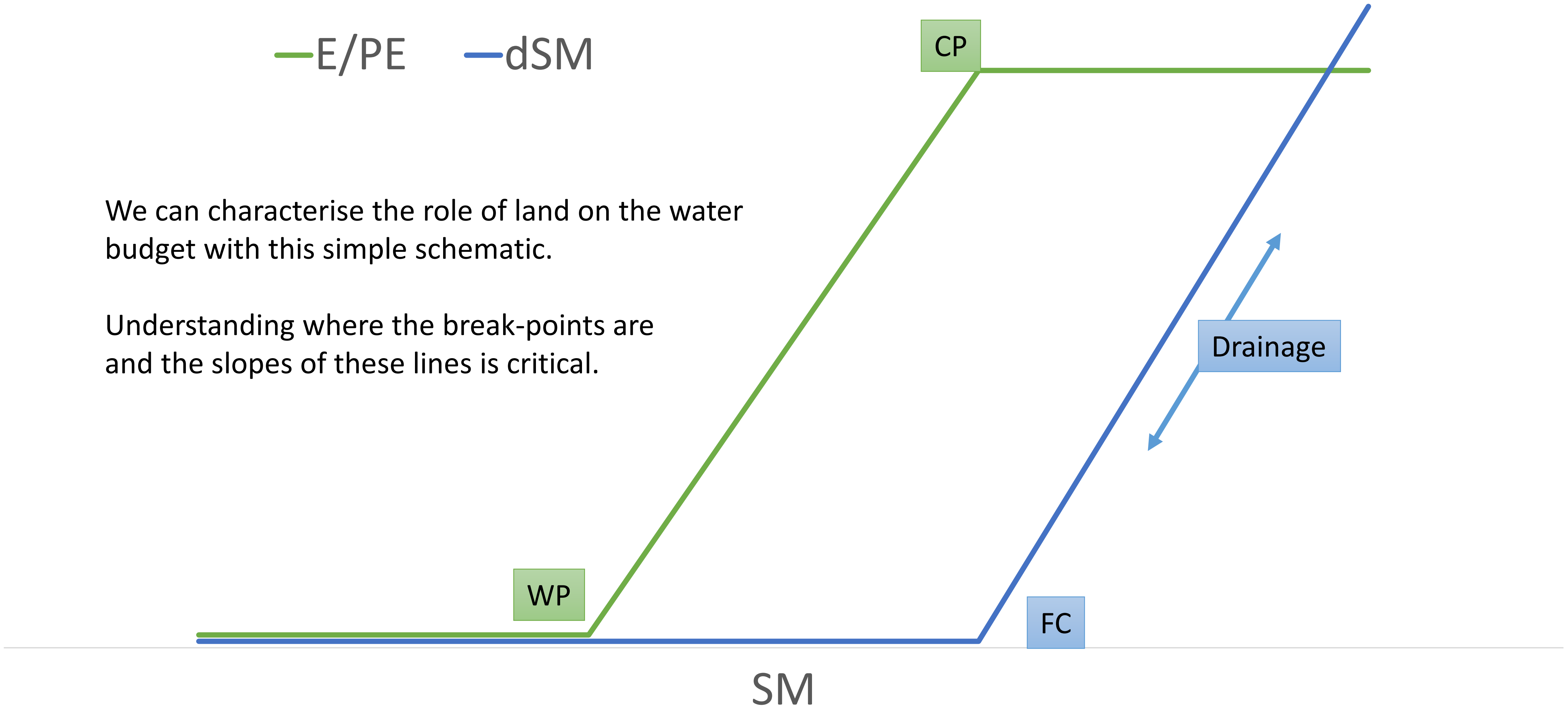




How soil moisture controls evaporation and drainage

We can characterise the role of land on the water budget with this simple schematic.

Understanding where the break-points are and the slopes of these lines is critical.



Land-Atmosphere and Water-Ecosystem impacts

Paper in AGU Advances, April 2021: 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

Paper in Nature. March 2021. Soil moisture–atmosphere feedback dominates land carbon uptake variability

Vincent Humphrey et al.