CHESS: Climate, Hydrology and Ecology research Support System

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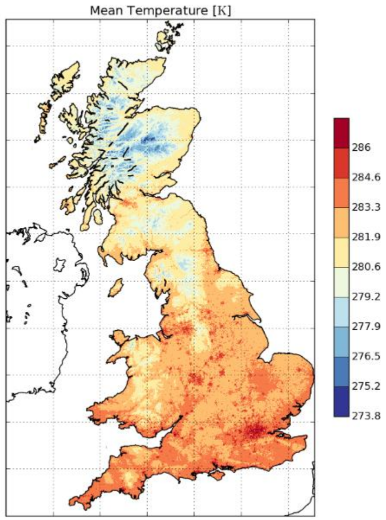

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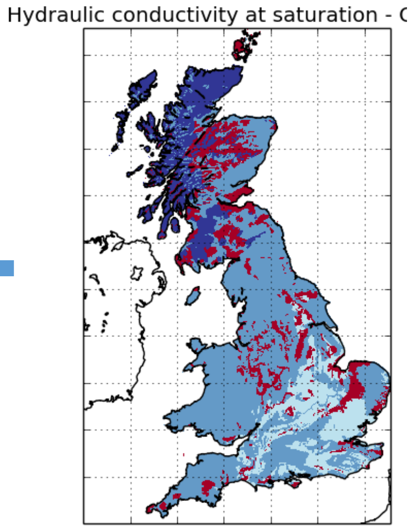

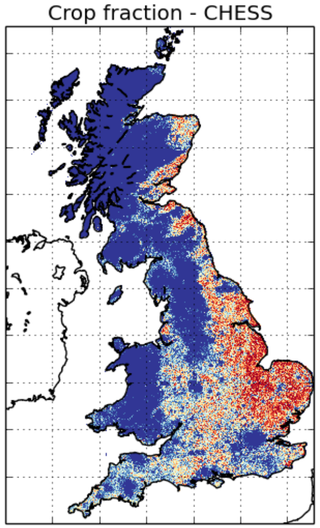

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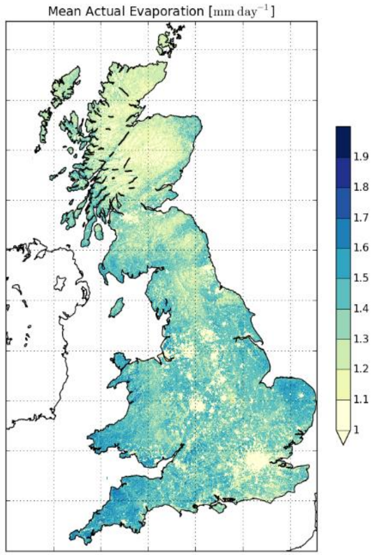


1961 to 2015, 1km, daily

CEH LandCover2000

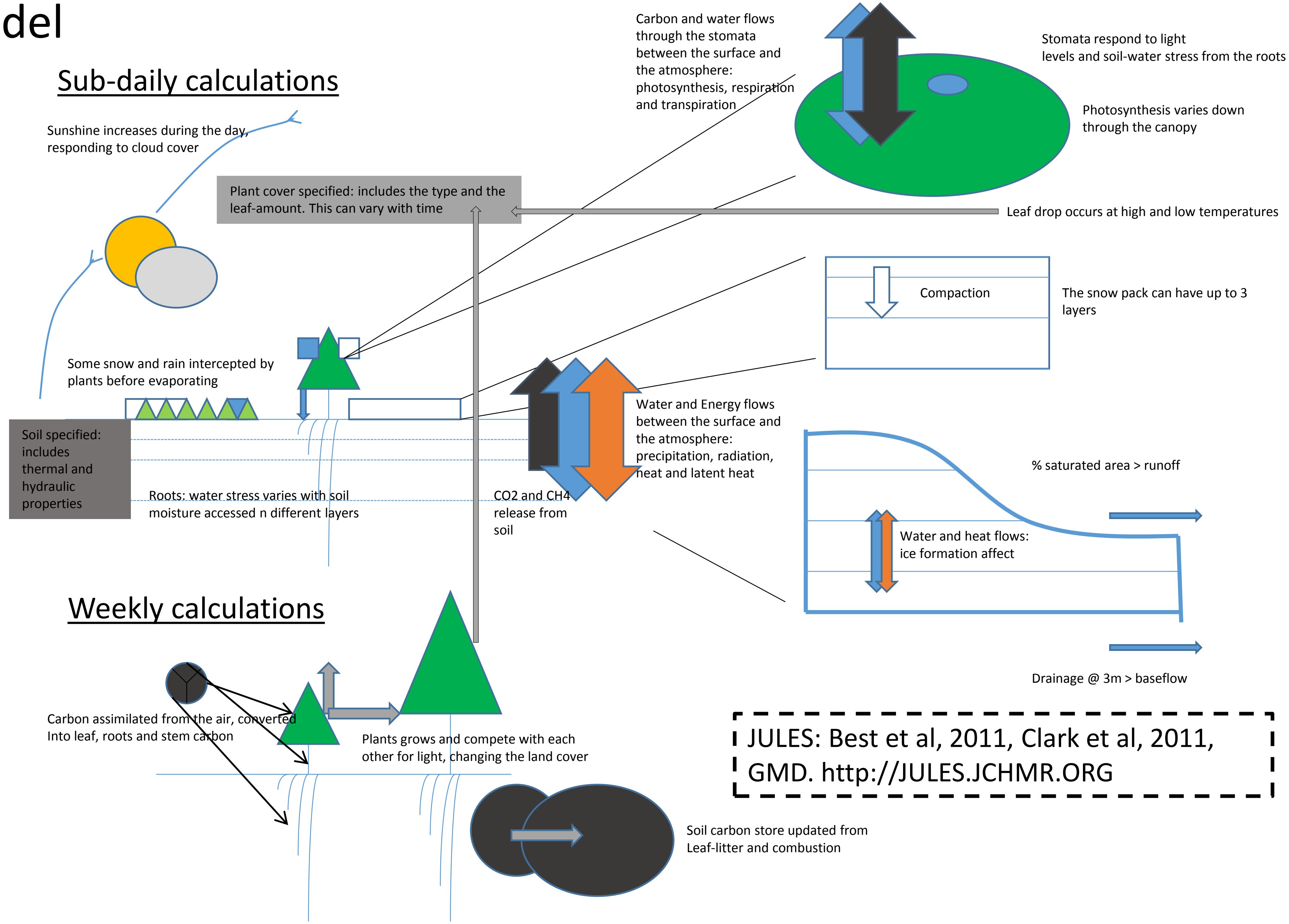
HWSD soils

Disaggregated MORECS data

CEH GEAR rainfall

CHESS met data: Robinson et al, 2017

JULES model



Sub-daily calculations
Sunshine increases during the day, responding to cloud cover
Carbon and water flows through the stomata between the surface and the atmosphere: photosynthesis, respiration and transpiration
Stomata respond to light levels and soil-water stress from the roots
Photosynthesis varies down through the canopy
Plant cover specified: includes the type and the leaf-amount. This can vary with time
Leaf drop occurs at high and low temperatures
Compaction
The snow pack can have up to 3 layers
Some snow and rain intercepted by plants before evaporating
Soil specified: includes thermal and hydraulic properties
Water and Energy flows between the surface and the atmosphere: precipitation, radiation, heat and latent heat
% saturated area > runoff
Roots: water stress varies with soil moisture accessed n different layers
CO2 and CH4 release from soil
Water and heat flows: ice formation affect
Weekly calculations
Drainage @ 3m > baseflow
Carbon assimilated from the air, converted Into leaf, roots and stem carbon
Plants grows and compete with each other for light, changing the land cover
JULES: Best et al, 2011, Clark et al, 2011, GMD. http://JULES.JCHMR.ORG
Soil carbon store updated from Leaf-litter and combustion

Calculation of Interception

Spatial distribution of intensity of rainfall.

$$f(P) = \left(\frac{\mu}{P}\right) \exp\left(\frac{-\mu P_i}{P}\right)$$

where P (kg m^{-2} s^{-1}) is the area-average rainfall rate, P_i (kg m^{-2} s^{-1}) is the rainfall rate over a small area and μ is the fraction of the grid box area over which the rain is assumed to fall. In CHESS, this is set as 1.

Throughfall (T_f) is then calculated:

$$T_f = P\left(1 - \frac{C}{C_m}\right) exp\left(-\frac{\varepsilon C_m}{P \Delta t}\right) + P\frac{C}{C_m}$$

where C (mm) is the amount of rainfall stored on the leaves, C_m (mm) is the maximum capacity which depends on the leaf area index of the vegetation and ε is a tuning factor.

Fraction (F) is assumed the fraction that is wet and used to calculate the evaporation.

$$F = \frac{C}{C_m}$$

Rest of Hydrology

Runoff generation: PDM (Pareto Distribution):

$$f_{sat} = 1 - \left(1 - \frac{\theta}{\theta_s}\right)^{B/_{B+1}}$$

Soil Moisture redistribution: Darcy Richards Equation:

$$W = k\left(\frac{d\psi}{dz} + 1\right)$$

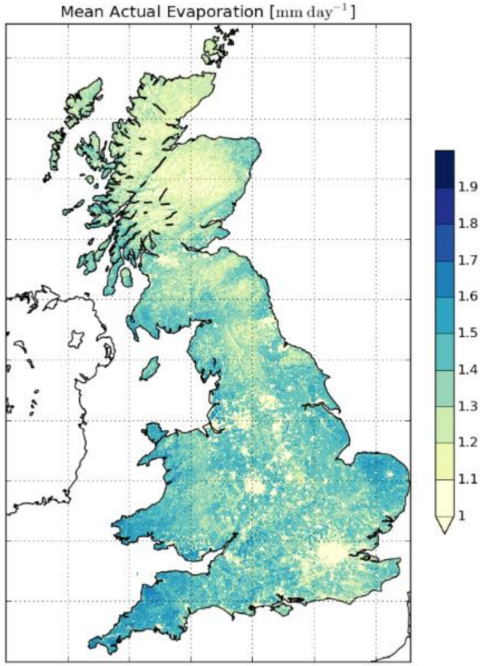
With van Genuchten (1980) formulations:

$$\left(\frac{\theta}{\theta_s}\right) = \frac{1}{\left[1+(\alpha\psi)^{\left(\frac{1}{1-m}\right)}\right]^m}$$

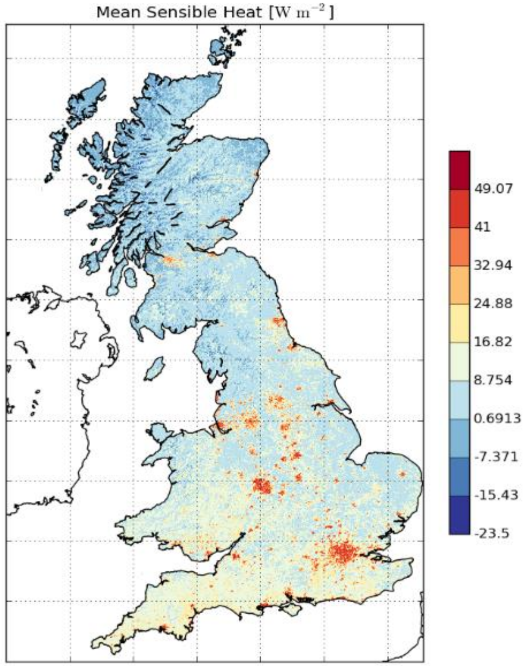
$$k = k_s\left(\frac{\theta}{\theta_s}\right)^{0.5}\left[1 - \left(1 - \left(\theta/_{\theta_s}\right)^{1/m}\right)^m\right]^2$$

Where ψ_s (m) is the suction at saturation and k_s (kg m^{-2} s^{-1}) is the conductivity at saturation while α and *m* are model parameters.

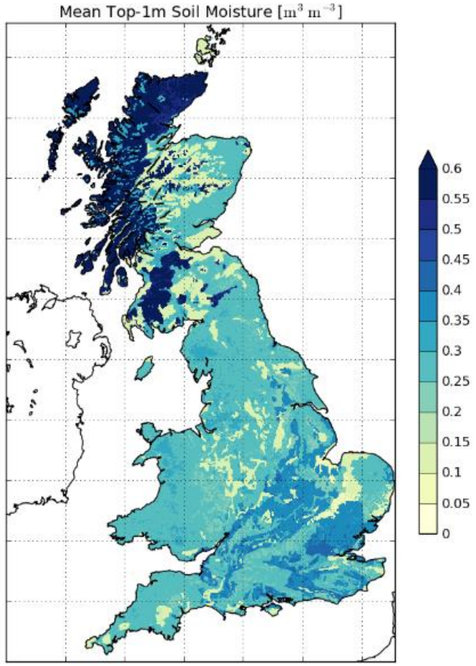
RESULTS



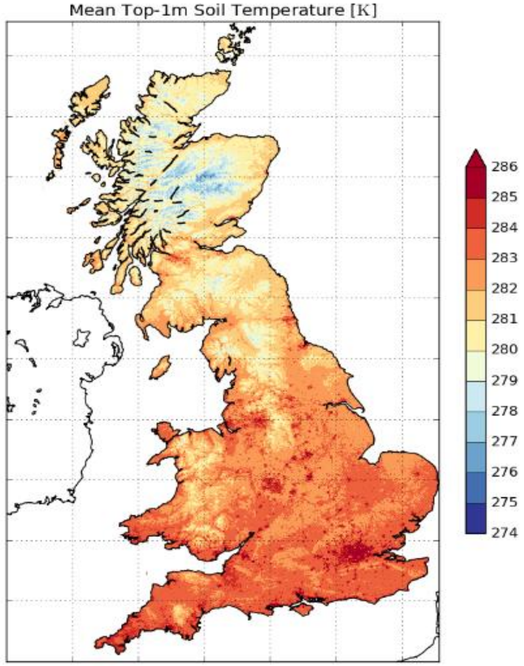
Mean Actual Evaporation [$\mathrm{mm\ day^{-1}}$]
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1



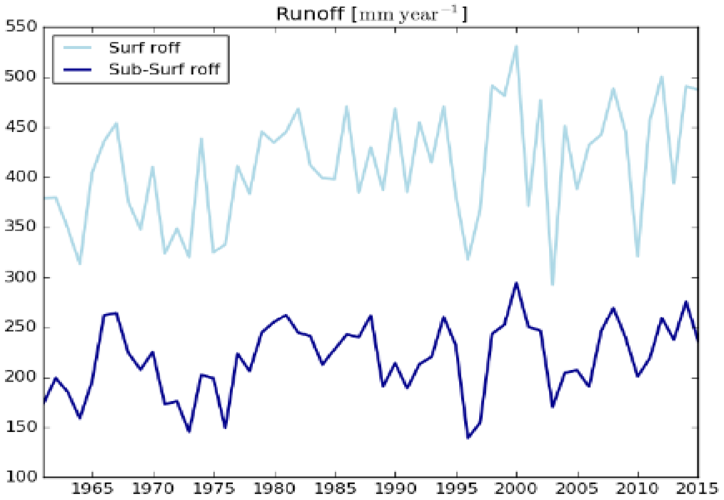
Mean Sensible Heat [$\mathrm{W\ m^{-2}}$]
49.07
41
32.94
24.88
16.82
8.754
0.6913
-7.371
-15.43
-23.5



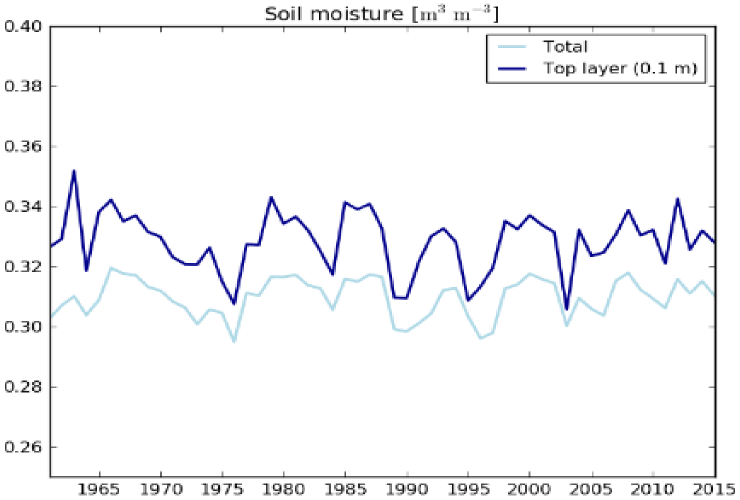
Mean Top-1m Soil Moisture [$\mathrm{m^3\ m^{-3}}$]
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0



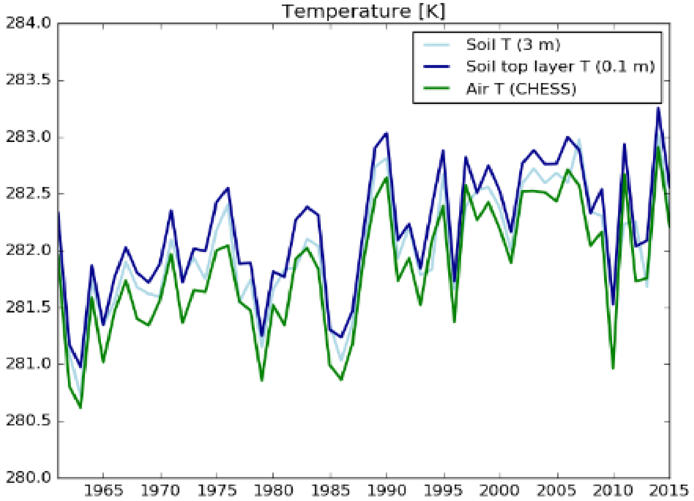
Mean Top-1m Soil Temperature [K]
286
285
284
283
282
281
280
279
278
277
276
275
274



Runoff [$\mathrm{mm\ year^{-1}}$]
Surf roff
Sub-Surf roff
550
500
450
400
350
300
250
200
150
100
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015



Soil moisture [$\mathrm{m^3\ m^{-3}}$]
Total
Top layer (0.1 m)
0.40
0.38
0.36
0.34
0.32
0.30
0.28
0.26
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015



Temperature [K]
Soil T (3 m)
Soil top layer T (0.1 m)
Air T (CHESS)
284.0
283.5
283.0
282.5
282.0
281.5
281.0
280.5
280.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015

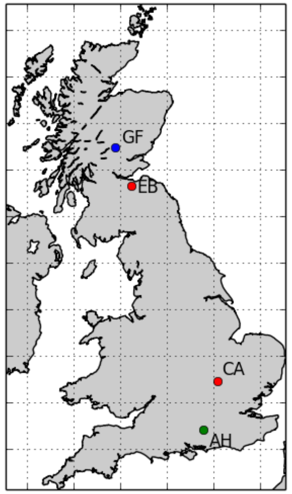
Questions to be asked……

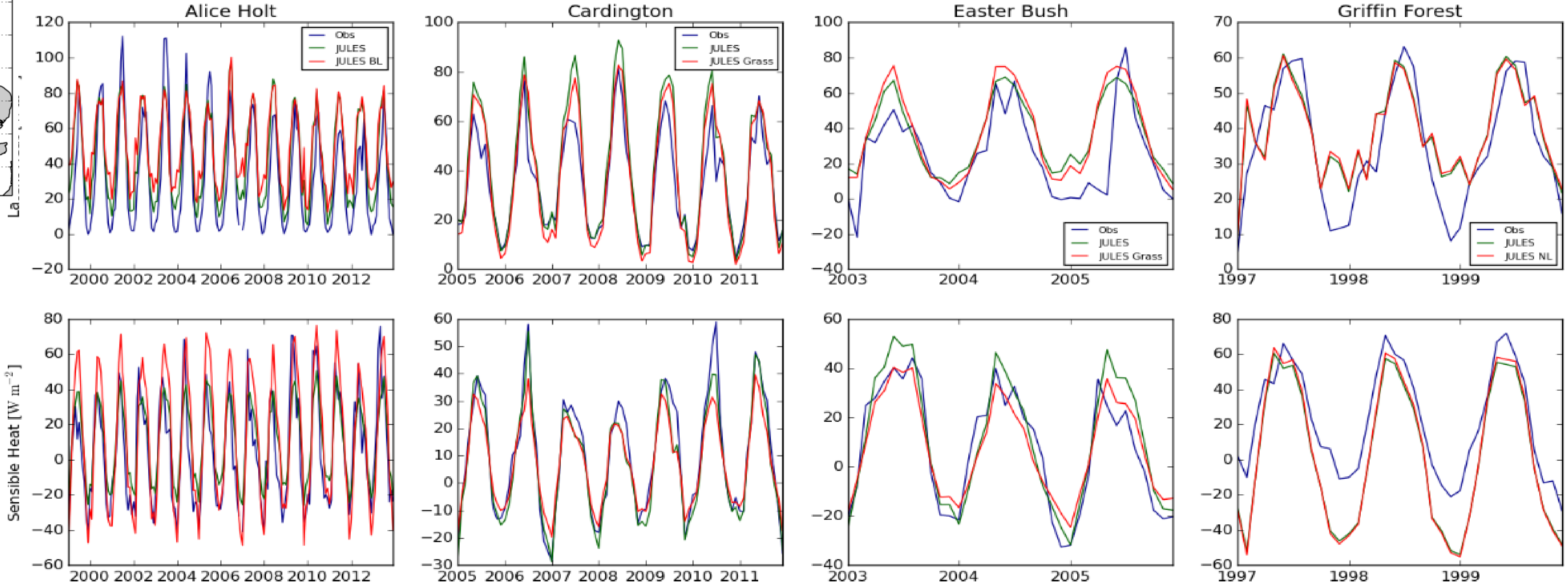
Precipitation increase: 2.95 mm per year

Runoff increase: 1.6 mm per year

PET increase: 0.7 to 0.77 mm per year

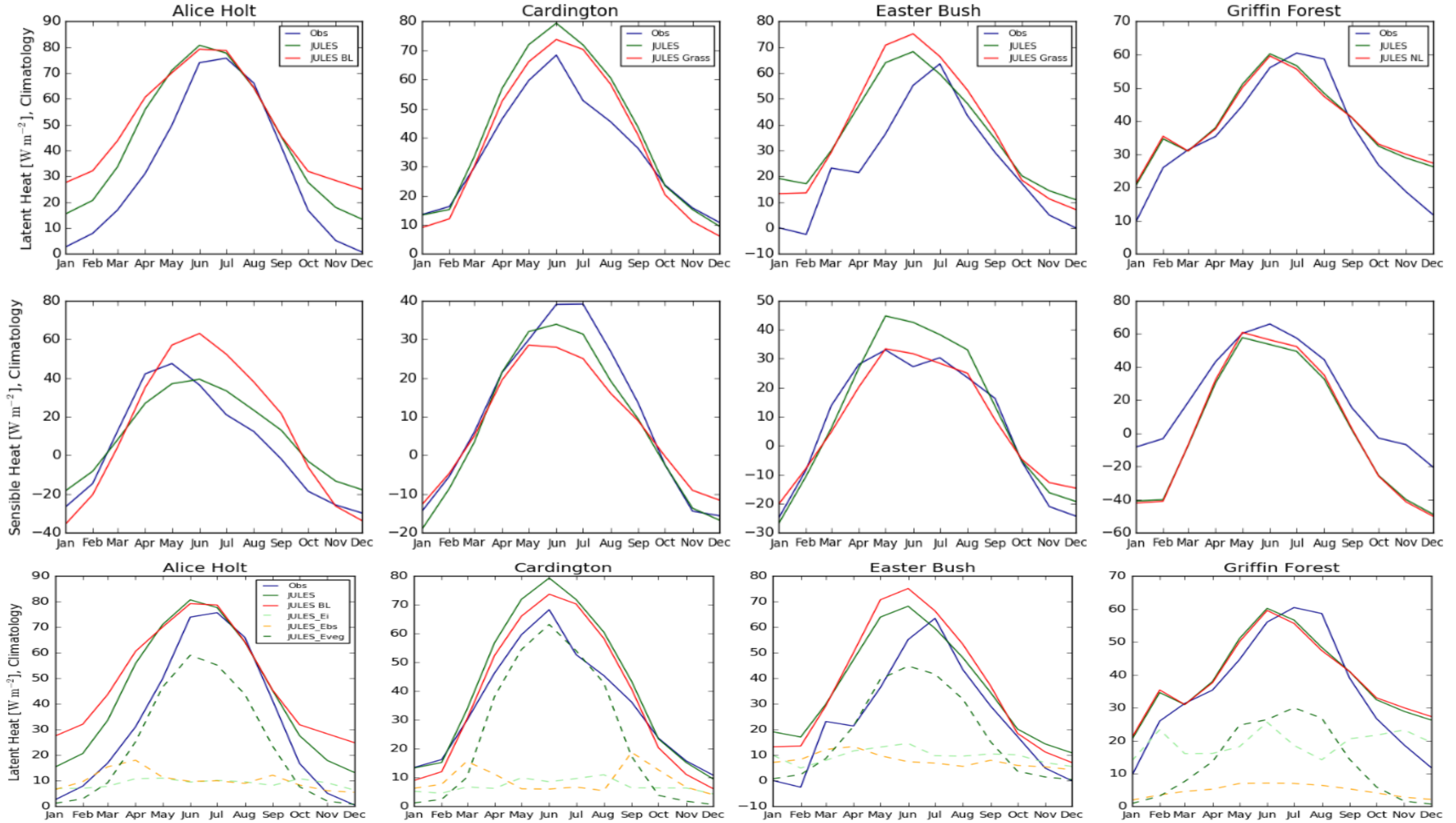
- Is the evaporation of GB and the regions increasing or decreasing?
- Which components of the evaporation are contributing to the trend?
- What meteorological changes are driving these changes?
- What impact does the increase in atmospheric CO_2 have on the trend?





Long term downward trend in Evapotranspiration at Alice Holt.

Pers. Comm. (Matt Wilkinson) – not to be trusted……



	Evaporative Fraction as %		P (mm yr^{-1})	Transpiration, T_r		Bare Soil Evaporation, B_S		Interception, I	
	Obs	Model		% E_{tot}	% P	% E_{tot}	% P	% E_{tot}	% P
Alice Holt	88	81	832	54	29	24	13	22	11
Cardington	77	85	562	60	45	22	17	18	13
Easter Bush	77	77	876	50	21	24	9	27	12
Griffin Forest	61	95	1215	35	11	13	4	52	17

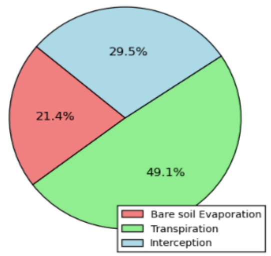
EVALUATION

Van den Hoof et al (2013): forest interception to range from 13% to 25% **of the total evaporation** while for grasses it is more like 10%.

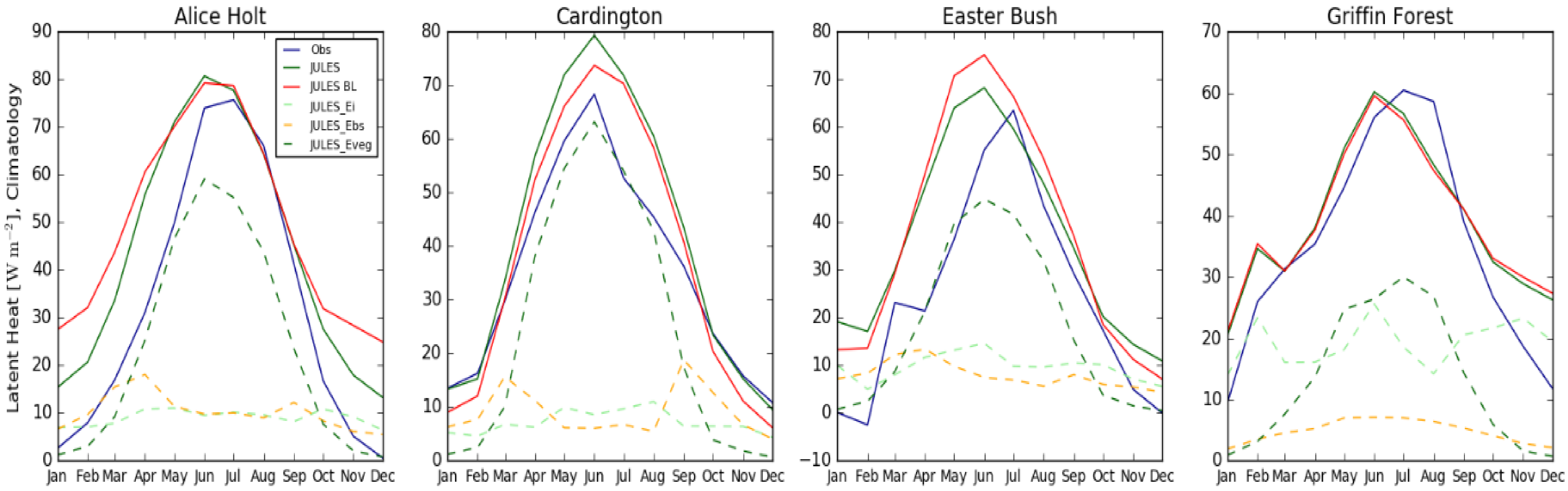
Nisbet (2005) forest interception about 20% for broadleaf trees and 35% for needleleaf **of rainfall**

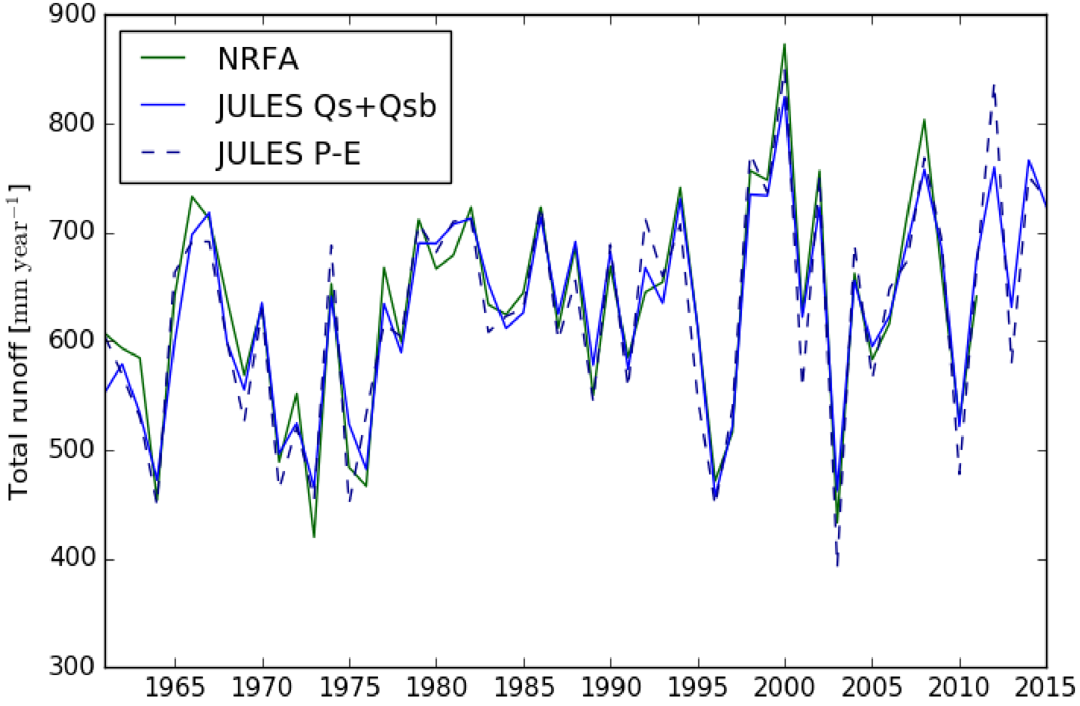
Both about right…….

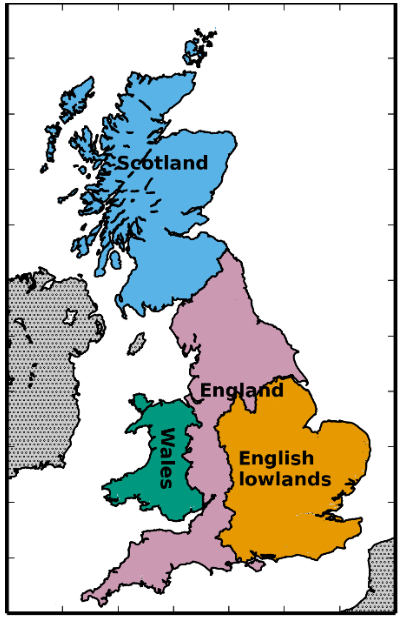
Overall overestimate by about 10%

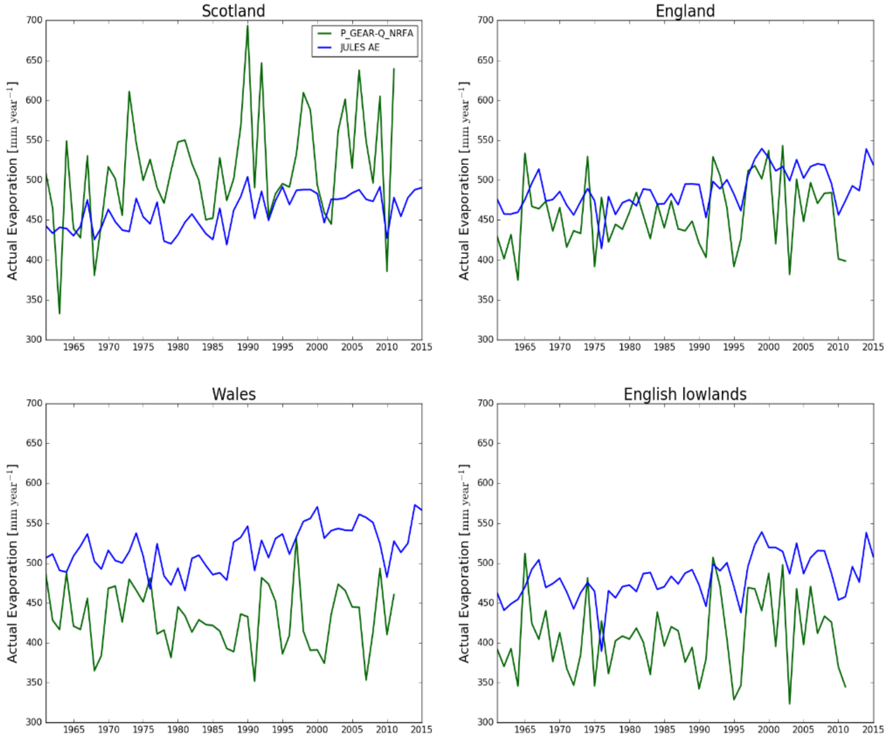


Zooming in

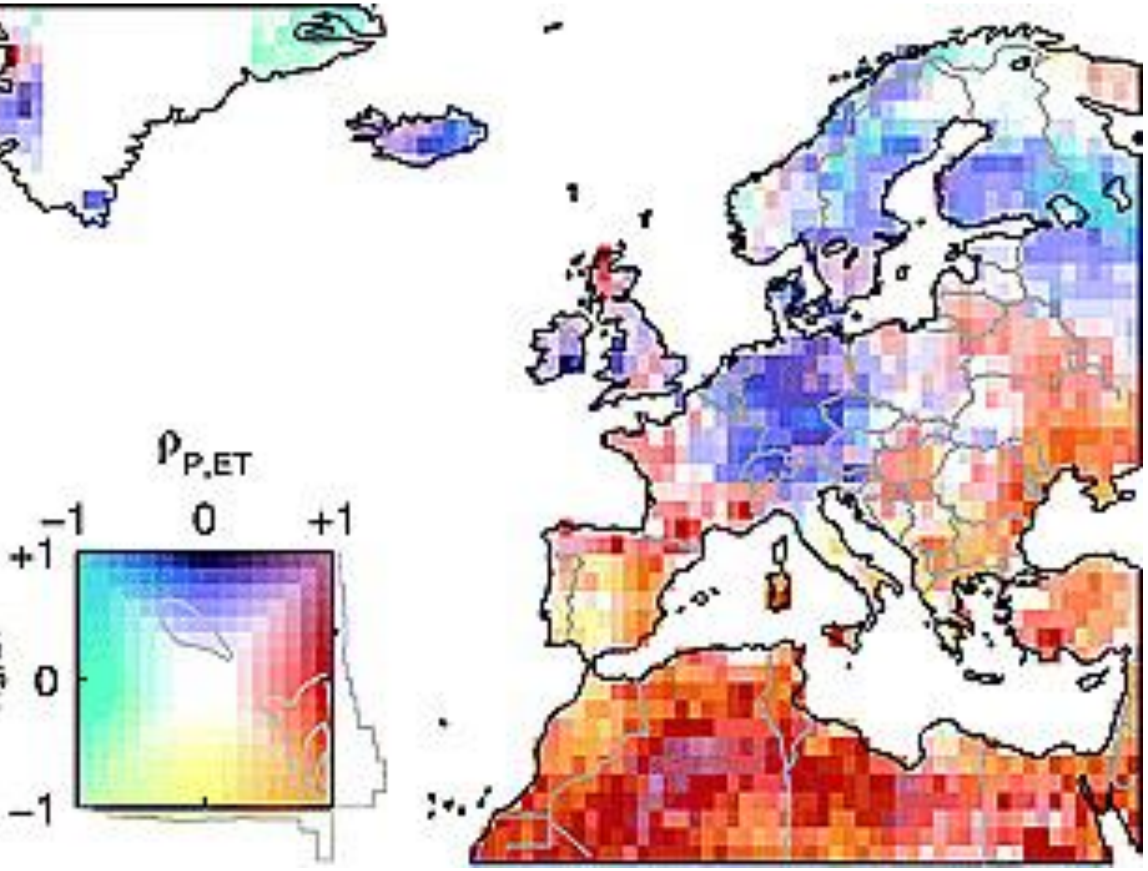

Alice Holt
Cardington
Easter Bush
Griffin Forest
Latent Heat [W m⁻²], Climatology
Obs
JULES
JULES BL
JULES_Ei
JULES_Ebs
JULES_Eveg
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec



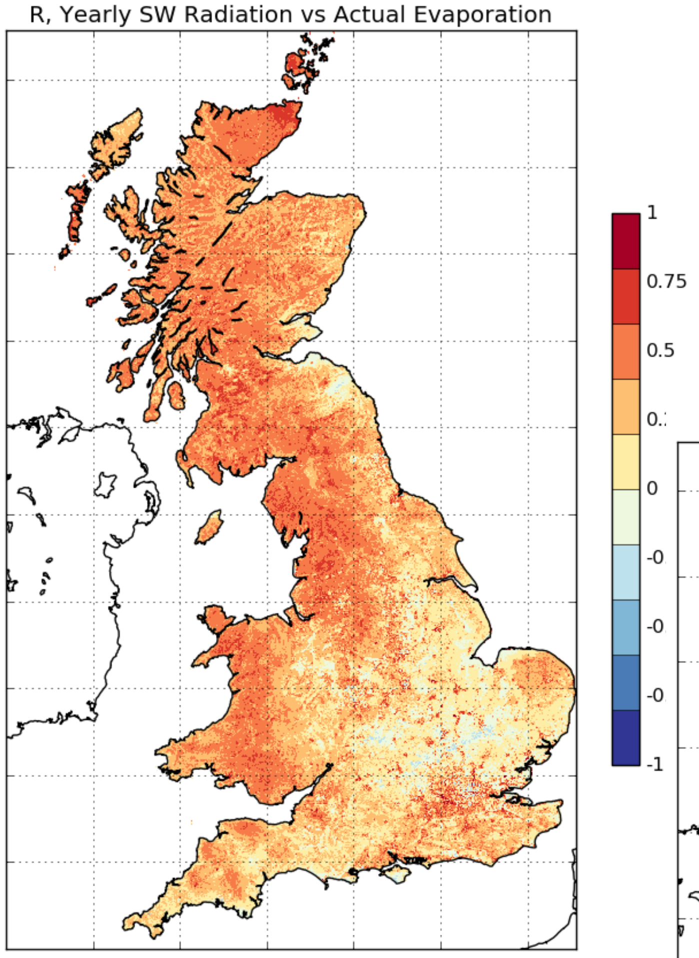


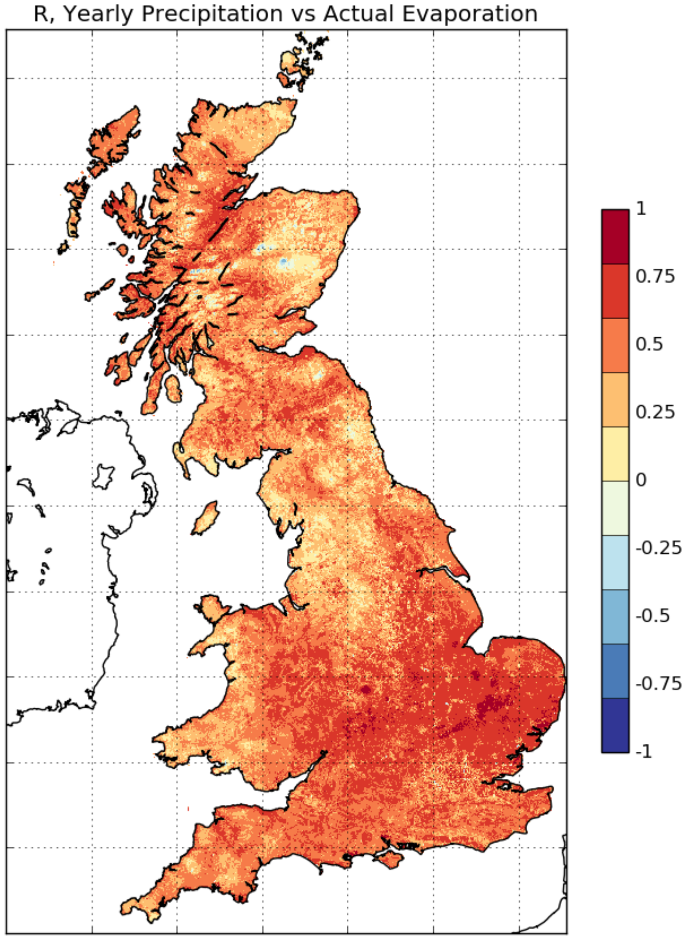


Annual average (mm yr⁻¹)	Precipitation	Model runoff	Observed runoff	Model Evap.	Observed Evap.	Bias in Evap (% Observed)
Scotland	1485	1032	972	458	513	-10.5%
Wales	1377	863	945	516	432	+19.5%
England	825	342	369	485	456	+4.5%
English Lowlands	681	206	273	479	408	+17.5%

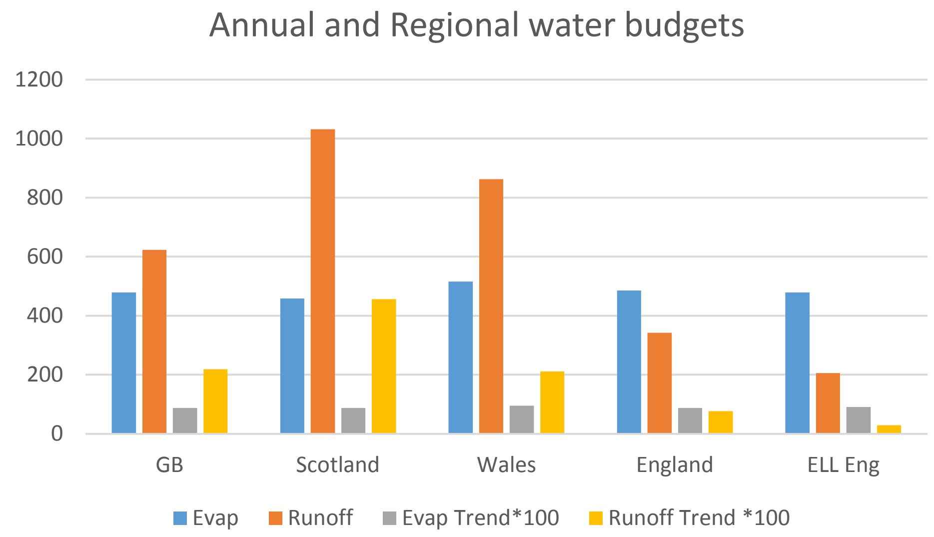


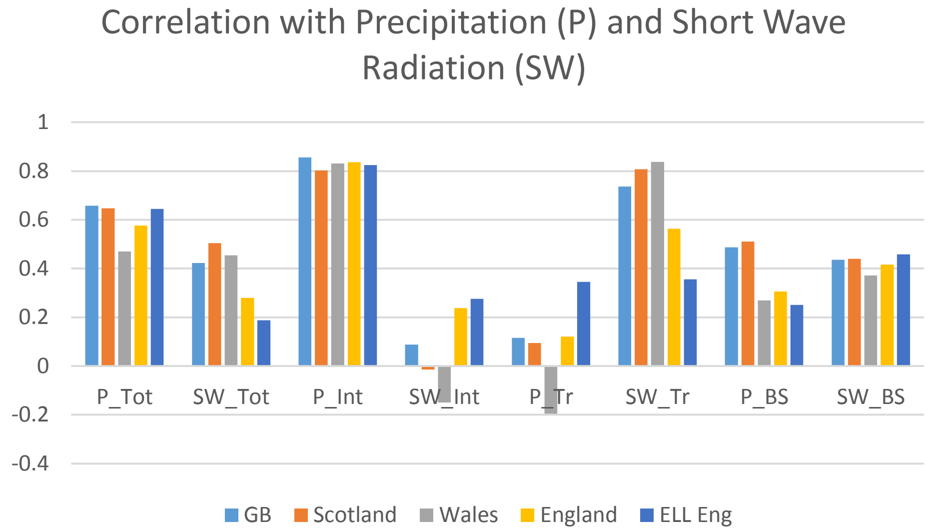
Teuling et al, 2009. A regional perspective on trends in continental evaporation. GRL



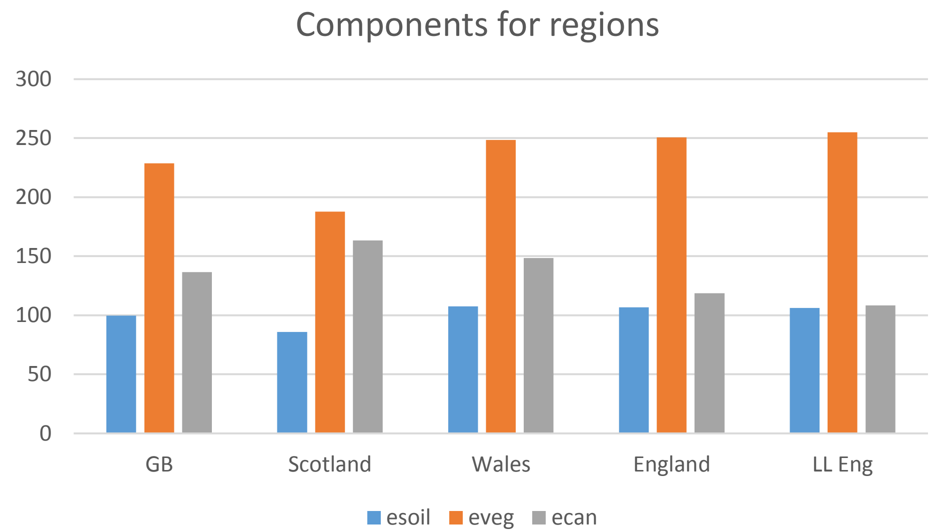


Correlation of annual Evapotranspiration with Precipitation and ShortWave Radiation





R	P v E_{tot}	S_W v E_{tot}	P v I	S_W v I	P v T_r	S_W v T_r	P v B_S	S_W v B_S
GB	0.66	0.42	0.86	0.09	0.11	0.74	0.48	0.44
Scotland	0.65	0.50	0.80	-0.01	0.09	0.81	0.51	0.44
Wales	0.47	0.45	0.83	-0.15	-0.20	0.84	0.27	0.37
England	0.58	0.28	0.84	0.24	0.12	0.56	0.31	0.42
English Lowlands	0.64	0.19	0.82	0.28	0.35	0.36	0.25	0.46



Conclusions (Blyth et al, 2018, being submitted)….

1. Modelled evapotranspiration increases (0.9 mm per year) are higher than increases in PET (0.7 to 0.77 mm per year) and leave no trend in soil moisture.
2. There is a large contribution of interception to the overall evaporation in GB (30%). This is due to the combination of wet and windy areas (West Scotland) with evergreen needle leaf trees which have a high interception capacity.
3. The evaporation from a wet forest often exceeds the PET, drawing down energy in the form of negative sensible heat (i.e. cooling the air) to drive it.
4. Interception fraction scales with precipitation rather than energy. This confirms the summary of observations presented by Nisbet (2005).
5. Over the last 5 decades, precipitation has increased faster (2.96 mm yr^{-1}) than the PET (0.77 mm yr^{-1}). This increase in precipitation, combined with the high interception rates in GB explains why the trend in evapotranspiration is higher than the trend in PET.
6. The effect in the model of an increase in CO_2 was to reduce the upward trend in evapotranspiration (via a reduction in transpiration) by a factor of 38%. There was a smaller impact on the runoff with a 5% increase in overall runoff.