Derivation of RCM-driven potential evapotranspiration for hydrological climate change impact analysis in Great Britain: a comparison of methods and associated uncertainty in future projections

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Supplementary material

Sect. 1: PET methods and associated equations

PET method	Equation
FAO56 (Allen et al., 1998)	$PE[mm\ day^{-1}] = \frac{\lambda^{-1}\Delta(R_n - G) + \gamma\frac{900}{T+273}U_2(e_s - e_d)}{\Delta + \gamma(1 + 0.34U_2)}$
Penman-Monteith (modified) (Kay et al., 2003)	$PE[mm\ day^{-1}] = \frac{1}{\lambda}\frac{\Delta(R_n - G) + \rho C_p(e_s - e)/r_a}{\Delta + \gamma(1 + r_s/r_a)}$
Priestley-Taylor (Priestley and Taylor, 1972)	$PE[mm\ day^{-1}] = \propto \frac{1}{\lambda}\frac{\Delta}{\Delta + \gamma}(R_n - G)$
Turc (Turc, 1961)	$PE[mm\ day^{-1}] = 0.31\ \frac{T}{T+15}(R_{sn} + 2.09)\left(1 + \frac{50 - RH}{70}\right)$ $for\ RH < 50\%$ $PE[mm\ day^{-1}] = 0.31\ \frac{T}{T+15}(R_{sn} + 2.09)$ $for\ RH > 50\%$
Jensen-Haise (Jensen et al., 1990)	$PE[mm\ day^{-1}] = \frac{1}{\lambda}0.025(T + 3)R_s$
Makkink (Jacobs et al., 2009)	$PE[mm\ day^{-1}] = \frac{1}{\lambda}\frac{R_n}{R_s}\frac{\Delta}{\Delta + \gamma}R_s$
Priestley-Taylor Idso-Jackson (Shuttleworth, 1993)	$PE[mm\ day^{-1}] = \propto \frac{1}{\lambda}\frac{\Delta}{\Delta + \gamma}(1 - \alpha)\left(0.25 + 0.5\frac{n}{N}\right)S_0 - \left(0.9\frac{n}{N} + 0.1\right)\left(-0.02 + 0.261exp\left(-7.7 \times 10^{-4}T^2\right)\right)\sigma T^4$

Hamon (Oudin et al., 2005)	$PE[mm\ day^{-1}] = \left(\frac{N}{12}\right)^2 exp\left(\frac{T}{16}\right)$
McGuinness-Bordne (Oudin et al., 2005)	$PE[mm\ day^{-1}] = \frac{1}{\lambda} S_0 \left(\frac{T+5}{68}\right)$
Oudin (Oudin et al., 2005)	$\begin{cases} PE[mm\ day^{-1}] = \frac{1}{\lambda} S_0 \left(\frac{T+5}{100}\right) & if\ T > -5°C \\ PE[mm\ day^{-1}] = 0 & if\ T \leq -5°C \end{cases}$
Blaney-Criddle (Blaney and Criddle, 1950)	$PE[mm\ day^{-1}] = kTp_d$ with $p_d = 100 \frac{N_d}{\sum_{i=1}^{365} N_i}$
Thornthwaite (Xu and Singh, 2001)	$PE' = 16 \left(\frac{10T}{I}\right)^a$ $a = 0.49239 + 0.01792\ I - 7.71\ 10^{-5} I^2 + 6.75\ 10^{-7} I^3$ $PE[mm\ month^{-1}] = PE' \frac{N_m}{12} \frac{D_m}{30}$

Sect. 2: Notations and used values of meteorological variables

Values used in the PET calculations calculated from meteorological inputs and the equations used to calculate them

Symbol	Variable name	Units	Description	Formula
δ	Solar declination	radians	Angle between rays of the sun and the plane of the earth's equator.	$\delta = 0.4093\sin\left(\frac{2\pi}{365}J - 1.405\right)$ *With J Julian day number*
d_r	Relative earth-sun distance		Distance between earth and sun varies through the year due to the ellipse orbit of the earth around the sun.	$d_r = 1 + 0.033\cos\left(\frac{2\pi}{365}J\right)$
ω_s	Sunset hour angle	radians	Angle by which the ray of the sun reaches the earth's surface.	$\omega_s = \arccos\left(-tan\Phi tan\delta\right)$ *With Φ latitude (+ is north, - is south)*
N	Maximum possible daylight length	hours	Length of the period when the rays of the sun reach the earth's surface.	$N = \frac{24}{\pi}\omega_s$
e_s	Saturated water vapour pressure	kPa	Equilibrium of rates of vaporisation and condensation for a given temperature that occurs at particular vapour pressure, the saturated vapour pressure.	$e_s = 0.6108e^{\left(\frac{17.27T}{237.3+T}\right)}$ *With T temperature in °C*
e_d	Actual water vapour pressure	kPa	Actual water vapour pressure at dew point.	$e_d = 0.6108e^{\left(\frac{17.27T_d}{237.3+T_d}\right)}$ *With T_d temperature at dew point, °C*
Δ	Gradient of vapour pressure curve	kPa°C^{-1}	Gradient of vapour pressure curve is the slope of the non linear relationship between pressure and temperature.	$\Delta = \frac{4098e_s}{(237.3+T)^2}$
λ	Latent heat of vaporisation	MJkg^{-1}	Amount of energy needed for water to be transformed from a liquid to a gas, approximated as λ=2.45 MJkg^{-1}.	$\lambda = 2.501 - 0.002361T$ *With T as 20°C*
P	Vapour pressure	kPa	The change of pressure due to altitude	$P = 101.3\left(\frac{293 - 0.0065z}{293}\right)^{5.26}$ *With z elevation above sea level*
ρ	Absolute humidity/water vapour density	Kgm^{-3}	Absolute humidity or water vapour density is calculated using the ideal gas law.	$\rho = 3.483\frac{p - 0.378e_d}{T}$
RH	Relative humidity	[-]	Amount of water the air can hold at a certain temperature. In other words the percentage ratio of actual vapour pressure to saturated vapour pressure.	$RH = 100\frac{e_d}{e_s}$

Symbol	Variable name	Units	Description	Formula
f	Cloudiness factor or fraction	[-]	Amount of cloud cover in the atmosphere, related to number of bright sunshine hours in a day. Different coefficients can be used for humid and arid areas. Using the longwave coefficients for arid areas a simplified version of the formula can be derived. A second expression is given by Jensen 1990. In this formula the cloudiness factor is expressed as the effect of clouds on short-wave global radiation	Shuttleworth, 1993 $f = \left(a_c \frac{b_s}{a_s + b_s}\right)\frac{n}{N} + (b_c + \frac{a_s}{a_s + b_s} a_s)$ *With: n as bright sunshine hours (h),* *a_s is fraction of extraterrestrial radiation (S_0) for n=0,* *a_s+ b_s is fraction of extraterrestrial radiation for n>0,* *a_c and b_c are long wave coefficients for clear skies.* *N is the maximum possible daylight hours* Simplified version (Allen et al., 1998) $f = 0.9\frac{n}{N} + 0.1$ Jensen, 1990 $f = a_c \frac{R_s}{S_0} + b_c$ *With R_s solar (short-wave) radiation (MJ m^2/day)*
G	Soil heat flux	$MJm^{-2}month^{-1}$	Energy that moves from the surface to subsurface soil by conduction, depends on soil temperature fluctuations	Monthly formulation (Shuttleworth, 1993) $G = 0.14(T_{month2} - T_{month1})$
γ	Psychrometric constant (for water)	$KPa°C^{-1}$	Describes the thermodynamic properties of moist air at a constant pressure. Relates the partial pressure of water in the air to the air temperature	Shuttleworth, 1993 $\gamma = \frac{c_p P}{\varepsilon\lambda}$ *With c_p specific heat of moist air* *P atmospheric pressure* *ε ratio of molecular weight of water vapour to that of dry air*
S_0	Extraterrestrial radiation	$mmday^{-1}$ (Note that energy can be expressed in depth of water	The amount of solar energy that reaches the top of the atmosphere. Depends on angle of sun radiation and length of day.	Shuttleworth, 1993 $S_0 = 15.392 d_r(\omega_s sin\phi sin\delta + cos\phi cos\delta sin\omega_s)$

Symbol	Variable name	Units	Description	Formula
		equivalent using X[mm day^{-1}]= ρ		
R_s	Solar radiation	MJm^{2}day^{-1}	Amount of energy measured at the earth's surface including direct and diffuse short-wave radiation	Generalised form (Jensen et al., 1990) $R_s = S_0(0.25 + 0.50\frac{n}{N})$
R_{ns}	Net solar radiation	MJm^{2}day^{-1}	That part of the incident short wave radiation that is captured at the ground (reflection losses are taken into account), in other words, the absorbed incoming solar radiation.	Shuttleworth, 1993 $R_{ns} = (1-\alpha)R_s$ *With α albedo*
R_{nl}	Net long-wave radiation	MJm^{2}day^{-1}	Incoming (atmosphere to ground) minus outgoing (ground to atmosphere) long-wave radiation	$R_{nl} = -f\varepsilon'\sigma T^4$ *With ε' net emissivity between atmosphere and ground* *ε Stefan-Boltzmann constant* *T mean air temperature in °C*
R_n	Net radiation	MJm^2/day	Difference between ~~het~~the net solar radiation and the long-wave radiation	$R_n = R_{ns} - R_{nl}$