A global multiscale SPEI dataset under an ensemble approach

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PET formulations

Hargreaves formula:

Monthly average ET_m (mm/month) according to the Hargreaves method requires monthly average geo-datasets of 1) mean temperature (T_m, °C); 2) daily temperature range (TD, °C) and 3) extra-terrestrial radiation (RA, radiation on top of atmosphere expressed in mm/month as equivalent of evaporation), as shown below:

$$ET_m = 0.0023 * Ra * (T_m + 17.8) * T_d^{0.5} \quad \text{(mm/month)}$$

$$R_a = \frac{24(60)}{\pi} * 0.0820 * d_r * \left[\omega_s \sin(lat)\sin(\delta) + \cos(lat)\cos(\delta)\sin(\omega_s)\right] * 0.408$$ [1]

Where

Ra is extra-terrestrial radiation [mm month^{-1}]

ω_s is the sunset hour angle [rad]

$$\omega_s = ar\cos\left[-\tan(lat)\tan\delta\right]$$

Lat [rad] is the latitude, δ is the solar declination [rad]

$$\delta = 0.409 \sin\left[\frac{2\pi}{365} J - 1.39\right]$$

d_r is inverse relative distance Earth-Sun [rad]

$$d_r = 1 + 0.033 \cos\left(\frac{2\pi}{365} J\right)$$

where J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December).

[1] 0.408 is to convert [MJ m^{-2} day^{-1}] to [mm/day] http://www.fao.org/docrep/X0490E/x0490e07.htm

Thornthwaite's formula:

This formula is based mainly on temperature with an adjustment being made for the number of daylight hours. An estimate of the potential evapotranspiration, calculated on a monthly basis, is given by:

$$PE_m = 0 \quad \text{mm for } T_m <= 0°C$$

$$PE_m = 16 N_m \left(\frac{10 \bar{T}_m}{I} \right)^a \quad \text{mm for } 0 < T_m < 26.5°C$$

$$PE_m = -415.85 + 32.24 T_m . - 0.43 T_m^2 \quad \text{mm for } T >= 26.5°C$$

Where

m is the month 1, 2, …,12

T_m is the monthly mean temperature (°C)

$$a = 6.75*10^{-7}*I^3 - 7.71*10^{-5}*I^2 + 1.79*10^{-2}*I + 0.492$$

I is the heat index for the year, given by:

$$I = \sum i_m = \sum \left(\frac{\bar{T}_m}{5} \right)^{1.514} \quad \text{for m = 1, 2, …, 12}$$

N_m is the monthly adjustment factor related to hours of daylight, given by

$$N_m = \left(\frac{\theta}{30} \right) \left(\frac{h}{12} \right)$$

With

θ – length of the month (in days)

h – duration of daylight (in hours) on the fifteenth of the month = $\left(\frac{24}{\pi} \omega_s \right)$

where ω_s is the sunset hour angle given by

$$\omega_s = ar\cos\left[-\tan(lat) \tan\delta \right]$$

$$\delta = 0.409 \sin\left[\frac{2\pi}{365} J - 1.39 \right]$$

δ is the solar declination and, like ω_s and lat, is in radians.

J is the number of the day in the year between 1 (1 January) and 365 or 366 (31 December), in this case J of the 15th day in the month is used.

Performances indices

Acronym	Name/Description	Equation
R	Correlation Coefficient; The possible range of values is -1 to 1. A value of -1 indicates a perfect negative correlation, while a value of 1 indicates a perfect positive correlation.	$\frac{\sum_m (D_{w,m}-\bar{D}_w)(D_{o,m}-\bar{D}_o)}{\sqrt{\sum_m (D_{w,m}-\bar{D}_w)^2}\sqrt{\sum_m (D_{o,m}-\bar{D}_o)^2}}$
|Bias|	Absolute Bias; never negative, the smaller the value, the closer the predicted and observed values are.	$\|Bias\| = \frac{1}{N}\sum_m \|D_{w,m}-D_{o,m}\|$
RMSE	Root Mean Square Error; never negative, the smaller the value, the closer the predicted and observed values are.	$\sqrt{\frac{1}{N}\sum_m (D_{w,m}-D_{o,m})^2}$
CentRMSE	Centered Root Mean Square Error; never negative, the smaller the value, the closer the predicted and observed values are.	$\sqrt{\frac{1}{N}\sum_m ((D_{w,m}-\bar{D}_w)-(D_{o,m}-\bar{D}_o))^2}$
rRMSE	Relative Root Square Mean Error. *Note*: Model accuracy can be considered excellent when rRMSE < 10%, good if 10% < rRMSE < 20%, fair if 20% < rRMSE < 30%, and poor if rRMSE ≥ 30%. [*Li et al.*, 2013]	$100\ \frac{\sqrt{\frac{1}{N}\sum_m (D_{w,m}-D_{o,m})^2}}{\bar{D}_o}$
P|Bias|	Percent Absolute Bias; never negative, the smaller the value, the closer the predicted and observed values are.	$\frac{\sum_m \|D_{o,m}-D_{w,m}\|}{\sum_m D_{o,m}}$
RSR	Ratio of RMSE to the standard deviation of observation. *Note*: RSR values lower than 0.7 indicate satisfactory results [*Moriasi et al.*, 2007].	$\frac{\sqrt{\sum_m (D_{w,m}-D_{o,m})^2}}{\sqrt{\sum_m (D_{o,m}-\bar{D}_o)^2}}$
EF	Efficiency Index *Note*: A perfect model has an EF equal to 1; if EF is equal to 0, the predictive value is very low, matching with the mean of observations; EF can also be negative, if the observed mean is a better predictor than the simulation.	$1-\frac{\sum_m (D_{w,m}-D_{o,m})^2}{\sum_m (D_{o,m}-\bar{D}_o)^2}$
t-stat	t-statistics; the lower is t-stat, the higher is the model skill	$\sqrt{\frac{(N-1)Bias^2}{RMSE^2-Bias^2}}$

Table S1. List of the nine performance indices and related formulation used to compare the WFD dataset against other source datasets for precipitation and temperature, where: *N* is the number of months of the series, i.e. 480; $D_{w,m}$ and $D_{o,m}$ are the considered data values (temperature or precipitation) under WFD and other reference dataset, respectively, in month *m*; the overbars indicate the annual average calculated over the WFD (*w*) or other reference dataset (*o*) monthly climatological means; and σ_w and σ_o represent the standard deviation over the WFD (*w*) or other refeence dataset (*o*) monthly climatological mean.

Spatial distribution of RMSE against independent datasets

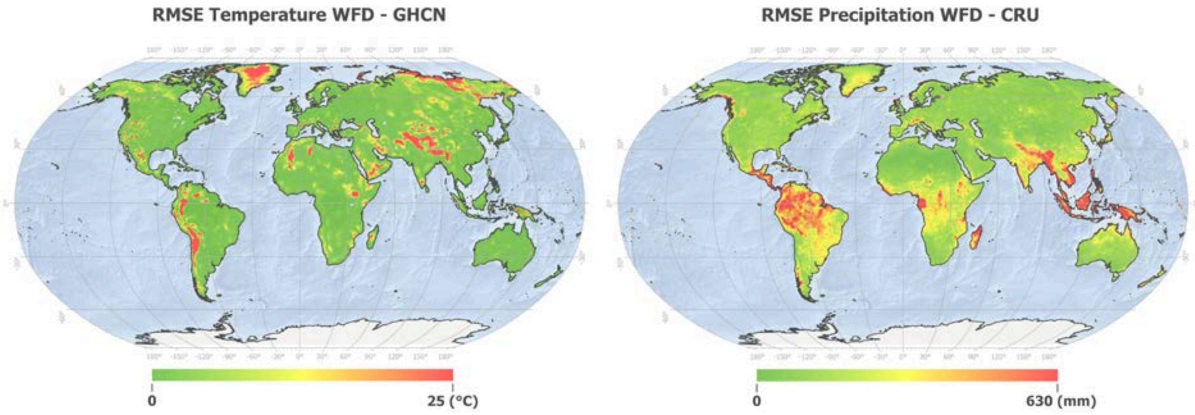

Figure S1. Maps of the distribution of RMSE for WFD vs. GHCN-CAMS (for Temperature; top) and for WFD vs. CRU4.05 (for Precipitation; bottom), highlighting the regions affected by the highest differences.

Example of CDO command for using data

The following CDO commands (*italics*), are those used to generate Figure 2.
Output NetCDF for each command are in bold, the last two (in blue) correspond to Figure 2a and b, respectively. Tre prefix TH means that the two PET formulations are combined.

cdo enspctl,50 -timsum -ltc,-1 T_WFD_HIST_1960_1999_spei_03.nc -timsum -ltc,-1 H_WFD_1960_1999_spei_03.nc ***TH_WFD_1960_1999_spei_03_lt-1_sum.nc***

cdo enspctl,50 -timsum -ltc,-1 H_GFDL_45_2040_2079_spei_03.nc -timsum -ltc,-1 H_MOHC_45_2040_2079_spei_03.nc -timsum -ltc,-1 H_IPSL_45_2040_2079_spei_03.nc -timsum -ltc,-1 H_MIRO_45_2040_2079_spei_03.nc -timsum -ltc,-1 H_NESM_45_2040_2079_spei_03.nc -timsum -ltc,-1 T_GFDL_45_2040_2079_spei_03.nc -timsum -ltc,-1 T_MOHC_45_2040_2079_spei_03.nc -timsum -ltc,-1 T_IPSL_45_2040_2079_spei_03.nc -timsum -ltc,-1 T_MIRO_45_2040_2079_spei_03.nc -timsum -ltc,-1 T_NESM_45_2040_2079_spei_03.nc -timsum -ltc,-1 H_CMCC_85_2040_2079_spei_03.nc -timsum -ltc,-1 H_GFDL_85_2040_2079_spei_03.nc -timsum -ltc,-1 H_MOHC_85_2040_2079_spei_03.nc -timsum -ltc,-1 H_IPSL_85_2040_2079_spei_03.nc -timsum -ltc,-1 H_MIRO_85_2040_2079_spei_03.nc -timsum -ltc,-1 H_NESM_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_CMCC_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_GFDL_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_MOHC_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_IPSL_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_MIRO_85_2040_2079_spei_03.nc -timsum -ltc,-1 T_NESM_85_2040_2079_spei_03.nc ***TH_2040_2079_spei_03_lt-1_sum.nc***

cdo enspctl,50 -timsum -ltc,-1 H_GFDL_45_2060_2099_spei_03.nc -timsum -ltc,-1 H_MOHC_45_2060_2099_spei_03.nc -timsum -ltc,-1 H_IPSL_45_2060_2099_spei_03.nc -timsum -ltc,-1 H_MIRO_45_2060_2099_spei_03.nc -timsum -ltc,-1 H_NESM_45_2060_2099_spei_03.nc -timsum -ltc,-1 T_GFDL_45_2060_2099_spei_03.nc -timsum -ltc,-1 T_MOHC_45_2060_2099_spei_03.nc -timsum -ltc,-1 T_IPSL_45_2060_2099_spei_03.nc -timsum -ltc,-1 T_MIRO_45_2060_2099_spei_03.nc -timsum -ltc,-1 T_NESM_45_2060_2099_spei_03.nc -timsum -ltc,-1 H_CMCC_85_2060_2099_spei_03.nc -timsum -ltc,-1 H_GFDL_85_2060_2099_spei_03.nc -timsum -ltc,-1 H_MOHC_85_2060_2099_spei_03.nc -timsum -ltc,-1 H_IPSL_85_2060_2099_spei_03.nc -timsum -ltc,-1 H_MIRO_85_2060_2099_spei_03.nc -timsum -ltc,-1 H_NESM_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_CMCC_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_GFDL_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_MOHC_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_IPSL_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_MIRO_85_2060_2099_spei_03.nc -timsum -ltc,-1 T_NESM_85_2060_2099_spei_03.nc ***TH_2060_2099_spei_03_lt-1_sum.nc***

cdo sub TH_2040_2079_spei_03_lt-1_sum.nc TH_WFD_HIST_1960_1999_spei_03_lt-1_sum.nc ***TH_2040_2079_spei_03_lt-1_anomaly.nc***

cdo sub TH_2060_2099_spei_03_lt-1_sum.nc TH_WFD_HIST_1960_1999_spei_03_lt-1_sum.nc ***TH_2060_2099_spei_03_lt-1_anomaly.nc***

References

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Moriasi, D. N. et al. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE* **50**, 885–900 (2007).