UCL work update

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Objective

Generation of climatic variables time series with statistical properties similar to the observed climate for hydrological impact studies.

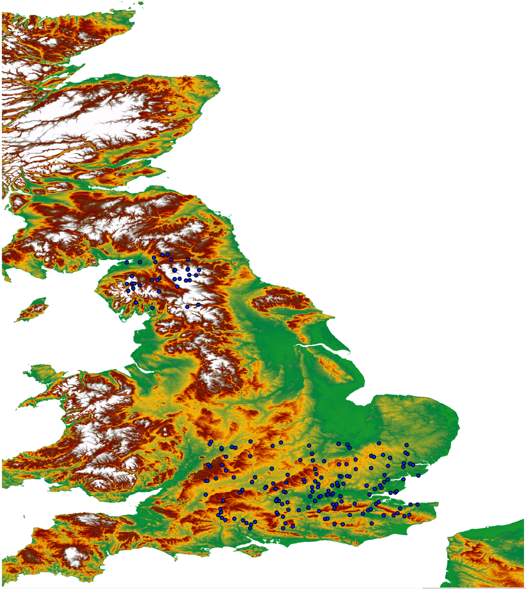
Eight hourly variables required as inputs in JULES:

- Rainfall rate ($kg/m^2 \times s$)
- Air pressure (Pa)
- Snowfall rate ($kg/m^2 \times s$)
- Air temperature (K)
- Wind speed (m/s)
- Specific humidity (kg/kg)
- Downward SW radiation (W/m^2)
- Downward LW radiation (W/m^2)

Data

- Hourly data from the British Atmospheric Data Centre (BADC), MIDAS Met Office dataset
- Period: 1950.01.01 - 2011.03.01
- Available variables: rainfall, snow, air pressure, air temperature, wind speed, downward SW radiation.
- Missing variables: specific humidity and downward LW radiation.

Domains



- 157 stations in the Thames catchment domain $(-2.0/+1.1\ ^{\circ}E$ and $+51.0/52.3\ ^{\circ}N)$;
- 35 stations in the Eden catchment domain $(-3.1/-2.1\ ^{\circ}E$ and $+54.3/55.0\ ^{\circ}N)$.

Basic Approach

- Model development using daily data;
- Disaggregate them at hourly time step;
- Derive the missing variables.

Hourly Disaggregation

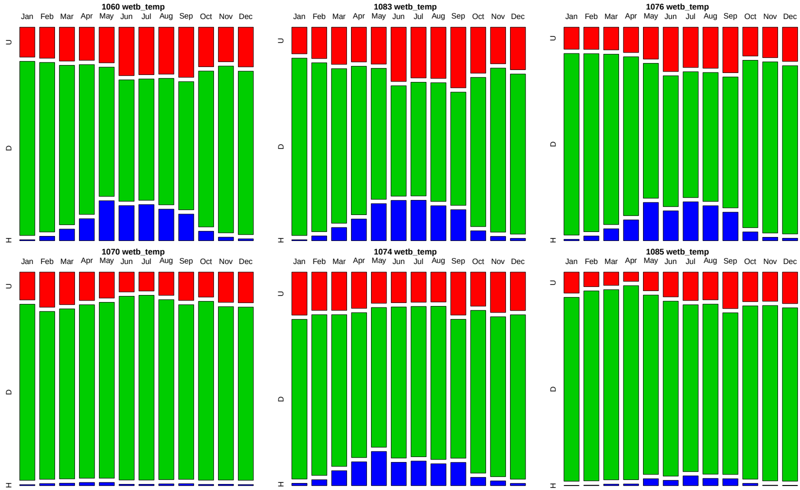
ANOVA model n.1

Variables' sub-daily structure predicted from the daily time series. Two-way Anova models fitted, separately month by month and station by station:

$$Y_{ij} = \mu + \alpha_i + \beta_j + \epsilon_{ij}$$

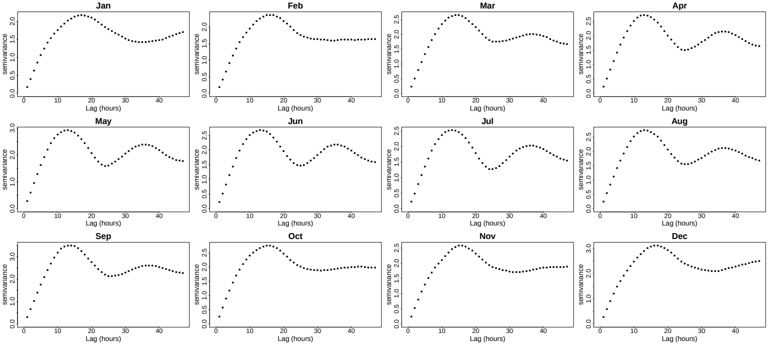
for each station:
Y_{ij} = the observation on day i and hour j;
μ = the variable overall mean;
α_i = the day effect (1:n, with n = length record);
β_j = the deterministic diurnal cycle and ϵ_{ij} are the residuals.

ANOVA model n.1: partition of variance



H: deterministic diurnal cycle;
D: day effect;

U: unexplained variation.



Variogram for wet bulb temperature series for Site ID: 1083

Chandler and Scott (2011)

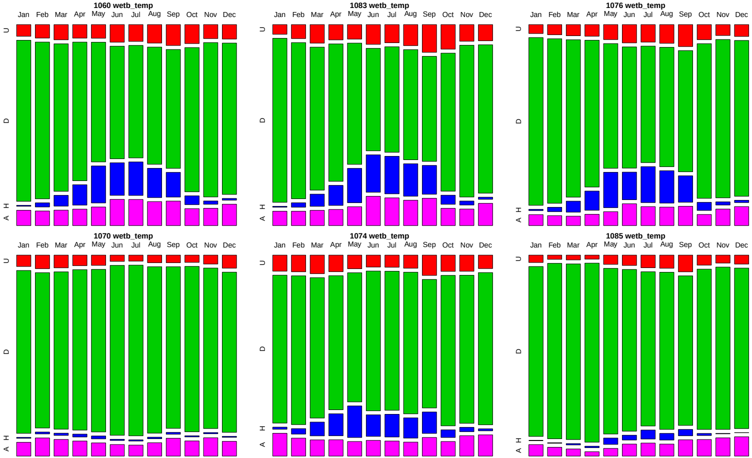
ANOVA model n.2

Variables' sub-daily structure predicted from the daily time series. Two-way Anova models fitted, separately month by month and station by station:

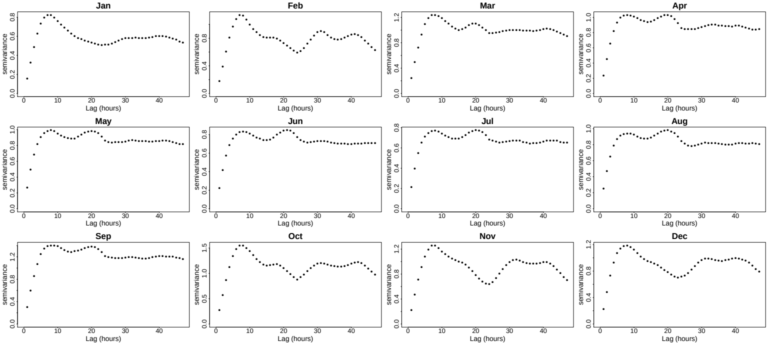
$$Y_{ij} = \mu + \alpha_i + A_i \times \beta_j + \epsilon_{ij}$$

for each station:
Y_{ij} = the observation on day i and hour j;
μ = the variable overall mean;
α_i = the day effect (1:n, with n = length record);
A_i = the amplitude variation of the diurnal cycle (variable from day to day within the considered month);
β_j = the deterministic diurnal cycle and ϵ_{ij} are the residuals.

ANOVA model n.2: partition of variance



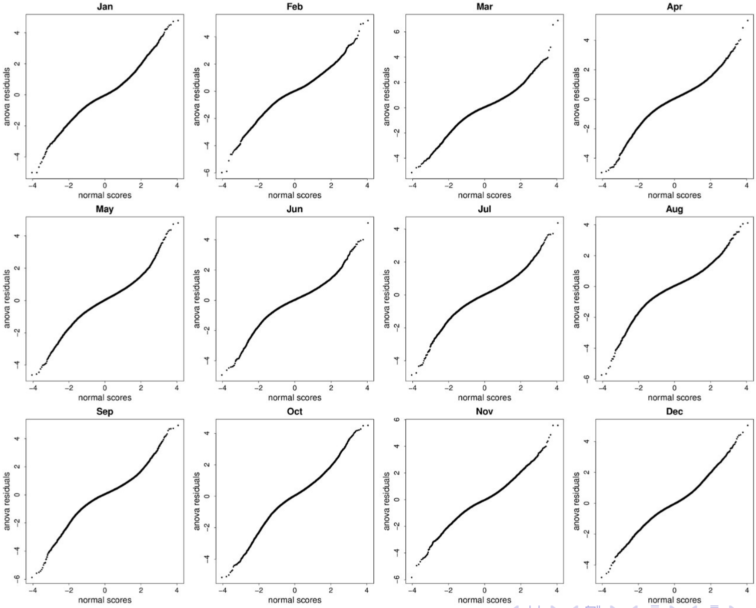
A: amplitude variation of the diurnal cycle;
H: deterministic diurnal cycle;
D: day effect;
U: unexplained variation.



Variogram for wet bulb temperature series for Site ID: 1083

Chandler and Scott (2011)

Normality plot of the anova residuals for the wet bulb temperature, Site ID: 1070



Specific Humidity

$$q_a = \frac{0.62197e_a}{P - 0.378e_a}$$

$$e_a = e_s - P \times (T_a - T_{wb}) \times (0.000666 - i0.000072 + 1 \times (0.000133 - i0.000007))$$

$$e_s = 6.11 \times 10^{\left(\frac{7.5T_a}{237.7+T_a}\right)}$$

q_a: specific humidity of the air (g/kg);
P: air perssure (hPa);
e_a: vapour pressure of air (hPa);
e_s: saturation vapour pressure (hPa);
T_a: air temperature (°C);
T_{wb}: wet bulb temperature (°C);
$i = 1$ if $T_a < 0$ and $= 0$ otherwise.

Gill (1981); Brice and Hall (2009); MetOffice (1997)

Long Wave Radiation

$$L_{clr} = 59.38 + 113.7\left(\frac{T_o}{273.16}\right)^6 + 96.96\sqrt{w/25}$$

$$w = 4650 e_o / T_o$$

$$e_o = e_a/10;$$

$$L_d = L_{clr} + \tau_8 c f_8 \sigma T_c^4$$

$$\tau_8 = 1 - \epsilon_{8z}(1.4 - 0.4\epsilon_{8z});$$

$$\epsilon_{8z} = 0.24 + 2.98 \times 10^{-6} e_o^2 \exp\left(\frac{3000}{T_o}\right);$$

$$f_8 = -0.6732 + 0.6240 \times 10^{-2} T_c - 0.9140 \times 10^{-5} T_c^2;$$

T_o: air temperature (K);
w: precipitable water (cm);
e_o: vapour pressure of air (kPa);
σ: Stefan-Boltzmann constant ($W/m^2\ K^4$);
c cloud cover linearly interpolated between 0.0 and 1.0;
T_c: cloud temperature, 11 K $<$ T_o at surface with ± 2 K seasonal variation.

Flerchinger et al. (2009); Kimball et al. (1982); Dilley and O'Brian (1998)

Standard approach in WG development

PRECIPITATION OCCURRENCE → PRECIPITATION AMOUNTS

↓

Non-precipitation variables: MAX TEMPERATURE
MIN TEMPERATURE
SOLAR RADIATION

VAPOUR PRESSURE
WIND SPEED
DEW POINT

Modelling strategy

PRESSURE

↙ ↓ ↘

WIND → TEMPERATURE ↔ PRECIPITATION
(rainfall and snow)

↙ ↙ ↓ ↘

WET BULB TEMPERATURE SW RADIATION CLOUD COVER

Modelling development

BASIC STRUCTURE → Fortran

to handle: data management,
model fitting,
time series simulation.

INTERFACE → R

to call all Fortran subroutines/functions.

Statistical model

Generalized linear models (GLMs)

Y_i is assumed to be generated from the same family of distribution with mean μ_i,

$$g(\mu_i) = x_i\beta = \eta_i$$

The GLM is composed of the three elements:

- A choice of distribution with mean μ_i.
- A linear predictor $\eta = X\beta$, a linear combination of unknown parameters β.
- A link function $g(.)$ such that $E(Y) = \mu = g^{-1}(\eta)$.

Next Steps

- Characterise daily variables in terms of their distributions.
- Identify the inter-variables relationships.
- Covariates selection in the models building.
- Calibration.
- Daily simulations.
- Hourly disaggregation.

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MetOffice, 1997: Metoffice surface data users guide.