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9-second gridded climate surfaces for Australia

Short summary

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This document summarises in plain language the methods applied to generate gridded Australian climate data.

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Short summary

Calculation of 9s gridded climate and projected climate change surfaces for Australia

1.1 Methods

Climate surfaces for the present were based on the ANUCLIM 6.1 (Xu and Hutchinson, 2011) 30 year average climate surfaces for Australia (1976-2005), with elevational lapse rate correction applied over the 9s GEODATA digital elevation model (Hutchinson et al , 2008). Radiative correction derived from the same DEM was applied to radiation and maximum temperature before calculation of evaporation, using the CSIRO TerraFormer software. Projected future climates were generated by applying within-model changes (e.g. MIROC5 2036-2065 – MIROC5 1976-2005) calculated at the native general circulation model grid resolution to these current surfaces, using ANUCLIM 6.1 prior to radiative adjustment. Summary statistics for each variable were then calculated (Figure 1) including variables described in Williams et al (2012).

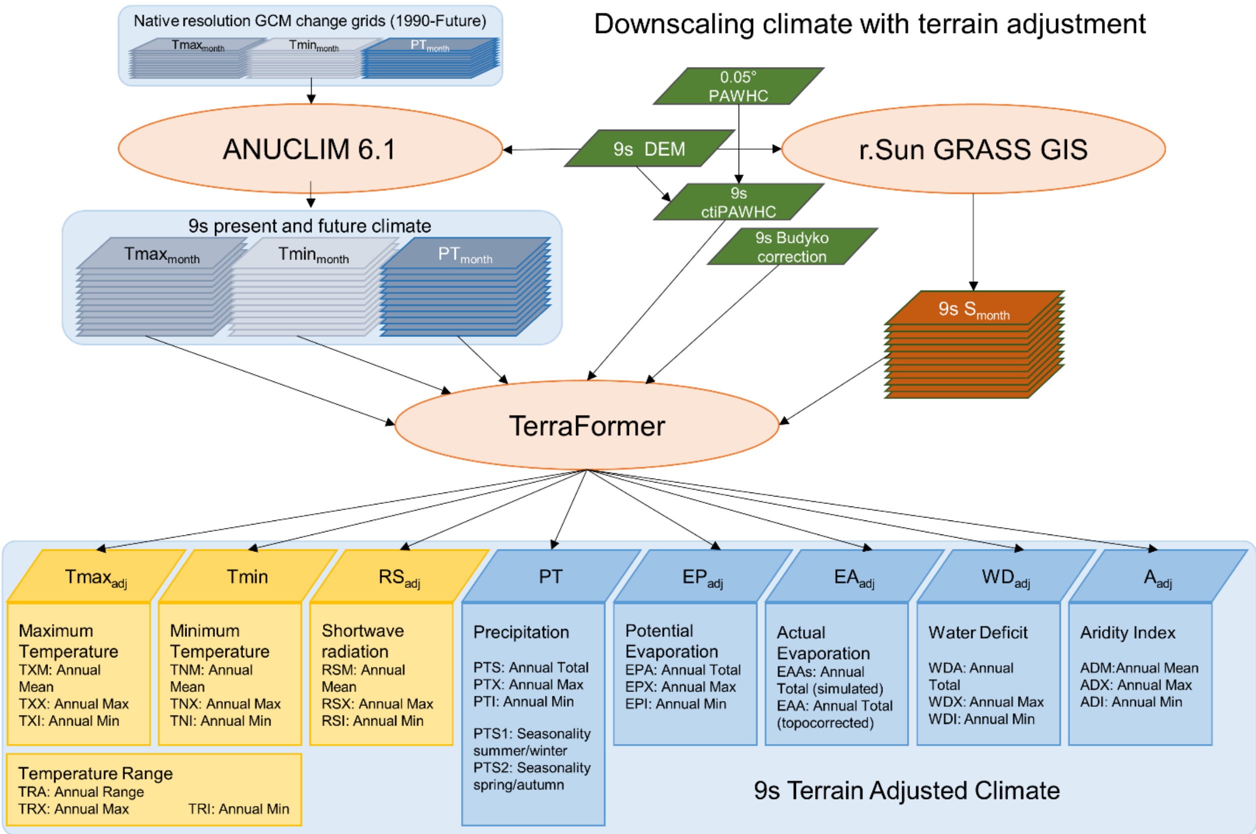

Figure 2: Calculation of present and future climate surfaces using a consistent approach for all time points.

An approach was taken which minimises the data requirements for projection of climate, whilst maintaining consistency of calculation across time points (Reside *et al.*, 2013). We followed Allen *et al.* (1998) FAO 56 p 76 "Calculation procedures with missing data" and Example 20 p77-78, which outlines standard procedures for the estimation of *Ep* (ET_0) as a function of monthly average daily maximum and minimum temperatures. Due to concerns as to the validity of derived or projected wind and humidity variables, we substitute the Priestley-Taylor formulation for the Penman-Monteith equation. Whilst FAO 56 Eq 50 (Hargreaves) is used for the estimation of *Rs*, we used the Samani (2000) derivation of *KT* (k_{Rs}) to deal with geographical variation in *KT*. Once *Rs* has been estimated from diurnal temperature range, we adjust both radiation and maximum temperature using the ratio *S* (shaded inclined radiation/unshaded flat surface radiation, calculated in GRASS using the r.sun routine) following Wilson & Gallant (2000).

All variables *Tmax, Tmin, Ppt, Rs, Ep, Ea* and *WD (Ppt-Ep)* are calculated monthly. These are then summarised as: Annual total or mean, Maximum monthly value, Minimum Monthly value, Maximum rate of month to month change and Minimum rate of month to month change. Interactions between variables such as temperature of the wettest month are avoided for climate change sensitivity reasons.

Potential Evaporation (*Ep*)

Humidity data is difficult to come by, since it is partly a function of local surface moisture. Estimates of humidity as a function of temperature are very unreliable for much of the tropics. Consequently we would be forced to make extreme assumptions about humidity in order to properly incorporate it into the Penman-Monteith formula.

Wind data is similarly sparse, but is also subject to topographic funnelling leading to strong local heterogeneity. Whilst this can be modelled for the present, the data has high commercial value and is not readily available. Projections of future wind by GCMs are non-standard and subject to local topographic interactions which would require further modelling. The use of a uniform $2m^{-s}$ wind speed effectively removes the contribution of wind to the Penman-Monteith formula.

We therefore apply the purely energy-driven Priestley-Taylor formula (Fig2) (e.g. Wilson & Gallant 2000), which requires as inputs *Tmax, Tmin, Tdew* and *Rs*. We estimate *Tdew* as *Tmin* which has minimal implications in the Priestley-Taylor approach. In the current algorithm, *Rs* is derived from diurnal temperature range to ensure consistency between variables at any site/time point.

Actual Evaporation (*Ea)*

Two actual evaporation products are produced, a raw modelled output (EAAS) and a remotely sensed adjusted output (EAA) based on data produced from AVHRR/MODIS blending following the CMRSET algorithm (Guerschman *et al.*, 2009).

a) Modelled output (Ea_{mod}). *Ea* is calculated monthly using the Budkyo framework (Budkyo 1958,1974, Choudhury, 1999) in a bucket model (Pike, 1964) as $E_a = \frac{(V+P).ET_p}{\left[(V+P)^n + ET_p^n\right]^{1/n}}$ where *V* is stored water, *P*, precipitation and recorded as an annual sum. The bucket size *Vmax* is calculated as a TWI corrected PAWHC value, according to Claridge *et al*. (2000).

b) Remote sensing corrected Ea_{corr}. Remote sensed Ea_{rs} in the present is taken as truth. The offset on the Phi axis of the Budyko framework between the modelled Ea_{mod} and Ea_{rs} in the present is used to correct all projected Ea_{mod} surfaces (Fig 3). By definition this results in $Ea_{corr}=Ea_{rs}$ in the present. The calculation is standard for all time points and scenarios.

Caveat: Due to the incorporation of remotely sensed information (particularly green vegetation cover) in the CMRSET calculation, EAA is affected by ground cover. Whilst this captures groundwater dependent ecosystems, it can also pick up a land use signal.

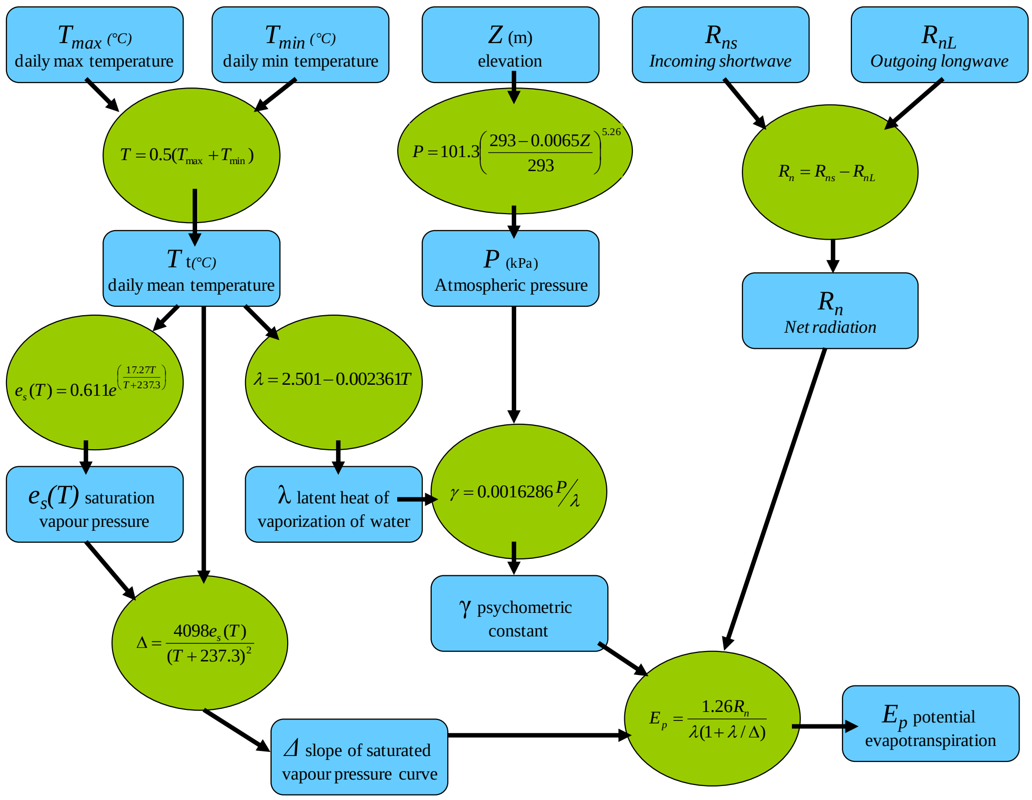

Figure 3: Calculation of *Ep* using the Priestley-Taylor approach. See Allen *et al* (1998) for further details.

1.2 Future climate scenarios

Future climate was calculated following the ANUCLIM 6.1 approach to generate monthly Maximum and Minimum Temperatures and Precipitation (Xu & Hutchinson 2013). Monthly change grids for these variables were calculated as within Generalised Circulation Model changes for long term averages centred on the relevant time points. Data were extracted from the CMIP5 database (Taylor et al., 2013) and calculations applied in the native grid resolution.

$\Delta Tmax_{month}$ = $Tmax_{month}$ (*projected* 2036-2065)- $Tmax_{month}$ (1976-2005)

$\Delta Tmin_{month}$ = $Tmin_{month}$ (*projected* 2036-2065)- $Tmin_{month}$ (1976-2005)

ΔPT_{month} = 100*[PT_{month} (*projected* 2036-2065)- PT_{month} (1976-2005)]/ PT_{month} (1976-2005)

Three future climate models were downscaled, using the RCP 8.5 high emissions future consistent with current trends:

The CanESM2 model

Chylek P, Li J, Dubey MK, Wang M and Lesins G (2011) 'Observed and model simulated 20th century Arctic temperature variability: Canadian Earth System Model CanESM2', ATMOSPHERIC CHEMISTRY and PHYSICS DISCUSSIONS **11**, 22893—22907 doi:10.5194/acpd-11-22893-2011

The MIROC5 model

Watanabe M, Suzuki T, O'ishi R, Komuro Y, Watanabe S, Emori S, Takemura T, Chikira M, Ogura T, Sekiguchi M, Takata K, Yamazaki D, Yokohata T, Nozawa T, Hasumi H, Tatebe H and Kimoto M (2010) 'Improved Climate Simulation by MIROC5. Mean States, Variability, and Climate Sensitivity', JOURNAL of CLIMATE **23**(23), 6312-6335, doi:10.1173/2010JCLI3679.1

The MPI-ESM_LR model

Stevens B, Giorgetta M, Esch M et al. (2013) Atmospheric component of the MPI-M Earth System Model: ECHAM6. Journal of Advances in Modeling Earth Systems, 5, 146-172.

1.3 Nomenclature

Temperature

Maximum Temperature

Short name	Name	Units
TXM	Maximum temperature – Annual mean	°C
TXI	Maximum temperature - monthly minimum	°C
TXX	Maximum temperature - monthly maximum	°C

Minimum Temperature

Short name	Name	Units
TNM	Minimum temperature – Annual mean	°C
TNI	Minimum temperature - monthly minimum	°C
TNX	Minimum temperature - monthly maximum	°C

Temperature range

Short name	Name	Units
TRI	Minimum monthly mean diurnal temperature range	°C
TRX	Maximum monthly mean diurnal temperature range	°C
TRA	Annual temperature range (TXX – TNI)	°C

Moisture

Aridity Index (precipitation/evaporation)

Short name	Name	Units
ADM	Mean annual aridity index (annual precipitation/ annual potential evaporation)	proportion
ADI	Minimum monthly aridity index	proportion
ADX	Maximum monthly aridity index	proportion

Evaporation

Short name	Name	Units
EPA	Annual potential evaporation	mm
EPI	Minimum monthly potential evaporation	mm
EPX	Maximum monthly potential evaporation	mm
EAA	Annual total actual evapotranspiration terrain scaled using MODIS	mm
EAAS	Annual total actual evapotranspiration modelled using terrain-scaled water holding capacity	mm

Precipitation

Short name	Name	Units
PTA	Annual precipitation	mm
PTI	Minimum monthly precipitation	mm

Short name	Name	Units
PTX	Maximum monthly precipitation	mm
PTS1	Precipitation seasonality 1- solstice seasonality composite factor ratio	Ratio
PTS2	Precipitation seasonality 2- equinox seasonality composite factor ratio	Ratio

Water Deficit (precipitation-evaporation)

Short name	Name	Units
WDA	Annual atmospheric water deficit (annual precipitation – annual potential evaporation)	mm
WDI	Minimum monthly atmospheric water deficit (precipitation - potential evaporation)	mm
WDX	Maximum monthly atmospheric water deficit (precipitation - potential evaporation)	mm

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