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9-second gridded continental climate variables for Australia: November 2014

Short summary

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This document summarises the methods applied to generate gridded Australian climate change variables for biodiversity modelling.

CSIRO Land and Water

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Important disclaimer

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

Climate surfaces for the present were based on the ANUCLIM 6.1 (Xu and Hutchinson, 2011) 30 year average climate surfaces for Australia, 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).

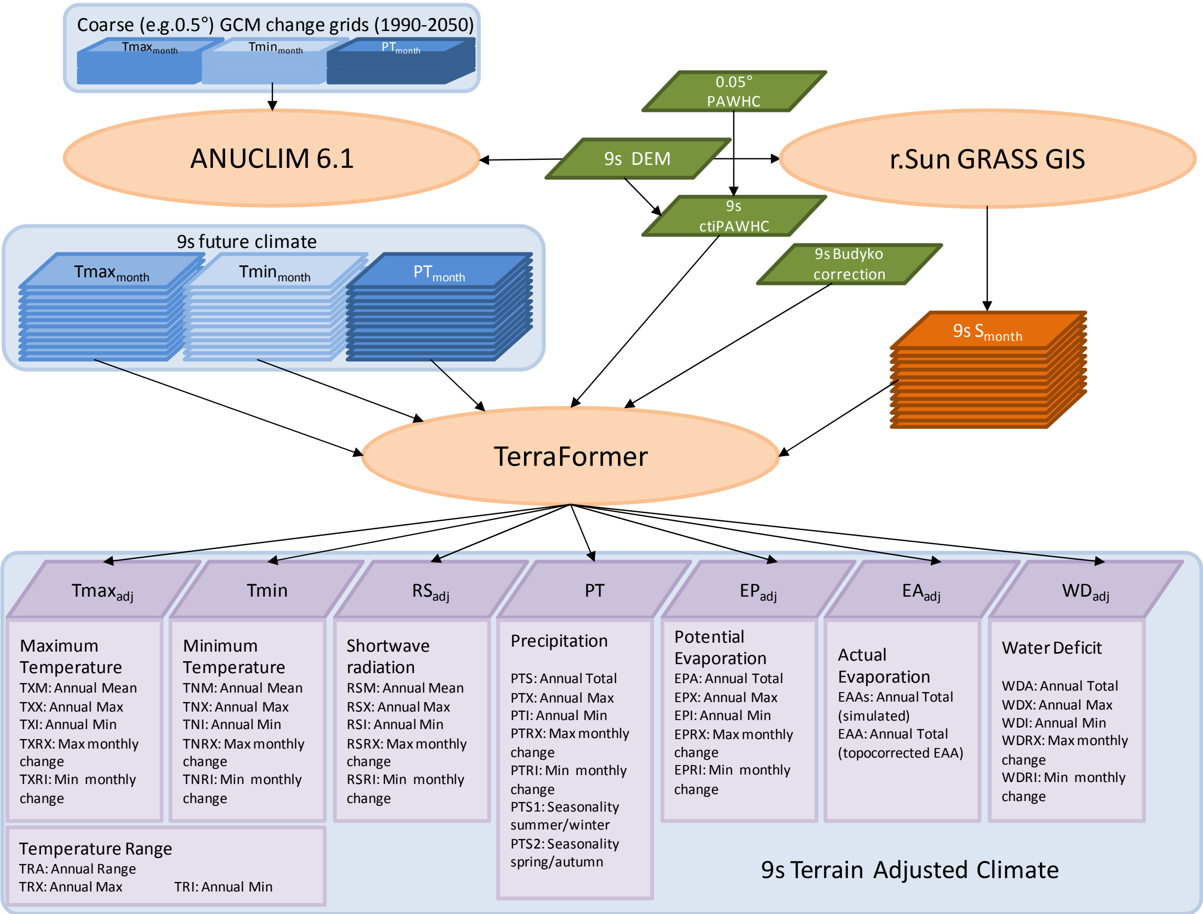

Figure 1: Calculation of present and future climate surfaces using a consistent approach for all time points.

An approach was taken which minimises the data requirements for projection of climate, whilst maintaining consistency of calculation across time points. 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 and a remotely sensed adjusted output.

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.

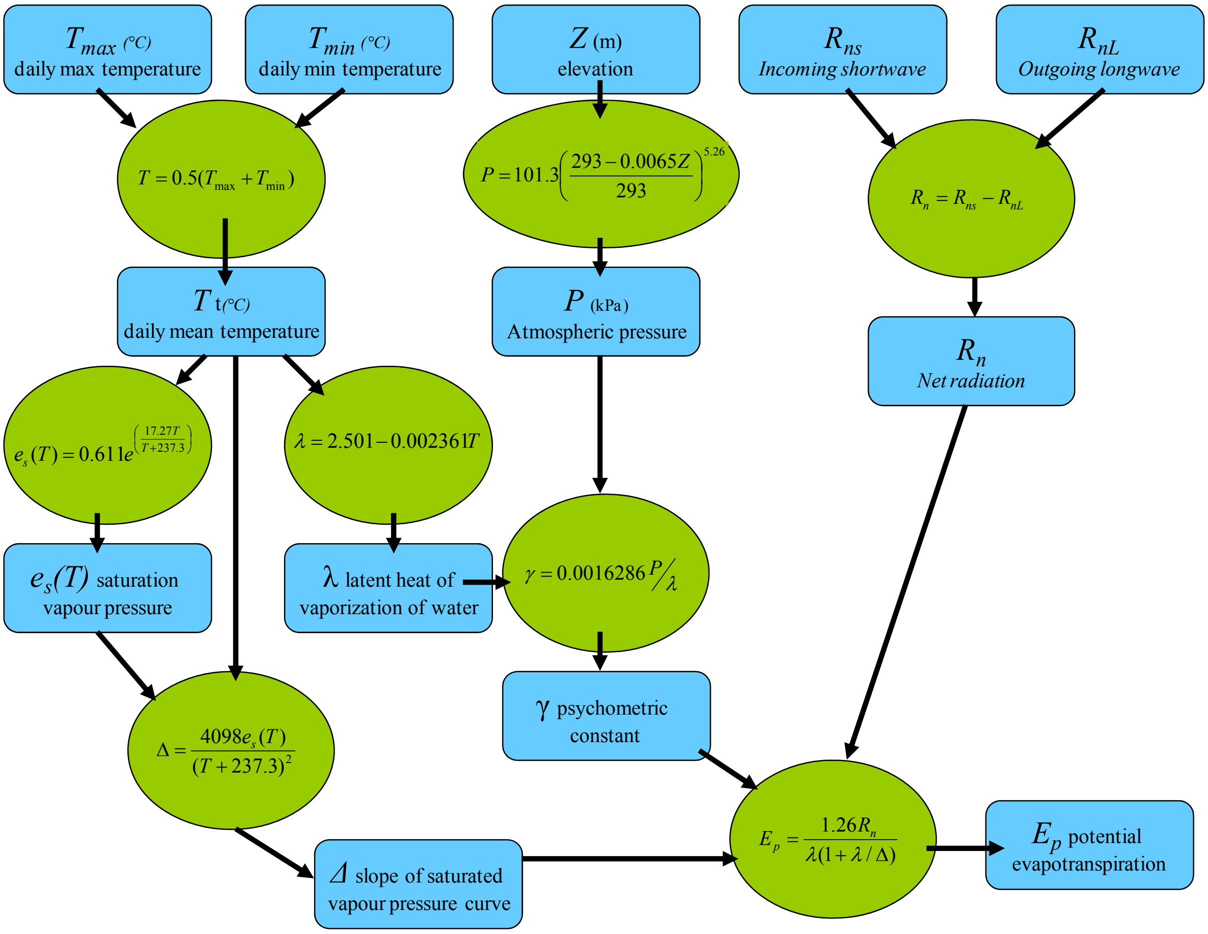

Figure 2: Calculation of *Ep* using the Priestley-Taylor approach. See Allen *et al.* (1998) for further details.

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)

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

Two future climate models were initially examined, 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 Max Planck Institute Model

Giorgetta MA, Jungclaus J, Reick CH, Legutke S, Bader J, Böttinger M, Brovkin V, Crueger T, Esch M, Fieg K, Glushak K, Gayler V, Haak H, Hollweg H-D, Ilyina T, Kinne S, Kornblueh L, Matei D, Mauritsen T, Mikolajewicz U, Mueller W, Notz D, Pithan F, Raddatz T, Rast S, Redler R, Roeckner E, Schmidt H, Schnur R, Segschneider J, Six KD, Stockhause M, Timmreck C, Wegner J, Widmann H, Wieners K-H, Claussen M, Marotzke J and Stevens B (2013) Climate and carbon cycle changes from 1850 to 2100 in MPI-ESM simulations for the coupled model intercomparison project phase 5. Journal of Advances in Modeling Earth Systems 5, 572-597. DOI: 10.1002/jame.20038.

The ACCESS1.0 Model

Bi D, Dix M, Marsland SJ, O’Farrell S, Rashid HA, Uotila P, Hirst AC, Kowalczyk E, Golebiewski M, Sullivan A, Yan H, Hannah N, Franklin C, Sun Z, Vohralik P, Watterson I, Zhou X, Fiedler R, Collier M, Ma Y, Noonan J, Stevens L, Uhe P, Zhu H, Griffies SM, Hill R, Harris C and Puri K (2013) The ACCESS coupled model: description, control climate and evaluation. Australian Meteorological and Oceanographic Journal 63(1), 41-64.

The GFDL Model

Dunne JP, John JG, Shevliakova E, Stouffer RJ, Krasting JP, Malyshev SL, Milly PCD, Sentman LT, Adcroft AJ, Cooke W, Dunne KA, Griffies SM, Hallberg RW, Harrison MJ, Levy H, Wittenberg AT, Phillips PJ and Zadeh N (2013) GFDL’s ESM2 global coupled climate–carbon earth system models. Part II: Carbon system formulation and baseline simulation characteristics. Journal of Climate 26(7), 2247-2267. DOI: 10.1175/JCLI-D-12-00150.1.

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Australian Government Department of the Environment (2014) Natural areas of Australia - 100 metre (digital dataset and metadata). Available at http://www.environment.gov.au/metadataexplorer/explorer.jsp

Budyko MI (1958) The heat balance of the earth’s surface, US Dept. of Commerce, Washington.

Budyko MI (1974) Climate and life. Academic Press, New York.

Choudhury BJ (1999)Evaluation of an empirical equation fro annual evaporation using field observations and results from a biophysical model. J. Hydrology 216: 99-110.

Claridge J, Williams KJ, Storey RJL (2000) Creation of the South-East Queensland depth index rescaled using CTI, Brisbane, Enhanced Resource Assessment 2000-05. A JVAP project QDN3A Technical Report. Queensland Department of Natural Resources.

Hargreaves GH, Samani ZA (1982). “Estimating potential evapotranspiration.” J. Irrig. Drain Eng., 108(3), 225–230.

Hutchinson M, Stein J, Stein J, Anderson H, Tickle P (2008) GEODATA 9 second DEM and D8. Digital elevation model version 3 and flow direction grid. Gridded elevation and drainage data. Source scale 1:250 000. User guide (3rd ed). 3 edn, (Fenner School of Environment and Society, the Australian National University and Geoscience Australia, Australian Government).

Pike JG (1964) The estimation of annual run-off from meteorological data in a tropical climate. Journal of Hydrology, 2: 116-123.

Samani Z (2000). “Estimating solar radiation and evapotranspiration using minimum climatological data (Hargreaves-Samani equation).” J. Irrig. Drain Eng., 126(4), 265–267.

Taylor KE, Stouffer RJ and Meehl GA (2012) ‘An overview of CMIP5 and the experiment design’ BULLETIN OF THE AMERICAN METEOROLOGICAL SOCIETY 93(4), 485-498 doi:10.1175/BAMS-D-11-00094.1

Wilson JP, Gallant JC (2000) Secondary topographic attributes. In: Terrain Analysis: Principles and Applications. (eds Wilson JP, Gallant JC) pp Page. New York, John Wiley & Sons.

Xu T, Hutchinson, MF (2011) ANUCLIM Version 6.1 User Guide. (The Australian National University, Fenner School of Environment and Society).

Xu T, Hutchinson, MF (2013) New developments and applications in the ANUCLIM spatial climatic and bioclimatic modelling package. Environmental Modelling & Software, 40, 267-279.

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