Data description to "CAMELS-AUS v2: updated hydrometeorological timeseries and landscape attributes for an enlarged set of catchments in Australia"

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1 Introduction

This summary provides an overview of the CAMELS-AUS v2 dataset, augmenting the description of changes provided in the CAMELS-AUS v2 publication submitted to Earth Systems Science Data. Here, we provide a description of files included in the data repository located at https://doi.org/10.5281/zenodo.12575680.

2 Catchment attributes and indices "master" table

Catchment attributes are listed by category within individual files, as listed in the sections below. For convenience, a combined "master" attribute table (*CAMELS_AUS_Attributes&Indices_MasterTable.csv*) is also provided which combines the attribute information from all the other tables.

2 Metadata

The *01_id_name_metadata.zip* file contains dataset sources and station information, as detailed in Table 1.

Table 1: Metadata provided in CAMELS-AUS v2

Short name	Description	Data source / notes
station_id	Station ID used by the Australian Water Resources Council.	Source dataset (HRS-2015; HRS-2022; or Saft et al. (2023))
station_name	River name and station name	

drainage_division	Drainage division, of the 13 defined by the BOM.	Bureau of Meteorology (BOM) website www.bom.gov.au and also provided in “bonus data” folder.
river_region	River region, of the 218 defined by the BOM.	
notes	General notes about data issues and/or catchment area calculations	

3 Catchment boundaries and area

The *02_location_boundary_area.zip* file contains all the shapefiles (e.g. basin outlets, catchment boundaries and nestedness). Related information is included in the *location_boundary_area.csv* file (Table 2).

Table 2: Basic catchment information provided in CAMELS-AUS v2

Short name	**Description**	**Data source / notes**
lat_outlet	Latitude and longitude at outlet. Note, in most cases this will be slightly different to the BoM published value because most outlets needed to be moved onto a digital streamline in order to facilitate flow path analysis.	This study For daystart_Q, see Jian et al., (2017)
long_outlet		
lat_centroid	Latitude and longitude at centroid of the catchment.	
long_centroid		
map_zone	Map zone used to calculate catchment area (function of longitude)	
catchment_area	Area of upstream catchment in km^2	
state_outlet	Indicates which state or territory of Australia the outlet is within	
state-alt	If the catchment crosses a state or territory boundary, the alternative state or territory is listed here, otherwise “n/a”	
daystart	Time (UTC) for midnight local standard time (for *state_outlet*). This is the day start time for T_{max} and T_{min} (see Fowler et al., 2021).	
daystart_P	Time (UTC) for 9am local standard time (for *state_outlet*). 9am is when once-per-day precipitation measurements are reported (see Fowler et al., 2021).	
daystart_Q	Time (UTC) for streamflow day start time, assuming local standard time for *state_outlet.* This varies by state/territory (Fowler et al., 2021).	
nested_status	"Not nested" indicates the catchment is not contained within any other. "Level1" means it is contained within another, except in cases where it is contained in another "Level1" catchment in which case it is marked "Level2". Same for “Level 3” and “Level 4”.	
next_station_ds	For nested catchments, *NextStationDS* ('DS’ meaning downstream) indicates the catchment they are contained within.	
num_nested_within	Indicates how many catchments are nested within this catchment.	

3 Streamflow data and uncertainty

The *03_streamflow.zip* file contains streamflow timeseries (Table 3), streamflow signatures (Table 4) and gauging statistics (Table 5). Note that only 39 streamflow signatures, all of them single output (ie. only a single number per catchment) are listed in Table 4. For users who need the complete set, please refer to the *signatures_TOSSH_AllOutput.mat* file that includes all outputs of TOSSH (Toolbox for Streamflow Signatures in Hydrology; Gnann et al., 2021) including the 49 signatures and associated information such as run-time messages.

Table 3: Streamflow timeseries data supplied with CAMELS-AUS v2

File name	Source data	Description / comments	Unit
streamflow_MLd.csv	HRS-2015; HRS-2022; or Saft et al. (2023)	Streamflow (not gap filled)	ML d^{-1}
streamflow_ MLd_infilled.csv		Streamflow gap filled by the BOM using GR4J (Perrin et al, 2003)	ML d^{-1}
streamflow_ mmd.csv		Streamflow (not gap filled) expressed as depths relative to CAMELS-AUS version 2 adopted catchment areas	mm d^{-1}
streamflow_QualityCodes.csv		Quality codes/flags as supplied by the HRS website, with meanings listed at www.bom.gov.au/water/hrs/qc_doc.shtml	-

Table 4: Streamflow signatures provided in CAMELS-AUS v2

Short Name	Description	Units	Data source / notes
sig_mag_BaseMag	Difference between maximum and minimum of annual baseflow regime	mm	Calculated using TOSSH after Gnann et al. (2021); the signature description is from tosshtoolbox.github.io/TOSSH/p2_signatures.html#list-of-signature-sets
sig_mag_BFI	Baseflow index	-	
sig_mag_Q_7_day_max	7-day maximum streamflow	mm/timestep	
sig_mag_Q_7_day_min	7-day min streamflow	mm/timestep	
sig_mag_Q_CoV	Coefficient of variation	-	
sig_mag_Q_mean	Mean streamflow	mm/timestep	
sig_mag_Q_skew	Skewness of streamflow	mm^3/timestep^3	
sig_mag_Q_var	Variance of streamflow	mm^2/timestep^2	
sig_mag_Q5	5-th streamflow percentile	mm/timestep	
sig_mag_Q95	95-th streamflow percentile	mm/timestep	
sig_mag_VarIdx	Variability index of flow, calculated from flow duration curve	-	
sig_freq_high_Q_freq	High flow frequency	-	
sig_freq_low_Q_freq	Low flow frequency	-	
sig_freq_zero_Q_freq	Zero flow frequency	-	
sig_dur_RespTime	Catchment response time	timestep	
sig_dur_high_Q_dur	High flow duration	timestep	
sig_dur_low_Q_dur	Low flow duration	timestep	
sig_dur_zero_Q_dur	Zero flow duration	timestep	
sig_timing_HFD_mean	Half flow date	day of year	
sig_timing_HFI_mean	Half flow interval	days	

sig_roc_AC1	Lag-1 autocorrelation	-	
sig_roc_AC1_low	Lag-1 autocorrelation for low flow period (the four months with the lowest average flows)	-	
sig_roc_BaseRecesK	Exponential recession constant	1/d	
sig_roc_FDC_slope	Slope of the flow duration curve	-	
sig_roc_FlashIdx	Richards-Baker flashiness index	-	
sig_roc_RecesK_early	Recession constant of early (exponential) recessions	1/timestep	
sig_roc_RecesVarSeasonality	Seasonal variations in recession parameters	-	
Short Name	**Description**	**Units**	**Data source / notes**
sig_roc_RLD	Rising limb density	1/timestep	Calculated using TOSSH after Gnann et al. (2021); the signature description is from tosshtoolbox.github.io/TOSSH/p2_signatures.html#list-of-signature-sets
sig_other_EventRR	Event runoff ratio	-	
sig_other_PeakDistribution	Slope of distribution of peaks	-	
sig_other_PeakDistribution_low	Slope of distribution of peaks for low flow period (the four months with the lowest average flows)	-	
sig_other_QP_elasticity	Streamflow-precipitation elasticity	-	
sig_other_RR_seasonality	Runoff ratio seasonality	-	
sig_other_SnowDayRatio	Snow day ratio (T_threshold = 2 degC)	-	
sig_other_SnowStorage	Snow storage derived from cumulative P-Q regime curve	mm	
sig_other_Spearmans_rho	Non-uniqueness in the storage-discharge relationship	-	
sig_other_StorageFromBase	Average storage from average baseflow and storage-discharge relationship	-	
sig_other_TotalRR	Total runoff ratio	-	
sig_other_ratio_Event_TotalRR	Ratio between event and total runoff ratio	-	

Table 5: Flow uncertainty information provided in CAMELS-AUS v2

Short Name	Description	Units	Data source / notes
start_date	Streamflow gauging start date (yyyymmdd)	-	HRS-2015; HRS-2022; or Saft et al. (2023)
end_date	Streamflow gauging end date (yyyymmdd)	-	
prop_missing_data	Proportion of data missing between start date and end date	-	
q_uncert_unique_curves	Number of unique rating curves considered in analysis by McMahon et al. (under review)	-	McMahon et al. (under review)
q_uncert_rmse_all	Root mean square error (RMSE) of the gauged versus rating curve discharges as a percentage of the mean discharge for all non-zero gauged values	%	
q_uncert_rmse_lower	As above but for the lower half of non-zero gauged values (daily discharges less than the published non-zero median value)	%	
q_uncert_rmse_upper	As above but for the upper half of non-zero gauged values (daily discharges greater than the published non-zero median value)	%	
q_uncert_days_above	The percentage of days for which the published discharge values exceed the maximum gauged discharge	%	
q_uncert_Q_above	The percentage of the total discharge volume that is above the maximum gauged discharge	%	

4 Catchment attributes

We categorized the catchment attributes into five categories (geology and soils; topography and geometry; landcover and vegetation; anthropogenic influences; and others), which are included in the *04_attributes.zip* file (Table 6). Note that the adopted landcover dataset (Lymeburner et al., 2015) can provide information over time; we tabulate the average temporal proportions as attributes, providing full timeseries information in *Landcover_timeseries.xlsx*.

Table 6: Catchment attributes included in CAMELS-AUS v2 (apart from climatic and hydrologic indices)

	Short name	Description	Unit	Data source	Notes/references
Geology and Soils	*geol_prim*	Two most common geologies (see list in cell below) with corresponding proportions.	-	Geoscience Australia (2008)	Preprocessed by Stein et al. (2011)
	geol_prim_prop				
	geol_sec				
	geol_sec_prop				
	unconsoldted	Proportion of catchment taken up by individual geological types, specifically: unconsolidated rocks; igneous rocks, siliciclastic/undifferentiated sedimentary rocks; carbonate sedimentary rocks; other sedimentary rocks; metamorphic rocks; and mixed sedimentary/igneous rocks.	-		
	igneous				
	silicsed				
	carbnatesed				
	othersed				
	metamorph				
	sedvolc				
	oldrock	Catchment proportion old bedrock	-		
	claya	Percent clay in the soil A & B horizons, for the stream valley in the reach containing gauging station.	%	National Land and Water Resources Audit (2001)	Preprocessed by Stein et al. (2011)
	clayb				
	sanda	As above, but % sand in the soil A horizon	%		
	solum_thickness	Mean soil depth considering all principle profile forms	m	McKenzie et al. (2000)	-
	ksat	Saturated hydraulic conductivity (areal mean)	mm h^{-1}	Western and McKenzie (2004)	Preprocessed by Stein et al. (2011)
	solpawhc	Solum plant available water holding capacity (areal mean)	mm		
Topography and geometry	*elev_min*	Elevation above sea level at gauging station	m	Gallant et al. (2009)	-
	elev_max	Catchment maximum and mean elevation above sea level	m	Hutchinson et al. (2008)	Preprocessed by Stein et al. (2011)
	elev_mean				
	elev_range	Range of elevation within catchment: elev_max-elev_min	m		-
	mean_slope_pct	Mean slope, calculated on a grid-cell-by-grid-cell basis	%	Gallant et al. (2012)	-
	upsdist	Maximum flow path length upstream	km	Hutchinson et al. (2008)	Preprocessed by Stein et al. (2011). For *strahler*, see Strahler (1957) For *elongratio*, see Gordon et al. (1992).
	strdensity	Ratio: (total length of streams) / (catchment area)	km^{-1}		
	strahler	Strahler stream order at gauging station	-		
	elongratio	Factor of elongation as defined in Gordon et al. (1992)	-		
	relief	Ratio: (mean elev. above outlet)/(max elev. above outlet)	-		
	reliefratio	Ratio: (elevation range)/(flow path distance)	-		
	mrvbf_prop_0 through to mrvbf_prop_9	Proportion of catchment occupied by classes of Multi-Resolution Valley Bottom Flatness (MRVBF). These indicate areas subject to deposition. Broad interpretations are: 0 – erosional; 1 – small hillside deposit; 2-3 – narrow valley floor; 4 – valley floor; 5-6 –extensive valley floor; 7-8 – depositional basin; 9 – extensive depositional basin	-	CSIRO (2016)	Gallant and Dowling (2003)
	confinement	Proportion of stream segment cells & neighbouring cells that are not valley bottoms (as defined by MRVBF)	-	Hutchinson et al. (2008)	Preprocessed by Stein et al. (2011)
Land Cover and Vegetation	*lc01_extracti*	Proportion of catchment occupied by land cover categories within the *Dynamic Land Cover Dataset* (DLCD): *mines and quarries (*ISO name: *extraction sites*) *lakes and dams (inland water bodies)* *salt lakes (salt lakes)* *irrigated cropping (irrigated cropping)* *irrigated pasture (irrigated pasture)* *irrigated sugar (irrigated sugar)* *rain fed cropping (rainfed cropping)* *rain fed pasture (rainfed pasture)* *rain fed sugar (rainfed sugar)* *wetlands (wetlands)* *closed tussock grassland (tussock grasses - closed)*	-	Lymburner et al. (2015)	Note, the source dataset has 13 timeslices; these attributes indicate the temporal average. The timeslices are separately supplied with CAMELS-AUS v2
	lc 03_waterbo				
	lc 04_saltlak				
	lc 05_irrcrop				
	lc06_irrpast				
	lc07_irrsuga				
	lc08_rfcropp				
	lc09_rfpastu				
	lc10_rfsugar				
	lc11_wetlands				
	lc14_tussclo				
	lc15_alpineg				

	Short name	Description	Unit	Data source	Notes/references
	lc16_openhum *lc18_opentus* *lc19_shrbsca* *lc24_shrbden* *lc25_shrbope* *lc31_forclos* *lc32_foropen* *lc33_woodope* *lc34_woodspa* *lc35_urbanar*	*alpine meadows (alpine grasses - open)* *open hummock grassland (hummock grasses - open)* *open tussock grasslands (tussock grasses - open)* *scattered shrubs and grasses (shrubs and grasses - sparse - scattered)* *dense shrubland (shrubs - closed)* *open shrubland (shrubs - open)* *closed forest (trees - closed)* *open forest (trees - open)* *open woodland (trees - scattered)* *woodland (trees - sparse)* *urban areas (urban areas)*			
	prop_forested	sum(LC_31, LC_32, LC_33, LC_34)			
	nv_grasses_n *nv_grasses_e* *nv_forests_n* *nv_forests_e* *nv_shrubs_n* *nv_shrubs_e* *nv_woodl_n* *nv_woodl_e* *nv_bare_n* *nv_bare_e* *nv_nodata_n* *nv_nodata_e*	Major vegetation sub-groups within the *National Vegetation Information System* (NVIS). Despite redundancy with the DLCD attributes (see above), these are included because NVIS quantifies alteration from 'natural' by differentiating between 'pre-1750' ('_n') and 'extant' ('_e'). Subgroups: *grasses* *forests* *shrubs* *woodlands* *bare* *no data*	-	DEWR (2006)	Preprocessed by Stein et al. (2011)
Anthropogenic Influences	*distupdamw*	maximum distance upstream before encountering a dam or water storage	km	Geoscience Australia (2004)	Preprocessed by Stein et al. (2011)
	impound_fac *flow_div_fac* *leveebank_fac* *infrastruc_fac* *settlement_fac* *extract_inf_fac* *landuse_fac* *catchment_di* *flow_regime_di* *river_di*	Dimensionless factors quantifying human impacts on catchment hydrology, in two broad categories: - Flow regime factors: impoundments (*ImpoundmF*), flow diversions (*FlowDivF*), and levee banks (*LeveebankF*). The combined effect is disturbance index *FlowRegimeDI*; - Catchment factors: infrastructure (*InfrastrucF*), settlements (*SettlementF*), extractive industries (*ExtractiveIndF*) and landuse (*LanduseF*). The combined effect is captured in *CatchmentDI.* *FlowRegimeDI* and *CatchmentDI* are combined in *RiverDI*	-	Stein et al. (2002), updated by Stein et al. (2011)	
Other	*pop_mean* *pop_max*	Average and maximum human population density in catchment across 3" grid squares.	km^{-2}	ABS (2006)	Preprocessed by Stein et al. (2011)
	pop_gt_1 *pop_gt_10*	Proportion of catchment with population density exceeding 1 person / km² and 10 people / km²	-		
	erosivity	Rainfall erosivity (spatial average across catchment)	MJ mm ha^{-1} h^{-1}	NLWRA (2001)	
	anngro_mega *anngro_meso* *anngro_micro*	Average annual growth index value for megatherm, mesotherm and microtherm plants, respectively	-	Xu and Hutchinson (2011)	
	gromega_seas *gromeso_seas* *gromicro_seas*	Seasonality of growth index value for megatherm, mesotherem and microtherm plants, respectively	-		
	npp_ann *npp_1* *through to* *npp_12*	Net Primary Productivity estimated by Raupach et al. (2002) for pre-European settlement conditions: - annually; and - for the twelve calendar months of the year	tC Ha^{-1}	Raupach et al. (2002)	Preprocessed by Stein et al. (2011)

5 Hydrometeorology

The *05_hydrometeorology.zip* file contains all hydrometeorological data (Table 7) and climatic indices (Table 8).

Table 7: Hydrometeorological time series data supplied with CAMELS-AUS v2. All timesteps are daily. All data were processed as part of the CAMELS-AUS v2 to extract catchment averages from Australia-wide AGCD/SILO grids.

Category	File name	Source data	Description / comments	Unit
precipitation	*precipitation_agcd.csv*	BOM's Australian Gridded Climate Data (AGCD) v1.0.1, (Evans et al., 2020) www.bom.gov.au/climate/maps/ AGCD provides 0.05° grids.	catchment average precipitation (Note, AGDC supersedes earlier AWAP data used in v1)	mm d^{-1}
	precipitation_var_agcd.csv		Spatial internal variance in precipitation	mm^2 d^{-2}
Category	**File name**	**Source data**	**Description / comments**	**Unit**
precipitation	*precipitation_silo.csv*	Scientific Information for Land Owners (SILO) project, Government of Queensland (Jeffrey et al., 2001) www.longpaddock.qld.gov.au SILO provides 0.05° grids.	catchment average precipitation	mm d^{-1}
Actual and potential evapo-traspiration (AET and PET)	*et_short_crop_silo.csv*		FAO56 short crop PET (see FAO, 1998)	
	et_tall_crop_silo.csv		ASCE tall crop PET (see ASCE, 2000)	
	et_morton_wet_silo.csv		Morton (1983) wet-environment areal PET over land	
	et_morton_potential_silo.csv		Morton (1983) point PET	
	et_morton_actual_silo.csv		Morton (1983) areal AET	
evaporation	*evap_morton_lake_silo.csv*		Morton (1983) shallow lake evaporation	
	evap_pan_silo.csv		Interpolated Class A pan evaporation	
	evap_syn_silo.csv		Interpolated synthetic extended Class A pan evaporation (Rayner, 2005)	
temperature	*tmax_agcd.csv*	AGCD (see above)	Daily maximum temperature	°C
	tmax_silo.csv	SILO (see above)		
	tmin_agcd.csv	AGCD (see above)	Daily minimum temperature	
	tmin_silo.csv	SILO (see above)		
Other variables	*vapourpres_h09_agcd.csv*	AGCD (see above)	Vapour pressure	hPa
	vapourpres_h15_agcd.csv			
	vp_silo.csv	SILO (see above)		
	radiation_silo.csv		Solar radiation	MJ m^{-2}
	vp_deficit_silo.csv		Vapour pressure deficit	hPa
	rh_tmax_silo.csv		Relative humidity at the time of maximum temperature	%
	rh_tmin_silo.csv		Relative humidity at the time of minimum temperature	%
	mslp_silo.csv		Mean sea level pressure	hPa

Table 8 Climatic indices provided in CAMELS-AUS v2

Short Name	Description	Units	Data source / notes
p_mean	mean daily precipitation	mm d^{-1}	Climatic signatures are calculated using code from Addor et al. (2017), using the following datasets (cf. Table 1) - Precipitation is based on AWAP rainfall. - PET is based on SILO Morton Wet Env. PET - temperature data is based on AWAP temperature For *p_seasonality* see Eq. 14 in Woods (2009)
pet_mean	mean daily potential evapotranspiration (PET) (Morton's Wet Environment)	mm d^{-1}	
aridity	aridity (pet_mean / p_mean)	-	
p_seasonality	precipitation seasonality (0: uniform; +'ve: Dec/Jan peak; -'ve: Jun/Jul peak)	-	
frac_snow	fraction of precipitation on days colder than 0° C	-	
high_prec_freq	frequency of high precipitation days, ≥5 times p_mean	d y^{-1}	
high_prec_dur	average duration of high precipitation events	days	
high_prec_timing	season during which most high precip. days occur (djf, mam, jja, or son)	season	
low_prec_freq	frequency of dry days (≤ 1 mm/d)	d y^{-1}	
low_prec_dur	average duration of low precipitation periods (days ≤ 1 mm/d)	days	
low_prec_timing	season during which most dry days occur (djf, mam, jja, or son)	season	

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