Network Common Data Framework file standards - ANUClimate

This document is intended for scientific researchers, data professionals and policy analysts who make use of the ANUClimate data products. It describes the content and purpose of the file format used to convey the data.

These standards are in compliance with Attribute Conventions for Dataset Discovery v1.3 (ACDD-1.3). Meeting these standards maintains a high level of interoperability with other established research facilities that use Climate and Forecast conventions 1.6, while allowing greater flexibility with a minimum of required attributes.

ANUClimate netcdf files are in the netcdf4 classic format (saved in HDF5 format on disk). Netcdfs are self-describing, with metadata contained in the file header. Netcdf4 classic format allows larger datasets, with better compression than netcdf3 (i.e., from ~58MB to ~26MB per file).

Software used in creation of ANUClimate netcdfs:

* Compiled Netcdf libraries version 4.2.1.1
* Files were created using Python (2.7+), netCDF4 library version 1.3.1, and numpy 1.11.0

Naming policy

File names are composed of several elements, separated by “\_” for distinct elements and “-“ for components of elements. The key elements of each product is listed in the filename to assist researchers identify their desired datasets.

ANUClimate\_v1-0\_tmin\_monthly\_1970-2016\_201510.nc

<model>\_<model\_version>\_<standard name>\_<frequency>\_<resolution>\_<dataset epoch>\_<time increment of file>.nc

<model> : model or instrument system generating the data

<model\_version> : the version of the model, used to separate iterations of a data product based on what model version generated it, default is v1-0

<standard name> : the variable standard name for the data represented in the file

<frequency> : the time component, one of daily, monthly, yearly or period mean

<dataset\_epoch> : the full temporal range of the dataset, inclusive, e.g., 1970-2016 includes from start of January 1970 to end of December 2016

<time increment of file> : date for which the file contains data, YYYY(MM(DD))

**Netcdf elements**

Dimensions

ANUClimate netcdf files have 3 dimensions with the correct standard name (<dimension> - “<name>”):

* latitude – “lat”
* longitude – “lon”

time – “time”

Each dimension has a size determined by the length of the 1D array that defines it.

Variables

ANUClimate netcdf files must have variables for:

* latitude – “lat”
* longitude – “lon”
* time – “time”
* coordinate reference system – “crs”
* data product – name varies, see variable names table

Attributes

Attributes allow direct identification of key aspects of the dataset for the research community and the software tools they use to analyse its contents. Attributes form a “key”: ”value” structure and are accessed programmatically as a dictionary within the Python programming language. Lists of standard attributes are below (after the “Postprocessing” section).

Time

Temporal representation of our ANUClimate netcdf data is composed of:

* Epoch – the period of time the dataset (as a whole) represents, the epoch, with the exception of the period mean datasets, start in 1970 and have data for each time increment from then till 2012, 2014 or 2016. Period mean datasets begin in 1976 cover till end 2005.
* Frequency – the timestep represented in the dataset, being daily, monthly, yearly and mean over a period. This determines how many files will be contained in the dataset. N.B., for distribution reasons, daily timesteps are collated into monthly files of daily grids of data.
* Time increment – the individual timestep(s) contained in the files and is referenced as a suffix on the filename (e.g., ANUClimate … 201212.nc would be for December of 2012). Daily files collated into monthly blocks have monthly timestep suffix in the filename, but the filename specifies ‘daily’ as the frequency and the file contains grids for each day of data
* Data source quality –ANUClimate model version 2.0 has three levels of data quality:
  + Alpha – data that hasn’t been quality checked by BoM, works on data two days prior
  + Beta – data that has been minimally quality checked by BoM, works on data two months prior
  + Stable – data that has been fully quality checked by BoM, works on data six months prior

Each timestep is contained in an array in the time variable, and the number of timesteps form the length of the 1D array (e.g., for daily data collated into monthly blocks, “time” array would have thirty one steps in January, thirty in June, etc.). Each time value is expressed as a number of increments from a reference date. The reference date is listed under the units attribute, and is commonly “seconds since 1970-01-01 00:00:00”. For example, October 2015 is entered in the netcdf time variable array as “1443657600.0”.

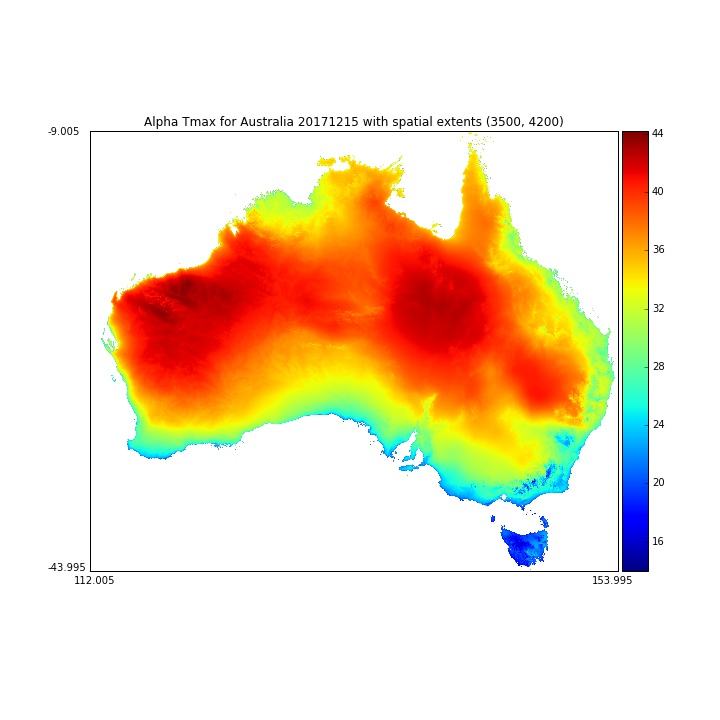
All time increments are taken as being the beginning of the period referenced, so all daily timesteps are listed as midnight of the day concerned, while all monthly/yearly/period-mean timesteps are as listed as midnight of the first day of the period.

All dates in attributes are in YYYY-MM-DD format.

**Space**

Scale and extent

ANUClimate products cover the Australian continent at approximately 1km x 1km grid cell resolution. The spatial extent of the ANUClimate product range are represented as a 3500 row by 4200 column array. This covers continental Australia, Tasmania as well as outlying island. In keeping with other large producers of netcdfs (e.g., [Climate and Forecasting standard](http://cfconventions.org/Data/cf-conventions/cf-conventions-1.6/build/cf-conventions.html#coordinate-types), [NOAA](https://www.esrl.noaa.gov/psd/data/gridded/data.noaa.oisst.v2.html)), all coordinates represent the centre point of each grid cells.



**Figure 1**. Representation of ANUClimate spatial extent showing minimum and maximum latitude and longitude

Geodetic Datum

Netcdfs representation of spatially varying data requires a commonly defined system of latitude and longitude (a datum) for it to be analysed effectively. ANUClimate datasets are derived from BoM point observations with latitude and longitude defined in terms of the Geodetic Datum of Australia 1994 (GDA94; EPSG code: 4283). As Australia physically shifts close to 7cm per year to the north-east, Geosciences Australia is currently modernising Australia’s datum to more accurately represent Australia spatial positioning in line with the World Geodetic System 1984 (WGS84; EPSG code: 4326) in use with Global Navigation Satellite Systems (GNSS, of which GPS is a part). The new datum is called GDA2020, and is based on the same ellipsoidal representation as GDA94 (GRS80 ellipsoid). When this new datum is formally adopted, ANUClimate dataset netcdfs will be reviewed.

**Testing**

Software used in testing

Once ANUClimate files are created in netcdf format, they require testing to ensure they are compatible with the main GIS and spatial tools available. Below are the main software libraries tested on:

* Netcdf libraries (netcdf 4.0+)
  + ‘ncdump –h <dataset name>’
  + Visual examination of the dataset metadata to confirm data types, array lengths, naming conventions and file structure are correct
* GDAL (2.1.3+)
  + Check if files are readable by GDAL through command ‘gdalinfo’
  + Test if subset and reprojection options available with command ‘gdalwarp’
    - Sample code and output below (on raijin, need “module load gdal” first):

gdalwarp -of netCDF -s\_srs EPSG:4283 -t\_srs EPSG:6933 -crop\_to\_cutline -cutline ./NSW\_abs\_shp/NSW\_condensed.shp ./ANUClimate\_v2-0\_temperature-max-alpha\_daily\_0-01deg\_20171222.nc test\_alpha\_gdal.nc

Creating output file that is 1689P x 971L.

Processing input file ./ANUClimate\_v2-0\_tmax-alpha\_daily\_0-01deg\_20171222.nc.

Using internal nodata values (e.g. -999) for image ./ANUClimate\_v2-0\_tmax-alpha\_daily\_0-01deg\_20171222.nc.

0...10...20...30...40...50...60...70...80...90...100 - done.

* QGIS (2.14)
  + Based on GDAL and python, important to check if the file can be opened and viewed correctly
  + Check properties to ensure correct origin lat/lon and resolution are listed; also check to make sure projection information is queried when layer first loaded
* ArcMap (10.4)
  + Similar to QGIS, test if files can be opened and properties viewed successfully
* Panoply (4.5.1)
  + Check if files can be plotted successfully as GeoX GeoY
  + Check attributes are listed correctly
* Python (2.7.6+)
  + Open with netCDF4 library and confirm header is correct
  + Access lat/lon/time/data arrays with numpy and plot with matplotlib

File processing time tests

ANUClimate Netcdf files are compressed with a chunking strategy to optimise the efficiency of read I/O and file size. Below is testing (done in Python 2.7.6) to confirm which chunking size and compression level is used.

netcdf file

import netCDF4 as nc

import numpy as np

src = '/g/data/rr9/fenner/prerelease/ANUClimate\_auto/script/nc\_output/ANUClimate\_v2-0\_tmax-alpha\_daily\_0-01deg/'

os.chdir(src)

ds = nc.Dataset(src+os.listdir('.')[2])

print timeit.timeit(str(np.nanmean(ds.variables['tmax-alpha'][:])))

print timeit.timeit(str(np.nanmean(ds.variables['tmax-alpha'][0:])))

print timeit.timeit(str(np.nanmean(ds.variables['tmax-alpha'][0,1500:,3000:])))

zlib = True, complevel = 9 (max)

No “chunksize” on data variable – filesize ~ 17MB

0.000142097473145

0.00012993812561

0.000258922576904

chunksizes = (1,10,10) – filesize ~ 29MB

0.000137090682983

0.000136137008667

0.000135898590088

chunksizes = (1,11,11) – filesize ~ 26MB

0.000119924545288

0.000146150588989

0.000146865844727

chunksizes = (1,100,100) – filesize ~ 17MB

0.000123977661133

0.000118017196655

0.000123023986816

**Postprocessing**

Once ANUClimate netcdfs are generated with correct metadata, the NCI makes the published data available to the research community through its THREDDS server. This is managed both as a catalogue of available datasets (<http://geonetworkrr9.nci.org.au/geonetwork/srv/eng/catalog.search#/home>) (used as the source of truth for netcdf file metadata), as well as the physical download of the datasets themselves (<http://dapds00.nci.org.au/thredds/catalog.html>). On the THREDDS server datasets can be downloaded as a time series for a point or in a grid.

The timeframes for coordinating the publication of these datasets through THREDDS are in Appendix 3.

**Variable names**

|  |  |  |  |
| --- | --- | --- | --- |
| **Filename** | **Description** | **Units** | **Standard name** |
| rain | Total precipitation | mm month-1 | rainfall |
| tmax | Maximum temperature | degree Celsius | max-temperature |
| tmin | Minimum temperature | degree Celsius | min-temperature |
| vp | Mean vapour pressure | HPa | vapour-pressure |
| srad | Solar radiation | MJ m-2 d-1 | solar-radiation |
| dis | Distance to a generalised coastline | km | distance |
| dem | Digital elevation model | m | dem |
| rat | Proportion of local area that is ocean | No unit | ocean-ratio |

**Table 1**. Variable naming convention. “Filename” refers to the variable name in the file, while “Standard name” refers to the variable name used for the netcdf variable within the file (N.B., only climate surfaces and static input parameters listed)

**Variable attributes**

|  |  |  |  |
| --- | --- | --- | --- |
| **Entry** | **Contained in** | **Description** | **Example** |
| long\_name | all except crs | Full description | Monthly daily minimum temperature: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2016 |
| standard\_name | all except crs | Short description | air\_temperature |
| units | all except crs | Units of measure of quantity | degree Celsius |
| axis | time lat lon | Cartesian axis | X (for longitude) |
| calendar | time | Used to derive time from number of increments from a reference point | gregorian |
| grid\_mapping | data | Ties data variable to the coordinate reference system | crs |
| coordinates | data | Ties data variable to coordinate axes | time lat lon |
| \_FillValue | data | No Data value (e.g., missing or invalid data) | -999. |
| coverage\_content\_type | data | Describes source of data (as per ISO 19115-1) | modelResult |
| grid\_mapping\_name | crs | short name for the coordinate reference system used | GDA94 |
| datum | crs | long name for the coordinate reference system used | Geocentric\_Datum\_of\_Australia\_1994 |
| inverse\_flattening | crs | used for projection transforms, denotes ellipsoidal form | 298.257222101 |
| semi\_major\_axis | crs | used for projection transforms, denotes ellipsoidal form | 6378137.0 |
| semi\_minor\_axis | crs | used for projection transforms, denotes ellipsoidal form | 6356752.314140356 |
| \_CoordinateTransformType | crs | used for projection transforms | Projection |
| \_CoordinateAxisTypes | crs | used for projection transforms | GeoX GeoY |
| spatial\_ref | crs | Identifies coordinate system for GDAL | 'GEOGCS["GDA94",DATUM["Geocentric\_Datum\_of\_Australia\_1994",SPHEROID["GRS 1980",6378137,298.257222101,AUTHORITY["EPSG","7019"]],TOWGS84[0,0,0,0,0,0,0],AUTHORITY["EPSG","6283"]],PRIMEM["Greenwich",0,AUTHORITY["EPSG","8901"]],UNIT["degree",0.01745329252,AUTHORITY["EPSG","9122"]],AUTHORITY["EPSG","4283"]]' |
| proj4text | crs | Identifies coordinate system for QGIS | +proj=longlat +ellps=GRS80 +towgs84=0,0,0,0,0,0,0 +no\_defs |

**Table 2**. Metadata attributes used for variables in Netcdf files

**Global attributes**

|  |  |  |
| --- | --- | --- |
| **Entry** | **Justification** | **Example** |
| geospatial\_lat\_min | geospatial descriptor | -44.0 |
| geospatial\_lat\_max | geospatial descriptor | -9.0 |
| geospatial\_lat\_units | geospatial descriptor | degrees\_north |
| geospatial\_lat\_resolution | geospatial descriptor | 0.01 |
| geospatial\_lon\_min | geospatial descriptor | 112.0 |
| geospatial\_lon\_max | geospatial descriptor | 154.0 |
| geospatial\_lon\_units | geospatial descriptor | degrees\_east |
| geospatial\_lon\_resolution | geospatial descriptor | 0.01 |
| time\_coverage\_start | Temporal descriptor | 2017-07-12 |
| time\_coverage\_end | Temporal descriptor | 2017-07-12 (can be same as start for daily files) |
| DOI | Digital Object Identifier | To be added |
| citation | how to cite this data product | Michael Hutchinson, Jennifer Kesteven, Tingbao Xu, 2014. Daily maximum temperature: ANUClimate 1.1, 0.01 degree, Australian Coverage, 1970-2014. Australian National University, Canberra, Australia. Obtained from http://dap.nci.org.au, made available by the University of Sydney. Accessed [Date accessed]. |
| references | original papers used in the preparation of the dataset | 1. Michael Hutchinson, Jennnifer Kesteven, Tingbao Xu, 2014. Daily total precipitation: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2012. Australian National University, Canberra, Australia., 2. Hutchinson, M.F., Mckenney, D.W., Lawrence, K., Pedlar, J., Hopkinson, R., Milewska, E. and Papadopol, P. 2009. Development and testing of Canada-wide interpolated spatial models of daily minimum/maximum temperature and precipitation for 1961-2003. Journal of Applied Meteorology and Climatology 48: 725�741., 3. Hutchinson, M.F. and Xu, T. 2013. ANUSPLIN version 4.4 User Guide. Fenner School of Environment and Society, Australian National University, Canberra. |
| keywords | identifies subject area of the dataset | EARTH SCIENCE > ATMOSPHERE |
| keywords\_vocabulary | source for keywords | NZSCR-FOR: http://www.abs.gov.au/ausstats/abs@.nsf/0/6BB427AB9696C225CA2574180004463E |
| summary | formal description of file contents | Daily maximum temperature for the Australian continent between 1970-2014. Daily maximum temperature regulates rates of plant growth and crop yield. Modelled by expressing each daily value as a difference anomaly with respect to the gridded 1976-2005 monthly mean daily maximum temperatures as provided by ANUClimate\_v1-0\_temperature-max\_monthly-mean\_0-01deg\_1976-2005. The daily anomalies were interpolated by trivariate thin plate smoothing spline functions of longitude, latitude and vertically exaggerated elevation using ANUSPLIN Version 4.5. There was an average of 675 Bureau of Meteorology data points available for each day between 1970 and 2014. Automated quality assessment rejected on average 2.6 data values per day with extreme studentised residuals. These were commonly associated with days following missing observations. Cross validation residuals for all accepted data points had a mean absolute value of 0.76 degrees Celsius and a root mean square value of 1.06 degrees Celsius. A comprehensive assessment of the analysis and the factors contributing to the quality of the final interpolated daily maximum temperature grids is in preparation. |
| id | dataset filename base (without ensemble or time increment) | ANUClimate\_v1-1\_temperature-max\_daily\_0-01deg\_1970-2014 |
| acknowledgment | Funding acknowledgement | The creation of this data was funded by The University of Sydney. |
| title | Formal long name for data array | Monthly daily minimum temperature: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2016 |
| source | model (or instrument) used in creating the data | ANUClimate\_v1-1 |
| publisher\_name | name of institution publishing included data | The University of Sydney |
| publisher\_url | website url of institution publishing included data | http://anuclimate.wordpress.com |
| publisher\_email | contact email of institution publishing included data | anuclimate@gmail.com |
| metadata\_link | link for geonetwork catalogue | http://geonetworkrr9.nci.org.au/geonetwork/srv/eng/catalog.search#/home |
| metadata\_uuid | unique identifier for metadata on geonetwork | e6452c77-fcce-4a5f-828f-9111e4e9b70c |
| institution | name of creator's institution | Australian National University |
| creator\_name | name of party who created the included data | Michael Hutchinson, Jennifer Kesteven, Tingbao Xu |
| creator\_email | email of party who created the included data | anuclimate@gmail.com |
| creator\_url | website url of party or parties who created the included data | http://anuclimate.wordpress.com |
| license | license owner and conditions description | Copyright 2017 ANU. Rights owned by The Australian National University (ANU). Rights licensed subject to Attribution Licence (CC BY 4.0) https://creativecommons.org/licenses/by/4.0/legalcode |
| Conventions | to identify which standards netcdf adheres to, needs capital C | ACDD-1.3 |
| cdm\_data\_type | use with THREDDS server as data type | grid |
| contact | contact details for creator | Michael Hutchinson, Professor of spatial and temporal analysis, 3.23A, Fenner School of Environment & Society, College of Medicine, Biology & Environment, Frank Fenner Building 141, Australian National University, Canberra, Australian Capital Territory, 0200, Australia, (+61) 2 6125 4783, Michael.Hutchinson@anu.edu.au, http://orcid.org/0000-0001-8205-6689 |
| history | lists changes made to the file, dynamically updated when file it modified using netcdf operators (nco) commands | Usually empty as it’s an automatically populated audit trail |
| date\_created | date netcdf was created (not published date) | 2017-12-11 |

**Table 3**. Metadata attributes attached to netcdf file header

**Appendix 1: Background**

From the University Corporation for Atmospheric Research (UCAR) Unidata (creators of the Network Common Data Framework (netcdf) format and libraries) website (<https://www.unidata.ucar.edu/software/netcdf/>):

*NetCDF is a set of software libraries and self-describing, machine-independent data formats that support the creation, access, and sharing of array-oriented scientific data.*

Netcdfs allow data arrays to be formatted clearly with attached information about the included data (metadata), which allows scientists and other users to analyse the data more effectively and efficiently.

Each netcdf is made up of several elements:

* dimensions
* variables
* attributes
  + variable attributes
  + global attributes

The basic data format is focused on dimensional array data (though point data can also be represented). In order to package the data array correctly, dimensions are used as coordinate axes with longitude (x), latitude (y) and time (z).

For these axes to be locatable spatiotemporally they are also created as variables and populated with one-dimensional arrays for each of the grid cell latitude, longitude and time increment references. Further variables are added to contain the data array itself, as well as the coordinate reference system that allows the dataset to be spatially analysed in the most widely used geospatial tools. All variables except the coordinate reference system are associated with one or more dimensions.

**Appendix 2: Sample netcdf description (Panoply)**

netcdf file: …/ANUClimate\_v1-0\_temperature-min\_monthly\_0-01deg\_1970-2016\_00000000\_201510.nc {

dimensions:

time = 1;

lat = 3474;

lon = 4110;

variables:

double time(time=1);

:long\_name = "time";

:standard\_name = "time";

:units = "seconds since 1970-01-01 00:00:00";

:calendar = "gregorian";

:axis = "T";

double lat(lat=3474);

:units = "degrees\_north";

:axis = "Y";

:long\_name = "latitude";

:standard\_name = "latitude";

float crs;

:name = "GDA94";

:datum = "Geocentric\_Datum\_of\_Australia\_1994";

:longitude\_of\_prime\_meridian = 0.0; // double

:inverse\_flattening = 298.257222101; // double

:semi\_major\_axis = 6378137.0; // double

:semi\_minor\_axis = 6356752.314140356; // double

:\_CoordinateTransformType = "Projection";

:\_CoordinateAxisTypes = "GeoX GeoY";

double lon(lon=4110);

:long\_name = "longitude";

:standard\_name = "longitude";

:units = "degrees\_east";

:axis = "X";

float air\_temperature(time=1, lat=3474, lon=4110);

:standard\_name = "air\_temperature";

:grid\_mapping = "crs";

:coordinates = "time lat lon";

:long\_name = "Monthly daily minimum temperature: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2016";

:units = "degree Celsius";

:\_FillValue = -999.0f; // float

// global attributes:

:geospatial\_lat\_min = -43.735; // double

:geospatial\_lat\_max = -9.005; // double

:geospatial\_lat\_units = "degrees\_north";

:geospatial\_lat\_resolution = 0.01; // double

:geospatial\_lon\_min = 112.905; // double

:geospatial\_lon\_max = 153.995; // double

:geospatial\_lon\_units = "degrees\_east";

:geospatial\_lon\_resolution = 0.01; // double

:DOI = "To be added";

:Metadata\_Conventions = "Unidata Dataset Discovery v1.0";

:citation = "Michael Hutchinson, Jennifer Kesteven, Tingbao Xu, 2017. Monthly daily minimum temperature: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2016. Australian National University, Canberra, Australia. Obtained from http://dap.nci.org.au, made available by the Ecosystem Modelling and Scaling Infrastructure (eMAST, http://www.emast.org.au) of the Terrestrial Ecosystem Research Network (TERN, http://www.tern.org.au). Accessed [Date accessed].";

:licence\_data\_access = "These data can be freely downloaded and used subject to the TERN-BY licence.";

:references = "The creation of this data was funded by the Terrestrial Ecosystem Research Network (TERN) Ecosystem Modelling and Scaling Infrastructure (eMAST) Facility under the National Collaborative Research Infrastructure Strategy (NCRIS) 2013-2014 budget initiative of the Australian Government Department of Industry, the Australian Government Department of Environment in support of the National Carbon Accounting System, and the Australian National University. Any publication of this data or works derived from these data, must include the following citation and prior email notification (eMAST.info@gmail.com). Please send reprints/citations of papers or oral presentations to the eMAST office.";

:contributor\_role = "principalInvestigator, author";

:keywords = "EARTH SCIENCE > ATMOSPHERE";

:summary = "Mean daily minimum temperature of each month, for the Australian continent between 1970-2016. Daily temperature regulates rates of plant growth and determines critical conditions such as frost on flowering and fruiting. Modelled by expressing each monthly value as a difference anomaly with respect to the gridded 1976-2005 mean daily minimum temperature for each month as provided by ANUClimate\_v1-0\_temperature-min\_monthly-mean\_0-01deg\_1976-2005. The monthly anomalies were interpolated by trivariate thin plate smoothing spline functions of longitude, latitude and vertically exaggerated elevation using ANUSPLIN Version 4.5. Monthly data values were calculated from Bureau of Meteorology daily data at stations where there were at least 25 days of record, giving an average of 634 data points per month between 1970 and 2016. Automated quality assessment rejected on average 2 data values per month with extreme studentised residuals. The root mean square of all individual cross validation residuals provided by the spline analysis is 0.73 degrees Centigrade. A comprehensive assessment of the analysis and the factors contributing to the quality of the final interpolated grids is in preparation.";

:publisher\_name = "Ecosystem Modelling and Scaling Infrastructure (eMAST) Facility: University of Sydney";

:id = "ANUClimate\_v1-0\_temperature-min\_monthly\_0-01deg\_1970-2016";

:spatial\_coverage = "Australia";

:acknowledgment = "The creation of this data was funded by the Terrestrial Ecosystem Research Network (TERN) Ecosystem Modelling and Scaling Infrastructure (eMAST) Facility under the National Collaborative Research Infrastructure Strategy (NCRIS) 2013-2014 budget initiative of the Australian Government Department of Industry, the Australian Government Department of Environment in support of the National Carbon Accounting System, and the Australian National University. Any publication of this data or works derived from these data, must include the following citation and prior email notification (eMAST.data@mq.edu.au). Please send reprints/citations of papers or oral presentations to the eMAST office.";

:title = "Monthly daily minimum temperature: ANUClimate 1.0, 0.01 degree, Australian Coverage, 1970-2016";

:standard\_name\_vocabulary = "Climate and Forecast(CF) convention standard names (http://cf-pcmdi.llnl.gov/documents/cf-standard-names)";

:source = "6572bca1-dc0d-422e-ac7e-89fbf6236d34";

:publisher\_url = "http://www.emast.org.au/";

:featureType = "grid";

:publisher\_email = "emast.info@gmail.com";

:keywords\_vocabulary = "ANZSCR-FOR: http://www.abs.gov.au/ausstats/abs@.nsf/0/6BB427AB9696C225CA2574180004463E";

:metadata\_link = "http://geonetworkrr9.nci.org.au/geonetwork/srv/eng/catalog.search#/home";

:metadata\_uuid = "degree Celsius";

:creator\_email = "emast.info@gmail.com";

:institution = "Australian National University";

:contributor\_name = "Michael Hutchinson, Jennifer Kesteven, Tingbao Xu";

:creator\_name = "eMAST data manager";

:license = "Copyright 2017 ANU. Rights owned by The Australian National University (ANU). Rights licensed subject to TERN Attribution Licence (TERN-BY) http://tern.org.au/datalicence/TERN-BY/1.0/";

:Conventions = "CF-1.6";

:cdm\_data\_type = "grid";

:contact = "Michael Hutchinson, Professor of spatial and temporal analysis, 3.23A, Fenner School of Environment & Society, College of Medicine, Biology & Environment, Frank Fenner Building 141, Australian National University, Canberra, Australian Capital Territory, 0200.0, Australia, (+61) 2 6125 4783, Michael.Hutchinson@anu.edu.au, http://orcid.org/0000-0001-8205-6689";

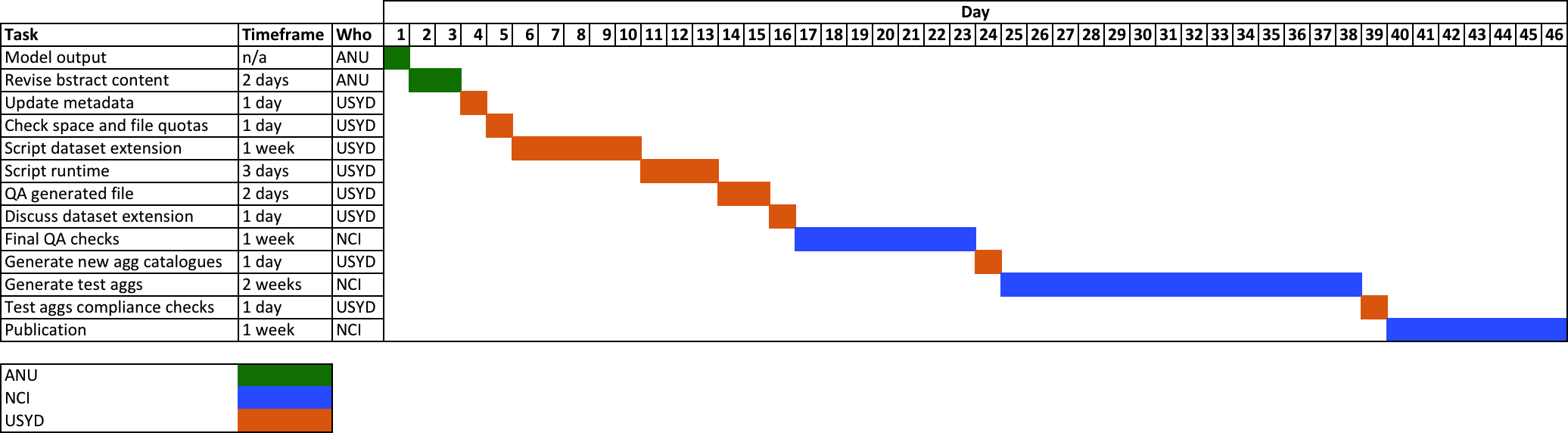
:creator\_url = "http://www.emast.org.au/";

:history = "Reformatted to NetCDF 2017-09-05.";

:date\_created = "2017/09/05";

}

**Appendix 3: NetCDF creation workflow and timeframes**



**Table 4**. Gant chart of netcdf file timeframes from model output to publication