

User FAQ for BARRA

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1. How is the BARRA reanalysis data being produced?

Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia (BARRA, Jakob et al., (2017)) is an atmospheric reanalysis that follows the Bureau of Meteorology's long-standing framework for operational regional and sub-regional numerical weather prediction systems, based on the Australian Community Climate and Earth Simulator System (ACCESS, Bureau of Meteorology (2013a,b)). The reanalysis is being produced in two steps. BARRA uses the atmospheric model Unified Model (UM, <https://www.metoffice.gov.uk/research/modelling-systems/unified-model>) and the land surface model Joint UK Land Environment Simulator (JULES, <http://jules.jchmr.org/>).

There are a number of global reanalyses available, however by focussing on a limited area of the globe, BARRA is able to provide a high resolution product. However limited area models or reanalyses require lateral boundary

conditions to provide information at the edges of the domain. For the boundary conditions we use the European Centre for Medium-Range Weather Forecasts (ECWMF) global atmospheric reanalysis product ERA-Interim (Dee et al., 2011), which has a nominal resolution of 80 km. The region covered by this model, henceforth referred to as *BARRA-R*, is the Australian continent, and the surrounding region including parts of southeast Asia and southern India, New Zealand, and south to the ice edge around the Antarctica, as shown in Figure 1. *BARRA-R* has an approximate model resolution of 12 km and the model extends over 70 levels up to 80 km into the atmosphere. *BARRA-R* reanalysis is the most computationally demanding step. The *BARRA-R* model *suite* uses a four-dimensional variational (4DVAR) data assimilation scheme to optimally combine observations and short model forecasts and provide the best representation of the atmosphere. This accounts for uncertainties in both the observations and model. This suite is based on the UK Meteorological Office's regional reanalysis suite developed for the European Union's FP7 reanalysis project Uncertainties in Ensembles of Regional ReAnalyses (Jermy et al., 2017).

BARRA-R drives convective-scale (1.5 km) downscaling models over smaller domains, using 70 levels up to 40 km in the atmosphere. These downscaling models are referred to as *BARRA-xx* (xx = SY, TA, PH, AD). In contrast to statistical or parametric downscaling, *BARRA-xx* uses model physics to generate 1.5 km horizontal grids that satisfy dynamical equations of the atmosphere and honour the land surface characteristics and heterogeneity. Based on our initial evaluation, we expect that *BARRA-R* will provide more accurate initial and boundary conditions for *BARRA-xx* than ERA-Interim.

Soil moisture fields in *BARRA* are initialized daily, with a global soil moisture dataset on 4 soil layers at 60 km resolution for the period 1990–2012, and 40 km soil moisture analysis from ACCESS-G from 2012 (Bureau of Meteorology, 2012). The first soil moisture data was generated using offline simulation of JULES with methods described in Dharssi and Vinodkumar (2017) and Zhao et al. (2017). This offline soil moisture was produced for ACCESS-S1 system. Within *BARRA-R*, soil moisture, soil temperature and skin temperature variables are corrected with land-only surface observations (not satellite) in each analysis cycle – that is, land surface data assimilation with extended Kalman filter (EKF). Sea surface temperature (SST) and sea ice fields in *BARRA* are initialized daily with Operational Sea Surface Temperature and Sea Ice Analysis (OSTIA, Donlon et al., (2012)) daily 5 km analysis fields. No analysis is performed on SST and sea ice in *BARRA*.

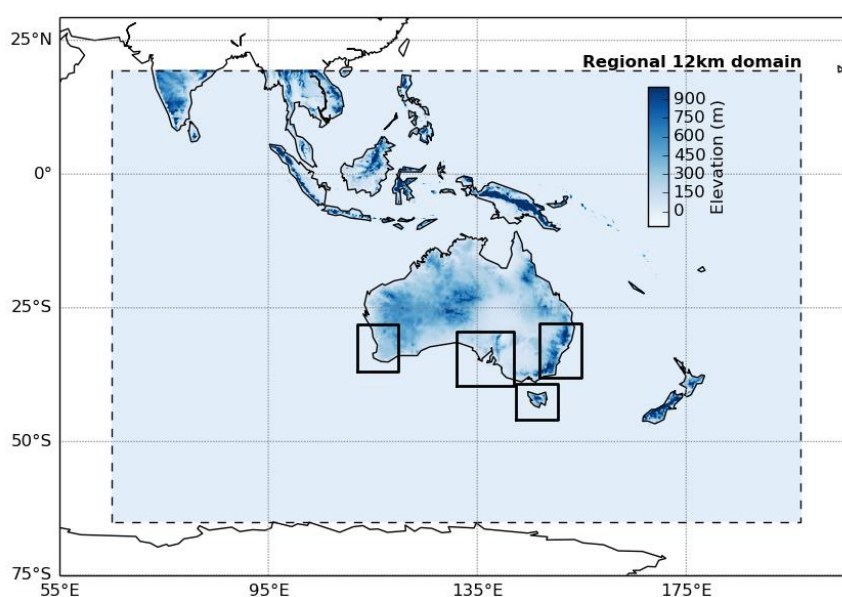


Figure 1 Domains of the regional reanalysis model *BARRA-R* (dashed box) and sub-domain models (solid boxes) for (from left to right) *BARRA-PH*, *BARRA-AD*, *BARRA-TA*, and *BARRA-SY*.

2. What is BARRA designed for?

BARRA is designed for providing multi-decadal (1990-2019) high spatial and temporal resolution, meteorological data from surface to lower stratosphere over Australia, New Zealand, and southeast Asia. We anticipate that in time BARRA (and its successors) will become an important complement to existing climate information. In common with other global (and regional) reanalyses, the use of such data is no longer restricted to the research community but more and more applications are likely to cross various sectors, including energy, agriculture, hydrology and emergency management to name just a few. BARRA will be providing information on the multi-decadal time scale required for assessing hazards and risks in the past and present climate. Due to its high spatial and temporal resolution, BARRA will also be well suited to the study of high impact historical events, such as the study of fire events.

The spatial resolution of BARRA-R is 12 km, higher than the existing global reanalysis data sets, including ERA5 the most recent reanalysis from ECMWF, at approximately 35 km resolution. In turn, BARRA-xx produces convective-scale 1.5 km data. BARRA-R and BARRA-xx provide parameters at an hourly time step and some at a 10-minute. Parameters provide information about surface conditions (such as temperature, precipitation, wind speed and direction, humidity, evaporation, soil moisture and soil temperature), information at (37) pressure and (70) model levels, and information on solar radiation and cloud cover. We note that while the BARRA model data extends up to 40-80 km, we have most confidence in the data up to a height of 25-30 km where we have most information. At this stage, our preliminary evaluations of precipitation, screen temperature, 10 m wind and screen dewpoint that BARRA-R and BARRA-SY are generally more skilful than the leading global reanalysis, ERA-Interim (manuscript in preparation). Further evaluations are underway by the BARRA team. We welcome you to collaborate closely with us to establish the skills and limitations of the BARRA data - email us at helpdesk.reanalysis@bom.gov.au

3. How are the data files named?

Note that the stream *spec_proc* has been eliminated in the data released in January 2019. The data previously organised under *spec_proc* is now organised under *spec*.

Note that a new file extension *.sub.nc* is used to distinguish files produced by post-processing.

Relevant for both BARRA-R and BARRA-xx:

The files are named so that they are self-descriptive and not dependent on the file structure for identification. The following structure defines the filename

<PAR>-<TYPE>-<PAR_STREAM>-<TIME_INT>-<MODEL_DOMAIN>-v1-<CYCLE_DATE>.[sub.]nc

PAR	Parameter name
TYPE	Output type, i.e., fc – forecast, an – analysis
PAR_STREAM	Parameter category prs ‡ – pressure-level parameter available hourly at 37 standard pressure levels slv – single-level parameters available hourly at single levels & multi-layers at the surface (mainly the surface) spec † - Subhourly parameters available every 10 minutes on single levels (mainly surface) cld ¥ – cloud-related parameters available hourly at 70 model levels mdl ¥ – model-level parameters available hourly at 70 model levels
TIME_INT	Temporal period of the field in ISO 8601 duration format ie. PT1H - one hour, PT10M - ten minutes
MODEL_DOMAIN	domain specific product name eg. BARRA_R or BARRA_TA

V1	Version 1, version of the processor used to produce the reanalysis. Note that the label v1.1 is used in cases where v1 files have been released to users, but are replaced by re-runs with updated forcing data.
CYCLE_DATE	Start time of the forecast cycle that produces the data. For BARRA-R, this is the base time t_0 of the 6-hour analysis window. The date time is expressed in ISO 8601 format <code>yyyymmddTHHMMZ</code> in UTC.
[.sub]	Additional label to reflect that the data file is produced from post-processing the original model output files.

‡ For prs files, we have only made 21 (out of 37) pressure levels for BARRA-XX available at this stage; see What are the pressure levels available in BARRA?

† For spec files, we have post-processed them to provide only hourly grids.

¥ The cld and mdl files are not available at this stage.

There are 4 files per day for each variable, for each output type, and for each model.

4. What do 'analysis' and 'forecast' mean in BARRA?

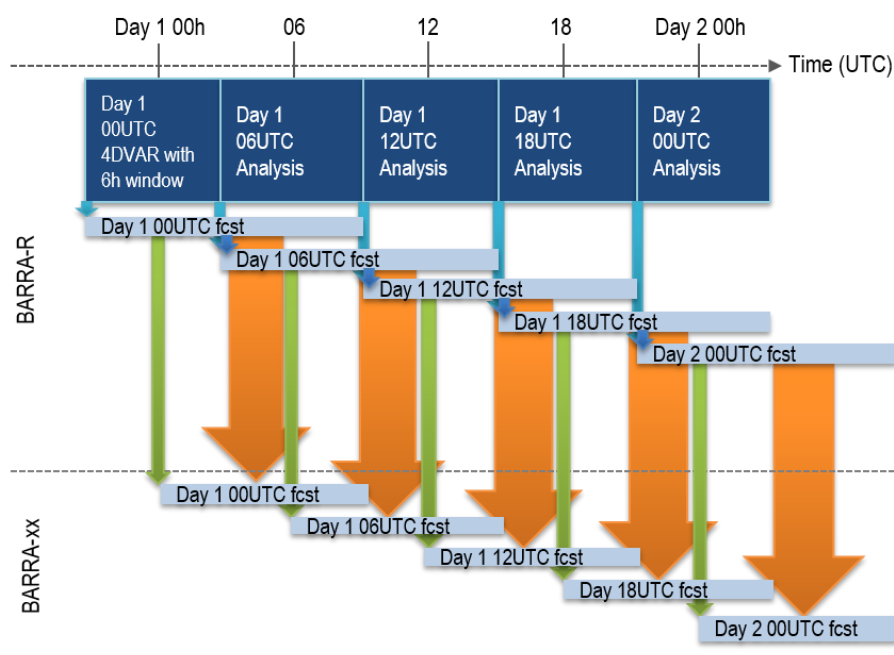


Figure 2 Cycling setup of the BARRA-R and downscaling model (BARRA-xx) suites. The dark blue boxes show the time ranges of the data assimilation analysis window and light blue boxes show the model forecasts. Arrows indicate data flow: Blue and green arrows refer to data for initial conditions, and orange arrows refer to data for lateral boundary conditions. The basetimes t_0 of the analysis and forecast cycles are 0, 6, 12, and 18Z.

Relevant for BARRA-R:

As is the case with other reanalyses, BARRA-R data are model forecasts that have been constrained by observations. The core of BARRA-R is the data assimilation system – four-dimensional variational analysis (4DVAR). It draws the model closer to observations, and is conducted 4 times a day centered at 00, 06, 12 and 18 UTC - this is labelled as basetime t_0 . The 4DVAR at a given cycle t_0 uses all the observations within a 6h window centered at t_0 to correct the short model forecast over this window. See Figure 2. For instance, the analysis cycle centred at $t_0=06$ UTC spans from 03 UTC (t_0-3h) to 09 UTC (t_0+3h), assimilates all the observations within this time-window to correct the short model forecast from the $t_0=00$ UTC cycle. The short model forecast synthesizes information from previous observations and our understanding of atmospheric behaviour.

The 4DVAR is operated on a perturbation forecast model (Lorenc 2003; Lorenc & Payne, 2007), which is of lesser complexity and lower resolution (36 km cf. 12 km) than the full forecast model, and produces analysis increments valid at t_0-3h . The increments correct the forecast fields from the previous cycle, to create the suitable initial condition for running the full forecast model from t_0-3h to t_0+9h . In other words, it is assumed that the lower-resolution increments, interpolated to high resolution, are suitable corrections for the higher-resolution 12 km model. During the forecast run for the cycle t_0 , the forecast fields valid at t_0-3h , t_0-2h and t_0-1h are not written out, as these fields may still be influenced by transient artefacts due to the slight imbalance introduced by the addition of the analysis increments; these fields are not archived due to storage constraints. The forecast fields valid at t_0 are labelled as "analysis", primarily due to convention, and are found in the directory:

```
/g/data/ma05/BARRA_R/v1/analysis
```

The forecast fields valid at t_0+1h , t_0+2h , ..., t_0+9h , are labelled as "forecast", and these data are found in the directory:

```
/g/data/ma05/BARRA_R/v1/forecast
```

Notice that the forecast fields (written out) from t_0 to t_0+3h are within the analysis window. Indeed, the forecast fields valid between t_0-3h to t_0+3h are considered as a 4d-analysis since they are within the analysis time-window spanned by the observations. Therefore, the available BARRA-R data provides 3-hourly regularly-spaced analysis fields valid at t_0 and t_0+3h , or hourly analysis fields valid only between t_0 to t_0+3h .

The forecast fields from t_0+3h to t_0+9h provide the model background fields to be used in the analysis in the next cycle.

Relevant for BARRA-xx downscaler:

BARRA-xx involves performing forecast-only runs of the model – 4 times a day. See Figure 2. For a given BARRA-xx forecast run in a given cycle t_0 , BARRA-R fields at t_0 provide the initial conditions, and BARRA-R forecast fields from t_0 to t_0+9h provide the boundary conditions. The forecast run yields forecast fields from t_0 to t_0+9h , which can be found in the directory:

```
/g/data/ma05/BARRA_xx/v1/forecast
```

The fields at t_0 , t_0+1h , and t_0+2h are not written out as the fine detail is only partially established due to model spin-up. These fields are expected to be more similar to the BARRA-R fields. Previous assessments based on operational NWP output have shown that the t_0+3h to t_0+9h provide more consistent depiction of smaller scale information.

5. What forecast time steps are available?

Note that from January 2019 only the non-overlapping forecast timestep fields will be available via project ma05

Relevant for BARRA-R:

BARRA-R performs a short-range (+9-hour) forecast run from t_0 to t_0+9h . Most parameters are output as hourly fields; these parameters are in the parameter categories 'prs', 'slv', 'cld', and 'mdl'. Their filenames are identified with "PT1H". For these parameters, the forecast fields are in the directory:

```
/g/data/ma05/BARRA_R/v1/forecast. Of the 9 time steps, the 6 time steps ( $t_0+1h$ ,  $t_0+2h$ , ...,
```

t_0+6h) are made available in each forecast file. The fields at time step t_0 are in the analysis files in the directory: `/g/data/ma05/BARRA_R/v1/analysis`

Parameters are output as 10-minute fields in the parameter category 'spec'; their files are identified with "PT10M" and contain 54 time steps ($t_0+10min$, $t_0+20min$, ..., $t_0+8h50min$, t_0+9h). The 'spec' data have been post-processed to provide only hourly grids at the same 6 time steps.

Relevant for BARRA-xx:

BARRA-xx performs a short-range (+9-hour) forecast run from t_0 to t_0+9h . Most parameters are output as hourly fields; these parameters are in the parameter categories 'prs', 'slv', 'cld', and 'mdl'. Their filenames are identified with "PT1H". For these parameters, the forecast fields are in the directory: `/g/data/ma05/BARRA_xx/v1/forecast`. There are only 6 time steps (t_0+4h , ..., t_0+9h) in each forecast file. The fields at t_0 , t_0+1h , and t_0+2h are not written out as they are expected to be more similar to the BARRA-R fields due to the time taken for small scale to spin-up in the forecast model. The choice of using a 3-hour spin-up was based on some initial assessments of operational NWP systems.

Some parameters are output as 10-minute fields in the parameter category 'spec'; their files are identified with "PT10M" and contain 37 time steps (t_0+3h , $t_0+3h10min$, $t_0+3h20min$, ..., $t_0+8h50min$, t_0+9h). The 'spec' data have been post-processed to provide only hourly grids at the same 6 time steps.

The BARRA-xx's parameter `cs_dsfc_sw_flg` is a special case where the grids are valid at t_0+3h , t_0+4h , ..., t_0+8h .

6. What observations have been used in the reanalysis?

Relevant for BARRA-R:

Only BARRA-R performs data assimilation and different types of observations are used. For conventional observations, we use surface data from land and ship synoptic observations, buoy and meteorological airfield reports (METARS), sondes and wind profilers, aircraft reports (AIREPS), and aircraft meteorological data relay (AMDARS). We assimilated satellite radiances from Advanced Infrared Sounder (AIRS), TIROS Operational Vertical Sounders (TOVS), Advanced TOVS (ATOVS), and Infrared Atmospheric Sounding Interferometers (IASI). We also use wind vectors derived from satellite-based scatterometers SeaWinds, Advanced Scatterometers (ASCAT) and WindSat, and from radiometric observations from GOES, Meteosat, MTSAT, Himawari-8, and MODIS. We also use bending angles of GPS radio occultation (GPSRO) from CHAMP, COSMIC, MetOp and GRACE missions. Central pressure observations of tropical cyclone tracks from IBTrACS (International Best Track Archive for Climate Stewardship) are also assimilated. Note that rainfall observations are not used in the current version of BARRA-R.

7. Are there any known issues with the data?

Users are referred to, `/g/data/ma05/KNOWN_ISSUES.PDF` which will be updated over time.

8. Where can I find metadata information?

Users are referred to, `/g/data/ma05/BARRA_*/v1/metadata/`

The BARRA data is stored in netCDF format, containing global attributes that inform how the files are being produced and variable-level attributes that inform how to interpret a variable.

9. How to interpret the 'time_bnds' variable?

Parameters are written with different time profiles; they can be instantaneous fields, time-accumulated fields (e.g., `accum_prcp`, `accum_ls_snow`), time-mean (e.g., `av_temp_scrn`, `av_temp_trpp`), time-maximum (e.g.,

max_temp), or time-minimum (e.g., min_temp) fields. 'time_bnds' variable exists only for parameters that are written out as time-accumulated, mean, maximum, or minimum fields, as 'time_bnds' indicates the time range used in the sum, mean, maximum or minimum calculations.

See also, <http://cfconventions.org/cf-conventions/v1.6.0/cf-conventions.html>

10. What is an 'instantaneous' field?

Instantaneous fields represent values of the model diagnostic at the timestep given, and do not necessarily represent time-instantaneous values. These fields can be considered to have no cell method time processing applied. See answer to How to understand the 'cell_methods' attribute? for more information about 'cell_method'.

11. How to interpret the 'time' variable in time-accumulated, time-mean, time-maximum, and time-minimum parameters?

The 'time' variables in these parameters record the time at the centre of the time range (given by 'time_bnds' variable) from which the accumulation, mean, maximum or minimum is taken. We suggest to ignore 'time' variable and use 'time_bnds' (when available) to indicate the parameter's valid time.

12. How to distinguish parameters written with different time profiles?

Parameters are written with different time profiles; they can be instantaneous fields, time-accumulated fields (e.g., accum_prcp, accum_ls_snow), time-mean (e.g., av_temp_scrn, av_temp_trpp), time-maximum (e.g., max_temp), or time-minimum (e.g., min_temp) fields. Time-accumulated parameters are named with a prefix 'accum_'. Time-mean parameters are named with a prefix 'av_'. Time-maximum parameters are named with a prefix 'max_'. Time-minimum parameters are named with a prefix 'min_'.

Files for time-accumulated, mean, maximum and minimum parameters contain additional variables 'forecast_period_bnds', and 'time_bnds'.

13. How to understand the 'cell_methods' attribute?

Parameters are written with different time profiles; they can be instantaneous fields, time-accumulated fields (e.g., accum_prcp, accum_ls_snow), time-mean (e.g., av_temp_scrn, av_temp_trpp), time-maximum (e.g., max_temp), or time-minimum (e.g., min_temp) fields. The variable-level attribute 'cell_methods' exists only for parameters that are written out as time-accumulated, mean, maximum, or minimum fields. For instance, for max_temp parameter, *cell_methods=time: maximum (interval: 1 hour)* indicates that the maximum is taken over a one-hour period. For accum_prcp parameter, *cell_methods=time: sum* indicates that it is a time accumulated field, but time interval is not shown, as it is from the start of the forecast. Users are referred to identify the time interval based on 'time_bnds' variable.

See also, <http://cfconventions.org/cf-conventions/v1.6.0/cf-conventions.html>

14. How to convert time-accumulated fields to regularly-spaced accumulation?

Note that this conversion is no longer required with the data released from January 2019.

Relevant for BARRA-R:

The model writes out the time-accumulation parameters (such as accum_prcp) as accumulation from the start of the analysis window. That is, for a given cycle t_0 , these grids are accumulations from t_0 -3h. The analysis fields are accumulations from t_0 -3h to t_0 . The first (hourly) forecast grid is the accumulation from t_0 -3h to t_0 +1h, the second forecast grid is the accumulation from t_0 -3h to t_0 +2h, and so on.

For the users' benefit, we have now post-processed the grids to provide only one-hour accumulation (hourly) grids. That is, for a given cycle t_0 , we have calculated the one-hour accumulation from t_0 to t_0+1h by computing $forecast(t_0+1h) - analysis(t_0)$. To calculate the one-hour accumulation from t_0+1h to t_0+2h , compute $forecast(t_0+2h) - forecast(t_0+1h)$, and so on.

Relevant for BARRA-xx:

The model writes out the time-accumulation parameters (such as `accum_ls_prcp`) as accumulations from the start of the forecast window. That is, for a given cycle t_0 , these grids are accumulations from t_0 . The first output (hourly) forecast grid is the accumulation from t_0 to t_0+3h , the second forecast grid is the accumulation from t_0 to t_0+4h , and so on.

For the users' benefit, we have now post-processed the grids to provide only one-hour accumulation (hourly) grids. That is, for a given cycle t_0 , As an example, we have calculated one-hour accumulation from t_0+3h to t_0+4h by computing $forecast(t_0+4h) - forecast(t_0+3h)$. To calculate the one-hour accumulation from t_0+4h to t_0+5h , compute $forecast(t_0+5h) - forecast(t_0+4h)$, and so on.

15. How to understand the 'forecast_period' variable and the 'forecast_period_bnds' variable?

Parameters are written with different time profiles; they can be instantaneous fields, time-accumulated fields (e.g., `accum_prcp`, `accum_ls_snow`), time-mean (e.g., `av_temp_scrn`, `av_temp_trpp`), time-maximum (e.g., `max_temp`), or time-minimum (e.g., `min_temp`) fields.

For parameters written as instantaneous fields, 'forecast_period' corresponds to the number of hours since the base time t_0 . For all other parameters, 'forecast_period' corresponds to half of the number of hours since t_0 .

The variable `forecast_period_bnds` exists only for parameters that are written out as time-accumulated, mean, maximum, or minimum fields. It identifies the hours, relative to t_0 , of the time range over which sum, mean, maximum, or minimum is calculated.

16. Why can't I access any of the sub-hourly, or model level fields?

Because of cost considerations, we had to limit the amount of data that is being archived on the NCI data disks. Less frequently requested data are being archived on tapes. At the moment, we have to ensure that the subset of fields available to project 'ma05' users fits well within our disk allocation. As we produce more years of the reanalysis, we continue to add to this. Following consultation, we have settled on an initial set of popular parameters on single levels and some of the parameters on most of the pressure levels. However, the sub-hourly fields and model level fields are too large to keep on the ma05 disk. The rest of the 1PB data (and growing!) are on the Mass Data Filesystem tape archive network at the NCI and these can only be retrieved by one of our technical staff.

If your project crucially requires these fields, please send an email to helpdesk.reanalysis@bom.gov.au explaining your needs, in particular the domain, time period and parameters required. While we cannot guarantee that we can accommodate all requests, we will do what we can!

17. When can I get access to the 'extra' parameters not yet available in 'ma05'?

See the answer to question '[Why can't I access any of the sub-hourly or model-level fields?](#)' – we are operating under limited resources and so we cannot make the full reanalysis available to ma05 users on disk. The information you provided in the survey of your requirement - completed on initiation to the project - will be used for revising which parameters and which level fields we can make available for users. We hope to

implement a 6-monthly review of the contents of the ma05 BARRA dataset and revise the collection based on users' demands.

The requirements identified through the survey results so far are wide-ranging and we would not be able to accommodate the intersect of all requests. If your project has crucial need for any field in particular please send an email to helpdesk.reanalysis@bom.gov.au and include purpose, parameters, field level and time period needed. You can use the parameter survey as a reference.

18. What are the pressure levels available in BARRA?

Note that not all pressure levels are available in the data released from January 2019.

The prs parameters are written out by the model on following pressure levels: 1000, 975, 950, 925, 900, 850, 800, 750, 700, 600, 500, 450, 400, 350, 300, 275, 250, 225, 200, 175, 150, 100, 70, 50, 30, 20, 10, 7, 5, 3, 2, 1, 0.7, 0.5, 0.3, 0.2, and 0.1 hPa.

For BARRA-xx, the data has been post-processed to release only 21 of the 37 pressure levels: 1000, 975, 950, 925, 900, 850, 800, 700, 600, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 20, and 10 hPa.

For BARRA-R, all 37 pressure levels are released over time.

We note that while the BARRA model data extends up to 40-80 km, we have most confidence in the data up to a height of 25-30 km where we have most observational data.

19. What are the soil layers available in BARRA?

Four soil layers are modelled in BARRA with JULES. The depths of these soil layers are 0 – 0.1 m (0.1 m thickness), 0.1 – 0.35 m (0.25 m thickness), 0.35 – 1 m (0.65 m thickness) and 1 – 3 m (2 m thickness). This is relevant for soil_moist and soil_temp slv parameters.

We however advise users to refrain from using the soil moisture from the deeper two layers (see KNOWN_ISSUE on [website](#)).

20. Why is there no accum_prcp, accum_snow, accum_conv_prcp, or accum_conv_snow parameter in BARRA-xx?

The accum_prcp parameter present in BARRA-R is the sum of large scale (resolved) precipitation (liquid and frozen) and the sub-grid precipitation from the convection parametrization. For forecast models with a grid spacing of 1.5km such as BARRA-xx, the assumptions involved in the convection parametrization are no longer valid, and convective rain and snow begin to be resolved. So *all* precipitation is considered to come from resolved processes (i.e. large scale) in the 1.5km analyses. As a result, these convection resolving models only produce accum_ls_prcp and accum_ls_snow.

21. How useful are accum_ls_prcp and accum_conv_prcp parameters in BARRA-R?

Relevant for BARRA-R:

The accum_prcp parameter present in BARRA-R is the sum of large scale (resolved) precipitation and the sub-grid precipitation from the convection parametrization, liquid and frozen. In other words, the two parameters are produced by two precipitation schemes in the model and are based on model definitions of what they are. The convection scheme can provide lots of light rain and output as "convective rain", even though they are not what we think of as convective. Therefore, looking at these two model fields separately is more useful to anyone who is interested in evaluating the specific model's convective schemes. For process studies, an alternative partition into convective and stratiform rain may be required.

22.How useful are accum_ls_snow and accum_conv_snow parameter in BARRA-R?

Relevant for BARRA-R:

As with accum_ls_prdp and accum_conv_prdp (see Why is there no accum_prdp, accum_snow, accum_conv_prdp, or accum_conv_snow parameter in BARRA-xx?), the accum_ls_snow parameter present in BARRA-R is the large scale (resolved) frozen precipitation and the accum_conv_snow is the sub-grid frozen precipitation from the convection parametrization. In other words, the two parameters are produced by two precipitation schemes in the model and are based on model definitions of what they are. Therefore, looking at these two model fields separately is more useful to anyone who is interested in evaluating the specific model's convective schemes. For process studies, an alternative partition into convective and stratiform snow may be required.

23.How are the data gridded in BARRA?

The UM grid discretization uses a horizontally staggered Arakawa B&C-grids (Arakawa & Lamb, 1977) and a vertically staggered Charney-Phillips grid (Charney & Phillips, 1953). The staggered agreement of fields allows for accurate finite differencing and geostrophic adjustment, but results in fields located on staggered grids displaced by half a grid spacing along the three axes (longitude, latitude and height). The vertical levels consist of interleaved "theta" and "rho" levels. The vertical levels are also constructed to comprise of terrain-following coordinates near the surface, and constant height surfaces in the upper atmosphere.

Readers are referred to Davies et al. (2005) for further information. For instance, see Eq. 4.1 for the calculation of the height above mean-sea-level of a model level.

The grid positions of model parameters neighbouring a central point (i,j,k) in grid length units are listed below.

Model parameters	longitude	latitude	Height
pressure, density	i	j	k
temperature, humidity, vertical wind speed	i	j	$k\pm1/2$
zonal wind speed	$i\pm1/2$	j	k
meridional wind speed	i	$j\pm1/2$	k

In the model-level data files distinguished by <PAR>='mdl', temperature, humidity, and vertical wind are stored on the model "theta" levels, and pressure and density are stored on the "rho" levels. The model-level fields are interpolated onto the pressure levels in the pressure-level data files distinguished by <PAR>='prs'.

Horizontal wind speed parameters on the pressure levels use a horizontally staggered Arakawa B-grid (Arakawa & Lamb, 1977) as they have been interpolated by the UM upon output. The B-grid is identically staggered for both the North-South and East-West wind speed components.

The grid positions of pressure level parameters neighbouring a central point on an isobar (i,j,q) in grid length units are listed below,

Pressure level parameters	Longitude	Latitude	Isobar
Pressure level zonal wind speed	$i\pm1/2$	$j\pm1/2$	q
Pressure level meridional wind speed	$i\pm1/2$	$j\pm1/2$	q

We have not destaggered the grids as there are many different ways to do so, and the best way to regrid staggered grids is unclear. We have therefore provided the data sets closely to what is written out by the model.

24. Why are some parameters being gridded differently?

See How are the data gridded in BARRA?.

25. Why are 'analysis' fields only available for BARRA-R?

See What do 'analysis' and 'forecast' mean in BARRA?.

BARRA-R is created by sequential cycles of data assimilation (i.e., analysis) and model forecasts. By contrast, the data for other the sub-domain models (BARRA-SY, BARRA-TA, etc) is produced solely by dynamical downscaling of the BARRA-R fields where that data assimilation is not carried out. Therefore, 'analysis' fields are not available for the sub-domain models.

26. What is the difference between max_max_wndgust10m and max_wndgust10m?

Relevant for BARRA-AD:

We added a new diagnostic max_wndgust10m when running BARRA-AD. This is the 10-minute maximum wind gust at 10 m height. Other domains (BARRA-R, BARRA-TA, BARRA-SY, BARRA-PH) are run with the diagnostic wndgust10m, which is 10-minute instantaneous wind gust at 10 m height.

We post-processed the 10-minute parameters to yield hourly grids, namely:

- max_max_wndgust10m (BARRA-AD only): Hourly maximum of 10-minute maximum wind gust
- max_wndgust10m (all domains): Hourly maximum of 10-minute instantaneous wind gust
- min_wndgust10m (all domains): Hourly minimum of 10-minute instantaneous wind gust

"instantaneous wind gust" is not instantaneous wind speed. UM follows the WMO's definition of wind gust as the maximum of the wind averaged over 3-second intervals.

27. How long is the BARRA dataset?

The time period of the BARRA-R and subdomain BARRA-xx datasets is just over 29 years in size, from 1990-01-01 to 2019-02-28. At this time there is no plan to extend the datasets further back or to keep the products near operational

28. How are the sub-domains BARRA-xx being defined?

See How is the BARRA reanalysis data being produced?.

Downscaling of BARRA-R is being conducted at 4 sub-domains, namely

- BARRA-SY: 147.0° to 155.0055° east in longitude, and -38.0° to -27.997° north in latitude
- BARRA-TA: 142.5° to 150.5055° east in longitude, and -46.0° to -39.1555° north in latitude
- BARRA-PH: 112.0° to 124.0015° east in longitude, and -37.0° to -26.9965° north in latitude
- BARRA-AD: 131.0° to 142.0025° east in longitude, and -39.5° to -29.4965° north in latitude

These sub-domains are defined in agreement with the external funding agencies. More sub-domains with the BARRA-R domain may be introduced in the future as further funding is sought to support the project.

29. How to cite BARRA data?

For BARRA-R:

Su, C.-H., Eizenberg, N., Steinle, P., Jakob, D., Fox-Hughes, P., White, C. J., Rennie, S., Franklin, C., Dharssi, I., and Zhu, H.: BARRA v1.0: the Bureau of Meteorology Atmospheric high-resolution Regional Reanalysis for Australia, Geosci. Model Dev., 12, 2049-2068, <https://doi.org/10.5194/gmd-12-2049-2019>, 2019.

For BARRA-xx:

A manuscript is under currently in preparation. For the meantime, please use,

Jakob, D., Su, C.-H., Eizenberg, N., Kociuba, G., Steinle, P., Fox-Hughes, P., and Bettio, L.: An atmospheric high-resolution regional reanalysis for Australia, Bulletin of the Australian Meteorological and Oceanographic Society, 30(3), Sept 2017, 16-23.

When the BARRA data set is finalized after production, we can provide doi numbers.

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