ACCESS-EMS-GBR

User Guide

Version 1.0

July 2025

Rebecca Jackson, Matthew Woodhouse, Clothilde Langlais, Mathieu Mongin and Mark Baird

CSIRO Environment

ACCESS-EMS-GBR User Guide

Citation

Jackson, R., Woodhouse, M. T., Langlais, C., Mongin, M. & Baird, M. (2025). ACCESS-EMS-GBR User Guide. Available at https://github.com/rebeccajackson1/access-ems-gbr.

Code access

The atmospheric component of ACCESS-EMS-GBR uses a regional configuration of the United Kingdom Met Office Unified Model (UM), developed by the Regional Model Evaluation and Development (RMED) team. The UM code, documentation and suite configurations are available to registered users under a licence agreement from the Met Office Science Repository Service (https://code.metoffice.gov.uk/). The Regional Nesting Suite for the atmosphere-only and coupled configurations of the model have the suite identifier ‘u-dn070’. The ancillary files required to run the nested atmospheric domains are generated by the Regional Ancillary Suite with identifier ‘u-dr306’.

The ocean component of ACCESS-EMS-GBR is the CSIRO Environmental Modelling Suite (EMS) hydrodynamic and biogeochemical marine model of the Great Barrier Reef. The EMS documentation, user guides and code are available to registered users via the EMS GitHub (https://research.csiro.au/cem/software/ems/ems-documentation/).

The Cylc workflow system (https://cylc.github.io) and Rose suite management system (https://metomi.github.io/rose) are available under the GNU General Public License.

Acknowledgement

ACCESS-EMS-GBR is set up for use by the Reef Restoration and Adaptation Program (RRAP). Funded by the partnership between the Australian Governments Reef Trust and the Great Barrier Reef Foundation, partners include: the Australian Institute of Marine Science, CSIRO, the Great Barrier Reef Foundation, Southern Cross University, the University of Queensland, Queensland University of Technology and James Cook University.

The RRAP partners acknowledge Aboriginal and Torres Strait Islander Peoples as the first reef scientists and carers of Country. We acknowledge the Traditional Owners of the places where RRAP works, both on land and in sea Country. We pay our respects to elders; past, present, and future; and their continuing culture, knowledge, beliefs, and spiritual connections to land and sea Country.

The model is currently run on the National Computational Infrastructure (NCI Australia), a National Collaborative Research Infrastructure Strategy (NCRIS) enabled capability supported by the Australian Government.

Contents

1 Introduction 3

2 Atmospheric model setup 3

2.1 Model code and suites 3

2.2 Defining domains 4

2.3 Generating ancillary files 4

2.4 Regional Nesting Suite 5

2.5 Running the model 6

3 Ocean model setup 7

3.1 Model code and configuration 7

3.2 Model domain 7

3.3 Hydrodynamic model 8

3.4 Biogeochemical model 8

3.5 Atmospheric forcings 8

4 Simulating marine cloud brightening 9

4.1 Emission file 9

4.2 Code branches 9

5 Analysing the model output 10

5.1 Atmospheric model output 10

5.2 Ocean model output 11

5.3 Analysis workflow 11

6 References 12

1 Introduction

ACCESS-EMS-GBR is a regional atmosphere-ocean model of the Great Barrier Reef (GBR). The model consists of a regional configuration of the Australian Community Climate and Earth System Simulator (ACCESS) atmospheric model, coupled to the CSIRO Environmental Modelling Suite (EMS) hydrodynamic and biogeochemical marine model of the GBR. The model can be run in the atmosphere-only (ACCESS-GBR) or coupled (ACCESS-EMS-GBR) configurations.

The model is currently configured to run on the National Computational Infrastructure (NCI Australia). Minimum requirements to obtain and run the model at NCI are:

- NCI account and project memberships (access, hr22, ki32, ki32_mosrs, p66, et4, ih54, xp65)
- Met Office Science Repository Service (MOSRS) account.
- Familiarity with the atmospheric and ocean models.

2 Atmospheric model setup

2.1 Model code and suites

The atmospheric model is a regional configuration of the UK Met Office Unified Model (UM). The UM code, documentation and suite configurations are available to registered users under a licence agreement from the Met Office Science Repository (https://code.metoffice.gov.uk/).

Regional modelling tools developed by the Regional Model Evaluation and Development (RMED) project include a Regional Ancillary Suite (RAS) and Regional Nesting Suite (RNS). The regional domains are defined in the RAS, which remaps and outputs global ancillary forcing data onto the required regional domain. The RNS allows for one-way nesting of the regional domain within either the global UM or a reanalysis dataset. The general workflow for RMED suites is:

1. Define domains and create ancillary files using the RAS.
2. Configure the science settings and run the model using the RNS.

The control suites for ACCESS-EMS-GBR have the following identifiers:

- RAS: u-dr306
- RNS: u-dn070

Detailed instructions for obtaining and running the ACCESS Regional Atmosphere Model (ACCESS-rAM), which uses a similar configuration to ACCESS-EMS-GBR (excluding interactive aerosol and cloud microphysics, and the coupled ocean model), is available from ACCESS-NRI: https://docs.access-hive.org.au/models/access_models/access-ram/.

The suites are stored on the MOSRS and can be obtained using the Rosie interface on NCI. Instructions for authenticating MOSRS accounts on NCI are available on the Confluence page:

https://opus.nci.org.au/spaces/DAE/pages/284950536/mosrs-setup+the+mosrs+authentication+package

2.2 Defining domains

The nested domains are defined by region and resolution in the RAS. ACCESS-EMS-GBR currently includes one regional domain, covering the GBR and north-eastern Australia (called 'NE AUS'). Details of the global and regional domains are provided in Table 1.

Table 1. Details of the global and regional atmospheric model domains

	Global	**Regional**
Region name	–	NE AUS
Region centre	–	18.5°S, 152.0°E
Resolution name	N216	4km
Horizontal grid spacing (lat x lon)	~65 km at the mid-latitudes	0.04 x 0.04 degrees (~4 km)
Grid points (lat x lon)	324 x 432	625 x 550
Domain boundary	global	6 - 31°S, 141 - 163°E
Vertical levels	70 (surface - 80 km)	90 (surface – 40 km)

2.3 Generating ancillary files

Ancillary files provide the forcing data required to run the atmospheric model. The RAS remaps the global ancillary files onto the required regional domain. The paths to the global ancillary files on NCI are already specified within the RAS. The regional ancillary output files can be found under `~/cylc-run/u-dr306/run1/share/data/ancils`.

The ancillary file paths and names are respectively handled by the `ancil_versions` and `ancil_filenames` files (also output by the RAS). The ancillary files only need to be created once and may be saved to any directory.

In the RNS, the path to `ancil_versions` is set in the `ancil_dir` variable under the regional domain settings. It is important to maintain the RAS `ancils` output directory structure to ensure that the correct paths are specified in `ancil_versions`.

2.3.1 Custom ancillary files

ACCESS-EMS-GBR uses a daily mean SST ancillary file derived from the Bluelink Reanalysis version 2020 (BRAN2020) near-global reanalysis product (Chamberlain et al., 2021). The BRAN2020 data are available on NCI under project 'gb6' (Bluelink Ocean Renalysis Data Collection). These data are available for use under a Creative Commons Attribution 4.0 International license. The python script used to create the global and regional SST ancillary files is available at:

https://github.com/rebeccajackson1/access-ems-gbr/tree/main/scripts/ancils/SST

When the model is run in the coupled configuration, the global and regional SST ancillary files will be updated with daily mean SST from the ocean model as the simulation progresses. Daily updating of the coupled ancillary files is handled by the `update_ocean_ancils` application. To avoid overwriting the ancillary files for coupled fields by parallel simulations, copies of the ancillary files will be created for the simulation dates and saved to the `cylc-run` directory at runtime by the `setup_ereefs` task. The `install_cold` application will update the file paths in `ancil_versions` to use either the BRAN2020 (uncoupled) or merged BRAN2020-GBR4 (coupled) ancillary files depending on the `run_eReefs` logical (True to run the coupled model).

2.4 Regional Nesting Suite

2.4.1 Driving model

The regional NE AUS domain is nested within the global UM as the driving model. The global model currently uses UM version 13.0 and a modified version of the Global Atmosphere version 8 / Global Land version 9 (GA8/GL9) science configuration (Willett et al., 2026). The global UM is run on the N216 grid (Table 1), which has a horizontal grid spacing of ~ 65 km at the mid-latitudes.

Daily start dump files from a nudged global simulation are used to initialise the driving model. The global-only suite used to generate the initialisation files is 'u-dl595'. The path to these files is specified in the RNS under `dm_ic_file` for the physical model and `dm_UKCA_init_file` for the aerosol scheme (both use the same files).

2.4.2 Regional model

The grid settings and science configuration for the regional domain are specified under the 'Nested region' sections of the RNS. The NE AUS domain currently uses the Regional Atmosphere and Land version 3.2 (RAL3.2) science configuration (Bush et al., 2024). The RNS obtains information on the regional domain by reading the ancillary files. The path to these files (via the `ancil_versions` file) is specified in `ancil_dir` under the 'Resolution setup' settings.

2.4.3 Model cycling

The model start and end dates are set by the `INITIAL_CYCLE_POINT` and `FINAL_CYCLE_POINT` variables under 'Cycling options'. The forecast length (hours) of each cycle is controlled by `runlen` in the 'Resolution setup' settings.

The regional domain may be free-running or re-initialised daily, depending on simulation needs and is controlled by the `FREE_RUN` setting in the RNS. When 'True', the regional domain will only be re-initialised at the beginning of the run, allowing simulated fields to evolve freely through time. When False, the regional domain is re-initialised at 00:00 UTC each day. The aerosol fields are re-initialised using output from the dump file written at the end of the previous cycle and are always free-running in both the global and regional domains.

The model is currently set up to re-initialise at 00:00 UTC each day. Each cycle has a 48-hour forecast period, with the initial 24-hours of spin-up used to smooth the transition between cycles.

2.4.4 Nudging

The simulated meteorology is constrained to reality by nudging the driving model's horizontal winds and temperature to the ERA5 (Hersbach et al., 2020) dataset. Nudging is implemented and controlled in the `glm_um` settings under 'Section 39 – Nudging'. The ERA5 data can be downloaded and formatted using the scripts available at:

https://github.com/rebeccajackson1/access-ems-gbr/tree/main/scripts/ERA5

2.4.5 General run setting

A `run_eReefs` switch is available under 'general run options' to allow the suite to be run as the atmosphere-only or the coupled ACCESS-EMS-GBR model. When 'True', additional options are available to specify:

- `eReefs_dir`: Path to the GBR4 model source directory, containing the executable, configuration files and libraries.
- `eReefs_hydro_init`: Path to initial conditions for the GBR4 hydrodynamic model.
- `eReefs_bgc_init`: Path to initial conditions for the GBR4 biogeochemical model.
- `coupled_ancil_dir`: Path to the coupled sea surface ancillary files that will be copied to the run directory and updated with GBR4 output as the simulation progresses. Daily ancillary updating is handled by the `setup_ereefs` application.
- `ancil_templates`: Name of the coupled ancillary files (currently only SST).
- `run_gbr1`: Option to nest the higher-resolution GBR1 (~1 km) domain in GBR4 (not currently recommended due to computational expense).

Directories for the GBR4 model will be created within the suite run directory (`~/cylc-run/u-dn070/run1/share/ereefs_data`), with sub-directories for:

- `ancils`: coupled sea surface ancillary files for the global and regional domains.
- `ereefs_forcing`: atmospheric forcing files and the hydrodynamic model outputs needed to drive the biogeochemical model will be saved here as the simulation progresses.
- `gbr4`: sub-directories for the hydrodynamic and biogeochemical model, containing copies of the executable, configuration files and libraries needed to run the model. The ocean model output is also saved here.

2.5 Running the model

Pre-requisites needed to run UM suites and the GBR4 model on NCI are:

- Authenticated MOSRS account
- Membership to NCI projects:
    - access – UM licensed software, modules and data
    - hr22 – Rose and Cylc modules
    - ki32 – Mirror of the source repository
    - ki32_mosrs – Mirror of the UM licensed source code

- ih54 and et4 – eReefs model configuration, executable and input files
- + others required to run ACCESS-EMS-GBR (see Section 1)

Once configured, the model can be run from either the RNS GUI by selecting 'play', or from the command line using the `$ cylc vip u-dn070` command. A Cylc GUI will be displayed, showing the model tasks, their status and output logs. The simulation can also be paused, resumed or stopped from the GUI.

3 Ocean model setup

3.1 Model code and configuration

When the `run_eReefs` option is 'True', the atmospheric model will run with the GBR4 model in the coupled ACCESS-EMS-GBR configuration. The EMS source code and documentation are available from: https://research.csiro.au/cem/software/ems/ems-documentation.

The GBR4 hydrodynamic and biogeochemical (BGC) models use the Sparse Hydrodynamic Ocean Code (SHOC), which simulates the physical state of the ocean and provides hydrodynamic forcings to drive the offline BGC models. The general workflow is:

1. Run the hydrodynamic model to output transport files: `shoc -p <path to .prm file>`
2. Run the BGC models using SHOC in transport-mode: `shoc -t <path to .tran file>`

The GBR4 configuration is available on NCI to users with membership to the ih54 and et4 projects. The source directory used for the ACCESS-EMS-GBR configuration is available at:

```
/g/data/ih54/projects/eReefs_MCB/access_ems_gbr/gbr4_H4p0_B4p2_ACCESS_
BRAN2020_G2Gv3_MCB/
```

and contains sub-directories for:

- `run_hydro`: SHOC executable and files required to run the hydrodynamic model.
- `run_bgc`: SHOC executable and files required to run the biogeochemical model.
- `prm`: configuration file (.prm), bathymetry and other files for the hydrodynamic model.
- `tran`: configuration file (.tran) and libraries for the biogeochemical model.

The GBR4 model can be restarted from the eReefs hindcast archive, available on NCI under project 'ih54'.

3.2 Model domain

The eReefs GBR4 domain has a horizontal grid spacing of approximately 4 km on a curvilinear grid, covering the GBR and part of the Coral Sea. Details of the GBR4 domain are provided in Table 2.

Table 2. eReefs GBR4 model domain

	Regional ocean
Region name	GBR4
Horizontal grid spacing	~4 km on a curvilinear grid
Grid points (lat x lon)	600 x 180
Domain boundary	7 - 28°S, 142 - 157°E
Vertical levels	48 (surface – 4 km)

3.3 Hydrodynamic model

The GBR4 hydrodynamic model is run from the `gbr4_hydro` application within the ACCESS-EMS-GBR workflow. The app loads required modules, specifies the configuration file and calls the SHOC executable using the '-p' flag to run the hydrodynamic model.

The configuration file for the hydrodynamics is called a 'parameter file' (indicated by a '.prm' suffix), and is where the boundary conditions, atmospheric forcings, science settings and output requirements are specified. The configuration file for the ACCESS-EMS-GBR simulations is saved in the source directory under `~/prm/gbr4_H4p0_ACCESS_BRAN2020_G2Gv3_scratch.prm`.

3.4 Biogeochemical model

The GBR4 BGC model is run in a similar way to the hydrodynamics, instead calling the SHOC executable with the '-t' flag to run in a more computationally efficient 'transport-mode', where the hydrodynamic outputs are used to drive advection and diffusion. The configuration file for the BGC is called a 'transport file' (indicated by a '.tran' suffix) and is saved in the source directory under `~/tran/gbr4_H4p0_B4p2_scratch.tran`.

3.5 Atmospheric forcings

Atmospheric forcings are provided to the model as a list of netcdf files (created and updated within the ACCESS-EMS-GBR directory at runtime). No regridding of the atmospheric model outputs is needed as this is handled by SHOC. The GBR4 model requires hourly mean forcings for atmospheric fields, with land grid cells masked with the nearest ocean value. Masking of land cells is needed to avoid problems arising over complex coastal regions when the fields are interpolated onto the GBR4 grid. The atmospheric forcing files are created by the `update_atmos_forcings` application.

4 Simulating marine cloud brightening

The sea salt emissions for the RRAP marine cloud brightening simulations are implemented using an emission netcdf file and additional UKCA code branches. Additional code branches are required to (1) specify the emission parameters and (2) allow sea salt to be emitted into the soluble Aitken mode in the aerosol scheme. The extra sea salt is emitted from the surface and is incorporated into the background sea spray aerosol emissions, simulated using 10-m wind speed and the Gong (2003) parameterisation.

4.1 Emission file

The emitted sea salt mass, location(s) and timing (constant or periodic) are specified in an emission netcdf file. The emissions are provided to the atmospheric model by adding the file path to the list of `ukca_em_files` in the UKCA configuration for both the global and regional domains (`rose-app-ukca.conf`). The emission file is created using a python script available at:

https://github.com/rebeccajackson1/access-ems-gbr/tree/main/scripts/emissions/SSflux

The script requires inputs of sea salt mass flux (kg gridbox^{-1} s^{-1}), a list of latitude and longitude coordinates (or polygon area) to apply the emissions, and the start and end dates (if not using constant emissions, specified up to hourly frequency).

The sea salt mass flux will be integrated over the entire gridbox (~16 km^2) and converted to an area flux (kg m^{-2} s^{-1}) using the gridbox area (km^2), ensuring that each grid box emits the same total mass.

4.2 Code branches

4.2.1 Additional sea salt emissions

A new aerosol tracer (‘SS_added’) and associated chemical species (NaCl), mean dry diameter, geometric standard deviation and fraction to be emitted into each soluble mode is specified in an additional UKCA code branch:

ukca.xm/branches/dev/matthewwoodhouse/um13.0_um13.0_added_SS

The branch is added to the list of `ukca_sources` in the RNS. Different emission size assumptions (mean particle diameter and mode distribution) are implemented by pointing the model to the required branch revision (Table 3).

Table 3. UKCA branch revision numbers for different sea salt injection size assumptions.

Revision	Mean dry diameter	Mode distribution
@5332	40 nm	50:50 soluble Aitken:accumulation
@5156	70 nm	30:70 soluble Aitken:accumulation
@5155	100 nm	30:70 soluble Aitken:accumulation
@5157	130 nm	30:70 soluble Aitken:accumulation

4.2.2 Aitken mode sea salt emissions

The atmospheric model uses the Global Model of Aerosol Processes modal version (GLOMAP-mode) aerosol scheme (Mann et al., 2012; Mann et al., 2010). By default, sea salt is only emitted into the soluble accumulation and coarse modes. To improve the representation of natural sea salt emissions and allow the sea salt emissions for marine cloud brightening to be distributed over the soluble Aitken and accumulation modes (Table 3), two code branches are added to the RNS:

- um.xm/branches/dev/matthewwoodhouse/vn13.0_SSinAit
- ukca.xm/branches/dev/matthewwoodhouse/um13.0_SSinAit

5 Analysing the model output

5.1 Atmospheric model output

The atmospheric model outputs ancillary formatted files in several segments per cycle and output stream. For simulations longer than one month, it is recommended to output daily means in 24-hour segments to minimise data storage requirements. One simulated day of hourly model output for the NE AUS domain is ~67 GB (2 TB per month), which is reduced to ~14 GB per simulated day (420 GB per month) when outputting daily means.

The output streams are organised by data type and use:

- aerosol: aerosol number concentration, composition and size.
- cloud: cloud fraction and the number and mass of hydrometeor classes.
- met: three-dimensional meteorological variables.
- surface: orography, land-sea mask, surface meteorology and fluxes.
- ereefs: atmospheric variables required to force the ocean model (output hourly).

Each output field has a unique STASH (Spatial and Temporal Averaging and Storage Handling) code that consists of a section and item number. Required model output fields can be added or removed from the ‘STASH requests’ table in the RNS.

A post-processing application (`um2nc`) has been added to the RNS to combine the output files for each cycle, remove the spinup period and convert to a single netcdf per simulated day. This capability was added to make analysis, storage and sharing of the datasets more efficient. The resulting processed netcdf output files are ~14 GB per simulated day, although size will vary depending on the requested STASH output.

5.2 Ocean model output

The ocean model outputs are in netcdf format and are on a curvilinear grid. The hydrodynamic model outputs a small number of surface-level variables (e.g. SST, used to update the SST ancillary files) and specially-formatted transport files required to drive advection and diffusion of the BGC tracers. The BGC model outputs three-dimensional variables as daily means, with a small number of surface fields also output as hourly means (e.g. surface temperature and PAR).

5.3 Analysis workflow

The python xarray package can handle analysis of the model outputs on both regular and curvilinear grids. An example Jupyter Notebook is provided to demonstrate the workflow for reading, analysing and visualising the model output:

https://github.com/rebeccajackson1/access-ems-gbr/tree/main/scripts/analysis

6 References

Bush, M., Flack, D. L., Lewis, H. W., Bohnenstengel, S. I., Short, C. J., Franklin, C., Lock, A. P., Best, M., Field, P., & McCabe, A. (2024). The third Met Office Unified Model-JULES Regional Atmosphere and Land Configuration, RAL3. *Geoscientific Model Development Discussions*, *2024*, 1-58. https://doi.org/10.5194/gmd-2024-201

Chamberlain, M., Oke, P., Fiedler, R., Beggs, H., Brassington, G., & Divakaran, P. (2021). Next generation of Bluelink ocean reanalysis with multiscale data assimilation: BRAN2020. *Earth System Science Data*, *13*(2). https://doi.org/10.5194/essd-13-5663-2021

Gong, S. (2003). A parameterization of sea-salt aerosol source function for sub-and super-micron particles. *Global biogeochemical cycles*, *17*(4). https://doi.org/10.1029/2003GB002079

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., & Schepers, D. (2020). The ERA5 global reanalysis. *Quarterly Journal of the Royal Meteorological Society*, *146*, 1999-2049. https://doi.org/10.1002/qj.3803

Mann, G. W., Carslaw, K. S., Ridley, D. A., Spracklen, D. V., Pringle, K. J., Merikanto, J., Korhonen, H., Schwarz, J. P., Lee, L. A., & Manktelow, P. T. (2012). Intercomparison of modal and sectional aerosol microphysics representations within the same 3-D global chemical transport model. *Atmospheric Chemistry and Physics*, *12*, 4449-4476. https://doi.org/10.5194/acp-12-4449-2012

Mann, G. W., Carslaw, K. S., Spracklen, D. V., Ridley, D. A., Manktelow, P. T., Chipperfield, M. P., Pickering, S. J., & Johnson, C. E. (2010). Description and evaluation of GLOMAP-mode: A modal global aerosol microphysics model for the UKCA composition-climate model. *Geoscientific Model Development*, *3*, 519-551. https://doi.org/10.5194/gmd-3-519-2010

Willett, M. R., Brooks, M., Bushell, A., Earnshaw, P., Smith, S., Tomassini, L., Best, M., Boutle, I., Brooke, J., & Edwards, J. M. (2026). The Met Office Unified Model Global Atmosphere 8.0 and JULES Global Land 9.0 configurations. *EGUsphere*, *19*(4), 1473–1517. https://doi.org/10.5194/gmd-19-1473-2026