EAE4027/5027 week 10 2022
Running a climate model: I

In this practical we will set up and run a coupled climate model on Gadi. In the week 11 practical we will analyse the output from our model runs.

We will run **ACCESS-ESM1.5**, one of the Australian coupled climate models developed by CSIRO (Ziehn et al. 2020). ACCESS-ESM1.5 includes atmosphere, ocean, sea ice, land surface and ocean biogeochemistry components coupled together and set up to run on Gadi. ACCESS-ESM1.5 runs have been contributed to CMIP6 and used in the latest IPCC report.

0) Choose your own adventure with ACCESS-ESM1.5

- In this practical we will discuss different options for setting up your model run, and you can choose the:
  a. Experiment type (atmospheric forcings): piControl, historical or SSP585
  b. Branch time from a previous simulation and year of the run
  c. Changes to the ocean model surface boundary conditions:
     i. ACCESS-ESM1.5 has many components, but no ice sheets or shelves! What does this mean for the climate system when they start melting!? We can add some extra freshwater to the surface of the ocean to represent the missing meltwater to find out.
     ii. ACCESS-ESM1.5 is a freely running climate model, so it is not constrained to match the observations and it has its own variability. But what if we want it to simulate an El Niño or La Niña in a certain year? We can nudge ("restore") SST in the equatorial Pacific to warmer or cooler conditions and see what this does.

1) Logging onto Gadi and checking settings

- Open a terminal and log onto Gadi
  ssh -Y user@gadi.nci.org.au
- Make sure that the project you are logged on with is **k10**. You can check this using:
  nci_account
  which will list *Project=xxx*
- If you aren't logged on with project k10:
  switchproj k10

```
nci_account
```

- Clear modules to prepare for running the model:

  ```
  module purge
  ```

2) Cloning a run and using payu

- ACCESS-ESM1.5 is run on Gadi using **payu**. payu was designed to help users of the NCI system run climate models. payu knows certain models (including ACCESS-ESM1.5) and how to run them. We will use payu to set up a run.
- You can clone a run configuration from GitHub following the instructions on either:
  - https://github.com/coecms/esm-pre-industrial
  - https://github.com/coecms/esm-historical
  - https://github.com/coecms/esm-ssp585

  based on which experiment type (atmospheric forcing) you want to run
- Get payu:

  ```
  module use /g/data3/hh5/public/modules
  module load conda/analysis3-unstable
  ```
- Create a directory in which to keep the model configurations (shown for historical):

  ```
  mkdir -p ~/access-esm
  cd ~/access-esm
  git clone https://github.com/coecms/esm-historical
  cd esm-historical
  ```
- If you have chosen to run a pre-industrial run, there are a few updates that are required:

  ```
  mv config.yaml config.yaml.bak
  cp -r /scratch/public/afp599/EAE4027/esm-pre-industrial_updates/* .
  ```
- Now let's look at what's been set up! Open up the master configuration file:

  ```
  cd esm-historical
  ls
  gvim config.yaml
  ```
- If you don't have X11 forwarding enabled, you can use vim in the terminal instead:

  ```
  vim config.yaml
  ```

  use the arrows to scroll up and down

  :q to quit
- PBS information
- Model components
  - Atmosphere – UM-HG3 version 7.3, includes coupling to the land surface model CABLE version 2.2.4

    - Ocean – MOM version 5, includes coupling to the ocean biogeochemistry model WOMBAT
    - Sea ice – CICE version 4.1
    - Coupler – OASIS-MCT version 3.5

  These have all been precompiled and are ready to run
- What is different across the three experiment types – the atmospheric forcings

  ```
  cd atmosphere
  ls
  gvim um_env.py
  ```

  Ancillary files that will be loaded are different – e.g. CO_2, ozone, aerosols, other atmospheric constituents

3) Choose and set the branch year and run year

- Climate models need some climate state to start from – i.e. conditions for all variables at all points in space. If the model run is starting from scratch these may be based on observational estimates or estimates from a different climate model run. As the model runs over many years (multiple centuries) it will equilibrate to its own climate state (that hopefully is close to the real world). Most runs make use of a pre-existing long equilibration run, and "branch" from a certain point in this, using the conditions for all variables at all points in space as the initial conditions.
- The branch year and run year are set in *warm-start.sh* and *config.yaml:*

  ```
  cd ..
  gvim warm-start.sh
  ```

  Line 16: change *project=p73* (which you have joined previously – if not, let me know!)

  Line 20: change the path to read: *export csiro_source=/g/data/$project/archive/CMIP6/ACCESS-ESM1-5/$expname/restart*
- If you are using vim:

  i to start editing
- Let's look at what branch options there are, i.e. what "restart" files are available for the different runs
    - The default branch year for the historical run starting in 1850 is year 0541 in PI-01
    - PI-01 has restart files saved every ten years, so you could say branch a run from year 0701, 0711, 0721, 0731 and so on
- Now let's update this branch year in *warm-start.sh*:
    - If you are running a piControl run, or a historical run for year 1850:

    Line 18: no change (expname=PI-01)
    Line 19: *specify a source year* with available restart files
  - If you are running a historical run for another year:
    Line 18: change *expname=HI-08*
    Line 19: *specify a source year* (1850, 1860, 1870… 1990, 2000, 2010)
  - If you are running an SSP585 run:
    Line 18: change *expname=SSP-585-08*
    Line 19: *specify a source year* (2015, 2020, 2030, 2040… 2090)
  - And *save the changes*
- And update the calendar information in *config.yaml*:
  - Line 50: for simplicity, *change the year to match the year you are branching from*
  - Exception: if you are branching a historical run in 1850 from PI-01, specify 1850 year
  - And *save the changes*
  - If you are using vim:
    esc to exit editing
    :wq to write changes and quit
- The model can be run for many years using some of the information at the end of the config.yaml script and the payu command – coupled climate models including ACCESS-ESM1.5 are computationally expensive to run so we will only be running one model year!

4) Modify the ocean surface boundary conditions (optional)

- As well as running the standard configurations of different experiments in ACCESS-ESM1.5 cloned from GitHub, we can make modifications to different model components and examine the resulting changes to the climate system. Here we'll take a look at modifying the surface boundary conditions of the ocean model component (MOM). More motivation and background can be found at the end of this document.
- The source code for the version of MOM used in ACCESS-ESM1.5 can be found at https://github.com/COSIMA/ACCESS-ESM1.5-MOM5 and specifically the source code for the surface boundary conditions are at https://github.com/COSIMA/ACCESS-ESM1.5-MOM5/blob/master/src/mom5/ocean_core/ocean_sbc.F90
- This shows a (very long) example of how the ocean model is actually written – what parts do we care about?

    - If we want to add an extra freshwater flux into the ocean model component, we can do this as a precipitation minus evaporation (P-E) correction – the ocean model normally receives information through the coupler about how much precipitation and evaporation the atmosphere component is simulating (this information is important for the ocean model to simulate surface salinity), and we can add an extra amount of freshwater into the surface layer of the ocean model that is treated like additional P-E
    - We can search *do_flux_correction* in the code and see how this is treated when then model runs
    - If we want the surface ocean temperature to be a specified value, we can do this by nudging the temperature towards this value. The model will want to simulate its own temperature, and we can specify how strongly we nudge it towards our desired temperature.
    - We can search *temp_restore_tscale* in the code and see how this is treated when the model runs
- Seeing what the code does is complicated, but the model is setup in a way that making the required changes to either add extra freshwater by a P-E correction or to restore SST is relatively straightforward (at least less complicated than going through all the code!)

To add extra freshwater:

- We need to tell payu to add a P-E correction file to the *work/ocean/INPUT* directory. First, choose a P-E correction file that you would like to use:
  ```
  ls /scratch/public/afp599/EAE4027/pme_forcing/*
  ```
- To see the different freshwater flux options, you can use ncview:
  ```
  module load ncview
  ncview /scratch/public/afp599/EAE4027/pme_forcing/directory_of_choice/salt_sfc_correction.nc
  ```
- Next you will need to add a line in *config.yaml* telling payu to use this file. In the ocean model section under the input list (below line 24) add:
  ```
  - /scratch/public/afp599/EAE4027/pme_forcing/directory_of_choice
  ```
  and *save the change*
- We also need to tell the ocean model to look for this file. This is done by adding a few lines to the ocean namelist as follows:
  ```
  gvim ocean/input.nml
  ```

- At the end of the *&ocean_sbc_nml* section (after line 357 and before the finishing / on line 358) add three new lines with the following:

  ```
  do_flux_correction=.true.
  zero_net_water_correction=.false.
  salt_correction_scale=1.0
  ```

  and *save the changes*
- If you are using vim, to save you scrolling down hundreds of lines:

  ```
  vim +336 ocean/input.nml
  ```

  make the required edits

  ```
  esc
  :wq
  ```

  The *salt_correction_scale* scales the magnitude of the P-E correction in the P-E forcing file – you can increase it, but at some point, the model will fall over because an unfeasible amount of freshwater has been added – let's try specifying a value between 1.0 and 10.0.

To restore SST:

- We follow a similar procedure, but in this case, we need to tell payu to copy two files into your *work/ocean/INPUT* directory – a restore mask to specify what region the SST will be restored within (in this case, the equatorial Pacific), and an SST file that specifies what temperature the SST will be restored too (either anomalously warm or cool conditions). These can be viewed:

  ```
  ls /scratch/public/afp599/EAE4027/sst_restoring/*
  ```

- Next add a line to *config.yaml* telling payu to use these files. In the ocean model section under the input list (below line 24) add:

  ```
  - /scratch/public/afp599/EAE4027/sst_restoring/Equatorial_Pacific_mask
  - /scratch/public/afp599/EAE4027/sst_restoring/SST_anomaly_of_choice
  ```

  and *save the changes*
- We also need to tell the ocean model to look for this file. This is done by modifying a few lines to the ocean namelist as follows:

  ```
  gvim ocean/input.nml
  ```

- In the *&ocean_sbc_nml* section starting on line 336 modify:

  Line 338: `temp_restore_tscale=6.0`

  Line 343: `read_restore_mask=.true.`

  and *save the changes*

5) Check the setup using payu

- In the run directory (e.g. esm-historical)

  ls

  ./warm-start.sh

  payu setup
- Now there are new directories, e.g. archive, with the restart files

  *ls archive/restart000/**
- And work:

  ls work/atmosphere/INPUT

  you can see all the atmospheric forcing files for your run

  ls work/ocean/INPUT

  you can see the ocean input files for your run, including your freshwater forcing file or SST restoring file and mask if you are modifying the ocean surface boundary conditions

  - If you are adding extra freshwater, check for *salt_sfc_correction.nc* here
  - If you are restoring SST, check for *restore_mask.nc* and *temp_sfc_restore.nc*

6) Run the climate model!

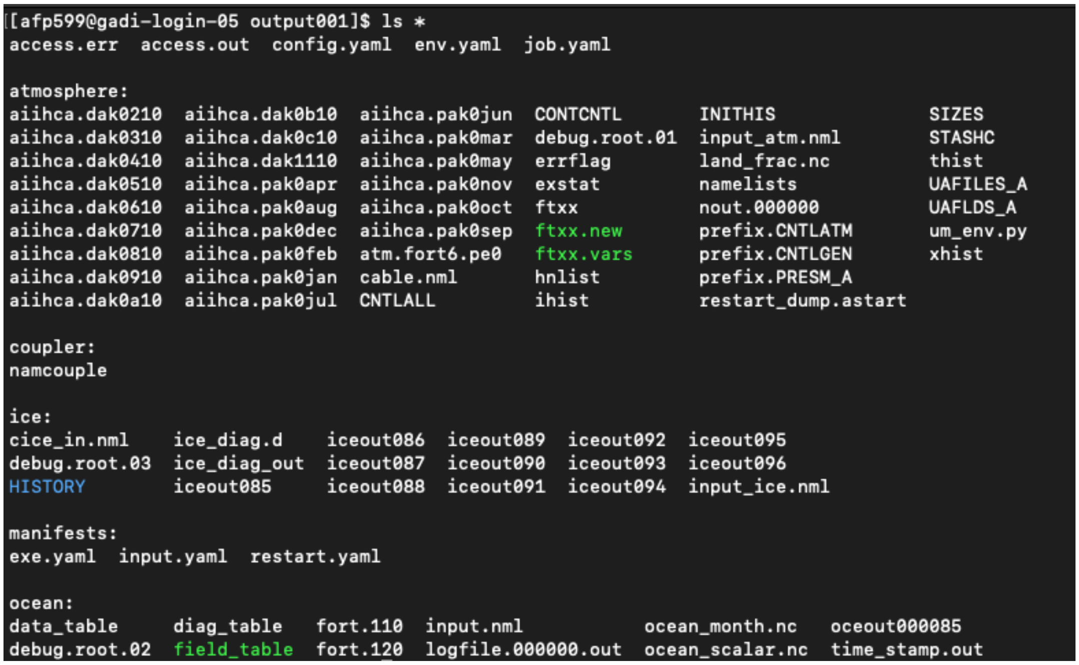
- First, clean up after the *payu setup*:

  payu sweep
- Then to run one model year:

  payu run
- To check your run is submitted and its progress:

  qstat -u user

  where *user* is your username
- The run should finish about 1 hour 20 minutes after it starts, with output in *archive/output001* and restart files for the next model year if you were to continue running it in *archive/restart001*
- Optional after the practical: check that your run has output data, it should look like this:



```
[[afp599@gadi-login-05 output001]$ ls *
access.err  access.out  config.yaml  env.yaml  job.yaml

atmosphere:
aiihca.dak0210  aiihca.dak0b10  aiihca.pak0jun  CONTCNTL       INITHIS              SIZES
aiihca.dak0310  aiihca.dak0c10  aiihca.pak0mar  debug.root.01  input_atm.nml        STASHC
aiihca.dak0410  aiihca.dak1110  aiihca.pak0may  errflag        land_frac.nc         thist
aiihca.dak0510  aiihca.pak0apr  aiihca.pak0nov  exstat         namelists            UAFILES_A
aiihca.dak0610  aiihca.pak0aug  aiihca.pak0oct  ftxx           nout.000000          UAFLDS_A
aiihca.dak0710  aiihca.pak0dec  aiihca.pak0sep  ftxx.new       prefix.CNTLATM       um_env.py
aiihca.dak0810  aiihca.pak0feb  atm.fort6.pe0   ftxx.vars      prefix.CNTLGEN       xhist
aiihca.dak0910  aiihca.pak0jan  cable.nml       hnlist         prefix.PRESM_A
aiihca.dak0a10  aiihca.pak0jul  CNTLALL         ihist          restart_dump.astart

coupler:
namcouple

ice:
cice_in.nml    ice_diag.d    iceout086  iceout089  iceout092  iceout095
debug.root.03  ice_diag_out  iceout087  iceout090  iceout093  iceout096
HISTORY        iceout085     iceout088  iceout091  iceout094  input_ice.nml

manifests:
exe.yaml  input.yaml  restart.yaml

ocean:
data_table     diag_table   fort.110  input.nml           ocean_month.nc   oceout000085
debug.root.02  field_table  fort.120  logfile.000000.out  ocean_scalar.nc  time_stamp.out
```

If your run wasn't successful, that's ok! There are many things that can go wrong. I will have extra output to analyse next week, but if you want to get your own run going, you can come and chat to me this afternoon between 3-4pm in room 227. Alternatively, you can email me at ariaan.purich@monash.edu (noting that I don't work Fridays).

- Next week we analyse our output – I'll provide instructions to view data using ncview which is a quick, easy and useful way to view data – it requires X11 forwarding, so if you don't already have that set up, it's recommended to install it. Other viewing options are also possible – for example using Jupyter notebooks, if you prefer.