

# EcoGENIE:

## A practical course in global ocean ecosystem modelling

### Lesson 1a: Running EcoGENIE and visualising output

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#### Stuff to keep in mind...

- We will be working with highly idealised ecosystems in a highly idealised ocean.
- The aim is to explore why the model behaves as it does.
- The assumption is that this will give us some insight into why the real world behaves as it does.
- It is up to you to question the validity of this assumption.

#### Background reading

- J L Sarmiento and N Gruber. *Ocean Biogeochemical Dynamics*. Princeton University Press, 2006  
**Chapter 4: “Organic Matter Production” (especially 4.3, “Analysis of Ecosystem Behaviour”)**
- B A Ward, S Dutkiewicz, O Jahn, and M J Follows. A size structured food-web model for the global ocean. *Limnology and Oceanography*, 57(6):1877–1891, 2012 **Description of an earlier version of the model, run in a higher resolution ocean circulation model.**

#### Preamble

Before you start it is necessary to retrieve some restart and observation files. At the terminal, enter the five following commands (hitting ‘return’ after each command)...

```
cd ~/cgenie_output/
wget http://www.seao2.info/cgenie/labs/Bristol.2016/BENW.worjh2.P04FeTDTL_HYBRID_new.SPIN.tar.gz
wget http://www.seao2.info/cgenie/labs/Bristol.2016/EXAMPLE.p0055c.RidgwellSchmidt2010.SPIN1.tar.gz
tar xfvz BENW.worjh2.P04FeTDTL_HYBRID_new.SPIN.tar.gz
tar xfvz EXAMPLE.p0055c.RidgwellSchmidt2010.SPIN1.tar.gz
cd ~/cgenie.muffin/genie-main/
```

## 1. Getting going with ECOGEM.

Yesterday you learnt how to run the standard “biogeochemical” version of cGENIE. Today, we are going to get started with the ‘ECOGEM’ package. This will allow us to extend the capabilities of GENIE to examine a range of questions relating to the role of physiology and community structure in regulating the biological pump.

Before all that, however, we need to understand the relationship between BIOGEM and ECOGEM.

**1.1. BIOGEM:** In BIOGEM, the biological pump is driven by an implicit (i.e. unresolved) biological community. As in the real ecosystem, the biological uptake of carbon and nutrients (such as phosphorus and iron) is limited by light, temperature and nutrient availability. Unlike the real ecosystem, any uptake is *directly* and *instantly* returned to dissolved organic matter (DOM) and inorganic nutrients in the ocean interior.

- surface inorganic nutrients  $\xrightarrow[\text{and export}]{\text{production}}$  DOM and deep inorganic nutrients

**1.2. ECOGEM:** In ECOGEM, biological uptake is again limited by light, temperature and nutrient availability, but here it must pass through an explicit and dynamic intermediary plankton biomass pool, before being returned to DOM or dissolved inorganic nutrients.

- surface inorganic nutrients  $\xrightarrow{\text{production}}$  plankton biomass  $\xrightarrow{\text{export}}$  DOM and deep inorganic nutrients

**2. Running the model.** We will start with the simplest possible configuration of ECOGEM, with just a single phytoplankton class. You can run this model at the command line, by entering the following command (note that this should be one continuous line) ...

```
./runmuffin.sh cgenie.eb_go_gs_ac_bg_eg.worjh2.BASESFeTDTL / BSS.NPD.SPIN 10  
BENW.worjh2.P04FeTDTL_HYBRID_new.SPIN
```

As before, we have five input parameters after `./runmuffin.sh...`

- |   |
|---|
| <p><b>1:</b> <code>cgenie.eb_go_gs_ac_bg_eg.worjh2.BASESFeTDTL.benw</code> → The ‘<i>base-config</i>’ file.<br/>Note the additional ‘_eg’ that marks the inclusion of the ECOGEM package.</p> <p><b>2:</b> <code>/</code> → The <i>user-config</i> directory.</p> <p><b>3:</b> <code>BSS.NPD.SPIN</code> → The <i>user-config</i> file (i.e. the experiment name).<br/>‘NPD’ stands for ‘Nutrients, Plankton, Detritus’.</p> <p><b>4:</b> <code>10</code> → The run duration, in years.</p> <p><b>5:</b> <code>BENW.worjh2.P04FeTDTL_HYBRID_new.SPIN</code> → The restart file.</p> |
|---|

Here we are telling the model to start from the endpoint of a previous experiment (a 10,000 year run of BIOGEM). This will save us a massive amount of time as we can start off with a ‘realistic’ global distribution of nutrients. (The restart here only applies to the biogeochemical part of the model. The ecological community will be initialised from some very low biomass.)

The model will run as before, except that now we have the ECOGEM debug option enabled, and you will get a lot of extra information about how the ecological model is configured. You will also see output much like the following,

\*\*\*\*\*  
 \*\*\* Initialisation complete: simulation starting ...  
 \*\*\*\*\*

model	year	* pCO2(uatm)	d13C02	* AMO(Sv)	ice(%)	<SST>	<SSS>	* <DIC>(uM)	<ALK>(uM)
\$N\$	0.00	278.011	-6.500	0.000	6.921	19.021	34.932	2231.144	2363.191
>>> SAVING BIOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	0.500			
>>> SAVING ECOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	0.500			
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	0.500			
\$N\$	1.00	277.625	-6.134	10.770	6.745	18.577	34.944	2230.541	2363.260
>>> SAVING BIOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	1.500			
>>> SAVING ECOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	1.500			
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	1.500			
\$N\$	2.00	277.587	-6.011	10.725	6.722	18.459	34.946	2230.696	2363.287
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	2.500			
\$N\$	3.00	277.592	-5.941	10.922	6.653	18.400	34.946	2230.999	2363.305
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	3.500			
\$N\$	4.00	277.602	-5.890	11.204	6.443	18.350	34.945	2231.342	2363.320
>>> SAVING BIOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	4.500			
>>> SAVING ECOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	4.500			
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	4.500			
\$N\$	5.00	277.621	-5.848	11.529	6.660	18.393	34.946	2231.705	2363.333
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	5.500			
\$N\$	6.00	277.630	-5.812	11.843	6.448	18.358	34.944	2232.048	2363.349
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	6.500			
\$N\$	7.00	277.643	-5.780	12.132	6.575	18.399	34.944	2232.390	2363.366
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	7.500			
\$N\$	8.00	277.654	-5.752	12.386	6.612	18.424	34.944	2232.720	2363.384
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	8.500			
\$N\$	9.00	277.660	-5.725	12.608	6.497	18.417	34.943	2233.036	2363.404
>>> SAVING BIOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	9.500			
>>> SAVING ECOGEM	TIME-SLICE	AVERAGE	CENTERED	@ year	:	9.500			
>>> SAVING BIOGEM	TIME-SERIES	AVERAGE	CENTERED	@ year	:	9.500			
\$N\$	10.00	277.670	-5.701	12.864	6.559	18.450	34.944	2233.350	2363.424

\*\*\*\*\*  
 \*\*\* Simulation complete: shutdown starting ...  
 \*\*\*\*\*

The extra lines (e.g. >>> SAVING ECOGEM TIME-SLICE AVERAGE CENTERED @ year : 0.500) confirm that ECOGEM is writing ecological time-slices at the same time as BIOGEM is writing its own time slices. (ECOGEM is not currently set up to save time-series data in the same way as BIOGEM.)

**3. Viewing 2D time-slice output.** Following the same convention as we saw for BIOGEM, ECOGEM time-slice output will be saved in

```
~/cgenie_output/BSS.NPD.SPIN/ECOGEM/.
```

**3.1.** Open the 'fields\_ecogem\_2D.nc' file by locating it in the correct directory, and double clicking on it in the file transfer window. Alternatively, you can open Panoply by selecting 'File' → 'Open', and clicking through.

**3.2.** You should now see a list of 2D arrays that were output by ECOGEM. Looking at the 'Long Name' description, simply click on a variable of interest. If a menu window pops up, just click on 'Create' or hit the 'Return' key.

**3.3.** Check the Panoply settings to make sure you really know what you are looking at.

1. Which time-slice (i.e. simulation year) are you looking at?
2. What is the data range (i.e. colour scale)

**Note:** You can change the default settings in Panoply to avoid changing things every time you open a new file. First click on 'Panoply' → 'Preferences...'. Here you can switch off interpolation and the grid overlay under the 'General' menu. You can disable the spuriously precise coastline under 'Lon-Lat Plots'.

**4. Comparing to observations** Models are usually intended as an approximation of the real world. It might, therefore, be useful to check if our approximation is in anyway realistic. We can do this by comparing the model output to observations.

**4.1.** You can download a compilation of key biogeochemical variables by typing ...

```
cd ~/cgenie_output/  
wget http://www.seao2.info/cgenie/labs/Bristol.2016/GEnIE_observations.nc.tar.gz
```

Extract the contents of this archive by typing ...

```
tar xfvz GEnIE_observations.nc.tar.gz  
cd ~/cgenie.muffin/genie-main/
```

The last command will return you to the `genie-main` directory.

**4.2.** You can now open the `GEnIE_observations.nc` file in Panoply. Open it in the same way as you opened the `fields_ecogem_2D.nc` file.

**4.3.** You can now compare the model output to key biogeochemical variables, such as surface chlorophyll or phosphate.

- Does the model perform well or poorly with respect to reproducing these variables?

**Note:** ECOGEM only saves a limited number of surface (2D) data arrays. You can look at other variables (in 2D and 3D) by opening the corresponding BIOGEM files, ‘fields\_biogem\_2D.nc’ and ‘fields\_biogem\_3D.nc’ in Panoply. They can be found in the ‘~/cgenie\_output/BSS.NPD.SPIN/BIOGEM/.’ directory.

Bear in mind that we restarted the model from a previous simulation with BIOGEM. Some of the state variables may take a long time (i.e.  $\gg 10$  years) to adjust to the new model configuration (especially at depth).

**5. Zooplankton.** In the next section we will look at extending the NPD run to include a zooplankton population.

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## References

A. Ridgwell, J. C. Hargreaves, N. R. Edwards, J. D. Annan, T. M. Lenton, R. Marsh, A. Yool, and A. Watson. Marine geochemical data assimilation in an efficient earth system model of global biogeochemical cycling. *Biogeosciences*, 4(1):87–104, 2007. doi: 10.5194/bg-4-87-2007. URL <http://www.biogeosciences.net/4/87/2007/>.

J L Sarmiento and N Gruber. *Ocean Biogeochemical Dynamics*. Princeton University Press, 2006.

B A Ward, S Dutkiewicz, O Jahn, and M J Follows. A size structured food-web model for the global ocean. *Limnology and Oceanography*, 57(6):1877–1891, 2012.