EcoGEnIE:
A practical course in global ocean ecosystem modelling

Lesson 2: Increasing ecological complexity

In the last lesson we looked at the results of some simulations based on 'NPD' and 'NPZD' type ecosystem models. Here we will begin to incorporate a bit more ecological complexity.

1. Plankton size classes. We are going to add a few more plankton size classes, so we have small, medium and large phytoplankton and zooplankton.

1.1. Save the *ecosystem configuration* file under a new name (e.g. 3P3Z.eco), replacing the existing plankton populations with the ones described in Table 1.

Table 1: Plankton functional groups and sizes.

j	PFT	Diameter (μm)	j	Functional Type	Diameter (μm)
1	Phytoplankton	0.6	4	Zooplankton	6.0
2	Phytoplankton	6.0	5	Zooplankton	60.0
3	Phytoplankton	60.0	6	Zooplankton	600.0

1.2. To run the model with this new configuration, change the name of the *ecosystem configuration file* in the *user-config* file . . .

```
eg_par_ecogem_plankton_file ='3P3Z.eco'
```

1.3. Save the new *user-config* file under a different name (e.g. BSS.3P3Z.SPIN), and you can now execute the model at the command line . . .

```
qsub -j y -o cgenie_log -V -S /bin/bash
runmuffin.sh cgenie.eb_go_gs_ac_bg_eg.worjh2.BASESFeTDTL / BSS.3P3Z.SPIN 10
BENW.worjh2.PO4FeTDTL_HYBRID_new.SPIN
```

2. Viewing 2D time-slice output. Open up the 2D time-slice data for the new model, following the same procedure as in the previous lesson. You will now see a lot more time-slice variables have been loaded into Panoply. We have all the same diagnostics as before, plus some new ones relating to the new plankton populations you have just added. We also have a load of other arrays describing the size distribution and diversity of the photosynthetic community (non-phototrophic populations are ignored in these metrics). These were not included before, because there was only one phytoplankton population.

2.1. Size fractions: Variables beginning "eco2D_Size_Frac_..." give the chlorophyll biomass in three size fractions...

- picophytoplankton (diameter $\leq 2~\mu$m)

- nanophytoplankton ($2 <$ diameter $\leq 20~\mu$m)

- microphytoplankton (diameter $> 20~\mu$m)

2.2. Size metrics: Any other variables beginning "eco2D_Size_..." give metrics describing the phytoplankton size distribution.

- eco2D_Size_Mean: Geometric[1] mean phytoplankton diameter, weighted by carbon biomass

- eco2D_Size_Stdev: Geometric[1] standard deviation[2] of phytoplankton diameter, weighted by carbon biomass.

- eco2D_Size_Minimum: Diameter of smallest phytoplankton contributing $>0.1\%$ of the total phytoplankton carbon biomass.

- eco2D_Size_Maximum: Diameter of largest phytoplankton contributing $>0.1\%$ of the total phytoplankton carbon biomass.

Notes:

[1] We use the geometric mean and standard deviation, because phytoplankton biomass is approximately log-normally distributed across the phytoplankton size range.

[2] The geometric standard deviation describes the *relative* size range of the phytoplankton. For a geometric standard deviation of σ, $\sim$68.2% of the phytoplankton carbon biomass will be in cells no more than σ orders of magniude smaller or larger than the geometric mean size.

2.3. Diversity metrics: Any variables beginning "eco2D_Diversity_..." give metrics describing the phytoplankton diversity.

- eco2D_Diversity_Threshold: the threshold diversity index. The number of species contributing $>0.1\%$ of the total phytoplankton carbon biomass [Barton et al., 2010].

- eco2D_Diversity_Berger: the inverse Berger(-Parker) index [Berger and Parker, 1970]. The proportion of carbon biomass made up by all but the single most dominant population. For example, if the dominant population accounts for 40% of the total carbon biomass, inverse Berger(-Parker) index is 0.6.

- eco2D_Diversity_Simpson: the inverse (Gini-)Simpson index [Simpson, 1949]. This is effectively the probability that two samples taken at random from the community will be from a different species (note that the probability of selecting a population is dependent on carbon biomass, not cell abundance). If we define the proportional biomass of each species as its relative contribution to the total carbon biomass in the community, the inverse Gini(-Simpson) index is calculated as one minus the sum of the squares of the proportional biomasses of each species.

- eco2D_Diversity_Shannon: the Shannon(-Wiener or -Weaver) index [Shannon, 1948]. With the proportional biomass defined as above, the Shannon index is defined as the sum of [the proportional biomass multiplied by the logarithm of the proportional biomass] for each species.

The threshold index is a fairly crude measure of the total number of species in the community, relative to a small and arbitrary threshold of relative biomass. This index is not very sensitive to the relative biomass of individual species (although one very successful species can raise the absolute value of the threshold, thus lowering the diversity).

The other three indices do more to quantify the evenness of the community. The more unequal the proportional abundances, the smaller the value of the index. If almost all the abundance is concentrated into one type and all the other types are very rare, the latter three indices can become very small. A community with fewer species, but with more evenly distributed biomass, may well have higher values for these three diversity indices.

Have a look at some of these metrics, but bear in mind that they summarise the diversity of a phytoplankton community that includes just three species. They are probably not that revealing, so we will come back to them later.

Instead, have a look some of the other metrics describing the model ecosystem.

- What are the global distributions of the different size classes?

- How do the global biomass distributions compare to variables such as temperature[1], or primary production ('Uptake Fluxes C')?

- How does nutrient, light and temperature limitation vary between the size classes?

- How can you explain the distribution biomass according to the different limiting factors?

Think back to the lectures. What traits of the three size classes determine their global distributions?

3. Create your own ecosystem. Save the *ecosystem configuration* file under a new name and add some more plankton populations. Update `eg_par_ecogem_plankton_file` in the *user-config* and save this under a new name. Run the new model.

- How many populations can you get to coexist?

- What effect do the new populations have on the community as a whole?

- What effect, if any, do they have on the strength of the biological pump?
  (look at bio_fpart_POC in `fields_biogem_3D.nc`.)

Just bear in mind that the more populations you put in, the slower the model will run!

References

A D Barton, S Dutkiewicz, G Flierl, J Bragg, and M Follows. Patterns of diversity in marine phytoplankton. *Science*, 327(5972):1509–1511, 2010.

W H Berger and F L Parker. Diversity of planktonic foraminifera in deep-sea sediments. *Science*, 168 (3937):1345–1347, 1970.

C E Shannon. A mathematical theory of communication. *The Bell System Technical Journal*, 27(379-423 and 623-656), 1948.

E H Simpson. Measurement of diversity. *Nature*, 163:688, 1949.

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[1]Ocean temperature is saved in '`fields_biogem_3D.nc`'