Climate Modeling Homework 6, Due Tuesday May 27th

The website http://coast.ocean.washington.edu/~neil/NPZvisualizer has a set of simulation models for coastal marine ecosystems. Read the questions/tasks below before you start.

Open the URL in a web browser. You will need a reasonably up-to-date version of Internet Explorer, Firefox or Safari with JavaScript enabled. The NPZvisualizer immediately starts a simulation when the page loads.

There are slider controls on the right to adjust parameters of the ecosystem model. If you need to start over at the beginning, click the REW button in the upper left, or the "reload" button in your browser. You can reset the default parameters with the RESET PARAMS button on the top right.

1. The equations that govern the NPZ (nutrient, phytoplankton, and zooplankton) model are

$$\frac{dP}{dt} = \mu(N)P - I(P)Z - m_p P$$

$$\frac{dZ}{dt} = (1 - f_{excret})I(P) - m_z Z$$

$$N + Z + N = N_{total} = const.$$

where m_p and m_z are the mortality of phytoplankton and zooplankton respectively.

$$\mu(N) = \mu_0 \frac{N}{k_s + N}$$

$$I(P) = I_0 \frac{P}{K_s + P}$$

This form is known as Michaelis-Menten Kinetics which allows the growth rate for phytoplankton to saturate at a certain value. Please answer the following questions (this is an exploration so a total of one to two pages is all that I expect). Note that the areas of the circles shows the concentrations of the various constituents.

a. Allow the NPZ model to run to equilibrium and watch how the state variable circles change – these values are also graphed in the lower right. Describe the time variability of the ecosystem. [You can slow down the simulation with "days/sec" slider in the upper left area if you wish.]

b. Decrease the P max growth rate slider. Describe how the balance in the various boxes in its equilibrium configuration changes.

c. Increase the P mortality slider. What is different about the final equilibrium?

d. Increase the Z max growth rate to 1.3. What is going on?

2. Now switch to the dinoflagellate model dino-0D. The equations for this model are

$$\frac{dP}{dt} = \mu(N)P - I(P)Z - m_p P$$

$$\frac{dZ}{dt} = (1 - f_{excret} - f_{egest})I(P)Z - \xi Z^2$$

$$\frac{dD}{dt} = m_p P + f_{egest} I(P)Z - r_{re\min} D + \xi Z^2$$

$$\frac{dN}{dt} = -\mu(N)P + f_{ecret} I(P)Z + r_{re\min} D$$

where for this model

$$I(P) = I_0 \frac{P^2}{K_s^2 + P^2}$$

In this case, I want you to estimate the biological carbon export for each case (in petagrams of carbon/year). You will need to convert the nitrogen concentration using the Redfield ratio and the molar weight of carbon. The way this model is constructed, there is no effective source or sink for nitrogen, total nitrogen is conserved. To convert detrital concentrations to carbon export, you will need a sinking rate to convert the concentration to petagrams of carbon/year. Try to be as quantitative as you can given the graphic nature of the model output.

a. Using the base case, calculate the carbon export assuming that the sinking rate is 8m/day and that this model represents the really productive part of the world's oceans where dinoflagelates grow which make up only 5% of the total surface area of the oceans.

b. Decrease the maximum growth rate for the phytoplankton to about 0.5 per day, and assume a sinking rate of 1 m/day and calculate the carbon export assuming that this ecosystem covers the entire oceans. This represents the subtropical oceans where productivity is lower and smaller phytoplankton dominate.

c. Think about what would happen if there is a limiting nutrient for phytoplankton growth, such as iron, and choose a parameter to change in the model to model this effect. Describe which parameter you chose and why, and how the results depend on that parameter.

d. One possible scenario that may give rise to changes in ocean ecosystems is that nutrient supply to the upper ocean would be less because the water column would become more stratified. To model this with this system, make the nutrient supply negative (about 0.2) for a month or so, then return it to zero and describe changes in the export.

e. Ocean acidification is thought to potentially effect ecosystems by making zooplankton that form calcium carbonate shells stressed. Choose a parameter to change that would model the effect of an increase in the acidity of the water and determine how export of carbon would be impacted.