Box Model Exercise

1. This is a simplified model of the ocean where box A represents the surface Indian and Pacific Oceans, box B represents the surface Atlantic Ocean, and box C represents the deep ocean. The river inflow rate, volume exchange rates between basins, and the total volume of each basin are noted.

   Currently this system is not in steady state. Examine the model and determine what process(es) is missing. If necessary, modify the model to maintain the system in steady state.

   Discuss any missing processes and why they are necessary to maintain steady state. What are the possible processes you could include to keep the system in steady state? Which of these options produces the most realistic ocean? In these types of box model, all processes are highly parameterized and idealized. Describe as best as you can, what processes in the real ocean are represented by the processes you added.

2. Now we will investigate chemical dynamics in our simplified ocean. Calculate the concentrations in each basin for one of the following conservative elements taking into account their vertical profile in the ocean:
   a. Calcium – Group 3
      i. River dissolved concentration: 364 μmol L^{-1}
   b. Magnesium – Group 4
      i. River dissolved concentration: 160 μmol L^{-1}
   c. Molybdenum – Group 1
      i. River dissolved concentration: 5 μmol L^{-1}
   d. Vanadium – Group 2
      i. River dissolved concentration: 20 μmol L^{-1}

Assess the system and determine whether the relative concentrations in the boxes make sense compared to the real ocean.

3. Repeat part 2, only this time use the following non-conservative elements:
   a. Nitrogen – Group 1
      i. River dissolved concentration: 30.0 μmol L^{-1}
   b. Phosphorus – Group 2
      i. River dissolved concentration: 1.30 μmol L^{-1}
   c. Silicon – Group 3
      i. River dissolved concentration: 193 μmol L^{-1}
   d. Iron – Group 4
      i. River dissolved concentration: 0.70 μmol L^{-1}

After you've obtained steady-state concentrations for each box determine whether the vertical profile of your nutrient matches field observations. Determine what important process is missing and add it to the model.

Again, discuss any missing processes and why they are necessary to maintain steady state. What are the possible processes you could include to keep the system in steady state? Which of these options produces the most realistic ocean? In these types of box model, all processes are highly parameterized and idealized. Describe as best as you can, what processes in the real ocean are represented by the processes you added.

4. Now you're nearly finished. Calculate the residence time of the nutrient you analyzed in Part 3 for each box in the model. If the river input doubled, how long would it take for the system to reach steady state? What implications do these observations have for the real ocean? Are all nutrients in steady state with respect to their fluxes into or out of the ocean? Which are most out of balance? What are the likely impacts of this imbalance and how soon are they likely to be observed?