EOS 423 // EOS 518

Lab 3.1: Modeling carbonates and their ages

Due: 1:30 pm March 10, 2023

You have two weeks to complete this assignment and upload your responses as a PDF to Brightspace. You are not excluded from working with others (pairs are recommended), but each person will submit their own copy of the assignment. **Responses to questions should be typed, using complete sentences and standard grammar.** Double check that your image resolution is high enough to read. If you write your response in a word processor, please export to .PDF before submitting your response.

A pair of students will be randomly selected on each Monday to initiate and lead a discussion of the assignment. Be prepared to show your progress and discuss any challenges you still face.

Note: because this final assignment is a two-week assignment, it will be worth twice as much as a normal weekly assignment.

Name: ____________________

Question	1	2	3	**Total:**
Marks:	8	5	7	20
Score:				

1 Introduction

In this assignment, you will expand your 1D sedimentary transport model to simulate the growth, build-up and demise of carbonate platforms. You will also explore how to build age models, and use them to interpret geochemical time series. We have provided two Jupyter notebooks with code to help you (one relevant to modifying the transport model, the other to building age models).

Questions

Question 1 (8)

You and your research group have puzzled out how to measure vibranium (Vi) isotopes in carbonate rocks. You have used this knowledge to build the first record of δ^{5000}Vi change in paleoseawater. Because vibranium is magic, you can also directly date it, allowing you to assign absolute ages to horizons in each of your measured sections (sections A, B and C). Your data come from a basin where sediment is pure carbonate. Use the `assignment_3_Q3.ipynb` notebook for this question, provided to you by Princess Shuri, your scientific collaborator.

(a) For each of the three sections, make side-by-side plots of lithology vs. height and isotope values (x-axis) vs. height (y-axis). Be sure to include a legend that describes what is plotted.

  i. (1 point) Describe the depositional environment observed in each section. Are there any lithology changes up-section? What could be driving any observed changes?

  ii. (1 point) Are there the same number of δ^{5000}Vi excursions in each section? If not, what is an explanation for any differences section-to-section?

  iii. (1 point) For sections B and C, if you assume that sedimentation rate is constant within each colummn, what can you say about the relative durations of any excursions present (i.e., are some longer/shorter/same duration as others)?

(b) Make compound Poisson-gamma process age models for each section using the set parameters found in the Jupyter notebook. Make side-by-side plots of lithology vs. height and age (x-axis) vs. height (y-axis). For a given height, plot the median age prediction and 95% confidence intervals. Be sure to include a legend that describes what is plotted.

  i. (1 point) Pick a section, and experiment with the age model parameters `p_lam` and `g_shape`. Holding one constant, change the other. What happens to the resulting age model, and why?

  ii. (1 point) For each section, how does sedimentation rate vary with stratigraphic height, considering both short- and long-term trends apparent in the age models. To examine short-term fluctuations, it will be helpful to zoom-in on portions of the age vs. height subplot that has closely-spaced age anchors. What could be causing any observed trends?

  iii. (1 point) How does average accumulation rate change from section-to-section (i.e., (total height) / (age_bottom - age_top))? What accounts for any differences?

(c) Based on your produced age models, make a plot of age (x-axis) vs. isotope signal (y-axis) for each of the three sections (so one figure, but with three distinct models shown in three distinct colors). For a given age, plot the median isotope prediction with 68% confidence intervals. Be sure to include a legend that describes what is plotted.

i. (1 point) Where, in general, is uncertainty largest (i.e., largest range of isotope values for a given age), and why?

ii. (1 point) Look back to your answer to **Q1.a.iii**. Were you correct in your inferences about relative durations of the excursions? If not, why not?

Question 2 (5)

In this question, you will modify the provided `Diffuse1D` *class* to include carbonate production. You have been provided a the start of a python method to determine carbonate production as a function of water depth and the degree to which that water is connected to the deep ocean (restriction). The following questions will guide you through the steps needed to incorporate this function into your `Diffuse1D` model.

(a) (1 point) The only parameter passed to provided function is *self*. *self* refers to a specific instance of an object in python, which means that this function needs to live inside the **object** that represents our diffusion model (`class Diffuse1D`). Once the `produce_carb()` function is inside the object, it can manipulate properties of the *self* instance. Which properties inside `produce_carb()` are undefined in the current `Diffuse1D` class?

(b) (1 point) The intensity of light in water decreases exponentially with depth, as described by the equation:

$$\mathrm{l_z = l_0 e^{-kz}}$$

Here, l_z represents the light intensity at a particular depth, l_0 represents the intensity at the surface (equal to 1), k is the clear water light extinction coefficient (equal to 0.2), and z represents the depth.

Carbonate production is partly dependent on the intensity of light. Beyond a certain minimum light threshold, Carbonate production saturates, meaning that increasing light intensity does not lead to any further increase in production. To capture this saturation effect, a hyperbolic tangent function can be combined with the light decay equation:

$$\mathrm{P_z = P_{max}\ tanh(\frac{l_z}{l_k})}$$

Here, P_z represents the carbonate production at a specific depth, $P_{\max}$ is the maximum potential production (set as 1), and l_k represents the light intensity at the base of the carbonate production saturation zone (set as 0.1).

Produce a graph showing the relationship between light intensity and depth, as well as the relationship between carbonate production and depth.

(c) (1 point) Use the equations above and scipy's `interp1d()` function to define carbonate production at any depth. Define this function as `self.prod_z_fun` in the initialization function (`__init__`) in your Diffuse1D class.

Please provide the lines you added to the `init()` function in your written response to this question.

(d) (1 point) Restricted waters have a negative impact on the carbonate production, due in part to the increased sensitivity to salinity changes (evaporation) and temperature changes. As modelers, our goal is to create productive waters near deep water and restricted waters near shallow water. To achieve this, we plan to use a convolution of a Gaussian window and the model bathymetry to scale the carbonate production function based on the amount of nearby deep water (this calculation is provided in `produce_carb()`).

To set the value of carbonate production under ideal conditions, we will create a parameter called `self.carb_rate`. In the initialization function (`init()`) of your Diffuse1D class, set the value of `self.carb_rate` to 0.003. You will also need to modify one line in the `produce_carb()` function to apply this scaling.

Please provide the line(s) you added to the `init()` function and the line(s) you modified in the `produce_carb()` function as your response to this question.

(e) (1 point) To enable carbonate production in your model, you need to remove the coastline sediment flux used previously and call the `produce_carb()` function with each call to `run_step()`. You will need to modify the `run_step()` function accordingly.

Please provide a copy of your modified `run_step()` function as your response to this question.

Question 3 (7)

Run your modified `Diffuse1D` model using the initial conditions in the provided jupyter notebook.

(a) (3 points) Make a figure showing the initial carbonate platform topography, the final carbonate platform topography, and the topography from at least 3 intermediate time steps. Describe the evolution of the reef front over time. (Does it prograde? Back step? Does the platform area grow or shrink?)

(b) (3 points) Triple the long term subsidence rate and rerun the model. Make a figure showing the initial carbonate platform topography, the final carbonate platform topography, and the topography from at least 3 intermediate time steps. Describe how the reef/platform that develops is different from the previous output? Why have these changes occurred?

(c) (1 point) If you tripled the subsidence rate again, what do you predict would happen? Why? (make a guess, and *then* check with the model if you want!)