EOS 423 // EOS 518

Lab 2.2: Using Fourier Analysis to interpret Modeled Basins

Due: 1:30 pm March 14, 2025

You have one week 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 Monday to initiate and lead a discussion of the assignment. Be prepared to show your progress and discuss any challenges you still face.

Name: ______________________________

Question	1	2	**Total:**
Marks:	19	8	27
Score:			

1 Introduction

In this assignment, you will analyze model outputs from your 1D sedimentary transport model. You have been provided a jupyter notebook with code that includes a 1D transport model and some functions to extract stratigraphic columns and time series of parasequence thicknesses from the model output.

Questions

Question 1 (19)

The provided notebook has been set to initial conditions with two sea-level signals that have distinct frequencies and amplitudes (similar to the inferred history in **Spectral analysis of the Middle Triassic Latemar limestone** by Linda Hinnov and Robert Goldhammer 1991). There is an asymmetric sea level signal with an amplitude of 2 meters that repeats every 100,000 years and a sinusoidal sea level signal with an amplitude of 3 meters repeats every 20,000 years. In this question you will explore how sedimentation and subsidence rates affect the preservation of cyclicity in parasequence thicknesses.

(a) (2 points) Run the model with the provided initial conditions and plot a time series of the parasequence thicknesses (vertical distance between flooding surfaces) for at least three stratigraphic columns across your model (select columns from the left, middle, and right sides).

(b) (3 points) Remove the mean parasequence thickness from each time series and plot the cumulative sum (np.cumsum) of these modified time series. How are these new plots related to the sea level history in your basin? Include a cartoon or figure showing the ideal scenario in your response. Take note of differences between sections and describe the possible causes for those differences, if there are any.

(c) (2 points) Using the same three stratigraphic columns, make a figure with an upper sub-plot showing parasequence thickness vs. parasequence number and the lower sub-plot of showing the discrete Fourier transform (frequency on the x-axis and amplitude on the y-axis). *This figure is the same style of figure you made in the previous assignment.*)

(d) (2 points) Interpret the frequency spectrum of the three datasets in the context of the known sea level boundary condition. What frequency should you see, given the sea level boundary condition?

(e) (2 points) Create the same figure as in part **C** using the de-meaned cumulative sum of parasequence thicknesses that you created in part **B**.

(f) (2 points) Interpret the frequency spectrum of the three datasets in the context of the known sea level boundary condition. If the results are different than part **C**, how and **why** are they different?

(g) (2 points) The preservation potential of the modeled sea level boundary condition depends on the subsidence rate and sedimentation rate in your model. What minimum conditions must be true to preserve **every** sea level cycle with a parasequence (describe in words)?

(h) (2 points) Make the necessary changes to your boundary conditions (sedimentation rate and/or subsidence rate) so that every cycle is recorded by deposition and rerun the model.

Repeat the analysis from part **C** or **E** (choose the one that you believe to be more useful) and provide a figure showing that analysis for your three stratigraphic columns.

(i) (2 points) Interpret the frequency spectrum of the new model output in the context of the known sea level boundary condition. *Hint: you should be able to resolve the true ratio of the two sea level cycles at least somewhere in this final model.*

Question 2 (8)

An autocylic model Shallowing or coursening-upward parasequences are indicative of progradation. These parasequences are the fundamental building block of the sedimentary record and their presence indicates that accommodation space was filled faster than it was created, locally. The the previous question, you demonstrated that the thickness of parasequences was related to a complex interplay of sediment supply, eustatic sea level, and time. In this question, you will use your model to simulute stacked parasequences without invoking any periodic variations in sea level.

Start with the original model from question 1. Remove the periodic components from your sea level boundary condition. Set the total subsidence rate to 200 meters over the model run time of 3 million years, and set coastal sediment flux rate to 0.08 m^2 per year.

You will now model scenario that could represent a nearby river delta that sometimes send sediment towards our modeled location and sometimes sending sediment elsewhere. To do this, your sediment flux will alternates between an **ON** and **OFF** state with a fixed probability of a switch occuring that is equal to **0.001** per year. You can imagine this **ON** and **OFF** state represents the river avulsing to or away from our location. During the **OFF** state sediment flux should be 0, and during the **ON** state the sediment flux should be equal to 2 meters squared per year. To calculate whether or not the flux should switch during each year, you can use np.random.uniform(0,1,1) to draw a random value (uniformly) from 0 to 1. If that value is less than **0.001** the sedimentation rate in the model should switch its state (from **ON** to **OFF** or **OFF** to **ON**.)

(a) (2 points) Your temporal boundary condition in this model run is random, but random comes in many flavors and colors that are best described by the spectral properties of a time series. Make a figure that contains two subplots. In the first subplot, plot the time series of the duration between **ON/OFF** switches (we will call these the time-lags). The second plot should be a discrete Fourier transform of the time-lags (frequency on the x-axis and amplitude on the y-axis). A log scale on both axes can be helpful here. You do not need to limit your time-lags to duration of the transport scenario for this part, so feel free to run a much longer simulation of **ON/OFF** switches to better resolve the spectral characters of this random process.

(b) (2 points) Run your model with settings described at the start of the question. Extract at least five series of parasequence thicknesses from your model run. Compare the spectral properties of these *time-series* to the properties of the random source term that you analyzed in part **A**.

(c) (2 points) So far, you have considered the probability of avulsion as constant through time. What if that probability depends on the time since the last avulsion event? Design a new **ON/OFF** switch where the probability of avulsion increases with duration of time since the last avulsion. Let the probability reset to **0.001** each time avulsion occurs. Similar to part **A**, analyze the spectral properties of the time-lags associated with your new random process. Add the time series and discrete Fourier transform for this new random process to the figure you generated in part **A**. Compare the spectral properties of both time series.

(d) (2 points) Rerun your model with this new river avulsion process. Extract at least five parasequence thickness series from the model run, and compare the spectral properties of these *time-series* to the properties of the source term that you designed and analyzed in part **C**.