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Homework Assignment #3: Coastal Processes, Light + Nutrients, Primary Production

Answer the following problem set and upload to Brightspace by the date above. The answer key will become available upon the due date. You are highly encouraged to start the problem set early to address any questions you may have prior to the deadline. This problem set is intended to be open book/notes. Short answer questions should be in your own words. Show all work and clearly delineate how you arrived at your answer, where applicable. *Please submit your homework as a PDF on Brightspace with your name in the file name.*

DUE APRIL 12, 2023 AT 7:00 PM (25 points)

1. Coastal Processes (4 POINTS)
Shorelines are dynamic; climate and coastal processes change the geography of shorelines over time. For each of the below processes, give an example of how each can shape our coastlines.

a.) Waves: The energy from breaking waves can cause erosion and transport sediment.
b.) Tides: Tides can cause tidal currents which transport sediment; in some cases, tidal currents can create tide-dominated deltas.
c.) Winds: Winds can carry fine particles, sand, and sediment, transporting and depositing them to new locations.
d.) River inputs: River currents cause the erosion of land as water flows from rivers towards the ocean.
e.) Currents: Currents can cause sediment deposit downstream.
f.) Sea level change: Sea level change impacts the vertical location of tides and waves. causing wave energy to be focused on new locations.
g.) Tectonics: Plate movements at active margins cause changes in the crust.
h.) Anthropogenic activities: Humans build houses on coastlines and remove trees and plants whose roots retain sediment. This results in a coastline more susceptible to erosion.

2. Sea Level Rise (6 POINTS)
Assume that you are a coastal engineer tasked with designing a seawall to protect a city from rising sea levels. How would you consider local and eustatic sea level rise in your design? What are the differences between the two types of sea level rise, and how might they impact your design decisions? Provide examples of potential challenges and solutions related to local and eustatic sea level rise that you would need to consider in your design.

As an engineer, it is important to consider sea level rise in the design of coastal structures. The sea level determines where wave energy will be focused, and has significant impacts on coastal morphology including erosion, headland formation, and cliff recession. Eustatic sea level rise refers to the change in sea level on a global scale. Eustatic sea level rise is caused by events such as the expansion of water due to climate change and changes in the volume of a major ocean. Local sea level rise focuses on events that impact a smaller region, such as dams and tectonic motion.

To design a seawall to be resilient against sea level rise, it is important that the coastal engineers use projections to predict sea level rise on both a local and global scale. This is challenging as sea level rise projections are dependent on greenhouse gas concentration in the atmosphere. Coastal engineers must also assess the physical forces at work within the local environment, such as waves and currents, and predict the ways that these forces may change due to a rise in elevation. To understand the impact of sea level rise on the local environment, coastal engineers can use time series data from NOAA buoys, WIS stations, etc. to measure the change in sea level over time. Coastal engineers can also utilize local resources, like records and photos, to understand how the coastline has changed over time in response to the change in sea level. Armed with all of this information, coastal engineers can calculate appropriate dimensions and safety factors for the seawall to withstand sea level rise and protect the city.

3. Nutrients (11 POINTS)

a.) Name two common primary production limiting elements and where on earth each element is commonly a limit. (2 pts)

Iron: Equatorial Pacific, Southern Ocean, Central North Pacific

Nitrogen: Mid-ocean

b.) Define eutrophication and describe the effects of eutrophication on the Northern Gulf of Mexico near the mouth of the Mississippi River. (2 pts)

Eutrophication occurs when an excess of nutrients, often nitrogen, are deposited into a body of water, leading to an increase in algal blooms. These blooms feed bacteria, a process which removes oxygen from the bottom water. This can cause anoxic events and kill organismsin the water column. The nutrients often seep into a river from agricultural runoff and are eventually deposited into a larger body of water. This phenomenon occurred on the Northern Gulf of Mexico, with fertilizer from the farming regions of the Midwestern United States reaching the Mississippi River and being transported to the Gulf. This accumulation of nutrients is responsible for the dead zone in the Gulf and has resulted in changes to the local fish population.

c.) Explain how the quality and quantity of light in the ocean impacts primary production. How can each limit primary production? Where on earth are each at a maximum and minimum? (2 pts)

The quantity of light refers to the amount available for photosynthesis, and is influenced by a variety of factors. Clouds, season, time of day, and latitude all impact the quantity of light that reaches depth. The quantity of light is at a maximum at low latitudes with clear skies and reaches a minimum at high latitudes with cloudy skies.

However, not all light can be used for photosynthesis. The quality of light refers to the wavelength, or color. Different wavelengths have different absorption spectrums, with blue light penetrating the deepest. Light quality can be limited with a variety of factors such as the angle of the sun, atmospheric absorption and scattering, the roughness of the water surface, and the clarity of the water. In the clear open ocean with smooth surface conditions, the largest quantity of light is able to penetrate to depth. This value is at a minimum in shallow, turbid waters in coastal zones.

d.) Iron fertilization has been proposed as a geoengineering solution for climate change, where iron is added to the ocean to stimulate phytoplankton growth and sequester carbon dioxide from the atmosphere. How does iron fertilization relate to the Redfield ratio? What are the potential benefits and drawbacks of iron fertilization as a strategy for mitigating climate change?

In your answer, be sure to discuss how iron fertilization affects phytoplankton growth and define the Redfield ratio. You may also want to discuss the potential environmental impacts of large- scale iron fertilization, such as changes to ocean productivity, nutrient cycling, and ecosystem structure. (5 pts)

The modified Redfield ratio describes the ratio of nutrients needed for photosynthesis: 106:16:1:0.01 (C:N:P:Fe). This ratio is subject to the law of the minimums, stating that the first nutrient to "run out" will be the limiting factor on photosynthesis. According to the Redfield ratio, iron is the nutrient needed in the smallest amount, but is still the limiting factor on photosynthesis growth in large regions of the ocean. Iron fertilization has been proposed as a geoengineering solution for climate change; iron fertilization would promote photosynthesis in regions where iron is the limiting nutrient. This increase in photosynthesis would sequester more carbon dioxide from the atmosphere in the form of glucose. With more primary production, there may be positive impacts on the ocean food web. Krill populations may grow, increasing squid, seal, and fish populations in return. However, it is also possible that, after the initial bloom in primary production, an anoxic event could occur which could be severely detrimental to the oceans.

4. Deltas (4 POINTS)
Compare and contrast the three types of deltas in Galloway's Classification: river-dominated, wave-dominated, and tide-dominated. In your answer, describe the key

characteristics, sedimentation patterns, and dominant processes associated with each type of delta.

Galloway classifies deltas into three categories: river-dominated, wave-dominated, and tide-dominated. River dominated deltas, like the Mississippi, transport sediment downstream, moving particles of different sizes according to river velocity. Known as “bird-foot deltas” , sediment accumulates in a quiet environment when the mean river velocity decreases, resulting in branchlike patterns.

Tide-dominated deltas occur where tidal currents are the overpowering force. The tidal currents carve out the land, resulting in a series of lobes separated by tidal flow, like the Ganges.

Wave dominated deltas, like the Nile, are formed by waves gradually eroding the sediment in the region. The Nile was formed by waves from the Mediterranean, resulting in a large overwash fan.