**Coast Line Evolution**

**(Instructor version)**

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1. **Introduction**

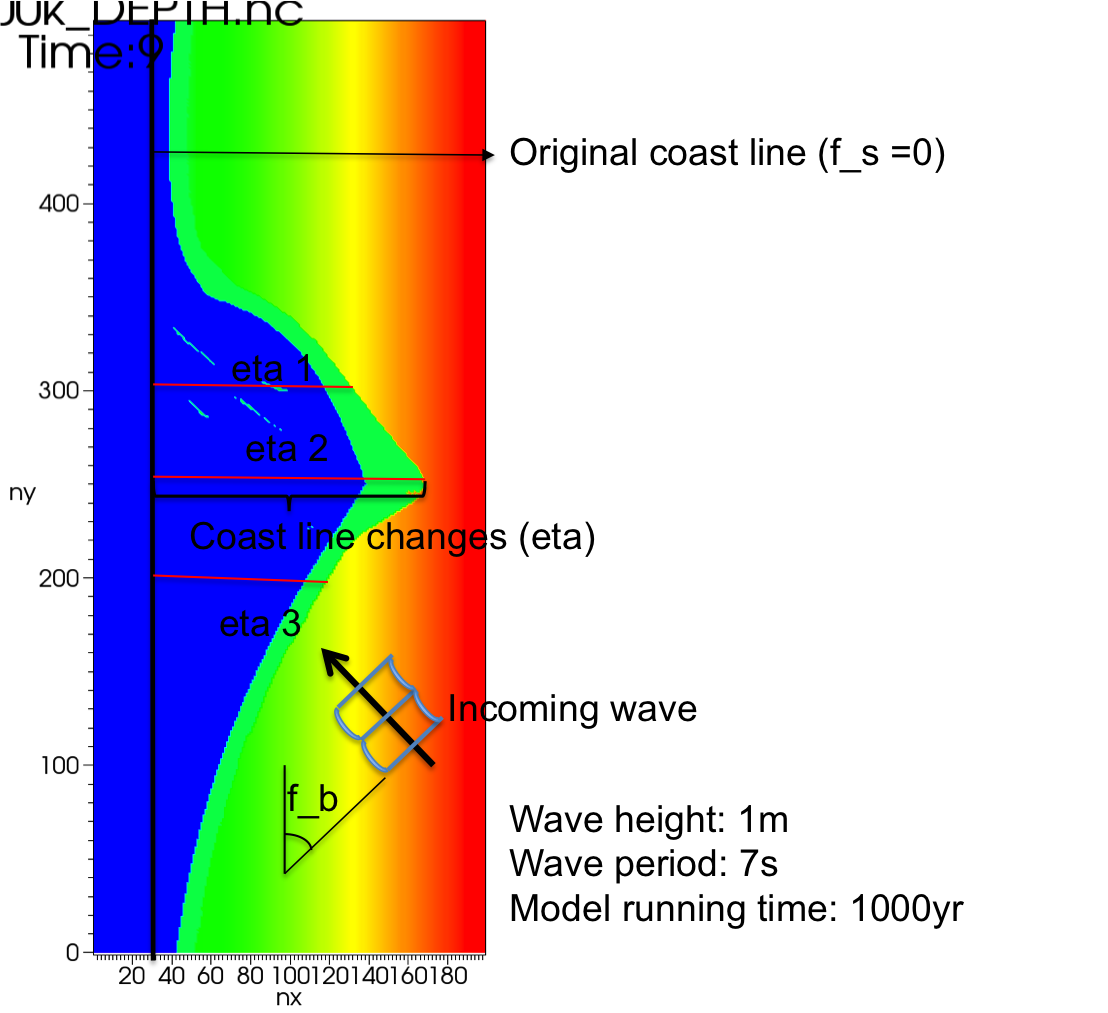
Coasts are often highly scenic and contain abundant natural resources. The majority of the world’s population lives close to the sea. It has been estimated that about 3 billion people (50%) live within 60km of the world’s shorelines. The original development of urbanized societies was associated with deltaic plains in semi-arid areas, and the first cities appeared shortly after the geomorphological evolution of these plains (Day et al., 2007). The coast plays an important role in global transportation, and is a major tourist destination.

The shoreline is where the land meets the sea, and its location and morphology is continually changing under the influence of changing environmental conditions. Coastal scientists have attempted to understand the shoreline in relation to the processes that shape it, and interrelationships with the adjacent shallow marine and terrestrial hinterland environments. Explaining the geomorphological changes that are occurring on the coast is becoming increasingly important in order to manage coastal resources in a sustainable way even when sea level is rising or wind and ocean conditions are changing.

**2 Model Approach**

Here, we focus on sandy, wave-dominated coastlines on time-scales ranging from years to millennia and on a spatial scale ranging from kilometers to hundreds of kilometers. Shoreline evolution results from gradients in wave-driven alongshore sediment transport. We use a 'one-line' modeling approach, where the cross-shore dimension is collapsed into a single data point. We calculate the coastline evolution with different ocean dynamics, mainly wave dynamics. The following figure shows the main output parameters; including the amount of sediment transported alongshore (Qs), the alongshore current (Sxy), and the shoreline position changes (eta).

Controlling parameters are sediment input (e.g. sediment from the river in Figure 1), and wave climate. Wave climate includes parameters like wave height, wave period, wave angle with the coastline, and breaking wave height, which is the critical height at which waves collapse. In the spreadsheet CoastLineEvolution\_practise.xls, it shows the equations to calculate Qs, eta, and Sxy.



One model that can model coastline evolution processes more elaborately is CEM. The Coastline Evolution Model (CEM). More detailed information on CEM can be found on this website: (http://csdms.colorado.edu/wiki/Model:CEM)

Related literature:

Ashton A.D. and Murray A.B., 2006a. High-angle wave instability and emergent shoreline shapes: 1. Modeling of sand waves, flying spits, and capes. Journal of Geophysical Research,111, F04011, 19pp. Doi: 10.1029/2005JF000422

Ashton A.D., and Murray A.B., 2006b. High-angle wave instability and emergent shoreline shapes: 2. Wave climate analysis and comparisons to nature. Journal of Geophysical Research,111, F04012, 17pp. Doi: 10.1029/2005JF000423

**Practice:**

*Question for Students 1*

*A coast is the transitional zone between land and ocean, which factors do you think will influence its evolution? (Hint: deltas are build of sediment, think about which factors control the amount of available sediment amount and transporting agents)*

Answer for Instructors 1

The evolution of coasts and deltas are determined by accumulation of river-borne sediments upon entering the ocean or a lake and the energy of ocean processes for sediment transport. Deltas thus are controlled by how much sediment is transported into the delta, and that how much sediment is leaving the system. There are two sources for sediment to the delta: river sediment flux, and the sediment moving from the adjacent areas in the ocean by processes called longshore transport. So the factors that will influence the coastline and delta evolution are both the river conditions (river water discharge and sediment flux), and ocean conditions (tidal currents, and waves).

*Question for Students 2*

*2A Transport of sediment alongshore is determined by alongshore currents, which results of wave activity. Waves induce a radiation stress in the alongshore direction, which then drives the alongshore current.*

*Worksheet ‘Sxy’ in your spreadsheet allows calculation of alongshore currents. Which are the main factors that determine the Sxy and why? What happens to the alongshore current if wave height increase? How about wave angle, at what angle will we get the maximum alongshore current (Hint: attain this through plotting a graph of Sxy as a function of wave angle)?*

Answer for Instructors 2A: Alongshore currents are controlled by both incoming wave height and wave angle. Wave power increases with larger wave height, thus its influence on the alongshore currents will increase accordingly.

Secondly, the radiation stress due to breaking waves has a component in alongshore direction, which will be greatly influenced by wave angle (the angle of the incoming wave and the shoreline).

The relationship between Sxy and wave angle is complicated; Sxy reaches a maximum when the incoming wave angle is about 45°, and decreases both when wave angle increases or decreases. When wave angle is 0°, all sediment movement will be in cross-shore direction, and there will no alongshore sediment transport, and when wave angle is 90°, the influence of waves on the coastline will be so small, the coast line will be stable. (Please look at graph in the excel sheet)

*2B Your workheet ‘Qs’ shows the equations for calculation of alongshore sediment flux. What happens to Qs when wave height increase? How much would the range of wave heights in the United States be today? (http://www.intellicast.com/Travel/Weather/Marine/Waves.aspx)*

*Plot a graph of Qs as a function of wave height, and pay attention to the wave height ranges (Hint: use the range for US today, or for a major hurricane).*

Answer: Qs is proportional to wave height, so Qs will rise when wave height increases. As shown in the figure (see in the instructor version of the spreadsheet), Qs raises about 48 m3/s when wave height changes from 1 to 10 m.

Please discuss with students that this is caused by the dramatic exponent: H12/5

*2C What happens to Qs when the wave period increases? Plot a graph of Qs as a function of wave height, and pay attention to the wave period ranges (see the following figure, we are looking at wind-driven waves). Compare the difference of trend with the relationship between Qs and wave height.*

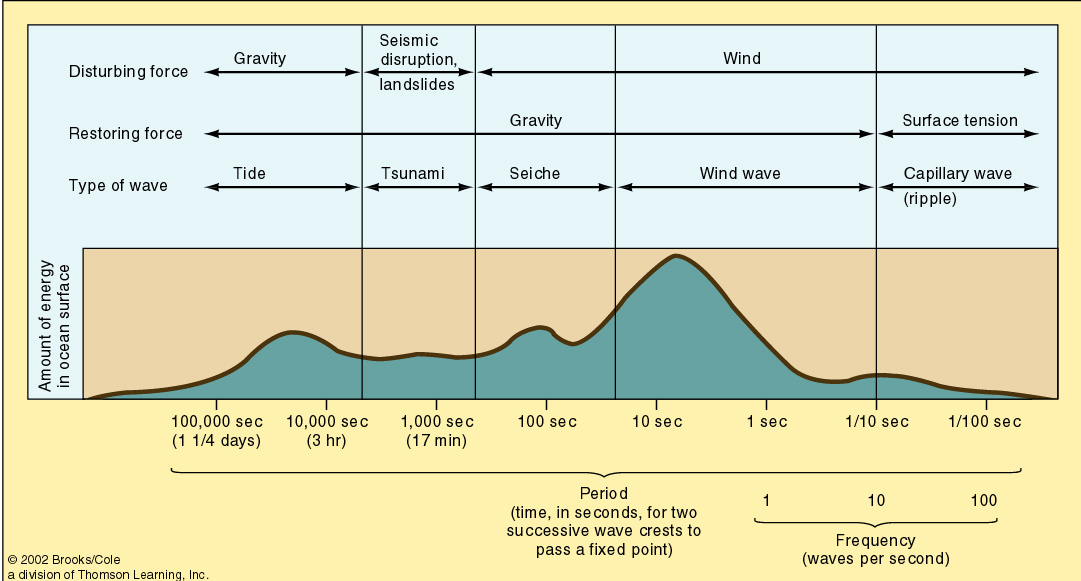


Figure 2 Ranges of wave periods

Answer: Qs will increase when the wave period increases; because the wave power depends on the wave period. However, the trend is much more modest than the relationship with the wave height; Qs changes just slightly with wave period, from 0.06 to 0.18 m3/s when wave period changes from 0.1 to 20s. From Figure 2, it could be obtained that the range for wind wave period is about 0.1s to 25s.

*2D What happens to Qs when the breaking wave height increase? Plot a graph of Qs as a function of breaking wave height. Notice that breaking wave height depends on water depth, waves will break when waterdepths are smaller that 1/7 of wave height. Will Qs be larger in shallow water, or in deep water?*

Answer: Qs will decrease when breaking wave height increases. From the equation, it shows that r is inversely proportional to H\_b, while r is proportional to K2, thus Qs, thus H\_b is inversely proportional to Qs.

This can be explained by the fact that wave power on the bottom is stronger in shallow water, as the wavebase (the depth upto which wave could affect the bottom) is about ½ a wavelength from the water surface.

*2E What happens to Qs when the angle of incoming wave and shoreline changes? Plot a graph of Qs as a function of wave angle; what will happen if wave angle is 0, or 90°? When will Qs get its maximum?*

Answer: The relationship between Qs and wave angle is more complex than other parameters. Qs is maximal when the wave angle is about 40°, and decreases both when wave angle increases and decreases. When the wave angle is 0°, all sediment movement will be in cross-shore direction, and there will no alongshore sediment transport, and when wave angle is 90°, the influence of wave on coast line will be very small, the coast line will almost keep constant.

*Question for Students 3*

*Worksheet ‘eta’ shows the equation to calculate coastline changes with time, what are the factors that determine the value of eta? Try to formulate a hypothesis on how the different factors will work and why. Subsequently plot the graph of eta as a function of these factors and describe the relationships.*

Answer for Instructors 3

Answer: The factors that determine coastline changes include Qs, t, and D\_sf. eta is proportional to the increase of Qs and t, but oppositely proportional to D\_sf. It is easily to see that coastline will grow faster when sediment flux is abundant, thus it is obvious that eta will increase with Qs. As the coastline is in the condition of deposition, eta will all increase with time. However, eta is opposite to D\_sf (the effective water depth) for the reason that for a given coast, the larger the D\_sf, it means that the wider zone that is taken into consideration for alongshore sediment transport from the coast, thus the growing rate of coastline to the ocean will become much slower. (The graph are all shown in the excel sheet)

*Question for Students 4*

*Consider a delta system that has archieved an equilibrium status, which means that the incoming sediment is the same as that eroded by ocean dynamics (for example,* wave *activities). What will happen if a dam is constructed in the basin, which greatly decrease the sediment flux to the delta? Can you give an example? What would happen when the storm frequency increases because of global warming?*

Answer for Instructors 4

The delta will be eroded and the coastline of delta will retreat for the first situation as less sediment is transported to the system, so the outgoing sediment amount is larger than the incoming amount, the example could be the Ebro delta in Spain, or the abandoned part of the Yellow River delta in China.

The other situation causes intensification of oceanic hydrodynamics, which will increase the erosion of delta, so if the incoming sediment from the river keeps constant, then the delta will be eroded and the coastline will retreat.

Note for Instructors on Wave radiation stress and generation of longshore current theory:

Longuet-Higgins and Stewat (1960, 1964) have defined the radiation stress as “the excess flow of momentum due to the presence of the waves”. The radiation stress is the “excess” momentum in that the dynamic pressure is used, and hydrostatic pressure being subtracted from the absolute pressure. This ensures that the assessed momentum is due solely to the presence of the waves.

When a wave breaks parallel to the shore, there is an onshore-directed radiation stress (Sxx), a momentum flux associated with the waves, and a longshore-directed radiation stress (Syy) resulting from the effects of the wave motions on the hydrodynamic pressures. When the waves approach the coast at an angle with respect to the shoreline, each of these two portions of the radiation stress have longshore component, which combine to yield Sxy , longshore-directed of radiation stress that is moving toward the shoreline. Sxy is mainly determined by wave energy flux. When a wave breaks, the dissipation of Sxy within the nearshore area will serve as the direct cause for the generation of longshore currents.

References:

Komar, P.D., 1998. The Generation of Waves and Their Movement Across the Sea in Beach Processes and Sedimentation (Second Edition), 160~168.

Komar, P.D., 1998. Wave-Generated Currents in the Nearshore Sea in Beach Processes and Sedimentation (Second Edition), 336~365.

Anderson, R.S. and Anderson S.P., Geomorphology: The mechanics and Chemistry of Landscapes. P512~514.