CTB3300WCx – Introduction to Water and Climate

WS 2 – Coasts

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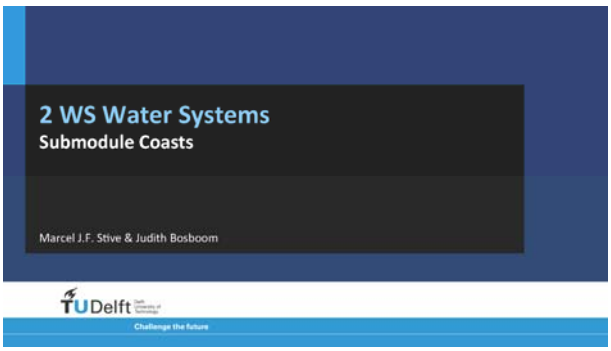
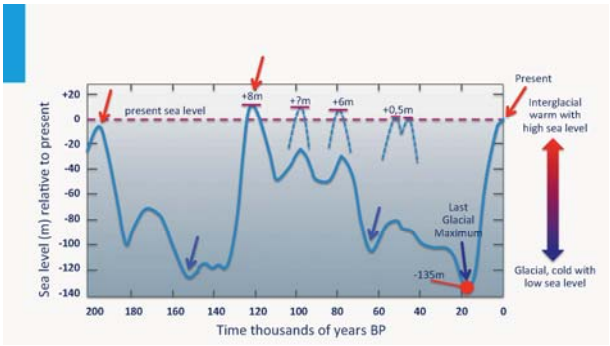
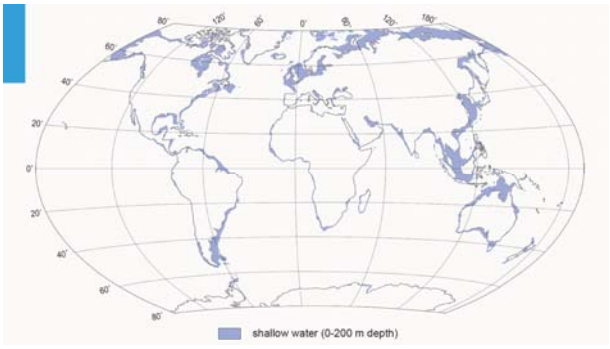


In this module we will explore the origin and evolution of beaches. We will start by looking at a fairly large time scale, spanning many thousands of years.

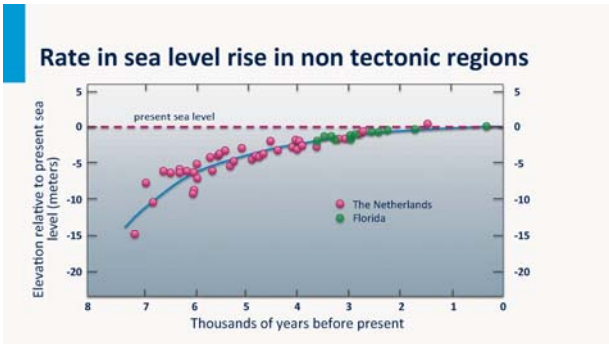


As this graph shows, the last two hundred thousand years, the earth has experienced a number of glacial or cold and interglacial or warm periods. About 20.000 years ago, the Earth experienced the Last Glacial Maximum, a cold period. Presently, we are in the warm period of the Holocene interglacial. Note that the sea level was as low as 135 m below present sea level at the Last Glacial Maximum, rising fast since. Around the last Glacial Maximum, the shallow North Sea basin was almost completely dry.

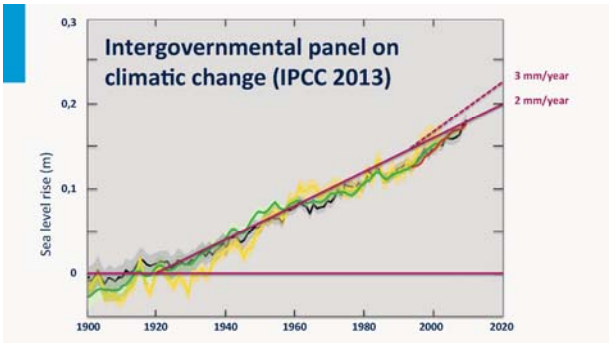
As a result, for quite some long time, one could actually travel, by land, from the European continent to the UK. As the sea level was rising, the basin experienced flooding. It is this drowning process, that has created our present-day North Sea.
But rising sea levels have not just impacted the North Sea.
All around the globe, the relatively shallow areas that surround our continents have been drowned.
We call these areas continental shelves.



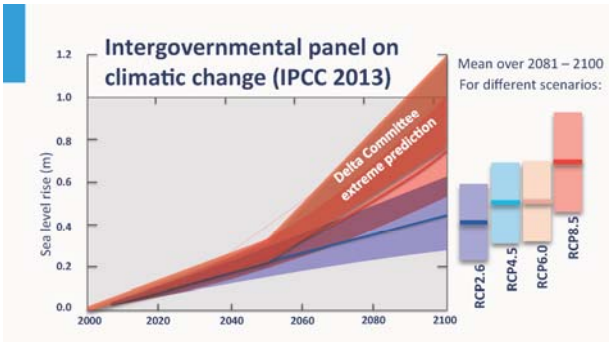
They are nowadays recognized as the underwater land masses that extend from the continents. The shallow seas, covering the shelves, have water depths up to and often less than 200 m. The continental shelves are covered by sediments, which were eroded, during millions of years, from continental rock. On land, mechanical and chemical processes caused the breakdown of rock into smaller particles. These particles were then carried to the continental shelf by rivers, glaciers and wind. The drowning of the continental shelves since the last Glacial Maximum, was due to the rather large rates of sea-level rise.



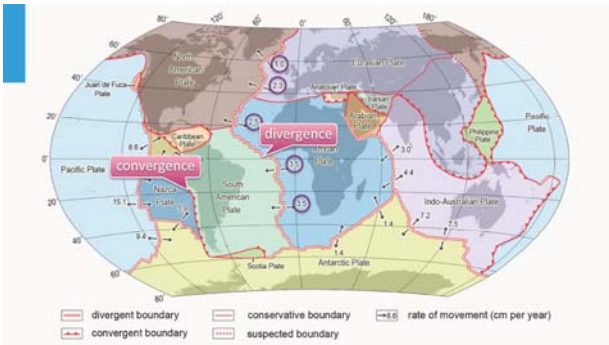
However, in the last thousands of years, the rate of sea-level rise has leveled off, to about 1 to 3 mm/year in the last century. As a result, this eustatic or absolute sea-level rise is presently of secondary importance. This can of course change again if the rate of sea level rise will increase significantly in the future.



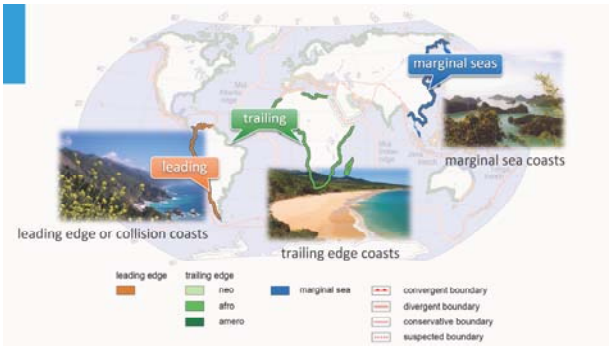
There are observations that suggest that sea level is starting to rise faster, say 3 or 4 mm/year.



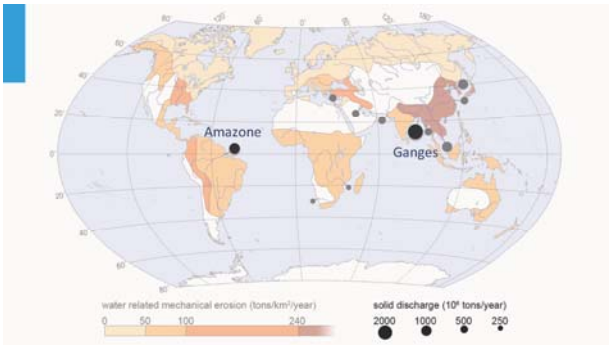
The latest projections of the IPCC even indicate that sea level rise may increase to as much as 4 or 7 mm/year. In the Netherlands, we have also made an extreme projection, which will eventually call for major protection. On a large spatial scale, first order features of the world's coastlines are determined by their position on the tectonic earth plates.



In this graph we see the delineation of the many earth plates that form the earth's crust. We call this the lithosphere. The lithosphere is divided in 12 large, tightly fitting plates and several small ones. In the graph the rate of movement of the diverging plate boundaries are indicated. The order of magnitude of the movements is cm's per year. Interesting isn't it? We are on cm's per year moving earth plates right now. We see that plates collide or converge on one side and diverge on the other side. Inman and Nordstrom in the early 1970's were the first to observe that the first order character of a coast is determined by its position on the earth plates. As illustrated in this graph, three main classes of coasts are distinguished:



the first class are leading edge or collision coasts associated by the leading edge of a crustal plate; they are characterized by rugged, cliffed coastlines, tectonic activity and a narrow shelf; the second class are trailing edge coasts that are located away from plate boundaries and are generally tectonically stable because the continent and adjoin ocean floor are of the same plate, they have wide continental shelves; and finally the third class marginal sea coasts, these are tectonically stable coasts protected from the open ocean by island arcs at converging plate boundaries. Most of the world's larger deltas are located on trailing edge and marginal sea coasts.

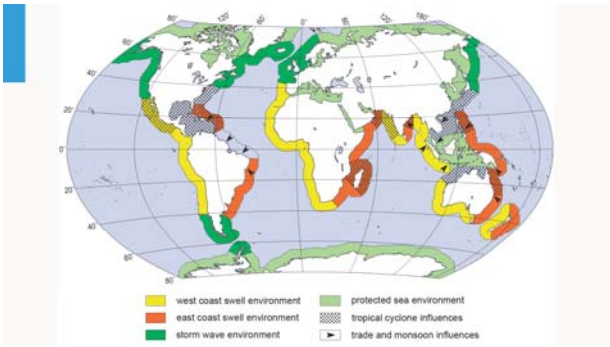


These coasts combine ample sediment supply with wide and flat shelves. This combination ensures a rapid building out of the coast. Let us have a closer look at the location of two important deltas: the Amazon and the Ganges. You may check that they are indeed located far from plate boundaries. Also note, in both cases, the large catchment areas that supply these deltas with sediment. As we suggested before, when it comes to the fate of a coast, the eustatic or absolute sea-level rise is presently only a second order effect. And this is especially true for delta regions. So what then are the primary factors?

What are these factors?

- availability or shortage of sediment
- subsidence leading to relative or local sea level rise

There are two: the 1st factor is the availability or shortage of sediment. An example is a river providing a high sediment load to the coast. Or think of the cut-off of this sediment supply due to man-made structures. The 2nd factor in many low-lying regions is local, mainly human-induced subsidence or sinking of the land. For instance, ground water extraction may lead to soil compaction. As a result, the land sinks relative to the sea. Locally, this leads to a relative sea level rise, even if the absolute sea levels do not change. These two factors, rather than absolute sea level rise, determine the coastal sediment budget. Therefore, they define whether the coast accretes, is stable or erodes.



Regional and local features of coastlines are also affected by tides, wind waves, storm surges, monsoons, typhoons - which are also called cyclones or hurricanes - and tsunami. These forcings vary considerably from region to region or even from coast to coast. On top of that the sediment size varies greatly. Therefore, on a regional and local scale each beach is different.

Now, let us finally look at a real beach. It will not come as a surprise that we chose a Dutch beach in its contemporary setting. You may have observed that beaches are made up of loose material. Let us listen to Max on a Dutch beach. Actually, beaches are made of whatever loose material is available. If you ask a visitor what a dutch beach is made of, they will probably say "light-colored sand". But what does this sand consist of? It's actually tiny grains of quartz and feldspar, the two most common minerals found in solid rock. But, how did all these grains end up here at the beach? And where do they come from? You probably can guess, but if you want to know the details, watch the video The Origin and Evolution of a Beach. You will learn that these grains originate primarily from the Rhine river basin and are transported by the river to the coast where the river's capacity to carry the sediment along flow dies. Then you may wonder, why does it not pile up at the mouth of rivers that deliver it? Why does it form into beaches that stretch for as much hundred km down the coast? You may have noticed that waves usually approach the coast at an angle, not straight on. This is because the wave directions are

determined by the wind, that created the waves. When waves from a certain direction approach the coast, they tend to become more and more parallel to the coastline, but a small angle remains. Let us observe Max at the beach with oblique waves, throwing some tracers into the water. How does this process influence the movement of these markers? With every breaking wave, they move towards the beach, but they are transported along the coast as well.. Now Max uses dye: look at the aerial shot of the surf zone with a cloud of dye injected in the middle of the surfzone. The dye shows the water outside the surf zone hardly moves at all. In the surf zone however, the water clearly moves down the coast. It is the process of wave breaking that drives this so-called along shore currents. Sediment is brought into suspension by the breaking waves and moves along with the current. This is the so-called longshore transport. So we think of the beach as ‘a river of sand’, confined between the beach face and the outer edge of the surf zone. It is this river of sand that distributes the sediment and creates long stretches of beach. So now you have gained some understanding of beach processes. And the homework video - The Origin and Evolution of a Beach - will teach you more. The processes that we discussed are strongly influenced by human interventions. These interventions are mostly directed towards exploiting our unique coastal resources. The various types of interventions that mankind made, still makes and will make will be discussed in the submodule Coastal Interventions.
See you there!