Cardiff Case Studies
Astudiaethau Achos Caerdydd

Physical Geography

The effects of climate change and ocean acidification on *Corallina* seaweeds

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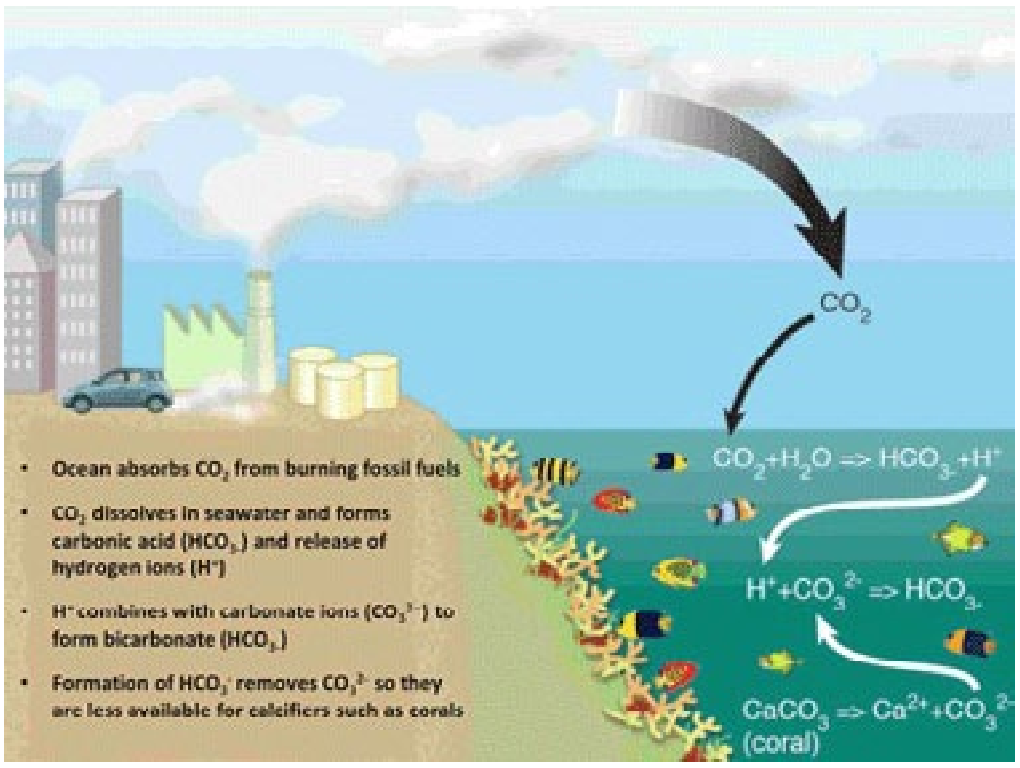
Introduction

Significant increases in the concentrations of greenhouse gases in the Earth's atmosphere owing to human combustion of fossil fuels and deforestation, is having profound effects on the world's oceans. Two of the main effects on the marine environment are increased sea surface temperatures due to climate change, and ocean acidification. Increased sea surface temperatures are caused by the global warming effect of climate change. As the world's atmosphere warms up, our oceans slowly absorb the heat. To date, the oceans have absorbed over 80% of the heat added to the atmosphere by climate change. This has caused an increase in global average sea surface temperature of approximately 0.69oC.

Ocean acidification refers to a decrease in ocean pH (increasing acidity) over decades or more that is caused by uptake of carbon dioxide (CO2) from the atmosphere. Because human activities are releasing CO2 into the atmosphere very quickly (a major cause of climate change), the ocean is taking up CO2 faster today than it has in the past. When CO2 dissolves in seawater, it acts like a weak acid and, through a series of chemical reactions, causes an increase in the acidity of the seawater, i.e. an increase in free hydrogen ions (H+). Additionally, increased CO2 concentration in seawater also causes a reduction in carbonate ions (CO32+), which are very important building blocks of calcifying marine species, i.e. those species that deposit shells, tubes, or other skeletal structures out of calcium carbonate (CaCO3), e.g. corals. Since the industrial revolution, the pH of the world's oceans has decreased by approximately 0.1 units, which represents a 30% increase in H+ ions and a significant decrease in the availability of CO32+ to marine species.

As humans continue to release greenhouse gases into the atmosphere, climate change and ocean acidification will continue at a speed never seen before in the Earth's history. Predictions of future concentrations of greenhouse gases in the atmosphere made by the Intergovernmental Panel on Climate Change (IPCC), show that by the year 2100 we can expect increases in sea surface temperature of approximately + 4oC and a further decrease in pH of 0.3 – 0.5 units (i.e. a 90 – 150% increase in hydrogen ions).



The problem

Increases in sea surface temperatures (SSTs) and acidity of the world's oceans are likely to have significant impacts on marine species. For example, many species live at their temperature limits and thus may not be able to adapt to an increase in temperature over such a short time period. Additionally, species that deposit CaCO3 could be significantly negatively impacted by ocean acidification (OA) given the reduction in the availability of CO32+ ions as well as a general increase in acidity that may lead to dissolution of CaCO3 structures in the long-term.

Red seaweeds of the genus *Corallina* are very important in the coastal zone of temperate regions around the world, though because roughly 80% of the mass of these seaweeds is made from CaCO3, they are likely to be impacted by increased SST and OA. In the coastal zone, *Corallina* species are extremely abundant and provide habitat for numerous invertebrate species, shelter from the stresses of intertidal life via their physical structure, and important substratum for the settlement of other seaweeds and microalgae. Any impact on *Corallina* species will therefore have significant effects throughout the entire coastal ecosystems that they support. It is therefore extremely important to understand how and in what manner increased sea surface temperatures and ocean acidification will impact *Corallina* species.

How are we answering these questions?

This project is analysing the present-day ecology of *Corallina* species in the north-eastern Atlantic region. When we fully understand this we can examine how these species will react to future seawater conditions. In addition, as climate change and ocean acidification have been impacting the oceans since the Industrial Revolution, *Corallina* species may have already been impacted and thus examining this impact may help us make future predictions.

Corallina present-day ecology:

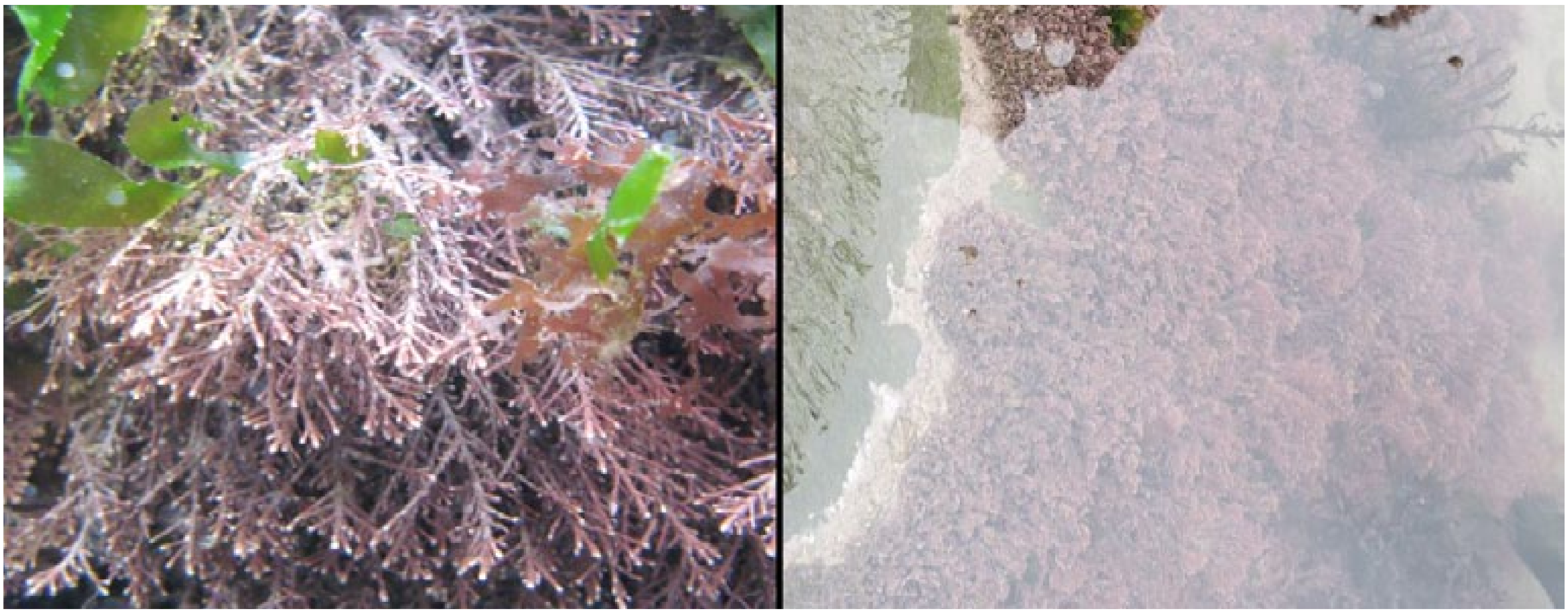
To learn about the present-day ecology of *Corallina* we have examined the photosynthesis, growth, calcification, reproduction and other interesting parameters of *Corallina* at a UK coastal site, during every season, whilst recording important environmental variables e.g. temperature, light, seawater pH etc. For comparison to this, we have performed the same work on the coasts of northern Spain and Iceland, to see if *Corallina* species have adaptations to the different environments in which they grow along this transect.

***Corallina* recent-past ecology:**
To examine whether *Corallina* species have already been affected by climate change and ocean acidification, we have assessed *Corallina* collections of The Natural History Museum, London, to make comparisons to the results of the same tests conducted on present-day samples. In particular, we have examined the composition of the CaCO3 skeleton of the species, which is known to vary with seawater temperature.

***Corallina* future responses:**
To examine the responses of *Corallina* species to future climate change and ocean acidification impacts, *Corallina* samples will be grown in seawater that has been manipulated to have future predicted concentrations of CO2 (and thus future acidity and carbonate ion concentrations). During these incubations we will measure the same parameters that we have assessed along the coastlines of the UK, Spain and Iceland, and compare how the species react to these future conditions to what we know already of the present-day and recent-past ecology. This will allow us to determine in which direction (positively, negatively, or not at all) the species will be impacted in the future.

Activities for follow up work

In relation to this project specifically, the following field study with follow up lab / data analysis work could be performed: Perform a field-trip to a local intertidal zone (rock pool environment) and use basic quadrat methods to assess the relative abundance of *Corallina* seaweeds in comparison to other major seaweed groups, e.g. greens, browns, other non-calcified red seaweeds. Whilst in the field, analysis of changes in the water chemistry of rock-pools in which *Corallina* are found growing can be undertaken. For example, significant changes in rock pool seawater temperature and pH occur when the tide is out, and these can easily be assessed e.g. every 15 minutes, using simple thermometers and pH probes. Additionally, *Corallina* and other seaweed samples can be collected and returned to a laboratory where the invertebrates that inhabit the fronds of the seaweeds can be assessed, e.g. counted, identified, drawn etc. This will demonstrate the abundance and importance of *Corallina* species in UK intertidal environments and how a loss of these species could impact invertebrates that rely on them for habitat and shelter, and highlight the important environmental conditions, e.g. temperature and pH, that *Corallina* currently experience under present-day climate conditions.



Close-up of *Corallina* officinalis (left) and mixed *Corallina* assemblage in a rock pool in Devon, UK (right)

Further Information

For activities that are more generally related to ocean acidification, the UK Ocean Acidification Research Programme have developed a series of 8 experiments for teachers and students of varying degrees of complexity please see http://www.oceanacidification.org.uk/pdf/Eight_experiments_on_ocean_acidification_for_school_teaching.pdf; or go to www.oceanacidification.org.uk, navigate to the 'Resources' tab and the pdf file can be found under the heading 'Additional resources from the wider ocean acidification community'.

Adding up the change: Capturing the cumulative effects of dynamic shorelines

Author: Dr Eli Lazarus

Introduction

Dynamic as sandy shorelines are, some changes in shoreline morphology last longer than others. Visit a beach before and after a stormy weekend and you can appreciate the volume of sand that an energetic weather event can move: what was a broad, sloping beach before the storm might look excavated and flat afterward. But how long do these changes last? In a few weeks' time, you may find the beach again recharged with sand, evidence of the storm effectively erased. Do short-term changes like these bear any relationship to changes in shoreline position over longer time scales?

Findings

Insight into why some reaches of shoreline erode while others accrete is a fundamental question in coastal geomorphology. When investigating the physical processes that drive patterns of shoreline change, scale matters. Signatures of different physical processes get embedded in records of shoreline change, but revealing them depends on measuring the right spatial and temporal scales. Imagine taking a walk—perhaps a very long walk—along a beach (Fig. 1). On the scale of 10–100 m, the beach morphology you cross is largely a function of wave swash. Where the waves are running up the beach, shapes in the sand form, obliterate, and reform rapidly. The amount of change those shapes exhibit (their variance) is small relative to the total size of the beach. On the scale of 100–1000 m, changes in shoreline position are larger, and shoreline shape may be related to wave-driven currents and sandbars in the surf zone, the area close to shore where waves are breaking. Walk a few kilometres and you might be aware of having followed subtle but noticeable undulations in the shoreline. Shoreline changes at this multi-kilometre scale tend to derive from gradients in wave-driven transport of sediment alongshore. On stretches of shoreline where more sand flows in than flows out, the shoreline accretes; where more sand flows out than flows in, the shoreline erodes. Such changes are typically slow, but cumulative. They can even reflect aspects of the regional-scale coastal environment, such as prevailing weather patterns.

One tool capable of accurately measuring shoreline position over long distances is LIDAR (an acronym for 'light detection and ranging'), an instrument that uses a laser to map topography from a low-flying aircraft. Lidar surveys are especially useful for their high-resolution geospatial data. However, a survey is only a snapshot of the coast at a particular moment in time. Furthermore, because LIDAR data are expensive to collect, surveys tend to be flown infrequently—annually at best. They provide poor temporal constraints on fine-scale changes that only more frequent recording can capture. For example, the rate at which beach features change at spatial scales smaller than 100 m is significantly faster than the interval between most LIDAR surveys. At larger spatial scales, however, comparisons of shoreline surveys repeated over several years can yield intriguing patterns of change (Fig. 2). At spatial scales of a few hundred meters and smaller, the shoreline exhibits the same degree of change (the same variance) regardless of whether the surveys are taken a few months or several years apart. At spatial scales of a few kilometres, shoreline position shows little variability from year to year but significant changes emerge from records spanning a decade or more.

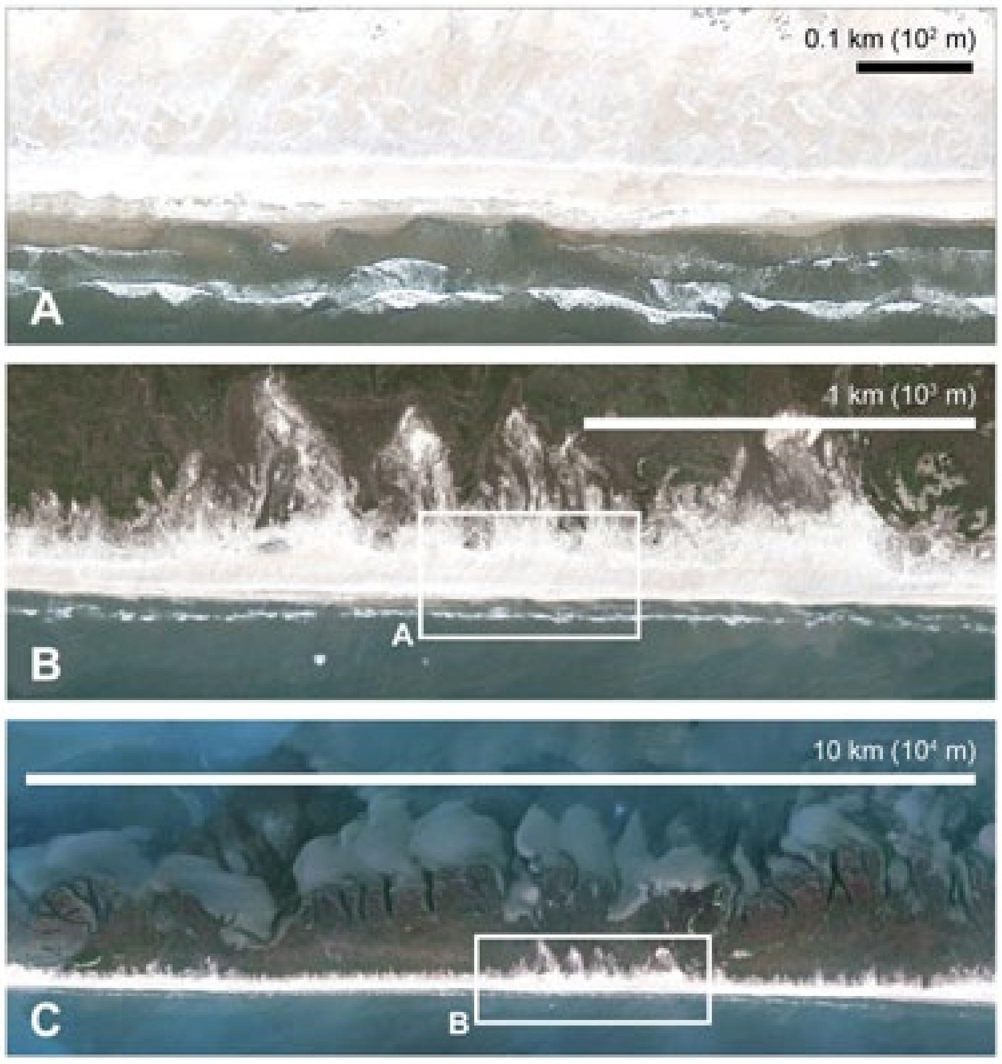


Figure 1: Aerial views of the same beach at increasing spatial scales. Different physical processes are relevant to shoreline changes at the scale of each panel: (A) wave swash; (B) sandbars and surf-zone currents; and (C) gradients in alongshore sediment transport. (Background images courtesy of Google Earth™)

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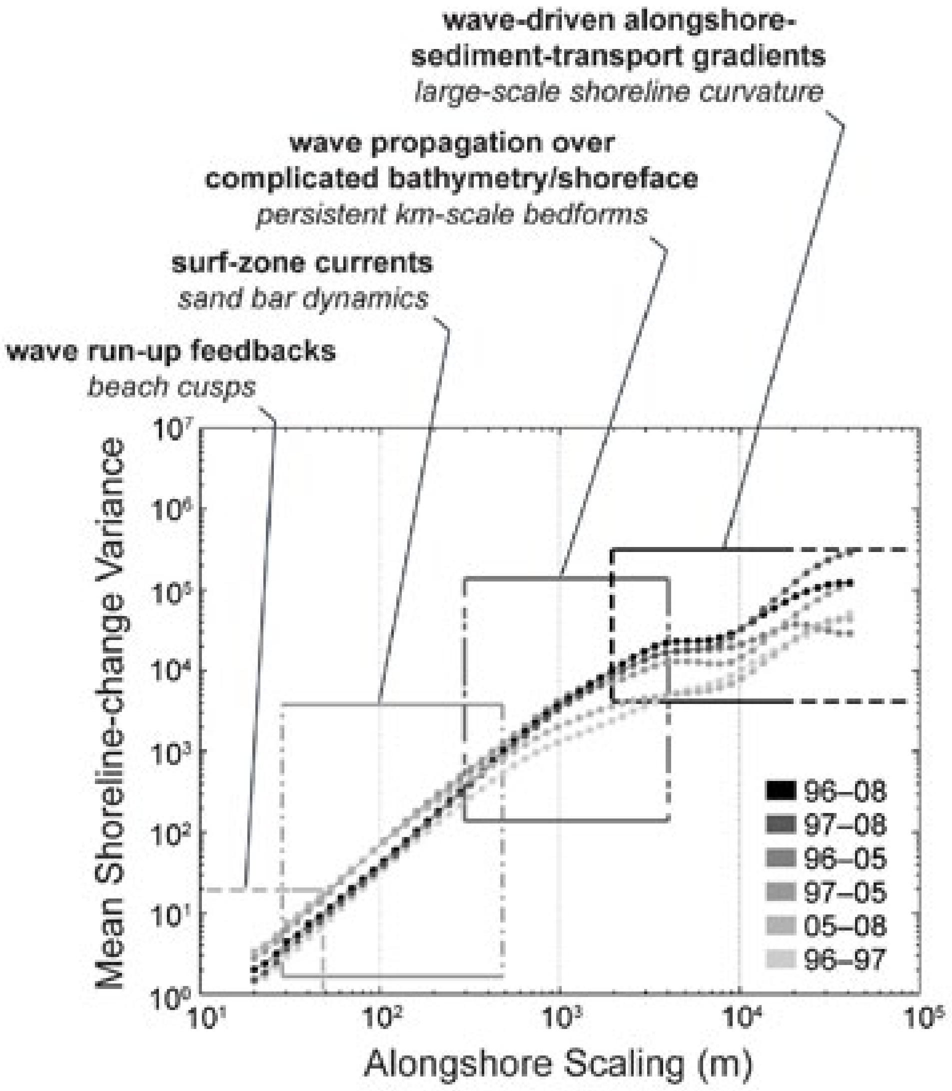

Figure 2: Mean variance in shoreline change relative to alongshore spatial scale, and the different physical processes that typically affect those scales. Variances plotted in light grey indicate relatively short intervals between shoreline surveys; the longest interval (12 years) is in black.

Conclusions

This spatial-temporal relationship has important ramifications for observing and quantifying shoreline change. Wave-swash processes can have dramatic short-term effects, but they exert limited influence on long-term shoreline change compared to the processes operating at larger scales, such as gradients in alongshore sediment transport. Ultimately, the signatures of sediment-transport dynamics that a coastal geomorphologist is able to record depends on the spatial and temporal scales preserved in her or his shoreline measurements. If you are that geomorphologist, ask yourself: do you have the vantage, in space and time, to see evidence of the dynamics you are look for?

References

- List, J. H., A. Farris, and C. Sullivan (2006), Reversing storm hotspots on sandy beaches: spatial and temporal characteristics, Marine Geology, 226, 261–279
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- Lazarus, E., Ashton, A., Murray, A. B., Tebbens, S., Burroughs, S. (2011), Cumulative versus transient shoreline change: Dependencies on temporal and spatial scale, Journal of Geophysical Research–Earth Surface, 116, F02014, doi: 10.1029/2010JF001835

Further information

- Introduction to Coastal Processes and Geomorphology: https://sudartomas.files.wordpress.com/2012/11/introductiontocoastalprocessesandgeomorphology.pdf