Dynamic systems:

Modelling the coastal environment

Dr Andres Payo is a coastal geoscientist at the British Geological Survey. He specialises in applying quantitative geomorphology methods to coastal protection approaches to ensure that coastal communities continue to thrive in a sustainable manner. He is currently developing the Coastal Modelling Environment (CoastalME) software, which can simulate and predict coastal responses to human activity to inform stakeholders in coastal development and protection ventures.

Coasts provide us with a wide variety of vital resources and services. They support our fisheries and tourism industries, and play an important role in the cycles that affect the climate and environment. They have also historically served as our links to other parts of the globe, allowing us to trade and interact with those previously beyond our reach, which has shaped our societies into those we live in today. It is no surprise, then, that over a third of the human population live close to the sea – the majority of the world's cities are located on the coast, despite coastal regions only constituting 4% of global land cover.

The coastline is dynamic and ever-changing. It is governed and shaped by a wide range of physical processes and forces. Therefore, while these areas provide great support to a nation's society and economy, there are great risks associated with coastal development that should be considered heavily during investment and planning. Modelling is a significant method of visualising the processes at play in the coastal environment. Dr Andres Payo of the British Geological Survey is currently working on developing such models and tools to help stakeholders anticipate coastal change so that they can make informed decisions during development and allow us to continue using the vital resources the coasts provide in a sustainable manner.

ENERGETIC ENVIRONMENTS

Energy levels can vary widely at different parts of the coast, from relatively calm beaches enclosed in bays to rocky cliffs exposed to the harsh conditions of the open sea. It is this energy that moulds the landscape – coasts facing high levels of energy endure high levels of erosion from powerful waves, while low-energy coasts experience low-power waves and thus face little erosion. Landforms such as wave-cut platforms and headlands are common on high-energy coasts, forming through wave action and the geology of the area. Cliffs are rarely uniform in terms of their geology, typically constituting layers of different types of rock that erode with varying levels of ease. Softer types of rock may be eaten away by wave

Example of hard defence method.
Low crested breakwater at Happisburgh, east coast of UK.

Working with nature requires understanding how sediment is transported by waves and currents. Photo shows Andres setting up a streamer trap used to measure sediment fluxes on beaches.

action, leaving protrusions of harder rock extending into the sea.

The numerous processes that shape the land of the coastal environment take place at a range of time-scales that ultimately change the morphology of the coastline at different rates. Waves and tides move sediment instantaneously, while large-scale morphological change may not be notable for decades or centuries. Despite their dynamic and ever-changing nature, humans have settled near coasts for millennia owing to the resources and services they provide, including the easy transport of goods across the seas and the bountiful produce that supports millions of people worldwide. However, settlement in the coastal zone is not without risk. Erosion, coastal flooding, and harsh weather conditions are often endured by those living in these areas. Therefore, sustainably managing and responding to these factors is vital if we are to continue our coastal development.

COASTAL PROTECTION

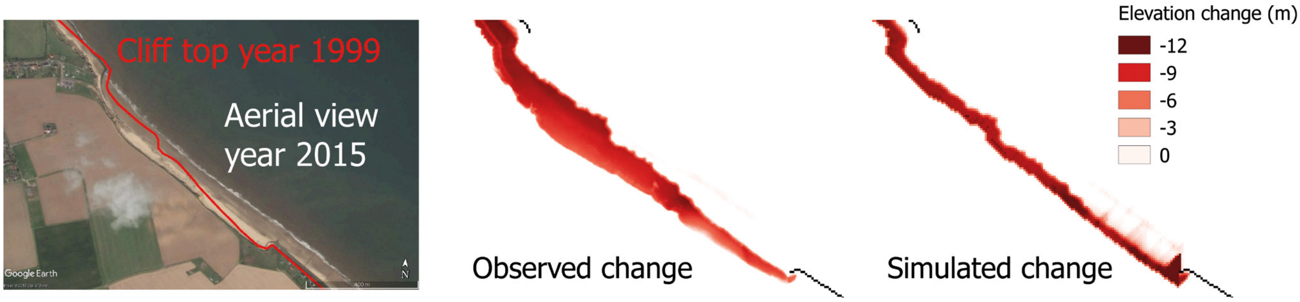
Responses to protect human settlements from such difficult conditions can exacerbate the problems such responses were implemented to solve or move them elsewhere. For example, "hard" methods of stabilising eroding coasts, such as the deployment of jetties or seawalls, affect sedimentation processes and wave energy, respectively. The implementation of a jetty to protect a harbour from erosion may cause sand to build up at the end of the jetty and ultimately accumulate in the harbour if it is not dredged, which can be a costly process. Similarly, seawalls are often built to protect structures from rising sea levels. However, wave energy often builds behind the wall resulting in larger, more forceful waves that defeat the wall's purpose. It is, therefore, vital that we find methods of preserving our coastal communities and reduce the risks of coastal development, which typically increase as city expansion continues, without impacting natural geomorphological processes. In these cases, nature should not be fought. Attempting to prevent the onset of coastal change will incur increasing costs throughout the future; it makes sense to work with natural processes rather than against them.

The majority of the world's cities are located on the coast, despite coastal regions only constituting 4% of global land cover.

UNSUSTAINABLE PATHWAYS

The development of infrastructure is at risk of becoming locked into unsustainable pathways that do not consider the dynamic nature of the environment. Developers and stakeholders are likely to focus on protecting and maintaining their existing assets, which hinders expansion into more sustainable methods. Therefore, they will face the ever-increasing cost of continually responding to the extreme events that are expected to occur as the climate changes, instead of developing a resilient community that can adapt to the challenges of the future environment. This has already been observed in the use of "hard" approaches to erosion, which are short-term and, as stated above, are likely to delay or relocate the problems they were implemented to solve. These methods are expensive to implement and maintain, which, along with the environmental issues they contribute

The team observed and simulated 16 years (1999 to 2015) of erosion at Happisburgh.



to, render them unsustainable in the long-term. There is a need to implement sustainable coastal management practices and develop adaptable and resilient communities that will be able to respond to the changing planet in an environmentally friendly manner. To do this, it is important to predict how long-term processes might affect and geomorphologically change coastal systems in the future by employing models that simulate and predict this.

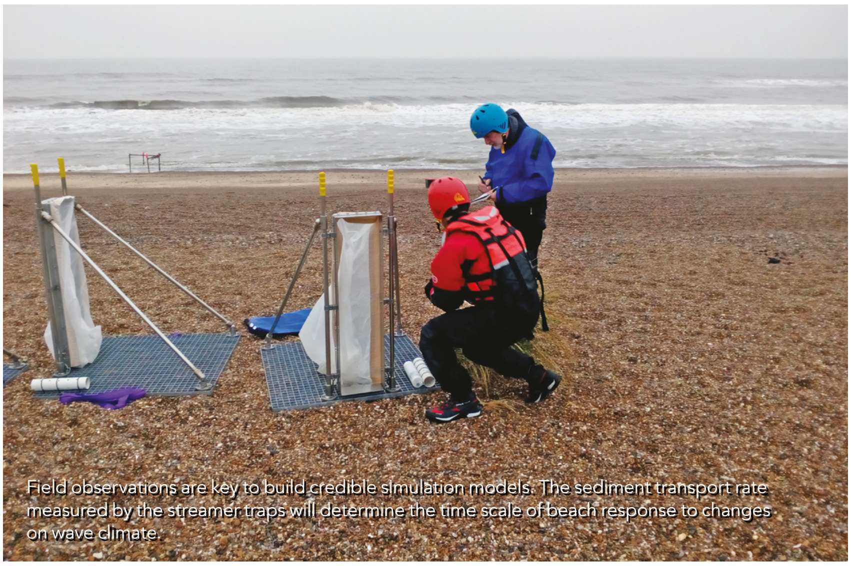
MODELLING THE FUTURE

Models are extremely useful tools for examining processes and systems which occur over large spatial and temporal scales that we cannot directly observe. They can be used to simulate future scenarios and ultimately inform decision makers and stakeholders during investment, planning and construction; models are vital for sustainable development. Dr Payo's work focuses on coastal system models which simulate and predict processes such as waves, tides, hydraulics and sediment conservation. He uses these models to inform investors of likely geomorphological change over the upcoming decades so that it may be considered during the development of coastal infrastructure.

Four main types of models are applied to coastal systems, which include conceptual, physical, numerical and statistical methods. Each of these modelling methods has its own advantages and disadvantages when they are applied to a coastal system, yet all four are vital in research. Conceptual models represent a system based on its key components, and while they are useful for visualising the processes that occur in their respective system, they cannot predict the changes caused by these processes within a location or time-scale. Physical models are recreations of processes and systems at an observable scale (for example, they may include small scale-versions of large-scale systems), and allow the observation of events that cannot be modelled in other manners. However, differences between the scale of the modelled and actual systems may affect the results. Numerical models can easily and cheaply simulate changes in a coastal system due to storm events. However, they are less adept at modelling slow changes under non-storm conditions. Finally, statistical models build on data from the past to identify and assume trends and cycles that can then be used to forecast future conditions. However, the coastal system is dynamic and ever-changing, and the future may not necessarily follow the patterns of the past.

This work is fundamental if we are to continue sustainably using the resources that coastal environments offer us.

Combining different types of modelling approaches may be a more prudent method of forecasting system-wide coastal change which is vital for informing developers exploring sustainable development and intervention strategies. Dr Payo's modelling tool, CoastalME, can simulate the geomorphological change of a coastline over several decades while considering interactions between different landforms and human activity. This work is fundamental if we are to continue sustainably using the resources that coastal environments offer us without damaging and hindering natural processes.



Field observations are key to build credible simulation models. The sediment transport rate measured by the streamer traps will determine the time scale of beach response to changes on wave climate.

Behind the Research

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Research Objectives

Dr Payo's area of expertise lies in modelling geomorphic coastal change.

Detail

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Bio

Dr Andres Payo is a Coastal Geomorphologist at the British Geological Survey and specialises in quantitative geomorphology applied to coastal protection against flooding and coastal erosion at decadal and longer time scales. Using the systems of systems approach, he is interested in the use of long-term analytical capacity to avoid maladaptation of long-lived infrastructure systems.

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Personal Response

What changes to coastal communities do you foresee in the upcoming years?

" I foresee coastal communities becoming more adaptable and resilient to coastal geohazards such as coastal flooding and coastal erosion. For places where reallocation of people and assets is a viable option, I will expect a transition from traditional "hold the line" management to a more resource-efficient, working-with-nature approach. Citizens will become more aware of the trade-offs between removing coastal defences at places, allowing some erosion to occur that will feed the nearshore with sediments that build beaches downstream which reduces the risk of flooding and coastal erosion naturally. For places where reallocation is not an option, citizens will have to learn how to live with occasional flooding and make investments knowing that risk levels today will be different than in the future. "

What do you most enjoy about your work?

" What I most enjoy about my work is working across a broad range of disciplines for the public good. Being the only scientist in my family, I have been always keen on putting research into practice and therefore I share the BGS core values of knowledge, impartiality and societal impact. The expertise within BGS allows me to work on areas as different as landscape evolution modelling, quaternary geology and shallow geophysics among others. "