LONG TERM EVOLUTION OF INCISED COASTAL CHANNELS ON THE ISLE OF WIGHT, UK: INSIGHTS FROM NUMERICAL MODELLING

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1. Introduction

Incised coastal channels or coastal gullies are found in numerous locations around the world where the shoreline morphology consists of cliffs. The coastal gullies found on the Isle of Wight are known locally as 'Chines' and debouche (up to 45m) through the soft cliffs of the south west coast. The base level of the Chines is highly dynamic, with episodes of sea cliff erosion causing the rejuvenation of the channel network. Consequently a key factor in Chine evolution is the relative balance between rates of cliff retreat and headwards incision caused by knickpoint migration. Specifically, there is concern that if contemporary coastal retreat rates are higher than the corresponding rates of knickpoint recession, there will be long-term a reduction in the overall extent of the Chines and their associated habitats.

Despite the wealth of literature concerning incised channels in general (e.g. Schumm et al. 1984; Darby and Simon, 1999) there are only a few studies that focus on coastal incised channels (e.g. Schumm and Phillips, 1986; Burkard and Kostachuk, 1995) and only one (Flint, 1982) that specifically focuses on the incised coastal channels found on the Isle of Wight, which are the subject of this study. The lack of scientific literature concerning such features is somewhat surprising given that they are of great geomorphological significance and exhibit fundamental differences in their development compared to other incised channels. In an attempt to provide a long-term context for these issues, in this paper we explore the Holocene erosional history of the Chines using a numerical landscape evolution model. Of particular interest is the question of whether the channels are relic components of an incised channel system that has now been truncated by coastal erosion during Holocene sea-level rise, or whether the channels are actively incising in response to base-level changes forced by shoreline cliff retreat. In the case of the former scenario, ancillary questions relate to the extent to which the incision was associated with low sea-level stands or climatic shifts.

2. The study site

The incised coastal channels that are the focus of this study are located along the south west coast of the Isle of Wight, located just off the southern coast of England. The shoreline consists of soft cliffs of sands, shales and marls which vary in height from 15m to 100m and which are retreating at rates of up to 1.5m a^{-1} due to a combination of wave erosion and landslides. This coast is divided into several low-order drainage networks that flow to the sea through deeply incised valleys, known locally as 'Chines'. The combination of deep incision, which provides a sheltered environment, and unstable side-wall surfaces provides unique habitats that support a diverse range of rare flora *(Philonotis marchica, Anthoceros punctatos)* and fauna *(Psen atratinus, Baris analis, Melitaea cinxi)*. An understanding of the historical geomorphic evolution of the Chines therefore underpins the long term management of the associated biodiversity.

3. Modelling

Current landscape evolutions models do not include process representation of the interactions occurring at the terrestrial-marine boundary. In the case of the Chines it has been established that cliff retreat and sea-level change have important implications for the development of the features (Leyland and Darby, 2005), although the long term connotation of these relationships is not known.

3.1. Process representation and parameterisation

In an effort to explore these drivers of development the model GOLEM (Tucker and Slingerland, 1994, 1996, 1997) was used in conjunction with custom codes that perform the various supplementary functions of interest. These included a cliff recession function that controls the position of the Chine outlet boundary, a sea level change routine and a climate change module, observable in the model as a dynamic effective precipitation value. Although cliff retreat rate is governed by a mean user defined value, actual recession events occur stochastically. Sea-level rise in the area is well documented throughout the Holocene (e.g. Waller and Long, 2003), however climate change is not and in order to obtain a dataset spanning the Holocene, average rainfall from the last 50 years was multiplied by a normalised climate index as derived by Coulthard et al. (2002). GOLEM simulates knickpoint recession in the Chines using a detachment-limited channel erosion law (1) wherein erosion rate (E) is a power function of drainage area (A) and stream gradient (S) with model parameters (k, m and n) defined using empirically-derived data.

$$E = kA^m S^n \qquad (1)$$

The model also includes representation of mass wasting processes such as threshold landsliding, a mechanism of widening observed to occur in the Chines as a response to channel incision.

3.2. Model setup

A MATLAB script was written that controlled the run time and parameter setup for GOLEM, as well as calling a user defined combination of the custom process functions. A typical model loop thus consisted of running GOLEM for a short time (e.g. 50 model years), then operating a combination of one, two or all of the custom functions before running GOLEM again with the updated inputs and parameters. The loop was then repeated until a pre-defined model run time (in the following scenarios 10,000 years) was reached.

4. Results

In order to explore the Holocene evolution of the Chines a range of scenarios relating to the key drivers (cliff recession and climate change) of their development were modelled. The simulation in which realistic conditions were reproduced (Fig. 1) broadly replicated observed incised coastal channel morphologies. This suggested that a degree of confidence could be placed in the modelling process and the next stage was to begin to elucidate which of the combined drivers exerted the most significant control on the formation of the features.

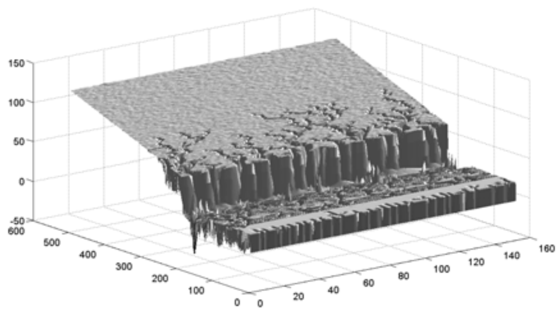

Fig. 1. Scenario 1: Realistic Holocene changes in sea-level rise, cliff retreat and climate variation.

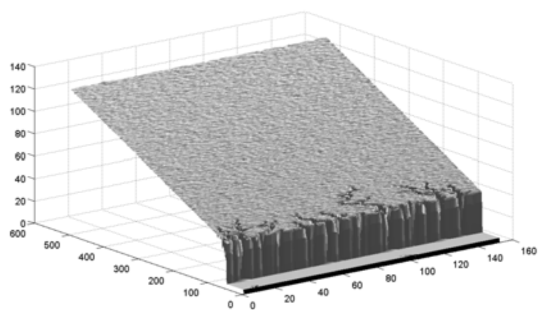

Fig. 2. Scenario 2: No coastal erosion and half the realistic effective precipitation.

A scenario matrix was devised that allowed the effects of parameter value changes in a single process function and across a combination of the three to be evaluated. Fig. 2 reveals that a 50% reduction in the effective precipitation throughout the Holocene inhibits the development of the gully network, as does an increase in the rate of cliff recession (Fig. 3). In the latter case the gullies are destroyed as they cannot incise at a rate equal to or greater than that of the cliff recession.

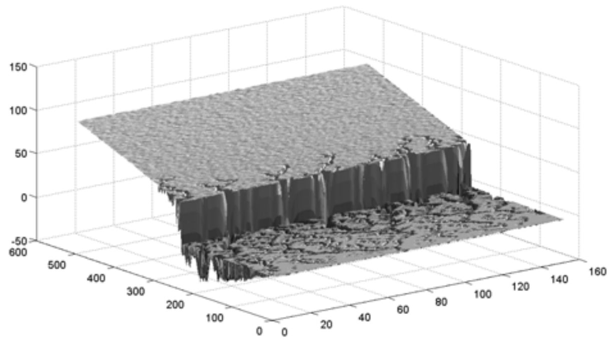

Fig. 3. Scenario 3: Constant effective precipitation of 10^3mm a^{-1} with cliff erosion of 1m a^{-1}.

5. Conclusions

Moderate rates of effective precipitation induce a realistic incised channel network, providing there is a step cliff profile present. Such a step profile is shown to be produced by sea-level rise and associated cliff retreat, however the modelling reveals that high rates of cliff retreat destroy the networks.

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