# Assessing Changes in Palaeo-Coastal Morphology Using 3D Surface Modelling

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*The model discussed in this paper was developed as an illustrative tool for Wessex Archaeology as part of a wider study of the South coast of England. This paper is an examination of methods used for combining multibeam bathymetric data with SRTM topography data to produce a single 3D surface model. The primary use of this model has been to study changes in coastal morphology although it has also proved effective in mapping dendritic systems. Issues regarding the accessibilty of surface models to a wider audience are also discussed.*

*Keywords:* 3D, Fledermaus, palaeo-landscape, submerged landscape.

## 1. Introduction

This project was the result of an intuitive development process which started out as a request for a simple illustration. The desire was to represent the topography of the submerged landscape of the South coast of England alongside the current terrestrial landscape without biasing potential readers with a coastline (Figure 1). This was done in order to go beyond concepts of submerged landscapes and instead to represent a total ancient landscape (COLES, 1998; FISCHER *et al*., 2010; GAFFNEY *et al*., 2007).

This process led to discussions on how landscapes are represented in archaeological literature and further uses for this model. This paper will go through the development process, focusing on data sources, how the data was edited and issues pertaining to how the datasets are now represented.

This project started out to address specific requirements raised during Wessex Archaeology's involvement in the South Coast Regional Environmental Characterisation, commissioned by the Marine Environment Protection Fund. In addition to fulfilling these requirements, wider issues regarding the modelling of submerged landscapes raised by WESTLEY *et al*. (2004) were used as a standard from which to work. The end result was by no means a perfect representation of the ancient South coast and the limitations of this model will also be discussed.

## 2. Aims

The aim of this presentation is to look at how modelling techniques widely used in marine geophysics can be adapted to further our understanding of what are now partially submerged palaeo-landscapes. In addition to looking at the methods used to produce the model, this paper also looks at what data can be incorporated, and how to make it as accessible as possible for archaeologists that are not familiar with the programs used to create it.

## 3. Methods

This model was developed using IVS Fledermaus (v.6.7, later v.7), a suite of software designed around the preparation, analysis, and presentation of data used in 3D visualisation and surface modeling. This includes gridding data (Average-gridder), editing readings within PFM files and producing 3D surfaces (DMagic and Fledermaus). Within archaeology, Fledermaus is usually used to analyse bathymetric datasets obtained as part of a wider survey, often including sidescan sonar and magnetometry data. As part of an integrated archaeological survey it can be used to study wreck sites and associated seafloor disturbances. In this case, however, the aim was to incorporate both terrestrial and marine topography into a large scale landscape model.

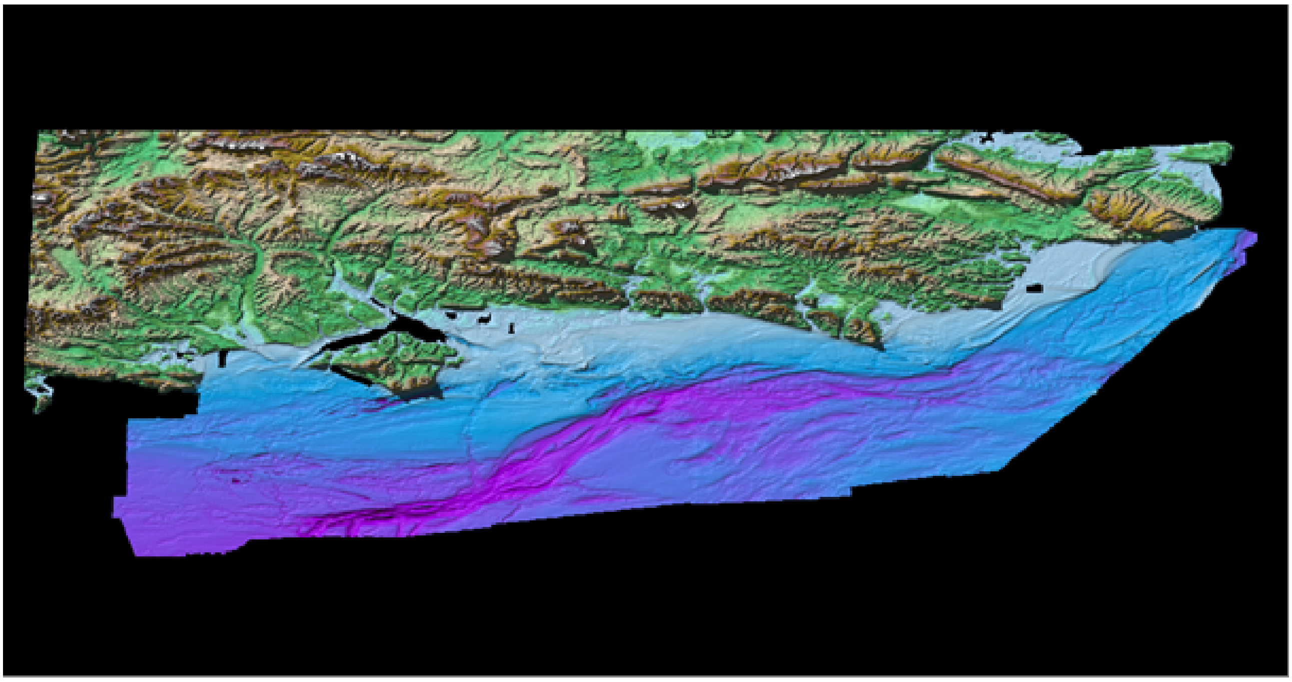

**Figure 1:** *An image of the model developed for the south coast of England highlighting the modern coastline around the Isle of Wight.*

### 3.1. Creating the base model

Shuttle Radar Topography Mission (SRTM) data, with a digital elevation model (DEM) of 90m resolution, was obtained for zones 36_02 and 37_02 (srtm.csi.cgiar.org). This dataset uses mean sea level as its datum and includes some of the intertidal zone. The data were then converted into a PFM file using a Bin size of 100m and a vertical resolution in metres. Once the PFM was created it was possible to edit the dataset as a 3D model in Fledermaus. This allowed the required section of the South coast of Britain to be selected.

The PFM format also allowed individual soundings from the inter-tidal zone to be deleted in order to reduce the influence of land reclamation on the model. This was done by consulting United Kingdom Hydrogrphic Office charts and noting the mean high water spring (MHWS) and the mean low water spring (MLWS) sea levels at 19 locations along the south coast of Britain. These values were used to obtain means for the entire south coast at both MHWS (4.9m) and MLWS (0.7m). The soundings in the SRTM PFM which fell between these values could then be rejected to remove the inter-tidal zone. As the vertical resolution of the PFM was only set at metre accuracy, this range was changed to include all *z* values greater than 0m and less than 5m. Once the PFM had been edited, the remaining soundings were then re-exported as an '*xyz*' file.

Since the SRTM data used mean sea level (MSL) at 0m, it was necessary to adjust the bathymetric dataset which used Chart Datum (CD) for 0m. The bathymetric dataset was obtained as part of a regional environmental and characterisation (REC) assessment carried out by the British Geological Survey (BGS), with a cell size of roughly 100m. In order to convert from CD to MSL, the difference between the MHWS and MLWS values (4.9m) for the south coast was divided by two (2.1m) and added to the CD *z* values.

Once both the SRTM and bathymetric datasets were in the same scale, the *xyz* values were put into the Average-gridder program and converted into a single digital terrain map (DTM). In order to fill the spaces created by editing out the inter-tidal zone it was decided to create a new surface based on surrounding soundings. This was done by reducing the resolution of the DTM by increasing the line weight diameter and cell size used. After a process of trial and error, a weight diameter of 8 and a cell size of 0.0015 degrees were chosen as the best balance between surface integrity and detail.

### 3.2. Adding colour

The DTM was then put into DMagic where it could be coloured and shaded to produce '.sd' files. The first colour map developed for this area used a blue scale to emphasize topographical features without differentiating between land and sea (Figure 2). These features were further enhanced by using strong shadows and high levels of vertical exaggeration while shading.

The model was then developed to make it more accessible to those not familiar with Fledermaus. Two sets of contours were created, the first for a detailed look at features in plan while the second used fewer intervals for a more regional interpretation.

In addition to contours, the colour maps used were also adapted to improve accessibility. These included greyscale images and a colour map, similar to that used by COLES (1998) when illustrating Doggerland. A colour map was then developed using a similar scheme to UKHO charts (yellow: >10m; green: 0 - 10m; blue: -5 - 0m; light blue: -10 - -5m; white: <-10m). Soft shading

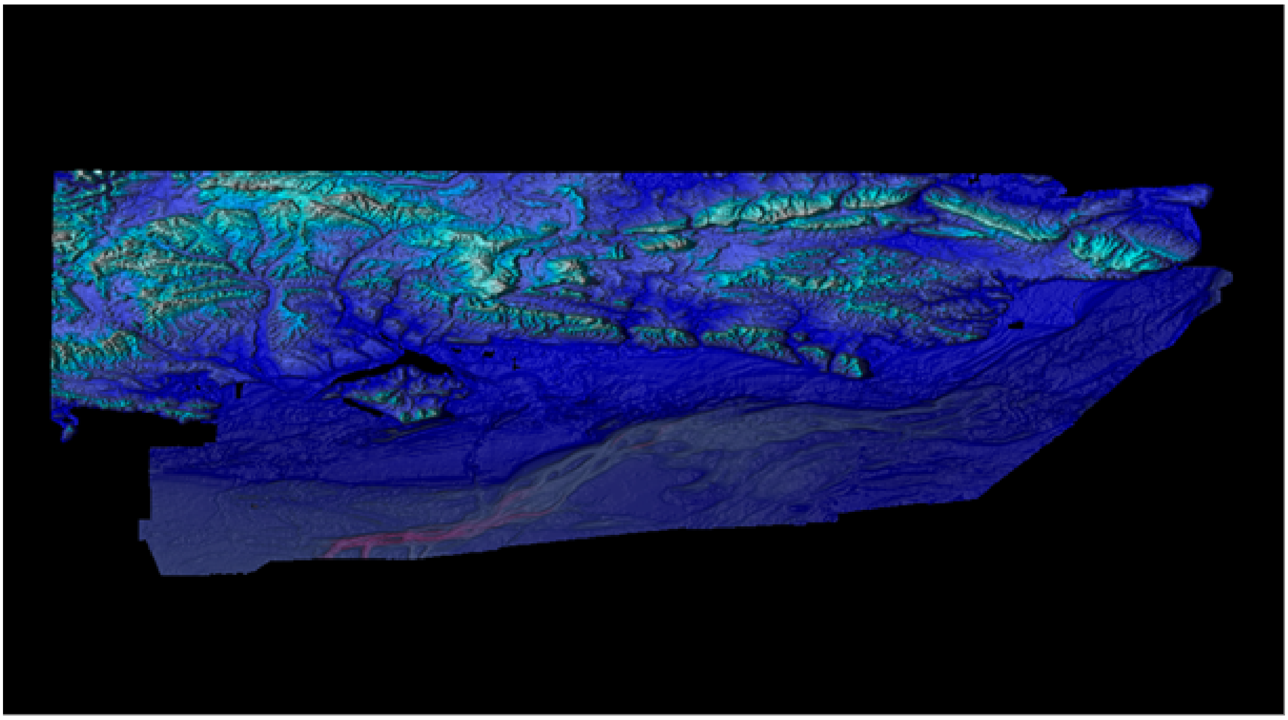

**Figure 2:** *South Coast model focusing on topography and removing the differentiation between land and sea.*

and low vertical exaggeration were used to reduce the impact of topography on the image (Figure 3). By combining the contours with the chart colour map it was possible to produce images using a widely recognised notation and thus hopefully improving accessibility.

By using the chart colour map, but reducing the values by 5m increments, it became possible to emphasize features at increasing depth. This also provided a rough estimate of changes coastal morphology at levels ranging from 5m below MSL to 60m below MSL.

If desired a layer could also be added in Fledermaus at a specific depth to act as an artificial sea.

### 3.3. Incorporating historic sea-levels

Once a method for illustrating changes in sea-level had been developed existing sea-level curves could be input into the model to illustrate coastal morphology for given periods (FUNNELL, 1995; JELGERSMA, 1979; SIDDALL *et al*., 2003; WESSEX ARCHAEOLOGY, 2008). Local sea-level curves were used for renditions of the more recent palaeo-landscape, while less accurate global sea-level curves were used for further back in time.

It was possible to calibrate the model at roughly 10,000 years before present using vibrocore data. This was obtained from a project conducted by Wessex Archaeology in the Arun channel (WESSEX ARCHAEOLOGY, 2008). Peat deposits within the vibrocores provided environmental information and specific sea-level data, which could be dated to within a relatively short time span using carbon dating (Figure 3). This allows the a specific sea level to be dated from between 9131 +/- 45 to 9629 +/-50 years BP.

### 3.4. Defining dendritic systems

River features were also added to the model in order to emphasize the dynamic aspect of the landscape (Figure 3). This was primarily achieved using the modern topography which forms the base of the model. There are several drawbacks with this approach. For example, since the locations of these rivers are based on a single topographic image, they cannot all be assumed to have been active at the same time.

Two methods were used to identify dendritic systems in the model. Both of these required a two dimensional raster image which could be used in ArcGIS. The first method was to use the flow analysis tools in ArcGIS to produce a shapefile which could then be draped over the three dimensional surface in Fledermaus. This result was difficult to adjust, however, in order to follow the paths of known palaeo-channels.

The second method involved drawing in the dendritic systems by hand in ArcGIS. This was done by tracing river valleys and under filled valleys from a raster image of the topographic model. The locations of the under filled valleys could then be compared to known palaeo channels identified in seismic data acquired from a number of projects conducted by Wessex Archaeology in the region. The resulting shapefile could then also be draped on the three dimensional model. This method produced a model which was much easier to edit and adjust to coincide with sub-bottom data and previous work in the region (GUPTA *et al*., 2007; WYMER, 1999).

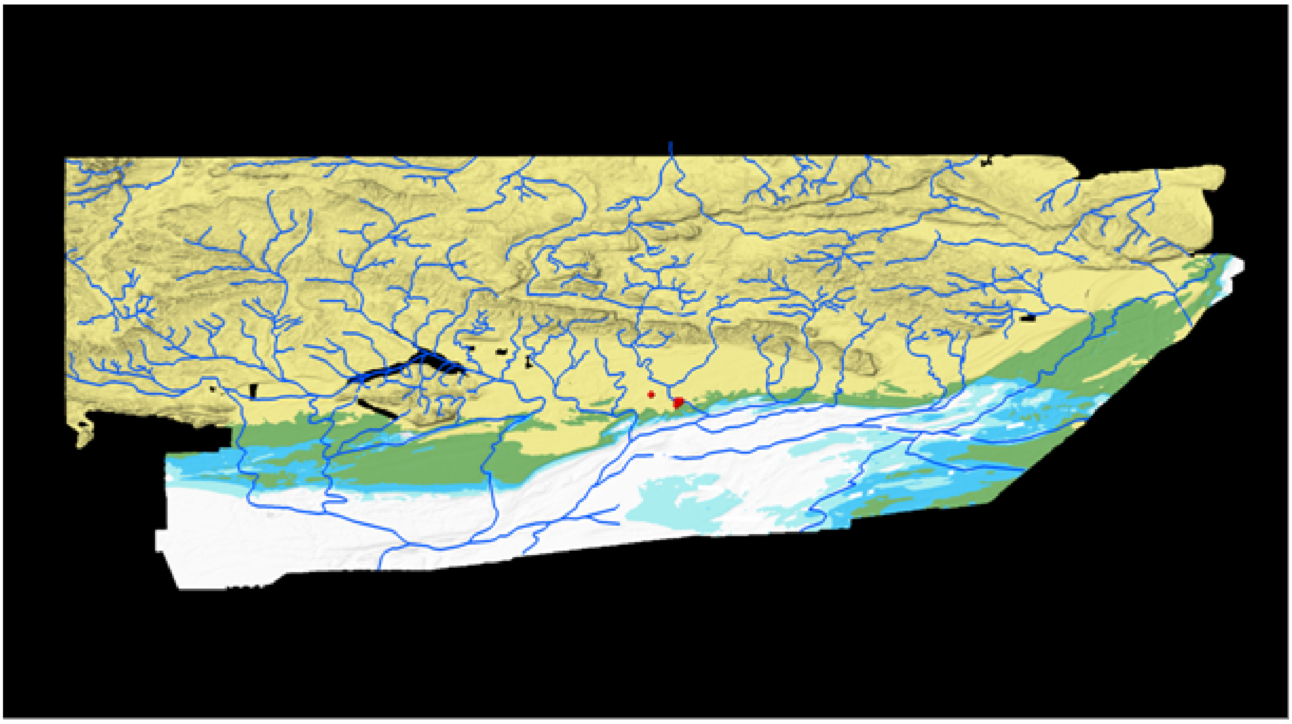

**Figure 3:** *South coast model using the UKHO colour scheme at 35m below MSL, 9131 +/- 45 to 9629 +/-50 years BP. The dendritic system has been draped over the model and the red dots indicate the locations of peat deposits in the Arun channel.*

### 3.5. Editing modern features

A similar approach was attempted in order to study the coast of East Anglia and the southern North Sea. The depositional environment in this area is significantly different to that of the South coast of England. As a result, identifying submerged ancient features is much more difficult due to a combination of erosion and overlying modern features.

Among the obvious modern features are several large sandbanks at the northern limit of the bathymetry dataset. These are most likely the result of modern deposition and would significantly skew attempts to study the prehistoric landscape through GIS surface analysis, as well as being aesthetically distracting. It was therefore decided to try and remove these modern deposits and create a new surface similar to the surrounding topography.

This was done by creating a PFM of the combined SRTM and bathymetry data in DMagic, similar to that used for editing the inter-tidal zone of the south coast. This was used to edit out the largest of the sand banks down to a level roughly equal to the surrounding seabed. The remaining soundings were then exported and a new SD file created in DMagic. Dmagic also enabled the export of this SD file as an ArcView Grid file.

An MXD was then created and the ArcView Grid file imported into ArcMap and displayed as a raster image. A fishnet of points 500m apart was then created using the Fishnet tool in ArcToolbox (Figure 4). Depths were assigned to these points based on surrounding topography displayed as Fledermaus profiles.

These new depth points were then exported as an 'xyz' file and gridded with the SRTM and bathymetry datasets. A Weight Diameter of 3 and a Cell Size of 300m was chosen in order to fill the gaps left by the low density of data covering the removed sandbanks while maintaining surface detail.

## Conclusions

Once the model was developed it was possible to locate known archaeological sites in a landscape set at an appropriate sea level. Using slope analysis, topographic features associated with sites were identified and highlighted. With the regional model complete, it was a simple task to extract particular areas for isometric illustrations of archaeological sites (Figure 5).

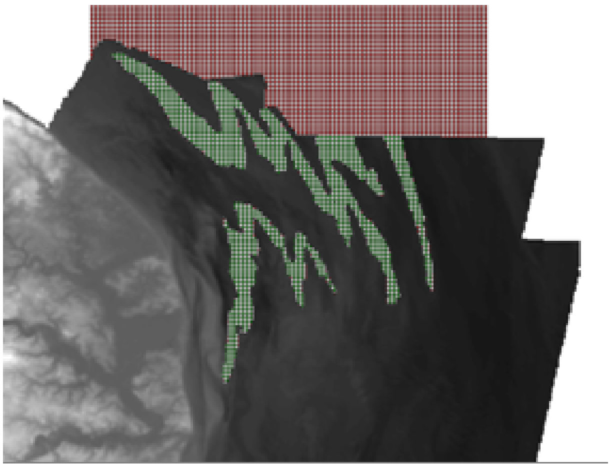

**Figure 4:** *Greyscale raster image of East Anglia with sand banks removed and visible fishnet displayed in ArcView.*

The issue of resolution is one that needs to be looked into further. Multibeam bathymetry data can gridded to a 2m resolution for some areas, although often not readily available for large areas. The Fledermaus platform allows for the easy incorporation of additional datasets, making it possible to expand areas of study and fill gaps where data were previously unavailable.

Although high resolution models are the ideal, they may not necessarily be required for a particular project and tend to be rather unwieldy for large area models. In the case of the surface model described here, high resolution was not a primary concern and, as described above, resolution was intentionally dropped as an editing tool. Further work should be done to compare flow analysis based on models gridded at different resolutions. It may be that if one is able to use considerably lower resolution models for identifying major water ways. On the other hand small differences in the final model may have large cumulative effects resulting in different drainage patterns. In the case of this model, the results of the flow analysis were checked against known river courses and palaeo-channels. This external check of the results has allowed for a reasonable level of confidence in the quality of the surface model.

There are certain areas which can still be improved. In particular it is important to note that despite changing the sea level we are always looking at modern topography. Although it would be difficult to rebuild features which have eroded away, it may be possible to remove some modern deposits.

This could be done by using a similar method to that used to identify palaeo-channels. Surfaces can be produced using points extracted from seismic datasets which correspond to bedrock. Unfortunately the quantities of these data are rather limited and are better suited to detailed local studies. The surfaces shown in seismic data are also difficult to date unless they have been sampled. This means that although modern deposits are removed the subsequent surface may not necessarily be a closer approximation to the palaeo-landscape. However, the use of sub-bottom data certainly provides us with a useful insight into the site formation processes at work and can help asses the limits of the model.

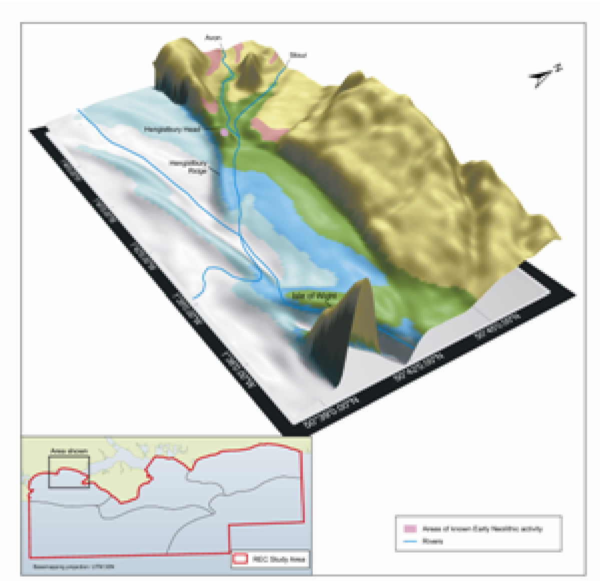


**Figure 5:** *Isometric view of Christchurch Bay highlighting Neolithic Hengistbury Head set at 5m below MSL.*

The use of seismic data certainly seems to hold high potential. Although it is currently best suited to smaller scale studies than the one attempted here, this could soon change. Advances in interpretative software and the volumes of data available may soon make it far easier to produce larger, more detailed surfaces from two dimensional sub-bottom records.

Models of this type are useful tools both for visualising past landscapes and for interpreting individual site locations. Although the model discussed here is limited to the South coast of England, there are existing SRTM and bathymetric data sets available for large parts of the United Kingdom. It is hoped that a similar approach may be used in these regions using the tools and techniques developed for the English South coast.

Bathymetric models have been used elsewhere to try and identify indicators of sea-level change (WESTELY *et al*., 2010). The approach presented here offers some possibilities on how these datasets might be edited to give and otherwise interrogated. It is hoped that techniques developed here may help produce closer approximations of the morphology of past landscapes. Being able to interrogate this model through flow analysis may also help identify otherwise unrecorded palaeo-channels. This may in turn influence our understanding of past settlement locations.

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