Modelling uncertainty in climate-induced sea level rise

[Excerpt only as this assignment likely to be set again for future MSc students]

INTRODUCTION

With IPCC (2007) predictions of a rise in sea levels of up to 89cm by the end of the 21st century, there is a strong incentive to model the vulnerability of coastal areas (particularly populated ones) to flooding and sea-borne damage. Traditional flooding models have focussed on short duration bursts and a dependency on slope, whereas flooding due to sea level rise is predominantly dependent on elevation ([REF]). This paper will address this by estimating (using Monte Carlo (MC) simulation methods) uncertainty in flooding location due to sea-level rise in an area of the Norfolk coast, based on 3 different Digital Elevation Models (DEMs):

Table 1: Comparison of Digital Elevation Models (DEMs) used

Digital Elevation Model (DEM)	Cell Size (m)	Height Resolution (m)	Height RMS Error (m)
OS Landform Panorama	50	1.0	5.0
OS Landform Profile	10	0.1	2.5
Environment Agency LiDAR	2	0.001	0.15

The bounding values of these 2007 IPCC sea-level rise predictions (11cm – 43cm) together with the 89cm possibility are shown (fig 1) extracted from these 3 DEMs and superposed over a base-map. Note that as the Panorama DEM has only 1.0m vertical resolution, only a +1m band is shown (close to 0.89cm). It is immediately apparent that as well as vertical resolution limitations, the large cell size of the Panorama DEM is poorly suited to mapping the relatively narrow river channel, whereas LiDAR DEM even highlights low-lying marshes.

.... (CUT) ...

MONTE CARLO SIMULATION METHODOLOGY

Because of the complexity of the shape of the coastal landscape and the gentle gradients, it is difficult to directly estimate how sensitive the range of areas flooded would be to DEM error ranges. Using the elevation RMS error data, MC simulations for each sea level rise, for each DEM were modelled in ArcGIS using a Python script (see Appendix).

....

.... raster calculations in ArcGIS are painfully inefficient (rasters get written to disk at almost every step!) Dramatic improvements might be achieved by performing more calculations within Python standard memory-based arrays (using the ArcGIS RasterToNumPyArray() function to translate). In this MC simulation, a uniform error distribution was used. However, ...

RESULTS

Considering each DEM in turn, maps are shown for each of the three sea level rises, indicating probability distribution of land remaining above sea-level. Thus to assess a 90% confidence level ignore red and orange pixels.

......

OS Landform Profile DEM

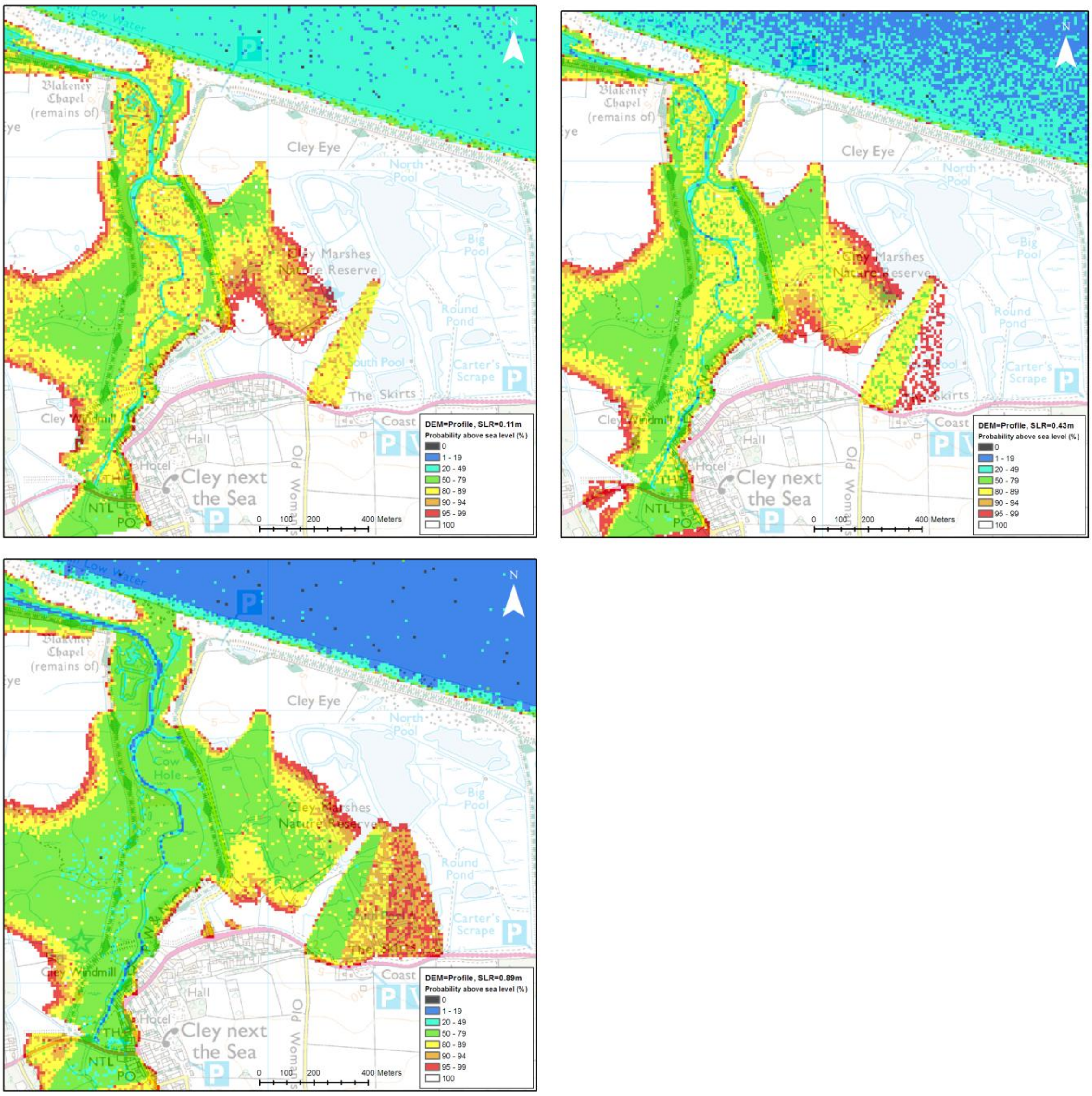

Figure 1: OS Landform Profile sea level Monte Carlo simulation results

More accurate 'Profile' data indicates more progressive change with sea level, swelling round the river channel. However, geometric artefacts are visible on the right, possibly due to errors from these maps being generated by digitizing paper maps followed by vector-to-raster conversions.

Environment Agency LiDAR DEM

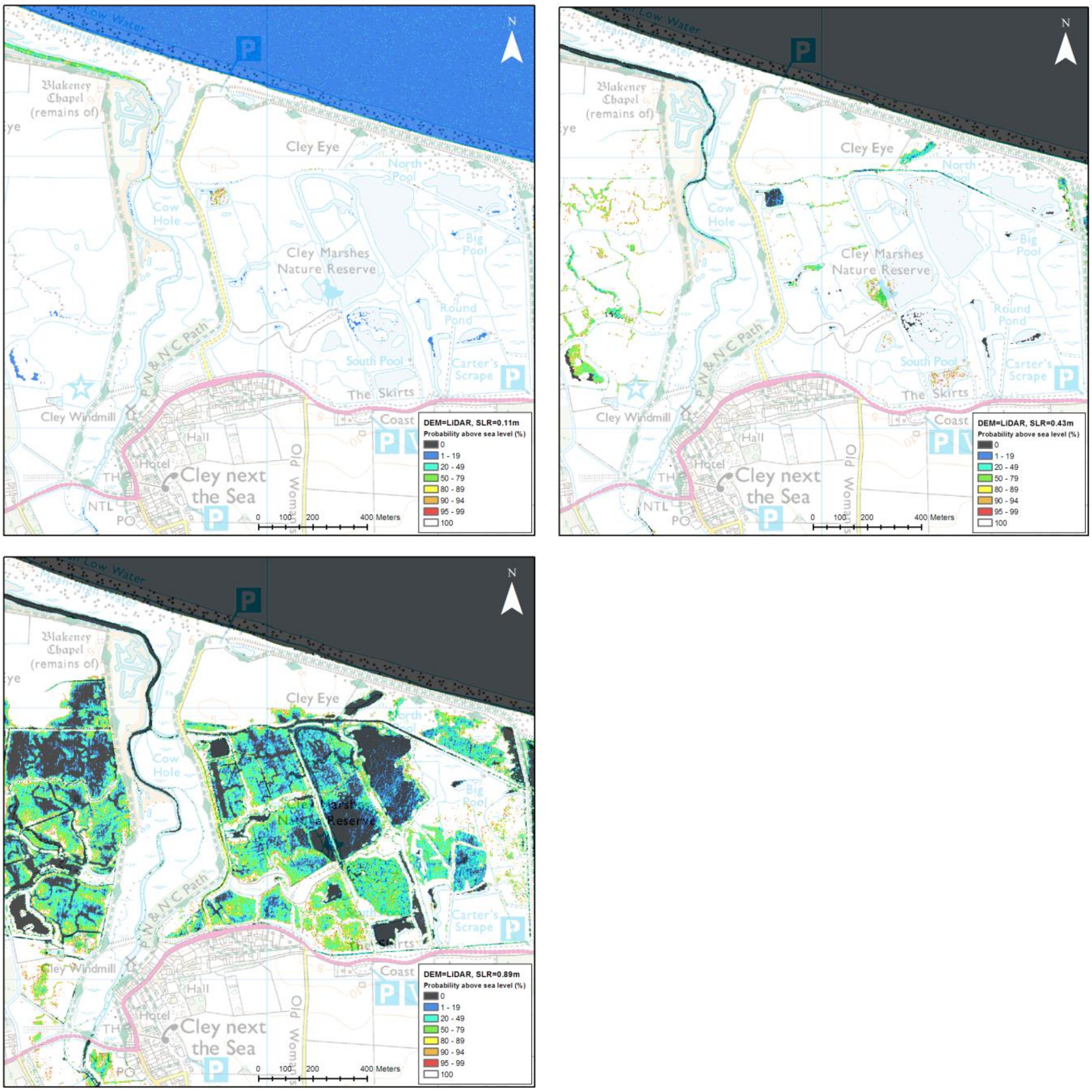

Figure 2: Environment Agency LiDAR sea level Monte Carlo simulation results

Conversely, the more accurate LiDAR data suggests the 2 lesser sea-level rises have limited effect. The 0.89cm rise highlights low lying marsh areas, suggesting potentially not a change of coastline as such, but perhaps a switch to predominantly saltwater rather than freshwater habitats.

ANALYSIS AND CONCLUSIONS

The LiDAR 0.89m SLR map shows the problem of using the "bath tub" method ([REF]) in which a grid cell is assumed flooded if below sea level: additional analysis of hydrological connectivity is required. However with rasters this can be problematic: 4-way pixel connections may under-estimate, whereas 8-way (diagonal) may over-estimate connectivity.

MC simulation can be helpful in assessing both probability of inundation and suitability of available DEMs – in the test region, the course resolution of the Landform DEMs were shown to be misleading.......