Prototyping mapping of flood protection structures form space using SAR time series and hydrographs

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Introduction

River embankments, dikes and levees provide essential flood protection, yet in many areas of the world embankment location and height are not recorded. As a result large scale hydrodynamic flood models can lack local relevance.

The objective of our study is to use a time-series of satellite data to infer the location of river embankments. In this proof of principle study, the River Bedford Ouse (Cambridgeshire, UK) is used as test location.

Methodology

- Process a sequence of Sentinel-1, data acquired during a single flood event, to detect flood extent. Apply cross-sections to the main channel, through this flood extent.
- Examine flood extent at each cross section to deduce embankment location. If flood extent stops expanding, but discharge continues to increase, an obstacle is preventing flood expansion. Figs. 1 & 2 illustrate the correlation between flood level and width.
- Distance from river to estimated embankment location is measured and a position error is estimated with validation data (e.g. manual interpretation of LIDAR data to locate structures).

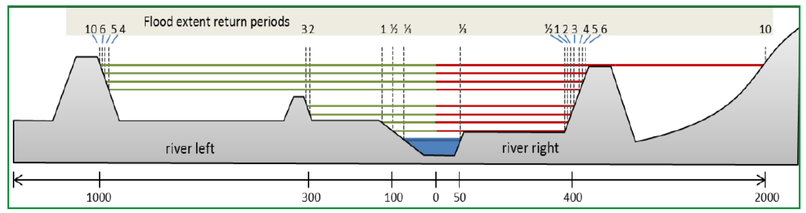

Figure 1 - *Cross-sections of flood extent (derived from remote sensing imagery) can indicate embankment location, left or right of river.*

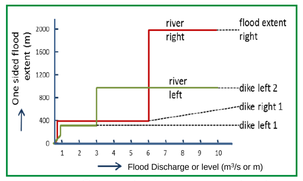

Figure 2 - *Conceptual diagram: extraction of embankment position from the relation between discharge/level and flood extent. Plateaus indicate presence of structures.*

Early results

Figure 3 – *Typical Sentinel-1 raw image*

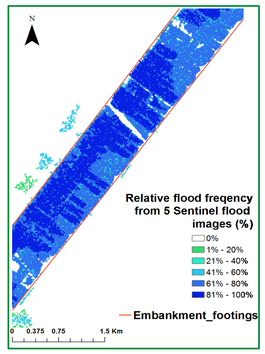

Figure 4 – *Relative flood frequency plot , red line indicates embankment location*

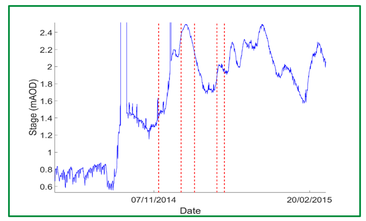

Figure 5 – *Hydrograph of water levels at Bedford Ouse in December 2014. Sentinel overpasses times are also shown in red.*

- Five flood extent maps were derived from a series of Sentinel 1a images for the flood of December 2014. An example raw satellite image is shown in Fig. 3.
- The processed 'relative flood frequency map' from these 5 data is shown Fig. 4.
- The hydrograph for this flood (Sentinel overpass times in red) is shown in Fig. 5

- Combining time series of Sentinel data, the inferred embankment location is located at maximum flood extent (Fig 6).
- The errors between the inferred and actual embankment locations are estimated and shown in Fig. 7

Figure 6 – *Error between estimated and actual embankment location is measured*

Discussion

This proof of principle work was successful in locating local flood embankments at a test location in the UK, using a time series of freely available satellite data.

Positional errors for right of bank (Fig. 7) suggest detection is on average 150m short of the actual embankment location, though many cross sections are closer.

Those with larger errors may be explained by the method allocating areas of water beyond the embankment location as flood edge (no breach of defences) or, equally, holes in the flood map indicating no flooding detected, where there is indeed water. This can be due to misdetection or masking of the water signal due to presence of vegetation and trees.

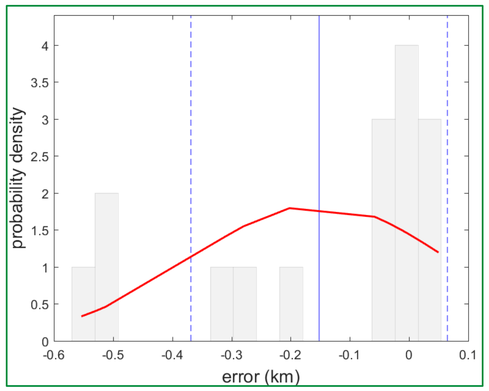

Figure 7 – *Histogram of embankment location errors: The red line is a normal distribution fitted to this data. The blue lines indicate mean (solid blue) and 1 standard deviation from the mean (dashed blue).*

The next stage is to use gauged data to constrain the flood detection algorithm, and examine potential to find embankment heights.