Abstract
How accurate are the flood maps that are meant to display the vulnerability of coastal areas to sea level rise? Such maps are now easily accessible and provide good illustrations of possible consequences of climate change (see Fig. 1), however there is no clear indication about their reliability, which makes them difficult to use numerically (e.g. for insurance companies). We propose to extend the concept of flood map using probability theory, and compute for each location the probability of flood rather than a binary flood flag. The main novelty is in providing a methodology for the computation of probability maps relying on Bayesian inference. As required by this approach, all quantities must be probabilistic, including the DEM. Having an uncertain topography helps to determine where the flood is likely to affect the land, and how likely it will occur, with a probability between 0 and 1.

Our contribution is in using the algorithm we have developed [2] that allows one to estimate an uncertain DEM from a stereo pair of digital images, rather than using off-the-shelf or commercial DEMs that are not provided with a spatial error map. The results we obtained from an image pair taken near Sines are shown in Fig. 2. The standard deviation map illustrates the spatial variability of the topographic reconstruction quality across the scene, emphasizing the lack of information in noisy or poorly textured areas. Not taking into account this spatial distribution in the flood map computation would produce inconsistent results.

Moreover, all the error sources could be combined in a rigorous way to produce hazard maps, for instance by integrating the effects of both probability distributions of elevation and sea level rise, the latter quantity also being uncertain. For instance, probabilistic flood maps for a given date could be inferred from all the available stereo image data sets and the sea level rise models, the error propagation helping to minimize the loss of information during all the required data processing steps.

Fig. 1 – Simulated flood map for the Sado estuary © Google, topographic data provided by NASA (http://flood.freetree.net). The dashed area corresponds to a sea level rise of 3m.
Fig. 2 – (a) and (b) aerial stereo images provided by Municipia SA, (c) reconstructed disparity map showing the topography, (d) error map or standard deviation in pixels [black=0, white=2]

SUMMARY
Flood maps are usually computed by thresholding digital elevation models (DEM) without taking into account errors on the topography. Even if scientists wish to do so in the future, the only information about DEM uncertainty available now is a RMS error at best. Thus, we propose to use our recent work on uncertainty estimation, allowing us to reconstruct a DEM and the spatial distribution of errors as well. Indeed, relevant flood maps can be derived rigorously if the elevation data comes with error bars. Flood probability maps could be directly computed, either for predefined sea levels, or for uncertain sea level rise predictions coming from global climate change models. The Bayesian framework allows for a rigorous management of various error sources so as to produce physically meaningful vulnerability maps. We plan to apply this methodology to several test sites on the portuguese coast using high-resolution digital aerial imagery.