A comparison of remotely sensed elevation data sets for flood inundation modelling

Wilson, M.D., Atkinson, P.M.

Department of Geography, University of Southampton,
Southampton SO17 1BJ
matt.wilson@soton.ac.uk

Hydraulic models of overland flow allow river discharge to be related to flood inundation extent, and provide the capability to simulate flooding based on a scenario discharge. By far the most important boundary condition for such models is surface elevation. Floodplain topography is the principal variable that affects the movement of the flood wave, and the prediction of inundation extent. Land surface height data are, thus, a critical input to a hydraulic model of flooding, controlling the flow of water across the floodplain. The greater the detail represented in the land surface data, the greater the accuracy possible in predicting flood inundation extent.

Remote sensing is able to provide spatially distributed measurements of surface elevation. However, unlike traditional surveying methods, remotely sensed elevation may contain surface features such as buildings or vegetation. These features may be desirable as they affect the movement of the flood wave (e.g. buildings). However, any surface feature which does not prevent the flow of water should be removed from the elevation data. This may be achieved in data of a fine spatial resolution using interpolation algorithms such as kriging (Lloyd and Atkinson, 2000).

The spatial resolution and vertical accuracy of different elevation data sets vary greatly, and can produce significant differences in model output. This has implications for the routine use of flood inundation models for flood risk assessment. It is, therefore, important to assess the suitability of the different elevation data sets available for use with flood inundation modelling.

In this paper, three remotely sensed elevation datasets were used to predict flooding: (i) Light Detection And Ranging (LiDAR), (ii) stereo photogrammetry, and (iii) repeat-pass ERS interferometric SAR (InSAR). A summary of the data used is given in Table 1.

Table 1. Summary of data used.

Elevation	**Source**	**Spatial resolution (m)**	**Cost for this research (academic rates)**	**Platform**	**Coverage**
LiDAR	Environment Agency	2	8 km2 was obtained free of charge for this paper (£800 + VAT per km2 otherwise).	Airborne	Limited
Photogrammetry	Infoterra	10	£680 + VAT for 34 km2	Airborne	Limited
Interferometric SAR	Landmap	25	No cost to UK academia	Satellite	Global

Airborne LiDAR is a pulsed laser system that records the time-varying amplitude of the laser backscatter wave from the Earth's surface (Bufton *et al*. 1991, Richie 1995, Richie *et al*.

1996, Richie 1996). Aircraft position is predicted using a differential GPS receiver. LiDAR data have an extremely fine spatial resolution and may, therefore, be considered to be the most appropriate source of data for flood inundation modelling. In the UK, the Environment Agency fly LiDAR on a regular basis, and provide data at a reduced price for academics. However, the availability of LiDAR data remains limited and the cost relatively high.

Photogrammetry is a well-established technique capable of producing elevation data from stereo aerial orthoimagery which may be an acceptable alternative to LiDAR data. The spatial resolution of the data is determined by the flying height of the aircraft. In this case, data with a moderate spatial resolution of 10 m were available.

InSAR is also a well-established technique (e.g., Bamler and Hart, 1998; Rosen *et al*., 2000) capable of producing elevation models. InSAR exploits the phase differences of two or more SAR images acquired from different orbit positions, possibly at different times. The phase difference is essentially related to the geometric path length difference for each point in the images, which depends on surface topography. The altitude of each point in the image can, therefore, be predicted using knowledge of the interferometer geometry. Data used here were provided by the Landmap project at a spatial resolution of 25 m.

InSAR was compared to Ordnance Survey Land-Form PROFILE data by Wilson and Atkinson (2002). Flooding was predicted using both datasets on the River Nene, Northamptonshire. Neither dataset was found to be ideally representative of the floodplain surface. The spatial resolution of the InSAR data (30 m) resulted in numerous “mixed pixels” of above surface features. This limited the ability of the model to produce a smooth prediction of inundation, and may limit the use of the data to areas where there are relatively few above-surface features.

In this paper, LiDAR and photogrammetric elevation were used as an alternative to InSAR data for modelling flood inundation on the Avon river, Hampshire, England. Each dataset was used to predict flood inundation for a 60 day event during a series of major flooding which occurred in the UK in Autumn 2000. Both alternative datasets are provided by airborne remote sensing and have a finer spatial resolution than the InSAR data. The expected utility of the data may, therefore, be greater.

Predictions were conducted using the LISFLOOD-FP flood inundation model (Bates and De Roo, 2000, De Roo et al., 2000, Horritt and Bates, 2001). The 1D linear kinematic Saint-Venant equations were applied within the channel, and flow on the floodplain was approximated using a flow-continuity equation. Change in the volume of water in a cell over time is equal to the fluxes into and out of it. Flow rates were calculated based on the height of the water surface above the land, and the Manning friction coefficient.

Three phases of modelling were undertaken. Firstly, the LiDAR and photogrammetric data were coarsened to a spatial resolution of 25 m to facilitate direct comparison with InSAR data. Secondly, surface features were removed from the LiDAR and photogrammetric data prior to modelling at 25 m. Thirdly, LiDAR and photogrammetric elevation data were used to model flooding at a spatial resolution of 10 m, using both the original LiDAR data and after the removal of surface features.

Predictions using each elevation dataset were compared to aerial photography of flooding acquired close to the flood peak. The most accurate prediction of inundation was obtained using the LiDAR data (after the removal of above surface features), followed by photogrammetric data.

References

BAMLER, R., HART, P. (1998) Synthetic aperture radar interferometry, *Inverse Problems,* **14,** R1-R54.

BATES, P.D., DE ROO, A.P.J. (2000) A simple raster-based model for flood inundation simulation, *Journal of Hydrology,* **236,** 54-77.

Bufton, J. L., Garvin, J.B., Cavanaugh, J.F., Ramos-Izquierdo, L., Clem, T.D., Krabill, W.B., 1991, Airborne lidar for profiling of surface topography, *Optical Engineering,* **30,** 72-78.

DE ROO, A. P. J., VAN DER KNIJFF, J., SCHMUCK, G., BATES, P. (2000) A simple floodplain inundation model to assist in floodplain management, In *New Trends in Water and Environmental Engineering for Safety and Life: Eco-compatible Solutions for Aquatic Environments,* Balkema, Rotterdam.

HORRITT, M. S., BATES, P.D. (2001) Predicting floodplain inundation: raster-based modelling versus the finite element approach, *Hydrological Processes,* **15,** 825-842.

LLOYD, C.D. AND P.M. ATKINSON (2002) Deriving DEMs from LiDAR data with kriging, *International Journal of Remote Sensing* (in press).

RITCHIE, J. C. (1995), Airborne laser altitude measurements of landscape topography, *Remote Sensing of Environment,* **53,** 91-96.

RITCHIE, J. C., MENENTI, M., WELTZ, M.A. (1996), Measurements of land surface features using an airborne laser altimeter: the HAPEX-Sahel experiment, *International Journal of Remote Sensing,* **17,** 3705-3724.

RITCHIE, J. C. (1996), Remote sensing applications to hydrology: airborne laser altimeters, *Hydrological Sciences- Journal -des Sciences Hydrologiques,* **41,** 1996.

ROSEN, P. A., HENSLEY, S., JOUGHIN, I.R., FUK K. LI, MADSEN, S.N., RODRIGUEZ, E., GOLDSTEIN, R.M. (2000) Synthetic Aperture Radar interferometry, *Proceedings of the IEEE,* **88,** 333-382.

WILSON, M.D., ATKINSON, P.M. (2002), The use of elevation data in flood inundation models: A comparison of Landmap and Ordnance Survey Land-Form PROFILE, *Proceedings of the 10th annual conference on geographical information systems research UK (GISRUK).*