Towards improved urban flood detection using Sentinel-1: dependence of post- to pre-flood double scattering cross-section ratio on building orientation.

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. High resolution SAR sensors are now commonly used for flood detection for operational flood incident management and flood forecasting.

. Automated detection tends to be limited to rural areas owing to the complicated backscattering mechanisms occurring in urban areas.

Urban flood detection using Sentinel-1 and WorldDEM data

. We’ve recently developed a method for detecting urban flooding using Sentinel-1 and WorldDEM DSM data (1).

- change detection technique that estimates flood levels using pre- and post-flood images.

- searches for increased SAR backscatter in post-flood image due to double scattering between water and adjacent buildings, compared to that in pre-flood image where double scattering is between unflooded ground and adjacent buildings (increase occurs because permittivity of water is higher than that of unflooded ground).

- local flood level estimated from DTM heights at flooded and unflooded double scatterers near flood edge.

- assumes flood depth is small compared to building heights.

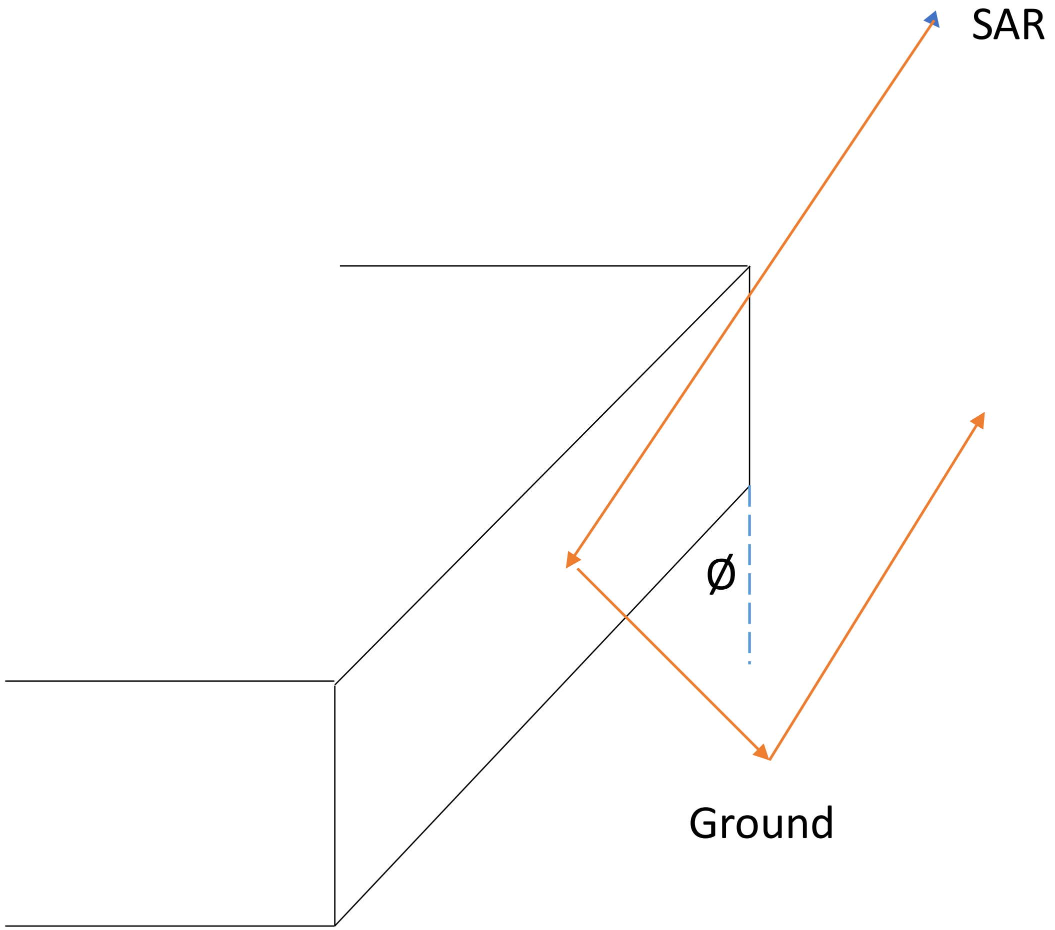


Fig.1. Double scattering between wall and ground (SAR flying into paper)
(φ = angle between wall and satellite flight direction).

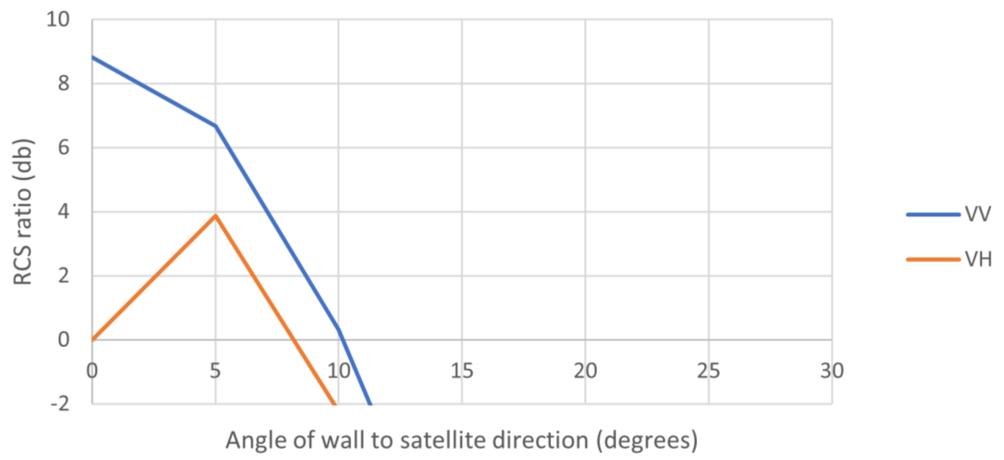


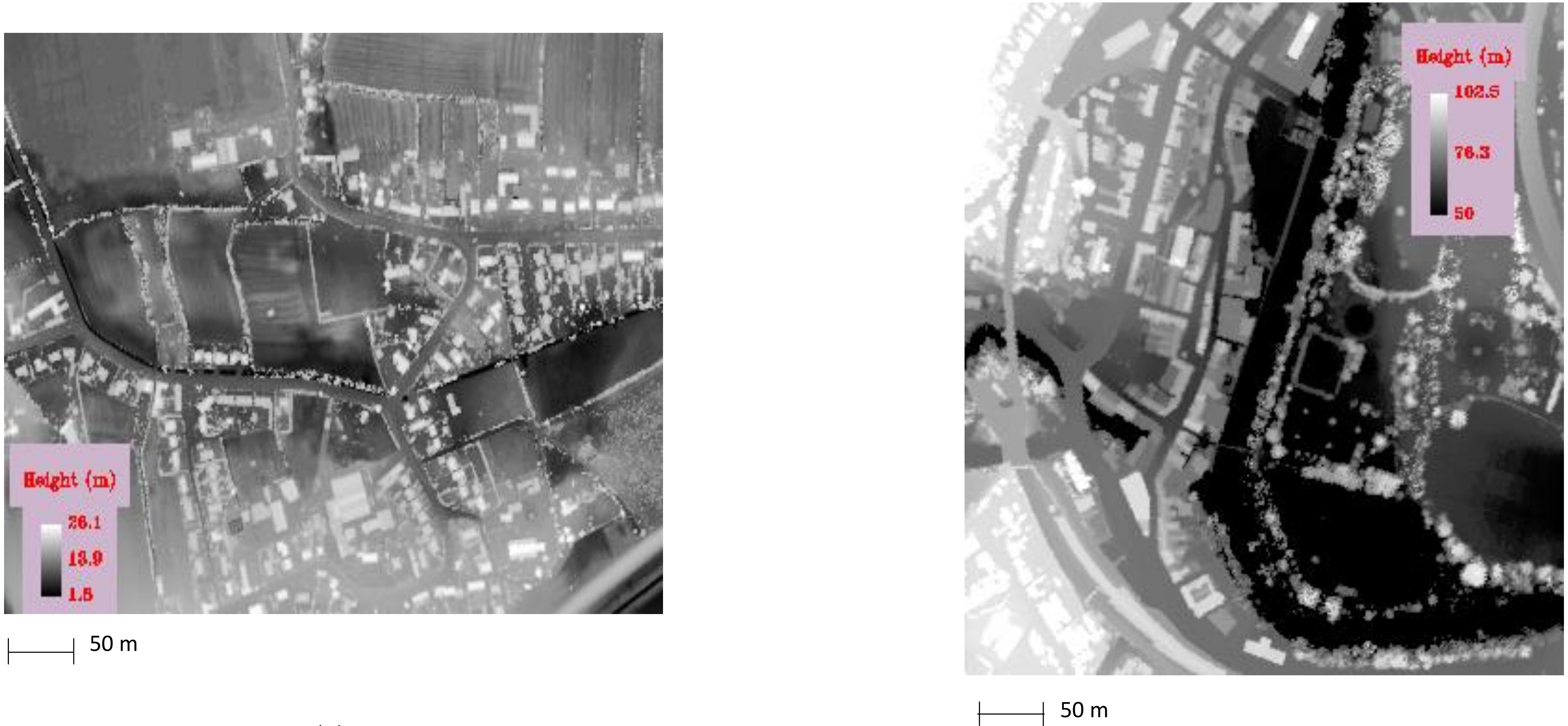
Fig. 2. Post- to pre-flood RCS ratio *r* (db) versus angle *φ*, for incidence angle = 35°, water/asphalt height s. dev. = 0.001/0.0014 m, water/asphalt correlation length = 0.2/0.15 m.

. Franceshetti et al. (2002) model used to estimate the double scatterer RCS ratio for C-band SAR. Geometric Optics (GO) was used to estimate scattering from assumed smooth building wall, and Physical Optics (PO) to estimate scattering from a slightly rough ground.

. VV polarization is better than VH, and for VV polarization the RCS ratio is high at φ = 0° but falls rapidly to 0 db at φ = 10°. This implies that few double scatterers might be detected in an urban area, which wouldn't favour our method.

. However, experiments on real images have questioned the veracity of models (3). This prediction might be unduly pessimistic. For example, the building walls might be rough or there might be windows in the buildings.

Empirical study to examine relationship between RCS ratio and φ.



(a)

(b)

Fig. 3. Environment Agency LiDAR images of urban study sites for UK Winter 2019-20 floods, (a) Fishlake, (b) Pontypridd. 3 post-flood images from 2 study sites were examined. Error on $\varphi < 5°$.

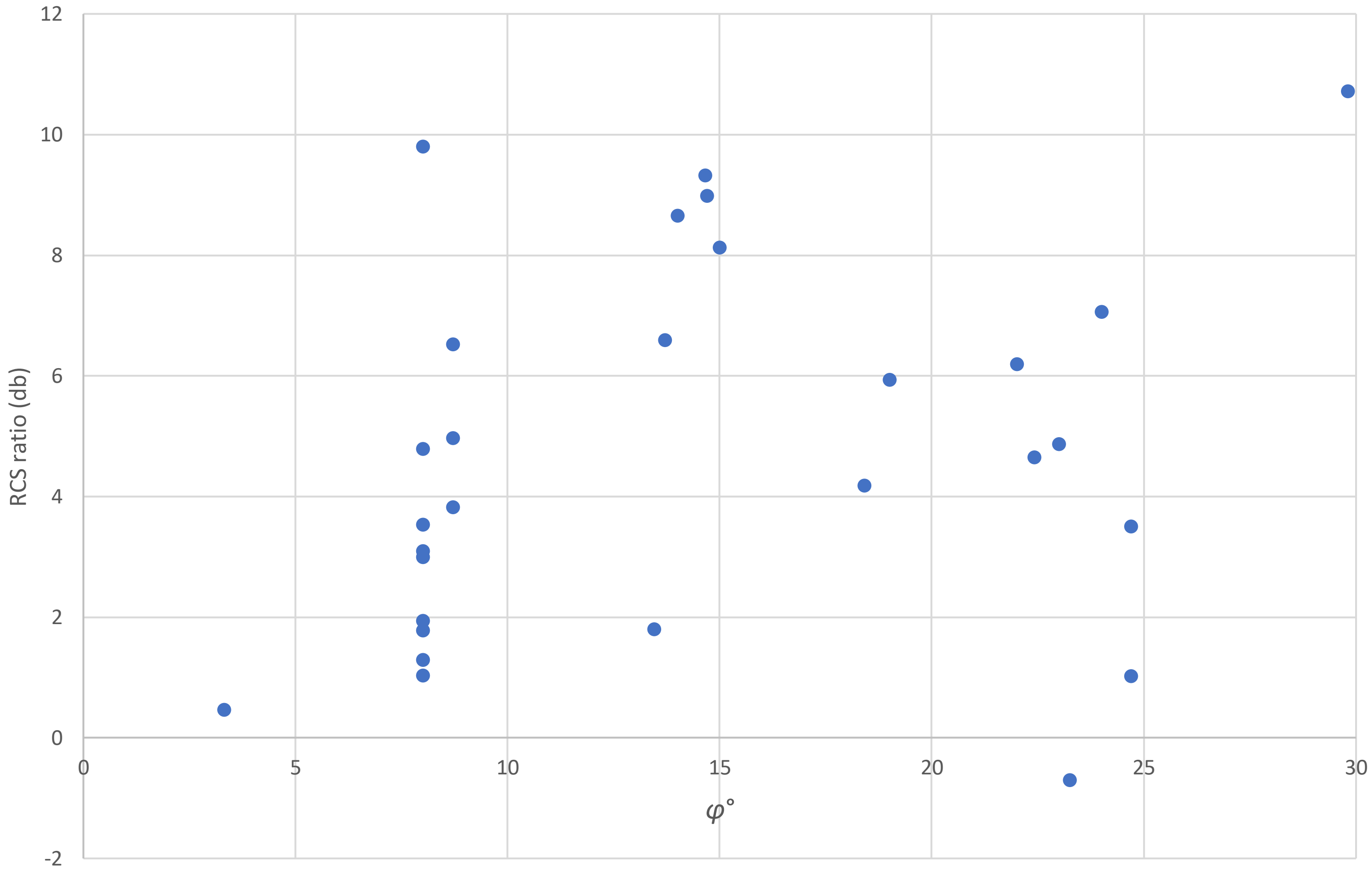


Fig. 4. Post- to pre-flood RCS ratio versus φ for flooded urban double scattering pixels for Fishlake 14/Nov/2019 flooding (VV polarisation).

Conclusions

Overall, our results indicated that –

(a) almost half (24 out of 52) of the flooded urban double scatterers with high RCS ratios (> 3 db) occurred in the φ range 10 - 30°, so that the theoretical model severely underestimated these,

(b) several hundred flooded double scatterer ground heights could be estimated per sq. km, enough to determine an accurate average local flood level,

(c) in high density housing there were less of these due to the presence of adjacent buildings.

References

1. Mason D.C., Dance S.L., Cloke H.L. (2021). Flood detection in urban areas using Sentinel-1 and WorldDEM data. *J. Applied Remote Sensing*, **15**(3), 032003 (2021), doi: 10.1117/1.JRS.15.032003.

2. Franceshetti, G., Iodice, A., Riccio, D. (2002). A canonical problem in electromagnetic backscattering from buildings. *IEEE Trans. Geoscience Rem. Sens*. 40(8), 1787, 1801.

3. Ferro A., Brunner D., Bruzzone L., Lemoine G. (2011). On the Relationship Between Double Bounce and the Orientation of Buildings in VHR SAR Images. *IEEE Trans. Geoscience Rem. Sens Letters*, 8(4), 612-616. (2011).