

Flood Detection with Synthetic Aperture Radar: A Case Study of Houston, Texas Following Hurricane Harvey (2017) using C- and X-Band Observations



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Background

Hurricane Harvey produced record-breaking rainfall of up to 60 inches resulting in extensive flooding in Houston, Texas, in late August and early September of 2017. The slow forward motion of the storm following landfall left much of the area unobservable to optical remote sensing instruments for several days due to cloud cover.

The active nature of Synthetic Aperture Radar (SAR) instruments allows for observations through clouds, which can supplement efforts to estimate hurricane-induced flood impacts. A growing fleet of SAR constellations has helped lower the latency of imagery following a hurricane, allowing for more timely detections of flooding to help support emergency response efforts. Here, we compare the water detection ability of publicly available C-band Sentinel-1 from the European Space Agency (ESA) with X-band Airbus TanDEM-X observations from the NASA Commercial SmallSat Data Acquisition (CSDA) Program.

Methodology

Using the USDA Cropland Data Layer (CDL) from 2017 as reference, permanent open water pixels within the AOI were isolated to derive local statistics and create a unique threshold from each SAR image.

- Binary water/no water maps were created by setting a threshold of the mean backscatter value over permanent water pixels.
- Maps were generated with thresholds ranging from the mean value only to the mean plus one standard deviation in 0.25-standard deviation intervals to determine which performed best.

The accuracies of the derived water extent were assessed using randomly distributed "ground truth" points which were manually assigned water/no water values based on the ground conditions present in cloud-free PlanetScope observations from 31 August 2017. This methodology is based on Olofsson et al. 2014, which established recommendations for assessing the accuracy of land cover classification maps.

Results

TDX Floodmap (0.0 std)		
Results (%)	UA (false +)	PA (false -)
Water	89.18	96.57
No Water	99.22	97.37

Overall Accuracy 97.23%

S1 Floodmap (0.75 std)		
Results (%)	UA (false +)	PA (false -)
Water	95.18	87.68
No Water	97.29	99

Overall Accuracy 96.93%

Classified Pixels	Truth Points	
	Water	No Water
Water	478	58
No Water	17	2150

Classified Pixels	Truth Points	
	Water	No Water
Water	434	22
No Water	61	2186

Accuracy statistics for the best-performing estimates of water extent for each sensor.

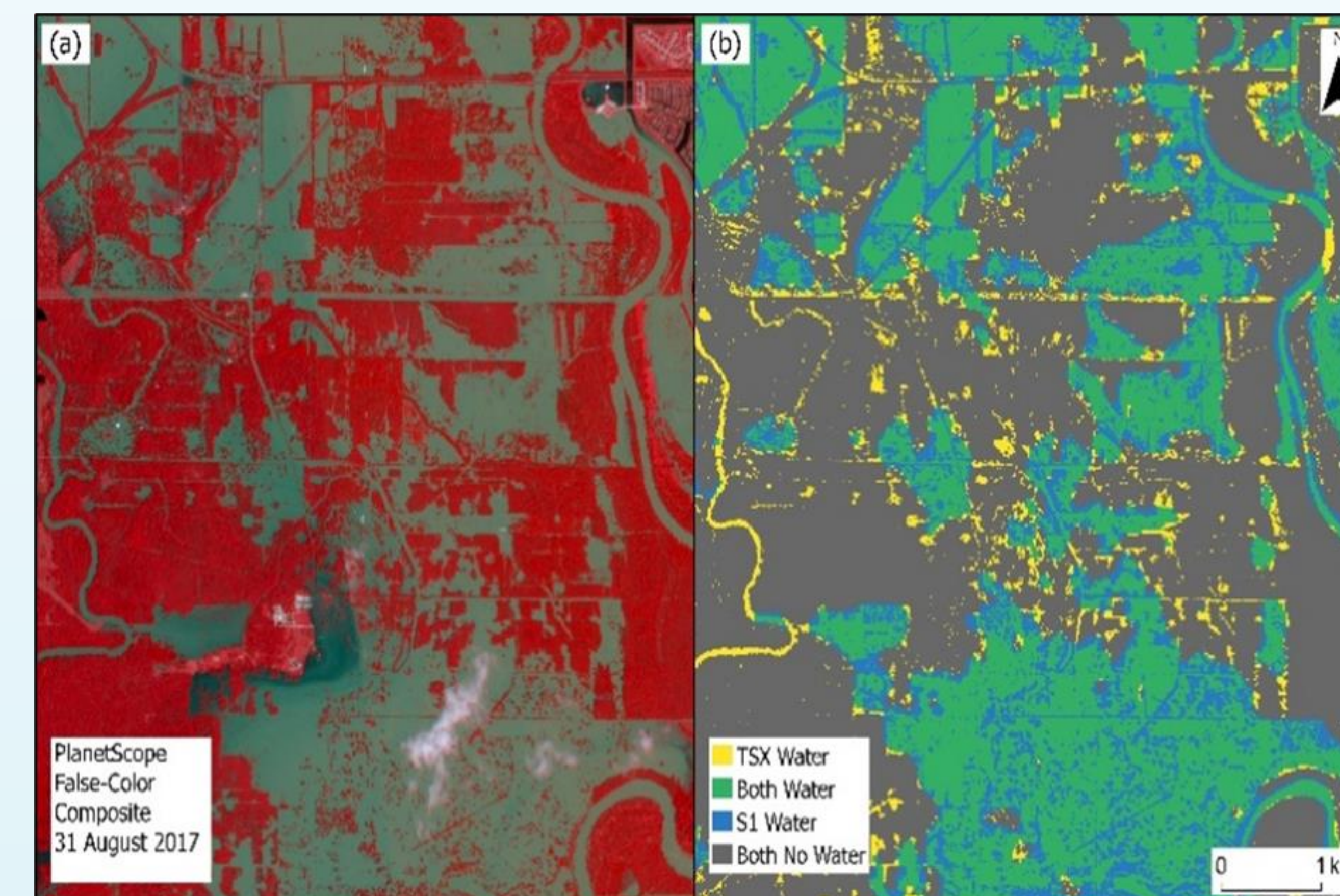
- 2703 total points were tested over the 1,915 km² AOI.

- The mean value threshold performed best for the X-band TanDEM-X data, as overprediction increased with the threshold value.

- For the C-band Sentinel-1 data, underprediction was prevalent at the mean threshold and decreased with increasing threshold value.

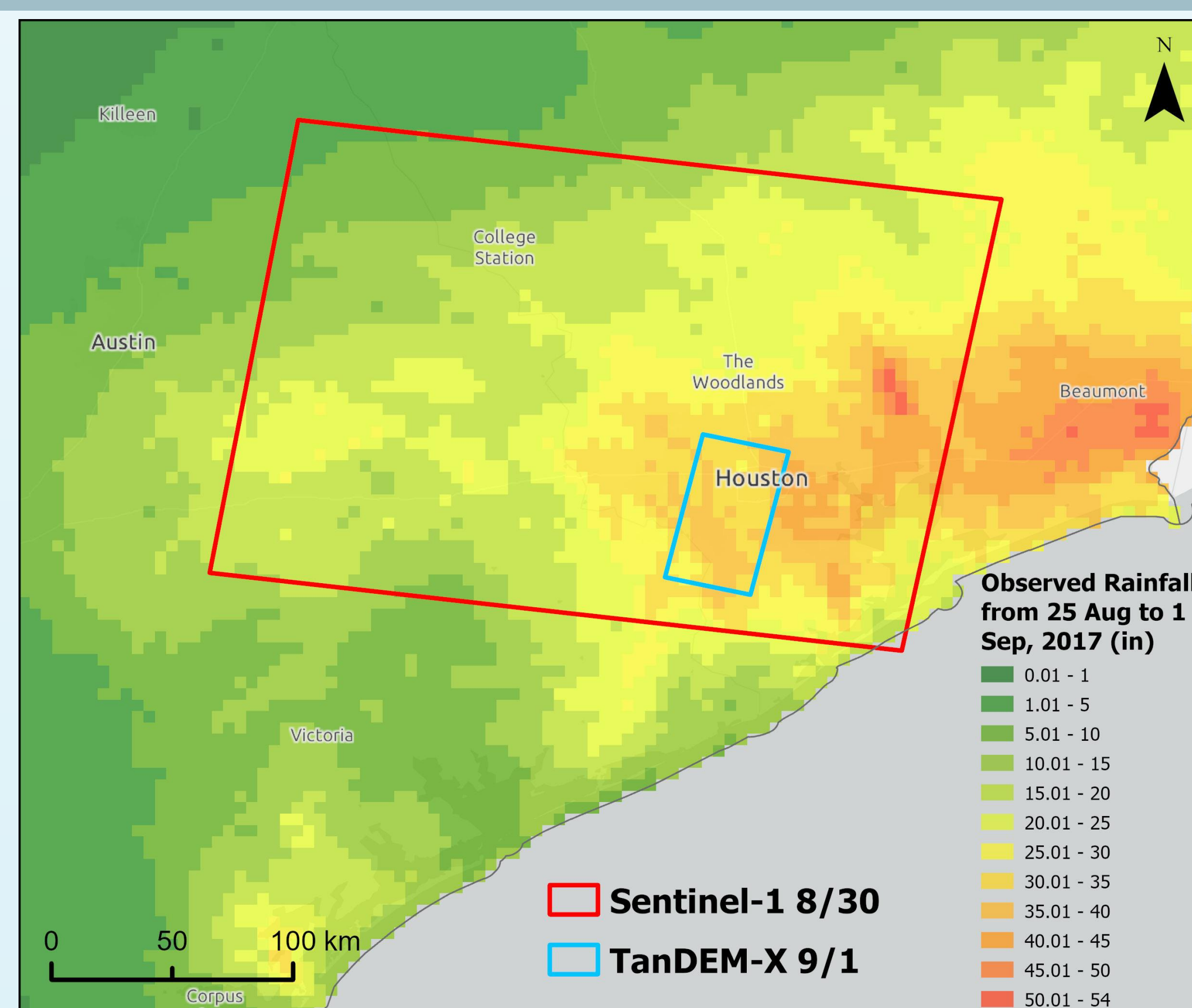
- Maximum accuracy was achieved at +0.75 standard deviation before starting to overpredict slightly at 1.0.

- The ~3m resolution of the TanDEM-X imagery enabled the detection of narrow channels and small water bodies not large enough to be resolved in the 30m Sentinel-1 data.

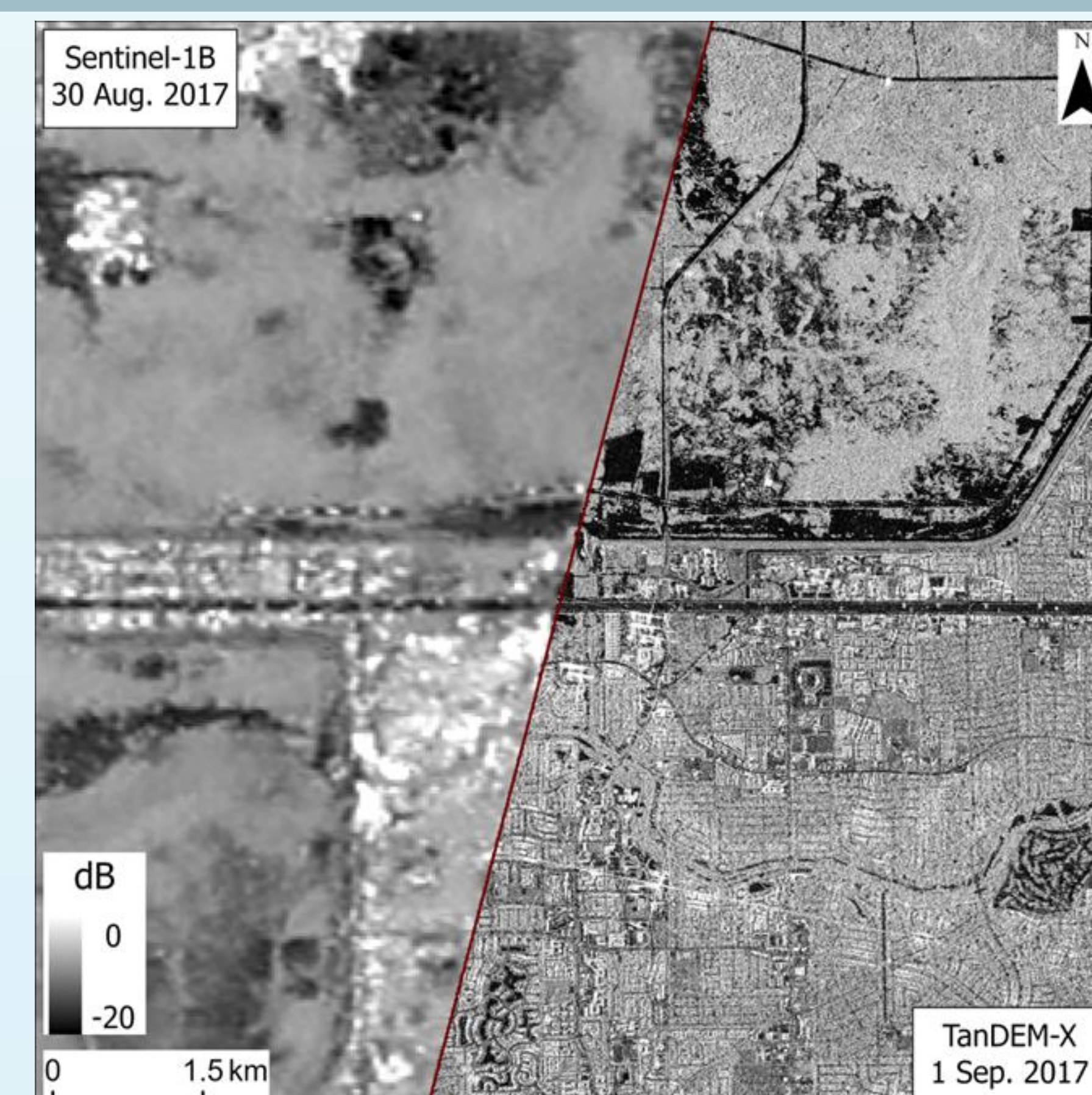


a) PlanetScope False-Color Composite (NIR, R, G)
b) SAR-derived water extents using S1B and TDX imagery

Data



Footprints of the Sentinel-1 and TDX scenes used for analysis overlaid upon NWS Advanced Hydrologic Prediction Service (AHPS) daily rainfall totals from 25 Aug. to 1 Sep. 2017 in inches.



Edge of 1 Sep. TanDEM-X swath (~3 m) overlaid upon Sentinel-1 (30 m) from 30 Aug. 2017 to show differences in resolution.

Conclusions

- Under-prediction of water in the TanDEM-X image was noted in areas with very shallow inundation and/or emergent vegetation.
- Over-prediction was prevalent over roads in urban and suburban areas for both X- and C-band observations.
- The difference in wavelength and spatial resolution result in Sentinel-1 observations covering a much larger area on the Earth's surface, an advantage over TanDEM-X for large-scale flood events. Conversely, the high spatial resolution of TanDEM-X could offer greater value in estimating the magnitude of urban flood events.

Acknowledgements

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Citations:

Sentinel 1: ASF DAAC 2023, contains modified Copernicus Sentinel data 2017, processed by ESA.

TanDEM-X: Airbus Defense and Space GEO Inc U.S. 2017.

Olofsson, P.; Foody, G.M.; Herold, M.; Stehman, S.V.; Woodcock, C.E.; Wulder, M.A. Good Practices for Estimating Area and Assessing Accuracy of Land Change. *Remote Sens. Environ.* 2014, 148, 42–57

The co-polarized (HH) stripmap TanDEM-X data used for this study was obtained through the NASA CSDA Program, while publicly-available co-polarized (VV) interferometric wide Sentinel-1 data was retrieved from the NASA Alaska Satellite Facility (ASF) SAR Distributed Active Archive Center (DAAC). Both scenes were processed to Radiometric Terrain Corrected (RTC) images for analysis.