EGU2020-13743
https://doi.org/10.5194/egusphere-egu2020-13743
EGU General Assembly 2020

Generating an exclusion map for SAR-based flood extent maps using Sentinel-1 time series analysis

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Change detection has been widely used in many flood-mapping algorithms using pairs of Synthetic Aperture Radar (SAR) intensity images. The rationale is that when the right conditions are met, the appearance of floodwater results in a significant decrease of backscatter. However, limitations still exist in areas where the SAR backscatter is not sufficiently impacted by surface changes due to floodwater. For example, in shadow areas, the backscatter is stable over time because the SAR signal does not reach the ground due to prominent topography or obstacles on the ground (e.g., buildings). Densely vegetated forest is another insensitive region due to low capability of SAR C-band wavelengths to penetrate its canopy. Moreover, although in principle SAR can sense water over different land cover classes such as arid regions, streets and buildings, the backscatter changes over time could not be detected because in such areas the scattering variation caused by the presence of water might be negligible with respect to the normal "unflooded" state. The identification of the abovementioned areas where SAR does not allow detecting water based on change detection methods, hereafter called exclusion map, is crucial for providing reliable SAR-based flood maps.

In this study, insensitive areas are identified using long time-series of Sentinel-1 data and the final exclusion map is classified in four distinctive classes: shadow, layover, urban areas and dense forest. In the proposed method the identification of insensitive areas is based on the use of pixel-based time series backscatter statistics (minimum, maximum, median and standard deviation) coupled with a local spatial autocorrelation analysis (i.e. Moran's I, Getis-Ord Gi and Geary's C). In order to evaluate the extracted exclusion map, which is quite unique, we employ a comprehensive ground truth dataset that is obtained by combining different products: 1) a shadow/layover map generated using a 25m-resolution DEM and the geometric acquisition parameters of the SAR data; 2) 20m resolution imperviousness map provided by Copernicus, as well as a high-resolution global urban footprint (GUF) data provided by DLR; 3) a 20m tree cover density (TCD) map provided by Copernicus. In the end, the exclusion map is used to mask out unclassified areas in the flood maps derived by an automatic change detection method, which is expected to enhance flood maps by removing areas where the presence or absence of floodwater cannot be evidenced. In addition, we argue that our insensitive area map provides valuable information for improving the calibration, validation and regular updating of hydraulic models using SAR derived flood extent

maps.