Multi-temporal Sentinel-1 coherence to detect floodwater in urban areas

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MAPPING THE «BLIND SPOTS»

Unclassified areas
OBJECTIVE: TO REDUCE UNCLASSIFIED AREAS

- Human settlements represent a large fraction of unclassified areas
- Difficulty to detect floodwater in urban areas complicates the estimation of number of persons affected by event

Research questions:
- Does advanced SAR data processing provide a means to reduce the unclassified areas?
- Can we detect floodwater in urban areas using SAR coherence in addition to SAR intensity?
What happens when a flood occurs in urban areas?

- Enhanced double bounce
- No change / Increase / decrease in intensity
LIMITATIONS OF SAR INTENSITY FOR MAPPING FLOODWATER IN URBAN AREAS

• Shadow and signal blockage caused by tall buildings and/or narrow streets may cause the water on the ground not to impact the backscatter.

• If we consider the angle between the flight direction and the street alignment, the increase is high for small angles, while it is reduced for higher angles.

• As a consequence, the increase of the Double-Bounce due to the presence of floodwater may not be sufficiently high if buildings are not parallel to the SAR flight direction.
The InSAR coherence is the normalized cross correlation between images and it is related to the change in the spatial arrangement in time of the scatterers within a SAR image pixel.

A coherence image is built using two images taken before the event (pre-event coherence) or with one before and one during the flood event (co-event coherence).

InSAR coherence is affected by temporal decorrelation, which means that it decreases also for reasons other than catastrophic events.

Working hypothesis: in areas where double-bounce occurs the co-event InSAR coherence (CC) decreases with respect to the pre-event one.
1. Mapping of open water using SAR intensity
2. Extraction of pre-event and co-event coherence maps
3. Calculate and threshold the coherence difference map
4. Identification of double-bounce objects, i.e. buildings
5. Mapping floodwater in urban areas
6. Merge the two flood maps (open water & floodwater in urban areas)
TEST CASE 1: HOUSTON (USA) 2017

We test the approach taking advantage of the enhanced observational capabilities of Sentinel-1:

- high revisit time
- small orbital tube
- high spatial resolution

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Parameterization of “water” and “change” classes

Chini et al., TGRS, 2017
IDENTIFICATION OF DOUBLE BOUNCE OBJECTS

Building map derived from Sentinel-1 (i.e. that produce high backscatter intensities and that are coherent over time)
TEST CASE 1: HOUSTON 2017

Digital Globe VHR imagery and crowdsourcing

RGB Intensity

RGB coherence

Flood map

FEMA inundation model
**TEST CASE 2: BELEDWYNE (SOMALIA) 2018**

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TEST CASE 2: BELEDWYNE (SOMALIA) 2018

RGB Intensity

RGB coherence

Flood map

26/04/2018
TEST CASE 2: BELEDWYNE (SOMALIA) 2018

RGB Intensity

RGB coherence

Flood map

14/05/2018
TEST CASE 2: BELEDWYNE (SOMALIA) 2018

From UNITAR-UNOSAT
Test case 3: Mozambique 2019

Flood extent map derived from Sentinel-1 data acquired on 19/03/2019 at 16:14 UTC

Legend
Binary Flood Mask

Map Projection: Universal Transverse Mercator (UTM) Zone 31N

Scale: 1:3,023,000

Test case 3: BEIRA (MOZAMBIQUE) 2019

‘ON DEMAND’ M AREAS
CONCLUSIONS

• InSAR coherence extracted from pairs of Sentinel-1 observations is impacted by the appearance of water on the ground.

• We introduce a retrieval algorithm based on the monitoring of InSAR coherence to map floodwater in urban areas.

• Reference data acquired during high magnitude events confirm the high potential of for mapping floodwater in urban areas (along with evidence provided by other groups working on this topic).

• The combination of multi temporal intensity and coherence is needed to reduce the unclassified areas and produce more accurate inundation maps, especially in urban areas.
OUTLOOK

• More testing is needed to better understand the current limitations of such methods.

• In particular, more studies are needed to better understand what the possible reasons for a drop in coherence are and how, for example, the structure of urban settlements (e.g. height of buildings, width of streets, orientation of buildings), the presence of vegetation inside towns and the atmospheric conditions (heavy rain and clouds) impact flooding-related changes of coherence and thus classification uncertainties.

• The processing of SLC data leads to a much increased IT cost compared to GRD data (substantial upgrade of the hardware & processing environments is needed).
ALTERNATIVE APPROACH TO FILLING THE GAPS

- Generate flood maps for a range of discharge scenarios using physically-based models
- Assimilation of satellite EO-derived flood map into the model to find the most likely scenario
- To use model results to map water inside “blind spots”

Simulated Flood Map (different discharge scenarios)  Observed Flood Map 24 August 2017
FURTHER READING


Thank you

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Acknowledgements to our sponsors:
TEST CASE 1: HOUSTON 2017

In target areas a significant drop in coherence is observed between images acquired before and during the flood. We think that this is due to the appearance of floodwater.
LIMITATIONS OF INSAR COHERENCE

• The InSAR coherence is generally affected by temporal decorrelation, which means that it decreases also for reasons other than catastrophic events.

• It is mandatory to focus the analysis only on the Double-Bounce objects.

• The InSAR coherence is generally affected by spatial decorrelation, so that it decreases with the increase of the perpendicular baseline.

• Sentinel-1 is a perfect candidate given that the relatively narrow orbit tube (i.e. small perpendicular baseline of interferometric acquisitions)
The enhanced and systematic observational capabilities of Sentinel-1, high revisit time and small orbital tube, could be effectively used for a more accurate detection of floodwater in urban areas.

The high sensitivity of the Interferometric SAR (InSAR) coherence to small changes in the scene was already exploited to map floods in urban areas using very high-resolution SAR sensors, such as COSMO-SkyMed.

In this presentation, we use the InSAR coherence from Sentinel-1 (5m and 20m spatial resolution) and take advantage of its high sensitivity w.r.t. the presence of water within building areas is demonstrated.
TEST CASE 2: BELEDWYNE (SOMALIA) 2018

08/05/2018