GAMMA REMOTE SENSING

Co-seismic displacement vector retrieval for the Iran-Iraq Earthquake using Sentinel-1

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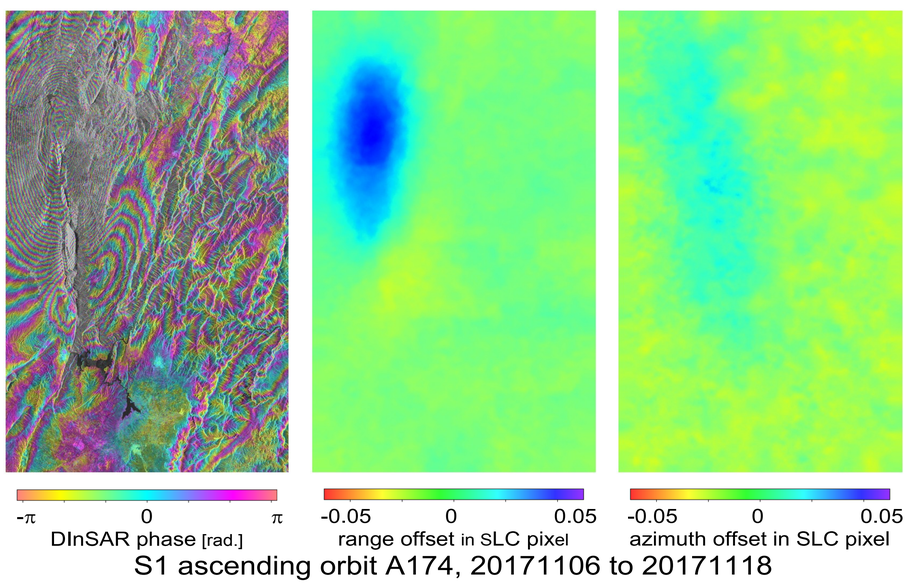
Abstract

We used Sentinel-1 data to map the co-seismic displacement of the Iran-Iraq earthquake 2017. The focus of our work is on the assessment of different methods to retrieve the east-west, up-down, and north-south components using differential interferometry as well as offset-tracking.

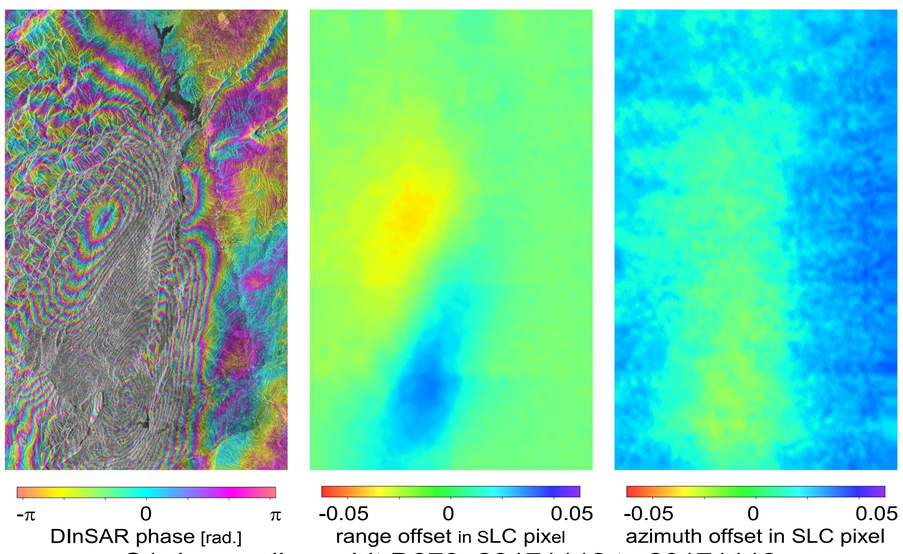
Displacement vector estimation methodology

Using Sentinel-1 co-seismic pairs in both ascending and descending orbits, six displacement components were determined using differential interferometric SAR (DInSAR) and offset tracking. For each component and map pixel the direction vector was expressed in ENU (East-North-Up) coordinates. The relation between the components determined using DInSAR and offset-tracking, the vectors indicating the direction of these components, and the ENU displacement vector can be expressed as [A][x] = [b] . The rows of the matrix A are the direction vectors of the DInSAR and offset-tracking observables, [x] is the displacement vector in ENU coordinates, and [b] contains the DInSAR and offset-tracking values. The displacement vector in ENU coordinates was estimated for each point in the scene based on the selected displacement components using Singular Value Decomposition (SVD). The Least-Squares solution permits estimation of the sensitivity to measurement errors and can reveal inconsistency between partially redundant measurements.

Data used and processing



S1 ascending orbit A174, 20171106 to 20171118



S1 descending orbit D079, 20171112 to 20171118

Remarks on the processing:

- To avoid phase jumps between subsequent bursts in the co-seismic differential interferograms the co-registration was adjusted for the co-seismic displacement.
- An iterative minimum-cost flow unwrapping was iteratively applied: an initial unwrapped and then spatially filtered solution was subtracted, the residual unwrapped and added.
- To use the line-of-sight (LOS) DInSAR displacement component in the East-North-Up (ENU) displacement vector retrieval, the LOS direction vector was calculated per geocoded pixel.
- To optimize the offset tracking quality and avoid aliasing effects, large matching windows and an oversampling of the SLC data in both range and azimuth direction were used.
- The location indicated in the up component of solution 1 by a star (★) indicates the reference location assumed to be stable.
- To use the range and azimuth offsets in the retrieval of the ENU displacement vector, the range and azimuth offset direction vectors were calculated per geocoded pixel.
- DInSAR, offset tracking, geocoding, and the displacement vector estimation using SVD was performed using the GAMMA Software [1,2].

Conclusions

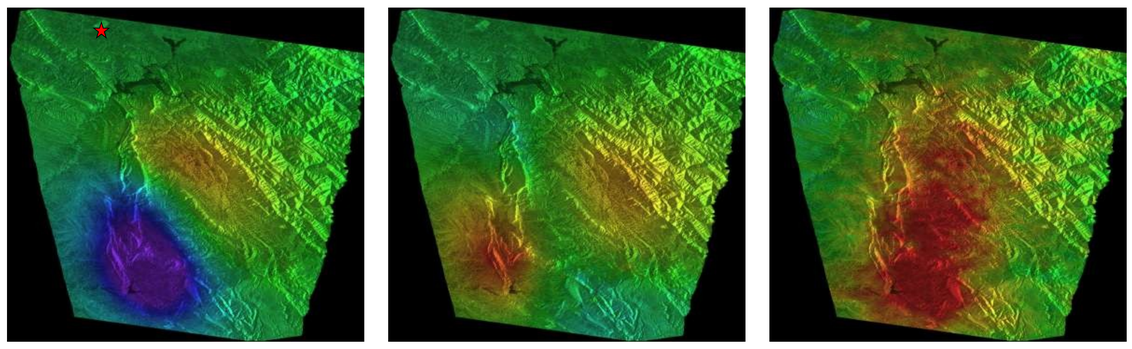
- The combined use of Sentinel-1 DInSAR and offset tracking, using the presented SVD methodology, permitted mapping of the displacement vectors for dm scale displacements.
- The additional use of the offset field has two main advantages:
  - the North component of the displacement vector can be determined
  - the co-registration can be optimized to avoid phase jumps between S1 bursts

Iran-Iraq Earthquake 2017

North-East of Baghdad, at the Iran-Iraq border, a magnitude 7.3 earthquake took place in the evening of 12 November 2017. With more than 600 persons killed, it was the deadliest earthquake of 2017. The earthquake was located in the zone of continental collision between the Arabian and Eurasian Plates. Mapping the displacement vector field instead of just the interferometric line-of-sight components permits to better understand and model the earthquake mechanism.

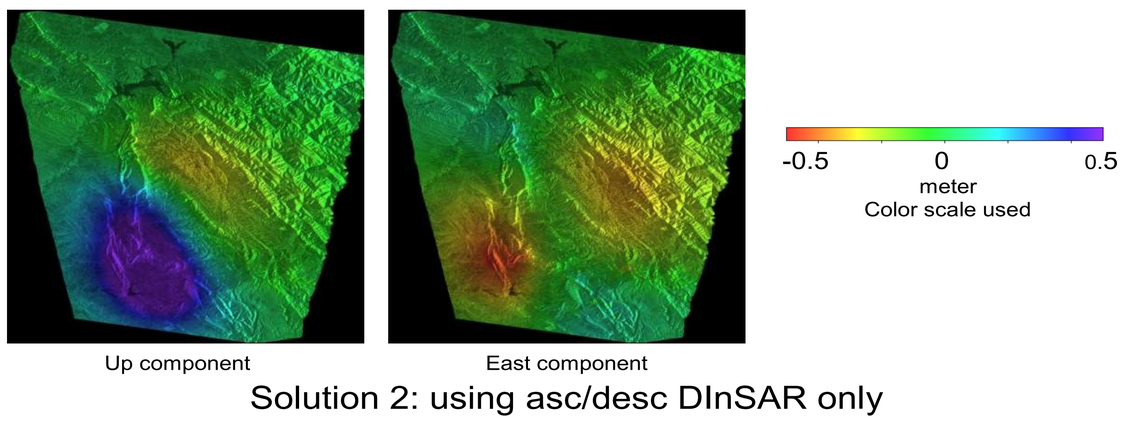
Results

Co-seismic displacement vector components of the Iran-Iraq earthquake of 12-Nov-2017



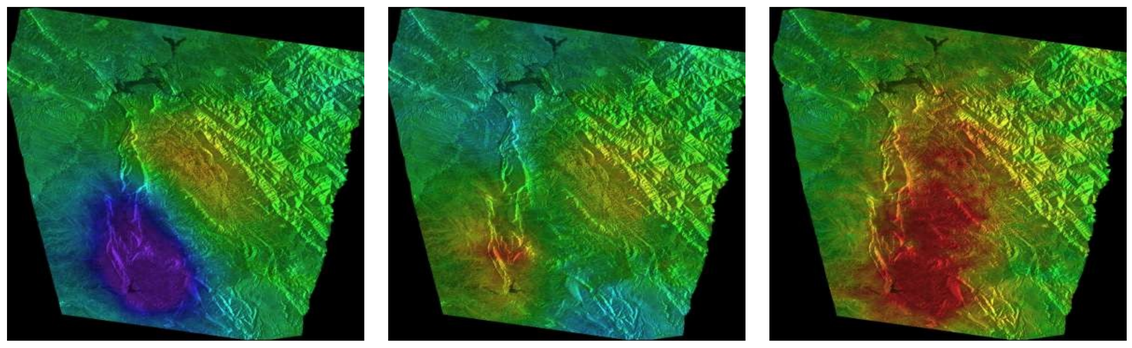
Up component | East component | North component

Solution 1: using asc/desc DInSAR and azimuth offsets



Up component | East component

Solution 2: using asc/desc DInSAR only



Up component | East component | North component

Solution 3: using azimuth and range offsets only

Discussion

- Using only the ascending and descending orbit DInSAR unwrapped phases means only two components are available. In the direction perpendicular to these components (which is almost in the north direction) there is no sensitivity. The SVD method identifies this and sets this component to 0.0.
- Based on the indicated standard errors of the components and the consistency of the values (if redundant values are provided) the SVD method determines an error estimate for the calculated displacement vector components (see Table 1).
- Using the range offsets (solution 3) instead of the DInSAR unwrapped phases (solution 1) results in a lower quality result for the Up and East components.
- The error of the north component is clearly higher than the error for the Up and East components. Nevertheless, the error of the north component is clearly lower than the observed displacement values.

Table 1: One standard deviation error of displacement vector East, North, and Up components, estimated under the assumption of a DInSAR LOS displacement error of 0.015m, an azimuth offset error of 0.10m and a range offset error of 0.05m.

input components used	sigma_Up	sigma_East	sigma_North
asc/desc DInSAR and azimuth offsets	0.015 m	0.020 m	0.072 m
asc/desc DInSAR	0.013 m	0.013 m	NA
asc/desc azimuth and range offsets	0.043 m	0.065 m	0.072 m

References

[1] General Information on the GAMMA Software:
http://www.gamma-rs.ch/uploads/media/GAMMA_Software_Information.pdf
[2] Technical reports, conference and journal papers:
http://www.gamma-rs.ch/uploads/media/GAMMA_Software_references.pdf

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