Measuring Earth displacement with ENVISAT ASAR Interferometry: Earthquake in Bam, Iran.

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The earthquake of Dec. 26, 2003 in Bam, Iran caused massive loss of life and property: tens of thousands of people died in the catastrophe. Although the earthquake's magnitude (6.5) was not exceptionally large, the location of its epicentre increased its deadliness.

Since the launch of ENVISAT by the European Space Agency (ESA) in 2002, its advanced synthetic aperture radar (ASAR) sensor has been available for measurements of the Earth's radar reflectivity. Earlier sensors such as the ERS satellites, Radarsat-1 operate(d) using similar principles. The radar transmits microwave pulses at C-band frequency (wavelength 5.6cm) and records both the amplitude and phase of the echoes reflected back from the Earth's surface.

The satellite is maintained within a repeat orbit configuration: ENVISAT returns to the same track every 35 days. If one compares the phase of echo returns recorded from multiple passes, then a high fidelity estimate of *en bloc* surface movement between acquisitions can be made. That is, assuming that the scattering mechanism within each resolution cell does not change in the intervening time, and one can compensate for other known influences - e.g. topography, using a digital elevation model (DEM).

The first ASAR interferograms showing the Bam earthquake signature were reported in (Small 2004). We have now generated ASAR interferograms using two descending and two ascending images acquired in ASAR's image mode (IM) with beam IS2. Figure 1 shows an interferogram generated from ESA-standard image mode single look complex (IMS) products derived from two descending orbit acquisitions. Topographic effects on the phase measurements were modelled and subtracted to generate a DEM-flattened interferogram, which was then unwrapped and terrain-geocoded. The relative distance between the two satellite paths (baseline) was extremely small (less than 3m). The SRTM3 DEM was used for reference. A rewrapped interferogram (4π interval) is shown for visualisation purposes.

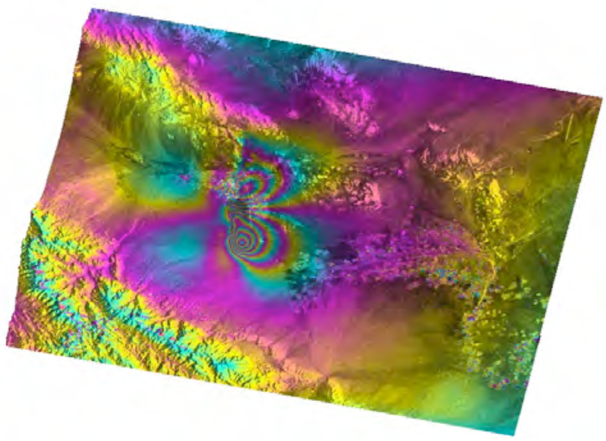

Figure 1. The image shows a DEM-flattened interferogram calculated using a pair of ENVISAT ASAR image mode acquisitions (descending orbits): the interferogram was first unwrapped, then rewrapped with a 0-4π colour cycle and terrain-geocoded using the SRTM3 DEM.

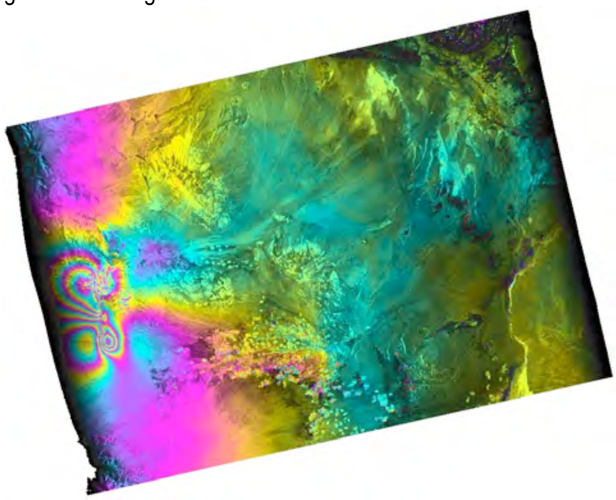

Figure 2. The image shows a DEM-flattened interferogram calculated using a pair of ENVISAT ASAR image mode acquisitions (ascending orbits): the interferogram was first unwrapped, then rewrapped with a 0-4π colour cycle and terrain-geocoded using the SRTM3 DEM.

Similar processing was performed using two ascending orbit ASAR IM acquisitions. Fortunately, as in the descending case, the ENVISAT repeat orbit provided a near zero metre baseline, minimising the influence of topography on the interferometric phase. Unfortunately, in the ascending orbital track, the earthquake event is situated close to the near-range border of the acquired data - substantial portions of the earthquake's signature west of the city of Bam are cut off in standard IMS products. We therefore relied instead on RSL's SAR processor MSP to focus level 0 (raw) signal data to single look complex (SLC) level 1 products. If one relaxes a widespread constraint (full chirp requirement) during the range compression step, then additional coverage (with progressively reduced local resolution) can be made available. A DEM-flattened interferogram from the pair is shown in Figure 2. Coverage is increased compared to that reported in (Jónsson et al. 2005).

Each unwrapped interferogram provides an estimate of the relative motion of the Earth in the direction of viewing of the satellite. That direction is different for the ascending and descending satellite tracks – we retrieve sample-by-sample 3D vectors during the geolocation step. That knowledge enables estimation of 3D vectors describing the total relative motion of the Earth's surface in the course of the earthquake event.

A relatively new ASAR data product (made available by ESA in 2005) is the wide swath single look complex (WSS). ASAR's wide swath (WS) acquisition mode differs from image mode (IM) in that it uses the ScanSAR technique to increase the available swath width. In ScanSAR acquisitions, the Doppler spectrum used to generate the synthetic aperture is split into bursts with only a subset of the full spectrum acquired - the along-track resolution is therefore reduced in comparison to IM. WSS products provide burst-by-burst records of the radar echoes. Figure 3 shows an example of the WSS product's image structure for the area of the city of Bam. Note how the same area is covered by multiple bursts: time along-track does not increase monotonically, as with conventional SAR products.

Given that the bursts from the two passes are favourably synchronised, two such products may be combined to generate interferograms. After interferogram generation multi-looking may be applied to produce smaller and simpler products. Figure 4 shows an overlay of detected and multi-looked terrain-geocoded IMS and WSS products, indicating that the generally high geometric quality of ASAR products (Small et al. 2005) may be extended to the WSS case.

Processing methodologies necessary to generate interferograms from WSS products covering the Bam earthquake are reviewed.

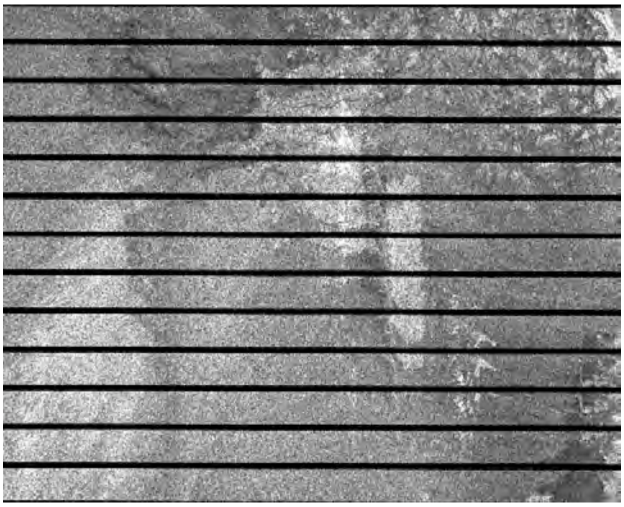

Figure 3. Wide Swath Single Look Complex (WSS) product image structure – Bam city area

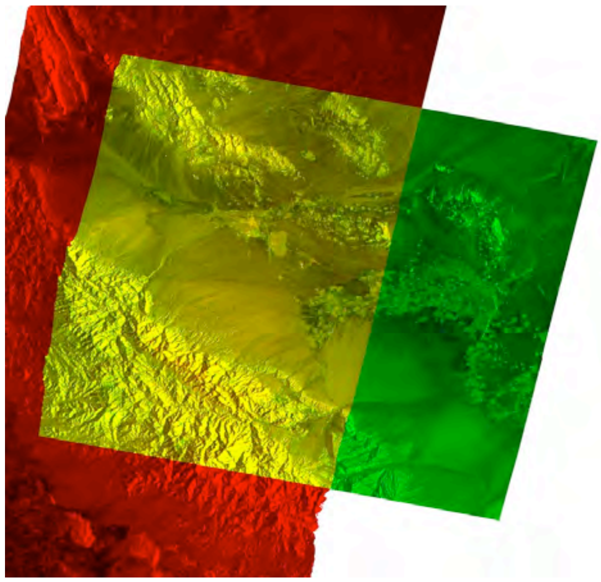

Figure 4. Overlay of terrain-geocoded Image Mode and Wide Swath Single Look Complex (WSS) products

REFERENCES

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