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GLOBAL MONITORING OF FAULT ZONES AND VOLCANOES WITH SENTINEL-1

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ABSTRACT

Sentinel-1 represents a major step forward in enabling us to monitor the Earth's hazardous tectonic and volcanic zones. Here, we present the latest progress from the Centre for the Observation and Modelling of Earthquakes, Volcanoes and Tectonics (COMET), where we provide deformation results to the community for volcanoes and the tectonic belts.

For the estimation of seismic hazard, we require relative accuracy on the order of 1 mm/yr between points 100 km apart. This requires mass processing of long time series of radar acquisitions. As of January 2018, we are producing interferograms systematically for the entire Alpine-Himalayan belt (∼9000 x 2000 km) and the majority of subaerial volcanoes. Currently we make interferograms and coherence products available to the community, but we plan to also provide average deformation rates and displacement time series, in the future. The results are made available through a dedicated COMET portal, and we are in the process of linking them to the ESA G-TEP and EPOS.

COMET also responds routinely to significant continental earthquakes, larger than ∼Mw 6.0. The short repeat interval of Sentinel-1, together with the rapid availability of the data, allows us to do this within a few days for most earthquakes. For example, after the Mw 7.8 Kaikoura earthquake we supplied a processed interferogram to the community just 5 hours and 37 minutes after the Sentinel-1 acquisition.

In this paper we provide an overview of some of the latest results for tectonics and volcanism and discuss how the accuracy of these products will improve as the number of data products acquired by Sentinel-1 increases.

Index Terms— Sentinel-1, InSAR, Tectonic strain, Earthquake response, Volcano monitoring

1. STRAIN MAPPING

There is a high degree of correlation between where earthquakes occur and the presence of strain in the crust, and strain rate maps can therefore provide useful constraints on seismic hazard [1]. Global strain rate maps currently rely on GNSS networks, but the spatial resolution is generally too coarse to provide a complete picture of strain localisation. Velocities derived from Sentinel-1 InSAR measurements, on the other hand, can be used, in principle, to derive strain rates almost everywhere above sea level, with sufficient resolution to sample the underlying strain field completely.

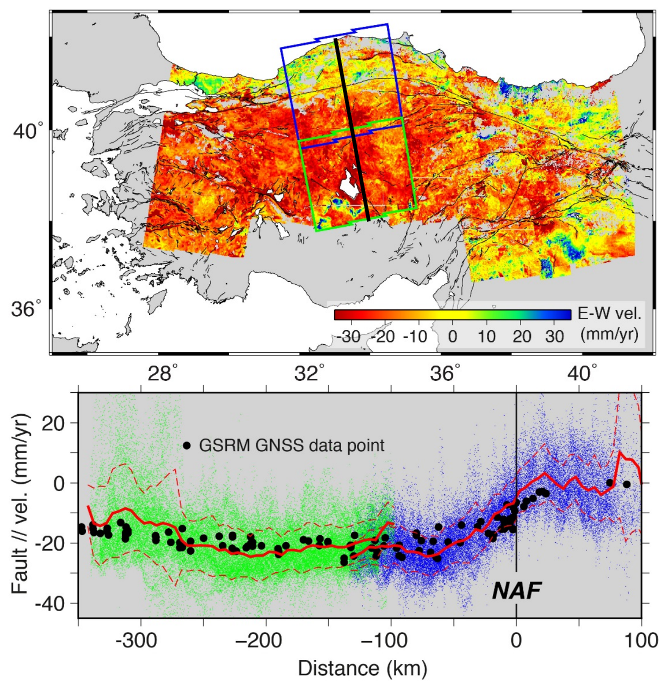

Fig. 1. Above, mean eastwards velocity in Turkey, relative to Eurasia, derived from 3 years of Sentinel-1 data. Below, profile from South to North along black line above, and comparison to GNSS. NAF marks the North Anatolian Fault.

Noise associated with interferometric measurements at long spatial wavelengths is mostly due to the variation in tropospheric delay. Assuming that the noise between any two points is sampled from a distribution with a constant standard deviation, σ_n, the standard deviation of the line-of-sight velocity is given by

$$\sigma_v = \sigma_n \sqrt{\frac{12\Delta t}{T(T^2 - \Delta t^2)}}, \qquad (1)$$

where Δt is the time interval between acquisitions, and T is the mission length. Fig. 1 shows the mean eastwards velocities for Turkey derived from Sentinel-1 line-of-sight velocities after three years of data, assuming there is fault-parallel motion only. Fitting Equation 1 to the residuals between a smoothed GNSS field and the line-of-sight velocities gives $\sigma_n = 12$ mm, for points separated by 150 km. This implies an accuracy of 1 mm/yr is achieved after three years for $\Delta t = 12$ days. The accuracy will continue to approve with time. Fig. 2 shows the distribution and number of interferograms produced by the COMET automatic processing as of January 2018.

Fig. 2. COMET LICS portal showing number of interferograms processed per frame (http://comet.nerc.ac.uk/COMET-LiCS-portal).

2. EARTHQUAKE RESPONSE

Rapid processing and delivery of the results of SAR data after an earthquake are useful for a number of reasons. They indicate the distribution of faulting and damage, which can guide the emergency and scientific responses in the field, in the days following the event. Initial acquisitions can then be used to constrain a comprehensive fault mode, while subsequent acquisitions provide time-sensitive constraints on post-seismic processes. This leads to improved understanding of the event, and what might follow.

An example of COMET rapid processing is shown for the Mw7.8 Kaikoura earthquake in Fig. 3. These results were used by GNS Science in their initial response, and later in the scientific interpretation [2].

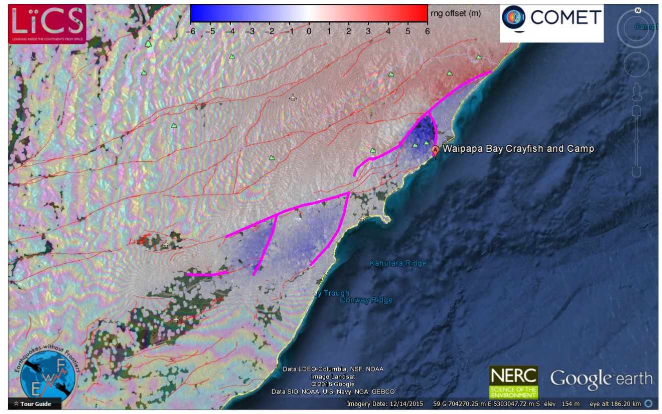

Fig. 3. First COMET result for the 2016 Mw 7.8 Kaikoura Earthquake, New Zealand, posted online 5.5 hours after satellite acquisition, on 15th November 2016.

3. VOLCANO MONITORING

Deformation is a key indicator of volcanic unrest, and is often associated with flow of magma to shallower depths. The operational nature of Sentinel-1, with frequent revisits and rapid data delivery, makes it suitable for monitoring subaerial volcanoes globally.

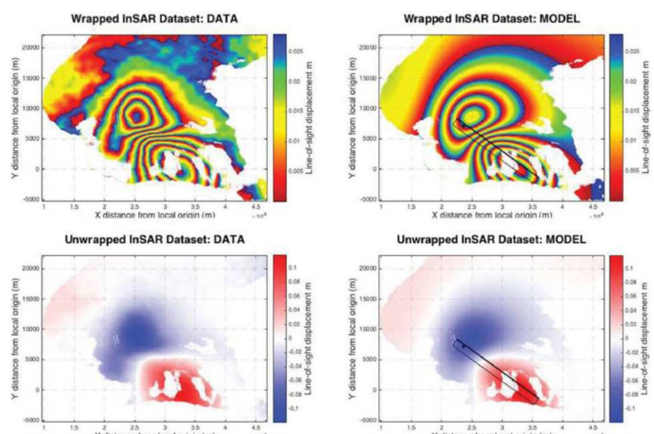

Fig. 4. Monitoring of volcanic activity at Cerro Azul in the Galapagos, in response to a request from the Ecuadorian Instituto Geofisico (IG). Left, Sentinel-1 descending interferogram spanning 8 to 20 March 2017. Right, model of dike with maximum a-posteori probability (MAP). Panels above show the interferometric phase and those below show the unwrappped phase. Lag time was 6.5 hours from receiving the request to delivery of interpreted Sentinel-1 results, and 10.5 hours to the delivery of the MAP deformation model.

Currently, we include most subaerial volcanoes in our mask for automatic processing at standard resolution (Fig. 2), but will add in high-resolution processing of subframes in the near future. Fig. 4 shows an example of a COMET rapid response to volcanic unrest in the Galapagos in 2017. In this case we were alerted to the event by the Ecuadorian Instituto Geofisico (IG), but we are also working on automatic detection algorithms that will alert us to new deformation automatically.

4. REFERENCES

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