A Survey of Volcanic Deformation in Java Using ALOS InSAR

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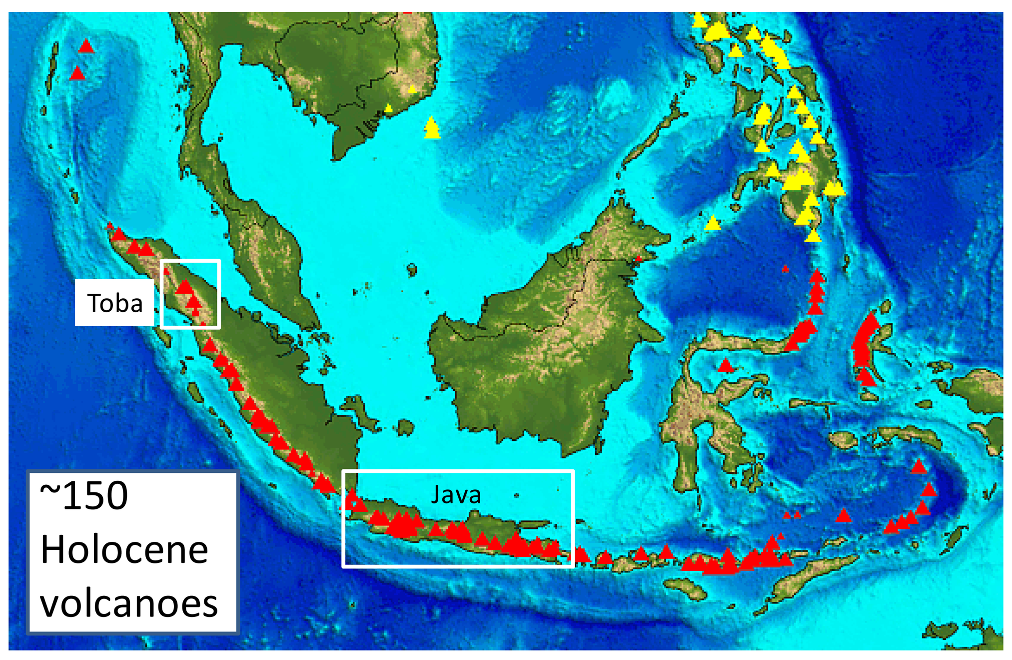
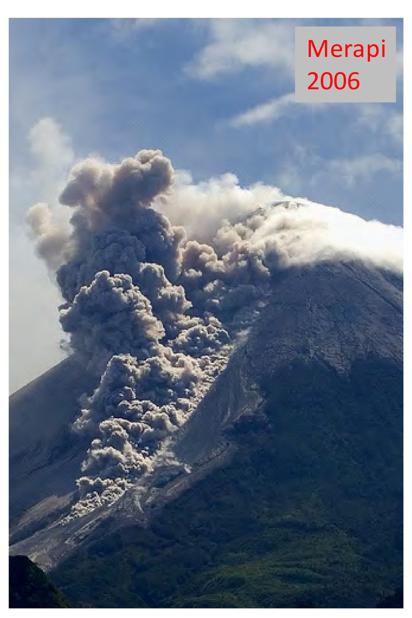
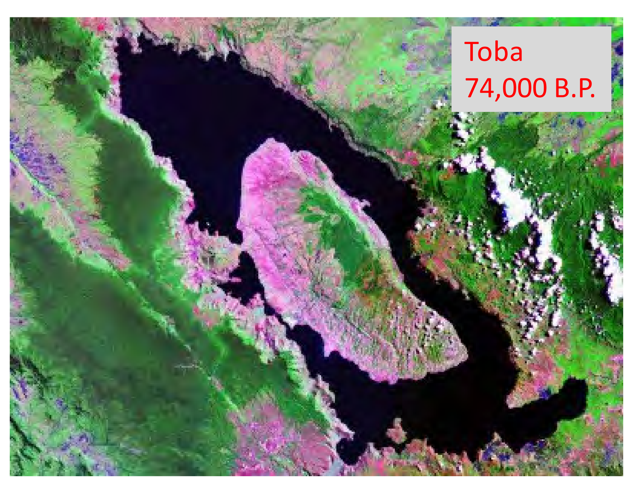
Indonesian Volcanism and InSAR

Monitoring deformation of Indonesian volcanoes is an important endeavor for geohazard mitigation. There are many volcanoes capable of relatively ordinary but still devastating eruptions such as that of Merapi in 2006, as well as "supervolcanoes" such as Toba with a history of massive, world-changing eruptions. However, it is impractical to monitor Indonesia's huge number of Holocene volcanoes using ground-based techniques. Satellite interferometry has provided a relatively easy way to monitor large areas for deformation. While C-band data has been used to detect and measure volcanic deformation in dry areas such as the Andes, the sensitivity of its 5-cm wavelength to changes in vegetation make it less useful in wet climates. The advent of JAXA's L-band ALOS PALSAR instrument, with a 24-cm wavelength less sensitive to vegetation, provides an opportunity to begin monitoring deformation in tropical island arcs.



Global Volcanism Program, Smithsonian Institute

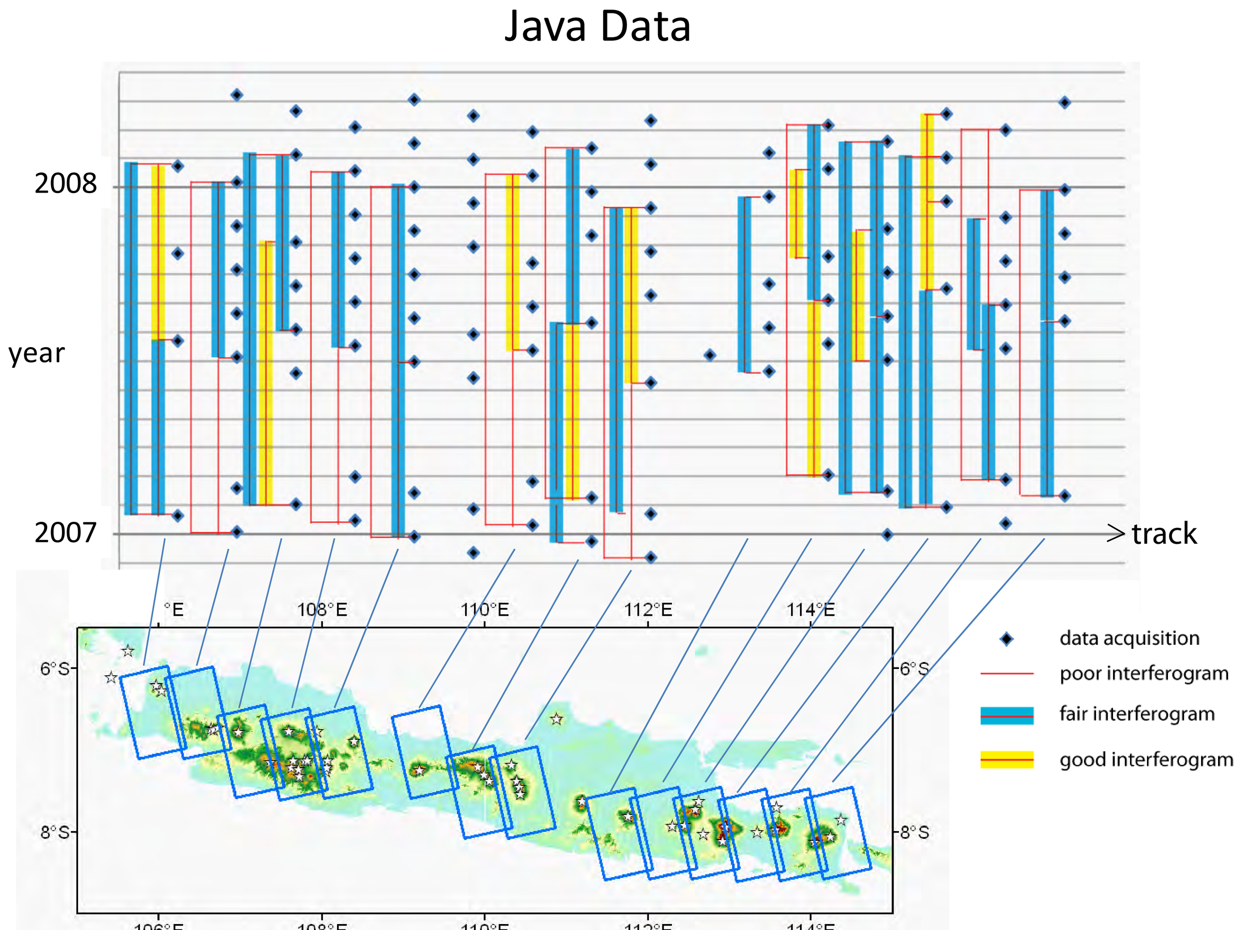


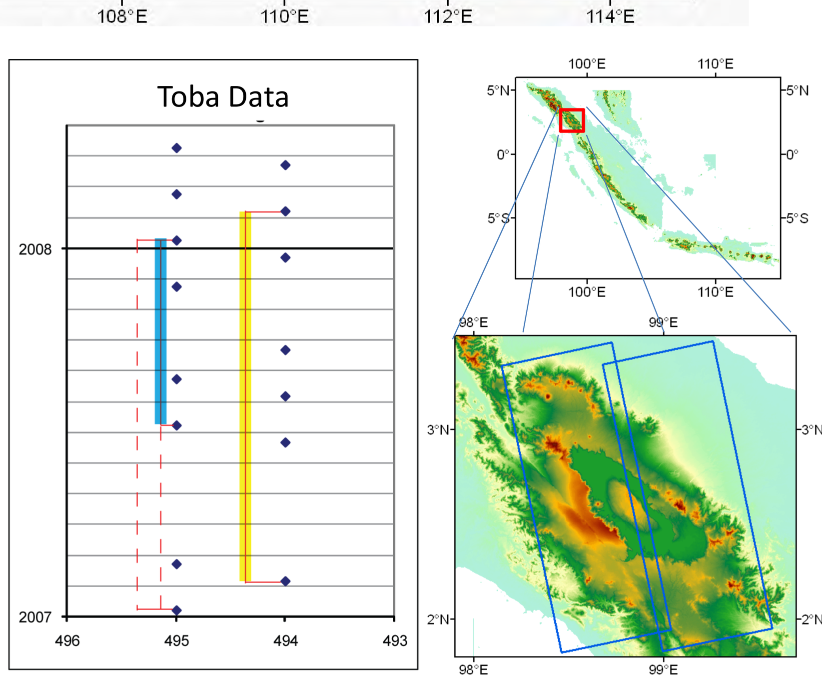


Data Coverage

This survey covered all but two of Java's Holocene volcanoes (the latter excluded due to lack of available imagery). Temporally, whenever possible a 1-year and both of the intervening 6-month interferograms were processed, as well as a few interferograms covering other time intervals. This suite of data allowed half of the tracks to be covered by at least one good interferogram (> 95% of the area correlated), and all tracks by at least one fair interferogram (> 80% of the area correlated). Relatively small areas of volcanic deformation could pass undetected within a decorrelation "hole" in a fair interferogram, whereas only tiny areas of deformation could hide in a good interferogram.

Java Data

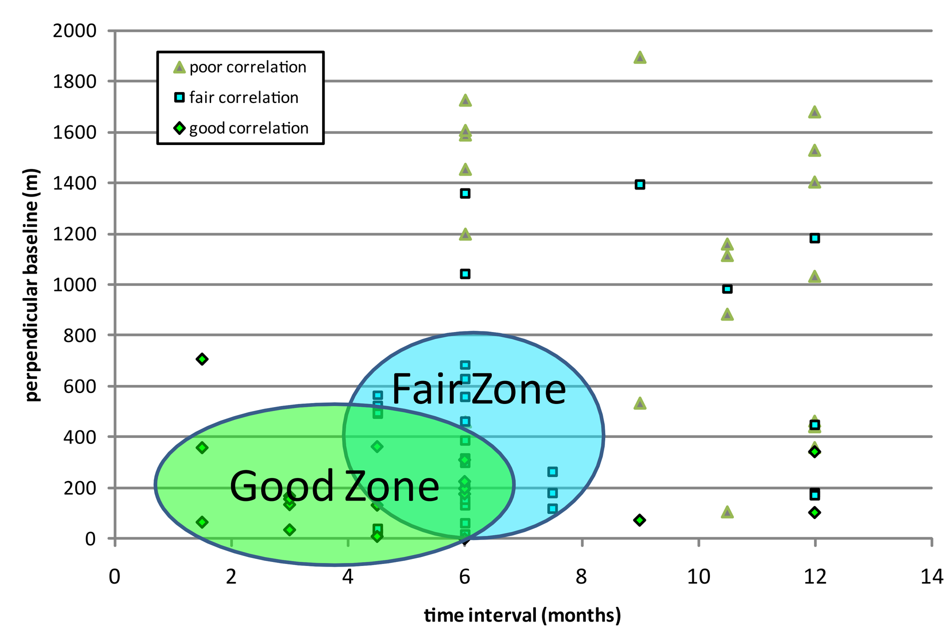


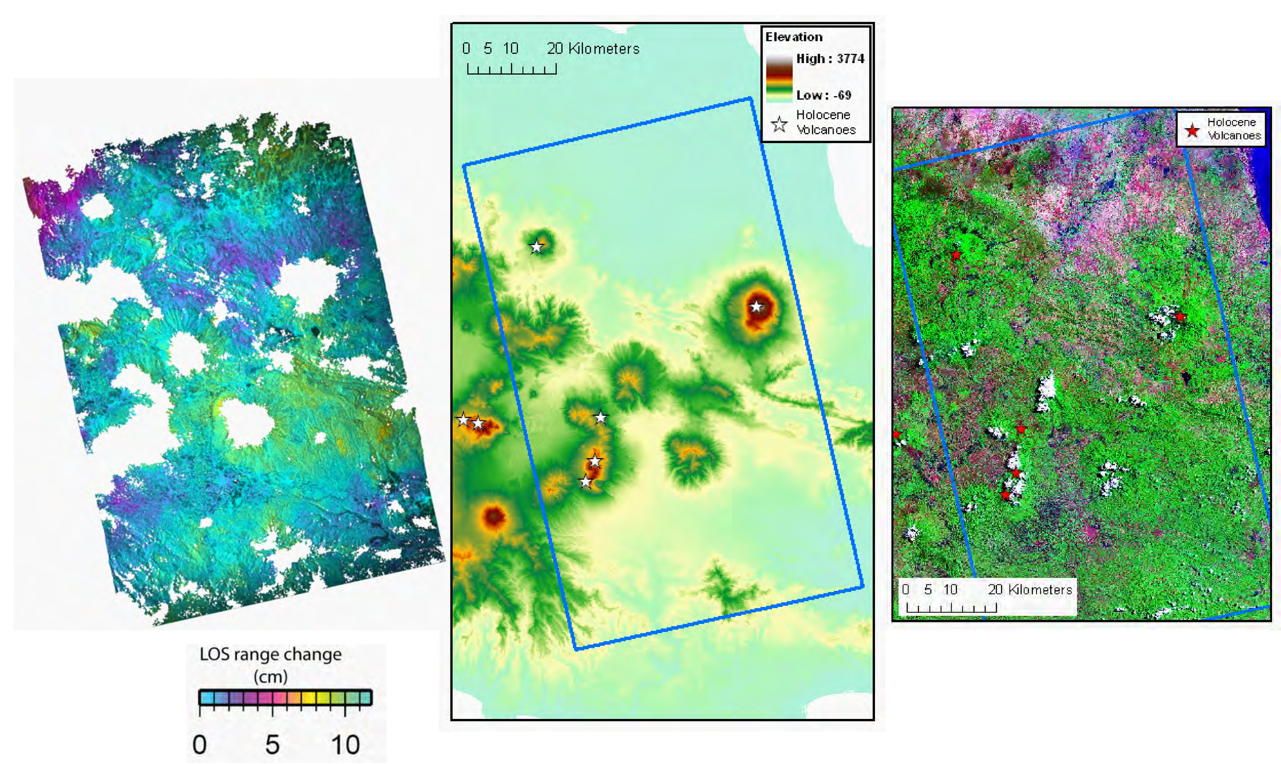


Decorrelation

Despite the decreased sensitivity to temporal and geometric decorrelation, interferograms in this region often have substantial decorrelated areas. Coherence between the two images generally decreases with longer time intervals and with longer perpendicular baselines (the component of the distance between the satellite positions perpendicular to the look angle), indicating that both temporal and geometric decorrelation are still factors. Also, the volcanic edifices are preferentially decorrelated, an effect that may be due to topographic relief and/or vegetation. While decorrelation due to topography may be corrected by future processing improvements, using current techniques deformation can only be monitored effectively using interferograms with time intervals of 6 months or less and perpendicular baselines shorter than ~700m.

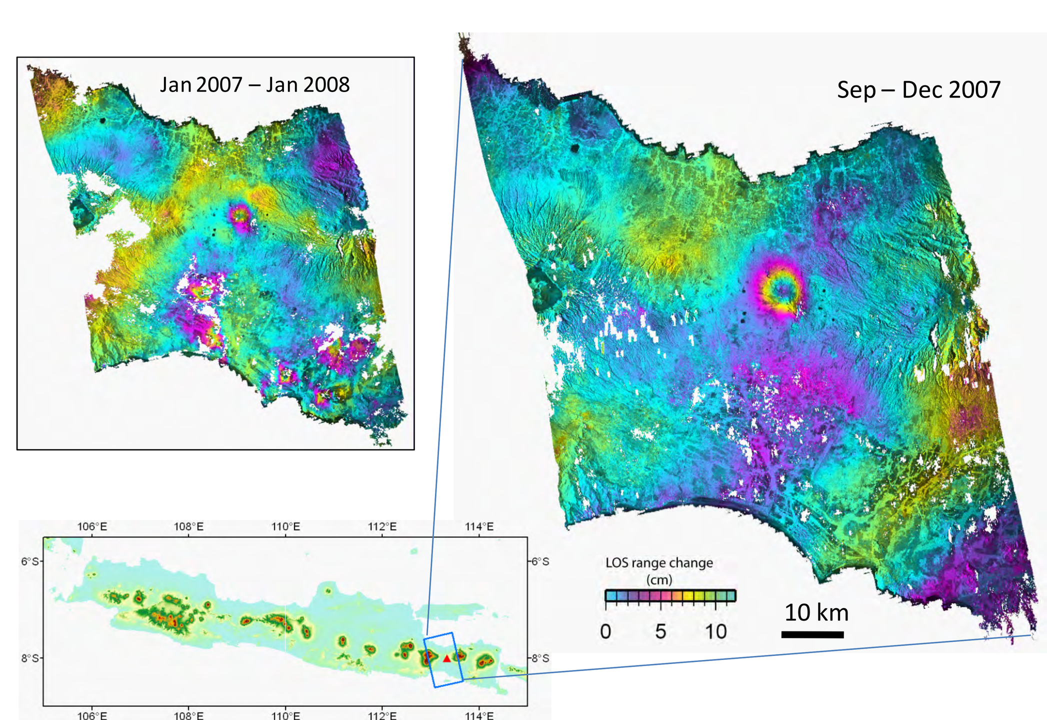
Effects of Baseline & Time Interval

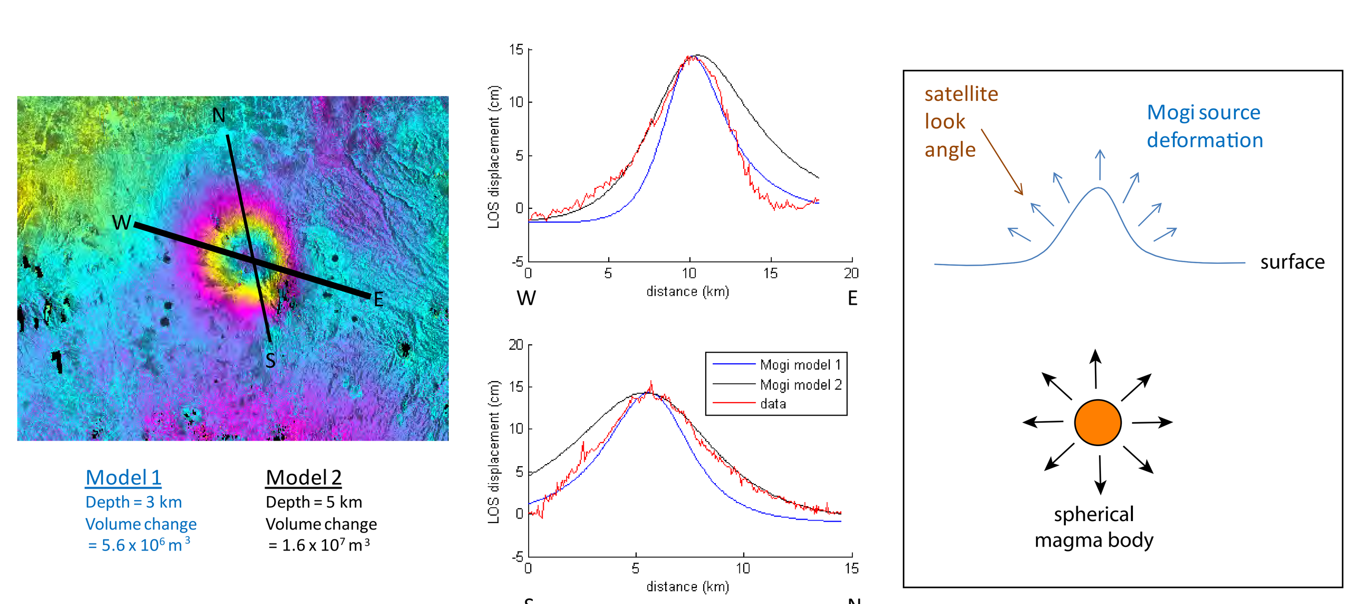




Likely Volcanic Deformation at Lamongan

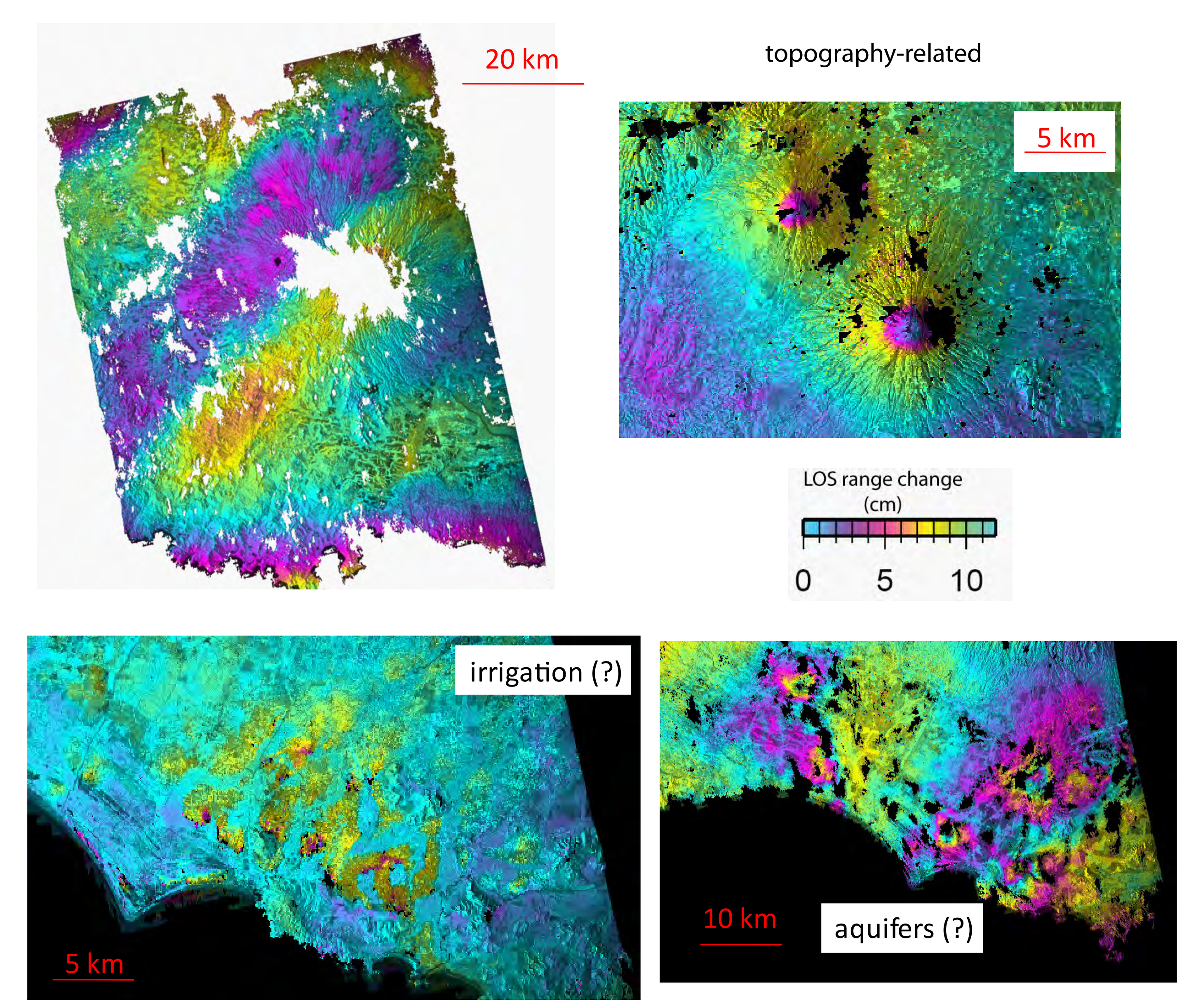
Over the study period, only one convincing instance of probable volcanic deformation was apparent. The isolated, circular signal appears on independent interferograms, is not correlated with topography, is located in a (dormant) volcanic zone, and can be modeled to first order by a Mogi source. However, there is an asymmetry in the deformation signal which is opposite in sense to the asymmetry expected due to the satellite look angle. Therefore, this signal cannot be completely modeled by a simple spherical source in an elastic half-space. Possible explanations include non-sphericity the magma body, heterogeneity in the elastic structure of the crust, and contamination by non-volcanic signal.





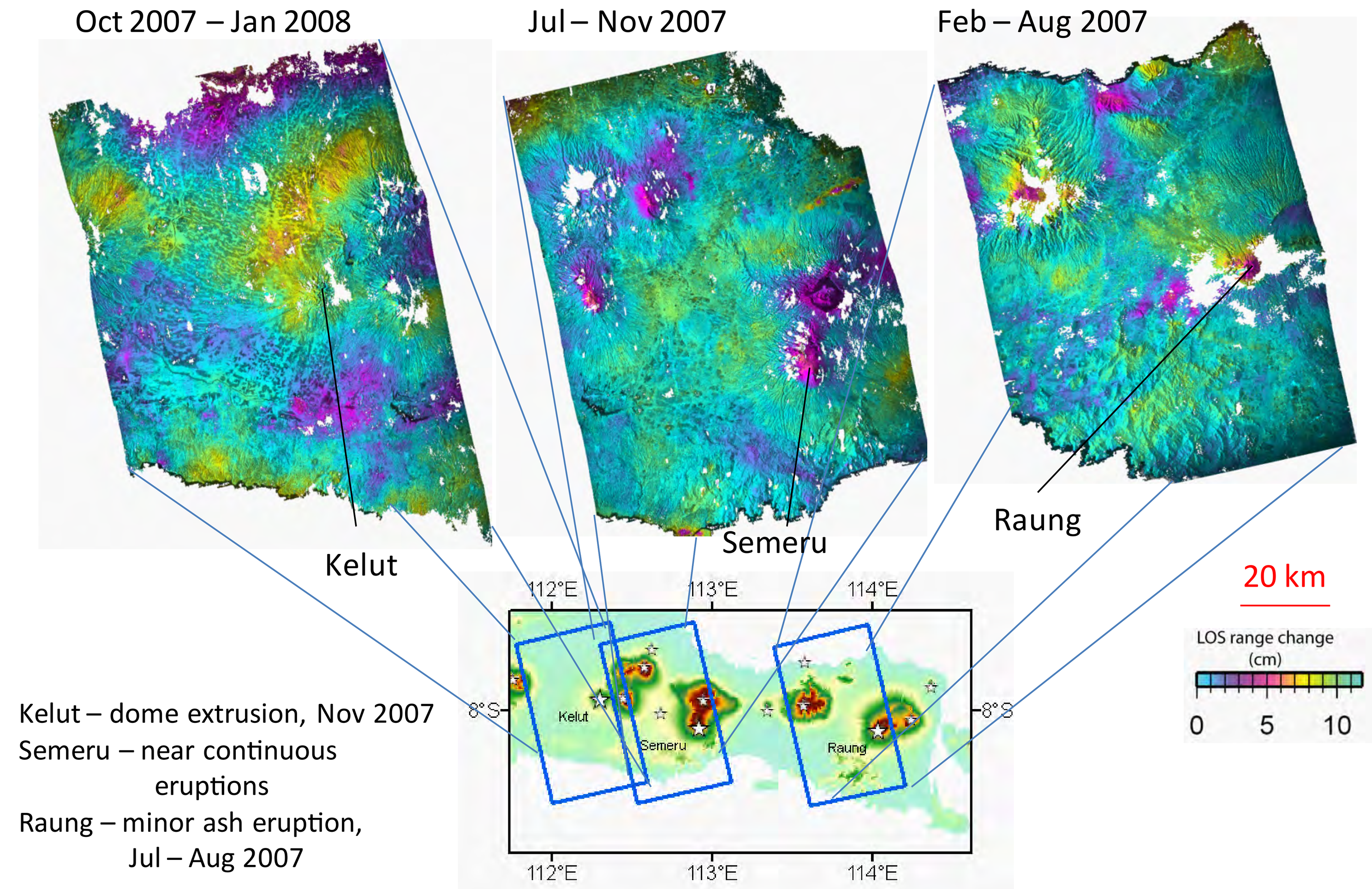
Non-Volcanic Signal

Even if the interferogram is perfectly correlated, non-volcanic sources of signal may still interfere with the ability to detect volcanic deformation. The three primary contributors to non-volcanic signal are the atmosphere, hydrology, and geometric errors. Long-wavelength phase variations are usually due to atmospheric effects and do not substantially hinder detection of volcanic sources. However, atmospheric effects or geometry errors may result in phase variations which are correlated with topography, which may mimic or mask true ground deformation on volcanic edifices. Hydrology generally produces shorter-wavelength signal: irrigation results in patches of shallow deformation with sharp boundaries at the edges of agricultural areas, while recharge or extraction of deeper aquifers produces broader, higher-amplitude signals which are more similar to the effects of volcanic deformation. Topography- and aquifer-related signals impose a detection threshold upon volcanic deformation, in that volcanic deformation smaller than ~10 cm or shallower than ~500 m may be difficult to distinguish from non-volcanic signal sources.



Unclear Relationship Between Deformation and Eruption

Of the three Javanese volcanoes which had eruptions during the study period, one shows no obvious deformation. The other two might exhibit small amounts of deformation, but in both cases any deformation is masked by signal which is almost certainly related to topography rather than volcanism. More InSAR-based study of known eruptions is required before measured deformation can be related to future eruption potential in a meaningful way.



Kelut – dome extrusion, Nov 2007
Semeru – near continuous eruptions
Raung – minor ash eruption, Jul – Aug 2007

Potential Future Improvements

- Processing changes to improve correlation
- Apply atmospheric corrections
- Time series analysis of shorter-interval interferograms
- Study deformation associated with known eruptions
- Expand survey temporally and spatially (Sumatra, other Indonesian islands, other tropical volcanic arcs?)