GEOPHYSICAL RESEARCH LETTERS, VOL. 35, L16302, doi:10.1029/2008GL034654, 2008

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A multi-temporal InSAR method incorporating both persistent scatterer and small baseline approaches

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Received 30 May 2008; revised 10 July 2008; accepted 16 July 2008; published 19 August 2008.

[1] Synthetic aperture radar (SAR) interferometry is a technique that provides high-resolution measurements of the ground displacement associated with many geophysical processes. Advanced techniques involving the simultaneous processing of multiple SAR acquisitions in time increase the number of locations where a deformation signal can be extracted and reduce associated error. Currently there are two broad categories of algorithms for processing multiple acquisitions, *persistent scatterer* and *small baseline* methods, which are optimized for different models of scattering. However, the scattering characteristics of real terrains usually lay between these two end-member models. I present here a new method that combines both approaches, to extract the deformation signal at more points and with higher overall signal-to-noise ratio than can either approach alone. I apply the combined method to data acquired over Eyjafjallajökull volcano in Iceland, and detect time-varying ground displacements associated with two intrusion events.
Citation: Hooper, A., (2008), A multi-temporal InSAR method incorporating both persistent scatterer and small baseline approaches, *Geophys. Res. Lett.*, *35*, L16302, doi:10.1029/2008GL034654.

1. Introduction

[2] Spaceborne interferometric synthetic aperture radar (InSAR) is a valuable technique for measuring surface deformation because of the high spatial resolution achieved and the ability to acquire the data remotely. However, problems due to changes in scattering properties of the Earth's surface with time and look direction limit the applicability of InSAR. Where measurement is possible, signal due to displacement of the ground is overprinted by noise due to variation in atmospheric properties and inaccuracy in both satellite orbit and surface elevation determination.

[3] Multi-temporal InSAR (MT-InSAR) techniques, involving the processing of multiple acquisitions in time, provide one way to address these issues. Currently, there are two broad categories of MT-InSAR techniques, *persistent scatterer* (PS) methods including those that identify pixels based primarily on their phase variation in time [e.g., *Ferretti et al.*, 2001; *Kampes*, 2005] and those that use primarily correlation of their phase in space [e.g., *Hooper et al.*, 2004; *van der Kooij et al.*, 2006], and small baseline (SB) methods [e.g., *Berardino et al.*, 2002; *Schmidt and Bürgmann*, 2003]. The naming of the categories is inconsistent in that "persistent scatterer" refers to the type of pixel that is identified whereas "small baseline" refers to the methodology of interferogram formation. However, as the names are already established, I continue to use them here.

[4] In a synthetic aperture radar image, the value for each pixel is the coherent sum of contributions from all scatterers within the associated ground resolution element. Relative movement of these scatterers, or a change in the look or squint angle, causes the scatterer contributions to sum differently, an effect known as decorrelation [*Zebker and Villasenor*, 1992]. For ground resolution elements containing a persistently dominant scatterer the phase due to decorrelation varies little with time even if the dimmer scatterers move with respect to the dominant scatterer. Furthermore, the variation is also small when viewed from different look and squint angles. This is the principle behind a PS pixel. For resolution elements containing no dominant scatterer, on the other hand, phase variation due to decorrelation is often large enough to obscure the underlying signal. However, by forming interferograms only between images separated by a short time interval and with a small difference in look and squint angle, decorrelation is minimized, and for some resolution elements may be small enough that the underlying signal is still detectable. Decorrelation is further reduced by spectral filtering in range [*Gatelli et al.*, 1994] and discarding of the non-overlapping Doppler frequencies in azimuth. Pixels whose phase when thus filtered decorrelates little over short time intervals, which I refer to as slowly-decorrelating filtered phase (SDFP) pixels, are the targets of SB methods. Note that for pixels dominated by a single scatterer, the effect of range and azimuth filtering may be to increase decorrelation due to the coarsening of the resolution. Nevertheless, the decorrelation may still be low enough for many PS pixels that they also qualify as SDFP pixels. Thus SDFP pixels and PS pixels form two distinct, but potentially overlapping, sets of pixels. The phase of pixels selected by both methods will however differ due to the inclusion or absence of spectral filtering.

[5] There has been some debate about the relative merits of PS and SB approaches. However, as they are optimized for different models of ground scattering, the two approaches are in fact complementary, at least in the usual case where a data set contains pixels with a range of scattering characteristics. Here, I present a new algorithm that combines both PS and SB approaches to maximize the spatial sampling of useable signal. Improvement of the spatial sampling is important not only because the resolution of any deformation signal is increased, but also because it allows for more reliable estimation of integer phase-cycle

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0094-8276/08/2008GL034654$05.00