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Geophysical Research Abstracts
Vol. 18, EGU2016-15247, 2016
EGU General Assembly 2016
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Improved geodetic earthquake source modelling through correction of ionospheric disturbances in L-band InSAR data

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The use of L-band InSAR data for observing the surface displacements caused by earthquakes can be very beneficial. The retrieved signal is generally more stable against temporal phase decorrelation with respect to C-band and X-band InSAR data, such that fault movements also in vegetated areas can be observed. Also, due to the longer wavelength, larger displacement gradients that occur close to the ruptures can be measured. A serious draw back of L-band data on the other hand is that it more strongly reacts to heterogeneities in the ionosphere. The spatial variability of the electron content causes spatially long wavelength trends in the interferometric phase, distorts the surface deformation signal therefore impacts on the earthquake source analysis. A well-known example of the long-wavelength distortions are the ALOS-1 InSAR observations of the 2008 Wenchuan earthquake.

To mitigate the effect of ionospheric phase in the geodetic modelling of earthquake sources, a common procedure is to remove any obvious linear or quadratic trend in the surface displacement data that may have been caused by ionospheric phase delays. Additionally, remaining trends may be accounted for by including so-called ambiguity (or nuisance) parameters in the modelling. The introduced ionospheric distortion, however, is only approximated arbitrarily by such simple ramp functions with the true ionospheric phase screen unknown. As a consequence, either a remaining ionospheric signal may be mistaken for surface displacement or, the other way around, long-wavelength surface displacement may be attributed to ionospheric distortion and is removed. The bias introduced to the source modelling results by the assumption of linear or quadratic ionospheric effects is therefore unknown as well.

We present a more informed and physics-based correction of the surface displacement data in earthquake source modelling by using a split-spectrum method to estimate the ionospheric phase screen superimposed to the interferogram. This method is based on the dispersive nature of the ionosphere and separates the ionospheric component of the interferometric phase from the non-dispersive component related to topography, ground motion, and tropospheric path delay.

We study the ionospheric bias on the fault modelling results in a real-data case study of a non-complex earthquake rupture using the ionospheric phase screen estimations and the uninformed ramp removal in comparison. The test earthquake is the March 24 2011 Myanmar earthquake (Mw6.8), which is covered by ALOS-1. Here, the coseismic interferograms of both ascending and descending tracks show significant ionospheric distortions. We use the standard formulations of rectangular dislocations in an elastic half-space and run fully non-linear optimizations of the first-order fault parameters. We complement the optimization with a Bayesian model parameter uncertainties estimation to quantify the modelling bias in source model estimation with arbitrarily trend-corrected L-band displacement data compared to the correction based on the estimated ionospheric phase screen.

For this particular strike-slip earthquake we find that fault dip, fault slip and rake are affected by the above mentioned methods of mitigating ionospheric contributions. The spurious oblique strike-slip mechanism found in the seismological gCMT solution, previous InSAR studies and our result from standard ramp correction, becomes a pure vertical strike-slip rupture for the physically-informed ionospheric delay correction. With such improved static near-field observation of seismic ruptures we also contribute towards the combined use of geodetic and seismic data in earthquake source modelling.

The research of H.S and G.G. was and is funded by the Earth System Dynamics HGF Alliance. The ALOS data for this study are kindly provided by JAXA through the RA4 program under the project ID 1349.