A Tropospheric correction method for short and long-swath InSAR processing

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1. Introduction

For Interferometric Synthetic Aperture Radar (InSAR), small-magnitude long-wavelength tectonic signals are often masked by atmospheric delays (Fig 1). Even after sophisticated time-series InSAR techniques, tropospheric delays of up to 15 cm can persist in interferograms[1]. Current correction techniques are limited by auxiliary data or cannot account for the spatially-varying tropospheric properties. We propose a power-law correction estimated from the phase data that allows for a spatially-varying troposphere.

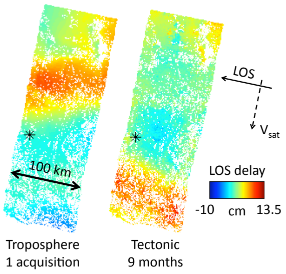


Fig 1. Tropospheric delays are mainly caused by spatio-temporal variation of water vapour, pressure, and temperature in the lower 15 km of the troposphere. In Mexico, for example, tropospheric delays reach a similar order of magnitude as the accumulated tectonic slow slip deformation signal over a 9-month period[1,2].

2. Current techniques and their limitations

Through auxiliary data it is possible to account for the spatial variability of the tropospheric properties (Fig 2). These methods are unfortunately limited by the spatial resolution of the source data. Alternatively a correction can be estimated from the phase data. Time-series InSAR techniques and filtering of the interferometric phase in space and time can be applied, but separating the atmosphere from non-linear deformation is challenging. The correlation between interferometric phase and topography can be estimated either in a non-deforming area or using a frequency band insensitive to deformation. This method can be successful for small areas, but does not account for a spatially-varying troposphere (Fig 2).

Correction method	Limitations
Weather models	Long runtime, spatial resolution, requires model inputs
Spectrometer	Cloud cover, scaling factors, temporal resolution
GPS	Limited by spatial station distribution
	auxiliary data
Time-series filtering	Hard to separate from deformation, filtering assumptions
Linear correction	Hard to separate from deformation, assumes no spatially-varying troposphere
	phase data

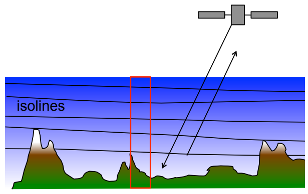


Fig 2. Linear phase topography correction methods can be successful for small areas (red rectangle). But over over larger regions they do not account for spatial variation of atmospheric properties. This can be significant across regions larger than 100 km. Applying the linear correction over sub-windows fails as the linear intercept is biased by deformation.

3. Power-law correction method

We approximate tropospheric delays by a power-law relationship. We assume relative tropospheric delays reduce to approximately zero at the height h_0 and above (Fig 3).

$$\Delta\phi_{tropo} = K\left(h_0 - h\right)^{\alpha}$$

With α the exponent, or gradient in the log-log plot (Fig 4), and K a coefficient describing the relation between tropospheric phase $\Delta\phi_{tropo}$ and topography h. We estimate K locally, from a freq band insensitive to deformation, which allows for a spatially-varying troposphere. In Fig 5 we present the seasonal variation of the power-law coefficients.

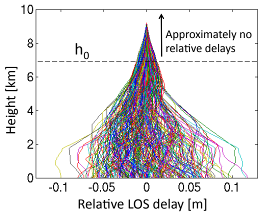


Fig 3. Relative tropospheric delays (sounding data) reduce to approximately zero at h_0 and above.

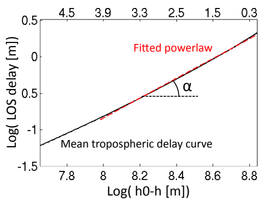
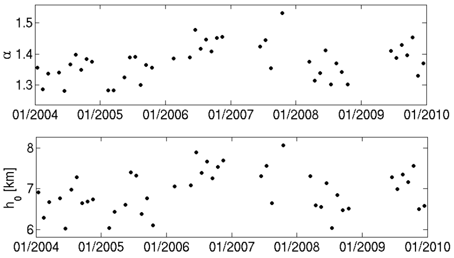


Fig 4. Log-log plot of the mean tropospheric delay. We estimate α from the linear fit over the lower topographic height range.

Fig 5. From sounding data we found the power-law coefficients α and h_0 to have a seasonal variation. From theoretical simulations, we found that the seasonal variation compared to a mean does not have a strong impact on the estimated correction.



4. Comparing correction techniques

We find a good correspondence between the tropospheric correction estimated using data from the Medium Resolution Imaging Spectrometer (MERIS) (Fig 6) and our proposed power-law correction technique (Fig 7). Over Mexico, different mountain ranges and climate can lead to a spatially-varying tropospheric signal (e.g. 31 Dec 2004). While conventional linear corrections fail, we are capable of estimating this signal using the power-law relationship.

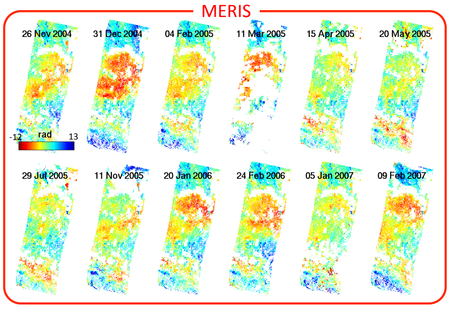


Fig 6. (top) Tropospheric correction estimated using data from the MERIS onboard Envisat. As the MERIS data is simultaneously acquired with the SAR data , MERIS is capable of capturing the atmosphere at the right instant. Out of 18 interferograms generated over Mexico, 7 have more than 85% cloud cover.

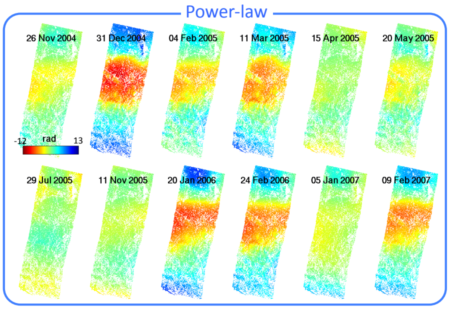


Fig 7. (bottom) Estimated tropospheric delays using the proposed power-law method. In our estimation we used a power-law coefficient α of 1.4 and a reference height h_0 of 7 km, corresponding to the mean value of the seasonal variation (Fig 5). We applied the power-law locally over 50 windows and estimated K in a non-deforming frequency band (2-8 km).

5. Conclusions

We present a new tropospheric correction technique for InSAR data. We approximate the tropospheric delay using a power-law relationship. Our correction is estimated from the phase data itself. Different from other phase-estimated correction techniques, the power-law accounts for spatially-varying tropospheric properties. This is especially of importance for large regions (> 100 km). We apply the power-law locally and estimate the relation between phase and topography from a frequency band insensitive to deformation. Our estimated tropospheric delays using the power-law are consistent with independent estimates made using MERIS.

Acknowledgements

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[1] Hooper et al., 2012, *Recent advances in SAR interferometry time series analysis for measuring crustal deformation*, Tectonophysics, doi: 10.1016/j.tecto.2011.10.013
[2] Bekaert, 2010, *InSAR time series analysis of the 2006 slow slip event on the guerrero subduction zone*, Mexico., M.S. thesis, Delft University of Technology,

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