A Survey of Temporal Decorrelation from Spaceborne Repeat-pass SIR-C L-band InSAR Observations

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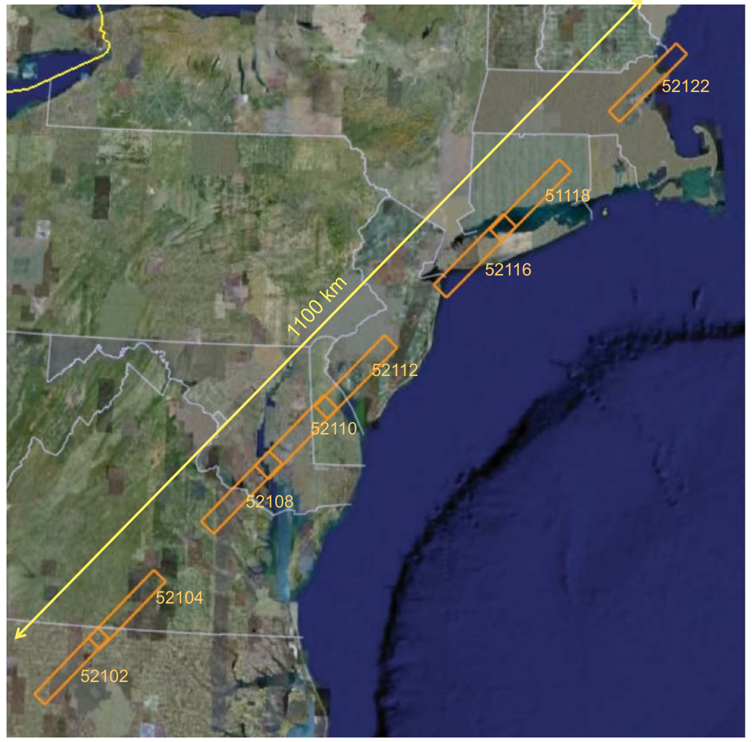
Abstract

The SAR/InSAR component of the NASA DesdynI mission for measuring vegetation 3-D structure from space, consists of one of four possible approaches. These are:

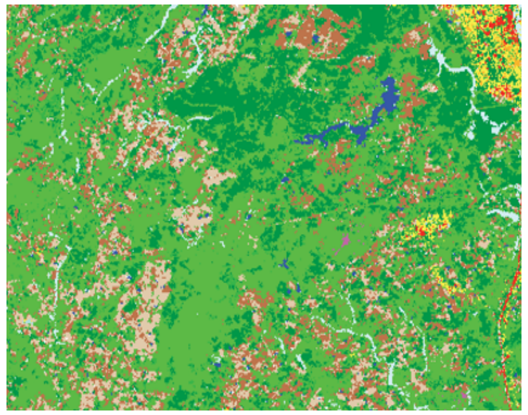
- Use of radar backscatter (single-pol, dual-pol or quad-pol) to relate backscatter to biomass, in a manner that is consistent with methods used to achieve this relationship developed over the last fifteen to twenty years
- Use of interferometric height and a secondary source of bare earth elevation data (such as the National Elevation Dataset, NED)
- Use of interferometric correlation magnitude data generated from repeat-pass observations (single- or mulit-baseline) for estimating the vegetation vertical structure, or
- Use of PolInSAR (polarimetric-interferometry) relative phase for determining the vertical extent of the canopy

The work shown in this poster describes an ongoing effort to utilize repeat-pass InSAR observations from satellite data to explore relationships between the different data types and landcover classes. To this end, we have processed over one million (1,000,000) hectares of 30m resolution InSAR data from one-day repeat-pass SIR-C, which overflew the eastern coast of the United States in October of 1994. While this particular set of repeat-pass observations had baselines that varied from only +/- 30 meters (translating into a vertical wavenumber of $kz \le 0.006$ rad/m; or ≤ 1 deg/m), thus making it difficult to convert interferometric phase into height, the data set is ideal for exploring the effect of temporal decorrelation because of the short repeat-period between observations and the minimal sensitivity to volumetric decorreltion (i.e. the only observed decorrelation is due to thermal noise and temporal changes).

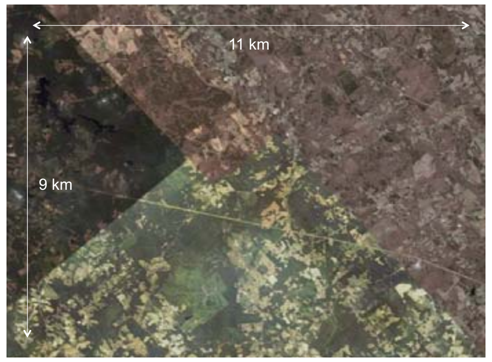
This poster illustrates the results from these comparisons, and shows that the effect of temporal decorrelation is significant enough to preclude the use of repeat-pass correlation magnitude only measurements for estimating vegetation height. A tandem InSAR mission would correct this problem, as would a more extensive reliance on interferometric phase.



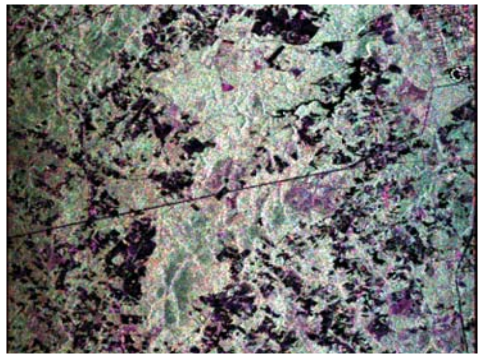
Individual SIR-C scene boundaries overlain on a Google Earth image of the Eastern US. The repeat-period between observations was one day (almost ideal), with an interferometric baseline of less than 30 meters. In all, more than 1 million hectares of 30m data were analyzed.



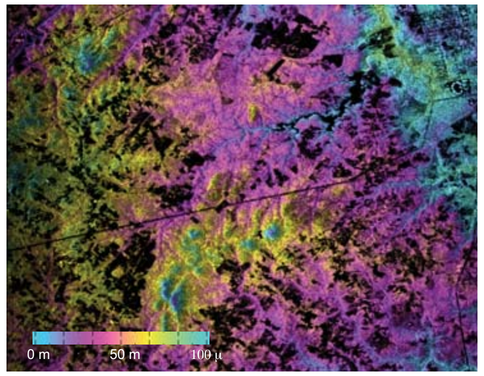
Classes from the 1992 National Land Cover Dataset (http://edc.usgs.gov/products/landcover/nlcd.html) were used to explore dependencies of the interferometric correlation on landcover type. The data, available in map coordinates, were projected into the radar coordinate system to a sub-pixel accuracy, allowing for a unprecedented and detailed analysis to be performed.



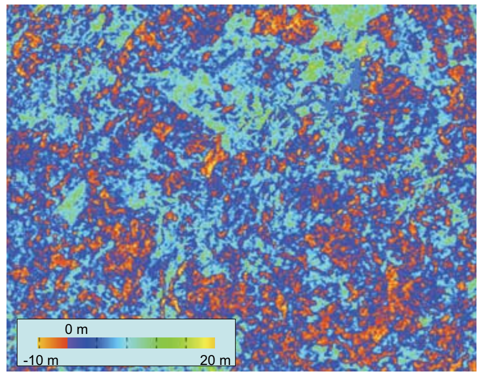
A close-up GoogleEarth image of a portion of scene 52102 in North Carolina. This scene was chosen for illustration because of a strong weather-related decorrelation feature across the image.



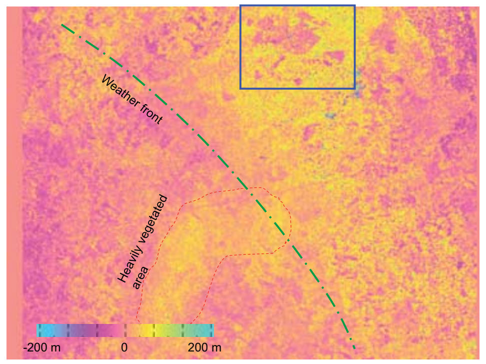
A quad-pol L-band backscatter image from SIR-C. In this image, polarizations are colored as: HH, HV, and VV. The color white indicates polarization independent scattering, greenish hues, volume scattering and red or violet, a strong surface component.



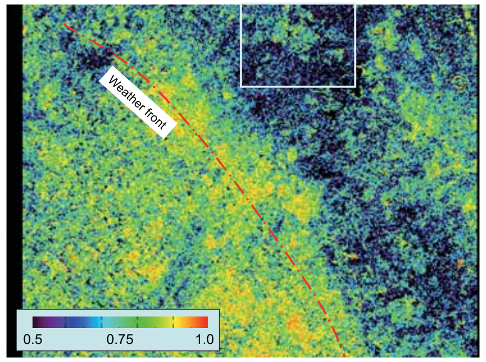
The SRTM DEM overlain on the SIR-C L-band HH backscatter image. A moderate amount of topography is evidenced throughout the image.



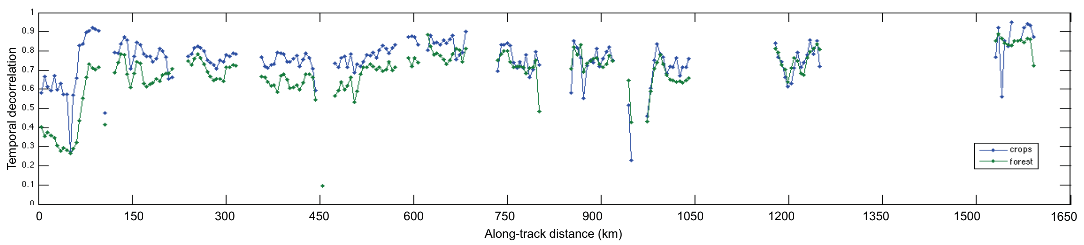
The National Elevation Dataset (NED) subtracted from the SRTM derived DEM. Height differences on the order of 15 meters are seen, likely due to the presence of vegetation, or slight errors in the two datasets.



The SIR-C L-band measured height after removing the SRTM derived topography. Clear signatures of differential topography related to the presence of trees can be seen in the data (boxed region), even in areas of large temporal decorrelation (see figure to the right). Other features show topographic trends as well as a weather related trend.

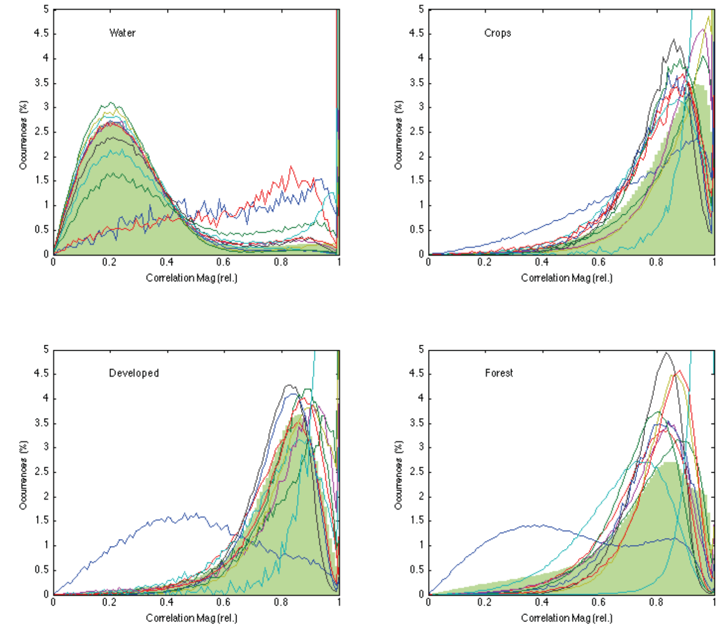


The interferometric L-band correlation magnitude. Note the poorly correlated areas (upper right) do not coincide with ground features in the optical, radar, or classification images. Nonetheless, regions of poor correlation (white box) do not appreciably affect the interferometric phase measurement in the image to the left. A clear signature of a weather front can be seen, which effectively divides the image into two parts, one well correlated, and the other, not.

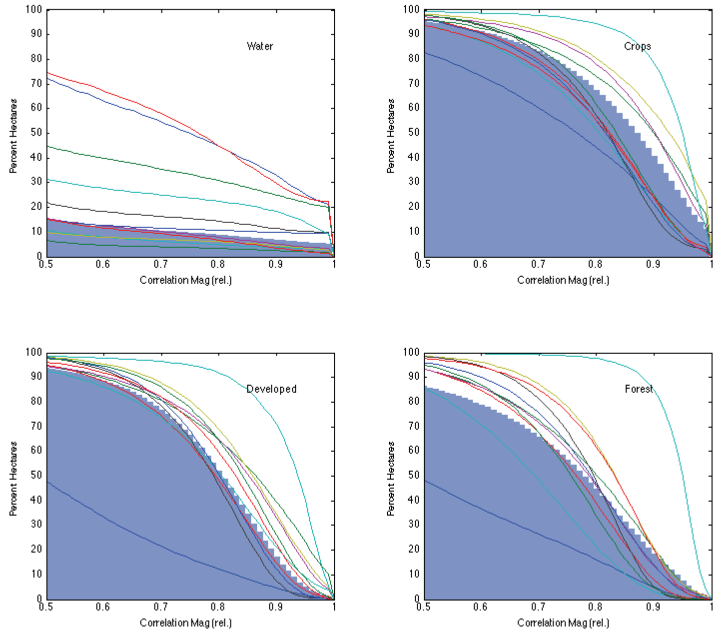


A plot of temporal decorrelation as a function of location in the along-track swath (see Google-Earth image to the left). The leftmost part of this plot begins in North Carolina and ends in Southern Canada. To make this plots, effects such as thermal noise and classification differences were taken into account. In the above, note the following:

1. all interferometric measures show some degree of temporal decorrelation (I.e. in no instance, is the temporal decorrelation sufficiently close to unity).
2. there is a general trend from high temporal decorrelation to low temporal decorrelation as the plot goes from left ot right (increasing latitude).
3. there is also a general trend in the difference between the degree of temporal decorrelation seen between crops and forested areas as the plot increases in latitude. Note the similarity in shape of the temporal decorrelation signatures, irregardless of the degree of decorrelation and the target type. This is indicative of a weather related signature.
4. the increased difference of temporal decorrelation seen for forests compared to crops is likely due to the larger volume of scatterers that can decorrelate for vegetation as compared to crops.
5. the reduced temporal decorrelation seen for the high latitude regions (along-track distance of 1500km) is likely due to the higher percentage of conifers in the region, the higher degree of leaf-off condition that occurs this time of the year, and/or a calmer weather situation in the region.



Probability density functions of temporal decorrelation as a function of land cover type. Individual scene pdf's are shown as colored lines. The pdf of temporal decorrelation for the entire 1 million hectare region is shown as a shaded green histogram in the background. Note the clear dependence of decorrelation on landcover type and scene location.



Cumulative distribution functions derived from the pdf's described above for the four different landcover types. Plots such as these can be used to determine what percentage of the time a certain level of decorrelation would be observed. Note that in all but a few cases, temporal decorrelation is always present. Some marked deviations from the mean behavior (shown as the blue shaded histogram) are from the northern scenes, where temporal decorrelaton was less than an issue for the southern scenes. One example of information that can be derived from these plots, is to be able to say that for forested regions, that on average, 40 percent of the forested pixels have a temporal correlation magnitude of greater than 0.8. This has meaningful implications for phase measurement accuracy and the use of correlation magnitude only measures of vegetation height, and therefore in the choice of satellite orbits and/or a repeat-pass mission versus a tandem mission.

Conclusions

A large region of one-day repeat-pass SIR-C L-band data was processed for examining the effects of temporal decorrelation. The significant finding of the analysis are:

1. Some degree of temporal decorrelation can be seen everywhere.
2. The degree of the decorrelation is dependent on land cover type, and latitude, and is likely weather dependent.
3. The temporal decorrelation does not significantly effect the phase information, but use of the correlation magnitude in estimation algorithms for vegetation structure may prove problematic.
4. The season (fall) that the observations took place may play a factor as well.
5. There are clear wind signatures in the data, and where present, effect forests more than crops.
6. Cumulative distribution curves were generated that can be used as a reference for a mission design that requires statistics on the probability of experiencing a certain degree of temporal decorrelation.