GEODETICALLY ACCURATE INSAR DATA PROCESSOR FOR TIME SERIES ANALYSIS

Howard A. Zebker[1], Scott Hensley[2], Piyush Shanker[1], and Cody Wortham[1]

[1]Departments of Electrical Engineering and Geophysics,
Stanford University, Stanford, CA 94305-2155
[2]Jet Propulsion Laboratory, California Institute of Technology,
Pasadena, CA 91109

1. INTRODUCTION

We present a new InSAR processing approach that capitalizes on the precise orbit tracking available with modern radar satellites, with applications for temporal observation of the Earth's surface. Our method uses accurate orbit information along with motion compensation techniques to propagate the radar echoes to positions along a non-inertial, virtual orbit frame in which the location and focusing equations are particularly simple, so that images are focused without requiring autofocus techniques and are computed efficiently. The motion compensation requires two additional focus correction phase terms that are implemented in the frequency domain. If images from an interferometric pair or stack are all computed along the same reference orbit, the flat-Earth topographic correction is not needed and image coregistration is simplified, obviating many difficulties often encountered in InSAR processing. This is particularly important in modern, time series analysis of terrain [1,2]. We process several data sets collected by the ALOS PALSAR instrument, and find that the geodetic accuracy of the radar images is 10-20 m, with up to 20 m of additional image distortion needed to align 100x100 km scenes with reference digital elevation models. We validated the accuracy using both known radar corner reflector locations and by registration of the interferograms with digital maps. The topography-corrected interferograms are free of all geometric phase terms and clearly show the geophysical observables of crustal deformation, atmospheric phase, and ionospheric phase [3].

2. APPROACH

Our processing method begins with definition of a particular reference orbit and the equations needed for radar image focusing and pixel location. The reference is a perfectly spherical orbit at constant heading over a non-rotating planet, which is in fact a physically unrealizable non-inertial orbit. Since actual satellites cannot obtain this orbit, we use motion compensation techniques to modify the radar echoes such that they appear to have been acquired along the reference orbit. We focus the image using analytic expressions for matched-filter Doppler and Doppler rates, and show that two focus correction phase histories must be added to the radar echo to properly focus the image. Processing multiple radar acquisitions to coordinates defined by the same reference orbit facilitates easy combination to form interferograms, interferogram stacks, and time series acquisitions. This obviates the time consuming and inaccurate resampling steps required in many processing systems to account for InSAR baselines. We then use an iterative algorithm for mapping the interferograms as expressed in radar coordinates to evenly spaced and known geodetic coordinates, so that the images may be readily combined with other data types.

3. ACCURACY

We assess the geodetic accuracy of the system by analyzing data acquired over a set of GPS-surveyed radar corner reflectors, plus by computing the misregistration of dead-reckoned images with digital elevation models from the SRTM mission and from the USGS. Estimated errors from these comparisons are shown in the following tables:

Table 1. Pinon Flat Corner Reflector Locations

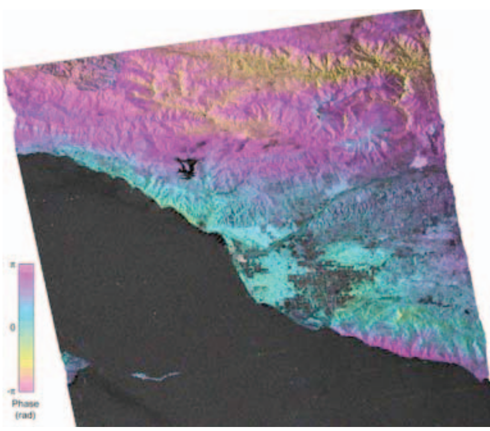
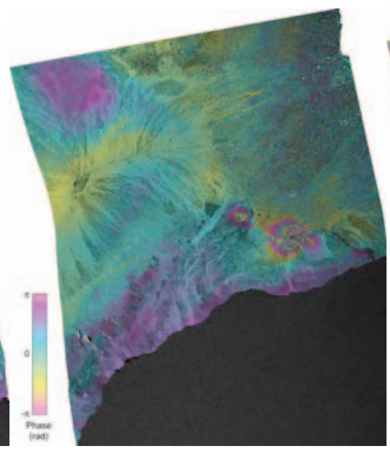
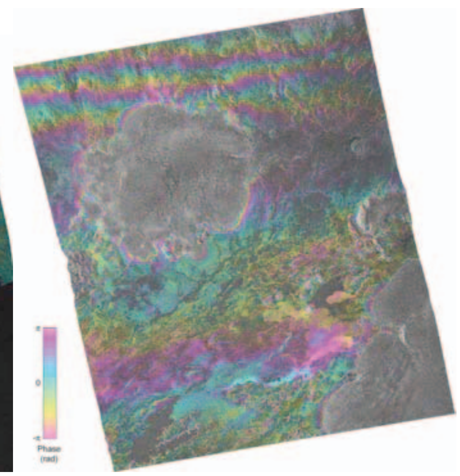
Measurement	Latitude (deg)	Longitude (deg)	Latitude error (m)	Longitude error(m)
Reflector aligned with ascending orbit				
InSAR location, unregistered image	33.61233	-116.4570	9	-18
InSAR location, registered image	33.61215	-116.4567	-11	9
Ground GPS survey	33.61225	-116.4568	--	--
Reflectors aligned with descending orbit				
InSAR location, unregistered image	33.61215	-116.4579	-11	0
InSAR location, registered image	33.61213	-116.4577	-13	18
Ground GPS survey	33.61225	-116.4579	--	--
InSAR location, unregistered image	33.60729	-116.4517	-9	9
InSAR location, registered image	33.60727	-116.4516	-11	18
Ground GPS survey	33.60737	-116.4518	--	--

Table 2. Image Registration Offsets

Scene	Range offset at center (m)	Azimuth offset at center (m)	Additional stretch Range (m)	Additional stretch Azimuth (m)
Ventura	-15.8	18.2	9.4	15.2
Hawaii	-21.5	24.0	14.1	25.4
Iceland	2.0	2.9	44.0	29.4

4. IMAGE RESULTS

Finally, we present several interferograms processed by our processor from L-band ALOS PALSAR data in order to demonstrate applicability to a variety of applications. Scenes are from, left to right, Ventura, CA, Hawaii, and Iceland. Geodetic accuracy is given in Table 2 above.

Ventura, CA   Hawaii   Iceland

5. COMPUTATIONAL EFFICIENCY

As one aim of our processor is make the InSAR processing task efficient and inexpensive, we have implemented our codes on desktop, multicore machines that process images such as those shown above in approximately 5 minutes each. Parallel processing architectures supported by open source tools make this feasible, so the processing speed is an essential part of our work. We are working with the Jet Propulsion Laboratory to make the software user friendly ad are releasing it open source for the radar community, and encourage ease of access and continued improvement from scientists and engineers worldwide.

5. REFERENCES

[1] A. Ferretti, C. Prati, and F. Rocca, “Nonlinear subsidence rate estimation using permanent scatterers indifferential SAR interferometry,” *IEEE Trans. Geosci. Remote Sens.,* vol. 38, no. 5, pp. 2202-2212, Sep. 2000.

[2] P. Berardino, G. Fornaro, R. Lanari, and E. Sansosti, “A new algorithm for surface deformation monitoring based on small baseline differential SAR interferograms,” IEEE Trans. Geosci. Remote Sens., vol. 40, No. 11, pp. 2375- 2383, Nov. 2002.

[3] H. A. Zebker, S. Hensley, P. Shanker, and C. Wortham, Geodetically Accurate InSAR Data Processor, submitted to IEEE Trans. Geosci. Rem. Sensing, 2009.