TROPOSPHERIC CORRECTION FOR INSAR USING INTERPOLATED ECMWF DATA AND GPS ZENITH TOTAL DELAY FROM THE SOUTHERN CALIFORNIA INTEGRATED GPS NETWORK

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1. INTRODUCTION

Interferometric Synthetic Aperture Radar (InSAR) is a technique used to generate images of surface deformation or elevation. It combines two images from a Synthetic Aperture Radar (SAR) satellite, to enable measurements of the vertical component, and has proven to be a powerful technique for mapping topography changes down to sub-centimeter level [1]. One significant error source in InSAR imaging is the propagation delay of radio signals in the atmosphere [2]. A major contribution to the delay is the highly variable water vapor content in the troposphere and it was suggested that a spatial or temporal change in relative humidity of 20 % would lead to 10 cm of errors in deformation products [3]. The current way to reduce tropospheric effects in InSAR images is to average several independent interferograms [3]. In this statistical method the tropospheric delay is regarded as white noise, implying that there is no correlation between variations in the tropospheric delay and topography. Nevertheless, when comparing the tropospheric delay and the topography it is evident that correlation exists, hence new methods are needed. An alternative approach to reduce tropospheric errors in InSAR images is to use Zenith Total Delay (ZTD) estimated from the Global Positioning System (GPS). Corrections using interpolated ZTD from GPS have shown promising results [e.g. 4; 5; 6]. However, the limited spatial coverage of GPS stations raises the need of a method with higher spatial resolution. Here the high spatial resolution is achieved by a Stretched Boundary Layer Model (SBLM), which interpolates data from the European Centre for Medium-Range Weather Forecasts (ECMWF) using a Digital Elevation Model (DEM). We present results from correcting three interferograms from Envisat in 2006 using both SBLM correction maps, interpolated GPS correction maps, and a combined SBLM and GPS correction map.

2. DATA

The InSAR data were taken from Envisat track 170 spanning from the Los Angeles basin in the south to Death Valley in the north. In order to evaluate the results, InSAR images without any other source of decorrelation than from atmosphere was desired. An example could be that for longer temporal baselines surface deformation in the area is apparent. With this in mind, three interferograms with short temporal baselines were selected. Two of the pairs had a temporal baseline of 35 days (July-August and October-November) and one with a temporal baseline of 105 days.

The GPS data were taken from stations in the Southern California Integrated GPS Network (SCIGN). Most of the stations selected were located inside the Envisat track, but data were also taken from adjacent stations outside the area in order to mitigate edge effects when interpolating the data. The number of stations used was 132 to 135 stations.

For the SBLM we used the 4-hour deterministic forecast of precipitable water vapor, surface temperature and surface pressure from ECMWF and a DEM from USGS National Elevation Database.

3. METHODS

The interferograms from the three pairs of Envisat SAR images were processed using the Repeat Orbit Interferometry package (ROI_pac) software (version 2.3) [7]. The processing was done with SNAPHU unwrapping [8] and the topographic component of the interferometric phase was removed [9].

The GPS data were processed using the GIPSY-OASIS II software [10] estimating the ZTD. The processing was done separately for each day using the GIPSY-OASIS II software in Precise Point Positioning (PPP) mode [11] using JPL's Flinn final precise orbit solution. A 7-degree elevation cutoff was applied together with the Global Mapping Function [12]. The resulting GPS ZTD data were interpolated using Inverse Distance Weighted (IDW) [13] and Gaussian interpolation.

The ECMWF data were interpolated each day of the InSAR overpass using the SBLM. The SBLM assumes that the water vapor and temperature profiles are unchanged above the boundary layer. Within the boundary layer the shape of the profiles are also unchanged and this is accomplished by stretching the profile to fit the topography and then combine the stretched profile within the boundary layer with the original profile above the boundary layer. The total amount of water vapor, Total Precipitable Water Vapor (TPW), was then obtained by integration of the topography corrected water vapor profile. The TPW were converted to ZWD [14] and then ZTD by using the SBLM surface pressure maps.

The ZTD maps (from both GPS and SBLM) were then converted into ZTD correction maps (difference between two maps) and combined ZTD difference maps were created. The combined maps were designed so that the ECMWF field agreed with the GPS data at the sites of the GPS stations. This was done by calculating the difference in ZTD between GPS and SBLM maps at the locations of the GPS stations. Then the difference was interpolated using IDW and Gaussian interpolation and added to the ECMWF surface.

4. RESULTS AND OUTLOOK

The resulting correction maps (GPS, SBLM and the combined) were applied to the three InSAR images and the root-mean-square (RMS) errors of the InSAR images were calculated both before and after applying the corrections. A reduction of the RMS errors of 15-32% was seen for two of the InSAR images whereas the RMS error for the third image increased with 3-8%. In all short-interval InSAR images gradients of different magnitudes were seen, indicating a residual orbit error [15]. The orbit errors were estimated by fitting a plane to the remaining errors after the tropospheric correction of the images [16] and were then removed from the InSAR images. As an example Fig. 1 shows one of the original InSAR images, a GPS correction map, and the corrected InSAR image (both troposphere and orbit corrected). After both ZTD difference maps and orbit correction was applied to the InSAR images, the RMS error decreased for all images with 15-68%.

The results show that it is possible to reduce tropospheric errors in InSAR images using available data sets together with simplistic algorithms. Future work consists of further developing the combination of the ZTD from GPS and weather models and implementing it into the GPS Explorer portal [17] in the project Real-Time In Situ Measurements for Earthquake Early Warning and Spaceborne Deformation Measurement Mission Support. In this project the aim is to develop tropospheric correction maps that are generic enough to extend to other geographical areas as well as to extend to various weather models and GPS delay datasets. Additionally, there is today ongoing work of studying algorithms for elevation-based interpolation of weather model data with the AIST project Online Services for Correcting Atmosphere in Radar.

5. REFERENCES

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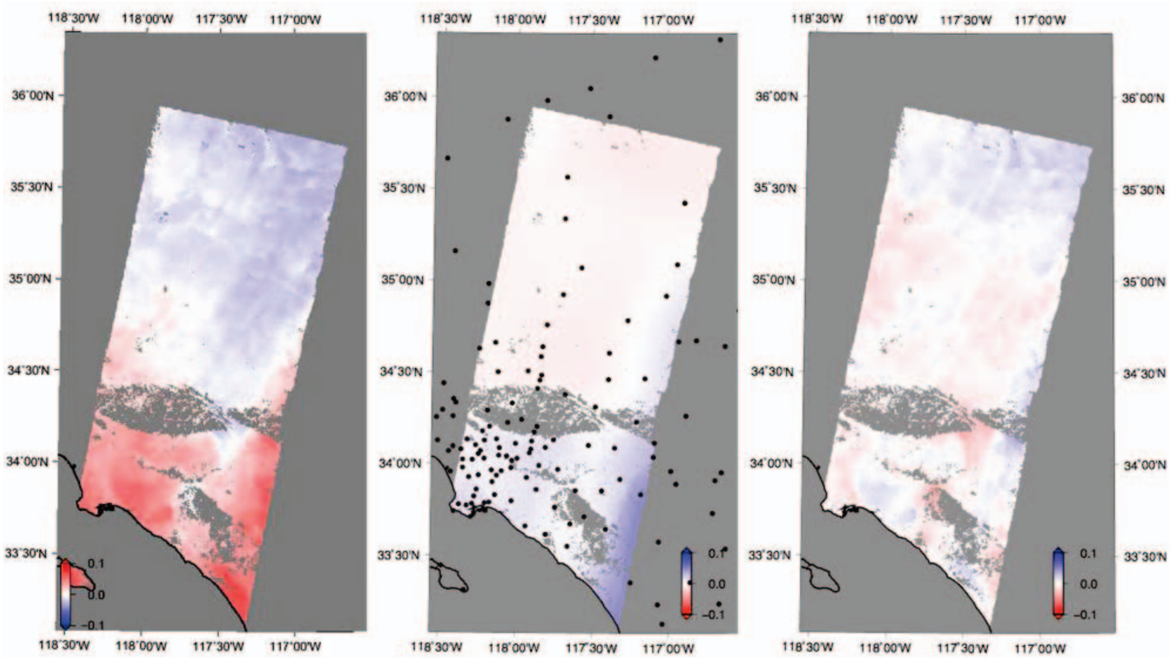

Fig. 1. The original July-August InSAR image (left), the GPS correction map (center), and the troposphere and orbit corrected InSAR image (right). Black dots in the correction map indicates the location of the GPS stations.

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