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Interferometric Point Target Analysis with JERS-1 L-band SAR Data

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Abstract— **Interferometric Point Target Analysis (IPTA) is a method that exploits the temporal and spatial characteristics of interferometric signatures collected from point targets that exhibit long-term coherence to map surface deformation. This paper demonstrates the viability of this technique for L-Band data collected by the JERS-1 sensor during the time period 1992-1998. A data set covering Koga, Japan is used for demonstration and indicates regions of substantial subsidence.**

Keywords: Interferometric Point Target Analysis (IPTA), JERS, surface deformation, subsidence

I. INTRODUCTION

Interferometric Point Target Analysis (IPTA) is a method that exploits the temporal and spatial characteristics of interferometric signatures collected from point targets that exhibit long-term coherence to map surface deformation. Use of the interferometric phase from long time series of data requires that the correlation remain high over the observation period. Ferratti et al. proposed interpretation of the phases of stable point-like reflectors [1,2]. Use of the phase from these targets has several advantages compared with distributed targets including lack of geometric decorrelation and high phase stability.

JERS-1 collected a global L-band (1.275 GHz) SAR data set from 1992-1998 at a 10 meter range and 5.5 meters in azimuth resolution. The satellite operated with a look angle of approximately 35 degrees. Validity of IPTA has been confirmed for a series of ERS data [3]. Differential interferometry with JERS-1 SAR has also been demonstrated [4]. Combined, these justify a study of IPTA feasibility using data from JERS-1.

II. IPTA PROCESSING APPROACH FOR JERS-1

IPTA processing for ERS data has been reported [3]. Fig.1 shows the IPTA processing flow. Processing begins by assembling a set of SAR data acquisitions covering the time period of interest. Having as many acquisitions as possible leads to improved temporal resolution of non-linear deformation. The image stack is processed to single look complex (SLC) images and coregistered to a common geometry.

An initial set of candidate point targets is then selected. Points suitable for IPTA exhibit stable phase and a single scatterer dominates the backscatter within the resolution element. A phase model consisting of topographic, deformation and atmospheric terms is subtracted from the interferograms to generate a set of point differential interferograms [3]. The topographic component of the phase model is obtained by transforming the DEM into radar coordinates using baselines derived from the orbit state vectors. If no DEM is available, it is still possible to perform the analysis by initially assuming a flat surface.

Processing proceeds by performing a least-squares regression on the differential phases to estimate height and deformation rate. The estimates are relative to a reference point in the scene. Residual differences between the observations and modeled phase consist of phases proportional to variable propagation delay in the atmosphere, non-linear deformation, and baseline-related errors. The interferometric baseline can also be improved using height corrections and unwrapped phase values derived from IPTA. Spatial and temporal filtering is used to discriminate between atmospheric and non-linear deformation phase contributions. The atmosphere is uncorrelated in time, whereas the deformation is correlated. The IPTA process can be iterated to improve both the phase model and estimates of deformation by using the initial estimates of atmosphere phase, deformation, heights, and baselines.

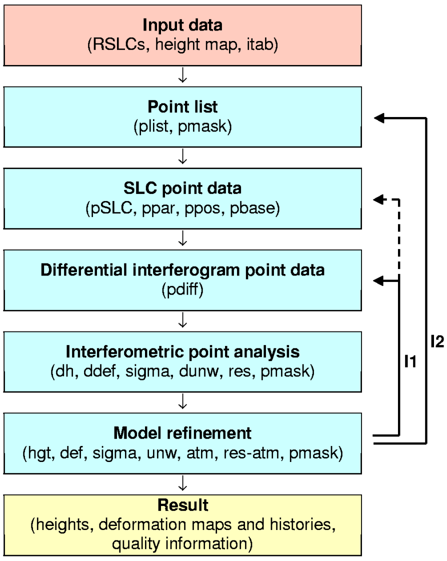

Figure. 1. Interferometric point target analysis (IPTA) processing flow

In the following we examine aspects where JERS may differ from ERS with regards to IPTA processing. These aspects are availability of points, baseline quality, and sensitivity for deformation measurement. Our JERS-1 test site is centered on Koga, Ibaraki-ken, 50 km north of Tokyo, Japan. A total of 38 images comprise the stack, spanning the period from September 1992 through September 1998. The initial test area is a 20.25-km in range x 33.75-km in azimuth.

A. Baseline quality

For JERS-1, the critical perpendicular baseline $B_\perp$ is approximately 6 km compared to the ERS value of 1.06 km. Spatial phase unwrapping of an interferogram is difficult for values of $B_\perp > 25\%$ of the critical value. Baselines for the test site are shown in Fig.2. Most of the acquisitions have baselines that exceed 25% of $B_\perp$ and therefore are excluded from standard 2-D differential interferometric analysis. The spread of the JERS baselines is similar to the ERS case considering the larger value of the critical baseline for JERS-1.

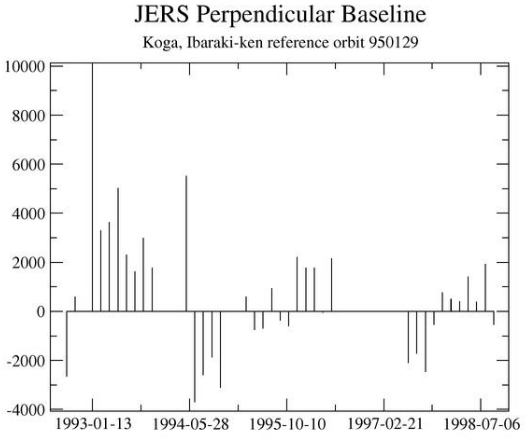

Figure. 2. Baselines in meters for the 39 JERS acquisitions over Koga, Ibaraki-ken.

Estimates of the ERS baselines have sufficient accuracy for the initial IPTA iteration because the ERS precision state vectors have sub-meter accuracy. Baseline errors for JERS-1 can be hundreds of meters when obtained from the orbit state vectors. These baseline errors cause phase ramps in the differential interferograms. Estimates of the residual fringe rate in the individual interferograms are used to refine the baselines, thereby improving the IPTA phase model.

B. Availability of Points

Essential for IPTA processing is that there are enough point targets in the scene. Scattering is dominated by features on the scale of the wavelength or larger. From this aspect, there should at least be as many point scatterers for ERS as JERS. In general, higher resolution should lead to more point targets, independent of frequency. For the JERS data, point target candidates were selected using variability of the backscatter as a selection criterion. The standard deviation of the residual phase is then used later on as the measure of the point quality.

In Fig. 3 is shown the phase regression for a point pair prior to inclusion of the atmospheric phase in the IPTA phase model. This regression was then performed over the entire set of point candidates. Of these points 38360 were found to have a residual phase standard deviation < 1.2 radians. In Fig. 4 is shown a small section of the multilook image of Koga with the point targets highlighted. This verifies that there are sufficient point targets within the urban scene for IPTA analysis. The number of targets found is on the same order (100/sq. km) as for ERS for a similar urbanized region [3].

In Fig. 5 are the IPTA derived height values displayed using a cyclical color table. The linear deformation rates over the scene are shown in Fig. 6 indicated subsidence greater than 3 cm relative to stable regions towards the North.

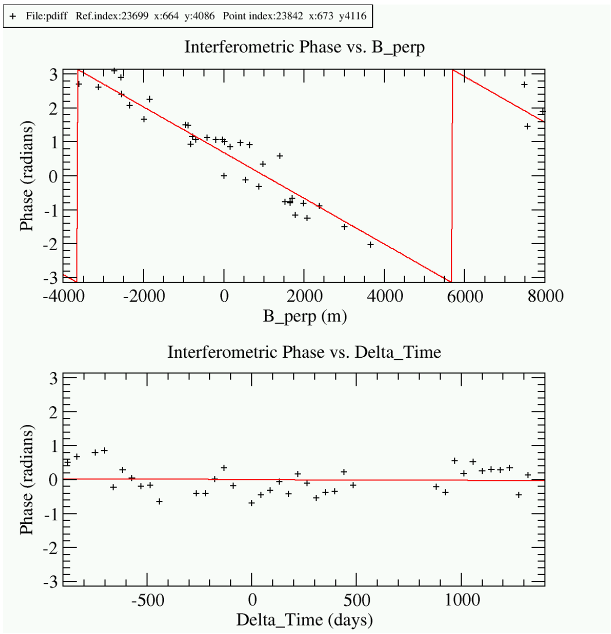

Figure. 3. Phase regression for two points with a separation of 180 meters. The equivalent height error is 5.52 meters and the average deformation rate is 0.16 mm/year.

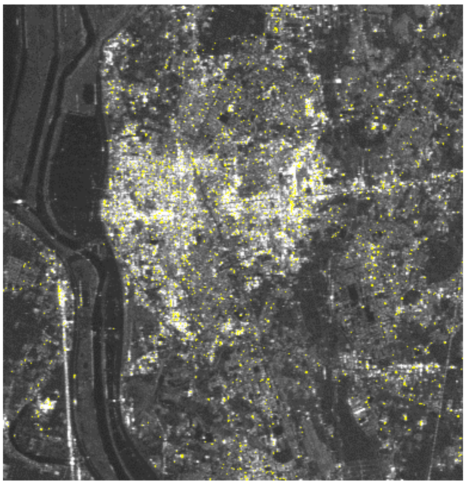

Figure. 4. JERS-1 multi-temporal slant range image of Koga, Ibaraki-ken showing point locations with phase standard deviation < 1.2 radians.

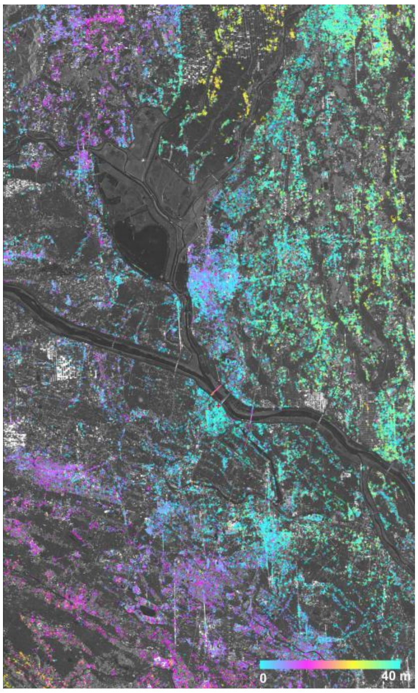

Figure. 5. Differential heights derived from JERS data using IPTA displayed using 40 m/color cycle. The reference point is located at the red + near the image center.

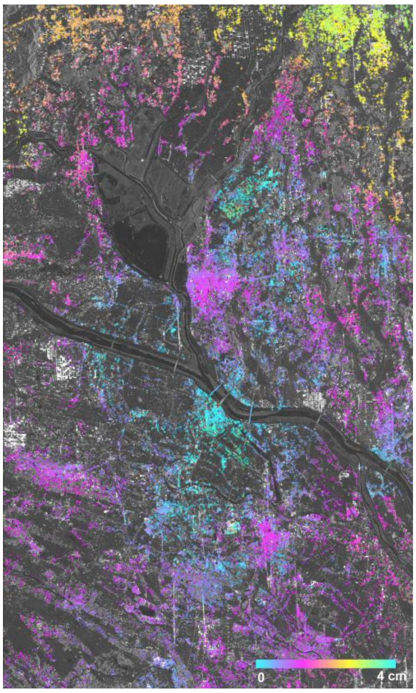

Figure. 6. Linear deformation rate derived using IPTA displayed using 4 cm/color cycle. The reference point is located at the red + near the image center.

The sensitivity of phase to deformation is directly proportional to the radar frequency. Therefore the phase for JERS is 0.24 of the ERS value for an equivalent LOS deformation. The variable path delay due to tropospheric water vapor is approximately independent of frequency [5]. For JERS-1, the ionosphere can contribute significant variations in path delay especially in Polar Regions [6]. L-band and C-band data are expected to have similar performance for measurement of deformation in areas where the phase residuals are dominated by variable atmospheric delay. The deformation history of point near the scene center located approximately 10-km from a stable reference area is shown in Fig. 7.

III. CONCLUSIONS

The presented work confirms that IPTA processing of JERS-1 data sets regions is possible with good results. Sufficient numbers of point targets can be identified. The quality of IPTA results with JERS still needs quantitative assessment.

Baselines clearly larger than useful for standard interferometric analysis could be used in IPTA to obtain more information on deformation history. Estimation of baselines with large errors was identified as the main complication as compared to IPTA with ERS data.

The large archive of JERS-1 data is a resource that can be exploited for historical assessement of subsidence on a global scale using the IPTA methodology.

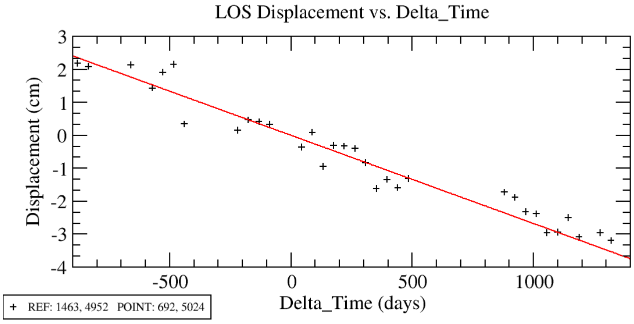

Figure. 7. Deformation history of a point derived with IPTA. Scatter about the regression line shows non-linear deformation and noise.

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