COSMO SKYMED AO PROJECTS - 3D RECONSTRUCTION AND STABILITY MONITORING OF THE THREE GORGES DAM

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ABSTRACT

Cosmo SkyMed is a constellation of Satellites launched by the Italian Space Agency providing Synthetic Aperture Radar images in interferometric mode in X band with a resolution of 3m and revisit time of a few days. In this work, two Cosmo SkyMed datasets of 29 images each, acquired along ascending and descending orbits are exploited for studying the stability of the area of the Three Gorges Dam in China. The short observation time allowed by the short revisit time can generate troubles when distinguishing between seasonal dilation and displacement. Nonetheless, the preliminary analysis clearly highlights movements of the riverbanks around the dam.

Index Terms— Cosmo SkyMed; Three Gorges Dam; PSInSAR

1. INTRODUCTION

The Three Gorges Dam along the Yangtze River in China is the largest hydroelectric project in the world. 2.3 km long, the dam is 185m high and it created a water reservoir 660km long. Its power generator is the largest in the world, having a huge impact on economy, environment, civil protection, with both positive and negative consequences [1, 2].

The stability of the Dam is clearly a key and extremely sensitive factor for the Hubei region and for the whole Chinese country. Several instruments are installed on the Dam structure and new technologies are continuously investigated to provide new and complementary measurements [3,4,5,6]. Interferometry Synthetic Aperture Radar (InSAR) has been proved to be an economic and convenient way for this task.

The authors of this paper worked in the past 5 years in close relationship with Chinese experts and adopted InSAR technologies to study the stability of the Dam [7,8,9]. However, the works that have been carried out till now were based on small archives of Envisat images, with a ground resolution of about 20m and a revisit time of 35 days. High Resolution (up to 1m) and high revisit-time (up to few days) Cosmo SkyMed data started being available in 2010, and offer new interesting potentialities. Previous studies by the authors with Cosmo SkyMed data on urban areas in Shanghai highlighted unique details of subsidence caused by tunnel excavation [10]. In this work, we present some preliminary outcomes retrieved in the Three Gorges area with data provided within a Cosmo SkyMed AO project launched by the Italian Space Agency.

2. STUDY AREA

The analyzed area is about 50 sqkm centered around the Three Gorges Dam. It includes the dam itself and surrounding buildings, the towns of Zigui and Sandoupingzhen and a couple of topographic relieves. An overview of the area of interest in shown in Figure 1.

Figure 1. The Three Gorges Dam and surroundings as seen from Google Earth.

3. THE DATASET

The dataset is formed by two Cosmo SkyMed tracks, one ascending and the other one descending, 29 images each. The data have been acquired by all Cosmo satellites, from

February to August 2011. The acquisitions are stripmap in interferometric mode. Figures 2 and 3 show the data in the normal-temporal baselines space, with lines representing the connections between each image and a reference one, chosen as master image. Connections are colored according to the reported colormap, proportionally to an average value of coherence of the corresponding interferogram. One can notice high values on Normal Baseline, in particular along descending orbits.

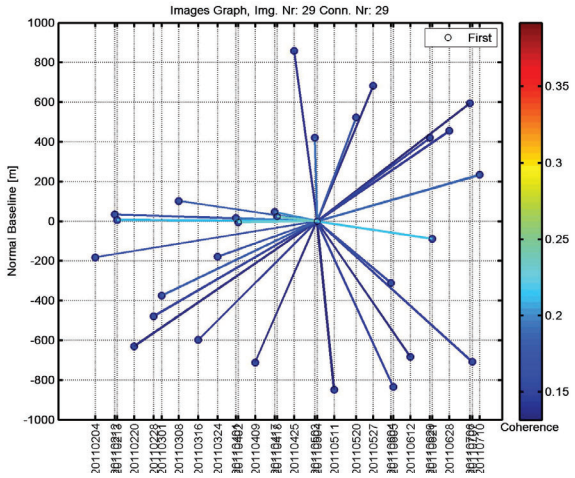

Figure 2. Cosmo ascending dataset, Three Gorges Dam

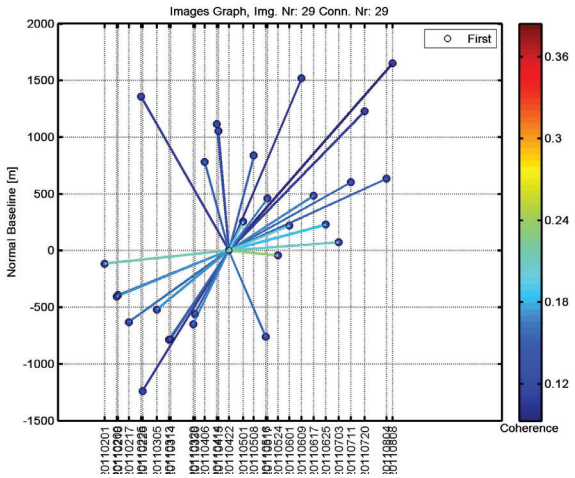

Figure 2. Cosmo descending dataset, Three Gorges Dam.

4. PRELIMINARY RESULTS

The reflectivity maps of the area of interest are shown in Figures 4 and 5, for the Ascending and Descending orbits respectively. The High Resolution SAR signal intensity itself is very interesting for appreciating the topography of the area and the Dam structure. The images reported in Figures 4 and 5 are in fact the geocoded reflectivity maps. The Height used for the geocoding process in SRTM DEM, which has a quite poor resolution in the imaged area. Unfortunately, it was not possible to retrieve better local information due to the sensitivity of the target. The reflectivity maps have been geocoded and visualized in Google Earth by SARPROZ [12], a software tool written by the authors to process series of interferometric SAR data. The optical data shown in the background are taken from Google Earth.

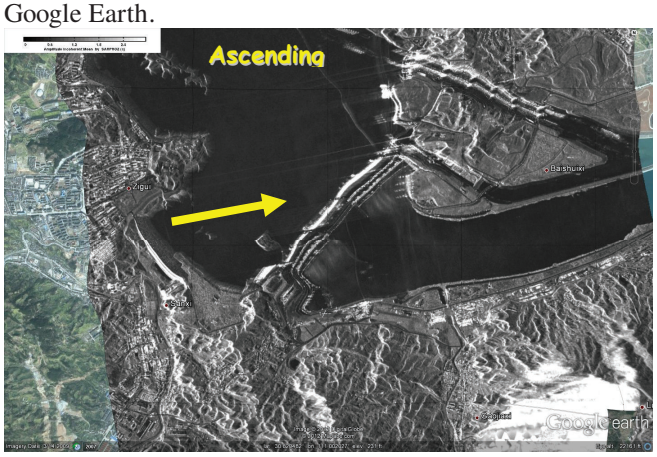

Figure 4. Reflectivity map of the area of interest, Ascending Cosmo dataset.

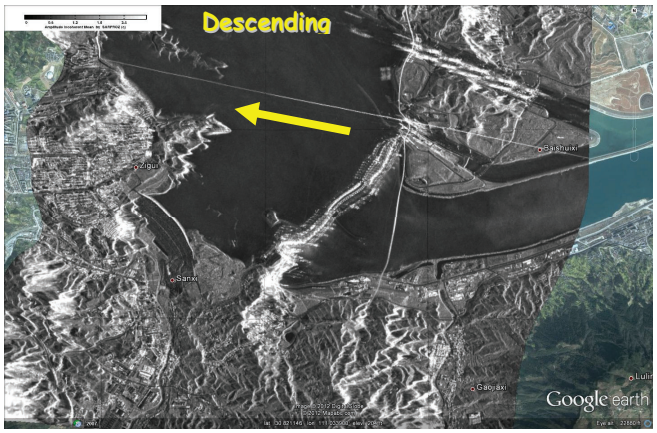

Figure 5. Reflectivity map of the area of interest, Descending Cosmo dataset.

To retrieve the terrain deformation, PSInSAR analyses were carried out in both datasets. The technique implemented to perform the study is the classic one easily found in literature [13]. Two main results have been extracted, the targets height and the linear displacement rate.

Figures 6 and 7 display the main outcome of the analysis, namely the terrain displacement rate observed in the analyzed time span. The colorscale of the two pictures ranges values from -60 to 20mm/year.

Figure 6 shows the linear deformation map obtained from the ascending dataset. It is very interesting to notice a series of subsiding areas along the riverbanks. The moving areas have been surrounded by circles to drive the reader's

attention. In particular, we notice a strong subsidence on the south west of the dam body.

Figure 7 is the corresponding map for the Descending case. The first macroscopic detail we notice is the identification of the same macro-subsiding area on the south west of the dam body, in good agreement with the Ascending case. Several details are then less visible, due to the different acquisition geometry. Also the motion intensity is slightly different, as a consequence of the different viewing angles. Though, even with different intensities it appears evident from both geometries that e.g. the down river banks have an opposite motion w.r.t. the upriver sides.

A very interesting behavior has been observed and reported in Figure 8. In the picture, 4 vertical structures are revealed by the presence of PSs on their top. From the Google imagery, shadows are found in correspondence of the structures, recognized as power pylons. The color of Figure 8 represents the target displacement, and the top of the pylons appears as uplifting. Such behavior should be surprising, but it finds its explanation in the thermal dilation of the structures. The analyzed time span is in fact only a few months, and a seasonal displacement is almost linear in such a period. It becomes then almost impossible to distinguish between thermal effects and actual terrain movement by observing too short times.

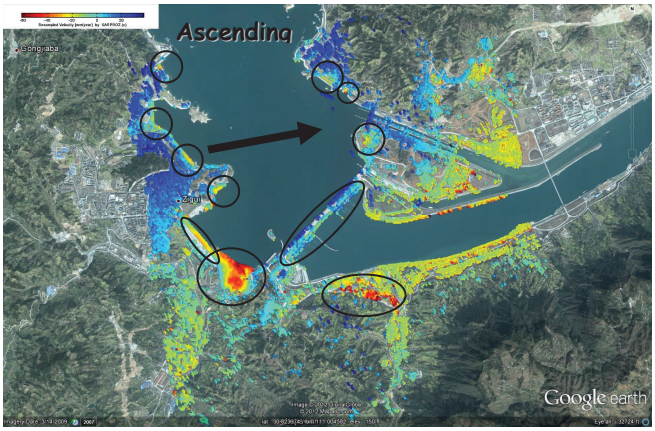

Figure 6. Linear deformation trend detected via PSInSAR analysis with Ascending Cosmo data over the Three Gorges Dam area

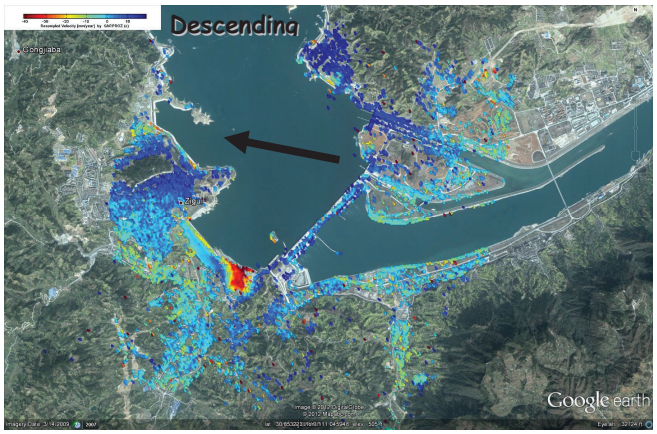

Figure 7. Linear deformation trend detected via PSInSAR analysis with Descending Cosmo data over the Three Gorges Dam area

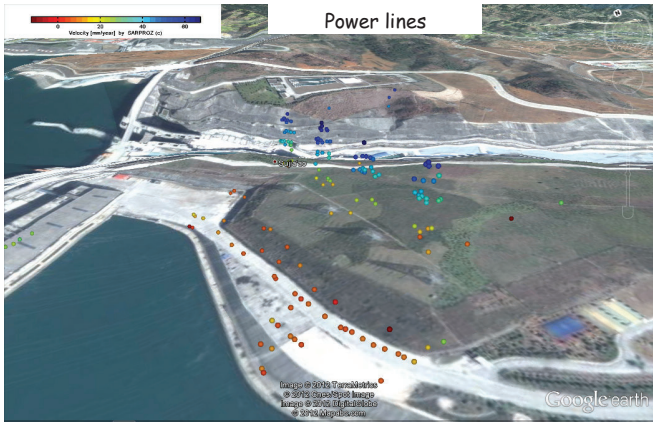

Figure 8. Example of a close up of the linear displacement trend around a target of interest: 4 power pylons right beside the Dam structure (shadows are visible on the optical picture). The top of the pylons seem uplifting, but the detected movement is actually thermal dilation. Due to the limited time span, it is very difficult to distinguishing between linear and seasonal motions.

5. CONCLUSIONS

In this paper, we analyzed 60 High Resolution Cosmo Skymed SAR images around the Three Gorges Dam in China along ascending and descending passes to retrieve information on the terrain displacement. The preliminary results show important movements of the river banks, landslides and a relative stretch between up and down river sides. The main challenge of the study has been the impossibility of separating seasonal movements from linear displacement due to the very short observed time. Works are still ongoing to merge ascending and descending results, interpret them and retrieve the high resolution 3D model of the Dam structure.

5. ACKNOWLEDGEMENT

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