HIGH RESOLUTION DSM GENERATION FROM ALOS PRISM
- PROCESSING STATUS AND INFLUENCE OF ATTITUDE FLUCTUATION -

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1. INTRODUCTION

One of the main objectives of the Advanced Land Observing Satellite (ALOS) mission is the creation and updating of maps on a scale of 1:25000 of Japan and other countries by providing high resolution land observation on a global scale. The Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) carried at ALOS was designed to generate worldwide topographic data in respects of its high resolution and stereoscopic land observation. According to this aim, we developed the algorithms of generating Digital Surface Model (DSM) for equipping the ground system which produces DSM semi-routinely in Earth Observation Research Center / Japan Aerospace Exploration Agency (EORC / JAXA) [1]. Following the accumulations of PRISM stereoscopic observation data since the launch, the characteristics of PRISM sensor geometry and the capabilities of the matching-algorithm for stereo images have been widely validated. This paper reports on the DSM processing status, over four year operations, including calibrations of the PRISM geometric model parameters, direct-triangulation-accuracies, DSM mosaics, and DSM error characteristics. Especially, we focused on an occasional waving error of DSM caused by an attitude fluctuation of ALOS. The detailed analysis and correction methods on the waving error are presented in this paper with inspection of satellite attitude data.

2. DSM PROCESSING STATUS

One of the technical challenges of PRISM is the precise direct geo-referencing (i.e., automatic image orientation) using the precision geometric model parameters. PRISM performs the along-track triplet stereo observations by forward (FWD), nadir (NDR), and backward (BWD) viewing independent panchromatic optical line sensors of 2.5m ground resolution in 35km wide swath. FWD and BWD sensors are arranged at an inclination of +/-23.8 degrees from NDR to realize a base to height ratio = 1.0. The direct geo-referencing of these triplet sensors enables the direct triangulation which provides an ability to generate DSMs without any Ground Control Points (GCPs). ALOS carries Global Positioning System (GPS) receiver for orbit determinations as well as Star Tracker (STT), Internal Reference Unit (IRU), and Angler Displacement Sensor (ADS) for attitude determinations [2]. The direct geo-referencing accuracy depends on the onboard orbit/attitude data and alignment stabilities between the orbit/attitude sensors and PRISM line sensors. We have calibrated these parameters so that the direct triangulation may achieve approx. 5m (rms) and 14m (rms) accuracies in planimetry and height respectively.

The along-track triplet stereo observation enables to generate more precision DSM frequently than usual pair stereo observations. We applied an exclusive algorithm for the image-matching of the triplet stereo images [1]. This algorithm has the high robustness against the matching blunders compared with the conventional pair stereo matching. The latest results of DSM validations with a Light Detection and Ranging (LiDAR) reference indicated that the relative height accuracy was approx. 5m (σ) [3]. We have already processed about three thousand scenes of DSMs over four year operations with the algorithm. To make up a global standardized data set of these DSMs, we apply mosaicking processes because the algorithm for DSM generations works on a scene basis of PRISM (i.e., 35km square). We tested the mosaicking process on 1°x1° tiles using these scene-based DSM archives. The intermediate results and issues of this ongoing mosaic processing are discussed in this paper.

3. INFLUENCE OF ATTITUDE FLUCTUATION AND ITS CORRECTION

An attitude fluctuation of an optical line sensor causes an along-track waving distortion of its image. The image distortion can not be corrected unless the attitude sensor measures the fluctuation sufficiently [4]. Relative distortions between those stereo images may cause along-track waving errors of their derived DSM as well. We have detected along-track waving errors, in some PRISM/DSM scenes processed with standard products, caused by an attitude fluctuation. We confirmed two kinds of error periods for the waving errors: approx. 1000m and 100m on the ground. The frequencies of these two periods were estimated at 6~7Hz and 60~70Hz respectively by the satellite ground speed (i.e., 6~7km/s). The peak-to-peak amplitudes of the waving errors were confirmed to be up to approx. 2m. These errors may not be negligible for users depending on their applications of DSM whereas the corresponding image distortion itself is sub-pixel level and we can hardly recognize them in a visual check. The ALOS provides the attitude data with STT, IRU, and ADS at sampling rates of 1Hz, 10Hz, and 676Hz respectively. A standard-product-processing uses only a composite of the STT and IRU at the sampling rate of 10Hz while the ADS was designed for on-orbit technical validations and is limited to an internal use. Therefore, we can attribute the waving errors of DSM to lack of the sampling rate of the attitude data in standard products because the Nyquist frequency of the composite of the STT and IRU is 5Hz against the waving errors of 6~7Hz and 60~70Hz. We examined the ADS data for the DSM scenes of waving errors and confirmed that they include jitter elements at the corresponding frequencies (i.e., 6~7Hz and 60~70Hz). Then, we applied the ADS data for the DSM processing. The results indicated that:

- Errors of 1000m period were corrected in most of DSM scenes.
- There were some DSM scenes left uncorrected for the errors of 1000m period.
- Errors of 100m period were not corrected at all.

With respect to the errors of 1000m period, following inspections revealed that the remaining errors were due to response errors of the ADS data at corresponding frequencies (i.e., 6~7Hz); we applied an additional response-rectification to the ADS data for the scenes left uncorrected. The physical source of the attitude fluctuation at 6~7Hz is considered to be a driving jitter of Data Relay Satellite Communication (DRC) antenna to Data Relay Test Satellite (DRTS). Hence, it affects only real time downlink observations in DRTS visible area. However, these periodical errors do not always appear even in real time downlink data. We have not yet understood a correlation factor of the error appearance and it is still under investigation. With respect to the errors of 100m period, we could not correct them with the ADS data at all although it includes the corresponding jitter elements. We suppose that all ADS may have some response errors at the corresponding frequencies (i.e., 60~70Hz); we are still investigating the relationship between the errors of 100m period and the ADS data. We tried to apply some adaptive filters (e.g., FFT) for eliminating directly the errors of 100m period as well.

4 REFERENCES

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