ADVANCE LAND-OBSERVATION SATELLITE (ALOS) AND ITS FOLLOW-ON SATELLITE, ALOS-2

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ABSTRACT

The Advanced Land-Observation Satellite (ALOS) was developed for close observation of the Earth’s surface and frequent monitoring of global environmental changes, using high-resolution optical sensors (visible and near infrared push-broom) and active microwave sensors (L-band synthetic-aperture radar), with four mission objectives: cartography, regional observation, disaster observation, and resource finding. It has been operational for three years since its launch in January 2006 and has acquired a large amount of land-surface data, supported by a Ka-band intersatellite communication system that downlinks to ground receiving stations. Using these sensors and the communication infrastructure, ALOS contributes to the monitoring of water, carbon, and global climate change. In this paper, we describe ALOS and its contribution to environmental monitoring. We also describe ALOS-2, the follow-on satellite system.

Keywords: ALOS, PALSAR, Kyoto and Carbon project, global mosaic.

1. INTRODUCTION

On January 24, 2006, ALOS was launched from the Tanegashima Space Center of the Japan Aerospace Exploration Agency (JAXA) into a Sun-synchronous orbit of medium height at 691.5km, with a 46-day recurrent cycle, carrying three high-resolution optical and microwave sensors. This satellite aims to monitor details of land-surface features in a frequent and quantitative fashion for four major application themes: the creation of 1.25,000 geographical maps, regional observations for environmental monitoring, information distribution for disaster mitigation, and resource finding. To meet these mission objectives, ALOS carries three instruments, a Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), the Advanced Visible and Near-Infrared Radiometer 2 (AVNIR-2), and a Phased-Array L-band Synthetic-Aperture Radar (PALSAR).

After launch, a commissioning phase for satellite functioning and validation, including the first light of the three sensors during the first four months (Jan. 24 to May 15, 2006), and an initial calibration phase for the sensors during the following five months (May 16 to Oct. 23, 2006) were successfully completed. The operational phase began on Oct. 24, 2006. The first light acquired individually in the second month yielded representative performances of the sensors, even without calibration, heralding the enriched land information that would later be acquired by ALOS and its sensors [1], [3].

In its operational phase, ALOS is programmed to systematically and repeatedly collect a world-scale minute data set (based on the predetermined mission observation plan) and to quickly collect regional disaster images based on urgent requests from commercial users. Observation repeatability and the combined use of radar and optical sensors provide a method for multi-spectrum monitoring of land surfaces by interferometric monitoring of deformation caused by earthquake-driven phenomena and volcanic activity, biosphere monitoring in the pan-tropical regions, boreal forest monitoring in the Eurasian and North American continents, cryospheric research in the polar region for estimation of ice-sheet flow rates, and ocean-surface monitoring. Specifically, the radar has an all-weather sensor adequate for remote sensing. The L-band synthetic-aperture radar on ALOS is very promising for Earth monitoring owing to its high signal penetration through vegetation-covered targets and its high sensitivity for detecting deforestation and clear-cut regions. Thus, JAXA is conducting a world-scale monitoring project while collaborating with international institutes.

Based on the success of the ALOS PALSAR in disaster mitigation and forest monitoring, JAXA has begun to build an ALOS follow-on satellite. Its main mission is to provide sufficient information to mitigate a disaster and to obtain maximum information on the forest status. The satellite will address requests received from the large user community, namely (1) enhance the interferometric capability, (2) improve the resolution, (3) increase the data-observation frequency, and (4) improve the polarimetry. In order to satisfy the above requests, the satellite mission has the following objective: to be an “L-band interferometric change detection mission fully utilizing interferometry and polarimetric performance.”

2. SATELLITE SYSTEM

ALOS was developed as a technology demonstration satellite with performance-improved, high-resolution optical and radar sensors to be applied to the four major mission objectives introduced above, and also to fill the
gap created by the termination of the Japan Earth Resources Satellite-1 (JERS-1) on Oct. 12, 1998 [2]. Since the goal of ALOS was to provide higher accuracy in sensor radiometry and geometries, the satellite was made larger in order to achieve the required accuracy. ALOS is the world's second largest (heaviest) satellite in the Earth observation domain, second only to the European Space Agency (ESA)-ENVISAT; it weighs four tons and measures 27.8m x 9m x 6.7m, and is supported by a high-power 7-kw solar generator with a 22m-long solar array paddle. The orbit is Sun-synchronous at a height of 691.25km, with a 46-day recurrence cycle and a sub-recurrent cycle of about two days. Since the three sensors have an imaging swath of 70km and one of them can change its off-nadir angle within ±44 degrees around the roll axis, any target can be observed within two and a half days after an image acquisition request is received. This can contribute significantly to disaster mitigation.

3. CALIBRATION AND VALIDATION

Calibration and validation (CALVAL) were conducted in the initial calibration phase, using 90% of the observation resources and mainly focused on achieving geolocation and radiometric accuracy. Sensor characteristics were measured by analyzing the raw data, since launch- and space-related circumstances might have changed the sensor characteristics. For use with CALVAL, JAXA set up world calibration sites for all of the sensors, in collaboration with researchers. The calibration sites located worldwide and all of the sensors can be monitored to determine the latitude and temperature dependence of any error. Optical sensors used the corners of buildings or four-way intersections as calibration points, where the geolocation was measured on the order of 20cm. PALSAR used corner reflectors or active radar calibrators for its reference points and the Amazon forest for its uniform target areas. The final calibration results are summarized in Table 3 for the orbital components PALSAR, PRISM, and AVNIR-2. Orbital determination accuracies were measured to 40cm for three sigma as the summation of the bias and random noise. PALSAR had excellent performance, with a radiometric accuracy of 0.6dB using all of the corner reflectors associated with the calibration experiments and 0.17dB using the Swedish 5m corner reflectors and a geometric accuracy of 9.3m (RSS). The polarimetric performance exhibited an amplitude variation of the VV/HH channels of 0.3dB and a phase of 0.3 degrees [3]. The optical sensor achieved the accuracy of the geometric requirements. From this point, we can say that ALOS achieved state-of-the-art accuracy at several points, and is sufficiently accurate to demonstrate the potential applications. Geometric accuracy of the optical sensors is difficult to achieve because the temperature dependence of the optical bench, which is the reference coordinate of the imaging plane, is slightly temperature dependent and has some unknown characteristics. Thus, the temperature and time dependence were monitored after the initial calibration phase.

4. APPLICATION PROGRAMS

In this section, we will introduce the application program being conducted by JAXA.

4.1 Forest Mapping Project – deforestation and carbon-stock monitoring using PALSAR data

JAXA’s JERS-1 science program of the 1990s concluded that the L-band SAR succeeded in monitoring the forest coverage changes in the pan-tropical and boreal regions and creating a map of surface deformation caused by solid Earth movements, even in vegetation-covered areas. This is due to L-band’s excellent signal penetration of vegetation cover and less backscattering from the clear-cut region, rather than the higher-frequency signals. Based on these facts, JAXA established the Kyoto and Carbon Initiative program in 2004 as an international SAR observation program to globally monitor the forest and interpret the forest status. This mission ended on October 12, 1998, upon termination of JERS-1 SAR satellite observations but lasted through the early 2000s for data processing and analysis, generating first-generation SAR mosaics over Southeast Asia, Africa, the Amazon, and North America. Although the unavailability of a digital elevation model resulted in geometric error, the radiometric sensitivity revealed the existence of the forest and its changes effectively when seasonal variations are compared. Based on this SAR sensitivity, JAXA and the collaborating researchers established the Kyoto and Carbon initiatives as a global land observation program using PALSAR [4] and covering four research themes: (1) mosaic production for seasonal and global land datasets, (2) forest observation, (3) wetland observation, and (4) desert observation.
Fig. 7-2 Browse mosaic of the Amazon region using the PALSAR FBD.

Fig. 7-4 Biomass map generated by the PALSAR amplitude images (Courtesy of R. Lucas)

Fig. 7-6 PALSAR image mosaic over the Sahara Desert and the under-land structure observed by PALSAR (P. Paillou [5])

Other applications
Sea-ice monitoring

4.2 Other applications

1) Solid-Earth monitoring (using Differential SAR Interferometry)
2) Disaster Monitoring
3) Wind-Speed monitoring around coastal regions

5. ALOS-2 PROGRAM

A follow-on mission to ALOS, ALOS-2, was recently approved by the Japanese government as a high-resolution Earth-monitoring satellite carrying an L-band SAR with enhanced performance.

5.1 Satellite system

The satellite system will be specialized for SAR and optical missions as individual satellites. The altitude will be 620km with a 14-day revisit time. This will improve the temporal decorrelation of recent L-band SAR satellites, i.e., JERS1 (44 days) and ALOS (46 days). The satellite has right- and left-looking capability by utilizing a tilting function and an electric SAR beam steering capability. Data will be recorded or directly downlinked to ground stations using the DRTS (TBD).

5.2 L-band SAR

5.2.1 Bandwidth

To improve the interferometric
performance of the ALOS PALSAR, the bandwidth will be expanded to 85 MHz, 44 MHz, and 14 MHz.

5.2.2 Strip mode for 3m resolution, SCANSAR mode covering 350km, and spotlight mode allowing 1m resolution in azimuth are being considered.

5.2.3 Polarizations Single POL, dual POL, and quad POL are adopted. To fill the gap made by full polarimetry, the satellite will have a linear compact polarimetry capability. Pol-InSAR over heavy-forest regions will be solved using the 14-day revisit SAR system.

5.2.4 Data rate : The data rate depends heavily on the SAR mode. In order to reduce the load in downlinking data to the ground, BAO data compression using 4 bits and 2 bits is being evaluated.

5.2.5 Dual-beam SAR In order to reduce the pulse-repetition frequency (PRF) for the higher-resolution SAR, a split-azimuth antenna will be used as a separate antenna. This may allow a reduction in the PRF and thus an expansion of the imaging swath.

5.2.6 Conventional mode In order to relax the technology for processing the SAR data, conventional mode (classical SAR technology) will be defined as processing JERS-1 SAR or PALSAR type data.

5.2.7 Interferometry SACNSAR-SACANSAR interferometry will be conducted utilizing transmission time control.

5.2.8 Imaging swath Four imaging swaths are considered, 25km (spotlight), 50km (strip), 70m (conventional), and 200 to 350km (SCANSAR narrow and SCANSAR wide).

5.2.9 TR modules will be used for quickly setting the incidence angle. The incidence angle will be adjustable from 7 to 70 degrees.

5.3 Mission observation strategy

In order to satisfy the mission request for disaster mitigation and forest monitoring, the following observation scenario will be implemented.

(1) Disaster mitigation: For Japan, basic data will be acquired within a 7 to 70 degree incidence angle over about one year, so that interferometry SAR data can be provided within several hours after a disaster occurs. In addition to the strip-map database, the SCANSAR data will be collected as a quick data-provision source.

(2) Forest monitoring: Monitoring of deforestation and forest degradation is a key issue for the year 2012. At least three times the coverage of conventional SAR or SCANSAR in wet and dry seasons will be achieved.

6. CONCLUSIONS

ALOS has been in orbit for three years. During this time, it has produced many returns, not only in an engineering sense but also in a scientific sense. Current satellite conditions will give us more information for environmental monitoring of the Earth. ALOS-2 was approved by the Japanese government as the ALOS follow-on satellite system. Two L-band satellites will shorten the observation time gaps in 2013 and will improve the environmental monitoring of the Earth.

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