Implementation of Systematic Data Observation Strategies for ALOS PALSAR, PRISM and AVNIR-2

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Abstract— **The Advanced Land Observing Satellite (ALOS) is scheduled for launch by the Japan Aerospace Exploration Agency (JAXA) in 2005, and it will carry three remote sensing instruments: an L-band polarimetric Synthetic Aperture Radar (PALSAR), an along-track 2.5 metre panchromatic resolution stereo mapper (PRISM) and a 10-metre multi-spectral scanner (AVNIR-2). The successor of the JERS-1 satellite (1992-1998), ALOS will not only provide enhanced sensor performance, but also feature an entirely new acquisition concept. Abandoning traditional, local-focused instrument operations, JAXA is implementing a comprehensive acquisition strategy, in which geographical region, sensor mode, acquisition timing and repetition frequency, are fixed in advance, to achieve spatially and temporally consistent, global coverage on a repetitive basis, at the same time as reducing programming and user conflicts.**

Keywords-ALOS; PALSAR; PRISM, AVNIR-2; acquisition strategy; mission planning

I. INTRODUCTION

A. The ALOS platform

ALOS is planned for launch by an H-IIA rocket from JAXA's Tanegashima Space Center in southern Japan in 2005 into a sun-synchronous orbit at 691 km. The orbital revisit period is 46 days, with a potential 2-day revisit capability for the side-looking instruments. ALOS will carry three remote sensing instruments: PALSAR, PRISM and AVNIR-2.

Data down-link will primarily be performed using JAXA's Data Relay Test Satellite (DRTS), which was launched into a geostationary orbit in September 2002. Transmission from ALOS to JAXA Earth Observation Center (EOC) can be performed via the DRTS at a data rate of 360 Mbps (K_a-band), either in real time mode, or from ALOS' on-board 96 Gbyte High-speed Solid State Recorder (HSSR).

Direct down-link from ALOS to local ground stations without the use of the DRTS can only be performed at a reduced data rate of 120 Mbps (X-band).

B. PALSAR

The **Phased Array type L-band Synthetic Aperture Radar (PALSAR)** is developed jointly by JAXA and the Japan Resources Observation Systems Organization (JAROS). It is a fully polarimetric instrument, operating in either single polarisation (HH or VV), dual polarisation (HH+HV or VV+VH), or quad-pol mode. The look angle is variable between 7° and 51° (8-60° incidence angle). The nominal ground resolution is ~10 and ~20 metres in the single- and dual-polarization modes, respectively, and ~30 metres in quad-pol mode. PALSAR can also operate in a coarse, 100 metre, resolution ScanSAR mode, with single polarisation (HH or VV) and 250-350 km swath width.

The data recording rate is 240 Mbps in single-, dual- and quad-pol modes, which thus requires down-linking via the DRTS. The ScanSAR however operates at 120 Mbps, which allows direct down-link of data to local ground stations within the ALOS ground network.

C. PRISM

The **Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM)** is a panchromatic (520-770 nm) radiometer with 2.5-metre spatial resolution. It has three independent optical systems for nadir, forward and backward looking to achieve along-track stereoscopy, and the forward and backward telescopes are inclined + and – 24 degrees from nadir to realise a 1.0 base-to-height ratio.

The wide field of view provides fully overlapped three-stereo (triplet) images (35 km width) without mechanical scanning or yaw steering of the satellite. The swath width is 70 km in nadir-only mode, and 35 km during triplet mode operations.

PRISM operates with a 240 Mbps data rate.

D. AVNIR-2

The successor to the VNIR and AVNIR instruments on JERS-1 and ADEOS, the **Advanced Visible and Near Infrared Radiometer type-2 (AVNIR-2)** on ALOS is a multi-spectral (NIR, R, G, B) radiometer with 10 metres ground resolution. The primary objectives of AVNIR-2 are disaster monitoring and land cover mapping and with its across-track viewing capabilities (+/- 44°), observation of disaster areas within 2 days' repeat is feasible. The side-looking capacity also allows simultaneous observations with the PALSAR – a unique property and a "satellite first". AVNIR-2 operates with a 120 Mbps data rate, which means that direct data downlink without the use of DRTS is possible.

II. DATA AND INFORMATION REQUIREMENTS

A. ALOS user groups

The ALOS mission is primarily scientific, with commercial interests playing a low-key secondary role. Expectations for operational or semi-operational applications are nonetheless high, as are the needs for large amounts of data.

A number of user groups are directly or indirectly involved in the mission and amongst significant institutional users in Japan should be mentioned: the Earth Remote Sensing Data Analysis Center (ERSDAC), the Geographical Survey Institute (GSI), the Ministry of Environment (ME), the Ministry of Agriculture, Forestry and Fishery (MAFF) and the Japan Coast Guard (JCG). ERSDAC – co-sponsor of the PALSAR instrument and representative for the Ministry of Economy, Trade and Industry (METI) – and GSI have global-scale observation interests, while ME, MAFF and JCG primarily focus on Japan and its vicinity.

Internationally important players are the ALOS Data Nodes – international space agencies designated by JAXA to care for regional distribution of ALOS data: ESA/CNES (for users in Europe and Africa), NOAA/ASF (the Americas), Geoscience Australia (Oceania), and JAXA itself (Asian users). To the international group should also be counted the 110 Principal Investigators participating in the ALOS Announcement of Opportunity.

There are naturally also extensive plans for ALOS exploitation within JAXA, primarily by the Earth Observation Research and applications Center (EORC), which is in charge of instrument calibration and validation activities, and the execution of a number of scientific programmes. This includes the ALOS Kyoto & Carbon Initiative [1], a global monitoring project, which involves the utilization of some 70,000 scenes during the first 3 years of the ALOS mission, to support regional-scale information needs posed by climate change science, multinational conventions, and environmental conservation.

B. Conflicting requirements

With such a large number of user groups and diverse interests, it is obvious that their data observation requests, in terms of area of interest, sensor mode, timing, etc., cannot be expected to correspond very well. Given, in addition, the fact that the three instruments on ALOS can be operated in a variety of modes – PALSAR alone has 132 technical options – the risk for programming conflicts between users becomes a real issue.

Indeed, early observation simulations by the ALOS Mission Management and Operations System revealed truly discouraging results with acquisition success rates in some cases in the order of a few percent. Observations were fragmented in both time and space and conflicts occurred even between users with evidently similar thematic interests. From an operational point of view, the need for coordination of the user requests became apparent.

C. Public and scientific needs

Following experiences gained from the JERS-1 mission (1992-1998), where the SAR instrument under the last 3 years of its lifetime had been used to acquire data in a consistent manner over the entire tropical and boreal zones of the Earth [2-8], realization of the importance of systematic acquisition planning had emerged at JAXA. This coincided with an increased concern amongst the general public regarding climate change, which in 1997 resulted in the UNFCCC Kyoto Protocol, and thereby explicit, high level political, requirements for systematic, cross-border, observations.

Article 10(d) of the UNFCCC Kyoto Protocol states that countries shall *"co-operate in scientific and technical research and promote the maintenance and the development of systematic observation systems and development of data archives to reduce uncertainties related to the climate system, [and] the adverse impacts of climate change..."*.

Although the article does not specify the nature of the "observation system" in question – most likely intentionally – it is an evident call for countries to use whatever resources available to help improve our knowledge about the global environment and the causes and effects of climate change.

Addressing the same topic, but in an even broader context, is the Carbon Cycle science community, whose major concern is incomplete understanding of the processes that govern the global carbon cycle, and the large uncertainties that are associated with current models and measurements. These uncertainties are partly results of lack of appropriate data or inadequacy of existing data sets. This deficiency is being addressed by the Integrated Global Observing Strategy Partnership (IGOS-P), which calls for a united multi-disciplinary scientific effort to resolve the present uncertainties, through the establishment of a dedicated global carbon cycle observation strategy.

IGOS-P state that *"The challenges [to a terrestrial carbon observation strategy] are to ensure that important existing observations continue and key new observations are initiated [and] to identify activities and agencies willing to contribute to establishing global carbon observations…"* [9].

Implementation of a systematic observation strategy for ALOS is an effort by JAXA to support the scientific and public information requirements above, at the same time as improving satellite operations and reducing user conflicts.

III. A SYSTEMATIC OBSERVATION STRATEGY FOR ALOS

A. The concepts of the ALOS observation strategy

In the design of the ALOS strategy, which is focused on the acquisition of data over regional scales, the following key aspects, outlined in detail in [10], have been taken into consideration:

- **Spatial consistency:** Undertaking continuous wall-to-wall acquisitions over extensive regions.
- **Temporal consistency:** Maintaining temporal homogeneity over regional scales, by carrying out acquisitions during limited time windows.
- **Revisit frequency:** Repetitive regional acquisitions, one or more times per year, to accommodate adequate monitoring of bio- or geophysical changes.
- **Timing:** Acquisitions performed during the same time period(s) every year to minimize temporal bias in the time series acquired.
- **Sensor consistency:** Selection of a limited number of operational default modes to maximize data homogeneity and minimize user conflicts.
- **Long-term continuity:** Strategy operations until the end of the ALOS mission life.

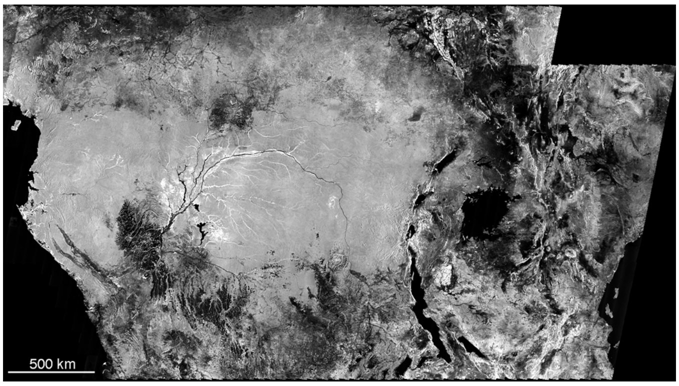

Figure 1. Example of regional-scale spatio-temporal consistency (JERS-1 SAR, Central Africa) GRFM © JAXA/JRC/JPL

B. Optimizing operations

The key challenge in the acquisition strategy planning process was to reduce the number of programming conflicts, which had inhibited initial simulations. Ironically for PALSAR, the sensor with the most numerous requests, a major cause for conflicts was its *too* flexible design with variable off-nadir angles, polarizations and spatial resolutions, combined with the associated need for pre- and post-calibration following every mode change.

Other issues to consider included time sharing between the three instruments and data down-link. With access to only one DRTS – geostationary over the Indian Ocean at E90° – acquisitions over the western hemisphere became a resource constraint and required particular attention.

Taking the strategic concepts outlined in (A) above into consideration, the following major actions were taken to optimize ALOS operations:

1) Limitation of operational default modes

For PALSAR, with 132 original mode options, six were identified as the main default modes to be used for operations (Table 1). The mode selection was made as a compromise taking scientific criteria, user requests, programmatic aspects and satellite operational constraints into consideration.

TABLE I. PALSAR DEFAULT OBSERVATION MODES

Polarization	Off-nadir angle (swath, resolution)
HH	34.3 deg. (70 km, 10 m)
HH	43.4 deg. (70 km, 10 m)
HH+HV	34.3 deg. (70 km, 20 m)
HH+HV	43.4 deg. (70 km, 20 m)
HH+HV+VH+VV	21.5 deg. (30 km, ~30 m)
ScanSAR (HH)	5-beam mode (350 km, 100 m)

For PRISM, the default mode is 3-telescope, or triplet, mode to enable stereo viewing. With a swath width of 35 km in triplet mode, two 46-day cycles are required to achieve a full regional coverage, during which the instrument is tilted alternately (+/– 1.5°) in across-track direction. PRISM will be operated in nadir viewing mode over the polar regions above 60° latitude north and south,

Default for AVNIR-2 is nadir viewing mode.

2) Separation of ascending and descending operations

As the two optical sensors are limited to operations during descending (daytime) passes, PALSAR operations are first and foremost planned for ascending (night) passes.

PALSAR acquisitions in descending mode are principally limited to low data rate (120 Mbps) ScanSAR, to minimize resource conflicts.

3) Space/time-based planning

To assure spatially and temporally homogeneous data collection over regional scales, the Earth has been divided into some 80 adjacent, non-overlapping geographical regions covering all land areas and coastal regions. Acquisitions are then planned in units of whole (46-day) repeat cycles, during which only one of the available default modes is selected.

The observation strategy is thus structured as a set of two-dimensional matrices – one each for PRISM and AVNIR-2, and two (ascending/descending) for PALSAR – with geographical regions in one dimension, and 46-day time units in the other.

Fig. 2 illustrates the concept for PALSAR for two given 46-day cycles. The filled polygons represent geographical regions scheduled for observation, with the colour indicating the prevailing default sensor mode during the two cycles in question (e.g. purple: HH@43.4°; blue: HH+HV@34.3°).

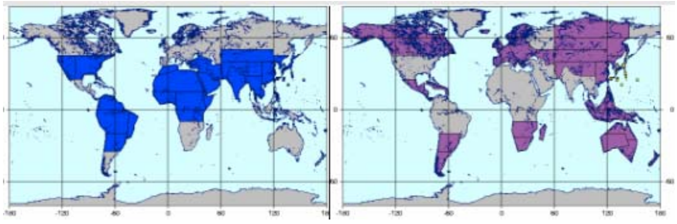

Figure 2. Observation plan concept: Reqions scheduled for acquisition during two given 46-day cycles. Colour indicates sensor mode.

4) Repetitive and long-term planning

To achieve recurrent observations with consistent timing, the PRISM, AVNIR-2 and PALSAR descending plans are planned in groups of 8 (46-day) unit cycles that will be repeated on an annual (368 days) basis during the mission life. The PALSAR ascending plan, which accommodates the largest number and variety of observation requests, comprises 16 cycles, which are repeated on a 2-year basis.

IV. TENTATIVE OBSERVATION STRATEGIES

The observation strategy for ALOS is being developed by JAXA EORC and refined through a series of computer simulations using the same Mission Management and Operations System software that will be utilized by during ALOS operations. As an indication of the complexity of the task, simulation of a 3.5-year (28 cycles) plan takes about 3 weeks to complete. At the time of writing, the observation plans for the three instruments are still being optimized.

The tentative plans are outlined briefly in the tables below.

TABLE II. PALSAR OBSERVATION STRATEGY

Mode	Coverage	Timing	Repetition
HH+HV/34.3°	Global	June-Aug.	Annual
HH+HV/34.3° (InSAR)	Global	June-Aug.	2 years
HH+HV/43.4°	Global	Dec.-Feb.	2 years
HH/43.4°	Global	Dec.-Feb.	2 years
ScanSAR	Global	Jan.-Dec.	Annual
ScanSAR	Wetland super sites	Jan.-Dec.	46-days (during 1 year)
Quad-pol.	Pol-InSAR super sites	Mar.-May	2 years

TABLE III. PRISM AND AVNIR-2 OBSERVATION STRATEGIES

Sensor	Mode	Coverage	Timing	Repetition
PRISM	Triplet (stereo)	Global	Jan.-Dec.	Annual
AVNIR-2	Nadir	Global	Jan.-Dec.	Annual
AVNIR-2	34.3° (PALSAR)	Selected sites	Variable	Annual

To compensate for cloud cover that unavoidably will affect PRISM and AVNIR-2 operations, the global plans above will, on a continuous basis, be complemented with additional observation requests in regions where cloud problems persist. In particular AVNIR-2, which can be down-linked without the use of the DRTS, is foreseen to accommodate a significant number of additional user requests via the regional Data Nodes (ESA/CNES, NOAA/ASF, GA, JAXA).

V. CONCLUSIONS

Acknowledging the critical public and scientific needs for consistent and repetitive information over extensive regions, JAXA is implementing a new data acquisition concept for ALOS. Ultimately a compromise, the strategy has been developed in collaboration with domestic and international stakeholders and science groups, to serve a range of multidisciplinary interests. The plan is furthermore anticipated to stimulate a multitude of new fine resolution remote sensing applications which local-focused operations and fragmented data archives have prevented in the past.

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