Initiating the ALOS Kyoto & Carbon Initiative

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Abstract - The ALOS Kyoto & Carbon Initiative is an international endeavour initialized by NASDA, with the main objective to support information needs raised by the UNFCCC Kyoto Protocol and by the international global carbon cycle science community, by provision of systematic, consistent, repetitive and regional scale data of the global forest cover. Of central importance for the Initiative is a Dedicated Data Acquisition Strategy for the polarimetric Phased Array L-band Synthetic Aperture Radar (PALSAR) sensor onboard the Advanced Land Observation Satellite (ALOS) satellite, which, as a major project output, is foreseen to result in an extensive data archive with consistent time series of dual-polarization (HH/HV) PALSAR data over any given land area on the Earth. Tentative plans for derived data products include regional scale image mosaics, maps of annual forest change, wetland flood distribution/duration, and rice cultivation.

1. BACKGROUND

1.1 The UNFCCC and the Kyoto Protocol

Climate change, caused by the rapid and uncontrolled increase of greenhouse gases in the Earth's atmosphere during the past 150 years, is a major public, political and scientific concern worldwide. Public concern resulted in the 1992 United Nations Framework Convention on Climate Change (UNFCCC), which is an official acknowledgement of the climate change phenomenon as such, as well as a recognition by international policy makers that immediate cross-border actions are required to halt and reverse the current destructive trend. The UNFCCC was in 1997 strengthened with the Kyoto Protocol, which provides legally binding national emission reduction commitments, as well as a time table for implementation. Although politically controversial and hotly debated in every aspect, it is clear that when – or if – eventually ratified, the Protocol will not only constitute a landmark agreement for the global environment, but also for the international scientific community in that it puts political pressure for quantitative measurements of carbon sources and sinks with high, verifiable accuracy.

While CO_2 released by burning of fossil fuels constitutes the single most important emission source, the Kyoto Protocol allows emissions to be balanced by vegetation, which may sequester or release atmospheric carbon depending on the land use, and this is where remote sensing potentially may come into relevance.

1.2 Global carbon cycle science

Viewing the climate change issue in a broader context than the Kyoto Protocol, the central role of the global carbon cycle has long been recognized by the international science community. The major concern here 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-diciplinary scientific effort to resolve the present uncertainties, through the establishment of a dedicated global carbon cycle observation strategy. This strategy involves characterization of the terrestrial, atmospheric and oceanic components of the carbon cycle by synergetic utilization of *in situ*, modelling and other measurement techniques, including remote sensing.

Although carbon cycle science thematically is more exhaustive than the Kyoto Protocol, we note that both relate to the same basic information needs - that for accurate measurements of carbon sources and sinks. Hence, research and support to one topic will inevitably also benefit the other, and vice versa.

2. THE ALOS KYOTO & CARBON INITIATIVE

2.1 Science justification

The ALOS Kyoto & Carbon Initiative is based on the conviction that remote sensing data - and here specifically ALOS PALSAR data - can play a significant role to support, partly or fully, some of the information needs posed by the Kyoto Protocol as well as by the scientific community dealing with the terrestrial carbon cycle. In a recent report [1] by the Terrestrial Carbon Theme working group of IGOS-P, the need for such support was voiced: *"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…"*. The ALOS Kyoto & Carbon Initiative is a response to this request.

In the Kyoto context, the concept of remote sensing is less well known, and active effort from the remote sensing

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community to meet the specific Kyoto needs by adapting mission design and intensifying R/D is required in order to assure that the technology is appropriately considered.

The Kyoto "data requirements" are however not easily understood and to this end a workshop was organized in 1999 by the ISPRS and the University of Michigan [2], to review the status and potential of remote sensing and to identify areas of potential support. The ALOS Kyoto & Carbon Initiative aims respond to three of the themes identified, as outlined in §2.2 - §2.4 below:

2.2 Provision of systematic data observations and data archives

The fundamental need for systematic data observations applies both to Kyoto as well as in the carbon cycle context. Article 10(d) of the 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..."*. IGOS-P, in turn, states that *"it is evident that further progress in our understanding of the global carbon cycle and its likely future evolution depends on improved observations of the terrestrial carbon processes"*.

Provision of systematic observations and establishment of data archives for long-term studies is clearly one of the *potential* strengths of remote sensing. However, sporadic observations with local emphasis, which presently is how (high resolution) remote sensing data most commonly are acquired, is not adequate as it does not provide a means for extrapolation of locally developed methods and results to a regional scale context. In order to make remote sensing data an attractive and useful data source in the context discussed here, data acquisitions should be planned in a systematic manner, with regional-continental scale coverage, fixed sensor characteristics, and a temporal repetition frequency adapted to the phenomenon to be monitored. Furthermore, long-term continuity of comparable sensor systems into, and beyond, the first emission commitment period (2008-2012), as well as parallel operations of sensors/platforms with complementary characteristics are also important points to consider.

The ALOS Kyoto & Carbon Initiative aims to respond to this need through the establishment of a Dedicated Data Acquisition Strategy in which the above points are taken into account as far as possible. Ultimately a trade-off, where ALOS technical constraints and other acquisition requirements also will have to be taken into consideration, the acquisition plan tentatively comprises PALSAR acquisitions of:

· all land areas at 36 months' repeat interval during the ALOS mission life time;

· all forested areas with at least 12 months' repeat interval during the ALOS mission life time;

· regional "super sites" (Amazon, Congo and Ob river basins; S-E Asia paddy areas; + TBD) every 46-day pass during one full year.

The basic PALSAR acquisition mode considered is dual polarizations (HH/HV) with a fixed (35° - TBD) off-nadir angle. The 12- and 36-months' repetition cycles are based on the concept "same area, same season" in order to minimize seasonal bias in the time series. Dry season is preferred in tropical regions, summer *or* winter (TBD) in temperate and boreal zones. Data takes with 46-days' repeat will be timed to capture a full flooding cycle, or rice cultivation cycle in the particular region of interest. As far as technically feasible, full polarization (experimental mode only) and synergy with the optical AVNIR-2 sensor will also be attempted.

2.3 Detection and quantification of changes in forest cover

A theme of central importance in the Kyoto Protocol, relating to the concept of afforestation, reforestation and deforestation (ARD) under Article 3.3: *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I"*. Since the Protocol exclusively relates to forest *change* areas (i.e. through ARD), quantification of biomass stocks is not a direct Kyoto requirement. However, in order to quantify the biomass loss following e.g. a deforestation event, some sort of *a priori* knowledge about the biomass level prior to the event is nevertheless required.

Comprising standing stocks and changes due to both human-induced and natural activities, the same basic data requirement is raised in the carbon context by IGOS-P: *"Estimates of above- and below- ground biomass provide fundamental information on the size and changes of the terrestrial carbon pool as land use and associated land management practices change"*. This theme can be divided into: (i) *identification* of areas subject to change, (ii) quantification of *biomass stocks*, and (iii) associated biomass *changes* therein.

For the ALOS Kyoto & Carbon Initiative to meet the need for (i), the 12-month time series of PALSAR data acquired within the data acquisition plan described above in §2.2 should be utilized. Plain identification of changes in forest cover is a rather straightforward task, which to a large extent can be performed in an operational manner. Annual forest change "ARD" maps, indicating areas of change between subsequent years due to e.g. clearfelling or regeneration, is a product tentatively foreseen.

Quantification of *biomass stocks* (ii) may partially be conceived with ALOS PALSAR. While stock inventories in mature forest stands above the L-band sensitivity range must be ruled out, retrieval of biomass-related biophysical parameters in sparse and regenerating areas may well be foreseen. Using SAR time sequences rather than single-date imagery strengthens accuracy and also provides for quantification of incremental *biomass changes* in regeneration or degradation areas (iii). The 12-month time series utilized under (i) for "ARD" mapping is foreseen to be essential also for this task.

It is acknowledged that retrieval of biomass-related forest parameters is still in a research stage and that additional work is required before robust operational methods will emerge. Yet, we believe that the systematic PALSAR observations planned within the ALOS Kyoto & Carbon Initiative will help to advance this important field of research.

2.4 Mapping and monitoring of certain methane sources

Irrigated rice is a significant anthropogenic source of CH_4, which presumably will have to be accounted for under the Kyoto Protocol from the second emission commitment period and onwards (2013-), when agricultural soils are included in addition to ARD. And amongst non-anthropogenic CH_4 contributors, floodplains and wetlands areas are sources of major importance. IGOS-P remark that *"satellite observation techniques and modelling tools should be developed to estimate methane fluxes from wetlands"* and while CH_4 fluxes *per se* cannot be measured by PALSAR, key input parameters to emission models in forms of the spatial and temporal variations of inundation can be provided, as already demonstrated by JERS-1 SAR [3]. The uniqueness and importance of L-band SAR in this context cannot be overly emphasized, as it is the only space-borne sensor configuration with the capacity of deriving such information.

Progressing on-going JERS-1 SAR R/D activities within NASDA with, regional-scale mapping of the spatio-temporal dynamics of irrigated rice and seasonally inundated wetlands is foreseen to be a major undertaking within the ALOS Kyoto & Carbon Initiative. PALSAR data acquired with 46-days' repetition during a period of one full year, will be required to characterize the rapid variations associated with forest inundation and rice cultivation, as listed in the tentative data acquisition plan outlined under §.2.2. Wetland regions tentatively under consideration include the drainage basins of the Amazon and Paraguay rivers in South America, the Congo river in central Africa, and the Ob river on the West Siberian Plan. As for irrigated rice, PALSAR coverage of major cultivation areas in South and South-East Asia is planned.

Derived data products will conceivably comprise time-sequences of co-registered regional-scale PALSAR mosaics and derived flood duration and rice cultivation maps.

2.5 Project organization

Given the sheer amount of data foreseen to be acquired and processed, and the scientific tasks to be considered, the ALOS Kyoto & Carbon Initiative will rely on close alliance with national and international institutions. Building on the existing network established within the JERS-1 Global Forest Mapping project [4], a decentralized organization will be employed, where collaborating parties are responsible for a certain data product and/or region of interest.

2.6 Scientific support and spin-off applications

Successful definition and implementation of the Dedicated Data Acquisition Strategy is indeed of paramount importance, as it constitutes the heart and foundation of the Initiative as such. In order to assure that the acquisition plan actually meets the Kyoto and carbon cycle science requirements, a Scientific Advisory Panel has been established, to which well-renowned scientists active in the relevant fields, including representatives from the UNFCCC and IGOS-P, have been invited. The panel will also be consulted in the definition phase of the products to be generated, as discussed briefly above under §2.2-2.4 above.

Note that not all PALSAR data collected are intended to be processed within the Initiative. Rather, one of the basic objectives of the acquisition plan is to provide the international science community - as well as policy makers and commercial users - with a comprehensive data archive from which consistent PALSAR time series can be found for an arbitrary location of interest. It is believed that this type of data archive will prove useful also for applications far beyond those of Kyoto support and carbon cycle science.

REFERENCES

[1] Cihlar J., *et al.* (Eds.), 2001. IGOS-P Carbon Cycle Observation Theme: Terrestrial and atmospheric components. A report to IGOS-P by the Terrestrial Carbon Theme Team.

[2] Rosenqvist, Å., Imhoff, M., Milne T. and Dobson C. (Eds.), 1999. Remote Sensing and the Kyoto Protocol: A Review of Available and Future Technology for Monitoring Treaty Compliance. Report (159 pp.). Ann Arbor, MI, USA, October 20-22, 1999.

[3] Rosenqvist Å., Forsberg B., Pimentel T., Rauste Y., and Richey J., 2001. The use of spaceborne radar data to model inundation patterns and trace gas emissions in the central Amazon floodplain. *International Journal of Remote Sensing [in press].*

[4] Rosenqvist Å., Shimada M., Chapman B., Freeman A., De Grandi G.F., Saatchi S. and Rauste Y., 1999. The Global Rain Forest Mapping Project - a review. *International Journal of Remote Sensing,* 2000, Vol. 21, No. 6&7, pp 1375-1387.