Overview of new developments in satellite geophysics in "Earth system" research

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Abstract

Space-borne Earth observation technique is one of the most cost effective and rapidly advancing Earth science research tools today and the potential field and micro-wave radar applications have been leading the discipline. The traditional optical imaging systems including the well known Landsat, NOAA - AVHRR, SPOT, and IKONOS have steadily improved spatial imaging resolution but increasing cloud covers have the major deterrent. The new Earth observation satellites ENVISAT (launched on March 1 2002, specifically for Earth environment observation), ALOS (planned for launching in 2004 - 2005 period and ALOS stands for Advanced Land Observation Satellite), and RADARSAT-II (planned for launching in 2005) all have synthetic aperture radar (SAR) onboard, which all have partial or fully polarimetric imaging capabilities. These new types of polarimetric imaging radars with repeat orbit interferometric capabilities are opening up completely new possibilities in Earth system science research, in addition to the radar altimeter and scatterometer.

The main advantage of a SAR system is the all weather imaging capability without Sun light and the newly developed interferometric capabilities, utilizing the phase information in SAR data further extends the observation capabilities of directional surface covers and neotectonic surface displacements. In addition, if one can utilize the newly available multiple frequency polarimetric information, the new generation of space-borne SAR systems is the future research tool for Earth observation and global environmental change monitoring.

The potential field strength decreases as a function of the inverse square of the distance between the source and the observation point and geophysicists have traditionally been reluctant to make the potential field observation from any space-borne platforms. However, there have recently been a number of potential field missions such as ASTRID-2, Orsted, CHAMP, GRACE, GOCE. Of course these satellite sensors are most effective for low spatial resolution applications. For similar objects, AMPERE and NPOESS are being planned by the United States and France.

The Earth science disciplines which utilize space-borne platforms most are the astronomy and atmospheric science. However in this talk we will focus our discussion on the solid Earth and physical oceanographic applications. The geodynamic applications actively being investigated from various space-borne platforms geological mapping, earthquake and volcano related tectonic deformation, generation of precise digital elevation model (DEM), development of multi-temporal differential cross-track SAR interferometry, sea surface wind measurement, tidal flat geomorphology, sea surface wave dynamics, internal waves and high latitude cryogenics including sea ice problems.

Keywords : Geopotential field, polarimetric SAR, satellite geophysics, physical oceanography, geodynamics, geological hazards.

1. Introduction

The discipline of geophysics has evolved to such an extent that the traditional geophysics disciplines have remained as the classical core disciplines, while new and applied geophysics serves the today's expanding community of Earth, planetary, and environmental science. Satellite geophysics is one such new discipline, in which various new research opportunities and new developments are being actively carried out. The term satellite 'geophysics' encompasses all aspects of traditional geophysics being researched and practiced from airborne, shuttle-borne and/or space-borne platforms. Among various Earth science disciplines, remote sensing or satellite geophysics techniques have been most effectively utilized for atmospheric science, meteorology, and oceanographic applications. However, increasing number of Earth's potential field satellites are put in orbit and geophysics research from various space-borne platforms started to play more significant roles in the global geophysics, specially on potential field related problems.

The traditional optical sensors and imaging radar techniques have continuously improved considerably, both in spatial and spectral resolutions in recent years. New hyperspectral optical imaging systems with greatly increased spectral resolution via increased number of channels have opened new application capabilities, specially in geological and Earth's surface cover mapping applications. Although the new developments in repeat orbit and tandem SAR interferometric techniques have attracted considerable interests from various Earth science application disciplines, both airborne and space-borne SAR data available to the users have still been very limited in operational frequency or in polarization. Practically most SAR systems available today for civilian use have been single frequency and single polarization system (e.g. ERS-1, JERS-1, ERS-2, RADARSAT-I), until very recently. Partially polarimetric ENVISAT with C-band ASAR system was launched in March 2002, and the ALOS with L-band fully polarimetric PALSAR, and fully polrimetric C-band RADARSAT-2 will be launched into orbit sometime in 2005.

The first NASA (JPL)'s polarimetric AIRSAR mission was tested and became operational in late 1987, but the routine acquisition of AIRSAR data started in 1990 mostly over the continental United States. This was followed by similar missions with improved and enhanced capabilities every year except 1997. The first PACRIM (or PACRIM-I now) was flown in 1996 over Australia, New Zealand, Papua New Guinea, Malaysia, Thailand, Brunei, Cambodia, Philippines and Taiwan with great success (NASA (JPL), 2000). The recent PACRIM-II AIRSAR mission in 2000 included a new hyperspectral MASTER simulator in addition to the original AIRSAR and the number of countries to be flown has been increased, including Korea and Japan.

Although the synthetic aperture radar (SAR) technology in general and in particular the polarimetric SAR technology are not too familiar to many Earth scientists, new developments with SAR and polarimetric SAR imaging systems provide us with new Earth and planetary research tools for geodynamic research, such as plate tectonics, and earthquake tectonics in addition to the traditional remote sensing applications.

2. Space-borne Geodynamics and Geodesy

Global geodynamics and geodesy sub-discipline include various research topics, which can most effectively investigated from a space-borne platforms. Some of these topics are

- Global geophysical fluid mass movements
- Geomagnetic field
- Gravity field
    - Static gravity field
        - Earth's gravity model
    - Time varying field
        - Satellite Laser Ranging (SLR)
- Earth's rotation and geodetic reference systems
    - Lunar Laser Ranging (LLR)
    - Very Long Baseline Interferometry (VLBI)

Solid Earth and ocean tides
Radar and Laser altimetry
Earth's core dynamics
Crustal movements

Many of above listed research can be carried out from the fixed permanent facilities on Earth, including SLR, LLR, and VLBI. Earth's core dynamics is a research problem which can best be studied utilizing theoretical investigation and very sensitive gravimetric measurements. However, most other geodynamic and geodetic problems can be very effectively studied from polar orbiting space-borne platforms.

3. Earth Potential Field Missions

The central task of geosciences today and in the next decades will be studying and trying to understand the Earth as a system: a system composed of solid, fluid and gaseous parts which show large variations in space and time and between of which complex interactions take place on quite different time scales. Characterizing such an extensive, complex and heterogeneous system requires very long and synoptic data series of the phenomena taking place within and between the various spheres of the system, beside of course the computer resources required for making use of such enormous data sets in the model development, improvement or validation. Long term global synoptic data sets can systematically only be acquired by near Earth satellites, which however in general provide a limited resolution because of the reduced sensitivity with altitude. A combination of satellite observations with more regional data sets obtained on ground or in the first few kilometers in the atmosphere is therefore the suitable observation scenario to follow.

One of the first potential field satellites was the MAGSAT which was a joint NASA/United States Geological Survey (USGS) effort to measure near-earth magnetic fields on a global basis. MAGSAT was launched into a low altitude orbit (300 - 600 km) with 90 degree inclination on November 2nd 1979 and operated until May 6th 1980. Objectives included obtaining an accurate description of the earth's magnetic field, obtaining data for use in the update and refinement of world and regional magnetic charts, compilation of a global crustal magnetic anomaly map, and interpretation of that map in terms of geologic/geophysical models of the earth's crust. Utilization of the MAGSAT data were limited at the time because it was an early attempt of using space-borne platform for potential field investigation.

Recently, however, there are a number of space-borne satellites planned and launched by various countries for various geophysical research objectives (Fig. 1). The number of countries which are interested in the Earth's magnetic field at various levels of altitudes as well as the solid Earth induction problems are reflected by these diverse full scale and micro-satellite systems.

Earth's gravity field can be studied from the Earth orbiting satellites by analyzing the orbit record data. For this reason, various radar altimeters starting with SEASAT-ALT, GEOS, ERS-1/2, TOPEX/Poseidon, JASON, and recently launched ENVISAT RA-2. Large Earth;s tectonic features and geological basins can be analyzed and modeled with the space-borne radar altimeter data. Geoid and global ocean tide models are also derived from the continuous coverage of radar altimeter data. In addition, further advanced modeling of storm surge and solid Earth and ocean coupling study can effectively carried out with the space-borne altimeters (Moon, 1982; Moon and Tang, 1988).

CHAMP (CHAllenging Minisatellite Payload) is a German small satellite mission for geoscientific and atmospheric research and applications, managed by GFZ. With its highly precise, multifunctional and complementary payload elements (magnetometer, accelerometer, star sensor, GPS receiver, laser retro reflector, ion drift meter) and its orbit characteristics (near polar, low altitude, long duration) CHAMP will generate for the first time simultaneously highly precise gravity and magnetic field measurements over a 5 years period. This will allow to detect besides the spatial variations of both fields also their variability with time. The CHAMP mission will open a new era in geopotential research and will become a significant contributor to the Decade of Geopotentials.

Recently however, there appears more ambitious potential field missions such as GRACE (Gravity Recovery and Climate Experiment), which deployed twin satellites with the

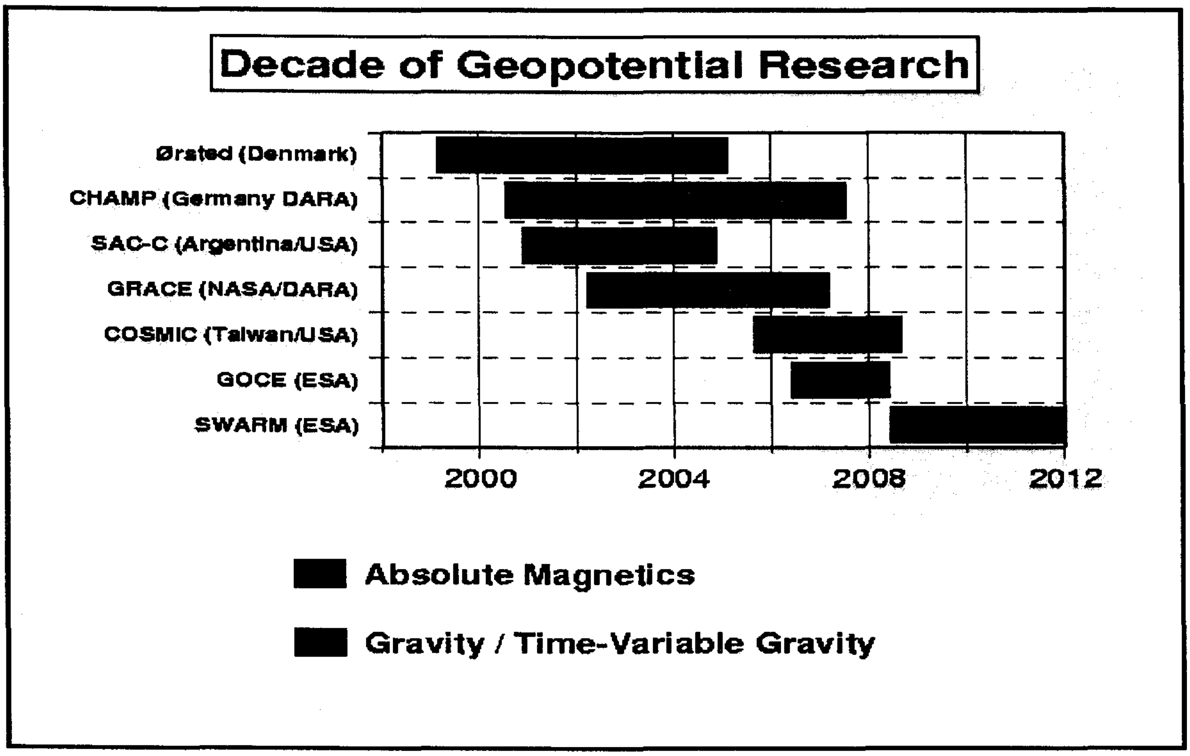

Figure 1. Earth's potential field mapping satellite missions and their time line (From NASA - GSFC).

objectives of accurately mapping the variations in the Earth's gravity field over its five year lifetime. The GRACE mission operates two identical spacecrafts flying about 220 kilometers apart in a polar orbit 500 kilometers above the Earth. GRACE will be able to map the Earth's gravity fields by making accurate measurements of the distance between the two satellites, using GPS and a microwave system. The GRAVE gravity data will be used to investigate the atmospheric mass movements, surface and deep currents in the ocean, runoff and ground water storage, exchange between ice sheets and glaciers.

4. Polarimetric Imaging Radar - Polarimetric SAR

The most common and traditional imaging methods for Earth and planetary surface have been optical cameras, which operate in the visible and IR range of electromagnetic spectrum. However, there are two problems with the optical image data, regardless of their spatial resolution - continuously increasing cloud cover over Earth's surface and lack of phase information in these data sets. For these reasons, the remote sensing community increasingly prefer the microwave imaging radars such as synthetic aperture radar (SAR) and the SAR systems have become more sophisticated with fully polarimetric capabilities.

The basic concept of radar polarimetry deals with the full vector nature of polarized (vector) electromagnetic wave throughout the frequency spectrum from Ultra Low Frequency (ULF) to the frequencies far above the Far Ultra Violet (FUV) (Boerner, 2000). New developments in radar polarimetry and radar interferometry technologies now bring the old SAR imaging applications to an era of new innovations. In addition to the all weather imaging capability of the SAR even in the dark, the additional polarimetric information provide us with whole new range of information.

The fundamental relationships of the radar polarimetry are obtained directly from Maxwell's equations for the source-free isotropic, homogeneous, free space. The full polarimetric measurement is defined by the complex scattering matrix

$$\left[\overline{\overline{S}}\right]=\begin{pmatrix} f_{HH} & f_{VH} \\ f_{HV} & f_{VV} \end{pmatrix}$$

$$= \exp\left[j\varphi_{HH}\right]\cdot$$

$$\cdot\begin{pmatrix} \sqrt{\sigma_{HH}} & \sqrt{\sigma_{VH}}\exp\left[j(\varphi_{VH}-\varphi_{HH})\right] \\ \sqrt{\sigma_{HV}}\exp[j(\varphi_{HV}-\varphi_{HH})] & \sqrt{\sigma_{VV}}\exp[j(\varphi_{VV}-\varphi_{HH})] \end{pmatrix}$$

which is constituted of relationships that include the complex pq scattering coefficients, where p is the transmitting and q is the receiving polarization. In monostatic case, the single look polarimetric data are fully defined by three backscatter coefficients $(\sigma^0_{HH}, \sigma^0_{HV}, \sigma^0_{VV})$, and the two differential phases $(\varphi_{VV}-\varphi_{HH})$ and $(\varphi_{HV}-\varphi_{HH})$ (Imbo, et al., 1999). Accurate representation of the polarimetric information with respect to the corresponding science and engineering application requirements will require focused collaborative research between the participants with diverse backgrounds.

Polarimetric interferometric SAR (e.g. XTI-1, XTI-2, ATI, etc. in AIRSAR terminology) modes are basically extensions of previous single frequency, single polarization SAR inteferometry but fully polarimetric information is expected to broaden the polarimetric SAR interferometry applications in considerable extent (NASA (JPL), 2000).

For plate tectonic and earthquake related geodynamic problems, cross-track interferometry (XTI-1, XTI-2) will be most useful. For space-borne applications, repeat orbit, and tandem orbit inteferometry, if available, are mostly used for the same types of problems.

5. NASA(JPL) AIRSAR

The NASA(JPL) airborne SAR (AIRSAR) system operates in the fully polarimetric mode at C-, L- and P-band simultaneously or in the interferometric mode in both C- and L-band simultaneously. (The detailed information on the NASA(JPL) ARISAR is available in the NASA(JPL) homepage and will not be repeated here). There are eight SAR antennas onboard the DC-8 (Figs. 1 and 2) and radar operating modes include POLSAR, XTI-1, XTI-1-ping pong, XTI-2, XTI-2_ping pong, and ATI.

The navigation system for AIRSAR includes the Motorola Six Gun GPS receiver and Honeywell Integrated GPS and INS(IGI). The specifications of the navigation units are: 0.020 aircraft heading accuracy, 0.010 roll and pitch accuracy, 0.03 m/s velocity accuracy per axis, and 16 m positioning accuracy with the Precise Positioning Service (PPS) (Lou et al., 1999).

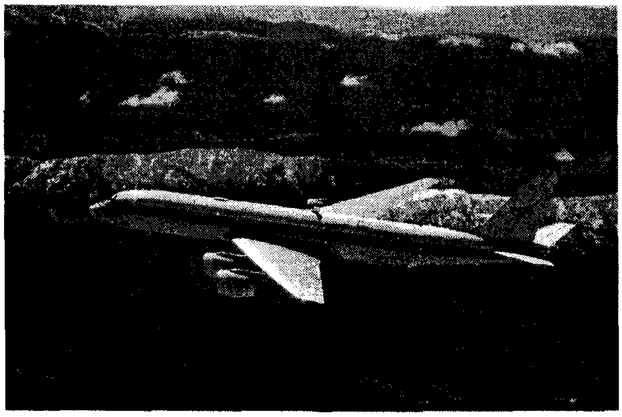

Figure 2. NASA DC-8 Flying laboratory

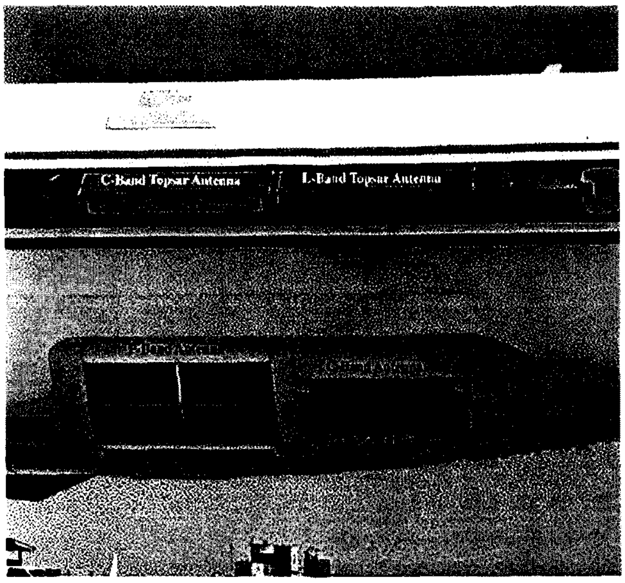

Figure 3. SAR (C-, L- and P-Band) antenna outside of DC-8

Figure 4. On-board computers and instruments inside DC-8

The calibration of the polarimetric data is established with the calibration tone in the receiver chain and with the corner reflector verification. Based on these calibration approaches, one can expect the polarimetric data to be better than 3dB absolute accuracy, better than 1.5 dB relative accuracy amongst the 3 radar frequencies, and better than 0.5 dB between the polarization channels (Lou et al., 1999). The relative phase calibration between the HH and VV channels is better than approximately 100.

The calibration of XTI data is usually much more difficult because of various parameters involved in the interferometric data processing such as the baseline vector. As an example, the absolute phase must be known if one wishes to estimate the height information from the polarimetric interferometric data without 2π ambiguity (Lou et al., 1999).

The ultimate purpose of the AIRSAR missions is to produce target imagery from various types of AIRSAR radar data. The real-time correlator onboard (Fig. 3) is a part of the AIRSAR radar facility included in the DC-8 and produces low resolution (app. 25 m) two look survey image. This onboard correlator is useful for assessing the general health of the radar and the success of the data taking in real-time.

The final processing of selected portions of the data to high quality, fully calibrated image products proceeds usually after the completion of the specific AIRSAR mission in collaboration with the PIs, often in close consultation with the NASA(JPL) specialists. The number of channels and processing modes are determined at this time.

6. PACRIM-II Korea Campaign

The PACRIM-II Korea campaign includes five regions as shown area in Fig. 4 and the primary data types were polarimetric SAR in four of the five.

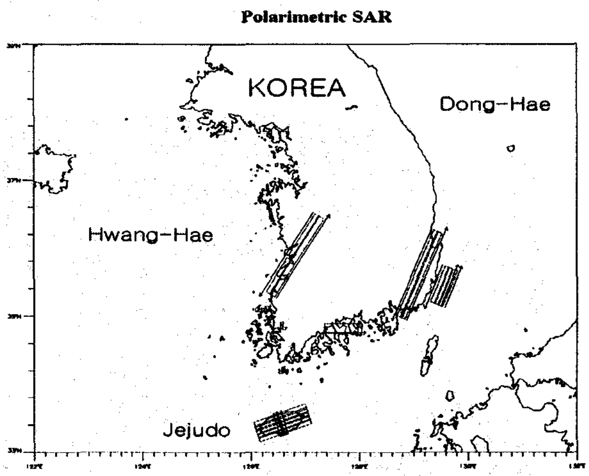

Figure 5. The AIRSAR/MASTER survey flight lines proposed by the Korean participating teams. The Yeosu MASTER line was later modified to optimize the sun angle.

Yeosu Transect was the only MASTER study area. There were also several areas where MASTER data were to be acquired as an option. The PACRIM-II Korea teams are made of scientists and engineers from twelve universities and four research institutions, including Korean Aerospace Research Institute (KARI), Korean Meteorological Agency (KMA), Korea Ocean Research and Development Institute (KORDI), and National Institute of Agricultural Science and Technology (NIAST). The science and engineering research objectives proposed in the PACRIM-II Korea Campaign include agriculture (crop monitoring), forestry (land cover classification), geology (environmental monitoring of mine tailing problems), oceanography (currents and waves), meteorology (coastal air-sea problems), coastal studies (mapping of the tidal flats), accurate DEM related mapping, archeology and geohydrology (including soil moisture).

7. MASTER Experiment

Although the NASA(JPL) AIRSAR missions have carried only the AIRSAR equipment in the past specifically for polarimetric SAR experiments, a full version of MASTER was added this time onboard DC-8 for the PACRIM-II mission in 2000. The hyperspectral capabilities of MASTER (MODIS & ASTER) simulator with liquid nigtrogen dewar (Fig. 5) could have provided us with additional research opportunities. The only primary MASTER data transect was planned in Yeosu and Icksan and Jeju Island areas added to this campaign as secondary MASTER study sites. However, the weather during the whole PACRIM-II Korea Campaign was heavily overcast and less than 3% of the originally planned MASTER were recorded. For this reason, MASTER research opportunities in Korean study sites are practically lost.

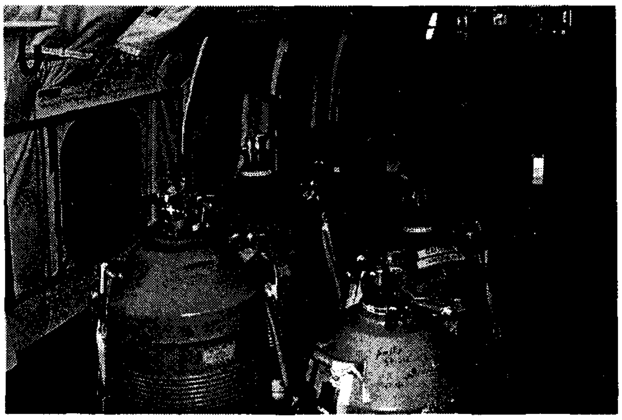

Figure 6. Liquid nitrogen dewar on-board the DC-8 for cooling of the MASTER simulator.

6. Ground Truth

All remote sensing research critically depends on the good ground truth data and it was no exception with the PACRIM-II Korea Campaign. Ground truthing was first planned by the groups of the investigators, who work in the same area and it was followed by a series of field work. In Gongju and Jeju study areas, in-situ soil moisture, roughness and other surface features were carefully measured and recorded during the duration of the actual AIRSAR/MASTER data acquisition.

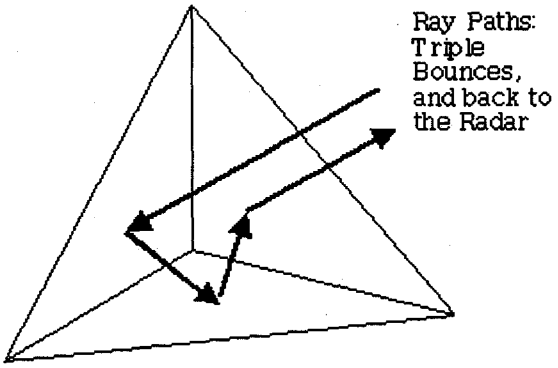

Figure 7. Schematic figure of the trihedral corner reflectors built and deployed in this experiment..

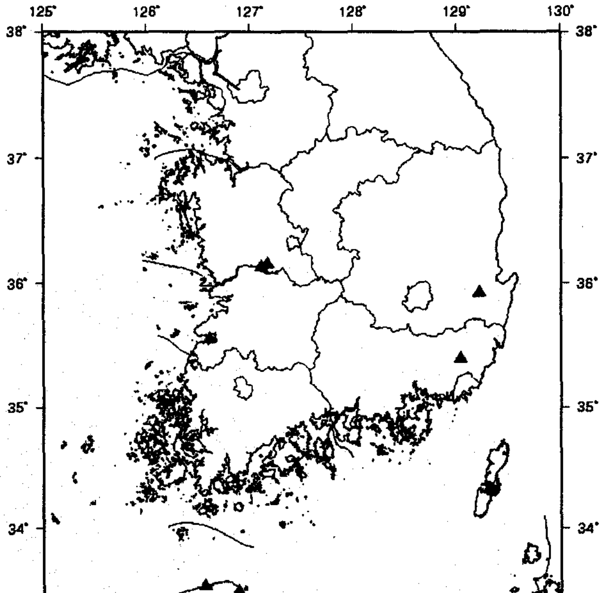

Figure 8. Location of the trihedral corner reflectors installed during the PACRIM-II Korea mission.

Several teams from the PACRIM-II Korea Campaign manufactured trihedral corner reflectors for calibration and also for ground reference point purposes. Total of nine trihedral corner reflectors in two sizes were installed at selected locations along the Gongju - Byunsan transect, Kyungju - Nakdong-River transect, and in Jeju Island including the summit of the Mt. Halla volcano. The schematic diagram of the trihedral corner reflectors built and deployed in this study is shown in Fig. 6 and the locations of the corner reflectors are shown in Fig. 7. Two different size corner reflectors were built and deployed for two different objectives: calibration of the polarimetric SAR systems and reference location of the ground control points.

In Ulsan area where AIRSAR ATI data acquisition was planned and successfully carried out for physical oceanographic applications, Doppler radar monitoring of currents and waves was planed with HF radar installations at three different locations. Off-shore buoy data were also planned to be collected by research vessels.

Other PACRIM-II Korea AIRSAR/MASTER Campaign participants have thus collected large volumes of agricultural, geological and forestry field data for the later classification and verification research.

8. Geodynamic Parameters

Although the PACRIM-II Korea AIRSAR / MASTER Campaign was originally planned as an interdisciplinary and collaborative remote sensing research project, one of the most important science objectives included was Earth system observation, focused on the surface geodynamic change monitoring at selected study sites.

Currently the most common geodetic and earthquake related geodynamic application tasks include observation of

- Vertical (uprising / subsidence) movements : precursors for a volcanic activities, precursors for an earthquake activities, etc.
- Horizontal displacements / movements: active fault movements, earthquake related displacements, etc.

Some of the Earth system observation parameters are summarized in Table 1 for selected geodynamic applications. Spatial (pixel) resolution of new Earth observation satellites sensors is now approaching 1 m or less for optical imaging systems and 3 m or less for space-borne SAR systems for civilian use. The most striking difference of SAR imaging systems from the optical imaging systems is the interferometric resolution, which is realistically achievable in the range of few centimeters, approximately half-wavelength of the signal wavelength, if the raw data is available and if one can utilize the phase information.

Selection of frequency and selection of preferred polarization of the SAR signal will depends on geodynamic applications and the users of a specific SAR system should investigate prior to actual design of the experiment. The information in Table 1 serves only as a guide for Earth observation and geodynamic research applications.

9. SAR Interferometry

In general, a SAR interferogram is obtained from two SAR images acquired from a slightly different positions, separated by a baseline, The acquisition of SAR data fro interferometric purposes can vary depending on the deployment geometry of the SAR antenna with respect to

Table 1 Summary of the polarimetric SAR application parameters for Earth system investigation

	Crustal movements /Tectonics	Arid land / subsurface mapping	Desertification
Frequency	X, C, (L)	L, (X, C)	X, C, (L)
Polarization	HH, VV, and (HV)	HH, HV, and (VV)	HH, HV and (VV)
Incidence angles	300 - 600	150 - 600	150 - 600
Time of data acquisition	Summer / winter	Driest / wettest season	Direst / wettest season
Pixel resolution required	< 20 m	15 - 50 m	15 - 20 m
Interferometric resolution	1.5 cm - 3.5 cm	App. 12 cm	1.5 cm - 3.5 cm

the direction of platform movement.

If the two antenna positions, which acquire SAR data either simultaneously or in sequence, decides the

- Cross-track SAR interferometry or
- Along-track SAR interferometry (Kim et al., 2003).

If the two antenna positions for interferometric SAR data acquisition is perpendicular with respect to the antenna platform movement, the baseline between the two antenna becomes perpendicular to the platform movement, and is called the cross-track SAR interferometry. If the two SAR antenna being used for interferometry is arranged along the platform flight line, the baseline between the two SAR antenna becomes parallel to the SAR antenna platform movement and the SAR interferometry is in such cases called the along-track SAR interferometry.

In airborne systems, two antennas used for interferometric data acquisition is separated by an optimum baseline distance and fixed to the aircraft body, either in the flight direction or in the perpendicular direction with respect to the flight direction. The former antenna arrangement is used for the along-track SAR interferometry and the latter is used for cross-track SAR interferometry. In these cases, two sets of SAR data to be used for interferometric applications are acquired simultaneously for both cases and there will be not any temporal decorrelation problem. However, the Doppler shifting processes of signal frequencies for the cross-track and along-track SAR data are completely different and the application of the cross-track and along track SAR interferometry is quite different. A typical example of cross-track SAR interferometry usage is generation of accurate digital elevation models (DEM) (Moon et al., 1998, Kim et al., 2001). Along track SAR interferometry is used for completely different situations and typical along-track SAR interferometry examples include Earth's target movement detection and sea surface current velocity measurement in oceanography (Kim et al., 2002).

In the case with the space-borne SAR systems with only one SAR antenna, one has to wait until the satellite or the SAR platform returns to the some orbit location in their near polar orbit to acquire the second set of SAR data, and the orbit geometry used for interferometry becomes the repeat orbit SAR interferometry. In this case, the baseline between the two antenna position with respect to the satellite platform orbit direction is neither perpendicular or parallel in most cases. However, most satellites with SAR systems (e.g. ERS-1/2, JERS-1, RADARSAT-1) have only one SAR antenna and interferometric SAR applications using these satellites are repeat orbit SAR interferometry (Moon et al., 1998; Kim et al., 2001).

10. Interferometric SAR Data Processing

We need two sets of single look complex (SLC) SAR data to generate a SAR interferogram. For this reason, we need either two sets of level 0 raw SAR data or two sets of SAR data processed to SLC data to form a SAR interferogram. If necessary, the data can be bandpass filtered at this stage and the next step is the multiplication of the first image data by the complex conjugate of the second image.

Given two SAR SLC image

First (Master) image	$S1(x, y)$
Second (Slave) image	$S2(x, y)$

The interferogram is formed by the complex multiplication of the two

$$I(x, y) = S1(x, y) * S2(x, y)^*$$

where $S1(x, y)$ and $S2(x, y)$ are the interferometric SAR image pairs separated by a baseline. In the repeat orbit SAR interferometry, the baseline between these two images usually varies and one has to estimate it accurately to improve the coherency of the interferogram. In the AIRSAR case, all of the C- L-band antennas for inteferometric applications have precisely known fixed baseline length as mentioned above. (Zebker and Goldstein, 1986, Lou et a;., 1999, Moon et al., 2002). The interferogram computed above can be phase unwrapped to generate a desired digital elevation model (DEM). The same term can be used to estimate the coherency image, which in turn can be used for estimating various surface backscattering effects.

11. Polarimetric SAR Interferometry

The vector concept of the polarimetric SAR data can be extended to the traditional SAR interferometry and utilize the additional information for more quantitative imaging of the scatters at the surface of Earth (Borner and Papathanassiou, 1998). The combination of SAR interferometry and polarimetry enables one not only to apply both techniques at the same time, it also offers new capabilities, especially maximization of phase coherence, which allows one to measure the effective phase scattering centers of different scattering mechanisms (Borner and Papathanassiou, 1998; Cloude and Papathanassiou, 1997). This in turn allows one to develop whole new ranges of applications in Earth sciences, although this new approach in polarimetric SAR interferometry focuses on the Earth's cover mapping and subsequent inversion (Papathanassiou and Cloude, 1997; Cloude and Papathanassiou, 1997).

12. Concluding Remarks

Geophysics has traditionally been a specialized discipline under the broadly defined "Earth science" topic until recent. However, Geophysics is becoming a more important and widely applicable science and engineering discipline which can play crucially important roles in the Earth and planetary exploration and development. With recent rapid developments in the computer technology and the space-borne remote sensing technology, the research opportunities in global geophysics has been increasing rapidly, specially for young geophysicists and new students who venture into the exciting field of geophysics.

There are large numbers of satellite missions directly related to Earth's ocean and solid Earth geophysics, including the potential field missions currently being planned by several countries. Unfortunately we do not have any geophysics related space mission planned, we can participate most of the foreign geophysics and planetary missions and test and utilize the new opportunities.

The PACRIM-II AIRSAR/MASTER mission, carried out over the Korean peninsula in September 2002, was the first interdisciplinary polarimetric SAR and hyperspectral optical imaging experiment in Korea. Similar NASA(JPL) AIRSAR transect was also flown over the Sejong Research site in March 2004. Currently the follow-up research projects are actively pursued: e.g. accurate DEM generation using cross-track interferometric data (XTI-1 and XTI-2) (Jeju Island), active imaging of faults systems (Kyungsang Basin) utilizing POLSAR and XTI data, and testing and investigation of POLSAR and XTI applicability for the investigation of tidal flats in the west and south coasts of the Korean peninsula. Although it is not possible to summarize the whole Korean AIRSAR/MASTER experiments in this short paper, some of the results will be present in future. Some of the preliminary results of the soil moisture mapping study carried out in Jeju Island using PACRIM-II polarimetric SAR data is presented in this issue (Kwon et al., 2002). Current research tasks and present status of each participating projects in the PACRIM-II Korea mission nevertheless appear to be challenging and yet encouraging.

13. Acknowledgments

Funding for some of the research mentioned in this paper were partially funded by NASA(JPL) and the NSERC of Canada Discovery Grant (A-7400).

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