The NASA/JPL Airborne Synthetic Aperture Radar's 1996 PacRim Deployment

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ABSTRACT

In November and December 1996, the NASA/JPL Airborne Synthetic Aperture Radar system (AIRSAR) embarked on a seven-week campaign to several Pacific Rim countries. This mission was jointly organized by NASA, Australia's Office of Space Science and Application, and University of New South Wales. The major purpose of the mission is to establish a collaborative effort in the area of radar remote sensing application between the United States and the Pacific Rim countries. SAR data were acquired for both U.S. researchers as well as the participating countries. In addition to Hawaii, we imaged areas of interest in New Zealand, Australia, Papua New Guinea, Malaysia, Brunei, the Philippines, Taiwan, Thailand, and Cambodia including coastal regions of some countries. The target areas of this multi-frequency, polarimetric and interferometric SAR system included volcanoes, sites for studies in geology, hydrology, and landuse mapping, and forested mountains to generate height maps of rugged and inaccessible areas.

INTRODUCTION

AIRSAR operates in the fully polarimetric mode at P-, L-, and C-band simultaneously (POLSAR) or in the along-track (ATI) or cross-track interferometric (XTI) mode in L- and C-band simultaneously. The system began collecting data in late 1987 on its first mission aboard a DC-8 aircraft operated by NASA's Ames Research Center in Mountain View, California. Since then, AIRSAR has flown missions every year and acquired images in North, Central, and South America, Europe, Greenland, and Australia. In POLSAR mode, the image products are fully calibrated and are stored in compressed Stokes matrix format that contains all the polarization information. In XTI mode, C-band cross-track interferometer data are used to generate a digital elevation model (DEM) and an incidence angle map. In this case, L-band radar could operate in either cross-track interferometer mode or polarimetric mode whereas P-band radar is always in polarimetric mode. By using the incidence angle map, all output images are geometrically and radiometrically corrected taking the topography into account and resampled to ground range with a 10 m by 10 m pixel spacing. The output images cover 10-12 km in the range direction for the 40 MHz chirp bandwidth mode.

On AIRSAR'S 1996 PacRim Deployment, data were collected over the following ten countries: the US, New Zealand, Australia, Papua New Guinea, Malaysia, Brunei, the Philippines, Taiwan, Thailand, and Cambodia as shown Fig. 1. Most of the data were collected in XTI-1 mode, i.e. C-band cross-track interferometer with L- and P-band polarimeter. This mode provides users with a DEM of the imaged site and geometrically corrected L- and P-band polarimetry data. With over 100 sites imaged, investigators will study the following topics: wetlands and peat swamp characterization, mangrove forest mapping, floodplain morphology, archaeology, cultural resource management, crop classification, forest classification, deforestation and regrowth monitoring, biodiversity, soil moisture estimation, carbon dynamics of indigenous rainforests, geologic mapping, DEM generation, volcanic hazards, mining exploration, coastline monitoring, mountain road planning and rehabilitation, and differential penetration of vegetation canopies.

In addition to AIRSAR, three other science instruments were also on-board the DC-8 aircraft. These were TIMS (Thermal Infrared Mapper), AES (Airborne Emission Spectrometer), and Cloud Radar (in Hawaii and New Zealand only). The main objective of TIMS was to image volcanoes and selected geologic sites in Australia. AES provides temperature and humidity profiles for the TIMS imaging of SO_2 concentrations in volcanic gas plumes. AES also monitored gas ratios such as $HCL:SO_2$.

In this paper, we will briefly describe the sites imaged in each country and their respective science objectives. In addition, we will outline our plan for data processing and data analysis.

HAWAII

Sites on three of the Hawaiian Islands were imaged, Oahu, Hawaii, and Maui. The Oahu site located on the summit of the Koolau Mountains was imaged to study differential radar penetration (C-/L-band) through distinct vegetation density

gradients. On the island of Hawaii, the Mauna Kea and Mauna Loa volcanoes were imaged to generate detailed digital elevation models of the summit regions. Two transects, one along the north shore of Hawaii and the other from Kohala Volcano in the northwest to the saddle between Mauna Loa and Mauna Kea, were imaged to study erosion patterns on the windward and leeward sides of the island. In addition, the rainforest on the flanks of Kilauea was imaged to study differential radar penetration along the vegetation gradient. Furthermore, the Kohala Ocean off the northwestern tip of the island of Hawaii was imaged in ATI mode to assist in the development of an ATI processor that will measure the radial component of the ocean current. Finally, we had an opportunity to image Haleakala volcano on the island of Maui on our way back from the PacRim deployment.

NEw ZEALAND

The New Zealand sites were coordinated through Landcare Research of New Zealand. The sites imaged included White Island, several sites on the North Island, Taupe, Ruapehu, Wanganui, Wairarapa, and Baring Head and a portion of the Southern Alps on the South Island.

White Island is a 3 km x 3 km active volcanic island located off the northern shore of the North Island. The objective is to generate a DEM for monitoring the ongoing deformation of the island. Ruapehu is the largest and highest volcano in New Zealand where steam explosions cause hot water to spill over the flanks of the crater lake. Both TIMS and AES data were taken in addition to AIRSAR data. Taupo is an indigenous rainforest and was imaged to study the forest composition and biomass. Wanganui was imaged to evaluate the use of SAR data for landslide detection and vegetation mapping. Wairarapa is an area of active deformation where the growing folds will be examined in three-dimensions. The area contains extensive terraces that act as markers in determining the deformation rates. Finally, the Southern Alps includes a portion of the Alpine fault system, a very active strike-slip fault similar to the San Andreas fault in California. The results from this study will be compared to a study site in the San Gabriel Mountains north of Los Angeles.

AUSTRALIA

AIRSAR spent two weeks in Australia mapping sites in all six provinces in mainland Australia. These sites were selected by Australian scientists and mining companies, and NASA scientists. Sites in Eastern and Southeastern Australia included Condamine, Goulburn, and Tarrawara, which were imaged to generate soil moisture maps. Mt. Fitton is an international radar calibration site rich in minerals and geologic features such as alluvial fans and sand dunes. Lake Acraman was imaged to study an ancient meteor impact crater whereas Cooper Creek was imaged to study the history of seasonal river channels in this desert region. In addition, a 500 km long transect was imaged over the Cunnamulla region just west of Brisbane to provide a valuable verification data set for the upcoming Shuttle Radar Topography Mapping (SRTM) mission.

In Northeastern Australia, Gilbert Range was imaged for hydrological studies and Lawn Hill was imaged to study a meteor impact crater. Weipa was a site selected for SRTM calibration. Queensland, also imaged in the 1993 AIRSAR Australian campaign, was mapped for a repeat-pass P-band interferometry study.

Central Australia is rich with geologic sites where a number of meteor impact craters were imaged and they included Mt. Toondina, Henbury, Glickson, Connolly, Wolf Creek, Strangways, and Liverpool, In addition, a number of geologic sites were imaged for the mining companies. In the Northern Territory, several mangroves and coastal wetlands were imaged and they included Endyalgout Island, Pt. Farewell, Munmarlary, Mary River, Gunn Point, Humpty Doo, and Daly River. In addition, we also imaged Darwin Harbour for research in coastal ship watch.

PAPUA NEW GUINEA (PNG)

AIRSAR'S flight over PNG was flown out of Townsville, Australia. Eight sites were imaged in which three were mining sites. The remaining sites included Manam Island, an active volcanic island which had a violent Strombolian eruption a few days after AIRSAR's overflight. Fly River was imaged for tropical wetland mapping and Lakekamu Basin, a Conservation International site, was imaged to map the topography and ecology of the tropical rainforest. In addition, Huon Peninsula and Ramu-Markham were imaged to study soil erosion, landslide, and landuse mapping.

MALAYSIA

Sites in Malaysia were selected by the Malaysian Center for Remote Sensing (MACRES) and included sites in Sarawak, Sabah, and the Malay Peninsula. The two sites in Sarawak were for landuse mapping of coastal area and mountainous region respectively, whereas Kota Kinabalu in Sabah, the tallest mountain in Southeast Asia, was imaged for land classification and coastal mapping. On the Malay Peninsula, Tioman Island on the east coast was imaged for landuse mapping of mangrove. In addition, Cameron Highland was imaged several times for landuse mapping as well as geologic studies. Muda Merbok was imaged to study landuse and rice crop whereas Terengganu was imaged for coastal zone management studies.

BRUNEI

AIRSAR mapped much of coastal Brunei in six passes and the main objective is to use AIRSAR data to update maps. In addition, the data will provide the Survey Department with their first experience with SAR data for potential applications such as landuse mapping.

PHILIPPINES

The sites in the Philippines were organized by various agencies in the Philippines and coordinated by the National Mapping Agency (NAMRIA) and the Department of Science and Technology (DSTO). They included four volcanoes, ecology sites, and geology sites. The active volcanoes imaged were Taal, Mt. Pinatubo, Mayon, and Kanlaon. In addition, Visayas, a mining site, was imaged for topographic studies of a very rugged mountainous area. Coastal Panay was imaged for landuse mapping as well as soil moisture studies. Los Banes is a rice research site whereas Magat Watershed is a vegetation classification site. Finally, we also imaged Manila and Cebu for urban mapping.

TAIWAN

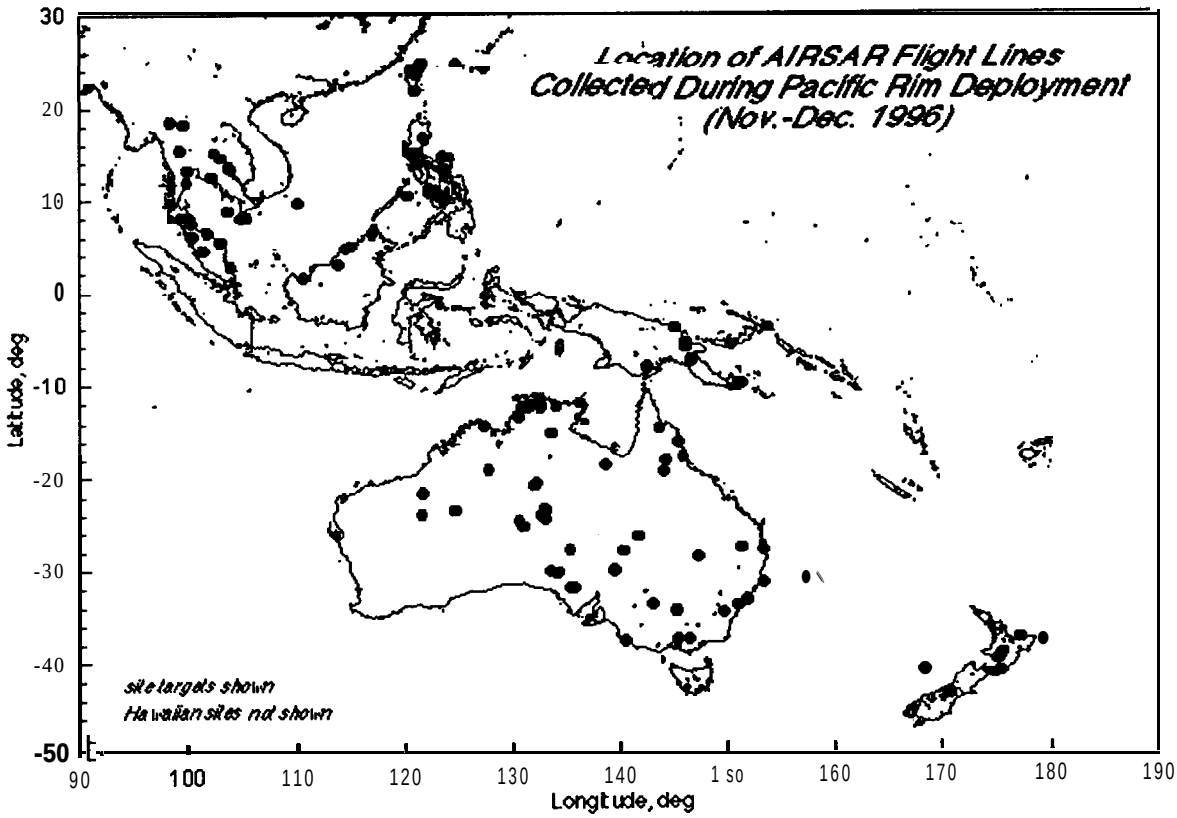
The Taiwan sites were organized by the Center for Space and Remote Sensing Research Center of National Central University in Chung Li. Two large study sites were selected for land cover and coastal zone mapping using both XTI and POLSAR modes. In addition, two transects were imaged for SRTM verification. One of these transects crossed the tip of the Oluan Peninsula in southern Taiwan whereas the other transect crossed central Taiwan.

THAILAND

Thailand's participation was organized through the Thailand National Research Council (NRCT) and 13 study sites were imaged. They included land cover mapping of Uthaithani, a wildlife sanctuary, and Ranong, a coastal mangrove forest reserve area and rubber plantation. In addition, AIRSAR imaged Lampang, a mining geology site, and Chanthaburi for land use classification. Nakhon Si Thammarat and Songkhla were imaged for wetlands studies whereas Prachuap Khiri Khan was imaged for coastline monitoring. A number of archaeology sites were imaged in northeast Thailand and Cambodia including the famous Angkor Wat in Cambodia. These data will assist the Fine Arts Department of Thailand as well as participants from the World Monuments Fund in cultural resource management and research. Finally, Chiang Mai and Surat Thani were imaged for forestry mapping and classification.

FUTURE PLAN

All the PacRim data have been survey processed and initial evaluation of data quality looks good. We have begun precision processing based on user requests. With just over 100 sites imaged, it could take two to three years to process all the sites. Data collected for agencies and companies in these countries are under a one year proprietary period from the date of precision data processing. In addition, we had the first PacRim Workshop in Pasadena in March, 1997 and began the process of forming research teams by discipline. It is our hope that by teaming up inexperienced SAR users with experienced AIRSAR scientists, this will shorten the learning curve for the former and enable all of us to better utilize the rich data set we collected during the PacRim Deployment. Future PacRim Workshops will be held annually at different participating countries to report exciting research findings and exchange ideas. For more information and updates, please consult AIRSAR's home page at: http//airsar.jpl .nasa.gov.


Location of AIRSAR Flight Lines
Collected During Pacific Rim Deployment
(Nov.-Dec. 1996)
site targets shown
Hawaiian sites not shown
Latitude, deg
Longitude, deg
30
20
10
0
-10
-20
-30
-40
-50
90
100
110
120
130
140
150
160
170
180
190