THE SPACEBORNE IMAGING RADAR-C, X-BAND SYNTHETIC APERTURE RADAR (SIR-C/X-SAR) MISSION OVERVIEW

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Overview

The Spaceborne Imaging Radar-C, X-Band Synthetic Aperture Radar (SIR-C / X-SAR) was launched on space shuttle Endeavour at 7:05 AM EDT, Saturday, April 9, 1994, Soon after launch, the radars were activated and began around the clock operations which lasted for the next 10 days. Endeavour landed at approximately 1:05 pm EDT, Wednesday April 20 at the Edwards Air Force Base facility in California, One hundred per cent of the science data planned for the first of at least two flights of SIR-C/X-SAR were acquired. These data will be used by the international science community to better understand the global environment and how it is changing (Evans et al., 1993), In addition to acquiring high quality data over all planned targets, observations of flooding in Illinois and Germany and three different views of Tropical Cyclone Odille were added to the mission plan. SIR-C data *were* downlinked, processed, and released over internet within 24 hours after launch. X-SAR data were processed in survey mode and displayed in real time on NASA Select television.

SIR-C / X-SAR is a cooperative experiment between NASA, the German Space Agency (DARA), and the Italian Space Agency (ASI). The SIR-C instrument and Ground Data Processor were developed by NASA's Jet Propulsion Laboratory (JPL). SIR-C provides increased capability over earlier orbital radar systems (Seasat, SIR-A, and SIR-B, and the European ERS-1 and Japanese JERS-1) by acquiring digital images simultaneously at two microwave wavelengths (λ): L- band ($\lambda \cong 24$ cm) and C-band ($\lambda \cong 6$ cm) (e.g. Evans et al., 1993). Vertically and horizontally polarized transmitted waves are received on two separate channels, so that SIR-C provides images of the magnitude of radar backscatter for four polarization combinations: HH (Horizontally transmitted, Horizontally received), W, VH, and HV; and also data on the relative phase difference between the HH, W, VH and HV returns.

X-SAR was developed by the Dornier and. Alenia Spazio companies with the Deutsche Forschungsanstalt fuer Luft und Raumfahrt e.v. (DLR), as a major partner in science, operations and data processing, X-SAR operates at X-band ($\lambda \cong 3$ cm) with VV polarization, resulting in a three-frequency capability for the total SIR-C/X-SAR system. Because radar backscatter is most strongly influenced by objects comparable in size to the radar wavelength, this multifrequency capability provides information about the Earth's surface over a wide range of scales not discernible with previous single-frequency experiments.

Figures 1 and 2 show examples of SIR-C/X-SAR images that were acquired and processed during the April flight. Figure 1 of Mount Pinatubo volcano in the Philippines is a false-color composite was made by displaying the SIR-C L-band HH return in red, the L-band HV return in green and the C-band HV return in blue. The summit crater of Mount Pinatubo produced by the June 1991 eruptions, and the steep slopes on the upper flanks of the volcano, are easily seen in this image. The red color on the upper slopes show the distribution of the pyroclastic flows which were erupted in June 1991. These flows are most easily visible in the C-band cross-polarized (CHV) data where the radar energy is absorbed by the unconsolidated deposits. At L-band (HH polarization in particular), the radar backscatter of these flows is comparable to the surrounding areas. The dark drainages are the smooth mudflows which continue to flood the river valleys after heavy rain. Radar images such as this one can be used to identify the full extent of the areas flooded by the mudflows, which are difficult to distinguish visually, and to assess the rate at which the erosion and deposition continues (P.J. Mouginis-Mark and C. Evans, personal communication).

Figure 2 is a false-color, three-frequency image of Oberpfaffenhofen Germany, located southwest of Munich. L-band total power was assigned red, C-band total power is shown in green and the X-band VV polarization appears blue. The dark area in the center of the image is Lake Ammersee. The two smaller lakes above the Ammersee are the Worthsee and the Pilsensee. On the right of the image is the tip of the Starnbergersee. The outskirt of the city of Munich can be seen at the top of the image. Blue areas corresponds to areas for which the X- band backscatter is relatively higher than the backscatter at L- and C-band; this behavior is characteristic of clear cuts or shorter vegetation. Similarly, the forested areas have a reddish tint. Finally, the green areas seen at the 'southern tip of both the Ammersee and the Pilsensee lakes indicate a marshy area. The Oberpfaffenhofen area is the major test site for X-SAR calibration and scientific experiments such as ecology, hydrology and geology.

Figure 3 shows a coverage map of SIR-C /X-SAR data acquired. Coverage priorities were determined by the SIR-C /X-SAR Science Team based on their individual experiment objectives, and research themes which were developed for the overall SIR-C/ X-SAR mission (Evans et al., 1993). Ecology investigations being carried out by science team members are focussed on mapping deforestation, and wetlands and flooding under forest canopies (e.g. Hess et al., 1990); and validating models to determine vegetation type, seasonal freeze/thaw transitions, and biomass (e.g. Dobson et al., 1992; Le Toan et al., 1992). The focus of hydrology experiments is to improve our understanding of where moisture is stored and how it is redistributed e.g. Wang et al., 1986; Rott and Mätzler, 1987). Data were also acquired to demonstrate the measurement of rainfall from space over the western Pacific in preparation for future rainfall measurement missions.

Data from SIR-C/X-SAR will be used by geologists on the science team in studies of volcanoes and tectonics, the history of past climate change; and soil degradation. There ' is also an experiment to determine areas that are susceptible to sand and dust storms by measuring aeolian roughness. Finally, the relatively low altitude of this shuttle mission will be particularly advantageous for oceanography investigations since SIR-C/X-SAR data are more sensitive to ocean features than satellites in higher orbits. Oceanographers will use data from SIR-C/X-SAR to study surface and internal waves and wave/current interactions (e.g. Liu et al., 1994). In addition, extensive wave energy information was collected over the Southern Ocean by an associated experiment provided by the Johns Hopkins Applied Physics Lab (Beal et al., 1986). The SIR-C/X-SAR Science Team will be reporting on their preliminary results in July, 1994.

All early-release data are available by anonymous FTP from jplinfo.jpl.nasa.gov. The current schedule for release of the first survey data CD-ROM is June, 1994. Calibrated, frame-processed images will be available from the Earth Observing System Data and Information System (EOSDIS) Land Processes Distributed Active Archive Center (DAAC) at the EROS Data Center (EDC) in Sioux Fall, South Dakota beginning in October, 1994. An educational CD-ROM introducing the basics of multiparameter radar image analysis (SIR-CED) is also available from EDC.

Conclusions

The unique perspective of space and the multiparameter capabilities of SIR-C/X-SAR allow us to explore our planet in a way that has never before been possible. The first SIR-C/X-SAR mission has provided a synoptic view of changes on a short temporal scale and a baseline from which we can assess longer-term changes in the future. The SIR-C /X-SAR data, in conjunction with aircraft and ground studies will provide critical data to validate algorithms used to produce maps of vegetation type, biomass, and stand conditions; snow, soil and vegetation moisture; and the distribution of wetlands.

The next flight of SIR-C/X-SAR is scheduled for August, 1994. In addition to gathering data over a different season, a new technology, radar interferometry, will be demonstrated from the shuttle platform. Using subsequent passes of SIR-C /X-SAR it may be possible to generate digital elevation models if the shuttle orbit can be repeated with sufficient precision, Once topography is determined, a third interferometric pass can be used to determine what, if any, topographic change has occurred in the intervening time between SAR overpasses (e.g. Massonnet et al., 1993). This demonstration will be carried out in preparation for TOPSAT, a mission planned for later this decade to measure topography and centimeter-scale topographic change globally using laser and radar interferometry (Farr et al., 1994). The focus of these experiments is to improve our assessments of natural hazards such as flooding, subsidence, mudflows and volcanic eruptions (e.g. Mouginis-Mark and Garbeil 1993) .

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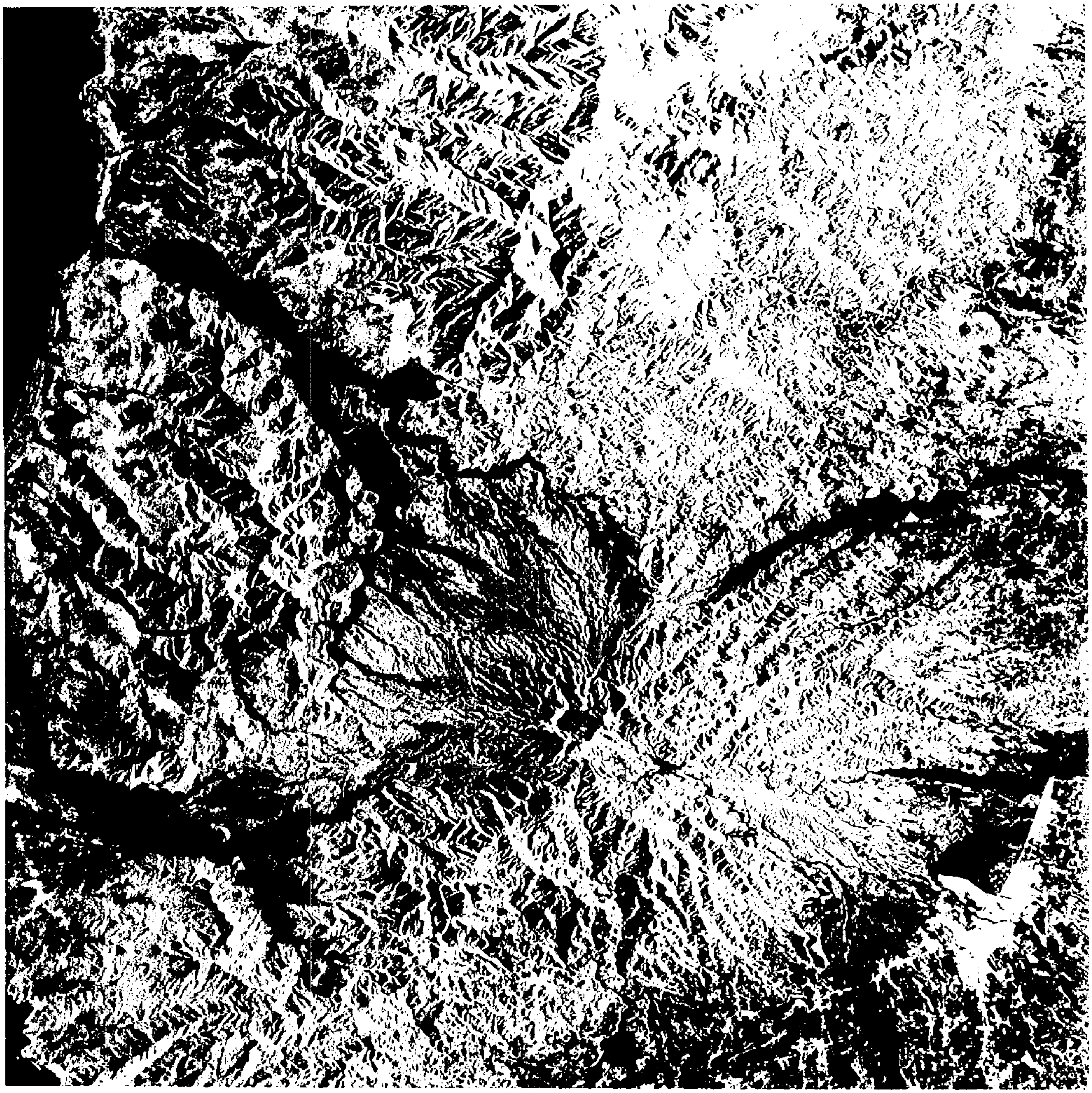
Figure Captions

Figure 1, False color L-band and C-band image of the area around Mount Pinatubo in the Philippines acquired by the Spaceborne Imaging Radar-C and X-Band Synthetic Aperture Radar (SIR-C/X-SAR) aboard the space shuttle Endeavour on April 13, 1994. The area shown is approximately 45 by 68 kilometers, centered at about 15 degrees north latitude, 120.5 degrees east longitude. North is up and slightly to the right.

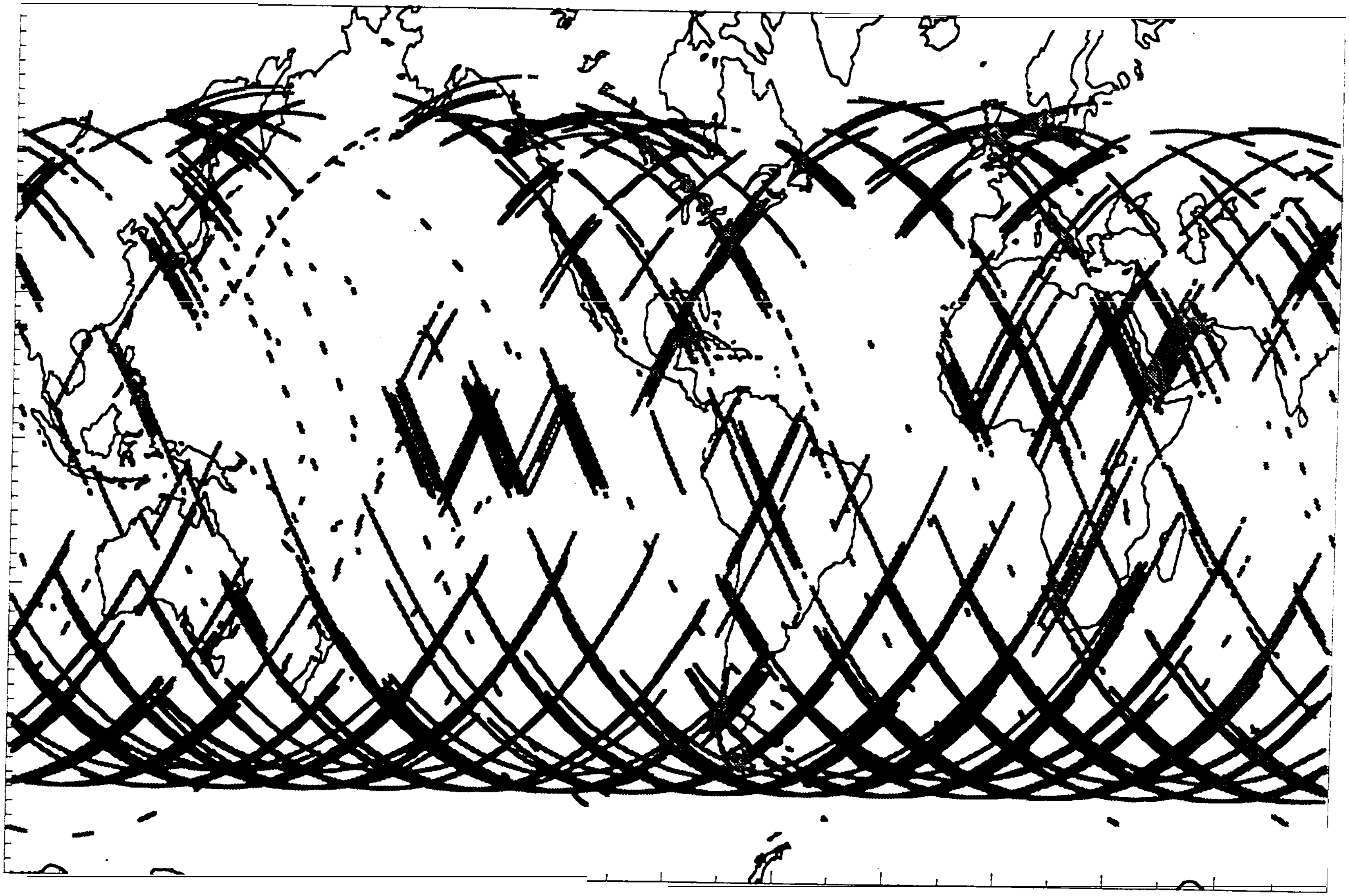
Figure 2. False-color, three-frequency image of Oberpfaffenhofen, Germany. This image was acquired by SIR-C /X-SAR on April 13, 1994, just after a heavy storm which covered the all area with 20 centimeters of snow. The image covers a 27- by 36- kilometer area. The center of the site is 48.09 degrees north and 11.29 degrees east. North is approximately up.

Figure 3. Coverage map for Flight 1 of SIR-C/X-SAR



Evans et al. Fig.1

Evans et al. Fig.2



Evans et al. Fig 3