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THE SIR-C EXPERIMENT: MEASURING NEW VARIABLES FROM SPACE WITH SAR

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ABSTRACT

SIR-C is a continuation of the Shuttle Imaging Radar (SIR) series of synthetic aperture radar (SAR) imaging systems flown by the Jet Propulsion Laboratory aboard the Space Shuttle. SIR-A, flown in 1981, showed that SAR can be a useful remote sensing tool in the fields of geology, hydrology, and oceanography. SIR-B added the capability of moving the radar's antenna in 1984, showing that multiple incidence angle images add materially to the usefulness of SAR. SIR-C will add the dimensions of wavelength and polarization, providing the most powerful system ever flown for SAR scientific studies of the earth.

Imaging radars have a unique role as remote sensors that can aid in answering fundamental questions about our planet. Synthetic-aperture radar (SAR) experiments such as Seasat, SIR-A, and SIR-B have shown themselves in the past to be a valuable addition to such sensors as Landsat MSS, Landsat TM, the Heat Capacity Mapping Mission, and various visible and infrared sensors. Thus, different properties of the surface can be understood from different segments of the electromagnetic spectrum, and currently it is necessary to evaluate many sources of data to address any specific problem. NASA's radar program attempts to evaluate the utility of sensors in the microwave portion of the spectrum towards satisfying these ends. The program began in 1978 with the launch of Seasat, a free-flying, earth-orbiting, SAR which provided the first synoptic radar imagery of the earth's surface. Not only was the experiment a success technologically, but the imagery returned introduced this new means of studying and observing the earth.

The radar program continued in 1981 with the launch of the second Space Shuttle. On board, as a part of the first Office of Space and Terrestrial Applications (OSTA) payload, was SIR-A, the first Shuttle-based imaging radar. The main objective of the SIR-A experiment was to acquire radar data over a variety of geologic regions to further our understanding of the radar signatures of geologic features. A second objective was to assess the capability of the Shuttle as a scientific platform for earth observations. SIR-A was successful in both respects. Its 8-hour film recorder was filled to capacity, and over ten million square kilometers were imaged, including all continents except Anarctica. One of the most exciting results was the imaging of buried dry-river channels in hyperarid regions of southern Egypt. The images showed channels which were later proved to be buried under 1 to 3 meters of sand cover and not visible on Landsat images or from the ground.

SIR-A and Seasat both operated at fixed look angles. Comparison of the data taken from the same areas shows that image intensity is a strong function of the incidence angle of the radar beam at the surface. In general, the response of the radar is controlled by surface topography at lower incidence angles and by average surface roughness at larger incidence angles. SIR-B further examined this phenomenon with a tiltable antenna which allowed the experimenter to vary the incidence angle and, with multiple passes over the same target, to acquire multiple incidence angle imagery. Such a data set can be used to produce curves of radar backscatter as a function of incidence angle, which can be used ultimately to characterize different types of terrain. All of the advantages of stereogrammetry can also be exploited by these data. The SIR-B experiment was flown on the Shuttle in October of 1984, and preliminary results show that, in spite of numerous Shuttle problems that limited the amount and quality of data collected, multiple-incidence angle SAR does add significantly to the correlation of radar imagery to surface units.

The next SIR project, called SIR-C, will further extend research into the applicability of SAR to remote sensing. SIR-C will continue to add dimensions to the evaluation by introducing the variables of wavelength and polarization to the data. The configuration of SIR-C will allow the experimenter independently to select:

(1) a look angle from 15 to 60 degrees in 1-degree steps

(2) a radar frequency of L-band (1.2 GHz) or C-band (5.3 GHz)

(3) all combinations of receive and transmit linear polarizations (HH, VV, VH, or HV)

(4) a trade-off between large swath width and resolution

In addition, the Shuttle carrying SIR-C will orbit at high inclination, allowing coverage near the poles. Also planned for the experiment is an advanced digital correlator which will produce images from the radar echoes in near-real-time.

The role of SIR-C in adding to the overall radar program is to provide unique information about surface units and processes that can be obtained through multiple polarization and multiple frequency data, especially in the fields of continental geology, renewable resources and ocean dynamics. Specifically, the goals are to increase the texture and surface-roughness information derivable from SAR; to enable better estimates of vegetative compostion and health by measuring such parameters as leaf orientation, canopy structure, and soil moisture; to allow a better estimate of the response of the surface of the oceans to wind stress and current motion and to assess the value of SAR in studying sea ice dynamics.

The uses of SAR in the field of continental geology have already been shown. The strong sensitivity of the radar return signal to surface slope variations allows the imaging of very subtle structural features exposed at the surface or covered by dense vegetation, alluvium, or ice sheets. Radar data provide information about surface roughness and large-scale topographic features related to erosional characteristics and resistance of rocks. This information can be used alone or in conjunction with data from other sensors to map lithological units and model geomorphic processes. Radar data also provide information about the dielectric properties of rocks, properties that are related to porosity, or, in some cases, directly to composition. The radar penetration capability is critical for characterizing parts of the earth's surface that are difficult to explore on the ground and that have not been imaged from space because of vegetation, cloud, or alluvium cover. More than 65% of the land area of the earth falls into one of the above categories and thus cannot be imaged from space using visible or IR sensors. This alone makes a full understanding of radar response to geologic features critical. Analysis of data from past SAR sensors has shown that it is often difficult to separate the effects on radar backscatter of the vegetation growing on a surface from those of the surface itself. SIR-C, with its multiple polarization capability, will help to solve this problem since the returns from vegetation are more highly depolarized that those of surface scatterers.

Another significant area in which SAR has value is that of renewable resources. Radar images can be used to determine the extent of vegetation cover and to monitor deforestation, especially in regions such as the tropics that are most often cloud covered. Because of the radar's sensitivity to the structure of vegetation canopies, radar images can be used in some cases to monitor both the type and vigor of agricultural crops. The ability to examine multiple frequency radar images is especially important to the analysis of canopies because of the ability of the higher frequencies to penetrate canopies in both directions and to provide a measure of attenuation. With the additional dimensions of SIR-C, the relationship of plant biophysical properties to the spectral, polarization and temporal transmissivity and backscattering coefficient of vegetation canopies can be studied. Further, because imaging radars are sensitive to soil moisture, it may be possible to map the spatial distribution of undercanopy soil-water boundaries with SAR. And again, the ability of a multiple-polarization SAR to distinguish vegetation from the underlying surface is crucial to this application.

Preliminary work with previous SAR sensors has shown that imaging radars have promise in determining wind-stress patterns and in monitoring current boundaries and dynamics. Previous SAR and other microwave sensors have measured strong expressions of mesoscale water mass boundaries and eddies. Ocean features smaller than the basic SAR resolution can be detected by their addition to the backscatter of the radar in a way similar to the measurement of land surface roughness. Because the SIR-C experiment will offer a near-polar orbit, flexible imaging modes, and rapid digital processing, it will offer the first opportunity to demonstrate the value of SAR for near-real-time global wave prediction. The dynamics of extreme (> 10 m) ocean waves will be studied, as will the forces which control the major ocean fronts and eddies.

One other important application to oceanography has been the understanding and monitoring of the dynamics of polar ice, especially in predicting the annual breakup of the ice pack. Ice covers about 7% of the earth and has a profound effect on its inhabitants, both directly in terms of its contribution to the ecosphere and indirectly by affecting such industries as shipping and fishing. Seasat has shown that SAR is capable of measuring ice pack translation. It is hoped that SIR-C will be helpful in discovering the interactions between the arctic ice cover and the surrounding polar atmosphere and oceans, and in discovering how these interactions affect the climate and short-term weather. An understanding of the dynamic properties of arctic sea ice may have bearing on the prediction of ice behavior. The abilities to measure surface roughness, surface topography, and motion all have application in this field.

The SIR-C experiment represents a broad step in the evolution of SAR technology. It will contain the first spaceborne C-band SAR, the first near-real-time digital correlation, and the first multiple polarization, multiple frequency SAR to observe the earth from space. With all of these "firsts", SIR-C will offer a unique chance for the scientific community to discover new advances in the uses of microwave remote sensing for furthering knowledge of our planet.

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BIOGRAPHY

Stephen D. Wall is a member of the Jet Propulsion Laboratory's Radar Remote Sensing Team. He led the Mission Operations Teams for the SIR-A and SIR-B, and has done work in the identification of surface units from multiple-angle SAR imagery. Mr. Wall has previously done spectrometric studies of condensates found on the surface of Mars and developmental work on visual and IR sensors for planetary landers. he is currently associated with the Venus Radar Mapper mission which will orbit and map Venus using a SAR in 1988.