1995127381

N95- 33802

NEW OBSERVATIONS OF BOLIVIAN WIND STREAKS BY JPL AIRBORNE SAR; PRELIMINARY RESULTS

Dan G. Blumberg and Ronald Greeley

Department of Geology, Box 871404,
Arizona State University, Tempe Arizona 85287-1404.
e-mail Blumberg@ASUIP2.SPAN.NASA.GOV

1. INTRODUCTION

In 1993 NASA's Jet Propulsion Laboratory Airborne Synthetic Aperture Radar system (AIRSAR) was deployed to South America to collect multi-parameter radar data over pre-selected targets. Among the sites targeted was a series of wind streaks located in the Altiplano of Bolivia. The objective of this investigation is to study the effect of wavelength, polarization, and incidence angle on the visibility of wind streaks in radar data. Because this is a preliminary evaluation of the recently acquired data we will focus on one scene and, thus, only on the effects of wavelength and polarization. Wind streaks provide information on the near-surface prevailing winds and on the abundance of wind-erodible material, such as sand. The potential for a free-flyer radar system that could provide global radar images in multiple wavelengths, polarizations, and incidence angles requires definition of system parameters for mission planning. Furthermore, thousands of wind streaks were mapped from Magellan radar images of Venus (Greeley et al. 1992); their interpretation requires an understanding of the interaction of radar with wind streaks and the surrounding terrain. Our experiment was conducted on wind streaks in the Altiplano of Bolivia to address these issues.

The Altiplano is a continental basin with an average elevation of ~ 4000 m lying between the Eastern and Western Cordillera of the Andes. The geomorphology of the Altiplano (Ahlfeld, 1972) exhibits sand dunes, sand sheets, alluvium, and sediments deposited in glacial lakes. Aerial photographs of the Altiplano show that the predominant aeolian features are sand sheets and dunes. These features align with the prevailing westerly wind direction. For the deployment of AIRSAR, we targeted a series of wind streaks downwind of the volcano Cerro Quisharo. These streaks were first identified as radar visible by Greeley et al. (1989) following the first Shuttle Imaging Radar experiment (SIR-A; Elachi et al., 1982). These streaks emanate from small hills eastward, where they merge with the alluvium of the Rio Cosapa. The aeolian sediments consist primarily of quartz and pumice originating in alluvium and the volcanoes located west of the site.

2. DATA

The data used for this report were collected on 02 June 1993, as quad-polarized SAR data in C, L, and P wavelengths (λ=5.6, λ=24, and λ=68 cm respectively) stored as a compressed Stokes matrix (CM-4130). The resolution of the data is 8.27 m in azimuth and 6.66 m in range; the flight azimuth was 228 degrees. These data were calibrated by JPL and decompressed at Arizona State University on a VAX/VMS system to produce nine multilook ground-detected images (C, L, and P bands and HH, VV, and HV polarizations), with the scene centered at 18°27'S, 68°30.5'W. Figure 1 shows the L-band V V data used in this study.

3. ANALYSIS

3.1 Wavelength

Previous studies of radar visible wind streaks were conducted with SIR-A (Greeley et al. 1989) and Magellan data (Greeley et al. 1992). These were single wavelength and polarization systems. McCauley et al. (1982) demonstrated that radar energy can penetrate loose, dry, unvegetated sand mantles to a depth of a few meters below the surface. The depth of penetration increases as a function of wavelength, as reviewed by Elachi (1987). Under these circumstances, it was reasonable to anticipate that the longer wavelengths of AIRSAR would reveal less of the wind streaks than the shorter bands due to reflection from the substrate. However, in the Bolivian scene the longer wavelengths tend to reveal more of the wind streak than the shorter wavelength. We propose three mechanisms that could explain this apparent anomaly: 1) if there is a relatively thin sand mantle over the area, there would be more contrast between the streak (with the thicker mantle) and the surrounding terrain in the longer wavelengths (assuming that even in the long wavelengths, the energy does not penetrate down to to the substrate). 2) vegetation; the longer wavelengths could penetrate the surface and interact with root structures more than the shorter wavelengths, as shown by Greeley and Blumberg (submitted); thus, if there is more vegetation in the surrounding terrain than on the streaks, there would be a higher contrast between the streaks and the surroundings; 3) if there is very low vegetation on the east part of the streaks (the area less visible in C-band), volume scattering will occur only at $\lambda = 5.6$ cm within the canopy layer.

Most of the plains are characterized by an abundance of clusters of paja brava (small bushes) and thola (clump grass) spaced less than 2 m apart, coppice dunes (small sand mounds located around plants) spaced 5 to 20 m apart, and active windblown sand. Thus, it is reasonable that C-band would interact more with the vegetation than the L- and P-bands. Using a radar classification algorithm for detecting biomass (Freeman et al., 1993) we find that 62% of the surface is classified as low vegetation, with the remainder being free of vegetation. This supports the possibility that there would be more interaction with C-band than L- and P-bands. Moreover, coppice dunes do not tend to be very deep and C-band energy would probably reflect away from the radar antenna (off the sand) whereas L- and P-bands would penetrate and scatter off the substrate. Depending on the thickness of the material in the wind streaks, which is unknown at this time, L- and P- bands would probably not penetrate through the streaks to the substrate. These factors would contribute to less contrast in the shorter wavelength than in the longer wavelengths.

3.2 Polarization

The effect of polarization in wind streak visibility was tested using both raw-calibrated data and enhanced images. Preliminary analysis shows that like-polarized channels tend to show more of the wind streaks than the cross-polarized data for the shorter wavelengths. Among these, HH enhances the visibility of the streaks slightly in comparison to VV. This may be due to the presence of aeolian ripples on the streak that interact more with the horizontal wave than with the vertical wave (the height of the ripples is significantly less than the wavelength). However, in P-band the streaks are visible independent of polarization, suggesting that ripples are smooth to both the vertical and horizontal energy at this wavelength.

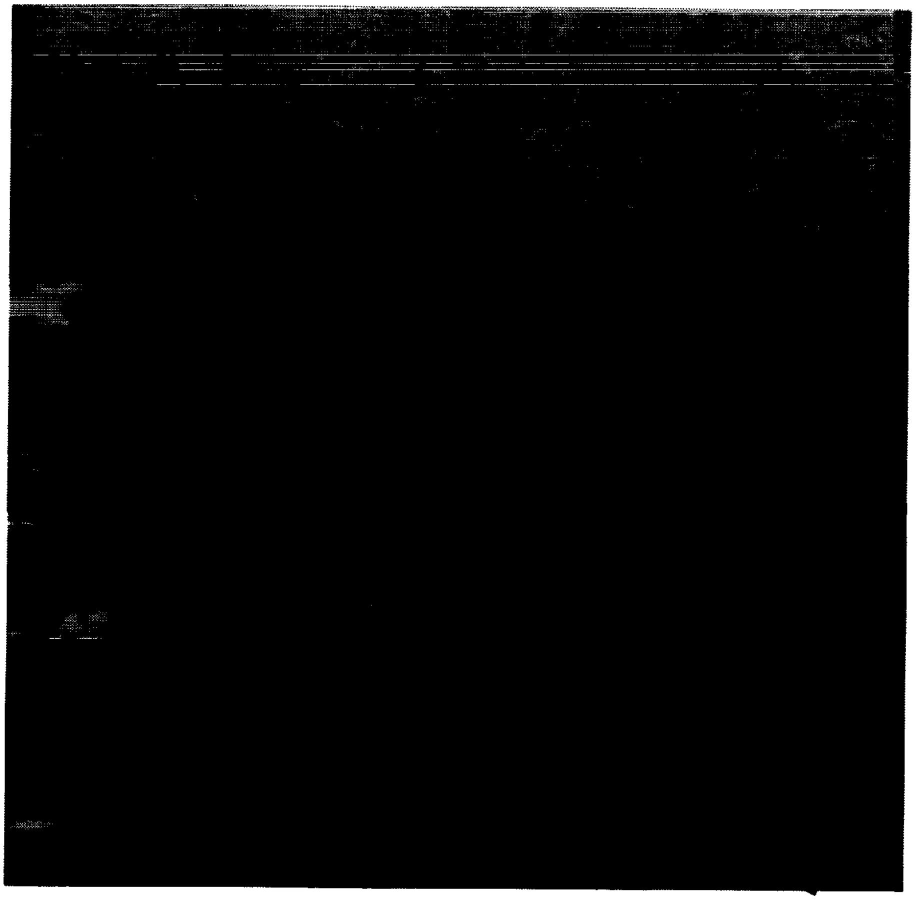

Figure 1. AIRSAR L-band vertical transmit and receive (V V) image of a series of wind streaks in the Bolivian Altiplano located downwind of the volcano Cerro Quisharo. Solid black arrows point to radar-visible wind streaks. Dunes (noted by open arrows) are visible in the AIRSAR images. The streaks provide information about near-surface winds and abundance of wind-erodible materials such as sand. The radar illumination is from top to bottom and flight azimuth is 228°. Image is centered at 18°27'S, 68°30.5'W. ASU - IPF Frame 963; CM4130.

3.3 Dunes

Greeley et al. (1989) showed that a single barchan dune could be detected within the streak in the SIR-A image. However, they noted that without prior knowledge of the existence of the dune, it probably would not have been found. The dune they observed was some 200 m across and 200 m long. The added resolution of AIRSAR over the 40 m resolution of SIR-A data, make this and additional dunes clearly visible as seen in Figure 1 (dunes noted by open arrows).

4. CONCLUSIONS AND FUTURE WORK

1. Preliminary results show that the visibility of wind streaks increases with the wavelength. However, this may not be the case in the absence of vegetation and this result needs to be tested.

2. We find that like-polarized channels are preferential for viewing wind streaks. We plan to test this result and determine if it results from local features such as ripples and vegetation. This will be done by selecting parts of streaks that are free of vegetation and by the use of other look angles to reduce the ripple affect.

3. Future work will include an analysis on the effect of incidence angle on the visibility of the streaks.

5. REFERENCES

Ahlfeld F., 1972, "*Geologia de Bolivia*" La Paz, Los Amigos del Libro, pp. 190.

Elachi C. et al., 1982, "Shuttle Imaging Radar.", *Science*, 218, pp. 966-1003.

Elachi C., 1987, "*Spaceborne Radar Remote Sensing; Applications and Techniques.*", IEEE Press, pp. 255.

Freeman A., B. Chapman, and M. Alves, 1993, "*MAPVEG Software Users' Guide.*", JPL Document D-11254, pp. 46.

Greeley and Blumberg. "Preliminary Analysis of Shuttle Radar Laboratory (SRL-1)Data to Study Aeolian Features and Processes.", *IEEE Trans. Geos. Remot. Sens.*, Submitted.

Greeley R., P. Christensen, and R. Carrasco, 1989, "Shuttle Radar Images of Wind Streaks in the Altiplano, Bolivia." *Geology*, 17, pp. 665-668.

Greeley, R., R.E. Arvidson, C. Elachi, M.A. Geringer, J.J. Plaut, R.S. Saunders, G. Schubert, E.R. Stofan, E.J.P. Thouvenot, S.D. Wall, and C.M. Weitz, 1992, "Aeolian Features on Venus: Preliminary Magellan Results." *JGR* 97 E8, pp. 13319-13345.