MARS: SEASONALLY VARIABLE RADAR REFLECTIVITY

L. E. Roth, R. S. Saunders, and T. W. Thompson
Jet Propulsion Laboratory, Pasadena, CA 91109

Since reflectivity is a quantity characteristic of a given target at a particular viewing geometry, the same (temporally unchanging) target examined by radar at different occasions should have the same reflectivity. Zisk and Mouginis-Mark (1980) noted that the average reflectivities in the Goldstone Mars Data (Downs et al., 1975) increased as the planet's S hemisphere passed from the late spring into early summer. We have examined the same data set and confirmed the presence in the data, of the phenomenon of the apparent seasonal variability of radar reflectivity (Roth et al., 1984; 1985). Objections were raised against our reports. These objections fell into three categories:

(1) Reflectivity variations may be present in the Goldstone Mars data. Their presence must be the result of an instrumental/calibration error.

(2) Reflectivity variations may be present in the Goldstone Mars data. Since there is a two-year interval between the two experiments, the variations must be the result of differences in the data reduction procedures applied first to the 1971 data and then to the 1973 data.

(3) Reflectivity variations are not present in the Goldstone Mars data. The variations were introduced into the analysis through comparing reflectivities obtained during two separate experiments. In other words, what appears to be a seasonally variable reflectivity is, in fact, the result of a joint analysis of two incompatible subsets of the combined data set.

Our work in FY'86 was mostly aimed at answering the listed objections. We have completed the effort aimed at validating the Goldstone (1971, 1973) Mars data set. We have reviewed the procedures followed during both the 1971 and 1973 Goldstone Mars experiments and examined the available records. We present here a summary of the principal findings pertaining to Objections (1) and (3).

System calibrations were a regular feature of each observing run. Included in the calibrations were: (1) Measurements of the system temperature. (2) Measurements of the antenna gain variations vs. elevations. (3) Measurements of the antenna gain variations due to structural modifications. (4) Measurements of the transmitter power. Early in each opposition transmitter calibrations were performed at the start and at the end of each run. Later, when no drifts were observed, the transmitter calibrations were discontinued. (5) Measurements of the additive noise of the microwave links (when links used). (6) Monitoring of the antenna pointing accuracy. Tracks of calibration radio sources were regularly scheduled and the results were folded into the operational procedures. We estimate the resulting total reflectivity calibration error to be less than 5% of the respective absolute values.

After having applied all the known corrections to the radar system sensitivity, global reflectivity averages were computed for each opposition. The results are:

$$\langle R \rangle (1971) = 0.0564$$
$$\langle R \rangle (1973) = 0.0625$$
$$\langle R \rangle (\text{All data}) = 0.0594$$

It is seen that the average reflectivity in the 1973 data (240 deg<Ls<325 deg) is higher than the average reflectivity in the 1971 data (200 deg<Ls<275 deg), in agreement with Zisk and Mouginis-Mark (1980) and Roth et al., (1984; 1985). Note that the ratio

$$\frac{\langle R \rangle (1973) - \langle R \rangle (1971)}{\langle R \rangle (\text{All data})} \times 100$$

is equal to 11%, a value twice that of the estimated calibration error. This discrepancy could be interpreted in the following manner: (1) The difference in the reflectivity averages in the 1971 and 1973 data is being caused by some unknown and unaccounted for instrumental error and calibration drift. This error is of the approximately same magnitude as all the known uncertainties. (2) The difference in the reflectivity averages in the 1971 and 1973 data is being caused by differences in coverage. The overlap is sparse and thus the difference in the mean 1971 and 1973 reflectivities could be caused by differences in coverage. (3) The difference in the reflectivity averages in the 1971 and 1973 data is being caused by changes in the target characteristics. Those changes may be caused by two agents: dust precipitation/removal or thawing of subsurface ice. Modeling exercises indicate that a shifting dust cover is not likely to be a major contributor to the observed reflectivity variations (Zisk and Mouginis-Mark, 1981; Roth et al., 1986a). The liquid-water hypothesis has not been supported by a credible model of the thermal regime in the upper 1 m of the Martian surface. Thus all three interpretations are about equally likely or unlikely, depending on the point of view. The liquid-water hypothesis could, in principle at least, account for the pattern of seasonal variability, whereas the other interpretations could not.

To address Objection (3), we investigated the statistical relationship between reflectivities and the areocentric longitude, Ls, separately for the 1971 and 1973 data (Roth et al., 1986b). The computations were carried out separately for the 1971 data, the 1973 data for the cases when the 1973 scan was taken at a higher solar longitude as the 1971 scan, and for all data combined. Conclusions: (1) Correlation coefficients between the mean reflectivity ratios and the lengths of the temporal separation of overlapping scans are positive for the 1971 Goldstone Mars data. This means that the average reflectivities in the 1971 data tend to increase as the S hemisphere passes from the vernal equinox to the summer soltice. (2) Correlation coefficients between the mean reflectivity ratios and the lengths of the temporal separation of overlapping scans is largely negative for the 1973 Goldstone data. The mean reflectivities in the 1973 data appear to undergo a mild decrease as the S hemisphere enters late summer. At

Crit=0.3 (for the definition of the quantity Crit see Roth et al., 1986b) there is an exception to this general trend. This exception is significant in that it shows that the data set is statistically inhomogeneous. Random removal of a few elements from the sample affects the sample statistics. Thus any conclusions based on purely statistical arguments have to be received with caution. Statistical inhomogeneity of the data deserves further investigation. (3) The apparent seasonal pattern in the behavior of the mean reflectivities is not the result of the joint analysis of the 1971 and 1973 data. This is our most important finding. The seasonal reflectivity variations may or may not be real. However, they are certainly a characteristic property of each individual subset, rather than of the combined (1971, 1973) Goldstone set. (4) Reflectivity variations in the 1971 data are consistent with the hypothetical presence of subsurface moisture passing through a seasonal freeze-thaw cycle. If the correlation coefficient for Crit=0.3 is ignored, reflectivity variations in the 1973 data are also consistent with the liquid water hypothesis, provided we accept a naive, intuitive notion that subsurface moisture in the subequatorial areas freezes after the S hemisphere passes the summer stoltice. (5) Consistency is not equivalent to a proof. Reflectivity variations could only be considered a proof of the existence of the subsurface moisture in the equatorial areas of Mars if the characteristic pattern of seasonal behavior were to be confirmed by further, preferably multifrequency, radar observations.

Downs, G. S., R. M. Goldstein, R. R. Green, G. A. Morris, and P. E. Reichley (1973). Martian topography and surface properties as seen by radar: The 1971 opposition. Icarus 18, 18-21.

Roth, L. E., R. Saunders, and G. Schubert (1984). Radar and the detection of liquid water on Mars (abstract). In Abstracts for Water on Mars Workshop, 63-65. Lunar and Planetary Institute, Houston.

Roth, L. E., R. S. Saunders, and G. Schubert (1985). Mars: Seasonally variable radar reflectivity. Lunar Planet. Sci. XVI, 712-713.

Roth, L. E., R. S. Saunders, and T. W. Thompson (1986a). Radar reflectivity of a variable dust cover. In Abstracts for Dust on Mars Workshop, 59-61. Lunar and Planetary Institute, Houston.

Roth, L. E., R. S. Saunders, G. S. Downs, and G. Schubert (1986b). Mars: Seasonally variable radar reflectivity II. Lunar Planet. Sci. XVII, 730-731.

Zisk, S. H. and P. J. Mouginis-Mark (1980). Anomalous region on Mars: Implications for near-surface water. Nature 288, 735-738.

Zisk, S. H. and P. J. Mouginis-Mark (1981). Alternate models for the Solis Lucas radar anomaly on Mars (abstract). In 3rd Int'l Colloq. Mars, 294-296. Lunar and Planetary Institute, Houston.