NASA CR- 141454

(NASA-CR-141454) PRELIMINARY ANALYSIS OF SKYLAB RADSCAT RESULTS OVER THE OCEAN (Kansas Univ. Center for Research, Inc.) 9 p HC $3.25 CSCL 22A
N75-14793
Unclas
G3/12 07567

Title of Investigation: A Joint Meteorological, Oceanographic and Sensor Evaluation Program for Experiment S193 on Skylab

Title of Report: Preliminary Analysis of Skylab RADSCAT Results Over the Ocean

RSL Advance Report of Significant Results

November, 1974

NASA Contract NAS 9-13642

Prepared for:

Principal Investigations Management Office
Technical Monitor: Z. H. Byrns
NASA Lyndon B. Johnson Space Center
Houston, Texas 77058

Type of Report: Advance Report of Significant Results

THE UNIVERSITY OF KANSAS CENTER FOR RESEARCH, INC.
2385 Irving Hill Rd.—Campus West Lawrence, Kansas 66044

THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER
Raymond Nichols Hall
2291 Irving Hill Drive—Campus West Lawrence, Kansas 66045
Telephone: 913 864 4836

PRELIMINARY ANALYSIS OF SKYLAB RADSCAT RESULTS OVER THE OCEAN

RSL Technical Report 254-2
CUNY Institutional Report 43

R. K. Moore, J. P. Claassen, and J. D. Young
The University of Kansas Center for Research, Inc.
Remote Sensing Laboratory
Lawrence, Kansas 66045

and

W. J. Pierson, Jr., and V. J. Cardone
City University of New York
Institute of Oceanography
New York, New York 11201

November, 1974

Supported by:

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Lyndon B. Johnson Space Center
Houston, Texas 77058

CONTRACT NAS 9-13642

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle
Preliminary Analysis of Skylab RADSCAT Results Over the Ocean

5. Report Date
November, 1974

6. Performing Organization Code

7. Author(s) R. K. Moore, J. P. Claassen, J. D. Young, W. J. Pierson, Jr., and V. J. Cardone

8. Performing Organization Report No.
RSL TR 254-2, CUNY #43

9. Performing Organization Name and Address
The University of Kansas
Center for Research, Inc.
Remote Sensing Laboratory
Lawrence, Ks. 66045

City University of New York
Institute of Oceanography
New York, NY 11201

10. Work Unit No.

11. Contract or Grant No.

12. Sponsoring Agency Name and Address

13. Type of Report and Period Covered
Advance Report of Significant Results

14. Sponsoring Agency Code
NAS 9-13642

15. Supplementary Notes
NASA Lyndon B. Johnson Space Center
Houston, Texas 77058

16. Abstract

Preliminary observations at 13.9 GHz of the radar backscatter and microwave emission from the sea have been analyzed using data obtained by the radiometer scatterometer on Skylab. Results indicate approximately a square-law relationship between differential scattering coefficient and windspeed at angles of 40° to 50°, after correction for directional effect, over a range from about 4 up to about 25 meters/sec. The brightness temperature response was also observed, and considerable success was achieved in correcting it for atmospheric attenuation and emission.

Measurements reported here were made in June, 1973, over Hurricane Ava off the west coast of Mexico and over relatively calm conditions in the Gulf of Mexico and Caribbean Sea. Many other observations were made with the Skylab instrument, but analysis awaits corrections to the data.

17. Key Words (Selected by Author(s))
Skylab
Microwave radiometer
Radar scatterometer
Wind measurement
Ocean waves
Radar Backscatter

18. Distribution Statement
Unclassified - Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
		7	

*For sale by the Clearinghouse for Federal Scientific and Technical Information, Springfield, Virginia 22151.

PRELIMINARY ANALYSIS OF SKYLAB RADSCAT RESULTS OVER THE OCEAN

R. K. Moore, J. P. Claassen, and J. D. Young

The University of Kansas Center for Research, Inc.
Remote Sensing Laboratory
Lawrence, Kansas 66044 U.S.A.

W. J. Pierson, Jr., and V. J. Cardone

City University of New York
University Institute of Oceanography
New York, New York 11201 U.S.A.

ABSTRACT

Preliminary observations at 13.9 GHz of the radar backscatter and microwave emission from the sea have been analyzed using data obtained by the radiometer-scatterometer on Skylab. Results indicate approximately a square-law relationship between differential scattering coefficient and windspeed at angles of 40° to 50°, after correction for directional effects, over a range from about 4 up to about 25 meters/sec. The brightness temperature response was also observed, and considerable success was achieved in correcting it for atmospheric attenuation and emission.

Measurements reported here were made in June, 1973, over Hurricane Ava off the west coast of Mexico and over relatively calm conditions in the Gulf of Mexico and Caribbean Sea. Many other observations were made with the Skylab instrument, but analysis awaits corrections to the data.

INTRODUCTION

Skylab was a manned spacecraft launched in May of 1973 and occupied by three different crews, one in May and June, one in August and September, and one from November into February of 1974. The spacecraft contained a set of earth resources experiments, including a microwave radiometer-scatterometer (Experiment S-193). Characteristics of the RADSCAT instrument have been described in various NASA publications and in some journals, so only the briefest summary will be included.[1]

The Skylab RADSCAT instrument operated at a frequency of 13.9 GHz (wave length 2.16 cm). It used a parabolic antenna with approximately a two degree beam at the half-power point. This beamwidth was effectively 1.54 degrees for the scatterometer where the two-way half-power point is used. The antenna could be mechanically scanned in four different modes:

1. In-Track Non-Contiguous (Overlapping measurements at angles of 0, 15, 29, 40 and 48 degrees between the antenna pointing direction and the vertical at the spacecraft, with 100 kilometers between centers of each set of measurements)
2. Cross-Track Non-Contiguous (Measurements at the same angles of incidence, but perpendicular to the track so they are spaced approximately 100 kilometers rather than overlapping)
3. In-Track Contiguous (Points at the same angles as for 1 and 2 for scatterometer and intermediate angles for radiometer, with the points spaced approximately 25 kilometers)
4. Cross-Track Contiguous (12 points over a 22 degree angular range about the center point; center point may be vertical or tilted ahead or to the side by 15, 30 or 40 degrees)

The radiometer had a precision (1σ) which varied with mode, but was in the neighborhood of 1°K. The scatterometer had a precision which varied with mode, but was usually between 5 and 7 per cent (about 0.25 dB). In the non-contiguous modes, the radiometer received both horizontal and vertical polarization, and the scatterometer transmitted horizontal, receiving both horizontal and vertical. In the contiguous modes, when both radiometer and scatterometer were used, the transmission for the scatterometer was with the same polarization as the selected radiometer and scatterometer receiver polarization. It was also possible to operate in a radiometer-only or a scatterometer-only mode, in which case both vertical and horizontal polarizations were used.

In this paper, preliminary data on backscattering and emission from the ocean are presented. All of the data shown are for the month of June, 1973. Preliminary indications are that good observations were obtained during August-September and December-January. However, the final revision of the data is incomplete for these months, so the results could not be presented.

During the winter mission, an antenna problem existed that prevented scanning in the along-track direction and resulted in degraded performance--a wider beam and higher sidelobes. Radiometer data for this period probably are not usable because of the high sidelobe level, but scatterometer data should be interesting.

HURRICANE AVA

We were fortunate that early in June the Skylab ground track passed near a Pacific Ocean hurricane off the coast of Mexico. This happened on 7 June, 1973.

Coverage for Hurricane Ava was not in the original plans for June 7 and the spacecraft was not in a mode for which its vertical axis was oriented towards the earth. However, calculations indicated that the orientation would be satisfactory in its solar inertial mode for cross-track coverage for most of the expected location of Hurricane Ava. Consequently, special arrangements were made to operate the radiometer-scatterometer during that time. Figure 1 shows the area covered, with a preliminary wind field estimate based upon a hurricane model developed at New York University[2] and upon pressure measurements at the eye of the hurricane and outside the area of the hurricane. The spacecraft approached from the northwest and traveled toward the southeast along a track indicated by the letter E in Figure 1. Letter A indicates the maximum incident-angle track (about 50 degrees), letter B indicates the 42 degree incident-angle track, etc. The path of the spacecraft was too far to the east to permit coverage into the very-high-wind-speed center of the hurricane. However, winds were observed up to about 50 knots (25 m/s) during sweeps 8, 9 and 10. Because of the solar inertial orientation of the spacecraft, operation of the RADSCAT instrument was not possible after the pass labeled 12, and in fact the data points for scan 12 are probably invalid.

Figure 2 shows a comparison of the 52-degree scatterometer response at vertical and horizontal polarizations with the wind speed calculated by the hurricane model. The tenth scan occurred at a point where the elevated radiometer temperature, as well as the elevated scattering coefficient, indicated that the rain was too heavy; so that the radiometer lost contact with the surface because of attenuation and most of the scatterometer signal was backscattered from the raindrops. The curves in Figure 1 have also been corrected for attenuation as determined by the radiometric brightness increase and for wind direction using a directional response curve obtained by Jones of NASA Langley Research Center.[3]

Figure 3 illustrates the magnitude of the corrections for the vertically polarized response. Note the increase in antenna temperature for the radiometer is much too great to be caused by variations in wind speed and consequently must be due to attenuation in the cloud. This was used to determine an attenuation correction of up to about 0.5 dB for the scatterometer as shown at the bottom. The aspect angle correction converts all responses to equivalent of wind responses, using Jones's model. Note that this correction changes rapidly as the spacecraft goes by the eye of the hurricane so that observation direction changes from downwind to crosswind.

The oscillation, with a minimum at cell 2 and a maximum at cell 6 followed by another minimum at cell 7, is probably a better representation of the true wind speed than that presented by the model wind-speed calculation shown, since the model does not take into account wind variations and rain bands which are normally found radiating from the center of a hurricane. Presumably this oscillation is in fact caused by passage of the spacecraft by a rain band.

The horizontally polarized antenna temperature also was plotted versus wind speed after a correction was made for apparent brightness temperature increases as shown in Figure 5. The correction was quite large where the rain and heavy attenuation occurred, and the deviation from the theoretical is larger at that point. Whether the lack of the oscillation attributed to a rain band in the scatterometer data has to do with some compensating effect or whether it represents more of a wind direction than wind speed effect on the scatterometer cannot be determined at this time.

DATA FROM THE CARIBBEAN AND GULF OF MEXICO

On June 5, 1973, the spacecraft flew across the Gulf of Mexico, the Yucatan Peninsula, and the coast of Honduras and on into the Caribbean Sea. Figure 6 shows the vertically polarized scattering coefficient at 30° compared with wind estimates for that region. The scattering coefficient has been corrected for aspect angle. Sizable variations in the shape of the curve between the scatterometer data and the wind speed data are probably due to the coarseness with which the calculations of wind speed could be made. For instance, the calculated wind speed response shows no effect of the coast of Honduras, but we know that the coast does have an effect.

Figure 7 shows the horizontally polarized responses for the same pass. They appear to compare somewhat better with the wind speed estimate than the vertically polarized responses, but not significantly so. In all cases, the responses are approximately as one would expect.

Figures 8 and 9 show similar comparisons for the vertically and horizontally polarized 50 degree responses.

All of the observations from passes across the Caribbean and Gulf of Mexico during 5 and 11 June were combined to determine the 30-degree vertical polarization wind speed response shown in Figure 10. The simple prediction is based upon small perturbation theory. Most points are relatively close to the simple prediction, except for a pair at wind speeds that may be low enough so that the capillary waves are not properly developed.

Figure 11 shows a similar response at 50 degrees. The slope of the response is greater than at 30 degrees and, with the exception of the very low wind speeds, the scatter of the data points about the theoretical prediction is less.

Figure 12 shows a similar comparison for horizontal polarization at 50 degrees.

We are indebted to Professor A. E. Basharinov of the Institute of Radioengineering and Electronics in Moscow for his suggestion to establish the consistency of the data by comparing estimated wind speeds based on 30-degree incidence angle and based on 50-degree incidence angle. The result is shown in Figure 13. The consistency is most encouraging, leading one to suspect that much of the scatter in the points shown on Figures 10, 11 and 12 would disappear if local wind speed measurements were used rather than wind speeds based upon a hindcasting model.

Figure 14 presents the data in a different way, comparing the wind speed estimated by meteorological methods and wind speed estimated using the scattering coefficient at both 30 and 50 degrees. The lines joining pairs of points on the graph connect observations made for the same spot on the ocean at two different incident angles.

OVER-LAND EXAMPLE

Figure 15 shows an example of the responses of the radiometer and scatterometer for travel across the surface of the land. These are merely presented as an illustration of the type of response observed over land without analysis. Analysis of these data will be the subject of separate papers.

CONCLUSION

The preliminary Skylab data from June of 1973 indicate good correspondence between radar and radiometric signals received from the ocean and wind speed. Apparently, much of the scatter of the data points is caused by coarseness of the available meteorological data rather than by deviations in the response of the scatterometer to the local wind speed. Corrections for aspect angle were made using a measurement by Jones at 40-degree incidence angle and 25-knot wind speed; presumably, improvements in these corrections will be possible when additional measurements of this kind are available. They should further reduce the scatter in the data.

This preliminary report of the Skylab RADSCAT data is most encouraging, but a great deal of additional data was collected and possible variations in response in different latitudes must await reduction and analysis of these other data.

REFERENCES

1. S-193 Microwave Radiometer/Scatterometer Altimeter Flight Hardware Configuration Specification, Rev. C, General Electric Company, Spec. No: SVS 7846, April 27, 1972.

2. Chow, Shu-Shien, "A Study of the Wind Field in the Planetary Boundary Layer of a Moving Cyclone," New York University Department of Meteorology and Oceanography, M.S. Thesis, 1971.

3. Jones, W. Linwood, Lawrence R. Shultz, and Norman D. Akey, "AAFE Radscat Observations of Wind Driven Seas," 1972 Fall Meeting of the URSI/IEEE Antennas and Propagation Group, Williamsburg, Virginia, December 12, 1972.

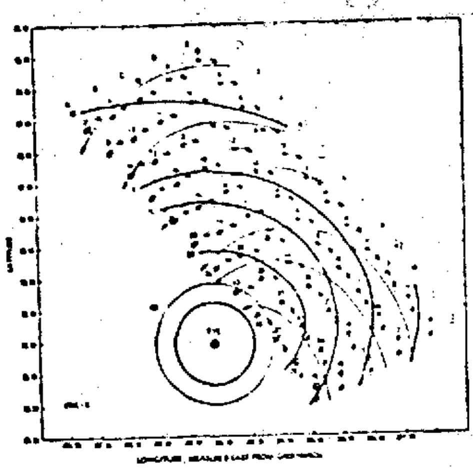


FIGURE 1 PRELIMINARY SKETCH OF WIND FIELD - HURRICANE AVA

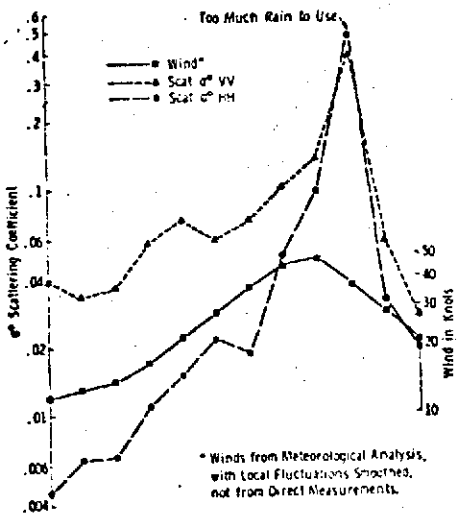
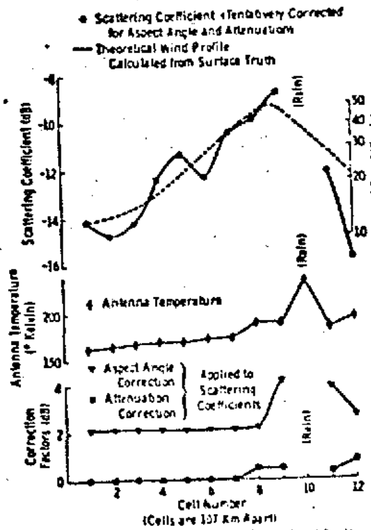


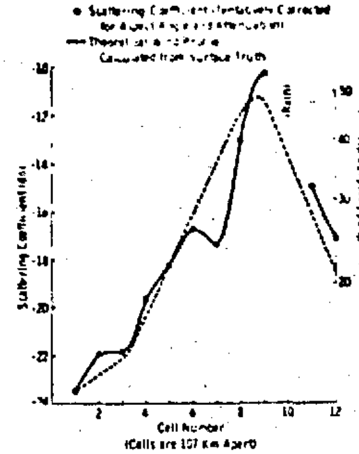
Fig. 2 Response of Scatterometer at 52° Over Hurricane Ava (Aspect Angle and Cloud Loss Corrections)

THE UNIVERSITY OF KANSAS SPACE TECHNOLOGY CENTER



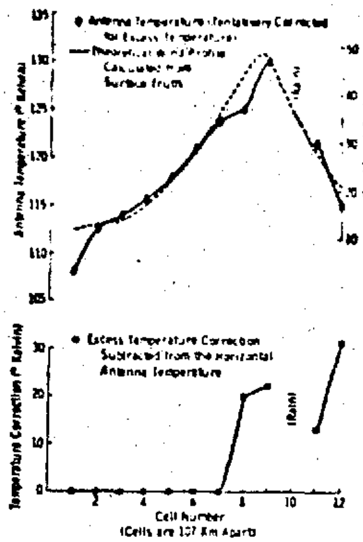
(Cells are 107 Km Apart)
Vertically Polarized Response at 52° Incident Angle for Hurricane Ava

FIGURE 3



Horizontally Polarized Scattering Response at 52° Incident Angle for Hurricane Ava

FIGURE 4



Horizontally Polarized Radiometric Response at 52° Incident Angle for Hurricane Ava

FIGURE 5

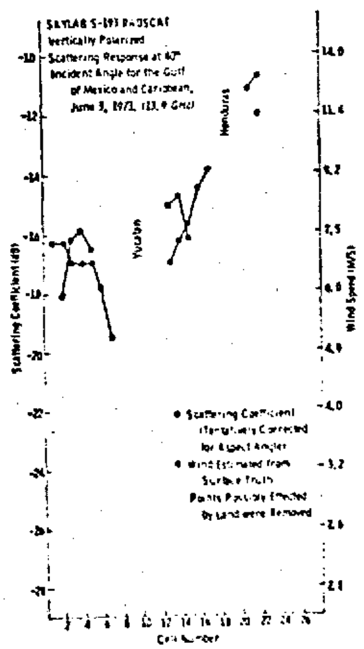


Figure 6

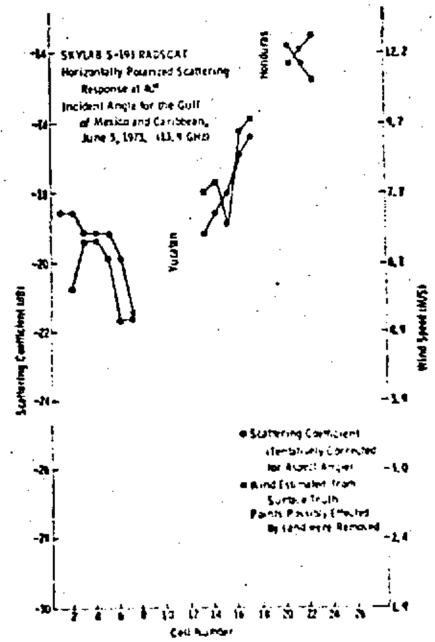


Figure 7

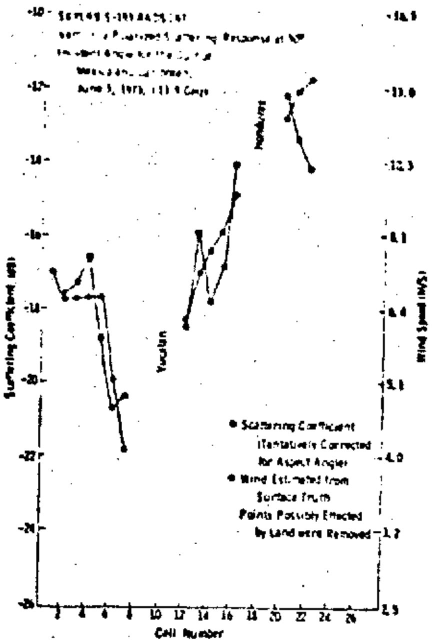


Figure 8

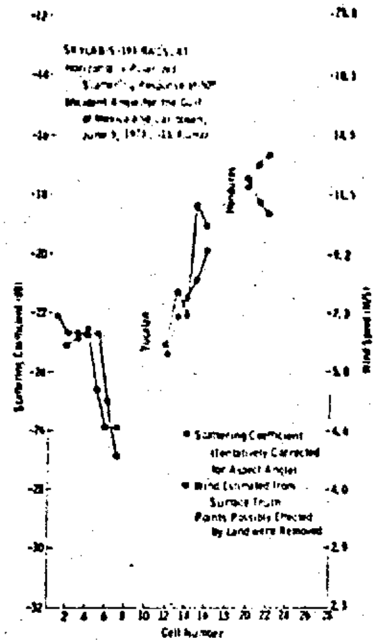
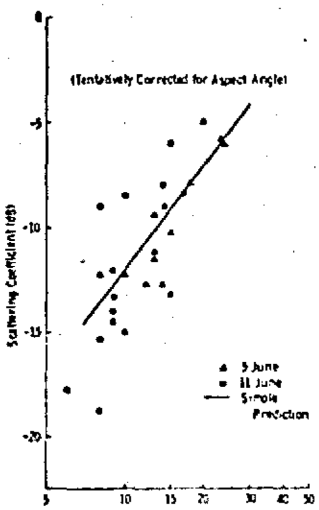
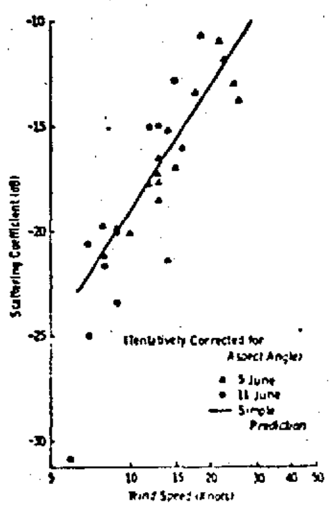


Figure 9



Wind Speed (Knots)
Vertically Polarized Radar Wind Response at 50° Incident Angle

FIGURE 10



Wind Speed (Knots)
Vertically Polarized Radar Wind Response at 50° Incident Angle

FIGURE 11

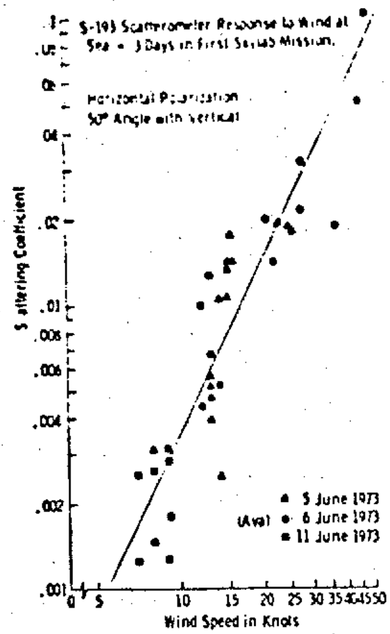


Figure 12

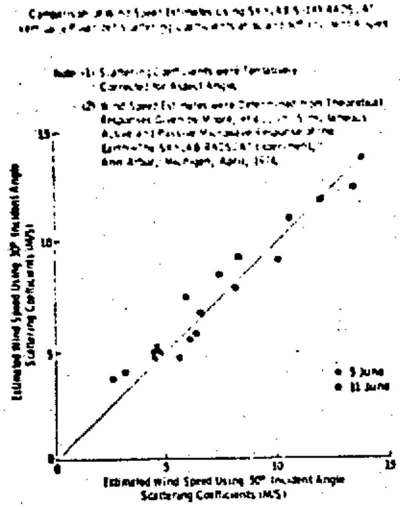


Figure 13

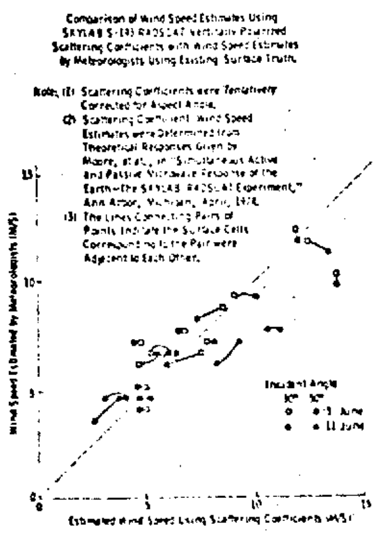


Figure 14

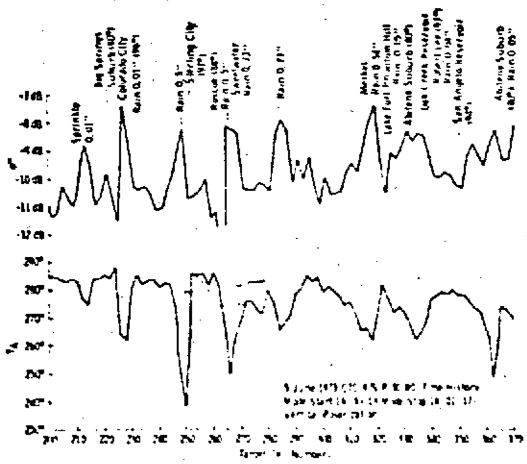


Figure 15. Back-scatter and radiometer temperature time history sample over land.