2.1D RANGE GATE DEPENDENCE OF SPECULAR ECHOES

J. L. Green

Aeronomy Laboratory, NOAA
Boulder, CO 80303

Some controversy has surrounded the interpretation of the enhancement of VHF radar echoes at vertical incidence (also known as partial reflections, specular reflections and Fresnel scattering) since they were reported by the Sunset (GAGE and GREEN, 1978) and the SOUSY (ROTTGER and LIU, 1978) radars. There is little doubt as to the observational fact of this enhancement since it has been observed by experimenters using at least eleven MST or ST radars. In addition to the Sunset and SOUSY radars, this result has been obtained in the lower atmosphere at the Platteville (ECKLUND et al., 1979; WESTWATER et al., 1983), Poker Flat (ECKLUND et al., 1980), Jicamarca (FUKAO et al., 1979), Arecibo (ROTTGER et al., 1981) radars as well as the three radars of the ALPEX experiment (BALSLEY et al., 1983). In the upper atmosphere, specular or partial reflections have been observed by VINCENT and BELROSE, 1978 and HOCKING, 1979. These vertical enhancements have been associated with increases in the static stability of the atmosphere (GREEN and GAGE, 1980), with a temperature gradient in the stratosphere (GAGE and GREEN, 1982a), have been used to monitor the height of the tropopause (GAGE and GREEN, 1982b), and have been associated with the passage of fronts (ROTTGER and LARSEN, 1983). This list is but a small part of the publications on this subject.

Since the publication of Fresnel Scattering Model for the Specular Echoes Observed by VHF Radar (GAGE et al., 1981) there has been concern over the prediction of this model that the radar reflectivity should vary as the square of the range gate length, ΔR. A comparison of specular echoes obtained with 300-m and 1-km range gates by the Sunset radar was used to illustrate this assertion.

In another theoretical analysis, HOCKING and ROTTGER (1983) predicted that on average specular reflectivity should be proportional to ΔR, but that it was possible under the right conditions for this ratio to approach ΔR^2.

A special mini-session was held on this subject at the MAP Workshop held at Estes Park, Colorado, May 1983. At that session, I stated that I would soon report on new investigations of the range gate dependence of specular echoes. Several suggestions as to the treatment and interpretation of the data made at that meeting have been incorporated into this report (D. T. Farley, W. K. Hocking, R. L. Woodman and possibly others, private communication by means of unsigned paper table napkins, 1982).

This report of measurements made at the Sunset radar during March and April, 1982 is confined solely to the observed dependence of the radar reflectivity of vertically enhanced echoes. (For further details of the Sunset radar, see Section 5.3 of this volume.)

The Sunset radar was carefully calibrated and characterized for these measurements. The practice of calibrating the received echoes power by comparison with the temperature of the background cosmic noise was abandoned in favor of daily calibrations with a stable noise source. The effective ΔR and the time response function of each range gate were obtained by direct measurement of the convolution of the transmitted waveform and the range gate filters. The radar reflectivity is presented as the magnitude of the coefficient of reflection, $|\rho|^2$ so that the recorded transmitted power levels could be incorporated.

It was known from previous experiments that the reflectivity of the vertically enhanced echoes varies with time. Since the radar could only observe with one particular range gate at a time, the range gate lengths were cycled. The data presented here are the median values of the total data set for a particular range resolution and antenna direction observed on a particular day. The observations in most cases were made during a four-hour period centered on the 12 UT NWS rawinsonde launch. Four sizes of ΔR were used, 150, 300, 1000, and 2400 m. Since the object here is the determination of the exponent of the ΔR dependence, Figures 1-2 are plotted as altitude vs.

$$\frac{\log (1000\ |\rho|^2)}{\Delta R\ (m)}$$

As suggested at the Estes Park Workshop, the range gate time response was measured. The response of longer range gates were convolved with the $|\rho|^2$ data from shorter range gates to enhance the comparison. This convolution represents an incoherent spatial average (powers summed) while a range gate is a coherent average (voltages summed). In the comparisons shown below, a departure from equality of the responses at different ΔR sizes is an indication of possible coherence.

Figure 1a is a typical comparison of the 1000 m and 2400 m range gate with a vertical antenna beam. The 1000 m data have been convolved with the 2400 m range gate function to enhance the comparison. In Figure 1b the vertical and the slant (15° from vertical) echoes are compared to show the altitudes with vertical enhancement. Except for perhaps 7 km, Figure 1a shows that indeed the 1000 m and 2400 m echo strengths are related by a ΔR dependence. This was typical of all the daily comparisons between these two range gates during this observation period.

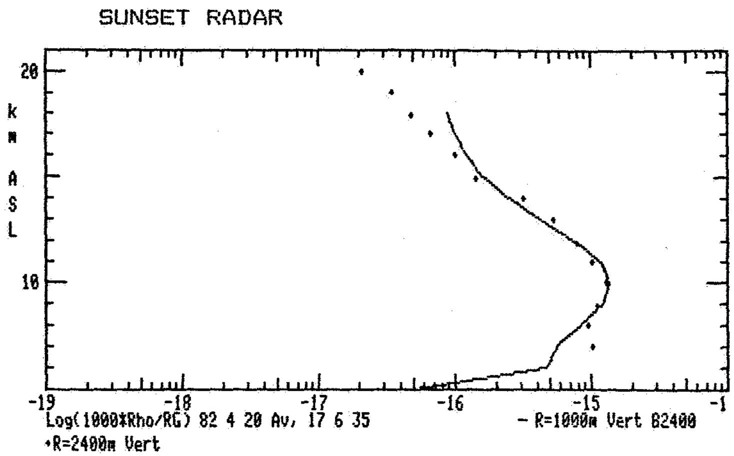
The results of observations using range gates shorter than 1 km were less consistent. The majority of the comparisons between 300 m and 1 km range gates showed a ΔR dependence, but about 25-30% showed a ΔR^2 dependence. In a few percent of the observations the 300 m range gate reflectivity was greater than that of the 1 km range gate. This behavior is illustrated in Figure 2a, a comparison of the 300 m and 1000 m range gates with a vertical antenna beam. Again, the data from the shorter range gate have been convolved with the range gate function of the longer. The reflectivities are equal between 6 and 8.5 km altitude, implying a ΔR dependence. However, between 8.5 and 11 km the reflectivity of the 1 km gate is larger, implying a dependence that approaches a ΔR^2 dependence. Around 12 km the 300 m reflectivities are larger. Between 13 and 15 km a simple ΔR dependence is again approximately the case. Figure 2c, a comparison of the vertical echoes with the slant echoes, shows a region of strong vertical enhancement between 6 and 14 km.

Figure 2b, a comparison of the 300 m range gate and 150 m range gate convolved with the 300 m gate function, shows the two reflectivities to be related by ΔR. However, over the entire data set from this experiment, the 150 m and 300 m gate length comparison was even less predictable than the 300 m and 1 km gate length comparison.

REFERENCES

Balsley, B. B., M. Crochet, W. L. Ecklund, D. A. Carter, A. C. Riddle and R. Garello (1983), Preliminary observations of vertical atmospheric motions between 3 km and 18 km using three closely-spaced ST radars, preprint, Sixth Symposium on Turbulence and Diffusion, AMS, Boston, MA.

a)



b)

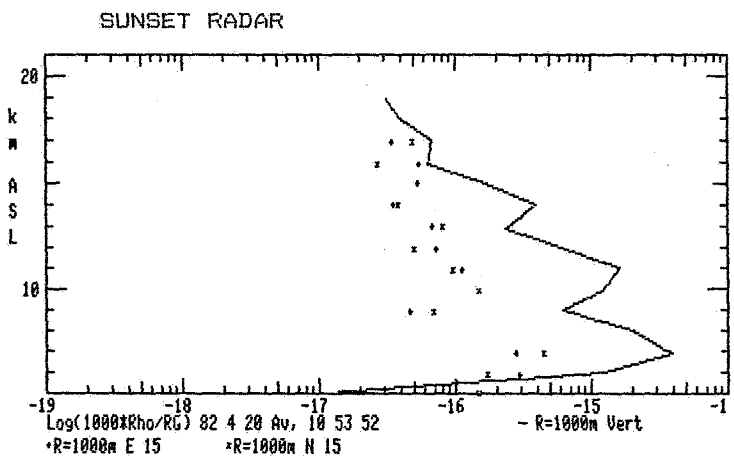


Figure 1. a. Comparison of a 2.4-km range gate and a 1-km range gate convolved with a measured 2.4-km range gate response function.
b. Comparison of reflectivity from vertical and slant antenna beam positions with a 1-km range gate.

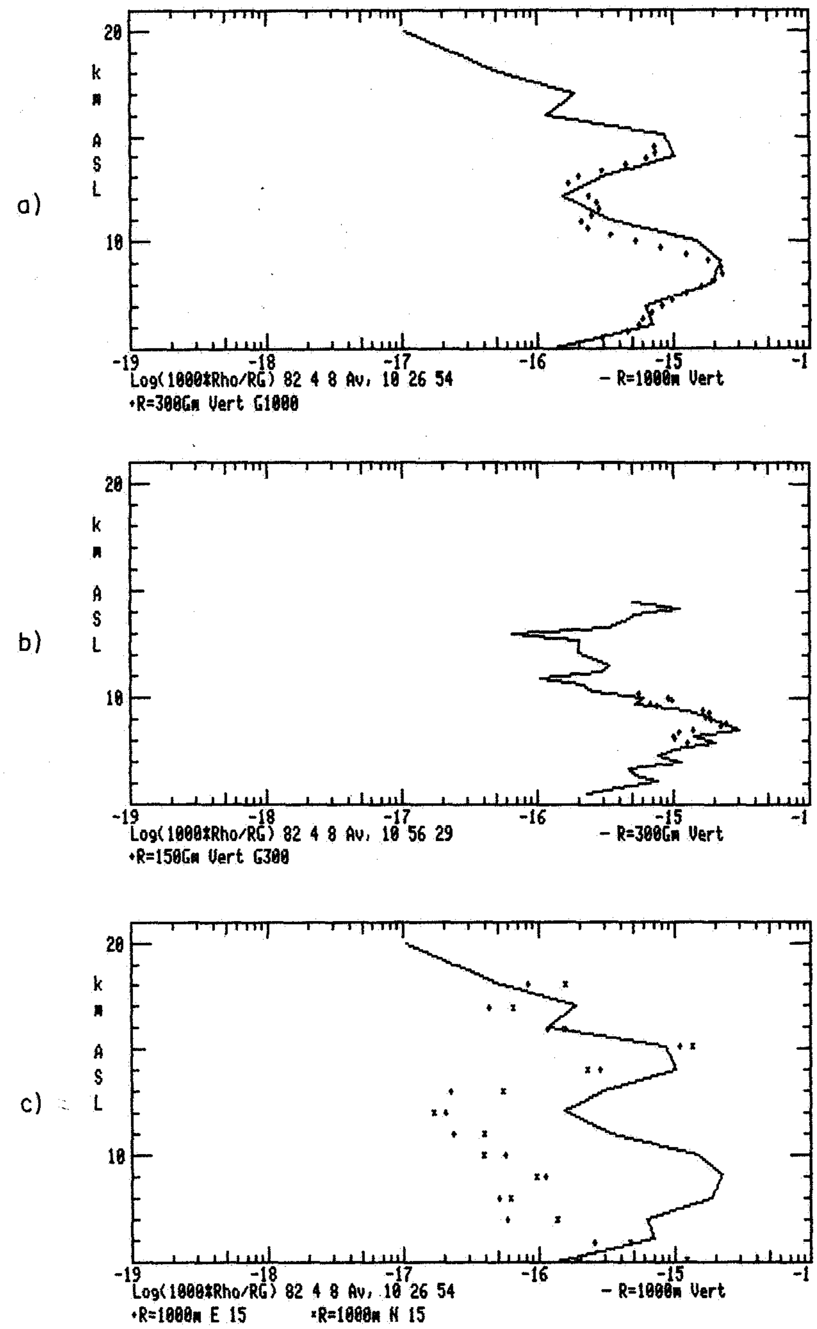


Figure 2. a. Comparison of reflectivity at vertical incidence with a 1-km range gate and a 300-m range gate convolved with a measured 1-km range gate response function. b. Comparison of reflectivity at vertical incidence of a 300-m range gate and a 150-m range gate convolved with a measured 300-m range gate response function. c. Comparison of reflectivity at vertical and slant incidence with a 1-km range gate.

Ecklund, W. L., D. A. Carter, B. B. Balsley (1979), Continuous measurement of upper atmospheric winds and turbulence using a VHF Doppler radar: Preliminary results, J. Atmos. Terr. Phys., 41, 983.

Ecklund, W. L., B. B. Balsley and D. A. Carter (1980), The Poker Flat Radar: Preliminary results between 3-20 km, Preprint, 19th Conf. on Radar Meteorology, AMS, Miami Beach, FL.

Fukao, S., T. Sato, S. Kato, R. M. Harper, R. F. Woodman and W. E. Gordon (1979), Mesospheric winds and waves over Jicamarca on 23-24 May 1974, J. Geophys. Res., 40, 1331.

Gage, K. S. and J. L. Green (1978), Evidence for specular reflection from monostatic VHF radar observations of the stratosphere, Radio Sci., 13, 991-1001.

Gage, K. S. and J. L. Green (1982a), A technique for determining the temperature profile from VHF radar observations, J. Appl. Meteorol., 21, 1146-1149.

Gage, K. S. and J. L. Green (1982b), An objective method for the determination of tropopause height from VHF radar observations, J. Appl. Meteorol., 21, 1159-1163.

Green, J. L. and K. S. Gage (1980), Observations of stable layers in the troposphere and stratosphere using VHF radar, Radio Sci., 15, 395-405.

Hocking, W. K. (1979), Angular and temporal characteristics of partial reflections from the D-region of the ionosphere, J. Geophys. Res., 84, 845-851.

Hocking, W. K. and J. Rottger (1983), Pulse-length dependence of radar signal strengths for Fresnel backscatter, submitted to Radio Sci.

Rottger, J. and C. H. Liu (1978), Partial reflection and scattering of VHF radar signals from the clear atmosphere, Geophys. Res. Lett., 5, 357-360.

Rottger, J., P. Czechowsky and G. Schmidt (1981), First low-power observations of tropospheric, stratospheric and mesospheric winds and turbulence at the Arecibo Observatory, J. Atmos. Terr. Phys., 43, 789-800.

Rottger, J. and M. F. Larsen (1983), Comparison of tropopause height and frontal boundary locations based on radar and radiosonde data, Geophys. Res. Lett., 10, 325-328.

Vincent, R. A. and J. S. Belrose (1978), The angular distribution of radio waves partially reflected from the lower ionosphere, J. Atmos. Terr. Phys., 40, 35-47.

Westwater, E. R., M. T. Decker, A. Zachs and K. S. Gage (1983), Ground-based remote sensing of temperature profiles by a combination of microwave radiometry and radar, J. Climate Appl. Meteorol., 22, 126-133.