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Short Communication

Evidence for Partial Reflection of VHF Radar Signals From the Troposphere

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Recently powerful VHF radar systems were introduced to investigate the dynamics of the lower and middle atmosphere (Woodman and Guillen, 1974; Green et al., 1975; Czechowsky et al., 1976; Rastogi and Bowhill, 1976). The mechanism responsible for the radar echoes was assumed to be scattering from refractive index variations caused by atmospheric turbulence.

The purpose of this letter is to stress that besides of pure turbulence scattering also specular (partial) reflection from stratified atmospheric layers has to be taken into account as a cause of these radar echoes. This considerably influences the evaluation and interpretation of data from VHF radars.

Experimental evidence, supporting the role of partial reflection to explain the radar echoes from the troposphere, was found during the first operation of the SOUSY-VHF-Radar of the Max-Planck-Institut für Aeronomie (Röttger and Czechowsky, 1978; Röttger and Liu, 1978):

1. Assuming pure volume scattering, it is deduced from the observed high radar echo power that the mean refractive index structure constant C_n^2 in several cases must be 1–2 orders of magnitude larger than currently accepted values (e.g. Gossard, 1977), or another mechanism than scattering has to be considered.

2. The correlation times of radar signals often are up to minutes in contrary to expected correlation times of a few seconds when assuming turbulence scattering (Woodman and Guillen, 1974).

3. The radar echo power is proportional to the correlation time which is just opposite to turbulence theory (Tatarskii, 1971).

4. The intensity variations of radar echoes often are quasi-periodic (periods of some ten seconds). This can be explained by interference or focussing due to reflection at thin layers or patches of enhanced humidity or temperature variations which are influenced by atmospheric waves.

5. Peak radar echoes are much weaker (up to 20 dB) and not as structured when swinging the radar beam from the vertical to off-vertical (12.5° zenith angle). This points to reflection at vertical incidence into rough, horizontally stratified layers (Röttger and Liu, 1978).

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The layers are estimated not to exceed a few ten meters in vertical extent. The vertical gradient of refractive index has to be about $10^{-7} m^{-1}$. The horizontal dimension of the stratified layers must be at least several 100 m.

6. The amplitude distributions of strong tropospheric radar echoes cannot be fitted to a Rayleigh distribution which would be expected for turbulence scattering. A better fit is possible when assuming that the signals contain a constant, partially reflected part. Phase distributions are not random (i.e. phases equally distributed between 0 and 2π), but also indicate consistent contributions from partial reflection.

7. Doppler spectra of strong radar echoes do not fit to a Gaussian shape which is anticipated if one assumes turbulence velocities to be normally distributed. High resolution spectra indicate strong spikes superimposed on Gaussian shaped spectra which must be caused by partial reflection.

It appears reasonable that partial reflection also should be considered to explain VHF radar signals (at quasi-vertical beam pointing) from the stratosphere and mesosphere. According to considerations on transhorizon propagation (Beckman and Spizzichino, 1963), the most appropriate mechanism responsible for VHF radar echoes from the troposphere, stratosphere and mesosphere is proposed to be a composition of (1) specular (partial) reflection at rather stable stratified layers, (2) diffusive reflection at rough layers and (3) scattering from turbulence. It seems to be a serious task to clearly separate in observations these three contributions.

Since partial or diffusive reflection often appears to occur, VHF radar systems, due to the longer wavelengths; are more favorable than higher frequency radars to detect these layers in the atmosphere and to make use of the strong radar echoes to investigate the dynamics of the lower and middle atmosphere.

References

Beckman, P., Spizzichino, A.: "The Scattering of Electromagnetic Waves from Rough Surfaces". Pergamon Press, 1963

Czechowsky, P., Klostermeyer, J., Röttger, J., Rüster, R., Schmidt, G., Woodman, R.F.: "The SOUSY-VHF-Radar for tropo-, strato- and mesospheric sounding", Proc. 17th Conf. Radar Meteor., pp. 349–353, Boston: Am. Meteor. Soc. 1976

Gossard, E.E.: "Refractive index variance and its height distribution in different air masses", Radio Science **12**, 89–105, 1977

Green, J.L., Warnock, J.M., Winkler, R.H., VanZandt, T.E.: "A sensitive VHF radar for the study of winds, waves and turbulence in the troposphere, stratosphere and mesosphere", Proc. 16th Conf. Radar Meteor., 313–315, Boston: Am. Meteor. Soc., 1975

Rastogi, P.K., Bowhill, S.A.: "Gravity waves in the equatorial mesosphere", J. Atmospheric Terrest. Phys., **38**, 51–60, 1976

Röttger, J., Czechowsky, P.: "VHF-radar echoes from the troposphere and stratosphere", Kleinheubacher Berichte **21**, 1978 (in press)

Röttger, J., Liu, C.H.: "Partial reflection and scattering of VHF radar signals from the clear atmosphere", submitted to Geophys. Res. Letters, 1978

Tatarskii, V.I.: "The effects of the turbulent atmosphere on wave propagation", Report TT-68-50464, Springfield, Va.: Nat. Techn. Inform. Service, U.S. Dept. of Commerce, 1971

Woodman, R.F., Guillen, A.: "Radar observations of winds and turbulence in the stratosphere and mesosphere", J. Atmospheric Sci., **31**, 493–505, 1974

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