Observations of Clear-Air Dumbbell-Shaped Echo Patterns with the CSU-CHILL Polarimetric Radar

Timothy J. Lang[1], Steven A. Rutledge[1], and Jeff Stith[2]

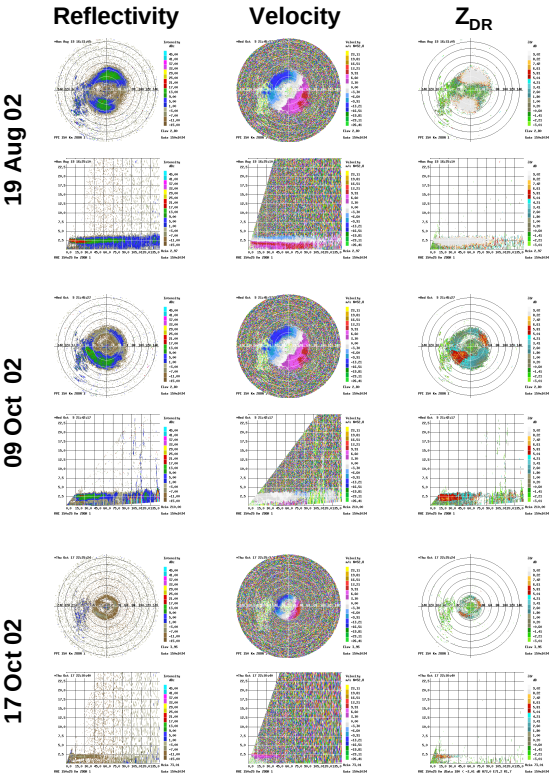
[1]*Colorado State University, Fort Collins, CO*

[2]*National Center for Atmospheric Research, Boulder, CO*

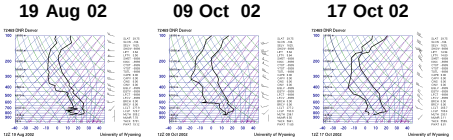
AMS Radar Conf 2003 - P1.3

1. INTRODUCTION

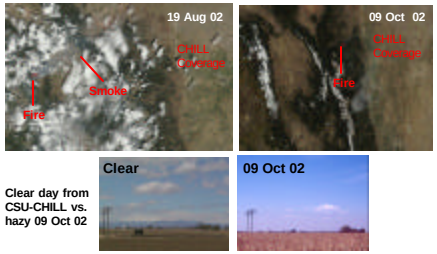
On a few occasions during the summer and fall of 2002, the CSU-CHILL S-band polarimetric Doppler radar observed dumbbell-shaped layers of enhanced radar reflectivity factor (Z_H) in clear air (i.e., no precipitation). These were horizontally widespread (1000s of km^2) layers, with the highest Z_H values (sometimes > 20 dBZ) arranged approximately perpendicular to the direction of the mean wind as estimated by Doppler radar methods. The echoes coincided with strongly positive differential reflectivity (Z_{DR}) measurements. The results suggest particles that are quasi-prolate in shape and aligned horizontally along the direction of the mean wind. It is suspected that these echoes were primarily caused by insect migrations. Why these migrations occurred is unclear, but may be related to nearby forest fires on these days.



2. NATURE OF THE ECHOES: SMOKE?

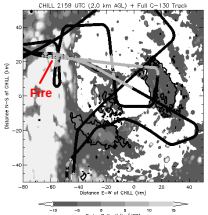


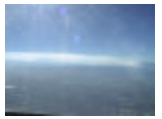
Soundings from these days indicated that the echoes were located near the top of the boundary layer, at temperatures above freezing. Visual observations tended to indicate widespread mid-level haze or plumes associated with nearby fires. Imagery from the MODIS instrument onboard the NASA TERRA satellite located a massive fire on 19 August in north central Colorado, and indicated advection of the smoke plumes from this large fire toward the CSU-CHILL coverage region. On 9 and 17 October haze and plumes were associated with small control burns in the foothills near CSU-CHILL. Radar observations of smoke plumes have been recorded in the literature (e.g., Rogers and Brown 1997; Banta et al. 1992; Doviak and Zrnic 1993), although these were echoes associated with narrow plumes, not widespread smoke layers. Indeed, plume dispersion models predict much narrower smoke fields than the echoes observed (Seinfeld 1986, chap. 14). The Z_{DR} values indicate oriented particles. Though prolate-shaped particles like ice crystals are known to fall with their major axis aligned horizontally, parallel to the ground (Pruppacher and Klett 1997, chap. 10), it is unclear how such small particles would be additionally oriented along the direction of the mean wind.

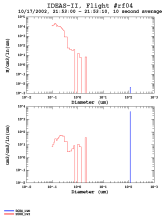


Clear day from CSU-CHILL vs. hazy 09 Oct 02

3. 17 OCT 02: NCAR C-130 FLIGHT (IDEAS2 PROJECT)

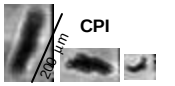






Horizontal cross-sections of Z_H (shaded contours) and Z_{DR} (> +4 dB - black contour) at 2 km AGL show that the C-130 (+ signs, dark=out of plume, light=in) did not see smoke in the dumbbell echo regions.

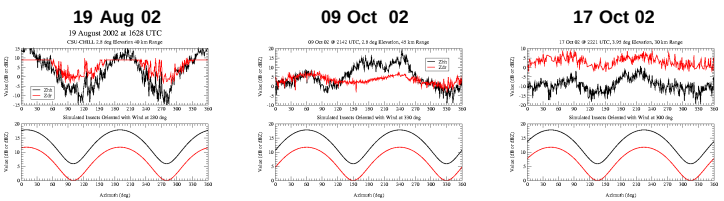
Haze not as widespread, and narrow plume is visible



Size distribution and CPI images show elongated but small particles in the plume. The radar observed larger particles falling out of the narrow plume to the NW while the C-130 flew in a region containing smaller particles. These *in situ* observations rule out smoke as the dumbbell echo source.

4. ECHOES AS INSECTS: SCATTER MODELING

Dumbbell-shaped radar echoes have been observed before with migrating insects (e.g., Mueller and Larkin 1985). However, these observations show insects near the ground. Generally, elevated insects only occur within narrow updrafts (Achtemeier 1991). However, the large Z_{DR} values and orientation of the echoes are consistent with the radar cross-sections of insects, which can be modeled as prolate spheroids (Riley 1985; Vaughn 1985; Zrnic and Ryzhkov 1998). Scattering calculations were made using a T-matrix model. Assuming the targets are oriented in a specific horizontal direction, and using an arbitrary size distribution, good agreement for the phase of the azimuthal variation of Z_H and Z_{DR} between observations and model is obtained, particularly for the strongest echo day (19 Aug 02). It is unclear what caused the migratory behavior. It may have been a response to the nearby fires - either insects vacating the fire area and being carried away by winds, or being attracted to the increase in CO_2 and attempting to travel upwind to the source. Or, an unrelated event may have been the cause.



References

Achtemeier, G. L., 1991: The use of insects as tracers for "clear-air" boundary -layer studies by Doppler radar. *J. Atmos. Oceanic. Technol.*, **8** , 746-764.

Banta, R. M., et al., 1992: Smoke-column observations from two forest fires using Doppler lidar and Doppler radar. *J. Appl. Meteor.*, **31** , 1328-1349.

Doviak, R. J., and D. S. Zrnic, 1993: *Doppler Radar and Weather Observations*. Academic Press, 562 pp.

Mueller, E. A., and R. P. Larkin, 1985: Insects observed using d ual-polarization radar. *J. Atmos. Oceanic. Technol.*, **2** , 49-54.

Pruppacher, H. R., and J. D. Klett, 1997: *Microphysics of Clouds and Precipitation*. Kluwer Academic Publishers, 954 pp.

Riley, J. R., 1985: Radar cross section of insects. *Proc. IEEE* , **73** , 228-232.

Rogers, R. R., and W. O. J. Brown, 1997: Radar observations of a major industrial fire. *Bull. Amer. Meteor. Soc.*, **78**, 803-814.

Seinfeld, J. H., 1986: *Atmospheric Chemistry and Physics of Air Pollution*. John Wiley & Sons, 738 pp.

Vaughn, C. R., 1985: Birds and insects as radar targets: A review. *Proc. IEEE* , **73**, 205-227

Zrnic, D. S., and A. V. Ryzhkov, 1998: Observations of insects a nd birds with a polarimetric radar. *IEE Trans. Geosci. Remote Sensing*, **36**, 661-668.

Acknowledgments

The authors would like to thank the staffs of the CSU -CHILL radar and the NCAR C -130 aircraft for data collection and assistance with interpretationof the observations. Discussions with CSU Atmospheric Science and NCAR/RAF personnel, as well as with David Atlas, Alexander Ryzhkov, Thomas Holtzer, Scott Isard, and Gary Achtemeier, were invaluable to this work. Gwo-Jong Huang and V. N. Bringi of CSU Electrical Engineering provided assistance with the scattering model. Sounding data were obtained from the University of Wyoming, and MODIS imagery came from NASA. The CSU-CHILL radar facility is funded by the National Science Foundation and the State of Colorado. The National Center for Atmospheric Research is funded by NSF.