The Search for a Practical Way to Implement Height Corrections in Large Wind Profiler Datasets

Leslie M. Hartten [1, 2], Paul E. Johnston [1, 2], Ahoro Adachi [3], Melissa A. Burt [4, 2], D. Matthew Coleman [4, 2], Nancy I. Rivera Rivera [4, 2]

[1] Cooperative Institute for Research in Environmental Sciences (CIIRES), University of Colorado, Boulder, Colorado, USA [2] NOAA Earth System Research Laboratory (ESRL), Boulder, Colorado, USA

[3] Meteorological Research Institute (MRI), Tsukuba, Japan [4] UCAR Significant Opportunities in Atmospheric Research and Science (SOARS®) Program, Boulder, Colorado, USA

1. Motivation and Approach

Wind profiling radars, first developed in the 1970's, have become commonly used in operational networks and during short- and long-term research campaigns. Recent work has shown that both atmospheric reflectivity gradients and data collection close to the radar can cause incorrect height assignment of the measured winds (Johnston et al., 2002). This can result in good winds being put into model analyses at the wrong altitudes. In addition, since the errors are larger for longer pulse lengths, it is difficult to merge data collected by one profiler operating in multiple modes into a single reasonable dataset.

The incorrect height assignment is only obvious under certain meteorological conditions, such as when there is a pronounced local speed minimum or maximum or a sharp shift in wind direction (Figure 1, Figure 2). In profiles that have fairly constant speed or direction, differences between profiles can be mistakenly identified as the result of different averaging volumes (i.e. smoothing) or of random errors. The problem is apparent in radial velocities on individual scans, in half-hourly profiles of horizontal wind, or in longterm mean profiles constructed from half-hourly winds.

Johnston et al. (2002) showed that profiles of reflectivity gradients measured by the wind profilers could be used to correct the height assignments on a profile-by-profile basis. The Tropical Dynamics and Climate Branch of NOAA/ESRL's Physical Science Division would like to find a quicker and simpler way to improve the height assignments in our many decades' worth of data. We have therefore used our archived profiler data to study atmospheric reflectivity gradients, and have then tried correcting heights using successively less simple assumptions about those gradients, as described in this poster.

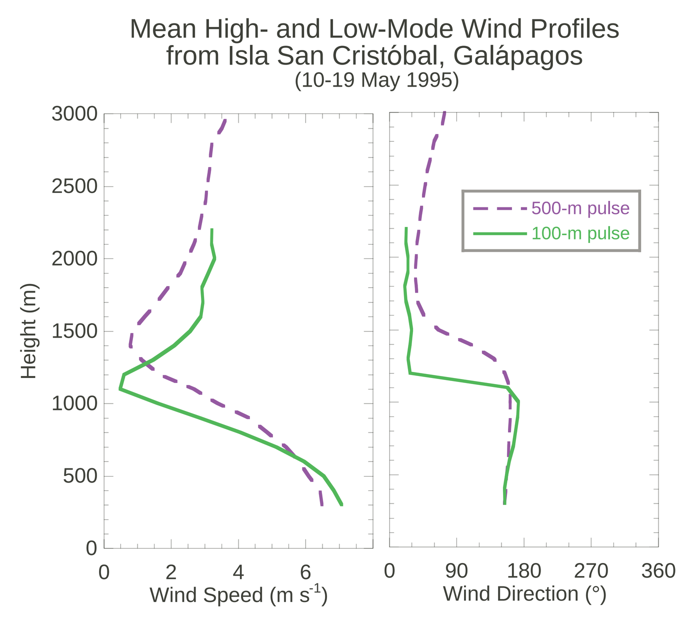

Figure 1. Mean profiles of wind speed and direction computed from high- and low-mode data collected by the 915-MHz profiler at Isla San Cristóbal, Galápagos during 10-19 May 1995.

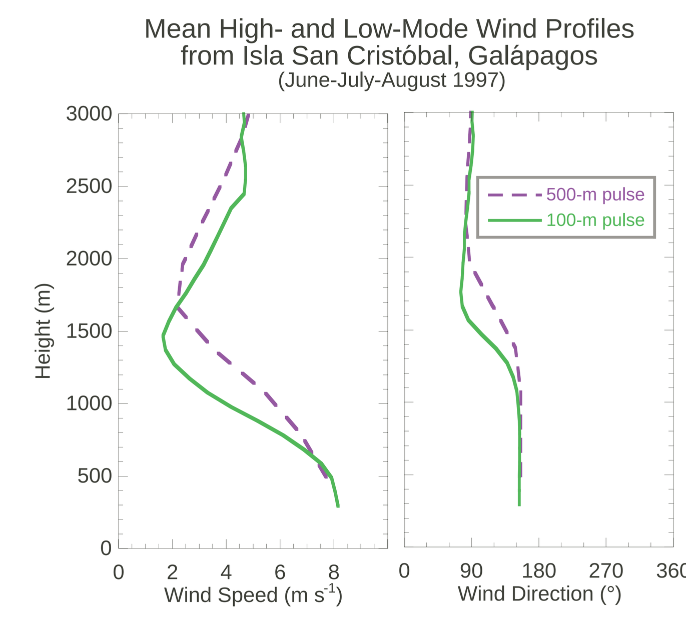

Figure 2. Mean profiles of wind speed and direction computed from high- and low-mode data collected by the 915-MHz profiler at Isla San Cristóbal, Galápagos during June-August 1997.

2. Data

The data used in this study come from 915-MHz Doppler wind profilers deployed at Betio Island, Tarawa, Kiribati (1.36°N, 172.92°E) and Isla San Cristóbal, Galápagos, Ecuador (0.90°S, 89.57°W) as part of the then NOAA Aeronomy Laboratory's Trans-Pacific Profiler Network. The Tarawa profiler, located in the west Pacific Warm Pool, was deployed from August 1994 through March 2003. The Galápagos profiler, situated in the heart of the east Pacific Cold Tongue, was installed in October 1994 and continues to operate. Both profilers are three-beam systems that operated in both high and low modes. Data were processed as described in Riddle et al. (1996) into half-hourly profiles.

Acknowledgements:

This research was funded through a grant from NOAA's Office of Global Programs to the NOAA Aeronomy Laboratory, now part of NOAA's Earth System Research Laboratory. We thank the staff and protégés of the SOARS Program, and Communications Mentors Amy Stevermer (CIRES) and Nicole Gordon (UCAR), for their support during portions of this researc. We also thank Kate Hartten for her patience and encouragement.

3. Simplest Method

One of the standard assumptions behind the version of the radar equation typically used with wind profilers is that the reflectivity of the atmosphere is uniform within the scanning volume. This is equivalent to saying that the reflectivity gradient, RG, equals 0 dB km^{-1}. For our first attempt at a simple height-correction method, we used the more general form of the radar equation presented in Johnston et al. (2002, equation 3) together with radar parameters appropriate for the Galápagos profiler. We assumed that RG was constant and equal to –2.17 dB km^{-1}, the median atmospheric reflectivity gradient derived by Doviak and Zrnic (1993) from an average reflectivity profile based on world-wide observations. We then performed height corrections on all half-hourly wind profiles in eight 10-day cases selected from El Niño (2), La Niña (2), and normal (4) conditions during 1994-1998. This was done by iteratively solving equation 7 of Johnston et al. (2002).

Figure 3 shows results for the 21-30 August 1995 case. The height correction lowered the altitude of the speed minimum and associated wind shift, but not to the level at which they are found in the 100-m mode. Mean profiles of the absolute differences between the individual profiles indicate that between 1000 and 2000m, differences between the two modes decrease after the high-mode profiles are adjusted, while differences below ~750m actually increase. These results are summarized for wind speeds in Figure 4.

Conclusion: adjusting high-mode heights by using a more general form of the radar equation and by assuming RG = –2.17 dB km^{-1} improves agreement with low-mode profiles, but not enough.

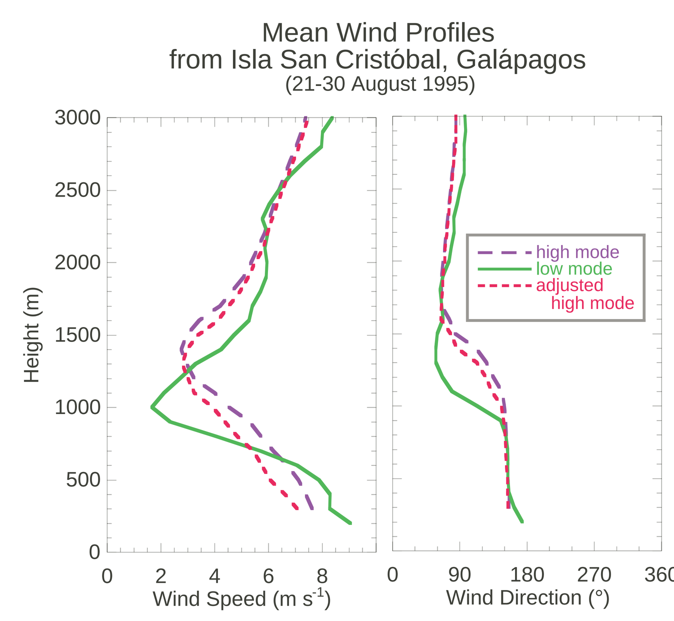

Figure 3. Mean profiles of wind speed and direction over the Galápagos during 21-30 August 1995. Original high- and low-mode profiles are plotted together with the adjusted high-mode profiles.

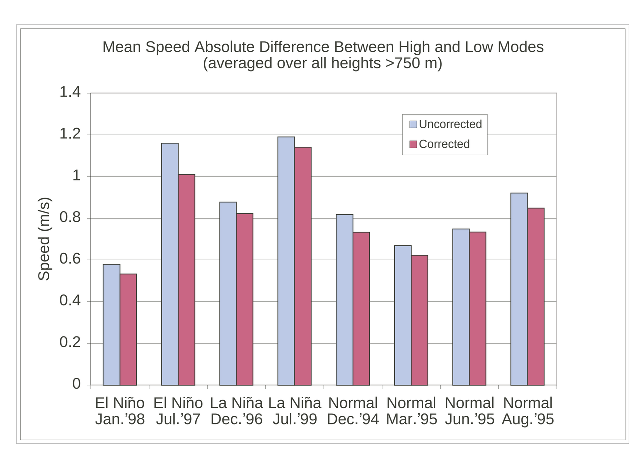

Figure 4. Summary of mean absolute differences between high and low modes before and after height corrections..

4. Reflectivity Gradient Climatology

We next turned our attention back to observed reflectivity gradients. First we looked at the spatial and temporal variability of RG calculated from half-hourly profiles of SNR collected at Tarawa and Galápagos. We used data from October 1994 through April 2001, focussing on the months of October, January, April, and July. Reflectivity gradients were calculated using only data collected in clear-air conditions by the oblique beams. Using half-hourly profiles and averaging them over just those months gave us a manageable number of profiles to analyze and enabled us to capture several annual cycles, one El Niño, and two La Niña periods.

The basic form of monthly mean RG profiles was quite similar over both the eastern and western equatorial Pacific. Examples from Tarawa and Galápagos are shown in Figure 5. At ranges less than ~1.5 km the RG has a large negative value that becomes less negative with range. Beyond that, the RG lies between –5 and 5 dB km^{-1}. The average Tarawa low-mode RG beyond 1.5 km was –1.85 dB km^{-1}. However, this mean gradient exhibited considerable variability. Statistically significant differences were found between the average of monthly mean gradients during December through February (–2.37 dB km^{-1}) periods and all March through April (–0.98 dB km^{-1}) periods, as well as during El Niño (0.24 dB km^{-1}) and La Niña (–3.79 dB km^{-1}) conditions.

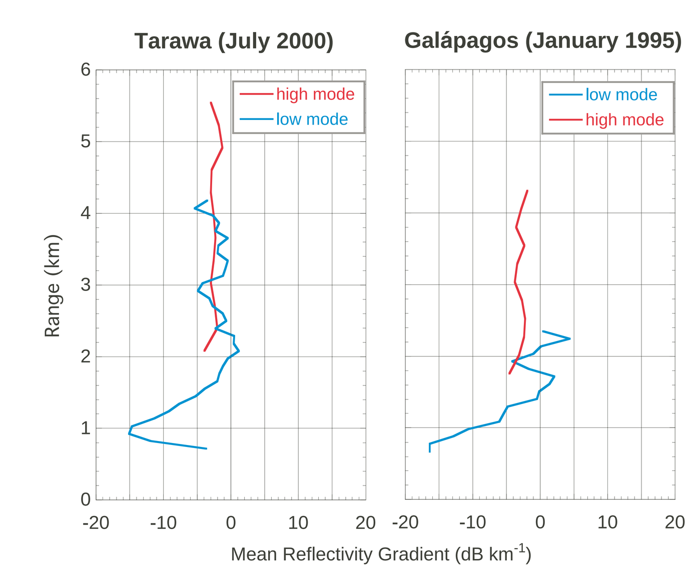

Figure 5. Monthly mean profiles of reflectivity gradient computed from high- and low-mode data Tarawa (left) and Galápagos (right). Note that the vertical axis is range, not height.

Conclusion: reflectivity gradient profiles over the tropical Pacific have structure in the lower troposphere; the profiles exhibit significant intraseasonal and interannual variability.

5. Less-Simple Method

We next used the results of our climatological study to test a set of slightly more complicated correction schemes. The schemes were still based on the more general form of the radar equation but used more complicated assumptions about RG. At ranges beyond 1500 m, ranges were adjusted by an offset based on RG = –2.17 dB km^{-1} (as above). At ranges from 1000 to 1500 m, various monotonically increasing profiles of RG were used (Figure 6). The four different resulting offsets are shown in Figure 7. Corrections were applied to all half-hourly profiles in eight 10-day cases (not always the same periods as in the simpler study).

Figure 8 shows resulting mean profiles for the 10-19 May 1995 case. The height correction resulting from the larger negative gradients improves the positioning of the speed minimum and wind shift, but in some instances degrades the lower portion of the profile.

Conclusion: adjusting high-mode heights by using a more general form of the radar equation and realistic, simply varying RG profiles improves agreement with low-mode profiles more than the simplest method described in Section 3; however, the large RG values at some levels can "overcorrect" the profiles during some time periods.

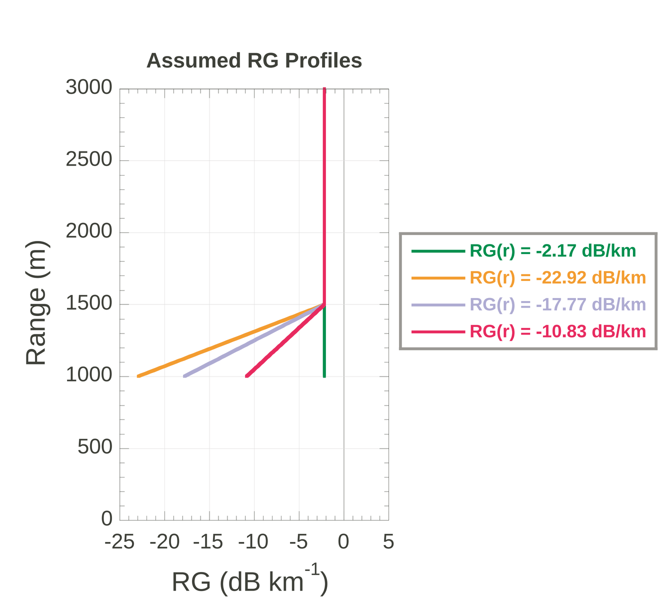

Figure 6. The linearly varying profiles of reflectivity gradient used in this portion of the study.

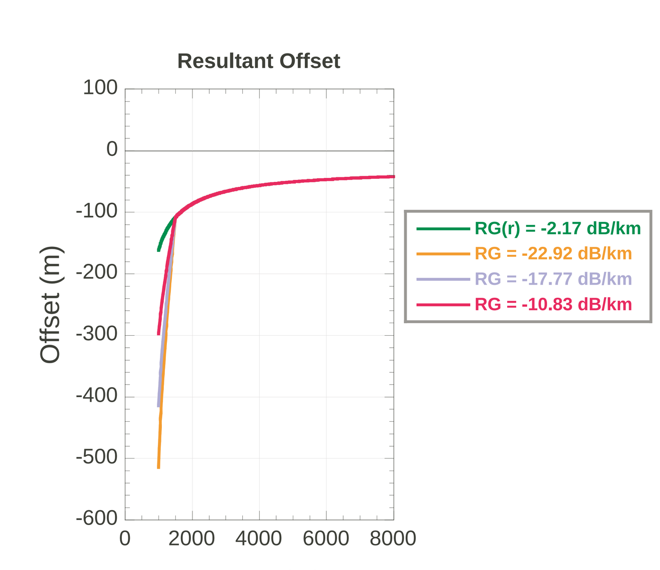

Figure 7. The range offsets for high-mode data collected by the Galápagos profiler, computed from the RG profiles in Figure 6 .

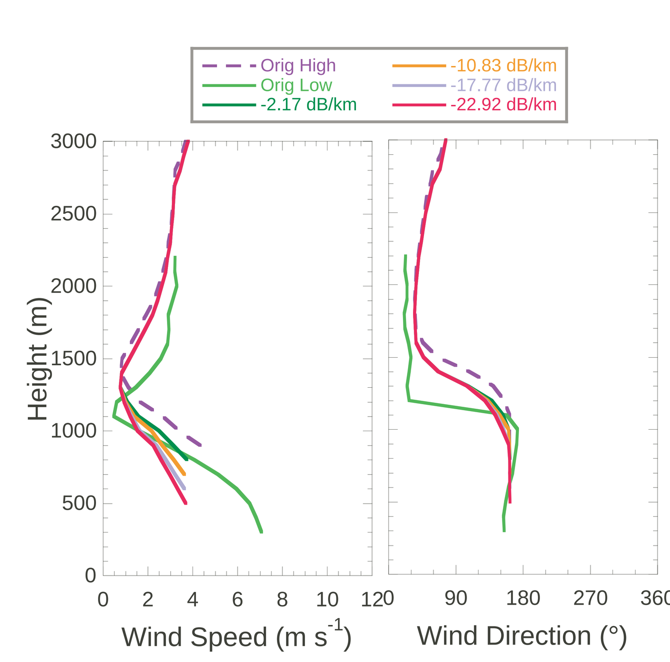

Figure 8. Mean profiles of wind speed and direction over the Galápagos during 10-19 May 1995. Original high- and low-mode profiles are plotted together with several adjusted high-mode profiles.

6. What's Next?

There are at least 2 tacks we could take to allow us to reasonably merge the different modes collected by our tropical profilers:

- establish a time-varying set of non-constant RG profiles for each site, and proceed to correct half-hourly winds as in Section 5
- correct the original radial velocities based on coincident RG measurements, as outlined in Johnston et al. (2002), and then re-caculate half-hourly winds.

7. How Can You Help?

We are looking for mid-latitude examples of *meteorologically interesting wind profiles* (i.e. with strong speed or directional shear) that were *observed by overlapping wind profiler modes*. The modes could be from 1 profiler or from 2 collocated ones. They do not have to be long-lived features; durations of a few hours would be fine. Please contact the lead author if you have any!

References:

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

Johnston, P. E., L. M. Hartten, C. H. Love, D. A. Carter, and K. S. Gage, 2002: Range errors in wind profiling caused by strong reflectivity gradients. *J. Atmos. Oceanic Technol.*, **19**, 934-953.

Riddle, A. C., W. M. Angevine, W. L. Ecklund, E. R. Miller, D. B. Parsons, D. A. Carter, and K. S. Gage, 1996: In situ and remotely sensed horizontal winds and temperature intercomparisons obtained using Integrated Sounding Systems during TOGA COARE. *Beitr. Phys. Atmos.*, **69**, 49-61.

Presented at the 7th International Symposium on Tropospheric Profiling: Needs and Technologies, 11 – 17 June 2006, Boulder, CO