A CLIMATOLOGY-BASED ASSESSMENT OF RADAR REFRACTION ERRORS

Raymond P. Wasky*, Jonathan Z. Gehman, Julius Goldhirsh
The Johns Hopkins University, Applied Physics Laboratory
11100 Johns Hopkins Road, Laurel, Maryland 20723-6099
http://www.jhuapl.edu/

Electromagnetic waves are refracted by vertical temperature and humidity gradients in the lower atmosphere. At near-horizontal elevation angles, refractive bending causes significant errors in elevation angle measurements. The theory of these refraction errors is very well established; given adequate vertical meteorology profiles, ray tracing can predict refraction errors with a high degree of accuracy. A well-known characteristic of the lower atmosphere is that refraction effects are highly variable, especially at certain geographic locations and times of year.

While detailed studies have been performed to quantify the impact of refraction on radar coverage and signal-to-noise ratio, the impact on elevation-angle measurements has not been very well studied. The authors have attempted to answer the question, "How does the variability of atmospheric refraction in the real-world impact elevation angle measurements?" by way of a climatology-driven study of four geographically dispersed locations. Meteorological data were obtained from World Meteorological Organization (WMO) stations at these locations for several different months, then analyzed using the RAYCAP (Ray Tracing Computer Analysis Program) model. Elevation-angle refraction errors were computed for both shipboard and airborne sensors, then monthly statistics (10/50/90th percentiles) were compiled at several elevation angles and ranges. While there are several caveats to be considered when interpreting these results, they nevertheless provide the most complete picture of real-world refraction error variability to date.

In performing this analysis, we contrasted our results with the more commonly-used "standard atmosphere" approach, in which the entire air column is assumed to follow an exponential decay, and the only meteorological input is refractivity at the surface, N_S. A primary conclusion of this study is that variability in the lower air column has a tremendous impact on day-to-day error variability and – in general – the "standard atmosphere" approach does not sufficiently capture this variability. For example, 90th percentile values can increase by an order of magnitude, relative to standard-atmosphere predictions, when full air-column variability is taken into account. Another conclusion is that geographic location is a major factor. For example, at one location studied, standard atmosphere predictions actually perform quite well, whereas at the other three locations, the strength and altitude of typical ducting events result in refraction error statistics that deviate from the standard model in fundamentally different ways.