Appendix S1. Methods for removal of wind-borne targets

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If the mean radial airspeed of targets in a pulse volume (PV) was less than 5 m sec^{-1} (i.e. likely dominated by slow-moving insects; Larkin 1991, Gauthreaux and Belser 1998, Gauthreaux et al. 2003, Buler and Dawson 2014), we classified the PV as dominated by wind-borne targets and set that PV's reflectivity to zero. We examined the distribution of reflectivity values of pulse volumes (PVs) classified as bird and wind-borne to gain insight into the efficacy of our screening process and to inform how these PVs are used in density calculations. We collected the reflectivity measurements of all PVs from the 267 accepted scans from the KBGM station during September 2010. We examined only PVs within 15 degrees of the primary axis of movement. Within this set, 8.56 million PVs were categorized as bird, 10.48 million PVs were categorized as wind-borne, and 2.20 million PVs were classified as no data (i.e. signal-to-noise ratio below minimum threshold).

Figure S1 shows the probability density function of reflectivity values— on the decibel scale (dBZ)—for bird PVs, wind-borne PVs, and the combined set of bird and wind-borne PVs. An interesting overall pattern is the presence of two distinct modes in these functions, which is consistent with the hypothesis of two distinct classes of pulse-volumes. The mode around 15 to 20 dBZ is consistent with expected measurements of migrating birds (see primary text). We do not know the identity of targets in PVs near the second mode at much lower reflectivity values (-5 to -10 dBZ), but these PVs represent typical atmospheric conditions during which wind borne targets are present (e.g., dust, smoke, insects) but there are no significant returns from birds or precipitation.

The functions for wind-borne and bird PVs differ systematically from the combined function. Wind-borne PVs show a much more distinct mode at low reflectivity values (-5 to -10 dBZ), and many fewer PVs with reflectivity greater than 10 dBZ. Bird PVs show a much more distinct mode near 20 dBZ, and retain a mode near -5 to -10 dBZ but with fewer PVs. Overall, the pattern is consistent with the interpretation that: (1) wind-borne targets have lower reflectivity values, (2) migrating birds have higher reflectivity values, (3) classifying PVs based on airspeed of the targets reduces the fraction of PVs dominated by wind-borne targets.

Overall, 67% of PVs classified as wind-borne have reflectivity values less than 1 on a linear scale (below zero on the decibel scale); for these PVs, setting them to 0 has little overall impact. The remaining 33% of PVs have non-negligible reflectivity values, but the distribution is shifted to considerably lower reflectivity values than that of bird PVs. Setting these to zero will lead us to slightly underestimate bird density because we ignore birds in PVs classified as wind-borne (either because the PVs are misclassified or because targets are mixed within a single PV). However, we view this as an appropriate and conservative choice compared with the alternatives. One alternative would be to leave the wind-borne PVs in the averages, which would likely overestimate bird densities slightly by not excluding insects and other targets. Removing wind-borne PVs entirely would lead to more significant over-estimation by removing the large fraction of wind-borne PVs with very low reflectivities.

Literature Cited

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Supplementary Figures

Figure S1. Probability density functions of reflectivity values for bird PVs (dashed line), wind-borne PVs (dashed and dotted line), and the combined set of bird and wind-borne PVs (solid line).

Figure S2. Frequency distribution of mean directions of radar targets before and after thresholding and before and after weighting directions by bird density for August 2010 from Dover, DE. Mean direction is noted with a black vertical line. A) No thresholding, no weighting; B) Thresholding, no weighting; C) No thresholding, weighting; and D) Thresholding, weighting.

Figure S3. Total bird density in cm^2 km^{-2} by Julian day for 2010 (dotted line) and 2011 (solid line).