Migrating birds: Assessment of Impact on 915-MHz Radar Wind Profiler Performance at the Atmospheric Radiation Measurement Program's Southern Great Plains*

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MIGRATING BIRDS: ASSESSMENT OF IMPACT ON 915-MHZ RADAR WIND PROFILER PERFORMANCE AT THE ATMOSPHERIC RADIATION MEASUREMENT PROGRAM'S SOUTHERN GREAT PLAINS SITE

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Abstract

The U. S. Department of Energy's Atmospheric Radiation Measurement Program is running a small network of 915-MHz radar wind profilers (RWPs) at its Southern Great Plains Cloud and Radiation Testbed site in northern Oklahoma and southern Kansas. Seasonal migration of passerines may cause significant interference with the operation of 915-MHz RWPs. The extent of this "bird jamming" depends on the radar's parameters, the place of deployment, the season, and the time of day. This poster presents a new diagnostic method for detecting possible bird contamination in RWP data, along with an evaluation of the method using a three-year data set for two RWPs.

Keywords: radar wind profiler, signal contamination, bird migration.

Introduction

The problem of bird contamination has been addressed by many researchers (Merritt 1995, Jordan *et al*. 1997, Cornman *et al*. 1998, Richner and Kretzschmar 2001, to name a few); however, a practical solution to the problem is yet to be found. The radar wind profiler (RWP) works with extremely weak clear-air signals, and a reflection from even a single material object like a flying bird might be many times more powerful than the atmospheric signal.

Unlike random noise, bird reflections have rather consistent characteristics, so that averaging does not eliminate them; moreover, simple time or frequency domain averaging tends to emphasize the bird signal at the expense of the atmospheric one. The problem is further exacerbated by technical issues such as nonlinear distortion of the signal due to saturation of receivers by bird reflections. Computing resources of a typical profiler are insufficient for real-time processing of the time series and/or individual spectra to reveal the weak atmospheric signal in the presence of strong interference. These difficulties make it highly unlikely that secondary processing will ever guarantee successful retrieval of wind characteristics from bird-contaminated radar data.

The objectives of the present work were (1) to develop an automated technique for detecting bird contamination through the analysis of spectral moments, the data usually available during routine profiler operation; and (2) to assess the impact of seasonal bird migration on performance of 915-MHz wind profilers.

The method was intended to be used with the LAP-3000 profiler. Argonne operates several of these RWPs at the Atmospheric Boundary Layer Experiments (ABLE) facility (Wesely *et al*. 1997, ABLE Data Archive at http://www.atmos.anl.gov/ABLE), and large data archives for several radars of the same type at nearby locations are available from the Atmospheric Radiation Measurement (ARM) Program (ARM Archive at http://www.archive.arm.gov). However, the described technique could be adapted for any other type of wind profiler.

Method

The method has been developed with the goal of detecting migrating passerines by using hourly spectral moment sets. We assume the usual data structure and working parameters for LAP-3000 operation as follows: the hourly data set is composed of moments (that is, signal amplitude, Doppler shift, and signal spectral width) from a RWP working in five-beam, two-power mode, with nine sets of moments per hour. Low- and high-power data were processed separately, although the method could be adapted for joint processing.

The proposed method uses three well-known facts to find occasions of bird-like signal:

- To function properly, an RWP requires horizontal homogeneity and vertical continuity of the atmospheric boundary layer (ABL), along with rather slow changes of ABL parameters with time. Hence, height-time patterns of returned signal should be very similar for all beams, and sharp disparity among beams for the same time/height locality might indicate bird interference.

- Bird contamination consists of reflections from numerous point targets that are randomly distributed over space and time; one should expect no correlation or correspondence of bird reflections among different beams.
- The bird signal has two other distinctive features: its power is usually much higher than the background atmospheric level, and its spectrum tends to be broader than the atmospheric one.

The method was implemented as a post-processing filter that searched through one-hour moments set to pick up bird-like structures and analyzed their number and temporal and spatial distributions to diagnose bird presence during this hour.

In certain meteorological conditions (*e. g.*, during thunderstorms), the atmospheric signal is at a very high level and/or exhibits abnormal variability. The proposed method is likely to produce erroneous results (false bird detection) in these conditions, but it nevertheless would alert operators about atmospheric conditions unfavorable to RWP operation.

Evaluation

The present study is based on (1) a 1997-1999 data set for the ARM central facility (Lamont, OK) from the ARM Program Data Archive and (2) the ABLE data for the 915-MHz profiler operated at Beaumont, KS.

A combination of 915-MHz and 50-MHz wind profilers, along with routine radiosonde launches at the ARM central facility, presents a good testing ground for evaluation of our method. The 50-MHz profiler is relatively insensitive to bird interference because of its longer working wavelength. For direct comparison of wind components from systems with different range gate structures, the data with better height resolution were averaged to match the range gates of the other system.

Any true evaluation of a bird detection method requires an independent bird detection system. Because no such system was available, we had to use circumstantial evidence of bird presence, like artifacts on signal-to-noise ratio (SNR) plots or characteristic distortion of the north-south wind component from the 915-MHz profiler as compared to other wind measurements.

Figures 1 and 2 present examples of scatter plots of the north wind component from the 915-MHz profiler, plotted against either radiosonde or 50-MHz profiler data. Data were sorted into "bird" and "clean" categories according to bird contamination detection by the proposed method. No height separation was performed; that is, all valid points from hourly wind profiles were placed on one or another scatter plot. Note significant

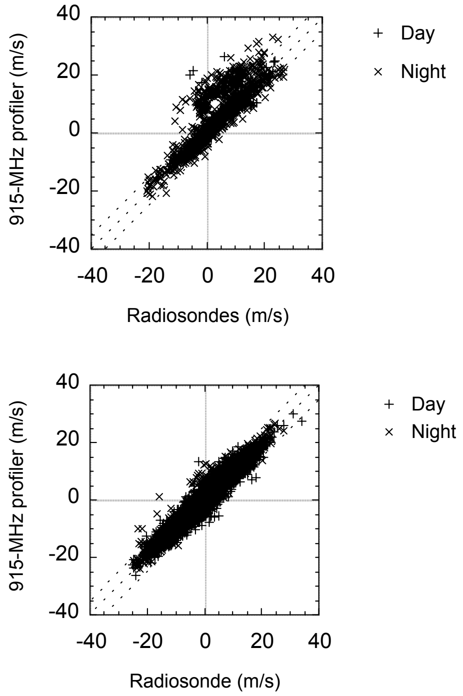

Figure 1. Scatter plot of north wind component by 915-MHz profiler against radiosonde data for the spring season of 1997; top – “bird” case; bottom – “clean” case. The dotted lines show coincidence and ±5 m/s difference.

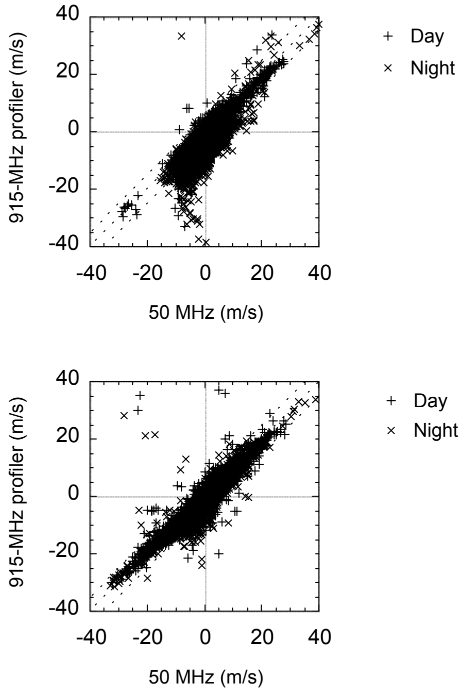

Figure 2. Scatter plot of north wind component by 915-MHz profiler 50-MHz profiler data for the fall season of 1998; top – “bird” case; bottom – “clean” case. The dotted lines show coincidence and ±5 m/s difference.

nighttime overestimation by the 915-MHz system of northern winds in springtime (Fig. 1) and southern winds in the fall (Fig. 2); this bias is most probably caused by bird interference.

Overall, scatter plots and corresponding statistics (Table 1) show good separation of contaminated profiles from uncontaminated ones. Most bird artifacts are found on "bird" plots, although some points from "clean" sections exhibit a bird-like bias. These points belong primarily to complicated cases when the proposed procedure misinterpreted some other phenomenon (*e.g.*, strong vertical motion) or bird presence was masked by a layered atmospheric structure.

Bird contamination at two sites in 1997-1999

Contamination from migrating birds can be detected by comparing wind profiles from 915-MHz and 50-MHz profilers (here termed the profile comparison method). A symptom of bird interference is a layer with an enhanced north-south wind component from the 915-MHz system and a general wind direction to the north during spring or to the south in the fall. This subjective procedure depends strongly on the speed difference considered large enough to reflect bird contamination and on the type of profile distortion that points to birds rather than other kinds of interference (ground clutter, precipitation, electromagnetic noise, etc.).

The 1998 wind profiles for the Lamont 915-MHz and 50-MHz systems were compared manually to compile a list of possible bird-contaminated profiles.

Reasonably good agreement was found between the two bird detection methods (proposed and profile comparison), both in time series behavior and in general coincidence rate (Table 2). The profile comparison method cannot detect cases of contamination by slow flying birds (when profile distortion is small) or peculiar cases of bird interference when the standard RWP routine (consensus averaging) fails to produce a wind profile at all. Another drawback of comparison with the Lamont 50-MHz system is its dead zone up to 2 km above ground level (AGL) (Coulter and Holdridge 1995). With a minimum of three points required to determine the local shape of the profile, the lowest detectable bird layer is at about 2.9 km AGL; this excludes a considerable part of the atmospheric layer where bird migration takes place.

Another manual method for detecting bird interference is use of the characteristic signature on SNR height-time plots (Wilczak *et al.* 1995). Drawbacks of this "visual" subjective method include (1) poor estimates of the time and space frame of an event; (2) inability to detect shorter events (less than 3-4 hours); and (3) effect on performance of the ABL structure. However, obvious bird artifacts on SNR plots do not necessarily mean that wind data were affected; *vice versa*, "bird-like" wind distortion sometimes occurs without noticeable bird signature on the SNR plot.

All available SNR plots in the ABLE archive for the Beaumont system for 1997-1999 were examined manually to produce a list of bird events; all moment data for the Beaumont and Lamont 915-MHz profilers for the same years were processed with the proposed automated method, and the results were passed through a simple filter to produce a list of bird events similar to the one from the manual procedure, namely nights with three or more hours of continuous bird contamination (Table 2).

The manual SNR method and the proposed procedure use the same data and look for essentially the same bird symptoms; however, one method is subject to human errors like bias or drift in criteria, while the other is free of human influence. If we consider the proposed method an "objective" substitute for manual processing, both wind profile and SNR based, the comparisons show that the substitute works rather well. The differences are those expected for manual processing by two operators or with different visualization schemes used to prepare SNR plots.

Bird migration seems to be more intensive during the fall than in the spring at both locations, for all three years. Possible reasons are (1) winter deaths that decrease the number of birds returning to nesting grounds in the spring and (2) the tendency of spring migration to use lower heights, taking advantage of the favorable low-level jet and so causing less interference to RWP operation. Overall, the usual period of intensive bird migration at tested sites is March through May in the spring and the middle July to the end of November in the fall.

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Table 1. Wind speed difference for 50-MHz versus 915-MHz systems at Lamont, for all heights between 2.0 and 6.0 km above ground level. "Bird" indicates bird contamination was detected by the proposed method. Spring is March, April, May; fall is August, September, October.

Year	Season	Type	#	Wind speed			North-south component			East-west component		
				$\bar{V}_1-\bar{V}_2$	$\overline{\lvert V_1-V_2\rvert}$	RMSD	$\bar{u}_1-\bar{u}_2$	$\overline{\lvert u_1-u_2\rvert}$	RMSD	$\bar{v}_1-\bar{v}_2$	$\overline{\lvert v_1-v_2\rvert}$	RMSD
1997	Spring	clean	8294	0.96	1.32	1.69	0.08	0.99	1.34	0.95	1.27	1.65
		bird	3535	0.27	1.85	2.84	-1.12	2.19	4.28	0.93	1.58	2.39
	Fall	clean	11191	-0.47	1.22	1.78	1.16	1.47	2.08	0.00	0.88	1.20
		bird	6572	-1.51	2.38	3.64	2.94	3.21	4.80	0.52	1.38	2.08
1998	Spring	clean	8641	0.32	1.04	1.53	0.01	1.03	1.69	0.31	0.97	1.41
		bird	506	0.11	1.38	2.13	-0.37	1.57	3.02	0.35	1.18	1.77
	Fall	clean	10753	-0.69	1.23	1.82	1.18	1.57	2.23	-0.06	0.91	1.33
		bird	4009	-1.60	2.53	4.09	3.05	3.49	5.11	0.11	1.21	1.93
1999	Spring	clean	8436	-1.62	2.73	4.11	-0.25	2.75	4.52	-0.47	2.06	3.50
		bird	1141	-2.96	4.40	7.45	-2.74	5.00	9.08	0.00	3.03	4.75
	Fall	clean	8316	-0.05	1.30	1.93	1.04	1.51	2.36	0.19	1.04	1.64
		bird	4475	-1.15	2.14	3.67	2.41	2.86	4.50	0.35	1.15	1.84
All	Spring	clean	25371	-0.12	1.70	2.71	-0.05	1.59	2.89	0.26	1.43	2.38
		bird	5182	-0.45	2.39	4.26	-1.40	2.75	5.62	0.67	1.86	3.03
	Fall	clean	30260	-0.43	1.25	1.82	1.13	1.52	2.21	0.03	0.94	1.38
		bird	15056	-1.43	2.35	3.72	2.81	3.19	4.80	0.36	1.27	1.97

Table 2. Comparison of the proposed automated procedure and manual processing methods (SNR method for Beaumont, 1997-1999; profile comparison method for Lamont, 1998). Data are expressed in hours per year. Numbers in parentheses correspond to first + second half of a year.

	Beaumont			Lamont		
Year	1997	1998	1999	1997	1998	1999
Manual	544 (232 + 311)	534 (185 + 349)	309 (133 + 176)		538 (70 + 468)	
Automated low power	548 (274 + 274)	606 (263 + 343)	430 (261 + 169)	961	536 (178 + 358)	578

Automated high power	736 (314 + 422)	848 (290 + 558)	645 (278 + 367)	1398	835 (110 + 725)	872
Automated low and high power	898 (402 + 496)	1012 (372 + 640)	805 (388 + 417)	1557	1017 (205 + 812)	969