THE WIRED BIRDER

Radar Ornithology

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So, you have settled into your morning routine of checking the weather radar online to see if you are going to blow off work today and go birding. The radar shows rings, veritable donuts in the sky (Figure 1, arrows). How do you interpret donuts in the sky — tornados, hurricanes, donuts?

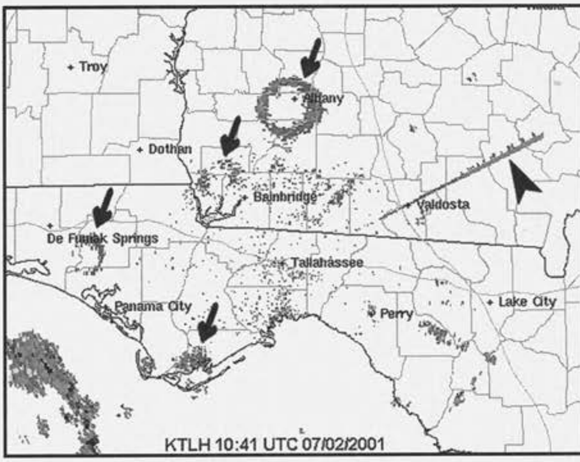

Figure 1: *Roost rings — base reflectivity image from the WSR-88D in Tallahassee, FL showing four roost rings (arrows) and a sun strobe (arrowhead). Image downloaded from the NOAA web site and processed by the author.*

Relax, the donuts in Figure 1 are roost rings, seen in an image from the Tallahassee, FL, weather radar site on July 2, 2001. Post-breeding Purple Martins assemble in large (thousands of birds) communal roosts at night. When they leave to feed in the morning, they fan out from the roost and reach altitudes where they are detectable by weather radar units. Hence, donuts in the sky. If you were to follow the image loop of this phenomenon, you would see small rings that grow in size and then dissipate, as the density of birds falls to below detection level. The diagonal spike to the right of this image is called a sun strobe. It is caused when the radar points directly at the sun.

Alternatively, suppose that you are in south Florida in March, checking on the weather radar in the evening. Beach day tomorrow or not – that is the question. You see this blob of stuff heading your way from Cuba (Figure 2). But it's not a storm, it's birds, lots of birds. Noel Wamer collected this series of images from the Key West, FL, radar on March 14, 2001, indicating clouds of migrants heading north during the course of the evening. Both the roost rings, and the migration across the Straits of Florida, are examples of the wonders of radar ornithology.

In this issue, the Wired Birder looks at the use of radar to study bird migration, movements, and behavior. The detection of birds by radar is not new: the earliest radar units, used in England during the Second World War, picked up incoming flocks of birds in addition to military targets. The establishment of the National Weather Service's NEXRAD (NEXt generation RADar) system coverage of the U.S. (including Puerto Rico and the U.S. Virgin Islands) in the 1990s provided a vastly

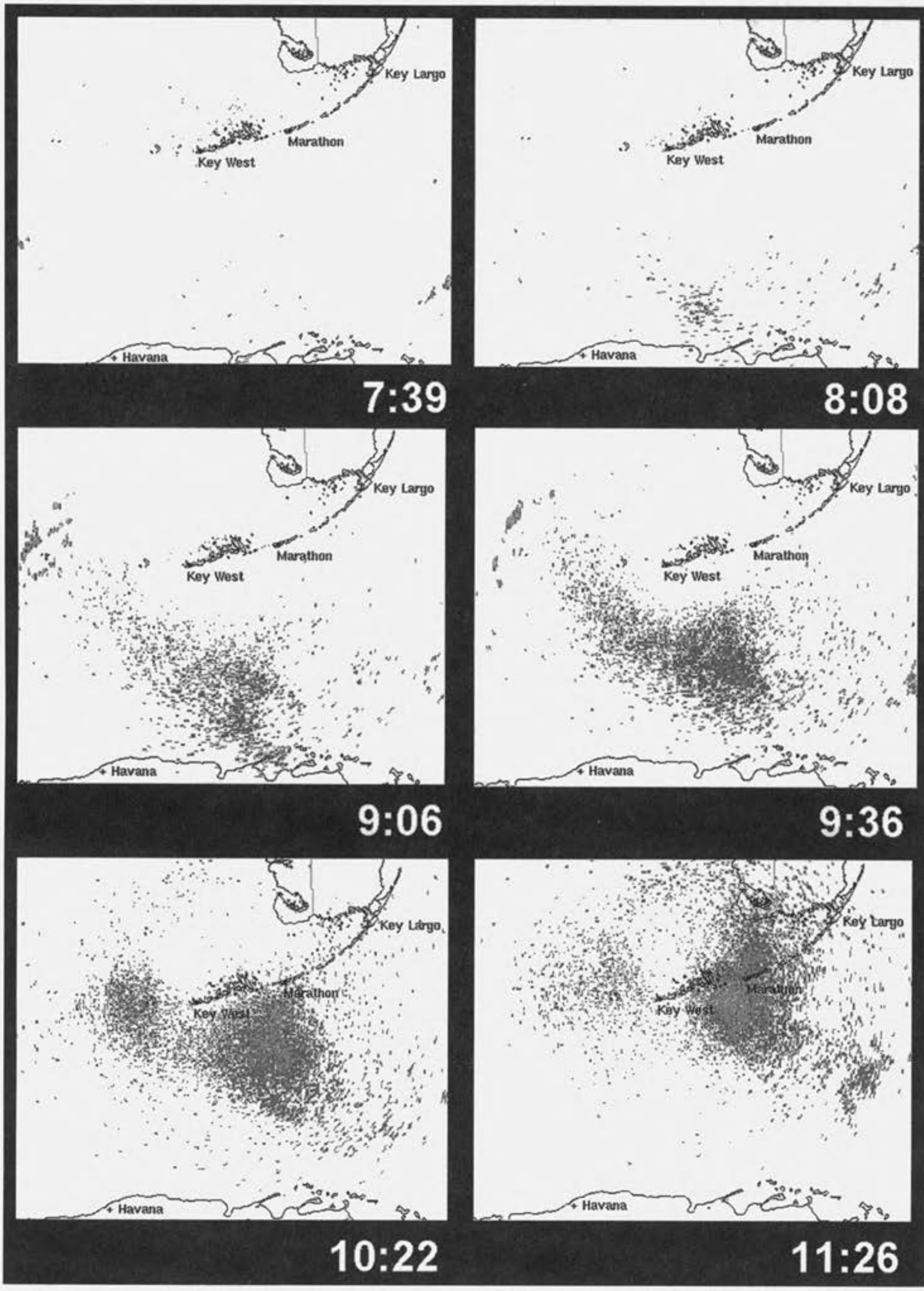

Figure 2: *Spring migration of birds over the Straits of Florida on the evening of March 14, 2001, as detected by the Key West WSR-88D, downloaded and processed by Noel Wamer <www.badbirdz.com/ktby031401.htm> – and used with permission*

improved tool for radar ornithologists. The NEXRAD system gives nearly total coverage of the country with sophisticated WSR-88D doppler radar units.

RADAR (RAdio Detection And Ranging) systems consist of a transmitter and a receiver. They transmit microwave (radio) signals, and listen for returning signals that have bounced off objects (airplanes, rain drops, birds, dust, etc.). Returning signals mean that an object has been detected, and the range (distance) to the object can be calculated from the time between transmission and reception (since microwaves travel at a known velocity). The amount of energy detected in the returning signal is converted to a reflectivity measure, which can be used to estimate the number or density of the objects. Of course, the operation is just a wee bit more complicated than this explanation.

WSR-88D transmitter/receiver units are 28-foot diameter parabolic dish antennas, housed in fiberglass domes, and elevated on towers (Figure 3). In operation, the antennas usually rotate at three revolutions per minute. Transmissions are very short (a few microseconds) and the pulse rate is around 1300 per second. Hence the radar spends most of its time listening. In fact, the radar is only transmitting for a total of seven seconds per hour. The width of the radar beam is approximately one degree. While the range of the WSR-88D is 124 nautical miles, the effective range for bird detection is approximately 60 nautical miles (111 km). The WSR-88D normally cycles from sweeps at 0.5 degrees elevation, to sweeps at 1.5, 2.5, 3.5, and 4.5 degrees. Note that these radars cannot detect anything directly overhead, and often returns within twenty nautical miles are contaminated by ground clutter. The basic displayed result is the Base Reflectivity (reported in decibels of reflectivity or dBZ); Figures 1 and 2 are base reflectivity images.

***Figure 3**: The Boston (BOX) WSR-88D radar in Taunton, MA — photograph by the author*

The radar operates in two modes: Precipitation and Clear-Air. Precipitation Mode is triggered whenever storms are detected, since it results in faster generation of data (more data sets per hour). Clear-Air Mode is more sensitive, slower, and results in more detailed data sets. Base reflectivity usually ranges from 5 to 75 dBZ in the Precipitation Mode and from –64 to +64 in the Clear-Air Mode.

Doppler radar relies on the Doppler effect to generate estimates of target velocity. The classic example of the Doppler effect is the sound of a train whistle as the train approaches the listener and then recedes. The frequency (pitch) of the whistle appears to increase as the train approaches (due to compression of the wave form) and decrease as the train moves away (expansion). The faster the train is moving, the faster the change in pitch. These changes in frequency can be measured and provide information on the velocity of the target. Perhaps the best known example of Doppler radar is the speed gun used in traffic enforcement (or the similar unit used for determining the speed of a pitch in baseball).

In the case of the WSR-88D radar, it is important to note that it can only measure radial velocity, that is, speed parallel to the beam. Hence, objects moving directly at or away from the radar are well detected, objects moving perpendicular to the beam are not (Figure 4). When viewing NEXRAD velocity scans, remember that negative numbers indicate objects moving directly toward the radar; positive numbers mean objects moving directly away. Objects moving perpendicular to the beam have near zero radial velocity (no matter how fast they may be moving relative to the ground). Background velocity information indicates wind speed (as detected by general returns from dust and other passive sources). Radial velocity images are reported in knots (kts). Objects traveling faster than the wind, or across or upwind, tend to be biological (birds, insects, bats, etc.).

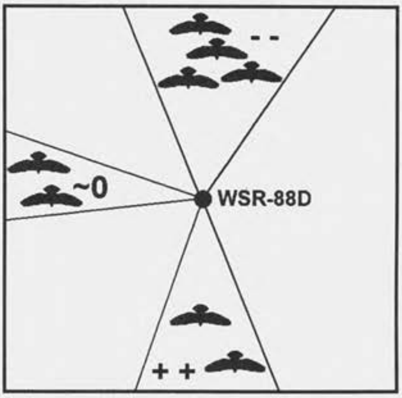

***Figure 4**: Doppler radar detection of radial velocity: Objects approaching have negative velocities, objects going away have positive velocities, objects moving perpendicular to the radial beams are not well detected.*

Birds on Radar

Like any airborne object, birds reflect microwaves and can be detected by radar, often using both the reflectivity and velocity scans. Of course, if the number of birds in a volume of airspace is low, then the likelihood of detection decreases. If the birds are flying very low (under the beam) or directly above the radar, they cannot be detected. Birds migrating at night are commonly most dense at around 1500 feet above ground, though some fly much higher. Diurnal migrators, such as raptors, commonly travel at up to 5000 feet. Based on the one-degree beam width, the 0.5-degree elevation of the beam gives optimal bird detection within the effective range of the beam, and often results in a donut-shaped pattern of detectable birds around the radar installation (none too close, none too far away). For a more detailed description of this phenomenon, visit the Clemson University Radar Ornithology Laboratory (CUROL) web site <http://virtual.clemson.edu/groups/birdrad/>, which has an excellent tutorial on radar.

Raptor Migration and Radar

One of the more celebrated discoveries of weather radar ornithology is the mapping and display of raptor migration, particularly near choke points that tend to concentrate birds. For instance, the annual migration of Broad-winged Hawks between North America and Central and South America tends to funnel birds along the western coast of the Gulf of Mexico, since soaring birds do not like to cross water.

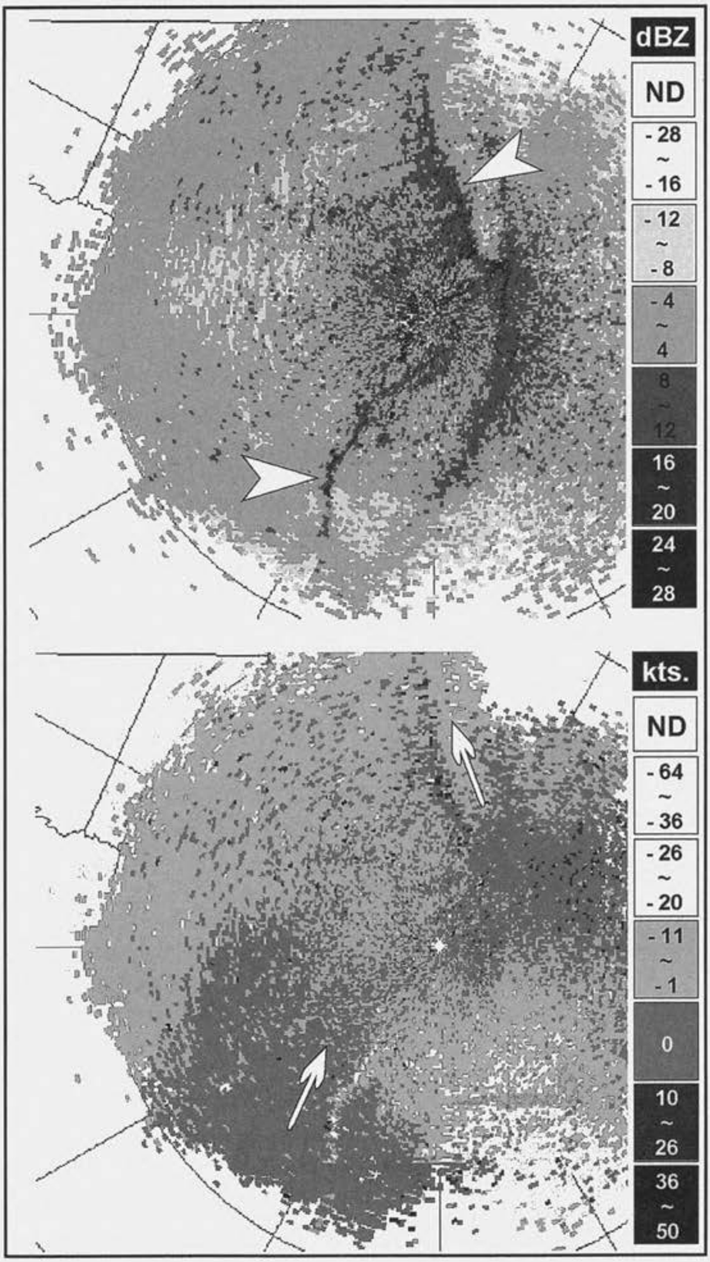

Figure 5: *Heavy streaming of raptors over Galveston, TX, in the spring of 2000 — (Upper) Base Reflectivity in dBZ, (Lower) Radial Velocity in knots. These images were obtained from, and are used with the permission of, the Clemson University Radar Ornithology Laboratory, Director, Dr. Sidney A. Gauthreaux. See text for details.*

Hence, the weather radars in Houston, Corpus Christi, and Brownsville are occasionally the focus of attention as long skeins of migrating raptors show up. In the early 1990s, this NEXRAD phenomenon was noticed and publicized by Frank S. Peace <web.we.net/~fspeace/>.

An example from the CUROL web site is shown in Figure 5 (these images were modified so that they could be printed in black-and-white). They show the Base Reflectivity and Velocity images from Brownsville, TX, on April 23, 2000, at 19:17 UTC (1:17 p.m. CST). Note the long skeins (arrowheads) of high dBZ returns to the north and south of the radar in the base reflectivity image (top). In the velocity image (bottom), you can see that the objects detected are actually moving rapidly from the south toward the radar, and away to the north (arrows) under light northwesterly winds. We know that these are probably mostly Broad-winged Hawks, Swainson's Hawks, and Turkey Vultures, because of the date and the flight pattern. Raptors and other soaring birds ride thermals, columns of rising air, until they run out of lift, and then they stream off at relatively high speed until they hit the next thermal. These images show birds streaming. Years of work by the CUROL researchers, lead by Dr. Sidney Gauthreaux, many researchers from other institutions, and volunteers, using hawkwatches, moonwatches, and other techniques, have verified (ground-truthed) the interpretation of these and other radar-detected phenomena.

Finally, estimates of the numbers and density of birds can be made on the basis of these radar observations. A high for the BirdCast (see below) program in the spring of 2000 was about 2000 birds per cubic kilometer. A tutorial on the acquisition, interpretation, and display of migration patterns of raptors using weather radar has recently been published by Dr. Gauthreaux (Gauthreaux, S.A., Jr., C.G. Belser, and A. Farnworth. 2001. How to use Doppler Weather Surveillance Radar to Study Hawk Migration. In *Hawkwatching in the Americas,* K.L. Bildstein and D. Klem, Jr., Eds., North Wales, PA: Hawk Migration Association of North America, pp. 149-160).

BirdCast

In the spring of 2000, a unique partnership between the National Audubon Society, the Cornell Laboratory of Ornithology, CUROL, and Philadelphia's Academy of Natural Sciences, with the financial backing of the U.S. EPA, culminated in the pilot radar ornithology project called BirdCast. During that spring, unfiltered and filtered NEXRAD images from the Philadelphia, Baltimore, and Washington, D.C. areas, and commentary and predictions from CUROL, were posted at <www.birdcast.org>. Part of the rationale for this project was to provide a mechanism for ground-truthing the radar data. For instance, if the radar suggested a major fall-out at a location, did ground observers actually see the birds there? Volunteers checked locations regularly for bird activity. All of these observations were compared online with the predictions based on the radar images. While not all of the data have been analyzed from that first year, the calculations and algorithms have proven fairly accurate. You can see some of the results at the web site <www.birdcast.org>. This site had over 3.2 million hits during the fall 2000 migration period.

The BirdCast project ran again this last spring (April 1 to May 31, 2001) and hopefully will be up and running for this fall migration season (funding was uncertain at press time). Check the BirdSource web site <www.birdsource.org> for updates on the status of BirdCast or any potential successors.

Do-it-yourself radar ornithology

WSR-88D data are available on the internet from a few sources. The most complete source is a subscription to WeatherTAP.com (at press time: $5.95/month or $63/year), which includes real-time data from all 150 of the WSR-88D sites (base reflectivity, radial velocity, and many other images), as well as downloadable loops of images. WSI Intellicast <www.intellicast.com> is free, and a fine source of WSR-88D base reflectivity images and loops. Unfortunately, Intellicast does not show radial velocity; the storm relative mean radial velocity that they do show is not useful for bird movements. You can also obtain base reflectivity images and loops directly from NOAA at <weather.noaa.gov/radar/national.html>. All of these images and loops are in GIF format, and the loops can be dissected into individual images (see Figure 4) using various computer software packages (I use Paint Shop Pro and Animation Shop by Jasc Software, Inc.).

Various projects/studies using radar

Weather radars have been used to study bird migration, distribution, and behavior in many other contexts. Weather radar has detected the fall-out of migrants on the Texas, Louisiana, and Alabama coasts and inland migration pathways. Portable radar units of different types have been used to count Marbled Murrelets in the Pacific Northwest. Some tracking radar units are capable of determining flap frequency, and therefore suggesting species of migrants. For these and other avian uses of radar, see the links at the end of this article.

Radar ornithology can have many practical applications for the birder. Certainly, the BirdCast information is useful for birders in the covered area, as well as generally interesting for all. Moreover, as described above, analysis and interpretation of WSR-88D data, while complicated, can be accomplished by anyone with Internet access and persistence. So, go explore the following web sites and see how you can have the National Weather Service help you find out about birds, instead of just weather.

Weather Radar and Radar Ornithology Web Sites:

Clemson University Radar Ornithology	virtual.clemson.edu/groups/birdrad/
BirdCast	www.birdcast.org
BirdCast NEXRAD interpretation	www.birdcast.org/interpret-nexrad.html
Radar Biota by Frank S. Peace (very slow to load but very interesting)	web.we.net/~fspeace/
NOAA Radar Information	www.srh.noaa.gov/radar/radinfo/radinfo.html
NEXRAD Radar Operations Center	www.roc.noaa.gov/
Accuweather Doppler Radar FAQs	personal.accuweather.com/iwxpage/paws/dopplerfaq.htm
Birds of the Upper Texas Coast	texasbirding.simplenet.com/nexrad/

Israeli Bird Radar Pictures www.birds.org.il/IsraeliBirdRadarPics.asp
Wind Profilers, Weather Radar and Birds www.msc-smc.ec.gc.ca/armp/king/radar/profbird.html
McGill U. (J.S. Marshall Radar Observ.) grappa.meteo.mcgill.ca/bird_migration.html
Weather Radar and its Application to Ornithology (meeting agenda and abstracts)
www.physics.brocku.ca/faculty/black/Galveston/agenda.html
Noel Wamer has posted a couple of interesting radar loops (including the original for Fig. 4)
www.badbirdz.com/ktby031401.htm
www.badbirdz.com/tlh062801.htm

Get your own images:
WeatherTAP www.weathertap.com
Intellicast Base Reflectivity images
www.intellicast.com/LocalWeather/World/UnitedStates/BaseReflectivity/
NOAA weather radar weather.noaa.gov/radar/national.html

Image Software:
Jasc Software (Paint Shop Pro, Animation Shop) www.jasc.com

Other types of radar, other types of bird studies:
Radar Studies of Marbled Murrelets www.fs.fed.us/pnw/olympia/wet/1999/radar.htm
www.nmnh.si.edu/BIRDNET/PacBirds/mamusurvey/mamuprotocol.html (see Appendix G)
Wing beat frequency (commercial) www.picotech.com/applications/signature.html
Center for Conservation Research and Technology www.ccrt.org/home.html

If you get tired of birds:
Radar Entomology Web Site www.ph.adfa.edu.au/a-drake/trews/
Entomological Radar Studies scrl.usda.gov/scrl/imms/radar/radar-insect-detection.htm
Dragonfly Migration Project Web Site members.bellatlantic.net/~dbarber/migrant/mig.html
Bats by radar www.batcon.org/batsmag/v14n3-3.html
virtual.clemson.edu/groups/birdrad/comment.htm

***David M. Larson** is the Production Editor of Bird Observer.*