AIRE: Aeroecological Interdisciplinary Research and Education

Advanced Radar Technologies for Studying Organisms in the Aerosphere

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Summary

- Aeroecology is an emerging discipline that has extraordinary potential for addressing transformative questions concerning the ecology of airborne organisms at broad spatial and temporal scales. Answers to these questions promise to greatly improve our understanding of the effects of global phenomena such as climate change and anthropogenic impacts on biodiversity and ecosystem integrity as well as to inform environmental management decisions.
- Weather radars (including national networks such as NEXRAD) currently collect enormous quantities of data in both real-time and in archived databases that offer vast potential for advancing research in aeroecology. In addition, ongoing advances in portable radar technology hold considerable promise for revolutionizing our understanding of climate change and the behavior of organisms in the aerosphere.
- Current radar products have limited utility for biological investigations owing, in part, to a lack of collaboration and understanding among radar scientists, atmospheric scientists, and ecologists, that results in a largely underutilized database of biological targets in the aerosphere and a paucity of tools with the resolution and capacity to detect and discriminate among organisms in the lower-most strata of the atmosphere where biological targets are most prevalent.
- Development of novel tools and radar products, such as continental scale "bio-scatter" maps, algorithms for distinguishing biological targets from weather-based targets, 3-D rendering of biological targets, quantification of aerial biomass, and a web interface for product dissemination and visualization, promise to advance research outcomes and educational outreach in aeroecology.

Aeroecology is an emerging scientific discipline that integrates diverse fields, such as atmospheric science, earth science, geography, ecology, computer science, computational biology, and engineering to broaden understanding about the ecological function and biological importance of the aerosphere (Kunz et al. 2008). The unifying concept underlying this new transdisciplinary field of study is a focus on the planetary boundary layer and lower free atmosphere (*i.e.,* the aerosphere), and the myriad airborne organisms that inhabit and depend upon this aerial environment for their existence. Because of their ability to move over large spatial scales, volant organisms such as birds, bats, and insects, contribute to the ecological integrity of multiple ecosystems that span geopolitical boundaries linked by migration or dispersal through the aerosphere. Investigating the behavior and movements of animals in the aerosphere presents formidable challenges, requiring creative integration of novel technological advances for data acquisition and analysis. Through its transdisciplinary approach and emphases on biotic-abiotic interactions at multiple spatial and temporal scales, aeroecology holds considerable promise for advancing understanding of the effects of global phenomena such as climate change and anthropogenic alteration of diverse landscapes on biodiversity, global health, and ecological integrity (Kunz et al. 2008).

Remote sensing tools offer exciting opportunities for investigating ecological processes at spatial and temporal scales that have traditionally thwarted authoritative understanding of ecological dynamics in the aerosphere. The NOAA National Weather Service (NWS) maintains and operates 159 Weather Surveillance Doppler Radar (WSR-88D) installations known as NEXRAD (Crum and Alberty 1993).

This network provides near contiguous coverage of the air space roughly covering the lowest 10 km for the continental United States.

NEXRAD data are continuously archived and made publicly available through the National Climatic Data Center (NCDC), providing an invaluable asset for broad-scale longitudinal studies. The benefits and uses of NEXRAD for weather monitoring and forecasting are well known; however, the use of this radar network for aeroecological studies remains limited. The capacity of radars to detect biological scatterers in the aerosphere has been known for 50 years and NEXRAD data have been used since the 1990s for quantifying coarse movement patterns of birds, flying arthropods, and bats by using clear-air mode reflectivity values to detect and track these biological targets (Gauthreaux and Belser 1998, Gauthreaux and Belser 2003, Diehl and Larkin 2005, Gauthreaux et al. 2008, Horn and Kunz 2008, McCracken et al. 2008). NEXRAD currently has a limited ability to reliably discriminate among targets of different biological origins, but operational upgrades to support dual-polarimetric capabilities to existing NEXRAD installations should greatly enhance abilities to discriminate among types of biological targets within the next five years.

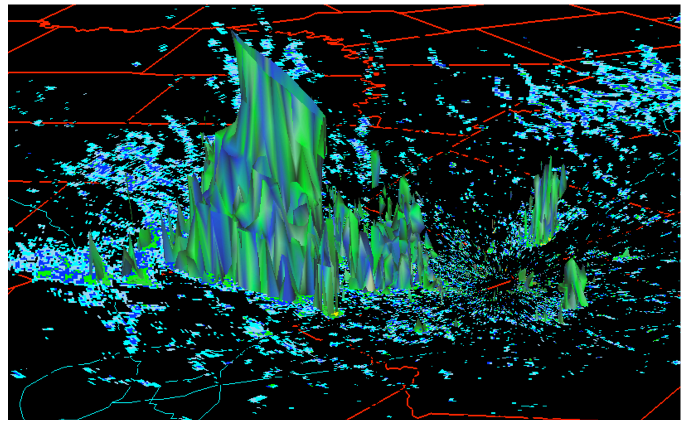

Fig. 1. 3-D isosurface of WSR-88D weather radar reflectivity (20 dBz) depicting a bio-cloud of Brazilian free-tailed bats (*Tadarida brasiliensis*) emerging from Bracken Cave, Texas on 15 July 2009 at 00:08 UTC.

In addition to NEXRAD, numerous other technologies exist for advancing radar aeroecology. For example, bio-scatter data from civil networks of terminal Doppler weather radars (TDWR) and air route surveillance radars (ARSR), tracking radar (Larkin et al. 2008, Westbrook 2008) could also provide valuable resources for understanding movements of airborne organisms, if these devices and their data outputs were made widely available. Additionally, the NWS maintains and operates a network of vertically pointing atmospheric radars known as wind profilers (Benjamin et al. 2004). The NOAA Profiler Network (NPN) regularly records biological scatter and these signals as well as those collected by other wind profilers (Wilczak et al. 1995), if properly processed, could provide an extraordinary resource for quantifying the distribution and movements of organisms in the aerosphere. Similarly, there are numerous small scanning radars designed to probe the air space close to the Earth's surface, which could be more effectively employed to advance radar aeroecology. Data from these systems will be invaluable for ground-truthing and validating results from network-wide (e.g. NEXRAD) studies as well as for investigating behavioral patterns of organisms at smaller spatial scales. These relatively small radars can function as fixed location installations such as those currently being tested by CASA (Collaborative Adaptive Sensing of the Atmosphere) or as mobile units capable of deployment at specific points of interest (Kunz et al. 2007). Several different types of mobile weather radars are applicable for aeroecological research and some mobile radars have been specifically developed and engineered for observing birds, bats, and insects in the aerosphere (Westbrook and Wolf 1998, Feng et al. 2004, Bruderer and Popa-Lisseanu 2005, Zhang et al. 2006). Most recently, the mobile MERLIN and VESPER radars produced by DeTect, Inc. have been used to quantify movements of aerial organisms for migratory research and avian risk assessment associated with operational wind energy facilities. Auxiliary devices, such as thermal imaging cameras and acoustic monitoring devices, can be used to validate and augment data from these small-scale mobile radar instruments (Gauthreaux and Livingston 2006, Kunz et al. 2007).

Despite a history of interest in using radar for biological research, persistent and significant limitations remain in using existing systems for biological monitoring and aeroecological research. In part, these problems stem from: 1) lack of a robust biological nexus within the radar community and conversely a lack of familiarity of radar products among ecologists; 2) absence of radar product outputs focused on bio-scatter; 3) the manner in which radar output data are filtered prior to release to the public; and 4) paucity of available funds to adequately address these concerns. The AIRE collaboration seeks to address these limitations and advance the study of aeroecology by assembling a diverse group of ecologists, atmospheric scientists, and radar scientists to identify and develop specific radar products with utility for scientific research and monitoring of airborne organisms and their biotic-abiotic interactions. Specifically, we have identified several types of radar products from existing installations, including:

- Continental scale "bio-scatter" maps
- Algorithms for discriminating biological targets from weather
- Algorithms for discriminating among aerial organisms based on dual-polarization characteristics
- 3-D volume rendering of biological "clouds" for assessing biomass of airborne targets
- Web portal interface for bio-scatter data dissemination and visualization for public education

Radar aeroecology has great potential for transforming scientific investigations in a diversity of research arenas. For example, these proposed products will be valuable for research on such topics as daily and nightly dispersal, migratory patterns, foraging behavior, distribution and quantification of aerial biomass, aerial biodiversity, phenological patterns related to climate change, impacts on land use policy, and so forth. In addition to basic scientific research, radar aeroecology has the potential to make significant contributions to human society by providing information on issues ranging from aviation safety, agricultural productivity, and siting of wind energy facilities. We expect that public dissemination of these radar products and tools will promote cutting-edge investigations from the greater research community, and also generate considerable interest associated with citizen science activities.

Given global threats to biodiversity, emerging infectious diseases, and the need to sustain ecological integrity, pressing needs exist for scientists to identify and use creative technological and analytical solutions for understanding biological phenomena at broad spatial and temporal scales in the aerosphere (Kunz et al. 2008). By developing new analytical and interpretive tools from existing and emerging radar technologies, the AIRE project will encourage scientists and citizens from a diverse set of disciplines to address contemporary conservation and ecological questions in unprecedented and transformative ways.

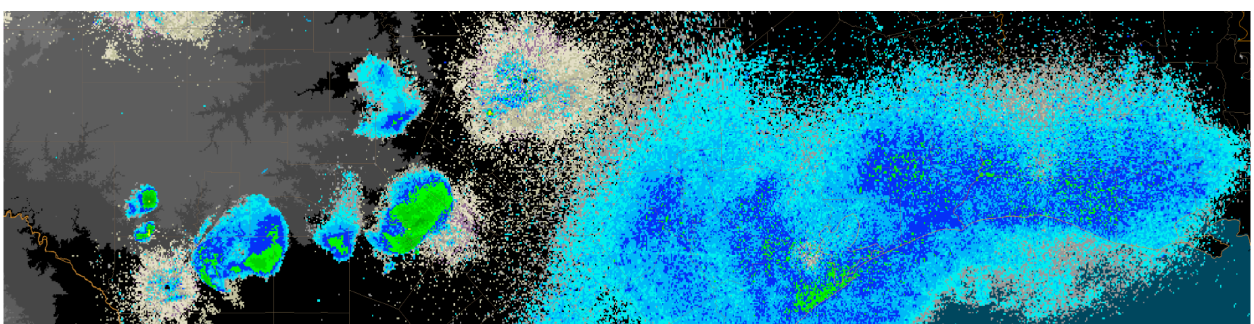

Fig. 2. Mosaic of WSR-88D weather radar composite reflectivity from 8 NEXRAD installations spanning from Del Rio, Texas to the gulf coast of Louisiana. Nine bat emergences are visible as distinct polygons of reflectivity. A 400 km swath of reflectivity along the gulf coast depicts birds movements on shore from flights over the Gulf of Mexico. Concentrated regions of volant arthropods are also visible. The image is valid for 01:25 UTC on 5 May 2009 with horizontal resolution of 1x1 km.

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