WEATHER RADAR EDUCATION AT THE UNIVERSITY OF OKLAHOMA: AN INTEGRATED INTER-DISCIPLINARY APPROACH

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Abstract

In recent years, the University of Oklahoma (OU) has invested heavily in the development of a strategic research initiative in radar meteorology. Several new faculty members, with interests in weather radar, have joined both the School of Meteorology (SoM) and the School of Electrical and Computer Engineering (ECE). This inter-disciplinary group of energetic meteorologists and engineers has established the Atmospheric Radar Research Center (ARRC) [Palmer et al., 2007]. The ARRC supports a broad portfolio of research interests, including radar polarimetry, phased array radar, profiling radar, advanced signal processing, retrieval algorithms, clutter mitigation, severe storm observations and detection, quantitative precipitation estimation, and general studies of atmospheric physics. In addition to research, one of the fundamental goals of the ARRC is providing OU students with a comprehensive, challenging education in the area of radar meteorology, emphasizing both the engineering and meteorological aspects of the field. A summary of the educational program in weather radar at OU is provided along with more specific information about the courses, which emphasize experimental design, operation, data analysis, and interpretation.

1. INTRODUCTION

Stemming from the educational activities of the ARRC, the weather radar curriculum at OU was completely reorganized in 2004. The underlying goal was to create a true inter-disciplinary environment where meteorology and engineering students would interact and learn from each other's experiences and backgrounds. In addition, the new curriculum was designed with a significant hands-on experience for the students by augmenting formal lecture courses with in-depth projects, including both hardware and data analysis themes. The development and use of Doppler radar and other meteorological instrumentation is an area where the interdependence between science and engineering is strong and where deficiencies in our current educational system are of concern [Takle, 2000; Committee on Engineering Education, 2005].

Here, a general overview of the weather radar curriculum development effort will be provided. In addition, specific information on courses and future plans are given.

2. GENERAL PHILOSOPHY AND GOALS

We achieve our educational goals, in part, by the creation and continual maintenance of a synergistic curriculum that synthesizes the complementary disciplines of meteorology and electrical/computing engineering. As an integral component of the weather radar curriculum, an innovative and coherent sequence of radar-related courses has been developed which serves both our undergraduate and graduate educational goals. The undergraduate phase of the program is the ideal time to excite students about pursuing graduate studies in the general area of instrumented observations of the atmosphere and in particular weather radar. This curriculum is not independent of the more traditional curricula of the two disciplines, but rather forms an important and integral component of them.

Given the importance of weather radar for many observational studies of atmospheric phenomena, it is essential to include a significant hands-on experience for the students [Cohn et al., 2006]. Our curriculum provides a complete theoretical framework with which to understand weather radar theory while also providing access to local weather radar systems. We have developed laboratory modules for many of the radar courses using the SMART radars, the PAR, the CASA IP-1 X-band radars, and the KOUN polarimetric Doppler radar. Experimental design, operation, data analysis, and interpretation are

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emphasized. It should be noted that the educational activities, within the ARRC, have been partially supported by the National Science Foundation's Division of Undergraduate Education through its Course, Curriculum, and Laboratory Innovation (CCLI) program.

With the goal of facilitating interdisciplinary participation, the courses that comprise this curriculum are generally cross-listed between ECE and SoM. By doing so, the standard requirements of each department are satisfied while allowing students the opportunity to participate in this program. Many of our radar courses could be considered difficult, even within ones own discipline. When taught by a faculty member from another department or when the emphasis is on an unfamiliar discipline, it is often difficult to fully engage in the course. As a conscious design decision in our courses, every effort is made to review necessary material during class with the goal of encouraging educational diversity among the students. Our faculty consists of scientists and engineers who have engaged in interdisciplinary research and education for years and are fully aware of the challenges of such endeavors. More importantly, we are keenly aware of the benefits of seamlessly integrating the disciplines and have organized this unique curriculum with this in mind.

3. COURSE DEVELOPMENT EFFORT

A summary of courses, which make up the Weather Radar and Instrumentation Curriculum at OU, is provide in Figure 1. As can be seen, the courses span both the undergraduate and graduate curricula. Many of the courses are new and others have been substantially modified. The specific topics for each course, and the continuity between courses, were compiled from the input of faculty members and scientists from OU, and other local interested groups. As mentioned earlier and with few exceptions, courses are cross-listed between meteorology and electrical/computing engineering. As the program develops and the research field evolves, it is anticipated that new courses may be added and others removed or significantly modified. Such changes are necessary, encouraged, and specifically designed into the administration of the curriculum.

More specific information concerning the content of the radar courses in the Weather Radar and Instrumentation Curriculum at OU is provided below.

- Radar Meteorology: This course develops quantitative relationships between the physical characteristics of a scatterer or set of scatterers illuminated by radar and the weather signal parameters measured by radar. The capabilities and limitations of the various radar system designs are examined to determine their impact on applications. A full treatment of Doppler principles, including interpretation of Doppler radar data, is provided. Polarimetric and phased array radar are introduced. Experience is gained in hands-on exercises with weather radars.

- Remote Sensing and Experimental Design: Overview of both in-situ and remote sensing instrumentation and principles. Ground-based, airborne, and satellite systems are covered. Radiometry for liquid/vapor water path estimation and temperature profiling are discussed. Optimal use of instrumentation for meteorological field campaigns is emphasized.

- Weather Radar Theory and Practice: Following an introduction to electromagnetic waves and propagation through the atmosphere, fundamental radar principles and trade-offs are covered in this course. Introductory coverage of antennas, transmitters, and coherent receivers are provided. All relevant theory is derived from basic electromagnetic theory. The radar signal is treated as a noise-corrupted stochastic process and appropriate mathematical tools developed. Derivation of the weather radar equation for both Rayleigh and Mie regimes is covered. Fourier analysis is introduced with particular emphasis on discrete-time signal processing. The Doppler spectrum and associated moments are discussed. Digital signal processing methods are developed for the estimation of the Doppler spectrum and the important meteorological information contained therein. Emphasis is placed on the implementation of processing algorithms using actual Doppler radar data.

- Weather Radar Applications: This course builds on the concepts that were presented in Weather Radar Theory and Practice. A variety of methods are presented to assist the student in identifying and interpreting meteorological structures using weather radars. An introduction to the interactions of electromagnetic waves in geophysical media is given. In particular, scatter from hydrometeors and refractive index variations are explored. The course presents quantitative precipitation estimation methods based on the radar reflectivity factor, attenuation, and dual-polarization observations. Students are introduced to the fundamental concepts of clear-air echoes and the estimation of winds under non-precipitating conditions. Throughout the course, emphasis is placed on the imple-

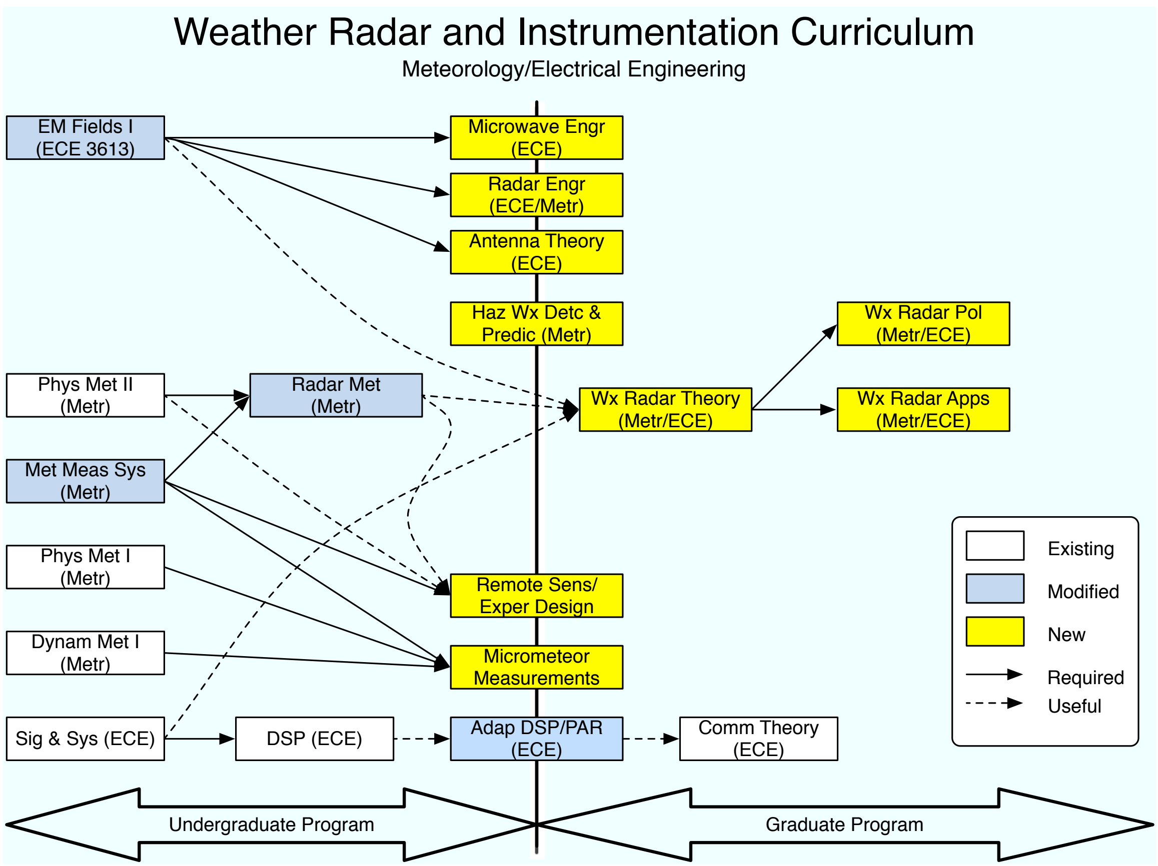

Figure 1: Diagram of the courses which compose the Weather Radar and Instrumentation Curriculum at the University of Oklahoma. Undergraduate and graduate courses are on the left and right side of the figure, respectively. Prerequisites are denoted through either dashed or solid lines.

mentation of processing algorithms using actual Doppler radar data.

- Weather Radar Polarimetry: This course provides fundamentals and principles for radar remote sensing through the understanding of wave scattering and propagation in geophysical media subjected to turbulent mixing and filled with hydrometers and other objects. The relations between polarization radar variables and physical parameters are established. Remote sensing techniques and retrieval methods for microphysics and transverse wind are introduced. Students learn why and how radar polarimetry and interferometry are used in weather studies: classification, detection, quantification and forecast.
- Antenna Theory: Radiation characteristics of antennas focuses on electrically large antennas found in meteorological applications. Methods of analysis for antennas and feed/radiating element components are addressed at circuit level. The student is taught to understand the influence of antenna performance of contemporary components viv overall radar system performance.
- Radar Engineering: The course introduces various radar system designs and their applications with an emphasis on weather radar. Radar system architecture and their functionalities and limitations of subsystems are discussed. Theories of radar detection and estimation in a noisy and clutter environment are examined. Existing technologies and advanced techniques to improve radar performance are provided.
- Adaptive DSP and Array Processing: Students learn the theory behind modern-day adaptive digital signal and array processing. Students are given a solid foundation of adaptive algorithms and the adaptive filter design process. Emphasis is placed on theory, as well as practical processing of real data.

4. CONCLUSIONS AND FUTURE PLANS

By many measures, the Weather Radar and Instrumentation Curriculum at OU has been a success, largely due to the vast radar infrastructure available in Oklahoma and the experience and participation provided by our NOAA partners. Currently, an approximate enrollment of 100 total students are participating in our radar courses every year. Given the hands-on emphasis, we anticipate managing this number in order to keep a quality, challenging experience for the students.

Plans are currently underway for the development of inter-disciplinary minors at the undergraduate level. In addition, a specific weather radar graduate program is planned between SoM and ECE in the near future. Our courses are continually evolving depending on interest and change in focus areas of the community. However, coordination of the overall curriculum is maintained through close communication within the Norman weather radar community providing a well-organized, challenging experience for our students.

Further information on the weather radar educational program at OU can be found at `http://arrc.ou.edu`.

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