ATMO 489: Radar Meteorology

Fall 2006 Course Syllabus

Instructor

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Teaching Assistant

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Course Schedule

Lecture: WF 12:40 – 1:30 PM, O&M 1210
Lab: M 11:30 – 1:30 PM, O&M 1201

Prerequisites

PHYS 208 or 219; ATMO 352

Course Objectives

As the class title states, this is a class in *radar meteorology* – the study of the atmosphere and weather using radar as the means of observation and measurement (Glossary of Meteorology, 2000). The principals and theory of radar operations, hardware, and analysis are covered using a physical approach supplemented by mathematical rigor when necessary. The foci of this class are on the 1) inner workings and operations of radar systems, 2) theory of radar remote sensing, and 3) identification, interpretation and analysis of operational and advanced research radar data and imagery. The class will be taught at an advanced undergraduate level. Little or no prior knowledge of radars is assumed.

To develop an understanding of Doppler radar hardware and operations, we will explore and operate the TAMU ADRAD (Aggie [rooftop] Doppler Radar, S-band). We will have the opportunity to view and interpret data from many other radars including the collaborative (TAMU, TTU, OU, NSSL) SMART (Shared Mobile Atmospheric Research and Teaching) radars (C-band, Doppler) (http://www.nssl.noaa.gov/smartradars/). In addition, we will have the chance to remotely explore and operate the National Science

Foundation (NSF) owned and Colorado State University (CSU) managed CSU-CHILL National Radar Facility (http://www.chill.colostate.edu/) via the Virtual CHILL system (V-CHILL, http://chill.colostate.edu/vchill/). The CSU-CHILL is an S-band polarimetric radar. See the class web page (http://www.met.tamu.edu/class/ATMO489-LC/) for more links to other research and operational radars.

Radar observations of meteorological (e.g., clouds, precipitation) and non-meteorological (e.g., insects in the clear-air) phenomena at multiple scales are considered – convective cells, multicell storms, gust fronts, sea breezes, rain and flash flood producing storms, snowstorms, microbursts, supercell storms, mesocyclones, tornadoes, hailstorms, electrical activity, squall lines, mesoscale convective systems and vortices, hurricanes, fronts and widespread precipitation. To fully explore these phenomena, computer-based directed learning and case studies are utilized.

Analysis includes the estimation of precipitation rates, identification of hydrometeor types and the determination of air motion in precipitation and the clear-air. Conventional, Doppler (both single- and multi-Doppler), dual-wavelength and polarimetric radar observations and techniques are discussed. Although the emphasis is on fixed ground-based precipitation radars, cloud radars and mobile- (vehicle), aircraft-, ship-, and space-based radars are also considered.

Required Textbook

Rinehart, Ronald E., 2004: *Radar for Meteorologists*, 4th Ed, Rinehart Publications, ISBN: 0-9658002-1-0, approximate cost: $40, http://radarwx.com.

Required reading will be assigned from Rinehart (2004) to accompany lectures, which will include supplementary material from the following books and reference material.

Other Recommended Books

Atlas, David (Ed.), 1990: Radar in meteorology: Battan Memorial, American Meteorological Society.

Battan, Louis J., 1973: *Radar Observation of the Atmosphere*, The University of Chicago Press (out of print).

Bringi, V. N. and V. Chandrasekar, 2001: *Polarimetric Doppler weather radar: principles and applications*, Cambridge University Press.

Doviak, Richard J. and Dušan S. Zrnić, 1993: *Doppler radar and weather observations,* 2nd Ed, Academic Press.

Meischner, Peter (Ed.), 2004: *Weather Radar: Principles and Advanced Applications*, Springer-Verlag.

Meneghini, Robert and Toshiaki Kozu, 1990: *Spaceborne Weather Radar*, Artech House Publishers.

Wakimoto, Roger M. and Ramesh Srivastava (Eds.), 2003: *Radar and atmospheric science: A collection of essays in honor of David Atlas*, American Meteorological Society.

Reference Material

Several professional journals published by the American Meteorological Society (e.g., Journal of Applied Meteorology, Journal of Oceanic and Atmospheric Technology, Bulletin of the American Meteorological Society, Monthly Weather Review, Journal of Atmospheric Sciences and Journal of Hydrometeorology), the American Geophysical Union (e.g., Journal of Geophysical Research – Atmospheres, Radio Science) and others contain useful information on radar meteorology theory, methods and applications.

Tentative Course Outline

<u>WEEK 1</u>: *Introduction to radar meteorology*

Summary: Course overview, history of radar and radar meteorology, introduction to radars, operations, and applications.
Reading: Rinehart (2004) Ch. 1

<u>WEEK 2:</u> *Radar hardware and operations*

Summary: Overview of the simplified block diagram of a radar and associated radar hardware, including the transmitter, waveguide, antenna, receiver, and signal processor; radar scanning strategies, operations and calibration.
Reading: Rinehart (2004) Ch. 2

<u>WEEK 3:</u> *Electromagnetic (radar) waves*

Summary: Review of the electromagnetic spectrum, basic electromagnetic theory, refractive index, refractivity, earth curvature, standard refraction, non-standard refraction and associated meteorological conditions.
Reading: Rinehart (2004) Ch. 3

<u>WEEK 4:</u> *Radar equation*

Summary: Radar equation for a point target, backscattering from a sphere, introduction to Rayleigh and Mie scattering, other point targets.
Reading: Rinehart (2004) Ch. 4

<u>WEEK 5:</u> *Distributed targets*

Summary: Distributed targets, time-to-independence, radar sample volume, radar equation for distributed targets, complex index of refraction revisited, Rayleigh and Mie scattering revisited.
Reading: Rinehart (2004) Ch. 5

WEEK 6: *Radar reflectivity*

Summary: Radar reflectivity, radar reflectivity factor and effective radar reflectivity factor; Logarithmic units and dBZ; calculation of reflectivity from hydrometeor size spectra.
Reading: Rinehart (2004) Ch. 5

WEEK 7: *Doppler velocity*

Summary: Doppler velocity, block diagram of a Doppler radar, maximum unambiguous range and velocity, recognizing range and velocity aliasing, other velocity artifacts.
Reading: Rinehart (2004) Ch. 6

WEEK 8: *Doppler spectrum*

Summary: Image recognition of idealized Doppler velocity wind patterns, Doppler spectrum, spread of the Doppler spectrum and spectrum width, sources of variance in Doppler spectrum.
Reading: Rinehart (2004) Ch. 7

WEEK 9: *Meteorological targets*

Summary: Common Hydrometeor Targets – clouds, rain, snow, bright band, and hail; rainfall size distributions, estimation of rain rate from radar reflectivity, Z-R relationships; examples of radar reflectivity and Doppler velocity from a wide variety of precipitation systems.
Reading: Rinehart (2004) Ch. 8

WEEK 10: *Attenuation*

Summary: Attenuation of radar by the atmosphere, clouds, and precipitation; identifying the presence of attenuation, correcting for attenuation using traditional methods
Reading: Rinehart (2004) Ch. 8

WEEK 11: *Clear-air return*

Summary: Source of clear-air radar returns in the boundary layer (particulates vs. refractive index gradients), detectable wind phenomena (e.g., boundary layer winds, microbursts, gust fronts, seabreeze), ground clutter, measuring refractive index and hence humidity changes from the clear air return.
Reading: Rinehart (2004) Ch. 9

WEEK 12: *Single- and multi-Doppler processing of velocity*

Summary: Single Doppler techniques [e.g., Velocity Azimuth Display (VAD)] and results (e.g., mean wind and divergence profiles). Multi-Doppler networks (including bistatic radars), techniques, and results (e.g., three dimensional winds in various precipitation and clear-air scenarios).
Reading: Rinehart (2004) Ch. 10

WEEK 13: *Dual polarization radar*

Summary: Linear dual-polarization radars, observables, techniques, and results; definition of differential reflectivity, differential phase, and linear depolarization ratio; rain rate estimation, hydrometeor identification, and attenuation correction using polarimetric techniques. Dual-wavelength radars and techniques.
Reading: Rinehart (2004) Ch. 10

WEEK 14: *Mobile radars*

Summary: Mobile ground-based, airborne, ship-based, and space-based radars and applications; cloud vs. precipitation radars.
Reading: Rinehart (2004) Ch. 11

Laboratory Assignments

Students will be given approximately six to seven laboratory assignments (i.e., problem sets or lab exercises). Students will have one to two weeks to complete each assignment. Students can freely discuss and collaboratively work on laboratory assignments. However, answers to lab assignments must be written in the student's own words. The nature of the assignments will vary from traditional problem sets to hands-on LINUX lab (Rm 1201) computer exercises with live or archived radar data. The lab computers will be utilized for many of the homework assignments. Laboratory exercises will make use of several excellent online resources and GARP data (e.g., NIDS reflectivity and velocity and LEVEL III reflectivity composites) for WSR-88D radar image recognition and analyses. In addition, students will utilize The Warning Decision Support System -- Integrated Information (WDSS-II) radar analysis software package) for displaying and analyzing WSR-88D Level II radar data. When possible, we will make use of local radar assets, including the TAMU ADRAD, in laboratory learning exercises.

> *Late Labs:* Lab assignments must be completed promptly. Grades on unexcused, late submissions will be **discounted 10% per day**.

Exams

Exams will be a mixture of short answer, word problem/problem solving, and multiple choice questions. **No unexcused absences**; all other absences and make-up exams should be arranged ahead of time if possible and will be handled in accordance with

University Rules. There will be three examinations, including the final exam. Each examination will cover approximately 1/3 of the class material.

Team Radar Project

The class will be divided into teams of about 3 students to work on radar projects. Teams will be responsible for collecting, analyzing, and interpreting radar data on an approved project of their choice. Collection of data may include team-led operation of the ADRAD during the semester. A short (10 page, 12-point font, double spaced) written report describing the data, methodology (including data collection), results, and conclusions will be due from each team during the last lab. In addition, each team will present a brief (10 - 15 minute) oral summary of their project and findings at the last lab.

Grading Policy

Percentage	**Assignment**	**Date**	**Comment**
25%	1st Examination	Wednesday, 4 October	Covers roughly first 1/3 of class material.
25%	2nd Examination	Friday, 3 November *RESCHEDULED!*	Covers approximately second 1/3 of class material
25%	3rd Examination (Final Exam)	Monday, 11 December **10:30 AM - 12:30 PM**	Covers approximately final 1/3 of class material.
15%	Laboratory Assignments; about 9 labs	Typically due within 7 to 14 days.	Unexcused late lab assignments will be penalized 10% per day.
10% (Oral=3%, Written=7%)	Team Radar Project	*Oral*: Monday, 27 November during lab period. *Written*: Friday, 8 December, 5 PM	Team oral presentation (10-15 minutes). Team written reports (maximum: 10 pages of double spaced text). No late reports or presentations will be accepted. More details given in class.

Letter grades will be assigned based on the following approximate guidelines:

90 - 100%	A
80 - 89%	B
70 - 79%	C
60 - 69%	D
<60%	F

Plagiarism Statement

The materials used in this course are copyrighted. These materials include but are not limited to syllabi, quizzes, exams, lab problems, in-class materials, review sheets, and additional problem sets. Because these materials are copyrighted, you do not have the right to copy the handouts, unless permission is expressly granted.

As commonly defined, plagiarism consists of passing off as one's own the ideas, words, writings, etc., which belong to another. In accordance with this definition, you are committing plagiarism if you copy the work of another person and turn it in as your own, even is you should have the permission of that person. Plagiarism is one of the worst academic sins, for the plagiarist destroys the trust among colleagues without which research cannot be safely communicated.

If you have any questions regarding plagiarism, please consult the latest issue of the *Texas A&M University Student Rules*, http://student-rules.tamu.edu, under the section "Scholastic Dishonesty."

Aggie Honor Code - "*An Aggie does not lie, cheat, or steal or tolerate those who do*."

Upon accepting admission to Texas A&M University, a student immediately assumes a commitment to uphold the Honor Code, to accept responsibility for learning and to follow the philosophy and rules of the Honor System. Students will be required to state their commitment on examinations, research papers, and other academic work. Ignorance of the rules does not exclude any member of the Texas A&M University community from the requirements or the processes of the Honor System. For additional information please visit: www.tamu.edu/aggiehonor/. By signing assignments and examinations at Texas A&M University, the following Honor Pledge shall be understood and thereby signed to by the student:

"On my honor, as an Aggie, I have neither given nor received unauthorized aid on this academic work."

Accommodations

The Americans with Disabilities Act (ADA) is a federal anti-discrimination statute that provides comprehensive civil rights protection for persons with disabilities. Among other things, this legislation requires that all students with disabilities be guaranteed a learning environment that provides for reasonable accommodation of their disabilities. If you believe you have a disability requiring an accommodation, please contact the Department of Student Life, Services for Students with Disabilities in Room B118 of Cain Hall, or call 845-1637.