

METEO 533 - CLOUD PHYSICS

Spring 2005

Instructor: Jerry Y. Harrington

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Class Meetings: 110 Walker Building on Mon., Wed., and Fri.
11:15 am - 12:05 pm

Office Hours: 4:30pm - 5:30pm Mon. and Wed., 1:30pm - 2:30pm Thurs.

Course Textbook: (also on library reserve)

A Short Course in Cloud Physics, 3rd Edition

R. Rogers and M. Yau

QC921.5 R63 1998

Other Recommended Textbooks: On 2-hour reserve in Earth & Mineral Sciences

Library - 105 Deike Building. (Other useful books on separate page)

Title	Author(s)	Call Number
<i>Microphysics of Clouds and Precipitation</i>	Pruppacher and Klett	QC921.5 P78 1997
<i>The Physics of Rainclouds</i>	Fletcher	QC921.5 F55 1962
<i>The Physics of Clouds</i>	Mason	QC921.5 M3 1971
<i>Elements of Cloud Physics</i>	Beyers	QC921.5 B9 1965
<i>Microphysical Processes in Clouds</i>	Young	QC921.5 Y68 1993

Organization and Grading: 3 - credit course, primarily lecture

Mid-term 1 (Mon, Feb 7, 7-9pm. Location TBD)	20%
Mid-term 2 (Mon, March 20, 7-9pm. Location TBD)	20%
Final	20%
Homework	20%
Paper	15%
Participation	5%

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Classroom Policies and Other Notes

Course Objectives and Intent: This course is designed to provide graduate students with diverse backgrounds a foundation in, and an overview of, clouds as typically found in the atmosphere. Our understanding of clouds will develop naturally through examinations of the fundamental physical processes operating across a wide variety of scales. We will place primary emphasis on microphysical properties of clouds since this ultimately determines the evolution of clouds.

Office Hours: These are hours that I have set aside during the week when I will drop what I am doing to assist you with any questions you may have about class (or other academic matters). Although this is the case, I tend to keep an “open door” policy at all other times. In other words, if my door is open, please do not hesitate to stop in if you have questions. As a caveat, please understand if I am too busy at some particular time to take your question. Sometimes, things come up which require my immediate attention. Although this is rare, I do hope you will understand if I ask you to come by at a later time (of course, I will not do this during my posted office hours). A word of warning. I am teaching 3 courses this semester and, because of this, I will be unusually busy. Hence, please do not be surprised if you cannot find me in my office at times other than my office hours. So, my advice would be to come during office hours if you can. If these hours do not work for most people, I will have to revise them.

Homework, Projects, and Tests: As you can see from the grade breakdown, homework is an important part of your grade. It is very difficult to learn the material in any class unless you spend a significant amount of time thinking about the subject matter and actually using the ideas. I try to design homework that accomplishes this. Homework is typically due 1 to 1.5 week(s) after the assigned date (although this will vary). I accept late homework without grade-reduction only if there are extenuating circumstances. Otherwise, I deduct 10 points (out of 100) for each day the homework is late. You will be required to turn in a final paper in this class. I'll discuss what this entails in class. Tests given in this course will be closed book, though a note card and calculators are allowed.

Participation: This is an important component of your education and I hope that you will take advantage of class time to ask questions no matter how “simple” you think they might be. Typically what you will find is that other students are also confused about exactly the same issue. So, ask away! Lets have a good time learning about how clouds work. How does participation figure into the grades? I keep track of who comes to see me, who asks questions/contributes in class, etc. All of these sorts of things go into participation. At the end of the course, I figure grades without participation first. I then look to see if participation boosts your score significantly. This means that participation can only help, not hurt, your grade.

Grades: As you are probably well aware of by now, grades below that of B are rare in graduate school. (That is, as long as you are working hard and learning a lot!) The way I assign grades in cloud physics is the following: At the end of the semester, I compute the mean score for the class. This score is the lowest A-. Scores above it obviously earn some form of an A whereas scores below it earn some form of a B. Please realize that I use this as a rough indicator only. There have been times when I have deviated from this rule. I won't hesitate to assign higher grades when if a

class performs exceptionally well, but I also won't hesitate to assign lower grades if a class performs poorly. Fortunately, I have had a situation like the latter only once in my career!

Textbooks: This course will be taught primarily through in-class lectures and extensive use of texts. As you may have noticed, there are no good, graduate-level, books on cloud physics available. We used to use Pruppacher and Klett's book for this class because of its advanced nature, but not only is it a terrible text, it is also no longer available (you can thank Kluwer for that). I have put all of the books you may need on reserve in the library. I will frequently suggest reading from these books for added insight etc. I highly recommend purchasing Rogers and Yau's *A Short Course in Cloud Physics*. Rogers and Yau's text is concise with good explanations of basic concepts and simple equations that are easy to look up. This makes it an excellent first-choice when you need a quick formula or idea explained. I typically look in R&Y's text first and then go to P&K for details. For those of you new to Atmospheric Science, I would suggest purchasing *Meteorology for Scientists and Engineers* by R. B. Stull (ISBN 0 - 534 - 37214 - 7). This book covers a lot of the basic ideas of meteorology and is a good reference for those with little background in the atmospheric sciences.

Academic Integrity: This is an issue that is of the utmost importance. It is ethically wrong to take the work of other people and attempt to pass it off as your own. Plagiarism and cheating are offenses that can, and will, result in either the failing of a homework/project/test or the entire class, depending on the offense. You can check out Penn State's official position on intellectual integrity at the following site: <http://www.ems.psu.edu/students/integrity/index.html>.

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Course Outline

I. INTRODUCTION

A. Overview of Clouds in the Atmosphere

B. Properties of Water

i. Chemistry of H₂O

ii. Molecular structure of liquid and ice

C. Thermodynamic Concepts

i. First and second laws

ii. Free energies and energy distributions

II. MICROPHYSICAL PROCESSES

A. Phase Nucleation

i. Free energy and nucleation rates

ii. Homogeneous and heterogeneous nucleation of liquid and ice

B. Vapor Deposition

i. Surface physics

ii. Growth equation development for drops and crystals

C. Collisional Interactions

i. Terminal fall speed regimes

ii. Collisions between hydrometeors

iii. Coalescence & break-up of drops

III. POPULATION AND CLOUD-SCALE EFFECTS

A. Supersaturation Development

B. Warm-Cloud Precipitation

C. Cold-Cloud Precipitation

D. Latent-Heat Effects

E. Cloud Electrification

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Useful Review Articles

- Beard, K. V., and H. T. Ochs, 1993: Warm-rain initiation: An overview of microphysical mechanisms. *J. Appl. Meteorol.*, **32**, 608-625.
- Blyth, A. M., 1993: Entrainment in cumulus clouds. *J. Appl. Meteorol.*, **32**, 626-641.
- Hudson, J. G., 1993: Cloud condensation nuclei. *J. Appl. Meteorol.*, **32**, 596 - 607.
- Saunders, C. P. R., 1993: A review of thunderstorm electrification process. *J. Appl. Meteorol.*, **32**, 642-655.

For a review of recent papers in the field try:

- Rasmussen, R. M., 1995: A review of theoretical and observational studies in cloud and precipitation physics: 1991-1994. in *Reviews of Geophysics*, supplement, 795 - 809. U.S. National report to International Union of Geodesy and Geophysics 1991-1994.

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Ideas for Term Papers

1. Microphysical-dynamical interactions (e.g. mass loading, latent heating, entrainment etc.)
2. Precipitation initiation in warm clouds
3. Colloidal stability of mixed-phase clouds
4. Evolution of drop spectra (collision-coalescence, effects of condensation, entrainment, turbulence, breakup)
5. Hail formation (origins of embryos, trajectories, stone morphology)
6. Precipitation efficiency (methods of estimation, physical factors, error analysis)
7. Ice crystal habits (surface kinetics vs. environmental influences, growth models/parameterization)
8. Ice nucleation and cloud glaciation (nature of nuclei, secondary ice production, ice multiplication)
9. Cloud formation at low temperatures and pressures (polar stratospheric clouds, chemical effects)
10. Scale interactions (parameterizations, heating profiles, cloud clustering)
11. Roles of clouds in global climate (radiative properties, energy balance, global water cycle)
12. Cloud condensation nuclei and/or ice nuclei (anthropogenic and natural sources, impacts on climate)
13. Remote sensing of clouds and precipitation (surface-based radar, satellite methods)
14. Aerosol-cloud interactions (scavenging mechanisms, effects on microstructure, effects on dynamics, aerosol modification)
15. Cloud electrification (charge separation theories, effects on global field, lightning, sprites)
16. Cloud chemistry (trace gas scavenging and reactions, acidic rain, regional and global budgets)
17. Many, many others....

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Library Reserve Textbooks

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<i>Storm and Cloud Dynamics</i>	Cotton and Anthes	QC921.6 D95 C67 1989
<i>Clouds and Storms</i>	Ludlam	QC921.5 L83
<i>The Structure and Properties of Water</i>	Eisenberg	QD169.W3E 35
<i>Ice Physics</i>	Hobbs	QC920.H6
<i>The Chemical Physics of Ice</i>	Fletcher	QD931.F48
<i>Atmospheric Science</i>	Wallace and Hobbs	QC861.2.W34
<i>Cloud Dynamics</i>	Houze	QC921.6 D95 H68 1993

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