ATS620
Thermodynamics and Cloud Physics
Fall 2023

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Office hours by appointment or Slack

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Office hours: Wednesdays 2 PM to 3 PM in Room 100 of ATS Main Bld.

Course time and location: 11:00 – 11:50 AM Mon/Wed, ATS West 121

Class Website: https://colostate.instructure.com/courses/166895
Slack channel: CSU Tropical workspace #ats620_f23 (by invitation)

Lectures and discussions will be recorded and live-streamed (Zoom) this semester.
Recordings will be available on the Canvas site. Links will be provided over Slack.

Please contact the instructors if you have special learning needs that should be accommodated in this class, and refer to https://disabilitycenter.colostate.edu/ for more information.

Course Objectives

The intent of this course is to introduce graduate students to key concepts in thermodynamics and cloud physics as applied to the atmosphere. These concepts include energy variables and energy calculations, thermodynamic diagrams, phase changes, and cloud microphysical properties and processes. A particular emphasis is placed on the formation of precipitation in warm and cold clouds.

Course Structure, Expectations and Grading Criteria

Course Material:
Class material will be delivered in lecture and discussion format, meeting for two 50-minute periods each week. Lectures are posted to the class website. At least 4 hours of effort (2 hours per each hour of class time) outside of class each week are expected to complete homework assignments and any outside reading needed to support learning.

Course Grading:
This class is graded on a letter basis, using the +/- options. Students are expected to notify the instructors of any planned absences from class and should make arrangements to make up missed assignments. Homework will be posted on Canvas and will submitted there as well (please take clear photos of or scan written work, do on your computer). The homework due dates, as well as exam dates will be listed on the class calendar online (the "Syllabus" page on Canvas) when the dates are known. Regarding late assignments, for

every weekday that an assignment is late, 10% will be taken off that assignment. *Your course grade will be based on your performance on two midterm exams, one comprehensive final exam and a number (5) of homework assignments. The midterm exams will be weighted 15% each, the final 20%, and the homework assignments 50% of your final grade.*

Course Texts:

There are no required texts for this class. The class slides posted to Canvas are the primary resource for this class. In addition, the following resources may be useful:

- Cotton, ATS620 past notes, available on Canvas. *Please do not distribute these notes outside of CSU.* Note that some nomenclature and explanations are different.
- Schroeder, An Introduction to Thermal Physics, Pearson, 1999.
- Rogers and Yau, A Short Course in Cloud Physics, Pergamon Press, 1989, Third Edition.
- Lohmann, Luond and Mahrt, An Introduction to Clouds from the Microscale to Climate, Cambridge University Press, 2016.
- Lamb and Verlinde, Physics and Chemistry of Clouds, Cambridge University Press, 2011.
- Cotton, Bryan and van den Heever, Storm and Cloud Dynamics, Academic Press, 2011, Second Edition.
- Pruppacher and Klett, Microphysics of Clouds and Precipitation, Kluwer Academic Publishers, 1997.
- Young, Microphysical Processes in Clouds, Oxford, 1993.
- Fletcher, The Physics of Rainclouds, Cambridge University Press, 1962.

Inclusion Statement

CSU Atmospheric Science is a leading global institution, and as such, all members of our community regardless of race, ethnicity, culture, religion, sexual orientation, gender identity and expression, physical ability, age, socioeconomic status or nationality are welcome as equal contributors. We value and appreciate diversity, and we believe that diversity on our campus strengthens our entire scientific community. It is my intent that students from all backgrounds and perspectives be well-served by this course, that students' learning needs be addressed both in and out of class, and that the diversity that the students bring to this class be viewed as a resource, strength, and benefit. Your suggestions are encouraged and appreciated. Please let me know ways to improve the effectiveness of the course for you personally, or for other students or student groups.

Academic Integrity

All students are subject to the policies regarding academic integrity found in the 2022 – 2023 General Catalog, found at http://catalog.colostate.edu/general-catalog/policies/, and the student conduct code (http://resolutioncenter.colostate.edu/conduct-code). Other information on academic integrity can be found at https://resolutioncenter.colostate.edu/academic-integrity/. Examples of academic dishonesty can be found in these sources. At a minimum, violations will result in a grading penalty in this course and a report to the Office of Conflict Resolution and Student Conduct Services. *Academic Integrity includes the honest use of AI/LLM tools.*

Special Statement on COVID-19

All students are expected and required to report any COVID-19 symptoms to the university immediately, as well as exposures or positive tests (even home tests).

- If you suspect you have symptoms, or if you know you have been exposed to a positive person or have tested positive for COVID (even with a home test), you are required to fill out the COVID Reporter.
- If you know or believe you have been exposed, including living with someone known to be COVID positive, or are symptomatic, it is important for the health of yourself and others that you complete the online COVID Reporter. Do not ask your instructor to report for you.
- If you do not have internet access to fill out the online COVID-19 Reporter, please call (970) 491-4600.
- You may also report concerns in your academic or living spaces regarding COVID exposures through the COVID Reporter. You will not be penalized in any way for reporting.
- When you complete the COVID Reporter for any reason, the CSU Public Health Office is notified. Students who report symptoms or a positive antigen test through the COVID Reporter may be directed to get a PCR test through the CSU Health Network's medical services for students.

For the latest information about the university's COVID resources and information, please visit the CSU COVID-19 site.

ATS620 THERMODYNAMICS AND CLOUD PHYSICS			
Topics	**Subtopics**	**HW**	**#Class**
	INTRODUCTION [1 Class]		
Introduction	• The importance of thermo / cloud physics		1
	THERMODYNAMICS [10 Classes + 1 Midterm Exam]		
The First Law	• Classical thermodynamics • Thermodynamic definitions • Dalton's Law of Partial Pressures • First Law of Thermodynamics • Joule's Law • Specific heats • Potential temperature • Enthalpy • Latent heating	HW1	3
The Second and Third Laws	• Entropy • Second Law of Thermodynamics • Carnot cycle • Third Law of Thermodynamics		2
Thermodynamic Potentials and Free Energy Functions	• Introduction • Helmholtz and Gibbs Functions • Thermodynamic Potentials • Chemical Potential		1
Equilibrium	• Introduction to equilibrium • Non-equilibrium conditions • Equilibrium in chem. reactions • Equilibrium vapor P vs. T • Equilibrium for mixtures • Gibbs phase rule	HW2	4
	CLOUD PHYSICS [17 Classes + 1 Midterm Exam]		
Nucleation and Activation	• Introduction to nucleation and activation • Homogeneous nucleation of water drops • Heterogeneous nucleation of liquid water • Activation of water-solute mixtures • Liquid cloud formation	HW3	4

Condensation	• Fick's law of diffusion • Energy balance at drop surface • Complete diffusional growth equation • Evaporation of drops • Impacts on DSDs • Supersaturation		2
Warm Rain Formation	• Collision-coalescence • Continuous collection equation • Collection kernels • Stochastic collection equation • Factors impacting the evolution of the droplet spectrum	HW4	3
Ice Crystal Nucleation	• Structure of ice • Homogeneous nucleation of ice by freezing and deposition • Heterogeneous nucleation of ice on flat and curved surfaces		2
Ice Particle Growth	• Growth mechanisms • Deposition • Capacitance • Habit theory • Fall speeds • Aggregation • Riming • Ice multiplication		3
Graupel and Hail Formation	• Energy balance at the surface • Dry and wet growth regimes • Hail growth models • Melting	HW5	1