ATS 620: Thermodynamics and Cloud Physics

Fall 2011 - Dr. Sonia Kreidenweis

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Class website: http://chem.atmos.colostate.edu/AT620/

User: AT620 Password: atmoschem

The GTA for this course is Rob Seigel (rseigel@atmos.colostate.edu). Office hours will be arranged by Rob.

SYLLABUS

I. Thermodynamics

a. Review and basic concepts: System, state, equilibrium, temperature; energy, work; reversibility; equation of state, properties of mixtures; atmospheric composition.

b. The First Law: Internal energy, heat, enthalpy; heat capacities and calculation of state functions; latent heat, Kirchoff's equation; adiabatic processes, potential temperature.

c. The Second Law: Cyclic processes; entropy, Carnot cycle and the Second Law; generalized statement of the Second Law; Helmholtz and Gibbs functions; thermodynamic potentials; stable and unstable equilibrium; state transitions; enthalpy.

d. Thermodynamics of Moist Air: Phase transitions; Clausius-Clapeyron Equation, geometrical interpretation; chemical potential; heterogeneous systems; equilibrium conditions; Gibbs phase rule; surface tension; equilibrium conditions for systems with curved interfaces, Laplace's equation for mechanical equilibrium.

II. Cloud Physics

a. Nucleation of Droplets: homogeneous nucleation; nucleation on flat insoluble surfaces; nucleation on curved insoluble surfaces; nucleation on water soluble particles.

b. Atmospheric Aerosols: Aerosol sources over land and ocean surfaces, total concentrations; instrumentation for aerosol measurements; size distributions; removal processes.

c. Cloud Condensation Nuclei: Measurement techniques; concentrations over land and ocean surfaces; supersaturation dependence; properties of CCN.

d. Nucleation of Ice: Structure of ice; homogeneous nucleation of ice by freezing and deposition; heterogeneous nucleation of ice on flat and curved surfaces.

e. Ice Nuclei: Mode of action of ice nuclei; measurement techniques; concentrations; sources of ice nuclei; properties of ice nuclei.

f. Droplet Growth Theory: Theory for diffusional growth; growth of a droplet population; evaporation of large drops accounting for ventilation; collision-coalescence growth; stochastic processes; fall mode of large drops; microphysical structure of warm clouds; theories of broadening of cloud droplet spectra by turbulence, inhomogeneous mixing, and ultragiant hygroscopic aerosols.

g. Ice Crystal Growth Mechanisms: Growth from the vapor phase; habit theory; capacitances for various ice crystal geometries; depositional growth rates, effects of ventilation; dimensions of natural crystals, ice crystal fallspeeds; growth by aggregation, growth by riming, formation of hail and growth rate of hailstones (wet and dry regimes); melting of ice particles; ice particle multiplication mechanisms.

h. Cloud Structure and Dynamics: Environmental conditions supporting various cloud types; cloud structure; microphysics

h. Atmospheric Electricity: Principles of atmospheric electricity; fair weather electric field, effects of atmospheric pollution; charge generation mechanisms; cloud electrification mechanisms.

i. Aerosol Indirect Effects on Climate: Discussion of multiple postulated indirect climate effects of aerosols; relationship to weather modification and geoengineering concepts

Course grading: Your course grade will be based on performances on two midterms, a comprehensive final exam and several (~10) homework assignments. The midterms will be weighted 20% each towards the course grade. The final will receive a weight of 30%, with the remaining 30% towards the homework assignments.

Texts: There is no required text for this class. The following resources may be useful:

You may access Prof. Cotton's notes, user "cotton", password "cloud9"
http://rams.atmos.colostate.edu/AT620old/AT620Notes.html
PLEASE -- **DO NOT DISTRIBUTE OUTSIDE CSU**

Verlinde and Lamb, Physics and Chemistry of Clouds, Cambridge University Press, ISBN-13: 9780521899109, 2011.

$85 from Cambridge University Press online
$67 from Barnes and Noble (free shipping)

Pruppacher and Klett, Microphysics of Clouds and Precipitation, Kluwer Academic Publishers, QC921.5.P78, 1997.

Young, Microphysical Processes in Clouds, Oxford, QC921.5.Y68, 1993.

Fletcher, The Physics of Rainclouds, Cambridge Univ Press, 1962.

Rogers and Yau, A Short Course in Cloud Physics, Pergamon Press, QC921.5.R63, 1989, Third Edition.

Approximate semester timeline

Week		M	W	F	Topics	HW / Exam
1	Aug	22	24	26	First and Second Laws of Thermodynamics	
2		29	31	2	Thermodynamics of Moist Air	1
3	Sept		7	9	Nucleation of Liquid Droplets	2
4		12	14	16	Nucleation, continued	3
5		19	21	23	Atmospheric Aerosols	4
6		26	28	30	Cloud Condensation Nuclei	5
7	Oct	3	5	7	Cloud Droplet Growth and Precipitation Development	Exam 1
8		10	12	14	Observed Microstructure of Warm Clouds	
9		17	19	21	Ice Crystal Nucleation	6
10		24	26	28	Ice Formation in the Atmosphere	7
11		31	2	4	Ice Crystal Growth Mechanisms	8
12	Nov	7	9	11	Cloud Electrification and Lightning	9
13		14	16	18	Deep Convective Clouds	Exam 2
		21	*23*	*25*	*Thanksgiving*	
14		28	30	2	Overview of Cloud Types and Roles in Climate	10
15	Dec	5	7	9	Aerosol Indirect Effects on Climate / Geoengineering	Snowflake

Yellow: *Substitute instructor, or make-up class required*

Final Exam: Thurs, Dec. 15 2:00-4:00p
http://registrar.colostate.edu/students/registration/finalexamschedule.aspx