EAS 6140 - Thermodynamics of Atmospheres and Oceans

Instructor:
Dr. Jie He (E-mail: Jie.He@eas.gatech.edu; Office: ES&T 2232)
Dr. Pengfei Liu (E-mail: Pengfei.Liu@eas.gatech.edu; Office: ES&T 3238)
Office hours: appointment by e-mail

Textbook:
Curry, J. A., & Webster, P. J. (1998). *Thermodynamics of atmospheres and oceans*. Elsevier. (link)

Course description:

Thermodynamics are inherent to the atmosphere and ocean. Winds and ocean currents owe their existence to the thermodynamic imbalance that arises from the differential heating of the Earth's surface by the sun. A key ingredient in the thermodynamic processes is water, which is able to change between three phases in Earth's climate. The formation of cloud and sea ice increases the Earth's reflectivity and cools the climate. On the other hand, water in its gaseous form has strong a greenhouse effect that acts to amplify the surface warming from increasing carbon dioxide. The thermodynamic feedbacks associated with water are key to understanding climate variability and the overall stability of the climate system.

The main objective of this course is to apply thermodynamic principles to understand the role of water in the Earth's climate system. The course closely follows the textbook "Thermodynamics of Atmospheres and Oceans" by Curry and Webster. It starts by developing the basic concepts of classical thermodynamics that are important for understanding the climate system. These basic concepts will then be applied to address major processes in the atmosphere and ocean, including cloud formation, precipitation processes and thermohaline circulation. The course finally delves into specific climate topics that bear a substantial thermodynamic component, including climate sensitivity, feedbacks and the hydrological cycle.

Course Material Overview

1. State of atmosphere and ocean
    - State variables. Ideal gas law. Hydrostatic balance.
2. First and second laws of thermodynamics
    - 1st and 2nd laws. Enthalpy. Heat capacity. Entropy.
3. Thermodynamics of water
    - Molecular structure of water. Phase equilibrium. Colligative properties of water solutions.
4. Moist process in the atmosphere
    - Moist adiabatic process. Conservative properties. Aerological diagrams.
5. Transfer processes
    - Radiation. Diffusion. Turbulence.
6. Nucleation and diffusional growth

- Surface tension. Nucleation of liquid & ice. Diffusional growth. Initial sea ice growth.

7. Cloud and precipitation
    - Cloud classification. Cloud radiation. Accretional growth. Precipitating and Non-precipitating clouds. Cloud parameterization.
8. Thermohaline processes
    - Skin temperature. Mixed layer processes. Instability in the ocean interior. Deep ocean convection.
9. Thermodynamics of climate change (optional)
    - Climate sensitivity. Water vapor feedback. Changes in hydrological cycle

Grading:
Homework: 20%
Homework will be given out at the end of every chapter and due one week later.

Exam I, II, Final: 40%
All exams will be closed book. Exam I covers the first half of the course and Exam II covers the second half. The final exam includes the whole course. The best 2 scores (out of 3) will be used for calculating the final grade.

Project: 40%
The class project will be a literature review delivered in class by each student at the end of the semester via a 25-30 minutes oral presentation followed by a 5 minutes question session. Students need to submit an abstract of no more than two pages at least one class prior to the presentation. The topic of the presentation is flexible as long as it is relevant to the course. Students can pick any material mentioned in class and expand on it or discuss any topic that applies thermodynamic theories. The project (including both presentation and abstract) will be evaluated by both students (40%) and the instructor (60%). Evaluation criteria will be sent to students prior to the presentation date to help guide the preparation. The evaluation form will be given to the presenter after the presentation to provide feedback.

- Grading scale: A(90-100), B(80-89.99), C(70-79.99), D(60-69.99), F(below 60).

Class material usage:
The instructor and students in this class, as members of the Georgia Tech community, are bound by the Georgia Tech Academic Honor Code. The instructor will make available copies of appropriate assignments, samples, and readings. Unauthorized use of any previous semester course materials, such as tests, quizzes, homework, projects, and any other coursework, is prohibited in this course. Using these materials will be considered a direct violation of academic policy and will be dealt with according to the GT Academic Honor Code.