ENV-413

Thermodynamics of the earth systems

Nenes Athanasios

Cursus	Sem.	Type
Environmental Sciences and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

The objective of this course is to apply thermodynamic principles to understand the role of water in the Earth System. The aim is to provide a broad conceptual framework for understanding the thermodynamics of oceans and atmospheres, so material can be integrated into other study disciplines.

Content

Part 1: Introduction

- Basic concepts (thermodynamic systems, states, state variables, processes and properties).
- Equation of state (Ideal gas law, kinetic theory for gases, hypsometric equation, equation of state for ideal gases, real gases, liquids, solid. Specific equations of state for air and seawater).
- The Earth system (composition, structure of the atmosphere, ocean and solid earth. Variation of pressure, density and temperature in each compartment)

Part 2: Framework

- First Law setup (Basic concepts & review, Work; expansion work, Heat: heat capacity, basics of heat transfer mechanisms)
- First law and applications (First law formulation, internal energy, enthalpy, specific heats, heat capacity, environmental engineering and earth system applications)
- Entropy (why is it needed? historical context and definition)
- Second law (formulation and different forms)
- First and second law combined, thermodyanamic relations, heat engines
- Isontropic (adiabatic) processes in the atmosphere and ocean
- Phase Equilibria (Gibbs phase rule, Phase changes and equilibria, chemical reactions and energy state, phase diagrams of water and multicomponent systems)

Part 3: Applications

- Moist thermodynamic processes in the atmosphere (Humidity variables; isobaric, adiabatic cooling; isobaric mixing; aerological diagrams)
- Chemical thermodynamics (aqueous solutions, activity, chemical potential, solution thermodynamics. Applications to the formation of atmospheric aerosol, its hygroscopic growth, and clouds).
- Nucleation and Diffusional Growth (Surface energy, surface tension and Kelvin effect. Nucleation of the liquid and ice phase. Diffusional growth of cloud droplets and ice).

Keywords

Thermodynamics; atmosphere; ocean; solid Earth; Earth System

Learning Prerequisites

Required courses

ENV-320: Physics and chemistry of the atmosphere

Recommended courses

Fundamentals of physics
Fluid mechanics

Learning Outcomes

By the end of the course, the student must be able to:

- Present application of thermodynamics to the Earth System
- Express the main laws of thermodynamics in its different forms
- Apply thermodynamic equations to study Earth System processes
- Model thermodynamic processes in the atmosphere
- Demonstrate the role of physical parameters of the Earth System
- Solve real problems of chosen applications in the atmopshere, oceans and solid Earth
- Design processes of relevance for the Earth System using thermodynamic principles
- Anticipate responses in Earth System components (aerosols, clouds) to anthropogenic or natural forcers
- Analyze Atmospheric components using thermodynamic principles

Transversal skills

- Use a work methodology appropriate to the task.
- Keep appropriate documentation for group meetings.
- Summarize an article or a technical report.
- Evaluate one's own performance in the team, receive and respond appropriately to feedback.
- Access and evaluate appropriate sources of information.

Teaching methods

- Lectures
- Assignment material before class
- Homework, in-class collaborative learning

Expected student activities

- Taking part to lectures
- Read assignement material before class/collaborative learning
- Active work in group project

Assessment methods

- Midterm exam: 30%
- Final exam in session: 70%

Supervision

Office hours	No
Assistant.e.s	Yes
Forum	Yes

Resources

Virtual desktop infrastructure (VDI)

No

Bibliography

- Thermodynamics of Atmospheres and Oceans, by Curry and Webster
- Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Seinfeld and Pandis

Ressources en bibliothèque

- Find the references at the Library

Notes/Handbook

- Lecture notes
- Lecture presentations

Moodle Link

- https://go.epfl.ch/ENV-413