ATMS 507 – Climate Dynamics

Semester

Spring 2022

Instructor

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Class Meeting times and locations

Meeting Time: TuTh 12:30pm-1:50pm
Meeting Location: TBD
Office Hours: TBD and by appointment

Course Description:

Investigates dynamical and physical processes that govern Earth's past, present, and future climates. Emphasizes *fundamental physical principles* that determine present climate, and both natural and anthropogenic climate changes across both spatial and temporal scales. Observations and climate models are used to examine past changes and potential future impacts.

Inclusivity

The effectiveness of this course is dependent upon the creation of an encouraging and safe classroom environment. Exclusionary, offensive or harmful speech (such as racism, sexism, homophobia, transphobia, etc.) will not be tolerated and in some cases will be subject to University harassment procedures. We are all responsible for creating a positive and safe environment that allows all students equal respect and comfort. I expect each of you to help establish and maintain and environment where you and your peers can contribute without fear of ridicule or intolerant or offensive language.

Prerequisites:

The course will focus on fundamental physical processes, which we will explore using a variety of conceptual analytical models. A good grasp of differential equations, multivariate calculus, as well as university-level mechanics and thermodynamics is required. Past course work in Fluid Dynamics, Geophysical Fluid Dynamics, or Dynamical Meteorology is recommended but not required for the modules on general circulation.

Textbook:

- Instructor's Notes
- Dennis L. Hartmann, *Global Physical Climatology*. 2nd Edition, Elsevier Academic Press, 2016.
    - Online version available through UIUC library https://i-share-uiu.primo.exlibrisgroup.com/permalink/01CARLI_UIU/gpjosq/alma998968830712205899
- Kerry Emanuel and Geoffrey Vallis: Climate Physics and Dynamics. WHOI GFD Summer School 2014 lecture notes
    - https://gfd.whoi.edu/gfd-publications/gfd-proceedings-volumes/2014-2/
- Geoffrey K. Vallis, *Atmospheric and oceanic fluid dynamics: fundamentals and large-scale circulation.* Cambridge University Press; 2017
    - Online version available through UIUC library https://i-share-uiu.primo.exlibrisgroup.com/permalink/01CARLI_UIU/gpjosq/alma998346839212205899

Additional References:

- Kerry Emanuel and Geoffrey Vallis: Climate Physics and Dynamics. WHOI GFD Summer School 2014 lecture notes
    - https://gfd.whoi.edu/gfd-publications/gfd-proceedings-volumes/2014-2/
- Murry L. Salby: *Fundamentals of atmospheric physics.* Academic Press 1996.
    - Online version Available through UIUC library https://i-share-uiu.primo.exlibrisgroup.com/permalink/01CARLI_UIU/q1ojeg/alma99717784012205899

Grading: (tentative):

- Assignments: 70%
- Term Project: 30%

Topics Covered:

- Introduction:
    - Fundamental Features of Earth's Climate: What we'll understand by the end of the course
    - Data: Observations, Reanalysis, and General Circulation Models

- Radiative Transfer
    - Review of Electro-Magnetic Radiation
    - Planetary Energy Balance
    - Elements of atmospheric radiative transfer.
    - Pure Radiative Equilibrium (PRE)
- Atmospheric Thermodynamics:
    - Stability
    - Moist Static Energy
    - Dry adiabatic lapse rate, moist adiabatic lapse rate

    - Radiative Convective Equilibrium

- Global Energy Balance
    - Greenhouse models
    - Radiative Forcing, Feedbacks, and Sensitivity
    - Ocean heat uptake and transient response
    - Climate as a Dynamical system

- Carbon Cycle response
    - Carbon reservoirs
    - Climate response to a ton of CO2
    - Transient Climate Response to Cumulative Emissions (TCRE)

- Spatial Structure of present and future climate
    - Radiative-Diffusive Energy Balance Models (Dry & Moist)
    - Polar Amplification
    - Land Amplification, Land Drying

- Land Surface
    - Surface Energy Budget
    - Evapo-Transpiration (Penman-Monteith Equation?)

- General Circulation of the Atmosphere
    - Review of Geophysical Fluid Dynamics: potential vorticity, shallow water equations, Rossby waves.
    - Meridional tropical circulation: Hadley Cell
    - Zonal tropical circulation: Walker Cell
    - Mid-latitude circulation: Ferrell Cell
    - General circulation and the Hydrological Cycle

- General Circulation of the Ocean
    - Sverdrup balance & wind-driven Gyres
    - Thermohaline Circulation
    - Ocean heat uptake
    - *Equatorial dynamics: Equatorial undercurrent, equatorial Rossby waves, equatorial Kelvin waves*

- Coupled Climate Variability:
    - Stochastic Climate Models: Hasselman Model,
    - El Nino Southern Oscillation: (stochastic and chaotic models)
    - The alphabet soup: PDO, IPO, IOD, AO, AMV.