AOS 801: Topics in Theoretical Meteorology
Fall 2017 – Radiation and Energy in the Climate System

Syllabus

Instructor

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Course Website: http://planck.aos.wisc.edu/aos801

Schedule

Lectures:	M/W 11 to 12:15 pm	AOSS 823
	Make-up Lectures: Friday 11 to 12:15 pm	AOSS 823

Course Overview

This course focuses on recent progress and current challenges in quantifying radiative and energetic processes in the climate system. Through a combination of overview lectures, reviews of seminal papers, and class projects, students will gain familiarity with foundational research into the key factors governing the principal flows of energy in the Earth-atmosphere system. Topics include: energy balance and heat transport, radiative forcing, radiative-convective equilibrium, climate thermodynamics, climate sensitivity, and feedbacks. Prior completion of ATM OCN 640 "Radiation in the Atmosphere and Ocean" is strongly recommended.

Grading

Lead Class Paper Reviews (3-4)	30%
Participation in Paper Reviews	10%
Team Project	20%
Term Paper	20%
Final Presentation	20%

A term project elucidating the finer points of a key topic covered in the course forms a significant component of the class. A short paper and in-class presentation describing the outcomes of this project will constitute 40% of the final grade. Students will also collaborate on a group project related to material covered during the first half of the course. The remainder of the grade will be based on participation in class paper reviews. You will lead the review of 3-4 seminal papers (or groups of related papers) over the course of the semester. To facilitate discussion, create a short Powerpoint presentation (typically ~10 slides) that provides a concise summary of 'the problem' being addressed, key methodological details, and central findings of the paper as they relate to the course themes. In the interest of time, it is important to focus on summarizing key points rather than presenting everything in the paper. On the last slide, please include three '*talking points*' (questions/comments to stimulate additional discussion). You will also serve as secondary reader on three other papers to provide additional commentary and support the discussion lead. You are asked to briefly look over all other papers that you are not leading or supporting a discussion directly (at a minimum read the abstracts and conclusions) so you can actively participate in the associated discussions.

Rough Schedule and Reference Materials

In addition to lecture notes that will be provided periodically throughout the semester, the primary reference materials for this class will be the following papers from the peer-reviewed literature that can be found on the course website:

Blue – student presentation   Yellow – covered in lecture   Green – additional reading

UNIT 1: REVIEW OF RADIOMETRIC CONCEPTS (2 CLASSES)

Overview: Refresher on basic radiative transfer concepts and theory

Topics:

- ☐ Basic Laws
  - Kirchoff
  - Boltzmann
  - Planck
  - Wien
- ☐ Radiative Transfer Theory
  - Radiances vs. Fluxes
  - Basic Radiative Transfer Theory
  - Two-steam Approximiation
  - Radiative Heating and Cooling

References

1. PPT or written class notes

UNIT 2: EARTH'S ENERGY BUDGET AND HEAT TRANSPORT (2-3 CLASSES)

Overview: Energy balance considerations from theory, observations, and models

Topics:

- ☐ Energy Balance (and Imbalance)
  - Top of Atmosphere Energy Balance
  - The Greenhouse Effect
  - Surface Turbulent Heat Fluxes
  - Energy Partitioning between TOA and SFC: Timescales and Impacts
- ☐ Energy as a Driver of Climate
  - Zonal Imbalances and Heat Transports

References

1. Pioneering Work: Dines (1917); Vonder Haar and Suomi (1971)
2. Imbalances: Hansen et al. (2005); Trenberth et al. (2014)
3. Modern Controversy: Trenberth et al. (2009); Stephens et al. (2012); L'Ecuyer et al. (2015)
4. Transports: Hartmann et al. (1985); Trenberth and Caron (2001)

UNIT 3: RADIATIVE FORCING OF CLIMATE (3-4 CLASSES)

Overview: Radiative forcing of the climate system and associated responses

Topics:

- ☐ Forcing vs. Response
- ☐ Greenhouse Gases
- ☐ Clouds
- ☐ Aerosols
  - o Direct Effects
  - o Indirect Effects
- ☐ Cloud-Aerosol Interactions

References

1. Forcing and Response: Hansen et al. (1997)
2. Water Vapor: Stephens and Greenwald (1991a)
3. Clouds: Harrison et al. (1990); Ockert-Bell and Hartmann (1992); Hartmann et al. (1992); Gleckler et al. (1995); Stephens and Greenwald (1991b); Ramanathan et al. (1989)
4. Aerosols: Yu et al. (2006); Wild et al. (2005); Matus et al. (2015)
5. Aerosol-Cloud Interactions: Twomey (1977); Albrecht (1989); Stevens and Feingold (2009)

UNIT 4: RADIATIVE EQUILIBRIUM AND CONVECTIVE ADJUSTMENT (3-4 CLASSES)

Overview: Equilibrium in the climate system

Topics:

- ☐ Convection
- ☐ Atmospheric latent heating
- ☐ Radiative equilibrium
- ☐ Convective adjustment

References

1. Foundational Papers: Manabe and Moller (1961); Manabe and Strickler (1964); Manabe and Wetherald (1967)
2. Role of Clouds: Stephens and Webster (1981)
3. Modern Applications: Posselt et al. (2008); van den Heever et al. (2011); Emanuel et al. (2006); Chavas and Emanuel (2014)

UNIT 5: ENERGY BALANCE MODELS (2 CLASSES)

Overview: The energy balance theory of climate and applications

Topics:

- ☐ Energy Balance Climate Models
- ☐ Ice-Albedo Feedback
- ☐ Faint Young Sun
- ☐ Representing Clouds in Energy Balance Models
- ☐ Time-dependent Energy Balance Models
- ☐ Stochastically-forced Energy Balance Models

References

1. Pioneering Papers: Budyko (1969); Sellers (1969)
2. Summary: North et al. (1981)
3. Time-dependent: Lorenz (1979); North and Cahalan (1981)
4. Stochastically-forced: Hasselman (1976); Robock (1978); Kim and North (1992)

UNIT 6: FEEDBACKS IN THE CLIMATE SYSTEM (3-4 CLASSES)

Overview: Introduction to climate feedbacks

Topics:

- ☐ Greenhouse Gas Feedbacks
- ☐ Biological Feedbacks
- ☐ Cloud Feedbacks
- ☐ The Infrared Iris Controversy

References

1. GHG: Rasool and de Bergh (1970); Held and Soden (2000)
2. Biological: Watson and Lovelock (1983); Wood et al. (2008)
3. Clouds: Ramanathan and Collins (1991); Clement et al. (2009); Dessler (2010)
4. Iris Controversy: Lindzen et al. (2001); Hartmann and Michelsen (2002); Lin et al. (2002)

UNIT 7: CLIMATE SENSITIVITY

Topics: Equilibrium climate sensitivity

References

1. Methods: Gregory et al. (2004); Hansen et al. (2005)
2. Observations: Forster and Gregory (2006)
3. CMIP5: Andrews et al. (2012a)
4. Rapid Adjustments vs. Equilibrium Responses: Andrews et al. (2012b); Sherwood et al. (2015) **or** Andrews et al. (2015)
5. Separating Forcing, Response, and Feedback: Chung and Soden (2015)
6. Kernels: Soden et al. (2008); Zelinka et al. (2012)

UNIT 8: ADDITIONAL TOPICS (INTERSPERSED THROUGHOUT COURSE, TIME-PERMITTING)

Topics:

- ☐ Entropy and Climate
  - entropy of radiation
  - Prigogine's theorem
  - Ziegler's principle of maximum dissipation
- ☐ The Water Cycle

References

1. Entropy Foundations: Paltridge (1975); Paltridge (1978); Paltridge (1981)
2. Entropy Observations and Models: Stephens and O'Brien (1993); O'Brien and Stephens (1995)
3. The Global Water Cycle: Trenberth et al. (2008); Rodell et al. (2015)
4. Water Cycle Trends: Wentz et al. (2005); Stephens and Ellis (2008); Adler et al. (2017)