Fundamental dynamics of Earth's Atmosphere and Climate

Spring 2018

ENVST-UA.360 and MATH-UA.228

Staff

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Meeting times and location

Lecture:	Monday & Wednesday	9:30-10:45	Warren Weaver Hall 312
Lab:	Friday (start 2/2/2018)	9:30-10:30	Warren Weaver Hall ___

Description of course

This course will be an introduction to the dynamical processes that drive the circulation of the atmosphere and ocean, and their interaction. The aim of the course is to develop both qualitative and quantitative understanding of the processes that generate weather and climate. The course is technical, involving physics and mathematics, but lectures will be driven by consideration of observations and experiments. Topics include the global energy balance, convection and radiation (the greenhouse effect), effects of planetary rotation, structure of the atmospheric circulation, structure of the oceanic circulation, climate and climate variability.

Prerequisites

Calculus I (or its equivalent), with a grade of B- or better but calculus III (vector calculus) is recommended. Students should also have some familiarity with introductory physics.

Textbook

Atmosphere, Ocean, and Climate Dynamics, by J. Marshall and R. A. Plumb (Academic Press, 2008)

Grading Philosophy and Expectations for the Course

This is a quantitative science course, and calculation is a big part of understanding the material, but I will not expect you all to be equally proficient. I encourage working together, especially in pairs or small groups that span abilities. I hope that interest in the subject matter will compensate for lack of background.

Assignments/Grade weights

Homework (20%): I will assign (nearly) weekly assignments, typically on Wednesdays and due back the following Wednesday at the beginning of class.

Lab activities and class participation (20%): Lab activities include data analysis, computer labs, and observations of tank experiments. *You are expected to attend every lecture and lab, unless you have a very good reason to miss it*. If you do miss anything, you'll be expected to make up the work.

Project (30%): Each student will do one project, which will consist of a short paper and presentation on a subject of interest that we will not cover in class. Your topic must be consistent with the themes of the course, and must be approved by me before Spring Break. It will be due near the end of the semester.

Final Exam (30%): At the end of the course, there will be a straight-forward final exam. The point of the exam is to force you to review the material from the course.

EAC Schedule - Spring 2018

	Monday	Wednesday	Friday (Discussion/Lab)
Week 1	* Course overview & syllabus * Intro to AOS & Climate - slideshow w/ features we seek to understand; discuss connection to climate - contrast weather vs. climate * Read Ch. 0-1.2	* Geometry of Earth and atmospheric composition * Continuum approximation: fluids, gasses and liquids * Read Ch. 1	No recitation during week 1
Week 2	* Introduce idea that each parcel of air is always considered an equilibrium thermodynamic system * Ideal gas law * Partial pressure * Adiabatic heating and cooling	* Clausius-Clapeyron relation for saturation vapor pressure * Properties of dry and moist air * Read Ch. 2.1-2.2 for Monday * Assign HW 1 (Ch. 1)	* GFD Lab 1 - Cloud formation * Discuss cloud formation, saturation, fog, dew point * Partial derivation of CC relation from first principles (dP/dT=LP/RT^2) * HW help
Week 3	* Blackbody radiation (fundamentals) * Earth-Sun system, albedo, planetary emission temperature * Sun's emission spectrum and atmospheric absorption spectrum * Read Sec 2.3	* The Greenhouse effect * 0D, 1-layer and leaky 1-layer models * Climate feedbacks (sec 2.3.4) * Read Ch. 3 before Monday * Assign HW 2 (Ch. 2)	* Discuss multi-layered and continuous models - climate model radiation codes * 2-layer GH model * Earth's radiation budget
Week 4	* Observed vertical temperature structure (troposphere, etc) * Chemical causes of T(z) * Hydrostatic balance * Isothermal atmosphere: p(z) and rho(z).	* Computing p & rho for given T(z) * Inverting isothermal relation to give z(p) -- usefulness of pressure coordinates and lack of sensitivity to T(z). * Stability of a parcel (begin ch. 4) * Read 4.1-2 * Assign HW 3 (Ch. 3)	* Lab demos: (1) Convection and (2) gravity waves in stratified two-layer system * Archimedes principle and HSB

EAC Schedule - Spring 2018

	Monday	Wednesday	Friday (Discussion/Lab)
Week 5	President's Day February 19	* Discuss stability - review/discuss ODE x" = x (sec 4.1.2). * Buoyancy and stable/unstable gradients of density (4.2) * Buoyancy frequency (4.4.1 - but as oscillations, not GWs) * Read Sec 4.3, 4.4.1	* Discuss gravity waves, mountain waves - look at data. * Discuss buoyancy, stability and convection from energetics point of view (4.2.3 & 4.2.4)
Week 6	* Dry convection in the atmosphere (4.3) * Adiabatic lapse rate * Potential temperature * Read 4.5 * Assign HW 4 (4.1-4.4)	* Temperature inversions * Working with potential temperature * Analyzing atmospheric stability	* HW/problems/concepts for Sections 4.1-4
Week 7	* Moisture (4.5): specific, saturation-specific and relative humidity * Saturated adiabatic lapse rate * Equivalent potential temperature * Read Sec 4.6-7 * Assign HW 5 (4.5-8)	* Atmospheric convection: types, structure, clouds - show slides and discuss detailed process - locations * Connection to OLR * Radiative-convective equilibrium * Read Sec 5.1	* Computer Lab - Analyzing OLR data with MATLAB (this will require significant time spent on introduction to MATLAB and on getting data read in - students should be assigned to work on this outside class)
Mar 12, 0018	Spring Break		
Week 8	* Meridional structure of radiative forcing and temperature (5.1) * Geometry of incoming radiation * Distribution of outgoing radiation * Energy balance/poleward heat flux * Seasonal effects * Read Sec 5.3-4	* Meridional-vertical temperature, potential temperature and equiv-pot temp structure (5.1.4) * Moisture distribution (5.3) * Winds (5.4) * Collect Project Proposals [Skip geopotential height]	* Computer Lab - Continuation and analysis of mean winds and temperatures from data * Discuss zonal and time averaging, averaging over eddies, jet stream * Read handout on fluid equations (and Sec 6.1-5 for advanced students)

EAC Schedule - Spring 2018

	Monday	Wednesday	Friday (Discussion/Lab)
Week 9	* Introduce fluid equations: momentum and mass conservation, thermodynamic equation * Use Lagrangian perspective, already introduced via consideration of parcels as systems * Read Sec 6.6	* Rotation: Centrifugal acceleration and the Coriolis effect (use inertial and non-inertial perspectives of inertial motion - apps/websites). * Rotating coordinates * Rotational momentum equation	* Rotation lab, computer demo, problems. * Inertial circles (Coriolis.m) * Taylor Columns (Lab 7)?
Week 10	* Discuss balance of terms in rotating momentum equation * Introduce Rossby number * Read 7.1-3 and/or Thermal Wind handout	* Geostrophic balance * High/Low pressure systems and accompanying winds * Connection to height of pressure surfaces (geopotential height)	* GFD Lab 8 or 9 - Thermal wind * Discuss effects of rotation and stratification qualitatively and quantitatively
Week 11	* Mathematical discussion of thermal wind balance and Taylor-Proudman * Application to atmospheric mean state - discuss computation to be completed in MATLAB * Read 8.1-2 [Skip Ekman 7.4 until later]	* Observed atmospheric general circulation * Hadley cell and angular momentum * Read Sec 8.3-5	* Computer Lab - Help finishing thermal wind computations
Week 12	* Zonally averaged energy and momentum budget and transport (8.4) * Latitudinal variations in climate (8.5) * [Read additional handout or external sources?]	* Catch-up/summary of atmospheric structure and circulation * Read Sec 9.1-2	* GFD Lab 8 and 11 - Hadley and BCI (same setup - just turn up rotation rate to get BCI) * Discuss overturning flow - be sure to explain connection to Earth's geometry * Discuss energetics and BCI

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	Monday	Wednesday	Friday (Discussion/Lab)
Week 13	* Physical characteristics of the ocean (geometry, properties of seawater, eqn of state) * Temperature, salinity and density structure - thermocline and mixed layer * Methods of measurement * Read Sec 9.3-4	* Scales of motion: Rossby number, velocity scales density gradients * Observed surface currents with satellite altimetry - connection to geostrophy * Thermal wind balance in the ocean * Read 7.4 and 10.1 (Ekman)	* GFD Labs 10 and/or 12 - Ekman * Discuss oceanic Ekman layers (mention atmospheric Ekman layers, too) * Read 10.2-3
Week 14	* Wind-driven ocean circulation and Sverdrup balance * Connect to observations * Read 11.1-5	* The oceanic thermohaline circulation and its connection to climate	* Review
Week 15	* Student Project Presentations	Final Exam Period	

NOTES:

* Projects can be used to cover material we are not able to get to. It would be especially appropriate for students to focus on projects that require integration of multiple results, ideas, techniques to address some issue in climate, for example.
* The ocean dynamics material may be swapped in favor of covering climate (Ch. 12 + other material)