AOSC 617: Atmospheric and Oceanic Climate

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Web description

The general circulation of the atmosphere and oceans, historical perspective, observations, and conceptual models; wind-driven and thermohaline circulation of the oceans. Seasonal cycle and monsoon circulations; interannual to interdecadal climate variability; climate change.

Background

Atmospheric and oceanic climate refers to the monthly/seasonal averaged distributions of circulation, temperature, moisture, and related eddy transports. The course will provide a dynamically oriented description of the observed distributions, with the intent of elucidating the dynamics of terrestrial climate. Both circulation structure and the underlying dynamical/thermodynamical constraints and mechanisms will thus be of interest. The availability of atmospheric and oceanic reanalysis data sets within the last decade has lead to improved 3D descriptions and new insights into atmospheric and oceanic general circulation. Historical perspectives will be supplemented by modern views of the general circulation, supported by theory and simple models of the involved dynamical processes. The course will advance understanding of climate variability and change, and climate sensitivity.

Books

- *Introduction to Circulating Atmospheres* — Ian N. James (Chaps 4-9)
  Cambridge University Press, 1995; Paperback; ISBN 0521429358
- *An Introduction to Dynamic Meteorology* — Holton & Hakim (Chaps 10-12) 5th Edition
  Academic Press, 2004; **ISBN-13:** 978-0123848666
- *Atmospheric & Ocean Fluid Dynamics: Fundamentals and Large-Scale Circulation* – Geoffrey Vallis, Cambridge Univ. Press: ISBN-10: 0521849691
- *The General Circulation of the Atmosphere* — David A. Randall
  http://kiwi.atmos.colostate.edu/group/dave/at605.html
- I*ntroduction to Geophysical Fluid Dynamics* — Benoit Cushman-Roisin
  Prentice Hall, 1994; ISBN 0133533018 Chapter 8
- *Physics of Climate* — Jose P. Peixoto and Abraham H. Oort
  American Institute of Physics, 1992; ISBN 0883187124
- *Theory of the General Circulation of the Atmosphere* — Edward N. Lorenz
  WMO Monograph, 1967

AOSC617: Course Outline

- **Atmosphere and Ocean Observing System**: In situ and remote sensing: COSMIC and COSMIC-2 (atmosphere), TRMM/GPM (precipitation), SMOS/SMAP (soil moisture), GRACE (groundwater), ARGO (ocean soundings), AQUARIUS (sea surface salinity)
- **Data Assimilation**: Objective Analysis; Data Initialization; Asynoptic data and 4D assimilation; 3D and 4D-Var; ECMWF assimilation system, including data type and distribution used in today's forecast
- **Earth-Sun Geometry:** Earth's orbit (eccentricity); Earth's rotational axis (precession, obliquity); the 100K, 26K, and 41K periods, and the 21K perihelion cycle.
- **Paleoclimate:** Quaternary period (from 2.5MYA), glacial epochs; Vostok ice core; orbital theory for ice ages. The past 20K years (since the last glacial maximum): Younger Dryas (13KYA) and its origin; the warmest and wettest period of this interglacial (6KYA); the Little Ice age (14-19th century).
- **Zonal-mean circulation and temperature distributions:** Thermal wind balance, tilt of the subtropical jet; why are there easterlies in the Tropics? Why is the tropical tropopause so cold? Stratospheric circulation: Polar night jet, NH and SH differences: Brewer-Dobson circulation; Hadley Circulation and its seasonality.
- **Angular Momentum conservation:** Viscosity and surface stress, sigma-coordinate equations, surface torque; zonal-mean angular momentum transport; planetary (atmos+ocean+solid earth) angular momentum conservation; Length of Day variations
- **General circulation of the atmosphere**: Halley and Hadley's explanation of the Trade winds; Hadley's 4-page paper (Philosophical Transactions, 1735); Ferrel and Thomson's shallow indirect cell in the midlatitudes; Bjerknes and Victor Starr's synthesis of the zonally-symmetric viewpoint with the role of eddies in general circulation; A modern synthesis by Mike Wallace (Encyc. Atmos Sci., 2003)
- **Held-Hou model for the Hadley Circulation**: Introduces consideration of thermal-wind balance in angular momentum dynamics: Surface energy balance; Radiative equilibrium temperature; model solution and its dependence on rotation rate, tropospheric height, and the equator-pole temperature drop; the equatorially asymmetric Held-Hou model; Hadley cell as a Carnot heat engine. Quasi-Lagrangian view of the Hadley Circulation.
- **Annual and zonal-mean meridional heat transport:** Radiative surplus in Tropics and deficit in the high latitudes: Meridional heat transport in the ocean and atmosphere
- **Stationary Rossby waves:** Orographically forced waves: The Charney-Devore model, "form drag" and multiple equilibria; low-frequency variability and climate regimes; annular modes

- **Sea-level pressure distribution:** Continental lows (highs) and oceanic (highs) and lows in summer (winter). Diagnosis of precipitation from sea-level pressure using large-scale vorticity dynamics - the Sverdrup balance; relationship of SLP and lower tropospheric vertical velocity
- **SST climatology:** The annual cycle in the Tropics despite the semi-annual cycle in insolation: Why? Coupled ocean-atmosphere interaction in the eastern equatorial basins: The Gill and Lindzen-Nigam models for tropical surface winds. Simple analytic model for the westward phase propagation of the SST annual cycle.
- **SST variability:** Canonical and non-canonical ENSO variability, biennial variability, Pacific decadal variability, and the non-stationary secular trend; tropical Atlantic variability, Atlantic Multidecadal Oscillation/Variability. SST's role in North American droughts and the drying of Sahel.
- **Surface fluxes** (radiative, sensible, latent heat) at both ocean and land surface; **Salinity** distribution
- **Circulation Teleconnections**: North Pacific Oscillation, North Atlantic Oscillation, Pacific North American pattern of winter variability, and ENSO's extratropical impact. Precipitation and temperature footprints
- **Arctic sea-ice distribution, variability, and trend:** Seasonal structure; variability mechanisms.
- **Atmospheric greenhouse, radiative equilibrium, and climate sensitivity:**
- **Recent surface warming of the Northern Hemisphere Continents:** Seasonality and the Contribution of multidecadal ocean variability

1 Mid-Term Exam: 35%

Final Exam: 50%

Class Participation: 15%