MPO 765: General Circulation of the Atmosphere

Spring 2020

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MSC 329, Mondays and Wednesdays, 10:30-11:45AM

Topics:

I. Introduction

A. History of the study of the general circulation

B. Averaged quantities and other representations of the data

C. Observations, analysis, and re-analysis

II. The Observed Zonally Averaged Circulation

A. Radiation, temperature, pressure, winds, moisture

B. The oceans, land, ice, and their effects

C. Interseasonal and interhemispheric differences

III. Understanding the Zonally Averaged Circulations

A. Simple climate models

B. Hadley cell models

C. First look at wave and eddy transports

D. Zonally averaged heat and momentum fluxes

E. Quasi-balanced response: Eliassen and Kuo theories

IV. The Observed Nonzonal Circulations

A. Mid-latitudes - the jets and planetary waves

B. Cyclones and baroclinic life cycles

C. Local heat and momentum fluxes

D. Variations in the tropics - ITCZs and monsoons

E. Interseasonal and interhemispheric differences

V. Understanding the Nonzonal Circulations: Mid-latitudes

A. Baroclinic instability and cyclogenesis

B. Fronts

C. Kinetic and available potential energy - the Lorenz Cycle

D. Forced planetary waves

E. Advanced theories of zonal and nonzonal Circulations

VI. Understanding the Nonzonal Circulations: Tropics

A. ITCZ Dynamics

B. Monsoons

C. Madden-Julian Oscillation

VII. The Stratosphere

A. Thermodynamic structure

B. The general circulation and seasonal variations

C. Stratospheric phenomena - waves, QBO, and sudden warmings

Assignments:

There will be a mid-term exam (15%), occasional homeworks (25%), one 30 minute presentation by each student (25%), and a final exam (35%).

Resources:

There is no single textbook for the class. Reading will be assigned from the following books on reserve in the library, and other papers will be handed out.

Reserve Books:

QC880.4.A8 G77 1993	Grotjahn, R.: *Global Atmospheric Circulations*
QC880.H65 2004	Holton, J. R.: *An Introduction to Dynamic Meteorology*
QC880.4.A8 J34 1994	James, I. N.: *Introduction to Circulating Atmospheres*
QC881.2.S8 L33 1999	Labitzke, K. and Van Loon, H.: *The Stratosphere*
fQC880.L65 1967	Lorenz, E. N.: *The Nature and Theory of the General Circulation of the Atmosphere*
QC981.P434 1992	Peixoto, J. P., and Oort, A. H.: *Physics of Climate*
QC880.4.A8 R35 2018	Randall, D.: *An Introduction to the Global Circulation of the Atmosphere.*
QC809.F5 V355 2006	Vallis, G.: *Atmospheric and Oceanic Fluid Dynamics*

Class Schedule and Assignments

January 13th and January 15th: No class due to AMS meeting.

January 17th:

Reading:

Grotjahn, Chapter 1.

Lorenz, E. N., 1991: The general circulation of the atmosphere: an evolving problem. *Tellus*, 1991, **43AB**, 8-15.

Topics, assignments, and scheduling.

What is the General Circulation?

Discussion of the evolution of our understanding of the general circulation.

Introduction to averaging paradigms.

January 20th: No class (holiday).

January 22nd:

Reading:

Peixoto and Oort, Chapter 4.

Grotjahn, Appendix.

Hakim, G. J., 2009: Linear algebra primer (handout).

Randall, D. A., 2003: Empirical orthogonal functions (handout).

Introduction to empirical orthogonal functions (EOFs).

Overview and discussion of the data sources for observing the general circulation.

January 27th:

Reading:

Grotjahn, Chapter 2.

Peixoto and Oort, Chapter 5.

Analysis of data.

Reanalyses.

First look at the zonal and temporal means.

January 29th:

Reading:

Grotjahn, Chapter 3.

Peixoto and Oort, Chapter 7.

More analyses of the mean state of the atmosphere.

Ocean temperatures and Ekman pumping.

February 3rd:

Reading:

Peixoto and Oort, Chapter 8 and Chapter 9.

Mean states of the oceans and the ice.

Basic energy balance models.

Introduction to the "ice-line model."

February 5th:

Reading:

James, Chapter 3.

The ice-line model and climate stability.

February 10th:

Reading:

M. I. Budyko, 1969: The effect of solar radiation variations on the climate of the Earth. *Tellus*, **5**, 611-619.

More results from the ice-line model.

Framework of the Held-Hou model of the Haldey circulation.

Homework #1 handed out.

February 12th:

Reading:

James, 4.1-4.3.

Held, I. M., and A. Y. Hou, 1980: Nonlinear axially symmetric circulations in a nearly inviscid atmosphere. *J. Atmos. Sci.*, **37**, 515-533.

Solutions and results from the Held-Hou model.

February 17th:

Reading:

Vallis, 11.1-11.4

Lindzen, R. S., and A. Y. Hou, 1988: Hadley circulations for zonally averaged heating centered off the equator. *J. Atmos. Sci*., **45**, 2416-2427.

Advancements from the Held-Hou model.

February 19th:

Homework #1 due.

Waves, eddies, and heat and momentum fluxes.

Homework #2 handed out.

February 24th:

Reading:

Holton, section 7.5.

Inertial stability and symmetric instability.

The response of balanced flows to sources of heat and momentum.

February 26th:

Homework #2 due.

Reading:

Grotjahn, sec 6.3.

Balanced symmetric response and the Kuo-Eliassen equation.

March 2nd:

Reading:

Holton, Sec. 10.1-10.2.1

James, Sec. 4.4-4.5.

More on the Kuo-Eliassen equation.

Understanding the response through Green's functions.

Pre-midterm discussion of previous homeworks and solutions.

March 4th:

Midterm exam.

March 16th:

Reading:

Grotjahn, Chapter 5, sections 5.1-5.8.

Heat and momentum fluxes in the mid-latitudes.

Baroclinic versus barotropic dynamics.

First thoughts on baroclinic instability.

Midterm reanalysis.

Discussion about presentations.

March 18th:

Reading: Holton, sections 6-6.1, and 8-8.2.

Baroclinic instability as seen in the two-level model.

March 23rd:

Baroclinic instability in the "real world."

Baroclinic life cycles.

Fronts.

March 25th:

Reading:

Holton, section 9-9.2

James, Chapter 5.1-5.3.

Frontal dynamics and ageostropic circulations.

Introduction to available potential energy.

Large-scale equations for APE and KE.

Homework #3 handed out.

March 30th:

Reading:

James, Chapter 6.1-6.4.

Eddy energy exchanges and the Lorenz cycle.

Stationary planetary waves.

April 1st:

Reading:

Holton, Ch. 11.1-11.3.

Vertically propagating planetary waves.

Introduction to tropical dynamics.

Scale analysis and the Helmholtz decomposition

April 6th:

Homework #3 due.

Reading:

Grotjahn, Sec. 5.10.

James 7.1-7.2.

Webster, P. J., 1987: The elementary monsoon. Chapter 1 of *Monsoons*, Fein and Stephens, eds. Wiley and Sons, New York. (handout)

Plumb, R. A., and A. Y. Hou, 1992: The response of a zonally symmetric atmosphere to subtropical thermal forcing: threshold behavior. *J. Atmos. Sci*., **49**, 1790-1799.

The Asian Monsoon and its dynamics.

April 8th:

Reading:

Mitchell, T. P., and J. M. Wallace, 1992: The annual cycle in equatorial convection and sea surface temperature. *J. Climate*, **5**, 1140-11156.

Hendon, H. H., and Murry L. Salby, 1994: The life cycle of the Madden-Julian oscillation. *J. Atmos. Sci.*, **51**, 2225-2237.

ITCZ and the Madden-Julian Oscillation.

Homework #4 handed out.

April 13th:

Reading:

Labitzke and Van Loon, *The Stratosphere.* Chapters 1 and 2.

Introduction to the stratosphere.

April 15th:

Homework #4 due.

Reading:

Labitzke and Van Loon, *The Stratosphere.* Chapters 3 and 4.

Stratospheric dynamics.

April 20th: No class.

April 22nd:

Student presentations.

April 24th (Friday class):

Student presentations.

May 1st 11:00AM:

Final Exam.