COURSE TITLE: PHYS335: Physics & Chemistry of the Atmosphere Fall 2017
Dates and Location: Tuesday & Thursday, 10:00 – 11:15am (Room: PHYS201)

INSTRUCTOR: Dr. Lynn Sparling (sparling@umbc.edu) Office: PHYS425 ph:410-455-6231

OFFICE HOURS: T & TH: 11:15-12:30, W&F: 12-1. Feel free to stop by outside these hours. Contact by email is preferred.

COURSE MATERIALS:

Text: Wallace, J.M. and P. V. Hobbs, *Atmospheric Science: An Introductory Survey*, 2^{nd} ed., Elsevier, 2006, also lecture notes, handouts, data sets.

DESCRIPTION: This course is an introduction to the basic physics that underlies a range of atmospheric phenomena from global scale wind patterns to smaller scale tornadoes, solar and infrared radiation, and the dynamics and thermodynamics of selected weather phenomena. The course will also cover the main physical and chemical processes behind current environmental issues including climate change, air quality and the ozone hole. Assignments will include individual research projects and analysis of atmospheric datasets using simple models to explain observations.

GRADING: HW (20%) Quizzes (20%) Midterm (20%) Final (25%) Class participation/Projects (15%)

A: > 87% B: 75-87% C: 60-74% D: 45-59% F: <45%

Homework will be assigned on Thursday and will be due the following Thursday. Graded work will also be returned each Thursday. See calendar and Bb for assignment due dates, exam/quiz dates, project due dates. There will be 10 quizzes, and class participation will include contributions to class and Bb discussions.

BLACKBOARD: *Check our course Bb site often for assignments, data and all related course information.* The weekly schedule and lecture topics will be posted there. Data will be posted in the Course Materials section. For your project, you may want to download additional data to further explore the topics covered in homework. Post questions about homework in the homework forums in the Bb Discussion section. Feel free to answer each other's questions. I will check the homework forums often.

You are encouraged to discuss and work together on the homework, but I expect individual writeups of the solutions to problems or data analyses *in your own words*. The development of a solution to a problem should be clear, and annotated with reasons for various steps or assumptions.

ACADEMIC INTEGRITY: *Copying other's work, using others' ideas without proper citation or cheating on exams are all violations of academic integrity and could result in an "F" in this course and being haunted by feelings of remorse for a long time thereafter. Don't do it.*

WEBSITES: (more will be added – see Bb):

Weather and climate research at NOAA: https://www.esrl.noaa.gov/psd/

Online tools for plotting global atmospheric fields (winds, temperatures, pressure, precipitation, etc.) for climate analyses:

https://www.esrl.noaa.gov/psd/data/20thC_Rean/

Weather events (fields every 3 hours) can be plotted using the North American Regional Reanalysis (NARR) meteorological data which can be found at

https://www.esrl.noaa.gov/psd/cgi-bin/data/narr/plothour.pl/

We will use the NOAA data for some HW assignments.

Some proficiency in coding/plotting is required for the data analysis assignments. You may use the language of your choice. I use IDL (Interactive Data Language) which runs on Linux, Windows or MAC platforms. There is an open source version called GDL (GNU Data Language) that runs on Linux and MAC (but not Windows). It can be downloaded here:

http://www.gnudatalanguage.sourceforge.net/

I will not accept Mathematica notebooks for assignments. Turn in the plots (with figure captions and labelled axes) and a brief writeup of the results.

COURSE OUTLINE (In order of presentation). The topic for each lecture will be listed on the calendar and learning goals will be highlighted at the beginning and end of each lecture. Lecture powerpoints will be posted on Bb.

I. Overview

• Composition and structure of the Earth's atmosphere

Basic geography, distribution of water & land, topography
Chemical constituents, trace gases
Ozone layer, water and carbon cycles
The distribution of atmospheric winds, temperature, pressure
Layers of the atmosphere: Boundary layer, troposphere, stratosphere, mesosphere, ionosphere
Hydrostatic balance, isobars, geopotential height

• Global energy balance

Geometric aspects of incoming solar radiation, dependence on orbital parameters, Vostok ice core data, seasonal variability
Incoming and outgoing radiation; visible, IR and microwave radiation
Blackbody radiation
Quantum mechanics and the Greenhouse effect

• Atmospheric motion and the general circulation

Length and time scales of atmospheric phenomena; climate vs. weather
Hadley circulation, ITCZ, zonal mean circulation
Polar and subtropical jet streams, Rossby waves, pressure highs & lows

II. Atmospheric thermodynamics

- Fundamental thermodynamic ideas
  - Ideal gas equation of state for dry and moist air
  - First Law: work, heat, specific heat and energy conservation
  - Second Law: entropy, adiabatic processes, potential temperature
  - Thermodynamic cycles
  - Land & sea thermal drivers of atmospheric motion; heat capacity, thermal conductivity
  - Thermal expansion of the ocean and sea level rise

- Thermodynamics of dry and moist air
  - Geopotential height
  - Lifting condensation level, level of free convection
  - Dry adiabatic lapse rate and static stability
  - Thermodynamic aspects of selected weather/climate phenomena, e.g. sea breeze, hurricanes…
  - Phase changes of water and the phase diagram, latent heat
  - Humidity, vapor pressure, Clausius-Clapeyron equation
  - Precipitation, latent heat release and atmospheric motion
  - CAPE (Convective available potential energy); the fuel for severe thunderstorms

- Static stability
  - Lifting condensation level (LCL), level of free convection (LFC)
  - Brunt-Vaisala frequency and gravity waves
  - Subsidence; heating by compression

- Thermodynamic aspects of various weather and climate phenomena:
  - A hurricane as a Carnot Engine, rain shadow deserts, monsoons…

Midterm Exam

III. Atmospheric Dynamics

- Kinematic and mathematical fundamentals
  - Scalar & vector fields
  - Fluid flow, vorticity and divergence
  - Rotating frames
  - Eulerian and Lagrangian frames, advection

- Atmospheric forces
  - Driving versus steering forces
  - Gravity, pressure gradient, Coriolis, friction, centripetal acceleration of curved flows
  - Pressure gradient force on isobaric surfaces
  - Geopotential height contours, surface and 500mb weather charts

- Atmospheric equations of motion
    - Conservation of mass, momentum and energy; F=ma for a fluid
    - Bernoulli equation
    - Geostrophic, cyclostrophic and gradient wind balance; tornados, weather systems
    - Waves
    - Severe weather, thunderstorms, droughts, hurricanes, lightning…

- The planetary boundary layer
    - Interaction between the earth surface and the atmosphere
    - Transport by advection, convection and diffusion
    - Intro to Turbulence

IV. Atmospheric Chemistry

Sources of atmospheric constituents: trees, cows, cars, forest fires, volcanos…
Air pollution and smog
Chemical rate equations
Clouds, rain, snow, hail & aerosols
Stratospheric ozone and the ozone hole
Greenhouse gases

V. Climate Change

- Observed changes in the climate
- Simple climate models and climate feedback mechanisms
- Impact of climate change on extreme events (e.g. hurricanes, floods, etc)

Other topics as time permits (e.g. satellites, remote sensing…)