COURSE TITLE: Atmospheric Dynamics Spring, 2019
COURSE NUMBER: PHYS731, Location: PHYS 226, day/time TBD by class consensus)
INSTRUCTOR: Dr. Lynn Sparling (sparling@umbc.edu).
OFFICE HOURS: Flexible, TBD by student schedules and by appointment.

TEXTS: Holton, J. R. *Introduction to Dynamic Meteorology*, 5th ed., (required).
Reference texts: Vallis, G., *Atmospheric and Oceanic Fluid Dynamics*, Cambridge University Press, 2006;
Martin, P., *Mid-Latitude Atmospheric Dynamics: A first course*
Other course material: papers and lecture notes

DESCRIPTION: Conservation laws, principles of rotating stratified fluids, shallow water equations; basic fluid flows and approximations to the primitive equations; quasi-geostrophic dynamics of mid-latitude synoptic systems, mesoscale and local phenomena (hurricanes, sea breeze, topographic forcing), atmospheric waves, barotropic/baroclinic instability, atmospheric boundary layer, transport/mixing.

PRE-REQUISITES: PHYS621 is highly recommended. In lieu of that, either grad/undergrad course work in meteorology OR a strong mathematical background may be sufficient. Interested students who have not taken PHYS621 should come and talk to me. Students have varied mathematical backgrounds, so the course will begin with a mathematical overview and practice problems, with a strong emphasis on conceptual understanding.

COMPUTATIONAL SKILLS: Students should have some experience with high-level languages such as Matlab, IDL, Python. We will use Jupyter notebooks (python v. 2.7) for data analysis and plotting; it works well with Linux, MAC or Windows OS. (Notebooks have already been created, so only minimal coding is required). Data analysis assignments will include exploring dynamics using statistical analysis(e.g. pdfs) scale-dependent analyses (e.g. FFT, wavelets, structure functions), correlations, plotting meteorological fields on the globe. Students should download the Anaconda python distribution from (https://www.anaconda.com/download). LaTex will be used for text/equations within the Jupyter notebook.

Required: Registration at the COMET MetEd site https://www.meted.ucar.edu/index.php which contains many excellent tutorial modules. A couple of assignments will involve completion of these modules. They are a valuable resource at all stages of your career; I often look to them to learn new things.

GRADING: Homework/data analysis assignments and class discussions/presentations (75%), final research project & presentation (25%). I will discuss grading rubrics in class. There will be no formal exams in this course.

Assignments will vary, depending on topic. They will include problems involving mathematical derivations, data analysis, analysis of meteorological maps, researching the literature. Work that is sloppy/unreadable or without clear mathematical development and discussion of results will be returned, with an option to resubmit. Where appropriate, results on problems should be checked using dimensional analysis or taking limiting values of parameters. You can post questions and discussion of homework problems to the Bb homework forums.

You will be required to give one 30-45 minute lecture chosen from a list of topics. It should be tutorial in nature and should include a short assignment for the class that you will grade. The final project is a research project that must include a data or model analysis component and be formatted in Latex as a journal article with sections on intro/background, description of data and analysis methods, results(plots, statistics,tables, etc), summary and conclusions, references. If you have chosen a direction for your PhD research, then a project focussing on any related/relevant dynamical aspect is highly recommended.

FORMAT FOR CLASS MEETINGS:

The format for class meetings will vary, depending on topic. The lecture will be shortened to allow for in-class work by students on the board, student presentations of their solutions to assignments, or class discussions on topics of interest or review of journal articles. Extra homework sessions will also be scheduled as needed.

MAIN COURSE OUTLINE: (Subject to some rearrangement as necessary. Time spent on each main area depends on student needs/background/interest.)

I: Review of relevant physics/math/computational skills and concepts

Vector calculus, curvilinear and natural coordinates, kinematics of vector fields (vorticity, divergence etc), partial differential equations and dispersion relations, oscillations, index notation.
Training on the use of Jupyter notebooks and Latex
Accessing and plotting climate (NCEP) and weather (NARR) reanalyses from NOAA/ESRL to illustrate dynamical concepts.

II. Brief review of 621-level dynamics/thermo:

Hydrostatic equation, scale height, geopotential, lapse rate
Equations for conservation of mass, energy and momentum
Lagrangian and Eulerian reference frames, Lagrangian derivative, advection
Atmospheric stability, buoyancy
Geostrophic and cyclostrophic balance, thermal wind, gradient wind, adiabatic motion
Equations of motion in pressure coordinates
Baroclinic and barotropic stratification
Vorticity equation; relation between potential vorticity and angular momentum
Shallow water equations

II: Topics in Atmospheric Dynamics

Lagrangian and Eulerian view of oscillations: Particles (parcels) vs. waves
Ertel's potential vorticity (PV) and shallow water PV
Gravity waves and topographic forcing, Rossby waves, inertia-gravity waves, Kelvin waves
Geostrophic adjustment, deformation radius
Barotropic and baroclinic instability
Energy equations and transformations
Ageostrophic circulations

Fundamentals of synoptic meteorology
- Quasigeostrophic Dynamics
- Omega equation, QG potential vorticity
- Polar and subtropical jet streams and jet streak circulations

Long-range transport of aerosols and gases; trajectory modelling

III. Planetary boundary layer

Boundary layer processes: PBL height, convective and shear induced turbulence, turbulent fluxes, pollution trapping, Reynolds decomposition, Ekman layer. Ekman pumping
Physical processes that impact the atmosphere from below, e.g. soil moisture, land-sea thermal contrasts, thermal inertia, brief overview of land-sea interaction
Selected mesoscale phenomena; e.g. low level jets, sea breeze, hurricanes
Mixing and transport

IV. Miscellaneous topics in climatology, climate change and atmospheric modeling
(as time permits, or student interest)

North American Oscillation (NAO), El Nino, climate change and the jet stream
Brief overview of data assimilation
The stratospheric polar vortex
Elements of WRF (Weather Research and Forecast) model; parameterizations of model physics
Others, depending on student interest

Academic Integrity: Working together on assignments is acceptable, but all submitted work must be your own, with your own discussion/interpretation of results.