Notes for online delivery in Winter 2021

- Lectures are delivered live during scheduled class times (900-1020am PDT, M/W) on Zoom. Each lecture is video recorded and available in Canvas.
- Let's start the first lecture 5 minutes earlier at 855am January 4 (M) to get familiar with the online environment.
- During Zoom lecture, you are welcome to ask questions by virtually raising hand. Make sure to unmute yourself before speaking. (To ensure quality, please mute yourself when not speaking.)
- Homework must be submitted online in Canvas/Assignments. For better quality, please scan handwritten notes/drawing using a scanner or scan app (e.g., Notes in iPhone or Adobe Scan, a freeware mobile app). Please combine multiple pages of your homework into one single file (in pdf or docs).
- I'm happy to set up a time weekly or bi-weekly to answer questions and/or for discussion.

SIO 217B (Winter 2021)

Atmospheric and Climate Sciences II: Atmospheric Dynamics

Instructor: Shang-Ping Xie, (office) MESOM 323, (email) sxie@ucsd.edu, (phone) 858-822-0053

Date, time, location: Mondays & Wednesdays, 9:00-10:20am, on Zoom

Synopsis: On the California coast, summer is dry and kept cool by the northerly winds and the ocean upwelling they induce. In winter, successive rain storms come ashore from the North Pacific Ocean riding on the westerly winds. The westerly winds aloft do not merely steer these storms eastward but cause some of these storms to wax and some to wane. The development of dynamical meteorology over the 20th century led to physical insights into how winter storms grow, move and decay, culminating into operational numerical weather prediction on which the public is dependent. This class surveys atmospheric dynamics that governs the large-scale flow and the variations. This subject is unavoidably mathematical, and you will need to develop (or already have) familiarity with aspects of vector calculus and partial differential equations. At the beginning of each lecture, we discuss rich weather variations as they unfold in real time. Understanding and predicting ever-changing weather motivated and drove the development of dynamic meteorology, and the weather discussion sets the background for mathematical theories that sometimes may seem dry. Our focus is on synoptic (10^3 km) to planetary (10^4 km) scale motions.

Learning objectives: Students will know how to derive and interpret governing equations for large-scale flow, understand fundamental concepts (e.g., geostrophic and thermal winds, vorticity, potential vorticity, quasi-geostrophic approximation, and Rossby waves), and apply them to interpreting large-scale wind variations.

Office Hours: Students are welcome to stay after class for questions and discussion. You can also make an appointment to meet on Zoom.

Grading: 60% homework, 30% final exam, and 10% participation.

Homework: This material is best learned by working through problems, and problem sets will be assigned approximately once per week. Homework will be graded, and each student's lowest homework grade will be dropped in the calculation of the final grade. Students are encouraged to work together on homework exercises as long as each student turns in only his or her own work. Please do not consult homeworks or solutions from previous years.

Exam: Final exam is take-home.

Textbook: *An Introduction to Dynamic Meteorology, Fourth Edition*, by J.R. Holton (2004) [here].

Other textbooks covering aspects of the material we cover that you may also find useful:

Mid-Latitude Atmospheric Dynamics by Jonathan Martin (2006) [here]: Detailed derivations and applications to mid-latitude synoptic cyclones, e.g., chapter 6 "Diagnosis of vertical motions."

Global Physical Climatology by Dennis Hartmann (1994) [here]

Atmosphere-Ocean Dynamics by Adrian Gill (1982) [here]: Comprehensive dynamics, especially regarding waves; nice discussion of the boundary wave, Rossby height, and Eady problem of baroclinic instability (sections 13.2-3)

An Introduction to Dynamic Meteorology, Fifth Edition, by J.R. Holton and G.J. Hakim (2012): with enhanced discussion of observations.

Useful Links

- Pressure fields with satellite IR images: surface, 500 & 300 hPa
- NWS San Diego Office: Current conditions (satellite, radar, soundings); Forecast discussion
- Global Circulation: Daily, weekly, monthly & seasonal means
- Analysis and Forecast Maps (large-scale)
- Surface station observations (real time & local)

Lecture schedule:

- Mon 1/04: Introduction (read textbook sections 1.1-1.2, 1.6.1), basic forces (1.4). Read also section 1.2.1 of J. Martin's text for a useful review of vector calculus.
- Wed 1/06: Coriolis force (1.4, 1.6.1, 1.5)
- Mon 1/11: Material derivative, momentum equation (2.1-2.4, 1.3), continuity equation (2.5)
- Wed 1/13: Energy equation, potential temperature, static stability (2.6-2.7)
- Mon 1/18: Martin Luther King Day
- Wed 1/20: Isobaric coordinates, summary of governing equations (2.7, 1.6.2, 3.1), Geostrophic/gradient wind (3.2)
- Mon 1/25: Trajectories, thermal wind, westerly jet stream (3.3-3.4)
- Wed 1/27: Vertical motion (3.5), circulation (4.1)
- Mon 2/01: Vorticity (4.2, 4.4), potential vorticity (PV) (4.3)
- Wed 2/03: Vorticity equation (4.4), Barotropic vorticity equation (4.5)
- Mon 2/08: Mid-term review, Planetary boundary layer, spin down (5.4)
- Wed 2/10: Waves, dispersion relationship, phase & group velocities (7.1-7.2)
- Mon 2/15: Presidents' Day
- Wed 2/17: Barotropic Rossby waves (7.7), downstream development
- Mon 2/22: Barotropic stationary waves in a zonal channel (7.7.2) & on a sphere (10.5.1)
- Wed 2/24: Quasi-geostrophic (QG) approximation (6.1-6.2)
- Mon 3/01: PV equation (6.3.2), PV inversion, Rossby height (6.3.3-4)
- Wed 3/03: 2-level model, baroclinic Rossby waves (8.2.1), Rossby radius of deformation
- Mon 3/08: Cyclogenesis, baroclinic instability, eddy meridional heat transport (8.1-8.2)
- Wed 3/10: Review
- Date to be determined: Final exam (take home).

Lecture slides/notes: Will be posted after each lecture on UCSD Canvas (https://canvas.ucsd.edu)

Homework assignments each week