SIO 235 – Ocean-Atmosphere Interaction and Climate

Spring 2022

Place: Speiss 330 in person
Meeting Time: 9:30 - 10:50 AM, Mondays and Wednesdays
Instructor: Shang-Ping Xie, MESOM 323; Tel: 822-0053; sxie@ucsd.edu
Prerequisites: any one of SIOC 217; SIOC 210, 212, or consent of instructor
Office Hours: After class or by appointment

Climate variability drives, and climate change exacerbates, extreme events such as heatwaves, droughts, and flooding. This class presents core coupled ocean-atmosphere dynamics addressing fundamental questions such as why climate varies from one year to another, how preferred patterns of climate variability arise, how climate will change in the face of increasing greenhouse gases in the atmosphere, and how predictable climate is.

We start with a description of major features of tropical climate, followed by discussion of interactive processes that cause climate to vary in space and time. We focus on tropical climate for two reasons: the ocean-atmosphere coupling is strongest there, and latent heat released in tropical convection drives the global atmospheric circulation. Subtropical climate and extratropical ocean-atmosphere interaction are also covered.

On the class website (canvas.ucsd.edu), lecture notes and podcast will be posted after each lecture. Slides and lecture notes from the previous year are also available there. Please go through the notes before each lecture and be ready for discussion.

Each student is required to make a 15-minute presentation on a topic of your choice based on a journal paper, and/or original research. A list of topics and references will be distributed about half way through the course.

Learning objectives. To know major patterns of tropical climate, develop a coupled ocean-atmosphere perspective to understand climate variability and predictability, and appreciate distinct dynamics of ocean-atmosphere interaction between the tropics and extratropics.

Homework must be submitted online in Canvas/Assignments. To ensure 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).

Grading (letter grade): final exam (30%; take home & open book), homework (40%), presentation (20%), and participation (10%).

1. **Energy balance**
   Review of key concepts (geostrophy, Ekman effect, potential temperature, static stability), energy (im)balance, and heat transport.
2. **Zonal-mean circulation**
   Hadley circulation, subtropical jet, role in precipitation and energy transport.
3. **Major precipitation/convergence zones**
   ITCZ, SPCZ, SACZ, hydrological cycle, moisture convergence, sea surface temperature (SST) effect
4. **Interaction of convection and circulation**
   Equatorial waves, weak temperature gradient, the Gill model, warm pool, Walker circulation
5. **Madden-Julian Oscillation**
   Circum-global structure, propagation, moisture mode, super cloud clusters
6. **Monsoons**
   Structure, seasonal march, land-sea thermal contrast, soil moisture, orographic effects
7. **Subtropical high and trade winds**
   Trade wind inversion, marine low clouds, cloud regime transition, cloud feedback, California climate
8. **Equatorial oceanography**

Upwelling, 1.5-layer model, thermocline adjustment to wind change, mixed layer heat budget, surface heat flux

9. Coupled feedback and mean climate
Northward displaced ITCZ, WES feedback, coupled model; equatorial cold tongue, annual cycle

10. Bjerknes feedback and El Nino/Southern Oscillation
Interannual variability, Bjerknes feedback, coupled instability; Ocean memory, oscillatory mechanisms

11. Seasonal prediction and teleconnection
Phase locking, climate prediction, Nino4 vs. Nino3; stationary waves, Pacific North American pattern

12. Atlantic variability
Atlantic Nino and meridional modes, cross-basin interactions; environmental control of tropical cycles, genesis potential, potential intensity

13. Indian Ocean variability
Semi-annual cycle, Wyrtki jets, Indian Ocean dipole, Indian Ocean capacitor

14. Extratropical variability
Atmospheric modes of variability, lagged o-a cross correlation, PDO, AMO

15. Extratropical influence on tropics
Zonal-mean energy theory, subtropical meridional modes

16. Regional change in warming climate
Radiative control of global precipitation, slowdown of tropical circulation, ocean warming pattern effect, ocean heat uptake

17. Review and synthesis

Textbook: Xie, S.-P., 2022: *Coupled Atmosphere-Ocean Dynamics: Climate Variability and Climate Change*. Elsevier Science, in press.

Reference books

Wallace, J.M., and P.V. Hobbs, 2005 (WH05): *Atmospheric Science*. Academic Press, pp.483. (descriptive, dynamical and physical meteorology at the upper undergraduate level)

COMET at NCAR: http://www.meted.ucar.edu/resource_modlist.php

Gill, A.E., 1982 (G82): *Atmosphere-Ocean Dynamics*. Academic Press, pp. 662. (Harmony of dynamics and observations)

Hartmann, D.L., 1994 (H94): *Global Physical Climatology*. Academic Press, pp. 411; 2nd Ed. pp. 498, Elsevier Science (2016) (Blend descriptive and dynamical approaches by a distinguished dynamist)

Holton, J.R., 2004: *An Introduction to Dynamic Meteorology*, 4th Ed. Academic Press, pp. 535.

Useful links.

NASA 7-day precip: Latest global precipitation distribution

NOAA PSL Map Room: SST, OLR, and atmospheric circulation

NOAA CPC Monsoons: Precipitation, SST, and atmospheric circulation

NOAA CPC El Nino monitoring

IPCC

Student presentations

In the week of May 23, each student is to make a 12-minute presentation (<10 ppt slides), followed by 3-minute Q&A. A computer will be available. Please load your ppt file before the class starts. Write a summary (1-2 pages) that discusses in your own words the background, major findings, significance, and implications of the paper(s). Please include the full reference (authors, year, title, journal). The final exam will feature questions from student presentations.

The talk should target at your fellow students so please include necessary background to motivate your audience. Key points to cover: what is the paper about? What are the major phenomena/science questions it addresses? What methods does it use and what are the major results? What are the major contributions of the research? What do you feel most excited at, and why? Do not just present the results but also provide the context/story for why these results are interesting/new/important.

Usually it is not feasible to present the whole paper in a 12-minute talk so you need to be selective, choosing the most important results and building a coherent story for your talk. Additional reading and synthesis with related papers help gain perspective. (One can find additional reading in the References section of the main paper or by searching on AMS/AGU journal sites. If you choose a short paper in *Nature, Science* or *Geophys Res Lett*, you might want to read one additional paper.)

Make sure that figures and text are big/clear enough for the audience to see. Use schematics as necessary.