SIO 235 – Ocean-Atmosphere Interaction and Climate

# Spring 2023 (2 lectures/week x 10 weeks, April 3-June 9)

**Place**: Speiss 330 in person (lectures recorded and available in podcast)

**Meeting Time**: 12:00 - 13:20, Mondays and Wednesdays

**Instructor**: Shang-Ping Xie, MESOM 323; Tel: 822-0053; sxie@ucsd.edu

Prerequisites: 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 slides and podcast will be posted after each lecture. Slides from the previous year are also available there. Please go through the reading before each lecture and be ready for discussion.

Each student is required to make a 12-minute presentation with 3-minute Q&A on a topic of your choice based on a journal paper, and/or original research. A list of topics and suggested papers will be distributed halfway 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 in the tropics and extratropics.

Homework will be assigned every other week on Wednesday, and your answers returned the following week.

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

**Lecture schedule** and reading

**1. Introduction** (reading in X23 textbook: sections 1.1, 1.2, 2.1)

Ocean’s role in climate, climate in the news, planetary energy balance, vertical structure of the atmosphere.

**2. Energy transport and zonal-mean circulation** (2.3, 2.4, Box 2.2)

Meridional energy transport, meridional overturning circulation, Hadley circulation, subtropical jet, moist static energy.

**3. Tropical convection** (3.1, 3.2, 3.3)

ITCZ, hydrological cycle, moisture convergence, SST effect, diabatic/latent heating, Q1

**4. Equatorial waves and tropical circulation** (3.4, 3.5, 3.6, 4.1.0; H04 11.4)

Kelvin/Rossby waves, the Gill model, warm pool, Walker circulation, weak temperature gradient, convective threshold

**5. Asian summer monsoon** (5.0, 5.1, 5.3)

Southwest monsoon, Tibetan high, Somali upwelling, land-sea energy contrast, orographic effects, monsoon onset, monsoon Asia vs. Sahara desert

**6. Subtropical climate** (6.1, 6.2, 6.3.1)

Trade wind inversion, low clouds, cloud-top cooling, cloud regime transition, cloud-SST feedback

**7. California climate** (5.5, 6.4)

Marine layer, coastal upwelling, North American monsoon, atmospheric rivers, snowpacks, Santa Ana wind, wildfires

**8. Equatorial oceanography** (7.1.1-4, 7.2.1-2, 7.2.5, 7.3)

Upwelling, reduced-gravity model, Yoshida jet, thermocline adjustment to wind change, mixed layer heat budget, surface heat flux

**9. Tropical mean climate** (8.1, 8.2, 8.3.1)

Northward displaced ITCZ, WES feedback, coupled model; equatorial cold tongue, south equatorial upwelling, annual cycle

**10. El Nino/Southern Oscillation** (9.1, 9.2, 9.3)

Interannual variability, Bjerknes feedback, coupled instability; Ocean memory, oscillatory mechanisms

**11. Seasonal prediction and global teleconnection** (9.4.1, 9.4.3, 9.5, 9.6.1, 9.6.3-4, 9.7)

Phase locking, El Nino diversity, climate prediction; teleconnection, PNA pattern, stationary waves in westerly flow

**12. Atlantic variability** (10.1.2, 10.2-3, 10.4.1, 10.5.1-3)

Atlantic Nino, meridional mode, ENSO influence; environmental control of tropical cyclones, vertical shear dynamics, genesis potential, potential intensity

**13. Indian Ocean variability** (11.1-2, 11.4, 11.5.1)

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

**14. Extratropical variability** (12.0-2)

Atmospheric internal variability (random in time but spatially coherent), lagged ocean-atmospheric cross correlation, Pacific decadal oscillation

**15. Extratropical influence on tropics** (12.4, 12.6)

Subtropical meridional modes, zonal-mean energy theory, interhemispheric energy transport

**16. Regional change in warming climate** (13.3.5, 14.1, 14.4.1, 14.7)

Radiative control of global precipitation, slowdown of tropical circulation, ocean warming pattern effect, ocean heat uptake

**17. Review and synthesis**

**Textbook** (available in PDF via the hyperlink from UCSD)

Xie, S.-P., 2023 (X23): [*Coupled Atmosphere-Ocean Dynamics: Climate Variability and Climate Change*](https://www.sciencedirect.com/book/9780323954907/coupled-atmosphere-ocean-dynamics). Elsevier, 424 pages.

**Reference books**

Wallace, J.M., and P.V. Hobbs, 2005 (WH05): [*Atmospheric Science*](http://www.sciencedirect.com/science/book/9780127329512). Academic Press, pp.483. (descriptive, dynamical and physical meteorology at upper-division undergraduate level)

COMET: http://www.meted.ucar.edu/resource\_modlist.php

Gill, A.E., 1982 (G82): [*Atmosphere-Ocean Dynamics*](http://www.sciencedirect.com/science/book/9780122835223). Academic Press, pp. 662.

Hartmann, D.L., 1994 (H94): [*Global Physical Climatology*](http://uclibs.org/PID/240821). Academic Press, pp. 411; 2nd Ed. pp. 498, Elsevier (2016)

Holton, J.R., 2004 (H04): [*An Introduction to Dynamic Meteorology*](http://roger.ucsd.edu/record%3Db7294699~S9), 4th Ed. Academic Press, pp. 535.

**Useful links.**

[NASA 7-day precip](https://gpm.nasa.gov/data/visualization/global-viewer)itation: Latest global precipitation distribution

[NOAA PSL Map Room](https://psl.noaa.gov/map/): SST, OLR, and atmospheric circulation

[NOAA CPC Monsoons](https://www.cpc.ncep.noaa.gov/products/Global_Monsoons/Global-Monsoon.shtml): Precipitation, SST, and atmospheric circulation

[NOAA CPC El Nino monitoring](https://www.cpc.ncep.noaa.gov/products/precip/CWlink/MJO/enso.shtml)

[IPCC](https://www.ipcc.ch/working-group/wg1/)

**Student presentations** (see topics-2023.docx for a list of suggested papers)

On June 2, each student is to make a 12-minute presentation (<10 ppt slides), followed by 3-minute Q&A. 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 your fellow students so please include the 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 about, 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 the Web of Science or Google Scholar. 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.