Notes for online delivery in Spring 2020

- Lectures are delivered live during scheduled class times (930-1050am PDT, M/W) on Zoom. Each lecture is video recorded and available in Canvas.
- Let's start the first lecture 5 minutes earlier at 925am March 30 (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.

Join live lecture on Zoom

https://ucsd.zoom.us/j/441686119

Meeting ID: 441 686 119

Time: **Mar 30, 2020 09:25 AM** Pacific Time

Every week on Mon, Wed

SIO 235 – Ocean-Atmosphere Interaction and Climate

Spring 2020

Place: Zoom at https://ucsd.zoom.us/j/441686119
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

The importance of ocean for climate is evident: most of solar radiation is absorbed at the Earth surface and the ocean occupies seventy percent of the Earth surface. Examples of ocean-atmosphere interaction effects are abundant, including the spontaneous generation of El Nino/Southern Oscillation (ENSO) that affects global climate. The class addresses such fundamental questions 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. Ocean-atmosphere interaction dynamics is key to answering these questions.

We start with a description of major features of tropical climate, followed by discussions 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.

No single textbook is adequate for the class. Key references will be given in class notes, which students are encouraged to read. On the class website (canvas.ucsd.edu), lecture notes will be posted in pdf 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.

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.

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, California climate
8. **Equatorial oceanography**
   Upwelling, 1.5-layer model, thermocline adjustment to wind change, mixed layer heat budget, surface heat flux
9. **WES feedback and meridional asymmetry**
   Northward displaced ITCZ, cloud feedback, coupled model

10. Bjerknes feedback and El Nino/Southern Oscillation
Equatorial cold tongue, annual and interannual variability, coupled instability

11. ENSO cycle and predictability
Ocean memory, oscillatory mechanisms, phase locking, seasonal climate prediction, Nino4 vs. Nino3

12. Atmospheric teleconnections
Stationary waves, Pacific North American pattern; extratropical influence on ITCZ

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

14. Atlantic variability
Atlantic Nino and meridional modes; cross-basin interactions, biases of climate models

15. Tropical cyclones and ocean feedback
Environmental control, genesis potential, maximum intensity, cold wake and ocean feedback

16. Extratropical ocean-atmosphere interactions
Atmospheric modes of variability, lagged o-a cross correlation, basin vs. meso-scale

17. Global warming
Atmospheric stabilization, radiative control of global precipitation, slowdown of tropical circulation, ocean warming pattern effect

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

First half
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.
Lindzen, R.S., 1990: *Dynamics in Atmospheric Physics*, Cambridge, pp. 310.

Second half
Philander, S.G.H., 1990 (P90): *El Nino and the Southern Oscillation*. Academic Press, pp.
Wang, C., S.-P. Xie, and J.A. Carton (eds), 2004 (WXC04): *Earth Climate: The Ocean-Atmosphere Interaction*. Geophys. Monogr., 147, AGU, pp. 414.

Access to journal articles. Most journals for this class are published by the American Meteorological Society (AMS) and American Geophysical Union (AGU). Free access via UCSD VPN.

http://journals.ametsoc.org/
AMS: J. Climate (JC), J. Atmospheric Science (JAS), Monthly Weather Review (MWR), J. Physical Oceanography (JPO), Bulletin of the American Meteorological Society (BAMS)

http://publications.agu.org/journals/
AGU: J. Geophysical Research (JGR), Geophysical Research Letters (GRL), Review of Geophysics (RoG)