Syllabus for MPO672 Fall 2011: ENSO Dynamics, Prediction and Predictability

Course Description:

This course will provide students with a comprehensive observational and mechanistic understanding of the El Niño and the Southern Oscillation (ENSO) phenomena and how ENSO impacts the natural variability of the global climate system. Topics will include: Observations and theories of the seasonal and interannual changes in the ocean circulation and temperature, and interactions with the atmosphere; equations of motion and theories of tropical ocean and atmosphere circulation; tropical wave dynamics; large scale air-sea coupling; mechanisms for ENSO: delayed oscillator theory, recharge oscillator theory, slow SST modes; ENSO prediction and predictability; ENSO-monsoon-Indian Ocean interactions; Global climatic response to ENSO; decadal ENSO variability; ENSO in a changing climate.

This course has a phenomenological focus, which complements current MPO course offerings. In particular, students who have taken dynamic and physical meteorology, ocean general circulation or geophysical fluid dynamics will be exposed to how general theory (e.g., wave dynamics) relates to a particular phenomena and current research foci. In addition, student will have the opportunity to design and implement numerical hypothesis testing experiments.

Text Books (Recommended, but not required):


Course Format: 1 exam (20%), Homework (4 problem sets two weeks to complete, some have a computation component, 40%), Project (10 page literature survey topic to be coordinated by instructor, or numerical model experiments to be coordinated by instructor, 40%)

Course Outline:

1) Basic observations of the coupled ocean-atmosphere system (2 weeks)
a. Mean conditions at the air-sea interface; annual cycle; intraseasonal variability; interannual variability throughout the tropics; decadal variability (North Atlantic Oscillation, Atlantic Multi-Decadal Oscillation, Pacific Decadal Oscillation, North Pacific Oscillation).

b. Observations of the tropical atmosphere (convective boundary layer; trade inversion; cloud and climate; vertical structure) and ocean (3-dimensional structure of temperature, salinity and currents).

2) Equations of motion and valid approximations for the tropical upper ocean (2 weeks)
   a. Mixed-layer theories (one dimensional); SST and surface fluxes
   b. Shallow water model; Two-layer model; mid-latitude quasi-geostrophic approximation; wind driven Ekman theory; Sverdrup flow
   c. Oceanic waves (tropical and extra-tropical; Kelvin waves, coastal Kelvin waves, Rossby waves); beta dispersion; boundary reflections; equatorial adjustment; normal modes; response to forcing.

3) Models of the tropical atmosphere (2 weeks)
   a. Hadley circulation; Gill Model; Lindzen-Nigam Model
   b. Atmospheric response to sea surface temperature anomalies, clouds; convection, boundary layer
   c. Remote atmospheric response to ENSO

4) Interactions between the tropical ocean and atmosphere (3 weeks)
   a. Development of a simple air-sea interaction model; unstable interactions; Bjerknes-Wyrtki mechanism; unstable modes (i.e., unstable Kelvin and Robbby waves)
   b. Theories for ENSO; delayed-oscillator (linear and non-linear); recharge oscillator; concept of ocean memory; off equatorial Rossby waves; ENSO time scale; SST modes (fast wave limit); irregularity of ENSO (chaos vs. stochastic forcing)
   c. Stochastic optimals, bred-vectors and ENSO predictability
   d. ENSO-monsoon interactions

5) Simple Coupled Models (2 weeks)
   a. The Zebiak-Cane coupled model formulation (i.e., intermediate coupled models; ICM)
      i. Modification to the ZC formulation and implications for ENSO
   b. Hybrid Coupled models
   c. ENSO periodicity, irregularity and predictability in simple models
   d. Hypothesis testing with simple coupled models

6) Seasonal-to-Interannual Prediction and Predictability in CGCMs (2 weeks)
   a. CGCM simulations of the annual mean, annual cycle and interannual variability
   b. ENSO prediction and limit of predictability estimates (basics of forecast initialization and verification)
c. Basin interactions and ENSO (role of the Indian Ocean; remote ocean teleconnections, sources of decadal variability, impact of ENSO on the Atlantic and extra-tropical oceans, role of local air-sea feedbacks)

d. ENSO variability in a changing climate