I. DESCRIPTION OF CLIMATE

Introduction to the global climate system (Ch. 1)
Definition of climate, time scales, spatial scales, description (observations) vs. explanation (theory) of climate, processes and mechanisms, multidisciplinary approach, area, volume, and mass fractions, and composition of air, water and ice.

Observations of atmosphere and ocean
Mean vs. variability, climatological mean, variability (daily, subseasonal, seasonal, interannual, decadal), surface climate (2m temperature and SST), horizontal and vertical structure, atmosphere (troposphere, stratosphere, mesosphere, thermosphere), dry and moist static stability, ocean (mixed layer, thermocline, deep ocean), static stability and convection, density of air, salt water, and ice.

II. PHYSICS OF CLIMATE

The global energy balance and atmospheric radiation (Ch. 2, 3)
Global mean energy balance, emission temperature, greenhouse effect, simple models (1 layers), Planck's law and blackbody emission, spectrum of radiation, absorption, emission, scattering, selective absorption and emission by gases, distribution of insolation with time and latitude, solar zenith angle and daily insolation, albedo at the surface and from space, variation of albedo, global radiative energy balance, multi-layer radiative equilibrium models.

Atmospheric moisture (Ch. 4, 5)
Observed structure of precipitation, humidity, clouds, moist static stability, influence on density, Clausius-Clapeyron equation and saturation vapor pressure, radiative-convective equilibrium models, convective adjustment, moist-adiabatic lapse-rate, contribution of greenhouse gases to atmospheric temperature profiles, clouds (radiative effects on terrestrial and solar radiation, net effects, ERBE), energy balance TOA (relationship with surface conditions, clouds, and water vapor) energy balance surface (Ch. 4) (role of albedo, surface wetness, surface wind), hydrological cycle (Ch. 5), energy balance of the atmosphere (condensational heating, radiative cooling).

Climate sensitivity and feedback mechanisms (Ch. 9)
Concept and measurement of climate sensitivity, simple models of climate sensitivity based on energy balance, feedback processes (water vapor, lapse rate, cloud, ice-albedo, polar amplification, biogeochemical, ocean heat uptake).
III. DYNAMICS AND CLIMATE

*The general circulation of the atmosphere (Ch. 6)*
Observed structure of the general circulation (u, v, T), Hadley and Walker circulation, Ferrell Cell, mechanisms, angular momentum conservation, meridional momentum and heat transports, role of land: monsoonal and desert climate.

*The general circulation of the ocean (Ch. 7)*
Meridional transports, wind driven circulation: Sverdrup balance, Stommel's ocean model, gyre circulation, western boundary currents, Ekman transport and Ekman pumping, oceanic upwelling, salinity and fresh water transports, global overturning circulation (THC), deep water formation, Rossby and Kelvin waves.

IV. VARIABILITY OF CLIMATE

*Natural climate variability (Ch. 8, 11)*
History of Earth's Climate (Ch. 8), natural climate forcings (solar irradiance, volcanoes), internal variability, climate theories (multiple equilibriums, snowball earth, breakdown of THC), astronomical theory for ice ages, ocean's role on climate (heat reservoir, reddening influence), ENSO: description, dynamics, large scale influences (Rossby waves, PNA), predictability, PDO, multivariate analysis (EOFs), annular modes (observations and dynamics of AO, AAO, PNA, NAO).

*Anthropogenic climate change (Ch. 12)*
Anthropogenic forcing of climate, greenhouse gases (types, potential, origins), aerosols (direct and indirect effect), urbanization and land surface change, air traffic, ozone chemistry and stratospheric ozone depletion, detection of climate change, the instrumental climate record, critiques of climate change, climate policy (IPCC, Kyoto protocol, Montreal protocol).

*Modeling and prediction of climate (Ch. 10)*
Type of models (stochastic, EBM, global GCMs of different sophistication), global GCMs, unresolved scales and parameterization, cloud parameterization, testing climate models with the past temperature record, projections of future climate change with global climate models, will ENSO or AMs change, interaction of GHGs and O3 depletion, uncertainties, sensitivity of climate.

GRADING:
Exams: 50% (mid term and final)
Class projects and homework: 50%