Knowledge Expectations for METR 4233
Physical Meteorology III: Radiation and Climate

Purpose: This document describes the principal concepts, technical skills, and fundamental understanding that all students are expected to possess upon completing METR 4233, Physical Meteorology III: Radiation and Climate. Individual instructors may deviate somewhat from the specific topics and order listed here.

Pre-requisites: Grade of C or better in METR 3123, METR 3223.

Students should have a basic understanding of the structure, physics, dynamics and thermodynamics of the atmosphere prior to starting this course.

Goal of the Course: This course introduces the physical processes associated with radiative transfer in the atmosphere and energy balance at the earth's surface. It uses radiative transfer and simple atmospheric dynamics to explain the general circulation of the atmosphere, the mean climate of the earth, climate variations in space and time, and climate change.

Topical Knowledge Expectations

I. Radiation and radiative transfer in the earth-atmosphere system.

- Understand the physical concepts of radiative transfer of energy, including radiation characteristics, quantities and units.
- Understand the concepts of radiation from a black body, including the temperature dependence of the total blackbody irradiance and the wavelength of peak emission.
- Understand the concepts of emission, absorption and scattering of radiation, including the differences between direct and diffuse radiation.
- For solar (short-wave) radiation, understand the definition of the albedo and know typical values for different surfaces. Understand the dominant causes of absorption and scattering of solar radiation in the atmosphere.
- For long-wave radiation in the atmosphere, understand the important constituents (greenhouse gases) and processes affecting emission and absorption.

II. Atmospheric energy balance

- Be able to compute the global equilibrium temperature for radiation balance at the surface for the earth with no atmosphere and for a one and two layer atmosphere.
- Understand the important processes in the surface energy balance, including their typical magnitudes.
- For the tropospheric energy balance, understand the roles of radiative transfer and latent and sensible heat fluxes.
- Understand simple concepts of the atmospheric boundary layer and surface layer, including turbulent transport of heat, moisture and momentum between the atmosphere and the surface.
- Understand the time variations of the surface energy balance, including the diurnal cycle and seasonal cycle of surface temperature over land and oceans.

III. Atmospheric general circulation.

- Be able to recall the major features of the atmospheric general circulation, including the jet streams, the mean meridional circulation, and the surface wind patterns.
- Understand the role of transport in the atmosphere and the oceans in balancing the radiative heating differences between the equator and the poles.
- Be able to use simple dynamical arguments to explain the mean Hadley circulation and the subtropical jet streams.
- Understand the concepts of transient and standing eddies (waves) in the atmosphere and their roles in transport of heat and momentum in middle latitudes, and in the existence of the Ferrel cell.

IV. Climate variability and climate change

- Understand the simple mechanisms for internal climate variability, including the long times scales provided by heat uptake in the oceans, and climate feedbacks such as ice albedo, water vapour and cloud feedbacks.
- Understand the radiative theory for the ice ages associated with solar orbital variations, and the need for feedbacks to explain the existence of ice ages.
- Understand the role of volcanic eruptions and stratospheric volcanic aerosols in climate variations.
- Be able to explain the main features of El Niño-Southern Oscillation, including the typical variations in the tropical Pacific Ocean and the atmosphere, and the remote impacts.
- Be able to provide a simple explanation of the natural carbon cycle and anthropogenic sources of greenhouse gases, including the timescales for stabilization of atmospheric concentrations of the major greenhouse gases.
- Understand the observational basis for climate change in the 20^{th} century, climate model simulations of climate change due to different forcing factors, and projections of greenhouse climate change in the 21^{st} century, including possible impacts in North America.
- Understand the mechanisms for the existence of the ozone layer in the stratosphere and its role in affecting UV radiation levels at the surface. Understand the health impacts of UV radiation. Be able to provide a simple explanation of the Antarctic ozone hole and global ozone depletion.