Knowledge Expectations for METR 3223
Physical Meteorology II: Cloud Physics, Atmospheric Electricity and Optics

Purpose: This document describes the principal concepts, technical skills, and fundamental understanding that all students are expected to possess upon completing METR 3223, Physical Meteorology II: Cloud Physics, Atmospheric Electricity and Optics. Individual instructors may deviate somewhat from the specific topics and order listed here.

Pre-requisites: Grade of C or better in METR 3113, METR 3213, MATH 3113.

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

Goal of the Course: This course provides an overview of cloud and precipitation processes including: the role of aerosols in cloud droplet and ice nucleation; development and application of the Clausius-Clapeyron equation for phase changes; the transformation of cloud particles into rain, snow, and hail by diffusion, collision and coalescence, and aggregation; cloud electrification; lightning; optical phenomena, and elementary concepts of meteorological radar.

Topical Knowledge Expectations

I. Cloud Microphysical Observations

- Understand the relationship between physical processes in the atmosphere and the scales of motion and features that can be identified. Know where micro-scale processes fall into this distribution and how they feed back onto other scales.
- Understand the limitations of current state-of-the-art platforms and instruments used for cloud observations.
- Be aware of the typical values of cloud particle characteristics in both convective and stratiform clouds and why they are different.
- Be aware of the differences between maritime and continental cloud properties, the role of aerosols in producing those differences, and its impact on cloud electrification.
- Understand the role of human activity on the sources and sinks of aerosols that are important to cloud properties.

II. Cloud Droplet and Cloud Ice Nucleation

- Understand the derivation of the Clausis-Clapeyron equation and the limitations of its application.
- Know what is meant by supersaturation.
- Understand the difference in saturation over water versus an ice surface.
- Be aware of the effect of curvature on the equilibrium saturation vapor pressure over a cloud droplet and how this affects the potential for homogeneous nucleation of a cloud droplet from pure water vapor.
- Understand the effect of hygroscopic aerosols on the equilibrium saturation vapor pressure over a cloud droplet.

- Be able to use a Kohler diagram to determine the stability of a cloud droplet for a given environment.
- Understand why supercooled cloud droplets occur naturally, i.e. most particle do not freeze until the temperature is well below 0°C.
- Be aware of the distribution and sources of ice nuclei in the atmosphere.
- Understand secondary ice nucleation through the Hallet-Mossop multiplication process.
- Be aware of the relationship between temperature, supersaturation and ice crystal habits.

III. Diffusional Growth of Droplets and Ice Crystals

- Understand how the change in mass of a droplet and ice crystal undergoing condensation or deposition can be computed from the general form of a diffusion equation.
- Understand the temperature dependence of diffusional growth.
- Understand why diffusional growth narrows the size spectrum of a population of cloud droplets but not a population of ice crystals.
- Understand the Wegener-Bergeron-Findeisen growth mechanism for ice crystals.
- Be able to discuss why condensation and deposition are not sufficient to explain the timing of observed precipitation.

IV. Growth by Coalescence, Riming and Aggregation

- Be able to define the terms coalescence, riming, and aggregation.
- Be aware of the size distribution of cloud and precipitation particles. Understand the differences between mono-dispersed, Marshall-Palmer, and Gamma distributions.
- Be aware of the relationships between particle sizes, densities, and terminal fall speeds in the atmosphere.
- Be aware of the processes that contribute to particle break-up and why rain drops greater than a certain size are seldom observed.
- Understand how to model the collision and collection of cloud-sized particles by larger precipitation particles.
- Understand the difference in “warm rain” and “cold cloud” processes.
- Understand the physical processes involved in the development of hail.

V. Precipitation and Radar

- Understand the differences in convective and stratiform precipitation processes and how that may affect the drop size distribution.
- Understand the role of seeder/feeder zones in precipitation formation.
- Understand the role of hydrometeor advection and vertical air motion in the spatial distribution of precipitation in mesoscale cloud systems.
- Understand the relationship between drop size distribution and radar reflectivity.
- Be aware of the basic form of the radar equation.
- Understand how radar reflectivity can be used to estimate rain fall.
- Understand what is meant by dual-polarimetric weather radar.
- Be aware of how the bulk characteristics of cloud properties can be derived from polarimetric weather radar.

VI. Cloud Electrification

- Understand Coulomb's law and the principle of superposition.
- Understand what is meant by electrostatic potential.
- Understand Gauss's law and how it can be applied to determine electric fields on conductors. Be aware of what is meant by a Faraday cage.
- Understand the concept of charge mobility, capacitance, conduction, break-down, dielectrics, and induction charging.
- Be aware of Maxwell's equations governing electromagnetic waves and the relationship between the magnetic and electric fields.
- Be aware of the instrumentation used to measure electric charge and lightning activity.
- Be aware of the global electric circuit and the distribution of lightning activity across the globe as a function of season.
- Be aware of the primary electric dipole structure of thunderstorms and when deviations from it may be expected.
- Be able to describe the fundamental role of cloud microphysics on the generation and separation of charge within a thunderstorm.
- Understand the role of advection in producing the observed distribution of charge within a cloud system.
- Understand how screening layers develop and what role they have on lightning activity.
- Be able to describe the sequence of events that occurs during a natural cloud-to-ground lightning strike. Understand what is meant by step-leaders, dart leaders, and return strokes.
- Be able to explain the difference between negative and positive cloud-to-ground strikes.
- Be aware of the distribution and typical values of peak current for positive and negative strikes and some of the reasons for these differences.
- Be able to describe differences in the wave forms of cloud-to-cloud and cloud-to-ground lightning.
- Understand the relationship between cloud-to-cloud lightning activity, cloud-to-ground flash rates, and vertical motions within clouds.

VII. Atmospheric optical phenomena

- Understand the concepts of refraction, diffraction, and scattering in the atmosphere.
- Understand the application of optical concepts to atmospheric optical phenomena such as rainbows, haloes, coronas, red sunsets and green thunderstorms.
- Understand the meteorological conditions favorable for the occurrence of various atmospheric optical phenomena.