

AT623 Syllabus

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Introductory overview

- Where does boundary-layer meteorology fit in the big picture of atmospheric science?
 - Momentum exchanges
 - Moisture exchanges
 - Energy exchanges
 - Dissipation
 - Air-sea interactions
 - Air-land interactions
 - Applications
 - * NWP -- people live in the boundary layer
 - * Air pollution dispersion
 - * Agricultural meteorology
 - * Aviation meteorology
 - * Military applications
- Boundary layers in engineering applications
- Characteristics of the atmospheric boundary layer
 - Definition
 - Turbulence
 - Surface fluxes
 - “Unstable” and “stable” boundary layers
 - The surface layer
 - Mixed layers
 - The stable boundary layer
 - The boundary layer top
 - Entrainment across the boundary layer top
 - The PBL depth
 - Internal profiles of temperature, humidity, and wind
 - Internal cloudiness
 - Coupling to clouds above
 - Coupling to the land surface

- Coupling to the upper ocean
- The bulk aerodynamic formulas
- Climatology of the surface fluxes of sensible heat, latent heat, and momentum
- The diurnal cycle of the boundary layer over land
- Stratocumulus clouds
- Shallow cumulus clouds
- Coupling to deep convection

Introduction to turbulence in the boundary layer

- Definition of turbulence
 - Many interacting vortices
 - Chaos
 - Energy cascades
 - How turbulence differs from waviness
- Preliminary discussion of the turbulence kinetic energy (TKE) equation, postponing the derivation until later
 - Shear production
 - Buoyant production
 - Dissipation
 - Third moment
 - Pressure terms
 - Advection terms
 - “Storage” term

Prototype instabilities

- Shearing instability
 - Basic mechanism
 - The effects of stratification
 - Breaking waves
- Convective instability
 - What is buoyancy?
 - Rayleigh-Benard convection
 - Thermals and plumes
 - Cumulus instability
 - Cloud-top entrainment instability

The surface layer

- Dimensional analysis and similarity theory
- Monin-Obukhov similarity theory
- The logarithmic wind profile
- Surface roughness
- The bulk aerodynamic formulas
- The limits of similarity theory

Higher-order closure

- Notation
- The Reynolds stress equation
- The TKE equation
- Return to isotropy
- Scalar variances and covariances
- Relation to diffusion and mass fluxes

Large eddy simulations

- History
- Current applications

Mixed layers

- What is mixing, and what is mixed?
- Linear flux profiles
- Diffusion versus advection
- Ekman layers
- Entrainment across the top of a mixed layer

Mass fluxes

- Introduction
- Generalization

Stratocumulus clouds in mixed layers

- Buoyancy in cloudy layers
- The buoyancy flux profile

- Cloud base
- Radiation at the cloud top
- Cloud-top entrainment instability

Partly cloudy boundary layers

- Basic concepts
- Sommeria and Deardorff
- Connection to mass fluxes
- Double Gaussians
- Buoyancy fluxes in partly cloudy layers

Interactions of the boundary layer with deep cumulus convection

- Cloud roots
- Updrafts
- Downdrafts
- Cold pools
- The effects of deep convection on the surface fluxes
- Elevated nocturnal convection

Frontiers

- Topographic effects
- Urban effects