AT623 Syllabus

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Introductory overview

• Where does boundary-layer meteorology fit in the big picture of atmospheric science?
  ▸ Dynamics across scales
    * Dynamics isn’t just large-scale dynamics
    * Small-scale dynamics is interesting and important in its own right
    * The interactions across scales are most interesting of all
  ▸ 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
  * Viscosity
  * No slip
  * Shear and vorticity
  * Leaves of grass
• Characteristics of the atmospheric boundary layer
  ▸ Definition
  ▸ Turbulence
  ▸ Surface fluxes and bulk aerodynamic formulae
  ▸ “Stable” and “unstable” boundary layers
  ▸ The surface layer
  ▸ Mixed layers
The boundary layer top
- Entrainment across the boundary layer top
- The diurnal cycle of the boundary layer over land
- Stratocumulus clouds
- Shallow cumulus clouds
- Deep cumulus convection

- Coupling to the land surface
- Mixed layers in the ocean and lakes
- Benthic boundary layers
- Climatology of the surface fluxes of sensible heat, latent heat, and momentum

**Introduction to turbulence in the boundary layer**
- Definition of turbulence
  - Many interacting vortices
  - Chaos
  - Many scales
  - Energy cascades
  - How turbulence differs from waviness
- Preliminary discussion of the turbulence kinetic energy (TKE) equation, postponing the derivation until later
  - Reynolds averaging
  - Shear production
  - Buoyant production
  - Dissipation
  - Third moments
  - Pressure terms
  - Advection terms
  - “Storage” term

**Where does turbulence come from?**
- 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

Where do fluxes come from?
- Diffusion and mixing-length theory
- Mass fluxes
- Penetrative convection

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

The second and third moment equations
- Notation
- The Reynolds stress equation
- The TKE equation revisited
- Return to isotropy
- Scalar variances and covariances
- The connection between gradient production and dissipation

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

Ekman layers
- Force balance perspective
• Energy perspective
• Spirals
• Ekman “pumping”

**Stratocumulus-capped boundary 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
• Buoyancy fluxes in partly cloudy layers

**Coupled mixed layers**
• Sloping edges
• ENSO

**Linking higher-order closure to mass fluxes**
• KPP
• EDMF
• Assumed distributions with higher-order closure
• Entraining and detraining plumes
• Diffusion and mass fluxes as limits that come from the variance equation
• Closure for sigma
• Double Gaussians

**Large eddy simulations**
• History
• Current applications

**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 and urban LES
• The grey zone