ATOC 515: Introduction to Atmospheric and Oceanic Turbulence

References: P. A. Davidson, Turbulence - An Introduction for Scientists and Engineers, Oxford, 2003; M. Lesieur, Turbulence in Fluids, Kluwer, 1992; Monin & Yaglom, Statistical Fluid mechanics, MIT press; S. B. Pope, Turbulent Flows, Cambridge, 2000; R. Salmon, Lectures on Geophysical Fluid dynamics, Oxford U Press, 1998; Tennekes & Lumley, A 1st course in turbulence, MIT press, 1972.

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Grading: There will be a mid-term test and a final exam. Percentages towards the final grade are as follows: homework 20%, mid-term and/or presentation 30%, final 50%.

Prerequisites:

1. Must have *enjoyed* a previous course on fluid dynamics
2. Familiarity with basic PDE's, ODE's, Fourier techniques and vector calculus. Just the basics.

The goal of the course is to familiarize students with the basic concepts that have helped us to at least begin to understand turbulence in a geophysical fluid setting. In order to do so, it is necessary to introduce the statistical framework with which to describe the turbulence. Using this we proceed to explore the processes active in atmospheric and oceanic boundary layers and to introduce the basic concepts employed in the study of homogeneous turbulence. Along the way, we will brush up against the important topics of the intermittency of intense turbulence as well as the nonlinear superposition of waves and turbulence.

1 The statistical basics

1. Properties of turbulence.

Laminar versus turbulent flow

The Reynolds number

2. Examples of turbulent flows

    Mechanical (shear-induced) turbulence

    Convective (buoyancy-induced) turbulence

3. Dimensional analysis, similarity and the Buckingham theorem

4. Navier-Stokes, heat diffusion & Boussinesq equations

5. Averaging and the Reynolds equations (RANS)

6. The closure problem

7. Simple closures, eddy viscosity

2 Atmospheric & oceanic boundary layers

1. Flow above smooth and rough boundaries

2. The planetary boundary layer

    Ekman layer (QG + viscosity)

    Geostrophic drag laws

    Mixing length theory

3. Stratification and the Monin-Obukhov theory

3 Homogeneous turbulence

1. Energy equations, mean & fluctuations

2. The energy spectrum and the spectral dynamics of turbulence

3. Kolmogorov's similarity hypotheses

    3D cascade phenomenology

4. 2D and quasigeostrophic turbulence

    Energy and enstrophy cascades

4 Depending on interest and time

1. Statistical theories of turbulence
2. Intermittency theories
3. Turbulence with waves

   Resonant interactions and conservation laws, β-plane turbulence, rotating stratified turbulence