2026/2027 GEOPHYSICAL FLUID DYNAMICS (ESP-GFD)

SSD: ICAR/01, GEO/12
30 hours, 6 CFU
Lecturers: R. Farneti, S. Salon

Aims: To introduce students to fluid dynamics basic principles and to the main topics of geophysical fluid dynamics

Syllabus

Part I Fluid Mechanics

Lecture 1 Introduction to Fluid Mechanics; Properties and definition of Fluids
Lecture 2 Fluid Statics; Pressure and Buoyancy force
Lecture 3 Tensors; Gradient, Divergence, Curl; Stokes and Gauss Theorems; Lagrangian Derivative and Streamlines
Lecture 4 Kinematics: Strain rates; Vorticity and Circulation
Lecture 5 Streamfunction; Relative motion near a point
Lecture 6 Conservation of Mass: Reynolds Transport Theorem; Continuity, Advection-Diffusion Equation
Lecture 7 Conservation of Momentum: Cauchy's Equation; Constitutive equation for Newtonian fluids
Lecture 8 Conservation of Momentum: Navier-Stokes Equations; Rotating frame of reference and Coriolis
Lecture 9 Conservation of Energy: Mechanical energy; Thermal energy equation
Lecture 10 Conservation of Energy: Bernoulli equation

Part II Geophysical Fluid Dynamics

Lecture 11 Introduction to Geophysical FD: scales of motion, rotation/stratification in atmosphere and ocean
Lecture 12 Rotating frame of reference: Coriolis force, inertial oscillations, acceleration on a 3-D rotating planet
Lecture 13 Governing equations of GFD: momentum, mass conservation, energy, equation of state
Lecture 14 Boussinesq approximation; scale analysis and further simplifications of governing equations; Rossby, Ekman, Reynolds numbers
Lecture 15 Geostrophy: geostrophic flows; Taylor-Proudman theorem; non-geostrophic flows; vorticity dynamics
Lecture 16 Friction and rotation: Ekman layers
Lecture 17 Barotropic waves: Kelvin, Poincarè, Rossby, topographic waves and analogies
Lecture 18 Stratification: static stability, Froude number, combination of rotation and stratification
Lecture 19 Mixing 1: mixing of stratified fluids, Kelvin-Helmoltz instability – Instability of a stratified shear flow
Lecture 20 Mixing 2: Taylor-Goldstein equation, Richardson number; turbulence in a stratified shear flow

Teaching methods: frontal lectures/exercises
Assessment methods: written examination
Other information: the course is delivered in English
Books: any textbook on Fluid Mechanics / GFD, but particularly:

- `Introduction to Geophysical Fluid Dynamics - Physical and Numerical Aspects' by B. Cushman-Roisin J.-M. Beckers (https://www.elsevier.com/books/introduction-to-geophysical-fluid-dynamics/cushman-roisin/978-0-12-088759-0) (http://www.ccpo.odu.edu/~klinck/Reprints/PDF/roisinGFD2010.pdf)
- `Physical Fluid Dynamics' by D. J. Tritton
- `Fluid Mechanics' by P. K. Kundu
- `Atmospheric and Oceanic Fluid Dynamics' by G.K. Vallis