

# 2025/2026 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, Poincaré, 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