

2024/2025 991DF Dinamica del Clima [SM23-FISICA]

Fisica dell'ambiente e Interdisciplinare

SSD: ICAR/01, FIS/06

48 hours, 6 CFU

Lecturers: Riccardo Farneti (rfarneti@ictp.it), Fred Kucharski (kucharsk@ictp.it), Erika Coppola (coppoale@ictp.it)

Aims: To introduce students to the physics and dynamics of climate, to the main theories of ocean and atmospheric circulations, and the basics of climate variability and change

Syllabus

Part I Ocean Dynamics

Lecture 1 **Fundamentals:** Geostrophy, Thermal Wind and Hydrostasy

Lecture 2 **Air-sea interactions:** the oceanic heat and freshwater budgets, the mixed layer

Lecture 3 **Ekman Dynamics:** the introduction to Friction

Lecture 4 **Ocean Waves:** Kelvin, Poincarè and Rossby Waves

Lecture 5 **Large scale ocean circulation theory:** Wind-driven gyres: Sverdrup flow, Stommel model

Lecture 6 **Large scale ocean circulation theory:** Wind-driven gyres: Munk model, topographic effects

Lecture 7 **Large scale ocean circulation theory:** buoyancy-driven and wind-driven global Meridional Overturning Circulation

Lecture 8 **Large scale ocean circulation theory:** Ocean heat transport and climate change

Part II Atmospheric Dynamics

Lecture 1 **Recap of some thermodynamics principles:** First and second laws of thermodynamics applied to the atmosphere, Thermodynamics equilibrium state for a closed atmosphere, atmosphere as a mixture of gases, its composition, including GHG and water vapor. Distribution of moisture sources and sinks in the atmosphere.

Lecture 2 **Some basics of Atmospheric Dynamics:** Laws of conservation of potential vorticity and applications.

Lecture 3 **Rossby wave recap:** Free Rossby waves, orographically forced Rossby waves, turning latitude.

Lecture 4 **Equatorial waves:** Dispersion relationships for equatorial waves, including Rossby-Gravity and Kelvin waves.

Lecture 5 **ENSO:** Enso phenomenon and teleconnections, positive atmospheric and oceanic feedback mechanisms.

Reduced gravity model for ocean thermocline, Gill model.

Lecture 6 **Large-Scale Adjustment to tropical heating:** Mechanism of remote rainfall responses to a tropical heating anomaly, including Ekman pumping, upper-level divergence, and thermal stabilization of the atmosphere.

Lecture 7 **Features of atmospheric General Circulation and Tropical zonal and meridional circulations:** Zonal mean circulations, role of eddy momentum and heat fluxes, Drivers of Hadley and Ferrell cells. Application of Sverdrup balance to atmosphere to explain walker circulation. Monsoons.

Lecture 8 **Modes of variability in the climate system:** ENSO, NAO, AO, PDO, AMO, SAM, and others, their impact on climate variables.

Part III Natural and Anthropogenic Climate Change

Lecture 1 **The global Energy balance** -Greenhouse effect- The energy balance at the top of the atmosphere

Lecture 2 **Atmospheric radiative Transfer and Climate** - Clouds and Radiation- The role of clouds in the Earth Energy Balance

Lecture 3 **Energy Balance of the Surface** - The surface Energy Balance - The Atmospheric Boundary Layer

Lecture 4 **The Hydrological Cycle** - The water balance - surface water storage and runoff -Modelling the land surface water balance

Lecture 5 **History and evolution of Climate** - Paleoclimate records - Historical records

Lecture 6 **Climate Sensitivity and Feedback** - Ice albedo feedback - Cloud feedback

Lecture 7 **Global and regional climate models** - What is a climate model - Atmosphere, Ocean and Land component

Lecture 8 **Natural and Anthropogenic Climate Change** - Detection and attribution - Emission scenarios - Projection of future climate - Long term climate change

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
- 'Essentials of Atmospheric and Oceanic Dynamics', by G.K. Vallis