

ESP DIPLOMA

PHYSICS AND DYNAMICS OF THE OCEAN

Academic Year 2021/2022

Part I: Descriptive Oceanography and Instrumentation (12 lessons)

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Descriptive Oceanography

1. **Introduction physical oceanography** – definition and aims.
2. **World ocean geography.**
 - Bathymetry, bottom shapes, and patterns
 - Coastal features and orography
 - Communications between different oceans and their interactions
3. **Temporal and spatial variability of motion in the ocean.**
 - Temporal scales, lifetime of circulation patterns
 - Spatial scales (basinwide circulation, gyres, mesoscale eddies and rings, meanders)
4. **State variables in the ocean.**
 - Temperature and salinity, definitions; geographic distribution (spatial and temporal characteristics), potential temperature
 - Density; measurements and calculations, spatial and temporal variability.
5. **The oceanic heat budget**
 - Heat budget terms
 - Direct and indirect estimates of heat fluxes
 - Geographic distribution of terms
 - Meridional heat transport.
6. **The freshwater budget**
 - Freshwater sources and sinks for the world ocean
 - Geographic distribution of terms
 - Estuarine and anti-estuarine circulation.
7. **Geostrophic currents**
 - Geostrophic approximation
 - Hydrostatic equilibrium
 - Thermal wind relation
 - Barotropic and baroclinic flows
 - Interior flow and boundary layers
 - Limitations of the geostrophic approximation.
 - Satellite sea level observations and estimation of the surface geostrophic flow
 - Calculations of the vertical geostrophic shear.
8. **Wind influence and bottom friction**
 - Ekman layer and Ekman balance
 - Ekman mass transport
 - Inertial oscillations

- Bottom boundary layer.
- 9. Vorticity in the ocean**
 - Definition of vorticity
 - Conservation of vorticity
 - Vorticity and friction
 - Ekman pumping
 - Ekman pumping and wind-driven circulation of the ocean
- 10. World ocean circulation and global processes**
 - Global conveyor belt, thermohaline circulation
 - Vertical convection and dense water formation - engine of the global conveyor belt
 - Western intensification
 - Eddies, gyres and rings
 - Coastal and open ocean upwelling and its importance.
- 11. Climate Change - natural and human-induced causes**
 - Greenhouse gases and impact on climate
 - Causes of melting ice glaciers and the sea-level increase
 - Relative contributions of global warming and ice melting to the long-term sea-level increase
 - Instrumental and proxies' records of long-term changes
 - Global warming and freshwater budget
 - Effects on the large-scale oceanic circulation.
- 12. Non-tidal sea-level variations**
 - Seiches, tsunamis and meteotsunamis
 - Seasonal, interannual and decadal variability, thermal expansion, and circulation variations
 - Long-term trend - relation to climatic change
 - Flooding of the low-lying coastal areas; causes, effects and mitigation
 - Venice example.

Oceanographic Instrumentation

- 13. Introduction**
 - Classical methods (Research vessels, XBT, CTD, Rosette, current meters, tide gauges, etc.).
- 14. Autonomous systems**
 - Moored buoys
 - Surface drifters
 - Sub-surface floats and profilers
 - Gliders and AUVs.
- 15. Remote sensing**
 - ADCP
 - Acoustic tomography
 - HF coastal radar.
- 16. Remote sensing from satellites**
 - Sea surface temperature & ocean colour
 - Altimetry
 - Scatterometry
 - SAR.

Part II:
Theory of Large Scale Ocean Circulation
(10 lessons)

Riccardo Farneti (rfarneti@ictp.it)

1. **Fundamentals:** Geostrophy, Thermal Wind and Hydrostasy
2. **Ekman Dynamics:** the introduction to Friction
3. **Ocean Waves:** Kelvin, Poincarè and Rossby Waves
4. **Wind-Driven Gyres I:** Sverdrup Flow
5. **Wind-Driven Gyres II:** Stommel Model
6. **Wind-Driven Gyres III:** Munk Model
7. **Wind-Driven Gyres IV:** Topographic Effects
8. **Thermocline Dynamics**
9. **Buoyancy-driven Meridional Overturning Circulation**
10. **Wind-driven Meridional Overturning Circulation**
11. **The Southern Ocean**

**Part III:
Ocean Variability: processes and impacts
(8 lessons)**

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1. Ocean Variability

Trends and variabilities

Unforced vs. forced variability

Modes of variability

2. The global Carbon cycle and the physical forcing

The solubility pump

The physical pump and biological pump

The eddies and the Carbon pumps

3. Seasonal Variability of the oceans

Mixed layer dynamics

4. Interannual Variability of the oceans

El Niño and La Niña

Indian Ocean Dipole

5. Decadal Variability 21

Atlantic Multidecadal Oscillation

Pacific Decadal Oscillation (PDO) and Pacific Interdecadal Oscillation (IPO)

Suggested readings

General Books

- Benoit Cushman Roisin (1994). Introduction to Geophysical Fluid Dynamics, 320 pp., Prentice Hall, Englewood Cliffs, New Jersey 07632.
- Robert H. Stewart (2000). Introduction to Physical Oceanography, Dept. Of Oceanography, Texas A&M University, 343 pp.
- Matthias Tomczak (2002). An Introduction to Physical Oceanography, Flinders University of South Australia in Adelaide, 13 lectures. (<http://www.mt-oceanography.info/IntroOc/newstart.html>)
- W. J. Emery & R. E. Thomson, Data Analysis Methods in Physical Oceanography, Elsevier
- Williams, R. G. and Follows, M. J. (2017). Ocean Dynamics and the Carbon Cycle: Principles and Mechanisms, Cambridge University Press, ISBN 978-0-521-84369-0
- Vallis, G. K. (2017). Atmospheric and oceanic fluid dynamics. Cambridge University Press.
- Olbers, D., J. Willebrand, and C. Eden (2012). Ocean Dynamics, Springer-Verlag, 704 pp.
- Talley, L., G. L. Pickard, W. J. Emery, and J. H. Swift (2011). Descriptive Physical Oceanography, Academic Press, 560 pp.
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Specialist references

- Underwater gliders for ocean research
- http://pordlabs.ucsd.edu/rdavis/publications/MTS_Glider.pdf
- Marshall et al., Review. North Atlantic Climate Variability: Phenomena, Impacts And Mechanisms. Int. J. Climatol. 21: 1863–1898 (2001) DOI: 10.1002/joc.693
- Sheinbaum, J. (2003). Current theories on El Nino–southern oscillation: a review. Geofisica internacional, 42(3), 291–305.
- Mantua, N. J., Hare, S. (2002). Pacific–Decadal Oscillation (PDO). Encyclopedia of global environmental change, 1, 592–594.
- Han, W., Vialard, J., McPhaden, M. J., Lee, T., Masumoto, Y., Feng, M., De Ruijter, W. P. (2014). Indian Ocean decadal variability: A review. Bulletin of the American Meteorological Society, 95(11), 1679–1703.