SEMESTER II

20-319-0201 OCEAN DYNAMICS
(CORE, Credit: 4)

After completion of the course the student will be able to:

1. Describe the governing equations of statics, kinematics and dynamics of the ocean.
2. Explain theories of wind driven ocean circulations.
3. Describe upwelling and downwelling mechanisms.
4. Describe frictionless currents such as inertial and geostrophic currents.
5. Explain barotropic and baroclinic instabilities.

Unit I

Statics of the ocean: fields of gravity, pressure and mass, barotropic and baroclinic fields, quasi static conditions, sigma-t surfaces, static stability- Equation for static stability criteria, Brunt Vaisala frequency, double diffusion. Richardson number, geopotential distance and dynamic height, Kinematics – field of motion, representation of field of motion in the sea, Recapitulation of conservation equations – mass and momentum, divergence, convergence , upwelling and divergence, non-linear terms in the equation of motion, equation of mean flow, Reynold's stress and eddy viscosity, scaling equation of motion, dynamic stability.

Unit II

Currents without friction- inertial motion, Geostrophic current, relative current and slope current, Helland-Hansen's formula, thermal wind equations, level of no motion and absolute currents. Homogeneous geostrophic flows over an irregular bottom. Generalization to non-geostrophic flows. Quasi-Geostrophic dynamics- Simplifying assumptions-Governing equations- Planetary waves in a stratified field-non-linear effects.

Unit III

Currents with friction- Ekman's solution to the equation of motion with friction, Ekman transport and upwelling, wind stress, bottom friction and shallow water effect, beta-plane and f-plane. Sverdrup's equation and its application, equatorial currents. Vorticity, Stommel and Munk theory – Western boundary currents. Kelvin and Rossby waves.

Unit IV

Barotropic Instability- Cause for instability, Linear Barotropic Waves. Linear wave dynamics. The Kelvin wave. Planetary waves (Rossby waves) waves on a shear flow. Linearized governing equations. Baroclinic Instability – cause for instability – linear theory.

References:

1. Introductory Dynamic Oceanography: S Pond & G L Pickard, 2nd Edn. Pergamon, 1983.
2. Atmosphere-Ocean Dynamics, Adrian E. Gill, International Geophysics series, Academic Press, First Edition, 1982.
3. Atmospheric and Oceanic Fluid Dynamics: Fundamentals and large–scale circulation, Second edition, Geoffrey K. Vallis, Cambridge University Press, 2017.
4. Introduction to Geophysical Fluid Dynamics, Cushman Rosetin, 1st Edn, Prentice Hall, 1994.
5. Geophysical Fluid Dynamics, J. Pedlosky, 2nd Edn, Springer, 1992.

Suggested Reading:

1. Geophysical Fluid Dynamics: An Introduction to Atmosphere—Ocean Dynamics: Homogeneous Fluids, Özsoy, Emin, Springer 2020.
2. Climate dynamics, Cook, Kerry H., Princeton University Press, 2013. 'Understanding weather and climate, Ed.7, Aguado, Edward, Pearson, 2013.
3. Dynamical Oceanography: J. Proudman, Methuen & Co. Ltd, 1963
4. Environmental fluid dynamics, Imberger, Jorg, Academic Press, 2013.
5. Introduction to Dynamic Meteorology, Ed.2 & 5 Holton, James R, Academic, 2013.
6. Infinite-dimensional dynamical systems in atmospheric and oceanic science, Boling, Guo, World Scientific, 2014.
7. Modelling atmospheric and oceanic flows, Larcher, Thomas von, American Geophysical Union, 2013.
8. Nonlinear climate dynamics, Dijkstra, Henk A, Cambridge University Press, 2013.
9. Numerical Methods and Models in Earth Science, Ghosh, Parthasarathi, New Indian Publishing Agency, 2011
10. Ocean Currents, G Neumann, Elsevier Publishing Company, 1968.
11. Oceanography for Meteorologists, H U Sverdrup, Biotech Books, 2002.
12. Physics of the earth, 4^{th} Edn.., Stacey, Frank D, Cambridge University Press, 2013.
13. Principles of Physical Oceanography, W J Pierson and G Neumann, Prentice-Hall and Englewood Cliffs, 1966.
14. The Dynamic Method in Oceanography, L M Fomin, Elsevier Applied Science, 1964.
15. Dynamics of the Equatorial Ocean, Boyd, John P., Springer, ISBN 978-3-662-55474, 2018
16. Relationships between Coastal Sea Level and Large Scale Ocean Circulation, Ponte, R.M., Meyssignac,B., Domingues, C., Stammer, D., Cazenave, A & Lopez, T. (Eds.), Springer, ISBN 978-3-030-45633-7, 2020.
17. The Ocean in motion, Manuel G. Velarde, Roman yu. Tarakanov, Alexey V. Marchenko, Springer, 2018.
18. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K. Vallis, Cambridge University Press, 2019.
19. Ocean circulation in three dimensions, Barry A. Klinger and Thomas W.N. Haine, Cambridge University Press, 2019.

20-319-0202 AIR SEA INTERACTION
(CORE, Credit: 3)

After completion of the course the student will be able to:

1. Discuss the structure of atmospheric boundary layer and its role in air-sea interaction.
2. Describe the fundamental theories of atmospheric turbulence.
3. Explain similarity theory for formulating air-sea flux.
4. Estimate the large scale momentum, moisture and heat fluxes, and its budget.
5. Identify large scale anomalies in air-sea interactions leading to interannual variability.

Unit I

Introduction to air-sea interaction – - atmospheric boundary layer and divisions - momentum, heat and moisture fluxes – turbulence – static and dynamic instabilities – methods of study – general characteristics - statistical properties – fundamental theories and hypotheses – turbulent kinetic energy – Richardson number – dynamic and kinematic fluxes – Reynolds stresses – turbulence closure – K theory and mixing length theory