COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Abstract

Faculty of Marine Sciences – Department of Physical Oceanography – M.Sc. Oceanography & M.Tech Ocean Technology – Syllabus Approved – Orders issued.

CONFERENCE SECTION

No.Conf.II/2941/1/AC-Marine Sc/2020 Dated, Kochi-22, 12.10.2020

Read:- Item No.I(d.1) of the Minutes of the Meeting of the Academic Council held on 08.07.2020

ORDER

The Academic Council at its meeting held on 08.07.2020 along with the recommendations of the Standing Committee resolved to approve, vide item read above, the revision of syllabi as per outcome based education framework of the following programmes offered at the Department of Physical Oceanography under the Faculty of Marine Sciences with effect from 08.07.2020, the date of the meeting of the Academic Council, as in Appendix.

1. M.Sc. Oceanography
2. M.Tech Ocean Technology

Orders are issued accordingly.

Dr. MEERA V.
REGISTRAR

To

1. Dr. Rosamma Philip, Dean, Faculty of Marine Sciences and Professor, Department of Marine Biology, Microbiology and Biochemistry, CUSAT, Kochi-16
2. Dr. R. Sajeev, Chairman BOS in Physical Oceanography, CUSAT, Kochi-16
3. The Head, Department of Physical Oceanography, CUSAT, Kochi-16
4. The Controller of Examinations/Joint Registrar (Academic)/ Assistant Registrar (Academic)
5. Academic A,C/Exam E/B/D/Exam Confidential Sections
6. Day File/Stock File/File Copy

Sr.

DEPARTMENT OF PHYSICAL OCEANOGRAPHY
SCHOOL OF MARINE SCIENCES

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

Scheme & Syllabus
(Applicable from 2020 Admission)

M. Sc. OCEANOGRAPHY

M.Sc. Oceanography
DEPARTMENT OF PHYSICAL OCEANOGRAPHY
(Scheme & Syllabus- Applicable from 2020 Admission onwards)

Semester – I (CORE COURSES)

Course Code	Course Title	Credit
20-319-0101	Introductory Physical Oceanography	4
20-319-0102	Geophysical Fluid Dynamics	4
20-319-0103	Ocean Instrumentation	3
20-319-0104	Ocean Observations (Practical)	1
20-319-0105	Physical Oceanographic Computations (Practical)	2
20-319-0106	Oceanographic Application Tools-I (Practical)	2
		C = 16

Semester – II (CORE COURSES)

Course Code	Course Title	Credit
20-319-0201	Ocean Dynamics	4
20-319-0202	Air-Sea Interaction	3
20-319-0203	Coastal and Estuarine Oceanography	3
20-319-0204	Dynamical Computations (Practical)	1
20-319-0205	Coastal Oceanography (Practical)	2
20-319-0206	Air-Sea Interaction (Practical)	1
		C = 14

Semester – III (CORE COURSES)

Course Code	Course Title	Credit
20-319-0301	Ocean Remote Sensing	4
20-319-0302	Numerical Ocean Modelling	3
20-319-0303	Ocean and Climate	3
20-319-0304	Ocean Climate Data Analytics (Practical)	2
20-319-0305	Ocean Modelling (Practical)	2
		C = 14

Semester – IV (CORE COURSES)

Course Code	Course Title	Credit
20-319-0401	Project Dissertation	**C =16**

LIST OF ELECTIVES

Course Code	Course title	Credits	Pre-requisites
20-319-0001	General Oceanography	3	GS
20-319-0002	Marine Hazards and Management	2	GS
20-319-0003	Marine Pollution	3	GS
20-319-0004	Ocean Optics	2	20-319-0101
20-319-0005	Marine Acoustics	4	20-319-0101
20-319-0006	Coastal Zone Management – I	3	GS
20-319-0007	Coastal Zone Management – II	3	20-319-0006
20-319-0008	Beach Dynamics	2	20-319-0101 & 20-319-0203
20-319-0009	GIS in Oceanography	2	GS
20-319-0010	Advanced Ocean Dynamics	3	20-319-0102 & 20-319-0201
20-319-0011	Wave Dynamics	3	20-319-0102 & 20-319-0201
20-319-0012	Marine Biogeochemistry	3	GS
20-319-0013	Ocean Circulation	2	20-319-0102 & 20-319-0201
20-319-0014	Remote Sensing (Practical)	2	20-319-0301
20-319-0015	Marine Remote Sensing Applications	3	GS
20-319-0016	Regional Oceanography	3	20-319-0101
20-319-0017	Ocean Engineering	4	20-319-0101 & 20-319-0203
20-319-0018	Applied and Computational Mathematics	4	GM/GP
20-319-0019	Ocean Ecosystem Modelling	2	20-319-0101 & 20-319-0201
20-319-0020	Statistical Methods in Oceanography (Practical)	1	GM/GP
20-319-0021	Polar Oceanography	3	20-319-0101
20-319-0022	Oceanographic Application Tools-II (Practical)	1	GS

GS – Graduate in Science GM – Graduate in Mathematics GP – Graduate in Physics

SEMESTER I

20-319-0101 INTRODUCTORY PHYSICAL OCEANOGRAPHY (CORE, Credit: 4)

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

1. Describe the spatial and temporal variability of physical properties of the ocean.
2. Classify different water masses of world oceans using T-S diagrams.
3. Describe the general characteristics of wind driven and thermohaline circulation of the world oceans.
4. Describe large scale oceanographic phenomena such as El-Nino, La-Nina, IOD, upwelling and downwelling.
5. Explain different heat budget terms.

Unit I

General introduction, major expeditions-Dimensions of the ocean, Geographical features of ocean - Physical properties of sea water-distribution of temperature, salinity, density and oxygen in space and time, mixed layer and barrier layer, Acoustic properties of sea water- sound velocity profile-SOFAR channel and shadow zone- Optical characteristics of sea water – Color of the sea.

Unit II

Heat budget of ocean: Radiation laws, insolation-long wave radiation-factors controlling short wave and long wave radiation- sensible and latent heat transfer, bulk formula for heat fluxes- Bowen's ratio- ocean heat transport- spatio-temporal variability of heat budget terms and net heat balance.

Unit III

Circulation and Water masses: General circulation of the atmosphere – wind driven currents in the world ocean – Equatorial current systems – Wyrtki Jet Under currents- Circulation in the Arabian Sea and Bay of Bengal- Somali current – wind stress Ekman spiral– Upwelling – Indian Ocean Dipole (IOD)- El Nino and La Nina. Formation and classification of water masses- T-S diagram-water masses of the world ocean- – thermohaline circulation - Identification of water masses.

Unit IV

Waves and Tides: General aspects of ocean waves, wave characteristics, sea and swell, deep and shallow water waves, storm surges and tsunamis- Tides and tide generating forces; their causes, variation and types, Tidal currents.

References:

1. Descriptive Physical Oceanography, Reddy, M. P. M., 2000, New Delhi Oxford & IBH
2. Descriptive Physical Oceanography: An Introduction.Ed.6, Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift, Elsevier, 2011.
3. Introduction to Physical Oceanography: R. H. Stewart, E-book, 2005
4. The Oceans, their Physics, Chemistry and General Biology, H.U. Sverdrup, Prentice Hall, 1969.
5. Introduction to Physical Oceanography, Third edition, John A. Knauss and Newell Garfield, Waveland press, Inc., 2017.

Suggested Reading:

1. Descriptive Physical Oceanography: An Introduction: G.L.Pickard and W. J. Emery, Pergamon, Edns.,1982, 1992.
2. Elements of Physical Oceanography, McLellan, Hugh J., Pergamon press (New York), 1965
3. Elements of Physical Oceanography: A Derivative of the Encyclopedia of Ocean Sciences, Steele, John H, Academic Press, 2010.
4. Essentials of oceanography, Trujillo, Alan P., Pearson, 2014.
5. Ocean Circulation & Climate: Siedler, Church & Gould, Academic Press, 1st Edn., 2001.
6. Ocean Circulation and Climate, Volume 103, Second Edition: A 21st century perspective, Siedler, Gerold, Academic Press, 2013.
7. Physical Oceanography (Vol. 2), Defant, Albert, 1961, New York Pergamon Press.
8. Physical Oceanography, A.S.N. Murty and V.S.N. Murty, A.P.H. Pub, viii, 430 p, 2010.
9. Principles of Physical Oceanography: G.Neumann & WJ Pierson, Jr., Prentice Hall,1st edn.,1966
10. Regional Oceanography: Tomczak M. & J.S.Godfrey, Daya Publishing House, New Delhi, 2004.
11. Oceanography Challenges to Future Earth, Komatsu, T., Ceccaldi, H., Yoshida, J. , Prouzet, P., Henocque, Y. (Eds), Springer, ISBN 978-3-030-00137-7, 2019.
12. Ocean circulation in three dimensions, Barry A. Klinger and Thomas W.N. Haine, Cambridge University Press, 2019.

20-319-0102 GEOPHYSICAL FLUID DYNAMICS
(CORE, Credit: 4)

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

1. List out fundamental equations of the fluid dynamics.
2. Derive the different terms in the conservation equations of mass and momentum for oceans.
3. Discuss dimensional analysis and the importance of various dimensionless numbers.
4. Describe the fundamental concepts in fluid dynamics
5. Apply standard mathematical techniques to solve numerical problems relevant to fluid dynamics.

Unit I

Fluid mechanics,– fluid properties – Newton's law of viscosity - Fluid statics - Pascal's law – equation of state– Thermodynamic variables-Static stability of ocean and atmosphere – Continuum hypothesis-Distinguishing attributes of geophysical flows- stratification and rotation. Distinction between the atmosphere and ocean. Vector, tensor, gradient, divergence and curl. Stokes' theorem, Gauss' theorem.

Unit II

Lagrangian and Eulerian representation – streamline, pathline, streaklines – Conservation of mass (equation of continuity) – Incompressibility - vertically averaged continuity equation - convergence and divergence – conservation of momentum – Euler's equation – Navier- Stokes equation – plane Couette flow - Plane Poiseuille Flow.

Unit III

Rotating frame of references – Coriolis force – Reynolds averaged equations, closure problem, eddy coefficients, Rotation - vorticity and circulation – Kelvin's theorem – one, two and three dimensional flows – velocity potential – stream function - Laplace equation - Bernoulli equation and applications.

Unit IV

Dimensional analysis- Buckingham's Pi theorem - non-dimensional numbers, Reynolds, Rossby, Ekman – Scaling analysis, Approximations – geostrophic, hydrostatic and Boussinesq. Conservation of temperature and salinity – advection, diffusion. Stratification, Froude number. Baroclinic mode. Linear continuously stratified fluid, barotropic and baroclinic instabilities.

References:

1. Fluid Mechanics, Kundu, P.K., Cohen, I.M., Dowling, D.R., 6th Edition, Academic Press, Elsevier, 2015.
2. Introduction to geophysical fluid dynamics physical and numerical aspects, Benoit Cushman-Roisin, Jean-Marie Beckers, 2nd Edition, Academic press, Elsevier 2011.
3. Atmosphere-Ocean Dynamics, Gill, A. E., International Geophysics Series, Vol. 30, 1982.
4. Fluid Physics for Oceanographers and Physicists: An Introduction to Incompressible Flow, Samual A. Elder and J. Williams, 2nd Edn, Pergamon Pr, 1989.
5. An introduction to fluid dynamics, Batchelor, G. K., Cambridge University Press, 2000.

Suggested Reading:

1. Geophysical Fluid Dynamics: An Introduction to Atmosphere—Ocean Dynamics: Homogeneous Fluids, Özsoy, Emin, Springer 2020.
2. An Introduction to Theoretical Meteorology, S. L. Hess, Holt, Rinehart & Winston, 1966.
3. Atmospheric and oceanic fluid dynamics fundamentals and large-scale circulation, Geoffrey K. Vallis, Cambridge University Press, 2006.
4. Climate dynamics, Cook, Kerry H., Princeton University Press, 2013.
5. Environmental fluid dynamics, Imberger, Jorg, Academic Press, 2013.
6. Fluid dynamics: An introduction. Reutord, M. Springer, 508pp. 2015.
7. Foundations of Fluid Mechanics, S. W. Yuan, Student International Edition, Prentice Hall, 1970.
8. Fundamentals of Geophysical Fluid Dynamics, James C. McWilliams, Cambridge University Press, 2006.
9. Geophysical Fluid Dynamics, J. Pedlosky, 2nd Edn, Springer, 1992.
10. Numerical Methods and Models in Earth Science, Ghosh, Parthasarathi, New Indian Publishing Agency, 2011.
11. Essentials of Atmospheric and Ocean Dynamics. Geoffrey K. Vallis, Cambridge University Press, 2019.

20-319-0103 OCEAN INSTRUMENTATION
(CORE, Credit: 3)

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

1. List out various platforms used in oceanographic measurements.
2. Describe the working principles of various oceanographic instruments.
3. Explain the basic sampling requirements for general oceanographic purposes
4. Explain the various navigational aids for obtaining positions at sea.
5. Describe the surface meteorological measurement techniques.

Unit I

Oceanographic platforms : research vessels and their facilities - aircrafts and satellites – Shallow and deep water buoys - drifting buoys - research towers – submersibles – drifting platforms – mooring –FLIP – unmanned platforms and autonomous robotic vessels – smart ocean sensors. Principles of navigation – classical and modern navigational methods – GPS & DGPS – Projections - Sampling requirements – sampling duration, interval and accuracy.

Unit II

Measurement of ocean depth – Lead sounding - Echo sounder, SONAR – side scan, multibeam, sub-bottom profilers. Measurement of light – optical sensors - Secchi disc – Turbidity meter, Silt meter, Lux meter. Water sampling devices: NRWB – modifications - horizontal water sampler - Rosette sampler- special water sampling devices.

Unit III

Temperature measurement - SST measurements from ships, buoys and satellites –subsurface temperature measurements - reversing thermometers, temperature profiling using MBT, XBT. Salinity measurements - titration method – salinity from conductivity – induction method – Autosal – CTD.

Unit IV

Measurement of currents - Direct reading and Recording Current Meters - Acoustic Current Meters - Electromagnetic Current Meters - profiling of currents using ADCP - surface and subsurface drifters – ARGO floats - oceanographic gliders. Measurement of waves - surface buoys – subsurface gauges-pressure gauges-resistant gauges. Measurement of Tides - Tide staff, Tide gauge and pressure gauge - Satellite altimetry - Inverted Echo Sounder - Surface meteorological measurement - atmospheric temperature, pressure, humidity and wind.

References:

1. Data analysis methods in Physical oceanography, Thomson, Richard E., Elsevier, Edns.1997, 2014.
2. Principles of Physical Oceanography: W J Pierson and G Neumann, Prentice Hall, 1966.
3. The Oceans- Their physics, chemistry and general biology: Sverdrup, Prentice Hall, 1942.
4. Descriptive Physical Oceanography, Reddy, M. P. M., 2000, New Delhi Oxford & IBH
5. Descriptive Physical Oceanography: An Introduction.Ed.6, Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift, Elsevier, 2011.

Suggested Reading:

1. Modern Observational Physical Oceanography. Carl Wunsch, Princeton University Press, 2015.
2. A Pictorial History of Oceanography Submersibles: J B Sweeny, London Robert Hale Company, 1970.
3. A Practical Handbook of Seawater Analysis, Strickland and Parsons, 2nd Edn, Miscellaneous Special Publications-Fisheries Research Board of Canada, 1972.
4. Descriptive Physical Oceanography: An Introduction: G. L Pickard and W.J Emery, Oxford Pergamon Press, 2003.
5. Instruction Manual for Oceanic Observations: U S Naval Oceanographic Office, H.O. Pub. 607, 1955
6. Introduction to Physical Oceanography: Robert H. Stewart, e-book, 2005.
7. Introduction to Physical Oceanography: W. S. Von Arx, 1st Edn., 1962.
8. Marine Sciences Instrumentation: Vol.1 & 2; Gaul, Roy D.; Plenum Press, 1962.

20-319-0104 OCEAN OBSERVATIONS (Practical)
(CORE, Credit: 1)

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

1. Apply practical skills for conducting high quality research.
2. Demonstrate and operate the modern oceanography/meteorology instruments on board.

Use and operation of instruments on board - GPS, Lead sounding - Echo Sounder, NRWB, Niskin and Horizontal water samplers, BT, XBT, CTD, Salinometer, Current meters, Tide gauge, Lux Meter, Turbidity meter, Silt meter, Anemometer and Psychrometer - Familiarization of hydrographic tools - Collection of environmental data – collection of sea water using oceanographic samplers. On board data collection.

20-319-0105 PHYSICAL OCEANOGRAPHIC COMPUTATIONS (Practical)
(CORE, Credit: 2)

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

1. Explain the basic syntax involved in Fortran program coding for performing mathematical operations.
2. Calculate various physical properties of sea water using computer programs.

Computer Programming in Fortran: Variables and data types – input and output - operators – built-in functions - control operations – loops – arrays – function and subroutine subprograms - file input and output – programming style and debugging.

Computation of density, potential temperature, specific volume anomaly, sound velocity, freezing point temperature – estimating salinity from conductivity – pressure to depth conversion – Brunt-Vaisala Frequency. Analysis of temperature and salinity profile data – interpolation – temperature gradient – Mixed Layer Depth – dynamic height.

20-319-0106 OCEANOGRAPHIC APPLICATION TOOLS - I (Practical)
(CORE, Credit: 2)

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

1. Design programs in Python for oceanographic applications.
2. Create Graphical plotting using Ferret and GMT.

Programming Python: Features of Python language – Python environment – print function - identifiers – programming rules – variables and data types – user input - operators – mathematical functions – string operations. The if statement – while and for loops. User functions - Modules and packages –math, random, numpy and pandas modules. File handling –plotting in python.

Ferret: installation – NETCDF data – line and contour plots – vector plots – multiple plots – ferret jnl files – transformation functions – World Ocean Atlas.

GMT: installation – basic command options – base map plot – line and symbol plots – 2D contour and image plots - vector plots – data extraction with awk command – multiple plots - writing text on figures.

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, 4th 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

Unit II

Dimensional analysis – similarity theory of neutral atmosphere – friction velocity - roughness length – Charnock's law - logarithmic wind profile - atmospheric stability – Monin-Obukhov similarity theory and flux-profile relationships – Monin-Obukhov Length - bulk-aerodynamic formulation of fluxes – methods of flux estimation: eddy correlation, gradient, profile methods and bulk methods – air-sea gas exchange

Unit III

Large scale air sea interactions – global wind stress distribution - shortwave and longwave radiation fluxes – sensible and latent heat fluxes – global data sets on fluxes – annual climatology of fluxes – heat budget and heat transport – evaporation, precipitation and freshwater budget - intra-seasonal air-sea interactions – inter-annual air-sea interactions - ENSO and IOD

References:

1. Introduction to Micrometeorology, S. Pal Arya, Academic Press, 2001.
2. Introduction to Boundary Layer Meteorology, R. B. Stull, Kluwer Academic Publishers, 1988.
3. Air-Sea Exchange: Physics, Chemistry and Dynamics, G. L. Geernaert, Kluwer Academic Publishers, 1999.
4. Ocean-Atmosphere Interactions, Yoshiaki Toba, Terra Scientific Publishing Company, 2003.
5. Intraseasonal Variability in the Atmosphere-Ocean Climate System. Lau, William K.-M., Waliser**,** Duane E. S. Springer. 2012.

Suggested Reading:

1. Atmosphere-Ocean Interaction, E. B. Kraus and J. A. Businger, Oxford University Press, 1994.
2. Recent Advances in the Study of Oceanic Whitecaps. Vlahos, P., & Monahan, E. C., Springer Nature. 2020.
3. Essentials of Oceanography, Trujillo, Alan P., Pearson, 2014.
4. Fundamentals of Tropical Climate Dynamics, Tim Li and Pang-chi Hsu, Springer International Publishing AG, 2017.
5. Indo-Pacific climate variability and predictability, Edited by Swadhin Kumar Behera and Toshio Yamagata, World Scientific Publishing Co. Ptc. Ltd, 2016.
6. Infinite-dimensional dynamical systems in atmospheric and oceanic science, Boling, Guo, World Scientific, 2014.
7. Mesoscale-convective Processes in the Atmosphere, Trapp, Robert J, Cambridge University Press, 2013.
8. Meteorology: understanding the atmosphere, Ackerman, Steven A, Jones & Bartlett Learning, 2015.
9. The Asian Monsoon, Clift,Peter D, Cambridge University Press, 2014.
10. The Oceans and Climate, Grant R. Bigg, Cambridge University Press, 1996.
11. Wind Stress over the Oceans, Ian S. F. Jones and Y. Toba, Cambridge University Press, 2009.

20-319-0203 COASTAL AND ESTRUARINE OCEANOGRAPHY
(CORE, Credit: 3)

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

1. Distinguish various coastal environments and processes.
2. List and explain different methods for coastal sediment transport estimation.
3. Explain the characteristics of different wave transformations.
4. Describe the generation of tides and perform harmonic analysis.
5. Describe the dynamics of Indian and global estuaries.

Unit I

Coasts and shorelines, coastal morphology, coastal land forms, types of coastal environment, coastal processes, factors influencing coastal processes. Beaches – classification and features, beach configuration & profiles, beach erosion & accretion, long shore bars, sand spits, atolls, mud banks-beach stability, coastal zone management, Oceanographic aspects in coastal zone protection, coastal uses and resources, coastal pollution, coastal zone of India, coastal hazards and mitigation measures.

Unit II

Wave transformation in shallow waters, effect of bottom friction, phenomena of wave reflection, refraction and diffraction, breakers, littoral currents. Sediment transport in coastal zone, wave action on sediments, alongshore and cross shore transport, rate of sediment transport, artificial nourishment - Sediment transport in coastal zone - characteristics of wind waves and swells - Significant wave height and period. Fetch limited and duration limited conditions.

Unit III

Tides-tidal constituents, Harmonic analysis of tides. Tides and tidal currents in shallow seas and estuaries. Sea level changes - Storm surges. Tsunamis.

Unit IV

Estuaries-importance of studying estuaries, classification and nomenclature, effect of river discharge and tides, salinity intrusion in estuaries, mixing and stratification, residual estuarine circulation, estuaries of India – monsoonal estuaries, Tidal prism, uses and issues associated with estuaries.

References:

1. Beaches and Coasts: C A M King, Edward Arnold, 1961.
2. Beaches Processes and Sedimentation: P D Komar, Prentice Hall, 2nd Edn., 1997.
3. Contemporary issues in estuarine physics, Arnoldo-Valle Levinson, Cambridge University Press, 2010.
4. Estuaries: A Physical Introduction: K R Dyer, John Wiley, 1973.
5. Sea-level science : understanding tides, surges, tsunamis and mean sea-level changes, Pugh, David, Cambridge University Press, 2015.

Suggested Reading:

1. Beaches and Coasts: R A Davis & D M Fitzgerald, Wiley Blackwell, 2004.
2. Relationships between Coastal Sea Level and Large Scale Ocean Circulation. Rui M. Ponte, Benoit Meyssignac, Catia M. Domingues, Detlef Stammer, Anny Cazenave, Teodolina Lopez., Springer, 2020

3. Shore protection manual Vol. 1, 2, 3, Coastal Engineering Research Centre, University of Michigan Library, 1973.
4. Coastal Hydrodynamics, Mani.J.S, PHI Pvt Ltd. New Delhi, 2012.
5. Coastal Oceanography: Yanagi Tetsuo, Kulwer, 1999.
6. Coastal Zone Management: D R Green, Thomas Telford Pub., 2009.
7. Coastal Zones: Solutions for the 21st Century, Baztan, Juan, Elsevier, 2015.
8. Estuaries: G H Lauff, AAAS, 1967.
9. Estuarine Ecohydrology, Erik Wolanski, Elsevier, Second Edition, 2015.
10. Estuary and Coastline Hydrodynamics: A T Ippen, McGraw Hill, 1966.
11. Tides - a scientific history, Cartwright, D.E. Cambridge University Press. 292pp. 1999.
12. Waves, tides and shallow-water processes. Open University Oceanography Series Vol.4. Oxford: Pergamon Press in association with the Open University, 187 pp., 1989.
13. Coastal engineering processes, theory and design practice, Dominic Reeve, Andrew Chadwick & Christopher Fleming, CRC Press, 3rd Edition, 2018.
14. Sediment transport in coastal waters; Sylvian Quillon; MDPI Publishers; 2019
15. Coastal engineering theory and practice, Vallam Sundar & S.A Sannasiraj, Advanced series on Ocean engineering, Vol. 47, Publisher: WSPC, 2019.

20-319-0204 DYNAMICAL COMPUTATIONS (Practical)
(CORE, Credit: 1)

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

1. Compute thermosteric anomaly, static stability and Brunt Vaisala frequency using temperature and salinity datasets.
2. Estimate relative currents, vertical velocity, geopotential anomaly, Ekman current and Ekman pumping.

Thermal structure, Static Stability, Specific volume anomaly, Dynamic depth, Relative currents, Level of No motion, Absolute currents, Divergence and convergence, Ekman spiral, Mass transport, Upwelling.

20-319-0205 COASTAL OCEANOGRAPHY (Practical)
(CORE, Credit: 2)

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

1. Estimate coastal accretion and erosion using insitu field observations.
2. Analyze the wave record data and estimate different wave parameters.

Preparation and interpretation of Bathymetric charts, Beach Profiles, Analysis of wave records, Tuckers' method-Wave power computation, Littoral drift and sand budget, Wave spectrum, Tide data analysis-harmonic analysis.

20-319-0206 AIR-SEA INTERACTION (Practical)
(CORE, Credit: 1)

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

1. Estimate air-sea fluxes from marine observational data.
2. Analyze Global Air-Sea Flux data.

Estimate statistical properties of turbulence – log wind profile – momentum flux from wind profile – fluxes and profiles under non-neutral stability condition – Richardson number – bulk, eddy correlation, gradient and profile methods of flux estimation.

Wind stress over global oceans – analysis of radiative and turbulent air-sea fluxes from moored buoy data – analysis of global heat flux data - heat budget analysis – heat transport – global freshwater fluxes and budget – inter-annual anomalies in fluxes during ENSO and IOD.

SEMESTER III

20-319-0301 OCEAN REMOTE SENSING
(CORE, Credit: 4)

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

1. Describe the fundamentals of ocean remote sensing and its applications for the benefit of society.
2. Explain the algorithms and principles of optical, infrared and microwave remote sensing.
3. Explain the principles of computation of geostrophic current and eddy kinetic energy by using microwave altimeter data.
4. Identify internal waves, oil slicks and bottom topography from satellite microwave ocean data.
5. Describe satellite image processing techniques.

Unit I

Introduction to Remote Sensing: Basic concepts – Electromagnetic radiation – solar and terrestrial radiation, atmospheric effects absorption, transmission and scattering. Spectral response of Earth's surface features. – Atmospheric windows – spectral signature. Remote sensing platforms: – Satellites, orbits and missions, near polar, geostationary and sun synchronous satellites. Sensors: swath, Resolution concepts – types-spatial, temporal, spectral and radiometric resolution- Active and passive remote sensing– Remote Sensing in Indian perspective- Indian Satellites and sensors for oceanographic applications. Basics of satellite image processing.

Unit II

Visible remote sensing: theory of ocean colour remote sensing optical properties of pure water, natural waters and atmosphere – optical pathways in the atmosphere – – Scattering and absorption of light – colour of the sea: phytoplankton, yellow substance, suspended particulate matter principle of estimation and its applications– case 1 and case 2 waters – satellite sensors for ocean color data. Clouds in visible remote sensing.

Unit III

Infrared Remote Sensing: thermal emission – atmospheric absorption – SST retrieval –atmospheric correction – effect of cloud – thermal skin layer – skin and bulk SST.- effect of surface films – Infrared radiometers -NASA pathfinder, global SST data: SST – applications. Cloud altitude based on cloud top temperature. Satellite and sensors for measurement of SST. LIDAR & shallow bathymetry.

Unit IV

Microwave Remote Sensing: Microwave emission of sea surface - atmospheric effects –Microwave bands, sensors – Passive and active microwave radiometers- retrieval of SST and salinity. Microwave Radar-measurement of ocean waves, Sea ice, oil spills. Water vapor and rainfall, Scatterometers: SAR & RAR- wind and radar backscatter – wind speed and direction. Altimetry: principles – SSH & sea surface height anomaly- Geostrophic currents, eddy kinetic energy, Planetary waves- SARAL and recent altimeters.

References:

1. Satellite Oceanography: An Introduction for Oceanographers and Remote Sensing Scientists: I.S. Robinson, Ellis Horwood, 1985.
2. Oceanographic Applications of Remote Sensing: Motoyoshi Ikeda and W. Dobson CRC Press, 1995.
3. Discovering the Ocean from Space: The Unique Applications of Satellite oceanography, I.S. Robinson, Springer, 2010.
4. An Introduction to Ocean Remote Sensing 2nd Edn., Seelve Martin, Cambridge Univ. Press. 2014.
5. Introduction to Satellite Remote Sensing Atmosphere, Ocean, Cryosphere and Land Applications, William Emery, Adriano Camps and Marc Rodriguez-Cassolac, Elsevier, 2017.

Suggested Reading:

1. Advanced Remote Sensing, Liang, Shunlin, Academic Press, 2012.
2. Application of Remote Sensing Technology to Marine Fisheries. An Introductory Manual: Fisheries, M.J.A.Butler, M.C.Mouchot, V.Barale and Lebanc.C, Technical Papers, FAO publications, Vol.295. 1988.
3. Measuring the Oceans from Space: The Principles and Methods of Satellite Oceanography: I. S. Robinson, Praxis Publishing, UK. 2004.
4. Introduction to Remote Sensing, James B. Campbell, Randolph H. Wynne**,** Guilford Press. **2011.**
5. Introduction to Satellite Oceanography, G.A. Maul, Springer, 1985.
6. Advances in Passive Microwave Remote Sensing of Oceans, 1st Edn., Victor Raizer, CRC Press, Taylor and Francis Group. 2017.
7. Fundamentals of satellite remote sensing, Chuvieco, Emilio, CRC Press, 2016.
8. Image Processing and GIS for Remote Sensing: Techniques and Applications-2nd Edn., Jian Guo Liu, Philippa J. Mason., Wiley Blackwell. 2016.
9. Methods of Satellite Oceanography: Robert H. Stewart, Publisher: Berkeley, California. 1985.
10. Observation of the system earth from space, Flechtner, Frank, Springer, 2014.
11. Remote Sensing of the Changing Oceans, Dan Ling Tang, Gad Levy, Malcolm Heron, James Gower, Kristina B. Katsaros and Ramesh Singh, Springer, 2011.
12. Satellite based applications on climate change, Qu, John J, Springer, 2013.
13. Satellite Microwave Remote Sensing: T.D. Allan, Ellis Horwood Series in Marine Science, Chichester. 1983.
14. Remote Sensing of the Asian Seas, Barale, Vittorio**,** Gade Martin (Eds.), Springer, ISBN 978-3-319-94065-6, 2019.
15. Satellite Image Analysis: Clustering and Classification, Borra, S., Thanki, R., Dey, N**.**, Springer, ISBN 978-981-13-6423-5, E-book, 2019.

20-319-0302 NUMERICAL OCEAN MODELLING
(CORE, Credit: 3)

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

1. Explain the finite difference method for solving differential equations
2. Formulate numerical schemes for modelling oceanographic processes
3. Explain the procedure of building ocean models
4. Elaborate the structure of large scale ocean models
5. Describe the method of validation of model outputs.

Unit I

Introduction - physical, mathematical, numerical and computer models - building mathematical models – analytical and numerical solutions to PDEs - initial and boundary value problems – Dirichlet and Newmann boundary conditions - advantage and limitations of mathematical models – classification of mathematical models.

Unit II

Finite Difference Method: Taylor's series – approximation of derivatives - forward, backward and centered difference methods – truncation error – solution using Euler's method – iterative methods – solution to Laplace equation - explicit, implicit, semi-implicit, leap frog and Predictor-corrector numerical schemes- consistency, convergence and stability of numerical schemes.

Unit III

Building ocean models : model domain and dimensions – conservation equations of momentum, mass, temperature and salinity - primitive equations - subgrid scale parameterizations – model resolution - Arakawa grids – vertical discretization schemes – initial and boundary conditions – model spin up - model validation – data assimilation - classification of ocean models.

Unit IV

Ocean Models : Buoyancy oscillation – modelling advection using FTFS, FTBS, FTFS, upwind, Lax and Lax-Wendroff schemes - CFL stability - modelling diffusion - advection-diffusion model - modelling inertial currents - 1D Ekman model – mixed layer model - shallow water models – tsunami and tide models – Ocean General Circulation Models (OGCM)

References:

1. Ocean Modelling for Beginners using Open Source Software, Kampf J. Springer, 2007.
2. Advanced Ocean Modelling: Using Open-source Software. Springer Science & Business Media. Kämpf, J, 2010.
3. Introductory Dynamical Oceanography, Stephen Pond & George L. Picard, Pergamon, 1983.
4. Introduction to Geophysical Fluid Dynamics – Physical and Numerical Aspects: Benoit Cushman-Roisin and Jean-Marie Beckers , Academic Press, 2010.
5. Modeling coastal and marine processes by Phil Dyke, Imperial College Press 2016.

Suggested Reading:

1. Atmospheres and Oceans on Computers: Fundamental Numerical Methods for Geophysical Fluid Dynamics, Røed, Lars Pette, Springer, 2019.
2. Computer Modelling in Atmospheric and Oceanic Sciences. Peter Muller and Hans Von Storch Springer, 2004.
3. Numerical Modelling of Oceans and Oceanic Processes. Lakshmi H.Kantha & Carol A. Claysor Academic Press, 2000.
4. Coupled Ocean Atmosphere Models. Nihoul J. C. J, Elsevier, 1985.
5. Introduction to Dynamic Meteorology, Ed.2 & 5 Holton, James R, Academic, 2013.
6. Modeling atmospheric and oceanic flows, Larcher, Thomas von, American Geophysical Union, 2013.
7. Modelling and Prediction of the Upper Layers of the Ocean. Kraus, E. B, Pergamon Press, 1977.
8. Modelling Coastal and Marine Processes. Phil Dyke, Prentice Hall, 2016.

9. Numerical Methods and Models in Earth Science, Ghosh, Parthasarathi, New Indian Publishing Agency, 2011.
10. Numerical Modelling of Ocean Circulation. Cambridge, Robert N. Miller, 2007.
11. Numerical Modelling of Ocean Dynamics. Kowalik Z. & T. S. Murthy, World Scientific, 1995.
12. Ocean Circulation and Climate: Observing and Modelling the Global Ocean. International Geophysical Series, Vol. 77, Gerold Sielder, John church and Jon Gould, Academic Press, 2001.
13. Ocean modelling and parameterization. Chassignet, E. P., & Verron, J. (Eds.), Springer Science & Business Media, 2012.

20-319-0303 OCEAN AND CLIMATE
(CORE, Credit: 3)

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

1. Describe the equations representing the climate of the ocean and atmosphere
2. Describe the different terms of heat balance in the climate system
3. Explain the ocean structure and circulation
4. Use simple greenhouse model to evaluate responses of varying greenhouse emissions on the Earth's temperature
5. Analyse the climate change data and recommend mitigation strategies

Unit I
Climate system: Planet earth – Radiative balance – Distribution of solar radiation – Simple radiation models. Greenhouse effect: Blackbody radiation – Greenhouse gases – Layer models of greenhouse effect. Ocean structure and circulation: Horizontal structure of the ocean currents – Meridional overturning circulation and vertical structure – Mixed layer –Thermocline – Geostrophic flow – Western boundary and eastern boundary currents.

Unit II
Ocean role in climate: Moderating influence of oceans – lag in the seasons – Ocean heat transport – Mixed layer heat budget. Climate variability in the tropics – El Nino and Southern Oscillation – Changing Oceans: Causes and implications of Global warming – Observed temperature records – Salinity variation –Sea level rise – Changing Ocean currents – Thermohaline slowdown – Ocean acidification, Ozone hole.

Unit III
Climate projections: Climate models – Projections of temperature, sea-level rise, ocean circulation, rainfall and acidification. Impacts of climate change: Future of nature – Food, water and health issues – Regional impacts. Climate change adaptations: Energy supply and consumption – Climate mitigation strategies – Economic scenarios – Climate policy – Global conflict/cooperation.

References:

1. Climate and the oceans, Geoffrey K Vallis, Princeton Primers in Climate, 2012.
2. Climate System Dynamics and modelling, Hugues Goosse, Cambridge, 2015.
3. Global Physical Climatology, Dennis L Hartmann, Elsevier, 2016
4. Climate Crisis: An introductory guide to Climate change, David archer and Stefan Rahmstorf, Cambridge, 2010.
5. Global warming: Understanding the forecast, David Archer, John Wiley and Sons Inc., 2012.

Suggested reading:

1. The Oceans and Climate. Grant Bigg. Cambridge Press, 2003.
2. Atmosphere, Ocean and Climate Dynamics. John Marshall and R. Alan Plumb, Elsevier Academic Press, 2008.
3. Introduction to Physical Oceanography, Third edition, John A. Knauss and Newell Garfield, Waveland press, Inc., 2017.
4. Descriptive Physical Oceanography: An Introduction.Ed.6, Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift, Elsevier, 2011.
5. Introduction to dynamic meteorology, Ed.2 & 5 Holton, James R, Academic, 2013.
6. The earth System. Kump L. R. Kasting J.F and Crane R. G., Prentice Hall, 3rd Ed. 2009.
7. Atmospheric and Oceanic Fluid Dynamics: Fundamentals and Large-scale circulation, Geoffrey K. Vallis, Cambridge University Press, 2017.
8. Demystifying Climate Models: A user guide to earth system models, Andrew Gettelman Richard B. Rood, Springer, 2016.
9. Climate Change and Climate Modeling, David J. Neelin, Cambridge University Press, 2011.
10. Climate dynamics, Cook, Kerry H., Princeton University Press, 2013.
11. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K Vallis, Cambridge University Press, 2019.

20-319-0304 OCEAN CLIMATE DATA ANALYTICS (Practical)
(CORE, Credit: 2)

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

1. Use a visualization software such as Ferret to generate graphs and maps of ocean data (Salinity, temperature, current velocity, mixed layer depth, T-S diagram).
2. Use a software for oceanographic data analysis and computation

Data and tools: NetCDF data – Ferret – Climate Data Operator (CDO). Hydrography: World Ocean Atlas of temperature and salinity – estimation of global ocean mixed layer depth and climatology – T-S diagram and water mass analysis – Mixed layer heat budget.

Ocean circulation: seasonal wind pattern over Indian Ocean-wind stress distribution-ocean circulation using global data sets-Argo buoy data-geostrophic currents-Rossby and Kelvin waves using gridded sea level data- Analysis of climate model data. ENSO - Southern Oscillation Index – Indian Ocean Dipole Mode- long term trends in Indian Summer Monsoon rainfall. Time-series and spatial data analyses – FFT, Wavelet, EOF.

20-319-0305 OCEAN MODELLING (Practical)
(CORE, Credit: 2)

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

1. Apply finite difference methods for solving differential equations.
2. Develop and execute numerical ocean models for various oceanic processes.

Approximation of derivatives using Taylor's series-reducing truncation error - solution to ODE using Euler Method-solving 1 and 2 dimensional Laplace equation-matrix and iterative methods-solution to time-dependent equations using various numerical schemes.

Modeling oscillation of a buoyant object in a stratified fluid – modeling 1 and 2D advection and diffusion – advection plus diffusion problems – advanced numerical schemes – modeling inertial currents – Coriolis force - 1D Ekman model for wind-driven currents – ocean mixed layer models – shallow water process and modeling – hands-on training on global models.

SEMESTER IV

20-319-0401 PROJECT DISSERTATION
(CORE, Credit: 16)

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

1. Undertake independent research work pertaining to an earth science related topic of his/her expertise.
2. Propose a scientific problem, carry out field or laboratory experiments, analyse and communicate.

ELECTIVES

20-319-0001 GENERAL OCEANOGRAPHY
(ELECTIVE, Credit: 3)

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

1. Describe the spatial and temporal variability of physical properties of the ocean.
2. Sketch Ekman spiral.
3. Define upwelling area.
4. Explain different heat budget terms.
5. Describe Ocean circulations

Unit I

General introduction - dimension of oceans - geographical features - physical properties of sea water and its measurement - distribution of temperature, salinity, density and oxygen in space and time.

Unit II

Water masses: formation and classification - T-S diagram - water masses of the world ocean with special reference to Indian Ocean – Heat budget of ocean - insolation – long wave radiation – effect of clouds – sensible and latent heat transfer- Bowen's ratio.

Unit III

Circulation: general circulation of the atmosphere – trade winds – wind-driven and thermohaline circulation - major currents of the world oceans – seasonal currents in the Indian ocean - upwelling and sinking with special reference to the Indian Ocean. El-Nino and La-Nina.

References:

1. Descriptive Physical Oceanography: An Introduction: G.L.Pickard and W. J. Emery, Pergamon, Edns., 1982, 1992.
2. Descriptive Physical Oceanography, Reddy, M. P. M., 2000, New Delhi Oxford & IBH
3. Descriptive Physical Oceanography: An Introduction.Ed.6, Lynne D. Talley, George L. Pickard, William J. Emery and James H. Swift, Elsevier, 2011.
4. Introduction to Physical Oceanography: R. H. Stewart, E-book, 2005
5. The Oceans, their Physics, Chemistry and General Biology, H.U. Sverdrup, Prentice Hall, 1969.

Suggested Reading:

1. Elements of Physical Oceanography: A Derivative of the Encyclopedia of Ocean Sciences, Steele, John H, 2010, Academic Press.
2. Introduction to Physical Oceanography, Third edition, John A. Knauss and Newell Garfield, Waveland press, Inc., 2017
3. Ocean Currents: G. Neumann, Elsevier, 1st edn., 1968.
4. Oceanography: An Invitation to Marine Science, Garrison,Tom S., Brooks Cole, 2016
5. Physical Oceanography (Vol. 2), Defant, Albert, 1961, New York Pergamon Press.
6. Physical Oceanography, A.S.N. Murty and V.S.N. Murty, A.P.H. Pub, 2010, viii, 430 p.
7. Principles of Physical Oceanography: G.Neumann & WJ Pierson, Jr., Prentice Hall,1st edn.,1966.
8. Oceanography Challenges to Future Earth, Komatsu, T., Ceccaldi, H., Yoshida, J. , Prouzet, P., Henocque, Y. (Eds), Springer, ISBN 978-3-030-00137-7, 2019 .
9. Ocean circulation in three dimensions, Barry A. Klinger and Thomas W.N. Haine, Cambridge University Press, 2019.

20-319-0002 MARINE HAZARDS AND MANAGEMENT (ELECTIVE, Credit: 2)

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

1. Learn at an introductory level, the various types of marine hazards
2. Closely understand the nature and severity of each of the marine hazard
3. Learn about the physics and physical forces bring about the cause and ill effects from such hazards
4. Discuss and appreciate the management tools, as available now to address each marine hazard.
5. The mitigation measures, action plans, early warning systems and post hazard management figure in the learning processes.

Unit I

General introduction- classification-overview of marine and atmospheric hazards-Tsunami-cyclones-storm surges-floods-coastal vulnerability-shore line changes-landslides-earthquakes-subsidence.

Unit II

Pollution - oil spills - chemical and other pollutants – toxic algal bloom - thermal pollution – radioactivity - remedial approaches – dredging – mining - sand excavation - structures and ship collision – fire on oil rigs.

Unit III

Winds, waves, currents as agencies bring about hazards - Hazard management -Mitigation measures - long term planning – pre hazard action plans - hazard monitoring and early warning systems – active post hazard management plans.

References:

1. Global Warming-The Complete Briefing: H. John, 4th Edn, Cambridge University Press, 2009.
2. Ocean Environmental Management: E. G. Frankel, 1st Edn, Prentice Hall, 1995.
3. Encyclopedia of Disaster Management: P. C. Sinha, Anmol, India, 2002.
4. Environmental Hazards-Assessing Risk and Reducing Disasters: K. Smith, 5th Edn, Routledge, 2009.
5. Essentials of Oceanography, Trujillo, Alan P., Pearson, 2014.

Suggested Reading:

1. The climate crisis, Archer, David, Cambridge University Press, 2010.
2. Geomorphological impacts of extreme weather, Loczy, Denes, Springer, 2013.
3. Coastal environments and global change, Masselink, Gerd, Wiley-Blackwell, 2015.
4. Interactions of land, ocean and humans, Maser, Chris, CRC Press, 2015.
5. Climate change and environment, Sundaresan, J., Scientific Publishers, 2013.
6. Global Environmental Change: Past, Present and Future: Karl K. Turekian, Prentice Hall; 1st Edition, 1996.

20-319-0003 MARINE POLLUTION
(ELECTIVE, Credit: 3)

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

1. Explain the types of marine pollution and its impacts
2. Discuss the marine factors involved in polluting the oceanic environment
3. Understand the mechanisms in transport and disposal of marine pollutants
4. Learn the principles of control and abatement of marine pollution
5. Evaluate the monitoring strategies and study the prevalent laws related to this subject

Unit I

Pollution of the marine environment, marine pollutants and their sources. Types of pollutants - inorganic, organic, biological, thermal, radioactive and non-point. Mitigation-source control.

Unit II

Marine factors involved in transport & dispersal of pollutants - the transport phenomenon, advective and diffusion aspects. Dispersal of pollutants in estuaries and near shore areas, physical oceanographic factors affecting marine pollution.

Unit III

Impacts of pollution on the oceans. Control and abatement of marine pollution, oil pollution, oil slicks and their management- chemical dispersants, containment of oil at sea- ecotoxicology-case studies. Coral bleaching. Indian scenarios and case studies. Monitoring strategies, water quality parameters and standards, hazardous material transport, Open Ocean dumping and incineration, monitoring and control, general laws on prevention on marine pollution.

References:

1. Coastal Pollution: C J Sindermann, CRC Press, 2005.
2. Oceanic Processes in Marine Pollution: JM Capuzzo & Kester,Krieger, 1987.
3. Marine Pollution: R B Clark, Oxford Uty Press, 2001.
4. Marine Environment Pollution: R A Geyer, Elsevier, 2000.
5. Ocean sustainability in the 21 st century, Arico, Salvatore, Cambridge University Press, 2015.

Suggested Reading:

1. Biodiversity in the marine environment, Goulletquer,Philippe et al., Springer, 2014.
2. Coastal zones, Baztan, Juan, ed., Elsevier, 2015.
3. Coastal Zones: Solutions for the 21st Century, Baztan, Juan, Elsevier, 2015.
4. Dispersion in Estuaries and Coastal Waters: R Lewis, Wiley, 1997.
5. Interactions of land, ocean and humans, Maser, Chris, CRC Press, 2015
6. Marine Pollution & Human Health: R E Hester, Royal Soc. Chem., 2011.
7. Marine Pollution: New Research: T N Hofer et al., Nova Science, 2008.
8. Oil Spill Response in the Marine Environment: J W Doerffer, Pergamon Press, 1992.
9. Remote Sensing for the control of Marine Pollution: Jean Marie Massin, Springer, 1984.
10. Water and Water Pollution: L L Ciaccio, Marcel Dekker, 1971.

20-319-0004 OCEAN OPTICS
(ELECTIVE, Credit: 2)

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

1. Explain the penetration of daylight into the sea when the inherent optical properties of the sea are known.
2. Describe the method for estimating the optical properties from remote sensing.
3. Apply algorithm for ocean colour application.
4. Demonstrate various absorptive characteristics of sea water which leads to identifying various parameters.
5. Discuss the biogeochemistry of the ocean.

Unit I

Introduction – Characterization of light field in water, radiance, irradiance, diffuse attenuation coefficient, water leaving radiance – Inherent and Apparent optical properties of sea water – Light scattering by water molecules – Raman scattering by water – Rayleigh scattering Mie scattering.

Unit II

Absorption characteristics of water constituents - Backscattering characteristics of water constituents – Fluorescence by phytoplankton and Dissolved Organic matter – Impact of bottom refection on upwelling radiance and volume reflectance in water – Colour of the sea. Optical properties of Case I and Case II waters-Refractive index of sea water-Remote sensing reflectance, reflectance albedo, Photo-synthetically Active Radiation.

Unit III

Hydro optical models-Bio-optical models, Composition of natural water and its relation to hydro-optics, Ocean colour remote sensing – Ocean colour sensors, Algorithms for Ocean colour data processing, Ocean colour application studies - Underwater photography and Imaging instruments.

References:

1. Coastal Ocean Optics and Dynamics, Volume 17, Issue 2 of JARE data reports: Oceanography, Oceanography Society, 2009.
2. Colour of Inland and Coastal waters -A methodology for its interpretation: Dimitry Pozdnyakov and Hartmut, Springer with Praxis Publishing, UK, 2003.
3. Light Absorption in Sea Water, By Bogdian Wozniak, Jerzy Dera, Springer, 2014.
4. Marine Optics: N. G. Jerlov, Elsevier, 2^{nd} edition, 1976.

Suggested Reading:

1. Optical Oceanography, N.G. Jerlov, Elsevier publishing company, 1968.
2. Physical Optics of Ocean Water, Shifrin, K.S., Springer, 1988.

20-319-0005 MARINE ACOUSTICS
(ELECTIVE, Credit: 4)

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

1. Describe the models of underwater sound wave propagation.
2. Explain the seasonal and spatial variability of ocean acoustic characteristics.
3. Discuss the application of acoustics on Marine habitat and ecosystem monitoring.
4. Describe source localization applications.
5. List and explain the passive and active acoustic sensors.

Unit I

Introduction to Ocean acoustics. Acoustic plane, spherical and cylindrical wave equations and their solutions. Sound velocity in fluids. Energy density. Acoustic intensity. Acoustic standards. The decibel scale.

Unit II

Reflection and transmission of plane waves: Normal incidence; fluid – fluid interface, fluid-solid interface, standing wave patterns, transmission through three media. Oblique incidence; fluid-fluid interface, angle of intromission, fluid-solid interface.

Unit III

Absorption of sound waves in fluids. Sound transmission loss in sea water. Sound velocity structure of the sea. Ray tracing. Refraction phenomenon. Sound channels. Surface and bottom reflections. Sound transmission in shallow water- ray and normal mode solutions. Attenuation in inhomogeneous fluids. Scattering from non-resonant bodies and bubbles. Bubble resonance. Scattering characteristics of marine life – non-resonant bodies.

Unit IV

Piezoelectric and magnetostrictive sonar transmitting and receiving transducers. Hydrophones. Radiation pattern of sonar transducers – array of discrete and continuously distributed source elements. Transmitting and receiving directivity factor and directivity index. Beam shaping for arrays.

Unit V

Active sonar signals, resolution and bandwidth: Source level, echo level. Masking by noise and reverberation. Improving signal-to-noise ratio. Additional parameters significant in active sonar. Echo sounding and sub bottom profiling. Diffraction of impulsive signal at rough surfaces. Average reflection coefficient for rough surfaces. Doppler effect of moving objects. Doppler navigation. Passive sonar: Fundamental characteristics. Acoustic output of ships. Passive detection range. Passive detection hydrophones. Array steering. Ocean acoustic tomography.

References:

1. Acoustical Oceanography- Principles and Applications: Clay and Medwin, Wiley, 1977.
2. Underwater Acoustics and Ocean Dynamics: Proceedings of the 4th Pacific Rim, Lisheng Zhou, Wen Xu, Qianliu Cheng, Springer, 2016.
3. Ocean Acoustics, Desanto, John (Ed.), Springer, 1979.
4. Underwater Acoustic Modeling and Simulation, Fourth Edition, Paul C. Etter, CRC Press, Taylor and Francis Group, 2013.
5. Fundamentals of Acoustics: L. E. Kinsler and A. R. Frey, Wiley; 4th edition, 1999.

Suggested Reading:

1. Ocean Acoustics, Kistovich, A., Pokazeev, K., & Chaplina, T. Springer. 2020.
2. A Demonstration of Ocean Acoustic Tomography- The Ocean Tomography Group Nature, 299, pp. 121-125, 1982.
3. Applied Underwater Acoustics: D. G. Tucker and B. K. Gazey, Pergamon Press, 1966.
4. Fundamentals of Ocean Acoustics, L. Brekhovskikh, Y. Lysanov, Springer-Verlag 1982.
5. Introduction to the Theory of Sound Transmission: C. B. Officer, McGraw-Hill, 1958.
6. Ocean Acoustic Tomography- A Scheme for Large Scale Monitoring: Munk, W. and C. Wunsch, Deep Sea Res., 26A, PP. 123-161, 1979.
7. Ocean Acoustics- Theory and Experiment in Underwater Sound: Tolstoy and Clay, Acoustical Society of Amer., 1987.
8. Principles of Underwater Sound for Engineers: R. J. Urik, McGraw-Hill Ryerson, 1983.
9. Sounds in the Sea: From Ocean Acoustics to Acoustical Oceanography, Herman Medwin, Cambridge University Press, 2005.
10. Underwater Acoustics: Leon Camp, Wiley- Interscience, 1970.
11. Underwater Observation Using Sonar: D. G. Tucker, Fishing News (Books), 1966.

20-319-0006 COASTAL ZONE MANAGEMENT - I
(ELECTIVE, Credit: 3)

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

1. Appraise the uniqueness of such regions.
2. Appreciate the inter-linkages within the diverse coastal ecosystems.
3. Describe the sensitiveness of coastal habitats and their response to global climate change(s).
4. Understand management approaches in coastal zones.
5. Apply tools to conduct integrated management of coastal zones.

Unit I

Concepts, definition and approach – general classification of coastal zones of the World – dominant natural processes - Asia –Pacific coastal zone - State of the environment – terrestrial and marine influence on coastal zone – catchment coast interactions.

Unit II

Coastal resources and utilization – conservation measures – developmental activities – human pressures and responses-hotspot management- hazards and vulnerability analysis. Management options - DPSIR - Matrix approach - participatory dialogues and stakeholder roles-voluntary partnerships - integrated management and planning – sustainable development.

Unit III

Legal Regime – law of the sea - territorial sea and EEZ – Indian coastal policy – implementation of policy – traditional practices and modern engineering innovation.

References:

1. Coastal Zone Management: Ramakrishnan Korakandy, Kalpaz Publications, 1st Edn. 2005.
2. CZM handbook: R. J. Clark, CRC Press; 1 edition, 1995.
3. Integrated CZM: Erland M, Wiley – Blackwell, 2009.
4. Sustainable Coastal Management & Climate Adaptation: R Kenchington, CRC Press, 2012.
5. Interactions of land, ocean and humans, Maser, Chris, CRC Press, 2015.

Suggested Reading:

1. Coastal environments and global change, Masselink, Gerd, Wiley-Blackwell, 2015.
2. Coastal Wetlands: an integrated ecosystem approach: Perillo G M E, Elsevier, 2009.
3. Coastal zones, Baztan, Juan, ed., Elsevier, 2015.
4. Coastal Zones: Solutions for the 21st Century, Baztan, Juan, Elsevier, 2015.
5. Fluvial Processes and Environmental Changes: A. Brown, T. Quine, Wiley; 1 edition, 1999.
6. Geomorphological impacts of extreme weather, Loczy, Denes, Springer, 2013.
7. Global challenges in integrated coastal zone management, Moksness, Erlend, Wiley-Blackwell, 2014.
8. Landscapes and landforms of India, Kale, Vishwas S., Springer, 2014.
9. Perspectives on Integrated CZM: W. Salomons, R. K. Turner, Lacerda, L.D. de, S. Ramachandran, Springer, 1999.

20-319-0007 COASTAL ZONE MANAGEMENT – II
(ELECTIVE, Credit: 3)

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

1. Conduct a management exercise at an advance level in CZM.
2. Explain various sampling and mapping techniques.
3. Understand the coastal zone in detail and assess minute, underlying causes that control various processes in coastal zone.
4. Implement proper management practices in the coastal zone.
5. Learn to perform and grow globally as an expert in coastal zone management.

Unit I

Global environmental change - climate change and impacts on coastal zone – sea level changes and coastal responses – approaches to sustainable coastal zone management – adaptive management in contextual scenarios.

Unit II

Coastal surveying methods – monitoring - approach to field work - sampling techniques - RS/GIS applications – EIA within the framework of CZM. Coastal engineering works – structures – impacts - shore protection and maintenance -dredging and impacts - ports and harbours - pre-requisites.

Unit III

Marine spatial planning and ICZM – concepts and application – coastal and marine spatial data – zoning and uses of coastal zone based on GIS and MSP.

References:

1. CZM Handbook: R. J. Clark, Taylor & Francis, 1995.
2. Port Engineering: G. Tsinker, John Wiley & Sons, 2004.
3. Advances in Coastal and Ocean Engineering: Philip L. F. Liu, World Scientific Pub Co Inc., 1997.
4. Sustainable Coastal Management & Climate Adaptation: R Kenchington, CRC Press, 2012.
5. Integrated CZM: Erland M, Wiley – Blackwell, 2009.

Suggested Reading:

1. Coastal Engineering Manual- Part I: Introduction, with Appendix A: Glossary of Coastal Terminology, U.S. Army Corps Of Engineers, Books Express Publishing, 2012.

2. Coastal Erosion, Response and Management: C. H. Roger and C. P. De Meyer, Springer; 1998.
3. Coastal Wetlands: An Integrated Ecosystem Approach: Perillo G M E, Elsevier, 2009.
4. Perspectives on Integrated CZM: W. Salomons, R. K. Turner, Lacerda, L.D. de, S. Ramachandran, Springer, 1999.
5. Statistical Data Analysis for Ocean and Atmospheric Services: H. J. Thiebaux, Academic Press, 1st Edn., 1994.

20-319-0008 BEACH DYNAMICS
(ELECTIVE, Credit: 2)

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

1. Understand the effects of human activities on a changing shoreline.
2. Attain knowledge on multiple issues in the coastal zones.
3. Understand how the currents, waves and tides shape the sand movements.
4. Identify how the warming climate affect the sea levels.
5. Engage the coastal community and policy makers aware of describing civil infrastructural projects.

Unit I

Beach features and classification – Beach cycles – Beach profiles – Erosion and Accretion- Beach Dimensions – Two dimensional beaches – Surf zone – Swash zone – Three dimensional beaches – Beach Quantification – Beach morphodynamics – coastal processes and shore face equilibrium-Coastline changes- Case study.

Unit II

Coastal boundaries – Beach Sediments – Sediment budget - Global changes in coastal sediments – Bar formation- Barrier beach formation -Wave climate – Surf zone – Waves generation- Wave transformation and wave set up – Wave transformation models Longshore currents – Rip currents – Onshore- Offshore sediment transport- Sediment transport models.

References:

1. Beaches and Coasts: C A M King, Edward Arnold, 1961.
2. Beach Processes and Sedimentation. 2 Edition, Komar, Paul D, Prentice Hall, Upper Saddle River (New Jersey), 544 p, 1998.
3. The Coastline: R S K Barnes, Wiley-Blackwell, 1977.
4. Coasts – An Introduction to Coastal Geomorphology: C F Bird, Blackwell Pub; 3 Sub edition, 1984.
5. Coastal Zones: Solutions for the 21st Century, Baztan, Juan, Elsevier, 2015.

Suggested Reading:

1. Coastal Environments- An Introduction to the Physical, Ecological, and Cultural Systems of Coastlines: R W L Carter, Academic Press, 1989.
2. Coastal ocean observing systems, Liu ,Yonggang , Kerkering, Heather, Weisberg, Robert H., Elsevier, 2015.
3. Coastal Sedimentary Environments: R A Davies, Springer; 2nd ed. 1985 edition, 2011.
4. Interactions of land, ocean and humans, Maser, Chris, CRC Press, 2015.
5. Landscapes and landforms of India, Kale, Vishwas S., Springer, 2014.
6. Pitfalls of shoreline stabilization Cooper, Andrew J G., Springer, 2012.
7. Practical guide to geo-engineering: with equations, tables, graphs and check lists, Srbulov, Milutin, Springer, 2014.
8. Quaternary sea-level changes: a global perspective, Murray-Wallace, Colin V., Cambridge University Press, 2014.

9. Sea-level science : understanding tides, surges, tsunamis and mean sea-level changes, Pugh, David, Cambridge University Press, 2015.
10. Waves on beaches: R E Mayer, Academic Press, New York, 1972.

20-319-0009 GIS IN OCEANOGRAPHY
(ELECTIVE, Credit: 2)

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

1. Explain basics of GIS.
2. Describe applications of GIS in Oceanography.
3. Demonstrate coastal zone habitat mapping.
4. Recognize cartographic importance of thematic mapping in Oceanography.
5. Identify the major coastal zone resources.

Unit I

Introduction to Geographical Information System (GIS) – data and analysis techniques – hardware and software – general applications. The Marine Geographic Information Systems – uses in various fields of oceanography – Data sampling – identification of ocean features – mapping seabed – GIS tools in fisheries.

Unit II

GIS and Coastal Zone – Planning in CZ – data analysis and applications using GIS – managing CZ resources – GIS as a decision support system.

References:

1. An Introduction to GIS: I Heywood, S Cornelius& S Carver, Prentice Hall; 2nd Edn., 2002.
2. GIS – An Introduction: T Bernhardsen, Wiley; 3rd Edn., 2002.
3. GIS & Multi Criteria Decision Making: J Malczewski, John Wiley & Sons, 1999.
4. GIS & Science: P. A.Longley, MF Goodchild, D J Maguire & D W Rhind, Wiley; 3rd Edn., 2010.
5. Geographic Information Systems in Oceanography and Fisheries: V D Valavanis, CRC Press, 2003.

Suggested Reading:

1. Coastal and Marine Geo Information Systems: D R Green & S D King, Springer, 1st Edn., 2003.
2. Hydrological applications of GIS, Gurnell, A. M., Wiley, 2014.
3. Innovations in GIS 5: S Carver, Taylor and Francis, 1998.
4. Integration of GIS and RS: J L Star, J E Estes and K C, McGwire, Cambridge University Press, 1997.
5. Managing Geographic Information System Projects: W. E Huxhold & A G Levinsohn, Oxford University Press, 1995.
6. Spatial Models and GIS New Potential and New Modes (GIS DATA): I Masser, F Salge, A S Fotheringham & M Wegner, CRC Press; 1st Edn., 1999.
7. Wetland and Environmental Application of GIS: JGLyon & J MaCarthy, Lewis Pub. 1995.

20-319-0010 ADVANCED OCEAN DYNAMICS
(ELECTIVE. Credit: 3)

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

1. Describe the fundamental models that used for the ocean dynamics, its approximations and boundary conditions.
2. Discuss the equatorial and costal ocean response to the surface winds through the generation of Kelvin waves and Rossby waves, its propagation and its reflection at the coastal boundaries.
3. Explain the Ekman pumping, Ekman balance and Sverdrup balance.
4. Discuss the different types of small scale instabilities in the mixed layer and its condition.
5. Discuss the different types of large scale instabilities in the ocean and conditions for their existence.

Unit I

Laplace and Fourier transforms, Eigen value problem, Sturm-Liouville equation, Hermite function, Linear Continuously stratified model, one and half layer model, two and half layer model, Approximations and boundary conditions, Types of waves (gravity, Kelvin, and Rossby waves), their dispersion relations, and phase and group speeds.

Unit II

Interior ocean response to wind forcing – Inertial oscillations, Ekman drift, Ekman pumping, radiation of Rossby waves, Sverdrup balance. Coastal ocean response to alongshore winds- coastal Kelvin waves, vertical propagation of Kelvin waves, Rossby wave radiation from eastern boundary. Equatorially trapped waves- how do they differ from off-equatorial waves, reflection of coastal Kelvin waves from an eastern boundary, equatorial Rossby waves, equatorial Kelvin wave and Yanai wave, Yoshida (Wyrtki) jet.

Unit III

Small-scale instabilities – convective overturning and Kelvin-Helmholtz (KH) instability, Mile's condition for KH instability, breaking of internal waves, small scale instabilities in mixed layer, mixed-layer processes and models. Large scale instabilities - barotropic and baroclinic instability, condition for existence of barotropic instability.

References:

1. Atmosphere-Ocean Dynamics, Gill, A. E., International Geophysics Series, Vol. 30, 1982.
2. Geophysical Fluid Dynamics, Pedlosky, J., Springer, Second Edition, 1992.
3. Ocean Dynamics, Olbers, D, Willebrand, J, Eden,C, Springer, 2012.
4. Geophysical Fluid Dynamics I : An introduction to Atmosphere-Ocean Dynamics: Homogeneous Fluids. Emin Ozsoy, Springer, 2020
5. Essentials of Atmospheric and Ocean Dynamics. Geoffrey K. Vallis, Cambridge University Press, 2019.

Suggested Reading:

1. A student's guide to geophysical equations, Lowrie, William, Cambridge University Press, 2011.
2. Atmospheric and oceanic fluid dynamics fundamentals and large-scale circulation, Geoffrey K. Vallis, Cambridge University Press, 2006.
3. Dynamics of the equatorial ocean, Boyd, P, Springer, 2018.
4. Environmental fluid dynamics, Imberger, Jorg, Academic Press, 2013.

5. Mesoscale-convective Processes in the Atmosphere, Trapp, Robert J, Cambridge University Press, 2013.
6. Modelling of Wind-driven circulation, J. P. McCreary, Hawaii Institute of Geophysics, 1980.
7. The Ocean in motion, Manuel G. Velarde, Roman yu. Tarakanov, Alexey V. Marchenko, Springer, 2018.

20-319-0011 WAVE DYNAMICS
(ELECTIVE, Credit: 3)

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

1. Describe the fundamental equations of wave motion.
2. Describe the kinematics (such as velocity of propagation, super position energy and particle trajectory) of linear surface gravity waves.
3. Describe the characteristics of linear waves (Poincare waves, Rossby Waves and coastal Kelvin waves) using dispersion relation.
4. Analyze any given wave data using Fourier transformations and explain the spectrum.
5. Describe different terms of a wave model.

Unit I

Scales of motion. Wave kinematics – plane wave, wave number, phase of a wave, wave frequency, phase speed. Wave equation, dispersion relation. Super-position of two waves – group velocity, standing waves (Seiches). Wave spectra. Finite amplitude waves. Equations of motion, shallow water equations.

Unit II

Surface gravity waves in non-rotating frame of reference – short wave and long wave approximation. Phase speed of a linear surface gravity wave. Dispersion relation of a linear surface gravity wave. Deep and shallow waters. Particle trajectory - deep and shallow water. Pressure perturbation - deep and shallow water. Energy of a surface gravity wave – kinetic and potential. Group velocity of a surface gravity wave. Energy balance equation. Wave models (SWAN and WAVEWATCH).

Unit III

Gravity waves with rotation – Poincare waves, inertial oscillations, Rossby wave – beta and f plane approximations, quasi-geostrophic approximation. Coastal Kelvin wave. Equatorial beta-plane, Equatorial waves. Normal modes in a continuously stratified fluid. Internal waves, WKB theory.

References:

1. Atmosphere-Ocean Dynamics, Gill, A. E., International Geophysics Series, Vol. 30, 1982.
2. Fluid Mechanics, Kundu, P.K., Cohen, I.M., Dowling, D.R., 6th Edition, Academic Press, Elsevier, 2015.
3. Waves in the Ocean, P.H. LeBlond and Mysak, L.A., Elsevier, 1981.
4. Waves in the Oceanic and Coastal waters, Leo H. Holthuijsen, Cambridge University Press, 2007.
5. Introduction to geophysical fluid dynamics physical and numerical aspects, Benoit Cushman-Roisin, Jean-Marie Beckers, 2nd Edition, Academic press, Elsevier 2011.
6. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K Vallis, Cambridge University Press, 2019.

Suggested Reading:

1. Fundamentals of Geophysical Fluid Dynamics, James C. McWilliams, Cambridge University Press, 2006.
2. Introduction to geophysical fluid dynamics physical and numerical aspects, Cushman-Roisin, Jean-Marie Beckers, Academic Press, 2009.
3. Ocean wave mechanics: Applications in Marine structures, V. Sundar, Wiley, 280pp. 2017.
4. Ocean waves and oscillating systems, J. Falnes, Cambridge University Press, 2004.
5. Waves in the Ocean and Atmosphere, Introduction to Wave dynamics Pedlosky, J, Springer, 2003.
6. Waves in the Ocean, Elsevier Oceanography Series, LeBlond, P.H., Mysak, L.A., 1978.

20-319-0012 MARINE BIOGEOCHEMISTRY
(ELECTIVE, Credit: 3)

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

1. Describe the carbon, oxygen, nitrogen and nutrient cycling in the oceans.
2. Explain how these cycles are influenced by physical processes such as ocean circulation, upwelling, entrainment, air-sea exchange and riverine input.
3. Describe the mathematical representations of nutrient uptake, light and nutrient limitations.
4. Explain how changes in the cycles are related to global change in past, present and future climate.
5. Describe how the anthropogenic changes influence these cycles.

Unit I

Introduction: Chemical composition of the ocean - Distribution of nutrients in the ocean - expression of chemicals as ‘tracers’ - conservation of tracers in the ocean – Cycles of carbon, nitrogen, phosphorus and sulphur. Nitrogen cycling – nitrification and denitrification

Unit II

Biology of the ocean: Organic Matter Production - composition of organic matter - Phytoplankton, Zooplankton and bacteria- Food web in the ocean, microbial loop. Ecosystem processes and role of Light. Ecosystem models: N-P, N-P-Z and N-P-Z-D models. Physical processes influencing primary productivity: upwelling – entrainment. Role of ocean currents and mixing, Light and nutrient limitation.

Unit III

Basic carbon dissolution chemistry in the sea water - solubility pump, biological pump - alkalinity of ocean and ocean acidification - air-sea gas exchange and oceanic pCO2. Carbon dioxide system and climate change - ocean acidification, coral reefs and mangroves, vegetation. Marine sediments and sedimentary cycles. Human impacts.

References:

1. Ocean Biogeochemical Dynamics, J. L. Sarmiento and Nicholas Gruber, Princeton University Press, 2006.
2. Ocean Biogeochemistry, The Role of the Ocean Carbon Cycle in Global Change Editors: Fasham**,** Michael J.R. (Ed.), Springer, 2003.
3. Biodiversity in the marine environment, Goulletquer, Philippe et al., Springer, 2014.
4. Biogeochemistry of Estuaries, Thomas S. Bianchi, Cambridge University Press, 2014.
5. Biogeochemistry of Marine Systems, Kenneth D. Black, Graham B. Shimmield, Wiley, 384pp. 2009.

Suggested Reading

1. Coastal environments and global change, Masselink , Gerd, Wiley-Blackwell, 2015.
2. Interactions of land, ocean and humans, Maser, Chris, CRC Press, 2015.
3. Marine conservation, Ray, Carleton G, Wiley Blackwell, 2014.
4. Marine Ecosystems: Diversity and Functions, André Monaco, Patrick Prouzet, 318pp. 2015.
5. Nitrogen in the Marine Environment, Douglas G Capone, Deborah A Bronk, Margaret R Mulholland, Edward J Carpenter, Elsevier, 2008.
6. The Arctic climate system, Ed.2 Serreze, Mark C., Cambridge University Press, 2014.

20-319-0013 OCEAN CIRCULATION
(ELECTIVE, Credit: 2)

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

1. Describe the fundamental ocean circulation theories such as Ekman theory, Sverdrup theory, Stommel theory and Munk theory.
2. Discuss the role of stratification and different types of instabilities in the ocean.
3. Explain the features of thermohaline circulation and abyssal circulation.
4. Describe the process such as subduction and ventilation.
5. Discuss the conservation of temperature and salt.

Unit I

Theories of wind-driven circulation, Sverdrup solution, frictional and inertial boundary regimes; instabilities, meanders and meso-scale features; role of stratification, topography and time dependence.

Unit II

Thermohaline circulation- Conveyor belt- Formation and distribution of water masses-subduction and ventilation- Abyssal circulation- mixing – Isopycnal and diapycnal mixing -Topographic steering, thermodynamic and salinity circulation, equations for salt and temperature conservation, Reynold’s fluxes and eddy diffusivity, thermocline and thermohaline circulation, mixed layer of the ocean.

References:

1. Introductory Dynamic Oceanography: S Pond & G L Pickard, 2nd Edn. Pergamon, 1983.
2. Dynamical Oceanography: J. Proudman, Methuen, 1953.
3. General Oceanography: G Dietrich, Wiley-Interscience, 1963.
4. Introduction to Physical Oceanography: W. S. Von Arx, 1st Edn., 1962.
5. Ocean Circulation and Climate, Volume 103, Second Edition: A 21st century perspective, Siedler, Gerold, Academic Press, 2013.

Suggested Reading:

1. Physical Oceanography: A. Defant, Vol-1, New York Pergamon Press, 1961.
2. Principles of Physical Oceanography: W J Pierson and G Neumann, Prentice Hall, 1966.
3. The Oceans- Their physics, chemistry and general biology: H. U. Sverdrup et al., Prentice-Hall, first edition, 1942.
4. Introduction to Physical Oceanography, John A. Knauss and Newell Garfield, Third edition, 2017
5. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K. Vallis, Cambridge University Press, 2019.
6. Ocean circulation in three dimensions, Barry A. Klinger and Thomas W.N. Haine, Cambridge University Press, 2019.

20-319-0014 REMOTE SENSING (Practical)
(ELECTIVE, Credit: 2)

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

1. Analyze and process satellite images using softwares such as SeaDAS.
2. Interpret various oceanographic processes such as upwelling, coastal erosion accretion etc. based on satellite data.

Data Processing: Softwares: SeaDAS, ENVI, IDRISI - OCM, MODIS-Ocean color, NOAA-SST, IRS-LISS-4. Applications: chlorophyll, suspended sediments and yellow substance (CDOM), generation of imageries and interpretation. Coastal habitat identification and assessment.

Sea surface height calculation-SARAL. Retrieval of Wind parameters from backscatter values-Scatterometry- reading and displaying the backscatter values-OSCAT data.

20-319-0015 MARINE REMOTE SENSING APPLICATIONS
(ELECTIVE, Credit: 3)

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

1. Explain fundamentals of remote sensing.
2. Describe the principles behind various satellite sensors.
3. Infer Potential fishing zone based on SST and Chlorophyll satellite data
4. Identify oil slicks and their potential damages.
5. Apply satellite data for coastline change detection.

Unit I

Basics of Remote sensing-electromagnetic radiation, solar and terrestrial radiation, Atmospheric effects, absorption, transmission and scattering – atmospheric windows- spectral signature.

Unit II

Retrieval of Chlorophyll- yellow substance-diffuse attenuation coefficient and PAR-Oceansat-OCM. MODIS and recent satellite sensors for biological studies. Mangroves, coral reefs and bleaching- NOAA-AVHRR, IRS, LANDSAT applications. Oil slicks on the Ocean surface. Water quality studies using recent sensors.

Unit III

Remote sensing application to coastal morphology: studies on erosion, accretion, suspended sediment concentration, wetland mapping, shoreline changes. LANDSAT, CARTOSAT applications.

References:

1. Measuring the Oceans from Space: The principles and methods of satellite Oceanography: I.S.Robinson, Springer, 2004.
2. Satellite Oceanography: I.S.Robinson, Ellis Horwood Ltd, 1985.
3. Advances in Passive Microwave Remote Sensing of Oceans 1st Edition, Victor Raizer, CRC Press, Taylor and Francis Group. 2017.
4. Methods of Satellite Oceanography: Robert H.Stewart, University of California Press, 1985.
5. Satellite based applications on climate change, Qu, John J, Springer, 2013.

Suggested Reading:

1. Advanced Remote Sensing, Liang,Shunlin, Academic Press, 2012.
2. An Introduction to Ocean Remote Sensing 2nd Edition, Seelve Martin, Cambridge Univ. Press. 2014.
3. Climatology from Satellites: E.C.Barret, Methuen Young Books, 1974.
4. Fundamentals of satellite remote sensing, Chuvieco, Emilio, CRC Press, 2016.
5. Introduction to remote sensing, Ed.3 & 5, Campbell, James B, Taylor and Francis, 2011.
6. Introduction to Satellite Oceanography: G.A.Maul, Springer, 2012.
7. Introduction to Satellite Remote Sensing Atmosphere, Ocean, Cryosphere and Land Applications, William Emery, Adriano Camps and Marc Rodriguez-Cassolac., Elsevier, 2017.
8. Oceanographic Applications of Remote Sensing: Motoyoshi Ikeda and W.Dobson, CRC Press, 1995.
9. Satellite Microwave Remote Sensing: T.D.Allan, Ellis Horwood Ltd, 1983.
10. The Application of Remote Sensing Technology to Marine Fisheries: An Introductory Manual-FAO Fisheries Technical Paper 295: M.J.A.Butler, M.C.Moucho, V.Baralet & C.LeBlanc, Food & Agriculture Org, 1989.
11. Remote Sensing of the Asian Seas, Barale**,** Vittorio**,** Gad**e** Martin (Eds.), Springer, ISBN 978-3-319-94065-6, 2019.
12. Satellite Image Analysis: Clustering and Classification, Borra, S., Thanki, R., Dey, N., Springer, ISBN 978-981-13-6423-5, E-book, 2019.

20-319-0016 REGIONAL OCEANOGRAPHY
(ELECTIVE, Credit: 3)

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

1. Describe the distribution of physical properties in the Indian Ocean.
2. Discuss the meteorological and oceanographic features of the Arabian Sea and Bay of Bengal.
3. Explain the different features in the Indian Ocean such as monsoon wind system, monsoon current system and Indian Ocean Dipole.
4. Identify the upwelling and downwelling regions in the Indian Ocean and describe the mechanism.
5. Discuss the different resources from the Indian Ocean.

Unit I
Introduction: history, major expeditions, IIOE - geographical and environmental features, uniqueness of Indian ocean- EEZ- sediment distributions – Arabian sea and Bay of Bengal system.

Unit II
Hydrography: Temperature, salinity, density and oxygen distributions, seasonal variations- General features of Red sea and Persian Gulf – Water mass – T-S diagram, T-S-V diagram- core method. Circulation: Sea level pressure distribution, wind systems and currents, monsoon current system – Somali current, Agulhas current, Leeuwin current, equatorial currents and under currents- upwelling in Arabian sea and Bay of Bengal – Indian ocean dipole mode –ITF

Unit III
Resources: Freshwater, chemicals and minerals, energy from tides, current, wave, salinity gradient energy conversion, OTEC, winds and geothermal energy.

References:

1. Regional Oceanography- an introduction: Tomczack and J.S.Godfrey Pergmon, 1994.
2. Descriptive Physical Oceanography: George L. Pickard and William J. Emery Elsevier, 1990.
3. Glimpses of Indian Ocean: S.Z. Qasim, Sangam books Ltd. 1998.

4. Introduction to Physical Oceanography: W. S. Von Arx, 1st Edn., 1962.
5. Ocean Circulation and Climate, Volume 103, Second Edition: A 21st century perspective, Siedler, Gerold, Academic Press, 2013.

Suggested Reading:

1. Applied Oceanography: Joseph M. Bishop, John Willey and sons Inc.1984.
2. Ocean Wave Energy Conversion: M.E. McCormick, John Willey and sons Inc. 1981.
3. The Encyclopedia of Oceanography Vol. I: Rhodes W. Fairbridge, Rein hold publishing corp, 1966.
4. CZM Handbook: R. J. Clark, Taylor & Francis, 1995.
5. Dynamics of the equatorial ocean, Boyd, P, Springer, 2018.

20-319-0017 OCEAN ENGINEERING
(ELECTIVE, Credit: 4)

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

1. Describe preliminary design criteria of a seawall.
2. List and detail different hard and soft protection techniques for coastal protection
3. Explain the sedimentation in coastal region and its remedial measures.
4. Describe different ocean based energy production technologies.
5. List and explain different types of offshore structures and their installation techniques.

Unit I

Engineering aspects in oceanography, Coastal protection structures- Sea walls, Groins, Breakwaters, Composite breakwaters, geo-textile systems, Artificial reefs, Beach fill stabilization, Artificial nourishment, Sediment bypassing. Impacts of coastal developments-Numerical models of shoreline changes.

Unit II

Marine structures and their functions, Environmental loading-Self-loading-fixed and floating structures, offshore platforms, underwater pipelines and cables. Hydrodynamic forces in unsteady flow- interaction of waves on structures, sea floor soil mechanics and related engineering operations.

Unit III

Natural and artificial harbors, Siltation and control, coastal inlets and stability-Dredging, different types of dredgers- spoil ground location criteria, environmental effects of dredging-DIA. Marine Corrosion, material selection, corrosion control and prevention.

Unit IV

Non-living ocean resources and exploitation, oceanographic factors involved in resource conservation and utilization. Energy from the sea – tidal, wave and thermal energy. Basic principles of desalination.

References:

1. Oceanographic Engineering: R L Weigel, Dover Publications, 2005.
2. Basic Coastal Engineering: Robert M. Sorensen, Springer; 3rd Edn., 2005.
3. Coastal Engineering: R Silvester, Elsevier Scientific Pub. Co., 1974.
4. Ocean Engineering – Goals, Environment, Technology: J F Brahtz, John Wiley and Sons, 1968.
5. Offshore Pipelines, Guo, Boyun, Elsevier, 2014.

Suggested Reading:

1. Coastlines, Structures and Breakwaters: NWH Allsop, Thomas Telford Ltd, 1998.
2. Maritime Engineering and Technology, Soares,Guedes, C R C Press, 2012.
3. Modeling Marine Systems: A M Davies, CRC Press, 1989Wave Energy – A Design Challenge: R Shaw, Ellis Horwood Ltd, 1982.
4. Physical Modeling in Coastal Engineering: R A Dalrymple, Taylor & Francis, 1985.
5. Pitfalls of shoreline stabilizationCooper, Andrew J G., Springer, 2012.
6. Practical guide to geo-engineering: with equations, tables, graphs and check lists, Srbulov, Milutin, Springer, 2014.
7. Ocean Wave Energy Conversion: M E McCormick, Dover Publications, 2007.
8. Sediment transport in coastal waters; Sylvian Quillon; MDPI Publishers; 2019
9. Coastal engineering theory and practice, Vallam Sundar & S.A Sannasiraj, Advanced series on Ocean engineering, Vol. 47, Publisher: WSPC, 2019.
10. Coastal engineering processes, theory and design practice, Dominic Reeve, Andrew Chadwick & Christopher Fleming, CRC Press, 3rd Edition, 2018.

20-319-0018 APPLIED AND COMPUTATIONAL MATHEMATICS (ELECTIVE, Credit: 4)

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

1. Demonstrate skills in linear algebra.
2. Explain the application of ordinary and partial differential equations.
3. Demonstrate the knowledge of special series and transformations.
4. Describe the theory behind time-series data analysis techniques such as spectral and wavelet analysis.
5. Demonstrate a knowledge of probability and statistical analysis.

Unit I

Vector algebra: Sets, groups, rings and fields, vector spaces, basis, inner product, linear transformations, spectral decomposition, singular value decomposition, QR and LU decomposition of matrices, vector calculus, system of linear equations, co-ordinate transformations; Lab - Matlab for solving spectral decomposition, singular value decomposition, system of linear equations.

Unit II

Ordinary and partial differential equations: Characterization of ODEs and PDEs, methods of solution, general solution of linear ODEs, special ODEs and PDEs, Euler-Cauchy, Bessel’s and Legendre’s equations, Diffusion equation, Laplace equation, Wave equation, Sturm-Liouville theory, numerical solutions, convergence and stability; Lab - Matlab programming for numerically solving ODEs and PDEs.

Unit III

Complex analysis: Analytic functions, Cauchy-Riemann conditions and conformal mapping, line and contour integration, Cauchy’s theorem. Special series and transformations: Laplace and Fourier transforms, Fourier series, FFT algorithms, wavelet transforms; Lab - Matlab programming for FFT, and wavelet analysis.

Unit IV

Probability and Statistics: Mean, median and mode, correlation and regression analysis, probability density function, standard PDF (Binomial, Gaussian, chi-square, t-dbn), sampling distribution, confidence interval, estimation of parameters and testing of hypothesis; Lab - Matlab programming for mean, median, mode, correlation and regression.

References:

1. Advanced Engineering Mathematics, Clarence Raymond Wylie, Louis C. Barrett, McGraw-Hill. 1995.
2. Advanced Engineering Mathematics, Erwin Kreyszig, Herbert Kreyszig, Edward J. Norminton, ISBN 978-0-470-45836-5, John Wiley & Sons, Inc. 2011.
3. Advanced Engineering Mathematics, M.D. Greenberg, Pearson education, Inc. 2009.
4. Advanced Mathematical Methods for Scientists and Engineers, Asymptotic Methods and Perturbation Theory, Carl M. Bender, Steven A. Orszag, Springer. 2013.

Suggested Reading:

1. Applied Statistics and Probability for Engineers, 5th Ed. Douglas C. Montgomery, George C. Runger, ISBN: 9788126537198, 8126537191, Wiley India Pvt. Ltd. 2012.
2. Methods of Applied Mathematics, Francis B. Hildebrand, Prentice-Hall Publications, Inc. 1965.

20-319-0019 OCEAN ECOSYSTEM MODELLING
(ELECTIVE, Credit: 2)

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

1. Explain the impact of physical processes on the marine food web.
2. List the mathematical formulations of energy uptake, growth, reproduction and decay of phytoplanktons.
3. Explain the chemical formulations of nitrification and denitrification.
4. Use simple Nitrogen-Phytoplankton-Zooplankton-Detritus models to understand the marine ecosystems.
5. Explain the challenges in ecosystem modelling.

Unit I

Impact of physical processes on biology, ocean food web (phytoplankton to fish and microbial loop), nitrogen cycle in the ocean, nitrification and denitrification, Advection-diffusion equation, first order chemical reaction.

Unit II

Growth rate of phytoplankton, nutrient limitation, light limitation, Liebig law of minimum, Michaelis-Menton representation, Redfield ratio, photosynthesis, size consideration of phytoplankton (Diazotroph, picoplankton and diatom), zooplankton grazing, a simple NPZD model, a coupled physical-ecosystem model, challenges involved in modelling of higher trophic levels and fishes.

References:

1. Ocean Biogeochemical Dynamics, J. L. Sarmiento and Nicholas Gruber, Princeton University Press, 2006.
2. Dynamics of Marine Ecosystems: Biological-Physical Interactions in the Oceans, 3rd Edition K. H. Mann, John R. N. Lazie, Wiley, 2013.
3. Empirical and mechanistic models for the particle export ratio, Dunne, J. P., R. A. Armstrong, A. Gnanadesikan, and J. L. Sarmiento Global Bio-geochem. Cycles, 19, GB4026, 2005.

4. Introduction to the modelling of marine ecosystem, W. Fennel and T. Neumann, Elsevier Oceanography Series, 72, Elsevier, 2004.
5. Ocean Biogeochemistry, The Role of the Ocean Carbon Cycle in Global Change Editors: **Fasham**, Michael J.R. (Ed.), Springer, 2003.

Suggested Reading

1. Phytoplankton productivity: Carbon assimilation in marine and fresh water ecosytems, Williams, P.J.B, Thomas, D.N, Reynolds, C.S, Wiley, 2008.
2. Technical description of the prototype version (v0) of Tracers of Phytoplankton with Allometric Zooplankton (TOPAZ) ocean bio-geochemical model as used in the Princeton IFMIP model, Dunne, J. P., A. Gnanadesikan, J. L. Sarmiento, and R. D. Slater Bio-geosciences, 7, 3593–3624. 2010.
3. Tools for Oceanography and Ecosystemic modelling, Monaco, A, Prouzet, P, Wiley, 2016.

20-319-0020 STATISTICAL METHODS IN OCEANOGRAPHY (Practical) (ELECTIVE, Credit: 1)

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

1. Calculate the statistical parameters and perform Test of hypothesis.
2. Apply statistical analyses such as EOF, Wavelet and FFT on ocean-atmospheric data sets.

Population and sample – mean, variance, range – confidence intervals – regression – least square method – multivariate regression – hypothesis testing – interpolation – linear, polynomial and spline methods – covariance.

Objective analysis – Empirical Orthogonal Functions – factor analysis – covariance and correlation – autocorrelation – spectral analysis – rotary and cross spectra – wavelet analysis – Fourier analysis and FFT – harmonic analysis - Digital filters – types of filters – Gibb's phenomenon – running mean filters.

20-319-0021 POLAR OCEANOGRAPHY (ELECTIVE, Credit: 3)

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

1. Basic understanding of the links between global climate and Polar Regions.
2. Role played by polar oceans in providing various ecosystem services.
3. Explain the hydrography and circulation in the polar region.
4. Familiarisation of various international polar programs and the role played by India.
5. Understanding the similarities and differences of polar oceans from rest of the oceanic regime.

Unit I

History of polar research and exploration: Past, present and future. Major international polar programs and Indian polar programs. Governance of Antarctic and Arctic regions and its protection. Polar natural resources: Anthropogenic demands and impacts. The impacts of anthropogenic activities and climate change on the polar oceans. Ozone holes-Impacts- Pollution in polar ocean - Emerging pollutants- Microplastics-SOLAS and MARPOL 73/78.

Unit II

Sea ice, Types, Sea ice properties, thermodynamics; sea-ice interactions with atmosphere, ocean; Regional wise distribution of sea ice (in Arctic, Southern Ocean and Antarctica): Gaining and losing Antarctic sea ice variability- trends and mechanism. Losing arctic sea ice-observations of recent decline and the long term context. Impacts of wave motions; Sea ice and climate instability; Low-latitude atmospheric dynamics and Arctic sea ice extent; teleconnections, polynyas and its importance. Observation methods for sea ice and polar oceans. Sea ice in earth system models-sea ice model mechanics. Applications from satellite platforms.

Unit III

Hydrography and circulation of Antarctic and Arctic oceans, Antarctic circumpolar current: Importance and dynamics. Southern Annular Mode: teleconnections, impacts and dynamics, Arctic oscillation: teleconnections, impacts and dynamics, subarctic seas as a source of Arctic change, Variability of Atlantic water inflow to the Northern Seas, freshwater flux from Northern seas and Atlantic Meridional Overturning Circulation. Arctic cyclones, Roles of polar oceans on deep ocean circulation and global climate system, Future of polar oceanography.

References:

1. A History of Antarctic Science (Studies in Polar Research): G. E. Fogg, Margaret Thatcher, Cambridge University Press, 2005.
2. A Farewell to Ice: A Report from the Arctic, Peter Wadhams E-book, 2017.
3. Introduction to Antarctica. Liggett, D., Storey, B., Cook, Y., Meduna, V. (Eds.)., Springer. 2015.
4. Introduction to the Physics of the Cryosphere. Melody Sandells and Daniela Flocco, Morgan & Claypool Publishers, 2014.
5. Southern Ocean: Oceanographer's Perspective. Jonah Young, Ice press, 2015.

Suggested Reading:

1. Arctic–Subarctic Ocean Fluxes: Defining the Role of the Northern Seas in Climate. Dickson, B., Meincke, J., & Rhines, P, Springer, 2008.
2. Biogeochemical Technologies for Managing Pollution in Polar Ecosystems. Bashkin, V, Springer, 2016.
3. Climate change in the Polar Regions. Turner, J., & Marshall, G. J., Cambridge university press. 2011.
4. National Research Council. Future Science Opportunities in Antarctica and the Southern Ocean. Washington, DC: The National Academies Press, 2011.
5. Polar Oceans from Space, Josefino Comiso, Springer. 2010.
6. Sea Ice, 3rd edition, David Thomas, ed., Wiley, 2017.
7. The New Arctic. Evengård, B., Larsen, J. N., & Paasche, (Eds.), Springer, 2015.
8. The Oceans and Rapid Climate Change. Past, Present, and Future. Seidov, Dan / Haupt, Bernd J. / Maslin, Mark A. (eds.) Geophysical Monograph Series, Wiley & Sons Ltd., 2001.
9. The Technocratic Antarctic: An Ethnography of Scientific Expertise and Environmental Governance. O'Reilly, J, Cornell University Press, 2017.

20-319-0022 OCANOGRAPHIC APPLICATION TOOLS - II (Practical)
(ELECTIVE, Credit: 1)

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

1. Explain the coding syntaxes in Matlab/Octave.
2. Write computer programs in Matlab/Octave for oceanographic computations.

Matlab/Octave: software installation - octave as a calculator (command window) - data types and variables – scalar, vectors and matrices – mathematical functions - input and output – script files - selective operations – loops – user functions – file input and output – graphical plot in octave.

Oceanographic computations in octave: sea water toolbox – computation of density, specific volume anomaly, potential temperature, sound velocity, freezing point and specific heat capacity – conversion of pressure to depth – gravitational constant -