Centre for Earth, Ocean and Atmospheric Sciences School of Physics

University of Hyderabad

2-Year M.Sc. in Ocean and Atmospheric Sciences

(Course Structure and Syllabus)

(As per National Education Policy 2020)

Vision Statement:

To become a global centre of excellence in Earth Sciences through innovative teaching and research to produce highly quality manpower capable of addressing relevant scientific and societal challenges

Mission Statements:

1. To provide a holistic understanding of planet Earth's dynamic processes, and linkages among the geosphere, the hydrosphere, the atmosphere and the biosphere through high quality teaching so as to enable the students to become leaders in academic and research institutions, and professional organizations.

2. To conduct innovative research in Earth Sciences, and promote national and international collaborations.

3. To build world class infrastructure for teaching and frontline research in Earth Sciences.

Course Content

S. No.	Course No	Course Name	Credit
SEMESTER – I			
1	OA411	Physics of the Atmosphere	4
2	OA412	Physics of the Ocean	4
3	OA413	Dynamics of the Atmosphere	4
4	OA414	Mathematical Physics	3
5	OA415	Tropical Meteorology	3
6	OA416	Practical-1: Statistical and Numerical computing	2
		Total credits	**20**
SEMESTER – II			
1	OA461	Dynamics of the Ocean	3
2	OA462	Geophysical Fluid Dynamics	3
3	OA463	Remote Sensing of the Ocean and Atmospheric Sciences	3
4	OA464	Numerical Weather Prediction	2
5	OA465	Modelling of the Ocean and Atmospheric processes	3
6	OA466	Practical-2: Ocean and Meteorological computations	3
7	OA467	Climate Change and its Impacts	3
		Total credits	**20**
SEMESTER – III			
1	OA511	Seminar on Break-through Papers	2
2	OA512	Practical-3: Model Simulations and Diagnostics	2
3	OA513	Summer Internship	4
4	OA526-OA547	Subject Elective – I	3
5	OA526-OA547	Subject Elective - II	3
6	OA526-OA547	Subject Elective - III	3
7	OA526-OA547	Subject Elective - IV	3
		Total credits	**20**
SEMESTER - IV			
1	OA661	Project Dissertation	20
		Total credits	**20**
		Cumulative credits (Semester I to IV)	**80**

List of Elective Courses

1. Cloud Physics and Atmospheric Electricity
2. Middle Atmosphere Meteorology
3. Geological Chemical and Biological Oceanography
4. Atmosphere and Marine Boundary Layer Processes
5. Aerosols and Atmospheric Chemistry
6. Diagnostic Studies of Atmospheric and Oceanic Processes
7. Satellite Meteorology
8. Satellite Oceanography
9. Ocean Acoustics
10. Marine Pollution
11. Ocean Optics
12. Agricultural Meteorology
13. High-Performance Computing in Atmosphere and Ocean Sciences
14. Ocean State Forecasting
15. Mesoscale modelling
16. Air Pollution Studies
17. Coastal Oceanography
18. Climate and Energy
19. Mountain Meteorology
20. Climate and Water Resources
21. General Geology
22. Space Weather

(More electives can be added depending on demands from the industry and expertise of the available faculty, subject to the rules of the UoH)

Program intake and eligibility:

Sl No.	Program	Seat Intake	Eligibility
1	M.Sc Ocean and Atmospheric Sciences	13 + 5*	With at least 55% marks in the Batchelor's degree in any branch of Science with Mathematics and Physics as compulsory subjects at the B.Sc. level or B.Tech/ B.E in Mechanical/Electrical Engineering * Sponsored

Admission Process: Through Central University Entrance Test (CUET), Conducted by National Testing Agency (NTA).

Program Objectives

1. To demonstrate a systematic, extensive, and coherent knowledge and understanding of the ocean and atmospheric system, its manifestations, variability and change, and their applications and implications for society

2. Equipped with relevant skills in the field of ocean and atmospheric sciences, along with a critical thinking of the established theories, latest developments, and ability to use modern state-of-the-art techniques for observations and analyses

3. To possess demonstrable knowledge and skills on the physical and dynamical processes of the ocean and atmospheric system and their manifestations, and to be enabled to lead as professionals catering to various research and developments, and operational needs in the domain, and contribute to application studies

4. To use the knowledge, understanding and skills in ocean-atmospheric sciences for critical assessment of a wide range of societal and economical complex issues such as droughts, floods, extreme events, monsoonal rain changes, global warming, ocean acidification, etc., and communicate their findings

5. To demonstrate critical and analytical thinking to pose and solve relevant scientific problems in ocean and atmospheric sciences, inclusive of weather and climate, in both individual and collaborative settings to address scientific challenges, and effectively communicate to appropriate level of audience

Program Learning Outcomes

- **PLO1:** To acquire fundamental and coherent scientific knowledge of the ocean-atmospheric system and its interactive components.
- **PLO2:** To utilize the state-of-the-art scientific and technical knowledge, and tools such as dynamical models and instrumentation, and remote sensing data to analyze and interpret ocean and atmospheric processes.
- **PLO3:** To develop and apply critical and analytical thinking to address scientific challenges in the ocean and atmospheric sciences in both individual and collaborative settings.
- **PLO4:** The program will provide practical knowledge on collecting ocean and atmospheric observations, carrying out model simulations, and analyzing various observed and reanalysed datasets for understanding of the physics and dynamics of the weather and climate, with focus on the Indian monsoon, and surrounding seas.
- **PLO5:** To be able to critically peruse and interpret current path-breaking research papers in ocean and atmospheric sciences and present findings succinctly as a seminar, and in complement, identify, analyse, synthesize, and communicate own scientific findings for public and professional audience at National and International levels.

- **PLO6:** To describe feedback in Earth's climate system and their potential roles in past, present and future climatic conditions, to be able to recognize and explain climate change projections and associated uncertainties.

- **PLO7:** To demonstrate the ability to identify, construct, and analyze the interactions between atmospheric, oceanographic, chemical, and biological processes through a range of spatial and temporal scales

Course Code: OA411		
Course Title: Physics of the Atmosphere		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
Bachelor level Physics and Mathematics

Course Description

This course covers fundamental topics related to atmospheric science, providing an in-depth understanding of key concepts. It delves into the physical processes governing atmospheric composition, thermal/vertical structure, radiation, and energy principles. The curriculum explores the equation of state, the zeroth, first, and second laws of thermodynamics, focusing on both dry and moist atmospheres. Students will gain proficiency in interpreting thermodynamic diagrams, understanding statics, and assessing atmospheric stability. Additionally, the course introduces the concept of Earth's climate systems, offering a comprehensive overview of the interconnected factors shaping our planet's climate.

Course Objectives

1) Introduce students to fundamental concepts and principles in atmospheric physics.
2) Explore the thermodynamics of dry and moist air, radiative transfer, saturated and unsaturated ascent, and thermodynamic diagrams.
3) Provide knowledge of the vertical variation of atmospheric variables (temperature, pressure, humidity, winds, etc.) crucial for quantifying the atmospheric state.
4) Cover saturated and unsaturated ascent, moist convection, surface turbulent fluxes, and vertical turbulent diffusion to enhance understanding.
5) Develop an understanding of the fundamental components of Earth's climate system.

Course Learning Outcomes

1. Acquaint with the overview of the fundamentals concepts of physics governingthe atmosphere.
2. Understand the basic thermodynamic concepts for the atmosphere related to atmospheric stability and cloud formation, and to be able to explain weather phenomena.
3. Demonstrate and understanding of solar and terrestrial radiation.
4. Understand the energy transfer processes between the earth’s surface and the atmosphere.
5. A pply fundamental physical principles in understanding atmospheric andclimate-processes from weather through climate change scales.

Detailed Syllabus

Unit -1: Fundamental of atmospheric sciences: The concept of the climate system – atmosphere, hydrosphere, cryosphere, biosphere, and geosphere

Unit -2: Vertical thermal structure of the atmosphere; composition of the atmosphere; hydrostatic equilibrium; Hypsometric equation and pressure at sea level.

Unit -3: Atmospheric Thermodynamics: Ideal gas laws and their application to the atmosphere; First law of thermodynamics, adiabatic processes, dry and moist air

Unit -4: The concept of the lapse rate, water vapour in the air, the second law of thermodynamics, the Clausius-Clapeyron equation; concept of static stability, thermodynamic diagrams.

Unit -5: Radiative transfer: Electromagnetic spectrum; blackbody radiation and radiation laws; physics of the absorption, emission, and scattering; radiative transfer in the atmosphere; atmospheric windows; introduction to remote sensing; atmospheric boundary layer and its evolution.

Reference Books

1. Wallace, J. M., and P. V. Hobbs, Atmospheric Science: An Introductory Survey, 2nd edition, Elsevier Academic Press, 2006.
2. Marshall J., and R. A. Plumb, Atmosphere Ocean and Climate Dynamics: An Introductory Text, Elsevier Academic Press, 2008.
3. Hess, L. S., Introduction to Theoretical Meteorology, Wiley Online Library.
4. Andrews, D. G., An Introduction to Atmospheric Physics, 2nd edition, Cambridge University Press, 2010.
5. Houghton, J. T., Physics of the Atmosphere, Cambridge University Press, 2002.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√		√

Course Code: OA412		
Course Title: Physics of the Ocean		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
Bachelor level Physics and Mathematics

Course Description

This course is to learn the basic concepts of the Physics of the Oceans, viz. important physical properties like temperature, salinity their distribution and variability. The course is also intended to understand the ocean processes and some geological oceanography concepts.

Course Objectives

1) To understand the physical properties of sea water, their distribution and variability
2) To understand the factors responsible for the variability of physical properties of sea water
3) To get versed with basic physical oceanographic processes
4) To understand the basic marine geological concepts and terminology

Course Learning Outcomes

1. Identify, explain, and interpret main features in spatial distributions of physical properties of seawater.
2. Understand and assess the importance of Ocean in terms of resource utilization in a sustainable manner.
3. Discuss and differentiate between the various ocean waves, and tides.
4. Evaluate the role of the different oceans in the global ocean circulation, with focus on Indian Ocean circulation.
5. Understanding the physics of the heat budget of the oceans, and governing processes.

Detailed Syllabus

Unit -1: General introduction: History of oceanography and major expeditions; physical properties of sea water; acoustical and optical characteristics of seawater.

Unit -2: Heat budget of the ocean: Spatio-temporal variability of heat budget terms and net heat balance; Salt budget of the oceans. Water type and masses: Formation and classification; identification of water masses; Temperature-Salinity (T-S) diagrams; characteristics of water masses in global oceans.

Unit -3: Surface gravity waves: Characteristics, shallow water transformation and breaking; long-shore and cross-shore currents; rip currents.

Unit -4: Ocean processes: Upwelling and sinking; mesoscale eddies; winter cooling and convection; Indo-Pacific Ocean warm pool; Seyshells-Chagos Thermocline Ridge (SCTR); tropical cyclones and upper ocean response; El-Nino and Southern Oscillation (ENSO); Indian Ocean Dipole.

Unit -5: Marine Geology: Continental shelf, Slope, Shelf sediments, submarine topography, mid-oceanic ridge system; Classification of the marine environment, Biogeochemical cycles; Marine ecosystem.

Reference Books

1. Stewart, R. L., Introduction to Physical Oceanography.
2. Waves, Tides and Shallow Water Processes: Open University Course Team and Butterworth-Heinemann Publications, Oxford, UK, 1999.
3. Talley, L. D., G. L. Pickard, W. J. Emery and J. H. Swift, Descriptive Physical Oceanography, 6th edition, Elsevier, 2011.
4. Lalli, C., and T. R. Parsons,. Biological Oceanography: An Introduction, Elsevier, 320 pp, 1997.
5. P. Trujulio and H.V. Thurman Essentials of Oceanography

Additional Reading Material

5. Pond, S. and G. L. Pickard, Introductory Dynamic Oceanography, 2nd edition, Butterworth-Heinemann, 1983.
6. Marshall J., and R. A. Plumb, Atmosphere Ocean and Climate Dynamics: An Introductory Text, Elsevier Academic Press, 2008
7. Defant, A., Physical Oceanography Vol.1, Pergamon Press, 1961.
8. Neumann, G., and W. J. Pierson, Principles of Physical Oceanography, Prentice-Hall, 1966.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√		√

Course Code: OA413

Course Title: Dynamics of the Atmosphere

Total Credits	Credits allocation	Examination Scheme
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411

Course Description

Dynamics of the Atmosphere is a pivotal subfield within fluid dynamics, focusing on understanding the fundamental mechanisms driving meteorologically significant movements in the atmosphere. As the cornerstone of weather and climate prediction, it occupies a central position in atmospheric sciences. Its core emphasis lies in elucidating the intricate fluid dynamics phenomena occurring on rotating surfaces.

Course Objective

1) Introduce students to foundational concepts and principles in atmospheric dynamics.
2) Impart understanding of the physical laws dictating atmospheric flow and weather phenomena.

Course Learning Outcomes

1. Understand the distinction of geophysical fluid dynamics relative to the general fluid dynamics under the constraints of Earth's rotation and stratification.
2. Discuss and familiarize about the various aspects of atmospheric circulations, their similarities, and distinctions from one another, and various time length scales.
3. Familiarize with the governing equations of the atmospheric flows and balances among the various forces that drive the motions.
4. Apply the approximation of the complex flows to a much simpler geostrophic flows and its importance in the geophysical fluid dynamics.
5. Differentiate various balanced motions in the atmosphere and understand the relevance of surface temperature/density gradients.

Detailed Syllabus

Unit -1: Introduction: The importance of geophysical fluid dynamics; distinguishing attributes of geophysical flows; scales of motions; the importance of rotation; the importance of stratification

Unit -2: The distinction between the atmosphere and ocean; data acquisition; the emergence of numerical simulations; scales analysis and finite differences; higher-order methods; aliasing.

Unit -3: The Coriolis force: Rotating framework of reference; free motion on a rotating plane; analogy and physical interpretation; acceleration on a three-dimensional rotating planet.

Unit -4: Equations of fluid motion in different coordinate systems: Cartesian, spherical and natural vertical pressure, and potential temperature

Unit -5: Geostrophic flows: Homogeneous geostrophic flows; homogeneous geostrophic flows over an irregular bottom; generalization to non-geostrophic flows.

Reference Books

1. Holton J. R., and G. J. Hakim, Introduction to Dynamic Meteorology, 5th edition, Academic Press, 2012.
2. Hess, L. S., Introduction to Theoretical Meteorology, Wiley Online Library.
3. Roisin, B. C. and J. M. Beckers, Introduction to Geophysical Fluid Dynamics, Academic Press, 2009.

Additional Reading Material

1. Proudman, J., Dynamical Oceanography, Methuen & Co Ltd, 1963.
2. Haltiner, J. G., and F. L. Martin, Dynamical and Physical and Meteorology, McGraw-Hill, 1957.
3. Fomin, L. M., The Dynamic Method in Oceanography, Elsevier, 1964
4.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√	√	√

Course Code: OA414		
Course Title: Mathematical Physics		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3--0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Notion of set theory, mapping between sets and invertibility of maps. Definition of group. Differential equations with constant coefficients, partial differentiation.

Course Description

Mathematical physics serves as the cornerstone of atmospheric science, offering a robust foundation for understanding complex phenomena. This course is meticulously crafted to equip students with the necessary mathematical tools and proficiency, enabling them to adeptly tackle challenges across various disciplines within the physical sciences. Crucially, it cultivates a mindset rooted in mathematical rigor and precision, which proves invaluable in any future endeavor, whether it be research, teaching, or scientific pursuits.

Course Objectives

1) To explain the basic concepts of vectors and scalars
2) To expose the students to the fascinating world of real and complex numbers
3) To introduce the special functions essential in solving physics problems
4) To model and solve physical phenomena using differential equations
5) To find power series solutions of differential equations

Course Learning Outcomes

1. Explain coordinate systems, real and complex linear vector spaces and their simple operator algebra.
2. Should be able to calculate the period of a given a function and express it as a Fourier series, obtain its Fourier transform.
3. Solve ordinary differential equations (ODEs) using different methods. Primarily derive solutions to ODEs in simple (1-Dimensional) Ocean and Atmospheric models.
4. Understand the Definition and properties of Laplace transform and use them to solve ODEs with given boundary conditions.
5. Solve PDE by applying separation of variable method in the cases with rectangular and circular boundaries in 1, 2 and 3 dimensions.

Detailed Syllabus

Unit -1: Linear vector space, subspace, linear dependent and independent vectors, basis, dimensions, Linear functional, dual space, Linear Operators, commutator, inverse of operators, rank, eigen values and eigen vectors of operators, Matrix representation of operators, Change of basis, norm and inner product, Cauchy-Schwarz inequality, ortho-normal basis, Gram-Schmidt procedure, linear operators in inner product space, Hermitian and Unitary operators, Direct sum, direct product and quotient spaces.

Unit -2: Fourier series and Fourier transforms, their properties & applications. Definition and properties of Dirac delta function.

Unit -3: Linear ordinary differential equations with constant coefficients and the Euler equation. Power series method of solving ODE. Extended power series methods (Frobenius method) obtaining Indicial equations and their roots; classification of the ODE based on the nature of roots of indicial equations and obtaining linearly independent solutions. Fuch's theorem and its application.

Unit -4: Definition and properties of Laplace transform, various identities involving Laplace transform, and using them to solve ODEs with boundary conditions.

Unit -5: Solution of PDE by separation of variable method in the cases with rectangular & circular boundaries in 1, 2 and 3 dimensions. Fixing coefficient using Fourier transform and Parseval's relation.

Reference Books

1. Linear Vector Spaces, R. R. Halmos, Springer (1987).
2. Outline of Fourier Analysis including problems with step-by step solutions, Hwei P. Hsu, Associated Educational Services Corp. (1967).
3. Operational Mathematics, V A Churchil, McGraw-Hill Book Company; Third Edition,(1972).
4. Ordinary Differential equations R. L. Rabenstein, Academic Press (1972).
5. An Introduction to Ordinary Differential Equations, E. A. Coddington, Prentice-Hall of India PVt LTD, (1992).
6. An introduction to partial differential equations for science students, G. Stephenson, Longman, (1970).
7. Mathematics for Physicists, Dennery & Kryzywicki,Dover Publications, INC,NY, 1996.
8. Mathematical Physics with Applications, Problems and Solutions, V. Balakrishnan, Ane Books Pvt. Ltd (2020)
9. Advances Engineering Mathematics, E Kreysizg, Wiley Estern Ltd. (1992)

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO				√	√		√

Course Code: OA415		
Course Title: Tropical Meteorology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412, OA413

Course Description

This course offers insights into diverse weather and climate phenomena across various temporal and spatial scales. Participants will gain comprehension of tropical extreme weather systems, including cyclones, thunderstorms, hailstorms, and dust storms. Additionally, the curriculum covers air-sea interactions, as well as the physics and dynamics of various global monsoons. Key climate drivers such as ENSO and IOD will be explored. A comprehensive understanding of these phenomena is crucial for detailed insights into weather and climate modeling predictions.

Course Objectives

1) Explore diverse tropical systems on both large and local scales.
2) Investigate the formation and vertical structure of mesoscale systems.
3) Examine the climatological features of various atmospheric variables globally.
4) Study the climatological features and seasonal evolution of the Indian summer monsoon.
5) Analyze the impacts of tropical ocean drivers, including ENSO and IOD, on the Indian summer monsoon.

Course Learning Outcomes

1. Differentiate large scale tropical phenomena such as the Madden-Julian oscillations Hadley and Walker circulations.
2. Demonstrate climatological features and seasonal evolution of Indian summer monsoon.
3. Differentiate various monsoonal phenomena and background mechanism, on various time scales from transient through decadal scales.
4. Examine impacts of tropical ocean drivers such as the ENSO and IOD on Indian summer monsoon.
5. Study the conditions necessary for formation of tropical cyclones, differentiate the intensities across regions of propensity, identify their morphological structures and their impacts, and familiarise with basics theoretical principles.

Detailed Syllabus

Unit 1: Large scale planetary systems: Trade wind and ITCZ; Hadley and Walker circulation; Jet streams; Madden Julian oscillation

Unit 2: Synoptic scale weather systems: Low- and high-pressure systems; easterly waves

Unit 3: Tropical cyclones: Grey-Sikka conditions; life cycle; structure in wind; temperature; introduction to various theories; cyclone movement; storm surges. Mesoscale systems: Thunderstorm; dust storm; hail storm; tornado; sea and land breeze.

Unit 4: Monsoons: climatological features and seasonal evolution of Indian summer monsoon; principal rain bearing systems including monsoon depressions, lows; mid-tropospheric cyclones; intra-seasonal variability of summer monsoon including active and break cycles; monsoon variability on interannual and decadal time scales; northeast monsoon

Unit 5: Indian Ocean Circulation: Northeast and Southwest monsoon winds; ocean surface circulation; equatorial current systems; under currents; circulation in Arabian Sea and Bay of Bengal; somali current; Indonesian Through Flow and Pacific-Indian Ocean exchange; Agulhas current and Indian Ocean-Atlantic exchange. Impacts, and process from tropical oceanic drivers such as the ENSO and IOD, Indo-pacific warm pool.

Reference Books

1. Monsoon monographs Vol-I and Vol-II, 2010 : India Meteorological Department
2. Rao, Y. P., South West Monsoon, IMD, 1976.
3. Pant, G. B., and K. Rupakumar, Climates of South Asia, J.Wiley and Sons: Chichester, 1997.
4. Chang, C. P. and T. N. Krishnmoorthy, Monsoon Meteorology, Oxford University Press, 1987.
5. Anthes, R. A., Tropical Cyclones, their evolution structure and effect, American Meteorological Society, 1982.
6. Asnani, G. C., Tropical Meteorology.
7. Trewartha, G. T., An Introduction to climate, McGraw-Hill.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√			√	√

Course Code: OA416		
Course Title: Practical 1 - Statistical and Numerical Computing		
Total Credits	**Credits allocation**	**Examination Scheme**
02	L-T-P: 0-0-2	Continuous Internal Assessment (CIA): 60 End Semester Examination (ESE): 40

Course Description

The course demonstrates familiarity with different statistical and numerical methods, and the implementation of these methods using computer programs.

Course Objectives

1) To familiarize with different statistical and numerical methods, their implementation
2) To develop practical knowledge to implement different statistical and numerical methods through FORTRAN programming
3) To get versed with processing different ocean and atmospheric data for the purpose of computing statistical metrics.

Prerequisite Course / Knowledge (If any):

Basic level statistics and mathematics, fundamental aspects of ocean and atmospheric sciences

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Acquainting with the basics of flowchart and then transforming into a computer language.
2. Know the basics commands of FORTRAN and develop subroutines and functions for statistics, special functions and applied mathematics.
3. Analyse various iterative methods for a nonlinear equation and their convergence analysis in FORTRAN.
4. Developing the program for differentiation, integration and complex differential equations.
5. Design algorithms to solve difficult mathematical problems in an efficient and easy way.

Detailed Syllabus

Unit -1: Fundamentals of programming logic and algorithm development

Unit -2: In this course, students will study and solve various numerical and statistical problems, by developing algorithms in FORTRAN (Force 2 compiler in Window OS/Gfortran in Unix) and MATLAB and executing them on computer using datasets provided (or to be downloaded as instructed).

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO		√	√	√		√	√

SEMESTER- II

Course Code: OA461		
Course Title: Dynamics of the Oceans		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412, OA413

Course Description

This course is formulated to understand the nature of forces in the oceans, their impact on the state and movement of ocean waters. It further deals with the nature of distinct ocean processes that are responsible for the ocean variability at different spatio-temporal scales of the ocean domains.

Course Objectives

1) To develop the knowledge on forces and process responsible in driving the oceans
2) To verse with the concepts of air-sea interactions that drive surface oceans
3) To disseminate the nature of ocean variability at shorter and longer time scales and its impact on physical properties of the ocean waters
4) To learn the concepts behind the oceans as climate drivers.

Course Learning Outcomes

1. Understand the distinction of geophysical fluid dynamics relative to the general fluid dynamics under the constraints of Earth's rotation and stratification.
2. Discuss and familiarize about the various aspects of oceanic and atmospheric circulations, their similarities, and distinctions from one another, and various time length scales.
3. Apply the approximation of the complex flows to a much simpler geostrophic flows and its importance in the geophysical fluid dynamics.
4. Differentiate various balanced motions in the atmosphere and oceans and understand the relevance of surface temperature/density gradients.
5. Study the important oceanic boundary currents and their driving mechanisms in light of wind driven circulation and the role of friction.

Detailed Syllabus

Unit -1: Nature of forces for Ocean, Barotropic and baroclinic fields, sigma t-surfaces, static stability, dynamic stability, double diffusion

Unit -2: Tides: Tide generation and propagation; characteristics of tides; spring and neap tides; diurnal and semi-diurnal tides; tidal current; tidal flushing; tides in estuaries

Unit -3: Ocean Circulation: wind-driven currents in the oceans; wind stress; Ekman spiral and transport; subtropical and polar gyres; major currents of the world oceans; thermohaline circulation; Ocean conveyor belt.

Unit -4: Ocean Currents without friction: Hydrostatic equilibrium; geopotential, isobaric and isopycnal surfaces, Geostrophic equation; inertial motion; level of no motion and absolute currents; quasi-geostrophic dynamics; simplifying assumptions and governing equations.

Unit -5: Ocean Currents with friction: Ekman's solution to the equation of motion with friction; drag co-efficient; Ekman transport and upwelling; bottom friction and shallow water effect; Sverdrup's equation and its application; equatorial undercurrent; Stommel's and Munk's theorem; westward intensification of ocean currents.

Reference Books

1. Atmosphere, Ocean, and Climate Dynamics: An introductory text by John Marshall and RA Plumb
2. Essentials of Oceanography by Thrujillo and Tharman
3. Introduction to dynamical Oceanography by S. Pond and G.L. Pickard
4. Fomin, L.M. Dynamics methods in Oceanography, Elsevier publication co.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√		√		√

Course Code: OA462		
Course Title: Geophysical Fluid Dynamics		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412, OA413, OA461

Course Description

This course deals with advance dynamics. It deals with circulation, waves, instabilities and energy budgets in the Earth's atmosphere.

Course Objectives

1) To enhance the knowledge about atmospheric dynamics
2) To develop understanding about atmospheric circulation and energy budgets
3) To enrich knowledge about different kind of instabilities

Course Learning Outcomes

1. Understand the dynamical concept of circulation of the atmosphere and apply it to land-sea breeze.
2. Develop mathematical background related to the rate of change of absolute vorticity, explain its applications under various conditions; understand the quasi- geostrophic approximation.
3. Develop a theoretical understanding of waves in the atmosphere and oceans, and identify the real-world analogues.
4. Study the role of friction in modifying the geostrophic winds in the boundary layer atmosphere; evaluate various types of eddy coefficients thereby get introduced to the relevance of the surface types and diurnal changes.
5. Develop a theoretical understanding of various large scale hydrodynamic instabilities and be able to differentiate their relative roles in various atmospheric and oceanic phenomenon such as the monsoons, mid-latitude storms, oceanic eddies.

Detailed Syllabus

Unit -1: Circulation and Vorticity: Kelvin's circulation theorem; Bjerknes circulation theorem; vorticity equation in cartesian and isobaric coordinates; divergence and vorticity of the geostrophic wind; scale analysis of the vorticity equation; potential vorticity conservation; Rigid-Lid approximation.

Unit -2: Waves in the atmosphere and Oceans: Concept of wave motion, acoustic waves, gravity waves, shallow water waves, Tsunami waves, Kelvin and Rossby wave.

Unit -3: Budgets: Mass budget; momentum budget; energy budget; salt and moisture budgets; Boussinesq approximation; flux formulation and conservative form.

Unit -4: Ekman Layer: Shear turbulence; friction and rotation; the bottom Ekman layer; generalization to nonuniform currents; Ekman layer over uneven terrain; surface Ekman layer; Ekman layer in real geophysical flows; Reynolds-averaged equations; Eddy coefficients; important dimensionless numbers.

Unit -5: Hydrodynamic instabilities: Barotropic instability and applications; introduction to baroclinic instability; Kelvin-Helmholtz instability

Reference Books

1. Roisin, B. C. and J. M. Beckers, Introduction to Geophysical Fluid Dynamics: Physical and Numerical Aspects, Academic Press, 2012.
2. Pedlosky J., Geophysical Fluid Dynamics, Springer, 1987.
3. Holton J. R., and G. J. Hakim, Introduction to Dynamic Meteorology, 5th edition, Academic Press, 2012
4. Gill A. E., Atmosphere-Ocean Dynamics, Academic Press, 1982

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√		√	√	√

Course Code: OA463		
Course Title: Remote sensing of the Ocean and Atmospheric Sciences		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412

Course Description

This course offers foundational concepts and hands-on training in utilizing remote sensing for atmospheric and oceanic science. Emphasizing practical skills, it explores diverse applications of satellite-derived parameters in meteorology and ocean sciences. Additionally, the integration of GIS tools enhances the presentation of results and outcomes, providing students with a comprehensive understanding of applying remote sensing techniques in these fields.

Course Objectives

1) Foster a fundamental understanding of both current and upcoming satellite missions and numerical weather forecasting.
2) Apply satellite-based observations to effectively monitor the environment and various meteorological processes and phenomena.
3) Utilize high-resolution satellite products to enhance model initial conditions.
4) Provide training on geo-informatics as a technology for integrating meteorology and climatology research, fostering applications for the geo-scientific community.

Course Learning Outcomes

1. Learn about principles, tools, and applications of remote sensing and GIS and recent advances in these fields.
2. Achieve fundamental knowledge and comprehension of the physical and computational basis of remote sensing.
3. Develop technical skills and competence in data and information acquisition, extraction, management and analysis; spatial and statistical modelling; mapping and visualization.
4. Describe how geographical information is used, managed, and marketedglobally. develop applications of environmental remote sensing and GIS which can directly enhance service delivery on land use management, ground water management/prospects, agriculture, forestry, food and water security, disaster management, etc.
5. Apply acquired knowledge and critical thinking skills to solve a real-world problem with appropriate remote sensing data and processing methods.

Detailed Syllabus

Unit -1: Introduction to remote sensing; basic concepts; electromagnetic radiation; solar and terrestrial radiation; atmospheric effects; absorption; transmission; scattering; spectral response of earth's surface features.

Unit -2: Remote sensing of atmospheric and ocean variables; atmospheric vertical and limb soundings; remote sensing platforms.

Unit -3: Satellite orbits- near polar geostationary and sun-synchronous satellites; swath; spatial, temporal, spectral, and radiometric resolution.

Unit -4: Examples of Indian atmospheric and ocean satellites including INSAT; sensors-active and passive sensors; sensor calibration; visible, thermal and microwave sensors and their applications in meteorology and oceanography.

Unit -5: The Visible, Infrared and Microwave remote sensing – the theory, principles and applications in Ocean and Atmospheric processes

Reference Books

1. Houghton, J. T., F.W. Taylor and C.D. Rodgers, Remote sounding of atmosphere, Cambridge University Press, 1984.
2. Stewart, R. H., Methods of Satellite Oceanography, University of California, 1985.
3. Robinson, I. S., Satellite Oceanography, Ellis Horwood, 1985.
4. Barret E. C., Climatology from Satellites, 1974.
5. Kidder, S. Q., and T.H. Van der Harr, Satellite Meteorology - An introduction, Academic Press, 1995.
6. Weng,Q., Remote Sensing and GIS Integration: Theories, Methods and applications, McGaw-Hill Professional, 2009.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√	√	√		

Course Code: OA464		
Course Title: Numerical Weather Prediction		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA413, OA461, OA462

Course Description

This course covers the essentials of Numerical Weather Prediction (NWP) and Data Assimilation, emphasizing data acquisition and quality control techniques pertinent to NWP. It delves into various global and regional coupled models, addressing the concept of atmospheric predictability and ensemble forecasting. Furthermore, the curriculum explores the integration of AI and ML techniques, showcasing their applications in weather and climate science prediction

Course Objectives

1) Gain a foundational understanding of Numerical Weather Prediction (NWP) and Data Assimilation.
2) Acquire knowledge of atmospheric/oceanic global and regional standalone as well as coupled models.
3) Explore data acquisition and quality control techniques integral to NWP.
4) Comprehend the concept of atmospheric predictability and ensemble forecasting.
5) Apply AI and ML techniques for advanced weather and climate prediction.

Course Learning Outcomes

- ➢ Discuss the development of dynamical weather prediction, and its advantages from traditional statistical prediction of weather.
- ➢ Understand the concept and steps for operational weather forecasting.
- ➢ To explain the requirements of data assimilation and initialization in Atmospheric/Ocean Sciences, and distinguish among various methods.
- ➢ To distinguish between the hierarchy of operational models and design the complexity of the model as well as operational set up from prediction, depending on the requirements and available computational requirements.
- ➢ Explain the distinctions between probabilistic and deterministic forecasts, and evaluate the prediction skills.

Detailed Syllabus

Unit -1: History of numerical weather prediction; Richardson's forecast; analysis of the initial tendencies; the causes of the forecast failure. Hierarchy of NWP models: mesoscale, regional, and global models.

Unit -2: Ensemble and super ensemble prediction systems; NWP model evaluation, correlation, skills, and bias correction. Initialization and data assimilation: Relevance of observations; model spin-up; the statistical framework for data assimilation; successive-correction methods; Optimum Interpolation (OI), three-dimensional variational analysis; introduction to 4-D VAR, Ensemble Kalman Filters, and/or other advanced methods.

Unit -3: Specific parametrization schemes used in NWP system: Choice of scale sensitive parametrization scheme; parametrization schemes (convection, cloud microphysics, PBL, air-sea interaction, and land-surface processes), sensitivity experiments.

Unit -4: Issues in NWP system: Challenges in weather forecasting; Chaos theory; Lorenz's butterfly effect; predictability; seamless prediction system (weather to climate prediction); present status of NWP system in India.

Unit -5: Concepts of AI and ML techniques and their application in NWP and climate science.

Reference Books

1. Coiffier, J., Fundamentals of Numerical Weather Prediction, Cambridge University press, 2012.
2. Warner, T. T., Numerical Weather and Climate Prediction, Cambridge University press, 2011.
3. Bhaskar Rao, D. V., Numerical Weather Prediction, Published by BS publishers and India Meteorological Society.
4. Daley, Roger, Atmospheric Data Analysis, Cambridge Atmospheric and Space Series, 1999.
5. Kalnay, E., Atmospheric modeling, Data Assimilation and predictibility, Cambridge University Press, 2003.
6. Krishnamurti, T. N., & L. Bounoua, An Introduction to Numerical Weather Prediction Techniques, CRC press, 2006.
7. Randall, D., An Introduction to Numerical Modeling of the Atmosphere, 2009.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√		√	√	

Course Code: OA465		
Course Title: Climate Change and Its Impacts		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
General understanding of Earth System and climate

Course Description

Climate change has vast socio-economic impacts and knowledge of the same is highly essential for better mitigation strategies. The present course is intended to understand the drivers of natural and anthropogenic climate change. The course targets a thorough understanding on varied interactions between different earth spheres, and the modulations impacted by human beings that are responsible for recent global warming.

Course Objectives

1) To provide understanding on the drivers of natural and anthropogenic climate change
2) To provide knowledge on the observed and probable adverse effects of extreme weather and climate events, their socio-economic impacts
3) To convey the essence of mitigating or combating recent global warming with eco-friendly strategies

Course Learning Outcomes

- Study the climate history of the earth on geological time scales, and differentiate between various internal and external drivers, and feedback.
- Interpret various methods and techniques to decipher the past climate signals in paleoclimate archives and differentiate their applications.
- Describe and quantify the role of greenhouse gases and aerosols in Earthâ€™s energy budget and climate system.
- Describe the current state of climate, and differentiate the projected climate change, and the range of uncertainties under various distinct radiative forcing scenarios, design various types of climate change simulations and be able to solve problems related to global warming and climate change.
- Inform the policy makers and stakeholders on the impacts attributable to the anthropogenic climate change, and facilitate knowledge to help formulating policies on climate change and mitigation.

Detailed Syllabus

Unit -1: Weather and climate: Concept of the weather and climate systems, interactions, and feedback; Climatology in atmospheric parameters, concept of air mass and fronts

Unit -2: Weather modification and climate change, causes and effects of climate change.

Unit -3: Climate classification systems and their importance.

Unit -4: Global warming: Relevance of greenhouse gases and aerosols; other climate drivers, climate feedback mechanisms, radiative forcing, Intergovernmental Panel for Climate Change (IPSS) Assessment Report – summary and findings

Unit -5: Past Climate: Paleoclimatic methods and archives and their application, climate change variability and feedback

Reference Books

1. Paleoclimates: Understanding Climate Change Past and Present : Thomas Cronin
2. Climate and Evolution: William Diller Matthew
3. Principles of Paleoclimatology : Thomas Cronin
4. Climatic Changes; Their Nature and Causes: Ellsworth Huntington
5. Barrry, R. G., and R. J. Chorley, Atmosphere Weather and Climate, 9th edition, Routledge publishers, 2010.
6. Neelin, J, D., Climate Change and Climate Modelling, Cambridge University Press, 2011.
7. Farmer, G. T. and J. Cook, Climate Change Science: A Modern Synthesis: The Physical Climate, Springer, 2013.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√		√	√	√

Course Code: OA466		
Course Title: Practical 2 - Oceanographic and Meteorological Computations		
Total Credits	**Credits allocation**	**Examination Scheme**
02	L-T-P: 0-0-2	Continuous Internal Assessment (CIA): 60 End Semester Examination (ESE): 40

Prerequisite Course / Knowledge (If any):
OA413, OA461, OA462

Course Description

Students will enhance their skills in visualizing and analyzing diverse global atmospheric and oceanic data formats using various visualization software such as NCL, MATLAB, Python, and Ferret. Through programming languages, they will create new variables like vorticity, divergence, convergence, and balanced winds using different datasets. The focus will be on developing climatological patterns globally for both oceanic and atmospheric variables. Additionally, students will identify and analyze various oceanic drivers, such as ENSO and IOD, and assess their impacts on a global scale

Course Objectives

1) Access diverse observed, satellite, and reanalyzed datasets in meteorology, oceanography, and climate from sources like NCEP/NCAR and ECMWF.
2) Utilize tools such as NCL, Ferret, MATLAB, Python, etc., to examine climatological features of different meteorological and oceanic variables.
3) Build analytical skills to estimate dynamical processes of phenomena like monsoons, Walker circulation, ENSO, and IOD through dataset analysis.
4) Employ statistical and graphical commands to analyze datasets, establish inter-relationships between phenomena, and assess inter-dataset uncertainties.

Course Learning Outcomes

- Familiarize and access the various available observed and reanalysed datasets related to meteorology, oceanography, and climate, and their utility from various data providers such as the NCEP/NCAR
- Develop capacities in carrying out analysis of datasets to estimate various physical properties of the geophysical fluids.
- Develop capacities in carrying out analysis of datasets to estimate various dynamical processes of typical phenomena such as monsoons, Walker circulation, and ENSO, etc
- Generate graphical visualizations of the processes.
- Analysis of the datasets using various statistical and graphical commands and establishes inter-relationships between various phenomena through application of statistics. Assess the inter-dataset uncertainties.

Detailed Syllabus

Unit -1: Computation and visualization software such as NCL/Ferret/MATLAB.

Unit -2: Computations: absolute vorticity; horizontal divergence; geostrophic, thermal, and gradient winds; relaxation methods; stream function and velocity potential, from NCEP/NCAR or equivalent circulation datasets.

Unit -3: Identification of ENSO and IOD events from the gridded SST datasets.

Unit -4: Calculation and presentation of Walker and Hadley circulations from reanalysis products

Unit -5: Computation of salinity from chlorinity and conductivity; density using temperature and salinity; Specific volume anomaly using temperature, salinity, and depth; computation of potential temperature; T-S diagrams and identification of water mass; Stability characteristics of the water column, Brunt-Vaisala frequency, and stability parameters; Computation of geostrophic currents; Estimation of wind stress curl and computation of wind-driven current; Estimation of the mixed layer, barrier layer, and thermocline depths

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO		√	√	√	√		

Course Code: OA467		
Course Title: Modelling of the Atmospheric & Oceanic Processes		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412, OA414

Course Description

This course educate the students about the concepts and hierarchy of ocean and atmospheric modelling. The students will get versed with the evolution of different ocean and atmospheric models, the theory and application of these models at various time scales.

Course Objectives

1) To introduce students to the concept of ocean and atmospheric modelling
2) To impart knowledge on numerical discretization, integration etc
3) To get versed with the theory of applying process specific models and general circulation models
4) To introduce the concepts of operational modelling

Course Learning Outcomes

1. Explain the need for numerical methods ocean and atmospheric modelling.
2. Will be equipped with knowledge of different numerical Techniques for solving partial differential equations related to the oceans and atmospheric dynamics
3. Describe the challenges in explicit simulation of high spatial and temporal resolution processes and provide examples of illustrative parameterization schemes.
4. Differentiate through the hierarchy of models and discuss approaches of Atmospheric/Ocean Modelling.
5. To carry out to the computer simulation of simple Weather /Ocean processes and/or phenomenon

Detailed Syllabus

Unit -1: Historical Background of atmospheric and ocean models; Hierarchy of numerical models: Filtering problem, barotropic model; equivalent barotropic model; two-level Baroclinic model; general circulation model.

Unit -2: Concept and steps of operational forecasting systems: Selection of the models; role of dynamics and physics; initial conditions; boundary conditions; pre-processing and post-processing; model diagnostics; deterministic and probabilistic forecasts; Dynamical and Statistical models; Spectral models, Earth System Model.

Unit -3: Finite difference Techniques: Taylor’s expansion; forward, backward, and central schemes; nonlinear instability and aliasing; Arakawa grids.

Unit -4: Time integration schemes: Explicit and implicit schemes; semi-implicit schemes; initial conditions; surface and lateral boundary conditions.

Unit -5: Ocean modelling: Hierarchy of ocean models; reduced gravity model; linear continuously stratified model; shallow water model; global ocean model; physical processes and parameterization schemes; concepts of parameterization - mixing processes, air-sea fluxes, tide, and waves. Coupling-Hierarchy of coupled models; coupling strategies; spin-up problems.

Reference Books

1. Coiffier, J., Fundamentals of Numerical Weather Prediction, Cambridge University press, 2012.
2. Warner, T. T., Numerical Weather and Climate Prediction, Cambridge University press, 2011.
3. Bhaskar Rao, D. V., Numerical Weather Prediction, Published by BS publishers and India Meteorological Society.
4. Krishnamurti, T. N., & L. Bounoua, An Introduction to Numerical Weather Prediction Techniques, CRC press, 1995.
5. Randall, D., An Introduction to Numerical Modeling of the Atmosphere, 2009.
6. Kampf, J., Advanced Ocean Modelling, Springer, 2010
7. Stephen Griffies, S., Fundamentals of Ocean Climate Models, Princeton University Press, 2004

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√	√	√	√	√

SEMESTER- III

Course Code: OA511		
Course Title: **Seminar on break-through Papers**		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 0-0-2	Continuous Internal Assessment (CIA): 60 End Semester Examination (ESE): 40

Prerequisite Course / Knowledge (If any):

Basic understanding on Ocean and Atmospheric Sciences. knowledge of state-of-the art ongoing research activities in the field of Ocean and Atmospheric Sciences

Course Description

This course is meant to give insights about breakthrough research. It will give a review of the particular topic.

Course Objectives

1) To Inspire and motivate the students
2) To develop critical analysis

Course Learning Outcomes

- Able to explain the different atmospheric and ocean processes
- Improve their critical analysis skills
- Identify research gaps and opportunities
- Enhanced interdisciplinary understandings

General Information

Student will study break-through papers (3 per student) assigned by the faculty, and deliver seminar.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO		√	√		√		

Course Code: OA512		
Course Title: Practical - 3 Model simulations and Diagnostics		
Total Credits	**Credits allocation**	**Examination Scheme**
02	L-T-P: 0-0-2	Continuous Internal Assessment (CIA): 60 End Semester Examination (ESE): 40

Prerequisite Course / Knowledge (If any):
OA413, OA461, OA462, OA415, OA506

Course Description

This study provides students with a foundational understanding of numerical weather prediction procedures and the governing equations employed in models. Students will gain familiarity with various regional and global atmosphere/ocean models. Through case studies on tropical extremes such as thunderstorms, cyclones, depressions, and heatwaves, the WRF model will be utilized. Additionally, students will explore the Ensemble Forecast System, including the evaluation of model performance, bias identification, systematic bias correction, and the utilization of multi-model ensemble forecasts.

Course Objectives

1) Acquire a foundational understanding of Numerical Weather Prediction (NWP) and atmospheric and ocean modeling.
2) Investigate the simulation of diverse weather extremes including tropical cyclones, heat waves, and flash floods utilizing regional models like WRF.
3) Analyze model outputs to assess factors influencing tropical cyclone intensification. Evaluate recent global coupled models and seasonal prediction models such as CMIP6 and NMME to understand their capabilities and limitations in simulating the Indian monsoon and its variability.
4) Explore the components of advanced regional ocean or atmospheric models and gain proficiency in implementing them on a Linux system.
5) Validate model outputs by comparing them with various observed and gridded climate data products.

Course Learning Outcomes

- Discuss various equations and terms used in a dynamical axis-symmetric tropical cyclone model, and port it on to a computing system Carry out control experiment to simulate the tropical cyclones in the Bay of Bengal, and tropical Atlantic.
- Set up numerical sensitivity experiments to explore the relevance of various Grey- Sikka parameters that are important for formation of the tropical cyclones in the north Indian Ocean tropical cyclones; importance of increasing SSTs and mid-level humidity, which could be deemed to be due to of climate change.
- Analyses the model outputs and evaluates the relevance of various factors for the tropical cyclone intensifications. Analyze various GCM outputs, such as the CMIP5 datasets for example, and validate processes such as monsoons, PDO, etc.
- Discuss various components of a state of art regional ocean or atmospheric model and familiarize with methods of implementation on a Linux system.
- To be able to validate model outputs with various observed and gridded climate data products.

Detailed Syllabus

Unit -1: Simulation of a tropical cyclone using an axis-symmetric tropical cyclone model (TCM).

Unit -2: Conducting sensitivity experiments with a TCM to understand the importance of various Grey-Sikka parameters.

Unit -3: Familiarizing with the models such as the WRF /ROMS/LCS; Validation of GCM simulations of tropical processes.

Unit -4: Delineation of decadal signals such as that of the pacific decadal oscillation using filtering methods; identification of dominant statistical patterns of the tropical pacific and tropical Indian ocean using EOF method.

Unit -5: Ensemble forecast system-evaluation of models performance, bias and systematic bias correction; multi-model ensemble forecast.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO			√	√	√	√	

Course Code: OA513	
Course Title: Summer Internship (Report and Presentation)	
Total Credits	**Credits allocation**
3	L-T-P: 0-0-3

Prerequisite Course / Knowledge (If any):
OA416, OA466, OA606

Course Description
During this course, students will engage in a 4-6 week research internship with reputable academic or research institutions. This hands-on experience offers invaluable training, allowing students to apply classroom knowledge directly to real-world projects. The internship serves as a platform for students to explore career interests, refine their skills, and identify areas for further development. Additionally, it facilitates the establishment of professional connections, laying the groundwork for future opportunities in the field.

Course Objectives

1) To Gain practical exposure to a diverse array of tools, techniques, and instruments utilized in esteemed institutes.
2) To Foster direct interaction with external experts and resource persons, enriching learning beyond classroom confines.
3) To Cultivate a broader understanding of Atmospheric Science by exploring diverse facets of the field.
4) To Enhance communication skills by imparting practical insights into Atmospheric Science concepts and applications

Course Learning Outcomes

- To work in national laboratories/universities and get exposed to on state of research topics.
- To integrate the expertise and knowledge acquired from the internship to narrow down future research directions.
- Develop interpersonal skills which will enable them to build professional relationships, and work within a team structure.
- Learn to communicate his/her research findings through report writing and develop presentation skills.
- Explore career opportunities in research prior to post-graduation.

General Information

Students to carry out summer internship training after Semester-III during summer vacation (4-6 weeks) at National Laboratories or Institutes such as MoES, ISRO, CSIR laboratories, IISc, IISERs, IITs, and state/central Universities.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO		√	√	√	√		

Elective Courses

Course Code: OA526 (Elective)		
Course Title: Cloud Physics and Atmospheric Electricity		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411

Course Description

This course offers a comprehensive introduction to the physics and dynamics of atmospheric clouds. Beginning with a brief overview of clouds and precipitation, and a refresher on fundamental thermodynamics, the focus primarily delves into the intricate microphysical properties of clouds. Understanding these properties is paramount as they govern the evolution and behavior of clouds. It also describe the atmospheric electricity in the light of thunderstorm.

Course Objectives

1) To foster comprehension of clouds and precipitation spanning from the macroscale to the microscale.
2) To explore the microphysical characteristics of clouds, encompassing their formation, growth, and thermodynamic interplay with precipitation particles.
3) To investigate the practical applications of cloud physics in contemporary research including cloud electrification studies

Course Learning Outcomes

- Know physics and dynamics of clouds and their climatic feedback and effects.
- Understand aerosol-cloud interactions role in Earthâ€™s radiative budget and hydrological cycle.
- Describe basic microphysical processes that are involved in cloud systems.
- Carry out meteorological work within the areas of clouds and precipitation.
- Understand the underlying phenomenon of lightning and thunder, devise the precautionary action plan to save from lightening.

Detailed Syllabus

Unit -1: Atmospheric aerosols: -sources, sinks, properties

Unit -2: Cloud condensation nuclei, thermodynamic theory of nucleation and growth cloud formation, properties, and classification, fog.

Unit -3: The microstructure of clouds, warm and cold clouds and their micro-physics theory of cloud droplet growth, precipitation types and mechanisms; artificial rain-making from real-world experiments

Unit -4: Atmospheric electricity: principles of atmospheric electricity, the life cycle of a thunderstorm cell, Global distribution of thunderstorms; cloud electrification mechanism, physics of lightening stroke, Global electric circuit

Unit -5: Observation of clouds and precipitation

Reference Books

1. Rodgers, R. R., and M. K. Yau, A Short Course in Cloud Physics, 3rd edition, Elsevier, 1996.
2. Pruppacher, H. R., and J. D. Klett, Microphysics of Clouds and Precipitation, Springer, 2010.
3. Mason, B. J., The Physics of Clouds, Oxford University Press, 2010.
4. Chalmers, J. A., Atmospheric Electricity, Pergamon press, 1967.
5. Pruppacher, H. R., and J. D. Klett, Clouds and Electricity.
6. Chalmers, J. A., Atmospheric Electricity, 2nd revised edition, Elsevier Science Ltd.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√			√	√

Course Code: OA527 (Elective)		
Course Title: Middle Atmosphere Meteorology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
bachelor-level mathematics and physics

Course Description

This course includes physical processes that occur in upper and middle atmosphere and describe that interaction of upper and middle atmosphere with troposphere through vertical transport momentum and energy. It describes different kind of atmospheric waves responsible for middle atmospheric energetics.

Course Objectives

1) To develop understanding of upper and middle atmosphere dynamics.
2) To Illuminate the significance of the upper and middle atmosphere.
3) To develop understanding of the meteorological variations in connection to changes in the middle atmosphere.

Course Learning Outcomes

- Understand the structure and composition of the middle atmosphere.
- Understand the processes involved in middle atmospheric dynamics.
- Understand the middle atmospheric circulations and their role.
- Evaluate the role of stratospheric warming and its connection with stratospheric quasi-biennial oscillation.
- Understand the experimental methods and measurement techniques involved in the middle atmosphere.

Detailed Syllabus

Unit -1: Composition and structure of the stratosphere, mesosphere, and thermosphere.

Unit -2: Changes in chemical composition – homosphere, heterosphere, ozonosphere; standard upper atmosphere; the ionosphere – composition morphology and general properties.

Unit -3: General climatology of the middle atmosphere, wind and temperature distribution; zonally averaged circulation energetics of the middle atmosphere.

Unit -4: Vertically propagating planetary waves; sudden stratospheric warming; waves in the Equatorial stratosphere; quasi-biennial oscillation (QBO).

Unit -5: Troposphere-stratosphere coupling; energetics of lower stratosphere; stratospheric warming, blocking situations in the troposphere.

Reference Books

1. Andrews, C.G, J.R Holton & C. Leovy, Middle Atmosphere Dynamics
2. Brasseur, G. and S. Simon, Aeronomy of the Middle Atmosphere
3. Holton, J. R., R.A. Craig, Introduction to Dynamic Meteorology : The Upper Atmosphere
4. Holton, J. R., Dynamic Meteorology of the Stratosphere
5. Mesosphere Physics of the Earth's Upper Atmosphere : C.O. Hines, I. Paghis, T.R. Hatz. & J.A. Fejer
6. Stratosphere-Troposphere interaction : K. Mohan Kumar.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√	√	√

Course Code: OA528 (Elective)		
Course Title: Geological, Chemical, & Biological Oceanography		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, OA412, Bachelor level Physics, Chemistry, and Mathematics

Course Description

To get versed with the geological, chemical and biological oceanography.

Course Objectives

1) To acquire knowledge of ocean basins, different landforms of oceans and its changes with time.
2) To understand different layers of the oceans in perspective of supporting different biological forms, their evolution and survival
3) To get versed with chemical properties of sea water, life cycle of distinct chemical constituents of sea water.
4) To elucidate different spatio temporal interactions that impact marine geology, biology and chemistry of the sea water.

Course Learning Outcomes

- Demonstrate fundamental knowledge of geology, chemistry and biology that unite the oceanographic processes.
- Understand and learn about the basic concepts of oceanography and marine geology with respect to sediment transport and accumulation in the marine environment.
- Understand the nature of the ocean floor and how ocean basins form and evolve in the context of the plate tectonic model.
- Gain knowledge of what and why and skills related to the physical, chemical and biological components and phenomena for a better understanding of oceanography and marine geology.
- Determine how the biological pump influences the distribution of chemical substances and biogeochemical cycles of the ocean.

Detailed Syllabus

Unit -1: Basics of Marine Geology; seafloor spreading; plate tectonics; evolution of ocean basins; Bathymetry and Physiography of the ocean floor; coastal water bodies – estuaries, lagoons, beaches, barrier islands, mudflats and wetlands.

Unit -2: Marine Sediments. Geochemical cycling of elements: Hydrothermal vents and hydrothermal alterations.

Unit -3: Ice ages and their causes; stable isotopes and their applications in paleoclimate reconstruction; oxygen isotopes in planktic and benthic forms; corals; marine sediment cores; paleo sea-level; paleo temperatures and productivity.

Unit -4: Chemical Oceanography: Chemical reactions: their basis and types; thermodynamic and kinetic considerations; concentration-activity difference; activity coefficient; chemical interactions and equilibria relevant to the Ocean; acid-base; ion-exchange; adsorption-desorption; dissolution-precipitation; reduction-oxidation; dissolution-colloid formation-precipitation; chemical speciation of important seawater systems; carbonate, phosphate and nitrate. Concentration and cycles of ions, Gases and fluxes

Unit -5: Biological Oceanography: Photosynthesis and respiration – Basic aspects of Calvin cycle; chlorophyll-a factors affecting it. Distribution of Chlorophyll-a, new production biological pump and F-Ratio; eutrophication. Algae, their characteristics and importance. Food web and trophic dynamics. species succession; species richness and diversity indices.

Reference Books

1. Lalli, M. C., and T. R. Parsol, Biological Oceanography: An Introduction, Open University Set Book
2. Riley, P. J., and R. Chester, Chemical Oceanography, Elsevier, 1983.
3. Wright, J., and A. Colling Seawater and its composition, properties and behavior, Open University, Elsevier, 1989.
4. K K Turekian – Chemical Oceanography
5. Pilson, M. E. Q., An Introduction to the Chemistry of the Sea, Prentice Hall, New Jersey, 431 pp, 1998.
6. Lecture Notes in Chemical Oceanography of Stanford University.
7. Lalli, C., and T. R. Parsons,. Biological Oceanography: An Introduction, Elsevier, 320 pp, 1997.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√			√	√	√

Course Code: OA529 (Elective)		
Course Title: Atmosphere and Marine Boundary Layer Processes		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA413, OA461, OA462, OA412

Course Description

In this course, students will delve into the fundamentals of atmospheric boundary layer depth, exploring its structure, turbulent characteristics, and mixed layers. Additionally, they will gain insights into the specifics of the marine boundary layer, examining various surface fluxes. The curriculum includes boundary layer modeling and the physical interactions between the ocean and the atmosphere.

Course Objectives

1) Interpret the significance of turbulence and its spectrum, distinguishing between different scales of fluxes within the boundary layer and marine boundary layer, particularly in the context of deep convection in the atmosphere.
2) Gain an understanding of the physical coupling between the ocean and atmosphere, focusing on momentum, heat, moisture, and buoyancy fluxes.
3) Explore boundary layer parametrization in models.
4) Examine the critical role of local air-sea interactions in shaping large-scale circulations in both the atmosphere and ocean, influencing various coupled phenomena.

Course Learning Outcomes

- Interpret the importance of turbulence and its spectrum; differentiate between various scales of fluxes across the boundary layer.
- Estimate turbulent stresses and describe the relevance of marine boundary layer for deep convection in the atmosphere.
- Understand how the ocean and atmosphere are physically coupled through momentum, heat, moisture and buoyancy fluxes.
- Explain the rationale behind common methods of estimating air-sea fluxes from observations and in numerical models.
- Discuss and give examples of how local air-sea interactions are critical for large- scale circulations in the atmosphere and ocean, and various coupled phenomena

Detailed Syllabus

Unit -1: Introduction: definitions and background; variables; wind and flow; turbulent transports; Taylor's hypothesis and observing techniques.

Unit -2: Boundary layer depth and structure; mathematical and conceptual tools; turbulence and its spectrum; spectral gap; mean and turbulent parts; basic statistical methods; rules of averaging; turbulent kinetic energy; kinematic flux, eddy flux; stresses.

Unit -3: Governing equations for turbulent flow: methodology; basic equations; simplifications and approximations; equations for mean variables in a turbulent flow; mixed layer theory; mixing and entropy; governing equations; model behaviour; surface fluxes and entrainment.

Unit -4: Deep convection and marine boundary layer: Controls on deep convection; MABL modification by downdrafts; boundary layer recovery; boundary layer modelling and parameterizations.

Unit -5: Physical interaction between ocean and atmosphere; wind stress and drag coefficient with respect to wind speed: momentum transfer, atmospheric impact on oceanic circulation.

Reference Books

1. Bigg, G. R., The Oceans and climate, Cambridge University Press, 1996.
2. Kagan, B, A., Ocean atmospheric interaction and climate modeling, Cambridge University Press, 1995.
3. Arya, S. P., Introduction to Micrometeorology, Academic Press, 2001.
4. Kraus E. B. and J. A. Businger, Atmosphere-Ocean interaction, Oxford University Press, 1995.
5. Stull R. B., Introduction to Boundary Layer Meteorology, Springer, 1988.
6. Geernaert, G. L., Air-Sea exchange: Physics, Chemistry and Dynamics, Springer,

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√	√	√

Course Code: OA530 (Elective)		
Course Title: Aerosols and Atmospheric Chemistry		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411

Course Description

This course aims to provide a foundational understanding of Aerosols and atmospheric chemistry, enabling students to comprehend the impact of atmospheric chemistry on air quality and climate feedbacks. Students will explore the chemical composition of the atmosphere, understanding its changes due to anthropogenic pressures and the resulting implications for ecosystems, human health, and climate. The curriculum covers gas-phase chemical reactions and photochemical processes in the atmosphere. Additionally, students will learn about the formation of aerosols from gaseous precursors and the interaction between gases and particles in the atmosphere. The course also delves into stratospheric chemistry, polar stratospheric clouds, and the phenomenon of the Antarctic Ozone hole.

Course Objectives

1) Cultivate an understanding of gas-phase chemical and photochemical reactions in the atmosphere, focusing on the chemical evolution of atmospheric aerosols.
2) Explore the interconnectedness of anthropogenic emissions, air pollution, and climate to gain insights into their relationships.
3) Develop an understanding of self-cleaning mechanisms in the atmosphere, fostering innovative ideas for mitigating air pollution.
4) Gain proficiency in measuring air quality and aerosols, including their sources of apportionment.
5) Acquire knowledge about stratospheric chemistry, with a specific focus on the formation and depletion of ozone.

Course Learning Outcomes

- Demonstrate knowledge of basic atmospheric chemistry and its role in environmental pollution and climate change
- How organic compounds, Sulphur and nitrogen-containing compounds are converted and give origin to the formation of photochemical oxidants, smog, and acidification, transformation of air pollutions in the particle phase, the chemistry of stratosphere.
- What a chemical gas-phase kinetics and reaction mechanisms are applied to problems in atmospheric chemistry.
- Describe the effect of weather on air pollutions, global influence from air pollutions, interaction between troposphere and stratosphere, aerosols and their properties.
- Describe how the measurement of air pollution gases and aerosols are made for policy and research objectives.

Detailed Syllabus

Unit -1: Atmospheric composition: aerosols, their sources and properties, the role of aerosols in the climate system, chemical kinetics of the atmosphere.

Unit -2: Tropospheric chemistry: Tropospheric constituents and oxidants, sources, and sinks; daytime and nighttime chemistry of different constitutes, tropospheric ozone formation and impacts.

Unit -3: Air quality: natural and anthropogenic pollution, atmospheric effects, such as smog, fog, acid rain, and visibility,

Unit -4: The concept of source apportionment, introduction to air quality modelling; Air quality-climate interactions and feedback

Unit -5: Stratospheric chemistry: stratospheric ozone, formation mechanism, catalytic cycles, stratospheric ozone destruction; polar stratospheric clouds, Antarctic Ozone hole

Reference Books

1. Hobbs, P. V., Introduction to Atmospheric Chemistry, Cambridge University Press, 2000.
2. Jacob, D. J., Introduction to Atmospheric Chemistry, Princeton University Press, 1999.
3. Wayne, R. P., Chemistry of Atmospheres, 3rd edition, Oxford University Press.
4. Pitts, B. J, F., and Jr. J. N. Pitts, Chemistry of the Upper and Lower Atmosphere, Academic Press, 2000.
5. Seinfeld, J. H., and S. N. Pandis, Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley, 2016

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√		√		√	√	√

Course Code: OA531 (Elective)		
Course Title: Diagnostic Studies of Atmospheric and Oceanic Processes		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA411, OA412, OA413, OA461, OA462

Course Description

Students will acquire knowledge about fundamental atmospheric and oceanic variables along with their measurement techniques. The course covers station models, map projections, and the analysis of diverse weather charts, emphasizing the kinematics of weather parameters. Various forecasting methods for different weather systems such as depressions, cyclones, and extreme weather events will be explored. Additionally, students will become familiar with the analysis and visualization of surface and upper air weather data, including oceanic data from sources like buoys, ARGO, satellites, model reanalysis, and global ocean data assimilation systems (GODAS).

Course Objectives

1) Investigate diverse methods of atmospheric and oceanic data collection, spanning from upper air to ground level, and develop proficiency in data visualization techniques.
2) Explore synoptic systems, including lows, depressions, deep depressions, and cyclones, with a focus on wind magnitude.
3) Study the kinematics of pressure and wind fields, gaining insights into different balance winds such as Geostrophic, hydrostatic, gradient, and thermal winds on a large scale.
4) Interpret various weather charts related to depressions and cyclones.
5) Examine different forecast methods for predicting weather and climate across various time ranges, including now, short-term, medium-term, and long-term forecasts.

Course Learning Outcomes

- To explore synoptic systems like lows, depression, deep depression, and cyclones based on wind magnitude.
- To get basic idea on kinematic of pressure fields.
- To learn different balance winds like Geostrophic, hydrostatic, gradient and thermal winds on large scale.
- To know the different weather charts which are using for forecasting on different time and space scale like now, short and medium range forecast.
- Collection of meteorological and ocean observations from different instruments and weather radars and satellites also.

Detailed Syllabus

Unit -1: Synoptic observations; pressure and wind systems; scales of atmospheric systems; primary-secondary and tertiary circulations; kinematics of the pressure field; pressure systems-intensification, movement, frontogenesis and frontolysis; slope of fronts; kinematics and dynamics; middle and high latitude weather systems; long waves and short waves; zonal index-anticyclones; cut off lows and blocking high; western disturbances.

Unit -2: Synoptic analysis: map projections; basic principles; surface, upper air and derived charts; aerological diagrams-use of special observations such as radar and satellite; representation and analysis of meteorological elements and systems on charts; weather prediction-short, medium and extended range forecasts; limits of predictability; subjective and objective methods of prediction; forecasting offices; charts prepared and services rendered to public; shipping; aviation; agriculture; storm warning.

Unit -3: Kinematics of the pressure field; characteristic curves; general expressions for their velocity and acceleration; movement of troughs; ridges and pressure centres; intensification and weakening; deepening and filling of surface pressure systems.

Unit -4: Kinematics of the wind field; relation between streamlines and trajectories; trajectories in moving cyclones and anticyclones; differential properties of the wind field; application of geostrophic, gradient, thermal winds, divergence and vertical velocity computations.

Unit -5: Synoptic data and collection; surface and upper air weather data transmission; code for inland, coastal and ship stations; upper air data; PILOT and TEMP codes; Station models; weather charts and analysis. Ocean data analysis and visualization: Buoys, ARGO, satellite, model reanalysis, global ocean data assimilation systems (GODAS).

Reference Books

1. Piettersen, B., Weather analysis and forecasting – Vol.1 & 2.
2. Riehl, H., Tropical meteorology, Mc-Graw Hill, 1954.
3. Hastenrath, S., Climate and circulation of the tropics, Springer, 1985.
4. Ramage, C. S., Monsoon meteorology, Academic Press, 1971.
5. Asnani, G. C.,Tropical Meteorology Vol. I & II.
6. Kurz, M., Synoptic Meteorology.
7. Pant, G. B., and K. Rupakumar, Climates of South Asia, J. Wiley & Sons, 1997.

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO		√	√		√	√	√

Course Code: OA532 (Elective)		
Course Title: Satellite Meteorology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA463

Course Description

This course offers insights, methodologies, and essential tools to effectively interpret a range of atmospheric phenomena observed through satellite imagery. It facilitates an understanding of diverse retrieval algorithms utilized for weather parameter analysis. Additionally, participants will gain proficiency in remote atmospheric sensing techniques, spanning radio frequency and optical methods.

Course Objectives

1) To develop knowledge about interpreting satellite image
2) To develop knowledge about meteorological products provide by different satellite
3) To develop knowledge about satellite retrieval of different atmospheric and oceanic parameters.

Course Learning Outcomes

- Gain knowledge of the different remote sensing techniques used for meteorology, including the strengths and limitations of the techniques.
- Describe the principles behind the radiation measurements used for passive and active remote sensing, and how usable information can be derived from remote- sensing data, including the limitations and sources of errors/uncertainty.
- Describe the orbital characteristics, accuracy, sampling limitations, use and limitations of various satellite sounding systems.
- Know operational and future satellite missions for atmospheric and meteorological parameter.
- Know how satellite images are acquired and interpreted for meteorological applications and weather forecasting; interpret weather satellite imagery using different techniques to disseminate knowledge to general audience.

Detailed Syllabus

Unit -1: Historical development; various satellites employed; TV and IR pictures of clouds; data acquisition systems; automatic picture transmission (APT);

Unit -2: Kepler's laws of planetary motion; orbits of satellites; choice of orbits; geosynchronous satellites; concepts of radiative transfer; propagation of solar radiation through the atmosphere; theory of radiative transfer in the atmosphere; radiative transfer in clear and cloudy skies; satellite techniques; visual and infrared sensing; atmospheric window; sensors employed for various measurements.

Unit -3: Meteorological satellite systems; the global weather satellite system; Meteosat satellites; NOAA satellites; future programs; retrieval of meteorological parameters; sea and land surface temperature measurements; measurement of rainfall, retrieval of cloud parameters; surface wind extraction by MW measurements;

Unit -4: Wind extraction by pattern tracking techniques; cloud motion and scales; methods for retrieval of atmospheric temperature and humidity profiles.

Unit -5: Interpretation of weather satellite imagery; subjective interpretation using different presentation techniques; interpretation using different channels; use of image animations; identification of cloud types using satellite imagery; large scale patterns; general circulation; Jet streams and Jet streak developments; blocking situations.

Reference Books

1. Kidder, S. Q., and T.H. Van der Harr, Satellite Meteorology – An Introduction, Academic Press, 1995.
2. Introduction to Meteorological and other Environmental satellites, WMO (Publications).
3. Deepak, A., Remote Sensing of Atmosphere & Oceans, Elsevier, 1980.
4. Training Course on Satellite Meteorology, ISRO Publications

Mapped to Programme Level Outcomes							
PLO	PLO1	PLO2	PLO3	PLO4	PLO5	PLO6	PLO7
CLO	√	√	√		√	√	

Course Code: OA533 (elective)		
Course Title: Satellite Oceanography		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA 501, OA412, OA463

Course Description

The course is aimed to provide basic understanding on the theory of remote sensing of the oceans using distinct wavelength bands. In addition the course elucidates the theory of using different satellites and their sensors for retrieving various ocean parameters using remote sensing.

Course Objectives

1) To convey the basic principles and understanding of the concepts of remote sensing.
2) To develop the knowledge on ocean remote sensing, various sensors and satellites available.
3) To get versed with the theory and understanding of ocean remote sensing through various wavelength bands/channels
4) To be familiarized with the state-of-the art satellites and sensors that are used for ocean remote sensing.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Gain knowledge of the different remote sensing techniques used for oceanography, and the strengths and limitations of the techniques
2. Describe the principles behind the radiation measurements used for passive and active remote sensing, and how usable information can be derived from remote-sensing data, including the limitations and sources of errors/uncertainty
3. Describe the orbital characteristics, accuracy, sampling limitations, use and limitations of various satellite sounding systems
4. Know operational and future satellite missions for oceanographic parameters.
5. Learn how satellite images are acquired, and interpreted for oceanographic applications such as ocean colour, sea surface temperature retrievals, etc.

Detailed Syllabus

Unit -1: Introduction to remote sensing; basic concepts; principles of aerial photography; electromagnetic radiation; solar and terrestrial radiation; atmospheric effects; absorption; transmission and scattering; spectral response of earth's surface features; atmospheric windows; concept of signature.

Unit -2: Remote sensing platforms; satellite orbits; near-polar, geostationary and sun-synchronous satellites; swath; spatial, temporal, spectral, and radiometric resolution; LANDSAT; SPOT; IRS; INSAT; SEASAT; ERS; JERS; MOS; RADARSAT; active and passive sensors; sensor calibration; visible, thermal and microwave sensors and their applications in oceanography; data transmission; reception; processing and dissemination; sea-truth data validation.

Unit -3: Visible remote sensing: Theory of ocean colour remote sensing; optical properties of pure water; natural waters and atmosphere; optical pathways in the atmosphere; reflection and refraction at the surface; scattering and absorption of light underwater; reflection from sea bed; colour of the sea; phytoplankton; yellow substance; suspended particulate matter; case 1 and case 2 waters; estimating water parameters; satellite sensors for ocean colour-CZCS, SeaWiFS, OCTS, MOS, MODIS, OCM, LISS I & II. Calibration and validation of ocean colour; applications.

Unit -4: Infrared remote sensing: Thermal emission; atmospheric absorption; IR sensors; SST retrieval; atmospheric correction; effect of cloud; thermal skin layer; skin and bulk SST; effect of surface films; infrared radiometers; AVHRR; ATSR; OCTS; MODIS; AATSR; TM; global SST data; NASA pathfinder; ASST-calibration and validation of SST; applications

Unit -5: Microwave remote sensing: Theory of microwave radiometry; microwave emission of sea surface; atmospheric effects; retrieval of salinity and wind vector; passive microwave radiometers- SMMR, SSM/I, TRMM/TMI and AMSR; active microwave radiometers; microwave interaction with the sea surface; low, intermediate and high incidence angles; wind and radar backscatter; scatterometers- SASS, AMI, NSCAT, SeaWinds; SAR; SAR imaging of wind speed and direction; ocean waves; internal waves; shallow bathemetry; altimetry- principles; atmospheric correction; sea surface height anomaly; ERS, T/P, Jason-1; observing planetary waves and eddy energy.

Reference Books

1. Robinson, I. S., Satellite Oceanography, Ellis Horwood, 1985.
2. Ikeda, M. and W. Dobson, Oceanographic Applications of Remote Sensing, CRC Press, 1985.
3. Stewart, R. H., Methods of Satellite Oceanography, University of California, 1985.
4. Allan, T. D., Satellite Microwave Remote Sensing, Ellis-Horwood Series in Marine Science, Chichester. 1983.
5. Maul, G. A., Introduction to Satellite Oceanography, Springer, 1985.
6. Barret E. C., Climatology from Satellites, 1974.
7. Robinson, I. S., Measuring the Oceans from space: The principles and methods of satellite Oceanography: Springer, 2004.

Course Code: OA534 (elective)

Course Title: Ocean Acoustics

Total Credits	Credits allocation	Examination Scheme
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Physics of the Oceans, Bachelor level Physics

Course Description

The present course is intended to emphasize the application of principles of marine acoustics and its utilization in sensing/profiling ocean bottom, sediments and distinct layers of the oceans.

Course Objectives

1) To make familiar to the theory and principles of sound propagation in the sea water.
2) To get versed with the theory of remote sensing of the ocean bottom and different ocean layers using marine acoustics.
3) To get knowledge on remote sensing the ocean bottom and bottom sediments, using the principles of sound propagation.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Acquire the knowledge on the behavior of sound, its behavior and propagation characteristics.
2. Understand the influence of distinct mediums and its boundaries in influencing acoustic propagation.
3. Conceptualizing sea water as a sound transmission media, with emphasis on distinct oceanic physical properties and marine provinces.
4. Acquire the knowledge on principles and techniques of sonar transmission.
5. Familiar with the concepts of applying sonar for echo sounding, doppler navigation, bottom topography etc.

Detailed Syllabus

Unit -1: 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 -2: 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 -3: 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; resonant swim bladder of fish.

Unit -4: 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 -5: 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; acoustic output of ships; passive detection range; passive detection hydrophones; array steering; ocean acoustic tomography

Reference Books

1. Kinsler, L.E., A.R. Frey, A. B. Coppens, and J. V. Sanders, Fundamentals of Acoustics, 4th edition, John Wiley & Sons Inc, 2000. :
2. Medwin, H., and C. Clay, Acoustical Oceanography, Academic Press, 1997.
3. Tucker, D. G., Underwater Observation Using Sonar, Fishing News Ltd, 1966.
4. Tolstoy, I., and C. Clay, Ocean Acoustics, Acoustical Society of America, 1987.
5. Theory and Experiments in Underwater Sound:N.N. Rao

Course Code: OA535 (elective)		
Course Title: Marine Pollution		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Physics and dynamics of the Oceans, Bachelor level Physics

Course Description

The course is designed to understand the impacts of marine pollution in various spheres of marine physical, chemical and biological domains. The mechanisms of sources, distributors and sinks of marine pollutants will be introduced and treating the marine pollution for better environment.

Course Objectives

1) To get versed with the marine pollutants, their sources and properties.
2) To elucidate the oceanic process or mechanisms of pollutant transportation and dispersion
3) To familiarize with the laws of treating, removing or dispersion of marine pollutants in perspective of eco-friendly environment.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To get knowledge on various types of pollutants and their impact on oceans
2. Understand various sources and sinks of marine pollutants.
3. Apply the concepts of physical oceanography in quantifying the dispersion, dissipation and transportation of marine pollutants.
4. Understand the status of national and international policies and agreements dealing with marine pollution management.
5. Identify the importance of marine pollution and management in perspective of environmental friendly nature and sustainable development.

Detailed Syllabus

Unit -1: Pollution of the oceans; kinds of pollution; marine pollutants and their sources; types of pollutants-physical, chemical, biological, thermal, radioactive, and non-point; oil and micro-plastic pollution; effects of pollution.

Unit -2: Oceanographic factors involved in dispersing pollutants; the transport phenomenon; advective and diffusion aspects; dispersal of pollutants in estuaries and near-shore areas.

Unit -3: Physical oceanographic factors affecting marine pollution.

Unit -4: Control and abatement of marine pollution; effluent outfalls; radioactive waste disposal; containment of oil at sea; oil slicks and their management; chemical dispersants; water quality parameters and standards; procedure and instrumentation

Unit -5: Monitoring strategies; global waste management and the oceans; hazardous material transport; carrying capacity; open ocean dumping and incineration; monitoring and control; general laws on prevention of marine pollution

Reference Books

1. Massin, J. M., Remote Sensing for the control of Marine Pollution, Vol. 6, Springer, 1984.
2. Geyer R. A., Marine Environment Pollution, Elsevier, 1980
3. Gross, M. G., Ocean Dumping and Marine Pollution
4. Duedall, I. W., J. M. Capuzzo and D. R. Kester, Oceanic Processes in Marine Pollution,1988

Course Code: OA536 (elective)		
Course Title: Ocean Optics		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Physics of the Oceans, Bachelor level Physics

Course Description

The course is designed to introduce the optical properties of sea water, for remote sensing and understanding the properties of sea water

Course Objectives

1) To introduce the optical properties of sea water
2) To get versed with distinguishing different types of sea water using optical properties of sea water through remote sensing
3) To apply the optical properties of sea water for understanding distinct ocean processes

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1) To introduce the optical properties of sea water
2) To get versed with distinguishing different types of sea water using optical properties of sea water through remote sensing

To apply the optical properties of sea water for understanding distinct ocean processes

Detailed Syllabus

Unit -1: Characterization of the light field in water; radiance; irradiance; diffuse attenuation coefficient; water leaving radiance; inherent and apparent optical properties of seawater.

Unit -2: Light scattering by water molecules; Raman scattering by water; Rayleigh scattering and Mie scattering.

Unit -3: Absorption characteristics of water constituents; backscattering characteristics of water constituents; fluorescence by phytoplankton and dissolved organic matter; the impact of bottom reflection on upwelling radiance and volume reflectance in water; colour of the sea.

Unit -4: Optical properties of Case I and Case II waters; refractive index of seawater; remote sensing reflectance, reflectance albedo, photosynthetically active radiation.

Unit -5: 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.

Reference Books

1. Jerlov, N. G., Marine Optics, 2nd edition, Elsevier Science, 1976.
2. Shifrin, K. S., Physical Optics of Ocean waters, Springer, 1988.
3. Pozdnyakov, D., and H. Graßl, Colour of Inland and Coastal waters:A methodology for its interpretation, Springer, 2003.

Course Code: OA537 (elective)		
Course Title: Agricultural Meteorology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, Bachelor level Physics

Course Description

This course aims to enhance understanding in agriculture and agricultural observation, covering aspects such as soil climate, radiation, soil temperature, soil moisture, evaporation, and evapotranspiration. Students will explore the impact of various weather hazards on agricultural fields. The curriculum will empower students to work with crop models in climate change scenarios, gaining insights into crop growth and yield tools. Additionally, the course will introduce different crop weather models, including empirical and statistical models, regression models, and growth and yield prediction models.

Course Objectives

1) Develop a foundational understanding of agriculture and gather diverse agricultural observations.
2) Explore different agro-climate zones, interpreting the climate variability and its impact on crop production.
3) Gain proficiency in utilizing crop models to enhance crop production and ensure food security.
4) Study the impact of natural hazards on various agricultural fields.
5) Investigate crop weather calendars and weather forecasts tailored for agriculture at short, medium, and long-range levels.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Discuss the relevance of soil characteristics and microclimate for agriculture.
2. Classify India in to various agro-climate zones, and interpret the variability of climate and crop production.
3. Give examples of various instrumentation used in agro-meteorology, and their applications
4. List crop phonology cycles of important crops.
5. Implication of weather and seasonality, and how the pest impact is related to the weather.

Detailed Syllabus

Unit -1: Agricultural meteorology-meaning and scope; components of agricultural meteorology; importance of weather and climate for agricultural production; role and responsibilities of agricultural meteorologists. Agrometeorological observations; agromet observatories; soil climate; radiation; soil temperature; soil moisture; evaporation and evapotranspiration; lysimeters; open pan evaporimeters; phenological observations and measurements; automatic weather stations.

Unit -2: Weather and climate in relation to plants and crops; principles of crop production; evaluation of crop responses to weather elements; impact of variability of climate on crop production; insects and plant diseases; climate classification; agro-climatic zones and agro-ecological regions of India.

Unit -3: Crop weather calendars; weather forecasts for agriculture at short, medium, and long range levels; agromet advisories, forecasts and warnings for agriculture and forestry; benefits of weather services to agriculture.

Unit -4: Weather hazards in agriculture: droughts, types of drought and their causes; prediction of drought; floods, hail, dew, frost and protection against them; windbreaks and shelterbelts; hail suppression, dissipation of fog, modification of frost intensity and severe storms; mulches and anti-transpirants; meteorological conditions in artificial and controlled climates; green, plastic, glass and animal houses.

Unit -5: Crop weather models: Empirical and statistical crop weather models; regression models; growth and yield prediction models; crop simulation models, e. g. CERES, WOFOST, SPAW, RESCAP, WTGROW; forecasting of pests and diseases; verification, calibration and validation of models. Climate change: greenhouse effect; CO_2 increase; global warming and its impact on agriculture; future scenario; global and Indian contexts.

Reference Books

1. Venkskevitch, G. Z., Agro meteorology , Israel Program for Scientific Transition, IPST press, Jerusalem, 300 pp., 1961.
2. Guide to Agricultural Meteorological Practices by WMO No.134, 1981. 4.
3. Lecture Notes for training Class IV Agricultural Meteorological personnel by WMO No.593, 1982. 5.
4. Reddy, S. J., Agroclimatic/Agrometeorological Techniques, Jeevan Charitable Trust, ICRISAT Colony, Secunderabad, 1993.

Course Code: OA538 (elective)

Course Title: High-Performance Computing in Atmosphere and Ocean Sciences

Total Credits	Credits allocation	Examination Scheme
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA506,OA416,OA464,OA466

Course Description

High performance computing is highly essential for simulations using global ocean, atmospheric models. The present course is designed to in introduce the need for HPC and utilizing different strategies of the same for running global ocean and atmospheric models

Course Objectives

1) To understand the essence of HPC computing facilities
2) To get versed with the strategies to optimum utilization of HPC
3) To get knowledge on developing model simulations in HPC environment
4) Familiar with different strategies and to work with HPC

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Understand the various architectures of HPCs.
2. Understand the multitasking and massive parallel processing with HPCs.
3. Acquire practical skills in utilizing parallel computing tools and learn to work with high-performance compilers.
4. Explore the integration of graphical user interfaces into high-performance computing systems and gain knowledge about data formats, enabling effective data visualization and interpretation.
5. Develop proficiency in local and wide area networking concepts, facilitating seamless data exchange between distributed computing resources.

Detailed Syllabus

Introduction to multitasking and massively parallel processing; various architectures; application of HPC in global and regional models; parallelism in weather and climate models; domain decomposition method; 1D, 2D and 3D parallelization of GCMs; MPI, PVM, SHMEM, message passing libraries; high-performance compilers; load balancing; inter-processor communication; network communication; graphical user interface; data formats; local and wide area networking; data flow and data mining.

Reference Books

1. Røed, L. P., Atmospheres and Oceans on Computers-Fundamentals, Springer, 2019.
2. Yang, L. T., and M. Guo, High-Performance Computing: Paradigm and Infrastructure, Wiley interscience, 2005.

Course Code: OA539 (elective)		
Course Title: Ocean State Forecasting		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA416,OA412,OA461

Course Description

The course is designed to introduce the essence of ocean state forecasting and its importance in operational perspective. The importance of ocean state forecast, forecasting methods and implications is explored in the course.

Course Objectives

1) To get versed with the need for ocean state forecasting and its applications in various aspects of socio-economic domains
2) Make familiarize with the processes and that are important for ocean state forecast
3) To elucidate the parameters, methods and strategies that are important for ocean state forecasting

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To understand the predictive importance of various ocean related phenomenon and their socio-economic importance
2. Acquire knowledge on various numerical methods related to ocean state forecast
3. Understand the scenarios of ocean related hazards and impacts in perspective of India
4. Know the type of region/process specific ocean models in perspective of distinct important ocean related predictions.
5. Apply the knowledge in ocean state forecasting for running various coastal and open ocean models.

Detailed Syllabus

Unit -1: Numerical techniques used in marine forecasting.

Unit -2: Forecasting of tides and currents in the North Indian Ocean; real-time forecasting of storm surges in India and its neighbourhood.

Unit -3: prediction of coastal upwelling, its importance and applications.

Unit -4: fronts and vertical thermal structure in the Bay of Bengal and the Arabian Sea; wave prediction in the North Indian Ocean; forecasting of salinity and flow structure in the Indian estuaries.

Unit -5: Status of Ocean state forecasting in India and global, regional and global models used for ocean state forecasting and the theory.

Reference Books

1. Schott, F. A. and J. P. McCreary, The Monsoon Circulation of the Indian Ocean, Progress in Oceanography, 2001.
2. Emery, W. J. and R. E. Thomson. Data Analysis Methods in Physical Oceanography, Elsevier Science, 2014. .
3. Miller, R. N., Numerical Modeling of Ocean Circulation, Cambridge University Press, 2006.
4. Kantha, L. H. & C. A. Clayson, NumericalModels of Oceans and Oceanic Processes, Academic Press, 2000

Course Code: OA540 (elective)

Course Title: Mesoscale modeling

Total Credits	Credits allocation	Examination Scheme
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA416, OA507,OA464

Course Description

This course offers insights into the techniques and methods integral to a contemporary operational mesoscale weather forecasting model. It provides knowledge about significant mesoscale atmospheric systems involved in cloud and precipitation formation, along with their associated dynamical processes. Additionally, the course explores the formation and causes of diverse extreme climate and weather events, such as heavy rainfall and tornadoes. Students will also gain an understanding of various regional models and data analysis related to specific weather events.

Course Objectives

1) Develop an understanding and demonstrate knowledge of the structure and formation of atmospheric conditions that foster the development and movement of mesoscale phenomena.
2) Provide exposure to tropical waves and their correlation with organized convection in the tropics, including their role in tropical cyclogenesis.
3) Grasp the concept and gain an overview of the structure, formation, and propagation of extreme and severe weather events.
4) Gain insights into mesoscale modeling, mesoscale data assimilation, and the intricacies of community mesoscale models such as MM5 and WRF. Additionally, explore mesoscale simulation techniques for intense convective events.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To get knowledge about different types of processes on different time spatial scales
2. To identify extreme weather events like heavy rainfall, tornadoes, and tropical cyclones.
3. To get an idea on regional models like MM5 and WRF. How to install, run those models.
4. To get information how to improve initial condition using different data assimilation techniques.
5. Finally, they will do model experiment for case studies (like extreme rainfall, excess and deficient monsoon years).

Detailed Syllabus

Mesoscale processes; scaling; observations and analysis; wave fundamentals; Lee waves and windstorms; orographically forced flows; orographic precipitation; differential heating; gravity currents and convective initiation; isolated convective storms; tornadoes; MCS - squall lines; heavy rainfall; internal structure of cyclones; rain bands – observations and theory; Hydrostatic approximation and nonhydrostatic dynamics, basics of meso-scale modeling; mesoscale data assimilation; details of some community mesoscale models (MM5 and WRF), mesoscale simulation of intense convective events.

Reference Books

1. Pielke, R. A., Mesoscale Meteorological Modelling, Academic Press, 2013.
2. Atkinson, B. W., Mesoscale Atmospheric Circulation, Academic Press Ray, P. S., Mesoscale Meteorology and Forecasting, American Meteorological Society, 1986.

Course Code: OA541 (elective)

Course Title: Air Pollution Studies

Total Credits	Credits allocation	Examination Scheme
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA411

Course Description

This course provides students with a fundamental understanding of Air Pollution, Air Quality

Modeling, and Management, empowering them to assume leadership roles in addressing both outdoor and indoor air pollution challenges. Recognizing that contemporary air pollution issues involve various scientific, human, ecological, social, economic, political, legal, and medical dimensions, the course focuses on comprehending the nature and parameters of Indian air emissions and air quality. It equips students with strategies for air quality modeling and management, enabling them to educate the public on real-world issues stemming from air pollution and broadening their perspectives.

Course Objectives

1) Develop a comprehensive understanding of air pollution sources, transport, and receptor systems.
2) Gain insight into air pollution measurement techniques, sources, and their impact on climate and health.
3) Acquire knowledge of air quality modeling, utilizing various models such as Gaussian and box models, while exploring the meteorological influence on air pollution sources.
4) Explore the roles of regulatory bodies and policymakers in air quality management.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To be able to identify the essential components of the air pollution phenomenon's, types, correlated effects, transformation processes and integrated approaches in controlling
2. Plan measurement and monitoring of air pollutants, select sampling and monitoring sites. select best sampling method according to properties of sampling location and parameters.
3. To be able to explain the common principles, routes and processes in controlling the gaseous pollutants and aerosol particles.
4. Practically exercise the major atmospheric pollution issues in recent days and therefore discuss the energetic solutions on a comparative basis of atmospheric pollution mitigation.
5. To explore air pollution modelling through inversion modelling, Gaussian and box models

Detailed Syllabus

Various sources and types of pollutants in the atmospheric environment; Reynolds averaging; closure problem; atmospheric diffusion; types of boundary conditions for modeling dispersion; solution of diffusion equation for instantaneous and continuous sources; dispersion from ground/ elevated sources; long and short-range dispersion, removal mechanism; dry and wet deposition; chemical removal; atmospheric surface boundary layer; similarity theory; wind rose, dispersion parameters and plume rise; Gaussian and box models; optical stack height; case studies for the dispersion of pollutants

Reference Books

1. Seinfeld, J. H., and S. N. Pandis, Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley, 2016.
2. Arya, S. P., Air Pollution Meteorology and Dispersion, Oxford University, 1988.
3. Arya, S. P., Introduction to Micrometeorology, Academic Press, 2001
4. Hinds, W. C., Aerosol Technology: Properties, Behavior, and Measurement of Airborne
5. Particles, Wiley-Interscience, 1999.

Course Code: OA542 (elective)		
Course Title: Coastal Oceanography		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Bachelor level Physics, OA412, OA461

Course Description

The course describes the various coastal oceanographic processes, coastal variability and vulnerability.

Course Objectives

1) To familiarize with the coastal variability and geomorphological changes on coasts due to the action of sea water
2) To understand the dominant processes responsible for coastal and estuarine changes
3) Get versed with coastal vulnerability in the context of global warming and sea level changes
4) To familiarize the strategies for coastal zone management

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To understand the mechanism of waves and its impacts on coastal changes
2. Acquire knowledge on various physical, dynamical and geomorphological processes associated with coasts
3. To get versed with the processes associated with various coastal hazards with mitigation strategies
4. Understand processes and dynamics associated with estuaries, coastal, coastal zone changes
5. To apply the knowledge in coastal oceanography for coastal zone management

Detailed Syllabus

Unit -1: Wave generating and restoring forces; shallow water waves; coastally trapped long waves; influence of sea-bed friction; wave spectra; refraction and shoaling of waves; seiches; waves-current interaction; wave transformation in shallow waters,

Unit -2: Tsunamis; breaking waves; phenomenon of wave reflection; refraction and diffraction; surf zone hydrodynamics; shoreline setup; swash and runup heights; wave generated alongshore currents; Rip currents; Storm surges.

Unit -3: Theory of tides; tides in rivers and coastal lagoons; general characteristics of estuaries; classification of estuaries; stratification; estuarine circulation and mixing; shear instability at an interface.

Unit -4: Entrainment and sedimentation in estuaries; dispersion processes, advective and turbulent diffusion; river-estuary-near-shore systems.

Unit -5: Sediment characteristics; sediment transport mechanisms; bedform dynamics; suspended particles in wave flows and vortices; morpho-dynamics- Beach profiles; tide range influence on beach morphology; lee side erosional beach realignment due to climate change; interaction of an estuary with the near-shore bay.

Reference Books

1. Holthuijsen, L.H., Waves in Oceanic and Coastal Waters, Cambridge, 2009.
2. Svendsen, I.A., Introduction to Nearshore Hydrodynamics, World Scientific, 2006.
3. Janssen, P., The Interaction of Ocean Waves and Wind, Cambridge, 2009.
4. Mani, J.S., Coastal Hydrodynamics, PHI, 2012.
5. Dean, G.R. and R.A. Dalrymple, Coastal Processes with Engineering Applications,
6. Cambridge, 2002.
7. Nielsen, P., Coastal and Estuarine Processes, World Scientific, 2009.

Course Code: OA543 (elective)		
Course Title: Climate and Energy		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA411, OA465

Course Description

This course deals with different renewable energy sources and assesments. The provides basics require for different energy sources

Course Objectives

1) To develop knowledge about renewable energies
2) To understand importance of the renewable energy in climate scenario

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Understand the fundamental weather and climate processes that influence atmospheric conditions.
2. Understand the concepts of solar radiation, solar geometry
3. Describe the measurement techniques used in meteorology and solar energy studies and demonstrate an understanding of solar and terrestrial radiation.
4. Understand the energy transfer processes between the earth's surface and the Atmosphere.
5. Able to assess the different energy sources and assessments.

Detailed Syllabus

Unit -1: Surface energy balance: Solar constant, solar geometry, atmospheric radiative transfer, clouds and aerosols, surface energy budget, urban energy use, sensors and observations.

Unit -2: Meteorological considerations for solar power: solar resource assessment, solar forecasting for different timescales, uncertainty estimation, types of solar systems.

Unit -3: Wind in the atmospheric boundary layer: boundary layer structure and evolution, surface layer, stability, log and power laws, flow over complex terrain, low-level jets, offshore winds, sensors and observations.

Unit -4: Meteorological considerations for wind power: wind resource assessment, wind forecasting for different timescales using statistical and numerical methods, uncertainty estimation, types of turbines, turbine wakes, wake interactions in wind farms, turbine and wake models.

Unit -5: LES and mesoscale models of wind farms; Solar-wind coupling: resource variability, power demand, optimization. Wave energy, tidal energy, ocean thermal energy conversation (OTEC), geothermal energy.

Reference Books

1. Ahrens, D., Meteorology Today, 11th Edition, Cengage, 2015.
2. Emeis, S., Wind Energy Meteorology, 1st Edition, Springer, 2013.
3. Garratt, J. R., The Atmospheric Boundary Layer, 1st Edition, Cambridge University Press, 1994.
4. Kaimal, J.C. and J. J. Finnigan, Atmospheric Boundary Layer Flows, 1st Edition, Oxford, 1994.
5. Kalogirou, S., Solar Energy Engineering, 1st Edition, Elsevier, 2009.
6. Stull, R., Introduction to Boundary Layer Meteorology, 1st Edition, Kluwer Academic, 1999.
7. Stull, R., Meteorology for Scientists and Engineers, 2nd Edition, Cengage, 1999.

Course Code: OA544 (elective)		
Course Title: Mountain Meteorology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA411, OA413

Course Description

This course describes the impact of mountains on atmospheric flow, convective feedbacks and general circulation. The course is also targeted to understand the impact of mountains on atmosphere and regional meteorology at various time scales

Course Objectives

1) To get versed with mountain influencing the atmospheric circulation
2) To know the importance of mountains in earth-climate system by understanding the impacting processes associated with mountains
3) To decipher the radiative and convective feedbacks associated with mountains, and their influence on meteorology
4) To get versed with regional meteorological processes and aspects influence by mountains

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Understand the impact of the orography on meteorology and on circulation system.
2. Understand the impact of mountains on atmospheric thermodynamics and energy budget.
3. Learn about the general properties of mountain perturbations in the atmosphere.
4. understand the theory of linear gravity waves in mountainous region.
5. Learn about the modeling aspects of the orography on atmospheric dynamics.

Detailed Syllabus

Unit -1: Latitudinal, altitude and topographical effects of mountain on meteorological elements; Circulation systems related to orography, mountain and valley winds;

Unit -2: Climatic characteristics of mountains, energy budgets, cloudiness, precipitation, evaporation, fog, lightening, snow avalanches and valley air pollution; some case studies, the equatorials mountains of New Guina, the Himalayas, sub- tropical desert mountains, the Rocky and the Alps.

Unit -3: General properties of mountain perturbations, adiabatic meso-scale perturbations in a straight atmospheric flow, adiabatic synoptic scale perturbations, computation, of the dissipation of mechanical energy resulting from a mountain perturbation modelling aspects of mountain waves, mountain generated momentum fluxes, theory of linear gravity waves, orographic gravity-wave drag, its parameterization and influence in general circulation models.

Reference Books

1. C David Whiteman, C. D., Mountain Meteorology: Fundamentals and Applications, Oxford University Press, USA.
2. Chow, F. K., S. F.J. De Wekker and B. J. Snyder, Mountain Weather Research and Forecasting: Recent Progress and Current Challenges; Springer Atmospheric Sciences, 2012.

Course Code: OA545 (elective)		
Course Title: Climate and Water Resources		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

OA411, OA465

Course Description

In this course, participants gain insights into the influence of climate on diverse water resources and its consequential effects on human life and the environment. The curriculum covers various adaptation and mitigation strategies, exploring the implications of these policies for achieving sustainable development. Case studies, including projects like the Ganga Damodar Project and Ganga Valley Project, provide practical examples and enhance understanding of water resource management.

Course Objectives

1) Explore the impact of climate change on water resources, emphasizing the intricate interaction between the two.
2) Examine the influence of climate and water resources on human health and the environment.
3) Gain insights into mitigation and adaptation strategies that influence policies and contribute towards sustainable development.
4) Study various case studies on water resources, along with government policies and projects related to water resource management.

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Understand the impact of climate change on water resources.
2. Understand the importance of mitigation and adaptation strategies.
3. Analyze potential conflicts between adaptation and mitigation efforts in managing water resources and their implications for policy and sustainable development.
4. Acquire practical skills in the assessment of water resources and policies of water resources.
5. Acquire knowledge about management strategies.

Detailed Syllabus

Unit -1: Climate impact on water resources: The need for vulnerability assessment, water-related adaptation to climate change in the fields of ecosystems and biodiversity, agriculture and food security, land use and forestry, human health, water supply and sanitation,

Unit -2: Infrastructure and economy (insurance, tourism, industry and transportation); adaptation, vulnerability and sustainable development sector-specific mitigation, carbon dioxide capture and storage (CCS); cropland management, afforestation and reforestation; potential water resource conflicts between adaptation and mitigation; implications for policy and sustainable development

Unit -3: Water resources assessment case studies; Ganga Damodar Project; Himalayan glacier studies; Ganga valley project; adaptation strategies in assessment of water resources; operation policies for water resources projects; flood management strategies; drought management strategies; temporal & spatial assessment of water for irrigation; land use & cropping pattern; coastal zone management strategies.

Reference Books

1. IPCC Report AR5
2. Shukla, P R, Subobh K Sarma, NH Ravindranath, Amit Garg and Sumana Bhattacharya, Climate Change and India: Vulnerability assessment and adaptation, University Press (India) Pvt Ltd, Hyderabad.
3. Preliminary consolidated Report on Effect of climate change on Water Resources, GOI, CWC, MOWR, 2008.

Course Code: OA546 (elective)		
Course Title: General Geology		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Bachelor level Geology

Course Description

In this study, students will explore the origin, evolution, and structure of planet Earth, delving into internal dynamic processes such as plate tectonics, continental drift, earthquakes, and volcanoes. External dynamic processes, including weathering, erosion, and deposition, will also be examined. The course covers fundamental concepts in geomorphology, the origin and structure of various rocks, and introduces basics in paleontology and palynology.

Course Objectives

1) Explore the dimensions, origin, early evolution, and contemporary changes of planet Earth.
2) Examine various processes, including internal dynamics (earthquakes, volcanoes) and external forces (deposition, weathering, and erosion).
3) Investigate the origin, structure, and compositions of different rocks.
4) Explore different types of maps, including topographic and thematic maps, as well as vertical profiles.
5) Gain an understanding of fossils and fossilization, micropaleontology, and Palynology, with a focus on the distribution of microfossils like foraminifera and their significance in oil exploration

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. To recognize the dimensions of the planet Earth, its origin and early evolution and its current changes
2. To identify the different processes like Internal (earthquakes, volcanoes.) and external (Deposition, weathering, and erosion)
3. Origin of different rocks and its structure and compositions.
4. To explore the maps like topographic and thematic and vertical profiles also
5. To understand fossils and fossilization; micropaleontology; Palynology: distribution of microfossils-foraminifera and the importance of microfossils in oil exploration.

Detailed Syllabus

Unit -1: Dimensions of earth, structure, composition, and origin of the earth; crust, mantle, and core. Internal dynamic process: Plate tectonics, continental drift, Earthquake, and volcanoes. External dynamic process: Weathering, erosion, and deposition.

Unit -2: Fundamental concepts in Geomorphology: Geomorphic processes distribution of landforms drainage patterns; landforms in relation to rocks types, paleochannels buried channels.

Unit -3: Origin of igneous, sedimentary and metamorphic rocks; sedimentary structures-petrographic character of conglomerate, sandstone, shale, limestones; introduction to sedimentary basins and deltaic systems; topographic maps; thematic maps; topographic and thematic profiles.

Unit -4: Palaeontology: Introduction to Palaeontology; fossils and fossilization; micropaleontology.

Unit -5: Palynology: distribution of microfossils-foraminifera, radiolaria, conodonts, ostracodes, diatoms; the importance of microfossils in oil exploration. Earth resources and environment.

Reference Books

1. Carlson, Richard W; The Mantle and core: Treatise on geochemistry;v.2 Amsterdam: Elsevier, 2005
2. Robert L. Rudnick; The Crust Treatise on geochemistry;v.2 Amsterdam: Elsevier, 2005
3. William Lowrie; Fundamentals of geophysics Cambridge University Press, 2007.
4. Thronbury, William D., Principles of geomorphology 2nd Edition New Delhi: CBS Publishers and Distributors, 2004.
5. Clifford Embleton and John Thornes; Process in geomorphology London Edward Arnold 1979.
6. G.W. Tyrrell; Principles of Petrology Bombay: B.I. Pub., 1980.
7. F.H.Lahee; Field Geology 6th edition Delhi : CBS Publishers & Distributers , 1987.
8. David M. Raup and Steven M; Principles of paleontology 2nd New Delhi : CBS Publishers, 2004

Course Code: OA547 (elective)		
Course Title: Space Weather		
Total Credits	**Credits allocation**	**Examination Scheme**
03	L-T-P: 3-0-0	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):
OA411, Middle Atmosphere Meteorology

Course Description

This course mainly deals with different processes in Sun interior and exterior. It also describes different space weathers occur on sun surface. Mainly talks about the Sun-Earth interactions

Course Objectives

1) To develop knowledge about the Sun interior process
2) To develop knowledge about space weather events

3) To develop knowledge about Sun-Earth interactions

Course Learning Outcomes

After completion of this course successfully, the students will be able to……

1. Identify, explain, and interpret the physical processes at the Sun.
2. Understand the processes involved in Sun-Earth interaction.
3. Understand the importance of the space weather and how it can disturb the technological systems.
4. Evaluate the role of space weather on the Earth's atmosphere.
5. Understand the experimental methods and measurement techniques involved in space weather.

Detailed Syllabus

Unit -1: Brief Introduction of Plasma physics

Unit -2: Sun-Composition and Structure, Solar radiation. Solar atmosphere, Sunspots and solar rotation, Solar Cycle, Solar wind, Solar Flares and Coronal Mass Ejections.

Unit -3: Earth’s atmosphere-ionosphere and magnetosphere. Propagation of CMEs in the IP medium, Interaction of solar wind with earth's magnetosphere, magnetic reconnection, geomagnetic storms. Implications of Space Weather Effects

Reference Books

1. Space Weather: Physics and Effects, By Volker Bothmer and I.A. Dagliz, Springer.
2. Solar Terrestrial Environment: Introduction to Geospace, By J.K. Hargereaves, Cambridge University Press.
3. Introduction to Space Physics, By Margaret G. Kivelson and Christopher T. Russell, Cambridge University Press.
4. Sun, earth and Sky, By Kenneth Lang, Springer Verlag.
5. Secrets of the sun, By Ronald Giovanelli, Cambridge University Press.
6. Beginners guide to Sun, By Peter Taylor and Nancy Hendrickson, Kalmbach Publishing Company.
7. Atmospheric Environment by T. Beer

SEMESTER-IV

Course Code: OA661	
Course Title: Project Dissertation	
Total Credits	**Credits allocation**
20	L-T-P: 0-0-20

Continuous Internal Assessment (CIA): 40

End Semester Examination (ESE): 60

Prerequisite Course / Knowledge (If any):

Course Description

Each student will undertake an M.Sc. project supervised by an assigned faculty member for 4 to 5 months. Students must secure their supervisor's consent for their project by the end of the third semester. Students will identify a research problem through an extensive literature review, honing their research skills. Emphasizing real-world applications, students are encouraged to utilize observations or cutting-edge weather and climate models in their projects. Students will submit their research findings as a dissertation at the culmination of the semester.

Course Objectives

1) To develop research skills by applying weather and climate processes.
2) To develop scientific demonstration and writing skill
3) To develop the skill of scientific communication for a practical understanding of Ocean and Atmospheric Science.

Course Learning Outcomes

1. Develop research interest, communication skills, analytical skills, including the ability to understand information, and interpret data required for research.
2. develop effective work habits, including time management, punctuality, and personal accountability.
3. Develop independent thinking, resourcefulness, and the ability to make decisions.
4. To identify a science problem, develop methods to address it, and draw accurate and precise conclusions. Write a focused scientific dissertation on the research findings.
5. Demonstrate openness, inclusiveness, sensitivity, and the ability to interact respectfully with all people and understand individuals' differences.

General Information

Students will carry out individual project dissertation preferably at National Laboratories or Institutes such as IITM-Pune, INCOIS-Hyderabad, NIO-GOA, TIFR-Hyderabad, PRL-Ahmadabad, SPL-Trivandrum, IISc, IISERs, IITs and state/central Universities