Syllabus for

M.Sc. in Atmospheric Science

(Academic Session: 2023-25)

P. G. Department of Atmospheric Science

Fakir Mohan University, Balasore, Odisha

M.Sc. in Atmospheric Science

(2-Years M.Sc. Programme 2023-25 onwards)

Introduction

Atmospheric Science deals with the study of structure and evolution of earth's atmosphere including wide range of phenomena that occur within it. It is the study of the Earth's atmosphere, its processes, the effects of small scale and largescale systems have on the atmosphere, and the effects of the atmosphere on these other systems. This program includes meteorology, atmospheric physics, chemistry and dynamics, agronomy and climatology. The design of the Master's program in Atmospheric Science is aimed at imbibing the students with fundamental scientific methodology in mathematics, physics and chemistry to enable them in appreciating, understanding and investigating the complex behaviour of Earth's atmosphere and climate systems. The applications of Atmospheric Science in the field of agriculture, aviation, water resources, disaster mitigation (due to extreme weather, severe storms, cyclone, etc.), air quality and climate prediction harbouring immense possibilities which are high lyre levant at present and in future, as several facets of the human life are intrinsically impacted by our atmosphere. Balasore is situated on the East coast of India with large river systems passing through the region and demographically an important location for the tropical weather systems. Extreme weather events such as tropical cyclones, thunderstorms, nor-westers are home to the region quite frequently and is quite vulnerable to the associated hydro-metrological disasters. A Master's degree program involving the climate of Balasore and northern Odisha can help in studying the extreme weather events in the region and its aspects of early prediction and warning.

Programme Objectives

1. To impart the basic and advanced knowledge of various processes and phenomena in the field of Atmosphere Science and Meteorology.
2. To provide skills in theory, numerical modelling of Atmospheric processes and their applications in weather forecasting and development of early warning systems for extreme weather events.
3. To train the students with quantitative and scientific reasoning skills for operational organizations, academia, research & development organizations.
4. To produce trained manpower in providing solutions to various challenges and issues related to atmospheric sciences and other interdisciplinary areas.
5. Application of knowledge in the field of natural disaster management, climate change adaptation in agriculture, water resources, air and pollution studies.

Programme Outcomes (POs)

After completing M.Sc. Atmospheric Science Programme, students will

- Understand the fundamental concept of the atmosphere physics and dynamics, basic principle and scientific theory related to the different weather and climate phenomena of physical world and their relevance in the day-to-day life.
- Develop problem solving skills and improve the analytical and systematic thinking ability.
- Competent towards scientific research at several Renown organisations in India and abroad.
- Be in a position to fulfil the current demand of employers in various industries, administrations and different academic and research institutes of National and International repute.
- Use their experimental skill and theoretical knowledge to start their own start up program (Private forecasting, Climate Modelling, Meteorological Instruments manufacturing etc.) and take initiatives to be an entrepreneur to meet the societal needs and environmental challenge.
- have essential practical, academic as well as software expertise, programming skills, modelling and simulation techniques, to do research in the interdisciplinary fields of data science, radiation physics, plasma physics, information science and space science.

PROGRAM SPECIFIC OUTCOMES (PSOs)

After completing M.Sc. Atmospheric Science Program, students will

- be able to enrich their knowledge in the Atmospheric Science like Modelling of Climate, forecasting skills (Weather prediction), Remote sensing techniques, Satellite data acquisition, Global Information System (GIS) etc.
- able to develop strong analytical skills, critical thinking and experimental skills.
- be in a position to understand the mysteries of nature such as Tropical cyclone, severe thunderstorm with lightening, Tornados, Hurricanes, Tsunami wave, Hail storm, Climate change effect, Cloud bursts etc.
- develop knowledge to handle any kind of scientific instruments used in Meteorology and Oceanography.
- be in a stage to apply their knowledge to identify, analyse problems and to provide effective solution in the recent environmental issues and disaster arises due to change in climate.
- have the knowledge about the recent developments and future possibilities in different branches of Atmospheric science.

P. G. Department of Atmospheric Science

Syllabus structure (M. Sc. in Atmospheric Science)

Approved by BOS on Dt. 29.08.2023

M.Sc. in Atmospheric Science		
Semester	Marks	Credit
1st semester	500	24
2nd semester	500*	24*
3rd semester	500**	24
4th semester	400	24
Total	1900	96

*One MOOC/SWAYAM course of 3/4 credits, is selected by the student of M.Sc. Atmospheric Science. After successful completion of the course the secured credit will be added to the 4th semester secured credit. In this case total credit and mark changes as per the transfer marks and credits.

**Choice based credit paper is selected by the student of other PG Departments of F. M. University.

Marking Pattern:

Paper Type	**Internal Evaluation**			**End Term Examination**			**Total**
	Home Assignment	**Quiz**	**Written (Internal)**	**Written/ Expt. (End Term)**	**Report/ Records**	**Viva-Voce**	
Theory	**10**	**10**	**20**	**60**	**NA**	**NA**	**100**
Practical	**NA**	**NA**	**NA**	**60**	**20**	**20**	**100**
Project	**NA**	**NA**	**NA**	**100 (Presentation)**	**200**	**100**	**400**

Syllabus for M. Sc. Programme in Atmospheric Science

Code	Name	Mark	Credits
I-Semester			
AS-101	Fundamentals of Earth System Science	100	4
AS-102	Physics of the Atmosphere	100	4
AS-103	Dynamics of the Atmosphere and Ocean	100	4
AS-104	Mathematical Physics and Statistics in Atmospheric Science	100	4
AS-105	Practical-1: Meteorological Instruments and Observational Techniques.	100	8
	Total	**500**	**24**
II-Semester			
AS-201	Modelling of Atmosphere and the Oceanic processes	100	4
AS-202	Synoptic Meteorology and Climatology	100	4
AS-203	General Circulation of the Atmosphere and Ocean	100	4
AS-204	Remote sensing and GIS in Ocean and Atmospheric Sciences	100	4
AS-205	Practical-2: Weather Analysis and Forecasting Laboratory and Remote Sensing and GIS Laboratory	100	8
	Total	**500**	**24**
III-Semester			
AS-301	Boundary Layer Processes and Air Pollution studies	100	4
AS-302	Elective-I	100	4
AS-303	Elective-II	100	4
AS-304	Disasters and Public Health Management (Choice based Credit paper for other subject P.G. students)	100	4
AS-305	Practical-3: Model Simulations and Diagnostics	100	8
AS-306	Fakir Mohan Studies (Non-Credit Paper)		
	Total	**500**	**24**
IV-Semester			
AS-403	Project Dissertation (Report, Presentation and Viva-voce)	400	24
	Total	**400**	**24**
	Cumulative credits (I-IV Semester)	**1900**	**96**

One combination of the subjects is needed to be selected for the electives in the 3rd semester:

1. (A) Elective –I: Numerical weather Prediction and Extreme Weather Events
   (A) Elective-II: Data Assimilation Techniques
2. (B) Elective –I: Science of Climate Change, its impact and Adaptation
   (B) Elective-II: Geophysical Fluid Dynamics

First Semester

AS-101: Fundamentals of Earth System Science

Objective	This course is designed to learn the basic concepts of Earth system science, such as evolution of earth and life, different bio-geo chemical cycles, Global warming (naturally or anthropogenic activity).
Pre-requisites	General Newtonian Mechanics, Ideal gas laws, Composition of Atmosphere. General Geographical Science
Teaching Scheme	

Unit		Hours
I	Basic concepts for Earth System Science: The origin and early evolution of the Earth and its atmosphere; Evolution of Geosphere and Biosphere; Earth as a system of interacting components-Geosphere, Biosphere, Atmosphere and Hydrosphere.	10
II	Life on Earth; chemosynthetic and photosynthetic processes; marine productivity; organic/inorganic carbon; warm/cold waters herbivores. Ecosystems; biodiversity; trophic dynamics; stability; interactions with the environment.	10
III	Biogeochemical Cycles such as Carbon cycle; Nitrogen cycle; Sulphur cycle; Phosphorus cycle; trace metals; Coupling of biogeochemical cycles and climate- Forcings, feedbacks and responses.	10
IV	Ocean carbon cycle; distribution and storage of carbon in the Ocean; Reservoir of carbon; role of biology; ocean carbon exchange with the atmosphere in the present climate; *variability* and trends of air-sea carbon exchange and its projected changes in the future climate.	10

V	Global change on short and long time-scales: Natural versus anthropogenic changes; global warming and greenhouse effect; role of long-term variability of solar luminosity; human modifications of the Earth system; Climate change and sustainability	10
	Total	50

Reference Books:

1. Lenton, T., Earth System Science: A Very Short Introduction, 1st edition, Oxford University Press, 2016.
2. Ehlers, E., and T. Kraft, Earth System Science in the Anthropocene: Emerging Issues and Problems, Springer.
3. Jacobson, M. C., R. J. Charlson, H. Rodhe, and G. H. Orians, Earth System Science: From Biogeochemical Cycles to Global Changes, Elsevier Academic Press, 2006.
4. Flechtner, F., N. Sneeus, and W.D. Schuh, Observation of the System Earth from Space - CHAMP, GRACE, GOCE and future missions, Springer, 2014.
5. Kump, L. R., J. F. Kasting, and R. G. Crane, Earth System Science, 3rd edition, Pearson Education, 2010.

Course outcomes: At the end of the course, the learner is expected

- To learn the origin and evolution of Earth and creation of life
- To acquire knowledge about the dependency between animal and plant.
- To study different Bio-geo chemical cycles.
- To learn air-sea carbon exchange processes
- To know the impact of climate change on biosphere.

AS-102: Physics of the Atmosphere

Objective This course is designed to learn the elementary concepts of Atmospheric science, different physical laws and equations used to represent the science behind Atmospheric phenomena. Thermodynamic and Radiative property of the atmosphere.

Pre-requisites General Newtonian Mechanics, Ideal gas laws, Thermodynamics and radiation physics.

Teaching Scheme

Unit		Hours
I	Elementary concepts of atmospheric sciences; vertical thermal structure and composition of the atmosphere hydrostatics of the	10

	atmosphere; geopotential; equipotential surface; hydrostatic equation; hydrostatic equilibrium; standard atmosphere.	
II	Gas laws and their application to the atmosphere; equation of state for dry and moist air; humidity parameters; virtual temperature; First and second laws of thermodynamics; specific heats of gases; internal energy; adiabatic processes; potential temperature; revisiting entropy; reversible and irreversible processes; Carnot's cycle.	10
III	Thermodynamics of water vapour; latent heat; the Clausius-Clapeyron equation; thermodynamics of the atmosphere; dry adiabatic lapse rate; case of unsaturated moist air saturated adiabatic lapse rate; pseudo-adiabatic cases; equivalent potential temperature; wet-bulb temperature; wet-bulb potential temperature and saturation potential temperature; Normand's propositions and Normand point.	10
IV	Atmospheric instability and convection-stability criteria; parcel method; Brunt-Vaisala oscillations; lifting; mixing and convective condensation levels; potential instability and latent instability; stability indices; slice method of stability analysis; cloud formation and types. Principles of thermodynamic diagrams and various thermodynamic diagrams.	10
V	Radiation: Laws of black body radiation; radiation transfer; solar radiation; latitudinal and seasonal variation; passage through the atmosphere–absorption, scattering and reflection; mean disposition of solar radiation; terrestrial radiation; absorption in the atmosphere; Raleigh and Mie scattering; atmospheric window	10
	Total	50

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.

Course outcomes: At the end of this course the learner is expected

- To learn the physical processes that occurs in the atmosphere.
- To explain the thermodynamic behaviour of Atmosphere.
- To gain knowledge about different thermodynamic equations and their use in Atmospheric Dynamics
- To study the Atmospheric instability.
- To know the process of radiation and scattering in the atmosphere.

AS-103: Dynamics of the Atmosphere and Ocean

Objective This course is designed to learn the elementary concepts of Atmospheric science, different physical laws and equations used to represent the science behind Atmospheric phenomena. Thermodynamic and Radiative property of the atmosphere.

Pre-requisites General Newtonian Mechanics, Rotational frame of reference, Thermodynamics and radiation physics, Mathematical Physics.

Teaching Scheme

Unit		Hours
I	Introduction: Objective, importance of geophysical fluid dynamics; distinguishing attributes of geophysical flows; scales of motions; importance of rotation; importance of stratification; distinction between the atmosphere and ocean; data acquisition; the emergence of numerical simulations; scales analysis and finite differences; higher-order methods; aliasing.	10
II	The Coriolis force: Rotating framework of reference; unimportance of the centrifugal force; free motion on a rotating plane; analogy and physical interpretation; acceleration on a three-dimensional rotating planet.	10
III	Equations of fluid motion in different coordinate systems: Cartesian, spherical and natural vertical-pressure and potential temperature, Geostrophic flows: Homogeneous geostrophic flows; homogeneous geostrophic flows over an irregular bottom; generalization to non-geostrophic flows; inertial motion and cyclostrophic flow;	10
IV	Gradient wind and thermal wind Currents without friction: Hydrostatic equilibrium; geopotential, isobaric and isopycnal surfaces, Geostrophic equation; inertial motion; level of no motion	10

	and absolute currents; quasi-geostrophic dynamics; simplifying assumptions and governing equations.	
V	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.	10
	Total	50

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.
4. Pond, S. and G. L. Pickard, Introductory Dynamic Oceanography, 2ndedition, Butterworth-Heinemann, 1983.
5. Olbers, D., J. Willebrand and C. Eden, Ocean Dynamics, Springer, 2012.
6. Additional Reading Material
7. Proudman, J., Dynamical Oceanography, Methuen & Co Ltd, 1963.
8. Haltiner, J. G., and F. L. Martin, Dynamical and Physical and Meteorology, McGraw-Hill, 1957.
9. Fomin, L. M., The Dynamic Method in Oceanography, Elsevier, 1964
10. Roisin, B. C. and J. M. Beckers, Introduction to Geophysical Fluid Dynamics: Physical and Numerical Aspects, Academic Press, 2009.
11. Dietrich, G., General Oceanography, John Wiley and Sons Inc, 1963.
12. Sverdrup, H. U., M. W. Johnson and R. H. Fleming, The Oceans: Their Physics, Chemistry and General Biology, Prentice Hall Inc, 1942.

Course outcomes: At the end of this course the learner is expected

- To find the solution of differential equations by numerical methods.
- To learn the dynamics of atmospheric due to rotation of Earth.
- To understand different geo physical motions in Atmosphere.
- To explain the fluid movement of the atmosphere and Ocean.
- To understand the physical phenomena behind the different ocean current

AS-104: Mathematical Physics and statistics in Atmospheric science

Objective	This course is designed to learn the elementary concepts of Mathematical Physics, differential equation which needs to be explain atmospheric behaviour, Probability theory and statistical techniques are introduced, which are essential to interpret the climate data.
Pre-requisites	Ordinary differential equations, Probability, Statistical analysis.
Teaching Scheme	

Unit		Hours
I	Vector calculus: Scalar and vector products and triple products, polar and axial vectors; scalar and vector fields, gradient, divergence, curl, conservative fields; vector integrations, Gauss' theorem, Stokes' theorem; differential vector operators; cylindrical and spherical polar coordinates.	10
II	Linear vector spaces: Vector spaces and representations; linear operators; matrices and their properties; special matrices; eigenvalues and eigenvectors; change of basis and similarity transformation; matrix diagonalization and its geometric interpretation; simultaneous linear equations.	10
III	Ordinary differential equations: First and second order equations; linear equations with constant and variable coefficients; series solutions; Partial differential equations: Wave and diffusion equations as examples; general and particular solutions; separation of variables; integral transform methods. Taylor's theorem, Laurent's theorem, elementary functions.	10
IV	Probability Theory, Conditional probability, Covariance, correlation, Moment, skewness and kurtosis; Probability distribution function, Multivariate distribution. Bernoulli, Binomial, negative binomial, Poisson and normal distributions; Theory of least squares and curve fitting; Correlation Simple; multiple and partial; Regression lines and regression coefficients; Multiple and partial regression; Test of Significance: Normal test, t-test, Chisquare and F-test,	11
V	Fourier analysis: Periodic functions and Dirichlet conditions; Fourier representation-real and complex series; Fast Fourier Transform (FFT), Wavelet analysis, Principal component analysis (PCA). Multivariate analysis,	09
	Total	50

Reference Books:

1. Riley, K. F., M. P. Hobson, & S. J. Bence, Mathematical methods for physics and engineering, Cambridge University Press, 2006.
2. Hassani, S., Mathematical physics, Springer, 2002.
3. Greenberg, M. D., Advanced engineering mathematics, Pearson Education, 2002.
4. Croft, A., R. Davidson and M. Hargreaves, Engineering Mathematics, Pearson education, 2001.
5. Spiegel, M. R., et al., Complex Variables (Schaum's series), McGraw-Hill education, 2009.
6. Brown, J. W. and R. V. Churchill, Fourier series and Boundary Value Problems, McGraw-Hill Education, 2015.

Additional Reading Material

1. Kalpan, W., Advanced Calculus,5th edition, Pearson, 2002.
2. Arfken, B., and H. Weber, Mathematical Methods for Physicists, Elsevier, 2005, 1182p.
3. Pipes, L. A., and L. R. Harvill,Applied Mathematics for Engineers and Physicists, Dover publications, 2014.

Course outcomes: At the end of this course the learner is expected

- To know advanced mathematical methods such as vector calculus used to understand the atmosphere.
- To learn the geometrical interpretation of matrix and its properties.
- To know the differential equations and solution in physics and its application in Atmospheric science.
- To learn the processes of statistical interpretation of data and its physical significance.
- To identify different signals through statistical analysis.

AS-105: Practical-1: Meteorological instruments and Observational Techniques

Objective This practical course enables the students to realize physically the basic electronic devices and its working principle. The knowledge acquired by the students helps them to design, test, troubleshoot, and rectify faults in electronic circuits of the meteorological instruments.

Pre-requisites Fundamental knowledge of Physics and electronics.

Teaching Scheme

- General measurement system: Principles; measurement of surface meteorological parameters-rainfall, wind, temperature, humidity, pressure, radiation, soil moisture and soil temperature; Aerosol and its size distribution and chemical compositions; trace gases; Ship-based and buoys observations. Radar, Lidar and Sonar techniques.
- Upper air observations: Pilot balloon; radiosonde/GPSsonde.
- Data analysis and forecasting: Surface and upper air data analysis; weather maps, T-Phigram; use of weather chart and T-Phigram for weather forecasting.
- Visit to India Meteorological Department (IMD).

Reference Books:

1. Handbook of Meteorological Instruments: H.M.S.O., LONDON,1965
2. W. E. K. Middleton and A. F. Spilhaus, Meteorological Instruments, 3rd edition, University of Toronto Press, 1960.
3. Pictorial guide to maintenance of meteorological Instruments: H.M.S.O., London, 1963
4. Guide to Meteorological Instruments and observing practices :2014 edition WMO Publications, May 2017

Course outcomes: At the end of this course the learner is expected

- To learn data acquisition techniques by using meteorological instruments.
- To know the working principles of instruments.
- To learn forecasting techniques by using weather map and T-phigram.

Second Semester

AS-201: Modelling of the Atmosphere and the Oceanic Processes

Objective	This course is designed to learn the different techniques and schemes used in modelling of atmosphere. Development of Primitive Ocean model to the state of art model.
Pre-requisites	Physics and Dynamics of Atmosphere and Ocean
Teaching Scheme	

Unit		Hours
I	Historical Background of atmospheric and ocean models; primitive equations and their simplification. Hierarchy of numerical models: Filtering problem, barotropic model; equivalent barotropic model; two level Baroclinic model; general circulation model.	10
II	Finite difference Techniques: Taylor's expansion; forward, backward and central schemes; nonlinear instability and aliasing; arakawa grids. Time integration schemes: Explicit and implicit schemes; semi-implicit schemes; initial conditions; surface and lateral boundary conditions.	10
III	Galerkin methods: spectral method; finite element method; spectral model. Parameterization of physical processes in the atmosphere: Basic concepts of parameterization - boundary layer, cumulus convection, radiation and land surface processes.	10
IV	Ocean modelling: Hierarchy of ocean models; reduced gravity model; linear continuously stratified model; shallow water model; global ocean model; physical processes and parameterization schemes; Parameterization of physical processes in the ocean: Basic concepts of parameterization - mixing processes, air-sea fluxes, tide and waves.	10
V	Coupling-Hierarchy of coupled models; coupling strategies; spin-up problems. Earth System model.	10
	Total	50

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 Additional Reading Material:
8. Haltiner, G. J., and R. G. Williams, Dynamic Meteorology & Numerical Weather Prediction, Wiley, 1980.
9. Muller, P., and H. V. Storch, Computer modeling in Atmospheric and Oceanic Sciences, Springer, 2004.
10. Kampf, J., Ocean Modeling for beginners, Springer, 2009.
11. Chassignet, E., and P. Verron, Ocean Modeling and Parameterization, Springer, 1988.
12. Miller, R. N., Numerical Modeling of Ocean Circulation, Cambridge University Press, 2007.

Course outcomes: At the end of this course the learner is expected

- To learn detail processes and important equations used in Atmospheric and Oceanic Model.
- To know the finite difference techniques and the surface and lateral boundary conditions.
- To gain knowledge about the concepts of parameterization and related physics
- To know the Hierarchy of ocean models and its working principles and parameterization schemes.
- To learn about the coupled model.

AS-202: Synoptic Meteorology and Climatology

Objective	This course is designed to learn the science behind the weather and climate of different geographical area. Different global oscillations and its teleconnection mechanism.
Pre-requisites	Physics and Dynamics of Atmosphere and Ocean, Basic Thermodynamics and Fluid Mechanics
Teaching Scheme	

Unit		Hours
I	Weather and climate; Components of the climate system and feedbacks to climate. Radiation climatology of the earth's	10

	atmosphere; geographical and seasonal distribution of incoming solar radiation; outgoing radiation; net radiation; terrestrial heat balance.	
II	Geographical and seasonal distributions of temperature, pressure, wind, precipitation, vertical distribution of temperature and winds. Climatology of air masses: Origin, movement and modification of air masses; fronts and convergence zones; weather associated with frontal zones.	10
III	Classification of climates: Koeppen and Thornthwaite's schemes. Large scale planetary systems: Trade wind and ITCZ; Hadley and Walker circulation; Jet streams; Madden Julian oscillation Synoptic scale weather systems: Low and high pressure systems; easterly waves	10
IV	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; heat waves; sea and land breeze.	10
V	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; impacts from tropical oceanic drivers such as the ENSO and IOD, northeast monsoon.	10
	Total	50

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.

Additional Reference

1. Pandharinath, N., Aviation Meteorology, B.S. Publications, 2012
2. Atkinson, B. W., Mesoscale atmospheric circulations.
3. Shaw, D. B., Meteorology over the Tropical Oceans, Royal Meteorological Society publication 1979.
4. Sellers, W. D., Physical Climatology, University of Chicago Press, 1965.
5. Neelin, J, D., Climate Change and Climate Modelling, Cambridge University Press, 2011.

6. Barrry, R. G., and R. J. Chorley, Atmosphere Weather and Climate, 9th edition, Routledge publishers, 2010.

Course outcomes: At the end of this course the learner is expected

- To understand the components of the climate system and feedbacks to climate.
- To know the climate associated with different geographical area.
- To learn some global Oscillations and circulations linked with tropical as well as equatorial climate.
- To acquire knowledge about the formation and intensification of Tropical Cyclones.
- To know the basic concept of Indian Monsoon and its variability.

AS-203: General Circulation of the Atmosphere and Ocean

Objective	This course is designed to learn the science behind the different fluid circulation due to change in geographical region. Wind driven mixing and circulation.
Pre-requisites	Physics and Dynamics of Atmosphere and Ocean, Basic Thermodynamics and Fluid Mechanics
Teaching Scheme	

Unit		Hours
I	General circulation of the atmosphere, angular momentum balance; zonal mean and time mean circulations; Walker circulation; zonally asymmetric components of the general circulation; a simple model of Hadley cell, ITCZ; maintenance of general circulation; transport of momentum, heat and moisture fluxes in the atmosphere.	10
II	Atmospheric energetics: Energy equation; internal and potential energies; frictional dissipation of kinetic energy; conversion of potential and internal energies to kinetic energy; available potential energy; Stationary and transient eddies; Lorenz energy cycle.	10
III	Atmospheric response to equatorial heating: Monsoons, ENSOs as explained by Matsuno-Gill solutions; teleconnections of tropical phenomena such as ENSO beyond tropics; Rossby wave source; introduction to decadal phenomenon such as the PDO.	10
IV	The observed mean ocean circulation; inferences from geostrophic and hydrostatic balance; ocean eddies. Wind-driven ocean	10

	circulation; mixed layer of the ocean; theories of wind driven circulation; Sverdrup solution.	
V	Thermohaline circulation; Conveyor belt formation; Abyssal circulation; mixing; Isopycnal and diapycnal mixing; ocean heat budget and transport	10
	Total	50

Reference Books:

1. Roisin, B. C. and J. M. Beckers, Introduction to Geophysical Fluid Dynamics, Academic Press, 2009.
2. Pedlosky, J., Ocean Circulation Theory, Springer, 1998.
3. Marshall J., and R. A. Plumb,Atmosphere Ocean and Climate Dynamics: An Introductory Text, Elsevier Academic Press, 2008.
4. Lorenz, E. N., The Nature and Theory of the General Circulation of the Atmosphere, WMO, 1967.
5. Holton J. R., and G. J. Hakim, Introduction to Dynamic Meteorology, 5th edition, Academic Press, 2012
6. Corby, G. A., The Global Circulation of the Atmosphere, Royal Meteorological Society, 1969.
7. Sverdrup, H. U., M. W. Johnson and R. H. Fleming, The Oceans: Their Physics, Chemistry and General Biology, Prentice Hall Inc, 1942.
8. Neumann, G., and W. J. Pierson, Principles of Physical Oceanography, Prentice-Hall, 1966

Course outcomes: At the end of this course the learner is expected

- To learn some global atmospheric and Oceanic Circulation.
- To understand the different types of energy associated with the atmosphere.
- To know the basic concept of ENSO, IOD, POD etc.
- To understand the theories behind wind driven circulation and mixed layer properties of Ocean.
- To learn the large scale Ocean Circulation and heat budget equations.

AS-204: Remote sensing and GIS in Ocean and Atmospheric Sciences

Objective This course is designed to learn the science behind Remote sensing, and its use in atmosphere and Ocean Science. Use of Satellite and data retrieval processes and GIS technology.

Pre-requisites Thermodynamics, Radiation Physics, Radar and altimeter principle,

Teaching Scheme Basic Geographical Science

Unit		Hours
I	Introduction to remote sensing; basic concepts; electromagnetic radiation; solar and terrestrial radiation; atmospheric effects; absorption; transmission; scattering; spectral response of earth's surface features.	10
II	Remote sensing of atmospheric and ocean variables; atmospheric vertical and limb soundings; remote sensing platforms; satellite orbits- near polar geostationary and sun-synchronous satellites; swath; spatial, temporal, spectral and radiometric resolution; 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	10
III	Visible remote sensing: Theory of ocean colour remote sensing; optical properties of pure water; natural waters and 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-I and their applications. Infrared Remote Sensing: Infrared radiometers; SST retrieval with atmospheric corrections and validation; application; skin and bulk SST; global SST data products.	10
IV	Microwave remote sensing: Theory and principles of microwave radiometry; passive microwave radiometers and its applications in ocean and atmosphere; active microwave sensors; principles; applications of SAR; scatterometers and altimeters for ocean and atmospheric studies.	10
V	Introduction to GIS; creation of point, line and polygon in form of shape file/Geo-database; geo-referencing of satellite data and digitized vector files using GIS software; geo-informatics; integration of attribute data; analysis using map algebra; map composition and finalization; web-GIS; application of ArcGIS and ERDAS.	10
	Total	50

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.

Course outcomes: At the end of this course the learner is expected

- To learn GIS and Remote Sensing techniques.
- To know about different types of satellite and sensors used to retrieve different atmospheric and oceanic parameters.
- To learn visible remote sensing.
- To gain an idea about microwave remote sensing.
- To know the process of satellite data retrieval techniques through different techniques and software.

AS-205: Practical-2: Weather Analysis and Forecasting and GIS and remote sensing Laboratory

Objective This course is designed to learn the use of meteorological instruments, programming languages and weather charts. Further it is designed to learn different type of software that is used in mapping the different classifications of Earth surface.

Pre-requisites Basic programming skills, handle electronic instruments

Teaching Scheme

- ❖ Meteorological instruments, sensors, radiosonde, meteorological parameters.
- ❖ GTS, weather codes and decoding of weather observations,
- ❖ Programming languages, Unix & shell programming, data formats, software tools for meteorological data, thermodynamic diagrams,
- ❖ Weather charts, air masses and fronts, jet streams and tropical disturbances;
- ❖ Synoptic features during different seasons, meso-scale systems.
- ❖ monsoon climatology, 850 hPa & 200 hP, ψ and χ fields, mass & wind fields.

- cyclone development, synoptic forecasting.

- **Remote Sensing**
  Remote sensing satellites and various data products (paper product & Digital), False Color Composition & Natural Composition, Formulation of Interpretation Keys, on screen Visual Image Interpretation. Satellite digital data Formats, Geo-referencing of Digital Image. Image enhancement techniques, Image ratio and image classification. Land, Ocean and Atmosphere Remote Sensing Data Formats, Processing, Interpretation & Analysis. GIS software, Creation of point, line and polygon in form of shape file/Geodatabase, Geo-referencing of satellite data and digitized vector files using GIS software, Geo-Informatics (Pction of Geo-database, Integration of attribute data, Analysis using Map algebra, Map composition and finalization, Web-GIS.

Course outcomes: At the end of this course the learner is expected

- To learn about meteorological instruments.
- To know the process of data acquisition system used by IMD.
- To learn the different Remote sensing and GIS techniques.

Third Semester

AS-301: Boundary Layer Processes and Air Pollution studies

Objective This course is designed to learn the importance of lower atmospheric layer in weather and climate variability. Study of Atmospheric Heat transfer, turbulence motion and air pollution of the lower atmosphere.

Pre-requisites Dynamics of Atmosphere and Ocean, Mathematical physics.

Teaching Scheme

Unit		Hours
I	Introduction: definitions and background; variables; wind and flow; turbulent transports; Taylor's hypothesis and observing techniques; 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.	10
II	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.	10
III	Deep convection and marine boundary layer: Controls on deep convection; MABL modification by downdrafts; boundary layer recovery; boundary layer modelling and parameterizations.	9
IV	Physical interaction between ocean and atmosphere; wind stress and drag coefficient with respect to wind speed; momentum transfer, atmospheric impact on oceanic circulation.	9
V	Air pollution: definition, sources, classification. Dynamics of pollutant dispersion and disposal. Effects on environment including living and non-living matter, ambient air quality monitoring techniques. Air pollution indices, standards, norms, rules and regulations. Removal processes. An introduction to air pollution meteorology. Air laboratory, High Volume Sampling, handy Sampler, Bio aerosols sampler, Indoor Air Sampler, stack sampling	12
	Total	50

Reference Books:
1. Bigg, G. R., The Oceans and climate, Cambridge University Press, 1996.
2. Kagan, B, A.,Ocean atmospheric interaction and climate modelling, 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, 1999.
7. Toba, Y., Ocean-Atmosphere interactions, Springer, 2003.
8. S. Pal Arya. Air Pollution Meteorology and Dispersion, Oxford University Press.
9. M. Lazaridis. First Principles of Meteorology and Air Pollution, Springer
10. Mark Z Jacobson. Air Pollution and Global Warming: History, Science, and Solutions. Cambridge University Press

Course outcomes: At the end of this course the learner is expected

- To learn the importance of Boundary layer, where most of the life persists.
- To derive the equation for turbulent flow.
- To know boundary layer modelling and parameterization.
- To learn the air-sea interaction processes and atmospheric impact on ocean circulation
- To know the pollution meteorology and dynamics of pollutant dispersion and disposal.

AS-302 (A): Elective-I Numerical Weather Prediction and Extreme weather events

Objective This course is designed to learn how to predict the weather, basically forecasting the weather and climate. Introduce the science of formation and prediction of Tropical cyclone, Tornado, heat wave, cloud burst etc.

Pre-requisites Dynamics of Atmosphere and Ocean, Basic equations used in Atmospheric Science.

Teaching Scheme

Unit		Hours
I	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.	10

II	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.	10
III	Dynamical and Statistical models; ensemble and super ensemble prediction systems; NWP model evaluation, correlation, skills, and bias correction. Extreme weather events, tropical cyclones, thunderstorms, heat waves, heavy rainfall, wildfire, Modelling and understanding the influence of Large Scale environment, Meso-scale processes, Oceanic Influences, Influence of domain size.	08
IV	Initialization and data assimilation: Relevance of observations; model spin-up; statistical framework for data assimilation; successive-correction methods; three-dimensional variational analysis; introduction to 4-D VAR and/or other advanced methods, Specific parametrizations 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.	12
V	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.	10
	Total	50

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. The emergence numerical weather prediction: Peter Lynch, Cambridge University Press, 2006.
7. Haltiner, G. J., and R. G. Williams, Dynamic Meteorology & Numerical Weather Prediction, Wiley, 1980.
8. Krishnamurti, T. N., & L. Bounoua, An Introduction to Numerical Weather Prediction Techniques, CRC press, 2006.
9. Randall, D., An Introduction to Numerical Modeling of the Atmosphere, 2009.

10. Muller, P., and H. V. Storch, Computer modeling in Atmospheric and Oceanic Sciences, Springer, 2004

Additional Reference or Books:

1. Mohanty et al. Monitoring and Prediction of Tropical Cyclones in the Indian Ocean and Climate Change, Springer
2. Y Charabi. Indian Ocean Tropical Cyclones and Climate Change, Springer
3. J. P. Terry. Tropical Cyclones, Springer
4. Kantha and Clayson. Small Scale Processes in Geophysical Fluid Flows, Academic Press
5. Eric P. Chassignet and J. Vernon. Ocean Modeling and Parameterization, Springer
6. Z. Kowalik& T. S. Murthy. Numerical Modeling of Ocean Dynamics,World Scientific Pub

Course outcomes: At the end of this course the learner is expected

- To Know the history of numerical weather prediction model.
- To learn the modelling techniques used in atmospheric science.
- To know dynamical and Statistical models; ensemble and super ensemble prediction systems.
- To learn model initialization and data assimilation techniques
- To know the science behind the extreme weather events.

AS-302(B): Elective-I: Data Assimilation Techniques

Objective This course is designed to learn the use of the best data to get better forecast. Different schemes and methods to use corrected observed and model output data for modelling purpose.

Pre-requisites Dynamics of Atmosphere and Ocean, Mathematical physics and statistical methods in Atmospheric Science.

Teaching Scheme

Unit		Hours
I	The observing systems: present & future, subjective and objective analysis, function fitting, method of successive correction, Statistical Interpolation; Univariate and multivariate analysis, dynamic and normal-mode initialization, variational methods, variational and ensemble based assimilation, Kalman filtering, sensitivity analysis.	10
II	Grid systems, vertical coordinates, boundary conditions, objective analysis and initialization, spectral methods, parameterizations of sub grid scale processes, singular value decomposition (SVD), Uncertainty analysis, error statistics,	10

	Empirical orthogonal functions, Fourier transforms, wavelet transforms, data assimiliation techniques for the use of mesoscale NWP models, nonlinear aliasing and instability, parameterizations of different physical processes , ensemble forecasting	
III	Objective analysis schemes, continuous data assimilation techniques, Predictability and Ensemble forecasting, Hydrostatic approximation and nonhydrostatic dynamics, basics of mesoscale modeling; mesoscale data assimilation, estimation theory, 3D-/4DVAR shallow water model and its adjoint, radar data assimilation basics, oceanic data assimilation at mesoscale and assimilation of altimetry data.	10
IV	Atmospheric equation of motion in spherical co-ordinates, wave and oscilation in atmosphere, Filtering approximation, Primitive equation and vertical co-ordinate, Shallow water equations, quasi-geostrophic filtering of inertial gravity wave. Initial and boundary value problems, lateral boundary condition for regional 10model, space discretization method.	10
V	Empirical analysis scheme, Introduction to least square method, Multivariate statistical data assimilation scheme, the physical space analysis scheme (PSAS), Advanced data assimilation scheme with evolving forecast error covariance, Dynamical and physical balance in initial conditions, Quality control of observations	10
	Total	50

Text/Reference Books:

1. Eugenia Kalnay. Atmospheric modeling, data assimilation, and predictability, Cambridge University Press
2. Arthur G., J.F. Kasper, R.A. Nash, C. F. Price., A. A. Sutherland. Applied Optimal Estimation, MIT Press
3. Pierre P. Brasseur and Jacques C.J. Nihoul. Data Assimilation: Tools for Modelling the Ocean in a Global Change Perspective, Springer

Course outcomes: At the end of this course the learner is expected

- To learn the statistical interpolation techniques and different type of filtering processes
- To evaluate the uncertainty in NWP model.
- To know different objective analysis schemes.

- To find the initial and boundary value problems.
- To learn the parameterization processes and statistical methods to fulfil the Scientific experiments.

AS-303(A): Elective-II Geophysical Fluid Dynamics

Objective	This course is designed to learn the science of Fluid flow in a rotating frame of references. Science of atmospheric and Oceanic circulation
Pre-requisites	Thermodynamics and Radiation Physics. Radar and altimeter principle.
Teaching Scheme	

Unit		Hours
I	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.	10
II	Waves in the atmosphere and Oceans: Concept of wave motion, acoustic waves, gravity waves, shallow water waves, Tsunami waves, Kelvin and Rossby wave.	10
III	Budgets: Mass budget; momentum budget; energy budget; salt and moisture budgets; Boussinesq approximation; flux formulation and conservative form.	10
IV	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.	10
V	Hydrodynamic instabilities: Barotropic instability and applications; introduction to baroclinic instability; Kelvin-Helmholtz instability	10
	Total	50

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

Course outcomes: At the end of this course the learner is expected

- To learn the different type of circulation and vorticity in atmosphere.
- To know some important atmospheric and oceanic waves.
- To learn mass budget; momentum budget; energy budget; salt and moisture budgets in atmosphere and ocean.
- To know the process of ocean circulation that is affected by wind flow.
- To learn different type of Instability.

AS-303(B): Elective-II Science of Climate Change, Its Impacts and Adaptation

Objective This course is designed to learn the science of climate change and the future prediction of climate. The adaptation and mitigation strategies followed due to the future scenario of climate change.

Pre-requisites Dynamics of Atmosphere and Mathematical physics. Basic knowledge of Climate change parameters.

Teaching Scheme

Unit		Hours
I	Climate change, Causes of Climate Change, drivers of climate change, characteristics of climate system components, greenhouse effect, carbon cycle, general circulation of wind, ozone hole in the stratosphere, ENSO and its teleconnections.	10
II	Impacts of climate in the Indian and Global context; observed and projected changes of IPCC, impacts on water resources, need for vulnerability assessment, related adaptation to climate change in the fields of ecosystems and biodiversity.	10
III	Agriculture and food security, land use and forestry, human health, water supply and sanitation, infrastructure and economy (insurance, tourism, industry and transportation).	10
IV	Adaptation, vulnerability and sustainable development sector-specific mitigation, carbon dioxide capture and storage (CCS); cropland management, afforestation and reforestation.	10

V	potential water resource conflicts between adaptation and mitigation; implications for policy and sustainable development climate variability and implications on disaster risk.	10
	Total	50

References:

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. Adger, W., Lorenzoni, I., & O'Brien, K. (Eds.). (2009). Adapting to Climate Change: Thresholds, Values, Governance. Cambridge: Cambridge University Press. doi:10.1017/CBO9780511596667
4. Intergovernmental Panel on Climate Change (IPCC). (2023). Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press. doi:10.1017/9781009325844
5. Betts, R., Arnell, N., Boorman, P., Cornell, S., House, J., Kaye, N., . . . Wiltshire, A. (2012). Climate change impacts and adaptation: An Earth system view. In S. Cornell, I. Prentice, J. House, & C. Downy (Eds.), Understanding the Earth System: Global Change Science for Application (pp. 160-201). Cambridge: Cambridge University Press. doi:10.1017/CBO9780511921155.009

Course outcomes: At the end of this course the learner is expected

- To learn the concept of climate change due to natural and anthropogenic variables.
- To know the projected changes in future noted by IPCC.
- To learn the changes of natural resources due to climate change.
- To know the adaptation strategies to wards changing climate.
- To learn policy and sustainable development of climate variability for better future.

AS-304 (Open Elective) Disaster and Public Health Management

Objective	This course is designed to learn different type of environmental pollutions, disasters and its management strategies by government agencies. Different type of diseases and their management strategies through the change in life-style and immunity development.
Pre-requisites	General constituents of atmosphere and its dependence upon the living and non-living things. Basic idea about diseases.
Teaching Scheme	

Unit		Hours
I	Environment and its composition, Sustainable use of natural resources, Renewable and non-renewable energy sources, Use of Solar power, Rain-water harvesting. Different type of pollution: Air pollution, Air-act 1981, Plume behavior, Different type of aerosol, Industrial and vehicular Pollution,	10
II	Environmental pollution act 1986, Vehicle scrapping policy, Water pollution, Water act 1974, Biological oxygen demand (BOD), $(BOD)_u$, $(BOD)_{10}$ etc., Oxygen sag curve. Wild-life protection act 1972, Forest conservation act 1980. Population Ecology, Human population growth curve, Natality, Mortality, Immigration, Emigration, Population pyramids,	10
III	Green revolution, white revolution, Chipko movement, Urbanization and its effect on society, Carbon foot print, Greenhouse gases emission strategies adopted by different countries. Agenda 21 of Rio Earth summit, Global warming, Global warming potential, Ozone holes.	10
IV	Disaster management: type of disaster (natural and manmade) and their cause and effect, Vulnerability assessment and Risk analysis of different disaster (Flood, Cyclone, Earthquake, Heat wave and lightening), Survival skills before and after Disaster, Preparedness measure, Disaster management cycle, Institutional arrangement of Disaster management, NDMA, SDMA, DDMA, NDRF and ODRAF.	10
V	Communicable and Non-communicable diseases, Air and water related and vector borne diseases in climate change scenario. Role of Centers for diseases control and Prevention (CDC), Epidemic and Pandemic, Different type of immunity (Active, Passive, Innate, Acquired and Herd Immunity)	10
	Total	50

Reference Books/Articles:

1. Bharucha E: A text book of Environmental studies, New Delhi: UGC
2. Dash MC and Mishra PC: Man and Environment, McMillon, London
3. Disaster Management and Mitigation Plan, 2013 of Dept. of health and Family welfare, Govt. of Odosha.
4. National Policy on disaster Management, 2009
5. Disaster Management Act2005 of Government of India
6. State disaster Management Plan, 2019 of Government of Odisha
7. The Disease Management Act, 2005 of Government of India

8. Standard Operating Procedure (SOP) issued by Government of India and Govt. of Odisha, on Public Health managements in the Website: www.mohfw.gov.in

Course outcomes: At the end of this course the learner is expected

- To know the sustainable use of natural resources
- To learn the different types of pollutions and its management through laws and change in human behaviour.
- To know about the different government agencies and their role during disaster.
- To know the different ways to protect the environment
- To lead a healthy and medicine free life.

AS-305: Practial-3: Model simulation and diagnostics Laboratory

Objective	Learn simulation and experimental techniques that enables them for pursuing research in Earth and Atmospheric science.
Pre-requisites	General computer programming skills. Knowledge of Windows and Linux system.
Teaching Scheme	

Model Simulations and Diagnostics

Simulation of a tropical cyclone using an axis- Symmetric tropical cyclone model (TCM); conducting sensitivity experiments with a TCM to understand the importance of various Grey-Sikka parameters; familiarizing with the models such as the WRF and ROMS; validation of GCM simulations of tropical processes; 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; ensemble forecast system-evaluation of models performance, bias and systematic bias correction; multi-model ensemble forecast

Course outcomes: At the end of this course the learner is expected

- To run a model and simulate different experiments.
- To learn the forecast techniques
- To visualise the propagation of extreme events like Tropical cyclone

Fourth Semester

AS-401: Dissertation (Report, Presentation and Viva-voce) (400 Marks)

Objective In this type of course the student can select any reputed research institute/Laboratory/University to perform project work which can be experimental or theoretical. The student can take up in depth and detailed study of specific topic in Atmospheric Science/Ocean Science/Air-sea Interactions/Extreme events with reputed scientist or professor as major project work for 4 months i.e. from January to April.

Pre-requisites Knowledge of Atmospheric Science

Teaching Scheme General computer programming skills. Knowledge of Windows and Linux system.

Each student will be allotted a small research project during 3rd semester based on their interest. Part of the assigned project work needs to be complete in 3rd semester and the remaining work will be done in the 4th semester.

Course outcomes: At the end of this course the learner is expected:

- To know the research methodology of Atmospheric Physics
- To know technical writing skills
- To know the process to take up research activities from a known topic.
- To get exposure from research laboratory.