Department of Meteorology and Oceanography

Rokkam Ramanadham Laboratoraries

Andhra University

Visakhapatnam

M.Sc. Meteorology

Syllabi and Model Question Papers

(Effective from 2021-2022 Academic year)

Approved Course Pattern and Syllabi w.e.f. 2021-2022 academic year M.Sc. (Meteorology)

First Semester

Course No.	Title of the Paper	Internal assessment marks	Semester end examination marks	Total Marks	Credits
Theory:					
M–101	Physics and Dynamics of Climate	20	80	100	4
M–102	Physical Meteorology	20	80	100	4
M–103	Dynamics of the Atmosphere	20	80	100	4
M–104	Physical Oceanography	20	80	100	4
Practicals:					
M–105	Meteorological computations	20	80	100	4
M–106	FORTRAN Programming	20	80	100	4
M–107	Viva-voce	-	50	50	2
	Total	120	530	650	26

Second Semester

Theory:					
M–201	Dynamical Oceanography	20	80	100	4
M–202	Geophysical Fluid Dynamics	20	80	100	4
M–203	Meteorology and Oceanography Instruments	20	80	100	4
M–204	Synoptic Meteorology	20	80	100	4
Practicals:					
M–205	Ocean Computations	20	80	100	4
M–206	Observational Techniques	20	80	100	4
M–207	Viva-voce	-	50	50	2
	Total	120	530	650	26

Third Semester

Theory:					
M–301	Numerical Weather Prediction	20	80	100	4
M–302	Air Sea Interaction	20	80	100	4
M–303	Applied Meteorology	20	80	100	4
M–304	Tropical Meteorology	20	80	100	4
Practicals:					
M–305	Numerical Weather Prediction	20	80	100	4
M–306	Synoptic Meteorology	20	80	100	4
M–307	Viva-voce	-	50	50	2
M-308	Computer Graphics (MOOC I)	-	-	100	2
M-309	Value added course(Intellectual Property Rights)	-	-	100	2
	Total	120	530	850	30

Fourth Semester

Theory					
M–401	Climate and Ocean Modelling	20	80	100	4
M-402	Satellite Meteorology and Satellite Oceanography	20	80	100	4
M-403	Dynamics of Climate Change	20	80	100	4
M-404	Agricultural Meteorology	20	80	100	4
M-405	Dissertation and Seminar	40	160	200	8
M–406	Viva-voce	-	50	50	2
M-407	Use of Satellite data in Meteorology & Oceanography (MOOC II)	-	-	100	2
M-408	Value added course (Research Methodology)	-	-	100	2
	Total	120	530	850	30
	Grand Total (1+2+3+4 semesters)	480	2120	3000	112

Program: M.Sc. Meteorology

Program Outcomes:

PO1: To impart and acquire the necessary knowledge and hands on training in conducting advance scientific research in the field of Meteorology.

PO2: To develop the contemporary and inculcate scientific approaches with continuous self-learning and collaborative team work.

PO3: To train the students on effective domain specific oral and written communication of scientific knowledge.

PO4: To encourage responsible scientific contributions that abide by academic integrity, adhere to intellectual ethics, and promote sustainable development.

PO5: To create awareness in the public domain about the weather and related disasters and management.

Program Educational Outcomes:

PEO1: To provide quality post–graduation education in Meteorology and to prepare students for entering teaching in degree, PG colleges and Universities, PhD/research programs within India (National laboratories or in R&D wings of various industries/university laboratories) or abroad.

PEO2: To pursue jobs in earth sciences, atmospheric sciences and oceanography laboratories, universities, NIT's, IITs among other related fields.

PEO3: To equip students with the knowledge and ability to solve meteorological problems of social relevance and to know the importance of weather in the real-time prediction like Cyclones, monsoons.

PEO4: To apply their meteorology skill set in prediction of thunderstorms, processes related to micro, macro and synoptic scale to large scale systems with latest numerical models and coupled models, strategic agriculture plan and yield prediction would be conducive to long-term sustainable development.

Program Specific Outcomes:

PSO1: Students will be equipped to understand three fundamental aspects in meteorological aspects: a) what to seek; b) how to seek; c) why to seek?

PSO2: Students will be able to (a) To elaborate concepts of meteorology with measurements; (b) To familiarize with basic laboratory instruments and understand the principle of measurements using those instruments with experiments on real time.

PSO3: Students will be able to (a) Describe fundamental principles of radiation;(b) Understand the basic processes related to convective systems ; (c) Describe the basics of modelling and advance modelling techniques; (d) Understand how genereal circulation and climate change policy making regulations.

PSO4: Students will be able to understand various facets of climate change and global warming that could be employed in early detection and help for policy making.

PSO5: Students will be able to gain hands on experience in different software and visual packages. This experience would enable them to begin a career in the field of meteorology in national and international research laboratories conducting fundamental research.

Program Learning Outcomes:

PLO1: To understand clarity of concepts on weather, climate on different space and time scales.
PLO2: To apply the physics and dynamics in the various convective processes with advanced research methods and modeling studies.
PLO3: Students will work on different type of research applications like agriculture, air pollution, aviation, hydrometeorology and disaster management with critical thinking and communicate the results through oral and scientific written.
PLO4: Student will learn and develop the basic principles of atmospheric and Oceanography instruments to build the hypotheses, to be able to extrapolate observations to conclusions.

PLO5: To be able to apply laboratory and filed experience in the context of getting employment in academic research laboratories as a skilled professional in data analysis and interpretation

Physics and Dynamics of Climate			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-101
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the classical mechanics and thermodynamics	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To address the global climatology and to demonstrate a scientific understanding of the physical and dynamical aspects of Earth's climate system
2. To concentrate on the causes and consequences of global warming and climate change and to impart knowledge on the changing climate over India
3. To evaluate the role of green house gases.

M.Sc. Meteorology
M-101/PO-101: Physics and Dynamics of Climate

Unit-I:
Introduction: Weather and climate concepts - World climate system - climate of the hemispheres. Global distribution of temperature, precipitation, pressure and winds - Circulation pattern during winter and summer seasons. Jetstreams. Monsoons: Asia, Australia, E. Africa and North America; Systems of climatic classification - Koppen - Thornthwaite.

Unit-II:
General circulation of the atmosphere - convective and meridional circulation - Rossby's Tricellular model - Palmen's modified model - Circulation indices - Experiments of General Circulation – Dishpan experiment; Dynamics of atmospheric circulation - Maintenance of the General circulation – Kinetic energy, angular momentum, absolute vorticity balance. NAO and Pacific oscillations.

Unit-III:
Global warming – Causes and consequences of global warming; Greenhouse effect, Effect of global warming on Indian monsoon systems, Volcanic eruptions and aerosols, Ozone hole; Acid rains, Nuclear winter, IPCC, Montreal Protocol, Kyoto Protocol and Copenhagen Protocol

Unit-IV
Fundamentals of Climate change - local and planetary evidences - carbon dating - theories of climate change; Paleoclimate - Climate change and variations in Earth's orbit; Climate trends - ENSO - Teleconnections of the world climate system - Impact of climate change on weather and climate; Climate change and agriculture.

Unit V:
Wind, temperature and rainfall distributions over India in summer monsoon and winter monsoon seasons. Observational evidence of climate change over India. Effect of global warming on Indian summer monsoon and

winter monsoon. Anomalous behaviour of Indian monsoon system. Extremes in Indian summer monsoon and winter monsoon seasons.

Text Books:

1. Physical climatology, William D. Sellers.
2. Climatology - Bernhard, Haurwitz and James M. Austin.
3. Dynamical and physical Meteorology, George J.Haltiner and Frank L. Martin.
4. Physics of monsoon, Keshava Murthy and Sankar Rao
5. Essentials of Meteorology – C. Donald Ahrens
6. Global Physical Climatology by Dennis L. Hartmann
7. Global Warming- The complete briefing by Sir John Houghton

Upon the successful completion of the course will provide		**Cognitive Level**
CO1	Knowledge on the Physics and Dynamics of climate in the regional scale and global scale	Understanding
CO2	Knowledge on the causes and consequences of global warming.	Understanding
CO3	Knowledge on the climate change effects and changing climate scenarios over India.	Understanding
CO4	This course is useful for planning and taking precautionary measures in the perspective of extreme weather, global warming and global climate change with special emphasis on India.	Analysing
CO5	The students will realize the importance of clean atmosphere, how to minimize the effects of global warming and climate change and how to combat with today's burning problem of global warming.	Analysing

Course Specific Outcome (CSOs)

CSO1 Students become familiar with global climatology, feedbacks leading to global warming and climate change.

CSO2 Student can understand the role of green house gases and learn the measures to be taken to reduce the effect of global warming.

CSO3 Students can understand their role to combat with global warming and climate change.

Learning Outcomes (LOs)

LO1: After the course, students will have broad understanding on the regional & global climatology and global warming, global monsoons, climatic classifications.

LO2: General circulation of atmosphere and its dynamics will be learned.

LO3: Causes and consequences of Global warming will be demonstrated

LO4: Evidences and impacts of climate change will be taught.

LO5: Students will learn the Climate change over India with special reference to the global warming.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Physical Meteorology			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-102
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the classical mechanics and thermodynamics	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To provide the knowledge on Physics of the atmosphere
2. To impart the knowledge on radiation and mechanisms of the various convective systems.
3. To demonstrate the cloud classification and formation mechanisms in cold and warm clouds
4. To evaluate the role of cloud physics and artificial rain making experiments.
5. To impart knowledge on thunderstorm characteristics through advanced research.

M.Sc. Meteorology
M-102/PO-102: Physical Meteorology

Unit-I:

The atmosphere- Composition of the atmosphere- major components- carbon dioxide, water vapour, aerosols, ozone and ozone depletion. Vertical thermal structure of the atmosphere-Scale height, Troposphere, Stratosphere, Mesosphere, Ionosphere, Thermosphere and Exosphere. Gas laws, Virtual temperature, the Hydrostatic equation, Geopotential, Hypsometric equation.

Unit-II:

The first law of Thermodynamics- joules law, Specific heat enthalpy. Adiabatic processes –concept of an air parcel, the dry adiabatic lapse rate, potential temperature, thermodynamic diagrams. Water vapour in air – moisture parameters, latent heat, saturated adiabatic and pseudo adiabatic processes, saturated adiabatic lapse rate. Static stability- unsaturated air, saturated air, conditional and convective instability. The second law of thermodynamics – entropy, the Clausius and Clapeyron equation

Unit-III:

Radiation: The spectrum of radiation – Black body radiation- Planck function, Wien's displacement law, Stefan Boltzmann law, radiative properties of non black bodies, Kirchhoff's law, green house effect. Scattering and absorption by air molecules and particles; Atmospheric windows, solar constant, radiative transfer in atmosphere, radiation balance at the top of the atmosphere, surface radiation budget, and net radiation.

Unit – IV

Clouds and precipitation: Cloud classification, cloud condensation nuclei, curvature and solute effects, growth of cloud droplets by condensation, collision – coalescence. Ice nuclei- Growth of ice particles in clouds Bergeron Findeisen process. Formation of precipitation, drop size distribution.

Unit – V

Artificial modification of clouds and precipitation - modification of cold clouds, modification of warm clouds, hail suppression, fog and cloud – dissipation, thunderstorm electrification – charge generation, lightning and thunder, global electric circuit. Nucleation scavenging, precipitation scavenging.

Text Books:

1. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin
2. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2
3. Physical Meteorology - H.G.Houghton
4. Atmospheric Thermodynamics - J.V.Iribarne and W.L.Godson.
5. J.M. Wallace, P.V. Hobbs, Atmospheric Science, 2nd ed., Academic Press
6. Meteorology for scientists and engineers –Roland B. Stull
7. Essentials of Meteorology – Donald Ahrens

Upon the successful completion of the course will provide		**Cognitive Level**
CO1	To understand the composition of the atmosphere, vertical structure of the atmosphere.	Understanding
CO2	To derive the hydrostatic , geopotential and hypsometric equation	Analyse
CO3	To Apply the first and second law of thermodynamics in Physics of the atmosphere, moisture parameters and stability of the atmosphere.	Analyse
CO4	To understand the spectrum of radiation, black body radiation and related laws, absorption, scattering and radiation balance of the surface and top of the atmosphere and radiation budget components.	Understanding
CO5	To understand the cloud formation, classification of clouds, growth of the raindrops, ice particles in warm and cold clouds. To understand the artificial modification of clouds and thunderstorm electrification.	Understanding

Course Specific Outcomes (CSOs)

1.To understand the basic structure of the atmosphere.
2.To understand the fundamentals of first law of and second law of thermodynamics.
3.To study Electromagnetic spectrum and radiation budget components at surface and top of the atmosphere.
4.To understand the physical mechanism of cloud formation in warm and cold clouds.
5.To understand the artificial rain making in clouds, Thunderstorm electrification.

Course Learning Outcomes (C LOs)

1. Student will learn composition of the atmosphere, quantification of scale height and applications of the hydrostatic equation.
2. Student will learn adiabatic and isothermal process, thermodynamic diagrams.
3. Student will learn atmospheric attenuation, absorption, scattering and radiative transfer in the atmosphere.
4. Student will learn growth of the raindrop, curvature and solute effects, precipitation mechanism, and classifications cloud droplets by collision and coalescence and Bergeron Findeisen process.
5. This study will help the microphysical characteristics of the clouds and associated thermodynamics in monsoon clouds and severe storms.

Contribution of Course Outcomes towards achievement of Program
Outcomes (1 – Low, 2 - Medium, 3 – High)

	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO1 2	PSO 1	PSO2
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Dynamics of the Atmosphere			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-103
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the classical mechanics and thermodynamics and Mathematics	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To address the dynamics of the atmospheric systems and related forces
2. To derive the different types of circulation systems and their applications
3. To evaluate the role boundary layer and energetics in the dynamics of the atmosphere.

M.Sc. Meteorology
M 103/ PO 103 Dynamics of the Atmosphere

Unit I

Inertial and Non Inertial frames- Fundamental Forces-Pressure Gradient Force, Gravitational Force, Friction or Viscous Force. Apparent forces- Centrifugal Force, Coriolis force, Effective Gravity. Momentum Equations- Cartesian Coordinate System, Spherical–Polar coordinate system. Scale analysis of momentum equations. Hydrostatic approximation.

Unit II

Balanced motion- Geostropic Wind, Gradient wind, Thermal Wind. Continuity equation – Horizontal divergence, Vertical motion. Isobaric coordinate system – Transformation of momentum & continuity equations. Rossby, Richardson, Reynolds and Froude numbers.

Unit III

Circulation & Vorticity – Bjerknes circulation theorem. Applications to Land & Sea breeze. Vorticity equation. Potential Vorticity – Application to Lee of the mountain trough, CAV Trajectories, Scale analysis of Vorticity equation, inertial flow, stream function and velocity potential.

Unit IV

Atmospheric boundary layer: Atmospheric turbulence, Boussinesq approximation, Eddy Transport of heat, moisture and momentum, Reynolds equations, Turbulent kinetic energy; Momentum equations for PBL – well mixed boundary layer, the flux – gradient theory, mixing length theory, Ekman layer, Surface layer, Modified Ekman layer: Secondary circulations; Prandtl layer- Logarithmic Profile Properties of Prandtl Layer.

Unit V

Atmospheric energetics – Energy equation. Kinetic energy. Internal energy, Potential energy, Morgules theory of conversion of Potential & Internal energies into Kinetic energy. Available potential energy, CAPE, CINE. Expression for APE

Text Books

1. An Introduction to Dynamical Meteorology, J.R.Holton

2. Dynamical and Physical Meteorology, G.J.Haltiner and Martin
3. Dynamic Meteorology, Ed.Wiin Nielsen, WMO Publication
4. Dynamic Meteorology, B.Haurwith
5. Atmospheric and Oceanic Fluid Dynamics by Geoffrey K Vallis

COS	**Upon the successful completion of the course will provide**	**Cognitive Level**
CO1	Students will have a firsthand knowledge about the application of basic fluid dynamic principles on the atmosphere and ocean.	Analysing
CO2	Students learn about the different kinds of atmospheric motions and about the boundary layer which forms a crucial part of the vertical structure of the atmosphere.	Knowledge
CO3	Along with the various energetic terms involved in the maintenance of atmospheric circulations.	Understanding

Course Specific Outcomes (CSOs)

1. In this course, students will learn about the various forces acting on the atmosphere and its evaluation along with the fundamental equations derived in different coordinate systems.
2. They will learn about the different types of winds in the tropics as well as the extra-tropics. In addition they will learn about the basic fluid structure of the atmospheric flow patterns.
3. The lowest component of the atmosphere which is the boundary layer that is crucial for many activities of human beings will also be learnt.
4. Lastly in this course, students will get to know the various types of energies associated with the atmospheric flow, their evaluation and their conversion from one form to another.

Course Learning Outcomes (CLOs)

1. Students who finish this course will have an opportunity to work as researchers in various laboratories doing fundamental research in meteorology and oceanography and can find a place as faculty members in different educational institutions.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

Physical Oceanography			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-104
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the classical mechanics and thermodynamics	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To address the Physical characteristics of Ocean
2. To derive the currents, circulation and waves in the world oceans
3. To Understand the water mass characteristics and marine biology and its applications

M.Sc. Meteorology
M-104: Physical Oceanography

Unit I:

Physical properties of seawater: Temperature, Salinity and Density; Temperature, Salinity and density distributions. Transparency of seawater, Sound in the sea, Light in the sea, Colour of seawater, Sea Ice. and anomalous properties of water.

Geographical distribution of T & S.

Unit II:

Waves: wave parameters, deep water waves, shallow water waves, transformation of waves in shallow water, wave generation and dissipation, wave theories.

Tides: tide producing forces, Types of tides, tidal theories. major tidal constituents-prediction of tides

Unit III:

Ocean circulation: wind induced currents, Upwelling, sinking; equatorial current system, warm and cold currents of major world ocean, seasonal currents in North Indian Ocean, west ward intensification of currents.

Unit IV:

Water masses: T-S diagram, Characteristics of water masses, Deep circulation water masses, Major water masses of the world oceans, Thermohaline circulation.

Unit V:

Marine geology: Continental shelf, Slope, Shelf sediments, submarine topography, mid oceanic ridge system, gas hydrates, manganese nodules, Bay of Bengal fans.

Marine biology: Classification of marine environment, Biogeochemical cycles. Influence of Physical parameters (Temperature, salinity, waves, currents, tides etc.). Nitrogen, Phosphorus and Silica controls, Residence time of elements in sea water. Marine Ecosystem: Mangroves, Coral Reefs.

Text books:

1. Introduction to Physical oceanography by M.P.M.Reddy.
2. Introduction to Physical oceanography by Robert.H.Stewart.

3. Introduction to dynamical oceanography by S.Pond and G.L.Pickard.
4. Oceans by Sverdrup, Johnson and Flemming.
5. Friedrich, H.: Marine Biology

COs	**Upon the successful completion of the course will provide**	**Cognitive Level**
CO1	General geographical taxonomic of physical properties related to world oceans	Understanding
CO2	Understanding the classification of waves and tide in the ocean	Knowledge
CO3	Analysing upwelling and ocean circulation, identify the hotspots which are key to Blue economy.	Analysing
CO4	Properties of western and eastern boundary currents.	Analysing
CO5	Understanding Marine biology particularly coastal area helps to initiate new pharma industry.	Understanding

Course Specific Outcomes (CSOs)

CSO1:Sea Ice formation, thermodynamics properties and its role on climate change .
CSO2:Transformation of waves near coastal shallow waters, their role on shoreline changes.
CSO3:Location and distribution of ocean minerals, clear energy sources (Gas Hydrates, manganese nodules ...) key role in Deep ocean mining and economy of the Country.
CSO4: Coral reef subsurface ecosystem, its classification and importance.
CSO5: How to protect Mangroves and its significance.

Course Learning Outcomes (CLOs)

LO1: Military (Submarine, Ships), Civilian (Ex. Fishing Industry) and Research applications.
LO2: Knowledge and understanding of density changes of major oceans.
LO3: Mathematical derivation of tidal, wave equations and its applications.
LO4: Waves and tides role in development or construction of any harbour or port in coastal area.
LO5:Using ocean circulation information understand the mass transport from one basin to another basin.
LO6: Transport of mass and heat from strong warm currents and its role on global climate.
LO7: Identifying the water masses, characteristics and its classification helps to understand the long-term changes (100 to 1000 years) in thermohaline circulation and its effect on global climate.
LO8: Understanding the health of coral reef gives at what rate ocean is warming.
LO9: Knowledge about the Ocean bathymetry and its classification.

Contribution of Course Outcomes towards achievement of Program
Outcomes (1 – Low, 2 - Medium, 3 – High)

	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO1 2	PSO 1	PSO2
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Meteorology Computations			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-105
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the classical mechanics and thermodynamics	Internal Assessment Semester End Examination Total Marks	20 80 100
COURSE OBJECTIVES			
1	To derive the dynamics and thermodynamics application using different kind of meteorological parameters.		

M.Sc. Meteorology
M 105/ PO 105 Meteorology Computations
Practical

1. Calculation of horizontal divergence from wind data
2. Calculation of absolute vorticity from wind data
3. Calculation of geostrophic wind
4. Calculation of gradient wind
5. Calculation of thermal wind
6. Calculation of vertical velocity
7. T - Φ gram analysis: analysis of aerological data
8. Potential temperature
9. Equivalent temperature
10. Equivalent potential temperature
11. Lifting condensation level
12. Equilibrium level
13. Stability indices

COs	**Upon the successful completion of the course will provide**	**Cognitive Level**
CO1	first-hand knowledge of computing various physical and dynamical parameters of the above subjects.	Knowledge
CO2	handling of datasets relating to the various meteorological conditions.	Handling

CSOs: The students who have successfully gone through this course will have

CSO1: A capacity to have a knowledge of estimating the winds, the stability conditions and circulation features associated with different weather patterns.

Course Learning Outcomes (CLOs)

LO1: Students by learning the various techniques and practical implications will now be empowered to work independently in a forecasting center or a research institute.

LO2: One of the key components of the learning outcome of this course is to have knowledge of identifying the weather patterns of different seasons.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2

FORTRAN Programming			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-106
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the computer science, Mathematics.	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To learn the fortran programming for various applications in the fluid dynamics.
2. To understand the importance of Fortran programming in the field of meteorology and Oceanography.
3. To understand the flow charts, data types, structures and arrays in the Fortran language.

M.Sc. Meteorology
M-106/PO - 106: FORTRAN programming

1. Correlation Coefficient and Linear Regression
2. Multiple Regression
3. Analysis of Variance (ANOVA)
4. Gauss Siedel Iterative Method
5. Newton Raphson Method
6. Simpson's $1/3^{rd}$ Method
7. Program for computation of winds

Upon successful completion of the course, the student will be able to:		**Cognitive Level**
CO1	**Understand the** basic structures of the Fortran programming.	**Understanding**
CO2	Update the knowledge on advance computational methods and applications.	**Knowledge**

Students will acquire the course specific outcome(CSOs)

CSO1 To understand the importance of Fortran programming in the field of meteorology and Oceanography.
CSO2 To understand the flow charts, data types, structures and arrays in the Fortran language.
CSO3 To study correlation coefficient, Regression and analysis of variance programs
CSO4 To understand the advanced computational techniques like Gauss Siedel Iterative method and Newton Raphson and Simpson's 1/3 method.

Students after completing this course will be able to (CLOs)

CLOs-1 Discriminate the Fortran data types, if then, while-do statement, structures and arrays.
CLOs-2 Apply their programming skills in different applications related to atmosphere and Ocean studies.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2

Viva-Voce			
Common syllabus for M.SC Meteorology/Physical Oceanography - I semester			
Course Category	Basic Science core course	Course Code	M-107
Course Type	Viva-Voce	Lectures-Training-Practical	3-1-0
Prerequisites	Knowledge on Physical oceanography and applications	Total Marks	50

COURSE OBJECTIVES
To evaluate the performance and knowledge of the student orally in the field of meteorology and Oceanography. To get the better placement opportunities and better performance in future.

COs	**Upon successful completion of the course, the student will be able to:**	**Cognitive level**
CO1	Student can improve softskills , communication skills	Knowledge
CO2	Student can able to demonstrate the specific knowledge on the specialised area	Analysis
CO3	This viva-voce will help for his career progression to enhance profession etiquette	Analysis

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

Second Semester

Dynamical Oceanography			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-201
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Physical Oceanography	Internal Assessment Semester End Examination Total Marks	20 80 100
COURSE OBJECTIVES			
1. To impart the knowledge on circulation systems in the Ocean **2.** To learn physical and dynamical behaviour of the waves **3.** To derive the mathematical equations for various applications in Oceans			

M.Sc. Meteorology
M-201: Dynamical Oceanography

Unit I:
Geostrophic currents: Barotropic and baroclinic fields, relative and slope currents, level of no motion, computation of relative currents in a two layer motion and in stratified ocean, Bjerkne's circulation theorem

Unit II:
Currents without friction: Inertial motion, Geo potential, Geo potential surface and Isobaric surface, potential temperature, Margules's equation for two layer ocean, level of no motion and absolute currents.

Unit III:
Currents with friction: Ekman's solution to the equation of motion with friction present, Ekman transport, bottom friction and shallow water effect, Sverdrup, Stommel and Munk theory of western boundary currents.Vorticity in the ocean.

Unit IV:
Waves: refraction and breaking in shallow water, Tsunamis, internal waves, effects of rotation-Kelvin, Rossby waves.

Unit V:
Tides: Ocean response to the tide producing forces, tidal analysis, tides at the coast and estuaries, tidal currents, storm surges. Tidal dynamics: Tidal movement, amplification and tidal wave propagation.

Reference books:

1. Introduction to dynamical oceanography by S.Pond and G.L.Pickard
2. Fomin, L.M. 1964. Dynamic method in oceanography. Elsevier publication co.
3. http://www.sciencedirect.com/science

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive Level
CO1	Physical and dynamical behaviour of internal waves, they play key role on submarine navigation.	Understanding
CO2	Derivation of Bjerkne's circulation theorem and its applications.	Analysing
CO3	Mathematical explanation (Margule's equations) of Ocean fronts and eddy dynamics. It is key to mesoscale Ocean modeling.	Knowledge
CO4	Ocean general circulation, its different theories and evaluation.	Understanding
CO5	Derivation of Ekman's theory and its solutions to equation of motion	Analysing

CSO	**Course Specific Outcomes (CSOs)**
CSO1	Ocean thermodynamic process and potential temperature
CSO2	Role of wave refraction on coastal deposition and erosion
CSO3	Tsunami information helps the Disaster management department (National and State). Relation between coastal kelvin waves and fresh water inputs to ocean
CSO4	Mathematical explanation (Margule's equations) of Ocean fronts and eddy dynamics. It is key to mesoscale Ocean modeling
CSO5	Mathematical explanation of inertial motion in the ocean and its trajectories

Course Learning Outcomes (CLOs)

LO1	Understanding and examining the wave refraction and wave breaking, it helps to Shipping and port Industry.
LO2	Understand the adiabatic processes in the vertical column of the ocean.
LO3	Knowledge on tsunami formation and its inundation.
LO4	Fundamentals of tsunami sources and its formation, propagation.
LO5	Storm surge characteristics and its prediction, it is also come under Disaster Management Rossby waves, its characteristics.
LO6	Behaviour of tidal currents in coastal connecting fresh water body.
LO7	Effect of vorticity on ocean circulation its different forms.
LO8	Practical knowledge on relative currents computation.
LO9	Tidal analysis techniques and its amplification process

Contribution of Course Outcomes towards achievement of Program
Outcomes (1 – Low, 2 - Medium, 3 – High)

	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO1 2	PSO 1	PSO2
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Geo-Physical Fluid Dynamics			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-202
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Physical and classical mechanics	Internal Assessment Semester End Examination Total Marks	20 80 100

COURSE OBJECTIVES

1. To learn the fluid dynamics and its application in atmosphere and Oceans.
2. To understand the wave motions in simplified equations .
3. To identify the barotropic and baroclinic instability in mean flow

To understand the relationship between the middle atmosphere and wave flow interaction in fluid dynamics

M.Sc. Meteorology
M 202/PO 202 Geophysical Fluid Dynamics

Unit I

Wave motion in the Atmosphere: Linearized equations, vertical sound waves, horizontal sound waves and internal gravity waves, surface gravity waves, inertial gravity waves, inertial oscillations, Rossby Waves, Gravity waves, the geostrophic adjustment process, equatorial wave theory.

Unit II

Simplified Equations for Ocean and Atmosphere: Geostropic Scaling, The Planetary, Geostrophic Equations, The Shallow Water Quasi Geotropic Equations, The Continuously Stratified Quasi Geostrophic System, Quasi geostrophy and Ertel potential vorticity, Energetics of Quasi Geostrophy, Rossby Waves, Rossby Waves in Stratified Quasi Geostrophic Flow

Unit III

Barotropic and Baroclinic Instability: Kelvin Helmholtz Instability, Instability of Parallel Shear Flow, Necessary Conditions for Instability, Baroclinic Instability, Linearized Quasi Geostrophic Equations, The Eady Problem, Two Layer, Baroclinic Instability, An Informal View of the Mechanism of Baroclinic Instability, The Energetics of Linear Baroclinic Instability, Beta, Shear and Stratification in a Continuous Model

Unit IV

Wave–Mean Flow Interaction: Quasi geostrophic Preliminaries, The Eliassen Palm Flux, The Transformed Eulerian Mean, The Non-acceleration Result, Influence of Eddies on the Mean Flow in the Eady Problem, Necessary Conditions for Instability. Charney -Drazin Theory.

Unit V

Middle Atmosphere Dynamics: Structure and Circulation of the Middle Atmosphere. The Zonal Mean Circulation, Vertically propagating Planetary waves, Sudden Stratospheric warmings, Waves in the Equatorial Stratosphere. The Quasi Bienniel Oscillation.

Text Books

1. Introductory dynamical Oceanography, Stephen Pond, G.L. Pickard
2. Atmospheric and Oceanic fluid dynamics, Geoffrey, K. Villas
3. Numerical Weather Prediction, G. J. Haltiner

COs	**The students pursuing this course will learn about the application of fluid dynamics to the**	**Cognitive level**
CO1	Frame work of the two fluids atmosphere and ocean of the planet Earth.	Understanding
CO2	This course will facilitate the students to get expose to the various facets of the combined system of earth's atmosphere and ocean.	Analysing

Course Specific Outcomes(CSOs)

CSO1 This course will teach about the different kinds of waves associated with the atmosphere and ocean

CSO2 The equatorial wave theory and the processes involved in the mid-latitudes will be taught.

CSO3 In this course the fundamental equations associated with the Earth's ocean and atmospheric system and the various instabilities in the atmosphere and ocean will be taught

CSO4 The necessary conditions in the wave mean flow interaction and the associated theories will also be taught.

CSO5 Apart from the tropospheric dynamics, the stratospheric dynamics and its influence on Earth's atmosphere and ocean will also be taught.

Course Learning Outcomes (CLOs)

1. Students of this course will find a suitable employment in various research centers like the Indian Institute of Tropical Meteorology (IITM) and the Geophysical Fluid Dynamics Laboratories (GFDL).

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2

Meteorology and Oceanography instruments			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-203
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Electronics and Physical meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. The instruments that are used to find the state of atmosphere and ocean at some given time. 2. Meteorological and Oceanographic instruments are the equipment used to measure different atmospheric parameters like temperature, humidity, pressure, wind speed, salinity, ocean currents and wave height.

M.Sc. Meteorology

M-203/ PO-203. Meteorology and Oceanography instruments

Unit-I

Measurements of air temperature - Liquid in glass and electrical resistance thermometer.Measurement of atmospheric pressure – kewpattern barometer, corrections of mercury barometer reading and aneroid barometer. Measurement of humidity - psychrometer, dew point hygrometer, electrical resistive hygrometer.

Unit-II

Measurement of surface wind- wind wane, cup anemometer, sonic anemometer.Measurement of precipitation-non recording rain gauges, tipping bucket gauge, optical rain gauge.Measurement of radiation-Pyrheliometer, Pyranometer, net radiometer. Measurement of upper air-pressure temperature and humidity, radio sonde, upper air wind - GPS system, pilot balloon observations.

Unit –III

Ground based remote sensing - Lidar, radar, Principles of radar, weather radar, precipitation estimation, radar equation for precipitation targets, Doppler radar-velocities measurements. Basic concept of satellite sensors – advanced very high resolution radiometer-AVHRR, advanced microwave sounding unit-AMSU, scatterometer, synthetic aperture radar, altimeter, ocean color monitor, passive microwave radiometer.

Unit –IV

Marine observations- method of observation of atmospheric pressure, air temperature, humidity, wind, precipitation, salinity and sea surface temperature on board ships. Hydrographic instruments- echo sounder, CTD

Unit-V

Measurement of dynamic properties of the sea-current meter and wave measurements, tide gauges. Platforms for ocean measurements-research vessels, mooring, satellites – geostationary, polar orbiting, sea glider, Argo floats.

Text Books:

1. Guide to Meteorological and Oceanographic Instruments. WMO – No. 8
2. Meteorological instruments – Knowles Middleton and Athelstan F. Splihaus
3. An introduction to Meteorological instruments and measurement – Thomas D. Defelice
4. http:// www.es.flinders.edu.au

5. Satellite Oceanography – An Introduction to Oceanographers and Remote Sensing scientists. I.S.Robinson, Ellis Forward Limited.
6. Descriptive Physical Oceanography by M.P.M. Reddy

COs	In this course, the candidate will familiarise himself	Cognitive level
CO1	basic parameters like temperature, pressure, and humidity, which are the basic parameters observed in the earth's atmosphere. The student will also learn the fundamental parameters of the atmosphere, namely the wind, its direction, and wind speed.	Understanding
CO2	The design of the instruments that measure the wind and the various types of instruments are taught here. The student will also learn about the different types of rain gauges used in the measurement of rainfall.	Knowledge
CO3	In addition they learn about the pilot balloon observation techniques used in radio sondes and GPS, which are useful for upper air measurements.	Knowledge
CO4	Ground based remote sensing instruments and the principles of basic satellite sensors	Knowledge
CO5	In addition, to the atmospheric observations, students will learn about the measurements of the different ocean parameters like salinity, SST, and currents by using CTD hydrographer sea gliders and Argo floats.	Understanding
CO6	It is critical to have an accurate observation of the above two fluids in order to define the final characters of the two fluids, such as the atmosphere and the ocean to have an accurate observation of the above two fluids.	Analyzing
CO7	The students pursuing this course will get the firsthand knowledge about the various instruments used, their designs, and how to measure the atmosphere and ocean parameters.	Analyzing

Course Specific Outcomes(CSOs)

CSO1: Students know about the various instruments used in measuring both the atmosphere and the oceans.

CSO2: The type of accuracy, calibration and the uses of these instruments will be known.

CSO3: The development, validation, and forecasting of the atmosphere and oceans rely heavily on observational techniques.

CSO4: Oceanographic instruments provide important data about tides and currents, as well as water quality characteristics such as chemical composition and salinity.

CSO5: The student knows how to apply statistical time-space methods used in analyses of geophysical data.

Course Learning Outcomes (CLOs)

CLO1: Students know about the various instruments used in measuring both the atmosphere and the oceans with type of accuracy, calibration and the uses of these instruments will be known. The development, validation, and forecasting of the atmosphere and oceans rely heavily on observational techniques.

CLO2: Oceanographic instruments provide important data about tides and currents, as well as water quality characteristics such as chemical composition and salinity. The student knows how to apply statistical time-space methods used in analyses of geophysical data.

CLO3: The student knows how to analyse and interpret geophysical problems and interaction between the various components in the climate system. The student knows how oceanography connects to relevant areas of mathematics, physics, computer science, geosciences, chemistry and meteorology.

CLO4: The student can apply advanced mathematical, computational and statistical methods to meteorological

problems

CLO5: This course provides an opportunity to the students to get a first-hand experience of the instrumentation used in Atmospheric Sciences.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Synoptic Meteorology			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-204
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Physical and Dynamical meteorology	Internal Assessment	20
		Semester End Examination	80
		Total Marks	100

Course Objectives

1. To demonstrate the structure, development, and decay of synoptic-scale weather systems, air masses and fronts
2. To address the kinematics of wind fields, pressure systems, monsoons, prediction and rain-bearing systems.
3. To provide basic understanding and principles leading to synoptic analysis.

M.Sc. Meteorology

M-204/ PO-204 Synoptic Meteorology

Unit-I:

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, Scales of atmospheric Motions, Weather charts and analysis, synoptic weather forecasting.

Air masses and fronts: Air mass production - Classification - Sources of air masses in winter and summer and their modification. Fronts and frontal surfaces – slope of frontal surface-Principal frontal zones - frontogenesis and frontolysis. Extra - tropical cyclones - formation - Life cycle - Structure and movement. Zonal Index, Anticyclones and blocking.

Unit-II:

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-III:

Kinematics of the wind field: Relation between streamlines and trajectories. Isotachs and contour analysis; tilt & slope of pressure/weather systems with height. Trajectories in moving cyclones and anticyclones. Differential properties of the wind field. Application of geostrophic, gradient and thermal winds, divergence and vertical velocity computations, Confluence, Difluence, Dines compensation

Unit-IV:

Indian monsoons: Land and sea breezes – Definition of monsoon – Monsoon theories, Objective Criteria of onset of southwest monsoon over Kerala**,** Synoptic features associated with onset, withdrawal, active and break situations of southwest monsoon. Rainfall distribution and rain bearing systems during summer monsoon season - monsoon depression, Mid - tropospheric cyclones and Onset vortex. Semi-permanent systems of summer monsoon, Variability of summer monsoon. Prediction of weather elements: Seasonal prediction of monsoon rainfall and date of onset of summer monsoon. Maximum and minimum temperatures – Fog**.**

Unit-V:

Northeast monsoon - onset and seasonal rainfall distribution – rain bearing systems. Storm surge, Prediction of the onset and rainfall of winter monsoon over South Peninsular India, Western disturbances, Extreme weather events over India, Heat waves and cold waves.

Text Books:

1. Weather analysis and forecasting – Vol.1 & 2 by B. Patterson
2. Tropical meteorology by H. Riehl
3. Climate and circulation of the tropics by S. Hasternath
4. Monsoon meteorology by C.S. Ramage
5. Jet stream meteorology by E.R. Reiter
6. Synoptic-Dynamic Meteorology in Midlatitudes: Volume II: Observations and Theory of Weather Systems by Howard B. Bluestein
7. Synoptic Meteorology-A Dictionary of Earth Sciences | 1999 | Ailsa Allaby and Michael Allaby

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	This course will provide knowledge on synoptic weather analysis,	Knowledge
CO2	This course will provide knowledge on the air-masses, fronts, extra-tropical cyclones	Knowledge
CO3	This course will provide knowledge on the kinematics of pressure fields, kinematics of wind fields, Indian monsoon system, prediction and Extreme weather events over India	Knowledge
CO4	This course provides basis for the synoptic analysis of weather systems, prediction of weather, monsoon variability, rain-bearing systems and for the understanding the circulation patterns.	Analysis
CO5	This is useful for the cop planning over India and the sector of generation of hydro-electric power	Analysis

Course Specific Outcomes (CSOs)

CSO1: Students will acquaint knowledge on the three dimensional structure and behavior of the real atmosphere, air masses, fronts and frontal systems

CSO2: tudents can understand the science behind the monsoon and importance of monsoon.

CSO3: Students can get an ability to apply their knowledge to real weather scenarios, crop planning and power generation sectors.

Course Learning Outcomes(CLOs)

LO1: After the course, students will have broad understanding on the analysis of weather charts, classification of air masses and fronts, frontal systems and blocking phenomenon.

LO2: The students will learn the movement of pressure systems, intensification and deepening of pressure systems.

LO3: Kinematics of the wind field, the stream line analysis, application of differential properties of wind field and computations of geostrophic wind, gradient wind and thermal winds, divergence and vertical wind velocities will be taught. This is useful in the weather anyalysis.

LO4: Different phases of Indian summer monsoon , rain-bearing systems, quasi-permanent systems, variability of monsoon and prediction will be learned. It gives good idea for starting of agricultural practices and crop planning.

LO5: Northeast monsoon confined to South Peninsular India will be learned. It demonstrates the rain-bearing systems in NE monsoon season and extreme events. It gives good idea for rabi crop planning.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Ocean Computation Practical			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-205
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Electronics and Physical meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

COURSE OBJECTIVES

1. To derive the shortwave, longwave, latent heat flux, sensible heat flux using atmospheric and Oceanic heat budget equation
2. To derive the physical characteristics of the Ocean
3. To derive the stability criteria and various applications like upwelling and sinking

M-205: Ocean Computations practical

1. Computation of short-wave Radiation at the Ocean surface
   a) Octa model, b) Synoptic approach
2. Computation of Long-wave Radiation at the Ocean surface
   a) Brunt's formula, b) Anderson's formula
3. Computation of Wind Stress at the ocean surface
   a) For different wind speeds (5, 10, 15 m/s),
   b) With variable coefficient of Cd
4. Computation of Latent Heat Flux at the Ocean surface
   a) For different wind speeds (5, 10, 15 m/s)
   b) With variable coefficient of Ce
5. Computation of sensible heat flux at the ocean surface
   a) For different wind speeds (5, 10, 15 m/s)
   b) With variable coefficient of Ch
6. Computation of Atmospheric Heat Budget.
7. Computation of Bowen's ratio.
8. Determination of Density using temperature and salinity.
9. Determination of Specific volume anomaly using S, T and D.
10. Stability and Richardson number.
11. Analysis of temperature data
    a. Vertical profiles
    b. Horizontal profiles
    c. Identification of Upwelling and sinking

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1:	Mathematical calculation of shortwave radiation using two different approaches	Analysing
CO2:	Longwave radiation and its estimation with the help of dual methods.	Derivation
CO3:	Wind stress computation using different wind speed and drag coefficient.	Computation
CO4:	Latent heat flux and role of wind speed, transfer coefficient.	Analysis
CO5:	Role of exchange coefficients on sensible heat flux.	Derivation
CO6:	Estimation of atmospheric heat budget and its variations with locations.	Computation
CO7:	Computation of stability of the water column.	Analysis

Course Specific Outcomes (CSOs)

CSO1	Knowledge on shortwave radiation estimate at particular location
CSO2	Ratio of sensible and latent heat fluxes
CSO3	Specific volume anomaly using hydrographic data.
CSO4	Upwelling and sinking signature from temperature profile.
CSO5	Knowledge on Richardson number and its criteria to determine the stability of the water column.
CSO6	Interpretation and identification of Upwelling and sinking signature from temperature profile.

LOS **Course Learning Outcomes(CLOs)**

LO1	Understand the role of sst and cloud on calculation Longwave radiation
LO2	Relation between different wind speeds and drag coefficients and its effect on Wind stress estimation.
LO3	Knowledge on Latent heat flux and wind speed relation
LO4	Ocean-atmospheric temperature difference role on sensible heat flux estimation.
LO5	Determination of atmospheric heat budget
LO6	Understand the Bowen's ration and role of evaporation
LO7	Significant of Specific volume anomaly and its calculation using vertical temperature and salinity profiles.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2

CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Observational Techniques			
Common syllabus for M.SC Meteorology/Physical Oceanography - II semester			
Course Category	Basic Science core course	Course Code	M-206
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Electronics and Physical meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

COURSE OBJECTIVES

1. This course provides an opportunity to the students to get a first-hand experience of the Instrumentation used in Atmospheric Sciences.
2. Student will handle sophisticated instruments and understand their working principles, maintenance and calibration procedures.
3. Through this course they will gain familiarity with many of the key instruments involved in weather observations.

M-206/ PO-206 Observational Techniques

1. Measurement of atmospheric pressure by Fortin barometer, Kew pattern barometer, gravity and temperature corrections.
2. Computation of MSL pressure and height difference between two stations.
3. Measurement of relative humidity and calculation of actual vapour pressure.
4. Measurement of wind velocity using anemometer and air meter.
5. Determination of wind direction and wind velocity at standard levels using Pilot balloon data.
6. Measurement of Bulk SST and Skin SST, Salinity.
7. Measurement of shortwave and Longwave radiation
8. Plotting the AWS data using Grapher software and Matlab.
9. Mapping of satellite derived data – SST, Air Temperature using Grads software and matlab.

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	To introduce students to different meteorological instruments used for taking atmospheric observations.	Knowledge
CO2	To impart knowledge on measurement techniques and calibration procedures.	Knowledge
CO3	Meteorological instruments are the equipment used to measure different atmospheric parameters like temperature, humidity, pressure, wind speed,	Knowledge
CO4	Meteorological instruments are described as the tools utilized to circumscribe the nature of the environment at any instant.	Analysis
CO5	Experience of operating and calibrating instruments and generating quality data.	Analysis
CO6	Ability to partake and integrate easily in experimental setups w.r.t. both field and laboratory based experiments	Analysis

Course Specific Outcomes (CSOs)

CSO1: Experience of operating and calibrating instruments and generating quality data.
CSO2: Ability to partake and integrate easily in experimental setups w.r.t. both field and laboratory based experiments.

Course Learning Outcomes(CLOs)

CLO1: Understand the history, operation, and use of meteorological instruments those monitor the atmosphere, with emphasis on practical applications.
CLO2: Modern meteorology includes a wide variety of in situ and remote sensing instruments that are designed to observe aspects of our atmospheric environment.
CLO3: Analyzing the resulting data, and producing realistic interpretations using appropriate statistical arguments.
CLO4: This course aims to provide useful reference information in a lecture format but to reinforce practical skills with both group and individual activities.

Contribution of Course Outcomes towards achievement of Program
Outcomes (1 – Low, 2 - Medium, 3 – High)

	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO1 2	PSO 1	PSO2
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1
CO6	3	1	2	-	-	-	-	-	-	-	-	-	1	1

Viva-Voce			
Common syllabus for M.SC Meteorology/Physical Oceanography -II semester			
Course Category	Basic Science core course	Course Code	M-207
Course Type	Viva-Voce	Lectures-Training-Practical	3-1-0
Prerequisites	Knowledge on basics of meteorology and applications	Total Marks	50

COURSE OBJECTIVES
To evaluate the performance and knowledge of the student orally in the field of meteorology and Oceanography. To get the better placement opportunities and better performance in future.

COs	**Upon successful completion of the course, the student will be able to:**	**Cognitive level**
CO1	Student can improve softskills , communication skills	Knowledge
CO2	Student can able to demonstrate the specific knowledge on the specialised area	Analysis
CO3	This viva-voce will help for his career progression to enhance profession etiquette	Analysis

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO1 0**	**PO1 1**	**PO1 2**	**PSO 1**	**PSO 2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

Third Semester

Numerical Weather Prediction			
Common syllabus for M.SC Meteorology/Physical Oceanography - III semester			
Course Category	Basic Science core course	Course Code	M-301
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Dynamics and Physical meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. To understand the various numerical methods
2. To impart knowledge on Quasi-geostrophic and primitive equation models and their applications
3. To understand the role physical processes and role of objective analysis in the numerical weather prediction models

M.Sc. Meteorology
M-301/ PO-301 Numerical Weather Prediction

Unit I

Numerical models – Filtered models: Filtering of sound and gravity wave models: Barotropic model; Equivalent barotropic model; Barotropic instability, Numerical methods – Computation of Jacobian and Laplacian; solution of Helmholtz and Poisson equations using relaxation method; Finite difference method- Forward and centered finite difference methods, semi–implicit method- computational instability.

Unit II

Quasi Geostrophic Models – Barotropic and Baroclinic models, Two level model; Quasi- Geostropic multi level models; Omega equation; Linear balanced model; Nonlinear balanced model. Short, medium and long range weather prediction.

Unit III

Primitive equation models–sigma coordinate system; Two level primitive equation model; multilevel primitive equation models. Introduction to meso scale models: Non-hydrostatic assumption, basic structure of MM5 and WRF models and their applications. Application of satellite and Remote sensing data in NWP.

Unit IV

Representation of Physical Processes. Inclusion of moisture, Kuos method and Arakawa Schubert's method. Boundary layer parameterisation, Deardorff's method. Radiation parameterisation- Representation of radiation in numerical models.

Unit V

Objective analysis- Cressman method, method of optimum interpolation. Initialization; Static initialisation; Dynamic initialisation–Normal mode initialisation, Newton relaxation or Nudging. Nonlinear instability, Aliasing. Arakawa Jacobian. Staggered grid systems. Data Assimilation.

Text Books

1. Numerical Weather Prediction G.J. Haltiner, John Wiley

2. Numerical Prediction and Dynamical Meteorology by G.J.Haltiner , R.T.Williams, John Wiley
3. Numerical weather analysis and forecasting by P.D.Thompson.
4. An Introduction to Dynamical Meteorology, J.R.Holton
5. Introduction to Theoretical Meteorology by S.L. Hess
6. Tropical Meteorology by T.N.Krishnamurti, WMO publications

COs	**M.Sc students of Meteorology course will be taught about the practical aspects of**	**Cognitive level**
CO1	handling the outputs of various Numerical models	Analysing
CO2	Interpreting the results of the various Numerical Weather Prediction products is the main outcome of this course.	Analysing

CSOs **Course Specific Outcomes (CSOs)**

CSO1 The students will be taught the fundamentals of numerical weather prediction and the various finite difference schemes used in the model integration along with the merits and demerits of each scheme.

CSO2 They will also be taught about the design of both the numerical models of the mid-latitudes and the tropical latitudes apart from the nuances of short, medium and long range weather prediction models.

CSO3 The latest meso-scale models and the widely used Weather Research and Forecasting (WRF) model will be learnt and the incorporation of satellite data in NWP models will be taught

CSO4 The important physics parameterizations like moisture, radiation, boundary layer and microphysics and how they are included in the NWP models will be learnt.

CSO5 Data processing, objective analysis and the methods of initialization, various types of grid systems along with data assimilation techniques will be learnt.

Course Learning Outcomes (CLOs)

1. Students who successfully finish this course will find a suitable place as an NWP specialist at the various forecasting centers like the India Meteorological Department (IMD), National Center for Medium Range Weather Forecast (NCMRWF) and various meteorological agencies in and outside India.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Air -Sea Interaction Common syllabus for M.Sc Meteorology and Physical Oceanography - III semester			
Course Category	Basic Science core course	Course Code	M-302
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Physical meteorology and Physical Oceanography, dynamical and synoptic meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. To provide the basic information related to Air-sea Interaction studies
2. To impart knowledge on atmospheric boundary layer, estimation of air sea fluxes
3. To provide a thorough investigation of large scale air-sea interactions and middle latitude interaction with special reference to Indian Monsoon

M.Sc. Meteorology
M-302 Air-Sea Interaction

Unit-I: The significance of Air-Sea Interaction: Atmospheric and Oceanic Interaction at various scales; Concept of Boundary Layer. Barrier Layer, surface Layer, Ekman Layer, Upper ocean boundary layer Atmospheric Heat Budget, Oceanic heat budget.

Unit-II: Estimation of Air-sea fluxes: Drag coefficient, wind stress, heat and moisture exchange coefficients, bulk formula for momentum flux, sensible heat flux and latent heat flux, Physical interaction between the ocean and atmosphere; Oceanic impact on the marine atmospheric circulation.

Unit-III: The Origin of Wind Waves: Properties of Instability Waves, Mixed layers, Thermoclines, Hot towers, Thermodynamics of hot towers, Breaking of the waves.

Unit-IV: Large Scale Air-Sea Interaction: Ocean – Atmosphere interaction in tropics; Characteristics of ENSO; ENSO and Air – Sea coupling; ENSO and the Indian Monsoon, Warm Pool in Indian and Pacific Oceans.

Unit-V:

Role of mid-latitude on Indian monsoon: Rossby wave dynamics, Silk Road Pattern, South Asian High, south Indian Ocean, Indonesian Through Flow, coupled models in air -sea Interaction studies

Text Books:

1. Atmosphere – Ocean Dynamics, Adrian E. Gill, 1992.
2. Climate and Circulation of the Tropics, S. Hasternath, 1988.

3. The Oceans and climate by G.R.Bigg, 1996.
4. Ocean – Atmosphere interaction and climate modeling, Beris A. Kagan, 1995
5. Air-Sea Interaction Law and Mechanisms by G.T. Csanady

Upon successful completion of the course, the student will be able to:		Cognitive level
CO1	Understand the principles of air-sea interaction processes, concept of boundary layer and also can differentiate between atmospheric and oceanic boundary layer.	Understanding
Co2	Derive and analyse the different methods to estimate the air-sea fluxes and the impact of ocean on marine atmospheric circulation.	Analysis
CO3	Learn the instability theories like Bjerkens and Kelvin Helmholtz, mixed layer, thermocline, hot towers and breaking of the waves.	Knowledge
CO4	Define and evaluate the small scale and large scale systems in tropical regions. and coupling mechanisms.	Knowledge
CO5	Distinguish the SSTs over Indian, Pacific and Atlantic Ocean SSTs in ENSO phenomena.	Analysis
CO6	Understand the Indian monsoon characteristics and their relationship with El Nino , IOD conditions.Analyze the basics of the feedback mechanism like cloud-albedo, Bjerkens, WES feed backs.	Understanding
CO7	Analyse the Indian Ocean warming influences the monsoons and other teleconnection parameters like Pacific ocean, walker circulation, current systems	Analysis

Course Specific Outcomes (CSOs)

1. To understand the basic air-sea interaction processes in the different time scales.
2. To derive the air-sea fluxes and physical interaction ,oceanic impact on atmospheric marine circulation.
3. To study the Instability and breaking of waves, Mixed layer dynamics and hot towers.
4. To understand the large scale interaction with special reference to ENSO and its impact on Indian monsoon, warm pool regions in the Pacific and Indian Ocean.
5. To understand the Mid latitude interaction on Indian monsoon and recent developments in the coupled models

Student can learn after completing the course (CLOs)

1. Learn different methodologies to describe the boundary layer.
2. Detail analysis and methods to estimate the drag and wind stress.
3. Application of this study will help them to parameterize the micro scale systems in the boundary layer.
4. Detail analysis of mixed layer and thermoclines .
5. Identify El Nino condition on real-time basis in models as well as in analysis.
6. Adopting of the methodology in recent coupled model simulations on monsoons and can easily analyze by the students.
7. The statistical metrics will be calculated with critical thinking and communicate in oral as well scientific publication.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO1 0**	**PO1 1**	**PO1 2**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Applied Meteorology			
Syllabus for M.SC Meteorology - III semester			
Course Category	Basic Science core course	Course Code	M-303
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100

Course objectives
1. This course aims to enable you to apply theoretical concepts and analytical techniques to the resolution of environmental and socio-economic problems that have an atmospheric origin. **2.** The monitoring of meteorological variables, together with the knowledge and modeling of underlying processes are key to understanding our interaction with the natural environment.

M. Sc. Meteorology
M-303: Applied Meteorology

Unit-I: Air Pollution Meteorology

Sources and Classification of air pollutants, Meteorology and air pollution. Micrometeorological studies in Air pollution - Monin – Obukhov length scale – Effects of air pollution on human health, animals, vegetation, materials and property, acid rains. Ekman-spiral characteristics, Urban Heat islands, Asian brown cloud, Forest fires. Detection of Aerosols. Modelling of Air Pollutants- Box Model, Gaussian Model, diffusion and dynamic models.

Unit-II: Aviation Meteorology

Role of meteorology in aviation, SIGMET, weather hazards associated with takeoff cruising and landing, inflight – icing, turbulence, visibility, fog, clouds, rain, gusts, wind shear and thunderstorms. Understanding the Jet stream. Nowcasting and very short range forecasting. Air masses and fronts: sources, origin and classification of air masses.

Unit-III: Hydrometeorology

Definition and its scope. Hydrological cycle and its components. Storm modelling, Rainfall return periods, PMP models. Rainfall-Runoff models, Flood forecasting, Drought categories and assessment techniques. Fundamentals of the evaporation and Evapotranspiration process, methods to determine evaporation: energy balance, aerodynamic; Penman-Monteith methods. Water balance techniques, stream flow analysis.

Unit-IV: Climate Change

Definition of climates-climate change on different time scales-decadal centuries and millennia. forcing influencing the climate and their variations. Greenhouse gases and global warming – GHGs trend, Global temperature trend, Global distribution of emissions, IPCC. The Kyoto Protocol, Climate change Extreme weather events, The Measurement of Climate Change, Global warming.

Unit V: Basics of Disaster

Disaster-Definition and Significance, Major Disaster events in India. Natural disasters: Famine, Cyclone, Tsunami, Earthquake, Volcanic eruptions, Fire and Rip currents. Disaster mitigation**:** Pre-Post disaster concept and principles of disaster mitigation - Risk assessment-Prevention, rescue and evacuation operations,

Preparedness**:** evacuation, search and rescue operation, FIRSTAID. Impact of disaster on physical, economic, spatial, political and social conditions during, post disaster, recovery and risk assessment.

Text Books:

1 Hydrometeorology - C.J.Wiesner
2 Aviation Meteorology – Navale Pandharinath
3 Atmospheric Chemistry and Physics of Air Pollution- John H. Seinfeld
4 Causes of Climate - J.G.Lockwood
5. Bryant Edwards (2005): Natural Hazards, Cambridge University Press, U.K
6. Carter, W. Nick, 1991: Disaster Management, Asian Development Bank, Manila.

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	Students learning this course will think about the basic elements like air pollutants, there classification, and the source of origin	Knowledge
CO2	In this course, the various weather hazards associated with aviation, the fundamental role of Meteorology, and how to avoid them are taught.	Understanding
CO3	The students will be exposure to the basic hydrological cycle and its components, modeling of rainfall, droughts and flood forecasts and various water balance techniques along with the evaporation process.	Analyse
CO4	The various agreements like the Kyoto Protocol under the aegis of the IPCC in the assessment of global warming	Knowledge
CO5	Natural disasters like cyclones, hurricanes, tornadoes, tsunamis, thunderstorms, winds, earthquakes, and volcanic eruptions ,mitigation and prevention methods .	Understanding

Course Specific Outcomes (CSOs)

CSO1: To develop an understanding the inter linkages of anthropogenic emissions, air pollution and climate.

CSO2: The knowledge of the design of factories and industries and their location will be given in a better and optimum way.

CSO3: Learning about the origin and fate of primary and secondary pollutants, self-cleaning mechanisms and ability to think of new ways to mitigate air pollution.

CSO4: This course learning outcomes includes the measurement of water bodies and the assessment of the inputs of climate change on various aspects of human life and natural and man-made disasters, as well as their mitigation, preparedness, and post-disaster preparedness.

CSO5: This course will prepare you for a career in meteorology-related science and research, with a focus on the use and interpretation of meteorological data and forecasts.

Course Learning Outcomes (CLOs)

CLO1: To develop an understanding the inter linkages of anthropogenic emissions, air pollution and climate.

CLO2: Learning about the origin and fate of primary and secondary pollutants, self-cleaning mechanisms and ability to think of new ways to mitigate air pollution.

CLO3: This course learning outcomes includes the measurement of water bodies and the assessment of the inputs of climate change on various aspects of human life and natural and man-made disasters, as well as their mitigation, preparedness, and post-disaster preparedness.

CLO4: This course will prepare you for a career in meteorology-related science and research, with a focus on the use and interpretation of meteorological data and forecasts.

CLO5: The design of factories in terms of their location, disaster observation of air pollutants, and disaster air pollution models are the learning outcomes. A student learning from this course will be knowledgeable about reducing weather hazards during their aviation operations.

CLO6: Meteorology briefings are an important aspect of aviation Meteorology, and students will find

employment in the Meteorology department.

CLO7: Students of this outcome will be employed as hydrologist by the Central Water Commission and disaster management authorities.

CLO8: Understand the impacts of meteorology on Aviation sector.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Tropical Meteorology			
Syllabus for M.SC Meteorology - III semester			
Course Category	Basic Science core course	Course Code	M-304
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the synoptic meteorology, Physical meteorology and Physical Oceanography	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To demonstrate tropical weather systems with an emphasis on tropical cylones,
2. To impart knowledge on rain-bearing systems and local insteabilites.
3. To provide basic understanding on the easterly waves, inversions, teleconnections and intrasesonal oscillations and variability of monsoon

M.Sc. Meteorology

M-304: Tropical Meteorology

Unit -I:

Global perspective of monsoon, CTCZ, Observational Aspects of ITCZ, ITCZ Theory, ITCZ over Indian ocean - structure and movement. Intraseasonal oscillations: 5-7 day, 30-50 day oscillations (MJO), 10-20 day oscillations. Observational Aspects of MJO, MJO theory, Regional circulation systems: Jet streams and their characteristics, Easterly waves-structure and movement, Trade wind inversion.

Unit II

Monsoon variability: Inter annual variability and decadal variability, Teleconnections of Indian summer monsoon with southern oscillation, El-Nino, La Nina, Indian Ocean dipole mode, NAO, Arctic Oscillation and Antarctica Oscillation, Reversal of monsoon system, winter monsoon.

Unit -III:

Monsoon rain bearing systems: Monsoon trough/CTCZ, Depressions, onset vortex, Mechanism of formation, structure and dynamics; Monsoon Elements; monsoon mesoscale process, seasonal prediction and predictability of monsoon, coupled monsoon system, the role of ocean in the life cycle of Indian monsoon system. Extremes in the monsoon season, Relation between Monsoon Index and Indian summer monsoon, Role of thermal inversion over Western Arabian Sea. ICRP programs with special reference to Indian Monsoon dynamics. Monsoon Mission.

Unit-IV:

Tropical cyclones: structure and mechanics – Life cycle, surface and upper air structures, budgets of momentum and energy, formation and movement – variability of hurricane intensity, Impact of global warming on the frequency of tropical cyclones, Fujiwhara Effect.

Unit-V

Thunder storms – CAPE and CINE, Favourable conditions for severe thunderstorms, influence of vertical wind shear, stability indices, Life cycle and structure of thunderstorm, Dust storm(Andhi), Kalabaisaki, Hail storm. Tornadoes: Tornadoes in Indian subcontinent, structure of Tornado

Text books:

1. Weather analysis and forecasting- Vol.1 and 2 by B.Petterson
2. Tropical meteorology by H. Reihl
3. Climate and Weather in tropics - H. Reihl
4. Climate and circulation of the tropics by S. Hasternath
5. Tropical Meteorology by G.C. Asnani.
6. Monsoon Meteorology P.K Das.
7. The physics of the monsoon R. N. Keshava Murthy and M. Sankar Rao
8. The Asian Monsoon- Bin Wang

COs	Upon successful completion of the course, the student will be able to:	Cognitive level
CO1	This course will provide knowledge on easterly waves, convergence zone and the tropical cyclones.	Knowledge
CO2	This course will provide knowledge on the intra-seasonal oscillations, monsoons and local instabilities like thunder storms and tornados.	Knowledge
CO3	After learning the course, students will have broad understanding on the circulation patterns and rain bearing systems in the tropics	Understanding
CO4	This course is useful for understanding the variability of monsoon on different time scales, rain-bearing systems, teleconnections, extreme weather systems and local instabilities.	Analysis
CO5	This course provides an insight on the waves and synoptic as well as meso-scale weather systems in the Tropics.	Understanding

Course Specific Outcomes (CSOs)

CSO1: Students will acquaint general knowledge on tropical weather systems, monsoons, ITCZ and mesoscale systems

CSO2: Students can understand the science behind monsoon variability and teleconnections.

CSO3: Students can understand the tropical circulation patterns and prediction.

Course Learning Outcomes (CLOs)

LO1: The course demonstrates ITCZ, intraseasonal oscillations, inversions, regional circulations and easterly waves.

LO2: Interannual and decadal variations, teleconnections of monsoon with global parameters will be learned.

LO3: The student gains knowledge on the monsoon rain-bearing systems, predictability of monsoon, relationship of monsoon with the thermal inversion over Arabian Sea and monsoon index.

LO4: The course demonstrates the details of cyclone activity in the tropics and impact of global warming on tropical cyclones.

LO5: The students acquire knowledge on the dust storms, tornados and local instabilities which contribute precipitation.

Contribution of Course Outcomes towards achievement of Program
Outcomes (1 – Low, 2 - Medium, 3 – High)

	PO 1	PO 2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO1 1	PO1 2	PSO 1	PSO2
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Numerical Weather Prediction			
Syllabus for M.SC Meteorology - III semester			
Course Category	Basic Science core course	Course Code	M-305
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. To perform the computation of dynamic variables and functions 2. Application of the computational methods on real-time basis

M-305 Numerical Weather Prediction practical

Part - A

1. Computation of vorticity using geopotential height: Solution of Laplacian
2. Computation of advection : Solution of Jacobian
3. Relaxation for solution of barotropic vorticity equation
4. Preparation of computer code for (3) to obtain tendency field
5. Computation of surface fluxes
6. Numerical computation of LCL
7. Numerical computation of moist adiabatic
8. Computation of heating rates –Kuo scheme
9. Barotropic Instability
10. Baroclinic Instability
11. Cyclone track forecasting using Mesoscale models

COs	**M.Sc students of Meteorology course will be**	**Cognitive level**
CO1	Taught about the practical aspects of handling the outputs of various Numerical models	Analysis
CO2	Interpreting the results of the various Numerical Weather Prediction products is the main outcome of this course.	Analysis

Course Specific Outcomes (CSOs)

CSO1 Practical knowledge acquired through this course mainly focuses on the yielding of NWP outputs from the various models.

CSO2 By learning how to develop the necessary software skills required to design a numerical model for weather prediction.

Course Learning Outcomes (CLOs)

LO1 The main learning objective is to empower the students with first-hand knowledge of predicting weather by numerical weather prediction models.

LO2 The knowledge acquired through this course will put the students in a numerical forecasting center which is a key component of operational Meteorology as well as national centers engaged in forecasting weather on various space and time scales.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Synoptic Analysis Practical			
Common Syllabus for M.SC Meteorology/Physical Oceanography - III semester			
Course Category	Basic Science core course	Course Code	M-306/PO-306
Course Type	Practical	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. To demonstrate the synoptic weather analysis and weather forecasting.
2. To impart knowledge on the tropical synoptic weather systems.
3. To address the analysis of western disturbance.
4. To address the analysis of break monsoon situation.

M-306/PO-306: Synoptic Analysis practical

1. Decoding weather messages of surface and upper air
2. Plotting of surface and upper air data and preparation of weather chart
3. Analysis of surface and upper data
4. Case study of Bay cyclone.
5. Case study of Monsoon disturbance.
6. Case study of western disturbance.
7. Case study of break monsoon situation

COs	The practicals demonstrate the synoptic weather analysis and forecasting of weather	Cognitive level
CO1	It is useful to various sectors like agriculture, power generation, industries etc.	Knowledge
CO2	This course will provide knowledge on the decoding the weather messages of surface and upper air.	Analysis
CO3	This course will provide knowledge on the plotting of surface and upper air data and preparation of weather charts.	Analysis
CO4	Bay of Bengal cyclones are devastating rain-bearing systems which provide copious amounts of rainfall to India. Analysis as well as forecasting of such systems is a challenging task to the meteorologists. Three case studies included in the practicals give an insight on the genesis, development and decay of tropical cyclones and their tracks.	Analysis
CO5	Majority of monsoon depressions in prime monsoon months (July and August) offer good amounts of rainfall in the central parts of India. One Case study of Monsoon disturbance will be studied. This provides knowledge on the distribution of rainfall activity, track and low level as well as upper level circulations in the troposphere.	Knowledge
CO6	Western disturbances are eastward moving rain-bearing systems which provide appreciable amounts of rainfall particularly over Northwest India. The students will learn the distribution of rainfall, movement of disturbance and circulation patterns.	Knowledge
CO7	Break monsoon situations occur in the months of July and August. August is more susceptible to breaks. The features related with the break monsoon situation will be learned.	Analysis

Course Specific Outcomes (CSOs)

The students will understand three dimensional structures of the weather systems and learn how to make a weather forecast.

The students will acquaint knowledge on the distribution of various weather parameters and rainfall in different synoptic weather systems.

The students will gain knowledge on the plotting of surface and upper air data and preparation of weather charts.

Course Learning Outcomes (CLOs)

LO1: The synoptic weather analysis and forecasting of weather using surface and upper data will be taught
LO2: The decoding weather messages of surface and upper air will be demonstrated.
LO3: Plotting of surface and upper air data and preparation of weather charts will be learned.
LO4: The synoptic surface and upper air data for three Bay cyclones will be analyzed.
LO5: The synoptic surface and upper air data for a monsoon depression will be analyzed .
LO6: The synoptic surface and upper air data for a western disturbance will be analyzed.
LO7: The synoptic surface and upper air data for a break monsoon situation will be analyzed.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Viva-Voce			
Common syllabus for M.SC Meteorology/Physical Oceanography - III semester			
Course Category	Basic Science core course	Course Code	M-307
Course Type	Viva-Voce	Lectures-Training-Practical	3-1-0
Prerequisites	Knowledge on Physical oceanography and applications	Total Marks	50

COURSE OBJECTIVES
To evaluate the performance and knowledge of the student orally in the field of meteorology and Oceanography. To get the better placement opportunities and better performance in future.

COs	**Upon successful completion of the course, the student will be able to:**	**Cognitive level**
CO1	Student can improve softskills , communication skills	Knowledge
CO2	Student can able to demonstrate the specific knowledge on the specialised area	Analysis
CO3	This viva-voce will help for his career progression to enhance profession etiquette	Analysis

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO 2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2

Fourth Semester

Climate and Ocean Modelling			
Common Syllabus for M.SC Meteorology/Physical Oceanography - IV semester			
Course Category	Basic Science core course	Course Code	M-401
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. To understand the basic components of the climate models and different types 2. To study the importance of the parameterization in the general circulation models. 3. To know the basic concepts of the Ocean models and the status of ocean models in India.

M. Sc Meteorology

M -401/PO -401 Climate and Ocean Modeling

Unit I

General circulation and climate modeling: Introduction to climate modeling. Energy balance models- their structure; zero dimensional energy balance models; one dimensional energy balance models. Radiative convective models: The structure of Global Radiative convective models: Radiation computation – Short wave radiation, long wave radiation, heat balance at the ground, Convective adjustment; Sensitivity experiments with radiative convective models. Meridional circulation models, mean meridional and eddy transport of energy and momentum.

Unit II

Two dimensional models- zonally averaged climate models – spatial and temporal structure; statistical and dynamical climate models; representation of convection, cloud cover, precipitation, radiation and surface characteristics in 2-D SDMs. Physics in climate models – Radiative transfer, Boundary layer; surface parameterization; Zonal circulation in tropics: climate variability and forcings, feedback processes, low frequency variability, MJO, ENSO, QBO, and sunspot cycles.

Unit III

Three dimensional atmospheric general circulation models – the structure of general circulation climate models. Numerical information – Grid point general circulation models; Phillips experiment. Spectral general circulation models- Spectral method; Triangular and rhomboidal truncation; spectral Transform method. Regional climate models: Formulation; boundary conditions, specific applications-ICTP-RegCM and ETA_Clim. Convection; large scale rainfall.

Unit IV

Introduction to Ocean modeling; Basic equations, wind driven barotropic models, simple thermohaline models, baroclinic models, mixed layer models. Shallow water models. Status of operational models in Indian Ocean: Global ocean models: Modular Ocean model (MOM), Princeton ocean model (POM), Regional oceanic Modelling Systems (ROMS). Interannual variability of ocean fields and its relationship with monsoon.

Unit V

Coupled Ocean Atmospheric Models, Physics in ocean modeling – Shallow water equation, sub-grid scale parameterization, Indian Ocean boundary conditions, model forcing conditions over Indian Ocean.

Text Books

1. A Climate Modelling Primer. A.H Sellers and K. Mc Guffie.
2. Introduction to three dimensional general circulation models. W.M.Washington and Parkinson.
3. Numerical Modeling of Ocean Circulation. Robert N. Miller
4. Numerical prediction and Dynamic meteorology. G.J. Haltiner and R.T. Williams. John Wiley.
5. Atmosphere, ocean and Climate dynamics by John Marshall.
6. Numerical models for Ocean circulation – Pond S. and Bryan.
7. Climate Modeling. Stephen H. Schneider and Robert E.Dickinson
8. Dynamics and modeling of ocean waves – Komen G.J and Cavaleri L.

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	Students of this course will be having a firsthand knowledge about the design of climate models and ocean models.	Understanding
CO2	climate models with reference to Zero dimensional, 1-Dimensional and 2-Dimensional climate.	Analysis

Course Specific Outcomes (CSOs)

Students pursuing this course will be learning about the

1. They will also learn about the general circulation modeling of the entire Earth's atmospheric system. In addition to this, they will learn about the nuances of designing standalone ocean model.
2. After learning this they will be in a position to design coupled ocean-atmospheric models which is the state of the art in climate modeling as per the agenda of the Inter-governmental panel on Climate Change.

Course Learning Outcomes(CLOs)

1. Students successfully finish this course will find a place as a climate scientist and researchers in the World Meteorological Organization, National climate centers and the other leading climate institutes in India and abroad.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2

Satellite Meteorology and Satellite Oceanography			
Common Syllabus for M.SC Meteorology/Physical Oceanography - IV semester			
Course Category	Basic Science core course	Course Code	M-402
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives
1. The aim of this course is to give the students a broad knowledge of different remote sensing techniques in meteorology and oceanography, with special focus on satellite measurements. 2. In addition to a focus on the differences between measurements of surface conditions and the atmospheric profiles, it is focused on the different spectral regions that are used to measure different meteorological and oceanography parameters

M. Sc Meteorology

M-402: Satellite Meteorology and Satellite Oceanography

Unit-I

Elements of remote sensing.Satellite orbits: Newton's laws, Kepler's laws, Kepler's equation, orientation in space, orbital elements, Geostationary orbits, Sun synchronous orbits, visible and infrared radiometers, multiscanner radiometers; Radiative Transfer: Electromagnetic radiation, black body radiation laws, non black bodies radiative transfer equation, Schwarzschild equation, gaseous absorption and scattering.

Unit-II

Satellite imagery: Creating images, spatial resolution, visible imagery, infrared imagery, water vapor imagery, microwave imagery, Image enhancement. Atmospheric and surface phenomena, tropical cyclones, thunderstorms, sandstorms, fog. Temperature and Humidity Retrieval: Sounding theory, retrieval methods, Limb sounding retrievals, the split window techniques, cloud top temperatures

Unit-III

Winds: cloud motion winds, Ocean surface winds, Tropical Cyclone winds- Dvorak technique. Clouds: clods from imagers, Threshold technique, histogram technique, multispectral technique, cloud top temperature. Precipitation: Visible and Infrared technique, Passive microwave technique, GOES precipitation index. Estimation of earth radiation budget, outgoing Long wave Radiation, Soil moisture, vegetation index.

Unit-IV

Ocean properties measurable from satellites. Ocean Color Remote Sensing: optical theory for Ocean color remote sensing, recovering useful information from ocean color, estimating water parameters from spectral band ratios, identifying Potential Fishing Zones.IR measurement of Sea Surface Temperature – estimation of SST, AVHRR, Oceanographic application of IR SST data. Passive microwave Radiometers: Physical principle of

passive microwave radiometry, retrieval of Salinity, SST and surface wind from microwave measurements, Oceanographic application of passive microwave data.

Unit-V

Radar Altimeters over the Ocean: Principles of satellite altimetry, measuring distance with a radar altimeter, Ocean currents from altimetry, estimating wave height and wind speed. Uses of Altimetry. Sea surface roughness and Scatterometry : Measuring the radar energy reflected from Sea, microwave interaction with Sea surface. Empirical relationships between wind and radar back scattering.

Synthetic Aperture Radar (SAR) imaging of the Ocean: principle of SAR, Range resolution, Aperture synthesis, SAR imaging of Ocean waves. Hydrodynamic modulation, Tilt modulation, Velocity modulation, Ocean information from SAR images, SAR imaging of ocean phenomena.

Text books:

1. Measuring the oceans from space- Ian S.Robinson
2. The principles and methods of satellite oceanography- Ian S. Robinson
3. Discovering the ocean from space- Ian S. Robinson
4. The unique applications of satellite oceanography – Ians Robinson
5. Satellite meteorology an Introduction – stanley Q. Kidder, Thomas H. Vander Harr
6. Satellite Meteorology R.R.Kelkar
7. Applications with Meteorological satellites – W. Paul Menzel
8. Fundamentals of Remote sensing – George joseph
9. Oceanographic applications of Remote Sensing – Motoyoshi Ikeda, Frederic W.Dobson

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	The aim of this course is to give the students a broad knowledge of different remote sensing techniques in meteorology and oceanography, with special focus on satellite measurement	Knowledge
CO2	Students of satellite meteorology and satellite oceanography will be exposed to various types of satellites and various data sets used for the analysis of both the atmosphere and the ocean.	Analysis
CO3	Satellite imagery, which is essentially a byproduct of satellite output, is the first source to interpret both the atmosphere and the state of the ocean. Various techniques used in the measurement of winds and precipitation will be taught in this course.	Knowledge
CO4	Apart from the above, the course teaches the ocean properties and their observations through satellites. The various techniques used in estimating the satellite derived SST and the salinity retrieval and the applications of satellite data in oceanography will be explained.	Analysis
CO5	Various instruments used in estimating the wave height and wind speed and the measurement of the radar energy in terms of back scattering along with SAR imaginary will be taught. Interpretation of satellite data and estimation of satellite derived products which are used as input to atmospheric and ocean models is the specific outcome of the course.	Analysis
CO6	Meteorological satellites have been shown to improve weather forecasts and early warning services of the Agency in its indispensable role as a source of data.	Knowledge

Course Specific Outcomes (CSOs)

CSO1: Meteorological satellites have been shown to improve weather forecasts and early warning services of the Agency in its indispensable role as a source of data.

CSO1: Students of this course will find employment in the Meteorology and Oceanography divisions of the various space agencies like ISRO, NASA, ESA and JAXA.

CSO2:Satellite meteorologists often work in groups or teams with people in related careers such as engineers, computer and communications technicians, science writers, data system analysts,

CSO3: The student has a good knowledge of the different remote sensing techniques used for meteorology and oceanography, including the strengths and limitations of the techniques

CSO4: The student has knowledge of the problems about the transfer of electromagnetic radiation through the atmosphere as well as having good knowledge on the interaction of the electromagnetic radiation and the surface.

Course Learning Outcomes (CLOs)

CLO1: Students of this course will find employment in the Meteorology and Oceanography divisions of the various space agencies like ISRO, NASA, ESA and JAXA. Satellite meteorologists often work in groups or teams with people in related careers such as engineers, computer and communications technicians, science

writers, data system analysts,

CLO2: The student has a good knowledge of the different remote sensing techniques used for meteorology and oceanography, including the strengths and limitations of the techniques.

CLO3: To develop knowledge about interpreting satellite image. knowledge about satellite retrieval of different atmospheric and oceanic parameters.

CLO4 Students will be able to demonstrate skills for the analysis and interpretation of satellites imagery of the Atmosphere from the different sources and can extract and analyses for the different extreme weather events (thunderstorms, cyclones).

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Dynamics of Climate change			
Syllabus for M.SC Meteorology - IV semester			
Course Category	Basic Science core course	Course Code	M-403
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the concerned specialization	Internal Assessment Semester End Examination Total Marks	20 80 100
COURSE OBJECTIVES			
1. To address the concept of global warming and climate change. 2. To demonstrate the various impacts of climate change. **3.** To explore the recent trends in the global warming.			

M.Sc. Meteorology

M-403 Dynamics of Climate Change

Unit – I:

The earth's changing climate: possible causes of climate change, natural Greenhouse effect-radiation balance, Importance of water, Greenhouse gases-Role of Carbon dioxide and Methane, Major uncertainties, recent trends in global warming. Greenhouse effect – global warming and rise in sea level, CO2 prediction models; Chlorofluorocarbons (CFCs) – depletion of ozone layers. Carbon cycle: Physical and biological carbon pump, Marine and Terrestrial carbon cycle.

Unit – II:

Impact of climate change on weather parameters: Global and regional surface air temperature, Precipitation, snow, Ice, Water vapor, winds, Waves, geopotential height and Jet stream. Extreme events: Heat waves, Droughts, Floods, Thunderstorm and Tropical cyclones. *Changes in the frequency of monsoon depressions over Bay of Bengal. Influence of subtropical systems over India.*

Unit-III:

Impact of Climate change on Oceans: Sea surface temperature, Salinity, sea level, circulation, Conveyor belt, upwelling and ocean heat content. Thermohaline structure, Heat and salt storages, Bio-geo chemistry, Fluxes across the air-sea interface.

Unit – IV:

Teleconnections: ENSO-Monsoon, Atlantic Multi-decadal Oscillation, Pacific Decadal Variability and other indices.

Prediction and detection of climate variability and change: Estimate of global mean radiative forcing, direct and indirect effect of aerosols.

Unit-V:

Detection and attribution of anthropogenic climate change, recent simulation of effects of increases in greenhouse gases.

Depletion of Ozone layer due to Global warming. *Recent temperature trends over Arctic Region and its effect on monsoon system.* Programes: CLIVAR and IPCC.

Text Books:

1. IPCC Fourth Assessment Report (AR4). Climate Change 2007: The Physical Science Basis.
2. Frances Drake. Global Warming: The Science of Climate Change. Hodder Arnold Publication.
3. R.P. Pearce. 2002. Meteorology at the Millennium. Academic Press.
4. C. Donald Ahrens. Essentials of Meteorology. Thomson Brooks/Cole.
5. Houghton, John. 1997. Global warming: the complete briefing. New York/Cambridge: Cambridge University Press.
6. Jasti S Chowdary, Anant Parekh and C. Gnanaseelan (2021). Indian summer monsoon variability: El Nino-Teleconnections and Beyond. Elsevier Publications.

COs	**Upon successful completion of the course, the student will be able to:**	Cognitive level
CO1	This course will provide knowledge on the causes and consequences of global warming and climate change.	Knowledge
CO2	Particularly the studies on the role of aerosols and teleconnections play crucial role in monsoon predictions.	Understanding
CO3	This course is useful for understanding the concept of global warming.	Understanding
CO4	This course is useful for understanding the concept of climate change and changes in the atmosphere & ocean.	Knowledge
CO5	After the course, students will have broad understanding on the dynamics of climate change and causative factors of climate change.	Analysis

Course Specific Outcomes (CSOs)

CSO1: Students can acquaint knowledge on the dynamics of climate change.

CSO2: Students can understand the causative factors of climate change and consequences of climate change.

CSO3: Students can understand the concept of teleconnections in the scenario of changing global climate.

Course Learning Outcomes (CLOs)

LO1: The student gains knowledge on the earth's changing climate, carbon cycle, concept of green house effect, depletion of ozone layer and recent trends in the global warming.

LO2: The impact of climate change on weather parameters in detail will be taught.

LO3: The student gains knowledge on the impact of climate change on the Oceans

LO4: The course gives an idea on the teleconnections between monsoon and the global parameters and the role of aerosols.

LO5: The course also concentrates on the anthropogenic climate change.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2

CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Agricultural Meteorology Syllabus for M.Sc Meteorology - IV semester			
Course Category	Basic Science core course	Course Code	M-404
Course Type	Theory	Lectures-Training-Practical	3-1-0
Prerequisites	Basics of the Physical meteorology and Physical Oceanography, dynamical and synoptic meteorology	Internal Assessment Semester End Examination Total Marks	20 80 100

Course Objectives

1. To understand the scope and applications of meteorology in agriculture
2. To apply the different method to protect the crop from adverse weather and pest and insects
3. To understand the prediction of yield using different statistical and dynamical models and its forecasting

M.Sc. Meteorology
M-404. Agricultural Meteorology

Unit-I:
Agricultural meteorology - its scope and aims; Radiation and the surface energy balance and its components: the long-wave budget; surface radiation temperatures; total radiation budget and complete surface energy balance; Special aspects of radiation and temperature in agriculture.

Unit-II:
Agro climatic classification, Climate zones, soil climatic zones. Role of weather variables in environmental stress, Relationship between weather, climate and agriculture. The soil and its heat balance - Diurnal and annual variations of soil;and its temperature variation at different depths.

Unit-III:
Fundamentals of the evaporation process, methods to determine evaporation, energy balance, aerodynamic and combination of Penman and others. Soil Moisture budgets. Index of moisture adequacy and agricultural droughts. Prediction of drought.

Unit- IV:
Crop protection from adverse meteorological phenomena. droughts, heavy rains, storms, cold waves and frost, heat waves, shelter from winds. Crop simulation modeling: empirical statistical models, crop weather modeling: dynamic simulation models: DSSAT modeling, weather and pesticide application.

Unit-V:

Agro meteorological forecasting: basic principles, crop-yield forecasting, Crop Weather calendars, crop weather diagram, agromet advisory services (AAS) and status of crop simulation models in India. NDVI,Remote sensing applications to agriculture, Climate change relating to agriculture. Agriculture-weather modification, Micrometeorology

Text Books:

1. Hydrometeorology - C.J.Wiesner
2. Agro meteorology : G.Z.Venkskevitch, Israel Program for Scientific Transition, IPST press, Jerusalem, 300 pp., 1961
3. Guide to Agricultural Meteorological Practices: WMO No.134, 1981.
   Lecture Notes for training Class IV Agricultural Meteorological personnel, WMO No.593, 1982.

COs	Upon successful completion of the course, the student will be able to:	Cognitive Level
CO1	understand the aim and scope and objectives of the argometeorology.	Understanding
CO2	understand the principles of radiation, soil heat flux variations, soil temperature and different climate classification.	Understanding
CO3	understand the concept of micro, meso and macro scales processes, temperature and wind profiles in crop canopies, role of temperatures on crop phenology.	Understanding
CO4	Understand the concept of evaporation process with different estimation methods.	Understanding
CO5	Identify the difference between mechanistic and deterministic models. and applications of DSSAT modelling.	Analysis
CO6	Student will understand the concept of climate change related to agriculture and agromet advisories, crop weather calendars.	Understanding

Course Specific Outcomes (CSOs)

1. To understand the concept of agricultural meteorology and its aim, scope and objectives, components of radiation and radiation budget.
2. To analyse the classification of the climate, soil temperature variations at different depths.
3. To understand the concept of hydrological cycle, water balance, evaporation process and its applications using different methods.
4. To understand the role of climate change impact on agriculture with different modelling applications.
5. To study the remote sensing application in agriculture , status of agro meteorology in India.

Course Learning Outcomes (CLOs)

1. Student can learn radiation and energy balance components.
2. Student can learn different climates and its classification based on vegetation.
3. Student can learn different methods different droughts.
4. Student can utilise the modelling applications related to agriculture.
5. Student can adopt the agromet advisories and climate change, global warming impact on agriculture.
6. This application will be useful for his/her research work /dissertation.

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**

	1													
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Dissertation and Seminar Common Syllabus for M.Sc Meteorology and Physical Oceanography - IV semester			
Course Category	Basic Science core course	Course Code	M-405
Course Type	Dissertation and Seminar	Training-Practical	3-1-0
Prerequisites	Basics of the Physical meteorology and Physical Oceanography, dynamical and synoptic meteorology	Internal Assessment Semester End Examination Total Marks	40 160 200

M-405: Dissertation and Seminar

COs: **Upon successful completion of the course, the student will be able to:**		Cognitive level
CO1	Prepare synopsis for the research work.	Knowledge
CO2	Select the appropriate data sets and methodology for their research work	Analysis
CO3	Frame hypothesis regarding their research work.	Understanding
CO4	Carry out the research work in a systematic manner.	Analysis

Course Learning Outcomes (CLOs)
1.The student will learn the critical thinking of the work objectives and evaluate the methodology. 2. The analysis of the results will be carried out through oral and scientific communication

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)														
	PO 1	**PO 2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO 1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2
CO4	2	2	2	-	-	-	-	-	-	-	-	-	-	2
CO5	2	2	2	-	-	-	-	-	-	-	-	-	1	1

Viva-Voce			
Common syllabus for M.SC Meteorology/Physical Oceanography - IV semester			
Course Category	Basic Science core course	Course Code	M-406
Course Type	Viva-Voce	Lectures-Training-Practical	3-1-0
Prerequisites	Knowledge on Physical oceanography and applications	Total Marks	50

COURSE OBJECTIVES
To evaluate the performance and knowledge of the student orally in the field of meteorology and Oceanography. To get the better placement opportunities and better performance in future.

COs	Upon successful completion of the course, the student will be able to:	Cognitive level
CO1	Student can improve softskills , communication skills	Knowledge
CO2	Student can able to demonstrate the specific knowledge on the specialised area	Analysis
CO3	This viva-voce will help for his career progression to enhance profession etiquette	Analysis

Contribution of Course Outcomes towards achievement of Program Outcomes (1 – Low, 2 - Medium, 3 – High)													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**
CO1	3	2	2	-	-	-	-	-	-	-	-	-	-	2
CO2	1	1	2	1	-	-	-	-	-	-	-	-	-	2
CO3	3	1	2	-	-	-	-	-	-	-	1	-	1	2