KERALA UNIVERSITY OF FISHERIES AND OCEAN STUDIES

SYLLABUS

M.Sc. ATMOSPHERIC SCIENCE

FACULTY OF OCEAN SCIENCE AND TECHNOLOGY

Fisheries station puduvype campus, Kochi-682508, Kerala

FACULTY OF OCEAN SCIENCE AND TECHNOLOGY

FACULTY BOARD OF STUDIES

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Dr. Abish B, Assistant Professor and Academic Coordinator (Atmospheric Science), Department of Climate Variability and Aquatic Ecosystems, Faculty of Ocean Science and Technology, KUFOS

INTRODUCTION

The climate on the earth has changed substantially from the past.There are natural and man made causes for such changes. This course will provide in-depth knowledge about the physics and dynamics of the atmosphere and about the factors that are responsible for the occurrence of extreme weather events.

OBJECTIVES

Atmospheric Science course combines elements of environmental science, meteorology, oceanography, Remote Sensing & GIS and more, offering a comprehensive understanding of climate dynamics, climate change impacts, and mitigation strategies. This program is designed to produce graduates capable of addressing the pressing challenges of climate change and environmental sustainability. Therefore, the curriculum is designed to include the relevant concepts in meteorology, oceanography, Remote Sensing & GIS, Climate sustainability, risk assessment, management, etc. Different forecast models used to predict the state of the atmosphere are also included in it. In the final semester, the students will do their dissertation at a leading State/Central Govt. research institution on a topic covered in the curriculum.

ELIGIBILTY

The students 50%or 5.5/10.00 or 2.2/4.0marksinBSc.Physics/Mathematics.

ASSESSMENT AND STANDARDS OF PASSING

The evaluation of the students in a course shall be based on his/her performance in various examinations, term papers/assignments/student seminars/records/ case studies and project reports.Assignments will be based on both internal and external evaluations.

EMPLOYMENT OPPORTUNITIES

Opportunities Awaiting Atmospheric Science Graduates:

- **Career Prospects**: Pursue a rewarding career in government agencies, research institutions, NGOs, or private organizations focused on climate change mitigation and adaptation.
- **Research and Development**: Pursue a career in research and development, driving innovation in renewable energy, climate modelling, and more.
- **Global Demand:** With climate change being a global concern, there is a growing demand for climate scientists across the world, offering international career opportunities.
- **Skill Development:** Acquire expertise in data analysis, programming languages (e.g., Python, R, MATLAB), and Geographic Information Systems (GIS).
- **Interdisciplinary Approach:** Develop a holistic understanding by integrating concepts from atmospheric science, oceanography, ecology, disaster management, artificial intelligence and machine learning.

Our distinguished alumni are in National Institute of Technology (NIT), Rourkela, IITM Pune, NPOL, Kochi, National Institute of Oceanography (NIO), Goa, Adani Green Energy, Ahmedabad, American University of Sharjah, UAE, University of Hertfordshire, UK, Leap Green Energy, Govt. of Tamil Nadu, ICCS Kottayam, Monk Space, New Delhi, Data Analyst, Hyderabad. Our students have also qualified INSPIRE, NET and GATE.

PROGRAM SPECIFIC OUTCOMES (PSO)

PSO number	Intended Programme Specific Outcomes (PSO) *Upon completion of M.Sc Atmospheric programme, the graduates will be able to:*
PSO 1	Gain a strong foundation in atmospheric dynamics, thermodynamics, and the fundamental principles governing atmospheric and oceanic processes.
PSO 2	Develop proficiency in the use of climate and weather prediction models, including numerical simulations and statistical downscaling techniques for accurate forecasting.
PSO 3	Master the use of satellite data, remote sensing technologies, and Geographic Information Systems (GIS) for environmental monitoring, weather analysis, and climate research.
PSO 4	Analyze the physical interactions between oceans and the atmosphere, including air-sea fluxes, ocean currents, and their influence on global and regional climates
PSO 5	Acquire advanced skills in processing and visualizing meteorological data using tools such as MATLAB, Python, and specialized meteorological software.
PSO 6	Understand the scientific principles of climate change, its impacts on ecosystems, and contribute to the development of mitigation and adaptation strategies in alignment with national and international policies.
PSO 7	Develop skills in forecasting extreme weather events and climate anomalies, contributing to early warning systems and disaster management frameworks.
PSO 8	Engage in fieldwork and practical exercises, applying theoretical knowledge to real-world atmospheric and climate-related challenges, including environmental impact assessments and field measurements.
PSO 9	Foster interdisciplinary research by integrating knowledge from related fields such as oceanography, climate science, and environmental management to solve complex atmospheric challenges.
PSO 10	Cultivate the ability to continuously learn and adapt to emerging trends in atmospheric science, maintaining a global perspective on environmental challenges and climate issues.

Assessment Criteria

The evaluation of each course shall contain two parts – Internal Assessment and External Assessment.

Core and Elective Courses - External: Internal Ratio - 50:50

Practicals, Field Diary – 100% Internal

The internal evaluation is to be done by continuous assessment of the following components.

Table 1: The internal evaluation criteria and marks for the core and elective courses.

SI NO:	CRITERIA	MARKS
1	Attendance	5
2	Assignment	10
3	Seminar	10
4	Test paper (Average of 2)	25
5	Total	50

Table 2: The internal evaluation criteria and marks for the Practical Exam.

SI NO:	CRITERIA	MARKS
1	Attendance	10
2	Practical exam & viva-voce	50
3	Lab performance	20
4	Record	20
5	Total	100

Industrial Visit

An industrial visit should be done before the end of the third semester. The field diary should be submitted for evaluation.

SEMESTER-WISE DISTRIBUTION OF COURSES

Semester	Course		No. of Credits	Hrs./ week	Core (C)/ Elective (E)/ Practical (P)
	Subject Code	Name			
Semester I	CS 2101	Introduction to Atmosphere	4	4	C
	CS 2102	Fundamentals of Physical Oceanography	4	4	C
	CS 2103	Introduction to Biosphere and Geosphere	4	4	C
	CS 2104	Mathematics and Statistics	4	4	C
	CS 2105	Linux/Python Programming (Practical)	3	6	P
	CS 2106	Remote Sensing and GIS	3	3	E
	CS 2107	Meteorological Observations (Practical)	2	4	P
		Total credits	**26**		
Semester II	CS 2201	Climatology	4	4	C
	CS 2202	Weather and Climate Disasters	4	4	C
	CS 2203	Ocean-Atmosphere Interaction	4	4	C
	CS 2204	Weather and Climate Forecasting	4	4	C
	CS 2205	Climate Dynamics	3	3	E
	CS 2206	MATLAB (Practical)	3	6	P
	CS 2207	Remote Sensing and GIS (Practical)	3	6	P
		Total credits	**25**		

Semester III	CS 2301	Climate change adaptation and mitigation	4	4	C
	CS 2302	Climate Risk Management	4	4	E
	CS 2303	Climate Projection and Climate Informatics	4	4	C
	CS 2304	Climate System Modeling	4	4	C
	CS 2305	Interpretation and Use of Climate Model Outputs (Practical)	3	6	P
		Total credits	**19**		
Semester IV	CS 2401	Dissertation (project work in the Department / Universities / Scientific institutes / Industrial organizations etc.)	**20**	_	C
		Total credits	**20**		

Total number of credits for all the four semesters	90

SEMESTER 1

CS 2101 : INTRODUCTION TO THE ATMOSPHERE

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Recall the fundamental concepts of the Sun-Earth relationship, including solstices, equinoxes, and the structure of Earth's atmosphere.	R	PSO 1
2	Identify the laws of radiation, atmospheric scattering processes, and their impact on solar radiation distribution and Earth's heat balance	A	PSO 1
3	Understand the gas laws and thermodynamic principles governing atmospheric processes, such as adiabatic processes, humidity, and temperature variations.	U	PS0 1
4	Describe the principles of atmospheric stability, hydrostatics, and cloud formation mechanisms, including the role of CAPE and CINE.	R	PSO 1
5	Explain the processes involved in the formation of clouds, precipitation, and atmospheric instabilities, and their effects on weather patterns.	U	PSO 1
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Sun, Earth and the Atmosphere - Sun-Earth relationship- solstices and equinoxes- motion of earth - structure and composition of the atmosphere- dry air, water vapour and aerosolsatmospheric optics: mirages, rainbows, haloes: atmospheric refraction, coronas, scattering.

UNIT 2

Concept of atmospheric radiation- Laws of radiation- solar radiation- solar spectrum and solar constant- distribution of solar insolation at the top of the atmosphere- latitudinal and seasonal variations- scattering and absorption of solar radiation in the earth-atmosphere - reflection -Mean disposition of solar radiation- Mean heat balance of earth-atmosphere system- effect of atmospheric gases- aerosols- clouds(surface and planetary albedo) on solar radiationatmospheric window- aerosol scattering- estimation of radiative heating and cooling- terrestrial radiation and its passage through the atmosphere- emission and absorption of terrestrial radiation- Rayleigh and Mie scattering- radiative transfer- greenhouse effect- fundamental link to general circulation.

UNIT 3

Gas laws and their application to the atmosphere- laws of thermodynamics- equation of state for dry and moist air- humidity parameters- virtual temperature- potential temperature- Pseudo adiabatic process- Equivalent temperature- Equivalent potential temperature- Clausius Clapeyron equation- Entropy- Reversible and irreversible process-*Carnot's* cyclethermodynamics of the atmosphere- dry adiabatic lapse rate- unsaturated moist air- saturated adiabatic lapse rate- Normand's proportions- Normand point- relative humidity- absolute humidity- dew point temperature- wet bulb temperature- mixing ratio

UNIT 4

Hydrostatics of the atmosphere- hydrostatic equation- hydrostatic equilibrium- geopotential; equipotential surface- standard atmosphere- Barometric altimetry- atmospheric instability and convection- stability criteria; parcel method- Role of convective available potential energy (CAPE) and convective inhibition energy (CINE) - Brunt Vaisala oscillation; Lifting, mixing and convective condensation - potential instability and stability indices- slice method of stability analysis- cloud formation and types.

UNIT 5

Cloud formation- condensation nuclei- nucleation and growth of cloud droplets- Kelvin equation- Solute effect- Kohler curve- Cloud classification- raindrop spectra- precipitation mechanism- Bowen's theory- Bergeron and Findeison process- Collision and coalescence process- precipitation of warm and cold clouds

Reference books:

1. Introduction to Theoretical Meteorology, Seymour L. Hess, Krieger, New York, 2006.
2. Physical Meteorology, John C Johnson, MIT Press, Cambridge, 1996.
3. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
4. Compendium of Meteorology for use by Class I & Class II Meteorological Personnel Vol. II, Part I, WMO Publications No. 364, 1977.
5. Atmospheric Thermodynamics (Second Edition), J V Iribarne & W L Godson, Springer, 1981.
6. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.
7. Fundamentals of Atmospheric Physics, Murry L Salby, Academic Press, 1996.

8. Clouds, Rain and Rain Making (second Edition), B J Mason, Cambridge University Press, 2010.
9. Thermodynamics of Atmosphere and Ocean, J. Curry and P.J.Webster, Academic Press, 1998.
10. The Atmosphere: a very short introduction, Paul I. Palmer, 2017.

CS2102: FUNDAMENTALS OF PHYSICAL OCEANOGRAPHY

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Recall key concepts in oceanography, including the history of exploration and significant expeditions.	R	PSO 1
2	Identify the physical properties of seawater and describe the distribution of temperature, salinity, and density.	A	PSO 1
3	Understand the acoustical and optical properties of seawater, and the factors influencing ocean heat and energy transfer.	U	PSO 4
4	Explain the formation and classification of water masses using temperature-salinity (T-S) diagrams.	U	PSO 4
5	Describe global ocean circulation, including major currents, wind-driven systems, and phenomena like thermohaline circulation and the Ekman spiral.	A	PSO 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C).			

UNIT 1

General introduction; History of oceanography and major expeditions- Physical properties of sea water- distribution of temperature, salinity, density and oxygen in space and time -acoustical and optical characteristics of sea water- heat budget of ocean- insolation- long wave radiation- effect of clouds- sensible and latent heat transfer- Bowen's ratio- Ocean heat transport- spatiotemporal variability of heat budget- Terms and net heat balance- mixed layer-thermoclin

UNIT 2

Water type and masses- formation and classification- identification of water masses- temperature/potential- salinity [T-S] diagrams- water masses of Atlantic, Pacific and Indian Ocean with spatial reference to Arabian Sea and Bay of Bengal- surface gravity waves-characteristics- shallow water transformation and breaking- long-shore and cross-shore currents- rip currents

UNIT 3

Global ocean circulation- major ocean currents- wind driven currents in the ocean- wind stressIndian ocean circulation- thermohaline circulation- Ekman Spiral and transport- subtropical and polar gyres- major currents of the world oceans- ocean conveyor belt- tides; tide generation and propagation- characteristics of tides- spring and neap tides- diurnal and semi diurnal tides- tidal current- waves; wave generation and wave characteristics- wave fraction

UNIT 4

Ocean processes- upwelling and sinking- mesoscale Eddies- winter cooling and convectionIndo-Pacific Ocean warm pool- El-Nino Southern Oscillation (ENSO)- Indian Ocean Dipole (IOD)- Major composition of sea water- major and minor constituents of sea water- constancy of Composition- factors affecting constancy

Reference books:

1. Stewart, R. L., Introduction to Physical Oceanography.
2. Talley, L. D., G. L. Pickard, W. J. Emery and J. H. Swift, Descriptive Physical Oceanography, 6th edition, Elsevier, 2011.
3. Waves, Tides and Shallow Water Processes: Open University Course Team and ButterworthHeinemann Publications, Oxford, UK, 1999.
4. Neumann, G., and W. J. Pierson, Principles of Physical Oceanography, Prentice-Hall, 1966.
5. Essentials of oceanography; Allen P. Trujillo and Harold V. Truman, PHI, New Delhi (10th Edition)

CS 2103 : INTRODUCTION TO BIOSPHERE & GEOSPHERE

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember the key geographical features of oceans and continents, including seafloor features like mid-ocean ridges and trenches.	R	PSO 1
2	Learn Earth's structural layers and explain concepts related to plate tectonics, seafloor spreading, and ocean basins.	R	PSO 1
3	Understand the composition of marine sediments and their classification based on sources and grain size.	U	PSO 4
4	Describe the interaction of the biosphere with Earth's spheres, focusing on marine ecosystems and the roles of phytoplankton and zooplankton.	U	PSO 4
5	Explain biodiversity, food chains, nutrient cycles, and the role of biosphere reserves in conservation and carbon sequestration.	U	PSO 6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

General Introduction-Oceans and Continents -Major Oceans and its dimensions -seafloor features-shoreline-Continental Shelf-Continental slope-Continental Rise-Mid ocean RidgesSeamounts-Guyots-Trenches-Island Arc-Atolls- Hydrothermal Vents and Cold Seeps

UNIT 2

Composition of Earth- Crust, Mantle, and Core- Continental and oceanic crust- Ocean basins and bottom materials- Turbidity currents- Submarine Canyons- Plate tectonics- Continental drift and sea floor spreading-Pangea-Gondwana- Methods for mapping bottom topographyMarine sediments-sources and types- Lithogenous, biogenous, hydrogenous and cosmogenous sediments-classification of sediments based on grain size

UNIT 3

The biosphere-the earth’s four spheres-types of biospheres-marine and terrestrial environment-oceanic, coastal and intertidal environment-phytoplankton and zooplankton

UNIT 4

Bio-diversity-Food chain and food web-primary producers- secondary productivity-primary, secondary and tertiary consumers-biodiversity and environment-nutrient cycling-carbon cyclenitrogen cycle-sulfur and phosphorous cycles

UNIT 5

Man and the Biosphere Programme (MAB)- Biosphere reserves-zonation of biosphere reserves-core, buffer zone and transition areas-major terrestrial and marine biosphere in India-carbon sequestration-role of biosphere reserves in carbon sequestration.

Reference Books

l. Life on the Planet Earth: by Harold J.
Morowitz 1980, W. W. Norton & Company
2. Geography of the Biosphere : An introduction to the Nature, Distribution and Evolution of the World's Life Zones:By Peter A. Furley ;1983, ButterworthHeinemann
3. Biosphere:ByHarshvardhan Bhaskar;2012, Publisher: Neha Publishers & distributors 4. Biosphere Origin And Evolution 1st Edition; NikolayDobretsov;Springer-verlag;
5. The Earth's Biosphere: Evolution, Dynamics, and Change: By Vaclav Smil; 2008 MIT Press
6. Harvesting the Biosphere : What we have taken from Nature: By Vaclav Smil 2012, MIT Press

CS 2104 : MATHEMATICS AND STATISTICS

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Learn key concepts in calculus, including limits, derivatives, integrals, and their applications in problem-solving.	R	PSO 2
2	Understand ordinary and partial differential equations, vector calculus, and explain the importance of Gauss's and Stokes's theorems in applied mathematics.	U	PSO 2
3	Apply matrix operations like transpose, inverse, and rank to solve linear algebra problems in mathematical and real-world contexts.	A	PSO 1
4	Understand statistical measures of central tendency, correlation, and regression analysis, and interpret their use in data analysis.	U	PSO 2
5	Apply sampling techniques and statistical inference methods to conduct hypothesis testing and analyze real-world data.	A	PSO 6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

Mathematics:

UNIT 1

Calculus: Introduction, functions, area, summation, the integral, slopes, the derivative, the concept of limit, the fundamental theorem of calculus.

UNIT 2

Integration and differentiation: Ordinary differential equations, partial differential equations, Taylor series expansion, vector calculus – gauss and strokes theorem.

UNIT 3

Matrices and their application: types of matrices, operations of matrices, transpose, symmetric, skew symmetric , adjoint and inverse of matrices, rank of a matrix.

Statistics

UNIT 4

Measures of central tendency- mean ,median, mode, stranded deviation, coefficient of variation, correlation & regression- simple and multiple regression

UNIT 5

Sampling Techniques : sampling Designs – simple random sampling , systematic sampling, cluster sampling, multistage sampling.

UNIT 6

Statistical Inference- estimation and testing of hypothesis, test based on z, t, f, CHI square, analysis of one way and two way.

CS 2105 : LINUX/PYTHON PROGRAMMING

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Recall the features, architecture, and utilities of Linux/Unix, including file handling, networking, and shell programming.	R	PSO 5
2	Understand Fortran's core concepts like data types, operators, loops, and arrays for structured programming.	U	PSO 5
3	Apply Python's syntax, control structures, and error handling to develop scripts and solve computational problems.	A	PSO 5
4	Understand advanced Python data structures (lists, dictionaries, tuples) and manage data and modules efficiently.	U	PSO 5
5	Apply shell scripting and Fortran/Python programming to automate tasks and manage files in Linux/Unix environments.	A	PSO 5
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Linux; introduction to Linux operating system- History of Linux- Features if Linux- architecture of Linux/Unix- Linux utilities- File handling utilities- Security by file permissions- process utilities- disc utilities- networking commands- filters- text processing utilities and backup utilities- applications, shell programming with Bourne again shell(BASH)- the shell as a programming language- shell meta characters- shell variables- shell commands - command substitution- the environment- quoting- test command- control structures- arithmetic in shellshell script and examples- functions- debugging.

UNIT 2

Fortran; Fortran fundamentals- integer constant- floating point constant- variables- arithmetic operator- relational operator- Fortran arithmetic and expression- input/output and format statements- declaration and initialization- branching and looping- arithmetic IF, logical IF, unconditional GO TO, computed GO TO, DO statement- nesting of DO loops- dimension statement- arrays- multi-demsional arrays- functions- sub-programs and sub-routinesprogramming style.

UNIT 3

Python: Introduction- python interpreter- argument passing- data types- numbers- stringsUnicode strings- Lists; flow control; IF statements, FOR statements- range function- passbreak and continue statements- loop functions- default argument values - keyword argumentsarbitrary argument list- unpacking argument list- lambda forms- documentation strings.

UNIT 4

Python data structures- using list as stacks and queues- del statement- tuples and sequencesets- dictionaries- sequences and other types- data modules; executing modules as scriptsthe module search path- compiled python files- standard modules- dir function- packages; importing from a package- intra-package reference- packages in multiple directories- python input/output- financier output formatting- old string formatting- reading and writing filesmethods of file objects- the pickle module- errors and exception; exceptions, handling exceptions, raising exceptions, user-defined exceptions, defining cleanup actions, redefined cleanup actions

Reference books:

1. Introduction to Programming with Fortran, Ian Chivers and Jane Sleightholme, Springer; 4th ed.ISBN-10: 3319755013, ISBN-13: 978-3319755014, 2018.
2. Fortran 90 Handbook Complete ANSI / ISO Reference Jeanne C. Adams Walter S. Brainerd Jeanne T. Martin Brian T. Smith Jerrold L. Wagener., 2016
3. A Primer on Scientific Programming with Python (First Edition), Hans PetterLangtangen, Springer, 2009
4. Head first programming: a learner's guide to programming using the python language, David Griffiths
5. Python Programming: An Introduction to Computer Science, John M. Zelle
6. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, Wes Mckinne
7. Das Sumitabh: UNIX Concepts and Applications, McGraw-Hill Companies.

CS 2106: REMOTE SENSING AND GIS

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember the key principles of remote sensing, including energy sources, electromagnetic radiation, and their interactions with the atmosphere and Earth's surface.	R	PSO 3
2	Understand the characteristics and applications of remote sensing systems, including active/passive sensors and various resolution types.	U	PSO 3
3	Apply GIS tools to conduct spatial data analysis, including proximity, elevation, and terrain profiling.	A	PSO 8
4	Understand the roles of satellites like IRS, LANDSAT, INSAT, and NOAA in climate and environmental monitoring.	U	PSO 3
5	Apply remote sensing and GIS integration in fields like Atmospheric science, oceanography, and agriculture, comparing ground truth data with remotely sensed information.	A	PSO 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction to Remote Sensing – Energy sources and Radiation principles, Energy equation, EMR and Spectrum – EMR interaction with Atmosphere – Scattering, Absorption – EMR interaction with Earth surface features reflection, absorption, emission and transmission – Spectral response pattern – Vegetation, Rocks, Soil, Water bodies – Spectral properties and characteristics.

UNIT 2

Types of remote sensing with respect to wavelength regions; active and passive remote sensing, Sensor types characteristics: imaging systems, photographic sensors, characteristics of optical sensors; FOV, IFOV; Sensor resolution - spectral, spatial, radiometric and temporal

UNIT 3

Introduction to GIS - GIS hardware components and GIS roles. Geographic data, Spatial data, Types of GIS database. Discrete and continuous data. Proximity analyses, Spatial operations: Centroids, Thiessen polygons - Terrain analyses: Elevation analyses, Terrain profiles - 3D views, Slope and Aspect, Shaded Relief - Overlays and Additional features, - GIS output: types, Maps, Legends and Supporting elements.

UNIT 4

Land observation satellites, characters and applications, IRS series, LANDSAT series, SPOT series, Sentinel Missions, High resolution satellites, character and applications, CARTOSAT series, IKONOS Series, QUICKBIRD series, Weather/Meteorological satellites, INSAT series, NOAA, GOES, NIMBUS Applications, Marine observation satellites, OCEANSAT.

UNIT 5

Integration of RS and GIS. Applications of RS and GIS in different areas of climate Science, atmospheric science, oceanography, agriculture and fisheries. Methodology for establishing ground truth, Comparison between ground truth and remotely sensed data

Reference books:

1.Brady NC & Well RR. 2002: The Nature and Properties of Soils. 13th Ed.Pearson Edu. 8. De Mess M.N. 2004: Fundamental of Geographic Information System. John Wiley & Sons
2. Bruce E. Davis, (2001), GIS Visual Approach, Second Edition
3. Burrough, P.A(1986) Principles of Geographical Information Systems for Land Resources Assessment, Clarandone Press, Oxford.
4. Elangovan K. 2006: GIS Fundamentals, Applications and Implementations. New India Publishing Agency.
5. Freeman Star J & Esles J. 1990: Geographic Information System: An Introduction. Prentice Hall.
6. Lille Sand T & Kaiffer R.1987: Remote Sensing and Image Interpretation. John Willey & Sons.
7. Lille Sand T. M & Kiefer RW. 1994: Remote Sensing and Image Interpretation.

Wiley.
8. Nielsen D.R & Wendroth 0. 2003: Spatial and Temporal Statistics. Catena
Verloggmbh Sabbins F. 1987: Remote Sensing Principle and Interpretation.
9. M. Anji Reddy, Textbook of Remote Sensing and Geographical Information systems, BS Publications, Hyderabad. 2011. ISBN: 81-7800-112-8
10. Tor Bernhardsen, (2007) Geographic Information System – An introduction", third edition,

CS 2107: METEOROLOGICAL OBSERVATIONS (PRACTICAL)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Recall conventional methods for measuring atmospheric parameters like pressure, temperature, humidity, wind, and soil moisture.	R	PSO 1
2	Understand the use of advanced instruments such as radiosondes, weather RADARs, disdrometers, and ceilometers in weather observations.	U	PSO 4
3	Apply oceanographic measurement techniques, including SST thermometers, XBT, CTD, and GPS, for marine data collection.	A	PSO 5
4	Analyze atmospheric aerosols using instruments like the and Sun photometer, and interpret aerosol optical depth data.	An	PSO 2
5	Analyze satellite-derived data on cloud cover, wind patterns, OLR, SST, and sea surface height anomalies for climate and weather research.	An	PSO 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction-conventional measurements of Pressure, Temperature, Humidity, Wind, Precipitation, Visibility, Clouds, Soil Temperature and Moisture.

UNIT 2

Radiosondes,Weather RADARS, Disdrometer, Ceilometer

UNIT 3

Oceanographic measurements, Measurement of SST, Protected and Unprotected thermometers, Reversing Water Bottles, MBT, XBT, CTD,.XCTD, Current Meters, Position fixing at sea, GPS.

UNIT 4

Atmospheric Aerosols - Aerosol optical depth- Aethalometer- Sun photometer- Analysis and interpretation using satellite data.

UNIT 5

Analysis and interpretation of satellite cloud cover, winds, OLR, SST and Sea Surface Height anomalies

Prescribed book:

Marine Observers'Handbook: Met. 0.887, MHSO, London

Additional Books:

1. PracticalAgricultural Meteorology: SrivastavaA.K. and P.K. Thyagi; New India Publishing Agency, New Delhi

2. The Practice of Weather Forecasting: Wickham P.G; HMSO, London 3. Weather and Climate: Woodcock R. G., Macdonald and Evans

SEMESTER 2

CS 2201 : CLIMATOLOGY

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember key concepts in climatology, including climate systems and classification schemes.	R	PSO 1
2	Identify components of the climate system and various climate types.	A	PSO 1
3	Describe the Earth's energy balance and the effects of solar radiation on climate.	U	PSO 6
4	Explain the Indian summer monsoon and the impact of ENSO and IOD.	R	PSO 4
5	Understand tropical cyclone characteristics and the influence of climate change.	U	PSO 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C).			

UNIT 1

Introduction to climatology- fundamental principles of climatology- the climate system- controls on climate- Global, regional and local climates, components of the climate system and feedbacks to climate- climate classification- Koeppen and Thornthwaite's schemes- Climate types and climatic zones- Climate change impacts on climate types

UNIT 2

Radiation climatology of the earth's atmosphere- Energy balance of the earth's atmospherespatial and temporal distribution of incoming solar radiation- outgoing radiation- net radiationterrestrial heat balance and other components of radiation balance- Radiation climatology of India- Impact of climate change in radiation balance

UNIT 3

Monsoon and rainfall climatology- climatological features and seasonal evolution of Indian summer monsoon- principle rain bearing systems including monsoon depressions- lows; mid tropospheric cyclones- intraseasonal variability of summer monsoon including active and break cycles- monsoon variability on inter annual and decadal time scales Impacts from tropical oceanic drivers such as ENSO and IOD- rainfall climatology of India- Temporal and spatial distribution- Rainfall and monsoon climatology of Kerala- Northeast monsoon- Rainfall distribution during northeast monsoon.

UNIT 4

Tropical cyclones- Frequency and tracks of cyclones and depressions over India- definition of cyclones- climate change and tropical cyclones- climatology of sea surface temperature and relationship with cyclones- life cycle of cyclone- rainfall distribution and cloud patterns in the cyclone- structure- vertical distribution of temperature and wind in the cyclone- role of satellites and radar tracking the cyclone movements- impact of climate change on cyclones- cyclone management and mitigation of cyclone effects.

Reference books:

1. Trewartha, G. T., An Introduction to climate, McGraw-Hill.
2. Asnani, G. C., Tropical Meteorology.
3. Chang, C. P. and T. N. Krishnmoorthy, Monsoon Meteorology, Oxford University Press, 1987.
4. Tropical Cyclones, their evolution, structure and effect: R.A Anthes, 1982.
5. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
6. Pant, G.B. and Kumar, K.R. 1997. Climates of South Asia. John Wiley & Sons, Chichester.320p

CS 2202: WEATHER AND CLIMATE DISASTERS

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember key concepts of weather-related disasters, such as tropical cyclones, droughts, and floods	R	PSO 1
2	Identify cyclone hazard zones and flood risk areas in India, with a focus on warning systems and forecasting methods.	A	PSO 7
3	Describe the impacts of climate change, including greenhouse gas increases, melting glaciers, and sea-level rise.	U	PSO 6
4	Explain disaster forecasting systems, including satellite and radar tools for tracking cyclones and predicting rainfall.	A	PSO 3
5	Understand concepts of disaster risk, vulnerability, and strategies for disaster reduction and climate adaptation.	U	PSO 10
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1 : Weather related disasters

Tropical cyclones: storm surges, strong winds, heavy rain - Cyclone hazard zonation of Indian Coast line- Cyclone warning system in India-Southwest monsoon: inter annual and decadal variability - droughts and floods- Monsoon onset date variability - Long break monsoon spells - early / late withdrawal of monsoon- Thunderstorms and lightning duststorms - associated Squall, Hail stones and Tornadoes - Short period heavy rain spells -cloud burst - Flash Floods - Non cyclone Strong Winds - Heat and Cold waves -Sunburns, heat burst- Fog - air pollution hazards

UNIT 2: Flood, drought and landslides

Flood Risk Zones in India - Flood forecasting and warning system in India, Drought Prone areas of India- drought management: Forecasting of droughts - Drought management short and long tern measures - landslides and avalanches-vulnerability and risk in India-risk mitigation-issues and challenges-monitoring, warning and preparedness.

UNIT 3: Climate and Climate change

Natural and anthropogenic climate change - increase of green house gases and their global impact on climate- melting of glaciers and polar ice - sea level rise and its impact - ozone depletion - IPCC AR6 report and future projections of climate.

UNIT 4: Forecast and warning of disasters

Cyclone warning system in India - Satellites and Radar network for cyclone warning-forecast of cyclone track and intensity - storm surge prediction - short and medium range forecast of monsoon rainfall- seasonal (long range) forecast of monsoon rainfall - prediction of climate change.

Unit 5: Disaster, hazard and vulnerability

Disaster, hazard, exposure and vulnerability, disaster risk reduction and management. risk ransfer, adaptation, resilience .Climate extremes and impacts-human impacts' and disaster losses-strategies for disaster reduction - national disaster management plans

Prescribed book:

'Global warming - the Complete Briefing (second edition): John Houghton, Cambridge University Press (2009)

Additional books:

1. Tropical Cyclones, their Evolution, Structure and Effects - by Richard A. Anthes (1982), American Meteorological Society, 208 pages
2. Severe Convective Storms - edited by Charles A. Doswell (2001),American Meteorological Society, 561 pages
3. Mesoscale Meteorological Modelling, third edition by Pielke RA Sr.,(2013), AcademicPress 4.Monsoon Vol I and 2 (2013), Editor Dr.AjitTyagi et al, India Meteorological department
5. Earth and Atmospheric Disasters Management - Pandarinath N and Rajan C.K. (2009), BS Publications Hyderabad India

CS 2203: OCEAN-ATMOSPHERE INTERACTION

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember concepts of ocean-atmosphere interaction, including mass and heat fluxes.	**R**	PSO 1
2	Identify components of the ocean's heat budget, such as sea surface temperature and thermocline roles.	**A**	PSO 4
3	Describe meridional heat and water transfer processes and atmospheric circulation patterns.	**U**	PSO 4
4	Explain convection zone shifts and their effects on the Indian summer monsoon.	**A**	PSO 1
5	Understand the coupling of ocean and atmosphere in relation to climate changes and phenomena like El Niño.	**U**	PSO 4
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C).			

UNIT 1

Scales of Ocean-Atmospheric interaction- Fluxes of mass- Momentum & heat- Atmospheric Boundary layer over ocean: Variations of wind, temperature and moisture in the vertical - air sea temperature differences- wind stress and wind stress curl - inversions - contrasts in properties of ocean and atmosphere- Atmospheric stability and wind profile- OceanAtmosphere heat- temperature and humidity differences - radio refractive index and its variation in the lower atmosphere during different atmospheric conditions, Air sea interaction in the coastal region, forcing due to surface stress: Ekman Transport, coastal upwelling and associated features.

UNIT 2

Heat budget of the ocean- Sea surface temperature- short and long wave heat fluxes- sensible and latent heat- Oceanic boundary layer- mixed layer - thermocline - Penetration of Solar Radiation - Turbidity - Fresh water flux - Salinity variation in the vertical, Energy balance at the ocean surface; Evaporation, Surface density changes and thermohaline circulation of the ocean, Effect of differential heating on the air-sea interface - eddies in the ocean, fronts, Bowen’s ratio- annual cycle of heat fluxes- spatial and temporal variation of heat-Wind wavesgeneration, growth and decay of waves- swell and currents induced by wind - Kelvin and Rossby waves Equatorial wave motions; their causes and effects on the processes in the air sea interface.

UNIT 3

Meridional heat and water transfers- Atmospheric circulation- Hadley and walker circulation and high latitude intrusion of westerlies- Tropical & subtropical jetstreams and its influence on climate- Ocean conveyer belt- Large scale air-sea interaction processes- El - Nino southern oscillation, Indian Ocean Dipole, EQUINOO: Observational details - Theories - Coupling of Ocean and Atmosphere.

UNIT 4

Shift in Zones of convection and their atmospheric and oceanic effects with special reference to Indian summer monsoon rainfall - SST anomalies and Monsoon - warm pool and cold pool in the north Indian ocean and their effect on Indian summer monsoon, Convection and SST: Active - Break cycles of Indian summer monsoon and its relation with ocean - Tropospheric Biennial Oscillations - Ocean in relation to long term changes in Monsoon and Climate.

Reference books:

1. Atmosphere - Ocean dynamics, Gill A.E, Academic Press, 1982.
2. Introduction to Boundary Layer Meteorology; Stull R.B.
3. Air-Sea Exchange: Physics, Chemistry and Dynamics: Geernaert G.L.
4. Ocean-Atmosphere interactions; Toba Y.
5. Fundamentals of atmospheric physics, Salby M.L., Academic press, 1996.
6. Introduction to Physical Oceanography, Stewart R.H., 2006

CS 2204 : WEATHER AND CLIMATE FORECASTING

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember the history of weather forecasting and the fundamentals of numerical weather prediction models, including their types.	R	PSO 7
2	Identify key components of numerical models, such as structure, dynamics, and numerical methods	A	PSO 1
3	Describe the importance of grid systems, vertical coordinates, boundary conditions, and data assimilation in numerical weather prediction.	A	PSO 2
4	Explain forecasting strategies, including synoptic, statistical, and dynamical methods, along with their limitations and uncertainties.	U	PSO 7
5	Understand the role of satellite and radar technology in nowcasting and interpreting NWP products for seasonal predictions.	U	PSO 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction- historical overview of weather forecasting- numerical models- model fundamentals- barometric model- barotropic instability- hierarchy of Numerical weather prediction models- short, medium and long range models, Equation systems.

UNIT 2

Model structure and dynamics- numerical methods- finite difference methods- forward and centered finite difference methods- implicit methods- computational instability- baroclinic instability- primitive equation model- 2-level primitive equation model- multi level primitive equation model

UNIT 3

Grid systems- vertical coordinates- boundary conditions- objective analysis and initializationdata assimilation- techniques for the use of mesoscale models-Numerical weather prediction models-non linear aliasing and instability- parameterization of different physical processesensemble forecasting- parameterization of clouds and precipitation- influence of model physics.

UNIT 4

Different forecasting strategies- synoptic, statistical, analogue, empirical and dynamical methods, Ranges of weather prediction and seamless prediction- skill of weather prediction at different ranges- limitations of weather predictions- sources of uncertainties- use of satellites and radars for nowcasting- prediction of individual weather systems- seasonal and intra seasonal prediction of Indian summer monsoon- interpretation of analysis of NWP derived products- their interpretation and their limitations- General circulation models and coupled models- heavy rainfall monitoring-forecasting and warming services.

Reference books:

1. Numerical Weather and Climate Prediction, Thomas Tomkins Warner, 2011.
2. Dynamic Meteorology and Numerical Weather Prediction (Second Edition), G J Haltiner and RT Williams, Wiley, 1983.
3. Predictability of weather and climate, Cambridge university press, T N Palmer, 2006.
4. T.N. Krishnamurti, 1996: An introduction to Numerical Weather Prediction Techniques, CRC, 304pp
5. Parameterization Schemes: Keys to understanding Numerical Weather Prediction Models David J Stensrud
6. Weather Analysis and Forecasting, Christo Georgiev Patrick Santurette, 2016.
7. Mesoscale Meteorological Modelling, R.Pielke, 2013

CS 2205 : CLIMATE DYNAMICS

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember key principles of geophysical fluid dynamics and the role of rotation in geophysical flows.	R	PSO 1
2	Identify conservation laws and hydrodynamic equations, including the Euler and Navier-Stokes equations.	U	PSO 1
3	Describe geostrophic and non-geostrophic flows, focusing on inertial motion and thermal wind dynamics.	A	PSO 1
4	Explain circulation and vorticity concepts, along with key theorems such as Rossby, Kelvin, and Taylor-Proudman.	A	PSO 1
5	Understand the effects of friction on ocean currents, including Ekman transport, upwelling, and Sverdrup's equation.	An	PSO 1
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction- geophysical fluid dynamics- distinguishing attributes of geophysical flows- scales of motions- importance of rotation- distinction between atmosphere and ocean- data acquisition- scale analysis and finite differences- higher order methods- aliasing- kinematicsReynolds number.

UNIT 2

Conservation principles- Euler and Navier stokes equations- local and material time derivatives- fundamental forces- basic laws of conservation- hydrodynamic equations in rotating frame of reference- geostrophic and hydrodynamic approximations- atmospheric stability- vertical coordinate system; Cartesian- isobaric- sigma- the balanced flow; inertial, cyclostrophic flow- gradient wind approximation- trajectory and streamline- thermal wind balance- barotropic and baroclinic atmospheres- circulation and vorticity- the circulation theorem- vorticity in natural coordinates- equations of motion- Rossby waves- Kelvin wavesStroke's theorem- Helmholtz's theorem- Bjerknes circulation theorem and it's interpretationTaylor-Proudman theorem.

UNIT 3

Geostrophic flows- homogeneous geostrophic flows- generalization of non geostrophic flowsinertial motion- thermal wind currents without friction- geostrophic Equation- inertial motionquasi-geostrophic dynamics- simplifying assumptions and governing equations-the continuity equation- thermodynamics of the dry atmosphere- moist atmosphere- potential temperatureadiabatic lapse rate- pseudo adiabatic lapse rate- Coriolis force- Bernoulli's theorem and it's applications.

UNIT 4

Currents with friction- Ekman's solution to the equation of motion with friction- drag coefficientEkman transport and upwelling- bottom friction and shallow water effect- Sverdrup's equation and it's application- equatorial undercurrent- Stommel's and Mink's theorem- westward intensification of ocean currents.

Reference books:

1. Geophysical Fluid Dynamics I: An Introduction to Atmosphere-Ocean Dynamics: Homogeneous Fluids, Ozsoy and Emin, 2020.
2. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012.
3. Geophysical Fluid Dynamics (Second Edition), J. Pedlosky, Springer, Berlin Heidelberg, 1972.
4. Atmosphere-Ocean Dynamics (International Geophysics Series, Volume 30), A E Gill, Academic Press, New York, 1982.
5. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
6. Dynamical and Physical Meteorology, G J Haltiner and F L Martin, McGraw-Hill, 1957.
7. Essentials of Atmospheric and Oceanic Dynamics, Georey K. Vallis, 2019.

CS 2206: MATLAB (PRACTICAL)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember fundamental concepts of MATLAB, including matrices, arrays, built-in functions, and basic plotting techniques	R	PSO 5
2	Understand conditional statements, linear algebra operations, and matrix manipulations for solving mathematical problems in MATLAB	U	PSO 5
3	Apply numerical methods for integration, differentiation, and solving ordinary differential equations (ODEs) using MATLAB.	A	PSO 2
4	Analyze climate variability data with MATLAB tools for statistical analysis, including time series and spectral analysis	An	PSO 5
5	Apply MATLAB to real-world climate applications, creating scripts to compute correlations, trends, and anomalies in data	A	PSO 7
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT I

Introduction to MATLAB- Matrices and Arrays, Array Creation, Matrix and Array Operations. Built-in-functions- Scalar functions, Vector functions, Matrix functions. Line plots, 2D and 3D plots. M-files: Scripts and functions. - Basic Matlab data structures, file i/o, string handling, code efficiency and analysis, Matlab debugger.

UNIT 2

Conditional Statements. Colon Operator. Characters and text, Structures, Linear Algebra, Operations on Nonlinear functions, Multivariate data, data analysis. Vector products and transpose: Multiplying Matrices, Identity matrices, System of Linear Equations, Permutations of Triangular matrices, Square matrices, Rectangular matrices. Nonsingular coefficient matrix. Iterative method for solving linear system of equations Inverses and determinants. Eigen values, eigen decomposition, Multiple Eigen values, Schur decomposition, Operations on non-linear functions.

UNIT 3

Introduction to Numerical Methods - Linear algebra, numerical integration and differentiation, solving systems of ODE's and interpolation of data.Data Visualization and Statistics - Basic statistical tools in Matlab and more advanced data visualization tools (2D and 3D data visualization). Graphics- Basic plotting functions, Creating Mesh and surface plots, Plotting Image Data, basic plotting functions. Creation mesh and surface plots.

UNIT 4

Practical applications on climate variability- Generic scripts -Means, STD-Anomalies Correlations-Hofmoeller (ACW)-Time series (SSTA..):detrending filteringInterpolation regular & irregular grids- EOFs REOFs CEOFs -Spectral analysis -Wavelets -Probability, Density Functions.Simple Climate Models- Energy balance box- model, ice-albedo feedback with multiple steady states.

Prescribed book:

A guide to matlab: Brian R. Hunt, Ronald L. Lipsman, Jonathan M. Rosenberg. Kevin R. Coombes, John E. Osbom, Garrett J. Stuck".

Additional book:

An Introduction to Numerical Methods: A MATLAB Approach, Second Edition
Abdelwahab Kharab (Author), Ronald B. Guenther (Author)

CS 2207 : REMOTE SENSING & GIS (PRACTICAL)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember key sources of satellite data, including Bhuvan, USGS, Copernicus, and NASA Power, along with data downloading procedures.	R	PSO 3
2	Understand the processes for reading and analyzing raw satellite images, including black and white images, false color composites, and georeferencing.	U	PSO 3
3	Apply GIS tools for tasks like proximity analysis, mosaicking, pan sharpening, and data conversion	A	PSO 3
4	Analyze spatial data using GIS features such as clipping, intersection, union, and advanced digitization tools.	An	PSO 3
5	Apply GPS technology for data capture and prepare map layouts for spatial analysis and visualization using GIS.	A	PSO 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

Introduction to various satellite Data -Satellite data download from various open-source website – (I) Bhuvan (II) USGS (III) Copernicus (IV) NASA Power data web-Reading Raw Image-Display, Analysis and interpretation of black & white images and FCC-Geo-reference of the toposheet and satellite imageries-Mosaicking of satellite Images-Pan sharpeningIntroduction to GIS features and Tools-Conversion Exercises in GIS-Proximity analysis in GISClipping, Intersection and Union- Feature Data creation-Digitization and working with advance editing tools in GIS-Location Data capturing using GPS-Preparation of Map Layout.

SEMESTER 3

CS 2301 : CLIMATE CHANGE, ADAPTATION AND MITIGATION

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember key concepts of IPCC modeling scenarios and changes in climate variables.	R	PSO 6
2	Identify impacts of climate change on ecosystems, food production, and drivers like solar irradiance.	A	PSO 6
3	Describe mitigation strategies, including decarbonization and carbon sequestration.	U	PSO 8
4	Apply adaptation methods, such as infrastructure development and early warning systems.	A	PSO 9
5	Analyse the governance structure of climate change and funding sources like the Green Climate Fund.	An	PSO 10
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction - IPCC modelling scenarios. Observed and projected changes in the climate system – temperature; precipitation; cryosphere; sea level; greenhouse gas concentrations (CO2 and Non CO2 gases); and extreme climatic events.

UNIT 2

Climate Change Impacts - Impacts of climate change on physical systems (Glaciers, snow, ice and or permafrost; Rivers, lakes, floods and or drought; Coastal erosion and/or sea level effects); biological systems (Terrestrial ecosystems; aquatic ecosystems); Humanand managed systems (Food production; Livelihoods, health and/or economics). Natural and anthropogenic drivers of climate change - solar irradiance; aerosols, water vapour and clouds; volcanic eruption.

UNIT 3

Climate change mitigation–decarbonizing energy production; use of clean energy and enhancing the energy efficiency in industries, transport, and buildings; carbon dioxide storage and capture; carbon neutral development or low carbon economy; enhancing the carbon sequestration capacity of forests and land use; climate smart agriculture; REDD+.

UNIT 4

Climate change adaptation Climate change adaptation - social, ecological asset and infrastructure development; technological process optimization; integrated natural resources management; institutional, educational and behavioural change or reinforcement; financial services including risk transfer; information systems to support early warning and proactive planning.

UNIT 5

Climate change governance - UNFCCC - Conference of Parties (COP); International Climate Agreement; Policy approaches for adaptation and mitigation, technology and finance; National Communications; Biennial Update Report; Intended Nationally Determined Contributions; Funding streams – Green Climate Fund, Forest Carbon Partnership Facility, Global Environment Facility, Adaptation fund, Bilateral and multilateral funds, and official development assistance fund, voluntary and compliance markets; global think tanks in climate change.

Prescribed book:

Understanding and Responding to Climate Change. National Academy of Sciences, USA (2008 edition)

Additional books:

1. Britannica 2010. Earth's Changing Environment.
2. John Houghton 2009 (4`h' edition) Global Warming - A complete briefing. Cambridge University Press.
3. Gribbin, J. 1979. Climate Change. Cambridge University Press. New York, 280p
4. Prasada Rao, G.S.L.H.V., Rao, G.G.S.N. and Rao, V.U.M. 2010. Climate Change and Agriculture in India. PHI Learning Private Limited. New Delhi, India.320p
5. Shukla, P.R. Sharma, S.K. and Ramana, P.V. 2002. Climate Change and Issues, Concerns and Opportunities. Tata McGraw-Hill Publishers, New Delhi.

CS 2302 : CLIMATE RISK MANAGEMENT

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Remember fundamental concepts of climate change, including global warming, climate variability, and paleo climate studies.	R	PSO 1
2	Identify the effects of climate change on ecosystems, food webs, health risks, and agriculture.	A	PSO 9
3	Describe the impact of climate change on the Asian summer monsoon and the influence of global SST anomalies and aerosols.	U	PSO 6
4	Apply mitigation and adaptation strategies, including greenhouse gas stabilization, renewable energy, and sustainable agriculture practices.	A	PSO 6
5	Analyse the significance of climate change policies in India, focusing on emissions reduction, green technologies, and forest conservation.	An	PSO 10
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction - Climate change and climate variability- Global warming – Paleo climate -Methods to study Paleo climate – Ice ages - Bond cycle - Abrupt climate changes-- Effects of climate change in biosphere and ecosystem-stressors in ecosystem-ecological thresholdchanges in the timing of seasonal life cycle-range shifts-food web disruption- pathogens, parasites and diseases-health impacts-extreme risks-agriculture and food supply impacts.

UNIT 2

Climate change in Asian Summer monsoon: Climate change in monsoon over India (Kerala) and the role of global SST anomalies – Extreme weather events – impact of Climate Change on the genesis of tropical cyclones over North Indian Ocean – Rapid intensification of tropical cyclones- Recent warming of the equatorial Indian Ocean and its impacts – Aerosol caused cooling of the Tibetan anticyclone and its impact – climate change in monsoon depression frequency

UNIT 3

Adaptation and mitigation in Climate Change: Stabilisation of green house gas emissions –role of forests – climate conventions and treaties – changes needed in energy and transport sectors – use of renewable energy sources– Climate change mitigation and adaptation measures.-Sustainable agriculture practices – Blue carbon – Carbon sequestration – Geoengineering- Methods for reducing the carbon footprints.

UNIT 4

Climate mitigation and adaptation – green technologies-reduction in emissions-increasing green cover-renewable energy- Climate change policies - Indian Climate change policies and planning.

CS 2303 : CLIMATE PROJECTION AND CLIMATE INFORMATICS

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning domains**	**PSO No.**
1	Remember basic concepts of global climate model simulations, including governing equations and vertical coordinate systems.	R	PSO 1
2	Identify downscaling techniques, including dynamical and statistical methods, for refining global climate models.	A	PSO 2
3	Describe climate forcings, uncertainties in models, and methods for bias correction and forecast verification.	U	PSO 8
4	Explain the role of parallel computing, machine learning, and AI in enhancing climate forecasts and deep learning's contribution to accuracy.	A	PSO 7
5	Understand the integration of climate models and data using ICT tools, including GIS and climate data analysis standards.	U	PSO 3
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Global climate model simulations- Simulation of atmospheric processes- Governing equations for atmospheric and oceanic processes- continuous equations- map projections- vertical coordinate system- Global, regional, mesoscale and coupled models

UNIT 2

Introduction to downscaling- dynamical and statistical downscaling- statistical forecast methods that combined projections of forcing and known models of natural and inertial variability- analysis of time series- analysing trends and detrend in climate data

UNIT 3

Climate forcings- uncertainties in weather and climate model- weather forecast verification methods across time and space scales- nesting strategies across different models- Impact of domain and model resolution- Bias correction techniques.

UNIT 4

Introduction to parallel computing- different types of parallel computing used in simulation of Atmospheric and oceanic phenomena- review of approach and modeling systems- simulation models- Machine learning & Artificial Intelligence (AI) in forecast models – Forecast improvement using AI- Deep learning for forecast improvement.

UNIT 5

Climate models and climate data from ICT perspective- GIS for climate data- climate translator - Common Information Model- metadata standard for climate models and simulation dataclimate data sources and analysis tools

Reference books:

1. Edwards, Paul N. “How climate models work”, excerpt from a vast machine
2. Computer models, climate data and the politics of global warming (MIT Press, 2010)
3. Jacobson MZ: Fundamentals of Atmospheric Modeling, Cambridge University Press.
4. Kantha and Clayson CA: Numerical Models of Oceans and Oceanic Processes, Academic Press.

CS 2304 : CLIMATE SYSTEM MODELLING

CO No.	**Expected Course Outcome** *Upon completion of this course, students will be able to;*	**Learning domains**	**PSO No.**
1	Remember the fundamental components of the climate system, including climate forcings and their roles in climate change.	R	PSO 1
2	Identify types of climate models, such as energy balance models and general circulation models, and their purposes in climate simulation	A	PSO 2
3	Describe the parameterization of climatic processes and the structure of energy balance models (EBMs).	U	PSO 2
4	Explain the concept of box models and their use in ocean-atmosphere interactions, including one-dimensional radiative-convective models.	A	PSO 4
5	Understand feedback mechanisms in the climate system, such as the ice-albedo and water vapor greenhouse effects, and their impact on climate sensitivity.	U	PSO 9
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Climate system: Climate forcings - External cause of climate change -Anthropogenic causes. Greenhouse gases, Troposphere aerosols and clouds -Natural forcings -Volcanic eruptionsOcean circulation changes. Climate feedbacks and climate sensitivity - Ice-albedo feedback mechanism - water vapour Greenhouse effectcombining feedback effects

UNIT 2

Introduction to climate modeling Types of Climate Models - Energy balance climate models, radiative-convective models, Dimensionally constraint models, General circulation models. Stable isotopes and interactive biogeochemistry. Sensitivity of climate models: Equilibrium climatic systems

UNIT 3

Parameterisation of climatic processes, Interaction of Statistical forecast methods that combined projection of forcings and known modes of natural internal variability statistical/dynamical methods that use elements of both of the previous method. Energy balance models (EBM)- Planetary radiation budget - Structure of EBM - Zero & One dimensional EBM. Parameter zings the climate system for EBM - Albedo- Outgoing long wave radiation (OLR)- Heat transport. EBM and Glacial cycle.

UNIT 4

Box models -Zonal box models - Simple Box model of the ocean-atmosphere Coupled atmosphere, land and ocean energy balance box model. Deceptively simple EBMs. One dimensional radiative Convective (1-D RC) models Radiation factors -Convective experiments. Sensitivity experiments with RC models - humidity - clouds - lapse rate. Development of RC Models - Cloud prediction – Model sensitivity. single Column models.

Prescribed Book

1. A Climate modeling Primer, Third Edition, Kendal McGuffie and Ann Henderson-Sellers, 2014.
2. Numerical Methods used in Atmospheric Models WMO-GARP Series No.17
3. Fundamentals of Numerical Weather Prediction, Jean Coi-er, 2011.
4. Numerical Prediction and Dynamic Meteorology G.J. Haltiner and R.T. Williams,

CS 2305 : INTERPRETATION AND USE OF CLIMATE MODEL OUTPUTS (PRACTICAL)

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Analyze approaches for interpreting climate models, such as weather typing and fuzzy classification, to assess their strengths and weaknesses.	An	PSO 2
2	Apply Monte Carlo methods, Markov chains, and stochastic techniques to simulate climate patterns using historical data.	A	PSO 1
3	Evaluate regression methods, including linear regression and neural networks, for their predictive accuracy in climate data analysis.	E	PSO 2
4	Apply Climate GIS tools and data sources like NetCDF and GRADS to manipulate climate data for research and policy development.	A	PSO 3
5	Evaluate the effectiveness of technologies and policies related to climate change in supporting adaptation and mitigation strategies	E	PSO 6
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

UNIT 1

Introduction to the various approaches and methods for interpretation ofclimate models. Weather typing- analogue method-hybrid approaches-fuzzy classification

UNIT 2

Monte Carlo methods. Weather generators – Markov chains- Stochastic methods. Regression methods- Linear Regression-Neural Networks-Canonical Correlation analysis-Kriging.

UNIT 3

Climate GIS- GIS for climate data. Data sources and analysis tools –NetCDF- GRADS-NCL-CDO. Conversion of climate data for practical applications- Perspective technologies and policies in relation to climate change

Prescribed Book

1. Statistical Analysis in Climate Research, Storch H, Zwiers FW , Cambridge University Press, 1999.
2. Statistical Methods in the Atmospheric Sciences (Fourth Edition), Daniel S. Wilks, 2020.
3. A Guide to Empirical Orthogonal Functions for Climate Data Analysis, Antonio Navarra, Valeria Simoncini, 2010

SEMESTER 4

CS 2401: DISSERTATION

CO No.	Expected Course Outcome *Upon completion of this course, students will be able to;*	Learning domains	PSO No.
1	Undertake independent research work pertaining to weather /Atmospheric science related topic of his/her choice**.**	C	PSO 9
2	Propose a scientific problem, carry out modelling or field experiments	A	PSO 9
3	Analyse the data from model outputs / observations, present and public the results.	An	PSO 8
4	Create a comprehensive project report that synthesizes research findings, analyzes implications, and presents conclusions clearly and logically.	C	PSO 7
5	Evaluate the significance of the research outcomes in the context of the broader field, identifying potential applications and areas for future research.	E	PSO 10
Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C)			

Student has to work on a research project of about six months duration, preferably in an external R&D organization and has to submit a project report by the end of the semester.