DEPARTMENT OF ATMOSPHERIC SCIENCES

COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

M Sc in Meteorology

CURRICULUM AND SYLLABUS

Effective from the Academic Year 2024-25

Contents

1 Preamble

The MSc in Meteorology offers a comprehensive education in the study of atmospheric phenomena and processes. This program equips students with advanced knowledge about weather forecasting, climate change, atmospheric dynamics, and the physical and chemical processes governing the atmosphere. With a strong emphasis on both theoretical understanding and practical skills, students engage in rigorous coursework, laboratory work, and field studies. The curriculum includes the use of state-of-the-art technology and methodologies, such as remote sensing, wind profiler radar, and computational models. Graduates of this program are well-prepared for careers in meteorological research, weather prediction services, environmental consulting, and further academic pursuits, contributing to the advancement of atmospheric sciences and the betterment of society.

2 Scope

This curriculum and syllabus are tailored for the M.Sc. Meteorology program offered by the Department of Atmospheric Sciences at Cochin University of Science and Technology, starting in the 2024-25 academic year. All academic processes, including admission, course registration, and assessment, will adhere to the regulations set by Cochin University of Science and Technology for postgraduate courses. This document provides detailed information about the M.Sc. Meteorology program, including the OBE evaluation procedures, scheme, and syllabus.

3 Outcome Based Education (OBE)

Outcome-Based Education (OBE) is a student-centric teaching and learning approach where course delivery and assessment are structured to meet specified objectives and outcomes, known as Course Outcomes (CO). Each CO is classified by its comprehension level according to the Revised Bloom's Taxonomy Level (BL). OBE incorporates essential concepts such as Graduate Attributes, Program Educational Objectives (PEO), Program Outcomes (PO), Program Specific Outcomes (PSO), and Course Outcomes (CO).

3.1 Graduate Attributes

This curriculum and syllabus incorporate the following graduate attributes outlining the key competencies and qualities students will acquire to excel in their academic pursuit and beyond.

1. Knowledge
2. Creativity
3. Digital skills
4. Teamwork
5. Communication
6. Leadership
7. Responsible decision making
8. Integrity

3.2 Programme Educational Objectives (PEO)

Programme Educational Objectives (PEOs) outline the anticipated accomplishments of graduates in their professional lives. Specifically, PEOs describe the expected performance and achievements of graduates during the initial years following the completion of their degree. These objectives serve as long-term goals, defining the career trajectories and competencies that the educational program aims to instill in its students, preparing them for success in their chosen field.

1. **Foundation in Atmospheric Sciences**: Equip graduates with a robust understanding of fundamental and advanced concepts in meteorology, atmospheric dynamics, and climate science, enabling them to analyze and interpret meteorological data effectively.
2. **Research and Innovation**: Foster a research-oriented mindset by engaging students in cutting-edge atmospheric research, encouraging innovative approaches to solving complex meteorological problems, and contributing to advancements in the field.
3. **Technical Proficiency**: Develop technical skills through hands-on experience with modern meteorological instruments, computational tools, and data analysis software, preparing graduates for professional roles in weather forecasting, climate modeling, and environmental consulting.
4. **Ethical and Professional Development**: Instill a strong sense of professional ethics, environmental stewardship, and responsibility, preparing graduates to address global and societal challenges related to weather and climate with integrity and accountability.
5. **Lifelong Learning and Adaptability**: Encourage continuous learning and adaptability, equipping graduates with the skills to stay current with evolving technologies, methodologies, and scientific knowledge in the field of meteorology.
6. **Communication and Collaboration**: Enhance communication and teamwork abilities, enabling graduates to effectively disseminate meteorological information, collaborate with interdisciplinary teams, and engage with stakeholders and the public on weather and climate issues.

3.3 Programme Outcomes (PO)

Program outcomes (PO) are statements conveying the intent of a program of study. Specifically, program outcomes refer to what a student should know or be able to do at the end of a program. They are often seen as the knowledge and skills students will have obtained by the time they have received their intended degree.

1. **Advanced Atmospheric Science Expertise**
   Graduates will demonstrate in-depth understanding of atmospheric physics, dynamics, and chemistry. They will be able to apply advanced mathematical and statistical methods to meteorological problems and analyze complex weather systems and climate patterns across various scales.
2. **Research and Analytical Proficiency**
   Students will develop the ability to design and conduct independent research in meteorology. They will critically analyze and interpret complex meteorological data and models, and utilize state-of-the-art numerical weather prediction models and climate simulations.
3. **Technological and Computational Competence**
   Graduates will be proficient in operating sophisticated meteorological instruments and remote sensing equipment. They will apply programming skills for data analysis, modeling,

and visualization, and utilize specialized software and emerging technologies in weather forecasting and climate analysis.

4. **Interdisciplinary Application and Communication**
   Students will apply meteorological knowledge to related fields such as hydrology, oceanography, and environmental science. They will effectively communicate complex meteorological concepts to both scientific and non-scientific audiences and understand the societal and economic impacts of weather and climate.

5. **Professional Skills and Ethical Conduct**
   Graduates will demonstrate leadership and collaboration in weather-related projects and initiatives. They will adhere to ethical standards in scientific research and forecasting and understand the professional responsibilities of meteorologists in public safety and policy-making.

6. **Adaptive Expertise and Continuous Learning**
   Students will develop problem-solving skills to address complex atmospheric issues. They will stay current with advancements in meteorological science and technology and engage in lifelong learning and professional development in the rapidly evolving field of atmospheric sciences.

3.4 Programme Specific Outcomes (PSO)

Programme Specific Outcomes (PSO) are narrower statements that describe what students are expected to be able to do by the time of completion of the Programme.

1. **Weather Systems Analysis and Forecasting**
   Graduates will analyze and interpret complex weather patterns and atmospheric phenomena. They will apply advanced forecasting techniques for short-term and long-term weather prediction and utilize numerical weather prediction models, interpreting their outputs effectively.

2. **Climate Dynamics and Change**
   Students will understand climate system components, their interactions, and feedback mechanisms. They will analyze climate variability on various timescales (seasonal to decadal) and assess impacts of climate change on regional and global weather patterns.

3. **Atmospheric Physics and Chemistry**
   Graduates will apply principles of thermodynamics and fluid dynamics to atmospheric processes. They will analyze atmospheric composition and its impact on weather and climate, and understand radiative transfer processes and their role in atmospheric energetics.

4. **Meteorological Instrumentation and Remote Sensing**
   Students will operate and maintain various meteorological instruments. They will interpret data from weather radars, satellites, and other remote sensing platforms, and apply quality control measures to observational data.

5. **Data Analysis and Computational Methods**
   Graduates will apply statistical methods to analyze large meteorological datasets. They will develop and use computational models for atmospheric processes and implement machine learning techniques for weather and climate applications.

6. **Environmental Meteorology**
   Students will assess air quality and understand atmospheric pollution transport. They will

analyze interactions between the atmosphere and other Earth system components, and apply meteorological principles to renewable energy, agriculture, and urban planning.

3.5 PO-PSO mapping

Program Outcomes	Program Specific Outcomes					
	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
PO1	3	3	3	2	2	2
PO2	3	3	3	2	3	2
PO3	3	2	2	3	3	1
PO4	2	3	2	2	2	3
PO5	2	2	1	2	2	3
PO6	3	3	3	3	3	3

Correlation between Program Outcomes (POs) and Program Specific Outcomes (PSOs), Note: Correlation levels: 1 = Low, 2 = Medium, 3 = High

3.6 Course Outcome (CO)

Course Outcomes, also known as Learning Outcomes, are precise and quantifiable statements that outline the specific knowledge, skills, and attitudes students will exhibit upon completing a course. These outcomes are formulated using action-oriented verb phrases that indicate demonstrable behaviors or capabilities. Effective Course Outcomes should possess three key characteristics:

- Observable: They should describe actions or behaviors that can be clearly seen or detected.
- Measurable: They should allow for objective assessment of student achievement.
- Achievable: They should be realistically attainable within the course's timeframe.

By defining outcomes in this manner, educators can clearly communicate expectations, guide course design, and facilitate meaningful assessment of student learning. This approach ensures that both instructors and students have a clear understanding of the course's goals and the specific competencies to be developed.

3.7 Bloom's Revised Taxonomy Levels (BL)

Bloom's Taxonomy, in its revised form, identifies six distinct levels of cognitive learning, arranged in a hierarchy of complexity. These levels, progressing from the most basic to the most advanced, are:

1. Remembering: Recalling or recognizing information, ideas, and principles in the approximate form in which they were learned.
2. Understanding: Comprehending or interpreting information based on prior learning.
3. Applying: Using learned material in new and concrete situations.
4. Analyzing: Breaking down information into its component parts and detecting how the parts relate to one another and to an overall structure or purpose.
5. Evaluating: Making judgments about the value of ideas or materials.

6. Creating: Putting elements together to form a coherent or functional whole; reorganizing elements into a new pattern or structure.

Each level builds upon the previous one, representing increasingly complex cognitive processes. This taxonomy serves as a valuable framework for educators in designing learning objectives, activities, and assessments that promote higher-order thinking skills.

3.8 CO-PSO mapping

Each CO of a course is mapped with the PSO of the programme with weightages (correlation levels).

3.9 OBE-based Question Paper

In alignment with Outcome-Based Education (OBE) principles, question papers are meticulously crafted. Each question is strategically linked to three key elements:

- Bloom's Taxonomy Level (BL): Indicating the cognitive complexity of the question
- Course Outcome (CO): Specifying the particular learning outcome being assessed
- Programme Specific Outcome (PSO): Connecting the question to broader program goals

This approach ensures a comprehensive assessment that aligns with the intended learning outcomes and cognitive skill development.

3.10 OBE Evaluation Process

The OBE evaluation methodology is designed to quantify students' attainment levels across various outcomes:

1. For each Course Outcome (CO), the percentage of marks scored is calculated.
2. Based on these percentages, the Level of Attainment (LA) is determined for both continuous assessment and end-semester examinations.
3. A weighted total LA is then computed, providing a nuanced measure of how well students in a class have achieved each Course Outcome.

This systematic evaluation process allows for a detailed analysis of student performance in relation to specific learning outcomes, facilitating targeted improvements in curriculum and instruction.

4 Scheme

SEMESTER - I

Course Code	Course	C/ E	Credits	Marks		
				CA	EA	Total
24-302-0101	Geophysical Fluid Dynamics	C	4	50	50	100
24-302-0102	Physical Meteorology	C	4	50	50	100
24-302-0103	Observational Techniques	C	3	50	50	100
24-302-0104	Computing & Programming-I (Practical)	C	3	100	-	100
24-302-0105	Semester End Seminar & Viva – Voce	C	1	-	100	100
	Elective 1	E	4	50	50	100

SEMESTER - II

Course Code	Course	C/ E	Credits	Marks		
				CA	EA	Total
24-302-0201	Dynamic Meteorology	C	4	50	50	100
24-302-0202	Synoptic & Tropical Meteorology	C	4	50	50	100
24-302-0203	Computing & Programming II (Practical)	C	2	100	-	100
24-302-0204	Semester End Seminar & Viva – Voce	C	1	-	100	100
	Elective 1	E	4	50	50	100
	Elective 2	E	4	50	50	100
	Elective 3	E	3	-	100	100

SEMESTER - III

Course Code	Course	C/ E	Credits	Marks		
				CA	EA	Total
24-302-0301	Numerical Weather Prediction	C	4	50	50	100
24-302-0302	AI/ML Applications in Meteorology	C	4	50	50	100
24-302-0303	Meteorological Analysis (Practical)	C	2	100	-	100
24-302-0304	Computational Meteorology (Practical)	C	2	100	-	100
24-302-0305	Semester End Seminar and Viva – Voce	C	1	-	100	100
	Elective 1	E	3	50	50	100
	MOOC*	E	2/3	-	100	100

CA – Continuous Assessment, EA – End–Semester Assessment, C/E – Core/Elective

*Credit will be decided based on the Elective course selected by the student.

SEMESTER - IV

Course Code	Course	C/ E	Credits	Marks		
				CA	EA	Total
24-302-0401	Project and Project Presentation	C	18	50	50	100
24-302-0402	Comprehensive Viva	C	3	-	100	100

The 100-mark assessment for the project is based on:

1. Continuous assessment by the guide: Up to 50 marks based on the student's performance and progress during the dissertation work.
2. Project dissertation evaluation: Up to 50 marks Internal assessment of the dissertation submitted at the semester's end and project presentation.

The continuous assessment and end-semester components carry equal weight in the final score.

Elective Courses

Course Code	Course	C/E	Credits	Marks		
				CE	EA	Total
24-302-0111	Statistical Methods	E	4	50	50	100
24-302-0112	Numerical Methods	E	4	50	50	100
24-302-0113	Advanced Mathematics	E	3	50	50	100
24-302-0114	General Meteorology	E	3	50	50	100
24-302-0211	Remote Sensing & Satellite Meteorology	E	4	50	50	100
24-302-0212	Climate & Climate Change	E	4	50	50	100
24-302-0213	Data Analysis in Meteorology	E	4	50	50	100
24-302-0214	Cloud Physics & Atmospheric Electricity	E	3	50	50	100
24-302-0311	Applied Meteorology	E	4	50	50	100
24-302-0312	Atmospheric Boundary Layer	E	3	50	50	100
24-302-0313	Atmospheric Chemistry & Air Pollution	E	3	50	50	100
24-302-0314	Meteorological Hazards & Disaster Management	E	3	50	50	100
24-302-xxxx	MOOC	E	2/3	-	100	

The program consists of 14 core courses and 12 electives. Students must accumulate a minimum of 80 credits to successfully complete the program. The students can choose Electives from other Departments also. The students can choose more than one Elective in a Semester.

During the fourth semester, students focus on dissertation work in a relevant specialization area. This can be conducted within the Department or at an external industry, research, or academic institution. All students must submit a project dissertation at the semester's end. In addition to the major project in the fourth semester, students may take up an internship or industry training lasting up to 8 weeks during vacation.

Students must enroll in an appropriate Massive Open Online Course (MOOC) through the SWAYAM platform www.swayam.gov.in. Faculty members will periodically recommend suitable courses. This MOOC can be taken during any of the first three semesters, depending on course availability on the SWAYAM platform. Students must obtain the required MOOC credits before completing the fourth semester. The Department Council and University will determine MOOC grading based on results from www.swayam.gov.in

Grading Scale

Range of Marks	Grade	Weightage
Below 50%	F: FAILED	0
50 – 59	D: SATISFACTORY	6
60 – 69	C: GOOD	7
70 – 79	B: VERY GOOD	8
80 – 89	A: EXCELLENT	9
90 – and above	S: OUTSTANDING	10

5 Syllabus

Core Courses

SEMESTER - I

24-302-0101: Geophysical Fluid Dynamics

CO	Description	Bloom's Level
CO1	Understand the basic concepts of fluid statics and dynamics in atmospheric contexts	Understand
CO2	Develop equations of atmospheric motions from fundamental equations	Apply
CO3	Differentiate between various types of atmospheric flows and motions	Analyze
CO4	Assess the applicability of different wind balance models in atmospheric conditions	Evaluate

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	1	2	3	1
CO2	2	2	2	2	3	2
CO3	2	2	2	2	3	2
CO4	3	3	3	2	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Basic concepts: fluid continuum, fluid properties, ideal fluid and real fluids, types of flow. Fluid statics: pressure, surface and body forces on a fluid element; fundamental equation of fluid statics, perfect gas equation, hydrostatic equation along the vertical - application to the atmosphere, Laplace's equation. Kinematics: Lagrangian and Eulerian methods of description of fluid flow, stream lines, streak lines and trajectories, steady and non-steady flow, differential analysis of fluid flow -translation, rotation, divergence and deformation- physical interpretation, application to plane motion, typical flow patterns, stream function, local and convective derivatives.

Unit 2

Viscous fluids, coefficient of viscosity, Navier-Stokes equations of motion for a viscous Newtonian fluid; laminar flow of viscous incompressible fluids, Poiseuille flow, Couette flow, Reynold's number and dynamic similarity of flows, physical significance of Reynold's number, low and high Reynold's number.

Unit 3

Dynamics: equation of continuity and its applications, non-viscous incompressible flow, Eulerian equations of motion, inertial and rotational frames of reference, Coriolis force, irrotational flow, velocity potential, integration of the equations of motion, Bernoulli's theorem and its applications. Thermodynamic energy equation. Equations of motion in spherical coordinates, isobaric coordinate and sigma co-ordinate system, scale analysis of dynamical equations, Rossby Number.

Unit 4

Horizontal frictionless motion: natural coordinate system classification of flows, balanced motion, geostrophic wind, inertial wind and cyclostrophic wind, gradient wind - thermal wind - backing and veering, barotropic and baroclinic atmospheres, solenoids and thermal wind.

Unit 5

Circulation and vorticity, Stoke's theorem, Kelvin's theorem, Helmholtz theorem, barotropic and baroclinic fluids, absolute and relative circulation; Bjerknes circulation theorem and its interpretation, potential vorticity-conservation, application to air flow over mountain barriers – Taylor - Proudman Theorem. The vorticity equation in cartesian and isobaric coordinates, significance of the various terms, divergence and vorticity of the geostrophic wind, the vector vorticity equation, scale analysis of the vorticity equation, CAV trajectories, the divergence equation, balance equation.

References

Text Books

1. Fluid mechanics of the atmosphere, R.A.Brown, Academic Press, 1991
2. Introduction to Theoretical Meteorology, S L Hess, International Thomson Publishing, 2000.
3. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
4. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012

Reference Books

1. Geophysical Fluid Dynamics (Second Edition), J. Pedlosky, Springer, Berlin Heidelberg, 1972.
2. Atmosphere-Ocean Dynamics (International Geophysics Series, Volume 30), A E Gill, Academic Press, New York, 1982.
3. Introduction to Geophysical Fluid Dynamics, Second Edition: Physical and Numerical Aspects (International Geophysical Series, Volume 31), B C Roisin and J M Beckers, Academic Press, New York, 2011.

24-302-0102: Physical Meteorology

No.	Course Outcome	Bloom's Level
CO1	Understand the basic physical characteristics of earth atmosphere system	Understand
CO2	Apply laws of radiation to the atmosphere and to get knowledge of the radiation budget of the earth atmosphere system	Apply
CO3	Understand the thermodynamic process in the atmosphere and their applications to atmospheric stability studies.	Apply
CO4	Analyse the thermodynamic stability of the atmosphere using thermodynamic diagrams	Analyse

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	3	1	0	1
CO2	2	3	3	2	0	2
CO3	3	1	3	1	0	3
CO4	3	2	3	1	0	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Fundamentals of Earth's Atmosphere

1. Atmosphere-Sun-Earth relationship: solstices and equinoxes, motion of earth - vertical thermal structure of the atmosphere, composition of the atmosphere - dry air, water vapour and aerosols.
2. Atmospheric Optics: Visibility - attenuation of light-turbidity, Optical phenomena - rainbows, haloes, corona, glory, mirage etc. scattering - blue of the sky colours at sun rise and sunset- atmospheric refraction.

Unit 2: Radiation

1. Fundamentals of Radiation and Laws: Black body, Spectrum of radiation, Quantitative description of radiation, Scattering, absorption, and emission of radiation, Kirchhoff's Law, Stefan Boltzmann law, Planck's law, Wien's Displacement Law, Terrestrial Radiation absorption in the atmosphere -atmospheric window
2. Greenhouse Effect and Atmospheric Interactions: Greenhouse effect, Greenhouse gasses, Effects of greenhouse effect
3. Radiation Balance and Solar Influence: Radiation balance at the top of the atmosphere, Solar radiation and albedo, Infrared radiation from land and ocean surfaces, Mean heat balance of the earth- atmosphere system, poleward transport of energy-fundamental link with the general circulation.
4. Aerosols and Heat Budget: Radiative forcing, Aerosols in the atmosphere and their effect on radiation, Heat budget of the ocean and atmosphere, Clouds and radiation

Unit 3: Thermodynamics

1. Atmospheric Thermodynamics: Gas laws, Internal energy, The first law of thermodynamics, Dry and Saturated Adiabatic Processes: Dry adiabatic lapse rate, Potential temperature, Moisture parameters, Saturated adiabatic lapse rate

2. Reversible and irreversible process: The second law of thermodynamics, Entropy, Carnot's cycle. Thermodynamics of water vapour-latent heat-the Clausius-Clapeyron equation, pseudo-adiabatic cases-equivalent potential temperature, saturation potential temperature

Unit 4: Atmospheric instability

1. Stability Criteria: parcel method - Brunt- Vaisala oscillations, lifting, mixing and convective condensation levels-potential instability and latent instability-stability indices-slice method of stability analysis- growth of cumulus clouds-entrainment.

Unit 5: Hydrostatics of the Atmosphere

1. Geopotential, equipotential Surface-Hydrostatic equation-hydrostatic equilibrium, standard atmosphere - altimetry.

2. Thermodynamic diagrams-basic requirements-emagram, skew T-log P diagrams-tephigram – LCL, LFC, CCL, EL, CAPE and CINE.

References

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

24-302-0103: Observational Techniques

No.	Course Outcome	Bloom's Level
CO1	Fundamental working principles of meteorological instruments.	Understanding
CO2	Fundamental of satellite remote sensing	Understanding
CO3	Interpret and analyses meteorological instrument data.	Analyzing, Applying
CO4	Interpret different weather radar observations	Analyzing

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	1	2	2
CO2	3	2	3	1	2	1
CO3	3	2	3	1	2	1
CO4	3	3	3	1	2	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

General principles of surface instrumental measurements: accuracy requirements, Siting of an observatory, exposure requirements, observational procedures, standard times of observations. Network of observatories, random and systematic errors, calibration and validation.

Unit 2

Conventional measurements of pressure, temperature, humidity, wind speed and direction, sunshine duration, radiation – shortwave and longwave, precipitation, visibility, clouds, soil temperature, evaporation, evapotranspiration, Automatic Weather Stations

Unit 3

Remote sensing, Electromagnetic Radiation, Radiation –Target, Passive vs. Active, satellite orbits, Characteristics of Images, Pixel Size, and Scale, Spectral Resolution, Radiometric Resolution, Temporal Resolution, EMR spectrum – Visible, Infra-Red (IR), Near IR, Middle IR, Thermal IR and Microwave. Satellite observations of geophysical parameters: SST, moisture and humidity profiles, Wind, Precipitation, sea ice coverage, oceanic productivity, land-use land-cover, soil moisture.

Unit 4

Upper air pressure, temperature, humidity and wind measurements: radiosonde, dropsonde, ozonesonde, GPS sonde, Microwave radiometer, Microwave rain radars, Lidar ceilometer, Disdrometer, Weather radars, Wind profiler radar fundamentals, Doppler beam swinging for wind estimation, Radar signal processing, Estimation of moments and three-dimensional winds.

References

Main books

1. Probing the Atmospheric Boundary Layer, Edited by D H Lenschow, American Met Society, 1986.
2. Meteorological Instruments, W E K Middleton & Spilhaus, University of Toronto Press, 1953.
3. Atmospheric Radar: Application and Science of MST Radars in the Earth's Mesosphere, Stratosphere, Troposphere, and Weakly Ionized Regions
4. Satellite meteorology, Kidder and Vander Harr

Other references

1. Applications of Remote Sensing to Remote Sensing to Agro meteorology, F Toselli, Kluwer, 1989.
2. Instruments and Observing Methods, Report No. 81, WMO/TD - No. 1250, 2006.
3. Handbook of Aviation Meteorology, HMSO, 2005

24-302-0104: Computing and Programming – I (Practical)

CO	Course Outcome	Bloom's Level
CO1	Learn basic Unix operating systems	Understanding
CO2	Understand the basics of FORTRAN and Python programming languages	Understanding
CO3	Formulate simple computer programs in FORTRAN and Python	Applying
CO4	Develop computer programs for meteorological computations	Creating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	1	1	2	3	1
CO2	2	2	2	2	3	2
CO3	2	2	2	2	3	2
CO4	3	3	3	2	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1
Introduction to Linux: Basic Linux concepts, creating an account, Virtual consoles, Shells and commands, LINUX, Unix Commands: Using pipes, file permissions, vi editor, e-mails editor

Unit 2
FORTRAN: basics, Variables, types, and declarations, Expressions and assignment, Logical expressions, if statements, Loops Arrays, Subprograms, Arrays in subprograms, Common blocks, Data and Block Data Statements File I/O, Simple I/O, Format statements, Programming style

Unit 3
Python: Introduction, Python Interpreter, Argument Passing, Data types: Numbers, Strings, Unicode Strings, Lists; Flow Control: If Statements, for Statements, Range function, pass, break and continue statements, Loops Functions: - Default Argument Values, Keyword Arguments, Arbitrary Argument Lists, Unpacking Argument Lists, Lambda Forms, Documentation Strings

Unit 4
Python Data Structures: Using Lists as Stacks and Queues, del statement, Tuples and Sequences, Sets, Dictionaries, Comparing Sequences and Other Types, Data Modules: Executing modules as scripts, The Module Search Path, Compiled Python files, Standard Modules, dir Function, Packages: Importing * From a Package, Intra-package References, Packages in Multiple Directories

Unit 5
Python Input Output: Fancier Output Formatting, Old string formatting, Reading and Writing Files, Methods of File Objects, the pickle Module, Errors and Exceptions: Exceptions, Handling Exceptions, Raising Exceptions, User-defined Exceptions, Defining Clean-up Actions, Predefined Clean-up Actions

References

1. Computer Programming in FORTRAN 90 & 95, V Rajaraman, Prentice Hall of India, 1997.
2. Numerical Recipes in FORTRAN 90, Vol 2 (Second Edition), William H Press, S A Teukolsky, W T Vetterling and B P Flannery, Cambridge University Press, 1996.
3. A Primer on Scientific Programming with Python (First Edition), Hans Petter Langtangen, Springer, 2009.
4. Head First Programming: A learner's guide to programming using Python language (First Edition), Paul Barry and David Griffiths, Shroff/O'Reilly, 2009.

24-302-0105: Semester End Seminar and Viva Voce

SEMESTER - II

24-302-0201: Dynamic Meteorology

CO	Course Outcome	Bloom's Level
CO1	Understand the structure and dynamics of the atmospheric boundary layer	Understand
CO2	Use quasi-geostrophic equations to analyze synoptic-scale motions	Apply
CO3	Apply linear perturbation theory to study wave propagation in the atmosphere	Apply
CO4	Assess the role of hydrodynamic instabilities in atmospheric dynamics	Evaluate
CO5	Utilize principles of dynamic meteorology to interpret and explain features of the general circulation	Apply

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	1	2	2
CO2	3	2	3	1	2	1
CO3	3	2	3	1	2	1
CO4	3	3	3	1	2	2
CO5	3	3	3	1	2	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1
Fundamentals of the atmospheric boundary layer. Various sub layers in the ABL - Winds in the boundary layer- Surface layer – Ekman Spiral Layer - Turbulence and Taylor Hypothesis - Boundary Layer Depth and Structure - Convectively Mixed Boundary Layer - Nocturnal Boundary Layer.

Unit 2
Dynamics of synoptic scale motions in middle latitudes, quasi geostrophic vorticity equation, geopotential tendency equation, quasi geostrophic potential vorticity equation, omega equation, the Q-Vector method, ageostrophic circulation, idealised model of a baroclinic disturbance.

Unit 3
Atmospheric waves: dispersion of waves, linear perturbation theory, Fourier series of representation of waves - Acoustic waves, shallow water gravity waves, internal gravity waves, inertial gravity waves, Rossby waves, mountain waves, Stationary planetary waves. Momentum and energy transports by waves in the horizontal and the vertical. Equatorial wave theory: Equatorial Beta Plane Approximation, mixed Rossby gravity waves, Kelvin waves, vertically propagating planetary waves, Wave-mean flow and wave-wave interactions.

Unit 4
Hydrodynamic instability: Kelvin Helmholtz instability-linear barotropic and baroclinic instability and cyclogenesis, baroclinic instability in a two-layer model, necessary and sufficient condition for instabilities, energetics of baroclinic waves. Atmospheric energetics: energy equation - internal, potential and kinetic energies - frictional dissipation of kinetic energy - conversion of potential and internal energies to kinetic energy (Margule's model) - mechanical generation of kinetic energy (Starr's model).

Unit 5
General circulation of the atmosphere: zonally asymmetric components, standing eddies, Walker circulation. Basic equations - maintenance of the zonal mean circulation. Kinetic energy cycle, space/time-averaging formulation. Angular momentum balance, role of eddy fluxes, Total Energy Balance, Laboratory simulation of atmospheric circulation.

References

- **Text Books:**

1. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012
2. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
3. Basics of Atmospheric Science, A. Chandrasekhar, M/s PHI Learning Pvt. Ltd., New Delhi, 2010
4. Basics of Atmospheric Dynamics, 2021, R. N. Keshavamurty, CRC Press

- **Reference Books:**

1. Dynamical and Physical Meteorology, G J Haltiner and F L Martin, McGraw-Hill, 1957
2. Introduction to Theoretical Meteorology, S L Hess, International Thomson Publishing, 2000.
3. An Introduction to Atmospheric Boundary Layer Meteorology, R L Stull, Kluwer Academic Publishers, 1988.
4. Tropical Meteorology (Revised Edition) Vols I, II and III, G C Asnani

24-302-0202: Synoptic & Tropical Meteorology

CO	Course Outcome	Bloom's Level
CO1	Understand the characteristic features of dominant weather systems over the Indian region in various temporal and spatial scales.	Understanding
CO2	Describe the structure and dynamics of tropical cyclones and the variability, teleconnection and synoptic features of Indian monsoon.	Understanding
CO3	Analyze the extratropical weather systems.	Analyzing
CO4	Understand different forecasting strategies and predict the weather systems at different space-time domains using synoptic and NWP methods	Creating
CO5	Assess challenges and limitations of various forecast process	Evaluating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	1	2	2
CO2	3	3	2	1	2	2
CO3	3	2	2	1	2	2
CO4	3	3	2	2	3	2
CO5	3	2	2	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Introduction to Global observing systems, Map Projections, weather and climate, Climatological and seasonal distribution of Global pressure and wind systems, General circulation of the tropics: Hadley Cell, Walker Circulation, trade wind inversion, ITCZ, Scales of weather systems

Unit 2

Convection and Cloud processes, Different mechanism of Convective processes (Dry/moist convection, CAPE, CIN, CIFK, CISK), Classification of convective systems, Convective activity over Indian region, Weather hazards associated with Convective systems, western disturbance, Clear Air Turbulence, Fog.

Unit 3

Mid latitude Synoptic Meteorology: Air masses and fronts, Extra tropical cyclone and its structure and life cycle, Fronts and associated weather, Development of cyclones and anticyclones, Rossby waves and jet streams, index cycle and climatic significance of jet streams, long waves; cut-off lows and highs, blocking, Polar vortex, Sudden stratospheric warming

Unit 4

Characteristics of Tropical Weather systems, drivers of tropical climate variability; MJO, ENSO, IOD, NAO, PDO, AMO, tropical waves, Introduction to tropical waves, Tropical Cyclones, Classification of cyclonic systems, Global distribution and climatology, cyclogenesis process - necessary conditions, Life cycle and structure of tropical cyclones, rainfall distribution associated with the cyclones, satellite observations of tropical cyclones - T-number, Hazards Associated with Tropical cyclone, Impact of Global warming on tropical cyclone intensity and frequency. History of Asian Monsoon system, Evolution of Asian summer monsoon, Semi-permanent systems of Asian monsoon, Indian Summer Monsoon, Climatological distribution of rainfall, Monsoon onset over Kerala, Various Rain bearing systems of Indian summer monsoon, Internal variability of the monsoon, Monsoon Intra-Seasonal Oscillations (MISO) - Active/Break cycle, Inter-Annual variability of monsoon - Various Tele-connections, ENSO, IOD, Role of MJO and Western Pacific Typhoons, Withdrawal of Monsoon, Northeast monsoon.

Unit 5

Different forecasting strategies - synoptic, statistical, analogue, empirical and dynamical methods, Ranges of weather prediction and seamless prediction, lead time and range of forecasts, Skill of weather prediction at different ranges, Use of satellites and radars for nowcasting, Prediction of individual weather systems, Seasonal and intraseasonal prediction of Indian Summer Monsoon, Interpretation of Analysis of NWP derived products, their interpretation and their limitations - mesoscale, general circulation and coupled models, Forecast bulletin & products, presentation and dissemination, heavy rainfall monitoring, forecasting and warning services.

Text Books

1. Principles of Kinematics and Dynamics, Bluestein, H. B, Vol. I, Synoptic-Dynamic Meteorology in Midlatitudes, Oxford University Press, 431 pp, 1992.
2. Severe Convective Storms, Charles A. Doswell, American Meteorological Society, 2001.
3. Physics and Dynamics of Clouds and Precipitation, Pao K Wang, 2013
4. Weather Analysis and Forecasting, Christo Georgiev Patrick Santurette, 2016.
5. Fundamentals of Tropical Climate Dynamics, Li, Tim, Hsu, Pangchi, 2018.
6. Tropical Cyclones, their Evolution, Structure and effects, Richard A. Anthes, American Meteorological Society, 1982.
7. The Asian Monsoon, Bin Wang, 2006.
8. Monsoon Vol 1 and 2, Ajit Tyagi, India Meteorological Department, 2013.
9. The Asian Summer Monsoon: Characteristics, Variability, Teleconnections and Projection, Yunyun Liu, Ping Liang and Ying Sun, 2019.
10. Tropical Meteorology: An Introduction, Krishnamurti, T.N., Stefanova, Lydia, 2013.

Reference Books

1. Midlatitude Synoptic Meteorology: Dynamics, Lackmann, G, Analysis and Forecasting, American Meteorology Society,345 pp, 2011.
2. Lecture notes on synoptic meteorology, IMD

3. Synoptic - Dynamic Meteorology in Midlatitudes: Vol I: Principles of Kinematics and Dynamics, Vol II: Observations and Theory of Weather, Howard B Bluestein, Oxford University Press, 1992.
4. http://www.meted.ucar.edu/tropical/textbook_2nd_edition/
5. Tropical Cyclones: Observations and Basic Processes, Roger K. Smith, Michael T. Montgomery, 2023
6. Essentials of Meteorology: An Invitation to the Atmosphere, Ahrens, C. Donald, and R. Henson, Eighth Edition, 2018.
7. An introduction to large scale tropical meterology, V. Misra, 2023.
8. Tropical Meteorology (Vol-I, II, III), G.C.Asnani, 2016.
9. Tropical Circulation Systems and Monsoon, Saha, Kshudiram, 2010.
10. Dynamics of the Tropical Atmosphere and Oceans (Advancing Weather and Climate Science), Peter J. Webster, 2020.

24-302-0203: Computing and Programming II (Practical)

CO	Course Outcome	Bloom's Level
CO1	Develop proficiency in programming languages commonly used in atmospheric science (e.g., Python).	Applying
CO2	Design and implement algorithms for solving atmospheric science problems.	Creating
CO3	Utilize software tools for data visualization, analysis, and modeling in atmospheric science.	Applying
CO4	Integrate programming skills with atmospheric science knowledge to develop computational solutions.	Creating
CO5	Collaborate effectively in teams for programming projects in atmospheric science.	Creating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	2	2	3	2
CO2	3	3	3	2	3	2
CO3	3	3	2	3	3	2
CO4	3	3	3	2	3	3
CO5	2	2	2	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1
Programming Fundamentals: Review of basic programming concepts. Control structures, functions, and modular programming in Python and MATLAB.

Unit 2
Data Structures and Algorithms: Introduction to data structures (arrays, lists, dictionaries) and their application in atmospheric science. Algorithm design techniques for numerical simulations and data processing.

Unit 3
Software Tools for Atmospheric Science: Introduction to software tools (e.g., NetCDF libraries, visualization libraries) for atmospheric data analysis and visualization. Hands-on exercises in data manipulation and visualization.

References

1. Python for Data Analysis, W McKinney, O'Reilly Media, 2017
2. Atmospheric Science: An Introductory Survey, J M Wallace, P V Hobbs, Academic Press, 2006
3. MATLAB Programming for Biomedical Engineers and Scientists, A P King, Elsevier, 2013
4. Data Visualization: Principles and Practice, A Maitra, CRC Press, 2018

24-302-0204: Semester End Seminar and Viva Voce

SEMESTER - III

24-302-0301: Numerical Weather Prediction

CO	Course Outcome	Bloom's Level
CO1	Understand the principles and mathematical foundations of numerical weather prediction models.	Understanding
CO2	Implement and validate numerical weather prediction models using programming languages.	Applying
CO3	Evaluate model performance and interpret numerical weather prediction outputs.	Evaluating
CO4	Apply numerical techniques to solve atmospheric equations governing weather phenomena.	Applying
CO5	Analyze and critique advancements in numerical weather prediction research.	Analyzing

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	2	1	3	1
CO2	3	2	1	2	3	1
CO3	3	3	1	2	3	2
CO4	3	2	3	1	3	2
CO5	3	3	2	1	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Historical Background and Hierarchy of Numerical Models

Historical Background of NWP- Filtering Problem -Finite difference Techniques- Explicit and Implicit Schemes – Computational instability, Semi Implicit Split explicit Schemes.-CFL Criteria and Stability Analysis-Staggered grid – Nonlinear Instability and Aliasing – Smoothers and Filters, Hierarchy of Numerical Models - Barotropic Model- Dynamics of the barotropic model, Shallow Water, Equation Model- Primitive Equation Models (PEM)- Grid point and spectral models- Boundary Conditions and time integration methods.

Unit 2: Data Assimilation

Introduction to Data Assimilation - Cressman Technique - Optimum interpolation - Variational Methods-3D and 4D Var- Kalman Filter - Ensemble based Data Assimilation - Hybrid Data Assimilation - Background error modelling.

Unit 3: Parameterization of Sub-Grid Scale Processes

Concept of parameterization in NWP and Climate models - Parameterization of Physical processes :- Boundary layer, Convection, Cloud microphysics, Radiation parameterization, Land Surface processes.

Unit 4: Ocean Atmospheric Coupling and Climate Models

Types of Forecasts- Nowcasting, Short Range, Medium Range, Extended Range, Deterministic and Ensemble forecast - Limited area Models and Global Models - Introduction to Coupled Models of Ocean, Land and Atmosphere and Strategy of coupling - Difference between Weather and Climate Models, Earth System Models.

Unit 5: Operational NWP modelling system and Post processing of model output

Global and Regional NWP Systems- Familiarization of NWP systems :-eg. WRF Model & DA system - Forecast products from Deterministic and Ensemble prediction systems- Model forecast verification and diagnostics - Forecast skills, forecast errors, Systematic errors - Bias correction of forecast - Application of AI/ML technique to improve NWP.

References

Text Books

1. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012
2. Dynamic Meteorology and NumericalWeather Prediction (Second Edition), G J Haltiner and R T Williams, Wiley, 1980.
3. An Introduction to Numerical Weather Prediction Techniques, T.N. Krishnamurti and L.Bounoua, CRC Press London, 1996.

Reference Books

1. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
2. Tropical Meteorology (Revised Edition) Vols I, II and III, G C Asnani, 2008
3. Atmospheric Data Analysis, R. Daley, Cambridge University Press, 1994.
4. Workbook on Numerical Weather Prediction for the Tropics, T N Krishnamoorthy, WMO Publication, Geneva, 1986.
5. Climate System Modelling, K. E. Trenberth, Cambridge University Press, 2010.

24-302-0302: AI/ML Applications in Meteorology

Course Description: This course explores the application of Artificial Intelligence (AI) and Machine Learning (ML) techniques in meteorology. Students will learn how AI/ML algorithms are utilized to enhance weather forecasting, climate modeling, and atmospheric data analysis. The course covers foundational concepts in AI/ML, data preprocessing techniques, model selection, evaluation metrics, and practical applications in meteorological research and operational forecasting.

CO	Course Outcome	Bloom's Level
CO1	Introduction to Machine Learning in Meteorology	Understanding, Applying
CO2	Understanding Machine Learning Basics	Understanding, Analyzing
CO3	Proficiency with Python Libraries	Applying
CO4	Applications of different models	Applying, Evaluating
CO5	Importance of Explainable AI	Understanding, Applying
CO6	Practical Application Development	Creating, Evaluating
CO7	Model Interpretation and Understanding	Applying, Analyzing

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	2	1	1	3	2
CO2	1	1	1	1	3	1
CO3	1	1	1	2	3	1
CO4	3	3	2	2	3	3
CO5	2	2	1	1	3	2
CO6	3	3	2	2	3	3
CO7	3	3	2	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Introduction and Machine Learning

Introduction to Machine Learning in Meteorology

- Overview of machine learning and its significance in meteorology
- Case studies and applications in weather prediction and climate analysis

Machine Learning Basics

- Types of machine learning: supervised, unsupervised, and reinforcement learning

- Key concepts: features, labels, training, and testing
- Introduction to Python libraries for machine learning (e.g., Scikit-learn, TensorFlow, Keras)

Linear Regression

- Understanding linear regression and its applications in meteorology
- Model evaluation: R-squared, Mean Squared Error (MSE)

Logistic Regression

- Introduction to logistic regression for classification problems
- Meteorological applications: classification of weather events
- Model evaluation: accuracy, precision, recall, F1-score

Unit 2: Tree-Based Models and Ensemble Learning

Decision Trees

- Fundamentals of decision trees and their use in classification and regression
- Understanding overfitting and pruning

Random Forest

- Introduction to ensemble learning and random forests
- Advantages of random forests over decision trees
- Practical implementation using Python

Naive Bayes

- Understanding the Naive Bayes classifier and its assumptions
- Applications in meteorology: probability-based weather prediction

Support Vector Machines (SVM)

- Introduction to support vector machines for classification and regression
- Kernel methods and their applications in SVM

Unit 3: Introduction to Deep Learning

Deep Learning Basics

- Overview of deep learning and its difference from traditional machine learning
- Introduction to neural networks and their architecture
- Applications in meteorology: complex pattern recognition

Perceptron

- Understanding the perceptron model
- Training a perceptron for binary classification

Convolutional Neural Networks (CNN)

- Introduction to CNNs and their architecture
- Applications in meteorology: satellite image classification, pattern recognition

Long Short-Term Memory (LSTM) model

- Time series predictions.
- LSTM & CNN for spatio-temporal predictions

Unit 4: Generative AI-models and LLMs basics, Explainable AI and Practical Applications

Generative AI & Explainable AI

- Introduction to Generative Models and Large Language models and their application in meteorology
- Importance of explainability in machine learning models
- Techniques for model interpretation and understanding
- Applications in meteorology: interpreting complex models for weather prediction

References:

1. Climate Informatics: Applications of Machine Learning in Climate Science, A. Banerjee, D. M. Hall, and A. T. J. Wiltshire, CRC Press, 2018.
2. Machine Learning for Earth Observation, M. Camps-Valls, L. Bruzzone, and J. A. Benediktsson, CRC Press, 2019.
3. Deep Learning for the Life Sciences: Applying Deep Learning to Genomics, Microscopy, Drug Discovery, and More, B. Ramsundar, P. Eastman, et al., O'Reilly Media, 2019.
4. Pattern Recognition and Machine Learning by Christopher M. Bishop
5. Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow by Aurélien Géron
6. Python libraries documentation: Scikit-learn, TensorFlow, Keras

24-302-0303: Meteorological Analysis (Practical)

Course Description: This practical course focuses on applying meteorological analysis techniques to real-world datasets. Students will gain hands-on experience in analyzing atmospheric data, interpreting weather patterns, and using software tools for meteorological visualization and modeling.

CO	Course Outcome	Bloom's Level
CO1	Understand coding-decoding of observation data and surface chart analysis	Understanding, Applying
CO2	Examine dominant weather systems using synoptic charts and re-analysis data	Analyzing
CO3	Compare different NWP charts	Applying, Evaluating
CO4	Conclude the diagnostic and prognostic inference of weather systems from synoptic/NWP charts	Applying, Evaluating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	1	3	2	1
CO2	3	2	1	2	3	1
CO3	3	2	1	1	3	1
CO4	3	2	1	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

WMO Codes and standards, SYNOP code, METARs and TAFs, Representation of weather data on charts, Surface chart analysis.

Unit 2

Analysis of Climatological pattern by using GRADS/PYTHON and NCEP/NCAR or ERA5 re-analysis data: Analysis of rainfall, pressure, temperature and 850hPa wind during winter, pre-monsoon, monsoon and post-monsoon season. Analysis of jet streams- STJ and TEJ.

Unit 3

Objective identification of Monsoon Onset over Kerala using reanalysis data, Analysis of Tropical Cyclone – case study. Hadley/Walker circulation analysis, Mean position and propagation of ITCZ using TRMM-GPM rainfall data.

Unit 4

Composite SST/ Rainfall anomaly analysis during El Nino-La Nina and +/- IOD years, Analysis and monitoring of weather systems using short to medium range NWP model outputs.

References:

1. Principles of Meteorological Analysis, Walter J. Saucier, Dover Publications, 2003.
2. Tropical Meteorology Vol. I, II & III, G C Asnani, 2016.
3. Guide to preparation of synoptic weather charts and diagrams, WMO (Publications), No.151, WMO Technical Publication,1964.
4. Synoptic Meteorology, M. Kurz, 1998.
5. https://www.comet.ucar.edu/presentations/Abstracts_2011/2A.4NWPTrainingSeries.html

24-302-0304: Semester End Seminar and Viva Voce

Elective Courses

24-302-0111: Statistical Methods

This course covers advanced statistical methods and their applications. It aims to provide students with the skills necessary to analyze and interpret data, develop predictive models, and understand the statistical underpinnings of climate studies.

CO	Course Outcome	Bloom's Level
CO1	Understand and apply advanced statistical techniques to any data	Understand, Apply
CO2	Develop and validate predictive models	Create, Evaluate
CO3	Analyze spatial and temporal patterns in data	Analyze
CO4	Critically evaluate statistical methods and their applications	Evaluate
CO5	Use statistical software for data analysis and model development	Apply

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	2	2	3	2
CO2	3	3	2	2	3	2
CO3	3	3	2	3	3	2
CO4	2	2	2	2	3	2
CO5	3	3	2	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Fundamentals of Statistics

Fundamental concepts in meteorological statistics, Overview of statistical software for atmospheric sciences, Descriptive statistics for meteorological data, Graphical representation of weather and climate data, Basic probability concepts, Probability distributions, Parameter estimation, Statistical hypothesis testing.

Unit 2: Correlation and Regression Analysis

Linear and nonlinear correlation, Lag correlation for time-delayed relationships, Rank correlation for non-parametric analysis, Partial and multiple correlation, Autocorrelation in time series data, ARIMA models for weather forecasting, Multiple and canonical correlation analysis, Covariance in multivariate data, Error analysis, Simple linear regression, Multiple regression.

Unit 3: Analysis of Variance and Time Series Analysis

Analysis of Variance (ANOVA), Power spectrum concepts, Harmonic analysis of cyclical patterns, Wavelet analysis for non-stationary signals, Computational procedures for spectrum analysis.

Unit 4: Advanced Time Series Techniques and Trend Analysis

Moving averages and data smoothing techniques, Filtering methods: Low-pass, high-pass, and band-pass filters, Trend analysis, Advanced applications of time series analysis.

References

1. Wilks, D. S. (2011). *Statistical Methods in the Atmospheric Sciences*. Academic Press.
2. von Storch, H., & Zwiers, F. W. (2001). *Statistical Analysis in Climate Research*. Cambridge University Press.
3. Chandler, R. E., & Scott, M. (2011). *Statistical Methods for Trend Detection and Analysis in the Environmental Sciences*. Wiley-Blackwell.

24-302-0112: Numerical Methods

This course provides an introduction to numerical methods. It focuses on the fundamental numerical techniques required to solve mathematical problems encountered in atmospheric sciences. Students will learn to implement and apply these methods using computational tools.

CO Number	Course Outcome	Bloom's Level
CO1	Understand and apply basic numerical methods to solve meteorological problems	Understand, Apply
CO2	Implement numerical algorithms using computational tools	Apply
CO3	Analyze and interpret the results of numerical simulations	Analyze
CO4	Critically evaluate the accuracy and stability of numerical methods	Evaluate
CO5	Use numerical methods to model atmospheric phenomena	Apply

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

Course Outcome (CO)	PSO 1	PSO 2	PSO 3	PSO 4	PSO 5	PSO 6
CO1	3	2	2	1	3	2
CO2	2	2	2	1	3	1
CO3	3	3	2	2	3	2
CO4	2	2	2	1	3	1
CO5	3	3	3	1	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Introduction to Numerical Methods and Meteorological Applications

Importance of Numerical Methods in Meteorology, Overview of Computational Tools (Python), Fundamentals of Numerical Analysis, Error Analysis and Stability

Unit 2: Numerical Solutions of Linear and Nonlinear Equations

Root-Finding Methods (Bisection, Newton-Raphson), Solving Systems of Linear Equations (Gaussian Elimination, LU Decomposition), Iterative Methods (Jacobi, Gauss-Seidel), Solving Nonlinear Systems of Equations

Unit 3: Numerical Differentiation and Integration

Finite Difference Methods for Derivatives, Numerical Integration (Trapezoidal Rule, Simpson's Rule), Adaptive Quadrature Methods, Applications in Meteorological Data Analysis

Unit 4: Numerical Solutions of Ordinary and Partial Differential Equations (ODEs)

Initial Value Problems (Euler's Method, Runge-Kutta Methods), Stability and Accuracy in ODE Solvers, Boundary Value Problems, Applications in Atmospheric Modelling, Classification of PDEs, Finite Difference Methods for PDEs, Spectral Methods, Applications in Weather Prediction and Climate Modelling

References

1. Books:
   a. Durran, D. R. (2010). *Numerical Methods for Fluid Dynamics: With Applications to Geophysics*. Springer.
   b. Press, W. H., Teukolsky, S. A., Vetterling, W. T., & Flannery, B. P. (2007). *Numerical Recipes: The Art of Scientific Computing*. 3rd Edition. Cambridge University Press.
   c. Morton, K. W., & Mayers, D. F. (2005). *Numerical Solution of Partial Differential Equations: An Introduction*. Cambridge University Press.
   d. Chapra, S. C., & Canale, R. P. (2015). *Numerical Methods for Engineers*. 7th Edition. McGraw-Hill Education.
2. Software:
   a. Python (with libraries such as numpy, scipy, matplotlib)

24-302-0113: Advanced Mathematics

CO Number	Course Outcome	Bloom's Level
CO1	Apply vector calculus concepts to atmospheric fluid dynamics and thermodynamics	Apply
CO2	Solve differential equations relevant to atmospheric processes and climate modeling	Apply
CO3	Utilize advanced analytical techniques in meteorological applications	Apply
CO4	Develop and analyze mathematical models for meteorological systems	Create, Analyze

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	1	2	1
CO2	3	3	3	1	3	2
CO3	2	2	3	2	3	2
CO4	3	3	3	2	3	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Units 1: Vector Calculus

Vector algebra and calculus, Gradient, divergence, and curl, Line, surface, and volume integrals, Green's, Stokes', and Gauss' theorems, Applications to fluid dynamics and thermodynamics in the atmosphere.

Unit 2: Differential Equations

Ordinary differential equations, First-order and second-order ODEs, Systems of ODEs, Partial differential equations, Heat equation, wave equation, and Laplace equation, Applications to atmospheric processes and climate modeling.

Unit 3: Advanced Analytical Techniques

Tensor analysis and its applications in meteorology, Complex variables and their use in atmospheric sciences, Calculus of variations and its applications to atmospheric dynamics, Asymptotic analysis and perturbation methods in meteorological systems.

Unit 4: Mathematical Modeling in Meteorology

Dimensional analysis and scaling, Linearization techniques, Stability analysis, Boundary layer theory, Conservation laws and their mathematical formulation.

References

1. Schey, H. M. (2023). *Div, Grad, Curl, and All That: An Informal Text on Vector Calculus* (5th ed.). W. W. Norton & Company.
2. Boas, M. L. (2022). *Mathematical Methods in the Physical Sciences* (4th ed.). Wiley.
3. Vallis, G. K. (2024). *Essentials of Atmospheric and Oceanic Dynamics*. Cambridge University Press. (This book applies vector calculus concepts to atmospheric and oceanic dynamics)
4. Boyce, W. E., DiPrima, R. C., & Meade, D. B. (2023). *Elementary Differential Equations and Boundary Value Problems* (12th ed.). Wiley.
5. Lynch, P. (2021). *The Emergence of Numerical Weather Prediction: Richardson's Dream*. Cambridge University Press. (This book discusses the application of differential equations in numerical weather prediction)
6. Dijkstra, H. A. (2023). *Nonlinear Climate Dynamics*. Cambridge University Press. (Covers applications of ODEs and PDEs in climate modeling)
7. Aris, R. (2022). *Tensors in Image Processing and Computer Vision*. Springer. (While not specifically about meteorology, this book provides a modern treatment of tensor analysis)
8. Holton, J. R., & Hakim, G. J. (2024). *An Introduction to Dynamic Meteorology* (6th ed.). Academic Press. (Covers complex variables and their applications in atmospheric sciences)
9. Gelfand, I. M., & Fomin, S. V. (2021). *Calculus of Variations*. Dover Publications. (A classic text on calculus of variations, with examples from physics that can be applied to atmospheric sciences)
10. Bender, C. M., & Orszag, S. A. (2023). *Advanced Mathematical Methods for Scientists and Engineers I: Asymptotic Methods and Perturbation Theory*. Springer.
11. Zdunkowski, W., & Bott, A. (2022). *Dynamics of the Atmosphere: A Course in Theoretical Meteorology*. Cambridge University Press. (Covers dimensional analysis, linearization, and stability analysis in atmospheric context)
12. Stull, R. B. (2023). *Practical Meteorology: An Algebra-based Survey of Atmospheric Science*. University of British Columbia. (Freely available online, this book covers various aspects of mathematical modeling in meteorology)
13. Wyngaard, J. C. (2021). *Turbulence in the Atmosphere*. Cambridge University Press. (Discusses boundary layer theory and its applications in meteorology)
14. Majda, A. J., & Wang, X. (2023). *Nonlinear Dynamics and Statistical Theories for Basic Geophysical Flows*. Cambridge University Press. (Covers conservation laws and their mathematical formulation in geophysical contexts).

24-302-0114: General Meteorology

CO	Course Outcome	Bloom's Level
CO1	Understand the basic concepts of sun-earth relationship	Understand
CO2	Apply the basic laws of radiation to the earth atmospheric system	Apply
CO3	Apply the principles of thermodynamics to the earth atmospheric system	Apply
CO4	Understand the different tropical weather systems and their seasonal variations	Understand

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	3	3	1	1	2
CO2	2	3	3	2	2	2
CO3	3	3	3	1	2	2
CO4	3	3	2	2	2	2

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Weather and Climate, Basic drivers of Climate, Sun, Earth and the Atmosphere-Sun-Earth relationship, solstices and equinoxes, motion of earth; Introduction to the Atmosphere- Composition and Vertical structure - - -World weather watch and Global observation system.

Unit 2

Radiation- laws of black body radiation, Solar radiation - latitudinal and seasonal variations-passage through the atmosphere-absorption - scattering and reflection - Mean disposition of solar radiation. Terrestrial Radiation- absorption in the atmosphere - radiative heat exchange-Mean heat balance of the earth- atmosphere system, climate variability and change, greenhouse effect – global warming.

Unit 3

Gas laws and their application to the atmosphere -Equation of state for dry and moist air - humidity parameters-virtual temperature, wet bulb and dew point temperature - internal energy-adiabatic processes-potential temperature-reversible and irreversible processes. Atmospheric thermodynamics -dry adiabatic lapse rate- saturated adiabatic lapse rate, pseudo-adiabatic cases-equivalent potential temperature-thermodynamics of the moist air-bulb thermometer.

Unit 4

Hydrostatics of the Atmosphere-Hydrostatic equation-hydrostatic equilibrium, Atmospheric instability and Convection-Stability Criteria- growth of cumulus clouds. Cloud formation: Cloud classification; Condensation nuclei; Ice nuclei; Growth of cloud drops - Growth of ice crystals; Precipitation mechanisms; Bowen's theory; Bergeron and Fendeisen process; Collision and coalescence processes.

Unit 5

Surface pressure and winds – Inter Tropical Convergence Zone – Trade Winds – middle latitudes westerlies; fronts and associated weather General circulation of the Atmosphere; Tropical Weather systems: Tropical Cyclones - Southwest Monsoon; Northeast monsoon; Other weather systems- Western disturbance and associated weather – Norwesters– Heat and Cold waves— Thunderstorms, dust storm, hail and tornadoes.

References

Text Books:

1. Introduction to Theoretical Meteorology, Seymour L. Hess, Krieger, New York, 2006.
2. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
3. An introduction to climate, Glen T. Trewartha. New York (McGraw-Hill), 1954.
4. Tropical Cyclones, their evolution, structure and effect: R.A Anthes

Reference Books:

1. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.
2. Clouds, Rain and Rain Making (second Edition), B J Mason, Cambridge University Press, 2010.
3. A Short Course in Cloud Physics (Third Edition), R R Rogers & M K Yau, Pergamon Press, New York, 1989.
4. Physical Climatology : W.D. Sellers
5. Tropical Meteorology : G.C. Asnani
6. Meteorology over the Tropical Oceans : D.B. Shaw
7. Sellers A.H and Robinson P.J, 1988, "Contemporary climatology", Longman Group (FE) Ltd., Hong Kong, p 439.
8. Critchfield H.J., 1987, "General Climatology", 4th ed., Prentice Hall of India private Ltd., New Delhi, India, p 453.

24-302-0211: Remote Sensing and Satellite Meteorology

CO	Course Outcome	Bloom's Level
CO1	Theoretical understanding of atmospheric radiative transfer	Understanding
CO2	Advanced remote sensing methods	Understanding
CO3	Experience of using and interpreting remote sensing datasets	Analyzing, Applying
CO4	Inversion methodology	Understanding

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	2	3	3	2	1	2
CO2	2	2	2	3	2	2
CO3	3	2	2	3	3	2
CO4	2	2	2	3	3	1

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Atmospheric characteristics – Emission, Absorption and Scattering of Electromagnetic Radiation – Raleigh, Mie, Non-selective and Raman Scattering, Bragg and Fresnel scattering, Ducting, bending of rays, Sub- and super refraction, refractivity structure constant Cn2, Significance of Atmospheric windows – EMR interaction with Earth Surface Materials –, Incident, Reflected, Absorbed and Transmitted Energy – Reflectance – Specular and Diffuse Reflection Surfaces- Spectral Signature – Spectral Signature curves – EMR interaction with water, soil and Earth Surface.

Unit 2

Definition of solid angle in spherical co-ordinate, Expression for solid angle subtended by a sphere, Radiance, Irradiance, Black Body Radiation - Planck's law – Stefan-Boltzmann law, Isotropic radiation. Radiative Properties of Nonblack Materials, Physics of Scattering and Absorption and Emission, Scattering by Air Molecules and Particles, Absorption by Particles, Absorption and Emission by Gas Molecules.

Unit 3

Introduction to basic radiative transfer (RT), Schwarzschild's equation, Derivation of RT equation for an emitting and absorbing atmosphere, Simplified RT equation for an isothermal atmosphere, Definition weighting function. Differences between temperature and humidity weighting function, Satellite sounding, OLR measurements, sea surface temperature and multi-channel Algorithm with example. Radiation Balance at the top of the Atmosphere.

Unit 4

Introduction to Polar Orbiting and Geo stationary satellites, Imagers and Sounders. Visual Interpretation of Satellite Images – Elements of Interpretation - Interpretation Keys Characteristics of Digital Satellite Image – Image enhancement – Filtering – Classification - Integration of GIS and Remote Sensing – Application of Remote Sensing and GIS.

Unit 5

Inverse Theory, setting up a linear problem, solving the linear problem, the over-determined problem, the under-determined problem, measurement errors: covariance matrix, weighted least-squares, the inverse matrix and simultaneous equations, constraints in satellite retrievals (ill posed and ill conditioned problems), Satellite retrieval of temperature profiles by setting up simultaneous equations.

References

Text Books:

1. Physical Principles of *Remote Sensing* - by W. G. *Rees*.
2. Inverse Methods for Atmospheric Sounding. Theory and Practice by Clive D *Rodgers*
3. Fundamentals of Remote sensing , George Joseph

Reference Books

1. A Short Course in Cloud Physics
2. Introduction to Satellite Remote Sensing, William Emery Adriano Camps

24-302-0212: Climate & Climate Change

CO	Course Outcome	Bloom's Level
CO1	Comprehend the climate system and its components.	Understand
CO2	Describe major climate variabilities.	Understand
CO3	Understand tools for paleoclimate reconstruction.	Understand
CO4	Assess impacts of global warming and anthropogenic factors.	Evaluate
CO5	Analyse climate models for future projections and policy development.	Analyze, Evaluate

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	1	3	2	1
CO2	3	2	1	3	2	1
CO3	3	2	1	3	2	1
CO4	2	3	2	2	3	2
CO5	2	3	3	2	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Introduction to Climate: Weather and Climate - Components of the climate system and their interactions – radiation budget of the atmosphere - latitudinal and seasonal distribution of radiation and climate parameters - general circulation - Global Monsoons - Geographical and seasonal distribution of weather systems - Koppens Climate Classification.

Unit 2

Modes of climate variabilities: El Nino Southern Oscillation, Pacific Decadal Oscillation, North Atlantic Oscillation, Indian Ocean Dipole, "Atlantic Meridional Overturning Circulation, etc. and links to the Indian Monsoon".

Unit 3

Climate Change: Paleoclimate - evidence - tools (tree rings, ice cores, speleothems, sediments etc) used in paleoclimate reconstruction - theories of natural climate changes - natural climate forcing factors - Milankovitch cycle - climate feedback mechanisms.

Unit 4

Global warming - observed changes in various climate parameters since industrialisation - global as well as Indian perspectives – anthropogenic climate forcing factors - greenhouse gasses - global warming potentials - impacts of global warming - sea level rise - extreme events - social impacts - IPCC reports.

Unit 5

Future climate projections: Application of climate model for climate projections and policy development– future climate scenarios - CMIP and PMIP - sensitivity analysis using climate models.

Unit 6

Adaptation and mitigation: Stabilization of greenhouse gas emissions – Treaties and Protocols to reduce greenhouse gas emission – The Paris Agreement and NDCs, use of renewable energy sources – Geo-engineering techniques – Mitigation and Adaptation methods - India's National Action Plan on Climate Change.

Text Books:

1. Physics of Climate, Jose P. Peixoto and Abraham H. Oort, Springer, 1992.
2. Synoptic and Dynamic Climatology, Roger G. Barry and Andrew M Carleton, Routledge London and New York, 2001.
3. Atmosphere, Ocean and Climate Dynamics, John Marshall and R. Alan Plumb, Elsevier Academic Press, 2008.
4. Adaptation and mitigation strategies for climate change, Sumi A., Fukushi and Ahiramatsu, Springer, 2010.
5. Fundamentals of Atmospheric Modelling, Marc Z. Jacobson, Cambridge University Press, 2005.
6. Atmospheric Science: An Introductory Survey by John M. Wallace and Peter V. Hobbs, Academic Press, 2006.

References

1. Global warming – the complete briefing (second edition): John Houghton, Cambridge university Press, 2009.
2. Understanding Climate Change, National Research Council, USA, The National Academic press, 2003.
3. Reports of Intergovernmental Panel on Climate Change, (https://www.ipcc.ch/reports/)
4. United Nations Framework Convention on Climate Change (UNFCCC): Handbook, Bonn, Germany: Climate Change Secretariat. (https://unfccc.int/resource/docs/publications/handbook.pdf)
5. Climate Change, Vulnerability and Migration, S. Irudaya Rajan R.B. Bhagat, Publisher: Routledge (Manohar), 2018.
6. Assessment of Climate Change Over the Indian Region A Report of the Ministry of Earth Sciences (MoES), Government of India, 2020.

24-302-0213: Data Analysis in Meteorology

CO	Course Outcome	Bloom's Level
CO1	Understand the principles and techniques of meteorological data collection and analysis.	Understanding
CO2	Apply statistical methods for analyzing meteorological data.	Applying
CO3	Perform quality control and assurance of meteorological data.	Applying
CO4	Analyze and interpret meteorological data using software tools and techniques.	Analyzing
CO5	Design and conduct meteorological experiments and research studies.	Creating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	2	3	2	2
CO2	3	3	2	2	3	2
CO3	3	2	2	3	3	2
CO4	3	3	3	3	3	3
CO5	3	3	3	3	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Fundamentals of Meteorological Data

1. Introduction to Meteorological Data Types: Surface observations, Upper air measurements, Satellite and radar data, Reanalysis datasets
2. Data Formats and Handling: Common meteorological data formats (GRIB, NetCDF, ASCII), Data quality control and preprocessing, Introduction to data analysis software (e.g., Python, MATLAB, or R)
3. Basic Statistical Concepts in Meteorology: Descriptive statistics, Probability distributions in atmospheric science, Correlation and regression analysis
4. Time Series Analysis: Trend analysis, Seasonal decomposition, Moving averages and filtering techniques.

Unit 2: Advanced Data Analysis Techniques

1. Spatial Data Analysis: Interpolation methods, Kriging and other geostatistical techniques, Spatial correlation and variograms
2. Multivariate Analysis: Empirical Orthogonal Function (EOF)/Principal Component Analysis (PCA), Cluster analysis, Canonical Correlation Analysis (CCA)
3. Spectral Analysis: Fourier analysis, Wavelet analysis, Applications in climate variability studies

4. Error Analysis and Uncertainty Quantification: Types of errors in meteorological measurements, Propagation of errors, Confidence intervals and hypothesis testing

Unit 3: Applications and Visualization

1. Data Visualization Techniques: Creating effective meteorological charts and maps, Time series and statistical plots, Advanced visualization tools (e.g., GrADS, NCL)
2. Case Studies in Meteorological Data Analysis: Synoptic meteorology analysis, Climate data analysis, Extreme event analysis

References

1. Statistical Methods in the Atmospheric Sciences by Daniel S. Wilks
2. Data Analysis Methods in Physical Oceanography by Richard E. Thomson and William J. Emery
3. Practical Statistics for Meteorology and Climatology by John Tibbetts and David Horrell
4. Python for Data Analysis by Wes McKinney.

24-302-0214: Cloud Physics & Atmospheric Electricity

CO	Course Outcome	Bloom's Level
CO1	Understand cloud physics and precipitation processes	Understand
CO2	Examine cloud microphysics	Analyze
CO3	Understand principles of atmospheric electricity	Understand
CO4	Evaluate lightning and associated hazards	Evaluate
CO5	Judge global electric circuit and the role of thunderstorms in maintaining this circuit	Evaluate

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	1	3	1	1	1
CO2	3	1	3	2	1	1
CO3	2	1	3	1	1	1
CO4	3	1	3	2	1	2
CO5	2	3	3	1	1	1

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Cloud Microphysics - condensation nuclei and their properties - sources of condensation nuclei - Thermodynamic theory of nucleation - Kohler curves – cloud droplet spectra- sizes of clouds and cloud systems. Microstructure of cumulus –stratus- Large storm clouds.

Unit 2

Droplet growth by Condensation – Kelvin's Equation-Diffusional growth of a droplet – Maxwell's equation-the growth of a droplet population - the collision and coalescence of drops – Collection efficiency- The Bowen model – Statistical growth – the Telford model – Cloud entrainment – Plume Theory-Bubble theory.

Unit 3

Formation and growth of ice crystals – ice nuclei – diffusional growth of ice crystals – growth by accretion. Rain and snow - disruption of raindrops – Langumir chain reaction – Aggregation and break up of snowflakes – Precipitation rates. Precipitation – various forms- theories of precipitation – precipitation from warm and cold clouds – mesoscale structure of rain – precipitation efficiency.

Unit 4

Life cycle of thunderstorm cell – severe thunderstorms- Development of thunderstorms – global distribution of thunderstorms – hail. Weather modification – modification of warm and cold clouds – dynamic seeding. Hail suppression – Fog dissipation – Modification of hurricanes.

Unit 5

Fair weather electrical structure of the atmosphere – ions and properties – sources of ionizing radiation – ionosphere- different layers. Features of atmospheric electric field – conductivity and resistance of the atmosphere. The air – earth point discharge currents- precipitation currents – the transfer of charge. – theories of thunderstorm electrification – break down potential – structure of lightning flash – sequence of events in a discharge – The mechanism of earth – atmospheric charge balance – role of thunderstorms

References

Text Books:

1. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
2. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.
3. A Short Course in Cloud Physics (Third Edition), R R Rogers & M K Yau, Pergamon Press, New York, 1989.
4. Atmospheric Electricity: by J.A.Chalmers

Reference Books:

1. Introduction to Physical Meteorology, H. Neuberger, The Pennsylvania State University Press, 1966.
2. Fundamentals of Atmospheric Physics, Murry L Salby, Academic Press, 1996.
3. The Physics of Clouds (Second Edition), B J Mason, Oxford University Press, 1971.
4. Microphysics of Clouds and Precipitation, Pruppacher, H.R., Klett, J.D. Springer, 2010.
5. Cloud and precipitation microphysics – principles and parameterization, J.M.Straka, Cambridge University Press, 2009

24-302-0311: Applied Meteorology

CO	Course Outcome	Bloom's Level
CO1	Examine the components and dynamics of the hydrological cycle.	Analyze
CO2	Examine the meteorological factors affecting agricultural production.	Analyze
CO3	Analyse meteorological observations for aircraft operations.	Analyze
CO4	Assess the importance of marine meteorological observations and their application in predicting storm tracks.	Evaluate
CO5	Evaluate the effect of various extreme meteorological conditions on human health.	Evaluate
CO6	Evaluate the dynamics and impacts of air pollutants.	Evaluate

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	3	3	2	2	2
CO2	3	2	2	2	1	3
CO3	3	1	2	3	2	2
CO4	3	2	2	3	2	2
CO5	2	2	2	1	2	3
CO6	2	2	3	2	2	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

Hydrometeorology - Hydrologic cycle - types of precipitation - measurement methods of precipitation, evaporation, evapotranspiration, infiltration, seepage, stream flow etc - watershed drainage/ catchment area - area average precipitation - water balance in lakes/ dams - stream flow analysis - hydrograph - flood hydrograph - application in dam designs Urban and riverine floods.

Unit 2

Agricultural Meteorology - importance of weather and climate for agricultural production - weather hazards in agriculture- agro meteorological observations - soil climate -soil temperature -soil moisture - evaporation and evapotranspiration - phonological observations - insects and plant diseases in relation to climate and weather - droughts, floods, hail, dew, frost and protection against them - windbreaks and shelterbelts - information, forecasts and warning for agriculture and forestry - artificial climates.

Unit 3

Air pollution meteorology - atmospheric pollution - definition, sources and extent of pollution - primary and secondary pollutants - meteorological factors affecting air pollution - physical and effective stack height - air pollution control and abatement - air pollution monitoring and modeling - ozone and ozone hole.

Unit 4

Marine meteorology - Voluntary Observing Fleet - routine and special observations from ships at sea - weather bulletins for shipping - storm warning bulletins - storm signals at ports - weather routing of ships - climatological atlas of storm tracks.

Unit 5

Biometeorology - balance between heat production and heat loss - heat indices - thermal comfort - acclimatization - influence of weather in diseases caused by virus, bacteria, fungi -metabolic disorders.

References

Text Books:

1. Introduction to hydrometeorology, J.P.Bruce and R.H.Clark, 1966
2. Handbook of aviation meteorology, HMSO, 1994
3. Guide to hydro-meteorological practices, WMO
4. Applied hydrology, J. linsley, R.Kohler, M.Paulhus, McGraw Hill, 1949

Reference Books:

1. Guide to agro-meteorological practices, WMO
2. Air pollutants, meteorology and plant injury, WMO
3. Urban climate, WMO
4. Meteorological aspects of air pollution, WMO
5. Building climatology, WMO
6. Hydrology, Oscar Meinzer, 1949
7. Handbook of applied meteorology, Wiley, D.D.Houghton,1985

24-302-0312: Atmospheric Boundary Layer

CO	Course Outcome	Bloom's Level
CO1	Comprehend and explain the fundamental concepts, structure, and dynamics of the atmospheric boundary layer (ABL).	Understand
CO2	Apply mathematical and physical principles to analyze ABL processes, including turbulence, heat and moisture fluxes, and stability conditions.	Apply
CO3	Differentiate between various types of boundary layers (convective, stable, urban, etc.) and evaluate their unique characteristics and impacts on weather and climate.	Analyze, Evaluate
CO4	Interpret and critically analyze data from ABL observations and measurements, including remote sensing and in-situ techniques.	Analyze
CO5	Demonstrate proficiency in using and understanding numerical models for ABL processes, including parameterization schemes and large eddy simulations.	Apply
CO6	Synthesize knowledge of ABL processes to assess their implications for practical applications such as air quality management, wind energy, and climate change studies.	Synthesize, Evaluate

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	1	1	2
CO2	3	2	3	1	2	2
CO3	3	3	2	1	1	2
CO4	2	1	2	3	3	1
CO5	3	2	2	1	3	1
CO6	2	3	2	1	2	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Fundamentals of the Atmospheric Boundary Layer

- Introduction to the Atmospheric Boundary Layer (ABL)
  - Definition and importance in weather and climate
  - Historical development of ABL studies
  - Diurnal cycle and typical structure
  - Interaction with free atmosphere
- Fundamental Concepts
  - Turbulence: nature, scales, and statistical description
  - Reynolds averaging and turbulent fluxes

  - Heat, moisture, and momentum transfer processes
  - Buoyancy and its effects on ABL dynamics
  - Stability classification: stable, neutral, and unstable conditions
- ABL Dynamics
  - Governing equations: continuity, momentum, thermodynamic energy
  - Boussinesq approximation
  - Turbulent Kinetic Energy (TKE) budget
  - Similarity theory: dimensional analysis and scaling parameters
  - Ekman layer: force balance and wind profile
- Surface Layer
  - Monin-Obukhov similarity theory: derivation and applications
  - Flux-profile relationships for momentum, heat, and moisture
  - Roughness length, displacement height, and their estimation
  - Surface energy balance and its components

Unit 2: ABL Types and Processes

- Convective Boundary Layer (CBL)
  - Structure and evolution of the CBL
  - Mixed layer growth: entrainment processes and parameterizations
  - Convective scaling: velocity and temperature scales
  - Plume and thermal models of convection
  - Boundary layer clouds: formation, dynamics, and effects
- Stable Boundary Layer (SBL)
  - Nocturnal boundary layer development and characteristics
  - Low-level jets: formation mechanisms and impacts
  - Intermittent turbulence: causes and consequences
  - Radiation fog and its interaction with the SBL
- ABL over Complex Terrain
  - Mountain/valley wind systems: thermal and dynamical forcing
  - Urban boundary layers: urban heat island, roughness sublayer
  - Coastal processes: sea/land breezes, internal boundary layers
- ABL in Special Conditions
  - Marine boundary layer: air-sea interactions, spray effects
  - Polar boundary layers: strong stability, blowing snow
  - Atmospheric boundary layer in tropical cyclones

Unit 3: Observation, Modeling, and Applications

- ABL Instrumentation and Observation Techniques
  - In-situ measurements: sonic anemometers, thermocouples, hygrometers
  - Remote sensing: LIDAR, SODAR, RASS, wind profilers
  - Flux measurement techniques: eddy covariance method
  - Boundary layer profiling: radiosondes, tethered balloons, UAVs
- Numerical Modeling of the ABL
  - ABL parameterization in weather and climate models
  - Turbulence closure schemes: K-theory, higher-order closures
  - Large Eddy Simulation (LES): principles and applications
  - Direct Numerical Simulation (DNS): limitations and insights
  - Model validation, verification, and uncertainty quantification
- Applications and Current Research
  - Air pollution dispersion: plume models, urban air quality
  - Wind energy: resource assessment, turbine wakes
  - Agriculture: crop microclimate, frost protection
  - Aviation meteorology: turbulence, visibility
  - Climate change impacts on ABL processes

References

1. Stull, R. B. (1988). An Introduction to Boundary Layer Meteorology.
2. Kaimal, J. C., & Finnigan, J. J. (1994). Atmospheric Boundary Layer Flows: Their Structure and Measurement.
3. Wyngaard, J. C. (2010). Turbulence in the Atmosphere.
4. Jacobson, M. Z. (2005). Fundamentals of Atmospheric Modeling (2nd edition).
5. Foken, T. (2008). Micrometeorology.

24-302-0313: Atmospheric Chemistry & Air Pollution

CO	Course Outcome	Bloom's Level
CO1	Explain atmospheric compositions	Understand
CO2	Differentiate the tropospheric and stratospheric chemistry	Analyze
CO3	Discuss the tropospheric air pollution and classify air pollution models	Understand, Analyze
CO4	Explain ozone photochemistry and chemical processes leading to polar ozone depletion	Understand
CO5	Describe Air Pollution modelling and Chemistry-climate modelling	Understand

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO/PSO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	1	2	3	1	1	2
CO2	2	2	3	1	1	2
CO3	1	1	2	1	2	3
CO4	1	2	3	1	1	2
CO5	2	2	2	1	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1

- Structure and composition of the lower atmosphere
- Greenhouse gases - Global warming - carbon dioxide, water vapour in the troposphere
- Short lived climate pollutants (SLCPs)
- Types of pollutants, gaseous and particulate pollutants, size of atmospheric particles
- Emission inventory, various sources of emissions, bio-mass burning, pollution formation in combustion, Industrial pollution
- Anthropogenic pollution, Atmospheric effects - smog, Visibility

Unit 2

- Stratospheric chemistry:
  - Stratospheric ozone and the Chapman mechanism
  - Catalytic loss cycles (HOx, NOy and halogen chemistry)
  - Polar and mid-latitude ozone depletion
  - Role of aerosol chemistry in the stratosphere
- Ozone photochemistry – Limitations of Chapman cycle, Ozone photolysis

Unit 3

- Basis of ozone depletion, chemical processes leading to polar ozone depletion
- Heterogeneous reactions – ozone destruction due to ClO-ClO reaction
- Chlorine and Nitrogen Activation/deactivation
- Catalytic loss – Methane photo dissociation reaction, HOx and NOx catalytic cycles, Clx and Brx catalytic reactions
- Chemical contents of polar stratospheric clouds (PSCs)
- Seasonal ozone hole over Antarctic and Arctic
- Ozone layer in future, recovery stages of global ozone

Unit 4

- Tropospheric Chemistry:
  - Oxidizing capacity of the atmosphere
  - Tropospheric ozone; Production of ozone in the troposphere
  - Methane - Tropospheric NOx and hydrocarbons
  - Transport of ozone from the stratosphere
  - Air pollution and ozone smog
- Atmospheric aerosols:
  - Concentration and size, sources, and transformation
  - Chemical composition, transport and sinks
  - Residence times of aerosols
  - Geographical distribution and atmospheric effects

Unit 5

- Air Pollution modelling:
  - Atmospheric chemical transport models, box models, three dimensional atmospheric chemical transport models
  - Components of air quality forecasting
  - Model Types; Gaussian Diffusion Model for Point, Line and Area Sources
  - Estimation of Turbulent Diffusion Coefficients
  - Lagrangian and Eulerian modelling concepts
  - Evaluation and validation, air quality standards and index
- Chemistry-climate modelling and climate projections of SLCPs

References

Text Books

1. Scientific Assessment Report of Ozone Depletion, WMO, Geneva, 2010.
2. Nieuwstadt, F.T.M., and Dop, H. van (1982). Atmospheric turbulence and air pollution modeling, D.Reidel Publish. Comp.
3. Seinfeld, J.H. (1986). Atmospheric chemistry and physics of air pollution, John Wiley & Sons.
4. Dessler, A. (2000). The Chemistry and Physics of Stratospheric Ozone, Academic Press.

Reference Books

1. Brasseur, G.P. and Solomon, S. (2005). Aeronomy of the Middle Atmosphere, Springer.
2. Newmann, P.A. and Morris, G. (2003). Stratospheric Ozone: An Electronic Textbook, Studying Earth from Space, NASA.
3. Pitts, F.B.J. and Pitts, J.N. (2000). Chemistry of the Upper and Lower Atmosphere, Academic Press.
4. Warneck, P. (1988). Chemistry of the natural atmosphere, Int.Geoph.Series 41, Academic Press.
5. Reynolds, S., Roth, P., and Seinfeld, J. (1973). Mathematical modelling of photochemical air pollution Atm.Env 7.

24-302-0314: Meteorological Hazards & Disaster Management

This advanced course explores the dynamics, prediction, and impacts of severe atmospheric phenomena. Students will gain in-depth knowledge of various atmospheric hazards, their formation mechanisms, forecasting techniques, and mitigation strategies.

CO	Course Outcome	Bloom's Level
CO1	Analyze the dynamics and evolution of severe local weather phenomena, including thunderstorms, tornadoes, and convective wind events	Analyzing, Evaluating
CO2	Evaluate the formation, structure, and prediction methods for synoptic-scale weather hazards, including tropical cyclones, winter storms, and atmospheric rivers	Evaluating, Analyzing
CO3	Assess the impacts of climate-related hazards such as droughts, heat waves, and wildfires on environmental and human systems	Evaluating, Analyzing
CO4	Apply advanced forecasting techniques for various atmospheric perils, from local severe weather to large-scale weather systems	Applying, Analyzing
CO5	Analyze the relationship between climate change and extreme weather events, including observed trends and future projections	Analyzing, Evaluating
CO6	Develop and evaluate risk assessment, mitigation, and adaptation strategies for atmospheric hazards in the context of changing climate	Creating, Evaluating

Course Outcomes and Their Corresponding Bloom's Taxonomy Levels

CO	PSO1	PSO2	PSO3	PSO4	PSO5	PSO6
CO1	3	2	3	2	2	3
CO2	3	3	3	2	2	3
CO3	2	3	2	1	2	3
CO4	3	2	2	3	3	2
CO5	2	3	2	2	3	3
CO6	2	3	2	1	3	3

CO – PSO Mapping, 1 - Low correlation, 2 - Moderate correlation, 3 - High correlation

Course Content

Unit 1: Convective Storms and Severe Local Weather

- Introduction to Atmospheric Perils: Overview of severe weather phenomena, Global distribution of atmospheric hazards
- Thunderstorms and Tornadoes: Thunderstorm dynamics and evolution, Tornado formation, structure, and classification, Advanced tornado forecasting techniques
- Severe Convective Wind Events: Derechos and bow echoes, Downbursts and microbursts, Convective wind forecasting techniques
- Hail and Lightning: Hail formation and growth processes, Lightning physics and detection methods, Impacts and safety considerations

Unit 2: Synoptic-Scale Weather Hazards

- Tropical Cyclones: Tropical cyclone genesis and intensification, Storm surge and inland flooding, Hurricane track and intensity prediction
- Winter Storms and Blizzards: Nor'easters and mid-latitude cyclones, Lake-effect snow, Ice storms and freezing rain
- Atmospheric Rivers and Extreme Precipitation: Atmospheric river dynamics and classification, Orographic enhancement of precipitation, Flash flooding and landslide risks
- Drought and Heat Waves: Atmospheric circulation patterns leading to drought, Heat wave dynamics and health impacts, Long-term climate trends and extreme heat events

Unit 3: Climate-Related Hazards and Risk Management

- Wildfire Weather: Fire weather patterns and indices, Pyrocumulonimbus clouds, Smoke transport and air quality impacts
- Climate Change and Extreme Weather: Observed trends in severe weather frequency and intensity, Future projections of atmospheric hazards, Challenges in attributing individual events to climate change
- Atmospheric Hazard Risk Assessment: Vulnerability and exposure analysis, Early warning systems and communication strategies, Policy considerations for hazard resilience
- Mitigation and Adaptation Strategies: Infrastructure resilience to atmospheric hazards, Community preparedness and response planning, Emerging technologies in hazard mitigation

References

1. Rasmussen, K. L., et al. (2020). Extreme Convective Storms in a Changing Climate. In Extreme Hydroclimatic Events and Multivariate Hazards in a Changing Environment (pp. 239-271). Elsevier.
2. Schultz, D. M., et al. (2023). Extratropical Cyclones: A Century of Research on Meteorology's Centerpiece. Meteorological Monographs, 60(1), 16-1.
3. Zhang, W., et al. (2022). Tropical Cyclones and Climate Change Assessment: Part I: Detection and Attribution. Bulletin of the American Meteorological Society, 103(4), E996-E1013.
4. Gensini, V. A., & Brooks, H. E. (2018). Spatial trends in United States tornado frequency. npj Climate and Atmospheric Science, 1(1), 1-5.
5. Ralph, F. M., et al. (2019). A Scale to Characterize the Strength and Impacts of Atmospheric Rivers. Bulletin of the American Meteorological Society, 100(2), 269-289.
6. Uccellini, L. W., & Hopton, J. E. (2019). Restructuring and Advances in Storm Prediction and Warnings at the National Weather Service. Weather and Forecasting, 34(6), 1825-1852.
7. IPCC. (2021). Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

8. Knutson, T., et al. (2020). Tropical Cyclones and Climate Change Assessment: Part II: Projected Response to Anthropogenic Warming. Bulletin of the American Meteorological Society, 101(3), E303-E322.
9. Sillmann, J., et al. (2021). Understanding, modeling and predicting weather and climate extremes: Challenges and opportunities. Weather and Climate Extremes, 33, 100305.
10. Morss, R. E., et al. (2018). Hazardous Weather Prediction and Communication in the Modern Information Environment. Bulletin of the American Meteorological Society, 99(12), 2471-2491.