DEPARTMENT OF ATMOSPHERIC SCIENCE
SCHOOL OF EARTH SCIENCES

M.Sc. Atmospheric Science
(Course Structure and Syllabus)
2022-2023
(As per National Education Policy 2020)

Central University of Rajasthan

October 2022

DEPARTMENT OF ATMOSPHERIC SCIENCE
SCHOOL OF EARTH SCIENCES

M.Sc. Atmospheric Science

(2-Years M.Sc. Programme)

Atmospheric Science is an umbrella term for the study of the Earth's atmosphere, its processes, the effects other systems have on the atmosphere, and the effects of the atmosphere on these other systems. This programme includes meteorology, atmospheric physics, chemistry and dynamics, aeronomy and climatology. The design of the Master programme in Atmospheric Science is aimed at imbibing the students with fundamental scientific methodology in mathematics, physics and chemistry to enable them to appreciate, understand and investigate the complex behavior of Earth's atmosphere and climate system using the aforementioned tools. The applications of Atmospheric Science to the study of agriculture, aviation, water resources, disaster mitigation (due to extreme weather, severe storms, cyclone, etc.), air quality and climate prediction harbor immense possibilities which are highly relevant at present and in future, since several facets of the human life are intrinsically impacted by our atmosphere. The curriculum of Masters Programme in Atmospheric Science launched in the University in 2016 adheres to the application of meteorology to the common people needs. The department has identified the thrust areas of research which include:

1. Numerical Modelling of Atmospheric and Oceanic Processes
2. Climate Dynamics and Variability
3. Indian Monsoon Studies
4. Mesoscale Modelling and Data Assimilation
5. Computational Methods in Atmospheric Science
6. Remote Sensing of the Atmosphere
7. Severe Convective Storms and Extreme Weather System
8. Desert Meteorology
9. Atmospheric Chemistry and Air Quality
10. Climate Change Impacts

Program: Intake and Eligibility

S. No	Program	Seat Intake	Eligibility
1	M.Sc. Atmospheric Science	30	*Bachelor's degree from a recognized University in any discipline of science /Engineering (Physics or Mathematics as one of the subject) with minimum of 50% marks or equivalent grade in aggregate for general category and 45% or equivalent grade in aggregate for SC/ST/OBC/PWD/EWS candidates.*

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

Programme Objectives

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

Programme Outcomes

1. **Knowledge:** Develop deeper insights in multiple aspects of Atmospheric Science for better scientific understanding and interpretation of various atmospheric phenomena.
2. **Modern tool usage:** Apply mathematical and computational tools and techniques to study atmospheric processes
3. **Conduct investigation of complex problems:** Demonstrate quantitative skills for interpreting atmospheric observations to numerical modeling and forecasting of weather systems.
4. **Enhance Instrumentation skill:** Explain the principles behind meteorological instrumentation and create graphical depictions of meteorological information.
5. **Analytical skill:** Demonstrate critical and analytical skills to interpret and predict weather systems using different products (model results, maps, satellite imagery, etc.).
6. **Communication:** Demonstrate skills for communicating their technical knowledge and scientific results.
7. **Research and Jobs:** Building foundation for higher studies and research as well as capability to get science jobs.
8. **Problem Analysis and Project:** Confidence for independent pursuit of projects, research, start-ups and entrepreneurship.
9. **Society and Sustainability:** Understand the impact of optimal solutions in societal and environmental contexts, and demonstrate the knowledge for sustainable development

Department of Atmospheric Science

M.Sc. Atmospheric Science

Credit Summary of Courses Offered by Department of Atmospheric Science (Academic Session 2022-23)

	Core Courses	Skill Enhancement Core courses (SEC)	Department Elective Courses (DEC)	Open Elective (OE) course/MOOCs/NPTEL	Total
Sem I	21				21
Sem II	15	03	03		21
Sem III	9	03	06	03	21
Sem IV		15	03	03	21
Total	**45**	**21**	**12**	**6**	**84**
Percentage	54	25	14	7	100

COURSE STRUCTURE

First Semester

S. No.	Course Type (CO)	Course Code	Name of the Course	Credit			
				L	T	P	Total
1	C1	ATS401	Fundamentals of Earth System Sciences	3	0	0	3
2	C2	ATS402	Physics of the Atmosphere	3	0	0	3
3	C3	ATS403	Dynamics of the Atmosphere	3	0	0	3
4	C4	ATS404	Statistical Methods for Earth Sciences	2	1	0	3
5	C5	ATS405	Tropical Meteorology and Climatology	3	0	0	3
6	C6	ATS406	Programming Techniques for Atmospheric Sciences	0	0	3	3
7	C7	ATS407	Atmospheric Chemistry, Air Pollution & Climate	3	0	0	3
			Total Credits	**21**			

Second Semester

S. No.	Course Type (CO)	Course Code	Name of the Course	Credit			
				L	T	P	Total
1	C1	ATS408	Fundamentals of Atmospheric Modelling	3	0	0	3
2	C2	ATS 409	Instrumentations in Atmospheric studies	2	0	1	3
3	C3	ATS410	Physics and Dynamics of the Oceans	3	0	0	3

4	C4	ATS411	Weather Analysis and Visualization Laboratory	1	0	2	3
5	C5	ATS412	Simulation of Atmospheric Process	1	1	1	3
6	SEC-I	ATS413	Dissertation-I	0	0	3	3
7	DEC-I	ATS***					3
			Total Credits	**21**			

DEC for Second Semester

S. No.	**Course Type (DEC)**	**Course Code**	**Name of the Course**	**Credit**			
				L	**T**	**P**	**Total**
1	DEC	ATS414	Desert Meteorology and Climate	3	0	0	3
2	DEC	ATS415	Computational Fluid Dynamics	3	0	0	3
3	DEC	ATS416	Climate Change and Disaster Management	3	0	0	3

Third Semester

S. No.	**Course Type**	**Course Code**	**Name of the Course**	**Credit**			
				L	**T**	**P**	**Total**
1	C1	ATS501	Mesoscale Modelling and Extreme Weather Events	2	0	1	3
2	C2	ATS502	Numerical Weather Prediction-Parameterisation and Data Assimilation	2	0	1	3
3	C3	ATS503	Remote Sensing and GIS for Atmospheric Science	2	0	1	3
4	SEC-II	ATS504	Internship	0	0	3	3
5	DEC-II	ATS***					3
6	DEC-III	ATS***					3
7	OE/MOOCs						3
			Total Credits	**21**			

DEC for Third Semester

S. No.	**Course Type (DEC)**	**Course Code**	**Name of the Course**	**Credit**			
				L	**T**	**P**	**Total**
1	DEC	ATS505	Cloud Physics and Dynamics	3	0	0	3
2	DEC	ATS506	HPC applications in Atmospheric	3	0	0	3

			Sciences				
3	DEC	ATS507	Boundary Layer Meteorology	3	0	0	3
4	DEC	ATS508	Air Quality Modelling and Management	3	0	0	3
5	DEC	ATS509	Upper and Middle Atmosphere Dynamics	3	0	0	3

Fourth Semester

S. No.	Course Type	Course Code	Name of the Course	Credit			
				L	T	P	Total
1	SEC-III	ATS510	Dissertation-II	0	0	15	15
2	DEC-IV	ATS**					3
3	OE/MOOCS						3
			Total Credits	**21**			

DEC for Fourth Semester

S. No.	Course Type (DEC)	Course Code	Name of the Course	Credit			
				L	T	P	Total
1	DEC	ATS511	Climate Change and Crop Modelling	3	0	0	3
2	DEC	ATS512	Hydrometeorology	3	0	0	3
3	DEC	ATS513	Radar Meteorology	3	0	0	3
4	DEC	ATS514	Aviation Meteorology	3	0	0	3
5	DEC	ATS515	Satellite Meteorology	3	0	0	3

Total Credits: 21 (Semester-I) +21 (Semester-II) +21 (Semester-III) +21 (Semester-IV) = **84 Credit**

A student is required to accumulate a total of 84 credits to fulfil the requirements for a Master of Science degree in Atmospheric Science.

- ***Minimum 5 students are required to run elective courses.***
- ***Open electives can be selected from any department of the University.***
- ***MOOCs can be selected based on the availability in consultation with the department***

Semester I
(All courses are Core and Compulsory)

Course Title: Fundamentals of Earth System Sciences		**Course code: ATS 401**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L -3; T-0; P-0
Course Prerequisite: Basic knowledge of intermediate level science (Physics, Chemistry, Mathematics)		
Course Description		
This course is aimed at providing a basic understanding of Atmospheric Science as a component of the Earth System Science. The interactions and interdependencies of different components of the Earth System and their impact on human life as well as climate will be elucidated with examples. Simple numerical calculations will be done to have a quantitative perception of several physical concepts introduced in this course.		
Course Objective:		
1. To develop knowledge regarding the inter-relationships of Earth System Science components and their impacts on Earth's atmosphere and climate. 2. To provide understanding of the atmospheric composition, structure and the forces that drive three-dimensional atmospheric motions. 3. To impart the knowledge of the typical vertical variation of atmospheric variables used to quantify the atmospheric state, including temperature, pressure, humidity, winds etc. 4. To introduce students to the basic concepts and principles of clouds and their formation mechanisms, together with the precipitation types, and their interactions with aerosols and radiation.		
Course Outcome/Learning Outcome		
1. Understand the interaction between fundamental components of the Earth System. 2. Compute the influence of the sun on Earth's atmosphere. 3. Understand basic equations governing atmospheric profiles. 4. Critically analyse the influence of atmospheric processes on cloud formation 5. Scientifically explain the functioning and inter-relationships of Earth System Science components and their impacts on climate and life on earth. 6. Generate curiosity to probe further the atmospheric and oceanic processes e.g. atmosphere ocean interaction, aerosol cloud interaction, hydrologic and biogeochemical cycles.		

Course Content

	Hours
<u>Unit-1</u> Components of the Earth System, internal structure of the Earth, soil composition, hydrological and biogeochemical cycles, Carbon flux, vegetation dynamics.	7
<u>Unit-2</u> Geological Time Scale, Radiation basics, Effective temperature of Earth, Mars and Venus, Earth's Energy Budget	8

Unit-3 Structure of the atmosphere and its composition, Thermodynamic state: distribution of temperature, density, pressure., Equations of state, Lapse rate, Virtual Temperature,	8
Unit-4 Planetary Atmospheres, Formation of Cloud droplets and Precipitation, Aerosol-Cloud interaction, Ozone depletion,	7
Unit-5 Fundamental forces in the Atmosphere and Ocean: Weather Events; Meteorological Seasons; Atmospheric scales	7
Unit-6 Characteristics of Ocean Basins, Properties of Seawater, Mixed layer, Thermocline, halocline, pycnocline, Ocean profiles, Upwelling and downwelling processes, Ocean Currents, Conveyer Belt, Gyres, Atmosphere-Ocean interaction.	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Lutgens FK, Tarbuck, EJ: The Atmosphere-An Introduction to Meteorology, Pearson.
2. Neil C: The Atmosphere and Ocean: A Physical Introduction (Advancing Weather and Climate Science), Wiley.
3. Maarten HP Ambaum: Thermal Physics of the Atmosphere (Advancing Weather and Climate Science), Wiley.
4. Bonan G: Ecological Climatology: Concepts and Applications, 2nd Edition, Cambridge.

Reference Books:

1. Atmospheric Science: An introductory survey by JM Wallace and PV Hobb
2. Practical Meteorology: An Algebra-based Survey of Atmospheric Science by Roland Stull
3. Will Steffen et al. (2020) The emergence and evolution of Earth System Science. Nature Reviews: Earth and Environment. Volume 1, pp 54-63.

e-resources:
http://www.igbp.net/globalchange/earthacomplexsystem.4.1b8ae20512db692f2a680001681.html
http://www.ccpo.odu.edu/SEES/ozone/class/Chap_8/8_4.htm
https://www.e-education.psu.edu/meteo300/node/538

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		1			1	3		
CO2	3		1			1			
CO3	3	1	3		2				
CO4	3		3		2			2	1
CO5	3		1			3	1	1	2
CO6			2		1	3	1		2

<table>
<tr><th colspan="2">Course Title: Physics of the Atmosphere</th><th>Course code: ATS 402</th></tr>
<tr><th>Teaching Scheme</th><th>Examination Scheme</th><th>Credits Allotted</th></tr>
<tr><td>Theory: 3 hours/ week</td><td>Continuous Internal Assessment (CIA): 40
End Semester Examination (ESE): 60</td><td>L -3; T-0; P-0</td></tr>
<tr><td colspan="3">Course Prerequisite: Basic Knowledge of Bachelor level Physics.</td></tr>
<tr><td colspan="3"></td></tr>
<tr><td colspan="3">Course Description</td></tr>
<tr><td colspan="3">This course introduces the physical processes associated with atmospheric composition, basic radiation and energy concepts, the equation of state, the zeroth, first, and second law of thermodynamics, the thermodynamics of dry and moist atmospheres, thermodynamic diagrams, statics, and atmospheric stability.</td></tr>
<tr><td colspan="3">Course Objective:</td></tr>
<tr><td colspan="3">1. To introduce students to the basic concepts and principles of atmospheric physics.
2. To understand the thermodynamics of dry and moist air, radiative transfer in the atmosphere, saturated and unsaturated accent, thermodynamic diagrams, turbulent fluxes.
3. To impart the knowledge of the typical vertical variation of atmospheric variables used to quantify the atmospheric state, including temperature, pressure, humidity, winds etc.
4. To impart the knowledge of saturated and unsaturated accent, moist convection, surface turbulent fluxes, vertical turbulent diffusion.</td></tr>
<tr><td colspan="3">Course Outcome/Learning Outcome</td></tr>
<tr><td colspan="3">1. Understand the atmospheric thermal structure, radiative transfer for solar and terrestrial wavelengths and cloud physics at the graduate level.
2. Compare dry and moist atmospheric processes
3. Demonstrate knowledge of the physical processes in the atmosphere.
4. Apply the knowledge of thermodynamic diagrams, calculate thermodynamic parameters.
5. Recognize the difference between ice and liquid microphysical processes
6. Discuss the mechanism of Atmospheric electrical processes.</td></tr>
</table>

Course Content

	Hours
Unit-1 Thermodynamics of dry thermals, Thermodynamic of moist air, thermodynamic properties of water; Clausius- Clapeyron (C-C) equation, moist processes in the atmosphere, adiabatic;	8
Unit-2 Radiative transfer in the atmosphere, shortwave and longwave radiation computation, radiative heating in the atmosphere, saturated and unsaturated accent	8
Unit-3 Thermodynamic diagrams, Moist convection, Aerodynamic formulae for surface turbulent fluxes, vertical turbulent diffusion,	7
Unit-4 Cloud physics; Nucleation and Growth of Cloud Droplets; Warm Rain Formation, Collision–coalescence,	7

Unit-5 Ice Crystal Nucleation and Growth, Homogeneous nucleation of ice by freezing and deposition, Heterogeneous nucleation of ice on flat and curved surfaces	7
Unit-6 Atmospheric Electricity; Principles of atmospheric electricity, Charge generation and separation mechanisms, Cloud electrification mechanism.	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Holton JR: An Introduction to Dynamical Meteorology, Academic Press
2. Howell JR, Siegel R, Menguc M. Pinar: Thermal Radiation Heat Transfer, CRC Press
3. Lynne D. Talley: Descriptive Physical Oceanography: An Introduction, Academic Press
4. Apel J R: Principles of Ocean Physics. Academic Press.
5. Introduction to Theoretical Meteorology by Seymour L. Hess

References:

1. Lecture Notes on Physical Meteorology For Integrated Meteorological Training Course

e-resources:

https://onlinecourses.nptel.ac.in/noc22_ph13/preview
https://archive.nptel.ac.in/courses/115/107/115107129/

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		2		2	1	1	1	
CO2	3	1	1		2	1			
CO3	3		2			3	1	2	
CO4	2	3	3		3			2	
CO5	3		2					2	
CO6	3		3		2	3	3	2	2

Course Title : Dynamics of the Atmosphere		Course Code: ATS 403
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA):40 End-Semester Examination (ESE): 60	L -3; T-0; P-0
Course Prerequisite: Basic Knowledge of Bachelor level Physics, Mathematics.		
Course Description		
Dynamic meteorology is the branch of fluid dynamics concerned with the cause of meteorologically significant motions of the atmosphere. It forms the primary scientific basis for weather and climate prediction, and thus plays a primary role in the atmospheric sciences		
Course Objective:		
1. To introduce students to the basic concepts and principles of atmospheric dynamics. 2. To impart knowledge of the physical laws governing the atmospheric flow, weather events.		
Course Outcome/Learning Outcome		
1. Understand the basics fluid dynamics. 2. Identify the governing dynamics behind any weather systems. 3. Understand about different attributes of atmospheric flow dynamics. 4. Understand the different flow patterns and its analysis. 5. Explain the dynamics of circular motions in atmosphere. 6. Explain the wave behaviour of atmospheric phenomenon.		

Course Content

	Hours
Unit-1 Basic Fluid Dynamics, Basics of Vector and Scalar; Concepts of Mathematical Operators, Concepts of Atmospheric Wind, Continuum theory, Reference Frame: Lagrengian and Eulerian; Local and Material Time Derivatives; Inertial and Rotating Frame;	8
Unit-2 Basic Laws of Conservation, Fundamental Forces for Earth's Atmosphere, Equation of Motion, Scale Analysis; hydrostatic approximations, geostrophic approximation; Prognostic and Diagnostic equations, Thermodynamics Equation, Continuity Equation,	8
Unit-3 Vertical coordinate system: Cartesian, Isobaric, Sigma, Isentropic, Governing Equations in Isobaric Coordinate Geostrophic wind, Rossby number, Thermal wind balance, barotropic and baroclinic atmosphere, Natural Coordinate system, Balanced flow: Inertial, cyclostrophic flow, Gradient wind approximation;	8
Unit-4 Trajectory and streamline; Divergence and Convergence, vertical motion, Kinematics, Rossby, Richardson, Reynolds, and Froude number, Surface pressure Tendency;	7
Unit-5 Circulation and Vorticity: circulation theorem; Vorticity in natural coordinates, Vorticity	7

and Divergence equation, scale analysis, Potential Vorticity, the potential vorticity equation, potential vorticity conservation, stream function and velocity potential.	
Unit-6 Atmospheric Scale; Atmospheric Waves: Perturbation theory: Inertial, Acoustic, gravity, Poincare, Rossby and Kelvin waves. Atmospheric turbulence: Mixing length theory, planetary boundary layer equations, surface layer, Ekman layer, eddy transport of heat, moisture and momentum, Richardson criterion.	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. An Introduction to Dynamic Meteorology by J. R. Holton
2. Mid-latitude Atmospheric Dynamics by J. E. Martin
3. Atmospheric Science: An introductory survey by JM Wallace and PV Hobbs
4. Atmosphere, Ocean, and Climate Dynamics: An introductory text by John Marshall and RA

Reference Books:

1. Practical Meteorology: An Algebra-based Survey of Atmospheric Science by Roland Stull
2. Lecture Notes on Dynamic Meteorology for Integrated Meteorological Training Course

e-Resources:

1. Introduction to Atmospheric Dynamics by Paul A. Ullrich (https://www.youtube.com/channel/UCrm3Nkw_0wPJxjOolmZe5iA)
2. Murtugudde Climate Academy (https://www.youtube.com/c/RaghuMurtugudde)
3. https://www.meted.ucar.edu/index.php
4. Atmospheric Dynamics- NPTEL lecture (https://www.youtube.com/watch?v=umI3VZa7ChU)

Assignments:

1. Problem Solving from Chapter 1 to 4 of "An Introduction to Dynamic Meteorology by J. R. Holton

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		2		2		1		
CO2	3		2		2		1		
CO3	3		2		2		1		
CO4	3		2		2				
CO5	3		2		2		1		
CO6	3		2		2		1		

Course Title: Statistical Methods for Earth Sciences		Course code: ATS 404
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 2 hours/ week Tutorial: 1 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L -2; T-1; P-0
Course Prerequisite: Basic Knowledge of Bachelor level of Mathematics		
Course Description		
This course includes different statistical tools and methods used in the earth sciences. Techniques of probability and data analysis as applied to problems in the earth and atmospheric sciences. Topics include probability, hypothesis testing, time series analysis, correlation and regression analyses. Tutorial work focuses on the use of statistical packages for data analysis.		
Course Objective:		
1. To understand the different mathematical methods used in the numerical weather prediction techniques for evaluating weather forecasts. 2. To study the different computer methods for the development of accurate and robust weather forecast systems. 3. To provide the exposure amongst students to use computers to develop and apply numerical algorithms for the solution of atmospheric related phenomena.		
Course Outcome/Learning Outcome		
1. Understand the basic knowledge of various statistical elementary tools 2. Critical thinking in the theory of probability distribution and its applications 3. Understand critically the problems that are faced in testing of a hypothesis 4. Apply different testing tools like t-test, F-test, chi-square test, etc. 5. Understanding of various advance techniques for parameter estimation 6. Application of statistics in atmospheric science for weather prediction and climate changes studies		

Course Content

	Hours
Unit-1 Descriptive Statistics, analysis of variance distributions, Probability, conditional probability, Notion of probability, Probability laws, Addition Rule and Complements, Independence and the Multiplication Rule, Conditional Probability and the General Multiplication Rule	8
Unit-2 Discrete and continuous distributions, Normal distribution, Standard Normal Distribution, Poisson's distribution, Random variables, Moments, Expectance operator, Gaussian statistics	8
Unit-3 Confidence intervals, Hypothesis testing, Null testing, *P* value, Hypothesis Tests for a Population Mean, Population Standard Deviation Unknown	7

Unit-4 Student T-test, Fischer's Z, and F-test, Correlation (Pearson's rho, Kendall's tau), Goodness-of-fit tests (KS, Chi squared), Chi-Square Test for Independence and Homogeneity of Proportions	7
Unit-5 Bayesian statistics, Markov Chain Monte Carlo methods, Kalman filter and Ensemble Kalman Filter	7
Unit-6 Application of statistics in weather prediction and climate change, trend analysis, test of significance,	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Storch H von and. Zwier FW: Statistical analysis in climate research, Cambridge University Press.
2. Emery WJ, Thomson RE: Data Analysis Methods in Physical Oceanography, Elsevier Science.
3. Sillmann TE, Gebbers R, Marwan N: MATLAB® Recipes for Earth Sciences, Springer.
4. Rohatgi, V. K., & Saleh, A. M. E. (2015). An introduction to probability and statistics. John Wiley & Sons.
5. Hogg, R. V., & Craig, A. T. (1995). Introduction to mathematical statistics.(5"" edition). Englewood Hills, New Jersey.
6. Cox, D. R., & Donnelly, C. A. (2011). Principles of applied statistics. Cambridge University Press.
7. Statistical Analysis in Climate Research by von Storch and Zwiers, Cambridge Univ Press.

e-resources:

1. E-PgPathshala, Statistics, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=+u3y6UdbIvOJ97LFeSCmHQ==

Assignments:

1. Role of Statistics in Atmospheric Science.
2. Elementary Properties on Probability.
3. Probability distribution and their application.
4. Tests of significance
5. Bayesian Statistics
6. Markov Chain Monte Carlo method
7. Application of statistics in climate studies

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3				2		2		
CO2	3				2		2		
CO3	3						2		
CO4	3	2					2	3	
CO5	3	2			2		2	3	
CO6	3	2					2	3	

Course Title: Tropical Meteorology and Climatology		Course code: ATS 405
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L -3; T-0; P-0
Course Prerequisite: Basic Knowledge of Bachelor level Physics, Mathematics.		
Course Description		
This course will provide an understanding of the different types of weather and climate phenomena. Also, different types of tools have been used to analyse these phenomena. Complete understanding these phenomena will help to understand the weather and climate modelling prediction in details.		
Course Objectives:		
1. To expose and familiarize students with key atmospheric variables and structures, the types of weather data available, how these data are collected, and some of the ways that these data are displayed, analysed, and used. 2. To introduce the concept of wide range of atmospheric phenomena and their roles in affecting weather and climate on local, regional, continental, and global scales		
Course Outcome/Learning Outcome		
1. Analyse and interpret conventional maps of surface and upper air data, reanalysis and IMD gridded data as well as soundings on a thermodynamic diagram. 2. Understand the mechanisms for the formation and evolution of Tropical events. 3. Explain the large-scale interaction with Monsoon dynamics. 4. Explain about the role of these phenomena in affecting the weather and climate over India 5. Analyse these weather/climate phenomena with different types of data sets. 6. Demonstrate the development and interaction of tropical air-sea interaction mode.		

Course Content

	Hours
Unit-1 Differential heating, Factors affecting temperature distribution, Global wind, pressure and precipitation distribution, Atmospheric Pressure Belts and Wind Systems, Trade wind inversion, Hadley and Walker circulation, ITCZ, Somali Jet and jet streams,	8
Unit-2 Monsoon trough, Indian Monsoon, Different types of Monsoons, active and break cycles; monsoon variability on interannual and decadal time scales depressions, South West and North East Monsoons,	8
Unit-3 intra-seasonal variability of summer, Indian summer monsoon indices, synoptic features associated with onset, withdrawal, break, active and weak monsoons, formation and movement of western disturbances,	8
Unit-4 Weather systems associated with fronts, extra-tropical cyclones, anticyclones and blockings, tropical oceanic drivers such as the El Nino-Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD),	7

Unit-5 Tropical Cyclones: theories relevant to forecasting the genesis, motion and intensity of tropical cyclones, Air masses and fronts, structure of cold and warm fronts;	7
Unit-6 Synoptic weather forecasting charts, Weather observations, and transmission, Prediction of Weather elements, hazardous weather elements	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. McGregor, GR, Nieuwolt S: Tropical Climatology, John Wiley and Sons, 1998.
2. Climatology by Dr D S Lal
3. Wallace JM and Hobbs PV: Atmospheric Science -An Introductory Survey, Academic Press.

Reference:

1. Defant F and Morth HT: Compendium of Meteorology, vol. I, Synoptic Meteorology, WMO publication, 1978.
2. Riehl H: Climate and Weather in the Tropics, Academic Press, 1979.
3. Saucier, WJ: Principles of Meteorological Analysis, Dover Publications, 1989.

e-Resources:

https://www.meted.ucar.edu/index.php

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						2	2	1
CO2	3	3				2	2	2	1
CO3	3	3	3	3	3	1	3	2	3
CO4	3	3	3	2	1	1	2	2	2
CO5	3	2	3	1	1	3	2	3	3
CO6	3	1	2	1	2	2	3	3	3

Course Title: Programming Techniques for Atmospheric Sciences		Course Code: ATS 406
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 6 hours/ week	Continuous Internal Assessment (CIA): 40 End - Semester Examination (ESE): 60	L -0; T-0; P-3
Course Prerequisite: Basic knowledge of Computer.		
Course Description		
In this course, students will study and solve various numerical and statistical problems, by developing algorithms in FORTRAN, Python, MATLAB and executing them on computer using dataset provided (Or to be downloaded as instructed). All problems will be specific to atmospheric sciences		
Course Objective:		
1. To impart the basic and advanced knowledge of programming languages. 2. To develop knowledge of computational techniques to study atmospheric processes 3. To provide skill of computation for analysing meteorological field. 4. To compete for research and technical positions in atmospheric Sciences		
Course Outcome/Learning Outcome		
1. Understand the basic structuring of Fortran 2. Articulating logic of programming through advance Fortran Programming 3. Understand the similarity and dissimilarity between Python and Fortran 4. Conduct simple to complex calculations and visualize data with Python 5. Visualize data effectively using MATLAB 6. Analyse large atmospheric datasets with MATLAB		

Course Content

	Hours
Unit-1 FORTRAN fundamentals: integer constant, floating point constant, variables, arithmetic operator, relational operator, FORTRAN arithmetic and expression, input/output and format statements, Conditional statement, looping, arrays, multidimensional arrays, functions, and subroutines,	16
Unit-2 Advance Fortran programming for differential equation; Numerical Integration; Interpolation; Basic Statistical analysis using Fortran; Creating Binary File;	14
Unit-3 Python-Introduction, Data types: Numbers, Strings, Unicode Strings, Loops; Python Packages: Importing from a Package, Python Input Output-Fancier Output Formatting, Old string formatting,	14
Unit-4 Reading and Writing Files, Data visualization with Python, Applications of Numerical Python, Scientific Python and Matplotlib: Use of Numpy, Scipy, Basemap,	14
Unit-5 Introduction to MATLAB: Starting MATLAB Layout of graphical user interface (GUI),	16

interactive commands operators and variables MATLAB help. Programming: arrays, matrices and vectors, script file, numeric, cell, Character Strings, built in functions (i.e., find, mean, max, min, sum, etc). eval function. File I/O (text, binary, netCDF, HDF), indexing, Symbolic Computation, basic program organization, debugging.	
Unit -6 Graphics: Line, scatter, bar, surface, contour plots, etc Figure properties (i.e., Axis labels, tick marks). Colormaps saving your plots Images in MATLAB, Statistical analysis of time series data, Non-linear algebraic equations, Analysis of Meteorological Data using MATLAB, Handling large datasets, Netcdf files	16
Internal Assessment	
CIA-1: Unit -1, 5	
CIA-2: Unit 3, 6 (half)	
ESE: All Units	

Textbooks:

1. Computer Programming in Fortran 90 and 95 by V. Rajaraman
2. Introduction to Modern Fortran for the Earth System Sciences by Dragos B. Chirila, Gerrit Lohmann
3. Langtangen HP: A Primer on Scientific Programming with Python (First Edition), Springer, 2009.
4. Paratap R: Getting Started with MATLAB: A Quick Introduction for Scientists & Engineers, 2010.

Reference Books:

1. Press WH, Teukolsky SA, Vetterling WT and Flannery BP: Numerical Recipes in FORTRAN, Cambridge University Press, 2000.

e-Resources:

1. NPTEL Computational Physics (https://nptel.ac.in/courses/115106118)
2. Python – Spoken Tutorial by IIT Bombay (https://spoken-tutorial.org/)
3. https://www.youtube.com/channel/UCUJFj-PXuWLRfFFHA44ZGYw

Fortran Assignments: Minimum Two Practical exercises must be finished to complete the course

1. Computation of Meteorological variables: Potential Temperature, equivalent potential temperature etc.
2. Computation of stability Index: SWEAT Index, Totals Total index, Bulk Richardson Number
3. Solution of algebraic and transcendental equation by Newton- Raphson's method
4. Numerical Integration by Trapezoidal and Simpson's Rule
5. Fitting of straight lines by Least square method
6. Computation of Correlation Coefficients: Product Moment Method and Rank Correlation Method
7. Data Interpolation

Python Assignments: Minimum Two Practical exercises must be finished to complete the course

1. Plotting timeseries of meteorological variables (Temperature, Precipitation)
2. Calculation, plotting and analysis of climatological mean, monthly and seasonal mean with proper global/country/state boundary
3. Calculation, plotting and analysis of statistical parameter (standard deviation, variance, correlation)
4. Data Interpolation
5. Reading and writing different data format (netCDF, Excel) of files

MATLAB Assignments: Minimum Two Practical exercises must be finished to complete the course

1. Plotting back trajectories
2. Reading NC files from reanalysis datasets
3. Plotting gridded data on Maps

4. Analysing timeseries data and data filtering
5. Working and conversion between different time formats: correlating data of different temporal resolutions

Instructions:

- Students must prepare/maintain a practical copy (one side line and one side white) and need to sign on a regular basis.
- Assignments provided in class should be signed and checked by concerned faculty in the next class.
- If two consecutive assignments are not duly signed, then third assignments onwards will not be checked
- Each student must install Cygwin in their Laptop or should have Linux OS (Preferably UBUNTU)

CO-PO Mapping

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**
CO1	3	2					2		
CO2	3	3					2		
CO3	3	1					2		
CO4	3	3					2		
CO5	3	3					2		
CO6	3	3					2		

Course Title: Atmospheric Chemistry, Air Pollution & Climate		Course code: ATS 407
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L -3; T-0; P-0

Course Prerequisite: Basic knowledge of chemistry (Intermediate level: knowledge of chemical kinetics, concepts of molecular orbitals), Basic knowledge of mathematics (differential equations, integration)

Course Description

This course is aimed to provide basic understanding of atmospheric chemistry so that they can relate the role of atmospheric chemistry on air quality and climate. The students will learn about the chemical composition of the atmosphere, how it is changing because of anthropogenic pressure, and the consequences for ecosystems, human health, and climate. They will learn about atmospheric gas phase chemical and photochemical reactions. They will also learn about the formation of aerosols from gaseous precursors and how gases and particles interact in the atmosphere.

Course Objective:

1. To develop an understanding of the gas phase chemical and photochemical reactions operating in the atmosphere and the chemical evolution of atmospheric aerosols.
2. To develop an understanding of the interlinkages of anthropogenic emissions, air pollution and climate.
3. To develop an understanding about self-cleaning mechanisms in the atmosphere to initiate new ideas pertaining to mitigation of air pollution.

Course Outcome/Learning Outcome

1. Understanding the gas phase chemical and photochemical reactions operating in the atmosphere.
2. Knowledge of atmospheric aerosol properties and it's chemical evolution in the atmosphere.
3. Understanding the fate and transport of primary and secondary air pollutants, as well as self-cleaning mechanisms and the ability to think of new approaches to reduce air pollution.
4. Understanding the associations between anthropogenic emissions, air pollution, and climate change.
5. Learning of basics modelling tools to identify the air pollution sources.
6. Enable the students to compete for numerous research positions and jobs in this field.

Course Content

	Hours
Unit-1 Evolution of the earth's atmosphere. Atmospheric chemical constituents, Half-life and residence time, spatial and temporal scales of variability, Altitude profile of atmospheric gases and aerosols, units for chemical abundance.	7
Unit-2 Chemical and photochemical processes, Tropospheric chemical cycles, Natural and anthropogenic air pollution sources, and pollutants, Air quality index.	7
Unit-3 Spatial, temporal and altitude variations of atmospheric ozone, Photochemical theory of ozone. The ozone layer and the ozone hole, sources, and sinks of tropospheric and stratospheric ozone. Antarctic ozone hole. Meteorological processes affecting tropospheric and stratospheric ozone	8

Unit-4 Atmospheric hydrocarbon chemistry, evolution of methane, gas to particle conversion, transformation of air pollutants. Greenhouse gases and global warming potential. Radicals and atmospheric oxidation mechanisms.	7
Unit-5 Atmospheric aerosols: Concentration, size distribution, sources, and transformation, residence times of aerosols, geographical distribution, and atmospheric effects. Stratospheric aerosols.	8
Unit-6 Aerosol Dynamics: Nucleation, Condensation and Coagulation; Radiative Effects, Gas to particle oxidation, Atmospheric effects- smog, acid rain, visibility, Black Carbon, Nitrate, Chloride and Sulphate	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Hobbs PV: Introduction to Atmospheric Chemistry, Cambridge University Press.
2. Seinfeld JH, Pandis SN: Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley-Inter science.
3. Finlayson-Pitts BJ, Pitts JN: Chemistry of the Upper and Lower Atmosphere Theory, Experiments, and Applications, Academic Press.
4. Wayne RP: Chemistry of Atmospheres, Oxford University Press.
5. Arya S Pal: Air Pollution Meteorology and Dispersion, Oxford University Press.
6. Hinds WC: Aerosol Technology: Principles, Behaviour & Measurements of Airborne particles, Wiley.

Reference Books:

1. Barbara J Finlayson-Pitts, James N Pitts Jr: Chemistry of the Upper and Lower Atmosphere: Theory, Experiments, and Applications, 1999, Academic Press
2. Daniel J Jacob: Introduction to Atmospheric Chemistry, 2000, Princeton University Press.

e-Resources:

1. http://cires1.colorado.edu/jimenez/AtmChem/CHEM-5151_S05_L1.pdf
2. http://www.srh.noaa.gov/srh/jetstream/atmos/layers.htm
3. http://en.wikipedia.org/wiki/Atmosphere_of_Earth
4. http://www.epa.gov/air/airtrends/2011/report/sixcommon.pdf
5. http://www.epa.sa.gov.au/xstd_files/Air/Information%20sheet/info_photosmog.pdf
6. http://acmg.seas.harvard.edu/people/faculty/djj/book/bookchap13.html#pgfId=105767
7. http://ozoneaq.gsfc.nasa.gov/
8. http://web.stanford.edu/group/efmh/jacobson/POLbook2/APGWCh12Figs.pptx

Assignments: Presentation of following topics

1. Composition, Structure, and Transport in the Atmosphere
2. Tropospheric and stratospheric ozone and its variation with meteorology
3. Atmospheric aerosol: physical, chemical, and optical properties
4. Geoengineering: Aerosols and its impact on climate
5. Tropospheric Chemistry
6. Air quality index

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		1						
CO2	3		2	2					
CO3	3		2	2					
CO4	3		3	3	3	2	3	3	
CO5	3	3	3	3	3	3	3	3	3
CO6	3		2	2		3	3	2	3

Semester – II

Course: Fundamental of Atmospheric Modelling		**Course code: ATS 408**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0

Course Prerequisite: Knowledge of Dynamic Meteorology, Calculus, Numerical methods.

Course Description

This course will introduce students to the Hierarchy of atmospheric models and impart knowledge on numerical discretization, integration & numerical instabilities. It will also educate students on different types of physical parameterization techniques, global and regional models used in weather forecasting.

Course Objective:

1. To introduce students to the Hierarchy of atmospheric models.
2. To impart knowledge on numerical discretization, integration & numerical instabilities.
3. To educate students on different types of physical parameterization techniques, global and regional models used in weather forecasting.

Course Outcome/Learning Outcome

1. Understand the basic concept of numerical modelling
2. Explain the dynamical instability in numerical model
3. Describe elements of different types of numerical models used in Atmospheric Science
4. Explain numerical stability for different numerical scheme.
5. Understand about the coupling of model physics and dynamics focusing on the dynamical core of the numerical model.
6. Understand the climate components used in climate modelling and explain differences between weather and climate modelling

Course Content

	Hours
Unit-1 Introduction to weather and climate models, Numerical Modelling vs. Other Modelling Approaches, Statistical Modelling, Components Numerical Modelling, and weather forecasting;	7
Unit-2 Atmospheric Instability: Thermodynamic and Dynamic instabilities, Inertial instability, Symmetric instability, Computational Instability, Barotropic and Baroclinic instabilities,	8
Unit-3 Model Components, Numerical Model Type; Grid point model; Spectral Modelling; Brief overview of Initialization, Boundary, Domain, Grids, Resolution, Physical parameterization, Data Assimilation, Nesting,	7

Unit-4 Different Schemes of Numerical discretization (finite difference, finite volume, spectral) and integration, CFL criterion, Computational Stability, Consistence and Convergence, Advection equation, Diffusion equation, Advection -diffusion equation	8
Unit-5 Dynamical core: WRF, MPAS, RAMS, RegCM, GFS, GEFS, Physics-dynamics coupling: Different types of coupling, coupling attributes, Couple numerical Model: Ocean-Atmosphere Coupling, Serial and Concurrent Coupling	8
Unit-6 Global and regional models used in weather forecasting and atmospheric simulations. Examples of atmospheric simulations; Climate Modelling, Components of Climate systems, Climate Projections, Climate Model Evaluation, Earth System Modelling	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. An Introduction to Dynamic Meteorology by J. R. Holton
2. Fundamental of Numerical weather prediction by Jean Coiffier
3. Numerical Methods Used in Atmospheric Models by F. Mesinger and A. Arakawa
4. Atmospheric modelling, data assimilation and predictability by Eugenia Kalnay
5. Demystifying Climate Models - A Users Guide to Earth System Models by Andrew Gettelman and Richard B. Rood

Reference:

1. Lecture notes on Dynamic Meteorology for the Advanced Met. training course prepared by Dr. Somenath Dutta.

e-resources:

- https://www.youtube.com/watch?v=gjB4Ohk90r8&feature=youtu.be
- https://www.meted.ucar.edu/education_training/courses
- https://www.youtube.com/watch?v=K_Wp3J_VAW0&t=667s
- https://www.youtube.com/watch?v=DoGn8e-isvw&t=652s

Assignments:

1. Install and run MIT single Column Model
2. Sensitivity study with RCM https://rcmodel.mit.edu/ (1D Radiative convective Model)

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3		1		1		1		
CO3	3						1		
CO4	3	2	1				1		
CO5	3						1		
CO6	3						1		

Course Title: Instrumentations in Atmospheric Studies		Course code: ATS 409
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 2 hours/week Lab: 2 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-2; T-0; P-1

Course Prerequisite: Basic knowledge of meteorology, theoretical knowledge of basic Instrumentations used in Atmospheric Studies

Course Description

This course provides an opportunity to the students to get a first-hand experience of the instrumentation used in Atmospheric Sciences. They get to handle sophisticated instruments and understand their working principles, maintenance, and calibration procedures. They also get an insight into laboratory protocols, working with gases and gas cylinders, precautions to be taken while handling equipment and assembling instruments and designing their own experimental setups and measurement campaigns.

Course Objective:

1. To inculcate an experimental mind-set and curiosity.
2. To train students in instrumentation and data analysis of Atmospheric observations.
3. To enable them to appreciate the value of good quality data and experimental protocols.
4. To prepare them for vast opportunities lying in the field of experimental Atmospheric Science.

Course Outcome/Learning Outcome

1. Development of basic laboratory etiquette and understanding laboratory protocols.
2. Familiarity of working with common instrumentation used in Atmospheric Studies.
3. Experience of operating and calibrating instruments and generating quality data.
4. Ability to partake and integrate easily in experimental setups w.r.t. both field and laboratory-based experiments.
5. Understanding and conducting meteorological observations.
6. Curiosity and interest in experimental Atmospheric Sciences

Course Content

	Hours
Unit-1 Laboratory protocols, Safety precautions, familiarizing with meteorological instruments used in Atmospheric studies, operation,	10
Unit-2 Maintenance, calibration, data retrieval and archival. Handling gas cylinders, pressure regulators, tubing and fittings. Connector types and uses.	10
Unit-3 Pressure, Temperature, humidity, radiation and wind measurements, Automatic weather station, Atmospheric soundings, lightning detector.	10
Unit-4 Measurements of aerosols and trace gases: micro tops, aerosol sample collection, ion chromatography, aerosol spectrometer,	10

Unit-5 O3, CO, NOx and SO2 measurements, Methane and Hydrocarbon measurements with Flame Ionisation Detector. Greenhouse gas measurements, Planning a Field campaign.	10
Unit-6 Setting up a Meteorological Field observatory, Field trips, and Case studies	10
Internal Assessment	
CIA-1: Unit-1,2,	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Heard D: Analytical Techniques for Atmospheric Measurement, 1st edition, 2006.
2. Srivastava, GP: Surface Meteorological Instruments and Measurement Practices, Atlantic Publishers & Dist, 2009.

Reference:

3. WMO: Guide to Instruments and Methods of Observation, WMO No 8, 2018.

e-Resources:

https://www.wmo.int/pages/prog/www/IMOP/CIMO-Guide.html
https://www.meted.ucar.edu/education_training/course/58

Assignments (theory and practical):

1. Conversion between volumetric and gravimetric units
2. Checking leaks and pressure in gas lines
3. Taking data from meteorological observatory
4. Calibrating trace gas instruments
5. Aerosol sample collection and analysis

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						2	2	1
CO2	3	3				2	2	2	1
CO3	3	3	3	3	3	1	3	2	3
CO4	3	3	3	2	1	1	2	2	2
CO5	3	2	3	1	1	3	2	3	3
CO6	3	1	2	1	2	2	3	3	3

Course Title : Physics and Dynamics of the Oceans		Course code: ATS 410
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Physics and Dynamics of fluid.		
Course Description		
Oceanography is the scientific study of oceans and seas. It deals with the distribution of oceanic water masses, morphology of the oceans along with its physical processes, dynamics of water masses and the role of oceans on controlling the global climate.		
Course Objective:		
1. To develop knowledge about oceanic processes. 2. To develop knowledge about air-sea interaction and its impact on atmospheric processes 3. To develop knowledge about the role of ocean as climate drivers.		
Course Outcome/Learning Outcome		
1. Describe the physical features of world Ocean. 2. Understand Ocean monitoring processes 3. Explain surface current pattern using oceanic theories 4. Describe the processes associated with deep ocean circulation 5. Describe the characteristics of ocean wave. 6. Explain the Tide generating forces, Coastal processes.		

Course Content

	Hours
Unit-1 Historical oceanographic explorations, Physical Characteristics of the Ocean: Ocean Basins, Hypsography of the continents and ocean floor –continental shelf, slope, rise and abyssal plains, Physical and chemical properties of sea water and their spatial variations; Vertical profile of temperature and salinity in the three major ocean	8
Unit-2 Conservation of Mass and Salt, Equation of state of Seawater; Ocean Heat Budget, Ocean Monitoring: Measurement of Temperature, Conductivity, Pressure, Salinity, Instruments used in oceanographic studies, Measurement of Ocean Currents	8
Unit-3 Dominant Forces for Ocean, Wind stress; Ekman Dynamics; Upwelling and downwelling; Surface current, Sverdrup theory; Geostrophic flow in Ocean, Equatorial current systems	7
Unit-4 Wind driven ocean circulation, Wind driven coastal currents; Westward intensification, Deep Ocean Circulation: Stommel and Munk's theories, T-S diagrams; mixing processes in the oceans; characteristics of important water masses	7
Unit-5 Wind generated waves in the oceans; their characteristics; shallow and deep-water	7

waves. Propagation, refraction, and reflection of waves. Breakers and surf; littoral and rip currents;	
Unit-6 Tides and tide generating forces, prediction of tides by the harmonic method; tides and tidal currents in shallow seas, Coastal Processes, Oceanic Hazards, Air-interaction; Ocean Modelling	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. An Introduction to Dynamic Meteorology by J. R. Holton
2. Atmosphere, Ocean, and Climate Dynamics: An introductory text by John Marshall and RA Plumb
3. Essentials of Oceanography by Thrujillo and Tharman
4. Introduction to Physical Oceanography: Robert Stewart

Reference:

1. Practical Meteorology: An Algebra-based Survey of Atmospheric Science by Roland Stull
2. Upper Ocean Mixing by JN Moum and WD Smyth, Oregon State University, Corvallis, OR, United States
3. History of the Equation of State of Seawater by Frank J. Millero, University of Miami, Oceanography Vol.23, No.3
4. Water Types and Water Masses by W J Emery, University of Colorado, Boulder, CO, USA
5. The Water Masses of the World Ocean: Some Results of a Fine-Scale Census by L. V. Worthington
6. Global water masses: summary and review by W. J. EMERY and J. MEINCKE, Oceanologica

e-Resources:

1. Introduction to Atmospheric Dynamics by Paul A. Ullrich (https://www.youtube.com/watch?v=uKv36HN_ObM&t=23s)
2. Murtugudde Climate Academy (https://www.youtube.com/c/RaghuMurtugudde)
3. https://www.meted.ucar.edu/index.php
4. ICTP-Postgraduate Diploma Programme: Ocean Dynamics https://www.youtube.com/watch?v=scOLenNxIi8&list=PLp0hSY2uBeP_w6R72DRq0_XQ7SbSI_CZl
5. https://www.youtube.com/channel/UC44Ys0T7YBeqRma6OqFYO0A

Assignments:

1. Using T-S diagram identify water mass
2. Problems associated with Ekman dynamics

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3						1		
CO3	3				2		2		
CO4	3		1		1		1		
CO5	3						1		
CO6	3						1		

Course Title: Weather Analysis and Visualization Laboratory		Course code: ATS 411
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 1 hours/ week Lab: 4 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-1; T-0; P-2
Course Prerequisite: Basic knowledge of computer and Meteorology		
Course Description		
This course demonstrates familiarity with key atmospheric variables and structures, the types of weather data available, the manner by which these data are collected, and some of the ways that these data are displayed, analysed and used with the different types of visualization Software (GrADs, NCL, CDO)		
Course Objective:		
1. To familiarize with the use of different types of atmospheric variables with different data formats. 2. Train students with the different types of visualization Software (GrADs, NCL, CDO etc), 3. To analyse the atmospheric variables for synoptic features during different seasons and different weather/climate phenomena.		
Course Outcome/Learning Outcome		
1. Students can demonstrate the ability to analyse and interpret conventional maps of surface and upper-air data as well as soundings. 2. Students will learn weather and climate data processing and visualization techniques. 3. They will learn analysis, manipulation and interpretation of the data of the different weather/climate phenomena. 4. Explain the use of different data sets for the calculation of different indices of synoptic-scale and tropical weather systems as well as of the general circulation of the atmosphere. 5. Understand the different types of weather and climate phenomena using different types of data sets 6. Calculation of mathematical functions used for the interpretation/analysis of weather/climate phenomena.		

Course Content

	Hours
Unit-1 Familiarization with Post-Processing and Visualization Software (GrADs / NCL / CDO), Installation of GrADS/NCL/CDO, Familiarization and visualization of atmospheric datasets (IMD Gridded and reanalysis data), Format of. ctl and netcdf file,	13
Unit-2 Plot of vertical temperature profile, Isotachs and contour analysis, variable declarations, mathematical functions, weather charts, jet streams, mid-latitude and tropical disturbances, different map projections using GrADs, area and time average calculation, Hovmoller diagrams	13

Unit-3 synoptic features of temperature, pressure, rainfall and wind during different seasons, plotting of climate during different seasons, anomaly calculation, Mean Sea level pressure, sea surface temperature and wind plots for cyclone development, Indian monsoon climatology of rainfall, wind pattern at 850 hPa & 200 hPa, divergence and vorticity calculation	13
Unit-4 synoptic features of Mean Sea level pressure, sea surface temperature and wind plots for cyclone development, Indian monsoon climatology of rainfall, wind pattern at 850 hPa & 200 hPa, divergence and vorticity calculation	12
Unit-5 Analyse the cases of strong and break monsoons using pressure, rainfall and wind fields and derive the basic features differentiating the weak and strong monsoons.	12
Unit-6 Finding out the El-Nino and La-Nina years and Indian Ocean Dipole (IOD) index from the different reanalysis datasets. Familiarization with multiple Data Formats. Calculation of Southern Oscillation Index (SOI)	12
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:
1. Wallace JM and Hobbs PV: Atmospheric Science -An Introductory Survey, Academic Press.
2. Das PK: Indian Monsoon,
3. Holton JR: An introduction to dynamic meteorology.

Reference:
1. Users Guides: for GrADS, NCL and CDO
2. Visualization and analysis software documentations from websites

e-Resources:
http://cola.gmu.edu/grads/
https://www.unidata.ucar.edu/software/netcdf/workshops/2012/third_party/CDO.html

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						2		
CO2	3		2	2	2		2		
CO3	3				2	1	2		
CO4	3		2		1	1	1		
CO5	3	1	1		1		1		
CO6	3						2		

Course Title: Simulation of Atmospheric Processes		Course Code: ATS 412
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 1 hours/ week Tutorial: 1 hours/ week Lab: 2 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-1; T-1; P-1

Course Prerequisite: Basic knowledge of meteorology and computer programming.

Course Description

This course is designed for the overview of different types of weather and climate models. The types of skill scores used for the verification of the weather/climate models are well explained in this module. Also, this course will provide the current state of the art of visualization used in meteorology, focusing on visualization techniques and tools used for meteorological data analysis. In addition, UNIX commands and shell programming are described in this course.

Course Objective:

1. To understand the dynamics and thermodynamics governing the ocean and atmosphere on spatial and temporal scales appropriate for climate systems.
2. To impact the knowledge of how precision, accuracy, and analysis techniques are used to provide a description of the state of the atmosphere in Global, Regional, mesoscale and coupled models.
3. To introduce the different types of skill scores, predictability and ensemble forecasting used in Global, Regional, mesoscale and coupled models Outcomes.

Course Outcome/Learning Outcome

1. Understand the different types of numerical models for weather/climate studies
2. Students will analyse and demonstrate the visualization of the different types of atmospheric data sets with the UNIX and shell programming.
3. Students can familiarize with operating system such as UNIX
4. Explain about the different skill scores in numerical weather prediction.
5. Understand the high-performance computing used in simulation of weather/climate models
6. Able to write the UNIX shell scripts for the data analysis, simulation and post processing

Course Content

	Hours
Unit-1 Governing equations for Atmospheric and Oceanic Processes: continuous equations, map projections, vertical coordinate system, Global, regional, mesoscale, and coupled models, Principles and problems of climate modelling, climatic processes in a Global Climate model	10
Unit-2 Climate forcings, Uncertainties in weather and climate model, Weather Forecast verification methods across Time and Space Scales, Nesting strategies across different models, Impact of domain and model resolution, model spin-up Types of forecasts and verification, standard diagnostics and skill scores, climate drift, climate geo-engineering, Bias correction techniques,	10
Unit-3 Introduction to downscaling, Dynamical and Statistical downscaling, Components of time series, Analysis of Time Series, analysing trends and detrend in climate data, Introduction to parallel computing, different types of parallel computing used in	10

simulation of atmospheric and oceanic phenomena.	
Unit-4 Unix/Linux Operating System, Introduction to UNIX/LINUX, basic commands, file management; directories, file permission, copy, move, delete files, making and deleting directories, pipes and filters, archiving files, process in Unix, Vi editor	10
Unit-5 Shell Scripting, what is shell, different types of shell, using shell variables, special variables	10
Unit-6 Shell scripting using arrays, basic operators, decision making, shell loops, loop control, shell substitutions, IO redirections, shell functions,	10
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Kantha and Clayson CA: Numerical Models of Oceans and Oceanic Processes, Academic Press.
2. McWilliams James C: Fundamentals of Geophysical Fluid Dynamics, Cambridge University Press.
3. Jacobson MZ: Fundamentals of Atmospheric Modelling, Cambridge University Press.

Reference:

1. D. V. Bhaskar Rao, Numerical Weather Prediction, BS Publication
2. Geoffrey K. Valllis, Essentials of Atmospheric and Ocean Dynamics

e-Resources:

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						2		
CO2	3		2	2	2		2		
CO3	3				2	1	2		
CO4	3		2		1	1	1		
CO5	3	1	1		1		1		
CO6	3						2		

Course Title : Dissertation-I		Course code: ATS 413
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Skill Enhancement Course	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-0; T-0; P-3
Course Prerequisite: Basic knowledge of meteorology		
Course Description		
Each student will work for a mini project under the supervision of formally assigned supervisor in the department for 3 to 4 months. In this project, student shall review recent research articles on given topic. Students must write and submit their research work in the form of dissertation based on their assigned work at the end of semester. This course provides an advanced understanding of research reading, writing and presentation		
Course Objective:		
1. To make students aware of research review writing. 2. To make students to present research review in seminar		
Course Outcome/Learning Outcome		
1 Develop an understanding of the fundamentals of research review writing 2. Develop demonstration skill 3. Able to use tools related to research articles 4. Develop Knowledge in recent research activities 5. Develop knowledge of Systematic review 6. Able to understand the pattern of scientific writing		

Dissertation -I Guidelines

1. GENERAL:

The manual is intended to provide broad guidelines to the M.Sc. students in the preparation of the dissertation-I report. In general, the project report shall be organized in scholarly fashion and described briefly and neatly. Each student will be assigned to the concerned faculty of the department.

Dissertation – I provide a basis for development research aptitude. In this course a student must review a topic given by the supervisor. Through literature review, students must explore maximum possible attributes of a given topic.

2. CHOICE OF TOPIC:

Choice of topic must decide by discussing with concern faculty

2. REPORT:

Student must prepare a report of review study and content should be arrange as follows:

1. Cover page & title page
2. Declaration
3. Certificate
4. Acknowledgements
5. Table of Contents
6. Abstract
7. Chapters
8. Conclusion
9. Learning

Students should prepare three hardcopies of Dissertation-I report and each copy should be signed by the Head of the Department and concerned Supervisor. One copy of the Dissertation report must be submitted to the

concerned supervisor and one copy to the head of the department on the day of exam and one signed copy should be kept with the student. Softcopy of Dissertation -I report must be submitted to the concerned supervisor with a copy to the Head of the Department a day before the final exam.
The Tables and Figures shall be introduced in the appropriate places.

4. MANUSCRIPT PREPARATION:

The dimensions of the dissertation should be standard A4 size paper may be used for preparing the copies, standard margin with **1.5 line spacing**, "**Times New Roman**" should be used as font. Font Size of different elements should be as follow

- Text - 12
- Heading – 14
- Figure/Table caption -10 with Italic.

Cover Page & Title Page - A specimen copy of the Cover page & Title page for report/thesis are given in Annexure I.

Declaration - A declaration given by student has been shown in Annexure II

Certificate-The Certificate as per the format shown in Annexure III

Abstract: Abstract should not exceed 300 words outlining the research problem, the methodology used for tackling it and a summary of the findings, typed in 1.5 linespacing.

Acknowledgements: The acknowledgements shall be brief and should not exceed one page. The student's signature shall be made at the right bottom above his / her name typed in capitals.

Table of contents - The table of contents should list all material following it as well as any material which precedes it. The title page, Certificate and Acknowledgment will not find a place among the items listed in the Table of Contents but the page numbers in lower case Roman letters are to be accounted for them. One and a half spacing should be adopted for typing the matter ender this head.
A specimen copy of the Table of Contents for report / thesis is given in Annexure IV.

List of Table-The list should use the same captions as they appear above the tables in the text.

List of Figures - The list should use the same captions as they appear below the figures in the text

List of Symbols, Abbreviations and Nomenclature - One and a half spacing should be adopted for typing the matter under this head. Standard symbols, abbreviations etc. should be used.

Chapters - The chapters may include

- Chapter I – Introduction/Background
- Chapter II – Fundamental of *Topic*
- Chapter III –Recent Advances
- Chapter IV- Research Gap pertaining to "Topic"
- Chapter V – Conclusion
- Chapter VI – Future Scope and Learning

Research output/outcome if any published or presented in conference/seminar/symposium may be included.

Citation Style: Check the guideline given in Dissertation-II

5. BINDING SPECIFICATIONS

Thesis should be hard cover book bound, the cover of thesis should be of light blue colour, printed with black ink and the text for printing should be identical as prescribed for the title page.

Student can follow the format of Cover page of Dissertation-II

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	1			2			2	2	1
CO2	1					3		2	1
CO3	1	3	2		2			2	1
CO4	2						3	2	1
CO5	1	2					2	2	1
CO6	1	2				1	2	2	1

Department Elective Courses (DEC)
Semester -II

Course: Desert Meteorology and Climate		**Course code: ATS414**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of meteorology		
Course Description		
This course is designed to cover the science of desert meteorology. It covers various topics related to science and processes, vulnerability and mapping aspects to desert meteorology and climate.		
Course Objective:		
4. To provide knowledge of a wide range of atmospheric phenomena and their roles in affecting weather and climate in deserts. 5. To understand the dynamic effects of deserts on meteorological processes. 6. To give exposure of various methods to detect the change in climate of deserts.		
Course Outcome/Learning Outcome		
1. Understand the fundamental weather systems of arid zones. 2. Describe meteorological, physiological features of deserts. 3. Understand the modelling of desert atmosphere, 4. Compare climates of deserts with another climate zone. 5. Assess vulnerability maps the desertification. 6. Learn about tools and techniques to aid in understanding meteorology and climate over desert region.		

Course Content

	Hours
Unit-1 Some basic concepts of atmospheric structure and dynamics, Definition of desert, causes of aridity, Dynamic feedback mechanisms,	8
Unit-2 The dynamics of desert heat lows, Dynamic feedback mechanisms in deserts; General meteorological, Physiographic, and vegetative characteristics of desert	8
Unit-3 Desert-surface physical properties- Albedo, Thermal properties, Aerodynamic roughness, Emissivity, Hydraulic properties;	8
Unit-4 Numerical modelling of desert atmospheres; Desert boundary layers; Intro-desert microclimates and variability; Monsoon pattern in deserts; Desert severe weather	7

Unit-5 Desertification-Indicators, mapping, and vulnerability assessment; Drought indices, Changes in climate and aridity in desert;	7
Unit-6 Different methods/tools of assessment Examples of atmospheric model applications in desert; Demonstration of tool to develop desert indices, Review of selected case studies	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Thomas T Warner, Desert Meteorology, Cambridge University Press
2. Sharon E. Nicholson, Dryland Climatology, Cambridge University Press
3. Stull, R., 2017: "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" - version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6
4. Keshavamurty & Sankar Rao: The Physics of Monsoon.
5. J. F. P. Galvin, An Introduction to the Meteorology and Climate of the Tropics, Wiley-Blackwell
6. Prakash, I. 2001. Ecology of Desert Environments. Scientific Publishers, Jodhpur.
7. W.J. Saucier, Principles of Meteorological Analysis, Dover Publications 2012
8. Laity, J. J. (2009). Deserts and desert environments (Vol. 3). John Wiley & Sons.

e-Resources:

World Meteorological Organization, Sand and Dust:
https://library.wmo.int/index.php?&lvl=categ_see&id=11462&main=1&id_thes=2
National Geographic: https://education.nationalgeographic.org/resource/desert

Assignments: Presentation of following topics

1. Atmospheric and surface energy budgets of deserts
2. Surface physics of the unvegetated sandy desert landscape
3. Dynamic interactions among desert microclimates
4. Effects of deserts on the global environment and other regional environments
5. Feedback mechanisms and their role in desert climate
6. Calculation of desertification indicator

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3								
CO3	3	3		3	3				
CO4	3			3			3	2	
CO5	3	3			3		3		3
CO6	3		3	3			3	3	3

Course Title: Computational Fluid Dynamics		Course code: ATS 415
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA):40 End Semester Examination (ESE):60	L-3; T-0; P-0

Course Prerequisite: Numerical Methods, Fluid Mechanics, Computer Programming languages.

Course Description

The primary objective of the course is to teach fundamentals of computational method for solving nonlinear partial differential equations (PDE). The emphasis of the course is to teach CFD techniques for solving incompressible and compressible N-S equation in primitive variables.

Course Objective:

1. To introduce and develop the main approaches and techniques which constitute the basis of numerical fluid mechanics for engineers and applied scientists.
2. To familiarize students with the numerical implementation of these techniques and numerical schemes, so as to provide them with the means to write their own codes and software, and so acquire the knowledge necessary for the skilful utilization of computational fluid dynamics (CFD) packages or other more complex software.
3. To cover a range of modern approaches for numerical and computational fluid dynamics, without entering all these topics in detail, but aiming to provide students with a general knowledge and understanding of the subject, including recommendations for further studies.

Course Outcome/Learning Outcome

1. Understand the role of numerical modelling in the field of fluid flow and heat transfer.
2. Learn about various discretization methods, solution procedures.
3. Describe turbulence modelling to solve flow and heat transfer problems.
3. Learn about modern CFD software for the analysis of complex fluid-flow systems.
4. Improve the students' understanding of the basic principles of fluid mechanics.
5. improve the students research and communication skills
6. Improve Mathematical background for numerical model development.

Course Content

	Hours
Unit-1 Basic equations of Fluid Dynamics: General form of a conservation law; Equation of mass conservation; Conservation law of momentum; Conservation equation of energy.	8
Unit-2 The dynamic levels of approximation. Mathematical nature of PDEs and flow equations. Basic Discretization techniques: Finite Difference Method (FDM); The Finite Volume Method (FVM) and conservative discretization.	8
Unit-3 Analysis and Application of Numerical Schemes: Consistency; Stability; Convergence; Fourier or von Neumann stability analysis; Modified equation;	7

Unit-4 Application of FDM to wave, Heat, Laplace and Burgers equations. Integration method for systems of ODEs: Linear multi-step methods; Predictor-corrector schemes; ADI methods	7
Unit-5 The Runge-Kutta schemes, Numerical solution of the compressible Euler equations: Mathematical formulation of the system of Euler equations; Space-centred schemes;	7
Unit-6 Upwind schemes for the Euler equations – flux vector and flux difference splitting; Shock-tube problem. Numerical solution of the incompressible Navier-Stokes equations: Stream function-vorticity formulation; Primitive variable formulation;	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Pletcher R, Tannehill J and Anderson D: Computational Fluid Mechanics and Heat Transfer 3e, CRC Press, 2012.
2. Versteeg HK and Malalasekera W: An introduction to computational fluid dynamics: The finite volume method 3e, Pearson Education, 2007.
3. Hirsch C: Numerical Computation of Internal and External Flows, Vol.1 (1988) and Vol.2 (1990), John Wiley & Sons.
4. Fergiger JH, Peric M: Computational Methods for Fluid Dynamics 3e, Springer, 2002

Reference:

1. Chung TJ: Computational Fluid Dynamics 2e, Cambridge University Press, 2010.
2. Fletcher CAJ: Computational Techniques for Fluid Dynamics, Vol. 1 and 2, Springer, 1991.
3. Patankar SV: Numerical Heat Transfer and Fluid Flow, Hemisphere, 1980.
4. Anderson JD Jr.: Computational Fluid Dynamics, McGraw-Hill International Edition, 1995.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3	3			3				
CO3		3							
CO4	3								
CO5	3								
CO6	3								

Course Title: Climate Change and Disaster Management		Course code: ATS 416
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic knowledge of meteorology, and data handling and analysis		
Course Description		
Climate change is now well known to increase in disaster numbers and intensities by aggravating hazards and the factors determining vulnerability of environment and society. This course focuses on the concepts, methods, framework, and tools for better disaster management, and strategies for climate mitigation and adaption		
Course Objective:		
1. To provide scientific, technical, and socio-economic knowledge on climate change. 2. To provide knowledge base to link climate change and disasters, risk, vulnerability, their impacts. 3. To enumerate on guidelines and tools for climate change adaptation and disaster risk reduction		
Course Outcome/Learning Outcome		
1. To understand the basic concept of climate change and disaster management. 2. To develop a strong knowledge of climate change impacts and disasters with focus on impacts, preparedness, and mitigation. 3. To appreciate and comprehend approaches and measures of disaster management, preparedness, and response. 4. To explain the guidance, framework, and organization for disaster risk management 5. To enumerate on guidelines and tools for climate change adaptation and disaster risk reduction 6. To describe the climate change mitigation and adaptations strategies		

Course Content

	Hours
Unit-1 Climate Change, Causes of climate Change, Climate Variabilities; Effect of trace gases and aerosols on climate, Radiative forcing, Climate impact on water, agriculture, and health, Socio-economic impact	7
Unit-2 Emissions Projections and Prediction, RCP Scenario, Climate Change Mitigation and Adaptation; Climate Vulnerability; IPCC and UNFCC guidance framework	7
Unit-3 Understanding the Phenomena of Disasters and Hazards; Types of Disaster and Hazard; Climatic extreme events and disasters, Impacts of Natural Disasters-Socio Economic Impacts, Physical and Environmental Impacts;	8

Unit-4 History of disaster management in India, Disaster management phases, Frameworks, guidelines, and organizations for Disaster Risk Reduction-global and India; Resilient, Development, Role of WMO and IMD in disaster management	8
Unit-5 Tools and Methods in Disaster Risk Management; Hazard Assessment; Vulnerability Assessment; Impact Assessment; Risk Assessment; Hazard Mapping, Early warning, and communication	8
Unit-6 Strategies for Disaster Risk Reduction: Preparedness, Mitigation, and Prevention; Emergency response and Crisis Management; Rural & Urban Disaster risk management	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Shaw R and Krishnamurthy RR: Disaster Management: Global Challenges and Local Solutions, Universities Press (India) Pvt. Ltd., 2009.
2. Prizzia Ross: Climate Change and Disaster Management, Sentia Publishing, USA, 2015.
3. Gupta AK, Nair SS, Chatterji S and B-Lux Florian: Disaster Management and Risk Reduction, Narosa Publishing New Delhi, 2013.
4. Gupta AK, Nair SS and Sharma VK: Disaster Risk and Impact Management, Astral Publishing, New Delhi, 2018.
5. Gupta AK, Nair SS: Environmental Extremes - Disaster Risk Management: Addressing Climate Change. NIDM New Delhi, India. 2012.
6. S.K.Singh, S.C. Kundu, Shobha Singh A: Disaster management, William Publications, New Delhi.

Reference Books:

1. Hardy T. John: Climate Change: Causes, Effects, and Solutions, John Willey & Sons Ltd.. 2003
2. R B Singh: Natural Hazards and Disaster Management: Vulnerability And Mitigation, Rawat Publications

e-Resources:

1. https://www.ipcc.ch/report/methodology-report-on-short-lived-climate-forcers/
2. https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/
3. https://www.ipcc.ch/report/sixth-assessment-report-working-group-3/
4. https://www.ipcc.ch/report/ar5/wg1/
5. https://www.ipcc.ch/report/ar5/wg2/
6. https://www.ipcc.ch/report/ar5/wg3/
7. https://ndma.gov.in/
8. https://nidm.gov.in/
9. https://unfccc.int/

Assignments: Presentation of following topics

1. RCP Scenario followed IPCC
2. Emission Inventory under IPCC guidelines
3. Radiative forcing due to short-lived climate forcing

4. Extreme Weather Events
5. Case study of Disaster in India
6. Case study on Climate Change Action Plan in different states of India
7. Vulnerability Assessment

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3					2	1		
CO3	3					1	2		
CO4	3		1			3	2	2	3
CO5	3	3	2			3	3	3	3
CO6	3		1			3	3	3	3

Semester – III

Course Title: Mesoscale Modelling and Extreme Weather Events		**Course code: ATS 501**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 2 hours/ week Lab: 2 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-2; T-0; P-1
Course Prerequisite: Knowledge of Physics and Dynamics of the Atmosphere.		
Course Description		
This course presents techniques and methods that used together, constitute the working components of a modern, operational mesoscale weather forecasting model. Also, this course provides knowledge of important cloud and precipitation forming mesoscale atmospheric systems, as well as the involved dynamical processes. In addition, the course will address the formation and causes of different extreme climate and weather events.		
Course Objective:		
1. To understand and demonstrate knowledge of the structure and formation of atmospheric conditions conducive for their development and movement of the mesoscale phenomena. 2. To provide the exposure of tropical waves and their relationship to organized convection in the tropics and to tropical cyclogenesis. 3. To understand the concept, overview of the structure, formation, and propagation of extreme and severe weather events.		
Course Outcome/Learning Outcome		
7. Demonstrate knowledge of a variety of mesoscale and small-scale atmospheric phenomena, including tropical storms, severe thunderstorms, and tornadoes 8. Learn the different types of mesoscale models and its dynamics 9. Understand the thunderstorm and lightning indices for mesoscale phenomena 10. Understand the structure and formation of extreme weather events 11. Students will demonstrate the implementation the mesoscale models such as Weather research Forecast (WRF) for 1-2 cases of the extreme weather event such as heavy rainfall events, severe thunderstorms, heat, and cold wave etc.		

Course Content

	Hours
Unit-1 Introduction to mesoscale phenomena, Mesoscale processes and modeling, scaling, observations and analysis, wave fundamentals, Lee waves and windstorms.	9
Unit-2 orographically forced flows, orographic precipitation, differential heating, gravity currents and convective initiation, isolated convective storms, MCS -squall lines, internal structure of cyclones, rain bands - observations and theory,	11
Unit-3 Hydrostatic approximation and nonhydrostatic dynamics, different types of	9

atmospheres, Thunder storms – CAPE and CINE, Thunderstorms and lightning indices,	
Unit-4 calculation of Lightning Potential Index, Favorable conditions for severe thunderstorms, influence of vertical wind shear, stability indices, Life cycle and structure of thunderstorm, Dust storm (Andhi), Kalabaisaki, Hail storm.,	11
Unit-5 Overview of WRF, Parameterizations in mesoscale models, Mesoscale instabilities, Overview of hazards: Tropical cyclones, Storm surges	9
Unit-6 Effects of Volcanic ashes on atmosphere, Cloud bursts, Tornadoes, Fog, Drought, Heavy rainfall and Flood forecasting, Land Slides triggered by heavy rainfall, Heat and Cold Waves, Man-made, natural and industrial disasters and warning systems.	11
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

8. Pielke RA: Mesoscale Meteorological Modelling, Academic Press.
9. Atkinson BW: Mesoscale Atmospheric Circulation, Academic Press.
10. Ray PS: Mesoscale Meteorology and Forecasts, American Meteorological Society.

Reference:

1. Vasquez T: Weather Analysis and Forecasting Handbook, Weather Graphics Technology.
2. Burt CC: Extreme Weather: A Guide and Record Book, W W Notron and Company.

e-Resources:

https://www.meted.ucar.edu/education_training/ucourse/77

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3					2	1		
CO3	3					1	2		
CO4	3		1			3	2	2	3
CO5	3	3	3			3	3	3	3
CO6	3		1			3	3	3	3

Course Title: Numerical Weather Prediction- Parameterization Schemes and Data Assimilation		Course code: ATS 502
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 2 hours/ week Lab: 2 hours/week	Continuous Internal Assessment (CIA): 40 End-Semester Examination (ESE): 60	L-2; T-0; P-1

Course Prerequisite: Basic understanding of physical and dynamical processes in atmosphere, modelling of atmospheric processes.

Course Description

The fundamentals of Numerical Weather Prediction (NWP) and Data assimilation, exposure on data acquisition and quality control techniques used for NWP, the concept of atmospheric predictability and ensemble forecasting.

Course Objective:

1. To learn the fundamentals of Numerical Weather Prediction (NWP) and Data assimilation.
2. To provide exposure on data acquisition and quality control techniques used for NWP.
3. To understand the concept of atmospheric predictability and ensemble forecasting.

Course Outcome/Learning Outcome

1. Understand the process of data acquisition, processing, and exchange of global meteorological observations for Weather research and forecasting.
2. Understand the feasibility of using objective analysed field over direct observation in Data assimilation
3. Explain about different physical parameterization scheme used for atmospheric simulation.
4. Identify suitable combination of physical parameterization scheme
5. Understand the difference between deterministic and probabilistic forecasting.
6. Explain about different types of Ensemble forecasting

Course Content

	Hours
Unit-1 Data Acquisition and Quality Control. Observation: in-situ & remote; Objective Analysis methods; Cressman technique, Optimum Interpolation scheme, etc; Implementation of simple weather & climate models and atmospheric processes, Data Quality Control;	9
Unit-2 Data Assimilation: 3D & 4D variational assimilation techniques; Reanalysis and analysis; Weather forecasting; Short, Medium, Extended, and long range; WRF, WPS compilation and library installation	11
Unit-3 Parameterization of Physical processes; Shortwave and Longwave parameterizations, Cumulus/ Convection parameterization, Cloud microphysics parameterization, WRF set-up and run; Compilation,	9

Unit-4 PBL parameterization, Land-surface processes parameterization, Gravity wave drag parameterization, Lightning parameterization; WRF Domain wizards and WRF Utility	11
Unit-5 Atmospheric Predictability, Butterfly effects, Probability and Ensemble Forecasting methods; WRF Modules	9
Unit-6 Perturbation of initial conditions, Multimodal ensemble, Limited Area Models (WRF, MPAS), Climate model evaluation and validation, WRF IDEAL Case	11
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Holton JR: An Introduction to Dynamical Meteorology, Academic Press.
2. Haltiner GJ and Williams RT: Numerical Prediction and Dynamic Meteorology, J. Wiley Pvt. Ltd.
3. Hess SL: Introduction to Theoretical Meteorology, Holt, Rinehart, and Winston, New York.
4. Wallace JM and Hobbs PV: Atmospheric Science -An Introductory Survey, Academic Press.
5. Thompson PD: Numerical Weather Prediction.
6. Randall D: An introduction to Atmospheric Modeling, Colorado State University, 2004
7. Kalna E: Atmospheric modeling, data assimilation, and predictability, Cambridge University Press

Reference:

1.WMO-GARP: Numerical Methods used in Atmospheric Models, Series No.17
2. IPCC report on "Climate Models and Their Evaluation"
3. GUIDELINES ON THE QUALITY CONTROL OF SURFACE CLIMATOLOGICAL DATA; WMO/TD-No. 111
4. Risbey, J.S., Squire, D.T., Black, A.S. et al. Standard assessments of climate forecast skill can be misleading. Nat Commun 12, 4346 (2021). https://doi.org/10.1038/s41467-021-23771-z
5. Alizadeh, O. Advances and challenges in climate modeling. Climatic Change 170, 18 (2022). https://doi.org/10.1007/s10584-021-03298-4
6. Parameterization of sub-grid scale processes WMO-GARP, Series No. 8.

e-Recourses:

- https://www.youtube.com/channel/UCsoB-6khD8q8a0YSNffwFEw
- https://www.youtube.com/channel/UCa6FQzjF25_Ynlv4H_PYzgg

Assignments:

1. Compilation of WRF-ARW model in Ideal Mode and simulation of any one ideal case

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	2					1		
CO2	3	1	1				1		
CO3	3		2		2		1		
CO4	3		2		2		2		
CO5	3						2		
CO6	3								

Course Title: Remote Sensing and GIS for Atmospheric Science		Course code: ATS503
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 2 hours/ week Lab: 2 hours/week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-2; T-0; P-1
Course Prerequisite: Basic knowledge of Meteorology		
Course Description		
The course will provide basic concepts and hand-on-training to students to use remote sensing in the field of atmospheric science and meteorology. It will further focus on various applications of satellite- derived parameters in meteorology. Application of GIS tool will provide additional features to present the various results and outcomes.		
Course Objective:		
1. To provide fundamental understanding about current and future satellite missions and numerical weather forecasting 2. To utilize satellite-based observations to monitor the environment and various meteorological processes/phenomena 3. To impart training on geo-informatics as a technology for integrating meteorology/climatology research and applications for geo-scientific community		
Course Outcome/Learning Outcome		
1. Develop the basic concept and process of remote sensing 2. Understand the various methods to process for analysis and interpretation of satellite images 3. Work on atmospheric and climate data using the remote sensing 4. acquire satellite images and their application in the field of meteorology 5. understand the types of GIS tools and process to prepare different maps for better presentation of results 6. work on GIS tools to present climate and meteorologic information		

Course Content

	Hours
Unit-1 Basics of Remote Sensing; Physics of remote sensing, Satellite datasets and familiarization with open data; Satellite data processing techniques, Aerial Photography and Photogrammetry, Global Positioning System, Image Interpretation	11
Unit-2 Image analysis and interpretations; radiometric and geometric corrections; supervised and unsupervised classification, NDVI calculation, preparation of landuse map, kappa coefficient, surface temperature estimation	9
Unit-3 Parameter Retrieval - Atmospheric, Land and Ocean; Application of Satellite - derived parameters in Meteorology	11

Unit-4 Application of satellite meteorological datasets - Rainfall variability, Air-Sea interaction, Extremes of Temperature and Precipitation	9
Unit-5 Introduction to raster vector data; digitization; Coordinate Systems and Map Projection; Georeferencing tools (Dissolve, union, merge, clip, buffer), spatial analysis	11
Unit-6 Working with multidimensional data, Interpolation techniques, Geoprocessing tool; Model builder tool, Application to climate data and analysis in GIS software	9
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Kelkar, R. R. (2007). Satellite meteorology. BS Publications.
2. Chuvieco, E. (2016). Fundamentals of satellite remote sensing: An environmental approach. CRC press.
3. Kidder, S. Q., & Haar, T. H. V. (1995). Satellite meteorology: an introduction. Gulf Professional Publishing.
4. Purkis, S. J., & Klemas, V. V. (2011). Remote sensing and global environmental change. John Wiley & Sons.
5. Doviak, R. J. (2006). Doppler radar and weather observations. Courier Corporation.
6. Rao, P. K., Holmes, S. J., Anderson, R. K., Winston, J. S., & Lehr, P. E. (1990). Weather satellites: Systems, data, and environmental applications.

e-Recourses:

1. E-PgPathshala, Progress in Climatology: Satellite Climatology and GIS, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=KwH6LnSyFhsLI6M9Z0+tvw==
2. E-PgPathshala, Radar and Satellite Meteorology, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=0Xvq9yUM2ILDrJ07FvlArQ==
3. E-PgPathshala, Remote Sensing and GIS, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=8zYwEsyFCoiPyJlPmzHDxg==

Assignments:

1. Identify Landsat scene(s) for your study area and use the USGS' Glovis website to select and download the data file(s).
2. Convert Landsat files raw digital numbers to radiance and reflectance measurements.
3. perform a supervised and unsupervised classification on a multi-band scene
4. To work on parameter retrieval
5. To work on various GIS tools and concepts: adding data, symbolizing features navigation tools, data view, layout view, layer properties, identify tool, measurement tool, vector data, raster data,
6. To read coordinate system information, define a coordinate system when one is not present, and re-project your GIS data to a new projection.
7. To create point files, digitize the shapefiles, and perform geoprocessing operations

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3	3							
CO3	3		3		3		3	2	2
CO4	3								
CO5	3	3						2	2
CO6	3	3	3		3		3	2	2

Course Title: Internship		Course code: ATS 504
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Project based skill enhancement course	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	3

Course Description

In this course, the students are expected to work in some research topic offered by an organization (Academic or research Institute) for one to one-and-half month. In this process, the students are expected to get hands on training through research. An internship experience provides the student with an opportunity to explore career interests while applying knowledge and skills learned in the classroom in a work setting. The experience also helps students gain a clearer sense of what they still need to learn and provides an opportunity to build professional networks.

Course Objective:

1. To get exposure and hands on practice of various tools, techniques, instruments available in other reputed institutes
2. To provide opportunity to interact with experts, resource person outside classroom
3. To have a wider exposure of the field and developing their understanding about different aspects of Atmospheric Science.
4. For communicating a practical understanding of Atmospheric Science.

Course Outcome/Learning Outcome

1. Learn about different tools used for the weather and climate analysis
2. Learn and get hands on with different meteorological instruments or computations
3. Correlate classroom learning with real time application
4. Develop skill of writing and demonstrating
5. Learn about different research activities in different renowned institute of Earth Sciences
6. Develop practical based skill in atmospheric Science

Assessment Method: Each student will submit his/her internship report. Evaluation will be based on report submission and presentation in the department based on their visit to respective laboratories/institutions/industry.

Guideline: Each student must submit a complete report and completion certificate from concern guide of respective institute/University. For Report writing student may follow Dissertation-I and Dissertation-II guidelines.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3					2	1		
CO3	3					1	2		
CO4	3		1			3	2	2	3
CO5	3	3	3			3	3	3	3
CO6	3		1			3	3	3	3

Department Elective Courses
Semester -III

Course: Cloud Physics and Dynamics		**Course code: ATS 505**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End-Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Atmospheric Physics and Thermodynamics		
Course Description		
This course provides a foundation and an overview of the physics and dynamics of clouds as typically found in the atmosphere. It will start with a short introduction to clouds and precipitation and a review of basic thermodynamics. The primary emphasis is placed on microphysical properties of clouds because this ultimately determines the evolution of clouds.		
Course Objective:		
7. To develop an understanding of clouds and precipitation from the macroscale to the microscale. 8. To study of microphysical properties of clouds including the formation, growth, and thermodynamic interactions of cloud and precipitation particles. 9. Applications of the cloud physics framework for modern research and cloud microphysics parameterization in numerical models and cloud electrification.		
Course Outcome/Learning Outcome		
1. Understand fundamental theory of cloud formation 2. Memorize the structure and feature associated with different cloud types 3. Demonstrate theoretical and applied topics of cloud and precipitation physics. 4. Compare and contrast microphysical processes operating in a given cloud/environment. 5. Explain the difference between ice and liquid processes in cloud. 6. Understand the mechanism of atmospheric electrical processes.		

Course Content

	Hours
Unit-1 Introduction: Classification of clouds, Cloud time scales, vertical velocities, and liquid water contents, Thermodynamic Variables: Various forms of potential temperature, Dry and moist static energy etc.,	8
Unit-2 Theories of entrainment, detrainment, and downdraft initiation in cumuli, The role of precipitation, Cloud merger and larger scale convergence, Updrafts and turbulence in cumulonimbus	7
Unit-3 Nucleation and Growth of Cloud Droplets – Homogeneous and Heterogeneous Nucleation on Soluble Surfaces, Kohler Curves, Condensation, Fick's law of diffusion,	7

Unit-4 Energy balance at drop surface, Complete diffusional growth equation, Evaporation of drops, Impacts on DSDs, Supersaturation, Warm Rain Formation, Collision – coalescence, Ice Crystal Nucleation and Growth,	7
Unit-5 Homogeneous nucleation of ice by freezing and deposition, Heterogeneous nucleation of ice on flat and curved surfaces, Ice Particle Growth: Growth mechanisms, Deposition, Capacitance, Habit theory, Fall speeds, Aggregation, Riming	8
Unit-6 Ice multiplication, Graupel and Hail Formation: Hail growth models, Melting, Atmospheric Electricity: Principles of atmospheric electricity, Charge generation mechanisms, Cloud electrification mechanism.	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Rogers RR and Yau Y: A Short Course in Cloud Physics, Pergamon Press, 3rd Edition, 1989.
2. Pruppacher and Klett: Microphysics of Clouds and Precipitation, Kluwer Academic Publishers, 1997.
3. 3. Houze RA: Cloud Dynamics, Academic Press.
4. Cotton WR and Anthes RA: Storm and Cloud Dynamics, Academic Press.

Reference:

1. Cotton WR, Bryan GH, and van den Heever SC, 2011: Storm and Cloud Dynamics, 2nd Edition. Academic Press.
2. Emanuel KA: Atmospheric Convection, Academic Press.
3. Ludlam FH: Clouds and Storms.
4. Lohmann, Luond and Mahrt: An Introduction to Clouds from the Microscale to Climate, Cambridge University Press, 2016.

e-Resources:

Cloud physics lecture series, IITM, Pune

- https://www.youtube.com/watch?v=d6NMtNgu6Dw
- https://www.youtube.com/watch?v=TNpMZPyCJSc
- https://www.youtube.com/watch?v=RPvY_yWl_g4

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		3		3		2		
CO2	3		3		3	2	2		
CO3	3		3		3	2	3		
CO4	3		3		3				
CO5	3		3		3	2	2		
CO6	3		3		3	2	2		

Course Title: HPC applications in Atmospheric Sciences		Course code: ATS 506
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of atmospheric science, computer application and UNIX/Linux operating system.		
Course Description		
Introductory course on High Performance Computing Systems, providing a solid foundation in parallel computer architectures, cluster operating systems, and resource management. This course will discuss fundamentals of what an HPC consists of, and how we can take advantage of such systems to solve large scale problems in weather and climate using different types of weather and climate models.		
Course Objective:		
1. To provide the overview of different types of parallel computing used for weather/climate studies. 2. To teach the basics of high-performance computing. 3. To understand how weather and climate models are applied to solving problems in atmospheric sciences with high performance computing. 4. To provide a phenomenological approach to understand the parallelization of weather/climate models in high performance computing architecture.		
Course Outcome/Learning Outcome		
1. Understand the basics of high-performance computing for weather and climate science 2. The students should be able to understand an overview of parallel computing and their architecture. 3. Understand the different types of Parallelization method 4. Explain the use of different types of data used in parallel architecture. 5. The students will be able to run the GCMs and RCMs on a parallel system. 6. Develop knowledge about hardware and specifications of HPC		

Course Content

	Hours
Unit-1 Introduction to multitasking and massively parallel processing, Basic parallel computing, Von Neumann Computer Architecture,	7
Unit-2 Flynn's Classical Taxonomy, Shared Memory, Distributed Memory, Hybrid Distributed-Shared Memory, General Parallel Terminology, different architectures	8
Unit-3 Application of HPC in global and regional models, parallelism in weather and climate models, domain decomposition method, 1D, 2D and 3D parallelization of GCMs, Message Passing Interface, PVM, SHMEM, message passing libraries	8

Unit-4 1D, 2D and 3D parallelization of GCMs, Message Passing Interface, PVM, SHMEM, message passing libraries	7
Unit-5 high performance compilers, load balancing, inter-processor, communication, network communication, graphical user interface, data formats, local and wide area networking. Compilation of mesoscale and global models in parallel architecture.	8
Unit-6 data formats, local and wide area networking. Compilation of mesoscale and global models in parallel architecture.	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

5. Røed Lars P: Atmospheres and Oceans on Computers-Fundamentals.
6. Yang LT and Guo M: High-Performance Computing: Paradigm and Infrastructure.
7. John Levesque and Gene Wagenbreth, High Performance Computing: Programming and Applications (Chapman & Hall/CRC Computational Science)

Reference:

1. Levesque J and Wagenbreth G: High Performance Computing: Programming and Applications, Chapman and Hall CRC.
2. High Performance Computing in Science and Engineering, Transactions of the High-Performance Computing Center, Stuttgart (HLRS) 2017, Editors: Nagel, Wolfgang E., Kröner, Dietmar H., Resch, Michael M.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3					2	1		
CO3	3					1	2		
CO4	3		1			3	2	2	3
CO5	3	3	3			3	3	3	3
CO6	3		1			3	3	3	3

Course Title: Boundary Layer Meteorology		Course code: ATS 507
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Bachelor level Physics, mathematics and dynamics meteorology		
Course Description		
This course explains how the earth and the atmosphere interact and how this interaction affects the atmospheric boundary layer. This course will discuss in detail about the different layer of the boundary layer of atmosphere and ocean. Also, how the boundary layer is changing spatially and evolving temporally is discussed in this course. The turbulence structure and the flux of energy in the atmospheric boundary layer by using theoretical and experimental results is discussed		
Course Objective:		
1. To provide a framework for understanding the basic physical processes that govern mass and heat transfer in the atmospheric boundary layer and the vegetated land surface. 2. To understand and describe fundamental turbulent processes in the atmospheric boundary layer over a diurnal cycle. 3. To understand the evolution of the boundary layer on a daily basis. 4. To understand the concept of turbulence and its concepts.		
Course Outcome/Learning Outcome		
1. Understand fundamental process of planetary boundary layer (PBL) 2. Explain the mechanism of microscale processes 3. Compare the evolution processes of boundary layers development over land and ocean 4. Explain about sources and mechanisms driving turbulence in atmosphere 5. Understand the evolution of diurnal and spatial feature of PBL 6. Identify the change in PBL associated with weather events.		

Course Content

	Hours
Unit-1 Introduction to the boundary layer and its significance, wind and flow, definition and qualitative description of temporal evolution and vertical structure; Virtual Potential Temperature,	8
Unit-2 Atmospheric turbulence, Boussinesq approximation, Prognostic equations for turbulent fluxes and variances; surface layer, zero plane displacement and roughness length	7
Unit-3 TKE equation, static and dynamic instability, Reynold’s number, Richardson number, Obukhov length, stability parameter relationships,	7

Unit-4 Closure problem in turbulent flow, first-order local closure; momentum, energy and moisture budgets, fluxes at surface and entrainment zone, drag and Bowen ratio methods	8
Unit-5 Similarity Theory, Buckingham Pi method, applications to wind profiles; Stable and convective mixed layer phenomena including nocturnal jets, thermals,	7
Unit-6 dust devils; boundary layer clouds, fair-weather cumulus, fog; geographically generated local circulations like slope and valley winds, sea/lake breeze, geographically modified flow, fetch, internal boundary layer.	8
Internal Assessment	
CIA-1: Unit-1, 2	
CIA-2: Unit-3 ,4	
ESE: All Units	

Textbooks:

1. Stull RB: An introduction to boundary layer meteorology, Kluwer Academic Publishers.
2. Arya S Pal: Introduction to Micrometeorology, Academic Press
3. Stull RB: Meteorology for scientists and Engineers, Brooks/Cole Thomson Learning.

Reference:

1. Foken T and Napo CJ: Micrometeorology, Springer.
2. Kaimal JC and Finnigan JJ: Atmospheric Boundary Layer Flows, Oxford University Press, New York/Oxford, 1994.

e-Resources:

https://www.youtube.com/watch?v=DNJMCQX6ZrI&list=PLBPoOsxO35OpgAePGXQTTkfbH63Fh6gF2
https://www.youtube.com/watch?v=JCuZHCwa6W0
https://www.atmos.albany.edu/daes/atmclasses/atm505/content_2022/module_2/Stull_chapter1.pdf
http://home.iitk.ac.in/~sghorai/NOTES/benard/node3.html

Assignment:

Presentation on following topics:

Sability parameter relationships
Boussinesq approximation
Obukhov length
Similarity Theory
Bowen ratio methods

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3								
CO3	3		3	2	2	1	3	2	
CO4	3		3	2	2	1	3	2	
CO5	3	2	2	2	1	3	2	2	2
CO6	3	1	2		1	2	3	1	3

Course Title: Air Quality Modelling and Management		Course code: ATS 508
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic knowledge of mathematics, atmospheric chemistry, and air pollution		
Course Description		
This course is aimed to give students a basic understanding of air quality modelling and management so that they can take on leadership roles in both outdoor and indoor air pollution. The current air pollution issues are the result of a convergence of scientific, human, ecological, social, economic, political, legal, and medical disciplines. This course helps students understand the nature and parameters of Indian air emission and air quality. Air quality modelling and management strategies to educate the public about real-world issues caused by air pollution, broadening their perspectives and horizons.		
Course Objective:		
1. To develop an understanding air pollution sources, transport, and receptor systems 2. Understanding of air pollution measurement technique, sources, and its impact on climate, and health. 3. Knowledge of the air quality modelling and meteorological influence on air pollution sources, 4. Learning of regulation bodies, policy makers, and their role in air quality management		
Course Outcome/Learning Outcome		
1. Understand the fundamentals of air pollution, including its sources and the effects on climate, health, and the environment. 2. Learning meteorology and stability conditions for air pollution dispersion modelling 3. Understanding of the measurement of ambient air and indoor air quality, as well as chemical composition and analysis 4. Apply and compare the importance of different air quality modelling. 5. Recognizing the relationships between local and transboundary sources of air pollution and meteorological parameters 6. Understanding source apportionment and emission inventories to identify air pollution sources		

Course Content

	Hours
Unit-1 Introduction to air pollution, types of air pollutants, sources & classification of air pollutants and air pollution effects, wind-rose, lapse rate and atmospheric stability, plume behaviour	7
Unit-2 Basic understanding of chemical and physical processes of pollutants, dispersion of air pollutants and Gaussian plume models: point, line and area source models, demonstration of AERMOD software	8

Unit-3 Ambient air quality monitoring techniques, Selection of monitoring locations, data analysis, Air quality index (AQI), Particulate matter, and its physical, optical, and chemical compositions,	8
Unit-4 Air quality receptor modelling techniques: UNMIX, PMF, CMB, identification of local and regional sources Air pollution forecast models: WRF-Chem, application of remote sensing/satellite-based data for air quality prediction	8
Unit-5 Emission inventory: emission sources, emission factors, activity data of different type of air pollution sources, compilation of emission load, basic consideration of emissions inventory development	7
Unit-6 Air quality standards, rules and regulations, Development of air quality management Programme, Clean air action plan, role of stakeholders, role of policy makers, guidance framework to reduce air pollution from transport, biomass bruning, and dust	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. De N.N. (2000) Air Pollution Control Engineering, McGraw-Hill International Edition.
2. Gammage R.B. and Berven B.A. (1996) Indoor Air Pollution and Health, Eds. 2nd, Lewis Publishers.
3. Godish T. (2004) Air Quality, Lewis Publishers, New York.
4. Griffin R.D. (2007) Air Quality Management, Taylor & Francis Publication.
5. Lutgens F.K. and Tarbuck E.J. (1996) The Atmosphere an Introduction to Meteorology, Printice Hall Publisher, New Jersey.
6. Stern A.C. (editor) (1976) Air Pollution (Vol. I-VIII), Academic Press, New York.
7. Turner D.B. (1994) Workbook of Atmospheric Dispersion Estimates, 2nd ed., Ann Arbor, MI, Lewis Publishers
8. Boubel, R.W., Fox, D.L., Turner, D.B., Stern, A.C., “Fundamentals of Air Pollution”, Academic Press. 2005.
9. Lodge, J.P. (Ed.), “Methods of Air Sampling and Analysis”, CRC Press. 1988

Reference Books:

1. Buonicore A.J. and Davis W.T. (1994) Air Pollution Engineering Manual, Air and Waste Management Association, New York, Van Nostrand Reinhold.
2. Lodge J.P. (Ed.) (1988) Methods of Air Sampling and Analysis, Lewis Publishers, Inc., Michigan.
3. Lutgens F.K. and Tarbuck E.J. (1998) The Atmosphere, Prentice Hall, New Jersey.
4. Perkins H.C. (1974) Air Pollution, McGraw-Hill, International Student Edition.
5. Rao C.S. (1991) Environmental Pollution Control Engineering, New Age International (P) Ltd., Publishers, New Delhi.
6. Seinfield J.H. and Pandis S.N. (1998) Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley, New York..

e-Recourses:

1. https://onlinecourses.nptel.ac.in/noc22_ce22/preview
2. https://airknowledge.gov/MODL-SI.html
3. https://www.sei.org/publications/foundation-course-air-quality-management-asia/

4. https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod
5. https://www.epa.gov/scram/air-pollutant-receptor-modeling

Assignments: Presentation of following topics

1. Air Quality monitoring network
2. CAAQMs data and trend analysis
3. PM and it's chemical constituents' data matrix
4. Air Quality dispersion modeling
5. Source apportionment modeling
6. Satellite-based data and predict air quality using machine learning
7. Development of emission inventory

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3	3							
CO3	3			3	3			2	
CO4	3		3		2	3	2	2	3
CO5	3	3	2		2	2	2	2	
CO6	3	3	3		3	3	3	2	3

Course Title: Upper and Middle Atmosphere		Course code: ATS 510
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End-Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Dynamic Meteorology.		
Course Description		
This course includes physical processes that occur in upper and middle atmosphere and describe that interaction of upper and middle atmosphere with troposphere through vertical transport of heat, energy, and momentum. This course also includes detail guide for aviation sector regarding meteorology aspect as well as describe aviation Hazards		
Course Objective:		
1. To develop knowledge about upper and middle atmosphere dynamics. 2. To provide an understanding about the role of upper and middle atmosphere. 3. To develop knowledge about meteorological condition that is important for aviation purpose.		
Course Outcome/Learning Outcome		
1. Understand an overview of middle and upper atmosphere dynamics. 2. Understand the interaction of middle and Upper atmosphere with troposphere. 3. Explain vertical transport of mass and momentum. 4. Understand the exchange of tracer between lower and middle atmosphere 5. Interpret the distributive change in ozone in middle atmosphere 6. Understand the effect of middle atmosphere towards large scale systems.		

Course Content

	Hours
Unit-1 Composition and structure of stratosphere, mesosphere and thermosphere, Changes in chemical composition- homosphere, heterosphere, ozonosphere.	8
Unit-2 Standard upper atmosphere structure. The ionosphere – composition morphology and general properties, ionospheric layers and functions, diurnal, seasonal variation	7
Unit-2 General climatology of the middle atmosphere, wind, and temperature distribution. Zonally averaged circulation energetics of the middle atmosphere.	8
Vertically Propagating Waves: Extratropical Rossby waves and Charney-Drazin criterion, Equatorial Waves and Gravity waves; Sudden Stratospheric Warming, Rossby, wave Breaking,	8
Unit-5 Large Scale Mixing and Transport, Brewer–Dobson Circulation, Residual (Diabatic) Circulation	7

<u>Unit-6</u> Tropical Tropopause layer, tropopause dynamics, Quasi–Biennial Oscillation (QBO), Stratosphere-troposphere coupling.	7
<u>Internal Assessment</u>	
CIA-1: Unit-1.2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

11. Andrews D, Holton J, Leovy C: Middle Atmosphere Dynamics, Academic Press, 1987.
12. Vallis GK : Atmospheric and Oceanic Fluid Dynamics, Cambridge University Press, 2006.
13. Brasseur GP and Solomon S: Springer Aeronomy of the Middle Atmosphere – Chemistry and Physics of the Stratosphere and Mesosphere, 2005.
14. An Introduction to Dynamic Meteorology by J. R. Holton

Reference:

1. Labitzke KG and van Loon H: The Stratosphere – Phenomena, History, Relevance, Springer, 1999.
2. Festschrift P: The Stratosphere: Dynamics, Transport, and Chemistry, Eds. Polvani, Sobel, Waugh AGU Monograph 190, 2010.

e-Resources:

- https://www.youtube.com/watch?v=B31I_4mz6XM
- https://www.youtube.com/watch?v=R9lxRnEMHw0
- https://www.youtube.com/watch?v=RRxqylbTAmE

Assignments:

Problems from Chapter 12 of An Introduction to Dynamic Meteorology by J. R. Holton

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3				2		2		
CO2	3				2		2		
CO3	3				2		2		
CO4	3				2		2		
CO5	3				2		2		
CO6	3				2		2		

Semester – IV

Course: Dissertation -II		**Course code: ATS 510**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Project based skill enhancement course	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	15

Course Description

Each student will work for M. Sc. Project under the supervision of formally assigned supervisor in the department for 4 to 5 months. Student shall complete the process of academic interaction to obtain teachers consent to supervise his/her project work by the end of third semester. In this project, a research problem will be framed through literature review to develop student's skill in conducting research. In this course, students are advised to do the problem related to real application to common people with the help of state-of-the-art weather and climate models. Students must write and submit their research work in the form of dissertation based on their assigned work at the end of semester

Course Objective:

1. To develop research skill through real application of weather and climate processes.
2. To develop scientific demonstration and writing skill
3. To develop the skill of scientific communication for a practical understanding of Atmospheric Science.

Course Outcome/Learning Outcome

1 Develop an understanding of the fundamentals of research review writing
2. Develop demonstration skill
3. Able to use tools related to research articles
4. Able to understand the pattern of scientific writing
5. Able to identify real existing problem and exposure to problem-based learning
6. Students might publish his/her thesis work in national/internationally reputed journals.

Dissertation-II Guidelines

1. GENERAL:

The manual is intended to provide broad guidelines to the M.Sc. students in the preparation of the dissertation report. In general, the project report shall organize in scholarly fashion and describe briefly and neatly the research work of the student leading to the discovery of new facts or techniques or correlation of facts already known.

2. NUMBER OF COPIES TO BE SUBMITTED:

Students should prepare **three hardcopies** of Dissertation report and each copy should be signed by the Head of the Department and concerned Supervisor. One copy of Dissertation report must submit to concern supervisor and another to Head of the Department on the day of exam and one signed copy should keep with the student. Softcopy of Dissertation report must submit to concern supervisor with a copy to the Head of the Department a day before of final exam.

3. CONTENTS OF DISSERTATION:

Dissertation material should be arranged as follows:

1. Cover Page Title page
2. Declaration

3. Certificate
4. Abstract (English)
5. Acknowledgements
6. Table of Contents
7. List of Tables
8. List of Figures
9. List of Symbols, Abbreviations and Nomenclature (Optional)
10. Chapters
11. References
12. Appendices
13. One page CV
The Tables and Figures shall be introduced in the appropriate places.

4. MANUSCRIPT PREPARATION:
The dimensions of the dissertation should be standard A4 size paper may be used for preparing the copies, standard margin with **1.5 line spacing**, "**Times New Roman**" should be used as font. Font Size of different elements should be as follow

- Text - 12
- Heading – 14
- Figure/Table caption -10 with Italic.

Cover Page & Title Page - A specimen copy of the Cover page & Title page for report/thesis are given in Annexure I.
Declaration - A declaration given by student has been shown in Annexure II
Certificate-The Certificate as per the format shown in Annexure III
Abstract: Abstract should not exceed 500 words outlining the research problem, the methodology used for tackling it and a summary of the findings, typed in 1.5 line spacing.
Acknowledgements: The acknowledgements shall be brief and should not exceed one page. The student's signature shall be made at the right bottom above his / her name typed in capitals.
Table of contents - The table of contents should list all material following it as well as any material which precedes it. The title page, Certificate and Acknowledgement will not find a place among the items listed in the Table of Contents but the page numbers in lower case Roman letters are to be accounted for. One and a half spacing should be adopted for typing the matter ender this head.
A specimen copy of the Table of Contents for report / thesis is given in Annexure IV.
List of Table-The list should use the same captions as they appear above the tables in the text.
List of Figures - The list should use the same captions as they appear below the figures in the text
List of Symbols, Abbreviations and Nomenclature - One and a half spacing should be adopted for typing the matter under this head. Standard symbols, abbreviations etc. should be used.
Chapters (tentative) - The chapters may include

- Chapter I – Introduction
- Chapter II - Literature Review
- Chapter III –Data and Methodology
- Chapter IV- Results and Discussion
- Chapter V – Conclusion
- Chapter VI – Future Scope and Learning

Research output/outcome if any published or presented in conference/seminar/symposium may be included.
Citation Style: Any works of other researchers, if used either directly or indirectly, should be indicated as reference at appropriate places in the report/thesis. Each reference Mentioned under References should cite properly in text.
Articles having more than two authors: (*First author* et al.,.)
Articles having two authors: (*author 1* and *author 2* ….)
Articles having one author: (author ….)
Author name should be written as follow: <Surname> <Initials of first name>

List of References - The citation may assume any one of the following forms provided a single dissertation report should have uniform reference style. Reference list entries should be alphabetized by the last names of the first author of each work.

If available, please always include DOIs as full DOI links in your reference list (e.g. "https://doi.org/abc"). Different types of articles (Journal articles, Articles by DOI, Book, Book Chapter, Online content, Dissertation) need to have proper reference style. Examples are given below.

Journal article

Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 105:731-738. https://doi.org/10.1007/s00421-008-0955-8

Ideally, the names of all authors should be provided, but the usage of "et al" in long author lists will also be accepted:

- *Smith J, Jones M Jr, Houghton L et al (1999) Future of health insurance. N Engl J Med 965:325–329*
- ***Article by DOI***
- *Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med. https://doi.org/10.1007/s001090000086*
- ***Book***
- *South J, Blass B (2001) The future of modern genomics. Blackwell, London*
- ***Book chapter***
- *Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230-257*
- ***Online document***
- *Cartwright J (2007) Big stars have weather too. IOP Publishing Physics Web. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007*
- ***Dissertation***
- *Trent JW (1975) Experimental acute renal failure. Dissertation, University of California*

A student can follow any reference style from any standard and recognized (SCOPUS, UGC Care, Web of Science) journals

Tables and Figures: Tables and Figure should be given after Reference section. Tables are attached first followed by figures. Each Table and figure should be labelled as per chapter in which it has been cited.

5. BINDING SPECIFICATIONS

Thesis should be hard cover book bound, the cover of thesis should be of light blue colour, printed with black ink and the text for printing should be identical as prescribed for the title page.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3						1		
CO2	3					2	1		
CO3	3					1	2		
CO4	3		1			3	2	2	3
CO5	3	3	3			3	3	3	3
CO6	3		1			3	3	3	3

Departmental Elective Courses
Semester – IV

Course: Climate Change and Crop Modelling		**Course code: ATS 511**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic knowledge of meteorology and data handling		
Course Description		
This course will provide better understanding of various process of climate change and agriculture. Course will enhance capacity of students to work on crop model in climate change scenarios by understanding the crop growth and yield tools.		
Course Objective:		
1. To introduce students with foundations related to climate change and agriculture. 2. To enhance skills to measure and prediction of climate variables and impact on crop yield 3. To provide understanding of how to use crop models for better crop production and food security.		
Course Outcome/Learning Outcome		
1. Understand the various process related to climate change 2. Develop the various concept of agrometeorology 3. Able to link the various factors and linkage between meteorology and agriculture 4. Demonstrate the linkage between climate, evapotranspiration, and crop productivity 5. Basic understanding of available crop models and key processes involved in crop growth model 6. Learn how to work on crop model simulation under climate change scenarios		

Course Content

	Hours
Unit-1 Description of the climate system, Feedbacks in the climate system, Emissions Projections, Introduction to link climate change and its impact on agriculture and food security; Agrometeorology	8
Unit-2 Elements and factors of weather and climate; Agrometeorological Observatory; Meteorological factors in photosynthesis; Role of CO_2 concentration and turbulence in photosynthesis.	7

Unit-3 Concept of Growing Degree Days, Soil-Plant-Atmosphere Continuum; Soil water dynamics and crop responses; Evapotranspiration - different methods of estimation of evapotranspiration, Penman Monteith, use of ET0 calculator	7
Unit-4 Radiation balance; Moisture Availability Index (MAI) and classification; Climate effect on crop water requirement and water productivity	7
Unit-5 Overview of cropping systems models; Experiments and data requirements in application of crop models; various source of free data for crop modelling,	8
Unit-6 parameterization and validation of simulation models; Analysis of crop model results, Analyze risks and uncertainties, impact of climate change on agriculture	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Mavi, H. S., & Tupper, G. J. (2004). Agrometeorology: principles and applications of climate studies in agriculture. CRC Press.
2. Stigter, K. (Ed.). (2010). Applied agrometeorology (p. xxxviii). HeidelbergVerlag Berlin: Springer.
3. Seemann, J., Chirkov, Y. I., Lomas, J., & Primault, B. (2012). Agrometeorology. Springer Science & Business Media.
4. Wallach, D., Makowski, D., Jones, J. W., & Brun, F. (2006). Working with dynamic crop models: evaluation, analysis, parameterization, and applications. Elsevier.
5. Prasada, G. S. L. H. V., Rao, V. U. M., & Rao, G. G. S. N. (2010). Climate change and agriculture over India. PHI Learning Pvt. Ltd..
6. White, J. W. (2009). Crop modeling and decision support. W. Cao, & E. Wang (Eds.). Tsinghua University Press.
7. Lobell, D. B., & Burke, M. (Eds.). (2009). Climate change and food security: adapting agriculture to a warmer world (Vol. 37). Springer Science & Business Media.
8. Yadav, S. S., Redden, R. J., Hatfield, J. L., Ebert, A. W., & Hunter, D. (Eds.). (2019). Food security and climate change. John Wiley & Sons.

Reference:
Le Corum Conference Centre- Montpellier, France, February 3-5, 2020, Crop Modelling for the Future, https://www.alphavisa.com/icropm/2020/documents/iCROPM2020-Book-of-Abstracts.pdf
e-Recourses:
E-PgPathshala, Agrometeorology, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=0Xvq9yUM2ILDrJ07FvlArQ==

Assignments:

1. Overview and application of Crop Simulation Models in Agriculture
2. Crop models and crop weather relationship
3. Crop Models - Input files, Experimental, Weather file, etc.
4. Assessing crop growth and yield using crop simulation models
5. Climate scenario data use methods
6. Simulating climate change impacts, simulating adaptation strategies and interpretation

CO-PO Mapping

COs	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**
CO1	3								
CO2	3								
CO3	3	3		3	3				
CO4	3						2	2	
CO5	3	3			3		2		
CO6	3		3	3			2	3	3

Course Title : Hydrometeorology		Course code: ATS 512
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Knowledge of meteorology and data handling		
Course Description		
This course is developed to provide better understanding of processes and phenomena related to hydrometeorology and it's concerned with hydrologic problems. It will also provide overview of linkage between hydrometeorology and human society considering the climate change scenarios.		
Course Objective:		
1. To introduce students with foundations related to precipitation, meteorology, and hydrology 2. To enhance skills to measure and prediction of precipitation and streamflow 3. To provide understanding of how multiscale hydrometeorological processes affect humans and the environment.		
Course Outcome/Learning Outcome		
1. Improve the understanding of water balance components and linkage with meterology 2. Able to describe general hydrometeorological processes 3. Develop the concept of groundwater flow and how to link with hydrometeorology 4. Learn about the methods and instruments used for flow measurement 5. Understanding of processes related to hydrometeorological hazards 6. Exposure to various adaptation and mitigation measure to handle the extreme events related to hydrometeorology		

Course Content

	Hours
Unit-1 Hydrologic cycle; Relationship between hydrology, meteorology, and climatology; Movement of water in all three phases; Importance of study of hydrometeorology;	7
Unit-2 Characteristics of precipitation; Extreme precipitation processes; Drought; Floods; Precipitation and Evapotranspiration measurements (In-situ and remote sensing techniques)	7
Unit-3 Stream and groundwater flows; Geomorphological modelling, flood forecasting and flood plain mapping, glacier melt, Snow hydrology	7
Unit-4 Instruments to measure stream flow and water levels, Human and Environment dimensions of hydrometeorology.	8

Unit-5 Weather and hydrologic hazards; Vulnerability assessment, mapping, Resilience of communities to hydrometeorological hazards	8
Unit-6 Climate change impacts on hydrometeorology; Adaptation and Mitigation measures, Demonstration tool to work on hydrology and climate change studies	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Rakhecha, P., & Singh, V. P. (2009). Applied hydrometeorology. Springer Science & Business Media.
2. Collier, C. G. (2016). Hydrometeorology. John Wiley & Sons.
3. Lakshmi, V., Albertson, J., & Schaake, J. (2001). Land surface hydrology, meteorology, and climate. American geophysical union.
4. Karamouz, M., Nazif, S., & Falahi, M. (2012). Hydrology and hydroclimatology: principles and applications. CRC Press.
5. Shelton, M. L. (2009). Hydroclimatology: perspectives and applications. Cambridge University Press.
6. Eslamian, S. (Ed.). (2014). Handbook of engineering hydrology: modeling, climate change, and variability. CRC Press.
7. Ward AD and Elliot WJ: Environmental Hydrology, CRC-Lewis Press, 1995.
8. Bruise JR and Clark RH: Introduction to Hydrometeorology.
9. Viessman WJ and Lewis GL: Introduction to Hydrology (5th ed.), Prentice Hall.
10. Srivastava, R., and, Jain, A. (2017). Engineering Hydrology, McGraw Hill Education.
11. Subramanya, K. (2013). Engineering Hydrology, 4th Edition, Tata McGraw Hill Education (India) Pvt. Ltd., New Delhi, India
12. Singh V., P. (1992). Elementary Hydrology, Prentice Hall.
13. Chow, V., T., Maidment, D. R., and, May, L., W. (1988). Applied hydrology, McGraw Hill, Singapore

e-Recourses:

1. Fondriest Environmental Learning Center https://www.fondriest.com/environmental-measurements/measurements/hydrological-measurements/streamflow-measurements/
2. World Meteorological Organization, Hydrology, https://library.wmo.int/index.php?lvl=categ_see&id=10059&page=34&nbr_lignes=509&l_typdoc=
3. E-PgPathshala, Hydrometeorology, https://epgp.inflibnet.ac.in/Home/ViewSubject?catid=0Xvq9yUM2ILDrJ07FvlArQ==
4. Hydrological Measurements and Analysis of Data https://nptel.ac.in/courses/105107129

Assignments:

1. Hydrometeorology: Review of Past, Present and Future Observation Methods.
2. Rainfall data Analysis
3. Computation methods for measuring Evapotranspiration
4. Extreme Events and Indices

5. Rainfall-Runoff relationships
6. Application of Darcy's law
7. Role of feedback mechanism and its impact on hydrology
8. Role Climate models and scenarios in climate change studies in hydrology
9. Hydrometeorological hazards, adaptation, and mitigation
10. Introduction to Hydrological Models

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO 1	3								
CO 2	3				3				
CO 3	3	3		3	3				
CO 4	3						2	2	3
CO 5	3	3			3		2		3
CO 6	3		3	3	3		2	3	3

Course Title: Radar Meteorology		Course code: ATS 513
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA):40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Physics, Basic Electronics, Atmospheric Physics		
Course Description		
Radar Meteorology is the subject which describes the applications of Radar in observing the atmosphere and different weather phenomena.		
Course Objective:		
1. Students can learn the ability to describe in class a variety of atmospheric phenomena depicted on radar imagery. 2. Students can learn the ability to quantify the reflectivity and radial velocity field as measured by radar given a description of a weather phenomenon. 3. Students can learn the ability to relate radar reflectivity to rainfall rate, and discuss factors that contribute to the uncertainty in the rainfall rate estimation. 4. Students can learn the ability to discuss basic principles of multi-parameter radar measurements.		
Course Outcome/Learning Outcome		
1. Understand fundamental about Weather RADAR 2. Compare between weather RADAR and Other types of RADAR. 3. Explain the principle of Doppler Weather RADAR 4. Demonstrate about the scanning strategy of DWR 5. Interpretation of radar imagery of the atmosphere. 6. Learn about different DWR products and its utility.		

Course Content

	Hours
Unit-1 Introduction to Weather radars, Basic principles of radar meteorology. Electromagnetic waves. Different frequency bands used in the weather radars and their applications; Principles of dielectrics. Radio wave propagation. Scattering by hydrometeors. Principles of pulsed radar, Attenuation of EM Waves v/s wavelength,	8
Unit-2 Scattering of EM waves (Rayleigh & Mie), Bending of radar beam with refraction (Sub & Super refraction), Effect of curvature of the Earth on the range of radar, Definitions of Beam width, Pulse width, PRF, Antenna gain, backscattering cross, Radar range equation. Concept of dB (dBZ, dBm & dBw)	7
Unit-3 Principle of Doppler Weather radar, Block diagram of Doppler Weather radar and explanation of its major components. Introduction to magnetron, Introduction to DWR Base products (Z, V and W),	7
Unit-4	8

Doppler Dilemma and its interpretation – Range and velocity ambiguities, Operation procedure of DWR – Scanning, Uniform Scan strategy used in IMD Doppler radars, Radar calibration, validation, Radar data dissemination and data Archival.	
Unit-5 DWR products – their interpretation and use in Nowcasting, Reflectivity (PPI, CAPPI, PCAPPI, MAX, VCUT, EBASE & ETOP), Radial Velocity (PPI, CAPPI, PCAPPI, MAX, VCUT, VVP_2), Spectrum Width (PPI, CAPPI, PCAPPI, MAX, VCUT, Layer Turbulence), Hydrological Products (SRI, PAC, VIL), Warning products (Severe Weather Index, HHW)	8
Unit-6 Analysis of severe weather events (thunderstorms, hailstorms, line squall, heavy rainfall prediction, aviation safety and tropical cyclones)	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:
1. Radar Meteorology: A First Course by Robert M. Rauber and Stephen W. Nesbitt
2. Radar Meteorology: Principles and Practice by Frédéric Fabry
3. Weather Radar Handbook, by Tim Vasquez

Reference:
1. Notes on Radar Meteorology for Advanced Course in Meteorology (IMD PUNE)
2. How to use and interpret Doppler weather radar (https://meteor.geol.iastate.edu/~jdduda/portfolio/How%20to%20read%20and%20interpret%20weather%20radar.pdf)

e-resources:
https://www.meted.ucar.edu/radar/basic_wxradar/index.htm (Weather RADAR Fundamental)
https://www.e-education.psu.edu/meteo3/l5_p8.html

Assignments:
- Image Interpretation of DWR
- IMD DWR

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3	3		3					
CO2	2	2		3		1			
CO3	3	3		2				1	
CO4			2	1	2	1	2	3	
CO5	3	3	3		3			3	
CO6	2								

Course Title: Aviation Meteorology		Course code: ATS 514
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Dynamic Meteorology		
Course Description		
This course aims to study meteorology and the resources used to obtain valid and reliable weather and flight-critical information and understanding of the physical properties of the atmosphere, weather effects, and other factors affecting the aviation sector. Students analyse case studies involving weather information and practice aeronautical decision-making skills.		
Course Objective:		
1. To develop knowledge about meteorological conditions that is important for aviation purpose 2. To impart knowledge on the role of meteorology in aviation. 3. To describe the concept of Clear Air Turbulence (CAT) and its applications 4. To illustrate the different weather hazards that affect the aviation sector		
Course Outcome/Learning Outcome		
1. Understand the impacts of meteorology on Aviation sector 2. Knowledge of physical properties of the atmosphere and affecting factors for aviation 3. Understand the techniques used in aviation sector to deal with severe weather. 4. Analyse weather conditions that cause hazardous flight environments through use of case studies. 5. Knowledge of proper decision-making skills 6. Prepare for a career in the meteorological services in air force and commercial aviation		

Course Content

	Hours
Unit-1 An overview of Aviation Organizations and their functioning, Effect of Weather on aviation, weather hazards associated with take-off cruising and landing,	8
Unit-2 inflight – icing probability, visibility, fog, clouds, rain, detection of low-level wind shear, turbulence, thunderstorms, Microburst, Gust front	7
Unit-3 Preparation of meteorological documentation for a flight, Observation, and reporting of weather for Aviation services (SIGMET, METAR/SPECI, TAF/Area forecast).	8
Unit-4 Clear Air Turbulence (CAT): definition, causes and intensity, Understanding the Jet stream, Selection of aerodrome sites and protocol	7
Unit-5 Interpretation of meteorological Radar and satellite data for aviation applications, Preparation of a Significant weather chart from numerical model forecast outputs received on internet	8

Unit-6 Guidance framework for aviation and meteorology, appropriate decision making in flight-based operations,	7
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All units	

Textbooks:

1. Vallis GK : Atmospheric and Oceanic Fluid Dynamics, Cambridge University Press, 2006.
2. Pandharinath and Navale: Aviation Meteorology, BS Publications, 2012.
3. Agarwal and Om Prakash: Aviation Meteorology for Pilots, Blue Rose Publishers, 2018.

Reference Books:

1. UK Met Office (1971): Hand book of aviation Meteorology, H. M. Stationery Off
2. Sverre Pettersen (1956): Weather Analysis and Forecasting, Volume 1, Published by McGraw-Hill.
3. Mike M.N. Mwebesa (1976): East African Observer's Handbook, (handbook of standard procedures for surface weather observing and recording of climatological data) Rev. ed. East African Community, East African Meteorological Dept. in Nairobi.

e-resources:

http://aviationweather.gov/adds/
http://www.education.noaa.gov/
http://aviationweather.gov/iffdp/
http://faa.gov/
http://www.faa.gov/library/manuals/aviation/pilot_handbook/media/PHAK%20-%20Chapter%2012.pdf

Assignments: Presentation of following topics

1. Atmospheric Phenomena affecting aviation sectors,
2. Atmospheric stability and lapse rates impact development of clouds, fog, thunderstorms, and adverse weather
3. Compare and contrast weather and weather services between the US and other countries
4. Aircraft familiarization, pre-flight planning

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3								
CO2	3								
CO3	3	3	3			2	3	2	
CO4	3	3	3	2	1	2	3	2	
CO5	3	2	2			3	2	2	2
CO6	3	1	2			2	3	1	3

Course Title: Satellite Meteorology		**Course code: ATS 417**
Teaching Scheme	**Examination Scheme**	**Credits Allotted**
Theory: 3 hours/ week	Continuous Internal Assessment (CIA): 40 End Semester Examination (ESE): 60	L-3; T-0; P-0
Course Prerequisite: Basic Knowledge of Remote Sensing and atmospheric radiation processes.		
Course Description		
This course will provide idea, methodology and basic tools ability to describe in class a variety of atmospheric phenomena depicted on satellites imagery and help to understand the various approaches of the different retrieval algorithms for the weather parameters. This course will also provide the knowledge of techniques for sensing the atmosphere remotely using radio frequency, optical, and acoustic methods.		
Course Objective:		
1. To develop knowledge about interpreting satellite image 2. To develop knowledge about meteorological products provide by different satellite 3. To develop knowledge about satellite retrieval of different atmospheric and oceanic parameters.		
Course Outcome/Learning Outcome		
1. Understand about different techniques of satellite systems. 2. Interpret satellite images for various weather systems. 3. Explains about different techniques of retrievals of geophysical parameters. 4. Understand the data processing at different levels of satellite retrievals. 5. Identify suitable satellite data for weather analysis and numerical modelling. 6. Extract and analyse different satellite data for different extreme weather events.		

Course Content

	Hours
Unit-1 Basic principles of satellite remote sensing: satellite orbits, sensor characteristics, view angle, passive and active remote sensing, meteorological satellites, polar orbiting & geostationary satellites, current and future meteorological satellites of the world.	7
Unit-2 Application of atmospheric radiative transfer in retrievals of geophysical Parameters; Satellite image interpretation and enhancement techniques; Satellite observations used in models (i.e., Radiance, SSMI, ATOVS, CMV, SATEM, SATOB, MODIS, GPS-RO, etc.),	7
Unit-3 Satellite image analysis for synoptic scale weather systems, mesoscale weather systems, tropical cyclones, estimation of central pressure by using Dvorak's Technique; Satellite image interpretation for different clouds	7
Unit-4	8

Cloud Remote Sensing: retrieval algorithm, vertical distribution, cloud remote sensing, cloud detection using multispectral technique, issues in cloud-masking, CO_2 slice technique;	
Unit-5 Aerosol and: aerosol remote sensing using ground-based (passive radiometer and LIDAR) and satellite platforms, Trace Gas retrievals; Ocean remote sensing: Ocean colour, SST retrieval; Scatterometer: Wind retrievals; altimetry;	8
Unit-6 Microwave remote sensing: Soil moisture, Precipitation (using active and passive); Remote sensing of cryosphere; Details features of Real Time Analysis of Product & Information Dissemination (RAPID) web-based tools for satellite Data/products visualization	8
Internal Assessment	
CIA-1: Unit-1,2	
CIA-2: Unit-3,4	
ESE: All Units	

Textbooks:

1. Kelkar RR: Satellite Meteorology, 2nd Edition, BS publication.
2. Kelkar RR: Weather Satellites, Indian Meteorological Society, BSP publication.
3. Liou KN: An introduction to Atmospheric Radiation, 2nd Edition, International Geophysics series, Vol 34.
4. Satellite Meteorology: An Introduction by Stanley Q. Kidder and Thomas H. Vonder Haar, Academic Press
5. Meteorological Satellite Systems by Su-Yin Tan, Springer

Reference:

1. Mao Z et. al. (2016) Aerosols Monitored by Satellite Remote Sensing, http://dx.doi.org/10.5772/65284, Intechopen
2. Wang, T., Shi, J., Letu, H., Ma, Y., Li, X., & Zheng, Y. (2019). Detection and removal of clouds and associated shadows in satellite imagery based on simulated radiance fields. Journal of Geophysical Research: Atmospheres, 124, 7207–7225. https://doi.org/10.1029/2018JD029960
3. Satellite meteorology- a review by Sahoo A et. al.
4. Lecture notes in India Meteorological Training on Satellite Meteorology
5. Recommended Method for Evaluating Cloud and Related Parameters, WMO Guideline (2012) WWRP 2012

e-Resources:

- https://www.meted.ucar.edu/index.php
- https://www.youtube.com/playlist?list=PLEE4C5C4C1DE6AAEC
- https://www.youtube.com/watch?v=EqL1l3pi-FY
- https://www.youtube.com/watch?v=iUhl_YoRBWY
- https://www.youtube.com/watch?v=QGsLiVeeFH4
- https://www.youtube.com/watch?v=XGN_uFU1Vtw

Assignments:

- https://www.youtube.com/watch?v=3s17I8oNVHE
- Satellite Image Interpretation – Identification of high- and low-level cloud, snow cover
- Satellite data download from MOSDAC and analysis.

CO-PO Mapping

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9
CO1	3		3		3		2		
CO2	3		3		3	2	2		
CO3	3		3		3	2	3		
CO4	3		3		3				
CO5	3		3		3	2	2		
CO6	3		3		3	2	2		

ANNEXURE I

(A typical Specimen of Cover Page & Title Page–DISSERTATION)

<Font Style Times New Roman - Bold>
TITLE OF DISSERTATION
<Font Size 22><1.5 line spacing>

DISSERTATION
<Font Size 14>

Submitted by
<Font Size 14><Italic>

NAME OF THE CANDIDATE
(Enrolment Number)
<Font Size 16>

Under the Supervision of
NAME OF THE SUPERVISOR
in partial fulfilment for the award of the degree of
<Font Size 14>

MASTER OF SCIENCE IN
ATMOSPHERIC SCIENCE
<Font Size 16>

DEPARTMENT OF…
SCHOOL OF ....
CENTRAL UNIVERSITY OF RAJASTHAN
MONTH AND YEAR
<Font Size 16>

ANNEXURE II

DECLARATION

I ...., student at the School of Earth Sciences, Central University of Rajasthan hereby declare and certify with my signature that my thesis entitled………………………… .... submitted to the Department of ...., Central University of Rajasthan, India in partial fulfilment of the requirements for the award of the Degree of Masters of Science is a record of original research work done by me and the dissertation has not been the basis for the award of any degree/diploma/associateship/fellowship or similar title of any candidate of any University. I have faithfully and accurately cited all my sources, including books, journals, handouts, and unpublished manuscripts, as well as any other media, such as the Internet, letters, or significant personal communications.

I understand the concept of "plagiarism" and declare that while drafting this dissertation I have refrained from plagiarism. I know that plagiarism not only includes direct copying, but also the extensive use of other's ideas without proper referencing or acknowledgement (which includes the proper use of references and quotation marks). A plagiarism report in terms of similarity report obtained from "TURNITIN" has been submitted along with my report.

If my dissertation found to be plagiarized at any point of time, I'll be solely responsible and will be ready to accept any decision taken by the competent authority including rejection of my dissertation.

Date: (Signature of student)
Place: (Enrolment Number)

ANNEXURE III

CERTIFICATE

This is to certify that the work presented in this thesis entitled ……………………………………………………………………………………………………… ……………………………………………………………………………………… in partial fulfilment of the requirement for the award of the degree of Master of science in Atmospheric Science from Department of Atmospheric Science, Central University of Rajasthan (CURAJ) is an original research work carried out by ………………………………………………… (ENROLLMENT NO: …………………..), final year student under my supervision and guidance during academic year ……………………… and has not been submitted anywhere else for the award of any degree.

To the best of my knowledge, the content of this thesis does not form a basis for the award of any previous degree to anyone else.

Date:
Place:

(Signature of Supervisor)
Seal

(Signature of Head of the Department)
Seal

ANNEXURE IV

(A typical Specimen of Table of Contents)

<Font Style Times New Roman, Font Size 14>

TABLE OF CONTENTS

Note: The above contents will be minimum. Student can also add heading and sub-heading as per requirement.

ANNEXURE V
Curriculum vitae

<Font Style Times New Roman, Font Size 14>

Photo

Personal Details
Name:
Date of birth: DD Month, YYYY
Place of birth:
Nationality:
Permanent Address:
Email Id:
Mobile No.:
Language:

Academic Qualification:

Degree	Year	Institution/University	Subject	CGPA/Percentage

Computation Skill:

Extra-Curricular Activities:

Any other Information:

The above information is correct as per my knowledge.

(Signature of the student)

ANNEXURE VI

(Specimen of ESE Question Paper Format)
CENTRAL UNIVERSITY OF RAJASTHAN
Semester-II, End-Semester Examination (ESE), October-2022

Course Code: **Title of the Course:**
Time: 3 hours **Max. Marks: 60**

"

General Instructions*: All questions are compulsory.* *6x10 = 60*

1. (a)

   (b)

   (c)

OR

   (a)

   (b)

2. (a)

OR

   (a)
   (b)

3. (a)
   (b)

OR

   (a)
   (b)

4.
   (a)
   (b)

OR

   (a)
   (b)

5. (a)
   (b)
   (c)

OR

   (a)
   (b)
   (c)

6. (a)
   (b)

OR

   (a)
   (b)

****