Savitribai Phule Pune University

(Formerly University of Pune)

Two Year PG Degree Program in Atmospheric Sciences

(Faculty of Science & Technology)

Revised Syllabi for

M.Tech. (Atmospheric Science) Part- I&II

(For Department of Atmospheric and Space Sciences, SPPU)

Choice Based Credit System Syllabus

To be implemented from Academic Year 2023-2024

Title of the Course: M. Tech. (Atmospheric Science)

Preamble:

The M.Tech. program in Atmospheric Science was started by the UGC in 1988 at the following universities : Andhra, Calcutta, Cochin and **Pune**. It was a post- M.Sc. course and a **common syllabus was followed at all the four universities.**

University of Pune through Circular No. 204 of 1988 introduced the course as M.Tech. (Atmospheric Physics) It was named as Atmospheric Physics since the program was housed in the Department of Physics.

The M.Tech. (Atmospheric Physics) course was revised and made as credit based syllabus through Circular No. 171 of 2003.

In 2003 the Management Council of University of Pune decided to transfer the three Government approved faculty positions of Atmospheric Sciences to Department of Space Sciences and rename it as Department of Atmospheric and Space Sciences. Accordingly through Circular no. 55 of 2004 the Statute Amendments were implemented.

From the academic year 2005-06 this course is being run in the Department of Atmospheric & Space Sciences. Through Circular No. 222 of 2005, the M.Tech. syllabus was revised and the course was made into a two year course. The syllabus was again revised in 2007, 2011 and 2012, 2018 and 2020.

The UGC through Gazette Notification of 2014 put the M.Tech. in the Engineering/ Technology Faculty. Therefore, M.Tech. (Atmospheric Science) through circular number 196/2015 dated 28/08/2015 has been shifted to Technology Faculty of SPPU. Presently the M. Tech. course is under Science and Technology faculty. The syllabus was last revised in 2023.

Programme outcome

- Develop thorough understanding in fundamental and advanced aspects of Weather and Climate Sciences and learn to explain various atmospheric and oceanic phenomena.
- Apply computational tools and techniques to solve numerical problems and thus to help study atmospheric and oceanic processes.
- Understand the principles behind meteorological instrumentation, satellite and surface based remote sensing observations and learn to interpret the data.

- Develop skills for performing numerical modeling of weather systems and interpret the results.
- Equip the students to take up the societal and environmental challenges related to the global warming and climate change issues.
- Cultivate skills to perform scientific research, generate results, write reports and manuscripts for publication.
- Trained manpower to take up challenging research topics for doctoral studies and jobs in the fields of atmospheric, oceanic and climate sciences.

Examination

- A student will have to complete a total of **88** credits, details of which are given in the enclosed course structure
- Each credit will be for **25** marks, **50 %** of the marks for continuous assessment and **50 %** marks for semester-end examination.
- Continuous assessment can be done through Seminars/ Assignments/ Oral test/ Written test.
- The Semester-end examination for theory courses will be in the form of written examination for the whole course.
- Laboratory Course: All the required practical have to be completed and the journal has to be certified by the Laboratory in-charge and Head of Department before the last date announced by the Teaching Committee. Without a certified Journal the student cannot appear for final laboratory exam. 50% marks will be for continuous assessment, of which 30% will be on the practical conducted/ test/ viva and 20% will be for the certified journal. 50% will be for final assessment of which 20% will be for Viva and 30% will be for the practical.
- Examination procedure for Internship Training and Project work are given in the detailed syllabus.
- As per the existing rules, the student has to obtain **40%** marks in the combined Continuous Assessment and Semester-End Assessment with a minimum passing of **30%** in both these separately. The rules of examination prescribed by the University will be applicable.

Backlogs

- The student has to clear at least **50%** of the credits of the first year before he/she can be allowed to take admission for the second-year course. If the University changes these rules, then the rules in force will be applicable.
- If the student has a backlog subject then he/she can improve the continuous assessment marks of that subject only when that subject is being offered in a particular semester and he/she will be required to register for that subject.

- If a particular subject is discontinued or not offered then the student will have to register for an alternative subject of equal number of credits in consultation with the Head of Department/ Teaching Committee.

Credit Framework for M. Tech. (Atmospheric Science)

Summary of the Credits distribution

Duration of the course: 2 Years, Semesters: 4

Major Core Courses: 54 Credits

Major Elective Courses: 16

Research Methodology: 4

On Job Training/ Internship: 4

Research Project: 10

Credits per semester: 22

Total credits for the two-year PG course: 88

M. Tech. Atmospheric Science
Course Credit Structure

Semester I Total Credits: 22		
Major Core Courses: 14 Credits		
Subject Code	**Subject Title**	**Number of Credits**
ATM-501-MJ	Fundamentals of Meteorology and Climatology	2
ATM-502-MJ	Atmospheric Thermodynamics and Radiation	4
ATM-503-MJ	Dynamic Meteorology	4
ATM-504-MJP	Laboratory Course I- Fortran Programming and Numerical Problem Solving	4
Major Elective Courses: 4 credits		
ATM-510-MJ	Introductory Earth Sciences	2
ATM-511-MJ	Space Meteorology	2
ATM-512-MJP	Laboratory Course- Python for Data Analysis and Visualization	2
ATM-513-MJP	Laboratory Course- R programming	2
Research Methodology: 4 Credits		
ATM-505-MJ	Methodology for Atmospheric Research	4

Semester II Total Credits: 22		
Major Core Courses: 14 Credits		
Subject Code	**Subject Title**	**Number of Credits**
ATM-551-MJ	Cloud Physics and Atmospheric Electricity	4
ATM-552-MJ	Physics and Dynamics of the Ocean	4
ATM-553-MJ	Synoptic, Tropical and Extratropical Meteorology	2
ATM-554-MJP	Laboratory Course II- Thermodynamic Diagrams and Atmospheric Data Analysis	4
Major Elective Courses: 4 Credits		
ATM-560-MJ	Dynamics of Atmospheric Waves and Instability	2
ATM-561-MJ	Atmospheric Boundary Layer	2
ATM-562-MJ	Physics and Dynamics of Middle Atmosphere	2
ATM-563-MJ	Extreme Weather and Natural Hazards (Seminar Course)	2
ATM-564-MJ	Hydrometeorology	2
ATM-565-MJP	Laboratory Course- Weather and Climate Data Analysis and Visualization Techniques	2
Internship: 4 credits		
ATM-581-OJT	Internship Training	4

Semester III Total Credits: 22		
Major Core Courses: 14 Credits		
Subject Code	**Subject Title**	**Number of Credits**
ATM-601-MJ	Atmospheric Instruments and Observational Techniques	4
ATM-602-MJ	Climate Physics and Modelling	4
ATM-603-MJ	Numerical Weather and Climate Modelling	2
ATM-604-MJP	Laboratory Course III- Numerical Methods for NWP and Atmospheric Dynamics	4
Major Elective Courses: 4 Credits		
ATM-610-MJ	Climate Services and Applications	2
ATM-611-MJ	Weather Radar	2
ATM-612-MJ	World Weather Analysis (seminar course)	2
ATM-613-MJ	Urban Meteorology	2
ATM-614-MJ	AI-ML for Meteorological Applications	2
Research Project: 4 Credits		
ATM-631-RP	Project Work I	4

Semester IV Total Credits: 22		
Major Core Courses: 12 Credits		
Subject Code	**Subject Title**	**Number of Credits**
ATM-651-MJ	Atmospheric Chemistry and Air pollution	4
ATM-652-MJ	Ocean Biology and Biogeochemistry	2
ATM-653-MJ	Parameterization and Data Assimilation in Numerical Models	2
ATM-654-MJP	Laboratory Course IV- Numerical Simulation of Weather and Climate	4
Major Elective Courses: 4 Credits		
Subject Code	**Subject Title**	**Number of Credits**
ATM-660-MJ	Agricultural Meteorology	2
ATM-661-MJ	Atmospheric Energetics and General Circulation	2
ATM-662-MJ	Satellite Observations for Meteorological Applications	2
ATM-663-MJ	Climate Communication	2
ATM-664-MJ	Solar and Wind Energy Resources	2
ATM-665-MJP	Laboratory course- Weather Chart Analysis	2
Research Project: 6 credits		
ATM-681-RP	Project Work II	6

MJ-Theory; MJP- Practical, OJT – On Job Training/ Internship, RP – Research Project.

UGC recommended Extra credit courses (Total credits 12, Compulsory, not counted towards final grades)

Subject Code	Subject Title	Number of Credits
CBCS-CS	Cyber Security	4
SDC01	Skill Development Courses	4
CBCS-HR	Human Rights Education	2
CBCS-IIC	Introduction to the Indian Constitution	2

Detailed Syllabus

1. Major Core Theory (MJ) Courses

ATM-501-MJ Fundamentals of Meteorology and Climatology (2 credits)

Course outcome

- Familiarise students with the basics of meteorology, basic relationship between Earth and Sun, vertical structure of the atmosphere.
- Understand the basic features of atmospheric circulation and seasonal variations.
- Learn Indian climatology and different weather systems that occur over the Indian subcontinent in different seasons.

Course content

Unit 1: Basics

Elementary concepts of weather and climate; earth-sun relationship; structure and composition of the atmosphere; Atmospheric pressure, temperature, wind, relative humidity, clouds, different forms of precipitation; diurnal variation of surface pressure and variation of pressure with height; diurnal variation of surface and air temperature and variation of air temperature with height; diurnal variation of wind, rainfall, humidity and cloudiness.

Definition and categorization of wind; squall, gustiness, gale, Beaufort scale, land and sea breeze, katabatic and anabatic winds, Buys-Ballot's law; basic ideas of general circulation. Visibility, causes of poor visibility, haze, mist, fog, tropical depression and storm.

Unit 2: Climatology

Definition of climate, physical factors of climate, rotation of the earth, seasons, climatic controls.

Climatic classification: methods of Koppen

Radiation climatology of the earth's atmosphere, geographical and seasonal distribution of incoming solar radiation, outgoing radiation, net radiation, terrestrial heat balance. Geographical and seasonal distributions of temperature, pressure, wind, evaporation, humidity, fog, clouds, precipitation and thunderstorms. Vertical distribution of winds. Upper air climatology during winter and summer.
Indian climatology: Climate zones of India; pressure, wind, temperature and rainfall distribution during the four seasons. Climatology of Western disturbances, fog, thunderstorm, hail, heat waves, cold waves, jet streams, tropical cyclones, south-west and north-east monsoon.

Books

1. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.

2. Atmosphere, Weather and Climate by R.J. Barry and R.G. Chorley (Methuen Publication)
3. General Climatology by Critchfield
4. An Introduction to Meteorology by S. Pettersen
5. The Monsoons by P.K. Das (National Book Trust, India)
6. General Climatology by H.J. Critchfield
7. An introduction to climate by G.T. Trewartha
8. Physical Climatology by W.D. Sellers
9. World Survey of Climatology by H.E. Landsberg (Ed.)
10. World Climatology – An Environmental Approach by J.G. Lockwood
11. Survey of Climatology by J.F. Griffiths & D.M. Driscoll
12. South West Monsoon by Y.P Rao
13. Monsoon Meteorology by C.P. Chang & T.N. Krishnmurti
14. Cloud Dynamics by R.A. Houze Jr.
15. Tropical Cyclones, their evolution structure and effect by R.A Anthes
16. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-502-MJ Atmospheric Thermodynamics and Radiation (4 credits)

Course outcome

The students will

- Learn about the dry and moist air characteristics in the atmosphere.
- Become familiar with the different moisture parameters used in meteorology.
- Understand how the laws of thermodynamics are applied to explain different physical processes in the atmosphere.
- Learn how different thermodynamic quantities are computed from meteorological measurements used for forecasting purpose.
- Understand how different laws of radiation are used to explain the radiation budget of the Earth-Atmosphere system.

Course content

Unit 1: 1 Thermodynamics

Ideal gas law, Equation of state for dry and moist air, Moisture variables, Virtual Temperature, First and Second law of thermodynamics, Potential Temperature, Parcel concept, Adiabatic Process of moist air, Equivalent Temperature, Equivalent Potential Temperature, Clausius – Clapeyron Equation, Thermodynamic Diagrams, uses of thermodynamic diagrams, LCL, LFC, Precipitable Water Vapor. Hydrostatic Equation and its application. Reduction of pressure to sea level. Stability and Instability of Atmosphere.

Unit 2: Radiation

Spectrum of Radiation, Diffuse and Parallel Beam Radiation, Black Body Radiation and Laws of Radiation, Absorptivity and Emissivity, Atmospheric absorption of solar radiation, Atmospheric absorption and emission of infrared radiation, Scattering of solar radiation,

Radiative transfer and global energy balance.

Books

1. Introduction to Theoretical Meteorology, S.L.Hess,
2. Physics of Atmospheres by H.G. Houghton. Cambridge
3. Atmospheric Sciences: An introductory Survey, by J.M. Wallace and P.V. Hobbs, Academic Press.
4. An Introduction to Atmospheric Thermodynamics by A.A. Tsonis, Cambridge
5. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-503-MJ Dynamic Meteorology (4 credits)

Course outcome

- Apply the concepts of fluid dynamics to explain atmospheric motion.
- Learn the forces acting in the atmosphere and the conservation equations governing atmospheric motion in different coordinate systems.
- Learn about the equations of motion in detail and understand various types of balanced flows in the atmosphere.
- Learn the rotational aspects of atmospheric motions with the help of parameters such as divergence, vorticity and circulation.
- Understand the concepts related to atmospheric motions such as barotropic and baroclinic atmospheres, stream lines and trajectories, thermal wind, barotropic and baroclinic atmospheres, etc.

Course content

Unit 1

Continuum Hypothesis, Lagrangian and Eulerian frames of references, velocity potential, stream function. Equations of motion in spherical co-ordinates, rotating frame, Coriolis force, Scale Analysis, Rossby number, Natural Co-ordinate System, balanced flow- Geostrophic Flow, Inertial Flow, Cyclostrophic Flow and Gradient Flow. Equations of continuity in spherical and Cartesian co-ordinates. Thermodynamic energy equation, Pressure as vertical co-ordinate and Basic equations in Isobaric Coordinates. Log-Pressure Coordinate System. Generalized vertical co-ordinates. Thermal Wind, veering and backing of geostrophic wind. Kinematics of Pressure Fields. Trajectory and Streamlines, Differential equation for streamlines.

Unit 2

Circulation, vorticity, divergence, Stokes Theorem, Divergence Theorem, Circulation theorems – Kelvin's Theorem and Bjerknes Theorem and applications of Circulation theorems – Sea Breeze and Land Breeze; General Circulation. Solenoidal Vector, Barotropic and baroclinic fluids. Helmholtz theorem for split of horizontal wind vector. Vorticity and divergence equations, Scale Analysis, Balance Equation, split of vorticity and divergence equations into rotational and irrotational terms.

Books

1. An Introduction to Dynamic Meteorology, J.R. Holton, Academic Press.
2. Dynamic Meteorology,AskelWiin Nelson, WMO Publication.
3. Introduction to Theoretical Meteorology by S.L. Hess,
4. Dynamic and Physical Meteorology by G.L. Haltiner and F.L. Martin, Mc Graw Hill.
5. Ceaseless Wind by Dutton
6. Weather Forecasting Vol I and II by S. Pettersen
7. The Physics of the Atmosphere by Houghton
8. The Physics of Monsoons R.N. Keshava Murthy and M.Shankar Rao, Allied Publishers, 1992.
9. Atmospheric Waves by Tom Beer
10. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-551-MJ Cloud Physics and Atmospheric Electricity (4 credits)

Course outcome

- Become familiar with the different types of clouds in the atmosphere.
- Learn about the droplet nucleation and the warm rain formation process.
- Learn the ice nucleation process and the development of hail and snow in clouds.
- Become familiar with the process of weather modification.
- Understand how the conversion of different phases of water inside a cloud is handled in numerical models.
- Become familiar with the different components of Atmospheric Electricity and the concept of Global Electric Circuit.
- Learn about different types of Lightning and the process of cloud electrification.
- Understand how the lightning detection system works.

Course content

Unit 1

Cloud Morphology, Warm Cloud Microphysics (Nucleation and Condensation, Kelvin equation, Kohler Theory), Growth of cloud droplets by collision and coalescence, Initiation of warm rain. Cold Cloud Microphysics (Nucleation and growth of ice), Types of Ice Nuclei, Bergeron-Findeisen Process. Types of microphysical processes and categories in clouds.

Weather modification (Artificial and inadvertent).

Unit 2

Atmospheric electricity in fair weather (Ions and Atmospheric conductivity, Space charges), Electric field, Air-Earth currents. Global Electric Circuit (Classical concept, validity and limitations).

The electrical structure of thunderstorms, Cloud electrification mechanisms, Physics of lightning, Transient Luminous Events, Lightning and Nitrogen fixation.

Unit 3: Seminars by Students

Fog and Boundary layer clouds, Middle level clouds, Cumulonimbus clouds and Thunderstorms, Tornadoes, Meso-scale convective systems, Clouds in Hurricanes and cyclones, Orographic Clouds, Frontal clouds, Polar Stratospheric Clouds, High Clouds and Contrails, Lightning in other Planets of Solar System.

Books

1. A Short course in cloud physics" R.R. Rogers,
2. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
3. Atmospheric Electrodynamics" H.Volland, Springer Verlag,
4. Physics of the Cloud by B.J. Mason
5. Microphysics of cloud and Precipitation by Pruppacher and Klett
6. Atmospheric Electricity by J.A. Chalmers
7. Earth's Electrical Environment- National Academy Press
8. Lightning by Valdamir A Rakov and Martin A. Uman
9. Cloud Dynamics by R.A. Houze
10. Clouds Rain and Rainmaking by B.J. Mason
11. Electrical Nature of Storms by D. McGorman and W.D. Rust
12. An Introduction to clouds, by Ulrike Lohmann, Felix Luond and Fabian Mahrt
13. An Introduction to Lightning by Vernon Cooray
14. Physical Processes in Clouds and Cloud Modeling, Khain and Pinsky, Cambridge University Press, 2018, ISBN 9781139049481, https://doi.org/10.1017/9781139049481.
15. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-552-MJ Physics and Dynamics of the Ocean (4 credits)

Course outcome

- Learn the physical characteristics of the ocean in detail, such as temperature, salinity, density and their vertical variations.
- Understand oceanic heat content, mixing processes, heat and momentum budgets.
- Study the atmosphere- ocean interactions, ocean circulation and it's variability, effects of climate variations and change on ocean circulation.
- Learn ocean dynamics and numerical modelling aspects.
- Study the role of oceans in climate change

Course content

Unit 1

Physical Characteristics of the Ocean: Ocean Basins, Sea floor features, Properties of sea water & Equation of State, Temperature, Salinity, Density and Oxygen characteristics, Vertical profile of temperature and salinity in the three major oceans. Classification of vertical structure of the ocean, Penetration of Solar Radiation, Turbidity

Water mass characteristics, Formation and Classification of water masses T-S diagram, Mixing processes in the oceans, Upwelling and downwelling processes, Oceanic heat, salt and momentum budgets, Thermohaline circulation and the oceanic conveyor belt.

Unit 2

Different layers of the upper ocean, Sea surface temperature, Mixed layer, Thermocline, halocline, pycnocline, upwelling, downwelling, General circulation of ocean, Observed mean circulation, typical scales of motion in the ocean, Wind stress, Geostrophic flow in Ocean – Surface ocean currents, Equatorial current systems; Ekman pumping, Ekman transports, Wind driven coastal currents; Theory of coastal upwelling, Sverdrup, Stommel and Munk's theories, Westward intensification. Marine boundary layer.

Unit 3

Ocean planetary waves, their generation and propagation; Propagation, refraction, and reflection of waves.

Dynamics governing circulation in the coastal ocean, Tides and tide generating forces. Tidal currents in shallow seas, estuaries and rivers, Storm surges and tsunamis.

Modes of variability in the ocean - Indian Ocean Dipole, Madden-Julian oscillation (MJO), El Nino, modes of Atlantic Ocean.

Unit 4

Ocean observation systems, introduction to numerical ocean models, Role of oceans in climate change

Books

1. Introduction to Physical Oceanography: Robert Stewart
2. Regional Oceanography: Tomzack and Godfrey
3. Principles of Ocean Physics by J.R. Apel, Academic Press.
4. Atmospheric and Ocean Dynamics A.E. Gill, Academic Press.
5. The Oceans, their Physics, Chemistry and General Biology byH.U. Sverdrup
6. Principles of Physical Oceanography by G. Neumann & WJ Pierson, Jr.
7. Descriptive Physical Oceanography by G Dietrich
8. Physical Oceanography Vol I & II by A. Defant
9. Introduction to Physical Oceanography by W.S. VonArx
10. Ocean Currents by G. Neumann
11. Tides, Surges and mean sea level by D. T. Pugh

ATM-553-MJ Synoptic, Tropical and Extratropical Meteorology (2 credits)

Course outcome

- Learn to understand features of weather systems at synoptic scale from observations and weather charts.
- Understand fundamental aspects of tropical wind systems, circulation, waves and convection.
- Detailed understanding of the monsoon circulation, Indian monsoon, synoptic features and spatiotemporal variations at different scales, intraseasonal and interannual variations.
- Understand the influence of different teleconnection influences on Indian monsoon.
- Learn important aspects of extratropical weather systems and interaction with tropical systems.

Course content

Unit 1: Synoptic Meteorology

Introduction to synoptic meteorology, scales of weather systems, introduction to synoptic weather observations, surface, upper air and special observations. Representation and analysis of fields of meteorological elements, synoptic charts, analysis of surface and upper air charts, stream-lines, isotachs and contour analysis; tilt and slope of pressure/weather systems with height.

Unit 2: Tropical Meteorology

Tropical Meteorology: Hadley cell, trade winds, equatorial trough, tropical convection, tropical precipitation and its spatial and temporal variation. ITCZ, easterly waves, convective systems, tropical cyclones-their structure and development, Gray's parameter, CISK, waves in equatorial atmosphere.

Pre-monsoon: cyclonic storms, tracks, and frequencies; fog, dust-storms, nor'westers, heat waves, pre-monsoon thunderstorms.
Monsoon: Ramage criteria for monsoon, SW and NE monsoons; monsoon over Asia, Australia and Africa; Characteristics of monsoon system, synoptic components of Indian summer monsoon Onset and advance of monsoon, active and break monsoon, strong and weak monsoon, synoptic features associated with onset, withdrawal, break active and weak monsoons and their prediction. Quasi biweekly Oscillation.
Post monsoon: cyclonic storm- tracks, frequency, northeast monsoon circulation and rainfall.

Impact of inter annual and climate variabilities on Indian monsoon system. Role of ENSO, IOD, Atlantic Nino and other such modes.

Unit 3: Extratropical Meteorology

Tropical and extratropical interactions, Air masses- characteristics, prediction and modification; fronts, frontogenesis and frontolysis, Margule's formula, structure of cold and warm fronts and polar-front theory. Extra-tropical cyclones and anti-cyclones, western disturbances, Jet streams: polar front jet, sub-tropical jet, tropical easterly jet, polar night jet, characteristic features of various jet streams, theories of formation, weather development, cloud and clear air turbulence (CAT).

Books

1. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
2. Atmosphere, Weather and Climate by R.J. Barry and R.G. Chorley (Methuen Publication)
3. An Introduction to Meteorology by S. Pettersen
4. The Monsoons by P.K. Das (National Book Trust, India)
5. South West Monsoon by Y.P Rao
6. Monsoon Meteorology by C.P. Chang & T.N. Krishnmurti
7. Cloud Dynamics by R.A. Houze Jr.
8. Tropical Cyclones, their evolution structure and effect by R.A Anthes
9. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-601-MJ Atmospheric Instruments and Observational Techniques (4 credits)

Course outcome

- Understand the working principle of surface and upper-air meteorological sensors.
- Familiarize with the sensor exposure requirements, errors in the measurements and corrections to be applied.
- Learn to interpret the surface weather data.
- Learn the principles, mechanism and applications of ground based remote sensing instruments.
- Understanding on the basic characteristics of the signals measured by the remote sensing instruments.

- Understand Satellite and RADAR remote sensing methods and their meteorological applications.

Course content

Unit 1: Surface and upper air observations

General principles of surface instrumental measurements, accuracy requirements, siting of an observatory, exposure requirements, observational procedures, standard times of synoptic observations. Conventional measurements of pressure, temperature, humidity, wind speed and direction, sunshine duration, radiation – shortwave and longwave, precipitation, visibility, clouds, soil temperature and soil moisture, evaporation. Self-recording instruments, Measurement control and data collection using data loggers Ocean temperature, salinity, wave height and currents measurements, ADCP moorings, Argo floats, Ocean Gliders, XBT, XCTD.

Upper air pressure, temperature, humidity and wind measurements: pilot balloons, radiosonde, dropsonde, ozonesonde, radiometersondes, GPS sonde.

Unit 2: Remote sensing observations

LIDARS, SODARS, Wind Profiler, radio-acoustic sounding systems (RASS), Microwave radiometer. Aerosol measurements. Disdrometer.

Fundamental aspects of satellite, Satellite orbits and attitude, principles of satellite motion, Kepler's laws; Observations in Visible, infrared, and microwave channels; Meteorological applications.

Fundamental aspects of weather radars, types of weather radars, meteorological applications.

Books

1. Probing the atmospheric boundary layer, D.H. Lenschow
2. Instruments and Techniques for probing the atmospheric boundary layer, D.H. Lenchow.
3. Guide to Meteorological Instruments and method of observation, WMO-8,
4. Meteorological Instruments byW.E.K.Middleton and A.F. Spilhaus,
5. Applications of Remote Sensing to Agrometeorology F.Toselli, Kluwer
6. Battan (1973), Radar Observation of the Atmosphere
7. Bringi and Chandrasekar (2001), Polarimetric Doppler Weather Radar, Cambridge Press
8. Doviak and Zrnic (1984, 1993), Doppler Radar and Weather Observations, Academic Press
9. Atlas (1990), Radar in Meteorology, AMS (Battan Memorial volume)
10. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-602-MJ Climate Physics and Modelling (4 credits)

Course outcome

- Introduces the climate system, past climates & methods of determining past climates.
- Understand components of the climate system, distinguishes between what constitutes as climate variability and climate change & further on processes & feedbacks that drive the climate system.
- Learn the history of climate models & teaches them of different types of climate models from the simplest energy balance models to the most complex earth system models.
- Learn how the models run experiments to determine future climate.
- Understand the international collaborations and mitigation measures undertaken; IPCC report.
- Familiarize with the concepts of mitigation, adaptation & sustainability.

Course content

Unit 1: Climate Change & Variability

Components of the climate system, Difference between climate change and variability, Overview of the climatic history of the earth, long term changes (Climate of Past century, past millennium, past glacial period). Methods of determining past climate. Possible causes of climate change - External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic), Air-sea interactions on different space and time scales.

General idea of internal dynamical processes of different components of the earth system, radiation budget of the earth system. Climate feedback processes and mechanism, low frequency variability. Climate tipping points, introduction to carbon cycle, water cycle (on climate scale)
Role of anthropogenic activities on the current climate change, understanding future climate & climate predictions, potential consequences, extreme events and climate disasters.

Unit 2: Climate Modelling

Definition of Climate Models, evolution of climate models (hierarchy of models), Simple climate model 0-D & 1-D climate models, Energy balance models and sensitivity studies (in the context of CMIP/IPCC). Intermediate complexity models, General Circulation models. Coupled ocean-atmosphere system, Earth system models, Future scenarios of ESM (in the context of CMIP/IPCC).

Unit 3: Vulnerability, Mitigation and Adaptation
Inferences from the IPCC report. International efforts to minimize climate change, General idea of sustainability, adaptability and mitigation. Importance of environmental impact assessment, General idea of climate vulnerability and resilience, discussion on the multifold impact of climate change, regional climate change.

Books:

1. Physical Climatology by W.D. Sellers
2. Foundation of Climatology by E.T. Stinger
3. Climate-Past, Present and Future Vol-I and II by Lamb
4. An Introduction to Climate by G.W. Threwartha
5. The nature and causes of climate change by Goodies, Paultikaf and Davies
6. Science of Climate Change IPCC, Cambridge
7. IPCC assessment reports
8. Climate of South Asia by G.B. Pant and Rupa Kumar
9. Climate System Modelling by Trenberth K.E.
10. The Physical Basis of Climate and ClimateModelling- WMO-GARP, No. 16
11. Three Dimensional Climate Modelling by Washington and Parkinson.
12. Climate Modelling Primer Henderson Sellers and McGuffie
13. IPCC Report
14. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-603-MJ Numerical Weather and Climate Modelling (2 credits)

Course outcome

- Learn the basics of Numerical Weather Prediction.
- Learn about various numerical techniques and equation solving methods used in NWP.
- Sigma coordinate system and primitive equation model.
- Advanced dynamic meteorological concepts such as Barotropic and Equivalent Barotropic Models, Quasi-geostrophic Vorticity Equation, Potential Vorticity Equation, etc.
- Understand the science and hierarchy of weather and climate numerical models, such as WRF, GFS and CFS.

Course content

Historical Back ground, Finite Difference Schemes for Space and Time, Trucation Error, Linear and non-linear computational instabilities, Staggered Grid, Aliasing, Arakawa Jacobian, Barotropic and Equivalent Barotropic Models, Thermodynamic Energy Equation and Quasigeostrophic Vorticity Equation in Isobaric Coordinates, Diagnostic Omega Equation, Tendency Equation and Potential Vorticity Equation, Primitive Equation Model, Sigma Coordinate System and Primitive Equation Model in Sigma Coordinate system. Introduction of various numerical models: GFS, CFS and WRF.

Books

1. An introduction to Dynamic Meteorology by J.R. Holton, Academic Press.
2. Numerical Methods used in Atmospheric Models WMO-GARP Series No.17
3. Numerical Prediction and Dynamic Meteorology G.J. Haltiner and R.T. Williams,

4. Parameterization of subgrid scale processes WMO-GARP, Series No. 8.
5. Numerical Weather Prediction by P.D. Thompson
6. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-651-MJ Atmospheric Chemistry and Air pollution (4 credits)

Course outcome

- Learn about the evolution and chemistry of the atmosphere
- Understanding on the carbon, Sulphur, nitrogen cycles and their role in the atmosphere
- Learn the importance of ozone, sources and sinks, ozone layer and ozone hole
- Learn about the atmospheric aerosols, types, geographical distribution, sizes etc
- Study meteorological aspects related to air pollution, air quality index, pollutant transport.
- Learn about the types of pollutants, emissions, their effects on health and atmosphere.
- Become familiar with emission inventory, measurements of particulate matter.
- Learn air pollution modelling.

Course content

Unit 1: Atmospheric Chemistry

Chemistry of the atmosphere: Evolution of earth's atmosphere, Nitrogen, hydrogen halogen, sulfur, carbon-containing compounds in the atmosphere, ozone and neutral chemistry, chemical and photochemical processes, hydroxyl and chlorine radical, chemical cleansing, oxidation, hydrocarbons in the troposphere, sources and sinks. Atmospheric Chemistry of the Troposphere – tropospheric chemical cycles, Chemical and dynamical life time of atmospheric constituent. Eddy diffusion and Turbulence.

Ozone in the Atmosphere: Evolution of the ozone layer, sources and sinks of tropospheric and stratospheric ozone, chlorofluorocarbons, ozone and UV-radiations, supersonic transport.

Atmospheric aerosols: Concentration and size, sources, and transformation, Chemical composition, transport and sinks, residence times of aerosols, geographical distribution and atmospheric effects.

Unit 2: Air Pollution

Atmospheric Pollution, type of pollutants, gaseous and particulate pollutants, size of atmospheric particles, emission inventory, various sources of emissions, bio-mass burning, pollution formation in combustion, Industrial pollution. Effect of air pollution on Human health, material and vegetation, Deposition of particulate pollutants in the respiratory system, air pollution meteorology, atmospheric chemical transport models, box models, three-dimensional atmospheric chemical transport models, components of air quality forecasting and modelling, Model Types; Gaussian Diffusion Model for Point, Line and Area Sources; Estimation of Turbulent Diffusion Coefficients; Lagrangian and Eulerian modeling concepts, Evaluation and validation, air quality standards and index, long range transport of pollutants.

Sources of anthropogenic pollution, Emission Inventory, Atmospheric effects- smog, visibility. Air pollution control at source, Settling chambers for particulate matter; Measurements of Particulate matters, SO_x, NO_x, and CO.

Books

1. Introduction to Atmospheric Chemistry by P.V. Hobbs
2. Atmospheric Chemistry and Physics : From Air Pollution to Climate Change by John H. Seinfeld, Spyros N. Pandis
3. Chemistry of the Upper and Lower Atmosphere by Barbara J. Finlayson-Pitts, Jr., James N. Pitts.
4. Chemistry of Atmospheres by Richard P. Wayne.
5. Basic Physical Chemistry for Atmospheric Sciences by P.V. Hobbs
6. O.G.Sutton, Micrometeorology
7. F.Pasquill, Atmospheric Diffusion.
8. Stull, Boundary layer Meteorology
9. Briggs.G.A , Plume Rise
10. Arya P.S , Atmospheric Boundary Layer
11. Panofsky and J.A.Dutton Atmospheric Turbulence
12. Air Pollution by Jermy Colls
13. Air Quality by YaelCelhal

ATM-652-MJ Ocean Biology and Biogeochemistry (2 credits)

Course outcome

- Understand the chemical composition and biological components and production in the ocean.
- Learn about the carbon cycle in the ocean with emphasis on carbon dissolution chemistry, ocean acidification and air-sea gas exchange.
- Understand the role of oceans in regulating the atmospheric CO_2.

Course content

Unit 1

Introduction: Chemical composition of the ocean, Distribution of chemicals in the ocean, expression of chemicals as ‘tracers’, conservation of tracers in the ocean

Biology of the ocean: Organic Matter Production, Nutrients, composition of organic matter, Phytoplankton, Zoo plankton and bacteria, Ecosystem processes and role of Light, Ecosystem models, N-P, N-P-Z and N-P-Z-D models

Organic Matter export: export production, regenerated production, new production, e-ratio, f-ratio and remineralization.

Unit 2

Carbon Cycle: Basic carbon dissolution chemistry in the sea water, solubility pump, biological pump, alkalinity of ocean and ocean acidification, air-sea gas exchange and oceanic pCO2Calcium Carbonate cycle and global climate: Glacial-Interglacial atmospheric CO2 exchanges, role of calcium carbonate, carbonate-silicate geochemical cycle, regulation of atmospheric CO2 and role of oceans

Books:

1. Sarmiento, J. L. and N. Gruber, (2007): OceanBiogeochemical Dynamics, Princeton University Press, pp-503.
2. Kump, L. R., J. F. Casting and R. Crane, (2010): The Earth System, 3rd edition, Prentice Hall, pp-420.

ATM-653-MJ Parameterization and Data Assimilation in Numerical Models (2 credits)

Course outcome

- Study the need and importance of parameterization and data assimilation in numerical models.
- Understand initialization and data assimilation techniques used in weather and climate models
- Learn about various subgrid scale processes and Physical parameterization schemes, and understand their merits and demerits.

Course content

Unit 1: Initialisation and Data Assimilation

Static, Dynamic, normal mode, Newtonian relaxation. 3d Var and 4d Var Concept of Kalman Filter

Unit 2: Parametrization

Subgrid scale processes, closure problem, Dry and moist adiabatic adjustment, cumulus parameterization. Shallow and deep convection, Kuo'sCumuluis Parameterization, Arakawa Schubert Parameterization, Grell Scheme, Betts Miller and Kain – Friesch Parametetization Schemes, Parameterization of PBL. Radiation parameterization. Orographic parameterization, Gravity wave drag and its parameterization.

Books

1. An introduction to Dynamic Meteorology by J.R. Holton, Academic Press.
2. Numerical Methods used in Atmospheric Models WMO-GARP Series No.17
3. Numerical Prediction and Dynamic Meteorology G.J. Haltiner and R.T. Williams,
4. Parameterization of subgrid scale processes WMO-GARP, Series No. 8.
5. Numerical Weather Prediction by P.D. Thompson

2. Major Elective Theory (MJ) Courses

ATM-510-MJ Introductory Earth Sciences (2 credits)

Course outcome

- Learn about the evolution and interior structure of the earth.
- Understand plate tectonics, continental drift, seismic activity and geophysical methods to evaluate plate tectonics.
- Understand the processes involved in rock formation.
- Study the weathering processes and soil formation.
- Study paleoclimate and Holocene monsoon variability, sea level changes, etc.

Course content

Unit 1

Evolution of the Earth, Laws of Universe and the evolution of the earth as planet, Interior of the earth and its evolution with geological time. Formation of internal layers and atmosphere, Evolution of the earth's atmosphere-, climate- and life, Geological Time Scale.

Earth's Crustal types: Continental and Oceanic, Crustal elements and Geodynamic processes (tectonics, erosion, uplift, deposition) responsible for the crustal evolution and morphology.

Plate tectonics and Geophysical methods: Continental drift and evolution of the theory of plate tectonics, Elements of plate tectonics (w.r.t. compressive, extensional and strike slip movements), Geophysical methods for plate tectonic evaluation (e.g., seismology, palaeomagnetism, magnetostratigraphy, GPS geodesy).

Processes and types of rock formations (igneous, metamorphic and sedimentary), mineralogical characteristics of the rocks, rock deformation. Geological framework of the Indian Subcontinent.

Unit 2

Weathering including weathering reactions, erosion, transportation and deposition of sediments. Soil forming minerals and process of soil formation, Identification and characterization of clay minerals, Soil physical and 4 chemical properties, soil types and climate control on soil formation, Cation exchange capacity and mineralogical controls.

Unit 3

Quaternary geology: Climate and Paleoclimates. Quaternary as chronostratigraphic unit, Standard sub-divisions of the Quaternary period and its climatic significance, Glacial-Interglacial stages, Milankovitch Cyclicity, Marine Oxy Isotope (MIS) stages, sea level oscillations.

Paleoclimates: climate change response of marine, glacial, fluvial, lacustrine, aeolian and biotic systems; paleoclimate proxy, feedback mechanism. Quaternary records of India: Records of Holocene monsoon variability, sea level changes, deglaciation, aridity etc.

Books:

1. The Inaccessible Earth: An integrated view to its structure and composition. By G. C. Brown and A. E. Mussett, CHAPMAN &. HALL
2. Looking into the Earth An introduction to geological geophysics, Alan E. Mussett and M. Aftab Khan
3. Physics of the Earth, By Frank D Stacey and Paul M Davis
4. Fundamentals of Geophysics by WILLIAM LOWRIE, Cambridge University Press
5. Lowe, J.J. & Walker, M.J.C., 1997. Reconstructing Quaternary Environments. 2nd Edition. Longman.
6. Ruddiman: "Earth's Climate, Past and Future
7. Bradley, R.S. 1985/1999. Paleoclimatology; reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego
8. Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment) by Alastair G. Dawson, A. G. Dawson
9. Global Tectonics by Philip Kearey, Keith A. Klepeis, Frederick J. Vine
10. Turback – Physical Geology

ATM-511-MJ Space Meteorology (2 credits)

Course outcome

- Become familiar with the structure and composition of the Sun.
- Learn Physical processes in gases and plasmas from the interior of the Sun to the Earth's atmosphere.
- Learn about the interaction of the Magnetic fields of the Sun and Earth.
- Understand how the sun drives large-scale plasma processes in near-Earth Space environment.
- Communicate to the public on how the Earth is coupled to space and Sun.

Course content

Brief Introduction of Plasma physics, Sun-Composition and Structure, Solar radiation, Solar atmosphere, Sunspots and solar rotation, Solar Cycle, Solar wind, Solar Flares and Coronal Mass Ejections.

Earth's atmosphere-ionosphere and magnetosphere. Propagation of CMEs in the IP medium, Interaction of solar wind with earth's magnetosphere, magnetic reconnection, geomagnetic storms. Implications of Space weather effects

Books:

1. Space Weather: Physics and Effects, By Volker Bothmer and I.A. Dagliz, Springer.
2. Solar Terrestrial Environment: Introduction to Geospace, By J.K. Hargereaves,Cambridge University Press.
3. Introduction to Space Physics, By Margaret G. Kivelson and Christopher T. Russell, Cambridge University Press.
4. Sun, earth and Sky, By Kenneth Lang, Springer Verlag.
5. Secrets of the sun, By Ronald Giovanelli, Cambridge University Press.
6. Beginners guide to Sun, By Peter Taylor and Nancy Hendrickson, Kalmbach Publishing Company.
7. Atmospheric Environment by T. Beer

ATM-560-MJ Dynamics of Atmospheric Waves and Instability (2 credits)

Course outcome

- Study the physics and dynamics of atmospheric waves and instability.
- Learn about planetary waves, how they propagate and their impact on weather and climate
- Understand different types of instabilities, how the atmospheric disturbances sustain themselves and how they impact weather systems.

Course content

Unit 1: Atmospheric waves

Equatorial Beta plane Approximation, Perturbation Theory, Wave motion in general, Atmospheric waves, Phase velocity, Group Velocity, Dispersion, Sound waves, Gravity waves, Inertial Waves Rossby waves, Haurwitz-Rossby waves, Mountain waves, Lee waves, Stationary planetary waves. Momentum and energy transports by waves in the horizontal and the vertical. Atmospheric Kelvin and Mixed Rossby Gravity Waves.

Unit 2: Atmospheric Instabilities

Dynamical Instabilties, Barotropic Instability, Baroclinic Inertial instability, Necessary condition of Barotropic and Baroclinic instability. Combined Barotropic and Baroclinic Instability. Kelvin - Helmholtz Instability.

Books:

1. An Introduction to Dynamic Meteorology, J.R. Holton, Academic Press.
2. Dynamic Meteorology,AskelWiin Nelson, WMO Publication.
3. Introduction to Theoretical Meteorology, S.L. Hess,
4. Dynamic and Physical Meteorology, G.L. Haltiner and F.L. Martin, Mc Graw Hill.
5. Ceaseless Wind by Dutton
6. Weather Forecasting Vol I and II by S. Pettersen

7. The Physics of the Atmosphere by Houghton
8. The Physics of Monsoons R.N. Keshava Murthy and M.Shankar Rao, Allied Publishers, 1992.
9. Atmospheric Waves by Tom Beer

ATM-561-MJ Atmospheric Boundary Layer (2 credits)

Course outcome

- Distinguish Atmospheric Boundary Layer (ABL) from rest of the troposphere, understand diurnal evolution, structure and important characteristics of the ABL and monsoon boundary layer.
- Learn conservation equations in the boundary layer and closure problem.
- Understand turbulent transport of energy and mass, turbulent kinetic energy and its budget in the boundary layer.
- Study surface energy balance.
- Learn about turbulence spectra in the atmospheric boundary layer.
- Study similarity theory and its applications, and boundary layer modelling concepts.

Course content

Unit 1

Structure, evolution and properties of atmospheric boundary layer. Convective, neutral and stable boundary layers. Surface boundary layer characteristics. Turbulent fluxes: Eddy transport of heat, moisture and momentum; Mixing length theory. Surface energy balance. Boundary layer turbulence.

Unit 2

TKE Budget, stability concepts, Richardson number, Obhukhov length. Governing equations in planetary boundary layer, closure problem. Ekman layer. Internal boundary layer, Similarity theory and its applications, Techniques for measurement of turbulent fluxes of momentum, heat and water vapour. Boundary layer modeling concepts.

Books:

1. Fluid Mechanics by L.D. Landau and E.M. Liftshifts, Pergamon Press.
2. Atmospheric Turbulence by Panofsky and J.A. Dutton.
3. Introduction to Boundary Layer Meteorology" Stull
4. The Atmospheric Boundary Layer, R.M. Stewart, WMO-523.
5. Micro meteorology by O.G. Sutton.
6. Micrometeorology by S.P. Arya, Academic Press
7. Atmospheric Boundary Layer Flows: Their Structure and Measurement. J. C. Kaimal and J. J. Finnigan, Oxford University Press.
8. An Introduction to Dynamic Meteorology, J.R. Holton, Academic Press.
9. "Practical Meteorology: An Algebra-based Survey of Atmospheric Science" -version 1.02b. Univ. of British Columbia. 940 pages. isbn 978-0-88865-283-6 . Stull, R., 2017.

ATM-562-MJ Physics and Dynamics of Middle Atmosphere (2 credits)

Course outcome

- Study the structure and composition of the middle and upper atmosphere
- Learn about the dynamical processes involved in the middle atmosphere
- Learn about the coupling and interaction between different atmospheric layers
- Study ozone and its variations in the stratosphere

Course content

Composition and structure of the stratosphere, mesosphere, and thermosphere, Changes in chemical composition - Homosphere, Heterosphere, Ozonosphere. Estimation Ozone: Total Ozone and Vertical Profile – Umkehr Method Seasonal and Spatial Variation of Ozone.

The ionosphere - composition morphology and general properties; influence on satellite and radio communication.

General climatology of the middle atmosphere, wind, and temperature distribution. Atmospheric waves and Atmospheric tides. Zonally averaged circulation energetics of the middle atmosphere. Quasi-Biennial Oscillation (QBO), Semiannual oscillation (SAO), Brewer-Dobson circulation and transport, The dynamics of the polar vortex, Stratospheric Sudden warming, the impacts of SSWs on surface climate.

Solar impact on the middle atmosphere, Lower atmosphere, and middle atmosphere interaction.

Books:

1. Middle Atmosphere Dynamics by C.G Andrews, J.R. Holton & C. Leovy
2. Aeronomy of the Middle Atmosphere by G. Brasseur and S. Simon
3. Introduction to Dynamic Meteorology by J.R. Holton
4. The Upper Atmosphere by R.A. Craig
5. Dynamic Meteorology of the Stratosphere and Mesosphere by J.R. Holton
6. Physics of the Earth's Upper Atmosphere by C.O. Hines, I. Paghis, T.R. Hatz& J.A. Fejer
7. Stratosphere-Troposphere interaction by K. Mohan Kumar
8. WMO/UNEP Scientific Assessment of Ozone Depletion, 2014, WMO, Geneva

ATM-563-MJ Extreme Weather and Natural Hazards- Seminar course (2 credits)

Course outcome

- Understand the physics behind extreme weather events and associated natural hazards such as extreme rainfall, extreme temperatures, floods, drought, etc.
- Learn to perform literature survey to collect the required information on specific topics, prepare reports and give presentations.

Course content

Topics for the seminar: Extreme precipitation, precipitation associated with storms such as cyclones and thunderstorms, cloud burst, extreme temperature, floods, droughts, heatwaves, cold waves, dense fog, climate change and extreme events.

Seminar topics on the above themes, and related to their observational and numerical modelling studies and studies based on data analysis can be selected for the seminar, under the supervision of a faculty member. A detailed report prepared based on the basic aspects and literature review also should be submitted for the evaluation. The seminar of 30-minute duration will be evaluated for 1 credit (25 marks) and the report will be evaluated for 1 credit (25 marks).

ATM-564-MJ Hydrometeorology (2 credits)

Course outcome

- Understand hydrometeorological processes and measurement of related parameters.
- Learn to assess variations in hydrometeorological processes in the climate change scenarios and help water resources management.

Course content

Hydrological Cycle, weather and hydrological hazards, droughts and floods, Factors affecting Runoff: Rainfall-Runoff Components; Hydrograph methods: Peak flow Equation; Run off variability; Urban runoff and modelling.

Precipitation and Evapotranspiration measurements. Rainfall networking; Radar rainfall estimation; Rainfall over catchments areas; optimization of rainfall Observations; Area depth Rainfall estimates; maximum probable rainfall; Free Surface Evaporation: Pan Evaporation water; budget and energy budget methods; mass transfer method; combined aerodynamic and budget method. Soil and plant evaporation Lysimetry. Soil moisture measurements.

Floods, Synoptic system causing floods, frequency analysis of rainfall, probability distribution.

Hydrometeorological modelling; Climate change impacts on hydrometeorological processes; water resources management.

Books

1. Introduction to Hydrometeorology by James R. Bruise and R.H. Clark
2. Introduction to Hydrology by Viessman
3. Cold Climate Hydrometeorology by D.S. Updhyay
4. Recent advances in the modeling of hydrologic systems: Series C : Mathematical and Physical Sciences, David S. Bowles and P. Enda O' Connel
5. Modelling components of hydrologic cycle. V.P Singh (Edited)

Land surface hydrology, meteorology and climate; Observations and Modelling, Venkataraman Lakmi, John Albertson and J. Sheake.

ATM-610-MJ Climate Services and Applications (2 credits)

Course outcome

- Understand climate variability and learn adaptation techniques and practices related to agricultural and forestry sector.
- Learn about risk assessment and early warning systems.
- Understand implications of climate change in energy sector.
- Learn about weather and health and water management strategies in changing climate scenario.

Course content

Concept of different sectors and climate services, Agriculture and Food Security: Climate Variability of Sunshine, Rainfall and Temperature. Agriculture policies, practices and technology to vulnerability of forestry and agriculture sectors.

Disaster Risk Reduction: Risk Assessment, Loss Data, Early Warning systems, Risk Reduction in sectors (Health, Water, Agriculture), climate risk management

Energy: Interactions of energy sector with other sectors (Ecosystems, Settlements, Health, Transport, Coastal Areas, Forestry, Agriculture). Impact on different energy subsectors to climate change projections and its implications.

Health: Factors relating weather and climate to health, current trends and gaps.

Water: Planning and management of water supplies and water management strategies under changing scenarios.

WMO framework and GFCS for climate services

Books:

1. Energy Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2017.
2. Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2014.
3. Appendix to the Agriculture and Food Security Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2014.
4. Disaster Risk Reduction Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2014.
5. Water Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2014.
6. Health Exemplar to the User Interface Platform of the Global Framework for Climate Services, WMO, 2014.

ATM-611-MJ Weather Radar (2 credits)

Course outcome

- Develop expertise in atmospheric RADAR functioning and its operations in different environments
- Study different types of RADAR and signal processing
- Learn how to interpret the RADAR products and their applications.

Course content

Radar principles, Classification of RADARS-Weather and Atmospheric Radar, Radar Hardware, History of radar in atmospheric investigation,nRadar Equation for Point Targets, Distributed Targets.
Derivation of Radar parameters-Doppler Velocity Measurements, Spectrum Width and turbulence, Meteorological Targets, Meteorological Uses of Weather Radar, Signal Processing of Radar returns and their applications

Books:

1. Radar Meteorology by L.J. Batton
2. Radar Observation of the Atmosphere By Battan (1973),
3. Doppler Radar and Weather Observations ByDoviak and Zrnic (1984, 1993),Academic Press
4. Radar in Meteorology, Atlas (1990), AMS (Battan Memorial volume)
5. Atmospheric Radar by Wayne K. Hocking, Jurgen Rottger, R.D. Palmer, T. Sato, P.B. ChilsonCambridge Press
6. Radar for Meteorological and Atmospheric Observations by ShoichiroFukao and Kyosuke Hamazu, Springer
7. Polarimetric Doppler Weather Radar By Bringi and Chandrasekar (2001),Cambridge Press
8. Radar and Atmospheric Science: A Collection of Essays in Honor of David Atlas (2003), AMS.
9. Radar Polarimetry for Weather Observations. 2019. Ryzhkov and Zrnic. Springer Cham, ISBN 978-3-030-05092-4.

ATM-612-MJ World Weather Analysis- Seminar course (2 credits)

Course outcome

- Develop expertise in providing updated information on the important meteorological conditions and weather features occurred all over the world.
- Training to prepare reports and give seminars on weather related topics.

Course content

Each student has to give seminar reporting on the world weather for the period identified by the Seminar teacher. Seminars will be evaluated for 25 marks. The student has to submit a seminar report incorporating the basic aspects of the weather features reported and review of the related literature, which will be evaluated for **25** marks. The seminar and report preparations should be carried out under the supervision of the faculty member.

ATM-613-MJ Urban Meteorology (2 credits)

Course outcome

- Learn the important features of urban weather and climate.
- Understand the urban heat island, urban air quality and human thermal comfort.
- Study urban effects on precipitation, urban flooding and effects of climate change in urban areas.
- Learn about the measurement and modelling techniques to better understand urban energy balance, hydrometeorological processes and air quality

Course content

Urban weather and climate, introduction to urban micrometeorology, key features of the urban environment, tropical urban climates; hydrometeorological aspect of the urban environment, urban water cycle and its response to precipitation extremes, urban flooding and droughts.

Urban land use classification, energy balance of urban surfaces, urban boundary layer, physical mechanisms behind the urban heat island, interaction between heat waves and heat island, thermal comfort. Urban air quality.

Urban effects on precipitation; modelling and observational techniques to study the urban energy and water balance and air quality; role of hydrometeorology in urban planning; Environmental impacts of urban expansion; effect of climate change in urban areas.

ATM-614-MJ AI-ML for Meteorological Applications (2 credits)

Course outcome

- Familiarise the students with machine learning algorithms, focusing on their practical application in Earth system Sciences data analysis and modelling.
- Learn fundamental principles and concepts behind deep learning techniques.

Course content

Unit 1

File formats and metadata; read, analyse and visualize the data using Python routines;

Basic concept of data pre-processing including familiarity with normalization formulae data transformation from one space to another space, employing supervised data splitting techniques to prepare the data for model training.

Basic concept of machine learning algorithm, Supervised Learning, unsupervised learning; generate insight for cluster, density and anomaly etc.

Unit 2

Supervised ML: Regression for forecasting or prediction-nowcasting, short-range forecasting etc.; Classification: category of the observation or data; image classifications-cloud category from a set of satellite images; K-nearest Neighbours; Linear regression (Polynomial regression, Regularization etc.); Logistic regression (classification algorithm); Support Vector Machines; Decision Tree and Random forest; Neural networks.

Unsupervised Learning: Clustering, find pattern in the data; Density estimation and Anomaly detection, Find PDF of un labelled data; Dimensionality reduction, Reduce the feature space to a manageable mode informative quantity.

Clustering, K-Means and other methods; Anomaly detection, One-class SVM and Isolation Forest; Visualization and Dimensionality Reduction, Principal Component Analysis (PCA) or Locally Linear Embedding (LLE).

Fundamentals of the Deep Learning algorithms.

ATM-660-MJ Agricultural Meteorology (2 credits)

Course outcome

- Understanding on the importance of weather and climate in agriculture production.
- Learn important weather and soil parameters, their variations and influence on crop growth and yield.
- Understand the impact of extreme events such as droughts and floods on crops.
- Relationship between weather elements and the outbreak and spread of diseases and pests and their forecasts.
- Understanding on agroclimatic classifications in India, season dependent agricultural practices in India.
- Familiarize with the crop yield simulation models.

Course content

Unit 1

Influence of weather and climate on agriculture, Important agro-meteorological parameters, their diurnal and seasonal variations and role in plant growth, evaporation and evapotranspiration, soil temperature and soil moisture, Concept of Growing Degree Days (GDD).

Agricultural droughts, Effects of floods, effect of weather elements on the outbreak and spread of diseases and pests, forecasting of pests and diseases.

Agroclimatic classifications, Rainfall Climatology for Agricultural planning, Effect of rainfall aberration on crops, Dependence of agricultural production in India on monsoon, agricultural season of India, sowing dates, Moisture Availability Index (MAI), agroclimatic normal for field crops. Drought monitoring and planning

Unit 2

Photosynthetically active radiation (PAR), influence of CO2 concentration variations on photosynthesis, Effects of temperature and moisture in plant growth, damage due to freezing temperature and high temperature for crops, soil temperature and crop yield, Soil moisture, water stress and plant development.

Crop yield forecast model, modeling crop growth and production. Concept of DSSAT.

Books

1. Agrometeorology: Principles and Applications of Climate Studies in Agriculture.By Harpal S. Mavi and Graeme J. Tupper
2. Food Products Press, An Imprint of The Haworth Press, Inc., New York
3. Hand book of Agricultural Meteorology. Edited by John .F.Griffiths
4. Drought Management on Farmland by J.S Whitmore , Kluwer Academic Publisher
5. Introduction to Agrometeorology by H.S.Mavi

ATM-661-MJ Atmospheric Energetics and General Circulation (2 credits)

Course outcome

- Understand general circulation features of the earth's atmosphere.
- Learn about zonal and meridional circulation.
- Understand energetics of the atmosphere.

Course content

Time mean fields and statistics of observed general circulation; zonally symmetric and asymmetric components; mean-meridional circulation and eddies; Maintenance of zonally mean circulation and eddies. Energetic of the atmosphere- Total Potential Energy, Available Potential Energy, Kinetic Energy. Conservation of angular momentum and Kinetic Energy.

Books:

1. The nature and theory of General Circulation of the atmosphere E.N. Lorenz WMO Publication.
2. The Global Circulation of the Atmosphere Edited By G.A. Corby, Royal Meteorological Society.
3. Global Atmospheric Circulationby Richard Grotfahn, Oxford University Press.

ATM-662-MJ Satellite Observations for Meteorological Applications (2 credits)

Course outcome

- Develop expertise in the meteorological applications of satellite observations.
- Learn about the basics of satellite remote sensing, laws, orbits, orbital parameters.
- Learn about identification of cloud types and patterns in satellite images.
- Learn the estimation of parameters such as SST, Temperature, Winds, rainfall, etc.
- Become familiar with the hardware and payloads on the meteorological satellites.
- Learn D'vorak's technique for tropical cyclone intensity estimation.

Course content

Unit 1:

Remote sensing principles, Application in meteorology. Signal Sensor, platform, Signature for Interpretation. Satellite orbits and attitude: principles of satellite motion, Kepler's laws, Sub satellitepoint, Apogee, perigee, node anti node**,** Electromagnetic spectrum, Radiation laws. Spatial Resolution Temporal Resolution ,Spectral Resolution, Radiometric Resolution.

Orbital mechanics orbital elements, satellite attitude. Types of orbits- earth- and sun-synchronous, polar orbiting and geostationary satellites. Concept of pitch roll and yaw.

Visible, infrared, and microwave channels; Scanning mechanism, IFOV and contrast enhancement in an image.

Identification of cloud types and patterns in satellite images, synoptic systems, estimation of SST, cloud top temperatures, winds and rainfall: temperature and humidity soundings.

Unit 2:

Hardware details of INSAT Meteorological Data Processing System (IMDPS) including Earth Station. Current and future meteorological satellites of the world. Payloads on Meteorological Satellites, NOAA, INSAT -3D, Meghatropiques, etc.

Quantitative product derivation from satellite data: Sea surface temperature, outgoing longwave radiation, cloud motion vectors, computation of NDVI. Algorithm for vertical temperature and humidity profiles. Microwave retrievals: TRMM satellite, Global Precipitation Mission, Global Precipitation Climatology Project. D'vorak's technique for tropical cyclone intensity estimation. Ozone and aerosol estimation using satellite radiance

Books:

1. Theory of Satellite Orbit in the Atmosphere by King Hele
2. Weather Satellite by L.F. Hubert
3. Meteorological Satellite by W.K. Widger
4. A guide to Earth Satellite by D. Fishlock
5. Advances in Satellite Meteorology by VinnichenkoGoralik

6. Satellite meteorology by Henri W. Brandli
7. Satellite Meteorology - WMO Technical Notes No. 124 and 153.
8. Satellite Meteorology, by R.R. Kelkar

ATM-663-MJ Climate Communication (2 credits)

Course outcome

The course aims to look at communicating climate reports and its relevance for an emerging scientific community (in this case, students) engaging with climate change impacts on various communities in different geographies. How does one translate scientific concepts into easy-to-understand formats? What are the benefits of doing so? What kind of additional socio-economic or cultural context is required to make the communication of climate change impacts relatable? How does one contextualize the finds of IPCC AR6 for diverse audiences?

The course urges students to reflect on the dominant climate change narrative. Also, by extension, it urges students to reflect on what is missing from the discourse. This allows students to contextualize and emphasize specific messages around climate change impacts for diverse audience groups and develop complementary and multiple climate narratives.

It also encourages them to think about the relevance of information to various audience groups. Does one communicate the exact same set of ideas and information to a farmer, safai kamgaar, garment factory worker, water-bride, and IT employee? Or, are their information needs unique to their socio-economic and geographic realities? What are their concerns regarding climate change?

Course content

The multi-dimensional nature of climate change and challenges in its communication so far, climate reporting v/s climate communication, key message and learnings from climate reports, relevance of climate reports for the non-scientific community, understanding different audiences and the need to communicate with them effectively, different forms of communication and their advantages and disadvantages, role of geographical diversity and socio-economic context on climate communication, contextualizing information based on the audiences, relevance of global reports in local contexts, translation of global reports for local contexts and audiences, introduction to the concept of narratives and their importance in effective communication, lost in translation - how and which information is necessary and in which context.

Books

1. IPCC Assessment Report 6
2. Assessment of Climate Change over the Indian Region, Krishnan et al., 2020. A report of the Ministry of Earth Sciences, Govt of India. Springer, ISBN 978-981-15-4327-2.
3. Multimedia sources of climate information and reporting
4. Scientific and non scientific articles on climate communication
5. Research reports and research articles

ATM-664-MJ Solar and Wind Energy Resources (2 credits)

Course outcome

- Understand solar and wind energy generation.
- Learn to analyse data related to solar radiation and wind.
- Learn site selection procedures for the installation of solar power and wind energy farms.
- Understand numerical modelling procedures for the prediction of solar radiation and wind at selected locations and regions.

Course content

Unit 1

Basics of solar energy conversion - solar thermal and solar Photo Voltaic (PV), Solar thermal and Solar PV devices and its performance variations w.r. t. E.M. spectrum; Historical and online solar radiation and wind speed data sources. Statistical validation with onsite measured data.

Solar Power Estimation, Solar radiation data analysis for solar thermal applications such as water heating, Solar radiation data analysis for solar concentrators, Solar radiation for Photovoltaic systems - Estimating energy from solar radiation and PV panel characteristics curve. Site selection procedures.

Unit 2

Basics of wind energy conversion and conversion techniques, Speed and direction measurements at multiple levels up to 100/120 m height, Instrumentation specifications and standards, practices

Wind Energy Estimation, Analysis of wind data series data for energy estimation - Definition of wind energy, wind velocity sensitivity of power estimation, data retrieval, Quality Control, data processing, Weibull distribution curve fitting, wind power density estimation, wind energy estimation from power curve of wind turbine, Wind data handling software, wind energy estimation software. Site selection procedure.

Unit 3

Wind and Solar Energy Forecasting, Need for wind/solar energy forecasting - linked with wind speed and solar radiation forecasting, Governing mechanism and implications, Forecasting models, frequencies and its adaptability for Indian conditions, Regional forecasting practices. Extreme weather condition analysis of a site - for solar and wind Power projects.

Books

1. Solar Energy Engineering, A A M Sayigh, 1977, Academic Press

2. Solar Energy –Principles of thermal collection and storage, S P Sukhatme, 2009, The McGraw Hill Publications

3. Solar Photovoltaic technology and systems, Chetan Singh Solanki, PHI publication, 2013

4. Solar Energy forecasting and resource assessment, Jan Kleissl, ISBN-13: 978-0123971777 ISBN-10: 0123971772

5. Technical Note No. 175. 1981. Meteorological Aspects of the Utilization of Wind as an Energy Source. WMO No. 575. 180 pp

6. Wind Energy Explained, J F Manwell, J G McGowan, A L Rogers, 2002/2009, WILEY Publications

7. Wind resource assessment and forecasts with artificial neural network (ANN), LAP Lambert Academic Publishing, 2014

8. Integrating renewables in electricity market, operational problems, 2013, SPRINGER publication

3. Major Core Practical (MJP) Courses

ATM-504-MJP Laboratory Course I- Fortran Programming and Numerical Problem Solving (4 credits)

Course outcome

- Learn FORTRAN programming.
- Learn to write FORTRAN programs for statistical and numerical methods computations.

Course content

Unit 1: Fortran Programming

FORTRAN fundamentals: integer constant, floating point constant, variables, arithmetic operator, relational operator, FORTRAN arithmetic and expression, input/output and format statements, declaration and initialization, branching and looping, Arithmetic IF, Logical IF, Unconditional GO TO, Computed GO TO, DO statement, Nesting of DO Loops, Dimension Statement, arrays, multi-dimensional arrays, functions, sub-programs and subroutines.

Unit 2: Numerical Analysis

1. Solution of algebraic and transcendental equation by Newton- Raphson's method
2. Numerical Integration by Trapezoidal and Simpson's Rule
3. Fitting of straight lines by Least square method
4. Computation of Correlation Coefficient, chi-squares Test, T-test.
5. Data Interpolation.
6. Estimating trends linear and Man kendall.
7. Power Spectrum Analysis
8. Finite difference schemes for first and second derivative.
9. Harmonic Analysis
10. Solution of Differential Equations by Runge – Kutta method.

Any six problems to be completed

ATM-554-MJP Laboratory Course II- Thermodynamic Diagrams and Atmospheric Data Analysis (4 credits)

Course outcome

- Learn to plot radiosonde data on thermodynamic diagram, calculate thermodynamic parameters, analyse and interpret.

- Get familiar with the different data sets: NetCDF, text, HDF, etc.
- Learn to analyze and interpret different in situ, ground based remote sensing, satellite, reanalysis and model datasets.
- Analyze the plots which help in gaining insights about the different data.

Course Content

Unit 1: Plotting and Analysis of Radiosonde data on Thermodynamic Diagram

Plotting and analysis of radiosonde data on thermodynamic diagram for different seasons and stations.

1. Estimation of LCL, CCL, LFC, and LNB.
2. Computation of K-index and Lifted Index
3. Computation of total precipitable water.
4. Computation of CAPE and CINE.
5. Computation of Conditional Instability

Unit 2: Observational data analysis

Familiarization with meteorological instruments and observations; Analysis of weather data, reanalysis data, satellite data, remote sensing and *in situ* instruments, aerosols using ground-based instruments; aerosol spectrometer, Athelometer.

1. Analysis of Aerosol Properties using Aerosol Robotic Network stations.
2. Analysis of aerosols using satellite based sensors; MODIS, TOMS, MISR etc.
3. Analysis of clouds/ aerosols, temperature vertical profiles using satellite sensors CloudSat, CALIPSO etc.
4. Analysis of surface meteorological data like temperature, pressure, wind speed, rainfall etc.
5. Analysis of upper air data; using radiosondes, ozonesondes
6. Analysis of cloud characteristics using ground based instruments; Ceilometer.
7. Analysis of precipitation characteristics using disdrometer, raingauge
8. Analysis of Reanalysis data using Grads/ Ferret etc.
9. Analysis of data from Radiation Sensors.
10. Familiarization with meteorological instruments and measurement procedures at an observatory/ field laboratory, report writing.

Any seven problems should be completed.

ATM-604-MJP Laboratory Course III- Numerical Methods for NWP and Atmospheric Dynamics (4 credits)

Course outcome

- Perform advanced computational exercises for time series analysis and numerical methods.
- Perform computations to estimate various dynamic meteorology and Numerical Weather Prediction related parameters to study atmospheric processes.

Course content

Computations in Dynamic Meteorology and NWP

1. Computation of Harmonic Analysis of a given time series.
2. Computation of geostrophic wind and geostrophic vorticity.
3. Computation of vertical velocity using Kinematic method.
4. To determine stream function from geopotential field using Relaxation method.
5. Computation of Velocity potential using observed or reanalysis wind data.
6. Objective analysis of geopotential height.
7. Five point and Nine point Arakawa Jacobian Scheme.
8. To determine geopotential heights from wind field-using linear balance equation.
9. Solution of non-divergent barotropic vorticity equation.
10. Computation of apparent heat source and moisture sink.
11. Estimation of pollution from point source.
12. Hands-on experience of DSSAT software

Seven practical exercises will have to be finished to complete the course.

ATM-654-MJP Laboratory Course IV- Numerical Simulation of Weather and Climate (4 credits)

Course outcome

- Develop expertise on the practical use of numerical models for weather and climate research.
- Learn to install numerical models in the computer
- Perform case study simulations of selected events and processes.
- Learn to analyze weather and climate model outputs and conduct group discussion about the results

Course content

Unit 1

- Overview of WRF/ Regional Climate Modeling System Components.
- Installation and Initialization of WRF/ Regional Climate Model.
- Test the installation and perform simulations (Ideal/ Real Cases).
- Analyze the output using visualization and analysis software.

Unit 2

- Overview of ocean models
- Perform analysis of ocean model output using visualization and analysis software with defined objectives to study ocean processes

Unit 3

- Overview of climate models
- Perform analysis of climate model output using visualization and analysis software with defined objectives to study the climate, its variations and change.

Students should complete WRF simulations as per details in Unit 1 and complete either Unit 2 or Unit 3.

Reference:

https://www.mmm.ucar.edu/weather-research-and-forecasting-model

https://www.ictp.it/research/esp/models/regcm4.aspx

4. Major Elective Practical (MJP) Courses

ATM-512-MJP Laboratory Course- Python for Data Analysis and Visualization (2 credits)

Course outcome

- Develop expertise in Python programming.
- Learn to write computer programs in Python for different computations.
- Lean to plot X-Y plots and contour color scale plots.

Course content

Unit 1

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

Unit 2

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

Unit 3

Python Input Output-Fancier Output Formatting, Old string formatting, Reading and Writing Files, Methods of File Objects, the pickle Module, Errors and Exceptions: Exceptions, Handling Exceptions, Raising Exceptions, User-defined Exceptions, Defining Clean-up Actions, Predefined Clean-up Action. Applications of Numerical Python, Scientific Python and Mat plot lib.

Unit 4

Analysis of reanalysis meteorological data and plot the results.

Books:

1. A Primer on Scientific Programming with Python (First Edition), Hans PetterLangtangen, Springer, 2009
2. Head first programming: a learner's guide to programming using the python language, David Griffiths
3. Python Programming: An Introduction to Computer Science, John M. Zelle
4. Python for Data Analysis: Data Wrangling with Pandas, NumPy, and Ipython, Wes Mckinney

ATM-513-MJP Laboratory Course- R programming (2 credits)

Course outcome

- Learn R-programming.
- Write computer programs in R for numerical and scientific computing applications.
- Lear to plot X-Y plots and contour colour scale plots.

Course content

An overview of R, R data types and objects, Reading and Writing in different types of file formats, Vectors, factors and univariate time series, Data frames and matrices, Functions, operators and loops, Graphics in R, Styles of Data analysis, Statistical Models, Applications of Numerical, Scientific and plotting., Simulation, code profiling

Books:

1. Zuur A., Ieno E., Meesters E. A beginner's guide to R , Springer, 2009

ATM-565-MJP Laboratory Course- Weather and Climate Data Analysis and Visualization Techniques (2 credits)

Course outcome

- Study data analysis and visualization requirements for atmospheric research.
- Learn programming using Ferret, GrADS and NCL.
- Learn to analyze large datasets and plot the results in different formats.

Course contents

Unit 1: Ferret

Introduction to Ferret, basics of programming, commands and syntax, Data sets basics– NetCDF, Binary, Ascii, gridded and non-gridded; special data sets, reading data; converting to NetCDF, defining variables and expressions, external functions, use of grids and regions, graphical output, contour plots, generating images and animations.

Unit 2: GrADS

Basics of GrADS. Basic commands, manipulating dimensions, variables, expressions and functions, graphics types, projection maps, generating graphics output.

Unit 3: NCL

Basics of NCL programming. Input, Export and Graphics Output File Formats; syntax, variables, expressions, algebraic operators, logical operators, functions, data types, arrays, conditional statements, loops, reading and writing different data types, graphics, map grid, map projection, contour and vector plots, overlay plots, advanced NCL features.

Unit 4: Case Study

Analysis of reanalysis meteorological data and plot the results.

Any two programming tools from the above can be selected to complete the course.

ATM-665-MJP Laboratory course- Weather Chart Analysis (2 credits)

Course outcome

- Develop expertise in meteorological chart analysis and interpretation
- Learn the steps involved in the analysis of meteorological charts
- Understand typical synoptic conditions over the Indian region in association with different seasons and learn to represent them on the charts
- Learn to interpret the expected weather conditions using the synoptic charts

Course content

Symbols associated with synoptic systems, variables plotted on synoptic charts; Attend map discussion/ weather chart analysis at the Meteorological department for familiarization.

Analysis of Surface and upper air weather charts of some typical synoptic situations over India:
a) Monsoon: Break Monsoon, Strong Monsoon, MTC and Monsoon Depression b) Western Disturbance c) Tropical Cyclone.

5. Internship (OJT)

ATM-581-OJT Internship Training (4 credits)

Course outcome

- Train the students to apply the knowledge gained in the classrooms for practical applications.
- Learn to carry out assigned tasks in an environment outside the University campus.
- Hands on training on meteorological observational techniques, high performance computing systems, data analysis and numerical modelling techniques.
- Learn to perform literature review of published research articles and write research reports.
- Learn to interlink classroom learning with solving research problems

Course content

During Internship training, students are expected to learn meteorological observations and analysis/ laboratory experiments and analysis/ use high performance computing systems/ numerical modelling techniques. The students may also choose to carry out literature survey of published research on a selected topic related to the atmospheric/ ocean/ climate sciences. The internship should be carried out under a supervisor. The duration of the training will be equal to three weeks full time load.

The Internship Training will be assessed for 4 credits in the following manner.

Continuous Assessment: - 2 credits to be given by the guide as continuous assessment. Semester-End-Assessment: - 2 credits for the viva-voce examination and report (which will be conducted by two examiners recommended by the Teaching Committee.)

The student has to obtain 40% marks in the combined Continuous Assessment and Semester-End-Assessment with a minimum passing of 30% in both of these separately.

If the student fails in Internship Training and wishes to improve the continuous assessment then he has to repeat the entire Internship Training either in the same topic or a different topic.

The place and topic of Internship training has to be approved by the Teaching Committee of the Department.

6. Research Project

ATM-631-RP Project Work I (4 credits)

Course outcome

- Learn different aspects of carrying out research on topics related to Atmospheric/ Climate/ Ocean Sciences.
- Learn how to define the research objectives by identifying gap areas in the published research, select datasets, numerical models and analysis techniques, perform analysis, interpret results.
- Learn to write project reports and research publications.

Course content

During the research project, students are expected to carry out research on a selected topic related to the atmospheric/ ocean/ climate sciences. The project should be carried out under the supervision of a faculty member at the University or a scientist at a research institution. The duration of the training will be equal to three weeks full time load, which may be distributed throughout the semester.

The steps involved during the execution of the project broadly involves: Choose a broad research field, perform literature review, identify gaps in the research already carried out and select a topic for the study, define objectives, devise methodology, perform analysis, interpret results and write report incorporating all the aspects of the study.

Guidelines: The place, topic of the project and supervisor has to be approved by the Teaching Committee of the Department. If the project is carried out outside the University department, there will be an internal guide from the University department. If the project is done in the University department then another faculty member will be the co-guide. The internal guide/ co-guide will be assigned by the Teaching Committee or Head of the Department. The student should interact with the guide regularly and also report to the Co-Guide/ Internal Guide on scheduled days.

The student will be required to submit a project report to the department at the end of the semester.

The project work will be evaluated for **1** credit by the Guide and **1** credit by the internal/ co-guide which will form the continuous assessment.

For the Semester-end examination, the project report will be evaluated by an examiner for 1 credit. The student will have to give a Viva-voce examination which will be evaluated for **1** credit by two examiners. The examiners will be assigned by the departmental examination committee.

The student has to obtain **40%** marks in the combined Continuous Assessment and Semester-End Assessment with a minimum passing of **30%** in both these separately.

If the student fails in the Project and wishes to improve the continuous assessment, then he has to repeat the entire project either in the same topic or different topic.

ATM-681-RP Project Work II (6 credits)

Course outcome

- Learn all aspects of carrying out research on Atmospheric/ Climate/ Ocean Sciences.
- Learn how to define the research objectives by identifying gap areas in the published research, select datasets, numerical models and analysis techniques, perform analysis, interpret results.
- Learn to write project reports and research publications.

Course content

During the research project, students are expected to carry out research on a selected topic related to the atmospheric/ ocean/ climate sciences. The project should be carried out under the supervision of a faculty member at the University or a scientist at a research institution. The duration of the training will be equal to five weeks full time load, which may be distributed throughout the semester. Research Project II can be continuation of the Research Project I.

The steps involved during the execution of the project broadly involves: Choose a broad research field, perform literature review, identify gaps in the research already carried out and finalize a topic for the study, define objectives, devise methodology, perform analysis, interpret results, write report incorporating all the aspects of the study.

Guidelines: The place, topic of the project and supervisor has to be approved by the Teaching Committee of the Department. If the project is carried out outside the University department, there will be an internal guide from the University department. If the project is done in the University department then another faculty member will be the co-guide. The internal guide/ co-guide will be assigned by the Teaching Committee or Head of the Department. The student should interact with the guide regularly and also report to the Co-Guide/ Internal Guide on scheduled days.

The student will be required to submit a Project report to the department the end of the semester.

The project work will be evaluated for **2** credits by the Guide and **1** credit by the internal/ co-guide which will form the continuous assessment.

For the Semester-end examination, the project report will be evaluated by an examiner for **1** credit. The student will have to give a Viva-voce examination which will be evaluated for **2** credits by two examiners. The examiners will be assigned by the departmental examination committee.

The student has to obtain **40%** marks in the combined Continuous Assessment and Semester-End Assessment with a minimum passing of **30%** in both these separately.

If the student fails in the Project and wishes to improve the continuous assessment then he has to repeat the entire project either in the same topic or different topic.

The place and topic of the Project has to be approved by the Teaching Committee of the Department.

7. Research Methodology

ATM-505-MJ Methodology for Atmospheric Research (4 credits)

Course outcome

The students will learn:

- Mathematical and statistical methods frequently used in atmospheric research
- To conduct literature survey, write reports and manuscripts in specific formats
- To prepare for oral and poster presentations of the results to present at conferences.

Course Content

Unit 1: Mathematical methods for atmospheric research

Ordinary Differential Equations. Partial Differential Equations and their solutions. Spherical harmonics, Legendre polynomial, Laguerre polynomial, Hermite polynomial, Bessel function.

Matrices: Hermitian and Skew Hermitian, orthogonal and unitary matrices, Eigen-values and Eigen-vectors of symmetric as well as non- symmetric matrices and their applications.

Fourier series, Finite Differences, Methods of obtaining eigen values, eigen vectors.

Laplace, Fourier and Wavelet transforms

Unit 2: Statistical methods for atmospheric research

Statistical analysis and its significance, Probability theory, probability density function least squares method.

Regression equation, coefficients of correlation by Rank Correlation as well as Product Moment method and their significance, partial and multiple correlations and their applications. Poisson and Gaussian distribution and gamma distribution, random walk.

Linear correlation, Rank correlation, Partial and multiple correlation. Normal, binomial, gamma. Students-t test, chisquare distributions. Multiple linear regression, Principal component analysis, canonical correlation analysis. Error Analysis, Sampling and Test of Hypothesis, Analysis of variance.

Softwares for statistical analysis

Unit 3: Literature survey and report writing

Training on conducting literature survey and writing summaries, selection of topics for research; Scientific journal specific formats of referring and listing the publications in the manuscripts,

familiarization with the formats of research papers, technical reports and research proposals. Research ethics.

Unit 4: Scientific Presentation

Oral presentation: Common formats for preparing presentations, identification of contents to present, preparing power point presentation, giving a presentation on selected topics.

Poster presentations: Size and format of the poster, designing a poster, preparing the results and contents for the poster, presenting the poster.

Books:

1. Partial differential equations of Mathematical physics, Vol. 1 by A.N. Tychonov and A.A. Samarski (S. Radding Holdenday Inc.).
2. Numerical Analysis - the mathematics of computing, Vol. 1 and 2, W.A. Watson, T. Philipson and P.J. Oates (Edward Arnold Publication).
3. Time Series Analysis and Forecasting O.D. Anderson (Butterworths Publication)
4. Numerical Methods in Engineering by Mario G. Salvadore and M.L. Baran.
5. Applied Mathematics for Scientists and Engineers by Pipes
6. Partial Differential Equations by Ralston and Wilf
