SAVITRIBAI PHULE PUNE UNIVERSITY

Department of Atmospheric and Space Sciences

Revised

Structure of Course and Detailed Syllabus

M. Tech. (Atmospheric Science)

Under Technology Faculty

Revised
2017

Preamble of the Syllabus: 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.

The UGC through Gazette Notification of 2014 has put M.Tech. in the Engineering/ Technology Faculty. Therefore, M.Tech. (Atmospheric Science) through circular number 196/2015 dated 28/08/2015 the M.Tech. (Atmospheric Science) has been shifted to Technology Faculty. The syllabus was approved in 2015.

Eligibility:

B.E./ B.Tech. in any of the following branches: Mechanical, Electrical, Electronics, Electronics and Telecommunication, Computer, Civil, Agricultural, Environmental, Chemical, Aerospace, Information Technology, Biomedical, Engineering Physics, Instrumentation, Production and Industrial.

55% marks or GPA of 3.5 out of 6.0 or 5.5 GPA out of 10. A relaxation of 5% marks or 0.5 GPA will be considered for reserved candidates who are domiciles of Maharashtra.

Admission: Will be through entrance test. Syllabus for entrance test to be framed by the department committee. There will be negative marking.

Examination :

A. Pattern A student will have to complete a total of 100 credits, details of which are given in the enclosed course structure

   i) Each credit will be for 20 marks. 10 marks for continuous assessment and 10 marks for final assessment.

Continuous assessment can be done through Seminars/ Assignments/ Oral test/ Written test.

ii) The final assessment for theory courses will be in the form of written examination for the whole course. As some of the optional courses are for smaller credit if a particular course is completed well before the term ends then the teacher concerned need not wait for the end of term examination to conduct the final assessment. The final assessment can be done in consultation with the Head of Department or Course Coordinator or the Chairman Examination Committee. However the result will be declared only after the end of term exams are completed.

Examination procedure for Internship Training and Project are given in the detailed syllabus.

B. Standard of Passing: 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 in force will be applicable.

C. ATKT Rules The student has to clear at least 50% of the credits of the first year before he can be allowed to take admission for the second year courses. 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.

M.Tech. (Atmospheric Science)

COURSE STRUCTURE

Course No.	Course Title	Credits
	FIRST YEAR {Semesters I and II}	
ATM-01-T	Introductory Meteorology & Earth Science	4
ATM-02-T	Mathematical and Statistical Methods	2
ATM-03-T	Atmospheric Instrumentation	4
ATM-04-T	Atmospheric Thermodynamics and Radiation	4
ATM-05-T	Physical and Dynamic Oceanography	2
ATM-06-T	Atmospheric Dynamics-I	4
ATM-07-T	Atmospheric Dynamics-II	4
ATM-08-T	Cloud Physics and Atmospheric Electricity	4
ATM-09-T	Numerical Weather Prediction	4
ATM-10-T	Parameterization	2
ATM-11-T	Atmospheric Boundary Layer and Turbulence	4
ATM-12-T	Satellite Technology and Application	2
ATM-22-L	Laboratory Course I	5
ATM-23-L	Laboratory Course II	5
	SECOND YEAR	
	Semester-III	
ATM-13-T	Climate Science and Modelling	4
ATM-14-T	Atmospheric Chemistry	2**
ATM-15-T	Tropical Meteorology and Monsoon	2**
ATM-16-T	Mesoscale Modelling	2**
ATM-17-T	Agrometeorology	2 **
ATM-18-T	Air Pollution	2 **
ATM-19-T	Hydrometeorology	2**
ATM-20-T	Middle Atmosphere	2**
ATM-21-T	Renewable Energy	2**
ATM-24-P	Internship Training	15
ATM-26-L	Laboratory Course- Mesoscale Simulation	4
	Semester-IV	
ATM-25-P	Project	25

**** Optional Courses**

Each Credit is of 15 Hours in the form of Lectures/ Tutorials/ Seminars/ Contact Hours: T- Theory; L- Lab work; P- Project/ Training

ATM-01-T Introductory Meteorology & Earth Science [4 Credits]

Basics

Definition of wind, squall, gustiness, gale, Beaufort scale, land and sea breeze, katabatic and anabatic winds, Buys-Ballot's law, geostrophic wind, visibility, causes of poor visibility, haze, mist, fog, tropical depression and storm, diurnal variation of surface pressure, surface and air temperature, wind, rainfall, humidity and cloudiness, basic ideas of general circulation (without mathematical derivations).

Synoptic

Introduction to synoptic meteorology, scales of weather systems, 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. Synoptic weather forecasting: prediction of weather elements such as rain, maximum and minimum temperature and fog; hazardous weather elements like thunderstorms, dust storms, tornadoes.

Climatology

Definition of climate, physical factors of climate, earth-sun relationship, ecliptic and equatorial plane, rotation of the earth, seasons, climatic controls. Climatic classification: methods of Koppen and Thornthwaite. Microclimate- basic concepts.

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 temperature and winds. Upper air climatology during winter and summer.

Indian climatology: Climate zones of India; pressure, wind, temperature and rainfall distribution during the four seasons. Western disturbances, fog, thunderstorm, hail, cold waves, subtropical jet stream, south-west and north-east monsoon, interaction of low and high latitude disturbances.

Earth Science

Earth as a planet of the solar system: its origin and internal structure, physical and chemical characteristics of the internal zones, crustal types, Archaean shields and Cratons, heat flow and temperature gradient.

Geomagnetism, magneto-stratigraphy, palaeomagnetism, convection current, geodynamics, continental drift, sea floor spreading, plate tectonics, drift of the Indian subcontinent; belts of compressional and tensional stresses, seismicity and volcanism, subduction zone, Benioff zone and island arcs, polar wandering, permanence of continents and ocean basins.

Books

1. Tropical Meteorology Vol. I & II by G.C. Asnani
2. Synoptic Meteorology by M.Kurz

3. WMO Training Manuals for class I & II, WMO (Publications)
4. Climates of South Asia *by* G.B**.** Pant & K. Rupakumar
5. IMD Forecasting Manuals and Reports, IMD (Publications)
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. Atmosphere, Weather and Climate R.J. Barry and R.G. Chorley (Methuen Publication)
13. South West Monsoon" by Y.P. Rao (IMD Publication) .
14. An Introduction to Meteorology by S. Pettersen
15. Elements of meteorology by Miller, Thompson and Paterson
16. General Meteorology by H.R. Byer
17. Monsoon by P.K. Das
18. Tropical Meteorology by T.N. Krishnamurthy
19. Tropical Meteorology by Riel.
20. Tropical Meteorology Vol 1, 2, 3, by G.C. Asnani
21. *Planet Earth- Cosmology, geology and the evolution of life and environment*, A. Emilianic, Cambridge University Press.
22. *Encyclopedic Dictionary of Applied Geophysics*, Sheriff R.E., Society of exploration geophysics, USA.
23. *Isostasy and Flexure of lithosphere*, Watts A.B., Cambridge University Press.
24. *Earthquakes*, Bolt B.A., W. H. Freeman and Company, New York.
25. *Manual of Geology (Vol. I and II)*, Dana J.D., Akashdeep Publishing House.
26. *A text book of general & engineering Geology*, Arora D.S., Mohindra Capital Publishers.
27. Earths Deep Interior by D.J. Crossley
28.. "Climate and Circulation of the Tropics" by S. Hastenrath, D.Ridel Publishing Company.
29. Tropical Meteorology - Vol I, II and III G.C. Asnani,
30 Monsoon Meteorology Chang and Krishnamurthy

ATM-02-T : Mathematical and Statistical Methods [2 Credits]

Module-1

Fourier series, Finite Differences, Methods of obtaining eigen values, eigen vectors.
Transform: Laplace, Fourier and Wavelet
Complex variables, Residue, Contour Integration and application of complex variables.
Spherical harmonics: Legendre Polynomial, Laguerre Polynomial, Hermite Polynomial and Bessel Function
Partial Differential Equations: Solution of Elliptic, Parabolic and Hyperbolic Partial Differential Equations.

Module-2

The probability theory,probability density function

Linear correlation, Rank correlation, Partial and multiple correlation. Normal, binomial, gamma, Weibull distribution. students-t test, χ^2 distributions, ANOVA. Multiple linear

regression, Principal component analysis, canonical correlation analysis. Error Analysis, Sampling and Test of Hypothesis, Analysis of variance.

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" Mario G. Salvadore and M.L. Baran.
5. Applied Mathematics for Scientists and Engineers by Pipes
6. Partial Differential Equations by Ralston and Wilf
7. Numerical Methods used in Atmospheric Models" WMO GARP-17.
8. Dynamic Meteorology and Numerical Weather Prediction" G.J. Haltiner and R.T.Williams, John Wiley and sons,
9. Numerical Analysis by Shastri

ATM-03-T Atmospheric Instrumentation [4 Credits]

Module 1

General principles of surface instrumental measurements, accuracy requirements, siting of an observatory, exposure requirements, observational procedures. standard times of 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. Ocean temperature, salinity, wave height, currents. Self recording instruments, Measurement control and data collection using data loggers, Argo floats, Ocean Gliders, XBT, XCTD.

Module 2

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

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

Module 3

Introduction to Radar, basic principles, Electromagnetic Waves, Radar Hardware, Radar Equation for Point Targets, Distributed Targets, Doppler Velocity Measurements, Spectrum Width and turbulence, Meteorological Targets, Clear-Air Return, Meteorological Uses of Weather Radar. A case study using Dual Polarized X-band Doppler radar XPOL.MST Radar, Signal Processing.

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" W.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. Radar and Atmospheric Science: A Collection of Essays in Honor of David Atlas (2003),

ATM-04-T Atmospheric Thermodynamics and Radiation [4 Credits]

Elementary concepts of atmospheric sciences: structure of the atmosphere and its composition, pressure and its variation with height, variation of temperature with height, Equation of state for dry and moist air , Adiabatic and Isothermal Processes, Humidity Parameters, Virtual Temperature, Standard Atmosphere, Barometric Altimetry, Laws of thermodynamics, Entropy, Potential Temperature, Pseudo- adiabatic Process, Equivalent Temperature, Equivalent Potential Temperature, Claussius – Clapeyron Equation, Stability and Instability, Thermodynamic Diagram: p, α – diagram, Emagram, T - ϕ gram, Uses of thermodynamic diagrams, Precipitable Water Vapor, Rate of Precipitation, Role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in thunderstorm development

Radiative Transfer in the Atmosphere- Temperature of the Sun and spectral distribution of solar radiation, long wave radiation, black body radiation budget of radiation energy. Passage of solar radiation through the atmosphere, Atmospheric Windows, emmisivity, Absorption spectra of atmospheric gases, optically thick and thin approximations, aerosol scattering, calculations of radiative heating and cooling. Terrestrial radiation and its passage through the atmosphere. Raleigh and Mie scattering. Role of atmospheric dust in radiation balance, effect of volcanoes.

Books

1. Introduction to Theoretical Meteorology" S.L.Hess,
2. Physics of Atmospheres by H.G. Houghton. Cambridge
3. Atmospheric Sciences: An introductory Survey" J.M. Wallace and P.V. Hobbs, Academic Press.
4. An Introduction to Atmospheric Thermodynamics by A.A. Tsonis , Cambridge

ATM-05-T Physical and Dynamic Oceanography [2 Credits]

Physical Characteristics of the Ocean : Ocean Basins, Properties of sea water & Equation of State, Temperature, Salinity, Density and Oxygen, Vertical profile of temperature and salinity in the three major oceans.

Water mass characteristics : Formation and Classification of water mass. 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. Indian Ocean Dipole (IOD)

General circulation of ocean. Observed mean circulation, typical scales of motion in the ocean, Wind stress, Geostrophic flow in Ocean -Ocean currents, Equatorial current systems; Ocean waves, their generation and propagation; bottom topography, oceanography data collection. Wind driven ocean circulation, Ekman pumping, Ekman transports, Wind driven coastal currents; Sverdrup, Stommel and Munk's theories, Westward intensification.

Books

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

ATM-06-T Atmospheric Dynamics- I [4 Credits]

Continuum Hypothesis, Lagrangian and Eulerian frames of references, velocity potential, stream function, two dimensional potential flows, Bernoulli's equation.

Equations of motion in spherical co-ordinates, rotating frame, Coriolis force, quasi-static approximation. Energy and angular momentum consistency of quasi-static approximations, Scale Analysis, Rossby number, Natural Co-ordinate System, Trajectory and Stream lines Blatons Equation, 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. Generalized vertical co-ordinates.

Differential Properties of wind Fields Translation, Divergence, Rotation and Deformation., Differtial equation for stream lines Vertical Variation of Winds Thermal Wind , veering and backing, hodograph Kinematics of Pressure Fields: Intensification and Weakening: Deepening and Filling.

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.

ATM-07-T Atmospheric Dynamics-II [4 Credits]

Vorticity and divergence equations, Scale Analysis, Balance Equation, split of vorticity and divergence equations into rotational and irrotational terms.

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. Log-Pressure Coordinate System, Equatorial Beta plane Approximation. Atmospheric Kelvin and Mixed Rossby Gravity Waves.

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

Time mean fields and other 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, Budgets of A_E ,K_E and K_z . Conservation of angular momentum and Kinetic Energy, Atmospheric Energy Equation. Walker Circulations, Southern Oscillation, North Atlantic Oscillation and North Pacific Oscillation

Books for ATM-06-T and ATM-07-T

1. An Introduction to Dynamic Meteorology" J.R. Holton, Academic Press.
2. Dynamic Meteorology" Askel Wiin 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. Ceasless Wind by Dutton
6. Weather Forecasting Vol I and II by S. Pettersen
8. The Physics of the Atmosphere by Houghton
10. The Physics of Monsoons R.N. Keshava Murthy and M.Shankar Rao, Allied Publishers, 1992.
14. Atmospheric Waves by Tom Beer
15. A course on Dynamic Meteorology, by N. Pandarinath
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.

5. Global Atmospheric Circulation " by Richard Grotfahn, Oxford University Press.
6. Fundamentals of Atmospheric Energetics " by Askel Wiin Nelson and Tsing-Chang Chen, Oxford University Press.
7. Dynamic Meteorology" A. Wiin Nelson, WMO Publication.
8. Piffer Lecture Series - IITM
9. General Circulation by Stewart WMO Publications

ATM-08-T Cloud Physics & Atmospheric Electricity [4 Credits]

Cloud Morphology, Warm Cloud Microphysics (Nucleation and Condensation), Growth of cloud droplets by collision and coalescence, Cold Cloud Microphysics (Nucleation and growth of ice), Ice in the atmosphere.
Structure and Dynamics of different cloud systems: Shallow layer clouds, Nimbostratus, Cumulus clouds, Thunderstorms and Tornadoes, Meso-scale convective systems, Clouds in Hurricanes and cyclones, Orographic Clouds.

Atmospheric electricity in fair weather (Ions and Atmospheric conductivity, Space charges), Electric field, Air-Earth currents, Precipitation currents and Point discharge currents. Global Electric Circuit (Classical concept, validity and limitations).
Weather modification (Artificial and inadvertent).

The electrical structure of thunderstorms, Cloud electrification mechanisms, Physics of lightning, lightning and nitrogen fixation.

Books

1. A Short course in cloud physics" R.R. Rogers,
2. Atmospheric Sciences: An introductory Survey" 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 M.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

ATM-09-T Numerical Weather Prediction [4 Credits]

Numerical Weather Prediction Historical Back ground, Finite Difference Schemes for Space and Time, Trucation Error, Laplacian and Jacobian, 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 , Spectral Model. Dynamical Downscaling and statistical downscaling.
Forecast validation techniques. Various methods of bias correction including quantile mapping.
Introduction of various numerical models

Data Assimilation- Static, Dynamic, normal mode,Newtanian relaxation. 3d Var and 4d Var Concept of Kalman Filter

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

ATM-10-T Parameterization [2 Credits]

Subgrid scale processes, closure problem, Dry and moist adiabatic adjustment, cumulus parameterization. Shallow and deep convection, Kuo's Cumuluis 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 Weather Prediction and Dynamic Meteorology by G.J. Haltiner and R.T. Williams, (John Wiley and Sons, New York)
4. Parameterization of subgrid scale processes WMO-GARP, Series No. 8.
5. Numerical Weather Prediction by P.D. Thompson

ATM-11-T Atmospheric Boundary Layer and Turbulence [4 Credits]

Definition, structure, evolution and properties of atmospheric boundary layer; Convective, neutral and stable boundary layers; Surface boundary layer characteristics; Characteristics of boundary layer turbulence, Taylor's hypothesis, Reynold's number, Reynold's decomposition and averaging, Eddy transport of momentum, heat and moisture.

Boussinesq approximation; Governing equations in the planetary boundary layer; closure problem, K-theory; flux-gradient relations; Prandtl mixing length theory; TKE Budget; Stability concepts- Richardson number, Obhukhov length; Similarity relations-basic understandings and applications. Ekman layer.

Types of boundary layers; Internal boundary layer; urban boundary layer; Flow over hills; Overview on the significance of boundary-layer studies in weather and climate research and air pollution research. Monsoon boundary layers- present understanding, future directions and challenges.

Turbulent flux measurements using eddy-covariance technique, Surface energy balance, Bowen ratio. Boundary-layer profiling using balloon sounding and remote sensing instruments.

General Turbulence theory, isotropic turbulence, geostrophic turbulence, velocity-velocity correlations, fully developed turbulence, Surface-layer turbulence spectrum, Kolmogorov similarity theory; Kolmogorov, and Obukhov scaling relations, Energy Cascade.

Numerical Modeling of surface layer and Atmospheric Boundary Layer: Surface layer parameterization, Parameterization of boundary layer, Large eddy simulation of PBL. Land Surface Processes.

Books

1. "Fluid Mechanics" L.D. Landau and E.M. Liftshifts, Pergamon Press.
2. "Atmospheric Turbulence" Panofsky and J.A. Dutton.
3. "Introduction to Boundary Layer Meteorology" Stull
4. "The Atmospheric Boundary Layer" R.M. Stewart, WMO-523.
6. "Micro meteorology" O.G. Sutton.
7. Micrometeorology by S.P. Arya, Academic Press
8. Atmospheric Boundary Layer Flows: Their Structure and Measurement. J. C. Kaimal and J. J. Finnigan, Oxford University Press.

ATM-12-T Satellite Technology and Application [2 Credits]

Remote sensing principles,Application in meteorology. Signal Sensor,A platform,Signature for Interpretation. Satellite orbits and attitude: principles of satellite motion, Kepler's laws, Sub satellite point, 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. 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, Megha tropiques 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 Vinnichenko Goralik
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-13-T Climate Science and Modelling [4 Credits]

Overview of Climate Variability and the Science of Climate Dynamics: The chemical and physical climate system, chemical and physical aspects of the climate system, components and phenomena in the climate system (Time and space scales Interactions among scales). Basics of radiative forcing, blackbody Radiation, solar energy input, globally averaged energy budget, first glance gradients of radiative forcing and energy transports by atmosphere and ocean, carbon cycle

Climate Models: Constructing a Climate Model, An Atmospheric model, treatment of sub-grid scale processes, Resolution and computational cost, an ocean model and ocean-atmosphere coupling, land surface, snow, ice and vegetation, summary of principal climate model equations, Climate system modeling, hierarchy of climate models, Climate simulations and climate drift, evaluation of climate model simulations for present day climate

The Greenhouse Effect and Climate Feedbacks: Global energy balance, A global-average energy balance model with a one-layer atmosphere, infrared emissions from a layer,The greenhouse effect: example with a completely IR-absorbing atmosphere, the greenhouse effect in a one-layer atmosphere, global average model, temperatures from the one-layer energy balance model, increases in the basic greenhouse effect climate feedback parameter in the one-layer global average model, climate feedbacks, climate response time in transient climate change.

Climate Model Scenarios for Global Warming: Greenhouse gases, aerosols and other climate forcings Scenarios, climate forcings and feedbacks, forcing by sulfate aerosols, commonly used scenarios, climate response time in transient climate change, transient climate change versus equilibrium response experiments, a doubled-CO_2 equilibrium response experiment, role of the oceans in slowing warming, climate sensitivity in transient climate change (Ice, sea level, extreme events), emissions paths and their impacts, the road ahead

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. Climate of South Asia by G.B. Pant and Rupa Kumar
8. Climate System Modelling by Trenberth K.E.
9. The Physical Basis of Climate and ClimateModelling- WMO-GARP, No. 16
10. Three Dimensional Climate Modelling by Washington and Parkinson.

11. Climate Modelling Primer Henderson Sellers and McGuffie
12. Neelin, J. D., *Climate Change and Climate Modeling* (Cambridge University Press, 2010)

ATM-14-T Atmospheric Chemistry [2 Credits]

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, 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.

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

ATM-15-T Tropical Meteorology and Monsoon [2 Credits]

Tropical Meteorology: Hadley cell, trade winds, trade wind inversion, tropical convection, tropical precipitation and its spatial and temporal variation. equatorial trough, ITCZ, easterly waves, convective systems, tropical cyclones-their structure and development, Gray's parameter, CISK, tropical easterly jet stream. quasi-biennial oscillation (QBO).

Pre-monsoon: cyclonic storms, tracks, and frequencies; dust-storms, nor'westers, heat waves, pre-monsoon thunderstorms.

Monsoon: monsoon over Asia, Australia and Africa; SW and NE monsoons over India; monsoon trough, onset and advance of monsoon, active and break monsoon, strong and weak monsoon, synoptic features associated with onset, break active and weak monsoons and their prediction. Tibetan anti-cyclone, off-shore vortices and trough, low level jet, Mascarene high, monsoon depression, mid-tropospheric cyclone, floods and draughts, westerly disturbances and their influence on monsoonal circulation, withdrawal of monsoon.

Post monsoon: cyclonic storm- tracks, frequency, northeast monsoon circulation and rainfall.

Variability of monsoon –Intra seasonal variation, Madden-Julian oscillation(MJO), Elnino and Southern Oscillation (ENSO), Indian Ocean dipole and Equinoo, Inter annual variation (IAV).

Books

1. South West Monsoon by Y.P Rao
2. Monsoon Meteorology by C.P. Chang & T.N. Krishnmoorthy
3. Cloud Dynamics by R.A. Houze Jr.
4. Tropical Cyclones, their evolution structure and effect by R.A Anthes
5. Meteorology over the Tropical Oceans by D.B. Shaw
6. Mesoscale atmospheric circulations by B.W. Atkinson
7. El Nino, La Nina and the Southern Oscillation by G.S. Philander
8. Tropical Meteorology by G.C. Asnani

ATM-16-T Mescoscale Modelling [2 Credits]

Definition of meso a, ß, ? scale.
Basic set of equations (for mesoscale meteorological simulations), Computation of Tensor analysis. Synoptically induced circulation. Thermally induced circulation.
Free atmosphere circulation (non convective and convective circulation).
Types of Models- Physical Models, Mathematical Models.
Formulation of mesoscale numerical models.
Assimilation and initialization of Atmospheric data for mesoscale modeling, parameterization of cloud microphysics.
Forecasting and nowcasting mescoscale phenomena.
Review of some existing Mesoscale models.

Books

1. Mesoscale Meteorological Modelling by Roger A. Pielke
2. Mesoscale Atmospheric Circulation by B.W. Atkinson
3. Mesoscale Meteorology and Forecasts edited by P.S. Ray

ATM-17-T Agrometeorology [2 Credits]

Module-I Solar radiation and crop:
Green leaf response to spectral radiation components, solar spectra and plant processes. Meteorological factors in photosynthesis: diffusion process, photochemical process, biochemical process, solar radiation and photosynthesis. Role of CO_2 concentration and turbulence in photosynthesis. Effects of temperature and moisture in plant growth. Soil temperature, thermal properties of soil, soil temperature and crop yield, heat transfer from plant leaves, damage due to freezing temperature and high temperature for crops. Concept of Growing Degree Days (GDD).Soil moisture, water stress and plant Development. Evaporation transpiration, Evapotranspiration.

Module- 2. Rainfall characteristic, Soil and crop growth:
Soil water balance, Radiation balance, climatic normal for crop and live stock production. Crop yield forecast model, modeling crop growth and production. Rainfall Climatology for Agricultural planning, sowing dates, Moisture Availability Index (MAI) and Assured rainfall drought, classification, Analysis. Climate change and crop production weather forecasting for Agriculture. Crop weather calendar, Effects of Pest and diseases in Agriculture production.

Books

1. Hand book of Agricultural Meteorology
Edited by John .F.Griffiths
2. Drought Management on Farmland by J.S Whitmore Kluwer Academic Publisher
3. Introduction to Agrometeorology by H.S.Mavi

ATM-18-T Air Pollution [2 Credits]

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. Measurements of Particulate matters, SO_x, NO_x, and CO.

Books

1.O.G.Sutton, Micrometeorology
2. F.Pasquill, Atmospheric Diffusion.
3. Stull, Boundary layer Meteorology
4 Briggs.G.A , Plume Rise
5 Arya P.S , Atmospheric Boundary Layer
6.Panofsky and J.A.Dutton Atmospheric Turbulence
7. Air Pollution by Jermy Colls
8. Air Quality by Yael Celhal

ATM-19-T Hydrometeorology [2 Credits]

Hydrological Cycle, Factors affecting Runoff: Rainfall-Runoff Components; Hydrograph methods: Peak flow Equation; Run off variability; Urban runoff and Modeling.

Rainfall networking; Radar rainfall estimation; Rainfall over catchments areas; optimization of rainfall Observations ;Area depth Rainfall estimates; maximum probable Rain fall; Storm Displacement.

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

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; water budgets.

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

ATM-20-T Middle Atmosphere [2 Credits]

Composition and structure of stratosphere, mesosphere and thermosphere, Changes in chemical composition - homosphere, heterosphere, ozonosphere. Standard upper atmosphere. The ionosphere - composition morphology and general properties.

General climatology of the middle atmosphere, wind and temperature distribution. Zonally averaged circulation energetics of the middle atmosphere, Vertically propagating planetary waves, Sudden stratospheric warming, waves in the Equatorial stratosphere, quasi biennial oscillation (QBO). Troposphere-Stratosphere coupling, Energetics of lower stratosphere, stratospheric warming, blocking situations in the troposphere.

Books

Middle Atmosphere Dynamics : C.G Andrews, J.R Holton & C. Leovy
Aeronomy of the Middle Atmosphere : G. Brasseur and S. Simon
Introduction to Dynamic Meteorology : J.R. Holton
The Upper Atmosphere : R.A. Craig
Dynamic Meteorology of the Stratosphere and Mesosphere : J.R. Holton
Physics of the Earth's Upper Atmosphere : C.O. Hines, I. Paghis, T.R. Hatz. & J.A. Fejer
Stratosphere-Troposphere interaction : K. Mohan Kumar

ATM-21-T Renewable Energy [2 Credits]

- 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.
- Basics of wind energy conversion and conversion techniques

- Wind Energy- Speed and direction measurements at multiple levels up to 100/120 m height,
  Instrumentation specifications and standards, practices
- Historical and on line solar radiation and wind speed data sources. Statistical Validation with onsite measured data.
- Extreme weather condition analysis of a site - for solar and wind Power projects

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

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

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.

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

ATM-22-L Laboratory Course- I [5 credits]

Chart analysis

1. Analysis of Weather Charts of some typical weather situations over India.
   a) Monsoon b) Summer c) Western Disturbance d) Tropical Cyclone.
2. Vertical Time and Space Sections
3. Analysis of Thermodynamic Diagram (including Computation of CAPE and CINE)

Numerical Analysis and Computer Programming

FORTRAN and C Programming.

3. Computation of Correlation Coefficient, chi-squares Test, T-test.
4. Estimating trends linear and Man kendall.
5. Power Spectrum Analysis
6. Low, high and band pass filters
7. Interpolation of data using cubic spline.
8. Numerical Integration scheme (trapezoidal, simpson and Quadrature method).
9. Second and fourth order finite difference schemes for first and second derivative.
10. Finite difference equivalents of first and second order differential coefficients.
11. Harmonic Analysis
12. Solution of Differential Equations by Runge – Kutta method.
13. Numerical solution of elliptic Partial Differential Equations using method of relaxation.
14. Computation of Vertical velocity by Graphical Method

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

ATM-23-L Laboratory Course- II [5 Credits]

Computations in Dynamic Meteorology and NWP

1. To obtain kinematic vertical velocity by
   a) using grid point data b) using station data
2. Five point and Nine point Arakawa Jacobian Scheme.
3. To determine from geopotential field stream function using Relaxation method.
4. To determine geopotential heights from wind field-using linear balance equation.
5. To determine stream function using double Fourier transform.
6. Subjective analysis of geopotential height.
7. Objective analysis of geopotential height.

8. Solution of non-divergent barotropic vorticity equation.
9. Computation of apparent heat source and moisture sink.
10. To determine the relation between SST anomaly and Surface Pressure over Arabian Sea for Pre and Post Monsoon condition.
11. Estimation of pollution from point source.
12. Input of station data of a meteorological parameter and converting the same from
13. Vector to RASTER using GIS software.

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

ATM-26-L Laboratory Course- Mesoscale Simulation [4 Credits]

a) Overview of WRF Modeling System Components
b) WRF preprocessing and Initialization
c) Running Ideal cases in WRF
d) Running Real cases in WRF
e) Visualizing output in NCL/Ferret/Grads.

Each student should do a separate case study.

ATM-24-P Internship Training [15 Credits]

During Internship Training students are expected to do literature survey or learn new techniques and carry out a mini project which will lead to a full project in the last semester. **The duration will be equal to six weeks full time load.**

The Internship Training will be assessed for 15 credits in the following manner.

Continuous Assessment:- Seven credits to be given by the guide as continuous assessment. **Semester-End-Assessment**:- 4 credits for the Internship report which will be evaluated by an examiner recommended by the Teaching Committee and 4 credits for viva-voce examination 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.

ATM-25-P Project [25 Credits]

Project can be a continuation of the Internship Training.
If the project is carried out outside the university department then there will be an internal guide from the university department who will be the co-guide. If the project is done in the university department then there will be a co-guide who will be assigned by the Teaching Committee or Head of Department. The student has to submit weekly report to the Guide/ Co-Guide/ Internal Guide.

The Project will be assessed for 25 credits in the following manner.

Continuous Assessment:- 8 credits to be given by the guide and 4 credits to be given by the co-guide as continuous assessment. **Semester-End-Assessment**:- 6 credits for the Project report which will be evaluated by an examiner recommended by the teaching committee and 7 credits for viva-voce examination 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 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 Internship Training and Project has to be approved by the Teaching Committee of the Department.

Field Trips: Field trips to the High Altitude Cloud Physics Laboratory and RADAR center of Indian Institute of Tropical Meteorology, at Mahabaleswar should be arranged to familiarize the students on the various instruments used for the measurements and various RADARs used in Atmospheric Sciences respectively. In addition the students should be taken to India Meteorological Department for familiarity with the observational methods.
