# UNIVERSITY OF PUNE

## Department of Atmospheric and Space Sciences

# REVISED

## Course Structure and Syllabi for

## M. Tech. (Atmospheric Science)

**July 2011**

## Background

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 following Statute Amendments were implemented.**

Subject: Atmospheric Physics -- to --- Atmospheric Science.
Department of Space Sciences --to --Department of Atmospheric & Space Sciences.
BOS in Space Sciences -- to BOS in Atmospheric & Space Sciences.

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.

As the teaching of this course is done jointly with Indian Institute of Tropical Meteorology (IITM), Pune, the syllabus has been revised through joint efforts between the scientists and teachers from both IITM and UoP.

## Examination

- A student will have to complete 100 credits offered under this course to get the degree of M.Tech. (Atmospheric Science).

- Each credit will be for 20 marks. 10 marks for continuous assessment and 10 marks for final assessment. The continuous and final assessment together will form one passing head.

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

- The final assessment for theory courses will be in the form of written examination for the whole course. As the 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.

**Backlogs**

- 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 student has a backlog course then he/she can improve the continuous assessment marks of that course only when the course is being run and he/she will be required to register for that course and attend the classes.

# M.Tech. (Atmospheric Science)

## COURSE STRUCTURE

| Course No. | Course Title | Credits |
|---|---|---|
| | **FIRST YEAR {Semesters I and II}** | |
| ATM-01-T | Introduction to Meteorology | 1 |
| ATM-02-T | Mathematical and Statistical Methods | 2 |
| ATM-03-T | Meteorological Instruments and Observational Techniques | 2 |
| ATM-04-T | Radar and Satellite Meteorology | 2 |
| ATM-05-T | Atmospheric Thermodynamics | 2 |
| ATM-06-T | Radiation | 1 |
| ATM-07-T | Cloud Physics and Atmospheric Electricity | 2 |
| ATM-08-T | Atmospheric Chemistry | 2 |
| ATM-09-T | Atmospheric Dynamics-I | 2 |
| ATM-10-T | Atmospheric Circulation & Vorticity | 2 |
| ATM-11-T | Perturbation Theory and Atmospheric Waves | 2 |
| ATM-12-T | Atmospheric Instabilities | 1 |
| ATM-13-T | Synoptic Meteorology and Climatology | 2 |
| ATM-14-T | Tropical Meteorology and Monsoon | 2 |
| ATM-15-T | Fundamentals of Earth Science | 1 ** |
| ATM-16-T | Mesoscale Modelling | 2 ** |
| ATM-17-T | GIS and its Application | 1 ** |
| ATM-18-T | Atmospheric Boundary Layer | 2 |
| ATM-19-T | Atmospheric Turbulence | 1 ** |
| ATM-20-T | Physical and Dynamic Oceanography | 2 |
| ATM-21-T | General Circulation and Atmospheric Energetics | 2 |
| ATM-22-T | Climate Change and Modelling | 2 ** |
| ATM-23-T | Numerical Weather Prediction | 2 |
| ATM-24-T | Data Assimilation and Parameterization | 2 |
| ATM-25-T | Agrometeorology | 2 ** |
| ATM-26-T | Environmental Pollution | 2 ** |
| ATM-27-T | Hydrometeorology | 2 ** |
| ATM-28-T | Middle Atmosphere | 2 ** |
| ATM-29-T | Extra-Tropical Meteorology | 1 ** |
| ATM-30-T | Space Weather | 2 ** |
| ATM-31-L | Laboratory Course I | 5 |
| ATM-32-L | Laboratory Course II | 5 |
| | **SECOND YEAR {Semesters III and IV}** | |
| ATM-33-P | Internship Training | 10 |
| ATM-34-P | Project | 40 |

**** 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**

**Detailed Credit Wise Syllabus for M.Tech. (Atmospheric Science)**

## ATM-01-T: Introduction to Meteorology [1 Credit]

Elementary concepts of atmospheric sciences: atmosphere and its composition, pressure and its variation with height, variation of temperature with height, 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).

Thermal structure of the troposphere, stratosphere, mesosphere and ionosphere, D, E, F-1 and F-2 regions, radio wave propagation, effect of earth's curvature.

**Books for ATM-01-T**


1. Atmosphere, Weather and Climate R.J. Barry and R.G. Chorley (Methuen Publication)
2. General Climatology" Critchfield
3. South West Monsoon" by Y.P. Rao (IMD Publication) .
4. An Introduction to Meteorology by S. Pettersen
5. Elements of meteorology by Miller, Thompson and Paterson
6. General Meteorology by H.R. Byer
7. Monsoon by P.K. Das
8. Tropical Meteorology by T.N. Krishnamurthy
9. Tropical Meteorology by Riel.
10. Tropical Meteorology Vol 1, 2, 3, by G.C. Asnani


## 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 to the study of dynamical instabilities in the atmosphere.
Partial Differential Equations, Bessel functions, Legendre Polynomials, Spherical harmonics.

**Module-2** Auto-correlation theory, standard statistical distributions

Linear correlation, Rank correlation, Partial and multiple correlation. Normal, binomial, gamma, students-t, $\chi^2$ distributions. Multiple linear regression, Principal component analysis, canonical correlation analysis. Error Analysis, Sampling and Test of Hypothesis, Analysis of variance.

**Books for ATM-02-T**


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 Meteorological Instrumentation and Observational Techniques [2 Credits]

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

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

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

**Books for ATM-03-T**

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

## ATM-04-T Radar and Satellite Meteorology [2 Credits]

**Module 1**

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

**Module 2**

Satellite orbits and attitude: principles of satellite motion, Kepler's laws, Sub satellite point, Apogee, perigee, node anti node ,orbital elements, satellite attitude. Types of orbits- earth- and sun-synchronous, polar orbiting and geostationary satellites

Visible, infrared, and microwave channels; identification of cloud types and patterns in satellite images, synoptic systems, estimation of SST, cloud top temperatures, winds and rainfall: temperature and humidity soundings.

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


1. Battan (1973), *Radar Observation of the Atmosphere*
2. Bringi and Chandrasekar (2001), *Polarimetric Doppler Weather Radar*, Cambridge Press
3. Doviak and Zrnic (1984, 1993), *Doppler Radar and Weather Observations*, Academic Press
4. Atlas (1990), *Radar in Meteorology*, AMS (Battan Memorial volume)
5. Radar and Atmospheric Science: A Collection of Essays in Honor of David Atlas (2003), AMS
6. Theory of Satellite Orbit in the Atmosphere by King Hele
7. Numerical Analysis by Shastri
8. Weather Satellite by L.F. Hubert
9. Meteorological Satellite by W.K. Widger
10. A guide to Earth Satellite by D. Fishlock
11. Advances in Satellite Meteorology by Vinnichenko Goralik
12. Satellite meteorology by Henri W. Brandli
13. Satellite Meteorology - WMO Technical Notes No. 124 and 153.
14. Satellite Meteorology, by R.R. Kelkar


## ATM-05-T Atmospheric Thermodynamics [ 2 Credits]

Structure and composition of the atmosphere, 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, $\alpha$ – diagram, Emagram, T - $\phi$ 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

## ATM-06-T Radiation [ 1 Credit]

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.

## ATM-07-T Cloud Physics & Atmospheric Electricity [ 2 Credits]

Atmospheric aerosols: Continental and Marine (Origin, Physical and Chemical characteristics), 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.
The electrical structure of thunderstorms, Cloud electrification mechanisms, Physics of lightning, lightning and nitrogen fixation.
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).

**Books for ATM-05-T, ATM-06-T and ATM-07-T**


1. Introduction to Theoretical Meteorology" S.L.Hess,
2. A Short course in cloud physics" R.R. Rogers,
3. Physical Meteorology" H.G. Houghton.
4. Atmospheric Sciences: An introductory Survey" J.M. Wallace and P.V. Hobbs, Academic Press.
6. Atmospheric Electrodynamics" H.Volland, Springer Verlag,
7. An Introduction to Atmospheric Thermodynamics by A.A. Tsonis , Cambridge
8. Physics of the Cloud by B.J. Mason
9. Microphysics of cloud and Precipitation by Pruppacher and Klett
10. Atmospheric Electricity by J.A. Chalmers
11. Earth's Electrical Environment- National Academy Press
12. Physical Meteorology by J.C. Jhonson
13. Lightning by M.A. Uman
14. Cloud Dynamics by R.A. Houze
15. Clouds Rain and Rainmaking by B.J. Mason
16. Electrical Nature of Storms by D. McGorman and W.D. Rust

## ATM-08-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.

Air Pollution: Sources of anthropogenic pollution, Emission Inventory, Atmospheric effects- smog, visibility. Measurements of Particulate matters, $SO_x$, $NO_x$, and CO.

**Books for ATM-08-T**

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-09-T Atmospheric Dynamics [2 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., Diffential equation for stream lines Vertical Variation of Winds Thermal Wind , veering and backing, hodograph Kinematics of Pressure Fields: Intensification and Weakening: Deepening and Filling.

## ATM-10-T Atmospheric Circulation & Vorticity [2 Credits]

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.

## ATM-11-T Perturbation theory & Atmospheric Waves [ 2 Credits]

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.

## ATM-12-T Atmospheric Instabilities [ 1 Credit]

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 for ATM-09-T, ATM-10-T, ATM-11-T, ATM-12-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
9. Tropical Meteorology by T.N. Krishnamurti
10. The Physics of Monsoons R.N. Keshava Murthy and M.Shankar Rao, Allied Publishers, 1992.
11. Tropical Meteorology - Vol I, II and III G.C. Asnani,
12. Monsoon Meteorology Chang and Krishnamurthy
13. Monsoon by P.K. Das
14. Atmospheric Waves by Tom Beer
15. A course on Dynamic Meteorology, by N. Pandarinath

## ATM-13-T Synoptic Meteorology and Climatology [ 2 Credits]

**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, duststorms, 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.

**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


## ATM-14-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-15-T Fundamentals of Earth Science [1 Credit]

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. *Planet Earth- Cosmology, geology and the evolution of life and environment,* A. Emilianic, Cambridge University Press.
2. *Encyclopedic Dictionary of Applied Geophysics*, Sheriff R.E., Society of exploration geophysics, USA.
3. *Isostasy and Flexure of lithosphere*, Watts A.B., Cambridge University Press.
4. *Earthquakes*, Bolt B.A., W. H. Freeman and Company, New York.
5. *Manual of Geology (Vol. I and II),* Dana J.D., Akashdeep Publishing House.

6. *A text book of general & engineering Geology*, Arora D.S., Mohindra Capital Publishers.
7. Earths Deep Interior by D.J. Crossley

## ATM-16-T Mescoscale Modelling [ 2 Credits]

Definition of meso α, β, γ 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 existing Mesoscale models: ARPS, RAMS, MM5, WRF, etc.

**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 GIS and its Application [1 Credit]

Introduction, functions of GIS; Spatial data base – position, attributes; data base structure, data bas management; geographic data types - vector and raster; introduction to coordinates system and map projections; Application of GIS in Agriculture, forestry, snow mapping, etc.

**Books**

1. An introduction to Geographical Information System by Ian Heywood, Sarah Cornelius and Steve Carver
2. An introduction to Geographic Information Systems by Kang-tsung Chang

## ATM-18-T Atmospheric Boundary Layer [ 2 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 (sodar, RASS, Lidar, microwave radiometer).

## ATM-19-T Atmospheric Turbulence [ 1 Credit]

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. Radiation parameterization, Envelope Orography and Drag Parameterization.

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

**Books for ATM-18 & 19 -T**


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-20-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 for ATM-20-T**


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-21-T General Circulation & Atmospheric Energetics- [ 2 Credits]

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-Available Potential Energy; Kinetic Energy, Budgets of $A_E$ ,$K_E$ and $K_z$ . Conservation of angular momentum. Atmospheric Energy cycle.

**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. "Climate and Circulation of the Tropics" by S. Hastenrath, D.Ridel Publishing Company.
4. Tropical Meteorology" by T.N. Krishnamurthy, WMO Publication.
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
10. Climates of South Asia by G.B. Pant and Rupa Kumar

## ATM-22-T Climate change and modelling [ 2 Credits]

**Module- I**

Definition of Climate Long term changes (Climate of Past century, past millennium, past glacial period). The ice age and glacial chronology. Methods of determining past climate. Possible causes of climate change- External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic**)**. General idea of internal dynamical processes of the atmosphere, oceanic processes, Cryospheric processes, land processes. Basic Radiation processes. Climate feedback mechanism.

**Module- II**

Climate Modelling - Definition of Climate Models, Simple climate model- 0 - D models, 1 – D climate models Energy balance models and sensitivity studies, Radiative Convective model. Two dimensional climate model. Ocean-Atmosphere interaction and simple Ocean-Atmosphere coupled models. General Circulation Climate Models- Dynamics and Physics of General Circulation Climate Model. Land Surface parameterization in General Circulation Climate Model. Simple models of El-Nino and Southern Oscillations. Review of various climate models.

**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


## ATM-23-T Numerical Weather Prediction [ 2 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, Relaxation Methods- Simultaneous and Sequential Relaxation, Under and Over Relaxation, Solution of Poisson's Equation by Relaxation Method, Thermodynamic Energy Equation and Quasigeostrophic Vorticity Equation in Isobaric Coordinates, Diagnostic Omega Equation, Tendency Equation and Potential Vorticity Equation, Two Parameter Baroclinic Model, Primitive Equation Model, Sigma Coordinate System and Primitive Equation Model in Sigma Coordinate system , Spectral Model. Dynamical Downscaling.

## ATM-24-T Data Assimilation and Parameterization [2 Credits]

Basic concepts of Objective analysis and Initialization- Static, Dynamic, normal mode and 4-D data assimilation.
Introduction to Parameterization – Convective Adjustment Scheme, Kuo's Cumuluis Parameterization, Arakawa Schubert Parameterization, Review of other convective parameterization schemes; Radiation Parameterization- Solar Radiation and Terrestrial Radiation.

**Books for ATM-23-T, ATM-24-T**


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-25-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-26-T Environmental 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, evaluation and validation, air quality standards and index, long range transport of pollutants.

**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-27-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-28-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**

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|---|---|
| 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-29-T Extra Tropical Meteorology [1 Credit]

**Extra-tropical meteorology**: air masses- characteristics, prediction and modification; fronts, frontogenesis and frontolysis, structure of cold and warm fronts and polar-front theory. Margule's formula, Extra-tropical cyclones and anti-cyclones, western disturbances, cut-off lows and highs, blocking highs.

**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. Atmosphere, Weather and Climate R.J. Barry and R.G. Chorley (Methuen Publication)
2. Weather Forecasting- Part-1, S. Pettersen
3. Atmospheric Sciences: An introductory Survey" J.M. Wallace and P.V. Hobbs, Academic Press.

## ATM-30-T Space Weather [ 2 Credits]

Earth as a magnet: magnetic field of the earth, ionosphere, Van-Allen radiation belts, plasmasphere, magnetosphere

Sun as a magnet: solar corona / solar wind, solar eruptive phenomena, filament eruptions, solar flares shocks & energetic particles, types of solar wind (slow & fast), Co-rotating Interaction regions (CIRs), coronal holes, Coronal Mass Ejections (CMEs), techniques of observations of CMEs, CME models, observational signatures.

Space Weather studies: Propagation of CMEs in the IP medium, ICMEs, magnetic clouds, estimation of arrival time of CMEs, interplanetary scintillations, interaction of solar wind with earth's magnetosphere, magnetic reconnection, geomagnetic storms.

Implications of Space weather effects: Effect on satellite electronics, satellite charging, satellite drag, heating of the neutral atmosphere, aurora, electric currents in the ionosphere, plasma irregularities, induced currents on the ground, effect on radiowave propagation, effect on communications and navigational outages, SBAS techniques for aviation such as WAAS, GAGAN.

**Books:**


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


## ATM-31-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.

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

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

## ATM-32-L Laboratory Course II [ 5 Credits]

**Computations in Dynamic Meteorology and NWP**
**GRADS and Matlab**

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 and Analyzing the same using Arc GIS.
14. WRF model case study

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

## ATM-33-P Internship Training [10 Credits]

Internship training will be for a minimum duration of 6 weeks and can be taken at University/ Research Institute/ Industry and Organizations dealing with work related to Atmospheric Sciences. (Exact duration will be as per the University calendar).

At the end of the Internship Training the student has to submit an Internship report to the University which will be assessed for 10 credits in the following manner.

5 credits for the report to be given by the guide as continuous assessment. 5 credits for viva-voce examination as final assessment.

## ATM-34-P Project [40 Credits]

Project will be for a minimum duration of 24 weeks and can be taken at University/ Research Institute/ Industry and Organizations dealing with work related to Atmospheric Sciences.

Project will be spread over two Semesters (III and IV). (Exact duration will be as per the University calendar).

The project will be evaluated as follows.
At the end of the third semester student will be required to appear for a mid project assessment and give a viva on the progress made. This will be evaluated for 10 Credits by a panel of two examiners. The guide will not be an examiner. A report on the progress made will be given by the examiners to the student with a copy to the guide.

In case the student is away on field trip and cannot appear for a Mid-Project Viva Voce exam (like he is away in Antarctica etc), he will have to submit a written report which will be evaluated by two examiners for five credits each and the sum total will be given.

If the student fails to appear for the Mid-Project viva or submit the report at the end of third semester, his term will be extended by another semester. A Mid-Project evaluation or report is mandatory at the end of third semester before he submits the final project report in fourth semester.

At the end of fourth semester the student will be required to submit a Project Report to the university.

The Guide will evaluate for 10 credits.

The project report will be evaluated by the external examiner for 10 credits.

After the external examiner gives his report the student will have to give a Viva-voce examination which will be evaluated for 10 credits by two examiners.

Mid Term Assessment and the evaluation by Guide together will be considered as Continuous Assessment. The assessment by external examiner and viva is considered as final assessment.

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