Savitribai Phule Pune University

Department of Atmospheric and Space Sciences

Revised

Course Structure and Syllabi for

M. Sc (Atmospheric Science)

February 2015

Background

The M. Sc. (Atmospheric Science) Course was introduced by the University of Pune, as a separate Course vide Circular No 266 of 2005. This was a self-supporting course.

Atmospheric Science is recognized as a subject for M. Sc. degree for the UGC/CSIR NET.

Eligibility conditions for M.Sc. (Atmospheric Science)

- Any B.Sc./ B.E./ B.Tech. Both Physics and Mathematics should be subjects at graduation.

- **Minimum percentage of Marks/ Grade requirement**

  The candidates should have obtained in aggregate 55% marks or 3.5 GPA on a 6 point scale or 5.5 GPA on a 10 point scale.

  A relaxation of 5 % marks or 0.5 GPA on a 10 point scale or 0.3 GPA on a 6 point scale will be considered for reserved candidates who are domiciles of Maharashtra.

Examination

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

- 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.

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

- 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.

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 university changes these rules, then the rules in force will be applicable.

- If the student has a backlog subject then he/she can improve the continuous assessment marks of that subject only when that subject is being offered in a particular semester and he/she will be required to register for that subject.

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

M. Sc (PPPR)

- Admissions will be as per university rules for M.Sc. (PPPR)

- M.Sc. (PPPR) students from the Indian Institute of Tropical Meteorology (IITM), Pune will be admitted as laid down in the MOU between University of Pune and IITM as sponsored students.

  The number of courses to be taken, rules of passing, the grades and the number of attempts etc. for M.Sc. (PPPR) students are as notified by the university.

- Following are the compulsory courses for the M.Sc. (PPPR) students.

  AS-03-T Fundamentals of Earth Sciences, Synoptic Meteorology and Climatology
  AS-04-T Physical Meteorology
  AS-05-T Dynamic Meteorology I
  AS-08-T Tropical Meteorology and Ocean Sciences

  The remaining courses which are required for completing the M.Sc. (PPPR) theory can be chosen from the list of theory courses given on page 4.

M. Sc (Atmospheric Science)

List of Courses and Structure

Course No.	Course Title	Credits
AS-01-T	Mathematical, Statistical and Numerical Methods- I	5
AS-02-T	Mathematical, Statistical and Numerical Methods- II	5
AS-03-T	Fundamentals of Earth Sciences, Synoptic Meteorology and Climatology	5
AS-04-T	Physical Meteorology	5
AS-05-T	Dynamic Meteorology I	5
AS-06-T	Dynamic Meteorology II	5
AS-07-T	Meteorological Instruments and Observational Techniques	5
AS-08-T	Tropical Meteorology and Ocean Sciences	5
AS-09-T	Cloud Physics and Atmospheric Electricity	5
AS-10-T	Numerical Weather Prediction	5
AS-11-T	Climate Sciences	5
AS-12-T	Atmospheric Chemistry and Air Pollution *	5
AS-13-T	Space Meteorology *	5
AS-14-T	Solar Physics *	5
AS-15-T	Agricultural Meteorology *	5
AS-16-T	Aviation Meteorology *	5
AS-17-T	Satellite & Radar Meteorology *	5
AS-18-T	Upper Atmosphere *	5
AS-19-L	Laboratory Course I	5
AS-20-L	Laboratory Course II	5
AS-21-P	Project Work I	10
AS-22-P	Project Work II	10

T- Theory; L- Lab work; P- Project

Each Credit is of 15 hours in the form of Lectures/ Tutorials/ Seminars/ Contact hours.

* Optional Courses (One course each for 3rd and 4th Semesters)

Detailed Syllabus for M.Sc. (Atmospheric Science)

AS-01-T: Mathematical, Statistical and Numerical Methods- I

Mathematical Methods (3 credits)

Properties of matrices: Vector spaces, linear dependence and independence, basic properties, basis and rank of a matrix, symmetric and skew symmetric, Hermitian and Skew Hermitian, orthogonal and unitary matrices, homogeneous and non-homogeneous linear simultaneous equations and their consistency, Eigen values and Eigen-vectors, Cayley-Hamilton theorem and its applications**,** various techniques for computation of inverse of matrices to find solutions of non-homogeneous equation, Eigen-values and Eigen-vectors of symmetric as well as non-symmetric matrices and their applications.

Complex analysis: Differentiable and Analytic functions, singularity, Taylor's series, Laurent series, calculus of residue, contour integration,

Vector calculus: Gradient, Divergence, Curl, Line integral, Surface integral, Green's theorem, Gauss divergence theorem and Stokes' theorem.

Differential Equations: Ordinary Differential Equation Euler's Method, Taylor Series method, Runge Kutta method (2^{nd} and 4^{th} Order) and Partial Differential Equation, classification of differential equations. Solving Elliptic, Parabolic and Hyperbolic partial differential equations.

Statistical methods (1 credit)

Measures of central tendency and dispersion, moments, scatter diagram, least squares method. Regression equation, coefficients of correlation by Rank Correlation as well as Product Moment method and their significance, partial and multiple correlations and their applications,Principal component Analysis, tests of significance, Students'- t, Chi square tests, ANOVA.

Numerical Methods (1 credit)

Finding roots of Algebraic and Transcendental Equations by Bisection, Regula Falsi and Newton – Raphson's methods, Finite difference schemes, Interpolation: Newton's Forward and Backward Difference, Sterling's interpolation and Lagrange's Interpolation.

Numerical Integration: Trapezoidal rule, Simpson's 1/3 and 3/8 rule. Gaussian quadrature.

AS-02-T: Mathematical, Statistical and Numerical Methods- II

Mathematical Methods (2 credits)

Transforms: Fourier series, Fourier transforms, convolution, inverse Fourier transforms and their applications in solving boundary and initial value problems. Fast Fourier Transforms

Special Functions: Legendre polynomial, Hermite polynomial, Laguerre polynomial, introduction to Bessel functions. Time series analysis, trends and periodicities

Statistical Methods (1 credit)
Probabilty and statistics: theory of probability and probability distribution, binomial distribution and Pseudo random number generation by Monte Carlo technique. Poisson and Gaussian distribution and gamma distribution, random walk, t-and chi-square distribution.

Numerical Methods (2 credits)
Numerical solutions of Simultaneous Algebraic Equations. Generation of random number, Monte-Carlo technique.

Concept of finite element method, solution of ordinary differential equation, Euler method, Taylor series, Runge Kutta method, solution of partial differential equations, elliptic equations. Approximation of function by cubic spline, harmonic analysis, spectral analysis, use of filters.

Books for AS-01-T & AS-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 by Mario G. Salvadore and M.L. Baran.
5. Applied Mathematics for Scientists and Engineers by Pipes
6. Partial Differential Equations by Ralston and Wilf
7. Numerical Methods used in Atmospheric Models WMO GARP-17.
8. Dynamic Meteorology and Numerical Weather Prediction by G.J. Haltiner and R.T.Williams, John Wiley and sons,
9. Numerical Analysis by Shastri

AS-03-T: Fundamentals of Earth Sciences and Synoptic Meteorology and Climatology

Fundamentals of Atmospheric Sciences (1 credit)

Elementary concepts of weather and climate; earth-sun relationship; structure and composition of the atmosphere; Atmospheric pressure, temperature and their variation with height , wind, relative humidity, solar and terrestrial radiation, clouds, different forms of precipitation; diurnal variation of surface pressure and variation of pressure with height; diurnal variation of surface temperature and variation of temperature with height; Categorization of wind: squall, land and sea breeze, katabatic and anabatic winds, winds associated with storms, gustiness, gale, Beaufort scale, Buys-Ballot's law, geostrophic wind; basic ideas of general circulation

Fundamentals of Earth Sciences (2 credits)
Earth as a planet of the solar system: origin and internal structure, physical and chemical characteristics of the internal zones, crustal types, Archaean shields and Cratons, heat flow

and temperature gradient. Types of rocks, major constituent minerals and their (chemical) composition, stability of minerals, climatic belts, effect of climate on processes of weathering and erosion, sediment cycle, radioactive minerals and dating methods, palaeoclimate, quaternary ice age, factors affecting sea level, sea level changes, with reference to India. Geological time scale; Space and time scales of processes in the solid Earth.

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, Basic concepts of seismology and internal structure of the Earth, seismicity and volcanism, subduction zone, Benioff zone and island arcs, polar wandering, permanence of continents and ocean basins. Internal structure, constitution and magnetism of planetary bodies. Concepts of stress and strain. Behaviour of rocks under stress; Folds, joints and faults. Earthquakes – their causes, measurement and prediction. Himalayan and stable continental region earthquakes, reservoir induced seismicity; seismic hazards; earthquake prediction.

Synoptic Meteorology & Climatology (2 credits)

Introduction to synoptic meteorology, scales of weather systems, synoptic weather observations, network of observatories; surface, upper air and special observations; satellite and radar observations.

Rrepresentation 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.

Extra-tropical meteorology: air masses- characteristics, prediction and modification; fronts, frontogenesis and frontolysis, Margule's formula, structure of cold and warm fronts and polar-front theory. Extra-tropical cyclones and anti-cyclones, western disturbances, frontal and baroclinic models,

Jet stream: 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).

Definition of climate, physical factors of climate, earth-sun relationship, ecliptic and equatorial plane, rotation of the earth, seasons, climatic controls. Physical climatology: solar radiation, terrestrial radiation, heat, energy and water balance, evaporation and evapotranspiration. Climatic classification: Methods of Koppen.

Radiation climatology of the earth's atmosphere, geographical and seasonal distribution of incoming solar radiation, outgoing radiation, net radiation, terrestrial heat balance. Geographical and seasonal distributions of temperature, pressure, wind, evaporation, humidity, fog, clouds, precipitation and thunderstorms. Vertical distribution of temperature and winds.

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 for ATM-03-T

1. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
2. Atmosphere, Weather and Climate by R.J. Barry and R.G. Chorley (Methuen Publication)
3. General Climatology by Critchfield
4. An Introduction to Meteorology by S. Pettersen
5. The Monsoons by P.K. Das (National Book Trust, India)
6. General Climatology by H.J. Critchfield
7. An introduction to climate by G.T. Trewartha
8. Physical Climatology by W.D. Sellers
9. World Survey of Climatology by H.E. Landsberg (Ed.)
10. World Climatology – An Environmental Approach by J.G. Lockwood
11. Survey of Climatology by J.F. Griffiths & D.M. Driscoll
12. South West Monsoon by Y.P Rao
13. Monsoon Meteorology by C.P. Chang & T.N. Krishnmurti
14. Cloud Dynamics by R.A. Houze Jr.
15. Tropical Cyclones, their evolution structure and effect by R.A Anthes
16. Planet Earth- Cosmology, geology and the evolution of life and environment, A. Emilianic, Cambridge University Press.
17. Encyclopedic Dictionary of Applied Geophysics, Sheriff R.E., Society of exploration geophysics, USA.
18. Isostasy and Flexure of lithosphere, Watts A.B., Cambridge University Press.
19. Earthquakes, Bolt B.A., W. H. Freeman and Company, New York.
20. Manual of Geology (Vol. I and II), Dana J.D., Akashdeep Publishing House.
21. A text book of general & engineering Geology, Arora D.S., Mohindra Capital Publishers.
22. Earths Deep Interior by D.J. Crossley

AS-04-T: Physical Meteorology

Equation of state for dry and moist air, Humidity Parameters, Virtual Temperature, Laws of thermodynamics, Entropy, Potential Temperature, Pseudo- adiabatic Process, Equivalent Temperature, Equivalent Potential Temperature, Clausius – Clapeyron Equation, Hydrostatic equation and its application, Stability and Instability, Thermodynamic Diagrams: 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, emissivity, Absorption spectra of atmospheric gases, optically thick and thin approximations, aerosol scattering. Terrestrial radiation and its passage through the atmosphere. Rayleigh and Mie scattering. Radiation climatology of the earth's atmosphere, geographical and seasonal distribution of incoming solar radiation, outgoing radiation, net radiation, terrestrial heat balance.

Books for ATM-05-T

1. Introduction to Theoretical Meteorology By S.L.Hess,
3. Physical Meteorology By H.G. Houghton.
4. Atmospheric Sciences: An introductory Survey By J.M. Wallace and P.V. Hobbs, Academic Press.
5. An Introduction to Atmospheric Thermodynamics by A.A. Tsonis , Cambridge
6. Physical Meteorology by J.C. Jhonson
7. An Introduction to Atmospheric Radiation By K. N. Liou , Academic Press.

AS-05-T: Dynamic Meteorology -I

Fundamentals (3 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, quasistatic 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.

Basic equations: inertial and non-inertial frame, pressure gradient force, gravitational force, viscous force, centripetal and Corolis forces, equation of motion in rotating coordinates, in tangential local coordinate system, in spherical coordinate system and in isobaric coordinate system, scale analysis of the equation of motion, thermodynamic energy equation and equation of continuity, vertical velocity. Geopotential, equipotential surface, hydrostatic equation and hydrostatic equilibrium.

Circulation and 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.

AS-06-T: Dynamic Meteorology -II

Perturbation Theory , Atmospheric waves and Atmospheric Instability (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

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

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General Circulation (1 credit)

Observed zonally symmetric circulations, meridional circulation models, mean meridional and eddy transport of momentum and energy, angular momentum and energy budgets; zonally asymmetric features of general circulation; standing eddies; east-west circulations in tropics, Maintenance of zonally mean circulation and eddies, Walker circulation.

Basic principles of general circulation modelling; grid-point and spectral GCMs; role of the ocean in climate modelling; interannual variability of ocean fields (SST, winds, circulation, etc.) and its relationship with monsoon, concepts of ocean – atmosphere coupled models.

Atmospheric Boundary Layer (2 credits)

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

TKE Budget, stability concepts, Richardson number, Obhukhov length. Governing equations in planetary boundary layer, closure problem. Ekman layer. Internal boundary layer, Techniques for evaluation of turbulent fluxes of momentum, heat and water vapour. Surface energy balance.

Books for AS-05-T & AS-06-T

1. An Introduction to Dynamic Meteorology By J.R. Holton, Academic Press.
2. Dynamic Meteorology By Askel Wiin Nelson, WMO Publication.
3. Introduction to Theoretical Meteorology By S.L. Hess,
4. Dynamic and Physical Meteorology By G.L. Haltiner and F.L. Martin, Mc Graw Hill.
5. 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 - (Revised Edition)Vol I, II and III By G.C. Asnani,
12. The Monsoons by P.K. Das (National Book Trust, India)
13. Atmospheric Waves by Tom Beer
14. A course on Dynamic Meteorology, by N. Pandarinath
15. The Atmospheric Boundary Layer By R.M. Stewart, WMO-523.
16. Micro meteorology By O.G. Sutton.
17. Micrometeorology by S.P. Arya, Academic Press
18. Atmospheric Boundary Layer Flows: Their Structure and Measurement. By J. C. Kaimal and J. J. Finnigan, Oxford University Press.

AS-07-T: Meteorological Instruments and Observational Techniques

Surface and Upper Air Observations (2 credits)
General principles of surface meteorological measurements, accuracy requirements, siting of an observatory, exposure requirements, observational procedures. standard times of observations. Conventional and self recording measurements of pressure, temperature, humidity, wind speed and direction, sunshine duration, radiation, precipitation, visibility, clouds, soil temperature and soil moisture, evaporation. Measurement of sea surface temperature and other ocean parameters.

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

Surface based Remote Sensing observations (2 credits)

Working principle and applications of LIDARS, SODARS, Weather RADARS, Wind Profiler, radio-acoustic sounding systems (RASS), Doppler radar, MST Radar, Microwave radiometer.

Fundamentals of Satellite Meteorology (1 credit)
Satellite orbits and attitude: principles of satellite motion, Kepler's laws, orbital elements, Types of orbits-polar and geostationary, earth- and sun-synchronous, Satellite derived products and their applications.

Meteorological satellites, multi-scanner radiometers and their applications in the observation of weather parameters.

Books:
1. Probing the atmospheric boundary layer ,By D.H. Lenschow
2. Instruments and Techniques for probing the atmospheric boundary layer
   By D.H. Lenchow.
3. Guide to Meteorological Instruments and method of observation WMO-8,
4. Meteorological Instruments By W.E.K.Middleton and A.F. Spilhaus,
5. Applications of Remote Sensing to Agrometeorology By F.Toselli, (Kluwer)
6. Radar Meteorology by L.J. Batton
7. Theory of Satellite Orbit in the Atmosphere by King Hele
8. Weather Satellite by L.F. Hubert
9. Meteorological Satellite by W.K. Widger
10. Satellite Meteorology - WMO Technical Notes No. 124 and 153.
11. Satellite Meteorology, by R.R. Kelkar

AS-08-T: Tropical Meteorology and Ocean Sciences

Tropical Meteorology (3 credits)

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

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

Monsoon: SW and NE monsoons; monsoon over Asia, Australia and Africa; monsoon trough, onset and advance of monsoon, active and break monsoon, strong and weak monsoon, synoptic features associated with onset, withdrawal, break active and weak monsoons and their prediction. monsoon trough, 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. Monsoon of East Asia.

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

Madden-Julian oscillation(MJO), Elnino and Southern Oscillation (ENSO), Quasi-biennial Oscillation (QBO), Indian Ocean Dipoles

Fundamentals of Ocean Sciences (2 credits)
Dimension of the oceans, geographical features, spatio-temporal variations of temperature, salinity, density and oxygen. Formation and classification of water masses. T-S diagram. Water masses of the ocean, mixing processes in the oceans.

General aspects of Ocean currents and circulation, important current systems, thermohaline circulation and the oceanic conveyor belt, Coriolis effect and Ekman spiral. Convergence, divergence, upwelling and sinking. Biological productivity in the oceans, General circulation of ocean.

Ocean waves, their generation and propagation, Wind generated waves and their characteristics; shallow and deep water waves. Propagation, refraction, and reflection of waves. Wave spectrum, principles of wave forecasting, storm surges and tsunamis, Tides and tide generating forces. prediction of tides by the harmonic method; tides and tidal currents in shallow seas, estuaries and rivers.
Oceanic boundary layer : Sea surface temperature, Mixed layer, Thermocline, Upwelling, Penetration of Solar Radiation, Turbidity, Waves, Swell and Currents induced by wind, Kelvin and Rossby waves – Fresh water flux- Salinity variation in the vertical.

Sverdrup, Stommel and Munk's theories; upwelling and sinking with special reference to the Indian ocean. geostrophic motion; barotropic and baroclinic conditions; oceanic eddies, Wind driven coastal currents; typical scales of motion in the ocean. Characteristics of the global conveyor belt circulation and its causes. Equatorial current systems; monsoonal winds and currents over the North Indian Ocean; Somali current. Indian Ocean Dipole.

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. The Monsoons by P. K. Das (National Book Trust, India)
5. IMD Forecasting Manuals and Reports, IMD (Publications)
6. Tropical Meteorology by T.N. Krishnamurti
7. Tropical Meteorology by H. Reihl (McGraw-Hill).

8. Tropical Meteorology (Revised Edition)Vol 1, 2, 3, by G.C. Asnani
9. Mesoscale atmospheric circulations by B.W. Atkinson
10. El Nino, La Nina and the Southern Oscillation by G.S. Philander
11. Meteorology over the Tropical Oceans by D.B. Shaw
12. The Oceans, their Physics, Chemistry and General Biology by H. U. Sverdrup
13. Principles of Physical Oceanogrphy By G. Neumann and W. J. Pierson, Jr.
14. Descriptive Physical Oceanography by G. Dietrich
15. Physical Oceanography Vol I and II by A. Defant
16. Ocean Currents by G. Neumann
17. Principles of Ocean Physics by J. R. Apel, Academic Press
18. Atmospheric Ocean Dynamics by A. E. Gill, Academic Press

AS-9-T: Cloud Physics and Atmospheric Electricity

Cloud morphology

Warm Cloud Microphysics (Homogeneous and Heterogeneous nucleation, Kohler theory, CCN, Collision and Coalescence Process, Formation of rain).

Cold Cloud Microphysics (Ice Nucleation, Hail formation, Bergeron-Findeisen Process.)

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.

Cloud Seeding experiments.

Ions and electrical conductivity, Fair weather electricity, Electrical currents in the atmosphere, Global Electric Circuit.

Electrical structure of storms, Theories and experiments on Cloud Electrification.

Lightning discharges and mechanism,

Lightning Electric fields, lightning location systems.

Upward lightning and sprites.

Nitrogen fixation by lightning.

Books:

1. Cloud Physics, By R. R. Rogers
2. Cloud Dynamics, By Robert A. Houze
3. Atmospheric Sciences: Introductory Survey, By J. M. Wallace and P. V. Hobbs
4. Microphysics of Clouds and Precipitation, By H. R. Pruppacher and J. D. Klett
5. The Physics of Clouds, By B. J. Mason
6. A Short Course in Cloud Physics, By M. K. Yau.
7. Lightning, By M. A. Uman
8. The Electrical Nature of Storms, By McGorman and Rust
9. Atmospheric Electricity, By J. A. Chalmers
10. The Earth's Electrical Environment, National Academy Press, USA
11. Atmospheric Electrodynamics, By H. Volland
12. CRC Handbook on Atmospherics, Ed. H. Volland
13. Lightning: Physics and Effects, By Vladimir A. Rakov and M. A. Uman

AS-10-T: Numerical Weather Prediction

Numerical weather prediction 3 credits

Historical Background, Filtering of sound and gravity waves, Finite difference schemes, Explicit, Implicit and Semi Implicit Schemes, CFL Criteria and Stability Analysis, Staggered grid, Nonlinear Instability and Aliasing, Arakawa Jacobian, Relaxation methods, Barotropic Model, Equivalent Barotropic Model, Two level Baroclinic Model, Primitive Equation Models in sigma coordinate system, Spectral and finite element models, Boundary Conditions and time integration. Basic Principle of General Circulation modeling, grid-point and spectral GCMs; role of the ocean in climate modelling; interannual variability of ocean fields (SST, winds, circulation, etc.) and its relationship with monsoon, concepts of ocean – atmosphere coupled models

Parameterization & data assimilation 2 credits

Parameterization of subgrid scale processes-basic concepts, Cumulus Parameterization, radiation parameterization and PBL parameterization; Objective analysis and Initialization-Basic Concepts. Data assimilation techniques, application of satellite and remotely sensed data in NWP.

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

AS-11-T: Climate Sciences

Climate Change & Variability (2 credits)

Overview of the climatic history of the earth. Long term changes (Climate of Past century, past millennium, past glacial period). Methods of determining past climate. Possible causes of climate change- External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic**)**. General idea of internal dynamical processes of the atmosphere, oceanic processes, Cryospheric processes, land processes. Man's impact on climate, Greenhouse gases and global warming, basic radiation processes. Climate feedback mechanism.

Climate Prediction, future climate, potential consequences, International efforts to minimize climate change and their effects. Indian scenario.

Climate variability and forcings; feedback processes, low frequency variability.

Climate Modelling (2 credits)

Definition of Climate Models, Simple climate model- 0 – D & 1 – D climate models, Energy balance models and sensitivity studies, Radiative Convective model. Two dimensional climate model. General Circulation Climate Models- Dynamics and Physics of General Circulation Climate Model. Coupled ocean-atmosphere system, Air-sea interaction on different space and time scales, Simple Ocean-Atmosphere coupled models.

Seminar: Recent developments in Climate Research **(1 credit)**

Books:

1. Physical Climatology by W.D. Sellers
2. Foundation of Climatology by E.T. Stinger
3.Climate-Past, Present and Future Vol-I and II by Lamb
4. An Introduction to Climate by G.W. Threwartha
5.The nature and causes of climate change by Goodies, Paultikaf and Davies
6. Science of Climate Change IPCC, Cambridge
7. IPCC assessment reports
8.Climate of South Asia by G.B. Pant and Rupa Kumar
9. Climate System Modelling by Trenberth K.E.
10.The Physical Basis of Climate and ClimateModelling- WMO-GARP, No. 16
11. Three Dimensional Climate Modelling by Washington and Parkinson.
12.Climate Modelling Primer Henderson Sellers and McGuffie

AS-12-T: Atmospheric Chemistry and Air Pollution

Atmospheric Chemistry (3 credits)

Evolution of the earth's atmosphere. Nitrogen, hydrogen halogen, sulfur, carbon-containing compounds in the atmosphere, other atmospheric constituents. Oxygen and carbon budgets. Half-life, residence time and renewal time of chemicals in the atmosphere, spatial and temporal scales of variability. Present chemical composition of the atmosphere close to the earth's surface and their variation with height, units for chemical abundance. Chemical and photochemical processes, Tropospheric chemical cycles: carbon cycle, nitrogen cycle, sulphur cycle. sulphur in the stratosphere**.**

Total amount of ozone, Geographical and temporal variations of total ozone, Measurement techniques. Photochemical theory of ozone. Evolution of the ozone layer, sources and sinks of tropospheric and stratospheric ozone, Man's influence on stratospheric ozone, chlorofluorocarbons. ozone and UV-radiations. Unperturbed stratospheric ozone, Umkehr effect, anthropogenic perturbations to stratospheric ozone, Meteorological processes affecting tropospheric and stratospheric ozone, Ozone destruction by NO. Antarctic ozone hole.

Atmospheric aerosols: Concentration and size, sources, and transformation, residence times of aerosols, geographical distribution and atmospheric effects. Stratospheric aerosols. Overview of different aerosol measurement techniques. Atmospheric transport behavior, Aerosol Dynamics: Nucleation, Condensation and Coagulation; Radiation Properties.

Air pollution (2 credits)

Natural and anthropogenic pollution, Sources of anthropogenic pollution, primary and secondary pollutants. Atmospheric effects- smog, acid rain, visibility. Air pollution measurements. Ambient air quality standards, Stability of atmosphere and its influence on pollutant dispersion, Effects of source configuration, Plume rise, Line sources, Area sources. Air Quality Modelling - Lagrangian and Eulerian modeling concepts, Gaussian Plume model for continuous sources, Point, Line and Area Sources; Receptor Modelling and source apportionment; Recent advances in air pollution modelling.

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. Air Pollution Meteorology and Dispersion. by S. Pal Arya
6. Micrometeorology, by O.G.Sutton
7. Atmospheric Diffusion. by F.Pasquill
8. Plume Rise, by Briggs.G.A
9. First Principles of Meteorology and Air Pollution, by Mihalis Lazaridis
10. Aerosol Technology: Principles, Behavior & Measurements of Airborne particles, By W.C. Hinds, Wiley, NY 1982
11. Smoke Dust and Haze, by S.K. Friedlander, Oxford Univ. Press, 2000.

AS-13-T: Space Meteorology

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, effects on power grids, Space Radiation Protection.

Solar Effects on Stratosphere.

Books:

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

AS-14-T: Solar Physics

Composition and structure of sun, Solar interior and seismology, Sunspots and solar rotation, Solar Cycle,
Magnetically controlled solar phenomena, Magnetic fields in solar interior and flux emergence.
Photosphere, Chromospheres and Coronae
Solar Flares and Coronal Mass Ejections
Solar Corona and Solar Wind - Optical, radio and X-ray data
Sun in radio wavelength- solar radio bursts, noise storms
Sun in X-ray wavelength-
Data from recent satellites: GOES, SOHO, STEREO, SDO, etc.

Books:

1. Solar System Astrophysics, By J. C. Brandt and P. W. Hodge
2. The Magnetic Field of the Earth, By Roland T. Merrill, Michael W. McElhinny, Phillip L. Mcfadden, A.P.
3. Earth's Magnetospheric Process, Ed. B. M. McCormac, D. Reidel Publishers
4. Physics of the Magnetosphere, Eds. R. L. Corovillano, J. T. McCaulley and H. Radosky, D. Reidel Publishers
5. Solar System Plasma Physics, Vol. I, II and III, Eds. C. F. Kennel, L. J. Lanzenrutti and E. N. Parker
6. Solar Terrestrial Physics, Ed. E. R. Dyer, D. Reidel Publishers.
7. Physics and Chemistry of Solar System, By John S. Lewis
8. The Sun by Michael Stix.
9. Lectures on Solar Physics by H.M. Antia, A. Bhatnagar, P. Ulmschneider
10. Physics of Solar Corona by Markus Aschwanden
11. Sun from Space by Kenneth R. Lang
12. Dynamic Sun by B.N. Dwivedi
13. The sun and Heliosphere as an Integrated system by G. Poletto & S.T. Suess

AS-15-T: Agricultural Meteorology

Influence of weather and climate on agriculture, Important agro-meteorological parameters, their diurnal and seasonal variations and their role in plant growth, evaporation and evapotranspiration, soil temperature and soil moisture, Concept of Growing Degree Days (GDD), agromet observation networks, Applications of Remote sensing techniques. Importance and scope of Agricultural Meteorology.

Agricultural droughts – classification, floods, hail, dew, frost, Protection against weather hazards; shelter belt and windbreaks, frost protection; irrigation. Effect of weather elements on the outbreak and spread of diseases and pests, forecasting of pests and diseases.

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

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

Crop yield forecast model, modeling crop growth and production. Agricultural weather services, agrometeorological forecasting. Impacts of climate change and variability on agricultural crops and production, adaptation.

Books

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

AS-16-T: Aviation Meteorology

Meteorological organization for aviation in India; International Civil Aviation organization, Meteorological broadcasts for aeronautical purposes,
Meteorological support for Air traffic services;

- Pilot briefing and flight documentation, Aviation weather forecast and warning services, Aviation weather codes and practices
- Elements of air navigation and pressure pattern flying, Altimeter setting Procedures. QFE, QFF and QNH
- Effects of weather on aircraft flights: Aircraft accidents and their investigations.
- Detection of Low Level Wind Shear, Microburst, Gust front, Turbulence (eddy dissipation rate) and Icing probability
- Preparation of meteorological documentation for a flight
- Preparation of METAR, SPECI and TREND, TAF and SIGMET forecasts
- Interpretation of meteorological Radar data for aviation applications
- Interpretation of weather satellite data for use aviation applications
- Preparation of a Significant weather chart from numerical model forecast outputs received on internet

Books:

1. Handbook of aviation meteorology. Meteorological Office, Great Britain
2. Meteorology and Flight: A Pilot's Guide to Weather. Tom A. M. Bradbury
3. Manual of Aviation Meteorology, Airservices Australia, 2007
4. Aviation Weather, FAA Guide

AS-17-T: Satellite & Radar Meteorology

Satellite Meteorology

Remote Sensing, Principles of Remote Sensing, Application in Meteorology, Introduction to Satellite Meteorology including Orbital Mechanics.).

- Meteorological Satellites, Polar Orbiting, Geostationary satellites, Current and future meteorological satellites of the world. Payloads on Meteorological Satellites, NOAA, INSAT -3D, Metop.

- Processing of data from Imagers, INSAT Meteorological Data Processing System (IMDPS). Generation of images in various channels. Retrievals of meteorological products from the imager data including water vapor. Atmospheric motion vectors, Sea Surface Temperature and Upper Troposphere Humidity (UTH), Outgoing Long wave Radiation (OLR), Quantitative Precipitation Estimates (QPE), Rainfall, Fog, Minor atmospheric constituents/aerosols/ Fire /smoke, Enhancement techniques, Gray scales, Pseudo Color Images.

- Principles of Sounding, Processing of data from Infrared and Microwave Sounders. Retrieval of products from sounder, Vertical temperature, humidity and ozone profiles. Interpretation of Satellite images of various channels and identification of typical clouds and weather systems from cloud imageries, use of various satellite derived products, satellite Bulletin and its interpretation. Tropical cyclone, its identification and grading using Dvorak's technique.

Radar Meteorology

Radar principles.

Doppler Radar, Wind profiler, MST Radar, LIDARS
Scattering of microwaves by precipitation / precipitating particles. Scattering by a sphere, Scattering by rain and ice crystals.
Minimum detectable power, receiver noise, radar equation for a point target, part played by various parameters in the radar equation. Radar equation for an extended target.
Practical importance of radar set constants and the radar cross section. Effect of wavelength, wave lengths commonly used. Types of scans used in weather radar, their merits.

Classification of radar echoes.

Convective and stratiform types, bright band echo from lightening, tornadoes, squall lines.Study of severe storms and cyclones,
Measurement of rate and amount of precipitation, effect of circular polarization, use of circular polarization in weather radar research, non-precipitating / precipitation echoes, super-refraction, limitations of weather radar.
Elementary ideas of cloud physics. Drop size distribution in various types of rain.
Relation between drop size, terminal velocity, rate of rain fall and radar echo intensity.
Study of Disdrometer and its application.

Doppler radar

Doppler radar principles and its limitations. Doppler principle of velocity measurement, unambiguous velocity and range. Doppler dilemma. Spectrum width. Introduction to DWR (Physical visualisation/inspection), RAINBOW workstation.
Principles of dual polarized doppler radar. Advantages over conventional doppler radar techniques.

Radar base products and derived products
Introduction to reflectivity products and their utilization. Detection of turbulence, shear, gust front, microburst, and tornado, , icing hail probability and hail size, determination and tracking, TC structure, intensity, rainfall distribution and other parameters, inputs for storm surge prediction

Books
1. Radar Observation of the Atmosphere By Battan (1973),
2. Polarimetric Doppler Weather Radar By Bringi and Chandrasekar (2001), , Cambridge Press
3. Doppler Radar and Weather Observations By Doviak and Zrnic (1984, 1993), , Academic Press
4. Radar in Meteorology, Atlas (1990), 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

AS-18-T: Upper Atmosphere

Upper Atmosphere (4 credits)

Composition and structure of Troposphere, Stratosphere, Mesosphere and Thermosphere, Changes in chemical composition - homosphere, heterosphere, ozonosphere. Standard upper atmosphere. Estimation Ozone: Total Ozone and Vertical Profile – Umkehr Method Seasonal and Spatial Variation of Ozone . The ionosphere - composition morphology and general properties and Radio Wave Propagation. Effect of Sphericity of the Earth

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 and their interaction with the Troposphere, Quasi biennial oscillation (QBO). Troposphere-Stratosphere coupling, Energetics of lower stratosphere.

AS-19-L: Laboratory Course I

Computer Programming and Numerical Analysis (3 credits)
FORTRAN fundamentals: integer constant, floating point constant, variables, arithmetic operator, relational operator, FORTRAN arithmetic and expression, input/output and format statements, declaration and initialization, branching and looping, Arithmetic IF, Logical IF, Unconditional GO TO, Computed GO TO, DO statement, Nesting of DO Loops, Dimension Statement, arrays, multi-dimensional arrays, functions, sub-programs and subroutines.

Numerical Analysis

1. Solution of algebraic and transcendental equation by Newton- Raphson's method
2. Numerical Integration by Trapezoidal and Simpson's Rule
3. Fitting of straight lines by Least square method
4. Computation of Correlation Coefficients: Product Moment Method and Rank Correlation Method
5. Solution of simultaneous non-homogeneous equation.

Synoptic Analysis (1 credit)

Analysis of Weather Charts (Surface and upper air) of some typical synoptic situations over India

a) Monsoon b) Western Disturbance c) Tropical Cyclone.

Analysis of vertical section and vertical time section.

Thermodynamic Diagrams (1 credit)

1. Plotting and analysis of Tephigram , estimation of LCL, CCL, LFC, EL, height of the base and top of the cloud and precipitable water.
2. Study of the instability of the atmosphere and forecasting of thunderstorms using Tephigram.
3. Computation of CAPE and CINE with radiosonde data.

AS-20-L: Laboratory Course II

Computations (4 credits)

1. Solution of ordinary differential equations by Runge-Kutta Method
2. Computation of Harmonic Analysis of a given time series.
3. Computation of geostrophic wind and geostrophic vorticity
4. Computation of divergence and vorticity by finite difference technique.
5. Computation of vertical velocity using equation of continuity.
6. To determine stream function from geopotential field using Relaxation method.
7. Subjective analysis of geopotential height.
8. Objective analysis of geopotential height.

Meteorological observations and analysis (1 credit)

Analysis of data collected from the ground based instruments of the Department.

AS-21-P: Project Work I & AS-22-P: Project Work II

Project works I & II have to be taken up during 3rd and 4th semesters.

The projects will be evaluated at the end of 3rd and 4th semesters as follows:

At the end of 3rd and 4th semester, student will be required to submit a Project Report to the university. The project work will be evaluated by the guide for 4 credits which will form the continuous assessment. For the Semester-End examination the student will have to give a Viva-voce examination which will be evaluated for 6 credits by two examiners.

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.

Field Trips: Field trips to Indian Institute of Geomagnetism, Alibag and the Cloud Physics Laboratory and RADAR center of Indian Institute of Tropical Meteorology, Mahabaleswar should be arranged to familiarize the students on the various instruments used for the measurements of parameters of earth sciences and various RADARs used in Atmospheric Sciences respectively. In addition the students should be taken to IMD for the Weekly Map Discussion and to see their observatory.
