Savitribai Phule Pune University

Department of Atmospheric and Space Sciences

Revised
Course Structure and Syllabus for
M.Sc. (Atmospheric Science)
Under Faculty of Science and Technology

Revised
May 2018

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.

The syllabus was last revised in 2017. From the academic year 2018-19, the course is being revised to an **80**-credit system, with **60** compulsory credits and **20** elective credits. This will be implemented from the academic year 2018-19 for those taking admission in to M.Sc. first year.

Examination

- A student will have to complete a total of **80** 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 some of the courses are for lesser credits, 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.
- Laboratory Course: All the required practicals have to be completed and the journal has to be certified by the Laboratory Incharge and Head of Department before the last date announced by the Teaching Committee. Without a certified Journal the student cannot appear for final laboratory exam. 50% marks will be for continuous assessment, of which 30% will be on the practicals conducted/ test/ viva and 20% will be for the certified journal. 50% will be for final assessment of which 20% will be for Viva and 30% will be for the practical.
- As per the existing rules the student has to obtain **40%** marks in the combined Continuous Assessment and Semester-End Assessment with a minimum passing of **30%** in both these separately. The rules of examination prescribed by the University will be applicable.

Backlogs

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

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

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 per the conditions laid down in the MOU between Savitribai Phule Pune University (SPPU) 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-02-T Physical Meteorology
  AS-03-T Tropical Meteorology and Climatology
  AS-04-T Dynamic Meteorology I
  AS-06-T Advance Dynamic Meteorology

  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 and page 5.

Semester I		
Core Courses: 20 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-01-T	Mathematical, Statistical and Numerical Methods	2
AS-02-T	Physical Meteorology	4
AS-03-T	Tropical Meteorology and Climatology	4
AS-04-T	Dynamic Meteorology I	4
AS-05-T	Fundamentals of Earth Sciences	2
AS-22-L	Laboratory Course - I	4
Elective Courses:		
Subject Code	**Subject Title**	**Number of Credits**
N/A	N/A	N/A
Semester II		
Core Courses: 16 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-06-T	Advance Dynamic Meteorology	4
AS-07-T	Fundamentals of Ocean Sciences	2
AS-08-T	Numerical Weather Prediction	4
AS-09-T	Space Weather	2
AS-23-L	Laboratory Course - II	4
Elective Courses: 4 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-12-T	Meteorological Instruments and Observational Techniques	4
AS-24-L	R/Python programming	4

Semester III		
Core Courses: 12 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-10-T	Climate Sciences	4
AS-25-L	Laboratory Course - III	4
AS-26-P	Project - I	4
Elective Courses: 8 Credits		
AS-13-T	Middle Atmosphere	4
AS-14-T	Introduction to Climate Services	2
AS-15-T	Agricultural Meteorology	4
AS-16-T	Ocean Biology and Biogeochemistry	2
AS-21-S	World Weather Reporting	2
Semester IV		
Core Courses: 12 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-11-T	Cloud Physics and Atmospheric Electricity	4
AS-27-P	Project - II	8
Elective Courses: 8 Credits		
Subject Code	**Subject Title**	**Number of Credits**
AS-17-T	Atmospheric Energetics and General Circulation	2
AS-18-T	Satellite Meteorology	2
AS-19-T	Radar Meteorology	2
AS-20-T	Atmospheric Chemistry and Air Pollution	4

UGC recommended courses (Additional 10 credits)		
Subject Code	**Subject Title**	**Number of Credits**
	Cyber security/Information security	4
	Skill based credits	4
	Human rights education	2

Courses which can be opted for by students from outside departments.

Semester ….		
Core Courses:		
Subject Code	**Subject Title**	**Number of Credits**
AS-02-T	Physical Meteorology	4
AS-03-T	Tropical Meteorology and Climatology	4
AS-10-T	Cloud Physics and Atmospheric Electricity	4
AS-11-T	Climate Sciences	4
Elective Courses:		
Subject Code	**Subject Title**	**Number of Credits**
AS-18-T	Satellite Meteorology	2
AS-19-T	Radar Meteorology	2
AS-20-T	Atmospheric Chemistry and Air Pollution	4

T- Theory; L- Lab work; P- Project; S: Seminar/Report
Each Credit is of 15 hours in the form of Lectures/ Tutorials/ Seminars/ Contact hours.

Detailed Syllabus for M.Sc. (Atmospheric Science)

AS-01-T: Mathematical, Statistical and Numerical Methods [2 credits]

Module-1 (1 credit)

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

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

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

Transform: Laplace, Fourier and Wavelet

Module-2 (1 credit)

The probability theory, probability density function least squares method.

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

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

Books:

1. Partial differential equations of Mathematical physics, Vol. 1 by A.N. Tychonov and A.A. Samarski (S. Radding Holdenday Inc.).
2. Numerical Analysis - the mathematics of computing, Vol. 1 and 2, W.A. Watson, T. Philipson and P.J. Oates (Edward Arnold Publication).
3. Time Series Analysis and Forecasting O.D. Anderson (Butterworths Publication)
4. Numerical Methods in Engineering 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, G.J. Haltiner and R.T.Williams, John Wiley and sons
9. Numerical Analysis by Shastri

AS-02-T: Physical Meteorology [4 credits]

Module 1 (3 credits)

Structure and composition of the atmosphere: Pressure and its variation with height, variation of temperature with height. Laws of thermodynamics, Equation of state for dry and moist air, Humidity Parameters, Virtual Temperature, Standard Atmosphere, Barometric Altimetry, Potential Temperature, Pseudo- adiabatic Process, Equivalent Temperature, Equivalent Potential Temperature, Claussius – Clapeyron Equation, Thermodynamic Diagrams. Uses of thermodynamic diagrams: LCL, LFC, Precipitable Water Vapor, Role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in thunderstorm development. Hydrostatic Equation and its application. Reduction of pressure to sea level. Stability and Instability of Atmosphere: Parcel Method.

Module 2 (1 credit)

Diffuse and Parallel Beam Radiation, Black Body Radiation and Laws of Radiation, Absorptivity and Emissitivity, Atmospheric absorption of solar radiation and infrared radiation,

Raleigh and Mie scattering. Radiative transfer and global energy balance.

Books

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

AS-03-T: Tropical Meteorology and Climatology [4 credits]

Basics (1 credit)

Definition of climate, physical factors of climate, earth-sun relationship, rotation of the earth, seasons, climatic controls. Basic ideas of general circulation (without mathematical derivations). Definition of wind, squall, gustiness, gale, Beaufort scale, land and sea breeze, katabatic and anabatic winds, Buys-Ballot's law, 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.

Synoptic (2 credits)

Introduction to synoptic meteorology, scales of weather systems, synoptic weather observations, surface, upper air and special observations. Representation and analysis of fields of meteorological elements, synoptic charts, analysis of surface and upper air charts, stream-lines, isotachs and contour analysis; tilt and slope of pressure/weather systems with height. Synoptic weather forecasting: prediction of weather elements such as rain, maximum and minimum temperature and fog; hazardous weather elements like thunderstorms, dust storms, tornadoes.

Tropical and extratropical interactions: (Extratropical 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).

Climatology (1 credit)

Climatic classification: methods of Koppen

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

Books:

1. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
2. Atmosphere, Weather and Climate by R.J. Barry and R.G. Chorley (Methuen Publication)
3. General Climatology by Critchfield
4. An Introduction to Meteorology by S. Pettersen
5. The Monsoons by P.K. Das (National Book Trust, India)
6. General Climatology by H.J. Critchfield
7. An introduction to climate by G.T. Trewartha
8. Physical Climatology by W.D. Sellers
9. World Survey of Climatology by H.E. Landsberg (Ed.)

AS-04-T: Dynamic Meteorology I [4 credits]

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

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

Books

1. An Introduction to Dynamic Meteorology, J.R. Holton, Academic Press.
2. Dynamic Meteorology, 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. Ceaseless Wind by Dutton
6. Weather Forecasting Vol I and II by S. Pettersen
7. The Physics of the Atmosphere by Houghton
8. The Physics of Monsoons R.N. Keshava Murthy and M. Shankar Rao, Allied Publishers, 1992.
9. Atmospheric Waves by Tom Beer

AS-05-T: Fundamentals of Earth Sciences [2 credits]

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

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

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

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

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

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

Books:

1. The Inaccessible Earth: An integrated view to its structure and composition. By G. C. Brown and A. E. Mussett, CHAPMAN &. HALL
2. Looking into the Earth An introduction to geological geophysics, Alan E. Mussett and M. Aftab Khan
3. Physics of the Earth, By Frank D Stacey and Paul M Davis
4. The Earth's Magnetism-An Introduction for Geologists, Roberto Lanza and Antonio Meloni
5. New Theory of the Earth by Don L. Anderson, Cambridge University Press
6. Fundamentals of Geophysics by WILLIAM LOWRIE, Cambridge University Press
7. Lowe, J.J. & Walker, M.J.C., 1997. Reconstructing Quaternary Environments. 2nd Edition. Longman.
8. Williams, M., Dunkerley,D., De Decker, P., Kershaw, P. & Chappell, J. 1998. Quaternary Environments. 2nd Edition. Arnold.
9. Ruddiman: "Earth's Climate, Past and Future
10. Bell, M. & Walker, M. J.C. 1992. Late Quaternary Environmental Change; physical and human perspectives. Longman Scientific and Technical, New York.
11. Bradley, R.S. 1985/1999. Paleoclimatology; reconstructing climates of the Quaternary. 2nd Edition Harcourt Academic Press: San Diego
12. Ice Age Earth: Late Quaternary Geology and Climate (Physical Environment) by Alastair G. Dawson, A. G. Dawson
13. Tectonics by Eldridge M. Moores, Robert J. Twiss
14. Global Tectonics by Philip Kearey, Keith A. Klepeis, Frederick J. Vine
15. ARCHEAN CRUSTAL EVOLUTION Edited by K.C. CONDIE
16. Cratons and Fold Belts of India by R S Sharma, Springer
17. Earth as an Evolving Planetary System, By Kent C. Condie, Elsevier

AS-06-T: Advance Dynamic Meteorology [4 credits]

Waves and 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.

Boundary Layer Meteorology (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. Similarity theory. Boundary layer modeling concepts.

Books:

1. Fluid Mechanics by L.D. Landau and E.M. Liftshifts, Pergamon Press.
2. Atmospheric Turbulence by Panofsky and J.A. Dutton.
3. Introduction to Boundary Layer Meteorology" Stull
4. The Atmospheric Boundary Layer, R.M. Stewart, WMO-523.
5. Micro meteorology by O.G. Sutton.
6. Micrometeorology by S.P. Arya, Academic Press
7. Atmospheric Boundary Layer Flows: Their Structure and Measurement. J. C. Kaimal and J. J. Finnigan, Oxford University Press.
8. An Introduction to Dynamic Meteorology, J.R. Holton, Academic Press.
9. Dynamic Meteorology, Askel Wiin Nelson, WMO Publication.
10. Introduction to Theoretical Meteorology, S.L. Hess,
11. Dynamic and Physical Meteorology, G.L. Haltiner and F.L. Martin, Mc Graw Hill.
12. Ceaseless Wind by Dutton
13. Weather Forecasting Vol I and II by S. Pettersen
14. The Physics of the Atmosphere by Houghton
15. The Physics of Monsoons R.N. Keshava Murthy and M.Shankar Rao, Allied Publishers, 1992.
16. Atmospheric Waves by Tom Beer

AS-07-T: Fundamentals of Ocean Sciences [2 credits]

Physical Characteristics of the Ocean: Ocean Basins, Sea floor features, Properties of sea water & Equation of State, Temperature, Salinity, Density and Oxygen characterstics, 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. Biological productivity in the oceans

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; Wind driven ocean circulation, Ekman pumping, Ekman transports, Wind driven coastal currents; Sverdrup, Stommel and Munk's theories, Westward intensification.

Ocean waves, their generation and propagation; bottom topography, Propagation, refraction, and reflection of waves. Wave spectrum, storm surges and tsunamis, Tides and tide generating forces. Tidal currents in shallow seas, estuaries and rivers.

Sea surface temperature, Mixed layer, Thermocline, Upwelling, Penetration of Solar Radiation, Turbidity, Waves, Swell and Currents induced by wind, Oceanic Kelvin and Rossby waves

Indian Ocean Dipole, Madden-Julian oscillation (MJO), Elnino and Southern Oscillation (ENSO)

Books

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

AS-08-T: Numerical Weather Prediction [4 credits]

Numerical Weather Prediction (2 credits)

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

Initialisation and Data Assimilation (1 credit)

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

Parametrization (1 credit)

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

Books

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

AS-09-T: Space Weather [2 credits]

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

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

Books:

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

AS-10-T: Climate Sciences [4 credits]

Climate Change & Variability

Overview of the climatic history of the earth. Long term changes (Climate of Past century, past millennium, past glacial period). Methods of determining past climate. Possible causes of climate change- External (Milankovitch variation and Solar activity) and Internal (natural and anthropogenic**)**.

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 variability and forcings; feedback processes, low frequency variability.

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

Climate Modelling

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.

Books:

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

AS-11-T: Cloud Physics and Atmospheric Electricity [4 credits]

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

Weather modification (Artificial and inadvertent).

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).

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

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

Books

1. A Short course in cloud physics" R.R. Rogers,
2. Atmospheric Sciences: An introductory Survey by J.M. Wallace and P.V. Hobbs, Academic Press.
3. Atmospheric Electrodynamics" H.Volland, Springer Verlag,
4. Physics of the Cloud by B.J. Mason
5. Microphysics of cloud and Precipitation by Pruppacher and Klett
6. Atmospheric Electricity by J.A. Chalmers
7. Earth's Electrical Environment- National Academy Press
8. Lightning by M.A. Uman
9. Cloud Dynamics by R.A. Houze
10. Clouds Rain and Rainmaking by B.J. Mason
11. Electrical Nature of Storms by D. McGorman and W.D. Rust

AS-12-T: Meteorological Instruments and Observational Techniques [4 credits]

Surface and Upper air observations (3 Credits)

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

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

Ground based remote sensing observations (1 Credit)

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

Books

1. Probing the atmospheric boundary layer, D.H. Lenschow
2. Instruments and Techniques for probing the atmospheric boundary layer, D.H. Lenchow.
3. Guide to Meteorological Instruments and method of observation, WMO-8,
4. Meteorological Instruments by W.E.K.Middleton and A.F. Spilhaus,
5. Applications of Remote Sensing to Agrometeorology F.Toselli, Kluwer
6. Battan (1973), Radar Observation of the Atmosphere
7. Bringi and Chandrasekar (2001), Polarimetric Doppler Weather Radar, Cambridge Press
8. Doviak and Zrnic (1984, 1993), Doppler Radar and Weather Observations, Academic Press
9. Atlas (1990), Radar in Meteorology, AMS (Battan Memorial volume)

AS-13-T: Middle Atmosphere [4 credits]

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

The ionosphere - composition morphology and general properties.

General climatology of the middle atmosphere, wind and temperature distribution. Atmospheric waves and Atmospheric tides. Zonally averaged circulation energetics of the middle atmosphere. Quasi Biennial Oscillation (QBO), Semiannual oscillation (SAO), Stratospheric Sudden warming.

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

Books:

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

AS-14-T: Introduction to Climate Services [2 credits]

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

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

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

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

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

Books:

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

AS-15-T: Agricultural Meteorology [4 credits]

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. Importance and scope of Agricultural Meteorology.

Agricultural droughts – classification, Effects of floods, hail, dew, frost or crop growth. 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. Concept of DSSAT.

Books

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

AS-16-T: Ocean Biology and Biogeochemistry [2 credits]

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

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

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

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

Books:

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

AS-17-T: Atmospheric Energetics and General Circulation [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- Total Potential Energy, Available Potential Energy, Kinetic Energy. Conservation of angular momentum and Kinetic Energy.

Books:

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

AS-18-T: Satellite Meteorology [2 credits]

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

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

Visible, infrared, and microwave channels; Scanning mechanism, IFOV and

contrast enhancement in an image.

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

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

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

Books:

1. Theory of Satellite Orbit in the Atmosphere by King Hele
2. Weather Satellite by L.F. Hubert
3. Meteorological Satellite by W.K. Widger
4. A guide to Earth Satellite by D. Fishlock
5. Advances in Satellite Meteorology by Vinnichenko Goralik
6. Satellite meteorology by Henri W. Brandli
7. Satellite Meteorology - WMO Technical Notes No. 124 and 153.
8. Satellite Meteorology, by R.R. Kelkar

AS-19-T: Radar Meteorology [2 credits]

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

Books:

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

AS-20-T: Atmospheric Chemistry & Air Pollution [4 credits]

Atmospheric Chemistry

Chemistry of the atmosphere : Evolution of earth's atmosphere, Nitrogen, hydrogen halogen, sulfur, carbon-containing compounds in the atmosphere, ozone and neutral chemistry, chemical and photochemical processes, 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

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

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

Books

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

AS-21-S: World Weather Reporting [2 credits]

Each student has to give two seminars reporting on the world weather for the period given by the Seminar teacher. Each Seminar will be evaluated for ten marks. The student has to submit a seminar report at the end of the Semester which will be evaluated for **20** marks.

AS-22-L: Laboratory Course - I [4 credits]

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. Data Interpolation.

Plotting and Analysis of Tephigram (1 credit)

Plotting and analysis of Tephigram for different seasons and stations.

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

AS-23-L: Laboratory Course-II [4 credits]

1. Analysis of aerosols using ground-based instruments; aerosol spectrometer, Athelometer, Aerosol Robotic Network stations.
2. Analysis of aerosols using satellite based sensors; MODIS, TOMS, CALIPSO, MISR etc.
3. Analysis of surface meteorological data from IMD; temperature, pressure, wind speed, rainfall
4. Analysis of upper air data; using radiosondes, ozonesondes
5. Analysis of clouds vertical profiles using satellite sensors, MODIS, CloudSat, CALIPSO
6. Analysis of cloud and precipitation characteristics using ground based instruments; Ceilometer, disdrometer, raingauge
7. Analysis of surface and upper air weather charts for Monsoon
8. Analysis of surface and upper air weather charts for Western Disturbance
9. Analysis of surface and upper air weather charts for Tropical Cyclone
10. Analysis for vertical time and space section

Any seven practicals needs to be completed to finish the course.

AS-24-L: R/Python programming [4 credits]

Python

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

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

Python Input Output-Fancier Output Formatting, Old string formatting, Reading and Writing Files, Methods of File Objects, The pickle Module, Errors and Exceptions: Exceptions, Handling Exceptions, Raising Exceptions, User-defined Exceptions, Defining Clean-up Actions, Predefined Clean-up Action

Applications of Numerical Python, Scientific Python and Matplotlib

(or)

R

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

Books:

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

AS-25-L: Laboratory Course- III [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. Computation of Velocity potential using observed or reanalysis wind data.
8. Subjective analysis of geopotential height.
9. Objective analysis of geopotential height.
10. Hands-on experience of DSSAT software

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

AS-26-P: Project-I [4 credits]

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

At the end of **3rd** semester, student will be required to submit a Project Report to the University.

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

For the Semester-End examination the student will have to give a Viva-voce examination which will be evaluated for **2** 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.

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

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

AS-27-P: Project-II [8 credits]

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

At the end of **4th** semester, student will be required to submit a Project Report to the University.

The project work will be evaluated by the guide for **3** credits by the Guide and **1** credit by the internal/ co-guide 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 4 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.

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

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