UNIVERSITY OF CALCUTTA

Notification No. CSR/ 66 /18

It is notified for information of all concerned that the Syndicate in its meeting held on 13.07.2018 (vide Item No.11) approved the Syllabus of Two-Year (Four-Semester) M.Sc. Course of Study in Atmospheric Science under CBCS in the Post-Graduate Departments of the University and in the affiliated Colleges offering Post-Graduate Courses under this University, as laid down in the accompanying pamphlet.

The above shall be effective from the academic session 2018-2019.

17/08/18

(Debabrata Manna)
Deputy Registrar (Acting)

SENATE HOUSE
KOLKATA-700073
The 17th August, 2018

Department of Atmospheric Sciences

University of Calcutta

CBCC Syllabus,(M.Sc.) Atmospheric Science

Fundamentals of Atmospheric Sciences

Basic concept of different layers of our atmosphere and their coupling,

Composition of troposphere,Lapse rate,Hydrostatic equation,Basic concepts of Thermodynamics,Basic concept of radiation,Solar parameters and solar constant.

Composition of Stratosphere,Ozone hole over Antarctica and different theories,Atmospheric response due to different pollutant.

Different calamities and Recent climate change,Basic concept of Lightning activity,Earthquake,Heat stroke,Thunderstorm,Cyclone and flood.

Course Catalogue

Orientation of the M.Sc. Course in Different Semesters

1st Semester

CORE COURSES	**Theory**	**Practical**	**16 credits**
ATMOS C11: Physical Meteorology	40	10	3+1 credits
ATMOS C12: Dynamic Meteorology	40	10	3+1 credits
ATMOS C13: Synoptic Meteorology	40	10	3+1 credits
ATMOS C14: General Climatology	40	10	3+1 credits
SUPPORTIVE COURSES			**2 credits**
ATMOS S11: Upper Atmospheric Dynamics	50		2+0 credits

2nd Semester

CORE COURSES	**Theory**	**Practical**	**14 credits**
ATMOS C21: Numerical weather Prediction	30	10	2+1 credits
ATMOS C22: Air Pollution & Atmospheric Chemistry	30	10	3+1 credits
ATMOS C23: Cloud Physics & Atmospheric Electricity	30	10	2+1 credits
ATMOS C24: Meteorological Instrumentation	40	10	3+1 credits
& remote Sensing			
SUPPORTIVE COURSES			**2 credits**
ATMOS S21: Oceanography	40		2+0 credits
OPTIONAL COURSES			**2 credits**
ATMOS O21: Tropical Meteorology	30	10	1+1 credits
ATMOS O22: Climate Sciences	30	10	1+1 credits

3rd Semester

CORE COURSES	**Theory**	**Practical**	**12 credits**
ATMOS C31: Atmospheric Data Analytics	30	10	3+1 credits
ATMOS C32: Micro & Meso Scale Meteorology	30	10	3+1 credits
ATMOS C33: Seismology, Geophysics and Geodesic	30	10	3+1 credits
SUPPORTIVE COURSES			4 **credits**
CBCC A	50		2+0 credits
CBCC B	50		2+0 credits
OPTIONAL COURSES			**2 credits**
ATMOS O31: Geographical Information Systems	30		2+0 credits
ATMOS O32: Aviation Meteorology	30		2+0 credits

4th Semester

CORE COURSES	**Theory**	**Practical**	**12 credits**
ATMOS C41: Middle Atmospheric Dynamics	30	10	3+1 credits
ATMOS C42: Agro & Hydro Meteorology	30	10	3+1 credits
ATMOS C43: Dynamics of Coupled Systems	20	10	3+1 credits
SUPPORTIVE COURSES			**4 credits**
ATMOS S41: Introduction to Global Modelling	30	10	1+1 credits
ATMOS S42: Atmospheric Weather Extremes	20	10	1+1 credits
SEMINAR ON PROJECT WORK	30		0+1 credits
GRAND VIVA	40		0+1 credits

University of Calcutta

M.Sc. Syllabus – Atmospheric Science, 2018

ATMOS C11: Physical Meteorology

Radiation: concept of atmospheric radiation, laws of radiation, solar radiation, solar spectrum and solar constant, distribution of solar insolation at the top of the atmosphere, scattering and absorption of solar radiation in the earth-atmosphere, effect of atmospheric gases, aerosols, clouds(surface and planetary albedo) on solar radiation, solar radiation at the earth's surface, atmospheric window, absorbing elements and their spectrum distribution, optically thick and thin approximations, aerosol scattering , estimation of radiative heating and cooling. Terrestrial radiation and its passage through the atmosphere, emission and absorption of terrestrial radiation, Raleigh and Mie scattering, radiative transfer, green house effect, net radiation budget.

Thermodynamics: state of the atmosphere: main constituents of dry air, carbon dioxide, ozone, ozone depletion, water vapour and aerosols, vertical thermal structure of the atmosphere: troposphere, stratosphere, mesosphere, thermosphere and exosphere; environmental lapse rate; standard atmosphere; hydrostatic equilibrium; hydrostatic equation; geopotential; equipotential surfaces. Basic concepts of thermodynamics- composition of atmosphere, composition of ocean, equation of state for air, equation of state for seawater, virtual temperature, potential temperature, relative humidity, absolute humidity, dew- point temperature, equivalent potential temperature, mixing ratio, wet bulb temperature, first and second law of thermodynamics, clausius- clapeyron equation. Adiabatic processes in the atmosphere and ocean, hydrostatic equation, thermodynamics of water,stability criteria of the atmosphere and ocean. Lapse rate, stability indices, thermodynamic diagram, thermodynamic feedbacks in the climate system, parcel theory.

Practical: T-φgram description, analysis and use in identifying weather conditions, computer programming of radiative and thermodynamics variables to analyze the role of different fundamental/ derived variables in the genesis of different weather system.

Suggested Text Books & Study Materials

- Dynamical and Physical Meteorology- G.J.Haltiner And F.L.Martin
- Physical Meteorology- H.G. Houghton
- Atmospheric Thermodynamics- J.V. Iribarne And W.L. Godson
- Introduction to Theoretical Meteorology- S. L.Hess
- Atmospheric Sciences: An Introductory Survey- J.M. Wallace And P.V. Hobbs
- An Introduction to Atmospheric Thermodynamics- A.A.Tsonis
- Physical Meteorology-J.C.Jhonson
- An Introduction to Atmospheric Radiation- K.N. Liou

ATMOS C12: Dynamical Meteorology

Pressure gradient force viscous force gravitational force centripetal acceleration and centrifugal force gravity revisited coriolis force and the curvature effect, constant angular momentum oscillations,

structure of static atmosphere: the hydrostatic equation, pressure as a vertical coordinate, a generalised vertical coordinate, kinematics, scale analysis, total differentiation, total differentiation of a vector in a rotating system, the vector form of the momentum equation in rotating coordinates, component equations in spherical coordinates, scale analysis of the equations of motion, geostrophic approximation and geostrophic wind, approximation prognostic equation: rossby number, the hydrostatic approximation, the continuity equation, a eulerian derivative, a langrangian derivative, scale analysis of the continuity equation, the thermodynamic energy equation, the thermodynamics of the dry atmosphere, potential temperature, the adiabatic lapse rate, static stability, scale analysis of the thermodynamic energy equation, the boussinesq approximation, the thermodynamics of the moist atmosphere, equivalent potential temperature, the pseudoadiabatic lapse rate, conditional instability.

The horizontal momentum equation the continuity equation, the thermodynamic energy equation, balanced flow- natural coordinates, geostrophic flow, inertial flow, cyclostrophic flow, the gradient wind approximation, trajectories and streamlines, barotropic and baroclinic atmospheres, vertical motion- the kinetic method, the adiabatic method, surface pressure tendency

The circulation theorem, vorticity, vorticity in natural cordiantes, the vorticity equation, Cartesian coordinate form, the vorticity equation in isobaric coordinates, scale analysis of the vorticity equation, potential vorticity, shallow water equations, barotropic potential vorticity, Ertel- potential vorticity in isentropic coordinates, equations of motion in isentropic coordinates, the potential vorticity equation, integral coordinates on isotropic vorticity. Rossby & inertial gravity waves. The Rayleigh theorem, eady stability problem, transient growth of neutral waves, downstream development.

Practical: calculation of horizontal divergence from wind data, calculation of absolute vorticity from wind data, calculation of geostrophic wind, calculation of gradient wind, calculation of thermal wind, calculation of vertical velocity, FORTRAN PROGRAMMING.

Suggested Text Books & Study Materials

- An Introduction to Dynamic Meteorology- J.R.Holton
- Dynamic and Physical Meteorology- G.J. Haltier And Martin
- Dynamic Meteorology-B. Haurwitz
- Dynamic Meteorology- Ed.Wiin Nielsen, WMO Publication

ATMOS C13: Synoptic Meteorology

Analysis of surface, upper air and other derivative charts: scalar fields and their kinematics—pressure field, temperature and moisture fields. Evaluation of wind analysis, differential properties of wind field, streamline-isotach analysis, examples of some patterns in the wind field.

Air mass, sources and classification of air masses, fronts and frontogenesis, classification of fronts, Margules equation for frontal slope, extra- tropical cyclones, waves in the mid latitude westerlies, western disturbances and its associated weather in Indian region.

Indian summer monsoon, SW monsoon onset, semi-permanent systems, active and break phase of monsoon, monsoon depression, withdrawal of SW monsoon, NE monsoon.

Easterly waves, its structure and associated weather. Tropical cyclone, formation and its horizontal and vertical structure, movement of TC, landfall and associated weather.

Practical: Synoptic Coding and Decoding Plotting Of Surface & Upper Air Charts: Interpretation And Implication Of Different Weather Systems And Writing Forecast On The Basis Of Chart Analysis

Suggested Text Books & Study Materials

- Weather Analysis And Forecasting Vol. 1 & 2- B. Patterson
- Tropical Meteorology- H. Riehl
- Climate And Circulation Of The Tropics- S. Hasternath

References

- Monsoon Meteorology- C.S. Ramage
- Jet Stream Meteorology- E.R. Reiter

ATMOS C14: General Climatology

Introduction of climatology, fundamental principles of climatology, the climate system: controls on climate. Global climate classification, earth-sun relation, coastal effect on climate, orographic effect on climate, different climate zone, trends of climate and its variability, climate modification, Indian climatology: seasonal pattern of different weather elements: western disturbances, kalbaishaki (pre-monsoon local severe storms), monsoon(SW & NE), tropical cyclones, heat waves and cold waves, green house warming, interannual variability of climate & its effect on biosphere, different climate methods. Regional distribution and seasonal variation of cloud, precipitation and fog etc

Climatic classification, climatic regions of the world, climate in the equatorial, tropical, subtropical and Polar Regions

Applied climatology: climate and water resources, climate and biosphere, climate and agriculture

Practical: Analysis of variation of surface temperature,Trend of rainfall,Trend of lightning activity over Kolkata

Suggested Text Books & Study Materials

- Physical Climatology- William D. Sellers
- Climatology- Bernhard – Haurwitz and J.M.Austin
- Dynamical And Physical Meteorology- George J. Haltiner and F.L.Martin
- Physics of Monsoon- Keshav Murthy and Sankar Rao
- Essentials of Meteorology- C. Donald Ahrens
- Foundation of Climatology-E.T.Stinger
- An Introduction to Climate- G.W.Threwartha
- The Nature and Causes of Climate Change- Goodies, Paultikaf and Davies

ATMOS S11: Upper Atmospheric Dynamics

Airglow emissions, classification of airglow emissions, experimental arrangements, characteristics and excitation mechanism of different, emissions. Diurnal and seasonal variation of different emissions. Role of sun on, different atmospheric emissions. Ionosphere and its layers, ionospheric density profile, aurora. The interaction of energetic solar photons with the upper atmosphere,chemical and ionic reaction in the thermosphere, dynamics of thermosphere and ionosphere, spectroscopic

emission,ion and neutral composition of upper atmosphere, temperature in upper atmosphere,solar energetic particle precipitation,ionospheric TEC, slab thickness, SSAOs, MSAOs, gravity wave influence in the thermosphere and mesosphere, disturbances in the equatorial ionosphere induced by acoustic gravity wave, wave-equation of AGWs. Thermospheric wind, electric current effects on wind, equatorial spread F, connection between ionosphere and atmospheric tides, long term trend in the upper atmosphere.

Suggested Text Books & Study Materials

- Aeronomy Of The Middle Atmosphere: G. Brasseur And S.Simon
- The Upper Atmosphere: R.A Craig
- Dynamic Meteorology Of The Stratosphere And Mesophere: J.R. Holton
- Physics Of The Earth's Upper Atmosphere: C.O. Hines, I.Paghis, T.R. Hatz & J.A. Fejer
- Stratosphere-Troposphere Interaction: K. Mohan Kumar

ATMOS C21: Numerical Weather Prediction

Numerical models, filtered models, filtering of sound and gravity waves model, barotropic model, equivalent barotropic model, barotropic instability, hierarchy of NWP models, short , medium & long range models

Numerical methods- finite difference methods- forward and centered finite difference methods, implicit methods- computational instability , application to advection scheme, computation to jacobian and laplacian ; solution of Helmholtz and poisson equations using relaxation method, baroclinic models- two level model, quasi geostrophic multi-level models, omega equation, linear balanced model, non-linear balanced model,baroclinic instability, primitive equation model, sigma coordination system, two level primitive equation models, multi level primitive equation models ,introduction to mesoscale models: non hydrostatic assumption, basic structure of MM5 and WRF models and their applications, objective analysis- cressman method, method of optimum interpolation, initialization, static initialization, dynamic initialization- normal mode initialization, Newtonian relaxation or Nudging.

Grid systems, vertical coordinates, boundary conditions, objective analysis and initialization, data assimiliation techniques for the use of mesoscale NWP models, nonlinear aliasing and instability, parameterizations of different physical processes , ensemble forecasting.

Objective analysis, initialization of the data for use in weather prediction models, data assimiliation techniques, spectral methods, parameterizations of sub grid scale processes.

Suggested Text Books & Study Materials

- Numerical Weather Prediction G.J. Haltiner, John Wiley
- Numerical Prediction And Dynamic Meteorology G.J. Haltiner, R.T. Williams, John Wiley
- An Introduction To Dynamic Meteorology- J.R.Holton, Academic Press
- Numerical Weather Analysis And Forecasting P.D. Thompson

ATMOS C22: Air Pollution & Atmospheric Chemistry

Chemistry of the atmosphere: evolution of earth's atmosphere, nitrogen, hydrogen halogen sulphur carbon containing compounds in the atmosphere, ozone and neutral chemistry, chemical and photochemical processes, chemical and dynamical life time of atmospheric constituents, ozone inthe

atmosphere: evolution of the ozone layer, sources and sink of the tropospheric and stratospheric ozone, cholorofluorocarbons, ozone and uv radiation, supersonic transport, atmospheric aerosols, concentration and size, sources and transformation, chemical composition, transport and sinks, residence times of aerosols, geographical distribution and atmospheric effects. Air pollution: sources of anthropogenic pollution, atmospheric effects- smog, visibility, definition, types of pollutants (gaseous, particulate matter) sources and effects of pollutants(point, area, volume) forest fires, industrial sources etc. the atmosphere over land and ocean , different regions of atmosphere and pollutants terrain, the PBL and its significance, qualitative geometry of pollutions the stability of atmosphere and its role in pollution. Dynamics of ABL, equation of motion, Prandtl's theory of mixing layer, turbulence, convection, Richardson number, K-theory of diffusion, relative and particle-Taylor theory, the plume puff and continuous plume, rise of plume in different environment, entrainment, thory of plume rise, the Gaussian plume and modelling of plume, dispersion , Brownian motion , random walk and turbulent theory of diffusion, effects of pollutants on chemistry of the atmosphere, hydrosphere and lithosphere- acid rain, indoor pollution, smog formation , transport mobility and partition of pollutants. Air water soil pollution and their effects. Urban heat intensity. Adiabatic lapse rate, temperature inversion.

Practical: monitoring air quality, analyses, stud on fog, smog, changes in air quality

Suggested Text Books & Study Materials

- Fundamentals Of Air Pollution By Richard W. Boubel Et Al.
- Pollution: Causes , Effects And Control Third Edition By Roy M. Harrison
- Air Pollution By M.N. Rao, H.V.N. Rao
- Introduction To Atmospheric Chemistry By P.V. Hobbs
- Atmospheric Chemistry And Physics: From Air Pollution To Climate Change By John H. Seinfeld, Spyros N. Pandis
- Chemistry Of The Upper And Lower Atmosphere By Barbara J. Finlayson-Pitts, Jr James N.Pitts
- Chemistry Of Atmosphere By Richard P. Wayne
- Briggs. G. A , Plume Rise
- Pasquill, Atmospheric Diffusion
- Air Pollution By Jermy Colls
- Fundamentals Of Air Pollution- Daniel Vallero
- Introduction To Environmental Engineering And Science- Gilbert M. Masters

ATMOS C23: Cloud Physics & 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, Artificial precipitation, Hail suppression, Fog and Cloud dissipation , Radar observation of cloud and precipitation , Rain – drop spectra. Droplet Break up, Atmospheric aerosols: Continental and Marine (Origin, Physical and Chemical characteristics). Fair weather electric field in the atmosphere and potential gradient, Ionization in the atmosphere condensation currents, point discharge currents, Air-Earth currents, point discharge currents, electrical fields in thunderstorm, theories of thunderstorm electrification, electro – dynamic coupled models, lightning discharge , sprite, the global electric

circuit (classical concept, validity and limitations), atmospheric optics: mirages rainbows, haloes: atmospheric refraction, coronas, atmospheric electricity ionization in the atmosphere, fair weather electric field, potential gradients conductivity, conduction currents, air- earth currents, point discharge currents, electrical characteristic of thunderstorms, theories of thunderstorm electrification, tornadoes, water spouts, lightning discharges, global air electric circuit. atmospheric chemistry: minor constituents, the sulphur compounds, the nitrogen compounds, the carbon compounds, photo chemical pollution and smog with industrial application, atmospheric aerosols, rain out and wash out mechanisms.

Practical: computation of cloud characteristics with satellite and remote sensing observations

Suggested Text Books & Study Materials

- Cloud physics by R.Rogers
- Cloud, Rain and Rainmaking by B.J. Mason
- Atmospheric Physics by J.V, Iribrane & H.R.Cho
- Atmospheric Electricity by Calmers
- Electricity of the free atmosphere by Yminganiton
- The physics of clouds by B. J. Mason
- A short course in cloud physics R. R. Rogers
- Cloud Dynamics by R. A. Houze
- Microphysics of cloud and precipitation by Pruppacher and Klett
- Atmospheric Sciences: An Introductory Survey J.M. Wallace And P. V. Hobbs Academic Press
- Atomopheric Electrodynamics H Volland Springer Verlag
- Storm and cloud dynamics by W. R. Cotton and R. A. Anthes

ATMOS C24: Meteorological Instrumentation and Remote Sensing

Barometer, hygrometer, anemometer, rain gauge, evaporimeter, thermometry, altimeter, upper air measurement, measuring solar and earth radiation, chart recorder, data logger,conventional measurements of pressure, temperature, humidity, wind, precipitation, visibility, clouds, soil temperature and humidity. Ocean temperature, salinity, wave, height, currents, self recording instruments, radiosondes, radiometersondes, ozonesonde, LIDARS, SODARS, RADARS: basic concept of amplifier , oscillator, receiver, working principle of radar,different types of radar, radar antenna, PPI display, radar network of IMD, components of radar, function of radar components, Doppler weather radar, Doppler principle, Doppler shift, primary and secondary products available from DWR, details of the products, interpretation of radar echoes/imageries, special characteristics of various weather systems visualized from radar.

Satellite meteorology: atmospheric satellite system, orbits and characteristics of different atmospheric satellite system, geostationary system, polar orbiting system component of satellite systems, meteorological satellites, polar orbiting & geo stationary satellites, current and future meteorological satellites of the world. Visible and infrared rafiometers, multiscanner radiometer.

Remote sensing in meteorology: remote sensing of atmospheric variables, environment with electromagnetic energy, remote sensing techniques (WP-RASS), measurements of particulate matters, SOx, NOx , CO_2 and CO. Vertical sounding, limb sounding, Schwarzchild's equation. Satellite image interpretation and enhancement techniques, cloud type identification and Neph analysis,synoptic scale

weather systems, mesoscale weather systems, tropical cyclones, estimation of central pressure by using Dvorak's technique. GPS, active and passive microwaves sensor and their application for ocean surface winds, sea surface temperature and soil moisture.

Practical: data collection and analysis of meteorological data and information using the simple meteorological instruments pertaining to weather analysis and forecasting

Suggested Text Books & Study Materials

- Guide to meteorological instruments and methods of observation. Sixth edition WMO- No-8.
- Compendium of lecture notes on meteorological instruments WMO- No-622.
- Air- sea interaction instruments and methods edited by F.Dobson ,L.Hasses and R.Davis, Premium Press New York.
- Satellite oceanography- an introduction to oceanographers and remote sensing scientists J.S.Robinson, Ellis Horward Limited.
- Instruments and techniques for probing the atmospheric boundary layer D.H.Lenchow
- meteorological instruments W.E.K.Middleton and A.F. Spilhaus
- applications of remote sensing to agrometeorology F.Toselli,Kluwer
- Remote Sensing of Atmosphere- J.T.Houghton, F.W. Taylor and C.D.Rodgess
- Introduction to Environmental Remote Sensing- E.C. Baratte and L.F. Curtis

ATMOS S21: Oceanography

Equation of state of seawater, current system including under current their formation and theories, oceanic fronts, subtropical current system, western and eastern boundary currents, Somali current, Thermohaline and abyssal circulation, formation of water masses, mixing and double diffusion, TSV programs, computation of divergence and estimation of vertical velocity, acoustics and optics, equation of motion of frictionless ocean currents, scale analysis, barotropic and baroclinic approximation, Geostrophic currents in a stratified ocean, the 2-D approximation, marine pollution, pathways of transfer of various pollutants and their fates in the sea, remote sensing of the ocean, physical properties of seawater: temperature, salinity and conductivity, density, sound in the sea, light in the sea, colour of seawater . Temperature, salinity and density distributions. Transparency of seawater, heat budget of oceans: heat budget terms, short and long wave radiation, evaporation , heat conduction, oceanographic instruments: temperature measurements, protected and unprotected reversing thermometers, MBT, XBT, sea gliders, CTD. Current measurement: Lagrangian and Eulerian methods with examples, ADCP, position fixing at sea, GPS wave and tide measurements, marine geology: continental slelf, slope, shelf sediments, mineral resources of the world ocean, submarine topography, mid oceanic ridge system. Manganese and other deposits and the factors control their distribution. Beach material, shape and size. Beach terminology, marine chemistry: composition of seawater, constancy of composition, dissolved gases oxygen in the ocean transfer of particle aerosols, plankton and climate bio-geo chemical cycles, marine environment and their characterstics, marine eco system, rocky shore, sandy shore, mangroves and seaweed.

Suggested Text Books & Study Materials

- Descriptive Physical Oceanography By G.L.Pickard And W.J.Emery
- Oceans By Sverdrup And Johnnson And Flemming
- Descriptive Physical Oceanography By M.P.M. Reddy
- Introductory Dynamic Oceanography By S.Pond And G.L. Pickard

- Elements Of Physical Oceanography By Mcclellan
- Introduction To Principles Of Dynamical Oceanography By Neumann And Pierson

ATMOS O21: Tropical Meteorology

Introduction of the tropical region over the globe, circulation cell theory, Hadley cell, walker 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, Idea of global 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, northeast monsoon circulation and rainfall.

Pre and post monsoon cyclonic storms, tracks, and frequencies, fog, dust storms, Nor'westers, heat waves, pre monsoon thunderstorms

Madden –Julian oscillation (MJO), EL-Nino and southern oscillation (ENSO), quasi-biennial oscillation (QBO), Indian Ocean Dipole (IOD) and monsoon.

Suggested Text Books & Study Materials

- Tropical Meteorology Vol I &II By G.C. Asnani
- Monsoon Meteorology By C.P.Chang & T.N. Krishnamurti
- Cloud Dynamics By R.A.Houze
- Tropical Cyclones, Their Evolution Structure And Effecr By R.A. Anthens
- Meteorology Over The Tropical Oceans By D.B.Shaw
- Elnino, La Nina And The Southern Oscillation By G.S. Philander

ATMOS O22: Climate Sciences

Concepts of weather and climate- world climate system- climate of the hemispheres. solar radiation- heating and cooling rates of the atmosphere- latitudinal distribution of the radiation balances of the earth's surface, atmosphere and earth's atmosphere system . Global distribution of temperature precipitation pressure and winds- circulation pattern during winter and summer seasons. Jet streams. Monsoons- Asia, Australia, E.Africa and North America, Systems of climatic classification- Koppen- Thornthwaite.

General circulation of the atmosphere- convective and meridional circulation- tri cellular model- Palmen's modified model- circulation indices- experiments of general circulation- Dishpan experiment; dynamics of atmospheric circulation- maintenance of the general circulation- climatic changes- local and planetary evidences- carbon dating- theories of climate changes, paleoclimate- climate change and variations in earth's orbit, climate trends ENSO- teleconnection of the world climate system, ozone hole, nuclear winter, global warming- consequences of global warming, volcanic eruptions and aerosols, impact of climate change on weather and climate; climate change and agriculture.

Suggested Text Books & Study Materials

- Physical Climatology- William D. Sellers
- Climatology- Bernhard, Haurwitz And James M. Austin
- Dynamical and Physical Meteorology- G.J. Haltiner And F.L. Martin
- Physics of Monsoon- Keshav Murthy And Sankar Rao
- Essentials of Meteorology- C. Donald Ahrens
- Climate Change Causes: Effects And Solution by J. T. Hardy
- International Relations and Global Climate Change by U.Luterbacher, D.F. Sprinz

ATMOS C31: Atmospheric Data Analytics

Statistical Techniques in Meteorology: Empirical Distribution and Exploratory data analysis. Probability and Statistics: theory of probability and probability distribution, binomial distribution and random walk, conditional probability measures, hypothesis testing, Method of multivariate Data analysis, linear Regression model: Least Square for parameter estimation, Goodness of Fit, residual analysis. Historical development of Soft computing, Diversification of concept of soft computing, concept of Artificial Intelligence in meteorology, Fundamentals of soft computing, Advantages and disadvantages of soft computing over conventional computing in meteorology Application of Artificial Neural Network, Genetic Algorithm, Fuzzy Logic, Rough Set theory, Probabilistic Reasoning, Simulated Annealing in meteorology data analysis and forecasting, chaos theory and Graph theory in meteorology Concept of Fractal Geometry in weather analysis.

Practical: Use of various soft computing tools for pattern recognition, classification, GrADS, MATLAB and ENVIS packages.

Suggested Text Books & Study Materials

- Statistical methods in Atmospheric Sciences by Daniel S. Wilks
- Time series Analysis and Forecasting by O. D. Anderson
- Statistical Analysis in Climate Research by Hans Von Storch, Francis W. Zwiers
- Neural Networks, Fuzzy Logic and Genetic Algorithms: Synthesis and Applications by S. Rajasekaran, G.A. Vijayalakshmi Pai

ATMOS C32: Micro & Meso Scale Meteorology

Micrometeorology: Boundary layer definition, wind and flow turbulence, Taylor's hypothesis, boundary layer depth and structure.

Spectral gap, mean and turbulent parts, rules of averaging, Reynold's averaging, turbulence kinetic energy, different fluxes in boundary layer.

Boussinesq approximation, Applying Reynold's averaging to governing equations, turbulence closure problem, 1st order turbulence closure, similarity theory, Ekman spiral, planetary boundary layer(PBL)parameterization for mesoscale models.

Mesoscale meteorology: defination of atmospheric scales,energy generation and scale interactions,predictability of mesoscale systems.

Governing equations for mesoscale motions,approximation to governing equations,sound waves,mesoscale waves,gravity waves,inertia gravity waves,mesoscale wave generation and maintance.

Thermally-driven flows: sea-land breezes,mountain-valley circulation.

Mesoscale instabilities,isolated convective storms,mesoscale convective system,basics of mesoscale modeling.

Practical: Development of computer code to compute the following; Lifting condensation level (LCL),Level of free convection(LFC),Convective available potential energy(CAPE),Convective inhibition energy(CINE),Wind shear(Speed & Detection)Interpretation and conclusion for weather development, Development of computer code for grid point atmospheric mode, Development of Parameterization schemes.

Suggested Text Books & Study Materials

- Mesoscale Meterological Modelling by Roger A. Pielke
- Mesoscale Atmospheric Circulation by B.W.Atkinson
- Mesoscale Meteorology and forecasts edited by P.S.Ray
- Micrometeorology by O.G.Pasquill

ATMOS C33: Seismology, Geophysics and Geodesic

Earth materials and the Internal Constitution of the Planet. Seismic waves, Geomagnetism, Elastic constants, Elastic rebound theory, Propagation of seismic waves, Equations of motion, Magnitude frequency analysis, Attenuation, Ray theory, Reflection, Refraction, Total internal reflection, Gutenberg-Richter Law.

Anomalous behaviour of atmosphere and ionosphere before and during earthquakes, LAIC theory, Drifting Constituents, sea-floor spreading and Plate Tectonics Chemical weathering Soils, Interface between the Geosphere, Hydrosphere. atmosphere and Biosphere, deep Sea and Global Ocean Circulation.

Working principle of Seismometer, Different models of earthquake prediction.

Practical: Application of GIS to view the surface features for weather system

Suggested Text Books & Study Materials

- Introduction to Seismology by Petter M. Shearer,Cambridge University Press

ATMOS O31: Geographical Information Systems

Geographical Information System(GIS): Introduction-Background & History - The Essential Elements of a GIS: An Overview; Basic Principles of GIS; Components of GIS: Hardware, Software, Data, People 'C' Language and its Utility in GIS: Data Base Creation Organization and Management in GIS; Raster Vector and Data Models; GIS Functions: GUI Graphic User interface, System Analysis and Database Management System, Data Entry (Raster/Vector) Edit and Validation, Manipulation & Analysis, Display and Product Creation, Raster Vector Data Model, Basic Principles of 3D Models in GIS Pattern Recognition, Classification, Topology, Error Correction.

Suggested Text Books & Study Materials

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

ATMOS O32: Aviation Meteorology

Aerodrome Forecast, Route Forecast ,Terminal aerodrome Forecast, Take-off Forecast, Landing Forecast, General Visibility, Run way Visibility, Aviation Hazards, Warning Systems, Special Forecasts, Clear Air Turbulence, Diagnostic and Prognostic analysis, Flight Information regions, Now-casting, Accidents and Incidents, Meteorological Hazards to aviation, Take off, landing, in flight icing, turbulence, Visibility, fog, clouds, rain, gust, wind shear, thunderstorms.

Method: Aviation Instruments, now casting the Aviation

Suggested Text Books & Study Materials

- Aviation Meteorology (Jeppesen Sanderson Training Products) latest edition by Peter F. Lester
- References and Supplies Private / Instrument/Commercial Pilot Manuals (Jeppesen Sanderson Training Products) latest edition
- Aviation Weather Services (AC 00-45E)U.S. Department of Transportation(FAA)

CBCC A
CBCC B

ATMOS C41: Middle Atmospheric Dynamics

Structure and circulation of the middle atmosphere, Zonal mean circulation of the middle atmosphere, Vertically propagating planetary waves, Waves in the equatorial stratosphere, Kelvin waves, Rossby-gravity waves, Quasi- Biennial oscillation, Brewer- Dobson circulation transport in the stratosphere, Dynamical and chemical transport. The static structure of the middle atmosphere, zonal mean temperature and wind distribution, composition of the middle atmosphere, observational techniques, Introduction and classification of wave types, wave disturbances, atmospheric thermal tides, free travelling planetary waves, equatorial waves gravity waves , Stratospheric sudden warming extratropical planetary scale circulation, interaction between middle and lower atmosphere- Radiative links, dynamical links: vertically propagating planetary waves. Interannual variability in the stratosphere.

Suggested Text Books & Study Materials

- Middle Atmosphere Dynamics By David G. Andrews
- Middle Atmosphere Dynamics : C.G. Andrews, J.R Holton & C. Leovy
- Stratosphere- Troposphere interaction: K. Mohan Kumar

ATMOS C42: Agro & Hydro Meteorology

Agro meteorological parameters, Pan evaporation, Actual evaporation, transpiration, Potential evapo-transpitration, Empirical relations,Radiation balance,Photosynthesis Agro meteorological variation of crops life, PSR-Curves Agro Climatic Classification and cropping pattern, crop weather calendar. Catchments averages of rainfall, Thssin's –method, Isohytal- method.Depth duration and Area curves,

design rainfalls, PMP, PSP, Rainfall- runoff relation. Models- analysis, Flood Fore casting, UG,IUH, dynamic models, mathematical models, statistical models, conceptual models. water balance, Infiltration, percolation. Agro climatic classification of India, concept of water balance, physical factors affecting plant production, photosynthesis of physical factors, different agents of photosynthesis, various agro climatic indices, crop growth, agricultural meteorology and climatology, weather and agricultural activity, micro climate modification, pollution influence crop production, climate change influence crop production, modelling aspects, factors affecting runoff, rainfall runoff components, hydrograph methods, peak flow equations, runoff variability urban runoff and modelling, rainfall networking, radar rainfall estimation, rainfall over catchment areas, Area- depth rainfall estimation, maximum probable rainfall, storm displacement, maximum observed flood, synoptic system causing floods, design flood, frees surface evaporation, pan evaporation, water budget and energy budget, method, mass transfer method, soil moisture measurement, flood control, irrigation, water pollution abatement, water management in India –past & present, erosion process, impact of erosion, erosion control. Agromet observation networks, applications of remote sensing techniques. Importance and scope ofagricultural meteorology. Agricultural droughts – classification, moisture availability index(MAI), agroclimatic normals for field crops. Drought monitoring and planning.

Practical: Thessin's method, Isohytal methods for catchment rainfall, evaluation of PET and AET from empherical retions. Peak flows, Average flows, Base flow separations.

Suggested Text Books & Study Materials

- Hydrometeorology: Forecasting and Applications. By Kevin Sene.
- Introduction to Hydrometeorology by James R. Bruise and R.H. Clark
- Introduction to Hydrology by Viessman
- Land surface hydrology, meteorology and climate; Observation and Modelling, By Venkataraman Lakmi, John Albertson and J. Sheake.
- Applied Hydrometeorology P.R. Rakhecha and Vijay P. Singh
- Landscape Agroecology Paul A.Wojtkowski
- Introduction to Agrometeorology : H.S. Mavi

ATMOS C43: Dynamics of coupled system

The transfer laws of Air -Sea Interface: Momentum transfer in laminar flows, Flux and Force in Air-Sea Momentum Transfer: Charnock's Law. Sensible and Latent Heat Transfer. Wind waves and the Mechanisms of Air -Sea Transfer: Instability Theory. The wind wave phenomenon, Momentum transfer in a breaking waves. Mixed Layers: Mixed layer Turbulence. Atmospheric and Oceanic Mixed layer mixed layer budgets. Bunker's Air -Sea Interaction Cycles.

Suggested Text Books & Study Materials

- Atmosphere-Ocean Dynamics, Adrian E. Gill, 1992.
- Climate and Circulation of the Tropics, S. Hasternath, 1988.
- The Oceans and climate by G.R. Bigg, 1996.
- Ocean –Atmosphere interaction and climate modeling, Beris A. Kagan,1995
- Air-Sea Interaction Laws and Mechanisms by G T Csanady

ATMOS S41: Introduction to Global Modeling

Description of the global climate system and its components, Earth's energy budget, Modelling of the climate system, what is a climate model? Types of models, A hierarchy of model, Energy balance models, Intermediate complexity models, General circulation models

Evaluating model performance, The response of the climate system to a perturbation, Climate forcing and climate response, definition of feedback, Transient response of the climate system, Direct physical feedbacks, Water vapour feedback and lapse rate feedback, Cloud feedback, Cryospheric feedbacks, Geochemical, biogeochemical and biogeophysical feedbacks. The carbonate compensation, Interaction between plate tectonics, climate and the carbon cycle, Interactions between climate and the terrestrial biosphere, Brief history of climate: causes and mechanisms, Internal climate variability, El Niño- Southern Oscillation, The North Atlantic Oscillation, The Southern Annular Mode, Future climate changes, Emission scenarios, The purpose of the scenarios and scenario development, Climate projections for the 21st century, changes in global mean surface temperature, The spatial distribution of surface temperature and precipitation changes, Changes in ocean and sea ice, Changes in the carbon cycle and climate- carbon feedbacks, Long term climate changes, The carbon cycle, Sea level and ice sheets.

Introduction to Spectral Model. Fourier and Legendre Functions. Finite difference in Space. Time differencing schemes. Spectral transform method. Mathematical aspect of Spectral Model. Spherical Harmonics. Gaussian Quadrature Spectral Truncation schemes. Spectral Energetics. Six tutorial based on the above topics.

Suggested Text Books & Study Materials

- Introduction to three dimensional general circulation models. W.M. Washington and parikson
- A climate modelling primer. A.H. Sellers and K. McGuffie
- Numerical prediction and dynamic meteorology. G.J Haltiner and R.T. Williams. John Wiley
- Climate System Modelling by Trenberth K.E.
- The Physical Basis of Climate and Climate Modelling- WMO- GARP, No.16
- An Introduction to Global Spectral Modelling by T.N. Krishnamurti, H.S. Bedi, V.M.Hardiker.

ATMOS S42: Atmospheric Weather extremes

Origin of Extreme Weather, Water And Heat, Air Masses, Fronts And Mid Latitude Cyclones, Thunderstorms, Hail, Lightning, Tornadoes, Tornado Intensity, Tornado Frequency, Tornado Safety, Tropical Cyclones (Hurricanes), Origin of Tropical Cyclone, Hurricane structure (Northern Hemisphere), Tropical Cyclone size, Cyclone Damage, Enhanced By High Tides, Storm Surges, Drought And Famine, El Nino. Extreme Systems: Cyclones and Super Cyclones with associated phenomenon Storm Stage, Gale Winds, very heavy rainfall, Floods, Soil Salinity, casualities and diseases. Thunder stroms and associated phenomenon hail lightning gale winds, Tornadoes, Tsunami, Cold- Waves, Heat Wave, Nor'wester, Andhi, Severe Fog, Drought, Statistical Analysis of extreme functions.

Suggested Text Books & Study Materials

- Atmosphere, Weather and Climate R.J. Barry and R. G. Chorley (Methuen Publication)
- Weather Forecasting – Part-1, S. Pettersen

Project Work

A project performance report based on the research training during the third and fourth semester course will have to be submitted in the final semester. A presentation of the accomplishments will be required before a panel of experts. Evaluation will be based on both the project report and presentation.

Grand Viva

Students will be evaluated on all the topics discussed in the two years four semester M.Sc. course by a panel of experts.