COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY

(Abstract)

Faculty of Marine Sciences – Department of Atmospheric Sciences – M.Sc Metereology & M.Tech Atmospheric Sciences – Syllabus approved – Orders issued.

CONFERENCE SECTION

No. Conf II/2941/1/AC-Marine Sc/2020 Dated, Kochi-22, 12.10.2020

Read : Item No 1(d) of the Minutes of the meeting of the Academic Council held on 08.07.2020

ORDER

The Academic Council at its meeting held on 08.07.2020 along with the recommendations of the Standing Committee resolved to approve, vide Item read above, the revision of syllabi as per Outcome Based Education frame work of the following programmes offered at the Department of Atmospheric Sciences under the Faculty of Marine Sciences with effect from 08.07.2020, the date of the meeting of the Academic Council as in appendix.

1. M.Sc Metereology
2. M.Tech Atmospheric Science

Also resolved to approve the proposal to start a new academic programme "M.Tech Climate Change and Disaster Management' and authorized Sri. Baby Chakrapani, the Chairman, Board of Studies in Atmospheric Sciences, to work out the details of the programme.

Orders are issued accordingly.

Dr. MEERA V
REGISTRAR

To

1. Dr. Rosamma Philip, Dean, Faculty of Marine Sciences and Professor, Department of Marine Biology, Microbiology and Biochemistry, CUSAT, Kochi - 16
2. Sri. B Chakrapani, Chairman, BOS in Atmospheric Sciences, CUSAT, Kochi - 16
3. The Head, Department of Atmospheric Sciences, CUSAT, Kochi - 16
4. The Controller of Examinations/Joint Registrar (Academic)/ Assistant Registrar(Academic)
5. Academic A/C/Exam E/D/Y/IRAA for Information/Exam Confidential Sections
6. Day File/Stock File/File Copy.

MSc Meteorology

Description

This program is intended to provide a comprehensive training in understanding, modelling and prediction of atmospheric processes to undergo higher studies in the subject as well as to train them to suit for the needs of the society.

Apart from learning core Meteorology subjects the students can choose inter-disciplinary, intra-disciplinary and skill-based electives depending upon their interests, under the choice based credit system. This will also equip the students for the collection, management, supply and application of atmospheric data for the needs of a variety of public and private sectors. The course also demonstrates how these create opportunities or pose problems for the successful operation of natural and human systems. The aim of the course is that after successful completion, the students will be able to compete for careers in Meteorology and related subjects.

This programme was developed in response to industry and research institution requirements for applied meteorology related positions. The growing attention of the society to climate change, its mitigation and adaptation to it, generates considerable interest to this course.

Syllabus for M.Sc. Meteorology Course (Effective from 2020 Academic Year)

Semester I

Course Code	Paper	Core/Elective	Credits
20-302-0101	Geophysical Fluid Dynamics	C	4
20-302-0102	Physical Meteorology	C	4
20-302-0103	Observational Techniques	C	3
20-302-0104	Computing and Programming-I (Practical)	C	3
20-302-0105	Semester End Seminar and Viva – Voce	C	1
20-302-0106	Introductory Physical Oceanography	E	4
20-302-0107	Advanced Mathematics	E	4
20-302-0108	Numerical and Statistical Methods	E	4
20-302-0109	General Meteorology	E	3

Semester II

Course Code	Paper	Core/Elective	Credits
20-302-0201	Dynamic Meteorology	C	4
20-302-0202	Synoptic Meteorology & Weather Forecasting	C	3
20-302-0203	Tropical Meteorology	C	3
20-302-0204	Computing and Programming II (Practical)	C	2
20-302-0205	Semester End Seminar and Viva – Voce	C	1
20-302-0206	Global Climate and Climate Change	E	4
20-302-0207	Remote Sensing and Satellite Meteorology	E	4

Semester III

Course Code	Paper	Core/Elective	Credits
20-302-0301	Numerical Weather Prediction	C	4
20-302-0302	Advanced Dynamic Meteorology	C	4
20-302-0303	Meteorological Analysis (Practical)	C	2
20-302-0304	Computational Meteorology(Practical)	C	2
20-302-0305	Semester End Seminar and Viva – Voce	C	1
20-302-0306	Applied Meteorology	E	4
20-302-0307	Cloud Physics and Atmospheric Electricity	E	3
20-302-0308	Air – Sea Interaction	E	3
20-302-0309	Atmospheric Chemistry And Air Pollution	E	3
20-302-0310	Disaster Management	E	3

Semester IV

Course Code	Paper	Core/Elective	Credits
20-302-0401	Project and Project Presentation	C	15
20-302-0402	Comprehensive Viva	C	3

20-302-0101 GEOPHYSICAL FLUID DYNAMICS

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Understand the basic concepts of fluids
- Smoothly bridge to Geophysical Fluid Dynamics from the knowledge of classical Fluid Mechanics
- Understand the basic kinematics and dynamics of the atmosphere
- Apply the basic knowledge to different types of balances observed in the atmosphere
- Apply the dynamics to different formulations of co ordinate systems
- Analyse and interpret the various non dimensional numbers in fluid dynamics with special reference to atmospheric motion.

Unit 1

Basic concepts: fluid continuum, fluid properties, ideal fluid, actual fluids, types of flow; D' Alembert's Paradox; statics: pressure , surface and body forces on a fluid element; fundamental equation of fluid statics: application to compressible and incompressible fluids, perfect gas equation, hydrostatic equation along the vertical, application to the atmosphere, Laplace's equation.

Unit 2

Kinematics: Lagrangian and Eulerian methods of description of fluid flow, stream lines, streak lines and trajectories, Blaton's equation, steady and non-steady flow, decomposition of the field of motion in the vicinity of a point, translation, rotation, divergence and deformation, physical interpretation, application to plane motion, typical flow patterns, stream function, divergence and vorticity in different co-ordinate systems, local and convective derivatives.

Unit 3

Viscous fluids, coefficient of viscosity, Navier-Stoke's equations of motion for a viscous Newtonian fluid; laminar flow of viscous incompressible fluids, Poiseuille flow, Couette flow, Reynold's number and dynamic similarity of flows, physical significance of Reynold's number, low and high Reynold's number.

Unit 4

Dynamics: equation of continuity and its applications, non-viscous incompressible flow, Eulerian equations of motion, inertial and rotational frames of reference, Coriolis force, irrotational flow, velocity potential, integration of the equations of motion, Bernoulli's theorem and its applications. Equations of motion in spherical coordinates, isobaric coordinate and sigma coordinate system, scale analysis of dynamical equations, Rossby Number.

Unit 5

Horizontal frictionless motion: natural coordinate system classification of flows, balanced motion, geostrophic wind, inertial wind and cyclostrophic wind, gradient wind - thermal wind - backing and veering, barotropic and baroclinic atmospheres, solenoids and thermal wind.

Material

Text Books:

1. Fluid mechanics of the atmosphere, R.A.Brown, Academic Press, 1991.
2. Introduction to Theoretical Meteorology, S L Hess, International Thomson Publishing, 2000.
3. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012.
4. Geophysical Fluid Dynamics I: An Introduction to Atmosphere-Ocean Dynamics: Homogeneous Fluids, Ozsoy and Emin, 2020.

Reference Books:

1. Geophysical Fluid Dynamics (Second Edition), J. Pedlosky, Springer, Berlin Heidelberg, 1972.
2. Atmosphere-Ocean Dynamics (International Geophysics Series, Volume 30), A E Gill, Academic Press, New York, 1982.
3. Introduction to Geophysical Fluid Dynamics, Second Edition: Physical and Numerical Aspects (International Geophysical Series, Volume 31), B C Roisin and J M Beckers, Academic Press, New York, 2011.
4. Classical Mechanics in Geophysical Fluid Dynamics, Morita O, Taylor & Francis, 2019.

20-302-0102 PHYSICAL METEOROLOGY

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Understand the basic physical characteristics of earth atmosphere system
- Apply laws of radiation to the atmosphere and to get knowledge of the radiation budget of the earth atmosphere system
- Understand the thermodynamic process in the atmosphere and their applications to atmospheric stability studies.
- Analyse the thermodynamic stability of the atmosphere using thermodynamic diagrams

Unit 1

Sun, Earth and the Atmosphere-Sun-Earth relationship, solstices and equinoxes, motion of earth - vertical thermal structure of the atmosphere, composition of the atmosphere - dry air, water vapour and aerosols. Atmospheric Optics - Visibility - attenuation of light-turbidity, Optical phenomena - rainbows, haloes, corona, glory, mirage etc. scattering - blue of the sky-colours at sun rise and sunset- atmospheric refraction.

Unit 2

Radiation- laws of black body radiation, radiation transfer. Solar radiation - latitudinal and seasonal variations-passage through the atmosphere-absorption - scattering and reflection - Mean disposition of solar radiation. Terrestrial Radiation-absorption in the atmosphere -atmospheric window - radiative heat exchange-influence of clouds on radiation fluxes- influence of aerosols, radiative cooling of atmosphere, aerosol on scattering and their impact on direct and diffuse radiation, diurnal minimum and maximum temperature. Mean heat balance of the earth- atmosphere system, atmospheric green-house effect - poleward transport of energy-fundamental link with the general circulation.

Unit 3

Gas laws and their application to the Atmosphere-Equation of state for dry and moist air-humidity parameters-virtual temperature. First and second laws of thermodynamics-specific heats of gases- internal energy-adiabatic processes-potential temperature-entropy-reversible and irreversible Processes-Carnot's cycle. Thermodynamics of water vapour-latent heat-the Clausius-Clapeyron equation. Thermodynamics of the atmosphere-dry adiabatic lapse rate-case of unsaturated moist air-saturated adiabatic lapse rate, pseudo-adiabatic cases-equivalent potential temperature-thermodynamics of the wet-bulb thermometer-wet-bulb potential temperature and saturation potential temperature- Normand's Propositions-Normand point.

Unit 4

Hydrostatics of the Atmosphere-Geopotential, equipotential Surface-Hydrostatic equation-hydrostatic equilibrium, standard atmosphere - altimetry. Thermodynamic diagrams-basic requirements-emagram, skew T-log P diagrams-tephigram-use of tephigram for height calculations in aerological soundings.

Unit 5

Atmospheric instability and Convection-Stability Criteria- CAPE and CINE - parcel method - Brunt- Vaisala oscillations, lifting, mixing and convective condensation levels-potential instability and latent instability-stability indices-slice method of stability analysis- growth of cumulus clouds-entrainment.

Practical

- Prepare the Tephigram and calculate different moisture parameters.
- Find the stability of the atmosphere using the tephigram method.

Material

Text Books:

1. Introduction to Theoretical Meteorology, Seymour L. Hess, Krieger, New York, 2006.
2. Physical Meteorology, John C Johnson, MIT Press, Cambridge, 1996.
3. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
4. Compendium of Meteorology for use by Class I & Class II Meteorological Personnel Vol. II, Part I, WMO Publications No. 364, 1977.

Reference Books:

1. Atmospheric Thermodynamics (Second Edition), J V Iribarne & W L Godson, Springer, 1981.
2. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.

3. Fundamentals of Atmospheric Physics, Murry L Salby, Academic Press, 1996.
4. Clouds, Rain and Rain Making (second Edition), B J Mason, Cambridge University Press, 2010.
5. Thermodynamics of Atmosphere and Ocean, J. Curry and P.J.Webster, Academic Press, 1998.
6. The Atmosphere: a very short introduction, Paul I. Palmer, 2017.

20-302-0103 OBSERVATIONAL TECHNIQUES

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Understand the basic conventional surface and upper air observation techniques in Meteorology
- Differentiate between the conventional and non-conventional observations in Meteorology
- Examine various ocean parameters
- Understand satellite measurements of different geophysical parameters
- Interpret different weather radar observations

Unit 1

General principles of surface instrumental measurements: accuracy requirements, Siting of an observatory, exposure requirements, observational procedures, standard times of observations. Network of observatories, random and systematic errors.

Unit 2

Conventional measurements of pressure, temperature, humidity, wind speed and direction, sunshine duration, radiation - shortwave and longwave, precipitation, visibility, clouds, soil temperature, evaporation, evapotranspiration, Automatic Weather Stations.

Unit 3

Satellite observations of geophysical parameters: SST, moisture and humidity profiles, Wind, Precipitation, sea ice coverage, oceanic productivity, ocean waves and currents, topography, land-use land-cover, soil moisture.

Unit 4

Upper air pressure, temperature, humidity and wind measurements: pilot balloons, radiosonde, dropsonde, ozonesonde, GPS sonde, Microwave radiometer fundamentals, Microwave rain radars, Lidar ceileometer, Disdrometer.

Unit 5

Weather radars, Wind profiler radar fundamentals, Doppler beam swinging for wind estimation, Radar signal processing, Fourier transform analysis, Estimation of moments and three-dimensional winds.

Material

Text Books:

1. Probing the Atmospheric Boundary Layer, Edited by D H Lenschow, American Met Society, 1986.
2. Meteorological Instruments, W E K Middleton & Spilhaus, University of Toronto Press, 1953.
3. Atmospheric Radar: Application and Science of MST Radars in the Earth's Mesosphere, Stratosphere, Troposphere, and Weakly Ionized Regions, W K Hocking, 2016.
4. The Introduction of Self-Registering Meteorological Instruments, Robert P. Multhauf, 2019.

Reference Books:

1. Applications of Remote Sensing to Agro meteorology, F Toselli, Kluwer, 1989.
2. Instruments and Observing Methods, Report No. 81, WMO/TD - No. 1250, 2006.
3. Handbook of Aviation Meteorology, HMSO, 2005.
4. Manual on the WMO Integrated Global Observing System, 2019.
5. Weather Radar Data Requirements for Climate Monitoring, 2020.

20-302-0104 COMPUTING AND PROGRAMMING – I (Practical)

Outcome: (Cognitive Level – Apply)

After completing the course, students will be able to

- Learn basic Unix operating systems
- Understand the basics of FORTRAN and Python programming languages
- Formulate simple computer programs in FORTRAN and Python
- Develop computer programs for meteorological computations

Unit 1

Introduction to Linux - Basic Linux concepts, creating an account, Virtual consoles, Shells and commands, LINUX, Unix Commands: Using pipes, file permissions, vi editor, e-mais editor.

Unit 2

FORTRAN- basics, Variables, types, and declarations, Expressions and assignment, Logical expressions, if statements, Loops Arrays, Subprograms, Arrays in subprograms, Common blocks, Data and Block Data Statements File I/O, Simple I/O, Format statements, Programming style.

Unit 3

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.

Unit 4

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.

Unit 5

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 Actions.

Material

1. Computer Programming in FORTRAN 90 & 95, V Rajaraman, Prentice Hall of India, 1997.
2. Numerical Recipes in FORTRAN 90, Vol 2 (Second Edition), William H Press, S A Teukolsky, W T Vetterling and B P Flannery, Cambridge University Press, 1996.
3. A Primer on Scientific Programming with Python (First Edition), Hans Petter Langtangen, Springer, 2009.
4. Head First Programming: A leaner's guide to programming using Python language (First Edition), Paul Barry and David Griffiths, Shroff/O'Reilly, 2009.
5. Introduction to Programming with Fortran, Ian Chivers and Jane Sleightholme, Springer; 4th ed.ISBN-10: 3319755013, ISBN-13: 978-3319755014, 2018.
6. Essential Python for the Physicist Hardcover , Giovanni Moruzzi, Springer; ISBN-10: 3030450260, ISBN-13: 978-3030450267, 1st ed., 2020.
7. Python Crash Course: A Hands-On, Project-Based Introduction to Programming (2nd Edition), Eric Matthes., No Starch Press; 2 edition, 2019.

20-302-0106 INTRODUCTORY PHYSICAL OCEANOGRAPHY

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Understand physical properties of sea water
- Examine different components of heat budget of oceans
- Interpret different water masses of world oceans
- Analyse general circulation of the ocean and its link with the atmosphere
- Differentiate between ocean waves and tides

Unit 1

General introduction, dimension of the oceans, geographical features, physical properties of sea water, distribution of temperature, salinity, density and oxygen in space and time, PSU and TOES -10, acoustical and optical characteristics of seawater-SOFAR channel shadow zone- colour of the sea.

Unit 2

Heat budget of ocean: insolation - long wave radiation - effect of clouds - sensible and latent heat transfer, Bowen's ratio-ocean heat transport - spatio - temporal variability of heat budget terms and net heat balance.

Unit 3

Water masses: formation and classification - T-S diagram - merits and demerits water masses of the Atlantic, Pacific and Southern Ocean with special reference to Indian Ocean - identification of water masses.

Unit 4

Circulation: general circulation of the atmosphere - wind driven currents in the Pacific and Atlantic oceans - wind stress, Ekman spiral major currents of the Pacific and Atlantic Oceans -thermohaline circulation- upwelling- El Nino and La Nina-Walker circulation.

Unit 5

Indian Ocean: Major expeditions - wind: Northeast and Southwest monsoon pattern, winds - ocean surface circulation - equatorial current systems - Under currents - circulation in Arabian Sea and Bay of Bengal - Somali Current- Upwelling areas in Indian ocean - mixed layer variability - eddies winter cooling - Indian ocean warm pool and Dipole.

Material

Text Books:

1. Principles of Oceanography, J R Apel, Academic Press, New York, 1999.
2. Introduction to Physical Oceanography, Stewart R H, e book, 2008.
3. Tides, Surges and mean sea level (First Edition), D. T. Pugh, Wiley, 1987.

Reference Books:

1. Descriptive Physical Oceanography: An Introduction, Pickard and Emery, Elsevier, 1990.
2. Descriptive Physical Oceanography: An Introduction, (Sixth Edition), Talley, LynneD, Elsevier, 2011.
3. Introduction to Physical Oceanography (Third Edition) , John A. Knauss, Newell Garfield, 2016.

20-302-0107 ADVANCED MATHEMATICS

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Use special functions for specific problems in earth sciences
- Apply Fourier series for a set of Atmospheric variables
- Analyse complex variables
- Conclude with numerical techniques
- Develop higher level Mathematics in practical problems of Atmospheric Science

Unit 1

Periodic functions, Dirichlet's theorem, Euler's formula, expansion of odd and even functions, half range series, Fourier integrals- sine and cosine transformations, Fourier transforms of derivatives of functions, Parseval's identity, Discrete Fourier Transforms, Harmonic analysis, use of Fourier transformations to solve boundary value problems, Application to heat conduction, Application to wave equations. Fourier transform of derivatives, transfer functions, Inverse Laplace transform.

Unit 2

Partial differential equations, parabolic, elliptic and hyperbolic differential equations, formation of partial differential equations, methods of separation of variables, equation of vibrating string, one dimensional wave equation, one dimensional heat flow, 2-D heat flow, Laplace equation. Applications of Partial Differential Equations.

Unit 3

Complex variables, continuity and differentially analytic and conjugate functions, Cauchy-Riemann equations, Line integrals of complex functions, Cauchy's integral theorem, Taylor and Laurent series, residue theorem, Singular points, conformal mapping, linear conformal transformations.

Unit 4

Special functions, Gamma function, Beta function, their relation, Legendre polynomial, Expansion of Pn (u)in powers of u, Rodrigue's formula, Zeroes of Pn (u), recurrence formulae, Expansion of functions in a series of Legendre polynomials, Legendre functions of first and second kind- recurrence formulae, spherical harmonics, Bessel function, recurrence formula, generating function, orthogonally, expansion of f(x) in terms of Bessel series.

Material

Text Books:

1. Higher Engineering Mathematics (42nd Edition), B S. Grewal, Khanna Publishers, 2013.
2. Introduction to the special functions of mathematical physics with applications to the physical and applied sciences, John Michael, 2005.
3. Theory & Problems of Differential Equations (Schaum's Outline Series), Frank Ayres, Schaum Publishing Co. 1952.
4. Mathematical Physics (3rd Edition) by Kakani and SL Hemrajani and C, 2018.

Reference Books:

1. Fourier Analysis with Applications to Boundary Value Problems (Schaum's Outline Series), M R Spiegel, McGraw Hill, 1974.
2. Numerical Methods for Science and Engineering, R P Stanton, Prentice Hall,1961.
3. Complex Variables (Schaum's Outline Series), M R Spiegel, Mc Graw Hill, 1968.
4. Advanced Calculus (5th Edition), W Kaplan, Pearson, 2002.
5. Fourier Series and Boundary Value Problems (8th Edition), J Brown and R Churchill, Mc Graw Hill, 2011.

20-302-0108 NUMERICAL AND STATISTICAL METHODS

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Apply different numerical schemes to solve algebraic equations
- Develop numerical algorithms for numerical differentiation and integration
- Develop different finite different techniques for the solution of differential equations
- Design appropriate correlation analysis for meteorological data
- Design appropriate time series analysis for future projection

Unit 1

Numerical Solution of Algebraic and Transdental Equations: Iterative algorithm- Newton Raphson Procedure-Solutions of Polynomial and Simultaneous Linear Equations- Matrix Inversion-Gauss Elimination-Methods of Factorization-Solutions of Tri-diagonal systems- Relaxation Procedure.

Unit 2

Numerical Differentiation and Integration, Finite Difference Approximation of Derivatives: Laplace Equation-Jacobis and Gauss Seidel Method-Successive Over Relaxation Method-Parabolic equations- iterative methods.

Unit 3

Brief history of statistics Some fundamental concepts Statistical software. Descriptive statistics, Graphical representation, Basic probability concepts, Probability distributions, Parameter estimation, Statistical hypothesis testing.

Unit 4

Correlation and Regression Analysis: Linear and Nonlinear Correlation, Lag Correlation, Rank Correlation, Partial and Multiple Correlation, Auto Correlation, ARIMA, Multiple, Canonical Correlation Analysis, Co-Variance, Error Analysis, Simple and Multiple regression, Analysis of Variance(ANOVA).

Unit 5

Time Series and Multi Variate Analysis: Power spectrum concepts, Harmonic Analysis, Wavelet Analysis, Computational Procedure for Spectrum Analysis, Moving Average, Smoothing, Low pass High Pass & Band pass Filters, Trend Analysis.

Material

Text Books:

1. Introductory Methods of Numerical Analysis, S S. Sastry, PHI Learning Pvt. Ltd., 2005.
2. Numerical methods for Scientific and Engineering Computation, M K Jain, New Age International, 2003.
3. Statistical Methods in Atmospheric Sciences (4th Edition), D S Wilks, 2019.

Reference Books:

1. An Introduction to Numerical Analysis (2 nd Edition), K E. Atkinson, John Wiley & Sons, 1989.
2. Introduction to Numerical Analysis (2 nd Edition), F.B. Hildebrand, Dover Publications, 1987.
3. Statistical Analysis in Climate Research, H Storch and F W Zwiers, Cambridge University Press, 1999.
4. Principal Component Analysis Meteorology and Oceanography, Preisendorser, ElSevier, 1988.

20-302-0109 GENERAL METEOROLOGY

Outcome: (Cognitive Level – Apply)

After completing the course, students will be able to

- Understand the basic concepts sun- earth relationship
- Apply the basic laws of radiation to the earth atmospheric system
- Apply the principles of thermodynamics to the earth atmospheric system
- Understand the different tropical weather systems and their seasonal variations

Unit 1

Sun, Earth and the Atmosphere- Sun - Earth relationship, solstices and equinoxes, motion of earth; Introduction to the Atmosphere- Composition and Vertical structure - Weather and Climate - Climatic data and normals - World weather watch and Global observation system.

Unit 2

Radiation- laws of black body radiation, Solar radiation - latitudinal and seasonal variations-passage through the atmosphere-absorption - scattering and reflection - Mean disposition of solar radiation. Terrestrial Radiation- absorption in the atmosphere - radiative heat exchange- Mean heat balance of the earth- atmosphere system, green-house effect - global warming.

Unit 3

Gas laws and their application to the atmosphere -Equation of state for dry and moist air - humidity parameters-virtual temperature, wet bulb and dew point temperature - internal energy-adiabatic processes-potential temperature-reversible and irreversible processes. Atmospheric thermodynamics -dry adiabatic lapse rate- saturated adiabatic lapse rate, pseudo-adiabatic cases-equivalent potential temperature-thermodynamics of the moist air-bulb thermometer.

Unit 4

Hydrostatics of the Atmosphere - Hydrostatic equation - hydrostatic equilibrium, Atmospheric instability and Convection - Stability Criteria - growth of cumulus clouds. Cloud formation: Cloud classification; Condensation nuclei; Ice nuclei; Growth of cloud drops - Growth of ice crystals; Precipitation mechanisms; Bowen's theory; Bergeron and Fendeisen process; Collision and coalescence processes.

Unit 5

Surface pressure and winds - Inter Tropical Convergence Zone - Trade Winds - middle latitudes westerlies; fronts and associated weather General circulation of the Atmosphere; Tropical Weather systems: Tropical Cyclones - Southwest Monsoon; Northeast monsoon; Other weather systems- Western disturbance and associated weather - Norwesters- Heat and Cold waves– Thunderstorms, dust storm, hail and tornadoes.

Material

Text Books:

1. Introduction to Theoretical Meteorology, Seymour L. Hess, Krieger, New York, 2006.
2. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & Peter V Hobbs, Academic Press, 2006.
3. An introduction to climate, Glen T. Trewartha. New York (McGraw-Hill), 1954.
4. Tropical Cyclones, their evolution, structure and effect: R.A Anthes, 1982.

Reference Books:

1. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.
2. Clouds, Rain and Rain Making (second Edition), B J Mason, Cambridge University Press, 2010.
3. A Short Course in Cloud Physics (Third Edition), R R Rogers & M K Yau, Pergamon Press, New York, 1989.
4. Physical Climatology, W.D. Sellers, 1965.
5. Tropical Meteorology, G.C. Asnani, 1993.
6. Meteorology over the Tropical Oceans, D.B. Shaw, 1978.
7. The Atmosphere: a very short introduction, Paul I. Palmer, 2017.
8. Atmposphere: an intro to Meteorology, Lutgens, Tarbuck, Tasa (12 th edition), 2015.

20-302-0201 DYNAMIC METEOROLOGY

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Understand the basic parameters in dynamic meteorology such as divergence, circulation and vorticity
- Apply the concepts of barotropic and baroclinic atmospheres and their role on weather processes
- Understand the quasi geostrophic system and its application in weather processes
- Assess the physical processes in the planetary boundary layer and its link with the general circulation of the atmosphere
- Analyse divergence, vorticity and circulation for a given structure of the atmosphere
- Calculate numerical problems based on basic concept and various theorems in dynamic meteorology

Unit 1

Circulation and vorticity, Stoke's theorem, Kelvin's theorem, Helmholtz theorem, barotropic and baroclinic fluids, absolute and relative circulation; Bjerknes circulation theorem and its interpretation, potential vorticity-conservation, application to air flow over mountain barriers - Taylor - Proudman Theorem.

Unit 2

The vorticity equation in cartesian and isobaric coordinates, significance of the various terms, divergence and vorticity of the geostrophic wind, the vector vorticity equation, scale analysis of the vorticity equation, CAV trajectories, the divergence equation, balance equation.

Unit 3

Dynamics of synoptic scale motions in middle latitudes, quasi geostrophic vorticity equation, geopotential tendency equation, quasi geostrophic potential vorticity equation, omega equation, the Q-Vector method, ageostrophic circulation, idealised model of a baroclinic disturbance.

Unit 4

Fundamentals of the atmospheric boundary layer. Various sub layers in the ABL - Winds in the boundary layer- Surface layer - Ekman Spiral Layer - Turbulence and Taylor Hypothesis - Boundary Layer Depth and Structure - Convectively Mixed Boundary Layer - Nocturnal Boundary Layer.

Practical

- Problems in Dynamic Meteorology
- Computations in Dynamic Meteorology

Material

Text Books:

1. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012.
2. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
3. Basics of Atmospheric Science, A. Chandrasekhar, M/s PHI Learning Pvt. Ltd., New Delhi,2010.

Reference Books:

1. Dynamical and Physical Meteorology, G J Haltiner and F L Martin, McGraw-Hill, 1957.
2. Introduction to Theoretical Meteorology, S L Hess, International Thomson Publishing, 2000.
3. An Introduction to Atmospheric Boundary Layer Meteorology, R L Stull, Kluwer Academic Publishers, 1988.
4. Tropical Meteorology (Revised Edition) Vols I, II and III, G C Asnani, 2016.
5. Fundamentals of Tropical Climate Dynamics, Tim Li, Pang-chi Hsu, 2017.
6. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K. Vallis, 2019.
7. Quasi-Geostrophic Theory of Oceans and Atmosphere: Topics in the Dynamics and Thermodynamics of the Fluid Earth, Fabio Cavallini and Fulvio Crisciani, 2014.

20-302-0202 SYNOPTIC METEOROLOGY AND WEATHER FORECASTING

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Describe different types of weather systems
- Analyse characteristic features of dominant weather systems over Indian region
- Interpret and classify different scale of the weather features and forecasting strategies
- Assess challenges and limitations of various forecast process
- Predict weather systems at different space-time domains using synoptic and NWP methods
- Devise and develop forecast process
- Create real time forecast

Unit 1

Scales of weather systems, Map Projections, Climatological and seasonal distribution of Global pressure and wind systems, Representation and analysis of fields of meteorological elements on synoptic charts, Introduction to Global observing systems.

Unit 2

Convection and Cloud processes, Different mechanism of Convective processes (Dry/moist convection, CAPE, CIN, CIFK, CISK), Classification of convective systems, Convective systems over Indian region, Radar and Satellite observations of Clouds, Weather hazards associated with Convective systems.

Unit 3

Characteristics of Tropical Weather systems, MJO, ENSO, IOD, tropical waves, Mid-latitude weather systems, Air masses and Fronts, Major Jet Streams, Extra-Tropical Cyclones, Western Disturbances, Easterly waves, Land-sea breeze, Clear Air Turbulence, Fog, Polar vortex - Sudden Stratospheric Warming, Tropical-Extra Tropical Interactions.

Unit 4

Different forecasting strategies - synoptic, statistical, analogue, empirical and dynamical methods, Ranges of weather prediction and seamless prediction, Skill of weather prediction at different ranges, Limitations of weather predictions - Sources of uncertainties, Use of satellites and radars for nowcasting, Prediction of individual weather systems, Seasonal and intraseasonal prediction of Indian Summer Monsoon, Interpretation of Analysis of NWP derived products, their interpretation and their limitations - mesoscale, general circulation and coupled models, Forecast bulletin & products, presentation and dissemination, heavy rainfall monitoring, forecasting and warning services.

Material

Text Books:

1. Principles of Kinematics and Dynamics, Bluestein, H. B, Vol. I, Synoptic-Dynamic Meteorology in Midlatitudes, Oxford University Press, 431 pp, 1992.
2. Severe Convective Storms, Charles A. Doswell, American Meteorological Society, 2001.
3. Cloud Dynamics, Robert A. Houze Jr., Academic Press, 1993.
4. Weather Analysis and Forecasting, Christo Georgiev Patrick Santurette, 2016.
5. Fundamentals of Tropical Climate Dynamics, Li, Tim, Hsu, Pangchi, 2018.

Reference Books:

1. Midlatitude Synoptic Meteorology: Dynamics, Lackmann, G, Analysis and Forecasting, American Meteorology Society, 345 pp, 2011.
2. Mid-latitude Atmospheric Dynamics: A First Course, Martin, J. E, Wiley Press, 324 pp, 2006.
3. Meso - scale Atmospheric Circulations, B.W.Atkinson, Academic Press, 1981.
4. Synoptic - Dynamic Meteorology in Midlatitudes: Vol I: Principles of Kinematics and Dynamics, Vol II: Observations and Theory of Weather, Howard B Bluestein, Oxford University Press, 1992.
5. Mesoscale Meteorological Modelling, R.Pielke, 2013.
6. http://www.meted.ucar.edu/tropical/textbook_2nd_edition/

20-302-0203 TROPICAL METEOROLOGY

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Describe characteristics and classification of cyclonic storms
- Understand the structure and dynamics of Tropical cyclones
- Describe Asian summer monsoon
- Assess the spatial and temporal variability of the monsoons
- Analyse the various tele-connections between monsoon and other global weather systems

Unit 1

Introduction to tropical waves, Tropical Cyclones, Classification of cyclonic systems, Global distribution and climatology, cyclogenesis process - necessary conditions, Life cycle of tropical cyclones, satellite observations of tropical cyclones - T-number, Hazards Associated with Tropical cyclone, Impact of Global warming on tropical cyclone intensity and frequency.

Unit 2

History of Asian Monsoon system, Evolution of Asian summer monsoon, Semi-permanent systems of Asian monsoon, Indian Summer Monsoon, Climatological distribution of rainfall, Monsoon onset over Kerala, Various Rain bearing systems of Indian summer monsoon.

Unit 3

Internal variability of the monsoon, Monsoon Intra-Seasonal Oscillations (MISO) - Active/Break cycle, Inter-Annual variability of monsoon - Various Tele-connections, ENSO, IOD, Role of MJO and Western Pacific Typhoons, Withdrawal of Monsoon, Northeast monsoon.

Unit 4

Ocean-Atmosphere coupling and monsoon, Aerosols and Monsoons, Land surface processes and monsoon variability, Scale interactions in monsoon, Asian summer monsoon anti-cyclone, monsoon extremes, Global warming and Indian monsoon.

Material

Text Books:

1. Tropical Cyclones, their Evolution, Structure and Effects, Richard A. Anthes, American Meteorological Society, 1982.
2. The Asian Monsoon, Bin Wang, 2006.
3. Monsoon Vol 1 and 2, Ajit Tyagi, India Meteorological Department, 2013.
4. The Asian Summer Monsoon: Characteristics, Variability, Teleconnections and Projection, Yunyun Liu, Ping Liang and Ying Sun, 2019.
5. Tropical Meteorology: An Introduction, Krishnamurti, T.N., Stefanova, Lydia, 2013.

Reference Books:

1. Global Perspectives on Tropical Cyclones, Chan, J. C. L., and J. D. Kepert, 2010.
2. Essentials of Meteorology: An Invitation to the Atmosphere, Ahrens, C. Donald, and R. Henson, Eighth Edition, 2018.
3. Intraseasonal Variability in the Atmosphere-Ocean Climate System, William K.M.Lau and Duane E. Waliser, Springer, 2005.
4. Tropical Meteorology (Vol-I, II, III), G.C.Asnani, 2016.
5. http://www.meted.ucar.edu/tropical/textbook_2nd_edition/
6. Tropical Circulation Systems and Monsoon, Saha, Kshudiram, 2010.
7. Dynamics of the Tropical Atmosphere and Oceans (Advancing Weather and Climate Science), Peter J. Webster, 2020.

20-302-0204 COMPUTING AND PROGRAMMING II (Practical)

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Understand Advanced Python programming
- Develop advanced level computer programs in Python for atmospheric and climate data analysis

Unit 1

Advanced Python including Classes and Regular Expression.

Unit 2

Numeric Python, Basics, Shape Manipulation, Copies and Views and Functions and Methods Overview. Advanced Numeric Python.

Unit 3

Scientific Python, Scientific Functions Scientific Input Output, ArrayIO: Basic support for I/O of one- and two-dimensional numerical arrays to and from plain text files, Fortran Format: Fortran-style formatted input/output, NetCDF, Reading and writing different data formats.

Unit 4

Python packages for reading and writing different data formats. Importing and mapping reanalysis data in Python, Reading a NetCDF file in Python (xarray), Modifying and selecting variables using xarray, Setting up a map with cartopy, Plotting contour and filled contour plots.

Material

Text Books:

1. Python Crash Course: A Hands-On, Project-Based Introduction to Programming (2nd Edition), Eric Matthes, 2018.
2. Fortran 90 Handbook Complete ANSI / ISO Reference Jeanne C. Adams Walter S. Brainerd Jeanne T. Martin Brian T. Smith Jerrold L. Wagener., 2016.

Reference Books/Sites:

1. https://www.learnpython.org/
2. A Hands-On Introduction to Using Python in the Atmospheric and Oceanic Sciences, Johnny Wei-Bing Lin, http://www.johnny-lin.com/pyintro
3. Introduction to Programming with Fortran, Ian Chivers and Jane Sleightholme, Springer; 4th ed.ISBN-10: 3319755013, ISBN-13: 978-3319755014, 2018.
4. Essential Python for the Physicist Hardcover , Giovanni Moruzzi, Springer; ISBN-10: 3030450260, ISBN-13: 978-3030450267, 1st ed., 2020.
5. Python Crash Course: A Hands-On, Project-Based Introduction to Programming (2nd Edition), Eric Matthes., No Starch Press; 2 edition, 2019.

20-302-0206 GLOBAL CLIMATE AND CLIMATE CHANGE

Outcome: (Cognitive Level – Apply)

After completing the course, students will be able to

- Differentiate weather and climate
- Learn components of climate systems and climate feedback mechanisms
- Understand simple atmospheric models and complicated ocean-atmospheric coupled models
- Understand international frame work for climate change science and climate conventions and treaties
- Understand the necessity of climate change mitigation and adaptations
- Apply the climate change science in Governement Planning and Policy
- Acquire the ability to generate climate and anomaly data

Unit 1

Introduction to Climate Change Science: Weather and Climate - Components of the climate system and their interactions – climate feedback mechanisms - climatological records and normal – Geographical and seasonal distribution of incoming solar radiation, outgoing radiation, net radiation, terrestrial heat balance - Geographical and Seasonal distributions of temperature, pressure, winds, humidity and precipitation, over the earth - Climate of India during the four seasons. Paleoclimatology (fossil studies, dendroclimatology, pollen grains, and corals).

Unit 2

Climate Change: Global warming - climate change natural and anthropogenic – greenhouse gases - Assessment Reports of IPCC- observed global climate changes – changes in climate extremes - observed climate change in India in temperature, rainfall, cyclones and monsoon- - Impact of Climate change on society, (health, water, agriculture, forestry and biodiversity)- droughts and their impacts - theories of Climatic change - Human impact on climate and potential consequences - Climate predictability.

Unit 3

Climate models: One, two and 3-dimensional climate models – History of climate modelling – Sensitivity of climate models – parameterization of climate processes – interactions in the climate system - Energy balance models and glacial cycles - Application of climate model for prediction and policy development– future climate scenarios - global warming and sea level rise - impacts of sea level rise – impact on fresh water sources – impact on natural ecosystems - International efforts to minimize climatic change and their impacts .Future of climate modelling- CMIP.

Unit 4

Mitigation and Adaptation in Climate Change: Stabilisation of greenhouse gas emissions – role of forests – changes needed in energy and transport sectors – use of renewable energy sources– sustainable agriculture practices – Importance of climate change mitigation and low carbon development-sectors with High Mitigation Potential-International Initiatives to Support Climate Change Mitigation. Adaptation measures: Landscape restoration (natural landscape) and Reforestation-Flexible and diverse cultivation to be prepared for natural Catastrophes-Research and development on possible catastrophes, temperature behavior, etc.-reventive and precautionary measures (evacuation plans, health issues, etc.).

Unit 5

Introduction to Climate Change Planning: The Role of National and Sectorial Institutions in Climate Change Planning- The Role of Sub-National Institutions in Climate Change Planning-A Methodology for Climate Change Planning-International Initiatives to Support Climate Change Planning- IndiaâĂŹs National Action Plan on Climate Change (NAPCC).

Material

Text Books:

1. Physics of Climate, Jose P. Peixoto and Abraham H. Oort, Springer, 1992.
2. Synoptic and Dynamic Climatology, Roger G. Barry and Andrew M Carleton, Routledge London and New York, 2001.
3. Atmosphere, Ocean and Climate Dynamics, John Marshall and R. Alan Plumb, Elsevier Academic Press, 2008.
4. Adaptation and mitigation strategies for climate change, Sumi A., Fukushi and Ahiramatsu, Springer, 2010.
5. Fundamentals of Atmospheric Modelling, Marc Z. Jacobson, Cambridge University Press, 2005.

Reference Books:

1. Global warming – the complete briefing (second edition): John Houghton, Cambridge university Press, 2009.
2. Understanding Climate Change, National Research Council, USA, The National Academic press, 2003.

3. Reports of Intergovernmental Panel on Climate Change, (https://www.ipcc.ch/reports/)
4. United Nations Framework Convention on Climate Change (UNFCCC): Handbook, Bonn, Germany:Climate Change Secretariat.(https://unfccc.int/resource/docs/publications/handbook.pdf)(https://unfccc.int/resource/iuckit/cckit2001en.pdf)
5. Climate Change, Vulnerability and Migration, S. Irudaya RajanR.B. Bhagat, Publisher: Routledge (Manohar), ISBN: 97811381063 1138106348, Edition: First, Pages: 305, 2018.

20-302-0207 REMOTE SENSING AND SATELLITE METEOROLOGY

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Gain practical experience of using and interpreting remote sensing datasets
- Develop experience on satellite data inversions
- Device the methodology for radiative transfer calculation

Unit 1

Definition - Components of Remote Sensing, - Energy, Sensor, Interacting Body - Active and Passive Remote Sensing - Platforms - Aerial and Space Platforms - Balloons, Helicopters, Aircraft and Satellites - Electro Magnetic Radiation (EMR) - EMR spectrum - Visible, Infra-Red (IR), Near IR, Middle IR, Thermal IR and Microwave - Definition of solid angle in spherical coordinate, Expression for solid angle subtended by a sphere, Radiance, Irradiance, Black Body Radiation - Planck's law - Stefan-Boltzmann law, Isotropic radiation.

Unit 2

Atmospheric characteristics -Emission, Absorption and Scattering of Electro Magnetic Radiation - Raleigh, Mie, Non-selective and Raman Scattering - EMR Interaction with Water vapour and ozone, - Atmospheric Windows - Significance of Atmospheric windows - EMR interaction with Earth Surface Materials -, Incident, Reflected, Absorbed and Transmitted Energy -Reflectance - Specular and Diffuse Reflection Surfaces- Spectral Signature - Spectral Signature curves - EMR interaction with water, soil and Earth Surface.

Unit 3

Introduction to basic radiative transfer (RT), Schwarzschild's equation, Derivation of RT equation for an emitting and absorbing atmosphere, Simplified RT equation for an isothermal atmosphere, Definition weighting function. Differences between temperature and humidity weighting function, Satellite sounding, Remote sensing of surface and vertical profile of temperature, OLR measurements, sea surface temperature and multi-channel Algorithm with example. Satellites - Classification - Based on Orbits and Purpose.

Unit 4

Visual Interpretation of Satellite Images - Elements of Interpretation - Interpretation Keys Characteristics of Digital Satellite Image - Image enhancement - Filtering - Classification - Integration of GIS and Remote Sensing - Application of Remote Sensing and GIS, Spectral resolution, spatial resolution and radiometric resolution.

Unit 5

Inverse Theory, setting up a linear problem, solving the linear problem, the over-determined problem, the under-determined problem, measurement errors: covariance matrix, weighted least-squares, the inverse matrix and simultaneous equations, constraints in satellite retrievals (ill posed and ill conditioned problems), Satellite retrieval of temperature profiles by setting up simultaneous equations, Introduction to Bayes'Theorem.

Material

Text Books:

1. Physical Principles of Remote Sensing, W. G. Rees, 1990.
2. Inverse Methods for Atmospheric Sounding. Theory and Practice, Clive D Rodgers, 2000.
3. Introduction to Satellite Remote Sensing Atmosphere, Ocean, Land and Cryosphere Applications, William Emery Adriano Camp, 2017.
4. Fundamentals of Satellite Remote Sensing: An environmental Approach, (Second Edition) Emilio Chuvieco, 2017.

Reference Books:

1. A Short Course in Cloud Physics, M.K. Yau, R R Rogers, 1996.
2. Remote Sensing and Image Interpretation, T M Lillesand, 2016.

20-302-0301 NUMERICAL WEATHER PREDICTION

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Understand the art of Mathematical Modelling
- Follow and understand the science and hierarchy of different weather models
- Formulate numerical finite difference schemes for the solution of partial differential equations
- Evaluate different components of the Modelling system
- Create the data input to the atmospheric Models
- Evaluate the merits and demerits of different physical parameterization schemes
- Evaluate different types of atmospheric ocean and climate models
- Finally, Practice Numerical Weather Forecasting

Unit 1

Historical Background- Filtering Problem -Finite difference Techniques- Explicit and Implicit Schemes - Computational instability,Semi Implicit & Split explicit Schemes.-CFL Criteria and Stability Analysis-Staggered grid - Nonlinear Instability and Aliasing - Smoothers and Filters. Spectral and Finite Element Methods: Introduction- Galerkin Methods-Transform Method - Spectral Model of Barotropic & Shallow water Equations- Overview of Primitive equation, Multilayer Spectral Models- Introduction to Finite element method.

Unit 2

Hierarchy of Numerical Models:Barotropic Model- Dynamics of the barotropic model - Properties of the barotropic flow . Equivalent Barotropic Model- Two level Baroclinic Model- Shallow Water Equation Model- Primitive Equation Models (PEM)- Properties and Dynamics of Single PEM. Boundary Conditions and time integration.

Unit 3

Data Assimmilation: Objective Analysis: Basic Concepts of Objective Analysis - Initialization -Static, Dynamic and Normal Mode initialization - Introduction to 3D and 4-D data assimilation.

Unit 4

Parameterization of Sub-Grid Scale Processes: Concept of parameterization, Boundary layer parameterization- Cumulus parameterization of Convection. Radiation parameterization, parameterization of aerosols, super parameterization.

Unit 5

Ocean Atmospheric Coupling and Climate Models: Types of Forecast- Short range, Medium Range, Extended Range Forecast and Ensemble forecast, Limited area Models and Global Modelling, Introduction to Coupled Ocean atmosphere Models and Strategy of coupling - Spin down problem, - Climate Modelling, Difference between Weather Forecasting Models and Climate Models.

Material

Text Books:

1. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012.
2. Dynamic Meteorology and Numerical Weather Prediction (Second Edition), G J Haltiner and R T Williams, Wiley, 1983.
3. Weather Prediction by Numerical Process, Lewis Fry Richardson, 2017.
4. Numerical Weather and Climate Prediction, Thomas Tomkins Warner, 2011.
5. Fundamentals of Numerical Weather Prediction, Jean Coiffier, 2011.

Reference Books:

1. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
2. Tropical Meteorology (Revised Edition) Vols I, II and III, G C Asnani, 2008
3. Atmospheric Data Analysis, R. Daley, Cambridge University Press, 1994.
4. Climate System Modelling, K. E. Trenberth, Cambridge University Press, 2010.
5. Predictability of weather and climate, Cambridge university press, T N Palmer, 2006.
6. An Introduction to Three-dimensional Climate Modeling (Second Edition),W.M. Washington & C. L. Parkinson, University science Books, Edwards Brothers Inc, 2005.
7. Methods of Sequential Estimation for Determining Initial Data in Numerical Weather Prediction, Stephen E Cohn, 2017.

20-302-0302 ADVANCED DYNAMIC METEOROLOGY

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Apply advanced concepts in dynamic meteorology
- Analyse the evolution of the weather systems based on dynamical concepts of energetics and instability mechanisms
- Apply concepts of atmospheric wave motion to diagnose different types of wave-induced weather patterns
- Evaluate the dynamic mechanism responsible for vagaries of weather systems

Unit 1

Atmospheric waves: dispersion of waves, linear perturbation theory, Fourier series of representation of waves - Acoustic waves, shallow water gravity waves, internal gravity waves, inertial gravity waves, Rossby waves, mountain waves, Stationary planetary waves. Momentum and energy transports by waves in the horizontal and the vertical.

Unit 2

Equatorial wave theory: Equatorial Beta Plane Approximation, mixed Rossby gravity waves, Kelvin waves, vertically propagating planetary waves, Wave-mean flow and wave-wave interactions. Application of Equatorial wave theory in planetary scale phenomena such as El-Nino, Madden Julian Oscillation, Sudden Stratospheric Warming.

Unit 3

Hydrodynamic instability: Kelvin Helmholtz instability-linear barotropic and baroclinic instability and cyclogenesis, baroclinic instability in a two-layer model, necessary and sufficient condition for instabilities, energetics of baroclinic waves.

Unit 4

Atmospheric energetics: energy equation - internal, potential and kinetic energies - frictional dissipation of kinetic energy - conversion of potential and internal energies to kinetic energy (Margule's model) - mechanical generation of kinetic energy (Starr's model).

Unit 5

General circulation of the atmosphere: zonally asymmetric components, standing eddies, Walker circulation. Basic equations - maintenance of the zonal mean circulation. Kinetic energy cycle, space/time-averaging formulation. Angular momentum balance, role of eddy fluxes, Total Energy Balance, Laboratory simulation of atmospheric circulation.

Material

Text Books:

1. An Introduction to Dynamic Meteorology (Fifth Edition), JR Holton and G J Hakim, Academic Press, New York, 2012.
2. Compendium of Meteorology, Part 1, Volume 1 Dynamic Meteorology, A W Nielson, WMO Publication, 1973.
3. The Nature and Theory of the General Circulation of the Atmosphere, E N Lorenz, WMO Publication Report, Geneva, 1967.
4. Basics of Atmospheric Science, A. Chandrasekhar, M/s PHI Learning Pvt. Ltd., New Delhi, 2010.

Reference Books:

1. Dynamical and Physical Meteorology, G J Haltiner and F L Martin, McGraw-Hill, 1957.
2. Introduction to Theoretical Meteorology, S L Hess, International Thomson Publishing, 2000.
3. Waves in the Ocean and Atmosphere: Introduction to Wave Dynamics, J. Pedlosky, Springer, Heidelberg, 2003.
4. Tropical Meteorology (Revised Edition) Vols I, II and III, G C Asnani, 2008.
5. Atmospheric Circulation System: Their Structural and Physical Interpretation, E. Palmen and C.E. Newton, Academic Press, New York, 1969.
6. Atmosphere-Ocean Dynamics, AE Giil, International Geophysics Series,1982.
7. Fundamentals of Tropical Climate Dynamics, Tim Li, Pang-chi Hsu, 2017.
8. Essentials of Atmospheric and Oceanic Dynamics, Geoffrey K. Vallis, 2019.

20-302-0303 METEOROLOGICAL ANALYSIS (Practical)

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Understand coding-decoding
- Analyse different weather charts
- Examine dominant weather systems using synoptic charts
- Compare different NWP charts
- Conclude the diagnostic and prognostic inference of weather systems from synoptic/NWP charts

Unit 1

Weather Codes - Plotting of Charts- Chart reading, Surface chart analysis, Analysis of NCEP/NCAR data using GRADS/ NCL/ Python4.

Unit 2

850 and 200 hPa wind analysis during JF, MAM, JJAS, OND, Hadley/Walker circulation analysis, Mean position and propagation of ITCZ using TRMM-GPM rainfall data.

Unit 3

Objective identification of Monsoon Onset over Kerala using reanalysis data, Analysis of Jetstreams and Tropical Cyclones.

Unit 4

Composite SST analysis during ElNino-LaNina and+/- IOD years, Analysis and monitoring of weather systems using short to medium range NWP model outputs.

Material

1. Principles of Meteorological Analysis, Walter J. Saucier, Dover Publications, 2003.
2. Tropical Meteorology Vol. I, II & III, G C Asnani, 2016.
3. Guide to preparation of synoptic weather charts and diagrams, WMO (Publications), No.151, WMO Technical Publication, 1964.
4. Synoptic Meteorology, M. Kurz, 1998.
5. https://www.comet.ucar.edu/presentations/Abstracts_2011/2A.4NWPTrainingSeries.html

20-302-0304 COMPUTATIONAL METEOROLOGY (Practical)

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Analyse various meteorological data using different software packages used in Atmospheric Science
- Design codes to develop simple Atmospheric Models
- Construct and predict weather using WRF model
- Evaluate the scope of regional climate models and radiative convective models

Unit 1

Graphical tools used in Atmospheric and Ocean Sciences for data analysis such as GRADS, FERRET & NCAR Graphics.

Unit 2

Meteorological Computations using MATLAB or SCILAB/GNU OCTAVE.

Unit 3

Formulation of simple Atmospheric models such as Barotropic, Quasi Geostrophic and Shallow Water Equation Models.

Unit 4

Numerical Experimentation/ Simulation of Synoptic & Mesoscale Weather Events using WRF model.

Unit 5

Experimentation with Energy Balance Models, Radiative Convective Models, 2 D Models and familiarization with Regional Climate Models.

Material

1. Workbook on Numerical Weather Prediction for the Tropics, T N Krishnamoorthy, WMO Publication, Geneva, 1986.
2. A Hands-On Introduction to Using Python in the Atmospheric and Oceanic Sciences, Johnny Wei-Bing Lin, http://www.johnny-lin.com/pyintro
3. http://cola.gmu.edu/grads/ , accessed on July 01, 2020.
4. https://ferret.pmel.noaa.gov/Ferret/, accessed on July 01, 2020.
5. http://ncl.ucar.edu/, accessed on July 01, 2020.

20-302-0306 APPLIED METEOROLOGY

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Examine the components and dynamics of hydrological cycle
- Examine the meteorological factors affecting agricultural production
- Analyse meteorological observations for aircraft operations
- Assess the importance of marine meteorological observations and their application in predicting storm tracks
- Evaluate the effect of various extreme meteorological conditions in human health
- Evaluate the dynamics and impacts of air pollutants

Unit 1

Hydrometeorology - the hydrologic cycle - precipitation data required for aircraft operations - snow and ice - infiltration and run off - stream flow - drainage area - observational methods - evaporation and evapotranspiration - watershed catchment area - water balance in lakes and reservoirs - precipitation and streamflow analysis - depth area duration of storm precipitation - unit hydrograph - extending stream flow records - application in reservoir design - river forecasting - ground water - human influence on the hydrological cycle.

Unit 2

Agricultural Meteorology - importance of weather and climate for agricultural production - agrometeorological observations - soil climate -soil temperature -soil moisture - evaporation and evapotranspiration - phonological observations and measurements - weather and climate in relation to plants and crops, insects and plant diseases - weather hazards in agriculture - droughts, floods, hail, dew, frost and protection against them - windbreaks and shelterbelts - information, forecasts and warning for agriculture and forestry - artificial climates.

Unit 3

Aviation meteorology - requirements of climatological data for siting of runways -meteorological observations and forecasts required for aircraft operations - organization of ICAO, DGCA - Air Traffic Control - FIR - coordination between MET and ATC -Current Weather observations / forecasts for aviation (METAR, SPECI, TREND) - aviation forecasts and warnings - aerodrome warning and SIGMET - documentation and briefing for national and international flights - aerodrome climatology.

Unit 4

Marine meteorology - Voluntary Observing Fleet - routine and special observations from ships at sea - weather bulletins for shipping - storm warning bulletins - storm signals at ports - weather routing of ships - climatological atlas of storm tracks.

Unit 5

Biometeorology - balance between heat production and heat loss - effect of climatic factors - influence of weather in diseases caused by virus, bacteria, fungi -metabolic disorders - acclimatization - climate and insect pests - thermal comfort - comfort indices.

Unit 6

Environmental meteorology - atmospheric pollution - definition, sources and extent of pollution - primary and secondary pollutants - meteorological factors affecting air pollution - physical and effective stack height - air pollution control and abatement - urban planning, urban and building climatology - air pollution monitoring and modeling.

Material

Text Books:

1. Introduction to hydrometeorology, J.P.Bruce and R.H.Clark, 1966.
2. Handbook of aviation meteorology, HMSO, 1994.
3. Guide to hydro-meteorological practices, WMO, 2009.
4. Hydrometeorology, Christopher G. Collier, 2016.
5. Agricultural meteorology and climatology, Branislava Lalic, Firenze University Press, 2018.

Reference Books:

1. Guide to agro-meteorological practices, WMO, 2012.
2. Air pollutants, meteorology and plant injury, WMO.

3. Urban climate, WMO.
4. Meteorological aspects of air pollution, WMO.
5. Building climatology, WMO.
6. Handbook of applied meteorology, Wiley, D.D.Houghton,1985.
7. Applied hydrology, J. linsley, R.Kohler, M.Paulhus, McGraw Hill, 1949.
8. Experimental Agrometeorology: A Practical Manual, Latief Ahmad, Raihana Habib Kanth, Sabah Parvaze ,Syed Sheraz Mahdi, 2017.

20-302-0307 CLOUD PHYSICS AND ATMOSPHERIC ELECTRICITY

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Understand cloud physics and precipitation processes
- Examine cloud microphysics
- Understand principles of atmospheric electricity
- Evaluate lightning and associated hazards
- Judge global electric circuit and the role of thunderstorms in maintaining this circuit

Unit 1

Cloud Microphysics - condensation nuclei and their properties - sources of condensation nuclei - Thermodynamic theory of nucleation - Kohler curves - cloud droplet spectra- sizes of clouds and cloud systems. Microstructure of cumulus -stratus- Large storm clouds.

Unit 2

Droplet growth by Condensation - Kelvin's Equation-Diffusional growth of a droplet - Maxwell's equation-the growth of a droplet population - the collision and coalescence of drops - Collection efficiency- The Bowen model - Statistical growth - the Telford model - Cloud entrainment - Plume Theory-Bubble theory.

Unit 3

Formation and growth of ice crystals - ice nuclei - diffusional growth of ice crystals - growth by accretion. Rain and snow - disruption of raindrops - Langumir chain reaction - Aggregation and break up of snowflakes - Precipitation rates. Precipitation - various forms- theories of precipitation - precipitation from warm and clod clouds - mesoscale structure of rain - precipitation efficiency.

Unit 4

Life cycle of thunderstorm cell - severe thunderstorms- Development of thunderstorms - global distribution of thunderstorms - hail. Weather modification - modification of warm and cold clouds - dynamic seeding. Hail suppression - Fog dissipation - Modification of hurricanes.

Unit 5

Fair weather electrical structure of the atmosphere - ions and properties - sources of ionizing radiation - ionosphere- different layers. Features of atmospheric electric field - conductivity and resistance of the atmosphere. The air - earth point discharge currents- precipitation currents - the transfer of charge. - theories of thunderstorm electrification - break down potential - structure of lightning flash - sequence of events in a discharge - The mechanism of earth - atmospheric charge balance - role of thunderstorms.

Material

Text Books:

1. Atmospheric Science-An Introductory Survey (Second Edition), John M Wallace & PeterV Hobbs, Academic Press, 2006.
2. A Short Course in Cloud Physics (Third Edition), R R Rogers & M K Yau, Pergamon. Press, New York, 1989.
3. Atmospheric Electricity, J.A.Chalmers, 1967.
4. An introduction to clouds: From the microscale to climate, Lohmann, Luuond, Mahrt F, 2016.

Reference Books:

1. Physics of Atmospheres (Third Edition), J Houghton, Cambridge University Press, 2002.
2. Introduction to Physical Meteorology, H. Neuberger, The Pennsylvania State UniversityPress, 1966.
3. Fundamentals of Atmospheric Physics, Murry L Salby, Academic Press, 1996.
4. The Physics of Clouds (Second Edition), B J Mason, Oxford University Press, 1971.
5. Microphysics of Clouds and Precipitation, Pruppacher, H.R., Klett, J.D. Springer, 2010.
6. Cloud and precipitation microphysics- principles and parameterization, J.M.Straka,Cambridge University Press, 2009.
7. Physical Processes in clouds and cloud modeling, Alexander P. Khain and Mark Pinsky, 2018.

20-302-0308 AIR-SEA INTERACTION

Outcome: (Cognitive Level – Evaluate)

After completing the course, students will be able to

- Understand the basic concepts air sea interaction processes
- Compare the atmospheric and oceanic boundary layer processes
- Differentiate between waves and swells and analyse the energetics of different waves
- Assess the influence of ENSO, Indian Ocean Dipole and SST anomalies on Indian Summer Monsoon
- Conclude the role of air sea exchanges on Climate in general and Climate in particular

Unit 1

Atmospheric Boundary layer over ocean: Variations of wind, temperature and moisture in the vertical - air sea temperature differences- wind stress and wind stress curl - inversions - contrasts in properties of ocean and atmosphere momentum transfer between air and sea, atmosphere's angular momentum balance dependence of exchange rates on air-sea velocity, temperature and humidity differences - radio refractive index and its variation in the lower atmosphere during different atmospheric conditions, Air sea interaction in the coastal region, forcing due to surface stress: Ekman Transport, coastal upwelling and associated features.

Unit 2

Oceanic boundary layer: Sea surface temperature - mixed layer - thermocline - Penetration of Solar Radiation - Turbidity - Fresh water flux - Salinity variation in the vertical, Energy balance at the ocean surface; Evaporation - Sensible heat transfer - Short and Long wave radiation, Heat budget of the ocean, Surface Density Changes and Thermohaline Circulation of the Ocean, Baroclinic instability, Effect of differential heating on the air-sea interface - eddies in the ocean, fronts, life cycle of a baroclinic disturbance.

Unit 3

Waves, swell and currents induced by wind - Kelvin and Rossby waves Equatorial wave motions; their causes and effects on the processes in the air sea interface - Free Waves in the Presence of Boundaries - Waves of large horizontal scale: normal modes, Resolution into Normal Modes for the ocean, adjustment to equilibrium in a stratified Compressible fluid, surface gravity waves, short-wave and long wave appropriations, Shallow-Water Equations Derivation based on hydrostatic Approximation Energetics of Shallow-Water Motion, Baroclinic Mode and Rigid Lid Approximation, Energetics of Internal Waves, Effects on Boundary-Generated Waves-Variations of Buoyancy Frequency with Height, Effects of Rotation, Rossby Adjustment Problem, Applicability to the Rotating Earth, Rossby Radius of Deformation.

Unit 4

El - Nino southern oscillation, Indian Ocean Dipole, EQUINOO: Observational details - Theories - Coupling of Ocean and Atmosphere- Shift in Zones of convection and their atmospheric and oceanic effects with special reference to Indian summer monsoon rainfall - Atmosphere - Ocean coupling - SST anomalies and Monsoon - warm pool and cold pool in the north Indian ocean and their effect on Indian summer monsoon, Convection and SST: Active - Break cycles of Indian summer monsoon and its relation with ocean - Tropospheric Biennial Oscillationin ocean and atmosphere - Ocean in relation to long term changes in Monsoon and Climate.

Material

Text Books:

1. Fundamentals of atmospheric physics, Salby M.L., Academic press, 1996.
2. Atmosphere - Ocean dynamics, Gill A.E, Academic Press, 1982.
3. Introduction to Physical Oceanography, Stewart R.H., 2006.

Reference Books:

1. El Nino, La Nina and Southern Oscillation, G.S. Philander, 1989.
2. Wind stress over the ocean, Jones I.S.F. and Toba Y., Cambridge University Press, 2009.
3. Atmosphere ocean interaction, second edition Kraus E.B. and Businger J.A., Oxford University Press, 1994.
4. The Oceans and Climate, G.R.Bigg, 2012.
5. El Nino Southern Osccillation phenomenon, E.S.Sarachik, Marc Cane, Cambridge University Press, 2010.
6. Atmospheric and Oceanic Fluid Dynamics: fundamentals and large scale circulation, Geoffrey K. Vallis, 2017.

20-302-0309 ATMOSPHERIC CHEMISTRY AND AIR POLLUTION

Outcome: (Cognitive Level – Analyse)

After completing the course, students will be able to

- Explain atmospheric compositions
- Differentiate the tropospheric and stratospheric chemistry.
- Discuss the tropospheric air pollution and classify air pollution models
- Explain ozone photochemistry and chemical processes leading to polar ozone depletion.
- Describe Air Pollution modelling and Chemistry-climate modelling.

Unit 1

Structure and composition of the lower atmosphere, Greenhouse gases- Global warming-carbon dioxide, water vapour in the troposphere- short lived climate pollutants (SLCPs) - 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. Anthropogenic pollution, Atmospheric effects- smog, Visibility.

Unit 2

Stratospheric chemistry: - Stratospheric ozone and the Chapman mechanism; Catalytic loss cycles (HOx, NOy and halogen chemistry); Polar and mid-latitude ozone depletion; Role of aerosol chemistry in the stratosphere. Ozone photochemistry - Limitations of Chapman cycle, Ozone photolysis.

Unit 3

Basis of ozone depletion, chemical processes leading to polar ozone depletion, Heterogeneous reactions - ozone destruction due to CLO-CLO reaction - Chlorine and Nitrogen Activation/deactivation. Catalytic loss - Methane photo dissociation reaction, HOx and NOx catalytic cycles, Clx and Brx catalytic reactions. Chemical contents of polar stratospheric clouds (PSCs). seasonal ozone hole over Antarctic and Arctic. Ozone layer in future, recovery stages of global ozone.

Unit 4

Tropospheric Chemistry: - Oxidizing capacity of the atmosphere; Tropospheric ozone; Production of ozone in the troposphere; Methane - Tropospheric NOx and hydrocarbons; Transport of ozone from the stratosphere- Air pollution and ozone smog; Atmospheric aerosols: Concentration and size, sources, and transformation, Chemical composition, transport and sinks, residence times of aerosols, geographical distribution and atmospheric effects.

Unit 5

Air Pollution modelling: - Atmospheric chemical transport models, box models, three dimensional atmospheric chemical transport models, components of air quality forecasting, Model Types; Gaussian Diffusion Model for Point, Line and Area Sources; Estimation of Turbulent Diffusion Coefficients; Lagrangian and Eulerian modelling concepts, Evaluation and validation, air quality standards and index - Chemistry-climate modelling and climate projections of SLCPs.

Material

Text Books:

1. Scientific Assessment Report of Ozone Depletion, WMO, Geneva, 2010.
2. Atmospheric turbulence and air pollution modeling, D.Reidel Publish. Comp., Nieuwstadt, F.T.M., and Dop, H. van, 1982.
3. Atmospheric chemistry and physics of air pollution, John Wiley & Sons, Seinfeld, J.H., 1986.
4. The Chemistry and Physics of Stratospheric Ozone, A. Dessler, Academic Press, 2000.

Reference Books:

1. Aeronomy of the Middle Atmosphere, GP Brasseur and S. Solomon, Springer, 2005.
2. Stratospheric Ozone: An Electronic Textbook, Studying Earth from Space, P A Newmann and G. Morris, NASA,2003.
3. Chemistry of the Upper and Lower Atmosphere, F B J Pitts and J N Pitts, Academic Press 2000.
4. Chemistry of the natural atmosphere, Int.Geoph.Series 41, Academic Press, Warneck, P., 1988.
5. Mathematical modelling of photochemical air pollution Atm.Env 7, Reynolds, S., Roth, P., and Seinfeld, J., 1973.
6. Atmospheric Chemistry and Physics from Air Pollution to Climate Change (3rd Edition) John H Seinfeld and Spyros N Pandis, John Wiley, 2016.
7. Air pollution: sources, impacts and controls, Vaishali Naik ,Saxena, Pallavi, 2019.

20-302-0310 DISASTER MANAGEMENT

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Understand natural disasters
- Describe geophysical disaster
- Evaluate meterological disasters
- Assess multi-hazard early warning systems
- Design vulnerability mapping

Unit 1

Natural Disasters- Meaning and nature of natural disasters, their types and effects. Monsoon vagaries -Floods, drought, thunderstorms and dust-storms, tornados, hailstorm, cyclonic storm and storm surges, earthquakes, landslides, avalanches, Volcanic eruptions, Heat and cold waves, Climatic change: global warming, Sea level rise, ozone depletion- air pollution hazards.

Unit 2

Man Made Disasters- Nuclear disasters, chemical disasters, biological disasters, building fire, coal fire, forest fire, oil fire, air pollution, water pollution, deforestation, industrial waste water pollution, road accidents, rail accidents, air accidents, sea accidents.

Unit 3

Disaster Management- Forecast and warning of disasters - Cyclone warning system in India - Satellites and Radar network for cyclone warning - disaster mitigation arrangements at national and global levels. International strategy for disaster reduction. Concept of disaster management, national disaster management framework; role of NGOs, community -based organizations and media. Central, state, district and local administration; Armed forces in disaster response; Disaster response; Police and other organizations.

Material

Text Books:

1. Disaster Management., Gupta HK., Indian National Science Academy. Orient Blackswan., 2003.
2. At Risk - Natural hazards, people's vulnerability and disasters. B. Wisner, P. Blaikie, T. Cannon, and I. Davis Wiltshire: Routledge. ISBN ISBN 0-415-25216-4, 2004.
3. Disaster Science and Management, Tushar Bhattacharya, 2017.

Reference Books:

1. Coping with Catastrophe: A handbook of Disaster Management, Hodgkinson PE & Stewart M. Routledge, 1991.
2. Global warming- the complete briefing (Fifth edition), John Houghton, 2015.

20-302-0401 PROJECT AND PROJECT PRESENTATION

Outcome: (Cognitive Level – Create)

After completing the course, students will be able to

- Undertake independent research work pertaining to weather / climate science related topic of his/her choice.
- Propose a scientific problem, carry out modelling or field experiments
- Analyse the data from model outputs / observations, present and publish the results.