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Koneru Lakshmaiah Education Foundation

Green Fields, Vaddeswaram, Guntur Dist-522502 Andhra Pradesh, INDIA. http:// www.kluniversity.in

Department of Atmospheric Sciences

Syllabus for Entrance Test for PhD Admissions

Part-I	Part-II
1. Frontier Areas in Meteorology 2. Advanced Dynamical Meteorology 3. Physics and Dynamics of Lower Atmosphere 4. Applied meteorology 5. Synoptic, Tropical and Satellite Meteorology 6. Numerical Weather Prediction 7. Global Navigation Satellite System. 8. Foundations of Atmospheric Science & Space Technology 9. Fundamentals of Satellite Communications 10. Atmospheric and Space Instrumentation 11. Aeronomy	1. Climate modeling. 2. Air-sea interaction. 3. Cloud Physics 4. Satellite Meteorology 5. Climate Change. 6. Ocean Modelling . 7. Weather and Climate Applications 8. Atmospheric and Weather Radars 9. Global Weather and Climate 10. Weather Hazards & Risk Assessment. 11. Advanced Satellite Navigation Systems

Part- I	
1	**Frontier Areas in Meteorology** Atmospheric models: GCMs, RCMs, Mesoscale models. Applications to studies on climate change; different scales of weather prediction; prediction of extreme weather eventscyclones, thunderstorms, heavy rainfall events. Dynamic down scaling, location specific forecast, simulation of regional and urban climate system. Interannual and intraseasonal variability of monsoons. Teleconnections to monsoon: ENSO, IOD, Eurasian and Himalayan snow cover. Field experiments: BOBMEX, INDOEX, ARMEX, CTCZ. The role of aerosols in monsoon physics. Climate and agriculture. Drought and increasing atmospheric CO2. Agro meteorological forecasting. Crop weather models. Crop pest/disease and climate relationship. Floods and flood forecasting. Atmospheric pollutantssources. Dispersion of pollutants. Transport models. Meteorological satellite systemsdata sources: INSAT, METEOSAT series. TRMM, SSMI , QUICKSCAT, MEGHATROPIQUES. Image interpretation and enhancement techniques. Ground based remote sensing techniques: SODAR, Radio acoustic sounding system, Lidar. Doppler Weather Radar, wind profiler, MST Radar. Scatterometer, Synthetic Aperture Radar, Altimeter. Climate change on different time scales decadal, centuries and millennia.

	Meteorological extremes. Climate variability on agricultural production. Micro climate , use of natural resources. **Text Books:** Numerical models for Ocean Circulation – Pond S. and Bryan Circulation models of Lakes and inland seas – T.J. Simons WAMD1 Group, 1988; The WAM – a third generation ocean wave prediction model Dynamics and modelling of ocean waves – Komen G.J and Cavaleri L.
2	**Advanced Dynamical Meteorology:** Unit- I:Atmospheric energetics – Energy equation. Kinetic energy. Internal energy, Potential energy, Morgules theory of conversion of Potential & Internal energies to Kinetic energy. Available potential energy. Expression for APE . General circulation of atmosphere – Maintenance of the mean circulation of kinetic energy balance of the atmosphere, Angular momentum consideration. Absolute vorticity consideration. Unit- II: Linear perturbation theory – Perturbation method. Properties of waves Sound waves, Gravity waves – External and Internal gravity waves, .Rossby waves, Inertial waves, Geostropic adjustment process. Unit- III: Dynamics of tropical atmosphere: scale analysis of tropical motions, cumulus convection and convective heating, equatorial wave theory, Scale interaction in the tropics- wave number domain, frequency domain, Diabatic potential vorticity. Text Books: 1. An Introduction to Dynamic Meteorology, J.R.Holton 2. Introduction to Theoretical Meteorology by S.L. Hess 3. Tropical Meteorology, by T.N. Krishnamurti, WMO publication
3	**Physics and Dynamics of Lower Atmosphere** **Atmospheric Stability** - Conditional, latent and potential instability, Stability of layers, Cloud formation, Precipitation mechanisms; Bergeron and Fendeisen process; Collision and coalescence processes. **Atmospheric motion** - Inertial and Non-inertial frames- Fundamental Forces-Pressure Gradient forces, Gravitational force. Frictional force. Apparent forces - Centrifugal Force, Coriolis force. Equations of motion. Hydrostatic approximation. Balanced motion: Geostrophic Wind, Gradient Wind, Thermal wind. Continuity equation – Horizantal divergence, Vertical motion; Circulation and Vorticity. Land and Sea breeze. Vorticity equation, barotropy and baroclinicity. **Atmospheric boundary layer (ABL) -** Reynolds stresses, Laminar and Turbulent flow; Vertical subdivisions of ABL and their characteristics; Drag coefficient. Bulk aerodynamic formulae. Vertical profile of wind speed; Richardson's Number and Monin-Obukhov length. **Atmospheric Modelling** - Dynamical equations for weather prediction; Numerical methods: Finite difference methods- forward, centered and Implicit schemes; CFL Criterion. Numerical Models: Quasi-Geostrophic Models: Linear and Non-linear Balance Models, Primitive Equation (PE) Models, Problem of initialization for PE models. Two Level PE Model in Momentum form; Staggered Grid Systems- Arakawa C grid, 3D General circulation models. **TEXT BOOKS:**

	1. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin 2. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2 3. Numerical Prediction and Dynamic Meteorology, G.J.Haltiner and R.T.Williams. 4. An Introduction to Dynamic Meteorology - J.R.Holton **REFERENCE BOOKS:** 1. Physical Meteorology - H.G.Houghton
4	**APPLIED METEOROLOGY** Droughts and low stream flows and Hydrology of urban areas.Hydrological forecasting: Classification of Hydrological Forecasts – data requirements – forecasting runoff from antecedent river flow – general seasonal and monthly flow forecasts. Forecasting rainfall for agriculture, flood forecasting Agrotropoclimatic surveys, forecasting strong winds, hail, wind chill causing animal losses, Frost forecasting to prevent crop damage. Crop water requirements and irrigation, protection of plants animals and soils from adverse environmental conditions, Agricultural droughts, Assessment techniques, crop weather models. Air Pollution Physicochemical concepts and Effects Diffusion of pollutants – role of derived meteorological parameters. Points, Line and Multiple sources or pollution, Air Pollution modelling – Guassian plume model, diffusion model – complex terrain model – risk analysis. Remote Sensing methods applicable to Hydrometeorology, Agrometeorology and Air Pollution Meteorology **Text Books:** 1. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin 2. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2 3. Physical Meteorology - H.G.Houghton 4. Atmospheric Thermodynamics - J.V.Iribarne and W.L.Godson
5	**Synoptic, Tropical and Satellite Meteorology** MeteorologyWeather systems over Atlantic, Pacific, Indian Ocean, Asia, Africa and America – Near equatorial Rain belts and Dry zones.Long range prediction of onset and seasonal rainfall of Indian summer monsoon, Short range and medium range predictions of monsoon rainfallSynoptic study of onset, withdrawal, active and break conditions of monsoon; Easterly jet and Findlater jet; Teleconnections of Indian summer monsoon rainfall with ENSO, IOD and NAO; Study of planetary scale systems over globe (ITCZ – Westerly jet stream); Structure and movement of 30 to 50 day oscillations and its connection with onset and rainfall of Indian summer monsoonLong range prediction of onset and seasonal rainfall of winter summer monsoon, Structure, movement and prediction of tropical cyclones over Bay of Bengal during winter monsoon; Interannual and Decadal variability of the monsoon, El Nino and southern oscillation.Application of satellite data products of QUICKSCAT, TRMM, SSMI, NOAA and INSAT, Study of jet streams over India using satellite data. Studies of

	Cloud, rainfall and mesoscale phenomena by satellites, Retrieval of temperature and humidity profiles using microwave sensorsRadar Studies of clouds and precipitation systems: Radar studies of rainfall scattering by microwaves, Calibration of radar with rain gauges, Doppler radar studies of cyclone, frontal and rain band studies, Micro Physical studies of precipitation using vertically pointing Doppler radar. Use of Radar in thunderstorms and severe storm studies; MST radar. **Text Books:** 1. Weather analysis and forecasting – Vol.1 & 2 by B. Patterson 2. Tropical meteorology by H. Riehl 3. Climate and circulation of the tropics by S. Hasternath **References:** 1. Monsoon meteorology by C.S. Ramage 2. Jet stream meteorology by E.R. Reiter
6	**Numerical Weather Prediction** Unit-I: Numerical models - Filtered models : Filtering of sound and gravity wave models: Barotropic model ; Equivalent barotropic model ; Barotropic instability. Numerical methods - Computation of Jacobian and Laplacian ; solution of Helmholtz and Poisson equations using relaxation method; Finite difference methods - Forward and centered finite difference methods, implicit method - computational instability. Unit-II: Baroclinic Models - Two level model; Quasi-geostrophic multi-level models; Omega equation; Liner balanced model; Nonlinear balanced model, Baroclinic instability. Primitive equation models - Sigma coordinate system; Two level primitive equation model; Multilevel primitive equation models. Introduction to mesoscale models: Nonhydrostatic assumption, basic structure of MM5 and WRF models and their applications. Unit-III: Objective analysis - Cressman method, Method of Optimum Interpolation. Initialisation ; Static initialisation; Dynamic initialisation- Normal mode initialisation, Newtonian relaxation or Nudging . Nonlinear instability, Aliasing. Arakawa Jacobian. Staggered grid systems **Text Books:** 1. Numerical Weather Prediction. G.J. Haltiner. John Wiley 2. Numerical prediction and dynamic meteorology. G.J. Haltiner and R.T. Williams. John Wiley. 3. Introduction to Dynamic Meteorology. J.R. Holton. Academic Press. 4. Numerical weather analysis and forecasting. P.D. Thompson
7	**Global Navigation Satellite System** **GNSS fundamentals:** Trilateration, Hyperbolic navigation, Transit, GNSS principle of operation, Architecture, Operating frequencies, orbits, Keplerian elements. **GPS Signals:** GPS and UTC Time, Signal structure, C/A and P-code, ECEF and ECI

	coordinate systems and WGS 84 datum, Important components of receiver and specifications. **GPS error Models:** Ionospheric error, Tropospheric error, Ephemeris error, Clock errors, Satellite and receiver instrumental biases, Antenna phase center variation, multipath, estimation of Total Electron Content (TEC) using Dual Frequency measurement, Various DOP's, UERE. **GPS data processing and position fixing:** RINEX navigation and observation formats, Code and Carrier phase observables, Linear combinations and derived observables, Ambiguity resolutions, Cycle slips, Position estimation. **Other satellite Navigation Systems**: Galileo, GLONASS, IRNSS, Space, control and ground segments and Signal characteristics. **TEXT BOOKS:** 1. Global Navigation Satellite Systems – G. S. Rao, McGraw-Hill publications, New Delhi, 2010. 2. GPS Theory and Practice - B.Hofmann Wollenhof, H.Lichtenegger, and J.Collins, Springer Wien, New York, 2000. **REFERENCE BOOKS:** 1. Introduction to GPS - Ahmed El -Rabbany, Artech House, Boston, 2002. 2. Global Positioning System Signals, Measurements, and Performance - Pratap Misra and Per Enge, Ganga-Jamuna Press, Massachusetts, 2001.
8	**Foundations of Atmospheric Science & Space Technology** **Structure of atmosphere** – Atmospheric composition, vertical thermal structure, environmental lapse rate; standard atmosphere; hydrostatic equation; Geopotential. **Thermodynamics** - Thermodynamics of dry air and moist air: Equation of state for water vapour; Moisture variables, vertical stability of the atmosphere: Dry and moist adiabatic lapse rates; stability of layers. **Radiation** - Solar and terrestrial Radiation: Characteristics, absorption and transmission of radiation through the atmosphere; Radiative cooling or heating of the atmosphere; Mean heat balance of the earth - atmosphere system; Atmospheric greenhouse effect. **Climate:** Weather and climate concepts; World climate system: climate of the hemispheres. Global distribution of radaition, temperature, pressure, winds, precipitation; Atmospheric circulation patterns during winter and summer seasons. Jet streams. Monsoons – Asia, Australia, E. Africa and North America. Koppen and Thornthwaite climate classifications. **Electrodyanamics and radio wave propagation-** Elements of vector calculus: divergence and curl; Gauss' and Stokes' theorems, Maxwell's equations: differential and integral forms. Wave equation, Poynting vector. Ground wave propagation, terrain and earth curvature effects. Tropospheric propagation; fading, diffraction and scattering; Ionospheric Propagation-refractive index, critical frequencies. **Remote Sensing:** Electromagnetic (EM) energy and radiation; electromagnetic spectrum, wavelength; absorption, reflection and scattering of radiation in atmosphere, albedo, laws of radiation; active and passive remote sensing, radiation terminology; interaction between EM radiation and matter in the optical/ thermal and microwave

	region; spectral signatures; Spectral, spatial, temporal and radiometric resolutions. Kepler's laws of universal planetary motion, Geostationary, Sun-synchronous and special purpose orbits; visible, IR and microwave imagery, vertical sounding; Limb sounding. **Signal processing -** DT Sequences and DT Systems - Analysis of LTI Systems, Z-Transforms and its applications; DFT and FFT Design and Realization of Digital IIR and FIR Filters: **Communications -** Analog communication systems: amplitude and angle modulation and demodulation systems, Noise performance in communication systems. **TEXT BOOKS:** 1. Compendium of Meteorology (WMO Pub.) - Physical Meteorology, 1973, Vol.1, No.2 2. General Climatology: by howard Critchfield. 2nd ed. Prentice-Hall, 1966 3. Fundamentals of Remote Sensing – George Joseph 4. John G Proakis, Dimtris G Manolakis, Digital Signal Processing: Principles, Algonithms and Applications, Pearson Education. 5. R. Collin, Antennas and Radio wave Propagation, McGraw Hill, 1985. ISBN 0070118086. 6. Advanced Electronic Communications Systems, by Wayne Tomasi, 6 Edition Pearson Education. **REFERENCE BOOKS:** 1. Meteorology Today - C. Donald Ahrens, Brooks Cole Pub., 2004. 2. Dynamical and Physical Meteorology - G.J.Haltiner and F.L.Martin 3. Physical Meteorology - H.G.Houghton. 4. World Climatic Systems - by John G. Lockwood, Hodder Arnold, 1985.
9	**Fundamentals of Satellite Communications** **Introduction:** Basic Concepts of Satellite Communications, Frequency Allocations for Satellite Services, Applications. **Orbital Mechanics:** Orbital Mechanics, Look Angle determination, Orbital perturbations. **Satellite Subsystems:** Attitude and Orbit Control System, Telemetry, Tracking, Command and Monitoring, Power Systems, Communication Subsystems, Satellite Antennas**.** **Satellite Link Design:** Basic Transmission Theory, System Noise Temperature and G/T Ratio, Design of Down Links, Up Link Design, Design Of Satellite Links For Specified C/N, System Design Examples. **Propagation Effects & their impact on Satellite – Earth Links:** Introduction, Atmospheric absorption, Cloud attenuation, Tropospheric Scintillations, Ionospheric Scintillations, Rain attenuation, Rain and Ice crystal Depolarization, Propagation impairment countermeasures. **Observational Techniques of atmospheric parameters** – Measurement of temperature: Electrical Resistance thermometers, Semiconductor thermometers, Bimetallic thermometers, Thermocouples.

	TEXT BOOKS: 1. Satellite Communications - Timothy Pratt, Charles Bostian and Jeremy Allnutt, WSE, Wiley Publications, 2nd Edition, 2003. 2. Satellite Communications Engineering – L.Pritchard, Robert A Nelson and Henri G.Suyderhoud, 2nd Edition, Pearson Publications **REFERENCE BOOKS:** 1. Satellite Communications: Design Principles - M. Richharia, BS Publications, 2nd Edition. 2. Fundamentals of Satellite Communications - K. N. Raja Rao, PHI, 2004 3. Satellite Communication - D.C Agarwal, Khanna Publications, 5th Ed. 4. Satellite Communications - Dennis Roddy, McGraw Hill, 4th Edition, 2009. 5. Satellite Communications - Robert M Gagliardi,, DTS Publishers Ltd. 6. Communication Systems - Simon Haykin, 4th Edition, John Wiley & Sons
10	**Atmospheric and Space Instrumentation** Measurement of Atmospheric Pressure – Mercury, Aneroid & Piezo – resistive barometers. Measurement of Humidity- Psychrometer, Hygrometer Measurement of Surface wind - Wind vane, Cup anemometer, Hotwire Anemometer, Sonic Anemometer. Radiosonde & Rawin measurement sensors Measurement of Precipitation – Recording & Non-recording precipitation gauges. Measurement of Radiation - Pyrheliometer, Pyranometer, Net Radiometer, Pyrgeometer **Radar principles and technology** - propagation, scattering and attenuation of microwaves in the lower atmosphere, weather radar signal processing and display, Weather Radar: Signal Processing and display, Phenomena observed, operational weather Radar. **Radar Measurements** -,Observation and estimation of precipitating systems, radar equation for precipitation targets. Doppler radar – Velocity measurements, Radar wind profiler – MST Radar, Lidar & Sodar, Observation of Tropical Cyclones, use of weather Radar in Aviation, observation of clear air turbulence. **Satellite Sensors** - Advance very high resolution radiometer, very high resolution radiometer, visible and infrared spin scan Radiometer, Atmospheric sounder – VAS, special sensor microwave imager – SSM/I, High resolution infrared Radiation sounder – HIRS, microwave sounding unit-MSU, Scatterometer, Synthetic Aperture Radar, Altimeter, Ocean Colour Monitor-OCM. **TEXT BOOKS:** 1. Radar Meteorology - Henry Sauvageot, Artech House, 1992. 2. Satellite Meteorology – An Introduction, Stanely Q Kidder, Thomas H VanderHaus, Academic Press Inc. 3. Guide to Meteorological Instruments and Methods of Observation. WMO-No. 8,

	World Meteorological Organization, 2008. **REFERENCE BOOKS:** 1. Radar Meteorology – S. Raghavan, Kluwer Academic Publishers, 2003 2. Weather Radar: Principles and Advanced Applications - Peter Meischner, Springer - Verlag, 2004
11	**Aeronomy:** **Neutral Atmosphere:** Structures and Composition: Nomenclature- Thermal structure of the atmosphere. Hydrostatic equation of the atmosphere structure. Scale height and geopotential height and geopotential height. Exosphere. **Chemical concepts in Atmosphere**: Thermodynamic considerations- Enthalpy. Elements chemical kinetics- Reaction rate constants and chemical life time of spieces. Unimolecular, biomolecular and termoecular reactions. Effect of dynamics on chemical species. **Ionoized atmosphere**: Photochemical processes in the ionosphere? Introduction to ionosphere- discovery. Continuity equation and photochemical equilibrium. Theory of photo- ionization and Chapman production function. Chemical recombination and electron density. Solar radiation and production of ionospheric layers. **Loss process in D, E and F regions**: different types of recombination processes. Chemistry of D,E and F regions. D region balance equations. D region chemistry – formation of water cluster ions. Electron attachment and negative ions, Linear and square law loss formulae and splitting of F layer. Vertical transport, ambipolar diffusion. **Morphology**: Spatial and temporal structure of the ionosphere- Diurnal, seasonal and solar cycle variations of D, E and F regions and F region anomalies. Space weather disturbances, Sudden Ionospheric Disturbances (SIDs), magnetic storm effects. **TEXT BOOKS:** 1. Introduction to Ionospheric Physics - H. Rishbeth and O.K Garriott 2. Upper Atmosphere and Solar Terrestrial Relations - J.K. Hargreaves **REFERENCE BOOKS:** 1. An Introduction to the Ionosphere and Magnetosphere. John Ashworth Ratcliffe,1972.

Part- II	
1	**Climate modelling:** **Unit-I:** **<u>General circulation and climate modelling: Introduction to climate modelling.</u>** Energy balance models - their structure; Zero dimensional energy balance models; one dimensional energy balance models. Radiative convective models : The structure of Global Radiative convective models : Radiation computation - Short wave radiation, long wave radiation, heat balance at the ground, Convective adjustment ; Sensitivity experiments with Radiative convective models. Two dimensional models - zonally averaged climate models - spatial and

	temporal structure ; statistical and dynamical climate models; representation of convection, cloud cover, precipitation, radiation and surface characteristics in 2-D SDMs. Unit-II: Three dimensional atmospheric general circulation models - the structure of General circulation climate models. Numerical information - Grid point general circulation models; Phillips experiment. Spectral general circulation models - Spectral method; Triangular and Rhomboidal truncation; Spectral Transform method. Unit-III: Physics in general circulation climate models - Radiative Transfer, Boundary layer; Surface parameterization; convection; Large scale rainfall. Regional climate models: Formulation; boundary conditions, specific applications. Ocean modelling: Basic equations, wind driven barotropic models, simple thermohaline models, baroclinic models, mixed layer models. **Text Books:** 1. Introduction to three dimensional general circulation models. W.M. Washington and Parkinson. 2. A Climate Modelling Primer. A. H. Sellers and K. McGuffie 3. Numerical prediction and dynamic meteorology. G.J. Haltiner and R.T. Williams. John Wiley.
2	**Air-Sea interaction:** Unit-I: The significance of Air-Sea Interaction; Atmospheric and Oceanic Interaction at various scales; Concept of Boundary Layer ; Atmospheric Heat Budget; Variations of wind, temperature and moisture over the sea surface. Air sea temperature differences; Wind stress and resultant drag coefficient with variation to wind speed; Upper ocean boundary layer. Oceanic heat budget. Unit-II: Physical interaction between the ocean and atmosphere; Radiation, Heat exchange through latent and sensible heat; Oceanic forcing by air-sea exchange of moisture and heat; Momentum transfer and drag; Oceanic impact on the marine atmospheric circulation. Unit-III: Large Scale Air-Sea Interaction: Ocean – Atmosphere interaction in tropics Characteristics of ENSO; ENSO and Air – Sea coupling; ENSO and the Indian Monsoon Warm Pool in Indian and Pacific Oceans **Text Books:** 1. Atmosphere – Ocean Dynamics, Adrian E. Gill, 1992.

	2. Climate and Circulation of the Tropics, S. Hasternath, 1988. 3. The Oceans and climate by G.R.Bigg, 1996. 4. Ocean – Atmosphere interaction and climate modeling, Beris A. Kagan, 1995
3	**Cloud Physics:** Unit-I:Cloud physics : Cloud classification; Condensation nuclei; Ice nuclei; Growth of cloud drops; Growth of ice crystals; Curvature effect; Solution effect; Rain drop spectra; Precipitation mechanisms; Bergeron and Fendeisen process; Collision and coalescence processes; Precipitation of warm and cold clouds; Weather modification; Artificial stimulation of precipitation relevance of artificial rain making experiments in India; Hail formation; Hail suppression; Fog: Different types of fog formation and dissipation; Radar observation of clouds and precipitation. **Unit-II:**Atmospheric optics: Mirages; Rainbows; Haloes: Atmospheric refraction; Coronas;Atmospheric Electricity: Ionisation in the atmosphere; Fair weather electric field; Potential gradients; Conductivity; Conduction currents; Air-earth currents; Point discharge currents; Electrical characteristics of thunder storms; Theories of thunderstorm electrification; Tornadoes; Water spouts; Lightning discharges; Global air-electric circuit. **Unit-III:**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. **Text Books:** 1.Cloud Physics by R.Rogers 1. Cloud, Rain and Rainmaking by B.J.Mason 2. Atmospheric Physics by J.V.Iribrane & H.R.Cho 3. Atmospheric Electricity by Chalmers 4. Electricity of the free atmosphere by Yminganiton 5. The Physics of clouds by B.J.Mason.
4	**Satellite Meteorology:** **Remote sensing for meteorology** - Overview of remote sensing systems for meteorology; earth stations for remote sensing and meteorological satellites; space based measurement systems for meteorology; Active and passive remote sensing; imagery and sounding. **Radiation measurements and estimation–** Mean Global Energy Balance; The First Satellite Experiment to Measure the Net Radiation; The Radiation Budget. **Radiative Transfer Equation (RTE) -** Derivation of RTE; Temperature Profile Inversion; RTE in Cloudy Conditions; **Meteorological satellite systems** – Series of Indian Remote Sensing Satellite, INSAT, Meteosat, NOAA, TRMM and SSMI; QuikSCAT, Oceansat2, Terra, Aqua, Megha- Tropiques satellite products. **Satellite meteorological data and products -** Satellite image interpretation and enhancement techniques, cloud type identification.

	Land surface temperatures from satellites; Infrared and microwave observations of sea surface temperatures (SST); Global SST retrieval algorithms from NOAA-AVHRR data. Vegetation spectral response and vegetation indices; Normalized Difference Vegetation Index; Normalized Difference Water Index; Normalized Difference Snow Index; Normalized Difference moisture Index. **Satellite based ocean and atmospheric parameters** - Satellite based rainfall estimations; cloud motion vectors; outgoing longwave radiation (OLR) and cloud top. Active and passive sensors for ocean surface winds; soil moisture using microwave radiometer; atmospheric temperature profile retrieval; limb sounding retrieval of trace gases; GPS-RO (Global Positioning System- radio Occultation) techniques to retrieve temperature and humidity profiles. Total Water Vapour Estimation. Determination of total Ozone and Geopotential Height. Microwave Estimation of Tropical Cyclone Intensity. Satellite measurement of Atmospheric Stability. Detection of forest fire and area estimation; Aerosol optical thickness; ISCCP; CLAVR; CO2 slicing. **TEXT BOOKS:** 1. Fundamentals of Remote Sensing – George Joseph 2. Satellite Meteorology: An introduction - S.Q. Kidder and T.H. Vonder Haar 3. Lecture Notes for Post Graduate Course on Satellite Meteorology and Global Climate, Vols.1, 2 and 3. ISRO Publications. 4. Applications with Meteorological Satellites - W. Paul Menzel, Technical document, WMO/TD No. 1078. **REFERENCE BOOKS:** 1. The use of satellite data in rainfall monitoring- E.C. Barrett and W. N. Martin 2. Remote sensing of atmosphere - J.T. Houghton, F.W. Taylor and C.D. Rodgers. 3. Satellite Meteorology - R.R. Kelkar, B.S.Publications.
5	**Climate Change** **The Climate system** – energy balance of the earth-atmosphere. History of climate change – glacial cycle, inter-glacial and insterstadial events, year to decadal variations, natural variability. **Global warming –** Anthropogenic climate change. Greenhouse gases (GHG) and global warming – GHGs trend, global temperature trend, global distribution of emissions, Sources of CO2 in the Land, Ocean and atmosphere. Future Emissions and Energy Resources, Current and Future sources of Methane, Biological sources of Nitrous oxide, societal resilience. Mitigation strategies: Reducing Carbon Emissions, Energy use and Emission trading, **Climate trends:** Teleconnections of the world climate system, consequences of global warming; Ozone hole; Volcanic eruptions and aerosols, Nuclear winter; Climate in relation to sunspot and cosmic activity. **IPCC Assessment of climate change:** Detection and Attribution of Climate Change: from Global to Regional scales. Short term climate change: Projections and Predictability. Long- term climate change: Projections, commitments and irreversibility. Climate phenomena and their relevance for future regional climate

	change. The measurement of climate change. Climate change and extreme weather events. Climate change impacts on ecosystems, agriculture. **TEXT BOOKS:** 1. Earth's Climate: Past and Future - Ruddiman, William F.2001. 2. Climate Change 2001 - Houghton, J.T., 2001, (ed). The Scientific Basis. 881pp. 3. Climate Change: A Multidisciplinary Approach - William James Burroughs 4. Current trends in Global Environment - A.L. Bhatia (2005). **REFERENCE BOOKS:** 1. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC 2013 report. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 2. Causes of Climate - J.G.Lockwood
6	**Ocean Modelling** **Unit-1**: Physical Modelling and Numerical (Mathematical) Modelling; Uses of modelling, different methods and approaches in modelling, Diagnostic models, prognostic models.Physics of Ocean modelling, Lagrangian and Eularian approaches in modelling, primitive equation models. **Unit-II** Model dimension and coordinates, Model domain, temporal and spatial resolution of the models. Model initialization; Model forcing... **Unit-III** Shallow water equation, sub-grid scale parameterization, 4 dimensional data assimilation; Model validation; Indian Ocean boundary conditions, model forcing conditions over Indian Ocean. Status of operational models in Indian Ocean – POM, MIKE21, ROMS, WAM etc. **Text Books:** Numerical models for Ocean Circulation – Pond S. and Bryan Circulation models of Lakes and inland seas – T.J. Simons WAMD1 Group, 1988; The WAM – a third generation ocean wave prediction model Dynamics and modelling of ocean waves – Komen G.J and Cavaleri L.
7	**Weather and Climate Applications** **Weather and climate data** - Sources for local, regional and global meteorological data; data from national and international sources; spatial and temporal resolution of data; Observational and model generated data. **Applications to hydrology** – Rainfall: interception and infiltration, surface runoff and sub- surface run-flow. Rainfall-Runoff models, Flood forecasting. Drought categories and assessment techniques. Effects of urbanization on climate and stream flow. Urban hydrology modeling and risk assessment. **Applications to air quality** - Sources and classification of atmospheric pollutants, Factors affecting atmospheric pollution. Atmospheric pollution at local, urban, regional, continental and global scales. Air quality standards and legislation. Transport and dispersion of atmospheric pollutants: estimation of pollutants. Application of weather data for air quality assessment using models. Effects of

	atmospheric pollution on human health, animals, vegetation, materials and property. Air quality risk assessment. **Applications to agriculture** - Relationship between weather and agriculture; climatic requirements of common agricultural crops, Plant phenology; effect of weather factors on the growth and development of plants; Weather factors conducive to infection; crop protection from adverse meteorological phenomena-droughts, heavy rains, storms, cold waves and frost, heat waves, strong winds. Crop-weather calendars; statistical analysis of crop and weather data; Agro-meteorological forecasting: basic principles, phenological forecasting, crop-yield forecasting, weather forecast and warning for agriculture. Principles of weather prediction for crops with special reference to India. **TEXT BOOKS:** 1. Hydrometeorology - C.J.Wiesner 2. Guide to Agricultural Meteorological Practices: WMO No.134, 1981. 3. Agroclimatic/Agrometeorological Techniques, S.Jeevananda Reddy, Jeevan Charitable Trust, ICRISAT Colony, Secunderabad, 1993 **REFERENCE BOOKS:** 1. Physico, Chemical aspects of Air pollution - Henry.C Perkins. 2. Hand book of Applied meteorology – David D. Houghton (John Wiley & Sons, 1985) 3. Atmosphere, Weather and Climate - Barry and Chorley (Routledge Publ., 2009)
8	**Atmospheric and Weather Radars** **Principles of Radar:** Doppler radar (Transmitting and receiving aspects) scattering cross section radar equation, Doppler Shift attenuation Practical considerations. Basic system antenna arrays, TR Duplexer and transmitting systems, receiving systems coding and decoding coherent integration. **Radar signal processing:** Spectral analysis of Radar signals discrete Fourier transform, power spectrum of random sequences spectral moment's extraction of structure constant velocity fields and turbulence parameters. Range ambiguities velocity ambiguities echo coherency direction of weakly scattering weather targets **Wind profilers and MST Radars:** studies on clear Air turbulence (CAT) using ST / MST radar Systems Observations of structure (Cn2 and Stratified Layers) winds, waves and Turbulence parameters **TEXT BOOKS:** 1. Doppler Radar & Weather Observations, R. J. Doviak, D. S. Zrnic, 2nd Edition, Dover Publications. 2. Electromagnetic waves & Radiation Systems – Edward C Jordan and Keith G.Balmain,PHI,Second Edition,India REFERENCE BOOKS**:** 1. Elements of Electromagnetics - Matthew N. O. Sadiku, Oxford University Press.
9	**Global Weather and Climate**

	Global atmospheric circulation - Atmospheric circulation patterns. Zonally averaged meridional and zonal circulations, zonally asymmetric components of the general circulation - standing eddies and Walker circulations. **Monsoon systems -** Land and sea breezes, Asian monsoons –onset, withdrawal, active and break monsoon situations. Monsoon rainfall distribution; monsoon rain bearing systems - monsoon depressions, Mid-tropospheric cyclones and Offshore vortices. **Mesoscale weather systems -** CAPE and CINE, Thunderstorm, Dust storm, Hail storm, mesoscale convective system, fog, tropical cyclones, extra-tropical frontal systems. **Global and regional Circulation systems**: Jet streams- Tropical Easterly jet, Subtropical Westerly jet, Somali jet over India. Easterly waves, Rossby waves and Kelvin waves. **Atmospheric –Ocean phenomena:** North Atlantic Oscillation, North Pacific Oscillation, El- Nino, La Nina, Southern Oscillation, Walker circulation, Hadley circulation, Tropical Biennial Oscillation, Indian Ocean Dipole. **TEXT BOOKS:** 1. Physical climatology - William D. Sellers. 2. Essentials of Meteorology – C. Donald Ahrens 3. Global Physical Climatology - Dennis L. Hartmann **REFERENCE BOOKS:** 1. Dynamical and physical Meteorology - George J.Haltiner and Frank L. Martin. 2. Monsoons - P.K.Das 3. Tropical Meteorology - G.C.Asnani 4. World Climate Systems, J.G.Lockwood
10	**Weather Hazards & Risk Assessment** **Weather hazards**: Types of weather hazards, vulnerability to weather elements, tropical cyclones, severe local storms, heavy precipitation, flash floods, fog, heat and cold waves, tornadoes. **GIS based Modelling** -Hydrological Modeling - water quality modeling, watershed management and modeling, saltwater intrusion models. Land-surface-subsurface Process Modeling - pipeline alignment studies, solid and hazardous waste disposal site selection, zoning atlas for industrial silting, environmental information system development. Ecosystem modeling, risk and hazard modelling. **Disaster Impact and Damage Analysis:** The use of satellite imagery for disaster relief and recovery; Impact analysis and preliminary damage assessment. **Pre-Disaster Risk Assessment**: Hazard Assessment; Elements at risk and vulnerability assessment; Types and methods of risk assessment, risk evaluation, cost-benefit analysis. **Risk Information for Risk Reduction Planning**: Risk evaluation, Visualization of risk information; Risk information and spatial planning. **TEXT BOOKS:** 1. Weather Risk Management: A guide for Corporations, Hedge Funds and Investors - Tang, K., Ed., Risk Books, 2010.