Subjects Taught:

Semester - I (Six Months)	Semester - II (Next Six Months)
• Observational Systems • Dynamic Meteorology • Physical Meteorology and Thermodynamics • Oceanography & Marine Meteorology • Climatology and Statistics • Synoptic Meteorology including Weather Analysis and Forecasting • Aviation Meteorology • Hydrometeorology • Environmental Meteorology • Satellite and Radar Meteorology • Met Telecommunication system • DBM & GIS	• Geophysical Fluid Dynamics • Advanced Physical Meteorology • Climate Science • Advanced weather analysis & forecasting • Advanced Aviation Meteorology • Numerical weather prediction • Physical Oceanography & Ocean-Atmosphere Interaction • Advanced Statistics • Computer Programming and applications • Hydrometeorology

Appendix-I

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Advanced Meteorological Training Course

(12 months duration)

Semester-I (6 months duration)

2019

Content

& 1 working week = 5 working days
 # 1 working day = 6 periods of 75 minutes

Subject	**Duration**	**Place**
Meteorological Observation System (Surface & UA)	18 working days[#]	MTI
Dynamic Meteorology	10 working days	MTI
Physical Meteorology and Thermodynamics	12 working days	MTI
Synoptic Meteorology including Weather Analysis and Forecasting	12 working days	MTI
Climatology & Meteorological Statistics including Climate Change & Climate services	14 working days	MTI
Oceanography and Marine Meteorology	5 working days	MTI
Hydrometeorology	7 working days	MTI
Environmental Meteorology		
Aviation Meteorology	5 working days	MTI
Satellite and Radar Meteorology& Met Telecommunication system	11 working days	MTI
Paper Review work, Special Lectures	11 working days	MTI
DBM & GIS	5 working days	MTI
Joining + Relief + midterm exam+ final exam + viva voce	3 working weeks	MTI
Total	25 working weeks = 6months. Afterwards they will go for 2 weeks OJT at IITM, NWA, Weather Central, INOSHAC, Agri-Met division, Instrument lab, Radiation lab, AMO Mumbai/AFS, Lohegaon, Pune.	

Meteorological (Surface & Upper Air) Observation System

Advanced Meteorological /Met-II Training Course: -

(Total duration = 18 working days = 18 x 6=108 periods of 75 minutes duration)

Theory of Meteorological variables (58 Periods)

- General principles of observations: representativeness of observations, Metadata, general requirement of a meteorological observatory, siting and exposure, measurement standards and definitions, uncertainty of measurements, source and estimation of errors uncertainty, calibration, validation and maintenance, Operational measurement accuracy requirements and instrument performance. Response characteristics of the instruments, lag and radiation errors, resolution, precision and accuracy, limitations of sensors and instruments (4 P)
- Vertical structure of the atmosphere, meteorological elements to be observed (4 P)
- Atmospheric Pressure: Units and scales, methods of observations, barometer - Fortin and Kew pattern - description reading, correction of barometer readings to standard conditions, reducing the value to mean sea level, exposure, electronic and aneroid barometers, QFE, QFF and QNH, barographs; comparison of barometers data. (4 P)
- Atmospheric Temperature: Units and scales, description of dry bulb, wet bulb maximum, minimum and soil thermometers, methods of working, reading and resetting. Stevenson screen/~~,~~ exposure; care of the instruments; thermograph; comparison of instruments data with standard instruments. Other methods of temperature measurements (4 P)
- Humidity – units and scales, measurement methods, types of hygrometer- definitions and specifications, distribution water vapour in the atmosphere, calculation of relative humidity from dry and wet bulb readings; pressure; dew point temperature, psychrometers, psychrometric tables, hygrograph, Formulae for the computation of measures of humidity, modern humidity sensors (4 P)
- Wind - definition of wind, units and scales, Beaufort scale, methods of measurements, all types of anemometer and wind vanes, pressure tube Dines anemograph, exposure conditions, high wind speed recorders, ultrasonic devices, 3-D wind sensors (4 P)
- Precipitation: definition, units and scales, Rain gauge - Description and working, self-recording raingauge exposure, automatic rain-gauges, measurement of snowfall and snow cover, precipitation gauge measurement errors and correction procedures, fast response rain gauges, optical rain gauges, disdrometers (4 P)
- Clouds – Units and scales, Classification, types, description, amount, height of base determination, direction of movement, Ceilometers, all sky view camera, Satellite cloud pictures. (4 P)
- Present and past weather – description, definition of various weather phenomena, symbolic representation (2 P)

- Visibility – definition, units and scales, measurement methods, visibility landmarks, night visibility, RVR observations, transmissometer (4 P)
- Codes – Surface, Ship, Upper-air, TEMP, Aviation Codes including preparation of charts. (20 P)

OBSERVING SYSTEMS AND THEIR MEASUREMENT

(Surface and Upper air - 50 Periods)

- Measurement at surface observatories and Automatic Weather Stations, Agromet observatories (4 P)
- Marine Observations: Ship Observations, ocean drifting buoys, moored buoys, ARGO, Airborn instrumentation, tidal and ocean current measurements (4 P)
- Measurements at Aeronautical Meteorological Observatories (3 P)
- Measurement at Radiation and BAPMoN stations (3 P)
- Introduction to Satellite observations, (4 P)
- Observations through remote sensors - based on satellites: atmospheric temperature and sea surface temperature measurements, measurement of water vapour and humidity, quantitative precipitation estimation through satellite and radar, clouds including type, base and height through satellite based sensors. (3 P)
- Types of Radar Measurements: Doppler Weather radars, multiparameter radars (especially polarimetric) and wind profiler radars and their capabilities in meteorology (besides wind measurement), use of the sun, radio stars and profilers calibration of radars (4 P)
- Measurement of upper air pressure, temperature, wind and humidity: Methods of upper wind observations, Radiosonde, Optical theodolite, Radio theodolite, Radars, Pilot balloon(PB), methods of calculations; with tail method; with constant rate of ascent, theodolite, balloon and accessories; computation of upper winds; PB ascent at night; determination of azimuth of a datum point by pole star method, selection of site for PB observatory; computation of meteor reports; principles of measurement of upper air temperature, pressure and humidity by meteorograph, radiosonde; principles of measuring winds by radar and radio theodolites, GPS radiosonde, GPS receiver, LIDARS, SODAR. GPS Radio-Occultation techniques (10P)
- Radiation- Definitions, units and scales, measurement methods, Surface Solar and IR radiation, solar (global, diffused, direct, UV-A and UV-B), terrestrial and net radiation, Radiometer, sondes, Direct and Indirect, Sunshine P (3 P)

Trace gases, ozone and Aerosol: Description of spatial and temporal distribution of trace gases, ozone and aerosols., Measurement Techniques: Column Ozone, Vertical distribution of Ozone, Surface Ozone, IMD's network for Ozone observation, Dobson spectrophotometer Measuring instruments for

trace gases, pollutants and aerosols, ozone sondes, Aerosol measurement technique, IMD's network for aerosol observation. (3 P)

- Lightning detector, atmospheric electricity measurements, potential gradient and conductivity measurements, lightning flash meters, networks for radio location of lightning. (3 P)
- Environmental parameters- instrumentation and techniques: Quality Assurance and Management of observing systems, Quality management, sampling meteorological variables, testing, calibration and quality check and inter comparison, Integrated Observing System, Targeted Observations, Field Campaigns, Instrument standardization and comparisons (2 P)
- Maximum sustained surface wind, gustiness, squall, gale, wind averaging (1-,2-,3-, 5-,10-, 30- and 60- min), wind conversion factor, impact of wind associated with tornado, thunderstorm, depression and cyclones (Beaufort scale, Saffir Simpson wind scale, Dvork scale etc.), classification of wind. (2 P)
- Measurement at Agromet Observatories. (2 P)

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DYNAMIC METEOROLOGY

(Total duration = 10 working days = 60 periods of 75 minutes duration)

Theory (45 periods)

Equation of Motion (4 P)

- Scope of Dynamic Meteorology. Concept of continuum. Basic conservation laws governing the atmospheric motion.
- Frame of reference: Time rate of change of a vector in an inertial and in a rotating frame of reference & their relation.
- Forces: Pressure gradient force; Coriolis force, gravitational force, and friction, Local change of a field, advection of a field variable, local (Eulerian) derivative & total (Lagrangian) derivative of a field variable.
- Map projections: Mercator, Lambert conformal and Polar stereographic; Coordinate systems: Cartesian and spherical polar coordinate systems
- Equations of motion in Cartesian coordinates.
- Equations of motion in spherical polar coordinates. Curvature terms.

Scale Analysis (3 P)

- Concept of order of magnitude. Non-Dimensional analysis of different field variables

- Definition of scale of a weather system. Scale analysis of momentum equation for mid-latitude/tropical synoptic scale / mesoscale system.

Geostrophic Approximation (3 p)

- Definition and properties of geostrophic wind. Vectorial expression for geostrophic wind. Schematic diagram to show how geostrophic balance is achieved.
- Rossby number. Use of Rossby number as a tool to test the validity of geostrophic approximation. Regions of atmosphere where Geostrophic is not a valid assumption.

  Relation between wind direction/speed and isobar/contour distribution under geostrophic relation. Latitudinal variation of geostrophic wind for given pressure gradients (say 2hPa/100km). Geostrophic scale.
- Ageostrophic wind, its definition and property. Vectorial expression for ageostrophic wind. Its relation with acceleration.

Hydrostatic Approximation (3 P)

- Simplification of vertical momentum equation for mid latitude synoptic scale system following scale analysis leading to hydrostatic approximation. Discussion on the validity and limitations of this approximation.
- Using above approximation, definition of atmospheric pressure at any point.
- Definition of geopotential and geopotential height of a point and corresponding units.
- Hypsometric equation and its use in computing thickness of a layer of atmosphere.

Natural Coordinate and balanced flow (4 P)

- Introduction to natural co-ordinate. Horizontal equation of motion in natural co-ordinate. Gradient balance and gradient wind. Physically possible different gradient flow. Examples. Sub & super – geostrophic flow. Special cases of gradient balance: -geostrophic balance, inertial balance, and cyclostrophic balance. Examples. Is gradient flow a balanced (no acceleration) flow?
- Different vertical co-ordinates, pressure (p), potential temperature (θ) etc. Pressure gradient force in p & θ co-ordinates. Horizontal equation of motion with p as in any vertical co-ordinate.

Vertical Variation of Wind (4 P)

- Thermal wind: Definition, Thermal wind equation and properties of thermal wind.
- Concept of vertical wind shear. Schematic explanation for horizontal temperature gradient leading to vertical shear of geostrophic wind.
- Application of the concept of thermal wind in explaining Sub tropical westerly jet, Tropical easterly jet, intensification of cold (warm) core low (high) with height, tilt of axis of low (high) towards cold (warm), cold and warm advection associated with veering/backing of geostrophic wind. How much N-

S temperature gradient creates a easterly jet of strength 100kt at 16km from a westerly of strength 20kt at surface (msl)?

- Analysis of the shear hodograph and stability conditions.
- Concept of barotropic and baroclinic atmosphere.

Continuity Equation and Convergence (3 P)

- Equation of continuity with different vertical co-ordinates: Importance of 'p' as a vertical co-ordinate. Application of continuity equation: Dines compensation principle. Concept & importance of level of non-divergence (LND). Kinematical method of computingω. Scale analysis of continuity equation. Concepts of incompressible fluid, homogeneous fluid and isotropic fluid. Moisture continuity equation.
- Divergence of an arbitrary vector field. Physical concept. 2-D (or 3-D) divergence as a fractional rate of change of area (or volume). Horizontal divergence in natural co-ordinate system & in other (Spherical polar or cylindrical) co-ordinate systems.

Kinematics of Wind Field (3 P)

- Stream lines and trajectory, their definition and differential equation, stream function, Baton's equation.
- Resolution of horizontal wind into pure translation, divergence, rotation, deformation. Invariance of divergence and vorticity under co-ordinate transformation. Equations and patterns of streamline for pure translation, divergence, rotation, deformation
- Velocity potential and stream function

Kinematics of Pressure Field (3 P)

- Mathematical definition of center of low, high & COL. Mathematical equation of trough & ridge. Expression for the velocity of an isobaric pattern. Mathematical equation for the slope of axis of low/high.

Circulation and Vorticity (7 P)

- Definition and mathematical expression of circulation. Circulation theorems, their detailed derivation, detail discussions on their application aspects. Detailed discussions about solenoidal vector.
- Concept of vorticity of an arbitrary vector field. Definition of atmospheric vorticity along with its mathematical expression. Physical meaning of Curl of any vector. Components of vorticity vector. Relation between circulation and vorticity.
- Vorticity for solid body rotation. Concept of planetary vorticity. Relative vorticity in natural co-ordinate. Explanation of curvature and shear vorticity with specific examples. Concept of potential vorticity.

- Vorticity equation in different co-ordinates. Physical interpretations for individual terms. Scale analysis of vorticity equation. Application of vorticity equation. Conservation laws for Barotropic (Rossby) potential vorticity & Baroclinic (Ertel) potential vorticity and their application.
- Vorticity advection

Pressure Tendency and Mechanism of Pressure Change (3 P)

- Pressure tendency equation: Its derivation and physical interpretation, in detail, of each term, representing different mechanisms of pressure change. Importance of net divergence in an atmospheric column. Different isobaric patterns and their movement.

Basics of Planetary Boundary Layer (5 p)

- A brief introduction to PBL: Definition of PBL. Importance of PBL. Characteristics of PBL: the turbulent motion. Types of turbulent motion: Convective turbulence and Mechanical turbulence. Conditions favourable for Convective turbulence and Mechanical turbulence. A general idea about depth of PBL and its diurnal and seasonal variation at a place. Richardson number
- Description of different sub layers in PBL.
- Boussinesq approximation and its physical interpretation. Governing equations in the PBL using Boussinesq approximation.
- Concepts of Reynolds average. It's difference from the mean part in perturbation theory. Precaution to be taken while Reynolds averaging.
- Concepts of eddy flux, eddy flux divergence in detail and their importance.
- Momentum flux, moisture flux

Practical (15 periods)

- Computation of divergence & vorticity using curvature method (3 P)
- Computation of geostrophic wind, gradient wind, vorticity (3 P)
- Computation of thermal wind and thermal advection (3P)
- Computation of vertical velocity using kinematic method (3 P)
- Use GrADS to plot divergence, vorticity, vertical velocity, advection etc. and compute tilt of synoptic systems with height and plotting of cyclone tracks etc. from IMD's NWP model output. (3 P)

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Physical Meteorology

(Total duration = 12 working days = 72 periods of 75 minutes duration)

Theory (45 Periods)

■ **Atmospheric Thermodynamics (15 Periods)**

- The Gas Laws, Concept of partial pressure of a constituent gas in a mixture of gasses, Dalton's law of partial pressure and equation of state for a mixture of gasses. (2 P)
- Moisture in the atmosphere, Moisture parameters (Dry Bulb temperature, wet bulb temperature, vapor pressure, saturated vapor pressure, specific humidity, mixing ratio, saturated mixing ratio, relative humidity, absolute humidity); Latent heat; Molecular weight of dry air, virtual temperature, (2 P)
- First law of thermodynamics and its application work, energy and specific heats of gas; enthalpy; adiabatic process, Poisson's equation, Potential Temperature, Thermodynamic Energy Equation. (3 P)
- Second law of thermodynamics: entropy and other thermodynamic functions of state viz., , Helmholtz free energy function and Gibbs free energy function , derivation of Clausius – Clapeyron equation using Gibbs free energy function; Thermodynamic diagrams; Normand's theorem; Saturated adiabatic and pseudo- adiabatic processes; Equivalent potential temperature, Dry and Moist static energy, Stability and instability by parcel and slice methods, conditional, convective and latent instabilities, convection and entrainment, role of Convective Available Potential Energy (CAPE) and Convective Inhibition Energy (CINE) in atmospheric convection. Stability indices and their significance in thunderstorm monitoring and forecasting (5 P)
- Hydrostatic equation: Geopotential, thickness and heights of constant pressure surfaces, Homogeneous, isothermal, dry adiabatic atmosphere and constant lapse rate atmospheres; Standard atmospheres; Barometric altimetry. Precipitable water vapor: Rate of precipitation, Total Precipitable Water (3 P)

■ **Theory of Atmospheric radiation: (18 Periods)**

- Electromagnetic spectrum: quantitative description of radiation; Kirchoff's Law, Planck's Law, Stefan-Boltzman's Law, Wien's displacement law, and Beer's Law; atmospheric radiative transfer: Concept on radiative equilibrium and discussion on radiative flux divergence. Scattering, Rayleigh, Mie and non-dimensional scattering, absorption, and emission of radiation; Schwarzchild's equation, Refractive index variations discontinuities, refractivity turbulence, optical depth (6 P)
- Solar radiation, direct and diffuse, and global radiation and their measurements; Solar constant and its measurements; Albedo of Earth, Details of aerosol scattering and their impact on direct and diffuse radiation, Atmospheric Aerosols turbidity and its impact on solar radiation. Climatology of insolation, Seasonal and latitudinal variation of insolation. (4 P)
- Terrestrial radiation: Absorption of terrestrial radiation by atmosphere; Greenhouse effect, Radiative cooling of the atmosphere; Heat balance of the earth and atmosphere, Anthropogenic greenhouse gases, greenhouse effect, its role and examples from atmosphere of Venus, "Runaway greenhouse effect" Sources of greenhouse gases, linked with anthropogenic activities. (5 P)

- Refraction, scattering and diffraction of solar, IR. Impact of dust and turbidity (3 P)

- **Theory of Atmospheric visibility**: Concept of atmospheric optics and optical phenomena. visibility meters; Measurement of visibility during day and night. Slant Visibility, Koschmeidar Equation, Runway Visual Range, Impact of hydrometeors and Lithometeors on visibility, impact of air pollution and photochemical processes in the Atmospheric boundary layer on visibility **(4 P)**
- **Basics of Cloud Physics**: Spatial and temporal scales of clouds i. e. multiscale structure of clouds (cumulus, cumulus congestus, Cb, stratus etc.). Nucleation formation of cloud droplets, droplet growth by condensation, precipitation mechanisms in cloud, concepts of partial pressure and role of different hydrometeor in convective and stratiform rain formation, Mechanism of the formation of fog and different types of clouds **(8 P)**

Practical (27 Periods)

- Analysis of Radiosonde data using tephigrams: Computation of virtual temperature & other thermodynamic parameters (Potential Temperature, Wet Bulb Temperature, Equivalent Potential Temperature, Equivalent Temperature, LCL, CCL, LFC, LNB). (7 P)
- Advanced analysis of radiosonde data for weather predictions: Study of stability conditions for given sounding data, identifying layers of instability. Computation of the precipitible water vapour amount. Computation of various stability Indices for prediction of thunderstorms (K-index, Lifted Index, Showalter Index). Energy computations like CAPE and CINE. (13 P).
- Computation of optical depth for use in radiation balance Studies. (7 P).

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SYNOPTIC METEOROLOGY

(Total duration = 12 working days =12×6=72 periods of 75 minutes duration)

THEORY (48 Periods)

- Scales of weather systems (Meso, Synoptic and Planetary scales) - Map projections - representation and analysis of fields of meteorological elements on synoptic charts - Vertical time/cross sections and their analysis. Wind and pressure analysis - Isobars on level surface and contours on constant pressure surface - Isotherms, thickness field - Slope of pressure systems - Streamline and isotach analysis. Preparation, analysis, interpretation, application and limitations constant PV charts (7 P)

- Winter season synoptic systems - Western Disturbance and Its structure and associated weather- Fog – cold wave – checklist for forecasting of western disturbances, Fog and cold wave. – satellite and RADAR features of western disturbances, Fog. (5 P)
- Pre-monsoon season synoptic scale weather – maximum temperature & heat wave -Ordinary

thunderstorm - Severe thunderstorm (Squall-line, Multi-cell, Super-cell) – Role of CAPE, CINE and Vertical Wind Shear – synoptic conditions for thunderstorm activity over different parts of Indian continent- Norwesters, Dust-storm (ANDHI), Hail storm, Tornado, Squall, sea breeze induced Thunderstorm- Meso-high, Gust front , Down-burst and Micro-burst - checklist for forecasting of thunderstorm and hailstorms.-satellite and RADAR features of western disturbances , Fog. (6 P)

- Asian summer monsoon - Monsoon onset over Kerala –semi-permanent systems – Active and Break monsoon phases – Monsoon depression – Mid Tropospheric Cyclonic circulations - Influence of northern hemisphere mid-latitude westerly troughs – discussion on tele connective influences from El-Nino, IOD, MJO, Kelvin waves , NW pacific typhoons – Monsoon and orography - Intra-seasonal variability of Monsoon (15 and 40 day modes) - Withdrawal of monsoon – Monsoon and the Indian ocean - Summer monsoons of Americas, Africa and Australia (8 P)
- North east monsoon in India. - Easterly wave and its structure and associated weather -satellite and RADAR features of easterly waves. (3 P)
- Tropical cyclone - Life cycle – horizontal structure – vertical structure- Cyclone Genesis - Intensification of cyclones – Eye wall replacement cycles – T-number –
  Movement of tropical cyclones - dynamical and statistical methods -Persistence, climatology and steering methods - Analogue techniques - Interaction with nearby cyclones. - NWP models for Tropical cyclones genesis, intensification and movement. Monitoring and prediction of heavy rain, gale wind, storm surge, Cyclone related warnings generation and dissemination. (6 P)
- Mid latitude Synoptic Meteorology: Zonal index & Index cycle. Air masses and fronts – Fronto-genesis - Slope of frontal surface - Extra tropical cyclone and its structure and life cycle - Fronts and associated weather - Development of cyclones and anticyclones - Jet Stream and Tropopause; long waves; cut-off lows and highs, blocking. (4 P)
- Diurnal and local effects - Sea and land breezes - Slope and valley winds - Mountain wave - Clear Air Turbulence. (2 P)
- Basics of Nowcasing - Meso-network - Use of radar and satellite in meso-scale analysis and forecasting. (2 P)
- Tools and Techniques for Synoptic Analysis. (5 P)

a. Digitized Forecaster's workstation (Synergy system in IMD),
b. Special Module available in synergy system for specific purpose, viz., Module for preparation of significant weather chart, Tropical Cyclone Module
c. check list for daily watch on severe weather events (e.g. Monsoon Watch, Daily Tropical Weather Watch for Cyclogenesis, Thunderstorm activities etc).

d. Preparation of report on severe weather.

Practical (24 Periods)

- General Surface chart analysis
- Streamline and isotach analysis
- Analysis of constant pressure charts
- Analysis of Jet streams
- Analysis of thickness charts and thermal wind
- Vertical time/cross section analysis

  Analysis of tropical weather systems-surface and upper air (one case each)
- *Western disturbance*

  Midlatitude-tropcal interaction
- *Monsoon systems*
- *Tropical cyclone*
- *Active and weak monsoon condition.*

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Climatology and Meteorological Statistics

(Total duration = 14 working days =14×6=84 periods of 75 minutes duration)

Climatology (48 Periods of 75 minutes)

- **Physical climatology:** Earth Sun relationship, Ecliptic and equatorial plane, Rotation and revolution of the earth Equinoxes, Solstices, Perihelion and Aphelion, Causes of seasons, the inverse-square law of solar radiation, Seasonal and latitudinal variation of insolation, Definition of climate, radiative forcing **(2 P)**
- **Climate classification**: Empirical and genetic classifications, Koppen, Thornthwaite'cschems, other classifications -Penman classification of climate, homoclimates climatic types and climatic zones. **(2 P)**

Indian Climatology (16 P):

- Four seasons - (Pressure and wind distribution for mid- season months) (2 P):
- Winter - Western disturbances, fog, thunderstorms, hail, cold waves, sub-tropical jet stream; Northeast monsoon - Interaction of low and high latitude disturbances, easterly waves (3 P)
- Pre-monsoon: Cyclonic storms, tracks, Frequency, the cyclone genesis, intensity, landfall and associated weather – gale wind, heavy rainfall and storm surge, western disturbances, fog, dust storms,

thunderstorms, Norwesters, heat waves, pre-monsoon thunderstorms, dust-raising winds, equatorial trough (3P)

- **Southwest monsoon season** – Onset and advance of southwest monsoon. Semi-permanent systems of monsoon, Factors affecting distribution of monsoon rainfall, Active-break cycle, Monsoon breaks, Synoptic systems in monsoon (monsoon lows and depression, MTCs, and monsoon trough). Interannual and intra seasonal variability of monsoon, links to El Nino/Southern Oscillation, mid-latitude interaction, Indian Ocean Dipole and Madden Julian Oscillation Index. (5 P)
- **Post monsoon season** - Withdrawal of southwest monsoon, Northeast monsoon (mean rainfall distribution, synoptic systems, inter-annual variability), Cyclonic storms in the Indian seas, trends in cyclonic disturbances, Western disturbances, Easterly waves. (3 P)

Synoptic Climatology (4 P):

- Climatology of air masses (January & July) - origin, movement and modification of air masses, fronts and convergence zones -weather associated with frontal zones, extra tropical cyclones - their origin, structure development and dissipation. Classification of climates, regions of blocking and cyclogenesis.
- Zonal index & Index cycle

Mean State of the global Atmosphere (8 P)

- Mean temperature structure (global distribution and vertical structure)
- Mean Geopotential Height structure
- Mean Atmospheric Circulation (global distribution, vertical structure, variability of the circulation)
- Precipitation, evaporation, runoff and cloudiness

Mean State of the Oceans (7 P)

- Sea surface properties and vertical structures of temperature, density and salinity, Mean Ocean circulation– **latitude-longitude dependence of climate features, the ocean thermohaline circulation,** (2 P)
- Tropical Biennial Oscillation, Mean state of the tropical Pacific coupled Ocean- Atmosphere system, Walker circulation, ENSO, IOD, Role of Ocean in the variability of Asian summer monsoon - interannual variability of date of monsoon onset and quantum of Indian summer monsoon rainfall, Active – Break cycle of monsoon, Relation between tropical deep Convection and SST (2 P)
- Ocean state and cyclones(1P)
- Role of ocean on climate(2p)

Climate Change and sea level rise: Ocean in relation to long term changes in Monsoon, tropical cyclones and Climate, Land use changes and climate **(2 P)**

Climate services: Climate monitoring, prediction, data management. Climate products and their application in agriculture, water, health and Disaster risk reduction etc.**(2P)**

Mean state of the cryosphere & Biosphere: Role of the cryosphere in the climate, General features of the cryosphere, effect of biota on climate (deforestation) **(2 P)**

Basics of Climate data analysis (3 P)

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Statistics (36 Periods)

Theory (24 Periods)

- Introduction - The purpose of statistics, Population and sample**,** Censuses and surveys**,** Descriptive statistics and inductive statistics**,** applications. Statistical variables - qualitative and quantitative, discrete and continuous variables. (2 P)
- Description of data patterns – center, spread, shape, and gaps & outliers, Histograms and bar charts, difference between bar charts and Histograms, various plots (Dot plots, Stem plots, Box plots, Cumulative plots, Scatterplots), Tabular displays (one -way and two-way tables). (2 P)
- Measures of central tendency – Mean, median, mode quartile, decile, and percentile, Standard Score (z-Score). (2 P)
- Variability - Range, Interquartile Range (IQR), mean deviation, quartile deviation, Sums of squares, Variance, Standard Deviation. (2 P)
- Basic probability concepts – events and event space, random variables, definition of probability, joint and conditional probabilities, odds, expectation, Bayesian theorem (3 P)
- Distributions - Distribution basics, Probability & cumulative probability distributions, Discrete & Continuous distributions – Binomial, Poisson, Gamma, Normal, Standard normal, log normal, Gumbel distribution Student's t, Chi-square, F-distribution etc.(4P)
- Estimation and Hypothesis Testing (2 P)
- Statistical Significance and Confidence Interval. (2 P)
- Time series analysis – basic concepts linear and non-linear trend, Principles of stochastic processes, Auto-correlation theory, Application of Auto-correlation and auto regressive processes, Spectral analysis, Co-spectral methods, Example: Analysis of Intra-seasonal oscillations, Compositing techniques and spatial correlation patterns. (3 P)
- Analysis of variance ANOVA/ MANOVA (2 P)

Practical (12 P)

- Calculating the statistics using the formulations.
- Introduction to Matlab, R-software and Python etc.
- Basic statistical analysis using MS Excel, R-software and Python

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Oceanography and Marine Meteorology

(Total duration = 5 working days = 30 periods of 75 minutes duration)

- **Acquisition and communication of** ocean data (2p)
- Physical properties of sea water, (5 P)
- Atmospheric Boundary Layer over Ocean:-(4 P)
- Oceanic boundary layer: (5P)
- Energy balance at the ocean surface (5P)
- Ocean waves and Swell, their generation and propagation, Tsunamis and Tides in the ocean (2 p)
- Marine Pollution and its impact on Coastal and Marine ecosystem (2P)
- Deep ocean circulation (2 P)
- Marine Meteorology: Marine Meteorological organization. Voluntary observing fleet. Meteorological broadcasts for shipping. Weather warnings issued to posts. Marine climatology. (3 P)

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ENVIRONMENTAL & HYDROMETEOROLOGY

(Total duration = 7 working days = 42 periods of 75 minutes duration)

Environmental Meteorology (30 P)

Chemistry of the Atmosphere-Chemical and photochemical processes, mass-momentum continuity equation, chemical and dynamical lifetime of atmospheric constituent. (2 P)

Ozone in the Stratosphere- Evolution of the ozone layer, Sources and sinks of stratospheric ozone, Chlorofluorocarbons, Ozone and UV-radiations, Impact of Supersonic transport. (2P)

Air Pollution- Type of pollutants, gaseous and particulate pollutants, tropospheric Ozone, its sources and sinks, ozone precursors (NOx, CO, CH4-NMHCs), Particulate Matters (PM10 and PM2.5), Black Carbon and Organic Carbon. Air quality standards and Air Quality Index, Precipitation chemistry, (3 P)

Air quality modelling, Environment Impact Assessment. Mixing length, Ventilation coefficient, and pattern of dispersal of smoke from stationary source under different wind and temperature conditions. (2P)

Aerosol Sources: Natural Sources, Anthropogenic Sources, Gas to particle conversion, Aerosol removal processes, Chemical composition of Aerosols, physical and chemical properties. CCN nuclei, Aerosol transport, distribution and residence time, Aerosol Size Distribution, Aerosol Radiation Characteristics, Rayleigh Scattering, MIE Scattering, Aerosol Radiative Forcing, Aerosol Optical Depth, Single Scattering Albedo, Modelling: The Climatic Effects of Anthropogenic Aerosols, Indirect Effect of Anthropogenic Aerosols (Twomey Effect) (7 P)

- **Micrometeorology** - Definition and generation of microclimates, elements of microclimatology, Urban meteorology (3 P)

- **Emission inventory-** Emission and concentration of pollutants, Various sources of emissions, anthropogenic emissions, bio-mass burning, pollution formation in fossil fuel combustion, bio-fuel, industries, suspended dust, power plants and forest fires. Impact of air pollution on Human health and vegetation. (2 P)
- **Basic ideas on Bioclimatology and Applied Climatology** (2 P)
- **Climate Change**-Global warming, climate trends and prediction, ozone depletion, ozone and health impacts, Greenhouse gas, Ocean acidification (7 P)

Basics of Hydrometeorology: (12 P)

HYDROLOGICAL CYCLE: Understanding the importance of Water and as the subject of observation, Hydrological information systems and its components. Uses of water resources information and types of water resources. (2 P)

OBSERVATIONS: Rainfall observations and units. Design of Network. Framework for network analysis and redesign. Optimum **Density of stations for a network. Different types of Rain gauge: Manual/non recording, recording.** (2 P)

RAINFALL ANALYSIS: Point rainfall, Concept of basin and catchment, major river basins in India. Estimation of point rainfall at ungauged point, generation of grid point data from point rainfall Estimation of average rainfall over basin/geographical areas. (3 P)

HYDROMETEOROLOGICAL DISASTERS: Definition of flood, Types of floods (seasonal, flash, urban). Causes of flood. Droughts, types of drought. Various indices for monitoring drought. Drought monitoring and prediction practices at India Meteorological Department., GLOF, cloudburst, landslides etc. Hydro-meteorological services provided by India Meteorological Department. (3 P)

RAINFALL MONITORING: Rainfall Normal, Rainfall monitoring and Operational Rainfall Statistics. (2 P)

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Aviation Meteorology

(30 periods)

TOPIC	Sub topic	Objective: On completion the trainees should be able to:	No. of periods
1. An overview of Aviation Organisations and their functioning.	1. Definitions 2. WMO, ICAO, CAeM 3. Functioning of IMD's Aeronautical Meteorological Organisation 4. The rights and responsibilities of aviation met offices, the terms and conditions of MoU/ LoA with AAI and other users 5. Meteorological publications of ICAO, DGCA, AAI, and IMD 6. Registers and formats used in Aviation met services 7. Regulatory materials (Annex-3/ CAR/ Codes/ Manual)	List the mandate of the organisations Describe the functioning of MWO, AMO and AMS Describe the role and responsibilities of Aviation Met Forecaster Documents and procedures to be maintained Describe the rights and responsibilities of aviation met offices, the terms and conditions of MoU/ LoA with AAI and other users Describe the various publications, registers and formats their use in aviation met service provision Aviation circulars issued by IMD.	4
2. Effect of Weather on aviation	1. Effect of various atmospheric parameters on different phases of flight operation 2. Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere	Explain the effect of weather elements on aircraft operation Explain Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere Explain the concept of airport minima, low visibility procedures, categories of runways	5

	3. Airport minima, low visibility procedures, categories of runways 4. Special weather phenomenon affecting aircraft operations Mountain waves CAT Icing Atmospheric Obscurity Contrails Microburst Low Level Wind Shear Thunderstorm. Dust storm and Hailstorm 5. Climatology of weather hazards	List the weather hazards and explain its effect on aircraft operation Describe broad features of climatology of hazardous weather for each FIR	
3. observation and reporting of weather for Aviation services	1. METAR code and template 2. Local SPECIAL Criteria 3. Reporting of meteorological elements in METAR/ SPECI 4. Concepts of TREND forecast 5. Prepare a METAR/ SPECIAL message with TREND forecast using the given observations 6. MET Report/ SPECIAL Report Template 7. Examples	Explain the latest METAR code form and Template Explain the SPECIAL criteria Prepare a METAR/ SPECIAL message using the given observations Explain the latest MET Report/ SPECIAL Report template Prepare a MET REPORT/ SPECIAL message using the given observations Issue TREND forecast Verify TREND forecast	5

4. Terminal Aerodrome Forecast (TAF)	1. Description of the TAF code form and Template 2. Forecast of various elements in TAF 3. TAF verification procedures	Explain TAF code and general concepts Prepare TAF using given information/ products/ Charts Verify TAF	4
5. Area/ Local forecast	1. Description of Area/ Local forecast template 2. Verification procedures	Prepare Area/ Local Forecast using given information/ products/ Charts Verify Area/ Local forecast	2
6. Take-off forecast	Description of take-off forecast	Issue take-off forecast Verify take-off forecast	1
7. Route Forecast	1. Instructions on preparation of MET- T3 2. Preparation of a route forecast in MET- T3 form 3. Preparation of a route forecast wind/temperature in chart form from NWP model	a. Prepare the route forecast in MET-T3 format. b. Prepare a route wind/temperature forecast for various levels in chart form from WRF model (IMD web site)	2
8. Warnings	Aerodrome weather summary of an aerodrome (Climatological data base), Aerodrome warning, wind shear warning, SIGMET warning	Familiarise ADWRNG criteria, WSWRNG and SIGMET warning criteria.	2
9. Tools for forecasting &Forecast verification	1. Tools and products available for aviation weather forecasting and their use. 2. Forecast verification procedure	Familiarise (a) the source of information/ products and their use in aviation weather forecasting (b) Explain NWP products, Meteograms, Satellite and DWR products useful for the issue of aviation forecast and warnings	4

		(c) Operationally desirable accuracy of forecast	
10. Competency assessment	WMO competency standards	Familiarise competency assessment requirements and standards	1
11.Astronomical information	Concepts if sun rise, sunset, moon rise and set, phases of the moon Elevation and azimuth angle and their effect on aircraft operations		
12	Analysis of weather related aircrafts accidents/ incidents.		

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Satellite and Radar Meteorology & Met Communication and Information system
(Total duration = 11 working days = 66 periods of 75 minutes duration)

Satellite Meteorology (36 Periods)

(36 Periods)

Theory (22 periods)

- Remote Sensing: Principles of remote sensing, Application in meteorology, Introduction to satellite meteorology, Orbital mechanics. (1 P)
- Meteorological Satellites: Polar, geostationary and low-inclination orbits, Current and future meteorological satellites of the world. Payloads on meteorological satellites, INSAT, Kalpana, Meteosat, GOES, Himawari, FY, NOAA, Metop, MeghaTropiques, Scatsat-1, Oceansat, Exposure to fundamental concepts like resolution, calibration, navigation, registration, NEDT (Noise equivalent differential temperature) (2P)
- Meteorological Data Processing System / Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS): Hardware details, Earth station. (2 P)
- Systems and Techniques: Automatic Weather Station (AWS), DTH-based Digital Cyclone Warning Dissemination System (DCWDS), GPS technique for Integrated Precipitable Water Vapour (IPWV) measurement. (2 P)

- Satellite derived products, SST, CTT, CTP AOD, OLR, AMV and wind derived Products, UTH, Rainfall products (IMSRA &HE), Fog, Snow, Rainfall Products, Concepts of Image Enhancement techniques, and RGB Images from Imager & Normalized Difference of Vegetation Index (NDVI) from CCD etc. and their application in forecasting/ nowcasting ~~of~~ Details features of Real Time Analysis of Product & Information Dissemination (RAPID) web-based tools for satellite Data/products visualization (4 P)
- Basic Principles of Sounding: Processing of data from infrared and microwave sounders. Retrieval of products from sounders, Temperature and humidity profiles and total ozone. Interpretation and use of sounder products (3 P)
- Interpretation of Satellite Images: Characteristics of various channels, Identification of typical clouds and weather systems from cloud imageries, Satellite bulletin and its interpretation. Tropical cyclones, their identification and grading using Dvorak's technique. Interpretation of microwave channel images. Image Enhancement Techniques, Interpretation of Imagery and Products (like RGB) from INSAT/Foreign Satellites, Satellite based tools for nowcasting, Concept of rapid scan images and its use. (4 P)
- Assimilation of satellite data in NWP models. (2 P)
- Use of satellite in very short range forecast to now casting. (2 P)

Practical (14 Periods)

- Study of typical satellite images from both geostationary and polar orbiting satellites, Identification of different types of clouds and weather systems from satellite images, Interpretation of microwave channel images. (3 P)
- Issue of satellite bulletins. (2 P)
- Assessment of T-number of tropical cyclone from satellite images using Dvorak's technique. (6 P)
- Use of satellite-derived products for weather analysis and forecasting. (3 P)

Applied Radar Meteorology (18 Periods)

- Basics of radar Meteorology:
  Electromagnetic waves, Atmospheric interactions (Attenuation, Scattering, Refraction/Reflection). Importance of using microwave frequencies for remote sensing. Microwave devices commonly used.
- Introduction to Weather radars
  Different frequency bands used in the weather radars and their applications. Principles of pulsed radar, Polarimetric radars, Phased array radars, etc.

- Definitions of

  Beam width, Pulse width, PRF, Antenna gain, back scattering cross section, Reflectivity factor (η) and radar reflectivity factor (Z), Doppler shift.
- Principle of Doppler Weather Radar

  Block diagram of Doppler Weather radar and explanation of its major components, Doppler radar moments, Doppler Dilemma, velocity unfolding techniques with examples. Range unfolding concepts. Radar equation for a point/hard target and for volume distributed/soft target (derivation) and discussion on the range contrast with those; Interpretation of RADAR echoes; RADAR depiction of various phenomenon; radar estimation of precipitation; identification of convective and startiform precipitation, melting band.
- Limitations and artifacts of Weather Radar, Common misconception/errors in radar products/data (viz. Anomalous propagation/ducting, non-Rayleigh targets, resolution and partially filled scanned volume, beam blocking/shielding, non-meteorological targets, beam geometry, shorter wave rain attenuation, bright band, evaporation, multiple reflections, transmit to receive polarization change).
- DWR network in India. DWR Operational Scan strategies. IMD Standards.
- DWR products

  Introduction to DWR Base products – PPI, RHI, CAPPI, MAX, ETOP, EBASE, VCUT. Need for presentation methods and uses.
- Derived Products

1. Hydrological Products (SRI, PAC, VIL, PRT, Catchment etc.) - The basic algorithms employed, limitations of the algorithms.
2. Wind Products (VAD, VVP, UWT, Shear, etc.)- The basic algorithms employed, limitations of the algorithms.
3. Severe weather/Nowcast Products (Thunder Storm Warning, Hail Warning and quantification, Tornado Vortex signature, Severe Weather Index, Gust Front detection, Squall warning, Forecast-Track Product) - The basic algorithms employed, limitations of the algorithms.

- Analysis of severe weather events (thunderstorms, hailstorms, line squall, heavy rainfall prediction, aviation safety and tropical cyclones) recorded by DWR and development of the nowcasting technique for their prediction.

  Application of DWR data in NWP for nowcasting and forecasting. Introduction to Some models like SWIRLS, WDSSII, ARPS, DELHI PP etc

  Signal Processing techniques and QC.

  DWR Data formats. Proprietary and Open-source formats. Tools available in open domain for analysis. Installation and data handling/product generation and analysis Hands-on

DWR Meta data and data flow path - Concept of DWR Central Server, the need, compliance as to Climate Data Base Management System of WMO. DDGM(UI) Web server.

Calibration of DWR (Transmitter, Receiver)- Antenna Positioning tests- Radar Product Validation methods. DWR Maintenance.

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Basics of Meteorological Communication and Information systems (12 P)

- Importance of Met. Telecommunication, Overview of National & International Meteorological Telecom. Setup, GTS, RTH New Delhi (AMSS, CIPS, SYNERGY, PWS, CLISYS), VSAT, SADIS etc.
- Introduction to WIS (GISC, DCPC, NC, Meta data).
- Introduction to LAN, MAN, WAN, Ethernet &Fiber Optic cable, communication protocol, TCP / IP, VPN, etc.
- Introduction to communication devices like MODEM (wireless/ wireline), SWITCH, HUB, ROUTER, etc.

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GIS (12 P)

UNIT I FUNDAMENTALS OF CARTOGRAPHY &GIS: (2 P)

Definition of Map- Classification based on function, scale, characteristics; Ellipsoid &GeiodCoordinate systems: Projections- Functions- types of Map projections; Evolution of cartography- Geo-spatial, spatial & non spatial data- Introduction to GIS, Basic spatial concepts; Evolution of GIS, and Components of GIS.

UNIT II GIS DATA MODELS AND DATA STRUCTURES:(2 P)

Point, Line, Polygon/ Area, elevation and surface- Tessellations- Attributes & levels of measurements, Data sources- Database structures- Entities-; Data Model-Conceptual, logical, physical; Map scanning & digitization, Registration and Geo-referencing- raster data Model- Grid- Vector Data Model-topological properties; raster Vs Vector Comparison- File formats for raster and vector; Data conversions.

UNIT III RASTER & VECTOR DATA ANALYSIS: (2 P)

Raster data analysis: Local, neighbourhood and regional operations- Map Algebra- Vector data analysis: Topological Analysis, point-in-polygon, line-in-polygon, polygon-in-polygon- proximity

analysis: buffering, thiessen polygon- non topological analysis: attribute data analysis. Surface analysis- slope, hill shade, contour, DEM, DTM- point data to surface interpolation; Network analysis- creating data network, shortest path analysis: Understanding spatial analysis- operators and functions.

UNIT IV ADVANCED GIS: (2 P)

Web based GIS: Definition, Merits, Map server- Architecture- Spatial Data infrastructure: terrain and watershed concepts; Vector data handling – overlay, dissolve, clip, union, intersect operations, Site suitability analysis. Handing multilayered datasets using SQLite; GPS data integration: Concepts of RDBMS; PostgrSQL with PostGIS.

UNIT V INTRODUCTION TO OPEN SOURCE GIS SOFTWARES & HANDS ON LABORATORY EXCERCISES :(4 P)

Introduction to QGIS &GRASS, GDAL environments - installation of supported plugins - data handling capabilities

1) Geo referencing & spatial rectification of digital map.
2) Projection & re-projection of spatial data.
3) Data conversions – vector to raster, raster to Vector, netcdf to raster
4) Populate attribute database and querying on attribute data
5) Vector Analysis- Buffering, Overlay & network analyses, etc (site suitability example, identification of suitable locations for AWS)
6) Raster Analysis- measurements, arithmetic & logical overlaying, and choropleth maps, etc
7) Handling multiple vector and raster datasets
8) Generation of DEM: from contours, spot heights and watershed analysis
9) Map outputs, Map compilation, 3D visualization
10) Interpolation of spatial datasets: Weighted theisson polygon, etc

Demonstrate MeteoInfo open source suite to view and analyse meteorological and spatial data.

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DATABASE MANAGEMENT SYSTEM

Total Duration = 18 Periods of 75 minutes

S. No.	Name of Topic	Course content
1.	**Introduction (1P)**	An overview of database management system – History, Purpose of database system, database system vs file system, Database system concept and architecture, data model schema and instances, database

		language and interfaces, advantages and disadvantages of database system.
2.	**Basic concepts of DBMS (1P)**	Introduction and applications of DBMS, Purpose of data base, Data Independence, Database System architecture- levels, Mappings, data definitions language, DML, Overall Database Structure, Database users and DBA
3.	**Relational Model(1P)**	Structure of relational databases, Domains, Relations, Relational algebra–fundamental operators & syntax, relational algebra queries
4.	**Entity-Relationship model (2P)**	Basic concepts, Design process, constraints, Keys, Design issues, E-R diagrams, weak entity sets, extended E-R features -generalization, specialization, aggregation, reduction to E-R database schema
5.	**Relational Database design(2P)**	Functional Dependency – definition, trivial and non-trivial FD, closure of FD set, closure of attributes, irreducible set of FD, Normalization, Decomposition using FD- dependency preservation, Multi-valued dependency, Join dependency.
6.	**Query Processing & Query Optimization(2P)**	Overview, measures of query cost, selection operation, sorting, join, evaluation of expressions, transformation of relational expressions, estimating statistics of expression results, evaluation plans, materialized views
7.	**Transaction Processing Concept (2P)**	Transaction concepts, properties of transactions, serializability of transactions, testing for serializability, System recovery, Two- Phase Commit protocol, Recovery and Atomicity, Log-based recovery, concurrent executions of transactions and related problems, Locking mechanism, solution to concurrency related problems, deadlock, two-phase locking protocol.
8.	**Distributed Database (1P)**	Distributed data storage, concurrency control, directory system.
9.	**Security (1P)**	Introduction, Discretionary access control, Mandatory Access Control, Data Encryption
10.	**SQL Concepts (3P)**	Basics of SQL, DDL, DML, DCL, structure – creation, alteration, defining constraints – Primary key, foreign key, unique, not null, check, IN operator, aggregate functions, Built-in functions–numeric, date, string functions, set operations, sub-queries, correlated sub-

		queries, join, Exist, Any, All , view and its types., transaction control commands
11.	**PL/SQL Concepts (2P)**	Cursors, Stored Procedures, Stored Function, Database Triggers
		Database Management of meteorological data Basics of Quality Control of Meteorological data

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Appendix-II

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Advanced Meteorological Training Course

(12 months duration)

Semester-II (6 months duration)

2019

Content

& 1 working week = 5 working days
 # 1 working day = 6 periods of 75 minutes

Subject	Duration	Place
Geophysical fluid dynamics.	10working days*	MTI
Advanced Physical Meteorology.	10 working days	MTI
Advanced weather analysis & forecasting.	9 working days	MTI
Advanced Aviation Meteorology	5 working days	MTI
Climate Science.	10 working days	MTI
Physical Oceanography & Ocean-Atmosphere interaction.	7 working days	Faculties from INCOIS, NIOT and IITM are to be invited at MTI.
Numerical weather Prediction.	20 working days	MTI,IITM or NWP division of HQ & NCMRWF
Advanced Statistics	4 working days	MTI, IITM
Computer Programming & application.	5 working days	MTI ,IITM, C-DAC
Hydro Meteorology	5 working days	MTI
On the Job training	2 working weeks	MTI or other Institutes of MoES.
Mid-term& final exam+Viva-voce+Projectpresentation+Relief+ CH	4 working weeks	MTI
Total	85 working days+6 working weeks = 17working weeks+6 working weeks=23 working weeks	

Geophysical fluid dynamics: -

(Total durations =10 working days =60 periods of 75 minutes duration)

Quasi-geostrophic theory (6 P):

Quasi-geostrophic approximations, Beta-plane approximation. Governing equations in isobaric co-ordinates using quasi-geostrophic approximation. Quasi-geostrophic vorticity equation: Thermodynamic energy equation, Geopotential tendency (χ) equation: Conservation of quasi-geostrophic potential vorticity. Diagnostic ω (omega) equation (With and without diabetic heating term)

Advanced Planetary Boundary Layer (15 p)

- Derivations of governing equations for mean motion in PBL.
- K-Theory/ Flux-gradient theory/ Similarity theory. Its limitation. Mixing length theory.
- Derivation of logarithmic vertical profile of horizontal wind in viscous sub layer using similarity theory. Concept of roughness length and Von-Karman constant.
- Ekman layer: Derivation of vertical profile of mean horizontal wind in atmospheric/ oceanic Ekman layer. Derivation of depth of Ekman layer. Concept of Ekman layer pumping. Secondary circulation. Spin down. Derivation of the Relation between mass transport in oceanic Ekman layer and surface wind stress. A dynamical explanation for El-Nino and La-Nino. Convective boundary layer (CBL) or well mixed boundary layer. The turbulent kinetic energy equation. Physical interpretation, in detail, of the Buoyancy production or loss (BPL) term and mechanical production (MP) term in association with convective and mechanical turbulence, concept of Flux Richardson number. Monin-Obukhov theory and Kolmogorov theory.

Atmospheric waves and instabilities (12 P)

- **Perturbation Theory-**Why perturbation method has been proposed? Hypothesis in Perturbation method. To show that perturbation method can remove non- linearity from governing equation.
- **Atmospheric waves - Basic concepts:** Wave number, Frequency, Phase speed and group velocity. Sound wave, Rossby wave, Gravity wave (external, internal and inertia), simple inertia wave, Kelvin wave, Mixed Rossby Gravity wave- dispersion relation and physical interpretation. Eliassen-Palm flux and its conservation law.
- **Dynamics of stratified fluids (5P):** Concepts of stratification, Static stability, The importance of stratification: The Froud number, Boussinesq approximation,
- **Hydrodynamic instability (10 P):** General definition of Hydrodynamic instability. Classification of Hydrodynamic instabilities. Static instability: Derivation of the criterion for Brunt-Vaisalla instability. Dynamic instabilities: Inertial instability, barotropic instability and baroclinic instability. Derivation of the criteria for above instabilities. Energetics and mechanism of above instabilities. WISHE

Atmospheric energetics (7 P)

- **Fundamentals of atmospheric energetics:** Energetics aspects of General circulation- Definition of Atmospheric energetics. Different form of atmospheric energies, viz., internal energy, potential energy and kinetic energy. Derivation of global internal energy, global potential energy and global kinetic energy equation. Detailed physical interpretations of generation of potential energy, internal energy and its conversion into kinetic energy. Detailed physical interpretation for generation mechanism of global kinetic energy, its conversion into potential and internal energy and the dissipation of kinetic energy. Belt of sub-tropical anticyclone, the source region for global kinetic energy. Global energy equation. Dynamical explanation for the Sun to be source of atmospheric energy. Equivalence of internal and potential energy in a stably stratified hydrostatic atmosphere. Physical explanation for the proportionality of I.E and P.E in hydrostatic and stably stratified atmosphere. Introduction to total potential energy (TPE), derivation of its expression. Concept of available potential energy (APE) and the derivation of the expression for it. Qualitative comparison of APE in a region based on day-to-day charts. Concept of zonal APE, KE, PE and eddy APE, KE, PE.
- **Angular momentum budget of atmosphere (5 P)-** Global angular momentum balance equation. Interpretation of mountain torque, frictional torque and meridional transport of zonal angular momentum. Different mechanisms for meridional transport of zonal angular momentum. Concept of Hadley and Walker circulations.

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Advanced Physical Meteorology

(Total Duration = 10 working days=60 Periods of 75 minutes)

Theory (Duration = 50 Periods)

- Atmospheric Electricity: Ions in the atmosphere (sources and sinks), Conductivity and its measurements, Basic concepts regarding fair weather electric field and its measurements. Air-earth current (Conduction currents and Maxwell Currents) and its measurements, Space Charge in the atmosphere, Global Electric Circuit and its maintenance. Electrical Structure of thunderstorms. Lightning (CG and Cloud discharges) mechanisms, Upward discharges (Sprites, Blue Jets, Blue Starters, Elves). Thunderstorm electrification mechanisms. Global Electric Circuit. The concepts of lightning arrestors and lightning detectors (10 P)
- Upper Atmosphere and Ozone: Different techniques of exploration of upper atmosphere; thermal structure of troposphere, stratosphere, mesosphere and thermosphere and their physical explanation, QBO and stratospheric warming; Tropospheric Ozone: Chemical Properties of Ozone, Units of Measurements, Formation of Tropospheric Ozone, Health Effects. Stratospheric Ozone: Formation of

Ozone in Stratosphere, Stratospheric Ozone Depletion, Antarctic Ozone Hole, Impacts of UV Radiation, Stratospheric Ozone Depletion over the Arctic, Control Strategies and International Treaties, ozone temporal and spatial variations of Ozone; measurements of total ozone; Umkher effect. Ozone hole, CFC and related concepts. (10 P)

- Cloud Physics and Weather Modification : Homogeneous Nucleation, Atmospheric aerosols and condensation nuclei, , Heterogeneous Nucleation (curvature and solute effects), Kohler Curves, growth of cloud droplets by diffusion and by collision and coalescence; growth and initiation of precipitation in non-freezing clouds. ; ice nucleation, Formation mechanisms of graupel, hail and snow, Bergeron-Findeisen mechanism of growth of precipitation. , Weather Modification (Hail Suppression and precipitation enhancement) experiments, . Simple cloud models. Analysis of available observations related to Cloud Physics: Surface, airborne and satellite (like MODIS), Field campaign like CAIPEX (18 P)
- Concept of mixing height, ventilation coefficient, pollution potential, plume dispersion, wind roses and their importance, air mass trajectory (2 P)
- Advanced concept of Air pollution; Atmospheric Pollution, type of pollutants, gaseous and particulate pollutants, size of atmospheric particles, emission inventory, various sources of emissions, bio-mass burning, bio-geochemical cycles, pollution formation in combustion, Industrial pollution. Acid rain, smog and impact of air pollution on human health and structures. Indoor pollution. Structure of urban boundary layer. Air quality monitoring & forecasting. Air quality index. Transport model in ABL for dispersion of aerosol/air pollutants. (10 P)

Practicals (10 P)

- Ventilation co-efficient.
- Study of surface wind data at a station.
- Computation for preparing wind roses
- Graphical preparation of typical wind roses
- Running Transport model
- Air mass back trajectory calculation
- Dust concentration estimation using Dream Dust Model

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Physical Oceanography & Ocean – Atmosphere Interaction

(Duration = 7 working days= 42 Periods of 75 minutes)

- **Physical properties of seawater and upper ocean vertical structure:** Temperature, salinity, density, mixed layer, isothermal layer, barrier layer, thermal inversion-diurnal warm layer-cool skin-stability-

vertical mixing-mixing in Ocean-Richardson Number-Kelvin Helmholtz instability Richardson number- Double Diffusion and Salt Fingers. Vertical structure of other properties-light, sounds, nutrients, oxygen and chlorophyll. **(8 P)**

- **The significance of Ocean-Atmospheric Interactions. Concept of a system (Ocean/Atmosphere). Ocean-Atmosphere boundary layers:** Concept of Boundary Layer formation; Atmospheric Boundary Layer, Oceanic Boundary Layer, structure and Evolution, Water(SST) Temperature, Air Temperature, Moisture and wind profile Evolution. Air sea temperature differences. Fresh water flux - Salinity variation in the vertical - Barrier layer. Turbulence, characteristics of Boundary Layer Spectrum. Integral scales of Eddies, K-theory /Taylor micro scale, Kolmogorov scale and Larger Scale, and Monin- Obukhov Similarity theory. **(9 P)**
- **Mixed layer heat and salt budget:** radiative and turbulent heat fluxes-mixed layer heat-salt budget equation. **(4 P)**
- **Introduction to dynamics:** Forces and equation of motion-conservation of mass-continuity equation-divergence-convergence-vertical velocity-conservation salt-residence Time-Scaling of equation-Rossby Number-Ekman Number. **(4 P)**
- **Currents without friction:** Geostrophic balance, inertial balance, cyclostropic Balance-Thermal wind balance-level of no motion-dynamic topogrphy-Barotorpic and Baroclinic circulation-geostrophic velocity-geostrophic velocity at equator-preliminary concept of barotropic and baroclinic instabilities-hydrostatic approximation-f-plane and beta-plane approximation-Boussinesq approximation-incompressibility. **(6 P)**
- **Currents with friction:** Ekman Dynamics-Ekman Spiral-Ekman Transport-Ekman Pumping-Coastal wind driven upwelling-open ocean upwelling-equatorial upwelling. **(5 P)**
- **General Ocean circulation:** Seasonal variability of Indian Ocean circulation. Sverdrup balance-westward Intensification-Introduction to equatorial Kelvin wave-coastal Kelvin wave-Rossby wave-preliminary information of delayed oscillator mechanism (ENSO and IOD). **(6 P)**

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Numerical Weather Prediction (Theory)

(Total duration = 20 working days = 120 period of 75 minutes)

Theory (65 periods)

- **Numerical Methods (10 P):** Different methods for solving model equations: Initial and boundary conditions, Finite difference method: space and time differencing technique, truncation errors, and Implicit & semi implicit scheme. Numerical stability criterion (CFL), Discrimination technique used for basic governing equations, Spectral method, Spectral representation, spectral co-efficient, spectral

transform, Triangular and Rhomboidal truncation. Finite Element techniques, special discretization on icosahedral-hexagons, etc

- **Dynamical models (5 P):** Non-divergent barotropic model, Prediction of geopotential using this model. Equivalent Barotropic model, Derivation, Determination of Equivalent level. Two-layer baroclinic model, Prediction of mean and thermal vorticity using this model. Introduction to sigma and eta coordinate. Primitive equation model in vertical coordinates. Unified model for seamless prediction, Earth System Model
- **Parameterization of physical processes (12 P):** Dry and moist adiabatic adjustment, saturation point (LCL). Cumulus parameterization schemes. Surface forcing, shallow and deep convection, verification methods for convection schemes. Parameterization of PBL. Radiation. Principle of radiative transfer. Gravity wave drag and its parameterisation Biosphere and Land surface processes. Parameterisation of air-sea interaction processes, Cloud microphysical parameterization
- **Data Assimilation (20 P):** Introduction, philosophy and principle of data assimilation for NWP, Different objective analysis schemes, Cressman techniques, OI scheme (Optimum interpolation). Different formats of data and their inter-changeability. Decoding and quality control of GTS conventional/non-conventional observations, Doppler data, processing of non-GTS (satellite radiance) observations, Ensemble data Assimilation technique, Regional data assimilation system: variational data assimilation, 3D & 4 D variational data assimilation technique (WRF, GFS Var), balance in initial condition, estimation theory, introduction to Kalman filtering, Processing Doppler Radar Data for quality control and mesoscale data assimilation. Oceanic data assimilation: data assimilation at mesoscale, assimilation of altimetry data. Initialization: Static Dynamic, Normal mode, Dynamic normal mode & Physical, Nudging, Synthetic data generation/vortex initialization. Ensemble Data Assimilation techniques, Hybrid Data Assimilation, Storm-scale Data Assimilation, Observation System Simulation Experiment (OSSE), Radiance Assimilation, Reanalysis and Reforecast.

  Operational Numerical Models (10 P): Operational NWP modelling system: Global Forecast System (GFS and UM), Regional and mesoscale forecast system (WRF, ARPS), Nowcast model, Couple Model (Climate Forecast system,ERPS), Ensemble prediction system, multi-model ensemble technique, Cyclone model Hurricane WRF, vortex relocation and initialization, Antarctica model Polar WRF, Air quality model WRF (Chem), Storm Surge modelling, Ocean State modelling, Coupled forecasts of tropical cyclones (Time slot may be decided as per availability)1) Introduction to coupled forecasts of tropical cyclone including theory 2) Ocean Atmosphere coupled processes associated with cyclogenesis 3) State of the art models used in major forecasting centers.

- **NWP Products (8 P):** Different products: Direct and Derived, Post processing of model output: Model output verification: Verification methods for short & medium range forecast. Forecast skills, Forecast errors, Systematic errors. Down scale of NWP model like location specific forecast, NWP products for aviation services, hydrological services, agro-meteorological services, NWP products for localised severe weather, monsoon rainfall prediction, prediction of Western disturbances. NWP based objective cyclone forecast system, NWP based location specific forecast, GIS application for NWP, NWP products in Web, NWP Data Management, Meteograms, Probabilistic forecast from EPS.Products from GFS, CFS, GEFS and coupled model. HYSPLIT (forward and backward trajectory). NWP products from other global/regional forecasting centres.

Practical (55 Periods)

- Simple programmes on Cressman technique, Statistical Interpolation. Initialization of numerical models Applications of an operational variational assimilation scheme in numerical weather prediction (shallow water model). Radar & Satellite Data assimilation, Fog forecasting (onset, duration and dissipation). SkewT-LogP computerized plots and analyses. (15 P).
- Linux O.S, script writing, an introduction to High Performance Computing System, Pre-processing of observations, Configuration of WRF model with GFS, Experiment with nesting and nest down techniques, WRF data assimilation, data sensitivity experiments, sensitivity experiments for physical parameterization. (15 P).
- Model diagnosis: Graphics package for illustration of NWP products, Case study of monsoon depression, cyclonic storm, localised severe weather with the use of derived products like divergent, vorticity, flow pattern, SkewT-LogPdiagram, precipitable water content, vertically integrated moisture flux, rainfall etc. Use of model verification tool MET. Model outputs verification tools/ post-processing: Exercises based on the Verification packages such as MET, MODE, R, etc. Visualization of model outputs based on graphic packages such as VAPOR, NCL and RIP, MATLAB. (15 P).
- Experiments with nowcast tool, one-dimension column model, storm scale NWP model ARPS, Cyclone prediction, storm surge prediction. Case studies with Radar & Satellite Data assimilation, Fog forecasting (onset, duration and dissipation). (10 P).
- Hands on with coupled forecasts setups using both OM/HYCOM. Demonstration using test cases to show the improvements of coupled forecasts in comparison with un-coupled forecasts.

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Advanced Weather analysis & forecasting

(Duration = 10 working days= 60 Periods of 75 Minutes)

Theory (36 Periods)

- **Impact based weather services:**
- **Some basic concepts in impact-based forecast and warning services:** Basic concepts of Hazards, forecast uncertainty, exposure, Vulnerability, risk and Risk matrix. Basic concepts of the different Paradigms in operational Weather services: Weather forecast & Warning, Impact based forecast & warning and Impact forecast & warning.
- **Evolving towards impact forecasting:** What is an Impact-based Forecast and Warning service? Steps for Implementing Impact-based Forecast and Warning Services- Development of the Risk Matrix, Identification of weather events and hazards, Assessment of Vulnerability of identified hazards, development of impact table, Development of Advisory table. Key elements of an impact-based forecast and warning service. Benefits of impact-based forecast & warning services.
- Very Short Range (up to 24 hours) forecasting using mesoscale models – their use in aviation and general forecasting.
- Short Range (1 to 3 days) forecasting using regional and global models.
- Numerical model downscaling techniques
- Model Output Statistics (MOS) and their use in Short Range (1-3 days) forecasting of weather elements
- Techniques for forecast verification – skill scores for circulation characteristics and magnitude (intensity) of weather elements.
- Quantitative Precipitation Forecasting in the different seasons and in situations with (a) monsoon depressions (b) tropical cyclone (c) western disturbance (d) active monsoon

a. Numerical Model Forecast outputs routinely available on the World Wide Web – Indian model output products available on the web – near real time atmospheric and oceanic data (analyzed and in maps or as grid point data) routinely available on the web. Interpretation of NWP models analysis and predictions.

- Human intervention in model output forecasts before dissemination as forecasts and warnings to users
- Medium, Extended and Long range NWP forecast outputs – Ensemble, Super Ensemble and Multi Model Ensemble forecasts
- Probabilistic forecast, extreme weather forecast and (Ensemble Prediction system) EPS grams.
- Interpretation of EPS grams

PRACTICALS (24 Periods)

- Exercises using reanalysed global data and GrADS and other available software
- 850 and 200 hPa winds and jet streams of Jan, Apr, Jul and Oct (JAJO)

- Hadley circulation using mean meridional winds 0E-180E and 180E-0E (JAJO)
- Walker circulation using mean zonal winds 05S-05N
- 850 and 200 hPa Stream function of Jan-April-July-Oct (JAJ0)
- 850 and 200 hPa Velocity Potential of JAJO
- Vertical velocity at 500 hPa of JAJO
- Vorticity/divergence at 850/700 hPa levels
- Construction of air parcel trajectory using 06 hourly reanalyzed / forecast wind data
- Exercises using grid point data sets and GrADS software
- Sea Surface Temperature JAJO
- GPI rainfall rate JAJO
- Outgoing Longwave Radiation JAJO
- Vertically Integrated Moisture (TMI) JAJO
- Quick Scat winds JAJO of tropics
- Extrapolation using Doppler Radar and Satellite Pixel data for Nowcasting weather (1 to 3-hour forecasting)
- Use of Meso-scale model outputs for short range prediction of weather elements (1 to 24-hour forecasting)
- Use of Regional and Global model outputs (1-5 days forecasting) for four seasons.
- Impact-Based Forecasting Hands on exercises: Preparation of warnings, Developing impact tables, Vulnerability assessments. Impact based forecast and warning.

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Advanced Aviation Meteorology

Total duration = 30 Periods of 75 minutes

TOPIC	**Sub topic**	**Objective: On completion the trainees should be able to:**	**No. of periods**
13. SIGMET	1. Template for SIGMET	Explain the SIGMET template Issue SIGMET from the given information Verify SIGMET Explain SIGMET Test procedures	5
	2. Elements of SIGMET		
	3. Types of SIGMET		
	4. Issue of SIGMET		
	5. Verification of SIGMET		
	6. SIGMET Test procedures		

14. Aerodrome warning, Warning for light aircrafts and Wind shear warning	1. Responsibility of AMO and AMS in issuing warnings 2. Warning elements and Warning format/ Template 3. Issue Aerodrome warnings 4. Verification of aerodrome warnings 5. Issue wind shear warning	Explain the responsibilities of AMO and AMS in relation to issuance of warnings List the warning elements Explain the format of the warnings Issue Aerodrome warnings Issue wind shear warning Verify the warnings	4
15. Tropical Cyclone Advisory Centre and Volcanic Ash Advisory Centre	1. Responsibility of TCAC and VAAC 2. Template of TCAC advisory with example 3. Template of VAAC Advisory with example	List the responsibilities of TCAC and VAAC Explain the templates of TCAC advisory and VAAC advisory and explain given advisories. Use the advisories in SIGMET preparation	3
16. World Area Forecast Centre (WAFC) Products	1. Objectives and responsibilities of WAFS 2. WAFC products: Specifications and their validity. 3. Weather symbols used in SIGWX charts 4. Reception of products and data formats	List the WAFC products available Describe a given SIGWX chart. Use WAFC products in briefing	2
17.Briefing and documentation including case study exercise	1. List of documents to be provided 2. List of items to be displayed in met offices 3. Briefing of low level flights	List the items to be provided in documentation List the items to be displayed in an aviation met office	5

	4. Online Briefing System (OLBS) of IMD	To retrieve the products from OLBS or other sources and prepare briefing folder for scheduled flights. To upload messages/ forecasts/ warnings on OLBS Prepare a briefing folder for flights covering various levels.	

18.Aeronautical Telecommunication Network (ATN)	1. Basics about aeronautical telecommunication net work	Explain the aviation telecommunication network AMSS and SADIS Describe the filing time and transit time and priority of aviation met messages Explain ROBEX scheme Explain method to identify the errors in the messages and rectify and resubmit them Explain VOLMET and other meteorological broadcasts	2
	2. AMSS and SADIS		
	3. Filing time, transit time and priority of various aviation meteorological messages		
	4. Basic concept of OPMET and ROBEX scheme		
	5. Monitoring of data transmission and rectification of errors of the messages in error queue in AMSS.		
	6. Basics of VOLMET broadcast and other meteorological broadcasts		
19. Accident Investigation	1. Introduction	Explain the procedures to be followed by various offices	2
	2. Responsibilities of AMS/ AMO in accident investigation		
	3. Responsibilities of RMC		
	4. Preparation of Reports		
20. VIP/VVIP movement	1. Basic procedure to be followed during VIP/ VVIP Flights	Explain the procedures to be followed by various offices	1
	1. Basic functions, siting and use of airport meteorological system	1. List and Describe the components of airport Met. instruments system	1
	2. Reporting of manual RVR	2. To narrate the procedures of assessing RVR manually	1
	3. NOTAM Procedure	3. Explain NOTAM procedure	1

21.Airport Meteorological Instruments			
22. Competency standards & safety audit	1. Competency requirements 2. Competency standards 3. Safety oversight audit	(a) Explain the WMO competency requirements (b) Familiarise competency assessment standards (c) ICAO Universal Safety Oversight Audit Programme (USOAP) requirements (d) DGCA safety audit & Action Taken Report requirements	3
	Operational ceilings of various aircraft and their performance limitations (wherever applicable)		
Space Weather	Concept of space weather and its effect on aviation		
	Aerodrome Climatology preparation		
	Visibility land mark-Polar diagram		
Total classes			**30**

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Climate Science

(Total duration = 60 periods of 75 minutes)

- Global Climates in brief **(4 P)**
  Asia, Africa, North America, South America, Europe, Australia, Arctic and Antarctic.
- Angular momentum cycle **(4 P)**
- Water Cycle **(4 P)**
- Energetics and the Ocean-Atmosphere Heat Engine **(4 P)**
- Variability in the climate system **(12 P)**

- Monsoon (southwest and northeast) Variability, diurnal, intraseasonal, Interannual, inter-decadal, long term trends from observations, Teleconnection patterns, Walker circulation, tropical –extratropical interaction (5 P)
- El Nino/ Southern Oscillation, Climatology, Dynamics and prediction, links with global climate, Madden Julian Oscillations, Coupling of Ocean and Atmosphere in ENSO – Indian Ocean Dipole– Relation between ENSO.IOD and Indian monsoon, Indian Ocean Dipole, statistics, dynamics and links with global climate., Feedback process between different forcings (5P)
- North Atlantic Oscillation, Arctic Oscillation, North Pacific Oscillations, PDO, NH Teleconnection Patterns (2P)

- Climate modelling and prediction: Climate models – a brief review, Constructing a Climate Model, An atmospheric model, an ocean model and ocean - atmosphere coupling, Climate simulations and climate drift, Evaluations of climate model simulations for Indian monsoon, , Extended and long range prediction-: Scope and different methods, statistical and dynamical approaches for long range forecasting, types of forecasts and verifications, standard verification methods, Communication of uncertainty in the forecasts, , Operational long range forecasting system in India– history and status, **(12 P)**
- Science of Climate Change: Basics of global climate and Climate Change, Climate Feedbacks -water vapour, cloud, oceans, snow and ice, Greenhouse gases, aerosols and other climate forcings, Observed climate change over India and globe - Ice, sea level, extreme events, Future climate projections, Discussion on IPCC report **(10 P)**
- Paleo-climatology **(4 P)**
- Hands-on training on analyses of observed climate data products (IMD gridded data, GPCP, CMAP, APHRODITE, ISCCP etc.) reanalysis (NCEP, ERA, MEERA, JMA etc), satellite data and climate model outputs (eg. CMIP5 data) using packages like GrADS, ferret, CDO etc. Interpretation of climate prediction and projection. **(6 P)**

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Hydro-Meteorology

(Total duration = 5 working days = 30 periods of 75 minutes)

RAINFALL ANALYSIS: Statistical Series different types of series in rainfall analysis. Probability distributions used in Hydrology: Normal, lognormal, Gamma, Gumbel etc. Extreme value analysis. Return periods. Rainfall intensity or depth–duration–frequency relationships. Mass rainfall curves. Depth–area–duration analysis. Probable maximum precipitation. Design storm. Estimation of Design Storm: Rainstorm, Estimation of Standard Project Storm. Standard project flood. (10 P).

GEOGRAPHICAL INFORMATION SYSTEMS IN RAINFALL ANALYSIS: Use of QGIS (open source GIS) in hydrological application (with practical). (6 P)

RAINFALL RUNOFF RELATIONS: Infiltration, infiltration capacity. Rainfall Runoff Models, Hydrograph and Unit Hydrograph. (2 P)

QUANTITATIVE PRECIPITATION FORECAST: Various methods of Quantitative Precipitation Forecast. Dynamical statistical technique, Synoptic Analog, Use of NWP outputs Rain-producing Weather Systems, Analysis of Real-time weather charts for rainfall forecasting, (2 P)

QUANTITATIVE PRECIPITATION ESTIMATE: Precipitation estimates from satellite and radar. Delineation of flood inundation from remote sensing satellite. Estimation of extreme rainfall, Flood forecast using hydrological models

Flash flood estimation and warning (6 P).

RAINFALL ANALYSIS FOR UNDERSTANING CLIMATE CHANGE AND VARIABILITY: Rainfall analysis for understanding climate variability and trends, of mean rainfall, extreme rainfall and intensities (intra seasonal, annual to decadal) (2 P)

SNOW HYDROLOGY: Observations, types of snow. Variation in characteristics of Snow (size, shapes of snow crystals, density) with age, estimation of snow cover from satellite imageries, Snow Melt Model (degree day method). (2 P)

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Advanced Statistics

(Total duration = 4 working days = 24 Periods of 75 minutes)

- Multivariate Regression Analysis including stepwise regression (2 P)
- Cluster and Factor Analysis (2 p)
- Principal Component Analysis/ Empirical Orthogonal Functions (2 P)
- Matrix concepts (2 P)
- Canonical Correlation Analysis (3 P)
- Discriminant Analysis, Log Linear Analysis (3 P)
- Advanced Time series Analysis & filters (3 P)
- Artificial Neural Network, weather Generators (2 P)
- Self Organizing Maps (1P)
- Principal component regression, spectrum analysis, Ensemble Empirical Mode Decomposition (EEMD) technique and intrinsic Mode functions (IMF). (4 P)

(1) Statistical Forecasting

Linear and Multiple Regression, Analysis of Variance, Goodness-of-fit measures

(2) Forecast Verification:

Contingency Tables, Brier Score, Reliability diagram, ROC diagram, Anomaly correlation

(3). Extreme Value Analysis (EVA) of Weather and Climate Data.

Distributions (EVD) for extremes (GEV, GP) Weibull (for Temperature, Wind Speed and Sea level), Gumbel, Freshet (Precipitation, Stream Flow, Economic Impact), Peaks Over Threshold (POT), Block Maxima (BM), Return Levels and Return Periods

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Computer Programming and applications

(Duration = 5 working days=30 Periods of 75 minutes duration)

Theory (16 P)

- HPC architecture-(1 P)
- Basics of MPI programming (2 P)
- Different data formats (ASCII, Binary, HDF, HDF-EOS, NetCDF, NetCDF4, GRIB, GRIB2 and its Conversions) (1 P)
- Basic Concepts of Parallel processing paradigms and parallel program execution (2 P)
- Fortran-90 Programming (2 P)
- Additional features in Fortran 90 and features in C, C+ & C++. (4 P)
- MATLAB (4 P)
- Database Management of meteorological data
- Basics of Quality Control of Meteorological data (if it is not covered under ' Function & Activities of NCDC...')

Practicals (14 P)

- FORTRAN practicals (Application in Numerical analysis & statistics) (8 P)
- Practical application of the graphic packages like Grads, Ferret, NCL graphics, Basic concepts of QGIS, Basics of shell Scripting (4 P)
- Basic concept of Networking (2 P)

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