Subjects Taught:

<table>
<tr><th><u>Semester - I (Six Months)</u></th><th><u>Semester - II (Next Six Months)</u></th></tr>
<tr><td rowspan="4">Observational Systems
Dynamic Meteorology
Physical Meteorology and Thermodynamics
Oceanography & Marine Meteorology
Climatology and Statistics
Synoptic Meteorology including Weather Analysis and Forecasting
Aviation Meteorology
Agriculture Meteorology
Hydrometeorology
Seismology
Astronomy
Environmental Meteorology
Satellite and Radar Meteorology
Met Telecommunication system
DBM & GIS
Management</td><td><u>Follow following Stream wise,</u>
<u>Semester-II syllabus</u></td></tr>
<tr><td>General Met. Stream</td></tr>
<tr><td>Electrical & Electronic or Instrumentation Engg. Stream</td></tr>
<tr><td>Agriculture Met. Stream</td></tr>
</table>

Appendix-I (Met.Gr.II)

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Met. Gr.-II Training Course

(12 months duration)

Semester-I (6 months duration)

For all disciplines

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
Applied Meteorology(AgriMet, HydroMet, Seismology & Astronomy etc.)	13 working days	MTI
Environmental Meteorology		
Aviation Meteorology	5 working days	MTI
Satellite and Radar Meteorology& Met Telecommunication system	11 working days	MTI
Management & administration	5 working days	YASHDA
DBM & GIS	5working 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 & APPLIEDMETEOROLOGY

(Total duration = 13 working days = 78 periods of 75 minutes duration)

A. 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)

B. <u>Applied Meteorology</u>

<u>Basics of Agricultural Meteorology (12 Periods)</u>

- Concept of Agricultural meteorology: Introduction to Agro meteorology, Scope and importance of agrometeorology, Familiarization with important activities of Agrimet Division, Weather, climate and crop, energy and water budget of crops, crop yield relationship with weather elements, crop weather calendar.
- Agromet observatory/Agromet observations: Agrometeorological instruments and their installation, special instruments used for field research in experimental crop field and procedure for taking observations. Maintenance, Inspection of observatories, Time of observations, use and archival
- Agroclimatic Zones: General concept, criteria for climatic classification, Troll and Papdakis's classification, climatic classification in India Objectives, Agroclimatic, classifications and their applications, Rainfall analysis, drought studies including drought monitoring, Evaporation, Evapotranspiration, Dry land farming, Pest & Disease etc.
- Agrometeorological information and weather forecasts for agriculture, Agromet advisory services (AAS): Importance of Agromet advisory services to farmers, Development from AAS to IAAS, Components of AAS bulletins, Preparation of special weather charts and bulletins for AAS, use of research data for operational work, Dissemination, Participatory approach and engaging with farmers, Feedback collection.

Basics of Seismology (12 Periods)

1. Seismology; Internal structure of the Earth; Plate tectonics; Physics of earthquake process; Types of faults and fault mechanisms; Seismicity and Seism tectonic features – (2 P)
2. Elastic wave theory; Seismic wave propagation & characteristics; Travel time tables; Velocity models; Seismic tomography – (2 P)
3. Earthquake source parameters; Magnitude, Intensity, Energy, etc.; Earthquake statistics; Digital data analysis and location of earthquakes; Seismological operations and information dissemination – (2 P).

4. Seismometry – Sensors; Recording systems; Communication systems; Local, regional and global networks; Micro-earthquake monitoring – (2 P)

5. Seismic Zoning; Seismic Hazard, Vulnerability & Risk; Seismic Microzonation; Disaster mitigation, management and preparedness – (2 P)

6. Earthquake precursors & prediction; Early warning of tsunamis – (2 P)

Basics of Hydrology: (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)

Basics of Astronomy (12 Periods)

1) BASIC DEFINITIONS IN ASTRONOMY & TYPES OF TELESCOPES AND THEIR MOUNTS*: Magnification, field of view, resolving power in context of telescopes and comparison with*

the abilities of humaneye. Spatial resolution and Rayleigh criterion. Stellar magnitudes, detectability limits of telescopes. Astronomical distances, parallax method. Plate scale-number and image sizes obtained with telescopes. Types of telescopes: Refracting type, coloraberrations, spherical aberrations, reflecting type. Newtonian, Cassegrain, Coude arrangement etc. Mounts: German equatorial, fork, horse-shoe, alt-azimuth. New telescopes for the future.

2) BLACK BODY RADIATION AND ASTROPHYSICAL CONSEQUENCE

Intensity, Flux, Luminosity, Stellar spectrum formation, Kirchoff's laws of radiation, Scattering of light by atoms and molecules – Rayleigh scattering, Raman scattering, single scattering albedo, Absorption and emission spectrum with both exhibiting line and band type spectra, Black body radiation laws and related special cases. Stellar spectral sequence and effective temperature. Stellar spectral classification and relation to HR diagram. Spectral line from a star and concepts of equivalent width, various types of line broadening effects.

Basic photometers and spectrographs, Low, Medium and High Resolution spectroscopy, Basic definitions, resolution, dispersion etc., Comparison of spectrometers, Grating and Fabry-Perot Spectrometers, Astronomical observations and data reduction

3) ATMOSPHERIC EFFECTS

Bond Albedo, Greenhouse effect, Absorption, scintillation, atmospheric extinction, scattering, turbulence, 'seeing effect', air-mass and extinction coefficient, 'seeing noise', 'seeing disk', scale length of Fried's parameter r0. Active and adaptive optics. Night sky brightness and night sky pollution.

4) NIGHT SKY EXPERIMENT: To estimate the temperature of an artificial star by photometry. To study the atmospheric extinction for different colors. To study the effective temperature of stars by B-V photometry.

5) CONCEPTS OF TIME, RA, DEC etc. and POSITIONAL ASTRONOMY:

Definitions of local time, UT, ST etc. co-ordinate system, Celestial Sphere, Zenith, Nadir, Celestial Horizon, Celestial Pole, Celestial Equator, Meridian, Ecliptic, First point of Aries and Libra (Definition only). Basic idea on three system of Celestial Coordinates: (i) Horizontal System ii) Equatorial System (iii) Ecliptic system

6) ASTRONOMICAL PARAMETERS and PHENOMENA:

Precession and Nutation (Basic idea), Conjunction, Opposition, Elongation, Eclipses, Occultation and Transit of Planets over the Solar disc (Basic idea).

7) CALENDRIC ASTRONOMY and Basics of SOLAR SYSTEM

Different types of Calendar: (i) Solar, (ii) Lunar, (iii) Luni Solar Indian National Calendar and Gregorian calendar. A brief description of Planets and Moon: Orbital period, rotation period, tilt in

rotation axis, Milankovitch cycle, Phases of the Moon, Basic structure of the Sun, Sunspot number, Asteroids, Meteors and Comets (Basic idea).

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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	Explain the effect of weather elements on aircraft operation Explain Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere	5

	QNH, QFE and ICAO Standard Atmosphere 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	Explain the concept of airport minima, low visibility procedures, categories of runways 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	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

	7. Examples		
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	4

		products useful for the issue of aviation forecast and warnings (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)

<u>Applied Radar Meteorology (18 Periods)</u>

- 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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Management Development program

Course Duration: **5 Days**

Objectives:

1. To realize self potential & further improve upon it.

2. Importance of attitude &behaviour for effectiveness.

3.To sensitize participants about importance of Management skill to enhance overall effectiveness & efficiency in personal life, professional life & social life, overall development.

Coverage:

Module I: Effective Leadership & Team building

Module II: Effective Communication & Presentation Skill and skill for forecast dissemination., media interaction

Module III: Time & Stress management-work-life balance

Module IV: Project Management & Quality Management

Module V: Organizational Behaviour

Module VI: Purchase Management & Procurement Rules

Module VII: Good Governance, RTI

Module VIIa: Knowledge management

Module VIIb: GOI Functioning service & financial management, Citizen Charter

Module one: Leadership & Teambuilding with OBL

Learning Outcomes:

Skills-building program will enable you to: -

1. Introspect on your current approach to leadership - Understand the "chemistry" of high-performing teams

2. Learn and practice Basic Leadership Skills to motivate and energize the people around you

3. Realize your own true potential-and, thereby, that of your organization/Dept. too.

Content:

- Attitude & Behavior
- Leadership skill & competencies
- Leadership Theories
- Leadership style & impact
- Demand of Leadership in service sector Be a Leader without limits
- Emotional intelligence in team & team building
- Transform your TEAM into Highly motivated, cohesive team, ready to take on the toughest of work challenges
- Sharpening skills to work well as members of team and also as leaders
- Developing high performance teams
- Aligning individuals to team objective
- Creating a positive work environment
- Interpersonal Relations
- Leading Change

Module two: Effective communication & Presentation skill

Learning Outcomes:

1. Sensitize the participants on the importance of effective communication at work.

2. Develop systematic & positive approach for verbal & nonverbal communication.

3. Polish their presentation, interpersonal & social networking skills

Content:

- Basics of effective communication
- Three style of Communication
- Work place communication: Skill & art of listening, speaking, reading & writing
- Nonverbal communication, Body language, Gestures, Postures
- Business presentations & writings
- Preparing Effective power point presentation
- Meeting management & team communication
- Electronic communication

- Media Communication & Public Relation

Module Three: Work –Life Balance (Time & Stress Management)

Learning outcomes

1. Understand and identify personal causes of stress

2.Apply some of the principles of time management to increase productivity on the job and at home, and enhance

the quality of work with less stress

Content:

- Self-knowledge and goal-setting
- Time Management Matrix
- Prioritizing: Put First Things First
- Planning & scheduling to make the most of your time
- Controlling Major Time Wasters
- Time management techniques
- Effects of stress
- Reactions to stress
- Identifying your stressors
- Gaining control and managing stress positively

Module Four: Project Management & Quality Management

Learning outcomes: This Module will facilitate you to get hold of basics of project management, tools and techniques to assess and appraise a project right from the setting up of project objectives, track and report them till the project closure.

Content:

- Project Management – Knowledge & principles
- Project Management Practices – activity based
- Project Appraisal /Evaluation Methodology & Practices
- Case Studies on project appraisal / /Discussion on various projects
- Quality Management

Module Five: Organizational Behaviour

Learning outcome

To sensitize participant about individual behaviour& organizational culture

Content

- *Individual Behavior*
- *Group Dynamics*
- *Effects of Informal group*
- *Factors affecting Performance*
- *Organizational theories*
- *Team Motivation*
- *Handling Conflicts*
- *Gender Issues*
- *Value & culture*
- *Decision Making*
- *Strategy management* ***Module Six: Purchase Management***

  Learning Outcome:

  OVERVIEW Purchasing Objectives of Purchasing Principles of Purchasing Functions of Purchasing Department. Methods of Purchasing Steps in Purchase Procedure.
- *Purchase Management*
- *Objectives of Purchasing*
- *Principles of purchasing*
- *Functions of Purchase Departments*
- *Procedures /steps /rules*
- *Method of purchasing*
- *Tendering & contracting*

  Module Seven Good Governance

  Learning outcomes:

  To understand various factors contributing to good governance

  Content:
- *Importance of good governance*
- *Administration & Management*
- *Transparency & accountability*
- *Responsiveness*
- *GOI structure & its functioning*

- *Service & conduct Rules*
- *Financial Rules*
- *Citizen Charter*
- *Knowledge Management*

  Methodology: This is a highly experiential and interactive program. It will involve: - Individual and group exercises - Case discussions and role plays - Diagnostic surveys, self-evaluation, and on-the-spot feedback - Learning-by-doing techniques

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Appendix-II (Met. Gr.-II)

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Met. Gr.-II Training Course

(12 months duration)

Semester-II (6 months duration)

(For Physics, Meteorology & Atmospheric Sciences, Mathematics & Statistics, Computer Science & Engineering and Civil Engineering disciplines)

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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Appendix-III

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Met. Gr.-II Training Course

(12 months duration)

Semester-II (6 months duration)

(For Electronics & Communication Engineering, Electrical & Electronics Engineering or Instrumentation Engineering disciplines)

2019

Content

Subject	Duration	Place
Radar Technology and Radar Meteorology	**5 working weeks = 5 x 5 = 25 Days = 25 x 6 = 150 Periods of 75 minutes**	**Information, Communication & Instrumentation Training Centre (ICITC), IMD, New Delhi**
Communication system	**7 working weeks = 7 x 5 = 35 Days = 35 x 6 = 210 Periods of 75 minutes**	**-Do-**
Meteorological instruments including hands on practice	**6 working weeks = 6 x 5 = 30 Days = 30x 6 = 180 Periods of 75 minutes**	**-Do-**
Mid-term & final exam+Viva-voce+Project presentation Relief+ CH	**4 working weeks**	**-Do-**
On the Job training	**2 working weeks**	**IMD or other Institutes of MoES.**
Total	**24 weeks = 6 months**	

& 1 working week = 5 working days

 # 1 working day = 6 periods of 75 minutes

Radar Technology and Radar Meteorology for Met II Trainees

Radar Technology (2 Weeks)

- Theory of Microwave devices: Magnetron, Klystron Amplifier, SSPA, Reflex Klystron, etc.
- Basics of Signal processing and radar moments quality control
- Concept of polarization- Horizontal, vertical and circular.
- Transmission media – Co-axial cable, wave guide.
- Block diagram of Doppler Weather Radar and explanation of different units: -
- Transmitter
- Receiver
- STALO
- RF amplifier
- Wave guides
- Parabolic Dish antenna
- Servo amplifiers
- Testing, upkeep, calibration and maintenance of the various modules (both software and hardware)/systems of Radar

Radar Meteorology (2 Weeks)

- Types of radar and their applications
- Principle of weather radar
- Effect of earth curvature on radar beam
- Scattering – Rayleigh and Mie
- Radar Equation for a point target and for extended target
- Principle of Doppler Weather Radar
- Range and velocity ambiguity
- Doppler Dilemma
- Products from DWR – Base and derived products their description, interpretation, validation and applications in now casting/forecasting including NWP.
- Discussion on the recorded events- Thunderstorm, hailstorm, tropical cyclones etc.
- Disdrometer, micro rain radar, TDWR, low level wind shear systems.
- Common scan strategy, product generation, task configuration, data transmission, central server, data archival and WMO CDBMS compliance.

Familarization Training (1 week): -

- DWR Kolkata/Delhi: - Introduction with hardware and software of DWR. (5 Days)

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Communication system

Total Duration = 7 working weeks =7 x 5 = 35 days = 35 x 6 = 210 Periods

Basics of communication system (18 P)

- **Introduction of communication:**
  Analog and Digital Communication, Wired and wireless communications including Mobile communication and latest technology, Cloud Computing, VMware, Artificial Intellegence, Internet of Things (IoT) & its applications, Mobile Technology, Frequency bands and their uses, Frequency bands allocation for mobile communication, ISO standards.
  Overview of Optical communications, Optical fibers and its types and properties, Signal degradation, international standards. The advantages and disadvantages of optical fiber communication over copper wire communication. Basics of TDMA, FDMA, CDMA and GSM / GPRS. Concept of 2G, 3G, 4G & other latest communication systems.
- **Satellite communication**:
  Concept of Satellite communications, Satellite Frequency bands, orbital mechanics, Satellite system, VSAT and LEO systems, Satellite Packet switching, Satellite signal processing. Earth station hardware including antenna and their configuration for reception and transmission of data, INSAT Satellite Payloads. Trouble shooting and rectification, special attention towards meteorological communication.

Networking (1 week = 30 P)

- Concept of networking, Protocols, Packet switching and circuit switching, networking devices, IP Scheme, private and public IP and masking etc., IP version 4 and 6, IP classification, Concept of www, FTP, sftp, ssl, http, https etc
- OSI 7-layer structure and description of each layer
- **Active devices:**
- **Router**: OS installation, Basic configurations, VPN tunnel, VOIP, HSRP, Load Balancing, bandwidth management, WAP etc.
- **Firewall**: Different types of firewall (Hardware and software and their basic concept and configurations including policy, IPS, IDS etc.
- **Switches**: Basic Configuration with VLAN configuration etc.
- **Load balancer:** Basic configuration for sharing of traffics.
- **Server:** basic configuration, ftp server, web server, mail server, data portal etc.
- **Configurations of Network servers and their functionalities:** DHCP, AAA, Proxy and others network management servers.
- **Passive components:** UTP, OFC (optical fiber cable)**, d**ifferent types of network modules and their functions. Jack panel, Wire Manager, pigtail, LIU, patch cord, HDPE, jacket, connectors, raceways etc. The concept of bandwidth and its management. Tools and all types of commands for troubleshooting and rectification of network. Backup and restoration of all network devices.
- **Security:** Fundamentals of Network Security, secure channels via encryption, Message Authentication codes, Authentication mechanism, Malware, Spyware, spam etc. Concept of

endpoint security and gateway level security, Antivirus including Internet Security, **M**PLS VPN (Virtual Private Network) concept, Lease line, National Knowledge Network (NKN), Internet etc.

Linux (1 week = 30 P)

- **Administration**: OS Installation and configuration of Server (all architecture), Email, web server, FTP server, DNS server, database, clustering). Deploy, configure and maintain systems including software installation, update and core services. Virtual IP concepts and its configuration, RAID configuration, SAN, NAS, shell scripting, Virtualization, Cloud Computing and Storage.
- **Parameters**: The selection of server parameters while configuring WEB/EMAIL/FTP servers.
- **Backup and restoratio**n: Procedure of backup and restoration for all types of servers full and incremental.

Web Designing/ Apps development (1 week = 30 P)

HTML, Java, PHP, GIS, XML etc. for developing and management of the CMS website, development and management of mobile based applications.

Data conversion and ingest to database including GIS platform and development. GIGW compliance, RSS feeds

Meteorological Communication Systems (42P)

Data format: All types of data format such as ASCII, Binary, BUFR, CREX, GRIB, HDF, NetCDF, XML, KML GML etc.

Communication Systems: AMHS, RTH, Aeronautical communication, AFTN, IWXXM, SWIM, OLBS, IVRS, VSAT, CIPS, SYNERGIE, SADIS, CLYSIS, NCDC, PWS, Video Walls, Video Conferencing, Tele-presence and other conferencing, WMO Information System (WIS), role and responsibilities of GISC, DCPC and NC.

GTS WMO Procedure: Protocols, WMO Headers & Routing, WMO File naming convention.

Metadata: Basics of Metadata, creation of metadata, XML, JSON, KML etc format.

NIC Email and SMS services:

Creation of request for new email ID, resetting of password, change of mobile number and other details, features of NIC email services, bulk SMS dissemination through NIC.

Cyber Security (1 week – 30 periods)

Introduction to Cyber security, Various types of attacks, incident reporting, corrective measures, CERT OTP, capcha, Web-audit, vulnerability and its removal, Cyber laws.

OJT in communications (1week = 30 P)

Trainees shall be attached to RTH and visit to AMSS site. Splicing of OFC, Power measurements.

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Meteorological instruments including hands on practice.
Total Duration = 6 working weeks =6 x 5 =30 days = 30 x 6 = 180 Periods

Advanced Upper Air Techniques: (12 P)

- Advanced upper air technologies of Radiosonde, LIDAR, Wind Profiler, SODAR, Types of radiosonde, sensors, sources of error, comparison of tracking methods, comparison of radiosondes, computation techniques, balloon performance in various environments, may be dealt with in detail& Ground Equipments.Airborne instrumentation, introduction to Dropsonde & rocket sonde, GPS radiosonde & pilot sonde observation- Instruments & Techniques.
- Overview of WMO practices and CIMO Guidelines.
- Horizontal sounding- Constant level balloons and their field of use, instrumentation, tracking station for constant levels, tracking from satellites.
- Microwave Radiometer and GPS based Radio occultation technique.

Ozone: (5 P)

Ozone and its importance in Meteorology, measurements of total ozone, vertical distribution of ozone and surface ozone, ozone sonde, Dobson and Brewer spectrophotometer.

Engineering practices: (2 P)

Tools, test equipments, materials, drawing, workshop practices, inventory management, engineering costing and cost consciousness in maintenance. Accident preventions personal safety and first aid.

Satellite Meteorology (32 P)

- Basic principles of radiation relating to satellite meteorology.
- Brief history of development of meteorological satellites and instruments on board these satellites.
- NOAA polar orbiting satellites and HRPT data reception and processing facility. Products generated from AVHRR and sounding data.
- Description of Geostationary meteorological satellites. Particularly details of INSAT system and its capabilities.
- Reception and processing of satellite Data. Generation of cloud imagery and derived products.
- MMRDPS, RAPID
- Cyclone Warning Dissemination System (CWDS).
- Basic principles of passive Microwave Remote Sensing. Brief of IRS (P4) i.e. ocean sat and the meteorological products from this satellite.
- Basics of Image interpretation and weather systems seen in the cloud imagery.
- Description of payloads on INSAT3-D, Kalpana satellites.
- Ground based GPS receivers for total precipitable water vapor measurements.
- Earth station for reception of VHRR and AWS data at Delhi & Pune respectively.

AUTOMATIC WEATHER STATIONS: (32 P)

- **Automatic Weather Stations:** Introduction, Purpose of establishing an AWS network, WMO No.8-CIMO Guidelines on Automatic Weather Stations
- Basic concept of telemetry, Satellite Communication, internet and GPS/GPRS communication, Earth and Space Segments, Various frequencies used for transmission and long-term planning in frequency allocations to different users, Types of AWS System, Overall concept of AWS, Installation of AWS, Testing and Maintenance. Agro-AWS, Network of Automatic Raingauge (ARGs)Stations **Sensors and Their Characteristics:** Types of sensors, analog, digital, serial, SDI-12 sensors. Different outputs of sensors and their characteristics, slope and offset calculations for a linear analog output sensor. Basic principle of measurement of atmospheric pressure, air temperature, relative humidity, wind speed, wind direction, rainfall, duration of sunshine, soil moisture, soil temperature etc. Interfacing of different sensors with the logger. Signal conditioning for different sensors.
- **Calibration Procedures:** Calibration procedures for various sensors in temperature chamber, Pressure chamber, wind tunnel etc. Laboratory and field testing of sensors.
- **Data Logger and Transmitter:** Components of data logger, and transmitter, Configuration and operation of Data logger and transmitter, different types of data loggers and transmitters in use troubleshooting procedures for data logger and transmitters in IMD network interfacing of sensors with data logger, Scheduling the sampling of meteorological parameters, configuration of data logger and transmitter through laptop using communication software. Uploading firmware, data backup.
- **Automation of surface observatories:** Hand held data loggers for surface and pilot balloon observation,
- **Power Supply:** Power requirements, use of battery and solar panel, calculation of power budget for a particular configuration, testing, installation and maintenance, usage of switched power to sensors for saving power. Solar power supply, UPS
- **AWS Data Format:** Study of data format, Generation of station identification code (BCH & BUFR codes), encoding and decoding. Mode of AWS data transmission. Pseudo Random Burst Sequence (PRBS) and Time Division Multiple Access (TDMA) techniques of data transmission.
- **PCMCIA Card/ Flash Card/USB drive:** Retrieval of AWS data from the field unit, reading and writing of AWS files (setup files, data files, log files etc) from the system to the card. Downloading of data files onto the computer for further processing.
- **Antenna:** Types of antenna (Crossed Yagi antenna for Tx, Parabolic Dish antenna for Rx), installation and testing, theory of polarization- RHCP/LHCP. Changing polarization of antenna, computation of azimuth and elevation angle for orientation of antenna. GPS Antenna, Understanding the utility of GPS for time synchronization, exposure conditions for antenna, GSM/GPRS Antenna
- **Receiving Earth Station: Hardware and Software** Components of Receiving Earth Station – Low Noise Amplifier, Down converter, Digital Readout Ground Station, Processing Server. Receiving, Processing softwares for decoding AWS data received in PRBS and TDMA techniques software for decoding AWS data and maintenance of AWS database, Coding of AWS

data in WMO format and transfer of the coded data to AMSS and to GTS. Maintenance of AWS and archival at Earth Station. Application of GIS to AWS data. AWS data servers (web and ftp).

- **Satellite Link Calculation:** Calculation of uplink (C/N_0) and downlink (C/N_0), EIRP, free space losses, Quality objectives of the Satellite link.
- **Complete AWS System:** Preventive maintenance of AWS system/ sensors and field calibration, Protection of system/ sensors in harsh environments, use of NEMA-IV enclosures and prevention of moisture ingress into the system. Role of IMD employees in nearby conventional observatories in validation and troubleshooting of AWS /ARG equipment.
- **Introduction to new IOT based Automatic Weather System.**
- **GPRS Data Transmission:** Basics of GPRS Modem, Configuration of GPRS Modem, Central GPRS receiving Server and its software details, Viewing & Downloading AWS/ARG Data.
- **Guidelines for selection of site for an AWS/ARG.**
- **Guidelines for construction of civil structures at the site.**

AVIATION MET. INSTRUMENTS: (40 P)

- Role of Meteorological instruments in aviation.
- Accuracy requirements – ICAO and WMO regulations on navigational Aids and safety measures. An introduction to various ICAO documents & meteorological requirements at airports.
- Runway complex and touchdown areas.
- Criteria for selecting site for installation of Airport Met. Instruments.
- Definition of category of Airports; Number of airport met. Instruments required per runway as per category and runway length.
- Transmission of measured values to MBR & ATC. Challenges in adverse weather like fog.
- Theory and principle of digital Current Weather Instruments System (DCWIS) (Wind Direction, Wind Speed, Temperature, Dew Point, QFE & QNH -); Installation, maintenance and calibration of DCWIS.
- Transmissometer (Single base and Dual base), their installation, testing and optical alignment and Calibration etc.; Reporting RVR practical aspects; Dual Base line transmissometers. Selection of baseline length of transmissomter, other type of RVR measurement instruments.
- Drishti Transmissometer: Installation procedure, Optical Alignment, Calibration, Drishti software, Data Validation procedure, Preventive & Corrective maintenance of Drishti System.
- Ceilometer & Ceilograph working; Installation and Maintenance of Ceilometers.
- Aviation Weather Observing Systems: Introduction, METAR/ Met Report GENERATION
- Signal cables (Armored & Flexible): Testing signal cables; Short Range Modems for communicating the digital data from field site to MBR through cable. Importance of liaising with Airports Authority of India.
- Optical Fibers: Types of optical fiber cables (Single Mode & Multi mode), Media Convertors, configuration of Media convertors, Optical Fibre Cable Jointing Instruments & Procedure

- Radio Modems; Frequencies allotment for AMIS. IP Configuration of Wireless Modems.
- An introduction to wind shear measuring instruments.

RADIATION INSTRUMENTS: **(17 P)**

- General requirement of meteorological instruments, measurement of sunshine and intensities of solar radiation.
- General principles of radiation measuring instruments and methods of observation.
- Pyranometers, Pyrheliometers, sunphotometer, net radiometer etc.
- Measurement of direct, global, diffuse and reflected solar radiation.
- Operation of microprocessor controlled Solar tracker and GPS based Solar Tracker Thermoelectric Pyrgeometer for net terrestrial radiation (Continuous measurements) and Net pyrradiometer for total net radiation.
- Measurement of UV radiations with UV radiometers.
- Familiarisation with uses of UV/IR/Vis range Spectrophotometer.
- Operation and maintenance of data loggers for radiation measurement calibration, maintenance and rectification of defects of instruments.
- Aerosol monitoring, Sky scanning radiometer, BC measurement, Athelometer, Naphelometer. Standards for Surface Meteorological Instruments and Calibration: Introduction to Primary & Secondary/Traveling Standards, Introduction to Calibration and Calibration facilities (Environmental chamber for Air Temperature & Humidity, Wind Tunnel, Pressure Vacuum chamber, Dead Weight tester for Pressure, Temperature Bath). Calibration of Rainfall sensors.

Air Pollution measurement: (9P)

AOD, Precipitation chemistry, PH meter, Conductivity meter, SO_2/ No_x/ SPM measurement

PRACTICAL WORK: (31 P)

OJT in Surface Instrumentation:

- Practical maintenance / servicing of conventional surface met. instruments.
- Practical maintenance / servicing of AWS.
- Practical maintenance / servicing of Airport Met instruments.
  Practical maintenance / servicing of Radiation Instruments.

OJT in UAL:

Study of circuit, Servicing & maintenance & actual familiarization of

- GPS Radio sounding system
- Calibration techniques: Study of manufacturing and calibration of Radiosonde & various sensors.

OJT in Radar Lab.

- Detailed study of circuitry, servicing, maintenance and operation of Radars.

- Familiarisation on DWR (Trainees to be sent field station for one week)
- Generation of DWR products at Rainbow/IRIS workstation at Radar Lab data centre.

OJT in Satellite Meteorology:

Practical circuit study of receiving equipment used for direct dissemination of meteorological data to MDD.

Practical study of reception, processing of data from Kalpana, INSAT 3D, Techniques used for generating various satellite-derived products. Servicing of various sub-system for CWDS

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Appendix-IV

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Met. Gr.-II Training Course

(12 months duration)

Semester-II (6 months duration)

(For Ag Met & Ag Physics disciplines)

2019

Content

Module	Sub Module	Duration	Institute
Agricultural Meteorology	**Agrimet Training in IMD offices, PUNE**	Eight weeks	At MTI, IMD, Pune. Faculties from other institutes are to be invited for teaching.
	Overview of general agricultural meteorology		
	Agromet Advisory Services for farmers		
	Agromet instruments, working principles and methods of observation (including crop observations) - hands on experience		
	Radiation instruments, their working principles, installation and observations – hands on experience		
	Agroclimatology of field crops		
	Hydrology of soil in relation to agriculture		
	Rainfall climatology for agricultural planning		
	Dew, fog, humidity in relation to agriculture		
	Soil and air temperature		
	Evaporation, evapotranspiration and potential evapotranspiration		
	Photosynthesis, radiation and energy balance of crops		
	Weather hazards affecting crops		
	Crop phenology		
	Agroclimatic classification		
	Effects of temperature on crops		
	Soil- water- plant relationship		
	Radiation, photoperiodism and their impact on crops		
	Global warming, climate change and their impact on Agriculture		
	Micrometeorology		
	Project work on operational agrometeorology / Agrometproduct generation		
	Agrimet Training in other institutes in PUNE		

	Abiotic stress management	Two weeks	
	Principles of GIS and their applications in agriculture		
	Role of weather, climate on livestock production		
	Working principles and methods of observation with specialized Agromet instruments		
	Visit to Experimental Farms, University and SDA		
	Agrimet Training in AHMEDABAD		
	Satmet and GIS products generation for use in operational AAS	One week	
	Eddy covariance and flux measurements		
	Agrimet Training in NEW DELHI		
	Agricultural statistics, statistical models and their applications	Four weeks	
	Crop weather analysis and development of models		
	Crop yield forecasting models		
	Medium range weather forecasting and Numerical Weather Products for use in AAS		
	Pest and diseases, concept of IPM and forewarning models		
	Impact of extreme weather events on Agriculture and Disaster management		
	Agrimet Training in HYDERABAD/JODHPUR		
	Drought climatology	Five weeks	
	Dryland agriculture		
	Application of crop simulation models with special reference to DSSAT		
	eAgromet training for use in operational AAS		
	National Natural Resource Management System (NNRMS) and monitoring of drought through		

	Remote Sensing		
	Operational district level AAS bulletin preparation – hands on training at ANGRAU (AMFU), Hyderabad		
	Total weeks	**Twenty (five months)**	

Institutes:

1. Pune:

IMD – All Offices of IMD, Pune

NIAM – National Institute of Abiotic Stress Management, Baramati, Pune

IITM – Indian Institute of Tropical Meteorology

CAFT – Centre for Advanced Faculty Training in Agricultural Meteorology

CDAC – Centre for Development of Advanced Computing

MPKV – Mahatma Phule Krishi Vidyalaya

SDA – State Dept. of Agriculture

2. Ahmedabad:

SAC – Space Application Centre

3. Jodhpur

CAZRI – Central Arid Zone Research Institute

4. New Delhi:

IASRI – Indian Agricultural Statistical Research Institute

NCIPM – National Centre for Integrated Pest Management

IARI – Indian Agricultural Research Institute

5. Hyderabad:

CRIDA – Central Research Institute for Dryland Agriculture

ICRISAT – International Crops Research Institute for the Semi-Arid Tropics

IIIT – International Institute for Information Technology

NRSC – National Remote Sensing Centre

ANGRAU – Acharya N G Ranga Agricultural University

PJTSAU – Professor Jayshankar Telangana State Agricultural University

Syllabus for the Submodules

AGRICULTURAL METEORLOGY

1. Overview of general agricultural meteorology:

Definition, aims and scope and importance of Agrometeorology, practical utility of Agrometeorology, agricultural meteorology in relation to the needs of end users, importance of meteorological processes in agriculture, micro-environment and plant growth and development, agricultural significance of the physical and biological variables in the environment, analytical tools and methods for agricultural meteorology, adaptation of plants and crops to the climate, necessity of adjusting farming system to natural environment. Importance of weather and climate for agricultural production, present challenges in agrometeorology and their solutions, historical background of Agrimet Division, organizational set-up and activities. institutes working on Agrometeorology- In India and abroad.

2. Agromet instruments: Theory, working principles and methods of observation (including crop observations) - hands on experience:

General instructions on selection of site for an observatory, dimension of an agromet observatories and orientation of instruments, installation, routine maintenance and observational procedures for agromet instruments. Theoretical and practical aspects of various censors and equipments used in agrometeorological research and applications(such as open panevaporimeters, lysimeter, pscychrometer, soil thermometers, soil heat flux plates,Dubdevani dew gauges, sunshine recorder, of maximum and minimum thermometers, dry and wet bulb thermometer, wind vane, anemometer, thermograph, barometer, rain gauge, dew gauge, line quantum sensors, canopy analyzer, spectral radiometer, leaf area meter, infrared thermometer and their calibration, soil moisture measuring instruments including neutron probe).

Classification of agromet stations, crop weather stations, general scheme for sample observations, periodical growth observations, pests and diseases observations, of experimental plots for crop weather observations, periodical observations of crop growth and yield components, soil moisture in the field, tabulation of data and scrutiny of crop observations (norms for scrutiny), history of crops, Special meteorological instruments for micrometeorological observations-photosynthesis system, dew point micro-voltmeter etc,Agromet Sensors. Automatic weather station-designing and construction and construction data logger and sensor.

Recording, transmission, reception, scrutiny, application and archival of agromet data: communication systems used for online transmission of data.

Practicals on:

- Observation, recording and tabulation of Agromet data at CAgMO - Hands on Experience,
- Measurement of plant growth (Phenometry) leaf size, leaf area index, length of stalks, thickness of tubers, no. of tillers and other growth (dry matter production and yield components / yield parameters.

3.Radiation instruments, their working principles, installation and observations – hands on experience:

Different types of radiation instruments - pyranometer, pyrgeometer, pyrheliometer and net pyradiometer for measuring global, reflected, diffused, albedo and net radiation.

Practicals on:

Hands on experience on radiation instruments and their observations, recording of data, evaluation of radiation charts.

4. Agroclimatology of field crops:

Introduction, crop growing seasons, spatial and seasonal distribution of meteorological parameters, climatic requirement of crops including water requirement at different growth stages, agroclimatology of cereals, pulses, oil seeds, cash crops, tubers and plantation crops, fiber crops, horticultural crops etc., influence of agrometeorological variables (such as rainfall, temperature, day length/photo-period, solar radiation and wind) on growth and yield of crops, crop evapotranspiration and irrigation requirement, drought tolerance mechanism, biotic risks and weather hazards. Agrometeorological forecasting, Agrometeorological services related to the crops, user requirements for climate information, management aspects of the weeds, and pests diseases of crops, climate risk management for dry land crops -- irrigation scheduling.

Practical's on:

location specific weather and climate sensitivity of crops.

5. Agricultural statistics, statistical models and their applications:

Frequency distribution grouping – extreme value distribution, probability and risk, probability based on normal distribution; measuring central tendency -- mean, median and mode; fractiles – percentile and decile methods; measuring dispersion-- the range , the variance and the standard deviation, measuring skewness; cluster analysis, classification trees, statistical inference and decision making – interval estimation, z-test, t-test; climatic periodicities and time series -- auto regression and moving average model. Method of least square method for curve fitting, Fischer's technique, experimental

designs, concept of design oriented statistical methods viz., completely randomized design (CRD), randomized block design (RBD), latin square design (LSD), method of confounding.
Multiple and partial correlation, simple regression, stepwise regression, standard error, test of hypothesis, conditional probability, Markov's chain of first and second order, c(exponential, logarithmic, lognormal, chi-square, Gumbel and incomplete Gamma distribution),SPI, Confidence intervals, return periods, analysis of time series, determination of trend, persistence or cycles in time series, harmonic analysis, fourier and spectrum analysis, interpolation and extrapolation and statistical quality control. Principal component analysis, non-parametric test in time series analysis.

Practicals on:

a) Statistical methods in agromet studies,
b) Correlation coefficients Simple, partial and multiple,
c) Simple and multiple regression analysis
d) Test of significance
e) Analysis of variance and designs.

6. Hydrology of soil in relation to agriculture:

Water and soil resources assessment for agrometeorology – information on physical characteristics of soil type such as bulk densities, field capacities, wilting points and water holding capacity, hydrological cycle and soil climate in relation to sustainable plant growth, sensitivity of soil respiration to soil temperature and moisture in plant growth, water runoff and soil loss, soil erosion by water or wind affecting agricultural areas--removing major nutrients from the soils affecting crop productivity, measures against degradation of agricultural soils (due to gully erosion, raindrop impact energy, compaction, etc.) -- strategic land-use practices, soil and water management practices, expansion of irrigation, water harvesting, building of terraces and diversion trenches.
General ideas, effect of water on photosynthesis, volume and mass relationship of soil constituents, soil wetness, soil profile, usefulness of soil moisture observations, characteristics of moisture in soil, methods of moisture determination - gravimetric, tensiometric, electrical resistance, neutron probe methods and TDR (time domain refractometer), Kinds of soil water, movement of water within soils, related terminologies viz., water intake, percolation, inter flow, permeability, hydraulic conductivity, moisture characteristics of soil, moisture movement under unsaturated conditions, infiltration, percolation and runoff, soil, water and plant growth, status of water in plant, potential plant, water balance, soil water potential, leaf water potential, relative leaf water content, soil moisture budget and irrigation requirements - climatic water balance, water absorption by roots, absorption of water by plants, plant growth under extreme moisture stress. Description of soil water balance models like

Ritche, FAO and other. Hydrological cycle, Evaluation and insitu measurements of various components of hydrological cycle, concept of hydraulic conductivity in saturated and unsaturated soils, evaluation of soil moisture fluxes and drainage components, water extraction pattern by plant roots, climatic water budgeting approach, Thornthwaite method, Palmer's two-layer model, Keig and Mc Alpine approach, soil moisture balance for rainfed and irrigated crops.

Practicals on:

i) Soil moisture measurements, different methods, computation of permeability, hydraulic conductivity, infiltration.

ii) Assessment of soil loss by universal soil loss equation.

7. Rainfall climatology for agricultural planning:

General concepts of rainfall with reference to crops, Gaussian distribution and Weibull distribution of rainfall, frequency analysis of rainfall, probability analysis of rainfall by incomplete gamma distribution, Dependable rainfall, Distribution of rainfall at commencement of crop season, effective rainfall and its importance in determining sowing time, Criteria for sowing rains, inter spell duration and its importance to crop sowing. use of basic and conditional probabilities in fixing sowing date., Characteristics of dry and wet spells and their extremes, concept of first and second order Markov's chain in determining probabilities of dry and wet spells, its advantages over other models. Application of incomplete gamma distribution in selecting sowing period, soil moisture balance, its computation and utility in finding ideal sowing dates, effect of soil type and texture on sowing of crops, meteorological and synoptic factors influencing sowing of rainfed crops, selection of crops and varieties based on time of commencement of sowing rain at the beginning of the season. Contingency plan

Practicals on:

Hands on experience in Markov's chain model for computation of dry and wet spells and rainfall probability analysis by incomplete Gamma distribution:

(i) Computation of the probability of deficient year P(D), deficient year preceded by a deficient year P(DD) by Markov Chain Model.

(ii) Computation of probability of dry week P(D), dry week preceded by a dry week P(DD); wet week P(W) and wet week preceded by a wet week P(WW) by Markov Chain Model.

(iii) Computation of the probability of 2 and 3 consecutive dry and wet weeks by Markov Chain Model.

(iv) Computation of probability of rainfall not exceeding 'X' amount (relating to agricultural operation) by using incomplete Gamma Distribution Model.

(v) Computation of probability of assured rainfall amount at X% probability level (relating to agricultural operation) by using Incomplete Gamma Distribution Model,
vi) Selection of crops and varieties based on time of commencement of sowing rain.

8. Dew, fog, humidity in relation to agriculture:

Dew, general concept, conditions favourable for formation of dew importance of dew to agriculture and its measurement, vertical distribution, dew duration, theoretical estimation, contribution of dew in water balance of dry- land crops, role of dew on the growth and yield of rabbi / winter crops and vegetable crops, adverse effects of dew, dew climatology over India, fog, its importance in distribution of natural vegetation and crops, Humidity, relation between transpiration and dry matter production, humidity in relation to internal water potential, transpiration and water requirement of crops, importance of humidity in crop growth, dew/fog harvesting.

Practical:

Recording of dew observation.

9. Drought climatology:

Concepts of drought, drought and aridity, classification of drought – metrological, agricultural, hydrological and socio-economic drought, historical perspective of meteorological, agricultural and hydrological droughts, intensity of drought probability, space-time characteristics of drought – spatial extent and beginning and end of the drought, causes of drought, its spatial occurrence over India, Monitoring and early warning of drought, Meteorological drought indices – Rainfall decile methods, Palmer drought severity index (PDSI), Standardized precipitation index (SPI); MAI,Agricultural drought indices – Crop moisture index (CMI), Water satisfaction index (WSI), Crop water stress index (CWSI); Hydrological drought indices – Surface water supply index SWSI); NDVI,CVI,Drought prediction, impacts of drought, Drought and agriculture – response of plant to drought condition, impact of drought on production of dry land crop, Socio--economic aspects of drought, Drought risk reduction strategies, Drought management – Adaptation, adjustment and mitigation of drought; Drought index insurance, Drought and desertification.

intensity of drought probability, its spatial occurrence over India, Synoptic study of droughts in India, Breaks in monsoon and its relationship to drought, association of droughts with global factors, forecasting of meteorological droughts, agricultural droughts, agriculture drought indices, Monitoring of agricultural droughts and agronomic measures to minimize effect of agricultural droughts, application of remote sensing in drought studies, NDVI,CVI integrated approach in forecasting/ monitoring agricultural drought.

Practicals on:

Computation of drought indices.

10. Soil and air temperature:

Diurnal variation of air temperature, grass minimum temperature gradient near the ground surface, concept of heat units in relation to agriculture, in relation to crop growth indices, various heat unit indices, Thermal properties of soil, thermal conductivity, thermal diffusitivity, heat capacity, Propagation of temperature wave within soil, heat gain/loss by soils, transmission of heat in the soil, soil freezing and the role of snow cover, diurnal variation of soil temperature and variation of soil temperature with depth, estimation of soil heat flux.

Practicals on:

i) Physical properties of soil, its analysis, analysis of variation of soil temperature with depth,

ii) Determination of thermal diffusivity and damping depth of soil,

iii) Computation of heat unit at various crop growth stages, significance of soil temperature to crops.

11. Evaporation, evapotranspiration and potential evapotranspiration:

Evaporation and physical processes involved in it, evaporation and water balance, measurement of evaporation, energy balance estimates of evaporation, definition of transpiration and its measurement, meteorological factors affecting transpiration, transpiration and dry matter production, significance of transpiration, evaporation versus transpiration. Methods of estimating / measuring evapotranspiration, concept of potential evapotranspiration, concept of evapotranspiration or consumptive use, mass transport model, theoretical models, resistance model, aerodynamic models of measuring evapotranspiration, Penman, Penman Monteith, Pan evaporation method,VanBavel and Priestlay - Taylor models, Models for estimating PET by Thornthwaite, Blaney-Criddle, Jensen Haise , Richie,Doorenbos Pruitt, their relative merits / demerits, Crop evapotranspiration and irrigation scheduling, Water and yield relationships, consumptive use, water use efficiency, relationship between water use and dry matter production, water balance models and irrigation scheduling based on evapotranspiration and other methods, Cocheme and Franquin water availability periods, effect of water deficit on different developmental stages of crops.

Practicals on:

i) Lysimetric observations and their entry in prescribed forms,

ii) Computation of ET through different models,

iii) Hands on experience in irrigation scheduling.

12. Photosynthesis, radiation and energy balance of crops:

Solar energy ("short-wave" energy) from sun and sky – direct and diffuse components of solar short wave radiation, estimation of global radiation on a horizontal surface, emission and reflection of radiation, variation in net radiation flux and its prediction from meteorological parameters, energy in the visible spectrum – light; the energy balance and its components. The nature of radiation, electromagnetic spectrum, basic definitions, elementary radiation laws, solar constant, attenuation of radiation by the atmosphere, albedo of different soils and vegetation, geographical, annual and diurnal distribution of solar radiation, terrestrial and net radiation. Radiation balance, energy balance over agriculturally important surfaces, evaluation of energy balance components, duration of sunshine, empirical relationship between sunshine and radiation, Radiation use efficiency and water use efficiency, Photosynthesis, basic processes of photosynthesis, Leaf area index (LAI) and its relation to photosynthesis, dry matter production as function of radiation and LAI, variation of LAI throughout the crop cycle, general concepts of radiation in relation to agriculture,photosynthetically active radiation, saturation light intensity and efficiency of light utilization , photosynthesis in relation to temperature and CO_2 concentration, respiration and net photosynthesis and factors affecting it, Leaf transmissibility, leaf arrangement, (phototaxy), extinction coefficient, Beer's and Montieth's law of distribution of radiation within plants canopy, radiation utilization in various crops, growth phases of field crops, comparison of radiation utilization between tropics and temperate regions, radiation and crop yield, photoperiodism and its practical applications, Photoperiodism and temperature, response of tropical plants to photoperiodism.

Practicals on:

i)Computation of LAI

ii)Computation of rate of photosynthesis.

iii)Seed germination test to study photoperiodic impact.

13. Weather hazards affecting crops:

Extreme meteorological events -- definitions and types, importance of meteorological data and information on extreme meteorological parameters, positive and negative impacts of extreme events on agriculture, early warning systems for extreme events, remote sensing techniques for disaster risk management, Prevention and preparedness for extreme events, Impact of extreme weather events on livestock productivity, reproductive performance and their amelioration strategies, vulnerability of ecosystem to natural disasters and extreme events, impact of natural disasters on vegetation and livestock in dryland and rangeland comprising grasslands, shrublands savannahs, and hot and cold deserts, socio-economic impacts of extreme events, Extreme events and risk management in

agriculture, propagation of disaster resistance crops, Index based insurance for risk management in agriculture. Hazardous weather elements *viz*. cold waves with low temperature, frost, snow, storms, fog, heat waves with high temperature affecting crops and livestock;Heavy rains and floods -- affecting crop physiology through water logging and root asphyxiation, causing environmental degradation through erosion and re-sedimentation; Hail – temporal and spatial distribution, hail prevention, hail forecasting methods, hail and crop damage ; Frost-- causes of frost, effect of frost on plants, intensity of frost damage to plants in relation to soil temperature and snow cover, protection against frost damage, forecast and warning of frost; Plant management, thermal insulation, application of water, direct air and plant heating; Tropical cyclones and storm surges – Geographical distribution of tropical cyclones, monitoring and forecasting of tropical cyclones, agrometeorological loss associated with cyclones , cyclone preparedness in the agricultural system, protection from the storm surge, environmental aspects of sand storm/dust storm and desert winds, Wind storms and dust storms – the physiological effects of strong winds on plants, erosion by wind, impact of sand and dust storms on agriculture and livestock, measures to protect crops from wind storms and sand storms, warning system of sand storm and dust storm for agricultural use .

Climatology of strong surface wind in India, damage caused, methods of protection – wind breakers, multiple belts and wind shelters, methods to prevent soil erosion, Economic impact, measures for reducing impact.

Practicals:

Assessments of water erosion and wind erosion by applying the standard formula.

14. Crop phenology, Crop weather analysis and crop weather calendar:

Definition of phenology, developmental scales, crop phenology and crop growth cycles, critical growth stages, role of temperature for the duration of all phonological stages, importance of the phenological scale for adjusting crop management practices, phenology of major crops *viz*. cereals, pulses, oilseeds, cash crops, tuber crops, effect of temperature, photoperiod, moisture stress and vernalization on phenology, phenological models, general ideas on crop weather relationship, crop weather calendars, preparation, content and application.

Practicals on:

- Crop observations - Phenology of major crops (*viz*. rice, wheat, maize, sorghum, cotton, sugarcane etc.), germination count, periodic growth observations,
- Preparation of crop weather calendars, Preparation of crop outlook

15. Agroclimatic classification:

General concepts, criteria for climatic classification, climatic classification and its application in agriculture, Koppen's, Thornthwaite's, Troll's and Papadakos's classifications. Agroclimatic indices and different agroclimatic zones, Thornwaite's, humidity, aridity and moisture adequacy indices, Moisture availability index, agroclimatic classification based on dependable moisture availability index, start, end and length of growing season, selection of crops and cropping systems based on length of growing season. agroclimatic classification based on principle component analysis, concept of agroclimatic zones, Agroclimatic Classification of India.

Practical on:

Computation of different agroclimatic indices.

16. Effects of temperature on crops:

Factors affecting soil and air temperature, concept of cardinal temperatures, optimum crop temperatures, Cardinal temperatures of field crops, Growing Degree days, heat tolerant crops, heat transfer from plants leaves. Leaf temperature in relation to air temperature. Low /high air temperature and plant injury, combined influence of temperature and photoperiod (day length) on crop development. Effects of temperature on photosynthesis and respiration of crop, Vant Hoff's Law of temperature coefficient, thermoperiodism, nyctoperiod.

Practical on:

Computation of growing degree days of different crops.

17. Agromet Advisory Services (AAS) for farmers:

Origin of concept of 'services to farmers', aim of operational agrometeorology, concept of agrometeorological advisory services – background, scheme, functions, application of weather based decision systems(Agro DSS),development of agrometeorological information, determining the requirements of users, participating approach and engaging with farmers, development of products and services to best meet the users' needs, panel of experts from multiple disciplines for preparing advisory, framing of AAS bulletins based on medium range weather forecasts (MWRF), Concept of integrated AAS, location(district and block levels) and area specific advisories – users' demand, Tiers of integrated AAS, and their functions, infrastructural facilities, multichannel dissemination like print media, electronic media etc., connectivity for real time dissemination, new dimension in dissemination technology – internet based communication system and use of mobile phones, mobile apps for AAS, providing training, education and extension support systems for agrometeorological services, extension activity for technology transfer, feedback mechanism, agromet product generation

for advisory preparation, utilization of location specific agromet products in advisories preparation, Techniques used for AAS impact quantification, Assessing the economic value of agrometeorological services, utility of weather forecast in Agrimet Advisories for minimizing the impact of extreme weather events, improving agromet advisory services based on feedback, better forecast – holistic approach, need for greater user feedback in improving the dissemination and communication of AAS.Introduction to crop weather watch group. Agromet advisory Services under climate change and variability condition -- provision for inclusion of advice relating to seasonal climate forecasts as well as inclusion of current local trends (such as flowering date and flood height etc.) to improve farmer's capability to deal with farming practices under changing climate. Concepts and need of AAS bulletin based on extended range forecast system (ERFS), extended range weather forecast used for preparation of AAS bulletin, inputs and approaches for framing ERFS agromet advisories.

Practical on:

i) Hands on experience for agromet product generation for advisories preparation,

ii) Hands on experience in preparation of AAS bulletins based on MRWF and ERFS,

iii) Hands of experience on online generation of AAS bulletins,

iv) Mechanism for collecting feedback.

18. Micrometeorology:

Definition and scope of micrometeorology in agriculture, micro, macro and meso scale meteorology, Influence of soil surface on microclimate, measurement and empirical relationships of wind and temperature profiles over different surfaces, Importance of lower region of atmosphere, Profiles of radiation, temperature, vapour pressure, humidity, wind and CO_2 in micro layers and within plant canopy under different stability conditions, their agricultural significance, Modification of microclimate due to cultural practices, intercropping, topography, shelter belts and wind breaks, micro climate within forests, green house climates. control of physical environment through irrigation, windbreaks, frost protection, manipulation of radiation and water use through intercropping systems.

Air temperature and sensible heat transfer, moisture near ground surface, Laminar and turbulent flow, turbulence and wind profiles near the ground surface, Distribution of important meteorological parameters in boundary layer, application of turbulent processes in agricultural processes like photosynthesis, Reynold stress and Richardson’s number, Artificial modification of microclimate, interception and disposition of solar radiation, roughness and zero plane displacement for short and and tall crops, implications of roughness in micrometeorology and plant environment. Energy balance over crops, Instruments and measuring techniques in micro meteorology.

Practicals on:

Hands on experience in micrometeorological experiments.

19. Crop yield forecasting models:

Fundamentals of crop modelling, Importance of yield prediction models, methods of crop yield forecasting, introduction to simulation models / DSS and their importance, DSS structure and crop simulation models, Weather based mathematical models for estimating yield and their limitations, use of agricultural technology in crop yield models, application of principal component analysis and neural network in yield forecasting, their advantages and disadvantages over other models, Application of curvilinear technique in crop yield forecasting, its relative merits and demerits in relation to conventional models, Fischer's regression, technique and its use in yield forecasting, Crop weather relationship, emerging from the formulation, yield moisture index, generalized monsoon index and their application in yield forecasting, limitation of different models.

Types of simulation models, calibration and validation of crop simulation models, characteristics of crop simulation models like DSSAT, Infocrop, WOFOST, APSIM etc., minimum data set (MDS), application of crop simulation models for framing agromet advisories,use of seasonal rainfall forecasting for informed cropping decisions--crop yield variability simulations of cropping systems; application of crop growth simulation model for climate change impact assessment – evaluation of crop responses (development, growth and yield) based on thermal time (GDD, ^{O}C) to reach specific development stage, crop yield responses with and without heat stress effects, implications of climate change on harvestable yield and final yield.

History and concept of 'Forecasting agricultural output using space, agrometeorology and land based observation (FASAL)', major crops considered under FASAL, identification of states and districts for generating National level yield forecast, different methods used under FASAL.

Practical on:

i)Identification of parameters for crop modelling.

ii)Crop yield prediction with statistical techniques using different meteorological parameters.

iii)Running of crop simulation model for crop yield prediction and for use in framing Agromet advisories.

20. Dryland agriculture:

Dryland farming – basic principles, problems of rainfed crop production, climatic factors affecting dryland farming, soil water balance for dryland crops and assessment of water stress, estimation of yield reduction in relation to soil moisture stress, sequential effect of water deficits,

resistance of crop to water stress, role of humidity and mulches in dryland agriculture, role of anti transpirants in conservation of soil moisture, Land and water management techniques in dryland farming in reducing water loss, management of dryland agriculture, introduction of heat- and drought- tolerant crop varieties, concept of contingent crop planning.

Practical on:

(I) Computation of soil water balance parameters for dryland crops

21.Pest and diseases, concept of IPM and forewarning models:

- Definition of pests (insects and diseases), kind of crop pests and their classification, population balance, classification of insects, insects of agricultural importance, insect pests with long range migration, methods and symptoms of infestation, impact of weather factors on insects and their infestation.
- Definitions, types of crop diseases and their causes, Classification of pests and diseases of field crops, disease progress in space and time, methods of infestation, symptoms of diseases- weather relationship, factors for development of diseases in field crops, their meteorological aspects, leaf wetness period for outbreak of diseases in relation to favourable weather conditions, Aerobiology, characteristic symptoms of virus diseases of plants, plant diseases caused by bacteria and fungi (plants without root system and chlorophyll).
- Development rates of insect pests, meteorological factors favourable for insect pests,Operational aspects, pest forecasting and its limitations, monitoring pests population – concept of ETL, various control measures, production of warnings and information for crop production measures and their methods of dissemination, Mathematical models for control of pests and diseases, forecasting the development of disease pathogens in plants by generating biological models, concept of IPM in balancing ecosystem , minimizing environmental pollution, vegetative wetting forecast to control plant disease, developing forewarning models for outbreak of pests and diseases, monitoring of pests and diseases using remote sensing techniques. Pest management under changing climate.
- Types of locusts in the form of various species of grasshoppers, their classifications and breeding habits, Meteorological conditions favourable for growth of locusts, life-cycle of desert locust, regional and seasonal distribution of locust breeding and their global migration. Importance of weather information (i.e., rainfall, temperature and wind) in locust control, Organizational set up of locust monitoring in India and in other countries, Role of India Meteorological Department in locust control.

Hands on practical:

(i) Exercise on climatic conditions favourable to outbreak of pests and diseases by multiple regression eqn.

(ii) Exercise on determining the threshold temperature for the development of pests.

(iii) Exercise on disease severity values for the infection of crop as a function as a function of leaf wetness period.

22.Global warming, climate change and their impact on Agriculture:

Direct and indirect effects of climate change on agriculture, climate change and crop production, shift of crop zones as a result of climate change, impact of CO_2 on food production, ozone hole and its impact on agriculture, Combined effects of CO_2, UV-B and/or O_3 on plants,Green house gases,agriculturalsources and sinks of greenhouse gases, physical and biogeochemical feedback processes, greenhouse effect and global warming, its impact on agriculture, (and possible remedial measures.)mitigation of agricultural emissions of greenhouse gases.

Climate change impact on components of water balance (i.e., precipitation, evaporation, actual evapotranspiration, soil moisture, and ground water resources) affecting agricultural production, impact on flood frequency, drought frequency, river flows, lakes, snow and land ice, glaciers and small ice caps, and their agricultural implications, prospects for adaptation measures, effects of higher CO_2 on soil fertility and productivity, climate change impact on soil dynamics and processes : implications for agriculture, adaptation to climate change impact.

CO_2 effects on plant growth process: plant stomatal density and stomatal functioning, plant water use efficiency, response of the plants to global warming – CO_2 fertilization effect, crop growth simulation model for climate change impact assessment – climate change impact on crop development and yield, biodiversity of crops and livestock and climate change, adaptation of agriculture and livestock to climate change, technological potential to adapt,

Differential responses of plant species to elevated CO_2 and global food security, impact of extreme weather events on food security, adversity of crop pest and diseases and food security, climate change impact on fisheries and forestry affecting food security., impact on risk of hunger – global hunger index

Climate Risk Management, meteorological conditions prevailing in green house, animal house, poultry house. Sensitivity, adaptation and vulnerability to climate change and extreme weather events. International policies, protocols, treaties for reduction in greenhouse gases and carbon emissions, carbon sequestration, carbon credit etc.

23. Benefits and Challenges of weather forecast in agriculture:

Weather forecasting for agriculture, Scope and use of of different types of forecast for agriculture and water resources management, techniques of different range forecasts, statistical and synoptic techniques and objective methods for MRF, numerical models for MRF and their potential – application of Model Output Statistics to NWP outputs to improve forecast skill and use of ensemble forecasting to produce improved medium range (3 to 10 days) weather forecast, verification of MRF.
Practical on: Hands on experience in MRF and extended range forecast.

24. **Principles of remote sensing (RS), geographical information system (GIS) and their applications in agriculture:**

Application of remote sensing and GIS in Agriculture

Concept of remote sensing (RS), spectrum of electromagnetic radiation, solar energy, reflectance, transmittance and absorptions, Atmospheric effects, energy interactions with earth surface features, spectral reflectance of vegetation, Soil and water, multi- spectral and thermal sensing, multi-spectral scanners and thermal radio-meters, visual interpretation of black and white colour images.

Satellite data collection, ground truth, computer aided digital data analysis and images processing, supervised and unsupervised classification, maximum likelihood classification technique, application in operational agrometeorology, preparation of classified maps, multistage, multispectral and multi-temporal approach for crop studies, detection of water stress, acreage and yield estimation, Computation of different vegetative indices, Limitations of optical RS, principle of microwave sensing, soil moisture estimation by microwave RS, Application in agriculture and water resources, meteorological and earth resources satellite, land – Sat, IRS and spot satellite systems.

Fundamentals of GIS, Spatial data analysis, retrieval of agromet parameters using satellite remote sensing data, Assessment of meteorological and agronomic conditions for decision making on drought using remote sensing, Operational use of remote sensing and GIS for soil and crop management – evapotranspiration, soil salinity, precision agriculture, crop growth and intercepted radiation, nutrient management, pest management, selection of growth trails and crop yield estimation, satellite based agro-advisory services, operational use of RS and GIS for irrigation scheduling, operational use of remote-sensing for identification of fishing zones, aquaculture and forest management through remote-sensing, other applications of remote sensing and GIS in agrometeorology.

Generation of Satmet and GIS products for use in operational AAS, National Natural Resource Management System (NNRMS) and monitoring of drought through Remote Sensing.

Practicals on:

i)Generation of composite NDVI images using INSAT data and monitoring of crop growth for application in framing agromet advisories.
ii)Determination of soil moisture using space borne passive microwave sensors.
iii)Soil moisture retrieval in vegetative region using Synthetic Aperture Radar (SAR) and optical data.

25. Role of weather, climate on livestock production:

Importance of livestock information, climate and animal husbandry, safeguarding animal husbandry – housing and production, assessing of pasture productivity and grazing, forecasting of animal diseases – fasciollasis, foot- and--mouth disease and vector borne disease, weather impact on animal health, Identification of weather elements, effect of low and high temperature on livestock, heat transfer from animals , weather impact on poultry, Agricultural droughts, floods, famine & their impact on livestock, Thermal indices for livestock, Contingent planning under drought situation to optimize livestock production, Livestock and its health, Dairy development, Poultry farming, Fisheries -- effect of climatic factors particularly temperature on fisheries, Management of agrometeorological as well as livestock data, Role of weather on development of pests & diseases of domestic animals, Weather based animal disease monitoring, Effect of weather conditions on animal production, loses of water from the body, growth rate and body weight, reproduction, grazing habits and food intake, milk production, sun-burnand photo sensitive disorders. Reducing impact of weather climate on livestock production, environmental modification, reducing impact of livestock production on climate.

Livestock management, provision of proper environmental conditions for livestock : milk cattle, goat and sheep, pigs, sucking pigs and poultry, adaptations and adjustments for livestock under changing climate.

Practicals on:

Hands on experience in formatting AAS bulletin using livestock related agrometeorological products.
(i) Exercise on expected milk production loss for cows due to high temperature.

26. Project work on operational agrometeorology/ Agromet product generation:

Collection and tabulation of data, review of literature, analysis of data, result discussion, presentation, submission of report/ dissertation.

27. Visit to Experimental Farms, University and SDA:

28. Examination and Viva voce:

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