Subjects Taught:

- Dynamic Meteorology
- Numerical weather Prediction
- Physical Meteorology
- Synoptic Meteorology and Aviation Meteorology
- Climate Science and Hydro-Meteorology
- Physical Oceanography & Ocean Atmosphere interaction
- Satellite Meteorology and Radar Meteorology
- Statistics and Computer programming & application

Appendix-VI

India Meteorological Department

Meteorological Training Institute

Proposed Revised Syllabus
For
Forecasters Training Course

(6 months duration)

For all departmental Met-B/Met-A, who have successfully completed Intermediate Training course in Gen Met or Integrated Met training Course.

2019

Proposed Syllabus for e-learning phase of Forecasters Training Course
Duration = 2 Months
Course content

Paper-I (Dynamic Meteorology & NWP)

Part-A: Dynamic Meteorology

1. Definition & Mathematical expression of Circulation. Absolute and relative circulation. Circulation theorems. Interpretation of terms in the circulation theorem. Application of circulation theorems.

2. Pressure tendency equation (No derivation): physical interpretation, in detail, of each term, representing different mechanisms of pressure change. Different isobaric patterns and their movement.

3. General definition of wave. Wave- amplitude, frequency, wave length, wave number. Definition & concept of Phase velocity, group velocity, Dispersion relation, dispersive wave, non- dispersive wave.

4. General definition of hydrodynamic instability. Categorization of hydrodynamic instability in different ways.

5. 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, favorable for Convective turbulence and Mechanical turbulence. Depth of PBL and its diurnal and seasonal variation at a place. Different sub layers in PBL.

6. Energetics aspects of General circulation: Definition of Atmospheric energetics. Different form of atmospheric energies, viz., internal energy, potential energy and kinetic energy. Expressions for internal energy.

Part –B: Numerical Weather Prediction

1. History of NWP. Hierarchy of NWP models. What is broadly understood by the term ‘NWP model’? Different components of a NWP model (basic concept only). Definition of Initial & boundary value problem (IVP & BVP). NWP as IVP+BVP.

2. Basic concepts of objective analysis & initialization.

Paper-II (Physical Meteorology)

Physical Meteorology

1. Thermal structure of the atmosphere; troposphere, stratosphere, mesosphere, thermosphere, and explanation of these. Basic ideas and concepts of QBO, and stratospheric warming. Tropopause breaks.

2. Air pollution: Basic ideas and concept of air pollution; sources, causes, Impact of air pollution on health, acid rain meteorological factors affecting air pollution, wind rose diagram.

Paper-III (Synoptic Meteorology & Aviation)

Part-A: Synoptic Meteorology

1. Double equatorial troughs – depiction of synoptic features in the equatorial regions in different seasons for the year.

2. Air masses and fronts: production and transformation of air masses; conservational properties, the exchange properties and formation of air masses; air mass sources in winter and summer; classification of air masses; types of transformation. – Surfaces of discontinuity; Typical structure of fronts; slope of frontal surfaces; classification of fronts; kinematics and dynamic boundary conditions; Frontogenesis and frontolysis; Frontogenetical fields; Principal frontal zones.

3. The Jet –streams. Various jet streams over the globe. Characteristics features of the various Jet Streams.

4. Winter season – Western disturbances and associated weather (cold waves & fog).

5. Hot weather season – Norwesters; Dust storms and dust raising winds, thunderstorms, hail storms, heat wave.

Part-B: Aviation Meteorology

1. An overview of Aviation Organisations and their functioning: Definitions: WMO, ICAO, CAeM. Functioning of IMD's aeronautical Meteorological Organisation. The rights and responsibilities of aviation met offices, the terms and conditions of MoU/ LoA with AAI and other users. Meteorological publications of ICAO, DGCA, AAI, and IMD. Registers and formats used in Aviation met services.

2. Effect of Weather on aviation: Effect of various atmospheric parameters on different phases of flight operation. Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere.

3. Observation and reporting of weather for Aviation services: METAR code and template. Reporting of meteorological elements in METAR. Concepts of TREND forecast. Prepare a METAR message with TREND forecast using the given observations.

Paper-IV: (Climate Science & Hydro-Meteorology)

Part-A: Climate Science:

1. Extra-tropical – Air mass climatology - January and July; Geographical distribution of Fronts, Frontal zones - Extra-tropical cyclones – frequency, regions of blocking and cyclogenesis.
2. Angular momentum cycle. Water Cycle.
3. Basic ideas of Agricultural meteorology including energy and water budget of crops, and crop yield relationship with weather elements, crop weather calendar.

Part-B: Hydro-Meteorology

1. Hydrological cycle
2. Hydro met Disasters, Flood and Drought

Paper-V(A): (Physical Oceanography& Ocean Atmosphere interaction)

1. Geographical data relating to oceans and their importance. Physical properties of sea water; T – S diagram
2. Marine pollution; its sources, causes and its impact on marine environment briefly.
3. Global warming and sea level rise and its importance for coastal areas, Small Island and marine ecosystem, in brief.

Paper-V(B): (Satellite Meteorology & Radar Meteorology)

Part-A: Satellite Meteorology.

1. Remote Sensing, principles of Remote Sensing, Application in Meteorology, Introduction to Satellite Meteorology including Orbital Mechanics.
2. Meteorological Satellites, Polar Orbiting, Geostationary satellites.

Part-B: Radar Meteorology.

1. Radar principle: Doppler Radar, Wind profiler, MST Radar, LIDARS

Paper-V(C): (Statistics and Computer programming & application)

Part-A: Statistics

1. Correlation & regression
2. Elements of sampling

Part-B: Computer programming & application

MS office, Internet browsing

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Class room learning Phase of Forecasters Training Course
Total duration = 4 months = 16 working weeks
Number of working days in one working week = 5
Total number of working days= 6 x 16= 80
Joining & induction= 1 day
Recapitulation of e-learning phase = 5 days
Test on e-learning phase =5 days
Relieving = 1day
Final Exam = 6 days (5 Theory & 2 practical (FN & AN))
Viva voce = 1day
Project Presentation =1 Day
On the Job Training = 15 Days
Number of working days available for training = 80-35=45 days
Number of periods in one working day: 6 periods each of 75 minutes duration
Total number of periods available for training = 45 x 6 = 270

Periods of teaching for each subject

Paper	Subject	Periods
I	Dynamic Meteorology (Theory + Practical)	26+10=36
	Numerical weather prediction (Theory + Practical)	18+8=26
II	Physical Meteorology(Theory + Practical)	20+8=28
III	Synoptic Met (Theory + Practical)	24+12=36
	Aviation (Theory + Practical)	28
IV	Climate Science	22
	Hydrometeorology	10
V(A)	Physical Oceanography& Ocean Atmosphere interaction	18
V(B)	Satellite Meteorology(Theory + Practical)	25
	Radar Meteorology	12
V(C)	Statistics (Theory + Practical)	10+7=17
	Computer programming & application	12
	Total number of periods	270

Dynamic Meteorology

Total duration = 36 Periods of 75 minutes

Theory (26 periods)

- **Circulation and vorticity (5 P):** Definition of vorticity along with its mathematical expression. Physical meaning of Curl of a vector. Components of vorticity vector. Relation between circulation and vorticity. Relative vorticity in natural co-ordinate. Explanation of curvature and shear vorticity with specific examples. Concept of potential vorticity. Conservation of potential vorticity (conceptual) and its application. Vorticity equation in different Co-ordinates (No derivation). Physical interpretation of different terms. Scale analysis of vorticity equation. Application of vorticity equation. Geostrophic vorticity.
- **Perturbation theory & Atmospheric Waves (5 P):** Why perturbation method has been proposed? Hypothesis in Perturbation method. To show that perturbation method can remove non- linearity from governing equation. Atmospheric waves: Rossby wave, Gravity wave (External, Internal & Inertia), Kelvin wave. Detailed discussion about their dispersion relation (No derivation), Phase speed & group velocity. Physical interpretations of above. Forced flow across a mountain, critical flow, sub critical flow, super critical flow, Froude number and its application.
- **Hydrodynamic instability (4 P):** Barotropic & Baroclinic instability, their definition, analysis, criteria and examples. Brunt-Vaisala instability: Definition & its analysis. Inertial instability: Method of analysis and instability condition. CISK: Definition and explanation.
- **Planetary boundary layer (4 P):** Boussinesq approximation and its physical interpretation. Governing equations in the PBL using Boussinesq approximation. Reynolds averaging technique. Concepts of eddy flux, eddy flux divergence in detail and their importance. Governing equations for mean motion in PBL. Definition of a closed system and an open system of equation. Assumptions to make the system of governing equations, closed. Turbulent kinetic energy equation (No-derivation) and the physical interpretation of different terms . Concept of Flux Richardson number. K-Theory/ Flux-gradient theory/ Similarity theory. Mixing length theory. Logarithmic vertical profile of horizontal wind in viscous sub layer using similarity theory. Concept of roughness length and Von-Karman constant. Vertical profile of mean horizontal wind in atmospheric/ oceanic Ekman layer. Depth of Ekman layer. Concept of Ekman layer pumping. Secondary circulation. Spin down. Relation between mass transport in oceanic Ekman layer and surface wind stress.
- **Fundamentals of atmospheric energetics (5 P):** Global internal energy, global potential energy and global kinetic energy equation (Derivation not required). Detailed physical interpretations of generation of potential energy, global internal energy and its conversion into kinetic energy. Detail 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 energies 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). Concept of available potential energy (APE). 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 (3 P):** Global angular momentum budget equation. Interpretation of mountain torque, frictional torque and meridional transport of zonal angular momentum. Different mechanisms for meridional transport of zonal angular momentum.

Practical (10 periods)

- Computation of horizontal divergence and vorticity using curvature method (2 P).
- Computation of geostrophic wind and geostrophic vorticity at a point using model wind data (2P).
- Computation of thermal wind and thermal advection (1 P).
- Computation of vertical velocity using kinematic method from model wind data (2 P)
- Use of GrADS for plotting of important IMD's NWP output viz., divergence/vorticity, vertical velocity etc. (3P)

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Numerical weather prediction

Total duration = 26 Periods of 75 minutes

Theory: (18 Periods)

- **Numerical Methods (2 P):** Basic concepts about different methods for solving model equations: Finite difference method. Implicit & semi implicit scheme. Numerical stability criterion (CFL). Spectral method.
- **Operational Numerical Models (3 P):** Operational NWP modelling system: Global Forecast System, Regional and mesoscale forecast system (WRF, ARPS), Nowcast model, Climate Forecast System, Ensemble prediction system, multi-model ensemble technique, Cyclone model Hurricane WRF, vortex relocation and initialization, Antarctica model Polar WRF, Storm Surge modelling, Ocean State modelling, Crop Weather Model.

- **Parameterization of physical processes (4 P):** Basic concepts of Planetary boundary layer, Land surface processes, Convection (Deep cumulus and shallow convection), Large scale condensation, Radiation (short wave & long wave parameterization), Cloud Radiation interaction, Dry and moist convective adjustment processes, Cloud microphysical parameterization
- **Data Assimilation (Pre-processing) (4 P):** Different objective analysis schemes, Cressman techniques, OI scheme (Optimum interpolation). Global Data Assimilation System: Decoding and quality control of GTS conventional/non-conventional observations (including Radar and satellite data), Regional and global data assimilation system: variational data assimilation, 3D vibrational data assimilation, technique (WRF Var)
- **Post-processing of NWP Products (5 P):** Different products: Direct and Derived, Post processing of model output: Model output verification: Forecast skills, Forecast errors, Systematic errors, Bias correction. Down scale of NWP model like location specific forecast, Statistical interpretation, NWP products for aviation services, hydrological services, NWP products for localized 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.

Practical (8 Periods)

- Basics of Linux O.S, Configuration of WRF model, Experiment with nesting and nest down techniques, sensitivity experiments for physical parameterization. **(2 P).**
- Model diagnosis: Graphics package for illustration of NWP products, Case study of monsoon depression, cyclonic storm, localized severe weather with the use of derived products like divergent, vorticity, flow pattern, precipitable water content, vertically integrated moisture flux, rainfall etc. Use of model verification tool MET. Bias correction (**3 P).**
- Experiments with nowcast tool, **(3 P).**

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Physical Meteorology

Total duration = 28 Periods of 75 minutes

Theory (20 Periods)

- **Thermal structure of the atmosphere**; Upper-troposphere-lower-stratosphere exchange processes. (1 P).
- **Theory of atmospheric visibility**; atmospheric optics (basic ideas). Slant Visibility and Runway Visual Range. Effect of air pollution and relative humidity on visibility. Meteorological Optical Range (MOR); concept and application. (4 P).
- **Cloud Physics** – Classification of clouds, Cloud Nucleation (Homogeneous and Heterogeneous) growth of cloud droplets by diffusion and by collision and coalescence; Cold clouds Ice nuclei; formation of ice, graupel, hail and snow; Bergeron-Findeisen Process, weather modification (Hail suppression and precipitation enhancement). (6 P).
- **Atmospheric Electricity,** Ions and electrical conductivity in the atmosphere, Electric field, air earth current and space charge, Electrical structure of the cloud and lightning discharge, thunderstorm electrification mechanism, (4 P).
- **Ozone**; Tropospheric and Stratospheric Ozone, Measurements of ozone, Destruction of Ozone, Ozone hole, CFC and awareness of Montreal protocol. (5 P).

Practical (8 P)

- Plotting of Tephigram and computation of LCL, CCL, LFC, LNB, Potential Temperature, Wet Bulb Temperature, Equivalent Potential Temperature, Equivalent temperature. (2 P)
- Study of stability conditions for given sounding data (Conditional Instability, CAPE and CINE). (2 P).
- Determining the precipitable water vapor content. (2 P).
- Computation of various Stability Indices for prediction of thunderstorms (2 P).

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Synoptic Meteorology and Advanced Weather analysis & forecasting

(Duration = 36 Periods of 75 Minutes)

Theory: (24 Periods)

1 Tropical Cyclones – life cycle; surface and upper air structure; pressure; temperature, wind, humidity and cloud fields; Energy aspects, formation of tropical storms, theories of formation, intensification and movement of tropical storms (3P)

2 Polar front jet stream – subtropical jet stream, polar night jet stream, Easterly jet stream, theories of formation, weather development, cloud and clear air turbulence. (2 P)

3 winter season –Disturbance from the east, fronts in the Indian region (2P)

4 Hot weather season –Tornadoes, Jet streams, cyclonic depression and storms in the Indian seas (2 P)

5 The southwest monsoon season: - Monsoon onset, strong monsoon, weak monsoon, revival of the monsoon, monsoon depressions, heavy rainfall, easterly jet stream, influence of extra tropical systems, Chinese weather systems, effect of typhoons and other systems from the east, withdrawal of the monsoon. Monsoon variability at various scales (4P)

6 The northeast monsoon season – strong and weak northeast monsoon, depressions and storms in the Indian seas, forecasting their information, movement, re-curvature, jet streams. (3 P)

7 **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. (4 P)

8 **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. (4 P)

Practical: (12 Periods)

1. Analysis and issue of inference and forecasts for a chart sequence for tropical cyclone, Satellite and RADAR pictures should also be used along with the chart sequence.
2. Use of synergie of Metcap+ for weather analysis and forecasting.
3. Analysis and issue of inference and forecasts for a chart sequence for a monsoon depression
4. Analysis of break monsoon condition and revival of monsoon
5. Analysis and issue of inference and forecasts of a widespread thunderstorm activity case
6. Analysis and issue of inference and forecasts for a chart sequence in a western disturbance case
7. Analysis and issue of inference and forecasts in an onset and advance of monsoon case
8. Analysis of extended charts – surface and upper air of January and July cases and their 24 hours' prognosis.
9. Interaction between westerly and easterly systems
10. Impact-Based Forecasting Hands on exercises: Preparation of warnings, Developing impact tables, Vulnerability assessments. Impact based forecast and warning.

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Aviation Meteorology

Total Duration = 28 Periods of 75 minutes

TOPIC	**Sub topic**	**Objective: On completion the trainees should be able to:**	**No. of periods**
1. An overview of Aviation Organisations and their functioning.	Regulatory materials (Annex-3/ CAR/ Codes/ Manual)		1
2. Effect of Weather on aviation	1. Airport minima, low visibility procedures, categories of runways	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	2
	2. Weather hazards to aviation		
	3. Climatology of weather hazards		
3. observation and reporting of weather for Aviation services	1. METAR/ localSPECI code and template	Explain the latest METAR/ SPECI code form and Template Explain the SPECI criteria Prepare a METAR/ SPECI 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	3
	2. Local SPECI Criteria		
	3. Reporting of meteorological elements in METAR/local SPECI		
	4. Concepts of TREND forecast		
	5. Prepare a METAR/ localSPECI message with TREND forecast using the given observations		
	6. MET Report/ SPECIAL Report Template		
	7. Examples		
4. Tools for	1. Tools and products available for	To describe the source of information/ product	1

forecasting	aviation weather forecasting and their use	and their use in aviation weather forecasting	
5. 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	2
6. 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	1
7. Take-off forecast	Description of take-off forecast	Issue take-off forecast Verify take-off forecast	1
8. Route Forecast	1. ROFOR Code 2. Decoding of the coded ROFOR in plain language 3. Instructions on preparation of MET- T3 4. Preparation of a route forecast in MET- T3 form 5. Preparation of a route forecast in ROFOR code form 6. Verification procedures	Describe ROFOR code Issue route forecast in ROFOR code Decode a ROFOR and prepare the route forecast in MET-T3 format. Verify ROFOR	3

9. SIGMET	1. Template for SIGMET 2. Elements of SIGMET 3. Types of SIGMET 4. Issue of SIGMET 5. Verification of SIGMET 6. SIGMET Test procedures	Explain the SIGMET template Issue SIGMET from the given information Verify SIGMET Explain SIGMET Test procedures	2
10. Aerodrome warning,	1. Responsibility of AMO and AMS in issuing warnings 2. Warning elements and Warning	Explain the responsibilities of AMO and AMS in relation to issuance of warnings List the warning elements	2

Warning for light aircrafts and Wind shear warning	format/ Template 3. Issue Aerodrome warnings 4. Verification of aerodrome warnings 5. Issue wind shear warning	Explain the format of the warnings Issue Aerodrome warnings Issue wind shear warning Verify the warnings	
11. 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	1
12. 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
13. Briefing and documentation	1. List of documents to be provided 2. List of items to be displayed in met offices 3. Briefing of low level flights 4. Online Briefing System (OLBS) of IMD	List the items to be provided in documentation List the items to be displayed in an aviation met office To retrieve the products from OLBS or other sources and prepare briefing folder for scheduled flights. To upload messages/ forecasts/ warnings on OLBS	2

		Prepare a briefing folder for flights covering various levels.	

14. 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		
15. Accident Investigation	1. Introduction	Explain the procedures to be followed by various offices	1
	2. Responsibilities of AMS/ AMO in accident investigation		
	3. Responsibilities of RMC		
	4. Preparation of Reports		
16. VIP/VVIP movement	1. Basic procedure to be followed during VIP/ VVIP Flights	Explain the procedures to be followed by various offices	1
17. Airport Meteorological Instruments	1. Basic functions, siting and use of airport meteorological system	List and Describe the components of airport met instruments system	1
	2. Reporting of manual RVR	To narrate the procedures of assessing RVR manually	
	3. NOTAM Procedure	Explain NOTAM procedure	
Total classes			**28**

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Climate Science

(Total duration = 22 Periods of 75 minutes)

- **Synoptic Climatology (2 P)**
- **Tropical:** climatology of SST, ITCZ, Sub-tropical anticyclones, trade winds, rainfall, OLR of January, April, July and October– annual frequency of tropical cyclones –upper winds and jet streams of January, April, July and October (2 P)
- **Global Climates in brief (3 P)**

  Asia, Africa, North America, South America, Europe, Australia, Arctic and Antarctic.
- **Energetics and the Ocean-Atmosphere Heat Engine (2 P)**
- **Variability in the climate system (6 P)**

- Interannual and interdecadal variability, Monsoon (southwest and northeast) Variability, diurnal, intraseasonal, Interannual, decadal, long term trends, Teleconnection patterns (2 P)
- El Nino/ Southern Oscillation, Climatology, Dynamics and prediction, links with global climate (2 hours)
- North Atlantic Oscillation, Arctic Oscillation, North Pacific Oscillations, (1P)
- Indian Ocean Dipole, statistics, dynamics and links with global climate (1P)

- **Climate modeling and prediction:** Mathematical simulation of climate, model simulations of mean climate, Fundamentals and methods of long range forecasting, IMD's long range forecast models, Dynamical models for long range forecasts, Skill of long range forecasts **(3 P)**
- **Science of Climate Change:** Basics of Climate Change (science), Climate Feedbacks (water vapour, cloud, oceans, snow and ice), Observed climate change over India and globe, Future climate projections, IPCC report results **(2 P)**
- **Climate services (2 P)**
- **Paleo-climatalogy (2 P)**

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<u>Hydrometeorology</u>

(Total duration = 10 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. (1 periods)

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. (2 periods)

RAINFALL MONITORING AT IMD: Rainfall Normal, Rainfall monitoring and Operational Rainfall Statistics at IMD. (1 periods)

RAINFALL ANALYSIS: Statistical Series different types of series in rainfall analysis. Extreme value analysis. Return periods. Rainfall intensity or depth–duration–frequency relationships. Mass rainfall curves. Depth–area–duration analysis. Probable maximum precipitation. (2 periods)

RAINFALL RUNOFF RELATIONS: Infiltration, infiltration capacity. Rainfall Runoff Models, Hydrograph and Unit Hydrograph. (1 period)

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, (1 period)

QUANTITATIVE PRECIPITATION ESTIMATE: Precipitation estimates from satellite and radar. Delineation of flood inundation from remote sensing satellite. (1 period).

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. (1 periods)

Nowcast and Forecast for early warning (special and temporal):

Heat wave warning

Estimation of extreme rainfall

IDF for urban storm water drain design

Flood forecast using hydrological models

Flash flood estimation and warning

Uncertainty analysis (for forecast / nowcast products)

Extended range (1month) and long range (3 months) drought situation based on extended and long range modelled weather products of IMD

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Physical Oceanography

(Total duration = 18 periods of 75 minutes)

- **Ocean Dimensions**, Shapes and Bottom Materials (1 P).
- **Physical properties of seawater**: Temperature, Salinity and Conductivity, Density, Sound in the sea, Light in the sea, Colour of seawater. Temperature, Salinity and density distributions. Transparency of seawater. (2 P).
- **Typical Distributions of Water Characteristics in the Ocean**: Collection and analysis of data, General statics and area descriptions. (2 P).
- **Water, Salt and Heat Budgets of the Ocean**: Conversation of volume, Conversation of salt, Conversation of Heat Energy; Heat budget of the oceans: Heat budget terms, Short and Long wave radiation, Evaporation, Heat conduction. Geographic distribution of Heat Budget terms. Heat budget of Arabian Sea and Bay of Bengal. (3P).
- **Ocean Observations**: Tides, Waves, Ocean currents, Bathymetry, Ocean colour, Transparency, Temperature, Salinity, Position fixing at sea and Marine Meteorological parameters. (3 P).
- **Waves, tides and currents**: Deep water waves, shallow water waves, wave propagation, sea and swell waves; Types of tides, Sea level variations, Storm surges and tsunamis; Warm currents, cold currents, Longshore currents, rip currents, tidal currents. (3P).
- **Circulation and Water Masses of the Oceans**: Thermohaline circulation, Wind-driven circulation, Circulation and water masses. Ocean-Atmosphere interaction in tropics. (4 P).

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Satellite Meteorology

(Total duration = 25 Periods)

Theory (18 Periods)

- Meteorological Satellites: low-inclination orbits, Current and future meteorological satellites of the world. Payloads on meteorological satellites, INSAT, Kalpana, Metosat, GOES, Himmawari, FY, NOAA/NPP/JPSS, Metop, MeghaTropiques, Scatsat-1, Oceansat. (2P)
- Data Processing: Meteorological Data Processing System / Multi-Mission Meteorological Data Receiving and Processing System (MMDRPS). Generation of images in various channels. Basic ideas about Retrievals of meteorological products from the Imager data such as Atmospheric Motion Vectors and wind derived products, Sea Surface Temperature and Upper Troposphere Humidity (UTH), Outgoing Long-wave Radiation (OLR), Rainfall estimates techniques, Fog, Aerosols, Fire, Smoke, Snow Cover. Aerosol Optical Depth (AOD) and Normalized Difference of Vegetation Index (NDVI) from CCD. Concepts of Image Enhancement techniques, and RGB Images. Details features of Real Time Analysis of Product & Information Dissemination

(RAPID) web-based tools for satellite Data/products visualization. (5 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. (3 P)
- Principles of Sounding: Processing of data from infrared and microwave sounders. Retrieval of products from sounders, Temperature and humidity profiles and total ozone. (3 P)
- Interpretation of Satellite Images: Characteristics of various channels, Identification of typical clouds and weather systems from cloud imageries, Use of various satellite-derived products, Satellite bulletin and its interpretation. Tropical cyclones, their identification and grading using Dvorak's technique. Interpretation of microwave channel images. Images and products from various international satellites (5 P)

Practical (7 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. (2 P)
- Issue of satellite bulletins. (2 P)
- Assessment of T-number of tropical cyclone from satellite images using Dvorak's technique, (2 P)
- Use of satellite-derived products for weather analysis and forecasting, (1 P)

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Applied Radar Meteorology (12 Periods)

- Introduction to Weather radars. Different frequency bands used in the weather radars and their applications. Principles of pulsed radar, Polarimetric radars.
- Limitations and artifacts of Weather Radar, Common misconception/errors in radar products/data.
- Principle of Doppler Weather radar. Block diagram of Doppler Weather radar and explanation of its major components. Introduction to DWR Base products. Doppler Dilemma and velocity

unfolding techniques with examples. Range unfolding concepts.

- Derived DWR products (Hydrological, Wind)
- Warning products (Severe Weather Index, HHW)
- 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
- DWR Data formats. Proprietary and Open-source formats. Tools available in open domain for analysis. Hands-on

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Statistics

Duration =17 Periods of 75 minutes

Theory (10 Periods)

(1) Empirical Distributions and Exploratory Data Analysis:

Numerical Summary Measures: Location, Spread, Symmetry, Standardized anomalies

Graphical Summary Devices: Stem-and-Leaf Display, Box and Scatter plots, Histograms

Exploratory techniques for Paired Data**:** Ordinary, Rank, Serial and Auto-Correlation

(2) Statistical Forecasting:

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

(3) Forecast Verification:

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

Practical (7 periods)

- Testing of null hypothesis
- Time series analysis: Trend analysis, Cross correlation & Auto correlation with different lag. Harmonic analysis
- Multivariate regression analysis
- Statistical Package (SPSS /SYSTAT/ R Software/ MS excel) for advanced statistical applications

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Computer Programming and applications

(Total duration = 12 Periods)

- telnet, ftp, ssh, scp (1P)
- Website design (basics of HTML, PHP, JAVA etc.) (2 P)
- Fortran-90 Programming (2 P)
- Numerical Analysis: Practicals, Fortran (2 P)
- Introduction to Linux: user management, basic commands, Basics of Shell scripting (2 P)
- Function & Activities of NCDC, modality of data supply from NCDC to different users. (2 P)
- Database Management of meteorological data (1P)
- Basics of Quality Control of Meteorological data (if it is not covered under ' Function & Activities of NCDC...')

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