Government of India
Ministry of Earth Sciences
India Meteorological Department
Meteorological Training Institute

Lecture notes on
Aviation Meteorology
(E- Module) of

Forecasters Training Course (FTC)

Prepared by

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Syllabus for Aviation Meteorology

(E-learning phase of Forecasters Training Course)

Duration = 2 Months

Paper-III (Part B -Aviation Meteorology)

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.

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.

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.

PREFACE

These lecture notes have been prepared to meet the requirements of IMD departmental trainees who will undergo the e-learning module of newly introduced forecaster's course from April 2015. I, as a faculty in the Meteorological Training Institute (MTI), Pune, have been involved in the teaching of various meteorological subjects in different courses for the last many years. It is, probably so, I have been assigned the job of preparing the e-learning module of the Forecaster's course for the aforesaid subjects.

*While preparing the "**Aviation Meteorology"** lecture notes, a due care has been taken to cover the syllabus of e-module. Brevity of the topics has been kept in mind without sacrificing the core content. Help of various published aviation notes / materials of IMD have been taken in the preparation of aviation met notes and thus all such materials are duly acknowledged.*

I humbly extend my sincere thanks to D.G. IMD, New Delhi, ADGM (R) and DDGM (Trg), Pune for entrusting responsibility on me for writing lecture notes. I expect that the trainees may find lecture notes useful in their e-module of Forecaster's course and even derive benefits after the training programme. Updating the lecture notes is a continuous process and accordingly they may be modified as per the expectations of the trainees in their future versions. The notes have prepared, edited and compiled in a short span of time and thus some inadvertent errors may be possible. I will appreciate the valuable criticism / suggestions of my seniors and trainees / colleagues offered for enhancing the quality of these lecture notes.

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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.

INTRODUCTION

Weather affects aviation activities at various stages of operation. In order to ensure safe operations in all weather situations, National Meteorological Services throughout the world are obliged by law to make meteorological observations and forecasts and to establish and to maintain monitoring and warning systems in their countries. The objective of Aeronautical Meteorology is to contribute towards the safety, economy, regularity and efficiency of air navigation.

World Meteorological Organisation (WMO) sets standards and guidelines for meteorological service for aviation through its Commission for Aeronautical Meteorology. International Civil Aviation Organisation (ICAO) which is responsible for civil aviation regulations co-operates closely with WMO in all matters related to meteorology and common regulations are agreed to by both organisations.

WORLD METEOROLOGICAL ORGANISATION (WMO)

WMO is an intergovernmental Organization and acts as a specialised agency of the United Nations (UN) for meteorology (weather and climate), operational hydrology and related sciences. It is the UN system's authoritative voice on the state and behaviour of the earth's atmosphere, its interaction with the oceans, the climate it produces and the resulting distribution of water resources that regulates all activities related to meteorology and climate.

HISTORY

WMO was evolved from the International Meteorological Organisation (IMO). On 23rd March 1950, the WMO was formally established. To mark this important event, a few years later, the WMO declared 23rd March as World Meteorological Day – a day, which has since been appropriately celebrated each year.

It has more than 180 members. During the first congress, Geneva, Switzerland, was accepted as WMO's Head Quarter. In December 20th 1951, WMO became a specialized agency of UN. WMO is open to all states and territories, which administers a meteorological service of its own.

THE PURPOSES OF WMO

i. To facilitate world-wide cooperation in the establishment of networks of stations for making meteorological observations as well as Hydrological and other Geophysical Observations related to meteorology and to promote the establishment and maintenance of centres charged with the provision of meteorological and related services.

ii. To promote establishment and maintenance of systems for the rapid exchange of meteorological and related information.

iii. To promote standardisation of meteorological and related observations and to ensure the uniform publication of observations and statistics.

iv. To further the application of meteorology to aviation, shipping, water problems, agriculture and other human activities.

v. To promote activities in operational Hydrology and to further close cooperation between meteorological and Hydrological services.

vi. To encourage research and training in meteorology and, as appropriate, in related fields, and to assist in coordinating the international aspects of such research and training.

WMO- ORGANISATION: WMO comprises of the following constituent bodies:

i. The Congress

ii. The Executive Council

iii. The Regional Associations

iv. The Technical Commissions

v. The Secretariat

THE CONGRESS

It is the general assembly of delegates representing members and as such is the supreme body of WMO. Some of other important functions of the congress are:

- To adopt technical regulations covering meteorological practices and procedures.

- To establish Regional Association, to determine their geographical limits, co-ordinate their activities, and consider their recommendations.

- To establish Technical Commissions, to define their terms of reference, co-ordinate their activities, and consider their recommendations.

THE EXECUTIVE COUNCIL

This is the main executive body of the Organization. Its responsibility, therefore, cover the whole wide range of WMO activities. The main functions of the executive council are;

- Implementing the decisions of congress within the financial resources made available.

- Keeping under review all developments, which directly or indirectly have a bearing on the effectiveness of the Organisation.

 Submitting proposals and recommendations to the subsequent congress, including the proposed program and budget for the coming four-year period on the basis of the secretary-general's proposal in this respect.

The Council also is responsible for selection and distribution of WMO awards and making arrangements for the IMO lecture, delivered at each congress.

REGIONAL ASSOCIATIONS

The aim of a Regional Association (RA) is to provide co-operation among National Meteorological and Hydrological Services (NMHS) in a given geographical region in dealing with special problems of a regional nature. There are ***six RAs***, which are given below.

RA I : Africa

RA II : Asia

RA III : South America

RA IV : North and Central America

RA V : South west Pacific

RA VI : Europe

India comes under RA II – Asia. The functions of RA are:

 To promote the execution of the resolutions of Congress and the Executive Council in its Region;

 To consider matters brought to its attention by the Executive Council;

 To discuss matters of general interest and to coordinate meteorological and related activities in its Region;

 To make recommendations to congress and the Executive Council on matters within the purposes of the Organization; and

 To perform such other functions as may be conferred on it by Congress.

TECHNICAL COMMISSIONS

There are ***8 Technical Commissions*** and these are composed of individuals who are experts in the technical fields concerned and who are designated by the member countries. The Technical commissions are responsible for studying meteorological and hydrological operational systems, applications and research.

The present structure of the commissions is as follows:

I. Basic Commissions

a. Commission for Basic System (CBS)

b. Commission for Instrument and methods of observations (CIMO)

c. Commission for Hydrology (Chy)

d. Commission for Atmospheric Science (CAS)

II. Applications Commissions

a. Commission for Aeronautical Meteorology (CAeM)

b. Commission for Agricultural Meteorology (CAgM)

c. Commission for Climatology (CCl)

d. Commission for Marine Meteorology (CMM)

Each Technical Commission elects its president and vice-president. The presidents of Technical Commissions may participate without vote in the meetings of the Congress and of the Executive Committee.

THE SECTRETARIAT

The permanent Secretariat of the Organization is composed of a Secretary-General and such technical and clerical staff as may be required for the work of the organization. The Secretary–General is appointed by the Congress on such terms as the Congress may approve. The staffs of the Secretariat are appointed by the Secretary–General with the approval of the Executive Council in accordance with regulations established by the Congress.

The general functions of the Secretariat are as follows:

- To serve as the administrative, documentary and information centre of the Organization;
- To perform day-to-day program-management functions under the guidance of the Executive Council and in close co-operation with the Technical Commission in connection with the scientific and technical programs approved by Congress;
- To make technical studies as directed by Congress or the Executive Council;
- To organize and perform secretarial duties at sessions of Congress, the Executive Council, the Regional Associations and the Technical Commissions within the limits of the appropriate provisions of these Regulations;
- To arrange for the issue with the provisional agenda of an explanatory memorandum summarising the problems to be discussed in respect of each item on the agenda of each constituent body;
- To prepare or edit, arrange for the publication of and distribute the approved publications of the Organization;
- To provide an appropriate public relations service for the Organization;
- To maintain records of the extent to which each Member implements the decisions of the Organization;
- To maintain files of the correspondence of the Secretariat;
- To carry out the duties allocated to the Secretariat in the Convention and the regulations of the Organization, and such other work as Congress, the Executive Council and the President of the Organization may decide.

COMMISSION OF AERONAUTICAL METEOROLOGY (CAeM)

The technical commission directly concerned with the service to Aviation Meteorology is the CAeM. This commission examines and deals with all aspects of meteorological service to International Aviation. It keeps constant watch on technological advances and changes in aviation so that meteorological services can be improved or adjusted to meet them. CAeM has a working arrangement with ICAO. All regulations of WMO and ICAO concerning the provision of meteorological services to aviation are identically worded and have same status in the two organizations.

INTERNATIONAL CIVIL AVIATION ORGANISATION

The ICAO officially came into being on 4th April 1947. It has its Head Quarters at Montreal, Canada. In October 1947, ICAO became the specialized agency of the United Nations (UN). Non- governmental organizations which also participate in ICAO's work include the International Air Transport Association (IATA), the Airports Council International, the International Federation of Air Line Pilot's Associations, and the International Council of Aircraft Owner and Pilot Associations.

OBJECTIVES

The main purpose of ICAO is to develop the principles and techniques for international air navigation and to foster the planning and development of international air transport so as to:

- Ensure the safe and orderly growth of international civil aviation throughout the world;
- Encourage the arts of aircraft design and operation for peaceful purposes;
- Encourage the development of airways, airports and air navigation facilities for international civil aviation;
- Meet the needs of the peoples of the world for safe, regular, efficient and economical air transport;
- Prevent economic waste caused by unreasonable competition;
- Ensure that the rights of contracting states are fully respected and that every contracting state has a fair opportunity to operate international airlines;
- Avoid discrimination between contracting states;
- Promote safety of flight in international air navigation;
- Promote generally the development of all aspects of international civil aeronautics.

ORGANISATION

ICAO is made up of an Assembly, a Council of limited membership with various subordinate bodies and a Secretariat. The chief officers are the President of Council and the Secretary General.

THE GENERAL ASSEMBLY

The sovereign body of ICAO is the Assembly and is composed of representation from all contracting states. The Assembly meets once in every 3 years, reviewing in detail the work of the Organization in technical, economic, legal and technical assistance fields and setting policy for the coming years. It also votes a triennial budget.

THE COUNCIL

The governing body of ICAO is the Council. It is composed of 33 contracting states elected by the assembly for a 3 years term. The assembly chooses the council member states. The Council together with its sub-ordinate bodies, the Air Navigation Commission, Air Transport Committee, The Committee on joint support for Air Navigation Services and Finance Committee provide the continuing direction of work of the Organization. One of the major duties of the Council is to adopt "International Standard and Recommended Practices" and to incorporate these Annexes to the Convention on International Civil Aviation. Both ICAO Assembly and the Council function from ICAO's Head Quarters at Montreal, Canada.

THE SECRETARIAT

The Secretariat is headed by a Secretary General. It is divided into five main divisions, the Air Navigation Bureau, the Air Transport Bureau, the Technical Assistance Bureau, the legal Bureau and Bureau of Administration and Services. Corresponding to each ICAO committee and Division, is a Section of the ICAO Secretariat, made up of staff members selected for technical competence in their respective fields, which supplies technical and administrative aid to the governmental representatives who make up the ICAO Council Committees and Divisions.

In order that the work of the Secretariat shall reflect a truly international approach, professional personnel are recruited on a broad geographical basis. In addition to the regular staff, the services of experts are obtained from member states.

AIR NAVIGATION COMMISSION AND METEOROLOGICAL DIVISION

The requirements of meteorological facilities for civil aviation during different phases of operation of aircraft are discussed along with other related problems concerning Aviation by periodical Air Navigation Conference held by ICAO. Matters of purely meteorological interests are discussed in Meteorological Division meetings. To coordinate action between ICAO and WMO in respect of provision of meteorological services to civil aviation, the meetings are held conjointly with the CAeM of WMO whenever meteorological aspects are to be discussed.

THE REGIONAL OFFICES

In dealing with international civil aviation on a world wide scale, there are many subjects which ICAO has had to consider on a regional basis. The Organization has set up eight geographical regions, both to facilitate detailed planning and to cater to different types of flying operations. The eight regions are:

1. The North American Region (NAM)

2. The South American Region (SAM)

3. The North Atlantic Region (NAT)

4. The South Atlantic Region (SAT)

5. The European Mediterranean Region (EUM)

6. The Middle East Region (MID)

7. The South East Asia Region (SEA)

8. The Pacific Region (PAC)

India is located in MID and SEA Regions and takes part in the Regional Air Navigation Meetings (RAN) of these regions which is held as a combined meeting. Similar combined RAN meetings are also held by NAM & NAT and SAM & SAT.

The ICAO Regional Offices to cater to the specific aviation needs of the regions are at Bangkok, Dakar, Cairo, Paris, Lima, Mexico City. The Regional Office at Bangkok is concerned with the MID/SEA region and is known as the Far East Asia and Pacific (FEAP) Office.

REGULATION AND PROCEDURES

The precision in procedures and systems of aviation activities worldwide is made possible by the existence of universally accepted Standards and Recommended Practices, commonly known as SARPs. SARPs cover all technical and operational aspects of International Civil aviation, such as safety, personnel licensing, operation of aircraft, aerodromes, air traffic services, accident investigation and the environment. The SARPs are incorporated as Annexes to the Convention on International Civil Aviation.

Sixteen out of Eighteen Annexes to the Convention are of technical in nature and fall within the responsibilities of the Air Navigation Bureau and its sections. The remaining two Annexes, Facilitation and Security, are under the purview of the Air Transport Bureau.

ICAO standards and other provisions are developed in the following forms:

Standards and Recommended Practices - collectively referred to as SARPs;

Procedures for Air Navigation Services - called PANS;

Regional Supplementary Procedures - referred to as SUPPs; and guidance materials in several formats.

RELATION TO CORRESPONDING WMO PUBLICATIONS

The regulatory material contained in Annex 3 is, except for a few minor editorial differences, identical with that appearing in the Technical Regulations (Chapter C.3.1) of the World Meteorological Organisation (WMO).

The aeronautical meteorological code forms referred to in Annex 3 are developed by WMO on the basis of aeronautical requirements contained in Annex3, or stated by the Council from time to time. The aeronautical meteorological code forms are promulgated by WMO in its Manual on Codes, Volume I (WMO No.306).

ICAO ADVISORY CENTRES

Volcanic Ash Advisory Centres (VAAC): The role of a VAAC is to provide expert advice to Area Control Centres (ACCs)/ Meteorological Watch Offices (MWOs) in its area of responsibility regarding the extent and forecast movement of a volcanic ash cloud. This information is required by the MWOs in order to issue SIGMETs for volcanic ash. ICAO has designated the following VAACs to provide advice to MWOs on the extent and forecast movement of volcanic ash within an agreed area of responsibility: Anchorage (United States), Buenos Aires (Argentina), Darwin (Australia), London (United Kingdom), Montreal (Canada), Tokyo (Japan), Toulouse (France), Washington (United States), and Wellington (New Zealand). In order to provide guidance to States, a set of International Airways Volcanic Watch (IAVW) procedures has been developed by ICAO and circulated to States in addition to the provisions in the relevant Annexes.

Tropical Cyclone Advisory Centre: It is a meteorological centre designated to provide advisory information to meteorological watch office regarding the position, forecast direction and speed of movement, central pressure and maximum surface wind of tropical cyclones. The following are the Designated TCACs: Miami (USA), Tokyo (Japan), New Delhi (India), La Reunion (France), and Nadi (Fiji).

INDIA METEOROLOGICAL DEPARTMENT- AVIATION METEOROLOGICAL ORGANISATION

India Meteorological Department is the national agency which is responsible in all matters related to provision of Meteorological support to aviation in India. The principal requirements in the aviation point of view are: (1) Supply of Current Weather Observations to all aeronautical users, (2) Issue of forecast and warnings on meteorological hazards to aviation and (3) Adherence to procedures and formats for dissemination of products to aviators. Service to International Civil Aviation is in accordance with the Standards and Recommended Practices (SARPs) of ICAO (Annex 3). Domestic Aviation (Civil, Defence, Chartered flights, Explorative missions, relief & rescue operations, VVIP/ VIP flights, flying clubs etc.) is governed by the aviation legislation, Civil Aviation Requirements (CAR) of Director General of Civil Aviation (DGCA), India. It is essentially an extension of SARPs of ICAO with some National Practices of IMD as accepted and required by the users.

India Meteorological Department caters to the needs of Aviation Services through a network of 4 Meteorological Watch Offices (MWOs – Chennai, Delhi, Kolkata and Mumbai), 18 Aerodrome meteorological offices (including four MWOs) and 54 Aeronautical meteorological stations.

Central Aviation Meteorological Division (CAMD) is the nodal office for the aviation services in the country. It also maintains liaison with ICAO, WMO, Airlines, DGCA, AAI, on technical aspects of aviation. Meteorological Training Institute (MTI), Pune, takes care of the training requirements. The installation and maintenance of Airport Meteorological Instruments are done by the DDGM (SI) at Pune. The telecommunication requirements for aviation are managed by the Telecommunication Division (ISSD) functioning at New Delhi and by the telecommunication unit of Airport Authority of India. Tropical Cyclone Advisory Centre (TCAC) of ICAO is functioning at IMD New Delhi.

The guidelines for meteorological service to aviation in India are given in "Manual on Procedures for Meteorological Services for Aviation in India" published by CAMD, India Meteorological Department. It is essentially the Annex 3, incorporating national practices also. The Aviation Weather Code Book, also published by CAMD, IMD closely resembles "Manual on Codes- WMO 306". These two publications are updated and revised from time to time in order to incorporate all the amendments and changes by WMO and ICAO.

FLIGHT INFORMATION REGION (FIR):

An airspace of defined dimensions within which flight information service and alerting service are provided. Indian airspace is divided into five FIRs, namely, Chennai, Delhi, Kolkata, Guwahati and Mumbai. The associated meteorological office providing services to an FIR should be a MWO. However, the responsibility of meteorological watch over Guwahati FIR is being handled by MWO Kolkata.

UP-KEEP AND MAINTENANCE OF AVIATION METEOROLOGICAL OFFICES

- The up-keep and maintenance of the briefing room and aviation meteorological office is very important and crucial.

- The briefing room shall always have a tidy look about it.

- The pilots regularly visit the meteorological office and a systematic display of all charts, satellite pictures, Radar pictures and other informative materials, is vital for their understanding of the weather.

- The latest charts and weather information have to be prominently displayed in the briefing room so that they are easily accessible to the persons visiting the briefing room.

MAINTENANCE OF REGISTERS

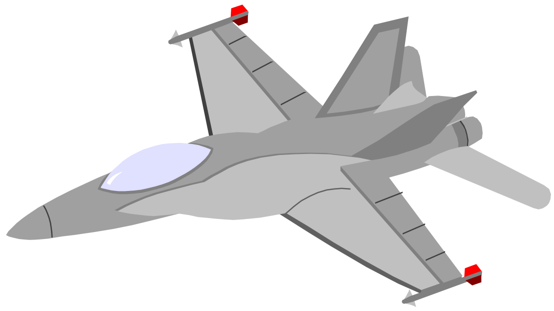
In order to streamline the routine activities of an aviation meteorological office, it is necessary to have certain registers maintained regularly. The list of registers to be maintained by MWOs, AMOs and AMSs are given below:

List of registers to be maintained by different types of offices Registers/ log books

	Registers/ log books			
Sl. No.		MWO	AMO	AMS
1	Accident register	X	X	X
2	Registers for noting lapses, deficiencies, procedural mistakes etc.	X	X	
3	Current Weather Register	X	X	X
4	Briefing Register	X	X	X
5	De-briefing Register	X	X	
6	Aviation Action Diary (Routine)	X	X	
7	Aviation Action Diary (Non- Routine)	X	X	
8	In-flight and Post-flight report register	X	X	
9	Aviation Log book	X	X	X
10	FIR Warning/ SIGMET Register	X		
11	Aerodrome Warning Register	X	X	X
12	Register for coded ROFORs, TAFs etc.	X	X	
13	Verification of Aviation Forecasts	X	X	
14	Register regarding Implementation of instructions and circulars	X	X	X
15	NOTAM Register	X	X	X
16	Radar Scope Observation Register	X	X	

UPDATION OF HANDBOOK PAGES : The hand book pages which give the basic information about an aviation meteorological office are to be kept up to date. Any change in the information contained in the Hand book shall be communicated to CAMD without delay, so that the contents remain current.

UPDATION OF AIP INDIA: Aeronautical Information Publication (India) gives details of services and facilities available at an aerodrome. The meteorological facilities available at an airport also are included in it. The aviation meteorological offices should send the changes in services for amending the AIP India on a quarterly basis to CAMD.



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.

EFFECT OF WEATHER ON AVIATION

INTRODUCTION:

The need of meteorological services for the safe, economic and efficient navigation of an aircraft to reach its destination is well known. The knowledge of jet streams and pressure patterns or a broader combination of these two can save time and fuel. However, the present day wide-bodied Jet aircraft fly much above the weather and, therefore, except for significant weather elements, importance of adverse weather during cruise has decreased. The influence of many other meteorological parameters on the aerodynamics and engine efficiency during various phases of aircraft operation is also very significant. With the advent of jet aviation and heavily loaded passenger or freighter aircraft doing long haul flights at high speed and at a very high rate of fuel consumption, flight planning, which takes into account all the meteorological parameters has become an absolute must to obtain maximum efficiency without compromising safety of aircraft operations.

WEATHER ELEMENTS:

Following weather elements affect the aircraft operations and payload:

i. Pressure
ii. Temperature
iii. Wind
iv. Humidity
v. Clouds
vi. Visibility

Pressure, Temperature and Wind have direct impact on:

i. Take-off Weight
ii. Landing weight
iii. Fuel Requirement
iv. Flying Time.

METEOROLOGICAL FACTORS AFFECTING AIRCRAFT OPERATIONS

Flight of an aircraft is dependent on the following four essential factors:

a) Total weight (W) of the aircraft
b) Lift (L) of the aircraft, which is generated by airflow over the wings.
c) Drag (D), which is the resistance to forward motion caused of the air
d) Thrust (T), which is supplied by the engines of the aircraft.

There are three phases in an aircraft flight. They are:
i) Take-off phase
ii) Cruise phase
iii) Landing phase

Surface meteorological observations made at an aeronautical meteorological stations, are required for each phase of the flight.

EFFECTS OF WEATHER ON AIRCRAFT AT VARIOUS PHASES OF FLIGHT

Wind

***Upper wind*:** Information on upper wind is required by the pilot and the operator for two reasons:

i) To navigate the aircraft between two places: In steady flight the aircraft moves forward in straight line in relation to the air in which it is flying. When there is a wind, the path of the aircraft is displaced in relation to the earth. Hence, the forecast wind velocities have an important influence on the route and altitude selected for a particular flight. The aim is to select a route and altitude which will give maximum tail-wind components. Knowledge of presence of jet streams is a necessity while planning the route. ii) *Planning of fuel load:* If there is a strong Headwind, the aircraft will take longer time to fly from one place to another than in still air. This means it needs more fuel, which may mean reducing the payload. If there is a strong tail wind the time taken is reduced and the fuel load can be reduced. For e.g. an aircraft that can cruise at 500 kts will take 6 hours to fly 3000 nautical miles in still air. If there is a 50 knot tail wind, the flight will take 5 hrs. 27 minutes, approximately 10% less time. Thus 10% less cruise fuel need be carried as compared to the still air load. This increases the potential payload.

***Surface wind*:** The pilot and the air traffic controller need to know both the surface wind speed and direction. The change of wind velocity with height is also taken into account in the flight planning calculations.
For in-flight conditions, for a given weight, there is a critical speed at which the aircraft ceases to be supported in the air. This is the stalling speed (Vs) and is the air speed at which an aircraft takes off or touches down. If the take-off or landing is directed into the wind of say Y knots speed, the ground speed of take-off or landing is Vs - Y. This slower speed permits safer operation. The pilot

and ATC use surface wind observations for the selection of runway. The pilot also uses the surface wind in planning the take-off weight.

If there is a strong headwind, take-off run is reduced, meaning aerodrome with short runways operations can be carried out with high value of W. On the other hand, if there is only a light headwind or calm, the aircraft may have to reduce weight (pay-load) in order to take off.
Knowledge of variations in wind speed is important in determining the stability of aircraft in take-off and landing phases.
Vertical wind shear: It is the change in horizontal wind velocity between one level and another. The pilot needs to know if there is a vertical wind shear in the descent to land and climb out areas. Some of the problems that may arise are:

- *When descending into decreasing wind speed the aircraft undershoots;*
- *When descending into increasing wind speed the aircraft overshoots.*
- *When climbing into increasing wind speeds the angle of climb increases; when climbing into decreasing wind speed, the angle of climb decreases.*

Cloud and Visibility

The pilot is required to see the ground throughout the final stage of an approach. There is a decision-making height from where the pilot should be able to see the runway. The visibility should be above a minimum value, which varies with aircraft type. Low clouds at destination may require the making of a diversion. Low clouds can cover the high grounds and can pause threat to the safety of aircraft. Clouds of vertical growth will have all adverse weather, like, turbulence, hail, lightning and icing. Reduction of in-cloud visibility can cause loss of situational awareness of a pilot if flown through.

Temperature

Upper air temperature:

For flight planning purposes, full details of horizontal and vertical temperature variations on the route will be required for the calculation of true airspeeds and corrections to indicated altitude as the instruments are calibrated at standard conditions. Also, the efficiency of engine depends on the temperature at the cruising altitude. Forecast air temperatures and heights of the tropopause are therefore important in deciding the optimum cruising altitude. The engine efficiency is greater with lower outside temperature. If the temperature is high, more fuel than the normal has to be used to maintain cruising power. The information is required during the planning stage of the flight when fuel load is being determined. The information on upper air temperature also tells the pilot the height of the Oo C isotherm above which icing can occur.
Surface temperature:
Engine efficiency is higher with lower temperatures. Lift is more with high pressure and lower temperature and hence runway length can be shorter for the given conditions for take-off.

Atmospheric pressure and density

Air pressure and temperature determine the air density and in turn determine the lift of the aircraft. Other factors being equal an aircraft must fly faster to maintain the height, when density of air is reduced. This faster speed induces a greater drag that has to be equaled by the engine thrust. The greater the thrust needed, the greater will be the fuel load required. This is the reason why high flying, high speed jet aircraft need so much fuel.
Another effect of reduced air density is to cause a decrease in engine power and in effect affects the climbing power of the aircraft. If the air density falls below a certain value, it may be necessary to reduce gross weight of the aircraft.
Considerable fluctuations of atmospheric pressure may occur near mountains, particularly in high winds. This will lead to erroneous readings of an aneroid altimeter. The pressure will be higher on

the windward side of the mountain and lower on the leeward side. This effect is taken into account by the pilots while deciding the clearing altitude.

WEATHER HAZARDS :

TURBULENCE AND WINDSHEAR

Introduction:

Wind shear can be defined as 'layers or columns of air, flowing with different velocities (i.e. speed and/or direction) to adjacent layers or columns'. Wind shear is a major hazard for aviation especially when operating at low levels. Depending on the flight direction relative to the velocity changes, shear may be felt as turbulence, but also as a sudden tail or head wind with respective consequences. It is seen that, besides convection, shear is the second major source for turbulence.

Light aircraft are prone to be buffeted, and are significantly affected even by light turbulence. Relatively few reports of turbulence are received from fast military jets which are designed to give a high degree of tolerance.

Categorisation:

The intensity of turbulence is categorized by the ICAO as follows:

- **Light**

Effects are less than those of moderate intensity.

- **Moderate**

There may be moderate changes in aircraft attitude and/or height but the aircraft remains in control at all times. Air speed variations are usually small. Changes in accelerometer readings of 0.5-1.0g at the aircraft's centre of gravity. Occupants, feel strain against seat belts. There is difficulty in walking. Loose objects move about.

- **Severe**

Abrupt changes in aircraft attitude and/or height. The aircraft may be out of control for short periods. Air speed variations are usually large Changes in accelerometer greater than 1.0 g at the aircrafts, centre of gravity. Passengers are forced violently against seat belts. Loose objects are tossed about.

- **Extreme**

Effects are more pronounced than for severe intensity. Wind shear, of itself, is not categorized in the same way, although when it ultimately makes its presence felt, the above turbulence categorized may become applicable.

Types of Turbulence:

- Convective turbulence
- Mechanical, mostly low-level turbulence
- Orographically induced turbulence
- Clear air turbulence (CAT)
- Low level jets
- Wake turbulence/wake vortices

Engine lost due to turbulence from http://climate.dot.gov/documents/workshop1002/kulesa.pdf

Convective Turbulence

a) Description

Convection is always associated with turbulence, which for that reason is referred to as convective turbulence. The origin and physical cause of turbulence are:
 The vertical currents within and around convective clouds are turbulent;
 Growing convective towers may generate gravity waves which propagate either radially away, for instance within the anvil or may also propagate vertically;
 Dry thermals (i.e. non-saturated ascending air);
 Downdraughts associated with precipitation or mid-level cold layers of air. These can produce line squalls near showers.

Thermal turbulence over land has a marked diurnal variation, with a maximum during the afternoon and a minimum overnight. Thunderstorms, in contrast, may last during the whole night and propagate over large distances of several hundred kilometers.

b) Effects on Aircraft

At its simplest, convective turbulence will result in ‘bumpiness’ in flight. As the intensity of turbulence increases, its effect will increase. Depending on aircraft type, severe turbulence may cause structural damage to an aircraft and injuries to passengers. In association with large storms, strong downdraughts or micro-bursts can occur producing a violent outflow of air which spreads outward on hitting the ground. Those downdraughts usually are caused by cool air sinking in the surrounding rising warmer updraught air. Though downdraughts originate very often from deep in the cloud, the associated risk is highest below cloud base. The downdraught forces the air close to the ground to spread radially outwards. The aircraft first experiences a headwind, lifting the aircraft up, then a sudden downdraught, followed by a strong tailwind. Both latter winds lead to a substantial loss of height if not counterbalanced. Downdraughts, therefore, can result in fatal accidents, particularly for small aircraft. A micro-burst can cause the aircraft to lose altitude, due to physical downdraught and loss of airspeed due to rapid change in wind speed and direction.
Updraught strength varies from 1 m/s in fair weather cumuli, to 5 m/s in shower clouds up to 65 m/s in severe Cumulonimbus. Downdraughts vary in a similar way with a maximum observed value of -25 m/s in CB. Dry thermals are felt as light to maximum moderate turbulence. The gravity waves close or above convective towers may either lead to related upward and downward motions, or they may be felt as turbulence, especially if their wave-lengths is of the order of 100 m or less, or, more significantly if the gravity waves break and cause turbulence. Prior to breaking, waves overturn which may lead to significant and immediate height losses. A micro-burst can cause the aircraft to lose altitude, due to physical downdraught and loss of airspeed due to rapid change in wind direction and strength.

Mechanical Turbulence

Mechanical turbulence results solely from shear. The latter is always found close to the surface where wind speed vanishes. Within the boundary layer and typically at night a low-level-jet may be found, which also might produce turbulence. Furthermore, turbulence may also be found close to the edge of the jet-stream at tropopause heights.

Description

Close to the ground mechanical turbulence is also often referred to as low-level turbulence. Surface friction is the primary cause of the vanishing wind at the surface. The intensity of mechanical turbulence depends upon (1) Wind strength, (2) Terrain roughness and (3) Atmospheric stability near the surface. In general, the stronger the wind and the rougher the terrain, the more intense the turbulence experienced. Light winds over a smooth sea give the least turbulence.

The steeper the lapse rate, the more readily vertical gusts develop and thus the more vigorous the turbulence is. In more stable air, vertical eddies are suppressed and turbulence is more damped – but very stable air and a sufficient displacement over large obstacles (hills/mountains) may lead to mountain or lee wave development. Details are given in Orographic Turbulence section of the notes.

Effects on Aircraft

At its simplest, mechanical turbulence will result in 'bumpiness' in flight. The intensity of turbulence will increase in accordance with the above mentioned criteria and flight speed. For any given intensity of turbulence, the faster the aircraft flies, the more it will be accelerated. The closer it is to the ground, the less time there is available to react to those accelerations. Ultimately, depending on aircraft type, severe turbulence may cause structural damage to an aircraft.

Orographic Turbulence

a) Description

If surface roughness increases and characteristic roughness heights increase as well, eg over cities, forests, small hills and larger hills, and finally mountains, the airflow suffers large corresponding displacements from its original level. Depending upon the stability of the air mass, this may result in triggering convection and associated turbulence. It may also generate gravity waves, commonly known as mountain waves, or may tend to return the airflow to its original level giving 'standing waves' and rotors. Orographic structure might be complex and so is the associated flow pattern. The airflow may be funnelled along valleys creating marked deviations from what might be expected from the undisturbed flow. Because of the blocking of the flow by mountains or hills, increased turbulence close to the ridges also may be found.

Turbulence may be experienced in association with mountain wave motions, particularly if the vertical currents are strong and the wave length is short. Turbulence-prone areas are most likely to be near wave crests and troughs, while at mid-levels, the flow may be quite smooth and laminar. Mountain waves may also break and can cause severe turbulence.

Rotors

Turbulent rotors in the lower troposphere are usually associated with high amplitude lee waves. Two types of rotors have been observed. The first type, often visible as harmless-looking cumulus or cumulus fractus lines paralleling the mountain rage, comprises a well-defined circulation under the crests of resonant mountain waves. This type of rotor contains moderate or severe turbulence and is often confined below the height of a frequently-observed upstream, near-mountain-top inversion. A second, less common, rotor type extends much higher than the upstream inversion. This type has been observed to contain severe or extreme turbulence, and is thought to be associated with a high-amplitude mountain-wave system resembling a hydraulic jump. Both rotor types present a hazard to aviation, although the second type of rotor is far more dangerous.

Effects on Aircraft

Mountain waves can be both an advantage and a disadvantage to aviation; mostly however the latter is the case. Experienced glider pilots look for the updraught side of mountain waves in order to gain altitude.

The inherent dangers are:

1) The rapid change in height can mean that a pilot caught unawares may very quickly conflict with aircraft at different flight levels, and more importantly, if caught in a downdraught may rapidly erode any terrain clearance margins, and ultimately cause impact with the ground. Such

effects will be most pronounced if the aircraft track is parallel with the ridge.
2) The laminar and smooth flow will break down to give rotors in the crests of the first one or two

lower level waves of the flow – turbulence should be expected to be severe in these regions, and may or may not be marked with 'roll cloud'. 3) If the wavelength is short, then an aircraft travelling swiftly through and perpendicular to the wave-train will experience a prolonged series of rapid fluctuations of vertical velocity. This will result in turbulent flight.

CLEAR AIR TURBULENCE (CAT)

a) Description CAT is the term used to describe medium- or high-level turbulence produced in regions of marked wind shear. CAT often - though not necessarily- occurs in the absence of cloud, making it difficult to detect visually.

b) Effects on the Aircraft: The degree of turbulence is categorised as per the ICAO definitions. For civil aviation, passengers may be made uncomfortable, or suffer injuries when not wearing their seat belts. In recent years, fatalities have also occurred. In extreme cases, structural damage may occur.

CAT is often reported:

1. on the cold (pole-ward) side of a jet-stream, near and below the core where the wind shear is greatest;
2. on the warm (equator-ward) side of a jet-stream, above the core. The stronger the jet, the more

likely that CAT will be present;

3. in developing upper ridges where the speed of the wind flow around the ridge approaches its limit due to curvature;
4. in sharp upper troughs where wind direction changes abruptly;
5. in regions of confluence and diffluence in jet-streams;
6. in cold areas where a narrow but marked line of CAT may occur;
7. If the core speed exceeds 100 kt and vertical wind shear 4kt/ 1000ft, moderate CAT within 150 nautical miles may be forecast;
8. CAT is rare above a well defined tropopause,
9. CAT may occur, or be intensified, over a region of convection, especially embedded frontal convection. CAT occurs more often over land, especially over mountainous land, than over the sea. 60% of CAT reports are near jet-streams.

The severity of CAT may be estimated if the horizontal and vertical wind shear values are known 47 Climatologically, CAT can be expected over North India in association with the sub-tropical westerly Jet in the winter season. Over Peninsular India, CAT in association with easterly jet can be anticipated during monsoon season.

LOW LEVEL JETS

a) Description

There are several forms of low level jets. The low-level jet seen over Indian region is the 'Somali Jet'. The Somali Jet is a feature of the northern hemisphere summer, and the development of the Asian Monsoon. When fully developed a SE'ly low level flow crosses the northern tip of Madagascar, before veering S'ly and then SW'ly across the Horn of Africa to become a SW'ly flow running parallel to the coasts of Yemen and Oman. The jet has important climatological effects, but with maximum winds of some 40 or 50 kt at the 850 hPa level, there is an aviation aspect to always consider.

b) Effects on Aircraft
The presence of low level jet implies that terrain clearance may be compromised, and difficulties during the landing phase may be encountered. Also the turbulence associated while crossing the boundary and the change of airflow across the wings may have adverse effect on the aircraft.

Wake Turbulence/ Wake Vortices
a) Description
Wake turbulence is a result of the vortices formed in the wake of aircraft. Vortices form on the top surface of each wing, and are left in the aircraft's wake. Helicopters also produce wake turbulence, with vortices generated from the main rotor blades.
Primarily, they are a function of the weight, size, and aerodynamic properties of the aircraft. However, once formed, they are known to sink with a speed of 1-2 m/s, and will be transported with the general wind flow.
b) Effects on Aircraft
As with all forms of turbulence, encounters at low level can prove fatal, with little room or time for recovery. Light aircraft which encounter the wake turbulence of heavy airliners may be violently tossed around.
The simplest precaution for pilots to take is to remain a safe distance behind the leading aircraft.

ICING
Icing occurs if precipitation aggregates on the aircraft or at or within parts of it. The dominant impact mechanism is that super-cooled liquid water impinges on the aircraft and freezes instantaneously. Icing may occur in-flight or at the surface (ground icing). The icing may also be categorized as airframe icing and engine icing.

Airframe Icing

a) Description
Airframe icing normally occurs when the ambient air temperature is below 0ºC and super-cooled water droplets are present.

There are five types of airframe icing:

 Rime Ice – white, porous, opaque, brittle and rough, hence disruptive to airflow. This occurs at low temperatures (<10ºC) and/or low liquid water contents as under those circumstances the released heat during the freezing process can be transported immediately to the environment.

 Clear Ice (glaze ice) – clear, tough, adhesive, dense and heavy, smooth hence little effect on airflow. It occurs usually at warm temperatures >10ºC and/or high liquid water contents, as then, during the freezing process, an ice-water mixture is formed which remains semi-liquid for about several seconds. Due to the relatively warm temperatures the released heat needs a longer time to be carried away by the ambient air flow. Super-cooled large drops or drizzle drops- with diameters ranging between 50 and 500 µm- may flow after impingement behind the protected zones on the wing and then freeze there (freezing drizzle).

 Mixed Ice – impingement of super-cooled water and ice. If super-cooled rain drops with diameter larger 500 µm hit the aircraft, extreme accretion of ice may occur (freezing rain).

 Hoar frost – thin 'coating' occurring in the absence of rain or cloud usually when aircraft is parked outside on cold winter nights. It has to be removed prior to take-off.

 Rain and snow mixed (sleet) is similar to freezing rain and can also lead to 'pack snow' that can block air intakes and other aircraft openings.

b) Effects on Aircraft

Small super-cooled cloud droplets freeze rapidly on contact with the aircraft, trapping in the ice to give a deposit of white rime on forward-facing surfaces. Larger droplets take longer to freeze, spreading out across the airframe before solidifying.

The intensity of icing is defined as follows:

Light Accumulation rate may create a problem if flight in this environment exceeds 1 hour.
Moderate Rate of accumulation is such that even short encounters are potentially hazardous. Anti-icing equipment must be used.

Severe Rate of accumulation is such that use of anti-icing equipment fails to reduce or control the hazard. Immediate diversion from the region is necessary. Apart from meteorological factors, the rate of ice build-up on the airframe also depends on the characteristics of the aircraft. Fast aircraft with thin wing cross-sections are more susceptible to deteriorating aerodynamics, and hence are more susceptible to ice accretion. Helicopters are particularly vulnerable to icing, since build-up of ice on the rotors can lead to imbalance, de-stabilizing the aircraft. Airframe icing is a serious aviation hazard.

Engine or piston icing occurs under conditions of high relative humidity close to freezing when the under-pressure in a piston causes the humidity to condensate and freeze within the engine. A fundamental requirement of airframe icing is the presence of sub-zero cloud droplets.
It may be noted that prolonged flight within a super-cooled, layered cloud can give rise to a greater degree of icing than suggested here. Also stratocumulus (SC) can sometimes give unexpected

severe icing, particularly when it lies in a sub-zero layer just below an inversion over the sea. A special risk exists in embedded convection, and especially near the overshooting tops.

The time actually spent flying in an icing environment is also an important consideration. Icing layers in clouds are usually only 2000-3000 ft. thick and rarely greater than 5000 ft. Cumulus-type clouds can usually be flown around whilst icing in layer clouds can usually be dealt with by altering height, either upwards or, if terrain permits, downwards.

Carburetor and Engine Icing

Some aircraft are prone to icing in the carburetor and air intakes. This is caused by a reduction in pressure leading to adiabatic cooling as the air expands. Carburetor icing is by far the most common form of ice-related problem affecting piston-engined aircraft. When humid air enters the venture in the carburetor, ice crystals are deposited. This constricts the venture and causes progressive power reduction. Carburettor icing frequently occurs when the ambient air temperature is above 0º C, the dominant factor being the moisture content of the air. The more humid the air, the higher the risk; hence engine icing is more likely on a warm, humid, cloud summer day, than on a cold, dry, clear winters day.

An additional problem for the engine is the build-up of ice on the rims and struts of intakes. In extreme cases large pieces of ice can break off and cause damage to the engine. Engine icing is most common when the air temperature is a few degrees above 0ºC and the relative humidity is greater than 60%. Pilots, therefore, use forecasted temperature data and an estimate of humidity to assess the engine icing risk. Typical high humidity scenarios are mist after heavy rain and the air just below stratiform cloud.

CUMULONIMBUS AND THUNDERSTORMS

Cumulonimbus (CB) clouds are a severe hazard to aviation, due to the likelihood of:

a) severe turbulence, b) severe icing, c) micro-bursts, generating squalls or gust fronts giving severe low-level turbulence; d) lightning, e) high liquid water content, and f) hail.

Whilst individual Cumulonimbus clouds may have a lifetime of 1½ hours, the most intense Cumulonimbus development and thunderstorm/ lightning activity is associated with Multi Cell Convective systems which may develop further into Supercells. Such systems are long lived due to the spawning of daughter cells and may last for many hours.

Hazards associated with thunderstorms:

For discussion on turbulence, icing, and microburst, the relevant sections of the note may be referred to.

Thunderstorms and Lightning

a) Description

Lightning can occur in and near Cumulonimbus clouds including the anvil layers and the sub-anvil atmosphere. The Meteorological glossary describes lightning as an electrical discharge of some 20 coulombs and a potential difference of some 108 or 109 volts. Electrical discharges may occur within the cloud, referred to as intra-cloud lightning, and between cloud and ground, referred to as cloud-to-ground-lightning. Generally, intra-cloud lightning is weaker than cloud-to-ground-lightning, but still may reach the same strength.
Thunder is the audible manifestation of the electrical discharge, caused by the violent heating and expansion of the atmosphere surrounding the path of the lightning strike. 53

b) Effects on aircraft

The effects of lighting on an aircraft (and its crew and passengers) are many. If lightning strikes a previously sound, metal bonded structure, the aircraft will remain structurally sound, and

the passengers and crew will not be directly affected by the strike's voltage and current, due to the Faraday Cage effect. However, entrance and exit burn marks will be evident on the skin of the aircraft. If the discharge is adjacent to or through structures such as aerials, then these structures may be destroyed. The effect of a lightning strike on both passengers and crew will induce shock, and possibly fear. At night a lightning strike may cause the crew to suffer temporary blindness, or degraded vision.
Lighting strikes on modern composite materials will cause de-lamination of the material. If such strikes are upon structurally important areas of the aircraft, its integrity may be compromised. For this reason, lightning strikes on composite helicopter blades are particularly hazardous.
Following a lightning strike, electrical/ electronic systems may fail, with circuit breakers tripping. Magnetic compasses will become untrustworthy. Radio communications and navigation equipment may be adversely affected.

Heavy rain

a) Description

There is no agreed international definition regarding rainfall intensity. Some use the following criteria:

Heavy rain is defined as rates in excess of 4 mm per hour.

Heavy showers are defined as rates in excess of 10 mm per hour.

Terms such as 'very heavy' have no official definition, but they, and terms like them, are used below to describe rainfall rates that are much greater than normally expected, and would be associated with thunderstorm activity. For aviation purposes rain rates are essentially a measure of rain water content.

b) Effects on Aircraft

Heavy or very heavy rates of rainfall will clearly have a detrimental impact upon general visibility. However, in addition to any true meteorological reduction of visibility, raindrops impacting the windscreen/ canopy will additionally reduce visibility.

Light, non-pressurised aircraft may find the heaviest rain rates allow water ingestion into the cabin/ cockpit/ engine compartments with subsequent risks to electronic equipment. Civil airliner engines are tested and certified to ensure that engines will normally not 'flame out' under conditions of intense rainfall and water ingestion.

Runway flooding or areas of deep standing water will affect braking action, and may result in asymmetric braking and possible sliding off runways. Low cloud (stratus pannus) may form in periods of moderate or heavy rain, when it had not previously been expected.

Hail

a) Description

Small hail (METAR code GS) is hail or graupel of less than 5 mm in diameter. True hail (METAR code GR) is hail of 5 mm or more in diameter. GS and GR may fall from Cumulonimbus. GS (not GR) may fall from Cumulus congestus (TCU). The phenomena should not be confused with Ice Pellets (METAR code PE) that originates from stratiform cloud.

Hail is formed in the updraughts of convective (TCU or CB) cloud. The stronger the updraught and the greater the cloud vertical extent, the larger the hailstone that can be sustained.

b) Effects on Aircraft

Hail of small size will have little effect on the structure of an aircraft, merely bouncing off the airframe. However, even small hailstones have a marked detrimental effect upon visibility. The onset can be rapid, surprising the pilot. Hailstones can attain sufficient size to cause damage to the skin of aircraft, which may affect the aircraft's aerodynamics, and possibly shatter windscreens. Hail may severely damage propellor blades and engine blades. Hail may block air inlets or may be deposited somewhere within air intakes. Sudden hail showers may leave an extremely slippery surface on runways and taxiways. So, even if the shower has passed and the visibility and cloud may be described as fit for attempting a landing, breaking action may be adversely affected.

HEAVY RAIN

For details of heavy rain, kindly refer to the discussion on heavy rain within the Cumulonimbus and Thunderstorm section.

Note that heavy rain may occur without the presence of a Cumulonimbus cloud. On such occasions, the cause will be due to thick, deep layers of cloud, as in the case of frontal or monsoon clouds, perhaps enhanced by orographic forcing. Nimbostratus ought to be reported (and indeed forecast) if such rainfall is expected to fall from non-convective clouds.

SNOW

a. Description

Snow is solid precipitation in the form of individual, usually branched, ice crystals, or an agglomeration of those ice crystals. The precise nature will depend upon the temperature and conditions in which they develop. At temperatures warmer than about -5º C the crystals tend to agglomerate.

b. Effects on Aircraft

Even slight rates of snowfall have a serious detrimental effect upon visibility. Non-melting snow flakes at sub-zero temperatures will be largely deflected in the air stream and may not adversely affect the majority of the airframe. However, where snow is deflected into engine nacelles or into cavities such as open wheel wells, the snow may collect and 'pack' to create obstructions. Such obstructions may restrict airflow into engines, or prevent retraction of landing gear.

On the ground, whilst stationary or taxiing, snowfall may accumulate on the airframe, disturbing the aerodynamics and adding to the all up weight of the aircraft. Windscreens may become obscured with snow, with windscreen wipers becoming ineffective. Pitot tubes may become blocked, with resultant errors in airspeed and altitude indication.

Wet (melting) snow may not get so easily be deflected by airflow, and may get readily 'pack' against blunt surfaces of the airframe. As noted above, when snow packs into and against engine nacelles, wheel wells, or engine intake grilles, significant consequences may result.

Runway contamination by snow will significantly degrade braking action. Snow accumulations will also obscure runway lights and possibly make it difficult to discern the runway from the adjacent grass areas, especially given that visibility will be anyway degraded.

Snow must be removed completely from an aircraft prior to take-off by appropriate means, usually through the application of a de-icing fluid. It is a fatal error to assume that snow on the aircraft, respectively on the wing, will be removed by aerodynamic forces during start and take-off. Indian airfields generally do not get affected by snowfall.

FOG

a) Description

Fog is the suspension of microscopic droplets of water, or in the case of ice fog, particles of ice. For aviation purposes, it is a condition that the horizontal visibility due to such phenomena is reduced to less than 1000 m. Fog may cover a large, continuous area or it may form in patches possibly only covering small parts of an airfield. If the fog layer is less than 2 meters deep overland it is termed shallow fog.

b) Effects on Aircraft

Fog seriously degrades visibility, to such a degree that landing may be impossible. Only the most expensive of aircraft (Civil Airliners/ military aircraft) may be able to 'auto land' under such circumstances, and then only at suitably equipped airports. Even allowing for the technical ability, airline and military procedures may prohibit 'auto landings' under certain conditions.
Ice fog has similar visibility restrictions, but in addition untreated taxiways and runways may be

coated with a thin layer of ice.
Pilots may be given a false sense of security when over-flying an airfield, since structures and runways may be quite clear to the pilot when looking down from directly above the airfield. However, when descending onto the approach, and trying to view the airfield at a slant angle through the fog, the pilot may very quickly lose all visual cues and find themselves in very serious difficulty.

LOW CLOUD/POOR VISIBILITY

a. Description

Low cloud and poor visibility may be overlooked as being potentially hazardous. They are also quite difficult to define since they will depend upon aircraft type, pilot skill and experience, the precise role the aircraft is performing, and the navigation aids available en route or at the departure/ destination/ alternate airfields.

Whilst the precise values may differ under the many varied possibilities, perhaps low cloud and poor visibility might best be described as having values that fall below the operating minima of either or both that of the aircraft and pilot.

Small amounts of low cloud (1 or 2 oktas say) may not generally be hazardous. As cloud amounts increase, then the risk to aircraft also increases. Poor visibility may likewise only affect small areas (in the form of showers, or in fog patches), and may be caused for many reasons (rain, mist, haze, smoke etc). Under such circumstances a pilot may be able to 'navigate around' the problems. Conversely, reductions to visibility can and often do affect very large areas and as such dealing with the problem can be much more difficult.

b Effects on Aircraft

When cloud base and/or visibility fall below acceptable values, the pilot is in a situation where there will not be sufficient time to take avoiding action should an obstacle be sighted. That obstacle may be natural (hill, or simply the ground), a structure (building/tower), or another aircraft.

SANDSTORMS AND DUSTSTORMS

a. Description

Dust storms and sandstorms are regions of raised dust and sand. The dust and sand are essentially raised by the wind, and are lofted to various heights dependent upon turbulence and instability and persistency of the flow that lifted the particles.
The size of dust and sand particles ranges from slightly sub-micron to several hundreds of micron. Clearly, smaller and lighter particles will be lifted more readily and to greater heights, and take longer to settle out, while the larger particles may remain airborne only for short distances of a few hundred meters.

b. Effects on Aircraft

Drastic reductions in visibility are likely to accompany dust and sand storms. Effective visibility may very likely be close to zero in some circumstances. Dust and sand ingestion into aircraft engines may cause reductions in power till complete engine failure.

SQUALLS/ LINE SQUALLS

a. Description

A squall is simply defined as a sudden, temporary increase of the wind. It is specified as an increase in the mean wind by at least 16 kt, to a minimum value of 22 kt, and sustained for a period of 1 minute, then dying away comparatively suddenly. Squalls may be associated with the gust front/ microburst from an individual Cumulonimbus cell. They may occur in a more organised fashion, when they are known as a 'line squall'. For details section on turbulence may be referred to.

VOLCANIC ASH:

Volcanic ash is another major threat to aviation. Truly speaking this is not a meteorological phenomenon, however, issuance of relevant warnings have become part of the routine meteorological services. During volcanic eruptions, large amounts of pulvarised rock are blasted upwards. The height to which they reach is determined by the severity of the blast. At times the ash plumes will reach stratospheric levels. The ash is then spread downwind by the winds aloft in the troposphere and stratosphere.

The dust in the troposphere settles fairly rapidly and can limit visibility over a large area. The major concern about volcanic ash is that it get ingested by aircraft engines at flight level. Cases of engine failures in different types of aircraft have been reported.

The volcanic dust also contains considerable pumice material. Leading edges such as wings, struts, and turbine blades can all be abraded to the point where replacement becomes necessary. Windscreens have been abraded until they become opaque.

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. Altimeter setting procedures, concept of QNH, QFE and ICAO Standard Atmosphere.

METAR and SPECI:

. METAR and SPECI are aviation weather reports encoded from the airport weather observations. METAR is the name of the code for aviation routine weather report which was introduced in 1 January 1968, internationally, and has been modified a number of times since then. A METAR is issued at hourly or half- hourly intervals. SPECI is the name of the code for an aviation special weather report. A SPECI can be issued at any time when certain criteria are fulfilled. Both METAR and SPECI have the same code form and both may have a TREND forecast appended.

METAR or SPECI contains the following information in the given order.

1. Identification of the type of report
2. Location indicator
3. Time of Observation
4. Identification of an automated or missing report, when applicable
5. Surface Wind (Direction and Speed)
6. Visibility
7. Runway Visual Range (if available)
8. Present Weather
9. Cloud amount, cloud type (only for cumulonimbus and towering cumulus clouds) and height of cloud base or where measured, Vertical Visibility
10. Air Temperature and Dew Point Temperature
11. Pressure- QNH and, when applicable, QFE (QFE included only in local routine and special reports)
12. Supplementary Information (included in accordance with regional air navigation agreement)

The code word CAVOK is used to replace the visibility, present weather and cloud groups when the following conditions occur simultaneously at the time of observation:

a) The visibility is 10 km or more;
b) No cloud of operational significance;
c) No significant weather phenomenon to aviation.
d)

At the end of a METAR or SPECI a section starting with the code word RMK may be appended. This section contains information required by the national authority of each country and is not disseminated internationally.

1. IDENTIFICATION GROUPS

METAR
Or
SPECI } **CCCC YYGGggZ (AUTO)**

This will have three parts:

- The report code name (METAR or SPECI)
- The ICAO location indicator of the reporting station, e.g. VOMM
- The day of the month and the time of the observation in hours and minutes UTC, followed by the letter Z

The indicator AUTO is inserted when the report contains a fully automated observation, that is, without human intervention.

2. SURFACE WIND

{ **KMH or**
KT or
MPS } **$d_n d_n d_n$ V $d_x d_x d_x$**

Normally there will be a five-figure group to indicate the ten-minute mean wind followed by an abbreviation to indicate the wind speed units used. The first three figures indicate the wind direction and the last two the wind speed.

Example: 31015KT

If during the ten minutes preceding the observation the maximum gust speed has exceeded the mean speed by 10kt or more, this gust has to be reported by inserting the letter G followed by the gust speed directly after the mean speed.

Example 31015G30KT

If during the ten minutes preceding the observation, the wind direction has varied by 60 degrees or more, but less than 180 degrees and the mean wind speed is more than 3kt, the two extreme directions should be indicated in clockwise order, with a letter V inserted between the two directions.

Example: 31015G30KT 280V350

NOTE:

The wind reported should be the mean over the ten minutes preceding the observation. If during this period there has been a marked discontinuity lasting at least two minutes, the mean values should be assessed over the period after the discontinuity. A marked discontinuity occurs when there is a wind direction change of 30 degrees or more with a wind speed of 20 kmph (10kt, 5 mps) of more, before or after the change or a wind speed change of 20 kmph (10 kt, 5 mps) or more.

SPECIAL CASES:

Variable: The wind direction is encoded as VRB only if:
(a) The wind speed is 6 kmph (3 kt, 2mps) or less;

(b) The wind speed is higher and the wind direction is varying by 180 degrees or more and a single direction is impossible to determine, for example when a thunderstorm is over the aerodrome.

Example: VRB02KT

Calm: This encoded as 0000 followed by the abbreviation for the wind speed units.

Example: 00000KT

Speeds of 100 kt (50 mps or 200 kmph) or more: The wind speed shall be preceded by the letter indicator P and reported as P99 kt (P49 mps or P 199 kmph)

Example: 240P99KT

The averaging periods for wind observations will be as follows:

At Mumbai (Bombay), Kolkata (Calcutta), New Delhi and Chennai (Madras)

- Two minutes for reports for Landing and Take-off and for inclusion in reports disseminated in abbreviated plain language locally over the aerodrome.

- Ten minutes for C.W. reports disseminated beyond the aerodrome except that when the 10-minute period includes a marked discontinuity in the wind direction and/or speed, only data occurring since the discontinuity should be used for obtaining mean values, hence the time interval in these circumstances should be correspondingly reduced. A marked discontinuity occurs when there is an abrupt and sustained change in wind direction of 30^o or more, with a wind speed of 10 knots before or after the change, or a change in wind speed of 10 knots or more, lasting at least 2 minutes.

At other stations:

- C.W. reports disseminated beyond the aerodrome as well as locally over the aerodrome-

a) Ten minutes in the case of stations equipped with Dines PT or electrical anemographs

b) Three minutes at other stations.

Reports for Take-off/Landing 2 minutes

- The averaging period for measuring variations from mean wind speed (gusts) reported accordance with 3.8.1.3.should be 3 seconds for local routine and special reports and for METAR and SPECI and for wind displays used for depicting variations from the mean wind speed (gusts) in Air traffic service Units.

3. VISIBILITTY:

CODE FORMAT**:**

VVVVDv VxVxVxVxDv

When there is NO marked directional variation in visibility, the minimum visibility will be reported in metres using four figures.

Example: 4000 (Four thousand metres)

Directional variations are NOT considered MARKED unless the minimum visibility is less than 5000 m and the variations are at least 50 percent of the minimum visibility.

When there is a marked directional variation in the visibility, the reported minimum visibility will be followed by one of the eight points of the compass to indicate the direction of this visibility.
Example: 4000NE (Four thousand meters to the North East).

If the lowest visibility is observed in more than one direction, then the most operationally significant direction shall be reported.

EXCEPTION:

When the minimum visibility is less than 1500 m and the visibility in another direction is more than 5000 m, the maximum visibility and its direction should also be reported.
Example: 1400SW 6000N (One thousand four hundred metres to the SouthWest and 6 km to the North)
If the maximum visibility is observed in more than one direction, then the most operationally significant direction is reported.

Averaging of Visibility

When instrumented systems are used for the assessment of Visibility, their output shall be updated at least every 60 seconds to permit the provision of current, representative values.

The averaging period shall be

a) 1 minute for local routine and special reports and for visibility displays in ATS units, and
b) 10 minutes for METAR and SPECI except that when the 10 minute period immediately preceding the observation includes a marked discontinuity in visibility, only those values occurring after the discontinuity shall be used for obtaining mean values.

Note:- A marked discontinuity occurs when there is an abrupt and sustained change in visibility, lasting at least 1 minutes, which reaches or passes through criteria for the issuance of SPECI reports.

4. RUNWAY VISUAL RANGE

CODE FORMAT

$$\left\{ \begin{array}{l} RD_RD_R/V_RV_RV_Ri \\ \text{Or} \\ RD_RD_R/V_RV_RV_RV_RVV_RV_RV_RV_Ri \end{array} \right\}$$

Where the Runway Visual Range (RVR) can be determined and when it is reported, the group starts with the letter R followed by the Runway designator DRDR and a / followed by the RVR in metres. Upto a maximum of four groups may be reported.

Example: R24/1100 (Runway visual range on Runway 24, greater than one thousand one hundred metres)

SPECIAL CASES

(a) When the RVR is assessed to be more than 1500 m it should be reported as P 1500
    Example: R24/P1500 (Runway visual range on Runway 24, greater than one thousand five hundred metres)
(b) When the RVR is below the minimum value that can be assessed the RVR should be reported as M followed by the appropriate minimum value that can be assessed.
    Example: R24/M0150 (Runway visual range on Runway 24, less than one hindered and fifty metres)
    Reporting scales of RVR are as follows:
    (a) Increments of 25 m, if RVR below 400 m
    (b) Increments of 50 m, if RVR between 400 and 800 m
    (c) Increments of 100 m, if RVR above 800 m

Any observed value, which does not fit the report scale in use, shall be rounded down to the nearest step in the scale.

The lower limit of RVR should be considered as 50 meters and 2000 meters the upper limit. Outside these limits, local routine and special reports and METAR and SPECI should merely indicate that the runway visual range is less than 50m or more than 2000m.

NOTE:

1. When the visibility is 5000 m or less, one of the phenomena IC, FU, HZ, DU, SA and BR is reported in the METAR/SPECI.
2. When the visibility is above 5km, the phenomena IC, FU, HZ, DU, SA and BR are not present by definition and are therefore not reported. For instance, if the visibility is 5000 m, it will be encoded as 5000 together with the phenomena IC, FU, HZ, DU, SA and BR, causing this reduction in visibility.
3. Whereas if the visibility is 5001 to 5999 m this is still encoded as 5000 (rounded down to the nearest 1000 m) in the METAR/SPECI but the phenomena IC, FU, HZ, DU, SA and BR will not appear.

5. **CLOUD or VERTICAL VISIBILITY**

$$\left\{ \begin{array}{l} N_sN_sN_sh_sh_sh_s \\ \text{or} \\ VVh_sh_sh_s \\ \text{or} \end{array} \right\}$$

NSC

Cloud groups consist of six characters under normal circumstances. The first three indicate cloud amount with:

1/8 to 2/8	being reported as	FEW (Few)
3/8 to 4/8	being reported as	SCT (Scattered)
5/8 to 7/8	being reported as	BKN (Broken) and
8/8	being reported as	OVC (Overcast)

The last three characters indicate the height of the base of the cloud in units of 30 m or 100 ft upto 3000 m (10000 ft) and in steps of 300 m (1000 ft) above.

Example: 3/8 of Stratocumulus with a base of 1850 will be encoded : SCT018

NOTE The cloud based is rounded down, in the case to 1800 ft.

CLOUD TYPE

Types of cloud other than significant convective clouds are not identified. Significant convective clouds are;

Cumulonimbus indicated by CB and

Cumulus congestus of great vertical extent indicated by TCU

The contraction TCU, taken from "Towering Cumulus", is an ICAO abbreviation used to describe this type of cloud.

REPORTED CLOUD GROUPS

The cloud group can be repeated to report different layers or masses of cloud but the number of groups should not normally exceed three. The following criteria should be followed when selecting cloud layers to be reported.

The lowest individual layer (mass) of any amount.

The next individual layer of more than 2/8

The next higher layer of more than 4/8

In addition: Significant convective clouds (CB or TCU) if not already reported in one of the three groups above.

Example: There are 1/8 at 500 ft
2/8 Cumulonimbus at 1000 ft
3/8 Cumulus at 1800 ft
5/8 Stratocumulus at 2500 ft

At mountain stations, when cloud base is below station level, the cloud group should read NsNsNs///.

Example: SCT///, FEW///CB

The reported cloud would be:

FEW005 FEW010CB SCT018 BKN025

NOTE:

1. The cloud groups are reported in ascending order of height.
2. When there are no clouds and the abbreviation CAVOK is not appropriate, the abbreviation NSC should be used.
3. When there are no clouds below 1500 m (5000 ft) or below the highest minimum sector altitude whichever is greater, no restriction to vertical visibility and the abbreviations CAVOK, the abbreviation NSC is used.
4. When Cumulonimbus (CB) and Towering Cumulus (TCU) have a common cloud base, the type of cloud is reported as CB and the amount of clouds is encoded as the sum of CB and TCU amounts at that cloud base.

VERTICAL VISIBILITY

When the sky is obscured and cloud details cannot be assessed but information on vertical visibility is available, the cloud group should be replace by a five character group the first two characters being VV followed by the vertical visibility in units of 30 m or 100 ft as for cloud base. When the sky is obscured but the vertical visibility cannot be assessed the group will read VV///.

Example: VV003 (Vertical visibility three hundred feet/ 90 meters)

AIR AND DEW POINT TEMPERATURE:

Code format: **T'T'/ TdTd**

The observed air temperature and dew point temperature, each as two figures rounded to the nearest whole degree Celsius, should be reported next.

Temperatures below 0 degrees Celsius will be preceded by M to indicate minus.
Example: Minus 9.5 degrees Celsius is reported as MO9.

NOTE: Air temperature and dew point values of .5 degrees will be rounded up to the higher whole degree.

Example:	Air temperature:	9.5 degree Celsius
	Dew point temperature:	3.3 degree Celsius
	Will be reported as 10/03	

PRESSURE – QNH

CODE FORMAT: $QP_HP_HP_HP_H$

The last group of the main part of the report should indicate the QNH rounded down to the nearest whole hectopascal. The group starts with the letter Q followed by four figures.

Example: A SNH of 995.6 hPa is reported as Q0995
NOTE: In some countries inches of mercury are used as the unit of QNH. In this case the indicator will be A (instead of Q).
Example: A QNH of 30.05 inches is reported as A 3005.

8. SUPPLEMENTARY INFORMATION:

CODE FORMAT:

$RE\ w^iw^i$ $\left\{ \begin{array}{l} \text{WS RWYDRDR} \\ \text{Or} \\ \text{WS ALL RWY} \end{array} \right.$

(WT_sT_s/SS^i)

$(R_RR_RE_RC_Re_Re_RB_RB_R)$

For international dissemination this section is used to report:
Recent weather phenomena of operational significance;
Information on wind shear in the lower layers; and

Other information only in accordance with regional air navigation agreement including

(a) sea surface temperature and the state of the sea, and
(b) state of the runway

Observations made at aerodromes should include the available supplementary information concerning significant meteorological conditions, particularly those in the approach and climb-out areas, and specifically the location of cumulonimbus or thunderstorm, moderate or severe turbulence, wind shear, hail, severe line squall, moderate or severe icing, freezing precipitation, marked mountain waves, sandstorm, dust-storm, blowing snow or funnel cloud (tornado or waterspout). Where practicable, the information should identify the vertical extent and direction and rate of movement of the phenomenon. As turbulence, wind shear and icing cannot, for the time being, be satisfactorily observed from the ground, evidence of their existence should be derived from aircraft observations during the climb out or approach phases of flight.

In local routine and special reports and in METAR and SPECI, the following recent weather phenomena, i.e. weather phenomena observed at the aerodrome during the period since last hour, whichever is the shorter, but not at the time of observation, should be reported, up to a maximum three groups, in the supplementary information:

• freezing precipitation	**REFZDZ, REFZRA**
• moderate or heavy precipitation	**REDZ, RERA, RESN,**
(including showers thereof**)**	**RESG, REPL, RESHRA**
`	**RESHSN, RESHGR, RESHGS**
• blowing snow	**REBLSN**
• dust-storm or sandstorm	**RESS ,REDS**
• thunderstorm	**RETS**
• funnel cloud (tornado or water spout)	**REFC**
• volcanic ash	**REVA**

In local routine and special reports, the following significant meteorological conditions, or combination thereof, should be reported in supplementary information:

-Cumulonimbus cloud CB

-thunderstorm	TS
-moderate or severe turbulence	MOD TURB,SEV TURB
-wind shear	WS
-hail	GR
-severe line squall	SEV SQL
-moderate or severe icing	MOD ICE, SEV ICE
-freezing precipitation	FZDZ, FZRA
-severe mountain wave	SEV MTW
-duststorm, sandstorm	SS, DS
-blowing snow	BLSN
-funnel cloud(tornado or water spout)	FC

Information on recent weather of operational significance observed at the aerodrome within the period since the last issued routine report or last hour, whichever is the shorter, but not at the time of observation and, where local circumstances so warrant, information on wind shear should be added in reports disseminated beyond the aerodrome. Information on recent significant weather should be added in the form, for example, "REFZRA". Information on wind shear should be added, if necessary, in the form "WS RWY 12" or "WS ALL RWY".

Significant directional variations in visibility particularly, those affecting the approach area, should be observed and reported. Directional variations in visibility should be reported with an indication of the direction of observation, for example, "VIS 2000M TO S".

RVR values above 1500 m and up to 2000 m are to be reported in METAR/SPECI and in special MET REPORTS a supplementary information which should not be disseminated internationally. If the horizontal visibility is 1500 m or less but RVR is more than 2000 m the same should be reported as "RVR ABV 2000 M" as supplementary information.

SELECTED SPECIAL REPORTS

These are issued on red colour paper to local ATC in abbreviated plain language and identified by the prefix "SPECIAL" and also transmitted outside the aerodrome of origin in coded message and are identified by the prefix "SPECI".

Selected Special Reports are recorded by all aeronautical meteorological stations recording routine observations. These are issued whenever changes of operational importance occur in the elements- *surface wind, visibility, Runway Visual Range, present weather and cloud* as detailed below:

a) ***Surface Wind***

i). When the mean surface wind direction has changed by 60^0 or more from that given in the latest report, the mean wind speed before and/or after the change being 10 knots or more;

ii) When the mean surface wind speed has changed by 10 knots or more from that given in the latest report;

iii) When the variation from the mean surface wind speed (gusts) has increased by 10 knots or more from that given in the latest report, the mean speed before and/or after the change being 15 knots or more.

b) ***Visibility***

When the visibility changes to or passes 800, 1500, 3000 or 5000 metres.

c) ***Runway Visual Range (RVR)***

When the RVR changes to or passes **150,350,600 or 800** metres.

These SPECIs are to be issued by all offices equipped with instrumental recording facilities of RVR.

d) ***Present Weather***

When the onset, cessation or change in intensity of any of the following weather phenomena or combinations thereof occurs:

- freezing precipitation
- freezing fog
- moderate or heavy precipitation (including showers thereof)
- low drifting dust, sand or snow
- blowing dust, sand or snow (including snowstorm)
- duststorm
- sandstorm
- thunderstorm (with or without precipitation)
- squall
- funnel cloud (tornado or waterspout).

e) ***Cloud***

1) When the height of base of the lowest cloud layer of BKN or OVC extent changes to or passes 30, 60, 150 , 300, or 450 m (100, 200, 500, 1000 or 1500 ft.)

2) When the amount of a cloud layer below 450 m (1500 ft) changes :

(i) from SCT or less to BKN or OVC; or

(ii) from BKN or OVC to SCT or less.

f) When the sky is obscured and the vertical visibility changes to or passes through one or more of the following values:
30, 60, 150 or 300M (100, 200, 300, 1000FT)

g) Air temperature

When air temperature has increased by 2 ^{0} C or more from that given in the latest report.

NOTE:

1) When a deterioration of one weather element is accompanied by an improvement in another element, a single Selected Special Report should be issued. It shall be treated as a deterioration report.

1) A Selected Special Report representing a deterioration in conditions should be disseminated immediately after the observation. A Selected Special Report representing an improvement in conditions should be disseminated only after the improvement has been maintained for 10 minutes; it should be amended before dissemination, if necessary, to indicate the conditions prevailing at the end of that 10 minutes period. A Selected Special Report representing a deterioration of one weather element and an improvement in another element should be disseminated immediately after the observation.

In local routine (METAR) and SPECI in abbreviated plain language;

a) the unit of measurement used for the height of cloud base and vertical visibility shall be indicated; and

b) when there is more than one runway in use and the heights of cloud bases are observed by instruments for these runways, the available heights of cloud bases for each runway shall be reported and the runways to which the values refer shall be indicated.

SPECIAL REPORTS

This message is identified with the prefix "SPECIAL" and supplied on red colour paper. However these are not disseminated outside the aerodrome of origin. These are issued to local ATC units in addition to Met. Report / Selected Special Report.

In addition to the Selected Special Reports, **special reports** should be issued for changes in cloud base and visibility by all aeronautical meteorological offices in India as per the following criteria :

Element	*Criteria*	*Issued by*
1) Cloud base	Whenever the height of base of cloud covering more than half the sky changes to or passes 90 or 120 metres (300 or 400 feet)	All stations equipped with ceilometers/ ceilographs.

2) Visibility	Whenever visibility changes to or passes 2000 or 4000 metres.	By all aeronautical meteorological stations recording routine observations.

Criteria for issue of SPECIAL Reports in India

1. In addition to the Selected Special Reports (SPECI) which are to be issued as per criteria given in appendix II Special Reports shall be issued for "Height of base of cloud" and "Visibility" by aerodrome meteorological offices in India as per the following criteria :

Element	Criteria	Issued by
a. Cloud base	Whenever the height of base of cloud covering more than half the sky changes to or passes 90 or 120 metres (300 or 400 feet)	All stations equipped with ceilometers/ ceilographs.
b) Visibility	Whenever visibility changes to or passes 2000 or 4000 metres.	By all aeronautical meteorological stations recording routine observations.

2. The SPECIAL reports shall be issued in addition to the METAR/SPECIS.

3. These SPECIAL reports shall be issued in plain language to local ATC purely for their local use. These reports are not to be disseminated beyond the aerodrome of origin.

4. Current Weather Reports satisfying the criteria for issue of special reports, issued at the routine hours of observations may be disseminated as "Special Reports" within the aerodrome and as 'METARS' beyond the aerodrome.

5. 'TREND' Forecasts shall be appended to these SPECIAL reports.

6. These reports shall be issued during the current weather watch period.

7. These SPECIAL reports shall be recorded in the Current Weather register in chronological order with the prefix SPECIAL in red ink.

8. Various current weather reports and their identification are summarized below :

No.	Type of report	Identification	
		Plain language report	Coded report
1.	Routine Report	MET REPORT	METAR
2.	Selected	SPECIAL	SPECI
3.	Special Report	SPECIAL	---

Landing forecasts (TREND forecasts)

1. Trend-type landing forecasts are issued in India.

2. A concise statement indicating the expected significant changes in Wind, Visibility, present weather & clouds given in a routine report or special report or selected special report is known as Trend forecast or landing forecast.

3. The period of validity of a trend forecast is 2 hours from the time of the MET REPORT or SPECIAL to which it is attached.

4. The change indicators are BECMG or TEMPO and these are used with the abbreviations FM, TL or AT followed by a time group in hours and minutes. AT is however not used with TEMPO.

5. BECMG describes changes where the meteorological parameters are expected to reach or pass specified values at a regular or irregular rate.

6. TEMPO describes anticipated fluctuations in meteorological parameters which reach or pass specified values and last for less than one hour in each instance and in the aggregate cover less than one half of the period during which the fluctuations are forecast to occur.

7. When no significant change is anticipated in all the elements (wind, visibility, present weather and clouds) during the next 2 hours, the trend is given as NOSIG.

8. If a trend is attached to a MET REPORT or SPECIAL of 1000 Z the validity period of the trend is from 1000 Z to 1200 Z. The use of FM TL and AT and their meanings are given below, when they are used with a Met report of 1000 Z.

Change group	Time when change Commences	Time when change will be completed
BECMG FM1030 TL1130	1030	1130
BECMG FM1030	1030	1230
BECMG TL1130	1000	1130
BECMG AT1130	1130	1130
BECMG (without any time group)	1000 or any time between 1000 and 1200	1200
TEMPO FM1030 TL1130	Temporary fluctuations during the period 1030 to 1130	
TEMPO FM 1030	Temporary fluctuations during the period 1030 to 1200.	
TEMPO TL1130	Temporary fluctuations during the period 1000 to 1130.	
TEMPO (without any time group)	Temporary fluctuations during the period 1000 to 1200	

9. The PROB group is not used in the Trend forecast.

10. Significant changes that form the criteria for inclusion in the trend forecast are as follows :

(i) Wind :

a) Change in mean wind speed by 10 kts or more.

b) Change in mean wind direction by 60° or more with mean speed remaining 10 kts or more either before and/or after the change.

(ii) Visibility

When visibility is expected to reach or pass 5000, 3000, 1500, 800, 600, 350 or 150 m. In the case of significant reduction in visibility the phenomenon causing the reduction will also be indicated.

Present weather: Onset, cessation or change in intensity of the following phenomena.

- freezing precipitation
- freezing fog
- moderate or heavy precipitation (including showers thereof)
- low drifting dust, sand or snow
- blowing dust, sand or snow (including snowstorm)

- duststorm
- sandstorm
- thunderstorm (with or without precipitation)
- squall
- funnel cloud (tornado or waterspout)
- Other weather phenomena given in (code table 4678) only if they are expected to cause a significant change in visibility.

End of significant weather is indicated by NSW (both in the code form as well as plain language form).

(iii) Clouds:

a) When the height of base of the lowest cloud layer of BKN or OVC extent reaches or passes 450 m (1500'), 300 m (1000'), 150 m (500'), 90 m (300'), 60 m (200') 30 m (100')

b) When amount of cloud layer below 450 m (1500') changes as follows:

BKN or OVC	→ ←	SCT to SKC

In the case of significant changes in clouds all cloud groups, including those layers not expected to change significantly, shall be given following the change group.

A change to clear sky will be indicated using the abbreviation SKC.

Now, the trainees may try to interpret the METARS with following examples :

METAR VILK 100930Z 05005KT 2500 HZ NSC 19/11 Q1014 NOSIG=
METAR VIAR 100930Z 32005KT 370V360 6000 SCT100 16/10 Q1017=
METAR VIJP 100930Z VRB02KT 1200 R27/1400N FU NSC 18/07 Q1014 NOSIG=
METAR VEBD 100930Z 17004KT 6000 SKC 24/08 Q1014 NOSIG=
METAR VEGK 100930Z 11003KT 2000 HZ SKC 19/12 Q1015 BECMG 1500=
METAR VISR 100930Z VRB02KT 4000 BR SCT012 SCT015 03/M02 Q1019 TEMPO 1500 SN=

TREND FORECAST – BASIC REQUIREMENTS

The following information will be highly useful for giving successful trend forecasts.

(i) Thorough knowledge of topography of the place

(ii) Climatological details (including normals / extremes) of seasonwise, monthwise frequency of variation, duration of various met. parameters, weather clouds etc.

(iii) Radar Pictures –(hourly / half hourly) distribution of range, height of prominent echos.

(iv) Satellite pictures (Visible, IR and Water vapour)

(v) Synoptic charts (Surface, Pilot and Upper Air)

(vi) Evolution of clouds, their nature and characteristics, formation of clouds / precipitation / Thunderstorms – Theory and practical knowledge

(vii) Experience / knowledge of fluctuation of various weather elements with respect to the place.

ALTIMETER SETTING PROCEDURES

THE ICAO STANDARD ATMOSPHERE

For many purposes, such as the graduation of pressure altimeters and the design and testing of aircraft, the average state of the atmosphere needs to be represented in definite terms, which can be used, as a basis of reference. Such a representation is termed as standard atmosphere. The standard atmosphere aims to specify the average variation of temperature with height, from which the corresponding variations of pressure and density can also be deduced. The standard atmosphere as defined by the ICAO (1964) is now used internationally by aviation. The following are the chief specifications of the ICAO standard Atmosphere (ISA) up to an altitude of 32 Km.

1. It is assumed that the air is dry and obeys the ideal gas law.
2. At the mean sea level, the pressure is 1013.25 hPa, the temperature is 15^{o}C and the density is 1.225 kg/m^{3}.
3. The acceleration of gravity is assumed to be constant and equal to 9.80665 m/sec^{2}.
4. A lapse rate of 6.5^{o}C per kilometer is assumed up to tropopause (at about 11 km). At tropopause, the temperature is –56.5^{o}C.
5. The Atmosphere is isothermal in the lower stratosphere until an altitude of approximately 20 km is reached. Thereafter the lapse rate is assumed to be negative and the temperature rises at the rate of 1.0^{o}C/km. At 32km altitude, the temperature is –44.5^{o}C.

For Aviation purposes, it is not necessary to specify the standard Atmosphere above 32 km.

PRESSURE ALTIMETRY

Pressure altimetry is the determination of altitude above mean sea level based on air pressure. An altimeter is an aneroid barometer that is graduated linearly in increments of altitude. The graduation (that is, the calibration of altitude against air pressure) is prescribed by the standard atmosphere.

At any time and place the real atmosphere usually differs from the standard atmosphere so that an altimeter typically does not give the true altitude. The indicated altitude (the altimeter reading) is the same as the true altitude only when air pressure and temperature match the standard atmosphere. Unless adjustments are made, the discrepancy between indicated and true altitudes can pose serious problems, especially during the crucial takeoff and landing phases of flight.

Changes in surface air pressure en route are one cause of differences between indicated and true altitudes. For example, as an aircraft travels toward a destination reporting a lower surface air pressure than its departure point, the altimeter will read higher than the true altitude. In order to adjust for this error, the altimeters are fitted with a sub-scale graduated in millibars or hectopascals. When the indicated height is zero, the sub-scale reads barometric pressure at the position of the instrument. The altimeter is constructed so that the altitude and pressure scales can be rotated relative to each other. The sub-scale can be adjusted so that the indicated the height (for example, above ground or above sea level) is correct at time of take off, and can if required, be adjusted during flight or in preparation for landing. The value to which the sub-scale is adjusted is called the altimeter setting.

In-flight adjustments of altimeters to surface conditions, however, do not correct for

]pressure variations that arise en route principally from temperature variations within the air column beneath the aircraft. Cold air is denser than warm air so that air pressure drops more rapidly with altitude in cold air than it does in warm air. Hence, within a column of cold air, a given air pressure occurs at a lower altitude than does the same air pressure in a column of warm air. This means, for example, that as an aircraft flies into a column of air that is warmer than specified by the standard atmosphere, the altitude indicated by the altimeter will be lower than the true altitude. Conversely, the altimeter aboard an aircraft flying into air colder than specified by the standard atmosphere will read too high.

The danger, of course, is that an erroneous altimeter reading may impede a pilot's ability to clear an obstacle such as a mountain peak. In practice, this hazard can be greatly reduced by an onboard computer that measures air temperature at flight level and makes an appropriate adjustment to the altimeter reading. Note that this correction is not based on the mean temperature of the air column so that, although the error is reduced, it is not eliminated.

In summary, differences between altimeter readings and true altitude arise from en route changes in surface air pressure and/or average air temperature. Even with adjustments in altimeter readings, pilots are well advised to follow the adage "cold or low, look out below". Hence, pilots should always select a flight altitude that will allow for a margin of safety, especially when flying over mountainous terrain or during conditions of restricted visibility.

ALTIMETER SUB-SCALE SETTING:

A requirement for the safety of air traffic is ensuring adequate vertical separation of aircraft flying in any one area. It is, therefore, essential that all aircraft flying in any one area should have altimeters whose readings are strictly comparable with each other. This can be achieved in two ways:

a) Altimeter readings are constantly corrected for change of surface pressure and of mean temperature at every point of flight to obtain the true height at any stage. This procedure is laborious and impractical in flight.

b) All aircraft flying in a given area set the sub-scale of their altimeters to a single value. Although true heights may not be indicated, the error will affect all the altimeters equally. Proper vertical separation can thus be maintained amongst the different aircraft. This system is followed universally.

There are several different pressure values, which may be set on an altimeter sub-scale. The pressure, which is set on the sub-scale, is usually referred to by its abbreviation in the international Q code; short definitions of the relevant groups are as follows:

QFE: The Atmospheric pressure at aerodrome elevation (or at runway threshold)

QFF: Barometric pressure at a stated place, reduced to m.s.l. according to standard met. Practice. This value is used only in the preparation of surface charts.

QNH: Barometric pressure over the airfield reduced to m.s.l. assuming that the rate of variation of pressure between the airfield and sea level is the same as the ISA.

CHOICE OF ALTIMETER SETTING:

On occasion the pilot of an aircraft may be free to exercise his personal preference in choosing an altimeter setting, but at other times he will be required to adopt a setting prescribed by Air Traffic Control. In either case it is advisable that he should be aware of the advantages and disadvantages of whatever setting is used. The main considerations influencing the choice of setting are concerned with the phase of the flight, i.e. taking-off, cruising or landing, terrain clearance, and with maintenance of vertical separation in controlled airspace. An altimeter set to the QFE for an aerodrome reads zero (strictly the height of the altimeter above ground) when the aircraft is on the ground at that aerodrome; this is sometimes referred to as the 'zero' setting and for obvious reasons has been widely used. While in the air, the QFF setting gives approximately the height of the aircraft above the aerodrome level, but this information becomes of less use, or even misleading, when away from the aerodrome. Even when carrying out circuits and landings it may lead to difficulty, but still more so on a cross-country flight.

There is much to be said in favour of a setting, which gives approximately the height above some more general level; mean sea level is an obvious choice. Such a setting would be provided by QFE, but as this is the pressure reduced to sea level in accordance with isothermal conditions it leads to inaccuracies when used with the pressure altimeter which, of course, assumes ISA conditions. The error in the indicated height would be small for heights near mean sea level, but the discrepancy increases in proportion to height and to the difference between standard and actual conditions.

These difficulties are minimized by the use of QNH, since with this setting the reduction is made according to the standard atmosphere and the instrument should therefore read the aerodrome elevation correctly on landing. It is the setting best suited to the construction of the pressure altimeter and gives the most satisfactory relation between indicated and true height under all circumstances, thereby providing a satisfactory measure of terrain clearance in transit.

Whatever altimeter setting is used indicated altitudes in flight are subject to the effect of variations in temperature and pressure with time and place. One of the ways to overcome this

problem is that all the aircraft set their altimeters to any fixed value so that desired flight separation can be achieved. This fixed value, which has been commonly used is 1013.2 mb (29.92 inch) and is known as standard QNH. Thus an aircraft leaving an airfield on a route flight will fly on local QNH setting initially, then at standard QNH at cruising altitude, and finally change to local QNH on joining circuit at the destination airfield.

Other useful references for further clarity and extended learning on the topics:

1. **Manual on Meteorological Services for Aviation in India (2012).**
2. **Lecture notes of IMTC course prepared by CAMD, New Delhi (2013-14).**
3. **Code books on Aviation Meteorology published by IMD.**

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