INDIA METEOROLOGICAL DEPARTMENT

FORECASTING MANUAL

PART V

TECHNIQUES OF HIGH LEVEL ANALYSIS AND PROGNOSIS

I: ORGANIZATION AND METHODS OF ANALYSIS

ISSUED BY

THE DEPUTY DIRECTOR GENERAL OF OBSERVATORIES (FORECASTING)

POONA - 5
One of the important recommendations of the ICAO MET V meeting (1959) related to the supply of documentation to international jet flights in chart form instead of in tabular form. International Airline Companies operating through India requested for early implementation of this recommendation. For this purpose, Extended Analysis and Prognostic (EAP) Centres were established at the 1960s, Bombay (Santacruz) and Calcutta (Crown) in 1963 and chart form of documentation was introduced from 1 January 1964. One of the problems that came up in this connection was the lack of suitable prognostic techniques for tropical areas. A Working Group with Dr. P.K. Das, Director, NHAC as convener and Shri N.C. Rai Sircar, Meteorologist-in-charge, MMO Santacruz and Shri D.V. Rao, Meteorologist-in-charge, MMO Dum Dum, as members, was set up by the DGO in 1962 to examine the existing techniques of high level analysis and prognosis with particular reference to their applicability to our area of interest. This Working Group compiled a Memorandum on the subject for the guidance of forecasters. The final draft of this Memorandum was ready by February 1967. It was decided that this Memorandum be published as Part V of the Forecasting Manual.

2. The Memorandum consists of eight chapters. The first four chapters dealing with meteorological organization for international aviation and methods of synoptic analysis are published in this report with some editorial changes. The remaining chapters relating to prognostic techniques and assessment of accuracy of forecast will be published in subsequent reports.

R. Ananthakrishnan
Deputy Director General of Observatories (Forecasting)
1.3 Looking into the future, it is not unlikely that supersonic aircraft with speeds exceeding Mach 2.5 may be used, in the not too distant future, as the normal means of intercontinental transportation. The very high altitudes and speeds at which these aircraft will operate, may well mean a shift in emphasis from certain factors now reckoned as important to others which are not considered so at present, such as the chemical composition of the upper atmosphere. The limits of tolerance of meteorological variables in aeronautical forecasts would also tend to become progressively more restrictive than at present. Schemes are already under way for bringing vertical take-off and landing aircraft (VTOL) into the realm of practical possibility. Such aircraft may demand more specialised meteorological information, such as the microstructure of vertical wind fields. To keep pace with this rapid development in the field of aviation, it is imperative that the available resources are utilised to the utmost.

1.4 The great majority of turbo-jet aircraft now fly at pressure altitudes of 7.5 to 14 km. It has been estimated that the fuel consumption at sea level of a turbo-jet aircraft is more than double the value at its optimum cruising level. A revised approach for landing, therefore, means a heavy increase in fuel consumption. The increased sensitivity of turbo-jet aircraft to certain atmospheric conditions demands accurate meteorological information for economic operation.

1.5 The first systematic study of meteorological requirements for jet aircraft operations was made by a special panel set up by the council of ICAO at its twentieth meeting in July 1956. This panel, now known as the Jet Operations Requirements Panel (JORP), made a number of significant and far-reaching recommendations. The sixteen basic recommendations made by the panel at their fourth meeting in 1959 are given in Appendix I.

1.6 A review of the meteorological requirements for jet aircraft flights was made by the India Meteorological Department as early as 1957 at the time of the introduction of the British Overseas Airways Corporations' Comet Service across India. This was followed by the publication of a brochure entitled "Review of Meteorological Requirements for Jet Flights over India" (1957). A consultation conference on the meteorological requirements of jet aircraft flights over India (MCCJ-I) was held in New Delhi in November 1957. This meeting was attended by representatives of many national and international airlines and of the Civil Aviation Department, Air Headquarters, Naval Headquarters etc. In addition to a review of progress in procedural matters, this meeting drew emphasis from some factors now reckoned as important to others which are not considered so at present. Schemes are already under way for bringing vertical take-off and landing aircraft (VTOL) into the realm of practical possibility. Such aircraft may demand more specialised meteorological information, such as the microstructure of vertical wind fields. To keep pace with this rapid development in the field of aviation, it is imperative that the available resources are utilised to the utmost.

1.7 In response to the request of international airline operators, a second consultation conference on meteorological requirements for jet aircraft operations (MCCJ-II) was held in Calcutta in April 1961. This meeting led to an exchange of views in the light of the experience gained in the four years between MCCJ-I and MCCJ-II. A decision was taken at this meeting to introduce new area meteorological watch procedures in the form of SIGMET and METAR information as developed by ICAO. It was felt that this time had also arrived for provision of documentation in the form of prognostic upper level charts at international airports.

1.8 At about this time, progress in techniques of analysis for high level aviation received considerable impetus from three new research centres started in the Department. The first to be formed was the Northern Hemisphere Exchange and Analysis Centre (NHX) at New Delhi. With the establishment of a radio teletype channel linking New Delhi with Moscow in 1960 and of a similar channel between New Delhi and Tokyo in 1961, a large volume of meteorological data for the northern hemisphere became available to Indian meteorologists for the first time. The Northern Hemisphere Analysis Centre was entrusted with the task of processing this data, preparing constant pressure charts and examining different techniques of prognostics. A scheme for routine

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* The speed of sound in air at NTP is 1193 km/hr (644 knots). Mach number (M) refers to the speed of the aircraft in relation to the speed of sound.
broadcast of analysed and prognostic charts by facsimile transmission was also put into operation. These charts are now being received at different centres in India and abroad.

1.9 In 1963 the International Meteorological Centre (IMC) was established at Bombay in connection with the meteorology programme of the International Indian Ocean Expedition (IIOE). Arrangements were made at the IMC for reception of data broadcast by RTT from different centres and a fairly wide coverage of data from the Southern Hemisphere was available at this centre in addition to the data for the northern hemisphere. The charts prepared and analysed at the IMC covered the area from 20°E to 155°E and 50°S to 45°N. On completion of the IIOE programme the IMC was shifted to Poona in June 1966 where it started functioning as the Indian Ocean and Southern Hemisphere Analysis Centre (INOSHAC). The Institute of Tropical Meteorology (ITM), started at Poona towards the end of 1962, also began devoting attention to problems of forecasting for low latitudes. Special units for extended area analysis and weather prognosis were also set up at the Main Meteorological Offices at Santacruz and Dum Dum in 1965. Following the experimental work on analysis and prognosis at these centres for about a year, the chart form of documentation for international services was introduced at the Main Meteorological Offices at Santacruz and Dum Dum from 5 January 1964.

1.10 A third consultative conference on the meteorological requirements of Jet aircraft (MCCJ-III) was held at Bombay in April, 1964. An important feature of this conference was an extensive discussion of the likely meteorological requirements for supersonic aircraft operations. The conference discussed the facilities necessary for implementation of recommendations made by ICAO MET/OPS Divisional Meeting (Jan-Feb, 1964). It made a number of recommendations for development of suitable meteorological instruments at international air ports and for preflight and inflight service including institution of RTF VOLMET broadcasts at Bombay.

1.11 In June 1966, a radio teletype circuit between Delhi and Melbourne (via Singapore) was established as a result of which basic meteorological data of the Southern Hemisphere began to be received regularly at the NHEC New Delhi.

1.12 The following chapters present a consolidated account of (a) the actual meteorological requirements for high level aviation and (b) the techniques of analysis and prognosis, which with some degree of success has been achieved in our meteorological centres. The methods described do not represent the final stage of development. With more experience and improvements in our understanding of weather in the tropics, the techniques of analysis and prognosis, are likely to undergo changes.

REFERENCES

2. Review of Meteorological Requirements for Jet Flights over India. 1957 - India Meteorological Department, New Delhi.
4. Meteorology in Relation to High Level Aviation over India and Surrounding Areas. 1957 - India Meteorological Department, New Delhi.

2.1 One of the important responsibilities of a national meteorological organization is to provide service for the safe, regular and efficient conduct of air transportation. Technical regulations of ICAO and WMO have laid down procedures for this purpose, according to which the operators, pilots-in-command and others concerned with international air transport are to be supplied with the meteorological information necessary for performing their respective functions. The operational procedures, which are followed in India, to provide the desired meteorological services are summarized below.

2.2 The services rendered to international aviation may be grouped under the following heads:

(a) Information for pre-flight operational planning
(b) Briefing and documentation at the time of departure
(c) Inflight meteorological service
(d) Short period landing forecasts
(e) Inflight and postflight reports.

2.3 Information for pre-flight operational planning

2.3.1 The required information for a specific flight is normally supplied to an airline operator 3 to 6 hours before the commencement of the flight. Some airline operators require meteorological information for advance or preliminary operational planning 5 to 24 hours in advance, but such cases are very few. On a few occasions, meteorological data are also supplied for the preparation of a flight plan for incoming aircraft from stations where operators do not have suitable staff for this purpose. Such flight plans are passed on to the concerned stations by the company's representatives for the use of their incoming flights. The documentation supplied for pre-flight planning consists of the following items:

(i) Forecasts of upper winds and temperatures:
   - for cruises: 500 mb (9 km), 350 mb (10.5 km) and 200 mb (12 km);
   - for ascent and descent: 850 mb (1.5 km), 700 mb (3 km),
     600 mb (4.5 km), 500 mb (5 km) and 400 mb (7.5 km).

(ii) Forecasts of upper winds and temperatures for the cruise, usually 500 mb (9 km), and for the descent phase, 600 mb (4.5 km), between the destination aerodrome and its alternate/alternates for use in the event of a diversion.

(iii) Relevant aerodrome forecasts for departure and destination aerodrome and their alternates.

Forecasts for the departure aerodrome and its alternates are required in the event of an aircraft's return, due to mechanical failure or other causes, before reaching the point of no return. Normally these aerodrome forecasts are valid for a period of 4 to 6 hours, commencing from 1 hour before the expected time of such landing.

(iv) Information regarding the general synoptic situation and expected weather conditions over and near the route.

(v) Take-off data consisting of forecasts of surface temperature, pressure and surface wind for the aerodrome of departure.

These are required for determination of the take-off gross weight (TOGW), and are needed by the operator within 3 hours of the time of departure. If the meteorological conditions prevent take-off at the desired all-up weight, it may become necessary for the operator to reduce the fuel figure and introduce an additional refuelling stop on the way. The relationship between TOGW and temperature is not fixed but, approximately, each degree rise in temperature decreases the allowable TOGW by about 250 kg. On the other hand, a 10 knot headwind can increase the allowable TOGW by 250 kg. Correct information on gustiness and wind shear in the take-off and approach area is also necessary for jet operations. Swept-back wing type jet aircraft are particularly sensitive to cross-wind variations. Some operators are
also interested in the density altitude* of the airport. Forecasts of temperature, wind and pressure for take-off purposes should be representative of the conditions prevailing over the runway in use. Therefore, distant reading meteorological instruments are installed at suitable sites near the runways at international airports.

2.3.2 The temperature and pressure forecasts are prepared from the current values and autographic records of the previous day. Due consideration is given to diurnal variations, the prevailing synoptic situation and the movement of thermal and pressure systems over the area concerned. For the purpose of take-off, the required accuracy of temperature forecasts is ± 1°C for pre-flight planning, and ± 3°C for preliminary planning. According to IATA requirements, pressure forecasts for pre-flight planning should be correct to ± 1 mb, while for preliminary planning the required limits are ± 3 mb. A verification of the temperature and pressure forecasts issued from Indian MMOs has shown that success to the desired extent has been achieved on more than 85% occasions.

2.3.3 The surface wind forecasts are based on the latest observations of surface and upper winds at lower levels, the normal for the aerodrome in question, the diurnal variation and the surface wind of the previous day corresponding to the time of take-off. In these wind forecasts the tolerance is ± 5° in respect of direction (mean); in respect of speed, the tolerance is ± 5 knots for speeds up to 25 knots and ± 20% of the mean speed for speeds exceeding 25 knots.

2.3.4 The airworthiness committee of ICAO, in one of its recent meetings, recommended that instead of using the term 'light variable' with reference to surface wind, a more precise statement may be made when practicable for take-off forecasts, to indicate whether the main component of the wind is along the runway and, if it is small or not. A component is considered small when it is between 5 to 10 knots, depending on the prevailing synoptic situation. The reason that prompted the committee to make this recommendation was that from experience it was found that during conditions forecast as 'light winds', there could be a tail wind component strong enough to appreciably affect the take-off distance of jet aircraft at the time of take-off. To forewarn the pilot-in-command of this possibility, it is necessary that forecasts of light winds should include, when practicable, more specific information of the expected range of wind speed and direction. Every attempt is made, therefore, at the MMOs to provide specific information of the range of wind direction based on current observations and the previous day's autographic wind record.

2.3.5 For forecasts of density altitude, a forecast of relative humidity corresponding to the time of take-off is needed in addition to QFE. The forecast of relative humidity is generally based on the latest observation and the previous day's trend, suitably modified in the light of the prevailing synoptic situation. Using forecast values of relative humidity and temperature, a forecast of virtual temperature is obtained from a nomogram. Density altitude is then read off from tables prepared for the purpose.

2.3.6 A close watch is maintained on weather conditions, upper winds and temperatures over the area concerned, and amendments to all forecasts are issued whenever necessary. The criteria used for the issue of amendments are the same as those stated in PANS-MET.

2.3.7 It may be mentioned that apart from the above, actual reports of surface wind, visibility, temperature, dew point temperature, clouds, QNH, QFE etc., are also supplied to the Air Traffic Control at half hourly intervals, so that the latest information is available to the pilot-in-command at the time of take-off or landing.

2.4 Briefing and Documentation

2.4.1 The pilot-in-command or his representative calls at the Meteorological Office for briefing as close to the departure time as practicable. At this stage his attention is drawn to (i) important synoptic features over the area covered by the flight, (ii) expected weather developments during take-off, cruise and landing, (iii) enroute winds and temperatures, (iv) position of jet-streams, (v) tropopause information, (vi) relevant inflight and post-flight reports (vii) current weather reports from stations along or near the route and (viii) latest radar range observations where available. All analysed current charts and the latest available enroute observations are exhibited for his benefit. SIGMETs of adjoining FIRs and warning messages for tropical storms exchanged with other stations are made available to the pilot.

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* Density altitudes is the atmospheric density expressed in terms of the altitude which corresponds to that density in the Standard Atmosphere (as defined in ICAO Annex-14).
to enable him to plan the course and altitude of the flight and choose the diversionary aerodromes.

2.4.2 The briefing is done on the basis of the documentation supplied for the flight. For short flights it is sufficient to supply a forecast for the route with the relevant aerodrome forecasts on the appropriate form. The documentation for long flights is, however, more elaborate and will contain the following items:

(i) Aerodrome forecasts for the aerodromes of departure and destination and their alternates
(ii) Information on enroute conditions
(iii) Latest forecast of wind, temperature and pressure over the aerodrome of departure for take-off
(iv) A blank airdt form for recording meteorological data such as temperature, wind, turbulence, icing, weather and clouds, during the flight.

2.4.3 The forecast for the aerodrome of departure is prepared by the MMO attached to the aerodrome, but forecasts for the destination and alternate aerodromes are prepared by the MMO in whose region they are located. Forecasts for the destination aerodrome and its alternates are received from the main meteorological offices concerned. On occasions when these aerodrome forecasts are not received in time, the forecasts are issued by the MMO at the departure aerodrome. This is brought to the notice of the pilot-in-command at the time of briefing, and a note to this effect is appended to the forecasts in accordance with instructions in PANS-MET.

An aerodrome forecast generally includes an appraisal of the surface wind, surface visibility, prevailing weather conditions and clouds.

2.4.4 Information on enroute conditions will consist of either (a) a pictorial cross-section/tabular form or (b) a chart form of documentation.

(a) The pictorial cross-section/tabular form of documentation provides an assessment of the general meteorological situation, pressure centres and their movements, significant weather, clouds (amounts, types and an indication of the altitudes of their bases and tops), surface visibility, upper winds, upper air temperature, icing, turbulence and surface pressure data. At Indian airports this information is supplied in Met T.34 form which is similar to ICAO model CR Attachment B of PANS-MET. Arrangements also exist for the exchange of advisory forecasts for remote sectors of certain long routes where the coverage of data is sparse. These advisory forecasts are included in the documentation with suitable amendments, if any, in the light of the latest observations received from the relevant areas.

(b) The chart form of documentation is supplied to all international jet air services by the Main Meteorological Offices at Bombay (Santacruz) and Calcutta (Dum Dum)*. The documentation comprises of the following:

(i) Fixed Time Prognostic Upper Air Charts for 500, 300 and 200 mb levels. These are issued twice a day at 02Z and 16Z based on 1200Z and 0000Z charts respectively. They are valid for a period of 18 hours centred at 02Z and 16Z respectively. These charts are based on model IL.4 of ICAO PANS-MET and indicate isohypos (contours) in gpm, isotachs at 20 knots interval and forecast spot winds and spot temperatures at selected points over belts covering international routes and alternates. The axis of the jet stream is also shown in these charts wherever necessary.

(ii) Prognostic Significant Weather Chart combining the lower significant weather (surface-850 mb) and upper significant weather (400-150 mb) on ICAO model SW. This chart is issued four times a day at 0000Z, 0600Z, 1200Z and 1800Z based on 1800Z, 0000Z, 0600Z, 1200Z charts respectively. It is a combination of fixed time and composite prognostic charts having a validity period of 18 hours. These charts give the expected location of high and low pressure centres (with the central pressure in millibars) at the mid-point of the validity period together with the direction of movement and speed where necessary. These are given to indicate duration of anticipated significant weather, where necessary, e.g. K 09/10.

2.5 Inflight Meteorological Service

2.5.1 The panel for co-ordinating procedures for the supply of information for all operations (PIA), which was set up by ICAO in 1959, made a thorough revision of the scope and contents of inflight meteorological service. ICAO M T V meeting (1959) at Montreal made a complete review of the then existing procedures, the reports of the PIA panel and of the Third Air Navigation Conference. It finally adopted the concept of an inflight service system, which is supplemented by an enroute forecast service. The combined ICAO MET/OPS and CAE Meeting (Paris 1964), suggested some further modifications. The modified inflight service system includes the following:

* This practice has not yet been introduced at MMOs Palam and Faridabad which also cater to international aviation.
(a) Area meteorological watch;
(b) Enroute forecast service; and
(c) Radio Telephony (RTF) VOLMET broadcasts.

2.5.2 Area meteorological watch is the function of the Meteorological Watch Office (MWO) which works in close collaboration with the MMO. This service is rendered by the issue of SIGMET messages for the occurrence or expected occurrence of one or more of the following phenomena within the Flight Information Region (FIR) served by the MWO-

(i) Active Thunderstorm Area
(ii) Tropical Revolving Storm
(iii) Severe Line Squall
(iv) Heavy Hail
(v) Severe Turbulence
(vi) Marked Mountain Waves
(vii) Wide-Spread Sandstorm/Duststorm.

These messages are originated at 3-hourly intervals beginning with 0100 GMT. They are valid for 4 hours allowing an overlapping period of one hour between two consecutive messages. These messages are based on the latest charts as well as on all other available additional information such as, radar weather reports, aircraft weather reports and selected special reports from stations in the FIR. Every effort is made to specify, as precisely as possible, the area likely to be affected by the weather in question. These messages are supplied to the local Flight Information Centre (FIC) for communication to the aircraft concerned in flight. They are also sent to the other MMOs and selected DMOs within the country as well as to MMOs in neighboring countries for information and for keeping pilots informed of likely weather developments in the FIR.

After the issue of a SIGMET message, a continuous watch is maintained on weather developments over the FIR. A special SIGMET message is issued, if considered necessary, at the nearest half or full hour GMT before the issue of the next routine SIGMET message. If none of the hazardous phenomena listed above occurs or is expected to occur in the FIR during the four-hour period commencing from the routine hour of issue, SIGMET message will not be originated (i.e., a 'null' SIGMET message will not be originated). Detailed instructions on the issue of SIGMET messages are given in the publication ‘Memorandum on Area Meteorological Watch-SIGMET Information’ issued by Deputy Director General of Observatories (Forecasting). A sample SIGMET message is given in Appendix II.

2.5.3 Enroute forecast service is rendered only on request from pilots in-flight or from the operator keeping watch on the flight. The information supplied is generally related to upper winds and temperatures on the route. QNH values at stations on and near the route are also supplied, if required, to enable the captain to check altitude of the aircraft above mean sea level.

2.5.4 Radio Telephony (RTF) VOLMET broadcasts of weather reports are made at present from Dum Dum and Santacruz. These broadcasts are in plain language and are issued at hourly intervals being valid for 9 hours at each synoptic hour. The period of validity is reduced at the successive two hours to 8 and 7 hours respectively. The aerodrome forecasts are issued at hourly intervals being valid for 8 hours at each synoptic hour. They are vallid for 4 hours allowing an overlapping period of one hour between two consecutive messages. These messages are based on the latest charts as well as on all other available additional information such as, radar weather reports, aircraft weather reports and selected special reports from stations in the FIR. Every effort is made to specify, as precisely as possible, the area likely to be affected by the weather in question. These messages are supplied to the local Flight Information Centre (FIC) for communication to the aircraft concerned in flight. They are also sent to the other MMOs and selected DMOs within the country as well as to MMOs in neighboring countries for information and for keeping pilots informed of likely weather developments in the FIR.

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specified limits in the next two hours and when (b) they are above the specified limits at the time of observation, but are expected to deteriorate below these limits during the next two hours. Trend forecasts for wind will be issued when the surface wind is expected to change by specified values in respect of direction and/or speed. Trend forecasts for weather are issued when the onset or cessation of thundery or freezing precipitations is expected. At present these forecasts are issued by the MMOs at Bongun, Santacruz and Palam at half hourly intervals as a routine measure. At MMOs these are supplied as a routine between 06 and 16Z only. Detailed instructions for the issue of trend forecasts are given in a pamphlet entitled "Take-off and Landing Forecast for Jet Operations" issued by the Deputy Director General of Observatories (Forecasting). A sample trend forecast is shown in Appendix III.

2.5.6 In addition to the above services, hourly/half hourly weather reports, selected special weather reports and warnings for thunderstorm, dust-storm and squall, fog etc., for the aerodrome and its alternatives are also supplied to the different units of the AIC for communication to aircraft in flight. These messages are also supplied to a few other meteorological offices as a routine measure. To ensure that observations representative of the runway are provided to the AIC without any loss of time, the observational unit is stationed at the control tower and has a panel of distant recording meteorological instruments which are installed near the runway. This arrangement is available at Bombay (Santacruz), Calcutta (Dum Dum) and New Delhi (Palam). Weather radars are also available at the following MMOs and DMOs in India to furnish radar echo data to incoming aircraft on request/reply basis or for use in preparing weather briefings:

**MMOs:** Bombay (Santacruz), Calcutta (Pun Dum) and New Delhi (Palam). Weather reports are also available at the following MMOs and DMOs in India to furnish radar echo data to incoming aircraft on request/reply basis or for use in preparing weather briefings:

**DMOs:** Agartala, Bangalore, Mohanbari.

Weather radar data considered operationally significant are supplied to the AIC. Continuous recording of cloud base with ceilometers is done at Bangalore, Bombay, Calcutta, Mysore and New Delhi (Palam).

2.6 Inflight Reports.

2.6.1 There are many areas such as oceans, deserts and uninhabited locations where the network of upper air observatories is sparse or observations are completely absent. This deficiency is particularly noticed in the developing regions of Asia and Africa. Aircraft flying over these areas can help the forecasters by providing inflight meteorological reports. In particular, scheduled services, over these areas can serve as a regular source of useful upper air data. Aircraft reports provide the only source of information for meteorological phenomena, such as, clear air turbulence, mountain wave, icing etc. These reports may be classified into two categories, viz., (i) routine and (ii) special.

2.6.2 Routine inflight observations are recorded in the AIREP form at approximately hourly intervals, and are reported to the AIC along with position reports. These meteorological reports should contain information about temperature, wind, turbulence, aircraft icing and supplementary information, if any, including present weather, r-value and cloud type. Aircraft on international flights with a flight duration of 4 hours or less are exempted from observing procedure.

2.6.3 Special inflight meteorological reports shall be recorded by all aircraft whenever moderate or severe icing or severe turbulence is encountered, whenever other meteorological conditions such as the phenomena included under the definition of SIGMET information are encountered which, in the opinion of the pilot-in-command, are likely to affect the safety or markedly affect the efficiency of other aircraft operations and when the meteorological office responsible for providing service for the flight makes a request for specific data. Special inflight meteorological reports are to be transmitted by the aircraft as soon as possible after they are recorded.

2.7 Postflight Reports

2.7.1 These are the records of meteorological observations made on the AIREP form during the flight. These forms are delivered to the meteorological office at the destination aerodrome or landing. They also normally contain a pictorial representation of weather conditions encountered during the flight. The pilot-in-command or a member of the crew is expected to call at the meteorological office for debriefing, particularly when he has encountered disturbed weather enroute. He gives an oral comment on the meteorological conditions during the flight and may also furnish other information in which the meteorologist may be interested.

2.7.2 The information obtained from inflight/postflight reports and verbal debriefing of pilots is helpful in preparing forecasts and for briefing pilots.
of subsequent flights. The information is also passed on to other meteorological offices, if considered significant.

2.7.3 Inflight and postflight reports, immediately on receipt, are plotted on appropriate constant pressure charts. These data, particularly from areas having no observatories or a sparse network, are helpful for the analysis of charts. Reports of significant weather phenomena such as icing, clear air turbulence etc. available from the above reports are also included in SIGMET messages.

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REFERENCES


3. Meteorological Telecommunications*

3.1 A meteorological organization cannot render the services discussed in the previous chapter, unless it is well supported by an adequate set-up for meteorological telecommunications. Communication facilities for the exchange of basic data have to be extremely efficient to enable the forecaster to make use of the latest data. Telecommunication facilities are available at international airports for the following purposes:

(i) exchange of synoptic data;
(ii) exchange of aeronautical meteorological data;
(iii) meteorological broadcasts for aviation;
(iv) air-ground communication; and
(v) facsimile transmission and reception.

3.2 Exchange of Synoptic Data

3.2.1 Synoptic observations (surface and upper-air) from departmental and part-time observatories are transmitted by high priority landline telegrams to the five regional collecting centres at Bombay, Calcutta, Madras, Nagpur and New Delhi. The observations are then transmitted over landline teletype channels to the Meteorological Communication Centre (MCC) at Bombay from where they are disseminated simultaneously to all the Forecasting Offices as well to the Northern Hemisphere Analysis and Exchange Centre (NHEAC) according to prearranged schedules.

3.2.2 Territorial broadcasts containing Calcutta regional data are made by radio telegraph from Calcutta; similar broadcasts containing data for the whole of India are made from New Delhi by radio teletype. New Delhi is also a Sub-Regional Broadcast Centre from where data of basic network stations over India and neighbouring countries are broadcast on radio teletype using 5 KW transmitters. The Sub-Regional broadcasts from Delhi also contain other items such as aircraft reports, ship's reports, weather analysis and warnings based on observations from weather satellites. While the data pertaining to India for inclusion in the Sub-Regional broadcasts are obtained over landline

* The contents of this chapter as supplied by the authors have been somewhat condensed.
teleprinter, the data for ex-Indian stations are collected by intercepting the appropriate meteorological broadcasts, through AFTN exchanges and over the northern hemisphere exchange links.

3.2.3 The Northern Hemisphere Exchange Network interlinking Washington, Offenbach, Moscow, New Delhi and Tokyo was established in pursuance of the recommendations of CSM-II (New Delhi, 1958). With the commissioning of this circuit by which New Delhi is linked with Moscow and Tokyo, data from the entire Northern Hemisphere is being received at New Delhi. These data are channelised to MMOs Palam and Dum Dum by direct T/P links with NBVC, New Delhi. For quick reception of northern hemisphere data at MMO Santeacruz and Weather Central, Poonam, these data are tapped at the Overseas Communication Centre, Bombay (through which data are exchanged between New Delhi and Tokyo) and transmitted to WTC through a subsidiary T/P link. Northern hemisphere data received through NH Circuits are also broadcast on RTT from New Delhi as Hemisphere Broadcasts. Through a link established between New Delhi and Melbourne (via Singapore and Bombay) in June 1966, basic meteorological data of the Southern Hemisphere are also being received.

3.3 Exchange of Aeronautical Meteorological Data

3.3.1 Fixed telecommunication circuits are operated between different aerodromes in India and neighbouring countries by the Civil Aviation Department. Transmissions are made by Morse, radioteletype or landline teletype. Routine reports, selected special reports, aerodrome forecasts, and SIGMET information are exchanged on this channel between meteorological offices of aerodromes, in accordance with Table 2 of ICAO Doc. 7967. Storm warnings are also exchanged on these circuits. The details of the aeronautical fixed telecommunication network (AFTN) are periodically published by the Director General of Civil Aviation, New Delhi. Telecommunication circuits which are primarily meant for the exchange of operational meteorological data are not utilised for the exchange of synoptic observations. However, at the request of the WMO, the Council of the ICAO agreed to the use of AFTN circuits for exchange of a limited volume of upper air data.

3.4 Meteorological Broadcasts for Aviation

These broadcasts are of the following types:

(a) RTF VOMET Broadcasts in plain language every half hour

(1) From Calcutta (Dum Dum) containing the actual observations of Calcutta (Dum Dum), Gaya and New Delhi (Palam) and the aerodrome forecasts of Calcutta (Dum Dum) and Delhi (Palam).

(b) From Bombay (Santacruz) containing the actual observations of Bombay (Santacruz), New Delhi (Palam) and Ahmedabad and the aerodrome forecasts of Bombay (Santacruz).

(c) Hourly VOR broadcasts from selected aerodromes in India at fixed times over the VOR channel in code during the open hours of VOR watch.

(d) Half-hourly VOR broadcasts from Bombay and Calcutta containing aerodrome reports in plain language.

3.5 Air-ground Communication Facilities

These facilities are used by meteorological services primarily for obtaining information about meteorological elements along the air-routes from aircraft in-flight and also to transmit any meteorological information required by pilots on request/reply basis.

3.6 Facsimile Transmissions

The Northern Hemisphere Analysis Centre at New Delhi broadcasts facsimile charts as a routine measure for the benefit of meteorological offices in and outside India. The transmissions include analysis for the surface, 500 mb, 300 mb, and 200 mb levels and prognostic chart for 500 mb level for the area between latitudes 10°W to 150°E (through 90°E) of the northern hemisphere and a surface analysis for the equatorial area 0°E to 160°E, 45°N to 45°S.

4. Future Developments

As a result of the implementation of World Weather Watch plan, adopted by the Fifth Congress of the WMO (Geneva, April 1967) major developments in the field of meteorological telecommunication, including the use of communication satellites, are expected during the coming years. On the national level continuous efforts are being made for speeding up the collection and transmission of basic meteorological data. Telex facilities are being introduced at a number of stations for this purpose. The introduction of SSB wireless system for speeding up data collection is also under consideration. All these will go a long way to meet the need of aviation.

References

4. Methods of Synoptic Analysis

4.1 In a principal forecasting centre the daily inflow of data is considerable both in volume and complexity. While different views may be held on the best method of organizing the data, a few principles of analysis are now widely accepted. In the present chapter these principles will be discussed with reference to the facilities available for the collection of data described in the previous chapter.

4.2 The basic aim of synoptic meteorology is to bring out the salient features, in space and time, of the synoptic scale circulations and their link with the associated weather. For this purpose the data must be carefully analysed in a manner which yields the maximum amount of information in return for the time and effort expended in the collection of data. It is, therefore, necessary to see that: (i) data from remote areas, which are sparse, are not missed, (ii) all the data, which are received, are plotted and (iii) communication faults are promptly corrected to avoid loss of valuable data.

4.3 It is also essential for the forecaster to know the number and type of reporting stations on his chart in order to check for missing data especially in regions south of 30°N, where the data coverage is generally poor compared to the coverage in higher latitudes and where the thermal and pressure gradients are also generally weaker than those prevailing in mid-latitudes. Abnormal departures from the normal values in these regions should, therefore, be treated with caution. Success in forecasting for these regions largely depends on the ability to spot significant changes in meteorological variables.

4.4 Analysis of Surface Variables

4.4.1 The primary purpose of surface analysis is to describe the pressure pattern. Over areas of dense coverage of data, the different pressure patterns can be readily constructed. In extra-tropical latitudes the Norwegian model is a reliable starting point. The important principles of analysis to be born in mind are:

(i) Fronts fit in natural trough lines. Some troughs are frontal but others, particularly in the tropics, are not so. The latter may coincide with squall lines. Cold fronts and squall lines may be distinguished by the thermal thickness pattern.

(ii) Pressure gradients generally change slowly with respect to space and time, except along organized lines of discontinuity.

(iii) Fronts are substantial surfaces which move with the wind field. The warm sector is characterized by nearly straight isobars with anticyclonic shear in the warm sector, except in well-organized systems, such as squall lines.

(iv) In regions of sparse network of data, the analysis is mainly based on continuity from earlier developments. Thus, pressure centres are displaced on the basis of the kinematic displacement and frontal movements are consistent with the speed of wind normal to the front. Cold fronts generally move with the wind speed normal to the front, while warm fronts move with a speed roughly three-fourths the normal wind component. In the absence of actual wind observations, geostrophic winds are used. Pressure tendencies are used to ensure reasonable continuity of the analysed pattern.

4.4.2 In regions south of 30°N, particularly over India, fronts are rarely observed. In general, forecasters devote more attention to lines of wind discontinuity. In the pre-monsoon season, they are associated with violent thunderstorms in northeast India. Sometimes, they are also referred to as squall lines. On many occasions, it will be observed that precipitation and thunderstorm activity are confined to a narrow zone just ahead of a squall line. An accurate demarcation of squall line is very useful on such occasions.

4.4.3 For the purpose of surface analysis, the following principles are generally followed for the presentation of data:

(i) Isobars are drawn at intervals of 4 mb in regions north of 30°N and at intervals of 2 mb in regions south of 30°N. Dotted lines are used to indicate isobars at odd intervals. If a separate chart is drawn to indicate pressure tendencies, then areas of pressure rise greater than 2 mb are hatched in blue, while a fall of more than 2 mb is hatched in red.

(ii) Fronts are indicated by coloured lines. The generally accepted colour scheme is: (Vide "Guide to Preparation of Synoptic Weather Charts and Diagrams" WMO No. 151, TP.71, 1964)

<table>
<thead>
<tr>
<th>Colour</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solid blue</td>
<td>Surface cold front</td>
</tr>
<tr>
<td>Broken blue</td>
<td>Upper air cold front</td>
</tr>
<tr>
<td>Solid red</td>
<td>Surface warm front</td>
</tr>
<tr>
<td>Broken red</td>
<td>Upper air warm front</td>
</tr>
<tr>
<td>Solid purple</td>
<td>Occluded front at surface</td>
</tr>
<tr>
<td>Broken purple</td>
<td>Upper air occluded front</td>
</tr>
</tbody>
</table>
4.5 Upper Air Analysis.

4.5.1 The main purpose of drawing contours on isobaric charts is to describe the wind field by an appropriate relationship between the wind and the contour patterns. In extratropical regions, this relationship is expressed by the geostrophic wind. But the geostrophic approximation does not prove to be equally effective south of 30°N.

4.5.2 Over regions of dense-data coverage, the use of differential analysis for constructing the contours of an isobaric surface plays a comparatively minor role. But, where the data coverage is inadequate, the technique is useful. Over ocean areas, a build-up, is obtained by adding the 1000 mb height to the 1000-500 mb thickness, which is used as an underlay. Suitable adjustments are made taking into account continuity and vertical consistency.

4.5.3 In preparing charts depicting the 1000-500 mb thickness, the following principles are generally followed:

(i) Thickness lines are concentrated on the cold side of frontal systems, because cold fronts are more intense than warm fronts.

(ii) Thickness lines are cyclonically curved behind cold fronts and anticyclonically curved in advance of warm fronts.

(iii) A cold trough in thickness contours occurs in the rear of a surface depression.

4.5.4 We can use the 500 mb chart, constructed on the above principles, to extrapolate upwards to 300 mb and 100 mb. In doing this, the correlation coefficient between 500 mb isotherms and the 100-300 mb thickness is useful.

4.5.5 The additional features, which are important to remember, for the analysis of individual pressure levels may be summarized under the following heads:

(1) 850 mb

The moisture pattern at this level is important from the point of view of cloud and precipitation forecasts. It is, therefore, useful to include the dew point on this chart. The pilot-balloon winds at 1.5 km may be used for the analysis of this chart. The chart may be constructed by direct analysis over areas with dense coverage of data. For other regions, the sea level (1000 mb) analysis may be used as an underlay and slopes of two or three degree latitude into the cold air from the surface may be taken to depict baroclinic systems.

Marked changes in the 850 mb pattern relative to the sea level may be only expected in regions of strong horizontal temperature gradient. Isotherms (generally indicated in red) are drawn by direct analysis in dense-data areas. In other areas, surface fronts are useful for locating zones of strong temperature gradients. A slope of 1/50 to 1/100 may be assumed for cold fronts and 1/100 to 1/300 for warm fronts. Isopleths of dew point are generally not drawn. Regions of moist air may be outlined by hatching moist areas where the dew point depression is less than 4°C, and dry regions where the dew point depression exceeds 15°C.

(ii) 700 mb

Additional data for this level are provided by pilot-balloon winds at 3 km and aircraft reports. The contours are drawn by direct analysis over dense-data areas. Over sparse data areas, statistical relations between 1000-700 mb and 1000-500 mb thickness contours have to be established. The 1000-500 mb thickness has to be converted into the 1000-700 mb thickness, and then added to the current 1000 mb chart. In drawing contours, small scale 'wiggles' are generally smoothed out. The final 500 mb analysis is generally used as an underlay to check for vertical consistency. Isotherms are generally drawn by direct analysis. Over sparse-data areas, the relations between 1000-500 mb thickness and 700 mb temperature have to be used.

(iii) 500 mb

As additional data for this level we may use (a) the previous 24 hour 500 mb prognostic chart, (b) pilot balloon winds at 6 km and (c) aircraft reports within ± 6 hours from the time of observation and within ± 1 km of the 500 mb surface. Direct analysis is generally possible over most regions of adequate data coverage. Over ocean areas, a build-up is obtained by adding the 1000 mb heights to the 1000-500 mb thickness, using the latter as an underlay. Suitable adjustments are made taking into account continuity and vertical
consistency. In extra-tropical latitudes, the 500 mb analysis is given considerable importance because it is the level nearest to the level of non-divergence in the atmosphere. However, it is not yet clear whether this also holds for the tropics. Many important weather developments in the tropics are often first located on charts at a higher isobaric level (300 mb). As the thickness of the 1000-500 mb layer is approximately proportional to the mean temperature of this thickness layer, this thickness chart will be helpful for analysis as an underlay.

(iv) 300 mb
As this is near the level of maximum wind, the position of the jet axis, together with isotachs, are shown on this chart. The axis of the jet and isotachs are generally indicated in blue. Additional data for this level are wind observations between 8 and 14 km and airrep data when available. Reasonably accurate relationships are available between 500 mb temperatures and 500-300 mb thickness values. Hence, knowing the 500 mb temperatures, we can form an estimate of the thickness, which may be added to the 500 mb contours. This 300 mb chart thus constructed may be used as an underlay for the current 500 mb chart for making suitable adjustments, if necessary. This level is still in the troposphere, so the isotherms tend to run parallel to contours. When the mid-latitude jet core is located between 250 and 200 mb the tropopause intersects the 300 mb surface near four to six degrees to the left looking downstream of the 300 mb jet axis. At this tropopause intersection there is a discontinuity in temperature gradient, with a reversal in the sign of the gradient.

(v) 200 mb
The contours are generally drawn by direct analysis, using the 300 mb contours as a guide. The principles are otherwise the same as for 500 mb.

(vi) 100 mb
At this level the height values become less reliable, but the wind data are of better quality. Direct analysis is generally made with a strong emphasis on continuity. The patterns are essentially the same as at lower levels in the main westerly belt, but the gradients are much weaker. A quasi-stationary cold low is a characteristic of the polar circulation in winter. This level is completely within the lower stratosphere, except at low latitudes. The temperature gradient is directed southward in summer. Over areas of sparse data, isotherms may be extended parallel to the contours.

4.6 The Jet Stream

4.6.1 Perhaps the most important feature from the point of view of high level aviation is the location of the jet stream. In trying to delineate the jet stream, the following considerations are generally kept in mind:

(i) The jet stream is usually located vertically above the region of maximum temperature gradient at the 500 mb level.

(ii) The cyclonic shear to the left of the jet looking downstream, is stronger than the anticyclonic shear to the right. The anticyclonic shear can not exceed a critical limit, which is approximately equal to the coriolis parameter.

(iii) The jet stream is also a streamline and, as such, tends to follow the contour. As a result when wind speeds increase along the jet stream, the axis of the jet is directed towards lower contour heights and vice versa.

(iv) The wind speed along the axis of a jet is not uniform. The characteristic feature is a succession of velocity maxima with intervals of comparatively weak winds. The velocity maxima and minima are connected with the wave pattern of the westerlies. The distance between successive maxima varies from about ten to twentyfive degrees latitude.

(v) There are two main jet streams which affect aviation in and around India. The first is the mid-latitude hemispherical jet which runs across northern Africa, southern Europe, the U.S.S.R., north Tibet, China and Japan. Secondly, there is an easterly jet running from South China to Malaya, the southern half of the Indian Peninsula and the west coast of Africa. The mid-latitude hemispherical jet shows a pronounced shift to the south in winter, when it can be located over north India and the southern periphery of the Himalayas. In the summer months, the mid-latitude westerly jet is displaced to the north of the Himalayan mountain barrier. The westerly jet is most pronounced between 300 and 200 mb levels. The easterly jet over the southern half of the Indian Peninsula is generally found only in the summer months, and is usually located at a higher level (200-100 mb).

An extensive treatment of the jet stream in extra-tropical latitudes is to be found in a monograph by Riehl et al (1954). For a very thorough treatment of the easterly jet over India, the reader may refer to a paper by Koteswaram (1958).
4.7 Analysis of the Layer of Maximum Wind and the Tropopause

4.7.1 To find the layer of maximum wind, a procedure somewhat similar to that outlined by Reiter (1956) is adopted. The wind speed is first plotted as a function of pressure for each reporting station. A smooth profile is then fitted to indicate

(i) the level of maximum wind (usually below 15 km);
(ii) shears of equal magnitude above and below this level; and
(iii) the direction of wind at each level. This method assumes a linear variation of wind shear from 500 to 300 mb and from 300 mb up to the level of maximum wind.

4.7.2 It may be stated, however, that an approximate idea of the location of the jet core may be obtained from the 300 mb chart. Imagine an observer stationed on the jet axis, and looking downstream.

(i) if the temperature to his right is higher than the temperature to the left, the thermal wind component will favour an increase of wind speed with height, i.e. the jet core lies above 300 mb;
(ii) if the temperature to his right is lower than the temperature to the left, then the wind decreases with height and the jet core is lower than 300 mb; and
(iii) if the temperatures on both sides of the observer are nearly equal, the jet core is very near 300 mb.

4.8 Streamline Analysis

4.8.1 A few forecasting centres in India have carried out experiments with streamline analysis. It is not very clear at this stage whether this represents a marked advance over the more conventional contour analysis, but it is expected that a clearer picture will emerge only after more experience has been gained. In its simplest form the technique consists of plotting the wind vector at each level and drawing free hand streamlines as tangential curves to the wind vector. But, on account of the sparse network of upper air stations in southeast Asia and Africa, there is a considerable subjective element in this form of analysis.

See also pp. 74-80 of "Jet Stream Meteorology" (1963) by E.R. Reiter.

4.8.2 The terminology to be used in streamline analysis has been formulated by Palmer et al., (1955). The principal features are:

(i) Singularities : These are points which act as sources or sinks, such as, the centre of a cyclone or an anticyclone. Streamlines either spiral inwards or outwards from a singular point.
(ii) Asymptotes : These are lines along which a series of streamlines converge or diverge. We may consider them as lines of convergence or divergence.
(iii) Neutral points : The point of intersection between two asymptotes is defined as a neutral point. This is visualised as a region of calm weather.

4.8.3 A number of other parameters are also sometimes used, such as, cusps, axes of dilatation etc., but the principal ones are those enumerated above. In the late thirties, Sen worked out a method of streamline analysis on the basis of Karman vortex street. By this means he was able to find an association between the stability of a train of vortices and the spacing between a cyclonic and an anticyclonic vortex.

4.8.4 In practice, however, we generally encounter several difficulties on account of sparse data. In some centres, attempts are made to delineate areas of convergence and divergence from the streamline pattern. As convergence implies accumulation of mass, the number of streamlines entering a convergence zone decreases. Similarly, the number of streamlines emanating from a zone of divergence increases. Attempts have been also made to infer convergence or divergence zones from the confluence (difluence) of streamlines, but the success achieved by these techniques has not been very encouraging.

4.8.5 With the existing network of upper air stations, it is also very difficult to draw streamlines which are spaced in inverse proportion to the wind speed. The main advantage of streamlines apparently lies in the fact that they enable us to infer the wind field over a given region but, as we have pointed out, unless the data coverage is improved this advantage is very difficult to realise in practice. Unfortunately, on account of the variety of radiosondes in operation in regions south of 30ºN, the isobaric contours often make it impossible to carry out a systematic and consistent analysis based on height values alone. For this reason, contours are generally drawn giving the greatest weightage to the prevailing wind. The actual difference between a streamline and a contour, therefore, as used for operational purposes, is very small.
APPENDIX - I

Meteorological requirements for jet aircraft (ICAO, 1959)

(Part III - Agenda item 3 - Meteorological requirements)

1. There is a requirement for meteorological services to be provided to serve operations up to pressure altitudes of at least 14,000 ft (4500 m).

2. There is a requirement for a forecast of air temperature, which is representative of the average air temperature over the runway to be used, at the average height of turbine-engined aircraft intakes, at the expected time of departure of a turbine-engined aircraft

   (i) to be available two hours before that time, with an accuracy of ± 1°C for pre-flight planning, and
   (ii) to be available two to six hours before that time, with an accuracy of ± 3°C for preliminary planning.

3. There is a requirement, for the climb as well as for the descent phase, for a forecast of wind velocity and air temperatures at selected pressure levels. Temperature forecasts should have an accuracy of ± 3°C.

4. There is a requirement for the meteorological office preparing aerodrome forecasts to keep them under continuous review.

5. There is a requirement that a forecast office, issuing aerodrome forecasts for more than one aerodrome, issue separate forecasts for neighbouring aerodromes whenever operationally significant differences are expected to occur.

6. There is a requirement, in certain cases, for a forecast of temperature at the aerodrome of intended landing, to be available at the aerodrome of departure for pre-flight planning.

7. (a) There is a requirement for a landing forecast for the aerodrome of intended landing and for alternate aerodromes when the aircraft is within one hour flying time from them, whenever instrument meteorological conditions are expected to obtain at the aerodromes concerned;
   (b) A non-routine landing forecast should have a period of validity of at least one hour; if landing forecasts are issued on a routine basis, every hour they should have a period of validity of two hours from the time of issue.
   (c) All landing forecasts issued should be kept under continuous review, and amendments thereto transmitted to the aircraft until it has completed its descent;

REFERENCES


A landing forecast should comprise forecasts of the following:

(i) Surface wind speed and direction over the runway complex and relevant gust information;

(ii) Runway visual range and slant visual range with respect to the designated instrument runway (as an interim arrangement slant visual range may be omitted and, where forecasting of runway visual range cannot be instituted, forecasts of aerodrome visibility should be substituted);

(iii) Amount and height of the base of low cloud in the final approach area;

(iv) Weather;

(v) Any other significant information (e.g. wind structure in the final approach area, icing conditions, etc.).

8. There is a requirement for forecasts of enroute upper air temperature with an accuracy of ± 3°C.

9. There is a requirement for forecasts of the level of the tropopause along and in the vicinity of the track.

10. There is a requirement for the forecasting of the locations and characteristics of any jet streams which are likely to occur within the area of operation.

11. There is a requirement for the forecasting of hail, clear air turbulence, turbulence in cloud, mountain waves and aircraft icing.

12. There is a requirement for reports of current air temperature, with an accuracy of ± 1°C, which are representative of the average air temperature over the runway to be used, (at the average height of turbine-engined aircraft intakes), for the purpose of checking the length of take-off run necessary.

13. There is a requirement for:

(a) meteorological reports for landing to include observations of runway visual range, slant visual range and the height of the base of low cloud in the final approach area;

(b) values of the runway visual range to be continuously determined, with an accuracy of ± 50 metres for values of 300 metres or less and of ± 100 metres for higher values and to be continuously available throughout descent whenever the aerodrome visibility or the runway visual range is of the order of 500 metres or less;

(c) changes in runway visual range in increments of 100 metres to be reported to the aircraft during descent;

(d) values of the height of the base of the low cloud in the final approach area to be continuously determined, with an accuracy of 10%, and to be continuously available, whenever the value is below 300 metres.

(e) the value of the height of the base of the low cloud in the final approach area to be reported to the aircraft during descent whenever the value coincides with, or passes through, one of the heights specified in PANS-MET Table I as criteria for special reports.

14. There is a requirement for climatological data to be made available in a form making it possible to determine, with sufficient accuracy, the monthly mean temperature for each hour of the day.

15. There is a requirement for monthly charts giving statistical information on upper winds and temperatures over air routes according to the specifications and details given below:

The charts should depict:

1) Mean vector winds in the form of streamlines and isotachs,
2) Standard vector deviation of wind,
3) Mean temperature,
4) Standard deviation of temperature.

16. There is a requirement that the maximum transit time for operational meteorological messages passed over ground channels should be as follows:

<table>
<thead>
<tr>
<th>Category of Information</th>
<th>Transit Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected special reports</td>
<td>As rapidly as possible and at least within the following times:</td>
</tr>
<tr>
<td>Amended aerodrome forecasts</td>
<td>Data originating up to 500 n.m. distant - 10 minutes.</td>
</tr>
<tr>
<td>SIGMET information</td>
<td>Free places 500 n.m. to 1000 n.m. distant - 15 minutes.</td>
</tr>
<tr>
<td>Special air-requests</td>
<td>Free places more than 1000 n.m. 20 minutes.</td>
</tr>
<tr>
<td>New or amended upper wind and temperature forecasts</td>
<td></td>
</tr>
<tr>
<td>Reports of routine observations.</td>
<td></td>
</tr>
<tr>
<td>Aerodrome forecasts</td>
<td></td>
</tr>
<tr>
<td>QNH values</td>
<td></td>
</tr>
</tbody>
</table>
Sample SIGMET message

NR 6. Bombay FIR (valid 111600 - 112000 G.M.T.)

Active thunderstorm area forecast over FIR east of 76 East and north of 20 North.

Marked turbulence associated with mountain waves likely between flight levels 050 and 150 over western ghats between 15 North and 20 North.

Aircraft reported severe turbulence over west coast near 16 north at flight level 105 at 111520 G.M.T.