INDIA METEOROLOGICAL DEPARTMENT

FORECASTING MANUAL

PART V

AVIATION METEOROLOGY

BY

N. S. BHASKARA RAO AND V. SURYA RAO

ISSUED BY

THE DEPUTY DIRECTOR GENERAL OF OBSERVATORIES
(FORECASTING)
POONA - 5
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**DIAGRAMS**
Introduction

As aeroplanes fly in the air, all aspects of meteorology are of interest to aviators. Yet it is beyond the scope of any single report of this nature to cover the whole matter of interest. Hence the subjects in this manual are restricted to (a) the procedural aspects of meteorological service to aviation, (b) such aspects of meteorological conditions which are of special interest to the aviator and which do not figure in other forecasting manual reports.

Chapters 1 to 4 deal entirely with the procedural aspects of the operational forecasts issued specially for that purpose. Chapter 5 deals with the procedural and technical aspects of some important weather phenomena which affect aircraft operations and which constitute aviation hazards. Chapter 6 deals with the impact of radar and satellite meteorology and is meant to initiate the readers to the vast potential utility of these modern techniques for operational forecasting. In Chapter 7 are given samples of typical forecasts with brief notes on the synoptic and technical reasoning behind their preparation.

Chapter 8 has been prepared by the Meteorological Office at Bombay Airport and gives how important is the meteorological data for flight planning purposes for the safe and economic aircraft operations.
CHAPTER 1

AERODROME FORECASTS

1. Requirement for Aerodrome Forecasts

Forecasts of terminal weather conditions are required by aircraft commanders and operators' local representatives to assess the usability of the aerodromes of intended landing and their alternates from a meteorological stand point. In particular, aerodrome forecasts for the destination, intermediate halts and alternate aerodromes are required for pre-flight operational planning for all aircraft flights. Forecasts of terminal weather conditions are also required by the aircraft commanders during the in-flight phases of a flight, especially of long-distance operations, to maintain a check on the planning of the flight and to amend it as required.

2. Format of Aerodrome Forecasts

Forecasts of terminal weather conditions follow the general form of the aerodrome weather report (METAR) and will be in the following formats:-

(i) In TAF Code form (FM 51 §) when disseminated beyond the aerodrome
(ii) In plain language for local use and for transmission to pilots and
(iii) Also in plain language for inclusion in documentation.

3. Contents of Aerodrome Forecasts

Aerodrome forecasts include the forecast values of the following meteorological elements, and expected changes, if any, in the forecast values of the elements during the validity period of the forecasts:-

(i) Mean surface wind direction and speed, and as available, maximum wind speed
(ii) Surface visibility
(iii) Weather conditions
(iv) Cloud—amount, type and height of base
(v) As required, other relevant available information.

4. Preparation of Aerodrome Forecasts

4.1 An aerodrome forecast (and amendments thereto) used in the provision of meteorological service to air navigation will be the forecast prepared by the Class 1 Met. Office associated with the aerodrome. If such a forecast cannot be obtained in time by another Class 1 Met. Office requiring it for provision of met. service, that office may prepare a provisional forecast for the relevant aerodrome. A provisional forecast will be qualified as such, in any use made of it.
4.1.1 Aerodrome forecasts included in documentation, except those prepared by
the meteorological office designated to prepare the aerodrome forecasts for the
aerodrome of departure and for other aerodromes associated with the met. office
at the departure aerodrome, shall be obtained on a routine basis or by special
request from the met. office responsible for the provision of these forecasts.
Whenever a provisional forecast is issued as per provisions of para 4.1, the
met. office serving the aerodrome of departure shall inform the Pilot-in-Command
of, and record in the document, the origin of the provisional aerodrome
forecast.

4.1.2 If the aerodrome forecast included in the documentation is extracted
from an aerodrome forecast of longer validity period, the fact should be
mentioned in the remarks column of the aerodrome forecast form.

4.1.3 In India, aerodrome forecasts will be issued by all Class I Met. Offices.
In the case of Class I Met. Offices with restricted forecasting watch, the
Class I Met. Office at the Regional Centre or the associated Meteorological
Centre at the State Capital (during its watch hours) will assume the responsibility
for the issue of the aerodrome forecasts during the closed forecasting watch hours
of the Class I Met. office concerned.

4.1.4 Aerodrome forecasts in respect of aerodromes at which no forecasting
offices function will be issued by the Meteorological Centres at the state
capital concerned or the associated Class I Met. office at the Regional Centre.

4.2 Amendments to Aerodrome Forecasts

4.2.1 Meteorological offices preparing aerodrome forecasts will keep the
forecasts under constant review in order to ensure that necessary amendments are
issued promptly as required.

4.2.2 Amendments to aerodrome forecasts should be issued at any time the
forecaster considers it advisable in the interest of safety and efficiency of
aircraft operations, including flight planning, operational control and in-flight
service to aircraft. In determining the need for an amendment, prime considera-
tion should be given to providing adequate advance warning of development of
conditions bearing on safety of en-route aircraft approaching the aerodrome of
landing.

4.2.3 Amendments to aerodrome forecasts shall be limited to changes of
operational significance consistent with the criteria given in Table I
(Appendix I).

4.2.4 Amended aerodrome forecasts will be in the same format as the routine
aerodrome forecasts preceded by the word "AMD". The amended forecasts will
extend only to the end of the forecast period of the current issue and will be
distributed to all offices to which the original forecast was sent.

4.3 Use of Change Groups

4.3.1 In framing aerodrome forecasts ambiguity should be, as far as possible,
avoided as that would lower the value of the forecasts for operational purposes.
Terms such as probablility (PROB), temporarily (TEMPO), intermittently (INTER)
etc. should find sparing use. Use of change groups to describe minor or
temporary changes in elements not significant for aircraft operation should be
avoided. The use of change groups in aerodrome forecasts (and amendments thereto) should only be limited to changes of operational significance.

4.3.2 Criteria governing the use of change groups in aerodrome forecasts will be the same as those governing amendments to aerodrome forecasts, except for the following modifications:

(i) Diurnal changes of surface wind will be indicated by means of change groups even if the changes do not satisfy criteria given in Table 1.

(ii) All weather elements indicated in Code 22 of Aviation Weather Codes 1972 will be indicated by use of change groups.

4.3.3 Change groups will be given in plain language form. A change group should be followed by a time group indicating the times during which the changes are expected to take place.

5. Period of validity of Aerodrome Forecasts

5.1 Routine aerodrome forecasts for preliminary, pre-flight and in-flight operational planning of international air navigation will have a validity period of 18 hours, issued at six hourly intervals as follows:

<table>
<thead>
<tr>
<th>Time of chart (GMT)</th>
<th>Time of issue (GMT)</th>
<th>Period of validity (GMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0400</td>
<td>0600-2400</td>
</tr>
<tr>
<td>0600</td>
<td>1000</td>
<td>1200-0600</td>
</tr>
<tr>
<td>1200</td>
<td>1600</td>
<td>1800-1200</td>
</tr>
<tr>
<td>1800</td>
<td>2200</td>
<td>0000-1800</td>
</tr>
</tbody>
</table>

5.1.1 18 hourly forecasts (and amendments thereto) will be exchanged with foreign met. offices as per actual operational requirements.

5.1.2 18 hourly forecasts will also be exchanged internally among all Class 1 Met. offices providing service for international air navigation.

5.2 Routine aerodrome forecasts for internal exchange for service to national air navigation will have a validity period of 9 hours, issued every three hours as follows:

<table>
<thead>
<tr>
<th>Time of chart (GMT)</th>
<th>Time of issue (GMT)</th>
<th>Period of validity (GMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td>0300</td>
<td>0600-1500</td>
</tr>
<tr>
<td>0300</td>
<td>0600</td>
<td>0900-1800</td>
</tr>
<tr>
<td>0600</td>
<td>0900</td>
<td>1200-2100</td>
</tr>
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<td>0900</td>
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<td>1500-2400</td>
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<tr>
<td>1200</td>
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<tr>
<td>1500</td>
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<td>2100-0600</td>
</tr>
<tr>
<td>1800</td>
<td>2100</td>
<td>0000-0900</td>
</tr>
<tr>
<td>2100</td>
<td>0000</td>
<td>0300-1200</td>
</tr>
</tbody>
</table>
5.2.1 Forecasting offices will issue all or some of the above 9 hourly Tafs, depending upon the charts prepared by them, their hours of forecasting watch and the W/T watch at the respective stations, taking into account the operational requirements also.

5.2.2 The 9 hourly Tafs will be exchanged internally between all forecasting offices, as necessary to meet the requirements of national services.

5.2.3 To meet the requirements of IAF and Naval Met. offices 9 hourly Tafs only will be issued.

5.2.4 Special Tafs valid for 9 hour periods may be requisitioned to meet the specific need of any flight in case the routine 9 hourly Taf does not meet the requirement. Such requisitions should, however, be restricted to the minimum.

5.3 For inclusion in MID/RTT broadcasts made from Beirut, aerodrome forecasts will be issued by Indian stations as follows:

9 hourly Tafs

<table>
<thead>
<tr>
<th>Name of Station</th>
<th>Time of issue (GMT)</th>
<th>Period of validity (GMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmadabad</td>
<td>2200</td>
<td>00-09</td>
</tr>
<tr>
<td></td>
<td>0100</td>
<td>03-12</td>
</tr>
<tr>
<td>Bombay</td>
<td>0400</td>
<td>06-15</td>
</tr>
<tr>
<td></td>
<td>0700</td>
<td>09-18</td>
</tr>
<tr>
<td>Delhi</td>
<td>1000</td>
<td>12-21</td>
</tr>
<tr>
<td></td>
<td>1300</td>
<td>15-24</td>
</tr>
<tr>
<td></td>
<td>1600</td>
<td>18-03</td>
</tr>
<tr>
<td></td>
<td>1900</td>
<td>21-06</td>
</tr>
</tbody>
</table>

18 hourly Tafs

<table>
<thead>
<tr>
<th>Name of Station</th>
<th>Time of issue (GMT)</th>
<th>Period of validity (GMT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmadabad</td>
<td>2200</td>
<td>06-24</td>
</tr>
<tr>
<td>Bombay</td>
<td>0400</td>
<td>12-06</td>
</tr>
<tr>
<td>Calcutta</td>
<td>1000</td>
<td>18-12</td>
</tr>
<tr>
<td>Delhi</td>
<td>1600</td>
<td>00-18</td>
</tr>
<tr>
<td>Lucknow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Madras</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5.4 A aerodrome forecasts for inclusion in VOLMET broadcasts will be valid for 9 hours, issued every 3 hours and will be amended hourly as necessary for inclusion in the broadcasts immediately following.

5.5 A aerodrome forecasts for destination and alternate aerodromes, given on request for inclusion in documentation will have a validity period commencing 1 hour before ETA, or earlier if requested, and will cover a period up to the ETA at the furthermost alternate plus 2 hours.
6. Height indication in aerodrome forecasts

6.1 The height indication in aerodrome forecasts will always be given as height above the official aerodrome elevation.

6.2 All heights will normally be given in metres. However, in aerodrome forecasts included in VOLMET broadcasts, cloud heights will be given in feet.

7. Limitations of Aerodrome Forecasts

7.1 Owing to

(i) the unavoidable limitations in the definitions of some of the elements, e.g. VVVV (visibility)
   \( h_b \) (height of base of cloud)
   \( h_i \) (height of icing level)
   \( h_t \) (height of Turbulence level)
   \( f_f \) (wind speed)
   \( f_m \) (maximum wind speed)

(ii) the variability of these elements over very short intervals of space and time, and

(iii) the present inadequacies of forecast techniques,

the specific values of any of the above elements given in aerodrome forecasts should be understood to be necessarily approximate, and the value of the element in question should accordingly be interpreted as representing the most probable mean of a range of values which the element may assume during the period of the forecast concerned and over the area concerned.

7.2 Similarly, when the time of occurrence or of change of an element is given in an aerodrome forecast (as indicated by GG and \( G_p \)), this time should be interpreted as representing the most probable mean of a range of times.

8. Compilation of Aerodrome Forecasts

8.1 Coded Aerodrome Forecasts

8.1.1 Aerodrome forecasts issued in code form will be in the TAF Code form (FM 51 B) of Aviation Weather Codes, 1972.

8.1.2 In the preparation of coded aerodrome forecasts, the following procedures will be followed:

(a) Of the three optional groups, the group (OGpGFpFp) will be included by all forecasting offices. The other two groups with indicator figures 6 and 5 will not be included in the coded TAF issued by Indian Stations.
(b) Other groups may be repeated/omitted as necessary in accordance with
the detailed instructions for each group keeping in view the following
points:—

(i) A complete description of forecast conditions should contain
information about wind, visibility, weather and cloud.

(ii) The description will be complete even when one or several of
the groups — apart from wind — is(are) omitted from the
message.

(iii) A group may be omitted without affecting the completeness of
the description (a) to indicate either that the element
contained in that group is expected to be absent or that its
future value is expected to be non-significant, (b) to
indicate that the element in question is not expected to
depart significantly from the preceding value it possessed
in the same validity period of the message.

(iv) When the omission of an element occurs after a change group,
the message should clearly indicate which of the two above
cases applies. For this purpose, use should be made as
necessary, of approved letter abbreviations, e.g. SKC, WX NIL
etc.

8.1.3 Information against the different groups will be given as follows:—

(a) TAF

The code name TAF is used as a prefix to the message, indicating
that it is an aerodrome forecast.

(b) CCCC

Under this group, the name of the aerodrome for which the
forecast is issued is given in ICAO four letter location
indicator. For stations for which no ICAO location indicator
has been specified, the name of the aerodrome will be given
in full.

(c) $G_1G_2G_3G_4$

The period of validity of the forecast will be indicated by
this group, $G_1G_2$, indicating the time of commencement of the
validity period and $G_3G_4$ the end of the validity period in
full hours G.M.T.

(d) $ddff/f_{m}f_{m}$

The direction (three figures) from which surface wind is expected
to blow rounded off to the nearest 10° (true), and speed in knots
(two figures), averaged for a 10 minute interval, will be indicated
by this group. When the forecast maximum wind is expected to exceed
the mean speed by 10 knots or more, the maximum speed will then be
indicated by adding/$f_{m}$ after $ddff$. Otherwise $f_{m}$ will be
dropped out, e.g. $ddff$ will be given as 25025 and $ddff/f_{m}$ will be
given as 25025/35.
Variable direction will be indicated by 'VRB' followed by speed (two figures) and 'Calm' by '00000'.

(e) **VVVV**

(i) This group will indicate the prevailing aerodrome surface visibility (in four figures) in metres, in increments of 100 metres up to 5 km and in increments of kilometres up to and including 9 kilometres. 9999 indicates a visibility of 10 km and above.

(ii) If the visibility is less than 5 km and is estimated to an accuracy greater than 100 metres, it is rounded off downwards to the nearest multiple of 100 metres. Similarly visibility greater than 5 km when estimated to an accuracy greater than 1000 metres, will be rounded off downwards to the nearest multiple of 1000 metres. e.g. expected visibility of 370 metres will be given as 0300 and a visibility of 5700 metres will be given as 5000.

(f) **W'W**

(i) Under this group, forecast significant weather will be indicated by means of Code 22 of Aviation Weather Codes 1972. Information 'F' 'mist' and 'haze' will be included in plain language.

(ii) When conditions are forecast that cannot be expressed by Code 22, the W'W' group will not be used except when significant weather is forecast to change into non-significant weather; in the latter case, 'WX NIL' will be used after the change group to indicate non-significant weather (see item (l)(ii)).

(g) **Nshshsh**

(i) This group is repeated as necessary to forecast 3 significant cloud layers (4 layers if CB cloud is forecast), the layers being selected on the following basis.

(a) the lowest individual layer (mass) of any amount 
   (N<sub>s</sub> equals 1/8 or more)

(b) the next higher individual layer (mass) the amount of which is greater than N<sub>s</sub> = 2 (N<sub>s</sub> equals 3 or more).

(c) the next higher individual layer (mass) the amount of which is greater than N<sub>s</sub> = 4 (N<sub>s</sub> equals 5 or more).

(d) CB clouds whenever forecast, but not covered under a, b, and c above, by means of a group referring exclusively to CB.

(ii) In any cloud group, N<sub>s</sub> is the total amount of cloud that the forecaster expects to be at the level given by h<sub>s</sub>h<sub>s</sub>h<sub>s</sub>. 
(iii) When clear sky is forecast, the cloud group is not used except after a change group (see item (1)(ii)) when the abbreviation SKC is used. Cloud groups are always used whenever $N_8 = 1$ to $9$.

(iv) When in the first cloud group, $N_8 = 9$ is forecast, the cloud group should read $9///$. 

(v) The amount of cloud is given in oktas (e.g. $4 = 4/8$). The height of the base of cloud above official aerodrome elevation is indicated by a three figure code (Code 9 of Aviation Weather Code, 1972). These code figures give direct reading in metres or feet as shown below:

For metres, multiply code figures by 30.

* e.g., code figure 002 = 002 x 30 = 60 metres.

For feet, multiply code figures by 100.

* e.g., code figure 002 = 002 x 100 = 200 feet.

(h) **CAVOK**

(i) CAVOK is used in replacement of the groups VVVV, w'w' and $N_6 C N_6 H N_6 H N_6$ whenever the forecaster expects the following conditions to occur simultaneously.

(a) visibility — 10 km or more
(b) cloud — No cloud below 1500 metres
(c) weather — No precipitation and no thunderstorm

(i) **GGF F F F**

(i) This group begins with the indicator figure '0' and will be included by all forecasting offices in India.

(ii) One or more groups may be used to give the forecast temperature(s) $T_F F_F$, at the time(s) indicated by $G_F G_F$, when this information is required.

(iii) For negative temperatures, the value is preceded by M

* e.g. 002 M07 indicates that the forecast temperature at 0200 GMT is minus 07° Celsius,

(j) **61h_1 h_1 h_1** and (k) **5BhbB_b**

These two groups will not be included by Indian stations.

(i) **913nnn**

(i) This group is used to indicate variations expected during the period of the TAF. When changes or supplementary phenomena are expected to occur during the period of the TAF, one of the abbreviations listed below is inserted along with a time group to signify that the groups following will describe the changes and the times of the changes.
GRADU - Gradual change during the period specified. The form GRADU GGG_eG_e should be used for indicating changes expected to take place at an approximately constant rate during the period beginning at GG and ending at G_eG_e; e.g. "GRADU 0204" indicates a gradual change between 0200 and 0400 GMT.

RAPID - Rapid change in less than half an hour. The form RAPID GG should be used when the change(s) is (are) expected to take place during a period lasting less than half an hour, GG referring to the time at which the change is expected to begin.

TEMPO - Temporary changes lasting less than one hour during the period specified. The form TEMPO GGG_eG_e should be used if the change(s) is (are) expected to last for a period of less than one hour in each instance and changes take place throughout the period which begins at GG and ends at G_eG_e, sufficiently infrequently for the prevailing conditions to remain those of the preceding part of the forecast; e.g. "TEMPO 1521" indicates a temporary change (or changes) between 1500 and 2100 GMT.

If the condition(s) is (are) expected to last more than one hour, the group GRADU GGG_eG_e is used or the forecast is divided into periods.

The group TEMPO GGG_eG_e is also used when the condition, if expected to recur, will not, in the aggregate, cover more than half of the forecast period during which the phenomenon is expected to occur (i.e.) the time between GG and G_eG_e.

INTER - Intermittent changes, frequent short period fluctuations throughout the period specified. The form INTER GGG_eG_e should be used if the change(s) is (are) expected to occur frequently for short periods of time, the conditions fluctuating almost constantly throughout the period which begins at GG and ends at G_eG_e, between those specified in the part of the forecast preceding the change group and those specified after this group; e.g. "INTER 0913" indicates intermittent changes between 0900 and 1300 GMT.

PROB - Probability (percent) of occurrence of conditions indicated in the groups following. The form PROB (percent) should be used for this group e.g. "PROB 20". The group "PROB (percent)" may appear after any group in the forecast. It may be used alone or in combination with a change group.

(ii) A TAF forecast shall cover the period G_1G_1 to G_2G_2. A change group shall be introduced when a significant change, in some or all of the elements forecast, is expected to occur at some intermediate time GG. Such a change group shall not be introduced until all the data groups necessary to describe the elements forecast in the period G_1G_1 to GG have been given. The change group shall be followed by a description of all the elements for which a significant change is forecast during the period GG to G_eG_e, beginning at GG. When an element is not described in the data groups which follow the change groups, the description of the element for the period between G_1G_1 and GG will remain valid during the period GG to G_eG_e also. When a group GRADU GGG_eG_e is used, the conditions described in the data groups which follow shall be considered to remain valid after the expiration of the
time \( G_0 \). When necessary, a second change group referring to conditions at a later time \( G_0 \) may be used.

(iii) If there is a requirement for the period between \( G_0 \) and \( G_2 G_0 \) to be greater than 9 hours, then the forecast period should be divided.

(m) Additional groups or supplementary information –

Appropriate abbreviations or plain language remarks may be added to the TAF to indicate expected directional variations in visibility.

8.2 Plain Language Aerodrome Forecasts

8.2.1 The following procedures will be followed in the preparation of plain language aerodrome forecasts included in VOMT broadcasts etc.

(a) Identification – The word 'FQST' will be used to identify an aerodrome forecast. "AMD FQST" denotes an amended aerodrome forecast.

(b) Period of Validity – The period of validity of the forecast should be given in the time group, e.g. "12/21".

(c) Identification of location – The aerodrome for which the forecast is given should be identified by the ICAO four letter location indicator, if available; otherwise the name of the aerodrome should be given.

(d) Wind (direction and speed, in that order and significant variations thereof, when appropriate).

(i) Direction should be given in degrees true using three figures followed by '/' (the word degrees should not be used). Speed should be indicated in knots in two figures. (the word knots will not be used in the written form of the message). When appropriate, the terms 'VRB' followed by speed in two figures and CALM should be used. Whenever maximum wind is forecast, it should be indicated by including 'Max....' after the wind information.

(ii) Directional and speed variations, if forecast, should be indicated, by means of appropriate change groups, in accordance with the 'SPECI' criteria for surface wind, given in Appendix I.

(e) Visibility – The name of the element should be included in the written form of the message and the units used (Metres/kilometres) should be specified clearly. When visibility is 5 kilometres or less, it should be expressed in metres, in steps of 100 metres e.g. VIS 0300 M; where the visibility is more than 5 kilometres but less than 10 kilometres, the units should be kilometres (to be indicated in steps of kilometres) e.g. VIS 7 KM; and when it is 10 KM or more, it should be given as 10 KM.

(f) Present Weather – Present weather should be in terms of Code 22 of Aviation Weather Codes 1972/Table III of PANS-MET. Information on 'Mist' and 'Haze' will also be included in addition.
(g) **Cloud**

(i) Information on cloud layers should be given as follows and in the order indicated.

(a) the lowest layer (mass), amount 1/8 or more
(b) the next higher layer (mass), amount 3/8 or more
(c) the next higher layer (mass), amount 5/8 or more
(d) CB, whenever forecast, and not covered by (a) to (c) above.

(ii) In plain language aerodrome forecasts included in VOLMET broadcasts etc., type of cloud should be mentioned only in case of CB. Other types should not be mentioned.

(iii) In plain language aerodrome forecasts included in VOLMET broadcasts and those supplied to ATC, if any, for communication to aircraft-in-flight, cloud heights should be given in feet only.

(iv) When clear sky is forecast without CAVOK conditions being applicable, the abbreviation 'SKC' should be used. If the sky is obscured, the term "sky obscured" should be used.

(h) **CAVOK**

(i) When the following conditions are expected to occur simultaneously, the elements 'visibility', 'cloud' and 'weather' will be omitted and the term "CAVOK" should be written against these three elements.

- Visibility - 10 KM or more
- Cloud - No cloud below 1500 metres (5000 feet)
- Weather - No precipitation and no thunderstorm

(ii) In plain language aerodrome forecasts, whenever variation of visibility is indicated following CAVOK conditions, information on clouds should also be included. If clear skies are expected during such periods of variation of visibility, this should be indicated by the use of "SKC"; if clear sky is forecast for a portion of the validity period and some cloud for the rest period, both should be indicated for the appropriate durations.

(i) **Temperature** - Forecast temperature, if included, should be given in whole degrees celsius in two figures. e.g. T 21. For temperatures below 0° celsius, 'MS' will be added to indicate negative temperatures e.g. TMSO8. The time to which the forecast temperature refers should also be given.

(j and k) Information on icing and turbulence will not be included by Indian stations.

(l) **Variations and supplementary phenomena** - Variations in some or all of the elements and supplementary phenomena, if any, should be indicated by the use of change groups as detailed under para 8.1.3(1).
8.3 Plain language aerodrome forecasts included in documentation

8.3.1 Aerodrome forecasts for inclusion in documentation should be prepared in Met T.10 or Met T.10 A forms. For flights for distances less than 500 n. miles, aerodrome forecasts should be prepared on page 3 of Met T.3 form.

8.3.2 Entries under the various columns will be made as follows:

(a) **Name of aerodrome or Location Indicator** - Identification of the aerodrome should be given by the ICAO four letter location indicator, where available; otherwise the name of the aerodrome should be given in full.

(b) **Period of Validity** - The period of validity of a particular aerodrome forecast will be indicated as per para 5.5.

(c) **Time and type of variation** -

(i) Time and type of variation should be indicated in terms of procedures given in para 8.1.3(1).

(ii) Whenever a change is indicated, a new line with appropriate details of the change should be started so as to make the information complete and unambiguous.

(d) **Surface wind direction and speed** - The mean direction (in the figures) should be given in degrees true to the nearest 10 degrees, followed by an oblique stroke and the mean value of the speed in knots (in two figures). The maximum wind speed should be added, when appropriate, preceded by the abbreviation Max. e.g. Max. 35. Where no wind is expected or expected to be variable, 'CALM' or 'VRB' followed by speed in two digits, respectively, should be given.

(e) **Surface visibility** - The value, if below 10 kms, should be stated. Visibility of 5 km and below should be given in four figures in metres and values above 5 km in kilometers in two figures. When visibility is 10 km or more, this should be expressed as 10 km.

(f) **Weather** - Weather remarks should be entered in terms of Code 22 of Aviation Weather Codes, 1972. Information on 'Mist' and 'Haze' will also be included in aerodrome forecasts included in all documentation issued in Met. T.3 forms and also in Met. T.4 forms for flights operating below F.L. 100.

(g) **Cloud** -

(i) Amount of cloud should be given by a figure denoting the number of oktas (e.g. 4 for 4/8). The type of cloud should be given in accordance with Code 3 of Aviation Weather Codes 1972. Both letters of the cloud abbreviations should be in capital letters and combination of clouds should not be given.

(ii) Only three layers of cloud (4 if CB is forecast) should be included in any one TAF, as per para 8.2.1 g, not counting layers given with change groups.
(iii) Cloud layers should be entered in the two columns as per procedures outlined in Aviation Met. Circular No.1969/2. (Appendix 3).

(iv) When clear sky is forecast, the cloud column should be left blank - 'SKC' should not be used.

(h) CAVOK - When values of visibility, cloud and weather conform to the specifications of CAVOK as given in para 8.1.3 h, 'CAVOK' should be entered across the appropriate columns and the values of these elements omitted.

(ii) Remarks - Remarks should include any available information or an indication of

(a) Temperature (in degrees celsius)

(b) Outstanding features of meteorological situation expected to affect the aerodrome during the period of validity of the forecast and not included under any of the individual elements, such as passage of a squall line.

(c) Provisional Forecast: If a provisional forecast has been supplied for any aerodrome under the provisions of para 4.1, remark to that effect should be entered in the remarks column.

(d) Period of validity: The original full period of validity should be entered in the remarks column whenever a TAF is not reproduced in its original form but the relevant portion is extracted and included.

9. Examples of Aerodrome Forecasts

A few examples of aerodrome forecasts are given in Appendix 2 both in coded as well as in plain language form.
## APPENDIX - 1

### TABLE 1 - CRITERIA FOR AMENDMENT OF AERODROME FORECASTS

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper winds</td>
<td>Change in direction of 30 degrees or more, provided the wind speed is 30 knots or more before or after the change; change in speed of 20 knots or more.</td>
</tr>
<tr>
<td>Upper air temperatures</td>
<td>Change of more than 5°C.</td>
</tr>
<tr>
<td>Aircraft icing</td>
<td>New expectation; intensity increasing; intensity decreasing from severe to light or from moderate to nil.</td>
</tr>
<tr>
<td>Freezing precipitation</td>
<td>New expectation; no longer expected.</td>
</tr>
<tr>
<td>Turbulence</td>
<td>Intensity increasing to moderate or to severe; intensity decreasing from severe to light or from moderate to nil.</td>
</tr>
<tr>
<td>Hail</td>
<td></td>
</tr>
<tr>
<td>Thunderstorm</td>
<td></td>
</tr>
<tr>
<td>Squalls</td>
<td>New expectation; no longer expected.</td>
</tr>
<tr>
<td>Tornado</td>
<td></td>
</tr>
<tr>
<td>Tropical revolving storm</td>
<td></td>
</tr>
<tr>
<td>Sandstorm or duststorm</td>
<td>New expectation; intensity increasing from conditions of rising sand (or dust) to sandstorm (or duststorm); intensity decreasing from a sandstorm (or duststorm) to condition of no rising sand (or dust).</td>
</tr>
<tr>
<td>Cloud conditions</td>
<td>Height of base of lowest cloud covering more than 4 oktas is expected to reach or pass through the values of 60 m, 150 m, 300 m.</td>
</tr>
<tr>
<td>Surface visibility</td>
<td>Expected to reach or pass through the values of 800, 1500, 3000 and 5000 m.</td>
</tr>
<tr>
<td>Surface wind</td>
<td>Change in direction of 30 degrees or more, with wind speed 20 kt or more before and/or after the change. Change in speed of 10 kts or more with speed before and/or after the change being 30 kts or more.</td>
</tr>
<tr>
<td>State of sea</td>
<td>Change affecting the safety of seaplane operation.</td>
</tr>
<tr>
<td>Significant front</td>
<td>(1) New expectation; no longer expected.</td>
</tr>
<tr>
<td></td>
<td>(2) Change of one hour or more in expected time to passage.</td>
</tr>
</tbody>
</table>
### Examples of coded and decoded aerodrome forecasts

<table>
<thead>
<tr>
<th>Type of Information</th>
<th>Location Indicator</th>
<th>Period of validity</th>
<th>Wind</th>
<th>Visibility</th>
<th>Weather</th>
<th>Cloud</th>
<th>Cloud</th>
<th>Cloud</th>
<th>Temperature</th>
<th>Supplementary Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) TAF VAPO</td>
<td></td>
<td>0000 to 0900 GMT</td>
<td></td>
<td>0800/06</td>
<td>6000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMPO 0104</td>
<td>2500</td>
<td>06 HZ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 0609</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodrome Forecast</td>
<td>POONA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0000 to 0900 GMT</td>
<td></td>
<td>0800/06</td>
<td>6 km</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMPO 0100 to 0400</td>
<td>2500</td>
<td>m Haze</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 0600 to 0900</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) TAF VRCC</td>
<td></td>
<td>0009 to 0900 GMT</td>
<td></td>
<td>00000</td>
<td>0100</td>
<td>46 FG</td>
<td>5 ST002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 0405</td>
<td>0200</td>
<td>7000 WMX</td>
<td></td>
<td>SKC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodrome Forecast</td>
<td>Calcutta</td>
<td>0000 to 0900 GMT</td>
<td></td>
<td>CALM</td>
<td>100m</td>
<td>FOG</td>
<td>5/8 ST</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 0400 to 0500</td>
<td>0200</td>
<td>7000m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) TAF VABB</td>
<td></td>
<td>0918 to 1200 GMT</td>
<td></td>
<td>2400</td>
<td>8000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 1011</td>
<td>1215</td>
<td>2000</td>
<td>95TS</td>
<td>55008</td>
<td>3CB20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMPO 1215</td>
<td>12035</td>
<td>2000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aerodrome Forecast</td>
<td>Bombay</td>
<td>0900 to 1800 GMT</td>
<td></td>
<td>2400/10</td>
<td>8000m</td>
<td>3/8 CU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>GRADU 1000 to 1100</td>
<td></td>
<td>2400/35</td>
<td>8000m</td>
<td>1/8 CB</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMPO 1200 to 1500</td>
<td></td>
<td>2000m</td>
<td></td>
<td>5/8 ST</td>
<td>3/8 CB</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In India, forecasts for short distance national flights are issued in Met. T.3 form. Forecasts for all low level flights of Flying Clubs, Helicopters etc. are also issued in this form. The low flying aircraft are mainly interested in getting as clear a picture of lower cloud layers as is possible. The codes for ROFOR/FIFOR etc. however provide for forecasting a number of cloud layers. While decoding these messages, it becomes obligatory to indicate in the Met. T.3 form all the information given in the coded messages. It has now been decided that the following procedures will be adopted to indicate cloud layers in Met. T.3 form.

(1) All layers of low cloud will be indicated against the "Lowest layer" with their bases, irrespective of the amounts.

(2) All medium and high clouds will be entered against the "Higher layer".

(3) When there are no low clouds present, the medium clouds will be entered against the "Lowest layer" and high clouds against the "Higher layer".

(4) In the absence of both low and medium clouds, high clouds will be entered against "Higher layer".

(5) When the flight level of an aircraft is definitely known to be below the height of cirrus clouds, information on high clouds will be omitted from the forecast issued for that particular flight.

Poona-5.
22nd October 1969
File - ATO 8501

Sd/-
( Y.P. Rao )
D.D.G.F.
CHAPTER 2

TAKE-OFF AND LANDING FORECASTS

1. TAKE-OFF FORECASTS

1.1 Introduction

Forecasts for 'Take-off' will form part of the service rendered for pre-flight operational planning.

1.2 Contents of 'Take-off' forecasts

Forecasts for 'Take-off' will be issued for surface conditions representative of the runway complex in regard to:

(a) Wind – Including information regarding variations
(b) Temperature
(c) Pressure (QNH)
(d) Any other element which may be agreed to locally between the Met. authorities and operators' local representatives.

1.3 Mode and frequency of issue

1.3.1 Forecasts for 'Take-off' shall be supplied when required within 3 hours before the estimated time of departure.

1.3.2 Forecasts for 'Take-off' are issued by Class I Meteorological offices only.

2. LANDING FORECASTS

2.1 Introduction

2.1.1 Supply of 'Landing Forecasts' is one of the important items of meteorological service for jet aircraft operations. This aims at providing the Pilot-in-Command with an accurate forecast for the aerodrome of landing, so that before commencing descent the pilot can make a decision as to whether he can land at that aerodrome.

2.1.2 Out of the two types of landing forecasts evolved by ICAO viz., (i) self-contained type and (ii) trend type, 'Trend type' landing forecast has been adopted in India. The trend part of the landing forecast is a concise plain language forecast which is appended to the latest aerodrome report or selected special or special report, to indicate anticipated changes in elements of operational significance.

2.1.3 The landing forecast will have a validity period of two hours from the time of observation of the aerodrome report or selected special or special report to which it is appended. This validity period will not be indicated separately.

2.1.4 In writing out the plain language messages, ICAO approved abbreviations may be used. Some important abbreviations are given in Appendix 1.
2.2 Composition of the Landing Forecast

2.2.1 A trend type landing forecast is composed of:

(a) an actual routine aerodrome report or selected special report or special report followed by

(b) a trend forecast indicating the significant changes in the existing conditions as described in the report, which are likely to occur during the validity period of the forecast (2 hours)

2.2.2 The trend part of the message follows the report immediately. The beginning of the trend is identified by one of the change indicators, 'GRADU', 'RAPID', 'INTER', 'TEMPO' as appropriate. When none of the above terms apply, the message will be identified by the word 'TRND'.

2.2.3 The order of elements in the trend type landing forecasts should be the same as those used in the reports to which the trend forecasts are appended. For example, when a change indicator ('TEMPO', 'GRADU' etc.) appears in a landing forecast, the elements which it governs should normally be in the following order:

Wind and its variations, visibility, weather, cloud conditions.

2.2.4 When no significant changes are expected during the subsequent two hours, the terms 'NOSIG' is written immediately after the report.

2.2.5 The term 'NOSIG' in conjunction with the report to which it is appended is a complete landing forecast.

2.3 Mode and Frequency of issue

2.3.1 At the time of issue of this report, trend type landing forecasts are being issued by Class I met. offices in India as follows:

2.3.1.1 On a routine basis throughout 24 hours:

- Bombay, Calcutta, Delhi and Madras

2.3.1.2 During the hours of operation of scheduled services:

- Agartala, Ahmedabad, Bangalore, Gauhati, Hyderabad, Mohanbari, Nagpur and Patna.

2.3.1.3 On request/reply basis:

- Jaipur, Lucknow, Trivandrum and Vishakhapatnam.

2.3.1.4 Issue of the trend forecasts on request/reply basis is done by appending the trend forecast to the latest routine, selected special or special report at the time of the receipt of the request and to subsequent reports until the plane has actually landed.

2.3.2 If after issue of an aerodrome report with appended trend forecast, conditions warrant the issue of a modified trend forecast before the issue of the next routine aerodrome report/selected special report/special report, a fresh landing forecast will be issued by appending the trend forecast to the latest aerodrome report. Such instances will generally be rare at aerodrome where half hourline are recorded.
2.4 Criteria for framing trend forecasts

2.4.1 Criteria for issue of trend forecasts in respect of surface wind, visibility, weather and cloud base are given below.

2.4.1.1 Surface wind

When the surface wind is expected to change by the following values, the trend forecast should indicate such expected changes:

(i) A change, in direction, of 30° or more associated with a mean wind speed exceeding 20 knots before and/or after the change.

(ii) A change in mean wind speed by 10 knots or more, the mean speed exceeding 30 knots before and/or after the change.

2.4.1.2 Visibility

When visibility in the report is below or when visibility is expected to fall below 5.0 km involving a change to, or passing any one of the following values, 5000, 3000, 1600, 800, 600, 400, and 200 metres, the trend forecast should indicate such expected changes.

2.4.1.3 Weather

When the onset or cessation of thunderstorm or freezing precipitation is expected, the trend forecast should indicate such changes.

2.4.1.4 Cloud

When the height of the base of cloud in the report is below, or expected to fall below 450 metres involving a change to, or passing any one of the following values, 450, 300, 150, 90, 60 and 30 metres, the trend forecast will indicate such expected changes.

A significant change in cloud amount should be a change from 4 oktas or less to more than 4 oktas, or a change from more than 4 oktas to 4 oktas or less, base remaining below 450 metres before and after the change.

2.4.1.5 The criteria are given in tabular form in Appendix 2.

2.4.1.6 Illustrative examples of trend forecasts are given in Appendix 3.

2.4.2 Use of change groups

2.4.2.1 The indicator 'PROB' should not be used in trend type landing forecasts.

2.4.2.2 The change indicators mentioned in 2.2.2 above shall be used in trend type landing forecasts in accordance with the following specification:
2.4.2.3 "GRADU" shall be used if the change(s) is(are) expected to take place at an approximately constant rate throughout the forecast period or during a specified part thereof;

2.4.2.4 "RAPID" shall be used instead of "GRADU" when the change(s) is(are) expected to take place during a period lasting less than half an hour;

2.4.2.5 "TEMPO" shall be used if the change(s) is(are) expected to last for a period of less than one hour and changes take place sufficiently infrequently for the prevailing conditions to remain those of the report;

2.4.2.6 "INTER" shall be used if the change(s) is(are) expected to occur frequently for a short period of time, the conditions fluctuating almost constantly between those in the report or those in the preceding part of the forecast, and those in the forecast itself;

2.4.2.7 "TEND" shall be used if none of the terms "GRADU", "RAPID", "TEMPO", and "INTER" applies. It should not be used if some other indicator has already appeared in the preceding part.

2.5 General

2.5.1 Landing forecasts are normally required by jet aircraft about one hour before the estimated time of landing. The underlying idea in appending trend forecasts to half hourly/hourly aerodrome reports as a routine is to enable the ATS units concerned to supply landing forecasts to aircraft approaching to land, with the least possible delay. On occasions when requests are received from jet aircraft for forecasts of landing conditions, more than two hours before the ETA, an aerodrome forecast (QFZ) covering the expected period of landing need only be supplied.

2.5.2 Landing Forecasts are intended to give precise information in respect of the elements, wind, visibility, weather and cloud which affect significantly the landing phase of jet operations. On this information, depends the aircraft commander's decision to commence descent and proceed to the destination aerodrome or to divert. These plain language forecasts should therefore be framed with all possible accuracy and precision. The idea behind furnishing "trend forecast" in plain language is to facilitate easy reading by the HF/RT operator and also to make information directly available in an understandable form (without the need even for mental decoding) to the aircraft commander. It should also be remembered that aircraft commanders of various nationalities whose knowledge of English will be limited, would be getting this information over radio-telephone. No deviations from ICAO specifications should, therefore, be made in framing these forecasts.
## Written and Spoken Forms of Terms most frequently used in Trend type Landing Forecasts

<table>
<thead>
<tr>
<th>Written Form</th>
<th>Spoken Form</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>CB</td>
<td>Cumulonimbus</td>
<td>No other type of cloud is indicated.</td>
</tr>
<tr>
<td>D35</td>
<td>Degrees</td>
<td></td>
</tr>
<tr>
<td>DZ</td>
<td>Drizzle</td>
<td></td>
</tr>
<tr>
<td>HZ</td>
<td>Dust Haze</td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>Feet</td>
<td></td>
</tr>
<tr>
<td>FZ</td>
<td>Freezing</td>
<td></td>
</tr>
<tr>
<td>FZDZ</td>
<td>Freezing Drizzle</td>
<td></td>
</tr>
<tr>
<td>FZRA</td>
<td>Freezing Rain</td>
<td></td>
</tr>
<tr>
<td>GRADU</td>
<td>Gradual or Gradually</td>
<td></td>
</tr>
<tr>
<td>GR</td>
<td>Hail</td>
<td></td>
</tr>
<tr>
<td>XX</td>
<td>Heavy</td>
<td></td>
</tr>
<tr>
<td>INCH</td>
<td>Inches</td>
<td></td>
</tr>
<tr>
<td>INTER</td>
<td>Intermittent</td>
<td></td>
</tr>
<tr>
<td>KM</td>
<td>Kilometers</td>
<td></td>
</tr>
<tr>
<td>KT</td>
<td>Knots</td>
<td></td>
</tr>
<tr>
<td>LSQ</td>
<td>Line Squall</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>Metres</td>
<td></td>
</tr>
<tr>
<td>MB</td>
<td>Millibars</td>
<td></td>
</tr>
<tr>
<td>MOD</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>MOV</td>
<td>Move or Moving</td>
<td></td>
</tr>
<tr>
<td>MS</td>
<td>Minus</td>
<td></td>
</tr>
<tr>
<td>MTW</td>
<td>Mountain waves</td>
<td></td>
</tr>
<tr>
<td>NM</td>
<td>Nautical miles</td>
<td></td>
</tr>
<tr>
<td>NOSIG</td>
<td>No significant change</td>
<td></td>
</tr>
<tr>
<td>OBSC</td>
<td>Obscure or obscured or obscuring</td>
<td></td>
</tr>
<tr>
<td>OCNL</td>
<td>Occasional or Occasionally</td>
<td></td>
</tr>
<tr>
<td>Written Form</td>
<td>Spoken Form</td>
<td>Remarks</td>
</tr>
<tr>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
</tr>
<tr>
<td>RA</td>
<td>Rain</td>
<td></td>
</tr>
<tr>
<td>RAPID</td>
<td>Rapid or Rapidly</td>
<td></td>
</tr>
<tr>
<td>RVR</td>
<td>Runway visual range</td>
<td></td>
</tr>
<tr>
<td>SA</td>
<td>Sandstorm or Duststorm</td>
<td></td>
</tr>
<tr>
<td>SCT</td>
<td>Scattered</td>
<td></td>
</tr>
<tr>
<td>SW</td>
<td>Severe</td>
<td></td>
</tr>
<tr>
<td>SH</td>
<td>Showers</td>
<td></td>
</tr>
<tr>
<td>SKC</td>
<td>Sky clear</td>
<td></td>
</tr>
<tr>
<td>SN</td>
<td>Snow</td>
<td></td>
</tr>
<tr>
<td>SPECIAL</td>
<td>Special Meteorological Report</td>
<td></td>
</tr>
<tr>
<td>STNR</td>
<td>Stationary</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>Temperature</td>
<td></td>
</tr>
<tr>
<td>TROG</td>
<td>Tropical Revolving Storm</td>
<td></td>
</tr>
<tr>
<td>TEMPO</td>
<td>Temporary or Temporarily</td>
<td></td>
</tr>
<tr>
<td>TEND</td>
<td>Tend or Tending to</td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>Thunderstorm</td>
<td></td>
</tr>
<tr>
<td>TSGR</td>
<td>Thunderstorm with Hail</td>
<td></td>
</tr>
<tr>
<td>TSSA</td>
<td>Thunderstorm with sand storm or duststorm</td>
<td></td>
</tr>
<tr>
<td>TURB</td>
<td>Turbulence</td>
<td></td>
</tr>
<tr>
<td>TYPH</td>
<td>Typhoons</td>
<td></td>
</tr>
<tr>
<td>VFR</td>
<td>Vertical</td>
<td></td>
</tr>
<tr>
<td>VIS</td>
<td>Visibility</td>
<td>(VIS is given in M upto and including 5000 metres; in KM for higher values).</td>
</tr>
<tr>
<td>VAR</td>
<td>Variable</td>
<td></td>
</tr>
</tbody>
</table>
CRITERIA FOR TREND TYPE LANDING FORECASTS

The criteria for indicating significant changes in trend type landing forecasts are summarised below.

<table>
<thead>
<tr>
<th>Element</th>
<th>Observed value (given in report)</th>
<th>Trend type landing forecast to be issued when one or more of the following changes are expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Surface wind</td>
<td>Mean speed</td>
<td>Change in direction</td>
</tr>
<tr>
<td>1.1</td>
<td>20 knots or less</td>
<td>30° or more</td>
</tr>
<tr>
<td>1.2</td>
<td>More than 20 knots</td>
<td>30° or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More than 20 knots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Any speed</td>
</tr>
<tr>
<td>1.3</td>
<td>Less than 30 knots</td>
<td>10 knots or more</td>
</tr>
<tr>
<td>1.4</td>
<td>30 knots or more</td>
<td>10 knots or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>30 knots or more</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Any speed</td>
</tr>
</tbody>
</table>

2. Visibility

<table>
<thead>
<tr>
<th></th>
<th>Visibility (200 m)</th>
<th>Visibility reaching or (400 m) reaching or surpassing (600 m) becoming any one of (800 m) lower than the following values: (1600 m) any one of the following values: (3000 m) following (5000 m) values:</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Less than 5 km</td>
<td></td>
</tr>
<tr>
<td>2.2</td>
<td>5 Km or more</td>
<td>Visibility becoming lower than 5 Km.</td>
</tr>
</tbody>
</table>

3. Weather: Thunderstorm or freezing precipitation

<table>
<thead>
<tr>
<th></th>
<th>Beginning of occurrence of one of these phenomena</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>None of the above phenomena occurring</td>
</tr>
<tr>
<td>3.2</td>
<td>One of the above phenomena occurring</td>
</tr>
<tr>
<td></td>
<td>End of occurrence of the phenomena</td>
</tr>
<tr>
<td>4. Cloud</td>
<td>Amount</td>
</tr>
<tr>
<td>----------</td>
<td>------------</td>
</tr>
<tr>
<td>4.1</td>
<td>Any amount</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Any amount</td>
</tr>
<tr>
<td>4.2</td>
<td>4/8 or less</td>
</tr>
<tr>
<td></td>
<td>5/8 or more</td>
</tr>
</tbody>
</table>
Appendix 3

Illustrative Examples for Trend Forecasts

I. Wind

Example 1: MRT REPORT 1100 VRCC 200/15 VIS 8 KM 8/8 1600 FT (500 m) T32 DP 26 QNH 1015 RAPID 1130 240/25

Example 2: MRT REPORT 1000 VABB 270/20 VIS 8 KM 8/8 1600 FT (500 m) T 28 DP 21 QNH 1018 INTER 270/35

II. Visibility

Example 1: MRT REPORT 0600 VABB 250/10 VIS 4000 M RA 5/8 1600 FT (500 m) T 20 DP 18 QNH 1008 RAPID 0615 VIS 3000 M

Example 2: SFLIGHTED SPECIAL 0810 VABB 250/10 VIS 1000 M 5/8 2000 FT (600 m) NOSIG

Note: The visibility in the report is expected to increase to 1400 M but not to 1600 M which is the significant limit. Hence NOSIG.

III. Weather

Example 1: SPECIAL REPORT 1415 VRCC 270/10 VIS 4000 M 5/8 2000 FT (600 m) 3/8 CB 1600 FT (500 m) RAPID TS 1440

Example 2: SFLIGHTED SPECIAL 1510 VRCC 200/15 VIS 6 KM 7/8 1600 FT (500 m) 3/8 CB 1000 FT (300 m) TRND TS Cease 1640

IV. Cloud

Example 1 (Base): MRT REPORT 0800 VCOM 270/10 VIS 6 KM 3/8 2000 FT (600 m) T 22 DP 18 QNH 1004 GRADU 3/8 1300 FT (400 m)

Example 2 (Amount): MRT REPORT 0700 VIFD 250/10 VIS 6 KM 6/8 1300 FT (400 m) T 20 DP 16 QNH 1010 GRADU 3/8 1300 FT (400 m)

****
CHAPTER 3
AIRFIELD WARNINGS FOR PARKED AND MOORED AIRCRAFT

1. Introduction

According to procedures laid down by the International Civil Aviation Organization, one of the items of meteorological information to be supplied to Aerodrome Control Towers is "Warnings for parked and moored aircraft". A comprehensive system of issue of warnings for parked and moored aircraft had been adopted in India in 1949 and the system continued without change till recently. From 1-8-1973, revised criteria have been introduced for the issue of these warnings as recommended by the Seventh Conference of Forecasting Officers, 1972.

2. Scope and utility of the warnings

2.1 As the very name indicates, these warnings are intended for the protection of aircraft parked and/or moored on the ground at an aerodrome.

2.2 These warnings are intended to provide advance information of the expected occurrence of phenomena hazardous for the aircraft parked and/or moored on ground with a view to enable proper precautions to be taken to protect such aircraft.

3. Warning elements

3.1 The elements for which these warnings are to be issued and the criteria for the issue of these warnings are specified in Appendix 1.

3.2 Reduction of visibility and lowering of cloud base expected to be associated with the warning elements should not be mentioned in the text of the warning.

4. Area coverage of the warnings

These warnings will be issued only for the aerodrome concerned and will be written as "Warnings for parked and moored aircraft for .......... aerodrome (Name)".

5. Responsibility for issue of the warnings

5.1 All Class I Met. offices and Met. centres at state capitals will issue these warnings for their respective aerodromes, during their forecasting watch hours.

5.2 During the closed forecasting watch hours of any Class I Met. office or the Met. centre at the state capital, the responsibility for the issue of these warnings will be taken over by the Class I Met. offices at the Regional Centre concerned.

5.3 In respect of aerodromes served by Class III met. offices where aircraft are normally parked or moored due to location of flying clubs etc., the required warnings will be issued by the associated Met. centres at the State capitals/Class I Met. offices at the Regional Centres.
5.3.1 In the case of the Met. centres at the state capitals maintaining restricted forecasting watch, the responsibility for issue of warnings for their associated Class III Met. offices will be assumed by the Class I Met. offices at the Regional Centre concerned.

6. Dissemination of the warnings

6.1 These warnings are meant purely for the protection of the aircraft parked and/or moored on the ground at the local aerodrome and hence are not to be disseminated beyond the aerodrome of origin.

6.2 The warnings issued should be passed on to the local Air Traffic Services Units. It is the responsibility of these units to disseminate these warnings locally to the various airline operators concerned.

7. Procedures for the issue of the warnings

7.1 As the warnings are intended to be used for the protection of parked and moored aircraft, it is necessary that these are issued sufficiently in advance, say at least 1/2 to 1 hour prior to the expected time of commencement of the phenomena to enable proper protective measures being taken in the matter.

7.2 The warnings should be clearly and precisely worded.

7.3 The period of validity of the warnings should preferably be short and may normally be limited to 4 or 5 hours. If the phenomena is expected to continue for a longer time, the warning can suitably be extended for a further period.

7.4 All attempts should be made to derive as much help as possible from the weather radar for issue of these warnings. For this purpose, the radar may be operated more frequently as necessary.

8. Models of airfield warnings

Models of airfield warnings are given in Appendix 2. These are merely illustrative and are neither mandatory nor exhaustive.
### Criteria for issue of warnings for parked and moored aircraft

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Element</th>
<th>Warning Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>Wind</td>
<td>(i) When wind speed is expected to reach 30 kts or more even in gusts;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(ii) When the mean wind direction is expected to change rapidly by 45° or more and the wind speed before or after the change is expected to be 20 kts or more;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(iii) For light aircraft, gliders and helicopters a separate warning shall be issued when the wind speed is expected to reach 17 kts or more even in gusts.</td>
</tr>
</tbody>
</table>

**Note:** While issuing warnings in respect of wind, its expected direction and speed shall be indicated.

| (2)   | Squall                 | Whenever squall is expected.                                                                                                                      |
|       |                        | **Note:** The expected speed and direction of wind in squall shall be indicated.                                                               |

| (3)   | Squally weather        | Whenever squally weather is expected.                                                                                                             |
|       |                        | **Note:** (i) Squally weather is characterised by frequent squalls with or without rain or persistent type of gusty wind. Such conditions are generally associated with low pressure systems or onset or strengthening of southwest monsoon. In squally weather, the wind direction remains fairly steady. |
|       |                        | (ii) Wind direction and speed during squally weather shall be indicated.                                                                          |

| (4)   | Duststorm/Sandstorm    | Whenever duststorm/sandstorm is expected.                                                                                                        |
| (5)   | Thunderstorm           | Whenever thunderstorm is expected to be accompanied by squall.                                                                                   |
|       |                        | **Note:** No warning is to be issued if thunderstorm is not expected to be accompanied by squall.                                                   |

| (6)   | Hail                   | Whenever hail is expected.                                                                                                                        |
| (7)   | Frost                  |                                                                                                                                                    |
| (8)   | Hoar frost              |                                                                                                                                                    |
| (9)   | Snow                    | Whenever any of these phenomena is expected.                                                                                                      |
| (10)  | Rime                   |                                                                                                                                                    |
| (11)  | Freezing precipitation |                                                                                                                                                    |
| (12)  | Rough Sea              | When the height of wave is expected to be 8\' (2.4 m) or more.                                                                                   |
| (13)  | Swell                  | When the swell is moderate or heavy.                                                                                                               |
Appendix 2

Model Airfield Warnings for Parked and Moored aircraft

1. **TS** accompanied with surface squall from NW speed reaching 30 kt, likely affect VMCC and VEBR airfields between 041100 to 041330Z.

2. Surface squall from SW, speed reaching 40 kt, likely over Gauhati airfield during 100930 to 101030Z.

3. Strong surface winds of 15 to 20 kt, occasionally gusting to 35 kt, from a westerly direction likely over Bombay airfield during the period 012030 to 020100Z.

4. Duststorm likely affect Jaipur airfield during the period 040900 to 041300Z; associated wind speed likely exceed 40 kt from southeast.

5. Under the influence of deep depression in southwest Bay thunderstorm and squally weather with surface wind from northeast, speed reaching 40 kt in gusts, likely over Vishakhapatnam airfield during the period 040030 to 040530 GMT.

****
CHAPTER 4

AREA METEOROLOGICAL WATCH: SIGMET INFORMATION

1. DEVELOPMENT OF CONCEPT AND PURPOSE

1.1 The system of in-flight service through Area Meteorological Watch developed by the ICAO Met.V Meeting (Montreal, 1959) aims at the supply to Air Traffic Service Units, on a routine basis, of the most significant meteorological information (SIGMET information) for a designated area which is normally the Flight Information Region. The relevant SIGMET information is to be issued by the Meteorological Watch Office (MWO) serving the FIR; the responsibility for communication of the information to aircraft-in-flight, as appropriate, is that of the Flight Information Centre of the FIR concerned.

1.1.1 The Area Meteorological Watch is to be supplemented, in certain cases, by an en-route forecast service, which will provide upper wind and temperature forecasts for a specified segment of the route.

1.2 The issue of SIGMET information is aimed at providing aircraft-in-flight advance notice of actual or impending weather developments or trends that are potentially hazardous. It is intended to serve all aircraft operations - Civil and Military, long and short haul. The SIGMET message provides information for the use of Flight Information Centres (FICs) in effecting expeditious and safe movement of aircraft under all operating conditions. In addition, it also serves as an aid for the duty forecaster at the aerodrome of departure for preflight weather briefing by pin-pointing the more critical weather developments during the subsequent few hours.

2. DEFINITION OF SIGMET INFORMATION

2.1 SIGMET INFORMATION, will be issued for the occurrence or expected occurrence at subsonic cruising levels, of one or more of the following phenomena within the FIR served by the MWO.

- Active thunderstorm area
- Tropical revolving storm
- Severe line squall
- Heavy hail
- Severe turbulence
- Severe icing
- Marked mountain waves
- Widespread Sandstorm/Duststorm

2.2 Apart from the above general SIGMET information which is for utilisation of all aircraft, SIGMET messages are also to be issued to meet the special requirements of SST aircraft and light general aviation aircraft.

2.2.1 SIGMET messages for SST aircraft will be identified as 'SIGMET SST' and will be issued for the following phenomena at the transonic levels and supersonic cruising levels:

(i) Moderate or Severe Turbulence
(ii) Cumulonimbus clouds
(iii) Hail

2.2.2 Additional SIGMET messages for light general aviation aircraft will be issued, whenever occasion demands, in respect of 'light or moderate 'hail' and moderate 'icing'.

2.3 The elements, turbulence, icing and hail, are assumed normally to be associated with an active thunderstorm area, tropical revolving storm and severe line squall. They need not be specifically mentioned when SIGMET information is issued in respect of active thunderstorm area, tropical revolving storm and severe line squall. However, these elements should be mentioned when actually observed (or reported by aircraft) or warrant special attention.

3. GENERAL CRITERIA FOR ISSUANCE OF SIGMET MESSAGES

3.1 In the foregoing paragraphs, the phenomena for which SIGMET messages are to be originated are broadly outlined and the following general clarifications for issue of SIGMET are given.

3.2 Active Thunderstorm Area

In tropical areas, during periods when thunderstorm activity is a frequent occurrence, SIGMET messages referring to active thunderstorm areas need be issued only when they pertain to intense or widespread thunderstorms. However, in the interests of safety of air navigation, radar echoes, presumed to be of thunderstorms, of 50 km or more in length should also be reported in SIGMET messages, unless there are indications that the echoes are dying.

3.3 Tropical Revolving Storm

The SIGMET for tropical revolving storm may be issued only from the stage when a cyclonic storm has been declared. In the case of a depression the associated phenomena will be covered by SIGMET message for "active thunderstorm area" or "severe line squall", etc. A tropical cyclone being a phenomenon distinct from the others, it is necessary to restrict its use only when a cyclonic storm with a ring of high winds and other associated phenomena are expected.

3.4 Severe Line Squall

SIGMET message for this item may be issued in connection with actual or expected occurrence of line squalls of the Nor'wester and similar types of thunderstorms in North India or those associated with depressions and cyclonic storms.

3.5 Heavy hail, severe turbulence, severe icing

It is difficult to forecast precisely the occurrence of these phenomena except as associated with any of the above mentioned phenomena. However, when any of these phenomena are reported by an aircraft or by a ground station (in the case of hail) and/or are inferred by the study of radar echoes, these items should be included in SIGMET messages.
3.5.1 Whenever hail and moderate/severe turbulence is reported by aircraft at transonic levels and supersonic cruising levels of SST aircraft or the phenomena are expected to occur at that level, the same should be included in SIGMET SST.

3.5.2 Similarly additional SIGMET messages for light general aviation aircraft are to be originated whenever 'light' or 'moderate' hail or 'moderate icing' is observed or expected.

3.6 Marked mountain waves

Attention of forecasters is invited to pp. 4–9 of WMO Technical Note No.18 on 'Aviation aspects of mountain waves'. Two important criteria which require to be satisfied for the occurrence of mountain waves are:

(a) a stable stratification of the atmosphere up to at least the 500 mb level preferably with an inversion or an isothermal layer in the lower levels not necessarily reaching to the ground.

(b) a wind flow normal to the mountain range, speeds of about 15 to 20 kts or more.

Presence of mountain waves in moist atmosphere is often revealed by the formation of typical wave clouds (alto-cumulus clouds, lenticular clouds etc.)

The two aviation hazards associated with mountain waves are:

(i) strong down drafts on the lee side of the mountain which are of considerable importance to low flying aircraft.

(ii) moderate to severe turbulence which can be created not only by wave formation but also due to the rough terrain; this turbulence can extend to several times the mountain height thus affecting even aircraft flying in the middle and upper tropospheric levels and even to lower stratospheric levels.

3.7 Widespread Sandstorm or Duststorm

Normally any area where widespread development of sandstorm or duststorm is expected or observed, is to be included under this category.

3.8 CB clouds

Whenever CB clouds are expected or reported at the transonic levels and supersonic cruising levels of SST aircraft, the same should be included in SIGMET SST.

4. RESPONSIBILITY FOR ISSUE OF SIGMET MESSAGES AND THEIR DISSEMINATION TO AIRCRAFT

4.1 SIGMET information will be issued by the Meteorological Watch Office (MWOs) at Bombay, Calcutta, Delhi and Madras in respect of the areas covered by the Flight Information Regions served by the associated FICs. This will be done through specially written advisory messages prepared by the said MWOs and supplied to the associated Flight Information Centres (FICs).
4.2 It will be the responsibility of the FIC to communicate the above information to aircraft in flight, as appropriate. SIGMET information covering a portion of the route up to a minimum of two hours flying time ahead of the aircraft should be passed on to aircraft, on ground initiative (FIC), during the entire flight.

5. PROCEDURE FOR ISSUING OF SIGMET MESSAGES

5.1 Each MMO will originate SIGMET messages as a routine, eight times a day at three hourly intervals, viz. 0100, 0400, 0700, 1000, 1300, 1600, 1900 and 2200 GMT.

5.1.1 SIGMET messages may not be issued for areas and periods where and when air operations do not take place.

5.1.2 SIGMET messages will include phenomena occurring or expected to occur during a period of four hours from the hour of issue. Every attempt should be made to indicate the times of commencement and cessation of adverse weather phenomena.

5.1.3 The Meteorological Watch Officer will ensure that a constant watch is maintained on weather developments over the FIR concerned giving specific attention to the requirements for issue of SIGMET information. For this purpose, besides information obtained from analysis of synoptic charts, he will ensure that maximum use is made of (i) radar weather information available at the station or exchanged from other stations (ii) aircraft weather reports (iii) selected special reports from stations in the FIR and (iv) relevant post-flight and debriefing reports.

5.1.4 Help in the nature of calling for special observations from aircraft on request-cum-supply basis may be utilised for issuing SIGMET information on development of weather potentially hazardous to aircraft operations.

5.1.5 Details regarding times of issue, periods to be covered and material to be used for issue of SIGMET messages are laid out in the Table below.
<table>
<thead>
<tr>
<th>Times of issue of SIGMET information (GMT)</th>
<th>To include phenomena occurring or expected to commence during (GMT)</th>
<th>Radar observation (GMT)</th>
<th>Synoptic chart Surface Upper Air</th>
<th>Aircraft reports and selected special reports received upto</th>
<th>Aerodrome information received upto</th>
<th>Any other information (Debriefing information etc.) received upto</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) 0100</td>
<td>0100-0500</td>
<td>0000</td>
<td>1800 and 2100</td>
<td>1800 and 0000</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>0400</td>
<td>0400-0800</td>
<td>0300</td>
<td>0000</td>
<td>1800 and 0000</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>0700</td>
<td>0700-1100</td>
<td>0600</td>
<td>0000 and 0300</td>
<td>0000</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>1000</td>
<td>1000-1400</td>
<td>0900</td>
<td>0300 and 0600</td>
<td>0000 and 0600</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>1300</td>
<td>1300-1700</td>
<td>1200</td>
<td>0600 and 0900</td>
<td>0000 and 0600</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>1600</td>
<td>1600-2000</td>
<td>1500</td>
<td>1200</td>
<td>1200</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>1900</td>
<td>1900-2300</td>
<td>1800</td>
<td>1200 and 1500</td>
<td>1200 and 1800</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>2200</td>
<td>2200-0200</td>
<td>2100</td>
<td>1800</td>
<td>1200 and 1800</td>
<td>-do-</td>
<td>-do-</td>
</tr>
</tbody>
</table>

Note: This table will be displayed prominently in the Met. Watch Offices.

5.1.6 Apart from issuing the SIGMET messages as per scheduled times given above, the MWO can originate, if the situation warrants, SIGMET messages in between two routine issues, either as an amendment to a standing SIGMET message already issued at a scheduled time or as a fresh SIGMET message in itself. Such messages will cover the entire FIR and will be valid for the remaining portion of the 4 hour period for which the immediately preceding routine SIGMET would have been issued (e.g. message issued at 1430 GMT will be valid for 1430 to 1700 GMT).

5.2 Use of Radar information

In issuing SIGMET messages, full use should be made of the latest available radar information from stations within the F.I.R. Radar information from other stations whose range extends into the FIR may also be made use of as required.
5.3 If a weather phenomenon specified in para 2 has already developed, a SIGMET message will be issued stating the present condition and expected developments during the period of validity of the message, viz. four hours. If the phenomenon is expected to continue beyond the time of expiry of the SIGMET message, the SIGMET message will be re-issued accordingly at the next routine hour.

5.4 If none of the hazardous phenomena listed in para 2 occur or are 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 'nil' SIGMET message will not be originated).

5.5 A suitable log book should be maintained by each MWO to keep a continuous record of issuance or non-issuance of SIGMET messages. A record of this type will be useful in dealing with investigation of accidents and references from operators.

6. COMPOSITION AND WORDING OF SIGMET MESSAGES

6.1 SIGMET messages should contain the following information as necessary and in the order indicated.

(a) identification of information which follows
(b) period of validity
(c) phenomenon
(d) description
(e) type of information (observation or forecast)
(f) location
(g) movement or expected movement
(h) expected development

6.1.1 A format for the preparation of SIGMET information messages and phraseologies to be used, as far as practicable, is given in Appendix 2.

6.2. As SIGMET messages are issued, as a routine, at three hour intervals, it would suffice if the position of the centres of cyclonic storms are specified with reference to the nearest synoptic hour (main or intermediate, viz. 00, 03, 06 etc. ... 21) preceding the routine hour of issue (vide para 5.1.5) on the basis of the latest available synoptic chart.

6.2.1 To give the extrapolated centre as the actual centre appears to be unrealistic and also not appropriate; it is far better to give the actual position on the latest available chart or the forecast position. For example, in the SIGMET message issued at 0100 GMT, the position on the 2100 GMT chart may be given as the actual position or the forecast position at 0300 GMT may be given (mid-point of the period of validity of the SIGMET message.)
6.2.2 When the centre of the cyclonic storm is outside the F.I.R., but when its associated weather is affecting or is likely to affect the FIR within the period of the warning, reference to its exact position, movement etc. need not be made unless it is expected to cross over into the F.I.R. concerned within the period of validity of the message. In such cases reference to it need be made only to the extent necessary to describe weather developments of direct concern to aviation.

6.3 SIGMET messages should be comprehensive but should also be as concise as possible to consume minimum W/T, R/T time. These may be worded clearly and concisely as per format at Appendix 2 avoiding unnecessary qualifying language and descriptive material.

6.3.1 In writing SIGMET messages in plain language, ICAO approved abbreviations may be used.

6.4 Areal extent of phenomena described in SIGMET messages may be defined with reference to principal or well-known aerodrome stations giving distances (in nautical miles) from these points when needed. In cases where potentially hazardous weather is widespread, it will be satisfactory to define its areal extent, according to the convenience of the forecaster, preferably in terms of latitudes and longitudes, with particular reference, if necessary, to the nature of terrain. Reference to popularly known major geographical features, such as Western Ghats, Assam Himalayas etc. may be made. Such reference to geographical features may be preferable particularly when hazardous weather phenomena are associated with them.

7. IDENTIFICATION OF SIGMET MESSAGES

7.1 Each originating MWO shall number its SIGMET messages serially, beginning with the first SIGMET issued for the day, the day being reckoned in GMT time.

7.2 The succeeding SIGMET message will automatically cancel the preceding SIGMET message.

7.3 A SIGMET message will, in general, relate to occurrence/expected occurrence of the same phenomenon or more than one phenomenon over more than one distinct area within the FIR. In all such cases the messages should be paragraphed in such a way that each para contains information about a single phenomenon over a single specified area. This would facilitate the FIC personnel to communicate to any aircraft the relevant portion of the total message which is of interest to its particular flight.

7.4 To amend the existing warning or incorporation of additional information, a fresh SIGMET message will be issued as indicated in para 5.1.6.

7.5 Similarly, if after the issue of a routine SIGMET message for a single phenomenon over a single specified area, the phenomenon is no longer expected to occur, a cancellation message should be issued at any time. Such cancellation messages may be worded as follows:

New Delhi 221700Z (.) Cancel SIGMET NR NINE

New Delhi FIR (.) Expected Thunderstorm not likely develop.
8. DISTRIBUTION OF SIGMET MESSAGES

8.1 Each MWO will ensure that SIGMET messages are originated at least five minutes before the routine time of issue and are immediately supplied to the local FIC/ACC.

8.1.1 In addition to the supply of the SIGMET information for the local FIR, SIGMET information from neighbouring FIRs within a distance 1100 n.m. from the boundaries of local FIR should also be supplied to the FIC/ACC for their use.

8.2 SIGMET messages will be exchanged with MWOs in other FIRs whose boundaries are within a distance of 1100 n.m. from the boundaries of the FIR concerned.

8.2.1 SIGMET messages will be exchanged on AFTN channels under 'DD' priority.

9. MODELS OF SIGMET MESSAGES

9.1 Models of SIGMET messages in respect of different phenomena are given in Appendix 1. The models are merely illustrative and by no means exhaustive or mandatory.
Appendix I

EXAMPLES OF SIGMET MESSAGES

1. Active Thunderstorm area

(i) NR 3 Bombay FIR SIGMET (Valid 201000-201400). TS observed at 200930 from 18N 73E to 22N 76E 50 nautical miles wide stationary weakening.

(ii) NR 6 Calcutta FIR SIGMET (Valid 261600-262000). TS observed at 261530 from 22N 86E to 25N 90E 70 nautical miles wide moving SE at 15 kts rapidly intensifying. Also expect gradually extend NE up to 28N 95E.


(iv) NR 2 Madras FIR SIGMET (Valid 031000-031400). Active TS area forecast between latitudes 8N and 12N and longitudes 76E and 78E stationary.

2. Tropical Revolving Storms and Severe line Squalls

(i) NR 4 Bombay FIR SIGMET (Valid 010400-010800). Cyclonic Storm centred at 010000 near 16N 69E expected move NE 10 kts intensifying. Severe line squalls likely area 150 nm around centre.

(ii) NR 3 Madras FIR SIGMET (Valid 200700-201100). Cyclonic storm with small core hurricane winds centred at 200600 near 16N 84E moving NNW 10 kts intensifying. Active TS area expected 150 n. miles around centre.

(iii) NR 5 Calcutta FIR SIGMET (Valid 211100-211400) severe line squalls 75 n.miles wide from 22N 86E to 25N 90E moving SE 15 kts. Also expect gradually extend Northeast up to 28N 95E.

Broken line TS observed at 211030 from 20N 85E to 22N 87E moving East dissipating.

3. Heavy Hail

NR 5 New Delhi FIR SIGMET (Valid 121130-121400). Heavy hail observed at 121100 near 26N 73E expected extend NE wards and dissipate.

4. Severe Turbulence

(i) NR 5 Calcutta FIR SIGMET (Valid 151600-152000). Severe CAT observed at 151530 over latitudinal belt 24N to 26N near longitude 79E at FL 380. Likely extend Eastward along jet stream axis Allahabad-Gauhati gradually.

(ii) NR 5 New Delhi FIR SIGMET (Valid 201200-201400). Severe turbulence in CB observed at 201130 near 28N 76E at FL 200. Area turbulence shifting East weakening.
5. Severe Icing

NR 4 New Delhi FIR SIGMET (Valid 081100-081400). Severe icing in CB observed at 081030 near 28N 79E at FL220.

6. Marked mountain waves

Mountain waves observed at 240630 lee side Western Ghats between 15N and 18N and extending 100 n.m. East. Likely cause extensive areas of strong up and down drafts and locally severe turbulence up to FL 200.

7. Widespread Sandstorm/Duststorm

NR 3 New Delhi FIR SIGMET (Valid 071000-071400). Widespread duststorm forecast over area 100 n.m. wide from 25N 72E to 28N 74E moving NE intensifying.

*****
<table>
<thead>
<tr>
<th>Item</th>
<th>Phenomenon</th>
<th>Description</th>
<th>Type of information</th>
<th>Location</th>
<th>Movement or expected (1) movement</th>
<th>Expected development.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active thunderstorm area</td>
<td>THUNDERSTORMS</td>
<td></td>
<td>FORECAST AT OBSERVED AT .......time</td>
<td>Area or FROM... TO...</td>
<td>STATIONARY, or MOVING...... Direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Tropical revolving storm</td>
<td>HURRICANE</td>
<td></td>
<td>FORECAST AT OBSERVED AT .......time</td>
<td>Position of centre, or area</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td></td>
<td>TYPHON</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>TROPICAL STORM CYCLONE (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Severe Line Squall</td>
<td>SEVERE LINE SQUALL</td>
<td></td>
<td>FORECAST AT OBSERVED AT .......time</td>
<td>FROM........ TO........</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Heavy hail</td>
<td>HEAVY HAIL</td>
<td>e.g. IN COLD FRONT, IN CUMULONIMBUS</td>
<td></td>
<td>Position or area</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Severe turbulence</td>
<td>SEVERE TURBULENCE</td>
<td>e.g., IN CLEAR AIR, IN CLOUDS, ABOVE MOUNTAINS</td>
<td></td>
<td>Position or area and layer or level</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Severe icing</td>
<td>SEVERE ICING</td>
<td>e.g., IN RAIN, IN CUMULONIMBUS IN NIMBOSTRATUS</td>
<td></td>
<td>Position or area and layer or level</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE/ INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Marked mountain waves</td>
<td>MOUNTAIN WAVE</td>
<td>e.g., VERTICAL SPILL</td>
<td></td>
<td>Position or area and layer or level</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
<tr>
<td>Widespread Sandstorm/ Duststorm</td>
<td>SANDSTORM (3) DUSTSTORM</td>
<td></td>
<td>FORECAST AT OBSERVED AT .......time</td>
<td>Area or FROM... TO... AND UPTO...</td>
<td>STATIONARY, or MOVING...... direction and speed (in kt)</td>
<td>INTENSITY-NO CHANGE, INTENSIFYING, WAKENING</td>
</tr>
</tbody>
</table>
Notes:

(1) The nature of the movement (actual or expected) will usually be indicated by one of the words "FORCAST" or "OBSERVED" in the message. If not, the appropriate word ("FORCAST" or "OBSERVED") may be inserted before the word "MOVING".

(2) Any other local name may be used and also the name of an individual hurricane.

(3) Any local name may also be used.

Introduction to the table

(1) In SIGMET information messages the validity period should always be indicated.

(2) The words used in preparing the message should, as appropriate, be those given in the table in capital letters. Other words may however be used if necessary. It is not always necessary to use an entry from every column.

(From - PANSMT - Attachment D)
CHAPTER 5

SOME IMPORTANT PHENOMENA WHICH AFFECT AIRCRAFT OPERATIONS

1. Introduction

Weather phenomena which cause poor visibility conditions and aircraft turbulence not only affect the smooth operation of aircraft but can also lead to aircraft accidents. Fog, mist, dust storms and heavy precipitation reduce visibility at airports to such an extent that diversions are necessitated resulting in dislocation of air services and consequent increase in the cost of aircraft operations. Tropical storms, severe local storms, tornadoes etc. not only drastically reduce visibility but also cause severe turbulence to aircraft leading to the most hazardous conditions for all phases of aircraft operations. Some of the important phenomena which adversely affect aircraft operations and the procedural aspects in connection with the same are dealt with in this chapter.

2. Visibility

2.1 Visibility is a factor of great importance in all aircraft operations and especially so in landing and take off phases. Recording and reporting of visibility is at present limited only to horizontal surface visibility, as it is not yet found feasible to record and report any other type.

2.2 Fog

2.2.1 One of the phenomena which cause very low visibility at airports is fog. Fog, by definition, is a condition in which the atmosphere contains a suspension of very small water droplets (ice crystals in ice fog) reducing the horizontal visibility at the earth's surface to less than 1000 m. In mist, which is otherwise similarly defined, the visibility is above 1000 m, but less than 4000 m. For reporting fog/mist the relative humidity should be above 75% as per the criteria laid down by World Meteorological Organization.

2.2.2 Fogs can be classified into four types based on processes which cause them i—

(i) Radiation fog which forms mainly due to the cooling of the ground by radiation at night.

(ii) Advection fog which forms as moist air is transported over relatively much colder surface.

(iii) Steaming fog caused by the evaporation from warm water into colder air.

(iv) Frontal fog which is caused by continuous rain ahead of a warm front.

2.2.3 Of the above, categories (i) and (ii) are most common and important, especially for tropical and sub-tropical latitudes. Even though they are treated as two distinct types, quite often fogs form as a result of a combined effect of the two processes. For example, when warm moist air from sea blows on to a colder land area during winter months, the cooling by the contact with the underlying surface alone may not be sufficient. Further radiational cooling during night can result in dense fogs in the early hours.
2.2.4 The conditions favourable for radiation fog are:

(i) A high relative humidity so that a little cooling is sufficient to reach saturation.

(ii) Little or no cloud to facilitate greater loss of heat by the ground due to radiation.

(iii) Light wind (in perfectly calm conditions copious dew may form without fog formation).

An inversion of temperature is sometimes stated as a favourable factor. A stable layer, especially an inversion, slightly above the ground is helpful for fog formation as the turbulent mixing will not extend to great heights and the resultant cooling is confined to shallow layers only.

2.2.5 Advection fog occurs when air moves over a cooler surface of land or sea, the surface temperature being below the dew point of the moving air. Over land, it is likely in winter. The humidity is often already high, for the air may have become saturated over the sea and further cooling by contact with land readily produces fog. Over sea it may form by:

(i) Transport of relatively warm air from land to colder sea.

(ii) Air flow from warmer part of sea over much cooler current.

2.2.6 The conditions for formation of steaming fog are:

(i) A marked surface inversion in the air before it moves over the sea.

(ii) A low air temperature about 0°C or below.

The invisible vapour given off from the water is recondensed on coming into contact with colder air.

2.2.7 Frontal fog is associated with the interaction between adjacent air masses. It occurs in one of two ways – either as cloud coming down to the surface with the passage of front or because of saturation occurring in continuous rain preceding warm front.

2.2.8 Synoptic situations favourable for fog formation

Fogs are quite common in different parts in India during the winter months. Over Northern India the frequency is maximum in January and December. In Brahmaputra valley of Assam the frequency is greater than 20 days per month. The river and abundant vegetation in the valley provide plenty of moisture in lower levels. The dry and cold circum-polar westerly flow at 1.5 km and above which is a normal feature in this area provides ideal conditions for fogs to occur almost as a daily feature. The next favourable area for fog formation is coastal areas of West Bengal. A shallow high pressure cell frequently forms over the central and adjoining north Bay bringing moist and relatively warm air into the land. This area is partly cooled by contact with the cooler land surface and thus conditions become highly favourable for the formation of radiation fog during the early hours of the morning. Over the Gangetic plains and in the plains of Punjab and West Rajasthan fogs generally occur associated with the eastward passage of western disturbances.

Incursion of moisture from the Indian seas from a southeasterly direction over

Fogs can occur both in the forward sector as well as in the rear of the western disturbances. Incursion of moisture from the Indian seas from a southeasterly direction over
the relatively colder land surfaces and the radiational cooling during the nights lead to fog formation in the forward sectors of these disturbances. In the rear of the western disturbances, the northwesterly flow brings in dry and cold airmass leading to clearance of skies. However, shallow layer of moist air left behind by the disturbance provides the necessary moisture for the formation of thick radiation fog under these conditions. If the winds in the shallow layers are very light, fog in the morning may occur for several days in succession. Over the peninsular India, fog is generally not so common except in suburban areas where pollutants from industrial and domestic sources lead to smogs and other low visibility conditions. Over the Deccan plateau (at places like Hyderabad and Bangalore) fog formation depends on synoptic changes in the air flow in shallow layers near the ground, which determine the supply of moisture.

2.3 Artificial dispersal of fog

Artificial dispersal of fog is a costly process. And therefore it is generally used only at very busy international airports where it becomes economically worthwhile. It is done by supplying the necessary heat so that the temperature remains above the dew point. The amount of heat required depends on the speed of the wind and its direction. The greater wind speeds which are usually present over aerodromes make this process more difficult. In India this has not been tried so far at any airport.

2.4 Dust-raising winds and dust-storms

2.4.1 In arid regions, sand or dust is raised by strong winds leading to poor visibility conditions. By definition, when the visibility falls below 1000 metres, such phenomena are termed dust/sand storms, and when visibility is above 1000 metres, but below 10,000 metres, the phenomena are known as dust haze. These phenomena go by several regional names like Haboobs in Sudan, Andhils in Northwest India etc.

2.4.2 Strong winds due to steep pressure gradients sometimes occur over Northern India especially in the hot weather season March to May. Under such conditions, the dust haze becomes a generally widespread phenomena covering large tracts across Rajasthan and spreads downwind to Punjab and West Uttar Pradesh. The vertical extent also is often great, reaching 20 to 25,000 feet (6-8 km), and may last for several days in succession on some occasions.

2.4.3 Dust-storms can also occur over limited areas as meso-scale phenomena associated with convective phenomena (thunderstorms). During the hot weather season, high instability conditions generally prevail over northwest India. Under the influence of disturbances in the lower levels moisture is inducted from the Arabian Sea in shallow layers near the ground and intense convective clouds develop resulting in thunderstorm activity and associated surface squalls. The high winds of the squalls result in the occurrence of dust storms which precede the associated cloud as it travels east or northeastwards. If there is sufficient moisture, the cloud itself may bring enough rainfall leading to sudden improvement in the visibility.

2.5 Action to be taken on occasions of poor visibility

2.5.1 As has already been mentioned in the foregoing paragraphs, visibility is of great importance to aircraft operations, especially in the landing and take-off phases, irrespective of the phenomena which cause a reduction in visibility. Lowering of visibility to less than 5000 metres is considered to be of significance to aircraft operations. Aircraft approaching or taking-off cannot see the
runway in poor visibility conditions and thereby landing/take-off becomes difficult. In view of this, immediate information about such conditions has to be communicated to the air traffic controllers so that they can warn the approaching aircraft about the same and divert them if necessary to other nearby airfields and also hold up the aircraft which are about to take-off. To enable this, information about poor visibility conditions is passed on, in the form of Selected Special Reports, immediately on the occurrence of such conditions, to the ATC and others interested in the aerodrome. These messages are also passed on to other stations so that aircraft departing from these stations can be advised in advance of the marginal conditions. These selected special reports are issued whenever visibility falls to a value equal to or lower than 5000, 1500 and 800 m. Similarly in order to indicate the improvement in the visibility conditions, selected special reports are issued whenever visibility increases to or exceeds the limits of 800, 1500 and 5000 m. These limits have been adopted based on the operating minima of different aircraft. These messages called SPECI are issued in code for dissemination outside the aerodrome and in plain language for use locally over the aerodrome.

2.5.2 In addition, reports are also issued purely for local use over the aerodrome for the deterioration or improvement of visibility through the limits of 4000, 3000 and 2000 metres. Detailed specifications for issue of selected special reports and special reports are contained in Appendices IV and VI of Aviation Weather Codes, 1972.

3. Intense convective phenomena

3.1 Other important phenomena which are of vital interest to all phases of aircraft operations are the intense convective actions which result in thunderstorms, squalls etc. Thunderstorms occur quite frequently in one part or other of India depending upon the season and the time of the day.

3.1.1 During the winter months, they are chiefly confined to north India and occur in association with the passage of western disturbances. The more intense hailstorms and the associated surface squalls often reach speeds of 40 to 50 kts. of these disturbances cause severe

3.1.2 During the hot weather season, intense thunderstorms develop in different parts of the country, their frequency increasing with the progress of the season. Over peninsular India, a sharp wind discontinuity develops between the moist flow from the Bay of Bengal circulating around the anticyclonic high pressure cell over the central parts of the Bay and the dry northwesterly current which arrives as a north or northeasterly flow over peninsular India. This discontinuity generally runs north/south between the east and west coasts of peninsular India. Intense thunderstorms develop in the afternoon and evening generally along or slightly to the east of this discontinuity. Of these thunderstorms, the more intense ones result in hailstorms and are accompanied by squalls of high speed. They are usually isolated in character and the development occurs rather rapidly. Cases are known in which a severe thunderstorm developed within 45 minutes from clear skies.

3.1.3 Over northeast India, violent thunderstorms known locally as Kalbaisakhis occur in this season, especially in late April and May. On rare occasions, tornadoes also develop in them. High speed squalls sometimes leading upto 60 kt and above occur with them. Severe hail and violent turbulence can be expected to be experienced in these storms. These storms can give heavy showers also. The storms of northwest India in this season have been dealt with in the proceeding section. The dust and thunderstorm activity of the season can extend well into June in these parts. On very rare occasion tornadoes are also known to originate in such storms.
3.1.4 During the southwest monsoon season, peninsular India is relatively free from thunderstorm activity and even though convective activity is vigorous, it is never violent. Thus, copious rainshowers may be given by large Cu and mild CB developments. Severe thunderstorms, intense turbulence and severe lightning are not common. Over North India, however, in the easterly branch of the monsoon circulation, thunderstorm activity is quite frequent and gives plenty of precipitation. However, these storms seldom attain the intensity and the violence of the hot weather season even though the tops of CBs of this season can be much higher than those of the previous season.

3.1.5 During the post-monsoon season (i.e.) Oct./Nov., thunderstorm activity is mostly confined to peninsular India and generally decreases from October to November. Extreme south Peninsula experiences the maximum number of thunderstorms and the frequency decreases northwards and westwards. These storms are generally more intense than those in the southwest monsoon season but less intense than those of the premonsoon i.e. hot weather season.

4. Forecasting Techniques for the occurrence and movement of severe convective storms and other hazardous phenomena associated with them

4.1 Thunderstorm

4.1.1 As in the case of any other weather phenomena to be forecast, a sound background/climatology of thunderstorm activity in different parts of India is a pre-requisite. Nos. 4, 5 and 6 of the Bibliography at the end give geographical distribution of thunderstorm activity over India and neighbourhood in different months/seasons. Nos. 36, 41, 43, 46, 59, 62, 66, 69, 77, 82, 98, 104, 109, 119 give the climatological data of CB tops as obtained from aircraft data and radar observations. In general it can be said that CB tops have the minimum height in the winter season (8 to 12 km) and maximum heights in the monsoon season (12-18 km). Traditional techniques like the Parcel and Slice methods of forecasting height of CB tops are too well known to be repeated here. Shearing of the top of CB clouds by very fast winds like the jets which results in the formation of Ci anvil and spread out of Ci to long distances downwind are also well known and such shearing usually limits the cloud tops to below the level of the maximum wind in such cases. More recently, (Rao and Dekate 1967) have found that the tops of CB clouds are limited with the environmental wind conditions.

4.1.2 The movement of thunderstorm clouds also depends upon environmental conditions and it has been shown that in general they move with the vector mean speed of the winds in the layer in which the cloud is imbedded. Hence movement of CB clouds (within the vicinity of a storm) can be anticipated (predicted) from the upper wind data of the station.

4.2 Squalls

4.2.1 While it is difficult to predict the likely speed of a squall at any given station or associated with any particular storm, recent studies have indicated that the direction of squalls can be predicted with some certainty. Actual squall direction is closely linked to the movements of the generating cloud itself (i.e. generation coincides with the direction of the movement of the storm within reasonable limits (Ref. 43, 64)). However, the direction from which squally winds are likely to be experienced at a station, depends both on the original direction of the squall itself as well as the relative position of the station with respect to the moving cloud.
4.2.2 Various studies have been made on the occurrence of thunderstorm activity either on a regional basis or in general terms. These can be broadly classified as:

(i) Forecast of occurrence of thunderstorms at a single station and its vicinity using different types of instability indices a list of which is given in the bibliography. It may be stated, however, that satisfactory results have not been obtained by the use of any single type of such indices and the relationships are purely statistical in nature and as predictables they have limited use only.

(ii) Synoptic techniques have also been published. These are too numerous to be enumerated here. In this connection reference is invited to Forecasting Manual, Part III-2.2 on "Summer - Norwesters and Andhvis and large-scale convective activity over peninsula and central parts of the country".

4.3 Hail

4.3.1 Hail is present always in CB clouds. But only when the hail reaches the ground, it is called a Hailstorm. Very little work has been done on the prediction of the hailstorms. A certain amount of wind shear in the vertical appears necessary for the production of large hail in the cloud so that hailstones can reach the ground before melting. Rao and Mukherjee (1958) have studied the case of hailstorm (over northwest India) and their findings seem to be that large shears in the vertical is a favourable factor. Also, according to them, 24 hrs. vectorial wind changes, indicate areas of possible hailstorm activity.

4.3.2 Browning and Ludlam (1962) have given a model of a severe hailstorm in which the various wind flows have been depicted, which is considered to be an important contribution towards the theory of severe local storms. They also find that large shears in the vertical are necessary for production of hailstorm.

4.3.3 As mentioned earlier, hail is always present inside a severe thunderstorm and larger hails are necessarily by-products of larger vertical velocities inside the cloud, which in turn means, steep lapse rates at least in the lower two-thirds of the atmosphere. Such conditions are found in India mostly during the hot weather season and upto end of June over northwest India. Hail can also be encountered in the clear air below the anvil of CB clouds, and many an aircraft have been caught unawares and damages to aircraft due to hail in those conditions have been reported.

4.3.4 Damage to aircraft on ground can be severe if aircraft are left unprotected during a hailstorm. For prediction of severe hailstorms in hot weather season, the forecaster has to be more on the alert for the incursion of sufficient depth of moist air on to land, as highly unstable conditions with near dry adiabatic lapse rate are invariably present in the season over the land areas. At inland places like Delhi, Hyderabad etc. near dry adiabatic lapse rates do exist day after day in this season extending upto 600 mb and sometimes even to greater heights.

4.4 Aircraft Icing

4.4.1 Aircraft icing is one of the major weather hazards to aviation. Ice on the airframe decreases lift and increases weight, drag and stalling speed. In addition, the accumulation of ice on exterior surfaces affects the control of the aircraft.
4.4.2 Two basic conditions must be met for ice to form on an airframe in significant amounts. First, the aircraft surface must be cooler than 0°C. Second, supercooled water droplets (i.e.) liquid water droplets at subfreezing temperatures, must be present. Water droplets in the free air, unlike bulk water, do not freeze at 0°C. Instead, their freezing temperature varies from an upper limit near -10°C to a lower limit near -40°C. The smaller and purer the droplets, the lower is their freezing point. When a supercooled droplet strikes an object such as the surface of an aircraft, the impact destroys the internal stability of the droplet and raises its freezing temperature. Therefore the possibility of icing must be anticipated in any flight through supercooled clouds or liquid precipitation at temperatures below freezing. In addition, frost sometimes forms on an aircraft in clear humid air if both aircraft and air are at subfreezing temperatures.

4.4.3 The type and shape of ice formation

Aircraft icing is basically of three types: rime ice, clear ice and hoar frost. In addition, mixtures of rime and clear ice are also common.

(a) **Hoar Frost**

This is the product of the sublimation of water vapour on the surface of the aircraft. It is similar to frost that is deposited on the ground and occurs when the surface of the plane is colder than the dew point of the air. **Hoar frost** develops on an aircraft when it flies quickly from cold air to warmer air as can occur on descent or when passing through a warm front into a warm humid air. This ice deposit is unlikely to have any serious effect on the aircraft flight but the sudden loss of vision by hoar frost on the wind screen may be an embarrassment to the pilot.

(b) **Rime Ice** is white, opaque and of a granular structure consisting of small ice pellets. This is formed at low temperatures by the instantaneous freezing of small supercooled water droplets on impact with the aircraft surfaces. This type of icing forms principally on the leading edges of the aircraft. Because of its granular structure, it is easily broken away and is seldom dangerous since it does not alter the aerodynamic properties of the wings to a serious extent.

This type of ice is generally encountered when flying through stratiform clouds or through stratocumulus clouds of small vertical extent, the temperatures of such clouds being below 0°C.

(c) **Clear Ice**

This type of icing is smooth and glossy in appearance and is the most dangerous type of icing as it alters the aerodynamic properties of the wings and the extra weight added to the plane may produce a serious loss of lift and increase the drag of the aircraft. When the freezing process is slow, and the supercooled water droplets flow over the surface, they link up to give a uniformly wet surface which freezes into clear ice, bonded firmly to the surface and very difficult to remove. This type of icing is generally encountered in clouds of some vertical development like the Cumulus and Cumulonimbus and forms in the portion of the cloud below 0°C where supercooled water droplets can be present.

4.4.4 The meteorological factors to be examined for formation of ice on aircraft in flight are:

(i) Super-cooled water content of the air;
(ii) Ice crystal content of the air;
(iii) Temperature and humidity;
(iv) Droplet and crystal size distribution.
4.4.5 Physical factors favourable for formation of aircraft icing

4.4.5.1 The atmospheric distribution of potential aircraft icing zones is mainly a function of temperature and cloud structure. These factors, in turn, vary with altitude, synoptic situation, orography, weather and season.

4.4.5.2 The most severe icing occurs in cloud when the later form in the air which is initially warm and moist, and when the clouds have recently developed or have recently ascended above the freezing level.

4.4.5.3 A long flight in altostratus or nimbostratus cloud will lead to considerable deposit of rime ice when the temperatures are below −8°C. In a developing cloud, the portion of the cloud at temperatures 0 to −8°C will have been above freezing level only for a short time and sufficient liquid water will be present to lead to clear icing which will sometimes be heavy. If actual or latent instability is present, a cumulus cloud with heavy icing in its top portion may develop in the Nimbostratus. The main hazard lies in the great horizontal extent of some of these cloud decks.

4.4.5.4 In the altostratus clouds, icing will be light and of the rime type. Heavy clear icing occasionally occurs in altostratus clouds and may be due to the presence of strong turbulent eddies arising from the instability at that level which produces altostratus congestus clouds.

4.4.5.5 Clouds at cirrus level are formed of ice crystals and so do not normally lead to ice deposits. However, icing of light intensity has been reported in dense cirrus anvil tops of cumulonimbus, where updrafts may maintain considerable water at low temperatures.

4.4.5.6 Very serious ice accretion may also occur during flight beneath cloud, if the aircraft encounters supercooled raindrops as they are falling to earth. Such icing is likely to be especially serious beneath frontal and orographic clouds because of the great extent of these clouds, both horizontal and vertical and the difficulty in reaching a region free from supercooled rain. Rapid deposition of ice frequently occurs under such circumstances and the aircraft may be forced to land unless there is a layer below in which the temperature is greater than 0°C in which it can fly.

4.4.5.7 The zone of probable icing in cumuliform clouds is smaller horizontally but greater vertically than in stratiform clouds. Further, icing is more variable in cumuliform clouds because many of the factors conducive to icing depend to a large degree on the stage of development of the particular cloud. Icing intensities may range from generally a trace in small supercooled cumulus to often light or moderate in cumulus congestus and cumulonimbus. The most severe icing occurs in cumulus congestus clouds just prior to their change to CB. Although icing occurs at all levels above freezing level in a building Cu, it is most intense in the upper half of the cloud. Icing is generally restricted to the updraft regions in a mature CB and to a shallow layer near the freezing level in a dissipating CB. Icing in cumuliform clouds is usually clear or mixed.

4.4.6 Altitude and temperature

It is widely accepted that aircraft icing is limited to the layer of the atmosphere lying between the freezing level and the −40°C isotherm. Icing has occasionally been reported at temperatures colder than −40°C in the upper parts of cumulonimbus and other clouds. In general, the frequency of icing decreases rapidly with decreasing temperature, becoming rather rare at temperatures below −30°C. Severe ice formation is generally uncommon below about −15°C except in vigorous convective clouds. The normal vertical temperature distribution
in the atmosphere is such that icing is usually restricted to the lower 30,000 feet of the troposphere.

The type of icing, also, is highly dependent on temperature. Clear ice usually occurs at temperatures just below freezing, whereas rime ice predominates at lower temperatures.

4.4.7 Orographic influence, high or steep terrain, particularly mountains, causes icing to be more intense than is usually under identical conditions over low, flat terrain. Icing is greater over the ridges than over valleys and greater on the windward side than on the leeward side. Moderate icing, usually clear, is experienced in convective clouds over mountainous terrain. The orographically induced updrafts permit the air to support larger cloud droplets than otherwise, so that icing is more intense.

4.4.8 For more details about aircraft icing, reference may be made to "Forecasters' Guide on Aircraft Icing" issued by the Air Weather Service of the U.S.A.F. (AWSM-105-39).

5 Turbulence

4.5.1 As aircraft flights depend upon the relative motion between the aircraft and the air, all changes in the state of the air will affect the flights. Turbulent air motions cause buffeting effect on the aircraft leading to irregular motions which not only affect the passenger comfort but also in extreme cases lead to severe structural damages of the aircraft. Aircraft turbulence is caused by eddies in the airflow. Aircraft response to these eddies depends on the size, shape and speed of the aircraft. The turbulence wavelengths of interest to aircraft operations are about 10 to 20 metres for very small low speed aircraft and increase with the size and speed of the aircraft. According to Reiter (1970), 'jet aircraft of present design' respond to atmospheric eddies of dimensions 20 to 200 metres with bumpy flight conditions, if the kinetic energy in this range of eddy sizes is of sufficient magnitude. For supersonic aircraft this eddy range will have to be increased by about 1 order of magnitude. Aircraft response to eddy motion is most pronounced when eddies are in the vertical plane.

4.5.2 Factors causing aircraft turbulence

4.5.2.1 Factors causing aircraft turbulence can be divided into four types:

(i) Convective cloud type
(ii) Thermals in clear air
(iii) Orographic and
(iv) Wind shear type

4.5.3 Convective cloud type

The most severe type of aircraft turbulence is encountered in vigorous convective clouds like cumulonimbus and cumulus congestus clouds in which high speed vertical updrafts co-exist with areas of comparable downdrafts side by side, leading to vigorous mixing and sharp shears. Hence any attempt to penetrate such clouds is bound to be hazardous and most accidents at cruising levels due to weather conditions can be attributed to these clouds. Recent studies have indicated that the turbulence associated with severe storm clouds is not only confined to visible cloud but also extends to varying distances about 10 nm beyond the cloud in many cases and even up to 20 nm in rare cases. Moderate to severe turbulence is also known to have been encountered on top of cumulonimbus clouds up to a height of 1500 metres above the top level. Rough air conditions
caused by convective clouds can also be encountered downstream of the cloud for fairly long distances. So, while briefing pilots, it is better to advise not only to fly inside the cloud but also in its vicinity or immediately on top of vigorous convective clouds.

4.5.4 *Thermals in clear air*

Turbulence is encountered by low flying aircraft during day time due to the thermals arising out of terrain heating. The severity of the turbulence is greatest in clear summer afternoons due to the intense ground heating. The effect of thermals on flying aircraft is generally confined to layers below 3000 metres.

4.5.5 *Orographic turbulence*

Orographic turbulence is caused by waves which form when strong winds blow normal to a mountain range. Lee waves can affect aircraft operations adversely, sometimes leading to severe loss of height. For more details regarding the formation of lee waves and their effect on aircraft operations, a reference is invited to WMO Technical Note No. 18 on "Aviation aspects of Mountain Waves" and FMU Report No. IV-10 on "Mountain Waves".

More recent studies have led to a general realisation in aviation circles that stratospheric disturbances induced by airflow over mountains may be comparable in importance with those produced by giant convective storms penetrating the tropopause. This has obvious implications for the supersonic transport aircraft operations.

4.5.6 *Turbulence due to wind shears*

4.5.6.1 *Definition*

The name *Clear Air Turbulence (CAT)* is now being generally used to refer to High Level Aircraft Turbulence which is normally found above 6 km exclusive of turbulence in cumulonimbus clouds. It does not exclude turbulence in cirrus or in haze layers and to that extent, it is a slight misnomer. Again it excludes turbulence at low levels in the clear air caused by thermals, referred to in section 4.5.4. Clear Air Turbulence at high levels is principally caused by vertical wind shears.

4.5.6.2 *Dimensions and levels of occurrence of CAT*

Aircraft encounter turbulent conditions in patches of horizontal extent generally ranging from 80 to 500 km (Clozman 1961, Reiter 1963). In the three cases studied by ¥ndlich (1964) the zones of turbulence had horizontal extents ranging from 15 km to about 300 km. The patches are believed to be elongated in the direction of the wind (Clem 1957). More recent studies revealed that these patches are generally inclined to the horizontal. The width of the bands/zones according to Bannon (1963) is usually small being about 16 km. In some of the cases for which reports are available in India from commercial aircraft, rough air was reported over a short distance as 15 km and intermittently over as long a distance as 2,000 km (Shaskara Rao and Sadagopan, 1968). The vertical extents of patches of turbulence also vary considerably from occasion to occasion. Clozman (1961) estimates that the patches have an average vertical extent of about 600 m with extreme values at 20-30 m on the lower side and 4500 m on the higher side. Patches of turbulence reported by ¥ndlich (1964) also lie within the above ranges with no particular preference to the mean value. Anderson's figures quoted by Bannon (1963) are of interest—out of 828 gust-sonde observations in USA, he found 769 turbulent layers, 6 of which were deeper than 2,000 m.
with a maximum layer depth of 8,000 m in one case. It is also obvious from the various published articles on CAT that the location of these patches and their dimensions change with time within the general area of favourable conditions.

Thus, we find that CAT is caused by micro-scale eddies which occur in meso-scale or bigger patches, which in turn lie in areas of synoptic scale extent, where the conditions are favourable. With the resolution allowed to the forecaster by the present frequency and network of observations, it is possible to forecast only the synoptic scale area within which the turbulent patches are likely to occur.

Shear type of CAT can occur at all levels wherever the vertical wind shears are large. In the very low levels, large shears can occur in shallow layers associated with onset of sea breeze, squalls, cold fronts etc. However, the name CAT, as mentioned earlier, is generally applied to shear type of turbulence at levels above 4-5 km. It was generally believed earlier that CAT which is often observed in the upper troposphere may not occur in the stratospheric levels. However, it has been reported that severe CAT was encountered by U-2 aircraft at heights around 65,000 feet. X-15 experimental aircraft of the USA are reported to have encountered severe buffeting at much higher altitudes.

4.5.6.3 High Level Turbulence

(1) The following list of factors that influence CAT at high levels (40 - 70,000 feet) have been given by Mitchell, et al (1970). (Symposium referred to in Ref.14).

Terrain Factors
Mountain Waves
Horizontal temperature gradient
Surface fronts
Jet Streams
Isentropic surfaces
Tropopause heights
Hammond technique
Thunderstorms
Pressure Troughs and Ridges
Climatic zones
Richardson Number
Hurricanes
Vertical Temperature Lapse Rate
Horizontal and Vertical wind shear
Divergent and convergent wind flow
Isentropic analyses

(2) The authors have also discussed the vertical and horizontal temperature gradients and found in general a temperature gradient of $5^\circ$C/120 nm. to be associated with CAT in the tropospheric range of 15,000 to 40,000 feet.

(3) It is also stated that the forecasts for U-2 flights were proved excellent by predicting CAT to occur in areas and near levels of large inversions as follows :-

\begin{align*}
\text{\(< 1.5^\circ\text{C} / 1000'\)} & \quad \text{No CAT} \\
1.5^\circ\text{C} / 1000' \text{ to } 2.5^\circ\text{C} / 1000' & \quad \text{Light CAT} \\
2.5^\circ\text{C} / 1000' \text{ to } 4.0^\circ\text{C} / 1000' & \quad \text{Moderate CAT} \\
\text{\(> 4.5^\circ\text{C} / 1000'\)} & \quad \text{Severe CAT}
\end{align*}
(4) According to them, horizontal and vertical temperature gradients are considered to be better indicators of turbulence in the 50 to 70,000 feet range than any other routinely available parameters. It has been emphasized that this includes large lapse as well as large inversion rates. A suggested relation between horizontal and vertical temperature gradient vs CAT given by Mitchell et al is given below:

<table>
<thead>
<tr>
<th></th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Turbulence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small temp. gradient</td>
<td>$&lt; 1^\circ C/25$ nm</td>
<td>$&lt; 1^\circ C/1000'$</td>
<td>VL - Smooth</td>
</tr>
<tr>
<td>Medium temp. gradient</td>
<td>$1^\circ C/25$ nm to $1^\circ C/12$ nm</td>
<td>$1^\circ C$ to $2^\circ C/1000'$</td>
<td>LT - Mod.</td>
</tr>
<tr>
<td>Large temp. gradient</td>
<td>$&gt; 1^\circ C/12$ nm</td>
<td>$&gt; 2^\circ C/1000'$</td>
<td>Moderate to severe</td>
</tr>
</tbody>
</table>

(5) According to the authors, temperature analyses along the 70 mb surface show frequently occurring wave-like patterns. These waves are about 300-1000 nm long. The following relations observed between wave patterns and turbulence are given by them.

<table>
<thead>
<tr>
<th>Type of wave</th>
<th>Dimensions of wave</th>
<th>Type of turbulence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large wave</td>
<td>Horizontal wave height $1/2$ the wave length $= 4/3$</td>
<td>Moderate or greater clear air turbulence</td>
</tr>
<tr>
<td>Medium wave</td>
<td>Horizontal wave height $-1/2$ the wave length $= 4/3$ to $3/4$</td>
<td>Light to Mod. CAT</td>
</tr>
<tr>
<td>Small wave</td>
<td>$-$do$-$</td>
<td>$&lt; 3/4$</td>
</tr>
</tbody>
</table>

According to Collis et al (1970) (Symposium referred to in Ref. 14), it was found that the best indication of turbulence frequency was the vertical vector wind shear and the horizontal deformation of the wind pattern.

**4.5.6.4 Physical parameters and occurrence of CAT**

Studies of CAT were conducted from various angles. Apart from the correlation obtained with vertical wind shear, correlations were also tried with various other physical parameters. These include Richardson's Number (Ri) which is defined as

$$ Ri = -\frac{9}{6} \left(\frac{d\nu}{dz}\right)^2 \left(\frac{de}{dz}\right) $$

The correlation between Ri and CAT does not however show any marked improvement over the correlation between vertical wind shear and CAT. CAT was found to occur with Ri numbers as low as 0.01 and as high as 5.0. Colson and Panofsky (1969) were of the opinion that Ri calculated in the usual way from synoptic data, is overestimated due to poor resolution of available data. Scorer (1963) states that CAT can still occur even when the Ri has large positive value (say 100) if the flux Ri is low. Even the meso-scale studies of Hindlich (1964) did not yield better results with Ri than with vertical wind shear. Colson and Panofsky studied the occurrence of CAT with various parameters and finally came
to the conclusion that "of all the parameters tested, the probability of moderate or severe turbulence was best related to vertical wind shear and Richardson number, with the wind shear being the better discriminant".

### 4.5.6.5 Synoptic flow patterns and CAT

From the results which have been published from time to time, it is seen that CAT conditions can be found in association with a large variety of synoptic situations. Glodman (1961) (Ref. No. 125) states that major synoptic features associated with high level turbulence are:

(i) Jet Streams
(ii) The Tropopause
(iii) High level lows and troughs.

Other situations mentioned by other workers are:

(i) Where the Jet Splits (Chambers 1955)
(ii) Where there is a confluence of Jets (Reiter and Nania 1964)
(iii) At the entrance to the Jet (Endlich 1964)
(iv) Near the exit regions of the Jets with marked diffuence (Chambers 1955) and
(v) East-West gradients (Rai Sircar and Verghese 1963).

It is seen from studies conducted with the help of research aircraft in India in 1972 (Project Exercise Storm Exchange) that significant turbulence (CAT) occurred where the difference between the observed vertical wind shear and computed thermal wind differ considerably.

In the report of analysis of the ICAO 1964/65 turbulence reporting programme, Colson (1968) has shown that there is a percentage frequency of occurrence of CAT with cyclonically covered flow patterns in the upper air (well marked troughs in the upper westerlies). It has also been generally realised that large (synoptic) scale environment favourable for CAT may be provided by the deformation fields associated with baroclinic development.

It has also been reported that CAT can be expected at all altitudes on the left side of the polar jet whereas on the right side it occurs only below and near the tropopause. Severe CAT is also to be anticipated when a jet crosses a mountain range at right angles.

#### 4.5.6 Vertical wind shears and horizontal temperature gradients

Statistics on vertical wind shear and CAT indicate that turbulence is generally encountered where the vertical wind shears reach or exceed 4 kt/1000 ft, being slight at the critical value and increasing in intensity with an increase in shears and becoming severe when the shears are of the order of 6-8 kt/1000 ft. It has been reported from a study of CAT conducted in USA that a wind shear criteria $\geq 0.8 \times 10^{-2} \text{sec}^{-1}$ (approximately 5 kt/1000 ft) applied to rawinsonde data specifies the presence or absence of turbulence correctly in 77% of all cases including 100% of cases involving CAT greater than light (Glover et al 1969).

Apart from the correlations obtained between the vertical wind shears and CAT occurrence a large amount of work has also been done in studies on correlation between the occurrence of CAT and the horizontal temperature gradients. It is stated that horizontal temperature gradients of 5°C per 100 n.m. are significant in denoting areas of CAT. The relationship between horizontal temperature gradients and CAT is not only valid in the troposphere but also seems to be valid
for lower stratospheric regions. In a study undertaken in Canada, regarding stratospheric turbulence and temperature gradients using a RB-5/-F USAF Weather Reconnaissance aircraft from January 1969 to June 1971, under the project name of "COLDSCAN", a definite correlation between the horizontal temperature gradients and the occurrence of CAT was established. The flights were at different levels between 45,000 and 65,000 ft.

In a study by Bhaskara Rao and Sadagopan (1968), they found that there is a good correlation between the thermal gradients at standard isobaric levels and the occurrence of CAT. In this study they have used synoptic analysis of thermal fields and the aircraft reports from commercial flights. The commercial air routes were all divided into sectors of approximately 7° of latitude/longitude and any one of the flight sectors was taken as a unit and the occurrence or non-occurrence of CAT was noted. These statistics were compared with the thermal wind calculated from the thermal gradients from constant pressure charts nearest to the time of flight, at 500 mb for flights between 400 and 600 mb levels and at 300 mb for flights between 200 and 400 mb levels. The summary of their results is given in Table I.

<table>
<thead>
<tr>
<th>Vertical wind shear (Kt/1000 ft) at appropriate levels</th>
<th>0-2</th>
<th>2-4</th>
<th>4-6</th>
<th>6-8</th>
<th>8-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases of severe turbulence</td>
<td>Nil</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>Nil</td>
</tr>
<tr>
<td>No. of cases of moderate turbulence</td>
<td>Nil</td>
<td>4</td>
<td>58</td>
<td>7</td>
<td>Nil</td>
</tr>
<tr>
<td>No. of cases of light turbulence</td>
<td>1</td>
<td>6</td>
<td>40</td>
<td>4</td>
<td>Nil</td>
</tr>
<tr>
<td>Total No. of route sectors considered</td>
<td>1092</td>
<td>880</td>
<td>206</td>
<td>17</td>
<td>Nil</td>
</tr>
<tr>
<td>% occurrence of moderate and severe turbulence</td>
<td>0.0</td>
<td>0.57</td>
<td>34.0</td>
<td>70.60</td>
<td>Nil</td>
</tr>
<tr>
<td>% occurrence of all types of turbulence</td>
<td>0.1</td>
<td>1.25</td>
<td>53.4</td>
<td>100.2</td>
<td>Nil</td>
</tr>
</tbody>
</table>

It is seen from the study that a predominant number of the reported cases of CAT were from areas where the thermal wind worked out to be around 4 kt or more per 1000 ft as calculated from the thermal gradients on the 500/300 mb charts.

4.5.6.7 Forecasting of CAT

As mentioned earlier, CAT is associated with a large variety of synoptic flow patterns. In India, the winter is a favourable season for anticipating CAT over North India in association with the sub-tropical Westerly Jet Stream which lies with its mean position near 27°N. CAT associated with this jet can occur anywhere between 500 to 200 mb levels and is therefore of importance to Jet aircraft.
For the cruising levels of SST aircraft, the *westerly jet stream* over Peninsular India during the monsoon months has the necessary vertical wind shears associated with it to cause CAT. CAT associated with this jet can be anticipated in layers between 200 and 70 mb.

Anticipation of CAT can best be done at the flight planning stage. Hence the forecaster should be able to delineate the probable areas of CAT from the data available on his charts and brief the aircrew suitably. From the constant pressure charts, the temperature gradients give an indication of the probable areas of CAT. Where and when vertical wind shears can be computed, CAT should also be anticipated when these shears are of the order of 4-5 kt/1000 ft or more. The thumb rules for assisting the detection and avoidance of CAT given by the 6th Air Navigation Conference are given in Appendix 1.

4.5.6.8 Turbulence Intensity

Recently the CAeM has recommended that for forecasting and debriefing of pilots, the intensity of turbulence (of any type) may be indicated in terms of the vertical accelerations suffered or likely to be suffered by the aircraft. These are given in Appendix 2.

4.5.6.9 Remote Sensing of CAT

The technique of remote sensing of CAT is still in infancy and it would appear that much more work has to be done before remote sensing can become an operational tool. However, some significant developments in remote sensing of CAT have been reported during the last few years. Browning and Watkins (1970) were able to observe wave-like echoes from clear air which is attributed to the development of Kelvin-Helmholtz instability. They used an S-Band radar (10.7 cms), of transmission power 1 megawatt. The vertical wind shear across the 400 metre depth of the atmosphere in which the waves are detected was as great as 16 mps and Ri number was close to 0.25 for some time before the development of the instability. Glover et al (1969) also reports the detection of CAT by the use of a multiwave radar set up. Experiments with the Doppler radars in detecting sharp wind shears (and thus probable areas of CAT) show promise of the possibility of remote detection of CAT for routine purposes. On-board indicators of CAT are also being developed. An infrared sensor developed in America has undergone flight test for 2 years in the late sixties on PAN American Jets and airforce planes. It is reported that it consistently gave the pilots an average of 3-1/2 minutes warning of approaching turbulence.
APPENDIX - 1

RULES OF THUMB TO ASSIST IN AVOIDING OR MINIMIZING ENCOUNTERS WITH CLEAR AIR TURBULENCE

Note: The following rules of thumb have been developed for westerly jet streams.

1. Jet streams stronger than 110 knots (at the core) are apt to have areas of significant turbulence near them in the sloping tropopause above the core, in the jet stream front below the core, in the jet stream front below the core, and on the low-pressure side of the core. In these areas there are frequently strong wind shears.

2. Wind shear and its accompanying clear air turbulence in jet streams is more intense above and to the lee of mountain ranges. For this reason, clear air turbulence should be anticipated whenever the flight path traverses a strong jet stream in the vicinity of mountainous terrain.

3. On charts for standard isobaric surfaces, such as 300 millibars, if 20-knot isotachs are spaced closer together than 60 nautical miles, there is sufficient horizontal shear for CAT. This area is normally on the poleward (low-pressure) side of the jet streams axis, but in unusual cases may occur on the equatorial side.

4. Turbulence is also related to vertical shear. From the winds-aloft charts or reports, compute the vertical shear in knots-per-thousand feet. If it is greater than five knots-per-thousand feet, turbulence is likely. Since vertical shear is related to horizontal temperature gradient, the spacing of isotherms on an upper air chart is significant. If the 5°C isotherms are closer together than two degrees of latitude (120 nautical miles), there is usually sufficient vertical shear for turbulence.

5. Curving jet streams are more apt to have turbulent edges than straight ones, especially jet streams which curve around a deep pressure trough.

6. Wind-shift areas associated with pressure troughs are frequently turbulent. The sharpness of the wind-shift is the important factor. Also, pressure ridge lines sometimes have rough air.

7. In an area where significant clear air turbulence has been reported or is forecast, it is suggested that the pilot adjusts the speed to fly at the recommended rough air speed on encountering the first ripple, since the intensity of such turbulence may build up rapidly. In areas where moderate or severe CAT is expected, it is desirable to adjust the air speed prior to the turbulence encounter.

8. If jet stream turbulence is encountered with direct tailwinds or headwinds, a change of flight level or course should be initiated since these turbulent areas are elongated with the wind, and are shallow and narrow. A turn to the right in the Northern Hemisphere, or to the left in the Southern Hemisphere, places the aircraft in more favourable winds. If a turn is not feasible due to airway restrictions, a climb or descent to the next flight level will usually find smoother air.
9. If jet stream turbulence is encountered in a crosswind, it is not so important to change course or flight level since the rough areas are narrow across the wind. However, if it is desired to traverse the clear air turbulence area more quickly, either climb or descend after watching the temperature gauge for a minute or two. If temperature is rising, climb; if temperature is falling, descend. Application of these rules will prevent following the sloping tropopause or frontal surface and staying in the turbulent area. If the temperature remains constant, the flight is probably close to the level of the core, in which case either climb or descend as convenient.

10. If turbulence is encountered in an abrupt wind-shift associated with a sharp pressure trough line, establish a course across the trough rather than parallel to it. A change in flight level is not so likely to alleviate the bumpiness as in jet stream turbulence.

11. If turbulence is expected because of penetration of a sloping tropopause, watch the temperature gauge. The point of coldest temperature along the flight path will be the tropopause penetration. Turbulence will be most pronounced in the temperature-change zone on the stratospheric side of the sloping tropopause.

12. Both vertical and horizontal wind shear are, of course, greatly intensified in mountain wave conditions. Therefore, when the flight path traverses a mountain wave type of flow, it is desirable to fly at turbulence-penetration speed and avoid flight over areas where the terrain drops abruptly, even though there may be no lenticular clouds to identify the conditions.

(From: Report of Sixth Air Navigation Conference.)

*****
"Moderate - There may be moderate changes in aircraft attitude and/or altitude but the aircraft remains in positive control at all times. Usually, small variations in air speed. Changes in accelerometer readings of .5 g to 1.0 g at the aircraft's centre of gravity. Difficulty in walking. Occupants feel strain against seat belts. Loose objects move about.

Severe - Abrupt changes in aircraft attitude and/or altitude; aircraft may be out of control for short periods. Usually, large variations in air speed. Changes in accelerometer readings greater than 1.0 g at the aircraft's centre of gravity. Occupants are forced violently against seat belts. Loose objects are tossed about."

(From: Report of Sixth Air Navigation Conference)
1. Radar Meteorology

1.1 Introduction

The invention of RADAR during the World War II for surveillance of enemy aircraft proved to be a great boon as the radars were put to many useful purposes in peace times. Radars are now widely used for a variety of purposes like surveillance of commercial aircraft for air traffic control, guidance to aircraft for approach and landing under instrumental flying conditions, navigation of ships especially when visibility is poor, avoidance of severe convective weather in flight and for monitoring of weather systems, etc. During the operation of war time surveillance radars, it was found that echoes from precipitation caused difficulties in monitoring of aircraft movements. Though the innovations like the "Moving Target Indicator" (MTI) greatly mitigated this difficulty, still some residual echoes from precipitation areas were sources of worry and annoyance. It was this very defect of the surveillance radars that later led to the development of the "Weather Radars".

1.2 Basic principles on weather radars

Weather radars are designed on the basic principle that when short pulses of microwave radio energy are sent out from a powerful transmitter, the hydrometeors (snow, ice particles and water drops) in the atmosphere scatter back enough of the energy to be detected by sensitive receivers. The time lapse between the transmission and reception is the time taken by the radar energy (electromagnetic radiation) in traversing the distance from the transmitter to the weather target and back. Weather radars, by actual and precise measurement of this time lapse, give us the "range" of the target i.e. its distance from the radar.

The well known radar equation gives the average power received back ($P_r$) as

$$P_r = \frac{P_t h A_e}{8 \pi r^2} F K \sigma \Sigma$$  \hspace{1cm} (1)

where

- $P_t$ = Peak power of the transmitted Pulse
- $h$ = The pulse-length
- $A_e$ = The effective aerial aperture
- $r$ = range
- $\Sigma \sigma$ = The total scattering cross section of all the scattering particles in unit volume.
- $F$ = The fraction of the radar beam intercepted by the target.
- $K$ = The attenuation factor.
Weather radars generally work at wavelengths from 3 to 11 cm. For this band of wavelengths, \( \Sigma \sigma \) works out to be

\[
\Sigma \sigma = \frac{284 \pi d^6}{\lambda^4} \quad \text{for spherical water drops} \quad (2)
\]

\[
\Sigma \sigma = \frac{55 \pi d^6}{\lambda^4} \quad \text{for spherical ice particles} \quad (3)
\]

The equations (2) and (3) show that the amount of energy received back increases directly with the 6th power of the diameters of the ice and water particles. Hence radars are able to detect more readily those clouds in which the drops have grown bigger and are reaching diameters comparable to those found in precipitation. Very small cloud droplets are not detected. Hence all the echoes seen on the radar scopes are called precipitation echoes, even if they are from clouds from which precipitation is not actually falling, because the echoes only represent those parts of the cloud in which the bigger hydrometeors are present.

It can also be seen from the above equations that the energy received back from the target is inversely proportional to the 4th power of the wavelength on which the radar is working. For local storm detection work, 3 cm radars are preferred and for cyclonic storm detection work, 10 cm radars are generally used. Of late, for detection of Clear Air Turbulence radars working on wavelengths of about 70 cm are also reported to be in use.

1.3 Types of weather radar displays

1.3.1 PPI Scope

When a radar pulse is sent out and is returned to the receiver, the return pulse can be exhibited on an oscilloscope with a suitable time base. By rotating the antenna in the horizontal plane, the range and direction of the different targets (precipitation areas) can be obtained. This type of display is called the Plan Position Indicator (PPI) Scope.

1.3.2 RHI and RMI Scopes

When the antenna is tilted in the vertical plane along a particular azimuth can be displayed. There are two types of scopes used for this display - (1) Range Height Indicator (RHI) and (2) Range Elevation Indicator (RMI) both of which give directly the height of the echoes at different ranges. RMI display gives the exact shape of the cross section of the target scanned as the horizontal and vertical scales are the same, in contrast to the RHI where the vertical scale is usually one order of magnitude bigger.

1.4 Types of information from radar data

Some of the important types of information which can be obtained from the data of weather radars are:

1. Instantaneous location of areas of precipitation around the radar station
2. Speed and direction of movement of precipitation areas.
3. Estimation of the intensity of precipitation.
4. Heights of tops of clouds and in some cases the heights of their bases.
1.5 Characteristics of different types of precipitation echoes

1.5.1 Convective Cloud type echoes

The greatest use to which weather radars are put is the detection of convective clouds, both when they are distributed randomly around the radar station or when they are arranged into patterns associated with marked synoptic situations like squall lines, frontal bands, spiral bands associated with cyclonic storms and/or the wall clouds around the eye of a cyclone.

(i) Random convective developments

The shape, brightness and size of the echoes as seen on the PPI scope often give a mimicking of the type of the clouds which they represent. Echoes from isolated convective clouds are small in areal extent, circular or oval in shape with well-defined edges. They are bright. Sometime after convection has started, there is a tendency for convective type echoes to merge into clusters and these are seen in this scope as bigger masses. Some of the individual echoes can still be distinguished.

(ii) Squall Lines

Marked convective cloud developments can often be seen on the radar scope as lines stretching generally perpendicular to their line of propagation. Such squall lines are usually found near low-level wind discontinuities. By taking frequent observations of the position of the line, the rate of propagation can be determined.

(iii) Frontal Bands

Frontal cloud bands are generally longer and more pronounced than the type mentioned in the preceding para.

(iv) Spiral Bands

The outer spiral bands of convective clouds of a tropical cyclone are the first to be seen on the radar scope as the storm approaches the station. Such echoes are identified by the shape and geometry of these echo patterns as seen on the radar scope.

(v) Wall clouds

When the centre of the storm comes within the range of the radar, the wall clouds with the central eye can be distinguished and the speed and direction of movement of the storm can be determined.

(vi) Stratiform cloud echoes

These appear on the radar scope as comparatively less bright echoes covering a large area, irregular in shape and with ill-defined edges.

When convective clouds dissipate and degenerate into stratiform clouds, they also have appearance similar to the stratiform clouds even though in such cases the areal extent of such clouds is generally much smaller than the stratiform clouds associated with synoptic systems.
1.6 For a fuller discussion on the utility, interpretation etc. of radar echoes, a reference is invited to the "Weather Radar Manual" (IMD 1965) and to "Use of Weather Radar for Aviation" (WMO Tech. Note No. 110-1970).

1.7 Radar network in India

Figure 6.1 shows the location, effective range and other details of the weather radars now being operated in India. This Figure also shows the radars that are likely to be commissioned during the next few years. As can be seen from the Figure, except for two areas, one near South Rajasthan and the other over East Uttar Pradesh and neighbourhood, the whole of India is well covered by the existing radar network. With the installation of the new aeronautical meteorological telecommunication channels, it would be feasible to prepare hourly charts of weather radar information of precipitation areas.

1.8 Operational use of radar information

Radar information is of great importance in providing necessary services for different phases of aircraft operations, especially for short-range forecasting. Radar information has greatly facilitated the issue of local forecasts, airfield warnings, trend forecasts etc. The movement of local storms and severe convective clouds can be followed on the radar scope. With judicious usage of upper air conditions, it is possible to estimate with fair confidence whether any of the stations within the range of the radarscope are likely to be affected by a storm and when.

Similarly, radar information can often help in pinpointing areas of severe disturbed weather conditions along a flight path, helping the briefing of pilots before take-off and in the issuance of SIGMET information for the aircraft-in-flight.

1.9 More recent developments

More recent developments in radar technology have indicated the possibility of detecting clear air turbulence from ground. Research in this field is being actively pursued in many developed countries by using multipulse radar facilities, doppler radars etc. Some of the recent works have been briefly mentioned in Chapter 5. These techniques are however yet to obtain the status of operational technology.

1.10 Radar climatology

From the observations collected through a number of years, several investigations were made by different workers covering such aspects as general height of CB clouds in different parts of India, locations around radar stations favourable for the formation of convective clouds, movement of individual cloud echoes, squall lines and systems associated with major synoptic conditions like cyclonic storms etc. Thus a sizeable amount of radar climatology has developed and several papers have been published from time to time in the Indian Journal of Meteorology and Geophysics. A selected list of such papers is given under references.
2. Satellite Meteorology

2.1 Introduction

2.1.1 The launching of the first Television and Infra Red Observation Satellite (TIROS-1) on April 1, 1960 has ushered in the era of space meteorology. Rocket photographs earlier indicated the potentialities of observing the earth's cloud cover simultaneously over large areas. The very first few pictures received from TIROS-1 have amply proved that a new dimension has been added to the observational methods.

Two features of the observations received from meteorological satellites make them unique. One is that since they cover large portions of the earth's surface, they give at a glance the cloud patterns associated with synoptic scale systems. For example, the tropical storms in their entirety including the spiral bands in the outer storm area can often be seen on a single frame of a television picture received from a meteorological satellite. Similarly the comma-shaped cloud formations associated with extra-tropical storms, the cloud bands of cold fronts, the long stretches of cloud bands associated with jet streams etc. can all be readily identified on these pictures.

2.1.2 Secondly, unlike the ground based observational network, the satellite data give a uniform coverage over the entire area under their view. Vast oceanic areas and sparsely populated arid zones of the earth are data holes, from which very few conventional observations are received. To the meteorologists and especially for the aviation meteorologists, these data holes are sources of constant worry, as they often have to provide prognostications for such areas. Many a time, not a single observation may be available from thousands of square miles of oceanic areas either to infer the exact locations of known disturbances in the area or to detect new developments. These difficulties have been greatly mitigated with the advent of meteorological satellite data.

2.2 Brief history of the developments in satellite meteorology

2.2.1 TIROS-I was the first of the met. satellites. 11 Satellites (TIROS I to XI) were launched in the TIROS series during the period 1960-67. This was essentially an experimental series to test various types of cameras, different orbits and to develop and test ancillary techniques; the automatic picture transmission equipment (APT) was flown on TIROS-8 and proved a success.

2.2.2 The TIROS series successfully established the operational importance of satellite observations; and to provide these on a real time basis, USA launched two polar orbiting satellites in Feb., 1966, one with picture storage capability (AVCS) and the other with local readout capability (APT). This series of operational satellites were called VSSA satellites.

8 satellites in the VSSA series have been flown, the last being VSSA 8, launched on 15 December 1968. All the odd-numbered satellites had AVCS systems, their data being read out at "Command and Data Acquisition stations (CDA)", at Fairbanks, Alaska and Wallops Island, Virginia. The even numbered satellites were equipped with Automatic Picture Transmission (APT) facility on board. As of date, VSSA 8 is still operationally in use. These satellites were put in nearly circular quasi-polar orbits at an average distance of 700 kms from the earth. At this height the orbital period works out to be approximately 100 minutes. They are synchronised in the sense that their tracks traversed each part of the earth at about the same local time on each day and each successive track falls progressively west of the previous one with a slight overlap.
2.2.3 The Nimbus series of satellites are essentially space laboratories, on which different types of scientific equipment on board are tested and the data acquired are planned to be used for specific experiments. So far four satellites in this series have been launched.

2.2.4 Geostationary satellites which are injected into such orbits that they always hover over a fixed spot on the earth, were first used mainly for communication purposes. However two such satellites named "Application Technology Satellites" (ATS) have meteorological observational facilities. ATS I was launched on December 9, 1966 and has its position above the equator near 150°W (Pacific Ocean). Its coverage is from 60°N to 60°S and from the west coast of America to Australia. ATS III was launched on November 5, 1967 with its position over Equatorial Brazil near 70°W. Its cameras cover the entire hemisphere lying between mid-Pacific and central Africa. ATS III has colour television. These satellites are at a distance of about 36000 km above the earth. They transmit TV pictures (on command) at intervals of about 25 minutes and thus provide continuous monitoring of the cloud systems.

An improved version of the operational satellites was developed, called the Improved TIROS Operational Satellites (ITOS). The first of these, TIROS-M, was put into orbit on January 23, 1970 and was called ITOS-1 in orbit. The second spacecraft in this series was launched on December 11, 1970 and became NOAA I in orbit. NOAA II was launched on October 15, 1972 and NOAA III on November 6, 1973. These satellites have their orbits at an altitude of about 1460 km above the earth surface with an orbital inclination of 102° and an orbital period of 115 minutes.

All the above types of satellites have been launched by the United States.

The Russians have their own met. satellite programme and have launched a series of satellites which are called "KOSMOS" satellites. The entire organisation associated with satellite meteorology is called the "Meteor system". So far the Russian satellites do not have the APT facility on board their satellites.

2.3 Data from Met. Satellites

2.3.1 The data received from meteorological satellites are of two categories - (1) those made in the visible part of the spectrum and (2) those made in the Infra-red part of the spectrum.

2.3.2 Visible Spectrum data

(i) TV picture data

All the satellites in TIROS series, the ESSA series, the ATS satellites, the Nimbus satellites, ITOS I and NOAA I had TV picture equipment. The TV pictures reveal the earth and its cloud cover and as pointed out earlier, they could be readily used for operational purposes. From ESSA satellites equipped with APT systems, pictures are received at an interval of 352 seconds and depending upon the location of the station, 3 to 4 pictures per track can be received by a ground station. Again depending upon the track of the satellite on any particular day, pictures from 2 to 3 tracks can normally be received. At the time of this writing, TV pictures are being received from ESSA 8 only.

The Nimbus satellites, ITOS I and NOAA I also are equipped with APT facilities and pictures from these satellites were also being received at ground stations.
(ii) Scanning Radiometer (SR) data

In NOAA II and III, the TV cameras have been replaced by High Resolution Scanning Radiometers which are sensitive to reflected radiation from the earth and its clouds. The scanning radiometer data is also linked to the APT system so that ground stations within the line of sight of the satellite can receive cloud imagery on a real-time basis.

It is reported that in all future American satellites on Polar Orbits, such scanning radiometers would be flown instead of TV systems.

2.3.3 I.R. Data

The infra-red (I.R.) scanning radiometers on board the satellites measure the outgoing radiations emitted by the earth and its atmosphere. A variety of infra-red radiometer systems have been flown on the met. satellites, such systems designed to meet some specific research or operational requirements.

The earth and its atmosphere have a mean temperature of about 250°K and radiates in the infrared with maximum intensity near about 10 µm. in the I.R. At this wavelength, the earth's surface and thick clouds have an emissivity close to one and are assumed for the purpose of satellite measurements to be black radiators. Thus the energy measurements can readily be converted into temperatures representative of the surface viewed.

All the scanning radiometers have their scans perpendicular to the track of the satellite. Thus the measurements are continuous along the scan and slightly overlapping along the track of the satellite. Some of the I.R. systems are briefly mentioned below.

(i) High Resolution Infra-Red data (HRIR)

This is a single sensor system with a very narrow angular view and is designed to get as high a resolution as possible. The HRIR measurements are made in one of the atmospheric windows. The earlier satellites had sensors to work in the 10 to 12.5 µm atmospheric window region but later satellites with refined sensors worked in the 3.4 to 4.8 µm region.

The spatial resolution of the HRIR data is about 8 to 12 km at the sub-satellite point in the early satellites and continuous efforts are made to improve the resolution. It is expected that the new family of satellites to be launched in the near future will have a resolution of about 2 km at the sub-satellite point.

The imagery made from scanning radiometer data are so designed that the coldest temperatures appear in the lightest shades of grey and the warmest in the darkest of the grey scale. Thus the cold tops of very high thick cloud areas are made to appear white, whereas the warm land and sea areas appear near black. Thus the night time imagery of clouds with fairly satisfactory resolution is obtained from the HRIR imagery.

The horizontal distribution of the temperatures derived from HRIR data can be converted into a 3-dimensional topography of the cloud field under view. Thus for operational purposes, heights of tops of clouds can be obtained using HRIR data.
(ii) **Medium Resolution Infra-Red data (MRIR)**

The MRIR system flown on TIROS and on NIMBUS II has a five channel system. One channel working on 6.4 to 6.9 \( \mu \)m in the strong water vapour absorption band is designed to provide information on water vapour distribution in the upper atmosphere. The second channel working in the atmospheric window over 8 to 12 \( \mu \)m is designed to provide information on near surface temperatures of the clear portions of the atmosphere and information on cloud cover where they are present. The third channel working at 14 to 16 \( \mu \)m in the strong carbon dioxide absorption band is designed to provide information on stratospheric temperatures and is utilised in following seasonal stratospheric temperature changes. The fourth sensor measures all the outgoing radiation in the 5 to 30 \( \mu \)m band in which 85% of the total radiation emitted by the earth and its atmosphere is contained. Data from this sensor are utilised in heat-budget calculation studies. The fifth is a scanning radiometer which actually works in the reflected radiation band (0.2 to 4.0 \( \mu \)m) which covers about 99% of the total solar spectrum. Like the 5 to 30 \( \mu \)m channel, the data from this channel is also utilised in the planetary heat-budget calculation studies.

Nimbus III and IV have similar but slightly different MRIR systems. The spatial resolution of the MRIR system is about 60 km at the sub-satellite point and is expected to be improved to 30 km by the time of the First Global GARP Experiment (FGGE) in 1977.

(iii) **A more recent development in the satellite technology is the Satellite Infra-Red Spectrometer (SIRS)** designed for atmospheric soundings. The SIRS system measures the differences in infra-red radiation between the earth and deep space in eight spectral band passes, each in about 0.1 micron width. The eight spectral bands are in the strong carbon dioxide absorption spectrum between 11 and 15 microns. In NIMBUS III the eight spectral bands are centred at 11.12, 13.33, 14.01, 14.16, 14.31, 14.45, 14.76, and 14.95 microns. By utilising the measurements in these different channels, it has been shown that temperature profiles of the atmosphere in the troposphere and lower stratosphere can be obtained. The derivation of temperature is based on the concept that the energies at different wave length observed by the satellite sensors correspond to the temperature of the gas \( \text{CO}_2 \) at different height levels, the levels themselves being dependent on the transparency of the gas at different wave lengths. In retrieving the temperature from the radiance measurements, it is assumed that \( \text{CO}_2 \) is uniformly mixed up in the atmosphere up to great heights. It is reported that the vertical sounding by satellites would be extended up to 10 mb regions in future satellite systems, with a horizontal resolution of about 30 km in the troposphere and lower stratosphere and 200 km for the upper stratosphere, during the next few years.

(iv) **Infra-Red Interferometer Spectrometer (IRIS)**

This is another system for vertical sounding, flown on NIMBUS satellites. This operates between 5 to 20 \( \mu \)m. From its observations, water vapour, ozone, as well as the temperature structure can be retrieved.

IRIS has the advantage of obtaining a complete radiation spectrum with relatively high spectral resolution. As a consequence, minimum spectral radiance observations can be used to specify atmospheric structure. However, IRIS data cannot be utilised on operational basis due to excessive computer time required for its data processing.
2.4 Use of Satellite Data for Operational purposes

2.4.1 The TV pictures can be put into operational use immediately on receipt through APT systems. Many of the synoptic systems can be easily identified from the associated cloud systems seen on the TV pictures. Figures 6.2 to 6.3 give some typical examples of cloud patterns associated with some of the important synoptic systems. Whenever they are available, they can be used for briefing the pilots about weather, especially over the oceanic areas and other data scanty regions. Over such areas, satellites may be the only source on many occasions to provide the necessary information on meteorological conditions; (e.g.) for flights from Bombay to Mauritius which lie entirely over the vast Indian Ocean area, satellite pictures come in handy in the prognostic work. Fig. 6.2 gives an example of how useful a satellite picture can be in delineating disturbed weather conditions along this route.

2.4.2 Location of tropical storms and following their day to day movement has been greatly facilitated by the advent of satellite observations. Fig. 6.6 is a composite picture which shows the track of a Bay System in an Arabian Sea cyclone in October-November 1971.

2.4.3 Thunderstorm cloud masses which develop in the afternoons during the hot weather season could be located with precision from the ITOS-I pictures as this satellite had day time track falling at about 1600 hrs local time. (Fig. 6.4)

Long bands of clouds like the ones shown in Fig. 6.5 are often associated with Jet Streams and thus facilitate the location of the jets for synoptic purposes.

Interpretation of TV picture data give many noteworthy features of the atmosphere of importance to operational purposes like widespread fog, thick dust haze, thunderstorms, state of sea etc.

2.4.4 VTPR data

Vertical temperature profiles of the atmosphere obtained from the radiation sensors on board the met. satellites are being worked out and disseminated by the National Environmental Satellite Service (NESS) through the Northern Hemisphere Telecommunication network. The data provide valuable information on the heights of pressure surfaces and temperatures at standard isobaric levels especially over data scanty regions, in the analysis of constant pressure charts and in the preparation of prognostic charts for documentation purposes.

2.4.5 Cloud heights

Processing of infra-red data from the high resolution infra-red sensors (HRIIR) would give a 3-dimensional mapout of the clouds and from this, the heights of tops of clouds can be obtained. Such data would facilitate operational work directly.

2.4.6 Winds

The cirrus plumes emanating from the tops of CB clouds are generally oriented in the direction of the wind at the CB top level. This provides a method of obtaining estimates of winds at the CB top level from the APT pictures. Routine extraction of such wind estimates and their use in the analysis of high level charts leads to a better analysis of CP charts. An example of a chart analysed with the help of such derived winds is shown in Fig. 6.15.
The ATS satellites take pictures at frequent intervals of about 25 minutes. Thus cloud displacements from one picture to another give a measure of the winds in the layer in which such clouds are embedded. Routine extraction of wind data is being done by NASA, U.S.A. for the low levels (850 and 700 mb) and at high tropospheric levels (200 and 300 mb), utilising the data from ATS satellites. These wind measurements are being utilised for numerical weather prediction work also in various countries. It is expected that a geostationary satellite will be put into orbit with its position over the Indian Ocean during the next two or three years. When the data from that satellite becomes available, then it will be possible to obtain winds over the data scantly regions in our part of the globe also.

2.4.7 Maximum winds in Cyclonic Storms

Methods have been developed to estimate the maximum winds of Cyclonic Storms from the TV pictures using the size and characteristics of the central mass of cloud as seen on the TV pictures. Recently an improved technique of estimating the maximum winds of cyclonic storms has been introduced and is given in Technical Memorandum NASA 50.

Note: Diagrams in respect of this chapter are given at the end, after References and Selected Bibliography.
CHAPTER 7

FLIGHT FORECAST - MODELS

1. At present, three types of flight forecasts are being supplied by the meteorological offices in India. The briefest one is a simple tabular form of forecast given in a small forecast form, called Met T-3 form, in which information on Significant Weather, Surface Visibility, Upper Winds and Temperatures up to the normal cruising levels of about 3000 m asl and Cloud distribution along the route are given. This kind of forecast is supplied to pilots/operators for flights of less than 500 nm distance. The height indications in this form are given in terms of "Pressure Altitude" in metres. A typical example of this kind of documentation is given in Appendix 1 at the end, with a note explaining the principles on which the forecast was based.

2. The second type of forecast is a cross-sectional forecast in which the anticipated cloud distribution and significant weather along the flight path is depicted pictorially. In all other respects, the forecast form (in this case called Met T-4) resembles the smaller form, Met T-3. This type of forecast is supplied for flights exceeding 500 nm distance. A typical example of a forecast in Met T-4 form is given in Appendix 2 to this chapter, together with a note explaining the basis on which the various elements were indicated in the forecast. Even though, in the diagram, the pictorial representation of clouds is shown in black, in actual practice, the clouds are depicted in green below the freezing level and in red colour above that level, with the freezing level itself being shown as a broken line. In the forecasts given in this form all heights are given in Flight Levels (Pressure altitude in hundreds of feet).

3. The flight forecasts normally cover the weather expected within 10 n.miles on either side of the flight path. However along advisory routes, the width of the flight path differs from the standard width and the details of such routes can be obtained from AIP-India (3rd edition), Pages PAC 3.2.5-3.2.22. Hence a forecaster has to keep such facts in mind while preparing the forecasts.

4. The significant weather given in such forecasts and the levels for which upper air information is supplied, depend on the cruising levels of the aircraft for which the forecast is meant. In the case of low-flying aircraft (which are generally piston-engined), the significant weather phenomena are to be given according to para 2.5.2.9.2. of PANS-MET and the upper wind information is generally given up to 3000/3600 m. For turbo-prop aircraft which generally fly between 4,2 and 6.0 km asl, the upper air information is provided up to 6.0 km and the significant weather elements forecast are as per para 2.5.2.5.3.2 of PANS-MET.

5. Both the forms mentioned in the preceding paragraphs have provision for indicating significant meteorological systems (depressions, cyclones, their position, expected movement etc.) which are likely to affect the weather along the flight paths.

6. All the Class I Met. Offices in India provide the above two types of forecasts. The third type of documentation, called chart form of documentation, is provided by the three Extended Analysis and Prognostic Centres situated at Bombay, Calcutta and Delhi Airports. In this type of documentation, the anticipated weather and upper air conditions over an extended area, are depicted on charts. The area generally covers almost
all the routes for which forecasts are to be issued by the respective RAP centres. At the time of this writing, the chart form of documentation provided by these centres consists of the following prognostic charts:

(i) The significant weather chart which contains information about spatial distribution of different types of significant weather expected during the validity period of the chart, the locations of the principal pressure systems and their anticipated movement, the positions of 0°C isotherm at Flight Levels 15, 30 and 45 and areas of Clear Air Turbulence.

(ii) Three upper air charts, depicting the prognostic contours (streamlines between 10°N and 10°S) for the 300, 250 and 200 mb levels. These charts also give spot winds and spot temperatures in the vicinity of principal air routes. Isotachs are also indicated by broken lines. Axes of the Jet Streams at each level are also indicated by double lines or thick lines with arrow heads.

7. The chart form of documentation has several advantages over the cross-sectional form and hence nowadays widely come into vogue at important international airports. From the forecasting office point of view, it reduces the work at busy aerodromes since a prognostic chart once prepared can be rapidly duplicated and given out for all the flights going out in different directions. From the operators/pilots' point of view, it is also advantageous in several respects. The upper wind data is now available to the pilot not only along his flight path but for adjacent areas also so that to avoid adverse winds along the direct route, he can probably plan to fly a slightly deviuous route and still gain time on the flight between the terminals and thus save fuel. Again, if by taking a slightly deviuous route, he can get strong favourable winds (tail components), he can do so planning his flight on the information given in these charts. Similarly, he can also change the course of his flight if very bad weather conditions are anticipated along the direct route. A typical model of chart form of documentation is given in Appendix 3 to this chapter; a note similar to the earlier two examples given in Appendix 1 and 2, is included in this case also.

8. In addition to the flight forecasts, the documentation also includes aerodrome forecasts for the destination aerodrome and its alternates which are prepared in accordance with the procedures discussed in Chapter I. Wind and temperature information for the ascent and descent phases of the flight is also included in the documentation by supplying the ascent/descent winds at the departure/destination aerodromes. For some types of aircraft, especially jet and turbo-prop aircraft, anticipated surface information at the time of take-off (called take-off data) also forms part of the documentation.

9. Pilots-in-Command come to the met. office for verbal briefing before take-off. At that time, the forecaster briefs the pilots with the help of the latest synoptic charts, the radar observations, satellite pictures, the latest current weather information from the terminal and its alternate aerodromes, SIGMET information pertaining to the different FIRs along the flight path and any significant aircraft reports of interest to his flight.

10. Many international operators have what are called 'Flight Despatch Systems' at important aerodromes. The flight dispatcher is trained to receive met. briefing and use the met. information supplied, in preparing flight plans etc. Such flight despatchers can and do take the briefing from the duty forecasters and the crew of the aircraft do not come for briefing to the met. office in such cases.
11. Modifications to any information supplied as part of the documentation or briefing should always be promptly conveyed to the flight crew_flight dispatchers directly as long as the aircraft is on ground and through the ATC, when the aircraft is airborne. Such modifications issued should be governed by the criteria laid down in Table II of PANS-MET, which is given below:

**Table II - Criteria for Amendment of Forecasts**

<table>
<thead>
<tr>
<th>Element</th>
<th>Criteria</th>
<th>Forcasts affected Flight, route and area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper winds</td>
<td>Change in direction of 30 degrees or more, provided the wind speed is 30 knots or more before or after the change; change in speed of 20 knots or more.</td>
<td>X</td>
</tr>
<tr>
<td>Upper air temperatures</td>
<td>Change of more than 5°C.</td>
<td>X</td>
</tr>
<tr>
<td>Aircraft icing</td>
<td>New expectation; intensity increasing; intensity decreasing from severe to light or from moderate to nil.</td>
<td>X</td>
</tr>
<tr>
<td>Freezing precipitation</td>
<td>New expectation; no longer expected</td>
<td></td>
</tr>
<tr>
<td>Turbulence</td>
<td>Intensity increasing to moderate or to severe; intensity decreasing from severe to light or from moderate to nil.</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>Hail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thunderstorm</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Squall</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Tornado</td>
<td>New expectation; no longer expected.</td>
</tr>
<tr>
<td></td>
<td>Tropical revolving storm.</td>
<td></td>
</tr>
<tr>
<td>Sandstorm or duststorm</td>
<td>New expectation; intensity increasing from conditions of rising sand (or dust) to sandstorm (or duststorm); intensity decreasing from sandstorm (or duststorm) to condition of no rising sand (or dust).</td>
<td>X</td>
</tr>
<tr>
<td>Cloud conditions</td>
<td>Change substantially affecting operation of aircraft.*</td>
<td>X</td>
</tr>
<tr>
<td>Significant front</td>
<td>(1) New expectation; no longer expected</td>
<td>X</td>
</tr>
<tr>
<td></td>
<td>(2) Marked difference in position.</td>
<td>X</td>
</tr>
</tbody>
</table>

* Determined in consultation with operator.

Note: Appendices 1, 2 and 3 to this chapter are given at the end, after References and Selected Bibliography.
CHAPTER 8

HOW METEOROLOGICAL INFORMATION IS USED FOR FLIGHT PLANNING

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1. Introduction

Flight planning is the pre-flight preparation of navigational information in order to obtain the time the flight will take and the fuel that will be consumed. The flight plan is based on forecast meteorological data and on standard aircraft performance charts. Time was when aviators using piston-engined short-haul aircraft could afford to do without any elaborate flight planning. With the advent of jet aviation and heavily loaded passenger or freighter aircraft doing long-haul flights at high speed and a very high rate of fuel consumption, flight planning has assumed considerable importance. The current fuel crisis has also served to enhance the significance of flight planning.

The following illustration will elucidate the need for proper flight planning. Let us assume that a modern Boeing 707 aircraft consumes about 6000 kg of fuel per hour of flight. If the aircraft was expected to make the flight in, say, 10 hours' time without proper planning the amount of fuel taken on board would have been at least 60000 kg. Supposing the meteorological factors enroute or at the destination were such as to enable the aircraft to complete the flight in 9 hours' time, the extra one hours' fuel weighing 6000 kg was really a waste and instead, with proper planning, an additional 60 passengers or equivalent cargo could have been carried. If the passenger fare was Rs.3000 for the trip the loss of revenue to the airline on this flight alone would be Rs.1,80,000.

Flight Planning is necessary for all the phases of flight operations namely, take-off and climb, cruise and descent and landing. It would depend on the type of aircraft and engine performance. It would also have to take into account several meteorological factors. It is well known that for an aircraft in flight the lift and drag are proportional to 1/2 \( \rho V^2 \) where \( \rho \) is the air density and \( V \) the flight velocity. As air density varies with temperature and pressure and the flight velocity is affected by wind, these are the meteorological factors that are of prime importance for flight. In addition, for landing and take-off additional factors like visibility and low-cloud ceiling over the aerodromes also become important. A good flight plan will therefore, attempt to provide the flight with such information as will enable it to operate with maximum efficiency from take-off to landing taking into account safety, revenue, payload and air traffic regulations.

2. Flight Planning for take-off

2.1 RTOW

An important parameter that is calculated for planning a take-off is the "Regulated Take-off Weight (RTOW)". The RTOW varies with meteorological factors like surface wind, temperature and pressure altitude and differs from aircraft to aircraft, runway to runway and airport to airport. RTOW is the maximum value of the sum of the weights of the aircraft, fuel and payload that would permit the aircraft to lift-off safely from the runway, also taking into account topography and surrounding obstructions. The following examples may serve to illustrate the effect of various factors on RTOW.
2.1.1 **Effect of runway utilisation on RTOW**

At Bombay the RTOW for a Boeing 707 (337 series) taking off from the 27 and of the 09-27 runway is 148,000 kg with calm wind, pressure altitude of 100 ft and temperature of 30°C. Under the same conditions of temperature, pressure and wind the RTOW of this type of aircraft is 142,000 kg only if the take-off is from the 09 and of the runway. The difference of 6000 kg is due to the need for a steeper climb in view of the surrounding topography near the eastern end of the runway.

2.1.2 **Effect of temperature and surface wind on RTOW**

For every airport a series of charts connecting RTOW with temperature and head/tail surface wind components for various types of aircraft and runway utilisation are normally available. These charts are used for determining RTOW for values of temperature and surface wind expected at the time of take-off on a particular runway.

The effect of temperature and surface wind component on RTOW may be seen from the following example. For a Boeing 707 (337 series) aircraft the RTOW is 148,000 kg for runway 27 at Bombay if the temperature is less than 31°C for any wind component while for the same runway when the temperature is 38°C the RTOW is 148,800 kg with a head wind of 10 kts, 146,000 kg with zero wind and 142,200 kg with 5 kt tail wind. The RTOW values for the same Boeing 707 (337 series) aircraft for runway 09 with varying temperature and wind components are given below:-

<table>
<thead>
<tr>
<th>Temp. (°C)</th>
<th>Wind Compt. Kts</th>
<th>RTOW (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>5 Tail</td>
<td>144,600</td>
</tr>
<tr>
<td>31</td>
<td>0</td>
<td>147,400</td>
</tr>
<tr>
<td>31</td>
<td>10 Head</td>
<td>148,300</td>
</tr>
<tr>
<td>38</td>
<td>5 Tail</td>
<td>136,300</td>
</tr>
<tr>
<td>38</td>
<td>0</td>
<td>138,600</td>
</tr>
<tr>
<td>38</td>
<td>10 Head</td>
<td>139,400</td>
</tr>
</tbody>
</table>

It may be seen from the example that higher the temperature the lower is the RTOW and the aircraft will be able to carry less revenue pay load. A similar effect will be there if the head wind component is less.

At the flight planning stage it is, therefore, very important to have accurate surface temperature and wind forecasts.

2.1.3 **Effect of pressure altitude on RTOW**

The standard ICAN atmosphere assumes a 1-v-1 pressure of 1013.2 mb, mean sea level temperature of 15°C and lapse rate of 6.5°C/km up to 11 km. Any variation from this standard atmosphere is to be taken note of since all the instruments on board an aircraft are calibrated to this atmosphere and suitable corrections are to be made time and again. For flight planning purposes also deviations from the standard atmosphere are to be reckoned with and allowances made accordingly.
Pressure altitude variations come under this category. It has been calculated that for a Boeing 707 aircraft every +100 ft departure in pressure altitude from the Standard Atmosphere reduces the RTOW by 500 kg while for a Boeing 747 (Jumbo) aircraft the corresponding reduction is 900 kg. This emphasizes the need for accurate observation and forecast of meteorological parameters at the aerodromes.

2.2 Time and distance for lift-off

For every aircraft a speed known as Engine Failure Speed has been specified. Once this speed has been reached during the take-off run of an aircraft within the specified distance it is safe for the aircraft to take-off. If, however, there is an engine failure before this speed is reached the take-off has to be abandoned. This engine failure speed referred to as Vf is specified to be attained at a particular distance known as 'lift-off distance'. The time taken to reach this lift-off distance and the lift-off distance itself depend on the gross weight of the aircraft, pressure, temperature and surface wind. The following information may illustrate this:

<table>
<thead>
<tr>
<th>Type of aircraft</th>
<th>Gross Wt. of aircraft</th>
<th>Press. Alt. ft</th>
<th>Surface Temp. °C</th>
<th>Wind Compl.</th>
<th>Lift-off distance ft</th>
<th>Lift-off time 5 sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boeing 707</td>
<td>130000</td>
<td>+100</td>
<td>30</td>
<td>zero</td>
<td>6200</td>
<td>53</td>
</tr>
<tr>
<td>(43’ series)</td>
<td>130000</td>
<td>+100</td>
<td>32</td>
<td>zero</td>
<td>8500</td>
<td>55</td>
</tr>
<tr>
<td>Boeing 707</td>
<td>130000</td>
<td>+100</td>
<td>30</td>
<td>10 kt head</td>
<td>6100</td>
<td>30</td>
</tr>
<tr>
<td>(33’ series)</td>
<td>130000</td>
<td>+100</td>
<td>30</td>
<td>10 kt tail</td>
<td>5600</td>
<td>41</td>
</tr>
</tbody>
</table>

If the lift-off distance is too large compared to the available length of the run-way the operation of the flight will be impossible and the aircraft may have to wait and take-off only after the meteorological conditions become favourable or after off-loading some payload. It may be seen that a 2°C increase in surface temperature can increase the lift-off distance by 300 ft. Similarly a 10 kt tail wind can increase the lift-off distance by 600 ft above the value for calm conditions. When the gross weight of an aircraft is high, surface temp. and surface wind values can assume critical importance and will have to be observed and forecast accurately.

3. Flight Planning for climb

Flight planning for climb is important not only from economic considerations but also for communicating to the Air Traffic Control the expected time and distance for reaching the cruising height so that they could ensure sufficient clearance between one aircraft and another. The time taken for attaining a particular height will depend on the gross weight of the aircraft and the mean conditions of temperature and wind during climb. Considering temperature alone, for various temperature departures from the Standard Atmospheric conditions, there will be a difference in the climb speed the aircraft will attain, the fuel consumed and a corresponding difference in the time taken for an aircraft to reach a specified height. For example, to reach a height of 28000 ft, a Boeing 707 (337) aircraft with a gross weight of 140,000 kg will require 21 mts to climb at a speed of 387 kts consuming 4159 kg of fuel under ISA temperature conditions.
If, however, the atmospheric conditions are such that an average temperature departure of +15°C exists during climb as compared to the ISA temperature, the climb will take 27 mts at a speed of 399 kts and the fuel consumption will be 4850 kg. There will be a further alteration in climb time due to variations in the wind component along the direction of climb. For example the climb speed of 399 kts will yield a ground speed of 389 kts if the component during climb is 10 kts head. The provision of accurate forecast wind and temperature data for various levels of climb such as 700 mb, 500 mb etc. is, therefore, important.

4. Flight Planning for Cruise

Certain flight levels with a constant separation are specified as per regulation for flight in one direction along a route while for flights in the opposite direction intermediate flight levels with the same separation would be available. Depending upon the weather the cruise level is decided, consistent with the Air Traffic regulations mentioned above. A condition generally attempted to be satisfied is that the flight should be above the CB clouds, and that areas of turbulence (both in clouds and clear air) are avoided. In normal practice the cruising level is kept constant, though, occasionally, it may be altered in the course of a flight, with the concurrence of the Air Traffic Control to avoid unfavourable weather conditions. The cruise is planned for constant speed i.e. in terms of the Mach number. From the Prognostic Charts pertaining to the flight level, the wind components along the track can be computed and the ground speed determined. Tables showing the true air speed and the fuel consumption for various aircraft weights for different temperatures at the cruising level are available for a constant Mach number. These enable one to calculate the fuel required over the cruise phase. An example may help clarify the importance of accurate temperature and wind forecasts during this phase. A deviation of +10°C in temperature from the forecasted value can necessitate a Boeing 707 (337 series) aircraft with a gross weight 130,000 kg cruising at 28,000 ft to increase the true air speed by 10 knots and to consume about 145 kg of fuel/hour more than what was expected. About the same additional fuel consumption will result if the actual head wind component during the cruise phase is 10 knots more than what was forecast.

5. Flight Planning for Descent

The most important parameter affecting the descent operation is the wind component. Charts and tables showing the time taken and distance needed for a particular type of aircraft to descend from a particular pressure altitude are available with flight planners. The effect of wind will be to cause variations in the time of descent (an increase in the time if the head component predominates and a decrease if the component is mainly tail). These variations in the time of descent would mean variations in fuel consumption, consequently affecting flight economy. An accurate descent wind forecast is thus an important requirement.

6. Planning for landing

6.1. Maximum landing weight

The limiting weather conditions for landing are far more stringent than for take-off. Poor visibility, low cloud ceiling and gusty winds pose hazards. Each type of aircraft has a set of stipulated weather minima below which landing is risky. For a Boeing 707 aircraft for instance, the
visibility limit for runway 27 at Bombay is 1200 M, and the limit for cloud
ceiling 300 ft, maximum cross wind 15 kts and maximum tail wind 7 kts. A pilot
confronted with any weather situation that is below the 'minimum for landing
may decide to hold over the airfield for some time if there is an expectation
of improvement. Alternatively, he might decide to fly to an alternate aerodrome
if conditions are better there. In both cases additional fuel and delay will
be involved. At the time of flight planning sufficient fuel reserved to cover
situations of such emergency is normally taken into account. If A is the
aerodrome of departure, B is the aerodrome of destination and C its alternate,
flight planning will usually allow fuel for the flight A to B plus three
percent for route deviation plus a quantity (say 500 kg) as approach fuel plus
fuel for the flight B to C plus one hour's holding fuel. The amount of fuel
and payload taken on board an aircraft and the fuel that is expected to be
burnt-off during the flight are also important factors to be taken into consi-
deration for landing. There is stipulation that the gross weight of an aircraft
should not exceed a weight known as Maximum Landing Weight. If this weight is
exceeded, it is likely the aircraft will sustain structural damage. For short
distance flights, in particular, the Maximum Landing Weight becomes very
significant. Carrying too much fuel on board for short flights can result in
the aircraft arriving at the aerodrome of destination with a gross weight above
the Maximum Landing Weight since the burn-off during the flight would have been
small. Under such conditions the aircraft may have to hold in the air till
sufficient fuel is consumed to bring the weight below the maximum landing
weight -- an uneconomical procedure. Proper pre-flight planning is, therefore,
necessary to see that such wastages are kept to a minimum and that maximum
utilisation of the aircraft for revenue payload is provided for.

It may be pointed out that the general tendency for head winds to be
exaggerated in forecasts can lead to less fuel consumption than anticipated,
ocasionally resulting in the gross weight of the aircraft exceeding the
Maximum Landing Weight on an aircraft reaching the aerodrome of destination.
This would necessitate wasteful 'burning off' of extra fuel.

6.2 Maximum speed at touch down

Another critical parameter during landing is the maximum speed at
touch down. Every pilot would strive to adjust his approach speed in such a
way that the maximum speed specified for touch down is not exceeded lest there
be structural damage. At the same time he has to see that the speed does not
go below that required to keep the aircraft in the air without stalling.
Usually the ground speed indicators in an aircraft are carefully watched to
see that the speed is within the prescribed limit. It is here that surface
wind comes into play. If, for example the aircraft is approaching to land on
the assumption that the surface wind is 15 kts head and the wind at the time
of landing shifts to a cross component or suddenly drops to calm, the speed
at touch down may exceed the prescribed limit and what is technically known
as 'heavy landing' may occur. An equally serious situation could be the sudden
increase of wind speed by say 20 kts in which case the engine loses power and
the aircraft may still be in the danger of a 'heavy landing'. It is therefore,
important that accurate surface wind estimates are given by current weather
observers and care taken particularly when it is gusty and there is a marked
'swing' in the surface wind direction.

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WORLD ORGANIZATIONS CONCERNED WITH SERVICE TO AVIATION

1. The two world organizations which are concerned with meteorological service to Civil Aviation are (1) The World Meteorological Organization and (2) The International Civil Aviation Organization. Different constituent bodies of these two organizations deal with detailed aspects of meteorological service to aviation as given below:

1.1 WMO

The first step towards setting up of an international meteorological body was taken in 1853, when a meeting was held in Brussels of representatives of a number of maritime countries, in an effort to obtain collaboration in international programme for meteorological observations by ships at sea. Subsequently in 1878, when there were sufficient national services for their directors to get together, a meeting was held in Utrecht in the Netherlands, to found the International Met. Organization (IMO). Although not an intergovernmental body, this organization developed steadily over the next seventy years.

Because of the increasing importance of the applications of meteorology to many human activities, including civil aviation, the need for some sort of more official sponsorship for international meteorology became apparent, and after World War II, a World Meteorological Convention was, therefore, drawn up and adopted by the Conference of Directors of the national services (in effect, the Conference of IMO) at their 1947 meeting in Washington. This Convention provided for the transformation of IMO into a new World Meteorological Organization, although the latter did not immediately come into being. The final transfer of the activities, functions, assets and obligations of IMO took place in March 1951 when the directors held their last meeting in Paris and the World Meteorological Organization (WMO) came into operation; its first forty-four members opened their first Congress in Paris on 19 March 1951. India was a founder member of both the IMO and WMO.

One of the first acts of the 1951 Congress was to initiate negotiations for the establishment of relationships with the United Nations, and with its Specialised Agencies; in effect, for the admission of WMO to the United Nations Family. The agreement for this came into force on 20 Dec. 1951 on which date, the World Met. Organization became a Specialised Agency of the United Nations. The Organization is open for membership to any state or territory which administers a meteorological service of its own and all Members whether states or territories enjoy equal technical rights within the Organization. The headquarters of the Organisations is located at Geneva in Switzerland.

1.1.1 Congress

The supreme organ of WMO today is the World Meteorological Congress which meets at least once every four years under the Chairmanship of the President of the Organization, who is a director of one of the national weather services. Besides fixing the policy, programme and budget of the Organization, the Congress adopts the Technical Regulations relating to meteorological practice. These regulations are, perhaps, one of the most important of all manifestations of WMO.
1.1.2 The Executive Committee

While the Congress concerns itself with major long-term matters, the implementation of its decisions rests with the 19 member Executive Committee which meets annually. Its members include the President and three Vice-Presidents of WMO, and the Presidents of the Six Regional Associations who are elected for the respective posts. In addition, the Executive Committee consists of another nine members who are specifically elected to the Executive Committee. All meteorological questions of international interest come within the terms of reference of the Executive Committee, which is in effect, the operational governing body of the organization. From it, information and directives go outwards to the other two main organs, the Regional Associations and the Technical Commissions.

1.1.3 The Regional Associations

The Regional Associations are six in number, one for each continent and the surrounding oceanic areas. The six Regional Associations are —

| Regional Association | I – Africa | II – Asia | III – South America | IV – North America | V – Australia | Vi – Europe |

India comes under the Regional Association II for Asia.

The Regional Associations are operational rather than scientific or technical bodies. The members of these associations are the Governments of the countries in the respective regions. The Regional Associations meet once in every four years, but in the interim, they may set up working groups of regional interest.

1.1.4 The Commission for Aeronautical Meteorology

The Technical Commissions are eight in number and are composed of individuals who are experts in the technical fields concerned, and who are designated by their governments. These commissions also meet once in every four years. The Technical Commission directly concerned with service to aviation meteorology is the commission for Aeronautical Meteorology. This Commission examines and deals with all aspects of met. service to international aviation. In order to coordinate its procedures with the requirements of the ICAO, this technical commission, meets in extra-ordinary sessions, as required, conjointly with the sessions of Air Navigation Conference and the Met.Division, which are the main bodies dealing with met. service to aviation on the ICAO side.

1.1.5 WMO Secretariat

At the very centre of the WMO comes the Secretariat, under the Secretary General, who is elected by the Congress. The system of regional and technical bodies described above makes this central nucleus to be very much more compact than would otherwise be the case. The Secretariat provides the central administrative machinery of the organization and of its many meetings like the preparation of agenda points, working papers etc. Points for discussion at the meetings should be communicated by the sponsoring countries to the WMO Secretariat at Geneva.
The Secretariat also plays a considerable role in the production of actual technical matter. It prepares specialised publications, most of them standard works, and some of them kept perpetually up to date, so that publication work really never ceases. The Secretariat also carries out the organizations' public relations with non-Member states as well as with the general public. In effect, the Secretariat is the link between the met. services of the world. The Secretariat is located at the WMO Headquarters at Geneva.

1.1.6 WMO Technical Assistance Programme

WMO's transformation into a specialised agency enabled it to participate in the United Nations Expanded Programme of Technical Assistance (EPTA) which was created in 1949. In 1966, the EPTA was amalgamated into the United Nations Development Programme and WMO continues to participate in this programme. Participation of WMO in these programmes enabled it to provide technical assistance to its Members in various met. fields. The WMO has, however, not relied solely on external sources of financing and support for its technical assistance activities. Starting with the Second Congress, various funds were created by WMO on its own. The Fourth Congress created the New Development Fund in 1964, which was in operation till the end of 1971. This fund provided assistance for development projects including equipment for the establishment of observational and telecommunication facilities and special projects. The Voluntary Assistance Programme (VAP) created by the Fifth Congress in 1967, became operational in 1968 and is continuing to operate. The purpose of this fund is aimed at assisting the implementation of the World Weather Watch (WWW) by providing services of experts. Assistance is also provided for other projects by providing instruments and equipment.

The impact of WMO technical assistance on economic development has been in the fields of Agricultural, Water Resources, Aviation and Shipping, Mitigation of Tropical Cyclone Damage, General Forecasting, Multi-purpose Climatological Information and Special Applications. Technical Assistance is also provided for building up Meteorological and Hydrological Services, in the fields of Organization of Services, Observational Networks, Met. Telecommunications, Training of Professional Personnel and Research Activities.

In the field of technical assistance, India Met. Department has also contributed its share by deputing its officers for WMO Expert missions for training of personnel, organization of met. services etc. in developing countries. India has received technical assistance by way of provision of met. rockets, VAP aid for implementation of RTH at New Delhi etc.

In some of the specialised fields, WMO Technical assistance is provided in collaboration with the United Nations organizations like the Economic Commission for Asia and Far East (ECAFE) which has its headquarters at Bangkok. An example of such a collaboration is the establishment of the "Typhoon Committee" for Southeast Asia.

1.2 The International Civil Aviation Organization

The International Commission for Air Navigation was created at Versailles in 1919, after World War I, had helped develop the aeroplane into a potent transport agent. The Second World War has a major impact on the technical development of the aeroplane and helped to develop a
a vast network of passenger and freight carriage. In 1944, representatives of fifty-two states attended a meeting at Chicago, U.S.A. and created the convention on International Civil Aviation. The permanent body charged with the administration of the 96 articles embodied in the convention is the International Civil Aviation Organisation, which has its headquarters at Montreal, Canada. The ICAO officially came into being on 4 April, 1947, after the convention was ratified by twenty-six States.

In 1947, the ICAO became a specialised agency of the United Nations, and thereby joined the United Nations Family. The organisation maintains close liaison with the United Nations and certain of the specialised agencies such as the International Telecommunications Union, the World Health Organisation, the Universal Postal Union etc. Liaison is maintained with the World Meteorological Organisation, and the UN Special agency, in the provision of meteorological service to air navigation.

1.2.1 The ICAO Assembly

The governing body of the ICAO is the Assembly. The full-scale assembly meets once in every three years. At this Session, the complete work of the organisation in technical, economic, legal and technical assistance fields is reviewed in detail and guidance given to other bodies of ICAO for their future work.

1.2.2 The ICAO Council

The executive body of ICAO is the Council which is a permanent body responsible to the Assembly and composed of twenty-one contracting states elected by the Assembly for a three-year term. The Council together with its subordinate bodies, the Air Navigation Commission, the Air Transport Committee, the Committee on Joint Support for Air Navigation Services and the Finance Committee, provide the continuing direction of the work of the organisation. One of the major duties of the council is to adopt "International Standards and Recommended Practices" and to incorporate these as "Annexes" to the convention on International Civil Aviation. Both the ICAO Assembly and the ICAO Council function from the ICAO headquarters at Montreal.

1.2.3 Air Navigation Conference and ICAO MetDivision

The requirements of meteorological facilities for civil aviation during the different phases of aircraft operations are discussed along with other problems concerning aviation by the periodical Air Navigation Conferences held by the Met. Division Meetings. In order to facilitate coordinated action between ICAO and WMO in respect of provision of met. services to civil aviation, the meetings are held conjointly with the Commission for Aeronautical Meteorology of the WMO, whenever meteorological aspects are to be discussed, as mentioned earlier. by ICAO. Matters of purely meteorological interest are discussed.

1.2.4 Regional Planning and 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 organisation has set up eight geographical regions, both to facilitate detailed planning and to cater to different types of flying operations. The eight regions are
(i) The North American Region (NAM)
(ii) The South American Region (SAM)
(iii) The North Atlantic Region (NAT)
(iv) The South Atlantic Region (SAT)
(v) The European Mediterranean Region (EUR)
(vi) The Middle East Region (MID)
(vii) The South East Asia Region (SEA) and
(viii) The Pacific Region (PAC)

India is located in the MID and SEA Region and takes part in the
Regional Air Navigation Meeting of these regions which is held as a
combined meeting for these two regions. These RAN meetings for the first
four regions also are held usually as combined meetings for two regions
together for e.g. the meetings are held for the region NAM/NAT and
SAM/SAT. Recently a regional meeting has been held at Honolulu, to
discuss the requirements for the air services in the Asia and Pacific
regions, necessitated by the admission of the USSR and China to the ICAO
convention. This meeting was known as ASIA/PAC RAN meeting and its
recommendations are under implementation as far as they concern India.

As a result of Air Navigation meetings held in these ICAO regions,
meetings which examine the requirements for air navigation and specify the
services and facilities and procedures that are found necessary, detailed
regional plans are drawn up. These plans include the enumeration of some
40,000 facilities to be established and operated or services to be
rendered at the points the meetings have defined and that the Council has
approved. On the other side, these plans enumerate the types of meteorolo-
gical offices to be set up at aerodromes, the facilities required at these
offices, requirements for exchange of operational meteorological information
based on the current and projected aircraft operations and other meteorolo-
gical facilities required for air operations.

Proposals for amendments to the regional plans are to be commu-
nicated to the ICAO Secretariat at Montreal by the sponsoring states. The
Secretariat in turn circulates these proposals to other States concerned
and submits the proposals together with the views of the States for approval
by the ICAO Council. After approval by the Council these amendments are
incorporated in the Plans.

A major effort is made by ICAO to secure implementation of the
regional plans by the states of each region and to help each government
to provide the services called for within its territories. For this
purpose ICAO has set up a number of regional offices. The Regional Office
at Bangkok is concerned with the MID/SEA Region and is known as the Far
East and Pacific (FEP) Office.

1.2.5 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. 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 the Bureau of Administration and Services.

In order that the work of the Secretariat shall reflect a truly
international approach, senior personnel are recruited on a broad geo-
 graphical basis. In addition to the regular staff, the services of experts
are obtained from time to time by loan or secondment from member States.
1.2.6 ICAO Technical Assistance Programme

As in the case of WMO, ICAO's transformation into a specialised agency enabled it to participate in the United Nations Expanded Programme of Technical Assistance (EPTA). ICAO's participation in the programme is based on the importance of aviation to the development of industry and agriculture. It provides (i) safe and rapid means of communication and transport, (ii) the means of cheap survey of natural resources and of public works, (iii) an important aid to the survey and construction of means of bulk transport such as railways and roads, (iv) the means of protection of crops, timber etc.

So far, the organisation has placed primary emphasis on the development of the ground services required by civil aviation, particularly aerodromes, air traffic control, communications and meteorological services. On the meteorological side, the technical assistance is provided for the organisation of meteorological services, training of staff in meteorological observing and forecasting work etc. India has provided assistance in this field by deputing the services of experts to serve with ICAO missions in developing countries.

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INTERNATIONAL PUBLICATIONS OF INTEREST TO AVIATION

1. The WMO and ICAO publications which lay down procedures for supply of meteorological information to Civil aviation are briefly mentioned below giving the scope and concept of each publication.

1.1 WMO publications

From the point of view of the practical meteorologist, the WMO publications fall into two categories:-

Basic documents and Technical publications

1.1.1 Basic Documents

These include the "Technical Regulations" for the operation of meteorological services and these are interesting, almost unique, even among the vast documentation published by the U.N. Agencies, in that they have virtually, the force of law. When such regulations are adopted by the Resolution of the WMO Congress, their implementation is implicit, and it is of international necessity that they should be put into practice. Most of these regulations, however, have two categories of content: first, those of which the implementation is obligatory and second, those for which it is at least advisable. These technical regulations are now issued in three volumes. The various items of the publication are grouped as indicated below:

Section A  — World Weather Watch
A.1 — The Global Observing System
A.2 — The Global Data — Processing system
A.3 — The Global Telecommunication system

Section B  — Research Activities
B.1 — Meteorological bibliography and publications:
Vol.1, Chapter B.1

Section C  — Interaction of Man and his Environment
C.1 — Meteorological Services to Marine Activities:
Vol.1, Chapter C.1
C.2 — Meteorological Services to Agriculture: Vol.1, Chapter C.2
C.3 — Meteorological Services for international air navigation:
Vol.II
C.4 — Operational hydrology: Vol.III

Section D  — Vol.II of this document deals with regulations governing service to aviation. It is on such publications as these, that the safety of millions, who travel every year by air, may depend.
1.1.2 Technical publications

These are equally important and cover virtually every aspect of the Organization's activities, the most important of these being the publication referred to as "Publication No.9". These technical publications are detailed below:

1.1.2.1 Publication No.9: The idea of internationally standardised observations, in fact, is at the core of what is perhaps the most important of all WMO's achievements - a document, known simply as "Publication No.9", which consists of four parts dealing with stations, codes and transmissions. This publication consists in effect of nothing less than a complete guide on the availability of basic meteorological data to the world's meteorological services.

The four volumes together give information about the meteorological network over the globe, the meteorological codes, facilities for transmission of observations and information for shipping as indicated below:

Volume A - This gives the details of the observing stations, the index number by which each station is identified, the name of the place, the precise geographical position, elevation and details of observations made.

Volume B - This set gives the exact description of all the international codes used to transmit the meteorological information and also the regional and national practices in respect of these codes.

Volume C - This set gives the types of broadcasts, the frequencies, the stations to which they refer, the data included in each of the broadcasts and the times of consolidated transmissions.

Volume D - Information for Shipping.

1.1.2.2 Technical Notes

WMO also undertakes to prepare what are known as Technical notes which deal with specific aspects of meteorology including subjects of interest to aviation. These are written by experts in their respective fields and provide authoritative guidance material. Those of interest to aviation have already been indicated under References and Bibliography at the end.

1.1.2.3 WMO Guides

Closely related to the Technical Regulations is the preparation of a series of Guides which form a kind of supplement to the Technical Regulations. These like the technical regulations, are meant to ensure uniformity on a worldwide scale in the different aspects of meteorological practices. These are known as WMO guides, and are issued on different subjects viz. "The Guide to Instruments and Methods of Observations", "The Guide to Climatological Practice", etc.

1.1.2.4 International Cloud Atlas

Another publication is the Cloud Atlas. This publication consists of a large number of illustrations of cloud formation, many of them in colour, together with relevant descriptions and classifications of the different types of clouds and provide authoritative information for identifying different cloud forms.
1.1.2.5 International Meteorological Tables

This publication contains a set of tables established in conformity with the various definitions and physical values adopted by WMO. This publication was intended to complement other WMO publications, in particular technical regulations. These tables are suitable for use by both meteorologists and scientists of other disciplines for documentation and routine meteorological work. This publication contains the following tables:

1. Conversion tables
2. Tables of dynamics of the atmosphere
3. Tables of atmospheric statistics
4. Tables of atmospheric thermodynamics
5. Astronomical and geodetic tables

1.1.2.6 International Meteorological Vocabulary (WMO No.182 TP 91)

This publication consists of three main parts, the multilingual meteorological nomenclature, the international meteorological definitions and the alphabetical indexes. The nomenclature contains the equivalent in the four official languages of WMO—English, French, Russian and Spanish—of terms used by meteorologists throughout the world. This is followed by the definitions of these same terms in the English and French languages. The alphabetical indexes are given in the four languages.

The main purpose of the vocabulary is to help standardise the use of meteorological terms, but an important secondary object is to provide a set of concise definitions of the terms often appearing in meteorological literature, particularly in WMO documents and publications.

1.2 ICAO Publications

A wide variety of technical, economic and legal publications is produced by the ICAO. These publications include such items as "Procedures for Air Navigation Services", "Annexes to the ICAO Convention", "Air Navigation Regional Plans", "Aircraft Accident digest" etc. The main publications dealing with meteorological service to aviation are briefly mentioned below:

1.2.1 "Annexes" to the ICAO Convention

In the air navigation field, a major objective of ICAO has been the establishment of "Standards and Recommended Practices", the uniform application of which is necessary or desirable for the operation of safe and efficient air services. Such standards are intended to ensure that there will be a high level of safety and that error and accident will not occur because of misunderstanding of procedures or lack of familiarity with equipment. At present there are fifteen sets of international standards and recommended practices which have been adopted by the ICAO Council as Annexes to the Convention on International Civil Aviation.
Annex 3 – Meteorology

Out of the fifteen Annexes, the Annex 3 concerns Meteorology and contains the standard and recommended practices in respect of aeronautical meteorological codes, meteorological communications and meteorological services.

Other Annexes

Other annexes of interest in the provision of met. service to aviation are:


Annex 5 – Dimensional units to be used in Air-Ground Communications – dealing with the reduction in the variety of dimensional systems for use in air-ground communications.

Annex 6 – Operation of Aircraft – Specifications which will ensure, in similar operations throughout the world, a level of safety above a prescribed minima.

Annex 10 – Aeronautical telecommunications – Standardisation of communication systems and radio navigation aids.

Annex 11 – Air Traffic services – Establishment and operations of air traffic control, flight information and alerting service.

Annex 13 – Aircraft accident Inquiry – Uniformity in the notification, investigation and reporting on aircraft accidents.

Each contracting state is bound to put the annexes into practice or to notify ICAO of any differences between its own practices and those established by the international standards.

1.2.2 Procedures for Air Navigation services (PANS)

These documents lay down in detail the procedures to be adopted in the provision of different types of service to Air Navigation. Such of the PANS dealing with meteorology are described below:

Procedures for Air Navigation Services – Meteorology (PANS-MET)

Doc. 7605/MET/526

This is the main document laying down the procedures of the different aspects of meteorological service to Aviation such as Information to Pilots-in-command, Air traffic services units, Operators etc., information for Flight Planning, Briefing and documentation etc. The day-to-day service to both international and national civil aviation is provided as per the procedures laid down in this document and the entire efficiency of the operational meteorological personnel depends upon a thorough knowledge of the structure of the contents of this document. The other PANS of interest to the met. personnel are:

(iii) PANS-ABC (Procedures for Abbreviations and Codes) – Doc. 8400.
1.2.3 Regional Plans

As a result of air navigation meetings held in each of the eight ICAO regions, meetings which examine the requirement for air navigation and specify the facilities and services and procedures that are found necessary, detailed regional plans are drawn up as mentioned earlier. A major effort is made by ICAO to secure implementation of the regional plans by the states of each region. Major changes in these 'Plans' are made by the periodical Regional Air Navigation meetings of the Regions concerned and finally approved by ICAO Council. India is concerned with the implementation of the Regional Air Navigation Plan for the MID/SPA Region — Doc.8700. The RAN Plan for EUM Region (European-Mediterranean), and AFIRegions (African-Indian Ocean) are also of interest to India in the provision of meteorological service to International air navigation.

On the meteorological side, the Plans contain generally the following tables:

- **Table 1** - Types of meteorological offices at the different aerodromes and facilities available there at.
- **Table 2** - Exchange of operational meteorological information.
- **Table 4** - Stations for MID RTT Broadcasts.
- **Table 5** - Volmet Broadcasts
- **Table 6** - Area Forecast System
- **Table Appendix A** - Storm Warnings

1.2.4 Other Publications

Other publications of interest are as follows:

1.2.4.1 ICAO Location Indicators (Doc.7910)

This document contains a list of four-letter location Indicators for geographical locations throughout the World and a list of addresses of centres in-charge of FIR and/or UIR. These indicators are to be used in all aeronautical messages in place of station names.

1.2.4.2 Manual of the ICAO Standard Atmosphere — (Doc.7488)

This is a very important and necessary document in a forecasting office as it contains a detailed specification of the ICAO Standard Atmosphere together with tables showing the detailed characteristics of the standard atmosphere. The data in the tables of the standard atmosphere are given in terms of the basic units and also in derived metric and English units.

The Manual also gives in the beginning, the basic concepts and formulae, followed by relationships between variables and then by derived quantities. Units and conversion factors are arranged in suitable tables.
1.2.4.3 Manual of Aeronautical Meteorological Practice - Doc. 8896-AN/693

This manual concentrates mainly on codes and message forms for aeronautical meteorological reports and forecasts. It also contains other pertinent information on operational meteorological requirements and procedures likely to be of interest to flight crews and other aeronautical personnel. Most of this information is a summary appearing in ICAO documents but is presented in a form intended to be more easily understandable, especially to non-meteorological personnel. The material in this document is intended for guidance only and is not intended to replace relevant national instructions or explanatory material.

1.2.4.4 Circular on Terrain Clearance and Vertical Separation of aircraft (Altimeter setting) - Circular No.26-AN/23

This circular describes a method for assessing the height of an aircraft above the terrain during all stages of a flight and for ensuring adequate vertical separation of aircraft during flight while en-route. This circular is also intended to be useful as a general reference on the subject of "altimeter setting".

1.2.4.5 Circular on Runway Visual Range (RVR) Observing and reporting practices - Circular 113-AN/85

This circular reflects current ICAO regulatory provisions and includes information on current practices which has been provided by a number of states. Also included is a detailed technical and theoretical material on the observing and reporting of runway visual range and information on progress with slant visual range determination in view of the close relationship between the two concepts of runway and slant visual ranges.

1.2.4.6 ICAO Lexicon - Doc. 8291

This lexicon brings together a number of terms, in English, French and Spanish which are relevant to the work of the International Civil Aviation Organisation (ICAO). In addition to strictly aeronautical terminology related to aircraft and their operation, the vocabulary presented in this publication extends to various allied fields to which an important part of ICAO's work is devoted, particularly meteorology and telecommunications. Besides providing a trilingual vocabulary, the Lexicon contains a list of definitions. The appendices to the volume contain lists of abbreviations, literal symbols, tables of units of measurement, and data on various scientific and technical subjects connected with aviation.

****
1. Publications containing information on procedures for meteorological service to Civil Aviation in India are issued by the Director General of Civil Aviation and the India Meteorological Department. These are dealt below in brief.

1.1. DGCA's Publications

These publications deal with all aspects of service to Civil aviation including met. procedures. The important publications are listed below.

1.1.1 AIP – India – Aeronautical Information Publication-India

As mentioned elsewhere, procedures for service to civil aviation are determined by ICAO. Each contracting state applies these procedures either in full or with differences, for service to air navigation in their respective states. The ICAO procedures applicable in India are detailed in this publication. The ICAO procedures for met. service to aviation are applied in India without differences and these procedures are also detailed in one section of this publication. All the procedures laid down in this publication are applicable both to the national and international air services and it is incumbent upon all the operators utilising Indian Airspace to follow these procedures strictly.

1.1.2 ARRADIO

This publication contains details of communication facilities available at different aerodrome stations in India. The met portion of the document gives information on broadcasts of meteorological information made for the benefit of aircraft operations.

1.1.3 Aeronautical Information Circulars (AICs)
Notices to Airmen (NOTAMs) (Class II)

These are issued from time to time indicating the changes in procedures and facilities/ introduced etc. for the benefit of aircraft operations in India. These circulars are also issued in respect of meteorological procedures and facilities, among other subjects.

1.1.4 Aeronautical Fixed Services in India

This publication contains information about the different communication channels available at the various aerodrome stations in India, their hours of operation, channels connecting important stations in neighbouring countries and other general information concerning the communication channels.

1.2. Publications of the India Meteorological Department

Publications issued by the IMD can be divided into two classes: –
(i) General and (ii) Special

1.2.1 General Publications

The general publications deal with the subject of meteorology as it affects aviation, and these are detailed below:
1.2.1.1 India's Climates - Summary for Airmen

This publication gives a short summary of the climates of India for the use of the airmen who have little previous knowledge of the meteorology of the country. The summary of the climates is given for six regions into which India has been divided. The climatic features are summarised first for the regions as a whole and then for each of the divisions comprising the region, with reference to the different seasons of the year. Brief summaries of the climates of Iran, Sri Lanka, Burma, Thailand, Cambodia, Laos and Vietnam have also been added as appendices.

1.2.1.2 Climatological Atlas for Airmen

This publication has been prepared as a companion volume to 'India's Climates - Summary for Airmen' mentioned above. This publication gives in pictorial form, the following information :-

(i) Mean pressure and prevailing wind

(ii) Normal Rainfall and number of rainy days

(iii) Frequencies of days of thunder, duststorm, fog, low cloud amounts and visibility

(iv) Upper winds at 0.5, 1, 2, 4, 6, and 8 kms

1.2.1.3 Meteorology for Airmen

This publication is divided into three parts.

Part I :- General meteorological features

This part deals with the general meteorological features over the country with particular reference to aviation.

Part II :- Climatology of Air Routes

Part II gives the climatological summaries, covering all elements, for the various air-routes radiating from the four main Indian aerodromes, viz., Bombay, Calcutta, Delhi and Madras. The material has been so arranged as to be of assistance to various aviation interests - airline operators, pilots and navigators, as well as air cadets and meteorological personnel appearing for examination in aeronautical climatology. The summary has been prepared for the four different seasons of the year.

Part III :- Climatology of aerodromes

This part deals with the climatology of different aerodromes in India and neighbourhood. Aerodrome weather diagrams of nine important Indian aerodromes and one foreign aerodrome (Cairo), prepared according to Model T of WHO Technical Regulations have also been included in this publication.

1.2.2 Special Publications

These publications deal with the important aspects of actual meteorological service to day-to-day air operations in India as detailed below :-
1.2.2.1 Memorandum on Area Meteorological Watch – SIGMET information

The issue of SIGMET information is one of the important aspects of meteorological service to aviation and is intended to provide aircraft in flight advance notice of actual or impending weather developments or trends that are potentially hazardous to aviation. The SIGMET message would provide information for the use of Flight Information Centres (FICs) in effecting expeditious and safe movement of aircraft under all operating conditions. In addition, it also serves as an aid for the duty forecaster at the aerodrome of departure for pre-flight weather briefing by pinpointing the more critical weather developments during the subsequent few hours. The detailed procedures for issue and supply of SIGMET information by Meteorological Watch Offices in India are dealt with in the above referred to publication.

1.2.2.2 Take-off and Landing Forecasts for Jet Operations

Another important aspect of meteorological service to day-to-day air operations is the issue of "Take-off and Landing Forecasts". Detailed procedures regarding the issue of these forecasts are contained in this publication. The supply of landing forecasts aims at providing the Pilot-in-Command, with an accurate forecast for the aerodrome of landing, so that before commencing descent, the Pilot can make a decision as to whether he can land at that aerodrome.

1.2.2.3 Aviation Weather Codes

This publication contains the different aeronautical meteorological codes used for the transmission of routine reports, selected special reports and different types of forecasts etc., required for service to aircraft operations, together with explanations and specifications of the symbolic figures and letters, and detailed notes on the use of the Codes.

1.2.2.4 Instructions on "Meteorological Service to Air Navigation"

Provision of meteorological service to air navigation consists of different items like supply of flight planning information to the airline operators, provision of briefing and documentation to the Pilot-in-Command, supply of actual and forecast meteorological information to airline operators and aerodrome control units, issue of SIGMET information and airfield warnings etc. The detailed procedures in respect of all such items, as adopted from the ICAO procedures for use in India, are given in this publication, amplifying the provisions by detailed instructions issued from time to time to the different aeronautical meteorological offices in India.

1.2.2.5 Forecasting Manual Report on Aviation Meteorology

This report, of which these Annexes I, II and III form a part, is intended to provide to the aeronautical meteorological forecaster, in a consolidated manner, information on the important procedural aspects of met. service to aviation and about the different meteorological phenomena which are hazardous to aviation in the different phases of aircraft operations. Information on the usefulness of the latest developments like Satellites and Radar, in the rendering of service to aviation has also been included in this report.
# REFERENCES AND SELECTED BIBLIOGRAPHY

## Chapter 1: Aerodrome Forecasts

<table>
<thead>
<tr>
<th>Reference</th>
<th>Date</th>
<th>Description</th>
</tr>
</thead>
<tbody>
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<td>2. -do-</td>
<td>1969</td>
<td>Instructions on &quot;Met. Service to Air Navigation&quot;.</td>
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<tr>
<td>5. -do-</td>
<td>1971</td>
<td>Procedures for Air Navigation Services - Abbreviations &amp; Codes (PANS-ABC-Doc 8400)</td>
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## Chapter 2: Take-off and Landing Forecasts

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<th>Reference</th>
<th>Date</th>
<th>Description</th>
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Chapter 3: Airfield Warnings

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Chapter 4: Area Met. Watch - SIGMET information


2. India Meteorological Department. Office of the DDGF, Poona. 1961 Area Meteorological Watch - SIGMET information.


****
Chapter 5: Some important phenomena which affect aircraft operations

I. General


4. India Meteorological Department


II. Fog


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<th>Author</th>
<th>Year</th>
<th>Title</th>
<th>Journal, Volume, Pages</th>
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<tr>
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**III. Severe Connective Phenomena.**

<table>
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<th></th>
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<th>Title</th>
<th>Journal, Volume, Pages</th>
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<tr>
<td>No.</td>
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<td>Year</td>
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<td>Title</td>
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<th>Reference</th>
<th>Year</th>
<th>Title and Details</th>
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* #*#*
FIG. 6-1 WEATHER RADAR NETWORK IN INDIA
FIG. 6.2 CLOUD DISTRIBUTION ALONG BOMBAY-MAURITIUS ROUTE

FIG. 6.3 SATELLITE PICTURE ON A MONSOON DAY

FIG. 6.4 THUNDERSTORM CLOUDS

FIG. 6.5 JET STREAM CLOUDS
FIG. 6.10 EXTRA TROPICAL CYCLONE
13 OCT. 1967

FIG. 6.11 WESTERN DISTURBANCE
TO THE NORTHWEST OF INDIA.

FIG. 6.12 SEVERE CYCLONIC STORM
IN THE BAY OF BENGAL

FIG. 6.13 INFRA-RED PICTURE OF
A CYCLONIC STORM ON 7 NOV. 69 1800 GMT
FIG. 6.15

(a) IS TAKEN FROM WMO TECH. NOTE 75. IT SHOWS CB TOPS GETTING BLOWN OFF BY STRONG WINDS ALOFT. AT 'A' CAN BE SEEN THE FRAYED EDGES OF THE CB PLUMES AND AT 'B' THE WELL DEFINED EDGES OF THE MAIN CLOUD. (b) GIVES THE SCHEMATIC REPRESENTATION OF THE BRIGHTNESS GRADATIONS OF CB TOPS PLUMES. (c) IS AN AFT PICTURE RECEIVED AT BOMBAY ON 6 DEC 1969 SHOWING THE AREA 75°-85°E AND 5°S-10°N WHERE LARGE NUMBER OF CB CLOUDS WITH PLUMES CAN BE SEEN.

(d) STREAMLINES ANALYSIS OF THE 200 MB CHAFT WHERE THE OBSERVED WINDS ARE PLOTTED IN THE CONVENTIONAL MANNER AND ESTIMATED WINDS ARE INDICATED BY ARROWS.
APPENDICES

to

CHAPTER-7
**APPENDIX I - TABULAR FORM OF FORECAST**

**Serial No.**

**MET-T-3**

**FLIGHT AND AERODROME FORECASTS**

**Flight No.** 1C 529  
**Route** MADRAS TO TRIVANDRUM

**Issued by** CLASS I Meteorological Office at MEENAMBKAM

**At** 0700 GMT 17-10-1973

**By** C.R.

---

**FLIGHT FORECAST**

<table>
<thead>
<tr>
<th>PRESSURE ALTITUDES</th>
<th>VOMM</th>
<th>LAT, 10°N</th>
<th>VOTV</th>
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<tr>
<td></td>
<td>7200m</td>
<td>120/20</td>
<td>120/15</td>
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<tr>
<td></td>
<td>5600m</td>
<td>090/03</td>
<td>090/15</td>
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<td></td>
<td>4200m</td>
<td>090/02</td>
<td>090/15</td>
</tr>
<tr>
<td></td>
<td>3000m</td>
<td>070/00</td>
<td>050/10</td>
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**LOWEST LAYER**

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<tr>
<th>Amount and Type</th>
<th>Altitude (ft)</th>
<th>Temperature (°F)</th>
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<tbody>
<tr>
<td>SCT CU</td>
<td>6000 m</td>
<td>30°C</td>
</tr>
<tr>
<td>ISOL CB</td>
<td>6000 m</td>
<td>30°C</td>
</tr>
<tr>
<td>SCT CU</td>
<td>9000 m</td>
<td>30°C</td>
</tr>
<tr>
<td>OCNL CB In Sh</td>
<td>9000 m</td>
<td>30°C</td>
</tr>
<tr>
<td>BKN ST</td>
<td>2500 m</td>
<td>30°C</td>
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</table>

**CLOUD**

<table>
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<th>Amount and Type</th>
<th>Altitude (ft)</th>
<th>Temperature (°F)</th>
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<tr>
<td>SCT AC</td>
<td>3000 m</td>
<td>30°C</td>
</tr>
<tr>
<td>BKN AS</td>
<td>3000 m</td>
<td>30°C</td>
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**SURFACE VISIBILITY**

| 9 km becoming 3000 m in ISOL SH |

**SIGNIFICANT WEATHER**

| ISOL TS/SH. MOD to SEV TURB IN CB |

**PRESSURE ALTITUDE OF O'C ISOThERM**

| 4600 m |

**LOWEST MSL PRESSURE**

| — |

**REMARKS**

| — |
## AERODROME FORECASTS

<table>
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<tr>
<th>Location indicator</th>
<th>Period of validity (G.M.T.)</th>
<th>Time and Type of variation (G.M.T.)</th>
<th>Surface wind mean Direction(Degrees True) Mean Speed (Knots) Maximum wind speed if forecast (Knots)</th>
<th>Surface visibility</th>
<th>Weather</th>
<th>C l o u d</th>
<th>REMARKS</th>
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<tr>
<td>VOMM</td>
<td>09-15</td>
<td>090/10</td>
<td>9 km.</td>
<td>–</td>
<td>3 SC 600m</td>
<td>5 AC 3000m</td>
<td>(e.g. outstanding features of meteorological situation such as frontal passage etc. and pressure, temperature and humidity information as required and as available) Temperature in °C.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TEMPO 09/15</td>
<td>4500m</td>
<td>RA</td>
<td>3 ST 240m</td>
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<td>VOTIV and VOCC</td>
<td>09-15</td>
<td>280/10</td>
<td>9 km.</td>
<td>–</td>
<td>3 SC 600m</td>
<td>5 AC 3000m</td>
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<td>7 AS 2700m</td>
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</table>

**HEIGHT** - Vertical distance from official aerodrome level.
The flight forecast and aerodrome forecasts were based upon the following synoptic features which were observed on the morning of 17-10-73.

*****

1. **OO GMT Surface Chart:** A low pressure area which was lying over Southeast Bay on 16-10-73 had moved to Southwest Bay and was lying off South Tamil Nadu Sri Lanka Coasts.

2. **Upper air conditions:** The associated cyclonic circulation over Southwest Bay was found extending from surface upto 4.5 KM A.S.L. A wind discontinuity at 850 MB was extending from Tricomalee to Minicoy i.e. roughly along Lat. 08°N.

3. **Constant Pressure Charts:** The low over Southwest Bay was seen between 850 and 500 MB.

4. **Inference:** Under the influence of the low, moist air incursion was taking place over south peninsula south of Lat. 13°N.

5. **Past weather:** Madras, Cuddalore and Cochin reported precipitation and CB development at 00Z. Madras and Cochin had also reported Thunderstorm at 00Z. Fairly widespread rain had occurred over south Peninsula south of Lat. 10°N. SCT rain had occurred over North Coastal Tamil Nadu and South Interior Mysore.

6. **Weather seen in 03 and 06 Z surface charts and forecast for VOMM-VOTV route:**

   Weather had improved over the entire south peninsula. Weather was, however, expected to deteriorate with convective activity normally occurring after 09Z, convergence at lower levels occurring over south peninsula and the further westward movement of the low pressure area over southwest Bay. Hence ISOL CB development upto LAT. 10°N and OCNL CB development between Lat. 10°N and VOTV was forecast for the route VOMM - VOTV.

**Aerodrome forecasts:**

**VOMM:** Taking into account the diurnal variation of TS activity over Madras in the month of October and the synoptic situation, only rain was forecast over Madras till 1500 Z.

**VOTV and VOCC:** Not much distinction could be made between the aerodrome forecasts for VOTV and VOCC under the prevailing synoptic situation. Surface wind from a westerly direction could be expected to be gusty and reach Max. 20K, with the development of large CU/CB, even in the neighbourhood. TEMPPO TS was also expected due to the low level convergence occurring over this area and the indication given by past weather. Squall was not expected. (Frequency of squall being zero in the month of October).

**VOMD:** Surface wind was expected to be Northwesterly with the surface low lying over South Bay and isobars having a N-SW orientation. The low level convergence over this area was much less compared to the area further south (line of discontinuity lies roughly along Lat. 08°N). A TEMPPO SH/TS with 2/8 CB development was; however, expected due to the presence of low over South Bay. The Surface wind from a NW-ly direction was normally expected to reach MAX 20 KTS with development of large CU/CB even in the neighbourhood. A squall of 35 K from a NW-ly direction was expected in association with TS.

*****
FLIGHT FORECAST

Issued by: CLASS I
Weather Office at: VOMM
Time of origin: 0700 GMT
Date: 3 DEC 1972
Track: DIRECT

SECTION 2: TABULAR - ANALOGUE - PICTORIAL
CORORDINATE - SECTIONAL FORM OF FORECAST

SECTIONS OF ROUTE

SYMBOLS FOR SIGNIFICANT WEATHER

THUNDERSTORM
TROPICAL REVOLVING STORM
SEVERE LINE SQUALL
RAIN
MODERATE TURBULENCE
SEVERE TURBULENCE
MODERATE AIRCRAFT Icing
SEVERE AIRCRAFT Icing
MARKED MOUNTAIN WAVES
WIDE SPREAD SMOKE OR DUST STORM
FREEZING RAIN
CLEAR AIR TURBULENCE
SPECIAL FEATURES OF THE METEOROLOGICAL SITUATION

FLIGHT LEVEL

U.S. NATIONAL WEATHER SERVICE

FLIGHT LEVEL

VECC
ZON
IBM
VOMM

FLIGHT LEVEL

310
480
450
420
390
360
330
300
270
240
210
180
150
120
90
60
30
10

0500/3 DEC 1972

SPECIAL FEATURES OF THE METEOROLOGICAL SITUATION

SEVERE CYCLONIC STORM LOCATED AT 08/0000 GMT "NEAR LAST KNOWN LOCATION": LIKELY MOVE WEST, LANDFALL LIKELY NEAR LAT. 50N AT ABOUT 31E 1200 GMT.

UPPER WIND

140 VRB/03 +03
300 VRB/03 +09
70 VRB/03 +14
50 VRB/03 +17

UPPER WIND "NEAR":

140 VRB/03 +03
300 VRB/03 +09
70 VRB/03 +14
50 VRB/03 +17

BASE OF LOW CLOUD IN FLIGHT LEVEL

30 DEC 06 IN RASH
10 DEC 03 IN HYSRH

SIGNIFICANT WEATHER

SCT RASH / TS
FAIRLY WIDESPREAD RA SQUALL / HYSRH

LOWEST M.S.L. PRESSURE

1012 MB
1008 MB

REMARKS

STRONG NORTHWESTERLY SURFACE WINDS OCCASIONALLY REACHING GALE FORCE LIKELY OCCUR OVER VOMM FIELD.
<table>
<thead>
<tr>
<th>Location Indicator</th>
<th>Period of Validity (GMT)</th>
<th>Time and type of variation (GMT)</th>
<th>Surface wind mean direction (Degrees True) Mean speed (knots) Maximum wind speed if forecast (knots)</th>
<th>surface visibility</th>
<th>Weather</th>
<th>Amount and Type, Height of Base (Height of Tops if forecast)</th>
<th>Amount and Type, Height of Base (Height of Tops if forecast)</th>
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<td>12/14</td>
<td>020/05</td>
<td>3000M</td>
<td>-</td>
<td>S KC</td>
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GOVERNMENT OF INDIA  
INDIA METEOROLOGICAL DEPARTMENT  
METEOROLOGICAL OFFICE  
CALCUTTA AIRPORT  
CALCUTTA-52.

Forecast for upper winds and temperatures issued by Met. Office Calcutta  
T.O.O. 0600 Z valid from 0900 Z to 1600 Z for IC  
of 5th Dec., 1972.

<table>
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<th>Flight level/pressure altitude (Metre)</th>
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<td>070/20</td>
<td>17</td>
<td>070/40</td>
<td>14</td>
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</table>

Freezing level: 165 → 165 → 175

SCT/TS/RASH South of 15 N

Fairly widespread rain squalls/Heavy showers.

Significant weather

MOD/SW TURB AND SW ICING

Duty Forecast

Date: 5/12/72
Take off data expected at 050900 for . . . . . . . . . . . . . . . . (Name of Airlines with service No) . . . . . . . . . . . .

Surface Wind ... 020/08
Temperature ... + 28
QNH ... 1011.5 MB
QFALT ... +62 feet.

Issued at . . . . . . . . . .

By . . . . . . . . . . . . . . . . .
Note regarding the principles followed in depicting Temperature, winds etc. in the Flight Forecast

****

1. On this day, a severe cyclonic storm was off Tamil Nadu coast. The general principles followed in depicting the various elements in this flight forecast are detailed below.

2. Synoptic situation

In view of the continuous round-the-clock watch being kept on weather, it would not be very difficult to locate a storm or follow its movement. Besides, for a system located in South-West Bay of Bengal the inferences of storm warning centres of Madras and Calcutta are consulted. The satellite weather bulletins are also available. In future, these storms will also be tracked by the Cyclone Warning Radars when these storms are near the coast. So, no special principles need be detailed in indicating the particular synoptic situations in case of cyclonic storms.

The storm was located at 12 N and 81.5 E (based on continuity, ships observation and the APT bulletin at 03 Z), a few hours earlier than the time of origin of forecast and about 12 hrs. before the expected time of arrival of aircraft at Madras. The storm was, therefore, about 150 Km off the coast. From the 03 Z charts it was also seen that the maximum pressure fall was at Cuddalore, and from the earlier history of the system it was inferred that the system would move west and the landfall would be near Cuddalore. With the normal speed of movement of 10 kmph, the storm was expected to strike coast about 15 hrs. after the chart time i.e. at 18 Z. But it is known that on many occasions the speed of movement reduces when the storm is close to coast and so it was expected that the land fall would be at 21 Z.

3. Upper winds

From the expected movement of the storm it was inferred that winds south of 18 N would come more into the grip of the system and some veering (in the Northern sector of the system) and strengthening would take place and later as the system moved West some backing (in the Southern sector) would also occur. Taking all these aspects into consideration the upper winds were indicated.

4. Upper Temperature

It is known that a tropical storm is of warm-core structure. However, in the lower levels due to cloud cover, precipitation etc. the temperatures near the storm area will be lower than those in the surrounding area. In the middle troposphere level the warm-core characteristic might be discerned and temperature may be slightly higher. This aspect was kept in view in indicating temperatures. This is also the reason for a probable abrupt rise of freezing level, though the rise was rather small.

5. Weather and cloud coverage

With a strong system in the South-West Bay, it may be seen in the 00Z wind chart that an anticyclonic sink area had developed over Orissa-Gangetic West Bengal in the lower and mid-troposphere. So, practically clear skies were expected from Calcutta to 20 N. However some high level Cirrus clouds diverging from the storm field could be expected over this area. In the middle sector from 20 N up to 17-18 N some medium clouds (AC) and low clouds SC and CU were expected. Towards 15 N at a distance of 300-400 Km (200 - 250 NM) the weather would start. This was also confirmed from the clouds and weather along the coast on the 03 Z chart. The SC clouds were seen from visag changing to cumuliform clouds near Ongole. With the system moving in, thunderstorm and rain would start from 16 N at the time the
Aircraft was expected to fly over the area. The weather from 15 N to Madras was naturally expected to be very bad with frequent CB, occasional rainsqualls, heavy showers and overcast clouds consisting of various types including low Stratus. Visibility would be considerably poor in heavy showers. The actual quantitative estimates of visibility and height of low clouds may vary very little from that expected by experience. In addition to severe turbulence and icing associated with CB clouds, moderate turbulence in CU clouds was also indicated. In the remarks column the likelihood of strong surface winds reaching occasionally gale force over VSNM was also given.

6. Aerodrome forecasts

   The same principles as outlined in para 5 have been adopted in framing the Aerodrome forecasts.

7. Take-off data

   The items enclosed with the model documentation are the standard requirement. QFE ALT. has been expressed in feet as preferred by the Airlines.