INVESTIGATIONS DIVISION TECHNICAL NOTE No.18

The data-set of pilots' reports collected during the 1976 Turbulence Survey.

by M.J.O. Dutton

April 1980

The data set of pilots' reports collected during the 1976 turbulence survey

Introduction

In the spring of 1976 a survey of turbulence experienced by aircraft was organised by the British Meteorological Office and carried out with the help of the meteorological services of Austria, Belgium, Denmark, Federal Republic of Germany, France, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland and USA.

The survey was made by issuing specially printed maps to pilots on ten 'Turbulence Reporting Days' and asking them to record on the maps complete turbulence histories of their flights on those days. The turbulence reporting days were 9, 12, 15, 18, 21, 24, 27 and 30 March 1976 and 2 and 5 April 1976. A map was issued to any pilot who was expected to make a flight of more than 200 km within the area of the map on a turbulence reporting day (0001 to 2359 GMT).

Two types of map were issued, one for Atlantic flights (Figure 1) and another for European flights (Figure 2). On the back of each map there was information about the survey and an example of the type of report required. The ICAO criteria for Moderate and Severe turbulence were also listed. (Figure 2a).

The response of pilots to the request for turbulence reports was quite good. About 4500 useful flight reports were received.

Each map received was given a unique four-digit number and, after coding, the data were sorted first in order of date and then in order of map number. The format of the data stored on magnetic tape is given in appendix IV.

Coding of the pilots' reports

For the purpose of coding, a flight was divided into discrete legs. A new leg was started whenever the pilot reported the time or when there was a significant change of direction of flight, intensity of bumpiness or cloud. The last three items were assumed constant throughout the leg. At the start of each leg the latitude and longitude (to the nearest 0.1 degrees), the flight level (hundreds of feet, pressure altitude) and the time (hours and minutes GMT) were recorded; it was assumed that these items changed at a constant rate along the leg and that their values at the end of a leg were the same as those values given at the start of the subsequent leg.

The symbolic form of the code is given in appendix I and the instructions issued to coders are reproduced in appendix II.

Table 1 is the coded version of the standard reports from a hypothetical flight, depicted in figure 3, and table 2 shows the associated special (plain language) reports entered on an ordinary 80-column FORTRAN Coding Form. A special report may be a wind, a report of a rapid temperature change, special cloud information or any other information that cannot be coded in the form of a standard report.

Quality Control of the data

Some items of the coded reports could easily be efficiently checked by a computer program, but others could only be effectively checked by visual inspection. The quality control process was therefore carried out in stages.

Stage 1 — A computer program checked the following items:-

Item	Check
MAP NUMBER	- Constant throughout a flight and different from all other map numbers.
DATE	- A valid turbulence reporting day.
SEQUENCE NUMBER	- Ø1 for the 1st leg of a flight, incremented by one for subsequent legs.
TIME	- Between ØØØ1 and 2359, and increasing throughout the flight.

When only two times were reported a check was made to ensure that the implied aircraft ground speed fell within reasonable limits; these limits were dependent of the length of the leg.

When more than two times were reported the average speed was calculated from the first and last reported times, and all intermediate times were estimated assuming constant ground speed. The agreement of estimated and reported times was tested using the relationship given in appendix III. Occasionally reported times did not satisfy that relationship even though they were coded exactly as the pilot had reported; if there was no obvious error in such cases, the reported times were not changed.

Having established that the reported times were valid, the time of start of any leg that did not with a reported time was estimated using the two nearest reported times.

FLIGHT LEVEL = Within the range 5∅ to 45∅

If the flight level group is 3888 the group 5BCQ must be 5998.

LATITUDE AND LONGITUDE = Within the area of the reporting map.

5BCQ = When 5BCQ = 5998, flight level group = 3888

The last leg of a flight must have 5BCQ = 5999

If C = 7, Q must be greater than 5.

If B or C or Q = 9, then BCQ = 999 or 998.

Stage 2

After a flight had passed the stage 1 check, a computer program produced, on film, from the coded report, a copy of the flight path and those parts of the report that required a visual check. Figure 4 shows a print from the film that was made for the flight shown in figure 3. The film was then projected onto the original map to ensure that the coded flight path was coincident with the reported path (within 0.2 degrees of latitude or longitude) and that the date, time, flight level and BCQ were correctly coded.

Stage 3

If any change had to be made as a result of the stage 2 check, the corrected flight report was submitted to a check similar to that at stage 1. Tests were also included to ensure that the item in the report which required correction had been altered and that no other item had been changed. If these tests failed, or if the latitude or longitude was changed, a film of the flight was produced and the stage 2 check repeated.

Stage 4

Special reports and standard reports were matched by a computer program to ensure that whenever the Q-code in the standard report indicated a special report, that report existed, and that for every special report there was a pointer (Q = 6, 7 or 8) in the standard reports.

Finally in an attempt to ensure that the corrections made had not introduced other errors, the whole data-set was re-subjected to the stage 1 and stage 3 checks.

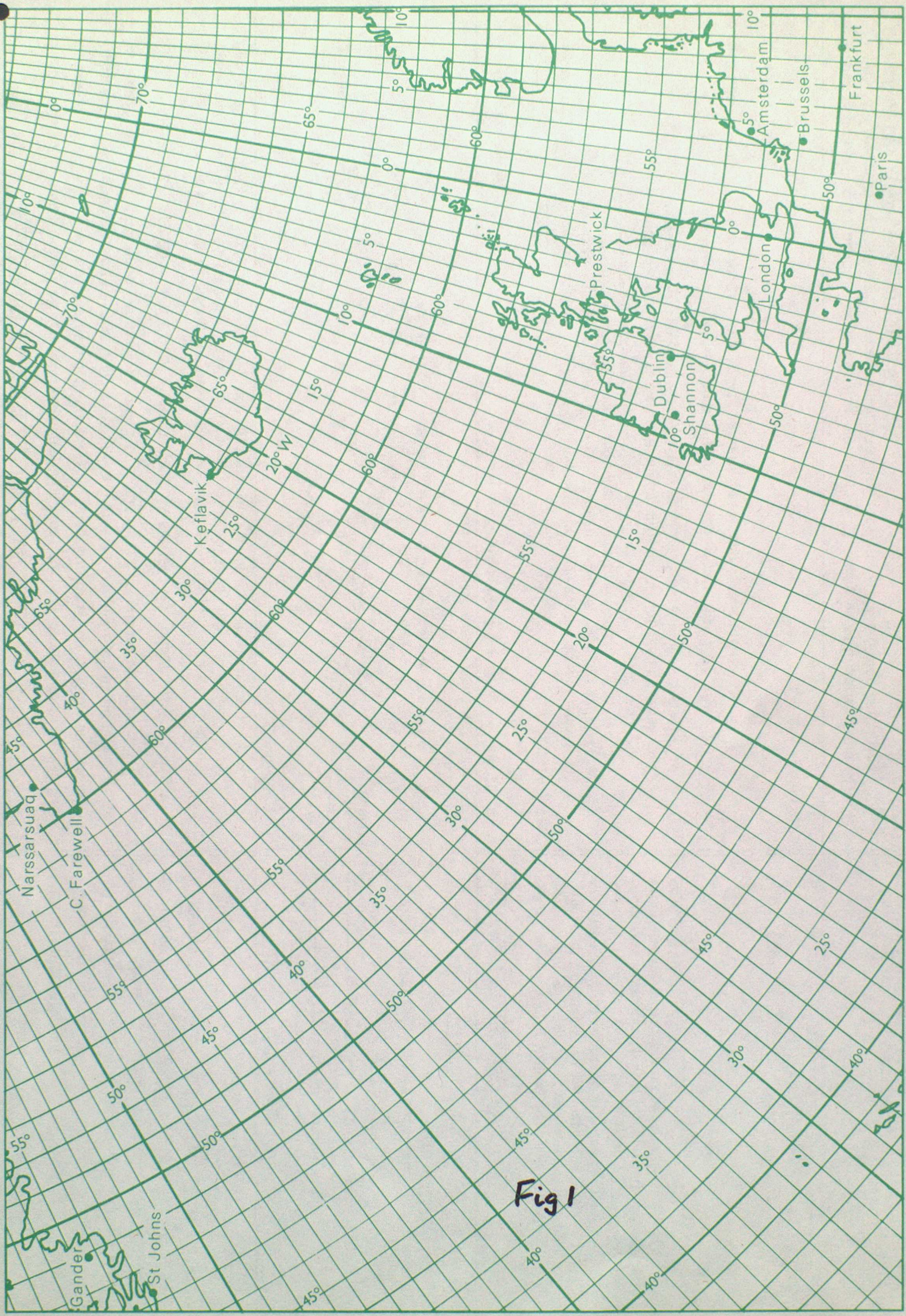

Amsterdam
Brussels
Frankfurt
Paris
London
Prestwick
Dublin
Shannon
Keflavik
20° W
Narssarsuaq
C. Farewell
Gander
St Johns

Fig 1

METEOROLOGICAL OFFICE TURBULENCE SURVEY

These maps are being issued on a few chosen days in order to help assess techniques of forecasting CAT. Captains are asked to complete the flight information section on the right and to describe the turbulence history of the cruise stage of their flight on the map overleaf. All turbulence, whether in cloud or in clear air, should be reported.

REPORTS OF NO TURBULENCE ARE AS IMPORTANT AS REPORTS OF TURBULENCE

For all points of the cruise stage within the area of the map indicate the track, flight level, and turbulence encountered. Mark the time (GMT) at convenient intervals. When LIGHT, MODERATE, or SEVERE turbulence is encountered show any cloud in the vicinity as in the example below.

Flight information

Date...

Aircraft type...

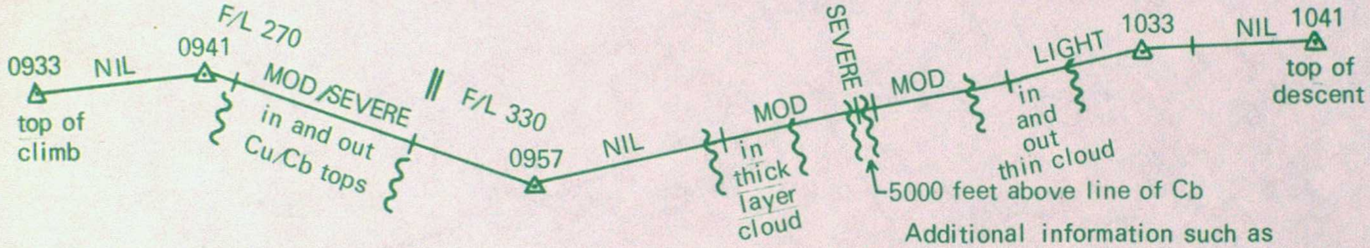
Company/Unit...

Flight number...

Departed.................................at..................GMT

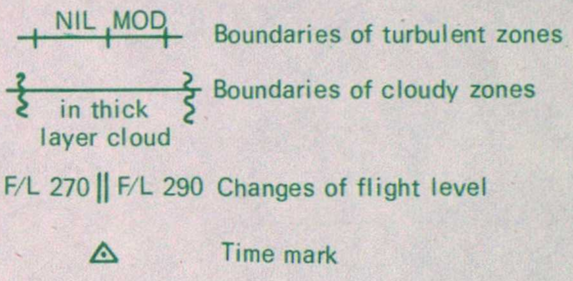
Arrived.................................at..................GMT

Example



Additional information such as wind measurements would be most welcome

Key



Turbulence criteria

(Based on ICAO Doc.8812, AN-CONF/6, 1969)

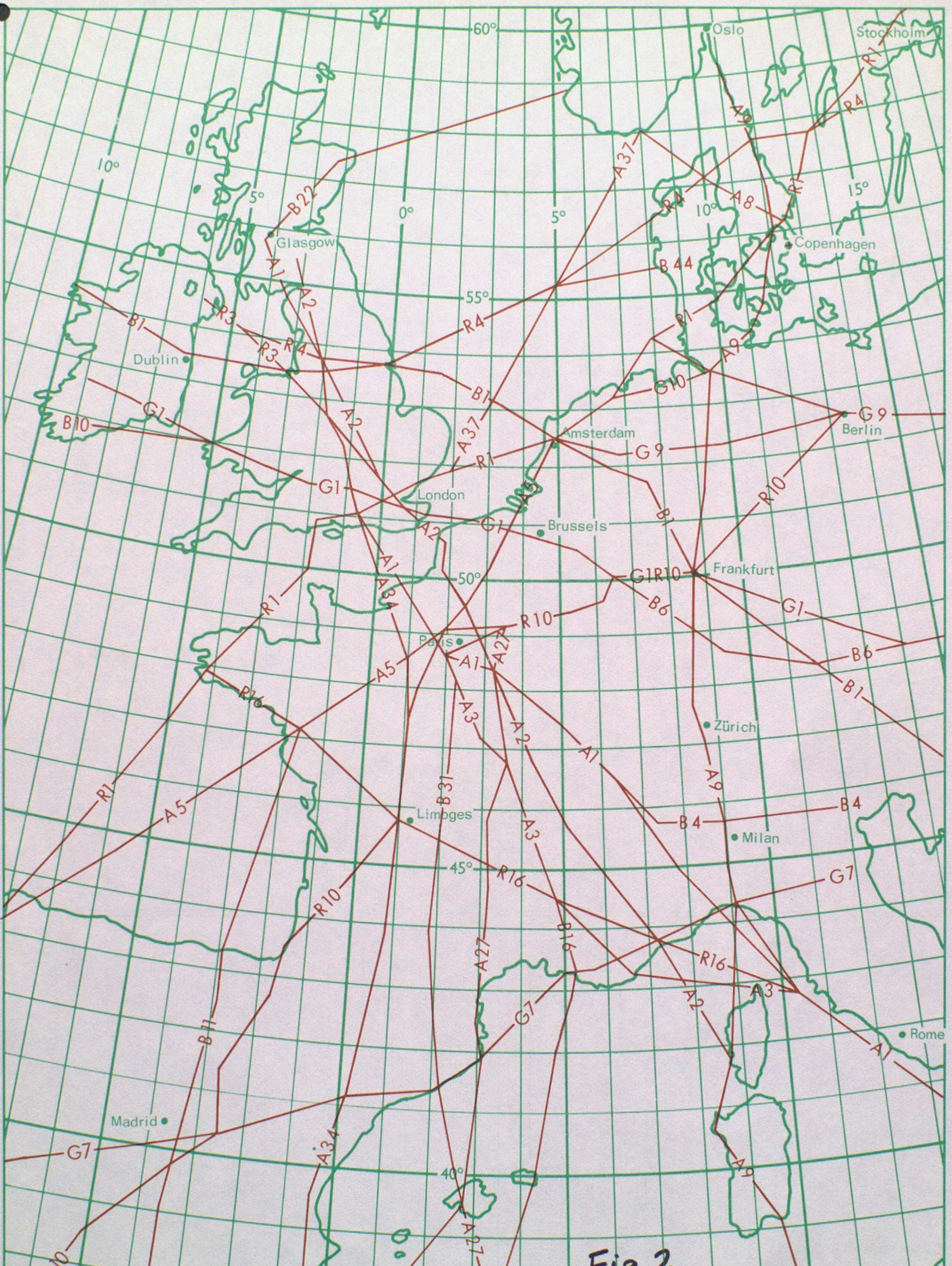
Description	Effects
Moderate	Moderate changes in aircraft attitude and/or altitude but the aircraft remains in positive control at all times. Variations in air speed are usually small. Loose objects move about. Occupants feel strain against seat belts. Peak changes in accelerometer readings at c.g. of 0.5 g to 1.0 g.
Severe	Abrupt changes in aircraft attitude and/or altitude. Variations in airspeed are usually large. Loose objects tossed about. Occupants are forced violently against seat belts. Peak changes in accelerometer readings at c.g. of more than 1.0 g.
Light/extreme	may be reported when effects are less/greater than these.

The reasons for this survey

A CAT survey in 1972 showed that a report of CAT from another pilot within one hour was more reliable than a forecast of CAT, but when the other pilot's report was more than three hours old the forecast was better.

The objects of this survey are to improve CAT forecasts and to find ways of combining recent reports from pilots with meteorological forecasts to make CAT warnings more reliable

Captains are asked to hand maps to a British meteorological office or to their company representative at their destination to be sent to The Director-General, Meteorological Office (Met O 9), London Road, Bracknell, Berks RG12 2SZ, U.K.



60°
Oslo
Stockholm
10°
5°
0°
5°
10°
15°
Glasgow
Copenhagen
55°
Dublin
Berlin
Amsterdam
London
Brussels
Frankfurt
50°
Paris
Zürich
Limoges
Milan
45°
Rome
Madrid
40°
Algiers

Fig 2

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REPORTS OF NO TURBULENCE ARE AS IMPORTANT AS REPORTS OF TURBULENCE

For all points of the cruise stage within the area of the map indicate the track, flight level, and turbulence encountered. Mark the time (GMT) at convenient intervals. When LIGHT, MODERATE, or SEVERE turbulence is encountered show any cloud in the vicinity as in the example below.

Flight information

Date ....

Aircraft type ....

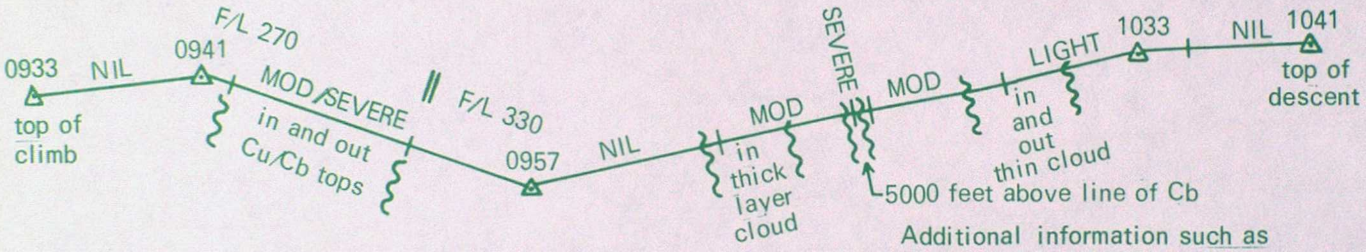
Company/Unit ....

Flight number ....

Departed .... at .... GMT

Arrived .... at .... GMT

Example



Additional information such as wind measurements would be most welcome

Key

NIL MOD — Boundaries of turbulent zones

in thick layer cloud — Boundaries of cloudy zones

F/L 270 || F/L 290 — Changes of flight level

△ — Time mark

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(Based on ICAO Doc.8812, AN-CONF/6, 1969)

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Moderate	Moderate changes in aircraft attitude and/or altitude but the aircraft remains in positive control at all times. Variations in air speed are usually small. Loose objects move about. Occupants feel strain against seat belts. Peak changes in accelerometer readings at c.g. of 0.5 g to 1.0 g.
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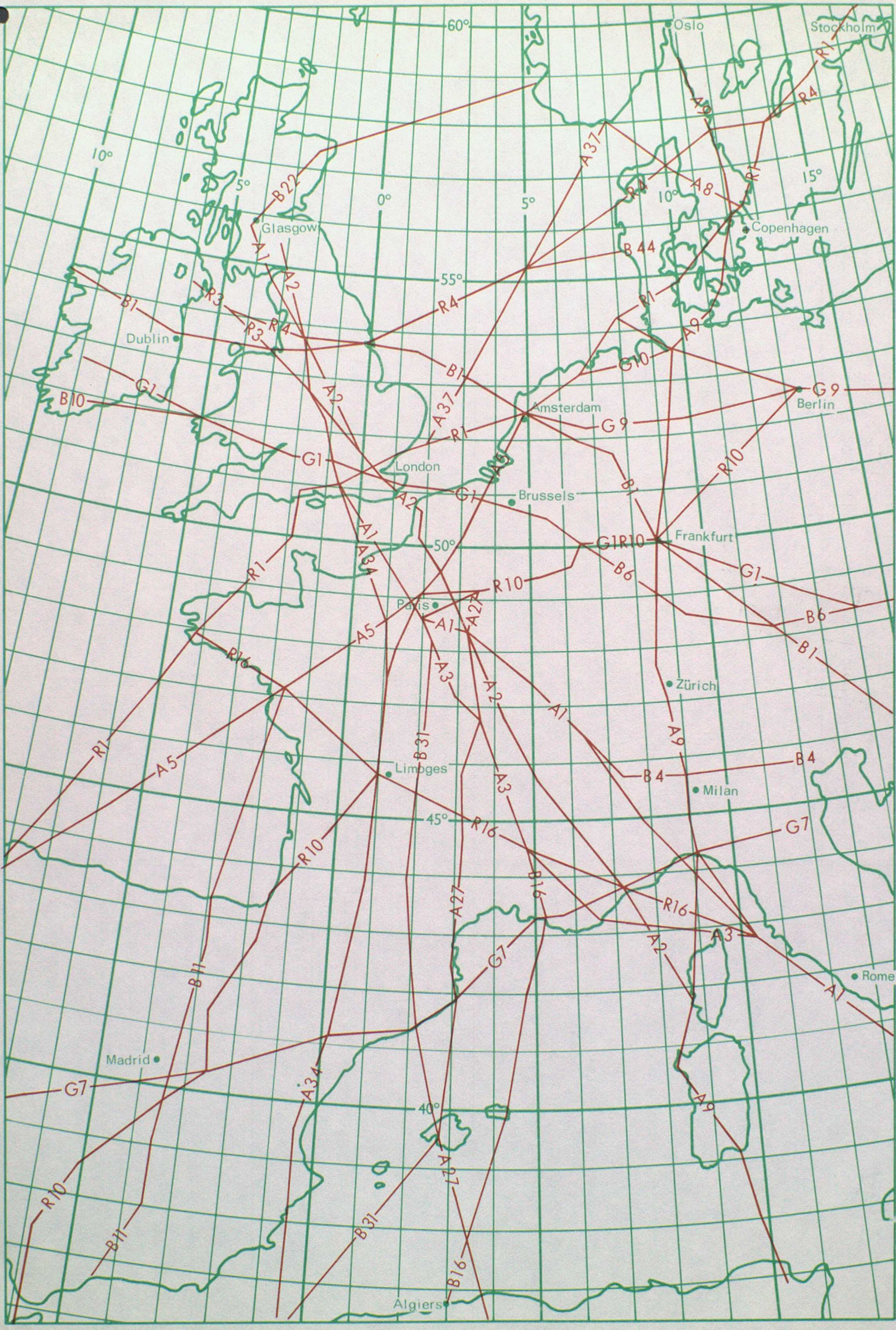

60°
Oslo
Stockholm
10°
5°
0°
5°
10°
15°
Glasgow
Copenhagen
55°
Dublin
Berlin
Amsterdam
London
Brussels
50°
Frankfurt
Paris
Zürich
Limoges
Milan
45°
Rome
Madrid
40°
Algiers
R1
R4
A9
A37
A8
B22
B44
A1
A2
R3
B1
G10
G9
G1
B10
A5
R10
A3
A34
A27
B6
B4
B31
R16
G7
B16
B11

METEOROLOGICAL OFFICE TURBULENCE SURVEY

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Flight information

Date ....

Aircraft type ....

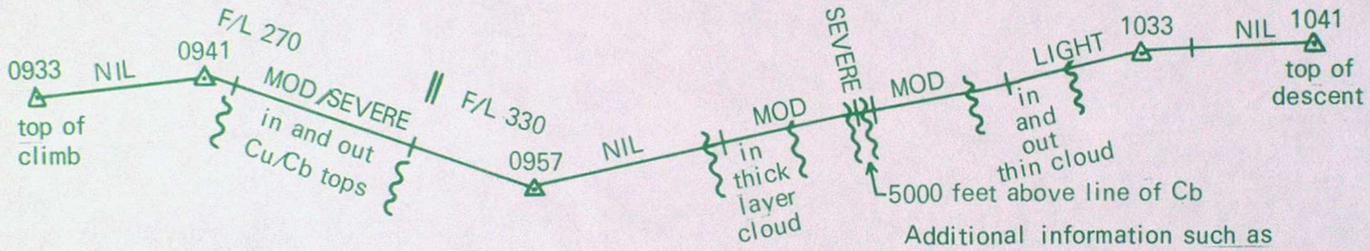
Company/Unit ....

Flight number ....

Departed .... at .... GMT

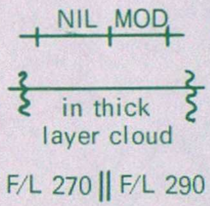
Arrived .... at .... GMT

Example



Additional information such as wind measurements would be most welcome

Key



Boundaries of turbulent zones

Boundaries of cloudy zones

Changes of flight level

Time mark

Turbulence criteria

(Based on ICAO Doc.8812, AN-CONF/6, 1969)

Description	Effects
Moderate	Moderate changes in aircraft attitude and/or altitude but the aircraft remains in positive control at all times. Variations in air speed are usually small. Loose objects move about. Occupants feel strain against seat belts. Peak changes in accelerometer readings at c.g. of 0.5 g to 1.0 g.
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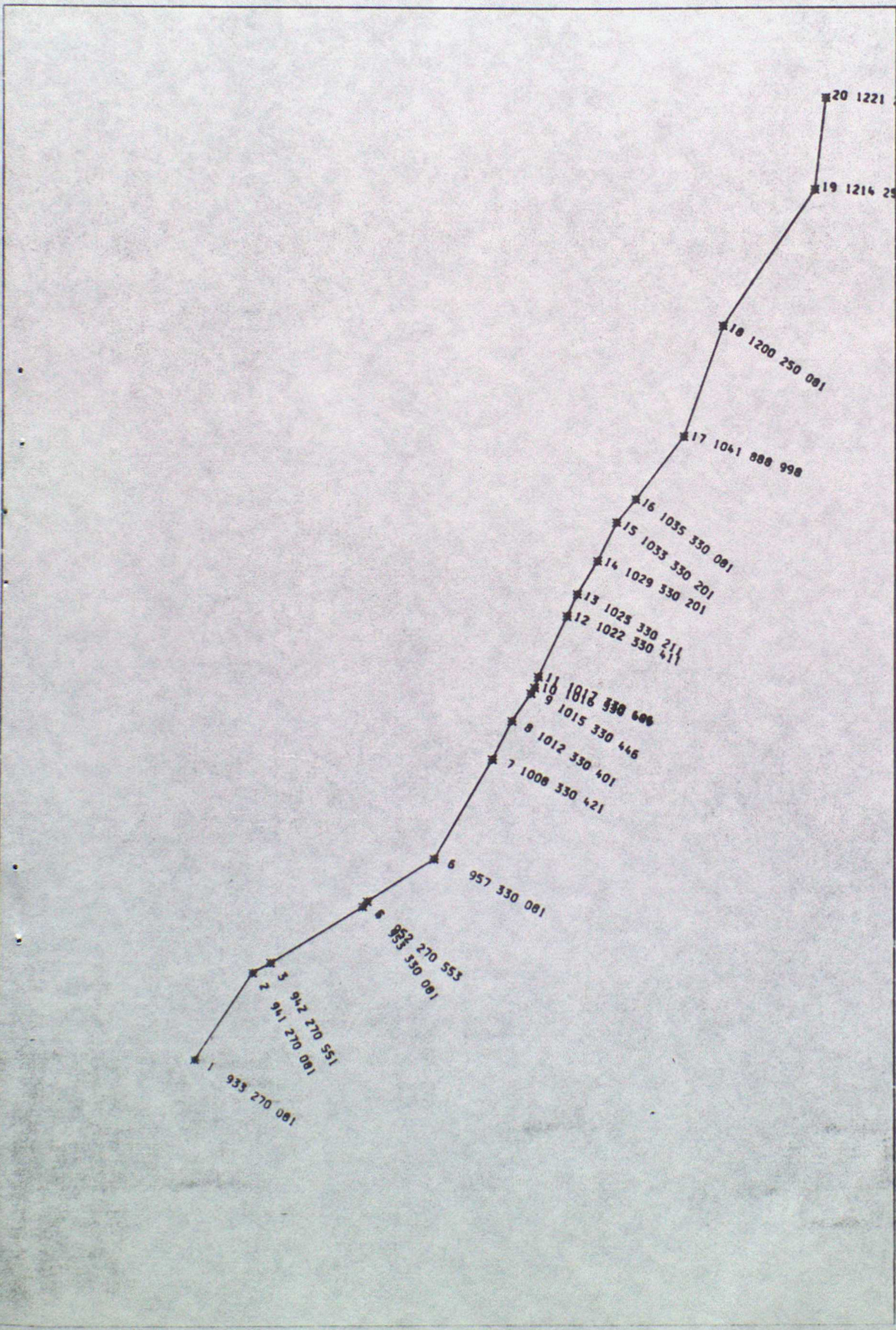
Fig 2a

MAP No. 2724

Figure 3

Figure 4

2724 760305



1	933	270	081
2	941	270	081
3	942	270	551
4	952	270	553
5	953	330	081
6	957	330	081
7	1008	330	421
8	1012	330	401
9	1015	330	446
10	1016	330	646
11	1017	330	401
12	1022	330	411
13	1025	330	211
14	1029	330	201
15	1033	330	201
16	1035	330	081
17	1041	888	998
18	1200	250	081
19	1214	250	081
20	1221	250	999

TABLE 1.

SHEET No

DATE

CAT CODING FORM

MAP No (NNNN)	DATE (YYMMDD)	SEQ (SS)	TIME (GGGG)	FLT LEVEL (3FFF)	LAT AND LONG (4LLL±LLL)	BCQ (5BCQ)	REMARKS
2724	76Ø3Ø5	Ø1	Ø933	3 27Ø	4 4Ø6 - Ø27	5 Ø81	Cloud code 8 because pilots are not asked to
~	~	Ø2	Ø941	3 27Ø	4 422 - Ø16	5 Ø81	give cloud information when they report NIL bumps.
~	~	Ø3	Ø942	3 27Ø	4 424 - Ø12	5 551	
~	~	Ø4	Ø952	3 27Ø	4 435 + ØØ9	5 553	Q - 3 because we do not know what the pilot
~	~	Ø5	Ø953	3 33Ø	4 436 + Ø1Ø	5 Ø81	reported for B and C on this short leg.
~	~	Ø6	Ø957	3 33Ø	4 444 + Ø26	5 Ø81	This leg extends to the change in bumpiness ;
~	~	Ø7	1ØØ8	3 33Ø	4 462 + Ø4Ø	5 421	we are not interested in a change in cloud
~	~	Ø8	1Ø12	3 33Ø	4 469 + Ø45	5 4Ø1	when bumpiness is reported as NIL.
~	~	Ø9	1Ø15	3 33Ø	4 474 + Ø5Ø	5 446	Q = 6 indicates a special report is associated with this leg .
~	~	1Ø	1Ø16	3 33Ø	4 475 + Ø51	5 646	The whole of this leg is considered to be
~	~	11	1Ø17	3 33Ø	4 477 + Ø52	5 4Ø1	near convective cloud. If the flight had
~	~	12	1Ø22	3 33Ø	4 488 + Ø6Ø	5 411	been through the line of Cb a new leg
~	~	13	1Ø25	3 33Ø	4 492 + Ø63	5 211	would have been started at 47.6° North.
~	~	14	1Ø29	3 33Ø	4 498 + Ø69	5 2Ø1	
~	~	15	1Ø33	3 33Ø	4 5Ø5 + Ø75	5 2Ø1	
~	~	16	1Ø35	3 33Ø	4 5Ø9 + Ø81	5 Ø81	
~	~	17	1Ø41	3 888	4 52Ø + Ø97	5 998	Flight level 3888 and BCQ - 5998 show that
~	~	18	12ØØ	3 25Ø	4 54Ø + 113	5 Ø81	the aircraft landed at an intermediate
~	~	19	1214	3 25Ø	4 563 + 15Ø	5 Ø81	airfield.
2724	76Ø3Ø5	2Ø	1221	3 25Ø	4 58Ø + 16Ø	5 999	
				3	4	5	
				3	4	5	
				3	4	5	

TABLE 2 SPECIAL REPORTS

FORTRAN Coding Form

PROGRAM		PUNCHING INSTRUCTIONS	GRAPHIC	PAGE OF
PROGRAMMER	DATE		PUNCH	CARD ELECTRO NU

COMM. | STATEMENT NUMBER | CONT. | FORTRAN STATEMENT

```
NNNNYYMMDDSSGGGG3FFF4LaLaLa±LoLoLo6RRR

2724766Ø3Ø5Ø91Ø15333Ø4474+Ø5Ø6ØØØ 5ØØØFT ABOVE LINE OF CB
          1Ø1Ø16333Ø4475+Ø516ØØØ 5ØØØFT ABOVE LINE OF CB
```

APPENDIX I

Coding of Pilots' reports

Code form for standard reports

NNNN YYMMDD SS GGGG 3FFF $4L_aL_aL_a \pm L_oL_oL_o$ 5 BCQ

NNNN	Map identification number
YY	Year eg 76
MM	Month eg 03 = March
DD	Day of month
SS	Sequence number of flight 'leg'.
GGGG	Time at start of 'leg' GMT
3	Indicator that flight level follows
FFF	Flight level
4	Indicator that latitude follows
$L_aL_aL_a$	Latitude at start of 'leg' in tenths of degrees eg 50^oN = 500
$L_oL_oL_o$	Longitude at start of 'leg' in tenths of degrees, +ve East -ve West
5	Indicator that bumps, cloud and quality information follows
B	Bumpiness, see code 1
C	Cloud, see code 2
Q	Quality of observation, see code 3
	NB. B = C = Q = 9 indicates the end of a flight record.

Code form for special reports

NNNN YYMMDD SS GGGG 3FFF $4L_aL_aL_a \pm L_oL_oL_o$ 6 RRR -------------

6	Indicator that length of a special report follows
RRR	Length of special plain language report
------	Content of special report.

Note A special report may be a wind, a report of a rapid temperature change, special cloud information or any other information that cannot be coded in the form of the standard report.

Special reports will be collected together at the end of the main data set. The Q code in the standard report will show when there is a special report associated with any flight 'leg'.

Code 1	**Bumpiness**	
B	Intensity	
Ø	Nil	
1	Very light or Nil to light	
2	Light	
3	Light to moderate	
4	Moderate	
5	Moderate to severe	
6	Severe	
7	Severe to extreme	
8	Extreme	
9	Indicates end of flight	

Code 2	**Cloud Information**
C	Cloud
Ø	No significant cloud
1	In, or in and out of, tenuous layer cloud
2	In, or in and out of, dense layer cloud
3	In, or near, wave cloud
4	Near convective cloud
5	In, or in and out of, Cu or Cb, no thunder or lightning reported
6	In Cb with thunder or lightning reported
7	See plain language special report
8	No cloud information available. Probably no significant cloud
9	Indicates end of flight

Code 3	**Quality of report**
Q	Quality
1	All information clear, unambiguous and consistent
2	Observation deduced partly by inference, eg time estimated by extrapolation from a reported time rather than interpolation between two reported times
3	Observation incomplete, inconsistent or doubtful
9	Indicates end of flight
*	5 will be added to code figures 1, 2 or 3 if special report of wind or other information is available.

APPENDIX II CODING OF PILOTS' REPORTS OF TURBULENCE

When a turbulence reporting map is received it will be stamped with a unique four-digit number. The information on the map will then be put into the code in the format described in appendix I. Most of the information will be coded as standard reports on a 'CAT CODING FORM' (appended).

Coding standard reports

The flight will be divided into legs. A new leg will be started whenever there is a change in one of the following

i) direction of flight

ii) rate of climb

iii) intensity of bumpiness

iv) significant cloud

or v) a time is given.

Cloud is not significant when bumpiness is reported as NIL, therefore, a new leg is not started when there is a change in the reported cloud while B = Ø (see code 1). For each leg of a flight the following information is coded.

NNNN enter map identification number

YY enter 76 for European maps and Ø6 for Atlantic maps

MM enter Ø3 for March or Ø4 for April

DD enter day of the month

SS enter Ø1 for the first leg, Ø2 for the second, etc

GGGG enter the time of the start of the leg when it is given in the map; otherwise enter 9999

FFF enter flight level at the start of the leg when it is known directly from the pilots report. When the aircraft is climbing or descending and the level is not known at the start of the leg enter 999

LaLaLa enter latitude at the start of the leg in tenths of degrees

LoLoLo enter longitude at the start of the leg in tenths of degrees, +ve East, -ve West

B enter reported bumpiness - see code 1

C enter reported cloud see code 2.

When B ≠ Ø and no cloud is reported code C = Ø

When B = Ø and no cloud is reported code C = 8

Q enter the quality of the information given for that leg - see code 3

To indicate the end of a flight code B = C = Q = 9.

Supplementary Information on coding

1. Coding of quality when times must be estimated by computer

a. Flights with no reliable time marks (RTM's) code Q = 2 for all legs.

b. Flights with one RTM code Q = 1 for any leg that is wholly within 60 nautical miles of the RTM, and Q = 2 for any other legs.

c. Flights with 2 or more RTM's.

Code Q = 1 for any leg between RTM's

Code Q = 1 for any leg wholly within 300 nautical miles of the first or last RTM.

Code Q = 2 for any other legs.

2. If top of climb (TOC) is not marked assume that it is reached 60 nautical miles from the start. When at least two RTM's are given do not estimate the time at TOC, the computer will calculate it, but if there are less than two RTM's assume that TOC is reached 10 minutes after the start of the flight.

3. If top of descent (TOD) is not marked assume that it is 60 nautical miles before the end of the flight. If no time is given at TOD and there are less than 2 RTM's assume TOD is 10 minutes before the end of the flight.

4. When an aircraft lands at an intermediate airport on route code from the TOD to that airport to the TOC from that airport as a single leg with flight level 3888 and the group 5BCQ = 5998.

5. For any short legs specifically coded to show a change of flight level code Q = 3.

Coding special reports

When a pilot reports something that cannot be coded in the standard form it is recorded as a special report. The existence of a special report is indicated in the standard report by adding 5 to the Q code and sometimes also by coding 7 in the C code, for that leg.

A special report is coded on a normal FORTRAN coding form. (An example of a special report is given in table 2). The symbols from NNNN to LoLoLo have the same meaning as in the standard report. RRR gives the number of additional fortran cards required for the special report.

The plain language section of a special report must be written in columns 34 to 72 but any of these columns may be left blank. The coded section of the first card of a special report must be complete (time may be coded as 9999 and flight level as 3999) but on the following cards of the same special report only NNNN and 6RRR need be entered.

CAT CODING FORM

SHEET Nº

DATE

MAP Nº				DATE						SEQ		TIME				FLT LEVEL				LAT AND LONG									CAT	CLOUD	QUALITY	SEQ		TIME				FLT LEVEL				LAT AND LONG									CAT	CLOUD	QUALITY
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
N	N	N	N	Y	Y	M	M	D	D	S	S	G	G	G	G	3	F	F	F	4	L_A	L_A	L_A	±	L_O	L_O	L_O	5	B	C	Q	S	S	G	G	G	G	3	F	F	F	4	L_A	L_A	L_A	±	L_O	L_O	L_O	5	B	C	Q
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
																3				4								5										3				4								5			
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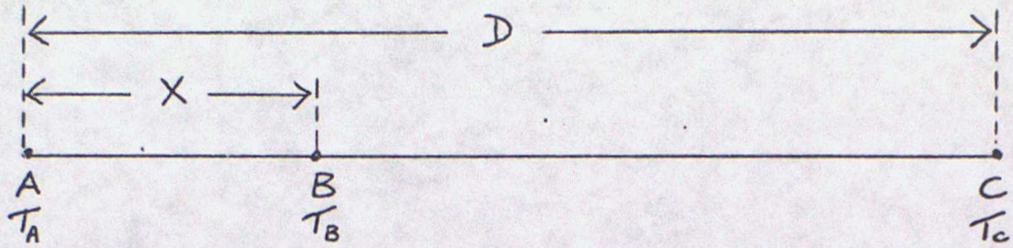
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

Appendix III

TEST FOR AGREEMENT BETWEEN REPORTED AND ESTIMATED TIMES



Consider the flight from A to C above. Times T_A, T_B and T_C are given and a time T_B' is estimated at B by linear interpolation.

Let T be $T_C - T_A$

D be the distance from A to C

X be the distance from A to B

One or more of the reported times is considered suspect if

$$\Delta T = |T_B - T_B'| > 0.05 + 0.15\left(1 - 2\left|\frac{X}{D} - 0.5\right|\right)T$$

Where all times are in hours.

This test provides a maximum tolerance when B is midway between A and C. Thus for a flight lasting one hour the tolerance on T_B varies from $\approx$ 3 minutes when B is very close to A or C, up to a maximum of 12 minutes.

Appendix IV - Details of turbulence data sets on magnetic tape

The tape is a standard IBM 2400 series 9-track magnetic tape with standard labels. There are two sequential files on the tape, both being in standard card-image format (EBCDIC characters). Both files have the following specification:-

Record Format	-	Fixed blocked
Record Length	-	80 bytes
Block Size	-	12960 bytes
Recording Density	-	1600 bits per inch (bpi)

The first file contains the standard reports with one record per leg of flight and the data in each record is arranged as follows:-

Columns	Item	Code
5-8	Map number	NNNN
11-16	Date	YYMMDD
23-24	Leg number	SS
29-32	Time	GGGG
37-4Ø	Flight level	3FFF
45-48	Latitude	4LaLaLa
53-56	Longitude	±LoLoLo
61-64	Turbulence, cloud, quality	5BCQ
73-8Ø	Data set sequence number	-

Only the following characters are coded in this file:-

Ø, 1, 2, 3, 4, 5, 6, 7, 8, 9, -, and blank.

The second file contains the special reports (mainly plain language reports) and the data is arranged as follows:-

Columns	Item	Code
1-4	Map number	NNNN
5-1Ø	Date	YYMMDD
11-12	Leg number	SS
13-16	Time	GGGG
17-2Ø	Flight level	3FFF
21-24	Latitude	4LaLaLa
25-28	Longitude	±LoLoLo
29-32	Length of special report (additional card images)	6GGG
34-72	Plain language report	-
73-8Ø	Data set sequence number	-

Both files have been sorted by Leg number within map number within date within region (i.e. Atlantic or European).