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ATIR
RADIO THEODOLITE SYSTEM EVALUATION
1994

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1. INTRODUCTION

The ATIR radiotheodolite CV-700 ground station system evaluations were performed during 3 separate trials undertaken at 2 operational Met Office sites as follows :-

1. BMETS Trial at Larkhill (Salisbury Plain) from 14th to 23rd February 1994.
2. "Phase I" Test at Hemsby(Norfolk) from 21st to 25th March 1994.
3. "Phase II" Test at Hemsby from 9th to 12th May 1994.

The BMETS Trial was conducted by Marconi Radar and Control Systems for the Ministry of Defence and incorporated the testing of 4 separate radiotheodolite systems to evaluate their suitability for field use by the Army. Data from the four systems (ATIR (Israel),AIR (USA), VAISALA (Finland) and DIEL (South Africa)) were compared with those obtained from the UK Met Office's Larkhill operational groundstation incorporating Cossor radar windfinding and Vaisala RS80 radiosonde data within a Vaisala PC-CORA system .

As winds were mainly light during the BMETS test there were few ascents which enabled evaluation of the winds at elevations less than 15 degrees. The Met Office therefore agreed to a request from ATIR to test their system at Hemsby (03496) during a week in March when stronger winds prevailed. However, the surface and upper winds during the chosen week were consistently very strong resulting in minimum balloon elevations as low as 6 degrees and ranges approaching 200 kms at burst. This caused tracking problems both with the radiotheodolite and ,to a lesser extent, with the radar. This first test proved that the radiotheodolite was not capable of accurate windfinding below elevations sometimes as high as 18° and it was agreed to leave the ATIR groundstation at Hemsby pending further changes to the windfinding software in Israel after which a second test was made.

Phases 1 and 2 of the ATIR Test were conducted by the Met Office's Upper Air Trials Team in association with the operational staff at Hemsby radiosonde station . As at Larkhill, the operational Vaisala PC-CORA system incorporated windfinding from a Cossor radar to enable comparison with the ATIR radiotheodolite winds. Additional wind validation was obtained from a second groundstation system at Hemsby used to evaluate Loran winds from the RS80-L radiosondes flown throughout .

This Report describes Phases 1 and 2 of the Hemsby tests. The full report of the Met Office's evaluation of the BMETS Trial is given in a separate paper [1].

2. ATIR CV-700 GROUND STATION

2.1 Principles of Operation.

The RDF (Radio Direction Finding) system is designed to track radiosondes in the 1680 mHz band. By changing the radiosonde data converter card the same system may be used with various radiosonde types including the Vaisala RS80, but during all 3 Trials in the UK in 1994 the VIZ Microsonde II was tracked. The ATIR system is also capable of using either digital or analogue data. During the 3 UK Trials the digital radiosondes were decoded using the ZEEMET decoder. The "scanning" process by which the RDF system keeps track of the radiosonde consists of a scanner continually generating azimuth and elevation error signals (derived from differences in the received signal strength as the radiosonde changes position).These error signals direct the tracking servo mechanism to bring the antenna to the point at which the errors are nullified. At this point the antenna boresight is aligned with the transmission source. This alignment process is continued throughout the flight. Continuous reading of the elevation and azimuth angles and the geopotential height of the radiosonde derived from the pressure, temperature and humidity data enable the balloon displacement and hence the winds to be evaluated.

(System diagrams of the ATIR ground station are given in Annexe 1)

3. TRIAL PROGRAM - GENERAL.

3.1 Comparison Rigs

On each comparison ascent an RS80-L loran radiosonde and VIZ Microsonde II were suspended about 1 metre below a bamboo cane which was deployed from a Graw unwinder attached to a large radar reflector suspended about 3 metres below the balloon. Once the unwinder had fully deployed the radiosondes were about 30 metres below the balloon.

3.2 Comparison Soundings

19 comparison ascents were made during Phase I and a further 14 comparisons were flown during Phase II. Details of the radiotheodolite siting and flight operations are given in Annexe 2. Comparison measurements from the 2 independent PC-CORA groundstations were synchronised at launch using a timer common to both systems. The ATIR system launch time was detected by a 4 hPa decrease in the pressure determined in the ground station computer. Post flight comparison of the temperature and humidity profiles enabled small timing corrections to be made to the ATIR data as tabulated in Annexe 2.

Details of comparison flight schedule and data flagging from both Phases I and II are summarised in Annexe 4.

3.3 Quality of Radar Winds.

The Cossor radar used to provide the reference wind measurements at Hemsby is one of the few remaining radars currently used in the UK for windfinding. Tests in 1984 of the windfinding performance of this type of radar showed that the RMS vector errors in the wind vary from about 0.4 $m.s^{-1}$ at 20km range to 1.5$m.s^{-1}$ at 80km, Edge et al.,[6] .These results were derived by tracking the same balloons with Cossor radars separated by 50 km at Bracknell and Crawley (West Sussex) . Operational RS3 radiosonde software was used to compute winds and this used a lower sample rate for the raw radar data than the PC-CORA or UAWNDS software.

In 1995/6 winds from the Aberporth (West Wales) Cossor radar were compared with winds from a high precision tracking radar at the same site. 4 comparison flights were made. The results showed that RMS errors in the Cossor winds computed using UAWNDS software were significantly smaller than those found in 1984. Elms et al .,[4].

During the ATIR Phase I test the mean flat range was about 107 km at 100 hPa increasing to about 157 km at burst. Maximum flat ranges on individual flights varied between 112km and 258 km and minimum elevations varied between 6 and 13 degrees.

During the ATIR Phase II test the mean flat range was about 26 km at 100 hPa increasing only to about 32 km at burst. Maximum flat ranges on individual flights varied between 6km and 78 km and minimum elevations varied between 12 and 35 degrees with only 3 flights having minimum elevations below 20 degrees.

Based on the recent Cossor windfinding error evaluations, estimates of the radar error (1 sd) in each component for each of Phases I and II of the ATIR test are displayed in Figures 3(a), 3(c), 4(a), 4(c).

3.4 Quality of Loran Winds.

The Loran windfinding used transmissions from the following 2 chains:-
FRENCH CHAIN GRI 8940
Lessay (Master) , Soustons (1st slave)
NORWEGIAN CHAIN GRI 7970
Ejde (Faeroes) (Master), Bo (Norway) (1st slave), Sylt (Germany) (2nd slave), Sandur (Iceland) (3rd slave), Jan Mayen (4th slave).

The RS80-L Loran radiosondes (all calibrations either July,Nov or Dec 1993) performed well measuring reliable winds to burst throughout both phases of the Trial apart from on flights 8 and 18 in Phase I test.
On flight 8 poor reception at long range caused Loran measurements to cease at pressures below 30 hPa. On flight 18 interference from another radiosonde caused Loran data to cease at pressures below 150 hPa . The Loran line fitting length was set to 60 seconds at all flight levels throughout the Trial. The RMS vector error in the Loran wind components would be expected to be in the range 0.5 $m.s^{-1}$ in the troposphere and up to 1 $m.s^{-1}$ at long ranges in the stratosphere. (Nash [7]).

4. PHASE I TEST (21ST to 25 TH MARCH)

4.1 Weather Conditions.

(Refer to Annexe 5 for the 12 GMT surface analyses. Launch time weather codes and other flight details recorded from the Flight Logs of the PC-CORA ascents are given in Annexe 6).

The weather during this week was dominated by a deep surface depression near Iceland the fronts associated with which caused strong surface southwest to westerly winds generally increasing to maximum values exceeding 50 just below the tropopause . A deep layer of air , from about 3km to 20km above sea level, with wind speeds greater than 30 $m.s^{-1}$ persisted throughout Phase I . Weather conditions at launch were generally cloudy ,but dry except during Flight 16 which was launched in slight rain .

4.2 Problems Encountered.

4.2.1 Cossor Radar Faults

As the strong winds resulted in unusually large ranges and low elevations, the Cossor radar encountered some tracking problems during flights 15 to 19 at ranges greater than about 150 km. Some of the radar winds from these ascents required to be flagged for exclusion within the minute data base,(see Annexe 4). Generally throughout the Trial , however the radar winds could be verified using the Loran data . As the Trial progressed ,a small bias (1 to 2 degrees) between the mean radar and Loran winds was identified by the DIFFRS comparison software. The radar technicians were alerted to this problem and optical sighting tests on radar reference points confirmed a 1 degree error in the reported radar azimuths .This was corrected prior to flight 9. The effect of this correction was to reduce the error, but a residual bias of under 1 degree still remained unexplained. Additionally, a random occasional fault in the Cossor radar's synchro drive caused a 10 degree error in the azimuths reported by the data processing unit. This caused readily identifiable errors in flights 9 and 11,sections of which have been flagged from the minute database.

4.2.2 Operational Faults

The strong surface winds caused crash launches on 2 occasions (Flights 10 and 15) ,both of which produced outages in the ATIR radiosonde geopotential height evaluation thereby preventing wind calculations. The remaining ascent (Flight 6) with no ATIR winds was caused by an operator key pressing error on the hand held CDU at launch. The radar reflector was not attached to the rig used for Flight 12 as surface winds were too strong .On Flight 12 therefore only Loran winds were available for comparison with the ATIR winds.

Note :Refer also to Annexe 4 ,Remarks column for further details of missing or excluded wind data.

2 VIZ radiosondes were rejected during preflight checks as they did not produce a signal.

4.3 Examples of Simultaneous Comparison Data

Examples of comparisons of simultaneous data at 1 minute separation on different days during Phase I of the Trial are displayed in Figures 1(a) to 1(d) inclusive. Note that the "atsim" profiles denote radiotheodolite winds recomputed from simulations using updated software provided from Israel in May 1994. It may be seen that there is little significant difference between the "atsim" and originally computed "atir" profiles. The tendency for the "atsim" profiles to appear displaced in time may to some extent result from the fact that timing corrections were not evaluated for the simulated profiles.

During Phase I all ATIR radiotheodolite ascents were affected by multi-pathing problems causing large errors in the computed winds. It is seen from these examples that the largest errors occurred in the westerly components i.e. along the tracking line of sight as, in this direction, errors in the computation of flat range caused by erroneous variations in elevations have greater effect . Table 1 shows the times into flight and elevation angles when errors in the radiotheodolite winds first became greater than 5 $m.s^{-1}$.

TABLE 1

FLT	MIN.	ELEV.	RNGE km
1	35	17	38
2	34	15	39
3	21	15	26
4	26	15	
5	19	16	20
6	--	--	--
7	19	15	26
8	21	10	38
9	4	12	8
10	--	--	--
11	2	14	9
12	--	--	--
13	27	9	53
14	19	12	36
15	--	--	--
16	27	9	57
17	14	13	20
18	31	8	55
19	18	10	35

Table 1 demonstrates that the critical elevation angle at which multipathing errors become significantly large varies with specific conditions during flight. On some flights these significant errors occurred with tracking elevations at least as high as 17 degrees, but elevations of 10 to 15 degrees were the more common range.

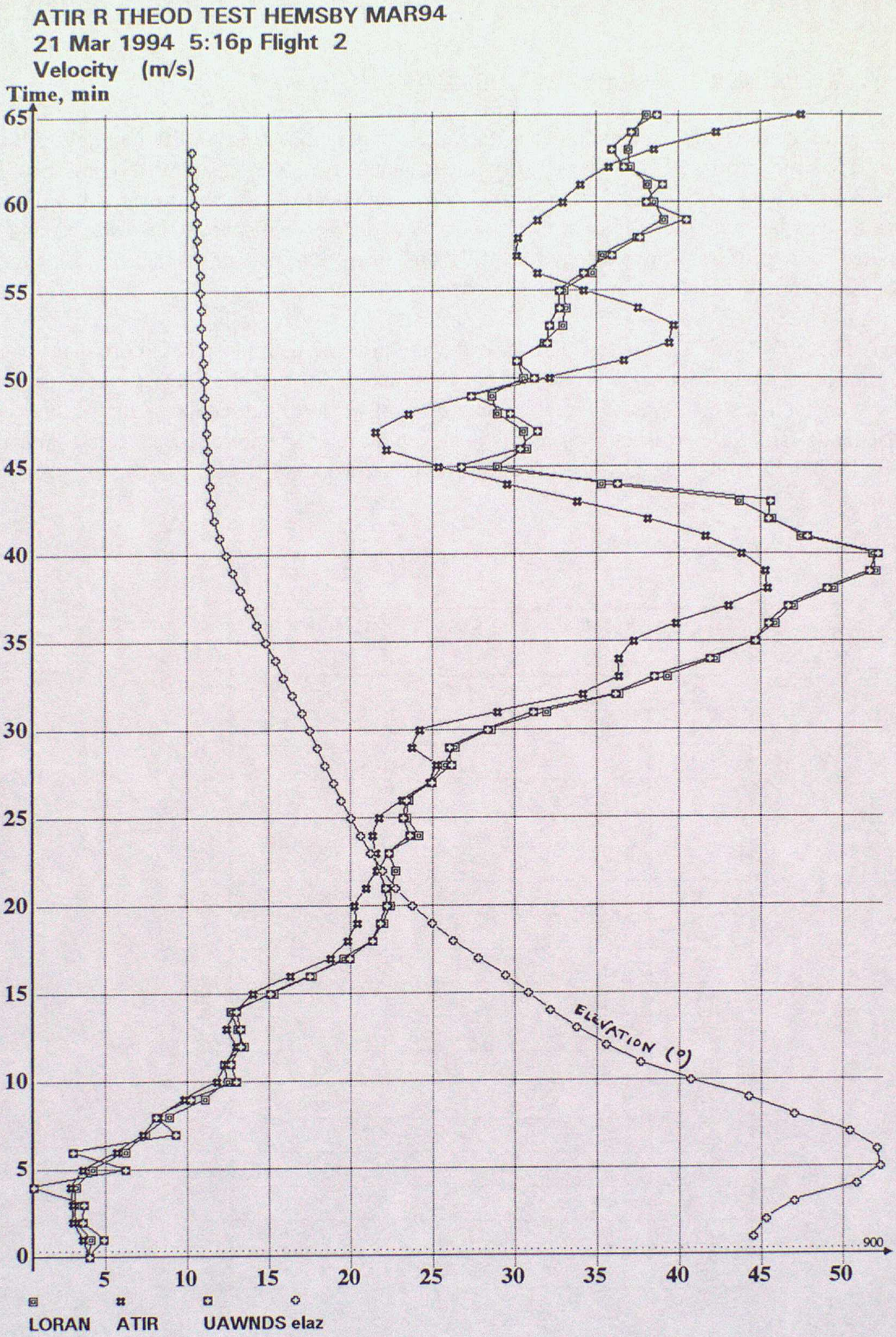


FIGURE 1 (a)

MULTI-PATHING CAUSING ERRORS IN RADIOTHEODOLITE MEASUREMENTS OF WIND SPEED AS ELEVATION DECREASES.

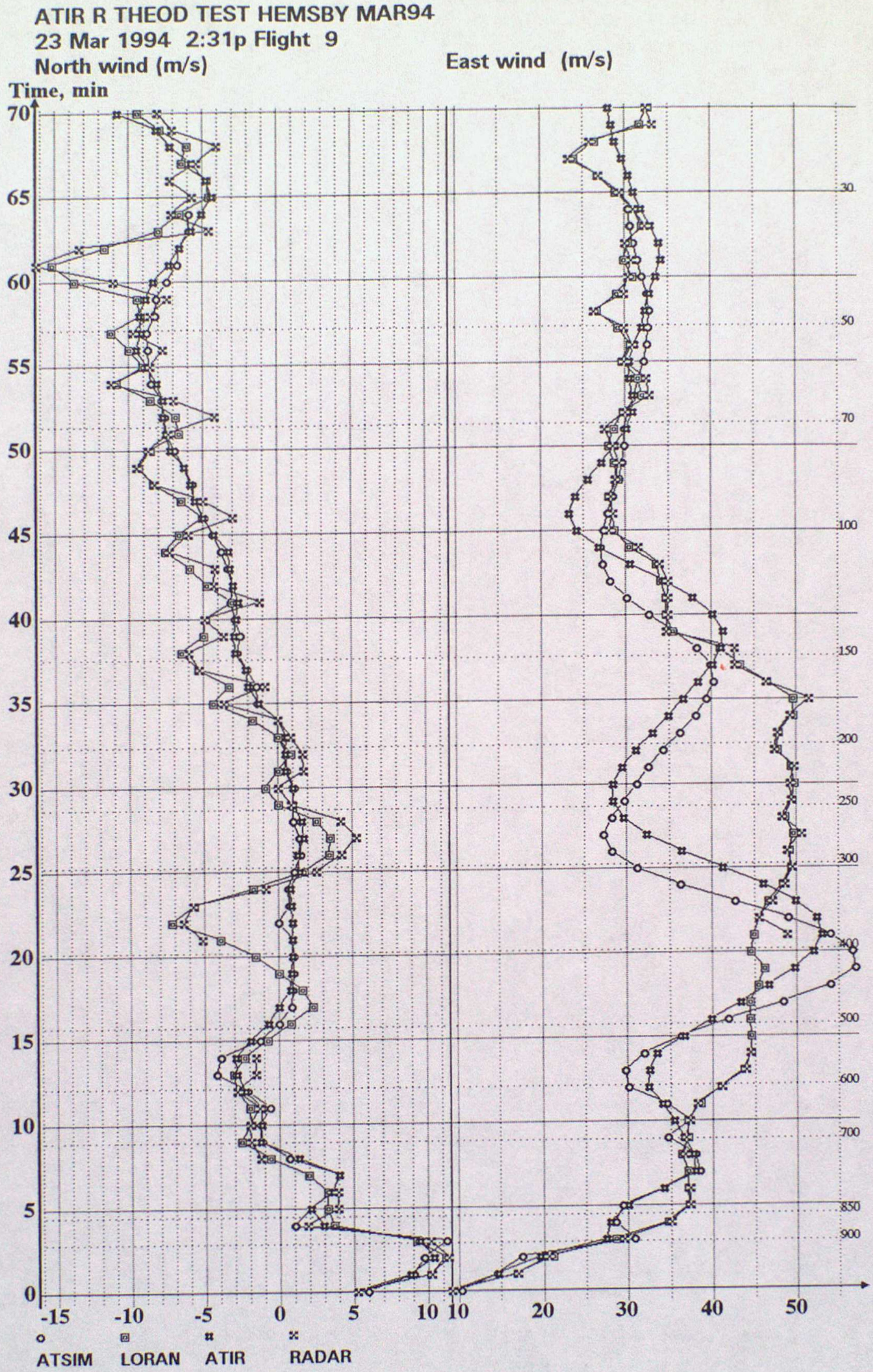


FIGURE 1 (b)

MULTI-PATHING OF RADIOTHEODOLITE SIGNAL-(ELEVATION < 12 DEGREES FOR ENTIRE FLIGHT)

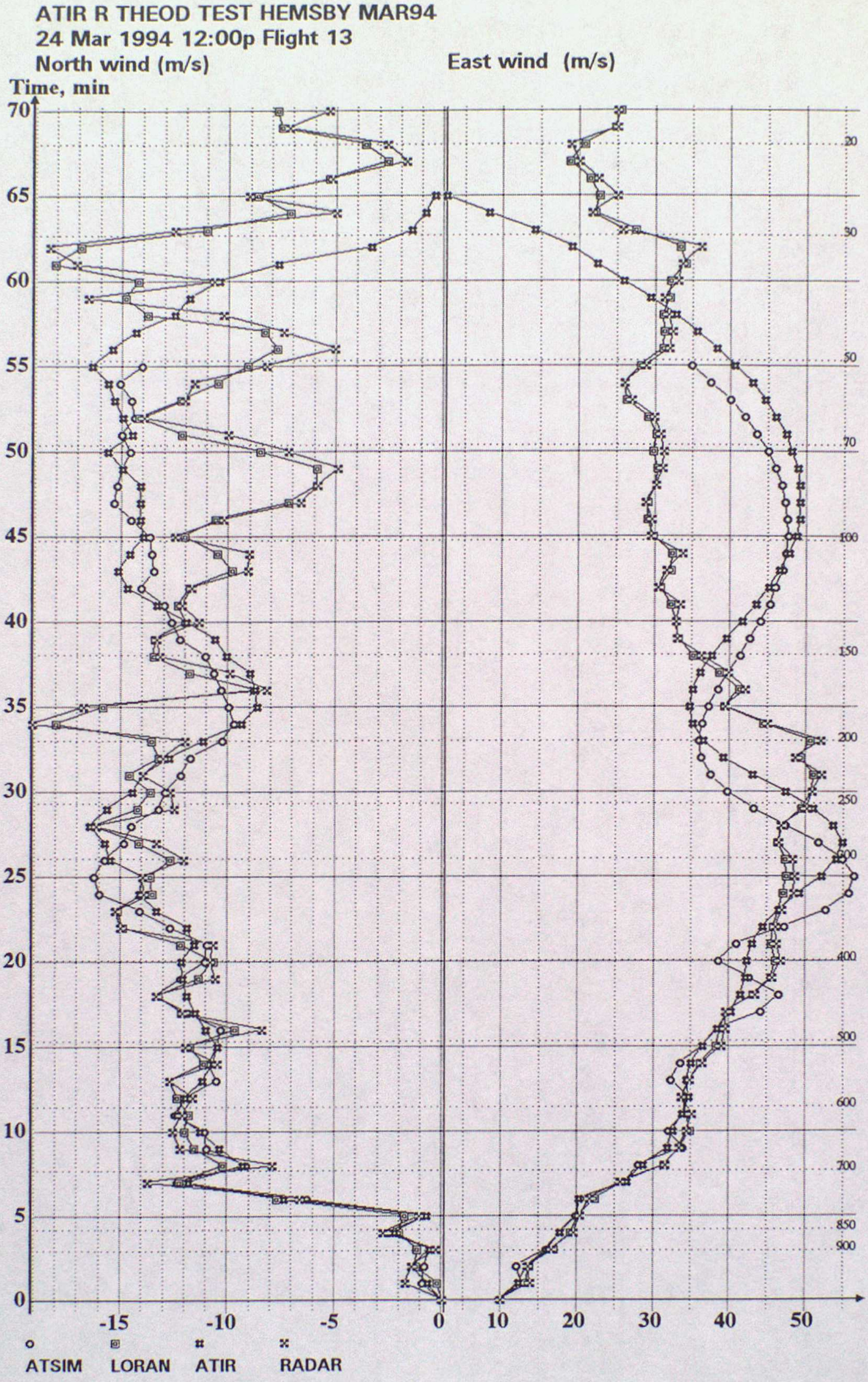


FIGURE 1 (c)

MULTI-PATHING OF RADIOTHEODOLITE SIGNAL . (ELEVATION < 12 DEGREES FROM MINUTE 15 TO BURST).

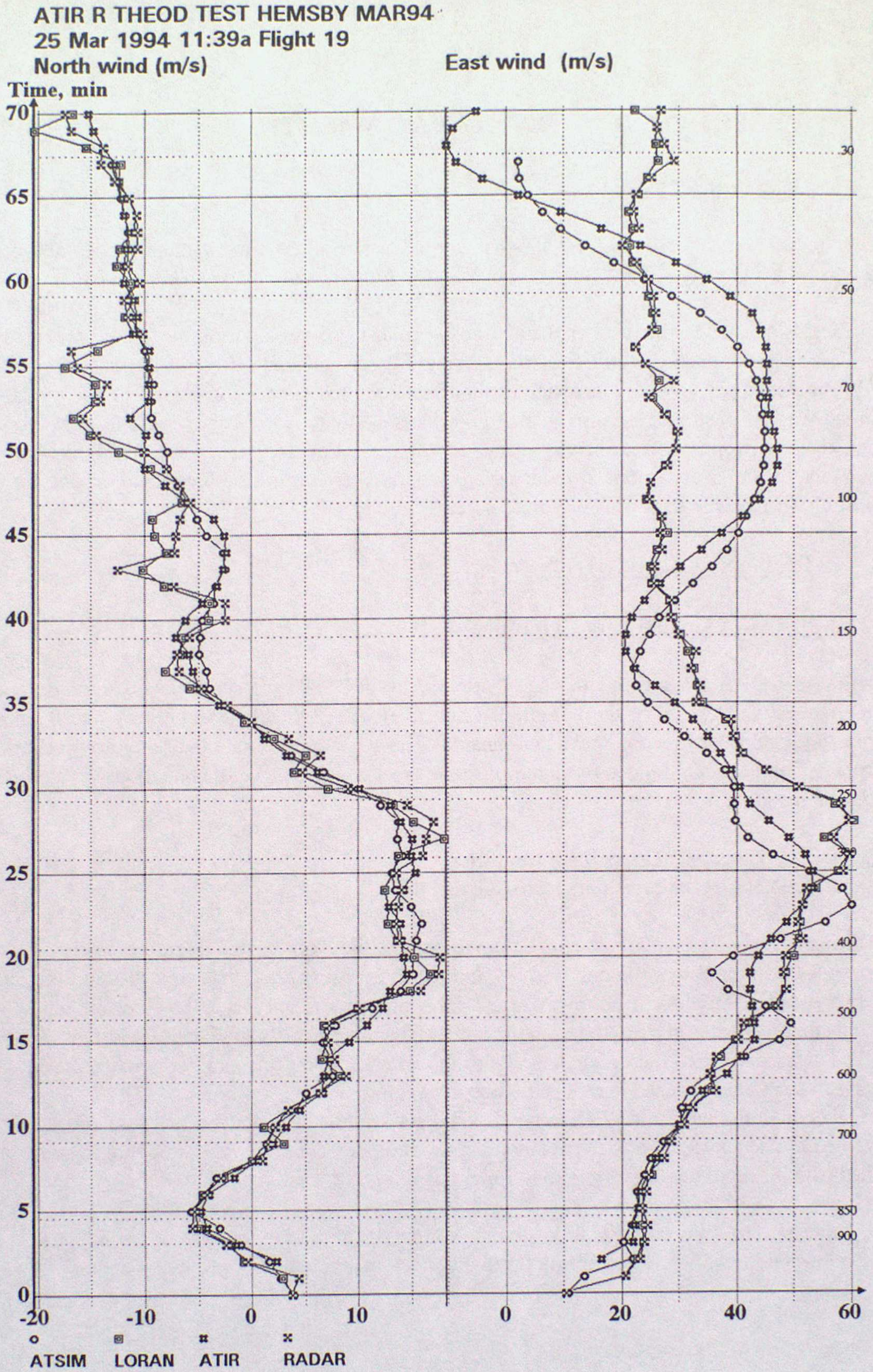


FIGURE 1 (d)

MULTI-PATHING OF RADIOTHEODOLITE SIGNAL (ELEVATION < 12 DEGREES FROM MINUTE 10 to BURST)

5. PHASE II TEST - MAY 9TH TO MAY 12TH

5.1 Weather Conditions.

(Refer to Annexe 5 for the 12 GMT surface analyses. Launch time weather codes and other flight details recorded from the Flight Logs of the PC-CORA ascents are given in Annexe 6).

A surface depression to the west of Britain moved south-eastwards during the week as a ridge persisted over Scandinavia and the North Sea maintaining easterly or south-easterly surface winds during the Trial. The upper winds were much lighter than had been experienced in Phase 1.(The maximum wind recorded was 32 $m.s^{-1}$ at 10.6 kms in flight 7). During flights 1 to 8 the winds reversed to westerlies during the mid troposphere, whereas the winds in the latter ascents of this Trial remained easterly throughout. Weather conditions at launch were generally dry with little low cloud except during flights 10 and 11 when low level stratus produced drizzle and fog .

5.2 Problems Encountered.

5.2.1 PC-CORA Ground station Problems.

Both the PC-CORA systems monitoring identical Vaisala RS80 radiosonde data experienced occasional audio frequency interference until flight 9 (inclusive) after which the source of interference (power supply to a cloud base recorder) was eliminated. The RS80 radiosonde data therefore contained some interpolated and missing values for some of these ascents. Radar wind evaluation was not affected by this interference.

5.2.2 Radiotheodolite Operational Problems

The main problems resulting in data loss were as follows;-

(1) During evening Flights 3, 4, 5 and 9 the radiotheodolite was unable to automatically track the VIZ radiosonde and therefore no winds were evaluated. It was suggested that condensation may have been affecting the drive circuitry. (Following the Trial ,water was found inside the elevation module and it is probable that the water ingressed during the intervening weeks between Phases I and II).
(2) The data cable from the radiotheodolite to the decoder was accidentally stretched during launch on Flight 12 which again caused loss of radiotheodolite data.
(3) On flight 1 the handheld CDU was used to set "azim/elev " instead of "auto track on" which is performed by the adjacent button. This required the radiotheodolite elevation module to be realigned and levelled which caused the loss of the first 7 minutes of ascent.

Note :Refer also to Annexe 4 ,Remarks column for details of missing or excluded wind data.
2 VIZ radiosondes were rejected during preflight checks as they did not produce a signal.

5.3 Examples of Simultaneous Comparison Data

Examples of simultaneous comparisons from Phase II are displayed in Figures 2(a) to 2(d) inclusive. The elevations and bearings from the Cossor radar are shown in the right hand columns of these figures. Note that "atsim" refers to resimulated data using revised software provided at the end of the Trial. This software revision generally produced insignificant differences from the originally evaluated winds ("atir") whereas in the BMETS Trial the resimulated winds using the same software had realised smaller errors than those originally evaluated. As elevations in the BMETS Trial were generally higher than those in Phase II it is probable that the software revision improved the fitting accuracy of the wind algorithms for high elevation data only.
The main features of these 4 example comparison profiles are as follows:-

Fig 2(a) Comparison data from Flight 2 in optimum conditions shows that the radiotheodolite is capable of evaluating winds with resolution close to that of the radar and Loran. Note the good definition of the shear levels especially between minutes 10 and 40 .

Fig 2(b) Comparison data from Flight 6 contains an example of improvement in the ATIR wind within a region of strong wind shear when the original data was re-simulated using the revised program. Note the differences between the original "atir" winds and the "atsim" winds at minutes 15 and 17, although it can be seen that there are little significant differences elsewhere .

Fig 2(c) Comparison data from Flight 11 indicate multipathing problems when the elevation angle reduces to below about 17 degrees. (The balloon on this ascent was deliberately underfilled to verify the performance of the radiotheodolite at lower angles). As in Phase I the simulated computation (not shown) using revised software did not significantly reduce the errors .

Fig 2(d) Comparison data from Flight 14 were obtained at elevations between 20 and 30 degrees and the ATIR measurements were not resolving fine structure in the vertical profiles as well as the Loran and radar measurements .

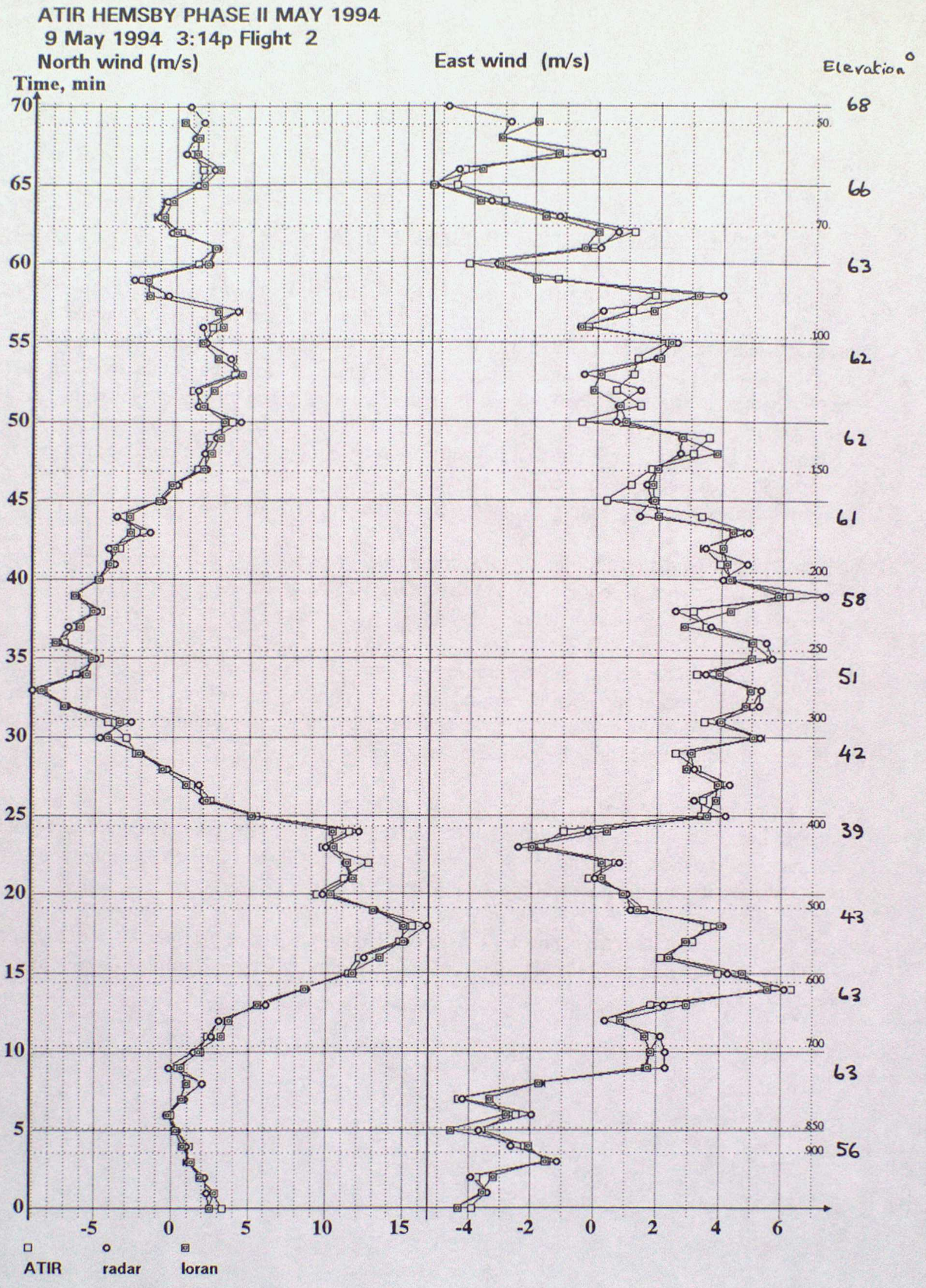

ATIR HEMSBY PHASE II MAY 1994
9 May 1994 3:14p Flight 2
North wind (m/s)
East wind (m/s)
Elevation°
Time, min
ATIR
radar
loran

FIGURE 2 (a)

ATIR HEMSBY PHASE II MAY 1994
10 May 1994 11:29a Flight 6

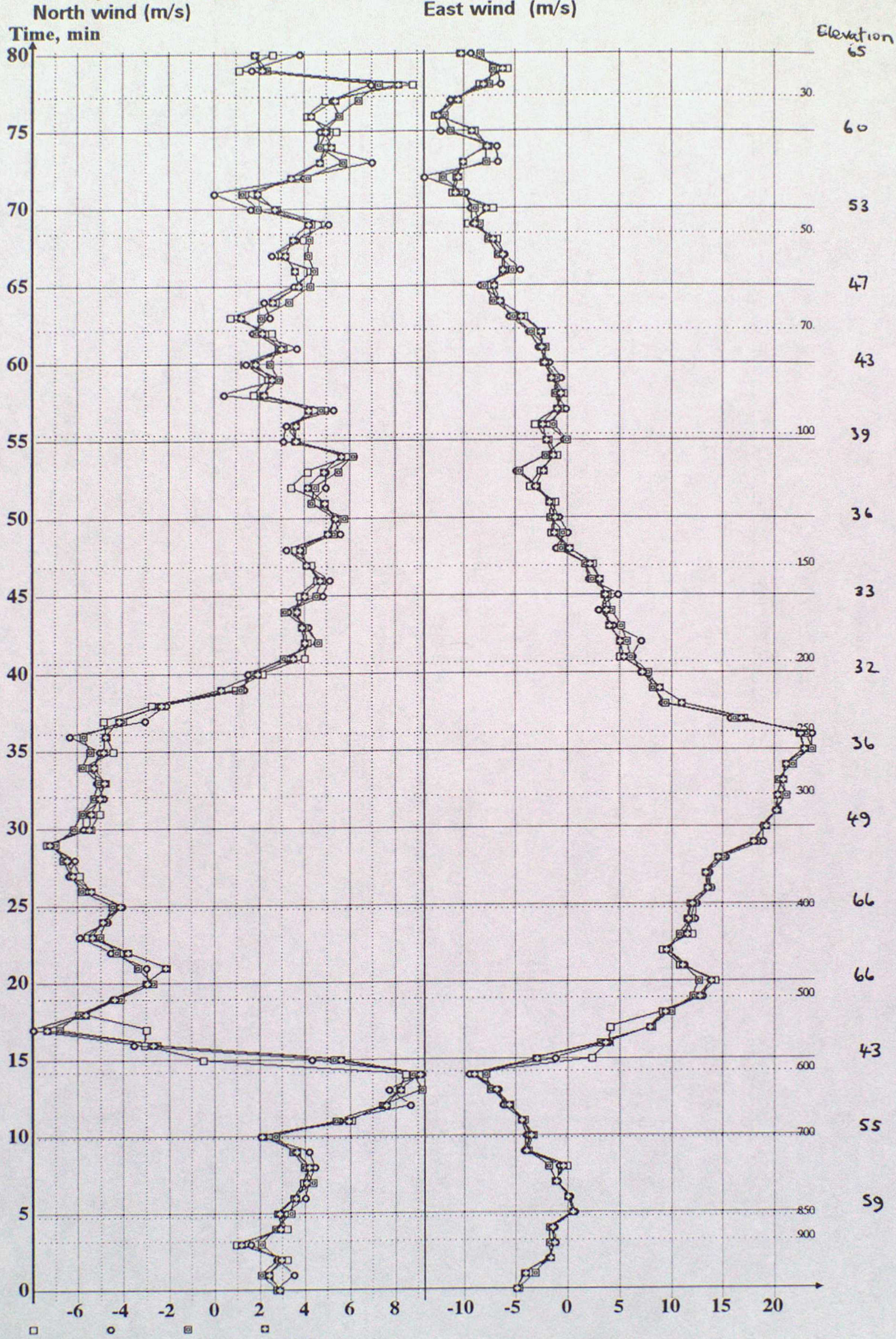


FIGURE 2 (b)

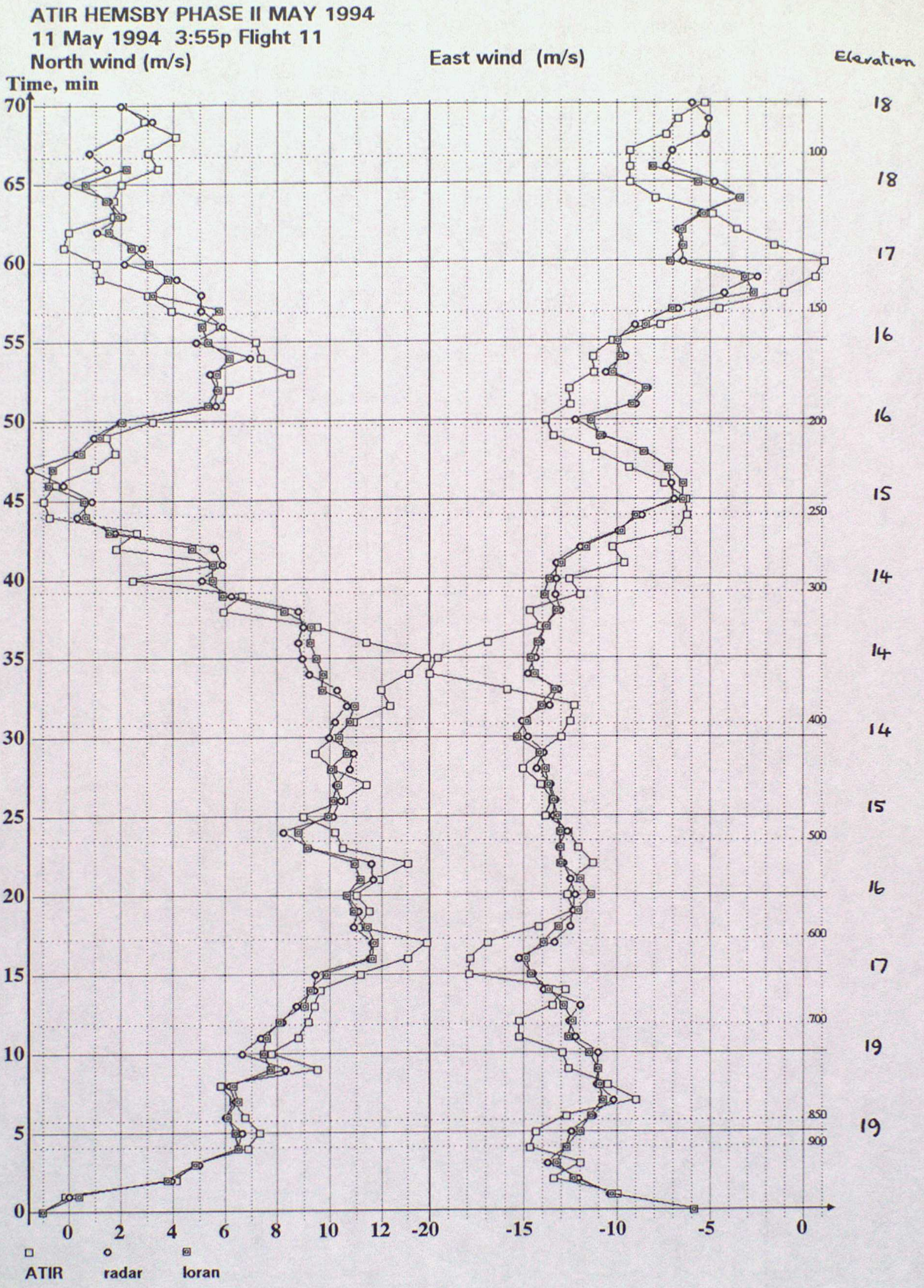
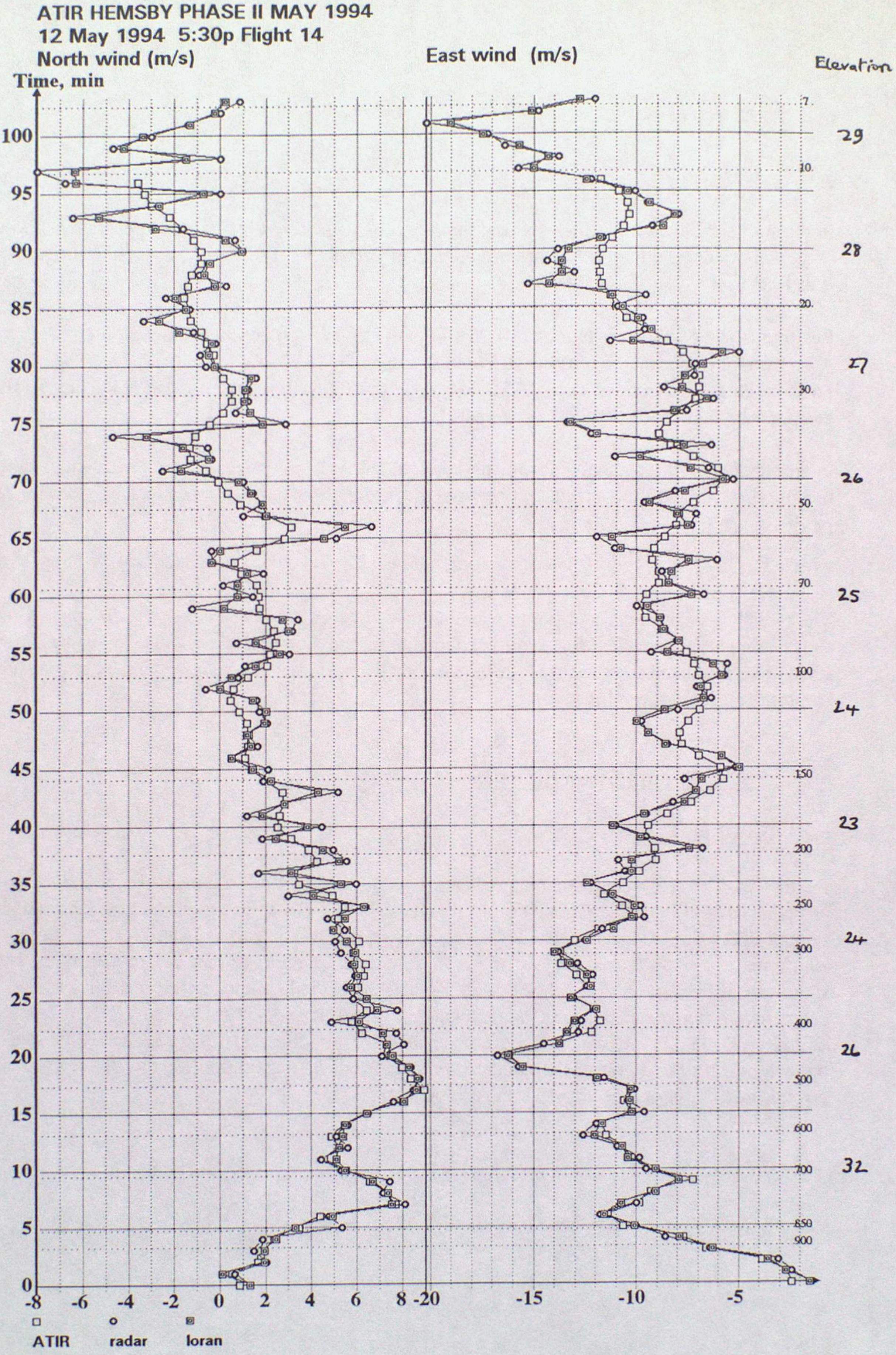

ATIR HEMSBY PHASE II MAY 1994
11 May 1994 3:55p Flight 11
North wind (m/s)
East wind (m/s)
Elevation
Time, min
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12
-20
-15
-10
-5
0
100
150
200
250
300
400
500
600
700
850
900
18
18
17
16
16
15
14
14
14
15
16
17
19
19
ATIR
radar
loran

FIGURE 2 (c)



ATIR HEMSBY PHASE II MAY 1994
12 May 1994 5:30p Flight 14
North wind (m/s)
East wind (m/s)
Elevation °
Time, min
ATIR
radar
loran

FIGURE 2 (d)

6. RESULTS

6.1 General

In the statistical diagrams which follow, simultaneous data from all available ascents have been used except where flagged in the "Remarks " columns of Annexe 4 . The sign convention in these diagrams is as follows:-

Positive Direct Differences (e.g. **ATIR-MET)** in the **(E-W)** component mean that the **ATIR** wind components **from the east** were **stronger.**
Positive Direct Differences (e.g. **ATIR-MET)** in the **(N-S)** component mean that the **ATIR** wind components **from the north** were **stronger.**

Interpretation of the standard deviations between the various wind measurements must take into account that, if there is no correlation between the errors of the two sets of winds being computed:-

$$(\text{s.d. of } \Delta u)^2 = Eu_1^{\,2} + Eu_2^{\,2}$$

where E_{u1} and E_{u2} are the rms errors of wind components measured by systems 1 and 2 respectively.
The radiotheodolite, radar and Loran windfinding errors are all independent of each other. Thus, the above relationship enables the errors attributable to the Loran and radiotheodolite measurements alone to be evaluated from the standard deviations incorporating the radar reference errors shown in Figures 3(a), 3(c), 4(a), 4(c).

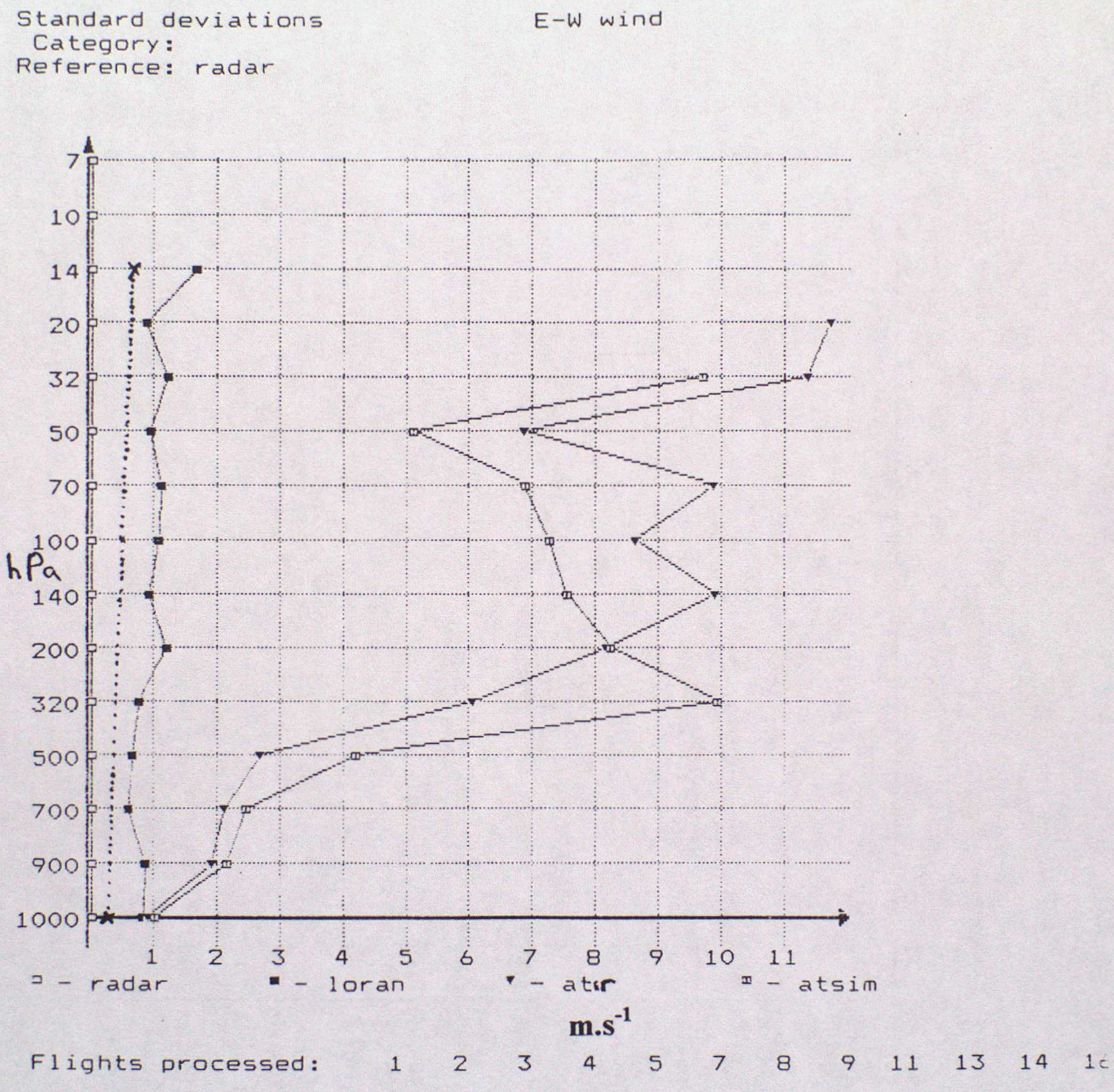
6.2. Wind Comparison Statistics

6.2.1 Phase I Results

Figures 3(a) to 3(d) show the bias ("Direct Differences") and standard deviations of the wind components as differenced from those computed by PC-CORA using the Cossor radar data during Phase I of the Trial. The large standard deviations shown in Figures 3(a) and 3(c) represent the errors which may be expected under "worst case" conditions of multi-pathing. Note that there was little significant difference in variability of the original "atir" wind component differences and the "atsim" component differences obtained from simulations using revised software from ATIR. The magnitude of the (ATIR-RADAR) standard deviations in the E-W direction (approximately parallel to the balloon bearing) was greater than that of the standard deviations in the N-S direction as the elevation errors caused larger range errors in this component.

HEMSBY ATIR PHASE I TEST   MARCH 1994

STANDARD DEVIATION OF E-W WIND COMPONENT DIFFERENCES



ESTIMATED RADAR ERROR x..........................x

FIG 3(a)

HEMSBY ATIR PHASE I TEST MARCH 1994

E-W WIND COMPONENT DIFFERENCES

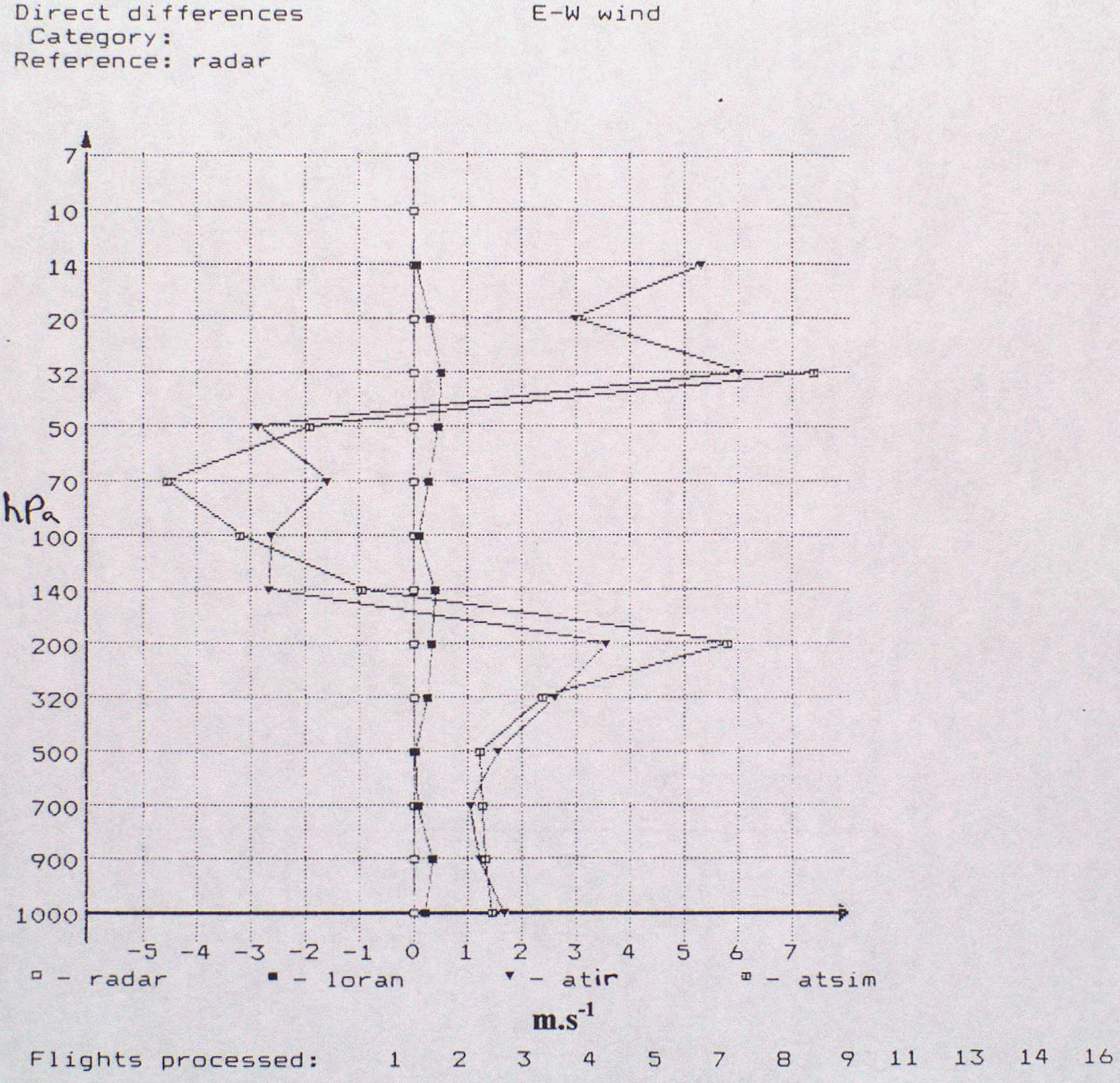
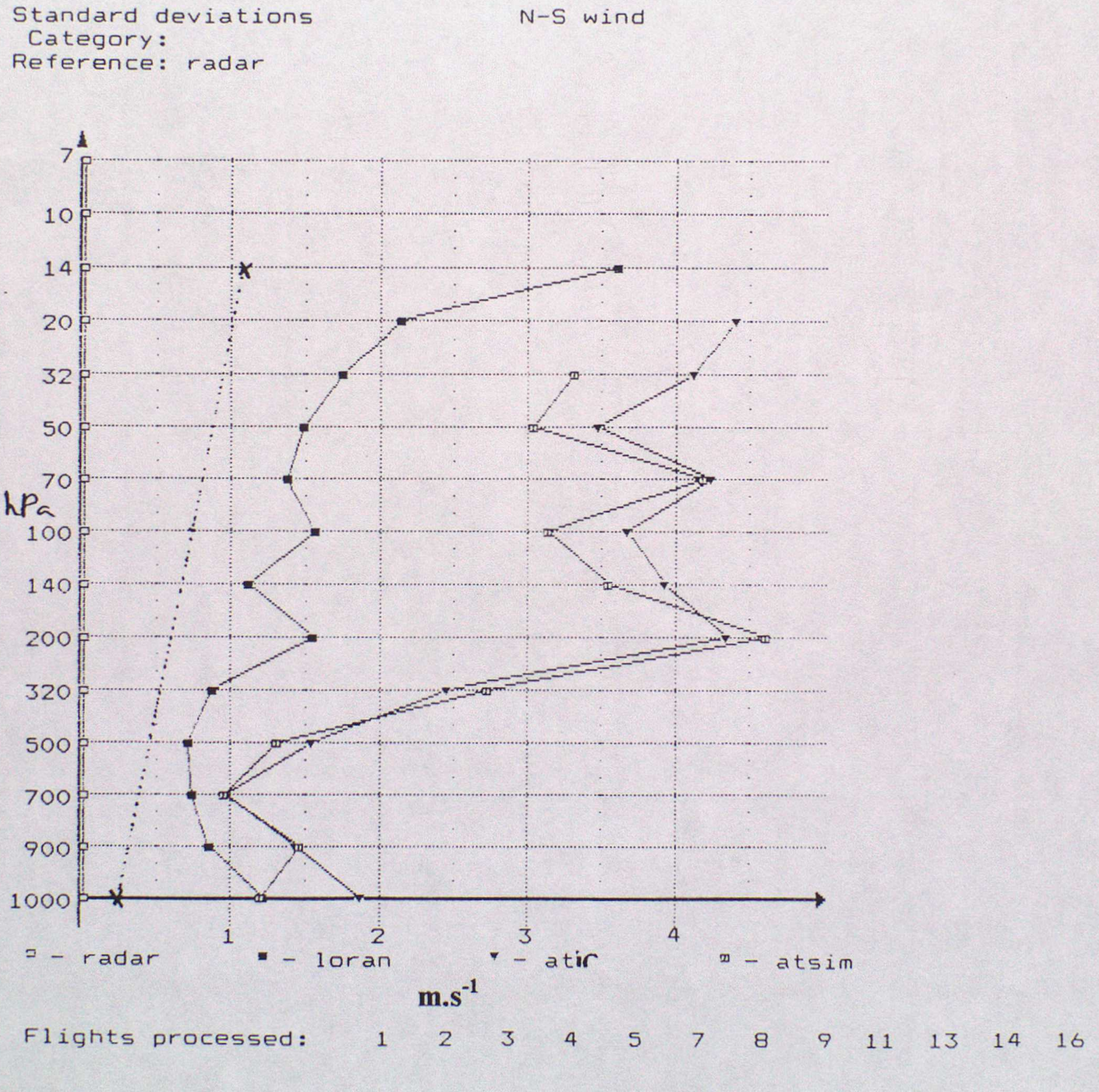


FIG 3(b)

HEMSBY ATIR PHASE I TEST MARCH 1994

STANDARD DEVIATION OF N-S WIND COMPONENT DIFFERENCES



ESTIMATED RADAR ERROR x..........................x

FIG 3(c)

HEMSBY ATIR PHASE I TEST MARCH 1994

N-S WIND COMPONENT DIFFERENCES

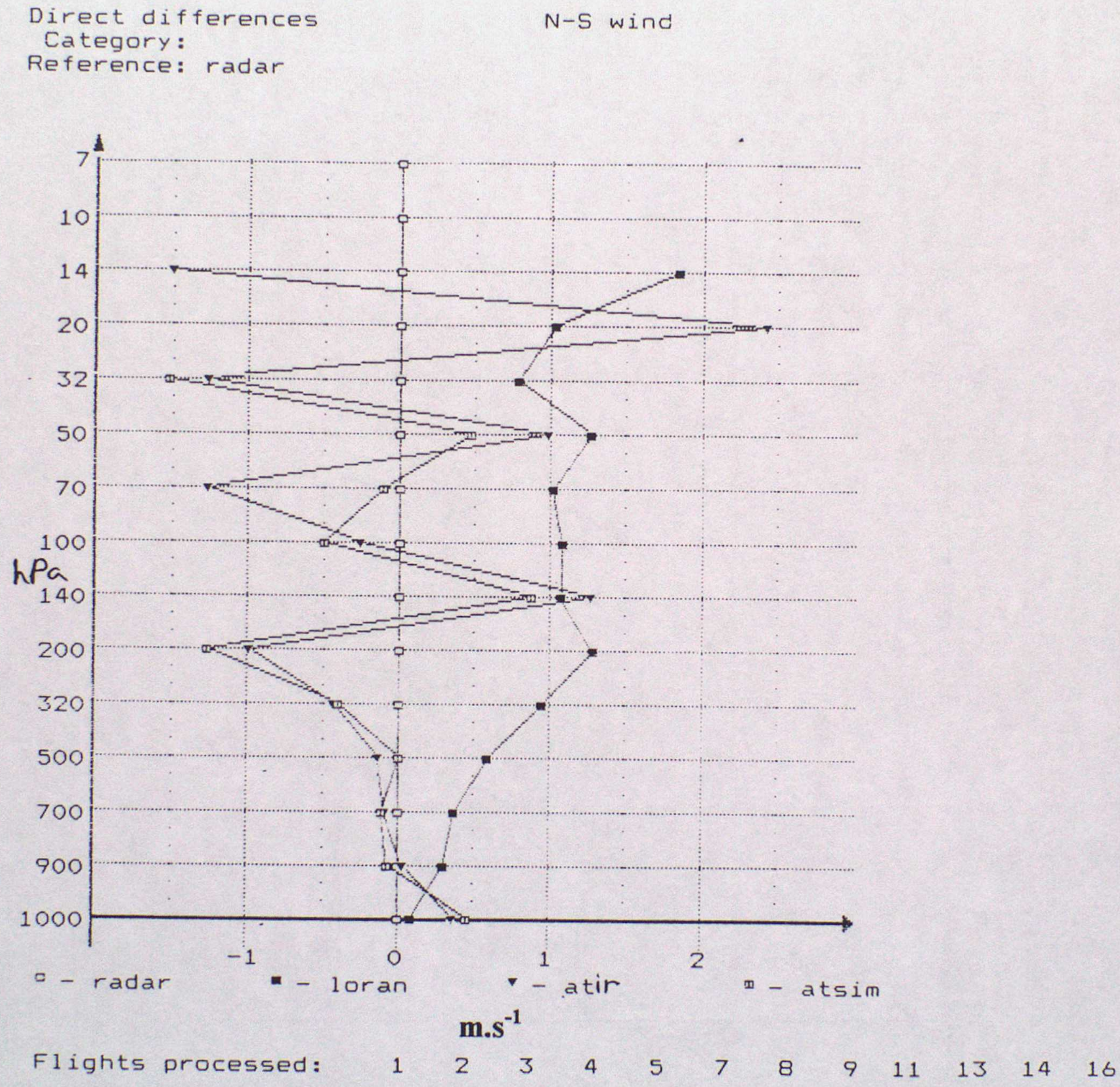


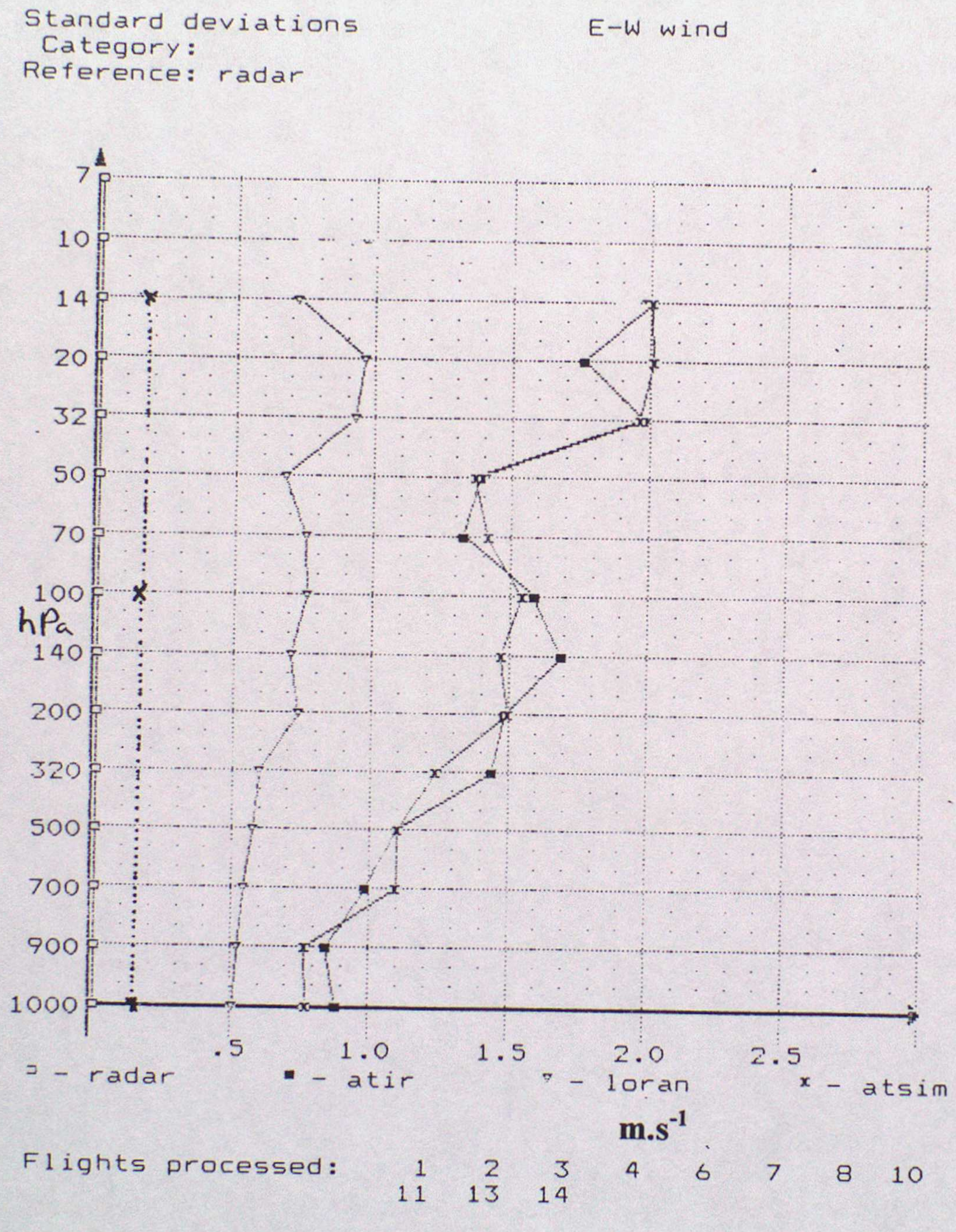
FIG 3(d)

6.2.2 Phase II Results

Figures 4(a) to 4(d) gives statistics in a similar form to those in the preceding section for the wind systems compared during Phase II of the Trial . The standard deviations and mean biases displayed in these results can be taken as the performance of the ATIR radiotheodolite system in optimum conditions and are of similar magnitude to results obtained in the previous BMETS test when multipathing ascents were excluded.

HEMSBY ATIR PHASE II TEST MAY 1994

STANDARD DEVIATION OF E-W WIND COMPONENT DIFFERENCES



ESTIMATED RADAR ERROR x..........................x

FIG 4(a)

HEMSBY ATIR PHASE II TEST MAY 1994

E-W WIND COMPONENT DIFFERENCES

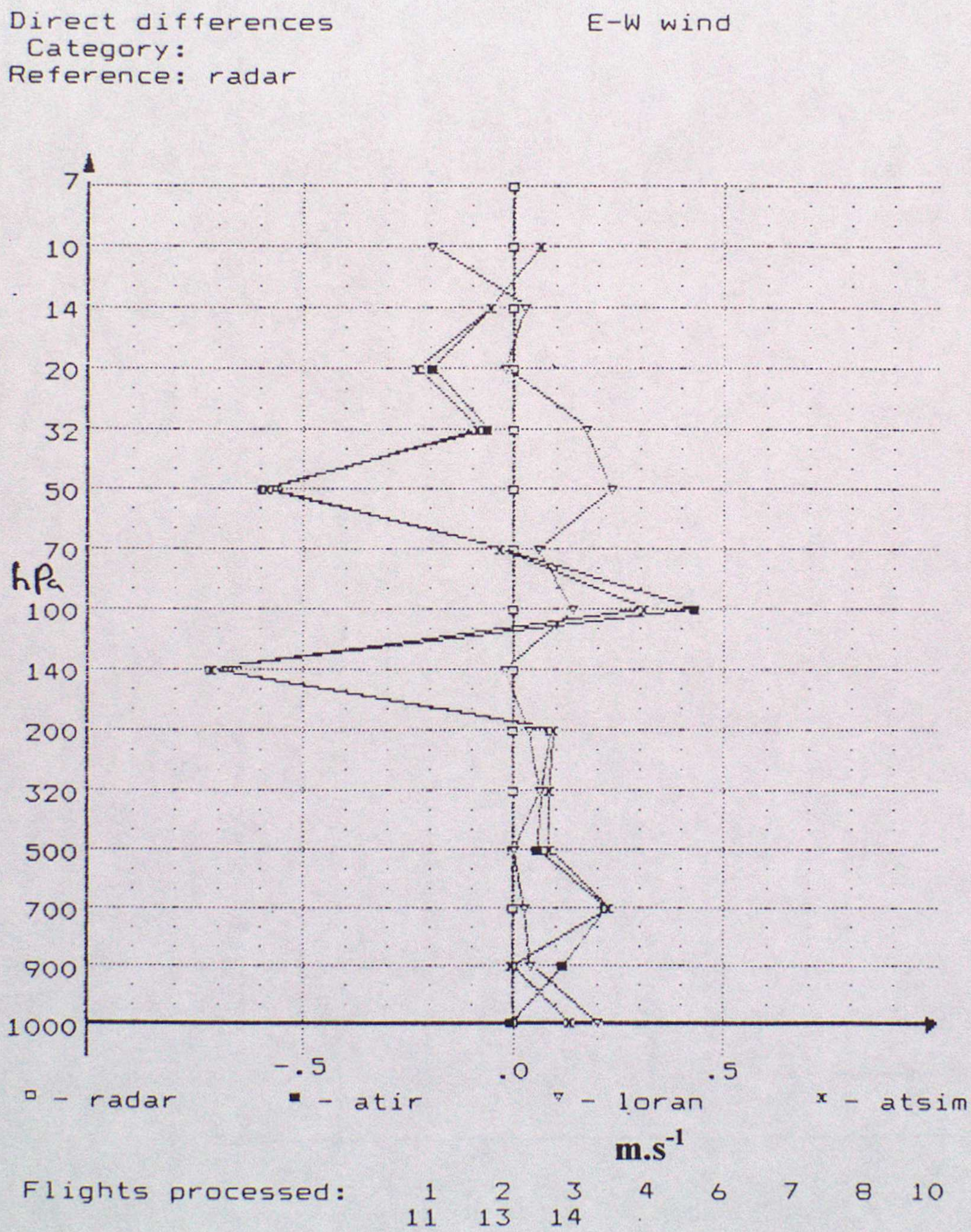
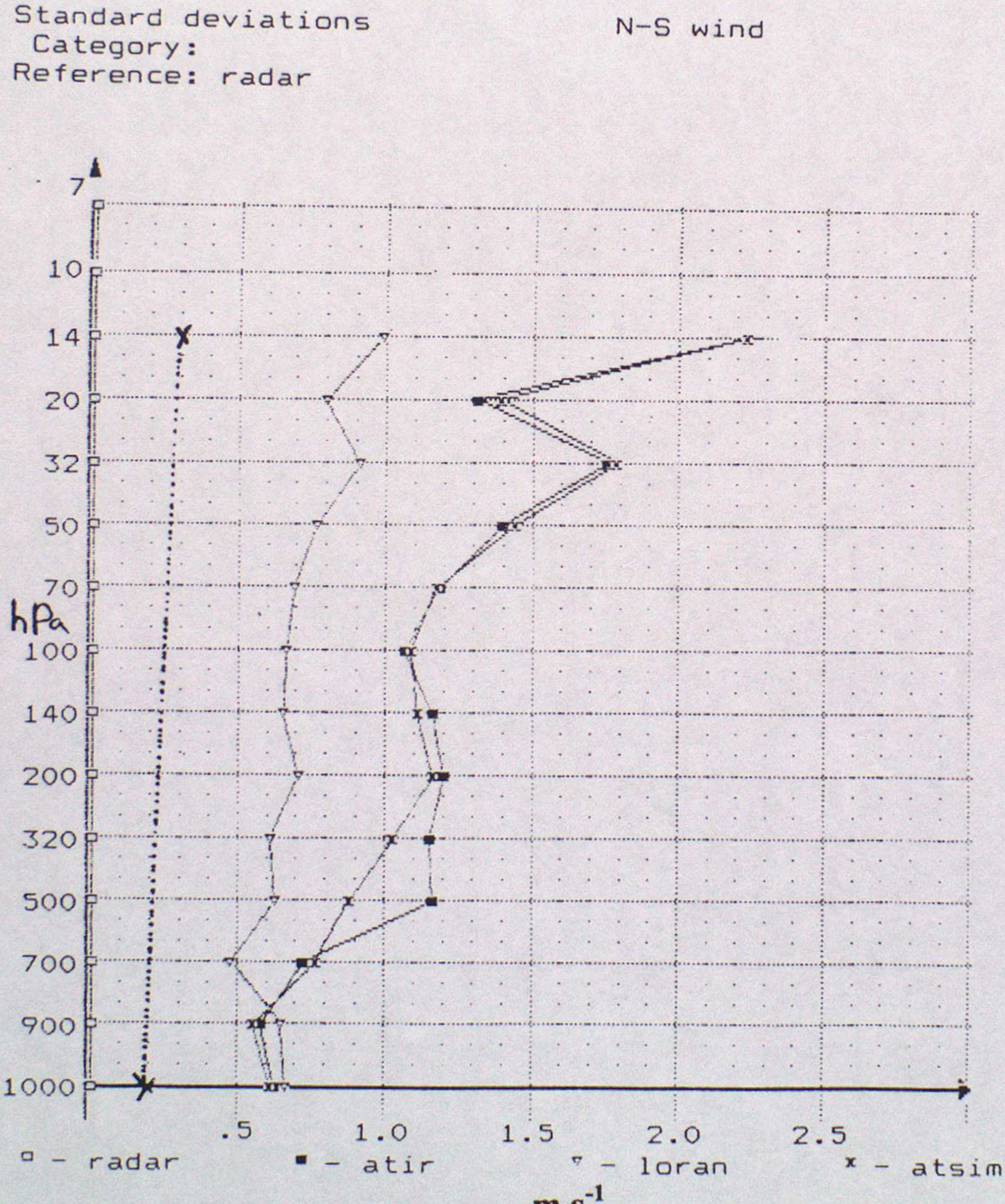


FIG 4(b)

HEMSBY ATIR PHASE II TEST MAY 1994

STANDARD DEVIATION OF N-S WIND COMPONENT DIFFERENCES



Flights processed: 1 2 3 4 6 7 8 10 11 13 14

ESTIMATED RADAR ERROR x..........................x

FIG 4(c)

HEMSBY ATIR PHASE II TEST MAY 1994

N-S WIND COMPONENT DIFFERENCES

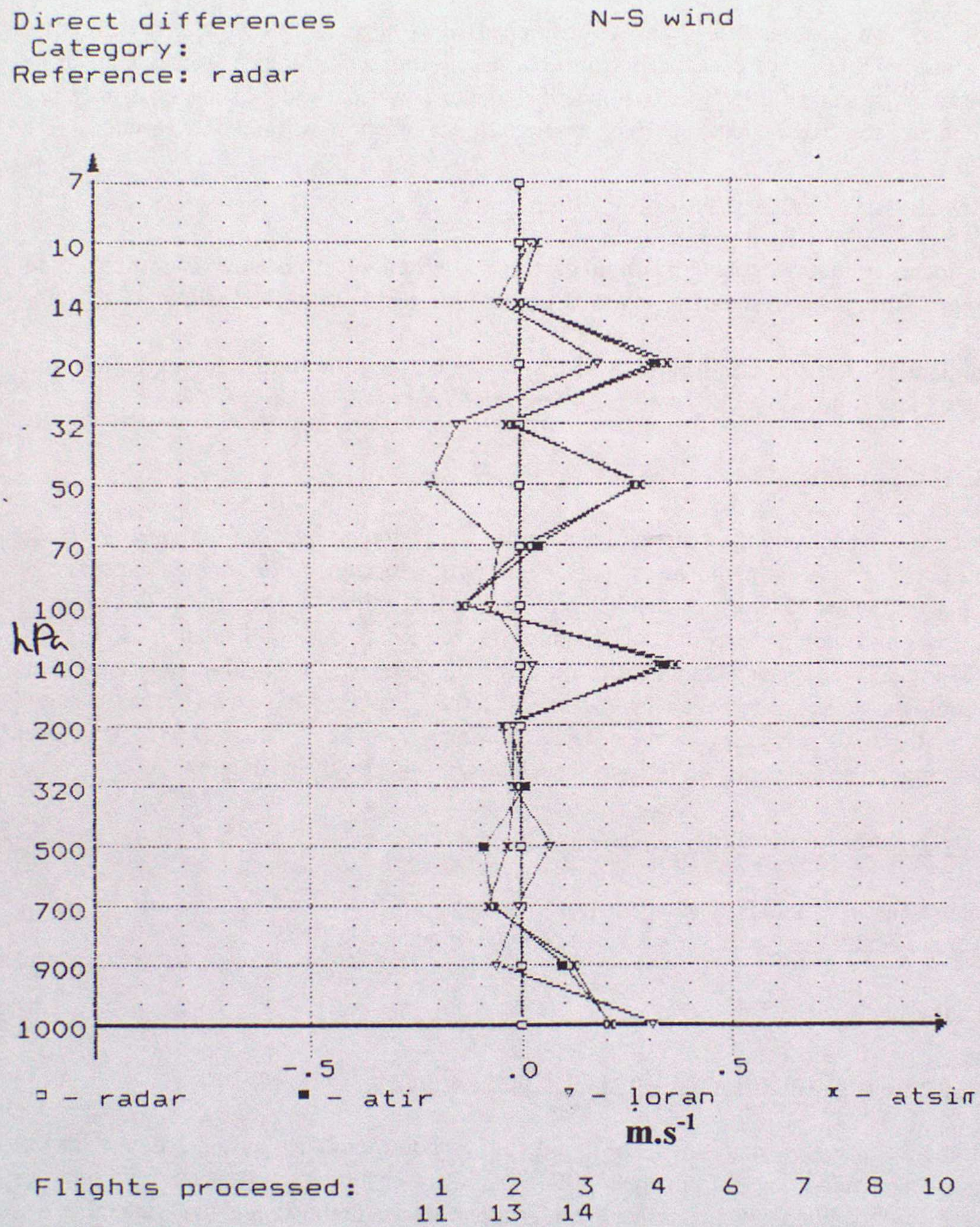


FIG 4(d)

7. OPERATIONAL EXPERIENCE AND RECOMMENDATIONS

7.1 VIZ Microsonde II

Of the 37 VIZ Microsondes tested during the two phases of the Trial there were 4 radiosondes which were rejected as failing to transmit.

7.2 Radiotheodolite Operations

The ATIR CV-700 system was assembled and re-positioned when necessary without problems. The preflight levelling and BIT tests were easily performed. Insufficient opportunities were available to assess the "auto-track" capability directly from launch ,but the elevation and bearing controls were adequate for the operator to drive the antenna to the required target generally within a few seconds.

7.3 Radiotheodolite System Recommendations.

7.3.1 It is recommended that weather proofing of the radiotheodolite antenna is improved to prevent water ingress during periods of severe weather or long term use in the field.

7.3.2 It is recommended that the CDU hand held display is better illuminated for night use and that the "azim elev" key is positioned further away from the "auto track" key.

7.4 Software Operations.

The programs were easy to use and the function keys facilitated switching between the various profile displays . During preflight operations however, immediately prior to launch, the ambiguous message "Flight Ready" appeared when F2 was pressed. The operator still required to press F1 at this stage to enable "Flight Ready **For Launch**" to prime the program to receive data through launch . Additionally ,if a delay occured immediately prior to launch ,the surface conditions ,which would already have been input during the preflight checks, may have changed significantly. This could have lead to measurement errors as the manually input surface wind data were incorporated as base values for the low level radiotheodolite winds and used to constrain the winds evaluated just above the surface).

7.5 Software Recommendations.

Remedy the ambiguity in the F1 and F2 messages prior to launch.
Change the software to enable surface observations to be input after launch.

8. SUMMARY

8.1 Wind Measurements During Medium and High Balloon Elevations.

The results from the 3 trials show that **when the signal to the radiotheodolite antenna is not subject to multipathing** the computed winds from the ATIR system are sufficiently adequate for upper air observations. In these conditions the computed winds from the radiotheodolite are generally less accurate than either radar or Loran measurements ,but **at least as accurate as Omega windfinding systems in current use .**

The Met Office would consider the use of the ATIR radiotheodolite at a radiosonde station where low elevations were uncommon.

8.2 Wind Measurements During Low Balloon Elevations.

The results from the BMETS Trial, all ascents from Phase 1 and Flight 11 from Phase II show that whenever elevations become lower than about 18 degrees the radiotheodolite tracking is likely to be degraded by multipathing. Under different siting and range conditions the critical angle when multipathing commences may be slightly higher or lower than 18 degrees ,but the likelihood of encountering winds strong enough to require low elevation observations is fundamental to upper air observations especially from temperate latitudes. Nash (3) has shown for example that in January to March 1993 ,30% of winds measured at 11kms in the British Isles were made with the angle to the balloon less than 10 degrees. (see Table 2 below):-

TABLE 2

Percentage of Operational Wind Observations at 11km Produced at Low Elevations for the first 6 months of 1993

	EUROPE	UK	USA	JAPAN	INDIA
Jan-Mar $\theta < 10°$	19	30	10	40	3
Apr-Jun $\theta < 10°$	3	5	3	12	0
Jan-Mar $15° > \theta > 10°$	25	25	20	39	8
Apr-Jun $15° > \theta > 10°$	17	21	18	34	1

10. REFERENCES

1. **Elms J.,Glennie and Nash** .BMETS Trial - Larkhill February 1994. (Met Office Report for DRA)

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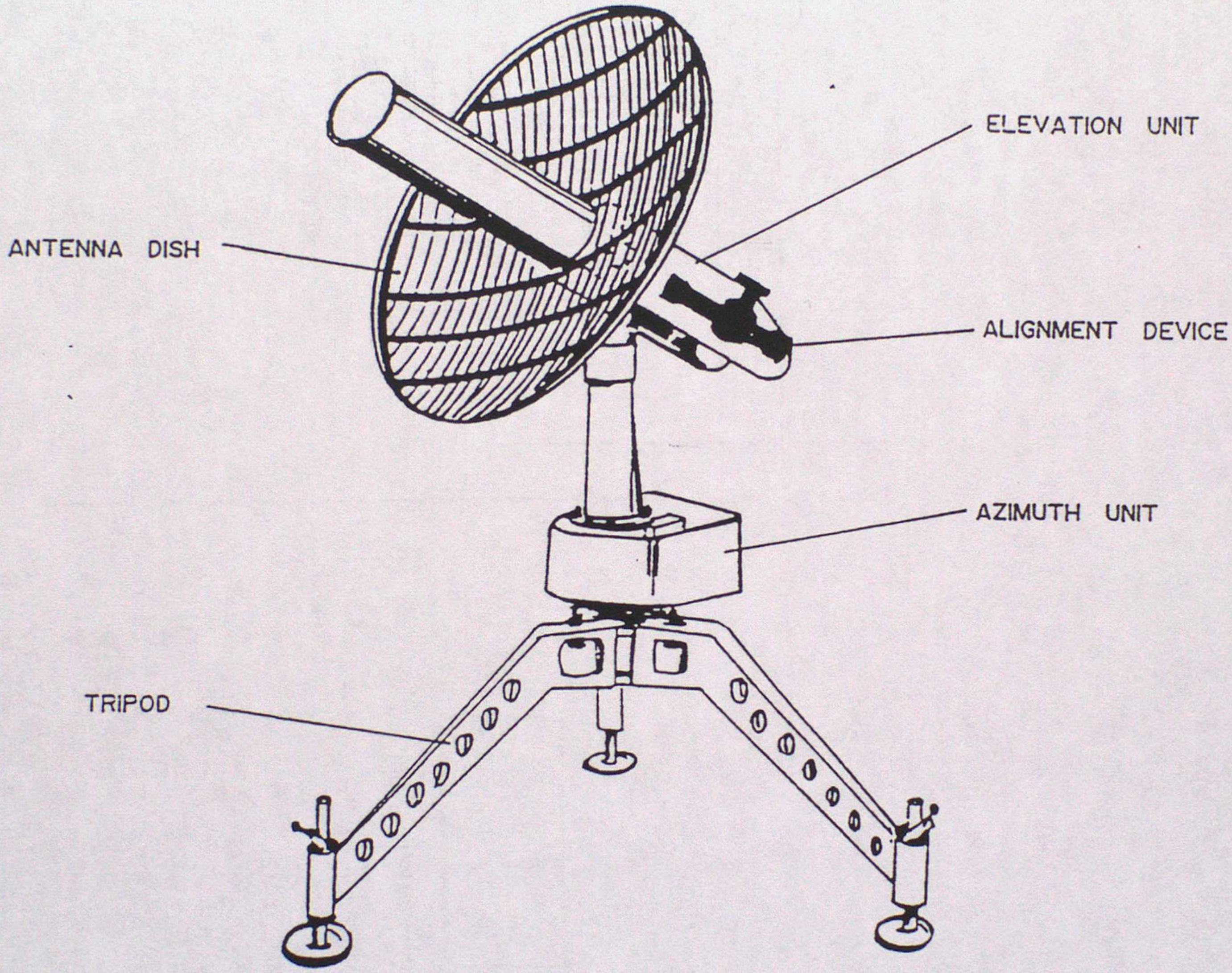
11. ACKNOWLEDGEMENTS

The Upper Air Trials Team is grateful for the support of the Senior Met. Officer ,Hemsby Upper Air Station and both the technical and operational staff for the extra work undertaken during these trials.
The help and training in use of the ATIR system given by Mr Doron Lavee ,systems engineer ATIR Ltd, was also very much appreciated.

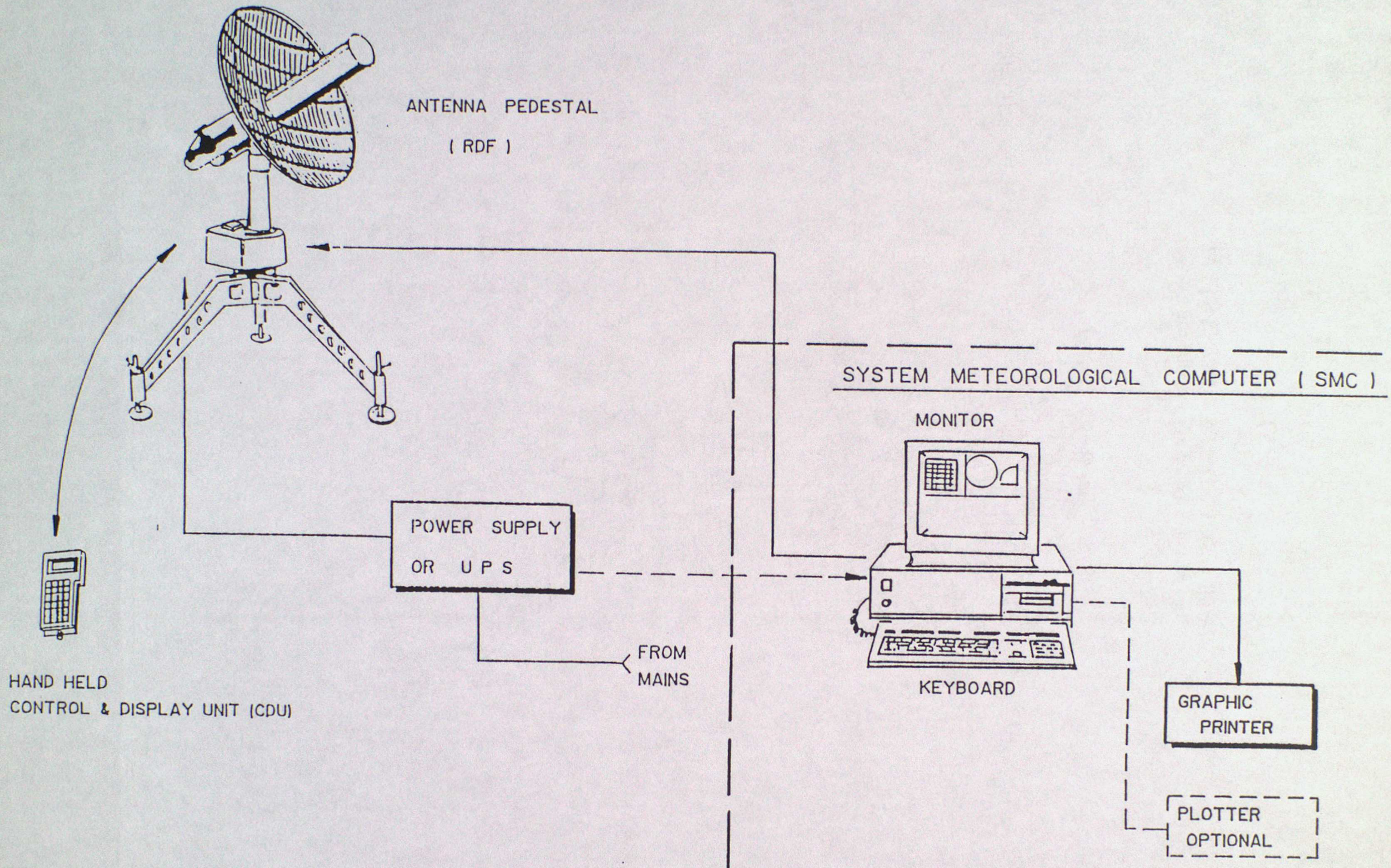
ANNEXE 1

CV-700 GROUND STATION SYSTEM

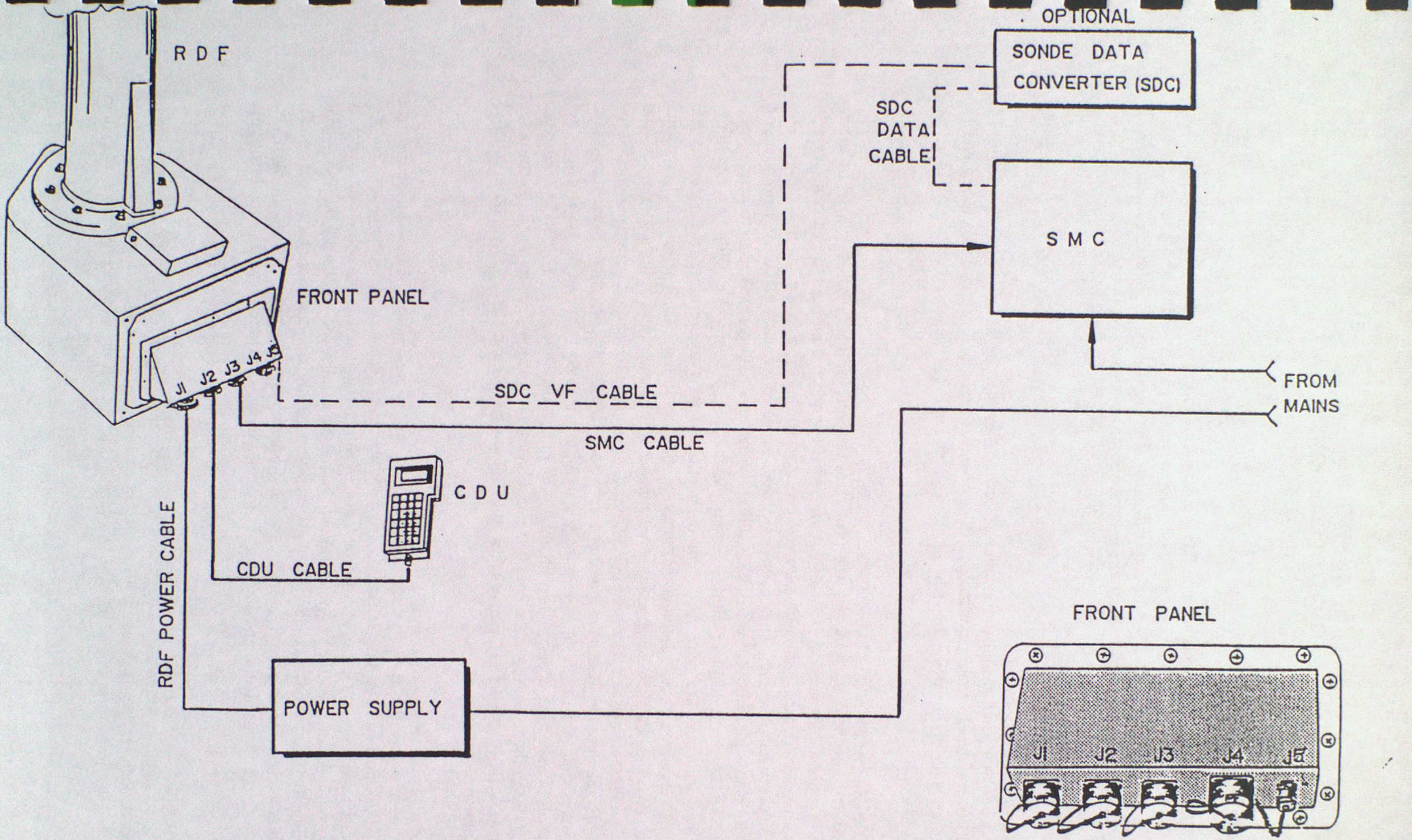
(Information supplied by the manufacturer)



CV - 700 RDF - MAJOR COMPONENTS



CV-700 SYSTEM



CV-700 SYSTEM - INTERCONNECTING CABLES

ANNEXE 2
TRIAL OPERATIONS

A1.1 Radiotheodolite Siting.

During Phase I the radiotheodolite was sited on flat ground to the north east of the Met Office buildings with an unobstructed view to the east. This same position was kept for Phase II whilst elevation angles remained high ,but during the last 2 days, the radiotheodolite was dissembled and moved to west side of the buildings, gaining an unobstructed view to the west whilst stronger easterly winds prevailed.

A1.2 CV-700 Flight Operations.

Pre-flight Procedure. - Radiotheodolite
The radiotheodolite was levelled and the azimuth checked prior to each ascent. A diagnostic "BIT" (Built In Test) was also performed prior to each flight to ensure reception of the data streams and to check that the antenna could move through 360 ° azimuth and 90° elevation within ATIR's test specification times .

Pre-flight Procedure - Radiosonde and Computer Checks.
The radiosonde was prepared by removing the protective cover from the carbon hygristor humidity element ,inhibiting the deployment of the built in suspension unwinder from the top of the radiosonde and filling ,wrapping and inserting the water activated battery .During the Trials a laptop computer was used as the ground station processor. The operator switched on the computer and ZEEMET decoder and typed in "CV" to obtain a menu from which he could select the required operation using function keys. Function Key F2 was used to display FLIGHT control panel whereby the receiver could be tuned to the radiosonde either using an auto scan facility or by manually tuning the receiver to the correct RF frequency. Once the operator was satisfied that the radiosonde signals were being successfully received and decoded by the ground station he selected the F1 function key to enter the pre-flight conditions. The software checked the transmitted pressure values with those read from the station barometer and if they were within 1 hPa the operator instructed the computer to apply a controls correction compensating for the pressure discrepancy at the surface. (Unlike the PC-CORA system the ATIR system does not perform "controls" calibration checks on the humidity or temperature data.) Just prior to taking the radiosonde outside to the launch area the operator pressed further function keys to obtain the message "FLIGHT READY FOR LAUNCH". He was then able to leave the ground station computer in order to launch the radiosonde .

Launch Procedure.
At the radiotheodolite position the operator checked the reception and quality of the radiosonde data using the CDU (Control and Display Unit) attached to the processor within the radiotheodolite. The RF signal level on a scale from 0 to 9 was also verified. Depending on the direction and speed of the surface winds, the operator decided whether or not to allow the radiotheodolite to "autotrack" the radiosonde from the surface. On most occasions ,due to rapidly changing bearings during these tests ,he manually drove the radiotheodolite antenna to the direction of the radiosonde using function keys on the CDU. Usually within 5 to 15 seconds the antenna was set to "autotrack" and tracking was verified using the attached telescope.

In Flight Procedure.
Periodic checks comparing the radar bearings with those from the radiotheodolite and the reception and validity of the radiosonde data were made. Profiles of the wind and radiosonde data could be displayed on the monitor, but unlike the PC-CORA system ,the ATIR system did not incorporate a real time

editing facility. The software recognised an increase in pressure at balloon burst and requested the operator to verify this event.

Post Flight Procedure.

During the Trials data interpolated at both 2 second and 1 minute intervals from launch were obtained using programs within the "Report" software provided by the ATIR system.

ANNEXE 3

DATA ANALYSIS PROCEDURES

A2.1 Analysis Software

The analysis software ("RSKOMP") used by the Met. Office for this report was developed by Sergei Kurnosenko (Central Aerological Observatory, Moscow) in liaison with the Met. Office Observation Provision Branch . (Kurnosenko ,1996 [5]). This software processed simultaneous data at exact minute intervals from launch. Such data were extracted from the detailed 2 second samples having been corrected for timing discrepancies as described in A2.2 below.

Statistical processing of the full range of meteorological variables was performed using the DIFFRS program written by Kurnosenko. The principles of the statistical processing are briefly described in Nash and Schmidlin [2] . Differences between the measurements of a given variable by each system were computed for the samples available each minute throughout the flight. The difference data were subdivided into the pressure bands indicated in Table A1 below. For each pressure band , the mean differences between two given system types and the associated standard deviation of the data set was computed. For wind observations the differences were computed for southerly and westerly components, rather than for wind speed and direction, since the component statistics are easier to interpret when upper winds are relatively weak.

TABLE A1
PRESSURE BANDS FOR MINUTE DATA

NOMINAL PRESSURE hPa	ACTUAL LAYER hPa
1000	SURFACE to 975
900	975 to 840
700	840 to 589
500	589 to 415
320	415 to 245
200	245 to 164
140	164 to 119
100	119 to 84
70	84 to 58.9
50	58.9 to 41.5
32	41.5 to 24.5
20	24.5 to 16.4
14	16.4 to 11.9
10	11.9 to 8.4
7	8.4 to 5.9

A.2.2 Timing Adjustments.

Accurate synchronisation of the data samples (to better than ± 1s, if possible) is necessary if radiosonde pressure , relative humidity and temperature comparison are to be valid . Several radiosonde comparison tests since 1991 have demonstrated that many of the ground systems corrupt the times assigned to data under certain circumstances, e.g. poor signal reception following launch. Thus ATIR were also asked to provide samples of measurements at 2s intervals . Data such as these had been successfully used to eliminate timing errors in recent international radiosonde tests in the U.K. and Japan. The timing corrections applied were deduced from comparison of detailed vertical structure in the temperature and humidity measurements measured by the different systems, structure often associated with temperature inversions . In previous tests, the response times of the temperature and relative humidity sensors used by the Vaisala RS80 radiosonde have been shown to be similar to those of the VIZ and AIR radiosondes. Thus, if timing is correct the detailed changes in temperature and relative humidity with time correlate very closely from system to system .The main exception to this rule occurs when the radiosondes emerge from cloud tops, since wetting of the sensing systems in the cloud may temporarily contaminate some sensing systems, and psychrometric cooling of wet sensors may also lead to false variations with time in the measurements.

All time corrections shown in the tables A2 and A3 were those **subtracted** from the ATIR 2 second data times of computations .These corrections ensured that the data was synchronised with 2 second MET data.
ATIR Minute data values were subsequently extracted from this corrected 2 second data set.

TIMING CORRECTIONS APPLIED TO PHASE I ,ATIR DATA

FLT	secs	FLT	secs	FLT	secs	FLT	secs
1	4	**7**	6	**13**	0	**19**	-78
2	0	**8**	6	**14**	46		
3	24	**9**	10	**15**	-130		
4	0	**10**	--	**16**	6		
5	0	**11**	222	**17**	6		
6	6	**12**	2	**18**	4		

TIMING CORRECTIONS APPLIED TO PHASE II ATIR DATA

FLT.	**secs**
7	8
8	8
10	8
11	-4
13	4
14	2

ANNEXE 4 COMPARISON DATA AND FLAGGING

HEMSBY ATIR RADIOTHEODOLITE TRIAL PHASE I
DATA USED IN COMPARISON STATISTICS

	SYSTEM			DATE	REMARKS
1	RAD		ATIR	21/3/94 1115	Loran not flown
2	RAD	LOR	ATIR	21/3/94 1716	Radar Mins 66-68 flagged. Much "interpolated" data on PC-CORA system.
3	RAD	LOR	ATIR	22/3/94 1133	Radar DPU bearing indicator changed prior to flight. Missing loran data from about 300-150 hPa
4	RAD	LOR	ATIR	22/3/94 1418	
5	RAD	LOR	ATIR	22/3/94 1713	
6	RAD	LOR		22/3/94 2126	No Theod data ."BIT" key pressed by mistake on CDU. Theod PTU data OK from 400 hPa ,but unable to simulate.
7	RAD	LOR	ATIR	22/3/94 2332	
8	RAD	LOR	ATIR	23/3/94 1117	Loran - poor signals at long range
9	RAD	LOR	ATIR	23/3/94 1431	Radar azimuth adjusted by +1 degree prior to launch following optical test. Radar data missing 500-400hPa (az synchro fault caused 10 deg jump)°°
10	RAD	LOR		23/3/94 1714	Theod . Crashed launch!!! Temp el. damaged Radar Pilot winds.
11	RAD	LOR	ATIR	23/3/94 1958	Radar synchro fault mins 12-17 .Missing winds 700-500,200-150 hPa.
12		LOR	ATIR	23/3/94 2316	Radar reflector not used -29 kt surface wind.
13	RAD	LOR	ATIR	24/3/94 1241	
14	RAD	LOR	ATIR	24/3/94 1456	Radar followed to 185 km.
15	RAD	LOR	f	24/3/94 1720	Loran tracker changed prior to launch just for test purposes. Theod . - VIZ sonde hit ground on launch.Pressure U/S hence no winds All Theod Pressure data flagged.Temps OK Radar - No winds above 300 hPa.
16	RADf	LOR	ATIR	24/3/94 1959	Radar - No winds above 220 hPa . Winds min 35 to end flagged.
17	RADf	LOR	ATIR	24/3/94 2151	Radar - No winds after 300 hPa. Winds min 34 to end flagged. Anom Temperatures
18	RAD	LOR	ATIR	24/3/94 2334	Radar- No winds after 250 hPa .Mins 40-42 flagged Loran - interference from another sonde -no data after 150 hPa.
19	RAD	LOR	ATIR	25/3/94 1139	Radar Mins 81,82 anomalous winds flagged

HEMSBY ATIR THEODOLITE TRIAL PHASE II
DATA USED IN COMPARISON STATISTICS

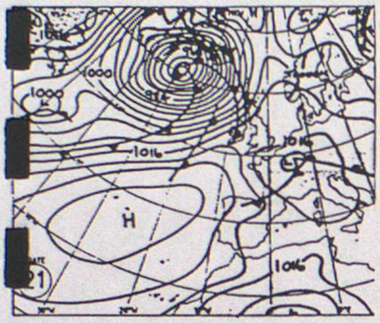
	SYSTEM			DATE	REMARKS
1	RAD	LOR	ATIR f	9/5/94 1140	ATIR Mins 1-7 FLAGGED Theod Not tracking due to operator error
2	RAD	LOR	ATIR	9/5/94 1514	
3	RAD	LOR	ATIR f	9/5/94 1717	ATIR Mins 12to end WINDS FLAGGED Theod not auto tracking
4	RAD	LOR	ATIR f	9/5/94 2011	ATIR Mins 8 onwards WINDS FLAGGED Theod not auto tracking
5	RAD	LOR	ATIR	9/5/94 2338	ATIR COULD NOT AUTOFOLLOW - NO WINDS
6	RAD	LOR	ATIR	10/5/94 1128	
7	RAD	LOR	ATIR	10/5/94 1438	
8	RAD	LOR	ATIR f	10/5/94 1718	ATIR Mins 71 -end flagged (Theod not auto tracking)
9	RAD	LOR	ATIR	10/5/94 2017	ATIR COULD NOT AUTOFOLLOW - NO WINDS
10	RAD	LOR		11/5/94 1118	
11	RAD f	LOR	ATIR	11/5/94 1554	(First flight after move theodolite to west of buildings) RADAR winds min 71 flagged MINIMUM ELEV = 14 DEGREES
12	RAD	LOR	ATIR	11/5/94 2048	
13	RAD	LOR	ATIR	11/5/94 1149	
14	RAD	LOR	ATIR	11/5/94 1731	

ATIR RADIO-THEODOLITE TRIALS (MARCH and MAY 1994)
SYNOPTIC CHARTS FOR PERIODS

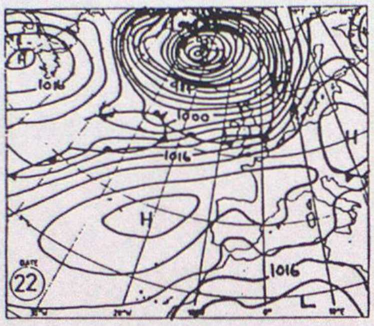
PHASE 1 (MARCH)

ANNEXE 5

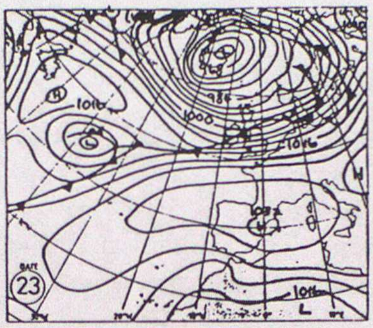
MONDAY



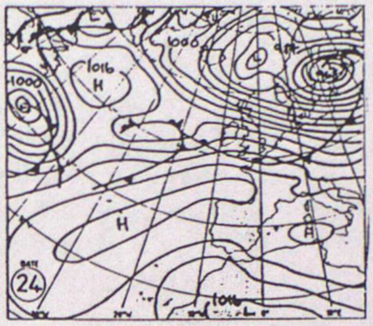
TUESDAY



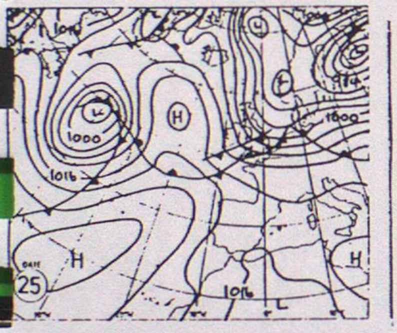
WEDNESDAY



THURSDAY

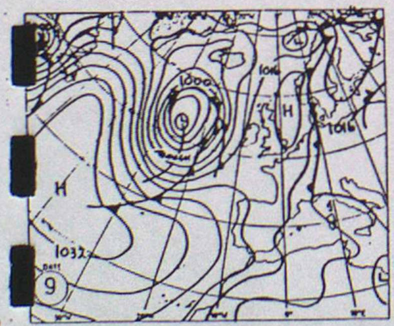


FRIDAY

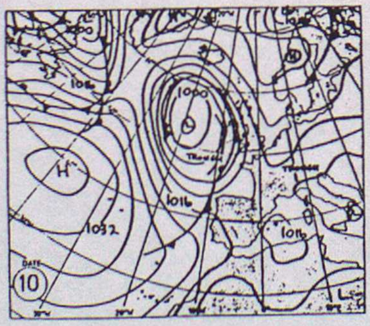


PHASE 2 (MAY)

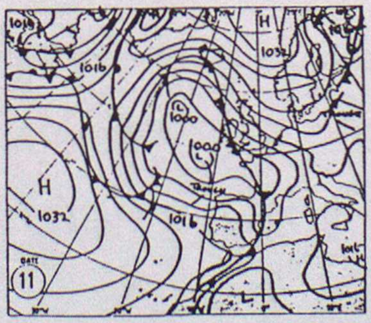
MONDAY



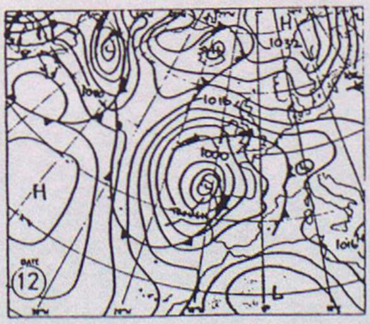
TUESDAY



WEDNESDAY



THURSDAY



<u>ANNEXE 6</u>

PC-CORA FLIGHT LOGS FOR RADAR AND LORAN ASCENTS

The information tabulated in the following pages was obtained from the PC-CORA 2 second "EDT" file output.

Key:-

Actl = Launch Time GMT
P,T U CORRECTIONS are PREFLIGHT CONTROLS CORRECTIONS in hPa X 10 , °C X 10 and percentage humidity respectively.
DD = Surface Wind Direction
FF = Surface Wind speed (m/s) from 10m anemometer.
CLOUD GROUP . WMO Cloud report at launch time
Wr WMO Weather code " "
Max Rge = Maximum flat range in kms.
Asct Rate = Ascent Rate (mean m/s)

MAXWIND
FF = Wind Speed (m/s)
DRN = Direction
TEM Min = Minimum Temperature of ascent (°C)
ELEV Mn = Minimum Elevation During ascent

BURST
Azi = Balloon azimuth at burst
t = End of flight code (5= burst)
Tim = Burst Time (mins from launch)

TRO,PAUSE
Tmp = Tropopause Temp (°C)
Hgt = " Height (dkm)

WIND INTERP
Tot = Total no. of seconds wind data "interpolated" by PC-CORA software.
Lt4 = " " " " " " in first 4 minutes only.
fgv = Time (seconds) of First good Loran wind value (as perceived by PC-CORA quality control)

LORAN INFORMATION:-
Station Identifiers:-
Mast = Master station
1 = Slave 1
2 = Slave 2 (etc)
The values quoted in columns headed by the Loran Station Identifiers are percentages of the total flight time when Loran signals were received from that Station.

ANNEXE 6

ATIR R.THEODOLITE TRIAL HEMSBY 94 (RADAR)

Stn.	Flt.	YYMMDDHH.	Actl.	SondeNum...	CORRECTION P	T	U.	Pres-	SURFACE Tmp-	Hum-	DD-	FF.	GROUP Cloud-	Wr.
496	1	94032111	1115	284534043	10	-3	0	1016	6	70	3	6	48501	03
496	2	94032117	1716	221138151	1	-1	-2	1019	5	75	35	4	12501	02
496	3	94032211	1133	163232453	13	-6	0	1014	8	89	24	9	854//	21
496	4	94032214	1418	221138042	10	-2	0	1013	10	83	23	9	854//	//
496	5	94032217	1713	221138043	8	-1	0	1013	11	86	24	9	885//	02
496	6	94032221	2126	153239041	9	-4	1	1013	11	90	23	8	885//	02
496	7	94032223	2332	153239152	9	-6	-1	1012	11	91	23	7	854//	02
496	8	94032311	1117	153239147	12	-3	-1	1008	14	84	23	10	854//	03
496	9	94032314	1431	153239141	8	-5	-2	1005	15	80	24	11	854//	01
496	10	94032317	1714	pilot	***	***	***	1004	15	75	25	13	755/2	02
496	11	94032319	1958	153238841	7	-4	-1	1004	14	76	25	14	875//	02
496	13	94032412	1241	153239145	17	-4	-1	1013	10	55	27	10	786//	03
496	14	94032414	1456	153239645	2	-1	0	1013	10	55	28	8	786//	02
496	15	94032417	1720	153239650	14	-7	0	1014	10	54	27	9	786/2	03
496	16	94032419	1959	153239655	5	-2	0	1013	8	68	26	4	25702	03
496	17	94032421	2151	153239444	8	-2	2	1013	8	69	23	5	60932	03
496	18	94032423	2334	153239450	10	-4	0	1012	7	86	23	3	855//	60
496	19	94032511	1139	153231445	9	-4	1	999	12	80	25	11	885//	01

		MAXWIND FF-	DRN--	HGT..	Max Rge.	HUM Min-	Max.	TEM Min.	ELEV	hPa Heights ..100----	50-----	30...	Asct Rate
1	94032111	54	296	24173	113	3	80	-79	12	15764	19863	22818	5.9
2	94032117	59	277	19667i	121	1	90	-74	10	15830	19939	-99	4.8
3	94032211	51	282	11666	127	5	97	-76	10	15944	20087	23094	6.0
4	94032214	53	292	10944	170	1	100	-76	9	15949	20100	23109	5.1
5	94032217	62	292	11009	124	15	100	-71	9	15955	20108+	-99	4.6
6	94032221	53	297	10233	108	8	99	-72	10	15981	-99	-99	5.0
7	94032223	60	309	10697	137	1	97	-74	9	16004	20179	23226	5.3
8	94032311	49	284	12870	143	1	97	-73	9	16044	20260	23341	6.0
9	94032314	195	339	7392i	182	1	96	-73	8	16037	20261	23343	6.3
10	94032317	112	329	4151	172	***	***	***	6	*****	*****	*****	4.8
11	94032319	167	333	5946	189	1	97	-69	7	16025	20277	23371	5.5
13	94032412	55	285	10838	151	1	92	-69	8	16013	20284	23377	6.4
14	94032414	55	287u	10697	183	1	76	-69	8	16036	20318	23412	5.7
15	94032417	57h	291	8995	81f	1	81	-67	7	16021	20286	23388	5.0
16	94032419	131q	42	15500	117T	1	94	-68	7	16051	20319	23453	5.3
17	94032421	166s	20	14868	120	3	99	-64	7	16043	-99	-99	4.6
18	94032423	67e	298	14123i	91t	14	98	-62	7	-99	-99	-99	4.3
19	94032511	63	255	9880	160	1	92	-69	8	16016	20315	23458	6.0

		BURST Azi-	Rge-	hPA-	t-	Tim-	HGT-.	TRO,PAUSE Tmp-	HGT-.	WIND INTERP Tot--	Lt4-	fgv
1	94032111	141	113	20	5	71	2506	-65	1066	34	34	2
2	94032117	146	121	41	5	72	2103	-70	1177	124	28	2
3	94032211	103	127	22	5	69	2489	-72	1204	48	48	2
4	94032214	105	170	12	5	93	2895	-66	1131	52	52	56
5	94032217	103	124	56	5	70	1948	-68	1205	40	40	6
6	94032221	106	108	64	5	62	1866	-63	1194	30	30	12
7	94032223	109	137	29	5	74	2348	-64	1118	42	42	8
8	94032311	98	143	21	5	70	2538	-73	1288	48	48	16
9	94032314	95	182	9	5	80	3074	-73	1289	214	56	60
10	94032317	91	172	52	5	70	2034	***	****	330	88	60
11	94032319	92	189	19	5	79	2621	-67	1180	220	62	66
13	94032412	107	151	16	5	71	2733	-62	1141	22	22	6
14	94032414	106	183	11	5	86	2972	-60	1112	100	44	18
15	94032417	-99f	-99	4	4	118	3598	-63	1157	38	38	14
16	94032419	-99f	-99	14	5	87	2801	-62	1125	322	104	2
17	94032421	-99f	-99	93	5	59	1646	-62	1140	280	40	12
18	94032423	-99f	-99	135	5	54	1415	-61	1097	16	16	2
19	94032511	95	160	11	5	82	2983	-56	1007	80	36	40

ATIR R.THEODOLITE TRIAL HEMSBY (LORAN)

Stn.	Flt.	YYMMDDHH.	Actl.	SondeNum...	CORRECTION P----	-T---	-U.	SURFACE Pres-	Tmp-	Hum-	DD-	FF.	GROUP Cloud-	Wr.
496	2	94032117	1715	221138151	3	-3	-2	1019	5	75	35	4	12501	02
496	3	94032211	1133	163232453	13	-6	0	1014	8	89	24	9	854//	21
496	4	94032214	1417	221138042	10	-2	0	1013	10	83	23	9	854//	02
496	5	94032217	1712	221138043	10	-1	-1	1013	11	85	24	9	854//	02
496	6	94032221	2125	153239041	10	-4	1	1013	11	90	23	8	885//	02
496	7	94032223	2332	153239152	8	-6	-1	1012	11	91	23	4	854//	02
496	8	94032311	1117	153239147	12	-3	-1	1008	14	84	23	10	854//	03
496	9	94032314	1431	153239141	9	-5	-2	1005	15	80	24	11	854//	01
496	10	94032317	1714	153238851	7	-4	-2	1004	15	75	25	13	755/2	02
496	11	94032319	1958	153238841	7	-4	-1	1004	14	76	25	14	875//	02
496	12	94032323	2316	153239055	7	-3	1	1003	13	78	25	14	756//	02
496	13	94032412	1241	153239145	17	-4	-1	1013	10	55	27	10	786//	03
496	14	94032414	1455	153239645	1	-1	0	1013	10	55	28	8	786//	02
496	15	94032417	1720	153239650	15	-7	0	1014	10	54	27	9	786//	//
496	16	94032419	1959	153239655	5	-2	0	1013	8	68	26	4	25702	01
496	17	94032421	2151	153239444	8	-3	2	1013	8	69	23	5	60932	03
496	18	94032423	2334	153239450	10	-4	0	1012	7	86	23	3	855//	60
496	19	94032511	1139	153231445	7	-4	1	999	12	80	25	11	885//	01

		MAXWIND FF-	DRN--	HGT..	Max Rge.	HUM Min-	Max.	TEM Min.	ELEV 80+-	Mn..	hPa Heights 100----	50-----	30...	Asct Rate
2	94032117	53	346	11375	122	1	90	-74	0	10	15824	19931	-99	4.8
3	94032211	52q	280	10591i	31f	5	97	-75	0	13	15943	20087	23093	6.0
4	94032214	53	294	10969	170	1	100	-76	0	9	15948	20099	23108	5.1
5	94032217	61	294	10993	125	14	100	-71	0	9	15954	20108+	-99	4.6
6	94032221	53	299	10213	109	8	99	-72	0	10	15981	-99	-99	5.0
7	94032223	59	309	10487	137	1	97	-74	0	9	16005	20180	23227	5.3
8	94032311	49e	286	12678	139t	1	97	-73	0	9	16044	20260	23340	6.2
9	94032314	50	274	12607	180	1	96	-73	0	8	16037	20262	23342	6.3
10	94032317	62	274	12230	169	1	95	-71	0	6	16016	20239	-99	4.9
11	94032319	63	272	11623	189	1	97	-69	0	7	16025	20277	23371	5.5
12	94032323	64	273	7396	150	1	99	-68	0	7	16011	20281	-99	6.0
13	94032412	53	287	10887	151	1	92	-69	0	9	16012	20283	23377	6.4
14	94032414	55	286	10074	171	1	76	-69	0	8	16035	20318	23412	5.6
15	94032417	57	245	35683	258	1	81	-67	0	6	16022	20287	23390	5.0
16	94032419	56	289	10807	189	1	94	-68	0	7	16051	20319	23454	5.3
17	94032421	55t	284	10461	150	3	99	-65	0	7	16040	20291	-99	4.7
18	94032423	67e	298	14123i	91t	14	98	-62	0	7	-99	-99	-99	4.3
19	94032511	62	256	9824	156	1	92	-69	0	8	16017	20316	23458	6.0

		Norwegian Chain Mast--	1---	2---	3---	4---	5.	French Chain Mast--	1---	2---	3---	4.
2	94032117	99	100	100	100	99	0	100	100	0	0	0
3	94032211	66	20	97	38	25	0	85	73	0	0	0
4	94032214	100	46	100	66	0	0	100	100	0	0	0
5	94032217	97	98	99	50	2	0	95	99	0	0	0
6	94032221	99	100	100	99	100	0	100	100	0	0	0
7	94032223	70	80	100	70	48	0	96	96	0	0	0
8	94032311	84	47	93	46	0	0	87	86	0	0	0
9	94032314	99	81	100	98	98	0	93	99	0	0	0
10	94032317	99	100	100	97	100	0	99	99	0	0	0
11	94032319	99	100	100	84	100	0	100	100	0	0	0
12	94032323	89	99	99	71	95	0	99	99	0	0	0
13	94032412	99	99	100	97	99	0	100	100	0	0	0
14	94032414	100	78	100	71	84	0	100	100	0	0	0
15	94032417	100	87	100	98	94	0	100	98	0	0	0

16	94032419	100	100	100	100	100	0	100	100	0	0	0
17	94032421	92	94	94	93	93	0	94	94	0	0	0
18	94032423	90	69	81	87	36	0	87	66	0	0	0
19	94032511	95	46	100	28	34	0	89	92	0	0	0

		BURST						TRO,PAUSE		WIND		INTERP
		Azi-	Rge-	hPA-	t-	Tim-	HGT-.	Tmp-	HGT-.	Tot--	Lt4-	fgv
2	94032117	147	122	41	5	72	2106	-70	1176	26	26	30
3	94032211	-99f	-99	22	5	69	2490	-72	1204	352	56	60
4	94032214	108	170	12	5	93	2897	-66	1130	56	56	60
5	94032217	105	125	56	5	70	1947	-68	1206	262	0	2
6	94032221	108	109	64	5	62	1866	-63	1194	56	56	60
7	94032223	112	137	29	5	74	2348	-64	1118	358	76	80
8	94032311	-99f	-99	11	5	79	2964	-73	1287	56	56	60
9	94032314	96	180	9	5	80	3069	-73	1289	16	16	2
10	94032317	93	169	48	5	69	2051	-71	1249	56	56	60
11	94032319	95	189	19	5	79	2620	-67	1181	76	76	80
12	94032323	94	150	45	5	57	2090	-65	1145	26	26	30
13	94032412	108	151	15	5	71	2745	-62	1138	102	16	2
14	94032414	108	171	16	5	80	2711	-60	1112	0	0	2
15	94032417	105t	258	4	4	119	3625	-63	1156	16	16	20
16	94032419	111	189	14	0	87	2800	-62	1125	0	0	2
17	94032421	-99f	-99	45	1	74	2093	-62	1144	16	16	20
18	94032423	-99f	-99	135	5	54	1415	-61	1097	16	16	2
19	94032511	97t	156	11	5	82	2978	-56	1006	374	56	60

THEODOLITE TRIAL (HEMSBY MAY 1994)RADAR

Stn.	Flt.	YYMMDDHH.	Actl.	SondeNum...	CORRECTION P	T	U.	SURFACE Pres	Tmp	Hum	DD	FF.	GROUP Cloud	Wr.
496	1	9405 911	1140	173233947	4	-5	-3	1019	12	81	13	5	22530	02
496	2	9405 915	1514	173233942	-7	-1	-2	1019	12	82	12	5	11430	02
496	3	9405 917	1717	163236854	-6	-7	0	1019	10	81	13	5	11430	02
496	4	9405 920	2011	173231553	0	-1	1	1020	9	90	10	3	11531	01
496	5	9405 923	2338	284730447	12	-1	0	1020	8	91	11	4	10931	02
496	6	94051011	1128	284730548	15	-3	-1	1018	11	77	12	6	31400	02
496	7	94051014	1438	284730553	11	-3	1	1017	11+	75	12	6	11404	03
496	8	94051017	1718	284730442	5	-1	0	1016	10	79	12	6	16402	02
496	9	94051020	2017	284730451	8	-4	0	1016	9	88	11	5	00907	03
496	10	94051111	1118	284730452	8	-1	0	1012	10	92	17	7	861//	50
496	11	94051115	1554	284730640	6	-2	-1	1010	10	93	8	6	861//	46
496	12	94051120	2048	284730645	11	-4	-1	1008	12	80	8	8	10932	05
496	13	94051211	1149	284730650	14	-4	-1	1010	15+	69	12	8	00900	02
496	14	94051217	1731	153239750	6	-3	-1	1011	14	75	13	2	21632	03

		MAXWIND FF	DRN	HGT.	Max Rge.	HUM Min	Max.	TEM Min.	ELEV 80+	Mn..	hPa Heights 100	50	30...	Asct Rate
1	9405 911	25	177	7992	27	1	86	-59	0	22	16209	20598	23865	5.3
2	9405 915	17	193	5169	9	1	85	-59	0	30	16241	20640	-99	5.0
3	9405 917	15	327	9024	6	1	88	-58	0	35	16228	20621+	-99	5.1
4	9405 920	29	336	8686	16	1	90	-58	112	34	16242	20635	23904	5.0
5	9405 923	31s	334	7496	5s	1	86	-58	56	27	16243	20641	23914	5.4
6	94051011	25	285	10478	20	1	86	-59	0	28	16233	20634	23925	5.3
7	94051014	32	278	10644	22	1	86	-61	0	31	16230	20646	23938	5.3
8	94051017	27	277	10893	19	1	78	-62	0	34	16236	20647	23939	5.5
9	94051020	18	277	11255	15	1	86	-63	0	23	16233	20653	23960	4.7
10	94051111	19	129	4612	47	1	90	-65	0	22	16219	20664	23962	5.8
11	94051115	19	128	4041	52	1	93	-61	0	14	16222	-99	-99	4.1
12	94051120	23	109	6401	78	1	88	-61	0	12	16204	20648	23948	4.4
13	94051211	23	112	7699	69	1	66	-61	0	15	16177	20634	23912	5.9
14	94051217	20	85	33398	63	1	89	-60	0	23	16178	20632	23905	5.6

		BURST Azi	Rge	hPA	t	Tim	HGT-.	TRO.PAUSE Tmp	HGT-.	WIND INTERP Tot	Lt4	fgv
1	9405 911	342t	27	14	5	91	2877	-52	1127	150	44	18
2	9405 915	36t	8	46	5	70	2113	-50	1066	62	52	56
3	9405 917	98	5	52	5	66	2034	-52	1089	60	52	32
4	9405 920	238	16	8	1	108	3280	-53	1124	112	96	100
5	9405 923	-99f	-99	10	5	96	3100	-56	1198	48	36	16
6	94051011	52	11	21	5	82	2612	-57	1060	42	36	14
7	94051014	22	13	13	5	92	2935	-59	1089	38	32	2
8	94051017	13	11	13	5	88	2927	-62	1138	42	32	2
9	94051020	354	15	28	4	85	2434	-63	1145	34	30	2
10	94051111	299t	47	13	5	83	2925	-65	1180	46	46	2
11	94051115	299	52	82	1	71	1753	-60	1139	32	32	2
12	94051120	290	78	24	0	96	2543	-61	1140	50	46	50
13	94051211	291	69	11	5	85	3034	-61	1097	28	28	2
14	94051217	282	63	6	5	103	3451	-60	1098	32	16	2

THEODOLITE TRIAL (HEMSBY MAY 1994) LORAN

					CORRECTION				SURFACE				GROUP	
Stn.	Flt.	YYMMDDHH.	Actl.	SondeNum...	P----	T---	U.	Pres-	Tmp-	Hum-	DD-	FF.	Cloud-	Wr.
496	1	9405 911	1140	173233947	4	-5	-3	1019	12+	81	13	5	22530	02
496	2	9405 915	1514	173233942	-7	-1	-2	1019	12	82	12	5	11430	02
496	3	9405 917	1718	163236854	-6	-7	0	1019	10	81	13	5	11430	02
496	4	9405 920	2012	173231553	-1	-1	1	1020	9	90	10	3	11531	01
496	5	9405 923	2339	284730447	11	-1	0	1020	8	91	11	4	10931	02
496	6	94051011	1129	284730548	15	-3	-1	1018	11	77	12	6	31400	02
496	7	94051014	1438	284730553	11	-3	1	1017	11+	75	12	6	11404	03
496	8	94051017	1719	284730442	5	-2	0	1016	10	79	12	6	16402	02
496	9	94051020	2017	284730451	8	-4	0	1016	9	88	11	5	00907	03
496	10	94051111	1119	284730452	8	-1	0	1012	10	92	8	7	861//	50
496	11	94051115	1555	284730640	6	-2	-1	1010	10	93	8	6	861//	46
496	12	94051120	2049	284730645	11	-4	-1	1008	12	80	8	8	10932	05
496	13	94051211	1150	284730650	12	-4	-1	1010	15+	69	12	8	00900	02
496	14	94051217	1730	153239750	7	-3	-1	1011	14	75	13	2	21632	03

		MAXWIND			Max	HUM		TEM	ELEV		hPa Heights			Asct
		FF-	DRN--	HGT..	Rge.	Min-	Max.	Min.	80+-	Mn..	100----	50-----	30...	Rate
1	9405 911	24	176	7457	28	1	86	-59	0	24	16209	20597	23865	5.3
2	9405 915	16	192	5111	9	1	85	-59	0	31	16243	20641	-99	5.0
3	9405 917	14	329	8889	6	1	88	-59	0	48	16227	20621+	-99	5.1
4	9405 920	24	338	8387	21	1	90	-58	106	35	16242	20636	23908	5.3
5	9405 923	31	337	7733	16	1	82	-58	76	37	16243	20645	23920	5.4
6	94051011	25	283	10115	19	1	86	-59	0	33	16233	20635	23928	5.4
7	94051014	31	280	10566	21	1	86	-61	0	31	16230	20641	23924	5.4
8	94051017	26	276	10790	19	1	80	-62	0	34	16232	20646	23952	5.4
9	94051020	17	273	11085	15	1	86	-63	0	26	16234	20653	23973+	4.7
10	94051111	18	131	4591	48	1	90	-65	0	22	16219	20664	23962	5.8
11	94051115	20	123	6306	50	1	93	-61	0	14	16222	-99	-99	4.1
12	94051120	22	110	6445	77	1	88	-61	0	12	16204	20648	23948	4.4
13	94051211	23	113	7515	69	1	67	-61	0	15	16177	20633	23912	5.9
14	94051217	21	84	33410	63	1	89	-60	0	23	16177	20632	23905	5.6

		BURST						TRO,PAUSE		WIND	INTERP	
		Azi-	Rge-	hPA-	t-	Tim-	HGT-.	Tmp-	HGT-.	Tot--	Lt4-	fgv.
1	9405 911	341	28	14	5	91	2873	-52	1128	328	16	2
2	9405 915	35	8	48	5	69	2092	-50	1070	284	32	2
3	9405 917	100	5	51	5	67	2053	-52	1090	412	16	2
4	9405 920	247t	21	4	4	119	3799	-53	1119	406	16	20
5	9405 923	230	12	10	5	96	3100	-56	1198	394	16	2
6	94051011	39	10	17	5	85	2768	-57	1060	326	34	2
7	94051014	26	13	15	5	87	2841	-59	1089	452	32	2
8	94051017	40	12	28	5	75	2439	-62	1137	264	0	2
9	94051020	4	14	35	1	81	2295	-63	1145	310	0	2
10	94051111	299	48	13	5	83	2923	-65	1180	58	0	2
11	94051115	300	50	99	1	66	1630	-60	1139	74	0	2
12	94051120	290	77	25	0	95	2509	-61	1139	32	0	2
13	94051211	291	69	11	5	85	3034	-61	1097	52	0	2
14	94051217	282	63	6	5	103	3455	-60	1098	48	48	22