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THE USE OF A WINDFINDING DROPSONDE FOR METEOROLOGICAL RECONNAISSANCE OVER THE NORTH ATLANTIC

by

P Ryder and W M Longworth

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1 Introduction

1.1 The Meteorological Office Cloud Physics Research Group (Met O 15) and the Meteorological Research Flight (MRF) have developed a windfinding dropsonde system for use from the MRF Hercules W2 aircraft. The specification of the sonde is provided in annexe 1 and figures 1 and 2. Further details are available in Ryder and Lewis (1979). Briefly, the sonde is designed to measure ambient temperature, humidity and pressure during its parachute controlled descent. The Loran C navigation aid is used to track the device and thereby provide an estimate of the windfield experienced by the sonde. The aircraft installation consists of a sonde test/calibration rig, a storage and ejection system housed in the ramp door of the Hercules and a computer based data logger designed to receive, process and store information from up to five sondes simultaneously.

1.2 The system was developed to aid research into the mesoscale structure and dynamics of weather systems over the North Atlantic. In such studies a pattern of atmospheric soundings is obtained at a set of grid points, typically separated by about 25 km, by dropping a sequence of sondes. Ideally data are required from all the grid points simultaneously. The ability to process data from up to 5 sondes at a time, combined with that of the Hercules to rapidly eject a sequence of sondes at such separations, allows a close approximation to the ideal. However this is at the expense of not providing fully analysed data in real time. The computing power available on board is sufficient only to process the large amount of data produced for storage on magnetic tape. Of course for research purposes this is an adequate, even desirable result.

1.3 It is suggested that the present system might be modified to provide a near real time meteorological sounding if data from only one sonde is processed at a time. This brief report discusses and demonstrates the sort of data which might be so produced. Some of the advantages and drawbacks of the approach are identified. An estimate of the cost and extent of the necessary development programme is presented.

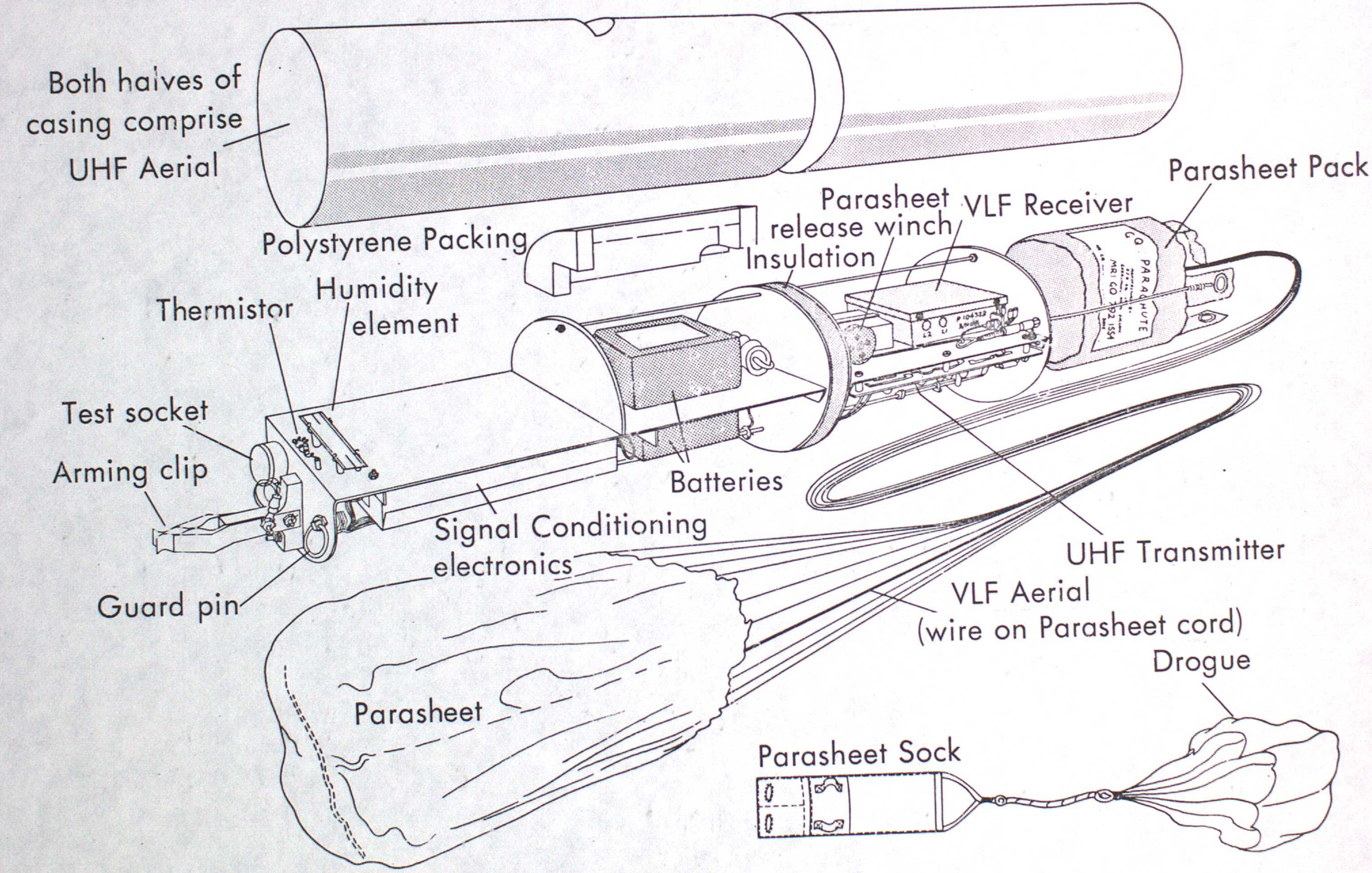

Figure 1 The Windfinding Dropsonde

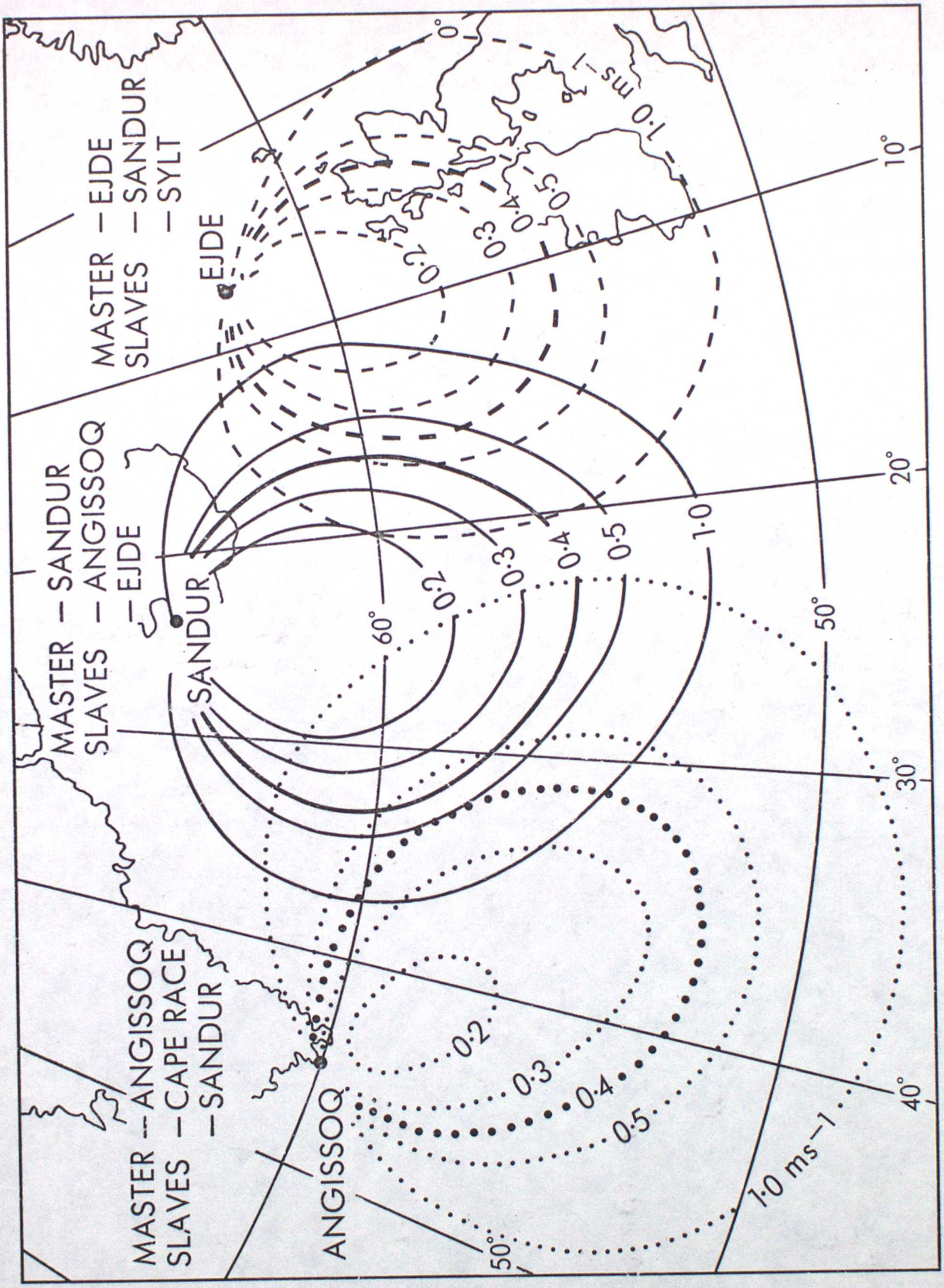

Figure 2

Predicted RMS 1 minute wind errors for daytime using the indicated Loran C transmitters

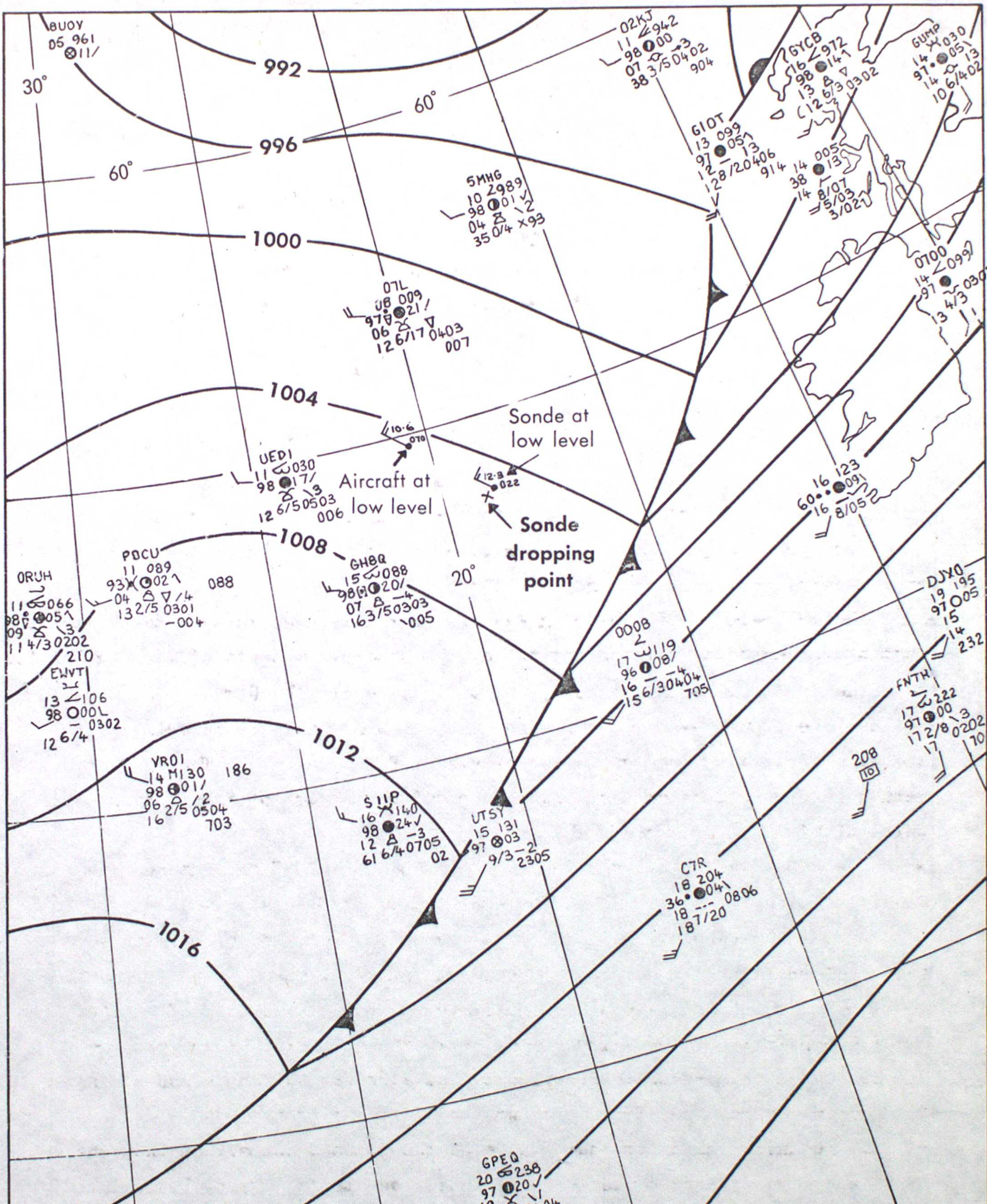

Figure 3 Surface Analysis 12z; 25.9.79

2 A Meteorological Reconnaissance Flight on 25 September 1979

2.1 On 25 September 1979 the MRF Hercules was tasked with carrying out a meteorological reconnaissance flight over the North Atlantic. The objective of such a flight is to make a number of meteorological observations at various locations on a specified track, and to communicate these to an appropriate meteorological centre. Such observations are reported in the standard NATO RECCO code. The information required includes:

(a) Section 1 (mandatory) specification of the wind vector, temperature, humidity and weather at a given flight altitude.

(b) Section 2 (optional) Specification of cloud amount and altitude of bases and tops. Specification of various surface properties such as sea state, surface wind, significant weather etc. Reports of icing, contrails and radar echoes. The section also includes the facility to report atmospheric sounding data, whether obtained by means of aircraft ascent/descent or a dropsonde. This takes the form of a listing of temperature, dew point and the wind vector as a function of pressure level.

(c) Section 3 (optional) Specification of temperature, dew point and the wind vector at intermediate flight levels.

2.2 The MRF Hercules flight plan was that normally used in such tasks except that a dropsonde was released at one of the observing points at the highest level possible, FL240 on this occasion, immediately before the Hercules descended to low level. Temperature, dew point and the wind vector were measured from the aircraft during the descent to provide a RECCO message. The dropsonde data were analysed after the flight to provide the sort of information which might have been provided in real time.

2.3 The sonde was released at 53°45'N, 18°55'W at 1201Z and entered the sea 10 minutes later some 28 Km from the release point on a bearing of 85°. The aircraft descended immediately and reached an altitude of 150' above sea level 24 minutes later some 240 Km from the same point on a bearing of 300°. These positions are superimposed on the analysed 12Z surface chart shown in figure 3. Figure 4 exhibits the variation of temperature and dew point with pressure observed by the aircraft and sonde and by the 12Z radiosonde released from Ocean Weather Ship 'L' at 57°00'N 19°54'W.

2.4 It is unfortunate for the purpose of the planned comparison that the release and subsequent descents took place close to the strong baroclinic zone associated with the front extending from 45°N 28°W to 55°N 12°W - see figure 3. As a result, although the meteorological conditions experienced by the aircraft and sonde were similar at high levels they became very different as the horizontal separation between them increased. It will be demonstrated below that these differences are almost certainly real and not a result of erroneous measurement from either platform. This points to the

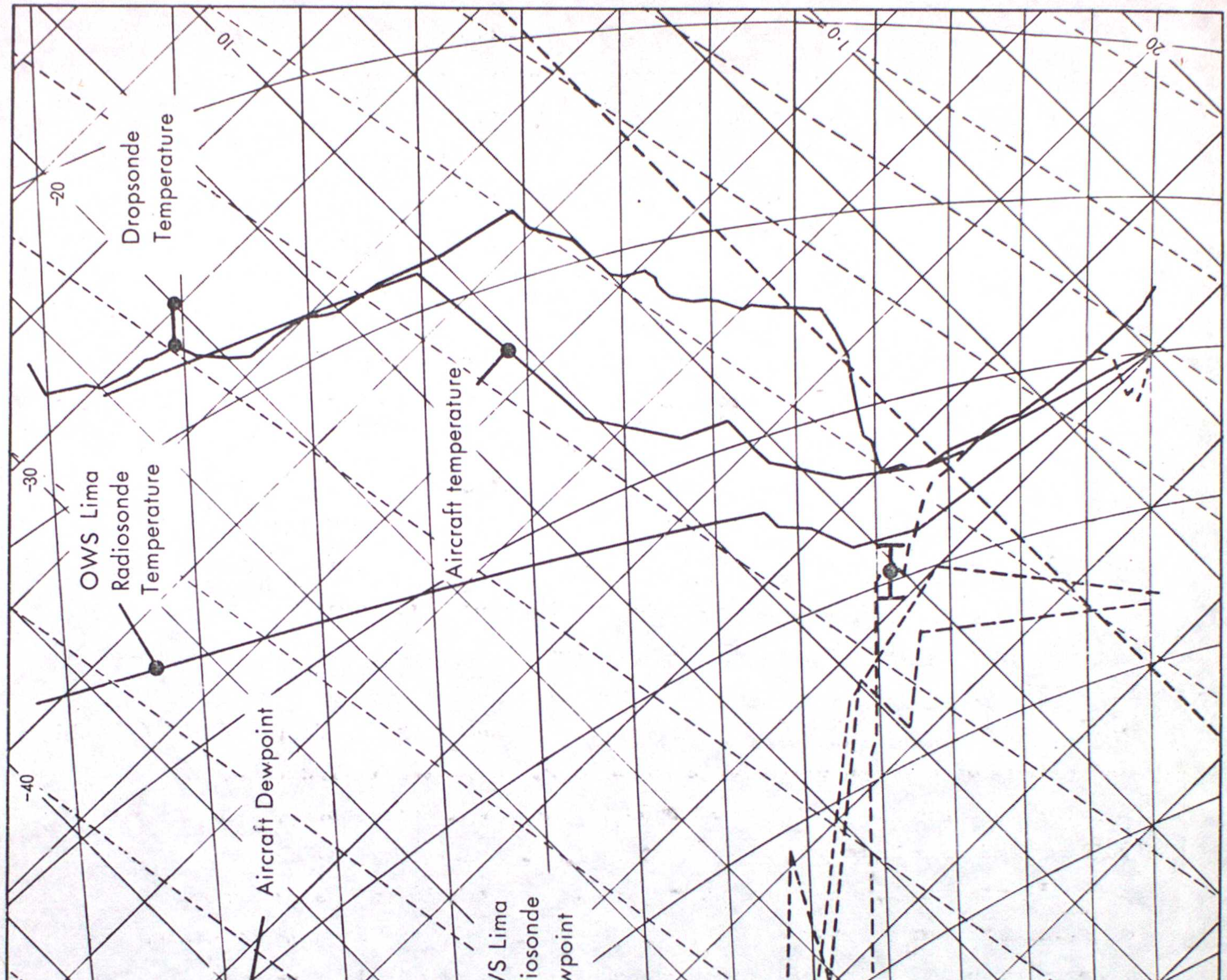

Figure 4 profiles for 12z; 25.9.79

great caution which is necessary in interpreting meteorological data obtained from an aircraft ascending or descending on a constant heading. Clearly the aircraft temperature/dew point profile is not representative of that above any point on the surface of the earth. As a result, estimation of the geopotential heights of pressure surfaces is not possible. Apparantly the descent on track results from the compromise between a desire to obtain a representative sounding whilst achieving the desired aircraft range. The use of a dropsonde overcomes this dilemma by providing sounding data whilst allowing the aircraft to remain at an efficient cruising level.

2.5 Inspection of figure 4 confirms that the difference between air temperatures measured by the aircraft and sonde is 0·5°C or less above 550mb. Below that altitude the aircraft temperature is always between that measured by the drop sonde at 53°45'N, 18°55'W and that measured by the OWS radiosonde at 57°00'N, 19°54'W. It is worthy of note that this continues to be true below 850mb where the horizontal temperature gradient is apparantly small.

2.6 There is some disagreement between the various estimates of dew point, particularly in the dry air above 750mb. Whilst part of this is doubtless real, the expected RMS error of the humidity sensor on the dropsonde is ± 5% RH. The effect of such an error on the dew point estimates is indicated in figure 4 and goes some way to account for observed differences. The hydrolapse between 400 to 450 mb indicated by the sonde, is almost certainly false and a result of sensing element recovery following the large thermal shock experienced at ejection. The data clearly show the presence and absence of cloud. On this occasion convective clouds with a base in the vicinity of 900 to 1600 ft and tops around 4000 ft are suggested. Although there are few ship observations in the area, those that are available are consistent with these assertions. No airframe icing is predicted above 53°45'N 18°55'W but in principle the simultaneous measurement of temperature and humidity can be used to predict potential icing zones.

2.7 Temperature measurements are output by the sonde every 0·7 seconds. The sensor time constant is about one second and the sonde terminal velocity near sea level is approximately 9 ms^{-1}. Thus an air temperature estimate within 10 m of the surface is to be expected. The lag of the humidity element is less certain, depending for example on its recent exposure. An estimate which is representative of the low level air over the sea is likely under most conditions. The dropsonde provides an estimate of pressure with an RMS error of about ± 2 mb. On this occasion figure 3 suggests a surface pressure of about 1005 mb at the point of entry of the sonde into the sea. The sonde indicates a value of 1002 mb. Such errors are greater than those required for the accurate plotting of surface charts but apparantly are not very different from those achieved by many ships. In practice it is reasonable to expect

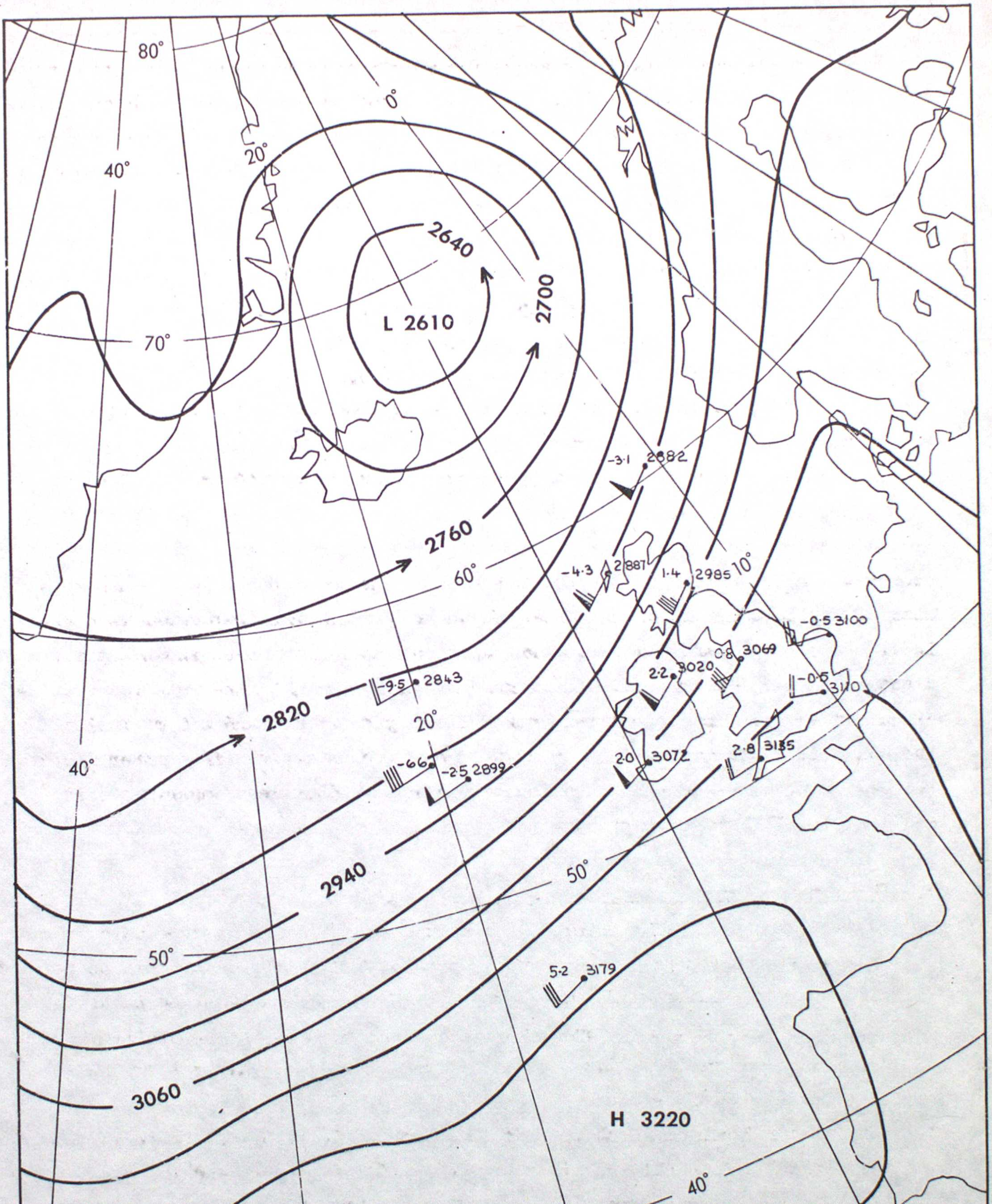

Figure 5 700mb Analysis 12z, 25.9.79

a useful 'surface' observation of temperature, humidity and perhaps, in data sparse areas, of pressure.

2.8 The surface wind cannot be estimated so readily from a sonde as the movement over some finite time interval is necessary to determine the mean vector centred on that time interval. Figure 2 shows the windfinding accuracy to be expected when this time interval is 60 seconds, as a function of position over the North Atlantic, for various existing Loran C transmitters. Accuracies north of Iceland and the Faroe Islands have not been calculated but values similar to those shown are expected in some areas of the Norwegian Sea. The use of a 60 second time interval provides a mean wind averaged over about 600 m in the lower atmosphere. Earlier studies suggest that errors increase rather more than linearly as this interval is decreased. Thus it is probably realistic to expect winds averaged over 15 seconds (≈ 150 m) to contain errors almost an order of magnitude greater than those shown in figure 2. The 'surface' wind vector shown in figure 3 is calculated from the final 15 seconds of Loran C data. It is in very good agreement with the geostrophic wind obtained from the same figure . Ryder and Lewis (1979) have confirmed the predictions of figure 2 at Aberporth and Bencula where sondes were tracked by both radar and Loran C.

2.9 A major use of sounding data is as input to numerical analysis and forecasting schemes. The compatability of the sonde measurements with the 700 mb numerical analysis prepared from routine upper air data for 12z on 25 September is demonstrated in figure 5. Aircraft measured winds and temperatures are also shown but the descent on track does not permit calculation of geopotential heights for reasons discussed above. Similar comparisons with analyses at 500 and 850 mb indicate that the sonde data are in excellent agreement with fields derived from other sources, and had they been available in real time would have doubtless contributed to analyses at all levels below FL240.

3. The creation of a real time dropsonde facility

3.1 A major rewriting of the control software for the 32K NOVA 1200 data logging computer will be necessary to allow calculation of meteorological data on board the aircraft. A feasibility study has been carried out to establish the nature of a possible solution and the effort required to achieve this. The objective has been to define a method of fulfilling the real time requirement rather than the optimum solution in any sense.

3.2 The proposed scheme is shown as a flow diagram in figure 6. Briefly, individual sonde calibration data obtained from pre-and in flight checks and the geographical position of launch are entered into the computer through a teletype. As in the present system, Loran C signals received locally at the aircraft are used to provide a starting point for sonde tracking after its ejection.

REAL TIME MET. DATA & TRACKING PROGRAM — FLOW DIAGRAM

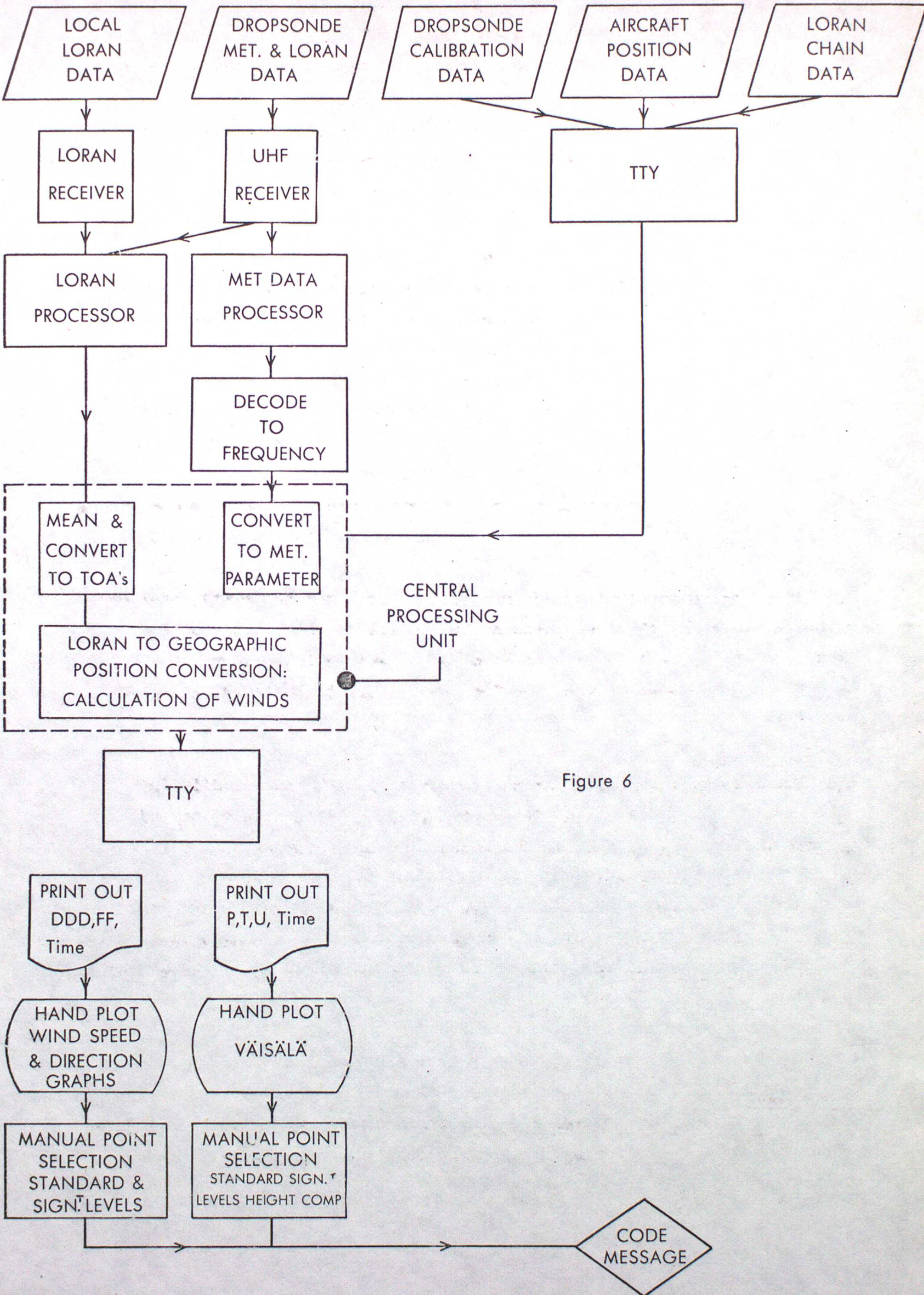

Figure 6

3.3 The conversion factors to change from Loran time differences to position may be entered through the teletype after calculation off line, or determined within the NOVA. Data received from the pressure, temperature and humidity sensors on the sonde are converted to meteorological parameters through use of standard transfer functions and calibration data. These are printed out as a time series on the teletype. They are transferred to a standard 'Vaisala' chart by hand to allow selection of significant points and calculation of the height of pressure levels. A number of possibilities are conceived for analysis of the wind data. Thus a simple time series of wind components averaged over regular defined periods can be printed out. Required winds at the standard and special levels can then be obtained by interpolation. Alternatively they can be recalculated on request from a time series of raw data stored in the computer. The latter option requires a significant but not impossibly large storage space. In any event, a coded message is prepared by the operator from the listed and plotted wind, temperature humidity and pressure data. The scheme requires a combination of machine and manual effort. Thus trained meteorologists are necessary as operators. The alternative of attempting a fully automatic machine based scheme is rejected as impracticable.

3.4 It is estimated that an SSP man year is required to modify, test and debug software for this new purpose. No additional aircraft equipment will be necessary but an investment of some £10K in laboratory hardware and software packages will be required to facilitate software development.

4. Conclusion

4.1 There is little doubt that the Meteorological Office windfinding dropsonde could provide data of synoptic value if this were to be made available in real time. It is suggested that provision of such a facility on the MRF Hercules would make more efficient use of the aircraft, whilst providing a type of sounding of greater meteorological value, than is obtained currently by the aircraft alone. The effort required to modify the existing dropsonde facility for this purpose is thought to be about 1 man year plus £10K for equipment.

References

Ryder, P and A F Lewis, - 'An aircraft dropsonde for atmospheric sounding' Met O 15 Internal Report No 12 (1979)

Annexe 1

Meteorological Office Windfinding Sonde Specification

Dimensions

Length	838 ± 3 mm.	)	
Diameter	125.5 ± 1.5 mm	)	see fig 1
Weight	3.5 ± 0.6 kg	)	

Element	Transducer	Accuracy
Pressure	National Semiconductor LX 1602A	± 2 mb
Temperature	Themistor: YSI 44005/Fenwell Unicurve	± 0.5° C
Humidity	VIZ Hygristor	± 5%
Wind	Loran-C Retransmission	See Fig 2

UHF Transmitter

Frequencies (MHz)	400.7 401.7 402.7 403.7 404.7	one of
Frequency Accuracy	± 0.001%	
Frequency Stability	± 0.01%	
Radiated Power Output	+ 34 dBm + 2dB - 0	
Modulated Bandwidth	50 Hz to 150 kHz to -3dB	

UHF Antenna — Dipole formed from Sonde skin

Loran -C Receiver

Centre Frequency	100kHz
Bandwidth	14 kHz ± 1 kHz

L F Antenna — Wire aerial along parasheet shroud line