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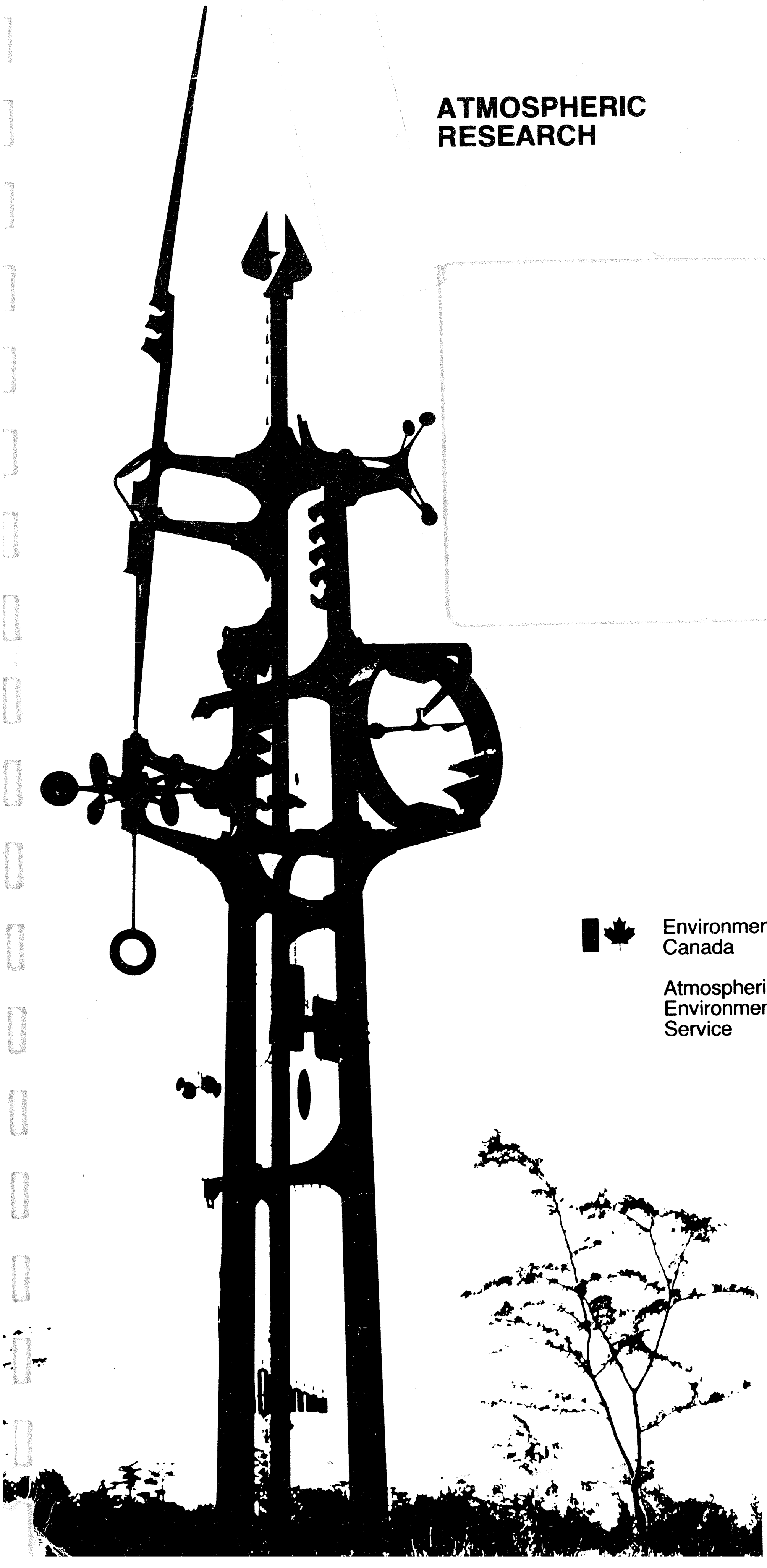

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ASKERVEIN '82: Report on the September/October 1982 Experiment to Study Boundary-Layer Flow over Askervein, South Uist

by

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CONTENTS

CONTENTS (cont'd.)

LIST OF TABLES

LIST OF TABLES (cont'd.)

LIST OF FIGURES

LIST OF FIGURES (cont'd)

Fig 5.2 (a-k) Normalized wind speeds at 10 m elevation along lines A and B during MF runs. Data plotted are averages for each run based on 1/2-hourly values of S, the ratio of the 1/2-hour average wind speed at a given location to the wind speed at RS for the same period. Different tower systems are identified:-

• AES
\+ ERA
Δ University of Hanover (FRG)

Sequence of runs is a) 1.22, b) 1.23a, c) 1.23b, d) 2.25, e) 2.27, f) 2.28, g) 2.29a, h) 2.29b, i) 2.01a, j) 2.01b, k) 2.02

Fig 5.3 Normalized wind speed at 10m height at CP as a function of reference site wind speed and wind direction. Data from period 29/9/82 - 3/10/82.

Fig 5.4 Wind speed profiles to 50 m at RS during MF runs 1.22, 1.23a, 1.23b and 2.02.

x Gill 3-cup anemometers (tachometer-generator type)
o Gill 3-cup anemometer (pulse type) on 10 m post
□ 3 cpt Gill propeller anemometer at 10 m level

\- - - - - - Subjectively drawn profiles

Fig 5.5 Wind speed and ΔS profiles to 50 m at RS and HT during MF runs: a) 2.25, b) 2.27, c) 2.28, d) 2.29b, e) 2.01a and f) 2.01b. Same notation as Fig 5.4 but with Gill 3-cup anemometer data at HT denoted by ●.

—·—·—. Log profile at RS based on $z_0 = 0.03$ m and using 10 m MF post data.

\------ ΔS profile calculated from velocity profiles drawn.

Fig 5.6 Surface roughness at RS for different wind directions

● based on 50 m profiles in Figs 5.3, 5.4
o based on 50 m profiles in Fig 6.14 and 6.16
x based on AES sonic anemometer measurements at $\Delta z = 10$m (Table 6.4)

Fig 5.7 TALA kite profile test, 26 September 1982, 11.15 - 13.15 BST • CAN, + ERA, x BRE. A linear Δz scale has been used to improve separation of data points.

LIST OF FIGURES (cont'd)

LIST OF FIGURES (cont'd)

ABSTRACT

The Askervein '82 experiment was a preliminary field study in preparation for a major field experiment (Askervein '83) designed to measure mean and turbulent boundary-layer flow properties over an isolated, low-profile hill. Both experiments are part of a continuing programme of theoretical, wind-tunnel and field studies of wind flow in complex terrain. These studies have applications to siting of wind generators, detailed calculation of wind loading on structures and pollutant dispersion in complex terrain.

The Askervein '82 experiment was conducted on and around Askervein (also known as Askernish Hill), a 126m hill located on the southern part of the west coast of South Uist, one of the islands of the Scottish Outer Hebrides. The field work was carried out during the period 13 September 1982 to 10 October 1982. During this preliminary experiment attention was primarily focussed on measuring the spatial variations in the near-surface mean wind field for selected wind directions in near neutral conditions. Profiles of wind speed and turbulence to 50m at the hilltop and at an upwind reference location were measured under similar conditions. Detailed intercomparisons were also made between different turbulence measurement systems in preparation for the main field experiment.

1. BACKGROUND TO THE ESTABLISHMENT OF THE TASK

Task VI of the IEA Programme of R&D on WECS is basically a project to 'carry out a major cooperative field experiment to measure, in detail, the spatial characteristics of mean wind and turbulence over a typical WECS hill site'. Data collected from the field experiment, which is being conducted in two phases (Askervein '82 and Askervein '83), will be used to assess the accuracy of both physical (wind tunnel) and mathematical models. The ultimate objective is to refine the modelling techniques, as necessary, to ensure that they adequately simulate the full scale flow. The techniques or models can then be applied to other sites, avoiding the necessity of complex and costly full scale measurements.

Initial discussions on the desirability of establishing this project as a part of IEA R&D WECS go back to early meetings of the technical representatives for Task II (Evaluation of wind models for WECS siting) and to discussions of the executive committee in November 1979. At that stage it was established that there was a need for high-resolution field data on flow over hills with a horizontal scale of order 1 km in order to improve our understanding of both the 'speed-up' and turbulence modifications induced by the type of low hills that would be suitable for WECS siting. A rather long incubation period followed, including a series of discussions at the executive committee and between potential participants in the experiment. Indeed it was June 1982 by the time the task had been finally approved by the executive committee and all of the formal notices of participation had been submitted. Participants in the experiment had, however, held a preliminary planning meeting in March 1982, selected the site for the experiment and drawn up a 'Detailed Programme of Work'. This is attached as Appendix A. Although there have been some minor changes, we have so far been able to keep more or less to the schedule and objectives laid out in that document.

Participants in the task are Canada (Operating Agent), Denmark, Germany, New Zealand and the United Kingdom. The project is organized primarily on a 'task sharing' basis (i.e. each participating country is responsible for its own expenses), although there are some general costs which are shared among the participants. There are many benefits from mounting these experiments collaboratively. In particular it is possible to draw on a much larger pool of expertise than is available in any one of the countries involved. It is also possible to deploy far more instruments and hence attain much better spatial resolution in our measurement programme than could be achieved individually. Personnel involved in the project all benefit from their contacts with others working in the same field and, so far at least, cooperation at all levels has been excellent.

2. SCIENTIFIC AND TECHNICAL BASIS FOR THE STUDY

Although there had earlier been a number of measurements of wind speeds on hilltops [see for example Davidson et al. (1964)] and some theories concerning the speed-up caused by terrain features [see Golding (1976) Ch.7], a detailed and quantitative theory of boundary-layer flow over low hills has only been established in the last few years. Developments are still in progress on some aspects of the theory but the key paper is probably that by Jackson and Hunt (1975). Working in terms of a 'fractional speed-up ratio',

$$\Delta S = \frac{U(x,\Delta z) - U_0(\Delta z)}{U_0(\Delta z)}$$

where Δz is height above the local terrain and $U_0(\Delta z)$ is the 'undisturbed' upstream velocity profile, they developed a theory to predict ΔS within a near-surface or 'inner' layer for flow over low two-dimensional hills. Mason and Sykes (1979) extended the theory to three-dimensional hills while Walmsley et al.(1982) and Taylor et al.(1983a) discuss further extensions to the theory and applications to real terrain. Recently, Hunt (1980) has reviewed simple rules of thumb for estimating maximum, near- surface, values of ΔS above hill and ridge tops. He suggests that for 2D ridges

$$\Delta S \simeq 2\,\frac{h}{L}$$

where h is the hill height and L is defined as 'the distance from the hilltop to the upstream point where the elevation is half its maximum'. For a three-dimensional, axially symmetric hill, Hunt implies that the 2D result will still apply but Taylor and Lee (1983) suggest that

$$\Delta S \simeq 1.6 \frac{h}{L}$$

is probably a better estimate.

For typical potential WECS hill sites ($h \sim 100$m, $L \sim 250$m) we can thus obtain increases of order 60% in near-surface wind speed while for slightly steeper hills increases of up to 100% are not uncommon. Since kinetic energy fluxes and hence the power available to a WECS are proportional to the cube of the wind speed, these increases are of enormous significance in the selection of suitable sites for wind turbines. In addition to modifications to the mean flow, the straining of the flow during its passage over a hill will modify the turbulence structure. Although there are some theories concerning this phenomenon [see for example Hunt (1980)] and a few measurements have been made [e.g. Bradley (1980)] there is still very little known about turbulence structure in the flow over hills. This will be of considerable significance to the design of large WECS (or any other structures to be erected on hilltop sites).

The Jackson-Hunt theory postulates that Reynolds stresses will play a significant role in modifying the flow only within an inner layer of depth ℓ which is defined by the equation

$$\frac{\ell}{L} \ln(\ell/z_0) = 2\kappa^2 \quad .$$

Here z_0 is the surface roughness length and κ is the von Kármán constant, which we will take as 0.4. In our typical case with L=250m, this gives $\ell \simeq 14$m if we take $z_0 = 0.04$m. Britter et al. (1981) argue that for $\Delta z \ll \ell_T$ (where ℓ_T is an inner layer depth for turbulence and $\ell_T \simeq \ell$) the turbulence is in an approximate local equilibrium with the velocity shear while for $\Delta z \gg \ell_T$ the turbulence changes can be estimated from 'rapid distortion theory'. Data from the Askervein experiments will be used to test these hypotheses.

Several field studies of the detailed structure of boundary-layer flow over low hills have been carried out recently including those on Brent Knoll [see Mason and Sykes (1979)], Kettles Hill [see Taylor et al. (1983b)] and Blashaval (Mason et al., private communication). None of these has been as extensive or detailed as the Askervein experiment, but both the Brent Knoll and Kettles Hill studies have provided confirmation of the magnitudes of fractional speed-up to be expected from Hunt's estimates. In the case of Kettles Hill, some comparisons are also being made between field data and detailed numerical and wind tunnel models [e.g. Teunissen et al. (1982), Teunissen (1983)].

3. SITE SELECTION FOR THE EXPERIMENT - ASKERVEIN

From the outset our aim was to mount the field experiment at a site which would be suitable as a location for a WECS installation. We therefore set out to locate 'a well-exposed coastal hill with good speed-up characteristics', which was not heavily forested. Initially we had thought in terms of a hill with a height of about 400m with L~1km and total length scale ~5km, but it soon became apparent that rather smaller hills were more common and better suited to our requirements. At an initial meeting of potential participants held in Ayr, Scotland in February 1980, several potential nearby sites were visited. In addition, the Canadian team proposed mounting the experiment on Kettles Hill in Alberta, Canada. However since most of the participants were based in Europe, the shipping and transport costs of mounting an experiment in western Canada made that choice of site undesirable, while the locations visited near Ayr, although potentially good for wind power, were deemed unsuitable from a topographic point of view. Several of the groups involved in that meeting then agreed to initiate or continue searches for the 'ideal' site. This was defined as possessing the following properties:

(a) it should be a potentially good WECS hill site;

(b) it should be suitable from a numerical modelling point of view;

(c) it should be such that representative measurements could be made at moderate heights (say < 10m) on the hill and over the surrounding terrain; and

(d) it should be easily accessible.

In physical terms the hill should:

(a) be reasonably isolated and have a uniform upwind fetch for the prevailing wind (a coastal hill would be suitable);

(b) possess a 'spectral gap' between the dominant wavelength of the hill and the size of the roughness elements;

(c) have a uniform ground cover, preferably grass, heather or low scrub, and a minimum of trees or buildings;

(d) if possible, though not essential, be axially symmetric or approximately two-dimensional or, alternatively, be located in an area with a very well defined predominant wind direction.

The next meeting of potential participants took place at the Risø laboratories in August 1980, prior to which Peter Taylor and Unsall Hassan (then with ERA, the U.K. participant) had visited a number of possible sites in the Outer Hebrides. Following discussion of some possible sites in Jutland (Denmark) and in Germany, the participants agreed that hills in the Outer Hebrides of Scotland offered the best potential sites for the proposed experiment and that Askervein on South Uist would be our first choice. This was confirmed at a 'site inspection and detailed planning meeting' of the participants held in the Outer Hebrides in March 1982. ERA Technology Ltd., (the U.K. participant) was able to secure the agreement of the local land owners and tenants and to arrange planning permission for the experiments and at that stage the planned experiment started to become a reality.

Askervein, or Askernish hill as it is sometimes referred to locally, is a 126m high hill located near the west coast of South Uist, toward the southern end of the Outer Hebrides island chain. The hill coordinates are 57° 11'N, 7° 22'W. It is essentially elliptical in plan form with a 1 km minor axis and a 2 km major axis. The major axis is oriented along a generally NW-SE line. The predominant wind directions during September and October (the period of the experiment) are from the SW and S at the nearest meteorological station (Benbecula) and moderate to strong winds are the norm at that time of year (see Table 3.1).

The basic Ordnance Survey (OS) map of the area (Fig. 3.1) shows that the hill is relatively isolated, apart from the hills Criribheinn and Layaval to the NE and E. To the SW there is a flat uniform fetch of about 3-4 km to the coastline where there are sand dunes and low (~ 5m) cliffs. The ground cover (see Figs. 3.2 and 3.3) is mostly heather, grass, low scrub and some flat rocks, plus some small lochs in the upwind terrain. Our initial estimate of surface roughness length was $z_0 \sim 0.05$m. Although the terrain has features at all length scales, especially on the NE face of the hill, it was anticipated that the main features of the wind field would be controlled by the overall shape of the hill and that there would be no difficulty in making representative measurements at a height of 10m above the surface. Although the hill is neither axisymmetric nor two-dimensional, its width-to-length ratio is greater than 2.0 for SW flow and some comparisons with 2D models should be appropriate.

Logistically the hill is a very good site, with the exception that is is too rugged to drive over. This problem was overcome by a helicopter lift of equipment to the hilltop. A working station (BS) was established near the foot of the hill to act as a base for logistical operations while an 'upstream' reference site (RS) was located about 3 km to the SSW of the hill near Daliburgh (see Figs. 3.1 and 3.4). The reference site was used to make detailed measurements of the 'undisturbed' flow prior to its encounter with the hill. Although the existing maps of the hill site were considered to be very good in terms of surface detail, they unfortunately had a contour interval of 7-8m (metric conversion of 25 feet). This was marginal for the manufacture of detailed, relatively large scale, wind-tunnel models of the hill and for application of the numerical model to be used. Consequently a custom-made, high-resolution, 2m-contour-interval map was produced from 1:10,000 stereo photo pairs purchased from the Ordnance Survey in the U.K. The new map (see Fig. 3.5) covers just the hill and its immediate surroundings and was originally drawn at a scale of 1:2000. The summit of the hill is at a height of 126m above sea level at location 075380E, 823732N, these numbers referring to the standard U.K. Ordnance Survey grid, which is overlaid on the figure. Since the summit point is somewhat to the NW end of the hill, a second reference location, ('centre point' or CP) was chosen (at 075672E, 823458N) as an additional point of reference on the hill. Note that on the OS grid in Fig. 3.5, RS is at 074312E, 820982N. A portion of one of the aerial photos from the stereo pair is shown in Fig. 3.6.

During the experiments most of the instruments were deployed in linear arrays through CP or HT. The lines are oriented at 043° (grid) and 133° (grid), approximately SW-NE and SE-NW along the minor and major axes of the hill, respectively. The three lines shown in Fig. 3.5 are referred to as A, AA and B, as shown, and locations along these lines are denoted by a code which includes the line identifier (e.g. A), the direction (e.g. SW) and the distance from HT (or, in the case of line AA only, from CP) in tens of metres. Thus ASW 50 is a point 500m from HT along line A in the direction 223°.

For modelling purposes the terrain to the SW of the hill is taken to have an elevation of between 6m and 10m above sea level. Thus the hill height is taken as being approximately 118m above its surroundings.

4. ASKERVEIN '82, OVERVIEW

The main aims of Askervein '82 were:

(a) to resolve the mean wind field in selected vertical cross-sections through the hill using cup anemometers on 10m masts and Tala kite systems;

(b) to make initial comparisons of wind speed, direction and turbulence characteristics between the hilltop and the upwind reference location; and

(c) to carry out a thorough field intercomparison of the different mean wind and turbulence sensors to be used in the main experiment.

The experiment was conducted between 13 September and 10 October, 1982. The first week was fully occupied with setting up the reference (RS) and base (BS) stations and in preparing equipment for a helicopter lift to the hilltop. This lift took place on 17 September by which time the 50m tower at RS had also been erected. It took about five days to deploy the various towers on and around the hill and the main series of experimental runs was conducted between 22 September and 2 October. Packing up and storing equipment in preparation for the 1983 experiment took up the final week.

Daily weather maps for the period are shown in Fig. 4.1. Note that, in this report, times will be given as British Summer Time (BST). This was used in preference to Greenwich Mean Time (GMT) to avoid confusion (BST= GMT+1 hr). The weather during Askervein '82 was generally unsettled with a series of depressions moving north-east across the area. The U.K. Meteorological Office/Royal Meteorological Society 'Weather Log' notes, inter alia, that 'on the 21st (Sept.) a vigorous secondary (depression) moved quickly across central areas (of the U.K.) bringing heavy rain, strong winds and squalls....' and that there 'was a tornado in north Belfast (Northern Ireland) on 26th Sept.'. This was associated with gale force winds which occurred throughout Britain between 26-28 Sept., but affected South Uist primarily on the 28th.

The hourly surface wind data (10m) from the meteorological station at Benbecula for the period 20 Sept. - 4 Oct. are plotted in Fig. 4.2. The station is at Balivanich airport and is well exposed for all wind directions. It is approximately 33 km north of Askervein at a similar west coast location.

For our study of the flow over Askervein we were primarily interested in collecting data for wind directions between 180° and 270° with moderate to strong wind speeds. We can see from the Benbecula data that these conditions occurred on about 5 days out of our 11 day core observing period (22 September to 2 October). In total we obtained 24 hrs of good near-surface mean flow data in 2-hr or 3-hr blocks, although some of these runs were for SE winds. We also collected profile data from two 50m towers at RS and HT and turbulence data on selected occasions. The periods during which the mean flow and sonic anemometer data sets were collected are shown in Fig. 4.2.

Routine upper air soundings from nearby stations [Longkesh (N. Ireland), Stornaway, Lerwick (Shetland), Shanwell (Dundee) and Aughton (Manchester)] were kindly made available to us by the local Meteorological Office. We also flew our own AIRsonde flights at the site to heights of 4 km during some of the data collection periods. We were primarily concerned with the structure within the lowest 1 km of the atmosphere for the present study and plots of our AIRsonde data up to this height are presented in Fig. 4.3. It is clear that most of the soundings show near-neutral conditions and minimal directional shears, as desired.

Details of the towers and anemometers will be given where appropriate in sections 5 and 6 of the report. Their locations on the hill are shown in Fig. 4.4. These positions were originally measured along the ground during installation of the towers and subsequently located accurately by theodolite survey. The two determinations agreed well after correction for slope effects. Locations are believed accurate to 1m. A detailed plan of the layout of towers at RS is given in section 6 (Fig. 6.2). At the hilltop we were forced to position the 50m tower slightly to the north of the exact HT location because of anchoring requirements. Also an additional 10m tower supporting a three-component Gill anemometer for turbulence measurements had to be placed a little to the WSW of HT to avoid interference from the 50m tower's guy wire.

The results from Askervein '82 can conveniently be divided into 'Mean Flow Measurements' and 'Turbulence Measurements'. Table 4.1 gives a summary of the measurements that were made and will be discussed in detail in the following sections.

5. MEAN FLOW MEASUREMENTS

The primary objective of the mean flow (MF) measurements during Askervein '82 was to measure spatial variations in mean wind with a view to subsequent comparison of these observations with model predictions. The actual measurements consisted of 2-hr or 3-hr blocks of 1/2-hr average wind speeds under relatively steady conditions from run-of-wind anemometers mounted on 10m posts, cup anemometer profile data from the 50m towers and Tala kite profiles at some locations. We will discuss each of these systems separately.

5.1 10m Mean Flow Measurements

5.1.1 Anemometer Systems

Up to thirty-four MF posts with cup anemometers at 10m were deployed along the lines A and B on the hill, (see Fig. 3.5) plus an additional system at RS. Twenty-five of the posts were operated by the Canadian group. These consisted of simple aluminum posts guyed at two levels and supporting an R.M. Young, photo chopper type, Gill 3-cup anemometer (Model 12102D; 1 pulse per revolution). Hemispheric, aluminum cups (1 metre per revolution) were used. The pulses were counted on either WP 5000 counters (manufactured by Aeolian Kinetics) or on electronic counter / display boxes designed and built by N. Koshyk and M.Austerberry at AES. The systems were powered by 6V or 8V Gates rechargeable sealed lead-acid batteries which could provide for more than six hours of operation when fully charged. Data were read manually from these systems at 30-minute intervals.

The University of Hanover used Friedrichs model 4011 tachometer generator 3-cup anemometers on their five 10m aluminum posts. They also deployed Friedrichs wind vanes to record direction. The data were recorded every two minutes at each tower on a battery-powered Microdata M200 logger system which was intended to operate continuously throughout the experiment. Unfortunately simultaneous problems were encountered with three of the systems on 25 September, most probably due to a lightning strike nearby, and they failed to operate after that time. The anemometer generator output (d.c.) was low-pass filtered with a time constant of two minutes but no filtering was applied to the vane signal. 1/2-hour values for comparisons with other mean flow systems were obtained by averaging fifteen consecutive two minute readings.

ERA Technology deployed five 10m masts equipped with either Casella anemometers (Model W200) with a mechanical counter or Vector Instrument Units consisting of a Model A100R cup anemometer and a Veeder-Root pulse counter.

For the manually-read systems one observer was assigned to every four or five posts. At the start of a run he/she would switch on and zero the counter (or read the current count) on each tower with time delays of 1, 2 or 3 min between towers depending on how quickly he could comfortably get from one tower to the next. Once all towers were initialized the observer would return to his first tower and, at zero time plus 30 mins, go around the towers recording the pulse counts for the 30 min duration at each tower. This procedure would be repeated at 1/2-hour intervals until the end of the run. The data would then consist of series of 30 min run-of-wind values at all towers with time offsets of up to 10 mins. Provided conditions remained steady throughout the run, four or six 1/2-hour values can be combined to give two- or three-hour average values. The time offsets are not considered significant for these averages.

5.1.2 Calibration and Intercomparisons

Most of the anemometers were wind-tunnel calibrated both before and after the experiment. The individual groups were satisfied with the performance of their systems relative to manufacturers specifications and, where there were differences between pre- and post-experiment calibrations, they were less than 1%. The critical point for the data is of course relative rather than absolute accuracy. We thus proceeded on the basis that the individual groups (AES, ERA and Univ. of Hanover) would be responsible for internal comparisons between their own individual anemometers and ran three field intercomparisons to detect any differences between wind speeds measured by the different groups. These were conducted in ambient wind speeds comparable to those encountered during the MF runs. For these tests, MF posts were set up 2m or 3m apart cross-wind. The results are listed in Table 5.1. In the third test comparisons with AES-operated tachometer-type Gill cup anemometers were also included. In addition to these tests some of the MF runs included two MF posts at HT, CP or RS locations to provide additional comparisons. At CP these comparisons were unsatisfactory, as will be noted later. As far as the MF intercomparison tests are concerned, however, the results were very good. We concluded that, for 2-hr averages, the values recorded by different AES-operated pulse-type Gill cup anemometers were good to within 1% and would be regarded as the standard. Relative to that the ERA-operated Casella anemometers read low by about 1% while the Vector Instruments system read high by about 3%. The FRG system was operated in only one MF test for which its 2-hr average was about 2% high. Individual 1/2-hour averages show some variations from these general rules, but in general the results are quite consistent. No corrections for these differences are included in the initial tabulations of data in this section. The AES data are based on the use of the calibration coefficients given in Table 5.2. The third test showed good agreement between the photo-chopper and one (T26) of the tachometer anemometers operated by AES, but clearly indicated that the T16 anemometer was malfunctioning. (There were drop-outs on the tape). We will note this later in reference to the profile data.

After considerable debate it was decided to install all of the posts vertically rather than perpendicular to the local terrain. This leads to two sources of error, both of which would be small in the ideal case of a very low hill but one of which may need to be considered when (as at Askervein) the local slopes are as large as 0.3 or 17°. In the first place we would anticipate that the flow parallel to the surface would be of the basic form

$$\dot{U} \propto \ln \frac{n}{z_0}$$

where n is the normal distance to the surface. For a true vertical displacement $\Delta z = 10$m, n would be about 9.55m for a slope of 0.3, but the difference in velocity, assuming a logarithmic profile would be only about 1% (assuming $z_0 = 0.05$m) and may be neglected. The other source of error arises from the fact that the axis of the cup anemometer is not perpendicular to the streamlines. To quantify this we define a tilt angle, θ, between the mean wind vector and the plane of the cups and designate it as positive when the anemometer is tilted into the wind (which would occur for posts on the lee side of the hill) and negative when tilted away from the wind (i.e. with the post on the upwind slope of the hill). Wind tunnel tests with two samples of the Gill cup anemometers (photo-chopper type) used by the AES group gave the results shown in Fig. 5.1. The speed ratio is wind speed recorded by the cup anemometer divided by the tunnel speed recorded by a pitot tube. The results are in general agreement with similar studies using a variety of cup anemometer types reported by Coppin (1982). Maximum discrepancies between the cup anemometer value and the true total wind speed (as against the component in the plane of the cups) due to tilt effects are about -4% [(Measured - True)/True] which occurs for $\theta = \pm 15°$. For $|\theta| < 15°$ there is an approximate 'cosine response'. Corrections for tilt angle have <u>not</u> been made in the initial analyses of the data presented here but may be considered in later analyses of specific runs. Attempts were made to determine upwash or effective tilt angles using streamers tied to the 10m posts but these did not give consistent or reliable results. It was therefore decided that the best approach, if any, would be to estimate the upwash angle from the average slope of the terrain in the neighbourhood of each MF post. This would have to be determined, for each wind direction, from the detailed topographic map of the hill.

No corrections have been made in the initial data processing for the overestimation of mean wind due to overspeeding of cup anemometers in a turbulent flow. Over rough surfaces and in highly turbulent flow these are known to be large (say 10% or greater) but recent estimates by Coppin (1982) for Gill cup anemometers in neutrally stratified flow at various heights above surfaces of different roughness suggest that in our case ($\Delta z = 10$m, $z_0 \simeq 5$ cm) the overspeeding should be only 0.5% and even at 2m should be less than 4%. These estimates should be valid on the upwind face of the hill and at the hilltop (where turbulent intensities will be lower than in the upstream flow), although in the lee of the hill turbulence intensities may be much higher and overspeeding effects could be more significant. Turbulence measurements on the downwind slope of the hill during Askervein '83 should provide additional guidance on this matter.

5.1.3 Mean Flow Post Runs and Results

We had initially planned to deploy the MF posts in several configurations along lines A, AA and B (see Fig. 3.5) but in the event we only used lines A and B and the configurations changed only slightly from run to run. We did however switch from a close (50m) spacing of towers near to the top of the hill in the early runs to a more uniform (100m) spacing over longer lines in the later runs. Taking account of this, the first three runs are designated as 1.22, 1.23a and 1.23b while the rest are identified as 2.25 on. The first digit identifies the configuration, the other two digits the date in either September or October, 1982 and, where two runs were conducted on the same day, these are labelled a and b. The runs are included in Table 4.1 and also identified in Fig. 4.2. Additional details are listed in Table 5.3 including upstream wind speed and direction and an estimate of potential temperature gradient in the lowest 500m from AIRsonde flights when available. The wind direction for each run is a critical piece of information which has a strong impact on the speed-up. It is particularly important in terms of wind-tunnel and numerical model simulations since the flow perturbations can vary quite strongly with wind direction. Table 5.4 lists the various measurements of wind direction that were used in determining, somewhat subjectively, the directions tabulated in Table 5.3. Wind directions were fairly steady during most of the runs as indicated by the Benbecula data in Fig. 4.2. The most notable exception is run 2.29a during which the wind shifted, fairly steadily, through about 60°. Additional wind direction data from RS will be given later.

The disposition of MF posts during each run is listed in Table 5.5. The locations can be identified on Fig. 4.4 while the exact horizontal distances of each location from HT are listed in Table 5.6 for reference.

The raw data set from each MF run consists of four or six 1/2-hour average wind speeds from each of the MF posts. This information is listed in Table 5.7. Tower locations can be determined by cross-reference to Table 5.5. We have also plotted the normalized wind speeds, S, along each of the MF post lines, normalized by the value at RS and averaged over each run, in Figs. 5.2 (a-k). The range of variation of normalized wind speed between individual 1/2-hour blocks is reasonably small (±10% or less) in most cases, although in run 2.29a the wind shift caused much larger variations (S = 1.18 to 1.93 near HT).

Some comments need to be made concerning the data at HT and CP where, for most of the runs, two different systems were operating at essentially the same location. For five of the runs an AES system (P10 or P17) and one of the University of Hanover MF posts (FRG1) were located side by side, about 2m apart, at HT while, for run 2.01a, both P1 and FRG1 were located at RS. Results from both of the systems at HT are plotted in the figures. In all cases they show good agreement with wind speed differences typically at the 2% level. Two MF posts (UK1, FRG5) were also located near CP but in this case the comparisons are rather confusing. For runs 1.22, 1.23a, 2.25, 2.27 and 2.29a the FRG5 system gives wind speeds about 10-20% higher than UK1. For run 2.29b the difference is down to about 5% and for runs 1.23b, 2.28 and 2.01a there is good agreement. At the present time we have no explanation for these discrepancies.

As noted in Table 5.5, wind speed data for some of the 1/2-hr blocks were occasionally missed at some towers. The average normalized wind speeds for the run have been included in Fig. 5.2 however, provided only one block was missed. More detailed analysis and interpretation of these data is planned in conjunction with numerical model and wind-tunnel model comparison runs. An analysis of the continuous 10m data from FRG1 and FRG5, located at RS and CP during the period 29 September to 3 October '82 has been carried out by Hoff and Tetzlaff (1983). Figure 5.3, taken from that report, shows the normalized wind speed at CP (i.e. $\bar{U}_{CP}/\bar{U}_{RS}$) as a function of reference site wind speed ($\bar{U}_{RS}$) for three different wind direction classes. The results are based on 109, 30-min-averaged data blocks between 16:00 hr on 29 Sept. and 10:30 hr on 3 Oct. The data suggests that speed-up is affected by stability or other effects for low wind speeds but is independent of wind speed for $\bar{U}_{RS} > \sim 7\text{m s}^{-1}$, when the stratification will almost certainly be near neutral.

5.2 Wind Profiles from the 50m Towers

5.2.1 Towers and Cup Anemometers

The '50m towers' were, strictly speaking, only 48m high, but with the top cup anemometer mounted on a pole extending upwards from the top of the tower we were able to reach a height of 49.4m. The two towers were of Danish manufacture and were identical although one had been purchased by ERA (U.K.) and one by Risø. They were erected by the Risø team, with assistance from the U.K. and Canadian groups when necessary, and instrumented with sonic (DK, CAN) and cup anemometers (CAN). At RS the 10m sonic and the lowest 2 cup anemometers were not placed on the 50m tower due to the possible effect of local terrain features but were mounted on a separate 10m tower about 30m to the SE (see Fig. 6.3).

Each tower (see Figs. 6.3 and 6.6) consisted of 16 sections of 3m each, bolted together with 8 M16 bolts in each flange. The cross-section of the tower was a square of 0.3m x 0.3m, with the lattice-work contained in each face. All construction was of solid cylindrical steel. The weight of each tower section was 40 kg.

The tower was guyed by 4 sets of 4 steel wires ($\phi = 8$ mm) connected to the tower at heights 12, 24, 33 and 42m, and anchored at four points. These were secured to large boulders, each approximately 30m from the tower base, with expansion bolts. The tower was erected with 11 sections in one piece by means of a manually operated Tirfor winch with remaining sections used as a lever. The 5 top sections were put in place one-by-one by means of a pulley at the top of a small extension mast.

The positions of the towers at RS and HT are shown in Figs. 6.2 and 4.4b. Details of the sonic anemometry are discussed in section 6. Each location was instrumented with seven Gill 3-cup, tachometer generator type anemometers (Model 12102). At RS these were equipped with aluminum cups (Model 12170A) while at HT moulded polypropelene cups (Model 12170B) were used. These variations were simply due to availability and there should be no significant difference between the characteristics of the two systems. The anemometers were calibrated before and after the experiment and showed minimal (<1%) changes. System identification numbers, deployment locations and calibration coefficients are listed in Table 5.8. They were mounted on 1.5m booms which pointed approximately SW from the towers, thus ensuring little or no tower interference effects. Voltage outputs, sampled at 2 Hz, were recorded in the same way as data from the Gill UVW anemometers. This is described in section 6.2.3.

5.2.2 Profile Data

The cup anemometer data have been blocked into 1/2-hour averages for our initial analyses. A list of the data available is given in Table 5.9 while the 1/2-hour averages and standard deviations are given in Table 5.10. Unfortunately we had a number of minor logger and signal-conditioning problems in some runs and the data are not quite as complete as we might have wished. They do however provide RS profiles for most of the MF runs and both RS and HT profiles in several cases. Profiles for the periods of the MF runs are plotted in Figs. 5.4 (RS only) and Fig. 5.5 a-f (RS plus HT). Most of the RS data can be well approximated by logarithmic profiles right up to the 50m level. There do however appear to be problems with the 10.2 and 34.2m levels in several of the profiles. At the 10m level we have also plotted Gill UVW data (from section 6.4.4 and Table 6.10) and MF post data where available.These seem to suggest that the 10.2m anemometer in the 50m RS profile was giving low values up until 28 September but was satisfactory from 29 September on. The same is true at the 34.2m level relative to the logarithmic profiles. The 10m anemometer system (T16) was subsequently used in MF test 3 (see Table 5.1) and gave low values. It would appear that there was an intermittent fault with this unit rendering the data unreliable. At HT, differences between the 10m MF post and Gill UVW winds and the 50m tower profile may be partly due to small differences in their locations.

Surface roughness values have been determined from the RS profiles and lie mostly in the range 0.02 to 0.05m with 0.03m providing the best estimate of a single representative value. The values are plotted as a function of wind direction in Fig. 5.6.

For the cases with HT data plotted in Fig. 5.5 we have (subjectively) drawn continuous profiles and calculated fractional speed-up (ΔS) values. In cases where we had HT but not RS data we have used the MF post result at RS and assumed a 0.03m value for z_0 to construct estimated profiles for the ΔS calculations. The ΔS profiles are included in Fig. 5.5. They all show considerable variation between the surface and the top of the tower. In particular there is a substantial reduction in ΔS between the 1m and 10m levels. Simple extrapolation beyond the 50m level would suggest that ΔS typically approaches zero at about 200m. These profiles will be important for model validation.

So far we have not discussed the profiles for MF runs 2.29a since there was a substantial wind shift during the run. The morning of 29 September was however one of the few observation periods with wind directions between 190° and 230° and more detailed analysis of these data may be warranted at a later date. Additional cup anemometer profiles at both RS and HT are plotted in Figs. 6.16 and 6.18 for sonic runs 7 and 11. The wind direction in both cases was approximately 160°. Surface roughness estimates from the RS profiles for these runs are included in Fig. 5.6.

Some profile data were also available from Gill UVW propeller anemometers mounted on the BRE 20m telescopic mast, which was located at approximately ASW 78 during most of the experiment. This will be discussed briefly in section 6.4.4.

5.3 TALA Kite Measurements

The TALA (Tethered Aerodynamically Lifting Anemometer) system, manufactured by TALA Inc. in the U.S.A. is essentially a sled kite and a spring balance. The kite is flown at a measured line length, height is determined from a measurement of kite elevation angle plus the line length and wind speed is determined from the tension in the line. The manufacturers assert that the kite can be flown to heights of 250m and in winds from 3 to 40m s^{-1} with a measurement accuracy of 1-2%.

During Askervein '82 four groups (BRE, ERA, AES and U. of Hanover) flew TALA kites with somewhat mixed success. It proved particularly difficult to fly them satisfactorily above the hilltop where it appeared that 'large eddy structures' tended to prevent the kite from flying stably and caused frequent crash landings. The AES group had previously encountered similar difficulties flying these kites in high (> 20m s^{-1}) winds so it could have been kite aerodynamics at high wind speeds rather than the flow structure that caused our problems. The most successful group were the team from BRE. They flew two kites, one on a fixed length line and flying between 110m and 120m, while the other was used to obtain a profile. Measurements were made noting the indicated wind speed at 10s intervals for 50-60 readings (8-10 mins). The mean and standard deviation of each set was calculated. Mean wind speeds at each height were then expressed as ratios of the mean speed at the fixed height. Other groups flew single kites and used essentially the same data handling procedures except that they recorded tension (in kg) rather than wind speed.

The TALA kite measurements can be divided into three sets: intercomparisons, upwind versus hilltop comparisons and BRE profiles.

5.3.1 TALA Intercomparison Tests

The first test was an attempt on the morning of 26 September 1982 to obtain profiles at a location near the shoreline to the NW of RS. Two groups got kites tangled and so only three of the groups obtained profiles which are shown in Fig. 5.7. Also shown are 8-min-averaged winds for line count 200 (114-118m height in this case) obtained by the BRE group as a function of time to give an indication of temporal changes. Unfortunately this was one of the kites whose lines became tangled during part of the test but the data available show a fairly steady situation. The kites were laterally separated by about 50-100m, and all were about 300m inland from the coast. It is clear from Fig. 5.7 that the three profiles are reasonably consistent. The two 'low' values to the left of the main sets of data correspond to the period from 13.00-13.10 when the BRE fixed altitude kite also showed a wind speed about 1 m/s below that which prevailed for most of the period.

The second test was conducted at RS between 11.00 and 11.30 a.m. (BST) on 4 October. All groups attempted to fly their kites at 50m elevation for comparisons with the cup anemometer at that level on the RS tower. This was achieved within about ± 2m elevation. To avoid kite entanglement problems groups were separated by approx 100m in a roughly N-S line. The wind direction was from approximately 50°-60°. The 10-min-averaged wind speeds obtained during this test are listed in Table 5.11. The cup anemometer speeds were measured in the field by recording voltage outputs using an integrating voltmeter but have also been processed in the standard way from cassette recorded values. Slight differences are consistent with temporal changes in the wind speed and the effects of the 100s time constant of the voltmeter. Since only a 1/2-hour's data was collected and the kites were separated by up to 400m, some of the variation between kites could be real. Even ignoring this we can conclude that we were able to measure wind speeds with an error of less than 5% and that the system has good potential for measuring profiles at several locations for intercomparison purposes.

5.3.2 Upwind and Hilltop Comparisons

Due to time and other constraints the only occasion during Askervein '82 on which we seriously attempted to undertake hilltop versus upwind TALA kite comparisons was on the morning of 2 October 1982. The conditions were not ideal with quite strong winds and light but driving rain. Four groups flew kites:

- BRE at the coast near RS.
- FRG near the SW base of the hill, (at approx. 200m ESE of BS)
- ERA near CP.
- AES at approx. BSE20, midway between HT and CP.

The three groups on the hill all had severe problems. In particular the FRG and ERA groups were not equipped with high speed 'tubes' for their kites and their readings went off-scale on some occasions. The kites flew very erratically at low levels on the hilltop and the AES team had their kite crash land on one occasion with the loss of its tail. Notwithstanding these problems we did manage to obtain some data. These were collected in 15-min blocks with the first 1-5 mins being used for altitude changes. BRE flew one kite at a constant line length at a height of approx. 120m. All other data were normalized to wind speeds from that kite in an attempt to eliminate the effects of temporal variations. The normalized values are listed in Table 5.12 and profiles of fractional speed-up relative to the BRE coastal profile are shown in Fig. 5.8. Wind directions indicated by the BRE 120m kite near RS were 191° ± 5° for the period 10.00-11.15. Hilltop values were essentially the same and the direction is in good agreement with the Benbecula airport record shown in Fig. 4.2. For the two ERA kite values given in the table some readings (~15%) were off-scale. The tube maximum (2.5 kg) has been assumed for these cases but we estimate that the resulting errors in wind speed will be less than about 2%.

There is clearly some scatter in the data plotted in Fig. 5.8 and there is also some uncertainty in the exact location of the hilltop kites which were flown from fixed ground locations and hence moved downwind with increasing height. However the pattern of decreasing ΔS with height is well defined and matches the ΔS profiles obtained from the 50m towers for similar wind directions shown in Figs. 5.5b, 5.5c very well. It also confirms the speculation made in section 5.2.2 that ΔS would approach zero at a height of about 200m. We hope to obtain more and better quality data from these TALA kite systems during ASKERVEIN '83.

5.3.3 BRE Profiles

The BRE group deployed their two-kite system on a number of occasions, usually chosen to coincide with MF runs. Their data are given in Table 5.13 while profiles of the wind speed ratio V/V_{ref} are shown in Fig. 5.9. Note that with their high altitude kite the BRE group were able to reach heights, Δz, of almost 500m. Data for Run 2.29a have not been plotted because of the large change of direction during that period. Note that because of possible calibration differences between kites V/V_{ref} is not always equal to 1.0 at

$\Delta z = z_{ref}$ but it is usually quite close. It can be seen from the table that there are often significant temporal variations in V_{ref} but that the plots of V/V_{ref} remove this quite effectively and give well-defined profiles. The directions noted on the figures are based on the average wind direction reported for the reference kite. While 'upstream blockage' effects due to the hill are a distinct possibility at the BS location there is no clear evidence of this in the profiles, which are approximately logarithmic with the exception of some points near the surface and the uppermost value for Run 1.22 (which was flown from RS). Since the profiles are essentially logarithmic we have, subjectively, extracted z_0 and u_* values. These are given in Table 5.14, assuming $\kappa = 0.4$ and using the average V_{ref} values also given in that table. The z_0 values are generally compatible with those obtained from the 50 tower profiles and from the sonic anemometer at RS although there are two substantially higher values (0.3m and 0.27m for runs 1.22 and 2.01a respectively). The agreement between sonic anemometer and TALA profile u_* values is noteworthy but probably fortuitous. We hope to deploy this type of system regularly at RS during Askervein '83. The shape of the upstream profile to heights of order L (the length scale of the hill) is an important input to both numerical and wind tunnel modeling activities.

6. TURBULENCE MEASUREMENTS

6.1 Objectives

The main objective of the turbulence measurements made during Askervein '82 was to obtain a direct intercomparison of the various systems being used by the participants for the measurement of turbulence. This intercomparison (referred to as the 'T-test' in this report) would provide the calibration and correction factors needed to make direct comparisons of the turbulence data obtained by the different systems when deployed at the various locations of interest. It was also desired to 'check out' the individual systems in an operational mode in order to identify and subsequently to rectify any unforeseen problems prior to the 1983 main experiment. Finally, it was desired to obtain as much 'preliminary' information as possible on turbulence characteristics and changes in the flow over the hill, bearing in mind that a complete investigation of these characteristics would be the main objective of the 1983 experiment.

6.2 Turbulence Measurement Systems and Calibrations

6.2.1 AES (Canada) Sonic Anemometer

The AES sonic anemometer used during the experiment was a Kaijo-Denki Model DAT-300 Ultrasonic Anemometer - Thermometer. It was mounted on a 10m tower (Δz = 10.1m) at RS (Figs. 6.1, 6.2) during the first part of the experiment, including the 'T-test'. On Monday, September 27 (during MF run 2.27) it was moved to the 47m level on the 50m tower at RS (Fig. 6.3), where it remained for the duration of the experiment. At both locations, it was mounted on a television antenna rotor which allowed it to be turned as desired through the full 360° of azimuthal angle and hence it could be pointed directly into the wind for all runs.

Tower interference effects were assumed negligible for both sonic anemometer locations since, at the 10m tower, the anemometer head was mounted atop the tower and extended well above it (about 1m - see Fig. 6.1) while at the 47m level on the main tower, it was on a boom mounted diagonally through the centre of the tower which placed it 1.5 metres (about 4 tower diameters) away from the tower. The boom pointed toward 180° grid, and no measurements were made for wind directions which would place the sonic head in the wake of the tower.

Turbulence outputs produced by the DAT-300 anemometer include the horizontal wind components A and B, which can be converted to the Cartesian velocity components u and v, the vertical velocity component w and the temperature T. These signals were available as analog outputs and were either recorded on analog tape (HP 3964A FM tape recorder) or were pre-filtered and digitized on-line for storage on the Winchester disk of a Plessey/DEC 11/23VZJ micro-computer system. The tape recorder, micro-computer and other electronic equipment were located in a 2.4m x 3.0m wooden instrumentation shelter situated at RS, about 10m away from the nearest tower (Figs. 6.1, 6.2 and 6.4). Fig. 6.5 shows a schematic layout of the details of the data collection and storage system.

The main advantage of the 11/23 system was that it permitted fundamental statistics ($\bar{U}$, σ_u, σ_v, σ_w, $\overline{uv}$, $\overline{uw}$, $\overline{vw}$, $\overline{wT}$) to be obtained in real time at any desired interval without interrupting the continuous collection and storage of the raw signals. Thus the basic turbulence statistics were available on-line while the stored data could be retrieved at a later time for further analysis (correlations, spectra, coherence, etc.).

Calibration of the DAT-300 anemometer is very simple as a result of improvements in its design over previous models of the same instrument. The only fundamental calibration actually required is a zero-flow adjustment of the electronic circuits which was performed at the site prior to the start of the experiment. Repeated zero-flow checks during and after the experiment indicated that no zero-drifts had occurred. A mean-flow calibration was also performed in a wind-tunnel prior to shipment to the site and confirmed the accuracy of the basic signals. No corrections for possible geometric deformities were applied as these were considered to be unnecessary for this instrument. The general characteristics and limitations of this type of anemometer are well known and can be found in its operating manual and in Kaimal (1980), which gives an excellent description of its accuracy and reliability as a turbulence sensor. For the purposes of this experiment, no corrections to the basic statistics were considered necessary.

The nominal frequency response of the DAT-300 is 0 (i.e.,DC) to 10 Hz (-3dB). Thus the sampling rate (f_s) chosen for digitization was 30 Hz and anti-aliasing filtering was carried out at a cut-off frequency (-3dB), f_c=15 Hz.

6.2.2 DK (Denmark) Sonic Anemometers

Five DK (Risø) sonic anemometers were used during the experiment, four on the 50m tower at HT (Fig. 6.6) and one on a 10m tower at RS (Fig. 6.1). All five units were Kaijo-Denki Model PAT-311 Ultrasonic Anemometers. The Model PAT-311 is a predecessor to the Model DAT-300 described above and its overall operation is similar to that of the DAT-300. The DK instruments had all been upgraded at Risø prior to the experiment by replacement of all original transistors with more modern ones in order to improve their stability and drift characteristics.

The four hilltop anemometer probe heads were mounted on 1.5m booms similar to that used for the AES sonic anemometer on the 50m tower at RS. The hilltop boom was pointed toward 225° grid. The level of the flange for probe mounting at the tip of the boom relied on the quality of machining of the parts and the tower being vertical and is estimated to be accurate to ± 1°. The heights of the anemometers on the tower were 3, 10, 30 and 47m (see Fig. 6.6) except in one run (12:00 - 14:00 on 3 Oct. '82) when only two levels, at 20m and 47m, were utilised.

Anemometer signal cables extended from a preamplifier ('junction box') mounted just under each boom, down the tower and along the ground toward the lee of the hill, where recording equipment was located in a trailer (Fig. 6.7) approximately 50m away.

The fifth DK sonic anemometer was mounted on a 10m tower (Δz=9.8m) at RS and remained there throughout the experiment (Fig. 6.1). Data from this unit were recorded by AES personnel and the output signals were handled in the same way as those of the AES sonic anemometer discussed above.

At Risø the instruments had been calibrated electronically as well as mechanically: electronically through matching of transmitter and receiver transducer pairs and by precise adjustment of the integration ramp in the analog circuit; mechanically through accurate measurements of the actual geometry of the individual probe heads. In the field the instruments were further calibrated by placing the probe head in an anechoic box immediately before a run to ensure that instrument zero was equivalent to zero wind in all components.

Because of the remoteness of the site and the inhospitable surroundings, signal recording was performed in traditional analog fashion onto two 8-channel HP 3968A FM tape recorders. In addition, the signals from the sonics were visually monitored on Brush ink pen recorders, where special events regarding weather or instruments were marked. Power was obtained from a portable Honda generator.

In order to proceed with the analysis, the analog tapes must be digitized to computer compatible format at a nominal sample frequency of 40 Hz with appropriate anti-aliasing filtering (i.e. 20 Hz). The time series of the raw sonic signals can then be transformed into series of u, v, w in two steps. First, the individual matrix for each probe (determined from the geometric measurements mentioned above) can be used to transform the measured components into Cartesian components. In this process corrections for average temperature and humidity can also be made. Following this, the average values of the resulting Cartesian velocity components can be computed. This provides the input for the last transformation in which the coordinate system is tilted and turned to elimate w and v. Time series prepared in this manner are then available for computation of turbulence statistics (spectra, etc.) for which detrending procedures can be applied as deemed necessary.

6.2.3 AES (Canada) Gill UVW Anemometers

Two Gill UVW 3-component propeller anemometers (Model 27004) were used by AES during Askervein '82. One was mounted atop a 10m tower at RS (Fig. 6.1) at an exact height of Δz=10.2m and the other was similarly mounted on a 10m tower at HT (Fig. 4.4b). Both anemometers were mounted on levelling plates which allowed them to be aligned with the w-component vertical and rotated to the azimuthal angle best suited for the experimental run in question. The range of acceptable wind angles for a specific anemometer orientation is about 250°, centred on the selected azimuthal direction.

The operational and response characteristics of the Gill UVW anemometer have been discussed extensively in the literature [e.g. Hicks (1972), Horst (1973a,b), Teunissen (1977)] and are now well understood. For the present experiment, Model 8234 polypropylene propellers were used. These are 18 cm in diameter and have a distance constant of about 3.3m, resulting in an upper frequency response limit (f_c) of about 0.5 - 1 Hz at the mean wind speeds encountered during the experiment (10-20 m s^{-1}).

The three analog signals from each Gill anemometer were transmitted via cable to the bottom of each tower where they were filtered (f_c=1.4 Hz), digitized (f_s= 2 Hz) and stored on cassette tapes using SEADATA Model 1250 Data Loggers. Full cassettes were returned to the laboratory to be played back through a SEADATA Model 12A Cassette Reader, which transferred the data to 9-track, computer-compatible tape. Statistical analysis was then performed on the 9-track tapes using standard procedures. For Askervein '83, it is planned to transport the Model 12A Cassette Reader to the site in order that preliminary results will be available after each experimental run.

Non-cosine-response corrections were applied to all Gill UVW data using the iterative procedure described by Horst (1973b) and Teunissen (1977). Wind-tunnel calibrations were carried out on all anemometers before and after the experiment, and no unacceptable changes in output characteristics were found.

6.2.4 BRE (U.K.) Gill UVW Anemometers

Four Gill UVW 3-component propeller anemometers were operated by BRE during Askervein '82. These units, including the propellers, were identical to the AES Gill anemometers described above. The BRE anemometers were mounted at four levels (5.6, 9.8, 14.8 and 19.8m) on a 20m telescopic mast extending upward from the rear of a Land Rover (Figs. 6.8, 6.9). During the early part of the experiment, the tower was erected at RS. On Thursday, September 23, it was moved to a position on line ASW at the upstream foot of the hill (see Fig. 3.5), which is the site shown in Fig. 6.8. Prior to this move, the anemometer at the 5m level was removed and mounted on a separate 10m tower at RS (see Fig. 6.1). This anemometer remained at RS until Saturday, September 25, when it was re-installed at the 5m level on the telescopic mast near the foot of the hill. No changes in the locations of the BRE anemometers were made after this date.

Analog signals from the anemometers were transmitted via cable to a 14-channel Sangamo Model 632 Sabre VI FM tape recorder located inside the Land Rover. The tapes were returned to BRE following the experiment and digitized at 2 Hz after anti-aliasing filtering at 1 Hz. Statistical analysis was then carried out using standard procedures. Fig. 6.10 is a schematic layout of the complete data collection/storage/analysis system. The BRE anemometers were calibrated in July of 1983 in the BRE wind-tunnel. No corrections for non-cosine response were applied to the data for preliminary analysis of the results. Thus the data presented in Sections 6.3 and 6.4.4 have not been cosine-corrected.

6.2.5 ERA (U.K.) Gust Anemometers

The ERA Gust Anemometer is a drag-sensitive device which is capable of measuring one horizontal component of turbulence velocity. It was developed by ERA [Morrison (1968)] and consists essentially of a perforated sphere (a ping-pong ball with holes drilled in it) mounted on a vertical sting connected to a strain-gauged flexure. Air moving past the sphere produces a velocity-dependent drag on it, the horizontal component of which is sensed by measuring the deflection of the flexure. The azimuthal direction of the measured component depends on the original orientation of the device. Two units, typically oriented 90° apart, are required to sense both horizontal wind components. In the originally designed operating mode, the flexure on which the strain gauges are mounted was immersed in a damping fluid. Because of potential problems with leakage of this fluid ERA decided to run them without it for this project and to attempt to remove the resonant component of the response during subsequent data analysis.

Two ERA Gust Anemometers were used during Askervein '82, allowing for measurement of the two horizontal turbulence velocities at a single point in space. These units were mounted on a 10m tower (Δz=10.0m) at RS during the 'T-Test' (Figs. 6.1, 6.2) and were moved to CP for the remainder of the experiment (Table 4.1). Analog signals from the units were recorded on a TEAC Cassette Recorder and were subsequently replayed into a processing system at ERA in Leatherhead. Fig. 6.11 is a schematic layout of the processing system.

The anemometers were calibrated prior to the experiment in a wind tunnel at Oxford University. Because the anemometers are drag-sensitive devices their outputs are proportional to velocity squared. The calibration confirmed this response and showed that no additional corrections were required.

6.2.6 FRG (Germany) Gill Anemometer Bivane

A single Gill Model 21003 Anemometer Bivane was used by the FRG team to measure turbulence during Askervein '82. This instrument was mounted on a 10m tower (Δz=10.0m) at RS during the 'T-test' on September 23 (Figs. 6.1, 6.2). Both the tower and the Bivane were moved to CP for the duration of the experiment, as indicated in Table 4.1.

The Gill Anemometer Bivane consists of a light, bi-directional wind vane which is free to rotate in the horizontal or vertical plane. A helicoid propeller (Model 8234 Polypropylene, diameter 18 cm, distance constant 3.3m) is mounted on the nose of the Bivane and produces an analog signal proportional to the magnitude of the instantaneous wind velocity. Potentiometers at each of the two vane axes-of-rotation give the instantaneous azimuthal and elevation angle of the wind vector. Thus the three signals can be combined to produce the three instantaneous orthogonal turbulence velocity components in a reference frame defined by the original orientation of the instrument.

The delay distance of the wind vane (50% recovery) is 1m and its damping ratio is 0.53. Additional details of its operation can be found in the operating manual for the instrument. In general, its sensitivity and response characteristics are similar to those of the Gill UVW anemometers described above. The instrument was calibrated in the University of Hanover's wind tunnel.

Signals from the FRG Bivane were transmitted by cable to a weatherproof data logger at the bottom of the 10m tower where they were amplified and multiplexed at a scan interval of 0.2s. Digitization was performed before storing the data on DC300 magnetic cassettes (ECMA46 format). The system is shown schematically in Fig. 6.12.

6.2.7 AES (Canada) Cup Anemometers

The AES cup anemometers from which turbulence information was obtained are the Gill Model 12102 units which were mounted on the two 50m towers at RS and HT and the 10m Gill UVW anemometer tower at RS (Fig. 6.1). These anemometers and details of their location and signal recording have already been described in Section 5.2.1. For purposes of turbulence measurement, their characteristics are similar to propeller anemometers in that they respond as a non-linear first-order dynamic system characterized by a distance constant (2.4m and 2.7m for aluminum and polypropylene cups respectively) as opposed to a time constant. They differ from fixed-axis propeller anemometers in that, for elevation angles within about ±15° of the plane normal to their axis of rotation, they respond to the total wind vector in the normal plane, rather than to only a single component. Thus for cups aligned vertically over a flat plane, the output signal is proportional to $V_h=(u_t^2+v_t^2)^{1/2}$ where u_t and v_t are the total instantaneous components (i.e., mean and fluctuating parts) in the horizontal plane. Nevertheless it can easily be shown (see Peterson et.al., 1976, for example) that to first order, the variance σ_h^2 of this signal is approximately equal to that of the fluctuating u-component alone (i.e., σ_u^2) and hence we can interpret σ_h^2 from the cups as being comparable to σ_u^2 from the propeller anemometers.

6.3 System Intercomparisons

The main turbulence system intercomparison experiment was dubbed the 'T-test' and was carried out on Thursday, September 23, between 1628 and 1728 BST. The objective of this experiment was to have all the different turbulence sensors measure the identical input turbulence over as long a period as possible and then to compare the individual estimates of the turbulence parameters produced by each system. It was therefore desired to locate the various sensors as close together as possible without creating mutual aerodynamic interference among them. This was done by placing the sensors at a nominal height of 10m and at 1-2m separations along a straight line perpendicular to the prevailing wind direction at the reference site. The reference site was chosen for the T-test because of the uniformity of the upstream terrain, which hopefully would ensure reasonable horizontal homogeneity of the turbulence and hence would minimize spatial effects on the results obtained.

All the turbulence systems described above except for the AES cup anemometers were mounted on nominal 10m towers along the line 334°-154° at the reference site. The AES cup anemometers were excluded from the 'official' test because of their unique nature relative to the other systems, although σ_h estimates for the test period were in fact available at Δz=3m and 6m levels. The locations of the sensors are shown in Figs. 6.1 and 6.2.

The experimental approach consisted of selecting the above line perpendicular to the most probable wind direction, installing the anemometry and waiting for winds from the desired direction (244° ± 30°) with an acceptable mean velocity ($> \sim 5$ m s^{-1}). As is usual in experiments of this type, the atmosphere was not particularly cooperative and several days were required before acceptable winds were encountered. In addition, some equipment malfunctioned or was not available during the period when the T-test was finally under way. As a result the official test did not include results from the DK sonic anemometer, while only mean speed and direction were obtained from the ERA gust anemometer and the reliability of these was considered marginal. In the case of the DK sonic anemometer, an independent, direct comparison with the AES sonic anemometer was carried out at a later date (1129-1159, Sunday, September 26th, $U \sim 7$ m s^{-1}, ϕ = 124°; see Table 6.1 for results). In the case of the ERA gust anemometer, direct comparisons will be made during ASKERVEIN '83, during which additional 'T-tests' are planned to ensure that all systems are operating satisfactorily.

The one-hour duration of the T-test was broken into two 1/2-hour blocks (nominally 1628-1658 and 1658-1728 BST) for statistical analysis purposes. Results from these blocks were then averaged to produce the values presented in Table 6.1. The exact times of the blocks corresponding to each system are also given in this table. Although they are not identical in all cases, they are considered to be close enough to the nominal time to make any differences in the data due to temporal effects (i.e., non-stationarity) acceptably small. Table 6.1 also shows, for each turbulence quantity, the ratio of the result from each system to the value obtained from the AES sonic anemometer, which was chosen as the 'standard' instrument for intercomparison purposes. Finally, Table 6.1 also shows some typical ratios of Gill UVW anemometer results to sonic anemometer results based on the nominal response characteristics of the former in atmospheric turbulence of the type encountered here. These were obtained from Teunissen (1980) and are typical of the results to be expected from the Gill UVW sensors.

The results of Table 6.1 show that for mean wind direction at least, all turbulence systems are in excellent (i.e. ± 2°) agreement with one another. For mean wind velocity during the T-tests the AES Gill is only 3% lower than the AES sonic while the BRE Gill is 13% lower, the latter result being likely due to the absence of non-cosine response corrections for the BRE Gill (this was subsequently confirmed during ASKERVEIN '83). The FRG Bivane is 6% higher than the AES sonic. The ERA Gust anemometer is 17% lower but its reliability is in doubt and, in addition, its time block is not a good match for the target period.

The turbulence intensities obtained during the T-test are seen to compare with the AES sonic results much as predicted for a typical Gill UVW anemometer system. The one major exception is the value of $\sigma_w/\bar{U}$ for the FRG Bivane, which can be interpreted as an indication of the superiority of the Bivane over the Gill UVW for measuring σ_w. The most important cross-product, $\overline{uw}$, is seen to agree very well with the AES sonic, except in the case of the BRE Gill. This may also be due to the absence of non-cosine response corrections. The Reynolds stress coefficients (Re) are a combination of the turbulence intensity values and the cross-product coefficient and reflect the same information in a different form.

As for the comparison of the AES sonic and DK sonic systems, which was carried out at a different time from the T-test, we would expect the results to be identical in view of the similarity of the two systems. The results of Table 6.1 show that for most parameters, this is indeed the case. The 7% difference in mean velocity, is likely due to temperature and humidity effects on the DK results (no corrections have been applied to these data) and will hopefully be eliminated on re-analysis of the data at Risø. The re-analysis will also include corrections for non-ideal geometry. The 10% difference in $\sigma_w/\bar{U}$, corresponding to 17% in σ_w alone, is rather more disturbing and is certainly unacceptable for useful estimates of turbulence changes from the two systems. However, it is almost certainly attributable to some obvious spiking in the w-component of the DK sonic and may also be removeable on re-analysis of the data.

The above intercomparison results show that there are substantial differences in the turbulence results obtained by the various systems when measuring the same input quantities. Some of these differences were expected while others could be attributed to obvious causes. For ASKERVEIN '83, it is intended that 'malfunctioning' type differences will be eliminated, while corrections will be made to the results to compensate for any unavoidable systematic differences between the various sensors. These corrections will be based on results from both the ASKERVEIN '82 T-test and from additional, more exhaustive tests of this type planned for ASKERVEIN '83.

6.4 Turbulence Results

6.4.1 AES Sonic Anemometer

The AES sonic anemometer system operated satisfactorily during most of the measurement period, with the exception that the DEC 11/23 microcomputer system became inoperative after Sunday, September 26. This was not a catastrophic failure, however, in that it merely precluded on-line analysis of the data in the field. Instead, the sonic signals were recorded on the HP analog tape recorder and were returned to Canada after the experiment for analysis in the laboratory. Thus no desirable data were lost during the experiment.

Table 6.2 summarizes the data obtained by the AES sonic anemometer system and correlates the individual experimental runs with the mean flow runs. A total of 20 hours of data was collected, 10 hours at Δz=10.1m and 10 hours at

Δz=47m. All data were analyzed in 1/2-hour blocks and were averaged over all the blocks in a run to produce the values given in Table 6.2. The individual values obtained for each block are presented in raw form in Table 6.3.

The optimum wind direction for the Askervein experiments is in the range $\phi \sim$ 160-270°, with ϕ = 223° (i.e., parallel to the minor axis) being the ideal value. For these angles, the wind approaches the hill over a relatively flat, uniform upstream fetch. Based on the general surface characteristics of this fetch (see Section 3 and Figs. 3.2 and 3.3), typical values for roughness length and the other turbulence parameters to be expected in the approach flow could be estimated from the various idealized models of atmospheric boundary-layer flow [e.g. ESDU (1974), Counihan (1975), Teunissen (1970)]. These typical values are listed in Table 6.4. Also shown in this table are the averaged turbulence parameters obtained from several of the experimental runs listed in Table 6.2, but grouped according to mean wind direction. That is, for each of the three directions shown in Table 6.4, results for all experimental runs within ±5° of these angles were averaged together to produce the characteristic values listed. The measured values are seen to agree very well with the idealized values for comparable wind directions. The roughness lengths were obtained from the uw and U values measured by the sonic anemometer and the assumption of the validity of the log-law velocity profile from the surface to at least the height of the anemometer. The observed variation is typical of that to be expected upon detailed inspection of the surface characteristics of the upstream terrain for each of these wind directions. The values given in Table 6.4 have also been plotted in Fig. 5.6 for comparison with the estimates obtained from the cup anemometer mean velocity profiles. The agreement between these two sets of values is reasonable and is typical of that to be expected for the two different methods of estimation of z_0.

Most of the AES sonic anemometer data summarized in Tables 6.2 and 6.3 have been permanently stored on digital magnetic tape and are available for additional statistical analysis (power spectra, scales, etc.). This analysis will be carried out in the near future as necessitated by the availability of other results with which to compare and the pending results from ASKERVEIN '83.

6.4.2 DK Sonic Anemometers

Some difficulty was experienced in the operation of the five Kaijo-Denki PAT-311 sonic anemometers, mainly, it is suspected, as a result of moisture in their respective junction boxes and corrosion on plugs, possibly due to wind-blown salt from the ocean. It is expected that these problems will be rectified for the main experiment. A total of 8.5 hrs of data were collected but at the present time analysis of the data from the sonic anemometers located at HT is not complete. We hope to report on it separately at a later date.

Table 6.5 presents information for the DK sonic on the 10m tower at RS. As was the case for the AES sonic data, 1/2-hour block lengths were used. Block-averaged values for each experimental run are given in Table 6.6.

6.4.3 AES Gill UVW Anemometers

Table 6.7 presents the data obtained during the experiment from the AES Gill UVW anemometers at RS and HT. Some difficulties were encountered in the electronics and data logging systems at various times during the measurement period and hence the data set is not as complete as we would have wished. All systematic problems have been identified, however, and will be rectified for ASKERVEIN '83.

The data of Table 6.7 are presented in a format similar to that used for the cup anemometer data of Table 5.10. Once again 1/2-hour blocks have been used with the start time for each block given at the top of each column.

The mean velocity values from Table 6.7 have been plotted where appropriate in Figs. 5.4 and 5.5 and are discussed in Section 5.2.2. The turbulence quantities of interest at present have been plotted in Figs. 6.14 to 6.18 and are discussed where appropriate in Section 6.4.7.

6.4.4 BRE Gill UVW Anemometers

The Gill UVW anemometers operated by BRE performed very reliably during the experiment and yielded an extensive turbulence data set. Table 6.8 summarizes the dates and times of the runs obtained. These runs were analyzed using two block lengths (10 min and 30 min), after which results could be block-averaged as desired. Table 6.9 shows a typical complete data set for Wednesday, September 22.

Note that no corrections for non-cosine response of the anemometers have been applied to the BRE data presented in this report. This will be a factor to be considered in interpreting the mean flow profiles from the BRE mast obtained during some of the MF runs. These data are listed in Table 6.10. It is hoped that the data can be reprocessed with cosine corrections in the near future.

6.4.5 ERA Gust Anemometers

Some difficulty was encountered in the analysis of data from the ERA gust anemometers, particularly for one specific unit and for conditions when the mean wind speed seen by this 'unit' was close to zero. Under these conditions, a large resonant component in the output signal produced serious errors in the fluctuating part of the output, although the mean value was not significantly affected. This problem was not identified until quite late in the programme, with the result that only limited useable information was obtained from the ASKERVEIN '82 experiment. Thus no data other than the 'T-test' results discussed in Section 6.3 are presented in this report. It is intended that these problems will be rectified prior to ASKERVEIN '83.

6.4.6 FRG Anemometer Bivane

The FRG Bivane system performed well during most of ASKERVEIN '82. Table 6.11 lists most of the results obtained from the system, while Hoff and Tetzlaff (1983) present some additional raw data. They note in particular (see Fig. 6.13) that at CP the 10m-level turbulence intensities $\sigma_u/\bar{U}$ and $\sigma_w/\bar{U}$ compare well with standard values found in flat terrain but that the values of $\sigma_v/\bar{U}$ are somewhat higher and indeed exceed $\sigma_u/\bar{U}$. In Table 6.11, the nominal data block length is 23 minutes, starting at the times shown in the table. Although the results from the Bivane system were quite satisfactory during ASKERVEIN '82, it is planned that FRG will replace it with four Gill UVW systems during ASKERVEIN '83 for the sake of consistency with other systems.

6.4.7 AES Cup Anemometers

The basic turbulence data obtained from the cup anemometers on the 50m towers at RS and HT are presented in Table 5.10 along with the mean velocity results already discussed in Section 5.2.2. The data are calculated in 1/2-hour blocks, and both the standard deviation ($\sigma_h \simeq \sigma_u$) and the turbulence intensity ($\sigma_h/\bar{U}$) are tabulated. As previously discussed, some anemometers or signal conditioning systems malfunctioned during part of the measurement period and hence no data are available for these times. Nevertheless, a reasonably extensive set of data was produced by this system, as indicated by the results presented in the table.

Figs. 6.14 display average profiles of σ_h at RS for the time periods shown using the basic data from Table 5.10. Figs. 6.15-6.18 show similar profiles for both RS and HT. Also shown in both sets of figures are the corresponding results from the AES sonic and Gill UVW anemometers. In general, the sonic anemometer results lie above the cup anemometer values as a result of the better frequency response of the former (no 'T-test' type corrections have been applied), while the Gill UVW results tend to lie between the two and are usually closer to the sonic values.

In Figs. 6.14, it is clear that the σ_h profiles at RS are roughly constant with height or decrease very slightly, which is what would be expected in an idealized surface boundary layer flow. Figs. 6.15-6.18 show a generally similar profile shape at HT. In addition, it is seen from the latter figures that the overall magnitude of σ_h is generally the same at HT as it was at RS, although it is perhaps justifiable to conclude that there is a significant decrease (~ 10% or so) in σ_h above $\Delta z \sim$ 5-10m. Such a decrease is generally consistent with the predictions of rapid distortion theory for the outer layer of the flow (i.e., $\Delta z > \ell_T$). On the other hand, the expected large increase in σ_h in the <u>inner</u> layer near the surface is really not evident, except perhaps in Fig. 6.16. We interpret this as an indication that the inner layer is considerably shallower than the 14m suggested by the Jackson-Hunt theory (Section 2), particularly in view of the speed-up results presented in Fig. 5.5. Consequently, extra attention will be paid to the lowest 10m of the flow during ASKERVEIN '83 in order to investigate these possibilities more thoroughly.

The fact that σ_h ($\simeq \sigma_u$) does not increase significantly as the flow passes over the hill above about 5m is very important from the point of view of structural loading on WECS and similar structures in that the fluctuating loads are directly dependent on the magnitude of σ_u. It is also worth pointing out that since σ_h is roughly constant and U increases by as much as 100%, the local turbulence <u>intensities</u> at the hilltop decrease by as much as 50% as the flow passes over the hill.

7. WIND TUNNEL AND NUMERICAL MODELLING ACTIVITIES

An essential part of the overall Askervein programme will be a comparison of the data collected during the two field experiments with the results of wind tunnel and numerical model simulations. Although the modelling work is not yet complete, the present section gives a brief summary of activities to date.

7.1 Wind Tunnel Studies

Two of the participants in IEA Task VI (Canada and New Zealand) and one additional institution (University of Oxford, U.K.) are involved in wind tunnel modelling activities related to Askervein. These activities fall into two main phases. First, each of the three groups will carry out an independent simulation of the flow over Askervein at a length scale appropriate to the size of its wind tunnel facility. Several wind directions will be investigated, the final choices being dictated by the combined full-scale data sets from the 1982 and 1983 field experiments. Mean velocity profiles at all full-scale tower locations, turbulence intensity profiles for all three velocity components, power spectra, autocorrelations and integral scales are typical parameters that will be obtained and compared with available full-scale results. The basic objectives of this part of the wind tunnel simulation work are

(i) to establish the reliability with which each of the facilities can reproduce the atmospheric flow using the techniques, equipment and scales indigenous to the facility; and

(ii) to intercompare the three sets of wind tunnel data in order to identify differences, if any, amongst the predictions produced by each facility and to attempt to explain the reasons for such potential differences.

The second phase of the wind tunnel work involves an exchange of models such that the smallest of the three will be tested in all three wind tunnel facilities and the next largest will be tested in two of them. In this way, it is hoped to eliminate from the comparison of results any differences caused by inherent characteristics of the equipment or techniques used and to isolate effects due to model scale alone.

The model length scales to be used for these experiments are 1:2500 (New Zealand), 1:1200 (Canada) and 1:800 (University of Oxford). As of this writing (October 1983) all models have been constructed and initial measurements have been carried out on two of them. Details of the procedures and comparisons with full-scale results will of course be given in separate reports, but a general idea of the methods to be used can be obtained from Teunissen (1983) and Teunissen et. al. (1982).

7.2 Numerical Modelling

The numerical model being used for simulation of the flow over Askervein is MS3DJH. This model, which is based on extensions of the theories of Mason and Sykes (1979) and Jackson and Hunt (1975), is described in detail in the papers by Walmsley *et al*. (1982) and Taylor *et al*. (1983a).

The basic theory is for surface boundary-layer flow above an isolated low hill and its intended application is to terrain features with horizontal scales from 0.1-10 km. The model predicts the variations in the near surface wind field caused by terrain features with low slopes under steady state conditions with neutral thermal stratification and uniform surface roughness. These are serious limitations, but they do simplify the model sufficiently so that it can be applied to real 3D terrain features with high spatial resolution (256x256 grid points in the horizontal) and still require only a very modest amount of computer time. The key steps in the model are:

(a) Linearization of the governing equations about the undisturbed velocity profile for uniform terrain.

(b) 2D Fourier analysis of the linearized equations.

(c) Approximation and analytic solution of the ordinary differential equations (in Δz) for the Fourier coefficients.

In applying the model, the use of 2D finite-area Fourier transforms implies that the lateral boundary conditions are those of periodicity in both x and y and, in effect, means that the terrain to be studied must be kept within the central portion of the solution region. For a hill of half width L, a domain size of about $(5L)^2$ is usually found to suffice. The model requires a representation of the terrain under scrutiny to be input as a regular grid. In the present case it is a 256x256 square grid derived from a contour map

(Fig. 3.5) by the application of series of orthogonal cubic splines under tension (See Salmon et al. 1981). The central portion of the grid retains all of the original contour information (except for a single 9-point smoothing at each grid point) while its perimeter is "blended" into a "zero-plane", flat outer region as dictated by the form of the numerical model. The "zero-plane" level is chosen so that the assumed incident wind encounters no abrupt terrain changes at the outer limit of the region. Thus, contour maps and cross-sectional plots of the terrain will be accurate in portraying the shape of the topographic features but not the absolute levels.

To date only one preliminary MS3DJH/3 computation using the Askervein topography has been completed. This was for an incident mean flow direction of 250° corresponding approximately to the conditions prevailing during run 1.23b. The roughness length assumed was 0.05m. Some results for the 10m level are shown in Fig. 7.1, together with the terrain cross-sections along the tower lines. Comparison with Fig. 5.2c shows good agreement in the magnitudes of normalized wind speed and in the variations with position on the upwind face of the hill, (along ASW) and along the ridge (line BNW-BSE). In the lee of the hill (line ANE) it can be seen that the observed reductions in wind speed are larger than those predicted. As a preliminary comparison, the results are very encouraging. It is intended that an extensive series of comparisons will be carried out and reported on at a later time.

8. ASKERVEIN '83

The 1983 main experiment was conducted between 14 September and 17 October 1983. During the core observing period from 25 September to 9 October, the weather was quite cooperative and we had four days with steady, moderate-to-strong SW winds. We were also able to obtain good data with both south and west winds. Preliminary (on site) analysis of the data indicated that most of the systems operated satisfactorily and reliable, comprehensive data sets will be forthcoming. The list of instrumentation given in the 'Detailed Program of Work' is basically correct although there were some changes in the numbers of units deployed (mostly increases!) and we used additional TALA kite systems to obtain wind profiles instead of deploying tethersonde systems as originally planned. At the time of writing (October 1983) it appears that Askervein '83 has been very successful and we are eager to push ahead with the analysis and interpretation of the data.

9. CONCLUSIONS

The present document is intended as an initial report of the Askervein '82 experiment and concentrates on a description of the experiment and the presentation of data without detailed interpretation. The data from the '82 experiment and our experiences in mounting it proved invaluable in planning Askervein '83 and have made a major contribution to its successful conduct. In addition, the data from Askervein '82 are of considerable value in their own right and will combine with the '83 data to provide a well-supported and detailed description of the flow over the hill. This will be used to evaluate and refine theoretical, numerical and wind-tunnel model studies of flow over hills to ensure that they realistically simulate the full-scale flow.

10. ACKNOWLEDGEMENTS

While being formally only a 'preliminary' study, Askervein '82 was in fact a major undertaking requiring a substantial amount of logistical support and local organization. Mrs. Elizabeth Moughton of ERA Technology Ltd. was primarily responsible for this aspect of the project and we are extremely grateful to her for her excellent work. In addition to the participants who have made contributions to this report, the success of the project relied heavily on the dedicated work of support personnel in the field. They included Jim Arnold, Wes Kobelka and Karl Vanek of A.E.S., Bjarne Breiting, Gunnar Dalsgaard and Finn Hansen of Risø, P. Bollin, R. Hartig and D. Wintermeyer of University of Hanover, David Redfearn and Paul Blackmore of BRE and Lionel Ballard, Masood Nourshargh and Andrew Pattenden of ERA Technology. The two 50m masts were designed by Gunnar Dalsgaard, who also devised the method for their erection, which, of necessity, was done with only manual power. We are also pleased to acknowledge the contributions in assisting with data analysis by Steve Derco and Bob Bloxam of AES and Kwong Sak Leung of ERA. The manuscript has been typed, with her usual proficiency, by Evonna Mathis. Some of the tables were prepared by Bea McKay while the figures were drafted by John Rautenberg and Brian Taylor.

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APPENDIX A

IEA PROGRAM OF R&D ON WECS ANNEX VI

STUDY OF LOCAL WIND FLOW AT POTENTIAL WECS HILL SITES

DETAILED PROGRAM OF WORK

March 1982 - June 1982

		Country Primarily Responsible
1.	Preparation of detailed plans for the preliminary and main experiments.	CAN
2.	Negotiations with landowners and local authorities to secure site access.	U.K.
3.	Make local arrangements for 'site inspection and detailed planning' meeting.	U.K.
4.	Report back to IEA executive committee.	CAN
5.	Attend site inspection and detailed planning meeting and finalize plans for preliminary experiment.	CAN, U.K. DK, FRG
6.	Acquire high resolution topographic map of site and run computer model (MS3DJH) for selected wind directions.	U.K./CAN
7.	Make local arrangements for preliminary field experiment (accommodation, trailers, power supplies, etc. etc.)	U.K.

May 1982 - April 1983

		Country Primarily Responsible
8.	Conduct wind tunnel tests on scale model of hill and prepare report to be used to assist in planning main experiment.	N.Z./CAN

Country Primarily Responsible

September - October 1982

9. Preliminary Field Experiment

The goals of this experiment are:

(a) A thorough field intercomparison of the different mean wind and turbulence sensors to be used in the main experiment.

(b) Resolution of the mean wind field in selected vertical cross sections through the hill using cup anemometers on 10m masts and TALA kite systems.

(c) Initial comparisons of wind speed, direction and turbulence characteristics between the hilltop and upwind reference location.

A minimum list of equipment and numbers of personnel involved in the preliminary experiment, of approximately three weeks duration, is given below. Participants may wish to expand or vary their contributions slightly. Data logging systems are assumed included with each instrumentation system.

Turbulence Instrumentation

No. of Units		
4	Sonic Anemometers on two 30m or 50m towers	CAN (1) DK (3) + 1 Tower UK (1 Tower)
2	ERA gust anemometers on a 10m tower	U.K.
3	3 Component Gill anemometers on 10m towers with cup anemometers at lower levels	CAN (2) FRG (1)

Mean Wind Instruments

No. of Units		Country Primarily Responsible
25	Cup anemometers on 10m posts	CAN (15) FRG (5) U.K.(5)
10	Cup anemometers for Mounting on 50m towers	CAN
2	Standard, rugged anemometers (possibly U2A system) on 10m towers	CAN
3	TALA kite systems	U.K. (1) CAN (1) FRG (1)

Other Items

1.5 KW Diesel Generator	FRG
Communications System	CAN/U.K.

Deployment of Instrumentation

A map showing the anticipated siting (approximate) of fixed and mobile towers is attached. It covers both the preliminary and main experiments. During the preliminary experiment fixed towers will be sited as listed below while movable 10m posts will be deployed in various configurations along lines A, AA, B, C, and D at different stages during the experiment.

- 50m towers at HT and RS
- 10m fixed towers near HT and RS (with U2A anemometers) and at HT2 (ERA gust anemometer system) ASW10, ASW5 and ANE5 - (3 cpt. Gill systems)

In addition, if available, a vehicle based, mobile 20m mast will be deployed along the road to the SW of the hill and at the shoreline to the W or SW of the hill.

TALA kites will be flown from RS, HT, and other locations.

	Country Primarily Responsible
Personnel	
It is anticipated that at least sixteen (16) personnel will be required for the operation of the experiment. The number is rather high as the TALA kites and some of the cup anemometer systems use manual data recording techniques. The anticipated division between groups in CAN (6), U.K. (5), FRG (3), and DK (2).	
November 1982 - February 1983	
10. Analyse data from preliminary experiment and forward to operating agent (CAN) for collation and synthesis.	CAN, U.K., DK, FRG
March 1983 - May 1983	
11. Prepare report on preliminary experiment and finalize plans for main experiment.	CAN
April / May 1983	
12. Attend detailed planning meeting to discuss results of preliminary experiment and to prepare for the main experiment.	All Participants
May - August 1983	
13. Prepare for main field experiment.	U.K., CAN, FRG, DK

September - October 1983

The main goals of this experiment are:

(a) Detailed resolution of mean wind and turbulence fields in several vertical cross sections through the hill using 10m masts and tethersonde profiling systems.

(b) A detailed study of the characteristics of turbulence above the hilltop to heights of at least 50m.

A minimum list of equipment and personnel for this experiment, of about six weeks duration (including setup and dismantling time) is given below. It should be regarded as provisional at this stage. Data logging systems are assumed included with the instrumentation.

Turbulence Instrumentation

No. of Units		Country Primarily Responsible
4	Sonic anemometers	DK (3) CAN (1)
4	ERA gust anemometers	U.K.
20	3 cpt Gill anemometers or equivalent system	CAN (12) FRG (8)
30	Rapid response cup anemometers	CAN (20) FRG (7) DK (3)

Climbable towers for the above will probably be:

2	30 - 50m towers	DK, U.K.
16	10m towers	CAN (10) FRG (4) U.K.(2)

Mean Wind Instruments

No. of Units		
35	Cup Anemometers on 10m Posts	CAN (25) FRG (5) U.K.(5)
2	Standard, rugged anemometers on 10m climbable towers	CAN
4	Kite or balloon supported tethersonde systems	CAN (2) FRG (2)
2	TALA Kite Systems	U.K.

Other Items

2	1.5 KW Diesel generators	FRG
	Communications system	CAN , U.K.

Personnel

The main experiment will require approximately sixteen (16) people on site during the data collection phase with an additional six (6) required for the setup and dismantling periods. Of the total of 22 a provisional division between groups is CAN (8), U.K. (6), FRG (5), DK (3).

Deployment of Instrumentation

The attached map shows anticipated siting of fixed and mobile towers. The deployment of instrumentation will probably be similar to that in the preliminary experiment with the addition of extra 10m fixed towers along lines A and B.

November 1983 - June 1984

15. Analysis of results from main experiment.	CAN, U.K., DK, FRG

July 1984

16. Attend meeting to discuss results of experiment and draft data report and final report (approx. 10 days).	All Participants

July - October 1984

17. Prepare, circulate and edit Final Reports	CAN

December 1984

18. Submit final report.	CAN

TABLES

Table 3.1 Climatological data for Benbecula - September and October. Based on years 1970-1979

BENBECULA

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED SEPTEMBER

MEAN SPEED (KNOTS)	360	030	060	090	120	150	180	210	240	270	300	330	VARIABLE	TOTAL
				DEGREES TRUE										
CALM	—	—	—	—	—	—	—	—	—	—	—	—	—	0.51
1-3	0.06	0.32	0.38	0.58	0.42	0.33	0.35	0.22	0.21	0.08	0.13	0.04	1.78	4.89
4-6	0.79	0.96	1.36	1.53	0.82	1.21	1.29	1.18	0.88	0.50	0.76	0.36	0.01	11.65
7-10	1.86	0.74	1.57	1.08	1.22	1.15	1.39	2.22	2.72	2.06	2.00	0.97	0.0	18.99
11-16	2.24	1.24	1.68	0.53	1.61	3.39	3.51	5.00	5.68	4.00	3.11	2.47	0.0	34.46
17-21	1.22	0.22	1.24	0.0	0.51	2.25	1.88	2.47	3.93	2.72	1.54	0.69	0.0	18.68
22-27	0.44	0.07	0.31	0.0	0.04	0.69	0.94	1.35	1.40	1.86	1.07	0.57	0.0	8.75
28-33	0.21	0.0	0.0	0.0	0.0	0.03	0.08	0.25	0.26	0.24	0.60	0.15	0.0	1.82
34-40	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.06	0.07	0.04	0.01	0.0	0.21
41-47	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.01	0.0	0.0	0.01	0.0	0.0	0.04
48-55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56-63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL 4 KTS OR MORE	6.78	3.22	6.15	3.14	4.21	8.72	9.11	12.50	14.93	1144	9.14	5.24	0.01	94.60

BENBECULA

PERCENTAGE FREQUENCY OF WIND DIRECTION AND SPEED OCTOBER

MEAN SPEED (KNOTS)	360	030	060	090	120	150	180	210	240	270	300	330	VARIABLE	TOTAL
				DEGREES TRUE										
CALM	—	—	—	—	—	—	—	—	—	—	—	—	—	0.59
1-3	0.12	0.31	0.52	0.69	0.32	0.39	0.52	0.27	0.17	0.09	0.05	0.03	1.16	4.65
4-6	0.70	0.98	0.60	0.73	0.70	1.26	1.18	0.67	0.52	0.38	0.73	0.30	0.03	8.78
7-10	2.00	2.43	1.05	0.83	1.02	2.23	1.88	1.84	1.61	1.10	1.09	0.75	0.0	17.85
11-16	1.95	2.10	0.95	0.23	1.36	4.42	5.50	4.37	3.87	3.49	1.88	1.77	0.0	31.90
17-21	0.79	0.31	0.17	0.05	0.40	4.48	3.47	3.74	2.41	1.96	1.33	0.89	0.0	20.00
22-27	0.51	0.03	0.01	0.01	0.15	2.28	2.45	1.33	2.08	1.56	1.20	0.85	0.0	12.46
28-33	0.39	0.0	0.0	0.0	0.0	0.39	0.67	0.31	0.38	0.24	0.32	0.23	0.0	2.93
34-40	0.0	0.0	0.0	0.0	0.0	0.01	0.30	0.05	0.05	0.05	0.19	0.12	0.0	0.78
41-47	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01	0.04	0.01	0.0	0.0	0.07
48-55	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
56-63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OVER 63	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL 4 KTS OR MORE	6.34	5.85	2.80	1.85	3.63	15.08	15.44	12.31	10.94	8.83	6.75	4.91	0.03	94.76

Table 4.1: ASKERVEIN '82 - SUMMARY SHEET

Date 1982	Nominal RS Cond.		Mean Flow Runs	Sonic Anemometers		50m Profiles		BRE· Mobile Tower	AIR-Sonde Flights	TALA kite Profiles	10m Turbulence Data				AES T/S at HT	U2A Data	
	wind speed (ms^{-1})	Direction		RS	HT	RS	HT				AES	FRG	ERA	BRE		RS	HT
	(10m)	(10m)	(Run No.)	(Run No.)					(No.)		(Locations)						
18 Sept. Sa						X					RS						
19 Sept. Su						x					RS						
20 Sept. M	10-15	260	RS Intercomp.1	1												x	
21 Sept. Tu	10-12	310-330	HT Intercomp.2	2a, 2b		x		At RS			RS			RS		x	
22 Sept. W	5-7	160-180	1.22	3		x		At RS		BRE	RS			RS		x	
23 Sept. Th	3-7	220-255	1.23a, b	4a,b,c,d		x		Near BS[6]	2	BRE	RS	RS	RS	RS		x	
24 Sept. F																	
25 Sept. Sa	6-8	130-140	2.25	5		x	x	Near BS		BRE	RS,HT					x	
26 Sept. Su	6.5	125		6		x				Test of 4 Near Shoreline	RS					x	
27 Sept. M	6	160	2.27			x[1]	x	Near BS	1	BRE	RS[1],HT	CP				x	
28 Sept. Tu	13-16	160-170	2.28	7	x	x	x	Near BS	1		RS,HT	CP	CP			x	
29 Sept. W	6-9	220-280[5]	2.29a, b	8a, b	x	x	x	Near BS	2	BRE	RS,HT	CP	CP		x	x	x
30 Sept. Th										Experiment Attempted							
1 Oct. F	9-13	150-160	2.01a, b	9		x	x	Near BS	2	BRE,FRG	RS,HT	CP	CP		x	x	
2 Oct. Sa	7-11	200	2.02	10a, b	x[2]	x	x		1	BRE,AES,ERA	RS,HT	CP	CP			x	
3 Oct. Su	7-8	150-160		11	x[3]	x	x				RS,HT						
4 Oct. M				12		x	x[4]			Test at 50m at RS, 4 kites	RS,HT						
5 Oct. Tu						x[4]											
8 Oct. F			MF Test at CP ERA & CAN.														

Footnotes:

[1] Partial data only
[2] Rain for some of this period
[3] 2 sonic levels only
[4] Dismantling checks
[5] Serious wind shifts during run 2.29a
[6] No 5m level

Table 5.1: Results of intercomparison tests among samples of Canadian British and West German anemometers used in the collection of mean flow data.

Anemometer	Half Hour Reading				1st Hr. Average	2nd Hr. Average	2 Hour Average
	1st	2nd	3rd	4th			
Test 1, 20/09/82, Start at 16:15*, Reference Station							
Casella (U.K.)	14.5	14.8	15.4	15.0	14.6	15.2	14.9
Gill Cup, P1 (Can.)	14.65	15.03	15.51	15.52	14.84	15.36	15.10
Gill Cup, P2 (Can.)	14.76	15.35	15.61	15.28	14.96	15.44	15.20
Test 2, 21/09/82, Start at 15:00, Near BSE20							
Casella (U.K.)	15.1	14.7	14.6	13.6	14.9	14.1	14.5
Gill Cup, P10 (Can)	15.20	14.85	14.75	13.80	15.02	14.27	14.65
Gill Cup, P12 (Can)	15.16	14.77	14.68	13.75	14.96	14.21	14.59
#3 (FRG)	15.7	15.1	14.8	13.9	15.4	14.35	14.88
Test 3, 08/10/82, Start at 11:00, Centre Point							
Vector Instruments (U.K.)	11.67	10.66	11.95	13.33	11.17	12.64	11.90
Gill Cup, P25 (Can)	11.31	10.37	11.51	12.88	10.84	12.20	11.52
Gill Cup, T16 (Can)	+9.37	+9.51	+9.51	+11.4	-	-	-
Gill Cup, T26 (Can)	11.32	10.40	11.52	12.93	10.86	12.23	11.55

* British Summer Time (BST)

\+ Suspect anemometer

Table 5.2 Calibration coefficients for MF cup anemometers

AES (Canada) - Gill 3-cup anemometers (pulse type)

The calibration equation used is

$$U(\mathrm{m\ s^{-1}}) = a_0 + a_1\ C(\mathrm{counts/min})$$

Anemometer Identifier No.	a_1	a_0	Anemometer Identifier No.	a_1	a_0
P1	.01684	.2734	P15	.01679	.2421
P2	.01694	.2159	P16	.01666	.2404
P3	.01669	.3020	P17	.01695	.2647
P4	.01694	.2383	P18	.01693	.2306
P5	.01687	.2995	P19	.01688	.2848
P6	.01656	.2873	P20	.01687	.2337
P7	.01679	.2336	P21	.01701	.2395
P8	.01705	.1602	P22	.01700	.2141
P9	.01686	.3067	P23	.01701	.2520
P10	.01691	.2397	P24	.01690	.2254
P11	.01702	.2596	P25	.01700	.2459
P12	.01688	.2408	P12 body/P5 cup	.01698	.1222
P13	.01717	.2138	P10 body/P3 cup	.01659	.2951
P14	.01707	.2041			

TABLE 5.3 ASKVERVEIN '82 - MEAN FLOW EXPERIMENTS

Run*	Duration	Average Wind[5] Speed at RS ($m\ s^{-1}$)	Provisional Wind Direction[1] ^{o}grid	$(\frac{\partial\theta}{\partial z})$ 0-500m $Km^{-1}x10^3$	Comments
1.22	14.00-16.00+	6.37	180	-	-
1.23a	10.00-12.00	3.34	230	0.10[2]	Rather low wind speed.
1.23b	14.00-16.00	6.36	245	0.95	Slight wind shift during run.
2.25	16.00-18.00	6.50	120	-	Poor direction - upstream hills.
2.27	12.00-15.00	6.04	165	0.55[4]	Showers during run.
2.28	12.00-15.00	11.89	175	1.80	Showers during run.
2.29a	10.00-12.00	5.91	(225)	0.80	Direction change during run.
2.29b	14.00-16.00	8.29	235	1.55	Steady wind, occasional rain.
2.01a	11.00-13.00	8.93	165	1.15	Cloudy but dry.
2.01b	14.00-16.00	10.45	155	0.85[3,4]	-
2.02	14.00-16.00	9.21	200	0.00[4]	Storms nearby but not on hill.

\+ Times are given in British Summer Time (GMT + 1 hr)

( ) Some wind data are more provisional than others, most should be good to 5°.

* First digit is a guide to the configuration. The next two give the day of the month (September then October) while if two runs were conducted on the same day they are a and b.

[1] Best estimate based on a composite of data from a number of sources including the sonic and 3 cpt Gill anemometers at RS, depending on what data were available during each run. Rounded to 5 degree intervals.

[2] Based on AIRsonde release and averaged over lowest 500m (applies to all runs).

[3] Strong (2K) inversion between 1.0 and 1.2 km on this occasion.

[4] Shallow (∿30m) unstable layer near surface on these occasions.

[5] Based on pulsed cup anemometer at 10m.

Table 5.4: ASKERVEIN '82 - MF EXPERIMENTS - WIND DIRECTION INFORMATION

Run	Benbecula Airport °true	RS Sonic (AES)	RS U2A (AES)	RS 3 cpt Gill	BRE 3 cpt Gill		AIRsonde flights °magnetic[5]	Hilltop Data		
								AES 3 cpt Gill	FRG	
					RS	BS			HT	CP
1.22	200 -190	167^{x}	180^{x}	177	179			-	189	186
1.23a	230 -250	222^{x}	-	230	226^{x}		226	-	221	224
1.23b	230 -250	250^{x}	250^{x}	243^{x}		245	254	-	238	242
2.25	140 -110	136^{x}	120	124		118		-	119	126
2.27	180 -200	-	160^{x}	-		167	183	176	179	185
2.28	200 -180	161^{x}	170^{s}	180		173	185	182	191	183
2.29a[4]	190 -260	262^{x}	260^{x}	228		226	240[2]	-	-	215
2.29b	250 -260	236	230	-		233	275[1,3]	220	-	221
2.01a	170 -160	-		168		162	182[2]	-	164[6]	164
2.01b	160	160	150	-		149	159[3]	-	-	-
2.02	200	205	198	182^{x}		-	212[2]	199^{x}	-	-

Notes

Unless otherwise indicated directions are in degrees grid

Benbecula airport data shows range of hourly values

AIRsonde flights originated at BS

Data is not always synchronous with MF runs, x indicates substantial time difference

U2A data based on series of 2 min averages at 1/4 - 1 hour intervals

^{s}indicates a single value during the run

AIRsonde directions are for lowest 100-200m - based on single flights

1 Reducing to 254 at 500m

2 AIRsonde flight 1/2 hour before run

3 AIRsonde flight 1/2 hour after run

4 Significant direction change during this run

5 °grid = °magnetic - 6° (1982), °grid = °true + 4.5°.

6 At RS

Table 5.5 Disposition of MF posts during MF runs. An entry in the table for a given location(see Figure 4.4) and experimental run number (summarized in Table 5.3) describes the tower at that location for that run. A blank entry indicates that a tower was not installed or was not functioning. Brackets around an entry indicate that the system was not operating satisfactorily or data is missing for part of a run. Data are only plotted in Fig. 11 if system was satisfactory for 75% of run.

			L O C A T I O N											
			BNW		ANE									
Run No	RS	HT	10	20	5	10	15	20	25	30	40	50	60	70
1.22	P1	FRG1			P2	P3			P6	P7	P8	P9		
1.23a	P1	P10, FRG1			P2	P3	(P4)		P6	P7	P8	P9		
1.23b	P1	P10, FRG1			P2	P3	P4	P5	P6	P7	P8	P9		
2.25	P1	P10, FRG1	P15	P17		P3				P7	P8	P9	P6	P4
2.27	P1	P10, FRG1	P15	P17	(P2)	P3				P7	P8	P9	P6	P4
2.28	P1	P10, FRG1	P15	P17	P2	P3		(P12^1)		P7	P8	P9	P6	P4
2.29a	P1		P15	P17				P12^1		P7	P8			P4
2.29b	P1	P17	P15		P2			P12^1		P7	P8	P9	P6	P4
2.01a	P1, FRG1	P17	P15		P2	P10^2		P12^1		P7	P8	P9	P6	P4
2.01b	P1	P17			P2	P10^2		P12^1		P7	P8	P9	P6	P4
2.02	P1	P17			P2	P10^2		P12^1		P7	P8	P9	P6	P4

	BSE											
Run No	10	20	30	40	40a	50	60	70	80	90	100	110
1.22	FRG2	FRG3	FRG4	UK1	FRG5	UK2	UK3	UK4	UK5			
1.23a	FRG2	FRG3	FRG4	UK1	FRG5	UK2	UK3	UK4	UK5			
1.23b	FRG2	FRG3	FRG4	UK1	FRG5	UK2	UK3	UK4	UK5			
2.25				UK1		UK2	UK3	UK4	UK5			
2.27				UK1	FRG5	UK2	UK3	UK4	UK5	P19	P22	
2.28				UK1	FRG5	UK2	UK3	UK4	UK5	P19	P22	
2.29a				UK1	FRG5	UK2	UK3	UK4	UK5	P19	P22	
2.29b				UK1	FRG5	UK2	UK3	UK4	UK5	P19	P22	
2.01a				UK1	FRG5	UK2	UK3	UK4	UK5	P19	P22	P25
2.01b				UK1		UK2	UK3	UK4	UK5	P19	P22	P25
2.02				UK1		UK2	UK3	UK4	UK5	P19	P22	P25

	ASW															
Run No	2.5	5	10	15	20	25	30	35	40	45	50	55	64	75	85	95
1.22		P13	P14	P15	P16	P17	P18	P19	P20	P22	P21	P25	P23	P24	P11	
1.23a		P13	P14	P15	P16	P17	P18	P19	P20	P22	P21	P25	P23	P24	P11	
1.23b		P13	P14	P15	P16	P17	P18	P19	P20	P22	P21	P25	P23	P24	P11	
2.25		P13	P14		P16		P18	P19	P20	P22	P21	P25	P23	P24)	P11	
2.27		P13	P14		P16		P18		P20		P21		P23	P24	P11	P25
2.28		P13	P14		P16		P18		P20		P21		P23	P24	P11	P25
2.29a		P13	P14		P16		P18		P20		(P21)		(P23)	P24	P11	P25
2.29b		P13	P14		P16		P18		(P20)		P21		P23	P24	P11	P25
2.01a		P13	P14		P16		P18		P20		P21		P23	P24	(P11)	
2.01b	P15	P13	P14		P16		P18		P20		P21		P23	P24	P11	
2.02	P15	P13	P14		P16		P18		P20		(P21)		P23	P24	P11	

[1] P12 anemometer body, P5 cup

[2] P10 anemometer body, P3 cup

BSE40 ≡ CP, BSE40a = CP (2 m separation)

P - Canadian towers

UK - British (ERA) towers, UK1, 2 & 3 are Cassella anemometers, UK4 & 5 are Vector Instruments anemometers.

FRG - West German Towers

Table 5.6: Actual locations of tower identification points. These locations give the horizontal distance (m) of the tower location from point HT.

Tower Location Identifier	Distance from HT(m)	Tower Location Identifier	Distance from HT(m)	Tower Location Identifier	Distance from HT(m)	Tower Location Identifier	Distance from HT(m)
BNW10	100.	ANE5	49.	BSE10	100.	ASW2.5	25.
BNW20	199.	ANE10	98.	BSE20	199.	ASW5	49.
		ANE15	147.	BSE30	298.	ASW10	98.
		ANE20	196.	BSE40,CP	401.	ASW15	145.
		ANE25	243.	BSE40a	403.	ASW20	191.
		ANE30	292.	BSE50	499.	ASW25	239.
		ANE40	390.	BSE60	604.	ASW30	287.
		ANE50	488.	BSE70	700.	ASW35	341.
		ANE60	588.	BSE80	791.	ASW40	384.
		ANE70	688.	BSE90	893.	ASW45	434.
				BSE100	986.	ASW50	484.
				BSE110	1083.	ASW55	530.
						ASW64	623.
						ASW75	733.
						ASW85	833.
						ASW95	933.

Table 5.7: MF experiment data: wind speeds and speed-up for 1/2-hour blocks.

The data are organized into Mean Flow runs with the AES data from MF posts P1 → P25 on one page and ERA and University of Hanover data from posts UK1 → 5 and FRG1 → 5 on a second page. Start times (BST) are given and data blocks 1, 2, 3 etc are for consecutive 1/2-hour periods. Wind speed (m s^{-1}) and normalized wind speeds relative to the P1 anemometer located at RS are both listed. If a blank or the value -1.00 appears in the tables then no data were available.

Anemometer locations are given in Table 5.5.

Table 5.7 (cont.)

```
RUN 1.22
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START       1       2       3       4       5       6
 1   14.00    7.75    7.16    5.19    5.36   -1.00   -1.00
              1.00    1.00    1.00    1.00   -1.00   -1.00
 2   14.04   10.35    8.45    7.56    7.84   -1.00   -1.00
              1.34    1.18    1.46    1.46   -1.00   -1.00
 3   14.06    9.53    8.35    6.91    7.07   -1.00   -1.00
              1.23    1.17    1.33    1.32   -1.00   -1.00
 4   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 5   14.00    5.24    4.16   -1.00   -1.00   -1.00   -1.00
               .68     .58   -1.00   -1.00   -1.00   -1.00
 6   14.02    4.83    4.55    4.80    4.78   -1.00   -1.00
               .62     .64     .92     .89   -1.00   -1.00
 7   14.04    6.03    5.76    5.36    5.46   -1.00   -1.00
               .78     .80    1.03    1.02   -1.00   -1.00
 8   14.06    6.16    5.10    4.98    4.90   -1.00   -1.00
               .80     .71     .96     .91   -1.00   -1.00
 9   14.08    6.04    5.28    4.79    4.98   -1.00   -1.00
               .78     .74     .92     .93   -1.00   -1.00
10   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
11   14.03    8.79    7.13    5.63    5.67   -1.00   -1.00
              1.13    1.00    1.08    1.06   -1.00   -1.00
12   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13   14.00   10.69   10.76    7.43    7.92   -1.00   -1.00
              1.38    1.50    1.43    1.48   -1.00   -1.00
14   14.00   11.17    9.48    7.03    7.33   -1.00   -1.00
              1.44    1.32    1.36    1.37   -1.00   -1.00
15   14.02   10.11    8.45    6.60    6.89   -1.00   -1.00
              1.30    1.18    1.27    1.29   -1.00   -1.00
16   14.04    8.75    7.36    6.06    6.36   -1.00   -1.00
              1.13    1.03    1.17    1.19   -1.00   -1.00
17   14.06    8.32    6.66    5.79    6.08   -1.00   -1.00
              1.07     .93    1.12    1.14   -1.00   -1.00
18   14.08    7.79    5.98    5.40    5.76   -1.00   -1.00
              1.01     .84    1.04    1.07   -1.00   -1.00
19   14.00    7.80    6.55    5.64    5.35   -1.00   -1.00
              1.01     .92    1.09    1.00   -1.00   -1.00
20   14.02    7.45    6.42    5.39    5.50   -1.00   -1.00
               .96     .90    1.04    1.03   -1.00   -1.00
21   14.04    7.20    6.00    5.58    5.39   -1.00   -1.00
               .93     .84    1.08    1.01   -1.00   -1.00
22   14.04    7.51    6.38    5.51    5.45   -1.00   -1.00
               .97     .89    1.06    1.02   -1.00   -1.00
23   14.00    8.55    7.12    5.55    5.59   -1.00   -1.00
              1.10     .99    1.07    1.04   -1.00   -1.00
24   14.00    7.91    6.74    5.09    5.31   -1.00   -1.00
              1.02     .94     .98     .99   -1.00   -1.00
25   14.02    7.05    5.77    5.14    5.10   -1.00   -1.00
               .91     .81     .99     .95   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 1.22

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	14.00	11.5 1.48	10.0 1.40	7.4 1.43	7.2 1.34		
UK2	14.02	11.6 1.50	9.7 1.35	7.5 1.45	7.2 1.34		
UK3	14.04	11.8 1.52	9.5 1.33	7.6 1.46	7.8 1.46		
UK4	14.00	11.4 1.47	9.5 1.33	7.0 1.35	7.4 1.38		
UK5	14.02	10.9 1.41	9.2 1.28	6.8 1.31	7.0 1.31		
FRG1	14.00	13.1 1.69	11.1 1.55	8.3 1.60	8.6 1.60		
FRG2	14.00	12.8 1.65	11.4 1.59	8.0 1.54	8.3 1.55		
FRG3	14.00	12.5 1.61	11.3 1.58	8.1 1.56	8.3 1.55		
FRG4	14.00	10.0 1.29	8.7 1.22	6.4 1.23	6.6 1.23		
FRG5	14.00	12.3 1.59	11.7 1.63	8.3 1.60	8.4 1.57		

Table 5.7 (cont.)

```
RUN 1.23A
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START        1       2       3       4       5       6
 1   10.00     2.79    2.52    3.38    4.65   -1.00   -1.00
               1.00    1.00    1.00    1.00   -1.00   -1.00
 2   10.02     4.53    3.88    4.78    7.16   -1.00   -1.00
               1.62    1.54    1.41    1.54   -1.00   -1.00
 3   10.04     3.93    3.22    3.47    6.30   -1.00   -1.00
               1.41    1.27    1.03    1.36   -1.00   -1.00
 4   10.36    -1.00    2.32    2.67    5.44   -1.00   -1.00
              -1.00     .92     .79    1.17   -1.00   -1.00
 5   -1.00    -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 6   10.00     1.84   -1.00    1.22    2.94   -1.00   -1.00
                .66   -1.00     .36     .63   -1.00   -1.00
 7   10.02     1.95    1.12    1.21    2.87   -1.00   -1.00
                .70     .44     .36     .62   -1.00   -1.00
 8   10.04     1.64     .98    1.12    2.65   -1.00   -1.00
                .59     .39     .33     .57   -1.00   -1.00
 9   10.06     1.86    1.19    1.39    2.88   -1.00   -1.00
                .67     .47     .41     .62   -1.00   -1.00
10   10.00     5.23    4.42    5.70    8.19   -1.00   -1.00
               1.87    1.75    1.69    1.76   -1.00   -1.00
11   10.03     3.08    2.50    3.38    4.94   -1.00   -1.00
               1.11     .99    1.00    1.06   -1.00   -1.00
12   -1.00    -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13   10.00     4.27    3.94    5.09    7.26   -1.00   -1.00
               1.53    1.56    1.51    1.56   -1.00   -1.00
14   10.02     4.17    3.58    4.60    6.65   -1.00   -1.00
               1.50    1.42    1.36    1.43   -1.00   -1.00
15   10.04     3.67    3.15    4.02    5.92   -1.00   -1.00
               1.31    1.25    1.19    1.27   -1.00   -1.00
16   10.02     3.08    2.56    3.22    4.85   -1.00   -1.00
               1.10    1.01     .95    1.04   -1.00   -1.00
17   10.04     3.13    2.54    3.16    4.83   -1.00   -1.00
               1.12    1.00     .93    1.04   -1.00   -1.00
18   10.04     2.68    2.18    2.61    4.22   -1.00   -1.00
                .96     .86     .77     .91   -1.00   -1.00
19   10.02     2.64    2.02    2.42    3.91   -1.00   -1.00
                .95     .80     .72     .84   -1.00   -1.00
20   10.00     2.41    1.86    2.16    3.52   -1.00   -1.00
                .86     .74     .64     .76   -1.00   -1.00
21   10.02     2.37    1.84    2.11    3.56   -1.00   -1.00
                .85     .73     .62     .77   -1.00   -1.00
22   10.00     2.36    1.86    2.14    3.48   -1.00   -1.00
                .85     .74     .63     .75   -1.00   -1.00
23   10.06     2.58    2.21    2.80    4.42   -1.00   -1.00
                .93     .88     .83     .95   -1.00   -1.00
24   10.10     1.75    2.18    2.95    4.44   -1.00   -1.00
                .63     .86     .87     .96   -1.00   -1.00
25   10.04     2.04    1.71    1.92    3.32   -1.00   -1.00
                .73     .68     .57     .71   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 1.23a

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	10.00	4.5 1.61	3.7 1.47	4.5 1.33	6.8 1.46		
UK2	10.02	4.4 1.58	3.7 1.47	4.4 1.30	6.8 1.46		
UK3	10.04	4.3 1.54	3.7 1.47	4.3 1.27	6.8 1.46		
UK4	10.00	4.5 1.60	3.7 1.47	3.8 1.12	6.7 1.44		
UK5	10.02	4.0 1.43	3.4 1.35	3.4 1.01	6.3 1.35		
FRG1	10.00	5.2 1.86	4.6 1.83	5.9 1.75	8.3 1.78		
FRG2	10.00	5.1 1.83	4.5 1.79	5.7 1.69	7.9 1.70		
FRG3	10.00	5.2 1.86	4.4 1.75	5.3 1.57	7.6 1.63		
FRG4	10.00	5.1 1.83	4.5 1.79	5.2 1.54	7.3 1.60		
FRG5	10.00	5.8 2.08	5.1 2.02	5.6 1.66	7.8 1.68		

Table 5.7 (cont.)

```
RUN 1.23B
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START      1       2       3       4       5       6
 1   14.00    5.43    6.77    6.24    7.00   -1.00   -1.00
              1.00    1.00    1.00    1.00   -1.00   -1.00
 2   14.02    8.98    9.22    8.39    9.29   -1.00   -1.00
              1.65    1.36    1.34    1.33   -1.00   -1.00
 3   14.04    7.96    8.45    7.80    8.88   -1.00   -1.00
              1.47    1.25    1.25    1.27   -1.00   -1.00
 4   14.06    7.17    7.77    6.60    7.77   -1.00   -1.00
              1.32    1.15    1.06    1.11   -1.00   -1.00
 5   14.00    5.22    5.95    5.49    6.32   -1.00   -1.00
               .96     .88     .88     .90   -1.00   -1.00
 6   14.02    3.41    4.03    4.64    5.24   -1.00   -1.00
               .63     .60     .74     .75   -1.00   -1.00
 7   14.04    3.35    4.21    4.23    5.46   -1.00   -1.00
               .62     .62     .68     .78   -1.00   -1.00
 8   14.06    3.33    4.29    4.11    5.52   -1.00   -1.00
               .61     .63     .66     .79   -1.00   -1.00
 9   14.08    3.72    4.95    4.33    5.53   -1.00   -1.00
               .69     .73     .69     .79   -1.00   -1.00
10   14.00    9.97   10.47    9.79   10.71   -1.00   -1.00
              1.84    1.55    1.57    1.53   -1.00   -1.00
11   14.07    6.02    6.94    5.78    7.19   -1.00   -1.00
              1.11    1.03     .93    1.03   -1.00   -1.00
12   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13   14.00    9.01    9.34    8.90    9.66   -1.00   -1.00
              1.66    1.38    1.43    1.38   -1.00   -1.00
14   14.02    8.14    8.55    7.95    8.94   -1.00   -1.00
              1.50    1.26    1.27    1.28   -1.00   -1.00
15   14.04    7.25    7.87    7.07    8.23   -1.00   -1.00
              1.34    1.16    1.13    1.18   -1.00   -1.00
16   14.04    6.17    6.76    5.98    7.12   -1.00   -1.00
              1.14    1.00     .96    1.02   -1.00   -1.00
17   14.02    6.36    6.78    6.29    7.37   -1.00   -1.00
              1.17    1.00    1.01    1.05   -1.00   -1.00
18   14.00    5.71    6.01    5.71    6.56   -1.00   -1.00
              1.05     .89     .92     .94   -1.00   -1.00
19   14.06    5.01    6.26    5.29    6.54   -1.00   -1.00
               .92     .93     .85     .93   -1.00   -1.00
20   14.04    4.63    5.78    4.95    6.32   -1.00   -1.00
               .85     .85     .79     .90   -1.00   -1.00
21   14.00    4.94    5.32    5.25    6.02   -1.00   -1.00
               .91     .79     .84     .86   -1.00   -1.00
22   14.02    4.84    5.61    5.24    6.17   -1.00   -1.00
               .89     .83     .84     .88   -1.00   -1.00
23   14.02    5.72    6.24    5.81    6.90   -1.00   -1.00
              1.05     .92     .93     .99   -1.00   -1.00
24   14.05    5.42    6.35    5.46    6.81   -1.00   -1.00
              1.00     .94     .87     .97   -1.00   -1.00
25   14.00    4.51    5.15    4.82    5.54   -1.00   -1.00
               .83     .76     .77     .79   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 1.23B

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	14.00	8.7 1.60	9.4 1.39	8.7 1.39	9.9 1.41		
UK2	14.02	8.6 1.58	9.2 1.36	8.5 1.36	9.8 1.40		
UK3	14.04	8.3 1.53	9.3 1.37	8.1 1.30	9.4 1.34		
UK4	14.00	8.4 1.55	8.7 1.29	8.1 1.30	9.2 1.31		
UK5	14.02	7.9 1.45	8.7 1.29	7.6 1.22	9.3 1.33		
FRG1	14.00	10.0 1.84	10.6 1.57	9.5 1.52	10.6 1.51		
FRG2	14.00	9.9 1.82	10.3 1.52	9.5 1.52	10.2 1.46		
FRG3	14.00	9.8 1.80	9.8 1.45	9.5 1.52	9.9 1.41		
FRG4	14.00	8.8 1.62	8.9 1.31	8.6 1.38	9.3 1.33		
FRG5	14.00	9.8 1.80	10.0 1.48	10.1 1.62	9.7 1.39		

Table 5.7 (cont.)

```
RUN 2.25
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.     1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START        1       2       3       4       5       6
 1   16.00     5.90    7.26    5.52    7.30   -1.00   -1.00
               1.00    1.00    1.00    1.00   -1.00   -1.00
 2   -1.00    -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 3   16.02     7.60    8.25    8.26    7.53   -1.00   -1.00
               1.29    1.14    1.50    1.03   -1.00   -1.00
 4   16.08     6.36    6.70    7.60    6.55   -1.00   -1.00
               1.08     .92    1.38     .90   -1.00   -1.00
 5   -1.00    -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 6   16.06     6.20    7.30    7.50    6.89   -1.00   -1.00
               1.05    1.01    1.36     .94   -1.00   -1.00
 7   16.00     7.66    7.98    8.53    7.55   -1.00   -1.00
               1.30    1.10    1.55    1.03   -1.00   -1.00
 8   16.02     6.62    7.96    7.95    7.08   -1.00   -1.00
               1.12    1.10    1.44     .97   -1.00   -1.00
 9   16.04     6.51    7.83    7.67    7.11   -1.00   -1.00
               1.10    1.08    1.39     .97   -1.00   -1.00
10   16.06     8.09    9.07    8.82    8.15   -1.00   -1.00
               1.37    1.25    1.60    1.12   -1.00   -1.00
11   16.08     6.58    7.77    7.59    6.95   -1.00   -1.00
               1.11    1.07    1.38     .95   -1.00   -1.00
12   -1.00    -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13   16.04     7.65    8.70    8.36    7.08   -1.00   -1.00
               1.30    1.20    1.52     .97   -1.00   -1.00
14   16.00     7.40    8.10    8.21    7.29   -1.00   -1.00
               1.25    1.12    1.49    1.00   -1.00   -1.00
15   16.02     8.06    8.62    8.94    7.86   -1.00   -1.00
               1.36    1.19    1.62    1.08   -1.00   -1.00
16   16.03     6.16    6.78    7.32    6.84   -1.00   -1.00
               1.04     .93    1.33     .94   -1.00   -1.00
17   16.00     8.07    8.38    9.31    7.88   -1.00   -1.00
               1.37    1.15    1.69    1.08   -1.00   -1.00
18   16.00     6.03    6.69    7.20    6.48   -1.00   -1.00
               1.02     .92    1.31     .89   -1.00   -1.00
19   16.02     6.27    6.90    7.28    6.44   -1.00   -1.00
               1.06     .95    1.32     .88   -1.00   -1.00
20   16.04     6.09    7.12    7.37    6.40   -1.00   -1.00
               1.03     .98    1.34     .88   -1.00   -1.00
21   16.00     6.82    7.40    7.68    7.00   -1.00   -1.00
               1.15    1.02    1.39     .96   -1.00   -1.00
22   16.06     6.28    7.28    7.36    6.56   -1.00   -1.00
               1.06    1.00    1.34     .90   -1.00   -1.00
23   16.03     6.98    7.83    7.77    7.48   -1.00   -1.00
               1.18    1.08    1.41    1.02   -1.00   -1.00
24   16.36    -1.00    7.34    7.30    6.73   -1.00   -1.00
              -1.00    1.01    1.32     .92   -1.00   -1.00
25   16.01     6.54    7.23    7.50    6.92   -1.00   -1.00
               1.11    1.00    1.36     .95   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 2.25

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	16.00	7.9 1.34	8.7 1.20	8.6 1.56	7.6 1.04		
UK2	16.02	8.2 1.39	8.9 1.23	8.9 1.61	8.3 1.14		
UK3	16.04	8.1 1.37	8.6 1.18	8.8 1.59	8.3 1.14		
UK4	16.00	7.7 1.31	8.7 1.20	8.7 1.58	7.9 1.08		
UK5	16.02	7.5 1.27	9.1 1.25	8.6 1.56	8.2 1.12		
FRG1	16.00	7.7 1.31	8.5 1.44	8.7 1.58	7.9 1.08		
FRG2							
FRG3							
FRG4							
FRG5	16.00	9.2 1.56	10.1 1.71	9.5 1.72	9.1 1.25		

Table 5.7 (cont.)

```
RUN 2.27
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.     1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START       1       2       3       4       5       6
 1   12.00    5.96    6.09    6.14    6.27    6.27    5.53
              1.00    1.00    1.00    1.00    1.00    1.00
 2   12.00   -1.00   -1.00    9.27    9.17    9.34    8.55
             -1.00   -1.00    1.51    1.46    1.49    1.55
 3   12.02    7.90    8.20    8.44    8.44    8.25    7.67
              1.32    1.35    1.38    1.34    1.32    1.39
 4   12.08    6.25    6.30    6.44    6.43    6.27    5.40
              1.05    1.03    1.05    1.02    1.00     .98
 5   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 6   12.06    6.08    6.24    5.98    6.45    6.51    5.63
              1.02    1.02     .98    1.03    1.04    1.02
 7   12.00    5.95    6.62    6.31    6.20    6.52    5.80
              1.00    1.09    1.03     .99    1.04    1.05
 8   12.02    5.66    5.76    5.65    5.48    6.14    5.49
               .95     .94     .92     .87     .98     .99
 9   12.04    5.80    5.82    5.66    5.81    6.19    5.10
               .97     .95     .92     .93     .99     .92
10   12.00    9.68    9.58   10.06   10.00   10.24    9.40
              1.62    1.57    1.64    1.59    1.63    1.70
11   12.03    6.64    6.89    7.12    6.99   -1.00    6.10
              1.11    1.13    1.16    1.11   -1.00    1.10
12   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
             -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13   12.00    8.81    8.80    9.22    9.19    9.43    8.63
              1.48    1.44    1.50    1.46    1.50    1.56
14   12.02    8.16    8.26    8.69    8.71    8.83    7.83
              1.37    1.36    1.42    1.39    1.41    1.42
15   12.02    9.16    9.31    9.84    9.81    9.90    8.93
              1.54    1.53    1.60    1.56    1.58    1.62
16   12.04    6.68    7.23    7.36    7.51    7.49    6.56
              1.12    1.19    1.20    1.20    1.19    1.19
17   12.04    8.85    9.31    9.75    9.66    9.53    8.77
              1.48    1.53    1.59    1.54    1.52    1.59
18   12.06    5.88    6.44    6.44    6.75    6.54    5.68
               .99    1.06    1.05    1.08    1.04    1.03
19   12.04    8.07    8.08    8.20    8.39    7.86    6.99
              1.35    1.33    1.34    1.34    1.25    1.26
20   12.00    6.05    6.31    6.30    6.50    6.64    5.76
              1.02    1.03    1.03    1.04    1.06    1.04
21   12.03    6.16    6.20    6.50    6.53    6.78    5.76
              1.03    1.02    1.06    1.04    1.08    1.04
22   12.06    7.29    7.65    7.76    7.45    7.02    6.26
              1.22    1.26    1.26    1.19    1.12    1.13
23   12.06    6.60    6.61    6.21    6.61    6.49    5.43
              1.11    1.08    1.01    1.05    1.04     .98
24   12.00    6.08    6.22    6.39    6.22   -1.00    5.65
              1.02    1.02    1.04     .99   -1.00    1.02
25   12.06    6.31    6.62    6.91    6.85   -1.00    5.65
              1.06    1.09    1.13    1.09   -1.00    1.02
```

Table 5.7 (cont.)

RUN NO. : 2.27

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	12.00	8.5 1.43	8.7 1.43	8.8 1.43	8.6 1.37	8.7 1.39	7.8 1.41
UK2	12.02	8.7 1.46	8.8 1.44	8.8 1.43	8.6 1.37	9.0 1.44	8.0 1.45
UK3	12.04	9.0 1.51	9.2 1.51	9.2 1.50	9.5 1.52	9.5 1.52	8.3 1.50
UK4	12.00	8.9 1.49	8.8 1.44	8.9 1.45	9.0 1.44	8.8 1.40	7.9 1.43
UK5	12.02	8.4 1.41	8.7 1.43	8.6 1.40	8.9 1.42	8.4 1.34	7.5 1.36
FRG1	12.00	9.4 1.58	9.5 1.56	9.9 1.61	9.8 1.56	10.1 1.61	9.2 1.66
FRG2							
FRG3							
FRG4							
FRG5	12.00	9.3 1.56	9.5 1.56	9.7 1.58	9.7 1.55	9.3 1.48	8.5 1.54

Table 5.7 (cont.)

```
RUN 2.28
AVERAGING PERIOD    30.0 MIN.
REFERENCE ANEM.     1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN  START       1      2      3      4      5      6
 1  12.00   10.19  11.61  11.12  12.80  11.89  13.75
             1.00   1.00   1.00   1.00   1.00   1.00
 2  12.00   16.18  19.24  17.02  19.24  17.98  20.53
             1.59   1.66   1.53   1.50   1.51   1.49
 3  12.02   10.69  11.41  15.08  17.24  16.35  18.30
             1.05    .98   1.36   1.35   1.37   1.33
 4  12.07   -1.00  10.40  10.29  12.52  11.94  14.07
            -1.00    .90    .93    .98   1.00   1.02
 5  13.04   -1.00  -1.00   9.09  10.98  10.61  12.19
            -1.00  -1.00    .82    .86    .89    .89
 6  12.04    8.76  10.26   9.98  12.23  11.90  14.07
              .86    .88    .90    .96   1.00   1.02
 7  12.06    9.25   9.89  10.48  13.03  12.81  14.48
              .91    .85    .94   1.02   1.08   1.05
 8  12.00    7.64   9.16   8.56  11.17  11.37  13.49
              .75    .79    .77    .87    .96    .98
 9  12.02    8.29   9.55   9.30  11.55  11.03  12.47
              .81    .82    .84    .90    .93    .91
10  12.00   17.55  21.22  18.64  21.02  19.91  23.08
             1.72   1.83   1.68   1.64   1.67   1.68
11  12.03   10.96  12.52  11.65  13.61  13.03  15.57
             1.08   1.08   1.05   1.06   1.10   1.13
12  -1.00   -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
            -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
13  12.02   16.17  19.07  17.10  19.29  18.23  21.13
             1.59   1.64   1.54   1.51   1.53   1.54
14  12.00   14.77  17.71  15.70  17.88  17.24  19.55
             1.45   1.52   1.41   1.40   1.45   1.42
15  12.05   17.70  20.02  18.18  20.39  19.75  22.53
             1.74   1.72   1.64   1.59   1.66   1.64
16  12.02   11.90  13.76  12.71  15.43  14.60  16.72
             1.17   1.19   1.14   1.21   1.23   1.22
17  12.08   17.53  19.07  17.76  19.74  19.26  22.36
             1.72   1.64   1.60   1.54   1.62   1.63
18  12.04   10.44  11.81  11.15  13.20  12.78  14.82
             1.03   1.02   1.00   1.03   1.07   1.08
19  12.04   14.05  15.69  15.17  16.77  16.37  18.49
             1.38   1.35   1.36   1.31   1.38   1.35
20  12.06   10.03  10.88  10.63  12.71  12.80  14.28
              .98    .94    .96    .99   1.08   1.04
21  12.00    9.43  11.05  10.05  12.63  12.44  15.00
              .93    .95    .90    .99   1.05   1.09
22  12.06   13.09  14.33  13.67  15.39  14.47  16.89
             1.28   1.23   1.23   1.20   1.22   1.23
23  12.03   10.11  11.99  11.01  13.25  12.88  15.44
              .99   1.03    .99   1.03   1.08   1.12
24  12.00    9.77  11.29  11.16  12.72  12.05  14.54
              .96    .97   1.00    .99   1.01   1.06
25  12.06   10.72  12.04  11.55  13.20  12.64  15.38
             1.05   1.04   1.04   1.03   1.06   1.12
```

Table 5.7 (cont.)

RUN NO. : 2.28

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	12.00	15.6 1.53	18.1 1.56	16.7 1.50	18.7 1.46	17.8 1.50	20.2 1.47
UK2	12.02	15.5 1.52	17.7 1.52	16.7 1.50	18.9 1.48	17.7 1.49	20.5 1.49
UK3	12.04	16.6 1.63	19.0 1.64	17.1 1.54	19.8 1.55	19.1 1.61	21.5 1.56
UK4	12.00	15.9 1.56	18.3 1.58	16.5 1.48	18.9 1.48	18.3 1.54	20.9 1.52
UK5	12.02	14.9 1.46	17.2 1.48	16.2 1.46	18.2 1.42	17.2 1.45	20.3 1.48
FRG1	12.00	17.9 1.76	22.0 1.89	18.8 1.69	21.1 1.65	20.3 1.71	23.0 1.67
FRG2							
FRG3							
FRG4							
FRG5	12.00	15.8 1.55	18.4 1.58	17.2 1.55	18.6 1.45	18.2 1.53	20.5 1.49

Table 5.7 (cont.)

```
RUN 2.29A
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START       1        2       3       4       5       6
 1   10.00     4.18     4.49    6.87    8.09   -1.00   -1.00
               1.00     1.00    1.00    1.00   -1.00   -1.00
 2   10.00     8.06     7.00    8.11   10.04   -1.00   -1.00
               1.93     1.56    1.18    1.24   -1.00   -1.00
 3   10.02    -1.00    -1.00   -1.00    3.78   -1.00   -1.00
              -1.00    -1.00   -1.00     .47   -1.00   -1.00
 4   10.08    -1.00    -1.00    3.87    5.66   -1.00   -1.00
              -1.00    -1.00     .56     .70   -1.00   -1.00
 5   10.04     3.17     3.59    4.76    7.04   -1.00   -1.00
                .76      .80     .69     .87   -1.00   -1.00
 6   -1.00    -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
 7   10.00     3.37     2.62    3.41    5.24   -1.00   -1.00
                .81      .58     .50     .65   -1.00   -1.00
 8   10.02     2.04     1.62    2.65    4.97   -1.00   -1.00
                .49      .36     .39     .61   -1.00   -1.00
 9   -1.00    -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
10   -1.00    -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
11   10.03     4.59     4.52    5.69    8.01   -1.00   -1.00
               1.10     1.01     .83     .99   -1.00   -1.00
12   -1.00    -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
              -1.00    -1.00   -1.00   -1.00   -1.00   -1.00
13   10.01     7.73     7.47    8.44   10.72   -1.00   -1.00
               1.85     1.67    1.23    1.33   -1.00   -1.00
14   10.00     7.32     6.49    7.51    9.56   -1.00   -1.00
               1.75     1.45    1.09    1.18   -1.00   -1.00
15   10.04     7.91     7.95    8.92   11.82   -1.00   -1.00
               1.89     1.77    1.30    1.46   -1.00   -1.00
16   10.02     5.24     4.63    5.46    7.76   -1.00   -1.00
               1.25     1.03     .80     .96   -1.00   -1.00
17   10.06     7.39     7.40    8.44   11.02   -1.00   -1.00
               1.77     1.65    1.23    1.36   -1.00   -1.00
18   10.04     4.09     3.86    4.70    7.38   -1.00   -1.00
                .98      .86     .68     .91   -1.00   -1.00
19   10.04     5.72     6.35    7.95    9.66   -1.00   -1.00
               1.37     1.41    1.16    1.19   -1.00   -1.00
20   11.06     3.45     3.29    4.28    6.47   -1.00   -1.00
                .82      .73     .62     .80   -1.00   -1.00
21   10.30    -1.00     3.15    3.83    5.99   -1.00   -1.00
              -1.00      .70     .56     .74   -1.00   -1.00
22   10.06     4.75     5.33    7.18    8.86   -1.00   -1.00
               1.13     1.19    1.05    1.10   -1.00   -1.00
23   10.33    -1.00     3.96    4.84    7.10   -1.00   -1.00
              -1.00      .88     .70     .88   -1.00   -1.00
24   10.00     4.38     4.01    4.83    7.04   -1.00   -1.00
               1.05      .89     .70     .87   -1.00   -1.00
25   10.06     4.13     4.47    5.84    7.64   -1.00   -1.00
                .99     1.00     .85     .95   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 2.29A

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	10.00	7.5 1.79	6.9 1.54	8.6 1.25	10.3 1.27		
UK2	10.02	7.1 1.70	6.8 1.51	8.8 1.28	10.4 1.29		
UK3	10.04	6.9 1.65	6.9 1.54	8.4 1.22	10.2 1.26		
UK4	10.00	7.3 1.75	6.6 1.47	8.5 1.24	9.9 1.22		
UK5	10.02	6.5 1.56	6.2 1.38	8.4 1.22	10.0 1.24		
FRG1							
FRG2							
FRG3							
FRG4							
FRG5	10.00	8.7 2.08	8.1 1.80	9.7 1.41	10.9 1.35		

Table 5.7 (cont.)

```
RUN 2.29B
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.     1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN  START      1       2       3       4       5       6
 1  14.00    7.80    9.00    8.45    7.89   -1.00   -1.00
             1.00    1.00    1.00    1.00   -1.00   -1.00
 2  14.00   12.21   12.81   12.02   11.23   -1.00   -1.00
             1.57    1.42    1.42    1.42   -1.00   -1.00
 3  -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
            -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
 4  14.08    5.41    6.10    5.53    5.30   -1.00   -1.00
              .69     .68     .65     .67   -1.00   -1.00
 5  14.04    7.29    8.35    7.38    6.91   -1.00   -1.00
              .93     .93     .87     .88   -1.00   -1.00
 6  14.06    5.17    5.69    5.24    5.50   -1.00   -1.00
              .66     .63     .62     .70   -1.00   -1.00
 7  14.00    4.98    4.74    5.01    5.27   -1.00   -1.00
              .64     .53     .59     .67   -1.00   -1.00
 8  14.02    3.48    3.76    3.62   -1.00   -1.00   -1.00
              .45     .42     .43   -1.00   -1.00   -1.00
 9  14.04    4.44    5.29    4.61    4.99   -1.00   -1.00
              .57     .59     .54     .63   -1.00   -1.00
10  -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
            -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
11  14.03    8.18    8.42    7.82    7.25   -1.00   -1.00
             1.05     .93     .92     .92   -1.00   -1.00
12  -1.00   -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
            -1.00   -1.00   -1.00   -1.00   -1.00   -1.00
13  14.03   12.46   13.14   12.13   11.62   -1.00   -1.00
             1.60    1.46    1.44    1.47   -1.00   -1.00
14  14.04   11.28   11.88   10.93   10.58   -1.00   -1.00
             1.45    1.32    1.29    1.34   -1.00   -1.00
15  14.00   13.13   13.51   12.60   12.32   -1.00   -1.00
             1.68    1.50    1.49    1.56   -1.00   -1.00
16  14.02    8.15    9.02    8.20    7.90   -1.00   -1.00
             1.05    1.00     .97    1.00   -1.00   -1.00
17  14.02   13.91   14.51   13.52   12.79   -1.00   -1.00
             1.78    1.61    1.60    1.62   -1.00   -1.00
18  14.04    6.88    7.92    7.13    6.92   -1.00   -1.00
              .88     .88     .84     .88   -1.00   -1.00
19  14.04   10.52   11.45   10.97    9.46   -1.00   -1.00
             1.35    1.27    1.30    1.20   -1.00   -1.00
20  14.36   -1.00    6.84    6.26    5.98   -1.00   -1.00
            -1.00     .76     .74     .76   -1.00   -1.00
21  14.00    5.84    6.95    6.22    5.57   -1.00   -1.00
              .75     .77     .74     .71   -1.00   -1.00
22  14.06    9.48   10.51    9.81    9.00   -1.00   -1.00
             1.22    1.17    1.16    1.14   -1.00   -1.00
23  14.03    7.27    8.03    7.08    6.92   -1.00   -1.00
              .93     .89     .84     .88   -1.00   -1.00
24  14.00    7.49    7.90    7.01    6.68   -1.00   -1.00
              .96     .88     .83     .85   -1.00   -1.00
25  14.06    7.81    7.94    7.42    7.30   -1.00   -1.00
             1.00     .88     .88     .93   -1.00   -1.00
```

Table 5.7 (cont.)

RUN NO. : 229B

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	14.00	12.1 1.55	13.1 1.46	12.1 1.43	11.3 1.43		
UK2	14.02	12.0 1.54	13.1 1.46	12.1 1.43	11.2 1.42		
UK3	14.04	11.9 1.53	12.7 1.41	12.0 1.42	11.1 1.41		
UK4	14.00	11.9 1.53	12.7 1.41	12.0 1.42	11.0 1.39		
UK5	14.00	11.2 1.44	11.9 1.32	11.4 1.35	10.3 1.31		
FRG1							
FRG2							
FRG3							
FRG4							
FRG5	14.00	12.8 1.64	13.5 1.50	12.9 1.53	12.0 1.52		

Table 5.7 (cont.)

```
RUN 2.01A
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START       1        2        3        4        5        6
 1   11.00     7.59     8.81     9.60     9.72    -1.00    -1.00
               1.00     1.00     1.00     1.00    -1.00    -1.00
 2   11.00    11.42    12.51    12.76    12.97    -1.00    -1.00
               1.50     1.42     1.33     1.33    -1.00    -1.00
 3   11.01    10.25    11.29    11.22    11.77    -1.00    -1.00
               1.35     1.28     1.17     1.21    -1.00    -1.00
 4   11.08     7.49     9.03     9.14     9.73    -1.00    -1.00
                .99     1.03      .95     1.00    -1.00    -1.00
 5   11.03     6.33     7.45     8.04     8.95    -1.00    -1.00
                .83      .85      .84      .92    -1.00    -1.00
 6   11.06     7.36     8.88     9.07     9.89    -1.00    -1.00
                .97     1.01      .94     1.02    -1.00    -1.00
 7   11.00     7.57     8.73     9.53     9.96    -1.00    -1.00
               1.00      .99      .99     1.02    -1.00    -1.00
 8   11.02     6.88     8.86     8.90     9.43    -1.00    -1.00
                .91     1.01      .93      .97    -1.00    -1.00
 9   11.04     6.27     8.26     8.28     9.02    -1.00    -1.00
                .83      .94      .86      .93    -1.00    -1.00
10   -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
              -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
11   11.02    -1.00     9.64     9.90    10.36    -1.00    -1.00
              -1.00     1.09     1.03     1.07    -1.00    -1.00
12   -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
              -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
13   11.04    11.65    12.57    12.65    13.19    -1.00    -1.00
               1.53     1.43     1.32     1.36    -1.00    -1.00
14   11.06    10.91    11.81    11.95    12.15    -1.00    -1.00
               1.44     1.34     1.24     1.25    -1.00    -1.00
15   11.00    12.30    13.05    13.26    13.46    -1.00    -1.00
               1.62     1.48     1.38     1.39    -1.00    -1.00
16   11.00     9.00    10.28    10.37    10.99    -1.00    -1.00
               1.18     1.17     1.08     1.13    -1.00    -1.00
17   11.02    12.48    13.83    13.66    14.26    -1.00    -1.00
               1.64     1.57     1.42     1.47    -1.00    -1.00
18   11.02     7.79     9.30     9.37     9.91    -1.00    -1.00
               1.03     1.06      .98     1.02    -1.00    -1.00
19   11.02     9.71    11.03    11.00    11.93    -1.00    -1.00
               1.28     1.25     1.15     1.23    -1.00    -1.00
20   11.04     7.43     9.39     9.47     9.97    -1.00    -1.00
                .98     1.07      .99     1.03    -1.00    -1.00
21   11.06     8.05     9.65     9.75    10.01    -1.00    -1.00
               1.06     1.10     1.02     1.03    -1.00    -1.00
22   11.04     8.89     9.99     9.80    10.62    -1.00    -1.00
               1.17     1.13     1.02     1.09    -1.00    -1.00
23   11.08     8.45     9.55    10.10     9.96    -1.00    -1.00
               1.11     1.08     1.05     1.02    -1.00    -1.00
24   11.00     7.22     8.92     9.69     9.31    -1.00    -1.00
                .95     1.01     1.01      .96    -1.00    -1.00
25   11.06     8.84     9.77     9.75    10.54    -1.00    -1.00
               1.16     1.11     1.02     1.08    -1.00    -1.00
```

Table 5.7 (cont.)

RUN NO. : 201A

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	11.00	10.8 1.42	11.8 1.34	12.4 1.29	12.8 1.32		
UK2	11.02	11.0 1.45	11.9 1.35	12.2 1.27	13.0 1.34		
UK3	11.04	11.4 1.50	12.9 1.46	13.2 1.38	13.9 1.43		
UK4	11.06	11.1 1.46	12.5 1.42	12.3 1.28	13.4 1.38		
UK5	11.00	10.6 1.40	12.0 1.36	12.1 1.26	13.0 1.34		
FRG1	11.00	7.4 0.97	9.0 1.02	9.4 0.98	9.4 0.97		
FRG2							
FRG3							
FRG4							
FRG5	11.00	11.5 1.52	12.1 1.37	12.5 1.30	12.6 1.30		

Table 5.7 (cont.)

```
RUN 2.01B
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.     1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN   START        1        2        3        4        5        6
 1   14.00    10.98    10.91     9.86    10.06    -1.00    -1.00
                1.00     1.00     1.00     1.00    -1.00    -1.00
 2   14.00    13.32    13.63    13.67    12.88    -1.00    -1.00
                1.21     1.25     1.39     1.28    -1.00    -1.00
 3   -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
               -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
 4   14.08    10.40    10.18     9.67    11.01    -1.00    -1.00
                 .95      .93      .98     1.09    -1.00    -1.00
 5   14.04    10.97    10.09    10.67    10.74    -1.00    -1.00
                1.00      .92     1.08     1.07    -1.00    -1.00
 6   14.00    11.03    10.57    10.49    10.43    -1.00    -1.00
                1.00      .97     1.06     1.04    -1.00    -1.00
 7   14.00    11.48    11.28    11.19    11.06    -1.00    -1.00
                1.04     1.03     1.13     1.10    -1.00    -1.00
 8   14.02    11.05    10.45    10.82    10.44    -1.00    -1.00
                1.01      .96     1.10     1.04    -1.00    -1.00
 9   14.04    10.71     9.99    10.26    10.07    -1.00    -1.00
                 .98      .92     1.04     1.00    -1.00    -1.00
10   14.02    12.71    12.42    12.36    12.31    -1.00    -1.00
                1.16     1.14     1.25     1.22    -1.00    -1.00
11   14.02    11.24    10.87    10.70    11.18    -1.00    -1.00
                1.02     1.00     1.08     1.11    -1.00    -1.00
12   -1.00    -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
               -1.00    -1.00    -1.00    -1.00    -1.00    -1.00
13   14.06    14.16    13.76    13.92    13.49    -1.00    -1.00
                1.29     1.26     1.41     1.34    -1.00    -1.00
14   14.08    13.60    13.08    13.29    12.68    -1.00    -1.00
                1.24     1.20     1.35     1.26    -1.00    -1.00
15   14.04    14.12    13.90    13.99    13.34    -1.00    -1.00
                1.29     1.27     1.42     1.33    -1.00    -1.00
16   14.02    11.81    11.85    12.61    12.00    -1.00    -1.00
                1.07     1.09     1.28     1.19    -1.00    -1.00
17   14.02    14.80    14.81    14.68    14.11    -1.00    -1.00
                1.35     1.36     1.49     1.40    -1.00    -1.00
18   14.04    10.75    10.88    11.22    11.09    -1.00    -1.00
                 .98     1.00     1.14     1.10    -1.00    -1.00
19   14.02    13.04    12.74    12.91    11.84    -1.00    -1.00
                1.19     1.17     1.31     1.18    -1.00    -1.00
20   14.06    11.06    10.80    11.39    11.11    -1.00    -1.00
                1.01      .99     1.15     1.10    -1.00    -1.00
21   14.08    11.04    11.10    11.58    11.23    -1.00    -1.00
                1.01     1.02     1.17     1.12    -1.00    -1.00
22   14.04    11.91    11.32    11.53    10.43    -1.00    -1.00
                1.08     1.04     1.17     1.04    -1.00    -1.00
23   14.10    11.53    11.27    12.14    11.42    -1.00    -1.00
                1.05     1.03     1.23     1.14    -1.00    -1.00
24   14.00    10.92    10.93    10.41    10.45    -1.00    -1.00
                 .99     1.00     1.06     1.04    -1.00    -1.00
25   14.06    11.52    11.28    11.54    10.64    -1.00    -1.00
                1.05     1.03     1.17     1.06    -1.00    -1.00
```

Table 5.7 (cont.)

RUN NO. : 2.01B

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	14.00	13.6 1.24	14.0 1.28	13.3 1.35	13.1 1.30		
UK2	14.02	14.2 1.29	13.7 1.26	13.8 1.40	13.3 1.32		
UK3	14.04	15.0 1.37	14.8 1.36	14.7 1.49	13.8 1.37		
UK4	14.06	14.5 1.32	14.2 1.30	14.2 1.44	12.7 1.26		
UK5	14.00	14.1 1.28	14.0 1.28	13.8 1.40	13.2 1.31		
FRG1							
FRG2							
FRG3							
FRG4							
FRG5							

Table 5.7 (cont.)

```
RUN 2.02
AVERAGING PERIOD     30.0 MIN.
REFERENCE ANEM.      1

WIND SPEEDS (M/S) AND NORMALIZED WIND SPEEDS
AN  START      1      2      3      4      5      6
 1  14.00   8.90   7.94   9.20  10.78  -1.00  -1.00
            1.00   1.00   1.00   1.00  -1.00  -1.00
 2  14.00  14.62  13.39  14.03  17.59  -1.00  -1.00
            1.64   1.69   1.52   1.63  -1.00  -1.00
 3  14.02  12.90  11.42  12.07  15.26  -1.00  -1.00
            1.45   1.44   1.31   1.42  -1.00  -1.00
 4  14.08   8.15   7.32   7.36   8.35  -1.00  -1.00
             .92    .92    .80    .77  -1.00  -1.00
 5  14.04   7.37   6.48   6.90   8.78  -1.00  -1.00
             .83    .82    .75    .81  -1.00  -1.00
 6  14.06   7.88   7.42   6.68   7.83  -1.00  -1.00
             .89    .93    .73    .73  -1.00  -1.00
 7  14.00   5.24   5.26   4.58   5.17  -1.00  -1.00
             .59    .66    .50    .48  -1.00  -1.00
 8  14.02   6.11   6.05   4.70   5.52  -1.00  -1.00
             .69    .76    .51    .51  -1.00  -1.00
 9  14.04   6.94   6.36   5.41   6.29  -1.00  -1.00
             .78    .80    .59    .58  -1.00  -1.00
10  -1.00  -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
           -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
11  14.03   9.69   8.63   9.48  11.20  -1.00  -1.00
            1.09   1.09   1.03   1.04  -1.00  -1.00
12  -1.00  -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
           -1.00  -1.00  -1.00  -1.00  -1.00  -1.00
13  14.04  14.66  13.12  15.15  17.61  -1.00  -1.00
            1.65   1.65   1.65   1.63  -1.00  -1.00
14  14.06  13.43  12.17  14.13  16.12  -1.00  -1.00
            1.51   1.53   1.54   1.50  -1.00  -1.00
15  14.32  -1.00  13.56  15.10  18.09  -1.00  -1.00
           -1.00   1.71   1.64   1.68  -1.00  -1.00
16  14.00  10.31   9.68   9.88  12.12  -1.00  -1.00
            1.16   1.22   1.07   1.12  -1.00  -1.00
17  14.00  16.40  14.94  16.01  19.77  -1.00  -1.00
            1.84   1.88   1.74   1.83  -1.00  -1.00
18  14.02   8.71   8.16   8.43  10.27  -1.00  -1.00
             .98   1.03    .92    .95  -1.00  -1.00
19  14.02  12.93  11.61  11.83  14.79  -1.00  -1.00
            1.45   1.46   1.29   1.37  -1.00  -1.00
20  14.04   8.11   7.17   7.51   8.98  -1.00  -1.00
             .91    .90    .82    .83  -1.00  -1.00
21  14.30   8.34   7.27   7.34   8.95  -1.00  -1.00
             .94    .92    .80    .83  -1.00  -1.00
22  14.04  11.56  10.49  10.50  13.51  -1.00  -1.00
            1.30   1.32   1.14   1.25  -1.00  -1.00
23  14.03   8.93   8.12   8.43  10.30  -1.00  -1.00
            1.00   1.02    .92    .96  -1.00  -1.00
24  14.00   8.98   8.09   8.40  10.19  -1.00  -1.00
            1.01   1.02    .91    .95  -1.00  -1.00
25  14.06  11.39  10.02  10.11  13.24  -1.00  -1.00
            1.28   1.26   1.10   1.23  -1.00  -1.00
```

Table 5.7 (cont.)

RUN NO. : 202

AVERAGING PERIOD : 30 Min.

REFERENCE ANEMOMETER: P1

SPEEDS (MS^{-1}) AND NORMALISED WIND SPEEDS

ANEMOMETER	START TIME	HALF HOUR BLOCKS					
		1	2	3	4	5	6
UK1	14.00	14.5 1.63	13.6 1.71	13.9 1.51	17.1 1.59		
UK2	14.02	14.1 1.58	13.3 1.68	14.0 1.52	16.7 1.55		
UK3	14.04	14.8 1.66	13.8 1.74	14.4 1.57	17.3 1.60		
UK4	14.06	13.9 1.66	12.8 1.61	14.0 1.52	16.8 1.56		
UK5	14.00	13.8 1.55	12.6 1.59	12.5 1.36	15.8 1.47		
FRG1							
FRG2							
FRG3							
FRG4							
FRG5							

Table 5.8 Calibration coefficients for 50m tower cup anemometers

The calibration equation used is

$$U(\mathrm{m\ s^{-1}}) = b_o + b_1 V \text{ (Volts)}$$

RS Tower				HT Tower			
Height on tower (m)	Anemometer ID No.	b_1	b_o	Height on tower (m)	Anemometer ID No.	b_1	b_o
3.0	14	12.64	0.28	1.8	30	12.19	0.26
6.0	15	12.53	0.30	5.1	31	12.16	0.27
10.2	16	12.58	0.30	9.0	26	12.15	0.30
14.7	17	12.58	0.31	16.2	27	12.17	0.30
24.3	18	12.62	0.27	24.0	28	12.20	0.26
34.2	19	12.57	0.30	33.6	32	12.29	0.21
49.4	20	12.59	0.30	49.4	33	12.44	0.19

Table 5.9 50m Tower and 10m Gill UVW Anemometer Data Availability

Periods of reliable, useful data listed in Tables 5.10 and 6.10 are:

DATE	RS	HT	PERIOD INCLUDES
21 Sept.	13.00 - 17.00*	-	S[+]2 a , S2 b
22 Sept.	13.00 - 17.00	-	MF[+]1.22, S3
23 Sept.	10.00 - 15.00	-	MF 1.23a & part of 1.23b, S4a, 4b
23 Sept.	16.00 - 17.30	-	S4d
25 Sept.	10.30 - 14.30		S5
25 Sept.	15.00 - 18.30	16.00 - 18.00*	MF 2.25
26 Sept.	10.00 - 15.00*		S6
27 Sept.		11.00 - 14.30	MF 2.27
28 Sept.	11.30 - 15.30	12.00 - 15.30	MF 2.28, S7
29 Sept.	09.30 - 13.30	10.30 - 13.30	MF 2.29a (-wind shift),S8a
29 Sept.	14.00 - 17.30*	13.30 - 17.00	MF 2.29b, S8b
1 Oct.	09.30 - 13.30	11.00 - 13.30*	MF 2.01a
1 Oct.		13.30 - 16.00*	MF 2.01b, S9
2 Oct.	10.00 - 15.00	14.30 - 15.30	Part of MF 2.02, S10a
3 Oct.	12.00 - 14.30	13.30 - 14.30	S11

Times are British Summer Time (GMT + 1).

*Cup anemometer data only.

[+] MF are mean flow runs, S are sonic anemometer runs.

Table 5.10 Data from 50 m tower cup anemometers - half-hour averages and standard deviations

Sites RS or HT are identified at the top of each table, RS1 or RS2 indicates only that two sets of data were collected on that day - although it may not all be included here. NAVG gives the number of individual values used to produce the average. For a 1/2-hour average, sampling at 2 scans/sec gives a maximum of 3600. Lower values than this indicates that the data collection started or ended during the half hour block or that some data were lost for other reasons. Times are British Summer Time (GMT+1).

SITE : RS DATE : 21/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1300 MEAN S.D. SD/MN	1330 MEAN S.D. SD/MN	1400 MEAN S.D. SD/MN	1430 MEAN S.D. SD/MN	1500 MEAN S.D. SD/MN	1530 MEAN S.D. SD/MN	1600 MEAN S.D. SD/MN	1630 MEAN S.D. SD/MN
3.0	9.42 1.82 0.193	10.32 2.04 0.198	8.88 1.95 0.220	10.01 1.91 0.190	9.59 1.90 0.198	9.54 1.79 0.187	9.25 1.81 0.196	8.57 1.68 0.196
6.0	10.51 1.90 0.181	11.52 2.10 0.182	9.94 2.02 0.203	11.18 1.94 0.174	10.62 2.08 0.195	10.70 1.88 0.176	10.37 1.95 0.188	9.54 1.80 0.189
10.2	11.33 1.87 0.165	12.46 2.04 0.164	10.72 2.01 0.188	12.10 2.26 0.187	11.65 2.12 0.182	11.67 1.95 0.167	11.43 1.96 0.171	10.25 1.76 0.172
14.7	12.80 1.84 0.144	13.97 1.92 0.138	12.13 1.90 0.157	13.60 2.26 0.166	12.97 2.09 0.161	13.16 1.85 0.141	12.82 1.96 0.153	11.69 1.77 0.151
24.3	14.20 1.73 0.122	15.51 1.92 0.124	13.21 2.52 0.191	15.08 2.15 0.142	14.28 2.08 0.145	14.55 1.65 0.113	14.11 1.74 0.123	12.88 1.58 0.122
34.2	14.29 1.56 0.109	15.79 1.77 0.112	13.30 2.41 0.182	15.29 2.02 0.132	14.49 1.92 0.132	14.81 1.52 0.103	14.36 1.55 0.108	13.20 1.38 0.104
49.4	15.47 1.56 0.101	16.99 1.82 0.107	14.78 2.07 0.140	16.54 2.05 0.124	15.59 1.95 0.125	15.81 1.46 0.093	15.58 1.54 0.099	14.17 1.42 0.100
NAVG	3598	3600	3600	3596	3600	3600	3600	3600

SITE : RS DATE : 22/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1300 MEAN S.D. SD/MN	1330 MEAN S.D. SD/MN	1400 MEAN S.D. SD/MN	1430 MEAN S.D. SD/MN	1500 MEAN S.D. SD/MN	1530 MEAN S.D. SD/MN	1600 MEAN S.D. SD/MN	1630 MEAN S.D. SD/MN
3.0	4.51 1.04 0.231	5.89 1.43 0.243	6.61 1.30 0.197	5.26 1.39 0.265	4.08 0.78 0.190	4.30 0.88 0.205	4.64 1.07 0.230	4.62 0.88 0.190
6.0	5.27 1.07 0.202	6.77 1.60 0.236	7.62 1.36 0.178	6.15 1.55 0.253	4.73 0.80 0.169	4.94 0.88 0.178	5.37 1.13 0.211	5.37 0.95 0.176
10.2	4.87 0.84 0.172	6.54 1.51 0.231	7.25 1.20 0.165	5.94 1.41 0.237	4.48 0.65 0.144	4.82 0.73 0.152	5.31 0.90 0.170	5.31 0.77 0.146
14.7	5.99 0.96 0.161	7.72 1.63 0.212	8.59 1.29 0.150	7.08 1.61 0.228	5.29 0.77 0.147	5.73 0.87 0.153	6.45 1.05 0.163	6.34 1.01 0.160
24.3	6.34 0.94 0.149	8.03 1.62 0.201	8.98 1.25 0.139	7.47 1.60 0.214	5.51 0.77 0.141	5.96 0.88 0.147	6.89 1.02 0.148	6.69 0.92 0.138
34.2	6.32 0.79 0.124	7.86 1.51 0.192	8.83 1.12 0.127	7.26 1.58 0.217	5.35 0.65 0.122	5.83 0.77 0.132	6.80 0.90 0.133	6.65 0.85 0.128
49.4	7.15 0.89 0.125	8.66 1.61 0.184	9.79 1.21 0.123	8.04 1.79 0.223	5.88 0.77 0.131	6.57 0.92 0.140	7.66 1.02 0.133	7.57 0.89 0.118
NAVG	3598	3600	3478	3600	3600	3600	3600	3600

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SITE : RS1      DATE : 23/09/82

CUP ANEMOMETERS :

         MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

           TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
          1000     1030     1100     1130     1200     1230     1300     1330     1400     1430

          MEAN     MEAN     MEAN     MEAN     MEAN     MEAN     MEAN     MEAN     MEAN     MEAN
          S.D.     S.D.     S.D.     S.D.     S.D.     S.D.     S.D.     S.D.     S.D.     S.D.
 HEIGHT   SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN
  (M)

   3.0    2.16     1.72     2.36     3.67     3.53     4.35     3.87     4.34     4.12     5.29
          0.55     0.36     0.72     1.27     0.72     1.21     1.04     0.95     0.88     1.04
          0.253    0.210    0.303    0.347    0.204    0.277    0.270    0.219    0.213    0.197

   6.0    2.64     2.14     2.86     4.30     4.17     5.08     4.59     5.07     4.85     6.18
          0.60     0.38     0.79     1.38     0.72     1.33     1.14     0.97     0.96     1.05
          0.227    0.178    0.276    0.320    0.172    0.263    0.249    0.192    0.197    0.169

  10.2    2.47     2.09     2.83     3.87     3.67     4.71     4.31     4.66     4.57     5.84
          0.43     0.26     0.64     1.29     0.51     1.09     0.97     0.72     0.83     0.82
          0.175    0.124    0.227    0.332    0.140    0.231    0.224    0.154    0.182    0.140

  14.7    3.09     2.70     3.69     5.00     4.83     5.84     5.57     5.78     5.81     7.14
          0.58     0.38     0.84     1.56     0.65     1.30     1.17     0.78     1.05     0.93
          0.188    0.141    0.227    0.311    0.135    0.222    0.209    0.134    0.181    0.130

  24.3    3.23     2.96     4.05     5.40     5.13     6.02     6.06     5.98     6.23     7.50
          0.57     0.36     0.84     1.65     0.58     1.34     1.21     0.80     1.10     0.92
          0.178    0.122    0.208    0.306    0.113    0.223    0.200    0.134    0.177    0.123

  34.2    3.27     3.08     4.17     5.34     5.00     5.81     5.84     5.69     6.09     7.28
          0.58     0.31     0.79     1.52     0.45     1.23     1.10     0.83     0.97     0.79
          0.177    0.099    0.189    0.286    0.089    0.211    0.188    0.146    0.160    0.109

  49.4    3.57     3.43     4.73     6.09     5.70     6.43     6.79     6.31     6.90     8.11
          0.60     0.31     0.83     1.53     0.43     1.39     1.12     0.88     1.08     0.92
          0.168    0.090    0.175    0.252    0.076    0.217    0.165    0.140    0.156    0.113


  NAVG       3598     3600     3600     3600     3600     3600     3600     3600     3600     3600


  SITE : RS2      DATE : 23/09/82

  CUP ANEMOMETERS :

           MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

             TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
            1600     1630     1700

            MEAN     MEAN     MEAN
            S.D.     S.D.     S.D.
   HEIGHT   SD/MN    SD/MN    SD/MN
    (M)

     3.0    5.94     5.81     5.62
            0.90     1.12     1.10
            0.152    0.193    0.196

     6.0    6.85     6.73     6.52
            0.91     1.15     1.13
            0.132    0.171    0.173

    10.2    6.22     6.85     6.49
            0.82     0.87     0.94
            0.132    0.127    0.145

    14.7    7.50     8.17     7.76
            0.86     0.92     1.05
            0.114    0.112    0.136

    24.3    8.05     8.69     8.29
            0.88     0.88     1.02
            0.110    0.101    0.123

    34.2    8.21     8.66     8.22
            0.77     0.73     0.89
            0.094    0.084    0.109

    49.4    8.89     9.56     9.20
            0.87     0.77     0.98
            0.098    0.080    0.106


   NAVG        514     3596     3600
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SITE : RS1   DATE : 25/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1030 MEAN S.D. SD/MN	1100 MEAN S.D. SD/MN	1130 MEAN S.D. SD/MN	1200 MEAN S.D. SD/MN	1230 MEAN S.D. SD/MN	1300 MEAN S.D. SD/MN	1330 MEAN S.D. SD/MN	1400 MEAN S.D. SD/MN
3.0	5.54	5.52	5.91	6.61	6.39	6.28	5.87	6.00
	1.09	1.41	1.29	1.38	1.30	1.18	1.19	1.25
	0.197	0.255	0.218	0.209	0.203	0.189	0.203	0.207
6.0	6.44	6.39	6.84	7.64	7.37	7.26	6.80	6.91
	1.15	1.54	1.30	1.44	1.35	1.21	1.24	1.27
	0.179	0.241	0.190	0.188	0.184	0.166	0.183	0.184
10.2	6.30	6.39	6.88	7.61	7.29	7.22	6.80	6.85
	1.03	1.52	1.19	1.30	1.27	1.10	1.16	1.13
	0.163	0.238	0.173	0.171	0.174	0.152	0.171	0.165
14.7	7.44	7.51	8.02	8.97	8.42	8.44	7.91	7.91
	1.11	1.59	1.23	1.30	1.36	1.15	1.28	1.23
	0.149	0.211	0.154	0.145	0.161	0.136	0.162	0.156
24.3	7.97	7.98	8.42	9.45	8.77	8.90	8.27	8.18
	1.04	1.56	1.19	1.22	1.31	1.13	1.23	1.18
	0.131	0.195	0.141	0.129	0.150	0.127	0.149	0.144
34.2	7.94	7.85	8.34	9.38	8.80	8.89	8.26	8.16
	0.91	1.39	1.07	1.05	1.20	0.96	1.14	1.10
	0.115	0.178	0.128	0.112	0.137	0.108	0.138	0.135
49.4	8.79	8.77	9.21	10.25	9.52	9.65	8.98	8.72
	1.03	1.43	1.08	1.06	1.28	1.03	1.13	1.13
	0.118	0.163	0.117	0.103	0.134	0.107	0.125	0.129
NAVG	3600	3598	3600	3600	3600	3600	3600	3600

SITE : RS2   DATE : 25/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1500 MEAN S.D. SD/MN	1530 MEAN S.D. SD/MN	1600 MEAN S.D. SD/MN	1630 MEAN S.D. SD/MN	1700 MEAN S.D. SD/MN	1730 MEAN S.D. SD/MN	1800 MEAN S.D. SD/MN
3.0	6.13	6.05	4.77	5.36	4.90	4.90	4.33
	1.17	1.22	1.06	1.20	1.03	1.04	0.92
	0.190	0.201	0.223	0.225	0.210	0.213	0.212
6.0	7.03	7.00	5.50	6.22	5.63	5.65	5.06
	1.20	1.23	1.13	1.27	1.04	1.08	0.98
	0.170	0.176	0.206	0.204	0.185	0.190	0.194
10.2	7.05	6.97	5.47	6.05	5.68	5.77	4.78
	1.13	1.09	0.94	1.05	0.86	1.00	1.28
	0.160	0.157	0.172	0.174	0.152	0.173	0.268
14.7	8.19	8.12	6.33	7.10	6.61	6.86	5.87
	1.20	1.12	1.11	1.18	0.99	1.07	1.50
	0.147	0.138	0.176	0.166	0.150	0.156	0.255
24.3	8.65	8.58	6.80	7.61	7.06	7.41	6.52
	1.14	1.08	1.13	1.18	0.96	1.05	1.43
	0.131	0.125	0.165	0.155	0.136	0.141	0.220
34.2	8.70	8.61	6.91	7.80	7.38	7.72	6.79
	1.04	0.94	1.05	1.02	0.93	0.94	1.65
	0.120	0.110	0.153	0.131	0.126	0.122	0.243
49.4	9.35	9.32	7.72	8.40	7.96	8.54	8.37
	1.05	1.03	1.12	1.00	0.90	0.97	1.70
	0.112	0.110	0.144	0.119	0.114	0.113	0.203
NAVG	3598	3600	3600	3600	3600	3600	3600

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SITE : RS        DATE : 26/09/82

CUP ANEMOMETERS :

               MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                 TIME  (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               1000      1030      1100      1130      1200      1230      1300      1330      1400      1430

               MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN
               S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.
HEIGHT         SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
 (M)

  3.0


  6.0


 10.2          6.77      6.00      5.93      5.89      5.88      5.63      5.17      4.61      4.00      4.70
               1.02      1.01      0.94      0.99      0.86      0.93      0.87      0.63      0.83      0.74
               0.151     0.169     0.158     0.168     0.147     0.165     0.169     0.136     0.208     0.158

 14.7          8.06      7.26      7.05      7.08      7.17      6.83      6.28      5.62      4.75      5.81
               1.11      1.15      1.11      1.23      0.99      1.12      1.10      0.81      1.06      0.95
               0.137     0.158     0.157     0.173     0.138     0.164     0.175     0.144     0.222     0.164

 24.3          8.57      7.69      7.48      7.58      7.74      7.30      6.72      6.01      5.18      6.36
               1.08      1.01      1.06      1.23      0.92      1.13      1.09      0.73      1.00      0.94
               0.126     0.132     0.142     0.162     0.118     0.155     0.162     0.121     0.192     0.147

 34.2          8.68      7.86      7.64      7.76      7.96      7.38      6.86      6.12      5.37      6.61
               0.93      0.92      0.97      1.10      0.79      0.98      0.89      0.63      0.85      0.81
               0.107     0.117     0.126     0.141     0.099     0.132     0.130     0.102     0.158     0.123

 49.4          9.26      8.38      8.09      8.38      8.75      8.04      7.47      6.67      5.86      7.57
               0.94      0.98      1.02      1.13      0.71      1.05      0.95      0.74      1.00      0.82
               0.101     0.116     0.126     0.134     0.081     0.130     0.127     0.111     0.170     0.108

NAVG            3600      3600      3600      3600      3600      3600      3600      3600      3600      3567

  SITE : RS        DATE : 28/09/82

  CUP ANEMOMETERS :

                 MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                   TIME  (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
                 1130      1200      1230      1300      1330      1400      1430      1500

                 MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN
                 S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.
  HEIGHT         SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
   (M)

    3.0          6.66      7.98      9.28      8.70     10.00      9.21     10.70     10.89
                 1.32      1.60      1.92      1.81      2.02      2.23      2.23      2.35
                 0.198     0.201     0.207     0.208     0.202     0.242     0.208     0.216

    6.0          7.73      9.13     10.63     10.14     11.52     10.64     12.38     12.64
                 1.38      1.68      2.04      1.88      2.09      2.42      2.32      2.51
                 0.179     0.184     0.192     0.186     0.181     0.227     0.187     0.198

   10.2          7.70      9.33     11.21     10.68     11.93     10.97     12.82     13.17
                 1.14      1.66      1.89      1.92      1.94      2.37      2.30      2.29
                 0.148     0.178     0.169     0.180     0.162     0.216     0.180     0.174

   14.7          8.96     10.60     12.48     12.06     13.45     12.38     14.57     15.00
                 1.29      1.77      1.95      1.96      1.98      2.52      2.29      2.39
                 0.144     0.167     0.156     0.163     0.147     0.204     0.157     0.159

   24.3          9.69     11.24     13.27     12.87     14.28     13.32     15.50     15.97
                 1.29      1.84      1.92      1.96      1.89      2.45      2.16      2.37
                 0.133     0.163     0.145     0.152     0.132     0.184     0.140     0.148

   34.2          9.88     11.37     13.48     13.21     14.46     13.59     15.74     16.39
                 1.20      1.71      1.83      1.81      1.75      2.25      2.07      2.30
                 0.121     0.150     0.136     0.137     0.121     0.166     0.131     0.140

   49.4         11.07     12.52     14.84     14.66     15.69     15.07     17.37     18.05
                 1.27      1.72      1.86      1.90      1.77      2.38      2.11      2.45
                 0.115     0.137     0.125     0.130     0.113     0.158     0.121     0.136

  NAVG            3600      3600      3600      3600      3600      3600      3600      3600
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SITE : RS1       DATE : 29/09/82

CUP ANEMOMETERS :

              MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               930      1000      1030      1100      1130      1200      1230      1300

              MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN
              S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.
 HEIGHT       SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
  (M)

   3.0        3.92      3.22      3.29      5.11      6.11      5.81      5.00      3.95
              0.93      0.98      1.26      2.22      1.35      1.38      1.30      0.83
              0.237     0.305     0.382     0.435     0.221     0.237     0.259     0.209

   6.0        4.54      3.78      3.94      6.05      7.10      6.71      5.83      4.59
              0.98      1.03      1.36      2.50      1.47      1.48      1.39      0.85
              0.217     0.274     0.346     0.413     0.207     0.220     0.239     0.186

  10.2        4.83      4.23      4.38      6.52      7.82      7.05      6.33      4.98
              1.19      1.07      1.39      2.54      1.43      1.40      1.57      0.90
              0.247     0.252     0.317     0.390     0.183     0.198     0.247     0.180

  14.7        5.22      4.69      4.90      7.21      8.56      7.78      6.97      5.43
              1.18      1.11      1.46      2.75      1.42      1.41      1.62      0.97
              0.227     0.236     0.298     0.381     0.166     0.181     0.233     0.179

  24.3        5.72      5.32      5.34      7.78      9.09      8.41      7.45      5.86
              1.16      1.12      1.42      2.93      1.39      1.33      1.67      1.01
              0.202     0.211     0.266     0.377     0.153     0.159     0.224     0.173

  34.2        6.17      5.91      5.69      8.17      9.34      8.64      7.76      6.23
              1.13      1.04      1.28      2.94      1.32      1.20      1.58      1.01
              0.183     0.175     0.225     0.360     0.141     0.139     0.204     0.161

  49.4        6.75      6.45      6.06      8.81      9.80      9.13      8.29      6.78
              1.08      1.02      1.12      3.01      1.23      1.23      1.65      1.10
              0.159     0.158     0.185     0.341     0.125     0.135     0.199     0.162


 NAVG          3600      3600      3600      3600      3600      3600      3600      3600
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SITE : RS2       DATE : 29/09/82

CUP ANEMOMETERS :

              MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
              1400      1430      1500      1530      1600      1630      1700

              MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN
              S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.
 HEIGHT       SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
  (M)

   3.0        5.96      7.12      6.67      6.05      6.28      6.01      4.23
              1.29      1.23      1.16      1.25      1.17      1.64      1.35
              0.216     0.173     0.175     0.207     0.187     0.272     0.318

   6.0        6.96      8.21      7.75      7.01      7.28      6.97      5.00
              1.37      1.23      1.15      1.25      1.19      1.82      1.51
              0.196     0.150     0.148     0.178     0.164     0.261     0.302

  10.2        7.74      8.78      7.98      7.64      8.13      7.46      5.58
              1.42      1.16      1.10      1.14      1.06      1.94      1.64
              0.184     0.132     0.137     0.149     0.130     0.260     0.293

  14.7        8.45      9.50      8.55      8.19      8.77      8.25      6.19
              1.47      1.17      1.12      1.13      0.99      2.06      1.78
              0.174     0.123     0.131     0.138     0.113     0.249     0.288

  24.3        9.09     10.23      9.10      8.66      9.37      8.99      6.85
              1.38      1.07      1.03      1.06      0.95      2.12      1.89
              0.151     0.104     0.113     0.122     0.102     0.236     0.275

  34.2        9.52     10.58      9.46      9.01      9.75      9.35      7.32
              1.25      0.93      0.94      1.06      0.87      2.03      1.85
              0.131     0.088     0.100     0.118     0.090     0.217     0.252

  49.4       10.26     11.20     10.02      9.60     10.39     10.04      8.07
              1.24      0.84      0.96      1.02      0.74      1.97      1.91
              0.121     0.075     0.096     0.107     0.071     0.196     0.237


 NAVG          3600      3600      3600      3600      3600      3600      3598
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SITE : RS1   DATE : 01/10/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	930 MEAN S.D. SD/MN	1000 MEAN S.D. SD/MN	1030 MEAN S.D. SD/MN	1100 MEAN S.D. SD/MN	1130 MEAN S.D. SD/MN	1200 MEAN S.D. SD/MN	1230 MEAN S.D. SD/MN	1300 MEAN S.D. SD/MN
3.0	5.74	5.72	5.46	5.97	6.90	7.49	7.52	7.94
	1.09	1.07	1.12	1.17	1.41	1.52	1.49	1.56
	0.190	0.186	0.205	0.195	0.205	0.203	0.199	0.196
6.0	6.61	6.63	6.38	6.84	7.97	8.72	8.73	9.18
	1.10	1.12	1.16	1.17	1.47	1.63	1.53	1.64
	0.166	0.169	0.182	0.171	0.184	0.187	0.175	0.179
10.2	7.13	7.31	7.01	7.53	8.61	9.42	9.55	9.98
	1.06	1.02	0.96	1.16	1.44	1.50	1.41	1.65
	0.149	0.140	0.137	0.155	0.167	0.159	0.148	0.166
14.7	7.71	7.83	7.52	8.06	9.17	10.02	10.21	10.70
	1.08	1.02	0.96	1.11	1.40	1.50	1.40	1.69
	0.140	0.130	0.128	0.138	0.152	0.150	0.137	0.158
24.3	8.38	8.47	8.09	8.64	9.71	10.55	10.91	11.37
	1.04	0.97	0.92	1.04	1.36	1.43	1.26	1.71
	0.124	0.115	0.114	0.121	0.140	0.136	0.116	0.150
34.2	9.06	9.06	8.58	9.16	10.24	11.06	11.43	12.00
	1.01	0.96	0.88	0.97	1.30	1.39	1.22	1.60
	0.112	0.106	0.102	0.106	0.127	0.126	0.107	0.134
49.4	9.95	9.78	9.08	9.78	10.82	11.64	12.11	12.65
	0.99	0.95	0.90	0.96	1.24	1.36	1.15	1.61
	0.100	0.097	0.099	0.099	0.114	0.117	0.095	0.127
NAVG	3600	3596	3600	3600	3600	3598	3598	3598

SITE : RS   DATE : 02/10/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1000 MEAN S.D. SD/MN	1030 MEAN S.D. SD/MN	1100 MEAN S.D. SD/MN	1130 MEAN S.D. SD/MN	1200 MEAN S.D. SD/MN	1230 MEAN S.D. SD/MN	1300 MEAN S.D. SD/MN	1330 MEAN S.D. SD/MN	1400 MEAN S.D. SD/MN	1430 MEAN S.D. SD/MN
3.0	7.77	7.72	7.61	7.85	6.46	7.79	7.61	7.78	7.07	6.31
	1.43	1.64	1.58	1.60	1.22	1.60	1.51	1.42	1.42	1.13
	0.184	0.213	0.208	0.204	0.188	0.205	0.198	0.183	0.201	0.179
6.0	8.91	8.86	8.80	9.08	7.42	8.91	8.73	8.94	8.10	7.28
	1.45	1.69	1.64	1.62	1.25	1.64	1.55	1.42	1.47	1.17
	0.163	0.191	0.186	0.179	0.169	0.185	0.178	0.159	0.181	0.160
10.2	9.66	9.73	9.52	10.09	8.16	9.88	9.57	9.37	8.72	8.03
	1.46	1.56	1.75	1.63	1.20	1.64	1.50	1.54	1.50	1.13
	0.151	0.161	0.184	0.161	0.148	0.166	0.156	0.164	0.172	0.141
14.7	10.32	10.41	10.13	10.80	8.82	10.52	10.19	9.96	9.25	8.53
	1.39	1.60	1.75	1.64	1.17	1.64	1.52	1.50	1.50	1.14
	0.134	0.154	0.172	0.152	0.132	0.156	0.149	0.151	0.163	0.134
24.3	11.03	11.20	10.77	11.64	9.63	11.26	10.89	10.65	9.80	9.18
	1.40	1.57	1.75	1.57	1.14	1.65	1.49	1.48	1.49	1.12
	0.127	0.140	0.163	0.135	0.119	0.147	0.137	0.139	0.152	0.122
34.2	11.68	11.99	11.38	12.46	10.40	12.03	11.48	11.39	10.45	9.80
	1.36	1.49	1.76	1.50	1.10	1.63	1.50	1.38	1.45	1.10
	0.116	0.124	0.154	0.121	0.106	0.135	0.131	0.121	0.139	0.113
49.4	12.47	12.88	12.19	13.25	11.18	12.81	12.26	12.11	11.11	10.45
	1.37	1.41	1.75	1.42	1.03	1.57	1.47	1.16	1.38	1.04
	0.110	0.110	0.143	0.107	0.092	0.122	0.120	0.096	0.124	0.099
NAVG	3600	3598	3600	3600	3600	3600	3600	3600	3600	3600

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SITE : RS2        DATE : 03/10/82

CUP ANEMOMETERS :

               MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                 TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               1200     1230     1300     1330     1400

               MEAN     MEAN     MEAN     MEAN     MEAN
               S.D.     S.D.     S.D.     S.D.     S.D.
HEIGHT         SD/MN    SD/MN    SD/MN    SD/MN    SD/MN
 (M)

   3.0         6.64     6.73     6.96     7.29     6.63
               1.25     1.38     1.40     1.46     1.42
               0.189    0.205    0.201    0.201    0.215

   6.0         7.70     7.78     8.08     8.40     7.60
               1.25     1.41     1.45     1.50     1.49
               0.163    0.181    0.179    0.178    0.196

  10.2         8.28     8.56     8.91     9.19     8.36
               1.32     1.41     1.37     1.42     1.38
               0.159    0.164    0.154    0.154    0.165

  14.7         8.85     9.12     9.44     9.73     8.96
               1.25     1.41     1.36     1.38     1.40
               0.142    0.154    0.144    0.142    0.157

  24.3         9.36     9.73     9.88    10.18     9.50
               1.20     1.39     1.33     1.27     1.42
               0.128    0.143    0.134    0.125    0.150

  34.2         9.83    10.24    10.29    10.54     9.96
               1.18     1.31     1.28     1.24     1.35
               0.120    0.128    0.124    0.118    0.135

  49.4        10.30    10.79    10.71    10.92    10.37
               1.10     1.17     1.27     1.12     1.32
               0.107    0.109    0.118    0.102    0.127


NAVG            3600     3600     3600     3600     3600
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SITE : HT        DATE : 25/09/82

CUP ANEMOMETERS :

             MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1600     1630     1700     1730

             MEAN     MEAN     MEAN     MEAN
             S.D.     S.D.     S.D.     S.D.
 HEIGHT      SD/MN    SD/MN    SD/MN    SD/MN
  (M)

   1.8       6.72     7.16     7.58     6.45
             1.09     1.34     1.06     0.96
             0.162    0.187    0.140    0.148

   5.1       7.54     7.90     8.53     7.24
             1.09     1.36     1.14     0.99
             0.145    0.173    0.133    0.137

   9.0       7.84     8.24     8.93     7.62
             1.04     1.37     1.14     0.97
             0.133    0.167    0.128    0.128

  16.2       8.50     8.95     9.67     8.38
             0.94     1.38     1.04     0.89
             0.110    0.154    0.108    0.106

  24.0       8.84     9.36     9.99     8.81
             0.85     1.28     0.92     0.80
             0.096    0.136    0.092    0.091

  33.6       9.00     9.59    10.12     9.02
             0.79     1.15     0.87     0.78
             0.088    0.120    0.086    0.086

  49.4       8.96     9.60    10.12     9.06
             0.76     1.10     0.84     0.81
             0.085    0.115    0.083    0.090


 NAVG          3600     3600     3598     3598
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SITE : HT        DATE : 27/09/82

CUP ANEMOMETERS :

             MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1100     1130     1200     1230     1300     1330     1400

             MEAN     MEAN     MEAN     MEAN     MEAN     MEAN     MEAN
             S.D.     S.D.     S.D.     S.D.     S.D.     S.D.     S.D.
 HEIGHT      SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN    SD/MN
  (M)

   1.8       6.47     8.65     8.16     8.01     8.48     8.46     8.51
             1.16     1.12     1.04     0.92     1.03     0.99     1.32
             0.179    0.129    0.127    0.115    0.121    0.117    0.155

   5.1       7.35     9.79     9.22     9.04     9.62     9.55     9.66
             1.21     1.05     0.98     0.85     1.00     0.94     1.29
             0.164    0.108    0.106    0.094    0.104    0.098    0.133

   9.0       7.62    10.01     9.45     9.26     9.86     9.77     9.94
             1.22     0.94     0.94     0.77     0.88     0.85     1.18
             0.160    0.093    0.099    0.083    0.089    0.087    0.119

  16.2       8.07    10.22     9.59     9.51    10.00     9.89    10.33
             1.20     0.89     0.94     0.73     0.82     0.80     1.03
             0.149    0.088    0.097    0.077    0.082    0.080    0.099

  24.0       8.15    10.17     9.50     9.46     9.92     9.84    10.34
             1.16     0.84     0.92     0.67     0.80     0.76     0.95
             0.142    0.083    0.097    0.070    0.081    0.077    0.092

  33.6       8.19    10.10     9.40     9.42     9.85     9.74    10.33
             1.12     0.82     0.90     0.62     0.82     0.75     0.92
             0.137    0.081    0.096    0.065    0.084    0.077    0.089

  49.4       8.22     9.99     9.21     9.24     9.72     9.58    10.34
             1.11     0.85     0.93     0.59     0.77     0.79     0.89
             0.135    0.085    0.101    0.064    0.079    0.082    0.086


 NAVG          3598     3598     3600     3600     3600     3600     3598
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SITE : HT DATE : 28/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1200	1230	1300	1330	1400	1430	1500
	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.
	SD/MN	SD/MN	SD/MN	SD/MN	SD/MN	SD/MN	SD/MN
1.8	15.21	18.54	16.12	17.96	17.07	19.20	18.96
	2.04	2.25	2.50	2.15	2.42	2.52	2.69
	0.134	0.121	0.155	0.120	0.142	0.131	0.142
5.1	17.12	20.72	18.18	20.33	19.26	21.65	21.36
	1.92	2.08	2.54	1.93	2.33	2.42	2.74
	0.112	0.101	0.140	0.095	0.121	0.112	0.129
9.0	17.10	20.66	18.18	20.51	19.45	21.86	21.55
	1.81	1.90	2.44	1.72	2.21	2.28	2.60
	0.106	0.092	0.134	0.084	0.114	0.104	0.121
16.2	17.24	20.72	18.30	20.86	19.92	22.47	22.31
	1.78	1.83	2.46	1.66	2.22	2.22	2.43
	0.103	0.088	0.134	0.080	0.112	0.099	0.109
24.0	17.14	20.54	18.17	20.73	19.95	22.56	22.40
	1.75	1.83	2.45	1.61	2.12	2.18	2.40
	0.102	0.089	0.135	0.078	0.106	0.097	0.107
33.6	17.23	20.54	18.30	20.75	20.25	22.76	22.62
	1.71	1.79	2.41	1.55	2.11	2.22	2.41
	0.099	0.087	0.132	0.075	0.104	0.097	0.106
49.4	17.36	20.64	18.36	20.62	20.36	22.76	22.53
	1.73	1.69	2.40	1.57	2.06	2.34	2.38
	0.100	0.082	0.131	0.076	0.101	0.103	0.106
NAVG	3600	3600	3598	3600	3600	3600	3600

SITE : HT DATE : 29/09/82

CUP ANEMOMETERS :

MEAN WIND SPEED (M/S) FOR THE PERIOD, STAND.DEV'N, AND S.D./MEAN

TIME (HHMM) (START TIME FOR 30 MIN. AVERAGES) (GMT+1)

HEIGHT (M)	1030	1100	1130	1200	1230	1300
	MEAN	MEAN	MEAN	MEAN	MEAN	MEAN
	S.D.	S.D.	S.D.	S.D.	S.D.	S.D.
	SD/MN	SD/MN	SD/MN	SD/MN	SD/MN	SD/MN
1.8		8.42	9.86	9.64	9.36	8.43
		2.47	2.29	1.43	1.89	0.92
		0.294	0.232	0.149	0.202	0.109
5.1		9.30	11.06	10.76	10.30	9.29
		2.74	2.48	1.49	2.02	0.88
		0.294	0.224	0.138	0.196	0.095
9.0		8.95	10.82	10.58	9.95	8.91
		2.74	2.41	1.52	2.04	0.78
		0.306	0.223	0.143	0.205	0.087
16.2		9.05	10.96	10.66	9.96	9.07
		2.79	2.37	1.46	2.06	0.75
		0.308	0.216	0.137	0.207	0.083
24.0		9.02	10.94	10.69	9.94	9.18
		2.72	2.30	1.41	2.03	0.71
		0.302	0.210	0.132	0.204	0.077
33.6		8.91	10.83	10.61	9.86	9.15
		2.65	2.16	1.41	1.99	0.67
		0.297	0.200	0.133	0.201	0.074
49.4		9.08	10.90	10.72	9.91	9.41
		2.63	2.10	1.36	2.00	0.70
		0.290	0.192	0.126	0.202	0.074
NAVG		3598	3596	3600	3600	3600

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SITE : HT        DATE : 29/09/82

CUP ANEMOMETERS :

            MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

              TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
            1330      1400      1430      1500      1530      1600      1630

            MEAN      MEAN      MEAN      MEAN      MEAN      MEAN      MEAN
            S.D.      S.D.      S.D.      S.D.      S.D.      S.D.      S.D.
HEIGHT      SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
 (M)

  1.8      11.59     12.70     13.27     12.55     11.43     10.40     11.57
            1.52      1.27      1.36      1.25      1.22      1.87      1.88
            0.131     0.100     0.103     0.100     0.106     0.180     0.162

  5.1      12.97     13.87     14.42     13.66     12.53     11.60     12.84
            1.51      1.12      1.11      1.05      1.04      1.93      1.91
            0.116     0.081     0.077     0.077     0.083     0.166     0.149

  9.0      12.71     13.48     13.93     13.22     12.41     11.69     12.89
            1.40      1.07      0.97      0.92      0.92      1.86      1.91
            0.110     0.080     0.070     0.070     0.074     0.159     0.148

 16.2      12.70     13.40     13.70     13.03     12.30     11.69     12.87
            1.38      1.10      0.98      0.87      0.91      1.77      1.92
            0.109     0.082     0.072     0.066     0.074     0.152     0.150

 24.0      12.60     13.26     13.46     12.80     12.20     11.65     12.84
            1.38      1.12      0.99      0.86      0.92      1.69      1.93
            0.109     0.084     0.074     0.067     0.075     0.145     0.150

 33.6      12.44     13.10     13.22     12.55     12.05     11.55     12.68
            1.33      1.13      0.94      0.87      0.91      1.64      1.89
            0.107     0.086     0.071     0.069     0.076     0.142     0.149

 49.4      12.51     13.17     13.18     12.50     12.12     11.60     12.73
            1.21      1.11      0.92      0.87      0.85      1.63      1.87
            0.097     0.084     0.070     0.070     0.070     0.141     0.147


NAVG         3592      3600      3598      3465      3468      3600      3600
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SITE : HT        DATE : 01/10/82

CUP ANEMOMETERS :

            MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

              TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
            1100      1130      1200      1230      1300

            MEAN      MEAN      MEAN      MEAN      MEAN
            S.D.      S.D.      S.D.      S.D.      S.D.
HEIGHT      SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
 (M)

  1.8


  5.1


  9.0      11.90     12.84     13.12     13.50     13.18
            1.05      1.39      1.33      1.49      1.46
            0.089     0.108     0.101     0.110     0.111

 16.2      12.33     13.46     13.83     14.18     13.92
            1.01      1.31      1.24      1.38      1.39
            0.082     0.097     0.089     0.097     0.100

 24.0      12.37     13.49     13.88     14.34     14.21
            1.01      1.30      1.16      1.29      1.31
            0.081     0.096     0.084     0.090     0.092

 33.6      12.48     13.46     13.87     14.46     14.42
            1.00      1.27      1.09      1.24      1.27
            0.080     0.094     0.079     0.086     0.088

 49.4      12.68     13.33     13.73     14.42     14.55
            0.97      1.32      1.05      1.25      1.20
            0.076     0.099     0.077     0.086     0.082


NAVG         3600      3600      3596      3600      3594
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SITE : HT        DATE : 01/10/82

CUP ANEMOMETERS :

             MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)    (GMT+1)
             1330      1400      1430      1500      1530

             MEAN      MEAN      MEAN      MEAN      MEAN
             S.D.      S.D.      S.D.      S.D.      S.D.
HEIGHT       SD/MN     SD/MN     SD/MN     SD/MN     SD/MN
 (M)

  1.8


  5.1


  9.0       13.47     14.28     14.36     14.29     13.68
             1.59      1.50      1.44      1.67      1.45
             0.118     0.105     0.100     0.117     0.106

 16.2       14.33     15.08     15.16     15.05     14.52
             1.53      1.49      1.37      1.59      1.42
             0.107     0.099     0.090     0.106     0.098

 24.0       14.65     15.41     15.45     15.30     14.76
             1.43      1.38      1.25      1.51      1.38
             0.098     0.089     0.081     0.099     0.093

 33.6       14.87     15.66     15.71     15.58     14.92
             1.40      1.28      1.19      1.44      1.36
             0.094     0.082     0.076     0.092     0.091

 49.4       15.00     15.75     15.72     15.62     15.08
             1.39      1.19      1.16      1.39      1.32
             0.093     0.075     0.074     0.089     0.087

NAVG          3594      3600      3592      3435      3596
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SITE : HT2       DATE : 02/10/82

CUP ANEMOMETERS :

             MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)    (GMT+1)
             1430      1500      1530

             MEAN      MEAN      MEAN
             S.D.      S.D.      S.D.
HEIGHT       SD/MN     SD/MN     SD/MN
 (M)

  1.8       12.75     14.01     16.95
             1.46      1.86      3.86
             0.114     0.132     0.228

  5.1       14.06     15.41     18.64
             1.22      1.73      3.88
             0.086     0.112     0.208

  9.0       13.96     15.33     18.07
             1.07      1.66      5.41
             0.077     0.109     0.299

 16.2       13.86     15.29     17.79
             0.97      1.67      6.23
             0.070     0.109     0.350

 24.0       13.63     15.13     17.51
             0.97      1.68      6.15
             0.071     0.111     0.351

 33.6       13.49     15.09     17.28
             1.00      1.66      6.15
             0.074     0.110     0.356

 49.4       13.60     15.11     17.12
             1.12      1.67      6.17
             0.082     0.110     0.360

NAVG          2153      3598      3194
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SITE : HT        DATE : 03/10/82

CUP ANEMOMETERS :

               MEAN WIND SPEED (M/S) FOR THE PERIOD,  STAND.DEV'N,  AND  S.D./MEAN

                 TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               1330     1400

               MEAN     MEAN
               S.D.     S.D.
HEIGHT         SD/MN    SD/MN
 (M)

   1.8        10.43    10.24
               1.49     1.33
               0.143    0.130

   5.1        11.86    11.94
               1.47     1.23
               0.124    0.103

   9.0        12.30    12.21
               1.41     1.19
               0.115    0.097

  16.2        12.93    12.91
               1.31     1.10
               0.102    0.085

  24.0        13.02    13.09
               1.25     1.07
               0.096    0.082

  33.6        13.07    13.18
               1.21     1.06
               0.093    0.080

  49.4        12.98    13.14
               1.23     1.02
               0.095    0.078

NAVG            3594     3596
```

Table 5.11 Wind Speeds (m/s) from TALA Kite Test at 50m at RS on 4 October 1982

Description	Time Period (B.S.T.)			
	11.00-11.10	11.10-11.20	11.20-11.30	Half Hour Average
Cup Anemometer at 49.4m a)	7.59	7.55	7.64	7.59
b)	7.51	7.54	7.62	7.56
TALA Kite Values:				
UK (ERA)	7.9	7.8	8.0	7.9
UK (BRE-Standard)	8.0	7.7	8.1	7.9
UK (BRE-High-Altitude)	7.3	7.4	7.5	7.4
CAN	7.9	7.6	7.4	7.6

a) Cassette recorded and processed data.

b) Manually recorded integrating voltmeter data.

Table 5.12 TALA Kite Data for 2 October 1982 (normalized to BRE fixed altitude kite)

Time Period (BST)	BRE 120m Kite		BRE Profile		AES Profile		ERA Profile		RS Windspeed at 50m ($m\ s^{-1}$)
	V^r_{120} ($m\ s^{-1}$)	θ (°grid)	Ht(m)	V/V^r_{120}	Ht(m)	V/V^r_{120}	Ht(m)	V/V^r_{120}	
10.05-10.15	15.59	183	35	.85	34	1.12	34	1.18	12.47
10.20-10.30	15.06	187	68	.92	63	1.18	66	1.24	
10.35-10.45	15.92	192	98	.98	89	1.12	(off	scale)	12.88
10.50-11.00	15.89	193	118	.99	110	1.15	(off	scale)	
11.05-11.15	14.54	195	168	1.04	149	1.19	(off	scale)	12.19
11.20-11.30	15.15	204	144	1.03	140	-	(off	scale)	

Wind direction near RS $\sim$ 190° (grid)

V^r_{120} is reference windspeed measured at a height of approximately 120m near RS.

Table 5.13 TALA Kite Data from BRE System

Page 1 of 3

Date and Location	Time (BST)	Profile			V/V_{ref}	Fixed level (ref)		
		Height(m)	V(ms^{-1})	Dirn(^{o}grid)		Height(m)	V_{ref}(ms^{-1})	Dirn(^{o}grid)
Sept.22/82 RS	14.25	14	8.75	201	0.80	120	10.95	190
	14.40	36	6.65	198	0.77		8.49	185
	14.51	67	5.55	182	0.88		6.30	177
	15.12	114	6.04	183	0.92		6.54	182
	15.28	272	7.28	189	1.05		6.95	185
	15.45	430	10.36	186	1.37		7.57	180
	16.05	198	9.39	192	1.06		8.83	181
	16.20	98	8.09	198	0.88		9.23	189
	16.35	48	7.14	197	0.79		9.01	192
Sept.23/82 BS	15.19	14	4.57	260	0.62	120	7.34	258
	15.33	34	7.16	258	0.85		0.46	250
	15.47	71	7.78	258	0.87		8.96	254
	16.01	124	7.96	264	0.97		8.75	256
	16.16	278	10.48	262	1.06		9.92	263
	16.33	466	11.42	260	1.17		9.79	257
	16.53	199	9.86	262	1.02		9.69	258
	17.08	96	9.47	259	0.96		9.83	255
	17.23	49	9.39	264	0.95		9.91	254
Sept.25/82 BS	15.34	14	8.38	125	0.85	114	9.90	135
	15.49	36	9.97	113	0.94		10.59	130
	16.06	68	8.29	111	0.89		9.34	124
	16.18	123	8.05	110	0.93		8.69	120
	16.33	261	10.28	116	1.07		9.63	119
	16.49	448	11.58	122	1.22		9.46	122
	17.07	184	10.72	114	1.07		10.02	126
	17.22	95	8.67	115	0.88		9.86	127
	17.45	47	8.46	118	0.91		9.32	128
	18.00	21	8.38	114	0.78		10.79	128

.....2

Table 5.13 TALA Kite Data from BRE System (cont'd.)

Date and Location	Time (BST)	Profile			V/V_{ref}	Fixed level (ref)		
		Height(m)	V(ms^{-1})	Dirn(°grid)		Height(m)	V_{ref}(ms^{-1})	Dirn(°grid)
Sept.27/82 BS	12.00	13	5.83	164	0.69	109	8.45	176
	12.15	35	6.55	166	0.83		7.93	180
	12.30	70	7.04	164	0.85		8.25	183
	12.45	119	7.07	173	0.90		7.85	182
	13.00	270	8.23	171	1.02		8.07	180
	13.17	424	9.72	174	1.10		8.75	180
	13.30	-	-	-	-		7.85	181
	13.45	186	8.44	169	0.98		8.65	179
	14.05	95	9.20	159	0.95		9.73	174
	14.19	49	7.52	158	0.82		9.19	172
	14.33	21	6.65	160	0.68		9.83	172
Sept.29/82 BS	10.00	34	6.42	184	0.75	119	8.60	192
	10.15	68	6.13	187	0.83		7.41	193
	10.30	122	5.83	202	0.86		6.76	200
	10.45	278	7.63	230	0.99		7.67	216
	11.03	484	10.21	241	1.08		9.43	238
	11.22	195	8.31	256	1.09		7.61	253
	11.31	97	8.67	261	0.96		9.07	254
	11.49	49	11.28	260	1.00		11.26	252
	12.02	22	8.16	271	0.80		10.21	266
Oct. 1/82 BS	10.45	14	7.24	172	0.63	120	11.52	168
	11.00	35	7.88	177	0.73		10.83	168
	11.15	71	10.06	176	0.90		11.18	169
	11.30	124	13.14	176	1.06		12.57	164
	12.15	275	14.09	169	1.17		12.07	162
	12.28	189	14.72	161	1.11		13.28	159
	12.47	46	12.70	138	0.94		13.52	164

.....3

Table 5.13 TALA Kite Data from BRE System (cont'd.)

Date and Location	Time (BST)	Profile			V/V_{ref}	Fixed level (ref)		
		Height(m)	V(ms^{-1})	Dirn(^{o}grid)		Height(m)	V_{ref}(ms^{-1})	Dirn(^{o}grid)
Oct. 1/82 BS	14.06	15	11.47	144	0.76	120	15.09	154
	14.08	34	14.04	142	0.92		15.24	154
	14.30	68	14.04	147	0.94		14.96	155
	14.42	112	14.89	149	1.03		14.42	154
	14.56	230	15.55	152	1.17		13.31	157
	15.10	168	15.63	146	1.07		14.64	156
	15.25	87	15.04	139	0.99		15.15	154
	15.38	48	13.82	138	0.96		14.37	149
	15.50	22	12.05	134	0.91		13.22	149

Table 5.14 z_o and u_* values from TALA Kite Profiles

MF Run	V_{ref}(m/s)	u_*(m/s)	z_o(m)	Wind Direction θ_{ref} (^{o}grid)
1.22	8.21	0.53 (0.41)	0.30	185
1.23b	9.18	0.43 (0.43)	0.025	256
2.25	9.76	0.46	0.025	126
2.27	8.60	0.40	0.050	178
2.01a	12.14	0.86	0.27	165
2.01b	14.49	0.70 (0.70)	0.024	154

u_* values in brackets are from the 10m sonic anemometer at RS for approximately the same period (see Table 6.3) where available.

TABLE 6.1: TURBULENCE SYSTEM INTERCOMPARISON RESULTS

	AES SONIC	AES GILL	BRE[1] GILL	ERA GUST	FRG BIVANE	TYPICAL GILL UVW RATIOS	AES[3] SONIC	DK[3] SONIC
TIME(BST)	1628-1728	1628-1728	1631-1735	1615-1655	1624-1712		SUN, SEPT.26, 1129-1159	
$\overline{U}$, ms^{-1}	7.16	6.95 (0.97)[2]	6.21 (0.87)	5.96(?) (0.83)	7.58 (1.06)		6.45	6.91 (1.07)
$\overline{\phi}$, °Grid	253	253	256	252(?)	256		124	124
$\sigma_u/\overline{U}$ [4]	0.157	0.142 (0.90)	0.148 (0.93)	-	0.138 (0.88)	(0.98)	0.172	0.169 (0.98)
$\sigma_v/\overline{U}$	0.108	0.089 (0.82)	0.103 (0.95)	-	0.103 (0.95)	(0.90)	0.112	0.116 (1.04)
$\sigma_w/\overline{U}$	0.081	0.061 (0.75)	0.057 (0.70)	-	0.076 (0.94)	(0.75)	0.087	0.096 (1.10)
$\overline{uv}/\overline{U}^2$	-0.0011	-0.0032	-	-	-		-0.0017	-0.0039
$\overline{uw}/\overline{U}^2$	-0.0043	-0.0042 (0.98)	-0.0035 (0.81)	-	-0.0043 (1.00)	(0.98)	-0.0043	-0.0043 (1.00)
$\overline{vw}/\overline{U}^2$	-0.002	+0.0006	-	-	-		-0.003	-0.0001
Re$_{uv}$ [5]	-0.063	-0.253	-	-	-		-0.088	-0.198
Re$_{uw}$	-0.343	-0.485 (1.41)	-0.415 (1.21)	-	-0.410 (1.20)	(1.33)	-0.287	-0.266 (0.96)
Re$_{vw}$	-0.020	+0.111	-	-	-		-0.038	-0.014

$\underbrace{\hphantom{AES SONIC — FRG BIVANE}}$

T-TEST, THURSDAY, SEPT. 23

NOTES:

1. NO CORRECTIONS FOR NON-COSINE RESPONSE APPLIED TO BRE GILL.
2. BRACKETED VALUES ARE RATIOS OF EACH QUANTITY TO CORRESPONDING RESULTS FROM AES SONIC ANEMOMETER.
3. AES/DK SONIC COMPARISON PERFORMED SEPARATELY FROM 'OFFICIAL' T-TEST.
4. σ_u, σ_v AND σ_w ARE STANDARD DEVIATIONS OF RESPECTIVE COMPONENTS.
5. Re$_{uv}$ IS DEFINED BY $\overline{uv}/(\sigma_u\sigma_v)$ AND SIMILARLY FOR Re$_{uw}$ AND Re$_{vw}$.

TABLE 6.2: SUMMARY OF DATA FROM AES SONIC ANEMOMETER AT RS
(BLOCK-AVERAGED VALUES FOR EACH RUN)

DATE	AES SONIC, RUN NO.	RUN PERIOD (BST)	AVG. DIRECTION $\overline{\phi}$, ^{o}GRID	AVG. VELOCITY, $\overline{U}$, ms^{-1}	AVG. $\sigma_u/\overline{U}$	AVG. $\sigma_v/\overline{U}$	AVG. $\sigma_w/\overline{U}$	AVG. $-\overline{uw}/\overline{U}^2$	AVG. Z_o, cm	MF RUN NUMBER	MF RUN PERIOD (BST)
MON, 20/09	S1	(1730-1800)	260	14.61	0.160	0.132	0.087	0.00467	2.88	-	-
TUE, 21/09	S2(a)	(1300-1430)	313	11.38	0.193	0.151	0.107	0.00631	6.51	-	-
TUE, 21/09	S2(b)	(1600-1700)	316	10.68	0.197	0.153	0.105	0.00728	8.17	-	-
WED, 22/09	S3	(1500-1700)	167	5.33	0.186	0.139	0.095	0.00602	5.87	1.22	(1400-1600)
THU, 23/09	S4(a)	(1030-1200)	222	3.24	0.261	0.155	0.087	0.00311	1.01	1.23(a)	(1000-1200)
THU, 23/09	S4(b)	(1407-1437)	240	5.67	0.215	0.128	0.081	0.00389	1.64	-	-
THU, 23/09	S4(c)	(1513-1613)	255	6.52	0.175	0.126	0.085	0.00484	3.20	1.23(b)	(1400-1600)
THU, 23/09	S4(d)	(1628-1728)	254	7.16	0.157	0.108	0.079	0.00426	2.21	-	-
SAT, 25/09	S5	(1345-1415)	136	7.11	0.164	0.197	0.091	0.00518	3.87	2.25	(1600-1800)
SUN, 26/09	S6	(1129-1159)	124	6.45	0.172	0.112	0.087	0.00431	2.26	-	-
MON, 27/09	*S	-	-	-	-	-	-	-	-	2.27	(1200-1500)
TUE, 28/09	S7	(1345-1515)	161	16.03	0.140	0.098	0.073	0.00324	-	2.28	(1200-1500)
WED, 29/09	**S8(a)	(1132-1302)	262	8.17	0.160	0.163	0.056	0.00137	-	2.29(a)	(1000-1200)
WED, 29/09	S8(b)	(1400-1600)	236	9.21	0.109	0.089	0.058	0.00163	-	2.29(b)	(1400-1600)
FRI, 01/10	-	-	-	-	-	-	-	-	-	2.01(a)	(1100-1300)
FRI, 01/10	S9	(1415-1545)	160	12.52	0.119	0.091	0.072	0.00322	-	2.01(b)	(1400-1600)
SAT, 02/10	S10(a)	(1135-1235)	-	-	-	-	-	-	-	-	-
SAT, 02/10	S10(b)	(1356-1556)	205	11.37	0.119	0.084	0.065	0.00292	-	2.02	(1400-1600)
SUN, 03/10	S11	(1330-1400)	160	10.63	0.106	0.088	0.074	0.00291	-	-	-

* SENSOR WAS MOVED FROM ΔZ = 10.1 m TO ΔZ = 47 m ON MON. 27 AND REMAINED THERE FOR ALL SUBSEQUENT RUNS

** SERIOUS WIND SHIFT OCCURRED DURING RUN 8(a)

TABLE 6.3: TURBULENCE DATA FROM AES SONIC ANEMOMETER - RAW VALUES FOR EACH 1/2-HOUR BLOCK

DATE	AES SONIC RUN NO.	BLOCK START TIME (BST)	$\overline{U}$, ms^{-1}	$\overline{\phi}$, ^oGRID	σ_u^2, m^2s^{-2}	σ_v^2, m^2s^{-2}	σ_w^2, m^2s^{-2}	$\overline{uv}$, m^2s^{-2}	$\overline{uw}$, m^2s^{-2}	$\overline{vw}$, m^2s^{-2}	$\overline{T}$, ^oC	Z, m	Z/L	ε, ^{o}	** Z_o, cm
MON, 20/09	S1	1730	14.61	260	5.49	3.72	1.62	0.390	-0.996	0.010	13.5	10.1	-0.010	0.7	2.88
TUE, 21/09	S2(a)	1300	11.30	314	4.39	2.91	1.46	-0.325	-0.820	-0.036	13.2	10.1	-0.013	0.4	6.79
		1330	12.23	313	4.81	3.27	1.72	-0.246	-0.920	-0.068	13.2	10.1	-0.015	0.4	6.12
		1400	10.60	313	5.20	2.62	1.24	-1.009	-0.696	-0.064	13.2	10.1	-0.014	0.3	6.61
	S2(b)	1600	11.12	317	4.94	3.62	1.31	-0.923	-0.762	-0.071	12.9	10.1	-0.010	0.7	7.13
		1630	10.25	315	3.96	1.91	1.21	0.169	-0.765	-0.113	13.3	10.1	-0.010	0.5	9.20
WED, 22/09	S3	1500	4.79	160	0.722	0.431	0.200	-0.111	-0.124	0.010	14.3	10.1	-0.164	-0.2	4.33
		1530	5.11	162	0.885	0.456	0.241	-0.132	-0.164	-0.003	14.9	10.1	-0.134	0.2	6.43
		1600	5.66	171	1.384	0.828	0.302	-0.095	-0.222	0.016	15.2	10.1	-0.036	0.9	8.25
		1630	5.79	173	1.044	0.512	0.287	0.029	-0.183	-0.003	15.3	10.1	-0.026	0.7	4.46
THU, 23/09	S4(a)	1030	2.17	219	0.130	0.073	0.031	-0.016	-0.014	-0.001	14.8	10.1	+0.190	-1.0	0.59
		1100	3.12	222	0.903	0.288	0.078	-0.306	-0.021	-0.011	15.0	10.1	+0.073	+0.1	0.17
		1130	4.44	225	1.913	0.552	0.166	0.411	-0.085	-0.006	14.6	10.1	-0.087	-0.1	2.27
	S4(b)	1407	5.67	240	1.48	0.525	0.213	0.110	-0.125	-0.020	15.0	10.1	-0.027	0.5	1.64
	S4(c)	1513	6.08	256	1.17	0.616	0.248	-0.029	-0.057	0.046	15.6	10.1	-0.096	0.4	2.62
		1533	6.95	253	1.41	0.735	0.362	-0.004	-0.249	-0.014	15.9	10.1	-0.038	1.0	3.78
	S4(d)	1628	7.24	254	1.26	0.617	0.330	-0.058	-0.237	-0.014	15.7	10.1	-0.035	1.0	2.62
		1658	7.08	253	1.25	0.584	0.323	-0.050	-0.201	0.004	15.8	10.1	-0.032	0.6	1.79
SAT, 25/09	S5	1345	7.11	136	1.36	1.96	0.419	0.147	-0.256	0.031	16.6	10.1	-0.102	0.9	3.87
SUN, 26/09	S6	1129	6.45	124	1.24	0.519	0.317	-0.070	-0.179	-0.016	15.7	10.1	-0.055	0.3	2.26
TUE, 28/09	S7	1345	15.29	163	3.56	1.57	1.07	-0.381	-0.625	0.033	15.0	47	-0.005	2.4	-
		1415	15.47	162	7.20	3.50	1.67	1.111	-1.005	0.222	15.3	47	-0.090	3.0	-
		1445	17.32	159	4.61	2.48	1.35	-0.133	-0.857	0.012	15.3	47	-0.080	2.6	-
WED, 29/09	S8(a)*	1132	8.99	260	1.38	2.81	0.293	0.779	-0.162	0.070	14.7	47	-0.511	2.4	-
		1202	7.80	270	1.60	0.768	0.178	-0.603	-0.090	0.021	13.6	47	-0.689	2.2	-
		1232	7.71	256	2.12	2.14	0.168	-0.232	-0.036	0.074	13.5	47	-1.78	2.2	-
	S8(b)	1400	9.15	238	1.31	0.541	0.246	-0.178	-0.127	0.009	13.7	47	-0.289	2.4	-
		1430	10.06	238	0.820	0.311	0.238	0.079	-0.124	0.007	14.2	47	-0.485	1.6	-
		1500	9.03	232	0.918	0.512	0.317	0.206	-0.182	0.003	14.8	47	-0.450	2.3	-
		1530	8.60	238	0.983	1.481	0.308	-0.301	-0.114	0.034	15.1	47	-0.555	3.0	-
FRI, 01/10	S9	1415	13.51	160	2.30	1.35	0.747	-0.214	-0.405	0.059	16.0	47	-0.150	2.1	-
		1445	12.02	163	2.20	1.17	0.742	-0.219	-0.537	0.047	16.2	47	-0.147	3.0	-
		1515	12.04	158	2.15	1.41	0.896	0.270	-0.539	0.031	16.3	47	-0.157	3.4	-
SAT, 02/10	S10(b)	1356	10.64	201	2.01	0.836	0.633	0.234	-0.527	0.007	17.2	47	-0.102	3.1	-
		1426	10.07	200	1.18	0.535	0.394	-0.075	-0.248	0.034	17.1	47	-0.141	2.7	-
		1456	11.16	207	2.07	1.35	0.507	-0.781	-0.262	0.035	16.8	47	-0.105	2.3	-
		1526	13.61	210	2.04	0.922	0.649	-0.175	-0.457	0.031	17.0	47	-0.123	2.4	-
SUN, 03/10	S11	1330	10.63	160	2.68	1.26	0.690	-0.287	-0.391	-0.047	16.5	47	-0.311	2.4	-

* SERIOUS WIND SHIFT OCCURRED DURING RUN 8(a)

** Z_o CALCULATED FROM u_* ($= \sqrt{-\overline{uw}}$) AND LOG-LAW ASSUMPTION FOR VELOCITY PROFILE

ε IS MEAN FLOW UPWASH ANGLE

L IS THE MONIN-OBOUKHOV LENGTH SCALE

TABLE 6.4: AVERAGED TURBULENCE CHARACTERISTICS IN APPROACH FLOW (RS) FOR OPTIMUM WIND DIRECTIONS (ΔZ=10.1 m)

$\overline{\phi}$, ^{o}GRID	167	255	315	IDEALIZED MODEL $\phi \sim 225^{o}$
DURATION OF RECORD, HOURS	2	2.5	2.5	-
AES SONIC RUN NOS.	S3	S1, S4(c), S4(d)	S2(a), S2(b)	-
$\overline{U}$, ms^{-1}	5.33	8.39	11.10	-
$\sigma_u/\overline{U}$	0.186	0.164	0.195	~ 0.18
$\sigma_v/\overline{U}$	0.139	0.120	0.152	~ 0.12
$\sigma_w/\overline{U}$	0.095	0.083	0.106	~ 0.08
σ_u/u_*	2.41	2.43	2.41	~ 2.5
σ_v/u_*	1.78	1.78	1.87	~ 1.8
σ_w/u_*	1.23	1.23	1.31	~ 1.2
Re_{uv}	-0.134	-0.023	-0.117	0
Re_{uw}	-0.340	-0.336	-0.318	~-0.33
Re_{vw}	-0.020	-0.024	-0.032	0
$^{*}K_{10}$	0.0060	0.00457	0.00655	~ 0.004
Z_o, cm	5.87	2.74	7.17	~ 3-5

$^{*}K_{10} \equiv u_*^2/\overline{U}_{10}^{\,2} = -\overline{uw}/\overline{U}_{10}^{\,2}$

TABLE 6.5: RAW TURBULENCE DATA FROM DK SONIC ANEMOMETER AT RS

DATE	BLOCK START TIME, (BST)	$\overline{U}$, ms^{-1}	$\overline{\phi}$, $^{o}GRID$	σ_u^2, m^2s^{-2}	σ_v^2, m^2s^{-2}	σ_w^2, m^2s^{-2}	$\overline{uv}$, m^2s^{-2}	$\overline{uw}$, m^2s^{-2}	$\overline{vw}$, m^2s^{-2}	ε^o,	Z_o, cm
SUN, 26/09	1129	6.91	124	1.36	0.647	0.439	-0.185	-0.205	-0.008	0.1	2.24
	1159	6.74	122	1.12	0.682	0.426	-0.265	-0.190	-0.001	0.3	2.05
WED, 29/09	1400	8.50	233	2.31	1.07	0.460	-0.533	-0.205	0.006	1.5	0.54
	1430	9.57	234	1.97	0.930	0.539	-0.162	-0.248	-0.008	1.3	0.73
	1500	8.91	227	1.56	1.02	0.471	-0.007	-0.190	0.000	1.0	0.42
	1530	8.24	231	1.93	1.82	0.485	-0.511	-0.204	0.039	1.4	1.18
SUN, 03/10	1330	9.58	168	2.68	1.26	0.695	-0.287	-0.391	-0.047	0.1	2.18

NOTES: 1. ε IS MEAN FLOW UPWASH ANGLE.

2. DATA HAVE NOT BEEN CORRECTED FOR TEMPERATURE, HUMIDITY OR GEOMETRY EFFECTS.

TABLE 6.6: SUMMARY OF DATA FROM DK SONIC ANEMOMETER AT RS (BLOCK-AVERAGED VALUES FOR EACH RUN)

DATE	RUN PERIOD (BST)	$\overline{U}$, ms^{-1}	$\overline{\phi}$	$\sigma_u/\overline{U}$	$\sigma_v/\overline{U}$	$\sigma_w/\overline{U}$	$-\overline{uw}/\overline{U}^2$	Z_o, cm
SUN, 26/09	(1129-1229)	6.83	123	0.163	0.119	0.097	0.00424	2.15
WED, 29/09	(1400-1600)	8.81	231	0.158	0.125	0.081	0.00307	0.72
SUN, 03/10	(1330-1400)	9.58	168	0.171	0.117	0.087	0.00426	2.18

NOTE: DATA HAVE NOT BEEN CORRECTED FOR TEMPERATURE, HUMIDITY OR GEOMETRY EFFECTS.

Table 6.7 AES Gill UVW anemometer results at RS and HT.

Sites RS or HT are identified at the top of each table, RS1 or RS2 indicates only that two sets of data were collected on that day - although it may not all be included here. NAVG gives the number of individual values used to produce the average. For a 1/2-hour average, sampling at 2 scans/sec gives a maximum of 3600. Lower values than this indicates that the data collection started or ended during the 1/2-hour block or that some data were lost for other reasons. SIG U, SIG V and SIG W are standard deviations of the respective components and T_u, T_v and T_w are the turbulence intensities. K10 is the surface drag coefficient $[=(u_*/U_{10})^2]$ and $RE_{uw} = \overline{UW}/(\text{SIG U} \cdot \text{SIG W})$. Times are BST = GMT+1 hr.

```
SITE : RS         DATE : 22/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM.TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
              1300      1330      1400      1430      1500      1530      1600      1630

DIRN(GRID)    165.4     181.1     186.1     181.0     170.0     172.6     182.2     184.1
UFWASH          3.1       3.5       2.9       2.9       2.7       3.5       3.6       3.5

U (M/S)       5.38      7.03      8.00      6.53      4.80      5.06      5.59      5.68

SIG U         1.010     1.650     1.330     1.640     0.811     0.897     1.090     0.970
Tu            0.188     0.235     0.166     0.251     0.169     0.177     0.195     0.171

SIG V         0.585     1.200     0.796     0.742     0.519     0.582     0.820     0.605
Tv            0.109     0.171     0.100     0.114     0.108     0.115     0.147     0.107

SIG W         0.400     0.493     0.540     0.406     0.334     0.411     0.418     0.392
Tw            0.074     0.070     0.068     0.062     0.070     0.081     0.075     0.069

UW           -0.203    -0.337    -0.348    -0.168    -0.127    -0.181    -0.203    -0.157

UV           -0.143    -0.726    -0.105    -0.575    -0.010    -0.053     0.046     0.068

VW            0.010     0.024     0.010    -0.004     0.015    -0.009     0.003    -0.003

K10*1000      7.013     6.819     5.438     3.940     5.512     7.069     6.496     4.866

REuw         -0.502    -0.414    -0.485    -0.252    -0.469    -0.491    -0.446    -0.413

NAVG           3598      3600      3478      3600      3600      3600      3600      3600
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SITE : RS1       DATE : 23/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1000      1030      1100      1130      1200      1230      1300      1330      1400      1430

DIRN(GRID)   232.3     226.0     228.1     232.1     226.7     226.3     228.2     236.5     237.3     242.5
UPWASH         1.6       1.0       2.0       2.3       2.4       2.3       2.1       2.1       2.4       1.8

U (M/S)      2.72      2.32      3.03      4.50      4.47      5.36      4.95      5.25      5.10      6.36

SIG U        0.604     0.370     0.804     1.460     0.706     1.280     1.160     0.865     0.970     0.931
Tu           0.222     0.159     0.265     0.324     0.158     0.239     0.234     0.165     0.190     0.146

SIG V        0.299     0.189     0.402     0.563     0.411     0.961     0.469     0.848     0.518     0.616
Tv           0.110     0.081     0.133     0,125     0.092     0.179     0.095     0.162     0.102     0.097

SIG W        0.135     0.061     0.156     0.289     0.258     0.335     0.258     0.373     0.331     0.401
Tw           0.050     0.026     0.051     0.064     0.058     0.062     0.052     0.071     0.065     0.063

UW          -0.006    -0.006    -0.017    -0.054    -0.086    -0.200    -0.068    -0.135    -0.110    -0.165

UV          -0.032    -0.017    -0.199     0.415     0.065    -0.759    -0.310    -0.282     0.156     0.141

VW           0.005     0.001    -0.004     0.002     0.000     0.046     0.001     0.046     0.003    -0.015

K10*1000     0.856     1.078     1.841     2.647     4.329     6.961     2.771     4.898     4.229     4.079

REuw        -0.078    -0.257    -0.135    -0.127    -0.475    -0.466    -0.227    -0.418    -0.343    -0.442


NAVG          3598      3600      3600      3600      3600      3600      3600      3600      3600      3600




SITE : RS2       DATE : 23/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1600      1630      1700


DIRN(GRID)   254.1     253.7     252.9
UPWASH         1.1       1.9       1.4

U (M/S)      7.15      7.07      6.85

SIG U        0.710     1.030     1.050
Tu           0.099     0.146     0.153

SIG V        0.497     0.589     0.583
Tv           0.070     0.083     0.085

SIG W        0.405     0.433     0.406
Tw           0.057     0.061     0.059

UW          -0.131    -0.208    -0.185

UV           0.011    -0.184    -0.149

VW           0.023     0.027     0.038

K10*1000     2.562     4.161     3.943

REuw        -0.456    -0.466    -0.434


NAVG           514      3596      3600
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SITE : RS1       DATE : 25/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1030      1100      1130      1200      1230      1300      1330      1400


DIRN(GRID)   157.1     148.9     156.0     147.4     149.3     153.0     149.6     143.1
UPWASH         3.3       3.1       3.5       3.3       3.6       3.0       3.6       3.6


U (M/S)      6.41      6.46      6.90      7.80      7.42      7.29      6.89      6.93

SIG U        1.090     1.510     1.240     1.380     1.320     1.160     1.220     1.220
Tu           0.170     0.234     0.180     0.177     0.178     0.159     0.177     0.176

SIG V        0.667     0.724     0.838     0.709     0.941     1.010     1.100     1.050
Tv           0.104     0.112     0.121     0.091     0.127     0.139     0.160     0.152

SIG W        0.437     0.459     0.489     0.538     0.503     0.475     0.487     0.480
Tw           0.068     0.071     0.071     0.069     0.068     0.065     0.071     0.069

UW          -0.254    -0.283    -0.336    -0.390    -0.336    -0.241    -0.275    -0.274

UV          -0.100     0.377    -0.100     0.275     0.430     0.255     0.461    -0.014

VW          -0.013    -0.035     0.007    -0.071    -0.037    -0.011    -0.072    -0.013

K10*1000     6.182     6.781     7.057     6.410     6.103     4.535     5.793     5.705

REuw        -0.533    -0.408    -0.554    -0.525    -0.506    -0.437    -0.463    -0.468


NAVG          3600      3598      3600      3600      3600      3600      3600      3600
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SITE : RS2       DATE : 25/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1500      1530      1600      1630      1700      1730      1800


DIRN(GRID)   136.5     136.0     125.9     123.4     118.0     129.4     129.1
UPWASH         3.2       3.2       3.0       2.9       3.6       3.2       3.0


U (M/S)      7.23      7.14      5.36      6.09      5.38      5.75      5.13

SIG U        1.190     1.260     1.090     1.220     0.976     1.080     0.995
Tu           0.165     0.176     0.203     0.200     0.181     0.188     0.194

SIG V        0.741     0.986     0.729     0.808     0.838     0.553     0.497
Tv           0.102     0.138     0.136     0.133     0.156     0.096     0.097

SIG W        0.509     0.476     0.400     0.448     0.422     0.419     0.358
Tw           0.070     0.067     0.075     0.074     0.078     0.073     0.070

UW          -0.314    -0.302    -0.164    -0.245    -0.206    -0.184    -0.145

UV          -0.047    -0.295    -0.246    -0.390    -0.157    -0.179    -0.176

VW          -0.017    -0.021    -0.015    -0.005    -0.013    -0.014    -0.009

K10*1000     6.007     5.924     5.708     6.606     7.117     5.565     5.510

REuw        -0.518    -0.504    -0.376    -0.448    -0.500    -0.407    -0.407


NAVG          3598      3600      3600      3600      3600      3600      3600
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SITE : RS        DATE : 28/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               1130      1200      1230      1300      1330      1400      1430      1500


DIRN(GRID)    181.1     186.3     187.9     185.5     176.3     174.4     170.7     170.7
UFWASH          0.5       0.4       0.4       0.3       0.4       0.6       0.8       0.6


U (M/S)        8.34      9.67     11.18     10.82     12.39     11.41     13.38     13.57

SIG U         1.380     1.640     2.010     1.910     2.090     2.550     2.330     2.450
Tu            0.165     0.170     0.180     0.177     0.169     0.223     0.174     0.181

SIG V         0.794     0.998     1.110     1.170     1.120     1.320     1.320     1.860
Tv            0.095     0.103     0.099     0.108     0.090     0.116     0.099     0.137

SIG W         0.553     0.661     0.767     0.711     0.777     0.757     0.857     0.873
Tw            0.066     0.068     0.069     0.066     0.063     0.066     0.064     0.064

UW           -0.343    -0.458    -0.742    -0.528    -0.705    -0.772    -0.783    -1.000

UV           -0.078    -0.026     0.325     0.084     0.038     0.130     0.121    -0.349

VW            0.058     0.035    -0.027     0.081     0.044     0.019     0.048    -0.005

K10*1000      4.931     4.898     5.936     4.510     4.592     5.930     4.374     5.431

REuw         -0.449    -0.422    -0.481    -0.389    -0.434    -0.400    -0.392    -0.468

NAVG           3600      3600      3600      3600      3600      3600      3600      3600
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SITE : RS1       DATE : 29/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               930       1000      1030      1100      1130      1200      1230      1300


DIRN(GRID)    196.1     189.9     219.7     245.7     257.2     269.7     251.3     250.6
UFWASH         -0.5       0.1       0.4       0.0       0.3       0.4       0.1       0.3


U (M/S)        4.66      4.00      4.31      6.35      7.50      7.21      6.21      4.79

SIG U         0.989     0.979     1.480     2.590     1.450     1.480     1.440     0.810
Tu            0.212     0.245     0.343     0.408     0.193     0.205     0.232     0.169

SIG V         0.900     0.348     0.619     1.870     1.380     0.726     1.080     1.300
Tv            0.193     0.087     0.144     0.294     0.184     0.101     0.174     0.271

SIG W         0.338     0.222     0.210     0.355     0.442     0.384     0.294     0.315
Tw            0.073     0.056     0.049     0.056     0.059     0.053     0.047     0.066

UW           -0.047    -0.041    -0.076    -0.141    -0.250    -0.252    -0.132    -0.056

UV            0.153    -0.124     0.013    -1.180     0.581    -0.048    -0.398    -0.382

VW            0.020    -0.003     0.000     0.009    -0.031     0.001    -0.013    -0.016

K10*1000      2.141     2.594     4.107     3.497     4.444     4.848     3.423     2.423

REuw         -0.139    -0.191    -0.245    -0.153    -0.390    -0.443    -0.312    -0.218

NAVG           3600      3600      3600      3600      3600      3600      3600      3600
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SITE : RS1       DATE : 01/10/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
               930      1000      1030      1100      1130      1200      1230      1300


DIRN(GRID)    185.2     185.4     175.9     173.9     168.3     167.0     164.0     155.9
UPWASH          0.4       0.2       0.4       0.5       0.8       0.6       0.8       1.0


U (M/S)       7.02      7.06      6.86      7.29      8.53      9.22      9.24      9.60

SIG U         1.030     1.060     1.110     1.110     1.420     1.610     1.460     1.630
Tu            0.147     0.150     0.162     0.152     0.166     0.175     0.158     0.170

SIG V         0.715     0.581     0.716     0.724     0.812     0.951     1.150     1.470
Tv            0.102     0.082     0.104     0.099     0.095     0.103     0.124     0.153

SIG W         0.458     0.452     0.431     0.488     0.554     0.574     0.615     0.640
Tw            0.065     0.064     0.063     0.067     0.065     0.062     0.067     0.067

UW           -0.195    -0.229    -0.241    -0.238    -0.415    -0.460    -0.443    -0.474

UV            0.096    -0.017     0.023     0.035     0.004    -0.043    -0.073    -0.162

VW            0.043     0.019     0.030     0.013     0.024    -0.003    -0.006     0.006

K10*1000      3.957     4.594     5.121     4.478     5.704     5.411     5.189     5.143

REuw         -0.413    -0.478    -0.504    -0.439    -0.528    -0.498    -0.493    -0.454


NAVG           3600      3596      3600      3600      3600      3598      3598      3598
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SITE : RS        DATE : 02/10/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
              1000      1030      1100      1130      1200      1230      1300      1330      1400      1430


DIRN(GRID)    182.2     187.5     188.7     195.4     188.5     195.9     196.0     194.4     193.4     191.4
UPWASH          0.3       0.5       0.3       0.6       0.2       0.4       0.5       0.0       0.3       0.4


U (M/S)       9.66      9.52      9.46      9.77      8.02      9.52      9.39      9.52      8.64      7.78

SIG U         1.370     1.650     1.650     1.630     1.200     1.600     1.530     1.400     1.430     1.130
Tu            0.142     0.173     0.174     0.167     0.150     0.168     0.163     0.147     0.166     0.145

SIG V         0.892     0.880     0.986     0.890     0.711     1.010     0.776     0.829     0.772     0.689
Tv            0.092     0.092     0.104     0.091     0.089     0.106     0.083     0.087     0.089     0.089

SIG W         0.550     0.564     0.533     0.549     0.431     0.524     0.507     0.579     0.552     0.497
Tw            0.057     0.059     0.056     0.056     0.054     0.055     0.054     0.061     0.064     0.064

UW           -0.351    -0.461    -0.335    -0.415    -0.237    -0.327    -0.373    -0.312    -0.373    -0.264

UV            0.079    -0.036     0.384     0.003     0.004    -0.328     0.134     0.217     0.055    -0.012

VW            0.016     0.013     0.004    -0.010     0.013     0.023     0.001     0.019     0.032     0.021

K10*1000      3.761     5.087     3.743     4.348     3.685     3.608     4.230     3.443     4.997     4.362

REuw         -0.466    -0.495    -0.381    -0.464    -0.458    -0.390    -0.481    -0.385    -0.473    -0.470


NAVG           3600      3598      3600      3600      3600      3600      3600      3600      3600      3600
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SITE : RS2       DATE : 03/10/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)    (GMT+1)
               1200      1230      1300      1330      1400


DIRN(GRID)     158.0     161.7     160.7     159.5     153.4
UPWASH           0.4       0.6       0.8       0.5       1.3


U (M/S)        8.07      8.18      8.42      8.79      7.95

SIG U          1.180     1.380     1.380     1.450     1.450
Tu             0.146     0.169     0.164     0.165     0.182

SIG V          0.782     1.050     1.050     0.967     0.998
Tv             0.097     0.128     0.125     0.110     0.126

SIG W          0.449     0.497     0.520     0.576     0.598
Tw             0.056     0.061     0.062     0.066     0.075

UW            -0.223    -0.309    -0.403    -0.409    -0.469

UV             0.094     0.015     0.063     0.048     0.273

VW            -0.024    -0.028    -0.028    -0.058    -0.041

K10*1000       3.424     4.618     5.684     5.294     7.421

REuw          -0.421    -0.451    -0.562    -0.490    -0.541


NAVG            3600      3600      3600      3600      3600
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SITE : HT        DATE : 27/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1100      1130      1200      1230      1300      1330      1400


DIRN(GRID)   161.7     177.6     178.5     176.5     179.3     179.4     171.3
UPWASH         2.8       3.9       3.7       4.1       3.7       3.7       3.3


U (M/S)      7.40      9.91      9.33      9.21      9.72      9.67      9.82

SIG U        1.210     0.903     0.905     0.732     0.835     0.806     1.130
Tu           0.164     0.091     0.097     0.079     0.086     0.083     0.115

SIG V        1.120     0.629     0.654     0.726     0.852     0.812     1.060
Tv           0.151     0.063     0.070     0.079     0.088     0.084     0.108

SIG W        0.297     0.309     0.300     0.292     0.272     0.273     0.303
Tw           0.040     0.031     0.032     0.032     0.028     0.028     0.031

UW           0.086     0.006    -0.005    -0.031     0.001    -0.025    -0.024

UV          -0.809     0.049     0.137     0.103     0.022     0.140    -0.603

VW          -0.065     0.006     0.000    -0.044    -0.023     0.003    -0.010

K10*1000    -1.578    -0.063     0.062     0.368    -0.013     0.264     0.248

REuw         0.240     0.022    -0.020    -0.146     0.005    -0.112    -0.070


NAVG          3598      3598      3600      3600      3600      3600      3598
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SITE : HT        DATE : 28/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1200      1230      1300      1330      1400      1430      1500


DIRN(GRID)   187.0     188.9     185.2     177.6     176.2     175.9     174.2
UPWASH         4.1       5.2       5.1       5.0       4.7       5.2       5.1


U (M/S)     16.27     18.60     16.05     18.34     18.04     20.10     19.39

SIG U        1.790     1.820     2.320     1.710     2.060     2.000     2.230
Tu           0.110     0.098     0.145     0.093     0.114     0.100     0.115

SIG V        0.990     1.370     1.090     1.260     1.380     1.490     2.330
Tv           0.061     0.074     0.068     0.069     0.076     0.074     0.120

SIG W        0.638     0.843     0.657     0.663     0.717     0.838     0.774
Tw           0.039     0.045     0.041     0.036     0.040     0.042     0.040

UW          -0.016    -0.124    -0.150    -0.106    -0.039    -0.178    -0.039

UV           0.312     0.286     0.753     0.457     0.195    -0.167    -1.830

VW           0.014    -0.012    -0.076    -0.059    -0.062    -0.160    -0.329

K10*1000     0.059     0.358     0.582     0.315     0.119     0.441     0.105

REuw        -0.014    -0.081    -0.098    -0.093    -0.026    -0.106    -0.023


NAVG          3600      3600      3598      3600      3600      3600      3600
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SITE : HT        DATE : 29/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                 TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
                1030      1100      1130      1200      1230      1300


DIRN(GRID)     209.9     221.8     240.5     252.6     229.9     231.9
UPWASH           0.5       1.9       2.5       1.4       2.1       1.8


U (M/S)         6.54      8.47     10.30     10.13      9.56      8.49

SIG U          1.910     2.750     2.530     1.440     1.980     0.748
Tu             0.292     0.325     0.246     0.142     0.207     0.088

SIG V          1.200     1.320     1.880     1.460     0.880     0.782
Tv             0.183     0.156     0.183     0.144     0.092     0.092

SIG W          0.327     0.392     0.454     0.349     0.380     0.368
Tw             0.050     0.046     0.044     0.034     0.040     0.043

UW             0.229     0.363     0.195     0.011     0.165    -0.021

UV            -1.230    -1.720    -1.230    -1.370    -0.084     0.059

VW             0.003    -0.002     0.098     0.040    -0.005     0.026

K10*1000      -5.354    -5.060    -1.838    -0.105    -1.805     0.291

REuw           0.367     0.337     0.170     0.021     0.219    -0.076


NAVG            3299      3598      3596      3600      3600      3600
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SITE : HT        DATE : 29/09/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

                 TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
                1330      1400      1430      1500      1530      1600      1630


DIRN(GRID)     229.2     220.6     219.3     217.2     223.9     238.9     228.4
UPWASH           3.1       3.1       3.2       3.3       4.4       4.0       4.2


U (M/S)        11.92     12.45     13.12     12.40     12.27     11.20     12.78

SIG U          1.200     1.060     0.845     0.810     0.868     1.750     1.750
Tu             0.101     0.085     0.064     0.065     0.071     0.156     0.137

SIG V          0.742     1.120     0.877     0.963     1.200     2.290     2.150
Tv             0.062     0.090     0.067     0.078     0.098     0.204     0.168

SIG W          0.400     0.496     0.569     0.534     0.510     0.478     0.473
Tw             0.034     0.040     0.043     0.043     0.042     0.043     0.037

UW            -0.026    -0.018    -0.104    -0.009    -0.046     0.114     0.031

UV            -0.176    -0.477    -0.083    -0.016    -0.198     2.000    -0.603

VW             0.020     0.016     0.035     0.102     0.078     0.245     0.087

K10*1000       0.183     0.117     0.604     0.060     0.305    -0.909    -0.191

REuw          -0.054    -0.034    -0.216    -0.021    -0.104     0.136     0.038


NAVG            3592      3600      3598      3465      3468      3600      3600
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SITE : HT2       DATE : 02/10/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1430     1500     1530


DIRN(GRID)   194.8    199.5    201.9
UPWASH         4.4      4.3      4.3


U (M/S)     13.39    14.65    18.10

SIG U        0.911    1.520    1.240
Tu           0.068    0.104    0.069

SIG V        0.904    1.300    1.230
Tv           0.068    0.089    0.068

SIG W        0.359    0.379    0.508
Tw           0.027    0.026    0.028

UW          -0.090   -0.104   -0.174

UV          -0.015   -0.763    0.171

VW           0.026    0.016    0.022

K10*1000     0.502    0.485    0.531

REuw        -0.275   -0.181   -0.276


NAVG          2153     3598     3194
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SITE : HT        DATE : 03/10/82


GILL 3-COMP. ANEMOMETER (AT 10.2 M. HEIGHT) :
  (AFTER ROTATION OF COORD.-SYSTEM TO ALIGN WITH MEAN FLOW)

               TIME (HHMM)  (START TIME FOR 30 MIN. AVERAGES)   (GMT+1)
             1330     1400


DIRN(GRID)   167.0    157.2
UPWASH         4.9      4.0


U (M/S)     12.39    12.02

SIG U        1.350    1.090
Tu           0.109    0.091

SIG V        1.410    1.370
Tv           0.114    0.114

SIG W        0.453    0.489
Tw           0.037    0.041

UW          -0.093   -0.076

UV          -0.446    0.260

VW          -0.100   -0.124

K10*1000     0.605    0.525

REuw        -0.152   -0.142


NAVG          3594     3596
```

TABLE 6.8 SUMMARY OF TURBULENCE DATA RUNS OBTAINED FROM BRE GILL UVW SYSTEM

DATE	RUN PERIOD (BST)	TOWER LOCATION	NOMINAL SENSOR HEIGHTS, m	$\overline{U}$, ms^{-1}	$\overline{\phi}$, °GRID
				APPROXIMATE VALUES, $\Delta Z = 10$ m	
TUE, 21/09	(1227-1715)	RS	5, 10, 15, 20	10	327
WED, 22/09	(1239-1727)	RS	5, 10, 15, 20	6	180
THU, 23/09	(1100-1734)	RS	10	5	240
THU, 23/09	(1356-1636)	ASW78	10, 15, 20	5	250
SAT, 25/09	(1526-1805)	ASW78	5, 10, 15, 20	7	118
MON, 27/09	(1036-1513)	ASW78	5, 10, 15, 20	5	160
TUE, 28/09	(1143-1538)	ASW78	5, 10, 15, 20	10	175
WED, 29/09	(0947-1601)	ASW78	5, 10, 15, 20	6	250
FRI, 01/10	(1045-1555)	ASW78	5, 10, 15, 20	9	155

Table 6.9 Typical output from BRE Gill UVW system for a single run (29/09).

'Time' refers to start time (BST) for each block. U-VAR is the variance (=σ_u^2) of the u-component, and similarly for other components. No corrections for non-cosine response have been applied, nor have the results been rotated to a reference frame with $\overline{W}=0$.

******** VELOCITY IN M/S

ASKERVEIN 29-SEP-82
HILL SITE 5M (A) ANEMOMETER

******** 10 MINUTE MEANS

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947	186.	3.818	.617	.535	.048	-.049
958	189.8	4.301	.493	.323	.048	-.040
1009	182.9	3.046	.284	.110	.018	-.014
1019	175.1	2.216	.099	.099	.012	-.012
1030	205.2	3.294	2.731	.309	.019	.098
1041	223.1	4.002	.489	.574	.019	-.004
1051	231.1	3.067	.231	.113	.015	-.023
1102	241.7	5.308	4.47	1.903	.069	.225
1113	229.5	4.338	1.509	.594	.021	.033
1123	242.2	3.699	1.198	1.367	.051	.007
1134	260.4	4.944	1.132	.473	.047	-.018
1145	253.5	7.312	1.416	.711	.071	-.062
1155	271.3	6.442	1.157	.861	.077	-.070
1206	274.3	5.675	.982	.451	.049	.006
1217	258.9	4.014	.387	.243	.035	-.013
1227	249.1	3.68	.396	.128	.021	-.014
1238	242.3	5.659	1.288	.302	.050	-.006
1249	248.7	5.769	2.411	.361	.045	.055
1300	247.	3.179	.263	.131	.026	-.037
1310	250.9	3.953	.336	.165	.032	-.031
1321	243.8	4.859	1.543	.266	.050	-.010
1332	247.1	6.711	.996	.243	.068	-.073
1342	247.9	6.646	.900	.294	.066	-.060
1353	242.6	7.417	1.801	.345	.090	-.073
1404	235.2	6.183	.745	.170	.062	-.054
1414	232.2	6.9	.91	.287	.067	-.067
1425	230.6	7.506	1.554	.37	.082	-.048
1436	235.7	7.476	1.438	.313	.069	-.123
1446	235.5	6.986	1.218	.351	.083	-.098
1457	234.1	6.545	1.724	.275	.090	-.148
1508	228.1	6.392	1.	.619	.063	-.050
1519	226.1	6.996	1.437	.304	.066	-.073
1529	231.2	6.211	1.014	.780	.056	-.080
1540	244.8	5.867	1.016	.255	.052	-.056
1551	240.6	6.312	1.357	.228	.054	-.032

******* RUNNING 30 MINUTE MEANS *****

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947 - 1019	186.2	3.721	.732	.323	.038	-.034
958 - 1030	182.6	3.188	1.026	.178	.026	-.022
1009 - 1041	187.7	2.852	1.25	.173	.016	.023
1019 - 1051	201.1	3.171	1.646	.327	.016	.027
1030 - 1102	219.8	3.454	1.309	.332	.017	.023
1041 - 1113	231.9	4.126	2.574	.863	.034	.066
1051 - 1123	234.1	4.238	2.911	.870	.035	.078
1102 - 1134	237.8	4.448	2.83	1.288	.047	.088
1113 - 1145	244.	4.327	1.538	.811	.040	.007
1123 - 1155	252.	5.318	3.495	.850	.056	-.024
1134 - 1206	261.7	6.233	2.192	.682	.065	-.050
1145 - 1217	266.4	6.476	1.632	.674	.066	-.042
1155 - 1227	268.2	5.377	1.868	.518	.054	-.026
1206 - 1238	260.8	4.457	1.349	.274	.035	-.007
1217 - 1249	250.1	4.451	1.438	.224	.035	-.011
1227 - 1300	246.7	5.036	2.286	.263	.038	.011
1238 - 1310	246.	4.869	2.751	.264	.040	.003
1249 - 1321	248.8	4.3	2.182	.219	.034	-.004
1300 - 1332	247.2	3.997	1.165	.188	.036	-.026
1310 - 1342	247.3	5.174	2.276	.225	.050	-.038
1321 - 1353	246.3	6.072	1.883	.268	.062	-.048
1332 - 1404	245.8	6.925	1.354	.294	.075	-.069
1342 - 1414	241.9	6.748	1.408	.269	.073	-.062
1353 - 1425	236.7	6.833	1.408	.267	.073	-.065
1404 - 1436	232.7	6.863	1.362	.275	.070	-.056
1414 - 1446	232.8	7.294	1.378	.323	.079	-.079
1425 - 1457	233.9	7.323	1.46	.345	.085	-.090
1436 - 1508	235.1	7.002	1.605	.313	.087	-.123
1446 - 1518	232.6	6.641	1.378	.415	.079	-.099
1457 - 1529	229.4	6.644	1.453	.400	.073	-.090
1508 - 1540	228.5	6.533	1.263	.568	.062	-.068
1519 - 1551	234.1	6.358	1.379	.447	.058	-.070
1529 - 1601	238.9	6.13	1.165	.421	.054	-.056

******** VELOCITY IN M/S

ASKERVEIN 29-SEP-82
HILL SITE 10M (A) ANEMOMETER

****** 10 MINUTE MEANS

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947	188.	4.349	.821	.534	.080	-.072
958	191.2	4.873	.477	.237	.077	-.047
1009	186.4	3.535	.291	.099	.021	-.011
1019	178.5	2.64	.111	.120	.017	-.015
1030	205.4	3.817	2.813	.320	.027	.101
1041	222.3	4.674	.479	.724	.032	.004
1051	230.5	3.534	.298	.130	.022	-.024
1102	241.7	5.805	4.209	2.229	.148	.398
1113	229.7	4.918	1.591	.548	.041	.106
1123	242.5	4.149	1.051	1.564	.073	.074
1134	258.	5.264	1.002	.458	.072	-.027
1145	252.7	7.528	1.232	.594	.111	-.098
1155	270.9	6.727	1.027	.780	.135	-.015
1206	273.9	5.974	.900	.393	.068	-.015
1217	257.6	4.509	.431	.274	.050	-.002
1227	246.2	4.217	.423	.163	.036	-.023
1238	240.8	6.298	1.244	.288	.087	.002
1249	248.	6.222	2.447	.388	.082	.154
1300	244.8	3.627	.343	.159	.039	-.029
1310	248.6	4.179	.372	.114	.055	-.040
1321	242.7	5.227	1.394	.299	.089	-.003
1332	246.5	7.224	.766	.232	.122	-.098
1342	247.1	7.227	.953	.296	.122	-.108
1353	242.4	8.14	1.767	.313	.119	-.047
1404	234.9	6.816	.830	.188	.090	-.060
1414	231.4	7.565	1.194	.177	.118	-.066
1425	231.	7.937	1.501	.330	.137	-.047
1436	234.5	8.043	1.191	.225	.148	-.132
1446	234.4	7.506	1.088	.278	.159	-.093
1457	232.8	6.994	1.765	.215	.143	-.207
1508	227.4	6.833	1.019	.574	.114	-.074
1519	225.9	7.368	1.301	.305	.115	-.086
1529	230.8	6.443	1.071	.810	.120	-.139
1540	243.4	6.383	.858	.260	.085	-.091
1551	239.5	6.656	1.321	.208	.082	-.042

****** RUNNING 30 MINUTE MEANS ****

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947 - 1019	188.5	4.252	.833	.290	.059	-.043
958 - 1030	185.4	3.683	1.136	.152	.038	-.024
1009 - 1041	190.1	3.33	1.324	.18	.022	.025
1019 - 1051	202.1	3.71	1.83	.388	.025	.030
1030 - 1102	219.4	4.008	1.431	.391	.027	.027
1041 - 1113	231.5	4.671	2.522	1.028	.068	.126
1051 - 1123	234.	4.752	2.906	.969	.070	.159
1102 - 1134	238.	4.957	2.742	1.447	.087	.193
1113 - 1145	243.4	4.777	1.432	.856	.062	.051
1123 - 1155	251.1	5.647	3.071	.872	.085	-.017
1134 - 1206	260.6	6.506	1.965	.610	.106	-.047
1145 - 1217	265.8	6.743	1.456	.589	.105	-.043
1155 - 1227	267.5	5.737	1.634	.482	.085	-.011
1206 - 1238	259.2	4.9	1.176	.277	.051	-.013
1217 - 1249	248.2	5.008	1.546	.242	.058	-.007
1227 - 1300	245.	5.579	2.3	.280	.068	.044
1238 - 1310	244.5	5.382	2.887	.278	.07	.042
1249 - 1321	247.1	4.676	2.3	.220	.059	.028
1300 - 1332	245.4	4.344	1.144	.191	.061	-.024
1310 - 1342	245.9	5.543	2.44	.215	.088	-.047
1321 - 1353	245.4	6.559	1.925	.276	.111	-.070
1332 - 1404	245.3	7.53	1.347	.280	.121	-.084
1342 - 1414	241.5	7.394	1.489	.266	.111	-.072
1353 - 1425	236.2	7.507	1.557	.226	.109	-.058
1404 - 1436	232.4	7.439	1.393	.232	.115	-.058
1414 - 1446	232.3	7.848	1.337	.244	.134	-.081
1425 - 1457	233.3	7.828	1.314	.277	.148	-.090
1436 - 1508	233.9	7.514	1.531	.239	.150	-.144
1446 - 1518	231.5	7.111	1.373	.355	.139	-.125
1457 - 1529	228.7	7.065	1.412	.364	.124	-.122
1508 - 1540	228.	6.881	1.274	.563	.116	-.100
1519 - 1551	233.4	6.731	1.28	.458	.107	-.105
1529 - 1601	237.9	6.494	1.097	.426	.096	-.091

******** VELOCITY IN M/S

ASKERVEIN 29-SEP-83
HILL SITE 15M (A) ANEMOMETER

****** 10 MINUTE MEANS

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947	191.1	4.734	.899	.558	.124	-.084
958	194.4	5.327	.423	.223	.1	-.066
1009	189.7	4.185	.281	.112	.032	-.025
1019	183.2	3.13	.118	.129	.015	-.007
1030	207.3	4.205	2.832	.386	.032	.009
1041	223.7	5.186	.386	.876	.034	-.000
1051	232.2	3.703	.322	.169	.035	-.044
1102	244.4	6.128	4.689	2.526	.168	.360
1113	232.4	5.449	1.887	.522	.044	.107
1123	247.8	4.496	1.208	2.112	.082	.066
1134	263.1	5.631	.881	.721	.087	-.060
1145	258	7.762	1.15	.905	.147	-.081
1155	276.8	7.328	1.038	.684	.156	-.015
1206	278.6	6.47	.996	.363	.088	-.033
1217	262.3	4.86	.380	.436	.062	-.018
1227	249.8	4.443	.383	.171	.051	-.052
1238	244.3	6.599	1.399	.302	.103	-.074
1249	252.2	6.592	2.611	.523	.095	.101
1300	250.4	3.978	.291	.195	.057	-.043
1310	253.5	4.343	.324	.178	.072	-.065
1321	245.3	5.514	1.312	.344	.127	-.063
1332	250.1	7.499	.775	.235	.129	-.092
1342	251.2	7.717	1.022	.400	.119	-.114
1353	246.3	8.866	1.892	.333	.113	-.047
1404	238.2	7.392	.803	.300	.090	-.074
1414	234.	8.1	1.232	.214	.155	-.110
1425	233.5	8.541	1.698	.429	.164	-.118
1436	237.7	8.458	1.141	.291	.193	-.182
1446	237.8	7.937	.985	.347	.195	-.115
1457	236.1	7.418	1.513	.276	.210	-.288
1508	229.7	7.311	1.125	.593	.176	-.126
1519	228.5	7.955	1.332	.278	.151	-.130
1529	233.6	6.836	.869	.973	.170	-.161
1540	247.3	6.714	.831	.277	.116	-.134
1551	243.8	7.129	1.504	.264	.122	-.131

****** RUNNING 30 MINUTE MEANS ****

TIME	DIRECTION	U-MEAN	U-VAR	V-VAR	W-VAR	UW-PROD
947 - 1019	191.8	4.749	.752	.298	.085	-.058
958 - 1030	189.1	4.214	1.078	.155	.049	-.033
1009 - 1041	193.4	3.84	1.345	.209	.026	-.007
1019 - 1051	204.8	4.174	1.833	.464	.027	.000
1030 - 1102	221.1	4.365	1.576	.477	.033	-.011
1041 - 1113	233.4	5.005	2.795	1.19	.079	.105
1051 - 1123	236.3	5.093	3.342	1.072	.082	.141
1102 - 1134	241.5	5.357	3.043	1.72	.098	.178
1113 - 1145	247.7	5.192	1.573	1.118	.071	.037
1123 - 1155	256.3	5.963	2.913	1.246	.105	-.024
1134 - 1206	266.	6.907	1.869	.770	.130	-.052
1145 - 1217	271.2	7.186	1.35	.651	.130	-.043
1155 - 1227	272.6	6.22	1.851	.494	.102	-.022
1206 - 1238	263.6	5.26	1.347	.323	.067	-.035
1217 - 1249	252.1	5.302	1.589	.303	.072	-.048
1227 - 1300	248.7	5.88	2.489	.332	.083	-.008
1238 - 1310	248.9	5.723	2.956	.340	.085	-.005
1249 - 1321	252.	4.971	2.412	.299	.075	-.002
1300 - 1332	249.7	4.612	1.072	.239	.085	-.057
1310 - 1342	249.6	5.786	2.501	.252	.109	-.073
1321 - 1353	248.9	6.91	2.019	.326	.125	-.090
1332 - 1404	249.2	8.027	1.589	.323	.120	-.084
1342 - 1414	245.2	7.992	1.639	.344	.107	-.078
1353 - 1425	239.5	8.119	1.671	.282	.119	-.077
1404 - 1436	235.2	8.011	1.468	.314	.136	-.101
1414 - 1446	235.1	8.366	1.394	.311	.171	-.137
1425 - 1457	236.3	8.312	1.346	.356	.184	-.139
1436 - 1508	237.2	7.937	1.393	.305	.199	-.195
1446 - 1518	234.5	7.556	1.283	.405	.194	-.177
1457 - 1529	231.5	7.561	1.403	.382	.179	-.182
1508 - 1540	230.6	7.368	1.319	.615	.166	-.139
1519 - 1551	236.5	7.169	1.323	.509	.146	-.142
1529 - 1601	241.5	6.893	1.098	.505	.136	-.142

```
********* VELOCITY IN M/S

ASKERVEIN 29-SEP-82
HILL SITE 20M (A) ANEMOMETER


           *******            10  MINUTE  MEANS

TIME    DIRECTION     U-MEAN    U-VAR    V-VAR    W-VAR    UW-PROD

 947      190.8       4.854     .982     .486     .159     -.086
 958      195.        5.271     .394     .167     .110     -.079
1009      191.        4.183     .218     .082     .027     -.022
1019      186.8       3.231     .110     .092     .020     -.014
1030      207.4       4.324    2.946     .243     .040     -.087
1041      223.2       5.407     .401     .826     .044     -.000
1051      231.1       3.705     .374     .167     .035     -.044
1102      243.8       6.189    4.538    2.577     .138      .191
1113      232.        5.57     1.934     .432     .033      .03
1123      248.7       4.599    1.022    2.283     .102      .009
1134      263.1       5.547     .869     .798     .103     -.116
1145      258.        7.576     .969     .880     .199     -.156
1155      276.5       7.041    1.099     .442     .182     -.122
1206      277.7       5.979     .775     .303     .127     -.114
1217      260.6       4.754     .304     .379     .061     -.037
1227      248.8       4.314     .336     .155     .045     -.043
1238      242.9       6.278    1.218     .278     .118     -.108
1249      250.8       6.281    2.107     .468     .101      .001
1300      248.4       3.889     .246     .122     .045     -.033
1310      251.1       4.136     .292     .125     .080     -.066
1321      242.9       5.394    1.226     .237     .151     -.093
1332      247.3       7.099     .550     .167     .159     -.119
1342      248.8       7.42      .769     .264     .162     -.141
1353      244.        8.508    1.541     .248     .128     -.108
1404      236.3       7.286     .788     .172     .092     -.101
1414      232.9       7.761    1.032     .139     .178     -.166
1425      232.9       8.08     1.388     .255     .210     -.231
1436      235.9       7.951     .906     .151     .239     -.223
1446      236.2       7.39      .869     .177     .230     -.152
1457      234.9       7.06     1.277     .164     .271     -.363
1508      228.5       7.027     .961     .463     .222     -.191
1519      228.        7.512    1.329     .252     .176     -.203
1529      232.4       6.413     .736     .680     .194     -.152
1540      245.2       6.245     .756     .200     .144     -.159
1551      240.8       6.692    1.344     .165     .150     -.215


       ******    RUNNING  30  MINUTE  MEANS    *****

  TIME          DIRECTION     U-MEAN    U-VAR    V-VAR    W-VAR    UW-PROD

 947 - 1019       192.3       4.769     .732     .245     .099     -.062
 958 - 1030       190.9       4.229     .935     .114     .053     -.039
1009 - 1041       195.1       3.913    1.327     .139     .029     -.041
1019 - 1051       205.8       4.321    1.941     .387     .035     -.034
1030 - 1102       220.5       4.479    1.735     .412    -.040     -.044
1041 - 1113       232.7       5.101    2.846    1.19      .089      .048
1051 - 1123       235.6       5.155    3.396    1.059     .086      .059
1102 - 1134       241.5       5.453    2.926    1.764     .108      .076
1113 - 1145       248.        5.239    1.48     1.171     .079     -.025
1123 - 1155       256.6       5.908    2.495    1.32      .135     -.087
1134 - 1206       265.9       6.722    1.716     .707     .161     -.131
1145 - 1217       270.7       6.865    1.388     .542     .169     -.131
1155 - 1227       271.6       5.925    1.599     .375     .123     -.091
1206 - 1238       262.4       5.015     .968     .279     .077     -.065
1217 - 1249       250.8       5.115    1.328     .271     .075     -.063
1227 - 1300       247.5       5.624    2.079     .300     .088     -.050
1238 - 1310       247.4       5.483    2.46      .289     .088     -.046
1249 - 1321       250.1       4.769    2.035     .238     .075     -.032
1300 - 1332       247.5       4.474    1.022     .161     .092     -.064
1310 - 1342       247.1       5.543    2.164     .176     .130     -.093
1321 - 1353       246.3       6.639    1.638     .223     .157     -.118
1332 - 1404       246.7       7.676    1.316     .226     .149     -.123
1342 - 1414       243.        7.738    1.332     .228     .127     -.117
1353 - 1425       237.7       7.851    1.373     .187     .133     -.125
1404 - 1436       234.1       7.709    1.175     .189     .160     -.166
1414 - 1446       233.9       7.931    1.126     .182     .209     -.207
1425 - 1457       235.        7.807    1.144     .194     .226     -.202
1436 - 1508       235.6       7.467    1.153     .164     .247     -.246
1446 - 1518       233.2       7.159    1.063     .268     .241     -.235
1457 - 1529       230.5       7.2      1.238     .293     .223     -.252
1508 - 1540       229.7       6.984    1.211     .465     .197     -.182
1519 - 1551       235.2       6.723    1.256     .378     .171     -.172
1529 - 1601       239.5       6.45      .98      .349     .163     -.175
```

Table 6.10: Mean wind speed data (m s^{-1}) from BRE Gill UVW anemometers during selected MF runs.

		Anemometer Heights (m)			
MF Run	Location	5.6	9.8	14.8	19.8
		Wind speeds (m s^{-1})			
1.22	RS	5.30	5.93	6.45	6.36
2.25	ASW78	5.86	6.79	7.52	7.28
2.27	ASW78	4.79	4.81	5.75	5.90
2.28	ASW78	8.98	10.37	11.10	11.14
2.29b	ASW78	6.73	7.22	7.72	7.33
2.01a	ASW78	6.87	7.55	8.18	8.07
2.01b	ASW78	8.84	10.00	10.96	10.99

Note that no cosine corrections were applied during the analysis of these data.

TABLE 6.11 SUMMARY OF FRG BIVANE TURBULENCE DATA (ΔZ = 10.0 m)

DATE	RUN STARTING TIME, (BST)	$\overline{U}$, ms^{-1}	$\overline{\phi}$, °GRID	$\sigma_u/\overline{U}$	$\sigma_v/\overline{U}$	$\sigma_w/\overline{U}$	u_*, ms^{-1}
THU, 23/09	1600	7.48	256	0.152	0.118	0.0789	0.476
	1624	7.65	257	0.132	0.0958	0.0754	0.505
	1649	7.34	255	0.143	0.110	0.0776	0.484
	1714	6.85	255	0.158	0.115	0.0793	0.484
MON, 27/09	1309	9.04	178	0.0855	0.132	0.0441	0.260
	1334	8.66	179	0.102	0.156	0.0481	0.336
	1359	8.77	172	0.123	0.151	0.0583	0.421
	1425	7.83	171	0.170	0.115	0.0511	0.140
TUE, 28/09	1245	18.41	194	0.100	0.101	0.0486	0.642
	1309	15.90	190	0.133	0.129	0.0504	0.591
	1334	18.10	181	0.105	0.097	0.0497	0.690
	1359	17.77	178	0.109	0.102	0.0504	0.595
	1429	19.51	177	0.109	0.109	0.0543	0.783
	1454	19.14	174	0.119	0.125	0.0552	0.842
	1520*	17.99	180	0.117	0.152	0.0555	0.777
	1529**	18.24	185	0.121	0.225	0.0557	0.636
	1545	20.74	176	0.116	0.127	0.0541	0.844
WED, 29/09	1404	11.87	233	0.0887	0.833	0.412	0.349
	1430	13.34	233	0.0704	0.0751	0.0448	0.396
	1455	12.47	230	0.0666	0.0916	0.0442	0.372
	1521	11.89	230	0.0807	0.111	0.0481	0.375
FRI, 01/10	1114	10.71	176	0.121	0.135	0.0565	0.493
	1139	12.35	172	0.123	0.131	0.0536	0.590
	1204	12.01	167	0.108	0.112	0.0545	0.544
	1230	12.46	166	0.112	0.122	0.0591	0.586
SAT, 02/10	1359	14.37	204	0.0940	0.120	0.0459	0.508
	1424	13.98	200	0.0777	0.145	0.0450	0.408
	1450	12.90	200	0.102	0.170	0.0487	0.475
	1515	15.28	211	0.0915	0.100	0.0488	0.478

NOTES: 1. ALL RUNS AT CP EXCEPT THU., 23/09, AT RS

2. ALL DATA BLOCKS 23 MIN. LONG EXCEPT * (8 MIN.) AND ** (15 MIN.)

FIGURES

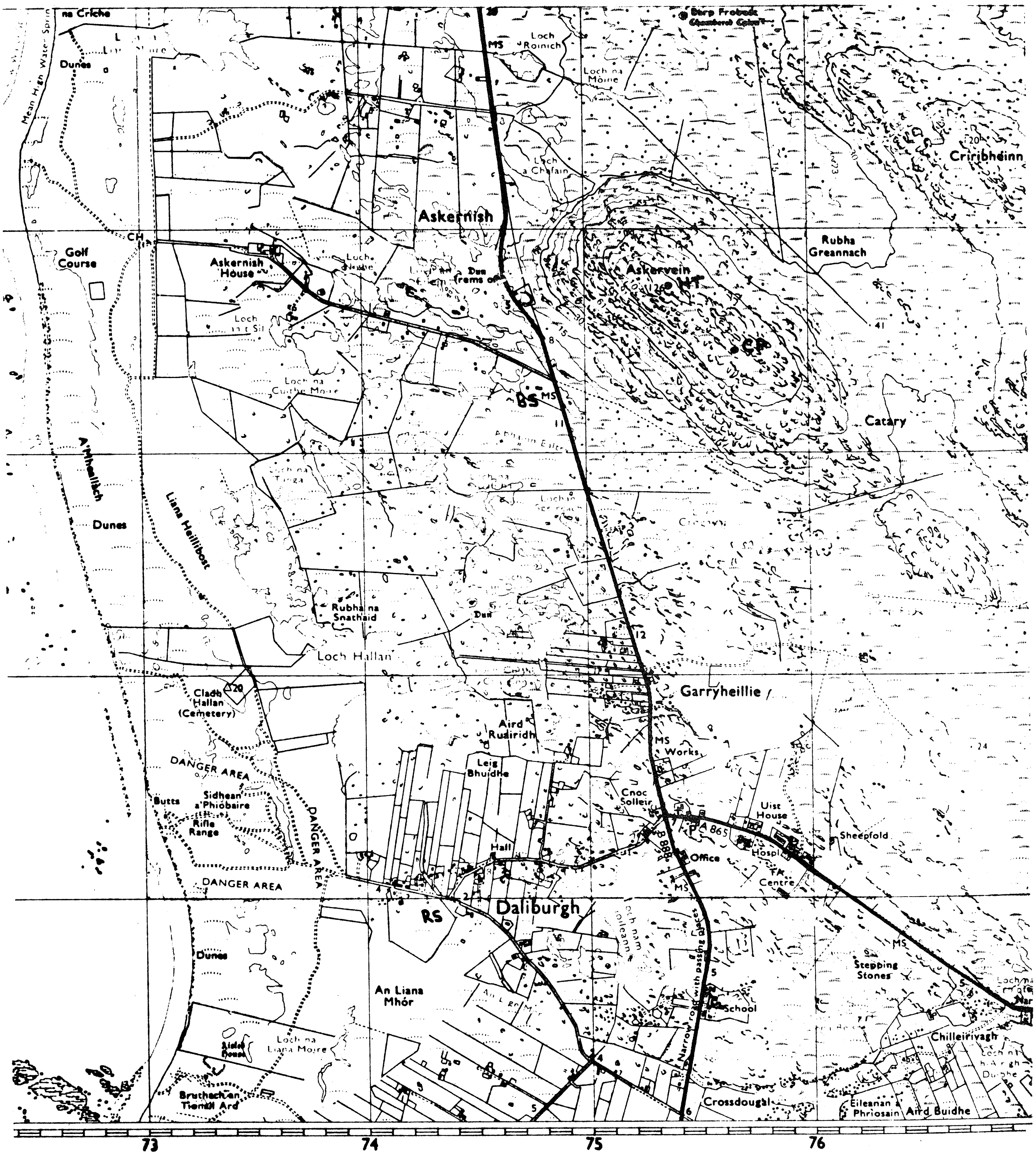


Fig 3.1 Askervein (South Uist, Scotland) and environs. From sheets NF72SW and NF72SE of the Ordance Survey 1:10,000 map series. The contour levels are in metres above local datum. Points of reference for the experiment are marked.

RS - reference site; BS - base station;
HT - hilltop; CP - centrepoint

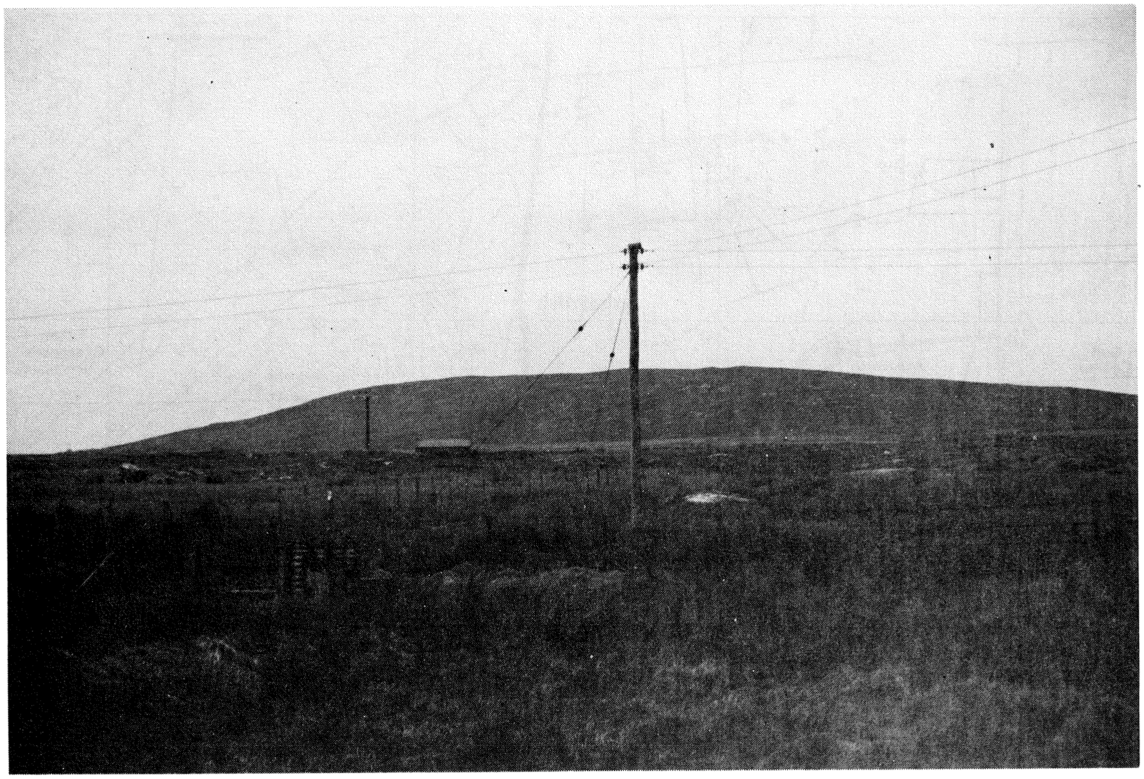


Fig 3.2 Askervein from the South.

Fig 3.3 View from the hilltop looking SW.

Fig 3.4 Photograph of RS looking approximately SSW and showing 50 m tower.

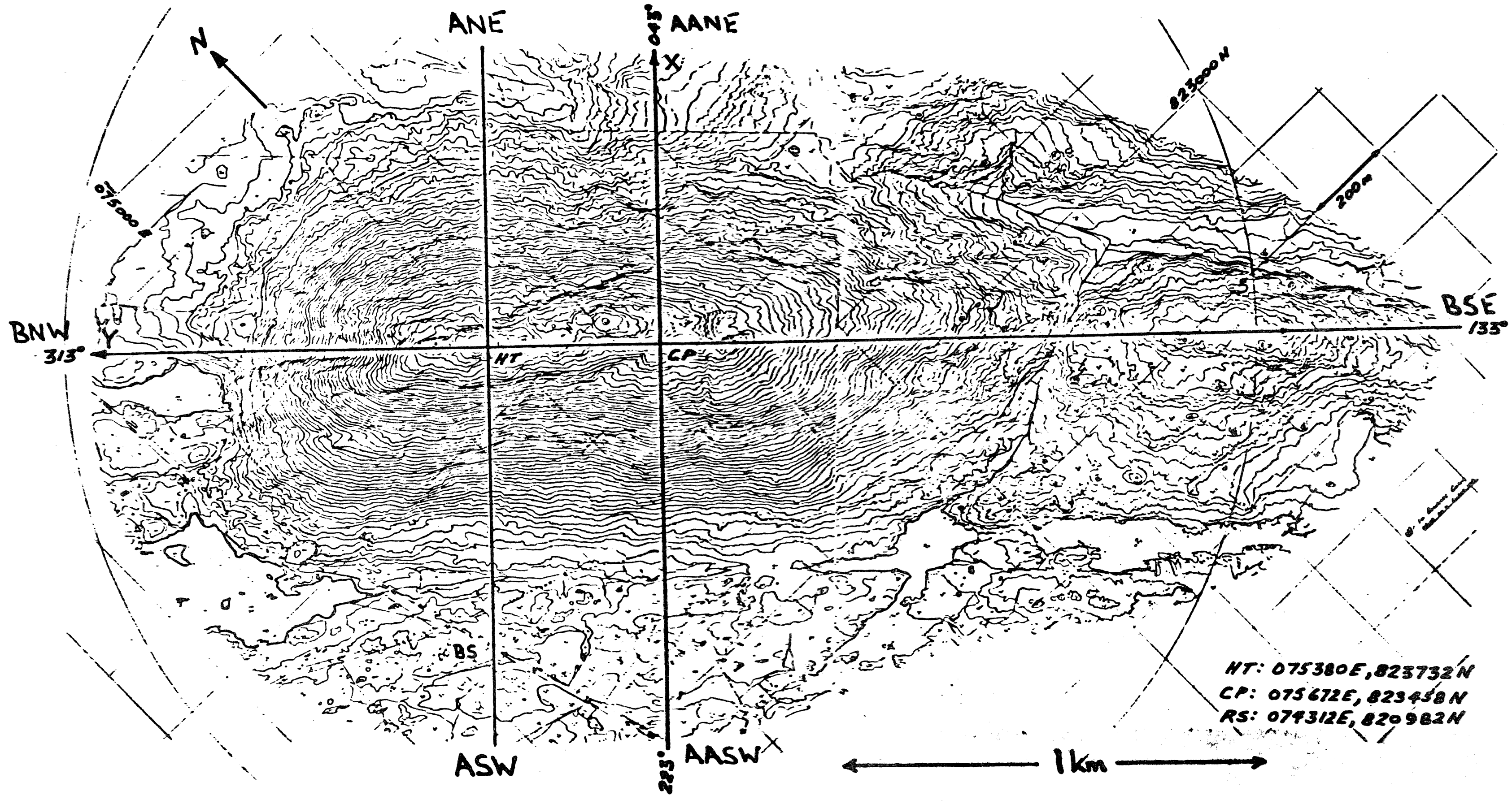
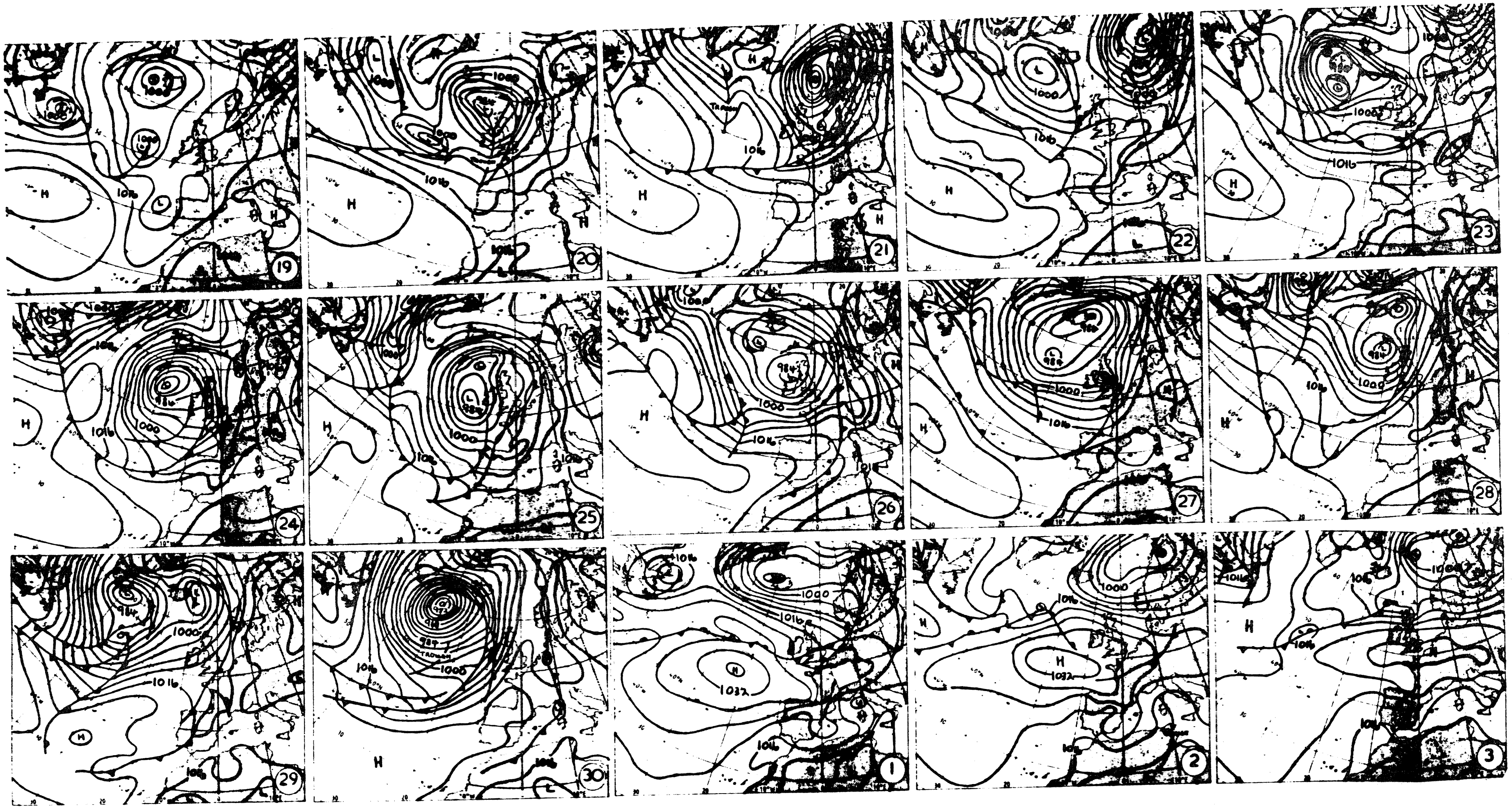


Fig 3.5 High resolution contour map of Askervein showing A, AA and B lines. OS grid lines are also marked. Original was drawn at 1:2000 scale with 2 m contour interval.

Fig 3.6 Aerial photo of Askervein - one of a set from which the contour map was drawn.



September 19 - October 3, 1982

Fig 4.1 Daily weather maps for the period of the experiment - reproduced from the Royal Meteorological Society Weather Log. Maps are for 13:00 BST (12:00 GMT)

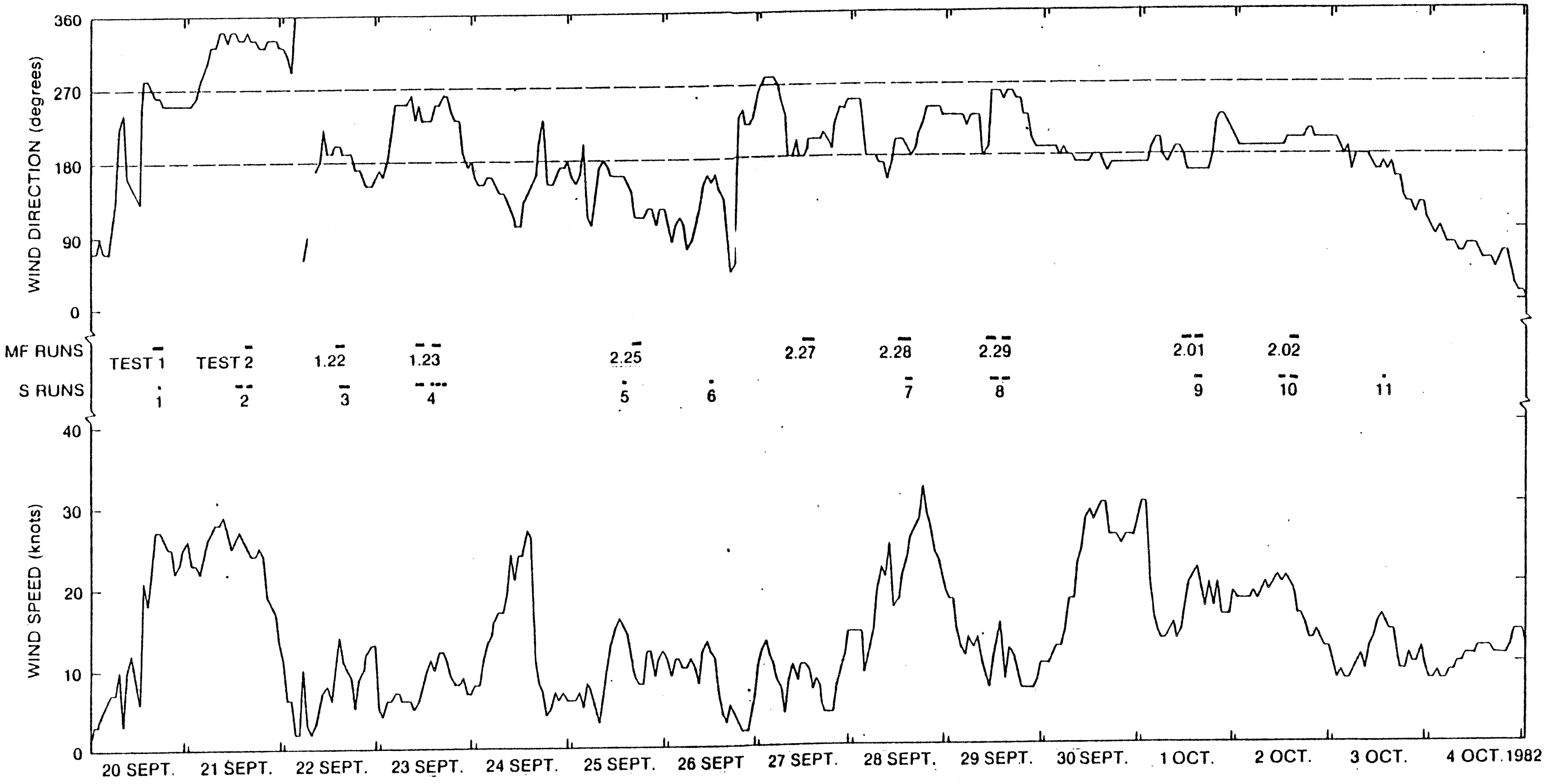
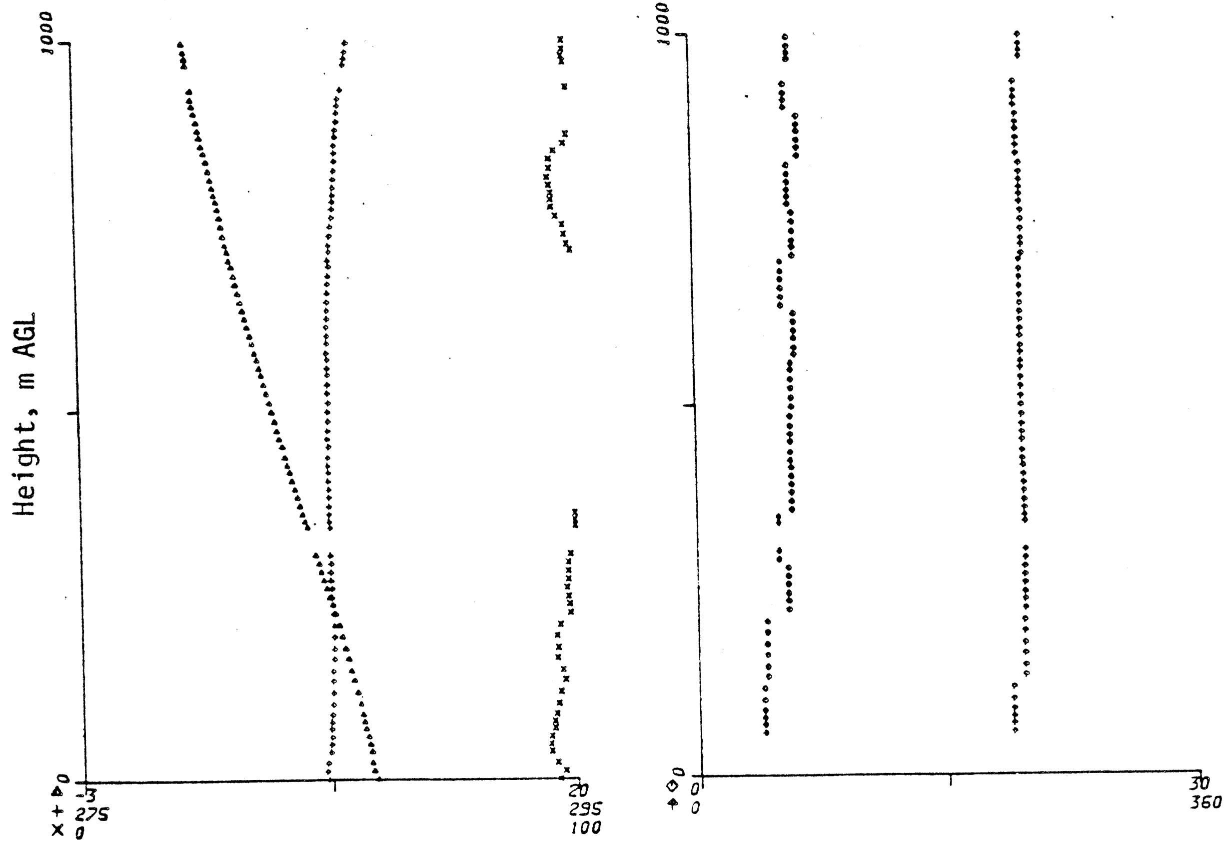


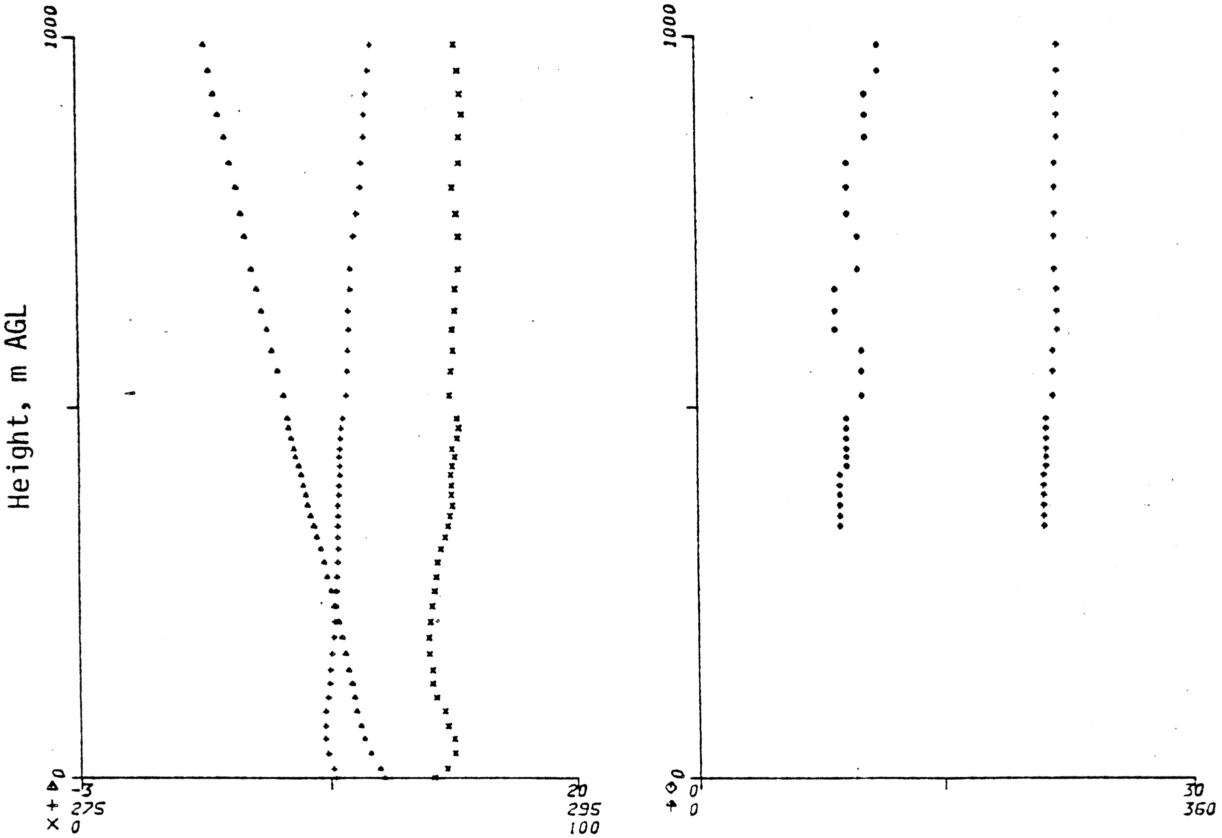
Fig 4.2 Benbecula airport surface winds for the period 20 September - 4 October 1982 showing mean flow and RS sonic data collection periods for the experiment. Large axis markers on time axis are at 00 hr BST, smaller ones are 00 hr GMT. Figure plotted from hourly observations reported by airport meteorological station.

Fig 4.3 AIRsonde profiles to 1000 m AGL obtained during Askervein 82.

Δ Dry bulb temperature, °C
\+ Potential temperature, °K
x Relative humidity %
♦ Wind speed m s^{-1}
↑ Wind direction °magnetic
Times are BST


82/09/23 11:09

82/09/23 15:12



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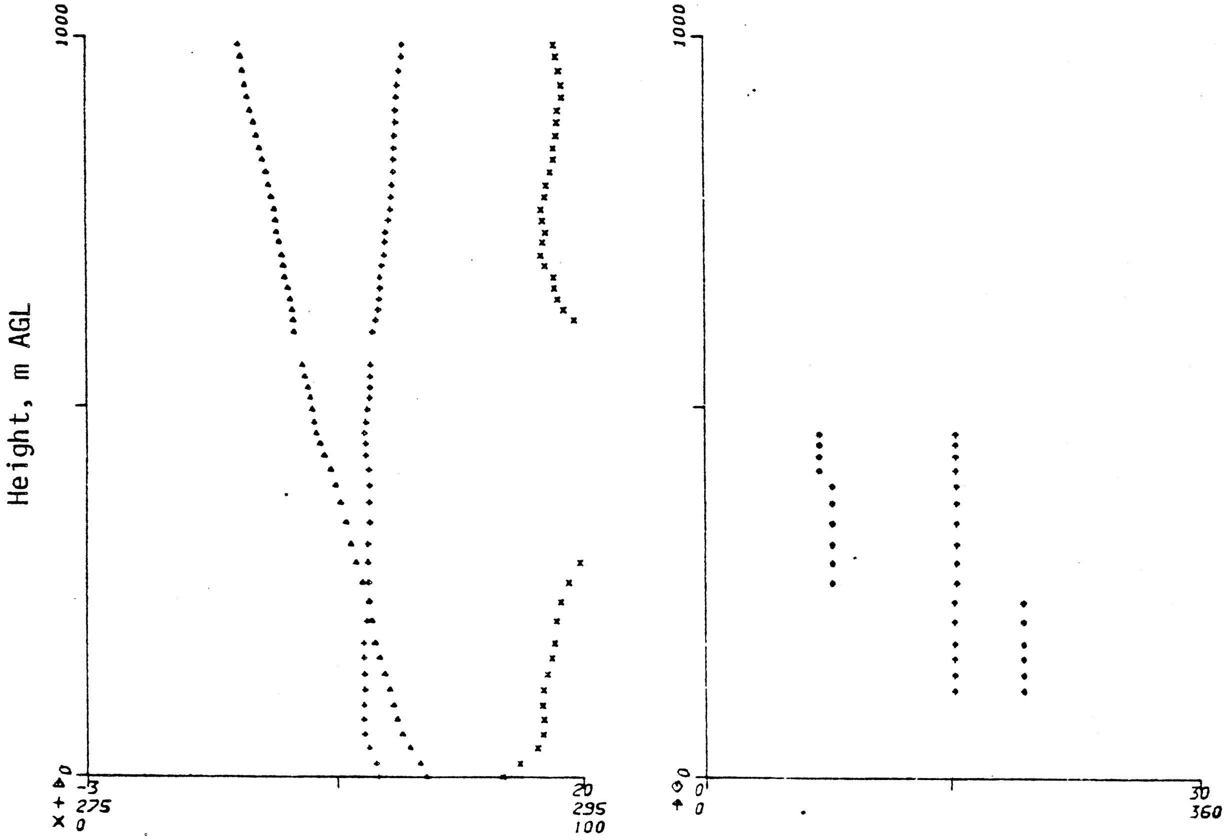

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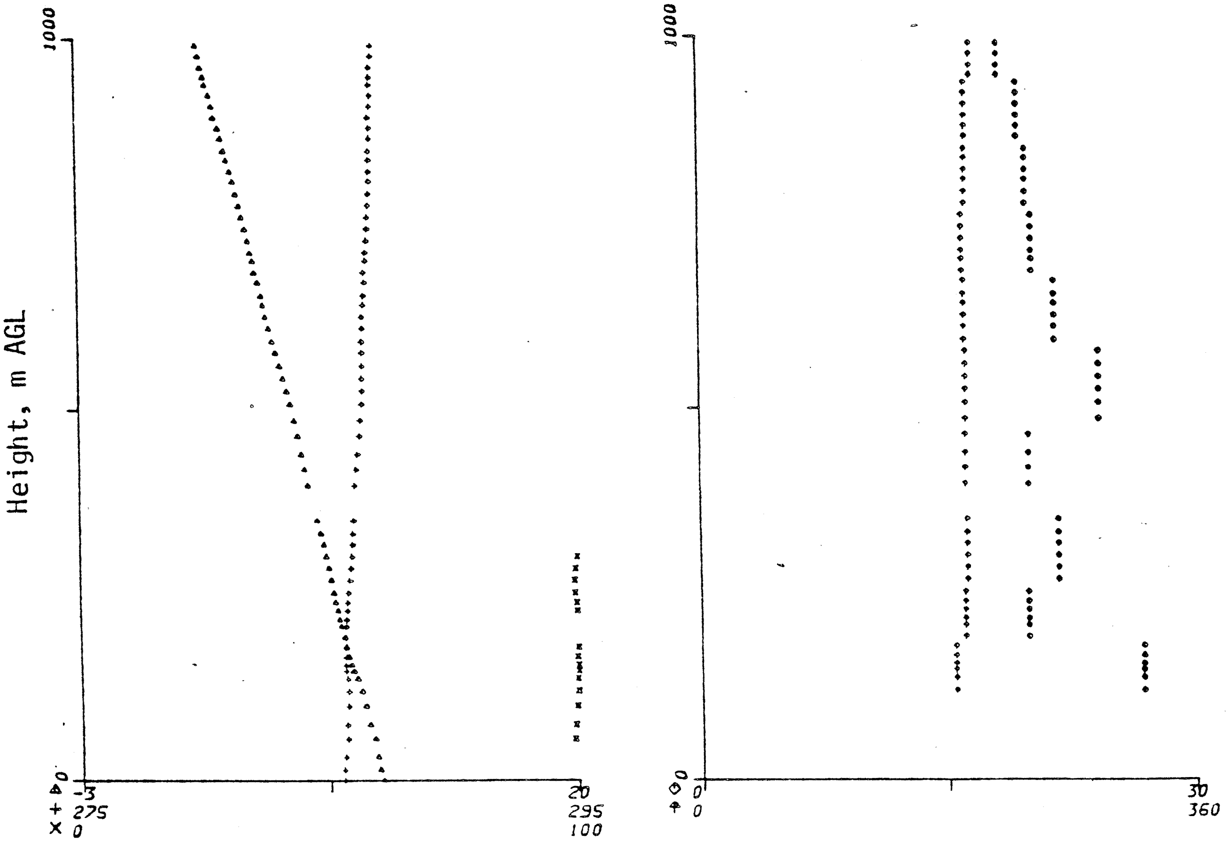

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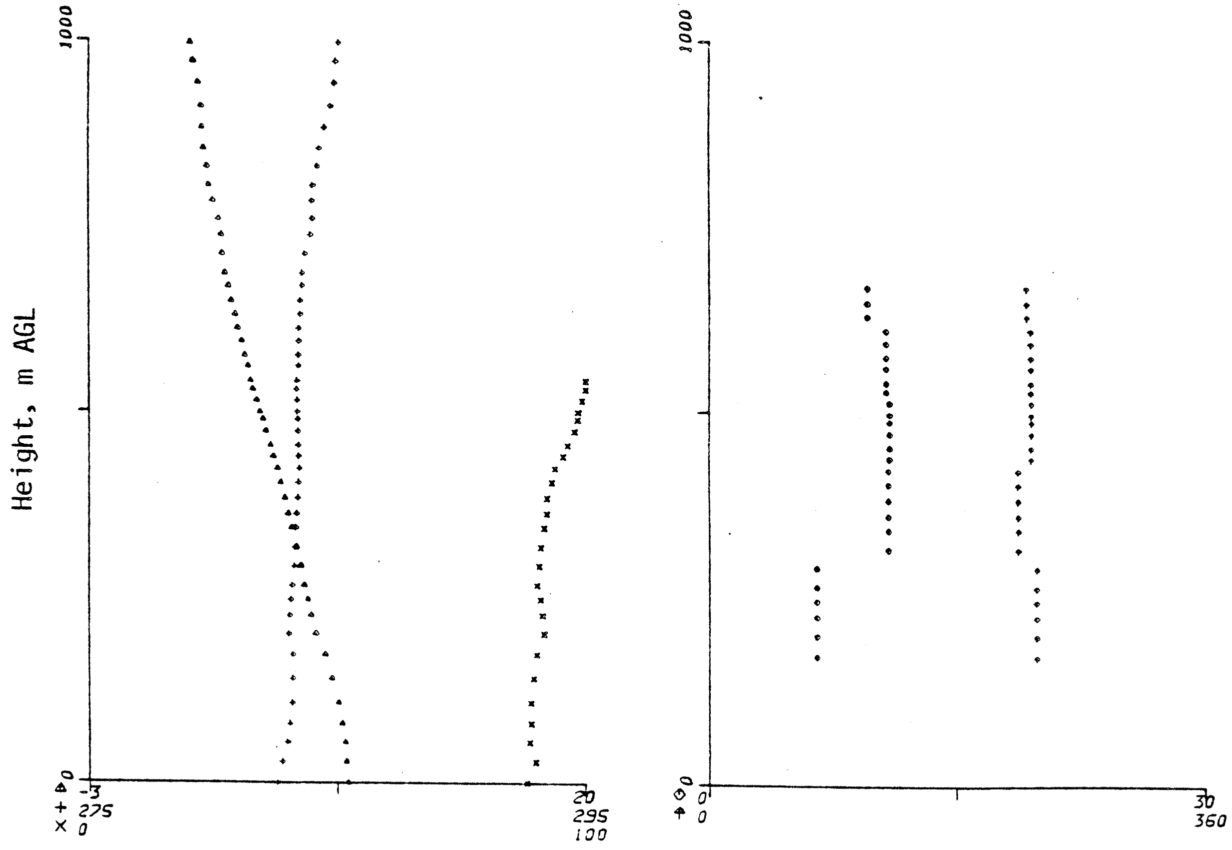
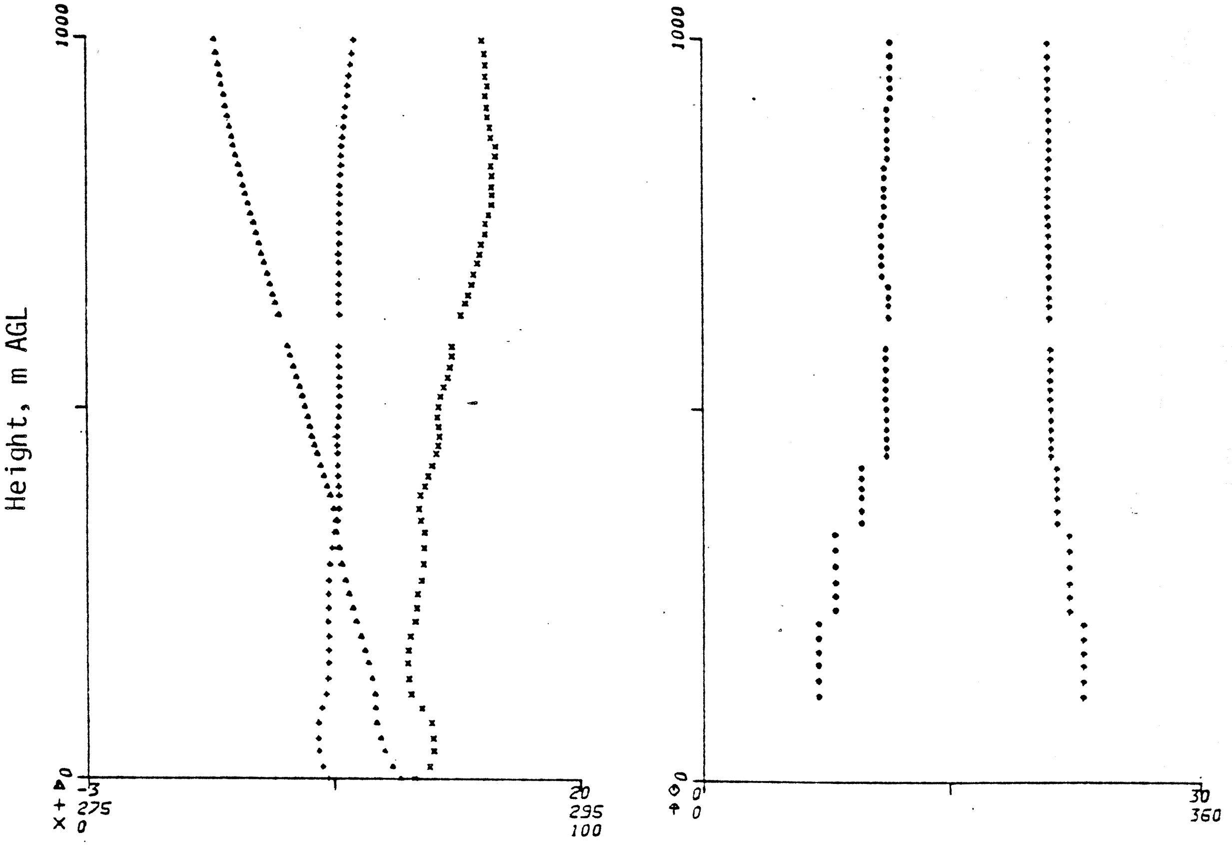


82/09/29 16:23



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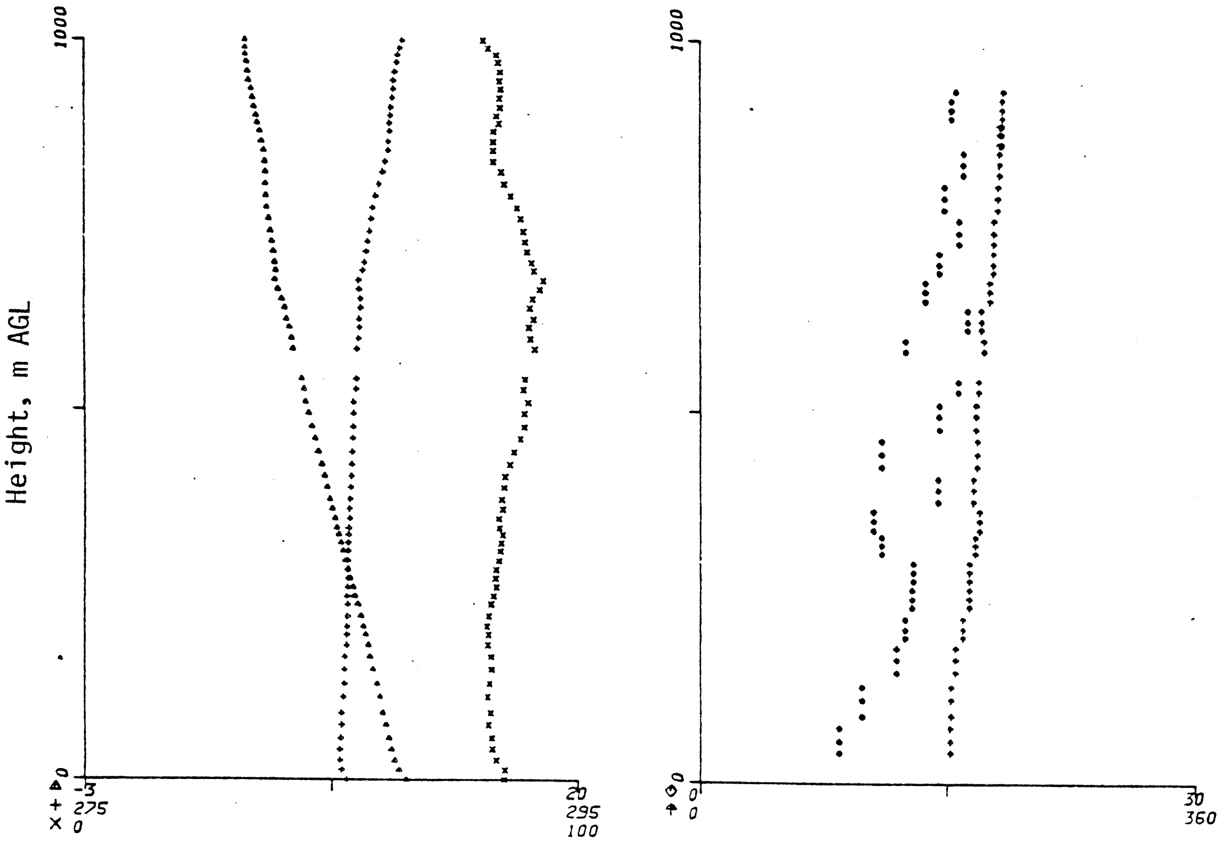

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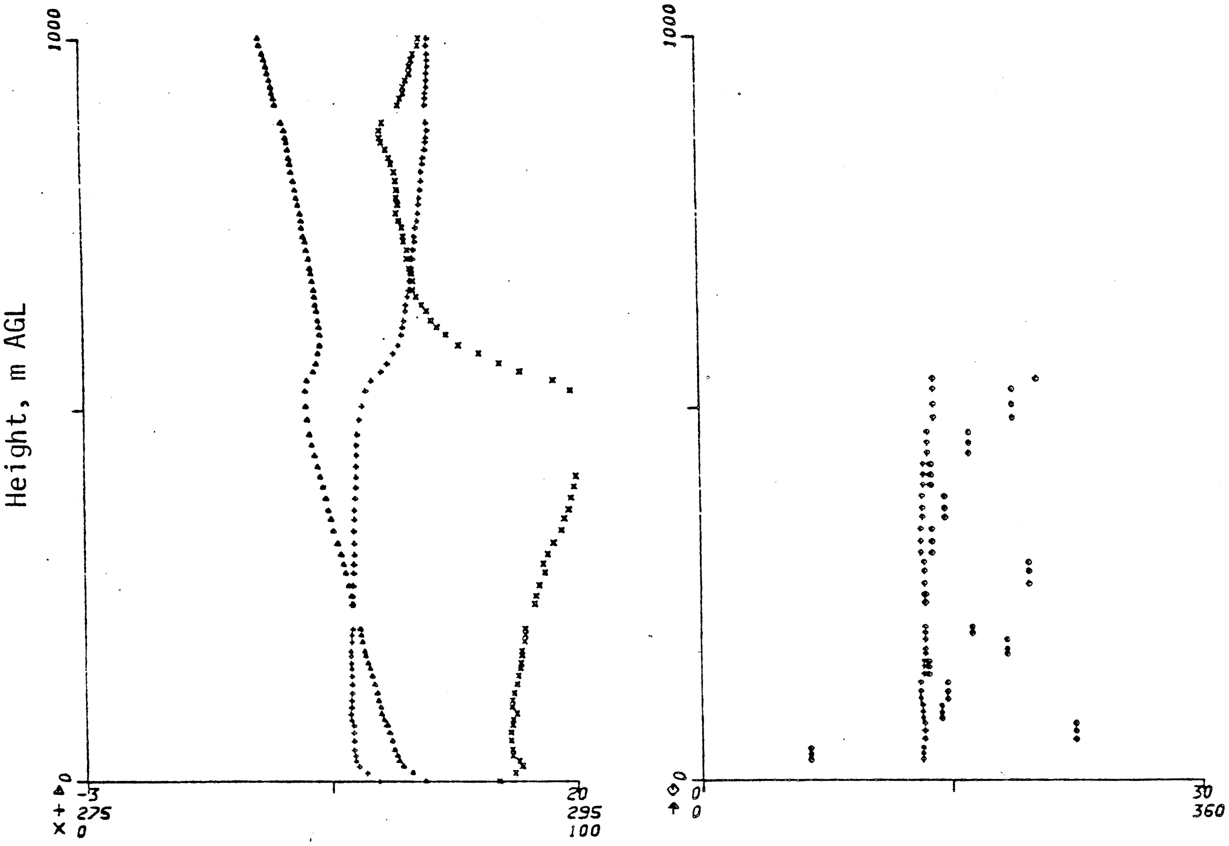
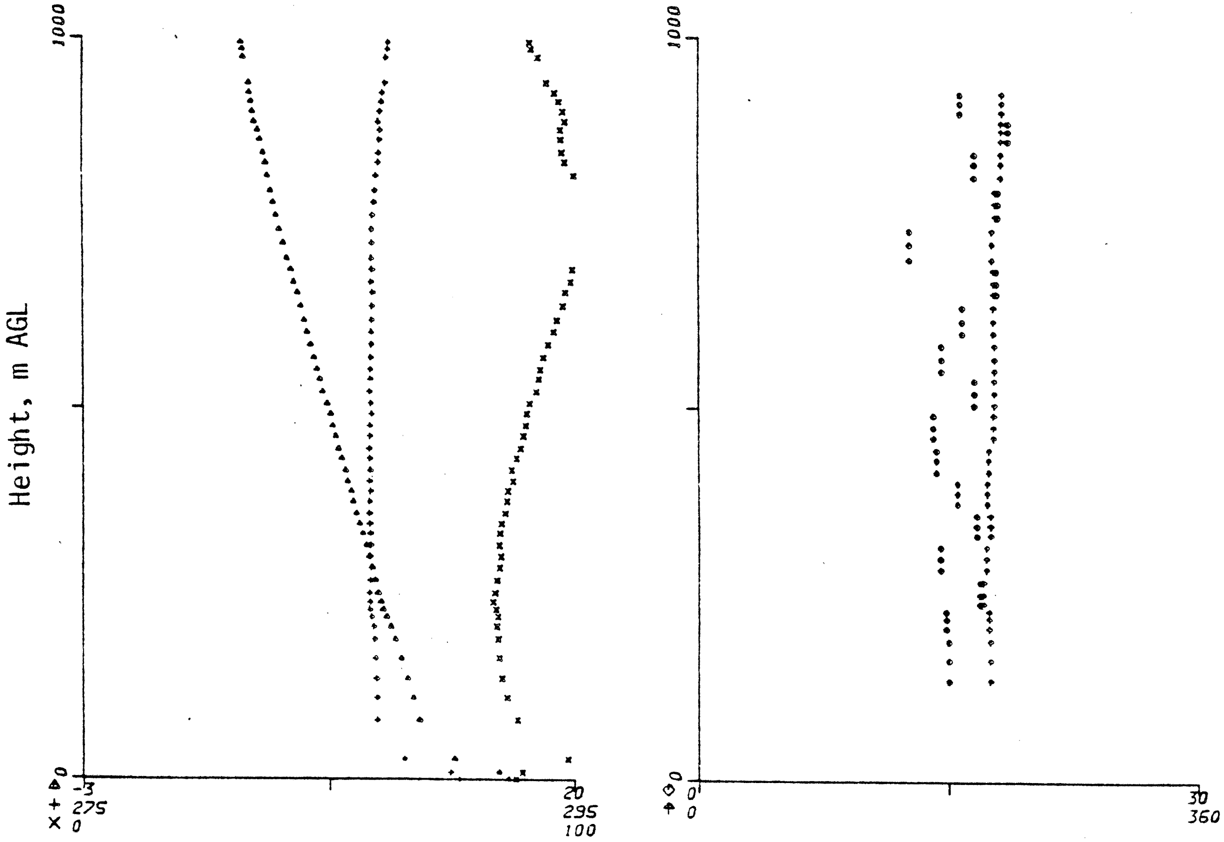


82/10/02 13:28



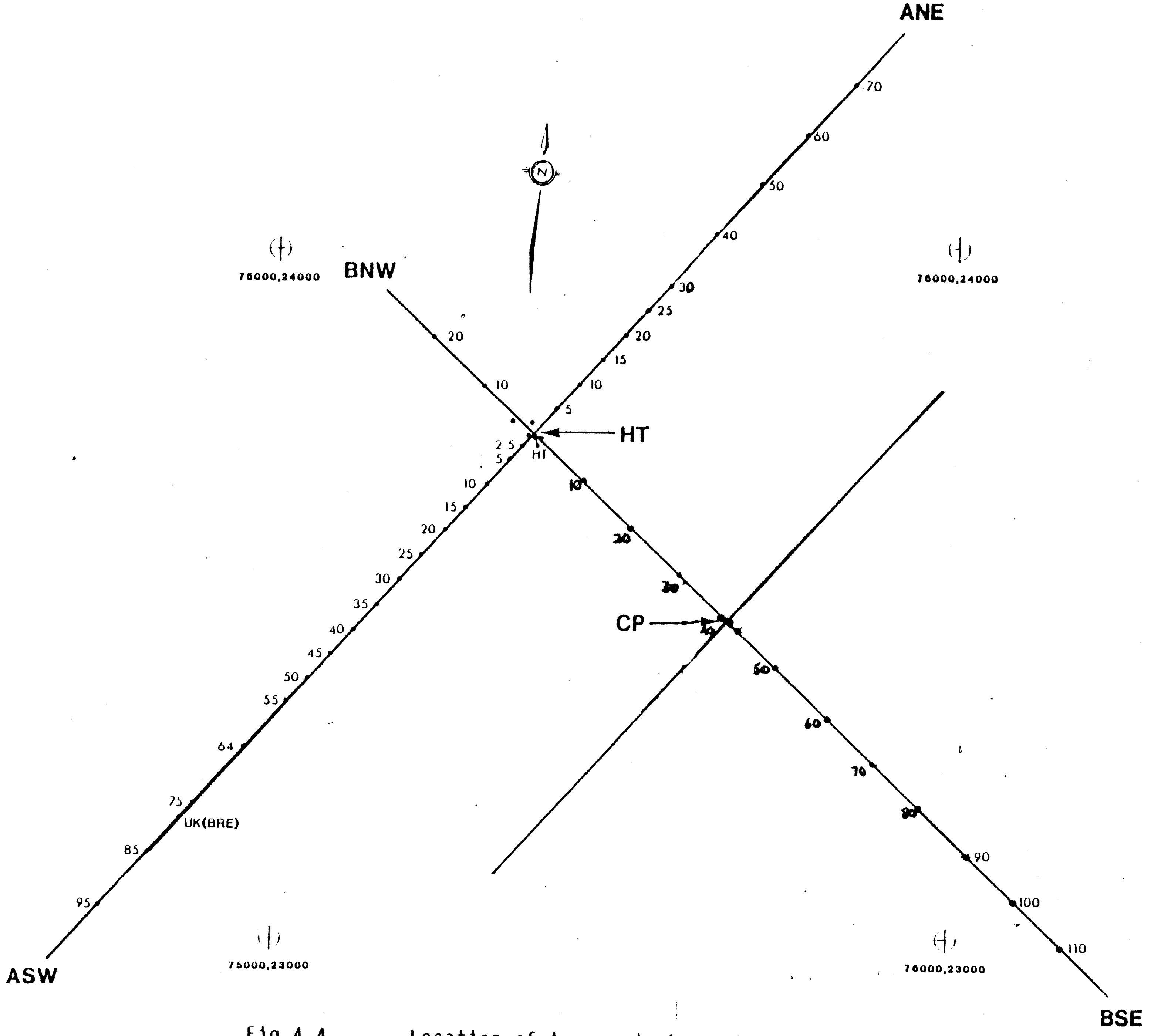
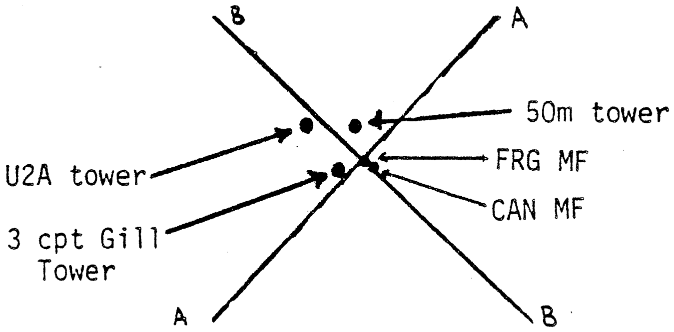
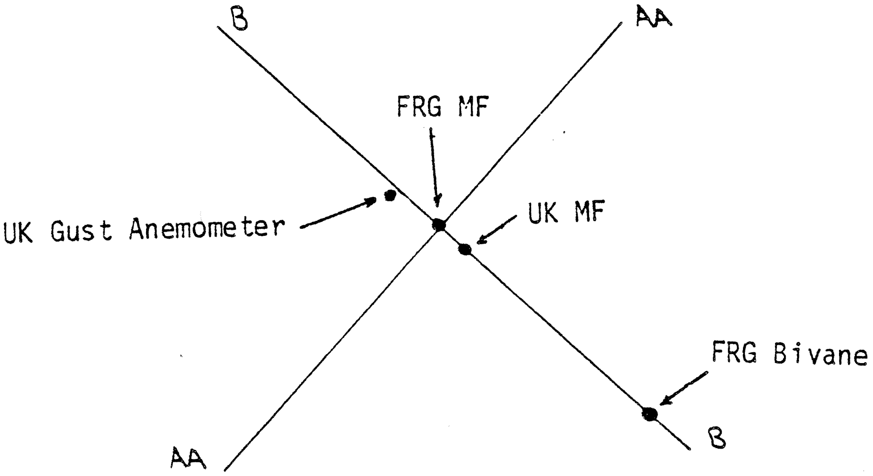


Fig 4.4 Location of towers during Askervein 82

a) Positions based on theodolite survey



b) Sketch of tower deployment near HT



c) Sketch of tower deployment near CP

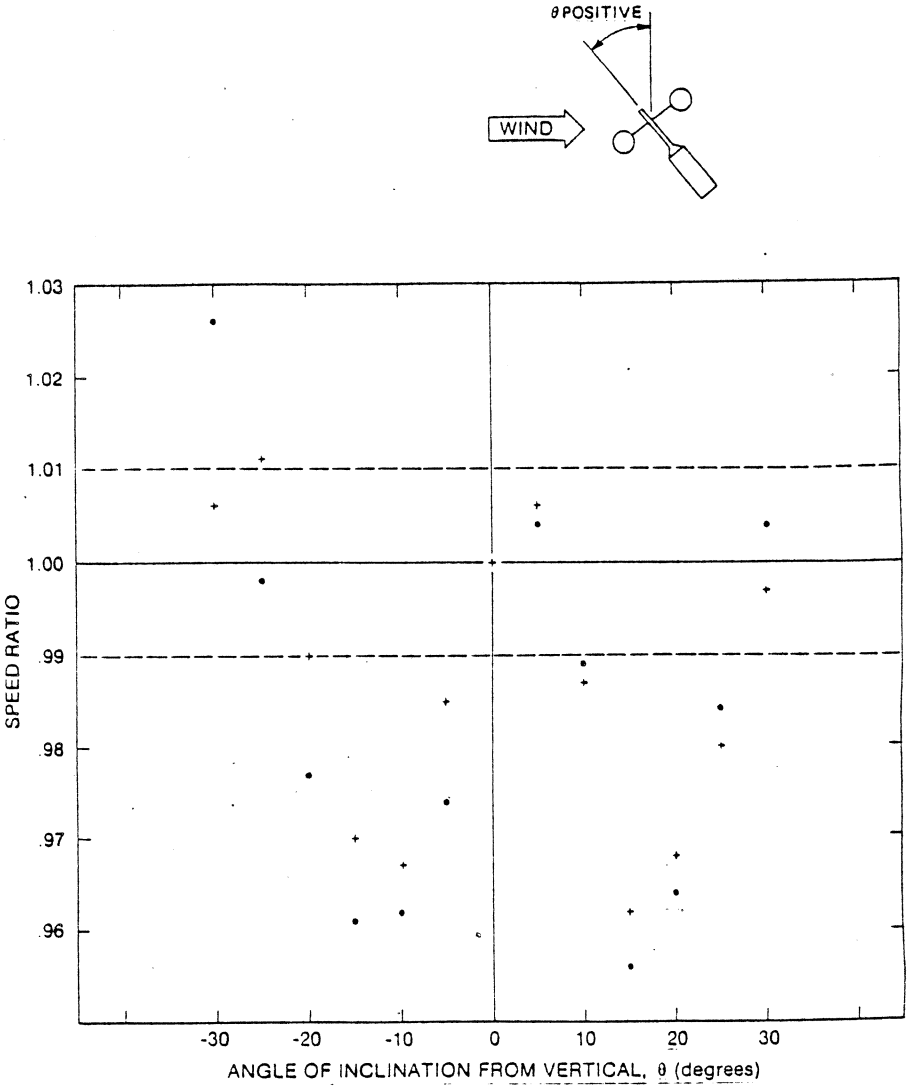


Fig 5.1 Results of AES wind tunnel tests on the response of Gill 3-cup anemometers to tilt angle. Based on measurements made 12/11/82.

- System P21
+ System P22

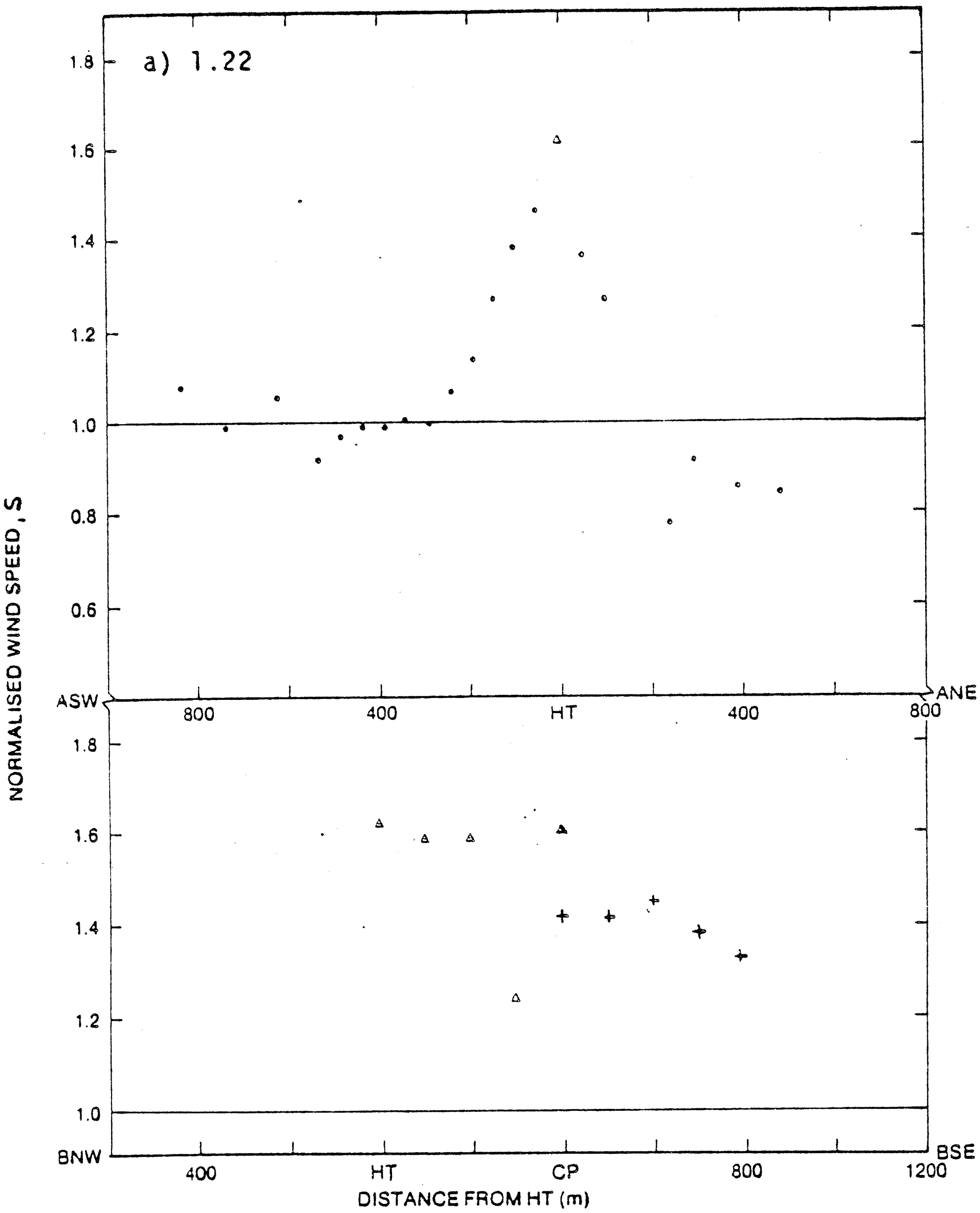
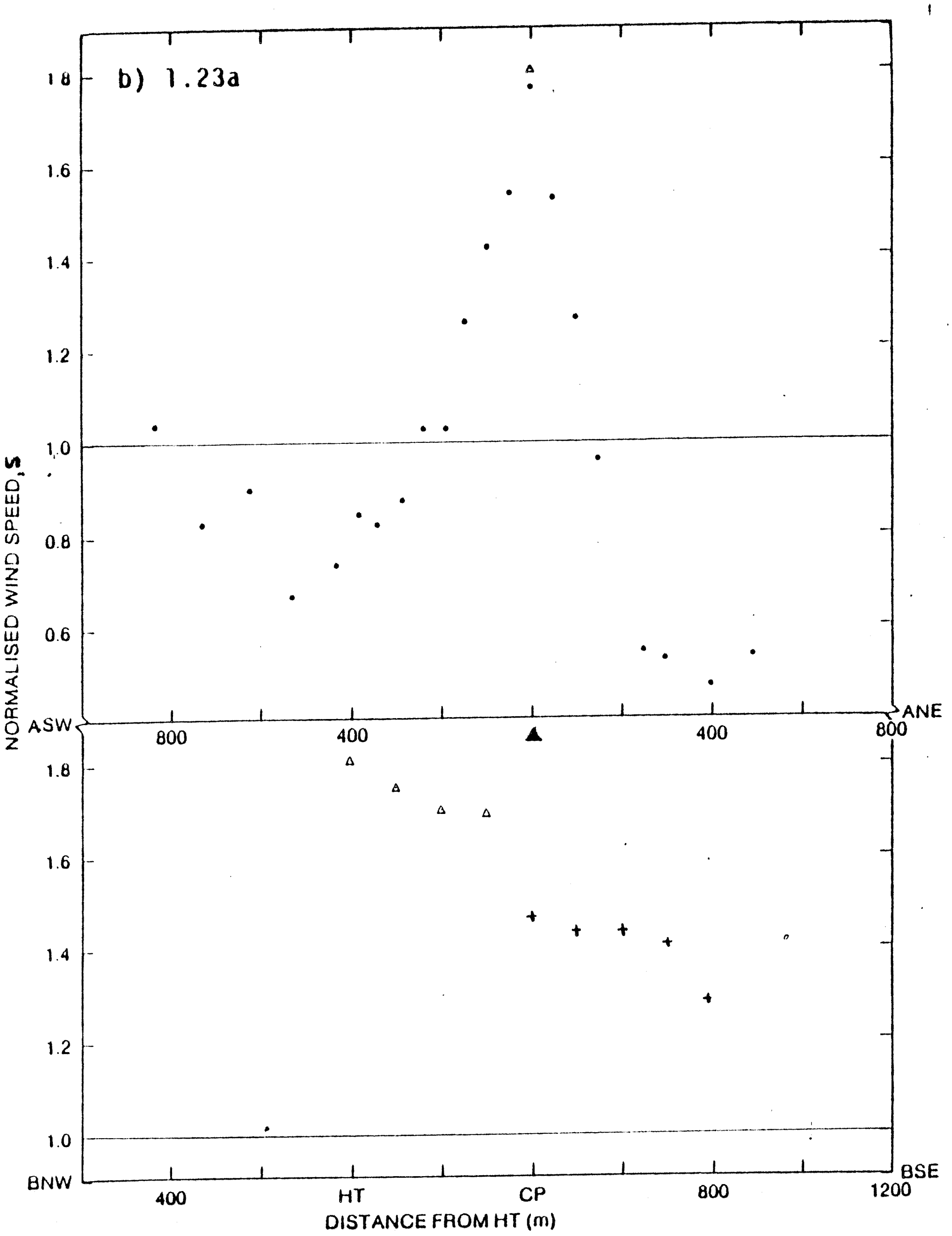
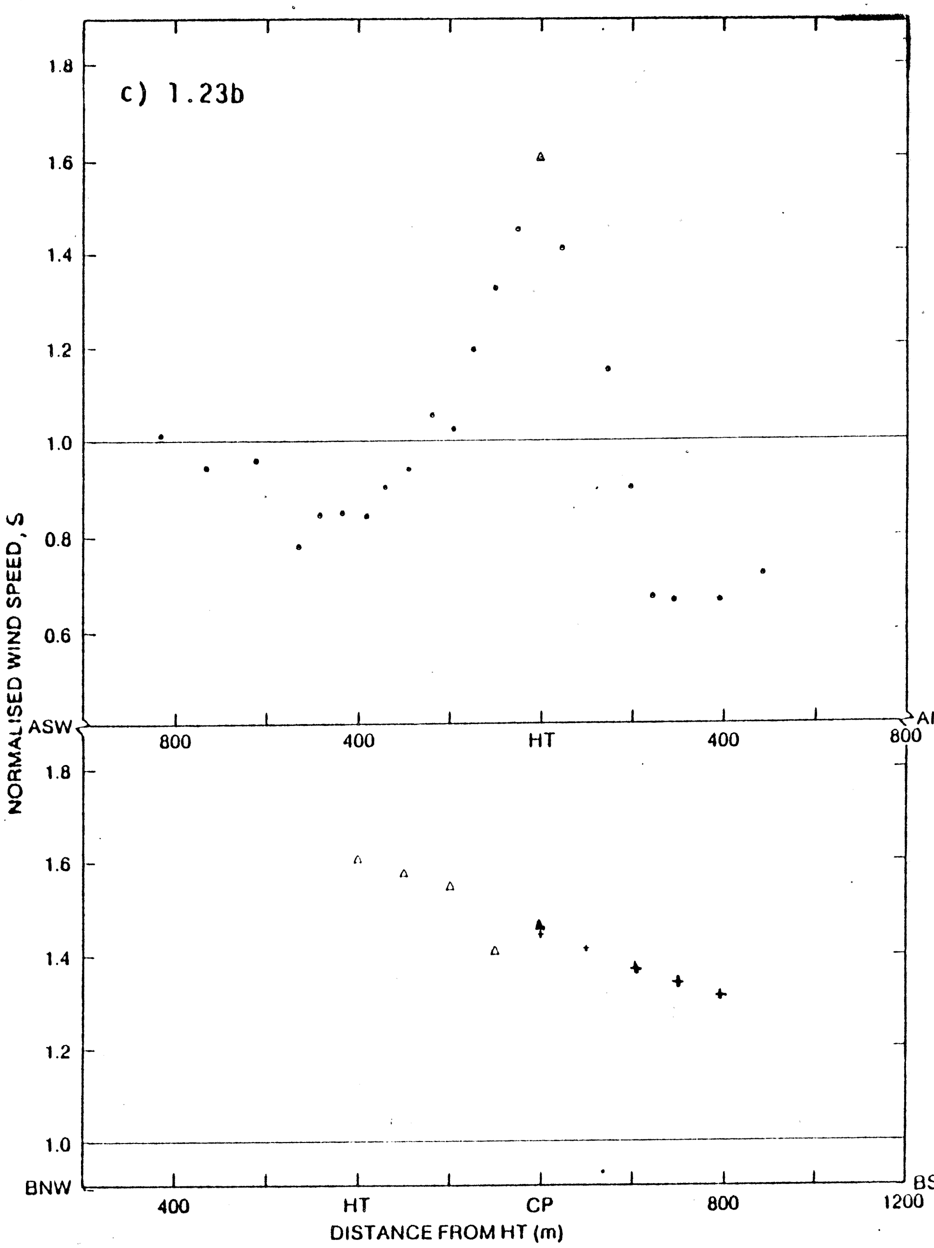


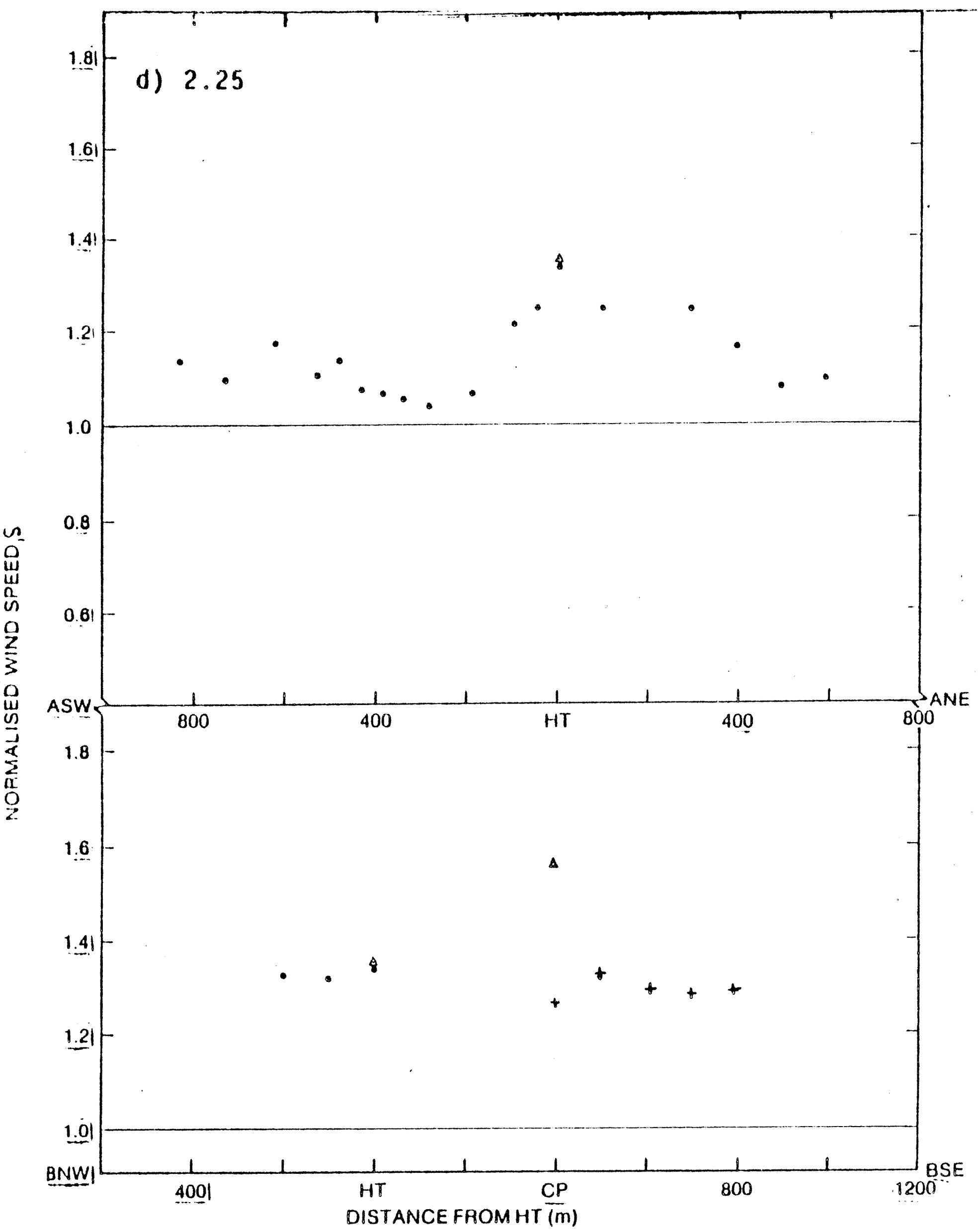
Fig 5.2 (a-k) Normalized wind speeds at 10 m elevation along lines A and B during MF runs. Data plotted are averages for each run based on half hourly values of S, the ratio of the half hour average wind speed at a given location to the wind speed at RS for the same period. Different tower systems are identified:-

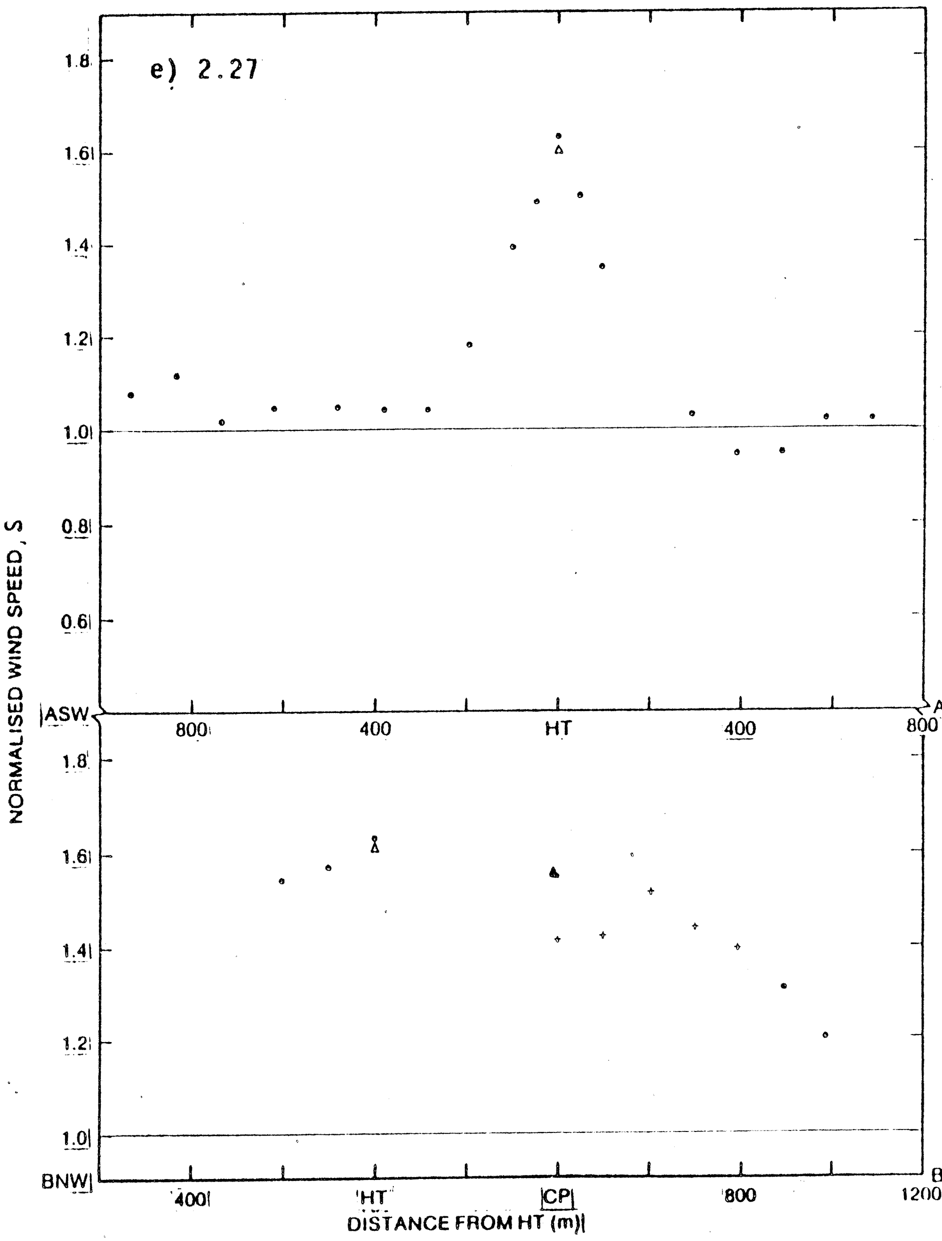
- • AES
- + ERA
- Δ University of Hanover (FRG)

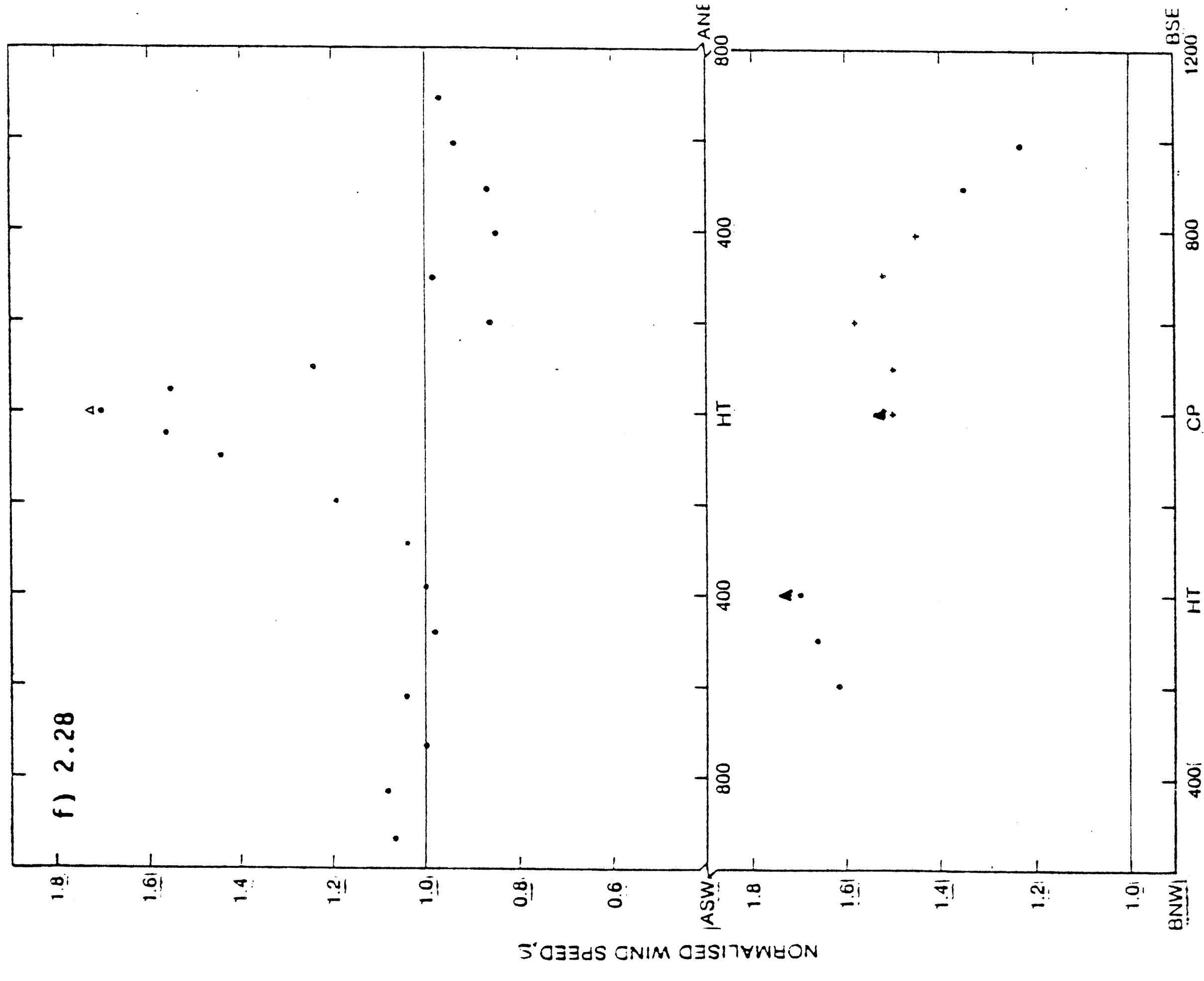
Sequence of runs is a) 1.22, b) 1.23a, c) 1.23b, d) 2.25, e) 2.27, f) 2.28, g) 2.29a, h) 2.29b, i) 2.01a, j) 2.01b, k) 2.02

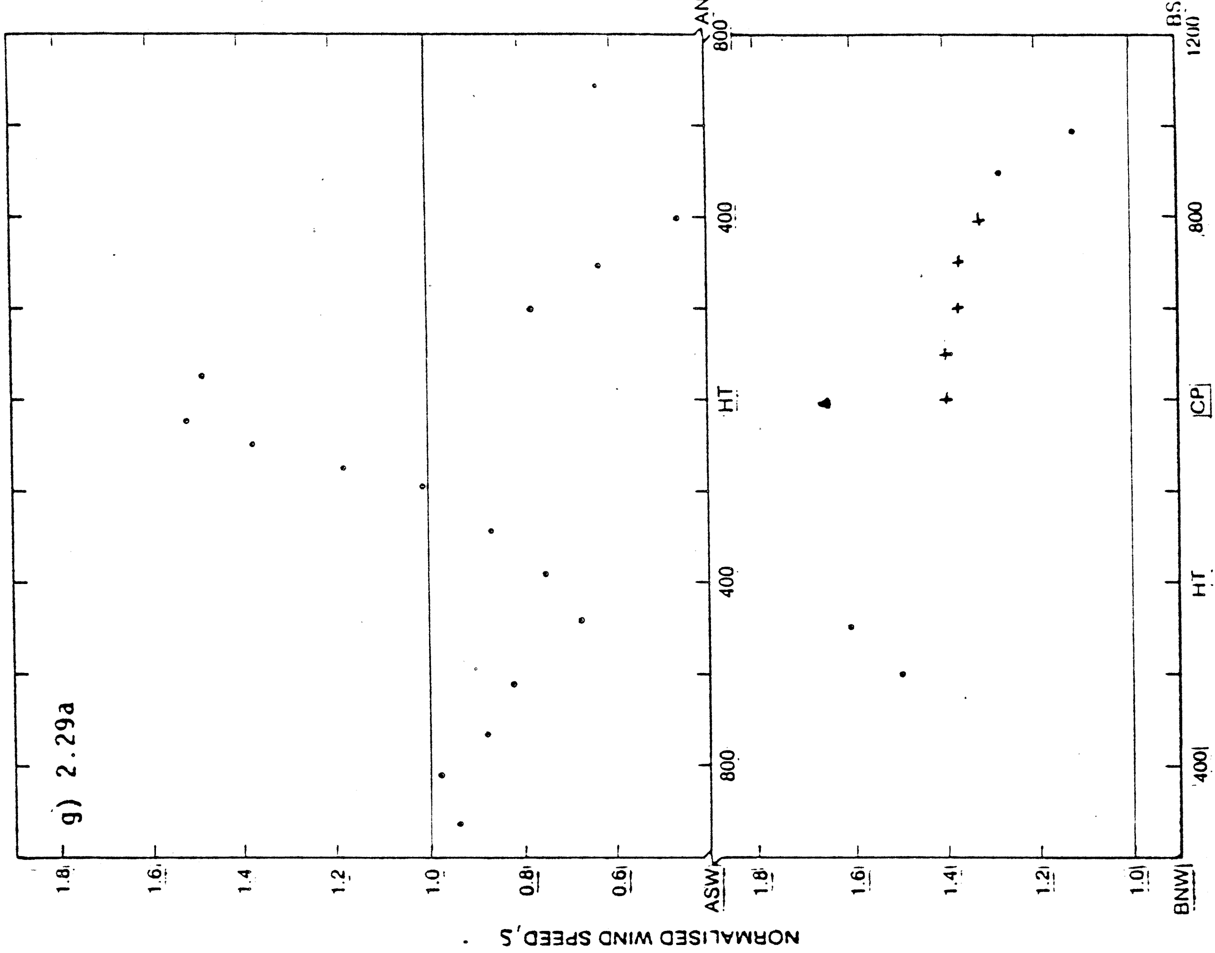

b) 1.23a
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
800
400
400
800
ANE
1.8
1.6
1.4
1.2
1.0
BNW
400
HT
CP
800
1200
BSE
DISTANCE FROM HT (m)

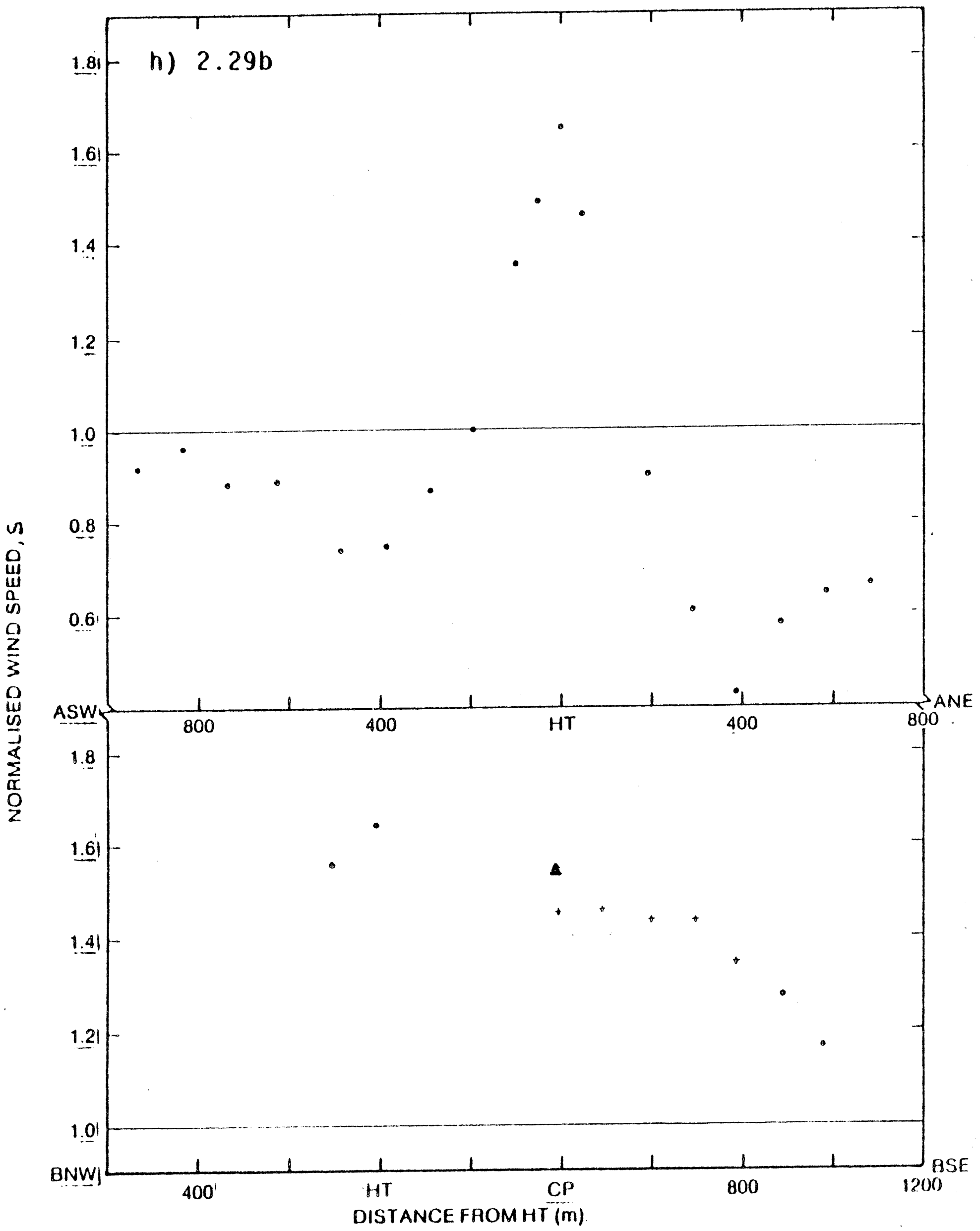

c) 1.23b
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
800
400
HT
400
800
ANE
1.8
1.6
1.4
1.2
1.0
BNW
400
HT
CP
800
1200
BSE
DISTANCE FROM HT (m)

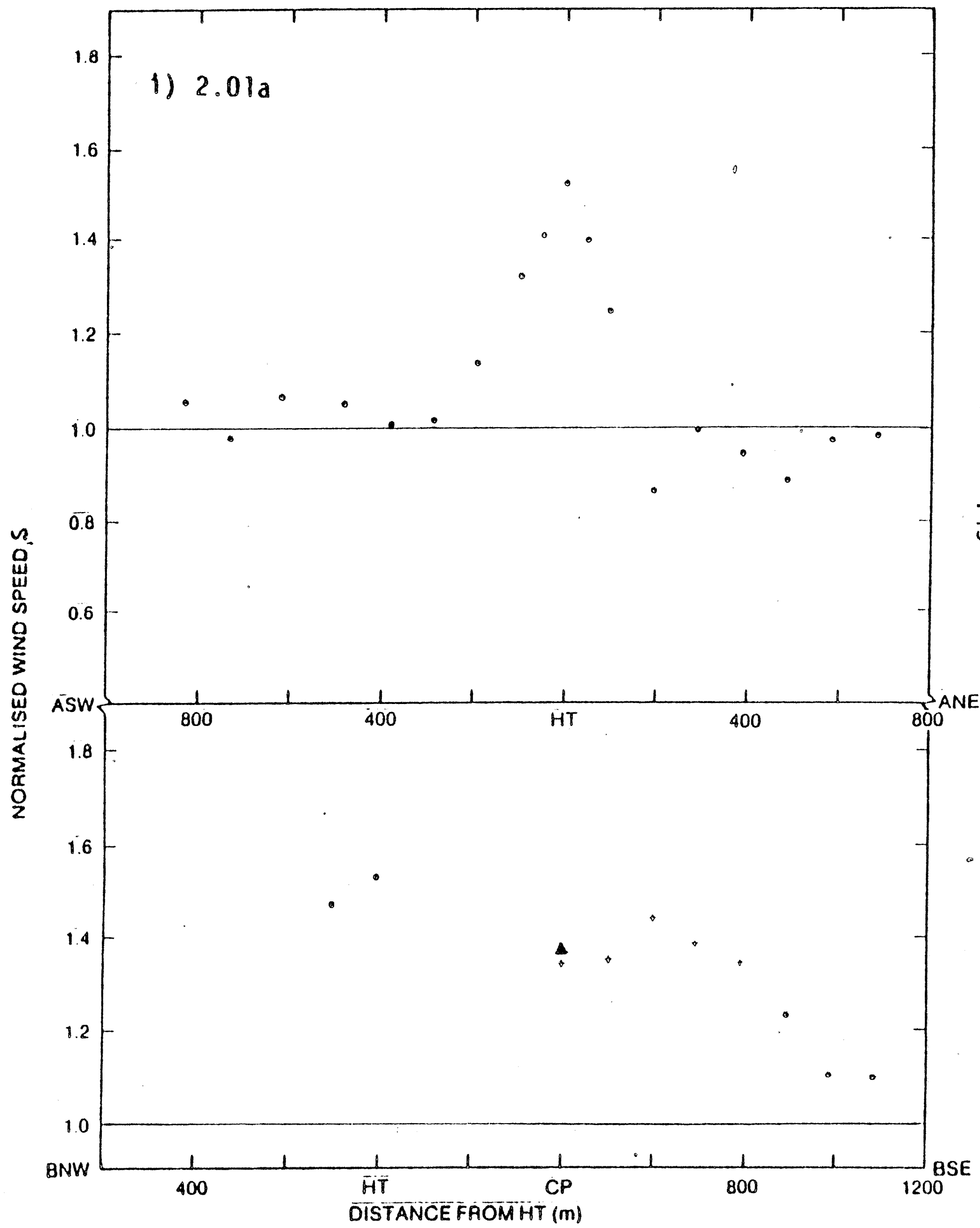

d) 2.25
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)

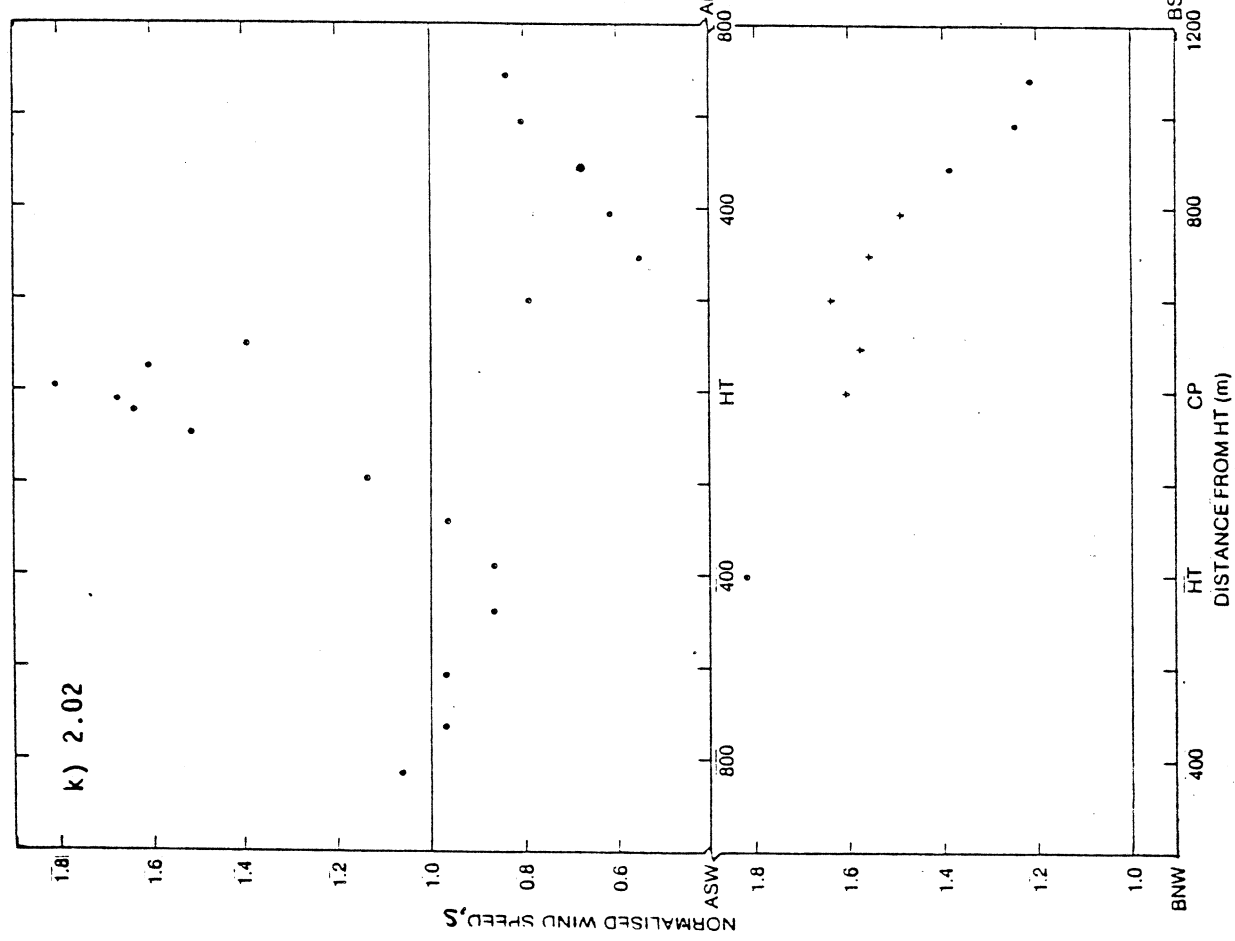

e) 2.27
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)

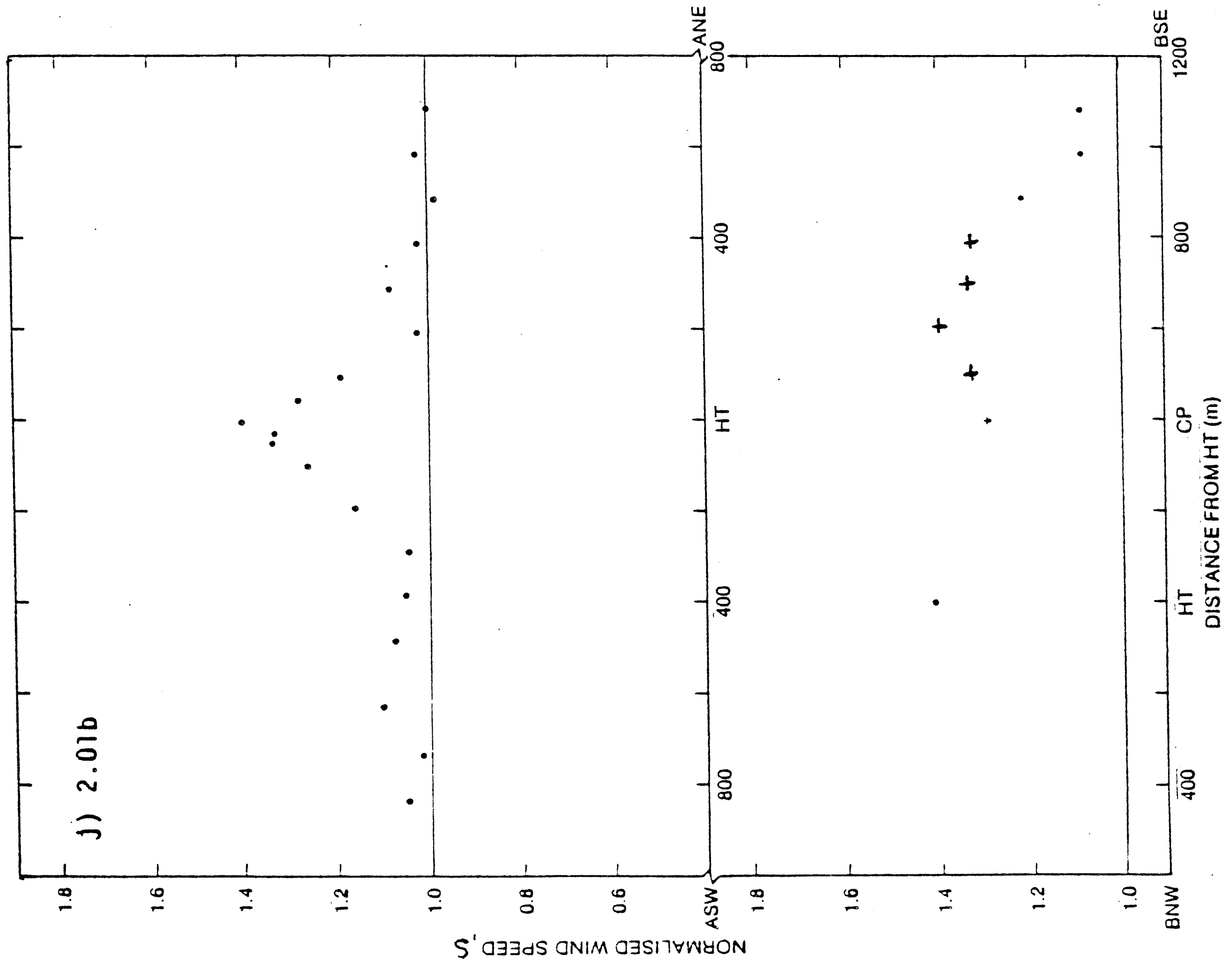

f) 2.28
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)


g) 2.29a
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)


h) 2.29b
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)


i) 2.01a
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
800
400
HT
400
800
1.8
1.6
1.4
1.2
1.0
BNW
BSE
400
HT
CP
800
1200
DISTANCE FROM HT (m)


k) 2.02
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
BNW
BSE
800
400
HT
400
800
1200
CP
DISTANCE FROM HT (m)


j) 2.01b
NORMALISED WIND SPEED, S
1.8
1.6
1.4
1.2
1.0
0.8
0.6
ASW
ANE
BNW
BSE
800
400
HT
400
800
1200
CP
DISTANCE FROM HT (m)

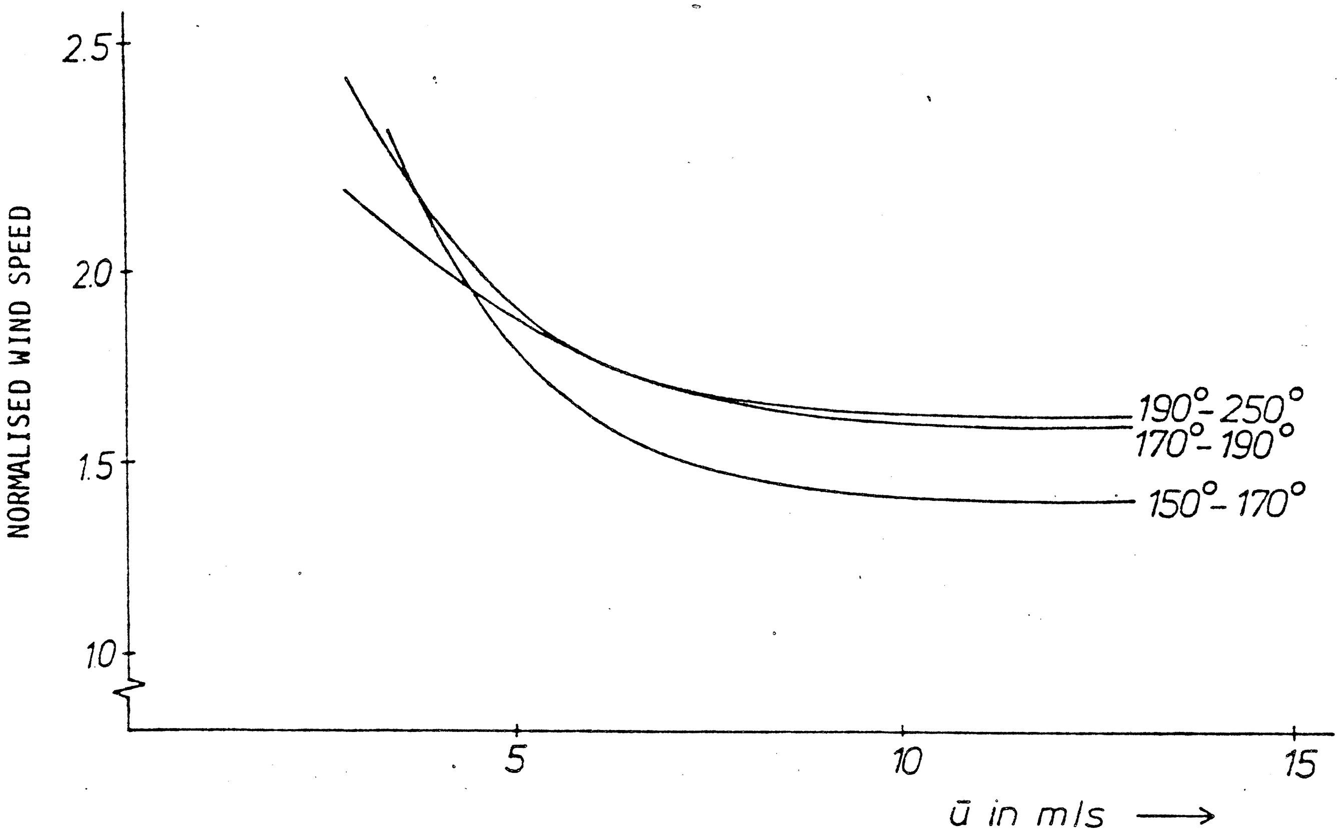


Fig 5.3 Normalized wind speed at 10m height at CP as a function of reference site wind speed and wind direction. Data from period 29/9/82 - 3/10/82.

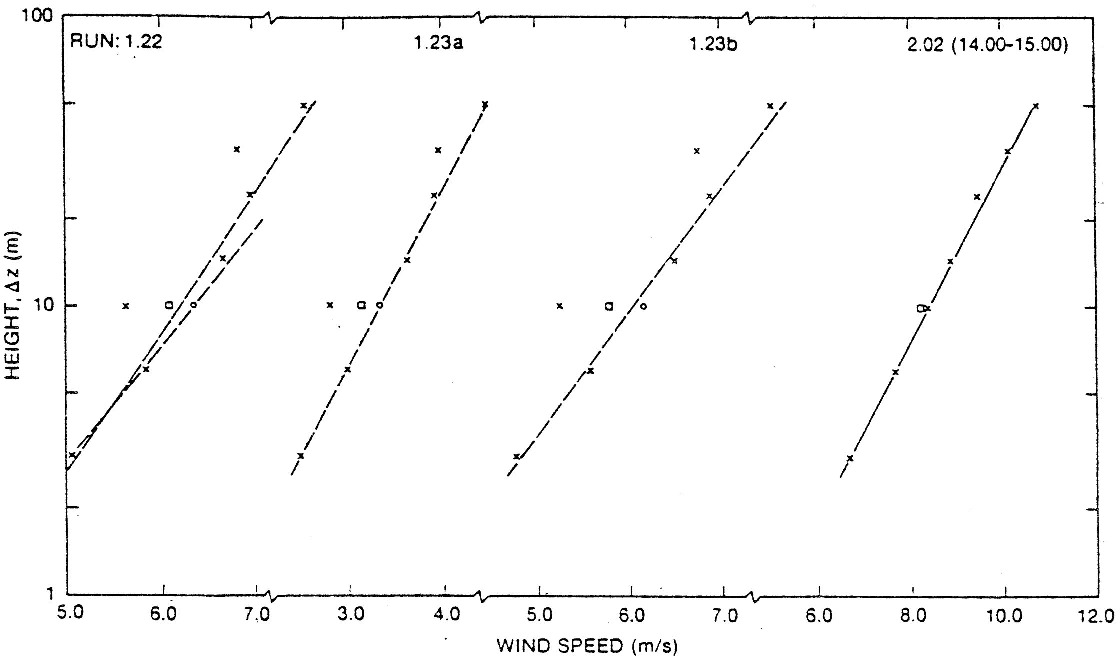


Fig. 5.4 Wind speed profiles to 50 m at RS during MF runs 1.22, 1.23a, 1.23b and 2.02.

x Gill 3-cup anemometers (tachometer-generator type)
o Gill 3-cup anemometer (pulse type) on 10 m post
□ 3 cpt Gill propeller anemometer at 10 m level

– – – – – – Subjectively drawn profiles

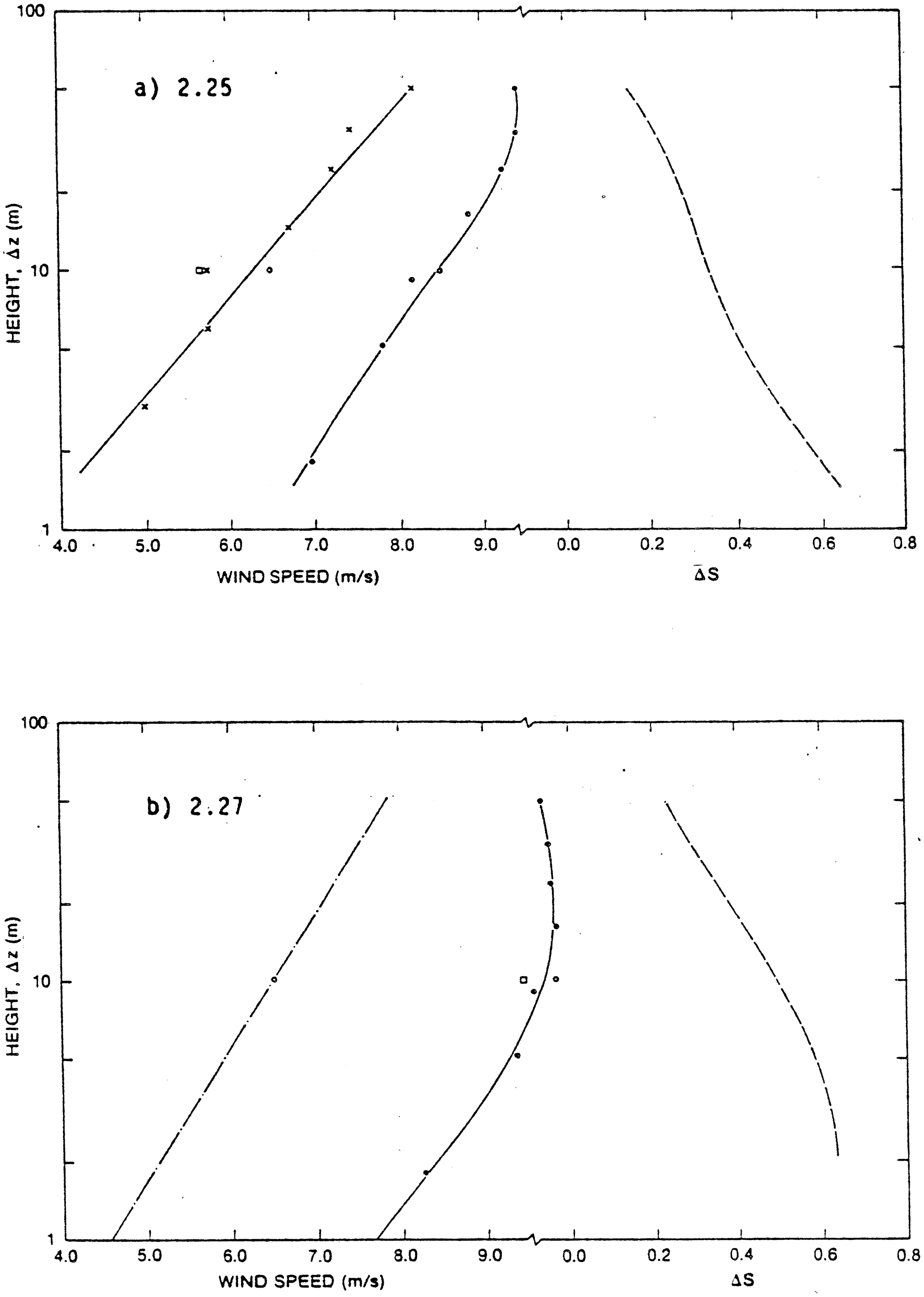
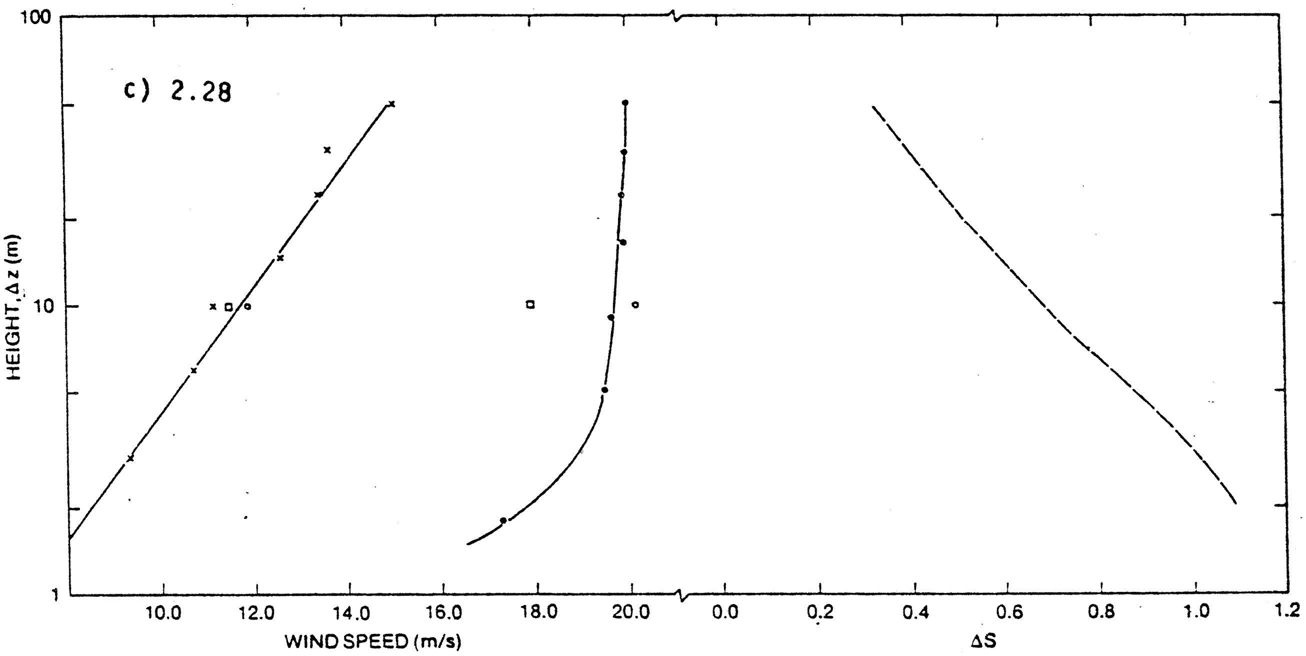
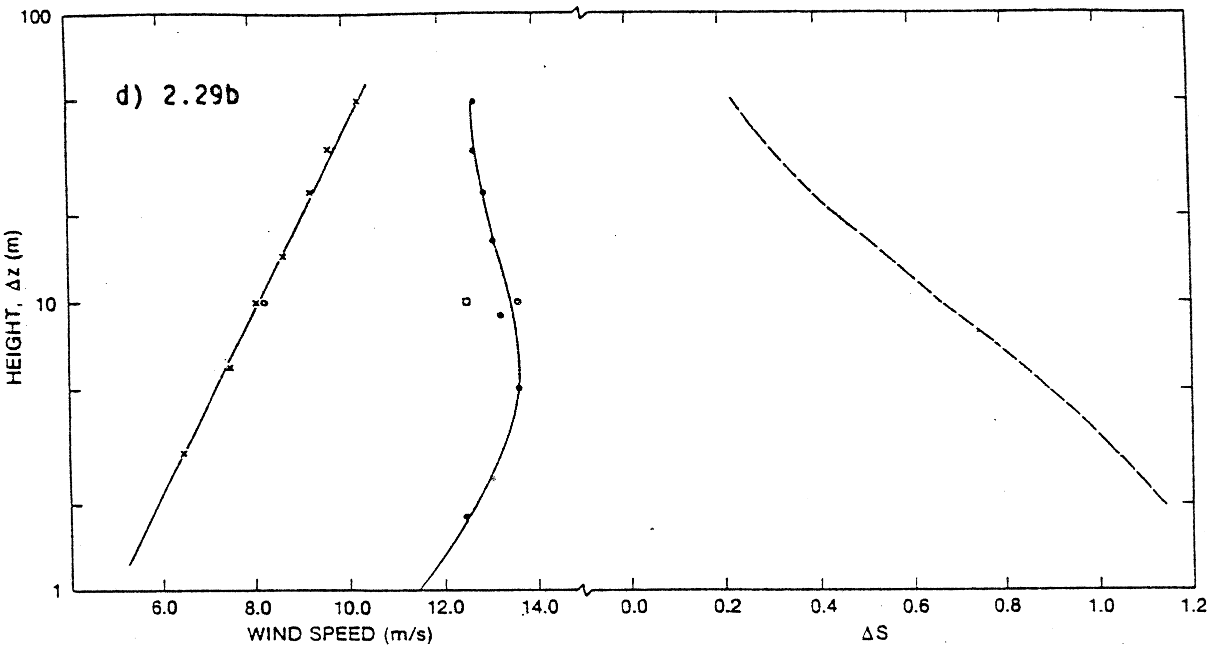


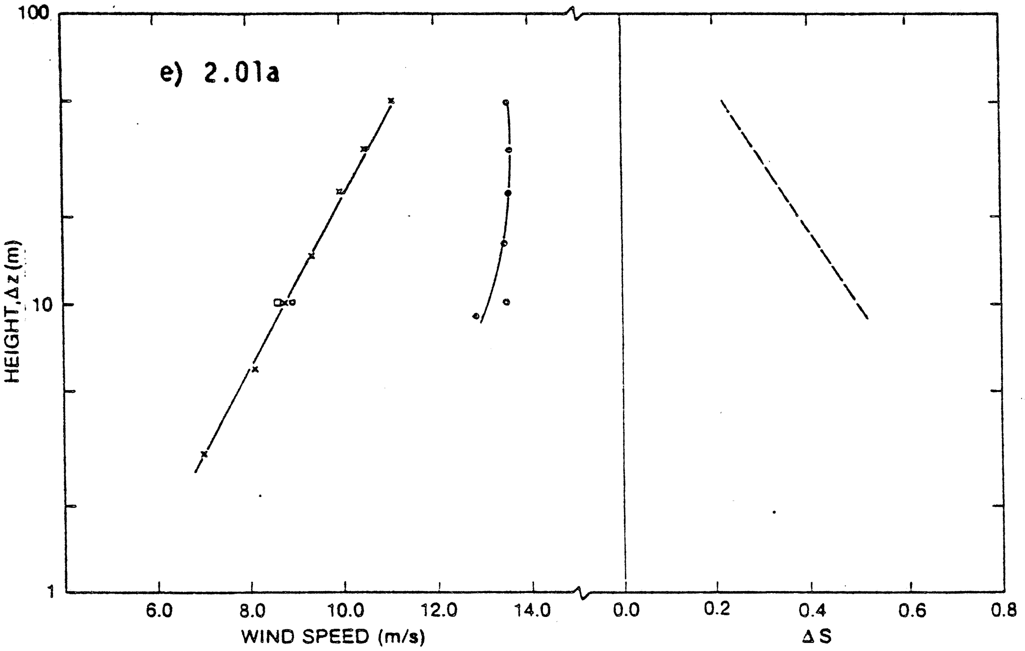
Fig. 5.5 Wind speed and ΔS profiles to 50 m at RS and HT during MF runs: a) 2.25, b) 2.27, c) 2.28, d) 2.29b, e) 2.01a and f) 2.01b. Same notation as Fig 5.4 but with Gill 3 cup anemometer data at HT denoted by •.

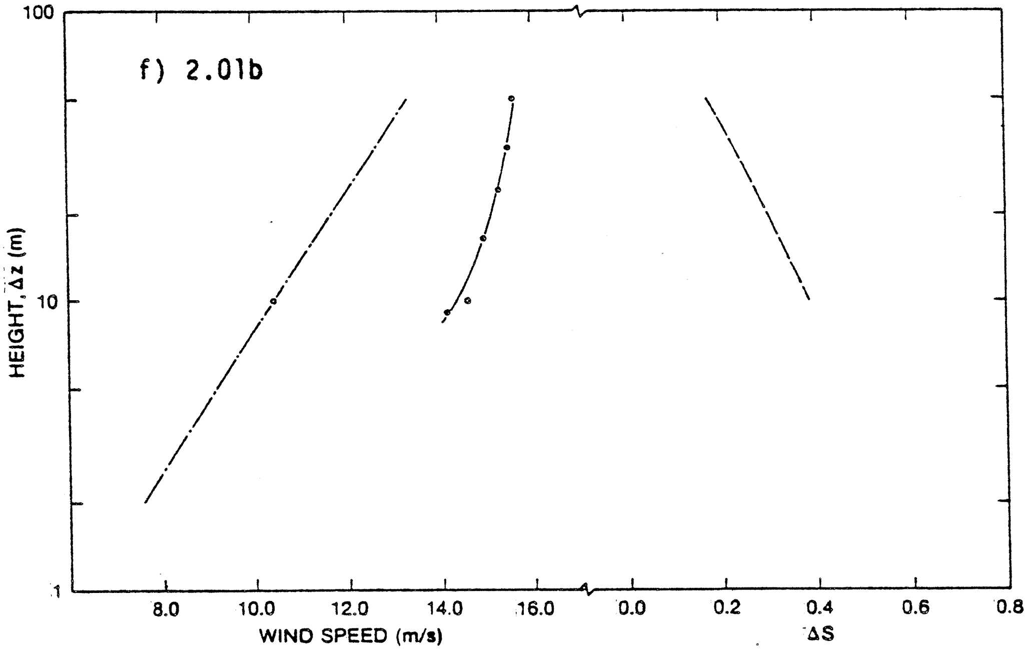
—— · —— · —— · —— Log profile at RS based on z_0 = 0.03 m and using 10 m MF post data.

- - - - - - - - - - - - ΔS profile calculated from velocity profiles drawn.


c) 2.28
100
10
1
HEIGHT, Δz (m)
10.0
12.0
14.0
16.0
18.0
20.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
WIND SPEED (m/s)
ΔS


d) 2.29b
100
10
1
HEIGHT, Δz (m)
6.0
8.0
10.0
12.0
14.0
0.0
0.2
0.4
0.6
0.8
1.0
1.2
WIND SPEED (m/s)
ΔS


e) 2.01a
100
10
1
HEIGHT, Δz (m)
6.0
8.0
10.0
12.0
14.0
0.0
0.2
0.4
0.6
0.8
WIND SPEED (m/s)
ΔS


f) 2.01b
100
10
1
HEIGHT, Δz (m)
8.0
10.0
12.0
14.0
16.0
0.0
0.2
0.4
0.6
0.8
WIND SPEED (m/s)
ΔS

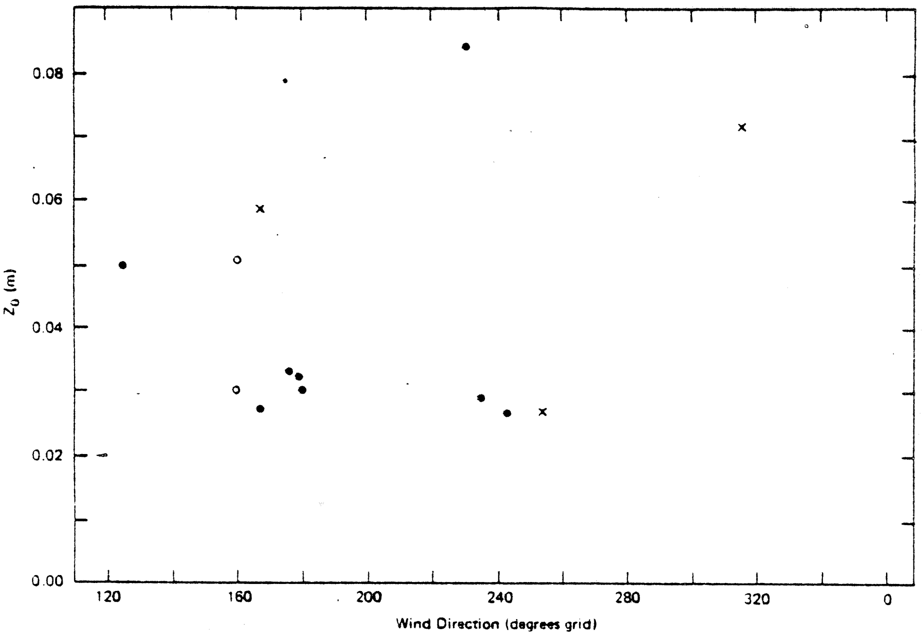


Fig. 5.6 Surface roughness at RS for different wind directions

- ● based on 50 m profiles in Figs 5.3, 5.4
- o based on 50 m profiles in Fig 6.14 and 6.16
- x based on AES sonic anemometer measurements at Δz = 10 m (Table 6.4)

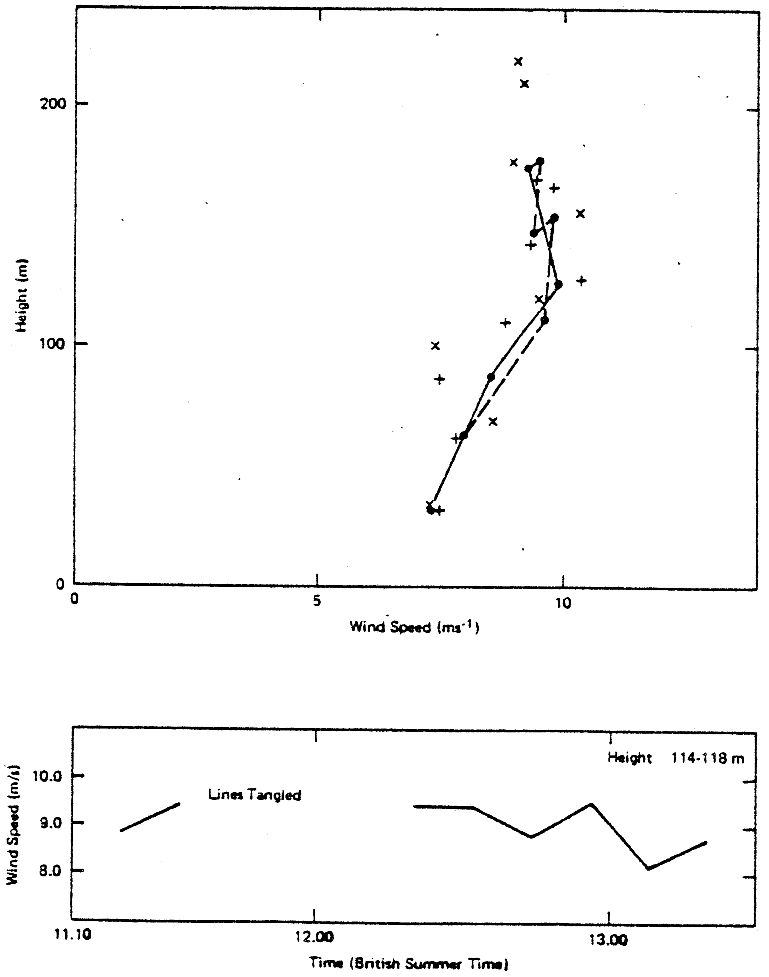


Fig 5.7 TALA kite profile test, 26 September 1982, 11.15 - 13.15 BST
• CAN, + ERA, x BRE
A linear Δz scale has been used to improve separation of data points.

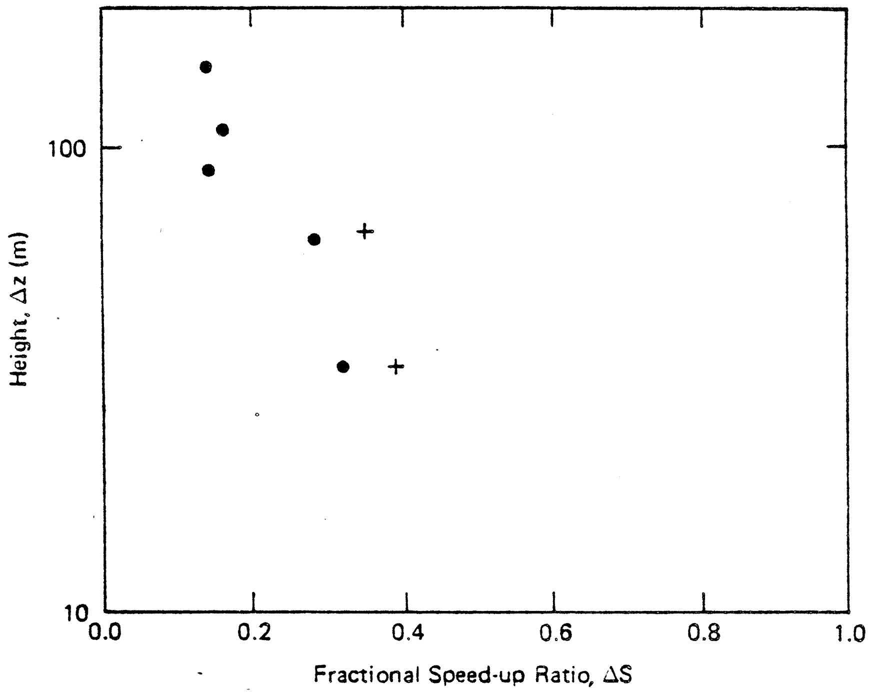


Fig 5.8 Fractional speed-up ratio profile near hilltop on 2 October 1982, 10.00 - 11.30 BST, based on TALA kite measurements.

• AES/BRE (near ASW20), + ERA/BRE (near CP)

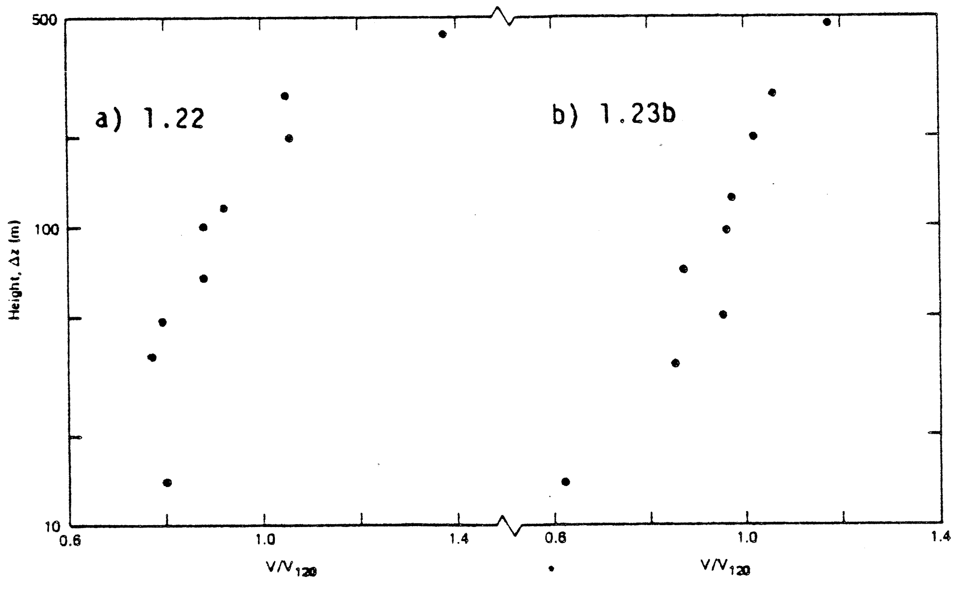


Fig 5.9 Profiles of wind speed ratios, V/V_{ref} from the BRE TALA kite system during MF runs a) 1.22, b) 1.23b, c) 2.25, d) 2.27, e) 2.01a, f) 2.01b. All profiles were flown near BS except for a) which was near RS.

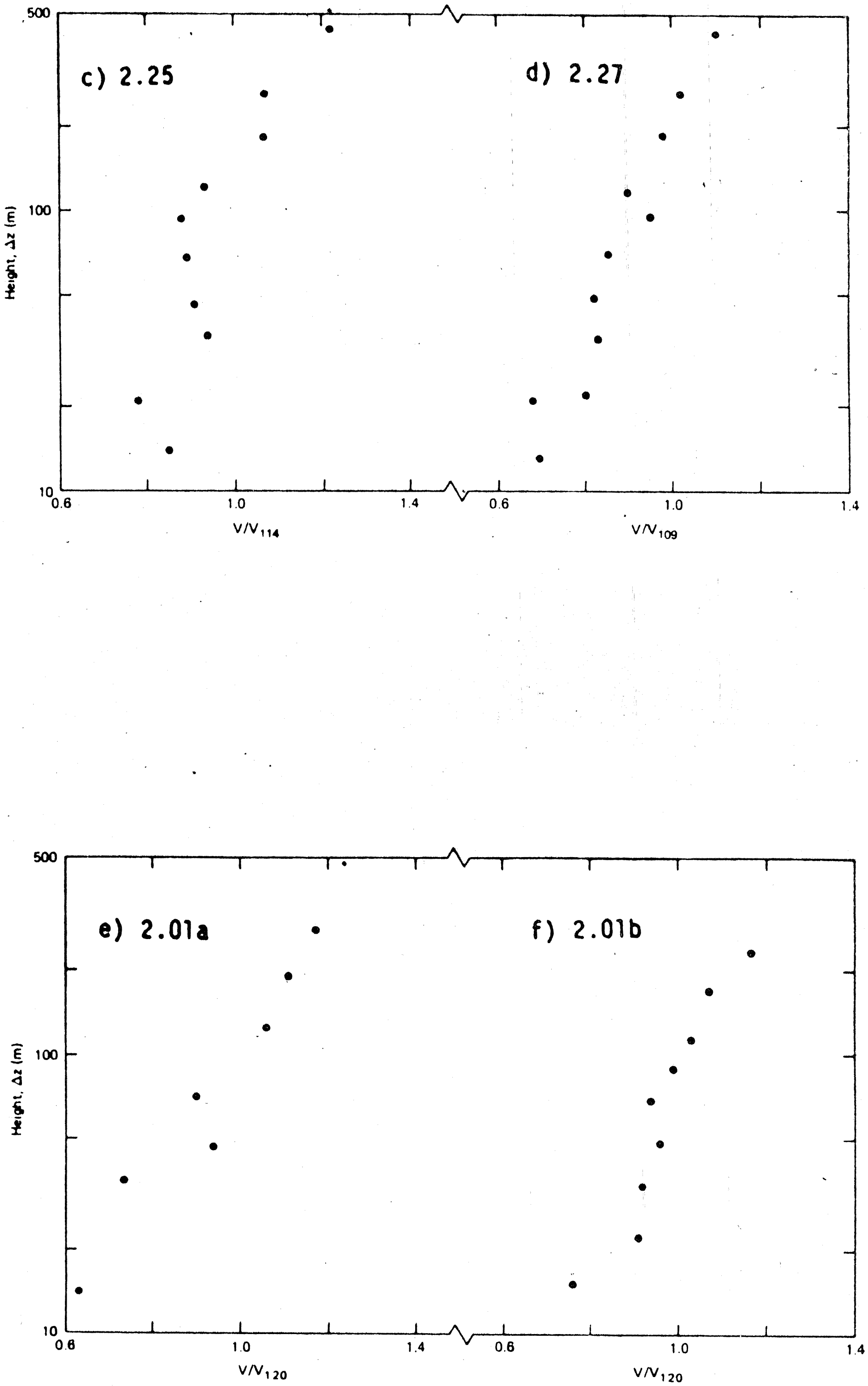

c) 2.25
d) 2.27
Height, Δz (m)
500
100
10
0.6
1.0
1.4
0.6
1.0
1.4
V/V$_{114}$
V/V$_{109}$
e) 2.01a
f) 2.01b
Height, Δz (m)
500
100
10
0.6
1.0
1.4
0.6
1.0
1.4
V/V$_{120}$
V/V$_{120}$

Fig. 5.9 (cont.)

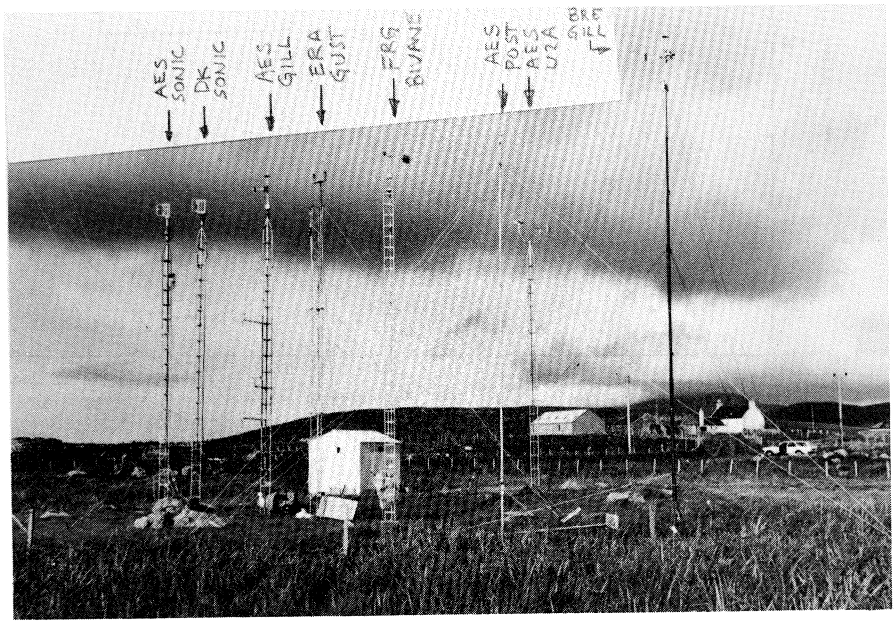


Fig 6.1 Photograph of towers and instrument shelter at RS.

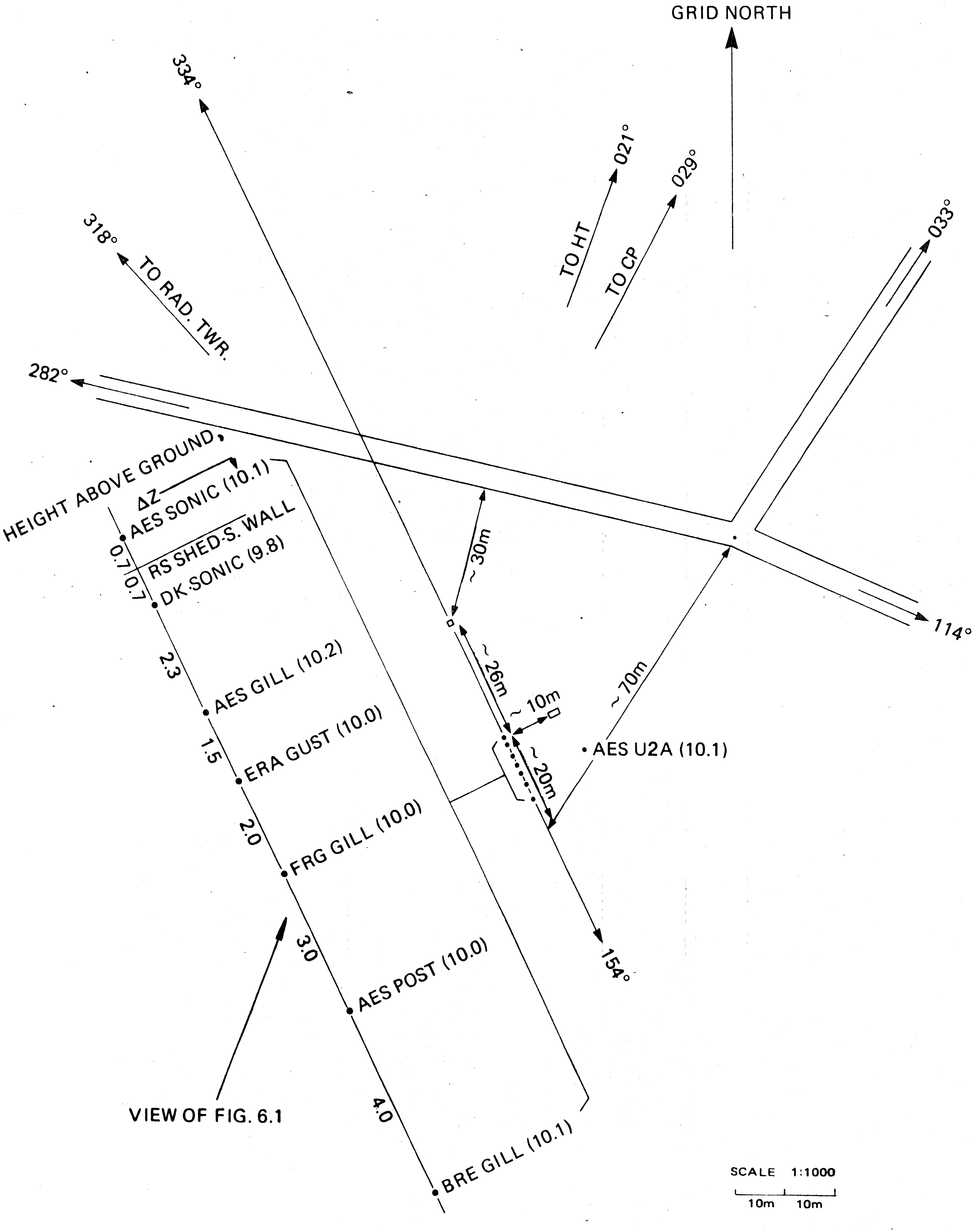


Fig 6.2 Schematic layout of RS

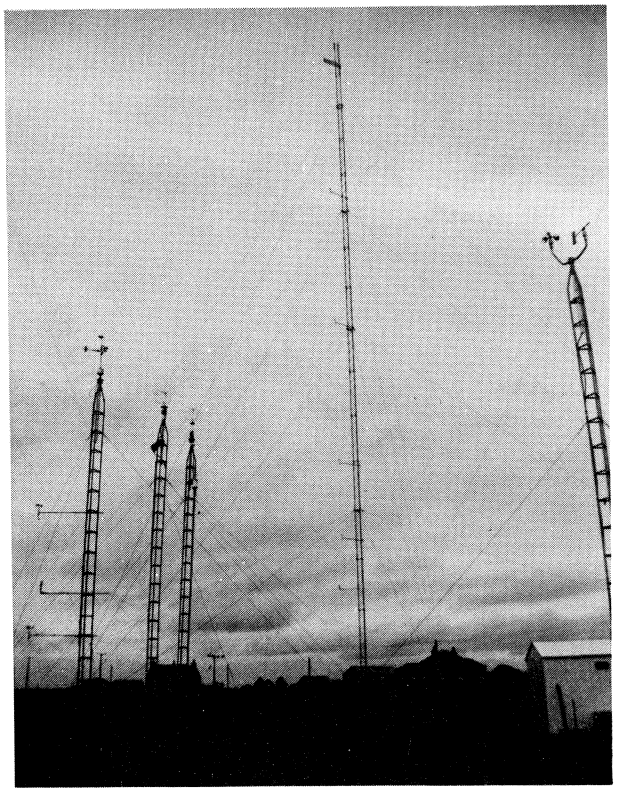


Fig 6.3 50 m tower at RS

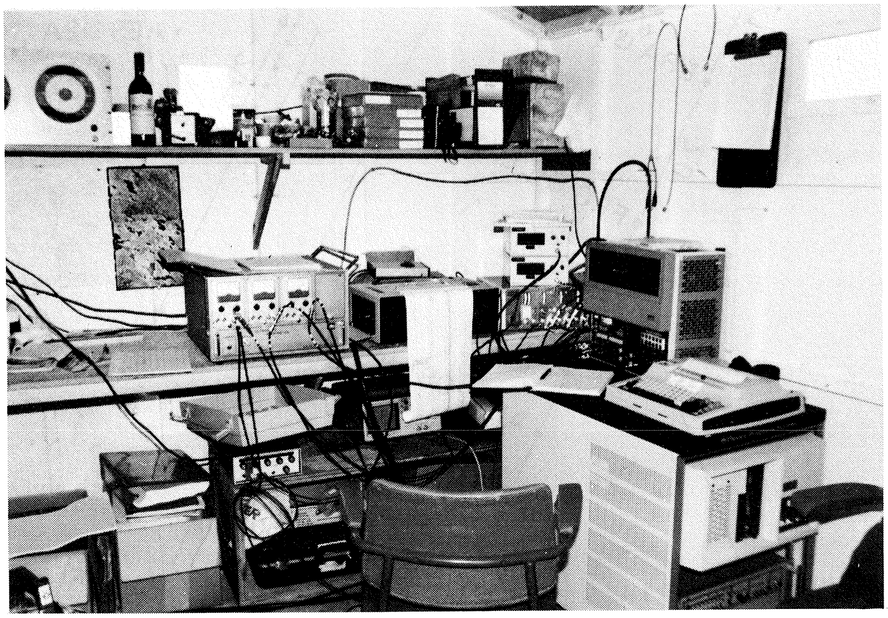


Fig 6.4 Photograph of instrumentation in shelter at RS including 11/23 micro-computer system, sonic anemometers and HP tape recorder.

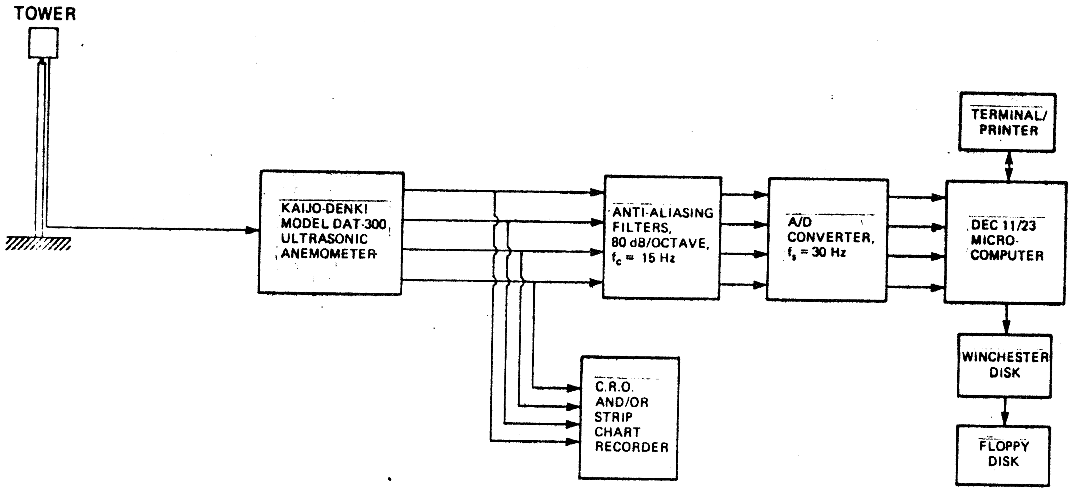


Fig 6.5 Schematic layout of AES sonic anemometer data collection and analysis system.

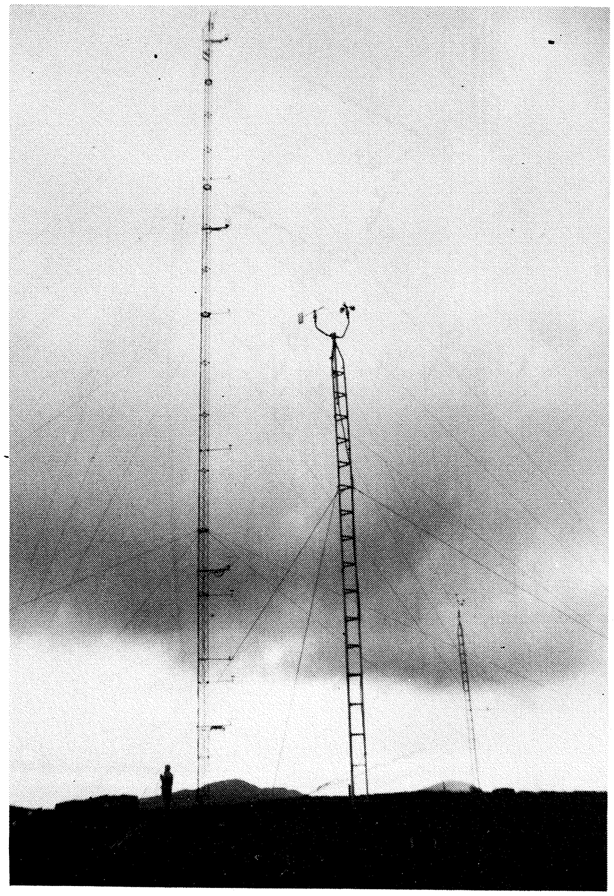


Fig 6.6a 50 m tower at HT - photograph

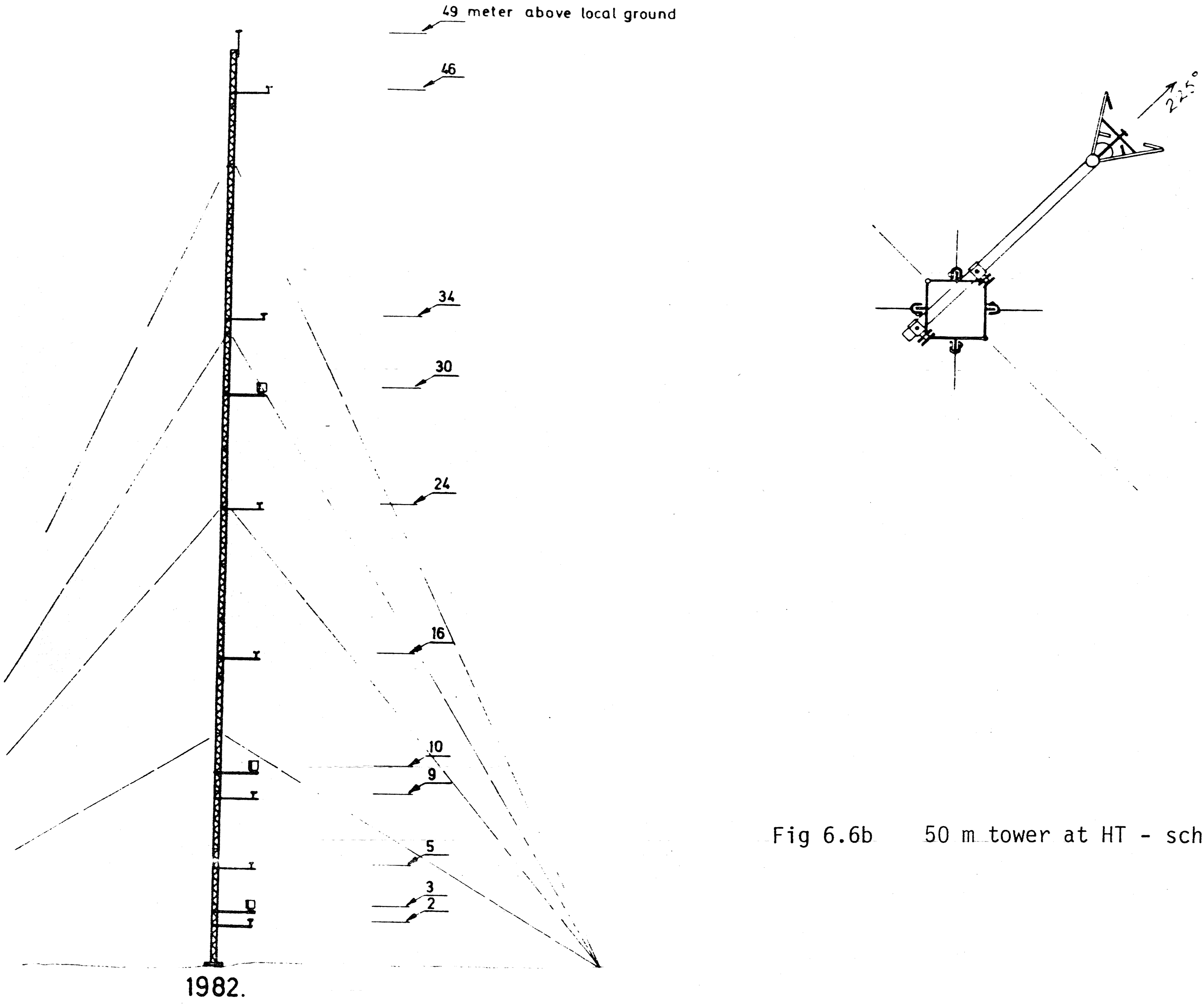


Fig 6.6b 50 m tower at HT - schematic layout

Fig 6.7 Photograph of DK caravan and AES tent at HT.

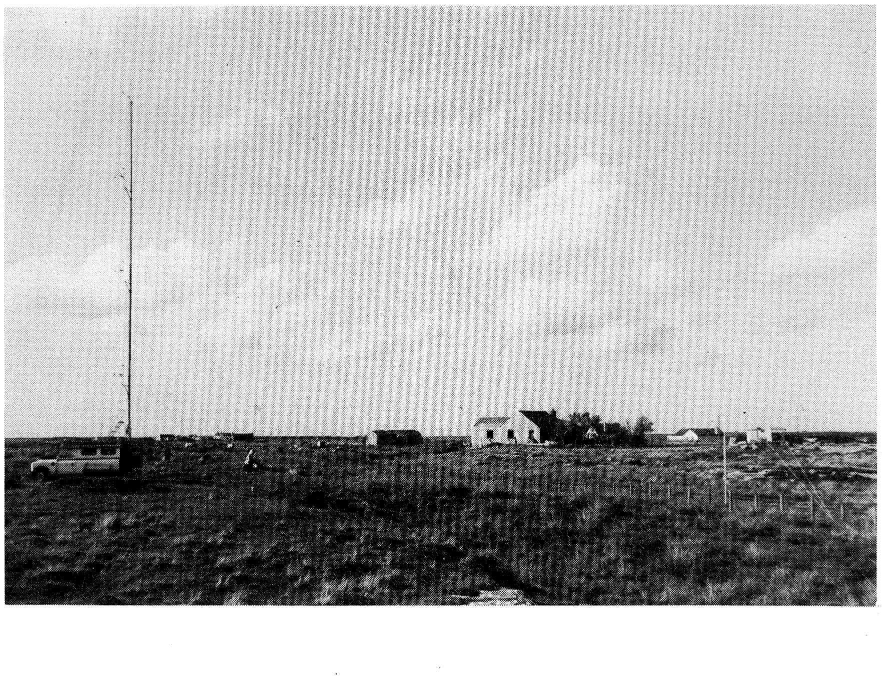


Fig 6.8 Photograph of BRE Land Rover and tower erected at foot of hill (ASW 78)

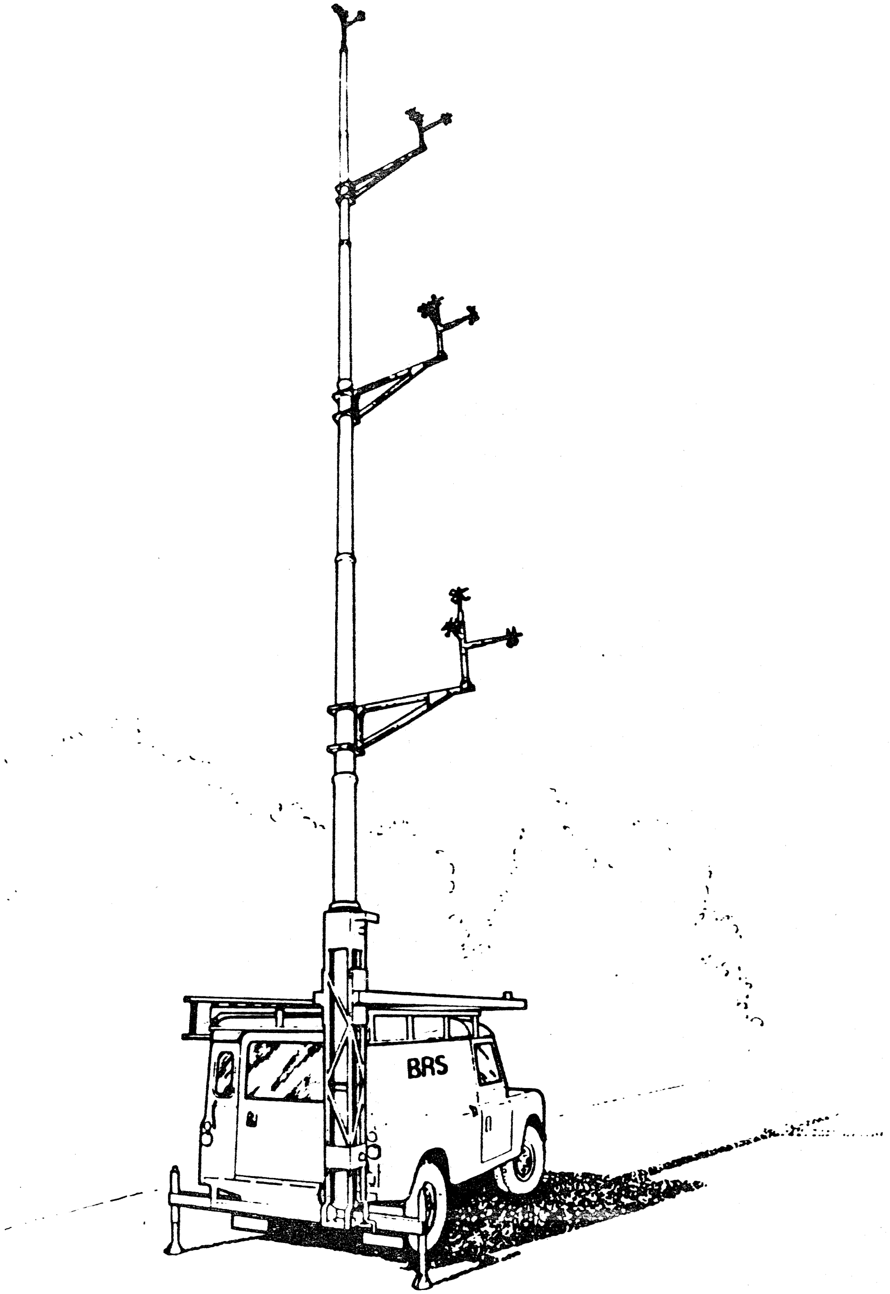


Fig 6.9 Schematic diagram of BRE telescopic mast.

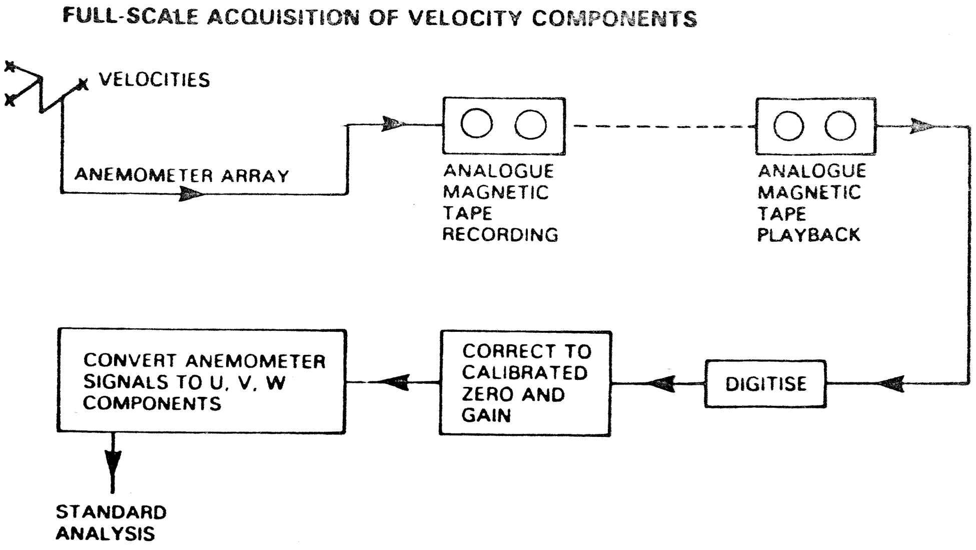


Fig 6.10

Schematic layout of BRE data collection and analysis system.

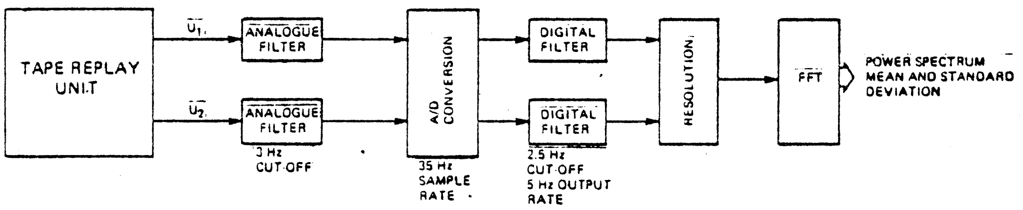


Fig 6.11 Schematic layout of ERA gust anemometer data processing system.

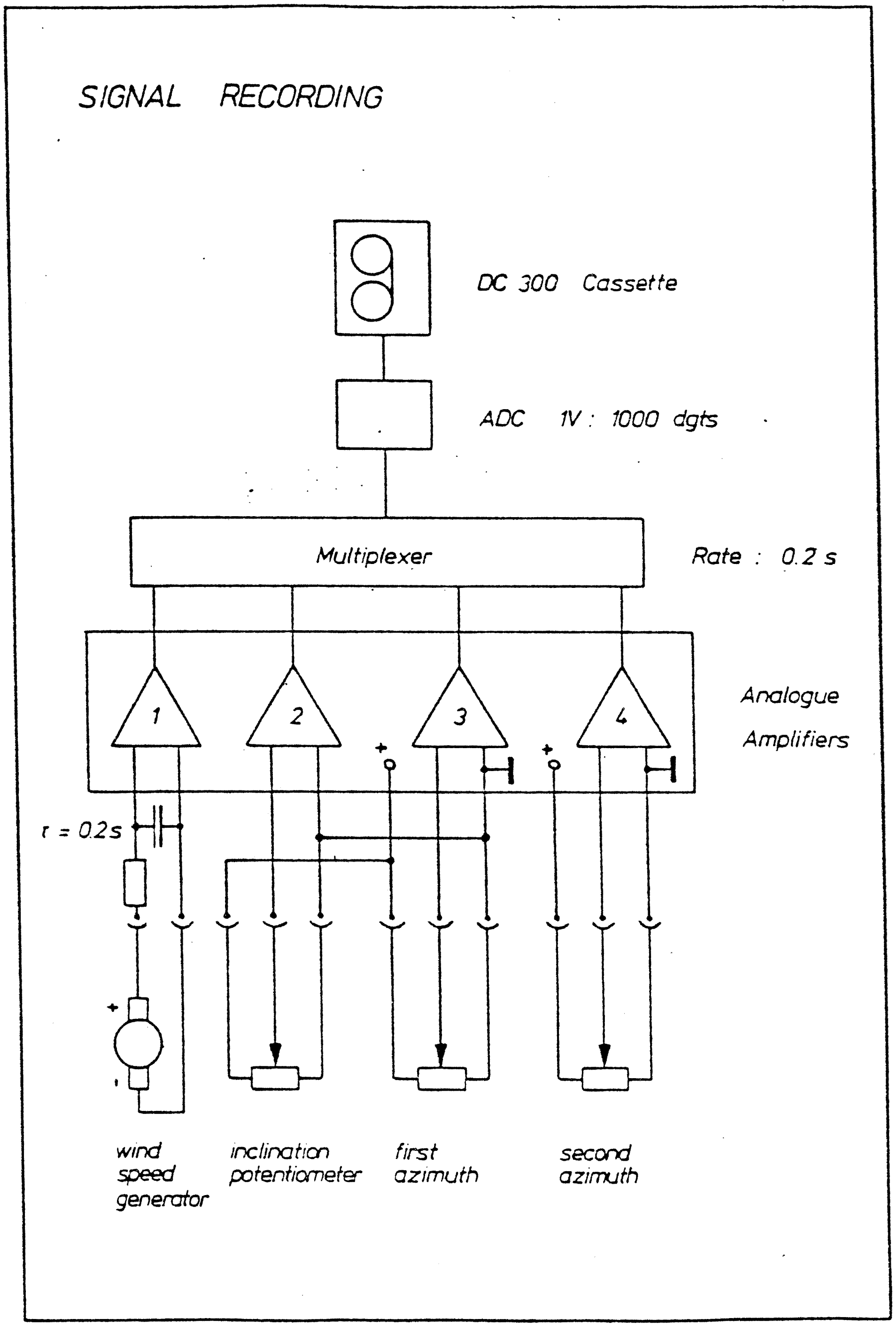


Fig 6.12 Schematic layout of FRG anemometer bivane data collection system.

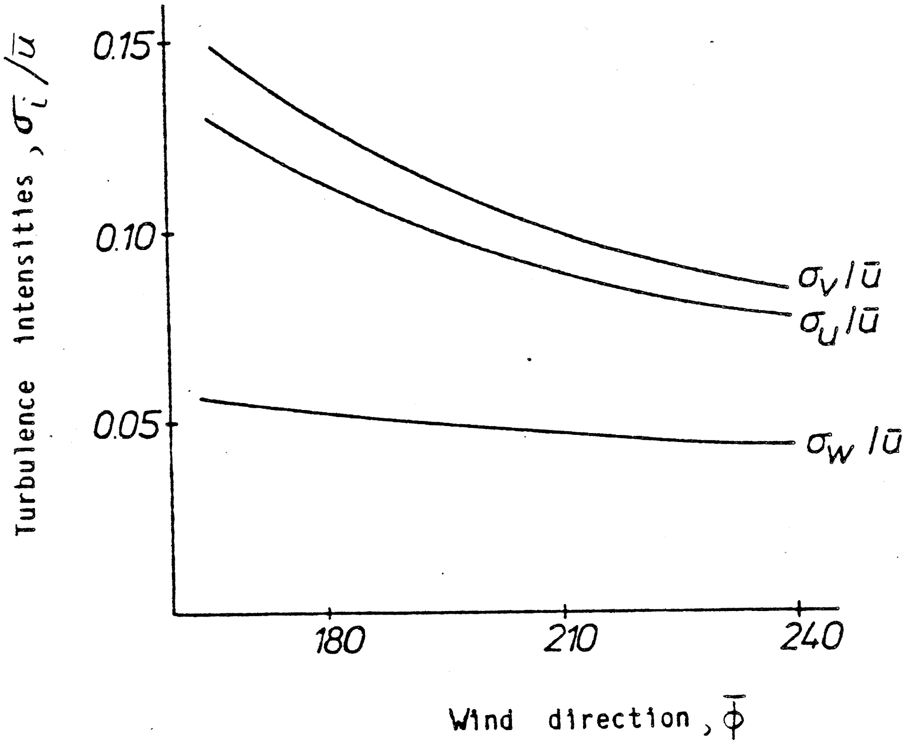


Fig 6.13 Turbulence intensities vs wind direction from FRG bivane measurements at CP (Δz = 10m). Lines are means based on data of Table 6.13.

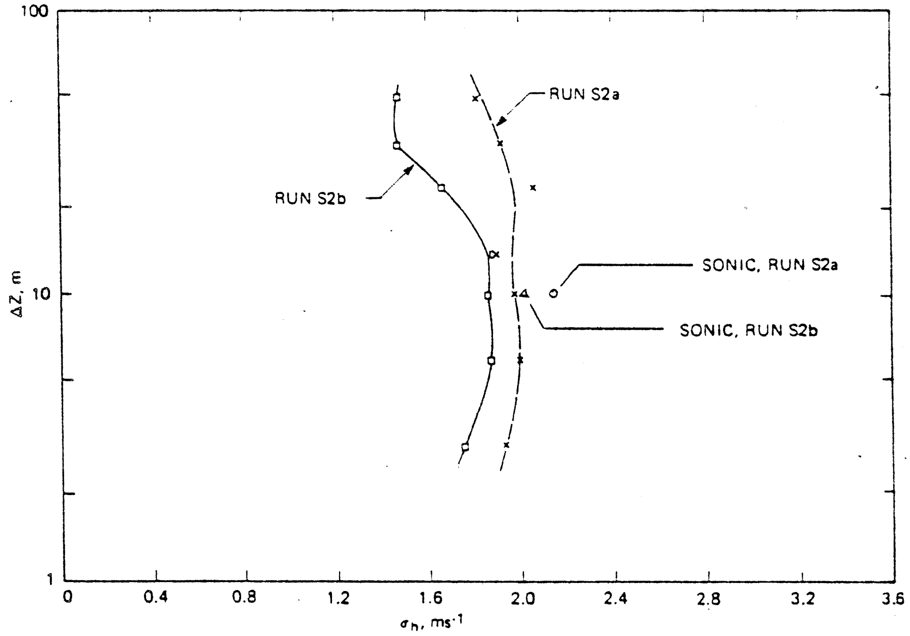


Fig 6.14a Turbulence profile results from AES cup anemometers at RS during sonic runs S2a (21/09, 1300-1430, $\overline{\Phi}$ = 313°, $\overline{U}$ = 11.38 ms^{-1}) and S2b (21/09, 1600-1700, $\overline{\Phi}$ = 316°, $\overline{U}$ = 10.68 ms^{-1}).

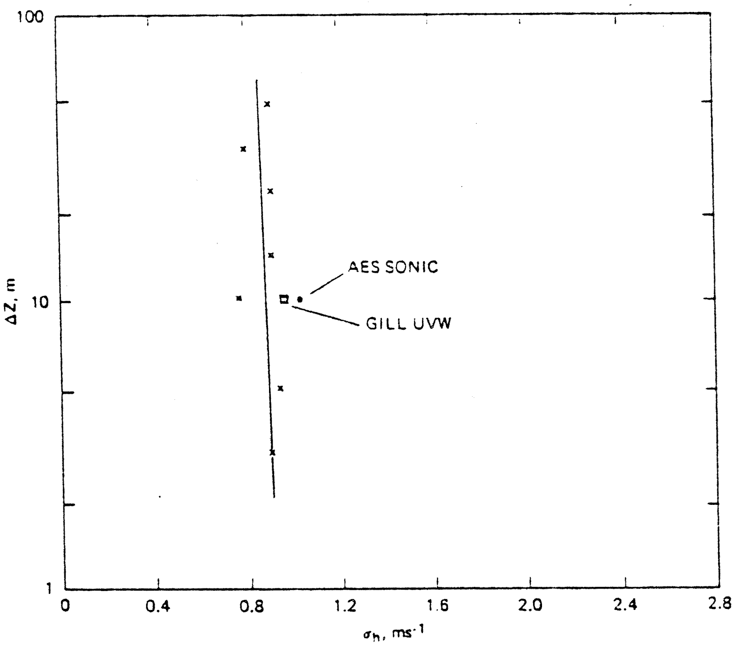


Fig 6.14b As Fig. 6.14a, but for run S3 (22/09, 1500-1700, $\overline{\Phi}$ = 167°, $\overline{U}$ = 5.33 ms^{-1}).

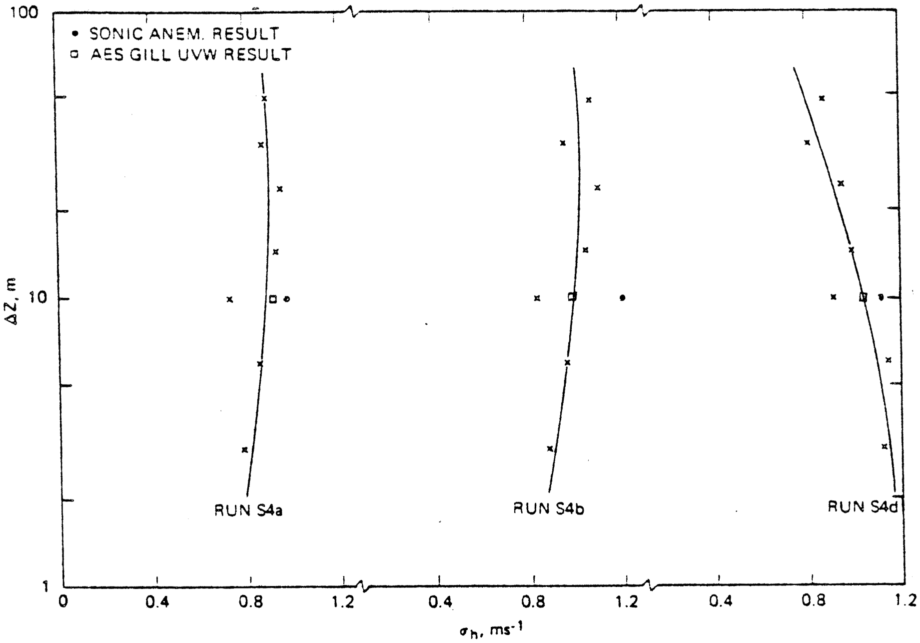


Fig 6.14c As Fig. 6.14a, but for runs S4a (23/09, 1030-1200, $\bar{\Phi}$ = 222°, $\bar{U}$ = 3.24 ms^{-1}), S4b (23/09, 1407-1437, $\bar{\Phi}$ = 240°, $\bar{U}$ = 5.67 ms^{-1}), and S4d (23/09, 1628-1728, $\bar{\Phi}$ = 254°, $\bar{U}$ = 7.16 ms^{-1})

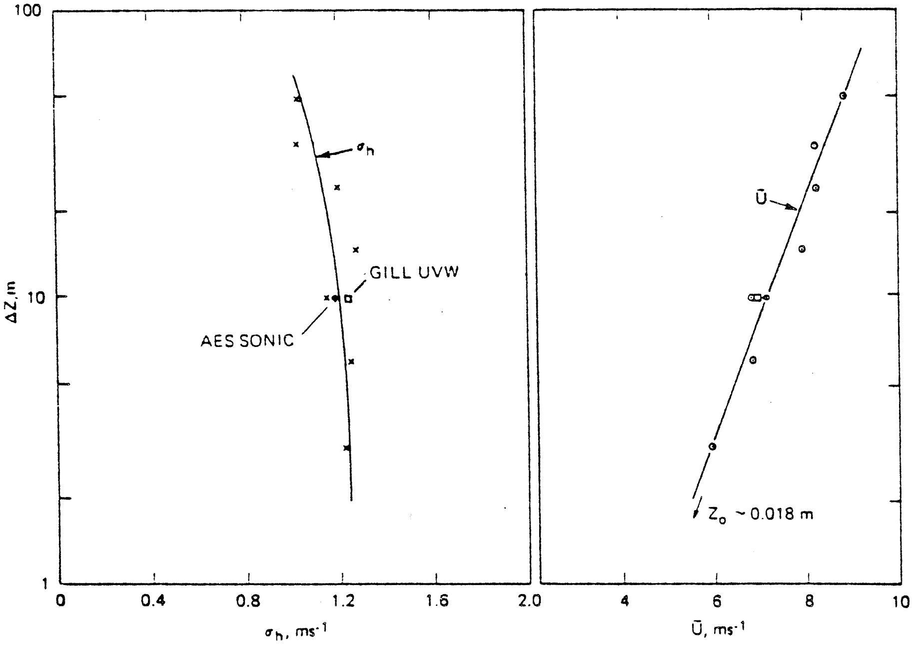


Fig 6.14d As Fig. 6.14a, but for run S5 (25/09, 1345-1415, $\bar{\Phi}$ = 136°, $\bar{U}$ = 7.11 ms^{-1}); mean velocity profile also shown. Note that cup anemometer and Gill UVW results are for 1330-1430.

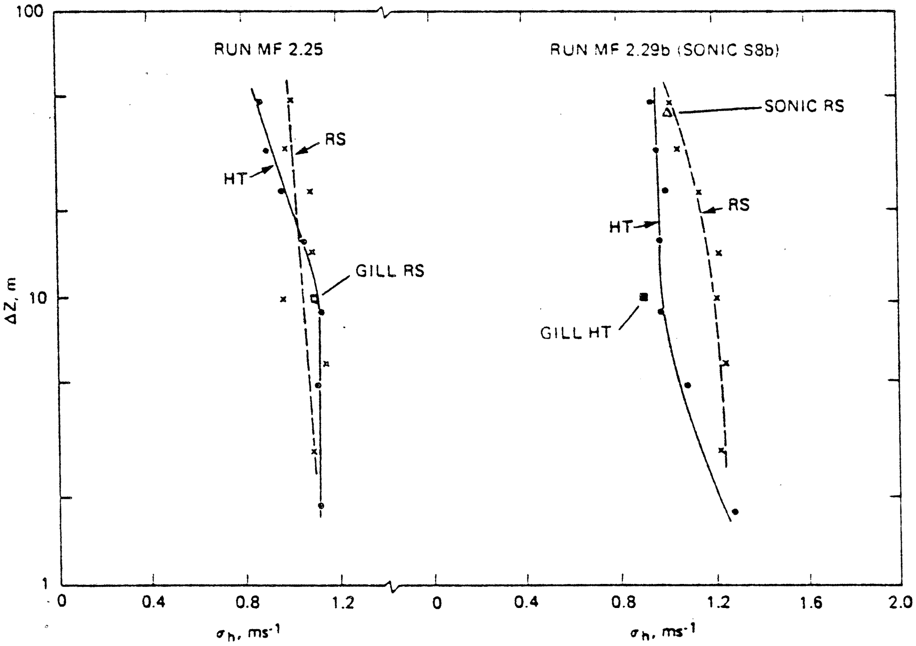


Fig 6.15 Turbulence profile results at RS and HT for MF runs 2.25 (25/09, 1600-1800, Φ = 118°, $\bar{U}$ = 6.50 ms^{-1}) and 2.29b (29/09, 1400-1600, Φ = 236°, $\bar{U}$ = 8.29 ms^{-1})

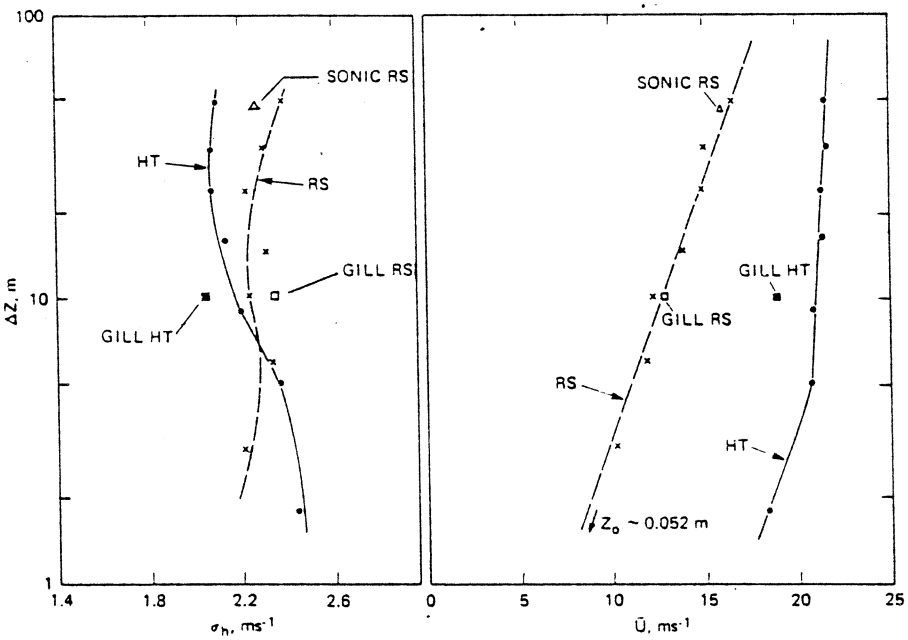


Fig 6.16 Turbulence and mean velocity profile results at RS and HT during sonic anemometer run S7 (28/09, 1345-1515, ϕ = 161°, $\bar{U}$ = 16.03 ms^{-1} at Δz = 47 m). Note that cup data are for 1330 - 1530.

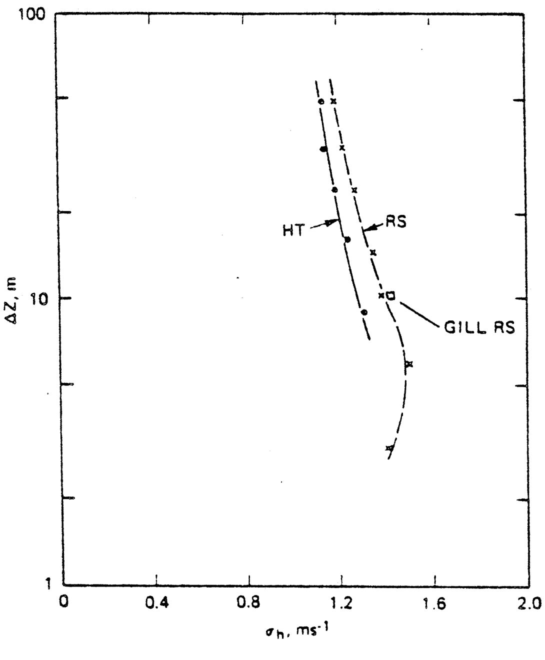


Fig 6.17 Turbulence profile results at RS and HT for MF run 2.25a (01/10, 1100-1300, ϕ = 162°, $\bar{U}$ = 8.93 ms^{-1})

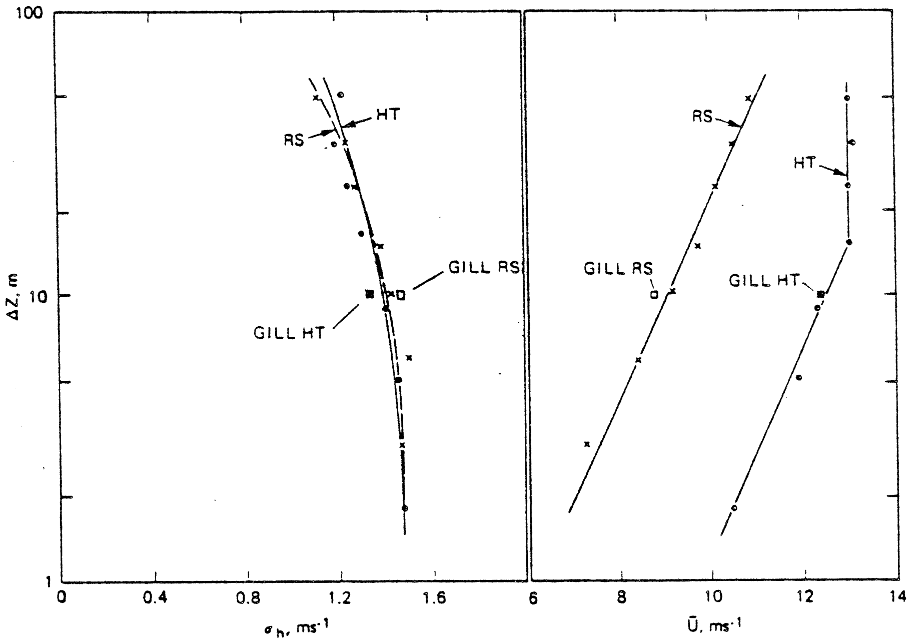


Fig 6.18 Turbulence and mean velocity profile results at RS and HT during sonic anemometer run S11 (03/10, 1330-1400, ϕ = 160°, $\bar{U}$ = 10.63 ms^{-1}) at Δz = 47 m).

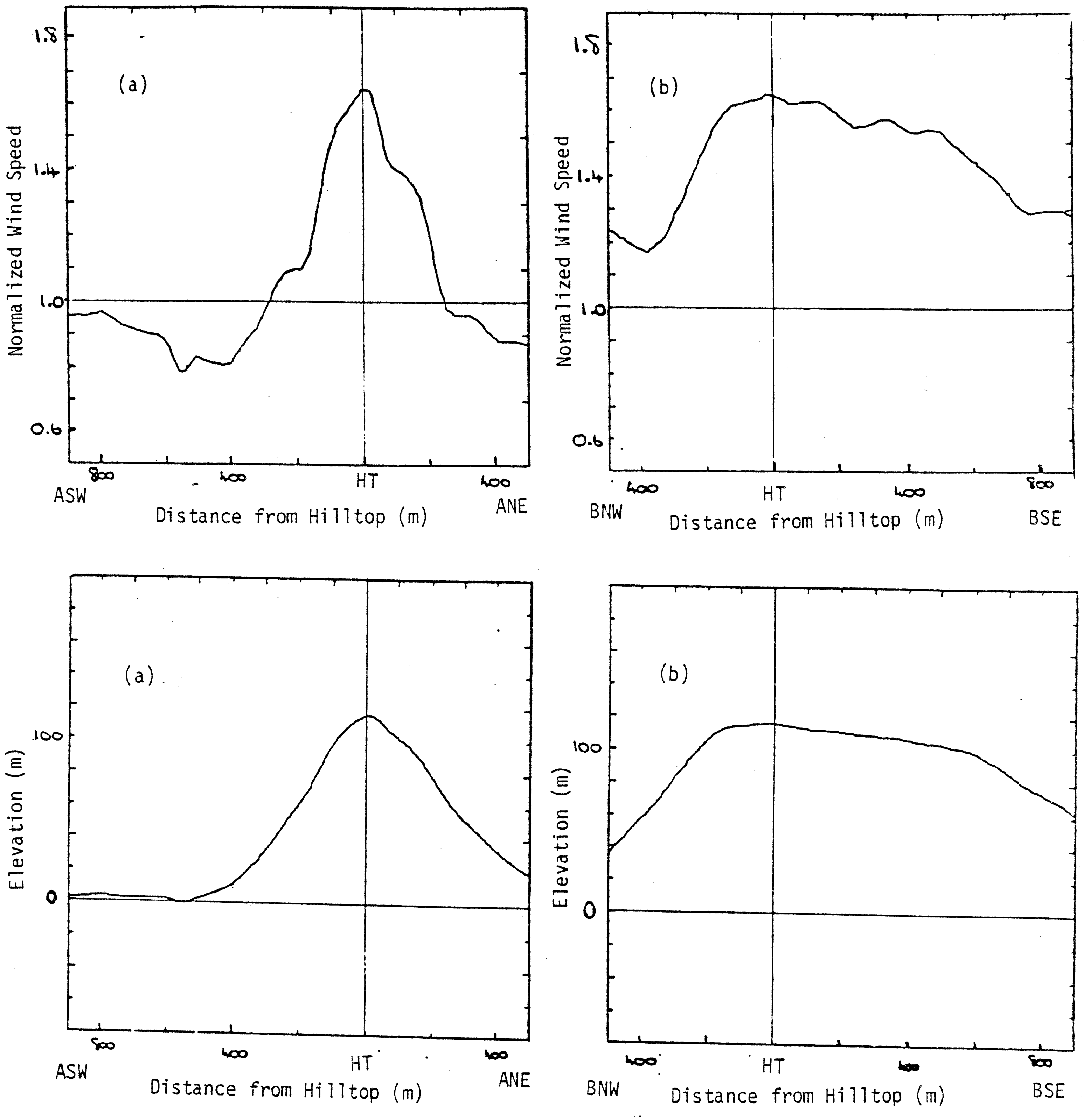


Fig 7.1 MS3DJH/3.1 simulation results for 10 m, normalized wind speeds along lines A and B. The incident wind direction is 250° Topographic cross sections along the tower lines are also shown.

Three Dark Figures
Making the Weather
In Folk, in Myth, in Legend,
A threefold test.
Shiva, Vishnu, Brahmin.
Father, Son, Holy Ghost.
Body, Mind, Spirit.
Triune, Triumvirate, Tribunal.
One is Isolate
Two is divisive
Three is Peace.
Three is Torment.
Three is Potent.
Power, Power, Power.
Air, Fire, Water.
Three Dark Figures,
Making the Weather.

Ron Baird, Sculptor