MRU Cardington Technical Note No. 10

The Vale of White Horse detachment
September - October 1992

by

A.J.Lapworth, S H Derbyshire W P Hopwood et al.

July 1993

Met. Office Research Unit
RAF Cardington
Shortstown
Beds, MK42 0TH

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1 Introduction

This was the third of a series of three detachments to obtain data on airflow over heterogeneous terrain - the previous two being at Aldermaston and Pershore. Prior to the start, a detachment document was compiled from contributions by several members of the unit. As distinct from previous documents of this nature, an effort was made to cover all aspects, including the scientific rationale, instrumental and logging details etc as well as the more usual flying notes. This proved a useful exercise as many problems were sorted out during the process of passing the various contributions round for checking and amendment. What follows is the final result although it was further amended during the detachment itself. It is reproduced here as a possible framework for future field work.

The balloon used was an MB24 flown from a field adjacent to a road in Oxfordshire. The balloon was storm bedded every evening. On site accomodation was all provided by a contractor, the first time this had been done. The balloon bed had been laid in advance. The main problems in practice were the time (about a fortnight) required to set up the surface site problems with the main electricity supply. The surface site had more instrumentation than had been used in the previous two detachments. The supply had a possible bad connection in the main supply on the road and a cable of inadequate current-carrrying capacity. Problems were also encountered with removing equipment at the end, due to the mud in the field resulting from the severe rain falling in September and October.

On the day the transport left from Cardington, it was discovered that our presence would cause problems to a local RAF training squadron. This was in spite of careful attention to full liaison with MATO mand NATS in the previous months. In the event, the notification procedures had to be amended slightly, as will be seen.

During the flying period, the decision was taken to bring down a second winch with KB65 cable on the winch to enable flying in stronger winds. Another change in plans was a rearrangement of the working pattern to enable flying to start earlier in the day. Thus some of the details of the hours given in the following pages are inconsistent.

Abstract

This is intended not as a straitjacket but as a reference for the scientific aims of the detachment. Comments welcome from all concerned.

2 Preliminary comments and background

Project RP15, under which most of our work falls, used to be officially 'Flow over heterogeneous terrain' and is now 'Observational validation of boundary layer models' (what's in a name?!). Both these aspects are relevant.

The main reason for going on detachment is to study flow over heterogeneous (non-uniform) terrain. There is a lot of theoretical and modelling interest in this issue, largely under the heading of 'aggregation'.

In a forecast or climate model, one must characterize the properties of a surface, e.g. its roughness, over a square of perhaps 100km×100km, by a very few numbers. In reality, over a country like Britain, such a square would usually encompass many different terrain types (forests, fields, towns, lakes, hills, etc.).

However a model can hold at any given height only one measure of wind, and only one measure of drag per grid-square. So in some sense these should be representative or aggregate values. If terrain were only slightly heterogeneous then all averages would amount to much the same. However with large changes, e.g. between very smooth and very rough surfaces, the problem is much more difficult.

Mason (1988) has shown that a model cannot in general combine the true area-average windspeed with the correct average drag under all conditions. Because of non-linearity the average velocity profile does not bear the same relation to average stress as in homogeneous conditions. Indeed since flow over different surfaces can be totally different at low levels the average wind is not terribly meaningful. However Mason has argued that the average *drag* is the most significant quantity for large-scale models, in which this drag directly determines Ekman pumping and hence the boundary-layer contribution to dissipation of weather systems (the rate of energy loss per unit area is in fact $\rho c_g G^3 \cos \alpha_g$).

The theory of aggregation is rather complex and not entirely sorted out yet. Basically however from Mason (1988) and Wood and Mason (1990) one can summarize:

1. For a given horizontal scale L (wavelength for inhomogeneity) there are *two* characteristic vertical heights (unfortunately).
2. The inhomogeneity in mean wind (temperature, humidity etc.) is largely confined to a very shallow surface layer with a height less than l_b, whereas the stress (or fluxes) vary on a deeper scale l_d. This is quite closely analogous to the fact that in

a conventional boundary layer the mean wind and temperature vary considerably very low down, whereas the stress and fluxes vary over the boundary layer height scale. In this analogy l_d corresponds to the boundary layer height h and l_b to a surface-layer height.

3. The diffusion height $l_d \sim L/c_d^{1/2}$ crops up frequently in diffusion from surface sources. Above l_d the flow can be assumed to be in horizontal equilibrium. [c_d is the drag coefficient for the height concerned, typically 0.01.]

4. Mason's blending height $l_b \sim L/\pi c_d$ is a height at which the wind is approximately in horizontal equilibrium, whereas the stress is approximately in local vertical equilibrium.

5. Mason has devised a 'heuristic model' based on these ideas. At the blending height l_b we take the mean wind and temperature as *constant*, i.e. the same over forest and field. However the stresses and fluxes will then respond to the local terrain using conventional surface-layer formulae applied at height l_b. So for instance in neutral conditions the ratios of surface friction velocities over smooth and rough terrain will then be $\ln(l_b/z_{01}) : \ln(l_b/z_{02})$, with more stress over the rough terrain. From this one can also work out the near-surface winds (?).

6. Fig. 1 illustrates these points, including the wind profiles

2.1 Measuring heterogeneous effects

Can we measure heterogeneous effects? If not, then they're probably not very important!

The simplest measure of heterogeneity at a single site is the variation in drag coefficients and transfer coefficients with wind direction, after making due allowance for local stability.

Grant (1991) concludes from the Aldermaston experiment that departures from 'standard' surface-layer results for ϕ_m and ϕ_ϵ were relatively small, supporting the concept of a blending height. At heights around 100m the flow was approximately homogeneous.

I would like to see us try to construct some kind of surface map from measurements of drag coefficient etc at various heights by taking the displacement $x \sim z/c_d^{1/2}$. This is similar to the ideas used by Grant (1991), but he did not try to construct a map. One could then try to optimize the correlation with the actual surface map (appropriately smoothed, probably over some characteristic angle). To be slightly negative for the sake of argument, if we can't do this with some success then I'm not sure how much we can really say about heterogeneity. It ought to work!

The concept of a heuristic model, i.e. a blending height where mean values are in horizontal equilibrium but fluxes in vertical equilibrium, seems worth clinging onto. I suspect that it forms a basis for incorporating displacement-height effects too.

A general property seems to be that the stress is affected by the rougher elements, which contribute to the drag coefficient more than their area density would suggest. By contrast these do not affect scalar transfer very much if they are reasonably sparse. There are two distinct reasons for this effect:

1. The physical nature of roughness elements, large drag behind a bluff body etc. with no direct counterpart in scalar equations.

2. The mathematical difference in boundary conditions, the boundary condition for velocity being roughly an imposed value as opposed to an imposed flux for scalars. The first case can be considered as a fixed surface value with variable 'resistances' (using the electrical analogy); the lowest resistance (equivalent to high z_0) tends to dominate the average. The latter case can also be considered via resistances, but here the highest resistance tends to dominate. See Fig. 2. Actually for 'mixed' boundary conditions neither would dominate.

So what tends to happen is that the drag coefficient c_d is *enhanced* above a naive area average by weighting towards the rougher elements, whereas the scalar transfer coefficient c_H etc. is *reduced* to compensate, i.e. to preserve the *resistance*. This can appear as very low values of z_{0t}/z_{0m}. See Wood and Mason (1991). The blending height can be considered as a measure of how large the 'large' values of roughness (or displacement height?) have to be to give much lower resistances, and hence exert a disproportionate influence. If we chose a large blending height (e.g. l_d, as in the literature pre-Mason 1988) then such disproportionate effects would be considerably reduced.

The issue of flow over hills, which Hignett and Hopwood have looked at, is not entirely unrelated; these effects too can be considered in terms of effective roughness lengths. Hills are perhaps best pigeonholed under 'complex' rather than heterogeneous terrain. In the latter case the trend seems to be away from effective roughness lengths, especially for patches which incorporate gross variations in stability (e.g. land/water). It's not entirely clear how to combine the two kinds of effect, but that's not our problem at the moment.

2.2 Humidity

Humidity measurement per se presents its own difficulties. Only relatively recently have we focused on this, but with Humicaps on the probes and the Ophir lower down we should be in as good a position as anyone to measure mean and fluctuating humidities.

Theoretically the transport of humidity ought to be the same as for other scalars except that the boundary condition is different. In fact it might be useful to look explicitly at the correlation between temperature and humidity at various heights as a way of testing this.

The difficulty in comparing observations with models of scalars in the surface layer is that *both* the surface roughness *and* the surface boundary value are to some extent adjustable over anything other than a flat plane. For temperature it seems best to use a *radiative* surface temperature, and define z_{0t} to match that value.

For humidity we could *either* set $z_{0q} = z_{0t}$ and thence diagnose surface humidity, *or* diagnose surface humidity from saturation at measured radiative surface temperature and hence evaluate z_{0q}. The first approach effectively regards 'vegetation resistance' to evapotranspiration as the unknown, whereas the second lumps unknowns into z_{0q}. Actually if the ground is saturated we can measure z_{0q} reasonably unambiguously.

It's not clear in advance whether the issue of averaging humidity over heterogeneous will be significant. Perhaps at best we can say whether or not it's 'effectively homogeneous' at given heights. Flux profiles should give a handle on this.

2.3 Quick assessment of likely humidity differences

Latent heat flux λE (where λ is latent heat of vaporization per unit mass) expected at say 100Wm^{-2}. Since $\lambda \simeq 2.5 \times 10^6 \text{J kg}^{-1}$, we have

$$E = \rho\overline{wq} = -\rho q_* u_* \simeq 4 \times 10^{-2}(\text{kg/m}^3)(\text{m/s})(\text{g/kg}) \tag{1}$$

Since $\rho \simeq 1\text{kg/m}^3$, for typical $u_* \simeq 0.3\text{ms}^{-1}$ we obtain $q_* \simeq -0.1\text{g/kg}$. Then for near-neutral surface layers the difference between mean humidities

$$\Delta\overline{q} \simeq \frac{q_*}{k_q}\Delta \ln(z/z_{0q}) \tag{2}$$

(actually this does not depend on z_{0q} despite appearances). Taking measurements at say 4m and 8m we obtain $\Delta\overline{q} \simeq -0.2\text{g/kg}$ — not large. For 1m and 12m we get -0.8g/kg — still not huge but I hope measurable.

2.4 Detailed questions/analysis

1. From *probes*: use

$$\overline{q}_s - \overline{q} = -\frac{q_*}{k_q}\left[\ln\frac{z}{z_{0q}} - \Psi_q\left(\frac{z}{L}\right) + \Psi_q\left(\frac{z_{0q}}{L}\right)\right] \tag{3}$$

   If we take k_q as known, from measuring T_s as a radiation temperature can then compute z_0^{eff}.

2. Similarly for surface instruments (Sonic/Ophir) should get local z_{0q} for the grass

3. From Michells use $\overline{q}_{12\text{m}} - \overline{q}_{1\text{m}}$ with Porton winds (i.e. a profile method) to estimate fluxes.

4. Surface energy balance: we have H, λE, Q^* (net radiation) — infer G (soil) as residual (so can't do full energy balance — probably no great loss.)

5. Compare Penman-Monteith ($\overline{U}$, T, r_c ...; have to measure/ assume stomatal resistance r_c) with Priestley-Taylor (close to prescribing a Bowen ratio)

6. other things with q' and T', e.g. correlation of $q'T'$, structure of $\overline{wq}$ and q^2 profiles, using probes, sonic, Ophir etc.

Beljaars and Holtslag say λE at grassy sites (Cabauw and the MESOGERS site) was well predicted using $r_c = 60\text{sm}^{-1}$ and $z_{0q} = z_{0h} = z_{0m}/6400$ under situations with sufficient moisture supply to vegetation.

3 Pershore

Phil Hopwood has done a lot of work on the Pershore data and combined this with data from Cardington and published sources. Using the concept of a footprint (Schmid and Oke 1990) with radiative temperatures enables us to match the surface roughness to measurements of wind and temperature at different heights. This has been validated at Cardington, I think. Whether it will all be published I know not.

4 This year

For instrumentation and logging see separate notes.

4.1 Site

(Map attached) The site presently chosen is Bagmere Barn, a grazing field about 1/2km south of Charney Bassett in the Vale of the White Horse, grid ref. SU 379939, 1°27'W, 51°38.5'N @64m amsl. The local terrain is fairly flat. The most significant topography is the Lambourn Downs, 6-10km to the South, up to 240m amsl. There is also a small hill up to 105m amsl about 6km to WNW, with a coniferous wood slightly closer, of dimensions 1km×2km in the same direction. Field boundaries are mainly tree-lined. About 4km to WSW is the village Stanford-in-the-Vale. to the East it is fairly open, with villages West and East Hanney about 3-4km away. They do say that to the East the fields tend to be larger, with somewhat lower hedges.

Appendix: scalar transport

The difference between scalars and velocity in flow over heterogeneous terrain arises mainly from the difference in boundary conditions, not from rate of diffusion within the atmosphere. Wood and Mason (1992) in fact assume that $\phi_m = \phi_h$. The argument can be summarized as follows:

1. The boundary condition for wind speed is formally a prescribed value (0) at $z = z_0$. The boundary conditions for scalars vary considerably. In some cases, e.g. for temperature at sea surface, they may obey analogous b.c.'s to wind, i.e. prescribed surface value (because the sea has a large heat capacity). For such cases, the results for z_{0t} should be similar to z_{0m} — at least the *averaging* process as such should not have any strong systematic effects on z_{0m}/z_{0t}. But frequently, especially over a relatively insulating surface, it is the flux rather than the surface value which is effectively specified. This prescribed surface flux (PSF) condition represents the extreme case and is studied by Wood and Mason. (Consider e.g. an ill-ventilated car on a sunny day.)

2. Mason (1988) and Wood and Mason (1992) suggest that, to a good approximation, wind and temperature can be considered horizontally constant at the blending height l_b, whilst below this height the profiles are close to local vertical equilibrium. This provides a simple 'heuristic model' as sketched in Fig. 1, which is well suited to patching heterogeneous terrain.

3. Consider the aerodynamic resistance $r_{a\theta} = -\Delta\overline{\theta}/\overline{w\theta}$, which varies of course with roughness length. If the temperature difference over different patches of the landscape is effectively constant (the PSV case) then clearly the ratio mean flux to $\Delta\overline{\theta}$ is the reciprocal of the harmonic mean of $r_{a\theta}$. On the other hand, if the flux is constant across the landscape (PSF case), again by simple arithmetic the ratio is the arithmetic mean. This is analogous to electrical resistors connected in series for the constant-flux (or constant-current) case, or in parallel for the constant $\Delta\theta$ (or constant p.d.) case. The PSF case is dominated by the lowest resistance (i.e. the *highest* roughness lengths) whereas the PSV case is dominated by the highest resistance (lowest roughness).

4. Hence if the scalar is assumed to be PSF then presence of a few very rough elements may significantly enhance c_D but have negligible effect on c_H. In Mason's heuristic model, discussion of drag and transfer coefficients is equivalent to resistances because wind U is assumed constant at height l_b.

5. By definition, in the neutral case

$$c_D^{\text{eff}} = k^2/[\ln(z/z_0^{\text{eff}})]^2 \tag{4}$$

and

$$c_H^{\text{eff}} = \frac{1}{r_a U} = k^2/[\ln(z/z_0^{\text{eff}})][\ln(z/z_{0t}^{\text{eff}})] \tag{5}$$

Thus if as argued above a few very rough elements may increase c_D but not c_H then they must consequently *decrease* z_{0t}^{eff}.

6. All effects such as difference between harmonic and arithmetic means vanish to first order in relative variations in $\ln(z_0/l_b)$, i.e. we need fairly large roughness changes to see anything. The significance of Mason (1988) using a considerably lower blending height than others is that roughness-length changes do not need to be quite so large (compared to other theories) to be significant.

7. From above arguments we can see why in Wood and Mason static stability can give very low z_0^{eff} values when turbulence collapses over certain patches. However implementation of a full surface energy budget would probably reduce this effect.

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Mason, P.J. (1988): The formation of areally-averaged roughness lengths. *Quart. J. Roy. Met. Soc.* **114** 399-420.

Schmid, H.P. and Oke, T.R. (1990): A model to estimate the source area contributing to turbulent exchange in the surface layer over patchy terrain. *Quart. J. Roy. Meteor. Soc.*, **116**, 965–988.

Wood, N. and Mason, P.J. (1991): The influence of static stability on the effective roughness lengths for momentum and heawt transfer. *Quart. J. Roy. Meteor. Soc.*, **117**, 1025–1056.

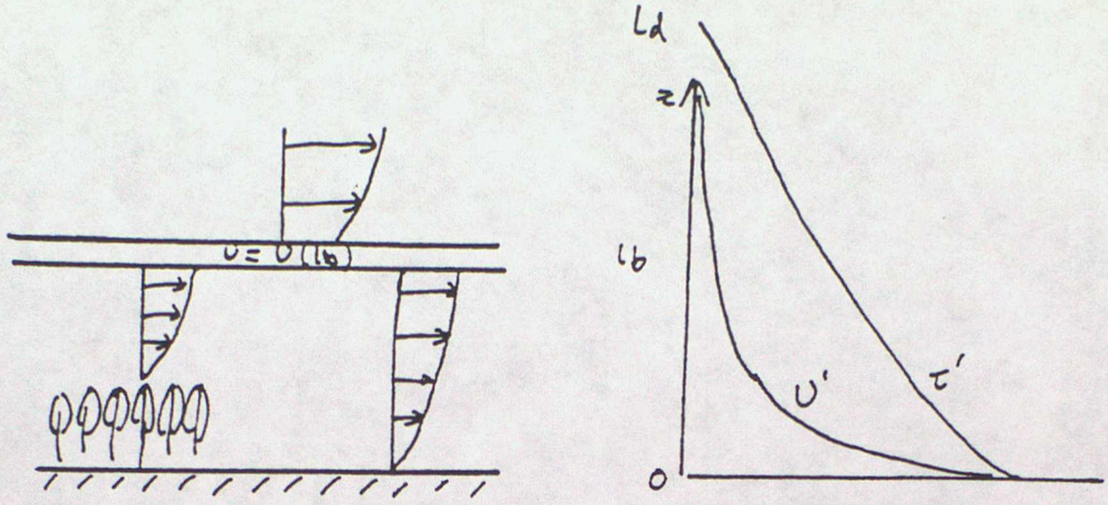


Figure 1: Sketch for Mason's heuristic model

5 Instrument deployment plan

shd et al., comments welcome from all concerned!

5.1 Main measurement aims

- From probes measure mean and fluctuating winds and temperatures as accurately or better than Aldermaston/Pershore. *Measure humidity (means and fluxes) to similar accuracy.*
- Similarly for surface site, esp. re humidity and humidity differences (to within 0.1g/kg if poss.).
- If at all possible get some surface and balloon measurements (especially the former) when ground is wet but drying out (to help measure z_{0q}).
- Gather good database for rainfall and state of ground, together with radiation measurements and enough info (inc. photos, sketches) on land-use and obstacles (esp. trees), sufficient to use simple models/formulae to predict latent and sensible heat fluxes.
- If possible get areal view by mounting camera with fish-eye lens high on cable.

See Appendix for further background. See Flight Scientist's Reminder Sheet re keeping logbook.

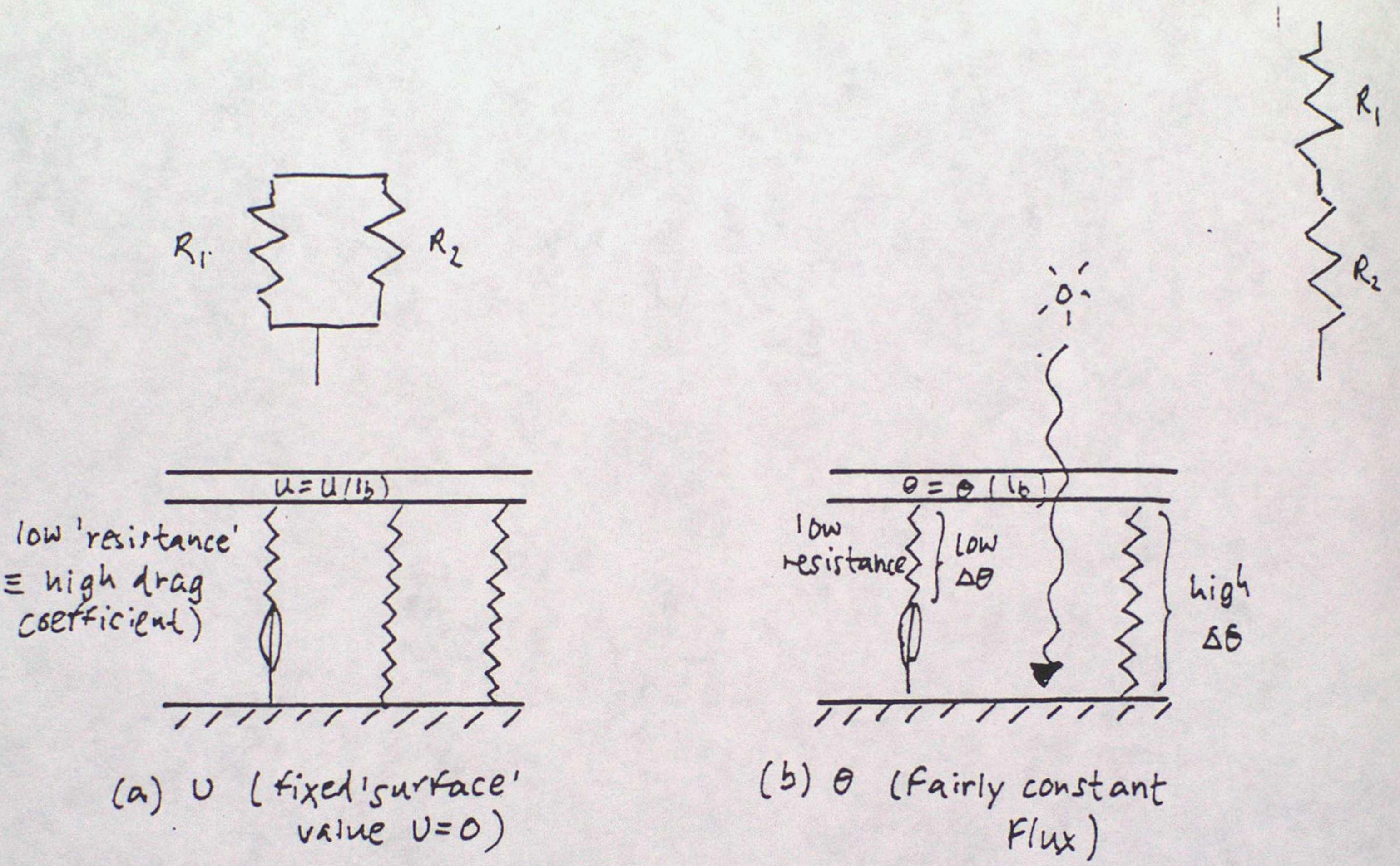


Figure 2: Electrical analogy for imposed fluxes and surface values (a) Velocity, constant surface value - equivalent to resistors connected in parallel. (b) Scalars, constant flux - equivalent (despite appearances) to resistors connected in series.

5.2 Probes

Basically the mixture as before. Humicaps I believe now on all probes and logging tested (?check). Deployment: (see Fig. 1). Prepared to fly 9 probes but exercise caution in strong winds or otherwise dodgy conditions. A consideration is that more probes may mean more cable oscillations or cable layback. Therefore on some days reduce probe numbers. IRT on Probe 13 as before, with viewing cone dipped 30° from horizontal [footprint radius = height/tan(dip) $\simeq$ 2000'.] *Cone angle is now adjustable ad lib.* Strain gauge to be flown as probe 0. General keep same probes in position.

5.3 Surface instruments

1. Sonics (2 × Kaijo — not the Gill sonic we had trouble with in past). One on Strumech beside Ophir. Other at 4m. Ophir to be checked against Michells at beginning, middle and end of detachment. Also Ophir windows to be cleaned weekly.
2. Michell hygrometers (2), including PRTs (?check). Heights 1m and 12m (previously suggested 4m, 8m but on second thoughts that was too close for accurate differencing) — if cable length permits. *Frequent intercomparisons necessary.*
3. As many Porton anemometers as available on Porton mast — 2 at same heights as Michells if possible.
4. Net radiometer, solarimeter, surface IRT.
5. raingauge, surface operational instruments (inc. John's box), ppn. recorder
6. PAB in van, Assman outside
7. grass thermometer (?)

5.4 Other instruments

1. Radiosondes, as per normal

5.5 Logging

W P Hopwood to check with people concerned. Surface instruments to be double-logged as before, i.e. both as probes and in surface averages. See Logging Plan

Appendix: background

The main reason for going on detachment is to study flow over heterogeneous (non-uniform) terrain. Such terrain is often regarded as 'bad' in idealized experiments or e.g. for exposure of operational instruments, but covers much of the UK, so is kindof important for forecasting.

The problem for forecast or climate models is *aggregation*, i.e. how to describe the properties of a surface, e.g. its roughness, over a square of perhaps 100km×100km, by a very few numbers. In reality, over a country like Britain, such a square would usually encompass many different terrain types (forests, fields, towns, lakes, hills, etc.). But a model can hold at any given height only one measure of wind, and only one measure of drag per grid-square. So clearly these must be representative or aggregate values in some sense. The process of aggregating together different pieces of the patchwork is only partly understood through maths and models, and there is a serious need for proper validation by good experiments.

By 'good experiments' I mean with good measurements of means *and* fluxes, both near surface *and* at heights well above normal mast heights, at an ideal heterogeneous site. For the first two points a balloon-probe system like ours, plus our surface site, is just about ideal, and most others are also-rans. As regards the site, I reserve judgment until I've seen it. There may be something to be said for the PJM idea to design-your-own terrain with a little help from the Forestry Commission.

Fixed-position measurements can help because measurements at different heights z respond to the surface at different upwind distances x. As a rule of thumb, $x/z \simeq 10 - 100$. The vagueness in this estimate reflects both the fact (which is part of nature) that the response to underlying terrain becomes fuzzed-out by turbulent diffusion before it hits our sensors, and also the presence of two scales in some of the theories (all complaints to: Dr P.J.Mason, Director of Research, The Met.). So for instance a lowish probe at 100m would respond to terrain at 1-10km upwind. This is sort of borne out by Pershore and Aldermaston results.

The key measurements are means and fluxes, i.e. $U, \overline{T}, \overline{q}$ and $\overline{uw}$, $\overline{wT}$, $\overline{wq}$ plus other info like radiation measurements.

Both temperature and humidity can vary a lot very close to the surface. So how do you *define* the surface temperature T or humidity q? Whereas we take the surface wind-speed as zero there is no such simple surface value for T or q. In order for our results to be useful to modellers, the best thing is to *define* surface T as a *radiation temperature* and if the ground is saturated define surface q as the saturation value at that temperature. (There are checks to be made afterwards as to whether certain numbers — e.g. z_{0q} — turn out reasonable; if not a slight rethink may be needed.)

[Further background in scientific plan for detachment, available from SHD.]

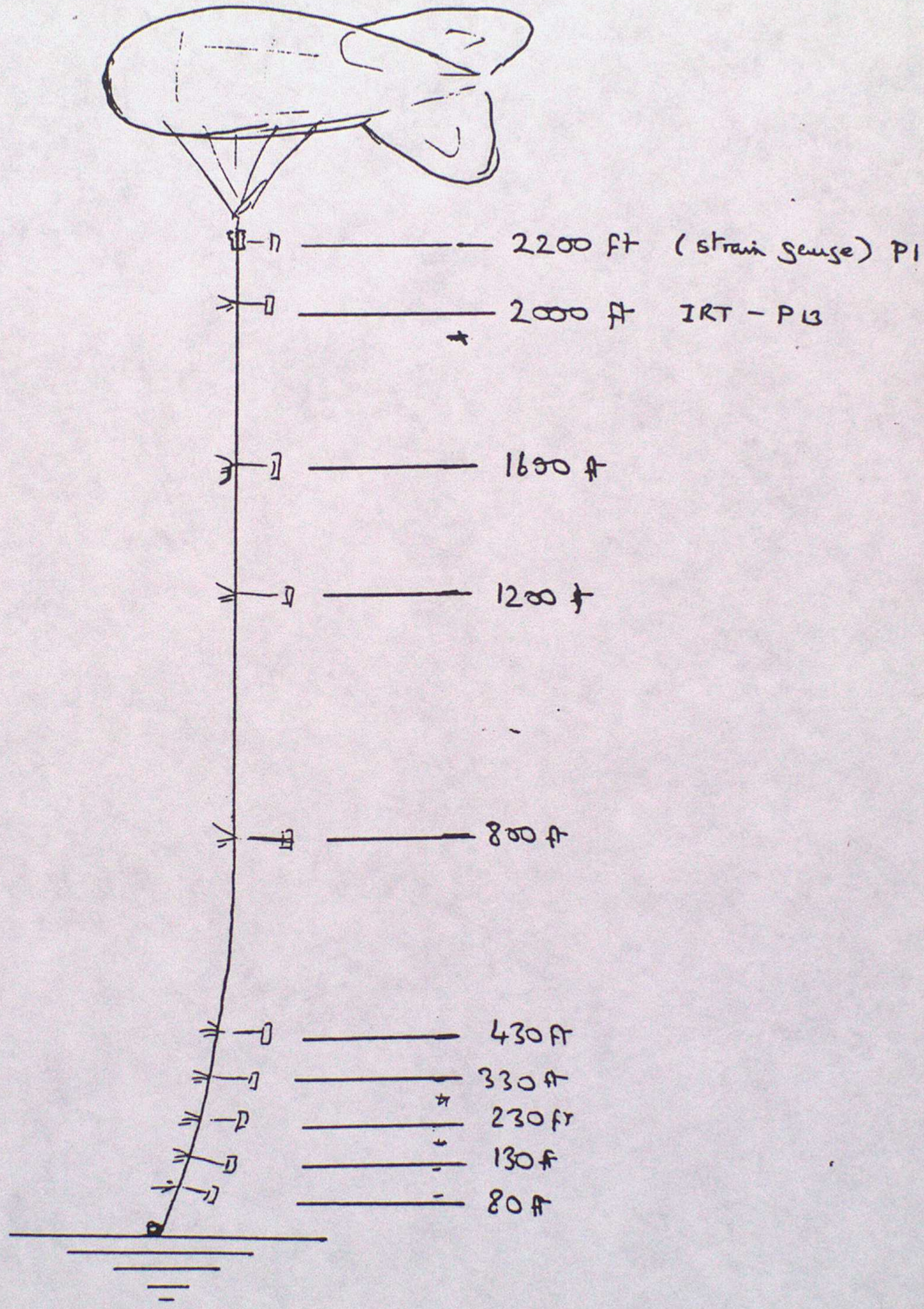


Figure 3: Probe disposition (subject to alteration)

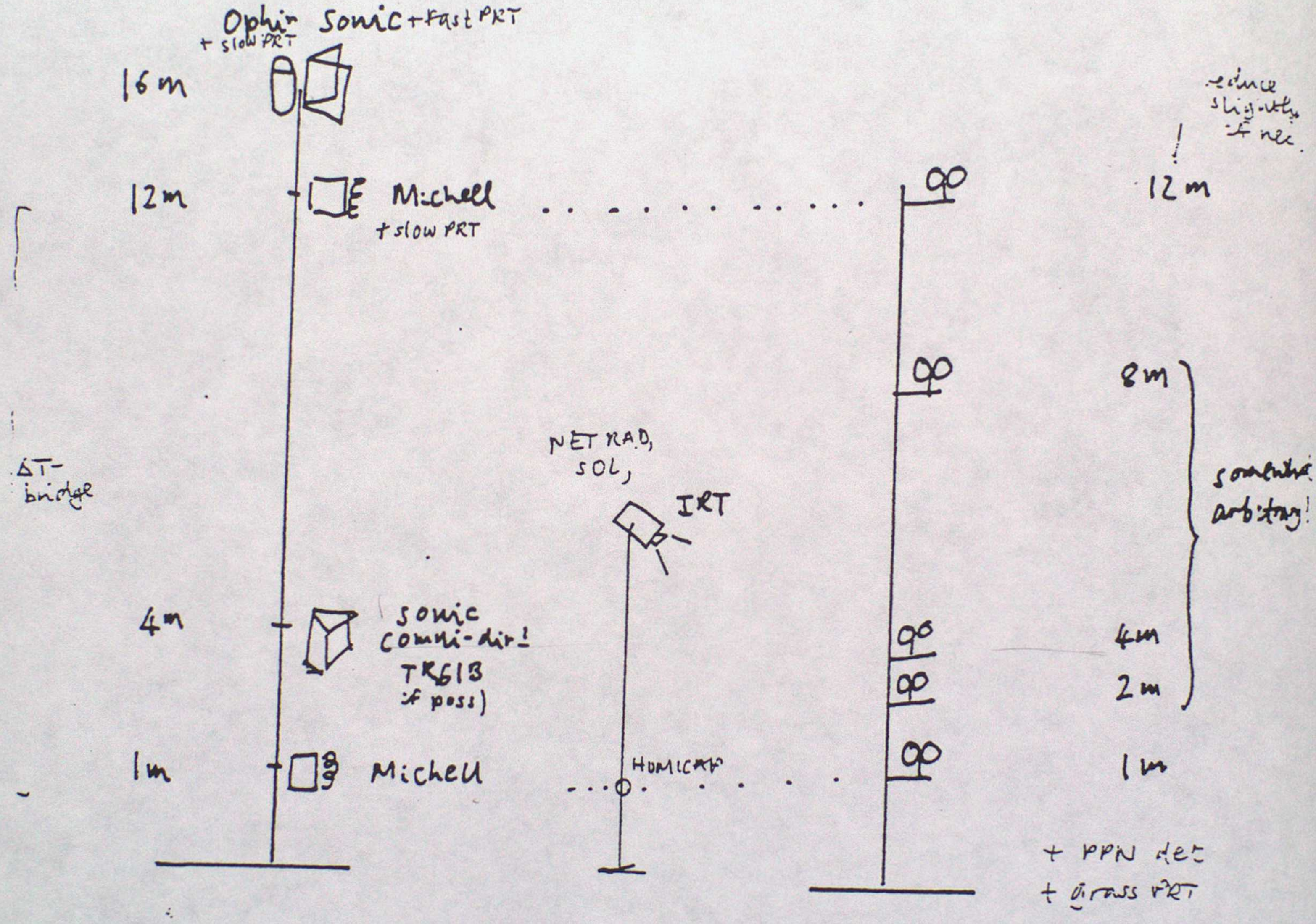


Figure 4: Surface site Mast arrangement only schematic! Michells require Portons at same height

6 Instrument logging plan

W P Hopwood et al., comments welcome...

6.1 Aims

The aims of the logging are to provide three types of dataset for subsequent analysis. Firstly, a fast sampled set of data encompassing a large proportion of the boundary layer giving mean and fluctuating winds, temperature and humidity taken whilst balloon flying. Secondly, a slow sampled dataset comprising of 10 minute and/or 30 minute averages of surface data taken continuously. And, thirdly, Radiosonde profile of instantaneous wind, temperature and humidity.

6.2 Computers

Two computers will be taken to Charney Bassett, namely ABLE and STABLE. As at Pershore they will Ethernetted together to allow data transfer and to maximise the use of having two tape drives. As ABLE possesses a larger amount of free disk space compared to STABLE the probes will be logged on this machine together with the Radiosonde flights. This will leave STABLE solely for the surface site. The probe and surface logging must at present be run on separate machines, as they both use the same global sections for transferring data to their respective display routines. In future, modifications should be made to enable them both to run on the same machine.

6.3 Logging

6.3.1 Surface Site - Slow Logging

The 'slow' surface data taken continuously will be logged via Tony's rack which consists of two 16 channel encoders. Into each encoder data will be passed from one of the sonics plus the various other surface instruments (see Appendix A). This data will be recorded at a rate of 20.625Hz implying that the rate division on the decoder boards in Tony's rack should be set to ÷1. The data will then be passed to the STABLE μVAX to form part of an half hour dataset that will be subsequently processed into 10 minute and 30 minute averages (Figure 1).

The block averaging rates set within the surface logging command file (SFCE_LOG.COM) should be set to 2 giving an overall sampling rate of 10.31Hz. To start the surface logging type SFCEGO and to stop type LOGSTOP (on STABLE (not on ABLE!!)).

From time to time the sonic anemometers will need rotating into the mean wind. The procedure to follow is to first stop the surface logging by typing LOGSTOP on STABLE, DPROC account; then rotate the sonics into the mean wind. Now update the sonic direction in SONIC_DIR.DAT. Only then restart the surface logging by SFCEGO as well as noting the time of the change and the change itself in the log book. Also, in the event of the surface logging stalling then the above procedure should also be followed noting the time of the restart in the log book.

6.3.2 Balloon Flying - Fast Logging

During balloon flights the 'fast' turbulence data provided by the probes will be recorded via the ground station into the ABLE μVAX. In addition, surface site data from the sonics, ophir, michells, etc., will be passed from the encoders within Tony's rack to the Ground station as probes 15 and 16 (Figure 1). This data will be recorded at a rate of 4.125Hz, that implies that the rate division on the ground station decoder boards should be set to $\div 5$.

The block averaging rates are set within the probe logging command file entered by typing LR on DPROC. They should always be set to $\div 0$ (blank) (ie. no block averaging) for all probes 1-16 as the logging program then automatically recognises the difference between a profile .PRF run and a level .TRB run.

To start the logging type GO, but remember to adjust the surface pressure and temperature in PT.DAT for the display programs.

6.3.3 Radiosondes

Radiosonde flight data recorded via the Digicora system will be logged on the ABLE μVAX by using the SONDE logging routine.

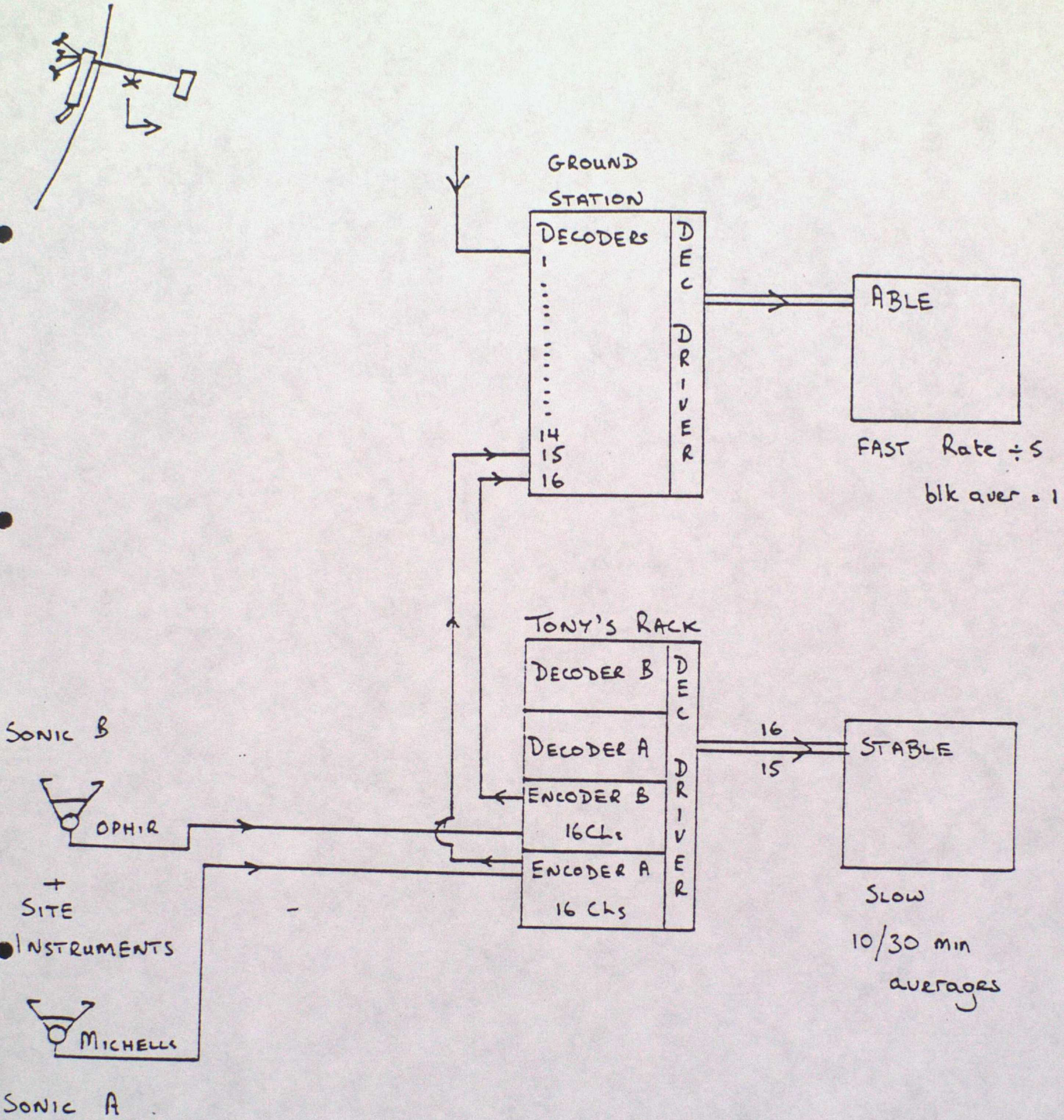


Figure 5: Instrument logging plan

Channel	Probe 15	Probe 16
1	A	-
2	B	-
3	W	Net Rad
4	TS	Ground PRT
5	Michell 12m	High PRT
6	12m PRT	-
7	Michell 4m	Low PRT
8	4m Diff	A
9	Porton 12m	B
10	Porton 8m	W
11	Porton 4m	TS
12	Porton 2m	Fast PRT
13	Porton 1m	IRT
14	Precip Det	Ophir CM
15	Pressure	Ophir CT
16	-	Solarimeter

7 Backing Up of Data

For data taken with the probe system the backups onto tape should be done daily or subsequent data could be lost due to insufficient disk space. Each days data should be put onto two identical tapes (A and B) so that there is always a backup should one tape be faulty. The tapes should be initialised to WANT01, WANT02, etc and the savesets should follow the convention of previous detachments, that is, DMddmmyyA.SAV where ddmmyy is the date the datasets were taken.

The processed datasets .STA from the surface site should be backed up at the end of each week. Again two identical tapes should be used and initialised in the same fashion as the probe tapes. The saveset names should follow the convention SURF01.SAV, SURF02.SAV, etc.,with the numbers representing the week number.

Allocation of channels in probes 15 and 16 for the surface site instruments.

8 Flight Scientists' Reminder Sheet

(see separate Instrument Plans, Balloon Plan and Scientific Background; also Balloon Breakaway Procedures). This note is basically a quick-ref for scientist in charge. Please correct any errors or omissions. Tick once-only actions when done.

8.1 Beginning of detachment

- Inform Brize in advance when forecasts to start
- Start log-book: start table of datasets on tape (including ALL relevant datasets). Write description of surface site with sketches of position and notes of any relevant points.
- position of centre-point relative to known landmarks (compass)
- drive upwind taking photos (also at end of detachment)

8.2 Operations

- Standard flying day: 1100-2100. Night watch 2300-0800. See roster for further details.
- At start of work check weather forecasts received (if not, ring Brize on 0993-840114; forecasts were requested for period 14/9-24/10 from 1100-2400 local)
- Check surface site operation; if nec., rotate sonics
- Put up sonde (not necessarily yourself!); extra sondes during flight if flying close to windspeed limit. Don't forget sondes are useful scientifically too!
- As soon as practicable make decision or provisional decision re flying. Does balloon need gassing? Consult balloon supervisor especially in marginal situations.
- Balloon-flying safety criteria are: No flying in Lightning Risk 1 or 2. Caution in LR3 (consult Brize). Prime consideration: cable tension not to exceed 1100kgf!!! Rule of thumb: no flying if gusts aloft >35 kts (mean winds around 30). Surface wind not to exceed 25 kts for bedding. Check top probe wind continuously — this probe within 200′ of balloon. Probe icing not expected to occur at 2000′ — but *don't* fly probes below 0°C (check temperatures).
- When balloon bedded, consider tomorrow or Monday's expected wind direction (refer to Brize forecaster). Always try to anticipate changes and e.g. bed early if winds becoming hazardous later.
- Rain is not necessarily a safety hazard (though will decrease balloon lift) but is bad for probe PRTs.

- Consider wind directions. S'ly wind off Lambourn Hills not good. Best directions probably NW-ish (say 250-340). However a good spread of directions over the detachment is desirable.
- Extended evening flying will imply overtime. The following criteria should be used. Humidity fluxes after transition probably small, so limited mileage in that side. Good stable boundary layers of interest to S H Derbyshire.
- A decision on weekend flying should be announced on Thursday night. Weekend overtime is expensive/lucrative and should not be wasted on dodgy conditions. Don't expect to fly more than 3 weekends.

8.3 Pattern of Work

Remember to log all ATC Messages

- PHONE BENSON 8.A.M. - PASS ON DECISION RE FLYING MADE NIGHT BEFORE
- 9.30 A.M. GET FORECAST FROM BRIZE
- 9.45 TELL BRIZE OF UPDATED DECISION RE FLYING. INFORM TROOPS. IF FLYING, INFORM LATCC MIL
- BEFORE LUNCH DECIDE ON WHETHER TO FLY IN EVENING AND INFORM TROOPS SO THEY CAN ARRANGE EVENING MEAL, AND SO NAV LIGHTS CAN BE PUT ON.
- BY FINAL DESCENT CHECK BRIZE MET RE WEATHER FOR NEXT DAY. IF FLYABLE, BED INTO EXPECTED WIND DIRECTION. TELL BRIZE RADAR WHEN YOU ARE DOWN FOR NIGHT. BRIEF MORNING PERSON ON 8 A.M. DECISION
- ON THURSDAY EVENING DECIDE ON WHETHER TO FLY AT WEEKEND. IF NOT FLYING, INFORM BRIZE RADAR. IF FLYING, INFORM TROOPS
- IF NOT FLYING AT WEEKEND, ON FRIDAY GET WEATHER FROM BRIZE OVER WEEKEND AND MONDAY. IF STRONG WINDS AT WEEKEND, BED INTO EXPECTED WIND DIRECTION, IF NOT BED INTO EXPECTED MONDAY WIND DIRECTION.

8.4 Flying and log-book

- Please try to write legibly in BLACK
- Each day should start with summary of weather and synoptic situation
- The following weather elements should be regularly recorded: Cloud, screen temp and humidity (from John's box), PAB, net radiation, wind, grass temp. Anything unusual which might affect later interpretation. Any 'nice examples' of inversions or anything else.
- Also carefully note precipitation and state of ground. *Try to get data when ground wet but drying out.*
- Strain gauge to be flown routinely as probe 1.
- For recommended probe heights see Instrument Plan. Fly with fewer on occasions especially in a wind (?) because more probes may mean more cable layback (Bad effect on wind measurements) and more oscillations (also Bad).
- Balloon diagram each day in log-book please (copy to balloonies and techs).
- Profile runs to compare adjacent probes (ascent rate about 100 ft/min). Return to original position.
- Screen dumps from DISP and PLOT to be pasted into log-book regularly (at least one for each run)
- also surface displays/numbers
- Pay close attention if lights come on in receiver rack. Flick lights off promptly and see if come on again. Any such problems must be highlighted in log-book. Be prepared to replace a probe (especially a lower one) if it misbehaves. Try to highlight any info re probes which could later be useful to the techs.
- General points on DISP. Watch ERR, DIP, BAT (9.1 abs min!). Compare fast and slow, dry and wet.
- note battery value on ascent and descent
- Consider flying camera with fish-eye lens at 1600' or so on one occasion
- Each day should end with SUMMARY in log-book. DON'T leave it till next day. Note all instrumental problems and general features/ evolution, weather ... also anything with serious safety implications.
- BACKUPS. Two tapes for each dataset!
- Especially important! Note change of sensors (time/date) including spare PRTs or Gills put on probes (so M J Brettle can worry about them later).

8.5 Surface site

- Check Portons are being regularly swapped over and any 'funnies' recorded in log-book. Ask M J Molyneux (?) to organize rota.
- Keep close eye on Michells — differences between them are crucial (again swapping)
- Remember to rotate sonic on strumech into wind AFTER stopping logging (?command?) and recording direction in SONIC_DIR.dat (?). AJL says there will be a prompt program for sonic dirn. Lower sonic to be rotated by hand *and recorded.*
- Ophir to be calibrated against Michells at least 3 times: (i) beginning, (ii) middle and (iii) end of detachment
- Ophir window to be cleaned weekly (and noted)
- Ophir offset and gains recorded
- Regularly check surface display routines and report any anomalies asap.

8.6 Non-flying days

Use constructively!

- At earliest opportunity check everything you can re humidity, and make back-of envelope calculations
- Plan later processing
- Discuss the experiment with anyone who will listen
- Discuss surface site and any funnies with relevant people
- Phone Cardington to keep them posted
- Map surrounding area

8.7 End of detachment

- Tell Brize forecasts can stop and thank them nicely
- photos of surrounding area if not already taken

9 Notes on logging and display programs

- Normally log on as DPROC.
- $COM : command-file subdirectory
- $LP : [dproc.logop] containing datasets etc

9.1 Sondes

- $SONDE logs sonde (wait for READY TO LAUNCH message!!!!) and creates e.g. RS*l.SND where * denotes date and l the id letter (A, B, C ...)
- $RSD displays sonde and creates RS*l.PLT
- To copy e.g. rs230991a.snd over to ABLE (from ABLE):
- $BAT COPY STABLE::DUA0:[DPROC.LOGOP]RS230991A.SND [DPROC.LOGOP]

9.2 Probes

- $LR to edit log.com file
- $GO submits this
- $DISP displays the numbers (check these!)
- $PLOT plots pictures
- $LOGSTOP stops probe logging (e.g. for profile run)
- $SETP edits file pt.dat to set surface pressure and temp for display routines height calculation

9.3 Surface

- To be written by MJM
- $HMR invokes humidity slide-rule

9.4 Tapes

- To insert: push in, pull flap back gently, wait for green light then press red.
- To extract: press red, wait for green on and red off, reverse flap.

- To initialize: $bat init drivename tapelabel (e.g. drivename is mua0:, tapelabel is vwh02).
- To backup from disk onto tape:

9.5 Sonde launch

1. Digicora — start by: RESET
   SOND Accept date
   AUTO TELEM (also to go back)
2. switch on spectrum analyser and amp.
3. Power up sonde and tune to correct frequency (careful of probes)
4. Run through CALIB tape as prompted
   enter surface obs
   place sonde elements in chamber
5. prepare balloon
6. Enter GC refs - humidity 0, t from GC thermometer
7. when accepted, soak battery and remove sonde from chamber
8. attach battery to time
   clip timer for desired time
   check connections on timer (B battery, S sonde)
   attach timer and cut wire!
9. check $sonde submitted and READY FOR LAUNCH message appeared
10. LAUNCH!

General notes: write your own comments

10 Notes on Radio Discipline

10.1 Why do we need it??

Because of the "transmit " button. Radio communication is unique in that it is impossible to speak and listen simultaneously. A conversation is only possible if regulated so that people speak in turn. Without proper radio discipline information is lost and time wasted by speaking to empty air or to people who are themselves trying to speak to you.

10.2 Initiating Conversation

Don't just transmit blind. First establish contact. The following simple procedure is equivalent to making a telephone ring:-

transmit:- STATION CALLED
STATION CALLING
STATION CALLING (NOTE REPETITION)
"OVER"

eg: "BALLOON BED"
"CARAVAN"
"CARAVAN"
"OVER"

This is sufficient to establish communication. Wait a while for a reply before trying again to give the station called a chance to organise their response. This should be equally simple.

eg: "CARAVAN"
"BALLOON BED"
"OVER"

Now the calling station (in this case the caravan) can pass their message or question knowing there is someone listening.

10.3 Maintaining Conversation

The golden rules here are to always end with "'OVER" before releasing the transmit button. Then the other person knows they can talk without missing anything and in the knowledge that you are listening.

Equally important never interrupt or assume that a pause is the end of a transmission. Remember that if the other person still has his finger on the transmit button you are wasting your breath. Reply only after you have heard "OVER".

Strictly every transmission should start with STATION CALLED, STATION CALLING. In view of the limited number of potential stations in MRU use, this is not always necessary.

10.4 Ending Conversation

By convention the station called is regarded as being in control and therefore has the last word. This is always "OUT" (not "OVER AND OUT"). There is no need for the other station to follow with an "OUT" of their own. It is obviously unwise to use "OUT" immediately after an important sentence as the control is then uncertain that the message has been received.

10.5 "Prowords"

By convention certain words are widely used in VHF communication and have strictly defined meanings. some potentially useful ones are as follows.

ACKNOWLEDGE:	meaning "Have you received and understood".
CORRECTION:	meaning "An error has been made, the correct version is ......".
SAY AGAIN:	meaning "Repeat your message".
STATION CALLING:	used when you are uncertain who is calling you.

11 Flying Operations

Updated Procedure 15th September 1992

11.1 Background

The NOTAM-ed area within which we are operating lies about three miles north of the southern boundary of the Oxford Area of Intense Air Activity (AIAA). This is an advisory area, and liaison should have been made with the users before attempting to fly a balloon there. However the CAA misplotted the position of our site and so did not communicate with the airfields in the area before issuing the NOTAM (advisory) and UKLB (mandatory to the military). Both of these were issued at extremely short notice despite our early notification. Thus RAF Benson and Brize Norton were suddenly excluded from part of their training areas without warning, at a time when intensive use had been planned. Benson has five squadrons of aircraft (two bulldog, one chipmunk and two helicopter) who all use the area for training (emergency landings etc with novice pilots). Brize also use the area and fly at heights above 3000 feet there, and there are other training aerodromes, such as Oxford (Kidlington) itself. Because the detachment (with money and time invested in balloon bed laying, site cabins etc) had already started when we became aware of this, we have insisted on our right to operate given us by the UKLB but have agreed to the following procedures to allow us to co-operate in the use of the airspace.

11.2 Procedures

On the evening before flying (possibly on Friday evening prior to Monday flying) a decision must be made on the likelihood of flying the next day, between what hours, and to what maximum height. This decision must err on the side of flying and to the maximum possible height as it will be impossible to retract afterwards. Make it clear if the heights given are above ground level (AGL) as Bagmere farm is 207 feet above sea level. The decision must be relayed by the person on morning watch to RAF Benson flying operations **0491-37766 Ext 2487 or 2555** before 8 a.m. when the pilots are briefed.

This decision will then be updated and fuller details given at 9.45 a.m. to Brize Radar on **0993-842551 Ext 7878** on the flying day. Brize radar will then pass the information to all other RAF stations including Benson. The information should include hours of operation, maximum height, angle of layback and direction. If anything changes, keep Brize informed. Also, at 9.45 am, inform London Radar (only if flying)

In addition the NOTAM has been updated by issuing a second NOTAM stating that all drogues and lights will be doubled up. Thus drogues will be attached at 250 feet intervals and navigation lights at 500 foot intervals.

If necessary, the balloon may need to be pulled down for a particular RAF operation but this should not be a common occurrence.

11.3 NOTAM information

1. The first CAA NOTAM covering the area was only finally issued on 3rd September although it left Mr Pashley's desk a month earlier. It is number **U2743/92** This covers the full airspace and is ADVISORY for both civilian and military aviation.
2. The second NOTAM will be issued as soon as possible after 15th September and updates the first NOTAM
3. UKLB (United Kingdom Low Flying bulletin) **No 3388** was issued on September 10th. It covers the area below 2000 feet and is MANDATORY for MILITARY aviation.

11.4 Telephone Numbers

1. CAA issuer of NOTAMS -Mr Pashley **0895-276100**
2. Military issuer of UKLB's S/L Sulley or Sgt Walters **0895-276062 or 276063**
3. University of London Air Squadron:
   O/C W/C Cullen **0491-37766 (GPTN 9261) Ext 2509 or 2510**
   CFI S/L Ewer
4. RAF Benson P.Met.O Hugh Brookes **0491-37766 (GPTN 9261) Ext 2208**
5. London Radar (West Drayton - military supervisor) 0895-426464

12 Balloon Flying and Safety Instructions

12.1 Introduction

The first part of these notes is intended to give the flight scientist enough information to allow him to make a reasoned judgement about whether or not it is safe to fly the balloon on any particular occasion. This is followed by sections on static lifts and bedding procedures

There are three main factors to be considered which affect the safety of the balloon and/or its operators:

a). Wind speed.

b). Risk of lightning strike.

c). Risk of icing (this is mainly a problem for the probes and not the balloon).

These will be dealt with in turn and recommendations made.

N.B. If there is any doubt consult the balloon supervisor (who really ought to be consulted anyway).

12.2 Wind speed and maximum gust limits

The following section describes the data available to us at present in deciding on the maximum safe cable tensions and windspeeds at which flying should take place in. This is followed by actual recommendations on these tensions and windspeeds.

There exists only one set of data for an MB24A balloon (i.e. one with rounded fins and rudder) flying on KB3 at wind speeds in excess of 25 to 30 knots. This was obtained at Caersws on 7 October 1989.

Diagram 1 shows these results as a plot of cable tension against wind speed. Also plotted on this graph are two possible models which describe the actual data obtained. One is for tension proportional to wind speed squared and the other for tension proportional to wind speed cubed. The mean wind speed for the complete 4200 second run is 29·4 $\pm$2·6 knots and the mean tension is 626 $\pm$73kg. A third curve plotted is the "wind speed squared" line plus five times the standard deviation of the mean tension.

The following facts concerning cable damage have emerged from previous flying experience:

a). KB3 will immediately break when subjected to a load of about 1600kg (i.e. less than three quarters its minimum breaking load of 2·25 tonnes) and when used with V-groove surge drums. This was established at an actual incident when the cable broke up on the surge drums on November 24th 1988

b). KB65 suffers internal damage and will eventually break after several reversals when subjected to a load of about 3100kg (i.e. less than half its breaking load of 3·25 tonnes) and when used with V-groove surge drums. This proved to be a repeatable result in two series of separate tests, using increasing loads on a winch.

c). KB65 does not suffer internal damage until subjected to a load of two-thirds of its breaking load of 6·5 tonnes when used with a U-groove drum. At this load it will eventually break after several reversals. This was established using one series of tests using increasing loads on a winch.

d). KB3 has not been similarly "tested" with U-grooves. It is possible however that KB3 running in U-grooves would not suffer initial internal damage until it was loaded to two-thirds of its 2·25 tonne minimum breaking limit (i.e. 1·6 tonnes). This is a big assumption and should not be relied on in practice. Tests will be conducted after the detachment.

The winch to be used for the Vale of The White Horse detachment is fitted with U-groove drums. However, a limit of 1100kg should be used. It can be seen from the graph that the five standard deviations line intersects the 1100kg line at a wind speed of 35 knots. It should be remembered that this represents a gust of 35 knots and in the case of the Caersws data gusts of up to 37 knots were experienced with a mean wind speed of 30 knots.

THE CONCLUSION, THEREFORE, IS THAT THE BALLOON SHOULD NOT BE FLOWN IF GUSTS IN EXCESS OF 35 KNOTS ARE EXPECTED. (IT IS LIKELY THAT IT WOULD BE ALL RIGHT TO FLY WITH A MEAN WIND SPEED OF 30 KNOTS BUT A VERY CLOSE EYE SHOULD BE KEPT ON THE CABLE TENSION, PARTICULARLY AS MEASURED BY THE TENSIOMETER AT THE POINT OF ATTACHMENT - TENSION MUST NOT EXCEED 1100 KG. THE TOP TURBULENCE PROBE WILL BE FLOWN ABOUT 200 FEET BELOW THE BALLOON AND THE WIND SPEED FROM THIS SHOULD ALSO BE WATCHED CAREFULLY).

Some further points to note:

The highest tensions in the cable can be generated with the balloon near the ground if a gust catches the balloon sideways on. In this position the drag is about ten times that in the nose on position and there is not sufficient cable to absorb shock loads.

The tension at the cable terminator is higher than that at the pulley block although not subject to the same strains.

Bedding and unbedding the balloon becomes very difficult, if not dangerous or even impossible, once the surface wind speed exceeds 25 to 30 knots. This may well place a wind speed limit on balloon operations sowewhat lower than that already considered for flying at altitude.

The shock absorbers on the winch "bottom" at 1·3 tonnes (25 cwt). So cable tensions in excess of this can only be absorbed by the cable or its catenary.

If flying close to the wind speed limit is considered and the wind speed at altitude is uncertain a radio sonde ascent should provide useful information. If flying goes ahead then further sonde ascents could be made to confirm the winds being measured by the upper probes.

12.3 Lightning risk

The hazard to the balloon and its operators from lightning is self evident and nothing more should need to be said. The forecast from Brize Norton will include an estimate of the lightning risk on a scale from one (very high risk) to five (no risk). The details of the scheme are given below;

1. Very high risk	Forecast:	High probability of cumulonimbus, hail, thunder, heavy rain, or heavy showers.
	Reports:	Cumulonimbus cloud, hail thunder, heavy rain/shower, relevant SFLOC.
2. High risk	Forecast:	Moderate probability of cumulonimbus or well developed altocumulus castellanus with hail or thunder or moderate/heavy rain/showers.
	Reports:	Moderate rain/shower.
3. Moderate risk	Forecast:	Convective development at sub-zero temperatures with precipitation.
	Reports:	Slight showers, significant amounts of castellanus.
4. Low risk	Forecast/ Reports:	Convective development with no precipitation justifying lightning risk three.
5. No risk		May be used if risks one to four do not apply.

Notes:

a). 'Convective development' includes castellanus likely to produce precipitation

b). The significance of reports of castellanus can only be assessed in the light of further available data, e.g. sonde ascents. It is suggested that amounts of castellanus of 4/8 or more, particularly if at more than one station, would certainly be 'significant'. This cannot be construed as a 'rule'. Given great potential instability, the first report of only 1/8 castellanus could well be highly 'significant'.

c). Each situation can only be assessed individually. It is worth noting that one should be extra vigilant where fronts, troughs or convergence zones are expected to cross the area, where an unstable north-westerly airstream exists, and in a north-easterly airstream in winter.

Balloon flying can take place in lightning risks of 4 or 5. With a lightning risk of 3 further advice should be sought from the forecaster. Usually, flying is permitted below cloud base. There should be NO FLYING IN LIGHTNING RISK 1 OR 2. If rain or dark clouds are noted during flying operations, the lightning risk should be queried. An important factor is thickness of convective cloud above the freezing level, a thickness of more than 5,000 to 10,000 feet giving a fair chance of lightning Thus lightning is more likely in cold weather when the freezing level is lower. If flying in marginal conditions it is well worth while asking the forecaster to check the radar for strong echoes every hour or two.

12.4 Icing

As it is not intended to fly the balloon above 2,500 feet and in view of the time of year it is unlikely that icing will be encountered. The existence of sub-zero temperatures in connection with convective development has already been covered under lightning risk. Flying under these marginal conditions would be unwise anyway.

The balloon itself is not seriously affected by icing. The main result of ice build-up is gradual loss of lift. The valve is designed to cope with a certain amount of icing.

The main result of icing is damage to probes, particularly Gill propeller blades and the 'fast' PRT element.

12.5 Simple Aerostatics

The balloon has a volume of 23,500 cu ft (650 cu metres) that gives a gross lift of 1637 lbs (744kgs) when filled with Helium under normal conditions of temperature and pressure. The balloon itself, with fittings, weighs 690 lbs (313.5 kgs). Thus when completely full on the ground, the net static lift is 970 lbs (441 kgs). The expansion ratio to 6000 ft is 0.83 - thus the net static lift at that height will be 0.83*1637-690=669 lbs (304 kgs), while at 4000ft the expansion ratio is 0.88, giving a net static lift of 0.88*1637-690=750 kg. The cable weighs 66 lbs (30kg) per 1000 feet, and the probes weigh 22 lbs (10kg) each. Thus the total load at 6000 feet is 6*66-9*22= 594 lbs (270 kg) giving only 0.6cwt (34kg) tension at the pulley block in the absence of wind, while the total load at 4000 feet is 4*66-9*22= 462 lbs (210 kg) giving 2.6cwt (131 kg) tension at the pulley block in the absence of wind. In practice, tensions less than around 2 cwt (100 kg) are unacceptably low - however even quite low winds will increase the tensions by this amount, but also causing a considerable layback of cable at low static tensions. It should be noted that provided the balloon is not filled above its pressure height (the height at which the valve will open on ascent), the net static lift will stay constant on ascent which simplifies calculations and saves gas. However to maintain cable tension, the balloon should be filled to a pressure height slightly below the maximum height to be used in the day.

To fill the balloon 88 percent full at sea level requires about 49 MRU bottles filled to 3000 psi, or about 58 bottles filled to 2500 psi or about 73 bottles filled to 2000 psi. Each bottle holds around 400 cu feet of gas at NTP when filled to 2700 psi.,which should give an increase in lift of around 26 lbs per bottle when pure. The bottles are in manifolded crates of 4 bottles per crate.

The static lift is difficult to measure on detachment as even light winds increase the net lift (static+dynamic) by 50 to 100 lbs. If measuring the lift, check that the tail guy is free.

Superheating by the sun can cause internal temperature excesses of 15 degrees or more, increasing the lift by 50 lbs and also lowering the pressure height. This is a regular cause of Helium loss and may require one or two bottles of Helium a day to make good.

The balloon has been shown to have a leakage rate when stored in the hangar giving rise to a loss of static lift of about 5 lbs per day. There is a loss of purity at the same time. This loss of lift and purity is mainly due to small leaks as diffussion through the fabric should only give a loss of 1 lb lift per day. Bedding trials over a few days showed that the background leakage rate was not significantly greater than in the hangar.

The balloon has a ballonet ceiling of 6500 feet above ground level. This should not affect operations, but if for any reason the balloon does exceed this height, the effect will only be noticable on the descent, near the ground.

The purity of the Helium is extremely critical in obtaining a good performance. If the purity drops to 90 percent then even if the balloon was filled with helium on the ground to an adequate static lift, by the time the balloon reached 1000 feet it would have valved off some of the gas due to the increased volume per unit lift of low purity gas.

12.6 Bedding

Full details on the balloon bedding procedure are given in appendices A and B but a short summary is given here.

The balloon can be fairly easily handled near the ground in windspeeds of up to 15 knots. Above this it becomes progressively more difficult until at speeds gusting 25 to 30 knots it may become very difficult or impossible. If bedding the balloon is impossible, then provided winds above 50-55 knots are not forecast, it is best to leave it flying on about 1000 feet of cable which should be above the turbulent surface air. With this length of cable there should be sufficient absorption of shock loads due to gusts.

If the balloon cannot be bedded and a wind significantly higher than 50 knots or a high lightning risk is forecast, consideration should be given to ripping the balloon which is done by giving a pull of greater than 20 lbs to the RED NYLON CORD ON THE STARBOARD SIDE OF THE BALLOON. This is not too awful an action to contemplate as there is a spare balloon and the ripped one is easily repairable. Only the gas is lost, together with some flying time while the second balloon is inflated.

The bedding operation involves setting the pulley (snatch) blocks onto the bed so that the balloon is pulled down facing into wind, pulling the balloon down and transfering it to a central strop, removing the radar reflector, running the handling guys through the pulleys and clipping them to the spider, pulling the balloon down on the spider until the ballonet blower and air relief valve can be removed, removing and pulling out the rigging leg with topping up hose attached, putting padding over the main rigging and then tensioning down with the ballonet sleeve undone and exhaust tube inserted. Be careful to ensure that it is the ballonet sleeve and NOT the neighbouring gas inflation sleeve which is colour coded RED. Finally the tail exhaust sleeves are undone and the tail folded and lashed down, AND THE RIP CORD TIED SECURELY TO ONE OF THE STAKE PLATES.

If possible lines should run from the main rigging patches under the balloon to the bed wires to stop the balloon twisting in a wind. The tensioning should be set to about two tonnes of the main cable when it has been taken off the flying cable (which has a limit of 4.25 tonnes) and transferred to the Tirfor. This should put a load of about 500 lbs on each of the patches, and may be increased from 2.0 tonnes to 2.5 tonnes in a high wind. The tension pressurises the balloon to withstand the wind, and should be in the range 10 to 20 mm water (i.e. 1 to 2 mb) The balloon can take up to around 60 mm water excess pressure although it will stretch greatly. However in the bedding position the main strain is on the patches, which stretch and eventually leave the fabric above them porous. As the balloon CANNOT VALVE GAS WHEN BEDDED (as the valve is not pressure but line operated) a check should be kept on the internal pressure and line tension, in particular when the sun falls on it first thing in the morning, causing the gas to expand.

Unbedding is the reverse of bedding (remembering to untie the rip line) except that the balloon must be inflated with air from a blower as it is raised. Otherwise in any wind the gas will surge around and the balloon will lie acrosswind rather than lining up with it. Another point to watch is the problems that arise if the wind is not in the same direction as when bedded. If the wind is greater than 15 knots it is probably best not to unbed in this latter case, but if unbedding is attempted the tail guy should be held on to until the handling guys have been unclipped and then released with care (there may be several hundred pounds force on it)

12.7 Air blower and exhaust valve

The balloon is not pressurised by the helium gas except insofar as the static lift exerts a pressure of 8mm water near the top of the balloon dropping to zero at the bottom. The main pressure is due to ram air entering through non-return flaps at the nose and tail air scoops. This is augmented by an airbooster giving a superpressure of 1.5 to 2.0 times the ram air pressure which should stop the nose dimpling in a steady air flow. The booster is highly desirable but not essential to operations and can be removed provided its duct is tied up. As the balloon rises the ballonet diaphragm expands downwards and the air displaced must be allowed to escape or the balloon will burst. This is accomplished by means of a metal can exhaust valve facing into wind, and set to open if the internal pressure exceeds the ram pressure by about 14 mm water(1.4 mb). This valve is important. If it is not attached to the balloon, its ducting must NOT be tied up. However in this case the balloon will not be able to maintain a high internal pressure and will dimple in gusts and high winds. For reference, there follows a table of ram air pressures expected for given windspeeds near the ground:

VELOCITY (KNOTS)	PRESSURE (mm water)
10.	1·7
20.	6·6
30.	14·9
40.	26·6
50.	41·5
60.	59·7

12.8 Navigation regulations

West Drayton (London radar) and Brize Norton ATC should be informed at the start of flying operations each day and when they are finished at the end of the day.

By day drogues are flown at 500 foot intervals on the cable. By night, a pair of lights (white over red) are flown under the balloon and this pair is repeated every 1000 feet. At least one pair must be below cloud base. A triangle of flashing lights must be set out on the balloon bed.

The balloon should also carry a radar reflector in the rigging.

The area has been NOTAMed and MATO has been informed.

12.9 Breakaways

In the event of a balloon breakaway there is a clearly defined procedure to be followed. This is detailed at Appendix C. copies of this will be posted in all "portakabins" on the field site.

If the cable suddenly goes slack, RUN UPWIND - this should avoid any entanglement in case it suddenly snaps taut again, and should save you from shock if the cable touches a power wire.

If the balloon sinks to the ground with its cable attached the greatest danger is usually from the cable falling over live power wires. Before phoning anybody, ensure that everyone is aware of the danger this can cause, and check that everyone is several metres away from any potentially live metal object.

If the cable breaks near the pulley block when the balloon is at altitude then it will probably trail cable a considerable distance over the countryside shorting power cables and causing damage. If the break is near the balloon it will rise (nose up) and may or may not burst (watch for this if possible). If it does not burst it will reach an equilibrium ceiling of 20,000 to 30,000 feet and drift downwind into the airways.

Appendix A

Balloon bedding procedures MB24A

1. Lay out groundsheets on bed and also position tail sheets.
2. Attach carabiners and bedding pulley blocks to bed wires as directed by bed supervisor. (Those for the bow and numbers 1, 2 and 3 guys on the 22ft bed mooring circle and number 4 on the 30ft circle with extension strop).
3. Clear balloon bed of all obstacles.
4. Lay out spider in approximate position.
5. Winch the balloon down and remove the radar reflector and untie the handling guys.
6. (Remove breakaway device battery and receiver pod. Tie off connector to rigging. - this is not applicable in 1992 but is included in case these notes are used in a future detachment)
7. Attach 6ft strop from a separate shackle on centrepoint to bellcrank mooring strop.
8. Pay out flying cable so balloon is flying on mooring strop.
9. Have 1 person steady balloon into wind using tail guy loosely reeved round 60ft mooring circle.
10. Disconnect flying cable and remove it from flying block.
11. Remove flying block from bed (or drop it into centrepoint hole), and cover centrepoint and bed earth plates with protective mats.
12. Haul in flying cable under hand tension as directed by bed supervisor.
13. Move spider to correct position beneath bow of balloon and attach it to the flying cable.
14. Reeve handling guys through bed pulley blocks and attach to appropriate legs of spider.
15. Check all spider legs, handling guys and blocks are free and not twisted or tangled. Have 1 person each side to monitor their free movement during subsequent bedding operations, and stop proceedings if problem is noted.
16. Bed supervisor will now instruct winch driver to start pulling down the balloon on the handling guys. The person at the tail to keep some tension on the tail guy.

17. At appropriate height the bed supervisor will instruct winch driver to stop hauling in while he and the two from either side of the balloon go underneath to disconnect ripline and attach it to the 30ft mooring circle. They also disconnect topping up hose rigging wire from main rigging shackle and pull it out to the port side, then reconnect all the other rigging legs on the shackle and position the rigging in the centre point hole under the balloon.

18. Bed supervisor then instructs hauling in to continue, until halted for removal of blower and flap valve. Person at the tail is then instructed to tie off tail guy and undo rudder air sleeve.

19. Remove blower and valve from bed area and position protective mats over close haul rigging.

20. Personnel are then repositioned to port and starboard sides and third person prepares to take in on the tail guy.

21. Bed supervisor then instructs winch driver to restart pulling down the balloon, and another person to untie the ballonet sleeve on port side (not red helium gas sleeve.) and fit air deflation tube.

22. Pull in tail guy tight and tie off, undo fin deflation sleeves to release air more quickly.

23. As the balloon settles, the tensions on the guys are taken in and the spider is transferred to the winch chassis using the Tirfor winch and load cell to take the tension off the flying cable. The tension is normally kept at around 1000kg.

24. Fins and rudder are now tied down under balloon, to stop movement. Sandbags may be hung from side tag patches, but these patches must NOT be tied to the bed.

25. Check topping up hose safe under balloon and rip cord tied off and clear.

26. Check handling guy tensions are roughly equal.

27. In the interests of safety, people should not stand between ropes or rigging wires. Take great care when moving around the balloon bed.

28. The tension set by the Tirfor should be altered according to changes in temperature and pressure in the balloon, due to local weather conditions.

Appendix B

Balloon unbedding procedures - MB24A

1. Test air blower, switch it off and position it near rudder.
2. Undo securing lines around rudder and fins and retie fin deflation sleeves. Untie sandbags if used. Secure blower tube in rudder sleeve.
3. Connect spider to flying cable and take in tension so that Tirfor can be removed from spider.
4. When ready to raise balloon, start blower and as tension increases the winch driver will allow balloon to slowly ascend.
5. A person should stay at the tail to slacken tail guy as appropriate. One person either side of balloon should ensure free running of handling guys and bedding pulley blocks, and also check rip cord does not come under tension.
6. When accessible, tie off the ballonet sleeve.
7. Balloon is allowed to slowly rise until bottom is accessible. Bed supervisor may instruct person at tail to tie off tail guy and stop blower temporarily as ballonet inflates. Supervisor will stop the ascent whilst protective mats are removed from close haul rigging, air blower and flap valve are installed and the topping up hose leg is refitted to the main rigging. Shackles should be spiked up tight.
8. Bed supervisor will instruct person at tail when to restart blower. He then slackens tail guy as balloon rises further.
9. Rip line is untied from bed wire, re-clipped to rigging and tied onto bellcrank strop with a clove hitch.
10. Check air blower fan is rotating.
11. When sufficient air is in tail and ballonet, the bed supervisor will instruct person at tail to tie off tail guy, stop blower and remove pipe from rudder with assistance from others if necessary. Tie off rudder deflation sleeve.
12. (Fit breakaway system pod to rigging and connect up cable to panel and battery. - this is not applicable in 1992 but is included in case these notes are used in a future detachment)
13. Bed supervisor will advise winch operator to pay out cable to transfer balloon to the strop. He and person from each side of balloon will now pull the spider to slacken the handling guys and release them from the spider and bedding blocks. The person at the tail will WAIT UNTIL ALL HANDLING GUYS HAVE BEEN UNCLIPPED and then slip the tail guy and allow the balloon to come into the wind, steadying balloon without retying tail guy. This operation can be critical if wind is strong and different in direction to when balloon was bedded.

14. Refit flying cable to flying block and balloon bell crank.

15. Tie up handling guys.

16. Test breakaway system.

17. When ready to raise balloon, fit radar target and transfer to flying cable. Disconnect mooring strop.

Appendix C

EMERGENCY

BALLOON BREAK-AWAY TELEPHONE PROCEDURE

FOR CHARNEY BASSETT, WANTAGE DETACHMENT

THIS PROCEDURE MUST BE FOLLOWED

IN THE EVENT OF A BALLOON BREAKAWAY

1. Leave one person to watch the balloon.

2. If the flying cable is still in the local area warn all personnel of the danger from it connecting a power wire to fences, winch etc.

    (a) Ring LATCC(Mil) MAIS 0895 42 Ext 6153, 6717 or 6718 followed by:

    (b) LATCC(Civ) Supervisor on West Drayton 0895 42 6015

3. Give the following information:-

    (a) Your unit:- you are the Met. Office Research Unit.

    (b) Your location: Charney Bassett, Nr Wantage, Oxfordshire - Grid Reference: SU 378937 51° 38.4′ N 1° 27.2′ W.

    (c) The colour, size and type of balloon: white coloured 24,000 cu ft MB24A.

    (d) The length and diameter: 24.5m long and 8.5m in diameter.

    (e) Size and weight of attached package(s): 20lbs each package x number of packages attached.

    (f) The length of attached cable: dependent on height of balloon on break-away.

    (g) The lifting agent: Helium.

    (h) The time, height and direction last seen: dependent on length of cable paid out and wind direction at balloon height.

    (i) The telephone you are speaking from: (0235) 868995.

    (j) Ask the controller to keep you informed of any information as to the balloon location and tell him a recovery party will be standing by.

4. If the balloon bursts and the balloon or cable causes a hazardous situation ie. the cable comes down on power lines then the person in charge of the balloon will take the necessary action to close off the area to all personnel until the Electricity Board has been contacted for advice. (Tel: Southern Electricity Board on (0793) 528181 Ext 4334; this will connect you to the control room between 0900 hrs -

1700 hrs Monday - Friday. Weekends and outside normal office hours dial (0793) 528181 which will connect you direct to the control room. This procedure should be followed even if a breakaway has occurred and the balloon has not burst. The fact that the balloon or its cable could be in contact with power lines anywhere, becomes a very real threat, once it is out of sight.

5. Contact **LOCAL POLICE** (Abingdon) on (0235) 776000 ask for control room and pass on all the above information.

6. Gather what facts are available as to the cause of the break-away and the consequences (make a note of them because it is easier than trying to remember them the next day).

7. **DO NOT LEAVE THE TELEPHONE UNATTENDED**

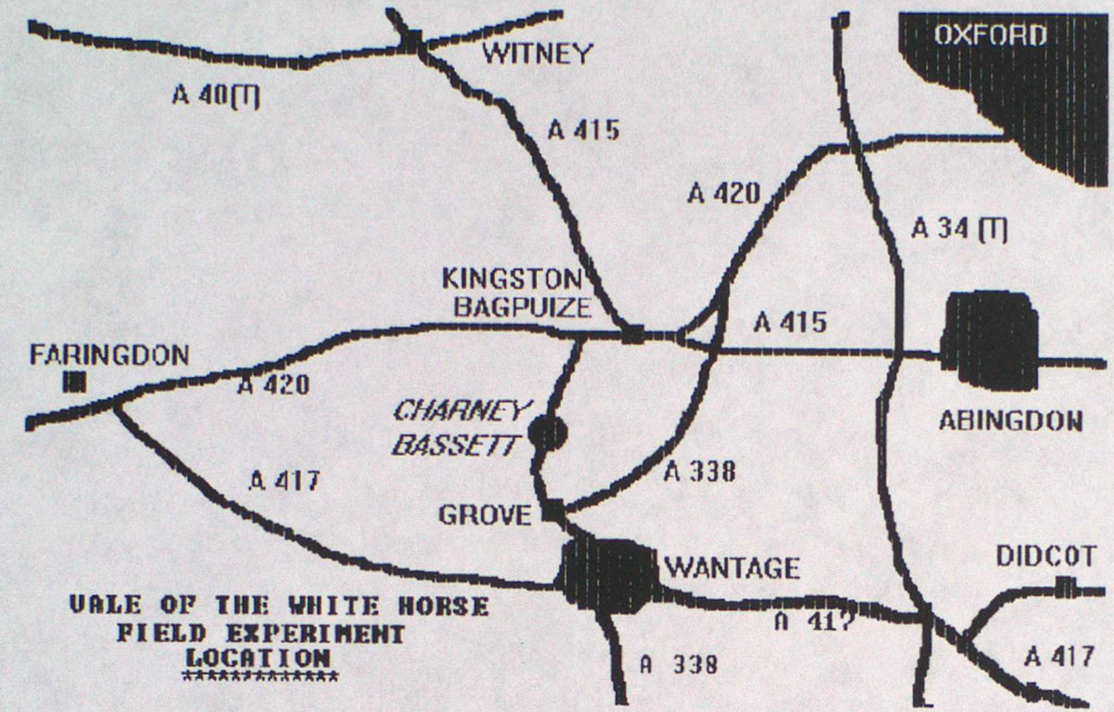
Appendix D

Useful Telephone Numbers

Cardington	Tel: 0462-851515 Gill Ext 6582
Bag Mere Farm field site, Charney Bassett, Wantage,Oxon.	Tel: Abingdon (0235) 868995 Fax: Abingdon (0235) 868904

Operational numbers	Brize Norton Met. Office	Tel: (0993) 840114 or (0993) 842551 Ext 7573
	Brize Radar	Tel: (0993) 842551 Ext 135214 Ext 7878 Ext 1350 (air traffic switchboard)
	London Radar (West Drayton) (military supervisor)	Tel: (0895) 426464
	RAF Benson (Flying Ops)	Tel: (0491)37766 Ext 2487,2555,2554
	RAF Benson (Hugh Brookes)	Ext 2208
Miscellaneous:	Basil Sharpus (the farmer)	Tel: (0235) 868254
	Ormond Guest House (Mr & Mrs Mudway)	Tel: (0235) 72409
Breakaway numbers	See separate sheet/notice for step-by-step instructions.	
National Press:	The Independent (news desk)	Tel: 071 253 122
	Oxford Mail	Tel:0865 - 244988 Ext 235
	Penny Wright	Tel: 0865 - 311521
Local Police (Wantage:	(for other than breakaway situations)	Tel: (0235) 776000 (ask for Wantage Police Station)
Digital :	(for computer maintenance)	Tel: (0256) 592000

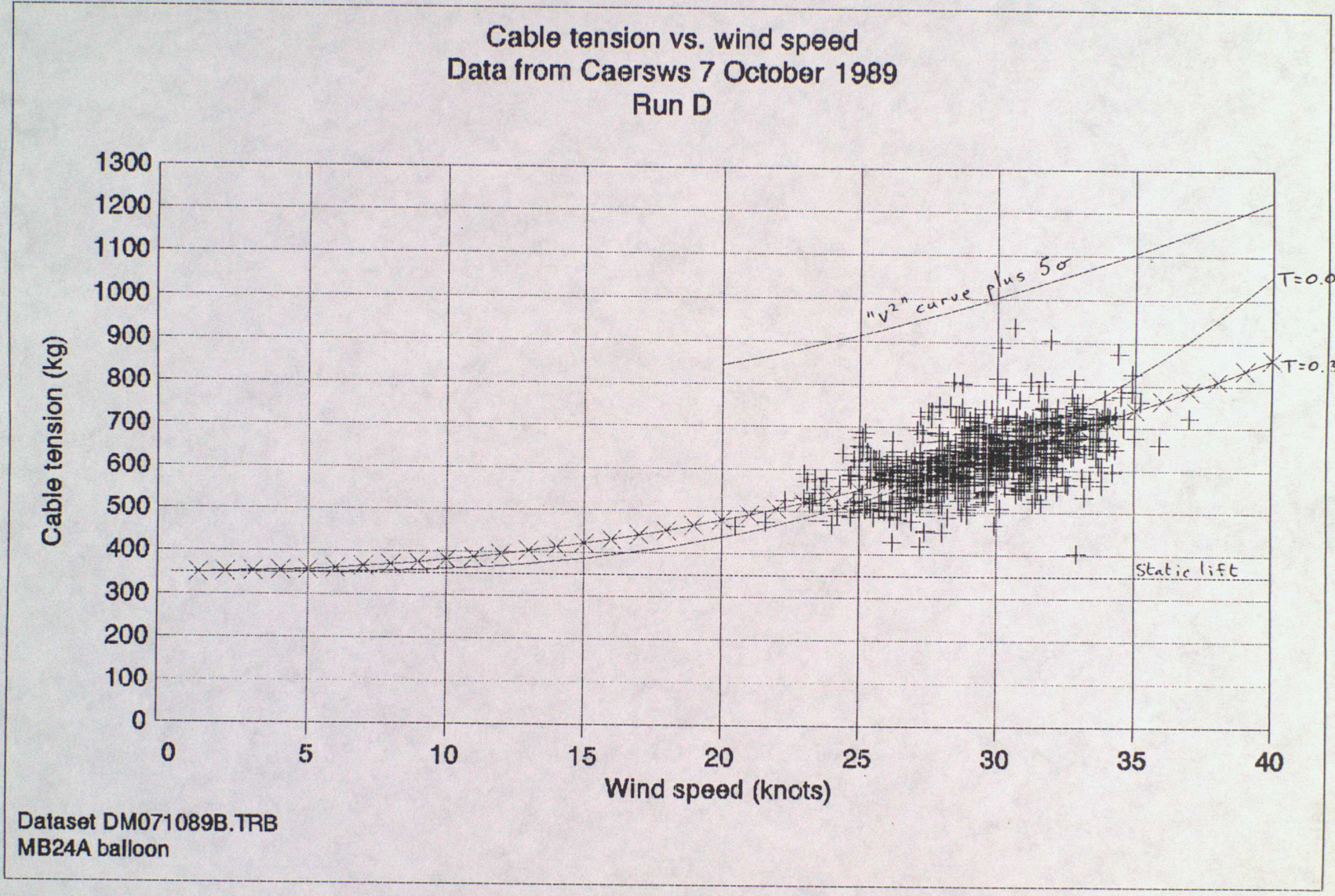
Serial Nos are GA00463 (STABLE) and 860214537 (ABLE)


OXFORD
WITNEY
A 40(T)
A 415
A 420
A 34 (T)
KINGSTON
BAGPUIZE
A 415
FARINGDON
A 420
ABINGDON
CHARNEY
BASSETT
A 417
A 338
GROVE
WANTAGE
DIDCOT
A 417
A 338
VALE OF THE WHITE HORSE
FIELD EXPERIMENT
LOCATION
****

METEOROLOGICAL OFFICE RESEARCH UNIT, CARDINGTON

THE VALE OF WHITE HORSE

FIELD EXPERIMENT 1992


Cable tension vs. wind speed
Data from Caersws 7 October 1989
Run D
Cable tension (kg)
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
40
Wind speed (knots)
"v²" curve plus 5σ
T=0.011V³+350
T=0.32V²+350
Static lift
Dataset DM071089B.TRB
MB24A balloon

METEOROLOGICAL OFFICE RESEARCH UNIT
RAF Cardington Shortstown Bedford MK42 0TH

Tel (0462) 851515+6584 *DocFax (0462) 851515 Ext 6580* *GPTN 8381+6584*

B.Parker
Press Office Manager
Room 703
Meteorological Office
London Road
Bracknell
Berkshire RG12 2SZ

Your Ref:
Our Ref: MORU/92/13/33

26 August 1992

Dear Barry,

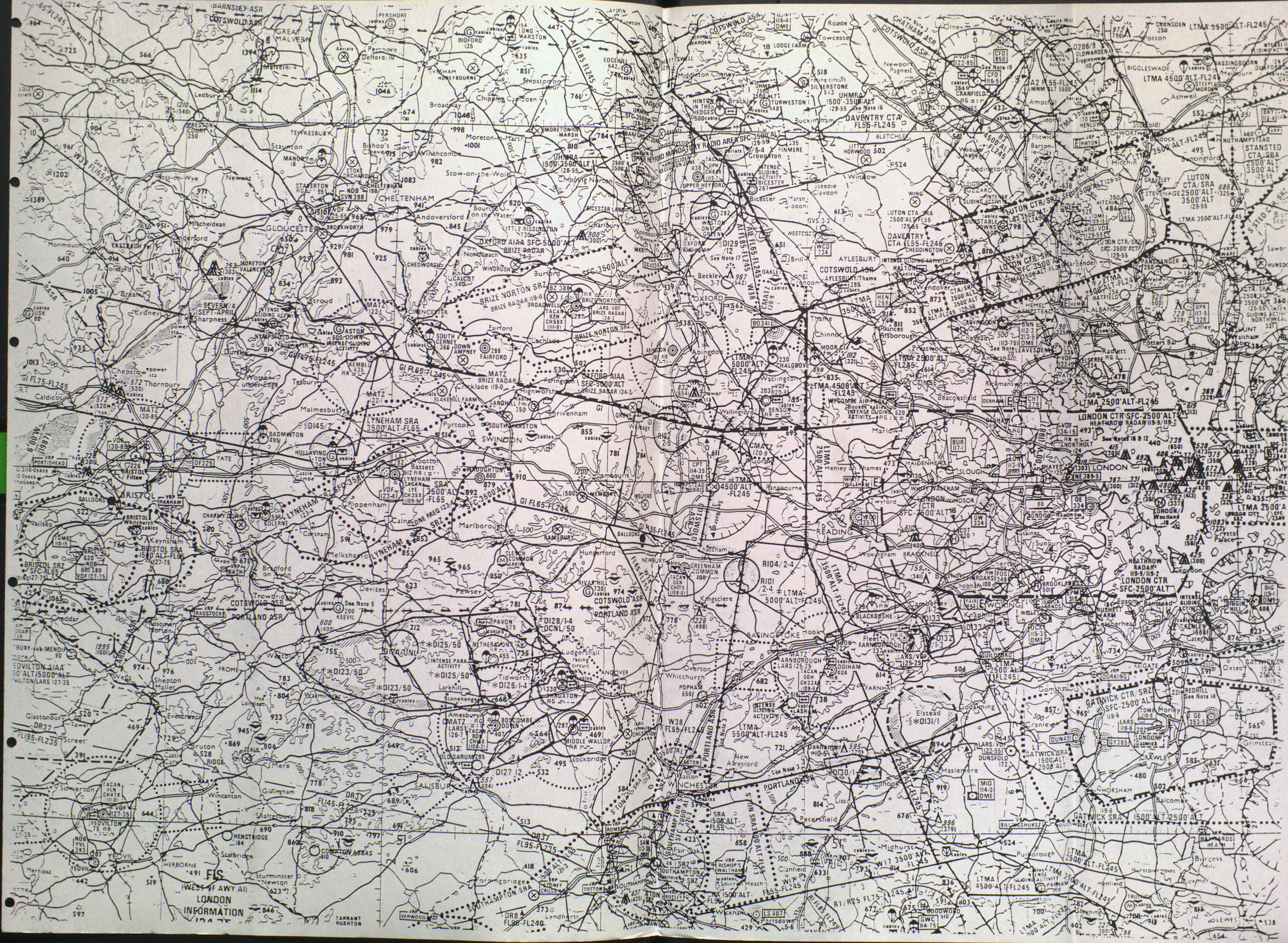
As agreed in our telephone conversation last month, I am sending you the following statement for information relating to our detachment to the Vale of White Horse this autumn. The site is about four miles to the north of Wantage.

" The Met.Office Research Unit based at Cardington in Bedfordshire is conducting a field experiment for the period 14th September to 23rd October 1992 in the Vale of White Horse, at a site near to the village of Charney Bassett in Oxfordshire (O.S.grid reference SU379939). The unit uses a 24,000 cubic foot helium filled tethered balloon flown at heights of up to 5000 feet to support turbulence measuring instrumentation. The balloon is a development of the wartime barrage balloons, but the envelope is constructed from a lightweight plastic material. The instruments are clamped to the tether cable and make measurements of wind, temperature and humidity variations in the lowest few thousand feet in the atmosphere. The results are transmitted to a ground station by a radio telemetery link and stored on a computer. A total of about three hundred million measurements will be made during the course of the experiment, and the data will take a year or more to analyse. The site has been chosen because of its combination of relatively level terrain with fields surrounded by trees. The results are used to determine the effect of the ground in slowing down the wind in the lower levels of the atmosphere, and also in heating up the air and providing it with moisture. The heat and moisture are particularly important in cloud formation. This information provides the understanding necessary to make improvements in the current generation of computer-run programs used to forecast the weather."

I hope this gives you sufficient information. Please ring me if you have any queries. With all best wishes.

Yours,

Alan Lapworth


COTSWOLD ASR
HEREFORD
Ledbury
Tewkesbury
CHELTENHAM
GLOUCESTER
Stroud
Cirencester
Malmesbury
BRISTOL
LYNEHAM SRA 3500'ALT-FL65
SWINDON
Marlborough
Hungerford
Devizes
Andover
SALISBURY
WINCHESTER
BASINGSTOKE
OXFORD
BRIZE NORTON SRZ
Abingdon
Wallingford
READING
Newbury
Aylesbury
Bicester
Buckingham
LONDON
SLOUGH
Guildford
Horsham
GATWICK CTR SFC-2500'ALT
LONDON CTR SFC-2500'ALT
HEATHROW RADAR
LUTON CTA
STANSTED
LTMA 2500'ALT-FL245
LTMA 4500'ALT-FL245
LTMA 5500'ALT-FL245
DAVENTRY CTA FL55-FL245
PORTLAND ASR
SOUTHAMPTON SRA
Petersfield
Yeovil
Wincanton
Shaftesbury
Sturminster Newton
FIS
LONDON INFORMATION

VALE OF WHITE HORSE DETACHMENT ROSTER

DATES			SHD	AJL	WPH	MJJS	REJS	IKNW	SS	TAJ	MJB	MJM	JS	DJB
Sept. 14	M	Setting up			↑	↑	↑ E		N	↑		↑	↑	↑
15	T					M	E		N					
16	W				↓	M	E		N					
17	T			↑		M	E		N	↓				
18	F			↓		↓ M	↓		N			↓ E	↓	↓
19	S					D			N			AE		
20	S					AE			N			D		
21	M			↑		↑ M	↑			↑ E	↑	N	↑	
22	T					M				E		N		
23	W					M				E		N		
24	T					M				E		N		
25	F			↓		↓ M	↓ E			↓	↓	N	↓	
26	S						AE					N	D	
27	S						D					N	AE	
28	M		↑	↕		↑		↑ E	↑		↑		N M	↑
29	T							E	M				N	
30	W							E	M				N	
Oct. 1	T							E	M				N	
2	F		↓			↓		↓ E	↓ M		↓		N	↓
3	S							D			AE		N	
4	S							AE			D		N	
5	M		↑				↑ E	↑ M		↑	N	↑		↑
6	T				↑		E			M	N			
7	W		↓				E			M	N			
8	T						E			M	N			
9	F				↓		↓ E	↓		↓ M	N	↓		↓
10	S						AE			D	N			
11	S						D			AE	N			
12	M				↑	↑ E			↑	N M		↑	↑	↑
13	T					E			M	N				
14	W					E			M	N				
15	T					E			M	N				
16	F				↓	↓ E			↓ M	N		↓	↓	↓
17	S					AE			>	N				
18	S					D			AE	N				
19	M	Clearing up.			↑		↑	↑ E	↑ M		↑		↑	
20	T					↑	M	E				↑		N
21	W				↓	↓	M	E				↓		N
22	T						M	E						N
23	F						↓	↓	↓		↓		↓	
24	S													

Night 30.

Weekday hours:

Standard balloon flying day : 1100 – 2100

Night watch (N) : 2300 – 0800

Evening watch (E) : 2100 – 2300

Morning watch (M) : 0800 – 1100

Weekend hours (if not flying) :

Day watch (D) : 0800 – 1530

Afternoon/evening watch (AE) : 1530 – 2300

Night watch (N) : 2300 – 0800

Notes :

1. Weekend flying will be done by staff staying on from preceding week.
2. Morning watch officer stays on to work day.
3. Evening watch officer stays on after working day
4. Return home on Friday evening will depend on circumstances prevailing at the time.
5. In all disputes the captains word is final.

Compiled by D.J. Bamber, 30/6/92.
(Issue 2 14/7/92)

VALE OF WHITE HORSE DISTRICT
Buckland
Buckland Marsh
Carswell Marsh
Hinton Waldrist
Longworth
Southmoor
Kingston Bagpuize
Fyfield
Tubney
Netherton
Frilford
Frilford Heath
Marcham
Garford
Sandford
Sunningwell
Shippon
ABING
Pusey
Gainfield
Hatford
Charney Bassett
Lyford
Lyford Grange
Shellingford
Stanford in the Vale
Goosey
Denchworth
West Hanney
East Hanney
Drayton
Sutton Courtenay
Steventon
Milton
Milton Heights
Milton Hill
Grove
West Challow
East Challow
Childrey
Sparsholt
Kingston Lisle
WANTAGE
West Lockinge
East Lockinge
Ardington
West Hendred
East Hendred
Harwell
Rowstock
Baulking
Fawler
Steventon Field
Drayton Cosse
Venn Mill
Common Barn
Botney Meadows
Gallows Bridge
A 420
A 415
A 338
A 34(T)
A 4130
B 4508
B 4507