The NERC MST Radar Facility at Aberystwyth
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IN CONFIDENCE

Minutes of the 37th Experimenters' Meeting

The Cosener's House, Abingdon, Tuesday 18th July 2006

Present:

Dr Ivan Astin[1]	(IA)	
Dr Jeffrey Chagnon[2]	(JMC)	
Miss Helen Clark[3]	(HAC)	
Dr Catherine Gaffard[4]	(CG)	
Dr David Hooper[5,6]	(DAH)	Secretary
Dr Lin Kay[7]	(LK)	
Dr John Nash[4]	(JN)	
Miss Emily Norton[8]	(EGN)	
Mr Tim Oakley[4]	(TO)	
Mr Tony Olewicz[5]	(ZAKO)	
Dr Sam Pepler[5,6]	(SJP)	
Mr Hugo Ricketts[8]	(HR)	
Dr Andy Russell[8]	(AR)	
Prof Geraint Vaughan[8]	(GV)	Chair

[1]University of Bath (UofB)
[2]University of Reading (UofR)
[3]University of Wales Aberystwyth (UofWA)
[4]Met Office (MO)
[5]NERC MST Radar Facility (NMSTRF)
[6]Rutherford Appleton Laboratory (RAL)
[7]Natural Environment Research Council (NERC)
[8]University of Manchester (UofM)

1. Minutes of the previous meeting

The minutes of the 36th Experimenters' meeting were accepted without correction.

2. Matters arising

> **ACTION ITEM 35.2.1:** SJP to investigate the possibility of renting the UofWA huts at Frongoch in order to ensure the continued facility for sonde launches.
>
> **ONGOING**

GV reported that he (and SJP) had written to Keith Lewis, the UofWA Director of Finance, but on receiving no reply had subsequently contacted Nigel Owen. A decision about the huts had yet to be made by the UofWA. GV noted that they had leased out another Frongoch shed to a private company (run by former members of the Shock Waves Group), so he remained hopeful.

ACTION ITEM 34.6.1: DAH and SJP to check on the status of the Aberystwyth MST radar within the peace time frequency allocation table.

ONGOING

DAH reported that no action had been taken on this since the last meeting. TO advised that this should be given a high priority since there was now so much demand for all parts of the radio spectrum. JN added that he thought 46.5 MHz was relatively safe, since they (the MO) always checked that it was reserved for wind-profiling in the frequency allocation tables, but that it was wise to apply for a license.

ACTION ITEM 35.3.1: DAH and SJP to introduce a frequently-updated weblog to report changes in instrument status.

ONGOING

DAH reported that SJP had done his part and had created a web interface to an XML-based system very soon after the last meeting. However, he (DAH) had yet to start using the system. GV commented that it was very important for this system to be actively used so that users could independently retrieve information about instrument performance without having to submit e-mail requests. SJP commented that the site reports from previous meetings already contained much of the information which would be back-populated into the system.

ACTION ITEM 35.3.2: DAH, SJP and ZAKO to investigate the potential cost of replacement transmitters.

COMPLETED

DAH reported that quotes in the range £200k - £400k covered a variety of options. JN warned that the Facility should only consider a manufacturer's main products, which would have been well tested. The MO's South Uist system was made to-order, rather than relying on a standard design, and so suffered from unexpected problems. TO thought that solid state technology was probably the best way forward. SJP added that this would be easier to maintain if the radar was to be run unattended for long periods of time. JN also thought that solid state transmitters were now the best option.

JN pointed out that the MO would soon be reassessing their requirements for upper air observations and that there may be a role for the Aberystwyth radar in a pan-European network. JN and LK were in agreement that development of the Facility should move forward taking both NERC's and the Met Office's future requirements into consideration. This topic of discussion was continued in Section 3.

ACTION ITEM 35.3.3: SJP and ZAKO to order a spare high-voltage transformer.

COMPLETED

The spare transformer has been delivered to site.

ACTION ITEM 35.4.1: SJP and ZAKO to arrange for disposal of junk items, for the renovation of the large shed, and for the installation of a car-port in place of the small shed.

ONGOING

ZAKO reported that all MST items had now been removed from the large shed. This action item is reported in more detail in Section 3.

ACTION ITEM 35.8.1: SJP to arrange for the installation of a sky-pointing camera at Capel Dewi.

ONGOING

SJP reported that he had filled out an order form, but had yet to send it off.

ACTION ITEM 36.3.1: SJP and DAH to introduce the supply of MST radar down time summaries to the Met Office on a quarterly basis.

COMPLETED

DAH explained that the Site Report to be presented at this meeting (Section 3) and the instrument performance descriptions given in the Annual Reports now summarise down-time within four major categories. Details are only given of those events which result in extended downtime. TO suggested that there needs to be a procedure for warning about downtime in advance. DAH and ZAKO clarified that they always sent a notification to the MO Operations team (with a copy to Myles Turp) when the radar was shut down during normal working hours. When the radar went down outside of normal working hours, such as occurred on the evening of Sunday 2nd July 2006 (when a thunderstorm passed over the site), notification was given first thing on the following working day. TO felt that nevertheless summaries should be provided more than once a year (the time elapsed since the last Experimenters' meeting). GV pointed out that if the web-log described in 35.3.1 were being actively used, the MO Operations team could also use this to review past causes of downtime. This resulted in a new action item:

ACTION ITEM 37.2.1: SJP to ensure that the new web-log system is used with immediate effect.

ACTION ITEM 36.4.1: ZAKO to obtain a quote for renovating the large site shed.

COMPLETED

This is reported in Section 5.

ACTION ITEM 36.6.1: DAH to carry out a systematic comparison between version-0 and version-3 data products.

COMPLETED

This is reported in Section 7.

3. Site operations report - ZAKO

MST Radar downtime is summarised - for the period from 1st April 2005 to 12th July 2006 - in four major categories. The reporting time has intentionally been extended back beyond the date of the last Experimenters' meeting - on 19th July 2005 - in order to include additional examples of unpredictable events and to emphasise their irregularity of occurrence.

Power disruptions accounted for 122.3 hours of downtime caused by just 5 incidents. At present the radar control and data acquisition program must be re-started manually after a power disruption. Consequently when a disruption occurs outside of normal working hours, the loss of data typically continues until the morning of the next working day. The new control and acquisition system, which is due to be installed in September 2006, will re-start automatically. Most of the power disruptions are caused by the loss of mains supply. 68 hours of observation were lost from 14 UT on 22nd April 2005 (a Friday) until 08 UT on 25th April 2005 (the following Monday). The power went down on the day when ZAKO left for his holiday. 7 hours were lost from 12 UT to 19 UT on 20th May 2005. 32 hours were lost from 00 UT on 22nd May 2005 (a Sunday) until 08 UT the following Monday when a UPS unit failed - this has since been replaced. 14 hours were lost from 18 UT on 5th June 2006 until 08 UT the following day. 1.3 hours were lost from 17:10 - 18:30 UT on 4th July 2006. ZAKO was on site outside of normal working hours in order to restart the radar on this occasion and thus he prevented the loss of an additional 12 hours of observation.

Thunderstorms accounted for 41.8 hours of downtime caused by 4 incidents. In the first 3 cases the radar was shut down pre-emptively in the afternoon and restarted first thing the following morning. 13.0 hours were lost from 19 UT on 19th June 2005 until 08 UT the following day. 14.5 hours were lost from 17 UT on 28th June 2005 until 07:30 UT the following day. 10.5 hours were lost from 21 UT on 2nd July 2006 until 07:20 UT the following day. In the 4th incident, only 3.8 hours were lost, from 15:40 UT on 5th July 2006 until 21:20 the same day, since ZAKO was on site outside of normal hours to restart the radar. Again this avoided the loss of an additional 12 hours of observation.

Maintenance only accounted for an accumulation of 44.7 hours of downtime and a further 4.5 hours were lost for miscellaneous reasons. There have been no problems caused by failure of a locking transmitter, to which the oscillators of all 5 transmitters are phase-locked. This has been a significant cause of downtime in the past. There are plans to phase-lock all transmitters to an external oscillator which will remove the risk of radar failure simply because a single transmitter is down. On one occasion, on 27th June 2006, the radar control and data acquisition PC crashed around 05 UT leading to a loss of 2.6 hours of cover.

The RAL Millimetre Wave Technology Group's 78 GHz cloud radar, which began operations at the MST Radar site in April 2005, was returned to RAL on 22nd June 2006. Owing to the fact that it was prone to overheating under warm conditions, it was not operated on a continuous basis. RAL are due to build an improved 94 GHz prototype model and need the existing instrument for test purposes.

A NERC-funded Vaisala LD40 laser ceilometer began operations at the MST radar site on 8th August 2005. It developed a problem on 4th September 2005. Operations resumed on 3rd October after Vaisala sent a replacement transmitter module.

The PC which logs data from the ceilometer, the surface met sensors and the surface wind sensors has been crashing rather often, which has lead to instances of lost data. The cause for this is not known, but it often coincides with times when the ceilometer encounters a change from cloudy to clear sky conditions. Other problems have been caused by the ZoneAlarm software, which was installed to protect the PC. This appears to be more trouble than it is worth.

The surface pressure sensor, which was stolen from the climate data logger in April 2005, has not been replaced. Despite the Police's initial excitement at the possibility that this might be used as a triggering device for a bomb, this theory now seems unlikely.

There has been a long-term problem with the tipping bucket raingauge not registering any rainfall. This was complicated by the fact that 2005 was a dry year. The problem was only confirmed in January 2006 when ZAKO poured water into the unit and it still failed to register anything. The problem appears to have been caused by the tipping mechanism. It is now registering rain again.

JN asked, by way of information, how much additional downtime ZAKO would expect if he (ZAKO) were not available on site. ZAKO reported that the mains power fluctuations associated with thunderstorms were the most serious cause of damage. The radar cannot subsequently be restarted until repairs have been carried out. JN suggested that an MO thunderstorm forecast could help to plan ahead for such incidents. However, the MO are becoming increasingly interested in severe weather events, including thunderstorms, and it was not without some reservations that he was suggesting measures which might result in them being observed less often. Nevertheless he assured ZAKO that the MO regarded him (ZAKO) as being very efficient and that they were very happy with the way in which he kept the radar going. GV suggested that the Facility should consider investing in an independent power supply. TO thought that the generator at South Uist might have cost the order of £10k.

The subject of the tipping bucket raingauge caused much discussion. When asked when it was last known to be working, DAH said that he could not be sure whether it had worked since it was returned from Campbell Scientific for recalibration in April 2005. ZAKO suspected that it was more likely to have stopped working only in October or November of 2005. TO drew attention to the fact that the more instruments being operated at a given site, the more staff resources were required to ensure that they were working correctly. He recommended quick-look plots as a rapid way of identifying problems. LK suggested that the Institute of Hydrology may be able to provide useful tips on how to monitor such instruments. JN recommended purchasing a spare raingauge or operating complementary instruments, such as a microwave radiometer or a cloud radar, at the site as a way of having independent indications of rainfall. GV pointed out that rainfall measurements were scientifically important. He suggested that it may be possible to operate the UFAM microwave radiometer at the radar site in-between campaigns. TO suggested that the onus was on a Facility, rather than the user scientists, to provide quality control checks. He and JN recounted the tale of a boundary-layer wind-profiler (BLWP) at Bilbao which was left running for 3 years without being checked. It was subsequently discovered that winds were only being recorded as blowing in one direction. Moreover, part of the frame of the instrument had rusted so badly that the instrument was rendered beyond repair. LK suggested that meetings were required more than once a year in order to avoid such problems going unresolved. DAH pointed out that the extra-ordinarily long interval since the last meeting was a result of GV being abroad on a field campaign during last winter. SJP pointed out that this was basically a scheduling problem. The Facility had achieved a large number of things during the past year but it did not have sufficient staff resources to do everything. JN commented that the standard of Facility management had increased in recent years. Thus the apparent severity of this problem was magnified by contrast. TO suggested that, in principle, the MO could take over looking after the surface met station, perhaps in return for reduced charges for the provision of wind-profile data. DAH pointed out that the problem of monitoring surface met data quality had already been partially solved since he had gone to great lengths, in January 2006, to understand (and to document) the format of the original Campbell Scientific data files. Previous to this he could only rely on a legacy computer program to interpret the file format. Since this program rewrote some of the data (to new files) with incorrect units and other data with missing units, DAH did not have much confidence in it as a basis for understanding the original data files.

ACTION ITEM 37.3.1: SJP and DAH to produce a plan for the monitoring of data quality in time for the 38th Experimenters' meeting.

4. Facility report - DAH

a) NERC funding. LK reported that a poor outcome of the 2004 NERC budget had resulted in the recommendation that the Services and Facilities (S&Fs) annual budget of £6M be cut by £0.5M. Consequently all S&Fs were subject to an extra-ordinary review by the Science and Innovation Strategy Board in March 2006. They were judged both by their likely contribution to the NERC science strategy and by how cutting-edge they were in terms of technology. The MST radar was seen as being unique and useful in the context of NERC's science priorities, but the technology was seen as being mature. This puts it under no immediate threat during the current contract period, which ends in 2010. However, the Facility is expected to reduce its cost to NERC. LK announced that it might be possible to invest in the Facility's infrastructure since capital investment did not come from the regular S&Fs' budget.

LK also reported that the question of MO and NERC co-funding for facilities which are of interest to both parties (including the MST Radar Facility and Chilbolton) are being discussed at the highest levels within both organisations. JN warned that the MO were probably more interested in conducting research using the new MO Kent dual-polarisation radar than in using Chilbolton. He also pointed out that cloud radar products might be more important from an operations point of view than data from the 3 GHz radar.

b) Site security. DAH reported that there had been no security incidents since the theft of the pressure sensors in 2005. The advice of Ben Herman, NERC's security adviser, had been followed in erecting a 2 m high fence around the new concrete instrument platform, which is located adjacent to the site bungalow. Work had been carried out to re-tension the barbed wire on the perimeter fence.

c) Site internet upgrade. Efforts by the NERC networking team, in conjunction with the UofWA, to upgrade the 56 kbps link to the radar site appear to have stagnated about 2 years ago. A quick solution to this problem, recommended by Owain Davies (an engineer from Chilbolton, who visited the MST radar site in December 2005), was to simply install a commercial broadband link. Chilbolton have used the same solution for the retrieval of data from a remote site. By creating a private local network behind the broadband router's firewall, this has the additional advantage of increasing security. As already mentioned, the ZoneAlarm firewall software installed on Windows PCs was proving to be more trouble than it was worth.

Two broadband links have been installed - one through the site bungalow telephone line (which is used for the UFAM equipment) and one through the site bungalow fax line (which is used for the MST radar equipment). Each link has a download speed of approximately 1 Mbps and and upload speed of 256 kbps. DAH attempted to move MST radar PCs onto the private network and broadband link in March 2006. However, this caused IP address conflicts when sending wind-profile data to the Met Office through their dedicated ISDN line. The transition therefore had to be postponed until June 2006 when the MO created a new method of delivering data. Files are now sent through the internet to a Demilitarised Zone outside of the MO firewall before being ingested. The MO aim to use the same technique for gathering data from a number of other remote sites.

TO questioned whether some redundancy should be left in the data transmission system in case the broadband link failed. DAH explained that since all connections - whether through a commercial Internet Service Provider (ISP), through the old NERC link or through the Met Office's ISDN line - ultimately relied on phone lines in the Capel Dewi area, all options were subject to the same threats. The MO ISDN line had previously been cut through by a hedge-strimmer (off-site) and the old NERC link had failed twice in the week following the final switch-over to the broadband connection owing to lightning damage within a BT exchange. SJP suspected that the cost of upgrading the old NERC line between the radar site and the UofWA would cost the order of several £10k. A commercial broadband link was consequently a much more cost-effective solution. Moreover, he thought that customer demand for higher connection speeds is likely to be the driving force behind relatively rapid improvements to the service. GV noted that the current broadband links were via Asymmetric Digital Subscriber Line (ADSL), which is much faster for download than for upload. The primary requirement at site is for uploading data to RAL and the UofM. He reported that during his recent field campaign in Australia, a symmetric DSL link had been available. DAH and SJP reported that such a service was not currently available for the Capel Bangor exchange. It was noted that speeds could be improved by creating an extra broadband link through the Lidar hut telephone line. TO pointed out that if the MO were to give up their dedicated ISDN line, this too could be used for a broadband connection.

d) The RAL 78 GHz FMCW radar. As reported by ZAKO in Section 3, this instrument has now been returned to RAL. DAH reported that he had carried out some initial MST radar and cloud radar comparisons with Adrian McDonald in September 2005. The results had been sufficiently encouraging to warrant a more detailed investigation being undertaken. JN had advised them to include laser ceilometer cloud base data in their studies, as it remains to be established whether the cloud radar is capable of observing the entire vertical extent of a cloud. It is known that it is primarily sensitive to the larger-sized droplets.

e) Laser ceilometer. DAH thanked JN's group for making available to him a Windows-based acquisition program for logging the ceilometer data. It had been written when the MO were carrying out tests on the same model of instrument. The program has a quick-look display for recently-acquired data which has allowed ZAKO to quickly identify problems and to restart the acquisition when necessary. As reported in Section 3, there have been several problems with the computer which is logging the data. TO recommended switching off the automatic Windows updates option on the PC. Once an automatic update has been carried out, the PC will not resume its normal functions until rebooted manually. DAH reported that he is in the process of defining metadata requirements for NASA-Ames format ceilometer data files. The new files will be made available in the near future. GV reported incidentally that the old UofWA SAOZ machine (Système D'Analyse par Observations Zénithales - a zenith-pointing UV-visible spectrometer which is used to retrieve mean values of total ozone and nitrogen dioxide) had recently begun operations at Capel Dewi.

f) Mesospheric observations. Mesospheric observations were reintroduced in April 2005, for the first time since 1999. A single (vertical beam) M-mode dwell has been inserted into the standard ST-mode observation cycle. This has allowed a complete picture of the occurrence of mesospheric echo layers to be built up for the first time. There have been a number of surprising results, including the occurrence of unusually persistent, strong and structured non-summer echoes for about a week in early November 2005.

JN asked whether any other information was available which could be of use in interpreting these results. DAH speculated that atmospheric modelling might help to establish the role played by tides in echo layer behaviour. GV commented that these were unique and scientifically interesting results and that they should be published. He noted that there was a small, but well-organised international community with interests in this area. He encouraged DAH to form collaborations in this field. IA expressed an interest in carrying forward this work. JN drew attention to the fact that the South Uist radar was capable of observing the summer echoes, but that owing to range aliasing the echoes had been interfering with the ST-mode observations. Consequently the observation parameters had been changed so that the mesospheric echoes were no longer seen. He wondered whether the MO might be interested in this sort of work owing to their developing interest in space weather.

5. NERC-funded upgrades - DAH

a) MST Radar control and data acquisition system. The existing system was built around a 1999 vintage WindowsNT PC and so cannot be maintained indefinitely. A serious limitation is that if it is not rebooted at least once a week, a system crash becomes inevitable. It was already mentioned in Section 3 that this system does not restart automatically after a power disruption and that this can lead to unnecessary loss of observation time. Owain Davies, from Chilbolton, carried out tests with a new (and improved) radar control and data acquisition system in December 2005. This highlighted a few important issues which had not been documented for the existing system. The new system is due to be installed operationally in September 2006, after the MO have accepted v3 data (described in Section 7) for operational assimilation. It will be relatively simple to adapt the v3 signal processing to work on (standard format) netCDF spectral files, whereas the v0 signal processing is inextricably linked with the highly-specific (but non-standard) existing format files.

b) Site shed replacement and refurbishment. The smaller and more dilapidated of the two site sheds was demolished in June 2005. A concrete base was laid in its place at the end of August 2005. A local architect visited the site in June 2006 to draw up plans for a replacement structure. DAH had brought a copy of the plans to the meeting to allow EGN to check whether it would meet the requirements for housing the mobile lidar system. EGN and HR confirmed that the maximum height of the trailer was less than 3 m and so would fit inside the proposed structure. Although the architect had thought that such a replacement structure should not require planning permission, he was advised by Ceredigion County Council that a planning application had been received for the site in the past and that this had set a precedent. Consequently it was advisable to submit one for the shed. DAH has served notice on the UofWA (who own the land), and ZAKO hopes to have arranged for the frame for the structure to be manufactured by a local blacksmith by September 2006.

LK suggested that whilst SJP and DAH were thinking about a planning application for the shed, they should consider the possibility of installing an external power generator, which might also require planning permission. He suggested that capital funds of up to £10k might be available to invest in this. TO pointed out that in addition to a generator, it was necessary to have an automatic switching unit to ensure that the generator started as soon as the mains power went down. He said that he would need to dig into his records in order to establish the full cost for the South Uist system. The generator had been bought as part of the radar kit, whereas the cost of the switching unit had been part incorporated into the cost of electrical work on the building.

JN raised the question of whether the MO had cleared their old radiosonde equipment away from Frongoch farm. TO reported that gas cylinders (of the short and fat variety) remained. ZAKO though that they could be taken for scrap, although they would have to be delivered to the scrap merchant, who was not willing to collect them.

c) Sky-pointing cameras. SJP reported that the requirements for cameras had broadened since the original idea of simply recording sky conditions. There were now the additional considerations of security and of remotely-monitoring equipment when the site is left unmanned. An order is due to be placed for the necessary equipment.

6. Science Presentations

a) The Future of Upper Air Observations at the Met Office - JN

JN will be stepping down as the head of the Upper Air Observation division of the MO, when he reaches 60 in April 2007. However, he does not anticipate retiring from the MO for several more years. TO, CG and Tim Hewison will be taking over many of his planning roles. The whole of the upper air observation network will be redesigned in 2010 or 2011. The automatic radiosonde launchers will reach the end of their expected lifetime around this point and it is anticipated that the number of sites will be reduced. The future observation network needs to look forward to the period 2010 - 2020, and to provide data at much higher temporal resolutions to fulfil the requirements of future Numerical Weather Prediction (NWP). The network will need to match the performance of the satellite systems in which the MO has invested heavily. Ground-based observations will move towards integrated observing sites rather than single system sites. These might, for example, combine BLWPs, cloud radars, radiometers, and possibly radiosondes. The interest will be biased towards forecasting extreme/high-impact weather events such as summer convection and fog. It is likely that an integrated-observing demonstration campaign will be carried out, together with European colleagues, in 2009. The question is being asked as to whether wind-profilers are needed in addition to weather radars. The Aberystwyth MST radar may be considered for its usefulness in providing more than just wind-profile information. There is a need to demonstrate within the MO just how uniquely powerful the Aberystwyth system is. Tests will need to be conducted in order to demonstrate the importance of its input in constraining forecasts.

A new COST (Co-operation in the field of Scientific and Technical Research) proposal has been submitted to carry on from the COST-720 action ("Integrated ground-based remote sensing stations for atmospheric profiling"). It was ranked 5th out of 100 proposals in the first round and a more detailed proposal must now be submitted. JN requested any interested parties to contact him as COST requires some co-ordination at the national level. GV suggested that EGN should become involved. GV was involved with a tropospheric water vapour proposal in the same round.

GV questioned how these developments might impact on the Aberystwyth MST radar. TO suggested that although there had been a focus on BLWPs in the past, in the future more emphasis might be placed on MST radars as components of integrated observing systems. It is likely that CG will be involved with the analysis of MST radar data. JN pointed out that short-term forecasts (particularly for severe weather events) will become increasingly important in the future. MST radars are particularly good for observing severe weather events whereas weather radars are not. GV drew attention to the fact that the MO's attempts to plan for their observation needs until 2020 stretched well beyond the 5 year funding cycles of NERC. He (GV) had gone through the exercise of considering replacement transmitters for the Aberystwyth MST radar back in 1999, but had concluded that the plan was untenable. However, he thought that now could be a good time for investment if a longer-term future were to be considered. TO highlighted the fact that they would need to present costed options for MO consideration before 2010. It was generally agreed that this would fit well with the timing of NERC-funding renewal in 2009. It was in the interests of both parties to suggest a combined NERC/MO funding option.

b) Climatology of low-tropospheric strong wind events observed by MST Radar from 1998-2004 - GV

GV presented this work on behalf of Graham Parton (GAP), who is in the process of writing up his PhD thesis. GAP had calculated wind speed probability distribution functions (PDFs) over the entire available altitude range for v0 data. He had not used v2 data owing to the low-altitude gaps associated with ground clutter. However, he noted that v0 data were not reliable for the higher altitudes. Consequently he focused his attention on 6 sets of 5 adjacent altitude bins over the range 1.55 - 4.40 km. He considered only the top 1% of the PDFs for each level, which implied wind speeds of above 30 - 40 m s^{-1}. An extreme wind event was required to last for at least 45 minutes and to extend over 3 or more levels, i.e. to have a depth of at least 1 km. 121 candidates were identified and these were subsequently classified (based on a combination of data from the MST radar, Nimrod, satellite imagery and synoptic charts) as sting jets (8 events), dry intrusions (32 events), tropopause folds (28 events), or warm sector winds (45 events). Only 7 events could not be classified. Warm sector winds are found ahead of cold fronts. Tropopause folds are found well away from cold fronts and are clearly visible in the MST radar return signal power. Sting jets are defined according to the Browning classification and are associated with a bent-back warm front on a satellite image. Sting jets tended to be associated with westerly winds, dry intrusion events with south-westerlies, tropopause fold events with north-westerlies and warm sector events with south-westerlies. An attempt was then made to consider the wind directions with respect to the synoptic systems and to classify the events relative to the Norwegian and Shapiro-Keyser cyclogenesis models. There are no sting jets within the Norwegian model, but they are associated with stages 3 and 4 of the Shapiro-Keyser model.

TO wondered whether there were plans to investigate the economic and human impacts of these severe weather events. GV did not regard this as a priority. JN commented that for the 27th October 2002 case, on which GAP had focused his initial work, strong winds persisted over East Anglia for about 6 hours and the jet appeared to regenerate. GV suggested that it was the cold conveyor belt catching up with the sting jet which caused the strong winds to persist, not regeneration of the sting jet. The MST radar saw a banded structure in the winds close to the jet and GV was interested to note that similar structures were seen in model runs which were not constrained by data assimilation. JN said that he was interested in the idea of sting jets passing over the South Uist radar, but that strong wind events tended to be complicated and so were hard to classify. He boasted that the strongest low-level winds seen at South Uist were 55 m s^{-1}, beating those seen at Aberystwyth.

c) UFAM wind-profiler measurements during CSIP - EGN

The objectives of CSIP were to better understand the processes which initiate convection and to improve the quality of the forecasts from the high resolution (1 - 2 km) mesoscale model. The UFAM BLWP was operated at Linkenholt, approximately 18 km to the north of Chilbolton. Ground clutter problems were reduced by erecting a 2 m high circular clutter screen (made from an old silage tin) around the instrument.

Attention was focused on two case studies. The first, for 1st August 2005, was characterised by the presence of two temperature inversions, which could be identified in the radiosonde profiles. These act as lids to prevent wide-scale convection. However, they can cause the Convectively Available Potential Energy to build up, eventually leading to much more severe storms. The boundary-layer height was derived from the BLWP signal-to-noise ratio (S/N) using a method described by Angevine. It was not found to be effective during the early hours of the day but performed well as the thermal structure of the boundary-layer became better defined.

The second case study, for 13th July 2005, was characterised by a sea breeze, which lead to a NE-SW aligned band of cloud which was visible in the MSG satellite images. The BLWP clearly detected an abrupt change from northerly to southerly winds and an increase in speed. Brief showers occurred in the Reading area around 17 UT. The S/N patterns were rather complicated but there was clear evidence of inverted-cup structures which are expected in association with thermals. Updrafts as large as 1.3 m s^{-1} were seen up to 1.5 km altitude. Transit times of approximately 7 minutes suggested that the horizontal extent of these structures was between 850 and 1260 m.

GV commented on the importance of thermal lids, which can also be clearly seen in MST radar return signal power despite the factor of 20 difference in observing frequency. TO suggested that the low S/N apparent at the lowest BLWP range gates might be caused by a slow recovery from T/R switching. JN suggested comparing against radiosonde profiles (of which there were many for CSIP) if there were any uncertainties as to whether the measured winds were reliable under such conditions. CG commented on how well EGN's presentation demonstrated the need for profiler observations at the highest possible resolution. The inverted-cup thermal structures were only clearly apparent in the high-resolution plots.

d) Convective inhibition beneath a cut-off low: a CSIP case study - AR

Attention has been focused on 15th June 2005, when convection was not as widespread as might initially have been expected. A single storm broke out near Oxford, forced by a convergence line interacting with reduced stability aloft. The latter was associated with a PV anomaly and dry air. A cut-off low passed over the British Isles interacting with a surface cold front, which is clearly seen as a shear layer in the MST-radar-derived winds. The PV anomaly shows up clearly in the UM plot. BLWP observations show convection breaking through a dry lid. Back-trajectory analysis shows that the dry air had two high-altitude origins. This work will be extended to consider 4th and 18th July 2005.

GV commented that the UM plot shows the merging of a tropopause fold with a pre-existing dry layer. JN questioned how realistic the back-trajectory data might be expected to be. AR clarified that they are derived from ECMWF analyses - not from the UM. GV added that nearly all features are a result of the model evolution, not of the data input.

e) Analysis of convectively-generated gravity waves using the Unified Model (UM) and MST Radar - JMC

This work is principally a modelling study of the generation of gravity waves from convective activity. However, for small-scale, rapidly-evolving, and localised dynamical processes which rely on sub-grid-scale parameterisation, the model uncertainties are large. It is hoped to use MST radar observations to test the validity of the outputs. The motivation for studying gravity waves is based on the facts that they drive the circulation of the middle atmosphere, that they can induce turbulence, that they can cause mixing along the tropopause, that they may affect the behaviour of convection or trigger new convection, and that they are fundamental to the dynamics of a stably stratified fluid. In the case of gravity waves produced by vertical acceleration (e.g. by convective updrafts), the group velocity is primarily in the vertical direction. Gravity waves can also be produced by inhomogeneous heating and phase changes, which lead to horizontal pressure gradients. These conditions lead to the generation of larger-scale waves, for which the group velocity is primarily in the horizontal. With a 12 km horizontal grid spacing, the model relies on a parameterisation of these processes. However, it is unclear how realistically they are represented at 1 km grid spacing.

A preliminary study has looked at a convective event occurring at around 8 km altitude over the North Sea. At 4 km grid spacing the model shows a coherent pattern of long-horizontal-wavelength waves propagating through the tropopause. At 1 km spacing the waves have shorter horizontal wavelengths and the overall pattern is much more "noisy". The waves are confined to near the tropopause level. Additional information is given by considering the redistribution of a tracer which is initially confined to the stratosphere. Stirring of the tracer, which is dependent on the convectively-generated gravity waves, is apparent in the 1 km simulation but not in the coarser simulations. Work has begun on two days for comparison with MST radar observations. In both cases the observations show convective activity reaching close to the tropopause level. However, in one case (28th July 2005 - the day of the Birmingham tornado) convectively-generated gravity waves can be seen propagating upwards through the lower-stratosphere, whereas in the second case (29th June 2005) they cannot. Model runs will be made at 1, 4 and 12 km grid spacing. The convective parameterisation is turned off for the 1 km runs. The objective of the study is to answer the following questions. Does the UM produce waves which behave in a similar way to those observed by the MST radar? Why is there a difference between the wave activity in the two observed cases? How are the simulated waves affected by the model configuration? Do the waves induce turbulence and mixing?

GV commented that clear inertia-gravity wave activity can be seen in the MST radar plots for the second case study (when convectively-generated gravity waves were not seen to propagate through the lower-stratosphere), but that they are not seen in the plots for the first case study (when convectively-generated gravity wave propagation occurred). He speculated that the inertia-gravity waves could be creating critical levels which act as a barrier to continued convectively-generated gravity wave propagation. The existence of critical levels is most likely to occur under conditions of low wind speeds in the lower-stratosphere since the inertia-gravity wave activity will result in significant changes in wind direction. Under conditions of higher lower-stratospheric wind speeds, the inertia-gravity wave activity will still be apparent in the wind speed but have less effect on direction. He drew attention to the fact that a manuscript based on Richard Worthington's inertia-gravity wave studies was in preparation. JN added that similar wave activity is also often seen in radiosonde data, especially for radiosondes launched from Camborne which is just 2 km inland from the coast. This causes a problem when reporting data at significant levels since the the changes in wind speed and direction require a large number of significant levels. DAH reported that a paper on MST radar observations of convectively-generated gravity waves at Aberystwyth had just been published:

Y. G. Choi, S. C. Lee, A. J. McDonald, and D. A. Hooper, Wind-profiler observations of gravity waves produced by convection at mid-latitudes, ACP, 2006, Vol.6, pp. 2825-2836, SRef-ID:1680-7324/acp/2006-6-2825, http://direct.sref.org/1680-7324/acp/2006-6-2825

f) Radar reflectivity in the troposphere at 46.5 MHz and its relationship to water vapour - HAC

Attention has been focused on 3 nights of water vapour lidar observations made at Capel Dewi. As might be expected, strong MST radar returns are associated with the edges of regions of enhanced water vapour concentrations. Moreover, the MST radar return power is weak where the water vapour concentration is low. A comparison with simultaneous radiosonde measurements leads to high confidence in the lidar measurements. This work could be extended to looking at other days from the archive.

HAC then presented some puzzling results she had found when looking at various gradients of the wind vector components - principally du/dx, dv/dy and dw/dz, all normalised by the wind speed. For example, small-scale structure is seen in du/dx and dv/dy for 9th August 1998. Although she had expected to see large-scale features associated with gravity waves, the observed features do not have an obvious source. The dv/dy patterns have a completely different structure to the dw/dz patterns. Such features are not apparent for all days. GV suggested comparing v0 and v2 data. He also suggested going back to the radial data as the Cartesian components represent combinations of information from several beam directions. JN suggesting looking at the consistency between data from the different beams. He commented that this was quite variable for the South Uist radar. The consistency is often found to be low for conditions of low radar return signal power. HAC responded that there was sometimes a correspondence between the wind derivatives and signal power structure at low altitudes.

g) Determining the antenna pattern of the UK MST Radar using celestial objects - IA
This work was principally carried out by Stephen Heywood, a final year undergraduate at UofB. It follows on from a study last carried out by Sheffield University in 1990, for which IA had carried out part of the analysis. The path of Cassiopeia A (also known as Cass A), a supernova whose emissions are significant within the VHF band, passes close to the centre of the NE6 beam on 17th December each year at around 17:30 UT (it makes another close crossing on 7th December). The only other possible radio star transit is provided by Cygnus A, though it does not pass so closely. The transit is marked by an approximately 8 dB enhancement in spectral noise power, which lasts less than an hour. This is superimposed on a diurnal noise power variation of approximately 4 dB which is associated with variations in the cosmic VHF noise background. This study was easy to carry out using v2 radial data as the noise power is quoted explicitly, whereas in v0 radial data files it is not. The Cass A transit is clearly visible in the data for every year back to 1990. Small interannual variations in absolute noise level are attributed to changes in the nature of the ionosphere, which can filter the cosmic noise. The patterns were remarkably similar for every year. The data for 1992 differed slightly in having a slightly higher peak power and a slightly earlier transit time. Special observations were made in 2005 so that NE6 beam observations were made every 47 s, as opposed to being made once every 230 s (nearly 4 minutes) during standard observations. The beam width was estimated by fitting a Gaussian curve to the noise power variations within the transit period. The study concluded that no significant change in beam width had occurred since this study was last undertaken in 1990.

GV expressed surprise at the fact that the timing of the events was so constant. He had expected to see a sawtooth variation over a 4 year period as leap years correct for the fact that the year length is close to 365.25 days. HR pointed out that this would only account for a yearly change of a quarter part in 365, which is close to 1 in 1500. DAH drew users' attention to the fact that the background diurnal noise power variation of approximately 4 dB produces a corresponding change in signal-to-noise levels. Signal power is much less affected by noise level variations. However, the change in signal-to-noise levels will have a small effect on useful altitude coverage during the course of a day. Variations in useful altitude coverage over the course of a day tend to be dominated by changes in refractive index structure.

7. Data Processing and Management

a) A comparison of v0 and v3 MST radar signal processing from the Met Office's point of view - TO
TO reported that DAH had introduced a new real-time signal processing scheme (known as version 3 or v3) in January 2006. It has been running in parallel with the existing (v0) processing scheme, which has allowed the MO to compare the performance of both data streams against their model over the period 1st February - 30th June 2006. Data quality aside, v3 processing leads to significantly higher data availability at altitudes above 15 km. The maximum useful altitude is typically 1 - 2 km above that for v0 processing. The random errors associated with v3 winds are lower than those associated with v0

at all altitudes. Moreover, the root mean square of the differences between observed and model values becomes significantly lower for v3 than for v0 data above 8 km altitude. The systematic directional bias of approximately 2° which the MO have always reported for v0 data has been approximately halved for v3 data. The errors in wind speeds are comparable for both data streams. Although there appears to be a systematic underestimate of approximately 0.5 m s^{-1} for v3 wind speeds above 10 km, the same has been reported for South Uist data. JN speculated that this could be caused by the mismatch between observation and model levels.

Although the quality of v0 data was high enough for MO assimilation purposes, and hence there was no motivation for change from their point of view, they are very happy with the improvements and are keen to switch to v3 data for operational purposes as soon as possible. There is a small worry about v3 data quality above 15 km altitude, but since the quality exceeds that of v0 data, this is not a limiting factor. The MO wish to continue receiving v0 data for the next three months, but now purely for test rather than assimilation purposes. They are also keen to collect data with observations made at both 6° and 12° off-vertical. Previous tests with v0 processing suggested that the random errors associated with winds derived from 12° beam observations were lower than those associated with 6° winds. They are keen to know whether the same is true for v3 processing. JN and TO acknowledged DAH and Myles Turp (MO) for their efforts in making v3 data available for CWINDE.

b) Some technical details of the v3 MST radar signal processing - DAH

Owing to the fact that it was already late in the afternoon, DAH did not give a presentation on the v3 processing, but merely highlighted some of the important features. The biggest change from v2 processing is that v3 identifies multiple signal components (typically two) within each radar return spectrum, as opposed to merely identifying the single strongest signal component. A radial-continuity algorithm identifies which of the signal components, from each range gate, leads to the most-likely clear-air profile and attention is subsequently confined to these primary signal components. Thereafter time-continuity and complementary-beam reliability checks are carried out as in the v2 processing. Multiple signal component identification is necessary for avoiding contamination by strong and persistent signals associated with ground clutter and interference.

v3 software was designed to be highly modular which makes it simple to modify. v3.0 began operations in January 2006. v3.1 was introduced in March 2006 to ensure that 30 minute MO messages began at 00 and 30 minutes past each hour. Previously 30 minute messages were generated at the end of each "run", a legacy grouping of observation cycles with an arbitrary length (currently 28 minutes). v0 messages for the MO are still generated in this way. However, the lack of a fixed time reference makes it difficult for the MO software to generate on-the-fly statistical measures of data quality. v3.2 software was introduced in June 2006 with an improved radial-continuity algorithm. The original implementation was largely effective, but would occasionally flag large sections (of up to several km) of apparently reliable data as being unreliable. Owing to the fact the processing scheme was effective at exploiting the redundancy in the wind-profile information, this is likely to have had a minimal impact on the Cartesian data products. However, such gaps would have been undesirable for users of radial data.

Interference has always occurred sporadically but has become much more common during the past few months - since the radar receiver, the pre-processing units, and the data acquisition PC were moved into a new rack. The cause of the problem is not known but an internal oscillation is suspected. The problem typically occurs in the early afternoon. ZAKO has created additional earthing points for several pieces of equipment and attempted to shield the radar interface unit by wrapping it in tin foil. However, the problem persists. The Doppler velocity and the signal power of interference signals are almost invariant as a function of range gate. This makes them easy to identify and to avoid as long as they are well separated from the atmospheric signals. This functionality was implemented in the v3.2 software. Earlier implementations of v3 processing did not specifically check for interference since it was already avoided where it was weak and was only apparent across a limited number of range gates. However, the frequency of occurrence of strong interference, which is apparent across a large number of range gates, has increased. Since the radial continuity algorithm is searching for the longest available profile, it will select an interference profile over an atmospheric profile under such circumstances. However, even then, wind-profiles contaminated by interference are typically rejected by the complementary-beam reliability check. A particularly bad case of interference on 27th April 2006 did not violate the complementary-beam test and so contaminated data were sent to the MO from the v3.1 processing scheme. The improved algorithm in v3.2 was effective at avoiding contamination when applied to data from 27th April 2006. DAH noted that nevertheless, interference could not be avoided in all cases.

Finally an attempt has been made to avoid contamination by hydrometeor returns. This is particularly a problem under conditions of stratiform rain, which can persist for several hours at a time. DAH concluded that more research needs to be conducted in order to design an effective precipitation detection algorithm. He has introduced a "low altitude correction" algorithm in v3.2 processing. The problem is only apparent below the 0° isotherm, which is to say within the lowest 1 or 2 km of the radar observations. The algorithm is only partially effective but is better than nothing.

c) Metadata standards with a view to long-term curation - DAH

DAH reported that he had had to invest a considerable amount of effort, during January 2006, to establish exactly how the Campbell Scientific logger was deriving the 10 minute sample values from the surface met sensors. Although this information is probably of minimal importance in the case of most of the sensors, it is scientifically significant in relation to the tipping bucket raingauge. Convective rain rates can vary widely and rapidly within the time scale of 10 minutes. A 10 minute rate of 10 mm hour^{-1} may conceal a peak rate of ten times that magnitude. Details of the sensors, their accuracies, and the measurement procedures have been included in a verbose metadata block in the new (NASA-Ames) surface met files. DAH reported that shortly after he had defined the new metadata standards he had attended a workshop organised by the Royal Meteorological Society Specialist Group on Observations in conjunction with the National Physical Laboratory. The theme of the workshop, "Standards and Measurement Traceability for Met Instruments", was highly relevant to the storage of data from the MST Radar Facility. It emphasised the need to record sufficient details about measurement procedures and accuracies to allow the data to be scientifically-useful in 100 years time. Changes to the way in which air and sea temperatures are recorded were cited as an example of how this information is vital for climate change studies. DAH reported that the metadata standards he had used for the surface met data were close to those recommended by organisers of the workshop. Consequently he regards the surface met files as representing the gold standard of data storage. The aim is to adopt similar standards when introducing any new files.

On a separate, but linked, issue, data from the Facility are being considered by a RAL team who are investigating long-term data curation. DAH read out the following explanation of their project:

CASPAR is an large-scale international project that is concerned with preservation of digitally encoded information. It receives funding from the European Commission's Sixth Framework Programme. One area of preservation concern is scientific data: how to ensure that it is accessible, understandable and usable in years to come. The Council for the Central Laboratory of the Research Councils (CCLRC) is the coordinating partner of CASPAR.

The CASPAR project is now investigating the preservation needs and gathering the requirements for a number of testbeds. As part of this activity, the project team is interested in speaking to users of the NERC MST Radar data held at the BADC. The aim is to understand how the data is interpreted and used in practice, and what preservation issues might arise in future. We would like to contact data users outside CCLRC who would be willing to cooperate in this way. In return for a small amount of your time, you would learn about CASPAR's goals and approach and about the future of digital preservation in general, and it will help us to produce tools which may be of assistance to you.

We envisage that one or two members of the CASPAR team would visit you to conduct an interview for about two hours; alternatively the interview might be done by telephone. Please contact Esther Conway (tel: 01235 446 367) if you would be interested in cooperating with CASPAR in this way.

8. Any Other Business

The next meeting was provisionally set for Tuesday 16th January 2007, to be held at the Cosener's House.