4.10 A 64 MHz RADAR WIND PROFILER SUPPORTING THE MET OFFICE'S ENHANCED OPERATIONAL UPPER-AIR OBSERVATION NETWORK

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Changes To UK Operational Upper Air Network

The Met Office is continuing with a programme to fully automate the upper air observation network in the UK. In late 2003, Met Office personnel staffed only two radiosonde stations and monitor the performance of four additional radiosonde stations where launch is fully automated. The total number of radiosonde stations has been reduced from 8 to 6 to facilitate savings in the costs of radiosonde expendables. Where the radiosonde stations have been closed wind profilers have been established nearby, so that upper wind coverage is sustained.

In eastern England a boundary layer wind profiler operating at 1290 MHz [located at Wattisham, NE of London] has become part of the operational network. In this case, relatively large numbers of aircraft temperature and wind measurements can be expected between 5 and 11 km in the areas close to London. Thus the boundary layer winds are intended to complement aircraft measurements and form the basis of an integrated upper air profiling system in the area.

In the Hebrides islands [to the west of northern Scotland] aircraft reports are rare apart from at cruise level, so here the radiosonde station was replaced by a profiler with a specification requiring 90 per cent data coverage from 1 to 12 km. The capability of the profiler to give wind measurements at high temporal resolution was considered to be appropriate for a location where there is high variability in the upper winds on most days and in an area remote from most other sources of operational wind observations. In practice, program delays led to the deployment of a 915 MHz boundary layer profiler at the chosen site, until the tropospheric system could be commissioned. In the long term it is intended that radiosonde, aircraft and wind profiler winds should be treated as an integrated wind measuring system.

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Choice Of Wind Profiler

The profiler deployed was chosen through a competitive tendering exercise. The tender was purely for an operational system capable of running without the need for maintenance visits more than twice per year. The system should be provided with a package of spares that would ensure continuous operations for a minimum of 10 years. The specification was performance based, with a requirement to provide winds of specified accuracy [random errors less than 2 ms^{-1}] from 1 to 12 km. It was intended that this reduction in the upper height requirement would allow profiler hardware and software costs to be kept below 0.5 million pounds sterling, whilst still allowing coverage to above the tropopause. The specification was written to allow a profiler system working at around 50 to 60 MHz or at around 449 MHz, but in practice both tenders proposed the use of VHF. The Met Office were concerned that with the frequent occurrence of driving rain and sea spray in the Hebrides that problems would be encountered with antenna corrosion, whereas the MST radar at Aberystwyth had been operating in similar conditions for more than 10 years using Yagi antenna at 46 MHz.

The result of the competitive tender was that a contract was placed with Radian Inc., Boulder, CO, USA. Shortly thereafter, Radian's profiler division was acquired by Vaisala, Inc. The terms of the contract renegotiated to take account of the change. An operational frequency of 64 MHz was chosen to minimise the size of the antenna field and to conform to local frequency emission controls. The antenna field and the 64 MHz radiofrequency electronics were provided under subcontract by ATRAD PTY, Adelaide, Australia.

Location Of Profiler

The choice of location for the tropospheric wind profiler in the Hebrides was between a civilian site, probably in a hilly area on the Isle of Lewis or in association with the military test range on South Uist. In this case the proposed site was very flat, near sea level, with the only significant hills to the southeast. It was known that at Aberystwyth, sea clutter and interference from other radio sources was largely avoided because the radar is located in a valley with steep sides. On the other hand La Ferte Vidame radar near Paris was built on a relatively flat site and suffered significant external interference. The advantage of being on a flat site is that small-scale variations in vertical velocity are likely to be of lower amplitude than on a site with a lot of orographically induced wave activity. Then it is easier to achieve horizontal winds with relatively low random error. As the Met Office provided forecasting at the range at South Uist, this clearly led to a second local use for the wind profiler winds. Hence, the decision was made to locate the profiler on the range and to take the risk of higher levels of radio frequency interference and sea clutter.

Description Of The Profiler

The test range was able to provide a building in which the control electronics for the profiler could be housed. This had some workshop and rest facilities for staff, so it provided the capability of supporting fault analysis and rectification once the system was installed, see Fig.1. Thus, although the location is very remote there was enough infrastructure to facilitate testing on site. The provided profiler employs a 144 Yagi Antenna array, driven in groups of 4. These are mounted on a precision concrete foundation 35m x 35m, see Fig. 2 The power is supplied to the antenna by 6 amplifier transmitter units, see Fig. 3, with the pattern of driving designed to allow graceful degradation of radar performance if one of the transmitters fails. The details of the design can be obtained from the manufacturers. The digital IF signal processing from the radar was newly developed by Vaisala and is similar to that implemented on the new Deutsche Wetterdienst Operational 482 MHz profilers. The operator interacts with the system through a local PC that may be accessed remotely from Met Office HQ through a Met Office network available at South Uist, see Fig. 4. The software suite currently uses a single peak selection algorithm. This has led to some problems described later. The suite also contains multipeak and Wavelet algorithms, but these have yet to be implemented on the system at South Uist as reliable software with these functions has only just been delivered for evaluation.

Progress In Commissioning The System.

The complete hardware and software was installed on site in June 2003. It had not been possible to run the system as a unit before taking it to South Uist because of radiofrequency transmission limitations at factory acceptance. Rectification of immediate problems with external interference through the communications port and internal interference from 32 MHz clocks in the electronics were completed within about a month, and a work round for the bleed through of power in the transmit/receive switch at 64 MHz was also implemented.

The radar transmits and receives in two modes, at high resolution [150m] from about 1 to 6 km and lower resolution [430m] from 3.4 to about 15 km. By July, the high-resolution measurements were considered satisfactory but there were large transient anomalies in the lower resolution measurements. These were eventually identified as originating from Polar Mesosphere Summer Echoes [PMSE] actually located at a height of about 86 km above the radar. Subsequently the profiler operational configuration was changed to prevent the range aliasing into the reporting range.

A 30-day acceptance test to prove the stability of the profiler operation was initiated at the beginning of August. By this time it was clear that the thermal stability of the transmitters was critical to reliable operation. However, the Mains power supply on the island was subject to short breaks, that did not affect profiler operation [supported by UPS], but did switch off the air conditioning in the building. In mid August the profiler locked up and it was impossible to control from Bracknell for three days. This fault was likely induced by thermal instability that resulted in side effects when certain software appeared to have taken over most of the control computer available memory. The profiler was restarted with improved diagnostics and improved air conditioning and the problem has not recurred since in 3 months of continuous operation without any significant intervention from Met Office HQ.

Results Of Acceptance Test

The system operating stability has been accepted, but since the backscattering conditions vary so much from day to day some independent housekeeping of satisfactory radar operation is required from the production staff.

Met Office boundary layer profilers are operated in 3 beam modes but interference and ground clutter affect different beams at different times so the Tropospheric system will be operated in 5 beam mode.

The measurement quality in terms of wind speed systematic bias was found to be satisfactory in comparisons with collocated radiosonde [30 test flights] , but the direction needs a small correction [Met Office responsibility].

Random errors in the high-resolution mode were generally within specification, but in the lower resolution mode, measurements were often outside of specification at heights above 8 km.

The reasons for this lie in the use of single signal peak selection algorithms, which occasionally selects incorrect peaks if ground clutter is asymmetric about zero and of similar magnitude to the atmospheric signal. Similarly relatively weak interference present in all range gates again corrupts the peak selection in the range gates when atmospheric signals are relatively weak. The Met Office hopes to take greater advantage of an opposing beam consistency-checking algorithm that is imbedded in the Vaisala software. It is hoped that during 5-beam operation, this algorithm may provide consistent wind measurements through its ability to identify many of the spurious peak selections

Contrary to Met Office expectations, the backscattering from even moderate rain appears to be of similar magnitude to the clear air signal in layer cloud. Thus, in this condition multiple peak selection algorithms are essential below the melting level, even at 64 MHz.

Examples Of Time Series From Profiler

In Figures 5 and 6, measurements of the u and v components from the South Uist profiler on two days from the acceptance test are presented as a time – height cross section. In Fig. 5 a cold front is moving slowly across the profiler site, aligned north-south. In the second case fronts were passing east to west across the site. These plots illustrate the stability of the profiler measurements and the information content on atmospheric variability obtained by observing at 30 minute intervals.

Conclusions

The Met Office has been pleased by the support from the contractors to rectify problems identified in this operational system. The challenge of the first time system integration in the Outer Hebrides Islands has, however, relied on a high skill level of the Met Office in the support of this program and successful deployment of this tropospheric wind profiler system.

Fig. 1 General view of 64MHz profiler, South Uist, looking towards the north

Fig. 2 Pictures of antenna field plus close up of individual Yagi antenna

Fig. 3 LHS rack mounted transmitters, RHS two electronics cabinets house the basic hardware

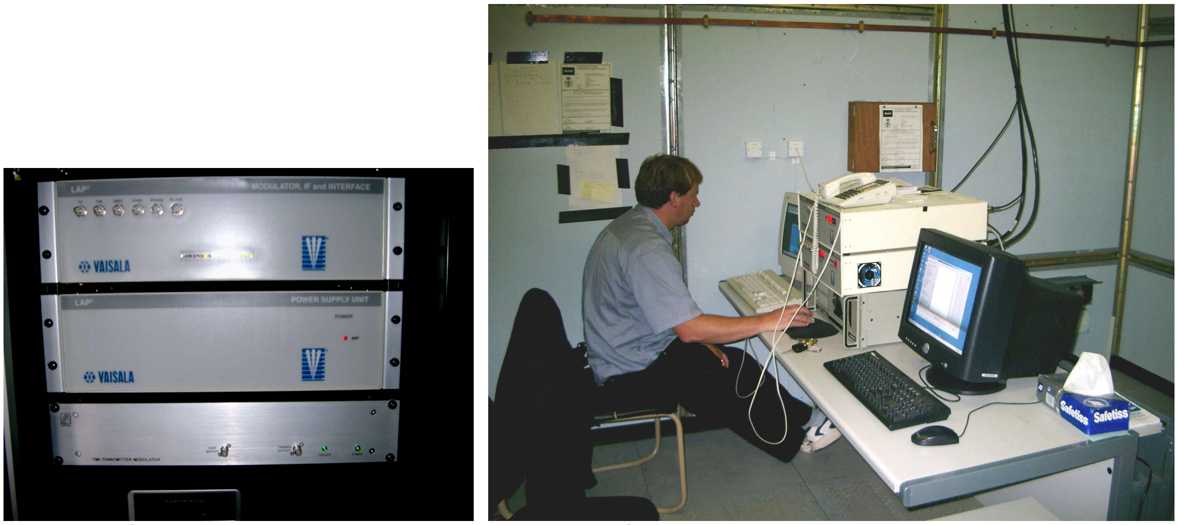

Fig. 4 LHS Rack mounted signal processing, RHS control computers for 915 MHz and 64 MHz

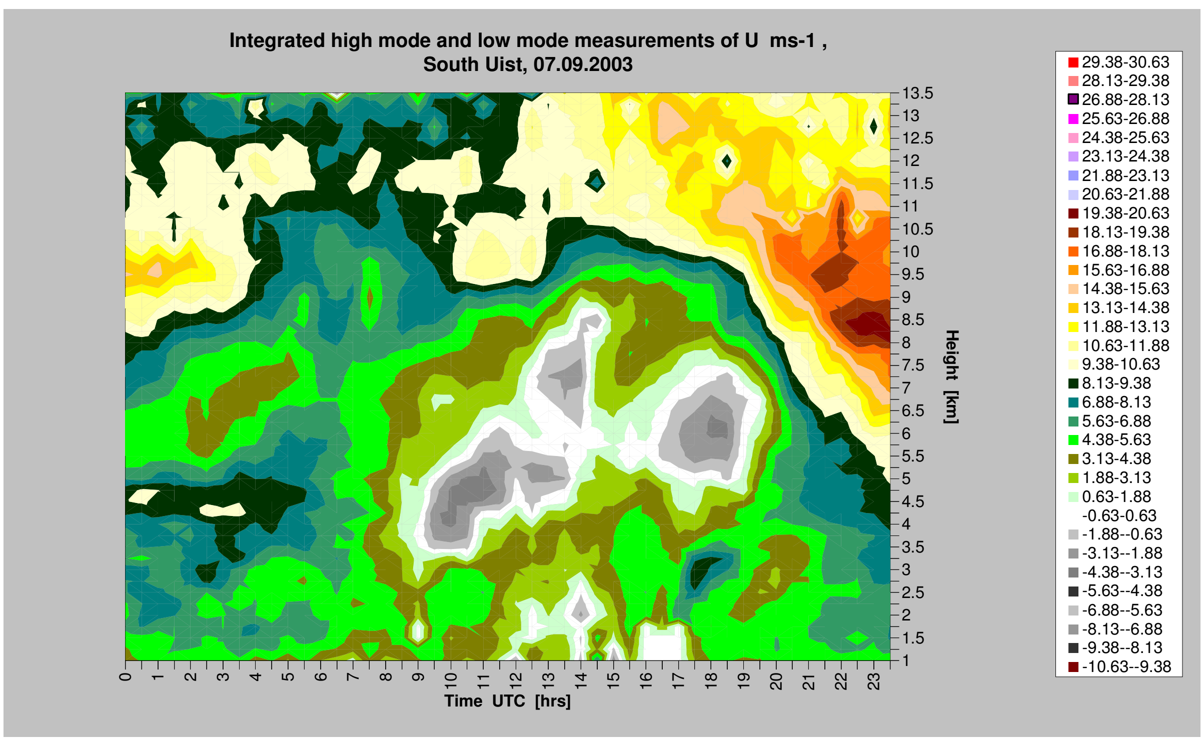

Fig. 5(a) Wind component contoured at intervals of 1.25 ms^{-1}

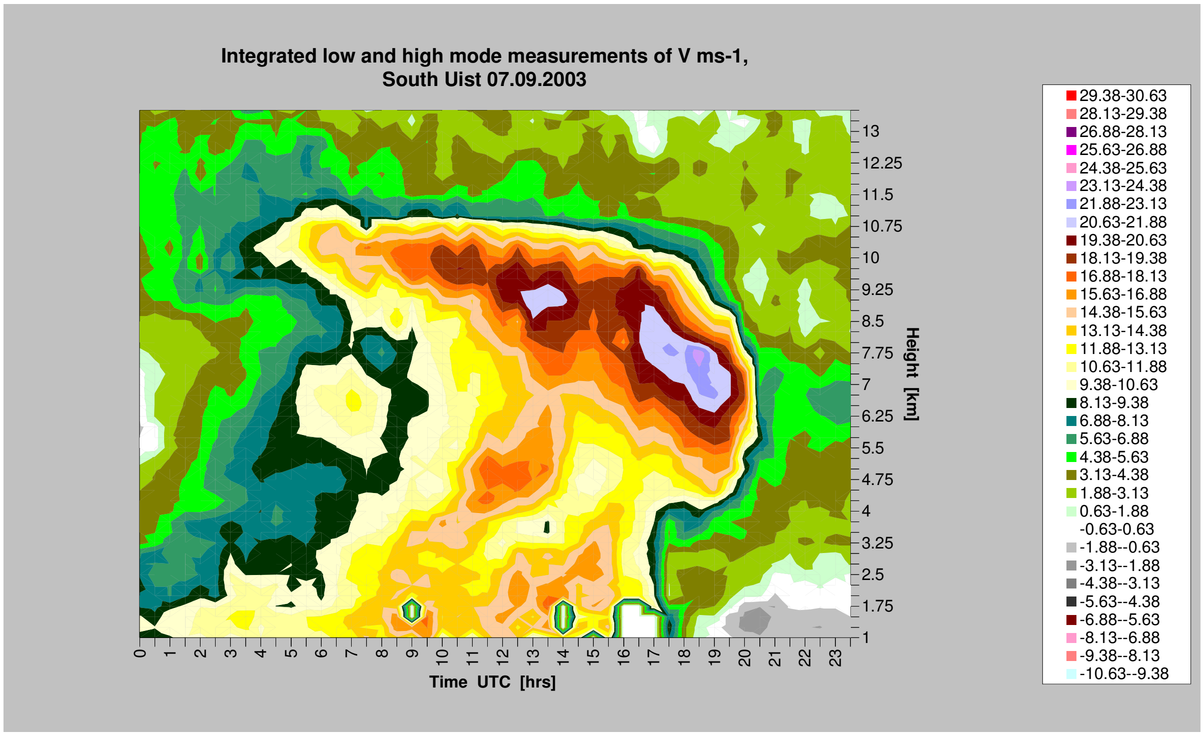

Fig. 5(b) Wind component contoured at intervals of 1.25 ms^{-1}

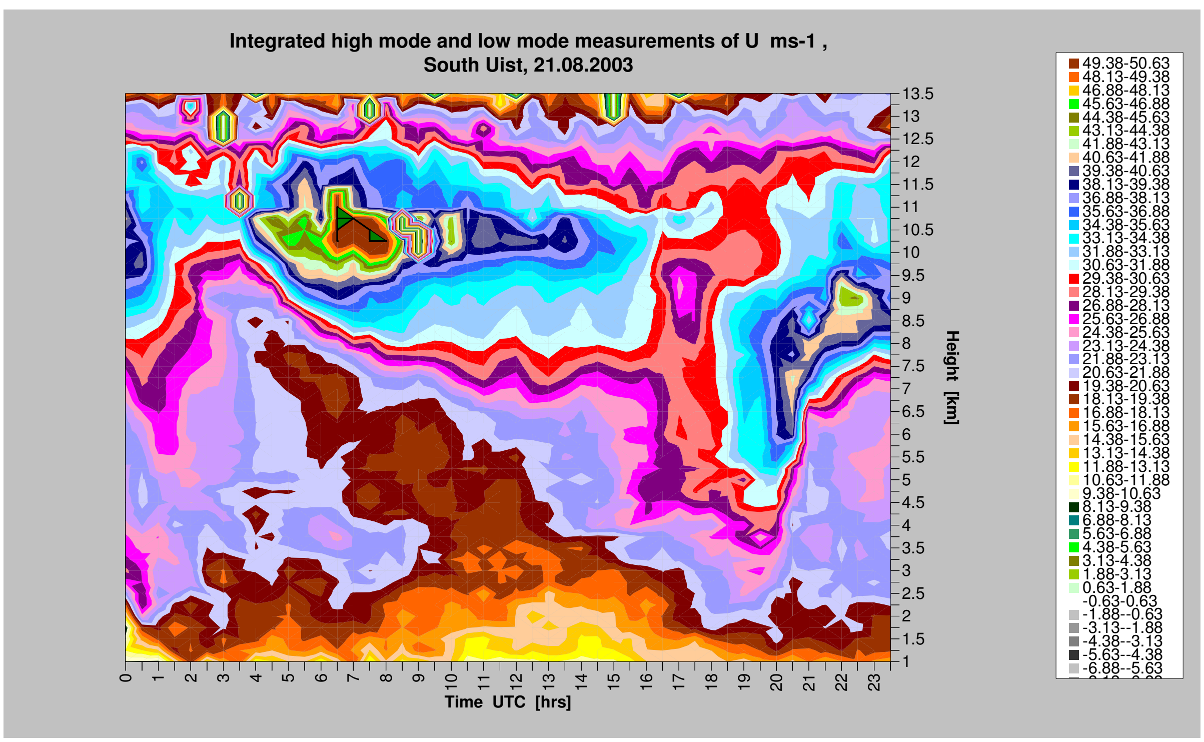

Fig. 6(a) Wind component contoured at intervals of 1.25 ms^{-1}

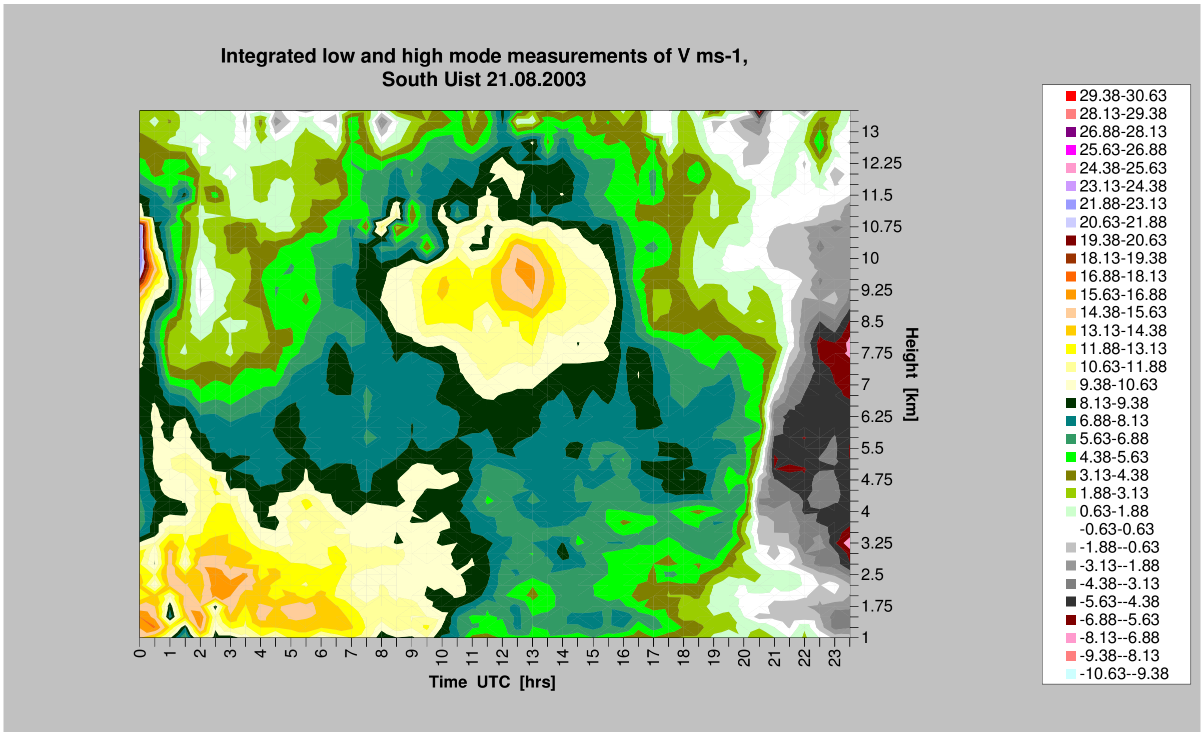

Fig. 6(b) Wind component contoured at intervals of 1.25 ms^{-1}