Initial tests of a small scale VHF Boundary Layer Radar

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Motivation

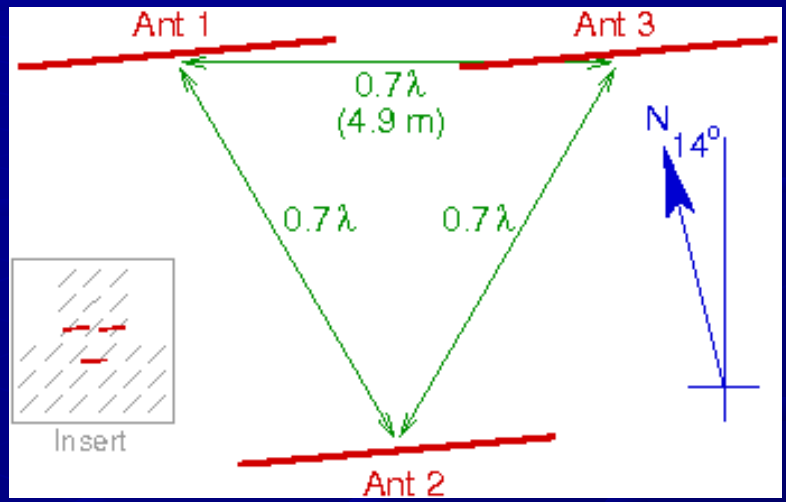
- Wind profiles of the Boundary Layer (BL) were previously predominately obtained using UHF radars, which are sensitive to Rayleigh scatter from birds, insects and precipitation
- This led to the development in the late 1990's of VHF Boundary Layer Radars (BLR), which are insensitive to these scatterers.
- Unlike larger stratosphere-troposphere (ST) VHF radars, VHF BLR require fast TR switching, quick receiver recovery and minimal ringing in the system.
- The Mini-BLR is based upon the larger VHF BLRs which have been successfully operated at a number of sites in Australia, New Zealand and The Netherlands.
- The Mini-BLR was developed to address the desirability for a small portable system. With only 3 antennas the Mini-BLR antennas will fit in an area less than 10 metres wide (depending on operating frequency).
- This system could be stored in a truck or trailer and rapidly deployed to enable observations of localized phenomena (i.e. tornadoes, bush fire winds)
- The simplicity and size are ideal for it to be utilized as an educational or research tool.

The Mini-BLR Radar

- Installed and tested 8th-13th October 2003 at the Buckland Park field stations

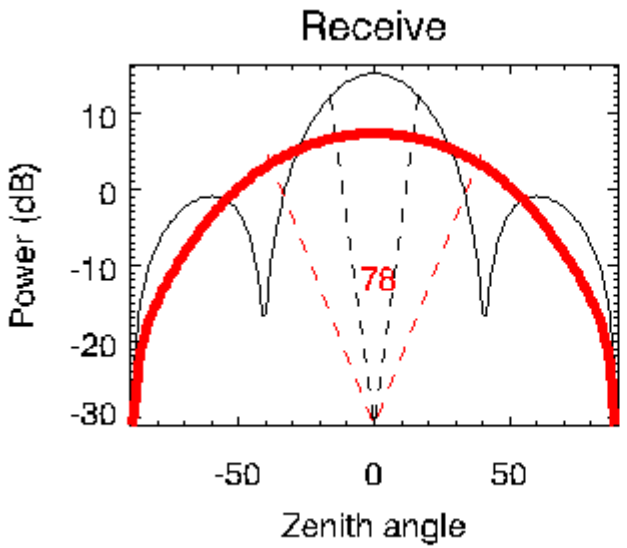
  (34^{o} 38’ S, 138^{o} 29’ E), located 35 km north of Adelaide.
- Transmission, reception and data acquisition is performed using the ATRAD's STX system, which is capable of operation between 30 and 60 MHz with minor hardware adjustments. For this trial the radar was operated at 42.5 MHz .
- Transmitter consists of three solid state modules capable of producing single or coded Gaussian shaped pulses with a wide range of peak powers and pulse lengths.
- The radar data acquisition system (RDAS) consists of 3 receiving channels with a wide range of bandwidths and range and time sampling parameters.
- An Acquisition computer fitted with data acquisition hardware and software controls the radar and acquires the data using 14-bit resolution. Following coherent integration this resolution is increased to 16-bit.
- The control program provides substantial flexibility in experiment sequencing and scheduling.
- An Analysis computer which is accessible through the internet provides a full interface to the analysis, display and radar system configuration.
- Full-Correlation analysis (FCA) is performed on the raw data to obtain wind velocities.

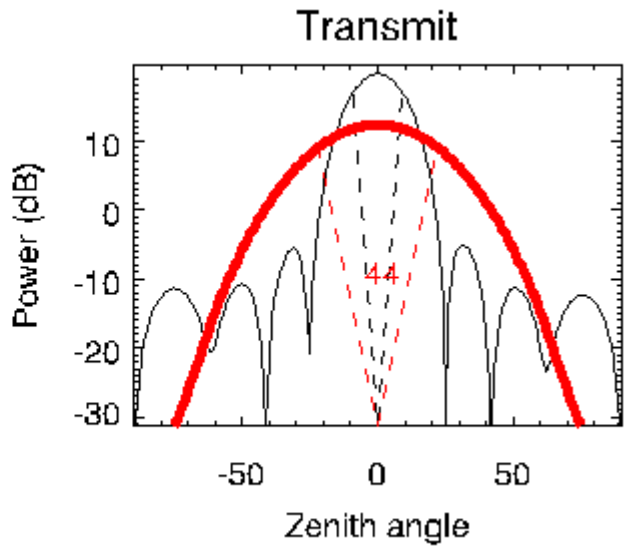
Mini-BLR Antenna Layout



- The antenna array consist of 3 three-element gamma-matched Yagi antennas arrange in an equilateral triangle.
- Each antenna connected through a transmit-receive switch to a transmitter module and separate receiver.
- Transmission occurs on all three antennas simultaneous with reception on each antenna individually.
- To achieve optimal wind measurements the spacing between pairs of antennas should result in cross correlation values of 0.5. This spacing corresponds to the pattern scale which is a function of the antenna beam-width and the polar diagram of the scatter (anisotropy).
- Below the BL the atmosphere is predominately well mixed and hence isotropic scatter dominates. Hence the pattern scale would be dependent upon the antenna beam-width only.

Antenna Polar Diagram (NEC2)





Parameter	Transmit	Receiver
Half-power full-widths (HPFW)	44	78
Antenna gain	12.3 dBi	7.35 dBi

The estimated transmit beamwidth suggests the expected pattern scale for isotropic scatter would be less than 0.83λ. The initial spacing of the antennas was initial set at 0.7λ. This spacing was found to produce cross-correlation values of >0.5 over a range of times and height and thus remained unchanged.

Mini-BLR Trial - operating parameters

- Two modes of operation were implemented, low and high.
- Low mode parameters selected to optimise lower height coverage, while high mode parameters selected to optimise upper height coverage.

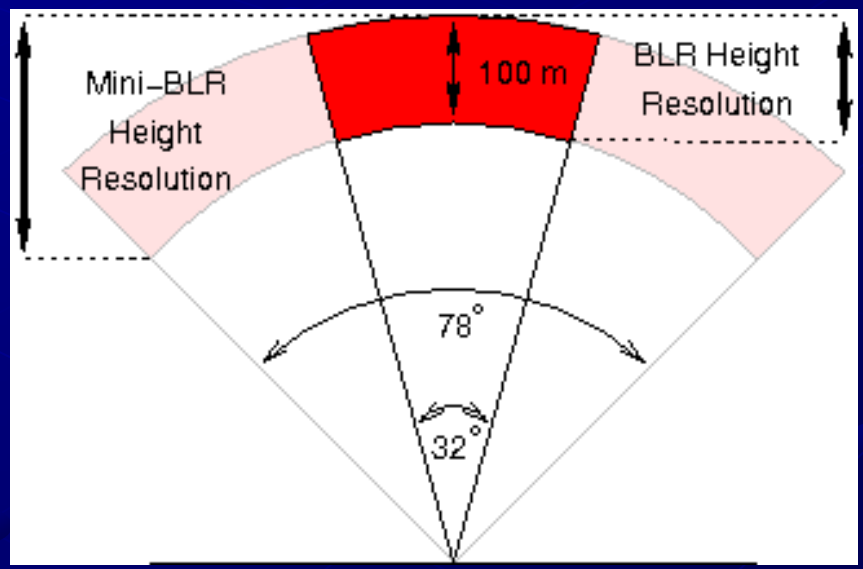
Parameter	Value
Pulse half power full-width	100 m (450 m)*
Height range (min)	300 m (1000 m)*
Height range (max)	3800 m (9800 m)*
Height sampling resolution	100 m (300 m)*
Pulse Repetition Frequency	10,000 Hz
Coherent Integrations	500
Effective Sampling time	0.05 s
Number of samples	1100
Acquisition length	55 s
Dead time	5 s

Buckland Park Mini-BLR operating parameters.

(* High mode parameters are shown in brackets)

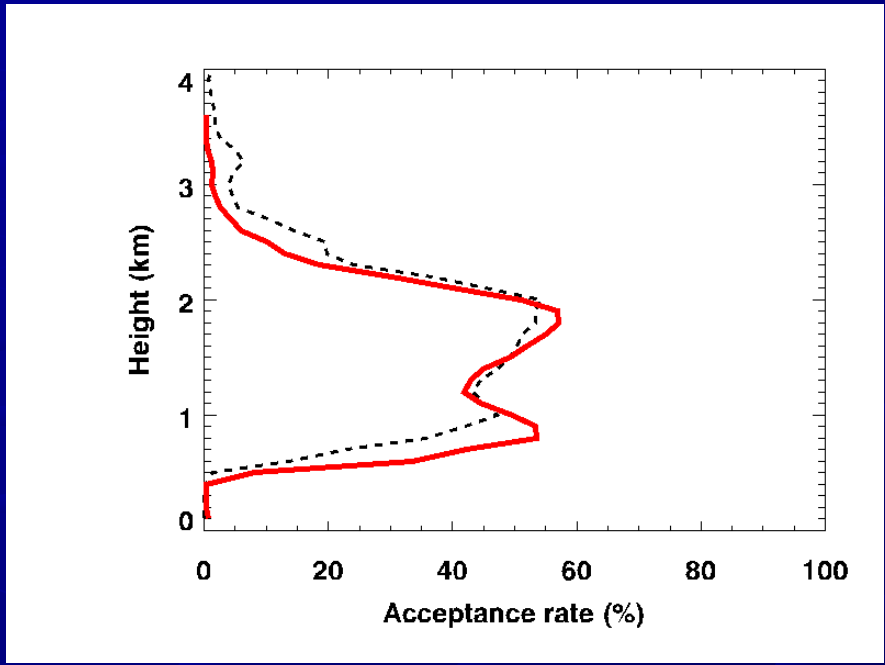
Results

- For validation of observations comparisons with a co-located 1kW 54.1 MHz VHF BLR were performed.
- While having less peak power the array of the VHF BLR consists of 27 antennas.
- The differing peak power, antenna gain and beam-width between the two radars complicates direct quantitative comparison of SNR and power.
- Feeder cables used for the mini-BLR were longer than the BLR cables, thus being an added source of attenuation during both transmission and reception.



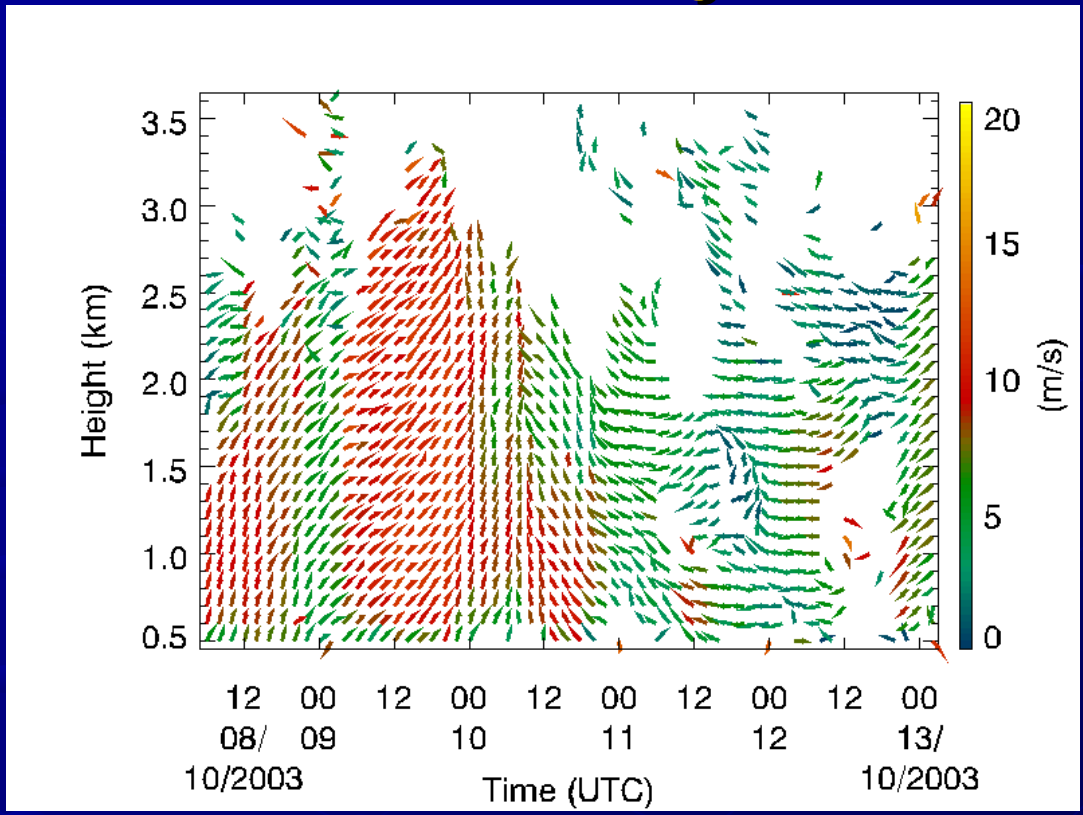
- Wind measurements should be directly comparable although greater beam smearing will be experienced by the mini-BLR due to it's wider beamwidth.

Acceptance rates



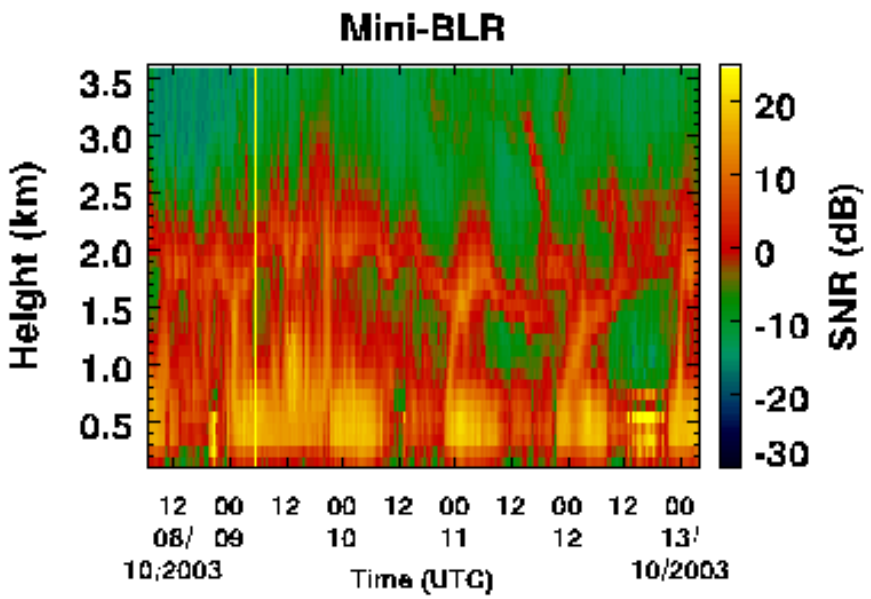
- Atmospheric conditions less than ideal during trial period, typically acceptance rates of BLR at 1-2 km are typically > 60 %. Superior lower height coverage of mini-BLR (red), below 2 km can be seen.
- Both radar are in close proximity to four 30 m masts, the larger BLR when operated at alternative sites has given superior lower performance (i.e. 50 % at 300 m). In a clutter free environment the mini-BLR would have improved lower height coverage.
- The feeder cables were not tuned for 42.5 MHz and could thus be a source of mismatching which would limit the lower height performance of the system.
- With shorter well-matched cables the lower (and higher) coverage of the mini-BLR would be improved.

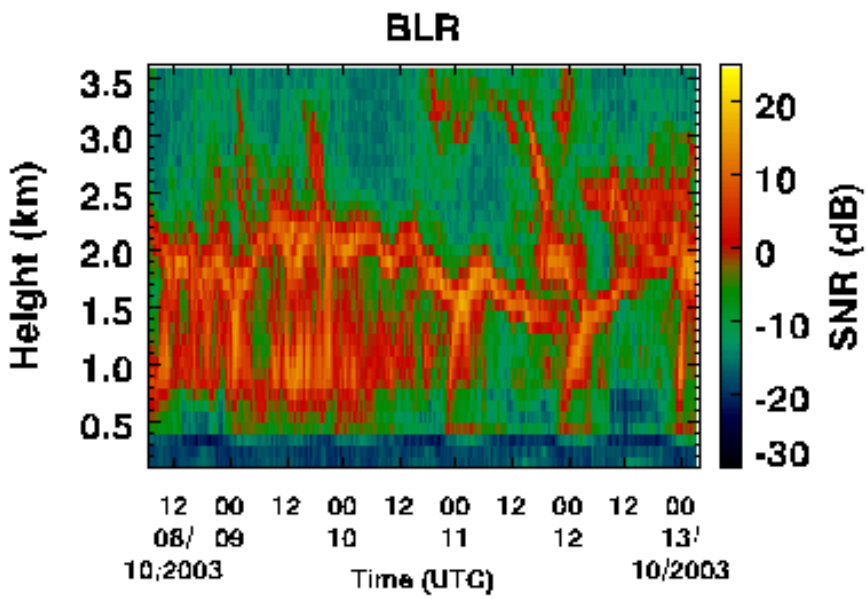
Wind Velocity Field



- Synoptic charts during the trial are dominated by a large slow moving high pressure system which passed south of the field site on the 11th of October.
- The wind direction during the period can be seen to rotate from NE around to SW over the five days. With very light winds measured on 11th October being associated with the high pressure system.
- The light dry winds associated with the high contributed to the lower coverage obtained by the radar during the trial. This is especially apparent on the 12th where reduced coverage up to 1.5 km was observed.

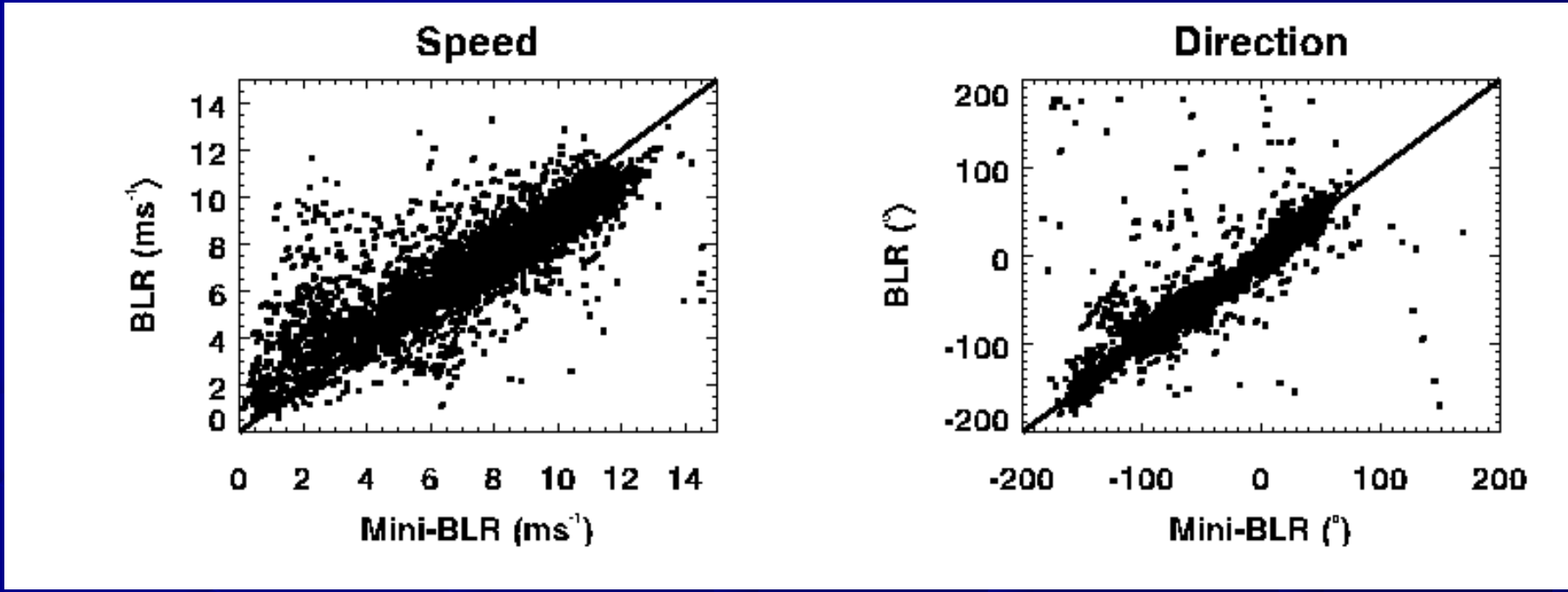
SNR





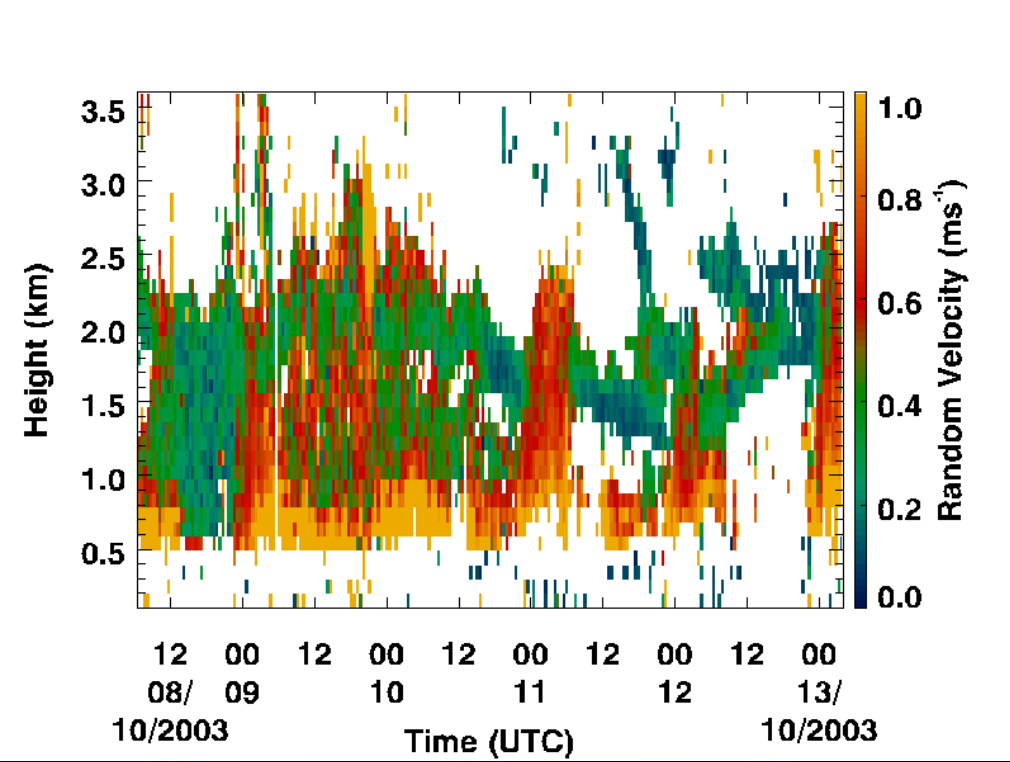
- Strong correlation in SNR between radars (i.e. inversion layer observed from 1.5 to 2 km).
- Stronger height smearing effect observed with mini-BLR.
- Only mini-BLR with superior receivers/TR switches detects diurnal growth of BL below 600 m just before 00 UTC.

Measured Wind Comparisons



- Very good agreement between measured wind speed. Mini-BLR magnitudes typically 5-10 % greater than BLR winds.
- Excellent agreement between measured wind directions.

Random Velocity



- The random velocity obtained from FCA represents an upper limit on the turbulence present.
- Strong random velocities can be seen near the ground below 1 km.
- Plumes of increased turbulence coincide with regions of increase SNR which is consistent with the active region associated with the growth of the BL during the morning.
- Low turbulence consistent with a very stable specular region associated with the inversion layer (observable on 11/10/2003 at 1.5 km).

Summary and Future Work

- A small scale VHF Spaced Antenna (SA) Boundary Layer Radar has been developed using only three antennas.
- This radar was deployed at a field site north of Adelaide for five days in October 2003.
- Comparisons of measurements with a 27 antenna VHF Boundary Layer Radar show excellent agreement with comparable performance.
- Measurements including the horizontal wind velocity, SNR, pattern scale and random velocity were obtained from 400 m to 3000 m
- Extended trials over a range of atmospheric conditions are needed as well as at different sites, with different ground clutter conditions.
- Further trials at different operating frequencies.
- Improvement to antenna array to increase both upper and lower height coverage.
- Further refinement of portability and simplification of the total installation method