Profiling Performance and New Developments

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Summary of presentation to VTMX workshop
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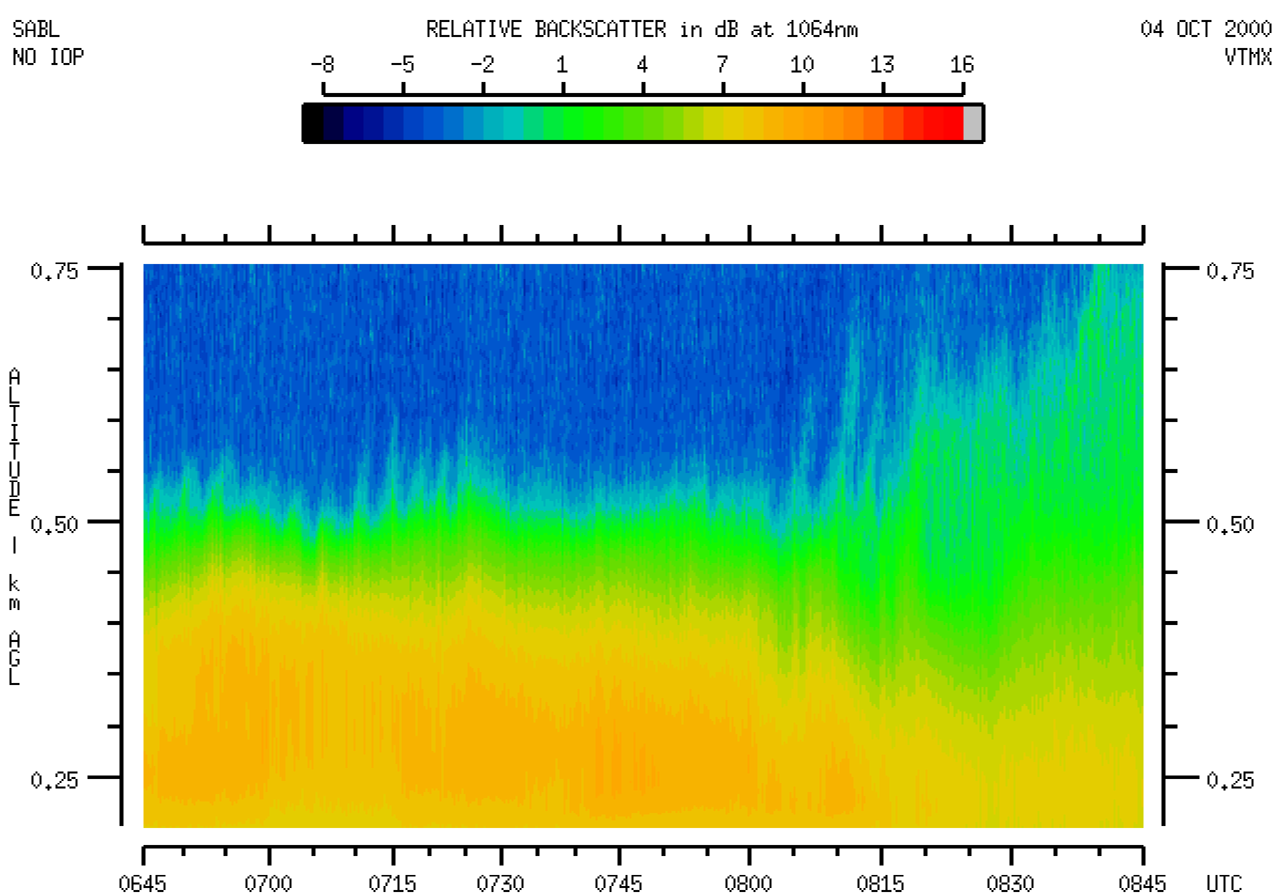
NCAR/ATD operated a range of profiling instruments in the Jordan Narrows at the southern end of the Salt Lake Valley during VTMX, including a backscatter lidar (SABL), a mini-sodar, a wind profiler (MAPR), radiosondes and a tethered balloon. The NCAR VTMX web site provides more information on the instruments and access to a wide variety of data plots and images. During the presentation, aspects of observations from SABL, the sodar, and MAPR were discussed, as were new wind profiler developments.

SABL



SABL (Scanning Aerosol Backscatter Lidar) was operated in vertically pointing and infrared (1 micron) only modes for the VTMX campaign. This instrument produced very detailed images showing interesting fine structure. An example is shown above. The features around 500 meters are suggestive of Kelvin-Helmholtz activity. Unfortunately the only wind profiles available at this time are sodar winds to 300 meters, however these do show a 6 m/s southerly jet at about 150 - 200 meters, weakening from about 8 UT.

The SABL images give lots of qualitative information, however it can be difficult to interpret such images quantitatively. The relationship between backscatter intensity and aerosol concentration is a complicated one (reference the discussion during the lidar session of the workshop). In gross terms, increased backscatter can be expected to indicate increased aerosol concentration (ignoring variations in aerosol size and type, and ignoring humidity variations since generally dry condition prevailed).

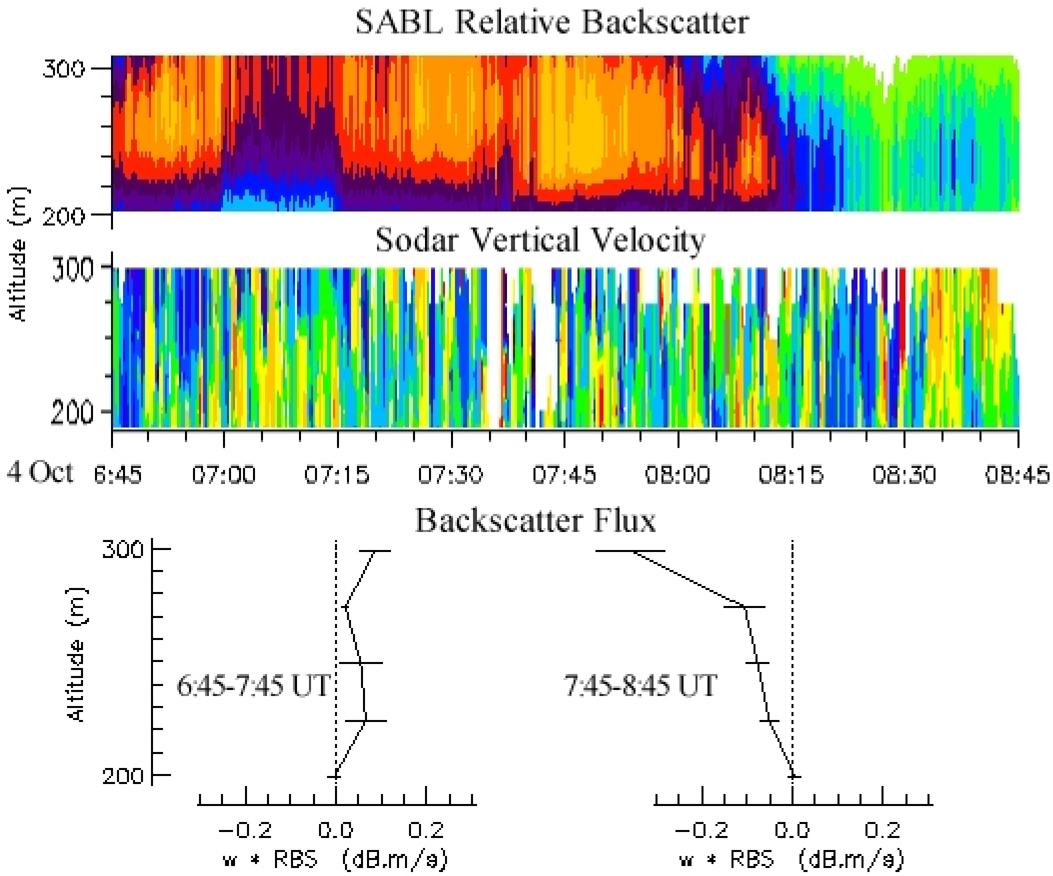
Some indication of the degree of mixing can be seen by considering the integrated backscatter, which suggests a slight rise in the total integrated backscatter up to 250m, and a decline in the region above. However total integrated backscatter was not conserved indicating that cleaner air was being advected into the region and demonstrating the need for caution in interpreting integrated backscatter. This data is considered further below.

SODAR

The sodar at the NCAR site (a Metek DSDPA.90-24 mini-sodar) was another very effective profiling instrument during VTMX. The sodar winds at the lowest range gates agreed well with surface anemometers and also produced winds up to the 250-meter level about 75% of the time. However a diurnal variation in sodar performance was observed. Generally the best performance (in terms of reflectivity, number of acceptable wind measurements, and maximum height of winds) was around local mid-night to around dawn. There was a secondary peak in performance late morning to early afternoon. The worse performance was during the evening transition (late afternoon and early evening).

The daytime peak appears to be related to convective boundary layer, as evidenced by a positive correlation between sensible heat flux as measured by a PNL sonic anemometer at the site and number of sodar winds. During the night, comparison of sodar performance and temperature lapse rates from soundings indicate that the peak in reflectivity results from nocturnal inversions. During the evening transition, as convective dies and before inversions develop, there seems to be a lack of thermal gradients to provide scattering targets for the acoustic signal (e.g., Crescenti, 1997.)

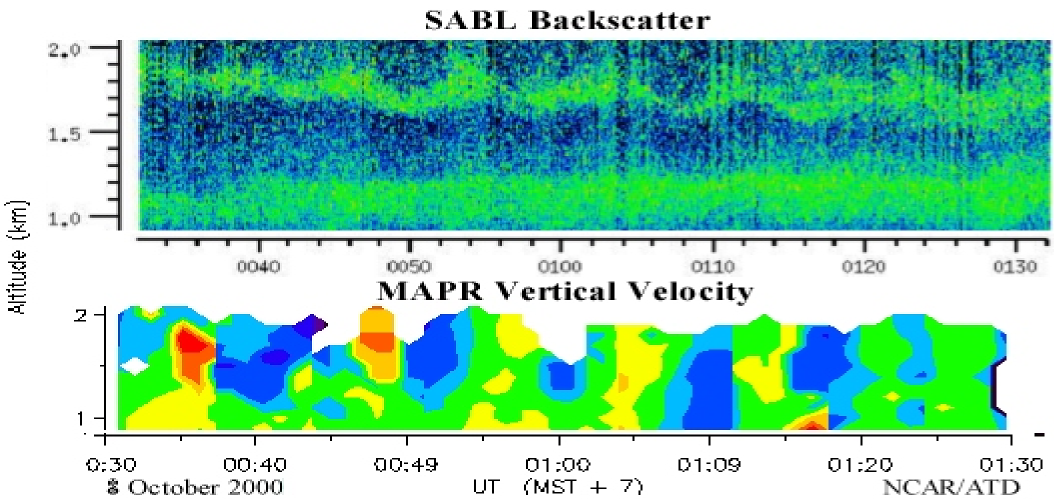
The sodar sometimes observed strong variability in vertical velocity, and particularly during the day, these appeared to be correlated with fluctuations in backscatter as seen by SABL. Similar, though weaker, such events were occasionally observed at night and an example is shown below (a subset of the data shown above).



The upper two panels show range-time contour plots of SABL backscatter and vertical velocity from the sodar (yellow/red is upward motion, blue is down) for the overlapping range bins of the instruments (200-300 meters). The profiles in the lowest panel show backscatter flux, which might be taken as some indication of vertical transport of aerosols (recalling however the uncertain link between backscatter and aerosol concentration). For the first hour, the sodar vertical velocity and lidar backscatter fluctuations were positively correlated indicating upward transport of aerosols. For the second hour, there was a negative correlation suggesting either downward transport of aerosols, or rather, upward transport of cleaner air. The southerly winds were gradually decreasing during the second hour, and clean air appears to have been mixed in. The correlation coefficients were low (around 0.2 to 0.3), however student-t tests indicate there is statistically significant correlation to about the 90% confidence level or better.

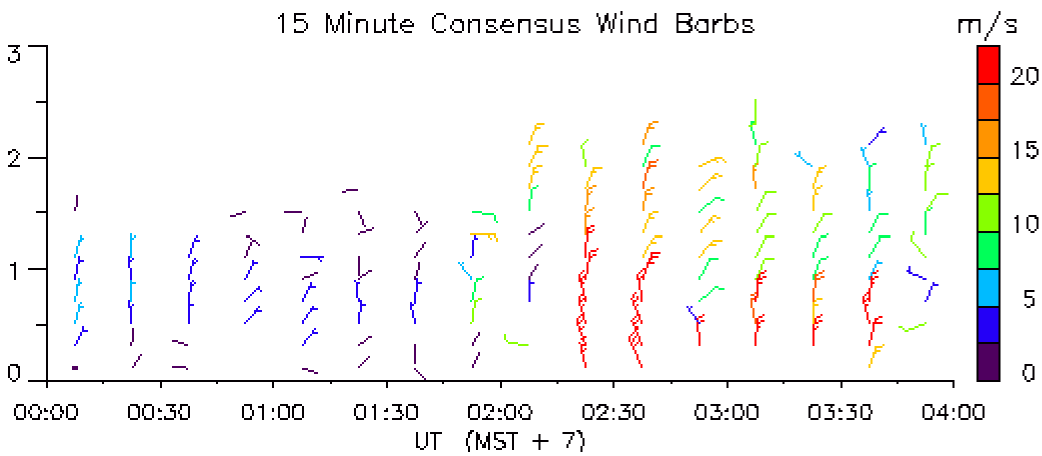
MAPR

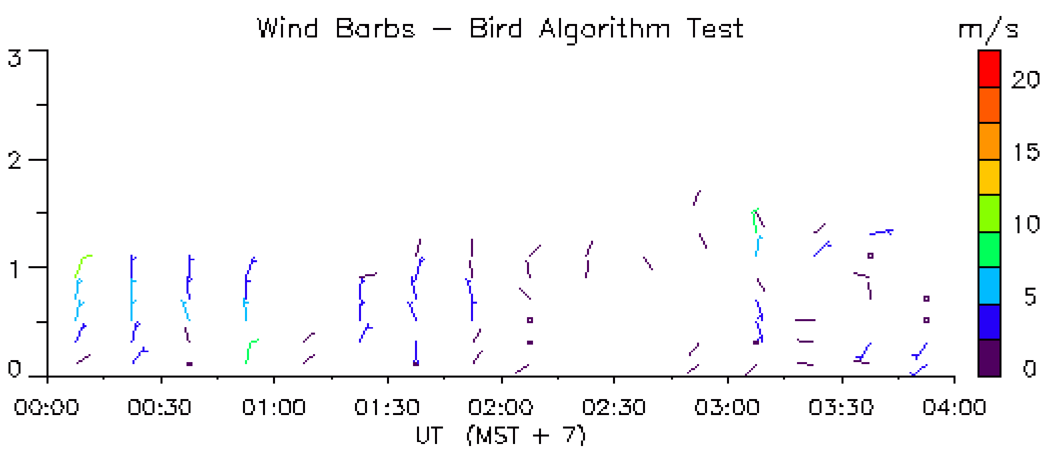
The wind profiler operated at the NCAR site was MAPR (Multiple Antenna Profiler Radar, Cohn et.al. 2001), an advanced UHF boundary layer profiler capable (at least during the day) of measuring horizontal winds every 1 - 5 minutes and vertical winds on even shorter time scales. An example of MAPR vertical winds correlating with oscillatory behavior seem by SABL is shown below. A sounding at 0 UT indicates a wind shear at about 2 km and near critical Richardson numbers, suggesting Kelvin-Helmholtz rolls may be being observed.



Unfortunately the VTMX environment was challenging to all boundary layer wind profilers. The stable (and dry) conditions of interest to VTMX produce weak atmospheric scatter in the UHF band, and thus weak signals for wind profilers. Like many other wind profilers, MAPR was also very seriously affected by large numbers of migrating song-birds (and possibly bats) during the night-time hours of the VTMX project, probably exacerbated at the NCAR site by funneling through the Jordan Narrows.

Bird reduction algorithms are being investigated. An example is the Merritt (1995) method, which selectively averages components of the Doppler spectrum based on statistics that indicate the presence of bird echoes.





Bird Algorithm Test : samcor 15 minute

This plot (8 October 2002) shows an example of the bird problem. The upper panel shows wind observations with no bird filtering; most of the strong northerlies after 2 UT are actually migrating birds rather than real winds. The lower panel shows the results of the application of a bird removal algorithm. Many of the strongly affected wind barbs have been removed, however few background winds were found, and there are still some dubious wind barbs (eg. at 3 UT). Tuning, pulse coding, and algorithm improvements will provide some improvements for future experiments, however new strategies may be required.

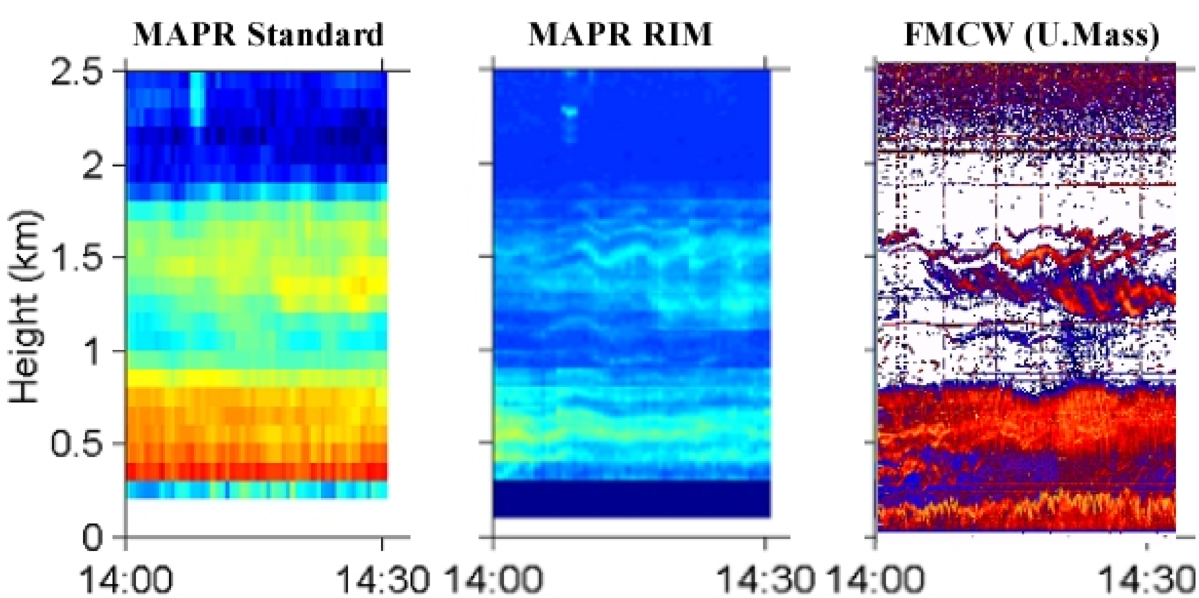
New Wind Profiler Techniques

RASS Wind Finding

RASS (Radio Acoustic Sounding System) acoustic waves provide alternate tracers for wind profiling (eg, Hirsch and Peters, 1998). The speed of sound is much greater than bird motion, and thus can be easily separated from birds in Doppler spectra. The technique is most easily applied to multiple antenna profilers like MAPR. Preliminary experiments on MAPR have given encouraging results, however there is more work do to, particularly in analysis algorithms and spectral processing. There are limitations to the technique. The range is limited (probably 500m to 1km). If there is strong bird contamination it is difficult to extract vertical motion and turbulence. Also the noise from RASS is annoying to nearby residents (as well as to the operators!).

RIM

RIM (Range IMaging) is a technique that can greatly improve the range resolution of a profiler (Palmer et.al., 1999). The frequency of the profiler is shifted from 915 MHz from pulse to pulse by about 1 - 2 MHz. As the wavelength changes, the phase of echoes change in a manner that can be precisely related to range using interferometric techniques. Depending on the application, the range resolution can improve from 100 meters down to around 10-20 meters.



The technique was applied to MAPR for the IHOP project in the Oklahoma panhandle, May & June 2002. The above figure shows observations from June 6. On the left is standard processing with 100-meter resolution, in the center is RIM processing for the same time period, and on the right are observations from the University of Massachusetts FMCW radar. The RIM processing clearly resolves billow like structures that are consistent with the FMCW observations. The technique is being refined to made high resolution wind measurements and it may be possible to spatially filter out bird echoes.

References

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