MRR Inter-Comparison January 25th – January 28th 2014

Towards the end of the 2nd installment of the OwLES field project, three of four Micro Rain Radars (MRRs) were installed in close proximity to one another to provide a baseline comparison in efforts to bolster confidence in data collected during the project. The three MRRs included in the comparison included the Sandy Island Beach MRR (hereby referred to as JRM), the Sandy Creek Central School Radar borrowed from Ron Smith from Yale University (hereby referred to as RBS), and the North Redfield MRR (hereby referred to as UUTAH2. The fourth MRR (UUTAH1) was not included in the inter-comparison because it was the most far removed from the main transect, and because it has previously shown to have compared well to UUTAH2 For the inter-comparison the JRM and RBS were relocated to North Redfield and installed as well as conditions would allow. The exact locations of the MRRs during the inter-comparison is shown below in Fig.1a.

Fig 1a MRR Locations during the inter-comparison, b) JRM Photo, c) RBS Photo

The inter-comparison lasted from 00 UTC Jan 25th – 15 UTC Jan 28th 2014. The weather during this period included both synoptic and lake-effect snow. Overall the comparison was successful, however there were several periods during the inter-comparison with missing data. Most of the missing data was from UUTAH2and was likely associated with a faulty connection between the computer and the junction box. A summary time-line of the event is shown in Fig.2, with additional detail in Table 1. There were additional minor issues with "ice on dish" periods; the most notable of which occurred on JRM between 18 UTC Jan 27th and 21 UTC Jan 28th. It is speculated that issue only occurred because the cold dish was installed during a time of heavy snow allowing for snow to melt and refreeze on the dish as the heater warmed up. It is difficult to tell if the ice had any significant effect on the data. A summary of the data is shown in Fig.3 as time/height contour plots for each radar. The letters correspond the NEXRAD weather radar images from TYX (Fig.4).

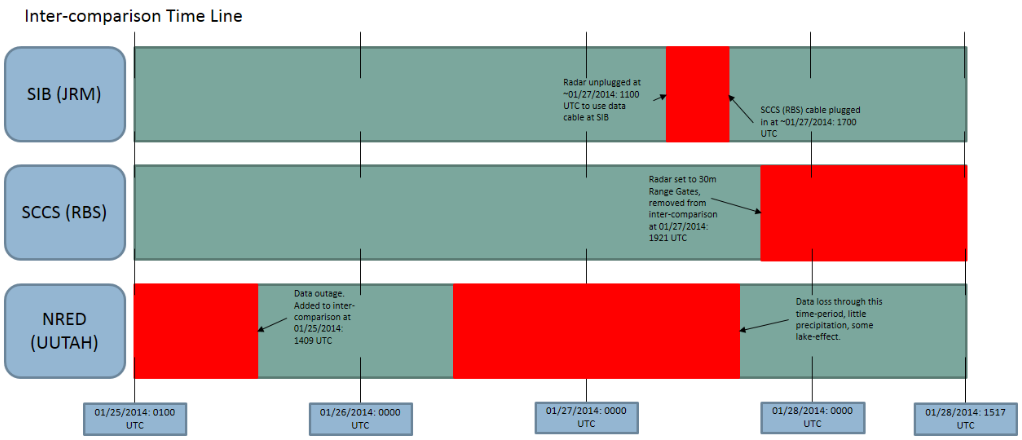

Fig 2 Summary timeline of data availability during the OwLES inter-comparison.

The time/height plots clearly show where data from UUTAH2 is missing. Towards the end of the Inter-comparison, RBS was removed from the inter-comparison and set to 30m range gates as an exploratory experiment to view the low-level structure of lake-effect snow. At first glance, the MRRs appear to compare fairly well, showing similar storm structure and reflectivity values. Storm echo-tops also appear to coincide quite well.

A quantitative assessment of the echo-top height is shown in Fig.5. This assessment focused on the period between 25 Jan 1400z and 26 Jan 1500z when all three radars were running at the same time. The metric used to approximate the echo-top was altitude of the highest range gate (below 5000m) with a reflectivity value > 4.5 dBZ. This metric was only applied to times in which at least one range gate reported a reflectivity value > 4.5dBZ. Some experimentation was performed using a different reflectivity threshold to find the echo-top, it was determined that while slightly different threshold did not largely change the results, the 4.5dBZ seemed to work the best, both eliminating false echo-tops due to seemingly random echos above the actual echo-top and limiting underestimations of the echo-top by stopping "too low" in the precipitation.

Table 1 Inter-comparison Summary

Inter-Comparison	Inter-comparison: JRM and RBS	Inter-comparison: JRM and UUTAH2	Inter-comparison: RBS and UUTAH2
Date Range	2014-01-25: 0001z – 2014-01-27: 1921z	2014-01-25: 1409z – 2014-01-28: 1517z	2014-01-25: 1409z – 2014-01-27: 1921z
Total Points Compared	4041	2661	1748
Reflectivity Agreement	Good	Good	Okay
Velocity Agreement	Poor	Good	Poor

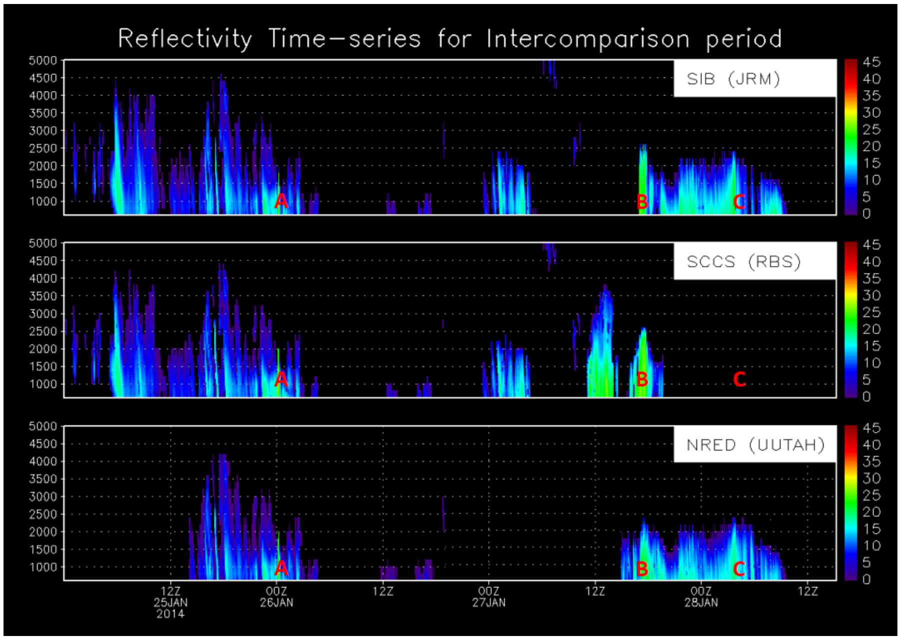

Fig 3 Time/Height reflectivity [dBZ] for the inter-comparison time period

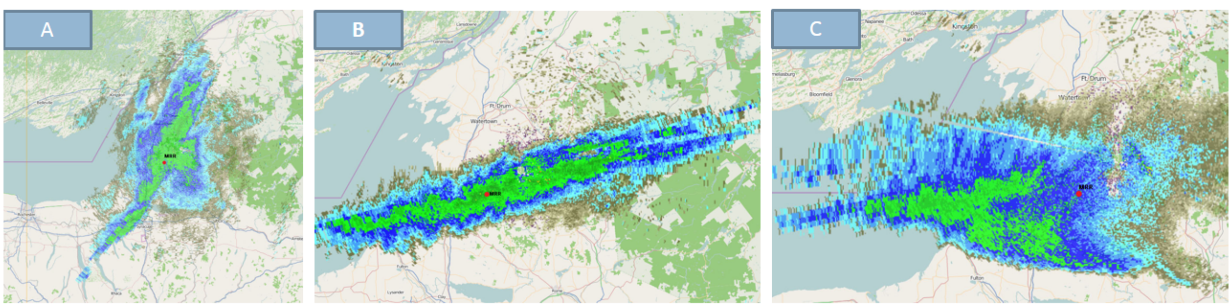

Fig 4 TYX Images corresponding to letters in Fig.3

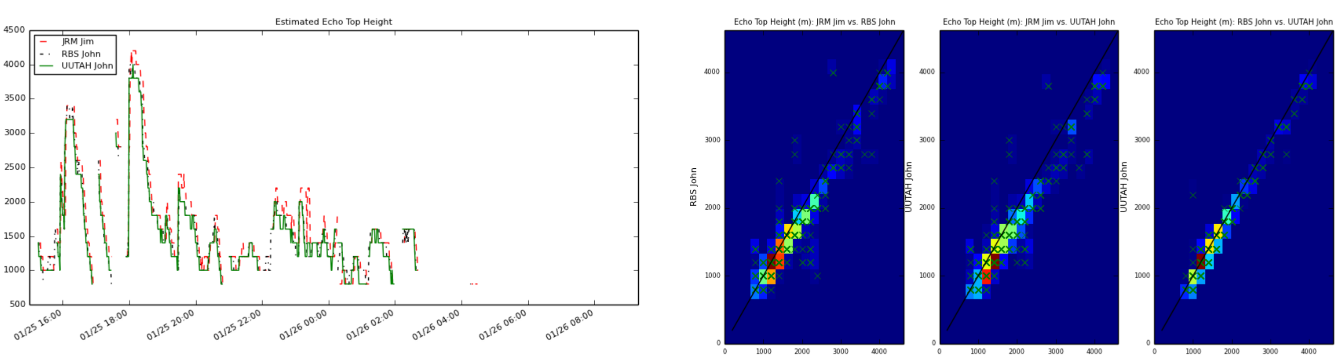

Fig 5 a) Echo-top vs. Time for the three MRR sites. b) Comparison of echo-top height between radars, plotted as a 2D histogram. Warm colors indicate higher occurrence of values. One-to-one line is shown in black

The summary analysis on the inter-comparison revealed that in general there was a minor, and generally consistent) bias in reflectivity returns associated with the UUTAH2radar. Contour Frequency Altitude Diagram (CFAD; Fig.6) analysis revealed that UUTAH2reflectivity values were on average ~1.5 dBZ lower than the reflectivity values from JRM and RBS. Reflectivity from RBS and JRM compared quite well.

The comparison between velocities did not go quite as well. JRM and UUTAH2compared very well with respect to velocity, however RBS was highly biased (CFADs shown in Fig.7). It is likely that the large velocity bias associated with RBS is due to a leveling issue with the dish. The leveling process for RBS was much more involved than the leveling process for the newer dishes, as there is no bubble level attached to the instrument. This process involved angle finding techniques that were difficult to perform in the windy conditions. The leveling process during the installation of RBS at SCCS was much more rigorous and it is likely that the velocity data here is much better than the velocity data collected during the inter-comparison, but due to the poor comparison with respect to velocity, these data need to be taken with a grain of salt.

Additional CFAD analysis was performed on the period between 25 Jan 1400zand 26 Jan 1500z when all three radars were running coincidently. The reflectivity values compared better during this time period than for the entire time-period, especially between UUTAH2 and JRM. There is currently no speculation as to why this is the case, except for the possibility that later-comparisons were potentially contaminated with short periods of snow, or ice, on dish. The velocity CFADS show differences similar to the differences seen for the inter-comparison period as a whole. An additional, though unlikely, source of uncertainty is the fact that the data cable for JRM was switched on Jan 27th. These CFADs are shown in extended Figs. 6/7.

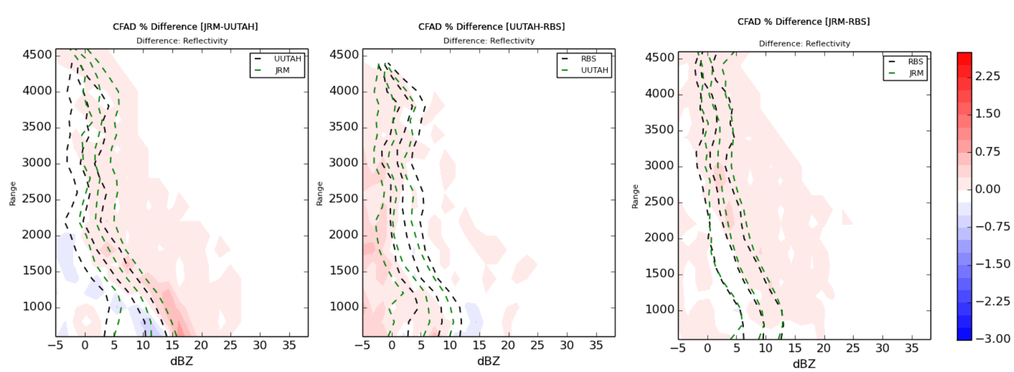

Fig 6 CFAD reflectivity differences (25 dBZ bins)

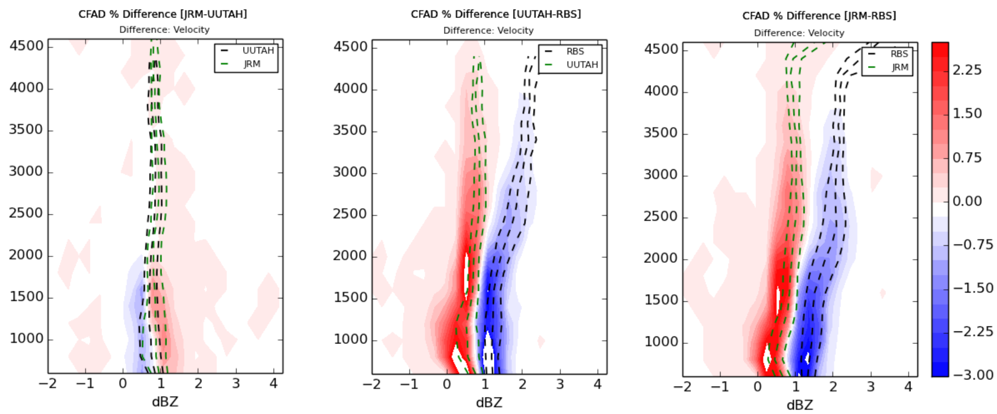

Fig 6 CFAD Velocity Difference (0.25 m/s bins)

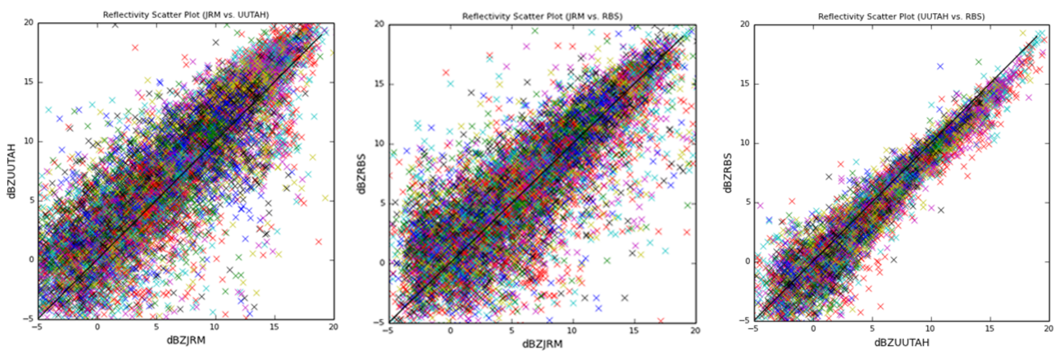

Fig 7 Reflectivity Scatter plots (one to one line shown in black)

Fig.7 shows scatter plots of reflectivity compared between MRRs. In general the one-to-one relationship is shown between JRM and RBS, with a slight constant offset associated with UUTAH2 However, there is a lot of spread in the comparisons involving JRM. This larger spread my just be a result of the fact that there are nearly twice the number data points in the JRM/ UUTAH2and JRM/RBS comparisons than there are in the RBS/UUTAH2comparison.

Figs. 8-10 show time-height reflectivity differences for each radar comparison. The data was run through an 8 minute moving average smoother to account for slight offsets in timing between the radars. These figures show some structure in the different biases between each radar. The data here is largely consistent with the CFAD results, with a consistent low bias seen in the UUTAH2reflectivity data. One visible exception is seen in the different plot between UUTAH2and JRM between roughly 07 UTC Jan 28 and 10 UTC Jan 28, where there is a robust reversal in the bias. It is possible that one of the radars experienced a period of "snow or ice on dish." Physical inspection of the MRRs during the morning of the 28th would not entirely support nor refute this idea, as the dishes themselves were clean of snow; however the sides of the dishes and, especially, the area where the RCP connects to the dishes had significant build ups of ice and snow. This was found for all MRRs. A brief CFAD analysis was performed without this period of data involved, and the results were not significantly changed.

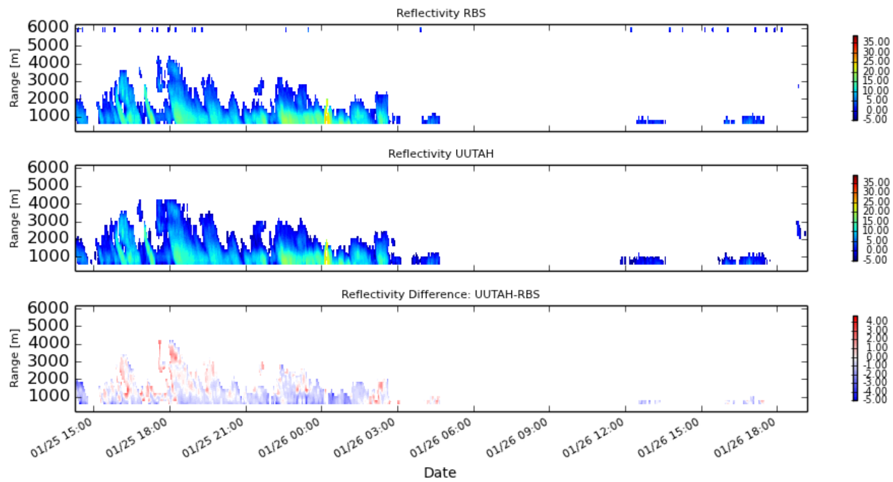

Fig 8 Time-height reflectivity difference UUTAH2 – RBS

A more detailed view of the time-height plots can be seen by taking the time-series of reflectivity values at specific heights (Figs. 11,12). These plots show that the MRRs did compare reasonable well with respect to structure, and that in general the variability throughout the storm was consistent between each radar. However, the suspected low bias in the UUTAH2 (rather than high bias in JRM) reflectivity data is seen quite well (Fig.12). Additionally, the reversal in bias from 07 UTC to 10 UTC Jan 28 is shown to have occurred at all height values within this range.

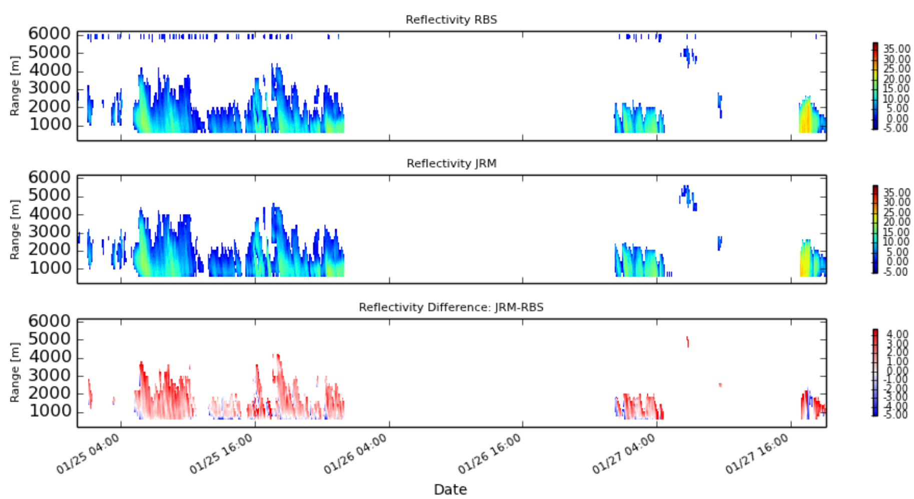

Fig 9 Time-height reflectivity difference JRM-RBS

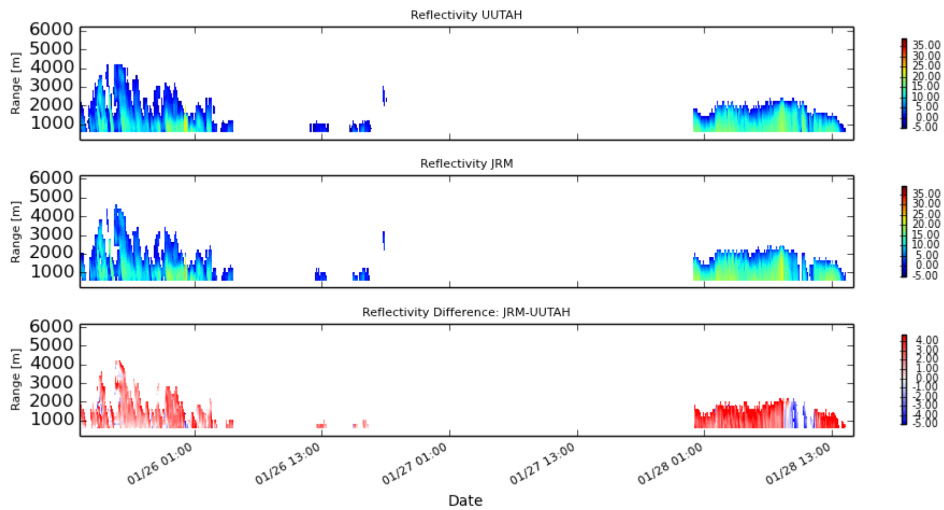

Fig 10 Time-height reflectivity difference JRM-UUTAH1

In summary, the inter-comparison went reasonably well, barring some periods of significant data loss from UUTAH2 Overall, I think the main goal of better quantifying some of the differences between the MRRs within the radar transect was achieved to a fair degree. Visually, storm structure and variability appeared to compare very well between all three radars. Additionally, the echo top range gate correlated well, both qualitatively and quantitatively. Some minor biases in reflectivity were noted, mostly associated with UUTAH2 It was determined that this was likely the biased radar as the reflectivity data from JRM and RBS matched up very well. From this analysis, it seems that this bias could be simply corrected but just adding a constant value to the reflectivity data from UUTAH2. Compared to the differences in radar observations from the different sites along the MRR transect, these reflectivity biases are quite small, and therefore likely do not have a major detrimental impact on the collected data.

The velocity data from RBS did not correlate well at all with the data from JRM and UUTAH2 however this was likely an issue with the leveling of the radar during the inter-comparison. The velocity data between UUTAH2and JRM compared very well.

As a final thought, the time-height plot from the RBS radar set to 30m range gates is shown in Fig.13. This plot shows a lot of low level structure that is entirely missed by the MRRs set up in their current configuration.

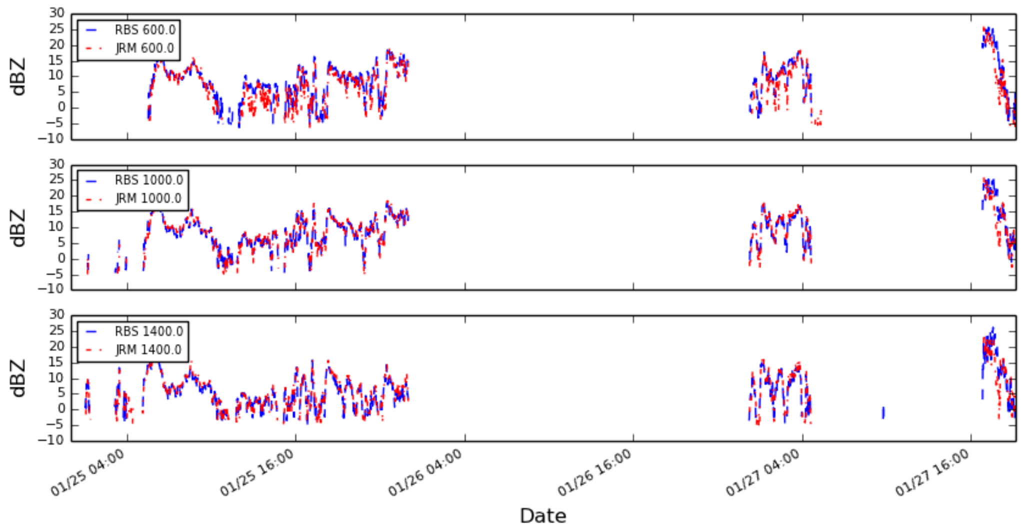

Fig 11 JRM and RBS Time-series reflectivity values at 600m, 1000m and 1400m range

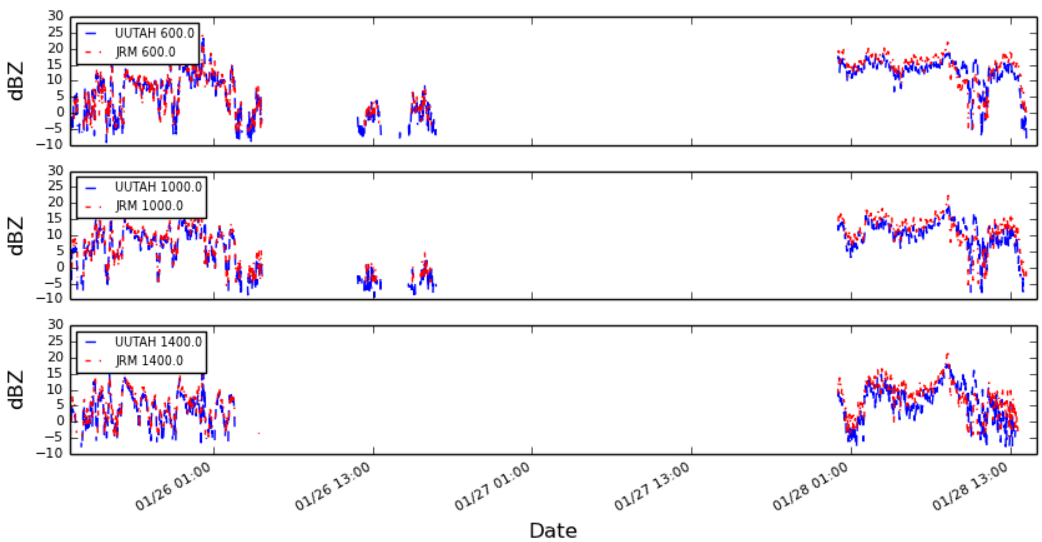

Fig 12 JRM and UUTAH2 time-series reflectivity values at 600m, 1000m, and 1400m range

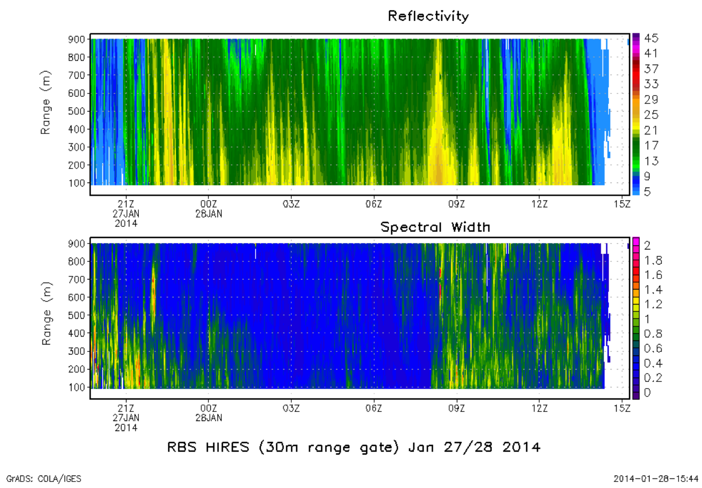

Fig 33 RBS hi resolution

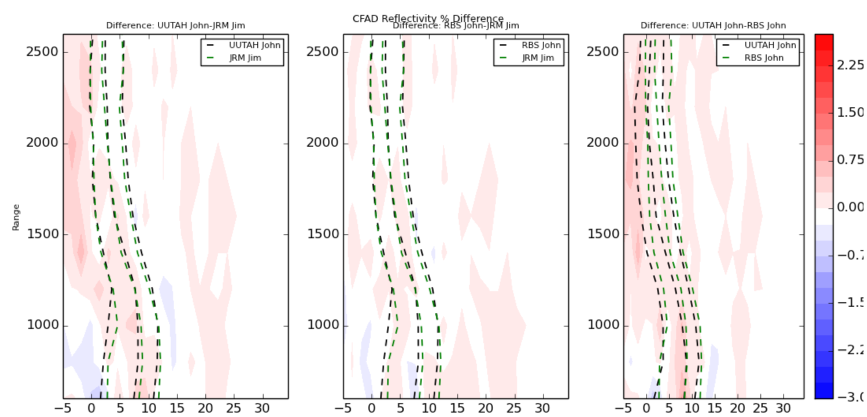

Fig 6 Ext. Reflectivity CFAD differences for period between 25 Jan 1400zand 26 Jan 1500z (25 dBZ bins)

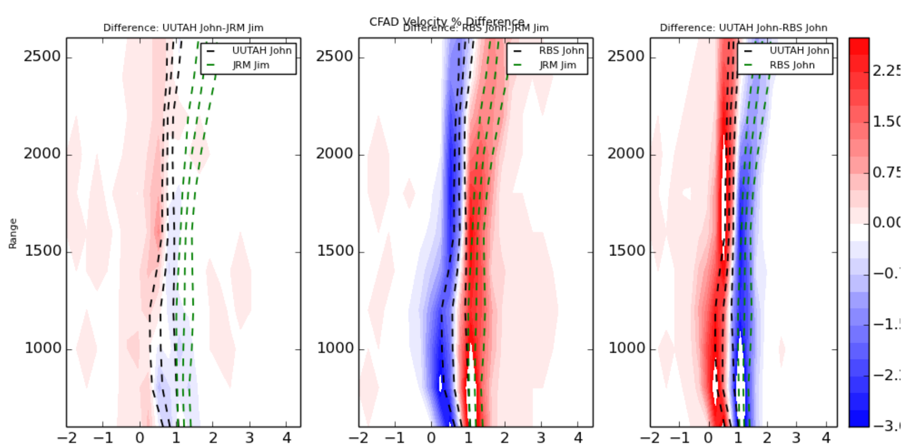

Fig 7 Ext. Velocity CFAD differences for period between 25 Jan 1400zand 26 Jan 1500z (25 velocity bins)