EXPLORATORY SATELLITE-DERIVED WINDS RESEARCH AT CIMSS

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ABSTRACT

Several advances in geostationary satellite-derived winds processing and assimilation are being explored at the Cooperative Institute for Meteorological Satellite Studies (CIMSS). This paper will focus on: 1) The study of winds derived from rapid scan imaging, 2) The use of the GOES short-wave IR channel near 3.9 microns for night-time low level cloud tracking improvements, and 3) Characterization of clear-sky water vapor winds for improved assimilation into objective analyses and NWP. Each of these exploratory studies will be briefly examined. Several other collaborative efforts are included throughout the abstract volume.

1. Winds from rapid scan imagery

Rapid scan imagery from GOES has been employed in operational forecasting for quite some time. The value of more frequent imaging is evidenced by the inclusion of a 15-minute update cycle over the CONUS sector in the current GOES schedule, and by the multitude of special NWS operational requests for more frequent sampling at 7.5 minute intervals (RISOP). Forecasters recognize the additional detail that can be captured from RISOP in events associated with rapidly changing cloud structures. On occasion, the research community has called special super rapid scan operations (SRSO). These SRSO events allow limited area coverage of one-minute interval sampling over meteorological events of interest.

1.1 GOES-10 Science checkout

Immediately after the launch of GOES-10, the satellite was put into a science test mode for almost a one-month period (March 16 – April 12, 1998). During this time, continuous 5 minute sampling over the CONUS domain was achieved in all available spectral bands.
These rapid scan data sets are used to test the impact of more frequent sampling on the UW-CIMSS/NESDIS wind-tracking algorithm (Velden et al. 1998).

Winds were derived over the central US from GOES-10 full-resolution water vapor (WV), infrared window (IR) and visible (VIS) images. Three images were employed in the displacement derivations. For our evaluation, the image spacing was varied at 5, 10, 15, and 30-minute intervals, with the shorter intervals nested inside the longer loops for the best inter-comparison. Currently, 30-minute intervals are used operationally.

Table 1 shows the vector quantities (unedited and objectively edited) derived using the different imaging intervals. There is a notable increase in the number of vectors in the VIS and IR channels (factor of two) when more frequent imaging is employed. The percentage of vectors objectively edited is also dramatically reduced, which indicates the increased quantities are generally coherent (in Table 1, EDITED = after editing). Little impact is seen with the WV channel. It should be noted that these statistics consider clear-sky WV vectors only (WV-tracked cirrus tracers are not included). This indicates the current operational 30-min. processing interval for the WV winds may be satisfactory.

Table 1. Vector quantity versus imaging interval for three spectral bands from GOES-10 for a limited area over the central US during March/April 1998.

Band	Interval	Number of Winds RAW	Number of Winds EDITED
VIS	30 minutes	8915	4187
	15 minutes	10867	5392
	10 minutes	14325	7437
	5 minutes	20378	12726
IR	30 minutes	6973	3412
	15 minutes	11238	5880
	10 minutes	12642	6428
	5 minutes	12990	6009
WV (clear)	30 minutes	7281	2640
	15 minutes	6958	2631
	10 minutes	6312	2348
	5 minutes	6251	1957

Table 2. Statistical evaluation of GOES-10 VIS winds (below 600mb only) versus collocated rawinsondes and AVN model first guess, as a function of image processing interval. BIAS and RMSE are in m/sec.

	GOES-10 *VIS* SAT	GOES-10 *VIS* GUESS
30 minutes		
BIAS	-1.21	-0.96
RMSE	5.92	4.01
Match Sample	662	
15 minutes		
BIAS	-0.67	-0.62
RMSE	5.82	3.97
Match Sample	782	
10 minutes		
BIAS	-0.71	-0.69
RMSE	6.02	4.59
Match Sample	1293	
5 minutes		
BIAS	-0.13	-0.85
RMSE	6.16	5.36
Match Sample	1963	

Statistical analyses of the wind sets (after objective editing) using rawinsonde verification are shown in Tables 2-4. This verification illustrates that the optimum processing intervals (based on data RMSE and bias relative to co-located AVN model background first guess fields used in the processing) are 5 minutes for VIS, 10 minutes for IR and 30 minutes for clear-sky WV. While the *absolute* RMSE may not be minimized at these times, our assessment takes into account the increase in vector density, and both the bias and RMSE *relative to the first guess*, since the end goal is to improve on the model guess field. These results show that more frequent image sampling improves the vector field density and quality. The optimal tracking time interval is dependent on the spectral band.

Table 3. Statistical evaluation of GOES-10 IR winds (after objective QC) versus collocated rawinsondes and AVN model guess, as a function of image processing interval. BIAS and RMSE are in m/sec.

	GOES-10 *IR* SAT	GUESS
30 minutes		
BIAS	-1.04	-0.60
RMSE	7.93	7.10
Match Sample	692	
15 minutes		
BIAS	-1.39	-0.74
RMSE	7.99	7.48
Match Sample	1232	
10 minutes		
BIAS	-1.52	-0.97
RMSE	7.64	7.41
Match Sample	1323	
5 minutes		
BIAS	-1.66	-1.08
RMSE	8.13	7.63
Match Sample	1273	

Table 4. Statistical evaluation of GOES-10 WV winds (after objective QC) versus collocated rawinsondes and AVN model guess, as a function of image processing interval. BIAS and RMSE are in m/sec.

	GOES-10 *WV* SAT	GUESS
30 minutes		
BIAS	-0.12	-0.80
RMSE	8.10	7.19
Match Sample	517	
15 minutes		
BIAS	0.56	-0.91
RMSE	8.58	7.42
Match Sample	512	
10 minutes		
BIAS	0.34	-0.87
RMSE	8.99	7.47
Match Sample	481	
5 minutes		
BIAS	0.34	-0.73
RMSE	9.58	7.46
Match Sample	411	

This study provides a preliminary look at the value added by geostationary satellite rapid scan imaging on wind vector determinations. It is demonstrated that the vector quantity and quality is notably improved in the VIS and IR channels using 5 and 10 minute imaging intervals, respectively, over the currently-employed 30 minute frequency. WV derived winds in cloud-less sky are less impacted, although cirrus cloud features tracked in the WV channel should also benefit as with the IR.

Further studies are being conducted. It is hoped that rapid scan imaging can become a routine part of the geostationary satellite observing system strategies worldwide. Quantities such as atmospheric motion vectors will benefit.

1.2 Hurricane applications

Special SRSO periods have been collected during several Atlantic hurricane events. The SRSO provides nearly continuous one-minute interval sampling, and these periods usually last 2 to 6 hours. Since hurricane cloud structures are characteristically fast evolving, the effects of rapid scan imaging on resultant vector wind fields should be promising. This is being evaluated with the UW-CIMSS algorithm.

Preliminary findings on a few cases are indicating the ability to retrieve mesoscale motions is notably enhanced using 3 to 5 minute imaging (Figure 1). However, use of the full 1-minute frequency is not optimal due to horizontal resolution limitations of the image pixels, and the navigation/registration inaccuracies. Applications of these data sets extend to hurricane genesis studies, and intensity change research. The impact of these data on numerical hurricane model forecasts is being examined

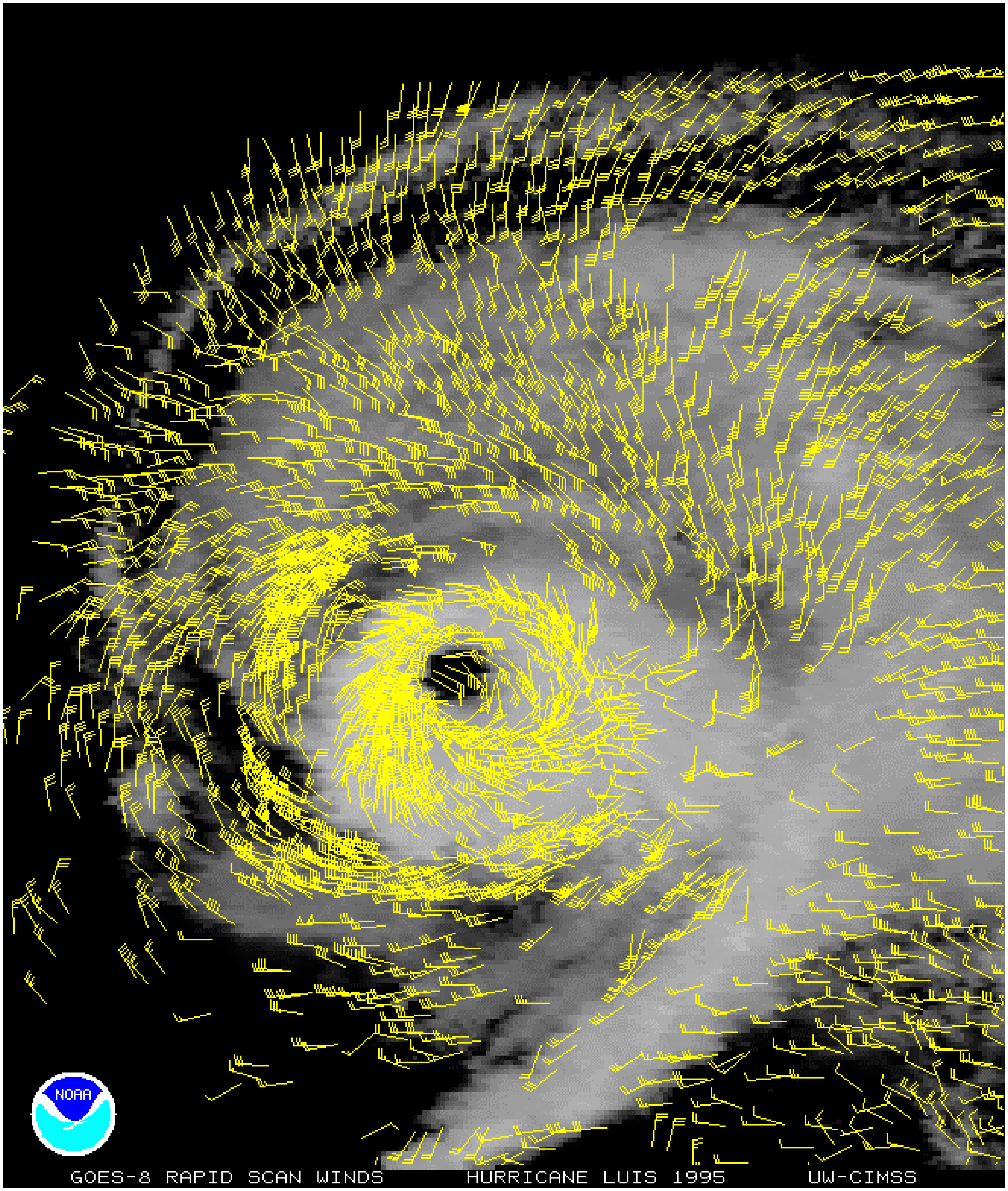

Figure 1. Satellite-derived winds from a 5-minute rapid scan sequence during Hurricane Luis of 1995. The vector field was derived from IR and VIS imagery

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1.3 Field experiments

During the NORPEX (NORth Pacific EXperiment) and CALJET (California JETs experiment) fields programs in 1998, several SRSO periods were collected during intensive observing periods (IOPs). These experiments were conducted over the Pacific Ocean, with special observations taken from multiple aircraft. These IOPs offer the opportunity to assess the value of satellite-derived data derived over marine environments. For selected case study periods, UW-CIMSS derived wind sets from the SRSO imagery at 5-minute intervals. These data are being assessed against in-situ marine data and in numerical model impact studies. Preliminary results are suggesting the increased ability of the SRSO winds to help identify tropospheric structures and impact mesoscale model forecasts.

2. Winds from the GOES 3.9 micron channel

Traditionally, the 10.7-micron long-wave IR channel has been used to track low-level (warm) clouds at night. The relatively low resolution and resolving power of this wavelength for warm clouds have been a limiting factor on vector yield. The new generation of GOES imagers contain a channel in the short-wave IR at 3.9 microns. The response of the GOES 3.9-micron channel to warmer temperatures is greater than that at 10.7 microns. Based on the principle that the emissivity of low level water cloud at 3.9 microns is less than at 10.7 microns, differencing techniques have been developed to delineate low cloud and fog. Presumably, this will also lead to improved edge detection of low-level clouds at 3.9 microns. Therefore, this principle is being applied to nighttime tracking of low level clouds with the hopes of improving the low-level wind vector yield.

Figure 2 shows an example of low-level vector tracers achieved using both the 3.9 and 10.7-micron channels at night. All of the processing algorithm settings used to derive the winds were identical, except for the replacement of the 3.9-micron imagery in the targeting and tracing modules. Vector height assignments used the 10.7-micron channel in both cases. It is quite evident from Fig. 2 that the 3.9-micron imagery increases the low-level vector yield. Several areas, which were void of vectors using the traditional 10.7-micron imagery, now contain coherent wind information.

Since the 3.9-micron channel is susceptible to reflection of visible light, its optimal use will be limited to non-sunlit domains at a distance from the day-night terminator. This distance needs to be defined through more research and extensive processing experiments. For daily operational processing, the point in time the 3.9 micron channel becomes desirable to use over the 10.7 micron channel needs to be determined. Studies are underway at CIMSS to further evaluate this product and answer these questions.

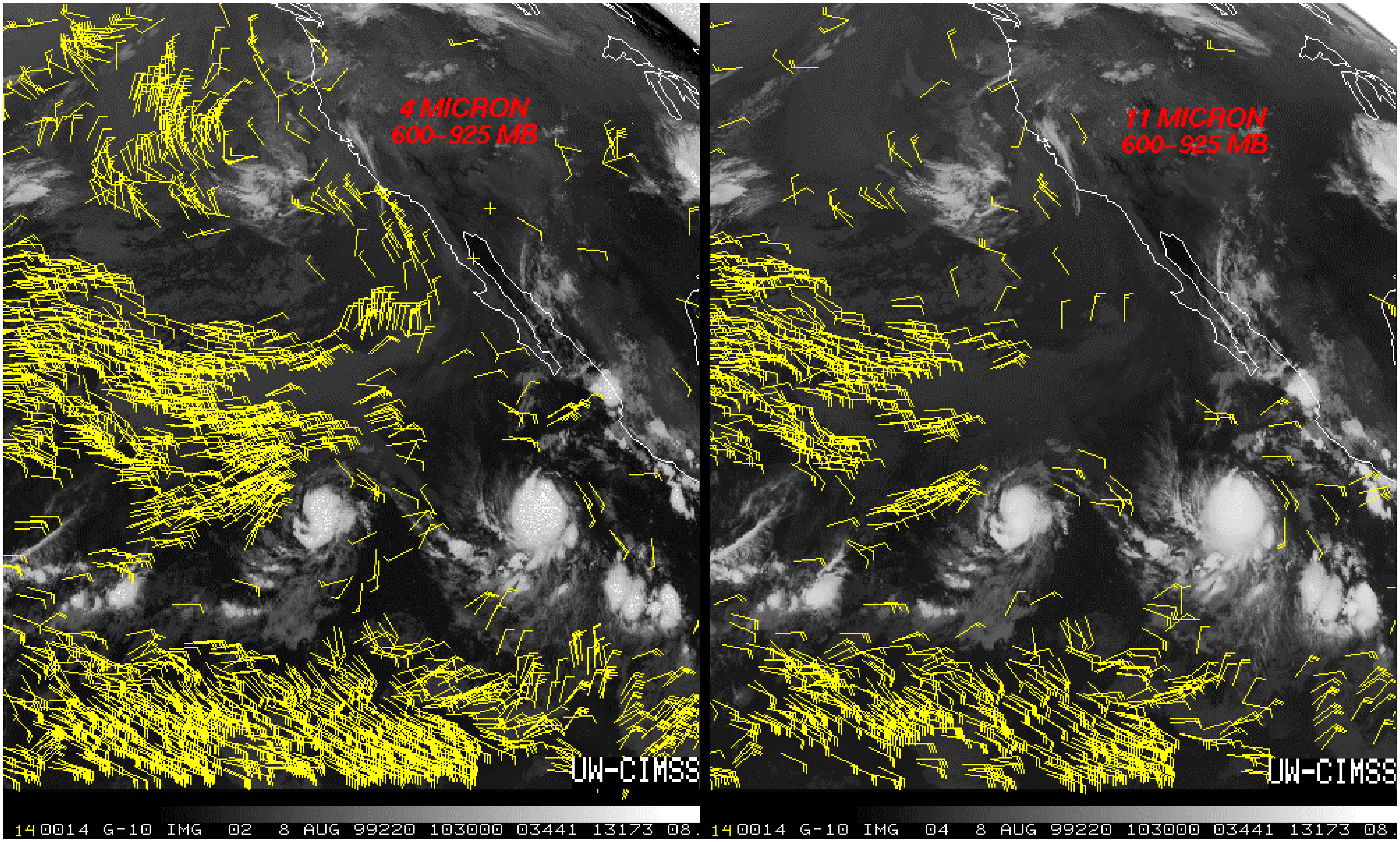

Figure 2. Example of low-level GOES-10 wind vector fields derived from 3.9 micron (left) and 10.7 micron (right) imagery. Plotted winds are those below 600mb only.

3. Characterization of clear sky water vapor winds

Since the 1980s, winds have been retrieved from geostationary satellite water vapor channels. These winds have met with mixed results in data assimilation studies. Part of the problem lies in the representativeness of the height assigned to the vector as a single level value. In reality, the features traced in the clear-sky WV channel represent layer quantities that must be treated differently than single-level reports.

In order to do this, the representativeness of the WV vectors as layer quantities must be defined. Specifically, what layer thickness do clear-sky WV vectors typically correlate with? As one approach, we subjected a large sample of clear-sky WV vectors to comparisons with collocated rawinsonde wind profiles. The level of best fit was calculated for each vector. This is defined as the minimum in the RMSE and/or normalized RMSE (NRMSE) when the vector is compared to the entire collocated rawinsonde wind profile. Figure 3 shows several levels as examples of the RMSE and NRMSE profiles that result from comparing WV winds assigned to these levels with collocated rawinsonde wind profiles over a period of about a month. Both clear and cloud WV examples are illustrated. The horizontal lines denote the selected WV height assignment levels while the arrows indicate the corresponding level of minimum values (or best vector fit). Fig. 3 suggests overall that the vector heights assigned by our current methodology match the best fit levels reasonably well, indicating the height assignments are good approximations for the tracer heights in general.

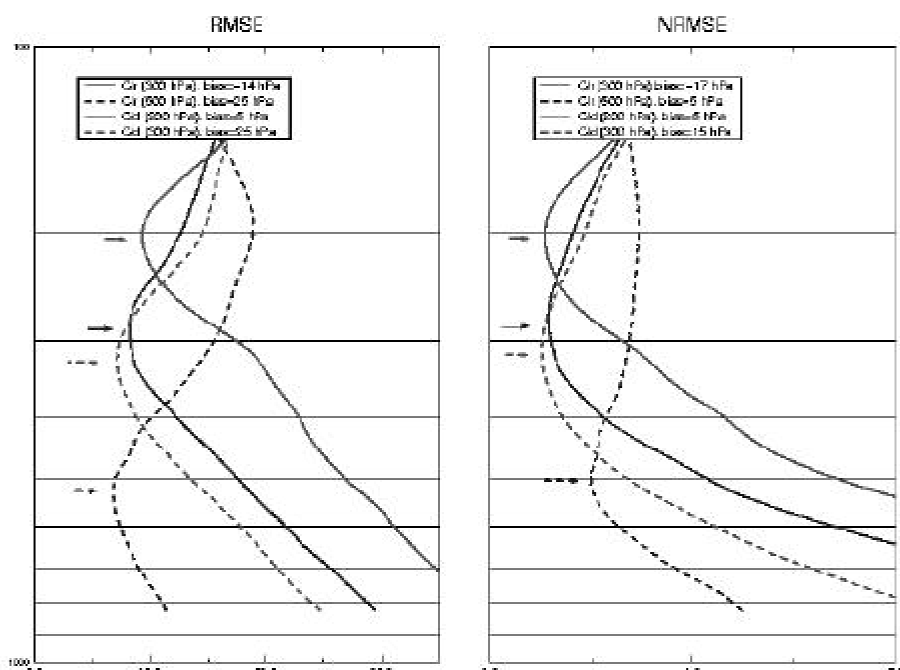

Figure 3. RMSE (left, m/s) and RMSE normalized by wind speed (NRMSE, right) for clear and cloudy WV winds against collocated total rawinsonde wind profiles. The legend indicates the selected height assignment (HA) levels while the arrows indicate the level of minimum RMSE values (LMV) for the respective profiles. Bias equals LMV minus HA.

However, the broadness of the RMSE profiles suggests the WV winds correlate with a layer rather than a single level, which agrees with theory. Therefore, a second analysis was performed in an attempt to isolate the representativeness of the WV winds as single-level approximations. An example is shown in Figure 4. In this plot the 400mb WV wind RMSE profiles are plotted against profiles from corresponding 400mb rawinsonde wind values. In other words, the 400mb rawinsonde report is compared to its own vertical profile in each case to isolate the natural correlation that exists between a measured single level report and its vertical profile of wind. This can then be compared to the WV profile. The differences will represent the layer over which the WV winds are representing motion relative to a single-level observation. Figure 4 indicates that this layer is on the order of 100mb for sharp profiles and 150mb for broad profiles. Broad (sharp) is defined as those RMSE profiles from the overall set of 400mb WV winds comparisons that were broader (sharper) than the overall mean profile. The RMSE profile gradients were also calculated and shown in the bottom panels (25 mb running average smoother applied).

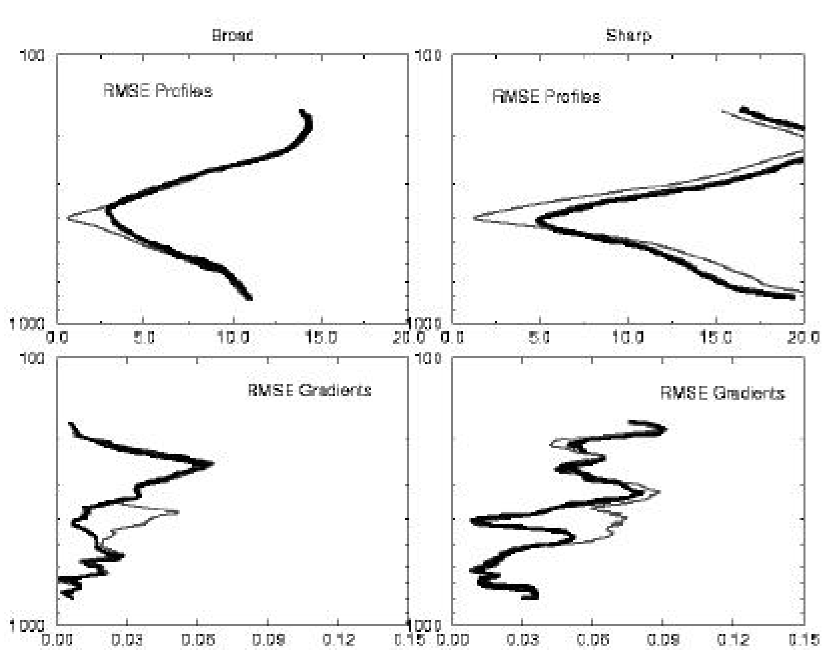

Figure 4. RMSE profiles (m/s) and gradients (m/s/2mb) for 400mb clear-sky WV winds (thick) and 400mb rawinsonde winds (thin) vs. entire collocated rawinsonde wind profiles for two categories of profile, broad and sharp. Broad (sharp) is defined as those RMSE profiles where the slopes calculated 150mb above and below 400mb were both lower (higher) than the overall mean sample profile.

The findings here suggest information on the representativeness of the WV winds as single level vector approximations. It is hoped that this type of information could aid the treatment of clear-sky WV winds in data assimilation.

REFERENCE

Velden, C.S., T.L. Olander and S. Wanzong, 1998: The impact of multispectral GOES-8 wind information on Atlantic tropical cyclone track forecasts in 1995. Part 1: Dataset methodology, description and case analysis. *Mon. Wea. Rev.*, **126**, 1202-1218.