P 1.22 COMPUTING DEEP-TROPOSPHERIC VERTICAL WIND SHEAR ANALYSES FOR TROPICAL CYCLONE APPLICATIONS: DOES THE METHODOLOGY MATTER?

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1. INTRODUCTION

Vertical Wind Shear (VWS) is well known as an important environmental influence on tropical cyclone (TC) structure and intensity change (McBride and Zehr, 1981; Zehr 1992; McBride 1995, and many others). The traditional way to parameterize VWS in most research studies, and in operational forecast applications, is to simply use the vector difference of the 200 and 850hPa wind fields based on global model analyses. For example, this is how the operational SHIPS model (DeMaria et al. 2005) employs VWS as a predictor of future TC intensity. DeMaria et al. (1993) derived statistical relationships between VWS (as calculated from 1deg operational analyses and using just the 200hPa and 850hPa wind fields) and intensity changes of Atlantic TCs. As expected, the VWS was negatively correlated with the intensity changes, but the explained variance was only around 15%.

However, the question remains as to whether this is the optimal approach to depict VWS in TC applications, as several issues can arise: 1) Global model analyses may not be adequate in highly-anomalous flow regimes such as associated with TCs. Tight quality control procedures may limit the assimilation of data in the TC vicinity, such as high-density satellite-derived wind vectors, particularly when the observations differ notably from the model background fields. 2) Hard-wiring the VWS calculation to just use the 850hPa and 200hPa levels may not be truly representative. Depending on things such as TC basin, latitude, time of year, etc., actual tropical tropospheric wind profiles may often not have maximum magnitudes right at these isobaric levels, so differencing them may not yield the true vertical shear that is present. 3) The use of only two discreet tropospheric levels to approximate deep layer vertical shear may be inadequate in many situations. If the environmental VWS profile is thin and elevated, it may align with the TC outflow and be opposed or deflected (Elsberry and Jeffries 1996). A deeper profile could undercut the outflow circulation and more effectively impinge on the TC core (Figure 1). Operational forecasters often note this effect in careful satellite imagery analysis.

In this study, we compare a different methodology to generate fields of VWS as produced by the University of Wisconsin-CIMSS. The CIMSS analyses use a 3-dimensional Recursive Filter objective analysis at high spatial resolution and put heavy weight on available high-density satellite-derived winds. Global model wind fields are only used as background analyses in satellite data-void regions. The resultant isobaric wind analyses are then used to create two layer-mean wind analyses; one upper-tropospheric and one lower-tropospheric. This approach differs from employing just the two discreet levels as in the traditional methodology.

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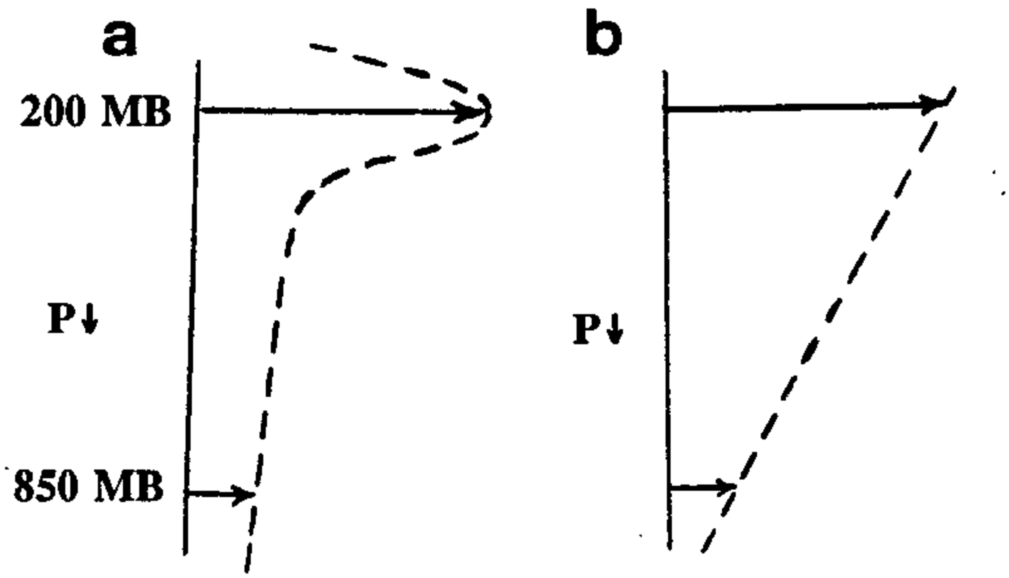

Figure 1. Schematics of the 200-850mb environmental wind shear profiles arising from (a) a low-latitude situation with upper-level winds maximized in a shallow layer, versus (b) linearly distributed over a deep layer as might exist in the subtropics during a trough interaction. [from Elsberry and Jeffries, 1996]

2. COMPARISON OF VWS METHODOLOGIES

A flow chart summary of the two methods to calculate VWS is shown in Fig. 2. While the TC vortex removal procedures are slight variants, the major differences are the source analyses and the shear computation. The SHIPS model relies on the GFS global model to provide the wind analyses, while the CIMSS method employs locally derived analyses that assimilate and heavily weight the available high-density satellite-derived winds (Velden et al. 1998; Velden et al. 2005). In Atlantic TC environments, these analyses have been shown to often better depict the details in the flow fields (Sears and Velden 2012), which could affect VWS values. While the GFS model also assimilates operational satellite-derived winds, the thinning procedures and stricter quality control measures likely ameliorate some of the information content, especially when the vectors are at odds with the background fields. The CIMSS wind and VWS analyses are routinely made available over all tropical basins via the Tropical Cyclones group web site at:

http://tropic.ssec.wisc.edu/

The other major difference in the estimation of VWS lies in the derivation procedure. The SHIPS uses the conventional approach of differencing the wind vectors from the 200hPa and 850hPa levels. While these two levels may adequately approximate the max wind profiles in typical tropical conditions, there are many instances when they do not. By using tropospheric layer-means instead of just discreet levels, the CIMSS approach will better represent flow and VWS conditions when either the environmental wind profile maxima are not at those levels, or the vertical profiles take on the characteristics similar to those presented in Fig. 1b.

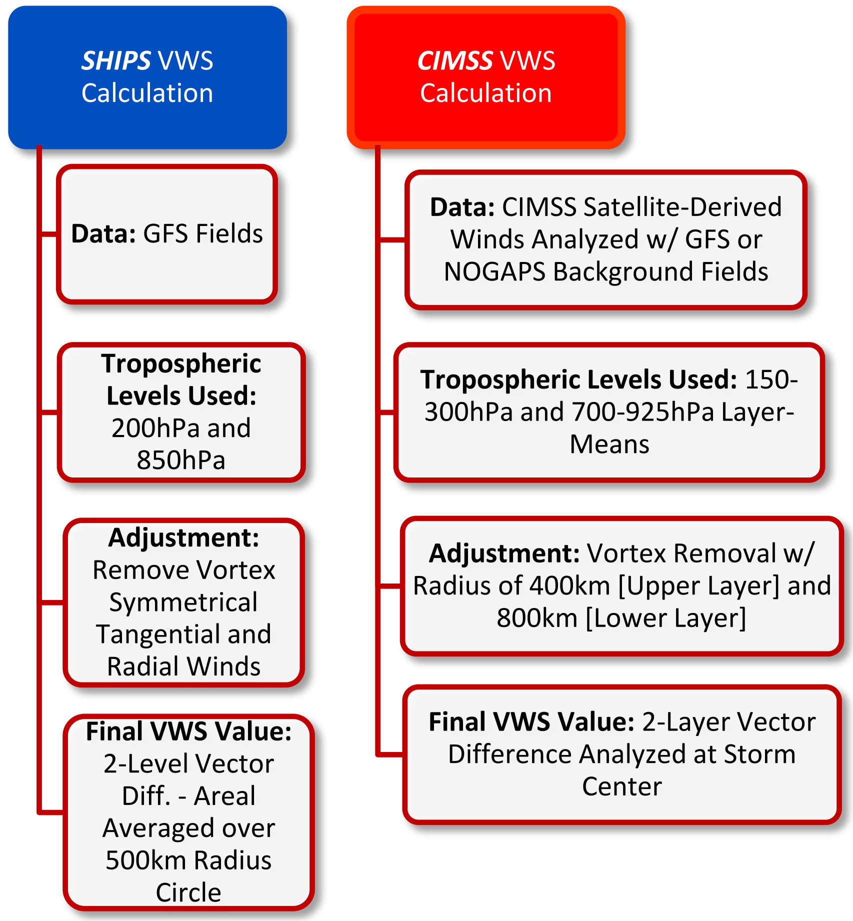

Figure 2. Comparison of methods used to calculate VWS by SHIPS (left) and at CIMSS (right).

3. EXPERIMENTS

To examine the varying approaches to deriving VWS analyses in more detail, we compare values produced 4 different ways:

1. CIMSS Analyses w/ CIMSS VWS Calculation Method (CIMSS approach)
2. GFS Fields w/ CIMSS VWS Calculation Method
3. CIMSS Analyses w/ SHIPS VWS Calculation Method
4. GFS Fields w/ SHIPS VWS Calculation Method (SHIPS approach)

These four experiments allow us to generally assess the variance between the two broad approaches (CIMSS vs. SHIPS), but also to separate out the impact of the two major differences described above. The dataset consists of coincident Atlantic analyses for storms TD strength or greater, over the period 2008-2011. This yields a comparison sample of 500 analyses.

4. RESULTS

Using the operational SHIPS VWS values as a benchmark, we find the following comparisons:

Experiment	Analysis Source | VWS Method	Benchmark	Correlation	Bias (kts)	RMSE (kts)
1.	CIMSS | CIMSS	SHIPS	0.72	4.7	8.2
2.	GFS | CIMSS	SHIPS	0.77	2.8	6.1
3.	CIMSS | SHIPS	SHIPS	0.82	-0.3	2.6

and with the CIMSS VWS values as the benchmark:

Experiment	Analysis Source | VWS Method	Benchmark	Correlation	Bias (kts)	RMSE (kts)
2.	GFS | CIMSS	CIMSS	0.83	-2.0	5.6
3.	CIMSS | SHIPS	CIMSS	0.79	-3.0	7.7

The results of experiment 1 show that the two approaches (CIMSS and SHIPS) only correlate at 0.72, suggesting that there are notable differences. The positive bias indicates that, in general, the CIMSS VWS values are stronger by almost 5 kts. When the GFS fields are employed with the CIMSS method (Exp. 2), the correlation with SHIPS rises to 0.77. This is not unexpected since the operational SHIPS also uses the GFS fields. Experiment 3 results show that when the SHIPS method is run on the CIMSS analyses, the correlation with SHIPS goes up to 0.82. Therefore, using the operational SHIPS VWS values as a benchmark, the choice of VWS computation method has more impact than the choice of initial analyses. This trend is also found when the CIMSS approach is used as the benchmark.

An example of the VWS magnitude differences that can result from the four experiment approaches is graphically illustrated in Fig. 3. During TC Bert, there are a couple of regimes characterized by a marked variation in the VWS values. Especially prominent are the differences between the two VWS calculation methods, while the choice of initial analysis type during this period is much less of an impact (consistent with the bulk statistical analysis above). The CIMSS shear values reach almost 40 kts, while the SHIPS are nearly half of that. These differences could have a major impact on intensity forecasts. While this example illustrates an extreme period in our sample, it does show that the shear calculation can matter significantly in some cases.

5. SUMMARY

The preliminary findings presented here illustrate how resultant VWS fields can diverge significantly in certain situations, depending on initial wind analyses used and especially the VWS calculation methodology. This could impact forecaster interpretation of the VWS significance in certain cases, and also influence objective method forecasts of intensity. We plan to further evaluate the differences shown above using correlations with TC intensity, case studies, dropwindsondes, and SHIPS model impact analysis to determine which approach seems to best represent actual conditions, and correlates best with subsequent TC intensity changes.

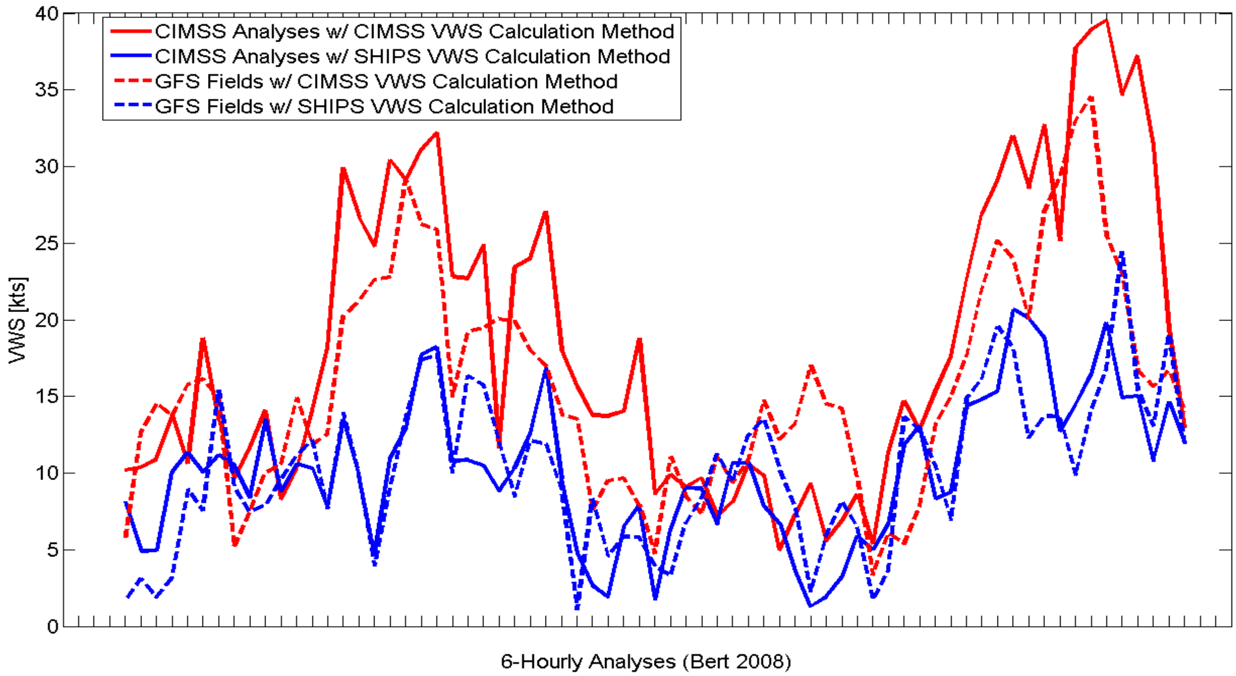

Figure 3. Time sequence (6-hourly analyzed values) of the 4 approaches to calculate VWS are shown with respect to their analyzed shear magnitude values (kts) for TC Bert (2008).

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