# NESDIS AND NWS ASSESSMENT OF GOES-8/9 OPERATIONAL SATELLITE MOTION WINDS.

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## ABSTRACT

NOAA/NESDIS recently began operational production of Satellite Motion Winds (SMW's) for both GOES-8 (October 1995) and GOES-9 (February 1996). Satellite cloud motion and water vapor motion wind vectors are generated at six hour intervals, for both the Northern and Southern Hemisphere, and the operational cloud motion winds are now being used in NCEP global forecast models. Beginning in March 1996, experimental high density SMW's have been generated, at approximately ten times the operational resolution. The coverage (spatial and temporal) available over data sparse oceanic regions provides important additional information on atmospheric flow patterns which supplement the conventional wind measurements obtained by ground-based rawinsondes and wind profilers. These data are expected to significantly improve the determination of initial conditions for global and regional numerical weather forecast models, potentially improveing the forecast skill. Assessment of the quality and utility of the operational SMWs is on-going both at NESDIS and the National Centers for Environmental Prediction (NCEP). Also, evaluations of the high density SMWs are being performed using a variety of methods, including collocations with rawinsondes and NCEP numerical forecasts. Case study comparisons of SMWs and NCEP initial forecast model analyses are underway, and plans for NCEP numerical forecast model impact studies using high density SMW's are presented.

# 1. INTRODUCTION

Operational cloud motion winds (CMW) and water vapor motion winds (WVMW) are produced for both GOES-8 and GOES-9 at six hourly intervals (00 UTC, 06 UTC, 12 UTC and 18 UTC). Approximately 400 CMW and 1000 WVMW vectors are produced at each cycle for each spacecraft. Examples of Northern and Southern Hemispheric coverage and density are given in figures 1a and 1 b. A description ofthe NESDIS operational production of GOES-8/9 SMW's is given in (Gray, et al; 1996), and the science and data processing techniques are described in (Merrill, et al; 1991, Nieman, et al; 1993 and Szejwach, 1982). The operational CMW's are currently being used by the Environmental Modeling Center (EMC) of NCEP in their global data assimilation system (GDAS) and global numerical forecast models (AVN and MRF).
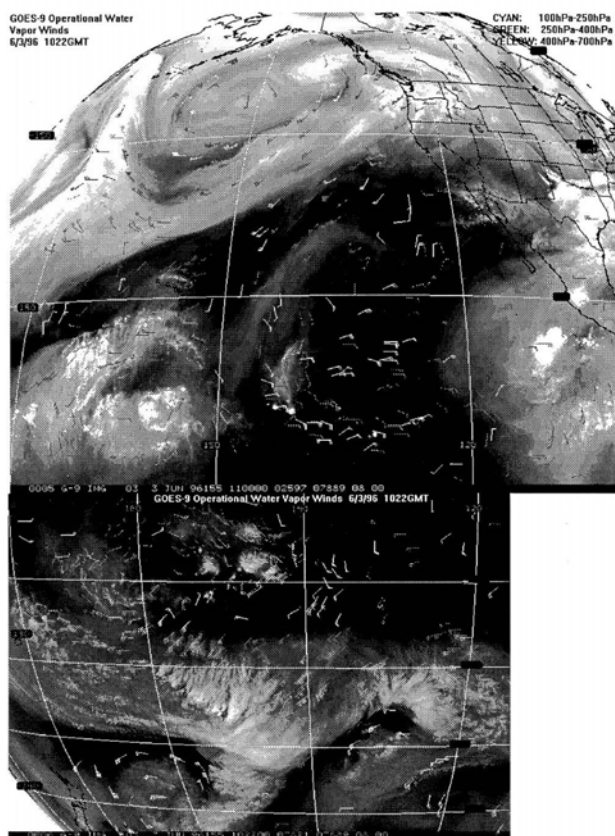


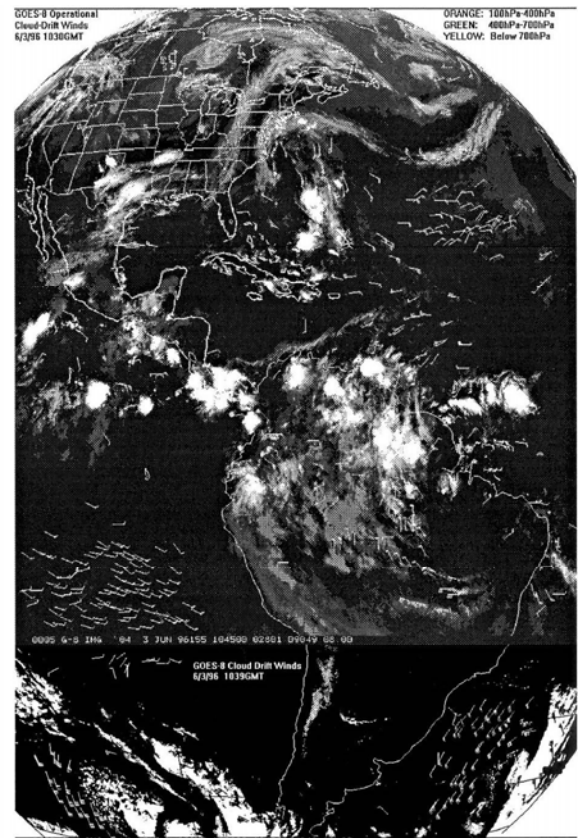Figure 1a. Spatial Coverage of Operational GOES-9 SMW's. Vectors Displayed are Water Vapor Winds

Figure 1b. Spatial Coverage of Operational GOES-8 SMW's. Vectors Displayed are Cloud Motion Winds

The NESDIS Office of Research and Applications (ORA) Forecast Products Development Team (FPDT) is also producing an experimental set of high density SMW's at six hourly intervals, using techniques developed at the NESDIS Advanced Satellite Products Team (ASPT) and the Cooperative Institute for Meteorological Satellite Studies (CIMSS), both located at the University of Wisconsin in Madison. The high density SMWs yield approximately ten times as many vectors as the operation, and have been demonstrated to improve numerical forecasts of tropical storm and hurricane positions. Examples ofthe coverage and density of the experimental high density SMW's are given in figures 2a and 2b.
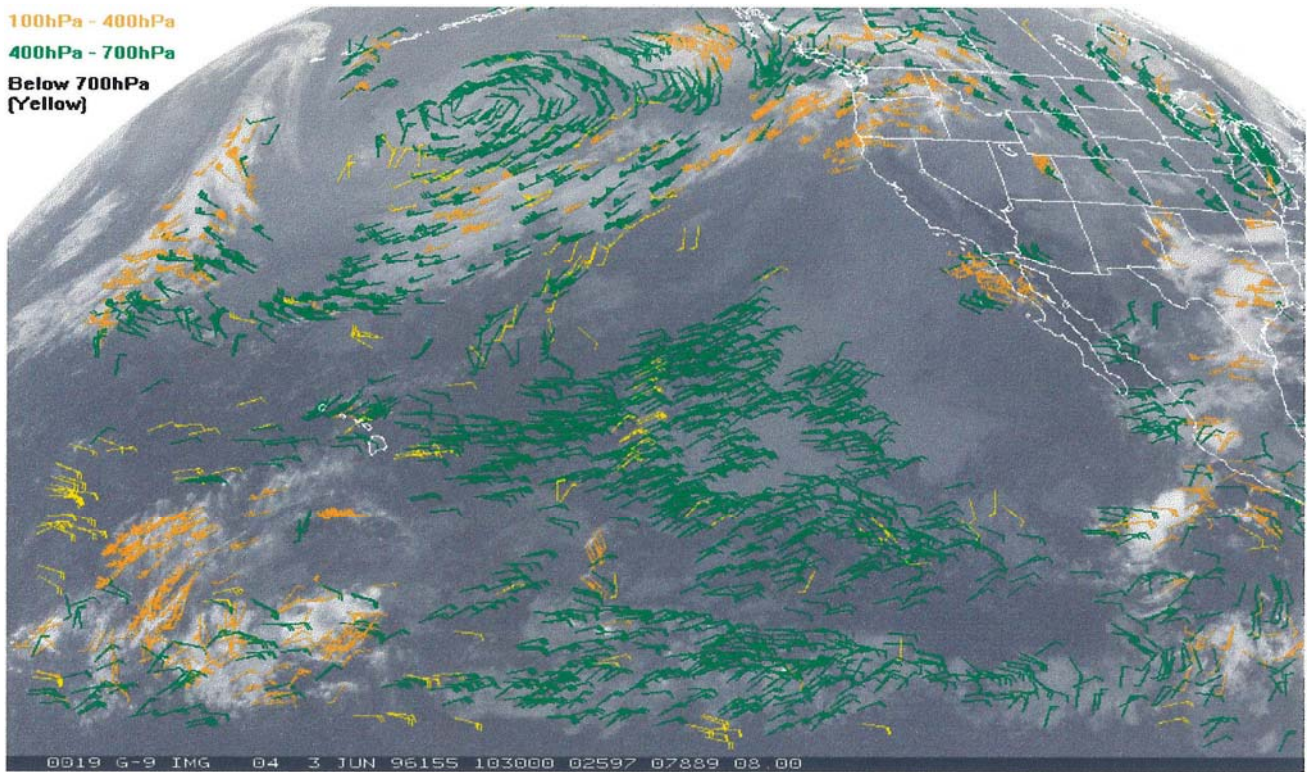
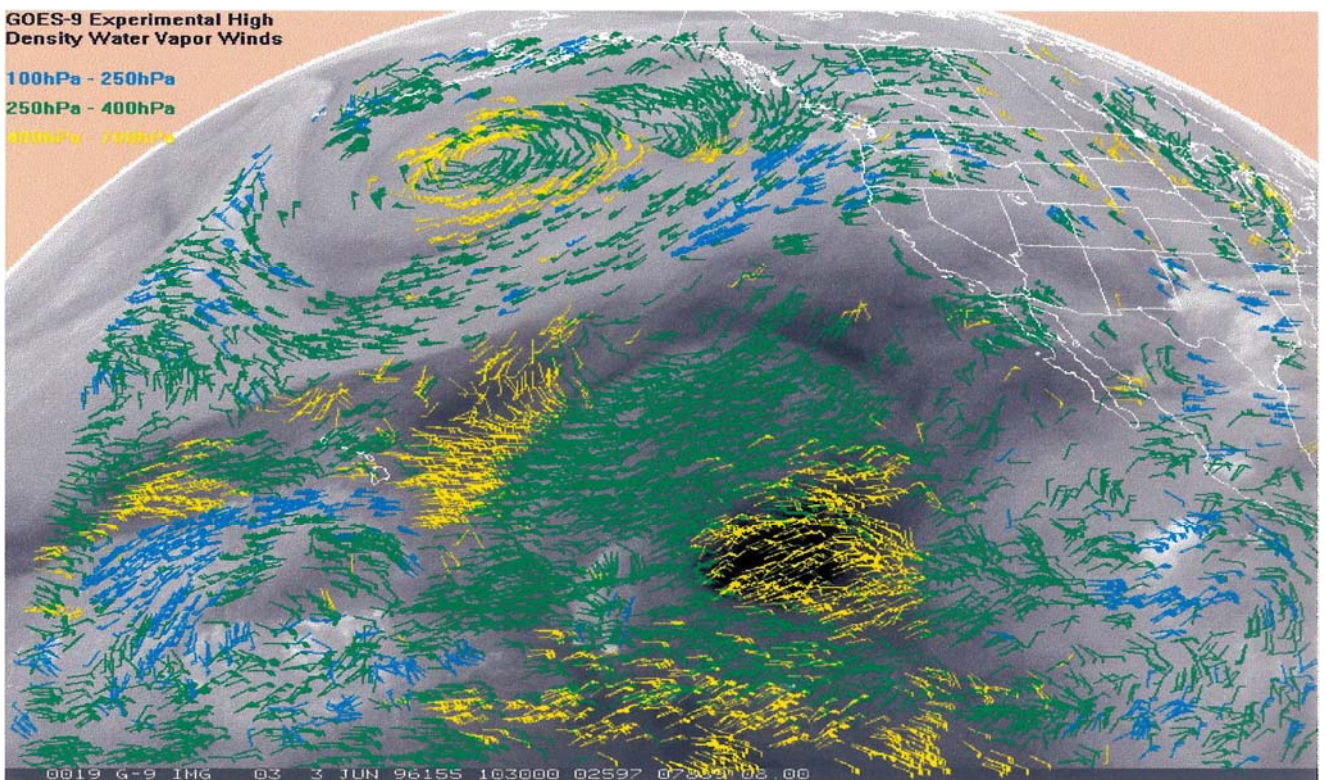Figure 2a. Experimental High Density GOES-9 Cloud Motion Winds



Figure 2b. Experimental High Density GOES-9 Water Vapor Winds

The FPDT is limited at this time to producing experimental high density SMW's from one satellite (currently GOES-9), for the Northern Hemisphere only. During the upcoming hurricane season (June 1 - November 30, 1996), the FPDT, ASPT and CIMSS plan a combined effort to provide high density SMW's from GOES-8 for use in monitoring and forecasting tropical systems to the NCEP Tropical Prediction Center (TPC), the Office of Atmospheric Research (OAR) Hurricane Research Division (HRD) and the U.S. Department of Defense (DoD) Naval Research Laboratory (NRL). Experimental high density winds from GOES-9 will again be available in the August/September time frame following the acquisition of additional workstation hardware at the FPDT.


## 2.     GOES-8/9 SMW STATISTICAL QUALITY ASSESSMENT

NESDIS and the NWS are collaborating in the assessment of the quality and utility of GOES-8/9 SMW's relative to ground truth measurements and in weather monitoring and forecasting activities. NESDIS produces weekly statistical evaluations of comparisons of GOES-8/9 SMW's and NCEP 6-hour GDAS wind forecasts collocated with rawinsonde reports over continental and island regions. The collocations are made at 00 UTC and 12 UTC, with a time window of +/- one hour and a spatial window of radius 100km. In addition, the FPDT is generating statistical collocations of the experimental high density SMW's. Figures 3a and 3b illustrate the number of GOES-9 SMW and NCEP GDAS Forecast collocations with rawinsondes on a weekly basis from March 28, 1996 through May 29, 1996. Approximately ten times as many experimental high density SMW's are produced each cycle as compared to the operational SMW's. Operational SMW collocations were available only for limited periods during this time frame. Several statistical quantities are computed based on the differences between the collocated SMW's, the GDAS six-hour forecast winds, and rawinsondes. The
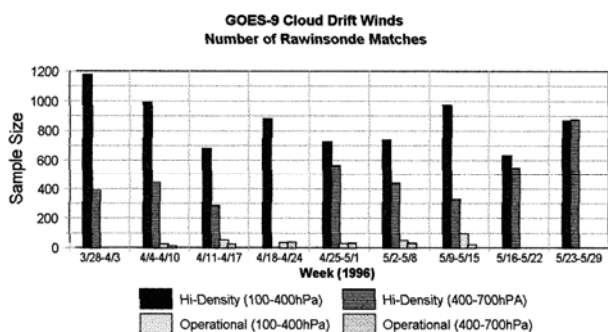


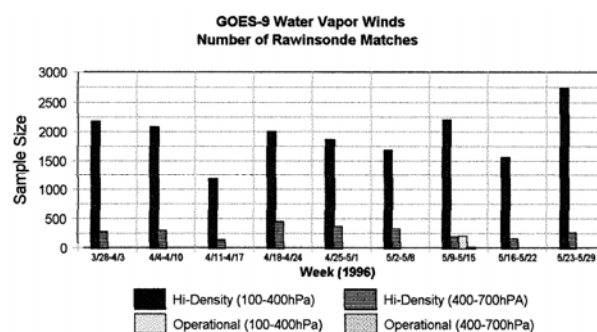Figure 3a.   Number of GOES-9 Cloud Motion Winds/GDAS Forecast Rawinsonde Collocations

Figure 3b.   Number of GOES-9 Water Vapor Motion Winds/GDAS Forecast Rawinsonde Collocations

rawinsonde winds and GDAS forecast winds are linearly interpolated to the pressure level of the associated SMW's. Figures 4a and 4b are time series plots of GOES-8 operational cloud motion wind speed bias and root mean square vector differences relative to collocated rawinsondes. Figures 5a and 5b are time series plots of GOES-8 operational water vapor motion wind speed bias and the root mean square vector differences relative to collocated rawinsondes. Statistics are not available for the last two weeks due to software problems.
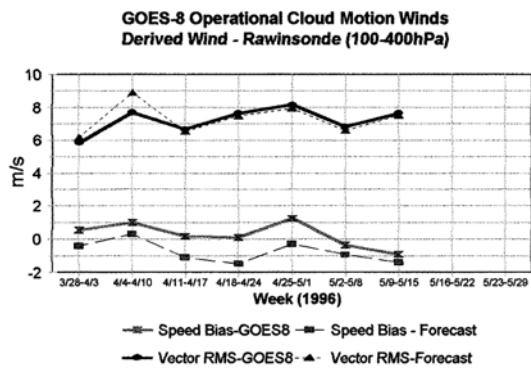
**Figure 4a.** Rawinsonde Collocations for Upper Level GOES-8 Operational Cloud Motion Winds
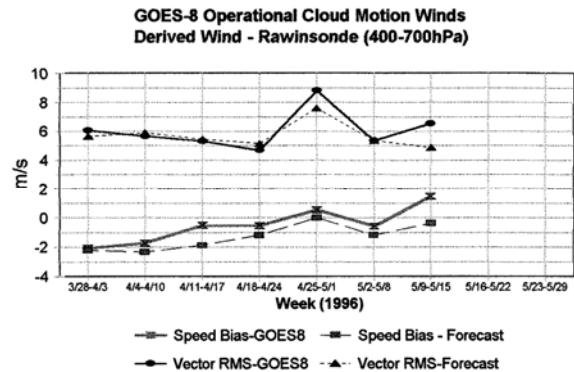


**Figure 4b.** Rawinsonde Collocations for Mid Level GOES-8 Operational Cloud Motion Winds

The operational GOES-8 cloud motion winds exhibit significantly smaller errors in speed bias (on the order of 1 meter/second) as compared to the six hour GDAS forecast. The vector RMS error of upper level (100hPa-400hPa) and mid level (400hPa-700hPa) cloud motion winds are comparable to the six hour GDAS forecast. The large RMS errors observed during the week of April 25, 1996 are unexplained at this time. The operational GOES-8 upper level water vapor winds exhibit similar characteristics to the cloud motion winds, both in speed bias and vector RMS statistics. The mid level operational GOES-8 water vapor winds have consistently larger vector RMS errors and speed biases as compared to the GDAS forecast. This is likely due to the difficulty of sensing lower in the atmosphere with the GOES-8/9 water vapor imager channel. It should be noted that the number of mid level water vapor winds is very small compared to the upper level vectors.
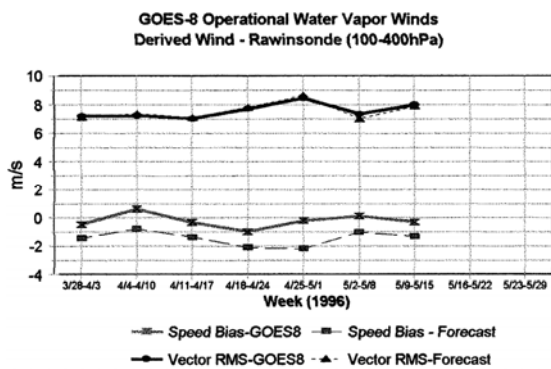


**Figure 5a.** Rawinsonde Collocations for Upper Level GOES-8 Operational Water Vapor Winds
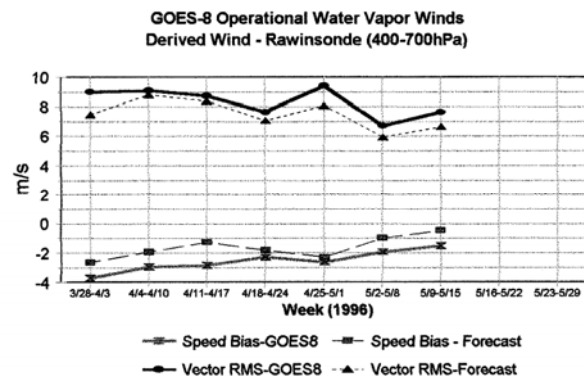


**Figure 5b.** Rawinsonde Collocations for Mid Level GOES-8 Operational Water Vapor Winds

Statistics available for GOES-9 operational winds are limited at this time to cloud motion vectors, and are shown in figures 6a and 6b. The GOES-9 cloud motion winds exhibit smaller errors in speed bias as compared to the six hour GDAS forecast, and the RMS errors of upper level (lOOhPa-400hPa) cloud motion winds are comparable to the six hour GDAS forecast, but the mid level (400hPa-700hPa) cloud motion winds have somewhat larger RMS errors than the GDAS forecast. It is important to note for both GOES-8 and GOES-9 that the rawinsondes used as ground truth in these collocations are obtained primarily over the continental U.S., where their influence on the GDAS analysis and six hour forecast is large. The GOES-8/9 SMW's provide coverage over data sparse oceanic regions, and their impact on
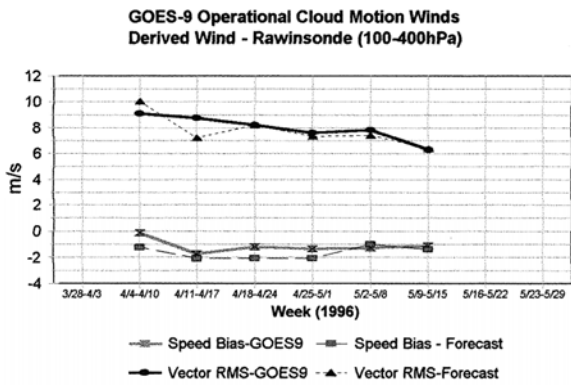
**Figure 6a.** Rawinsonde Collocations for Upper Level GOES-9 Cloud Motion Winds
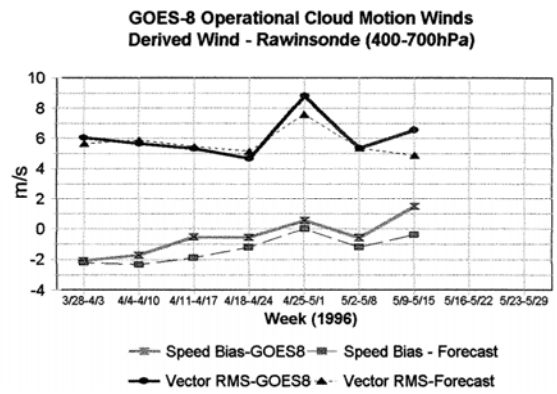


**Figure 6b.** Rawinsonde Collocations for Mid Level GOES-9 Cloud Motion Winds

numerical model forecast accuracy may be better measured through the use of analyses of differences in atmospheric flow patterns relative to NCEP forecasts as defined by the SMW's, as well as their effect on forecast skill through the use of parallel model impact studies. NESDIS and NCEP are planning to test the high density GOES-8/9 SMW's in their Global Forecast Model (AVN) using retrospective data from the summer of 1995, as well as in the Regional ETA Forecast Model for a three week period in September 1996.

Figures 7a, 7b, 8a and 8b depict the rawinsonde collocation statistics for the experimental high density SMW's, currently being produced for GOES-9. The upper level cloud motion and water vapor statistics continue the trend of improved speed bias as compared to the GDAS forecast, with comparable RMS errors. The mid level high density cloud motion wind statistics are similar to the GDAS forecast, with the mid level water vapor winds showing a degradation. Again, it must be recognized that the number of mid level water vapor winds is small, and their impact on forecast skill remains to be tested.
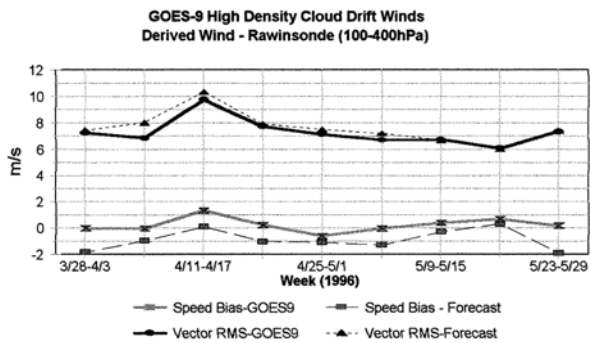


**Figure 7a.** Rawinsonde Collocations for Upper Level GOES-9 High Density Cloud Motion Winds
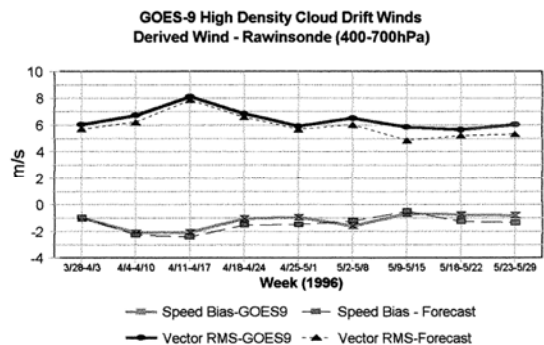


**Figure 7b.** Rawinsonde Collocations for Upper Level GOES-9 High Density Cloud Motion Winds

**GOES-9 High Density Water Vapor Winds**
**Derived Wind - Rawinsonde (100-400hPa)**



**GOES-9 High Density Water Vapor Winds**
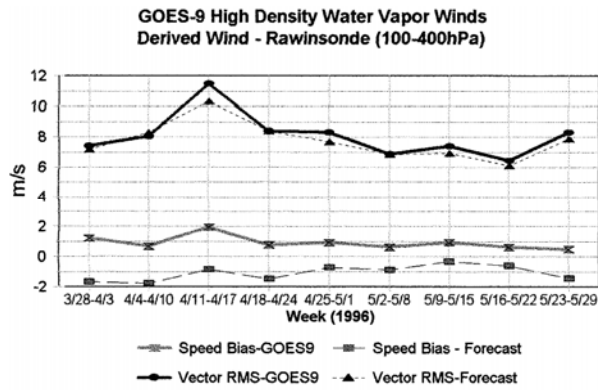**Derived Wind - Rawinsonde (400-700hPa)**

Figure 8a.   Rawinsonde Collocations for Upper Level GOES-9 High Density Water Vapor Winds
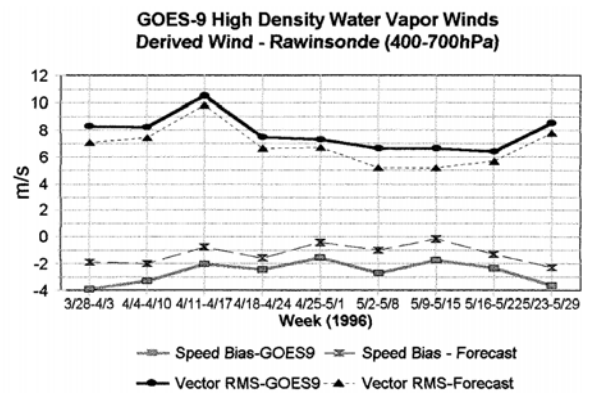
Figure 8b.   Rawinsonde Collocations for Mid Level GOES-9 High Density Water Vapor Winds

## 3.      QUALITATIVE ASSESSMENT OF GOES-9 HIGH DENSITY WINDS

Two cases are presented which examine the potential impact of high density winds on numerical forecast model analyses and forecasts. For these cases, a 6 hour forecast from the NCEP GDAS system is used along with GOES-9 high density winds. Water vapor winds were chosen as they provide more complete coverage as compared to cloud motion winds, and represent a relatively new form of satellite wind vectors.

The first comparison is of high density GOES-9 water vapor winds in the region of 20N latitude, 130W longitude on June 3, 1996. It should be noted that the longitude displayed in the figures is in error. The SMW's were computed using three successive images (1000 UTC, 1030 UTC and 1100 UTC). The 6 hour GDAS forecast in valid for 1200 UTC. Figure 9a shows the GOES-9 high density water vapor wind vectors, with heights ranging from 350hPa to 450hPa. The region represented by the image is approximately 1200km x 1200km. The flow pattern is generally from the east-northeast, with some convergence apparent near the center of the image, and cyclonic circulation in the southern area. Figure 9b depicts the vector differences between the SMW's and forecast (SMW-GDAS forecast). The vector differences are very consistent with one another, and define a strong cyclonic curvature. To better understand the implications of this field, it would be useful to review vector differences in the context of this evaluation. Figure 10 illustrates the basic concept of vector subtraction. Let u be the SMW vector and v the GDAS forecast wind vector, then u-v represents the vector differences shown in Figure 9b. Closer examination of the field of vector differences reveals that the GOES-9 SMW's are having the effect of reducing the anti-cyclonic flow and associated divergence present in the GDAS forecast field. This leads to an increase in the convergence at the 400hPa level, resulting in smaller upward vertical velocities. Displaying fields of vector differences can be a useful tool in interpreting the potential impact of SMW's on numerical forecasts and analyses. Of course, actual model impact studies are needed to determine the change in forecast skill as a result of these adjustments to atmospheric flow patterns, and are planned for the fall of 1996.
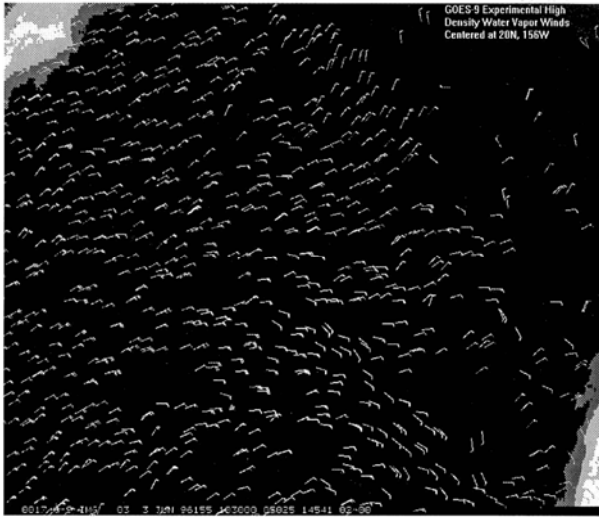
Figure 9a.   High Density GOES-9 Water Vapor Winds in the Vicinity of 20N, 130W. Heights are between 350hPa and 450hPa.
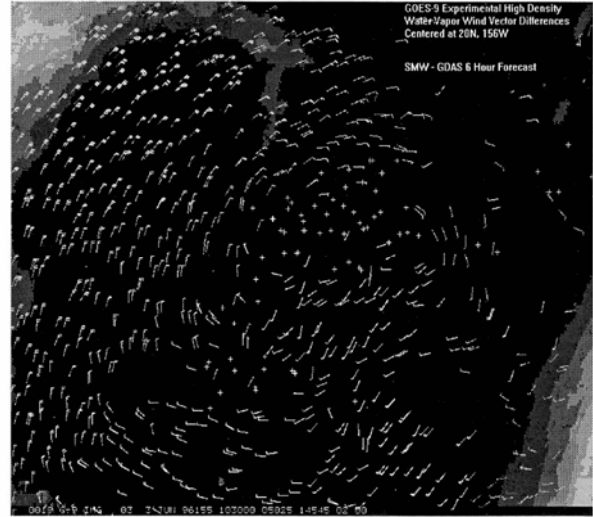


Figure 9b.   Vector Differences (GOES-9 Water Vapor Winds - GDAS 6 Hour Forecast)
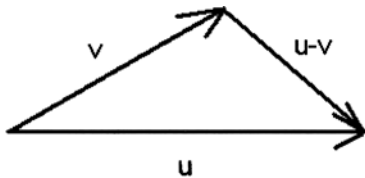


Figure 10.   Vector Subtraction

The second comparison is in the region of 50N, 145W in the vicinity of a closed upper level low. Figures 11a, 11b and 11c are the GOES-9 high density water vapor winds, the GDAS 6 hour forecast, and the vector differences for 1030 UTC on June 6, 1996 . The vector heights range between 350hPa and 500hPa. In this case, the influence of the SMW's is primarily to reduce the wind speed of the six hour forecast south of the low, and increase the wind speed to the north. The associated
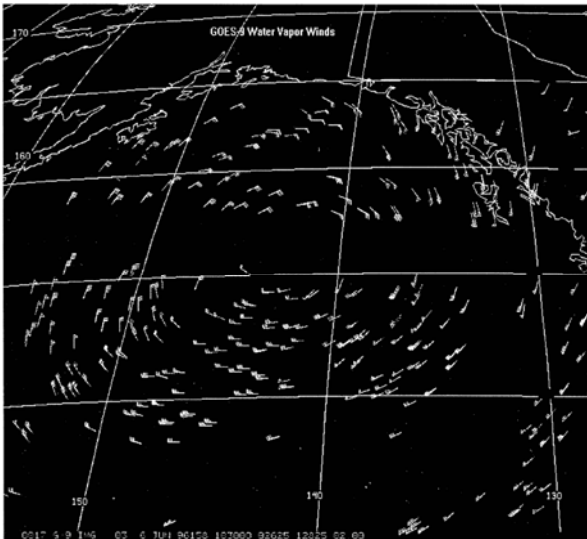


Figure 11a   GOES-9 High Density Water Vapor Winds (350hPa - 500hPa)
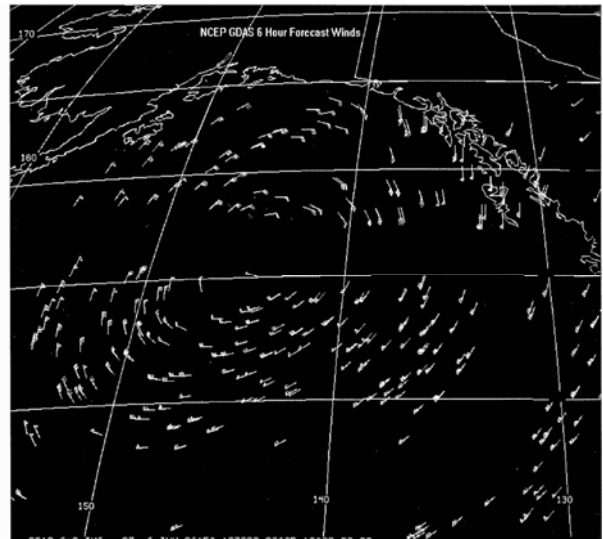


Figure 11b.   NCEP GDAS 6 Hour Forecast Winds (350hPa - 500hPa)

modification to the gradient structure is important information which is expected to be beneficial to weather forecast models.

## 4.    SUMMARY

The operational and high density GOES-8/9 cloud drift and water vapor wind vectors are being produced regularly at NESDIS. Evaluations, including both statistical comparisons and case studies, have demonstrated the excellent accuracy and coverage provided by these products. NESDIS plans to continue production of high density SMW's from GOES-8 in support of tropical storm and hurricane monitoring and prediction activities during the 1996 hurricane season.
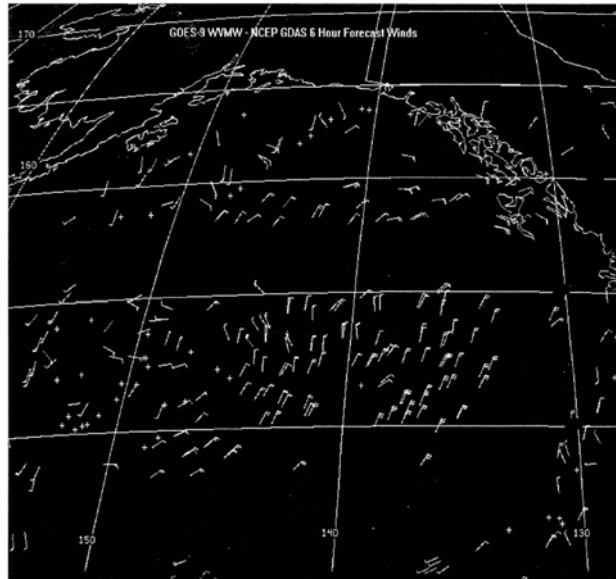


Figure 11c.   Vector Differences (SMW - GDAS)

Additional workstations will be available at the FPDT in August 1996, when GOES-9 high density wind production will resume. In September 1996, NCEP plans to perform a model impact study using the ETA/EDAS analysis and forecast system to assess the effect of high density GOES-8/9 SMW's on regional model forecast skill. Following a successful demonstration, both during the hurricane season and NCEP model impact study, NESDIS plans to implement the high density winds operationally in late 1996/early 1997.

## 5.    REFERENCES

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