Implementation of a State of the Art Automated System for the Production of Cloud/Water Vapor Motion Winds from Geostationary Satellites

An 18-month Progress Report on NASA contract NAG8-974

for the period of 1 July 1994 through 31 December 1994

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on behalf of

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FINANCIAL SUMMARY

Through 31 December, 1994 our spending on this contract totaled $63,290 out of $100,000 received. A no-cost extension was approved to carry the current contract through 30 June, 1995.

SCIENTIFIC SUMMARY

The focus of study and development in this reporting period centered on the testing and characterization of water vapor winds derived from GOES-8. Code additions and adjustments were added to the basic UW-CIMSS winds processing algorithm to account for the GOES-8 characteristics. After initial testing and code shakedown, high-quality GOES-8 water vapor wind sets were routinely being produced at UW-CIMSS and also by NESDIS in Washington D.C.

An initial evaluation of the GOES-8 data sets is encouraging. The existing UW-CIMSS tracking software was easily adapted to the GOES-8 data and implemented onto workstations at NESDIS for operational testing. Resulting data sets qualitatively appear promising. Relative to vector fields produced from previous satellites (GOES-7 and Meteosat-3), the GOES-8 is yielding more high-quality vectors. The wind fields appear very coherent with good spatial consistency and horizontal coverage. While structure function comparisons and analyses are not envisioned, the objective editing system employed in the UW-CIMSS algorithm essentially performs this task by applying a recursive filter analysis of the wind field as a final step. Indications are a high percentage of vectors are retained by the objective editor (discussed further later in the report).

Data sets produced by NESDIS on a routine basis have been monitored over a 12 week period. A statistical analysis indicates the overall vector RMS error relative to collocated rawinsondes is between 7 and 8 m/sec, with a bias very near zero. Unfortunately, there were no routinely produced GOES-7 water vapor wind sets for comparison [however, earlier indications (shown in the 12 month report) were that the GOES-8 vector RMS error was superior to GOES-7 by .5 to 1 m/sec]. Our analysis also included comparisons to coincident GOES-8 cloud drift wind vector fields. In general, the water vapor vector field is characterized by a slightly improved bias relative to the cloud drift winds, and an average vector RMS error within .5 m/sec of the cloud drift product. This results confirms earlier suggestions that the water vapor winds can compliment the cloud drift wind data in cloud-free environments.

Twenty-five GOES-8 water vapor wind data sets were derived during hurricanes Florence and Gordon at UW-CIMSS. For these cases, produced in a research mode for study, quality control (QC) constraints were varied to examine the impact on the quantity and quality of the data in hurricane environments. In general, a relaxation of the QC constraints did not appreciably affect the coherency of the vectors fields. Downweighting the guess contribution by a factor of two in the objective editor recursive filter analysis step: 1) had minor effects on the overall quantity of vectors 'passing' the editor QC, 2) due to the density and coherency of the vectors, it did not appear to increase the number of 'questionable' vectors allowed to be retained in the data set, 3) most importantly, there was an increase in the number of vectors retained in high-gradient and high-curvature areas. This last point has implications in hurricane environments. It can not be expected that relatively low-resolution global guess fields will adequately capture hurricane-scale circulations. For example, in the Florence and Gordon cases, reducing the guess constraints resulted in more winds being retained in the outflow regions which are characterized by sub-synoptic scale outflow jets. Hurricanes also can affect their environments by increasing the amplitudes of adjacent features (i.e. outflow to the north and east can 'build' ridging; transient circulations can be blocked or 'pinched'). The result is regions in the near-environment with gradients and curvature of greater magnitude than depicted in the first guess fields. Allowing looser constraints on the vector fields (by reducing the guess weighting) resulted in more vectors being retained in these areas as well, leading to an overall improvement in the analysis of the hurricane upper-level wind field and its interaction with the environment.

The Florence and Gordon data sets were delivered to the AOML-Hurricane Research Division in Miami for impact testing using their barotropic hurricane track forecast model (VICBAR). In agreement with previous impact trials using GOES-7 and Meteosat-3 water vapor wind sets, the GOES-8 winds resulted in very modest but positive impact on VICBAR track forecasts. Generally, a 1-4% improvement in mean forecast error (MFE) was realized out to 72 hrs. Nearly 2/3 of the 72 hr forecasts were improvements over the control runs (operational results), and about half of these resulted in MFE reductions of greater than 10%.

The reasons for the modest nature of the forecast improvements may be partially due to the characteristics of the numerical weather prediction system being employed. As part of the VICBAR system, a bogus (analytic) vortex representing the hurricane is applied in a post-analysis step. The chosen scheme employs a very large bogus vortex which is not highly sensitive to data within the radius of influence, which could fundamentally limit data impacts especially at the shorter forecast intervals. In addition, this is a limited area model and boundary conditions come into play at longer forecast intervals and may also limit data impact. Finally, and crucially, there is no vertical blending of information from 'special' (i.e. satellite) observations below 400mb. This particular model was tuned to Omega dropwindsonde data, which are primarily below 400mb. Since most of the water vapor motion vectors are above 350mb, their information is confined to affecting upper mandatory levels only. Unfortunately, the upper mandatory levels carry little weight in the deep layer mean wind analysis that is calculated and used to initialize the VICBAR forecast model. Under these constraints, moderate to large modifications to the upper-level wind fields from the water vapor wind data may not necessarily translate into appreciable forecast improvements.

For the reasons cited above, the wind data derived during Florence and Gordon will be tested in a more sophisticated analysis and forecast system. The data are being delivered to Dr. Krishnumurti's group at Florida State University. Experiments with a full primitive equations assimilation system that includes physical initialization will be conducted to assess the impact of the winds on hurricane track forecasts. We hope to have results of this study for the final report on this contract.

The hurricane data sets are used to assess some of the characteristics of the GOES-8 wind fields before and after the objective QC is applied. Hurricanes Florence and Gordon both occurred in November (1994), but over different regions (Florence in the central Atlantic and Gordon in the Caribbean/extreme western Atlantic). Considering first the combined data sets from both storms, the tracking statistics and height distribution (before the objective QC is applied) is shown in Fig. 1. The mean height (assigned by matching the associated brightness temperature values to the first guess temperature profile) is 295 mb, with a standard deviation of 57mb, and 95% of the winds are assigned heights within the 200-400 mb layer. These numbers vary only slightly if the sample is stratified by storm (Figs. 2 and 3). This mean height is slightly higher than was observed with Meteosat-3 data sets around tropical systems (typically mean heights near 325mb). This difference may be expected due to the broader contribution function associated with the Meteosat-3 channel. However, the differences noted here are not absolute since these storms were anomolous in the sense they occurred very late in the season. Given that lower tropopause levels are generally found late in the season, the actual differences may be magnified further when mid-season storms are examined with GOES-8. The height vs frequency distribution (Fig. 1) is fairly close to a normal curve, but skewed slightly to the lower heights as might be expected. Examination of the individual storm curves (especially pronounced in Florence) indicates a hint at a bi-modal distribution, with a secondary peak near 320mb. It is speculation that this peak represents high moisture associated with a mid latitude synoptic system to the north of the tropical cyclone. The effects of the objective editor (not shown) on the mean height were negligable (less than 5 mb). There is a slight tendency to redistribute the heights away from the peak, but no bias is indicated.

Figure 1 indicates that 47% of the raw targets were traceable over time to yield wind vectors. The effects of the objective editor (not shown) were to reduce this yield by around 40%. Varying the weight given to the first guess at this stage as discussed above had minimal effects on the overall quantity. Downweighting the guess by a factor of two resulted in 3%

more vectors, many of these in the hurricane circulation and near-environment as discussed earlier.

A presentation on the water vapor winds product was given during a recent workshop held at Florida State University (sponsored in part by NASA) entitled "Impact of satellite products on global analysis and medium range prediction". A special issue of the journal 'Meteorology and Atmospheric Physics' has been dedicated to the papers presented at this workshop. A manuscript describing the early results of the water vapor winds on NWP is in preparation, and will be included with the final report on this contract.

There was considerable interest generated during this workshop leading to collaborations with various groups wishing to explore this data source (i.e. NMC, ECMWF, FSU, NRL-Monterey). In particular, a quasi-operational demonstration with NMC is planned for February/March 1995. UW-CIMSS will monitor GOES-8 water vapor wind sets produced by NESDIS under operational constraints for a 4 week demonstration period. These data sets will be collected by NMC for global model impact studies. Assuming a successful demonstration, the winds will become part of the U.S. operational data base sometime in 1995.

We plan to give high priority to the continued evaluation of the GOES-8 water vapor motion winds in the remainder of this contract. Specifically, continuing to experiment with techniques to optimize the extraction of wind information from the imagery, as well as evaluate the product through NWP performance studies. In addition, an exploration of the possibility of extracting water vapor winds from the GOES-8 multi-channel sounder is envisioned.

PUBLICATIONS to date under contract NAG8-974

Velden, C.S., 1993: Investigation of water vapor motion winds. Post prints of *2nd International Winds Workshop,* Tokyo, Japan, 13-15 December (see activities report #1).

Velden, C.S., S.J. Nieman and S. Wanzong, 1994: Investigation of water vapor motion winds from geostationary satellites. Post prints of the *7th Conf. Satellite Meteor.*, Monterey, CA, June, pp. 360-363 (see activities report #2).

Velden, C.S., 1994: Winds derived from geostationary satellite moisture channel observations: Applications and impact on NWP. Invited talk given at the workshop entitled: *Impact of satellite products on global analysis and medium range prediction.* Florida St. Univ., Tallahassee, FL, November.

Schmetz, J., W. P. Menzel, C.S. Velden, F. Wu, L. van de Berg, S. Nieman. K. Holmlund and C. Geijo, 1995: Monthly-mean large-scale analyses of upper tropospheric humidity and wind field divergence derived from three geostationary satellites. Accepted in *BAMS.*

Velden, C.S., 1995: Impact of geostationary satellite water vapor channel data on weather analysis and forecasting. Post prints of *14th Conf. Weather Analysis and Forecasting,* Dallas, TX, January. (see activities report #2)

Velden, C.S., 1995: Winds derived from geostationary satellite moisture channel observations: Applications and impact on NWP. To be submitted to *Meteorology and Atmospheric Physics.*

Fig. 1

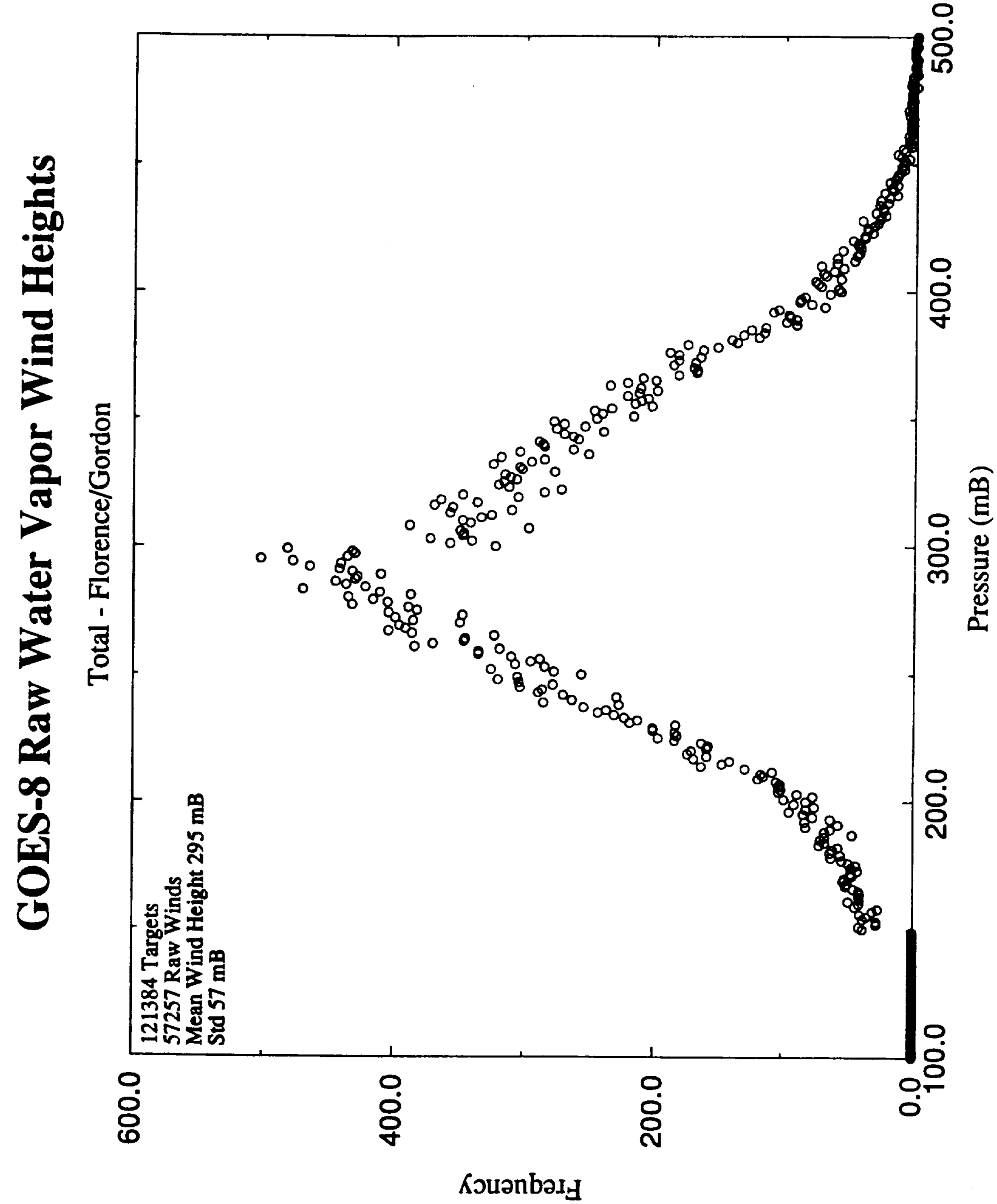

GOES-8 Raw Water Vapor Wind Heights
Total - Florence/Gordon
121384 Targets
57257 Raw Winds
Mean Wind Height 295 mB
Std 57 mB
Frequency
600.0
400.0
200.0
0.0
100.0
200.0
300.0
400.0
500.0
Pressure (mB)

Fig. 2

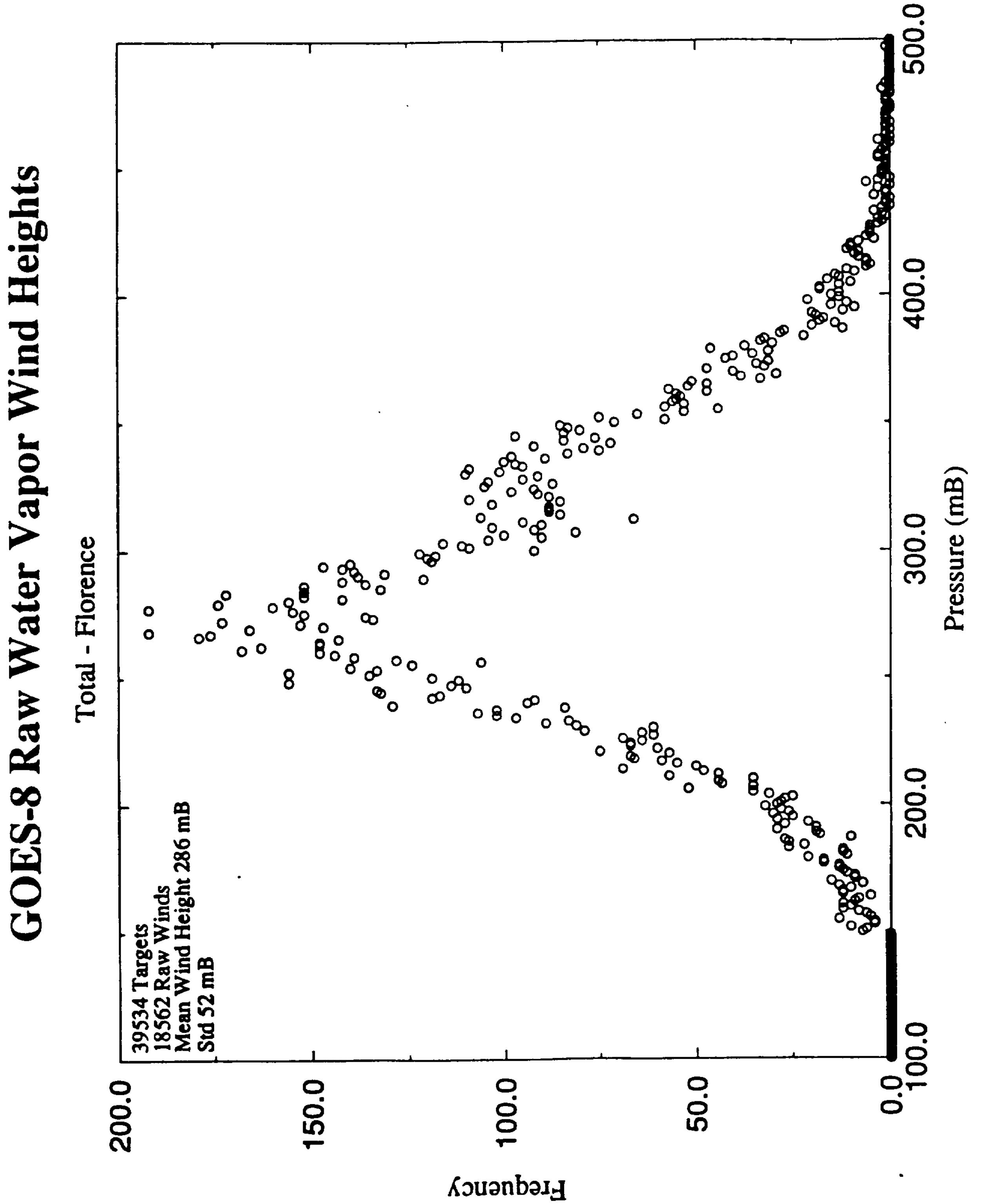
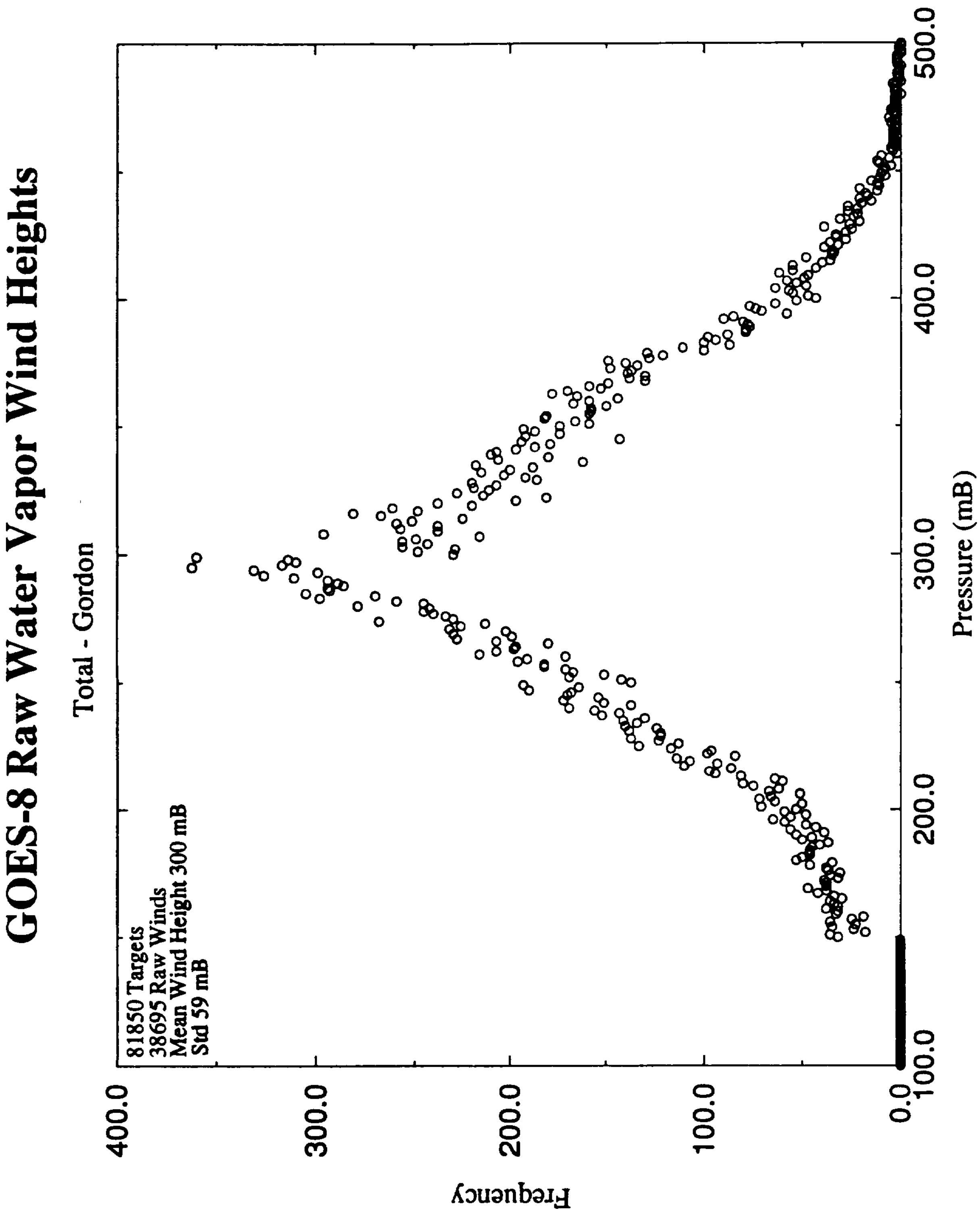

GOES-8 Raw Water Vapor Wind Heights
Total - Florence
39534 Targets
18562 Raw Winds
Mean Wind Height 286 mB
Std 52 mB
Frequency
200.0
150.0
100.0
50.0
0.0
Pressure (mB)
100.0
200.0
300.0
400.0
500.0

Fig. 3


GOES-8 Raw Water Vapor Wind Heights
Total - Gordon
81850 Targets
38695 Raw Winds
Mean Wind Height 300 mB
Std 59 mB
Frequency
400.0
300.0
200.0
100.0
0.0
Pressure (mB)
100.0
200.0
300.0
400.0
500.0