Progress Report

through April 1992

Investigation of Cloud/Water Vapor Motion Winds from Geostationary Satellite

Contract NAG8-892

Prepared by

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for

National Aeronautical and Space Administration
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Research work on NASA grant contract NAG8-892 began in November 1991. This report covers work done in the first half of the contract year. Efforts have been primarily focussed on two tasks; (a) comparison of wind fields produced at MSFC with the CO_2 autowind/autoeditor system deveoped at CIMSS and recently installed at NESDIS operations, and (b) evaluation of techniques for improved tracer selection through use of cloud classification predictors. Progress on both tasks is summarized below.

Research goals of this contract were stated in the proposal as;

(a) complete upgrades to the CIMSS wind system procedures for assigning heights and incorporating first guess information,
(b) evaluating these modifications using simulated tracer fields,
(c) adding an automated quality control system to minimize the need for manual editing, while maintaining product quality, and
(d) benchmarking the upgraded algorithm in tests with NMC and/or MSFC.

Work on all these tasks is underway and is detailed below. This work was done in collaboration with CIMSS NOAA/NESDIS scientists working on the operational winds software, so that NASA funded research can benefit NESDIS operational algorithms.

Task A: Comparison of a Wind Set Produced by MSFC with the New Operational CO_2 Autowind/Autoeditor: (C. Hayden, NOAA/NESDIS, C. Velden, CIMSS)

1. Introduction

In the spring of 1990 a team from the Cooperative Institute for Satellite Studies (CIMSS) joined with the NESDIS Interactive Processing Branch and the Satellite Analysis Branch at the VAS Data Utilization Center in introducing and testing a new software system for automated cloud motion winds with pressure altitude assignment using the CO_2 slicing method. Wind vectors generated during this demonstration were given to the NMC to investigate forecast impact. One of the highlights of this effort occurred on April 24 and 25, when the new pressure assignment method succeeded in correctly locating the altitude of thin cirrus tracers off the coast of California associated with a shortwave which would later affect the weather over the U.S. (Merrill et. al.,1990). The success of this venture created renewed interest in applied research for improving vectors obtainable from satellite imagery.

One consequence of this effort was an agreement with Marshall Space Flight Center (MSFC) that they use the April test case with their motion vector generating software for comparison with the new NESDIS system, the eventual goal being the amalgamation of better aspects of the two methods. MSFC agreed to this task, and subsequently delivered a data set to CIMSS which included vectors from visible, infrared window, and water vapor (6.7 micrometer) imagery for 25 April 1990 at 0000 UT. CIMSS evaluation of these data was conducted under this NASA contract and the results are the subject of this report.

At the time of the April 1990 test, CIMSS was in the process of developing a system for objective quality control of the winds generated from tracers. This quality control includes both pressure altitude reassignment by objective assimilation with other data and objective editing (Hayden, 1991; Hayden and Velden, 1991). Subsequently this system has been fully developed and is a part of the new wind generating system which became operational at NESDIS on February 12, 1992. The evaluation of the MSFC wind data by this quality control system is also discussed in this report.

It should be emphasized at the outset that this exercise was not intended to be a competition between wind generating systems. The MSFC software has been dormant for some time and was apparently not prepared to take full advantage of the forecast data provided to assist with pressure altitude assignment and quality control. Also, the MSFC system does not have the advantage of CO_2 slicing, and thus it cannot be expected to perform as will as the CIMSS sytem in altitude assignment of semi-transparent cirrus. As a result, the altitude assignment of many of the MSFC vectors is suspect. In some sense this is fortunate, because the MSFC set offers a strong challenge to the NESDIS assimilation and quality control system to which it was subjected. On the other hand, the MSFC system enjoys a considerable advantage in computer power, and many of the constraints laid on the NESDIS VDUC system can be relieved. It is of special interest to us to investigate this advantage.

2. Data Coverage and Quality Flag

At the onset of the testing, CIMSS scientists were not fully informed regarding the quality flag accompanying the MSFC vectors. After examining the data set we decided that only those vectors with a flag of zero constituted a fully acceptable vector, and for verification purposes we proceeded on that assumption. However, this resulted in a severe reduction in numbers, as the total data set of 2625 vectors was reduced to 636. The altitude distribution of these vectors is shown in Table 1 and Fig. 1 through 3.

Cloud Altitude	VIS	AWVO	AIR	TOTAL
High	87	168	41	296
Mid	97	0	37	134
Low	119	0	87	206

Table 1. Pressure altitude and type distribution of **MSFC sample** for 25 April 1990 0000 UT. All vectors are Flag=0. Classifications are Vis=visible; AWV0=6.7 micrometer; AIR=infrared window from imager, and High: P < 400; Mid: 700 < P < 400; low P > 700.

Results from Table 1 can be compared to Table 2, which shows the distribution of the NESDIS data set for the same time period. Also, Fig. 4 shows the distribution of NESDIS winds for comparison with Fig. 1-3

Cloud Altitude	VIS	AWVO	AIR	TOTAL
High	0	130	414	544
Mid	0	2	95	97
Low	229	0	57	286

Table 2. Pressure altitude and type distribution of **NESDIS sample** for April 25 00 UT. Vectors are Flag<4. Types and levels are the same as in Table 1.

Several things can be noted from this comparision;

(1) The MSFC data contains visible vectors at upper levels. It is our understanding that these have been height-assigned using coincident infrared window measurements and a climatological temperature profile. At NESDIS the visible is used only to produce low level vectors, and these heights are assigned at 950 mb.

(2) Neither data set produces a significant number of 6.7 micron vectors in the mid levels. This result is consistent with recent findings that most water vapor tracers are upper level, and not mid level, as once presumed.

(3) There are very few MSFC AIR vectors with a flag of 0 at high levels. There is apparently some difference in the way the height is assigned, as compared to the more numerous AWV0, which we do not understand.

3. Assimilation and quality control

As mentioned above, the 25 April 1990 data set received from MSFC was put through the NESDIS assimilation and quality control system. In this system, pressure altitude may be reassigned, based on the pressure profile of a penalty function derived for each vector. The function is computed from the fit of the vector to a three-dimensional analysis of the wind and temperature fields. A forecast from the National Meteorological Center is used as a background, and all vectors passing a gross quality control are included in the analysis. The penalty function is given by

$$((V(p)-SMW)/VV)^2 + ((T(p)-TC)/VT)^2 + ((P-PW)/VP)^2 \tag{1}$$

where SMW, TC and PW are the tracer vector, temperature and pressure initially assigned. In the NESDIS system the denominators VV, VT, and VP are currently given the weights 2, 10 and 100, meaning that a vector discrepancy of 2 ms^{-1} has the same weight as a temperature discrepancy of 10 degrees or a pressure reassignment of 100 hPa. Equation (1) is evaluated with a vertical resolution of 25 hPa, and the SMW is reassigned at the pressure which gives the smallest value, if that value is more than 25 hPa different from the original assignment. Only two restrictions apply, the vector cannot be reassigned above the tropopause as determined from T(p), and the minimum value of (1) must be less than 100.

Following altitude reassignment, the objective analysis is repeated, and the final "fit" of the vectors is used to provide a quality control flag. Vectors failing a minimum value are rejected, otherwise the quality flag is appended to the data.

As an application to the 25 April 1990 data set, all vectors with a flag of < 4 were included. As previously implied, this permitts the inclusion of some data with highly questionable altitude assignments. The reaction of the assimilation system was to reject most of these vectors. To avoid this result the denominators of (1) were varied, doubling the values for temperature and pressure to place less confidence on these assignments. Also, the weight of the vectors in the analysis preceding height reassignment was reduced, effectively giving more weight to the background field. Normal weights were restored for the quality control analysis. Results of thus assimilation test are shown in Table 3 and Fig. 1-3.

Cloud Altitude	VIS	AWVO	AIR	TOTAL
High	269	316	485	1070
Mid	199	59	145	403
Low	429	10	131	570

Table 3. Pressure altitude and type distribution of **MSFC sample** for 25 April 1990 0000 UT, **after assimilation**. Vectors are Flag$<$4. Types and levels are as in Table 1.

The distribution displayed in Table 3 is clearly an improvement over Table 1. In particular, the density of infrared window vectors at upper levels and visible vectors at low levels are more as anticipated. However, there are also indications that the assimilation quality control has been relaxed too much. For example, one should not anticipate any AWV0 at low levels, and only 22 vectors were rejected. The latter represents a much smaller percentage than typically is seen in the NESDIS processing. For qualitative comparison, the CIMSS winds produced for this time period are shown in Fig. 4.

4. Accuracy

The 25 April 1990 data from MSFC were evaluated in the traditional way by comparing them with collocated rawinsondes. Results of the original and assimilated data sets, as represented by Tables 1 and 3, are shown in Fig. 5. In these scatter diagrams, SMW-Rawinsonde is plotted against Forecast-Rawinsonde. Our goal in the processing of the satellite vectors is to achieve a lower value for the former and also a low correlation between the two. In the former case, success means that the SMW are more accurate than the forecast; in the latter case success indicates that that the SMW are not highly biased to the forecast. Bias is indicated by the narrowness of the distribution of points about the 45° line. Some degree of bias is unavoidable when the forecast is used in the derivation and/or quality control of the SMW, but one hopes for considerable scatter among the points.

Figure 5 indicates that there is rather large error and a rather strong bias to the guess in the original 69 match-ups. After assimilation, the accuracy is significantly improved and is representative of what is achieved with the NESDIS system. A good deal of bias to the forecast remains, as would be anticipated since the forecast was weighted more heavily than usual in the assimilation.

5. Conclusions

The principal conclusion that is drawn from this examination of the 25 April 1990 MSFC data set is that NESDIS should pay more attention to visible data to improve vector coverage. A second conclusion is that MSFC seems to have a superior technique for obtaining targets in the water vapor imagery. Certainly their density is much higher. Finally, it is encouraging to see that the NESDIS assimilation system was quite successful in blending the MSFC winds into the analysis, despite the deficiencies of the initial height assignment. Although an obvious bias to the NMC forecast is enforced by the reassignment, the end result in comparison to rawinsondes shows an rms improvement over the forecast.

This cooperative effort is a modest but encouraging start. Further work is planned to ensure that some of the advantages seen in the MSFC product will be incorporated into future NESDIS operatonal systems.

6. References

Hayden, C. M. and C. S. Velden, 1991: Quality control and assimilation experiments with satellite-derived wind estimates. *Preprint Volume, 9th Conference on Numerical Weather Prediction*, Denver, CO. Amer. Meteor. Soc., 19-23 October.

Hayden, C. M. 1991: Research leading to operational methods for wind extraction. *Proceedings of the Workshop on Wind Extraction from Operational Meteorological Satellite Data*, Washington, DC, 17-19 September, Eumetsat ISBN 92-9110-007-2.

Merrill, R. T., W P. Menzel, W. Baker, J. Lynch, and E. Legg, 1991. A report on the recent demonstration of NOAA's upgraded capability to derive cloud motion satellite winds. *Bull. Amer. Meteor. Soc.*, **72,** 372-376.

Task B. Use of Cloud Classification Predictors for Cloud Tracer Selection in Operational Winds Algorithms: (C. Moeller, CIMSS)

1. Background

The utility of cloud feature characteristics as additional information to automated cloud tracking wind algorithm is investigated here. The goal of this effort is to improve the quality of operationally produced cloud tracked winds, while eliminating computational time spent trying to produce vectors from cloud targets which are not likely to yield good quality vectors.

Automated wind vectors can be improved by limiting cloud tracer selection to tracers that are, more often than not, accurately tracked (via correlation technique) through time. A goal of this work that cloud tracer selection, currently based on pixel brightness and gradient thresholds, will also be based on cloud feature characteristics. The characteristics for describing cloud tracers include cloud albedo, fraction, multilayering, height of base and top, spatial distribution and orientation, connectivity (cloud and background), and type. These cloud characteristics are being compared to cloud tracers and vectors produced by the operational cloud tracking procedure in an effort to identify the conditions under which good (and bad) quality wind vectors are produced. Those characteristics demonstrating skill in identifying good (and bad) cloud tracers will be retained; those not demonstrating skill will be removed from the algorithm to reduce computational time.

2. Example Results

Cloud feature characteristics are extracted from geostationary VAS visible and infrared (11 micron window) satellite data for N x N pixel domains. Cloudy pixels are identified in both visible and IR data using sun-sensor dependent (visible) and temperature dependent (IR) thresholds. The various cloud characteristics are then computed, with the aid of a visible calibration and histogramming techniques from the visible and IR data. Cloud characteristic domains are collocated with cloud tracers for statistical evaluation of skill.

Examples shown below are collocations of possible wind tracers in the visible image loop (dark lines) and succesfully tracked winds (light lines) with cloud characteristics CFFX (cloud fraction) and BCON (background connectivity) are shown in Figs. 6 and 7 respectively. BCON is the connective nature of background (i.e. non-cloudy) pixels; values near one represent cases where a single cloud mass is present in the scene, and values near zero represent cases where many isolated holes in the clouds are present. Fig. 6 shows that good cloud drift winds are most often produced (on a percentage basis) from target scenes that are between 10% and 90% cloudy. Fig. 7 shows that good cloud drift winds result most often from target scenes with BCON less than about 0.70.

Further evaluations will be performed using both visible and IR cloud tracked winds.

3. References

Garand, L., 1988: Automated Recognition of Oceanic Cloud Patterns. Part I: Methodology and Application to Cloud Climatology. *Jour. of Clim.*, Vol.1, No.1, 20-39.

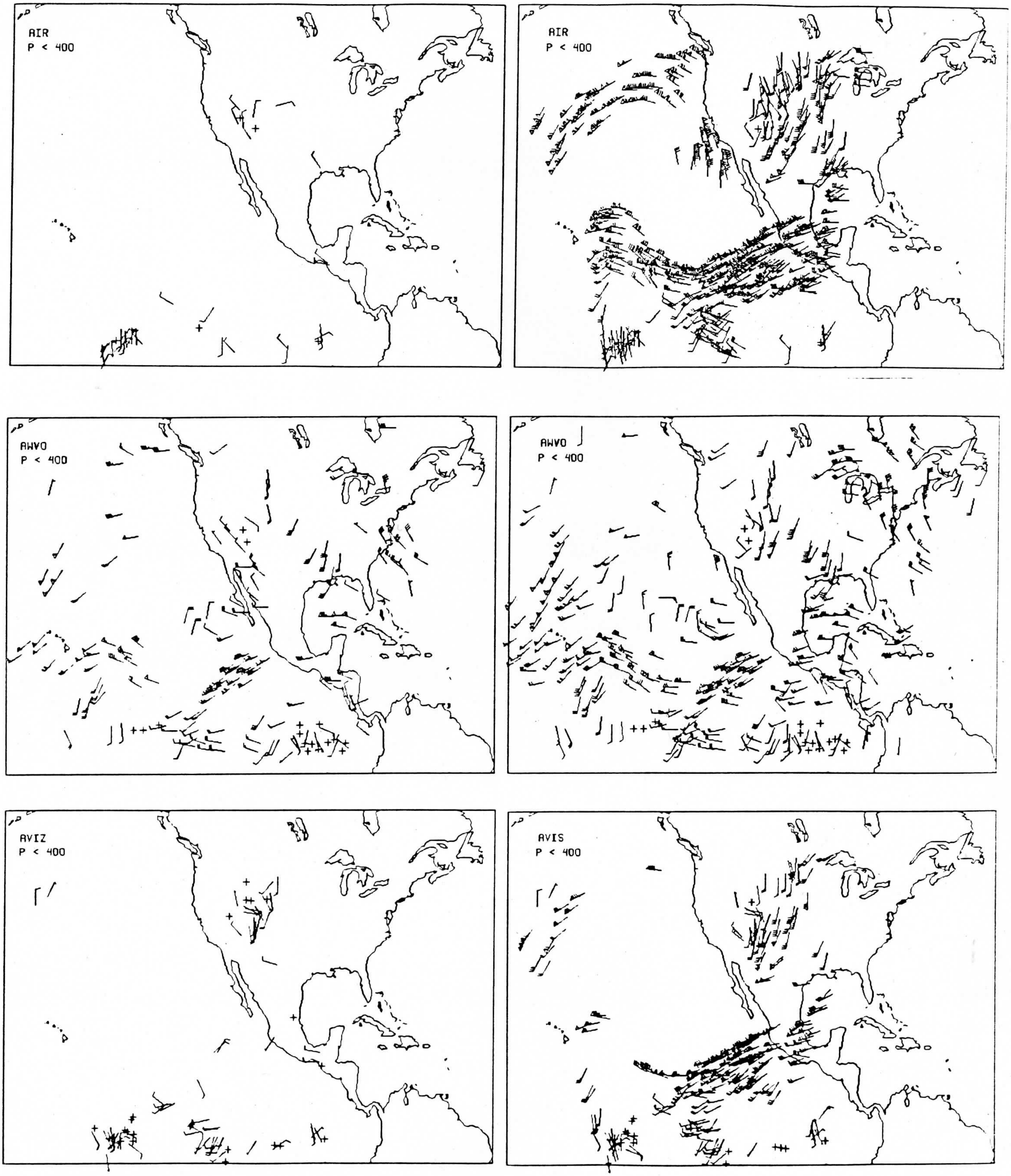

Fig. 1: Original (left) and assimilated (right) high level wind vectors in the MSFC data set. Vectors are shown for infrared (top), water vapor (middle) and visible (bottom) tracers. Only vectors with quality flag 0 are shown.

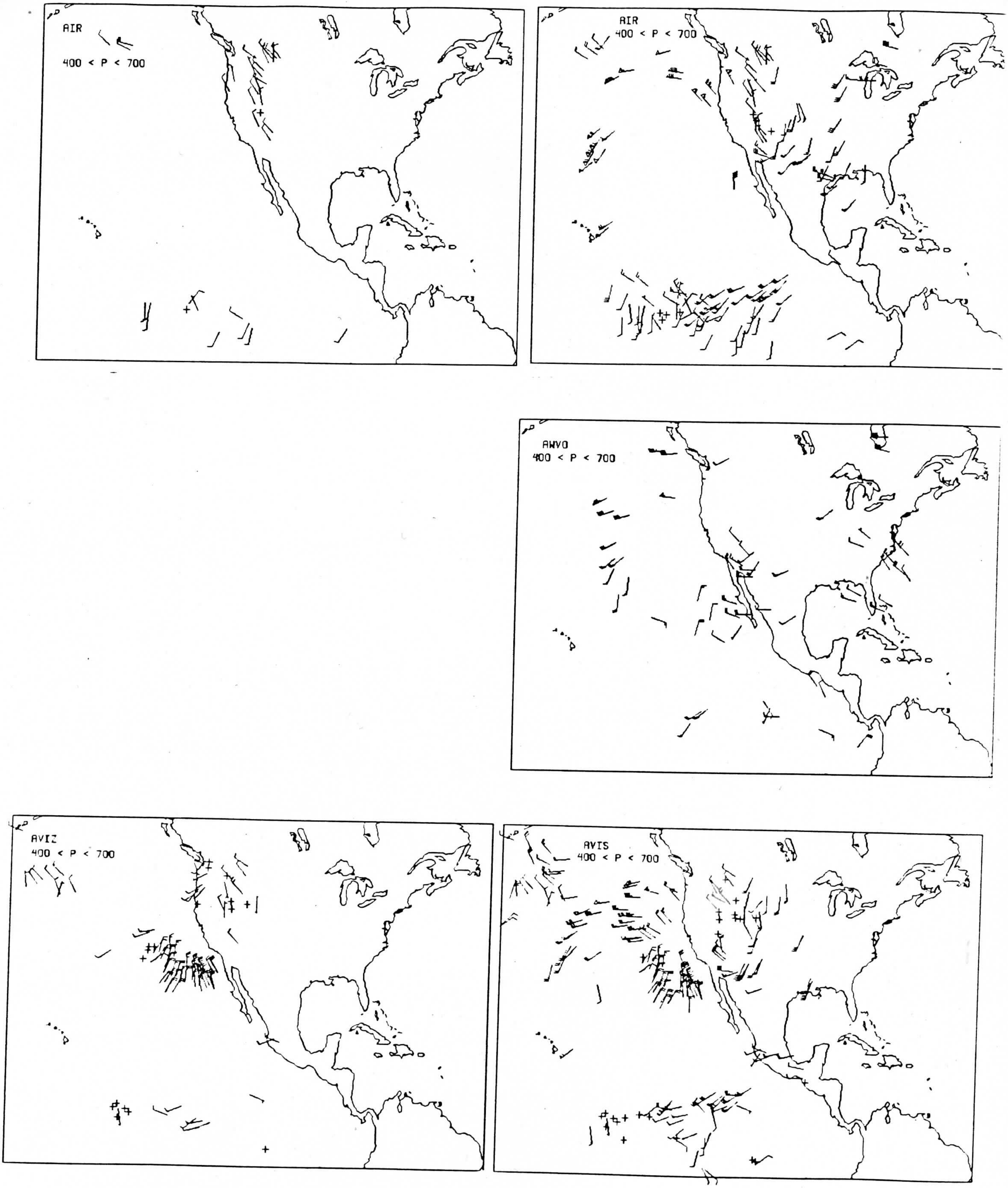

Fig. 2: Same as Fig. 1 but for mid-level vectors. There are no water vapor tracers assigned to midlevel in the original data set.

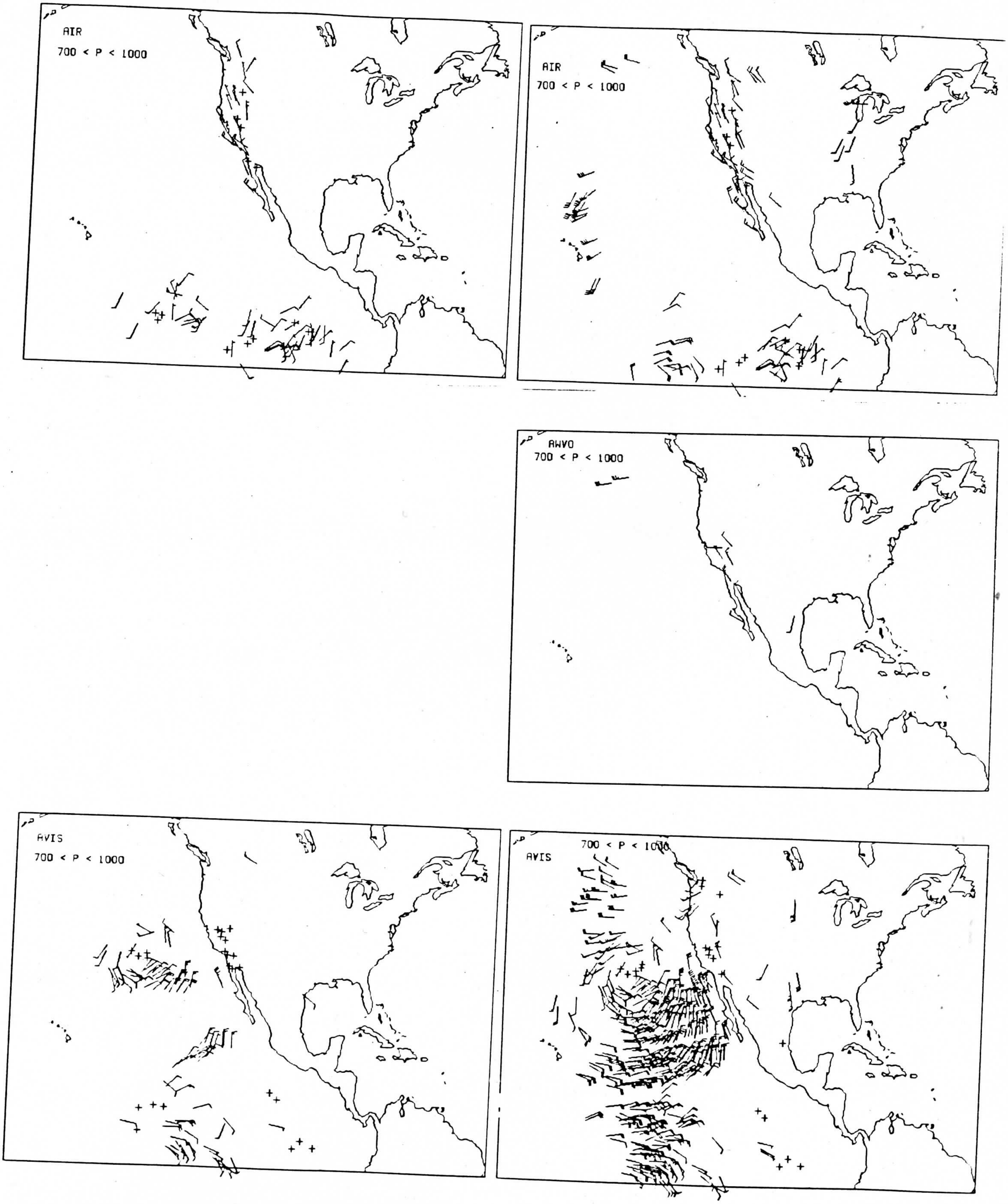

Fig. 3: Same as Fig. 1 but for low level vectors.

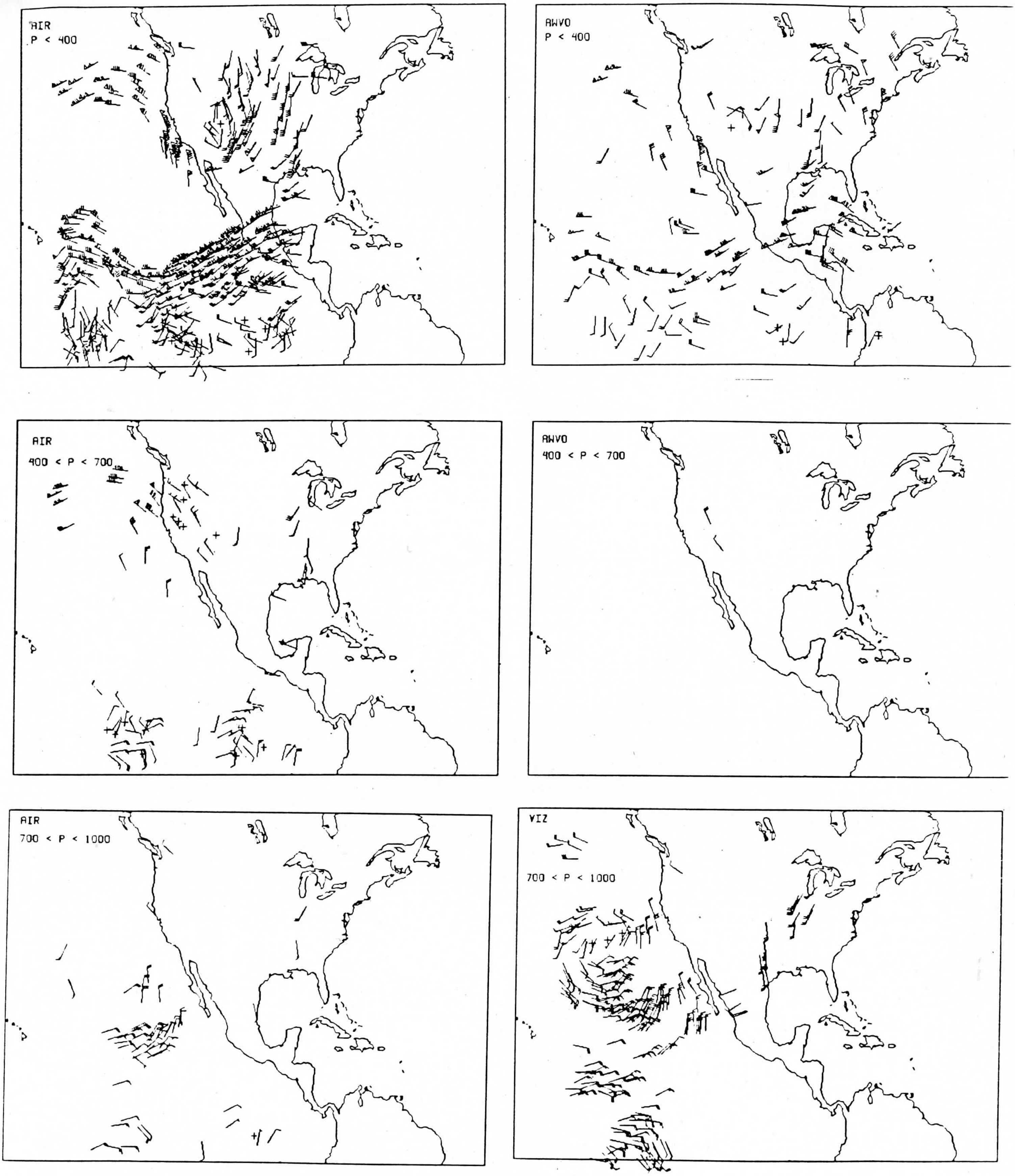

Fig. 4: Vectors generated at CIMSS for April 25, 1990, 00 UTC. Vectors have passed manual and automatic quality control. Visible tracers are used for low level winds only.

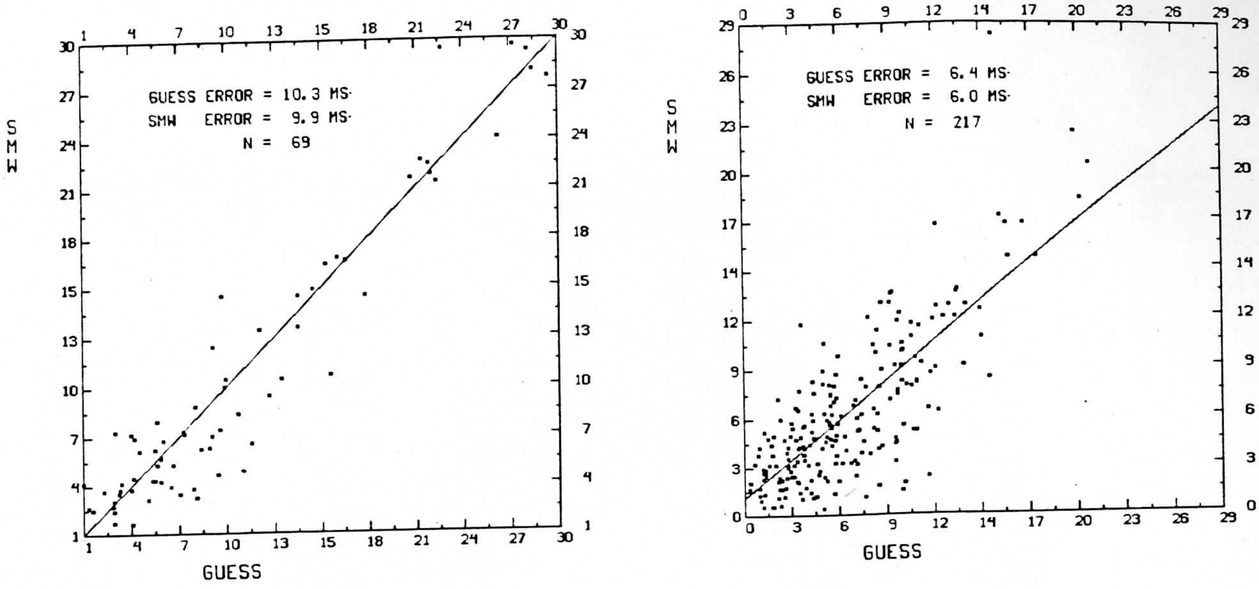

Fig. 5: Scatter diagrams for original (left) and assimilated (right) MSFC data set. Plots represent differences from collocated rawinsondes for vector (SMW-y axix) and for NWS forecast (Guess-x axis). Full sample statistics are shown on plots.

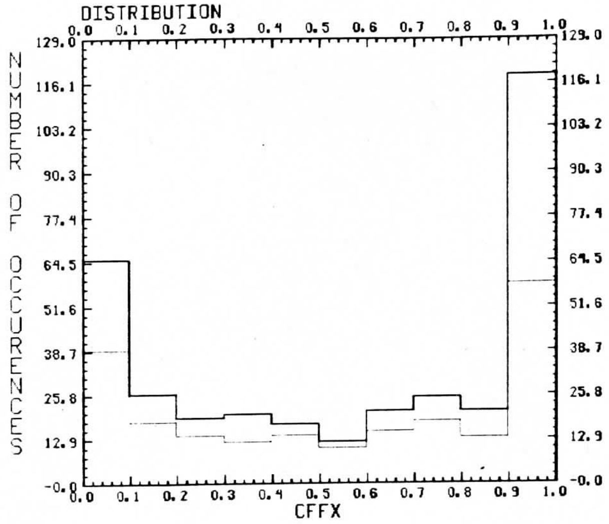

Fig. 6: Distribution of possible wind tracers in the visible image loop (dark lines) and succesfully tracked winds (light lines) as a function of cloud fraction CFFX

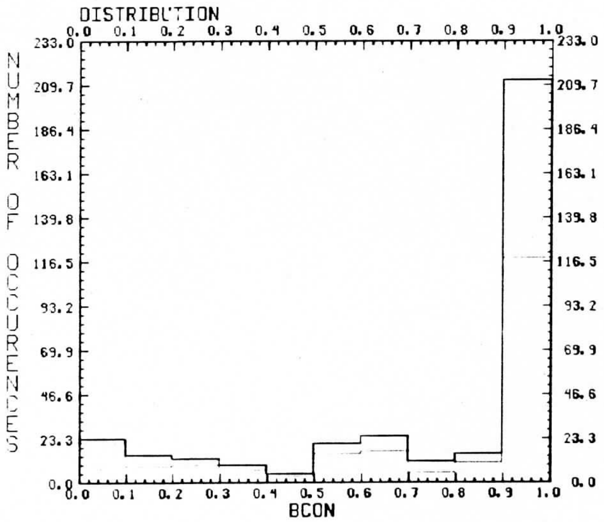

Fig. 7: Distribution of possible wind tracers in the visible image loop (dark lines) and succesfully tracked winds (light lines) as a function of background connectivity BCON. BCON is the connective nature of background (i.e. non-cloudy) pixels; values near one represent cases where a single cloud mass is present in the scene, and values near zero represent cases where many isolated holes in the clouds are present.

File

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CIMSS

24 April 1992

National Aeronautics and Space Administration
Marshall Space Flight Center
Attn: Gary Jedlovec
Code ED-43
MSFC, AL 35812

Re: Contract NAG8-892

Dear Dr. Jedlovec:

Please find attached the progress report for contract NAG8-892, "Investigation of Cloud/Water Vapor Motion Winds from Geostationary Satellite", covering the period through November 1991 through April 1992. Total expenditures through the end of March 1992 are $49.3K out of a contract total of $100.0K.

We have great interest in continuing this productive research effort. Can you please advise us on the disposition of the second year funding for a like amount. Thank you.

If you have any questions, please call Paul Menzel at (608) 263-4930.

Sincerely,

John P. Roberts

John P. Roberts
Assistant Director

enc.

cc: R. Kakar, NASA HDQTRS
W. Paul Menzel (NOAA/NESDIS)
William L. Smith (CIMSS)

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