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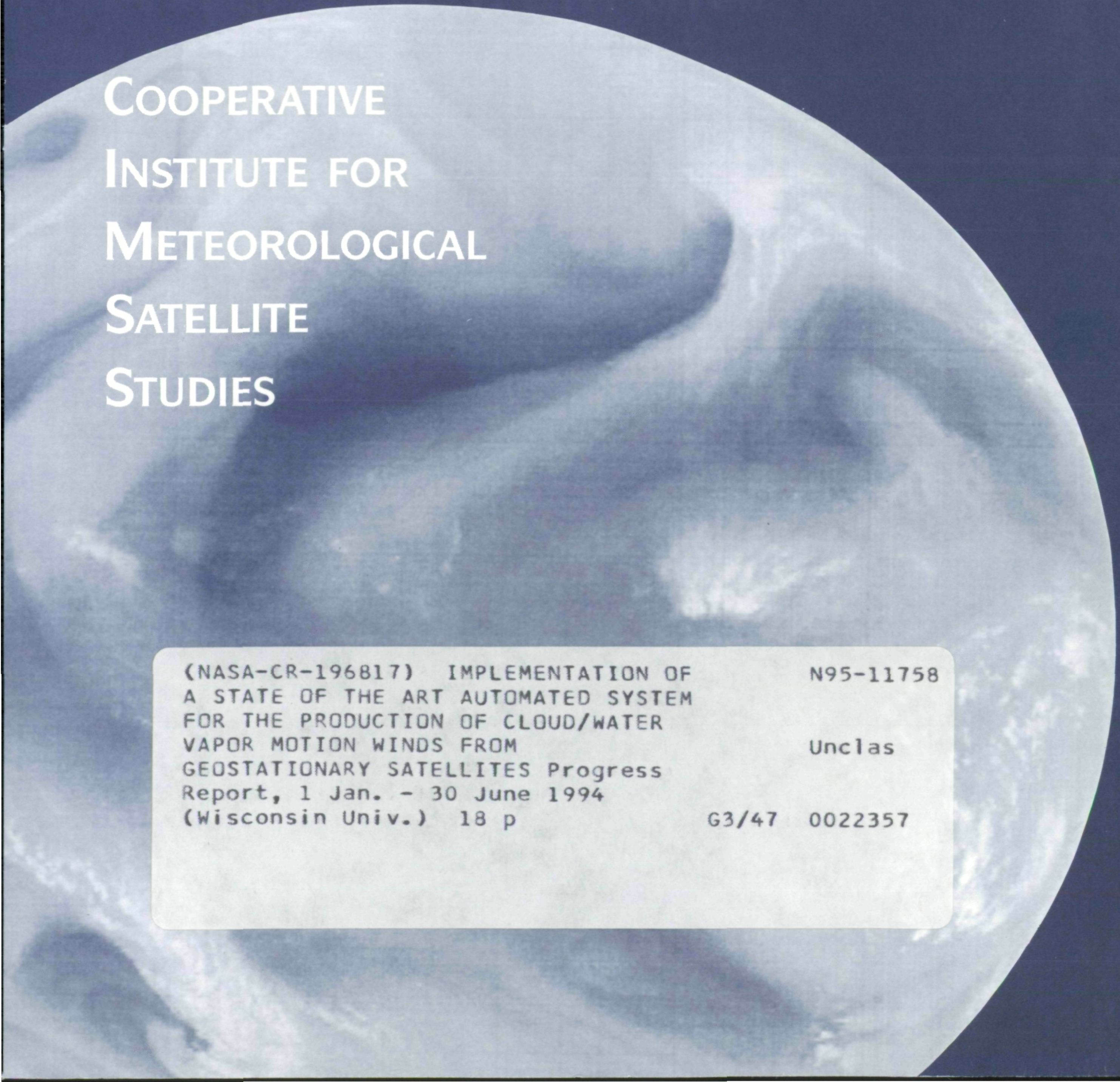

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Implementation of a State of the Art Automated System for the Production of Cloud/Water Vapor Motion Winds from Geostationary Satellites

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A 12-month Progress Report on NASA contract NAG8-974

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for the period of 1 January 1994 through 30 June 1994

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on behalf of

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FINANCIAL SUMMARY

Through 30 June, 1994 our spending on this contract totaled $48, 253 out of $100,000 received. Spending increased substantially this reporting period as contract activities were coordinated and activated (see Scientific Summary below). However, funds were prudently held in anticipation of a one-year no-cost extension to the contract to enable testing of preliminary results on promising data sources anticipated with GOES-8.

SCIENTIFIC SUMMARY

Significant progress was attained in this reporting period towards the overall goal of improving the CIMSS satellite wind algorithms through incorporation of new processing options, and testing/evaluating these options on data sets and through case studies. Several new strategies were implemented, and these are outlined below. In addition, data from GOES-8 have recently become available during system check-out and evaluation. Initial testing and software adjustments necessary to handle this new and improved data are briefly touched upon in this summary, and will be a main focus of the remaining funds and efforts under this contract.

The following upgrades to the CIMSS satellite wind processing system accomplished in this reporting period are summarized below:

1) Continued investigation into improved methods for vector height assignments. An H2O-intercept method has been developed for Meteosat data, and implemented. The routine has been applied and tuned for GOES-8. A new strategy involving the C02 slicing method has also been tested, but not yet implemented. This modification replaces the calculated clear radiance (using a forward model) with actual "warm" (clear) radiance values within the target box, if applicable. The results of this modification yield slightly higher overall target heights.

2) Improved tracer selection. Coakley-Bretherton spatial coherence analysis was added to the targeting phase. This filter allows us to force a high density of targets in areas of highly discernible features, while uniform or highly chaotic regions remain untargeted. Targets now also correspond directly to regions of highest brightness temperature gradient. Older methods targeted brightness temperature maxima, and applied an arbitrary gradient threshold which had to be exceeded. We have experimented with various gradient thresholds and spatial lengths in order to achieve an optimal target density that yields quality vectors.

3) Improved navigation. As GOES-7 station keeping became less reliable, it became apparent that the navigation strategy in the wind calculation would need revision. Previously, it was assumed that all images were similarly navigated. The new software treats the navigation problem individually for each image in the loop. This increases CPU time somewhat, but substantially reduces a source of error.

4) Improvements to the quality-control module (auto-editor) reported on in the last period have been implemented into the CIMSS package. This version has also been implemented into the NESDIS operational algorithm.

5) Most of the improvements to the CIMSS system have been incorporated into the NESDIS operational system. The entire procedure has been ported into the RISC workstation environment (previously, it was mainframe dependent). Transfer of updated code to NESDIS is immediate upon successful testing and evaluation at CIMSS.

6) GOES-8. Testing and evaluation of the wind tracking code using GOES-8 data is underway. The over-sampled nature of the data was addressed. Provisions were incorporated into the code to allow for rectangular search regions in line and element space. The improved signal-to-noise and resolution of the GOES-8 data should yield superior wind vector coverage. Preliminary results are confirming this, and vector quality is quite encouraging. However, significant further testing and evaluation is needed.

A major effort in this reporting period was devoted to an evaluation of the impact of water vapor tracked winds on numerical analyses and forecasts. Wind sets were produced from Meteosat-3 and GOES-7 data using the CIMSS algorithms during a 45-day period in March/April 1994. Two data sets were produced in real time each day (00 and 12 UTC), over a region covering roughly a 60 deg zenith angle from satellite subpoint (i.e., nearly full disk). The data sets were quality controlled using the auto-editor (no manual editing), and made available via Internet to NMC and ECMWF for their collection and model testing. As of the time of this writing, ECMWF had not yet conducted quantitative studies, but plan to shortly with a new 3D-VAR version of their global model (Graeme Kelley, personal communication).

To summarize, this demonstration has yielded the following findings (some are preliminary):

1) Successful data set production in real time ran at greater than 90%, with little manual intervention, demonstrating the robustness and reliability of the CIMSS satellite wind retrieval algorithm. Most cases that were not successful were due to missing images or first guess fields, and not the processing routines.

2) Resulting wind field coverage from water vapor winds is quite good and complimentary to cloud drift wind coverage (Appendix 1).

3) RMS comparisons with collocated rawinsondes yield values of under 8m/sec, which are comparable to operational upper-level cloud drift wind accuracy's (Appendix 1).

4) From a quantity and quality standpoint, there is good consistency between vectors derived from GOES-7 and Meteosat-3 water vapor data (Appendix 1).

5) Results from NMC indicate modest but positive improvements on global model forecasts result with the incorporation of the water vapor motion winds, especially over tropical regions (Appendix 2).

6) Preliminary results from model experiments run with the CIMSS regional assimilation system (CRAS) reveal similar modest improvements (Appendix 2), with suggestions of greater impact on a case by case basis (Appendix 1).

The impact of the water vapor winds on the regional model forecasts appears to be highly case dependent. While absolute forecast error improvements are not large in a domain-wide RMSE sense, regional forecasts may be more significantly affected. Qualitative examination of the cases run with the CRAS model indicates greatest positive impact occurs with active patterns in the eastern Pacific (i.e. upper-level jet streaks or circulations). These active periods correspond to some of the positive impact peaks in Fig. 3 of Appendix 2. Often these systems are not adequately defined by operationally available data (i.e. aircraft reports or cloud-tracked winds). A good example of this is illustrated in Appendix 1. These modest, but encouraging results have us enthusiastic about the prospects of applying the CIMSS wind retrieval system on the improved resolution and quality of GOES-8 data (more on this below).

Another potential use of the water vapor wind field product is in the area of climate diagnostics. A monthly-mean water vapor wind vector field was produced by averaging the daily-produced wind sets derived during March 1994. From this field, a divergence field was calculated. This monthly-mean divergence field was combined with a coincident monthly-mean upper-tropospheric humidity (UTH) field which is inferred from measured water vapor radiances with a physical scheme based on radiative forward calculations. The spatial pattern of the UTH field closely resembles the divergence of the wind field suggesting the upper-level water vapor transport patterns are largely determined by the large-scale circulation. These products can benefit projects such as GEWEX and PATHFINDER. A manuscript describing the products and the potential application to climate diagnostics is being submitted to BAMS (Schmetz et al. 1994).

At the time of writing, data from GOES-8 were becoming available on a routine basis as part of the science evaluation and system check-out phase. Due to the much-improved signal-to-noise and resolution over that of GOES-7, we were anxious to apply the wind tracking algorithms to the GOES-8 data. An example data set is shown in Fig. 4 of Appendix 2. As can be seen, the horizontal coverage is quite remarkable. A limited inter-comparison of GOES-7 and GOES-8 water vapor motion winds sets is also given in Appendix 2. While very preliminary, the result of the reduced RMSE with GOES-8 data is encouraging. We plan to give high priority to the continued development and assessment of the GOES-8 water vapor winds product in the remainder of this contract, with the goal of operational implementation sometime in 1995. Our plan is to continue experimenting with techniques to optimize the extraction of wind information from the imagery, as well as evaluate the product through NWP performance studies. Model impact studies similar to those conducted previously with GOES-7 and Meteosat are planned in the coming year in collaboration with NMC, ECMWF and AOML-HRD.

PUBLICATIONS

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. (Appendix 1)

Velden, C.S., 1994: Winds derived from geostationary satellite moisture channel observations: Applications and impact on NWP. Invited talk to be 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, 1994: Monthly-mean large-scale analyses of upper tropospheric humidity and wind field divergence derived from three geostationary satellites. Submitted to *BAMS*.

Velden, C.S., 1995: Impact of geostationary satellite water vapor channel data on weather analysis and forecasting. To be delivered at the *14th Conf. Weather Analysis and Forecasting,* Dallas, TX, January. (Appendix 2)

6.6

INVESTIGATION OF WATER VAPOR MOTION WINDS FROM GEOSTATIONARY SATELLITES

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1. INTRODUCTION

Water vapor imagery from geostationary satellites has been available for over a decade. These data are used extensively by operational analysts and forecasters, mainly in a qualitative mode (Weldon and Holmes 1991). In addition to qualitative applications, motions deduced in animated water vapor imagery can be used to infer wind fields in cloudless regimes, thereby augmenting the information provided by cloud-drift wind vectors. Early attempts at quantifying the data by tracking features in water vapor imagery met with modest success (Stewart et al. 1985; Hayden and Stewart 1987). More recently, automated techniques have been developed and refined, and have resulted in upper-level wind observations comparable in quality to current operational cloud-tracked winds (Laurent 1993).

In a recent study by Velden et al. (1993) it was demonstrated that wind sets derived from Meteosat-3 (M-3) water vapor imagery can provide important environmental wind information in data void areas surrounding tropical cyclones, and can positively impact objective track forecasts. M-3 was repositioned to 75W by the European Space Agency in 1992 in order to provide complete coverage of the Atlantic Ocean. Data from this satellite are being transmitted to the U.S. for operational use. Compared with the current GOES-7 (G-7) satellite (positioned near 112W), the M-3 water vapor channel contains a superior horizontal resolution (5 km vs. 16 km).

In this paper, we examine wind sets derived using automated procedures from both GOES-7 and Meteosat-3 full disk water vapor imagery in order to assess this data as a potentially important source of *large-scale* wind information. As part of a product demonstration, wind sets were produced twice a day at CIMSS during a six-week period in March and April (1994). These data sets are assessed in terms of geographic coverage, statistical accuracy, and meteorological impact through preliminary results of numerical model forecast studies.

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2. DATA SET DESCRIPTION AND EVALUATION

During March and April of 1994, M-3 and G-7 water vapor wind sets were routinely produced twice a day (around 00 and 12 UTC) at CIMSS. The wind sets were processed from full-disk imagery using fully automated procedures on a risc-6000 workstation. [See Merrill et al. 1991 for further details on the CIMSS automated winds processing system]. As a final step, an objective quality control procedure is invoked once the wind vector field has been derived (Hayden and Velden 1991).

The field of winds presented in Fig. 1 is typical of the data sets produced during the exercise. From a purely qualitative point of view, the horizontal coverage of the water vapor wind vectors shown in Fig. 1 is quite good in comparison to upper-level conventional and cloud-drift wind observations routinely available over oceanic areas. The very high-density coverage in the center of the figure is due to overlap of satellite coverage. It is noteworthy that, in general, there is a good agreement between satellites. It was found that the vertical distribution of the assigned vector pressure-heights (Hayden and Stewart 1987; Hayden and Velden 1991) was typically in the range of 200-500mb, with a peak near 300mb. It was also clearly demonstrated for future considerations that the water vapor wind sets could be created on a time scale commensurate with real time operations.

Statistical comparisons between the water vapor wind vectors and collocated western hemisphere rawinsondes (within 2.0 deg.) are shown in Table 1. Both vector speed bias and RMS were computed and compared. The results show values which are close to those of current operational cloud-drift winds.

Table 1. Statistical evaluation of water vapor motion winds produced at CIMSS in March 1994, vs collocated western hemisphere rawinsondes (N = no. of matches).

	GOES-7 N=2491	Meteosat-3 N=2791
Speed bias (m/s)	-.71	-.46
Vector RMS (m/s)	7.93	7.89

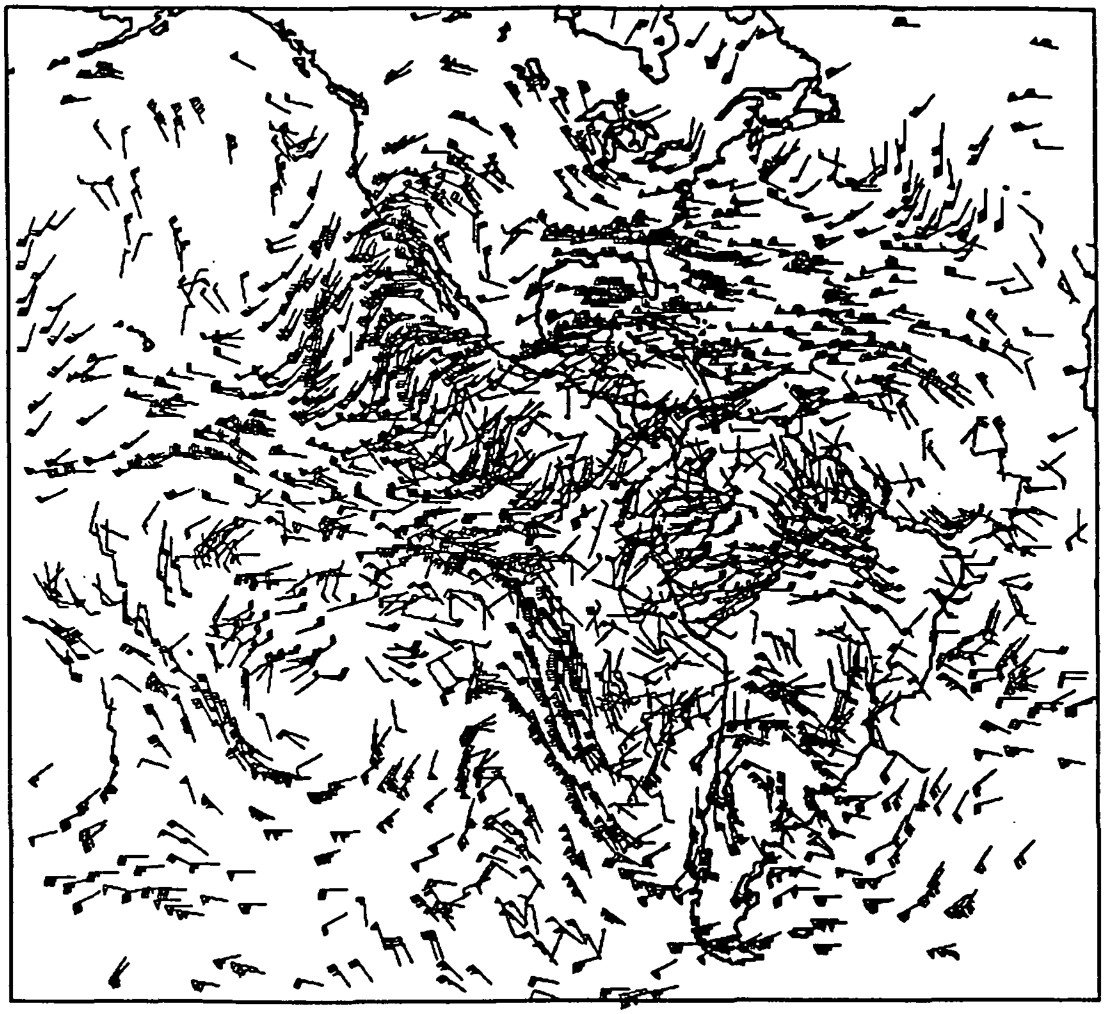


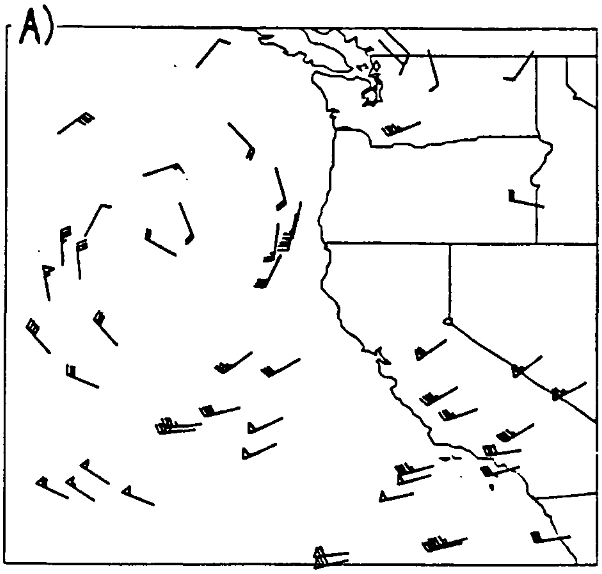
Fig. 1. Combined water vapor winds coverage from GOES-7 and Meteosat-3.

3. MODEL IMPACT EXPERIMENTS - PRELIMINARY FINDINGS

Another way of quantitatively evaluating new data types is through model impact studies. The wind sets derived at CIMSS were made available in near real-time to the modelling groups at NMC, ECMWF and CIMSS (for the model impact segment of this exercise, only winds derived over marine areas were made available). Both NMC and CIMSS produced parallel forecasts in near real-time, while ECMWF collected the data sets for future evaluation. NMC conducted the excerise on a T62 version of the global spectral model. The CIMSS model covers a regional domain at 150 km horizontal resolution and 39 vertical levels. As of this writing, model impact results were just becoming available, and the findings presented here are preliminary. Further and more complete results will be presented at the conference.

Overall, the impact of the water vapor data on upper-tropospheric forecasts in general can best be described as modestly positive, and case dependent. The CIMSS model yields fairly consistent ~5% improvements in 300 mb height RMS values in the 24-72 hr forecast range when evaluated against a verifying analysis over a North American domain. The impact can be much greater in certain synoptic situations (example given below). Very limited and preliminary results from the NMC forecast comparison is yielding very slight improvements to mean and RMS values of 200 mb forecast (72 hr) wind fields compared with verifying analyses on a global domain. The slight magnitude of the improvements may be an inherent manifestation of the fact that the verification is being done over the full globe, whereas the wind sets are limited to roughly 1/3 global coverage.

The impact of the data on NWP is perhaps best illustrated on a case by case basis. For example, a strong and well-defined circulation was evident in water vapor image loops on 24 March 1994 off the western coast of the U.S. This particular storm system became deadly as it crossed the U.S. mainland. Torrential rains and resulting mudslides hit southern California as the storm entered the west coast. Two days later, heavy rains and flooding was observed over many portions of the lower Mississippi and Ohio valleys. On 27 March, a series of tornadoes associated with the storm system killed over 40 people and resulted in extensive damage. Wind vectors derived on 24 March from animated water vapor sequences describe this circulation rather well (Fig. 2A), and contributed important information to the upper-level analysis of this event (Fig. 2B). Most of the vectors shown in Fig. 2A were assigned pressure-heights between 300 and 450 mb. It should be noted that there was little in the way of upper-level cloudiness associated with this particular circulation, making it a prime candidate to show the complimentary nature of the water vapor motion winds to cloud-drift winds (there were virtually no operational cloud drift winds defining the upper-level circulation).



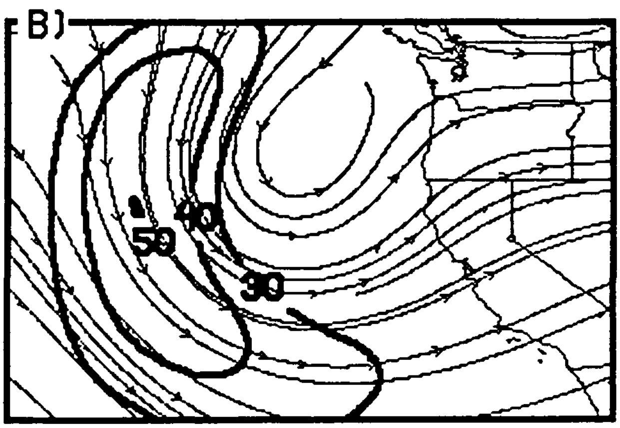


Fig. 2. A) Plot of water vapor motion winds describing the upper-level circulation off the west coast of the U.S. on 24 March 1994. B) CIMSS model wind analysis (EXP) of this feature at 400mb.

The impact of the water vapor data on the CIMSS model forecast of this event can be assessed by examining the differences between a control run (CON) which did not incorporate the water vapor wind data, and an experimental run (EXP) which included this information. An example is illustrated in Fig. 3, which shows 300 mb height difference fields (EXP minus CON) from model forecasts initialized at 12 UT 24 March. Within the model package, a 3-D variational wind-mass adjustment routine is activated in areas lacking in mass information (i.e. oceanic regions). This routine essentially spreads the relative wealth of wind information onto the mass field through gradient balance adjustments. At the initial time, a perturbation in the height difference field (+20/-10 m couplet) is observable off the west coast in the vicinity of the disturbance. This pattern is indicative of a sharper (and more potent) short wave trough in the EXP analysis compared to the control. This perturbation is maintained in the 24 hr forecast difference fields, and actually amplifies in the longer forecast intervals. By 48 hrs, the EXP forecast heights are greater then 30 m lower in advance of the transient upper-level trough associated with this event, and once again indicative of a stronger (and/or deepening) system relative to the control. These forecast difference fields are validated by comparing the forecast height fields from both runs to verifying analyses valid at the forecast time. To isolate the forecast impact of this particular system, the validation is only done over a region affected by the storm (i.e. the difference perturbations shown in Fig. 3). Using these criteria, the EXP height RMS errors relative to the CON are 12% lower at 24 hrs, 14% lower at 48 hrs, and 22% lower at 72 hrs.

These results suggest that the addition of the water vapor wind information to the analysis of the disturbance off of the west coast positively impacted the upper-level forecast of this particular event through 72 hrs. Other forecasted parameters associated with this storm were influenced as well. An examination of the 72 hr precipitation prognoses indicates that both the EXP and the CON forecast a major rain event from northern Mississippi through South Carolina (not shown). The EXP forecast, however, shifted the precipitation maxium slightly to the west, and increased it by 13 mm relative to the CON forecast. Overall, in an RMS sense, verification from rain gauge reports at 12 UT 27 March indicates the EXP forecast was superior. The 78 mm EXP forecast precipitation maximum was close to a raingauge report of 72 mm located just 100 km to the west.

4. SUMMARY

It has been demonstrated that motions deduced utilizing water vapor imagery from geostationary satellites can be translated into useful upper-tropospheric wind information over data void areas. Preliminary results from model impact studies are indicating that this information can positively influence and impact NWP on regional scales, and possibly on global scales as well. Current and future efforts are being directed towards

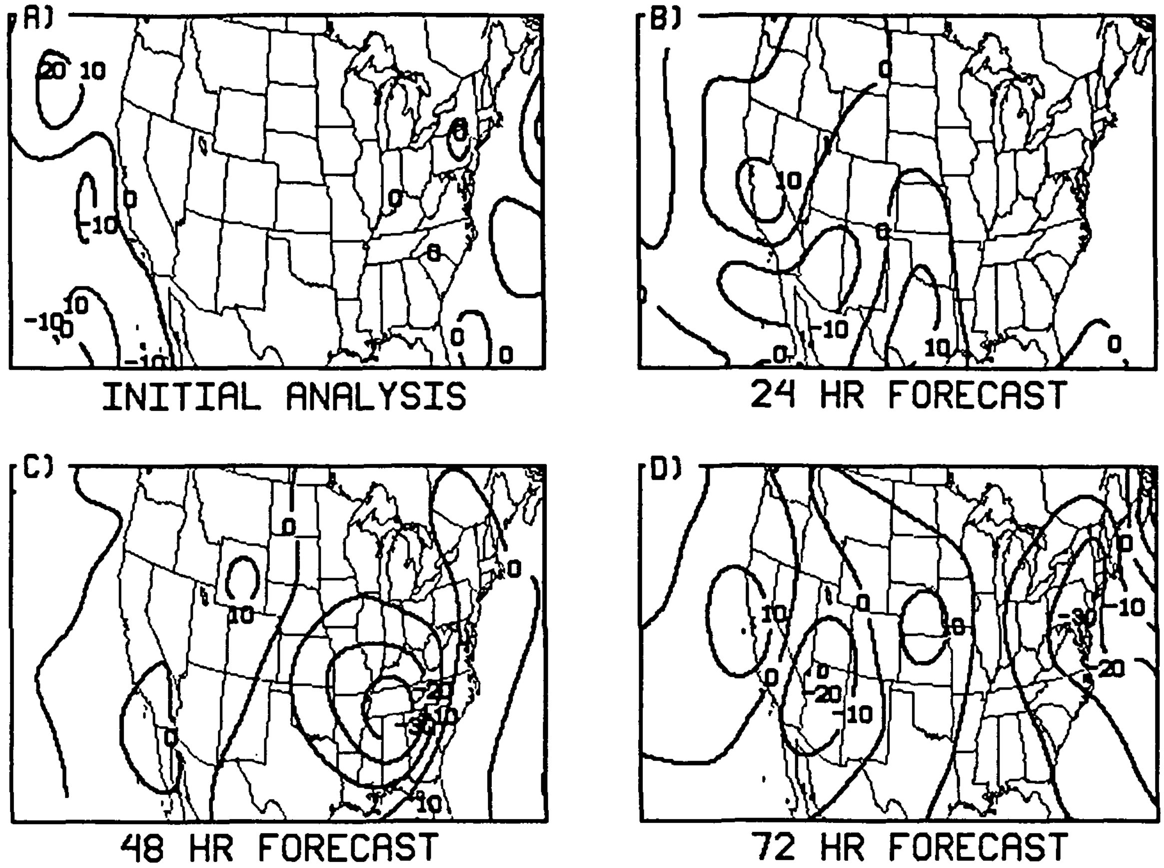


Fig. 3. 300 mb height difference (m) fields (EXP minus CON) from CIMSS regional model runs originating at 12 UT 24 March 1994.

refining the CIMSS wind extraction and quality control procedures to better account for the water vapor data and resultant motion vector characteristics. With the inclusion of a water-vapor imager on the next Japanese GMS satellite, it is envisioned that these data can compliment cloud drift wind observations to provide nearly complete global upper-tropospheric wind coverage.

Acknowledgements

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Appendix 2

IMPACT OF GEOSTATIONARY SATELLITE WATER VAPOR CHANNEL DATA ON WEATHER ANALYSIS AND FORECASTING

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1. INTRODUCTION

Recent studies have demonstrated the feasibility of deriving wind information from animated sequences of geostationary water vapor imagery in order to supplement conventional observations (Laurent 1993; Velden 1993; Holmlund 1993). Further work has examined the impact of these data on numerical weather prediction (NWP), and results suggest useful and complimentary upper-tropospheric wind information can be provided by these observations (Velden et al. 1993, Velden et al. 1994).

Development of algorithms at CIMSS to extract quantitative wind information from geostationary satellite water vapor data has progressed to the stage of quasi-operational testing and demonstrations. Full-disk wind sets derived from two different satellites (GOES-7 and Meteosat-3) were routinely produced on a twice-daily basis in March-April 1994, and delivered to NMC and ECMWF for assimilation into research versions of their respective global assimilation systems. In addition, the wind sets were included in real-time assimilations using the CIMSS regional-scale model to assess finer-scale impacts on NWP. Preliminary impact results included here are encouraging, and the full assessment along with case study evaluations will be presented at the conference.

With the recent successful launch of GOES-8, analysts and forecasters in the U.S. can expect satellite observations and products of unprecedented quality. One big improvement will be realized in the widely-utilized water vapor channel. The combination of higher resolution and reduced signal-to-noise will lead to an improved qualitative presentation for subjective analyses, but also should translate into superior quantitative products such as water vapor tracked winds. At the time of writing, GOES-8 imagery was just becoming available. First results of tracking GOES-8 water vapor features are reported on in this paper, with further findings and applications to NWP to be presented at the conference.

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2. BACKGROUND

Wind vectors derived from water vapor imagery are generated following the same general philosophy as with cloud drift wind tracking. Targets (structures in the imagery) are identified and tracked from successive images to derive motions (vectors), which are then assigned heights based on a best match between radiances (brightness temperatures) and a first guess temperature profile. In most cases, this height assignment will be representative of the layer of moisture being tracked, since the individual pixel radiances are achieved through contributions of energy over the depth of the attendant weighting function. Most vectors are assigned tropospheric pressure-heights in the 200-500 mb range, with a peak near 300-350 mb. As a final step, an objective quality control procedure is invoked once the wind vector field has been derived (Hayden and Velden 1991). Procedures to derive wind sets have become fully automated (Merrill et al. 1991; Holmlund 1993), and it has been demonstrated these data sets can be created on a time scale commensurate with real time operations.

Evaluation of the water vapor winds has centered on two approaches; statistical validation against rawinsondes, and model impacts. This paper focuses on the latter. Earlier studies have shown the water vapor tracked wind estimates to be comparable in quality to upper-tropospheric operational cloud tracked winds (Laurent 1993), with RMS values of 6.5-8 m/sec, and speed biases of less than 1 m/sec compared to collocated rawinsondes (Velden 1993; Velden et al. 1994). It was also demonstrated by Velden et al. 1994 that horizontal coverage is complimentary to wind information obtained through cloud tracking, and there is good consistency between observations derived from different satellites.

A first attempt to assess the potential importance of the water vapor tracked wind information on NWP was reported in Velden et al. 1993. In their study, a barotropic hurricane track forecast model was used to examine the impact of the winds on the analyses of Atlantic hurricane steering currents, and subsequent track forecasts. Modest improvements in track forecasts (relative to operational runs) were noted with the inclusion of the water vapor winds into the deep layer mean wind analyses which initialized the model. This was demonstrated by the fact that eleven out of fourteen 72 hr forecasts were improved, with a decrease in the mean forecast error of 8.2%.

3. IMPACT ON REGIONAL AND GLOBAL ANALYSES AND FORECASTS

Wind sets produced by CIMSS for a trial period in March-April 1994 (as described in Velden et al. 1994) were transmitted to NMC for model impact tests. NMC conducted the exercise using a T62 version of the global spectral model (similar to T126 AVN/MRF). Forecasts produced from analyses initialized with the water vapor winds are compared to operational forecasts in order to assess model impact. Shown in Table 1 are comparisons of results from 72-h forecasts for a 15-day subset of the trial period. The forecast fields are verified against model analyses. Two latitude-dependent domains are considered in order to examine regional impacts.

Table 1. Impact of water vapor motion wind data on 72-h forecasts from the NMC global spectral model during a 15-day trial period in March, 1994.

	opn	exp	fsp exp/opn
60N-60S			
200mb vector rms (m/s)	12.00	11.86	9/6
200mb acpsi	.809	.815	9/6
200mb acv	.741	.742	8/7
20N-20S			
200mb vector rms	10.51	10.22	9/6
200mb acpsi	.654	.681	12/3
200mb acv	.541	.550	8/7

opn = operational runs
exp = experimental runs with water vapor winds
fsp = frequency of superior predictions
acpsi = anomaly correlation of stream function
acv = anomaly correlation of v-component

Considering first the near-global domain, the impacts are not dramatic, as might be expected since the wind coverage over the mid latitudes is limited. It should also be noted that the wind sets produced by CIMSS cover only a portion of the western hemisphere, while the verification statistics are global, further limiting the potential impact. Despite these caveats, the impacts are slightly positive in all parameters examined. 9 of the 15 forecasts were improved, with a slight reduction in the overall 200 mb wind vector rms.

Greater impact is seen in the tropical band, a region of sparse conventional data, and abundant water vapor wind coverage. While still modest, a more substantial gain in forecast accuracy is noted, especially considering the rotational component of the wind (psi). For this particular parameter, 12 of the 15 forecasts were improved. These results suggest the winds are contributing to a better definition of circulations or wave-like features in the ITCZ region.

The water vapor wind sets were also provided to ECMWF for their evaluation. While acknowledging the impressive coverage of the winds (Graeme Kelly, personal communication), ECMWF had not yet accomplished a rigorous model impact test at the time of this writing. However, plans are to evaluate the impact of the winds using a new 3D-VAR version of their global model, and these results will be presented at the conference.

It is of interest to also examine the impact of the winds on regional scales. To accomplish this, forecast impact tests were conducted using the CIMSS regional assimilation system (CRAS), which is an adaptation of the Australian Bureau of Meteorology operational regional forecast model (Leslie et al. 1985). The model analysis covers a North American and adjacent waters domain at 150 km horizontal resolution, with 39 vertical levels. The forecast model operates with 20 vertical levels. Within the model package, a 3-D variational wind-mass adjustment routine is activated in areas lacking in mass information (i.e. oceanic regions). This routine essentially spreads the relative wealth of wind information onto the mass field through gradient balance adjustments. Experimental forecasts (EXP) including the water vapor winds are compared to control runs (CON) which contain only operationally available data.

An example of data impact on the model analysis and forecast fields is illustrated in Figs. 1 and 2, respectively. Shown in Fig. 1 is a plot of the 275-325 mb water vapor winds (large vectors) for 00 UTC on 22 March 1994. It should be noted that winds were only produced over marine areas. The vectors are overlain on a 300 mb model wind analysis difference field (EXP - CON), indicated by the smaller barbs (a barb length of one grid point interval equals 8 m/sec). As can be seen, differences at this particular level are modest, but can be as great as 6 m/sec such as in the trough off of the east coast of the U.S.

These analysis differences translate into 48-h forecast differences shown in Fig. 2. The 48-h EXP forecast 300 mb height field is overlain to show the large-scale pattern. In order to highlight the differences, in this figure a barb length of one grid point interval equals 5 m/sec. Fig. 2 shows small differences cover most of the domain, with notable differences in several locations including the EXP forecast tendency to amplify the ridge over the central U.S.

Model impact results from CRAS forecasts of 19 cases from the March/April 1994 trial period reveal a trend similar to that found with the NMC impact study. In general, a modest but positive improvement in RMS and bias statistics of upper-level height and wind fields are noted. An example of the forecast impact (72 hr) in terms of RMS at 400 mb is given in Fig. 3. In this figure, a comparison of CON and EXP forecast RMS errors (versus rawinsondes) is presented as a CON minus EXP value (meters) for each case. Positive model forecast impacts (reduced RMS errors as indicated by cases above the 0 line) produced by the addition of the water vapor winds to the analyses are indicated in 12 of the 19 cases. Only 3 cases exhibit a degraded forecast, and 4 had virtually no impact. These results are fairly representative for mandatory levels between 200 and 500 mb, where the greatest impact would be expected due to the vertical distribution of the data.

The impact of the winds on the regional model forecasts appears to be highly case dependent. While the absolute forecast error improvements are not large in a domain-wide RMS sense, regional forecasts may be more significantly affected. Qualitative examination of the cases run with the CRAS model indicates greatest positive impact occurs with active patterns in the eastern Pacific (i.e. upper-level circulations or jet streaks). These active periods correspond to some of the positive impact peaks in Fig. 3. Often these systems are not adequately defined by operationally available data (i.e. aircraft reports or cloud tracked winds). For an example, see Velden et al. (1994).

4. PRELIMINARY DATA FROM GOES-8

At the time of writing, data from GOES-8 were becoming available as part of system check-out. Although limited, observations were collected for several time periods in August 1994. Qualitatively, the GOES-8 water vapor imagery appears to be superior to the GOES-7 imagery, due to improved resolution (8 km vs. 16 km) and signal-to-noise. Wind algorithms were applied to extract water vapor vectors to assess (in a preliminary sense) and compare to GOES-7

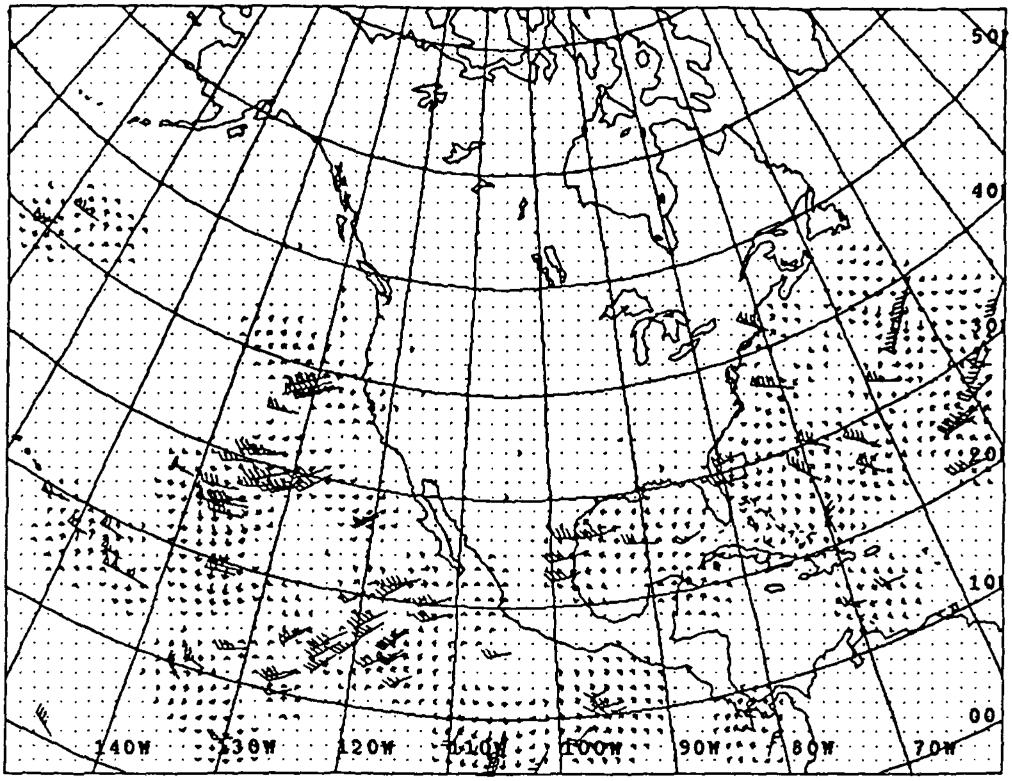

Fig. 1. Plot of 275-325 mb water vapor winds (large barbs, full stick = 5 m/sec and flag = 25 m/sec) over 300 mb CRAS wind analysis difference (EXP minus CON) field (arrow length of one grid length interval = 8 m/sec) for 00 UTC 22 March 1994.

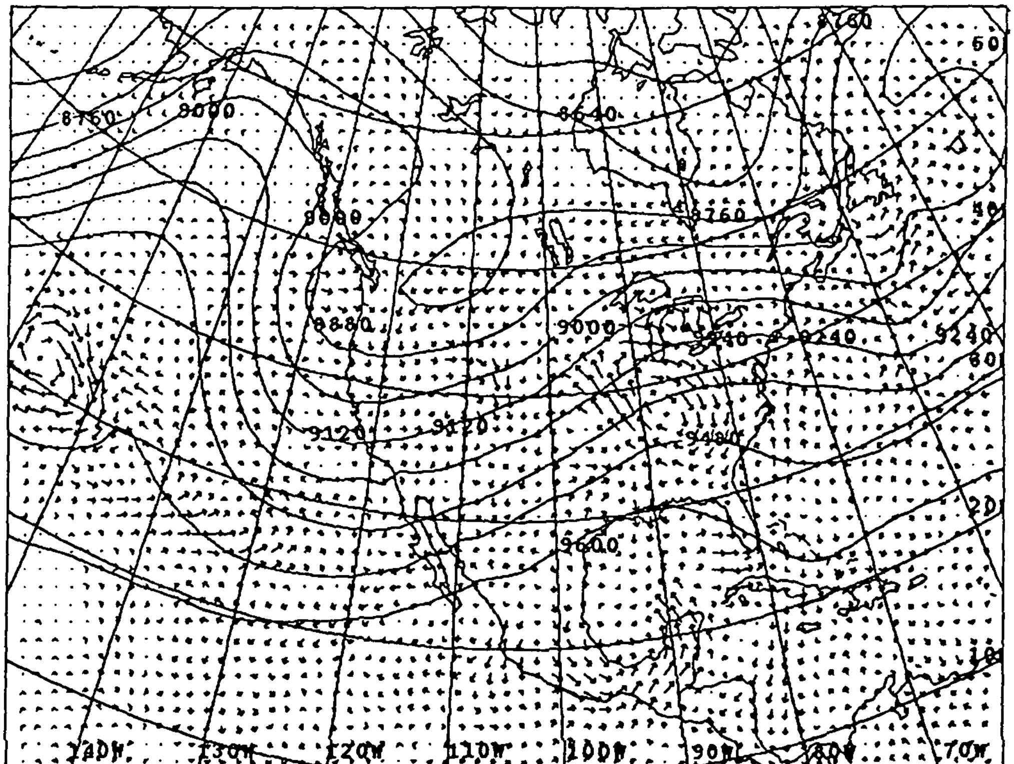

Fig. 2. Difference field (EXP - CON) from two CRAS 48 hr forecasts of 300 mb wind (arrow length of one grid interval = 5 m/sec) initialized at 00 UTC 22 March 1994. Also shown (contours in meters) is the 300 mb EXP height forecast.

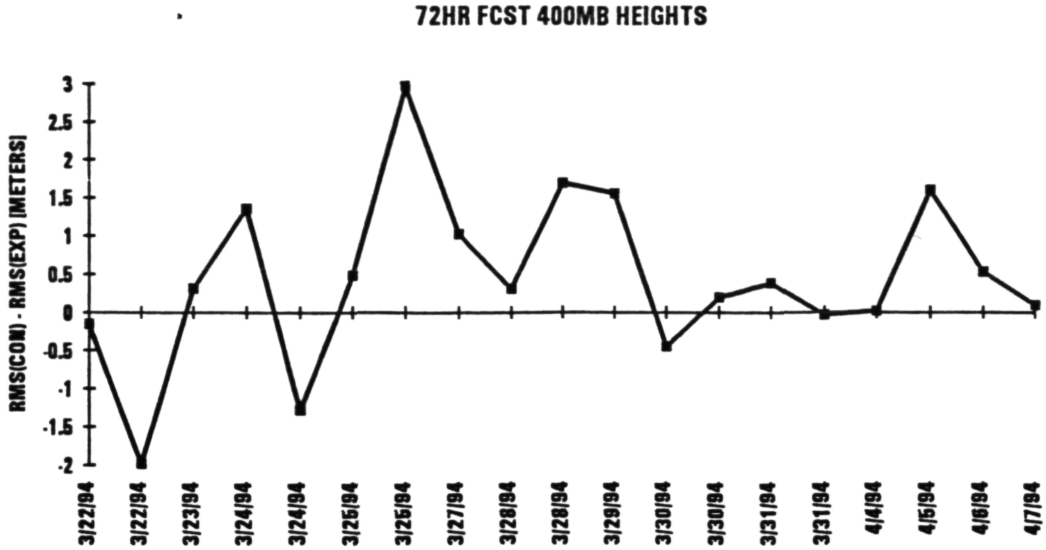

Fig. 3. Comparison of RMS errors (verified against rawinsondes) for CRAS model 72 hr forecasts of 400 mb heights for 19 cases in March/April 1994, expressed in terms of RMS(CON) minus RMS(EXP). Positive impact of the water vapor winds (EXP) is indicated in cases with points above the zero line. A few of the days contain multiple data sets (00 and 12 UTC).

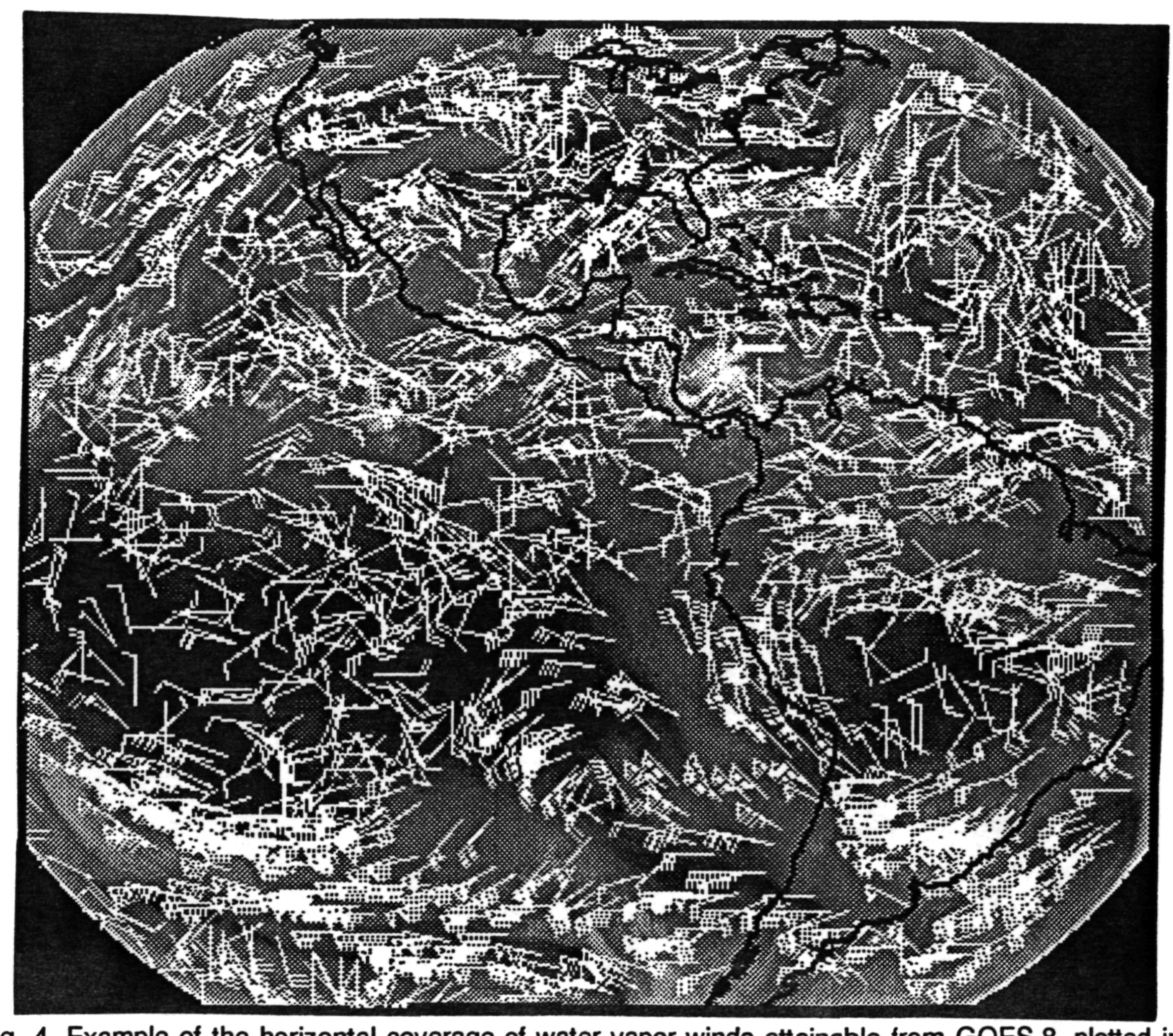

Fig. 4. Example of the horizontal coverage of water vapor winds attainable from GOES-8, plotted in knots over a GOES-8 water vapor image.

winds. An example of the typical coverage achieved with GOES-8 is shown in Fig. 4. Wind vector coverage is quite remarkable, and indicates a high degree of success in obtaining traceable features.

A limited inter-comparison of vector quality (GOES-8 vs. GOES-7) is shown in Table 2. For 7 days in August, collocated (space and time) wind vectors from each satellite were derived, quality-controlled and are compared to collocated rawinsondes. The results show a ~10% reduction in GOES-8 wind vector RMSE relative to GOES-7. While preliminary and limited, these results are quite encouraging. This assessment will continue as GOES-8 data become routinely available, and an update will be presented at the conference.

Table 2. Inter-comparison of GOES-8 and GOES-7 water vapor motion wind vectors verified against collocated rawinsondes for a 7 day period in August, 1994. NUM = number of comparisons. RMSE and BIAS are in m/sec.

	RMSE	BIAS	NUM
GOES-7	6.96	0.10	494
GOES-8	6.32	0.09	494

5. SUMMARY

Preliminary results from NWP impact studies are indicating that upper-tropospheric wind information provided by tracking motions in sequences of geostationary satellite water vapor imagery can positively influence forecasts on regional scales, and possibly on global scales as well. The data are complimentary to cloud-tracked winds by providing data in cloud-free regions, as well as comparable in quality. First results from GOES-8 winds are encouraging, and further efforts and model impacts will be directed towards optimizing these data in NWP. Assuming successful launches of GOES-J and GMS-5 satellites in 1995, high quality and resolution water vapor imagers will be available to provide nearly complete global upper-tropospheric wind coverage.

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