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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

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

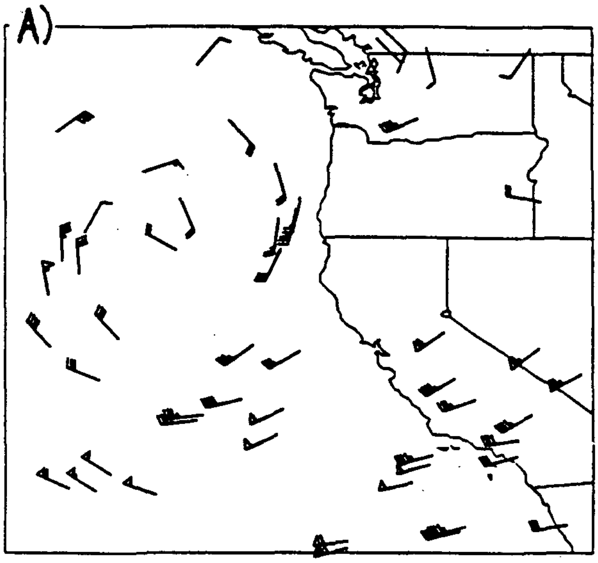
3. MODEL IMPACT EXPERIMENTS - PRELIMINARY FINDINGS

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).

A)



B)

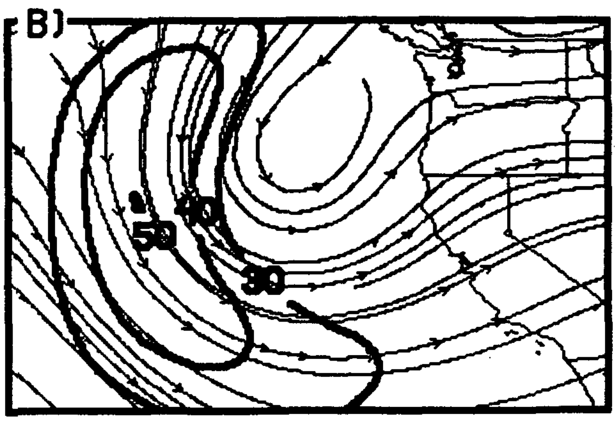


Fig. 2. A) Plot of water vapor motion winds describing the upper-level circulation off the west coast of the U.S. on 24 March 1994. B) CIMSS model wind analysis (EXP) of this feature at 400mb.

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

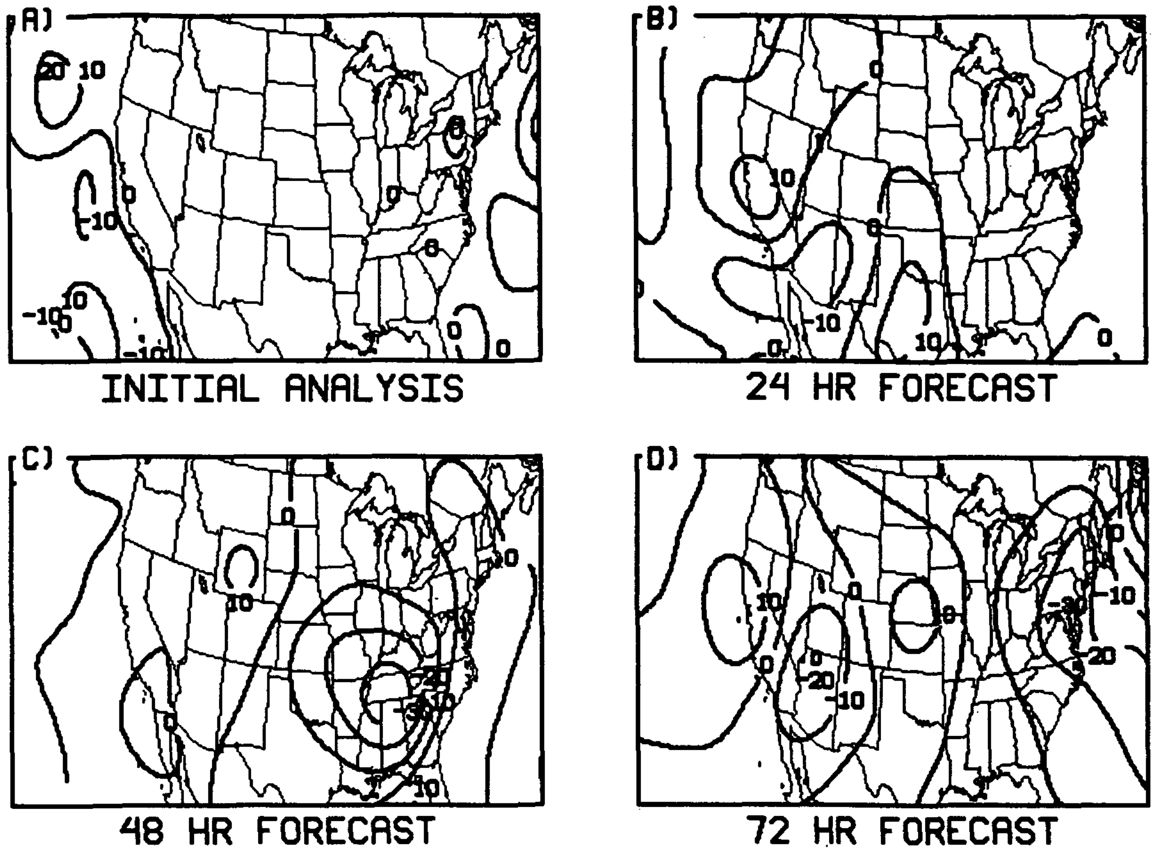


Fig. 3. 300 mb height difference (m) fields (EXP minus CON) from CIMSS regional model runs originating at 12 UT 24 March 1994.

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.

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