(NASA-CR-199772) UPGRADES TO THE NOAA/NESDIS AUTOMATED CLOUD-MOTION VECTOR SYSTEM (Wisconsin Univ.) 4 p

N96-16147

Unclas

G3/47 0084504

Appendix 6. Abstract from the 8th AMS Conf. on Satellite Meteorology, Atlanta, GA, January 1996.

NDB

NASA-CR-199772

1.1

1-4

Upgrades to the NOAA/NESDIS Automated Cloud-Motion Vector System

Steve Nieman [1], W. Paul Menzel [2], Christopher M. Hayden [2],
Steve Wanzong [1] and Christopher S. Velden [1]

[1] - Cooperative Institute for Meteorological Satellite Studies
Madison, Wisconsin

[2] - NOAA/NESDIS
Madison, Wisconsin

NAG 8-974
IN-47-CR
6455

I. Introduction

In the past, cloud-motion vectors (CMVs) were produced within NESDIS in a highly interactive way requiring a large investment in manpower. Operators displayed loops of geostationary imagery within several sectors of the full disk, selected suitable targets on the imagery, and followed them manually through subsequent images. Heights and vector displacements were computed automatically and displayed graphically over the imagery for inspection, but height assignment methodology was inaccurate when applied to semi-transparent cirrus. Operators often made judgments on the height of tracers based on their experience, and manual cloud heights were often substituted into the final product.

In 1992, the Cooperative Institute for Meteorological Satellite Studies (CIMSS) delivered the first version of the automated CMV software package to NESDIS. It was now possible to produce a full disk wind set without manual intervention. Suitable tracers were automatically selected within the first image of the loop and heights were assigned using several methods. Implementation of the CO2-slicing algorithm for assigning heights to semi-transparent features (Menzel et al., 1983) enabled more accurate height assignment without operator input. The tracking of features through the subsequent imagery was automated using the auto-correlation technique (Merrill et al., 1991). It was no longer necessary for operators to manually loop through imagery and "point and click" on features. Finally, an automated quality-control (QC) algorithm, the auto-editor (Hayden , 1993), was developed. Initially, the auto-editor was supplemented with manual editing. Normal operational procedure involved running the automated software, plotting the results, manually deleting vectors where appropriate, and then manually adding vectors to improve coverage.

Since 1992, CIMSS and NESDIS have made several changes to all aspects of the automated CMV software. The most significant of these changes involves a new tracer selection procedure, the introduction of the H2O-intercept height assignment technique, and full automation with a new version of the auto-editor. This latest version of the software has been running on GOES-8 data in Washington D.C. since the fall of 1994. Results have shown that, even without the benefit of manual QC, the automated GOES-8 cloud-drift winds are superior to any previous NESDIS CMV product.

II. Tracer Selection

The initial implementation of the tracer selection algorithm was very basic. For each target domain, the highest pixel brightness values were found, and local gradients were computed around those locations. Any of those gradients that were large enough and not too close to one another were assigned as target locations. In practice, the necessary gradient threshold was almost always met and the targeting grid was very coarse. The result was an extremely widespread and uniform field of targets (figure 1).

Figure 1. Typical target distribution resulting from GOES-7 imagery and the old tracer selection algorithm

In the new tracer selection algorithm, gradients are computed for each pixel within the targeting box and the maximum gradients undergo a pixel brightness check to ascertain whether they should

---

* *Corresponding author address*: Steve Nieman, Univ. of Wisconsin - Madison, Space Science and Engineering Center, Madison, WI, 53706.

be considered further. The pixel brightness check is more a means of filtering out clouds of certain levels than quality control.

All prospective targets now also undergo a spatial-coherence analysis (Coakley and Bretherton, 1982). Data within the target domain is divided into as many 3x3 boxes as possible and means and standard deviations of the 9 points within these boxes are computed. Boxes having standard deviations below a given threshold are deemed to be "coherent" and are input to a 2- dimensional cluster analysis scheme to obtain the mean brightness for any coherent clusters (i.e. signals). Presently two checks are employed to filter out unwanted targets. First, only two coherent signals are allowed. The presence of more than 20 percent of the coherent 3x3 boxes outside of the two largest clusters represents a multi-deck scene. Cloud-height diagnosis for multi-deck scenes is extremely difficult (Menzel et al., 1983) so they are eliminated. Second, scenes are not allowed to be too coherent. If more than 80 percent of the total number of 3x3 boxes within the target domain meet the standard deviation threshold, the scene is deemed to be too coherent and it fails to be a target. Scenes which are that coherent typically represent uniform coastal features.

As a result of the spatial-coherence filtering, the total number of targeting attempts within a given image can be increased significantly without any increase in the overall time necessary to process winds. The extra time used to complete a spatial-coherence analysis for all prospective targets is offset by the time saved by not having to height assign and track undesirable targets. The field of resulting targets from the new scheme (figure 2) shows a higher density of tracers in desirable locations, and almost none in the large clear areas that the previous scheme had targeted.

Figure 2. Typical target distribution resulting from GOES-8 imagery and the new tracer selection algorithm

III. H2O-Intercept Height Assignment

As mentioned, the development of the CO2-slicing algorithm was a major step in the automation of wind production. This is the preferred method for assigning heights to semi-transparent clouds, but the lack of a CO2-absorption channel on the current series of GOES imagers has necessitated the implementation of the H2O-intercept algorithm. Comparisons of the two methods have demonstrated that the H2O-intercept algorithm is an adequate replacement (Nieman et. al, 1993).

The algorithm is predicated on the fact that the radiances for two spectral bands vary linearly with cloud amount. Radiances from the infrared window and H2O-absorption bands are measured and compared to calculations of radiances for both of these bands for opaque clouds at varying levels in an atmosphere specified by a numerical prediction of temperature and humidity profiles. Measured and calculated radiances will agree for clear-sky and opaque cloud conditions. The cloud-top height is inferred from the linear extrapolation of measured radiances onto the opaque cloud calculations.

The measured radiances used to infer the linear relationship between the two bands are the average radiances for the cluster of clearest (warmest) fields of view and the cluster of cloudiest (coldest) fields of view within the observational area. If the calculated water-vapor radiance for clear sky is less than the measured water-vapor radiance, the calculated water-vapor radiances are adjusted to agree with the measured and the difference is attributed to an inaccurate transmittance used in the computation of clear-column radiance. Calculated warm radiances that are greater than measured are not adjusted since the low measurement may be the result of cloud contamination.

IV. Automated Quality Control

An important improvement to the automated wind production system came with the new version of the automated quality control algorithm (Hayden, 1993) shown in figure 3. The basic tool of the objective editor remains the 3-dimensional recursive filter objective analysis developed at CIMSS. This system has undergone an extensive upgrade with attention to improving quality control, especially the recursive-filter-flag (RFF), which is appended to each datum following the analysis. Differences in vector root-mean square error (VRMS) with respect to rawinsonde observations throughout the range of acceptable RFF flags amounted to 0.4 ms^{-1} in the old algorithm. The new configuration shows an expanded range of 1.1 ms^{-1} from the lowest acceptable RFF values to the highest. Thus, the resultant quality flag on the final winds should now be more meaningful to the user.

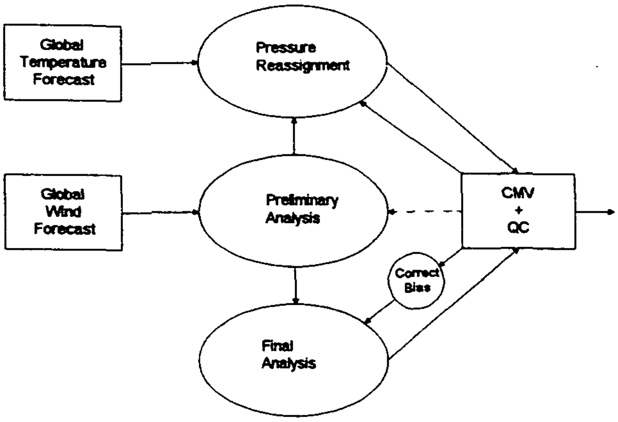

Figure 3. The objective editing system

Numerous suggestions from the operational community have found their way into the latest version. The pressure reassignment is now constrained to 150 hPa by the algorithm. A small percentage of the vectors (< 5 percent) are eliminated by this added constraint. Also, the revised editor has tightened the tropopause check to a threshold lapse rate of less than 0.5 K per 25 hPa above 300 hPa in hopes that it will be less likely to re-assign heights to some stratospheric value.

The revised editor contains an adjustment for the well documented slow bias of CMVs. The quarterly statistical summaries of the ECMWF routinely show this feature, with respect to both wind measurements and coincident speeds of the ECMWF forecast. For GOES-7 winds produced with the old automated system, the bias could reach -5 ms^{-1} at higher wind speeds. The bias is also present in comparisons with the NMC aviation forecasts, which are used in the derivation and quality control of GOES CMVs. To mitigate this slow bias, the revised editing procedure now increments each vector with 7 percent of the speed of the forecast, interpolated to its reassigned level, provided that the forecast wind speed is greater than 10 ms^{-1}. Philosophically, this is no different from the bias corrections routinely applied to radiance measurements to achieve agreement with forward calculations.

V. Results

The quality of CMVs is traditionally assessed through collocation with rawinsonde (RAOB) observations. More elaborate verification procedures involve the diagnosis of the impact the inclusion of a CMV dataset can have on a numerical model forecast. RAOB statistics are more useful for a fixed measure of product quality over a period of time. Therefore, that is what we present here.

Figure 4 shows verification statistics for GOES-7 cloud-drift winds (G7CD), GOES-8 cloud-drift winds (G8CD) and GOES-8 water-vapor motion winds (G8WV). VRMS and bias statistics are shown. All statistics are monthly means resulting from collocation to RAOBs within 2 degrees latitude and longitude and 25 hPa at 0000 UTC and 1200 UTC daily. All CMVs are the product of some version of the automated wind software. Operational G7CD winds still undergo a manual QC phase in which operators delete some vectors; the statistics represent conditions before those deletions occurred. G8CD and G8WV winds do not undergo go any manual QC.

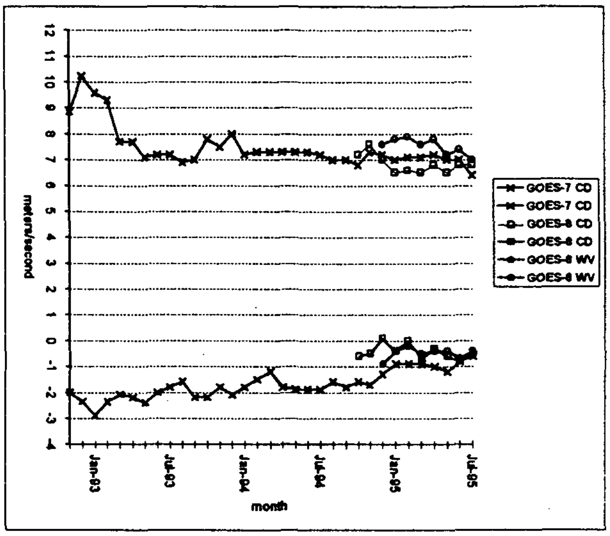

Figure 4. Monthly statistics for VRMS (upper curves) and bias (lower curves) for 3 NESDIS products

Statistics for the G7CD winds begin in November of 1992, shortly after the initial implementation of the automated software. During that first winter, VRMS and bias were high, mainly because the auto-editor was mistakenly not being run at 0000 UTC daily. This was corrected in the early spring of 1993 and the statistics improved. The winter of 1993-94 was much better in terms of VRMS and bias. The old auto-editor was still being run with a few minor modifications and it seemed to do a reasonable job. There was however, still some degradation in the CMVs early in the season. The unedited winds (not shown) tend to show an increase in VRMS as the mean wind speed increases during the winter. With the advent of the first auto-editor this was greatly reduced. The entire year of 1994 was the best ever for automated cloud-drift wind production as VRMS remained consistently at or just above 7ms^{-1}. In early

September 1994 the wind software was shifted from the IBM 4381 mainframe to IBM rs6000 workstations. This did not adversely affect the quality of the product and greatly decreased the amount of time necessary to complete a wind set. The new auto-editor also became operational at this time (although the bias adjustment was not yet being performed) and the quality of the G7CD product was as good or better than it had ever been for the next four months. In late December of 1994 the auto-editor began to apply a bias adjustment of 5%. This change was immediately apparent as the bias dropped almost 1 ms^{-1} and VRMS values improved by approximately 0.15 ms^{-1}. Experimentation with the G8CD product at CIMSS suggested that even better results could be attained with a bias adjustment of 7% and that change was implemented for the G7CD product in the early summer of 1995. The bias fell well below 1 ms^{-1} at that time and VRMS values were below 7 ms^{-1}.

G8CD wind production began in Washington in October of 1994. The GOES-8 products are not yet operational so they do not benefit from data acquisition priority and backup procedures that are routine for GOES-7. Thus the mean statistics are for a widely varying number of wind sets depending on availability, ranging from 60% to 90%. The initial implementation of the G8CD product included the new tracer selection procedures, the H2O-intercept method in place of the CO2-slicing algorithm and the new auto-editor using a bias adjustment of 7%. The VRMS and bias for the G8CD product have been routinely superior to those for the G7CD product by about 0.5 ms^{-1}.

G8WV wind production began in Washington in December of 1994 using the same software that produces the G8CD winds. New tracer selection procedures are not enabled for the G8WV product since clear air targets in areas of relatively weak water-vapor gradients are desired. A simple water-vapor brightness temperature comparison scheme is used for height assignment (the inclusion of window channel data during height assignment offers little in clear air since the water vapor channel can penetrate only to about 500 hPa). The bias for the G8WV winds is comparable to the G8CD winds, while the VRMS appears to be consistently greater by 0.5 to 1.0 ms^{-1}. Even so, VRMSs of 7.5ms^{-1} are greatly superior to any water-vapor wind product from previous geostationary satellites, and it is felt that the inclusion of numerous vectors in clear air will complement the coverage provided by the G8CD product.

VI. Summary

The latest version of the automated cloud motion vector software has yielded significant improvements in the quality of the GOES cloud-drift winds produced operationally by NESDIS. Cloud motion vectors resulting from the automated system are now equal or superior in quality to those which had the benefit of manual quality control a few years ago. The single most important factor in this improvement has been the upgraded auto-editor. Improved tracer selection procedures eliminate targets in difficult regions and allow a higher target density and therefore enhanced coverage in areas of interest. The incorporation of the H2O-intercept height assignment method allows an adequate representation of the heights of semi-transparent clouds in the absence of a CO2-absorption channel. Finally, GOES-8 water-vapor motion winds resulting from the automated system are superior to any done previously by NESDIS and should now be considered as an operational product.

References

Coakley, J. and F. Bretherton, 1982: "Cloud cover from high resolution scanner data: detecting and allowing for partially filled fields of view". *J. Geophys. Res.*,**87**, C7, 4917-4932.

Hayden, C.M., 1993: Recent research in the automated quality control of cloud motion vectors at CIMSS /NESDIS. *Second International Wind Workshop*, Tokyo, Japan, 1993, EUM P 14 ISSN 1023-0416,219-226.

Menzel, W.P., W.L. Smith and T.R. Stewart, 1983: Improved cloud motion wind vector and altitude assignment using VAS. *J. Clim. Appl. Meteor.*, **22**, 377-384.

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.

Nieman, S., J. Schmetz and W. P. Menzel, 1993: A comparison of several techniques to assign heights to cloud tracers. *J. Appl. Meteor.*, **32**, 1559-1568.