Recent Performance and Upgrades to the GOES-8/9 Operational Cloud-Motion Vectors

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I. Introduction

Fully automated processing of satellite-derived cloud-motion vectors from GOES-8/9 has recently been declared operational by the National Environmental Satellite Data and Information Service (NESDIS), an agency of the National Oceanic and Atmospheric Administration (NOAA). The National Centers for Environmental Prediction (NCEP) use the cloud-motion vectors over oceanic regions as input to their initial model analyses and subsequent forecasts. The Cooperative Institute for Meteorological Satellite Studies (CIMSS) in coordination with the Advanced Satellite Products Team and the Forecast Products Development Team of NESDIS continue to improve the processing techniques, upgrade the quality of the product, and investigate further capabilities. Improvements in tracer selection, automatic editing and height assignment techniques have been reported previously (Nieman et al., 1996; Velden et al., 1996). The goal of this paper is to discuss details of a new method for automatically adjusting the registration of the imagery used in the winds generation process. We will also show further examples of the operational product and demonstrate that the product quality is better than it has ever been and continues to improve.

II. Imagery Registration

Registration is a measure of the consistency of navigation between successive images. Features such as coastlines must remain stationary from image to image within a certain tolerance (Menzel and Purdom, 1994). The winds production process is much more sensitive to changes in registration, than to errors in absolute Earth location (i.e. navigation).

The advent of a 3-axis stabilized system with GOES-8/9 has made navigation more challenging. Non-rotating satellites are subject to differential heating, especially near local-midnight, and the result is a reduced ability to consistently navigate the imagery. Local midnight for both GOES-8 (0600 UTC) and GOES-9 (1200 UTC) falls within operational wind production cycles. Furthermore, these navigation problems around local-midnight are worsened during the periods just before and just after the eclipse, which occur twice a year near the time of Solar Equinox. The effects on registration quality were apparent in early non-operational GOES-8/9 winds processing, prompting NESDIS to perform manual registration corrections. These corrections have been necessary for approximately 5-10 percent of all winds generation cycles.

Automated registration quality control relieves the burden of manual intervention by applying the same pattern matching techniques used in the automated tracking algorithm (Merrill,

1989) to potential land features. Hundreds of initial landmark locations are screened for obvious cloud contamination using a spatial coherence analysis (Coakley and Bretherton, 1980) of the surrounding imagery. Each resulting landmark is sought in subsequent imagery within a small spatial tolerance using extremely tight correlation thresholds for determining successful matches. The tight correlation thresholds act to further screen landmarks with cloud contamination. Potentially undetected cloudy landmarks are eliminated by an analysis of the mean registration deviations suggested by all successfully correlated landmarks. Up to one fourth of this landmark sample can be eliminated if gross differences from the originally suggested mean deviation in registration occur, and a new mean is derived from the remainder. This check also guards against cases in which the registration exhibits varying shifts in different regions of the image. If more than one fourth of the landmarks show a large amount of scatter, less than 5 landmarks remain, or the diagnosed registration deviations are less than a predetermined tolerance, the process fails and nothing is done.

This software runs automatically at CIMSS during winds loop times (0,6,12,18 UTC) each day. During research and development, only 400x400 pixel infra-red window images centered over the Baja Peninsula for GOES-8 and GOES-9 are now obtained. Even with this strict limitation, the software is successful in diagnosing the quality of the imagery registration during winds generation cycles about 90 percent of the time, and corrections are suggested 5-10 percent of the time. The success rate varies depending on the time of day. Operational implementation will include a global landmark set, and it is expected that the success rate will near 100 percent for GOES-8 and the Northern Hemisphere sector of GOES-9 at that time. The Southern Hemisphere sector for GOES-9 will present a continued problem, since there is never enough cloud-free land anywhere in the imagery to diagnose navigation consistency.

An example of the registration adjustments made by this software for all successful 0600 UTC winds generation cycles during the early part of 1996 is shown in figure 1. Since 0600 UTC is the closest winds generation cycle to local midnight for GOES-8, there is a loss of data in the center of the series due to imagery blackout periods during eclipse. Registration specifications around local midnight for images which are 30 minutes apart are about 2.25 km in the north-south direction and 3.1 km in the east-west direction (Menzel and Purdom, 1994). Several days show shifts in registration which are beyond the specifications, but the period right after eclipse is most interesting. For well over a week, the imagery skipped to the west at least 3.5 km in the second image of the winds generation loop every day. Registration errors of this magnitude would lead to a wind speed error of approximately 2 meters/sec using the normal 30 minute imagery interval, thus the automated registration quality control algorithm is an important addition to wind production. The Forecast Products Development Team of NESDIS is now incorporating this software into their experimental high-density wind production (Gray et al, 1996) in Washington. It is planned that this enhanced product will become operational by the fall of 1996.

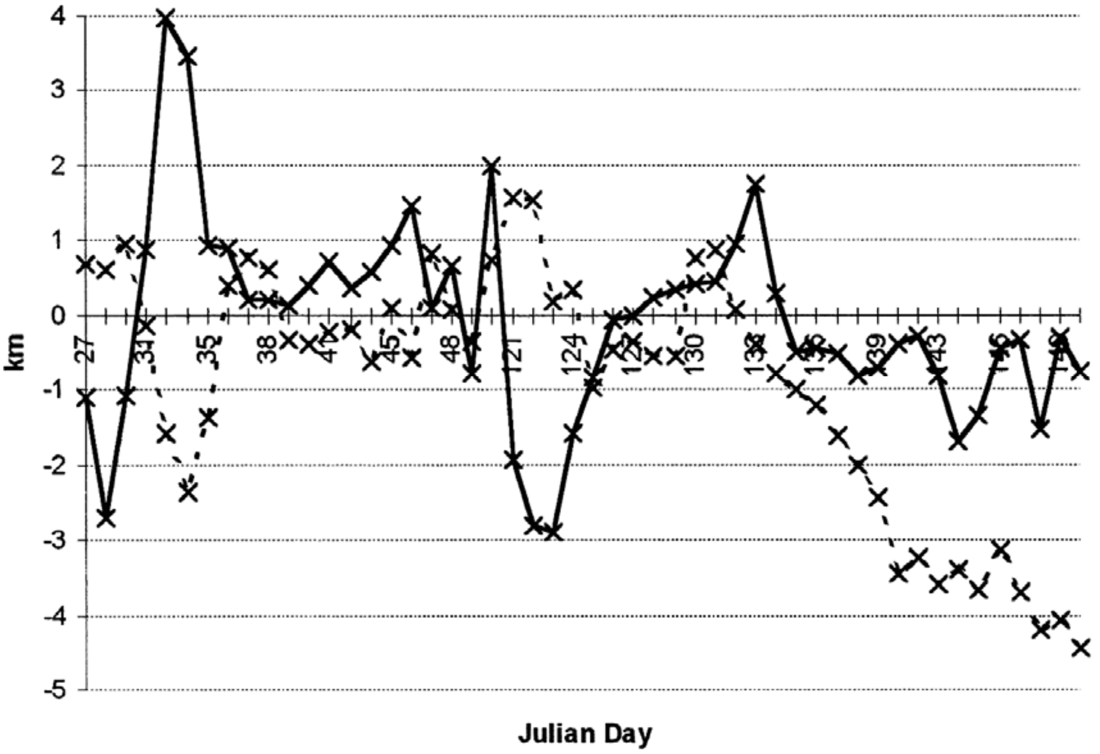

Figure 1. **Daily registration shifts (km) between the 0415 and 0445 UTC Northern Hemisphere GOES-8 images as diagnosed by the automated registration quality control software. The solid line represents shifts in the NS direction. The dashed line represents shifts in the EW direction.**

III. Example Coverage

An example of current operational GOES-8/9 cloud-drift wind coverage is shown in figure 2. Due to different scanning strategies with the current generation of GOES satellites, it is now not possible to obtain full disk imagery at an acceptable time interval for cloud-drift wind tracking. However, half hour imagery is available in two separate sectors for each satellite, and via separate winds generation runs in each of these sectors fairly complete coverage can be obtained. Winds are currently produced on high-end IBM RS6000 workstations at the NOAA Science Center. About 20-25 minutes is necessary to finish the calculations.

The forecast products development team within NESDIS is conducting an experimental high-density wind production effort in parallel to operational winds production (Gray et al., 1996). This experimental winds product offers approximately 10 times as many wind vectors but currently requires an hour or more to finish. Since NESDIS produces 4 winds products per cycle (GOES-8/9 cloud-drift and water-vapor) this high density mode of operation awaits the installation of more computer hardware before it can become operational. It is planned that each of the 4 products will run on separate workstations by mid summer, paving the way for a move into operations by the fall of 1996.

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The forecast products development team within NESDIS runs an experimental winds production effort in parallel to what is done operationally (Gray et al., 1996). This experimental winds product offers approximately 4 times as many wind vectors but currently takes an hour or more to finish. Since NESDIS produces 4 winds products per cycle (GOES-8/9 cloud-drift and water-vapor) this high density mode of operation awaits the purchase and implementation of more computer hardware before it can become operational. It is hoped that each of the 4 products will run on separate workstations by mid summer, paving the way for a move into operations by the fall of 1996.

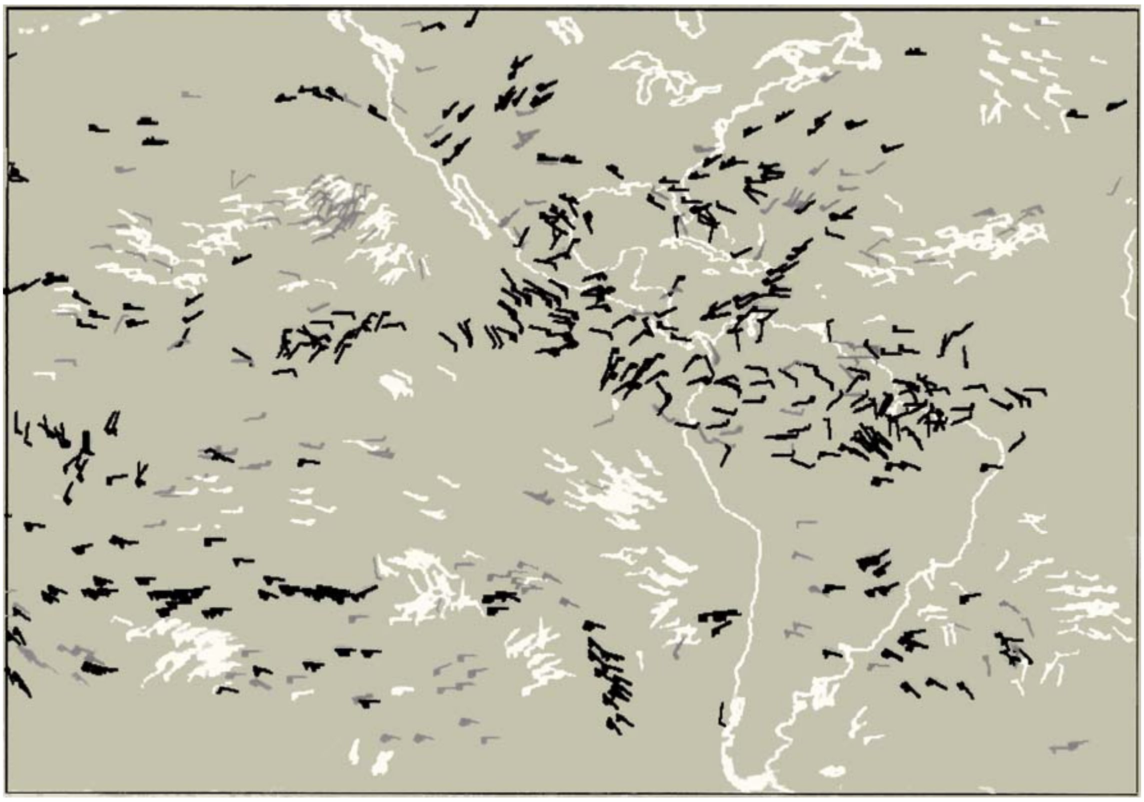

Figure 2. Operational GOES-8/9 cloud-drift winds for 1200 UTC 29 May 1996. Black winds are in the 100-400 hPa range, gray winds are in the 400-700 hPa range and white winds are in the 700-1000 hPa range.

IV. Product Quality

The traditional means by which the accuracy of cloud-motion winds is assessed is via collocation with radiosondes over continental regions (Hayden and Nieman, 1996). Although

The quality of NESDIS operational high- and mid-level cloud-drift winds has improved every year for the past 4 years, despite a gradual increase in automation over the period. In the fall of 1994 the winds production process was ported from the IBM mainframe to workstations. At this time, the upgraded automated quality control algorithm (Hayden and Purser, 1996) became operational, and operators at the Satellite Analysis Branch (SAB) lost the ability to manually augment the product in limited areas. Throughout GOES-7 production, SAB continued to perform manual quality control after automated production was finished, deleting about one third of available vectors. This practice has now ended due to the large volume of data that now needs to be processed. The operational cloud-drift wind products are fully automated, with no loss of product quality and, in fact, an increased number of vectors.

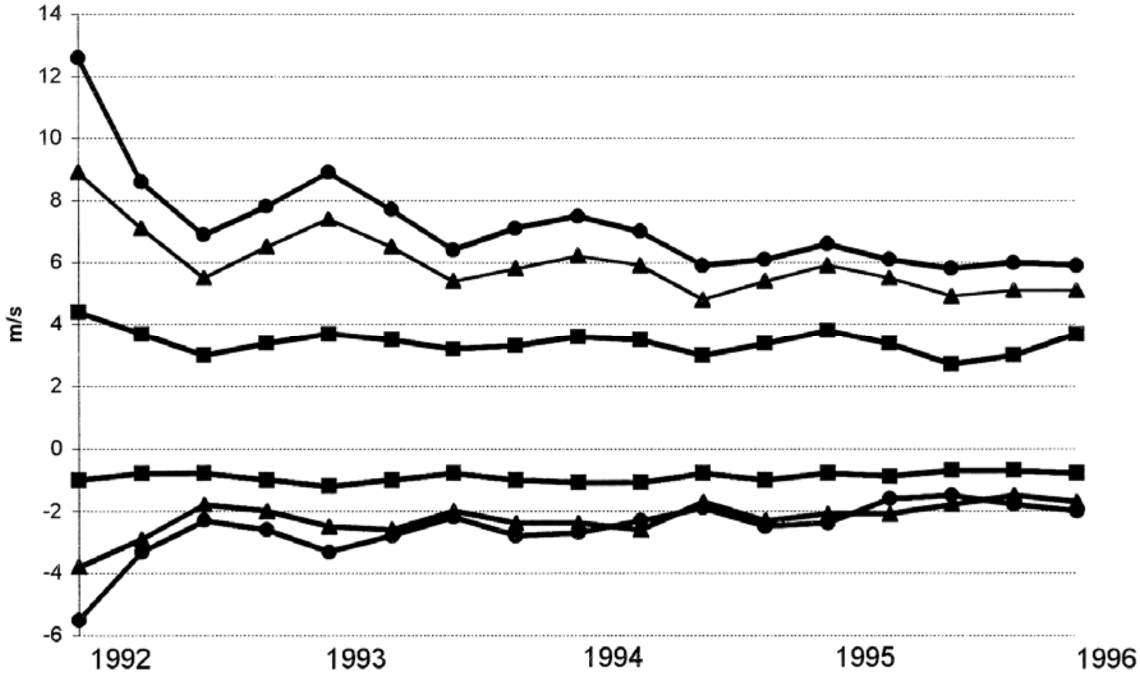

Figure 3. **GOES-7/8 verification statistics with respect to ECMWF model analyses within the Northern Hemisphere extratropical regions as reported by ECMWF. The top three curves represent mean vector RMS differences for high (circle), mid (triangle) and low (square) cloud-drift winds. The bottom three curves are labeled similarly and represent mean bias.**

V. Summary

NESDIS operational cloud-drift winds are now fully automated and their quality continues to improve each year. NCEP currently uses the operational cloud-drift winds in their initial analyses over oceanic regions. Automated techniques for correcting occasional inconsistencies in image navigation during wind production cycles should become operational in the fall of 1996, further improving the quality of the product. Finally, once new computing resources are available to NESDIS in the fall of 1996, the operational winds products will be produced at a much higher density, yielding approximately ten times as many vectors.

VI. Acknowledgements

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VII. References

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