# THE CURRENT STAGE OF DEVELOPMENT OF A METHOD OF PRODUCING CLOUD MOTION VECTORS AT HIGH LATITUDES FROM NOAA SATELLITES

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ABSTRACT

Cloud motion vectors can be measured using satellite images from the NOAA series of polar orbiting satellites. These vectors have been produced occasionally in a research mode for the past year. The vectors are probably slightly lower in quality as compared to those produced by geostationary satellites due to the longer interval between images. However positive impact on analyses at high latitudes can be large, especially where no other data are available.

Using the WINDCO programs on the McIDAS computer at the University of Wisconsin, cloud motion vectors can be obtained from a pair of orbits. Virtually every pair of consecutive passes over the poles can be used to measure these motions, but the resulting vectors have their greatest applicability if close in time to upper air synoptic observation times so they may be used in synoptic analyses.

In order to use the computer to process the satellite images, their rectification to a standard grid such as a polar stereographic map projection is necessary. The evolution of precise navigation systems now permits relatively reliable locating of position within the images, which reduces the error in the final vectors. In the winter with surface temperatures commonly lower than 30 degrees centigrade below freezing, enhancement of pictures over the total gray scale range is necessary for the human observer to see significant features of the clouds over the ice fields.

The WINDCO system selects likely targets for tracking, and attempts to find these same clouds on a later image from another pass. The wise use of computer resources mandates an efficient algorithm be used in searching for a match in the cloud patterns over the time interval. With present computer resources, the method is guided by using a first guess to search for a match in only a limited area. However the quality of the vectors measured depends on the quality of the first guess. After the vectors have been produced they can be edited and supplemented manually. Comparison of cloud motion vectors with collocated radiosondes shows an rms of 6.0 mps.

1. INTRODUCTION

Geostationary satellites have been used to measure cloud motion vectors for the last two decades. These provide information on the wind flow to about 55°N. How can one get cloud motion vectors at higher latitudes?

Polar orbiting satellites have long been considered a possible source of this type of information (Shenk and Kreins, 1969). However the usage of these vectors has been confined to research purposes until recently. Turner and Warren, (1989) and Herman (1989) have shown the possibilities of using automated systems to measure cloud motions at high latitudes.

A computer program known as WINDCO was developed by Smith and Phillips (1972), and converted to an automated system by Stewart, et al. (1985). This program is applied to AVHRR data from the NOAA series of satellites to measure cloud motion vectors at the University of Wisconsin.

Some of the details of the use of the technique of measuring cloud motions at high latitudes are given in this paper. Examples of the coverage at high latitudes are shown. In regions where cloudiness is too uniform or barely discernable, an enhancement is described showing how additional cloud vectors can be obtained. Comparisons of some measured cloud motions with radiosonde data indicate their reliability.

2. METHOD OF OPERATION

The NOAA satellite series are polar orbiters which pass over the north pole every 100 minutes. Resolution is 1 km for Local Area Coverage (LAC) or 3 by 5 km for Global Area Coverage (GAC). The width of each scan of the AVHRR instrument is about 2500 km.. This coverage permits viewing of the poles on each orbit, and almost completely overlapping coverage on three successive orbits equatorward to 70 degrees. From that latitude it is possible to obtain complete coverage from two orbits down to about 58 degrees latitude. At that latitude a gap in coverage begins and grows until the width of coverage at the equator is only about 30 km.

Satellite images are ingested into the McIDAS computer system for the computation of cloud motion vectors. These images are rectified to a polar stereographic projection in

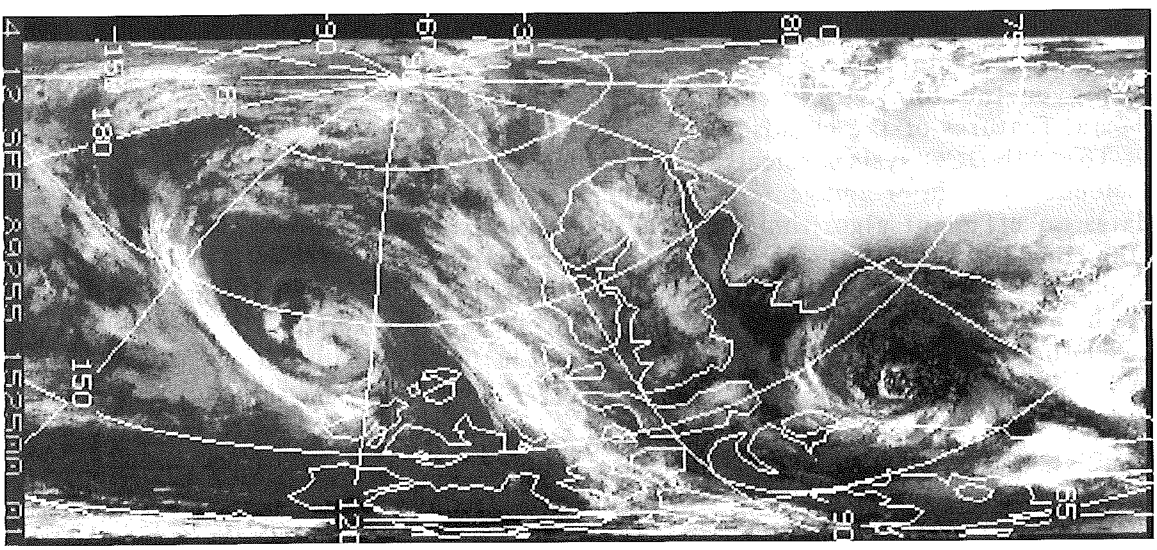


Fig. 1. Partial Arctic orbit from original enhanced NOAA-11 AVHRR GAC 10.7 micrometer image for 1525GMT September 12, 1989.

order to provide a common map for the WINDCO program. For visual tracking of a loop-like sequence the images are also enhanced by expanding the gray scale over the narrower range of temperatures found at high latitudes. The area scanned on each orbit amounts to more than half of the Arctic region. An example of part of the area of coverage in the Arctic on one orbit is shown in figure 1. The image has been enhanced to better define the different cloud temperatures. Coverage of about half the Arctic can be obtained from two successive orbits.

The WINDCO program operates in two phases. In the first phase likely cloud targets are selected. These targets are either the coldest clouds or are near regions where the gradient is strong. A sample is selected from all areas of the image unless gradients are small due to either a lack of clouds or uniformity of cloudiness. The second phase of the program uses a first guess to determine the most likely area to which the cloud has moved in the given time interval. A search is made for the best correlation fit between the two images in the vicinity. The best match between the two images for that target is selected and the cloud motion is measured relative to that displacement.

Figure 2 shows the enhanced, rectified image for part of the same region as in figure 1 depicting two cyclonic storms. The cloud motions made from this and the succeeding orbit are plotted on the picture. Low and middle level cloud vectors are shown in white and high cloud motions are in black. The circulation center near 79°N and 154°W is not well defined by the cloud motion vectors, probably due to two causes. First the disturbance is moving toward northern Canada from the west and has not yet passed over any radiosonde stations there. As a result, the first guess used in this case has miss-located the circulation center about 120 nm to the northwest of its cloud position. Secondly, the tightly wound circulation, together with the first guess caused the correlation routine to fail to produce cloud vectors where the cloud curvature indicates northeast winds.

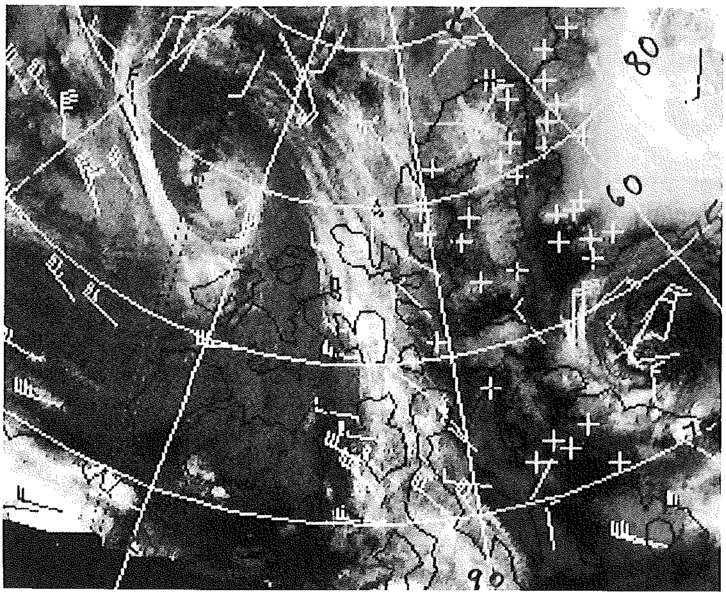


Fig. 2. Cloud motion vectors (in knots) overlaid on remapped enhanced NOAA-11 AVHRR GAC 10.7 micrometer image for 1525GMT September 12,1989. Low and middle cloud motion vectors in white, high cmv in black.

In most other cases when clouds are present, the system works well, however in the Arctic Ocean with cold temperatures and little moisture available in the atmosphere clear skies frequently occur. In that case the program may make matches with snow or ice features on the surface. Generally these are indicated by stationary or low velocity vectors. To avoid this as a practical matter, vectors less than 3 mps are discarded during winter. In figure 2 some of the mountains and snow fields of Ellsmere Island and Greenland have produced false, nearly calm, cloud motion vectors.

## 3. ACCURACY OF POSITIONING

In order for the WINDCO program to operate correctly, the AVHRR images must be translated from the satellite projection into a suitable uniform projection. For high latitudes the most favorable projection is a polar stereographic, while at middle and low latitudes a Mercator projection is preferred. For the most part the geographic positioning of landmarks has been good to excellent. When the remapped pictures are used as a loop to depict motion, landmarks have moved very little in general.

Figure 3 shows a remapped enhanced picture from NOAA-11 of the Arctic Ocean area north of Alaska. The most interesting feature about the picture is the large number of lead lines in the ice which are seen as darker and warmer lines in the picture. Two of the more prominent lines are labeled A to B, and A to C. At this time an anticyclone was centered near 76.°N latitude and 177°W longitude.

The lead lines have practically no movement during the 3 hour movie loop period and are thus a good indicator of the stability of the gridding in the picture. The cloudiness is at low to middle altitudes and during the course of the loop the clouds pass over the lead lines with little or no obscuration of them. The warmest portion of the lead lines have temperatures of -20 degrees centigrade, while the majority of the gray clouds have temperatures of -33 degree centigrade. The darker clouds are in the inversion layer with temperatures around -26 degree centigrade. The northernmost portion of Alaska is seen near the bottom of the picture.

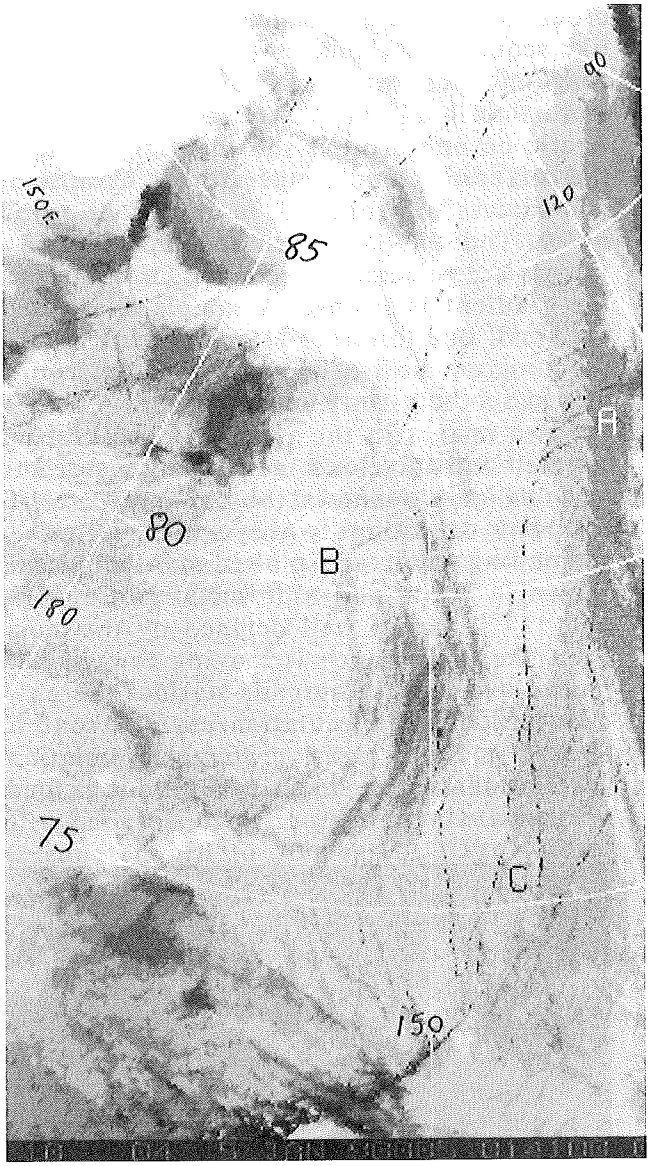


Fig. 3. Lead lines of remapped enhanced NOAA-11 AVHRR GAC 10.7 micrometer image for 0141GMT January 5, 1990.

## 4. DENSITY OF VECTOR OBSERVATIONS

One of the problems with using an automated technique for the selection of cloud targets is that the criteria for choosing a target have to be very specific. Certain limits are established in the computer program and these criteria can not be exceeded. In the Arctic, radiation from the very cold surface generally produces an inversion which creates difficulties for automated selection. This means there will be cases where clouds in the inversion zone will be warmer than the surface temperatures.

Another difficulty frequently encountered in the Arctic is that gradients at cloud edges appear to be less than those at lower latitudes. An example of this is shown for a cyclone over Hudson Bay in January in figure 4. The image is from NOAA-10 in the 11 micrometer window and has been rectified to a polar stereographic projection. The image has been enhanced to bring out as much detail as possible. The temperature range is from about -25 to -50 degrees centigrade.

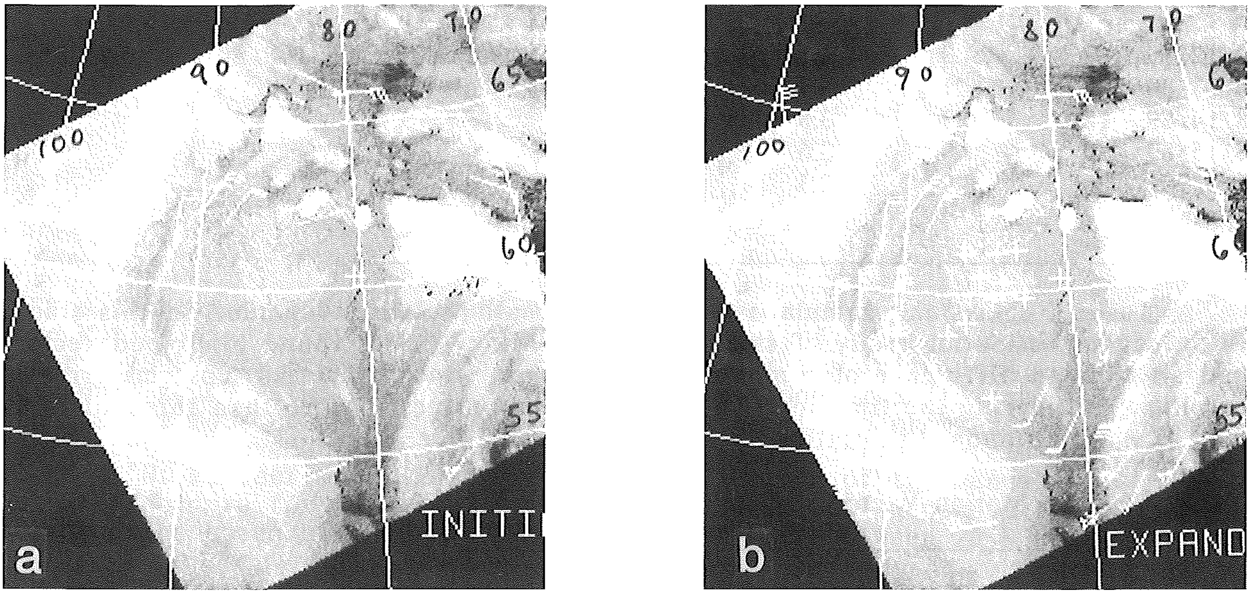


Fig. 4. Remapped NOAA-10 images in window channel for 2248 GMT January 27, 1991 showing the Hudson Bay region.
a. Original cloud motion vectors. b. Enhanced method used for selection of cloud motion vectors.

Figure 4a. shows the cloud motion vector locations measured in this case using the normal selection criteria. After these had been measured it was noted that there were additional cloud motions which seemed to be consistent with the first guess wind field's cyclonic flow over Hudson Bay. The few vectors (14) in figure 4a. do not adequately depict the circulation because there are too many areas where no targets were selected.

To remedy this, modifications of the target selector program were made. The first modification was to choose potential targets in all the areas where none had been selected on the first pass. The gradient criterion was then relaxed for these supplementary targets so that most were passed on for further processing. This increased the number of targets from 104 to 233, and the number of vectors that were produced by the correlation program increased from 14 to 60 (see figure 4b.). Although the amount of processing time used was more than doubled, the number of vectors more than quadrupled. The resulting flow pattern corresponded well to the NMC analyses (not shown).

## 5. VALIDATION

Cases from 5 days over northern Canada were selected for comparison with radiosonde winds. Table 1 lists the dates and the results of the wind comparisons. The first case is the one shown in figure 2, and the next three are from succeeding consecutive days, following the movement of the cyclonic storm. The last day has a larger number of comparisons because its images had a large number of small cloud elements. The overall majority of the clouds tracked were in the middle layer.

Table 1. Cloud Motion Vector Verification for Five Days

| Date | Number of vectors | Average vector diff. | Standard deviation | Root-mean square error |
|---|---|---|---|---|
| 8/12/89 | 7 | 4.2 | 3.1 | 5.2 |
| 8/13/89 | 9 | 7.1 | 3.7 | 8.0 |
| 8/14/89 | 18 | 6.3 | 3.8 | 7.4 |
| 8/15/89 | 8 | 7.0 | 3.6 | 7.9 |
| 6/6/90 | 36 | 3.9 | 2.3 | 4.5 mps |
| Total | 78 | | | |

Table 2 shows the cumulative statistics for all the cases included in this study. In an earlier validation study of satellite winds Whitney (1982) found low cloud vectors had an average difference of 5 mps from radiosonde winds. The 6.0 mps rms error is excellent considering the time interval between polar images is more than three times as long as that of standard geostationary images.

Table 2. Cloud Motion Vector Statistics for the Five-day Period

| Average vector diff. | Standard deviation | Root-mean square error |
|---|---|---|
| 5.2 | 3.0 | 6.0 mps |

## 6. CONCLUSION

The measurement of cloud motion vectors using the WINDCO method produces useful information from polar orbiting satellites. Further improvements in the system for Arctic conditions are under development.

## 7. REFERENCES


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