HIGH LATITUDE ATMOSPHERIC MOTION VECTORS: APPLICATION OF ANTARCTIC AND ARCTIC COMPOSITE SATELLITE IMAGERY

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Abstract

Deriving atmospheric motion vectors (AMV) from satellite observations has been successfully done for many years from geostationary platform (Velden et al., 2005) and more recently from polar orbiting platform (Key et al., 2003). However, from the point of view of the Antarctic, there is a gap in coverage between these two wind sets as depicted in figure 1. This has inspired an investigation of using Antarctic composite imagery – a combination of geostationary and polar orbiting observations (Lazzara et al., 2003) – to see if it would be able to generate AMV.

One requirement for this investigation is to increase the temporal resolution of the infrared Antarctic composites by increasing them to an hourly composite, allowing winds to be calculated within similar ranges as the geostationary and polar orbiting satellites. This is a benefit for other research and operational users of the composite. These hourly composites, although already accessible on some AMRC/Wisconsin servers, will be made more broadly available to the community in the upcoming months. The successful creation of hourly infrared composites over the Antarctic and adjacent Southern Ocean will have a ripple effect on other composites made over the Antarctic and Arctic (Lazzara and Knuth, 2009) as increases in their temporal resolution are planned in the near future.

This investigation is still in progress. AMV are successfully being calculated and derived from the composite observations (see figure 2). While the composites have the strength of observations from both geostationary and polar-orbiting platforms, it is not yet clear how well the AMV will validate as compared to the very limited radiosonde observations and aircraft reports in the Southern Hemisphere. While verification and validation activities are currently on-going, it is expected to continue this activity through the upcoming 2010-2011 field season. This bring rise to the critical importance of aircraft reports (AIREPs) from US Antarctic Program aircraft (e.g. 109th New York Air National Guard LC-130s, Royal New Zealand Air Force C-130, US Air Force C-17) and other aircraft that fly missions between the middle latitudes and the Antarctic. Their observations of wind enroute has the potential to provide a significant set of validating observations needed to determine if the composite AMVs will be on the order of accuracy as its cousin polar orbiting and geostationary wind sets.

1. INTRODUCTION

Wind information has been estimated with geostationary satellite data for many years (Velden et al., 2005) and more recently using polar-orbiting satellites (Key et al., 2003). However, from the point of view of the Antarctic and Arctic, there is a latitudinal gap in coverage between these two wind sets as depicted in Figure 1.

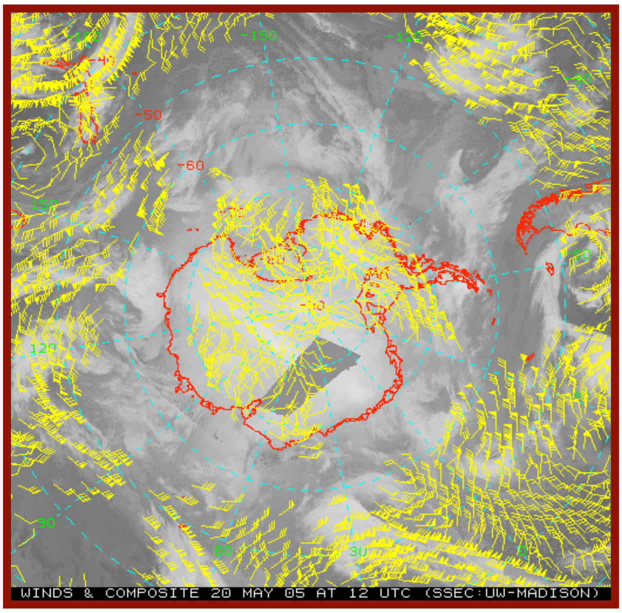

***Figure 1*. A sample Antarctic composite with geostationary and polar orbiting satellite derived atmospheric motion vectors plotted, which reveal the "ring" of missing observations about the continent.**

This has inspired an investigation using Antarctic composite imagery – a combination of geostationary and polar orbiting observations (Lazzara et al., 2003) – for the generation of atmospheric motion vectors (AMV).

AMVs are being derived routinely from hourly Antarctic composite images to build a dataset large enough to assess the quality of the winds. While the composites have the strength of observations from both geostationary and polar-orbiting platforms, it is not yet clear how accurate the wind information is, given the very limited rawinsonde and aircraft data in the Southern Hemisphere that can be used for validation. Initial comparisons with rawinsonde and aircraft wind observations indicate a vector root mean squared error that is higher than typical satellite-derived AMVs. This is most likely due to assigning a single time to the composite, which is made of data +/- 30 minutes from a nominal time. The varying times within images will be accounted for in a future release of the winds derivation software, which is expected to reduce the error.

While verification and validation activities are currently ongoing, it is expected that this activity will continue through the upcoming 2010-2011 field season. This brings rise to the critical importance of aircraft reports (AIREPs) from US Antarctic Program aircraft and other aircraft that fly missions between the middle latitudes and the Antarctic. Their observations of winds enroute has the potential to provide a significant set of validating observations needed to determine if the composite AMVs will be on the order of accuracy as its cousin polar-orbiting and geostationary wind sets. Similar datasets will be utilized for the Arctic verification and validation, where additional rawinsonde observations will be of help in evaluating the AMVs.

2. SATELLITE COMPOSITES

Satellite composites have been generated at the University of Wisconsin over the Antarctic for over eighteen years (Lazzara et al. 2003), and over the Arctic in the last few years (Lazzara and Knuth, 2009). These composites are a mosaic of satellite observations from both polar and geostationary orbit. The observational data once received at the University of Wisconsin is then cleaned up for any bad lines of data and remapped into a standard polar stereographic projection, The space background is removed from the data. Finally, the data are merged, with geostationary first and polar orbiting last via a conditional minimum method, to take into account limb darkening considerations. The final composite is then made available for distribution and any post-processing.

A variety of meteorological satellites are used in making up the composites, including GOES, MTSAT, METEOSAT, FY-2, Aqua/Terra and NOAA series. Additional satellites are added as they are available, including Kalpana and GOES for South America (See figure 2).

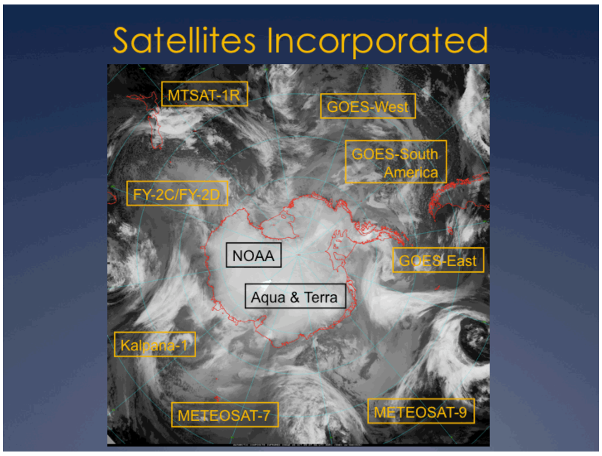

***Figure 2*. A sample composite image with the regions of the composite identified to show which satellite the observations originally are attributed.**

The composites are made in several spectral channels, including the infrared window channel, water vapor channel, shortwave and longwave infrared channels. Visible channel composites are under experimental investigation. The resolution of the resultant composite is a nominal five kilometers at the standard latitude of 60 degrees.

One requirement for this investigation is to increase the temporal resolution of the infrared Antarctic composites from three-hourly to hourly, thereby providing time increments small enough for wind-derived information on the same temporal scale as with geostationary satellites. This will also be a benefit for other research and operational users of the composite.. The improved methodology resulting in the successful creation of hourly infrared composites over the Antarctic and adjacent Southern Ocean will be applied to other composites made over the Antarctic and Arctic (Lazzara and Knuth, 2009), as increases in their temporal resolution are planned in the near future.

3. COMPOSITE CLOUD MOTION VECTORS

The Composite Cloud Motion Vectors (CCMVs) are developed using the same technique used in Key et al., 2003, and an example is given in Figure 3. In addition, we are running the CCMV derivation parallel on two machines to do sensitivity testing. This allows for the comparison of two different settings, for example two search box sizes to be validated against each other. By doing this we can find the settings that maximize the quality of the CCMVs.

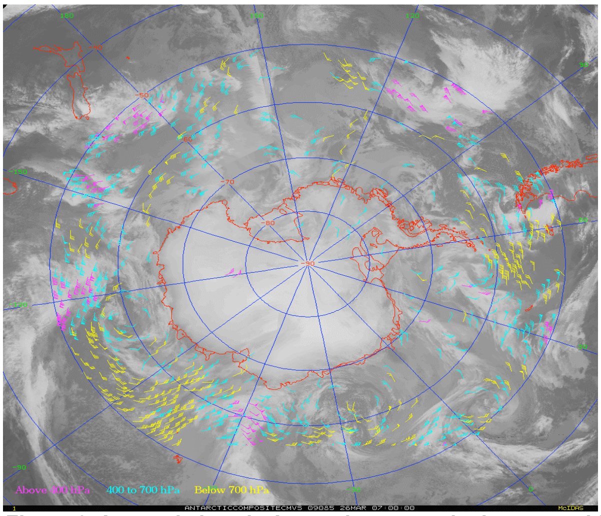

Figure 3. **A sample hourly Antarctic composite imagery with corresponding atmospheric motion vectors from 7 UTC on 26 March 2009.**

4. VALIDATION

AMVs are being derived routinely from the composite observations to build a dataset large enough to assess the quality of the winds on two different settings. While the composites have the strength of observations from both geostationary and polar-orbiting platforms, it is not yet clear how accurate the wind information is in the data void regions (Figure 1), given the very limited radiosonde and aircraft data in the aforementioned region that can be used for validation. Initial comparisons with radiosonde and limited aircraft wind observations indicate a vector root mean squared error of 8.5 ms^{-1}. Statistics given in Table 1 indicate an increase in average vector difference, vector and speed RMS with height. The speed bias is negative or slow below 500 hPa, however, it becomes slightly positive or fast at higher levels. On the other hand, the normalized vector RMS or VNRMS indicates a slightly better quality overall above 500 hPa. This is especially seen when the ckcirrus routine is removed due to a 3 ms^{-1} decrease in Vector RMS, resulting in a 10% improvement in the CCMV's VNRMS above 500 hPa .

	>=850 hPa	**850> to 500 hPa**	**Above 500 hPa**
Vector RMS	**4.89**	**6.48**	**9.46**
Vector Diff.	**4.37**	**5.50**	**7.96**
Speed RMS	**2.80**	**4.87**	**6.49**
Speed Bias	**-1.66**	**-0.35**	**+0.06**
AVHRR Spd	**15.49**	**18.88**	**33.98**
VNRMS	**.29**	**.34**	**.28**
Sample Size	**21**	**135**	**207**

Table 1. **Initial validation statistics of the CCMVs without ckcirrus routine.**

However, it is important to mention that tests to optimize the quality of the AMVs are currently being worked on and show promise in improving the results seen in Table 1. While verification and validation activities are currently ongoing, it is expected that this activity will continue through the upcoming 2010-2011 field season. This includes aircraft reports (AIREPs) from US Antarctic Program aircraft (e.g. 109th New York Air National Guard LC-130s, Royal New Zealand Air Force C-130, US Air Force C-17) and other aircraft that fly missions between the middle latitudes and the Antarctic. Their observations of winds enroute has the potential to provide a significant set of validating observations in the all important wind data void region, needed to determine if the composite AMVs will be on the order of accuracy as its cousin polar-orbiting and geostationary wind sets.

5. SUMMARY

Antarctic satellite composites have been used to demonstrate the ability to compute Atmospheric Motion Vectors, a derived quantity that is possible with the advent of hourly composites. These CCMVs represent the first potential to fill in an observational gap left by geostationary and polar orbiting satellite AMV data sets. The resultant CCMVs have been initially validated against weather balloon observations and aircraft reports in the Southern Hemisphere and Antarctic. The initial results show that the validation quality is much improved, especially above 500 hPa, when the software routine ckcirrus has been removed. This effort has revealed how important time stamping of the data is toward the resulting AMVs. Tests with MODIS mix winds offer an example of the resultant sensitivity caused with varying cross time stamps in Figure 4. While composite AMVs are not yet ready for model data assimilation, it is hoped that this work in progress will leave to that in the future.

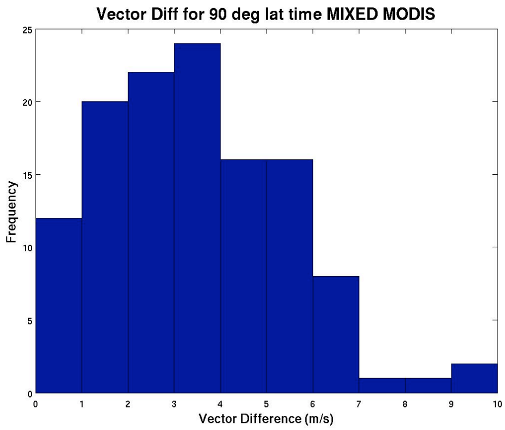

Figure 4. **Case study vector difference comparison of Mixed Modis AMV with closest 90 degree latitude crossing time stamp to Operational TERRA MODIS AMV.**

6. FUTURE WORK

This effort continues, as additional satellites are being added to the composite including FY-2D/FY-2E, NOAA-19, and MetOp-A. Arctic composite winds are now being generated and will expand this investigation to both polar regions. Focus will now turn toward testing techniques for optimal spatial and temporal resolution of the satellites. Time tracking of the satellite information to be used as auxiliary metadata information for computing the wind vectors is expected to improve the quality of the resulting AMVs. Issues such as parallax that are not being considered will be taken into account. All of these changes are expected to impact the AMV derivation software, and hence modifications will need to be made to incorporate these changes. Finally, validation efforts will continue, utilizing both traditional radiosonde observations and available aircraft observations.

8. ACKNOWLEDGEMENTS

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