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IWW7 REPORT ON THE DERIVATION OF AMVS FROM HIGH SPECTRAL SOUNDINGS

Summary and Purpose of Document

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CLOUD-DRIFT AND WATER VAPOR WINDS IN THE POLAR REGIONS FROM MODIS AND AIRS

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Abstract

Atmospheric Motion Vectors (AMVs) have been generated with data from geostationary satellites for over 20 years, and are used in numerical weather prediction systems. However, because geostationary satellites do not provide wind information poleward of the midlatitudes and the high-latitude rawinsonde network is sparse, the polar regions remain data poor in terms of wind observations. This paper reports on the status of a project for deriving tropospheric wind information at high latitudes from polar-orbiting satellite imagers, in particular the Moderate Resolution Imaging Spectroradiometer (MODIS). Terra and Aqua MODIS data will be combined in the same processing stream in the near future, providing more timely data at certain times of the day. Preliminary tests show that winds from the Atmospheric InfraRed Sounder (AIRS) are in general agreement with MODIS winds, but at a much lower density. Experiments with one direct broadcast site demonstrate that delay in obtaining MODIS data can be reduced substantially. Lastly, model impact studies from seven numerical weather prediction centers continue to show an overall positive impact of the MODIS winds on weather forecasts.

1. Introduction

In early 2001 a project was begun to derive tropospheric motion vectors (wind speed, direction, and height) using the Moderate Resolution Imaging Spectroradiometer (MODIS) on-board the National Aeronautics and Space Administration's (NASA) polar-orbiting Terra and Aqua satellites. Real-time generation of polar winds with Terra MODIS data began in mid-2002; real-time generation of Aqua MODIS data began later that year. In January 2003, the European Centre for Medium-Range Weather Forecasts (ECMWF) incorporated the MODIS winds into their operational forecast system. The winds are also used in the NASA Global Modeling and Assimilation Office's (GMAO) operational system. This paper describes planned improvements to the retrieval methodology, a first test with the Atmospheric InfraRed Sounder (AIRS), real-time data acquisition, and model impact studies.

2. Methodology

Cloud and water vapor tracking with MODIS data is based on the established procedure used for GOES, which is described in Merrill (1989), Nieman et al. (1997), and Velden et al. (1997, 1998). With MODIS, cloud features are tracked in the infrared (IR) window band at 11 μm and water vapor (WV) features are tracked in the 6.7 μm band. After remapping the orbital data to a polar stereographic projection, potential tracking features are identified. Water vapor targets are selected in both cloudy and cloud-free regions. Additional details are provided in Key et al. (2003). No significant changes to the methodology have been made over the past year, though a number are planned. A parallax correction is currently being tested, and will be implemented in the second quarter of this year (2004). Improvements to wind vector height assignment are being investigated, as is the use of additional spectral channels, primarily in the near-infrared portion of the spectrum. The impact of different first guess model fields on wind retrievals is being examined.

3. Terra and Aqua MODIS Winds

At present, winds from the Terra and Aqua satellites are generated separately. Some improvements in wind quality and timeliness could be obtained by combining imagery from the two satellites into the same processing stream. Figure 1 shows the frequency with which MODIS on the two satellites views a particular location on the surface over the course of a 24-hour period, as a function of latitude. At very high latitudes, the surface location is viewed on every overpass. In practice, data at extreme sensor scan angles would not be used so that the actual viewing frequency would be somewhat less. Nevertheless, there are multiple times per day when Terra and Aqua MODIS view the same location within a few minutes of each other.

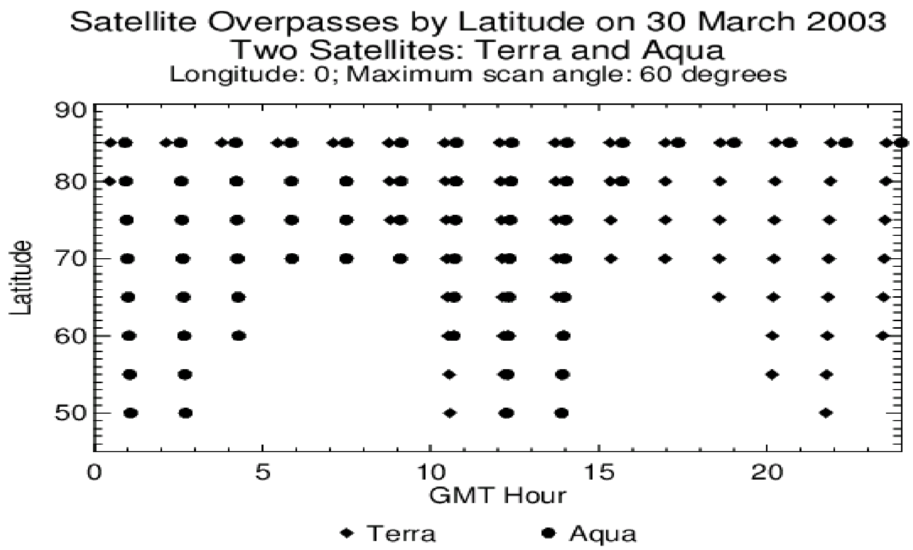

Figure 1. Frequency with which Terra and Aqua MODIS view a spot on the earth as a function of latitude over the course of a 24-hour period.

Both satellites will be incorporated into the same processing stream in the near-future, probably in the third quarter of 2004. This will require that imagery be corrected for parallax, as the two satellites will view the same cloud or water vapor features from different angles. Without a parallax correction, errors in location, and therefore wind speed and direction, can be significant.

4. Winds from AIRS

A preliminary study of wind retrieval using AIRS has been undertaken. In this study, features are tracked in *radiance space* in the same manner as with MODIS. Another possibility is to track features in *retrieval space*; i.e., track water vapor features in retrievals of the water vapor profile. In theory, tracking in retrieval space improves the height assignment. Research in this area is underway.

Figure 2 shows the area of overlap for three successive orbits for Aqua MODIS and AIRS. The area of overlap is the area for which winds can be generated, which is smaller for AIRS than for MODIS. Figure 3 gives an example of winds from AIRS by tracking water vapor features in radiance space. For MODIS, tracking is done at a 2 km resolution; for AIRS 16 km (13.5 km subpoint resolution) data are used. Overall the wind speeds and directions are in fair agreement, the most obvious difference being the much lower density of AIRS winds. The quality control step is reducing the number of vectors, possibly as a result of the different spatial resolutions. Spatial resolution might also be the primary factor in wind speed differences. A single AIRS (very narrow) channel was used in the tracking; AMVs are mostly are in a layer from 450 to 650 hPa. These results are preliminary and much more work is planned. In future studies a range of AIRS channels will be convolved for consistency with the MODIS band. Ultimately the goal is to track features in the AIRS moisture profile retrieval fields so that height assignment is specified before feature tacking.

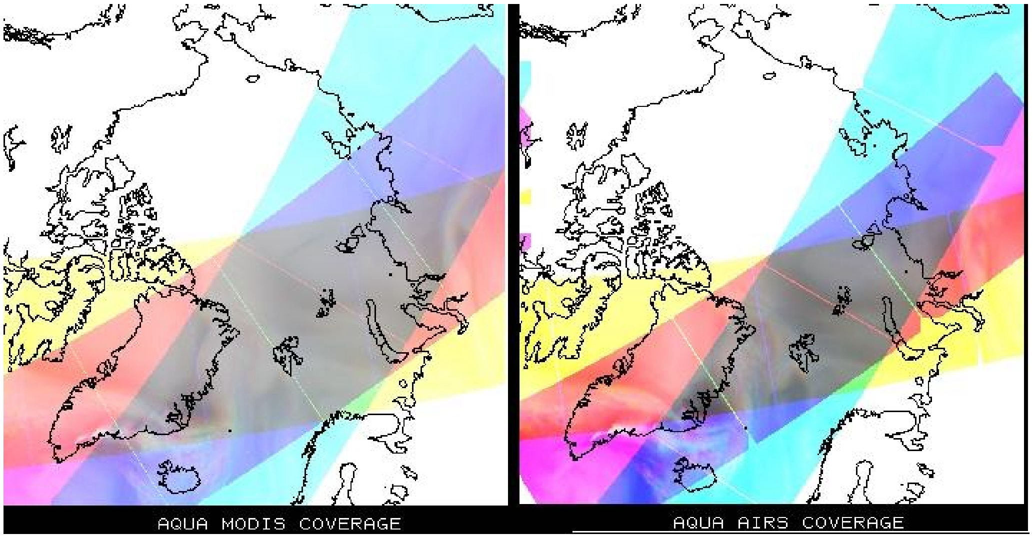

Figure 2. Overlap of three successive orbits for MODIS (left) and AIRS (right). The area of overlap can be used for wind retrievals. Note that AIRS coverage is less than MODIS coverage.

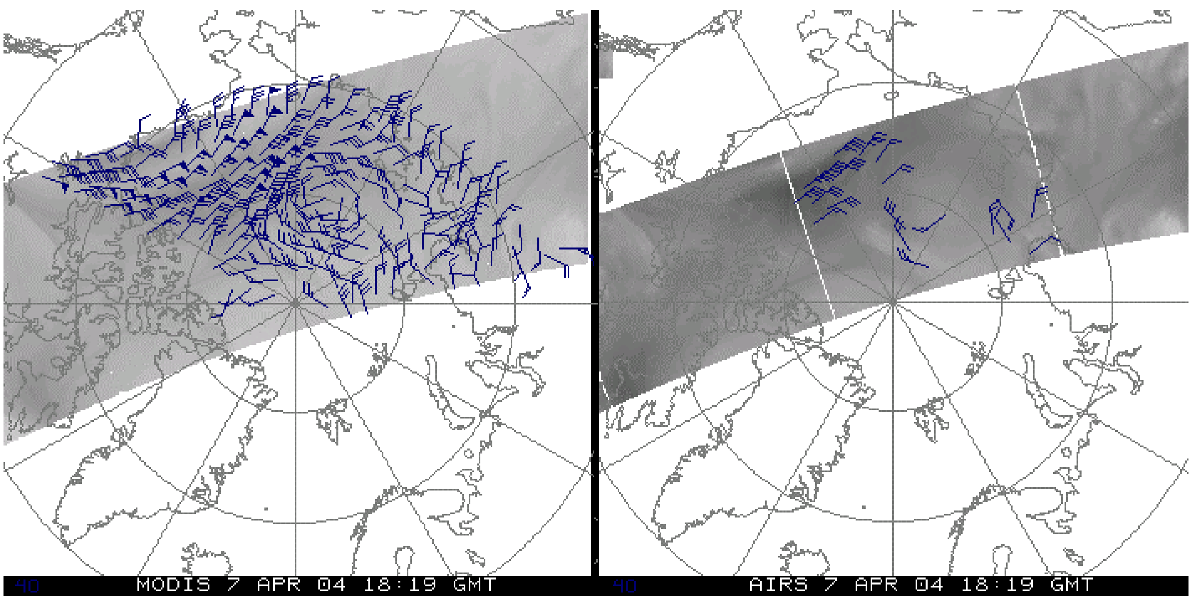

Figure 3. Winds from Aqua MODIS (left) and AIRS (right) over a portion of the Arctic on 4 April 2004.

5. Data Acquisition

Generally, the final winds product lags observing time (the time MODIS views an area) by about 3-5 hours (Figure 4). The lag is largely due to the delay in the availability of the raw (level 1B) MODIS data. MODIS data are acquired from the NASA Goddard Space Flight Center via a NOAA computer system (the NOAA “bent pipe”). An example of the delays in the availability of MODIS granules – 5 minute orbital segments – is shown in Figure 5 for Aqua MODIS. Delays are somewhat less for Terra than for Aqua.

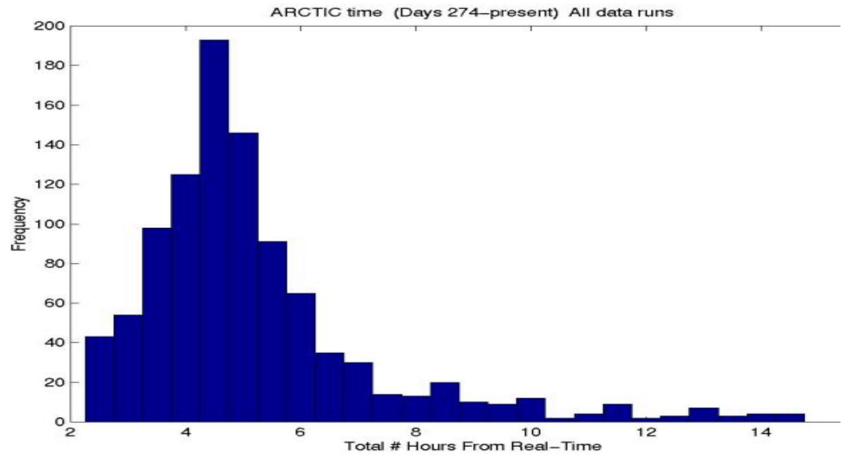

Figure 4. Frequency of the delay between the time of MODIS data acquisition (observation time) and the completion of the polar winds processing, including reprocessed image triplets. The average delay is in the 3-5 hours. Data are from January through August 2003.

The 3-5 hour delay in the availability of wind information is too long for many regional or limited area data assimilation systems. It may be possible to reduce the delay by obtaining data from direct broadcast (DB) sites. A collaboration has been established with the European Space Agency (ESA) regarding the acquisition of data from the DB site at Kiruna, Sweden. A two-week experiment gave promising results. Figure 6 compares the delay in obtaining Terra MODIS data through our current procedure and directly from Kiruna. For the area within the Kiruna station mask, the time delay can be reduced by approximately 1.5 hours on average.

Other direct broadcast sites being considered for direct MODIS acquisition include Svalbard, Norway, Fairbanks, Alaska, and McMurdo, Antarctica.

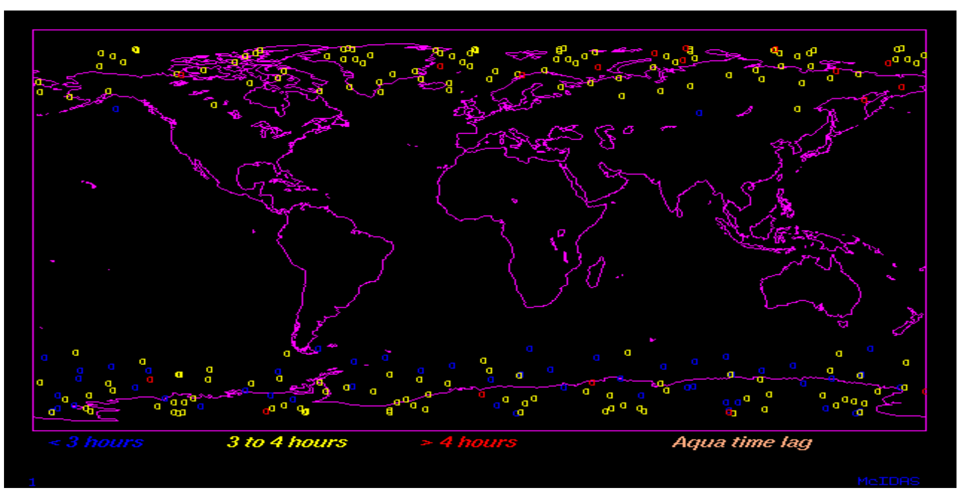

Figure 5. Time delay in the availability of Terra MODIS data, where the delay is the time between the image time and the time a granule is available on the NOAA "bent pipe". This histogram of time delays is for the south polar region.

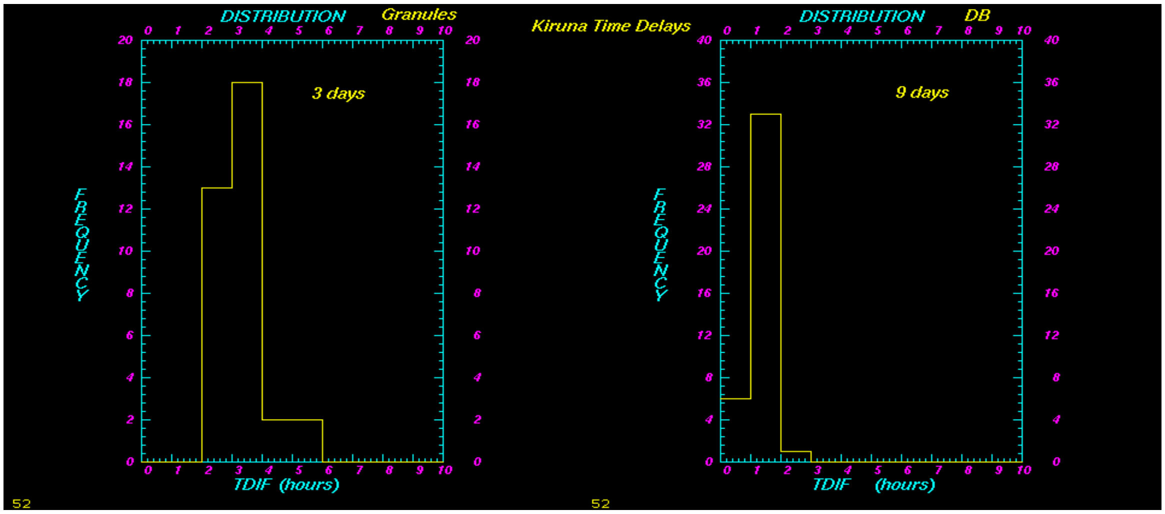

Figure 6. Terra MODIS data acquisition delays for the area covered by the Kiruna, Sweden direct broadcast station mask through the NOAA “bent pipe” (left) and directly from Kiruna (right). The mode is approximately 3 hours for the bent pipe and 1.5 hours for Kiruna.

6. Model Impact Studies

Given the sparsity of wind observations in the polar regions, satellite-derived polar wind information has the potential to improve forecasts in polar and sub-polar areas. Model impact studies continue to be performed at seven numerical weather prediction (NWP) centers:

- European Center for Medium-Range Weather Forecasts (ECMWF)
- NASA Global Modeling and Assimilation Office (GMAO)
- (UK) Met Office
- Canadian Meteorological Centre (CMC)
- Japan Meteorological Agency (JMA)
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC)
- Deutscher Wetterdienst (DWD) – Obtaining real-time winds

ECMWF and GMAO are using the MODIS winds in their operational systems. The other NWP centers are using the winds in experimental systems; some plan to incorporate them into their operational systems in the near future. The National Centers for Environmental Prediction’s (NCEP) Evironmental Model Center is currently formulating a polar winds impact study.

Overall, the impact of the MODIS polar winds on numerical weather forecasts is positive. Most centers have demonstrated a positive impact in the Arctic and Antarctic. Results for the Northern and Southern Hemisphere (poleward of 20 degrees latitude) vary, in some cases positive and in other cases negative or neutral. Impact studies will continue.

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