A Blended Polar Winds Product using Atmospheric Motion Vectors from MODIS Imager and AIRS Moisture Retrieval Data

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Year 2 Progress Report
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Proposed Work

The study and generation of polar winds from the Moderate Resolution Imaging Spectroradiometer (MODIS) imagery was pioneered at the University of Wisconsin by NOAA and the Cooperative Institute for Meteorological Satellite Studies (CIMSS) in the early 2000s. The MODIS polar winds product is composed of both infrared window (IR-W) and water vapor (WV) tracked features, resulting in atmospheric motion vectors (AMVs). The WV AMVs are only attainable at mid- and upper- tropospheric levels due to the MODIS WV atmospheric contribution function, while IR-W images also provide cloud tracers for vectors at lower levels. However, the WV AMVs yield a better spatial distribution than the IR-W since both cloud and clear-sky features can be tracked in the WV images.

As the next generation polar satellite era approaches, it is recognized that there is currently no WV channel planned on the Visible/Infrared Imager/Radiometer Suite (VIIRS), potentially resulting in a data gap with only IR-W derived AMVs possible. This scenario presents itself as an opportunity to investigate using Single Field of View (SFOV) Atmospheric Infrared Sounder (AIRS) moisture retrievals from consecutive overlapping polar passes to extract atmospheric motion from clear-sky regions on constant (and known) pressure surfaces; i.e., estimating winds in retrieval space rather than radiance space.

The goal is to generate a blended product of MODIS imager- and AIRS retrieval-derived AMV datasets. This will be important in preparation for the NPOESS Preparatory Project (NPP) where moisture retrievals derived using the Cross-Track Infrared Sounder (CrIS) could provide the fields to produce clear-sky AMVs.

We propose to:

- Determine to what extent AIRS-derived AMVs can provide coherent and good quality wind information, and characterize the errors. This technique has the potential to provide a 3-dimensional (profiles of wind) dataset, which would improve on the traditional cloud drift AMVs, while also addressing issues with AMV height determination.
- Blend the experimental AIRS moisture retrieval AMVs with the already proven MODIS AMVs in an optimal way to create superior 3-D polar wind fields.
- Perform NWP experiments with the blended product to determine the overall impact on numerical forecasts, and the relative contributions of each data type (MODIS vs. AIRS).

Year 2 Plans

Year 2 plans from the proposal:

Perform NWP experiments with the blended product to determine the overall impact on numerical forecasts, and the relative contributions of each data type (MODIS vs. AIRS). These experiments will be run at the NASA GMAO.

Year 2 Accomplishments

This is the status as of 30 November 2012.

During the second year we:

- Installed the 26 November 2012 International MODIS and AIRS Processing Package (IMAPP) software to process SFOV AIRS radiances to vertical profiles of temperature and humidity. This update results in less noisy moisture and ozone images.
- Modified the procedure to create images of moisture and ozone from the vertical profiles. Previously, a low pass filter was applied to the images to reduce the noise. Now, a bi-linear interpolation is applied to the image data to smooth the gradients between individual pixels. This artificially increases the image resolution from 16 km to 4 km. However, the cross correlation used in the winds algorithm is much better behaved at this resolution with smoother gradients.
- Generated two seasons of AIRS retrieval AMVs: 02 December 2011 to 09 January 2012 (winter) and 14 June to 31 July 2012 (summer).
- Retrieved from our archive the Aqua MODIS AMVs for the same time period, as above.

During the northern hemisphere summer, there is more moisture (compared to winter) resulting in many features to track. During that time period, 650 wind sets were generated resulting in 164,000 AIRS moisture and 135,000 ozone AMVs (see Figure 1 for an example spatial distribution of one wind set). During that same time, nearly 3 million Aqua MODIS winds were generated (Figure 2 is an example of one MODIS wind set). The following preliminary statistics and results are based on this time period.

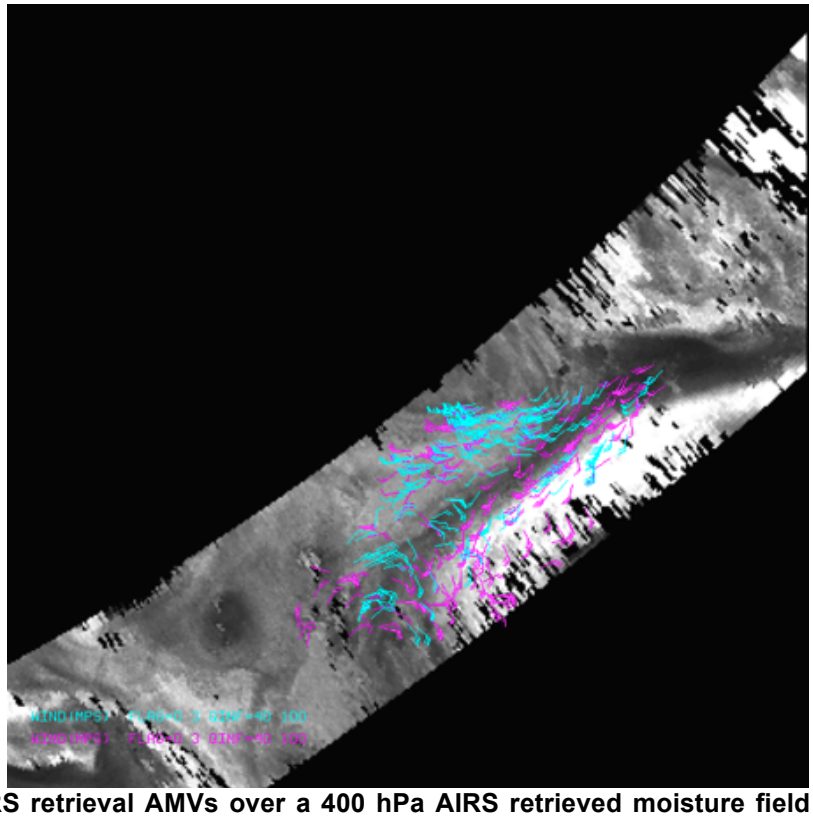

Figure 1. AIRS retrieval AMVs over a 400 hPa AIRS retrieved moisture field from 20 July 2012 0551 UTC. The north pole is in the center of the picture, with Greenland in the lower left region (not visible). These are all moisture and ozone tracked AMVs color coded by pressure level: yellow 700 to 1000 hPa; cyan 400 to 699 hPa; magenta above 399 hPa.

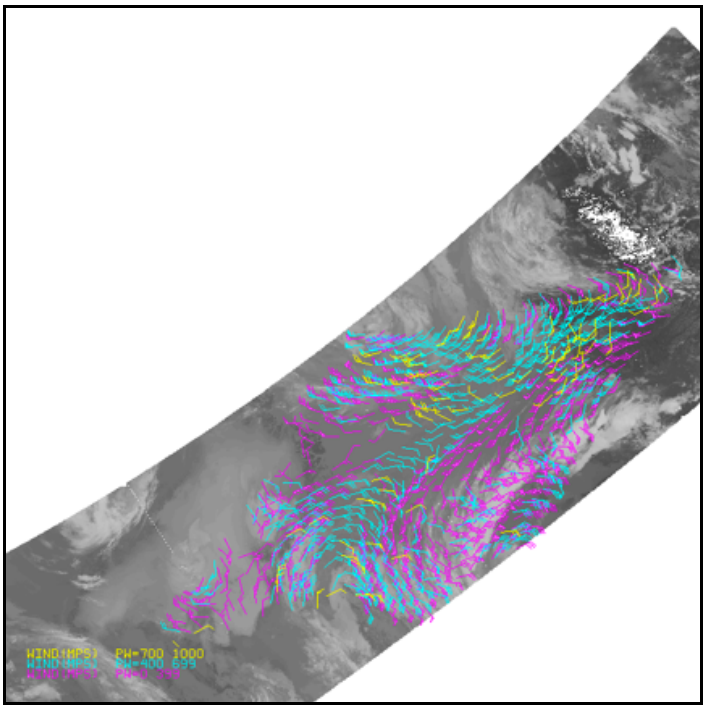

Figure 2. Same geographic region and time as Figure 1, with the Aqua MODIS AMVs displayed over a MODIS 11 micron image. The AMVs are from tracking clouds and features in both infrared and water vapor channels.

To compare co-located vectors from AIRS and MODIS AMVs, the following criteria were used:

- Located within 25 km
- Assigned pressure level within 15 hPa

This resulted in approximately 25,000 matches, or only 8% of the total AIRS winds. This percentage is low for two reasons: the AIRS AMVs are distributed vertically while the MODIS AMVs are at a single level at a specific geographic region and the AIRS dataset contains winds in the stratosphere.

Figure 3 depicts the distribution of the speed difference between the 25,000 matched AIRS and MODIS AMVs for the northern hemisphere summer. There is no bias (mean difference is -0.06 m/s) in this approximately Gaussian distribution.

The distribution of the pressure difference for co-located vectors is shown in Figure 4. The mean difference is nearly zero (-0.19 hPa) with a relatively even distribution from -15 to 15 hPa. Since the granularity in the MODIS AMVs is 12 hPa and the AIRS AMVs are on constant pressure surfaces, there are preferred difference values with higher and lower occurrences.

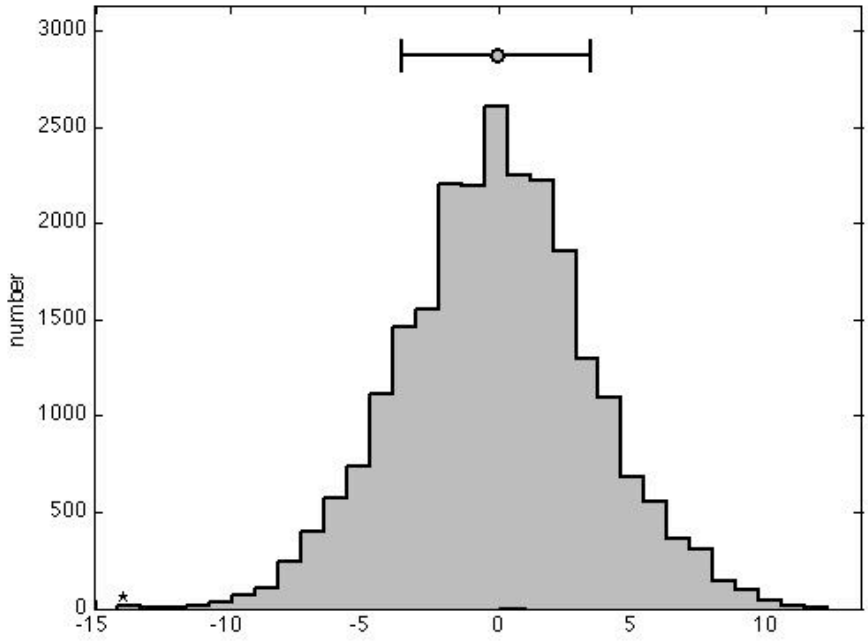

Figure 3. Histogram of the speed difference between co-located Aqua MODIS and AIRS retrieval AMVs. This is for the northern hemisphere summer: 14 June to 31 July 2012. Mean=-0.06 ms^{-1}; Standard Deviation=3.54 ms^{-1}.

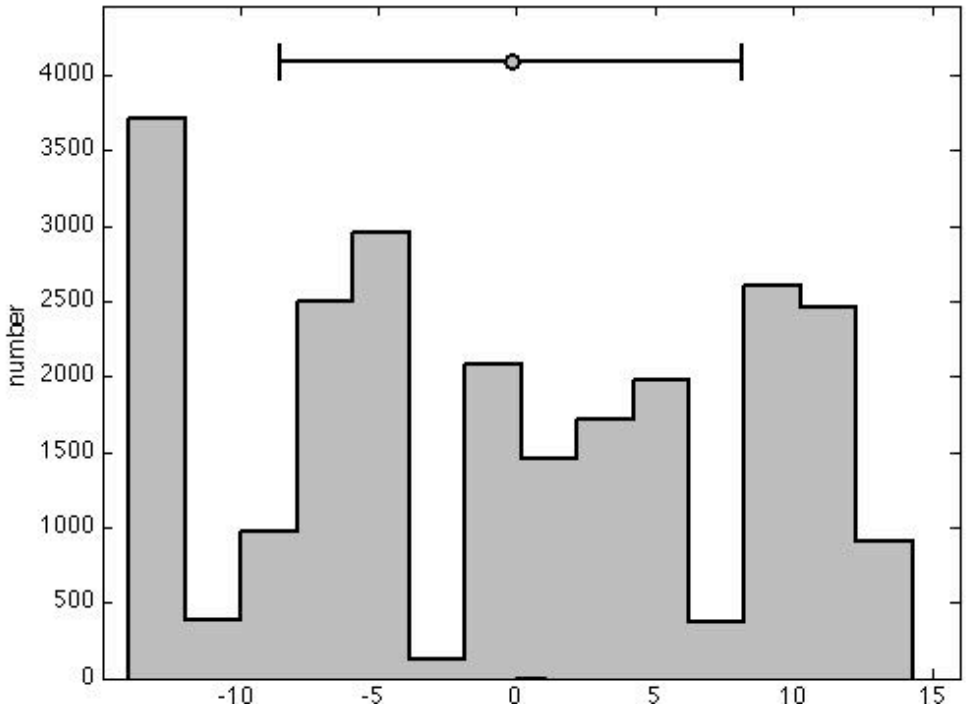

Figure 4. Histogram of the difference in AMV pressure levels between co-located Aqua MODIS and AIRS retrieval winds. This is for the northern hemisphere summer: 14 June to 31 July 2012. Mean=-0.19 hPa; Standard Deviation=8.35 hPa.

These preliminary results are encouraging for a number of reasons:

- The MODIS and AIRS co-located AMVs are similar and without a bias. The standard deviation of the speed difference was expected to be several meters per second, due to the different spatial resolution (2 km for MODIS vs. 16 km for AIRS).
- Only 8% of the MODIS and AIRS AMVs are co-located within 25 km and 15 hPa. For the quality control and blending of the two datasets, we will probably expand the spatial criteria. However, we expect the majority of the AIRS AMVs will be retained and provide additional information over just the MODIS AMVs, resulting in a measurable impact in the data assimilation and forecast experiments.

Conferences and workshops

Deriving Atmospheric Motion Vectors from AIRS Moisture Retrieval Data. 12th International Winds Workshop 20-24 Feb 2012, The University of Auckland, New Zealand.

Feature Tracked Winds from Moisture Fields Derived from Satellite Sounders. 2012 EUMETSAT Meteorological Satellite Conference. 3-7 September 2012. Sopot, Poland

Remaining plans

The winds datasets have been generated, the blending of the AIRS and MODIS winds is nearly complete, but the final task of evaluating the assimilation and forecast impact of the blended winds product in the GEOS-5 remains.

Accounts on the NCCS computers have been setup, computer time approved, and security training is complete. However, according to Tom Clune, the NCCS support staff cannot assist us in running the GEOS-5 in the configuration we need. He instructed us to contact Michele Rienecker, the director of the GMAO, to work with her group directly. Therefore, we are requesting a time extension to this project because the data assimilation and forecast experiments will be more difficult than originally planned.