Satellite-derived 3D winds from hyperspectral sounders: Derivation and impact in global models

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Abstract

The global measurement of 3D winds is recognized as an important dataset to improve medium- to long-range weather forecasts. At this time, vertical wind profiles through the troposphere are primarily from rawinsondes and aircraft ascents/descents, and are mostly confined to land areas. Wind information over mid- and low-latitude oceanic regions is limited to Atmospheric Motion Vectors (AMVs) from cloud and water vapor feature tracking using imagers on geostationary satellites. A similar technique is used with imagery from polar orbiting satellites over high-latitude regions. However, these geostationary and polar satellite-derived AMVs provide only single-level wind information at a particular geographic location.

To attain a 3D distribution of wind information, an AMV product is being developed based on tracking water vapor features retrieved from hyperspectral sounders. The retrievals produce spatial maps of humidity on pressure surfaces in clear sky and above clouds. The initial AMV product, available in near real-time, is based on retrievals from the Aqua Atmospheric Infrared Sounder (AIRS) and is being evaluated by several Numerical Weather Prediction (NWP) centers. Moreover, a two-month case of AMVs derived from IASI retrievals is currently being generated and analyzed.

The status of the project will be reported, along with a discussion on: (a) The 3D wind derivation technique as applied to AIRS and IASI; (b) assimilation statistics from the Gridpoint Statistical Interpolation (GSI) system; (c) and, the forecast impact in the Global Forecast System (GFS).

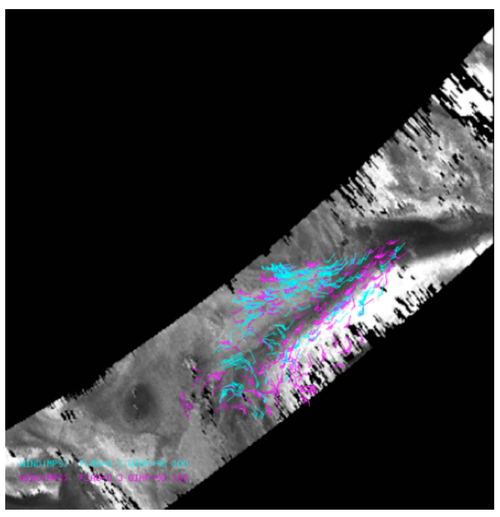
AIRS Retrievals

The AIRS Standard Retrieval Product provides profiles of retrieved temperature, water vapor, and ozone:
- Product generated from 3x3 Fields of View (FOV) of AIRS radiances
- Horizontal resolution of 40 km
- Too coarse for tracking features from successive orbits: One-pixel displacement = 6.7 ms^{-1}

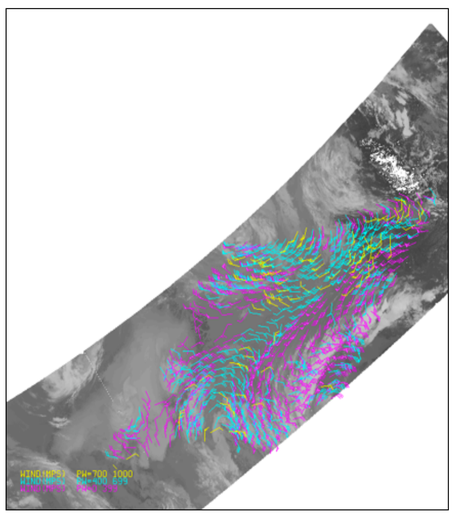
A similar algorithm was developed at SSEC using Single FOV (SFOV) AIRS footprints:
- University of Wisconsin-Madison CrIS, AIRS and IASI Hyperspectral Retrieval Software
- Distributed with the International MODIS/AIRS Processing Package (IMAPP)
- Retains the native horizontal resolution at 13.5 km/pixel
- Results in temperature, humidity, and ozone profiles at 101 pressure levels from 0.005 to 1100 hPa

Atmospheric Motion Vectors (AMVs)

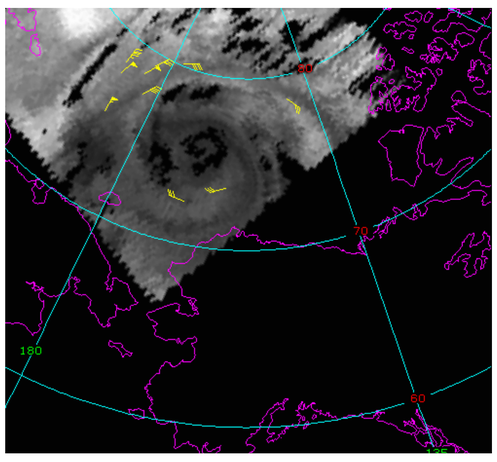
- AIRS moisture and ozone tracked AMVs (left) and MODIS infrared and water vapor AMVs (right)
- Wind barbs are color-coded by pressure level: yellow 700 to 1000 hPa; cyan 400 to 699 hPa; magenta above 399 hPa.
- The north pole is in the center of the picture, with Greenland in the lower left region (not visible).



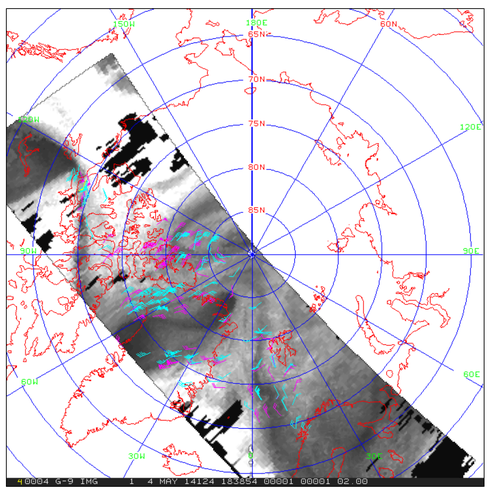
All AIRS retrieval AMVs displayed on a 400 hPa AIRS retrieved moisture field 20 July 2012 0551 UTC



MODIS AMVs on a MODIS IR image 20 July 2012 0551 UTC



Single level CrIS retrieval AMVs on a 390 hPa CrIS retrieved moisture field 1 September 2014 2117 UTC



All IASI retrieval AMVs displayed on a 400 hPa IASI retrieved moisture field 4 May 2014 1838 UTC

Acknowledgements

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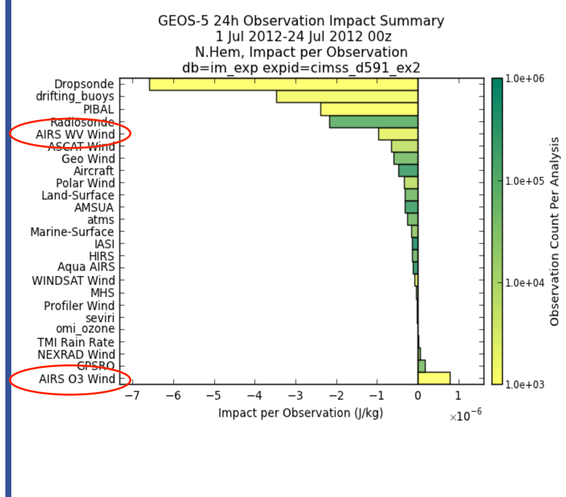
Assimilation: Impact per Observation

GEOS-5 24-hour Observation Impact
1-24 July 2012
Northern Hemisphere

Impact per observation is very good for the AIRS moisture AMVs: Ranked higher than all other satellite-derived wind datasets.

AIRS ozone AMVs have a negative impact: Likely due to the fast speed bias noted above.



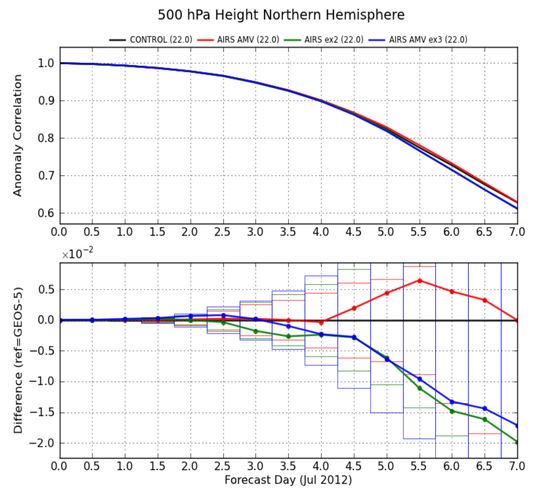
Forecast Impact

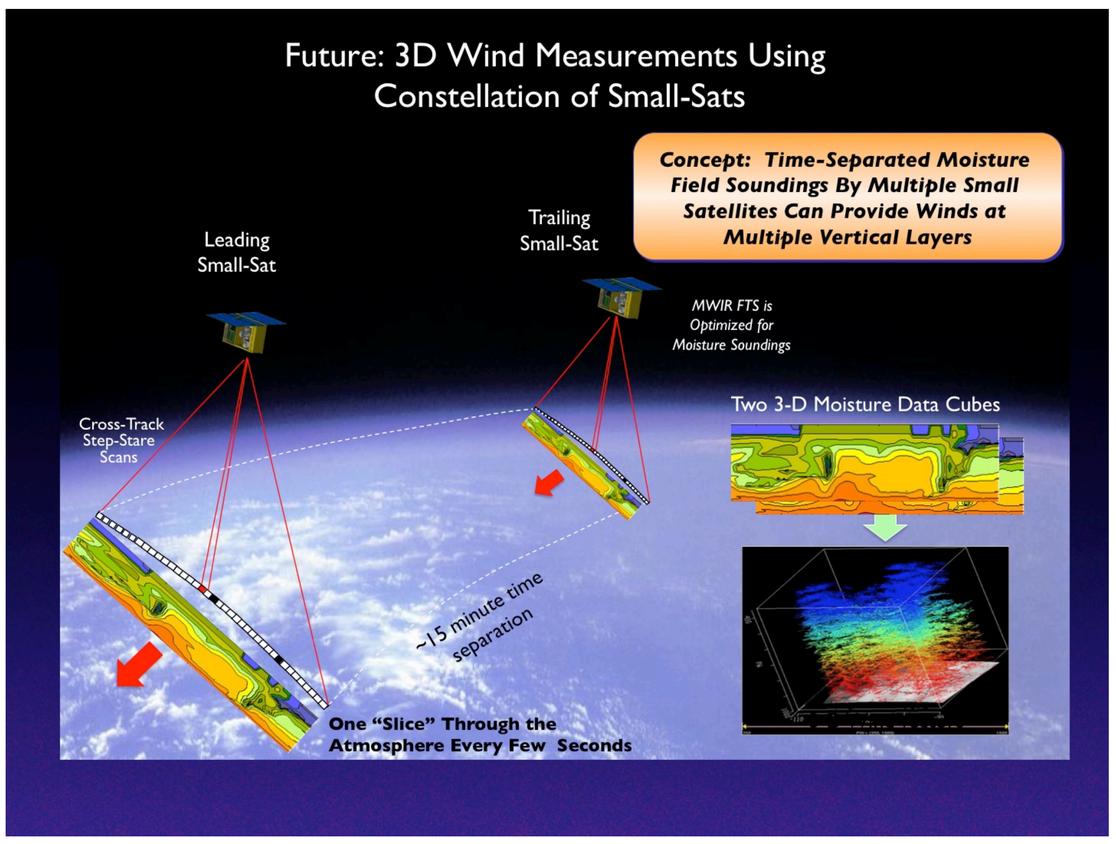
GEOS-5 500 hPa ACC score
1-24 July 2012
Northern Hemisphere

Control run in black. Two experiments:

Red: Addition of the AIRS AMVs. Slight improvement in ACC score after Day 4 (not statistically significant).

Blue: Removal of the MODIS AMVs decreases ACC score:
- AIRS AMVs can not offset loss of MODIS AMVs
- AIRS AMVs complement the MODIS AMVs
- AIRS AMVs are in clear sky or above cloud regions; MODIS AMVs include cloud-tracked features.

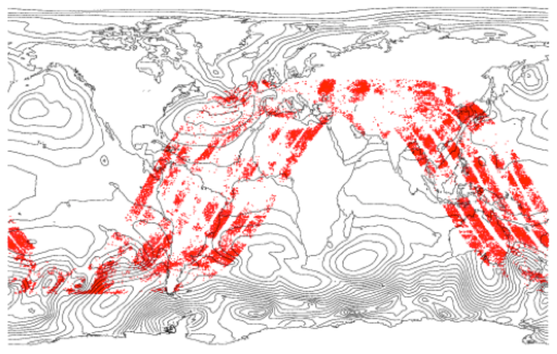




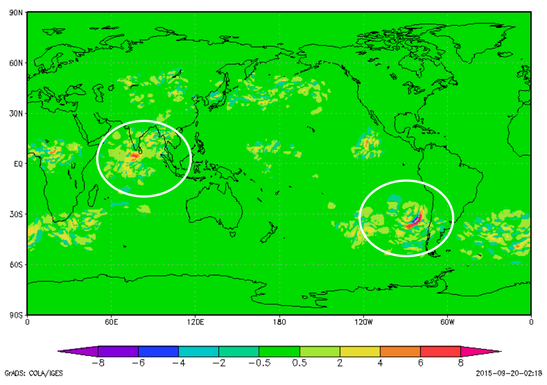
Six-satellite Constellation

Observing System Simulation Experiment (OSSE)

- 7 km GEOS-5 nature run from NASA Global Modeling and Assimilation Office (GMAO)
- Quick simulator: Probabilistically determine the 3D AMV fields along the swath as a function of pressure height, RH at that pressure, and the smoothed gradient of the RH field.



- High inclination orbit to maximize mid- and low-latitude coverage
- Simulated AMVs valid for 6-hour assimilation window



- Reduction in wind speed error (ms^{-1}) at 300 hPa for single analysis time in July
- Positive impact (yellow to red)
- Negative impact (blue to purple)