



The use of satellite-derived 3D winds from hyperspectral sounders in NWP global models

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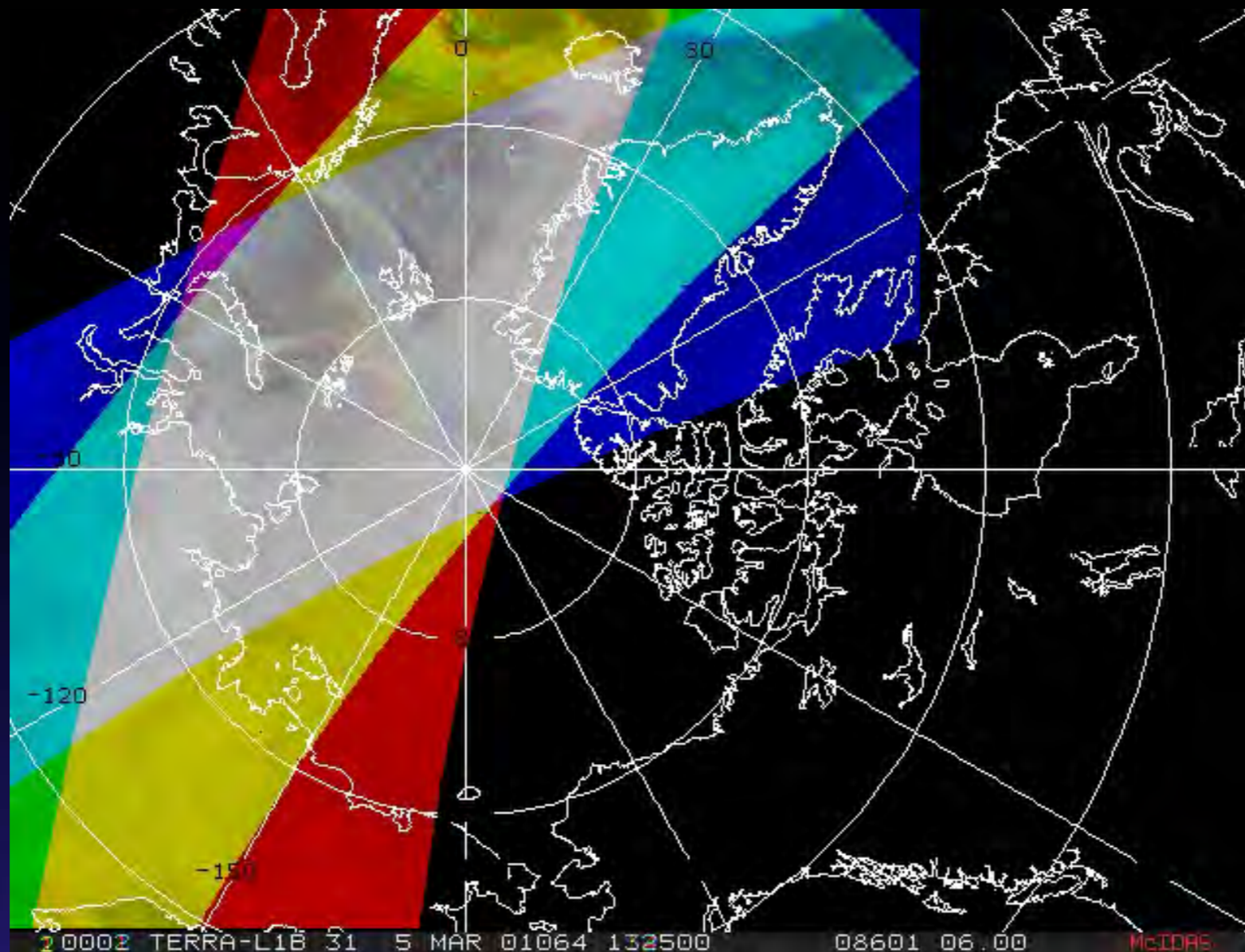
NASA Sounder Science Team Meeting
Greenbelt, MD
13 – 16 October 2015



Outline

- 1) Overview of polar winds product
- 2) Applying to retrievals of moisture (hyperspectral)
- 3) Assimilation and forecast impact
- 4) Real-time AIRS Atmospheric Motion Vectors (AMV) product

Satellite-derived Polar Winds



Unlike geostationary satellites at lower latitudes, it is not possible to obtain complete polar coverage at a snapshot in time. Winds must be derived for areas that are covered by three successive orbits. The gray area is the overlap between three orbits.

MODIS Winds in NWP



Current Operational Users:

- European Centre for Medium-Range Weather Forecasts (ECMWF) - since Jan 2003.
- NASA Global Modeling and Assimilation Office (GMAO) - since early 2003.
- Deutscher Wetterdienst (DWD) – since Nov 2003.
- Japan Meteorological Agency (JMA), Arctic only - since May 2004.
- Canadian Meteorological Centre (CMC) – since Sept 2004.
- US Navy, Fleet Numerical Meteorology and Oceanography Center (FNMOC) –since Oct 2004.
- UK Met Office – since Feb 2005.
- National Centers for Environmental Prediction (NCEP) and the Joint Center for Satellite Data Assimilation - since Nov 2005.
- MeteoFrance - since Jun 2006.
- National Center for Atmospheric Research (NCAR), Antarctic Mesoscale Model (AMPS) - since Oct 2006.
- Australian Bureau of Meteorology - since Sept 2007

Tracking humidity features from AIRS retrievals



Project Overview

- Determine to what extent AIRS-derived AMVs can provide useful wind information.
- Advantages:
 - a) 3-dimensional winds dataset
 - b) Implicit AMV height
 - c) Clear sky and above cloud
 - d) No water vapor imager channel after MODIS (polar orbiter)*

* Considered for VIIRS on JPSS-3



AIRS Retrieval

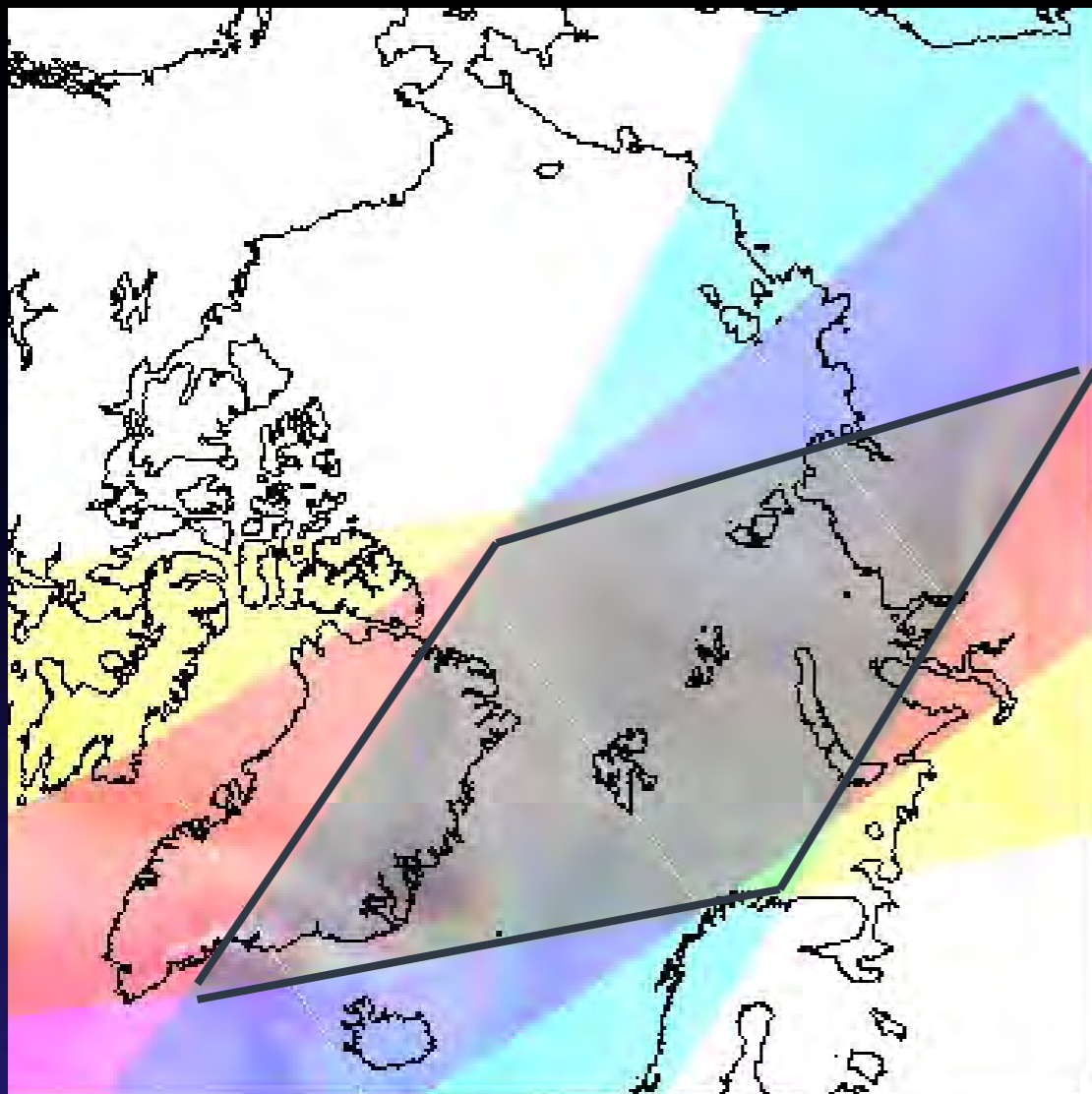
- Use the CIMSS SFOV AIRS retrieval algorithm
 - a) Need highest possible resolution
 - b) Retrievals of moisture and ozone mixing ratio at 101 pressure levels:
 - i. Away from tropopause and surface for AMVs
 - ii. Ozone: 103 to 201 hPa
 - iii. Moisture: 359 to 616 hPa
 - c) Elisabeth Weisz and Bill Smith, Sr.



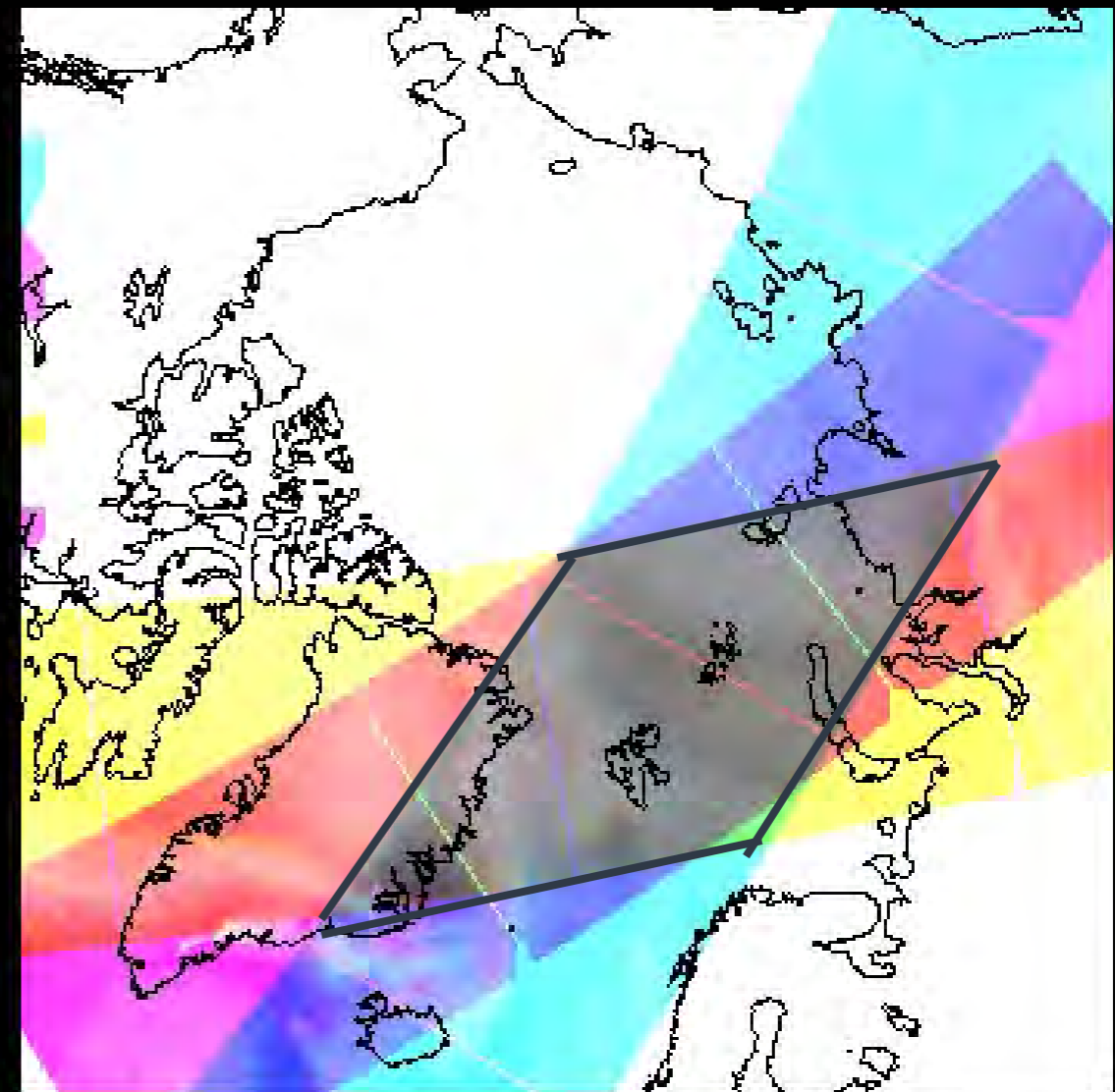
New Challenge: Lower resolution

- AIRS: 13.5 km; MODIS: 1 km
- Images at 16 km (AIRS) and 2 km (MODIS)
- Magnify images with bi-linear interpolation
 - a) Increase winds algorithm parameters to match magnification
 - b) Cross correlation for tracking features behaves much better
- Narrower swath

Polar Winds Coverage MODIS vs. AIRS



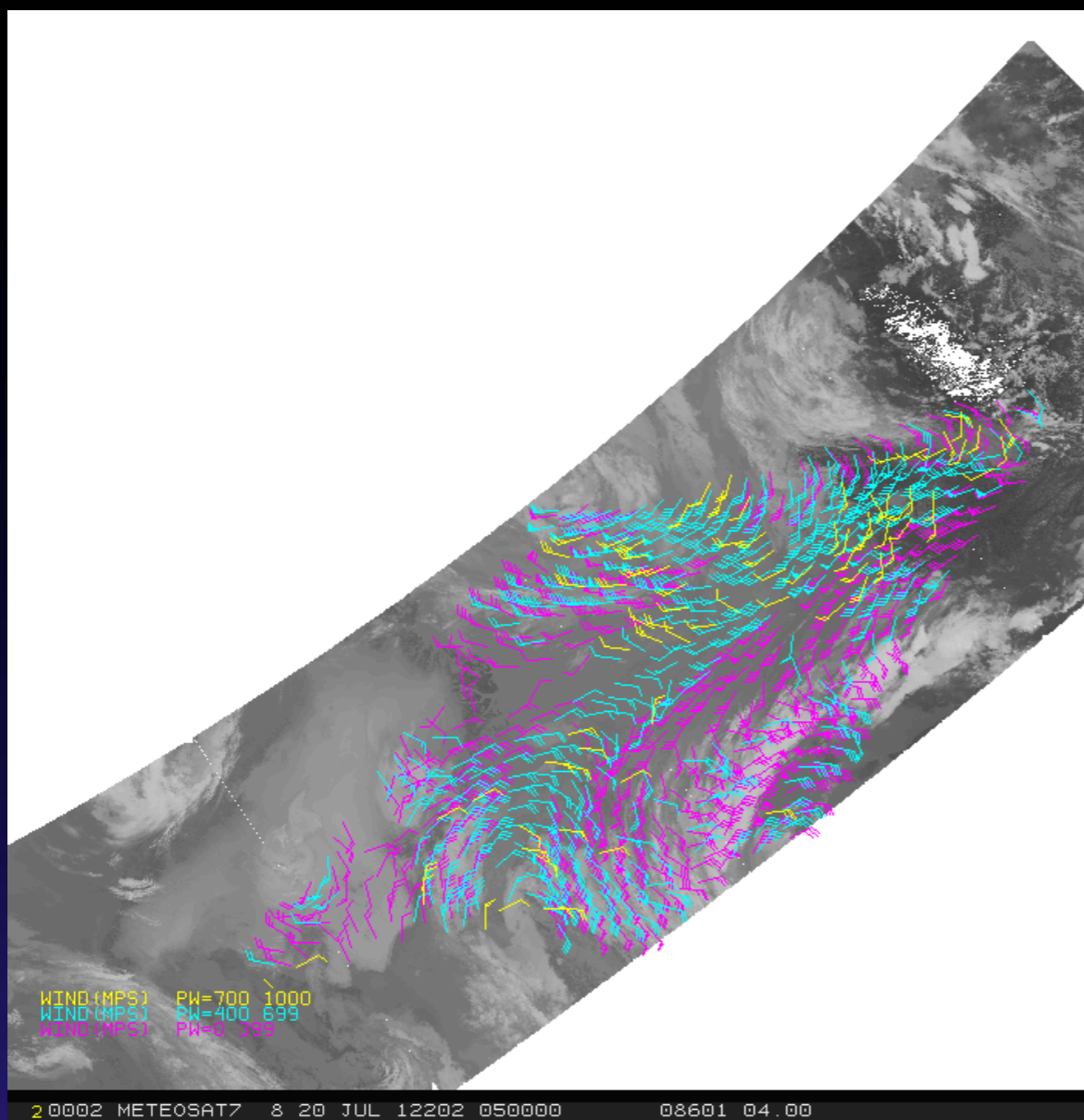
AQUA MODIS COVERAGE



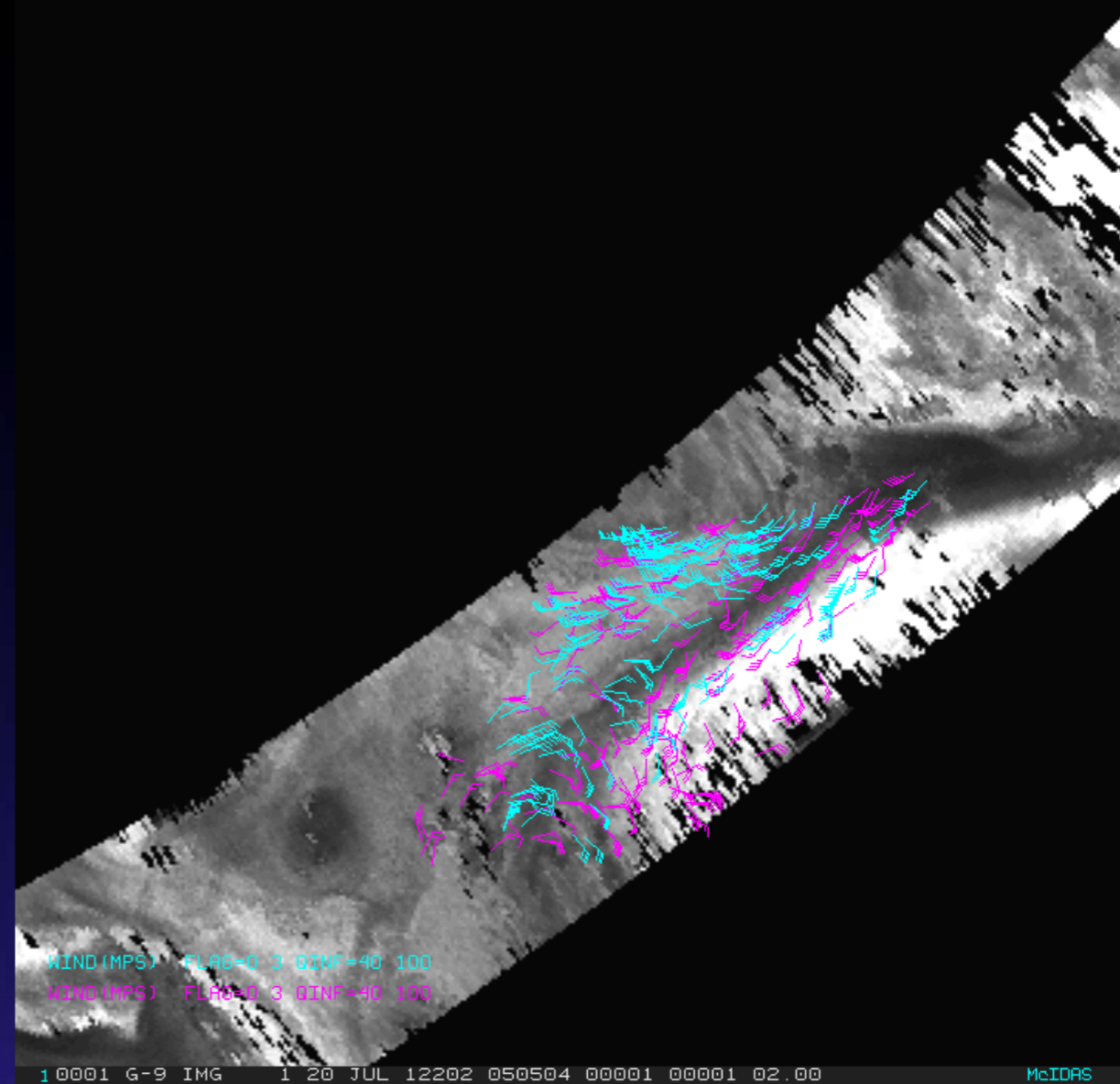
AQUA AIRS COVERAGE

Aqua MODIS AMVs

AIRS Retrieval AMVs at All Levels



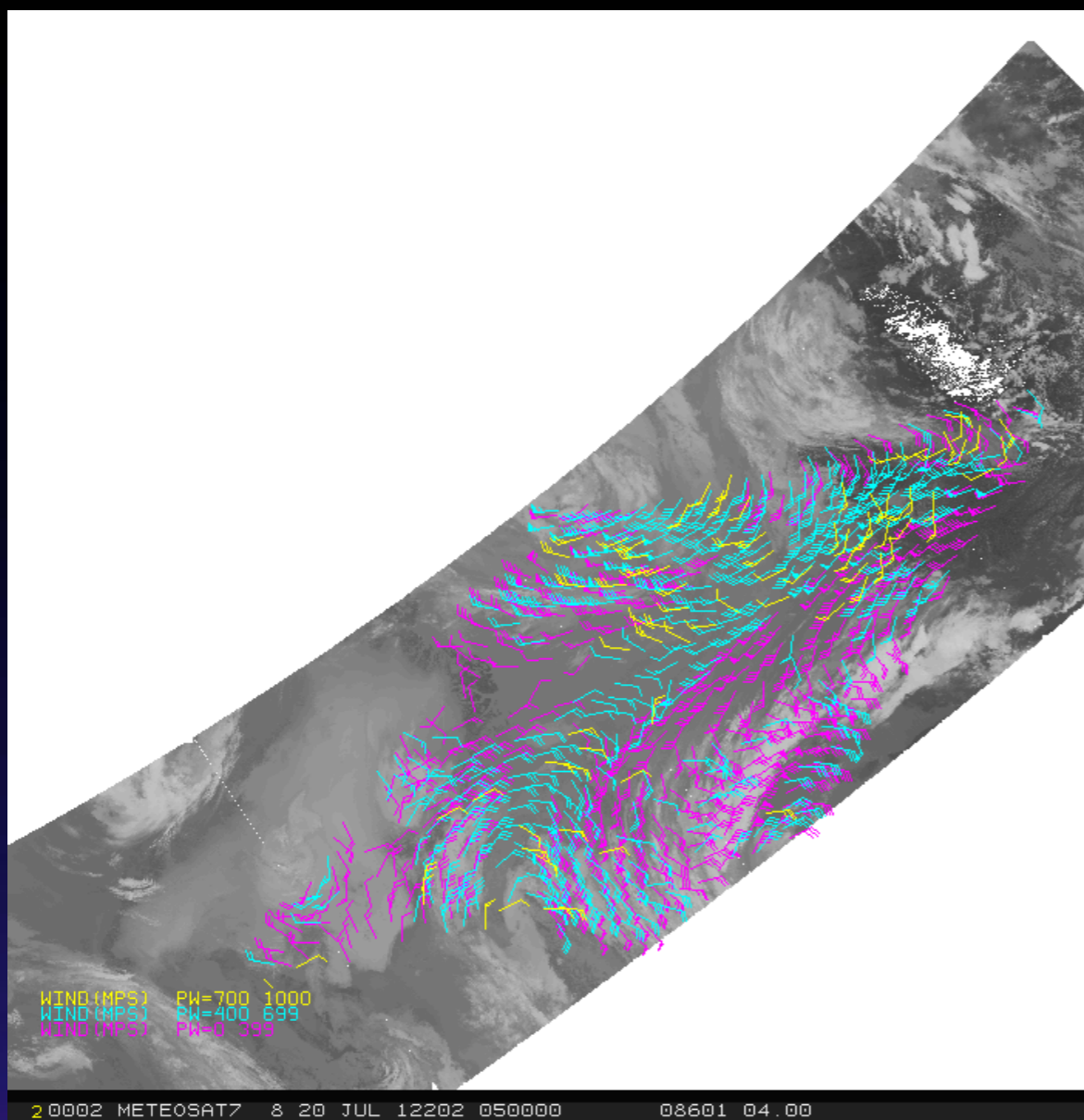
MODIS 20 July 2012 0551 UTC
Infrared and Water Vapor
(including clear sky)



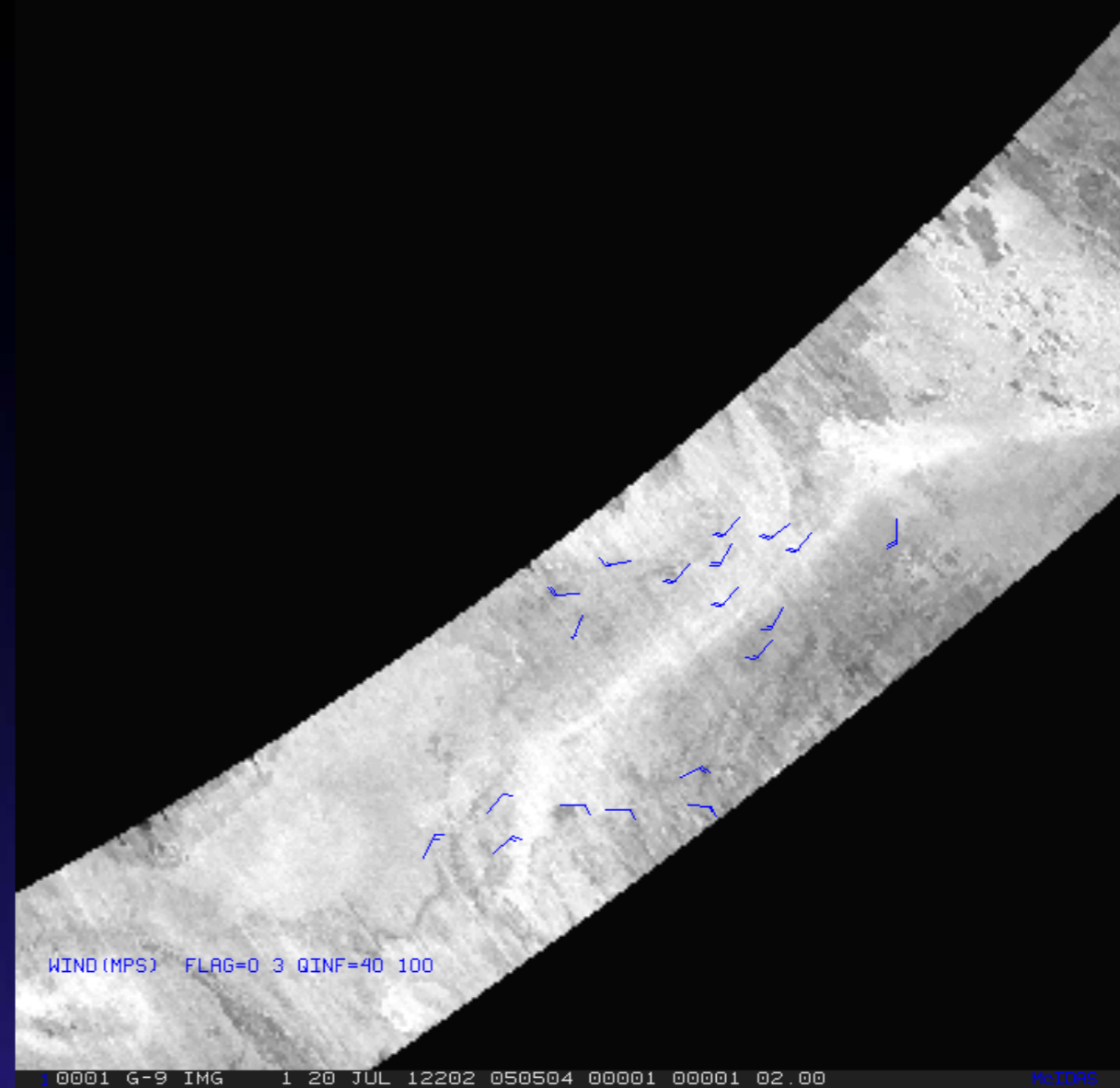
AIRS 20 July 2012 0505 UTC
Ozone: 103 to 201 hPa
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Aqua MODIS AMVs

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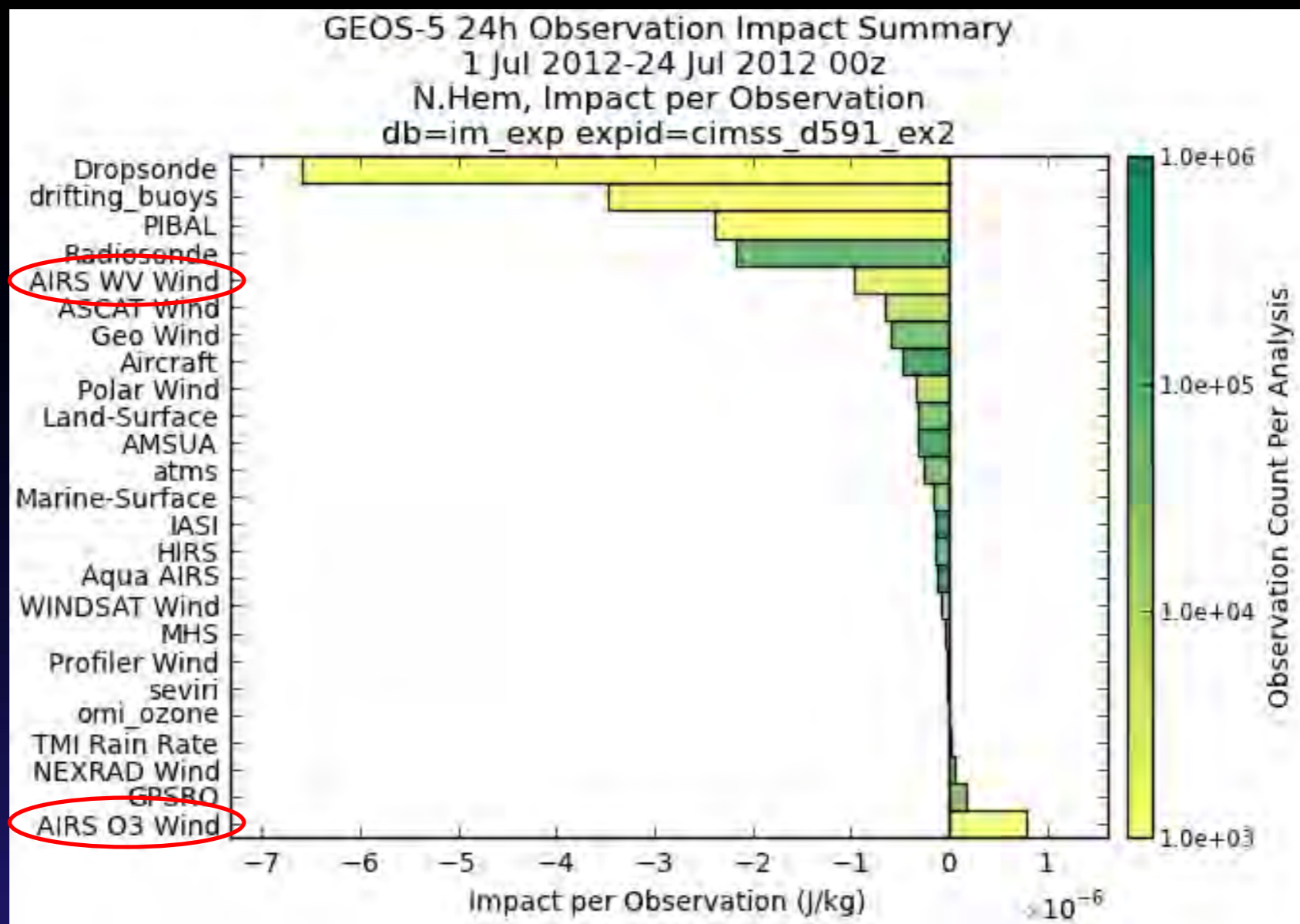
AIRS 20 July 2012 0505 UTC
Ozone: 103 to 201 hPa
Moisture: 359 to 616 hPa



Experiments

- GEOS-5 Forecast System (reduced resolution)
 - GEOS-5 AGCM + GSI analysis ($\sim 1/2^\circ$ L72)
 - 3DVar
 - 6-h assimilation cycle
 - 7-day forecasts, adjoint-based 24h obs
 - Impacts at 00z (dry energy norm, sfc-150 hPa)
- Dates: 14 June – 31 July 2012
- Experiments
 1. Control
 2. + AIRS winds
 3. + AIRS winds - MODIS WV winds
 4. - AIRS winds - MODIS all winds

Impact per observation



1 – 24 July 2012 00 UTC

GEOS-5 Forecast Impact: ACC

Two experiments

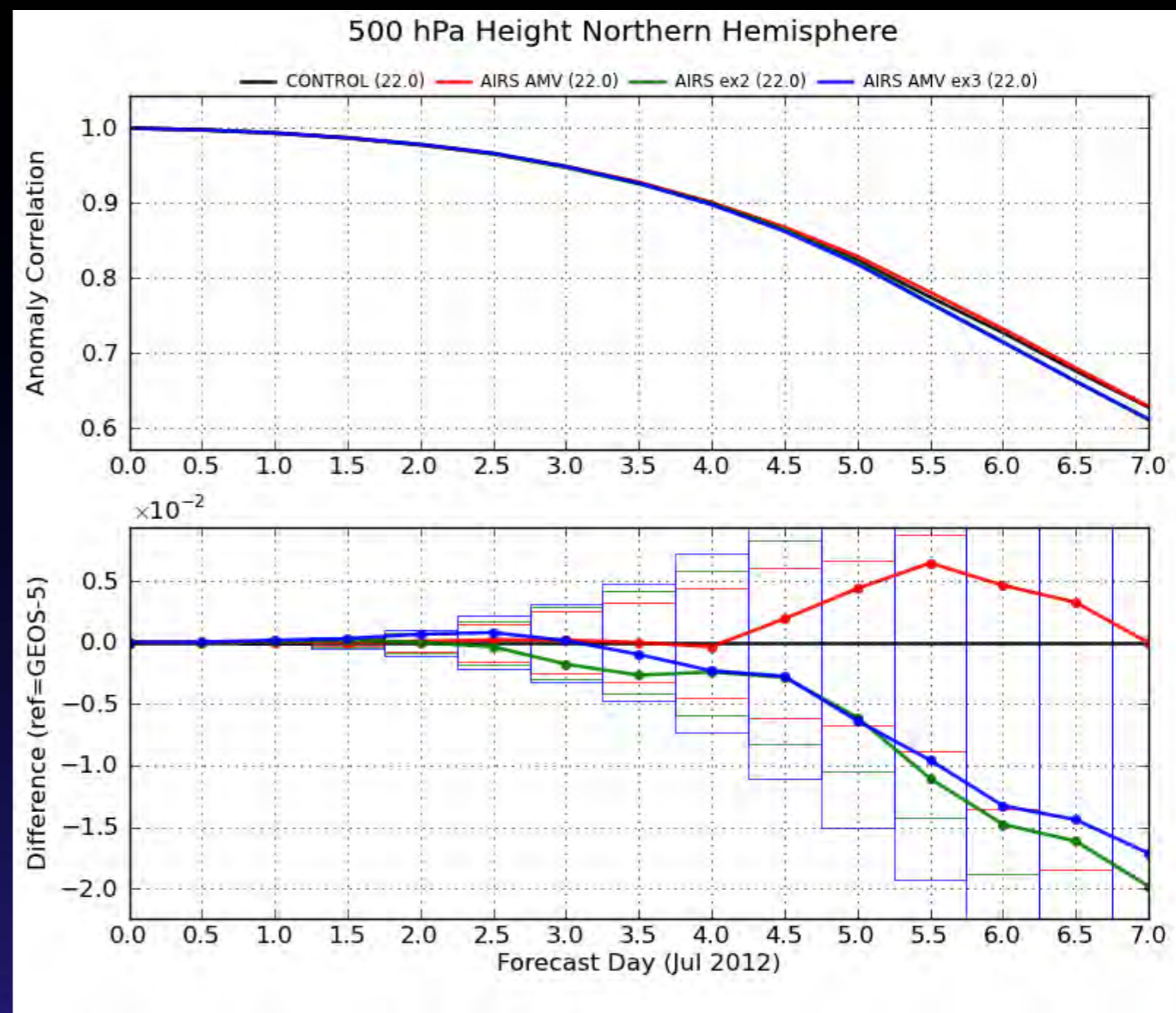


Control in black.

Red: **Addition** of AIRS AMVs. Slight improvement 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.



500 hPa Northern Hemisphere
1 – 24 July 2012 00 UTC



Summary of AIRS AMVs

- Impact per AIRS moisture AMV is ranked higher than all other satellite-derived wind datasets
- Neutral, or slightly positive, forecast impact due to the addition of the AIRS retrieval AMVs is encouraging:
 - AMVs are only in the polar region (poleward of 70° latitude)
 - Impact in the longer range forecast over the entire northern hemisphere (20° – 90° latitude)



New Award: NASA ROSES 2013 A.28

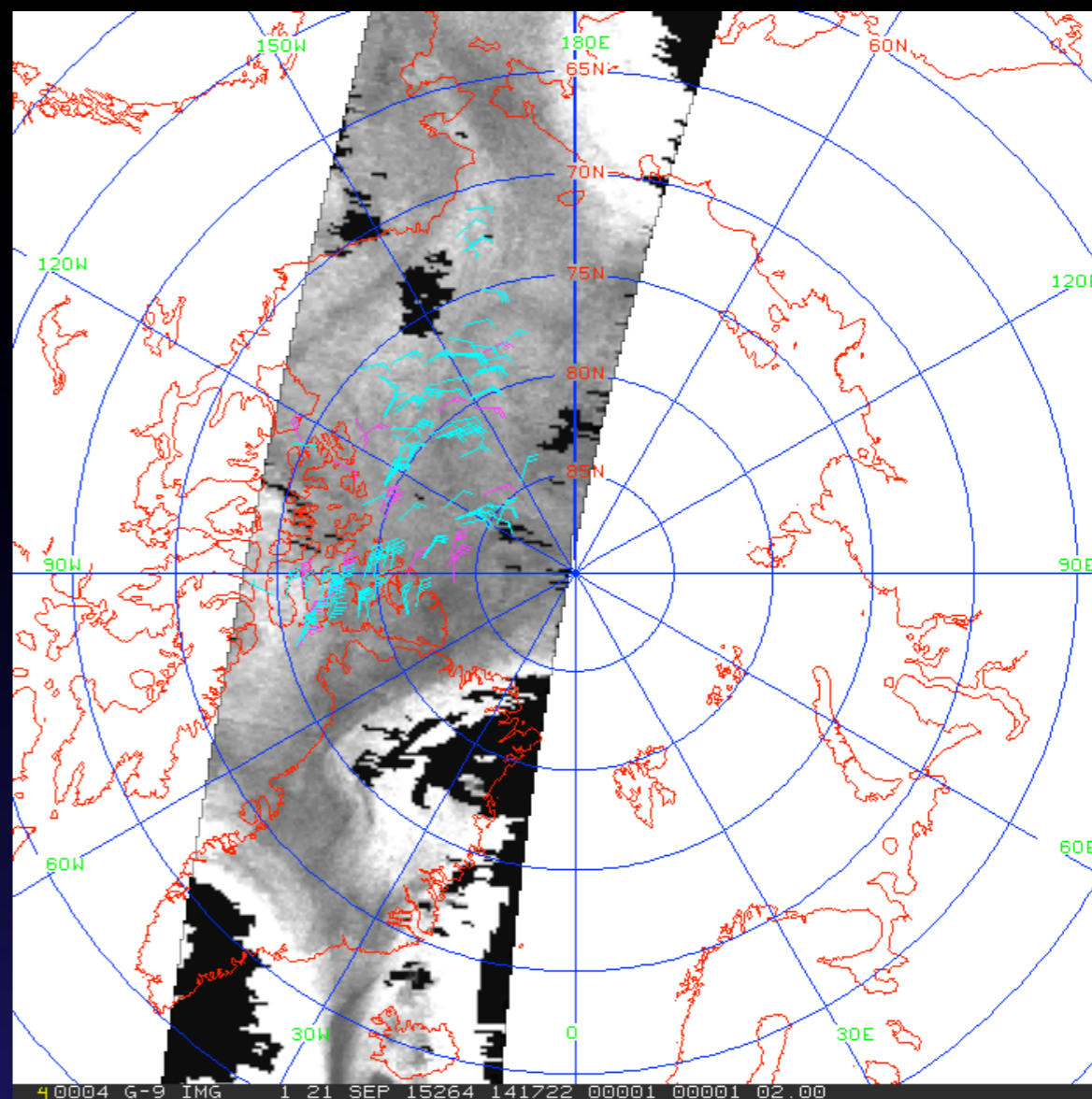
Real-time Generation of Atmospheric Motion Vectors from AIRS Retrieval Data

Goals

1. **Automate procedures** to generate AIRS AMVs in near realtime
2. Blend AIRS and Aqua MODIS AMVs
3. **Collaborate with NWP partners** for monitoring and assimilating the AMVs
4. Product available beginning in May 2015

Real-time AIRS winds

- Three to four 6-minute granules are reprojected to a polar stereographic projection:
 - 16 km resolution
 - Composited
- Bi-linear interpolation used to smooth gradients
- Winds are computed on 22 levels (343 to 753 hPa)
- Product is available in near real-time
 - Delayed by several hours
 - Similar delay to other polar winds products
 - 13-15 AIRS datasets per day at each pole
- AMVs generally cover the area poleward of 70° latitude over the course of a day



Preview: <http://stratus.ssec.wisc.edu/cgi-bin/polarwinds?airs>

Winds product: ftp://stratus.ssec.wisc.edu/pub/winds/retrieval_winds/airs/



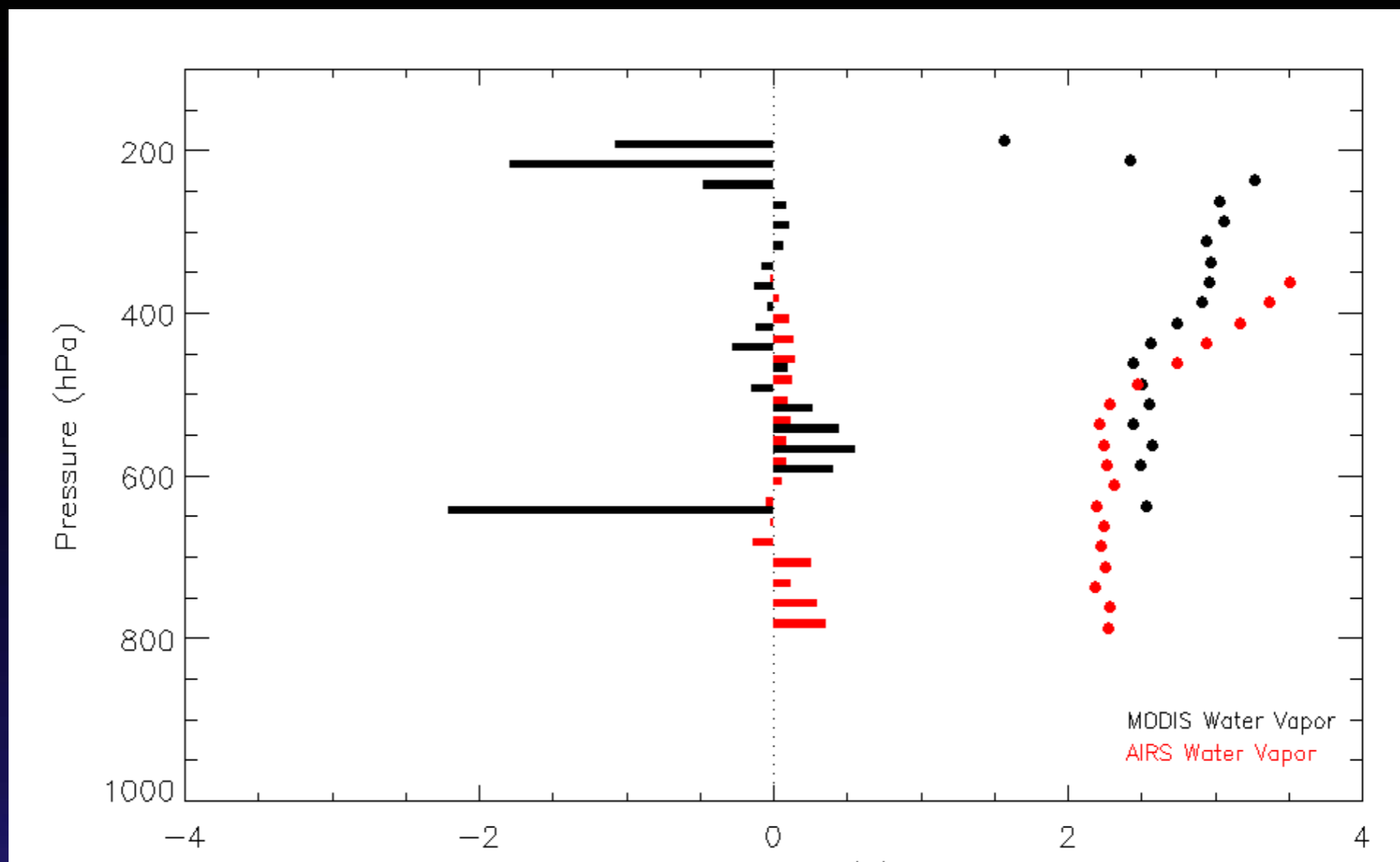
AIRS winds preliminary evaluation

U.S. Naval Research Laboratory (Randy Pauley)

- Observation impact looked good
- They are comparable to other polar winds in impact per observation and innovation statistics
- However, data volume low
 - Low resolution hyperspectral instruments
 - Only in the polar regions (dry atmosphere)

AIRS winds preliminary evaluation

NASA/GMAO (Will McCarty)



The mean and standard deviation of the observation departures (ms^{-1})
(Observation minus 6-hr Forecast) for AIRS and MODIS water vapor
winds
May to July 2015



Future Application of Technique

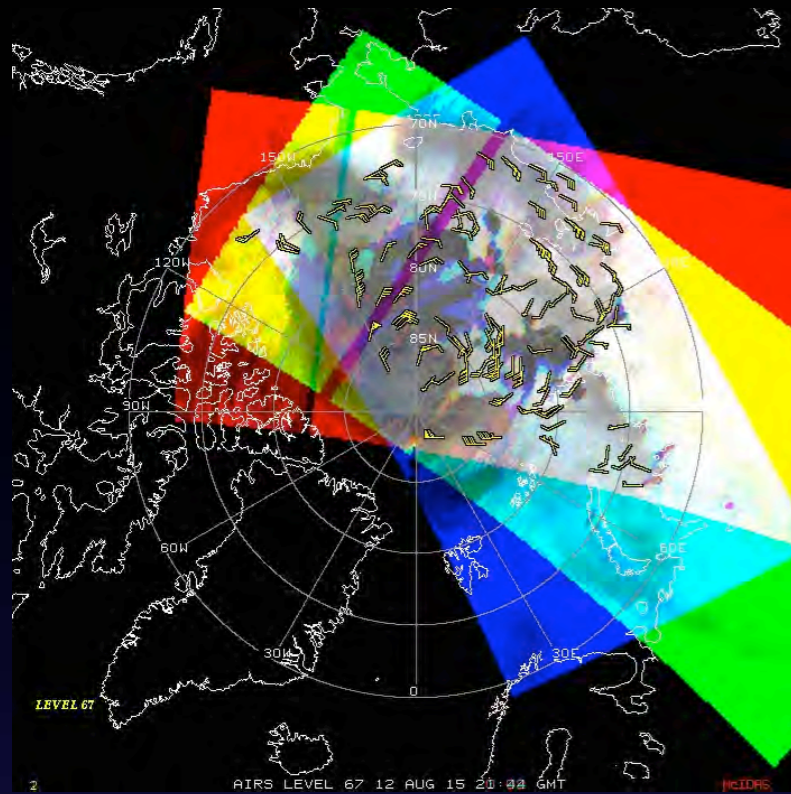
Technique can be applied to other satellites:

- **Polar imagery winds** are currently being generated from AVHRR (Metop-A and -B) and VIIRS (S-NPP)
- **SSEC SFOV retrieval algorithm** has been applied to **IASI** and **CrIS**
- Therefore, blended AMV products could be generated for:
 - **AVHRR/IASI** on Metop A- and B-
 - **VIIRS/CrIS** on S-NPP and JPSS
- Investigate cross-platform humidity feature tracking:
 - Shorter time interval between images
 - Coverage would extend further south
- And, perhaps other instruments.....

Winds from ATMS, IASI, and CrIS



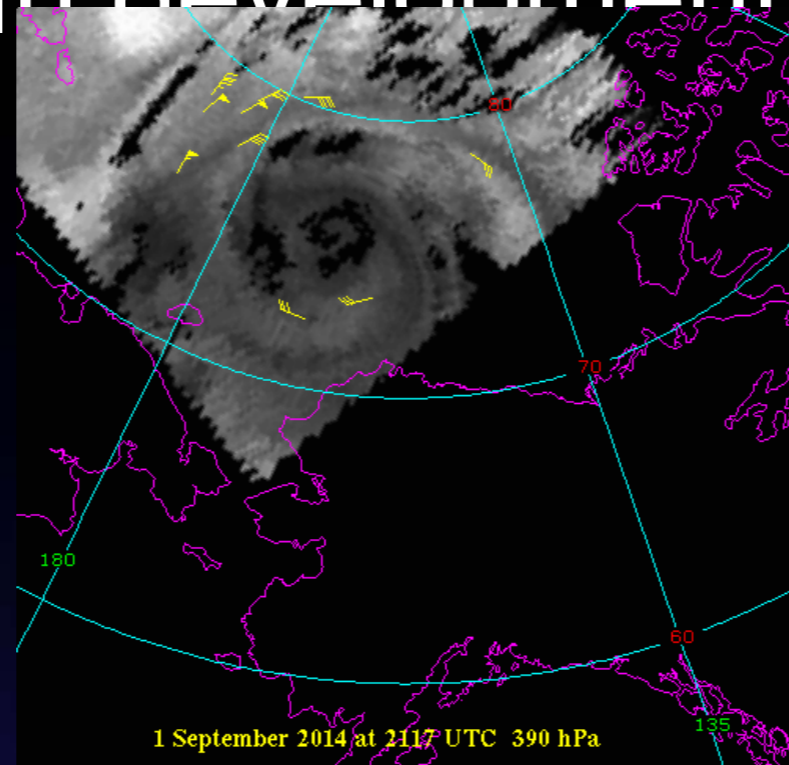
In development



ATMS

Advanced Technology
Microwave Sounder

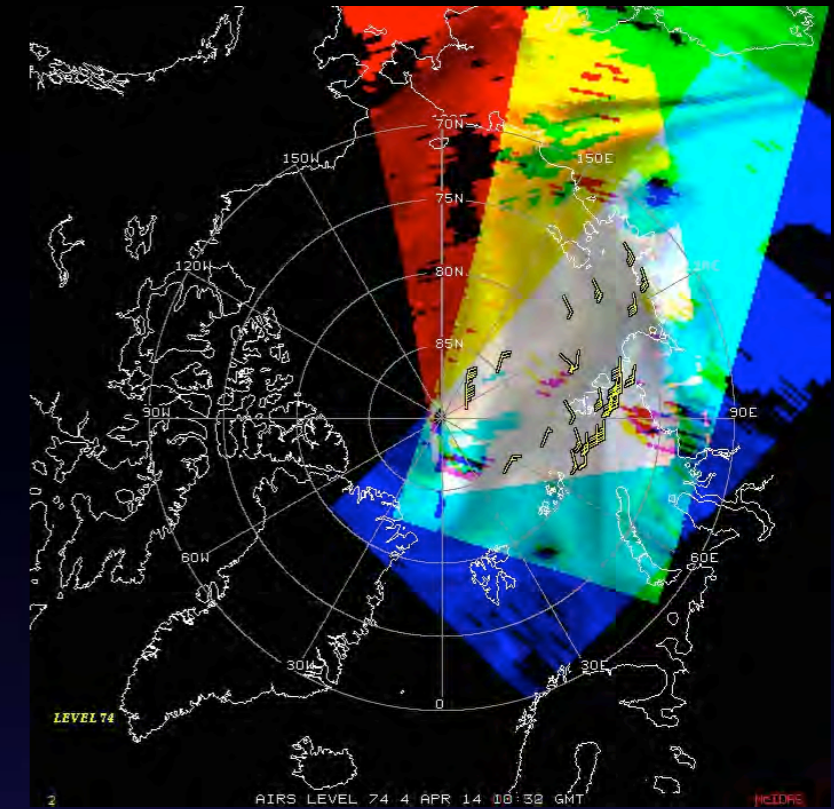
Suomi NPP



CrIS

Cross-track Infrared
Sounder

Suomi NPP

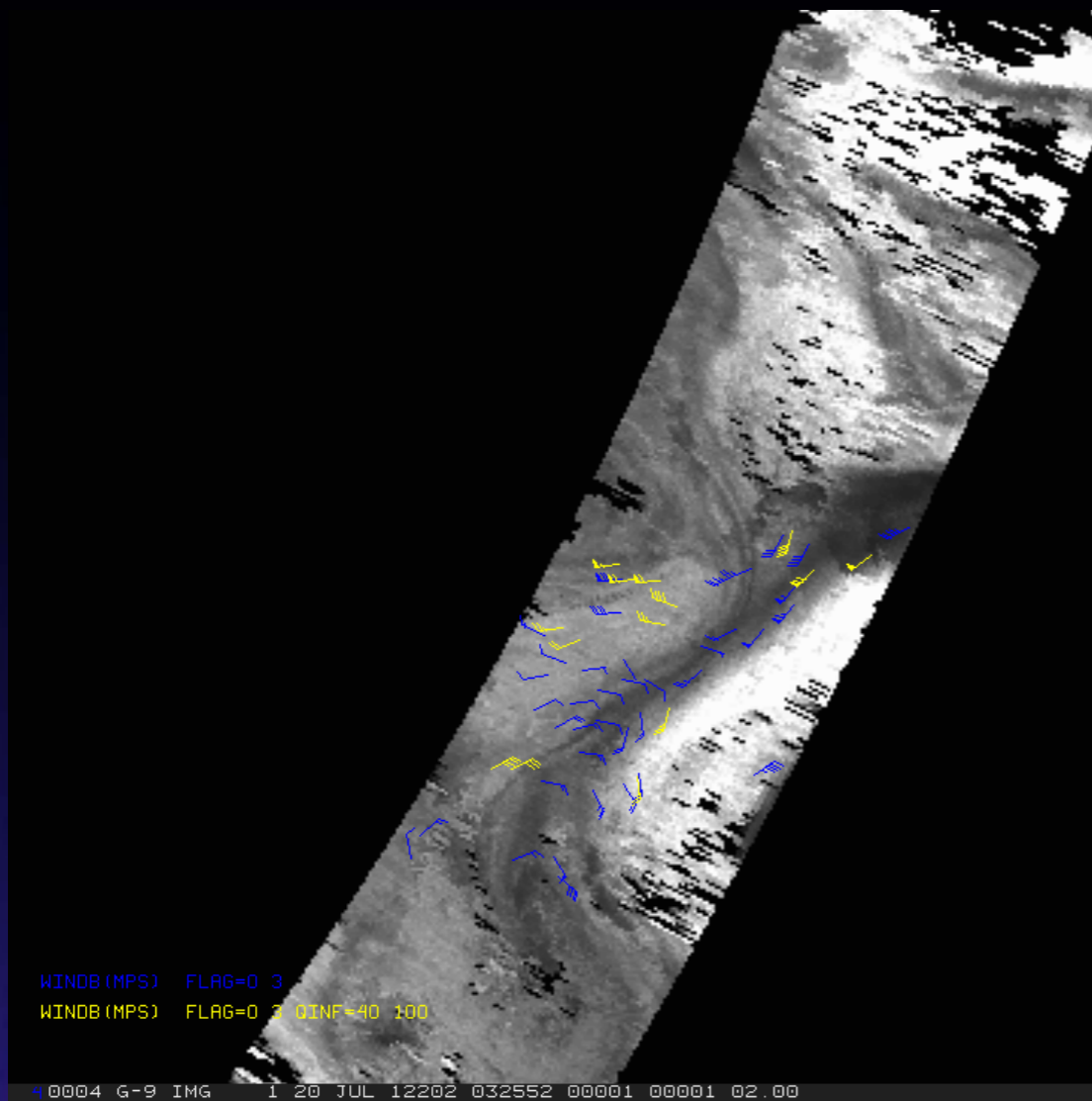


IASI

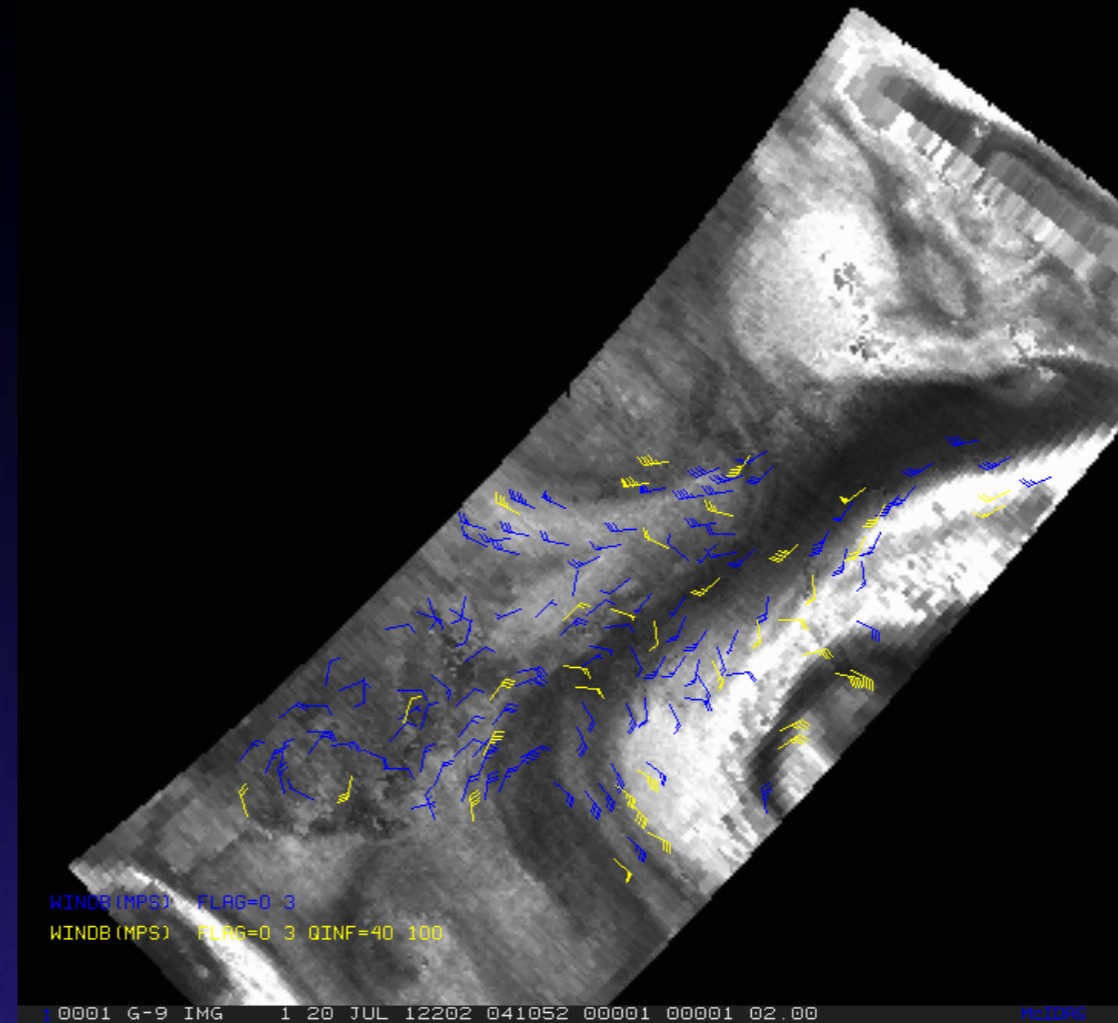
Infrared Atmospheric
Sounding Interferometer

Metop-A, -B

AIRS and ATMS Retrieval Images at 400hPa



AIRS 20 July 2012 0505 UTC



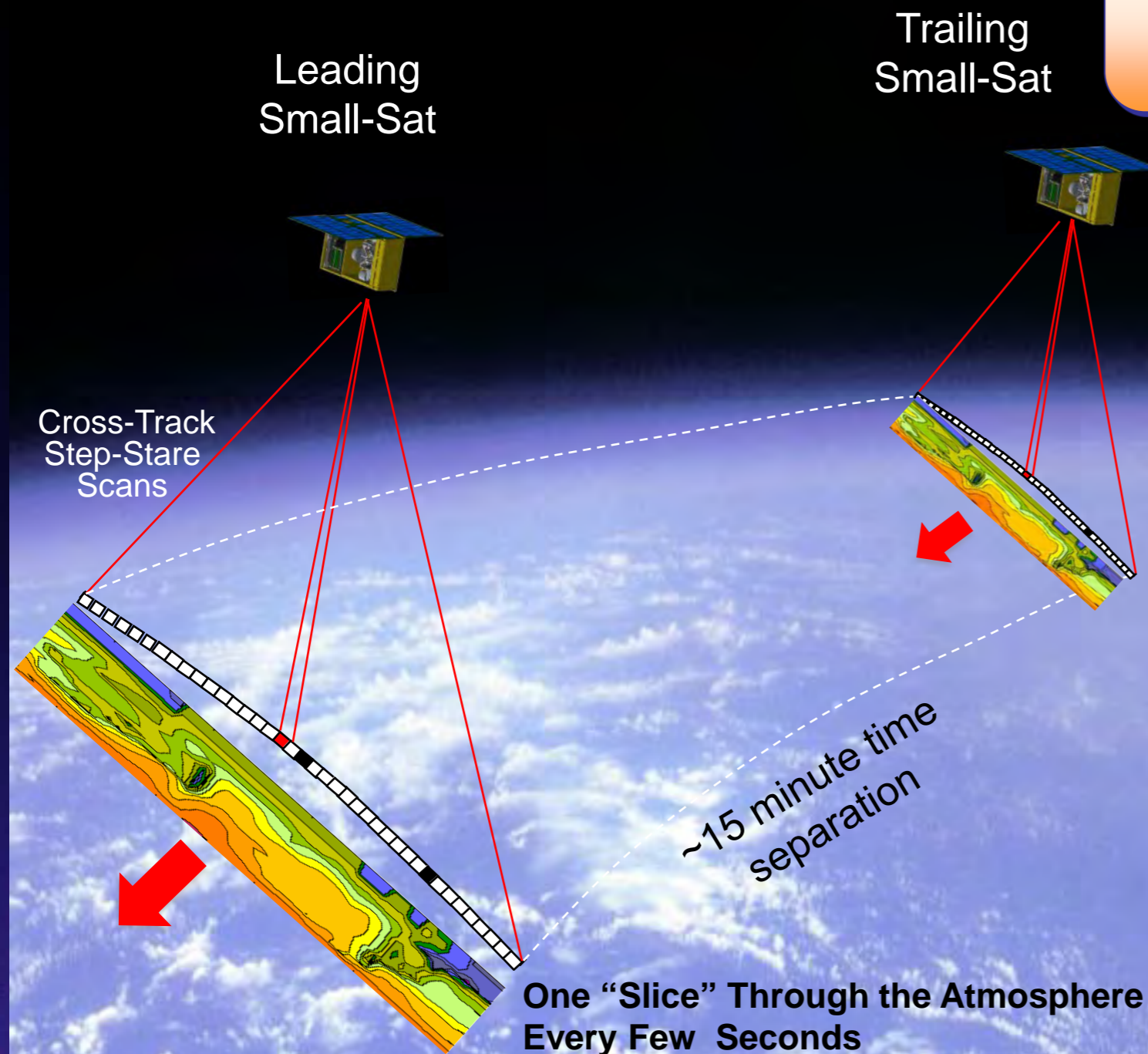
ATMS 20 July 2012 0551 UTC

Specific humidity retrievals.
All winds (blue); Quality controlled winds(yellow)

Future: 3-D Wind Measurements Using Constellation of Small-Sats

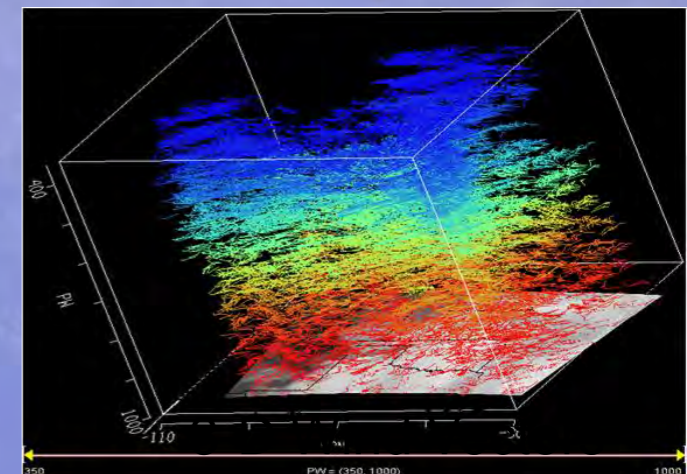
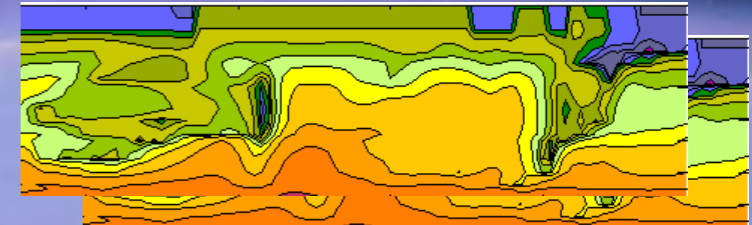


Concept: Time-Separated Moisture Field Soundings By Multiple Small Satellites Can Provide Winds at Multiple Vertical Layers



MWIR FTS is Optimized for Moisture Soundings

Two 3-D Moisture Data Cubes





Summary

- AIRS retrieval polar AMVs are being **produced routinely**:
 - They are being **considered** by US Navy, NASA/GMAO, JMA
- Interest in using other retrievals for winds:
 - **CrIS, IASI**: SSEC SFOV retrieval
 - **ATMS**: NOAA Unique CrIS/ATMS Processing System (NUCAPS)
- Investigating concept of **global 3D** winds from LEO satellite constellation

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