Evaluation of Aeolus Winds by Comparing to AIRS 3D Winds, Rawinsondes, and Reanalysis Grids

David Santek, Brett Hoover, Hong Zhang, Chia Moeller

University of Wisconsin-Madison
Space Science and Engineering Center (SSEC)
Cooperative Institute for Meteorological Satellite Studies (CIMSS)

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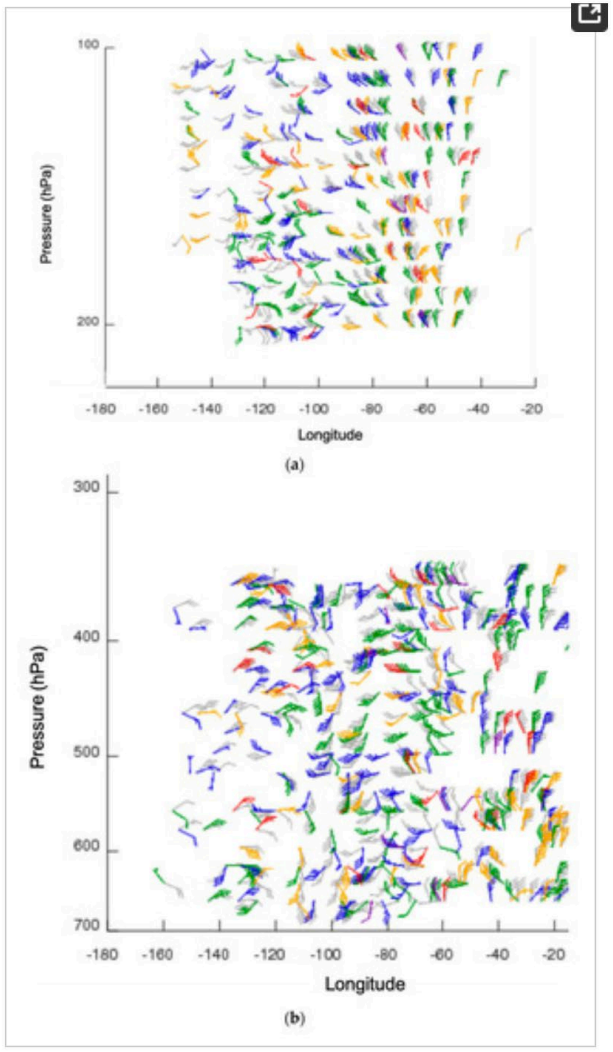
What are 3D winds?

Vertical distribution of wind information in the troposphere and stratosphere. Considering two methods:

- Direct measurement using Lidar (Aeolus)
- Tracking moisture and ozone features on pressure surfaces (Aqua AIRS retrievals)



Why compare AIRS 3D winds to Aeolus winds?

Motivation

Decadal Survey recommends a 3D tropospheric wind mission

Using a space-based LIDAR instrument and/or the use of hyperspectral infrared measurements

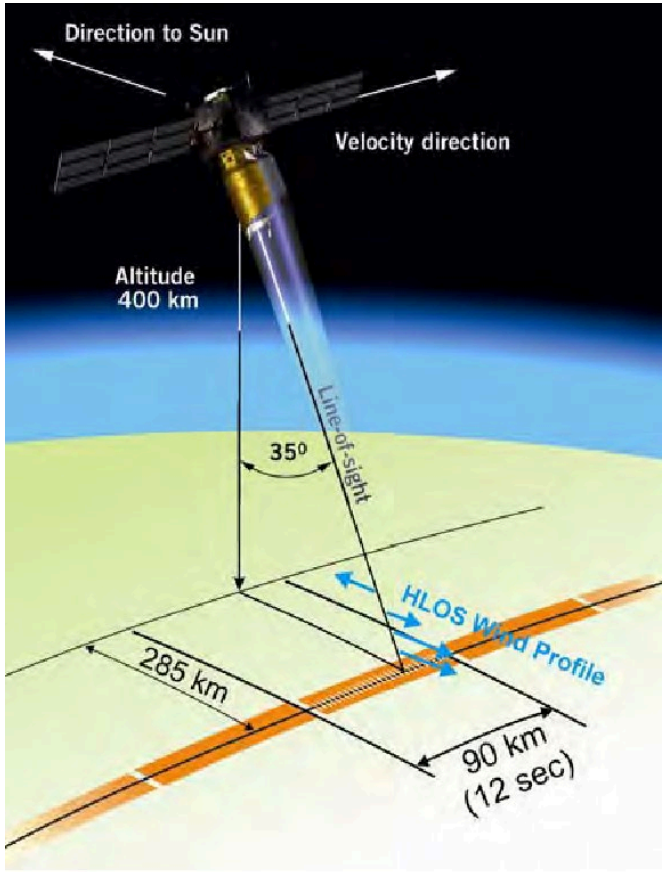
The combination of lidar winds and AMV winds might also provide some advantages where one is used to calibrate the other.

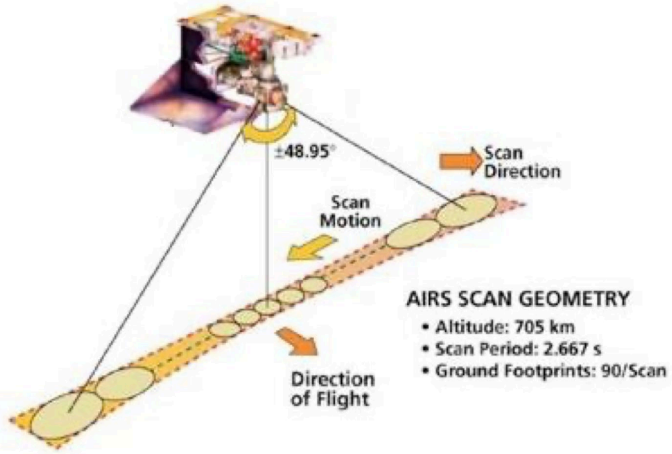
Targeted Observable	Science/Applications Summary	Candidate Measurement Approach	Designated	Explorer	Incubation
Atmospheric Winds	3D winds in troposphere/PBL for transport of pollutants/carbon/aerosol and water vapor, wind energy, cloud dynamics and convection, and large-scale circulation	Active sensing (lidar, radar, scatterometer); passive imagery or radiometry-based atmos. motion vectors (AMVs) tracking; or lidar**		X	X

Validation

They both provide a vertical distribution of winds throughout the troposphere and stratosphere in clear sky and above cloud

Aeolus vs AIRS





Atmospheric Infrared Sounder (AIRS)

Hyperspectral Infrared instrument

2378 Channels

Results in vertical profiles of temperature, humidity, ozone in the troposphere and stratosphere

Aeolus

AIRS

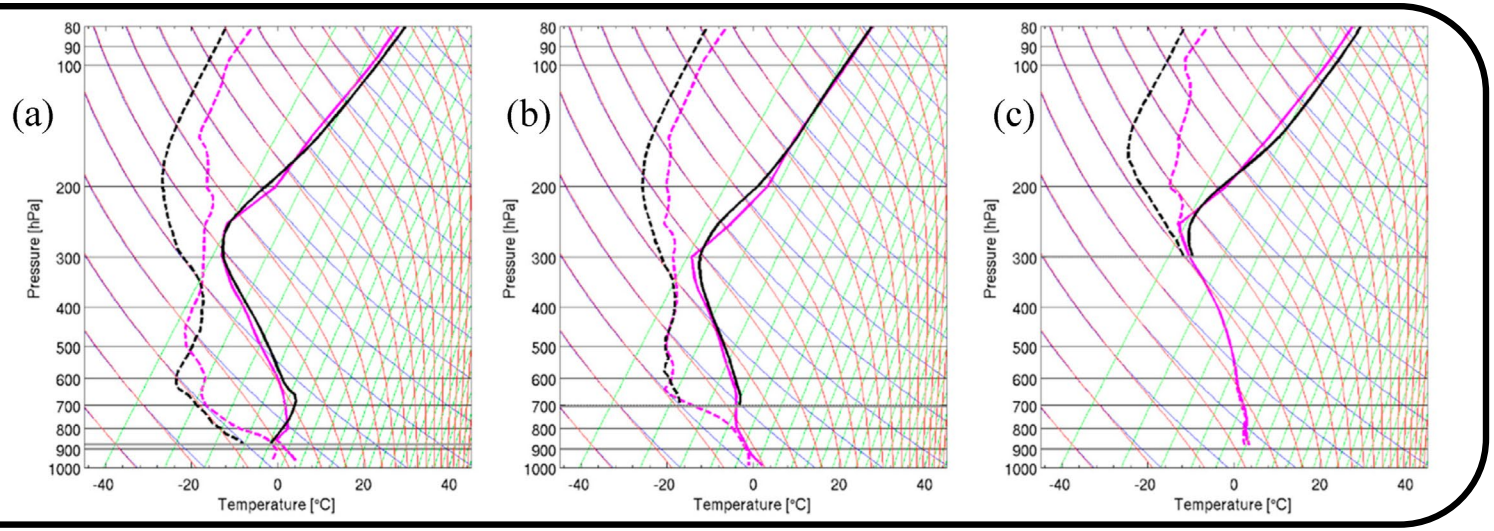
Aeolus vs AIRS Retrieval Winds

Aeolus: Doppler wind lidar (DWL) instrument. Single line-of-sight instrument, which results in the Horizontal Line of Sight (HLOS) component of the wind.

Mie: Particle (aerosols and clouds) Rayleigh: Molecular (cloud free)

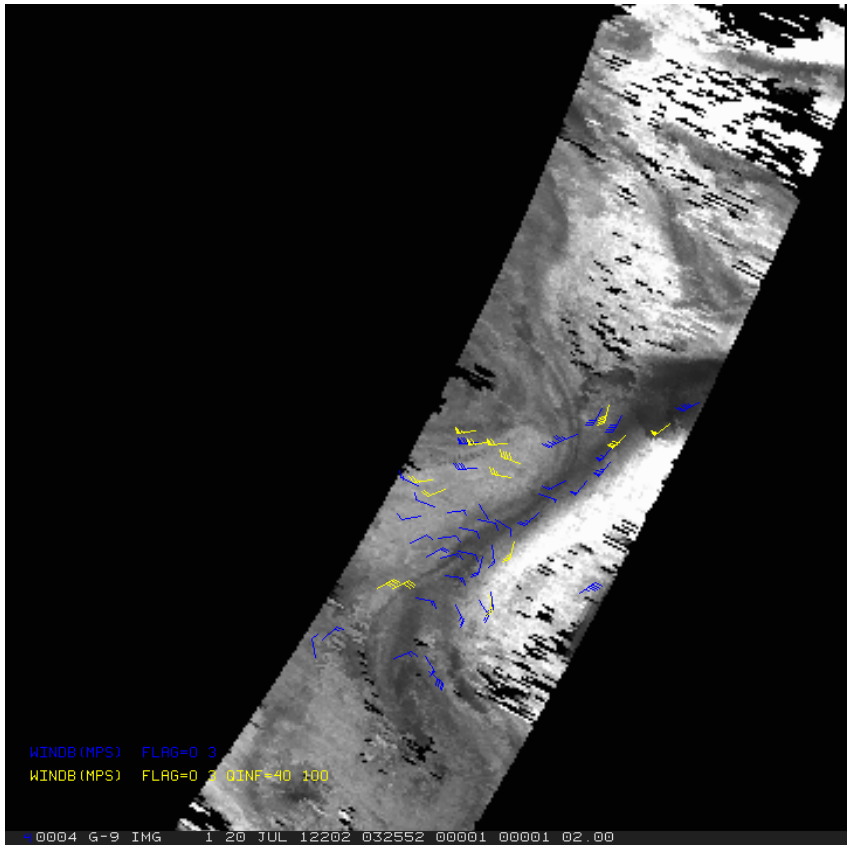
AIRS 3D winds: Winds derived from tracking moisture features (troposphere) and ozone gradients (stratosphere) on pressure surfaces from AIRS retrieved vertical profiles of temperature, humidity, and ozone in clear-sky and above cloud.

Example temperature and dewpoint profiles for clear sky (**a**), above low cloud (**b**), above high cloud (**c**) as compared to the model background. Retrievals (black) and NCEP/GFS (magenta).



AIRS 3D Winds

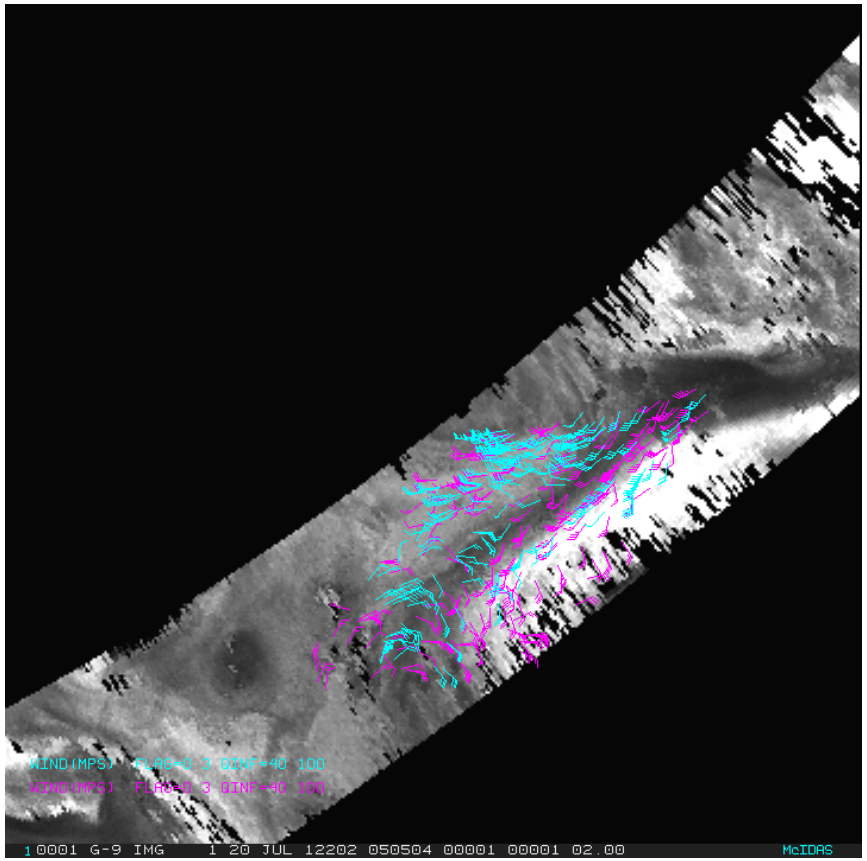
Atmospheric Motion Vectors (AMVs)



20 July 2012: 0325, 0505, 0643 UTC

Wind vectors on 400 hPa pressure surface centered on North Pole

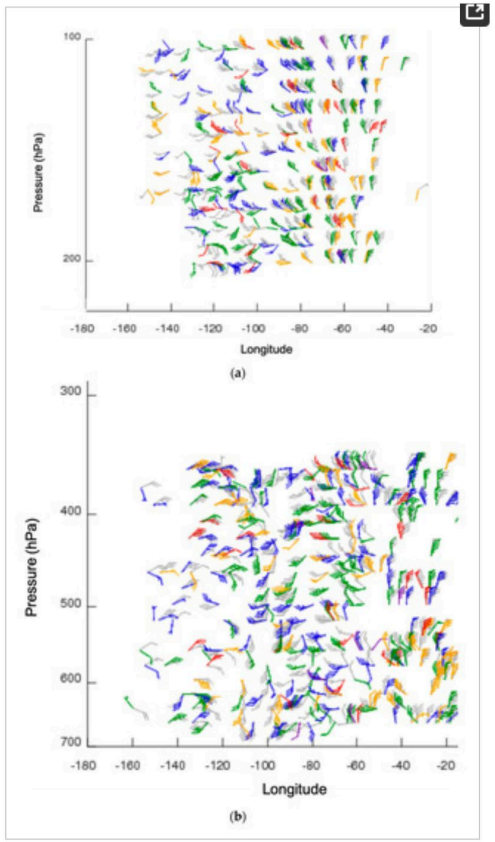
Blue: All winds Yellow: Quality controlled



AIRS 20 July 2012 0505 UTC

Ozone (magenta): 103 to 201 hPa

Humidity (cyan): 359 to 616 hPa



https://www.mdpi.com/2072-4292/11/22/2597

Aeolus vs AIRS winds

AIRS retrieval winds	Aeolus Rayleigh clear-sky
Humidity feature tracking	Molecular motion using Doppler Lidar
Total wind	Horizontal Line of Sight (HLOS) wind component
Better spatial coverage	Better vertical resolution
Average motion spanning 200 minutes	Near instantaneous

Account for differences

Total wind from AIRS AMVs was adjusted to equivalent HLOS wind (used viewing angle from co-located Aeolus winds)

For each AIRS AMV, co-located Aeolus winds were super-obbed in space and time

Comparisons

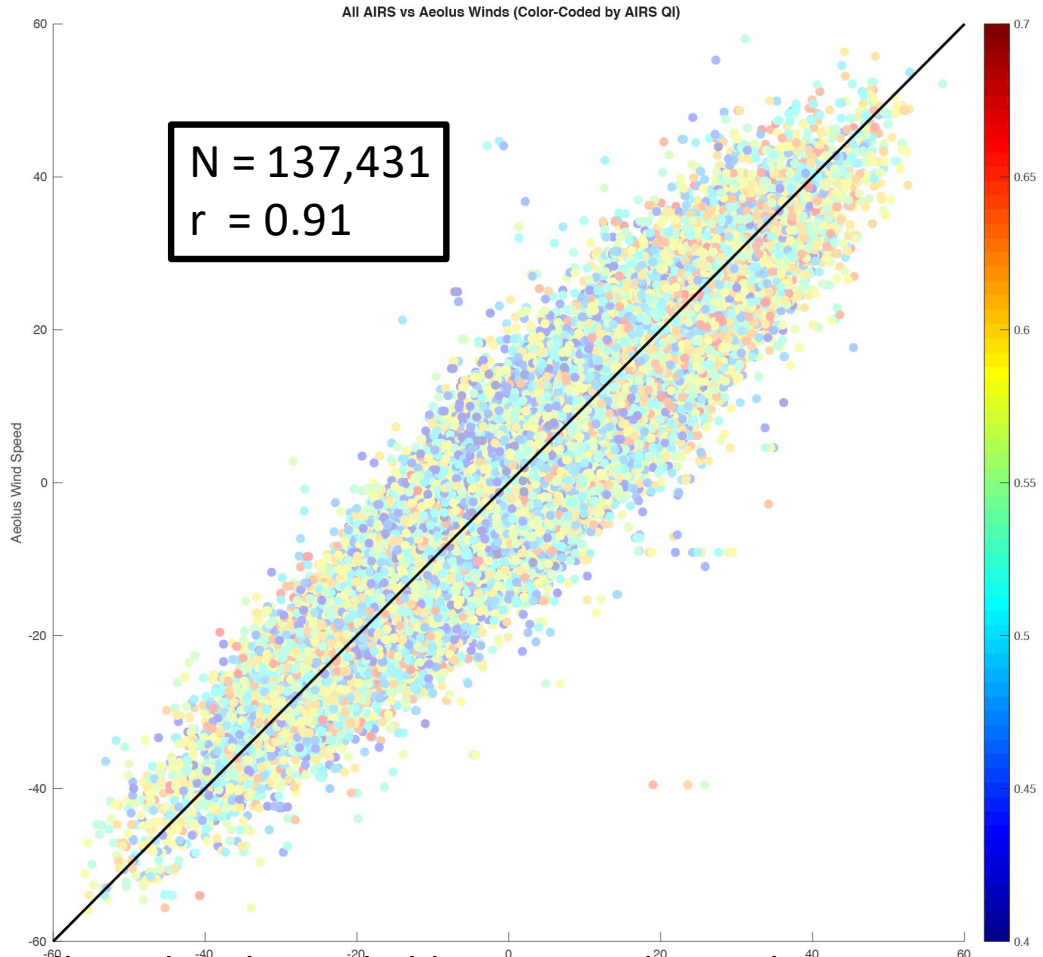
- August through September 2019
- Only polar regions
- Intercomparison
- Each compared to rawinsondes
- Co-located compared to ERA5 reanalysis
- Aeolus: Reprocessed and ESA-recommended QC

Co-location

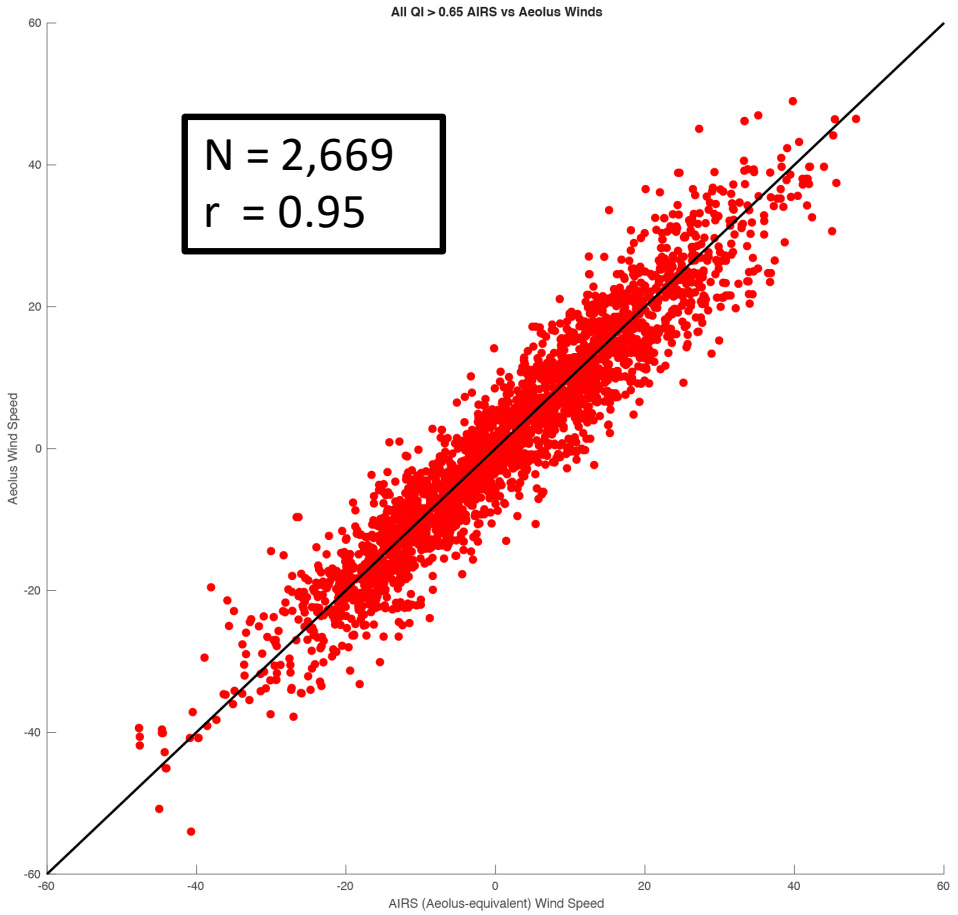
- Within 100 km (150 km for rawinsondes)
- +/- 90 minutes (+/- 60 min. for rawinsondes)
- +/- .04 difference in log10 pressures (approx. height)
  - +/- 60 hPa at 700 hPa
  - +/- 20 hPa at 200 hPa

Aeolus vs AIRS Winds

HLOS Wind Speed



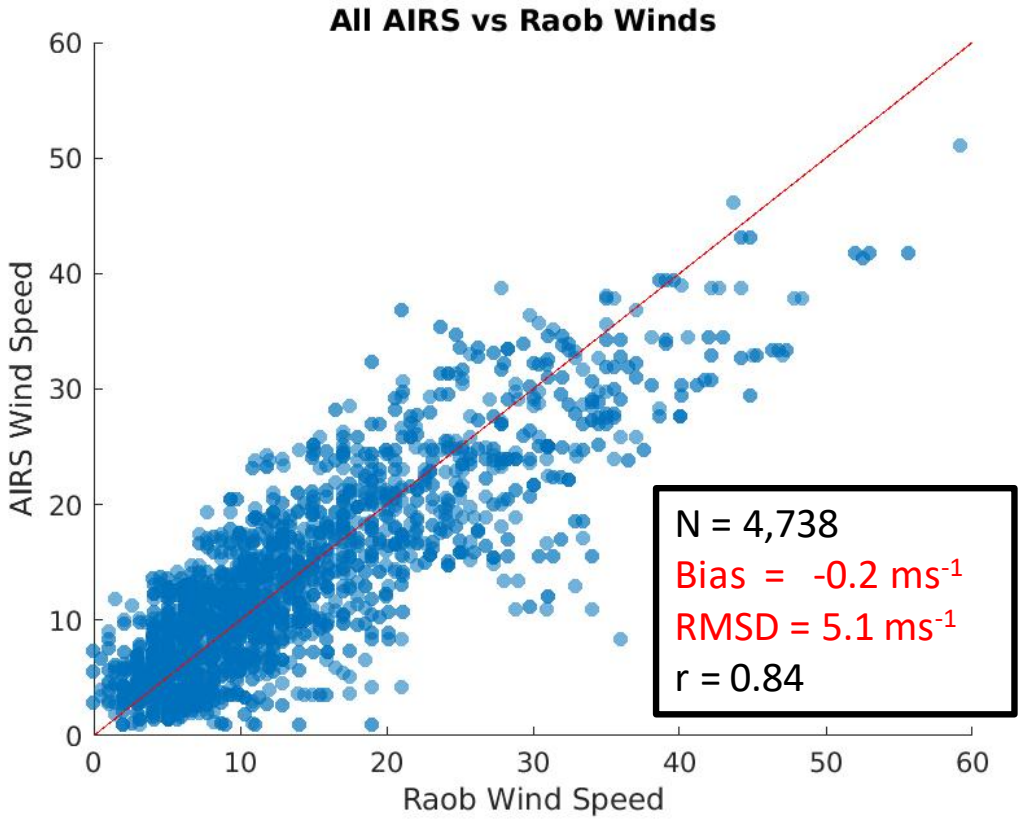
All winds color-coded by AIRS quality; polar region



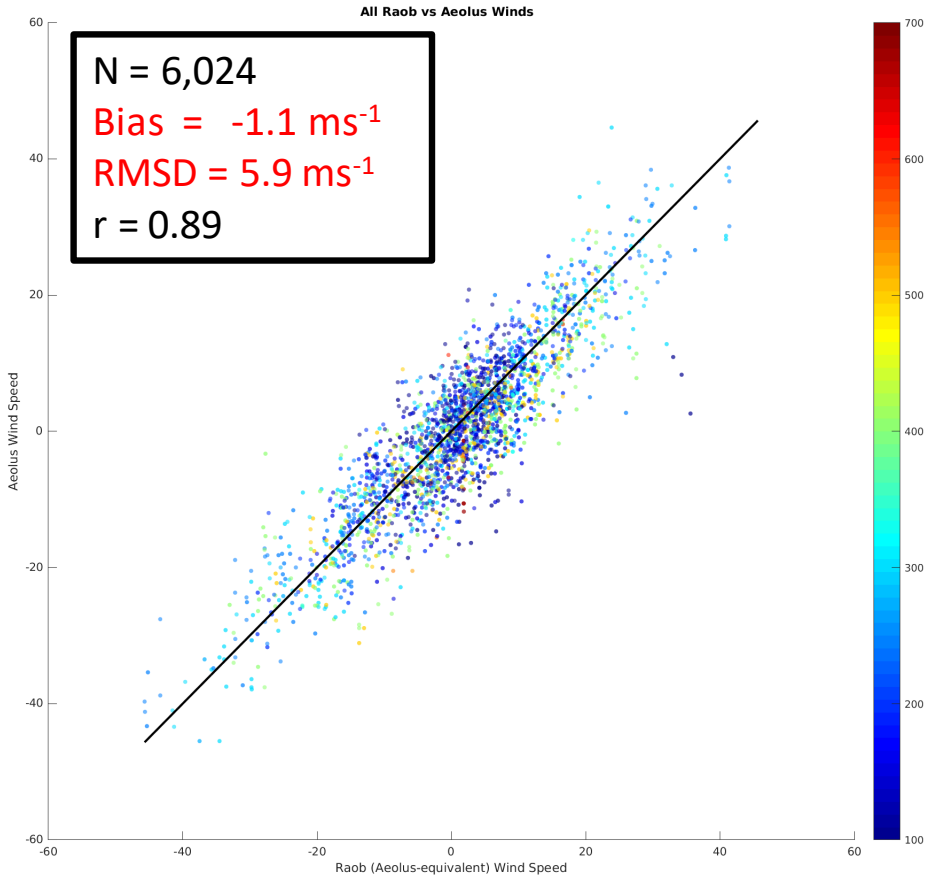
Highest quality AIRS winds; polar region

AIRS and Aeolus Winds Compared to Rawinsondes

Wind speed



AIRS total wind speed
Polar region



Aeolus HLOS wind speed color-coded by pressure
Polar region

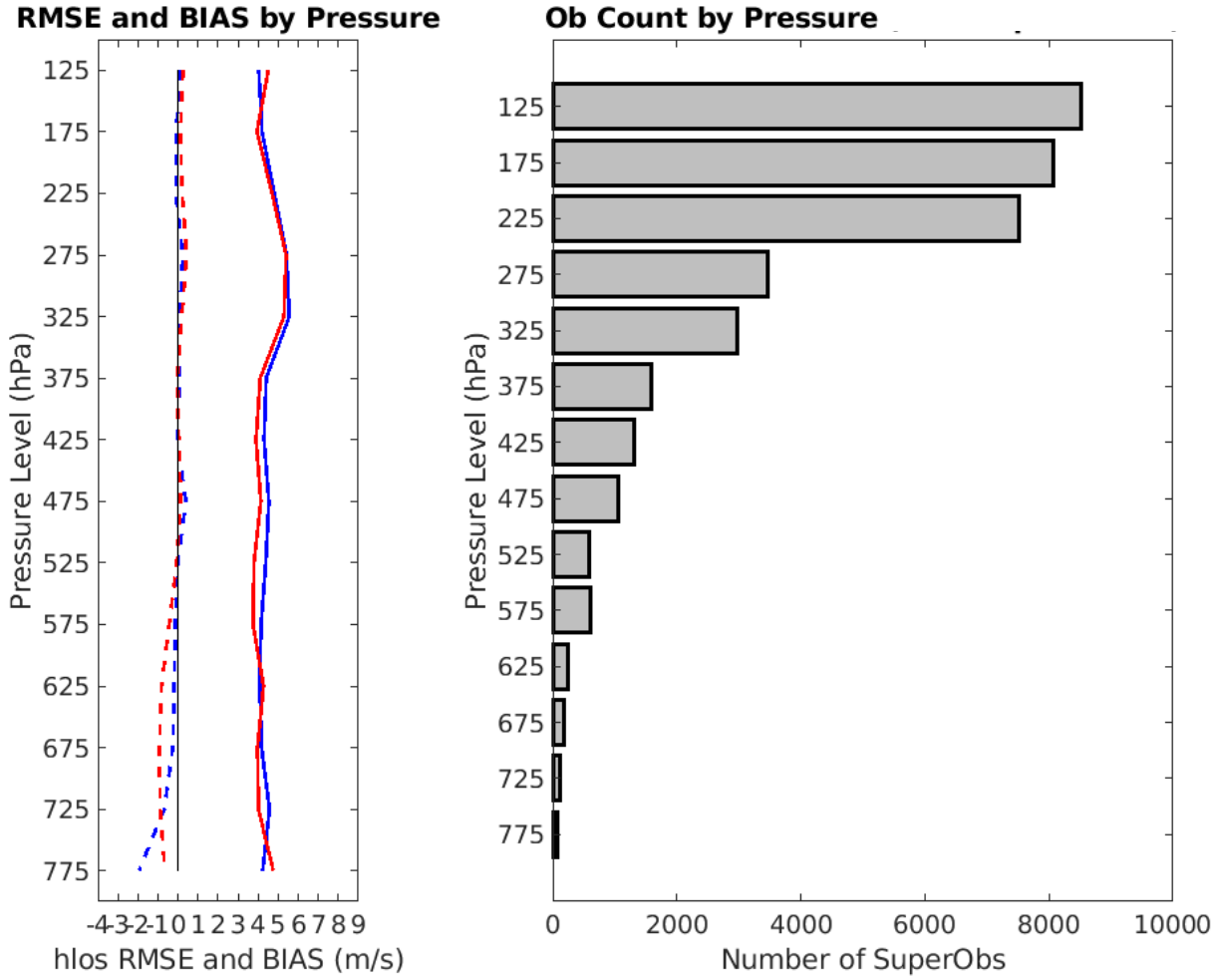
Comparisons to ERA5

Aeolus Rayleigh and AIRS 3D winds compared to ERA5 for 10 days in August and September 2019

~36,000 AIRS/Aeolus co-locations

AIRS and Aeolus have similar bias and RMSE throughout the entire profile

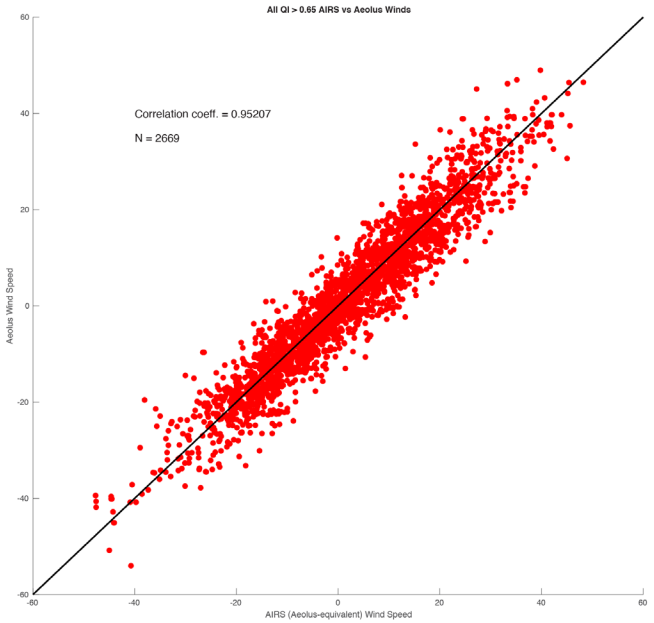
	AIRS vs ERA5	Aeolus vs ERA5
Bias	+0.02 ms^{-1}	+0.17 ms^{-1}
RMSE	4.57 ms^{-1}	4.52 ms^{-1}
Correlation	0.95	0.95



AIRS and Aeolus wind speed bias (dashed) and RMSD (solid) compared to ERA5

Summary

Since there are several inherent differences in the spatial coverage, temporal sampling, and wind measurement this high correlation indicates these two sources of 3D winds may be complementary, with similar quality.



This helps to justify a combined mission of a DWL with a hyperspectral IR instrument:

- DWL gives high-quality 3D profiles of HLOS winds along a path
- Hyperspectral IR will provide potentially similar quality total wind with improved horizontal spatial coverage (reduced vertical resolution).
  Note: Higher resolution hyperspectral instrument needed.