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Overview of AIRS V6 Validation Results and Plans

Eric Fetzer

NASA Sounder Science Team Meeting

October 15, 2015

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Why V6 Level 2 Validation?

- **We have about one billion AIRS/AMSU Level 2 retrievals**
  - ***Two orders of magnitude more than radiosondes.***

- **Each 1x1 degree global grid cell contains 15,000 AIRS/AMSU retrievals**

- **We need local constraints on:**
  - ***Retrieval biases.***
  - ***Retrieval variability.***
  - ***Vertical resolution.***
  - ***Error estimates.***
  - ***Spurious trends.***
  - ***Sampling biases.***
  - ***Performance relative to reanalyses.***

Do we know these everywhere we observe?

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Lots of Mature Data Products

AIRS Product	Product	Accuracy (V5)	Val Status (V5)
Core: Radiances			
AIRS IR Radiance	L1B-AIRS	<0.2K	Stage 3
AIRS VIS/NIR Radiance	L1B-VIS	15-20%	Stage 2
AMSU Radiance	L1B-AMSU	1-3 K	Stage 3
HSB Radiance	L1B-HSB	1-3 K	Stage 3
Core: Thermodynamic			
Cloud Cleared IR Radiance	L2	1.0 K	Stage 2
Sea Surface Temperature	L2	1.0 K	Stage 3
Land Surface Temperature	L2	2-3 K	Stage 2
Land Surface Emissivity	L2	10%	Stage 2
Temperature Profile	L2	1 K / km	Stage 3
Water Vapor Profile	L2	15% / 2km	Stage 3
Total Precipitable Water	L2	5%	Stage 3
Fractional Cloud Cover	L2	20%	Stage 3
Cloud Top Height	L2	1 km	Stage 3
Cloud Top Temperature	L2	2.0 K	Stage 3
Core: Composition			
Carbon Monoxide	L2	15%	Stage 2
Carbon Dioxide	Post-Proc	1-2 ppm	Stage 2
Total Ozone Column	L2	5%	Stage 3
Ozone Profile	L2	20%	Stage 2
Dust	L1B	0.5 K	Stage 1
Methane	L2	2%	Stage 2
OLR	L2	5 W/m2	Stage 3
Sulfur Dioxide	L1B & L2	1 DU	Stage 1
Research Products			
Dust	L2	TBD	TBD
HNO3	L1B-Post	TBD	TBD
NH3	L2	TBD	TBD
N2O	L2	TBD	TBD

Stage 1: Validation Product **accuracy has been estimated using a small number of independent measurements** obtained from selected locations and time periods and ground truth / field program effort.

Stage 2: Validation Product accuracy has been **assessed over a widely distributed set of locations and time periods** via several ground-truth and validation efforts.

Stage 3: Validation Product accuracy has been assessed, and the uncertainties in the product well-established **via independent measurements made in a systematic and statistically robust way that represents global conditions.**

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Over 300 papers based on AIRS Version 5 (compiled April 2015)

• Multiple quantities	106 papers
• IR Radiance	52
• Cloud Cleared Radiance	1
• Land Surface Temperature	6
• Land Surface Emissivity	1
• Temperature Profile	27
• Water Vapor Profile	16
• Clouds	14
• Carbon Dioxide	34
• Carbon Monoxide	18
• Ozone	4
• IR Dust	10
• Methane	7
• Sulfur Dioxide	7

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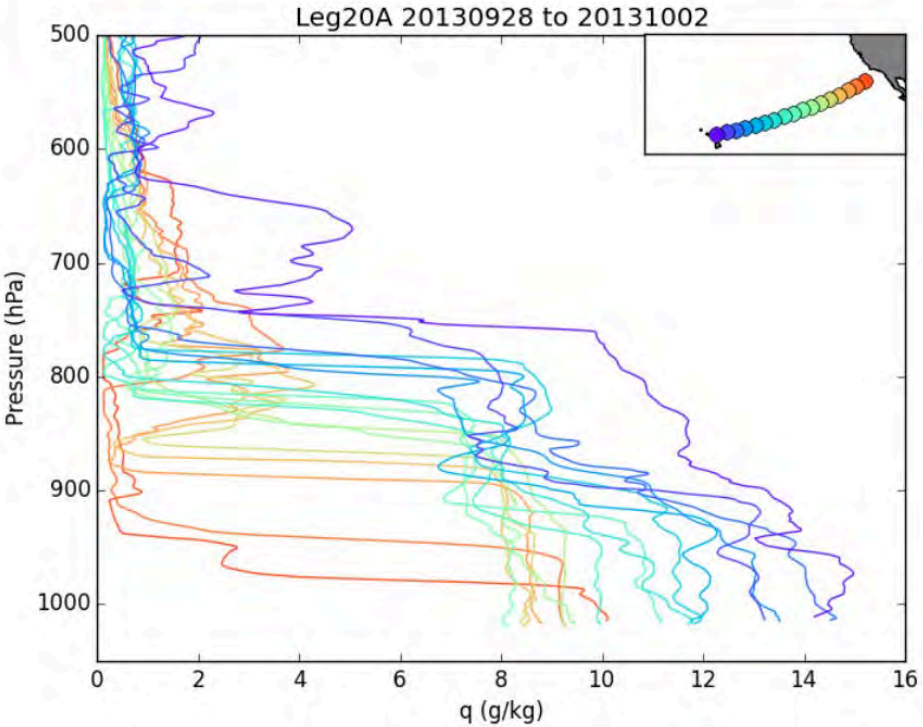
Science-Driven Validation
MAGIC: Northeast Pacific



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Validation in V6 'Test' Report

Version 6 Performance and Test Report

AIRS/AMSU/HSB Version 6
Level 2 Performance and Test Report

Edited by:

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Contributions by:

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December, 2012
Version 1.2

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Submit Questions to:
http://airs.jpl.nasa.gov/AskAirs

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Level 2 and Mean State Validation in the V6 Test Report

- **Level 2 comparisons:**
  - ***Temperature bias and trends; operational sondes (Irion).***
  - ***Ocean SST; SST-RTG/ECMWF (Susskind).***
  - ***Methane; HIPPO campaign (Xiong).***
  - ***Ozone; OMI (Irion).***
  - ***Cloud-cleared radiance; SST-RTG/ECMWF (Strow).***
  - ***SO_2 flag; OMI (Warner).***

- **Means:**
  - ***Surface air temperature; operational sondes (Dang).***
  - ***Surface temperature and emissivity; MODIS (Hulley).***
  - ***Cloud properties; CloudSat/CALIPSO (Dang).***
  - ***OLR; CERES (Susskind).***

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V6 Validation Publications

Boylan, P., J. Wang, S. A. Cohn, E. Fetzer, E. S. Maddy, and S. Wong (2015), Validation of AIRS version 6 temperature profiles and surface-based inversions over Antarctica using Concordiasi dropsonde data, *J. Geophys. Res. Atmos., 120,* doi:10.1002/2014JD022551.

Kahn et al., (2015), Pixel-scale assessment and uncertainty analysis of AIRS and MODIS ice cloud optical thickness and effective radius, *submitted.*

Kalmus, P., S. Wong, and J. Teixeira (2015), The Pacific Subtropical Cloud transition: A MAGIC Assessment of AIRS and ECMWF Thermodynamic Structure, *Geoscience and Remote Sensing Letters*, IEEE, PP(99), 1-5, doi:10.1109/LGRS.2015.2413771.

Wong, S., E. J. Fetzer, M. Schreier, G. Manipon, E. F. Fishbein, B. H. Kahn, Q. Yue, and F. W. Irion (2015), Cloud-induced uncertainties in AIRS and ECMWF temperature and specific humidity, *J. Geophys. Res. Atmos., 120*, 1880–1901, doi:10.1002/2014JD022440.

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We have LOTS of validation data

	Validation Categories by Geophysical Conditions						
	Ocean		*Land*			*Cold Polar*	*Global*
	Low lat	*High lat*	*Desert*	*Warm*	*Cold Season*		
Radiances							
IR	Aircraft						CrIS IASI
Vis/NIR							**MODIS** **VIIRS**
AMSU							**Aircraft,** **ATMS,** AMSU-A
HSB							**Aircraft,** ATMS, AMSU-B
Retrieved thermodynamic quantities							
CC Radiance							CrIMSS Aircraft GOES
Emissivity	**Ships**	**Ships**	**Field/Lab** **ASTER**	**Field/Lab** **ASTER**	**Field/Lab** **ASTER**	Lab	CrIMSS **ASTER** **MODIS**
SST	**Ships** **Buoys** **AMSR-E** **MODIS** **Reanalysis** CrIMSS TES	**Ships** **AMSR-E** **MODIS** **Reanalysis** CrIMSS TES	N/A	N/A	N/A	N/A	N/A
LST	N/A	N/A	Stations MODIS CrIMSS ASTER	Stations MODIS CrIMSS ASTER	MODIS CrIMSS ASTER	MODIS CrIMSS ASTER	N/A
Surface air temperature	**Buoys**	**Ships?**	**Met** **stations** **Sondes**	**Met** **stations** **Sondes**	**Met** **stations** **Sondes**	**Met** **stations** **Sondes**	CrIMSS TES
T (p>700 hPa)	**ARM** **TWP,** **others**	**ARM** **NSA**	**???**	**Many** **sondes**	**Many** **sondes**	**ARM NSA,** **Antarctica**	**TES?** CrIMSS
T (300<p<700 hPa)	"	"	"	"	"	**GPS RO** **Sondes**	**TES?** CrIMSS
T (100<p<300 hPa)	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**TES?** CrIMSS
T (p<100 hPa)	**GPS RO**	**GPS RO**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**TES?** CrIMSS
TPW	**Sondes** **AMSR-E**	**Sondes** **AMSR-E**	**GPS** **ground**	**GPS** **ground**	**GPS** **ground**	**GPS** **ground**	**TES?** CrIMSS
Surface air humidity	**Buoys**	**Ships**	**Met** **stations**	**Met** **stations**	**Met** **stations**	**Met** **stations?**	**TES?** CrIMSS
q(p>700 hPa)	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**GPS RO** **Sondes**	**Sondes,** **GPS RO**	**Sondes,** **GPS RO**	**Sondes**	**TES?** CrIMSS
q(300<p<700 hPa)	**GPS RO**	**GPS RO**	**GPS RO**	**Sondes** **GPS RO**	**Sondes** **GPS RO**	**Sondes**	**TES?** CrIMSS
q(p<300 hPa)	**Few** **sondes**		**Special** **sondes**	**Special** **sondes**	**Special** **sondes**	**N/A**	**TES?** **MLS** CrIMSS
Cld Frc	**ARM lidar** GOES	**ARM** **lidar**	**ARM** **lidar** GOES	**ARM lidar** GOES	**ARM lidar** GOES		**CloudSat/** **CALIPSO** **MODIS** CrIMSS VIIRS OMI AIRS Vis/NIR

							ISCCP
CTH/pressure	ARM lidar	ARM lidar	ARM lidar	ARM lidar	ARM lidar		**CloudSat/** **CALIPSO** **MODIS** CrIMSS ISCCP
CTT							**MODIS** CrIMSS OMI ISCCP
Cloud radii	Aircraft						MODIS ISCCP?
Cloud optical depth Cloud phase							**MODIS** ISCCP MODIS CloudSat/ CALIPSO
CO	**Aircraft**	**Aircraft**	**Aircraft** **ESRL**	**Aircraft** **ESRL**	**Aircraft** **ESRL**	**Aircraft**	**TES** **IASI**
Tot O3	**Aircraft** **Sondes** **Dobson** **Umkehr**	**Aircraft** **Sondes** **Dobson** **Umkehr**	**Aircraft** **Sondes** **Dobson** **Umkehr**	**Aircraft** **Sondes** **Dobson** **Umkehr**	**Aircraft** **Sondes** **Dobson** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**OMI** **TES** OMPS IASI
O3 Prof	**Aircraft** **Sondes** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**Aircraft** **Sondes** **Umkehr**	**TES** **OMI?** **OMPS?** **SBUV** **MLS** IASI? CrIMSS?
IR Dust Flag	**Aeronet**	**Aeronet**	**Aeronet**	**Aeronet**	**Aeronet**	**Aeronet**	**MODIS** **OMI**
Methane	**Aircraft**						TES
CO2							**Aircraft** TES
SO2							**OMI**
OLR							CrIMSS CERES

Bold: possibly better noise characteristics than AIRS so useable as validation 'truth'.

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Summarizing *dedicated* sonde sites

Excluding MAGIC, we have 30 total sites, consisting of:

- **7: 'Supersites' with >20 sondes for multiple seasons.**
- **8: Good sites with >20 sondes for 1 season.**
- **3: Okay sites with ~10 sondes for 1 season.**
- **12: poor sites with too few sondes**
  - ***May be useful for global mean constraints.***

- **Some climate conditions are poorly sampled. For example:**
  - ***Only Table Mountain, CA is near a continental desert.***
  - ***Few sondes over extensive tropical forests like Amazon, Congo, Indonesia.***
  - ***Few sondes at middle and high latitude oceanic sites.***
    - Dedicated sondes over Pacific may help.

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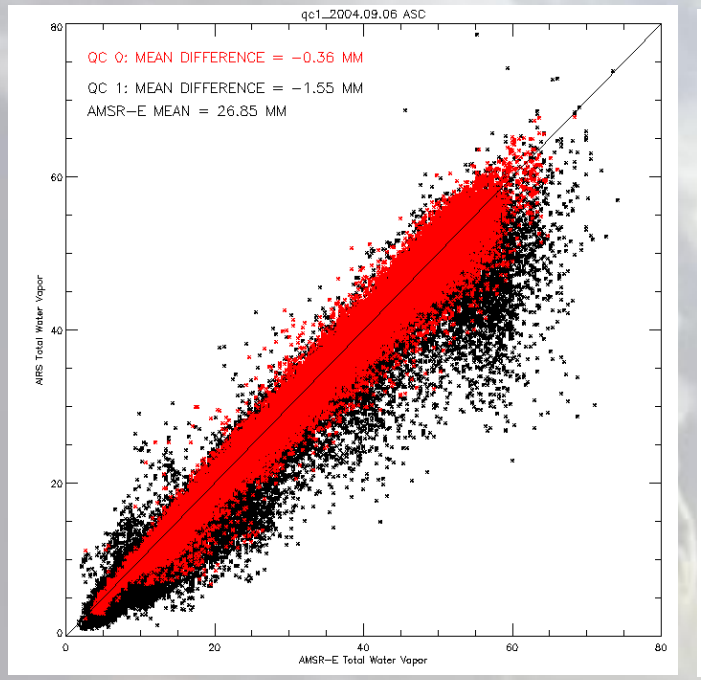
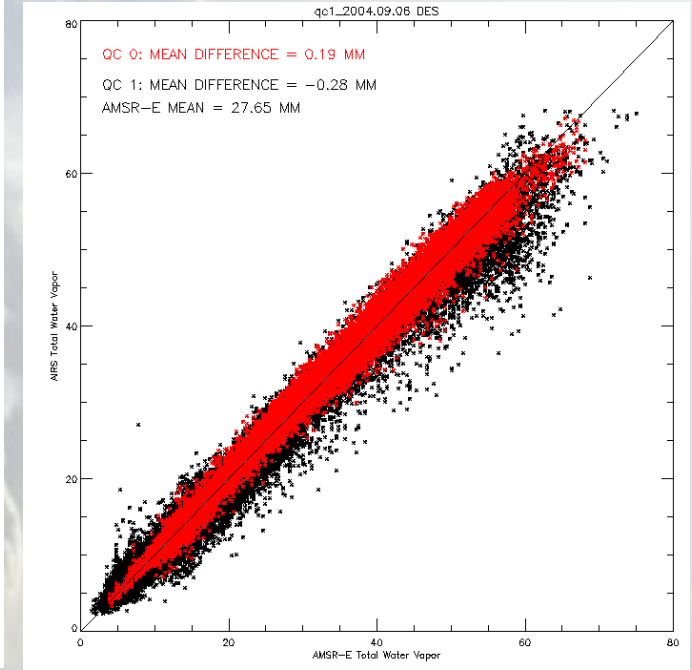
Version 6 Liens

- **Issues with ozone raised by Joel Susskind**
- **Known bias in daytime total water vapor.**

2004.09.06 Day



2004.09.06 Night



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A (Rough) V6 Validation Plan

- **Themes:**
  1. ***Long-term comparisons***
     - Operational sondes are in V6 test report.
     - Total ozone against OMI in V6 test report.
     - Brian Kahn submitted a MODIS cloud comparison paper.
     - TPW: ground-based GPS and AMSR-E (Yue and Fetzer)
  2. ***Boundary layer properties, especially over land***
     - Surface T and q (Van Dang)
     - Temperature and humidity inversions (Sung Wong)
  3. ***Dedicated radiosondes***
     - MAGIC (P. Kalmus)
     - Still need to examine ALL dedicated sondes
  4. ***Reanalyses as baseline for AIRS performance***
     - Surface T and q (Van Dang)

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Other Validation Analyses

- **GPS RO, Ozonesondes, CloudSat/CALIPSO**
- **Vis / NIR radiances; Kahn**
  - ***Compare L1B Vis / NIR with MODIS***
- **Microwave L1B radiances; Lambrigtsen**
  - ***Compare with AMSU on other platforms***
- **Tropopause properties; Fishbein**
  - ***Compare tropopause structure with GPS RO retrievals***
- **Trends in upper troposphere from SW cal drift; Aumann**
  - ***Examine effects of shortwave drift on retrieved products***
- **Other efforts supported by ROSES.**
  - ***Especially trace gases.***

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Summary: The Validation Plan

- **We have a prioritized list of analyses.**
  - ***We still have not exploited all our correlative data.***

- **Please let me know if you are planning a comparison between AIRS V6 and in situ or satellite data.**

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The V6 Validation Report: statistics by conditions (roughly 10 pages of tables).

Example from V5

DRAFT

Radiance (Level 1) Products

AIRS IR Radiance *Validation Status:* Val5. Validated for all conditions except high altitude polar winter.

Conditions Validated	RMS Requirement	Uncertainty Estimate	References
Ocean, $T_{surf} > 273$ K.	3%	0.2%	Aumann et al. [2006], Tobin et al [2006a]
Snow/Ice, $T_{surf} < 273$ K.	3%	0.1 K	Walden et al. [2006]

Further analyses: None anticipated.

AIRS VIS/NIR Radiance *Validation Status:* Prov. No quantative comparisons have been reported.

Conditions Validated	RMS Requirement	Uncertainty Estimate	References
Low latitude ocean, qualitative only.	20%	15-20%	Meeting presentations of images and cloud detection.

Futher analyses: Need quantitative comparisons with MODIS and in situ observations.

AMSU Radiance *Validation Status:* Val3. Comparisons for low and middle latitude land and ocean.

Conditions Validated	RMS Requirement	Uncertainty Estimate	References
Non-polar land and ocean.	0.25-1.2 K.	1-3 K ???	Rosenkranz and Barnet [2006]

Futher analyses: Extend analyses to ARM NSA and non-ARM sites.

DRAFT

Geophysical (Level 2) Products

Cloud Cleared IR Radiance *Validation Status:* Val3. Global comparisons at nonpolar latitudes against models.

Geophysical Conditions Studied	RMS Requirement	Uncertainty Estimate	References
All non-polar	1.0 K	Accuracy ~1 K, precision 0.3-8 K.	Meeting presentations comparing ECMWF and NCAR CAM3.

Futher analyses: Need published comparison against sondes.

Sea Surface Temperature *Validation Status:* Val1. Characterized for all conditions except polar oceans.

Geophysical Conditions Studied	RMS Requirement	Uncertainty Estimate	References
All non-polar	0.5 K	1 K ???	Auman et al. [2006] ???

Futher analyses: Need comparisons at very high latitudes.

Land Surface Temperature *Validation Status:* Prov. Compared against MODIS L3, ECMWF and Dome C.

Geophysical Conditions Studied	RMS Requirement	Uncertainty Estimate	References
Global using MODIS, ECMWF and Dome C data.	1.0 K	3 K ???	R. Knuteson, March 2007 Science Team Meeting

Futher analyses: Need more complete L2 analysis.

Temperature Profile *Validation Status:* Val4. Validated for all but polar winter conditions

Geophysical Conditions Studied	RMS Requirement	Uncertainty Estimate	References
Ocean, surface to lower stratosphere.	1 K / km	1 K / km	Divakarla et al. [2006], Fetzer et al. [2003, 2004, 2005], Nalli et al. [2006], Tobin et al. [2006]