AIRS Ozone
Version 4.0 to Version 5.0.7

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NOAA/NESDIS Camp Spring, MD, USA

Thanks To:
Gordon Labow (NASA), Shuntai Zhou (NCEP), Eric Beach (NOAA), Vitali Fioletov (MSC, Canada)

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Data Sets Used for Ozone Validation

- AIRS Retrieved Ozone Profiles and Matched O_3SNDS (WOUDC)

	Match/Region	Polar	Midlat	Tropics	Total
O_3SND	±3 HR	137	212	4	353
O_3SND	±12 HR	465	320	54	839

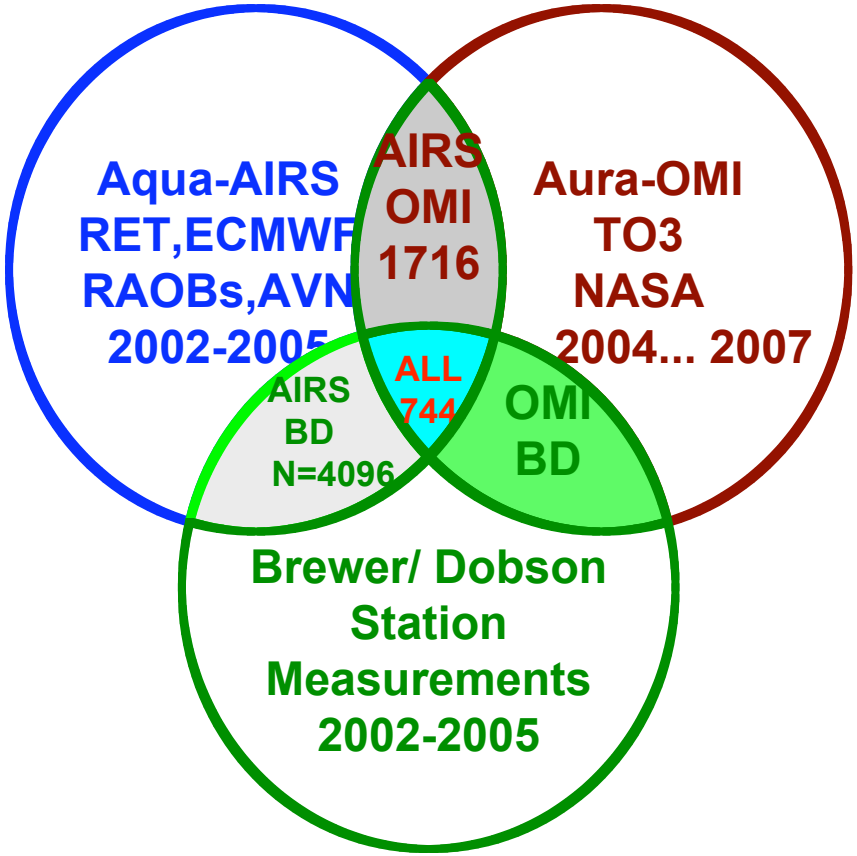
- AIRS- Total Ozone and Matched Brewer/Dobson (BD) Station Measurements

	Match/Region	Polar	Midlat	Tropics	Total
Total Ozone Stations	Day	1499	2282	315	4096

- AIRS Retrievals - Versions

Run	CLIM	FG-REG	Phy Ret	OWGT	Version
R1	UARS	ON	V4 CH (26)	0.75	V4.0
R3	UARS	ON	V5 CH(34)	0.5	V5 Baseline
R5	NEW CLIM	OFF	V5 CH (34)	0.5 - 2.0	V5.0*
R6	NEW CLIM	OFF	Bill's CH(41)	0.5 - 2.0	V5.0.7

Total Ozone Data Set Aqua-AIRS, Aura_OMI and Brewer/Dobson Ground Measuremnts



- A BD Measurement in a Day within 100 km Radius from AIRS Retrieval is Considered as a Match.
- Aqua_AIRS and BD Matches = 4096
  Number of Stations = 56
- Aqua-AIRS and Aura-OMI Matches = 1716
- Aqua-AIRS, Aura-OMI and BD Matches = 744
- OMI Overpass Data
  Bojan.bojkov@gsfc.nasa.gov
- http://avdc.gsfc.nasa.gov/phpgdv2/avdc_tablefile.php?

RECAP: AIRS Ozone Version 4 to Version 5.0.7
Experiments Performed in Support and Evaluation of AIRS Science Team Ozone Updates

- Q1. What Can we Expect if we Implement Current Version 5.0 (Call it As : V5.0 Baseline System)
- Q2: Whether the Proposed New Climatology (Suggested by JPL Group: Bill) for Ozone Helps the Current Version 5.0 ? **V5.0***
- Q3: Whether the Proposed New Ozone Channels (Suggested by JPL Group: Bill) Help Version **V5.0.7**
- Q4: What is the Optimum Damping Parameter (OWGT) ?
  - 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0

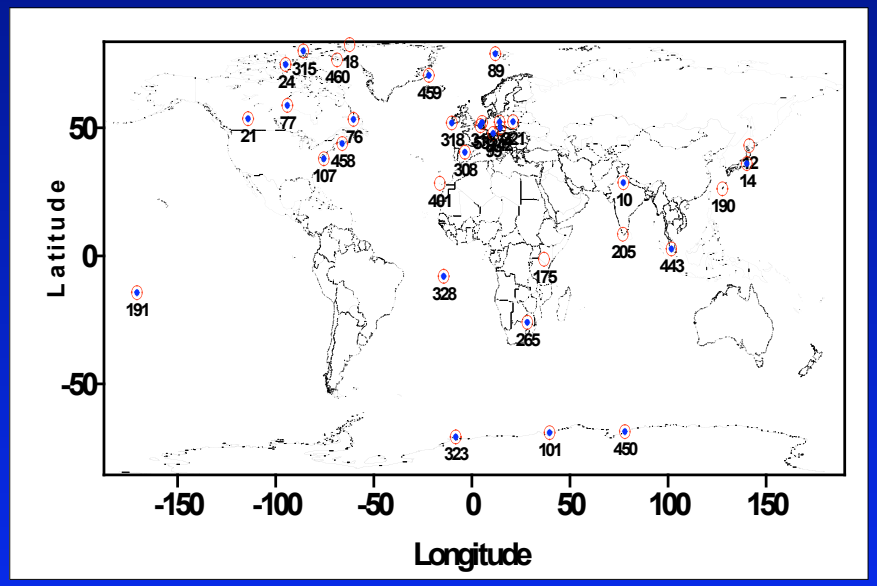
Run	CLIM	FG-REG	Phy Ret (PR)	OWGT	Version
R1	UARS	ON	V4 CH (26)	0.75	V4.0
R3	UARS	ON	V5 CH(34)	0.5	V5 Baseline
R5	NEW CLIM	OFF	V5 CH (34)	0.5 - 2.0	V5.0*
R6	NEW CLIM	OFF	Bill's CH(41)	0.5 - 2.0	V5.0.7

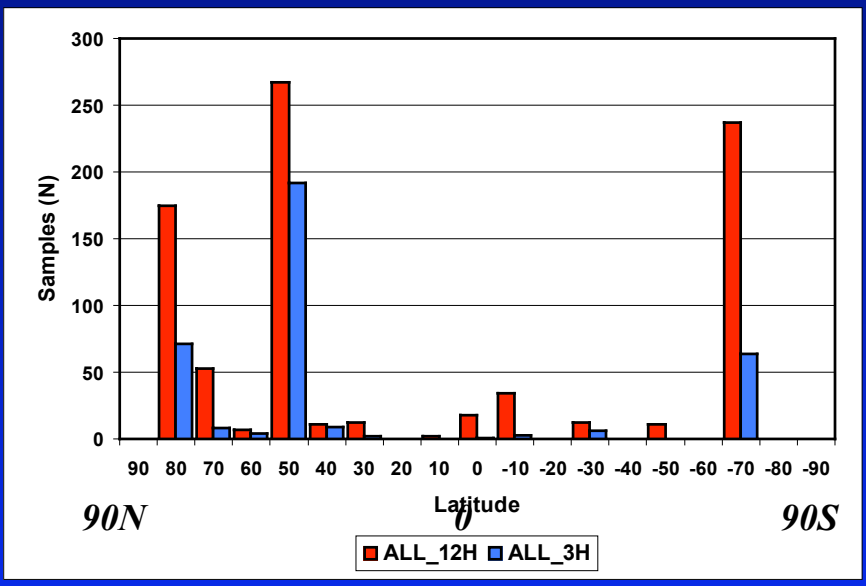
Consensus on Algorithm Insights and Concurrent Findings from the NOAA/JPL Ozone Working Group Led to V5.0.7 Ozone.

Results of V4.0 and V5.0.7

- AIRS Retrievals
  - » AIRS Retrieved Ozone Profiles with WOUDC O3SNDs (PR, FG, ECMWF)
    - – Version 4.0
    - – Version 4 *vs.* Version 5.0.7 (Call it V5)
  - » AIRS Total Ozone with Brewer/Dobson (BD) Measurements (PR, FG, ECWMF)
    - – Version 4.0
    - – Version 4 *vs.* Version 5.0.7 (Call it V5)
- Summary and Conclusions
- Future Plans

AIRS- O_3SND Matches (±3HR, ±12 HR Collocations)

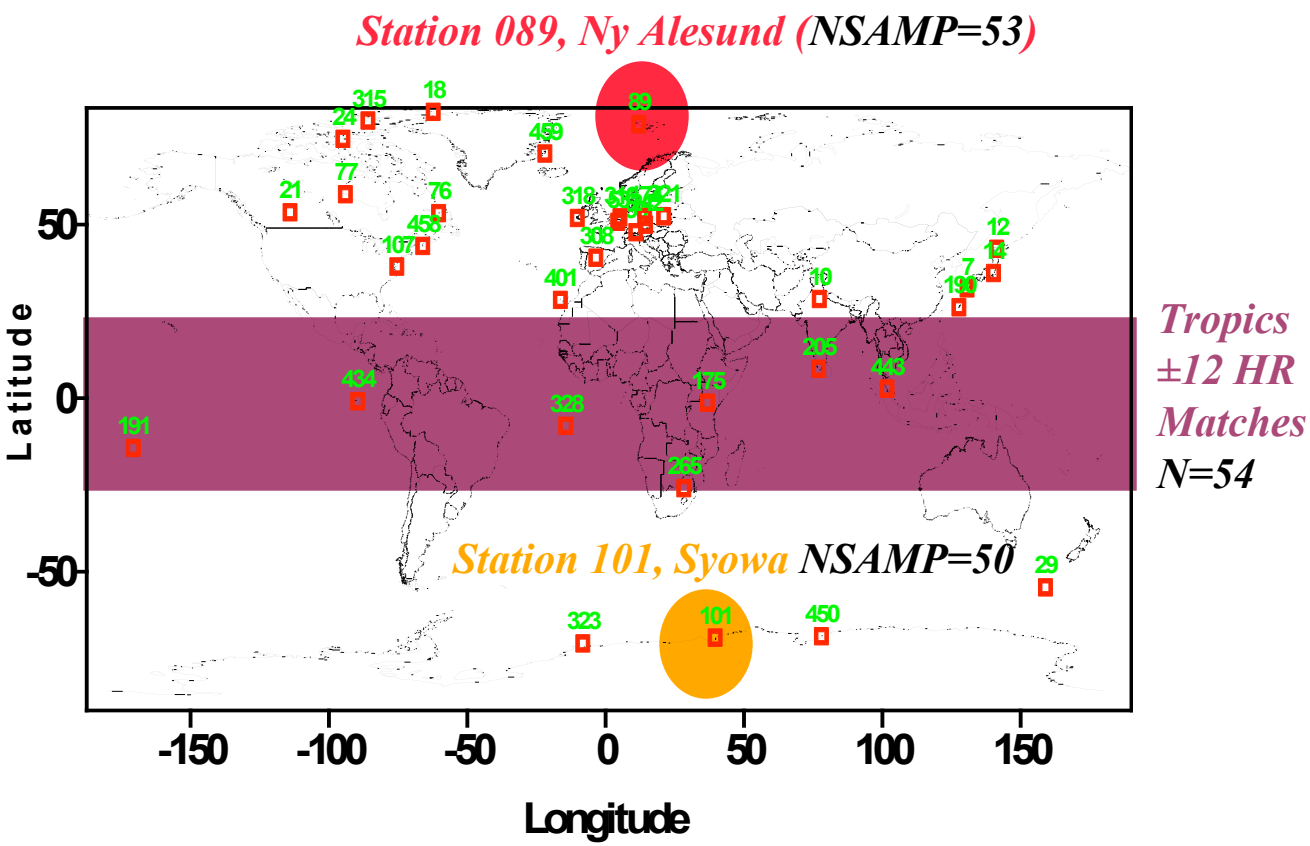




- Relaxing the Time Match Criteria (±12 HR) Increases the sample size
- ±3 HR Matches : 353, NSTNS:26
- ±12 HR Matches: 839, NSTNS : 35

	Match/Region	Polar	Midlat	Tropics	Total
O_3SND	±3 HR	137	212	4	353
O_3SND	±12 HR	465	320	54	839

Statistics for Individual Stations (STN 089, STN 101, Tropical Stations, and Global Samples



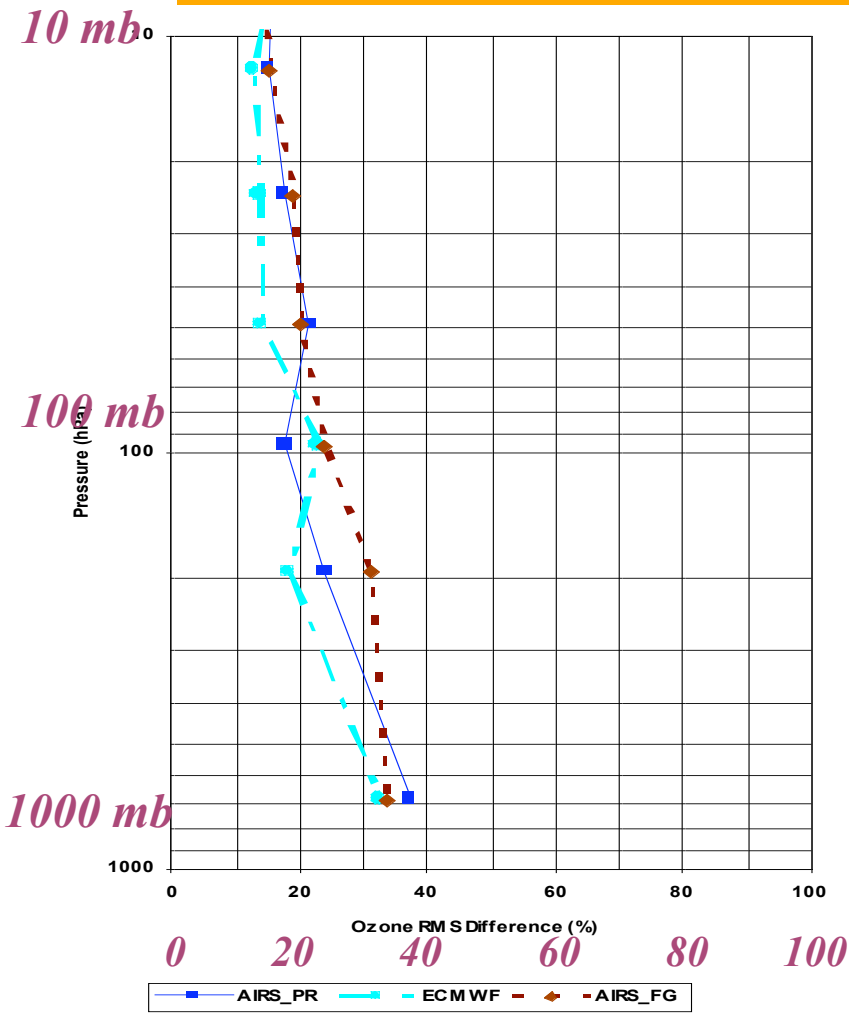
Layers Used for Statistics

Ozone		
Layer	Upper Prs (hPa)	Lower Prs (hPa)
1	0	2
2	2	4
3	4	8
4	8	16
5	16	32
6	32	66
7	66	126
8	126	260
9	260	1100

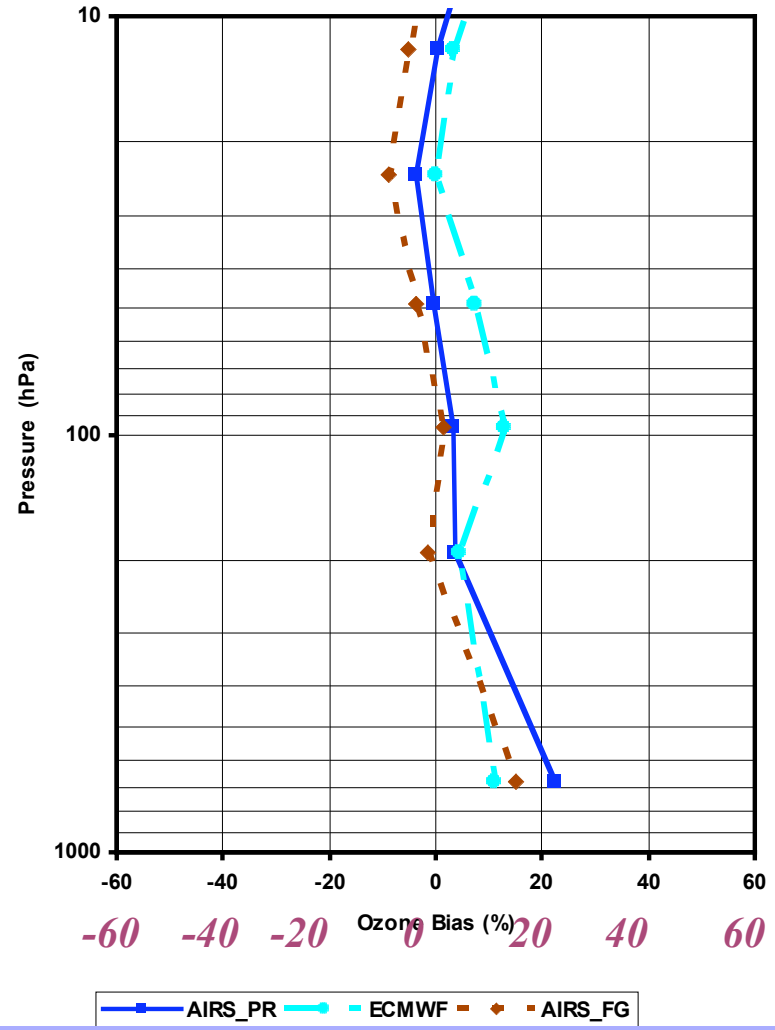
Ozone Profile Statistics – V4.0
O3SND vs. PR, FG, ECMWF

Polar = 137, Mid-Lat = 212, Tropics = 4 (±3 HR Matches, N353) – set 24

RMS Difference



Bias

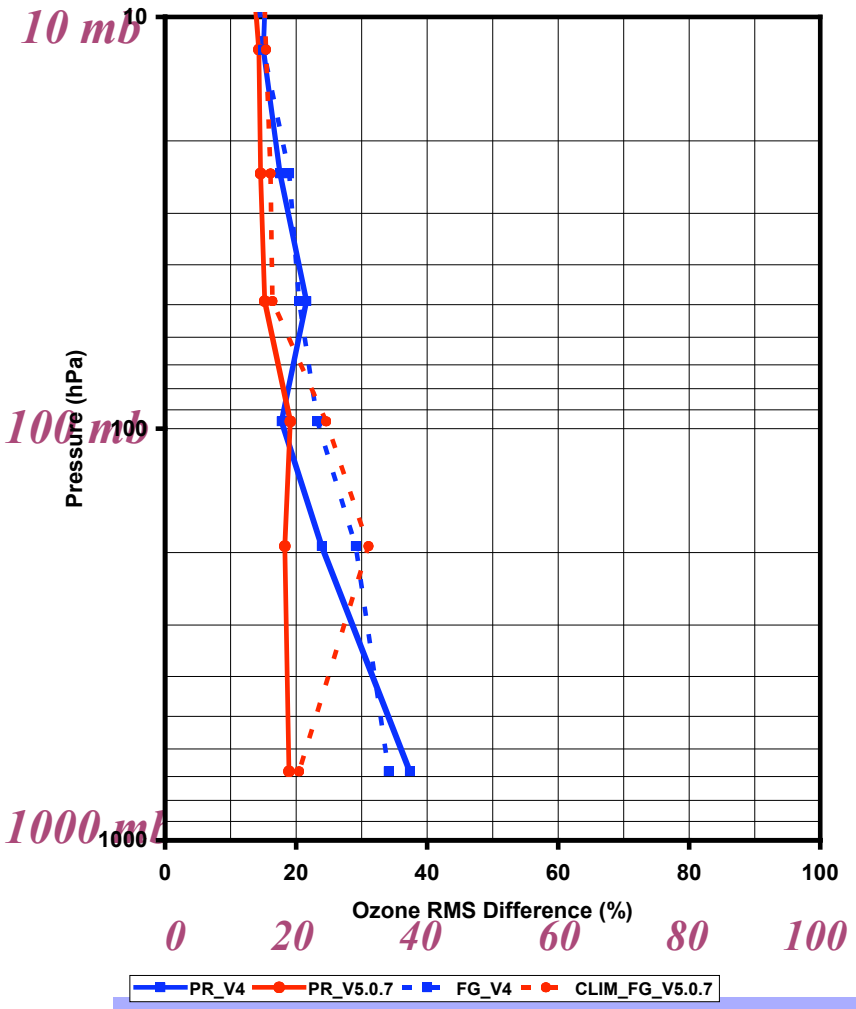


O3SND *vs.* AIRS Ret. ECMWF AIRS FG V4.0 Results

Version 4 vs. Version 5.0.7 ALL Data

Ozone Profile Statistics - Set 56

RMS Difference



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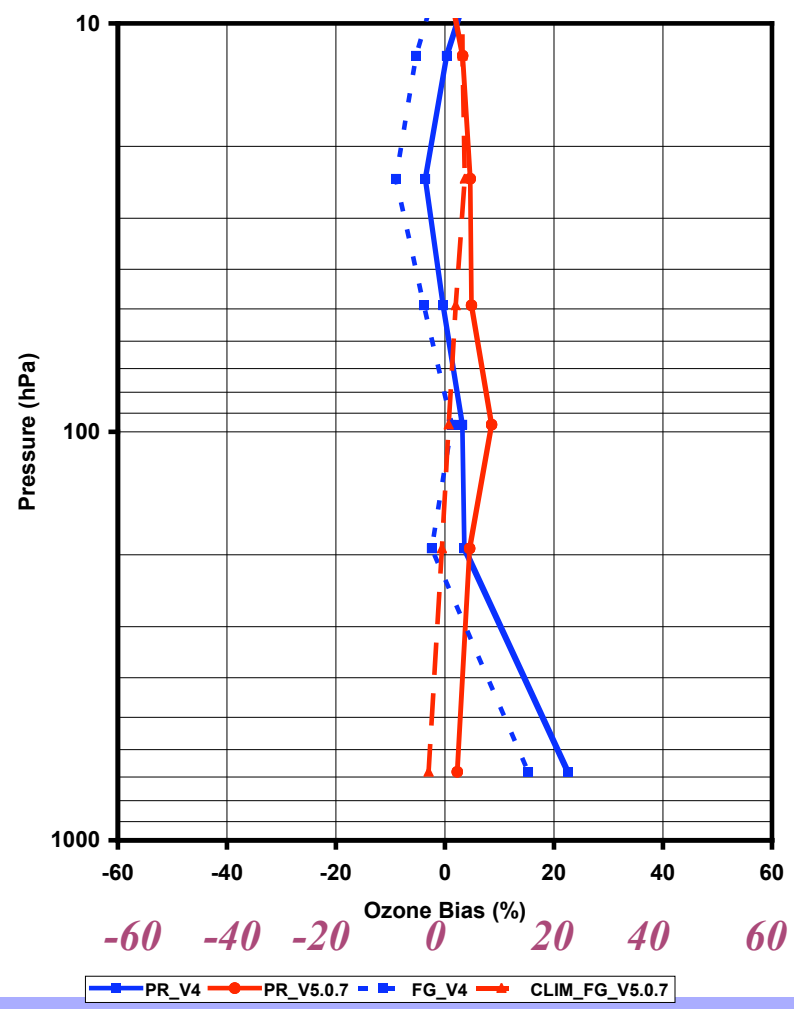


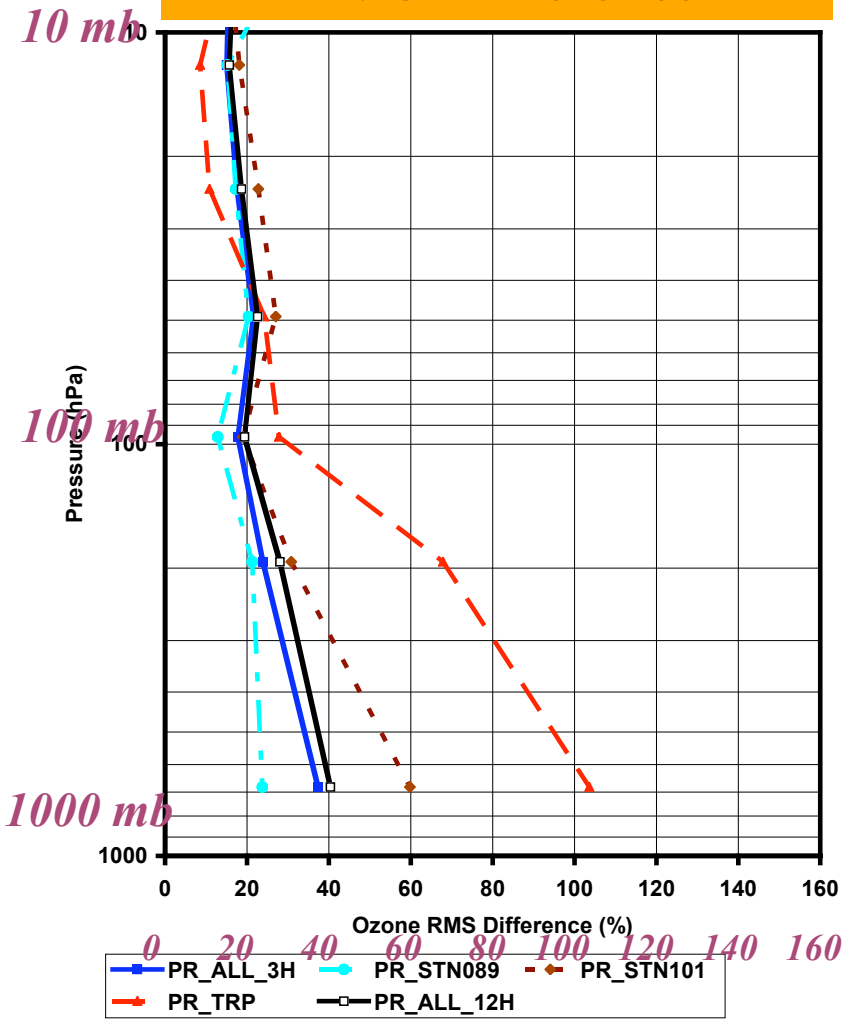
Solid Line (PR), Broken Line (FG)

V4.0 PR and FG V5.0.7 PR and FG

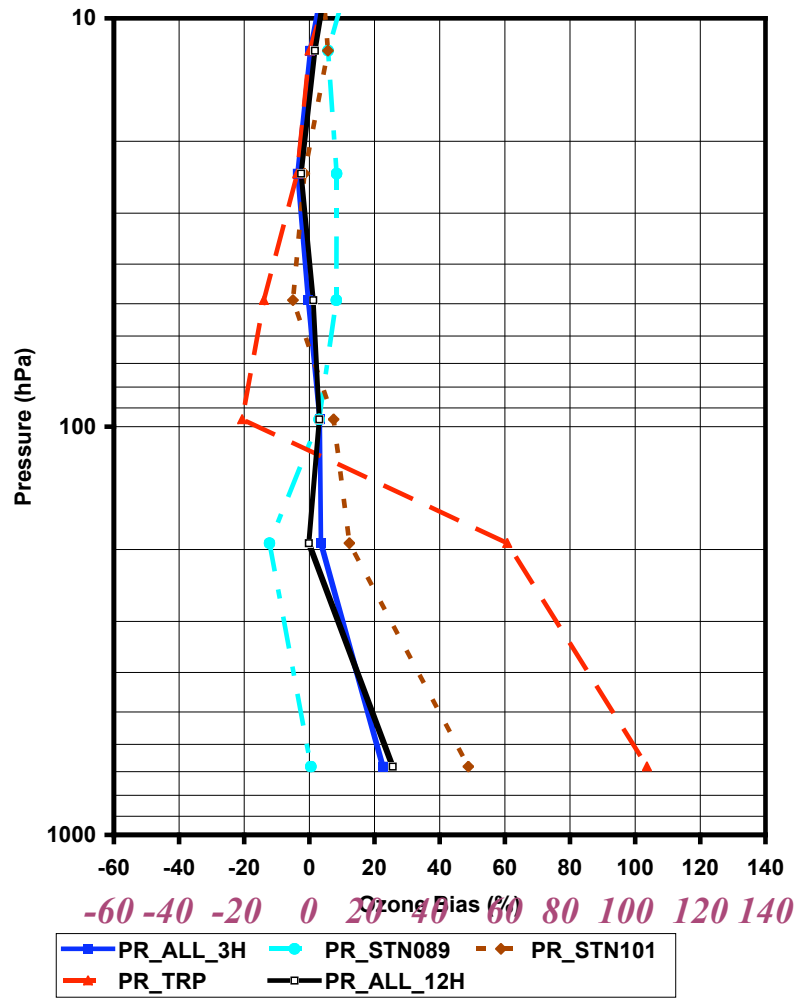
V4.0 Different Stations

ALL (N=353), STN 089 (N=53, NH),
STN 101(N=50,SH), Tropics (N=54, ±12HR) - set 34

RMS Difference



Bias

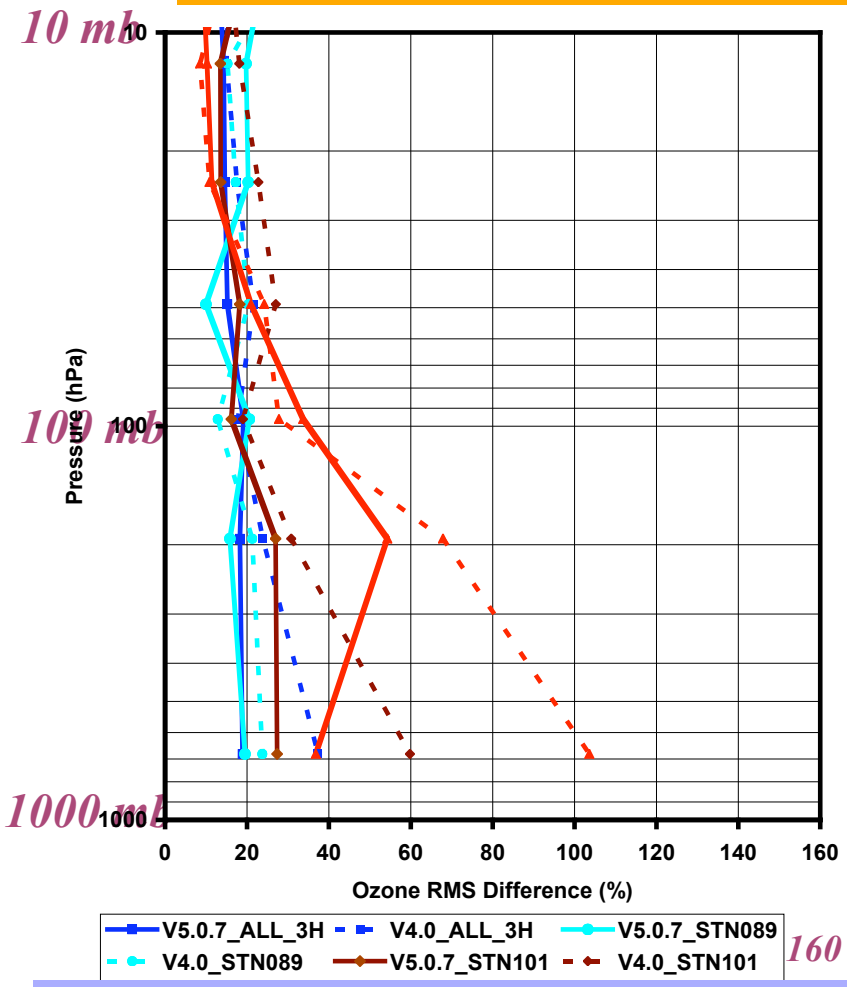


ALL_3H STN089 STN101 TRP_12H ALL_12H

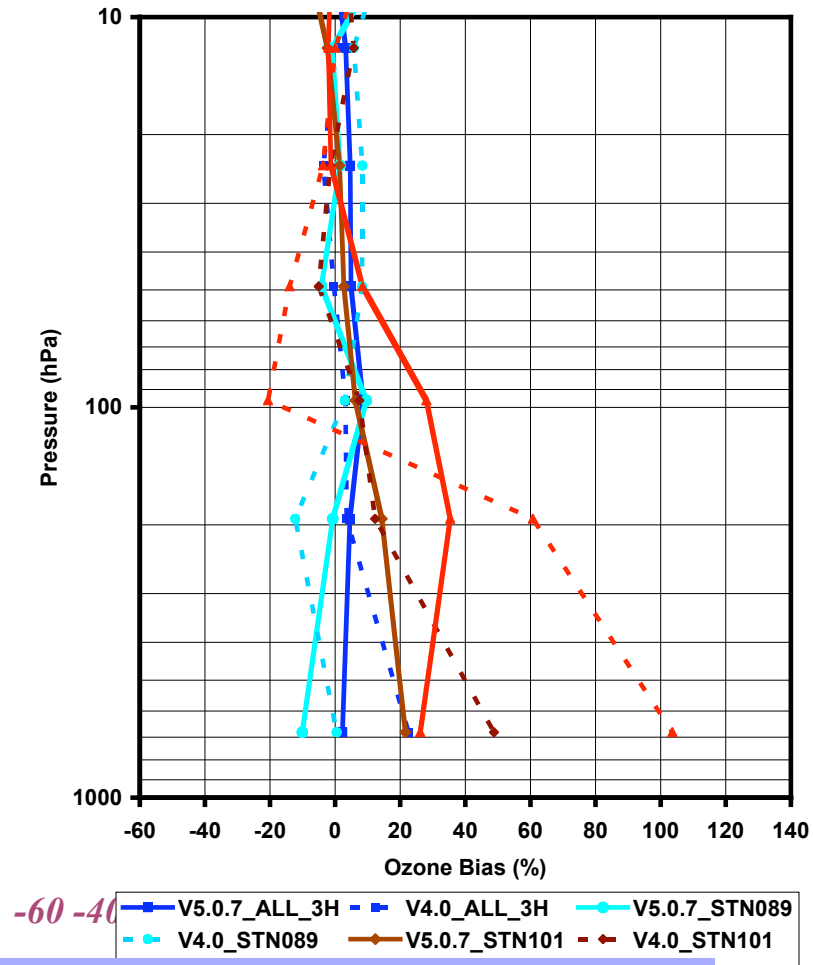
V4 and V5.0.7 Different Stations

ALL (N=353), STN 089 (N=53, NH), STN 101(N=50,SH), Tropics (N=54, ±12HR) - set 54

RMS Difference



Bias

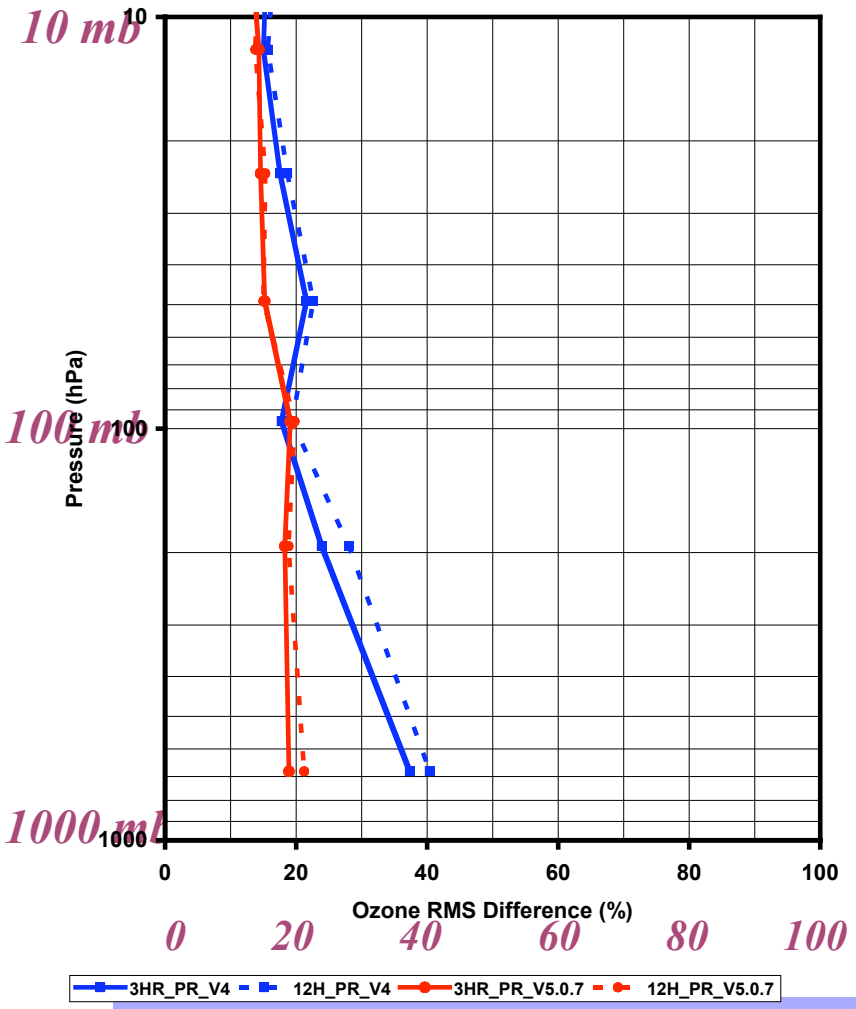


V4 Dotted lines, V5 Solid Lines

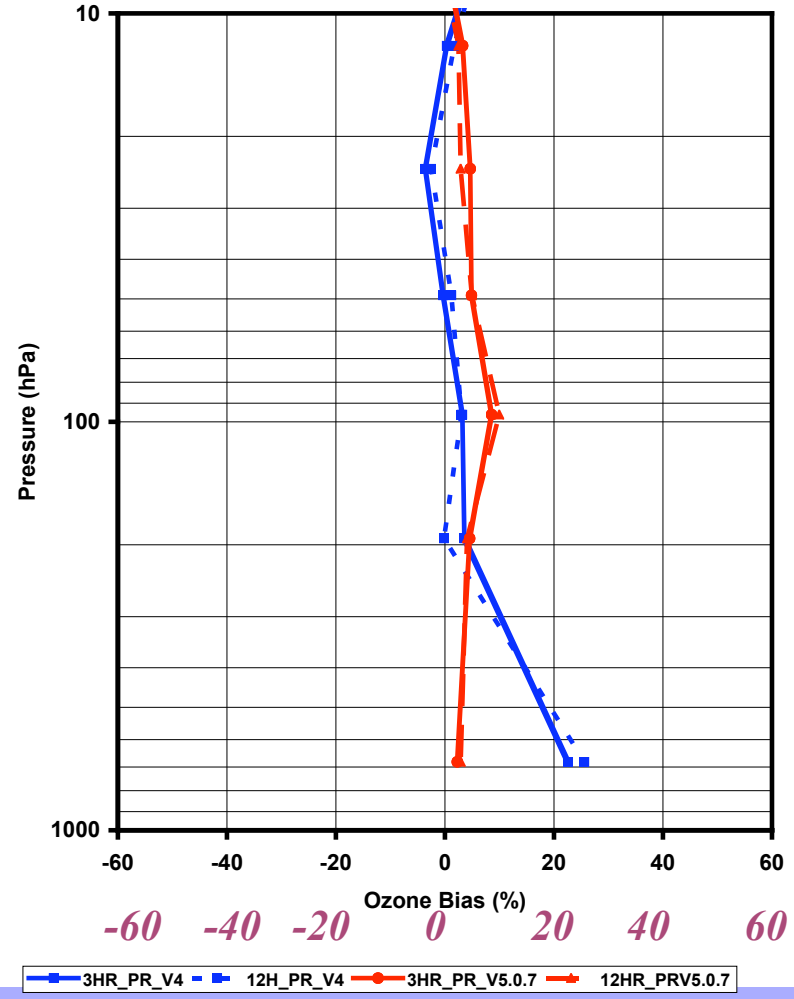
ALL_3H STN089 STN101 TRP_12H ALL_12H

Version 4 and Version 5.0.7 ALL Data
3 HR vs. 12 HR collocations (set 57)

RMS Difference



Bias



AIRS_PR_ALL_V4 AIRS_PR_ALL_V5.0.7

Solid Line (3HR), Broken Line : (12 HR)

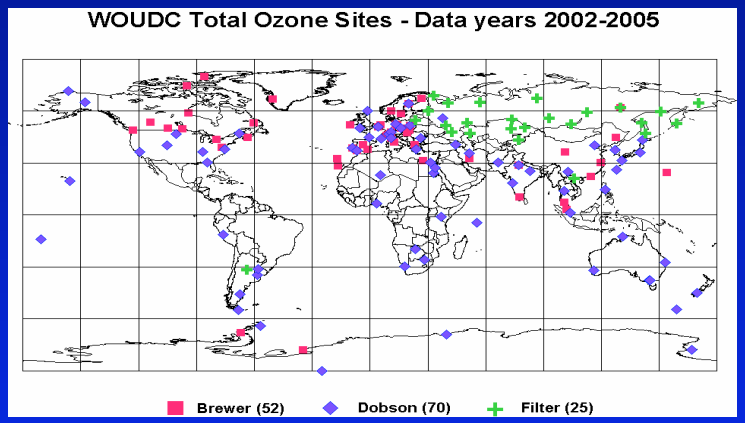
AIRS- Total Ozone Brewer/Dobson (BD) Station Matches

- A Measurement in a Day within 100 km Radius from AIRS Retrieval is Considered as a Match.
- Number of Matches = 4096

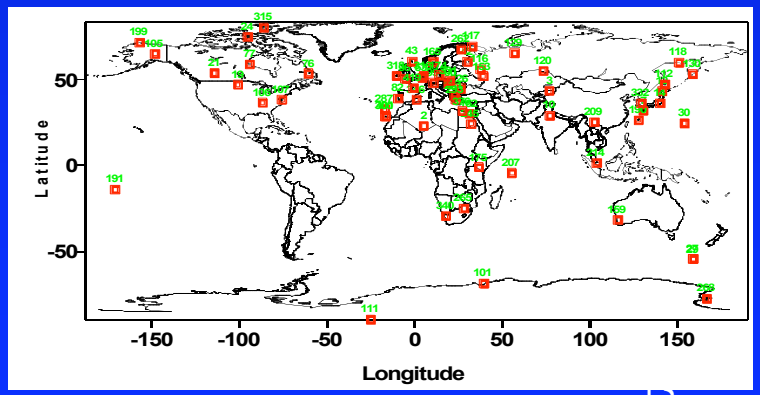
  Number of Stations = 56

	Match/Region	Polar	Midlat	Tropics	Total
Total Ozone Stations	Day	1499	2282	315	4096

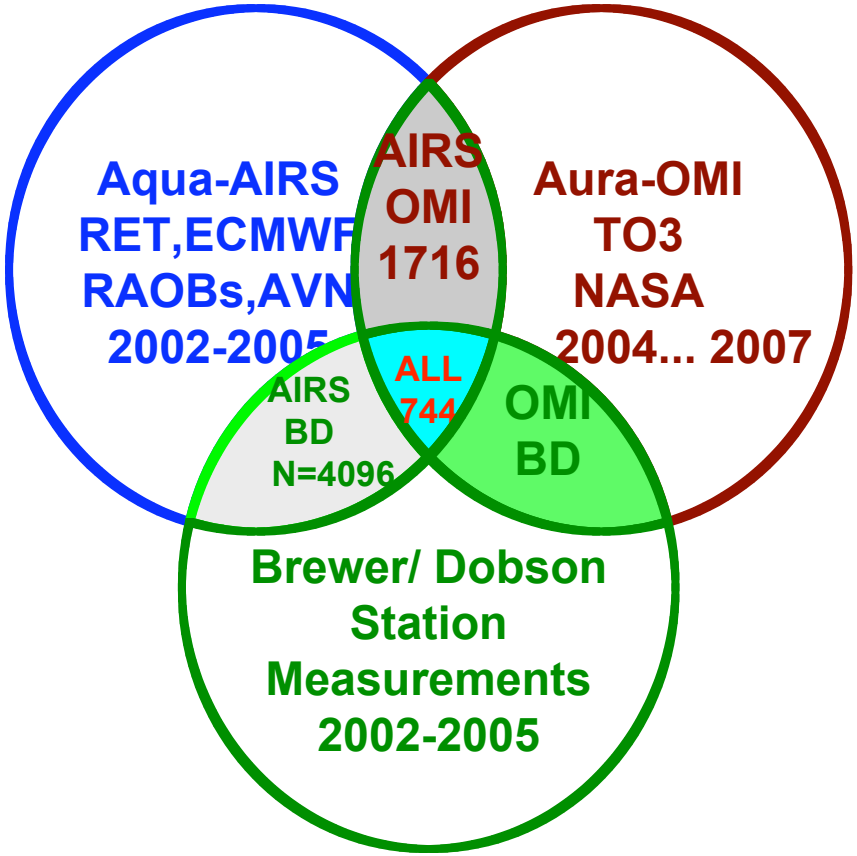
WOUDC BD STNs 2002-2005



AIRS-TO3 BD Matches



Total Ozone Data Set Aqua-AIRS, Aura_OMI and Brewer/Dobson Ground Measuremnts



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  Number of Stations = 56
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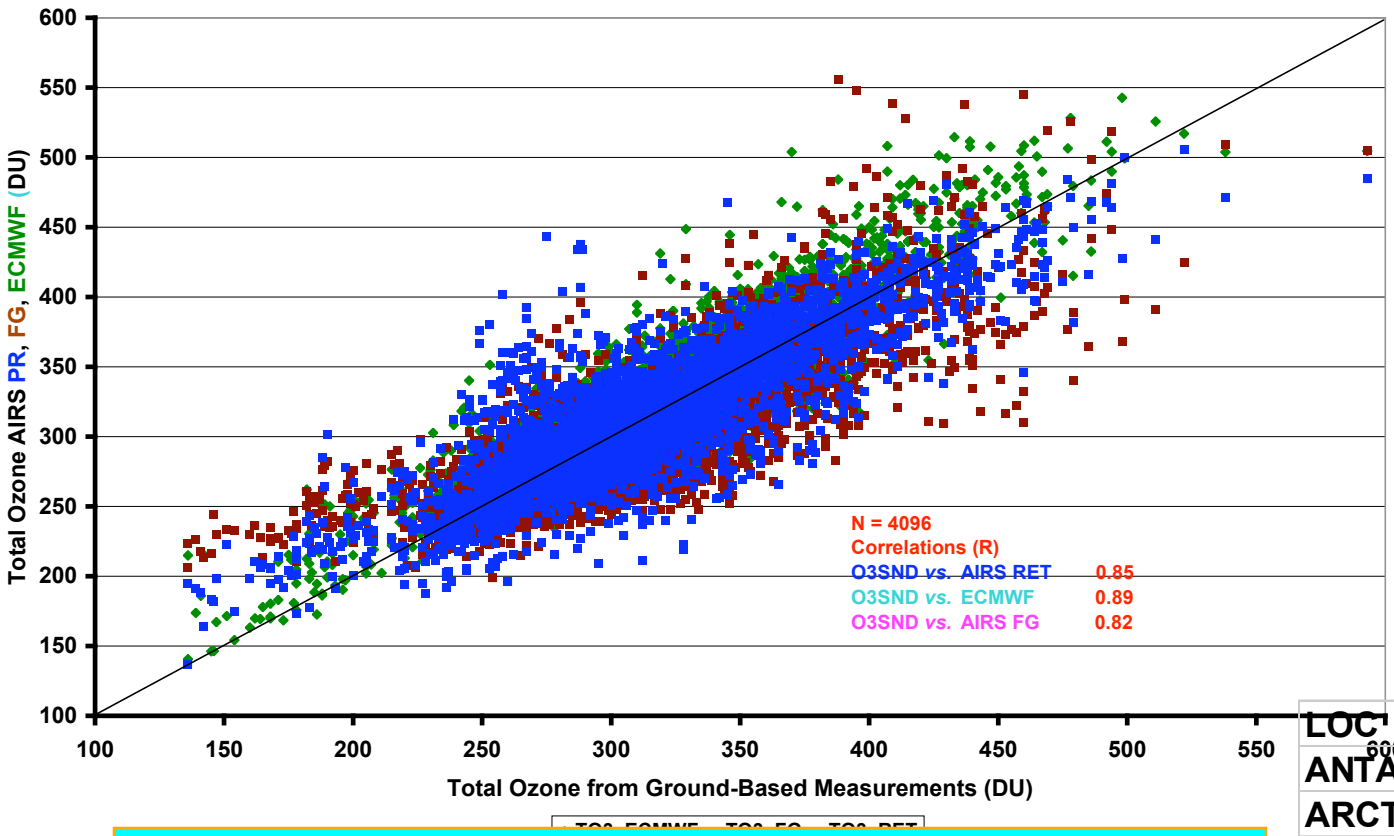
- Aqua-AIRS, Aura-OMI and BD Matches = 744
- OMI Overpass Data
  Bojan.bojkov@gsfc.nasa.gov
- http://avdc.gsfc.nasa.gov/phpgdv2/avdc_tablefile.php?

Version 4.0
AIRS Total Ozone vs. Dobson/Brewer Measurements
Station Locations and Accepted Samples

AIRS_PR ECMWF AIRS FG

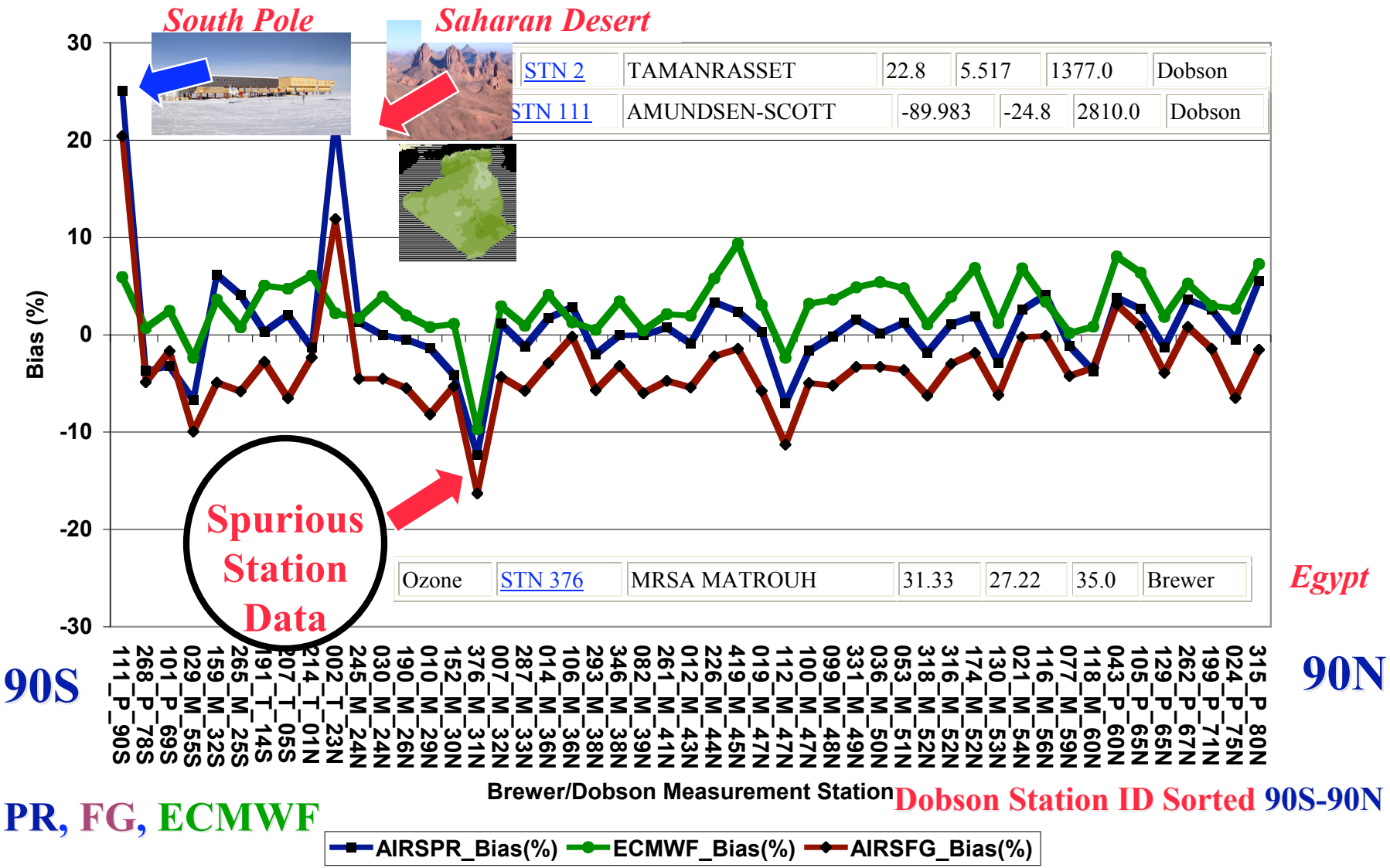


Region
High Latitudes 60°-90°N 60°-90°S
Mid-Latitudes 23°N-60°N 23°S-60°S
Tropics 0-23°N, 0-23°S
ALL Data

Ground-Based Brewer/Dobson Measurements

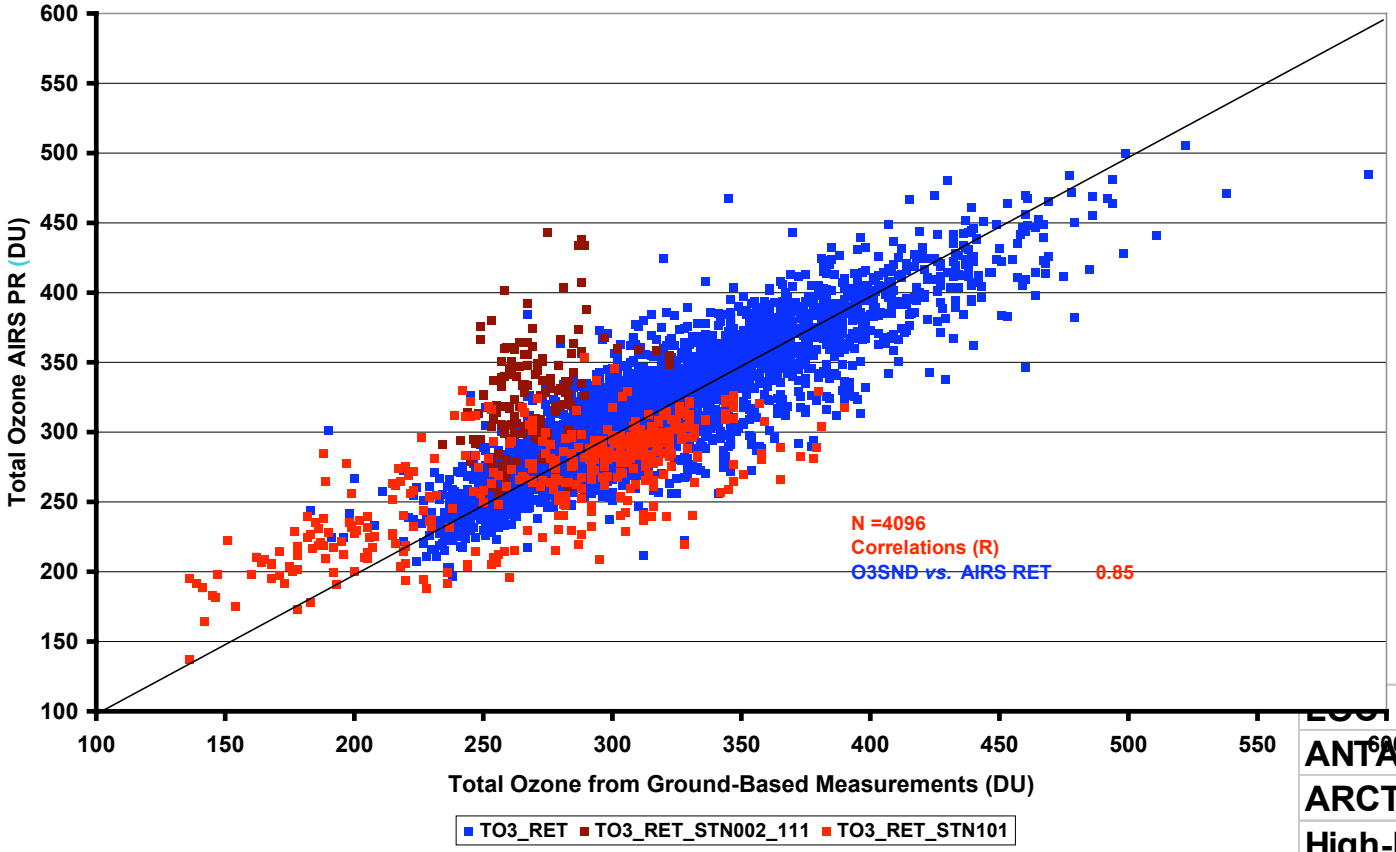
LOC	N
ANTARCTIC	491
ARCTIC	167
High-Lat	1491
Mid-LAT	2282
TROPICS	315
GLOBAL	4096

Total Ozone – V4 RET vs. BD STNS
Bias (%) - PR, FG, ECMWF



Version 4.0
AIRS Total Ozone vs. Dobson/Brewer Measurements
Station Locations and Accepted Samples

AIRS_PR STN002 STN101



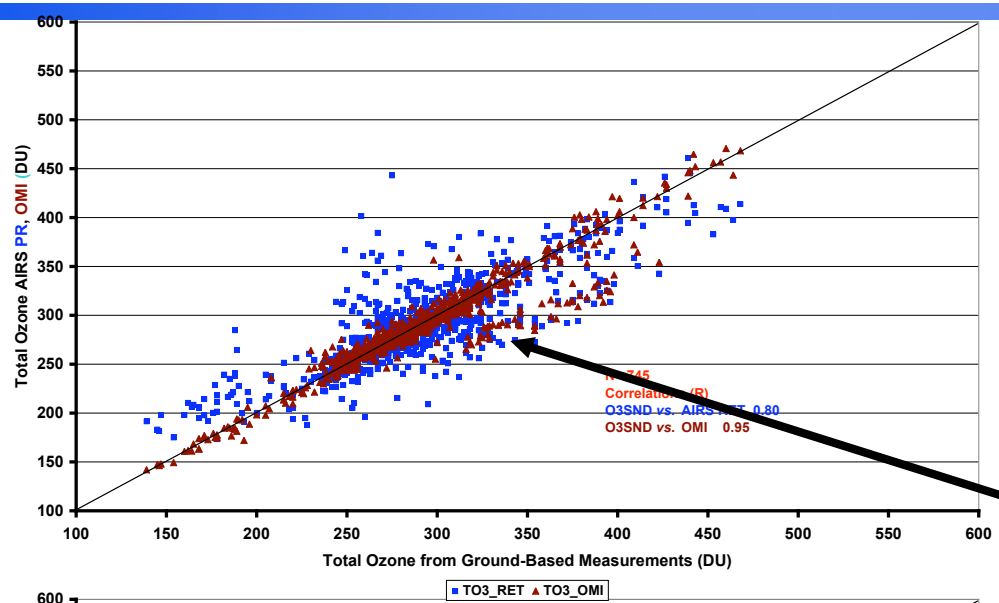
Region
High Latitudes 60°-90°N 60°-90°S
Mid-Latitudes 23°N-60°N 23°S-60°S
Tropics 0-23°N, 0-23°S
ALL Data

	N
ANTARCTIC	491
ARCTIC	167
High-Lat	1491
Mid-LAT	2282
TROPICS	315
GLOBAL	4096

Ground-Based Brewer/Dobson Measurements

Version 4.0
Measurements vs. AIRS-PR, OMI, ECMWF
Number of Samples : 744

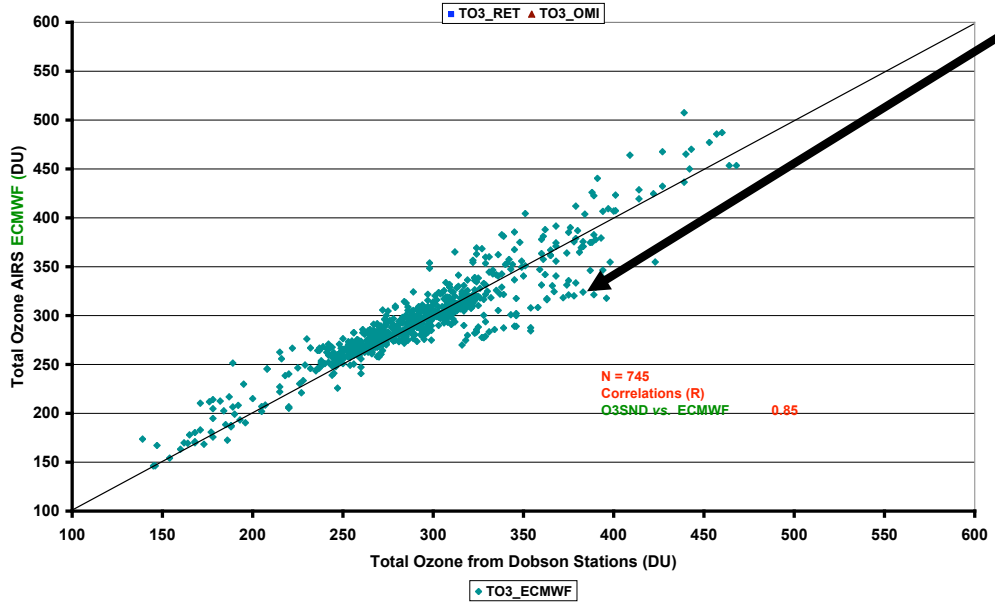
AIRS_PR Aura-OMI



Measurement vs. AIRS-PR
Measurement vs. Aura-OMI (N=744)

Bad Data Station 376

ECMWF

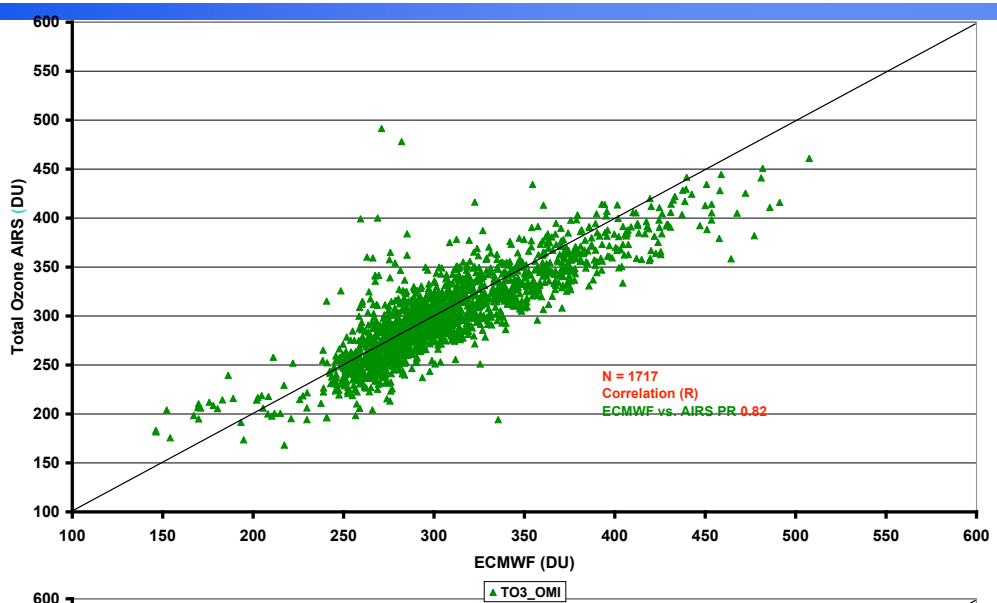


Measurement vs. ECMWF (N=744)

Measurements

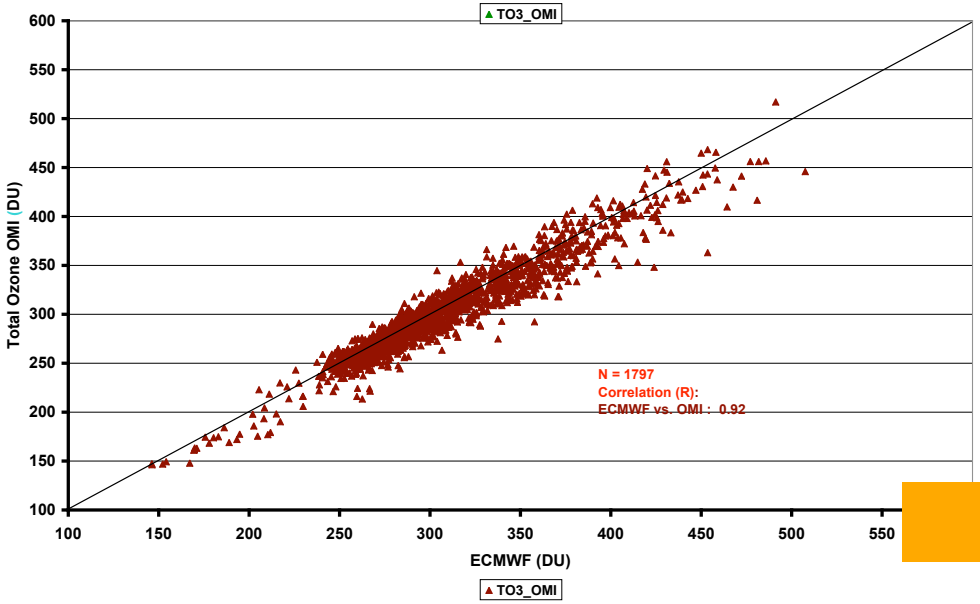
Version 4.0
ECMF vs. OMI, ECMWF vs. AIRS PR

AIRS_PR



ECMWF vs. AIRS
N=744

OMI



ECMWF vs. OMI
N=744

ECMWF

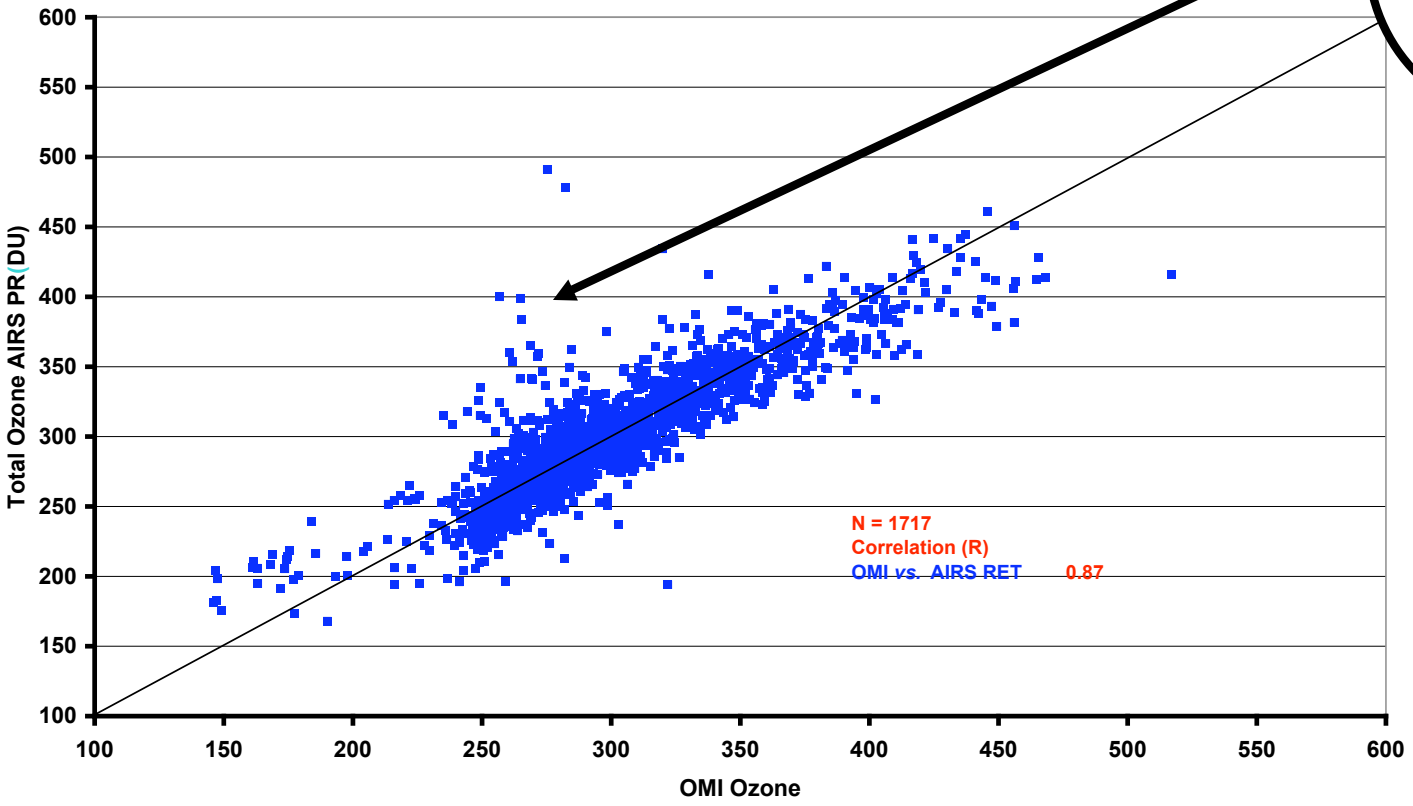
Version 4.0

OMI vs. AIRS-PR, ECMF vs. OMI, AIRS vs. ECMWF

OMI vs. AIRS V4.0 (N=1716)

Stations 002, 111 Data Sfc. Emiss

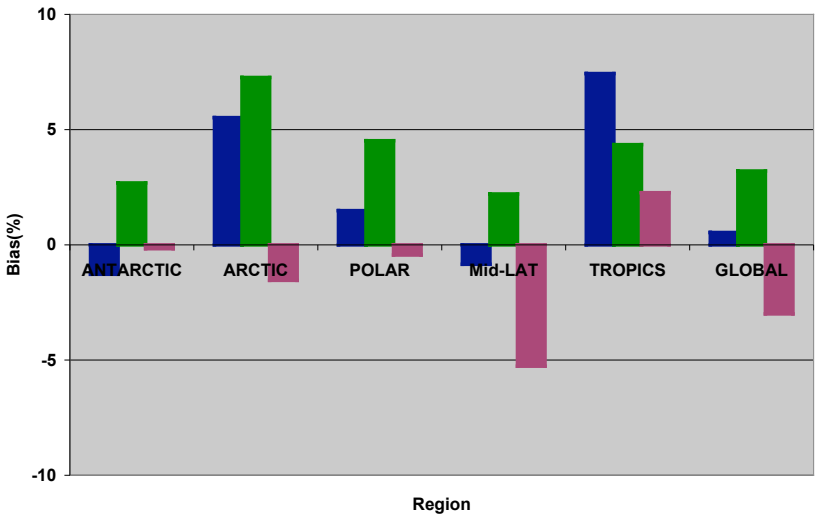
Aqua_AIRS_PR



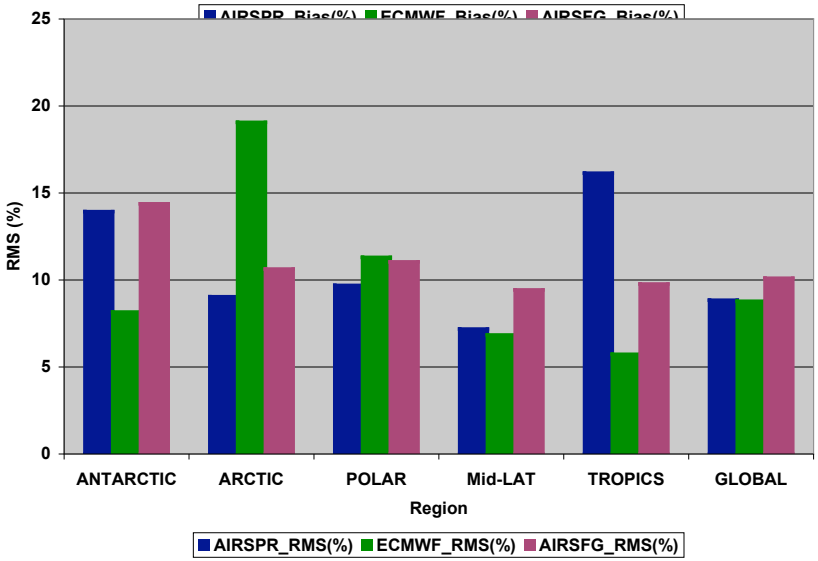
Aura-OMI

V4.0
Total Ozone – RET vs. Brewer/Dobson Measurements
High-Lat, Mid-Lat, Tropics, Global
Bias (%) - PR, FG, ECMWF

V4.0 Bias



V4.0 RMS



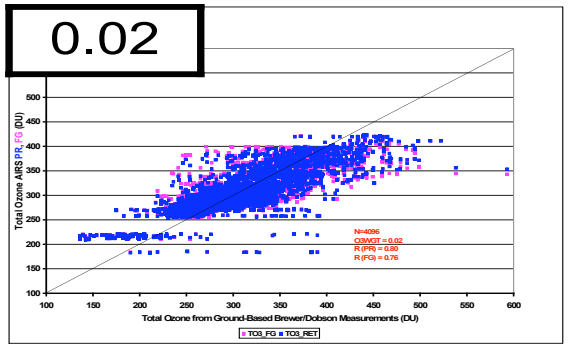
LOC	N
ANTARCTIC	491
ARCTIC	167
High-Lat	1491
Mid-LAT	2282
TROPICS	315
GLOBAL	4096

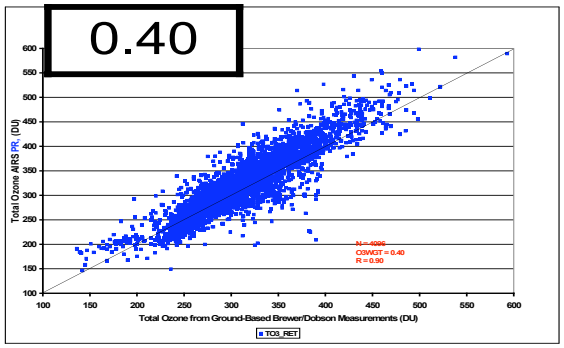
Region
High Latitudes 60°-90°N 60°-90°S
Mid-Latitudes 23°N-60°N 23°S-60°S
Tropics 0-23°N, 0-23°S
ALL Data

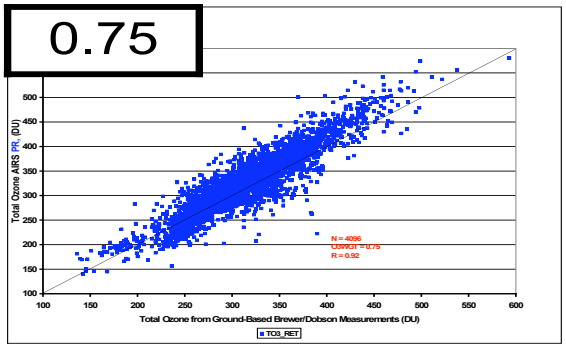
AIRS_PR ECMWF AIRS FG

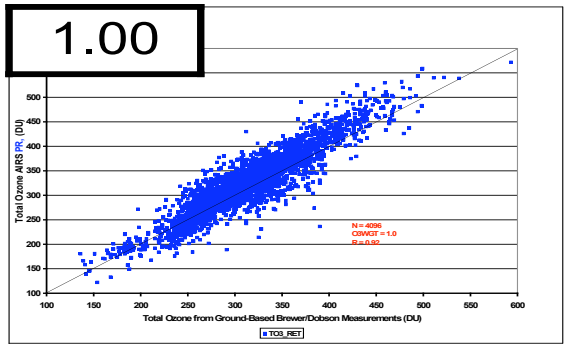
Version 4.0 vs. V5.0.7

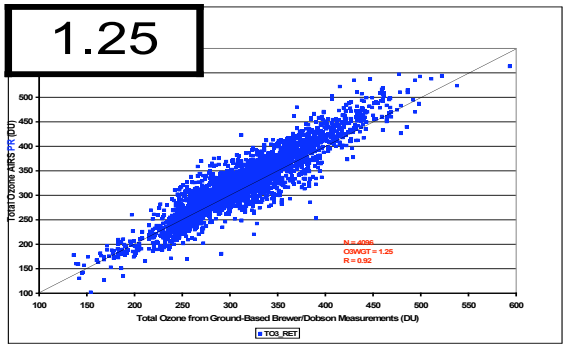
O3WGT for V5.0.7

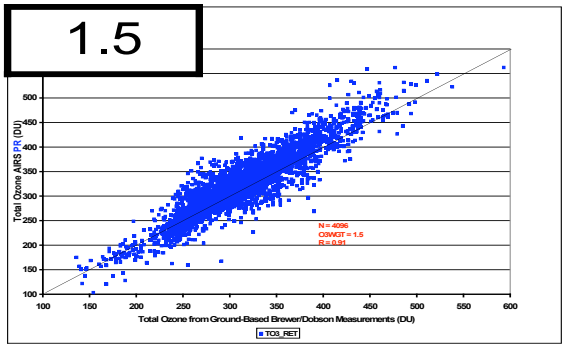


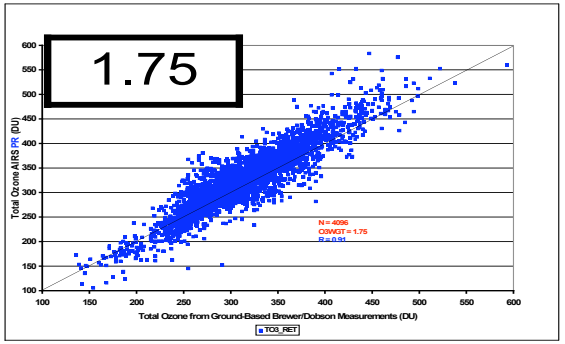


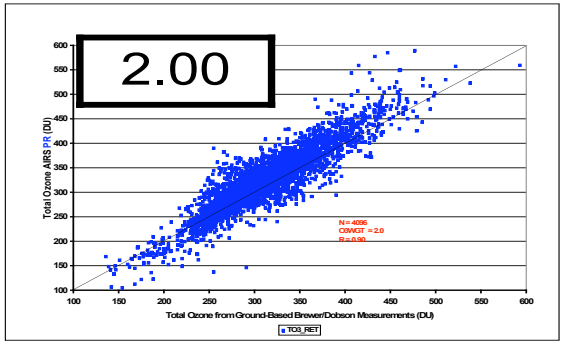










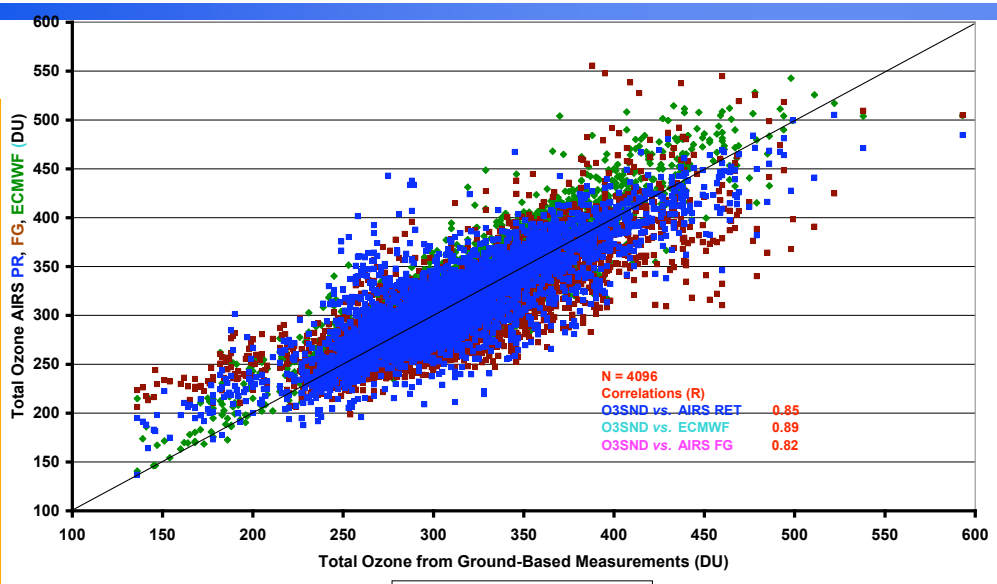


O3WGT Factors

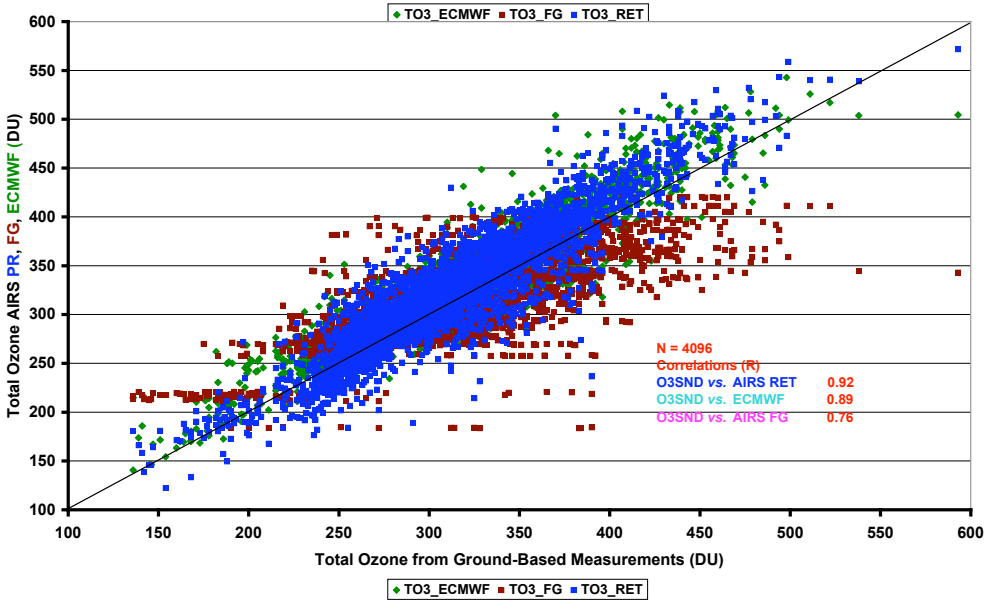
0.02	0.40	0.75
1.0	1.25	1.50
1.75	2.0	NONE

Measurement (BD Total Ozone) vs. V4.0, V5.0.7
Number of Samples = 4096

AIRS_PR ECMWF AIRS FG

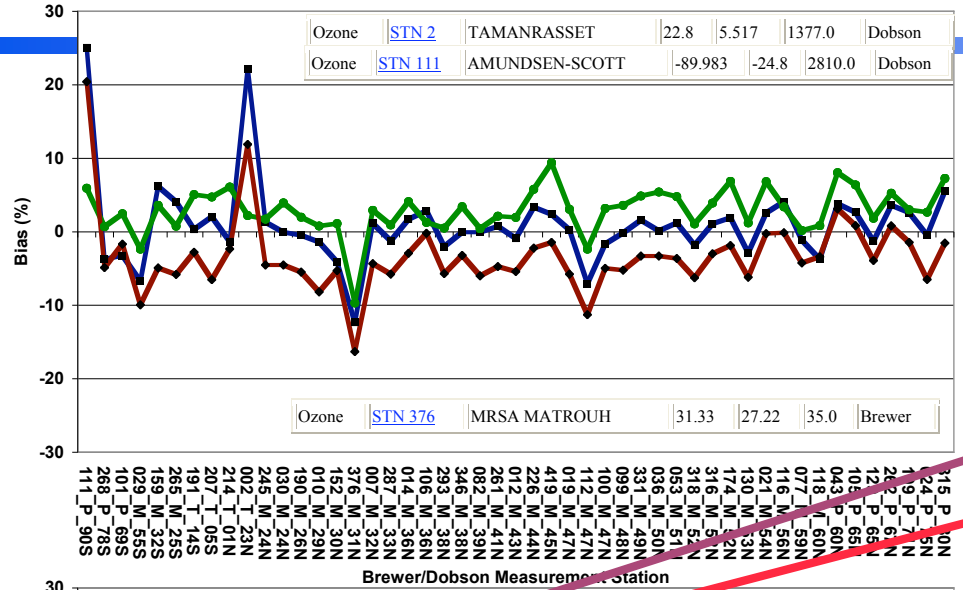


V4.0
AIRS_PR, ECMWF,
FG Regression Solution
N=4096



V5.0.7
AIRS_PR, ECMWF,
FG from Climatology
N=4096

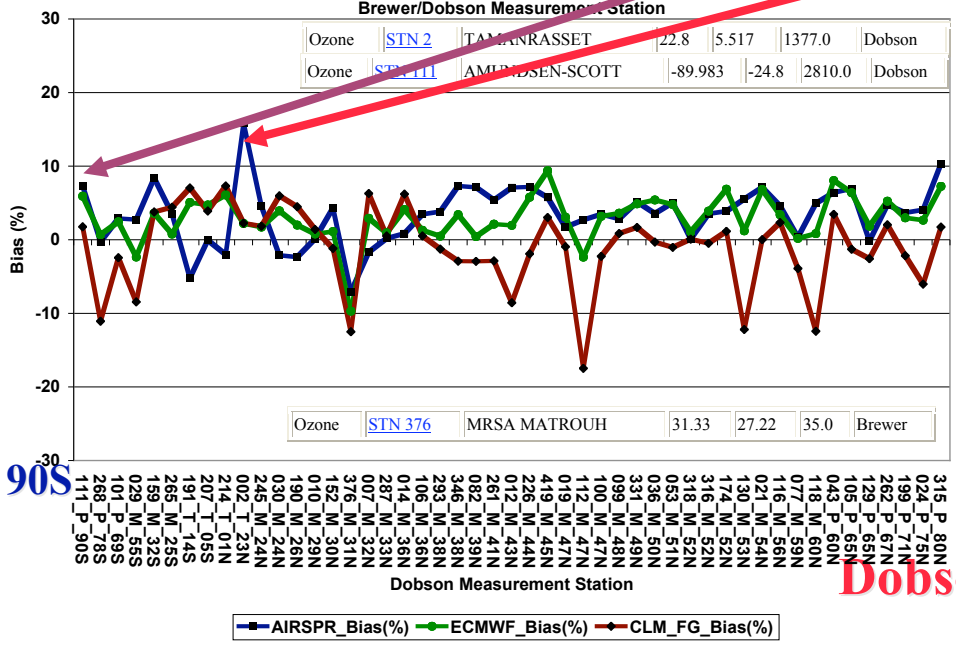
Total Ozone – V4 and V5.0.7 vs. BD STNS



PR, FG, ECMWF
V4.0

FG-Regression Solution

V5.0.7 Reduces Bias for STN 002 STN 111



PR, FG, ECMWF
V5.0.7

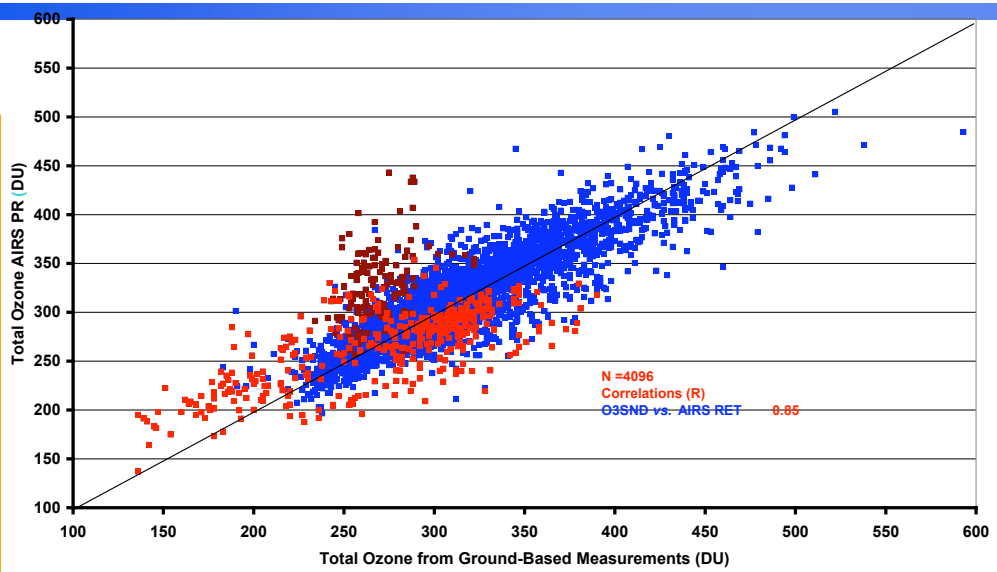
FG-from Climatology

90S 90N

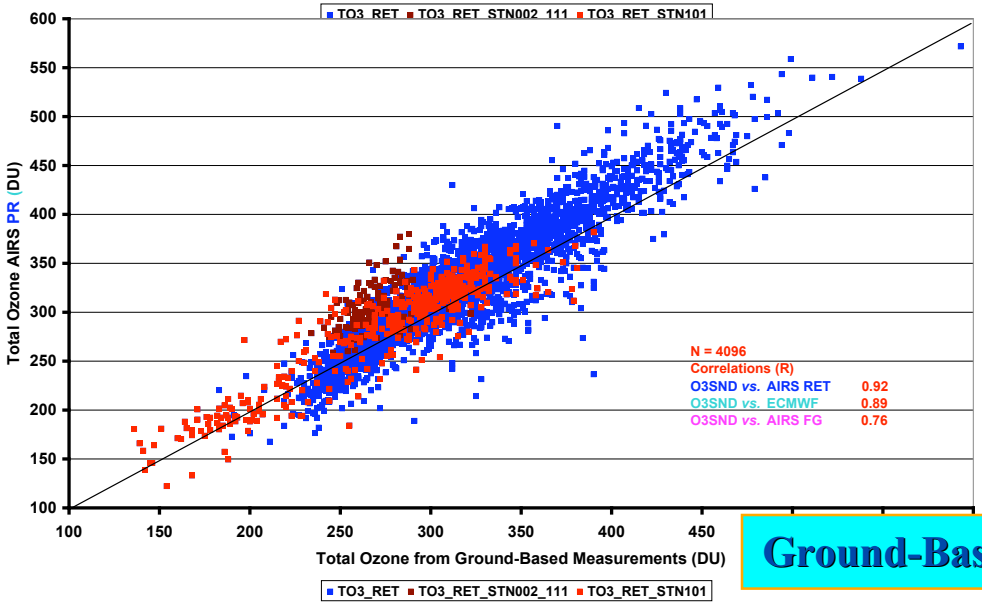
Dobson Station ID Sorted 90S-90N

Measurement (BD Total Ozone) vs. V4.0 PR, V5.0.7 PR
Number of Samples = 4096

AIRS_PR STN002 STN101



V4.0
AIRS_PR
AIRS_PR_STN002
AIRS_PR_STN101
N=4096

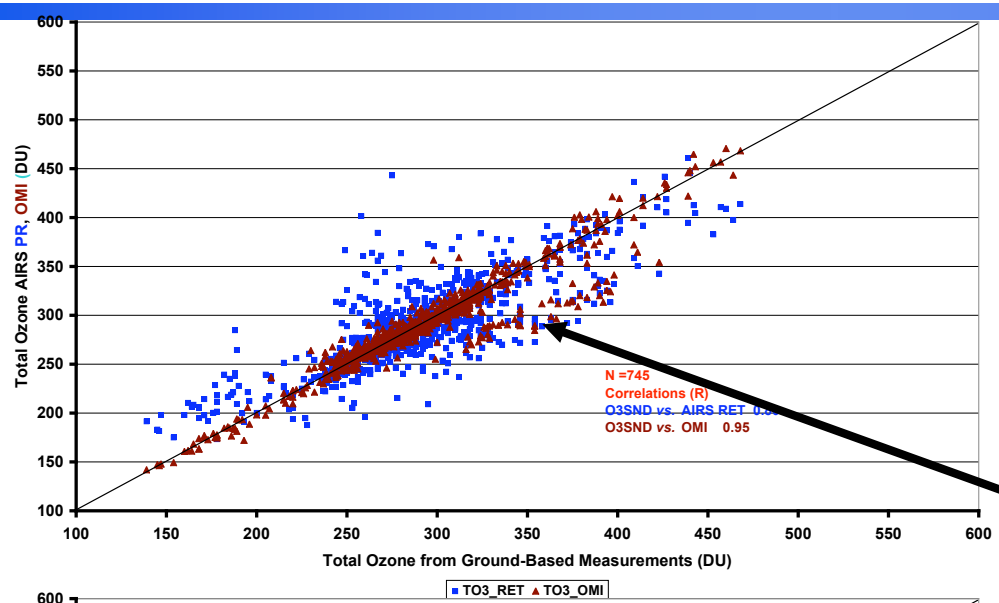


V5.0.7
AIRS_PR
AIRS_PR_STN002
AIRS_PR_STN101
N=4096

Ground-Based Brewer/Dobson Measurements

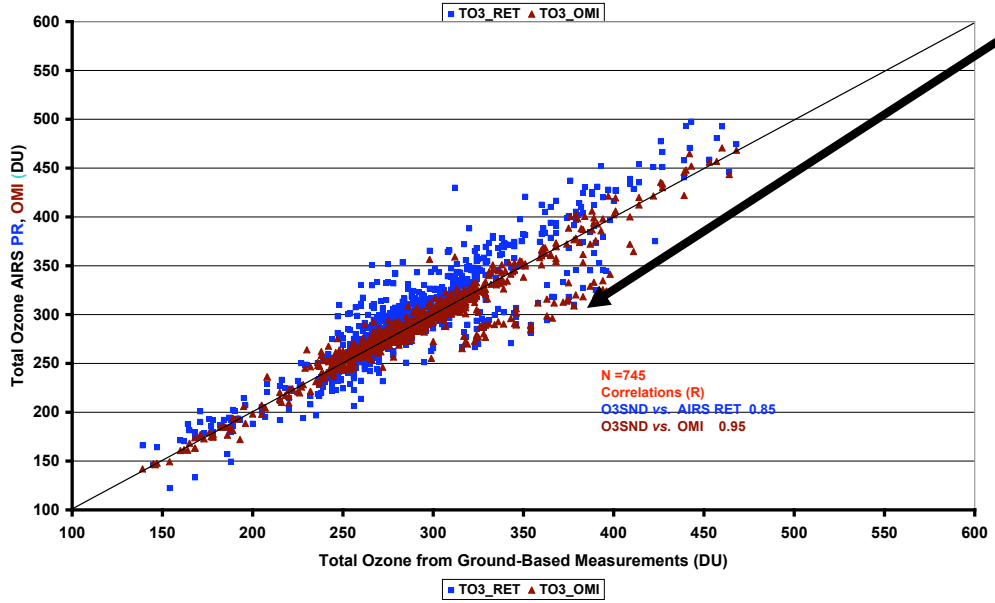
Measurements vs. AIRS-PR and OMI for V4.0, V5.07
Number of Samples : 744

AIRS_PR Aura-OMI



Measurement vs. Aqua_AIRS_PR V4.0
Aura_OMI

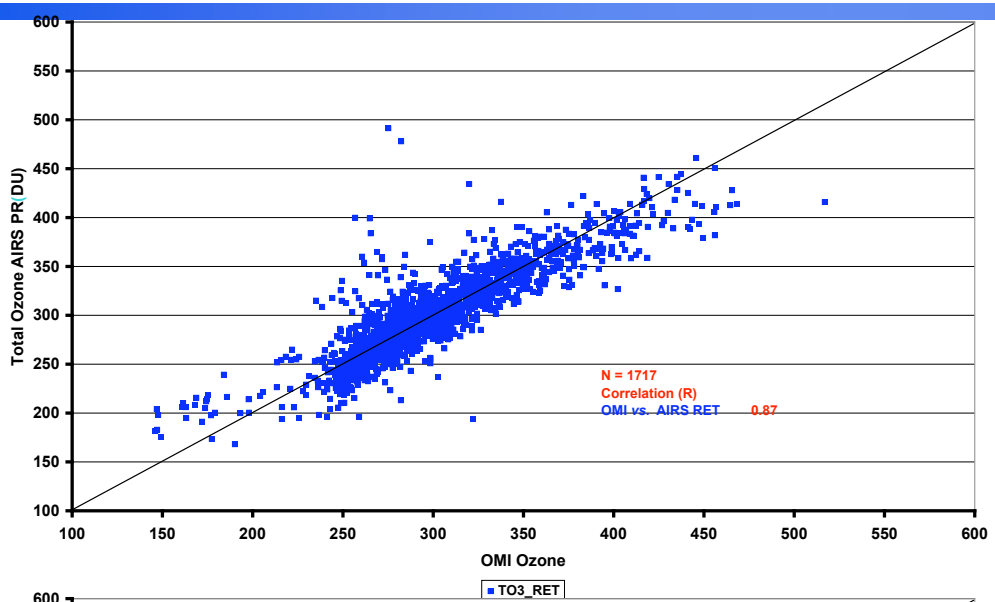
Bad Data Station 376



Measurement vs. Aqua_AIRS_PR V5.0.7
vs. Aura_OMI

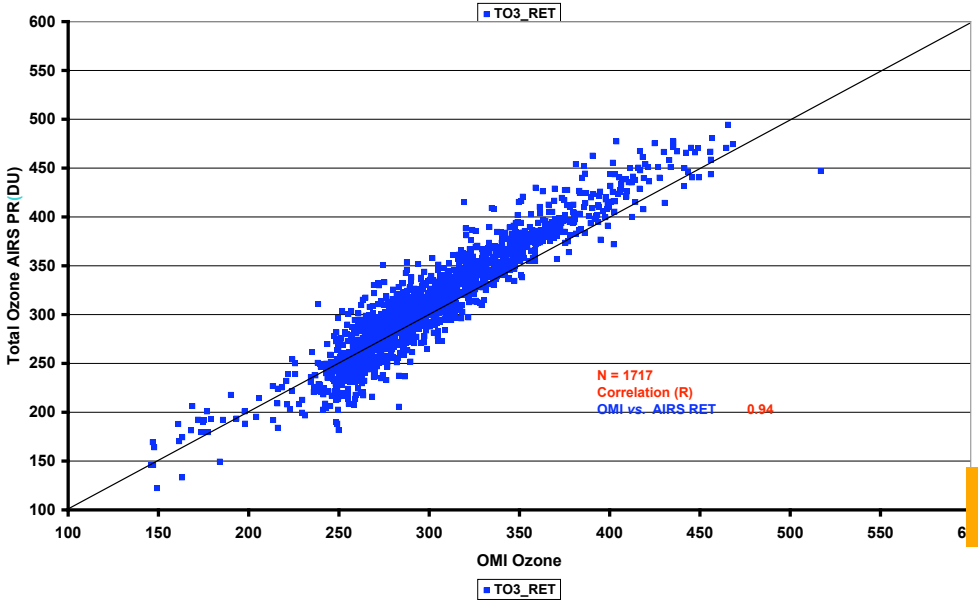
OMI vs. AIRS-PR for Version 4.0 and Version 5.0.7

AIRS_PR_V4.0



OMI vs. AIRS V4.0

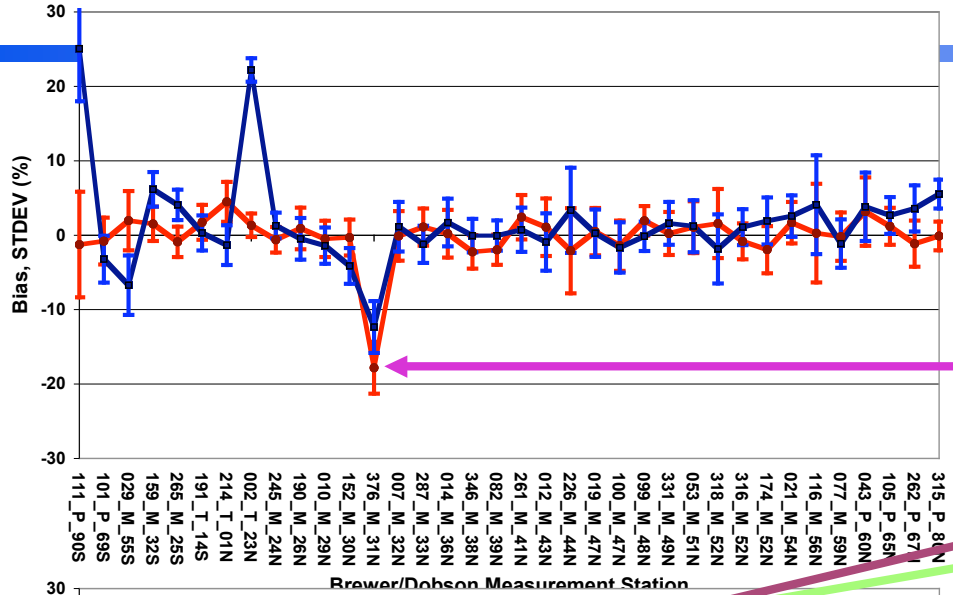
AIRS_PR_V5.0.7



OMI vs. AIRS V5.0.7

Aura-OMI

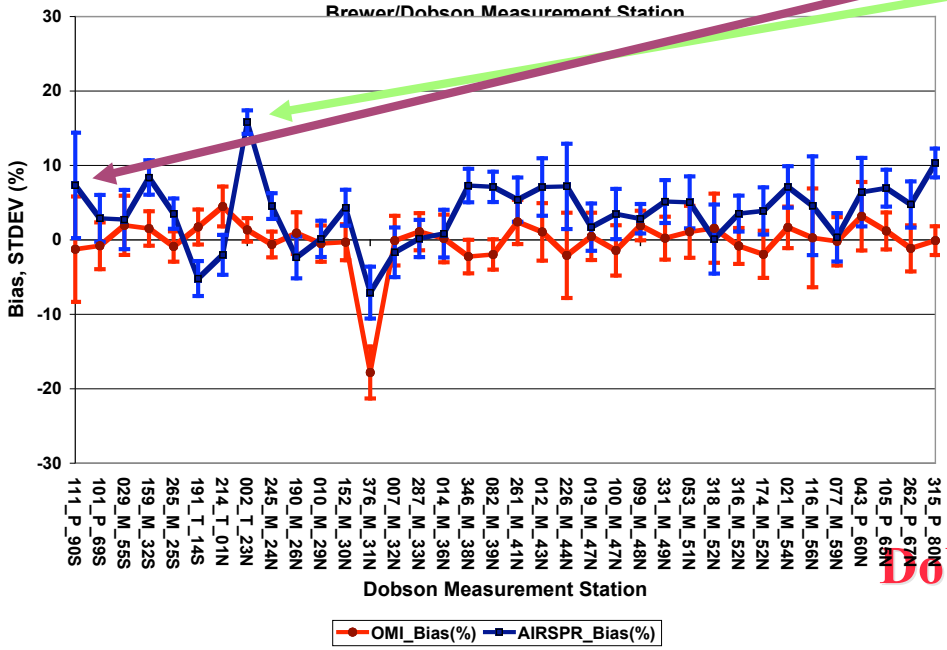
V4 and V5.0.7 AIRS_PR and OMI



AIRS PR and OMI
V4.0

Spurious Station Data

V5.0.7 Reduces Bias for STN 002 STN 111



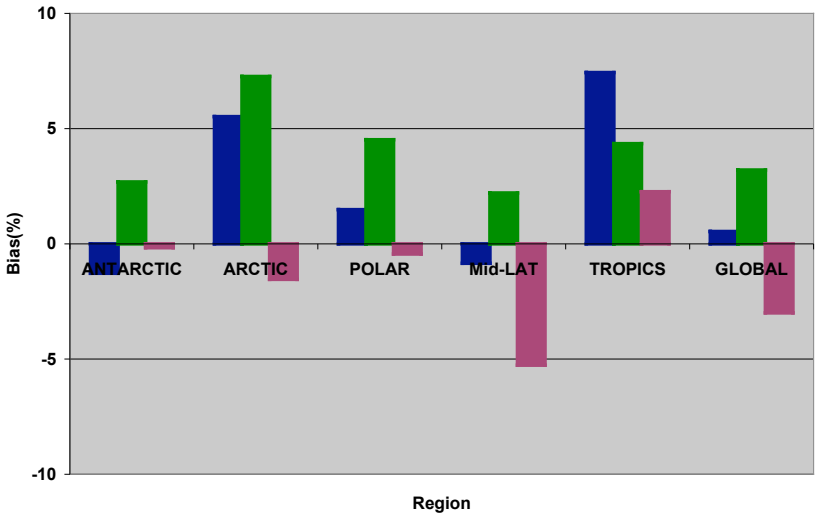
AIRS PR and OMI
V5.0.7

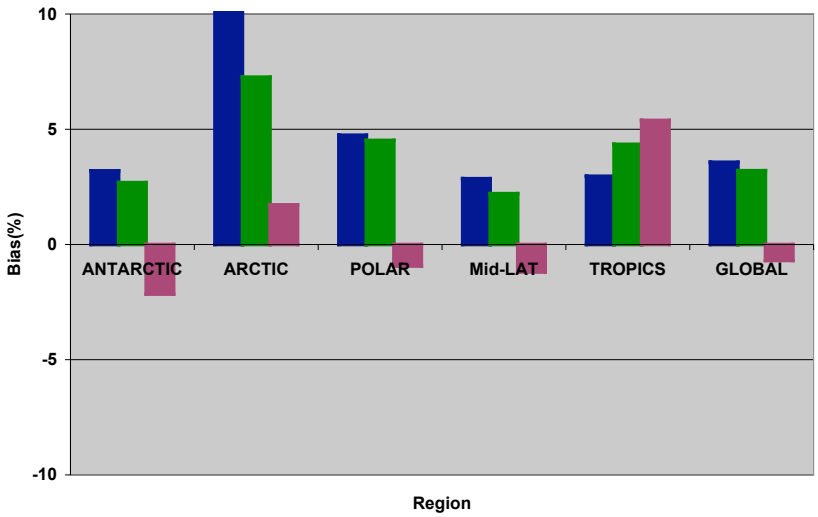
Dobson Station ID

V4.0 vs. V5.0.7
High-Lat, Mid-Lat, Tropics, Global

AIRS_PR ECMWF AIRS FG

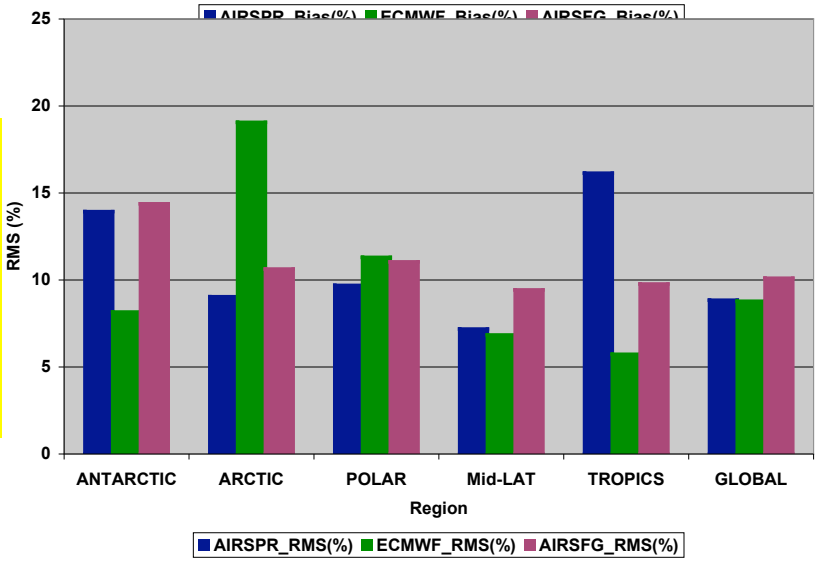
V4.0 Bias

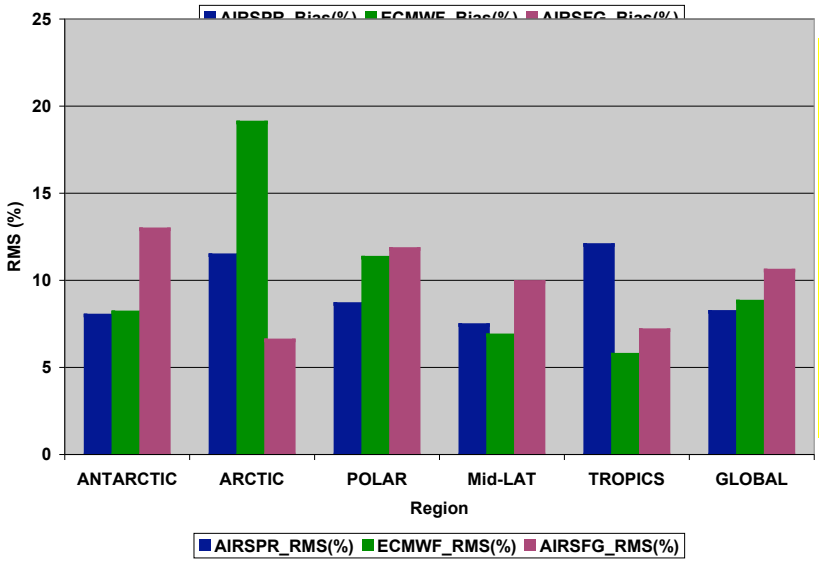




V5.0.7 Bias

V4.0 RMS





V5.0.7 RMS

Summary

- Version 4.0
  - » **Comment: As such ECMWF is not bad for FG training, but there is scope for improvement if we wish to pursue FG Training. The training sample do not cover any ozone hole events.**
- Version 5.0.7
  - » With New Climatology, and V5 Ozone Channels,O3WGT=1.0
    - – NO Regression (FG OFF, Replaced with New Climatology)
      - Removes All Confusion with ECMWF Training
      - Retrieval is 100% from AIRS
      - Improves Averaging Kernels
    - – Significantly Improves Bias in the Lower Troposphere
    - – Significantly Improves Retrieval in the Tropics
    - – Significantly Improves Retrieval over the Saharan Desert and South Pole stations where V4 has significant limitations.
    - – Slightly increases bias for higher latitudes
    - – Slightly Increases the Program Execution Time

Future Plans

- NOAA/NESDIS has AIRS Level-2/Level-1B Global Grids
  - » 2003/08/5 to Current
  - » 3 Deg. X 3 Deg. Resolution
  - » T(p), q(p), O3(p), CO2(p), CH4(p), CO(p), emissivity etc.
  - » Using these Global-Grid Data We could Generate Monthly Means, Zonal Maps etc.
- Improvements to FG Regression
  - » AIRS Science Team Version 5.0 has No FG for Ozone. But,
  - » Include More Global ECMWF Days During Special Ozone Events
  - » Using AIRS-O3SND Matches
    - – Information and Trends Come from the Measurements (Assuming Measurements have No Artifacts) and Provide Ability to See Changes
- Adapting to IASI, CrIS and Future Missions
- Website You Don't Like to Miss:

http://www.orbit.nesdis.noaa.gov/smcd/spb/iosspdt/testd1/iosspdt.php

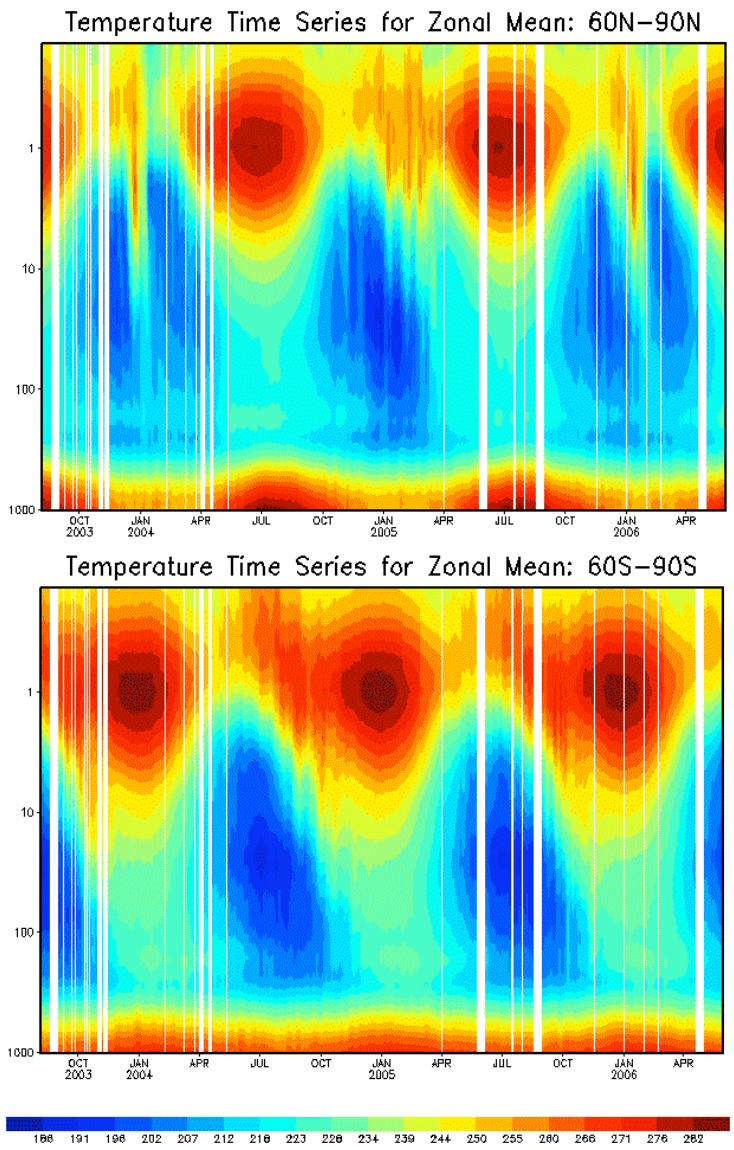
Future Work Using Global Grids
V4.0 Global Grids – Zonal Mean 60-90N, 60-90S

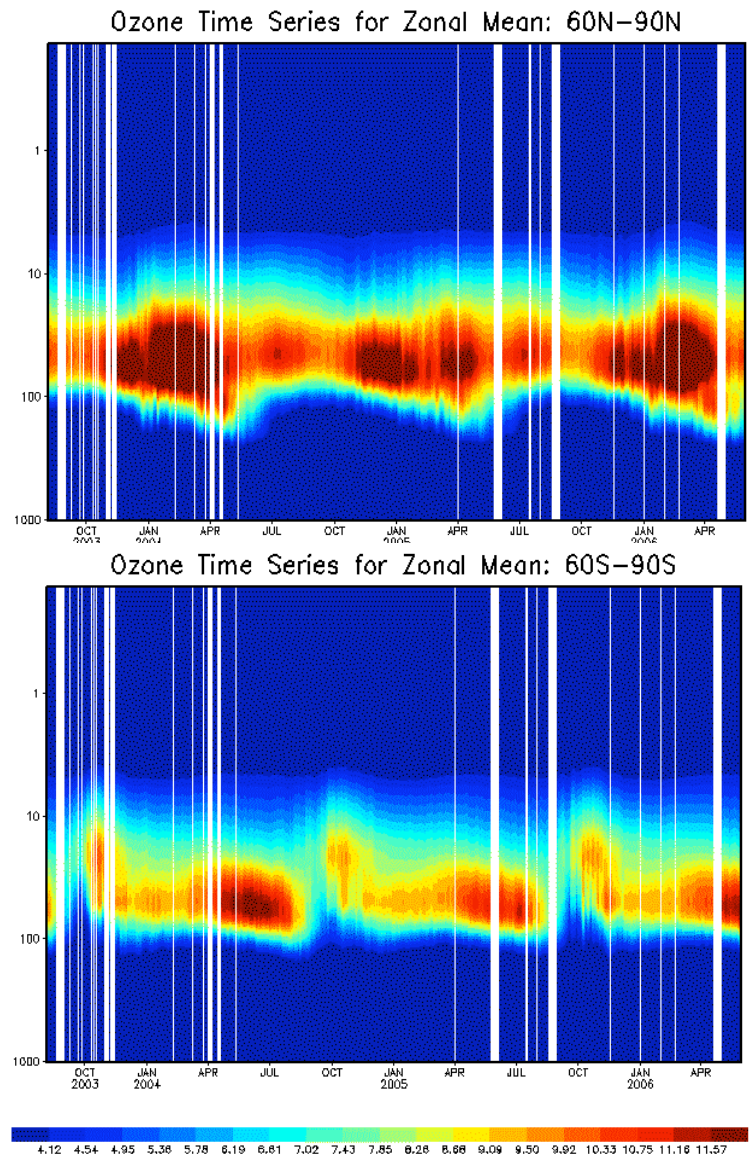
Temperature

Ozone

Zonal Mean Time Series 60N-90N

Zonal Mean Time Series 60S-90S





Evaluation of Atmospheric Infrared Sounder (AIRS) Ozone Profiles and Total Ozone Retrievals with Matched Ozonesonde Measurements, ECMWF Ozone Data, and Ozone Monitoring Instrument (OMI) Retrievals

1.0 Introduction
- » About AIRS and Ozone Retrievals (IR 9.7um)
- » About OMI (expected to be better)
- » Our approach – a cost effective approach with WOUDC
- » Validation studies using AIRS Intensive Field Campaign Data

2.0 Data Set Preparation
- 2.1 AIRS Retrievals
- 2.2 O3SND, ECMWF Matches
- 2.3 Total Ozone Brewer/Dobson (BD) Station Matches
  - – 2.3.1 AIRS Matches
  - – 2.3.2 OMI Matches
  - – 2.4 Statistical Metrics

3.0 Results and Discussion
- 3.1 Ozone Profile Validation
  - 3.1.1 Typical Comparisons (NH, SH, Tropics)
  - 3.1.2 Global Statistics (O3SND vs. AIRS PR, FG, ECMWF)
  - 3.1.3 NH, SH, Tropics (only AIRS PR)
- 3.2 Total Ozone Validation
  - 3.2.1 Total Ozone Validation with BD Stations
  - 3.2.2 Individual Station Comparisons BD STNS vs. AIRS PR, FG, ECMWF (Bias and RMS)
  - 3.2.3 Statistics over Tropics, Mid-Lat, High-lat and Global (bias, RMS)
  - 3.2.4 Comparison with OMI Stations
- 3.3 Global Grids – V4 and V5

- Summary & Conclusions
- Acknowledgements

Paper in Preparation

Backup Slides

Thank you for your attention

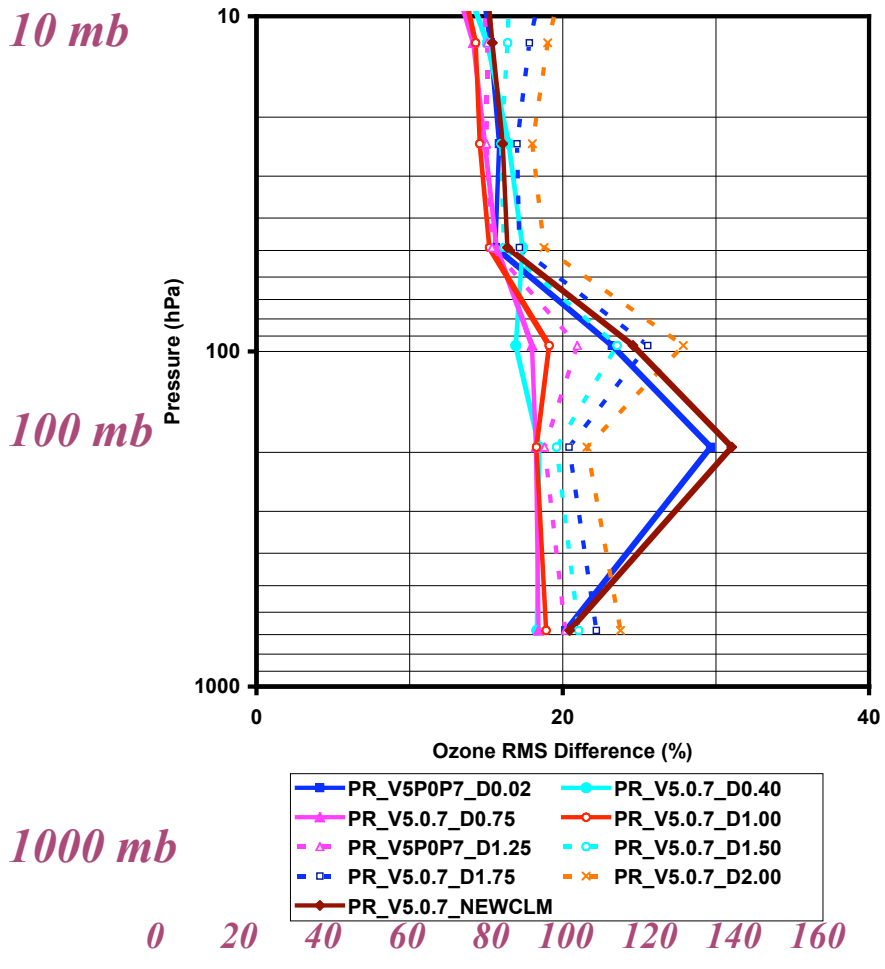
Integrated Observing System Science & Product Development Team (IOSSPDT)
NOAA/NESDIS Camp Spring, MD, USA

Global Match Plan

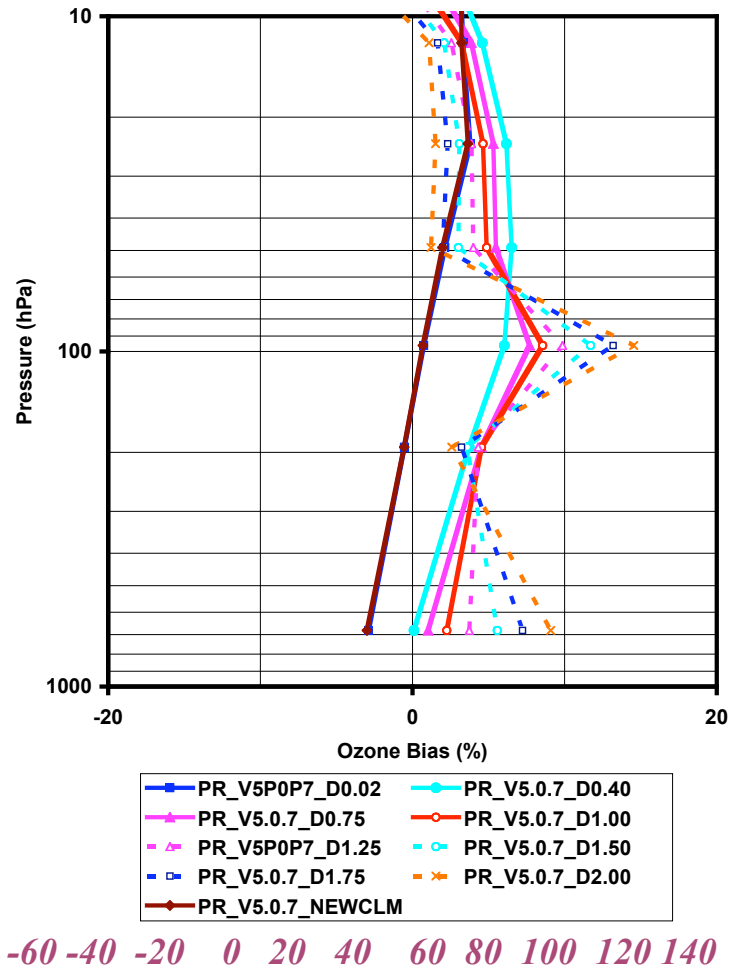
- Operational launch facilities have the best personnel to give details about the launching station, local dynamics, and the expertise in launching consistently and systematically.
- Set up a Overpass Data Set Group
  - » Provide satellite overpass and orbit information to RAOB/O3SND ground stations to launch special RAOB/O3SNDs.
  - » Provide them with additional satellite data to produce time series over the station (a win-win situation for ground station personnel)
  - » Receive very-rich matched data set for upgrading scientific algorithms

O3WGT Version 5.0.7 (set 48_49.xls)

RMS Difference

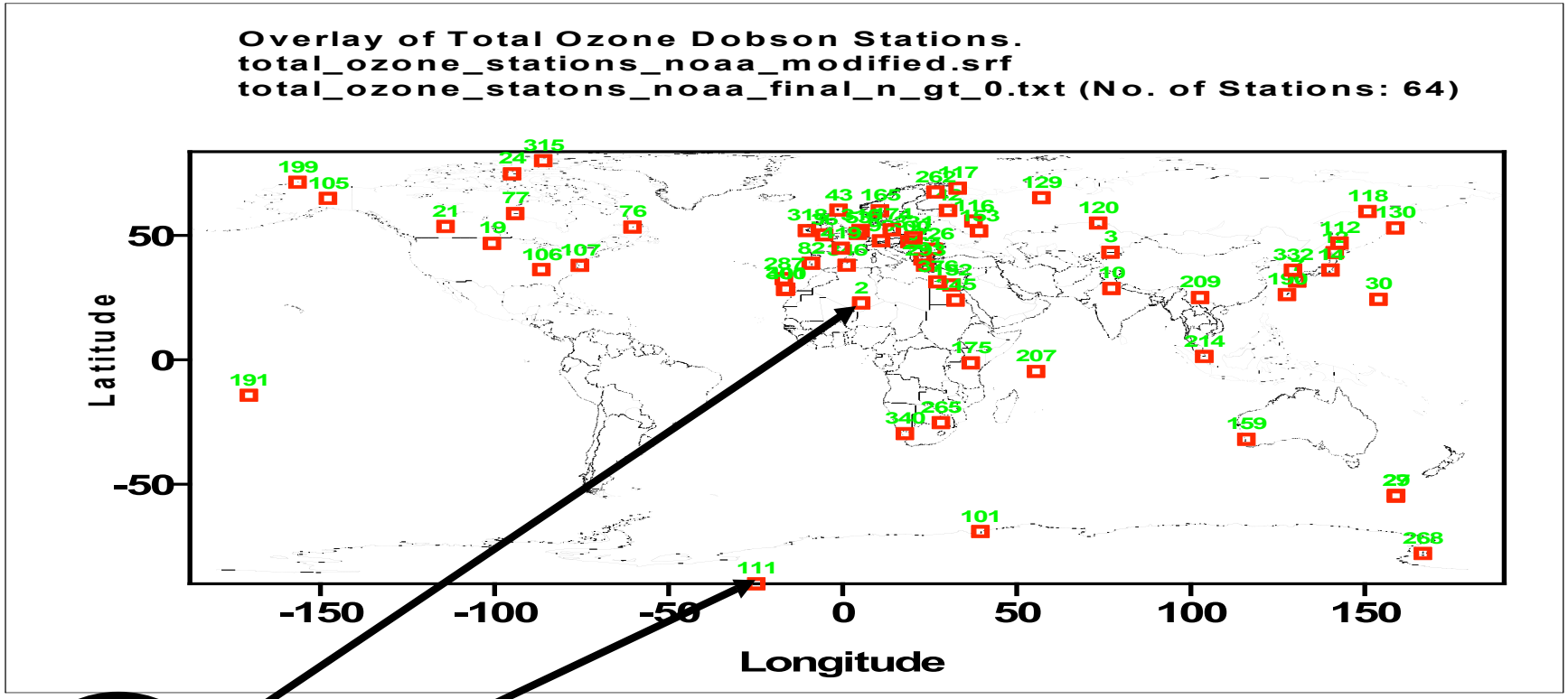


Bias



V5.0.7 O3WGT=1.0 is Chosen

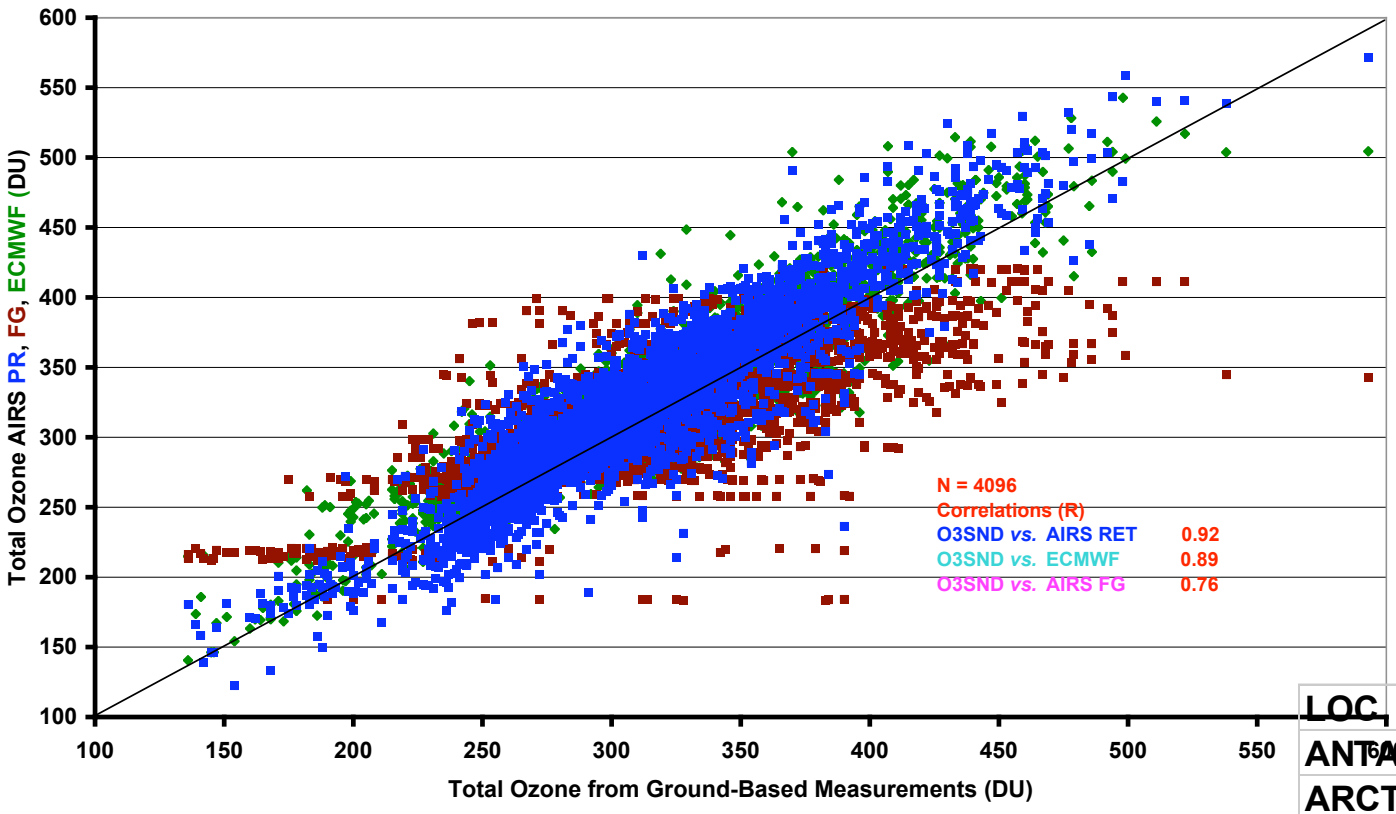
AIRS Total Ozone vs. Dobson/Brewer Measurements Station Locations and Accepted Samples



Stations
002, 111

Version 5.0.7, OWGT = 1.0
AIRS Total Ozone vs. Dobson/Brewer Measurements
Number of Samples = 4096

AIRS_PR ECMWF AIRS FG



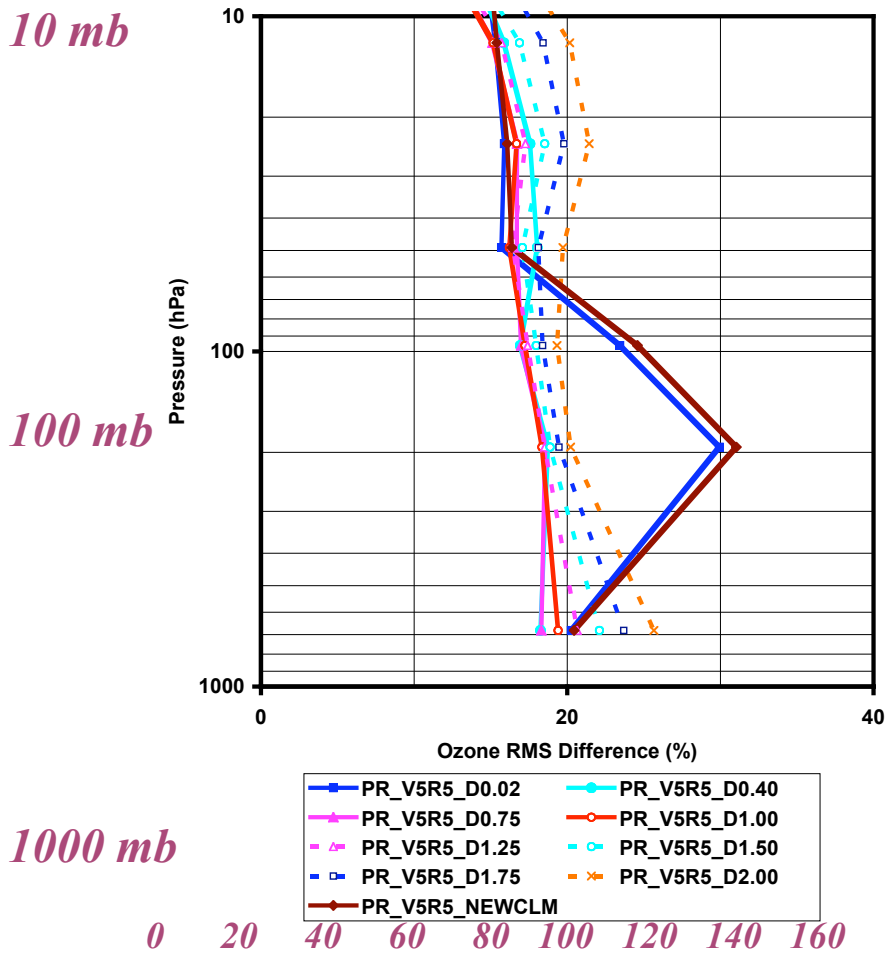
Region
High Latitudes 60°-90°N 60°-90°S
Mid-Latitudes 23°N-60°N 23°S-60°S
Tropics 0-23°N, 0-23°S
ALL Data

LOC	N
ANTARCTIC	491
ARCTIC	167
High-Lat	1491
Mid-LAT	2282
TROPICS	315
GLOBAL	4096

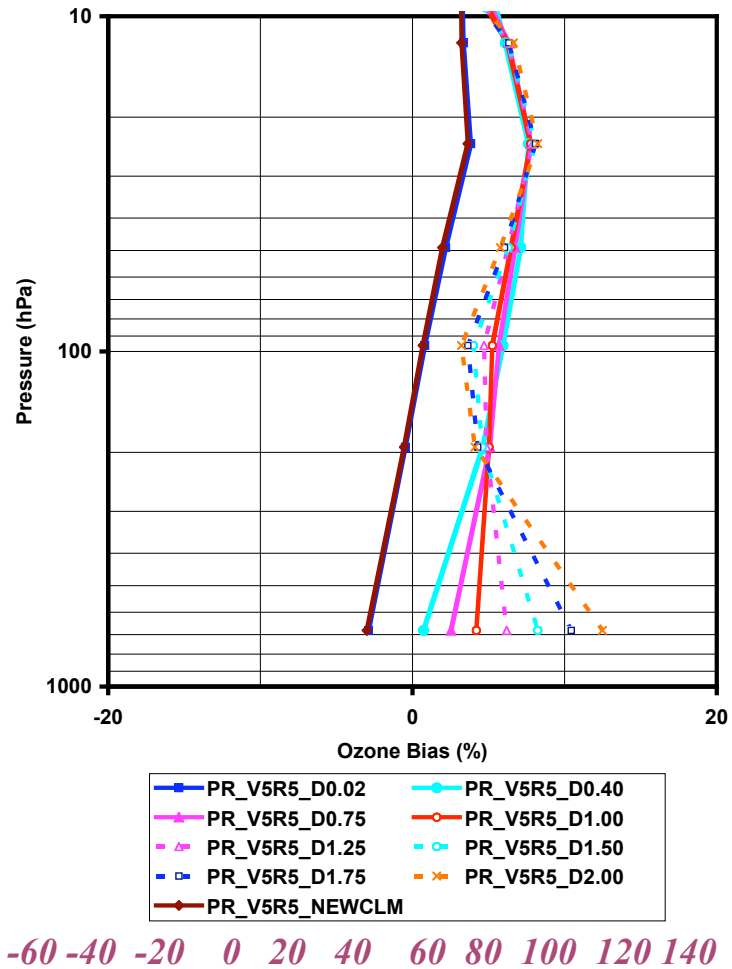
Ground-Based Brewer/Dobson Measurements

O3WGT Version V5R5 (set_50_51.xls)

RMS Difference

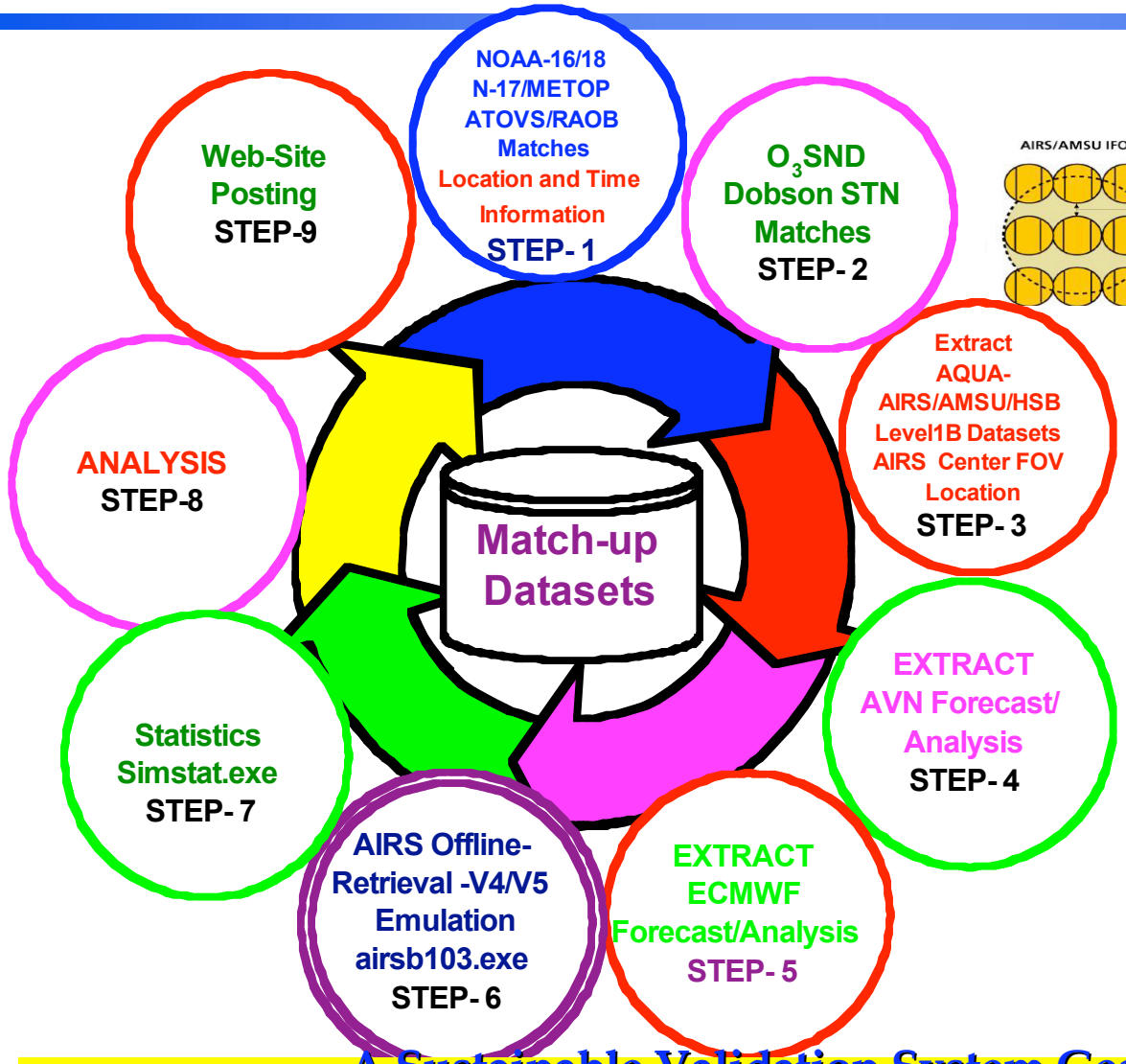


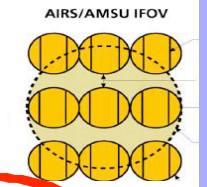
Bias



TRP_12H_V4 **TRP_12HR_V5****

The NOAA/NESDIS Aqua-AIRS Validation Match-up System





- Built Around Off-line AIRS Retrieval Version (Chris Barnet)
- Emulate Various AIRS Retrieval Algorithms V4, V5
- Simulating New Instruments (IASI/CrIS) Retrieval Algorithms
- Testing New Ideas in Retrieval Algorithm with Different A-priori information, First Guesses
- Repeatability with Upcoming Data, Versions, Upgrades

A Sustainable Validation System Geared for Current And Future Satellites

Summary

- NH profiles Data (Station 089, and Arctic Region) appears to agree more closely with other correlative observations compared to SH Station101 (and other Antarctica Stations) Data.
- AIRS V4.0 ozone retrieval for the lower troposphere in the tropical region has larger RMS differences.
  - Version 5.0.7 shows lot of improvement
- Total Ozone Retrievals from AIRS is Very Good
  - Bias < 2%, RMS Difference < 10%)
  - Individual Station Statistics are Very Promising
- Surface Emissivity Needs Attention In V4.0
  - Version 5.0.7 shows lot of improvement

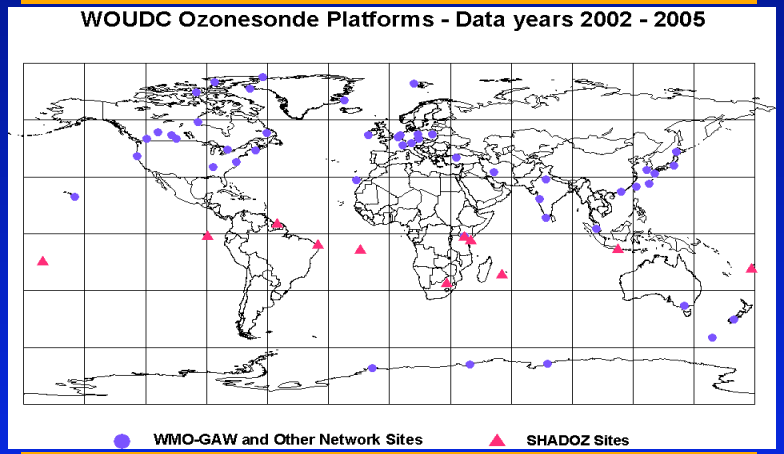
Summary

- AIRS Version 4.0 Ozone Profile Retrievals are Promising.
  - » Retrievals follow trends, seasonality patterns.
  - » The RMS & Bias are about 20% and 5% respectively above 300 mb.
    - – FG Underestimates Larger Values, Overestimates Smaller Values
    - – ECMWF Always Overestimates Ozone Values
    - – Physical Retrieval Corrects the FG to a Large Extent.
    - – Although the FG is Trained with ECMWF, AIRS_FG and ECMWF show Significant Differences in both RMS and Bias. As such ECMWF Ozone is not that bad, but there is some where some mis-match !!
    - – There is room to improve FG Regression
      - Improving the Training Sample with Ozone hole Events Data
  - » Version 4.0 physical retrieval (and the ECMWF also) has limited skill in matching lower tropospheric ozone from O_3SNDs.

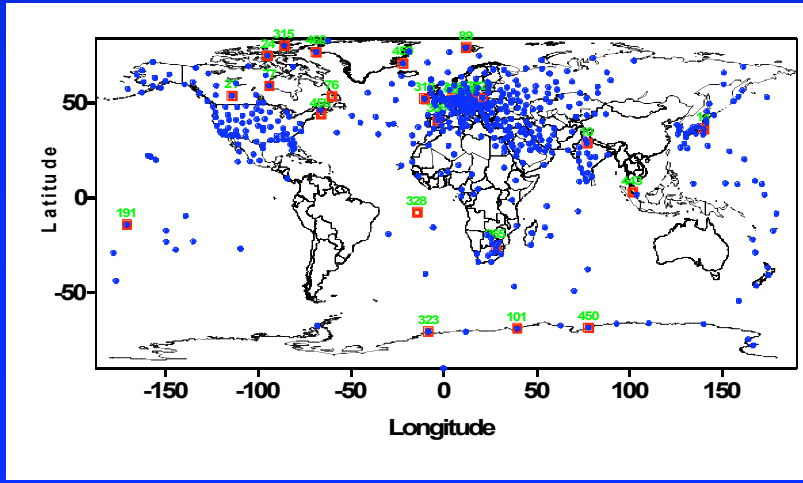
AIRS- O_3SND Matches

- Most of the WOUDC O_3SND Launches Use RAOB Launch Facilities – Location Match
- Frequency of O_3SNDs once a week or twice a week
- O3SND Launch Times Differ from RAOB Launch Times. Yet Many Matches
- ±3 Hrs 100 Km Match Criteria Yields
  Number of O_3SND Matches = 353
  Number of Stations = 26
- Relaxing the Time Match Criteria Increases Sample Size
- Satellite Orbit and Match Criteria Affects Station Matches

WOUDC O_3SND 2002-2005

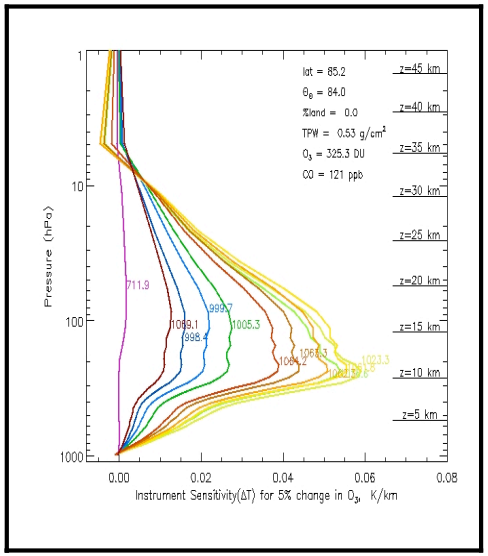


AIRS-O_3SND Matches



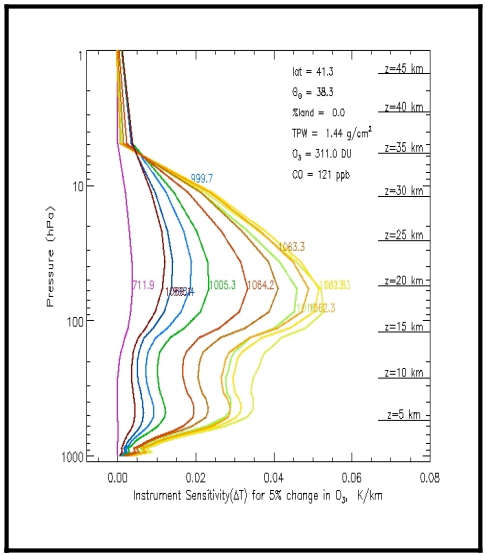
Statistics

Polar



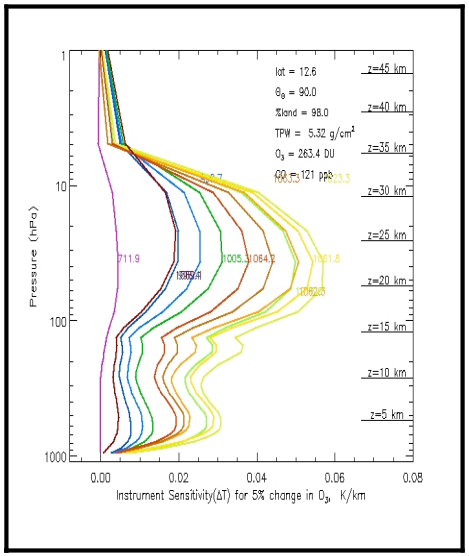
Latitude: 85.0
TPW: 0.5 cm
Total O3: 325 DU

Mid-Latitudes



Latitude: 40.0
TPW: 1.5 cm
Total O3: 311 DU

Tropics



Latitude: 12.0
TPW: 6 cm
Total O3: 263 DU

Validation Data - Ozone Measurements

- Dobson Spectrophotometer/Brewer Spectrophotometer – Total Ozone – DU
  - » Automated, Programmed to Make Measurements at regular observation times Accuracy : ±2%
- Balloon Based Measurements
  - » Broad Range of Altitudes and Accompanied Profile Measurements
  - » Correlative Data for Satellite Measurements –Validation, Complementary Data
    - – Instruments Used in the Launches Change (Make/Model/Error Characteristics)
    - – Launch Times Vary Among Stations (Once in Two Days, Once in a Week, etc)
- Satellite Instruments – Concept of Measurement/Method Differs
  - » Aqua-AIRS (Hyper Spectral Channels from 9.7 um Ozone Band)
  - » TOMS, SBUV (NOAA-16), SAGE
  - » EOS Chem Measurements – TES/OMI
- Match-up Times Used by the Validation Community Differs
  - » Some Validation experts consider even a one-day match.