Selection of in-orbit references for Global Space Based Inter-Calibration System

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- **MW Reference**
  - MSU/AMSU-A FCDR a robust in-orbit reference
- **Evaluating Solar reference for UV**
- **Conclusion**

Citation: 1 Bali, M., Mittaz, J. P., Maturi, E., and Goldberg, M. D.: Comparisons of IASI-A and AATSR measurements of top-of-atmosphere radiance over an extended period, Atmos. Meas. Tech., 9, 3325-3336, doi:10.5194/amt-9-3325-2016, 2016.

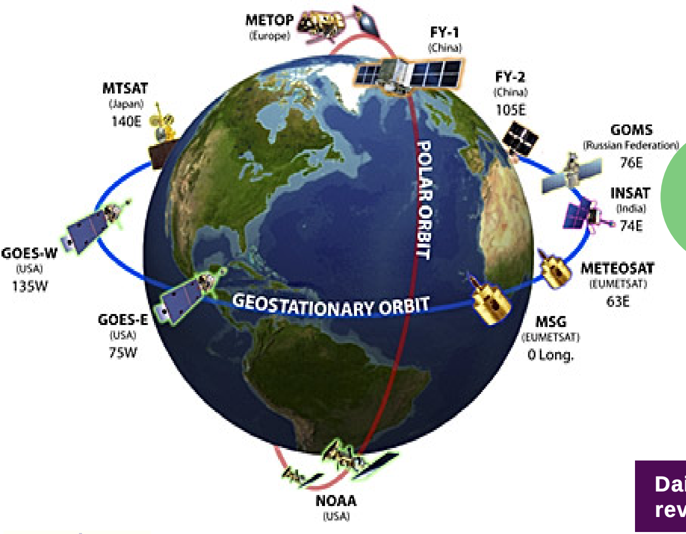
Citation 3:: Wang, L., Wu, X., Goldberg, M., Cao, C., Li, Y., and Sohn, S.-H.: Comparison of AIRS and IASI radiances using GOES imagers as transfer radiometers toward climate data records, J. Appl. Mete. Climatol., 49, 478–492, doi:10.1175/2009JAMC2218.1, 2010

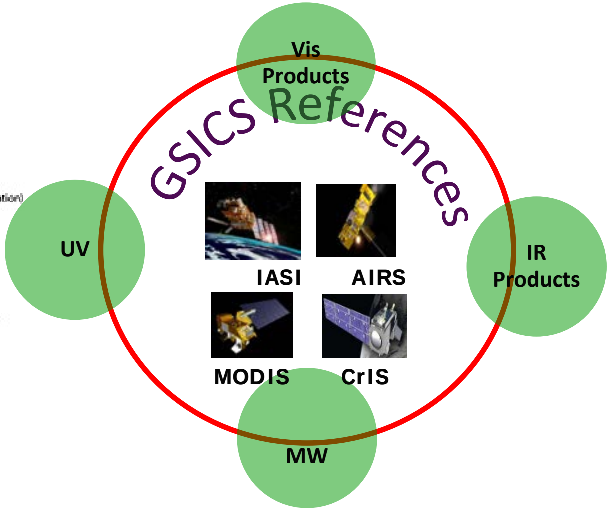
Citation 4: F. Yu, X. Wu, M. K. Rama Varma Raja, Y. Li, L. Wang, and M. Goldberg, “Evaluations of diurnal calibration variation and scan angle emissivity calibration for GOES imager infrared channels,” IEEE Trans. Geosci. Remote Sens., vol. 51, no. 1, pp. 671–683, 2013

GSICS Global Space-based Inter-Calibration System

GSICS Introduction

Global Space Based Inter-calibration System (GSICS) is an international collaborative effort initiated in 2005 by [WMO](#) and the [CGMS](#) to monitor, improve and harmonize the quality of observations from operational weather and environmental satellites of the Global Observing System (GOS)





Daily inter- comparison of GEO with IASI and AIRS reveal diurnal bias in the GEO (Yu et al 2013)

GSICS Reference Instruments are at

Intended Goals

Inter- comparisons with reference instrument should aid in re-calibrating monitored instrument -> reveal trends, temporal and temperature dependent biases.

Big Questions

How trustworthy are existing GSICS references (e.g., IASI-A AIRS)?
How do we pick references for other wavelength intervals?

Selecting in-orbit references-The Overarching GSICS Process

1. The instrument and channels an agency wishes to monitor
2. Purpose of inter- comparison (routine monitoring, diurnal bias, re-calibration, produce CDRs)
3. The method/s they would employ to monitor
   (e.g. single or blended references, use transfer target, stability criterion)
4. May consider scoring proposed by EUMETSAT and Reference Expectations gathered by the GSICS Survey
5. Demonstrated use of the instrument by member agencies and users for instrument monitoring
6. Comparison of Instrument design specification (Pre-launch testing) with In-orbit behavior
7. May consider if in-orbit status of key parameters of Candidate Ref instrument are monitored and available to users (such as ICVS)
8. Need to have information (e.g., global coverage, Equator crossing time, spectral response, etc.) related to the instrument available (say at WMO OSCAR or GPRCs)

Process accepted by GSICS consortium

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IR- Reference
How good are GSICS IR References

- Inter-compare Candidate reference with instruments/records of better stated accuracy and evaluate ...
  - Scan Angle Bias
  - Temperature Dependent Bias
  - Long term trends
  - Arrive at a set of recommendations when the instruments are most trustworthy as a reference.

IASI-A *
AIRS**

ATSR -2
AATSR

Full matrix applied on IASI and only part applied for AIRS

Radiometric Accuracy

*~better than 0.5 K (Illingworth et al 2009, ACP)

**~ better than 0.2 K (Chahine et al 2011, BAMS)

Designed for Climate applications

Expected ~better than 0.1K and stability better than 0.01K

Matrix accepted and used by FIDUCEO

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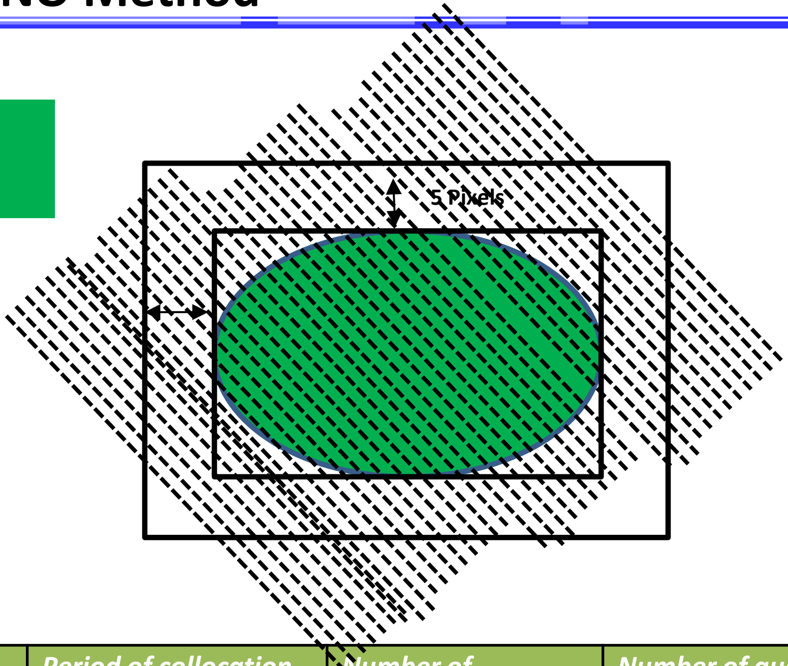
How good are IASI-A and AIRS

Method- GSICS Style SNO Method

GSICS Style SNO Collocations were generated



THRESHOLDS	
Standard Deviation of Collocated Pixels	< 0.5 K
Standard Deviation of Perimeter pixels	< 1 K
Time Difference	< 15 Mins
Time Span	2008/01-2011/03
Percentage of area of IASI pixel collocated with AATSR pixels	70%
Sat Zenith Angle difference	1º

Collocation	*Period of collocation*	*Number of Collocations*	*Number of qualifying Collocations used in this study*
AATSR Vs IASI –A	*1Jan2008- 31 Mar2011*	*10,047,594*	*1,447,030*
ATSR-2 Vs AIRS	*1Sep2002 – 30Nov2002*	*767, 354*	*23, 305*

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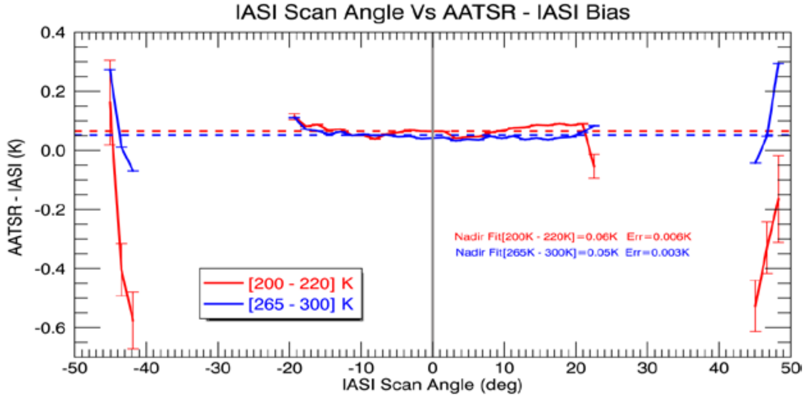
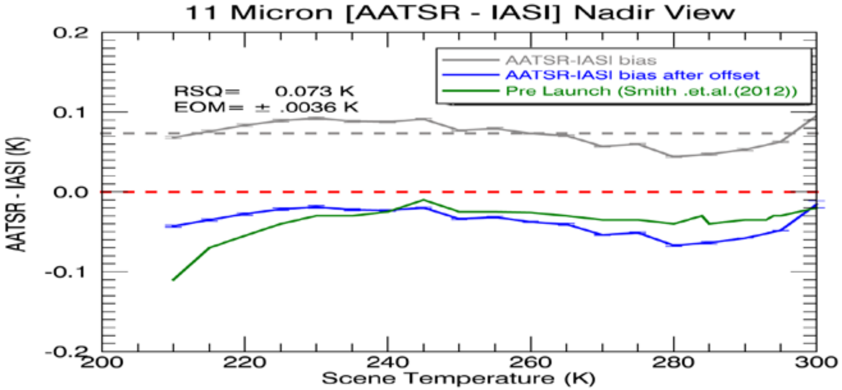
Inter- Comparison Results
Scan Angle





Scan angle dependence of the AATSR–IASI bias for cold (200–220 K) and SST (265– 300 K) temperature ranges. Neither AATSR nor IASI show any scan angle dependence in the −20 to +20◦ scan angle range.

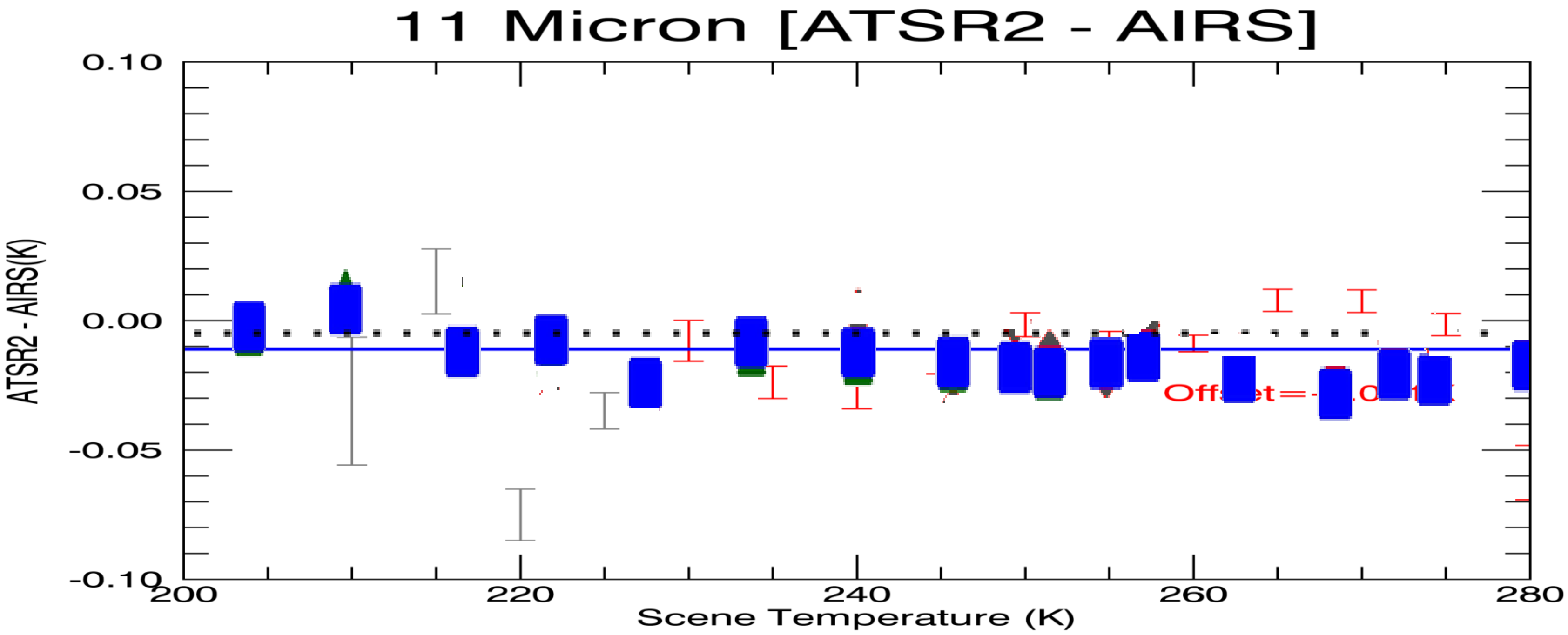
Temperature dependence of AATSR–IASI-A (in grey) bias over the period of 39 months.

Blue curve is also the same temperature dependence with an offset of 0.11 K (i.e. post launch) subtracted from it. This blue curve is similar to pre-launch (Smith et al., 2012) characteristics of AATSR to within hundredth of Kelvin.

IASI-A is nearly as good a pre-launch reference with an offset of 0.11K. Radiometric performance better than specs and previously thought.

Inter- Comparison Results

Temperature AIRS Vs ATSR-2



Pre-launch ATSR-2 and post launch inter- comparison with AIRS match to within a 100th of K

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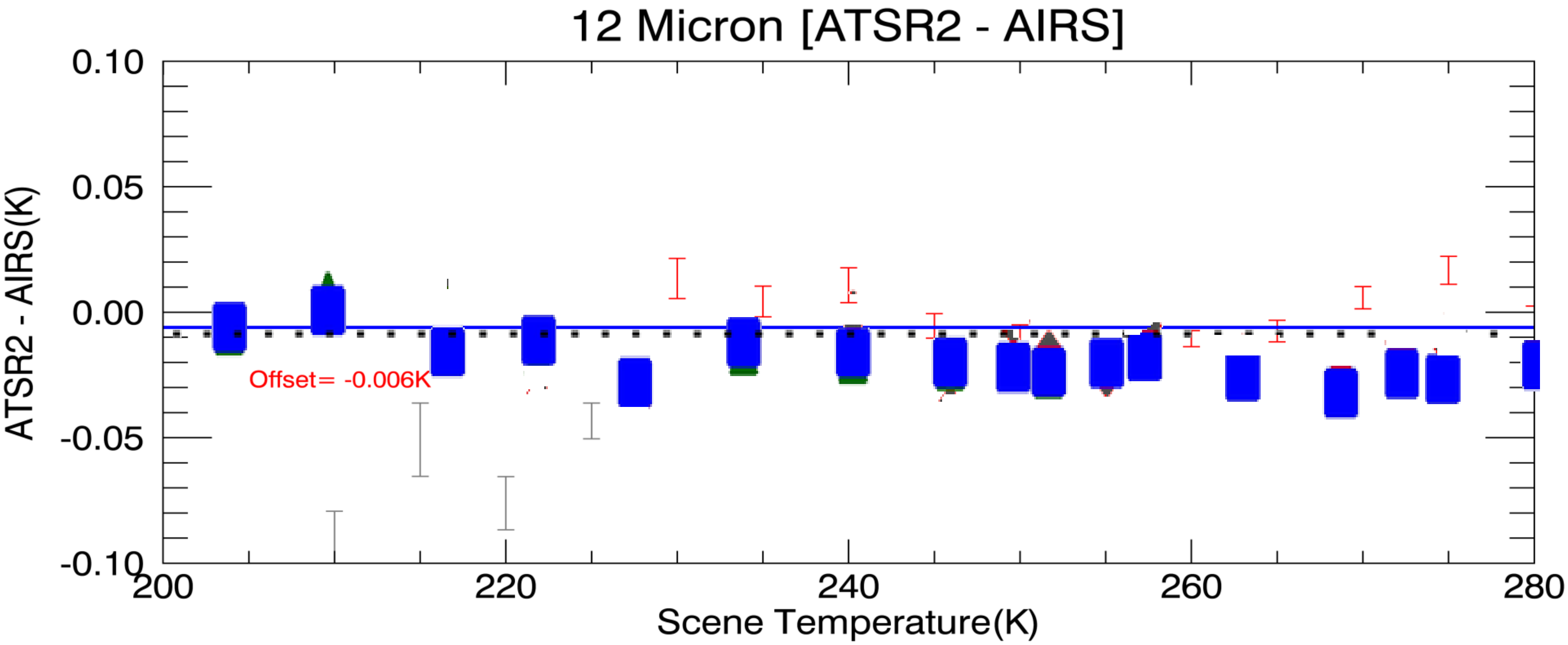
Inter- Comparison Results

Temperature AIRS Vs ATSR-2



Pre-launch ATSR-2 and post launch inter- comparison with AIRS match to within a 100th of K

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Lessons learnt from IR-Calibration

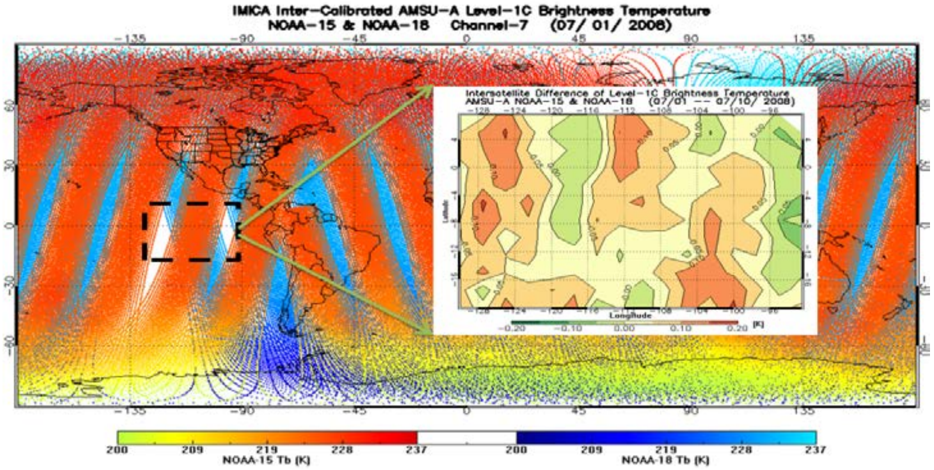
- Reference instruments are not carved in stone-> Can develop anomalies during their life times (Spectral Anomalies have been detected in IASI-A and IASI-B and differences between IASI-A and IASI-B exist .
- Community need multiple references that can reveal full scale of bias at different times and locations -> Challenge to combine references.
- Long time series of reference records is required for re-calibration.

Reference Records

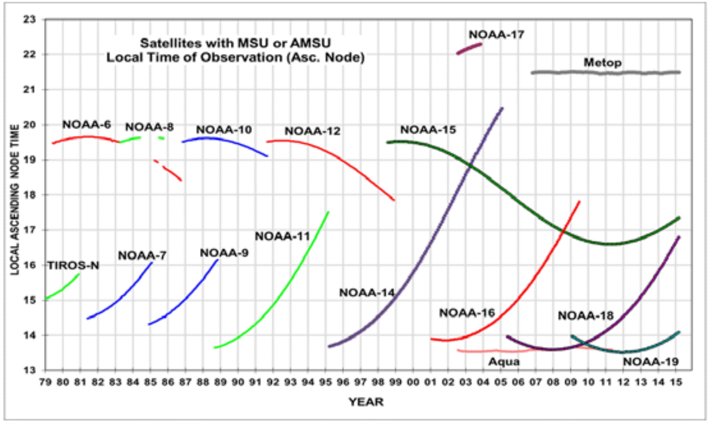
Highly stable radiances made by combining references that span large wavelengths , span wide scan angles and time

MW References
AMSU-A FCDR as a Reference for Cross-Calibration

- AMSU-A onboard six POES satellites were inter-calibrated using Integrated Microwave Inter-Calibration Approach (IMICA)
- 5 calibration errors were removed/minimized: nonlinearity, bias drift, frequency shift, sun-heating induced temperature variability in radiances;
- Inter-satellite Biases were reduced to 0.1-0.2K
- 19 years of swath data
- Dataset available from NCEI CDR website

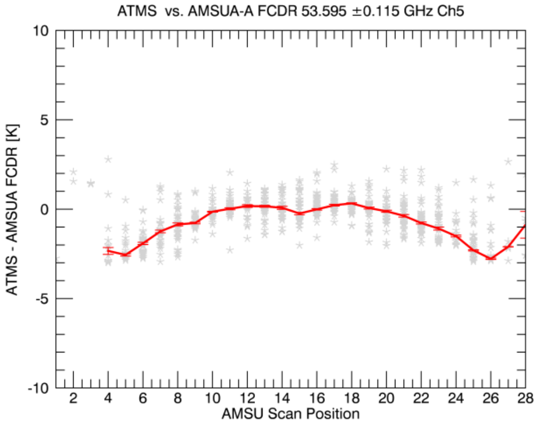


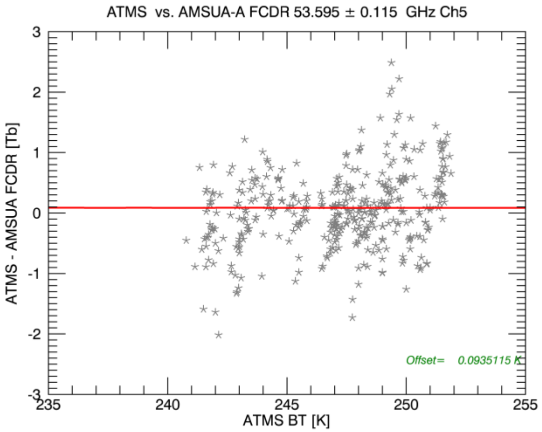
AMSU-A brightness temperature s for overlapping NOAA-15 and NOAA-18. Their differences for randomly selected region (e.g., within the dashed square) are within 0.1-0.2K.



Series of MSU/AMSU-A provide a long term reference records spanning over a large range of time and full span of scan angles.

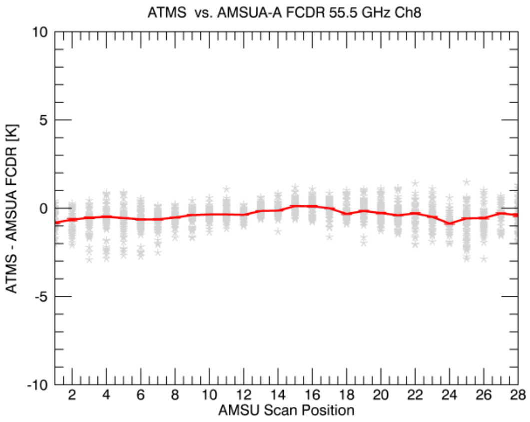
Monitoring ATMS-SDR by SNO inter- comparison with FCDR

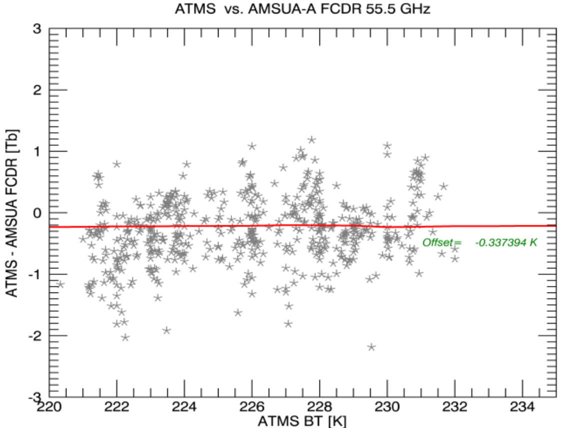




Inter- comparison of ATMS-SDR with FCDR show

- Low scan angle dependence of ATMS-SDR
- Post launch ATMS-SDR maintains nearly pre-launch level of accuracy.





MSU/AMSU-A FCDR a robust GSICS reference record that can provide radiances across several equatorial crossing times and scan angles

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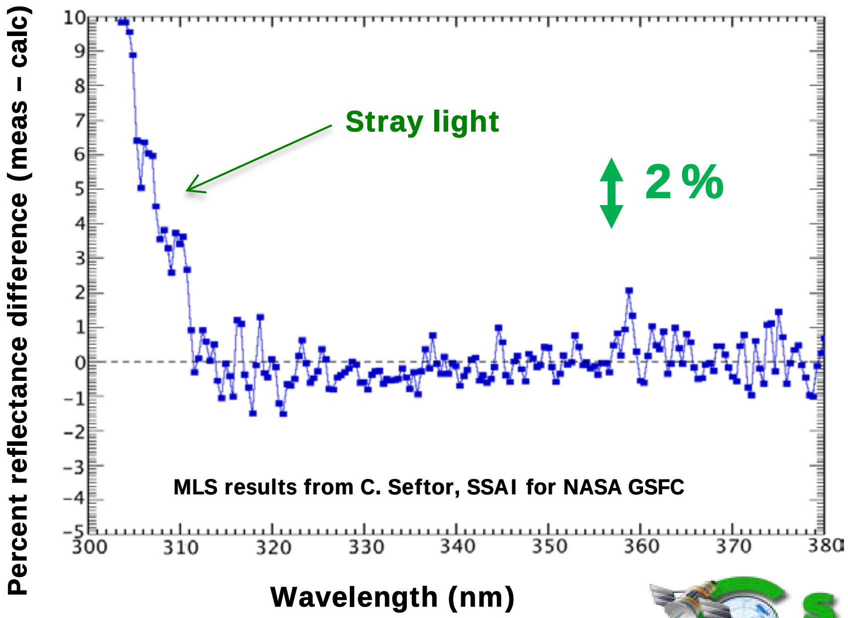
UV Solar References

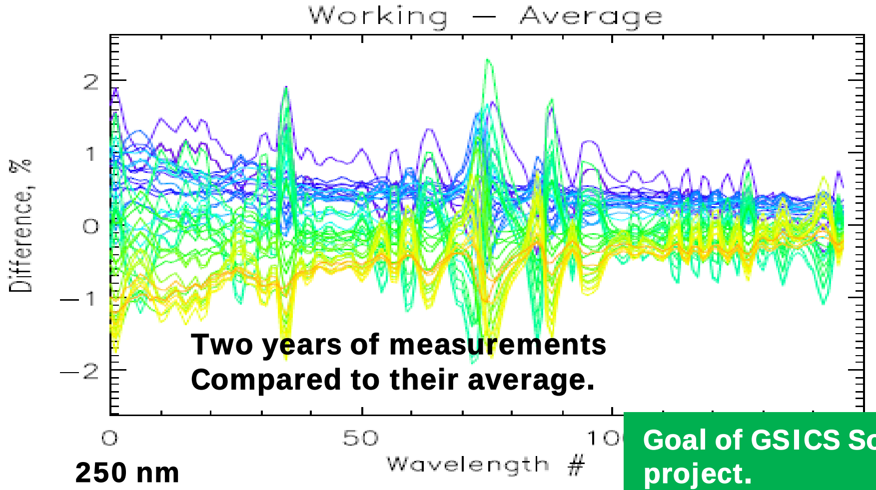
UV instruments such as OMPS and GOME-2 utilize solar viewing to gather reference data that is used for in-flight calibration and to create Radiance/Irradiance ratios to use in product algorithms.

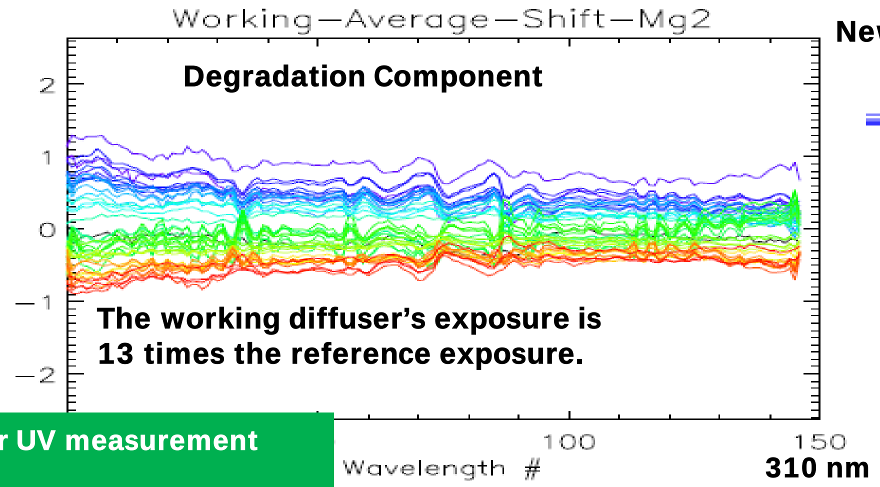
Key monitoring requirements place by the GSICS ozone community are:

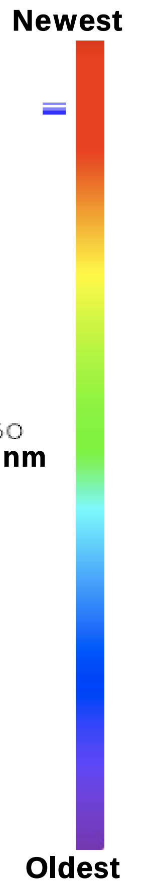
- Pre-Flight Laboratory calibration of the instrument
- Performance of (dual) diffusers for Solar Measurements and on-board sources (Diffuser and instrument degradation)
- Ability to track wavelength scales through measurement based methods.
- Performance Requirements (Are they good enough?
- Comparisons and monitoring by using
  - Internal consistency
  - Chasing orbits
  - Targets (desert, ice, open oceans)
  - Forward Models with specified ozone
  - SNO
  - No-local time difference zonal means
  - LEO/GEO underflights (new instruments)



OMPS Nadir Profiler Solar Measurements Model

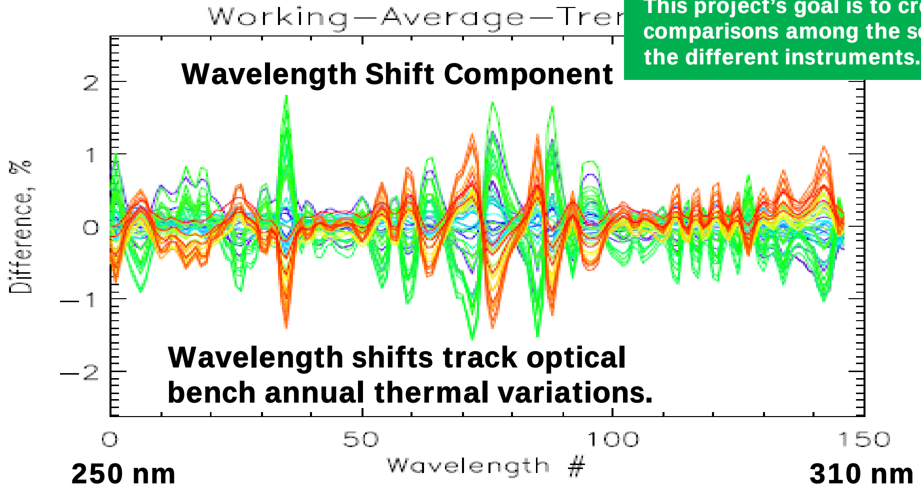


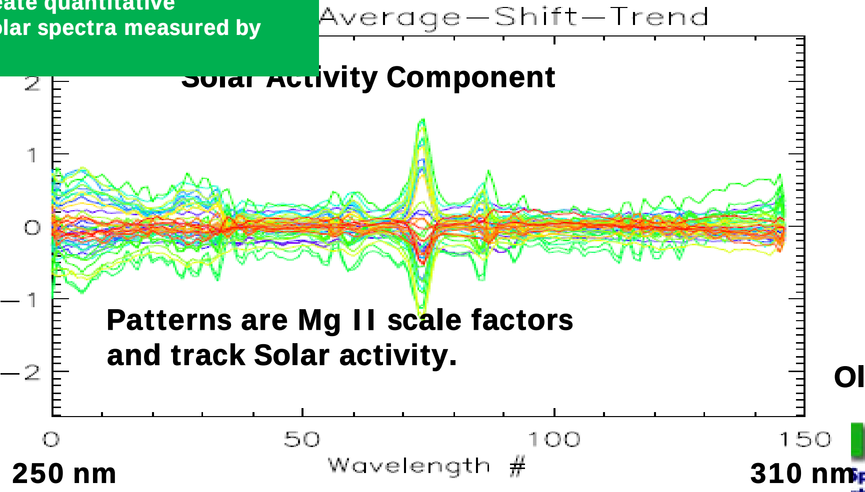




Goal of GSICS Solar UV measurement project.

This project's goal is to create quantitative comparisons among the solar spectra measured by the different instruments.





Summary and Conclusions

GSICS goals go beyond to routine daily monitoring-> Root Cause analysis -> Recalibration

- The GSICS community has identified a process for selecting reference instruments / reference records.
- The IASI-A , CrIS and AIRS have acted a robust references for monitoring GEO instruments globally.
- These instruments display nearly pre-launch level of performance in space.
- MSU/AMSU-A FCDR records due to their stability and accuracy are extremely useful as in-orbit references for monitoring MW instruments.
- New Projects for inter-comparing solar measurements and Earth reflectivity measurements have been initiated in the UV Subgroup. First cuts show promising results.

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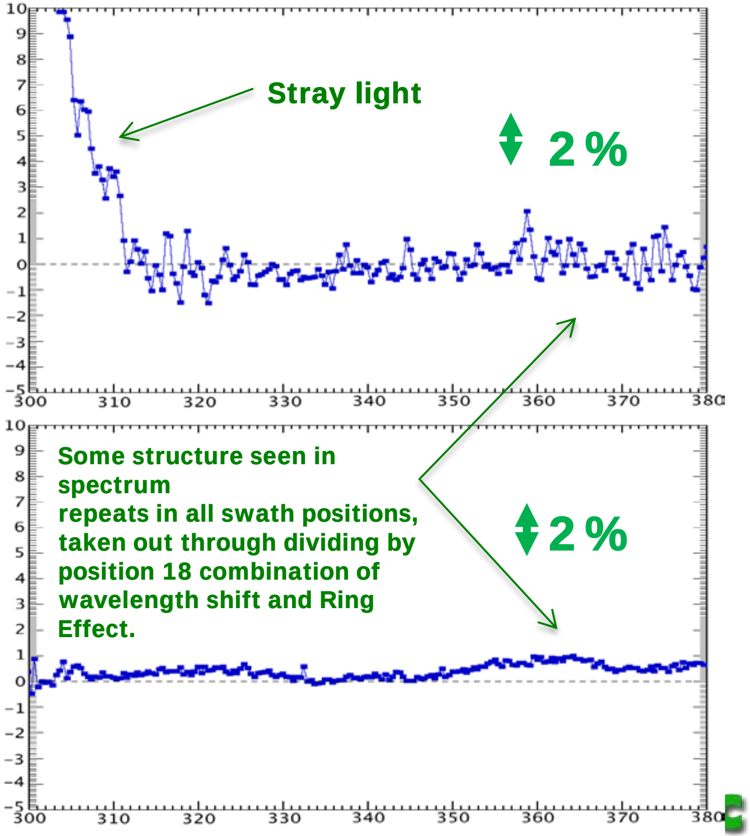
THANK YOU

OMPS TC comparisons with modeled Top-of-atmosphere reflectances using MLS ozone retrievals as truth are quite good

- **Co-locate MLS temperature and ozone profiles to OMPS TC measurements**
  - Reflectivity < 0.10
  - -20 < latitude < 20 degrees
  - June 2012
- **Calculate TOA reflectances (radiance / solar flux) from TC viewing conditions, MLS profiles using radiative transfer code (TOMRAD)**
- **Compare measured OMPS TC reflectance with calculated reflectance**
  - Agreement seen to within 1% for wavelengths > 312 nm
- **Stray light seen for wavelengths < 312 nm**
  - Consistent with pre-launch sensor characterization



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Application of IASI-A and AIRS

1. **IASI- A Vs AIRS of -0.042 K (± 0.05 K) and - 0.093K (± 0.05K) for 11 and 12 µm for cold .**
2. **IASI- A Vs AIRS . For warm (more than 260 K) temperature bias is -0.029K (± 0.01K) and -0.043K (± 0.01K) for 11 and 12 µm channels.**
3. **AIRS Vs ATSR-2 -0.015 K (±0.001K) in 11 µm and -0.011 (±0.004K) 12 µm channel**

IASI-A has a small spectral dependence of bias

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Conclusions

Stability and accuracy of IASI-A has been evaluated using GSICS style inter- comparisons of IASI-A and AATSR spanning 39 Months of data.

Results indicate that IASI-A has performed robust stable measurements during the period of study and provided pre-launch level of accuracy with an +0.11K offset.

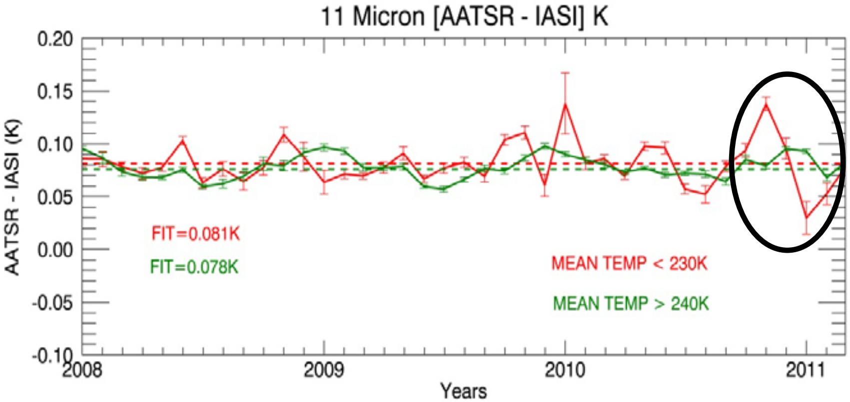
IASI-A has very small scan angle dependence

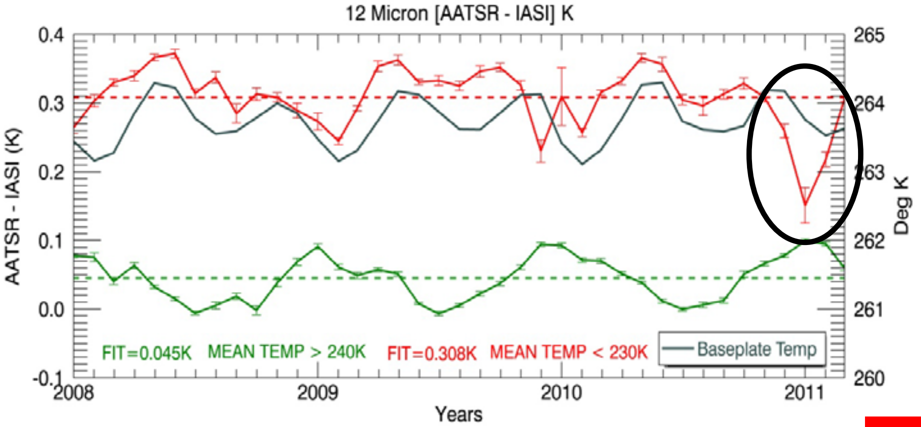
IASI-A nearly pre-launch level of reference radiances (+.07K)

IASI-A has a very small spectral dependence.

Overall IASI-A has been an in-orbit excellent reference for GSICS monitoring and can compliment

Inter- Comparison Results
Long Term Monitoring





Impact pf ENVISAT Orbital Changes

Time series of variation of AATSR IASI bias for 11 and 12 µm channels in the cold (red) and warm (green) temperature ranges. The bias at cold temperature in 12 µm is correlated (ρ=0.78) with the instrument baseplate temperature (grey curve in the lower plot).

IASI-A measurements maintain stability w.r.t AATSR over 3 yrs of study

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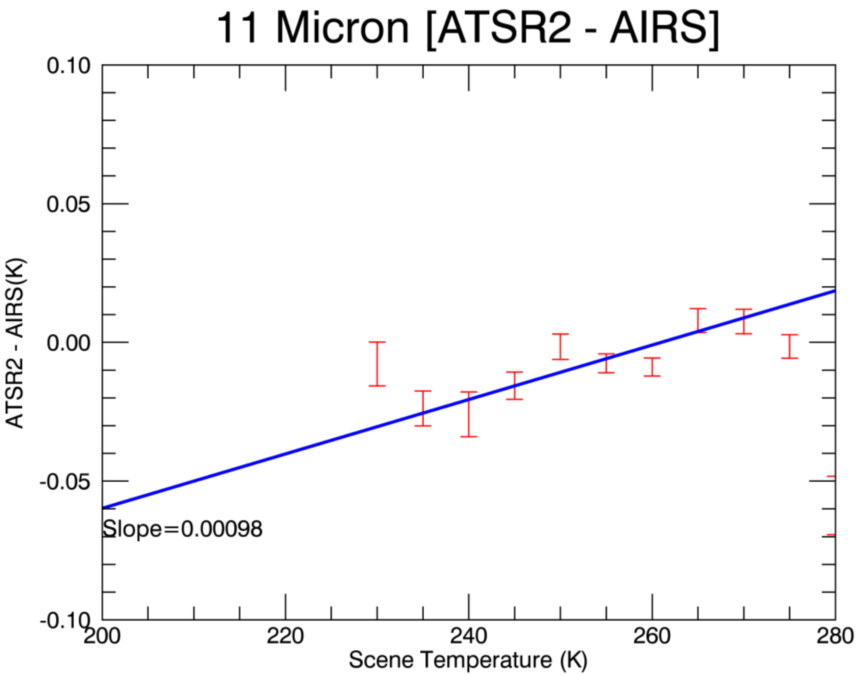
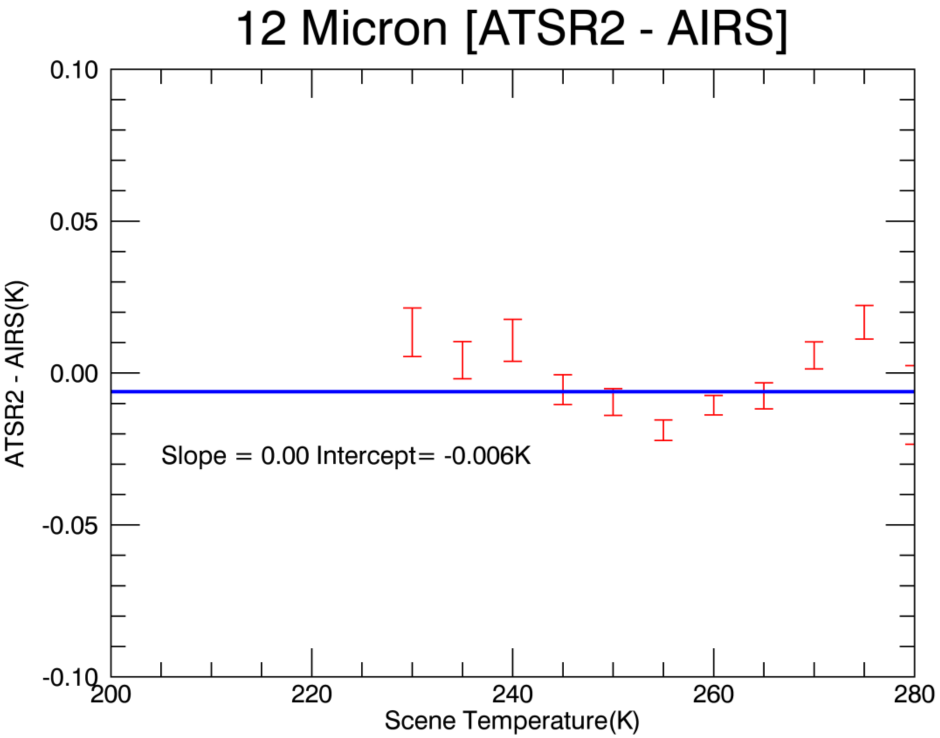


11 Micron [ATSR2 - AIRS]
0.10
0.05
0.00
-0.05
-0.10
200
220
240
260
280
Scene Temperature (K)
ATSR2 - AIRS(K)
Slope=0.00098



12 Micron [ATSR2 - AIRS]
0.10
0.05
0.00
-0.05
-0.10
200
220
240
260
280
Scene Temperature(K)
ATSR2 - AIRS(K)
Slope = 0.00 Intercept= -0.006K