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Grant Title: **Assessment and Optimization of IR Radiance Measurements for Climate, Assimilation, and Remote Sensing Applications, using high resolution spectra (S-HIS, AIRS, CrIS, and IASI) as transfer standards for other IR observations (MODIS, VIIRS, CERES, GOES)**

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Introduction

This final report describes the status of NASA grant NNX08AH96G to the University of Wisconsin-Madison, Space Science and Engineering Center at the end of the third and final year. The primary objective of this project is to assess and optimize the long-term consistency and accuracy of EOS IR radiances that form the basis for climate, forecasting, and key remote sensing applications from Terra and Aqua. This will be a comprehensive effort that addresses the full complement of available IR measurements and helps to establish the detailed post-flight radiometric characteristics needed to optimize a wide range of applications. The radiances themselves are considered to be key Earth System Data Records (ESDR) and specific combinations will become Climate Data Records (CDRs).

The foundation for this effort is the fundamentally high calibration accuracy achievable from high spectral resolution infrared measurements like AIRS and CrIS. High spectral resolution, coupled with broad spectral coverage, is also important to providing an effective transfer standard for lower resolution instruments. In addition to the space borne instruments from EOS, we make use of our Scanning High-resolution Interferometer Sounder (S-HIS) aircraft instrument validated with laboratory comparisons incorporating NIST standards, the MODIS Airborne Simulator (MAS) that provides very high spatial resolution, and the IASI high resolution sounder on MetOp. Both the S-HIS and IASI have continuous spectral coverage from about 3 to greater than 15 microns. The connection between instruments on platforms in different orbits is accomplished by using overlapping orbits at high latitudes, by comparing with GOES near nadir, and especially by using aircraft-based S-HIS spectra as a link. Direct aircraft radiance comparisons over the life of the EOS mission provide the only way to re-establish connection with NIST standards post launch.

Year 1 Accomplishments

The objectives and accomplishments in each of the proposed study areas is briefly presented here. Further details can be found in the attachments to this report. The overall objectives are to (1) re-establish the connection with absolute calibration standards and other performance characterization after launch and throughout a mission, and (2) transfer in-flight absolute calibration from high spectral resolution instruments to lower resolution measurements. Three examples of the progress in these objectives in year 1 of this project are provided in this report: 1) IASI radiometric validation study during JAIVEX, 2) AIRS/IASI inter-calibration on orbit using SNOs, and 3) absolute accuracy assessment of AIRS team total water vapor column product using ARM radiometers. Further details are contained in the references identified under the Accomplishments by Task section of this report.

On-Orbit IASI Radiometric Validation Study from the JAIVEX Campaign

In October 2006 the Europeans launched their first operational polar-orbiting satellite, MetOp-A. Among the new instruments flying on this platform, the Infrared Atmospheric Sounding Interferometer (IASI) has helped to strengthen an international effort to monitor and better understand our planet's environmental systems. To assess the accuracy of the data from this important instrument, American and European agencies successfully collaborated in the Joint Airborne IASI Validation Experiment (JAIVEx). Scientists and engineers from SSEC made significant contributions to JAIVEx during the Texas-based field campaign from 14 April to 7 May 2007 and to the data analysis that followed.

IASI was designed to gather operational meteorological sounding data with a very high level of accuracy, as part of the Global Earth Observation System of Systems (GEOSS). Begun in 2005 the GEOSS project seeks to utilize existing and new hardware and software to supply data and information at no cost to the global science community. In addition to improving medium-range weather forecasts, IASI data will complement the measurements from the U.S. advanced sounder, the Cross-track Infrared Sounder (CrIS), that is scheduled for launch in 2009 on the NPOESS Preparatory Platform (NPP).

Conducted shortly before MetOp-A went operational, JAIVEx was centered around three primary objectives. First, participants sought to validate and characterize the radiometric performance of IASI. The second objective was to validate the performance of different algorithms designed to retrieve temperature, humidity, ozone and carbon monoxide profiles from IASI spectral radiance measurements, over land and ocean, and under cloudy as well as clear sky conditions. Finally, the field program allowed participants to gather a diverse set of IASI spectra with co-located airborne and in-situ observations. This data set will further the development of innovative techniques to assimilate IASI data into numerical weather prediction models, utilizing as many channels as possible.

The IASI sensor design has roots in a concept developed at SSEC in the late 1980s. The concept also lead to the development of two aircraft-based, high spectral resolution infrared interferometer sounders that measure upwelling terrestrial and atmospheric emitted radiance: SSEC's Scanning High Resolution Interferometer Sounder (S-HIS) and the NPOESS Airborne Sounder Testbed-Interferometer (NAST-I). S-HIS and NAST-I have participated in numerous field campaigns where the data have been applied to the development and validation of radiative transfer models, atmospheric sounding algorithms, surface and cloud properties, and sensor trade studies. Primarily funded through the U.S. Integrated Program Office (IPO), both S-HIS and NAST-I contributed to the JAIVEx campaign as a part of the high altitude NASA WB-57 instrument suite.

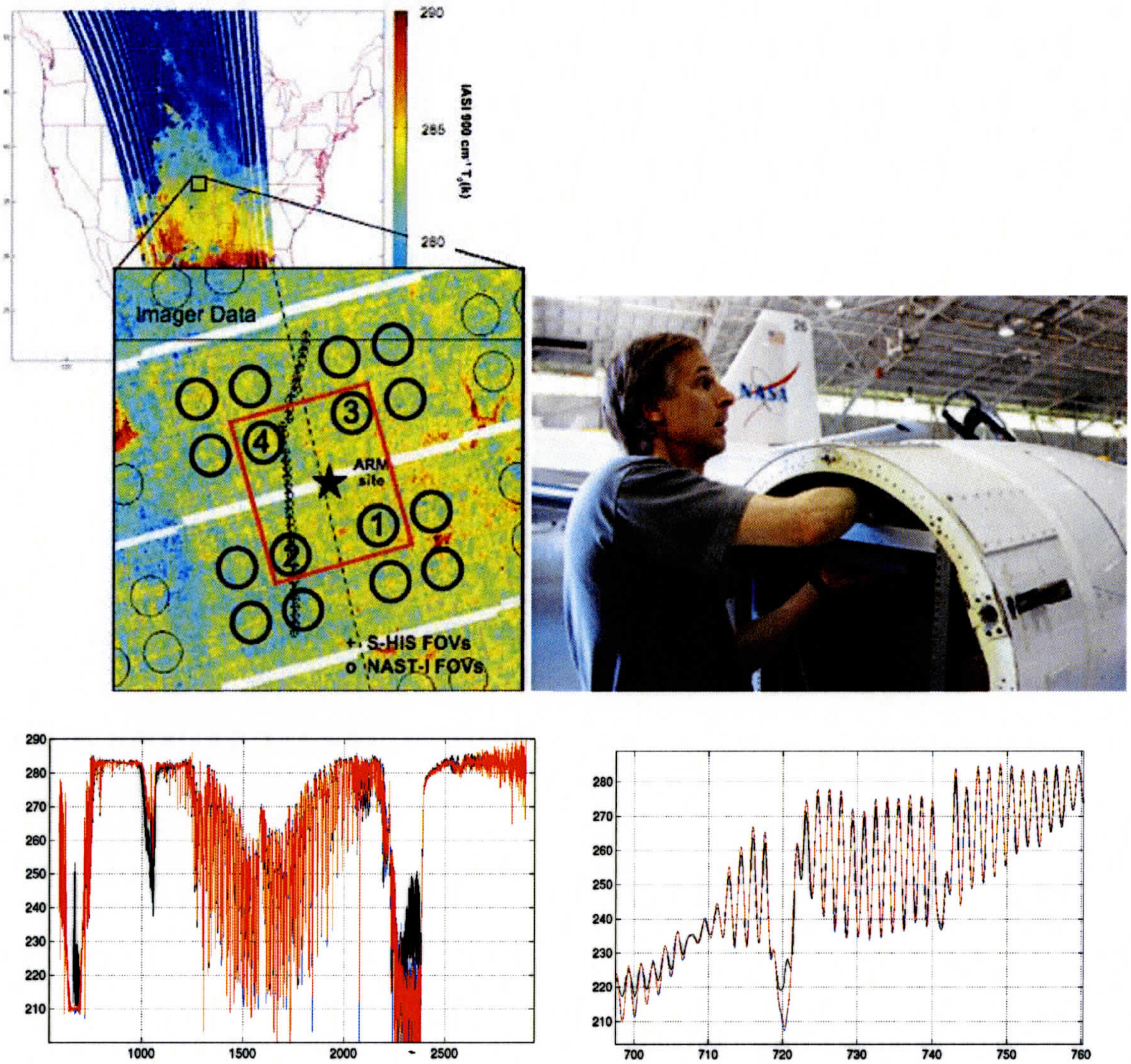

Figure 1. IASI 900 cm^{-1} window brightness temperature swath on 19 April 2007 (background image). ARM site enlargement shows imager data with individual IASI FOVs (large circles) and WB57 flight track with S-HIS and NAST-I nadir view FOVs. Spectral data averaged within the red box. IASI (black), NAST-I (blue), and S-HIS (red) measured brightness temperature, apodized to match S-HIS spectral resolution. Discrepancies are due to atmospheric contributions between the satellite (IASI) and WB57 aircraft (NAST-I and S-HIS).

JAIVEx also included a second aircraft: a modified BAe 146 from the United Kingdom. The Facility for Airborne Atmospheric Measurements (FAAM) BAe 146, carried the

Airborne Research Interferometer Evaluation System (ARIES). Much like S-HIS and NAST-I, ARIES is similar in design to IASI. The FAAM also carried a number of in-situ aircraft probes, and had the ability to release dropsondes to further assess the atmospheric state of the troposphere. Both aircraft flew out of Ellington Field in Houston, Texas, the home base of the NASA WB-57. This location provided access to uniform scene conditions for flights over the Gulf of Mexico and a wealth of ground-based measurements from the Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program central facility located in north central Oklahoma. For most of the field campaign the WB-57 flew at a nominal altitude of 59,000 ft, while the BAe 146 sampled the atmosphere below the WB-57 at altitudes between 100 and 35,000 ft. High-altitude observations coincident with the satellite overpasses provide NIST (National Institute for Standards and Technology) traceable validation of the on-orbit satellite observations. Flight durations of five to six hours facilitated comparisons of the MetOp-A operational measurement capability with observations from NASA's A-Train research satellites, primarily from the Atmospheric Infrared Sounder (AIRS) aboard the EOS Aqua platform. Because both MetOp-A and the A-Train are in ascending polar orbits with a four-hour time gap, a five- to six-hour aircraft sortie ensured that the aircraft sensor data could be used as a calibration transfer reference for each of the satellite systems. This project is focusing on results from one case, a clear sky IASI, S-HIS, and NAST-I measurement intercomparison which occurred over the ARM site on 19 April 2007. The 19 April 2007 flight offered a prime opportunity to compare IASI to both S-HIS and NAST-I measurements during clear sky conditions above the ARM site. The IASI ground swath was nearly centered over the ARM site, which provided coincident nadir views with the aircraft instruments within minutes of the MetOp-A satellite overpass.

Figure 1 shows the mean brightness temperature spectra for IASI (black), S-HIS (red), and NAST-I (blue) measurements within the red box in Figure 1. Because each instrument has a different spectral resolution, IASI and NAST-I data have been mathematically resampled to match the S-HIS spectral resolution. Spectral regions that provide atmospheric contributions (e.g., 2200-2400 cm^{-1}) between the satellite and aircraft altitude (about 59,000 ft) have noticeable differences resulting from the atmospheric emission that occurred above the aircraft. However, focusing on select spectral regions where the emission contributions are limited to sub-aircraft altitude, shows that measurements from all three instruments agree to within 0.2 K. Figure 2 shows the detailed comparison of the S-HIS and NAST-I airborne measurements compared to the satellite IASI. This first look at clear sky results from the flight on 19 April 2007 demonstrates that IASI performance is outstanding, with data suggesting that radiometric calibration is on the 0.1 K level. This level of agreement is comparable to that found in comparison with NASA AIRS sounder and is required for the development of climate quality products from the AIRS and IASI observed radiances.

Retrievals of temperature and water vapor from S-HIS for this JAIVEX case have been made using the UWPHYSRET reference retrieval code developed at UW-SSEC (Antonelli 2008a). Spectral residuals were examined for both S-HIS and IASI after retrieval to high light spectroscopic issues in a state of the art forward model

(LBLRTM/HITRAN). Figure 3 illustrates an observation minus calculation difference found after minimizing the atmospheric state for a S-HIS observation over the DOE ARM Southern Great Plains site. A particular focus has been on a quantitative demonstration of the impact of noise filtering using dependent set principle component analysis (PCA) on the retrieval of atmospheric state parameters (Antonelli 2008b). Figure 3 compares noise filtered and unfiltered spectral residuals. The noise filtering greatly improves the apparent signal to noise in the residual allowing, in principle, the retrieval of smaller signals in the upwelling observations. This investigation is particularly important for IASI retrievals where the signal to noise at full spectral resolution (resolving power > 2400) is below that of AIRS and CrIS sensors. The preliminary results suggest that while noise filtering has great potential, the underlying spectroscopic errors, below the unfiltered noise level but above the filtered noise level, will limit improvements in retrieval products until these errors are reduced as well.

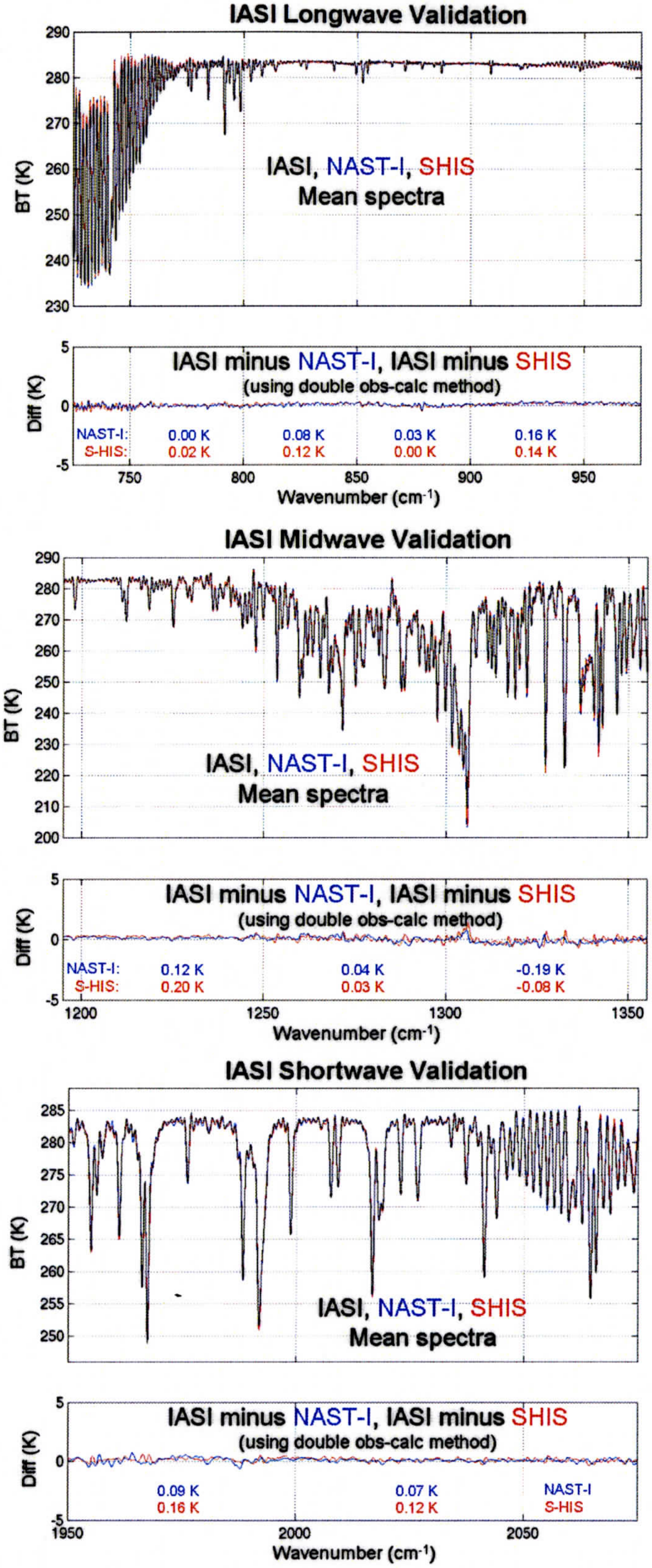

Figure 2. Excellent radiance agreement between IASI and airborne FTS sensors during JAIVEX.

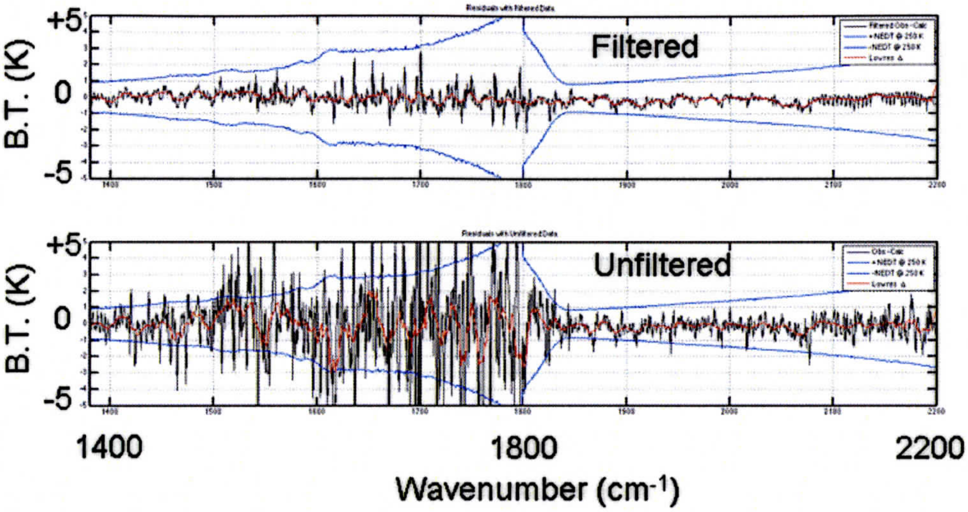

Figure 3. Retrieval residual of airborne S-HIS sensor during JAIVEX April 19, 2007 has been used to investigate the impact of noise filtering using dependent set PCA. The upper panel shows the observation minus calculation after minimization of atmospheric state parameters for noise filtered S-HIS data. The lower panel shows the same result before noise filtering. Note the carbon monoxide lines are visible between 2050 and 2200 cm^{-1} in the noise filtered result but are not apparent in the unfiltered data. This noise filtering technique shows promise for retrieving small signals contained in noise filtered IASI data, especially in the shortwave band.

On-Orbit Inter-calibration of AIRS and IASI using Simultaneous Nadir Overpasses (SNOs)

Notable work relevant to this project is a joint paper with L. Larrabee Strow, UMBC Physics Department and Joint Center for Earth Systems Technology, at CalCon 2008 titled "Inter-Calibration of the AIRS and IASI Operational Infrared Sensors". Material from that presentation (Strow et al. 2008) and one presented by Dave Tobin (Tobin 2009) is paraphrased in the remainder of this section with preliminary conclusions. Table 1 contains a summary of detailed differences over selected wavenumber bands while Figure 4 contains a plot of the AIRS minus IASI brightness temperature differences for the entire region of spectral overlap.

The goal is to potentially want to push understanding of calibration difference between AIRS and IASI to below 0.1K. The simultaneous nadir overpasses (SNOs) method is one very useful approach to performing this satellite intercalibration. Metop-A IASI and Aqua AIRS are in different sun synchronous polar orbits (AM and PM), so tight time/space overlaps limits SNOs to two very narrow latitude ranges centered at ±73.8 degrees. This also limits the SNOs to relatively cold high latitude spectra, esp. in window regions. Data from May 2007 to Feb. 2008 was used in this preliminary analysis. Matchup thresholds are 2 minutes and 30 km, from nadir orbit crossing point. This resulted in 284 SNO's each containing 3-4 IASI FOVs and 6-8 AIRS FOVs. Standard deviations of these individual measurements were computed and propagated into means over the 284 SNO's. Except for the shortwave, statistical errors in AIRS-IASI BT differences are roughly equivalent to the mean differences. We have cross-convolved each radiance with other instrument's SRF. Note that frequency re-calibration of AIRS was not done in this preliminary analysis, but will be at the 0.05K level or lower when it is implemented. Also note that variability with AIRS linear detector arrays is observed, suggesting further adjustments to AIRS calibration may be warranted.

Table 1. Preliminary AIRS – IASI Inter-calibration (Strow et al., 2008)

cm^{-1} range	SNOs (K)
690-755	0.04 ± 0.14
690-780	-0.04 ± 0.14
1350-1650	0.12 ± 0.06
1350-1450	0.10 ± 0.07
1450-1650	0.14 ± 0.05

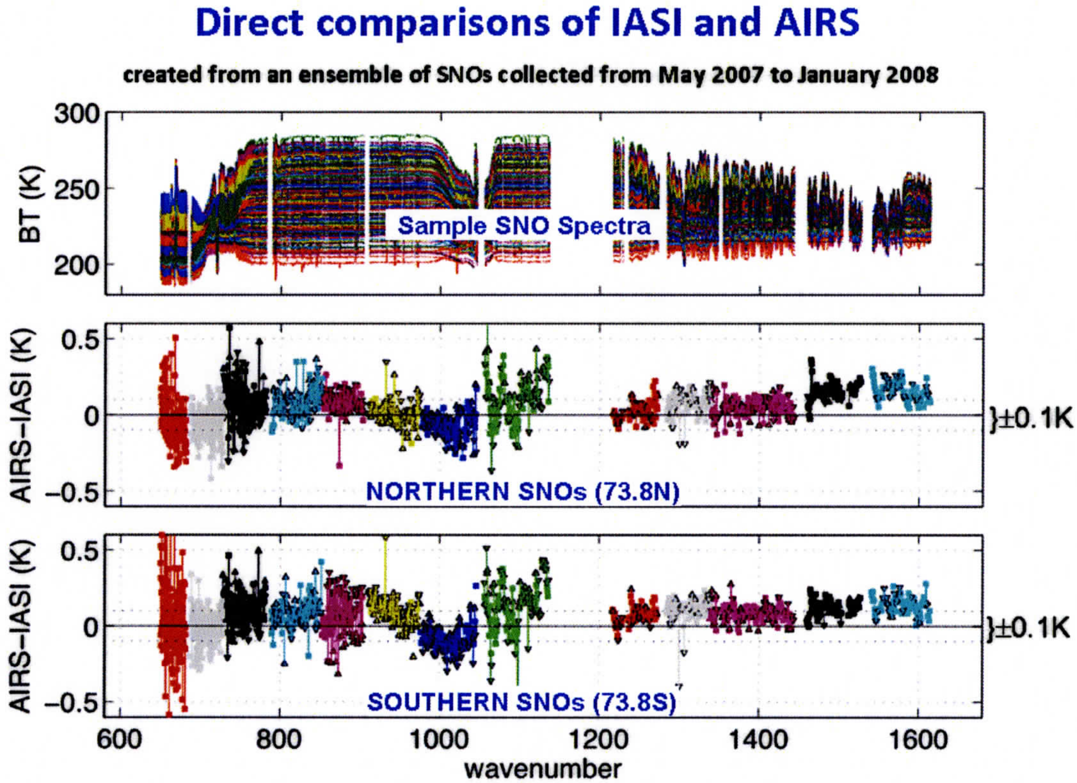

Figure 4. Preliminary AIRS-IASI Simultaneous Nadir Overlap (SNOs) (May 2007 – Feb. 2008) shows excellent agreement at a level approaching 0.1 K. This good agreement suggests that IASI will provide a useful radiance transfer standard to help in linking the EOS and NPOESS eras (Tobin 2009). The AIRS detector arrays are color coded in the bottom two panels.

Absolute Accuracy of AIRS Total Precipitable Water Vapor in Tropics, Mid-latitude, and Arctic Climate Zones

This section summarizes results of a detailed analysis of the diurnal dependence of the AIRS water vapor product and it's absolute accuracy which was been presented at scientific meetings supported by this project (Bedka et al. 2009; Knuteson et al. 2008). This work was done in collaboration with the DOE ARM program which is providing the ground truth measurements of the column water vapor amount.

Total precipitable water (TPW) is defined as the amount of liquid water that would be produced if all of the water vapor in an atmospheric column were condensed. It is a very useful parameter for forecasters to determine atmospheric stability and the onset of convection and severe weather. Since water vapor is a greenhouse gas, the TPW of the atmosphere also plays a critical role in climate. The development of a climate record of water vapor is an important goal of the NASA NPOESS Preparatory Project (NPP). The Atmospheric Infrared Sounder (AIRS on Aqua) provides the capability to retrieve water vapor at high vertical resolution, as well as monitor seasonal and diurnal trends. The Cross-Track InfraRed Sounder (CrIS) will extend this record on NPP and NPOESS. The purpose of this study is to establish the absolute accuracy of the retrievals of TPW from a satellite-based high spectral resolution infrared sounding instrument (e.g. AIRS) using ground-based instruments such as the microwave radiometer (MWR). Results are presented that highlight both the seasonal and diurnal variability of TPW at two measurement sites, and the accuracy with which satellite algorithms are able to capture this variability. This study focuses on TPW comparisons over three ground-based observation sites operated by the U.S. Department of Energy (DOE) Atmospheric Radiation Measurement (ARM) program. The ARM Tropical Western Pacific (TWP) site is located on the small island of Nauru which is close to the equator and represents tropical environments (high water amounts). The ARM Southern Great Plains (SGP) site is located at mid-latitude in the central United States, near Lamont, OK. Unlike the TWP site, the SGP site exhibits strong seasonal and diurnal variability in water vapor. The North Slope of Alaska (NSA) site is near Barrow, AK and represents an arctic environment (low water amounts).

This study considers co-located AIRS and MWR retrievals of TPW over the ARM sites between September 2002 and August 2008. Matchups were limited to AIRS overpasses with estimated TPW retrieval errors of 20% or less, where the distance between the AIRS observation and the MWR observation was 100 km or less, and the AIRS reported cloud fraction was 80% or less. The closest AIRS retrieval to the ARM MWR location was selected for each satellite overpass. To reduce the impact of the difference in spatial resolutions of the two products, the MWR data were averaged over 10 minute intervals centered on the AIRS overpass time, and matches were excluded if the uncertainty in this mean exceeded 1%. This eliminated instances in which the atmospheric water vapor was changing rapidly around the AIRS overpass time. During the time period examined, a total of 1068 AIRS overpasses of the SGP site met the given criteria. Figure 5 shows the percent difference between AIRS and MWR TPW grouped into 1 cm bins, plotted against the mean MWR TPW within each bin. Shown separately are the daytime + nighttime data (top), daytime data only (middle), and nighttime data only (bottom). Results from

TWP, SGP, and NSA, are plotted in blue, red, and green respectively. Error bars are the 95% confidence level in the uncertainty of the mean difference for a given bin. The largest error bars in this case indicate a very small number of data points within a given bin (for instance, in the SGP 5-6 cm bin, there are only 4 data points from during the daytime). Considering both daytime and nighttime data, the bias error is very close to the AIRS science team suggested error of +/- 5% for bins below 2 cm in the Arctic, between 1 and 5 cm for at the Southern Great Plains, and between 3 to 7 cm for the Tropical Western Pacific site.

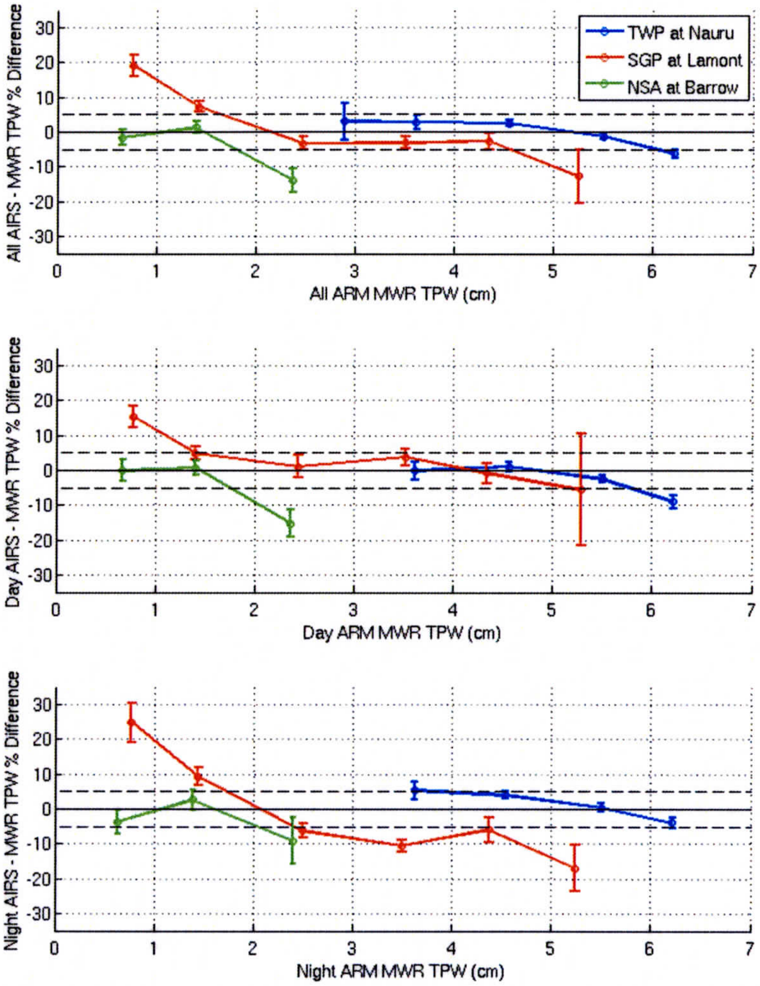

Figure 5. Evaluation of the absolute accuracy of the AIRS science team total precipitable water vapor (TPW) product in three climate regimes; tropical (TWP-Nauru), mid-latitude (SGP-Lamont), and arctic (NSA-Barrow). The ground truth column water vapor is provided by the DOE ARM Microwave Radiometers (MWRs) at each of the ARM sites. The MWRs have an absolute accuracy of 3% or better. The dashed lines indicate the stated AIRS product accuracy of 5%. The upper panel shows that AIRS product is meeting the stated accuracy for a day/night average in the tropics and arctic but exceeds 5% error at the extreme wet and dry water amounts at the Southern Great Plains (land site). A small day/night bias also is present in the AIRS (version 5) retrievals as can be seen by comparing the bottom two panels. The error bars show the 95% confidence level based on the number of samples within that 1 cm TPW bin.

Year 2 Accomplishments

The objectives and accomplishments in each of the proposed study areas is briefly presented here. The overall objectives are to (1) re-establish the connection with absolute calibration standards and other performance characterization after launch and throughout a mission, and (2) transfer in-flight absolute calibration from high spectral resolution instruments to lower resolution measurements. Two examples of the progress in these objectives in year 2 of this project are provided in this report: 1) AIRS/IASI intercalibration on orbit using SNOs and 2) absolute accuracy assessment of AIRS team total water vapor column product using ARM radiometers. Further details are contained in the references identified under the Accomplishments by Task section of this report.

On-Orbit Inter-calibration of AIRS and IASI using Simultaneous Nadir Overpasses (SNOs)

Notable work from Year 1 of this effort is summarized a joint paper with L. Larrabee Strow, UMBC Physics Department and Joint Center for Earth Systems Technology, at CalCon 2008 titled "Inter-Calibration of the AIRS and IASI Operational Infrared Sensors". This Year 2 report includes updates to that initial study, with analysis of SNO comparisons of AIRS and IASI using data for the entire mission duration to date. These results were recently presented at the second IASI workshop in Annecy France.

The overall goal of this task is to potentially want to push understanding of calibration difference between AIRS and IASI to below 0.1K. The simultaneous nadir overpasses (SNOs) method is one very useful approach to performing this satellite intercalibration. Metop-A IASI and Aqua AIRS are in different sun synchronous polar orbits (AM and PM), so tight time/space overlaps limits SNOs to narrow latitude ranges centered at ±73.8 degrees. Matchup thresholds are 20 minutes and 60 km, from nadir orbit crossing point. Over the time period from May 2007 to Nov 2009, this resulted in 8102 SNO's each containing ~32 IASI FOVs and ~45 AIRS FOVs. Standard deviations of these individual measurements were computed and propagated into means over the 8102 SNO's. Compared to the previous analysis using a much shorter time period, this is a much larger ensemble resulting is significantly lower statistical uncertainties in the computed IASI-AIRS biases. Except for the shortwave, statistical errors in AIRS-IASI BT differences are much less than the mean differences. We have cross-convolved each radiance with other instrument's SRF to account for differences in the sensors spectral characteristics. Sample results are shown in Figures 6 through 8. Figures 1 shows a time series of monthly mean biases (AIRS-IASI) for the spectral range 1460-1527 cm^{-1} covered by AIRS detector array M-04b, which is primarily sensitive to upper level water vapor fields. The figure shows a fairly large mean bias between AIRS and IASI (AIRS warmer by ~150 mK) but no significant change in the bias with time. A standard statistical analysis yields a slope of 0.9 +/- 5.6 mK per year. That is, the mean slope is less than its uncertainty, and we can say that the AIRS and IASI radiances show no change with time to the 5.6 mK (1-sigma) level. Figures 7 and 8 show mean differences between AIRS and IASI for the mission duration for the northern hemisphere SNOs (top panels) and southern hemisphere SNOs (bottom panels), with spectral regions color coded by AIRS detector arrays. Figure 7 shows the longwave spectral region. Specific differences found in the longwave region can be attributed to AIRS L1B spectral calibration artifacts (red detector array), AIRS A-B state calibration artifacts (magenta detector arrays), and an AIRS polarization calibration artifact (to be reviewed, yellow and blue detector arrays). Figure 8 shows differences for the midwave spectral region. Significant differences in the midwave region are found for some upper level water vapor arrays (black and cyan) while not for others (grey and magenta).

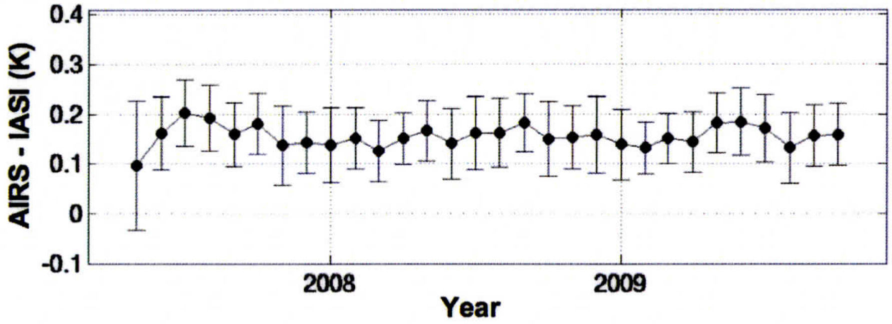

Figure 6. Monthly mean differences between AIRS and IASI for AIRS detector array M-04b covering 1460-1527 cm^{-1}.

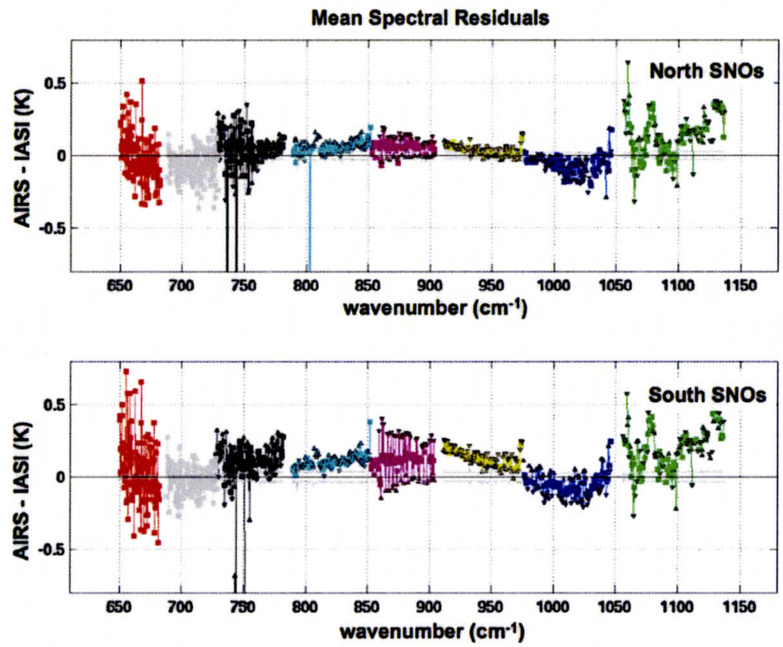

Figure 7. Mean differences between AIRS and IASI observations for the northern (top panel) and southern (bottom panel) SNOs, for the longwave spectral range. Spectral channels are color coded according to the AIRS detector arrays.

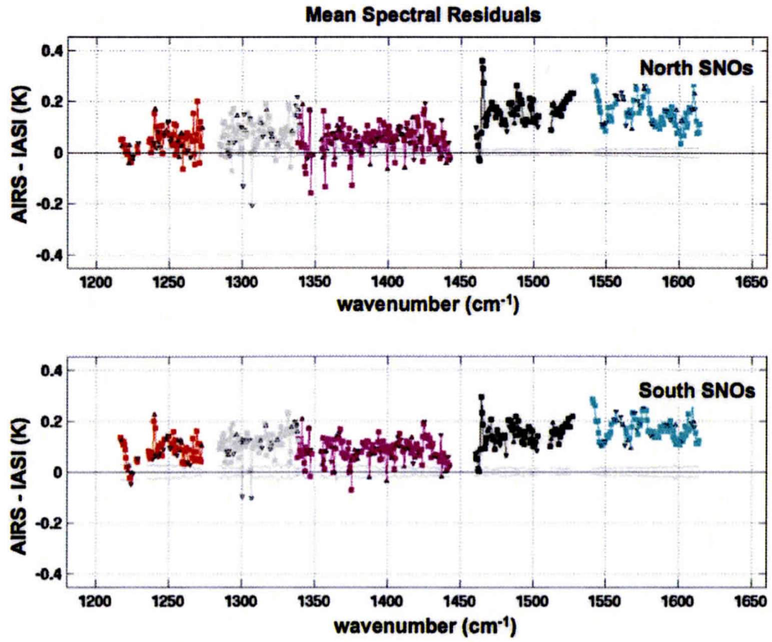

Figure 8. Mean differences between AIRS and IASI observations for the northern (top panel) and southern (bottom panel) SNOs, for the midwave spectral range. Spectral channels are color coded according to the AIRS detector arrays.

Absolute Accuracy of AIRS Total Precipitable Water Vapor in Tropics, Mid-latitude, and Arctic Climate Zones

This section summarizes results of a detailed analysis of the accuracy of the AIRS perceptible water vapor product. A full description of this study has been published in JGR (Bedka et al., 2010).

Satellite retrievals of PWV from AIRS over three climatologically diverse sites were compared with ground-based MWR data. Each location exhibited unique retrieval challenges, indicating that geographically specific considerations, such as a good characterization of the surface emissivity, may be important for accurate satellite retrievals. Results are summarized in Figures 9 and 10. The following conclusions may be drawn from this comparison:

1) Southern Great Plains land site: The AIRS daytime PWV is determined to be within the absolute accuracy goal of 5% for PWV amounts greater than 1 cm, but AIRS exhibits a moist bias in excess of 15% for low PWV amounts (< 1 cm) for both daytime and nighttime overpasses. Additionally, the AIRS retrievals have a significant nighttime dry bias of about 10% with respect to the MWR at PWV amounts greater than about 2 cm. The nighttime dry bias is largest during the summer months of the year when water amounts are highest. Preliminary investigation suggests that the nighttime dry bias exists on a significant spatial scale over the U.S. Great Plains and desert Southwest but not in the Eastern U.S. or Canada. The moist bias for low water amounts (observed during the winter) at

the SGP site could be a surface emissivity related error since no bias is seen at the ARM Arctic site for similar water amounts.

2) Tropical Western Pacific ocean site: The AIRS retrievals over the tropical ocean are within the AIRS science team suggested error of 5% for the entire range of PWV values observed in this study: between 3 and 6.5 cm.

3) North Slope of Alaska Arctic site: The AIRS retrievals of PWV from Barrow show a near zero bias for PWV values less than 2 cm and a fractional error of the bias that is within the 5% accuracy goal of the AIRS science team. However, it is important to note that the RMS error in this is still large, and individual samples can have errors of 50% or higher for very dry cases.

In summary, the AIRS PWV Version 5 product is very useful for climate process studies over both ocean and land which require knowledge of the total water vapor column with an accuracy of about 5% in monthly mean values, however there are two main caveats. The product accuracy is degraded for 1) low water amounts over mixed bare soil and vegetation and 2) night-time only measurements at moderate water amounts in the U.S. Southern Great Plains. The use of the AIRS Version 5 Level 3 PWV product for evaluation of monthly mean diurnal changes in water vapor has been shown to contain bias errors greater than the natural signal observed with ground-based sensors (see Figure 5). In particular, the night-time Version 5 Level 3 PWV product should used with caution for climate studies due to a possible underestimate in the total water vapor column over certain land types. This issue deserves further investigation. The authors anticipate that future versions of the AIRS PWV product will provide improvements to the retrievals over land in general and the PWV product in particular. The ability of the AIRS PWV product to detect significant climate trends in water vapor over ocean or land will be the subject of future work as it requires the characterization of possible time dependent bias errors not addressed in our Bedka et al. (2010) paper.

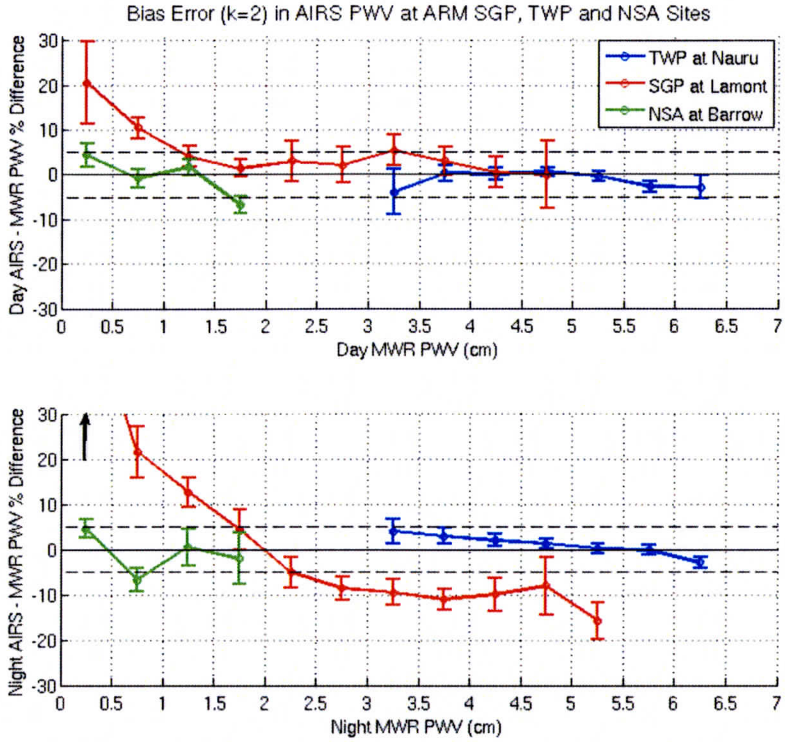

Figure 9. Percent difference between AIRS and MWR PWV for 0.5 cm bins, for daytime data only (middle), and nighttime data only (bottom). Data from SGP, TWP, and NSA are plotted in red, blue, and green, respectively. Error bars are the uncertainty in the mean % difference for a given bin (at the 95% confidence level).

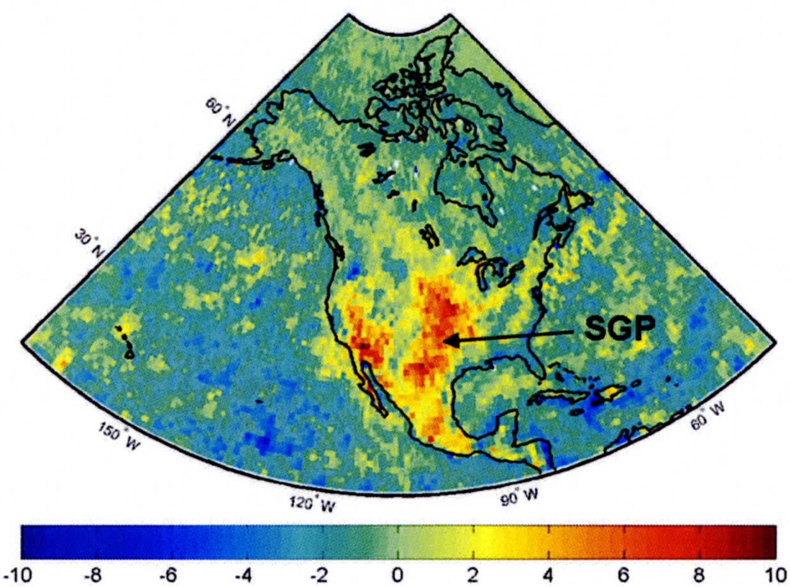

Figure 10. AIRS diurnal PWV difference (monthly mean day - monthly mean night) in mm, over North America for July, 2003. The location of the ARM SGP site is noted with an arrow.

Year 3 Accomplishments

This grant has supported training of the next generation of atmospheric scientists by funding a research assistantship (RA) for a Master's degree student. The thesis topic is the quantitative assessment of the climate quality of the methane profile in the Arctic retrieved from the NASA AIRS satellite, which is a very important region sensitive to climate change. In particular, the potential release of large amount of methane gas from melting of methane clathrate ("fire ice") in the permafrost and under the Arctic sea is a topic of current scientific interest. Figure 11 shows a preliminary assessment of AIRS science team version 5 methane profiles using in situ profile validation from the DC-8 aircraft in the 2008 ARCTAS (Arctic Research of the Composition of the Troposphere from Aircraft and Satellites) campaign. The results suggest that satellite profiles can provide useful input to chemical transport models such as the RAQMS model (http://raqms-ops.ssec.wisc.edu/).

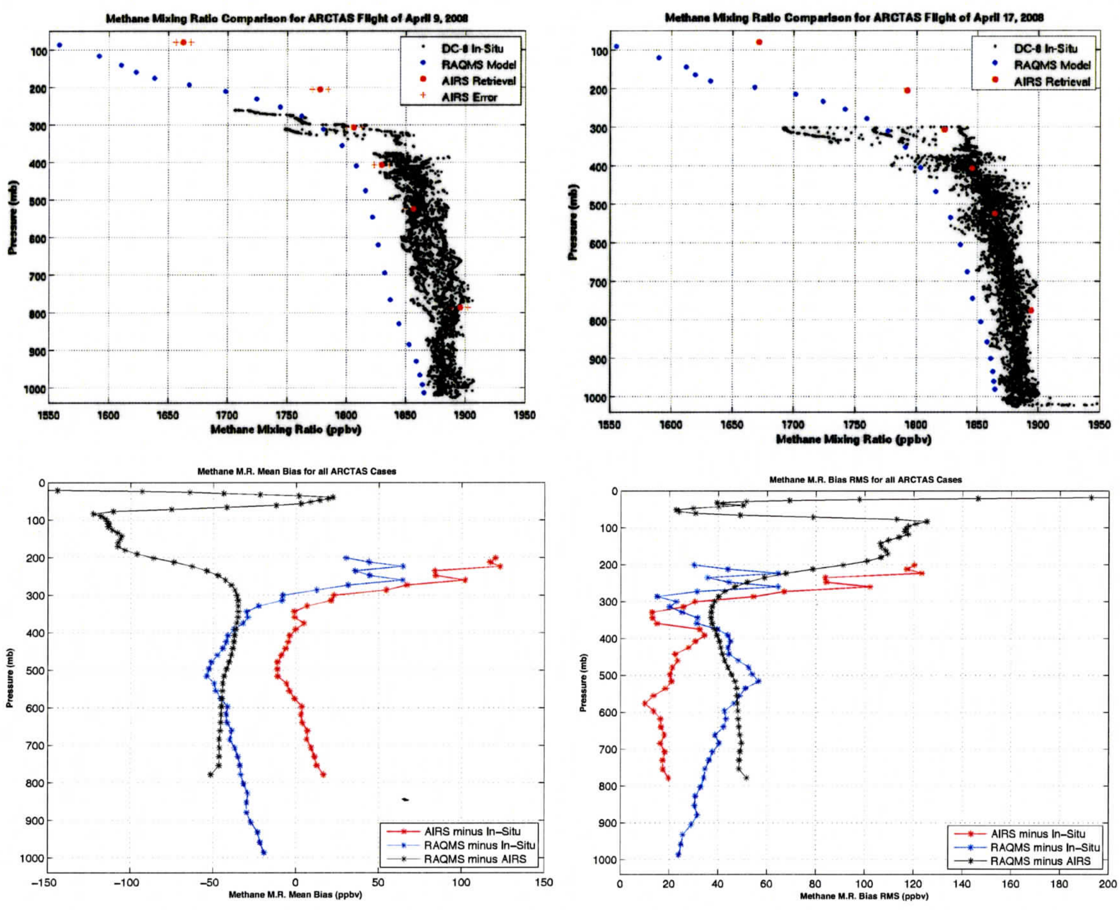

Figure 11. AIRS v5 Level 2 methane product evaluated using in situ aircraft data (ARCTAS) and compared to the RAQMS air transport model. The AIRS data is in reasonably good agreement with in situ methane measurements (K. Vinson thesis, unpublished UW-Madison).

The eleven citations listed in the reference section dated from 2010 and 2011 represent publications that were co-authored by investigators of this proposal on topics directly related to the objectives of this NASA grant to characterize the climate quality of the high spectral resolution radiances of AIRS/Aqua and IASI/Metop-A in preparation for CrIS/NPP. Topics include systematic biases found between AIRS and IASI and interpretation of those differences spectrally, GCICS activities supported by this grant, interferometer ILS effects of non-uniform scenes, and estimation of on-orbit systematic errors of CrIS/NPP using results of thermal vacuum testing. Additional detailed information can be found in the referenced citations.

Accomplishments by Task:

Task 1. S-HIS comparisons with AIRS, other Aqua/Terra instruments, and IASI

As discussed in the Year 1 report, efforts in the first year of this award were focused on the analysis of coincident observations of airborne FTS sensors with the IASI satellite during the JAIVEX campaign in 2007. Results are very positive and show very good agreement between Scanning-HIS and IASI. Since JAIVEx there have been no other flight opportunities for satellite radiance validation.

Task 2. Refined Radiometric Characterization of AIRS, S-HIS and IASI using PCA

Exploiting the redundancy of spectrally correlated information in high spectral resolution infrared radiance observations, Principal Component Analysis (PCA) is useful for extracting signals from the observations, noise filtering, and for characterization of variable artifacts within the data. Here, PCA has been used to investigate the spectral nature of observations from the Infrared Atmospheric Sounding Interferometer (IASI) with a focus on the effects of non-uniform scenes on the Instrument Line Shape (ILS). For IASI and other similar FTS systems, non-uniform scenes produce a non-uniform weighting of angles through the interferometer that can produce subtle distortions in the ILS from that of uniform scenes. For the PCA approach used here, it is found that the spectral signature due to the non-uniform scene effects are contained primarily within a single principal component, and that reconstruction of the radiance spectra with this component excluded provides an accurate and robust correction algorithm. Further investigation shows that pre-computed synthetic principle components representing the signatures of non-uniform scenes can be used in the correction, greatly reducing the computational expense of the algorithm. This work was presented at the 2008 International Radiation Symposium and is described in Tobin et al., 2008.

Task 3. Inter-comparisons of On-Orbit Instruments

As described in more detail earlier in this report, analysis has been performed of direct radiance simultaneous nadir overpass (SNOs) comparisons of AIRS and IASI at the orbital intersections at ±73.8 degrees latitude. The results show very good stability over time of the AIRS-IASI differences, but some significant mean differences which vary by AIRS detector array.

Using the approaches introduced in Tobin et al. (2006), we have performed comparisons of AIRS and MODIS IR radiances for the first day of every month for the duration of the Aqua mission to date. The longer term comparisons have demonstrated excellent stability of both AIRS and MODIS for some spectral bands, and have also shown subtle calibration differences regarding spectral response function knowledge and scan angle dependent biases. These results were presented at the 2008 International Radiation Symposium as well as other scientific conferences. The processing and analysis functions are now being automated to produce daily, near real-time, global comparisons.

Task 4. MODIS Calibration Studies using S-HIS

No direct MODIS calibration with S-HIS was accomplished during this time period.

Task 5. S-HIS Instrument Calibration

In 2007, an instrument power-up problem under high humidity conditions (> 60% RH) was observed. While the instrument problem did not result in the loss of any flight hours for the S-HIS, it required extensive purging of the electronics enclosure pre and post-flight during JAVIEX to mitigate the problem. The problem was diagnosed to be related to heightened humidity sensitivity of the interferometer control electronics. Extensive testing identified the ground connection of two address bits in an interferometer control electronics RAM module as the source of the problem. The address bits were soldered together and grounded. Post-fix testing showed no humidity sensitivity for the power-up sequence, with several successful instrument power-on and operation under >90% RH conditions.

Task 6. NIST reference sensor inter-comparison to S-HIS

No direct NIST sensor inter-comparisons were conducted in this time period.

Task 7. Conduct New Field Program with S-HIS

No flight opportunities were found for S-HIS during this time period.

Task 8. Participate in CrIS related reviews and NPP activities
Descoped from proposal by NASA.

Task 9. Participate in VIIRS related reviews and NPP activities
Descoped from proposal by NASA.

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