Methodology for the Validation of Water Vapor Profile Environmental Data Records (EDRs) From the Cross-Track Infrared Microwave Sounding Suite (CrIMSS): Experience with the DOE ARM Water Vapor Raman Lidar

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Abstract

Water vapor is a key component of the Earth's hydrologic cycle that plays an important role in the intensity of severe weather and hurricanes. Numerical weather prediction models are expected to show improved forecast skill when water vapor remote sensing observations are assimilated from operational weather satellites. Accurate water vapor vertical profiles retrieved from satellite radiances will also provide a valuable climate record for evaluation of NWP reanalysis products and for validating climate models.

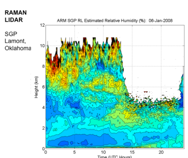
NASA and NOAA are operating the NPP satellite with CrIS and ATMS in a PM orbit while the European METOP IASI sensor occupies an AM orbit. Radiance data and products from both these platforms will contribute to weather forecasts from NWP centers. This paper describes the methodology developed for validation of the water vapor vertical profiles from the CrIS and ATMS (CrIMSS) Environmental Data Records (CrIMSS EDRs). The approach uses ground-truth measurements from the Department of Energy Atmospheric Radiation Measurement sites; Southern Great Plains, North Slope of Alaska, and Tropical Western Pacific. Along with radiosonde profiles, a validation profile of water vapor mixing ratio profile will be obtained from a ground-based ARM Raman Lidar at the SGP and TWP sites. These Raman profiles obtain their absolute calibration from a ground-based Micro-wave Radiometer (MWR) operating nearby. In a similar manner, the precipitable water vapor associated with the vertical integral of the CrIMSS water vapor profile will be compared against both the ARM MWR and measurements from the SuomiNet network of ground-based GPS receivers. Matchups of these data will be analyzed to make an independent assessment of the accuracy of the operational CrIMSS EDRs.

Preliminary assessment of this methodology using NASA AIRS L2 retrievals as a proxy for the CrIMSS EDRs have been performed. Results show a dry bias in AIRS L2 version 5 for summer, night-time observations in the Southern Great Plains. This is confirmed using time-interpolated radiosonde profiles. The result is consistent with Bedka et al. 2010 that showed a similar dry bias in PWV from MWR data. Assessment of CrIMSS EDRs is in progress.

Observations

RAMAN LIDAR

SGP Lamont, Oklahoma

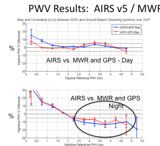


The ARM Raman Lidar (RL) is an active, ground-based laser remote sensing instrument that measures vertical profiles of water-vapor mixing ratio and several cloud- and aerosol-related quantities. Lidar (light detection and ranging) is the optical analog of radar, using pulses of laser radiation to probe the atmosphere. This system is fully computer automated. The self-contained system (requiring only external electrical power) is housed in a climate-controlled 8'x8'x20' standard shipping container.

SGP –Lamont, OK

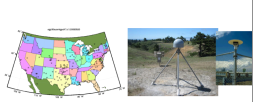
• *A second Raman Lidar has been deployed to TWP-Darwin.*

PWV Results: AIRS v5 / MWR & GPS



ARM SGP

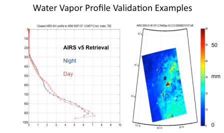
• GPS station locations of SuomiNet (UCAR) will be used to assess spatial distribution of PWV in the CrIMSS Cal/Val.



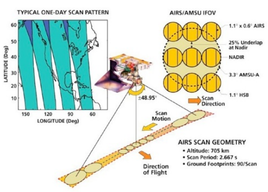
Bedka, S., R. Knuteson, H. Revercomb, D. Tobin, and D. Turner (2010), An Assessment of the Absolute Accuracy of the Atmospheric Infrared Sounder (AIRS) v5 Precipitable Water Vapor Product at Tropical, Mid-Latitude, and Arctic Ground-Truth Sites: September 2002 through August 2008, J. Geophys. Res., doi:10.1029/2009JD013139, in press.

ARM radiosonde launch – Vaisala P/T/Q

Water Vapor Profile Validation Examples



AIRS looks toward the ground through a cross-track rotary scan mirror which provides +/- 49.5 degrees (from nadir) ground coverage along with views to cold space and to on-board spectral and radiometric calibration sources every scan cycle. The scan cycle repeats every 8/3 seconds. Ninety ground footprints are observed each scan. One spectrum with all 2378 spectral samples is obtained for each footprint. A ground footprint every 22.4 ms. The AIRS IR spatial resolution is 13.5 km at nadir from the 705.3 km orbit. The AIRS Level 2 sounding products contain atmospheric temperature and moisture profiles from about 1 mb down to the surface with a horizontal resolution of about 45 km. The AIRS Level 2 product provides nearly complete daily global coverage in ascending (day) and descending (night) modes.



AIRS Scan Geometry with 30 cross track soundings between ±49° and a horizontal resolution of about 45 km

JPSS Cal/Val Methodology

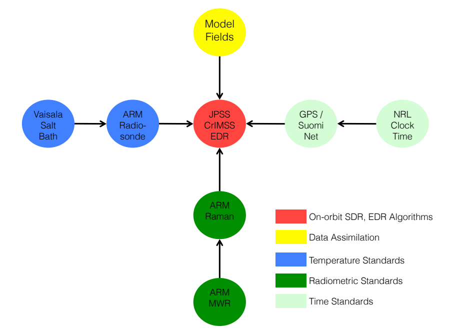
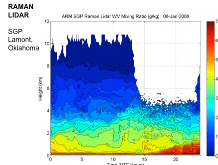


Figure 1 Traceability to international standards (SI) is an important characteristic of the JPSS Cal/Val methodology. This figure shows how the JPSS CrIMSS EDR data product will be be assessed using two or more independent observation datasets traceable to different absolute standards.

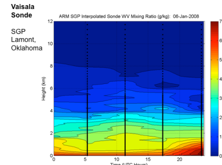
VALIDATION PRINCIPLES

- Use validation data with sufficient accuracy to achieve CrIMSS requirements.
- Use validation data that have known error characteristics, i.e. established SI traceability.
- Use two independent ways of validating each product which trace calibration to different SI standards (See figure above).

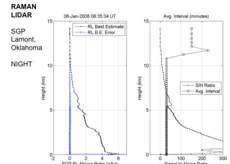
RAMAN LIDAR SGP Lamont, Oklahoma



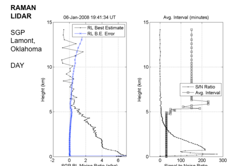
Vaisala Sonde SGP Lamont, Oklahoma



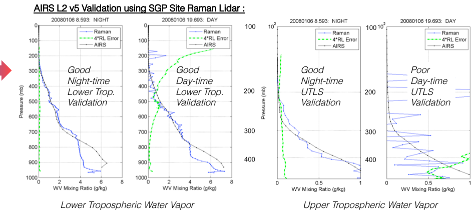
RAMAN LIDAR SGP Lamont, Oklahoma NIGHT



RAMAN LIDAR SGP Lamont, Oklahoma DAY



AIRS L2 v5 Validation using SGP Site Raman Lidar :



Lower Tropospheric Water Vapor *Upper Tropospheric Water Vapor*

VALIDATION METHODOLOGY

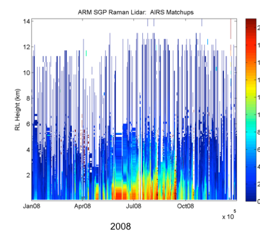
- Continuous Raman Lidar vertical profiles of water vapor mixing ratio (10 minute averages) are extracted for a time period including the satellite overpass time.
- A weighted mean is computed from the water vapor profiles at each Raman altitude range bin to achieve a signal to noise ratio greater than 4.
- AIRS-Raman difference profiles are computed at the Raman height bins.
- Reduction to layer averages is performed prior to computation of RMS statistics.

Acknowledgments

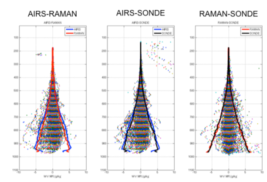
We acknowledge the U.S. Department of Energy as part of the Atmospheric Radiation Measurement (ARM) Climate Research Facility for the SGP site data used in this study. We would like to thank the Goddard Space Flight Center (GSFC) Data Archive for access to the AIRS Level 2 data products. This work was supported under NOAA grant NA10NES4400013.

AIRS/ARM Raman Lidar Results

AIRS-Raman Matchups at ARM SGP Site 2008



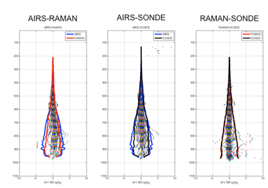
Annual 2008



Night-time Data Only Jan - Dec. 2008 (Full year)

Mixing ratio error (g/kg) is approximately constant with height while the median mixing ratio value decreases with height.

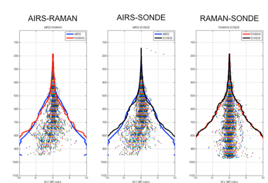
Winter 2008



Night-time Data Only June. Feb., & Dec. 2008 (Winter Only)

Raman and Sonde agree that AIRS profiles are unbiased in Winter.

Summer 2008



Night-time Data Only June, July, August 2008 (Summer Only)

Raman and Sonde agree that AIRS profiles are biased DRY at NIGHT in SUMMERin the Southern Great Plains.

Conclusions

- A methodology has been developed for the validation of CrIMSS water vapor profile EDR products and demonstrated on NASA AIRS L2 data.
- The ARM Raman Lidar at the SGP site has been used to validate the vertical moisture profile of AIRS v5 retrievals for the year 2008.
- A dry bias in the AIRS L2 night-time PWV in the summer season found by Bedka et al. 2010 is confirmed by the ARM Raman Lidar which identifies the error as confined to the boundary layer.
- This dry bias is further confirmed by comparison to interpolated Vaisala radiosondes launched at the ARM SGP site in Oklahoma.
- This method is ready for application to CrIMSS EDR products.

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