Analysis of Raman lidar and radiosonde measurements from the AWEX-G field campaign and its relation to Aqua validation

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[1] Early work within the Aqua validation activity revealed there to be large differences in water vapor measurement accuracy among the various technologies in use for providing validation data. The validation measurements were made at globally distributed sites making it difficult to isolate the sources of the apparent measurement differences among the various sensors, which included both Raman lidar and radiosonde. Because of this, the AIRS Water Vapor Experiment–Ground (AWEX-G) was held in October-November 2003 with the goal of bringing validation technologies to a common site for intercomparison and resolving the measurement discrepancies. Using the University of Colorado Cryogenic Frostpoint Hygrometer (CFH) as the water vapor reference, the AWEX-G field campaign permitted correction techniques to be validated for Raman lidar, Vaisala RS80-H and RS90/92 that significantly improve the absolute accuracy of water vapor measurements from these systems particularly in the upper troposphere. Mean comparisons of radiosondes and lidar are performed demonstrating agreement between corrected sensors and the CFH to generally within 5% thereby providing data of sufficient accuracy for Aqua validation purposes. Examples of the use of the correction techniques in radiance and retrieval comparisons are provided and discussed.

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1. Introduction and Background

[2] The Aqua satellite validation activity funded by NASA includes the use of different water vapor profiling radiosondes and Raman lidar systems for acquisition of measurements during Aqua overpasses. Numerous special measurement campaigns have been staged from various geographic locations in order to acquire data of the highest quality for calibration and validation of the satellite measurements and retrievals. It is fundamentally important that these special data sets possess higher absolute accuracy than required of the satellite data products for this validation technique to work. Early comparisons of many validation measurements with the Atmospheric Infrared Sounder (AIRS), through the use of the AIRS fast forward radiative transfer model, SARTA [*Strow et al.*, 2003], revealed apparent large calibration differences among the various water vapor profiling technologies being used. The differences were largest in the upper troposphere (UT) where differences between AIRS radiances and calculations of AIRS radiance using SARTA, when translated to UT relative humidity (RH), implied differences in the calibration of the water vapor measurement systems that exceeded 25% in some cases. This is to be contrasted with the Aqua retrieval accuracy goal, where a retrieval involves a minimization of differences between observed and calculated radiances, of 10% in 2-km layers. The apparent inadequacy of many of the validation measurement systems to provide data of sufficient quality to validate retrievals at this accuracy level created questions both about the validation sensor technologies and how to improve the quality of water vapor measurements used for Aqua validation. For this reason, a dedicated field program called the AIRS Water Vapor Experiment–Ground (AWEX-G) was held in October-November 2003 with the goal of resolving the measurement

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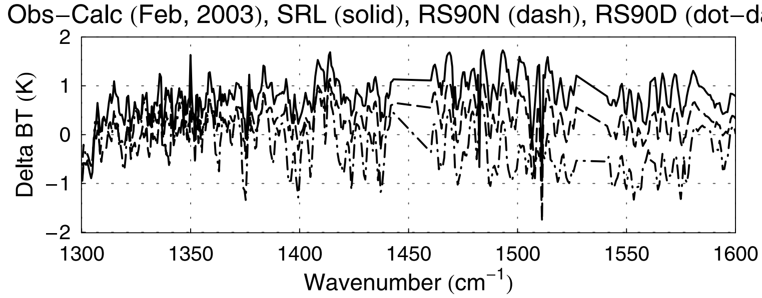

Figure 1. Mean comparisons of radiances observed by AIRS and calculations of radiances using version 3 of the AIRS fast model, SARTA, to demonstrate the state of the AIRS fast model validation effort as of February 2003. Three sets of water vapor input data acquired in coordination with Aqua overpasses are studied: (1) SRL water vapor measurements from fall 2002 at GSFC, (2) nighttime RS-90 radiosondes launched at the SGP site, and (3) daytime RS-90 radiosondes launched at the SGP site.

differences observed among Vaisala radiosonde and Raman lidar and to develop new analytical tools to improve the absolute accuracy of those measurement systems.

[3] This paper provides the motivation for the AWEX-G field campaign, discusses the field activities and the major results of the field activity and then puts those results in the context of Aqua validation. It is organized as follows. Early AIRS radiance validation comparisons are presented to illustrate some of the first discrepancies that were uncovered in the validation activity and that helped to motivate AWEX-G. The AWEX-G field campaign is then described and the major results summarized. This paper will focus mostly on the Raman lidar measurements and results, which included corrections to Raman lidar water vapor measurements that account for the temperature dependence of Raman scattering. A companion paper [*Miloshevich et al.*, 2006] provides the details of the radiosonde intercomparisons and radiosonde accuracy assessment that occurred during AWEX-G and correction techniques for Vaisala RS80-H and RS90/92 measurements that were derived from AWEX-G measurements. The radiosonde and lidar sensors are compared here both in terms of profiles and layer mean upper tropospheric precipitable water. These results are compared with the corresponding results from a similar lidar/radiosonde intercomparison experiment that was held in 2000. The effect of the new Raman lidar and radiosonde corrections on Aqua validation activities is then demonstrated using examples of both radiance and retrieval comparisons.

7. Summary and Conclusions

[51] The early AIRS comparisons using Aqua validation data demonstrated a large uncertainty in the water vapor measurements that were being acquired under the Aqua validation activity. Discrepancies between AIRS observations and SARTA calculations using Scanning Raman lidar and Vaisala RS90 radiosonde data indicated an apparent uncertainty in upper tropospheric water vapor calibrations of at least 25%. Other validation data showed even larger discrepancies. This was a motivator for the AIRS Water Vapor Experiment–Ground (AWEX-G) that took place between 27 October and 19 November 2003. The objective of AWEX-G was to bring together in one place various water vapor technologies in use for Aqua validation and operate them over an extended period in order to resolve the discrepancies observed.

[52] During AWEX-G various radiosondes (Vaisala RS80-H, RS90, RS-92, Modem, Sippican, SnowWhite) and Scanning Raman Lidar were operated along with the reference Cryogenic Frostpoint Hygrometer (CFH). The total precipitable water measurements of GPS were also studied with respect to MWR. The month-long comparison of GPS and MWR precipitable water measurements during AWEX-G indicated mean agreement of better than 3%. The conclusion was that GPS is an accurate precipitable water calibration source that can be used to constrain profile measurements of water vapor mixing ratio by Raman lidar, provided that ensembles of cases are used to reduce variability that can be introduced by the large-volume average used by GPS.

[53] Corrections for the effects of the lidar overlap function and the temperature dependence of Raman scattering on Raman water vapor measurements were also validated using the AWEX-G measurements. The combined effect of the overlap and temperature-dependence corrections on the SRL water vapor measurements was to reduce the water vapor mixing ratio in the upper troposphere by 10–15% at the highest altitudes. The temperature dependence correction is a sensitive function of the exact transmission characteristics of the lidar system. In the case of the SRL, the temperature dependence of the water vapor mixing ratio measurements can be essentially eliminated with careful selection of the bandpass characteristics of the water vapor interference filter.

[54] Atmospheric variability was found to be potentially a significant source of error in this study. For this reason radiosonde comparisons with CFH were limited to sensors flown on the same balloon as the CFH. Comparisons of sensors with CFH launched simultaneously but on different balloons consistently showed significantly higher variability. The contribution of atmospheric variability to the comparison of lidar and radiosonde was noticeable and required some manual rejection of data. On the basis of our experience in AWEX-G, it is suggested that, if possible, accuracy assessments of radiosondes be done with respect to sensors on the same balloon and that accuracy assessments of lidar be done with respect to other lidar systems so as to minimize the effects of sampling different atmospheres. In order to avoid the need for manual rejection of data, larger ensembles of lidar/radiosonde comparisons than acquired in AWEX-G are encouraged in future experiments.