Mid-Pacific Ground-Truth Data for Validation of the CrIMSS Sensor Suite Aboard Suomi-NPP

Andrew K. Mollner*[1], John E. Wessel[1], Stephen D. LaLumondiere[1], Petras Karuza[1], Michael Williams[1], Paul Belden[1], Kevin M. Gaab[1], William T. Lotshaw[1], Nicholas R. Nalli[2,3], Antonia Gambacorta[4], Quanhua Liu[3], Christopher D. Barnet[4], Anthony Reale[3], Changyi Tan[2,3], Flavio Iturbide-Sanchez[2,3]

*Corresponding author: Andrew.K.Mollner@aero.org

Aerospace Transportable Lidar System

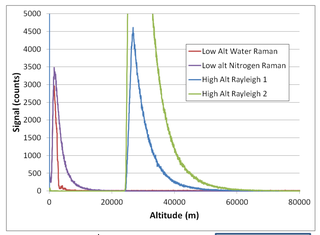
The Aerospace Transportable Lidar System 2 (ATLS-2) is stationed at the Pacific Missile Range Facility (PMRF) at Barking Sands, HI, and contains a suite of instruments designed to collect high quality ground-truth atmospheric profiles coincident with soundings by sensors aboard environmental satellites. ATLS-2 has a long heritage of providing ground truth data to support the calibration/validation of sensors aboard Defense Meteorological Satellite Program (DMSP) assets. ATLS-2 began supporting Suomi-NPP in 2012. Instrumentation includes:

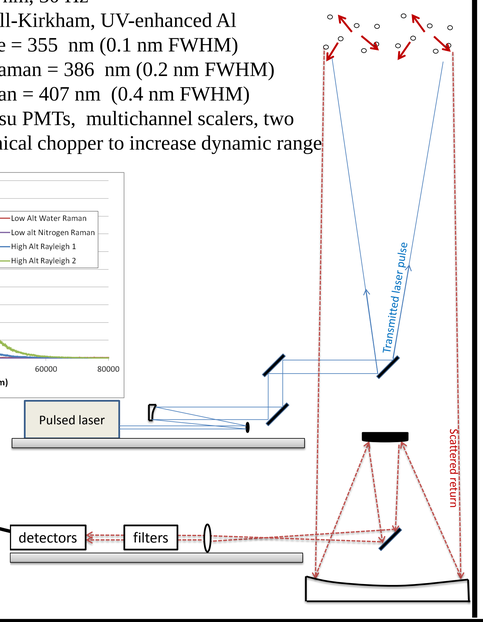
1. **UV lidar (Raman/Rayleigh/Mie)**
   - Water Vapor mixing ratio (1-20 km)
   - Temperature (30 – 60 km)
   - Cloud Depolarization (1-20 km)
2. **Vaisala RS-92 Radiosondes**
   - Temperature (0 – 30 km)
   - Relative Humidity (0 – 20 km)
3. **RPG-Hatpro Upward-Looking Radiometer**
   - Integrated Water Vapor
   - Cloud liquid water
   - Boundary layer water and temperature

Lidar System Details

- Pulsed laser illuminates molecules and particles
- Molecules and particles scatter laser light in all directions
- Light scattered back is collected, filtered, and recorded
- Signal strength indicates concentration of scatters and attenuation along the propagation path.
- Delay from the transmitted time indicates distance

➢Transmit: 15 W, 355 nm, 30 Hz
➢Receive: 36-Inch Dall-Kirkham, UV-enhanced Al
➢Filters: Rayleigh/Mie = 355 nm (0.1 nm FWHM)
Nitrogen Raman = 386 nm (0.2 nm FWHM)
Water Raman = 407 nm (0.4 nm FWHM)
➢Detectors: Hamamatsu PMTs, multichannel scalers, two altitude ranges/mechanical chopper to increase dynamic range





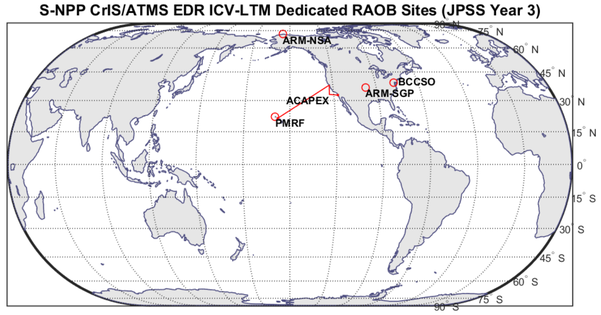
Ground-Truth Data Sets for CrIS/ATMS EDR Validation

The Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS), are a systems of advanced passive infrared and microwave sounding systems collectively also known as the Cross-track Infrared Microwave Sounding Suite (CrIMSS) aboard the Suomi NPP satellite launched in October 2011. Algorithms convert observed radiances into atmospheric vertical temperature and moisture profile (AVTP and AVMP, respectively) environmental data records (EDRs) (Gambacorta *et al.*, 2014; Divakarla *et al.*, 2014). The Aerospace Corporation collected ground truth data coincident with 40 satellite overpasses in May-Sept 2012, 35 overpasses in May-June 2013, and 24 overpasses in April 2014 to help calibrate and validate those data products.

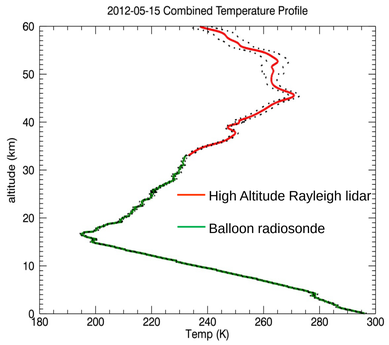
ATLS-2 at PMRF is one of several sites contributing data to the validation of the CrIS/ATMS EDR products (Nalli *et al.*, 2013; see figure to right). ATLS-2 is unique both in location (only mid-Pacific site) and in generating coincident lidar data products, and can provide a tropical Pacific island site in lieu of the loss of the ARM Tropical Western Pacific site in 2014.

Lidar data are collected for ±1 hr surrounding overpass time (local nighttime only). Radiosondes are launched 30 minutes prior to overpass time (day and night overpasses). Ground truth data consists of a combination of balloon-borne radiosondes, Rayleigh and Raman lidar, and upward-looking radiometer in order to provide high-accuracy profiles of pressure, temperature, and water vapor.

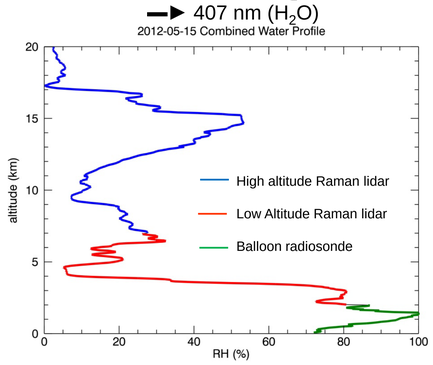
S-NPP CrIS/ATMS EDR ICV-LTM Dedicated RAOB Sites (JPSS Year 3)



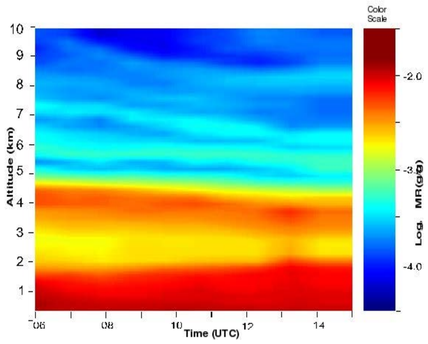
- High altitude temperatures by hypsometric calculations on **Rayleigh and Nitrogen Raman lidar** data



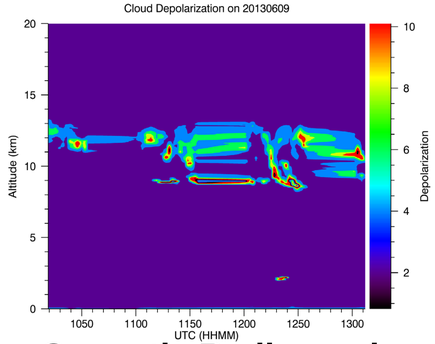
- Water mixing ratios by **vibrational Raman lidar**
  355 nm ➡ 386 nm (N_2)
  ➡ 407 nm (H_2O)



- Time evolution of water mixing ratio generated by processing full set of lidar data surrounding overpass.



- Cloud height and structure by ratio of parallel and perpendicular polarizations in Rayleigh/Mie data

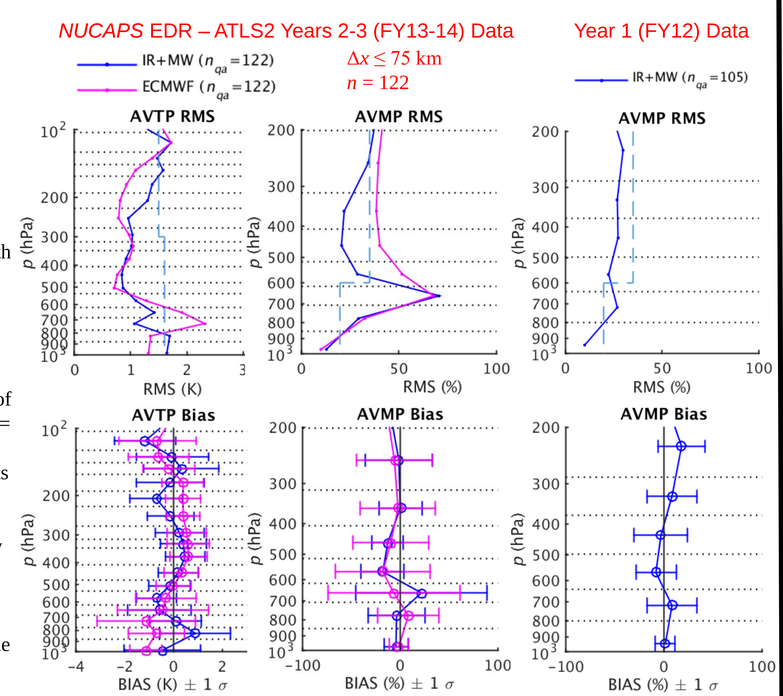


Statistical Comparison with NUCAPS EDR

The EDR cal/val team collects CrIMSS operational data collocated with the ground truth anchor points. These data include granules of EDRs generated by the operational NOAA Unique CrIS/ATMS Processing System (NUCAPS) algorithm (Gambacorta et al., 2014) and include ancillary data such as Sensor Data Records (SDRs) that are needed to run re-retrievals to assess different algorithms thus linking the product monitoring and algorithm development programs. Granules are collected at overpasses covering a 500 km radius centered at the ground truth site.

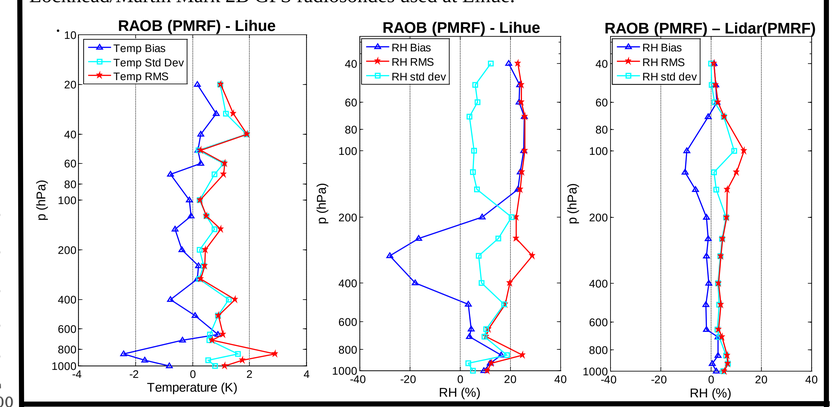
This is embodied within the NOAA/STAR Validation Archive (VALAR) and NOAA Products Validation System (NPROVS+) discussed in Nalli *et al.* (2014).

Shown at right are root mean square (RMS) differences and biases between ATLS-2 ground-truth data and EDR offline retrievals (NUCAPS emulation v1.4.2). The data shown are for Years 2 and 3 (FY13 and FY14) fields-of-regard (FOR) within 75 km of ATLS-2. For this sample (n = 122), the AVTP RMS meets the tropospheric requirements (dashed blue lines), but the NUCAPS and ECMWF moisture encounter difficulty resolving a strong, persistent subsidence inversion present at the site. Moisture data from Year 1, which lacked the inversion are shown for comparison.



Comparison with Lihue Synoptic Radiosondes

The weather station at Lihue launches daily radiosondes as part of the synoptic radiosonde network. Due to S-NPP overpass times, we obtain time-coincident data sets near 0 and 12 UTC. Differences show both orographic effects and potential errors in humidity data from the Lockhead/Martin Mark 2B GPS radiosondes used at Lihue.



References

- Nalli *et al.*, (2013) "Validation of Satellite Sounder Environmental Data Records: Application to the Cross-track Infrared Microwave Sounder Suite", *J. Geophys. Res. Atmos.*, **118**, doi:10.1002/2013JD020436.
- Divakarla *et al.*, (2014) "The CrIMSS EDR Algorithm: Characterization, Optimization and Validation", *J. Geophys. Res. Atmos.*, **119**, doi:10.1002/2013JD020438.
- Gambacorta, A. *et al*, (2013) "The NOAA/NESDIS/STAR Long Term Strategy of Environmental Data Records from Hyper Spectral Sounders: a cross-comparison among the AIRS, IASI and CrIS processing systems", *Proceedings of EUMETSAT Meteorological Satellite Conference*.
- Nalli et al., (2014) "Validation of Satellite Environmental Data Records (EDR): Application to Suomi-NPP", *Proceedings of EUMETSAT Meteorological Satellite Conference.*

Author affiliations

1. The Aerospace Corporation, El Segundo, CA.
2. IMSG, Inc., Rockville, MD.
3. NOAA/NESDIS/STAR, College Park, MD.
4. STC, Columbia, MD.

Support provided by the JPSS Ground Project through the Specialized Engineering, Evaluation and Test Services (SEETS II) Contract (NNG11VH00B) as well as The Aerospace Corporation's Civil and Commercial Programs Division and Independent Research and Development program

© 2015 The Aerospace Corporation