352 MARINE-BASED FIELD CAMPAIGNS SUPPORTING JPSS SNPP CRIS/ATMS SOUNDER VALIDATION AND USER APPLICATIONS

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1. INTRODUCTION

The Joint Polar Satellite System (JPSS) constitutes the next-generation, low Earth orbit, operational environmental satellite observing system in support of the U.S. National Oceanic and Atmospheric Adminstration (NOAA) (Goldberg et al. 2013). Since launch in 2011, the Suomi National Polar-orbiting Partnership (SNPP) satellite has served as the first satellite in the JPSS series. Onboard the JPSS series (including SNPP) are the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS) sounding system. These two instruments are synergistically designed to retrieve atmospheric vertical temperature and moisture profile (AVTP and AVMP) environmental data records (EDR) under non-precipitating conditions (cloudy, partly cloudy and clear) with optimal vertical resolution, similar to predecessor IR/MW sounding systems.

The current operational retrieval algorithm for CrIS/ATMS is the NOAA Unique CrIS/ATMS Processing System (NUCAPS) developed at NOAA/NESDIS/STAR (Gambacorta et al. 2012). The NUCAPS system is based upon the heritage EOS-Aqua Atmospheric Infrared Sounder (AIRS) Chahine et al. (2006) and Advanced Microwave Sounding Unit (AMSU-A) systems, with the EDR retrieval algorithm being a modular implementation of the multi-step AIRS Science Team retrieval algorithm (Susskind et al. 2003). Users of the NUCAPS EDR products include NOAA National Weather Service (NWS) Weather Forecast Offices (viz., Advanced Weather Interactive Processing System, AWIPS) for nowcasting and severe weather applications, as well as numerous basic/applied science research and investigations with data archived at NOAA data centers (e.g., NGDC and CLASS).

To support the intensive cal/val (ICV) and long-term monitoring (LTM) phases of the SNPP cal/val program for CrIS/ATMS sounder AVTP and AVMP EDRs, JPSS has directly and indirectly funded dedicated radiosondes leveraging several collaborating institutions (Nalli et al. 2013b). As part of the dedicated radiosonde observation (RAOB) program, JPSS has supported ship-based launches over open-ocean, including NOAA Aerosols and Ocean Science Expeditions (AEROSE) (tropical Atlantic Ocean) (Nalli et al. 2011) and, more recently, the 2015 CalWater campaign (North Pacific Ocean). An overview of the contributions of these marine-based field campaigns within the overall validation effort is briefly given in this work.

2. OCEAN-BASED SNPP SATELLITE CAL/VAL DATASETS

The NOAA AEROSE campaigns are a series of trans-Atlantic field experiments that have been conducted on an almost yearly basis since 2004 (Morris et al. 2006; Nalli et al. 2011). Since 2006, AEROSE has partnered with the NOAA PIRATA Northeast Extension Project (PNE) on campaigns in 2006, 2007, 2008, 2009, 2010, 2011, and two in 2013, all onboard the NOAA Ship *Ronald H. Brown*. More recently in early 2015, the AEROSE team participated as part of the ARM Cloud Aerosol Precipitation Experiment (ACAPEX), a campaign conducted onboard the *Ronald H. Brown* in support of the 2015 CalWater campaign over the North Pacific Ocean, and in late

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2015 AEROSE again partnered with PNE onboard the NATO Research Vessel (NRV) *Alliance*. Fig. 1 shows the cruise tracks for all the trans-Atlantic AEROSE campaigns (2004, 2006–2011, 2013, 2015) along with the 2015 CalWater/ACAPEX campaign.

One of the science objectives of AEROSE campaigns is satellite EDR cal/val (Nalli et al. 2006, 2011, 2013b), radiative transfer models (e.g., ocean surface emissivity) (Nalli et al. 2008), and cloud-cleared radiances (CCRs) (e.g., Nalli et al. 2013a). Satellite cal/val truth datasets acquired during AEROSE include dedicated RAOBs (Vaisala RS92 radiosondes dedicated to satellite overpasses and *not* assimilated into numerical models), Marine Atmospheric Emitted Radiance Interferometer (M-AERI) (Minnett et al. 2001; Szczodrak et al. 2007), electrochemical concentration cell (ECC) ozonesondes, and other ancillary shipboard data including Microtops sunphotometers and Vaisala ceilometers (Nalli et al. 2011). Sounder validation performed over open-oceans has the distinct advantage of having a uniform surface that is simpler to model (Nalli et al. 2006, 2011), and oceans are also where satellite data have the greatest impact on numerical weather prediction (NWP) (Le Marshall et al. 2006). Because the data are not assimilated, they constitute a uniquely independent dataset for satellite validation (Nalli et al. 2011).

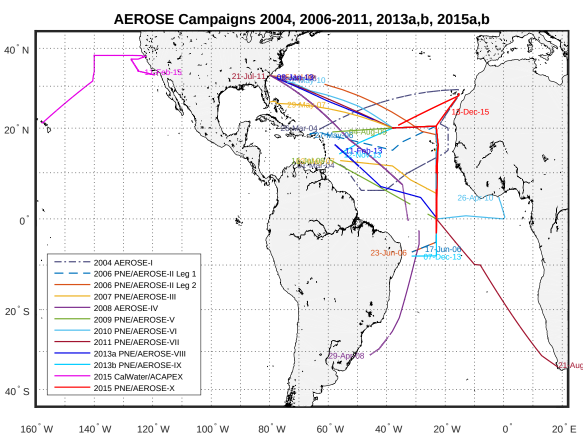

Figure 1: “Spaghetti plot” of AEROSE ship tracks and domain of 4–6 week cruise legs conducted in 2004, 2006–2011, 2013 and 2015, including the CalWater/ACAPEX campaign in early 2015).

The 2015 CalWater/ACAPEX, and AEROSE campaigns (2013a,b, 2015) have formed a significant component of the overall JPSS SNPP CrIS/ATMS EDR validation program. The ship-based dedicated RAOBs are launched over open ocean timed to coincide with twice-per-day SNPP (as well as twice-per-day MetOp) satellite overpasses to provide independent correlative truth data not assimilated into NWP models for validating AVTP/AVMP, and IR ozone profile EDRs, under non-precipitating conditions. Dedicated RAOB data acquired during AEROSE campaigns has also previously served as truth data in the validation efforts of the Aqua AIRS (e.g., Nalli et al. 2006; Maddy et al. 2012), as well as pre-launch phase SNPP CrIS/ATMS and GOES-R proxy datasets (e.g., Xie et al. 2013). Because these campaigns encompass unique marine meteorological phenomena germane to NUCAPS EDR users (Nalli et al. 2011), we present an assessment of NUCAPS EDR performance under these conditions in Section 3.

3. SNPP CRIS/ATMS SOUNDER VALIDATION AND SCIENCE APPLICATIONS

The ability of the NUCAPS EDR products to detect and resolve coherent marine meteorological features in these datasets will be highlighted here through qualitative cross-sectional analyses. Rigorous quantitative coarse-layer statistical analyses (e.g., Nalli et al. 2013b) for these cases has also been performed, but will be omitted from this extended abstract out of space constraints. Dedicated RAOB collocations with NUCAPS fields-of-regard (FOR) are facilitated via the NOAA Products Validation System (NPROVS) (Reale et al. 2012), which has been extended to acquire matchups for dedicated and reference RAOBs. Using this base RAOB-satellite collocation system, an EDR validation archive (VALAR) has been created whereby SDR/TDR granules in the vicinity of RAOB “anchor points” are acquired for running offline retrievals.

3.1 Tropical North Atlantic Ocean (AEROSE)

There were two AEROSE campaigns conducted during 2013, the first during Jan–Feb (2013a), the second during Nov–Dec (2013b), followed by the most recent campaign completed in Nov–Dec 2015. The AEROSE domain (cf. Fig. 1) is a region of substantial meteorological importance germane to satellite sounder data users (both SDR and EDR users), including Saharan air layers (SAL) (e.g., Dunion and Velden 2004; Nalli et al. 2005), tropical cyclogenesis, tropical water vapor, and tropospheric ozone/carbon/aerosol chemistry and transport (Morris et al. 2006; Nalli et al. 2011; Smith and Nalli 2014).

Figs. 2, 4 and 6 show the RAOB launch locations and satellite FOR collocations for three trans-Atlantic transects (NW-SE, N-S and SE-NW, respectively) obtained during the 2013a AEROSE cruise. There were a total of 113 radiosonde launches, of which

69 and 44 were dedicated to SNPP and MetOp-A overpasses, respectively. Cross-sectional contour analyses of relative humidity (RH) for these three transects are shown in Figs. 3, 5 and 7, respectively. The top plots show the measured RAOB-measured RH cross-sections, whereas the bottom plots show the RH calculated from the nearest collocated (accepted or rejected case) NUCAPS-retrieved AVTP and AVMP EDRs. In all three RAOB cross-sections we see a well-defined and persistent marine boundary layer (MBL) with high RH values generally at or below 800 hPa.

In the W-E transect (Fig. 3) the MBL hovers roughly between 850–800 hPa. There is a gradual W-E drying out of the free-troposphere (above 800 hPa) beginning around 70–65°W, with the exception of a large isolated pocket of moisture in the mid-to-upper troposphere (above 600 hPa) appearing around 38°W–30°W that overlies a dry layer from 800–500 hPa.

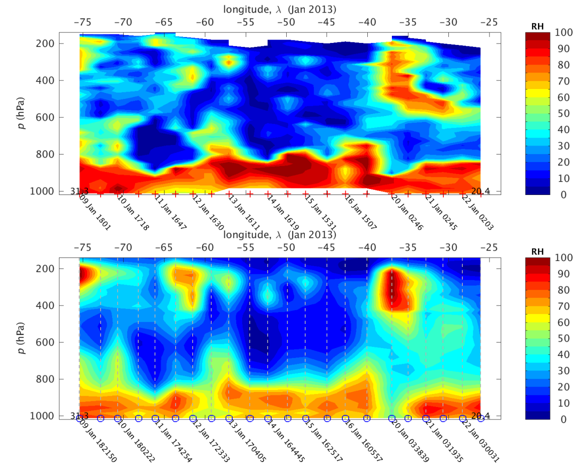

Figure 3: Zonal cross-sectional analyses of relative humidity (RH) for the AEROSE W-E transect shown in Fig. 2: (Top) RAOB cross-section, (bottom) collocated NUCAPS (offline v1.5) cross-section.

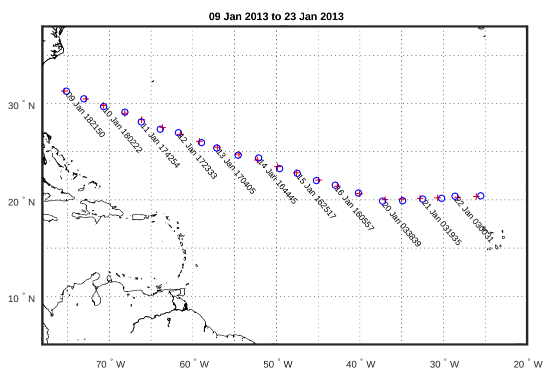

Figure 2: AEROSE 2013a dedicated Vaisala RS92 radiosonde launch locations (red +) and collocated NUCAPS nearest FORs within 100 km radii (blue circles) during the W-E zonal transect.

Following this, the cruise track then turned south (Fig. 5). The N-S cross-section (Fig. 5) shows extensive tropospheric drying throughout the visible column with the MBL becoming increasingly more shallow until the axis of the intertropical convergence zone (ITCZ) is reached at around 4°N. Although tropospheric moisture associated with the ITCZ begins to increase further west from the axis, the MBL remains suppressed with a shallow dry layer found sandwiched around 900 hPa. On the E-W return transit (Fig. 7) the low-to-mid layer moisture associated with the ITCZ gradually gives way to drying out again. In these figures, the lower level dry layers constitute SAL phenomena, whereas mid to upper tropospheric drying is related to subtropical Hadley subsidence.

Although Nalli et al. (2005, 2011) showed similar cross-sections for earlier AEROSE campaigns, this work includes collocated satellite EDR cross-sections derived from the SNPP NUCAPS algorithm (offline version 1.5) for direct comparison which we now consider (bottom plots). Before discussing them further, however, it is first noted that the vertical resolution of the NUCAPS AVTP and AVMP retrievals can be derived from the product effective averaging kernels (AKs). For the AIRS sounder (which employs the same basic retrieval algorithm as NUCAPS), Maddy and Barnet (2008) estimated the lower tropospheric vertical resolution for the tropical western Pacific to be 2.6 km and 2.9 km for temperature and moisture, respectively. Because we derived the NUCAPS RH from both products, we can assume the vertical resolution is approximately 3 km. This represents a fundamental limitation in the ability of an IR sounder to resolve certain fine scale vertical features. But with this caveat in mind, we nevertheless can observe the utility of the CrIS sounder for resolving the meteorological features of interest described above. Specifically, the NUCAPS EDR for the most part correctly observes gross features such as the MBL and large dry regions associated with subtropical subsidence. In Fig. 3 the isolated moisture pocket is captured, although the MBL below it appears to be obscured and the low level dry layer (possibly the leading edge of a SAL) is missed. However in Figs. 5 and 7 much of the large scale features are captured, especially the subsidence areas, the ITCZ and the height of the MBL. The dry filaments likely associated with the SAL in Fig. 5 are too shallow to be resolved by the sounder, but may

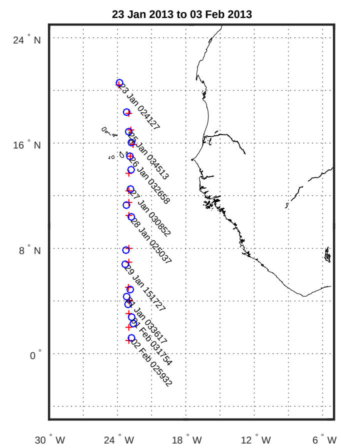

Figure 4: As Fig. 2 except for the N-S meridional transect.

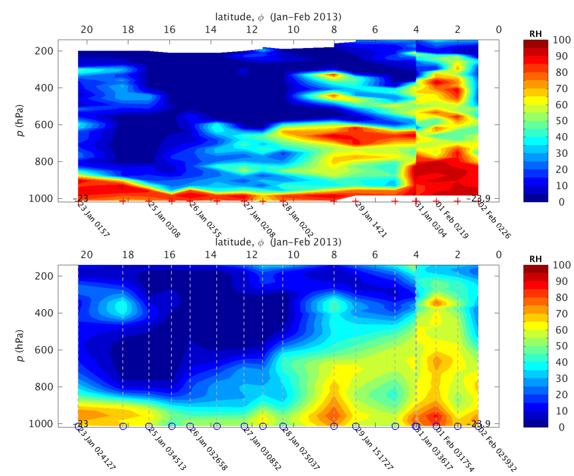

Figure 5: As Fig. 3 except for the N-S meridional transect.

at least be partially inferred by the suppressed vertical development of the MBL.

3.2 Northeastern Pacific Ocean (CalWater)

The CalWater campaign was conducted during Jan–Mar 2015 as a joint effort among different collaborating institutions. Several aircraft were deployed as well as the NOAA *Ship Ronald H. Brown*, the latter being where the ACAPEX sub-campaign was carried out in two back-to-back legs, first Honolulu, Hawaii to San Francisco, California, USA, followed by San Francisco to San Diego, USA. While numerous dropsondes were deployed from the aircraft, this work focuses solely on the dedicated RAOB sample launched by the AEROSE

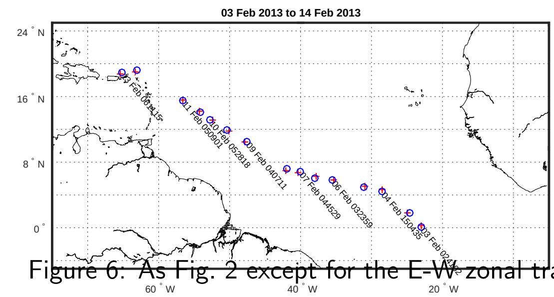

Figure 6: As Fig. 2 except for the E-W zonal transect.

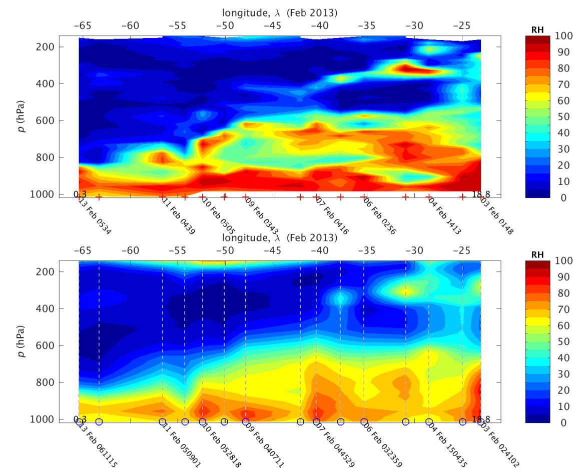

Figure 7: As Fig. 3 except for the E-W zonal transect.

team from the *Brown* during ACAPEX. Again, these dedicated RAOBs were not uploaded into GTS and thus not assimilated into numerical forecast models. The ARM Mobile Facility (AMF2) deployed onboard the *Brown* included a MAERI instrument along with two Vaisala ground stations that enabled dual-launches (e.g., Tobin et al. 2006). We note that during both legs of ACAPEX the ship spent a large fraction of time holding station at three locations within the vicinity of atmospheric river (AR) events (e.g., Neiman et al. 2008). Figs. 8 and 9 show the radiosonde launch locations and satellite FOR collocations for Legs 1 and 2, respectively.

Because of the substantial amount of time that the ship remained stationary while holding stations, we here plot RH cross-sections as a function of time (instead of space as with the AEROSE data) in Figs. 10 and 11. In the cross-sectional analyses the AR phenomena are clearly evident in both the RAOB and satellite NUCAPS data as ribbons of moisture throughout the troposphere up to 200 hPa (in contrast with the significantly drier tropospheric conditions

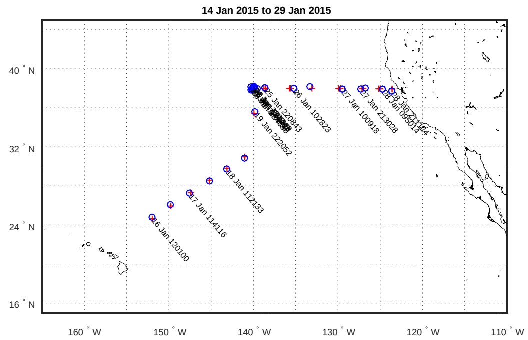

Figure 8: CalWater/ACAPEX 2015 dedicated radiosonde launch locations from the NOAA Ship *Ronald H. Brown* (red $+$) and collocated NUCAPS nearest FORs within 75 km radii (blue circles) during Leg 1 from Honolulu, Hawaii to San Francisco, California, USA.

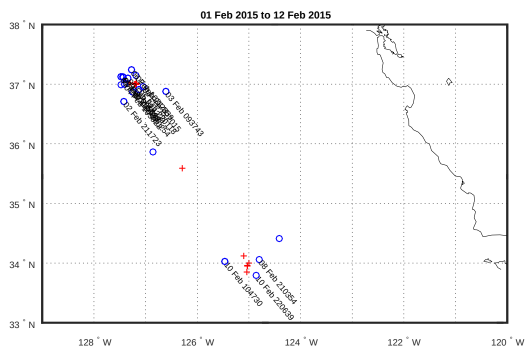

Figure 9: As Fig. 8 except for Leg 2 from San Francisco to San Diego, California, USA.

during AEROSE, Figs. 3–7). NUCAPS primarily has difficulty in regions of strong convection and thick, uniform cloud cover as is expected for an IR sounder, but still provides reasonable information in what would otherwise be data voids in near-realtime forecast user applications.

4. DISCUSSION AND FUTURE WORK

This work has presented CrIS/ATMS sounder NUCAPS EDR validation results based upon a unique collection of marine-based datasets obtained from both the Pacific and Atlantic Oceans under a range of very different thermodynamic meteorological conditions germane to users of sounder EDR (and SDR) products. The NUCAPS EDRs are demonstrated to be useful for observing the distribution of tropospheric water vapor, including mesoscale atmospheric rivers (ARs) and Saharan air layers (SALs) associated with

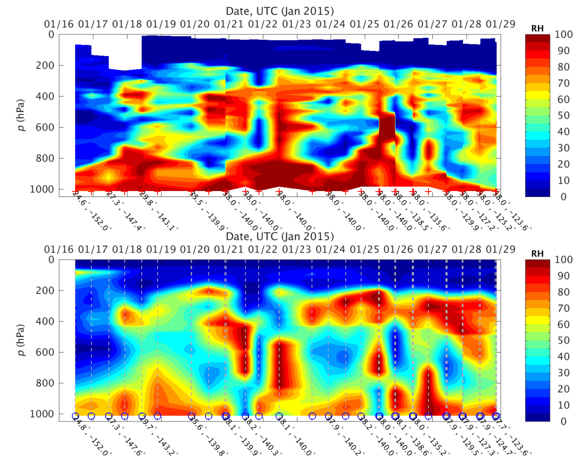

Figure 10: Temporal cross-sectional analyses of relative humidity (RH) for CalWater/ACAPEX Leg 1 shown in Fig. 8: (Top) RAOB cross-section, (bottom) collocated NUCAPS (offline v1.5) cross-section.

low-level aeolian mineral dust, as well as synoptic scale and ITCZ Hadley subsidence cells. We find that Pacific Ocean AR phenomena may be conceptually viewed as an inverse from Atlantic Ocean SAL — the former are defined by narrow corridors or filaments of high water vapor (i.e., "rivers") (e.g., Neiman et al. 2008) of marine origin that advect over the continent downstream, whereas the latter are narrow layers of dry, warm air of desert origin that advect over the ocean downstream (Dunion and Velden 2004; Nalli et al. 2005).

It should be borne in mind that while ocean cases are often considered "easy" within the satellite IR retrieval community, the data acquired during the AEROSE and CalWater/ACAPEX campaigns include atmospheric conditions that pose difficulties for sounder retrievals, including strong inversions associated with the SAL and subsidence, tropical convection within the intertropical convergence zone (ITCZ), heavy uniform cloud cover and precipitation associated with ARs, and IR attenuation from Saharan dust and smoke aerosols (Nalli et al. 2005, 2006, 2011). In an effort to observe and assess these otherwise "difficult" regions of meteorological interest, we collocated the single closest FOR with radiosonde launches, regardless of whether or not the retrieval was accepted or rejected by the algorithm quality control. While we have have focused on these campaigns as individual cases, they are included within the over all truth dataset used for SNPP sounder EDR validation (e.g., Nalli et al. 2013b). Oceans cover $\simeq$70% of the Earth's surface area this is where satellite data have the biggest impact

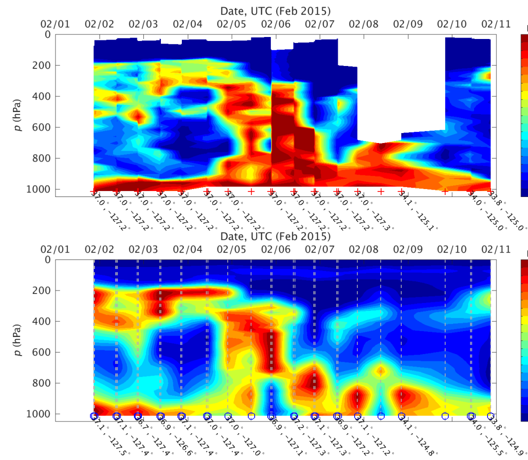

Figure 11: As Fig. 10 except for CalWater/ACAPEX Leg 2 shown in Fig. 9.

on NWP. Ocean-based truth data also carry unique value for cal/val given that the ocean surface is more straightforward to characterize radiatively, thus offering a greater degree of experimental control of variables. In statistical analyses (not shown here due to space constraints), the SNPP NUCAPS EDRs within the AEROSE domain were found to meet the JPSS Level 1 global performance specifications. Although not discussed in this work, ancillary data (e.g., MAERI, ozonesondes, etc.) also enable the possibility of cal/val "dissections."

Future work related to SNPP NUCAPS Long Term Monitoring (LTM) includes global AVTP, AVMP performance analysis (incorporating these datasets sampling SAL, dust/smoke, AR conditions), similar ozone profile analyses using dedicated ozonesondes, GRUAN reprocessing of of Vaisala RS92 RAOBs, application of averaging kernels in error analyses, collocation uncertainty estimates, calc − obs analyses (CRTM, LBLRTM, SARTA, etc.), support for sea surface skin temperature (SST) EDR validation, and support for EDR user applications (AWIPS, AR/SAL, atmospheric chemistry users, etc.)

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REFERENCES

Chahine, M. T., et al., 2006: AIRS: Improving weather forecasting and providing new data on greenhouse gases. *Bull. Am. Meteorol. Soc.*, **87 (7)**, 911–926.

Dunion, J. P. and C. S. Velden, 2004: The impact of the Saharan air layer on Atlantic tropical cyclone activity. *Bull. Am. Meteorol. Soc.*, **85 (3)**, 353–385.

Gambacorta, A., et al., 2012: The NOAA Unique CrIS/ATMS Processing System (NUCAPS): First light retrieval results. *Proceedings of ITSC-XVIII*, Toulouse, France, International TOVS Working Group (ITWG).

Goldberg, M. D., H. Kilcoyne, H. Cikanek, and A. Mehta, 2013: Joint Polar Satellite System: The United States next generation civilian polar-orbiting environmental satellite system. *J. Geophys. Res. Atmos.*, **118**, 1–13, doi:10.1002/2013JD020389.

Le Marshall, J., et al., 2006: Improving global analysis and forecasting with AIRS. *Bull. Am. Meteorol. Soc.*, **87 (7)**, 891–894.

Maddy, E. S. and C. D. Barnet, 2008: Vertical resolution estimates in Version 5 of AIRS operational retrievals. *IEEE Trans. Geosci. Remote Sensing*, **46 (8)**, 2375–2384.

Maddy, E. S., et al., 2012: On the effect of dust aerosols on AIRS and IASI operational level 2 products. *Geophys. Res. Lett.*, **39**, L10 809, doi: 10.1029/2012GL052070.

Minnett, P. J., R. O. Knuteson, F. A. Best, B. J. Osborne, J. A. Hanafin, and O. B. Brown, 2001: The

Marine-Atmospheric Emitted Radiance Interferometer (M-AERI): a high-accuracy, sea-going infrared spectroradiometer. *J. Atmos. Oceanic Tech.*, **18**, 994–1013.

Morris, V., et al., 2006: Measuring trans-Atlantic aerosol transport from Africa. *Eos Trans. AGU*, **87 (50)**, 565–571.

Nalli, N. R., C. D. Barnet, A. Gambacorta, E. S. Maddy, H. Xie, T. S. King, E. Joseph, and V. R. Morris, 2013a: On the angular effect of residual clouds and aerosols in clear-sky infrared window radiance observations 2. Satellite experimental analyses. *J. Geophys. Res. Atmos.*, **118**, 1–16, doi: 10.1029/2012JD018260.

Nalli, N. R., P. J. Minnett, E. Maddy, W. W. McMillan, and M. D. Goldberg, 2008: Emissivity and reflection model for calculating unpolarized isotropic water surface leaving radiance in the infrared. 2: Validation using Fourier transform spectrometers. *Appl. Optics*, **47 (25)**, 4649–4671.

Nalli, N. R., et al., 2005: Profile observations of the Saharan air layer during AEROSE 2004. *Geophys. Res. Lett.*, **32**, L05 815, doi:10.1029/2004GL022028.

Nalli, N. R., et al., 2006: Ship-based measurements for infrared sensor validation during Aerosol and Ocean Science Expedition 2004. *J. Geophys. Res.*, **111**, D09S04, doi:10.1029/2005JD006385.

Nalli, N. R., et al., 2011: Multi-year observations of the tropical Atlantic atmosphere: Multidisciplinary applications of the NOAA Aerosols and Ocean Science Expeditions (AEROSE). *Bull. Am. Meteorol. Soc.*, **92**, 765–789, doi:10.1175/2011BAMS2997.1.

Nalli, N. R., et al., 2013b: Validation of satellite sounder environmental data records: Application to the Cross-track Infrared Microwave Sounder Suite. *J. Geophys. Res. Atmos.*, **118**, 1–16, doi: 10.1002/2013JD020436.

Neiman, P. J., F. M. Ralph, G. A. Wick, J. D. Lundquist, and M. D. Dettinger, 2008: Meteorological characteristics and overland precipitation impacts of atmospheric rivers affecting the west coast of North America based on eight years of SSM/I satellite observations. *J. Hydrometeor*, **9**, 2247, doi: http://dx.doi.org/10.1175/2007JHM855.1.

Reale, T., B. Sun, F. H. Tilley, and M. Pettey, 2012: The NOAA Products Validation System. *J. Atmos. Ocean. Tech.*, **29**, 629–645, doi:10.1175/JTECH-D-11-00072.1.

Smith, J. W. and N. R. Nalli, 2014: Ozonesonde and NOAA-unique sounder measurements of AEROSE 2010 ozone via lightning-induced nitrogen oxides and biomass burning emissions over the tropical Atlantic Ocean. *AMS Annual Meeting*, Atlanta, GA, American Meteorological Society.

Susskind, J., C. D. Barnet, and J. M. Blaisdell, 2003: Retrieval of atmospheric and surface paramaters from AIRS/AMSU/HSB data in the presence of clouds. *IEEE Trans. Geosci. Remote Sensing*, **41 (2)**, 390–409.

Szczodrak, M., P. J. Minnett, N. R. Nalli, and W. F. Feltz, 2007: Profiling the lower troposphere over the ocean with infrared hyperspectral measurements of the Marine-Atmosphere Emitted Radiance Interferometer. *J. Atmos. Ocean. Tech.*, **34 (3)**, 390–402.

Tobin, D. C., et al., 2006: Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation. *J. Geophys. Res.*, **111**, D09S14, doi:10.1029/2005JD006103.

Xie, H., et al., 2013: Integration and ocean-based prelaunch validation of GOES-R Advanced Baseline Imager legacy atmospheric products. *J. Atmos. Ocean. Tech.*, **30 (8)**, 17431756, doi: 10.1175/JTECH-D-12-00120.1.