U.S. DEPARTMENT OF ENERGY | Office of Science

DOE/SC-ARM-17-019

ARM Radiosondes for National Polar-Orbiting Operational Environmental Satellite System Preparatory Project Validation Field Campaign Report

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June 2017

ARM CLIMATE RESEARCH FACILITY

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June 2017

Work supported by the U.S. Department of Energy,
Office of Science, Office of Biological and Environmental Research

Acknowledgments

We would like to personally thank both Donna Holdridge and Jim Mather for their interest and support in this intensive operational period (IOP). It has been greatly appreciated.

Additionally, we would like to recognize the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) community for their interest in this field campaign. Processing the Suomi National Polar-orbiting Partnership (SNPP) targeted radiosondes with the GRUAN algorithm has extended the relevancy of this campaign to a wider international community.

Acronyms and Abbreviations

AIRS	Atmospheric Infrared Sounder
ARM	Atmospheric Radiation Measurement
ATMS	Advanced Technology Microwave Sounder
BE	Best Estimate
COSMIC	Constellation Observing System for Meteorology, Ionosphere, and Climate
CrIS	Cross-track Infrared Sounder
Deg	degrees
DOE	U.S. Department of Energy
ENA	Eastern North Atlantic
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
GCOS	Global Climate Observing System
GDAS	Global Data Assimilation System
GFS	Global Forecast System
GOES	Geostationary Operational Environmental Satellite
GRUAN	GCOS Reference Upper-Air Network
IOP	intensive operational period
JPSS	Joint Polar Satellite System
K	Kelvin
km	kilometer
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NPROVS+	NOAA Products Validation System
NSA	North Slope of Alaska
NUCAPS	NOAA Unique-Combined Atmospheric Processing System
NWP	Numerical Weather Prediction
OP	overpass
PWV	precipitable water vapor
RO	radio occultation
SGP	Southern Great Plains
SNPP	Suomi National Polar-orbiting Partnership
SSEC	Space Science & Engineering Center (UW-Madison)
TWP	Tropical Western Pacific
UW	University of Wisconsin

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1.0 Summary

1.1 History of the Name: SNPP/JPSS/NPOESS/NPP

The Suomi National Polar-orbiting Partnership (Suomi-NPP or SNPP) satellite was launched in October 2011 and is serving as the bridge satellite between the National Oceanic and Atmospheric Administration (NOAA)'s legacy satellites and the Joint Polar Satellite System (JPSS). SNPP was previously known as the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) prior to reorganization of the program by the U.S. Congress and renaming of the satellite in honor of the meteorologist Verner Suomi.

1.2 Intensive Operational Period Overview

This IOP has been a coordinated effort involving the U.S. Department of Energy (DOE) Atmospheric Radiation (ARM) Climate Research Facility, the University of Wisconsin (UW)-Madison, and the JPSS project to validate SNPP NOAA Unique Combined Atmospheric Processing System (NUCAPS) temperature and moisture sounding products from the Cross-track Infrared Sounder (CrIS) and the Advanced Technology Microwave Sounder (ATMS). In this arrangement, funding for radiosondes was provided by the JPSS project to ARM. These radiosondes were launched coincident with the SNPP satellite overpasses (OP) at four of the ARM field sites beginning in July 2012 and running through September 2017. Combined with other ARM data, an assessment of the radiosonde data quality was performed and post-processing corrections applied producing an ARM site Best Estimate (BE) product. The SNPP targeted radiosondes were integrated into the NOAA Products Validation System (NPROVS+) system, which collocated the radiosondes with satellite products (NOAA, National Aeronautics and Space Administration [NASA], European Organisation for the Exploitation of Meteorological Satellites [EUMETSAT], Geostationary Operational Environmental Satellite [GOES], Constellation Observing System for Meteorology, Ionosphere, and Climate [COSMIC]) and Numerical Weather Prediction (NWP forecasts for use in product assessment and algorithm development. This work was a fundamental, integral, and cost-effective part of the SNPP validation effort and provided critical accuracy assessments of the SNPP temperature and water vapor soundings.

1.3 Radiosonde Launch Efforts

Vaisala RS-92 radiosondes were launched coincident with SNPP overpasses beginning in July of 2012. There were five phases of launches corresponding to five different phases in funding from the JPSS project to ARM for radiosonde purchases. Initially, radiosondes were launched from the ARM field sites including: North Slope of Alaska at Barrow (NSA), Southern Great Plains (SGP), and Tropical Western Pacific at Manus (TWP). Launches at TWP ceased in May 2014 with the closure of the site and were replaced with launches at the Eastern North Atlantic (ENA) site beginning in February 2015. A total of 169/414/444/190 SNPP overpasses were targeted in all five phases of this IOP at ENA/NSA/SGP/TWP respectively. Targeted SNPP radiosonde launches are anticipated to continue through the end of September 2017, four months after the submission of this report. See Table1 for more detailed information on the radiosonde launch efforts through May 2017.

Table 1. Radiosonde launch efforts by ARM site and phase of IOP. N_{OP} is the number of overpasses (OP) targeted and N_{BE} is the number of Best Estimates (BE) produced. *Note that Phase-5 will run through the end of September 2017.

	ENA	NSA	SGP	TWP
Location	Graciosa Island, Azores	Barrow, Alaska	near Lamont, Oklahoma	Manus Island, Papa New Guinea
Lat, Long	39.1°N, 28.0°W	71.3°N, 156.6°W	36.6°N, 97.5°W	2.1°S, 147.4°E
Altitude (m)	30.5	8.0	315.0	4.0
Regime	Mid-latitude island	Arctic, coastal	Mid-latitude continental	Tropical, island
Phase-1	---	07/12/12-12/09/12	07/24/12-01/11/13	07/23/12-06/03/13
Phase-2	---	06/17/13-09/29/14	06/08/13-09/28/14	06/10/13-05/29/14
Phase-3	02/01/15-09/23/15	02/10/15-09/29/15	02/02/15-09/29/15	---
Phase-4	10/03/15-09/25/16	10/03/15-09/30/16	10/01/15-09/26/16	---
Phase-5*	10/12/16-05/13/17	10/01/16-05/14/17	10/11/16-05/12/17	
$\mathbf{N_{OP}}$	169	414	444	190
$\mathbf{N_{BE}}$	167	399	391	172

NPP overpass predictions were determined using the UW-Madison SSEC overpass prediction tool limiting satellite view angle to <=30deg. Launch schedules were coordinated by UW-Madison and ARM personnel to include both day and night launches at each site and updated every 2 months. SNPP overpasses were targeted with either a single sonde launched 15 minutes prior to overpass or dual sondes launched 45 and 5 minutes prior to overpass. Single sonde targeting was used exclusively at ENA and TWP where only one sonde launch system was available, while a combination of single and dual launches were used at NSA and SGP where multiple sonde launch systems were available.

2.0 Results

2.1 Best Estimate (BE)

Combined with other ARM data, an assessment of the radiosonde data (sondewnpn datastream) quality was performed and post-processing corrections were applied producing an ARM site Best Estimate (BE) product for each launch. This was done by interpolating radiosondes onto a common pressure grid, scaling the water vapor profile, and interpolating to the overpass time if dual sondes were launched.

Scaling of the water vapor profile was done by multiplying the profile by a height-independent scale factor such that the total column precipitable water vapor (PWV) was equal to that measured by the ground-based microwave radiometer (mwrlos or mwr3cC1 datastreams) as discussed by Revercomb et al. 2003. This effort followed very closely similar efforts that were performed for the Atmospheric Infrared Sounder (AIRS) on the NASA Aqua satellite. Further science justification and details of the approach for this effort are described in detail in Tobin et al. 2006.

While the radiosonde launch sites were limited in number, the profiles consist of highly accurate measurements of a wide range of climatic conditions, which is ideal for assessing the accuracy of the SNPP CrIS/ATMS NUCAPS sounding products. At the NSA and SGP ARM sites, which have dual radiosonde launch capabilities; it was possible to estimate the short-term variability in temperature and water vapor simply by differencing the radiosondes in the radiosonde pairs and computing statistics. We found that the differences, which occur within approximately 40 minutes, are on the order of 3/4K for temperature and 5-30% for water vapor, and can be seen in Error! Reference source not found.. This variability in temperature and water vapor is of particular interest to this effort as it indicates the amount of variability expected when comparing radiosondes to satellite retrievals, which are nearly instantaneously viewing the scene.

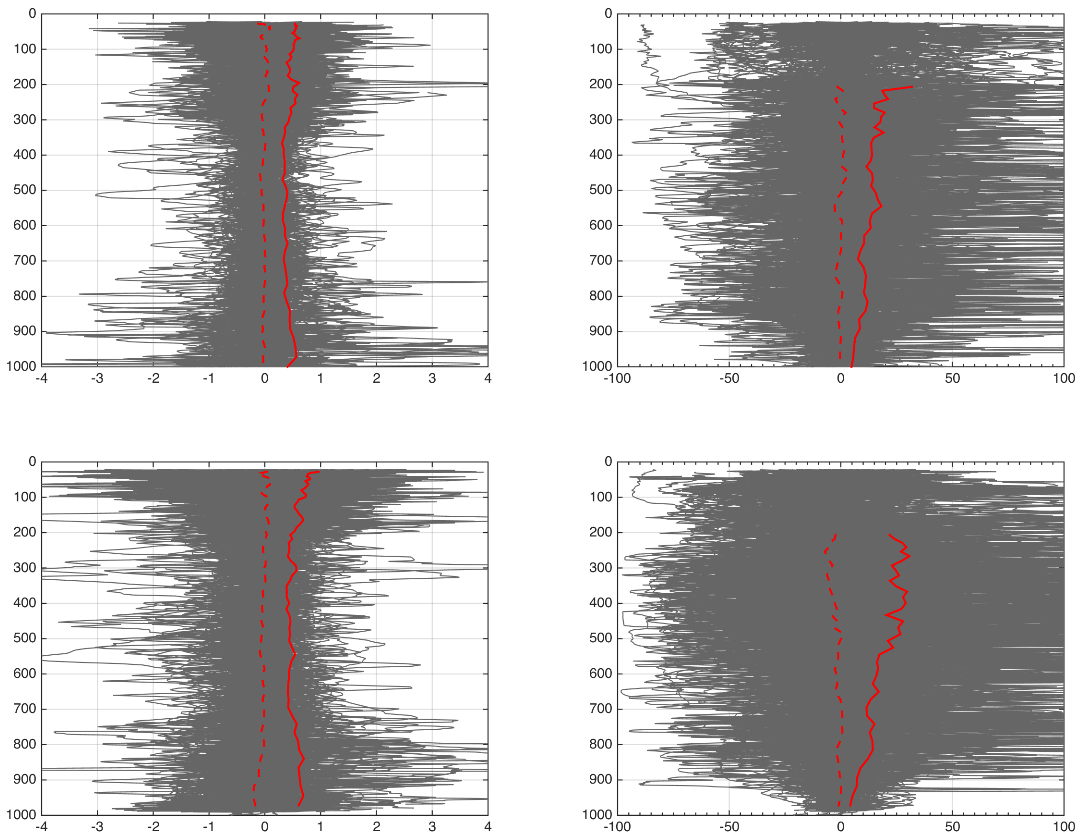

Figure 1. Difference between radiosonde pairs: temperature (left) and water vapor (right) at NSA (to prow) and SGP (bottom row).

2.2 Validation of SNPP NUCAPS Temperature Retrievals

Preliminary comparisons between the SNPP NUCAPS temperature retrievals and the BE measurements are shown in **Error! Reference source not found.**. Also shown are the differences between the Global Data Assimilation System (GDAS), which is the NCEP post-processed Global Forecast System (GFS) product, and the BE. These are shown for ALL SKY (clear and cloudy) conditions and for both day and night overpasses. Agreement between the GDAS and BE retrievals are very good. This result is not unexpected since the GDAS product is heavily weighted by synoptic radiosondes. The comparisons between NUCAPS and the BE are relatively good, but analysis is ongoing to determine what is happening at the surface at NSA and SGP.

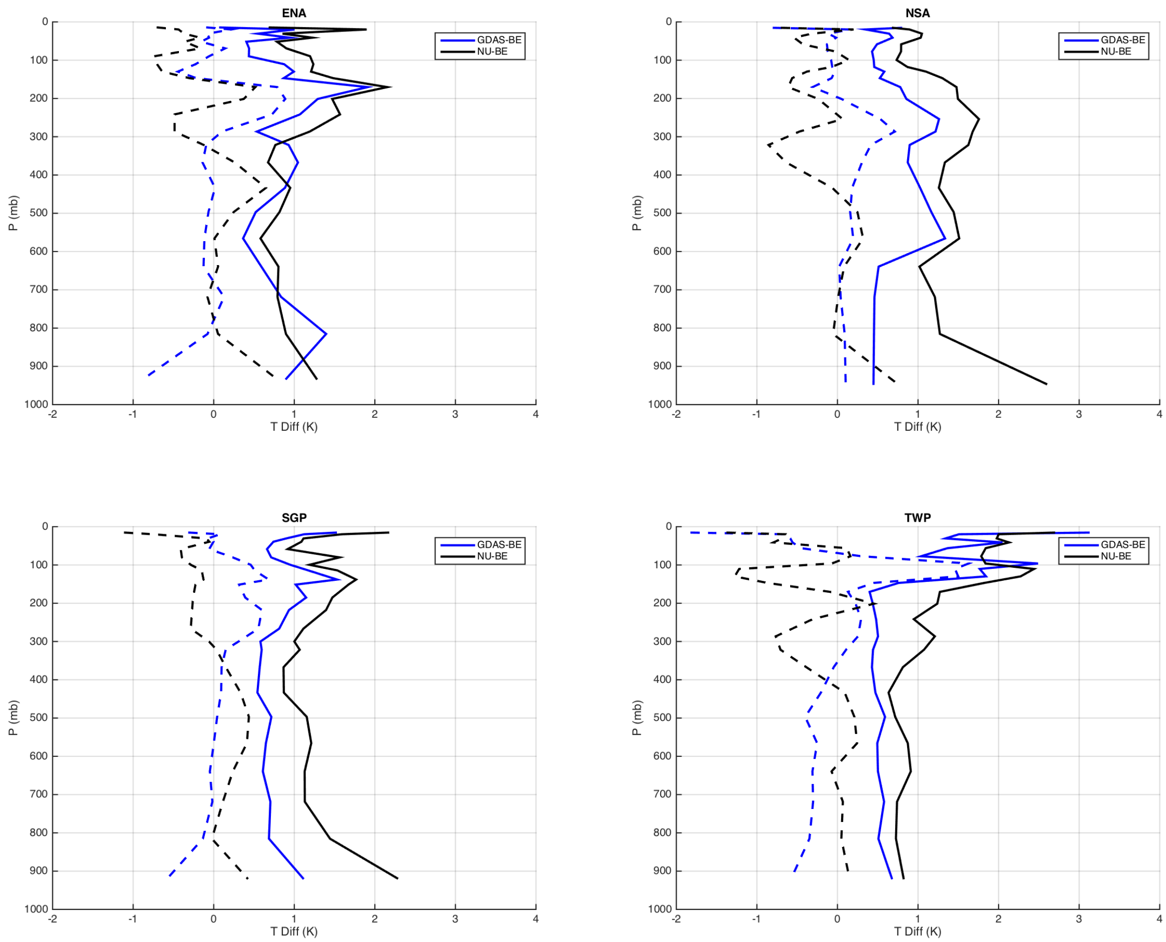

Figure 2. Temperature retrieval differences: SNPP NUCAPS—BE (black) and GDAS—BE (blue). Mean (dashed) and bias (solid).

2.3 COSMIC

In an effort to better understand upper-tropospheric and lower-stratospheric temperatures, an evaluation of SNPP NUCAPS temperature retrievals was made using the ARM BE profiles and the Constellation Observing System for Meteorology, Ionosphere, and Climate (COSMIC) radio occultation (RO) dry temperature products. A limited number of matchup cases (within 100km and 1.5 hours) were found, but it was evident that while NUCAPS was able to capture the overall structure through the atmosphere, it missed the smaller vertical structures like cold tropopause features that the ARM BE and COSMIC RO were able to resolve. A more detailed analysis was performed and a paper was recently submitted on this topic by Feltz et al. and is currently under review

3.0 Publications and References

3.1 Submitted

Feltz, ML, L Borg, RO Knuteson, D Tobin, H Revercomb, and A Gambacorta. "Assessment of NOAA NUCAPS Upper Air Temperature Profiles Using COSMIC GPS Radio Occultation and ARM Radiosondes." *Journal of Geophysical Research–Atmospheres*. Under review.

3.2 Posters and Oral Presentations

2016

Borg, L, DTobin, M Feltz, R Knuteson, T Reale, Q Liu, D Holdridge, and J Mather. Using ARM data to provide atmospheric state best estimates for satellite retrieval validation. ICM-8 (Oral Presentation), 25-29 April, 2016, Boulder, Colorado.

Borg, Lori, Tobin, D., Feltz, M., Knuteson, R., Reale, T., Liu, Q., Holdridge, D., and Mather, J. S-NPP EDR Validation at ARM (GRUAN) Sites. STAR JPSS Annual Science Team Meeting (Oral Presentation), 8-12 August, 2016, College Park, Maryland.

Borg, LA, M.L Feltz, DC Tobin, RO Knuteson, T Reale, DJ Holdridge, JH Mather, and Q Liu. CrIMSS Temperature and Water Vapor Retrieval Validation Using ARM Site Atmospheric State Best Estimates and GPS RO COSMIC. AMS - 21st Conference on Satellite Meteorology (Poster), 15-19 August, 2016, Madison, Wisconsin.

2015

Borg, L, and R Knuteson. Ground-based measurements for T,q profiles and TCWV. UK Met Office, Exeter. ISSWG-2 12th meeting (Oral presentation), 3-4 December, 2015.

Borg, L, D Tobin, T Reale, Q Liu, N Nalli, D Holdridge, and J Mather Validation of S-NPP CrIMSS atmospheric temperature and water vapor retrievals using coordinated ARM site radiosondes (Poster). Toulouse, France. European Organization for the Exploitation of Meteorological Satellites (EUMETSAT), 2015, P-1: Current and future satellites, instruments and their applications.

Knuteson, R, M Feltz, J Roman, J Gartzke, S Ackerman, H Revercomb, D Tobin, L Borg, T August, T Hultberg, and T Reale. Validation of level 2 temperature and water vapor profiles from JPSS and EUMETSAT operational polar satellites using DOE ARM, SuomiNet, and COSMIC datasets. Annual Symposium on New Generation Operational Environmental Satellite Systems, 11th, Phoenix, AZ, 4-8 January 2015. American Meteorological Society, Boston, Massachusetts, 2015, abstract only.

2014

Borg, L, D Tobin, R Knuteson, H Revercomb, A Reale, N Nalli, D Holdridge, and J Mather. Validation of Suomi-NPP CRIMSS retrievals of temperature and water vapor using ARM site best estimates of atmospheric state. Tenth Annual Symposium on New Generation Operational Environmental Satellite Systems, AMS 94th Annual Meeting (Poster); 2-6 February, 2014; Atlanta, Georgia.

2013

Borg, L, D Tobin, R Knuteson, D DeSlover, J Taylor, H Revercomb, C Barnet, N Nalli, D Holdridge, and J Mather. Suomi-NPP CrIMSS retrievals of temperature and water vapor: A comparison with ARM radiosonde. Joint 2013 EUMETSAT & 19th AMS Meteorological Satellite Conference (Poster). 16-20 September, 2013; Vienna, Austria.

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Revercomb, HE, DD Turner, DC Tobin, RO Knuteson, WF Feltz, J Barnard, J Bosenberg, S Clough, D Cook, R Ferrare, J Goldsmith, S Gutman, R Halthore, B Lesht, J Liljegren, H Linne, J Michalsky, V Morris, W Porch, S Richardson, B Schmid, M Splitt, T Van Hove, E Westwater, and D Whiteman. 2003. "The ARM Program's water vapor intensive observation periods: Overview, initial accomplishments, and future challenges." *Bulletin of the American Meteorological Society* 84(2): 217-236, doi:10.1175/BAMS-84-2-217.

Tobin, DC, HE Revercomb, RO Knuteson, BM Lesht, LL Strow, SE Hannon, WF Feltz, LA Moy, EJ Fetzer, and TS Cress. 2006. "Atmospheric Radiation Measurement site atmospheric state best estimates for Atmospheric Infrared Sounder temperature and water vapor retrieval validation." *Journal of Geophysical Research–Atmospheres* 111(D9): D09S14, doi:10.1029/2005JD006103.

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