Integrating NASA Aqua AIRS in a Real-Time NUCAPS Science-to-Applications System to Support Severe Weather Forecasting

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Key Points:

- A science-to-applications system was developed to process Atmospheric Infrared Sounder retrievals as NUCAPS-Aqua in real-time
- The system enabled delivery of low latency NUCAPS-Aqua for National Weather Service forecasters to assess in a quasi-operational testbed
- Two illustrative examples show use of NUCAPS-Aqua for analyzing convective storm environments during the 2022 Hazardous Weather Testbed

Abstract

In recent years, NOAA Unique Combined Atmospheric Processing System (NUCAPS) hyperspectral infrared satellite sounding retrievals derived from Joint Polar Satellite System (JPSS) polar-orbiting satellites have been documented as observations that add value to weather forecasting applications. NUCAPS is currently the operational algorithm delivering JPSS satellite sounding retrievals to the NOAA National Weather Service (NWS) and is based on the heritage Atmospheric Infrared Sounder (AIRS) Science Team algorithm for processing vertical temperature, moisture, and trace gas retrievals. For the Special Collection on "Twenty Years of Observations from AIRS", we highlight the methodology we implemented to develop a prototype science-to-applications system to enable real-time processing of AIRS satellite sounding retrievals through the NUCAPS algorithm (i.e., NUCAPS-Aqua) to support weather forecasting applications. The addition of NUCAPS-Aqua to experimental real-time pathways alongside operational JPSS NUCAPS soundings, facilitated assessment of NUCAPS-Aqua at the 2022 Hazardous Weather Testbed (HWT) Spring Experiment. Development of NUCAPS-Aqua described in this technical report includes preservation of microwave observations and calculation of a-priori regression coefficients. Additionally, the real-time processing and challenges with implementing a science-to-applications system are discussed. Two illustrative pre-convective forecasting examples analyzed by NWS forecasters during the 2022 HWT Spring Experiment are highlighted to demonstrate the benefit of NUCAPS-Aqua as (1) special afternoon soundings, (2) an additional observation to assess temporal trends using multiple satellites, and (3) a complement to observational and model analysis.

Plain Language Summary

This technical report describes the translation of science to applications in developing a system that enables rapid delivery of Aqua Atmospheric Infrared Sounder (AIRS) observations to the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) for weather forecasting applications. The addition of AIRS to experimental real-time pathways alongside operational satellite soundings from NOAA-20, increases the availability of satellite soundings available for weather forecasting and analysis. Two illustrative examples highlight the use of NUCAPS-Aqua by NWS forecasters for analyzing convective storm environments during the 2022 Hazardous Weather Testbed.

1 Introduction & Background

The National Aeronautics and Space Administration's (NASA) Aqua Atmospheric Infrared Sounder (AIRS) satellite sounding retrievals are now available in real-time (~1 hour latency) for weather forecasting applications as a result of a collaboration between NASA's Jet Propulsion Laboratory (JPL), Science and Technology Corporation (STC), the University of Wisconsin Space Science and Engineering Center (SSEC), and the NASA Short-term Prediction Research and Transition (SPoRT) Center at Marshall Space Flight Center. The authors developed a prototype science-to-applications system to make early afternoon sounding observations from Aqua available to the National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS). The goal of this project was to enable real-time processing of AIRS/Advanced Microwave Sounding Unit (AMSU) observations through the NOAA Unique Combined Atmospheric Processing System (NUCAPS) for rapid delivery to the NWS so that the retrieved *"NUCAPS-Aqua"* soundings could be available alongside NUCAPS soundings from the Cross-track Infrared Sounder (CrIS) and Advanced Technology Microwave Sounder (ATMS) on NOAA-20 (NUCAPS-NOAA20) within the operational environment. With this we addressed the need forecasters expressed for an increase in spatial coverage as well as temporal resolution of satellite soundings (Smith et al., 2019) specifically in the early afternoon to help improve situational awareness of the pre-convective environment ahead of severe storm development. In recent years, NWS operational meteorologists have started to integrate satellite soundings in forecasting activities, ranging from severe weather forecasting to aviation support (Berndt et al., 2016, 2020; Esmaili et al., 2020; Kalluri et al., 2022; Weaver et al., 2019). Through the support of the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction program (PGRR) NUCAPS soundings derived from the CrIS/ATMS instruments onboard Suomi National Polar-orbiting Partnership (SNPP) and later the NOAA-20 satellite were introduced to the NWS operational environment. Since 2015, regular interactions with NWS users through the NUCAPS Users Working Group, the JPSS PGRR Sounding Initiative, and testbed experiments have fostered opportunities for training, feedback on products, and discussing the advantages and limitations of products to encourage proper use (R. B. Esmaili et al., 2020). The 1:30 pm afternoon orbits of SNPP, NOAA-20, and Aqua are well-suited for diagnosing the pre-convective environment under clear to partly cloudy conditions, specifically the analysis of mid-level temperature and moisture fields and derived indices before storms develop (Bloch et al., 2019; Gartzke et al., 2017; Iturbide-Sanchez et al., 2018; Nalli et al., 2018). Currently, NOAA-20 soundings and gridded products are part of the operational NWS Advanced Weather Interactive Processing System (AWIPS) and have regularly been assessed by NWS forecasters at the NOAA Hazardous Weather Testbed (HWT; Calhoun et al., 2021; Ralph et al., 2013) Spring Experiment to garner stakeholder feedback- which has translated to tailoring products and visualizations to meet stakeholder needs (Berndt et al., 2020; Esmaili et al., 2020). The evaluation of NUCAPS at HWT has facilitated regular use of NUCAPS by forecasters in operations for a range of weather applications in data sparse regions such as the Pacific (Aydlett & Slaughter, 2022), to supplement model analysis (Rutt, 2021), and analyze complex convective environments (Edwards, 2021). Consistent feedback from the HWT Spring Experiment included requests for additional satellite soundings. As the CrIS instrument on SNPP aged, NOAA-20 became the only satellite from which to derive CrIS/ATMS NUCAPS soundings and the development of NUCAPS-Aqua presents an opportunity to meet emerging user needs for additional satellite soundings, enable preparation for future JPSS satellites, and demonstrate the value of multi-satellite analysis.

The prototype science-to-applications system described here leverages the Community Satellite Processing Package (CSPP; Huang & Goldberg, 2019) framework to rapidly process data downlinked at direct broadcast stations. NUCAPS is a flexible system designed to be sensor agnostic with the ability to process combined infrared and microwave soundings from SNPP, the JPSS Series, the MetOp Series, or Aqua. Despite the NUCAPS algorithm flexibility, real-time pathways and code that support processing AIRS/AMSU through the International MODIS/AIRS Processing Package (IMAPP; Huang et al., 2004) were never fully developed or translated to the CSPP framework within which the NUCAPS algorithm runs. However the Community Long-term Infrared Microwave Combined Atmospheric Product System (CLIMCAPS; Smith et al., 2021; Smith & Barnet, 2019, 2020) science code contained infrastructure suitable for adaptation to support real-time processing for this project. The NUCAPS science source code, including NUCAPS-Aqua, is maintained as part of CLIMCAPS that is funded by NASA to establish a continuous sounding record of the infrared and microwave instruments in low-Earth orbit. For the work described in this paper, we distinguish between NUCAPS-Aqua and NUCAPS-NOAA20. The former is a science product generated by NUCAPS source code that runs on AIRS/AMSU measurements received via direct broadcast stations across the contiguous United States and the latter is an operational product generated by NUCAPS that runs at NOAA on global CrIS/ATMS measurements. While there are a number of algorithm differences between NUCAPS-Aqua and NUCAPS-NOAA20, these are considered negligible for the evaluation presented here. The goal of this technical report is to describe the methodology we implemented to process AIRS/AMSU retrievals through the NUCAPS algorithm, real-time product production and delivery, and present illustrative examples of NUCAPS-Aqua. Section 2 describes the development of NUCAPS-Aqua and real-time production; section 3 describes two illustrative pre-convective forecasting examples analyzed by NWS forecasters during the 2022 HWT Spring Experiment and conclusions are presented in section 4.

2 Data and Methods

2.1 The NUCAPS Aqua Algorithm

The NUCAPS retrieval algorithm has its origin in the AIRS Science Team approach (Susskind et al., 1998, 2003). This method combines microwave (e.g., AMSU) and hyperspectral infrared (e.g., AIRS) measurements to retrieve a suite of atmospheric state parameters as profiles and surface variables globally in clear and partly cloudy scenes. A detailed discussion of the NUCAPS retrieval method is beyond the scope of this technical report and we refer the reader, instead, to the citations provided. We do deem it worthy, however, to distinguish a few aspects of

NUCAPS for AIRS/AMSU to differentiate it from other AIRS/AMSU approaches, notably AIRS V7.0 (Milstein & Blackwell, 2016; Susskind et al., 2014) and CLIMCAPS. In 2016, the AMSU channels 1 (23.8 GHz) and 2 (31.4 GHz) faltered and subsequently became defunct. The AIRS V7.0 system has since adopted an infrared-only approach and CLIMCAPS builds its long-term sounding record using AIRS/AMSU for the 2002–2016 period (before AMSU channel failure) and depends on CrIS/ATMS from 2017 onwards. In past versions of NUCAPS, AMSU channels 1 and 2 are used for four main purposes: (1) provide estimates of the predominant surface type in an observed scene (e.g., coast, water, land, sea ice and snow), (2) to improve the accuracy of cloud clearing (a method that removes cloud spectral signatures), (3) the a-priori regression retrievals (that uses all available infrared and microwave channels), and (4) stabilize the optimal estimation retrieval (e.g., converge on a solution) of temperature and water vapor in high-impact weather scenes. For the purpose of this project, we wanted to preserve as much of the AMSU information content as possible so that (1) the NUCAPS-Aqua soundings can be readily compared to those from NUCAPS-NOAA20 and (2) to preserve the value of the microwave observations in high-impact weather scenes which forecasters regularly analyze. In Fig. 1 below, we outline the NUCAPS-Aqua algorithm flow.

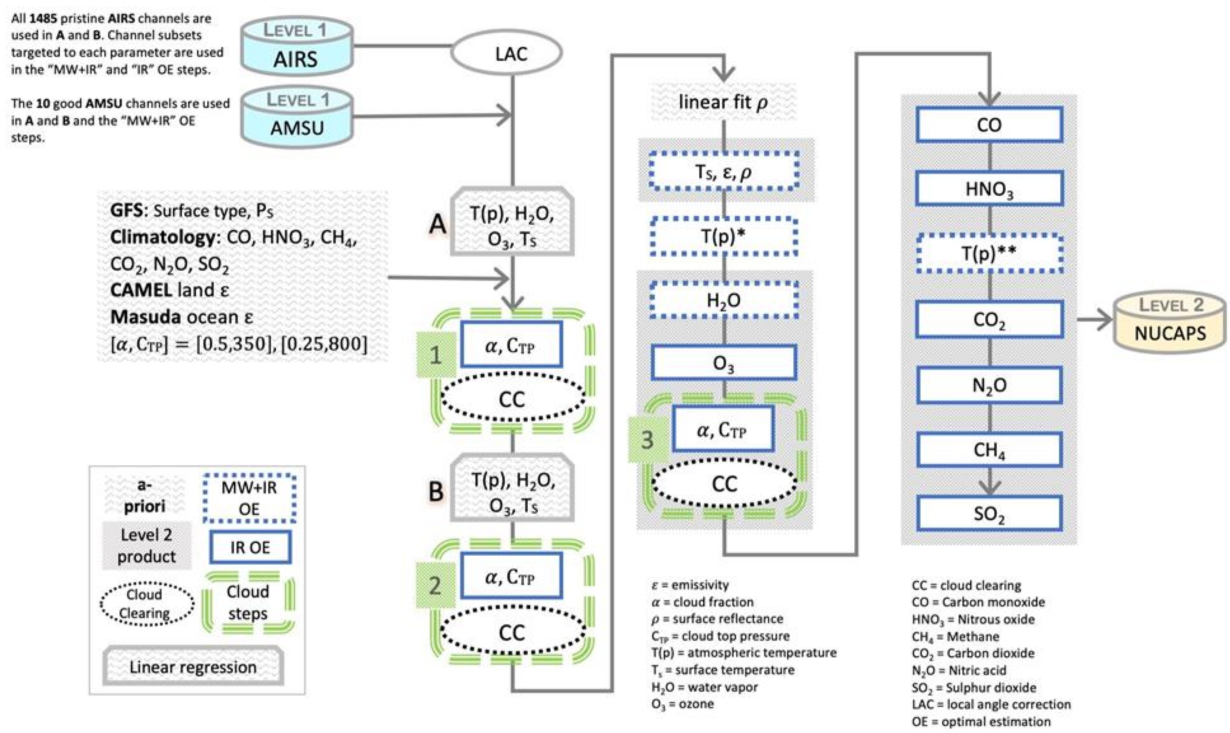

Figure 1: A flow diagram of the NUCAPS-Aqua science algorithm that ingests Level 1B AIRS and AMSU products (top left corner) and outputs the Level 2 retrieval product (solid grey boxes) as netCDF4 files.

As per Fig. 1, NUCAPS-Aqua combines the AIRS and AMSU measurements (ingested as Level 1B files) to retrieve surface temperature (T_s) as well as profiles of temperature (T(p)), water vapor (H_2O) and ozone (O_3) using a linear regression approach that employs singular value decomposition as a regularization and operates on principal components of all the AIRS and AMSU channels (Goldberg et al., 2003). Note that the AIRS radiances are first adjusted with a local angle correction and of the 15 AMSU channels, NUCAPS Aqua uses the remaining 10 good channels (3, 6 and 8 to 15). The 10 AMSU channels are not significantly affected by non-precipitating clouds and provide valuable information about tropospheric T(p) in high-impact weather scenes. They also provide valuable quality control of cloud clearing that is important for use of these retrievals in weather applications. In particular, channels sensitive to the lower troposphere (3 and 6) are valuable to remove biases in T(p) prior to the cloud clearing steps and/or reject cloud cleared radiances with cloud contamination.

This first regression step, labeled as “A” in Fig. 1, is referred to as a ‘cloudy’ regression because T_s, T(p), H_2O and O_3 are retrieved from Level 1B measurements that are uncorrected for clouds (i.e., the georeferenced Level 1B radiance measurements that can be contaminated by clouds). An a-priori of the full atmospheric state is assembled using these regression retrievals together with surface type and pressure from the Global Forecast System (GFS) model, climatologies (Smith et al., 2021) for the infrared-emitting trace gases (CO, HNO_3, CH_4, CO_2, N_2O and SO_2), the Masuda model for ocean emissivity and the 2007 Combined Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) and Moderate Resolution Imaging Spectroradiometer (MODIS) emissivity over land (CAMEL; Borbas et al., 2018; Feltz et al., 2018) database. This a-priori state is used to retrieve the cloud-cleared infrared radiances, as well as cloud fraction (α) and cloud top pressure (C_{TP}). A second linear regression retrieval (labeled “B” in Fig. 1) uses the cloud cleared AIRS radiances and the 10 good AMSU channels to improve the T_s, T(p), H_2O and O_3 retrievals with a better accounting of error due to clouds. After the regression retrieval steps, NUCAPS-Aqua retrieves one variable at a time using an optimal estimation (OE), or physical, retrieval approach that stabilizes the sounding retrievals with full error accounting in clear and partly cloudy scenes. The cloud clearing is iterated twice more, every time T_s, T(p), H_2O and O_3 improves. We explain this approach in more detail elsewhere (Smith & Barnet, 2019, 2020). All CLIMCAPS and NUCAPS configurations use the Stand-alone AIRS Radiative Transfer Algorithm (SARTA; Strow et al., 2003) in their OE retrievals. Use of SARTA is of vital importance to NUCAPS for latency, accuracy of core products, and experimental trace gas products. Providing data as quickly as possible after the satellite overpass is integral for integrating observations within weather forecasting operations where they need to analyze information to issue routine text products, forecasts, and warnings.

We calculated the regression coefficients using 19 focus days that were randomly selected from the period spanning 2005 through 2019 to cover all four seasons and include various extreme events, such as heat waves and thunderstorms. The training dataset linearly correlates T_s, T(p), H_2O and O_3 from the ECMWF (European Centre for Medium-range Weather Forecasts) model with ‘raw’ (i.e., uncorrected for clouds) and cloud cleared radiance measurements to generate coefficients for the two regression retrieval steps A and B (Fig. 1). These coefficients are generated using all 1485 pristine AIRS channels and the 10 good AMSU channels. Unlike the CrIS instrument, any channel on AIRS can be marked 'bad’ on individual scenes by the calibration software. We refer to this as a ‘popped’ channel. The AIRS team maintains channel property files that identify channels that are permanently bad or statistically are subject to popping. An AIRS channel is considered “pristine” when it adheres to the following criteria: (i) marked “good for Level-2” in all past and present AIRS channel property files, (ii) is not labeled “bad” by experts in the field and (iii) was not marked bad in more than ~0.5% of the scenes used for training. When applying the cloudy or cloud-cleared regression operators, the “popped” channels are removed dynamically from scene-to-scene using radiances that are reconstructed from the principal components of all good channels in that scene (Barnet et al., 2007).

2.2 Design of the Real-Time System

The real-time system (Fig. 2) consisted of a processing segment at SSEC and a formatting and delivery segment at SPoRT. AIRS and AMSU observations were downlinked at the SSEC direct broadcast station and Level 1B files were processed by the IMAPP software. We developed a custom AIRS/AMSU preprocessor to prepare the direct-broadcast Level 1B measurements as input to NUCAPS, as well as a post-processor to output NUCAPS-Aqua retrievals in the operational NOAA Level 2 format that is known as “environmental data records” (EDRs). By having NUCAPS-Aqua files in the same format as the operational NUCAPS-NOAA20, we were able to use existing data pathways for processing, delivery, ingest, and displaying NUCAPS within the NWS operational framework. SSEC posted the EDR files to a public ftp site for SPoRT to download and reformat for display in AWIPS. Once the data were reformatted for AWIPS, they were delivered to the NWS through the Unidata Local Data Manager (LDM; Emmerson et al., 1994). Additionally, the EDR files were processed through the SPoRT Gridded NUCAPS software (Berndt et al., 2020) for display online and reformatted for display in SHARPpy (Blumberg et al., 2017) and an interactive web-based skew-t viewer (e.g., NUCAPS Satellite sounding analysis and visualization system or Savvy). The web-based tools and open source SHARPpy supported non-AWIPS users and provides additional analysis capabilities that AWIPS lacks.

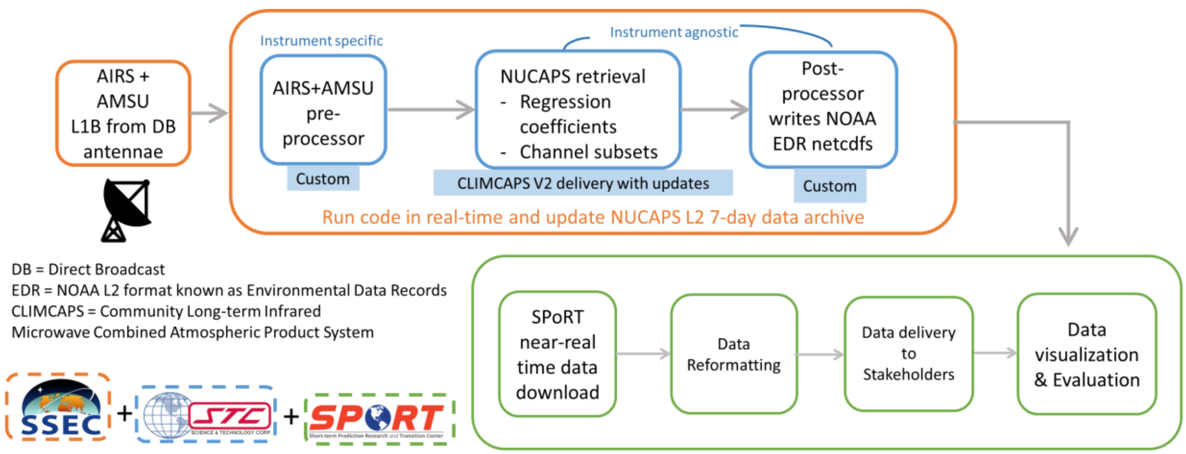

Figure 2. Schematic of NUCAPS-Aqua real-time processing system. Processing segments at SSEC (orange) and SPoRT (green), blue boxes represent custom code modifications by STC.

2.3 Challenges

Tailoring science code to a real-time applications system presented challenges to rapid processing and delivery of high quality products. Keys to a successful transition included compatibility with existing NWS operational infrastructure, maintaining low latency, preserving retrieval quality, and dealing with the limited spatial coverage of direct broadcast data. The use of data downlinked by direct broadcast capabilities presented interesting challenges due to the antenna’s limited line of site. Figure 3, as an idealized ascending orbit, demonstrates that (1) only data within reach of the antenna are captured resulting in partial granules, and (2) AIRS and AMSU field of view (FOV) mismatches result from these partial granules. These issues caused code failures to regularly occur. To mitigate these issues in the direct broadcast framework, granules sizes were reduced to only include scanlines with valid data in the FOV (Fig. 3). For example, an AIRS Level 1B granule may have a standard 90 x 135 size, but the NUCAPS-Aqua output will vary in size (e.g., 90 x 66 or 90 x 69 as examples). Retaining only valid scanlines for processing in NUCAPS means granule size varies and downstream tools must be able to account for this. This issue can also create AIRS and AMSU FOV mismatches. Therefore, AIRS scanlines are removed to match the AMSU FOV even if there is valid data (Fig. 3; gray boxes). Logic was written into the code to account for variations on missing granules and FOV mismatches that could occur. Last, quality flags were impacted by the lack of AMSU surface channels due to the 2016 outage; either yellow (e.g., failed infrared retrieval, successful microwave retrieval) or red (e.g., failed infrared and microwave retrievals) quality was assigned to the majority of retrievals. Once the methodology described in section 2.1 was implemented, the quality flags were appropriately coded as green (e.g., successful infrared and microwave retrievals), yellow, or red. This was important because stakeholders rely on the visual interpretation of the quality flags to know which soundings to trust for analysis.

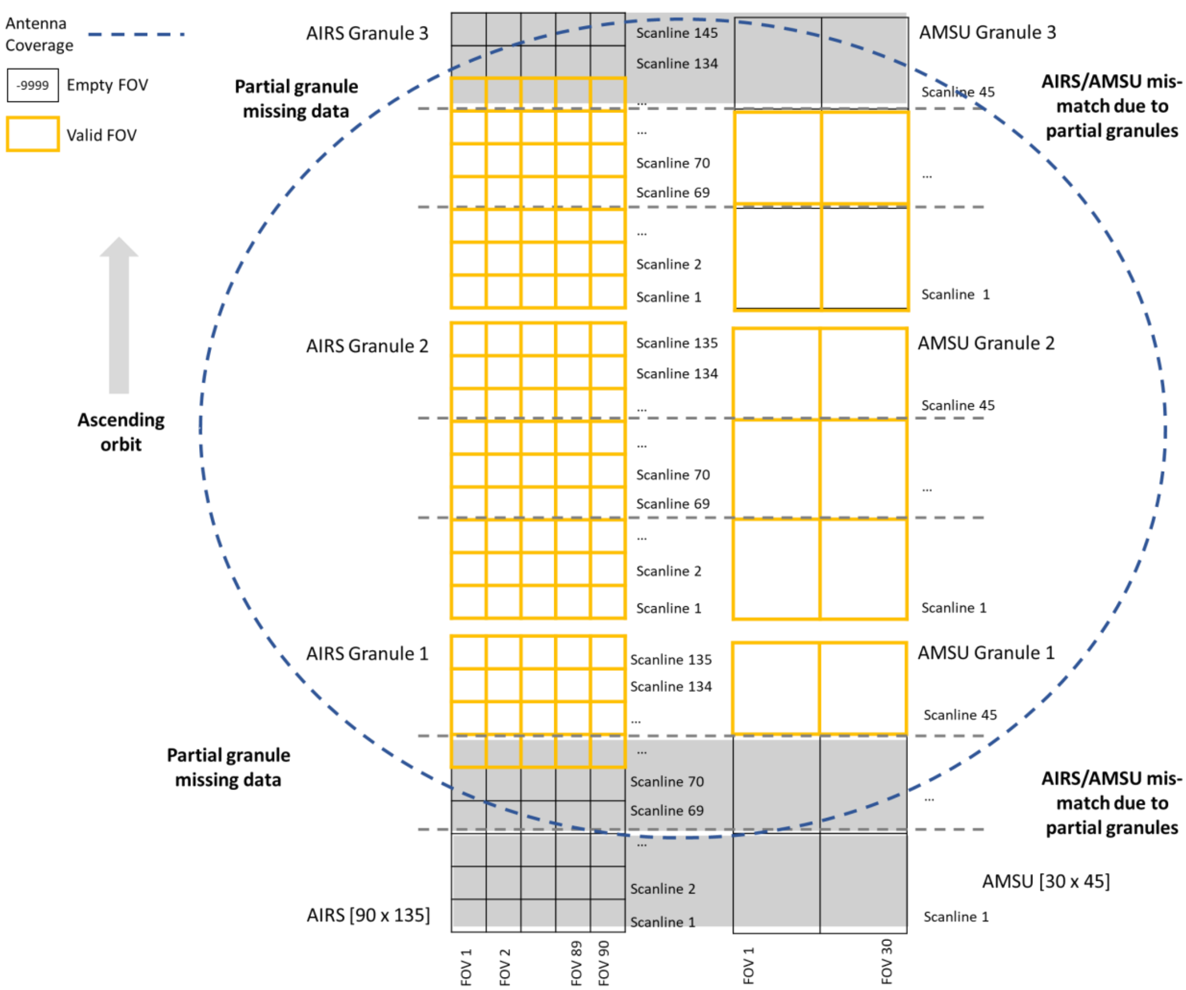

Figure 3. Idealized ascending orbit demonstrating the limitations of direct broadcast line of sight, AIRS granules (left) and AMSU granules (right). Yellow boxes represent FOV's containing valid data and gray boxes are omitted from processing.

3 Demonstration Examples

The science-to-applications system was put into real-time production in May 2022 prior to the start of the 2022 HWT Spring Experiment. During severe weather season, the HWT hosts several experiments in a quasi-operational setting where NWS forecasters have the opportunity to evaluate the latest research developments (Calhoun et al., 2021) and researchers have the opportunity to interact with the forecasters during the evaluation. The collaborative nature of the experiment facilitates a two-way path between stakeholders and developers to guide product development that is tailored for operational needs. The examples presented here were posted on the HWT blog during the 2022 HWT Spring Experiment and highlight the benefit of NUCAPS-Aqua as (1) special afternoon soundings, (2) an additional observational tool to assess temporal trends in combination with NUCAPS-NOAA20, and (3) a complement to observational and model analysis.

3.1 Special Soundings

Radiosonde launches routinely occur at 00 and 12 UTC; however, NWS upper air sites can launch special soundings at additional times upon request when a complex environment ensues. Due to limited resources and staffing, special afternoon soundings aren't as common. With the Aqua local overpass time in the early afternoon, NUCAPS soundings from both NOAA-20 and Aqua fill the observational gap between standard radiosonde launches and when special soundings are not available. On 15 June 2022 forecasters were assessing the potential for convection near Green Bay, WI (GRB; HWT Blog, 2022b). On this day, discrete convective storms moved from southwest to northeast through central WI from approximately 1645 to 1950 UTC. Subsequently a line of storms moved from west to east across WI into the evening hours. These storms produced high winds, hail, and 12 tornadoes in central WI from 2100 through 2300 UTC. During the HWT experiment, forecasters had access to a special 18 UTC sounding from GRB, NUCAPS-NOAA20, and NUCAPS-Aqua (Fig. 4a,b). The forecaster noted the increasing temperature, dew point, and low level lapse rates when analyzing the NUCAPS-NOAA20 sounding and subsequent NUCAPS-Aqua sounding. Qualitatively, the forecaster did indicate an improvement in how NUCAPS-Aqua captured the low levels of the atmosphere, especially moisture, when comparing both soundings to the GRB special sounding (Fig. 4a,b). Analyzing Gridded NUCAPS and focusing in on central WI (Fig. 4c-f) total precipitable water and 700-500 hPa lapse rates increased , when comparing NUCAPS-NOAA20 and the NUCAPS-Aqua overpass about an hour later. Both the soundings and gridded products show localized areas of convective potential in central WI and near GRB. This particular case represents the benefit NUCAPS-Aqua can provide when special observations aren't available to assess convective potential, filling a gap in the observational system. Additionally, the Aqua overpass about an hour after NOAA-20 makes it possible to assess trends in environmental characteristics important for pre-convective forecasting and identifying the potential for thunderstorm development as demonstrated in the qualitative forecaster analysis (HWT Blog, 2022b). From a qualitative perspective, NUCAPS-Aqua with the preservation of AMSU channels is complementary to NUCAPS-NOAA20 and the observed special sounding.

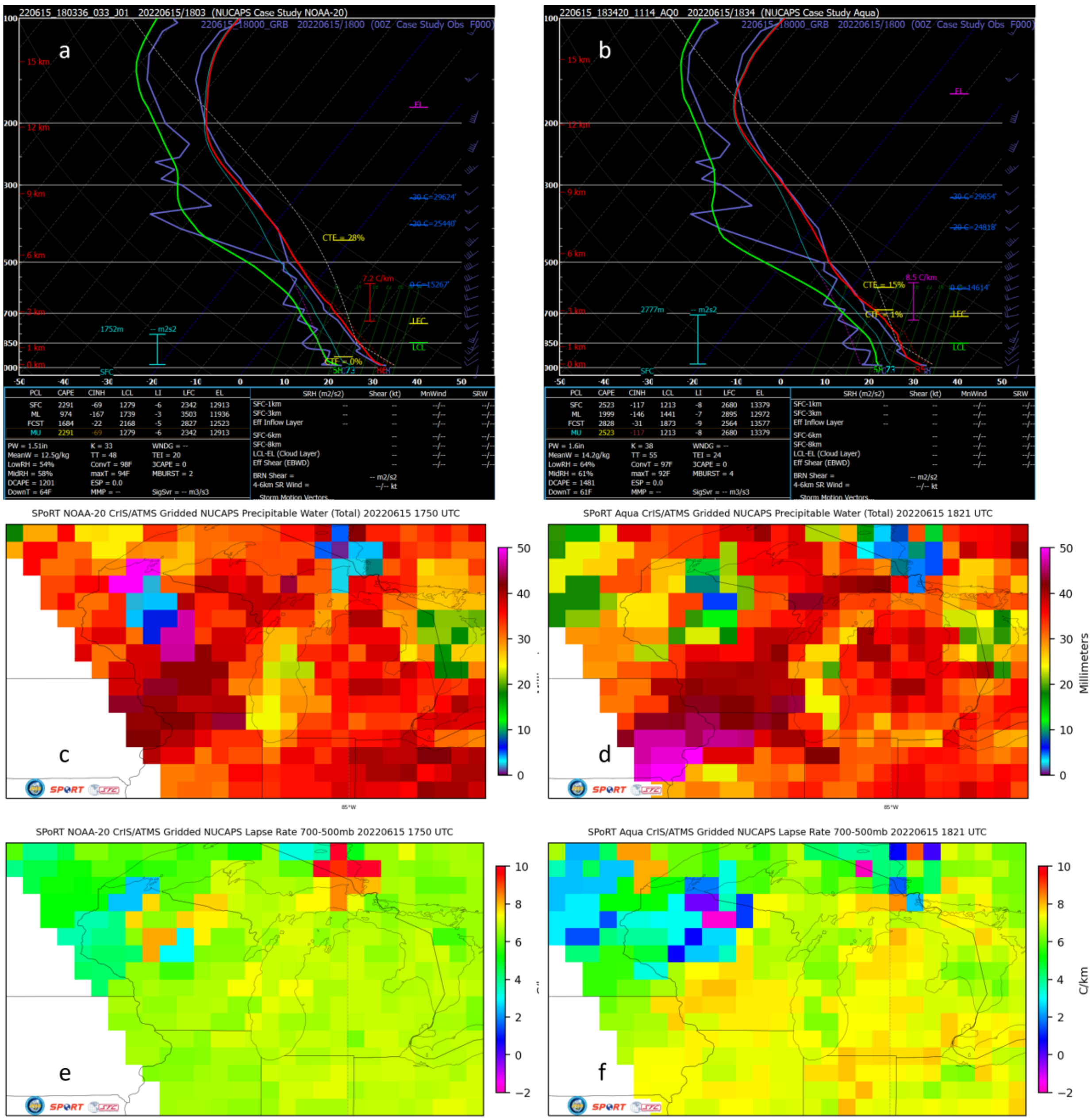

Figure 4. 15 June 2022 (a) 1803 UTC NUCAPS-NOAA20 sounding, (b) 1834 UTC NUCAPS-Aqua sounding, (c) 1750 UTC NOAA-20 total precipitable water (mm), (d) 1821 UTC Aqua, (e) 1750 NOAA-20 700-050 hPa lapse rates, and (f) 1821 UTC Aqua. Note in (a) and (b) temperature (red) and dew point (green) are in Celsius and the 1800 UTC Green Bay, WI (GRB) sounding is purple.

3.2 Multiple Satellites

During the previous day, 14 June 2022, forecasters were assessing an area of convection and high instability within the NWS Grand Forks area of responsibility. A secondary region of convection rapidly developed south of the main area of convection they were analyzing (HWT Blog, 2022a). Three NUCAPS overpasses were available (Fig. 5). A NUCAPS-NOAA20 overpass at 1823 UTC indicated 2094 J/kg of mixed layer CAPE in the region (Fig. 5a,b). A consecutive NOAA-20 overpass at 2003 UTC had mixed layer CAPE of only 1235 J/kg. With the sounding located near the edge of the scan (Fig. 5c,d), the forecaster noted, the potential limitations with an off-nadir view (HWT Blog, 2022a). Last, the forecaster analyzed a NUCAPS-Aqua overpass with nadir directly over the region of interest. The 1929 UTC NUCAPS-Aqua sounding had a mixed layer CAPE value near 3000 J/kg (Fig. 5e,f). The 3000 J/kg value was comparable to the first NOAA-20 sounding and the Storm Prediction Center Mesoscale Analysis graphic at 2100 UTC (e.g., 2000-3000 J/kg in the region). The second NOAA-20 overpass, with lower CAPE values, covered the area of interest with an off-nadir view. Whereas Aqua was directly overhead and NUCAPS-Aqua provided quality observations that increased confidence in the environmental conditions through a multi-satellite assessment. It is worth noting NUCAPS validation has verified there are no significant statistical differences between nadir and edge of scan observations for NUCAPS satellite products (Nalli et al., 2018). With three NUCAPS overpasses available before convection initiated, the forecasters were alerted to a region of high instability; the satellite observations indicated potential instability that the numerical models did not simulate (HWT Blog, 2022a). The example highlights the NUCAPS-Aqua overpass provided and additional observation and complimentary information when paired with NUCAPS-NOAA20, observations, and models and increased forecaster confidence in convective potential.

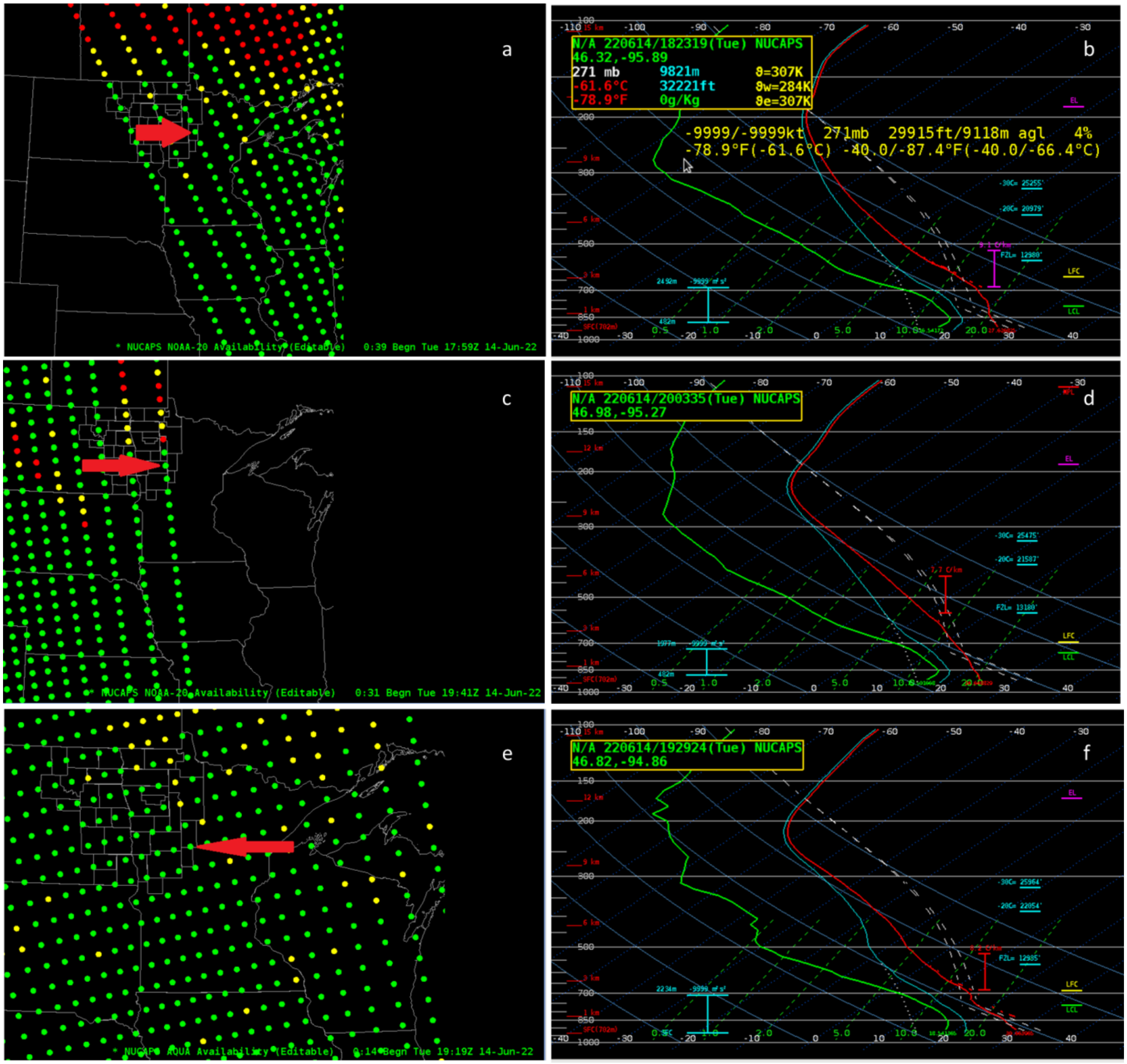

Figure 5. 14 June 2022 (a) NUCAPS-NOAA20 sounding locations beginning 1759 UTC, (b) 1832 UTC NUCAPS-NOAA20 sounding at the red arrow in a, (c) NUCAPS-NOAA20 sounding locations beginning at 1941 UTC, and (d) 2003 UTC NUCAPS-NOAA20 sounding at the red arrow in c, (e) NUCAPS-Aqua sounding locations beginning at 1919 UTC, and (f) 1929 UTC NUCAPS-Aqua sounding at red arrow in e. Note in (b), (d), and (f) temperature (red) and dew point (green) and are in Celsius.

4 Conclusions

A prototype science-to-applications system was developed to enable real-time processing of NASA's Aqua AIRS satellite sounding retrievals through the NUCAPS algorithm (i.e., NUCAPS-Aqua) to support weather forecasting applications. This technical report for the

Special Collection on "Twenty Years of Observations from AIRS", highlights the methodology we implemented to develop NUCAPS-Aqua, set up real-time processing, and show two illustrative examples. The system was developed by adapting NASA CLIMCAPS (e.g., Community Long-term Infrared Microwave Combined Atmospheric Product System) science code to rapidly process NUCAPS-Aqua within 1 hour of the satellite overpass with the goal of benefiting NOAA NWS forecasting operations and facilitating end user product assessment during the 2022 Hazardous Weather Testbed Spring Experiment. Key adaptations to the data pathway were necessary including compatibility with NWS operational infrastructure, maintaining low latency, preserving retrieval quality, and dealing with the limitations caused by direct broadcast line of sight. The NUCAPS-Aqua algorithm preserves as much of AMSU as possible. We calculated the a-priori regression coefficients using 19 focus days covering all four seasons and include various extreme events. These coefficients were generated using all 1485 pristine AIRS channels and the 10 good AMSU channels. The real-time system consists of an algorithm processing segment at SSEC and a formatting and delivery segment at SPoRT to create files and visualizations for stakeholder use. Two illustrative pre-convective cases analyzed by NWS forecasters during the 2022 HWT Spring Experiment are presented to qualitatively highlight the benefit of NUCAPS-Aqua as (1) special afternoon soundings, (2) an additional observational tool to assess temporal trends in combination with NUCAPS-NOAA20, and (3) a complement to observational and model analysis. The development of NUCAPS-Aqua presents an opportunity to meet user needs for more satellite soundings. As the NWS places greater emphasis on mesoscale analysis to bridge the watch to warning gap, satellite soundings from multiple satellites provide an additional tool to complement environmental analysis. In addition, qualitative assessments that utilize multiple satellites enable preparation for JPSS-2 and the future Geo-XO mission and there is an opportunity to evaluate Aqua's drifting orbit regarding the value of later afternoon orbits for the value of observations later in the convective life cycle.

Acknowledgments

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Open Research

The L1B AIRS and AMSU L1B radiance files processed through IMAPP (Huang et al., 2004; Space Science Engineering Center, 2021) and used in this project were accessed in real-time at: https://ftp.ssec.wisc.edu/pub/eosdb/aqua/airs/. These data were processed through a version of the CLIMCAPS (Smith & Barnet, 2019, 2020) code customized for real-time production at SSEC as outlined by the methodology described in this paper. The output was available in real-time during the spring 2022 season and the NUCAPS-Aqua case studies in this paper are available on zenodo: https://doi.org/10.5281/zenodo.7300376 (Berndt et al., 2022). To visualize the NUCAPS-Aqua EDR files software to process the case studies for ingest and display in SHARPpy can be found on GitHub at https://github.com/NUCAPS (Esmaili, 2020) under the SHARPpy and SHARPpy-converter-script repositories. Customized code for processing the case study NUCAPS-Aqua EDR files as Gridded NUCAPS (Berndt et al., 2020) is maintained at NASA MSFC SPoRT and runs in real-time production.

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