Hampton University (HU) and University of Wisconsin (UW) Satellite Atmospheric Sounding and Numerical Weather Forecast Website User's Guide*

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***** A website for illustrating the high-resolution satellite sounding data and their forecast products derived under the HU Severe Weather Research Center (SWRC) and UW NOAA JPSS Proving Ground and Risk Reduction program.***

Introduction

The University of Wisconsin-Madison Cooperative Institute for Meteorological Satellite Studies (UW-CIMSS) and the Hampton University Severe Weather Research Center (HU-SWRC) are partners in the Joint Polar Satellite System Proving Ground and Risk Reduction (JPSS/PGRR) project to improve convective weather forecasting. This objective is being obtained using Direct Broadcast Satellite (DBS) hyperspectral sounding radiances acquired at the UW, HU, and the Miami Fla. NOAA/Atlantic Oceanographic and Meteorological Laboratory (AOML) receiving stations. The DBS calibrated and Earth located radiance data are provided using the University of Wisconsin Community Satellite Processing Package (CSPP) installed on the DBS data processing computers co-located with the DBS antennas.

The satellite hyperspectral instruments providing these data are CrIS (Cross-track Infrared Sounder) on the US Suomi-NPP and JPSS-1 and the IASI (Infrared Atmospheric Satellite Interferometer) on the European Metop-A, Metop-B, and Metop C satellites. Temperature and water vapor soundings are derived from the radiances provided by these instruments, which have a time resolution from 1 to 9 hours, and a horizontal spatial resolution of ~ 15- km. These Polar Hyperspectral Sounding (PHS) soundings are combined with water vapor soundings derived from the GOES-16 Advanced Baseline Imager (ABI) radiances also received in real-time. These combined polar and geostationary satellite soundings, called 'PHSnABI', have a spatial resolution of 2-km and a temporal resolution of 30 minutes, with a capability to produce these products with a frequency of five minutes.

Currently the products are available for two large domains shown in figure 1: (1) a Severe Convective Storm/Tornado Domain (SCSTD) and (2) a Tropical Storm/Hurricane Domain (TSHD). PHSnABI soundings are assimilated on a continuous hourly basis to initialize an 8-km resolution Rapid Refresh (RAP), (https://rapidrefresh.noaa.gov/), configured Weather Research and Forecast (WRF) model (https://ral.ucar.edu/solutions/products/weather-research-and-forecasting-model-wrf) to provide 1 – 12 hour predictions of precipitation and convective initiation of severe storms and tornadoes across the US mainland (i.e., SCST domain), and to provide 1 to 3-day forecasts of Atlantic tropical storm/hurricane development, track, and associated precipitation and wind forecasts for the Mid-Atlantic and Gulf regions of the US (i.e., TSH domain).

In addition, the PHSnABI soundings are used to initialize a 3-km High Resolution Rapid Refresh (https://rapidrefresh.noaa.gov/hrrr/) configured WRF model for providing 1 to 12 hour high spatial resolution convective storm, precipitation, and flood forecasts for the Virginia/North Carolina region. The algorithms used to produce the combined polar and geostationary satellite soundings are described by Smith and Weisz (2017) and Smith et. al, (2020) and example applications of these data to Hurricane and Tornado numerical forecasting can be found in the publications by Shao and Smith (2019) and Smith, Zhang, Shao, and Weisz (2020).

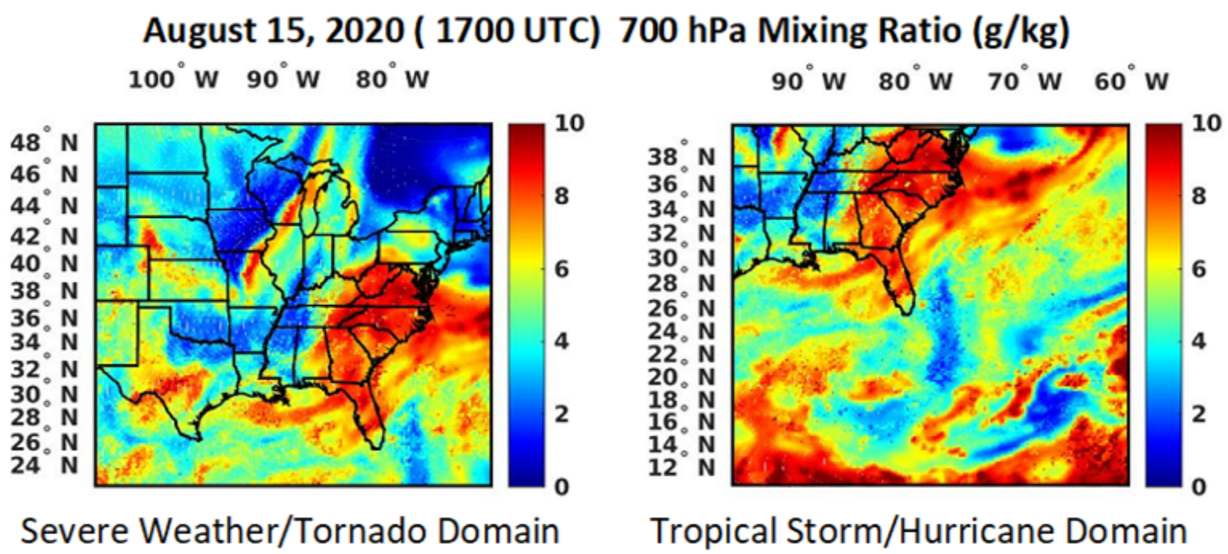

Figure 1. Image of 850 hPa mixing ratio obtained using the PHSnABI soundings produced at the UW for the SCST domain (left) and at the HU for the TSH domain (right).

I. Polar Sounding

A. *HU Polar Sounding*: (Produced at HU)
http://dbps.cas.hamptonu.edu/development/polar_sounding/

Atmospheric temperature and water vapor soundings are produced using the algorithm described by Smith and Weisz (2012, 2017). The sounding products shown here are produced at Hampton University. Derived product images are produced for the 500, 700, and 850-hPa level temperature (left panel on the webpage) and water vapor mixing ratio (left-middle panel on the webpage and shown in figure 2). Images for each variable are shown in two panels for each product: (1) 'SAT+RAP' panels, where the NOAA operational Rapid Refresh

(RAP) 2-hr forecast at the locations and times of the satellite data is used to fill in the gaps in the satellite coverage below optically thick clouds where no satellite soundings are available and (2) 'SAT-RAP' panels where the difference between the satellite sounding values and the NOAA operational RAP 2-hr forecast at the locations and times where the satellite sounding values are produced. The third product (right-middle panel on the webpage) shows both 'SAT+RAP' and 'SAT-RAP' for the Lifted Index (LI) and the Convective Available Potential Energy (CAPE) stability parameters.

Two additional panels are shown displaying the retrieved cloud top pressure and surface skin temperature. The final product (right-most panel on the webpage) shows the satellite ('SAT') derived relative humidity derived at the 150, 200, 250, 300, 350, and 400-hPa levels. It is noted that blank panels may result when the data from satellite orbit received is outside the limited boundaries of the display area shown. The actual digital data used to create these soundings and the retrieved sounding data values can be obtained by clicking on the URL in the 'Job' column of the main retrieval table. The retrieval folder names end in either 'hu' or 'uw'. The 'hu' or 'uw' indicates the DBS system (i.e., HU or UW) used to receive the raw satellite sounding data. Once in the folder, the retrieval is the 'mat' file. It is important to note that the polar satellite sounding data files contain the raw sounding values, before any bias correction has been applied, whereas the images display the 'bias-corrected' satellite sounding values as they are used in the Numerical Weather Prediction (NWP) application. The level 1 radiance data used to derive these soundings is provided in the folder and begins with 'IASI_xxx' for the IASI and 'GCRSO' and 'SCRIF' for CrIS.

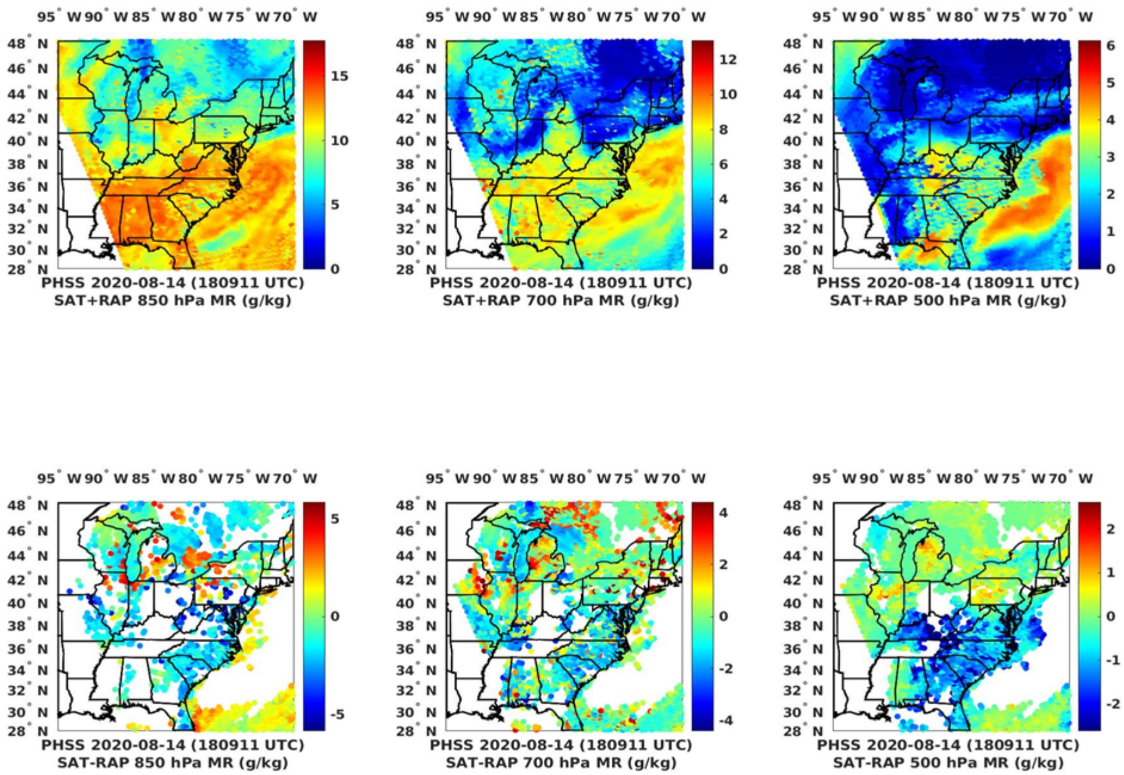

Figure 2. Polar satellite mixing ratio retrieval data produced at HU for August 14, 2020 at 18:09 UTC

B. *UW Polar Sounding:* (Produced at UW)
http://cas.hamptonu.edu/~adinorscia/UWPolar/

These derived product images are the same as mentioned above in the 'HU Polar Sounding' section, except these images are produced using the retrieval data from University of Wisconsin for the UW sounding domain shown in figure 1. The raw (i.e., not biased corrected) sounding retrieval files can be found at ftp://ftp.ssec.wisc.edu/DR/PHS/.

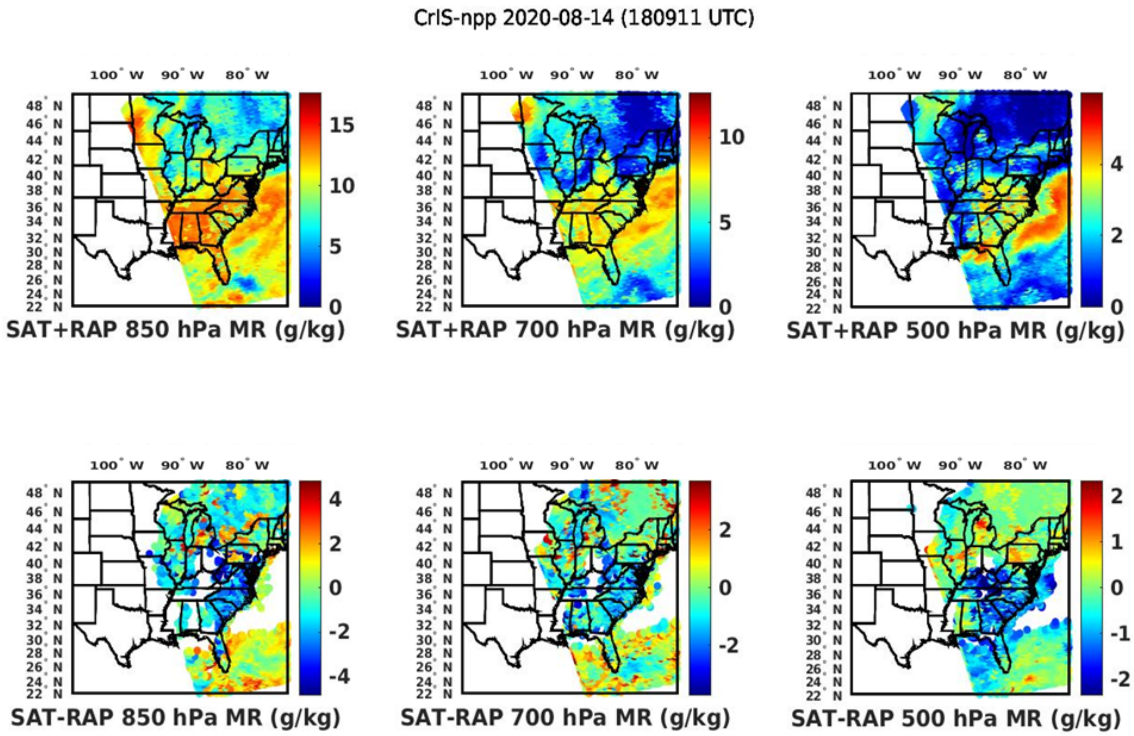

Figure 3. Polar satellite mixing ratio retrieval data produced at UW for August 14, 2020 at 18:09 UTC

II. Polar+GEO Sounding: http://cas.hamptonu.edu/~adinorscia/ABInPHS_plots/

This option provides products similar to the 'Polar Sounding' option but with 2-km spatial resolution and at 30-minute time intervals (the retrievals are produced every 30 minutes, but as of 2020 the plots are updated every hour due to current computer processing limitations). These soundings (PHSnABI) result from a k-d tree fusion (Weisz, et. al., 2017) spatial interpolation and extrapolation of low resolution Polar Hyperspectral Soundings (PHS) to GOES-16 ABI clear air retrieved sounding locations and times in order to provide the highest vertical, horizontal, and time resolution possible from the current polar and geostationary satellite systems. The high spatial and temporal resolution results are useful for atmospheric stability, water vapor, and surface skin temperature monitoring, since the ABI observes the radiance in numerous water vapor and "window" bands. However, since there is very little temperature profile information observed by the GOES ABI, the PHSnABI atmospheric temperature profile products are limited by the spatial resolution of the 15-km CrIS and IASI instruments and the 13-km/1-hr resolution of the RAP 2-hour forecast profiles, used in place of the ABI to spatially interpolate and temporal extrapolate of the PHS temperature soundings to the ABI footprint locations. The PHSnABI water vapor soundings are the most accurate and useful product of the combined PHS and ABI sounding retrieval system.

The annotations 'WithCurrentPolar' and 'WithPastPolar' indicate whether or not, respectively, PHS retrievals were available at the same time as the ABI data used to produce the products shown. The most accurate combined PHSnABI product is the 'WithCurrentPolar' result since time extrapolation of the PHS retrievals is not needed, to produce this product at the geographical location of the polar satellite overpass.

There are five different products for the 'WithCurrentPolar' retrievals and six different products for the 'WithPastPolar' retrievals. The first product shows six panels of 'SAT+RAP' and 'SAT-RAP' temperatures at the 850, 700, and 500-hPa pressure altitude levels. The second product, shown in figure 4, displays the same six panels as the temperature product but for the retrieved water vapor mixing ratio values. The third product shows the results for the LI and Total Totals stability indices as well as the retrieved cloud pressure and surface skin temperature. It is noted that the cloud pressure is blank for cloud-free ABI pixels and the surface skin temperature display shows blank regions ABI cloud-contaminated fields-of-view. The fourth product is only present with the 'WithPastPolar' retrievals and this is because these plots are updated hourly. These plots show the current satellite, RAP, and 'SAT+RAP' LI stability indices in the first three panels, and the bottom three panels show the 1-hour change in LI for each case. The intended use of the first four displays is to "nowcast" the geographical regions where there is a likelihood of severe convective storm development. The fifth product shows the relative humidity at six different upper tropospheric pressure altitudes (i.e., 150, 200, 250, 300, 350, and 400-hPa). This product is intended to support commercial aviation flight planning by displaying the altitude of relatively dry layers. The final product shows 'SAT+RAP' and 'SAT-RAP' relative humidity values at the 850, 700, and 500-hPa pressure altitude levels to indicate where the probability of lower tropospheric cloud formation is probable.

The PHSnABI (PHS and ABI) fusion data are plotted for two different domains and for users to compare the data to RAP data at the same location.

A. HU Total Domain Plots*:* http://cas.hamptonu.edu/~adinorscia/ABInPHS_plots/

These plots use the retrieval data produced at Hampton University and plotted on the Tropical Storm/Hurricane domain shown in figure 1. The data that is plotted can be found by going to the website address, http://cas.hamptonu.edu/~adinorscia/ABInPHS_Files/output/. GIF animations are also available for all figures when clicking on 'Click for GIF Animations'.

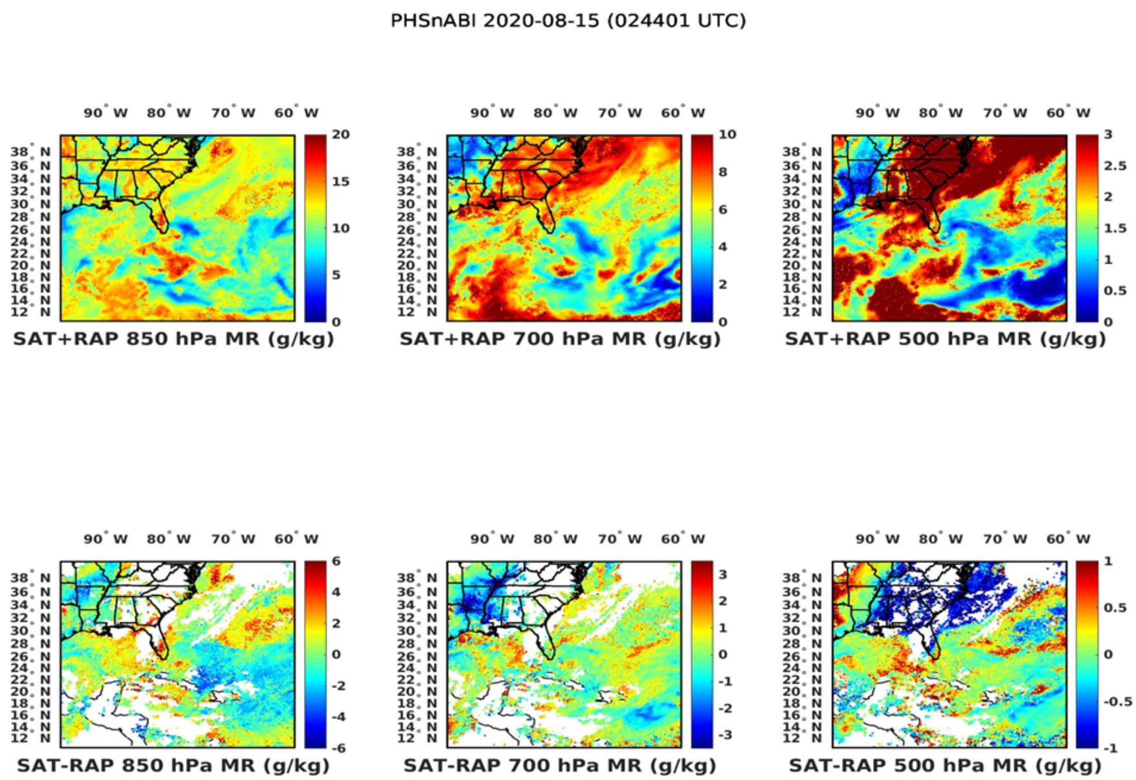

Figure 4. Mixing ratio data from PHSnABI produced for the TSHFD for August 15, 2020 at 2:44 UTC.

B. UW Total Domain Plots: http://cas.hamptonu.edu/~adinorscia/ABInPHS_plots/

These plots use the retrieval data produced at the University of Wisconsin and plotted on the Severe Weather/Tornado domain shown in figure 1. The data that is plotted can be found at these websites: (WithCurrentPolar) ftp://ftp.ssec.wisc.edu/DR/PHSnABI/ and (WithPastPolar) ftp://ftp.ssec.wisc.edu/DR/ABInPHS/. GIF animations are also available for all figures when clicking on 'Click for GIF Animations'.

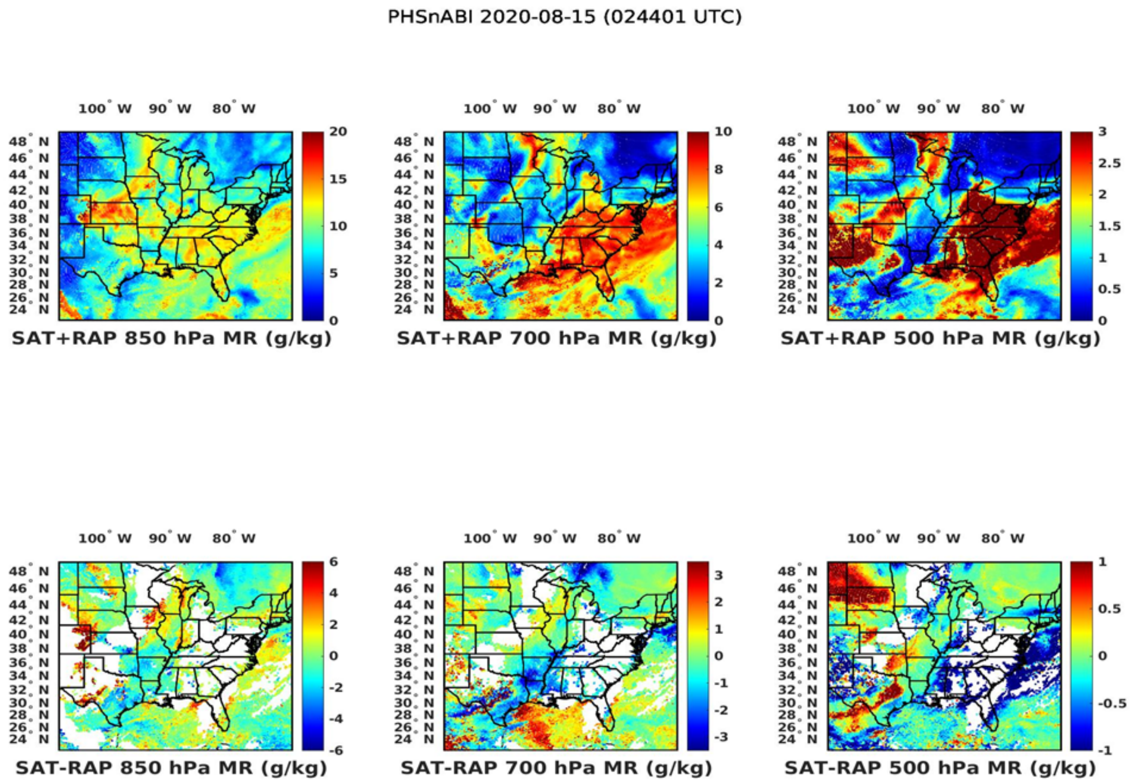

Figure 5. Mixing ratio data from PHSnABI produced at UW from August 15, 2020 at 2:44 UTC.

C. Fusion Sounding Map:
http://cas.hamptonu.edu/~adinorscia/InteractiveMap/FusionMap.html

With this option, the Hampton University fusion data is plotted onto a map where the user can click anywhere to see a PHSnABI sounding compared to the RAP 2-hr forecast sounding plotted for the same area and time. The sounding that is plotted is the average of the sounding data within 50 km of the clicked point. To load the sounding data and map, the user must select the date ('Today' or 'Yesterday'), the hour, and the atmospheric parameter for the map. The parameters that can be loaded onto the map include cloud pressure, surface skin temperature, and 'SAT-RAP' relative humidity values at 850, 700, and 500-hPa. Once the user makes these selections, they can click anywhere on the map to look at the soundings for the fusion and RAP data plotted onto the same Skew-T diagram. An example of this is shown in figure 6. In this figure, the date, hour, and parameter for the map are chosen at the top of the webpage. Once these selections are made, a map is loaded for the user to click anywhere to see the sounding comparison between

PHSnABI data and RAP data. The box on the left image depicts the area clicked in figure 6 and the sounding comparison for that selected area is seen in the right image of the figure. If a sounding does not load, that is because there is no PHSnABI data available for that location due to clouds. You can see that the PHSnABI sounding is much drier than the RAP profile 500 – 250-hPa layers. The comparison with the closest radiosonde (station 72248) observation, shown below, verifies the difference between the satellite sounding and the RAP 2-hr forecast profile.

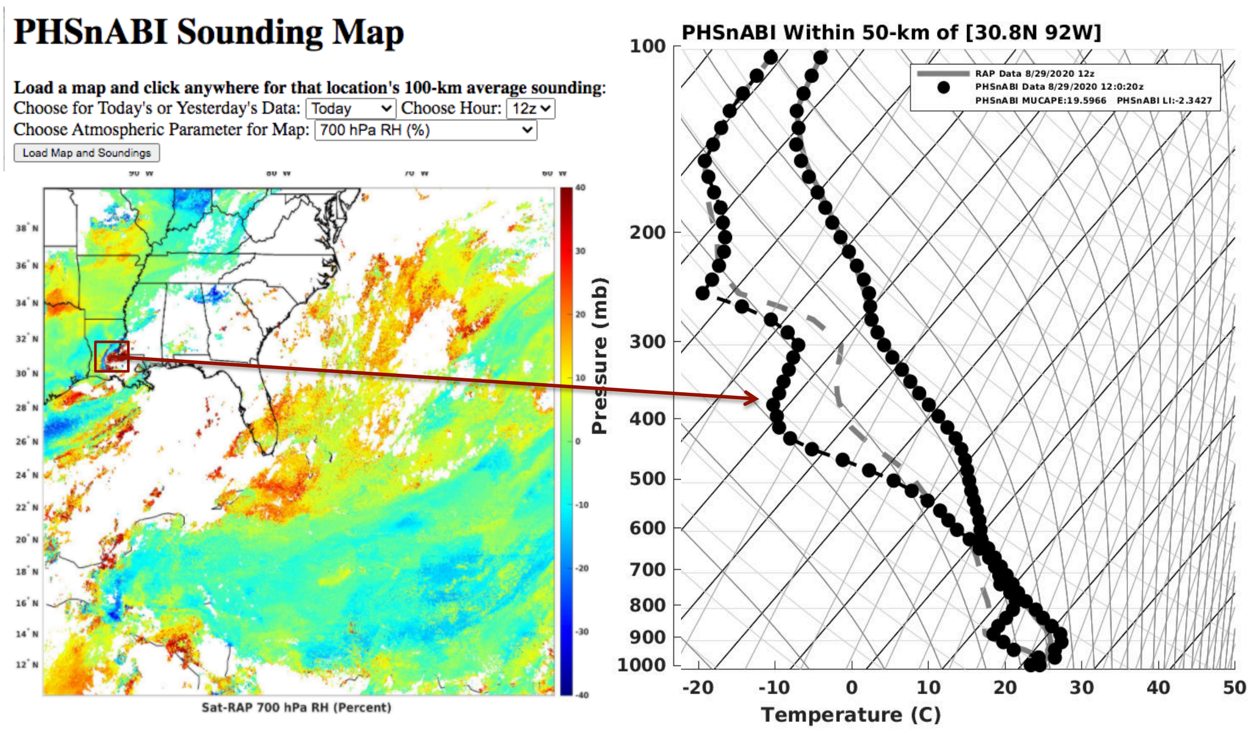

Figure 6a. The fusion map (left image) shows the cloud pressure for 12 UTC on August 29, 2020. Once you click on the fusion map, the corresponding sounding comparison will open for the specific area that was clicked (Box center on the Map). The comparison (right image) displays the soundings for PHSnABI and the RAP 2-hr forecast at the same time and place.

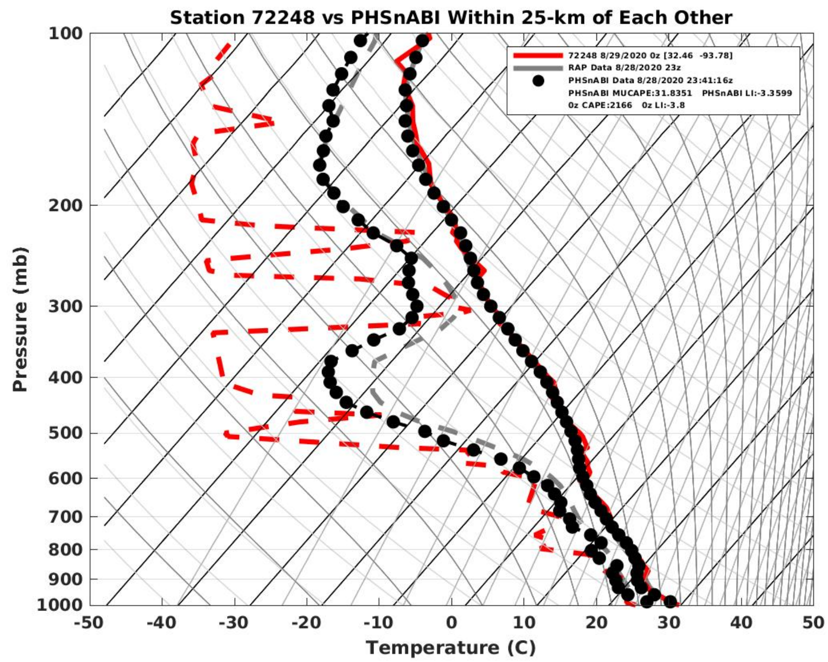

Figure 6b. Comparison between the 2-hr RAP forecast profile and PHSnABI satellite sounding with the radiosonde (station 72248) observation closest to the location chosen in figure 6a.

III. Radiosonde Comparison:

http://cas.hamptonu.edu/~adinorscia/InteractiveMap/interactive-map.html

The 56 radiosondes launched twice per day across the USA within the region of interest are used to validate the PHS and PHSnABI soundings. The user first selects the date, hour, and instrument that they want to compare with the radiosonde data. These instruments include CrIS, IASI, PHSnABI (for both HU and UW), and NUCAPS (the NOAA NESDIS operational combined infrared and microwave sounding retrieval). After selecting the inputs, the user can click on any red square next to a radiosonde station number to load the comparison. The red squares denote the locations where a radiosonde and satellite sounding comparison are available. Each Skew-T sounding plot illustrates the 00 UTC and 12 UTC radiosondes, the RAP 2-hr forecast sounding valid for the selected instrument's time and interpolated to the instrument's sounding location, and the selected instrument's sounding. The RAP and selected instrument soundings are averaged within 25 km of the radiosonde location. Statistics (mean and standard deviation of the differences between satellite profile retrieval and radiosonde) are provided for the temperature and dewpoint soundings for the time period chosen.

These statistics can be seen for the selected day, time, and instrument by clicking 'Selected Day's Statistical Plot' or for a range of dates by clicking 'Go To Cumulative Statistics Page' at the top of the page. After clicking on the Cumulative Statistics button, the user must choose the instrument, range of dates, and stations (type a single station number, multiple station numbers, or All for all stations). Also, at the top of the webpage, there is a 'Go To SPC Comparison Page' button.

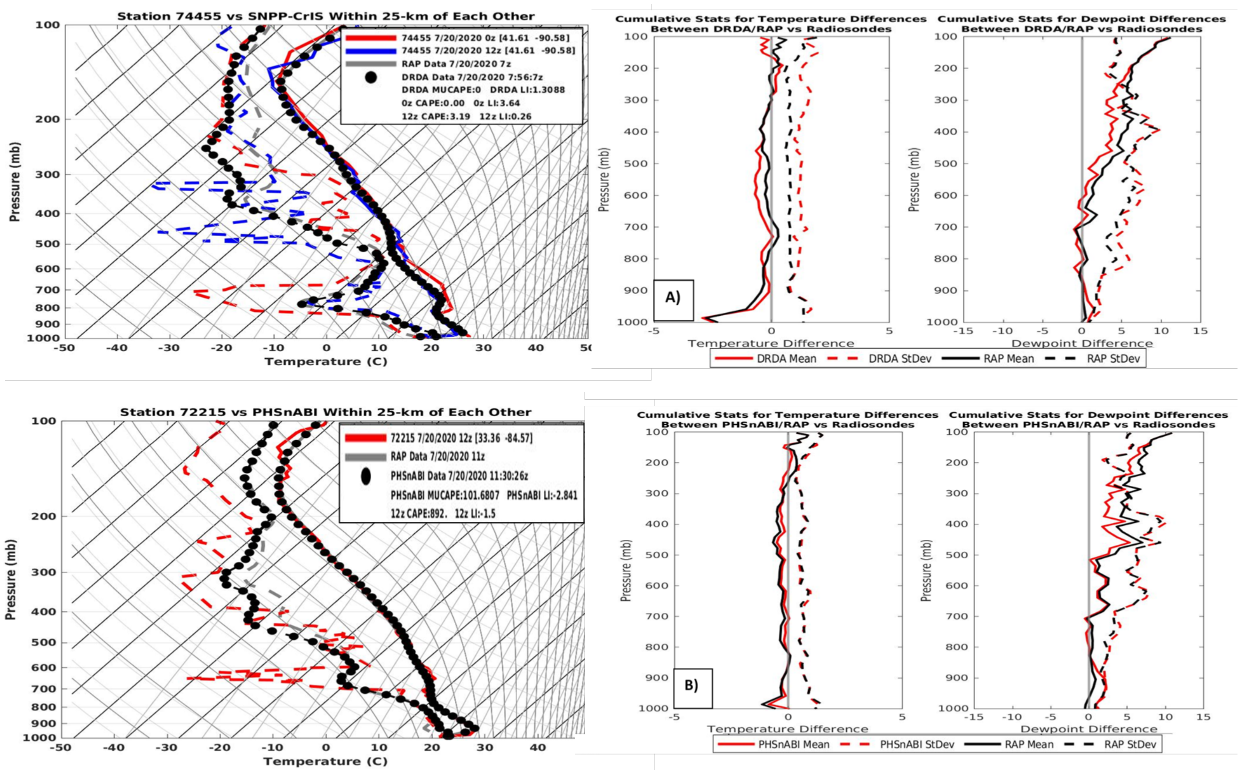

Figure 7A and B. Radiosonde comparisons (left images) and the selected time statistics (right images) for July 20, 2020 for SNPP-CrIS at 7:56 UTC (top) and for PHSnABI at 11:30 UTC (bottom).

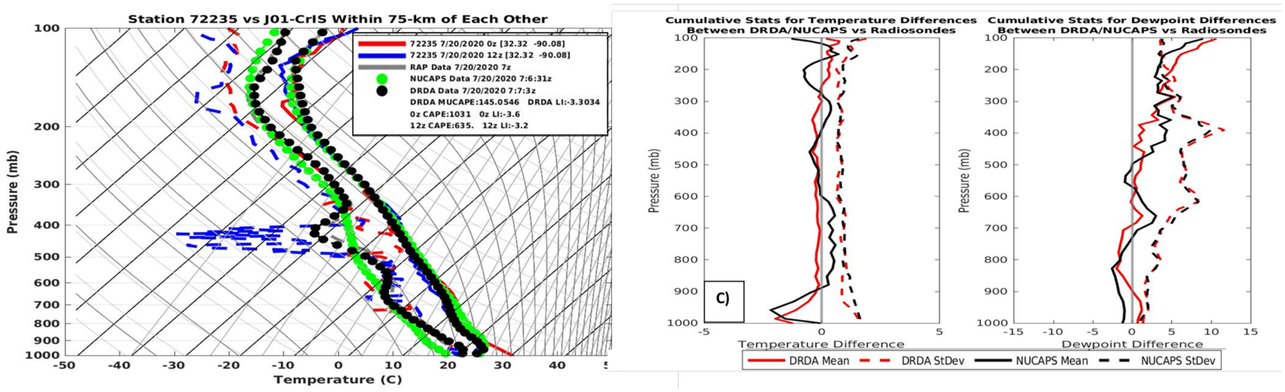

Figure 7C. The same as figure 7A and B, except these comparisons use data from J01-CrIS at 7:07 UTC and NUCAPS at 7:06 UTC.

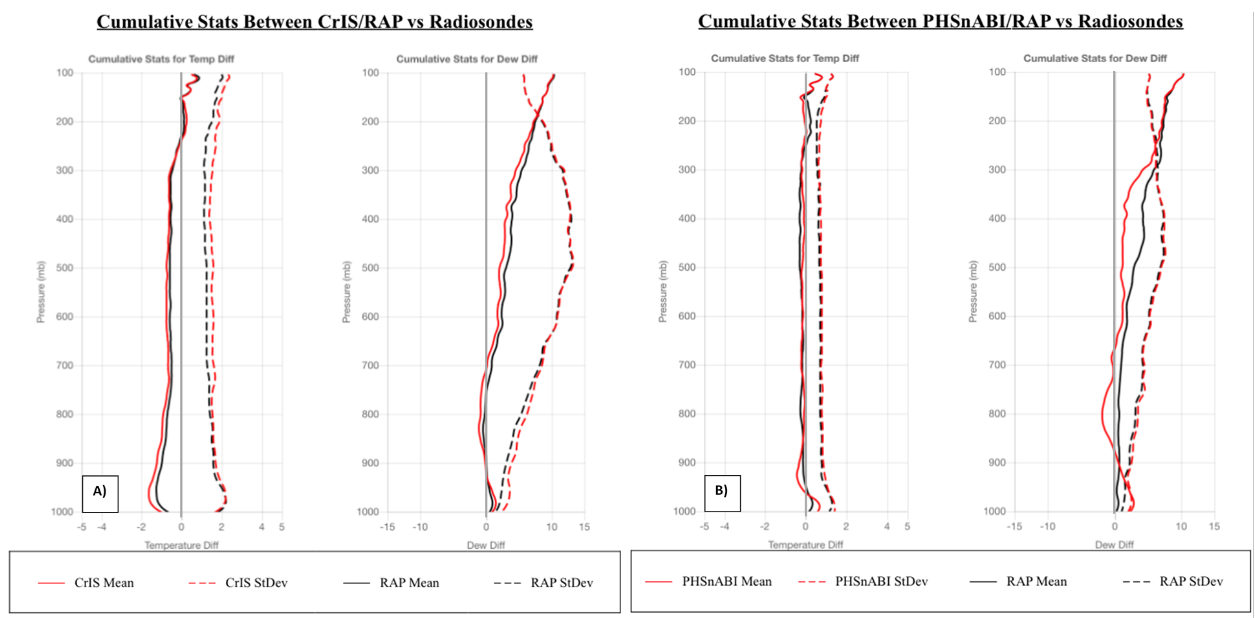

Figure 8A and B. July 2020 statistics showing mean and standard deviation temperature and dewpoint temperature differences between CrIS/RAP and radiosondes (left) and PHSnABI/RAP and radiosondes (right).

IV. SPC Comparison Page:

http://cas.hamptonu.edu/~adinorscia/InteractiveMap/SPCcompare.html

The Storm Prediction Center (SPC) comparisons plot PHS/PHSnABI stability indices along with storm reports to show the capability of the stability parameters to be used to forecast severe weather. The stability indices consist of CAPE and LI and the SPC storm reports are plotted within a 12-hour period after the time of the stability parameter measurements. To see these comparisons, the user must select the instrument, date, time, and stability parameter. When selecting the time, there are two options. First, 'SPC Storm Reports Within 12 Hours After AM Stability' plots the PHS/PHSnABI stability measurements from morning overpasses (0:00-11:59 UTC) and the storm reports within the 12-hour period after the overpasses. The other option, 'SPC Storm Reports Within 12 Hours After Yesterday's PM Stability' plots the PHS/PHSnABI stability data from the evening/night overpass (12:00-23:59 UTC) from the day before the user's chosen date and the storm reports within the 12-hour period after the overpass, which would have reports from the user's chosen date. This means the user is selecting the date they want for the storm reports, not at the time of the PHS/PHSnABI stability parameter.

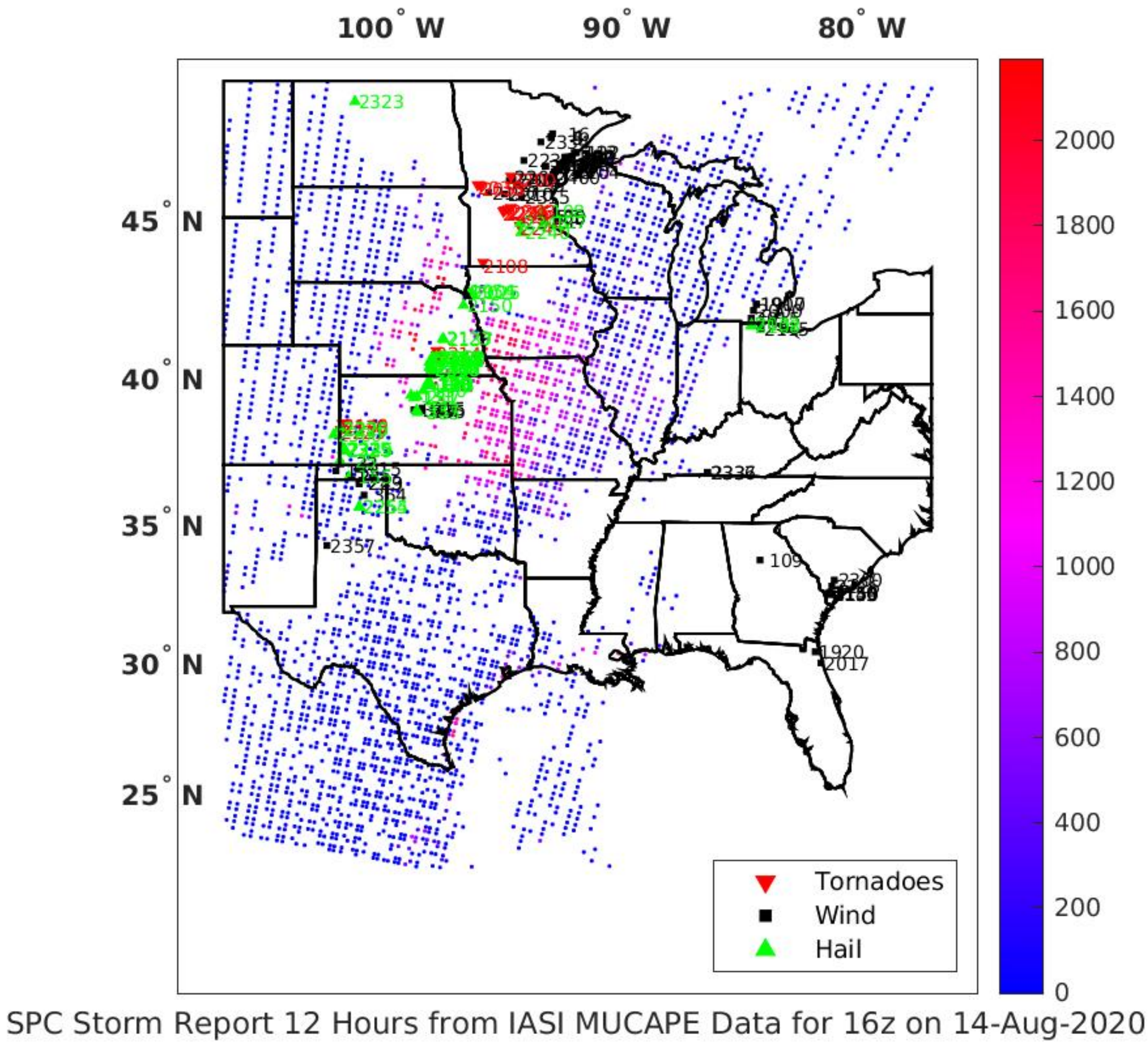

Figure 9. SPC comparison using IASI Most Unstable CAPE (MUCAPE) data from 16z on August 14, 2020. Although, no MUCAPE data is around the cluster

of tornadoes (red triangles) in Minnesota, an area of unstable MUCAPE is present starting around the cluster of hail reports (green triangle) and extending northeast, towards the tornado cluster and wind cluster (black boxes).

Questions regarding the applications and use of the PHSnABI product website should be directed to Professor Bill Smith Sr. at bill.l.smithsr@gmail.com or Mr. Anthony DiNorscia at anthonycdinorscia@gmail.com .

V. Forecast Products

As mentioned earlier there are three types of numerical forecasts conducted on a daily 24/7 operational basis:

(1) http://cas.hamptonu.edu/~qi.zhang/home/mainpage.html which accesses the large area HU and UW produced PHSnABI retrieval data, and US region hourly 0 – 12 hour forecasts of STP and precipitation from an 8-km Numerical Weather Prediction System, (2) 'http://cas.hamptonu.edu/~qi.zhang/Hurricane_8km/ which accesses western Atlantic, Gulf Coast, and South Eastern Mid-Atlantic region forecasts of surface pressure, wind, and accumulated precipitation forecasts, and (3) http://cas.hamptonu.edu/~qi.zhang/HWT3km/Mainpage.html which provides local area 3-km Numerical Weather Predictions of hourly precipitation and severe weather parameters including the Significant Tornado Parameter (STP), Significant Hail Parameter (SHIP), Supercell Composite Parameter (SCP), Energy-Helocity Index (EHI), Vorticity Generation Parameter (VGP), Lifted Index (LI), and the Most Unstable CAPE (MUCAPE). The local area can be moved around the continental USA, but ordinarily covers the Western VA, VA, and NC mid-Atlantic region. Particular questions regarding the SWRC forecast system and the products shown at the above website addresses should be directed to Qi Zhang at: qi.zhang@hamptonu.edu.

References:

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