3.7 WHY OPERATIONAL METEOROLOGISTS NEED MORE SATELLITE SOUNDINGS

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1. INTRODUCTION

Operational meteorologists use atmospheric soundings (profiles of temperature and moisture) to build an understanding of weather in the 3-dimensional atmosphere. The two traditional sources of soundings are radiosondes (in situ soundings) and numerical weather prediction products (modelled soundings). Here we discuss what value satellite soundings add and which data gaps still exist. We present evidence gathered from product evaluation campaigns funded by the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction (PGRR) program.

In 2002, with the launch of hyperspectral infrared instruments onboard polar-orbiting satellites, the vertical resolution of sounding observations from space improved enough that they became relevant to forecasters. In 2014 NOAA released satellite sounding products generated by the NOAA-Unique Combined Atmospheric Processing System (NUCAPS) into AWIPS-II (Advanced Weather Interactive Processing System) for the first time. AWIPS-II is the operational decision-support platform for the National Weather Service (NWS). Now forecasters are starting to use these high vertical resolution satellite soundings alongside radiosondes and forecast models to build their conceptual models of evolving weather systems.

At the Hazardous Weather Testbed in 2018, NOAA and NASA product developers together with operational meteorologists evaluated NUCAPS soundings to determine if they helped in characterizing pre-convective conditions to improve severe weather forecasting. NUCAPS soundings from the Suomi-NPP platform are available in AWIPS-II around 18:00 UTC, which is when Summer-time convection occurs. We see forecasters used NUCAPS soundings to characterize (1) the **vertical thermodynamic state** (2) **spatial gradients** of temperature, moisture and atmospheric instability so that they can identify areas of interest, and (3) **3-dimensional features** in the mid-to upper troposphere. The wide swaths of satellite soundings available from each overpass makes this possible, which is a feature unique to satellite observations; the network of radiosondes is simply too sparse to allow the interrogation of spatial gradients of atmospheric moisture or instability.

Now forecasters are looking forward to receiving a second set of NUCAPS soundings in the early afternoon from the NOAA-20 platform later in 2019 when it becomes operational. NUCAPS from S-NPP and NOAA-20 (~50 min apart) will provide two snapshots in time of vertical observations that will help forecasters, to some degree, verify whether areas of instability or thermodynamic extremes have the potential to develop into dangerous conditions. **Currently there is a gap in the availability of observations that depict how vertical atmospheric structure changes over time**. Operational sounding capability from geostationary platforms (with high temporal frequency observations) is limited to one or two vertical layers. We argue here that there is a need for hyperspectral instruments on geostationary orbit from which to retrieve high vertical resolution soundings to fill this data gap and better equip forecasters with the information they need to improve their decision making of severe weather.

2. DISCUSSION

2.1. Ways in which forecasters are learning to exploit NUCAPS

To assess the potential for severe weather development, forecasters need ready access to high quality data that they can visualize and interpret on the fly. There is no time to waste. The challenge for product developers is to customize their products enough to meet these needs so that they may improve, not impede, decision making in this fast real-time environment. HWT provides an opportunity each year for developers and forecasters to come together and evaluate products ahead of release in the operational environment. It gives them the opportunity to communicate with each other to better understand both product requirements (what do you need?) and product capability (what is possible?). In 2018 the

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goal was to evaluate whether an improvement in NUCAPS latency will improve its value to forecasters.

Figure 1 shows how NUCAPS is visualized in AWIPS-II, which is a common data access point and analysis framework for daily operational meteorology. Forecasters can overlay NUCAPS data onto other spatial data, such and GOES and model output, to see where sounding products are available. By clicking on the dots, a vertical profile or skew-T diagram is generated and can be analyzed alongside other model and radiosonde data. Forecasts can also display NUCAPS-derived parameters, such as lapse rates and convectively available potential energy (CAPE), in 2-dimensional planar views. This allows forecasters to quickly digest a lot of information. Feedback from the HWT endorsed this display strategy (see Appendix A).

Operational meteorologists are pre-occupied with three basic questions*: What happened? What is happening? What is going to happen?* Forecasters answer these questions by analyzing the vertical, spatial, and temporal information available to them from both models and in-situ observations. **NUCAPS generates sounding observations that are independent of models** and thus compliments these traditional sources by adding unique meso-scale information about the vertical atmosphere.

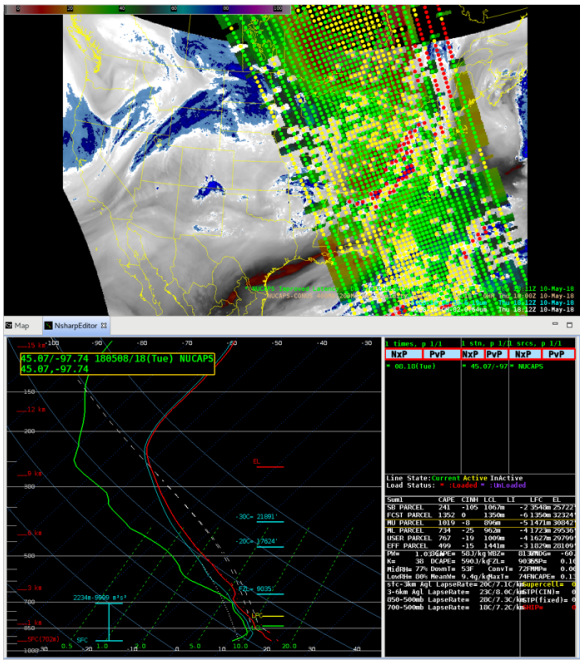

Figure 1: Example of NUCAPS availability (top) in AWIPS-II. Dots can be clicked by forecasters to display a skew-T diagram (bottom) for comparison to radiosondes and derived parameters. Color coding indicates data quality.

NUCAPS arrives on a forecaster desk around 2:30 pm, or 1800–2000 UTC, which is when forecasters would often call for the launch of a special radiosonde to help characterize pre-convective conditions ahead of an anticipated severe weather outbreak. With NUCAPS now in their native AWIPS-II environment, “it is like having hundreds of 1800 UTC radiosondes” (Smith and Nietfeld, 2018).

As 2,200 km wide swaths from pole-to-pole, NUCAPS soundings also capture spatial gradients. Each sounding is retrieved independent of its neighbors so that a planar view of NUCAPS temperature or moisture is spatially uncorrelated. This differs from model fields that are highly correlated in time and space. As spatially uncorrelated observations, **NUCAPS soundings are not constrained by convective parameterization and can depict sharp gradients** that guide forecaster attention to areas of interest. This is specifically an area where NUCAPS provides value in addition to radiosondes, which are spatially sparse and do not form a continual surface.

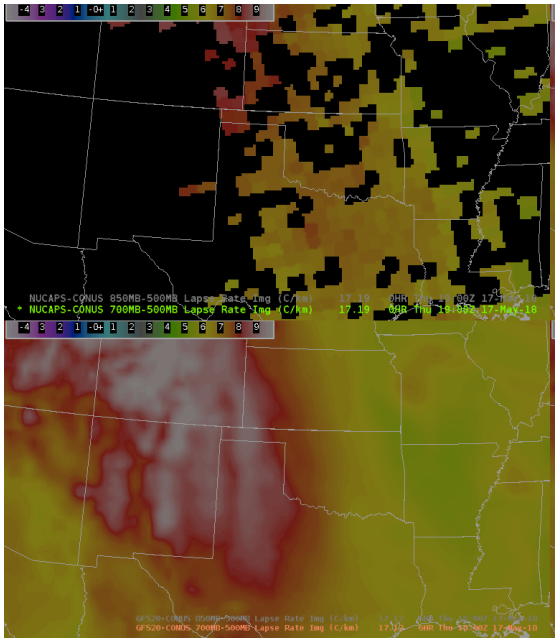

Figure 2: Gridded NUCAPS lapse rates as displayed in AWIPS (top) compared with GFS model output (bottom) for an event on May 19, 2018.

2.2. Future ways in which time-sequence of NUCAPS soundings could add value to forecasts

NUCAPS generates soundings from multiple satellite platforms and in 2019 will become operational for the NOAA-20 launched in Nov, 2017. This will add a second set of soundings (50 min apart) in the early afternoon when forecasters are evaluating storm potential. **Figure 3** shows a sequence of NUCAPS

from Suomi-NPP and the new NOAA-20 satellite to demonstrate this concept. At 17Z UTC the environment is becoming unstable, and from 18Z to 20Z, the instability is strengthening.

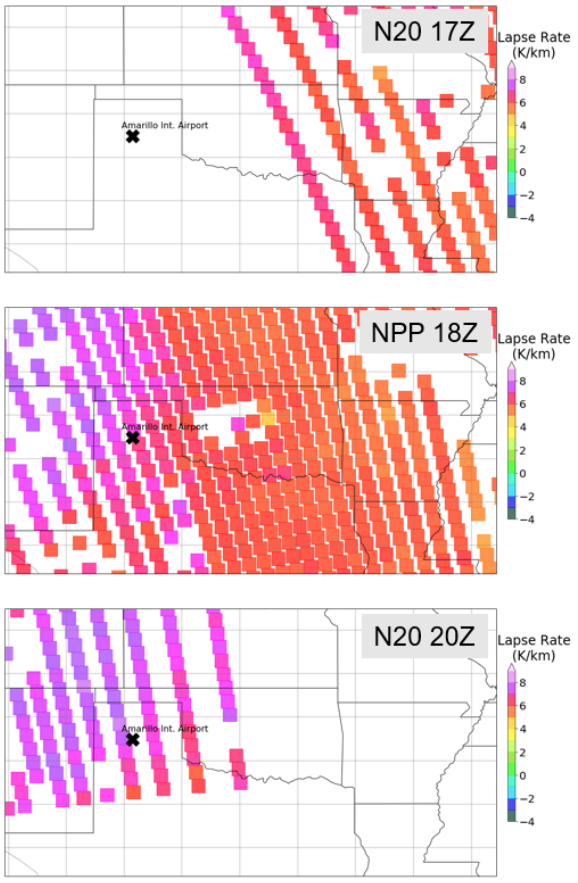

Figure 3: Snapshots of NUCAPS-derived lapse of instabilities from NOAA-20 (N20) at 17Z, Suomi-NPP at 18Z, and N20 at 20Z for May 19, 2018. The X indicates the location of the Amarillo International Airport.

As mesoscale observations of the thermodynamic state, the main application forecasters use **NUCAPS** for is to help them determine **what is about to happen next** by greatly improving their situational awareness of instantaneous conditions and localized feedbacks not captured by NWP systems in real-time (Doback 2017). In severe weather forecasting scenarios, NUCAPS soundings help characterize the pre-convective environment (**Figure 4**) to understand when and where storms may develop. The pre-convective environment evolves fast over a short, two to three-hour period. Thus, NUCAPS soundings must be readily available in this time period to be useful in this application. The addition of soundings from the NOAA-20 satellite will increase both spatial and temporal information with which forecasters can assess the evolution of atmospheric instability within this short forecasting window.

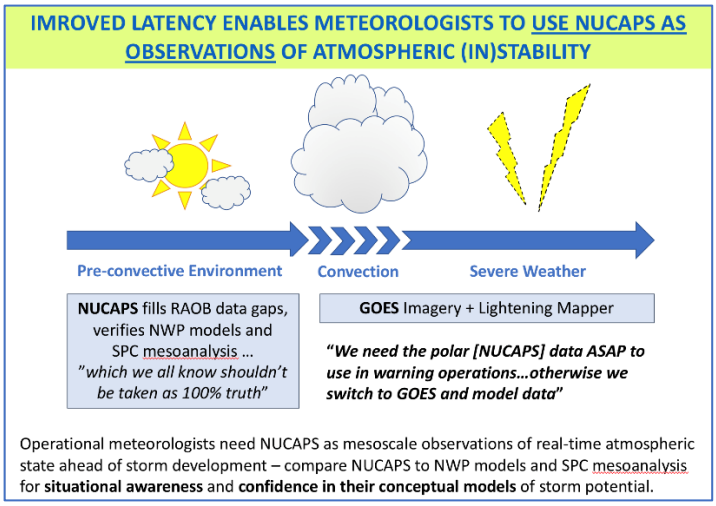

Figure 4: Graphic representation of data needs as weather evolves (Smith et al. 2018b).

3. CONCLUSION

Product latency is critically important in nowcasting. The period between when an observation is made and when it becomes available to forecasters largely determines its usefulness. In 2018 a low latency pathway for NUCAPS was tested at HWT and the response could not have been starker. Where feedback from the 2017 HWT evaluation was a "yes we can see its value but it arrives too late so has limited value", the 2018 HWT feedback was a resounding "yes we find it useful and would like more of them".

Why do forecasters voice their need for an even greater volume of high-vertical-resolution satellite soundings when they already have access to wide swaths of NUCAPS? The answer is twofold. Firstly, nowcasting stand to benefit greatly from high temporal frequency observations that are thermodynamically consistent with soundings. These include **observations of turbulence and wind** (which can be derived from soundings) at multiple layers in the troposphere. It is the characterization of fast evolving events with complex localized feedbacks not captured by modern-era NWP systems that is sorely missing in current observational networks. Secondly, in nowcasting scenarios forecasters are severely time-limited and under great pressure to focus their attention where it is needed. Nowcasting will benefit from targeted observations that save forecasters time by focusing their attention on fast evolving systems. If we can generate NUCAPS soundings (that include temperature, moisture and trace gases such as O_3, CO, CH_4 and SO_2) from instruments on a geostationary platform, then the thermodynamic and chemical environment can be measured at regular intervals so that sudden changes can be flagged for closer inspection. High temporal

frequency NUCAPS observations will help fill a critical data gap and equip forecasters to evaluate trends over space *and* time to verify those modelled by NWP systems.

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5. APPENDIX: FEEDBACK FROM HAZARDOUS WEATHER TESTBED 2018

Question: **How was NUCAPS utilized in your analysis today?**

"*I used gridded NUCAPS mid-level lapse rates to verify my initial analysis of the atmosphere. I compared NUCAPS to HRR/GFS/NAM and SPC Mesoanalysis. NUCAPS was the closest to the SPC Mesoanalysis, which added confidence to my perception of severe threat and which areas to watch.*"

"*NUCAPS gradients are helpful for situational awareness prior to convective development*"

"*NUCAPS was used during the pre-storm environment and comparisons of sounding derived parameters with SPC mesoanalysis showed good agreement. This increased my confidence in its use in an operational environment*."

"*A swath of NUCAPS soundings came in from a 1941 UTC pass… and showed high CAPE and modest mid-level lapse rates, thus supporting my idea of sub-severe convection*"

"*I had a chance to use NUCAPS to monitor the air mass in front of the squall line and found it to be a useful tool in the forecast process. It identified steep lapse rates and some mid-level drying that contributed to the high wind threat*"

"*NUCAPS helped verify gradients and severe weather concerns*"

"*I used NUCAPS to show instability and overall moisture in the mid- to upper troposphere*"

"*NUCAPS matched up well with RAP model soundings*"

"*I used NUCAPS to sample the boundary layer inflow into the shortwave trough*"

"*I was able to analyze the pre-convective thermodynamic environment using NUCAPS*"

"*Used NUCAPS to view the environment ahead of the supercell*"

"*NUCAPS was utilized to assess the environment during the afternoon just prior to convective initiation. A special 19 UTC sounding was launched and NUCAPS thermodynamic values matched well, lending confidence to the product*"

"*NUCAPS is useful as a pre-storm analysis tool…to determine convective potential*"

"*NUCAPS gave me confidence in the wind threat*"

"*NUCAPS showed environments that were becoming more moist and unstable, which would lead to SPS or SVR late in the forecast shift*"

"*I like being able to see the environment from the top down…A whole different perspective*"

Question: **How could NUCAPS be more useful to you in future?**

"*Improving the temporal availability*"

"*More frequent satellite passes*"

"*Hopefully the NOAA-20 satellite will provide additional and more timely data*"

"*The lower the latency time between the satellite pass and ingest of the soundings into AWIPS, the more likely I would be to use NUCAPS*"

"*Additional satellites that could provide additional NUCAPS data would be great"*

"*More timely. Right now it is too slow and too late*"

"*Having products in as close to real-time as possible is very helpful when assessing a rapidly changing convective environment*"

"*Reducing data latency in a warning environment is extremely important*"

"*Direct broadcast was very useful. When monitoring environmental changes before storms develop, the more recent the data, the better*"

"*Soundings closer to the expected development time of convection is very useful*"

"*I could see a real advantage to being able to get the data more quickly to the forecasters to pinpoint areas of potential convective development*."

"*NUCAPS needs to be offered as soon as possible to the forecasters. The faster we can translate that data and incorporate it into our severe forecast mindset, the better the public will be as we will have real data, not model derived, top-down that is not available anywhere else*."

"*Liked having it available much quicker after the pass and also helped diagnose the hail threat.*"

"*We need the JPSS data ASAP in order to use it in warning operations. If we need to wait hours, we won't use it because we will instead use GOES and model data*."

"*Timing is everything when using NUCAPS for convection.*"

"*Lower latency of NUCAPS is vital in increasing the utility of the profiles.*"