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EVALUATION OF NUCAPS PRODUCTS IN AWIPS-II: RESULTS FROM THE 2017 HWT

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1. INTRODUCTION

NUCAPS – the NOAA-Unique Combined Atmospheric Processing System – combines measurements from infrared and microwave instruments aboard polar orbiting satellites to retrieve temperature, moisture, and trace gas products. These satellite soundings are currently generated operationally from the instrument suites on MetOp-A/B (IASI/AMSU) and Suomi-NPP (CrIS/ATMS). Once NOAA-20 (CrIS/ATMS) becomes operational, twice daily NUCAPS soundings will be available from four separate satellite platforms. Unlike the single point source nature of upper-air soundings from a radiosonde, a swath of satellite soundings provides a 3-Dimensional representation of the atmosphere.

For the last three years NUCAPS soundings have been evaluated at the NOAA Hazardous Weather Testbed (HWT) within the NOAA/NWS weather forecasting and display toolkit, AWIPS-II (Advance Weather Interactive Processing System). The HWT is a joint facility located at the National Weather Center (NWC) in Norman, Oklahoma managed by the National Severe Storm Laboratory (NSSL), the Storm Prediction Center (SPC), and the National Weather Service Oklahoma City/Norman Weather Forecast Office (OUN). Each year at HWT, researchers and developers have the opportunity to directly interact with NWS forecasters as they test and evaluate new and improved satellite data products for National Weather Service operations. NUCAPS products were evaluated during the GOES-R/JPSS Experiment as part of the HWT Satellite Proving Ground. This testbed falls under the Experimental Warning Program (EWP), which focuses on the detection and prediction of small scale weather events, from minutes to hours in advance. The EWP GOES-16/JPSS experiment is held over four weeks, where each week products are evaluated in AWIPS-II by a different group of forecasters (three NWS forecasters and one broadcast meteorologist) in their typical shift environment, providing feedback to developers through daily debrief and surveys, live GOES-16 HWT Blog posts (HWT 2017a), as well as weekly "Tales from the Testbed" final evaluations presented by forecasters (HWT 2017b).

The continued improvement of NUCAPS products in AWIPS-II is driven by forecaster needs and feedback received through developer-user interaction at the HWT and elsewhere. Top-of-atmosphere (TOA) radiance measurements exhibit lower sensitivity to conditions in the boundary layer. As retrievals from such TOA measurements, NUCAPS soundings thus have higher uncertainty within the boundary layer. This is a weakness radiosondes or model fields do not have. However, unlike radiosondes and model fields, the strengths of NUCAPS soundings include high quality model-independent mid-tropospheric information as well as mesoscale consistency multiple times a day. In Section 2 we discuss how forecasters use NUCAPS soundings in operations to characterize and evaluating the pre-convective environment. Forecasters attest to the fact that NUCAPS sounding improve their situational awareness, help verify the quality of model forecasts, and supplement temporal and spatial gaps in traditional observations. For additional information on NUCAPS capabilities and characteristics within operational weather forecasting, please see the training modules provides by EWP (2017a,b).

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2. DISCUSSION

Although satellite soundings cannot replace models or in-situ measurements, NUCAPS value is in providing data that supplement and/or complement traditional forecasting techniques. NUCAPS soundings are particularly useful in a) regions where observations are sparse, b) during the temporal gap between 1200 UTC and 0000 UTC radiosonde launches, and c) when conventional observation/systems fail. In this section, we discuss four cases from the HWT (2017a) where forecasters found NUCAPS to add value to their evaluation of the pre-convective environment as model-independent observations that improve situational awareness and help identify regions to monitor closely as convection develops.

2.1 CASE #1 – Mixing Ratio

This first case highlights the value of high quality mid-level moisture observations as independent verification of model forecasts.

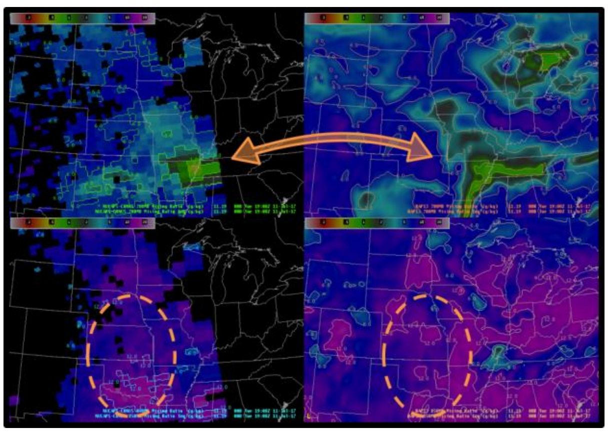

Figure 1: NUCAPS soundings add value in forecaster interrogation of mid-level moisture (700-300 hPa). When compared to RAP13 (right column), NUCAPS mixing ratio (left column) at 700 hPa (top row) correctly observes the magnitude and shape of the moisture gradient. However, in the boundary layer at 850 hPa (bottom row) NUCAPS sometimes has a dry bias. This case is described by forecaster ISU2004 (2017).

Figure 1 depicts water vapor mixing ratio at 700 hPa (top two panels) and 850 hPa (bottom two panels) for NUCAPS (left two panels) and the Rapid Refresh model, or RAP (right two panels). NUCAPS and RAP mixing ratios at 700 hPa both display a dry tongue stretching from Tennessee westward and up across Missouri (see orange arrows). Forecaster ISU2004 (2017) commented that they are "*very impressed how well NUCAPS matches up with the latest model data at 700 hPa*". At 850 hPa, however, the forecaster correctly noted that NUCAPS tends to be a bit drier in patches compared to mesoscale forecast models. This can be explained by the lower sensitivity TOA measurements generally have to boundary layer conditions. Efforts are underway to investigate how NUCAPS boundary layer can be improved.

Despite a dry bias closer to the surface, this case highlights how NUCAPS observations contribute valuable information on mid-level moisture – information that is model-independent and thus not influenced by erroneous theoretical assumptions and misrepresentation of dynamic processes.

2.2 CASE #2 – Identifying Freezing Layers

In this case a forecaster explains an innovative way of utilizing NUCAPS soundings to monitor important temperature levels within the atmosphere.

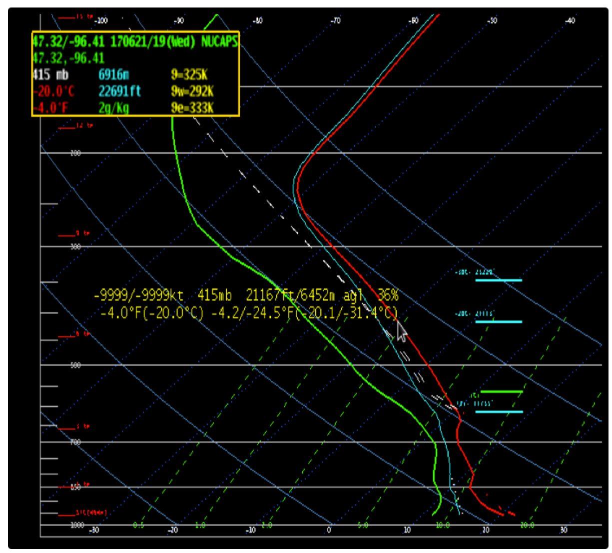

Figure 2: NUCAPS observed vertical temperature from the surface to top-of-atmosphere, this gives forecasters the ability to identify where important freezing layers occur used to. In this figure, a skew-T diagram of a 1900 UTC NUCAPS sounding which has temperature (red) and dew point temperature (green). The -30, -20, and 0 ºC freezing layers are indicated on the skew-T to the right of the temperature profile in cyan. The details of this case are discussed further by Ironman (2017).

During storm development, the forecaster used NUCAPS skew-T's to quickly locate freezing temperature levels such as 0 and -20 °C. In the NUCAPS sounding above (Figure 2) these temperature levels are easily identified by the cyan horizontal markers/labels, which are automatically generated in AWIPS-II on each skew-T figure (see cyan labels right of red temperature profile). The 0 and -20 °C temperature levels can be used when assessing 50 and 60 dBz radar heights to determine potential hail size aloft for warning issuance.

Although there are numerous products within AWIPS that can provide similar temperature level information, the forecaster points out that "*[m]any other tools use model data which can have their own errors, but NUCAPS is actual observation and can bring more confidence when analyzing storms in the vertical*" (Ironman, 2017).

2.3 CASE #3 – Lapse Rates

In this case a forecaster examined NUCAPS 700-500 hPa lapse rates against three models: High-Resolution Rapid Refresh (HRRR), Global Forecast System (GFS), and North American Mesoscale Forecast System (NAM).

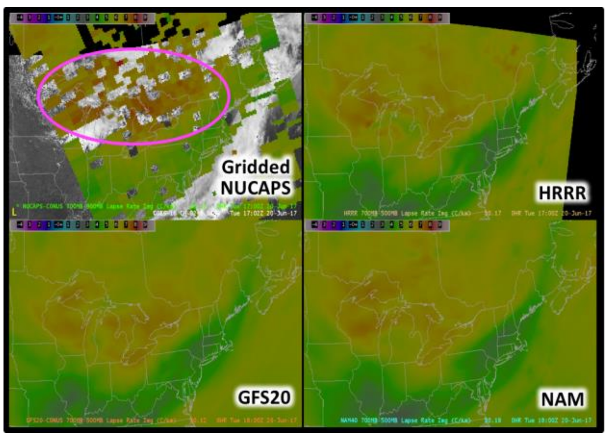

Figure 3: NUCAPS sounding observations have value when verifying and/or assessing forecast model fields. Here 1700 UTC NUCAPS (top left) 700-500 hPa lapse rate is evaluated against three models; HRRR – High Resolution Rapid Refresh at 1700 UTC (top right), GFS20 – Global Forecast System at 1800 UTC (bottom left), and the NAM – North American Mesoscale Forecast System at 1800 UTC (bottom right). Compared to these models, NUCAPS observes a stronger gradient in the 700-500 hPa lapse rate (magenta circle) which suggests greater atmospheric instability within this region. For a detailed discussion on this case see White and Smith (2017).

Comparing the four panels in Figure 3 above, NUCAPS (top left panel) is easily identified among the three models by its coarser resolution and data gaps due to opaque clouds. NUCAPS, however, still captured the lapse rates relatively well, both in terms of magnitude and spatial gradient. The forecaster commented that "*[w]hile specific values at various locations differ by relatively small percentages, patterns and gradients are overall fairly similar*" (White and Smith 2017). Over parts of the Great Lakes region NUCAPS observed slightly steeper lapse rate as indicated by the magenta circle in Figure 3. To investigate the meaning of this observation, the forecaster examined NUCAPS skew-T's around the Great Lakes and discovered that the 0 and -20 °C temperature levels corresponded roughly to the 700 and 500 hPa levels, respectively. Based on this evaluation, he suggested that as the day progresses there may be "*slightly more robust convective development in this region, than the model data alone imply*" (White and Smith 2017). And this is indeed what occurred.

2.4 CASE #4 – Derived Stability Parameters

Throughout this case, a forecaster used NUCAPS derived stability indices to analyze the pre-convective environment.

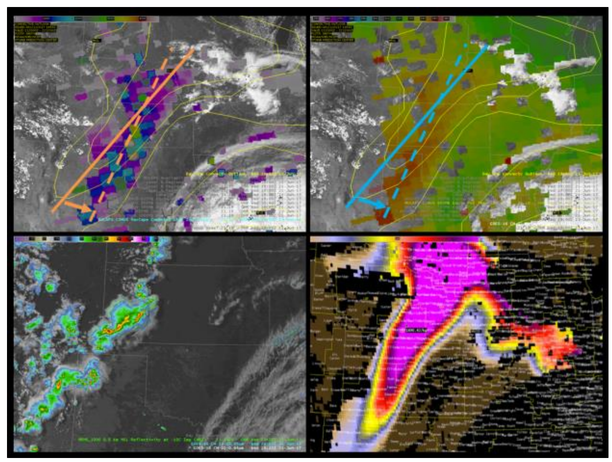

Figure 4: Stability parameters derived from NUCAPS soundings improved forecaster situational awareness and analysis of *what is about to happen* by providing observations of the atmosphere ahead of a storm. NUCAPS Convective Available Potential Energy (CAPE) (top left) and 850 hPa potential temperature (top right), displayed with SPC Day-1 Convective Outlook yellow contours, is compared to 2300 UTC MRMS – Multi-Radar/Multi-Sensor System 0.5 km mean surface level (MSL) reflectivity at -10 °C (bottom left) and 2100 UTC GOES16 – Geostationary Operational Environmental Satellite derived CAPE (bottom right). The details of this case can be found at White (2017).

In Figure 4, the top left shows 1900 UTC NUCAPS CAPE, with SPC Day-1 Convective Outlook contoured in yellow and labeled for regions of Marginal (MRGL) and Slight (SLGT) thunderstorm risk. From this comparison, the forecaster noted that NUCAPS Max CAPE has the highest values just to the east of the SPC "Slight Risk" region. Similarly, on examining NUCAPS 850 hPa potential temperature (top right), the greatest values are located eastward of the SPC "Slight Risk" contour. Therefore, both NUCAPS convective indices (CAPE and 850 hPa potential temperature) suggested a better placement for the axis of largest instability that is located slightly to the east of the SPC "Slight Risk" region. This eastward shift is represented in Figure 4 by the orange/blue arrows transitioning from the solid to dashed orange/blue lines. This tilted axis of greatest instability is also supported by derived CAPE from the Geostationary Operational Environmental Satellite (GOES-16) in the bottom right panel of Figure 4.

As the day progressed the strongest convection did in fact occur in Western Kansas as suggested by NUCAPS, and can be seen in the bottom left panel of Figure 4 by 2300 UTC Multi-Radar/Multi-Sensor System (MRMS) -10 °C reflectivity. The forecaster concluded that "*[NUCAPS] data indicated sufficient instability to keep convective development ongoing downstream and that increased intensity is possible as the storm moves into that region of higher instability"* (White 2017).

3. CONCLUSION

In this paper, we discussed what value NUCAPS soundings can have to forecasters when evaluating the pre-convective environment. A few cases were outlined and for the full set of forecaster evaluations, the reader is referred to HWT (2017a). We focused here on the value NUCAPS add to operational forecasting but forecasters in turn add critical value to ongoing NUCAPS algorithm and product development, such as product latency, boundary layer improvements, and different visualization modes (Smith et al. 2018b). Wheeler et al. (2017) outlined the important role forecasters play in maintaining an effective Research-to-Operations (R2O) pathway and ensuring that the recognition, support, and success of NUCAPS products among the operational forecasting community continues to increase each year. This is a direct result of the relationship established between NUCAPS developers and forecasters, that is built on active communication and following through with suggestions. The mutual benefits of developing and maintaining developer-user relationships are discussed by Smith et al. (2018a).

In May 2018 NUCAPS will be evaluated for the fourth time at HWT with improved boundary layer adjustments, improved products latency, as well as NUCAPS products from multiple platforms, namely MetOP-A/B and S-NPP.

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