USING NUCAPS TO OBSERVE THE THERMODYNAMIC STRUCTURE OF STRONG SAHARAN AIR LAYER OUTBREAKS ABOUT ITS SOURCE WITHIN THE DESERTS OF NORTHEAST AFRICA

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1. INTRODUCTION

The NUCAPS (Unique Combined Atmospheric Processing System) is an algorithm (Sun, 2017) that produces atmospheric sounding products from the Suomi National-Polar-orbiting Partnership (S-NPP), NOAA-20, MetOp-A, -B, and –C polar orbiting satellites. NUCAPS is a heritage algorithm based upon the Atmospheric Infrared Sounder (AIRS) Science Team algorithm (Susskind, 2003) that holds a modular architecture, specifically designed at NOAA/STAR to be compatible with "AIRS-like" sounding systems. NUCAPS combines infrared with microwave sounders to produce skew-T plots and plane gridded cross sections of temperature, moisture, trace gases and cloud-cleared radiances. NUCAPS has been gaining traction operationally toward demonstrating skill in diagnosing 3D profiling of cold air aloft, atmospheric rivers, as well as spring-summer pre-convective environments over the Central US and Alaska.

Under the auspices of NOAA's Joint Polar Satellite System (JPSS), NRL is conducting a four year study to determine the skill of the fairly nascent NUCAPS in identifying and profiling the vertical structure of the Saharan Air Layer (SAL). Because of its hot, dry and low level jet characteristics, the SAL has been well-studied as a negative influence toward tropical cyclone and hurricane development over the Atlantic basin (Dunion and Veldon, 2002). Much more work needs to be applied to understand the vertical structure during SAL development over the harsh deserts of northern Africa and the persistence of its existence and transport of Saharan dust for thousands of kilometers downstream into the Caribbean, Gulf Mexico, northern South America, and southeastern US. The investigation of NUCAPS skill in profiling the vertical structure of SAL has the potential of greatly assisting Caribbean-based forecasters toward issuing effective alerts of hazardous air quality associated with SAL, as it propagates westward across the greater Caribbean.

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This paper discusses a recent field campaign known as "AEROSE: the Saharan Dust AERosols and Ocean Science Expeditions" conducted onboard the NOAA research vessel *The Ron Brown (Nalli, 2004)*. One of the primary missions of this campaign was to explore NUCAPS skill in identifying SAL structure over a region near the source just offshore of Northwest Africa.
For NUCAPS evaluation, we will provide a case study approach during 13 March, during the time that the Ron Brown entered a fairly significant SAL outbreak and associated heavy dust content off Northwest Africa. Thanks to a wealth of sounding data collected by AEROSE, NUCAPS products can be directly evaluated with ground truth.

2. DISCUSSION

2.1 SAL Structure

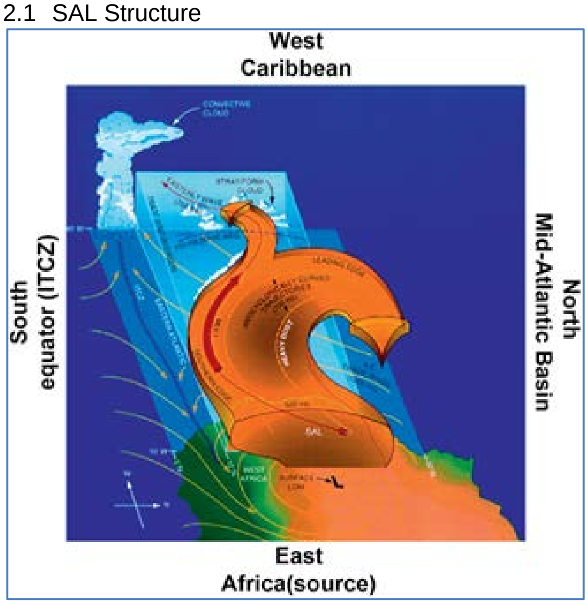

Figure 1. Three-dimensional conceptual view of the SAL and associated Saharan dust as it originates over the hot deserts of North Africa (bottom portion) and propagates west and northward into the open north tropical Atlantic basin (mid and upper extents). The southern flank of the SAL is bounded by the ITCZ to its south. (From Kuciauskas, et al, 2018).

Kuciauskas, et al, 2020, Using NUCAPS to observe the thermodynamic structure of strong Saharan Air Layer outbreaks about its source within the deserts of Northeast Africa

The SAL is an elevated air mass of hot, dry and typically thick concentrations of Saharan dust that originates over the environmentally challenging and harsh Saharan desert terrain in Northeast through Northwest Africa. Figure 1 provides a detailed illustration of the structure and extent of this air mass.

2.2 Case Study Approach

NUCAPS profiling of SAL will occur from two perspectives: a) the formation over the Saharan deserts during March12 and b) over the offshore region where the Ron Brown was positioned on March 13. Heavy concentrations of Saharan dust imbedded within the SAL existed during this time period and will be described next.

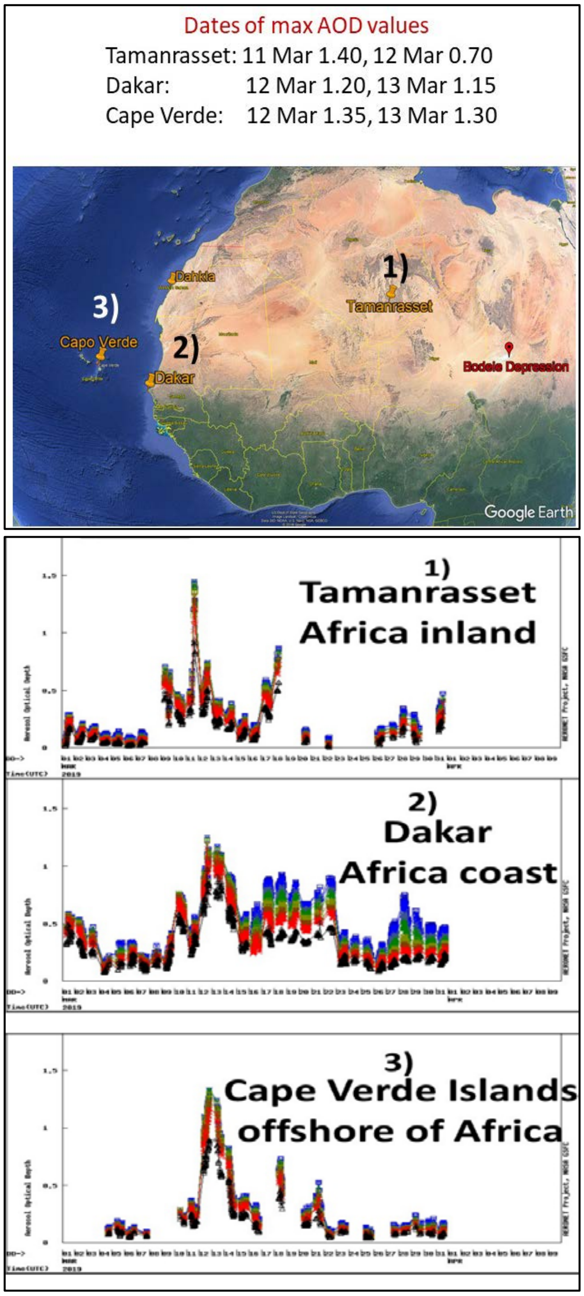

Figure 3. AERONET profiling of aerosol dust activity over 3 African sites during the month of March, 2019. The sites include Tamanrasset located in the interior of north central Africa, Dakar, situated oat the coast of northwest Africa, and Cape Verde, just offshore of Northwest Africa. AERONET profiles are courtesy of Emilio Cuevas-Agulla, Sid Baika, and Didier Tanre.

Figure 3 consists of AERONET dust aerosol optical depth (AOD) plots about the African region that depict high levels of aerosols during the period 11-13 March for all three sites. AOD values for each site. The AOD values over the desert region of Tamanrasset were maximized at 1.40 during the 11th, then decreased to 0.70 on the next day. The further downwind sites produced maximum AOD values but a day later. It is rare for this region to experience high values during this time of the year; typically the summer months have the highest dust content. Much of this dust moved into the open waters on the 13th, corresponding to times that the Ron Brown encountered poor visibility.

2.2.1. March 12: Profiling development of SAL over Africa

Figure 4a displays a Meteosat Second Generation (MSG)-derived DEBRA dust image of an extensive lofted Saharan dust development across northcentral and northwestern Africa. Within the murky yellow shades of extensive dust, one can see the individual lines leading back to the source of the dust. The active time for dust development is typically during the late morning through early afternoon times. On this day, NUCAPS skew-T profiles were compared to a nearby radiosonde site at Tamanrasset, annotated by 'R' in the figure. NUCAPS profiling of the SAL development region were conducted over the following sites in the figure: '1' (north of the SAL), '2' (within SAL development), and '3' (south of the SAL).

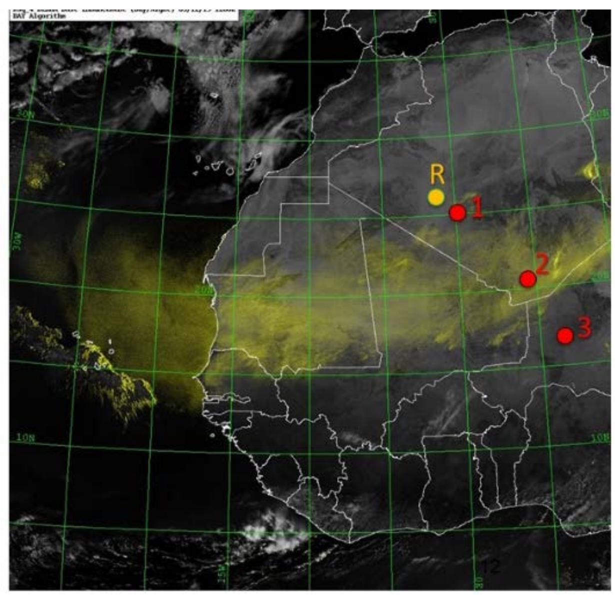

Figure 4a. NRL's DEBRA dust product on 12 March at 12 UTC. The annotations relate to the Figure 1b plots below, where: R=RAOB location at In-Salah, 1=outside SAL position, 2=inside SAL, and 3=outside SAL

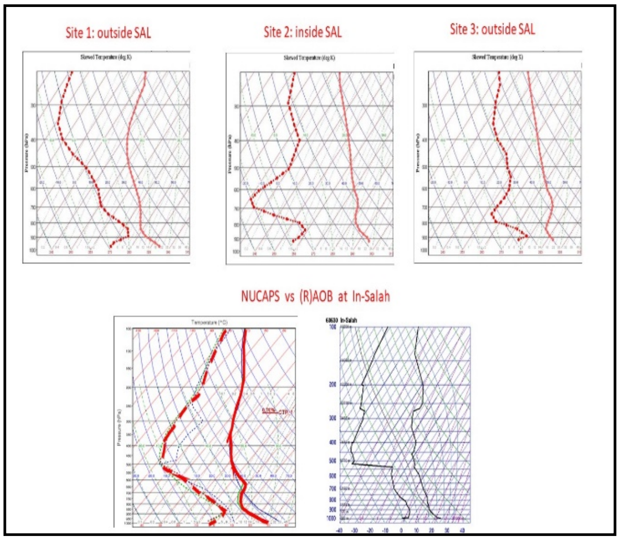

Figure 4b. Top panels: NUCAPS skew-T plots corresponding to positions '1', '2', and '3' as annotated in Fig. 4a. Bottom panels: NUCAPS skew-T (left) compared to RAOB at position 'R' position annotated in Fig. 4a. All plots are provided on 12 March at ~12 UTC.

The profiles at the top panel of Fig. 4b are used to compare NUCAPS soundings inside and outside of the developing SAL region. Focusing on the top middle plot, the skew-T plot, NUCAPS dew point temperature profile inside the SAL senses low level dryness (maximized around 600 hPa) within the SAL, compared to the adjacent profiles located just outside of the SAL. Additionally, the temperature profile is also shifted toward the warmer temperatures.

At the bottom panel, NUCAPS (lower left) was compared to the radiosonde site at Tamanrasset (lower right). As shown, the profiles vary at the lower levels, due to the coarser vertical resolution within the NUCAPS profiling. However, within the moisture field, NUCAPS eventually matches the minimum dew point temperature of the RAOB, around the 600 hPa level.

In both sets of comparisons, the low level NUCAPS profiling over land indicates difficulties in profiling the near surface measurements. Part of the effort is to correct the dew point and temperature values at these level with either model or in-situ observational data.

2.2.2 March 13: NUCAPS and AEROSE profiling offshore of Northwest Africa

A day after the previous case, the inland SAL and associated dust moved offshore and into the region traversed by the Ron Brown (Figure 5). For this case, NUCAPS skew-T's are compared to radiosondes launched onboard the Ron Brown. As shown in Figure 5, the locations of the plots are situated mostly north of the main dust region, however, observer reports onboard the Ron Brown indicated very thick haze throughout the day.

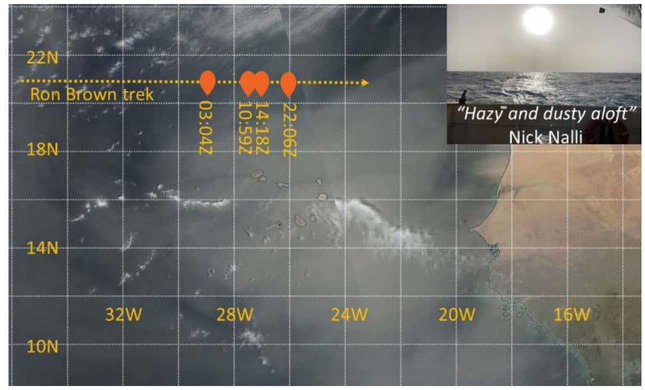

Figure 5. True Color image during the afternoon of March 13. The path of the Ron Brown is annotated. The orange bubbles indicate the positions of the ship-board radiosonde launches that are then compared to corresponding satellite-derived soundings generated during NUCAPS overpasses. An inset picture with caption in upper right reflect personal observations onboard the Ron Brown.

Figure 6 presents comparisons between the AEROSE radiosondes in red and NUCAPS in various other colors, depending on the satellite being applied (see Fig. 6 caption). Soundings between AEROSE and NUCAPS were matched up to within ½ hour of each other. As shown in all plots, the AEROSE soundings contained much more detail, especially within areas of sharp horizontal kinks in both temperature and moisture profiles. Of special interest is the dry area about the 900 hPa and 650-700 hPa levels. Overall, NUCAPS plots responded quite well in eventually reacting to dry regions in the lower levels. The patterns of profiles from the earliest to later times reflect the pattern of entering into more of the SAL influence, when focusing on the dry tongue extension about the 700 hPa level. Throughout this time period, NUCAPS compares well with AEROSE RAOBS above 600 hPa.

3. SUMMARY

In general, NUCAPS skew-T profile of the SAL were reasonable, from a generalized perspective. NUCAPS reacts to low level dry layers associated with SAL, although its coarser vertical resolution will never be able to capture sharp inversions, either within the temperature or dew point temperature profiles. As expected, NUCAPS performs better over water than over the harsh desert terrain within the Saharan desert. For each situation, modified NUCAPS surface parameters from outside sources would greatly enhance the temperature and moisture

This study is preliminary; NRL is working to provide a more comprehensive analysis by extracting most of the AEROSE 2019 datasets. Additionally, NOAA plans to conduct two AEROSE field campaigns onboard the Ron Brown during the spring and summer of 2020. The wealth of upcoming data will greatly provide a more robust approach to NUCAPS evaluations.

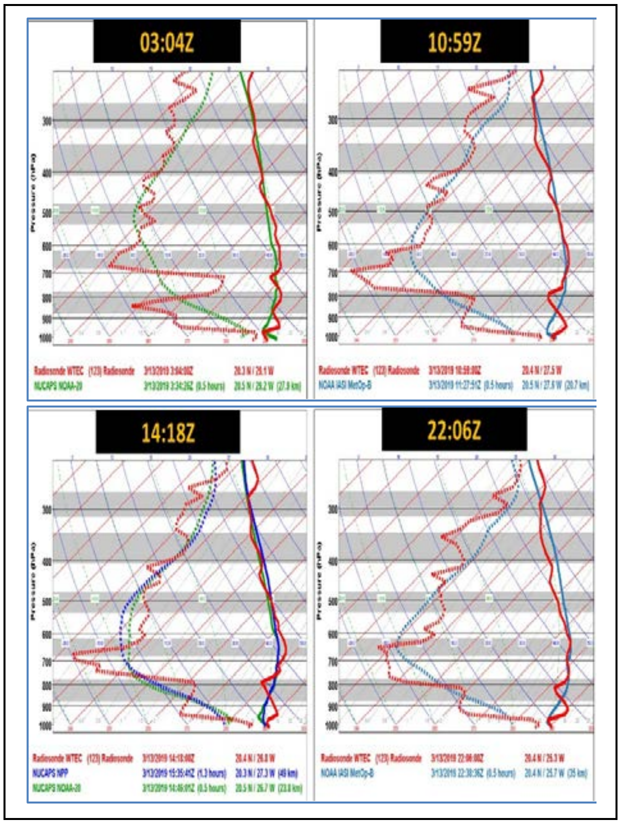

Figure 6. Skew-T plot comparisons between the AEROSE ship-board radiosondes and NUCAPS during March 13. The positions of each plot are mapped in Figure 5. Red solid and dashed plot temperatures and dew point temperatures. The colors represent the following:
Red = AEROSE 12Z radiosondes,
light blue = MetOp-B NUCAPS,
dark blue = NPP NUCAPS, and
green = NOAA-20 NUCAPS plots.

4. REFERENCES

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