

NUCAPS in AWIPS Training Talking Points, February 2022

1. Scott Lindstrom created this training, drawing on information from co-authors listed. Thanks to all!
2. NUCAPS defined: NOAA-Unique ~~CrIS-ATMS~~ Combined Atmospheric Processing System. You might also see the acronym HEAP: Hyperspectral Enterprise Algorithm Package, which contains the NUCAPS software. NUCAPS profiles are created using Infrared sounder (CrIS) and microwave sounder (ATMS) information from NOAA-20. NOAA-20 has an orbit such that it passes the Equator at 0130/1330 Local Time, and that translates to the times shown on the slide: around 05/17z along the East Coast, 06/18z over the Great Lakes, 09z/21z along the west coast (+/- an hour). Data are downlinked at Svlabard/McMurdo, and then processed and moved through different computers before ending up in the WFO's AWIPS, about 60-75 minutes after the observations are taken.
3. Profile production is a 2-step process:
 - a. Regression: A statistical relationship between the observed sounder values and the current state of the atmosphere, using coefficients derived from a couple focus days. The regression uses all data available.
 - b. Retrieval: like all retrievals, this will minimize an observation-calculation value. It uses a radiative transfer model (with a subset of the infrared sounder channels). Retrievals are iterative; convergence to a solution will not happen for infrared data in cloudy regions, nor for microwave data in regions of heavy rain. The radiative transfer model used has 101 levels, and that's how many levels can be found in AWIPS. It's far more resolution in the vertical than is warranted given the input data.
4. Cloud Clearing is an important part of this technique, because the presence of clouds will interfere with the satellite-based retrievals, so if you know where clouds are, then you can avoid problems by not trying a clear retrieval there. The biggest problems are with uniform cloud cover. If there are holes in the cloud deck, the sounders may be able to see through the holes to provide useful information.
5. Some examples of what 'clear' and 'cloudy' retrievals might look like. Again, the biggest problem is uniform clouds -- even if the clouds are very thin.
6. This picture shows CrIS footprints -- 30 groupings of 9 Fields of Regard -- that go into NUCAPS profiles. You'll note in AWIPS that each swath has 30 points. Here you can also see why uniform clouds are the big problem; it's not hard to envision a case where 1 (or 2) of the 9 Fields of Regard in a mostly cloudy scene will give good information.
7. This flowchart is meant to depict a retrieval. You start on the left with a first guess which emerges from the regression, and is also linked to climatology and surface pressures. A radiative transfer model (RTM) is used to compute -- calculate -- the state of the atmosphere given the first guess, and that is compared to the observations. Residuals -- the difference between the two -- are computed, and if those residuals are small, you've converged to a solution! (Congratulations!) If the residuals aren't small enough, then the profiles are modified and the skin temperature is nudged, and you cycle back through. Keep doing this until you converge, or until some number of iterations is exceeded.

8. This figure shows which CrIS channels are used in the retrieval. Note that not all are used. The red points in the graphs show the channels used for water vapor; the green points show channels used for surface temperature (these are necessarily window channels); the black points show channels used for atmospheric temperatures (these aren't window channels as they are giving information primarily from the mid-troposphere). Channel selection takes into account if more than one gas is absorbing -- that kind of channel is not used.
9. What are the strengths of NUCAPS profiles? Most of the information added is in mid-level water vapor. In part this is because mid-level temperatures are well-modeled, but atmospheric water vapor is a lot harder to initialize, so the observations from NUCAPS give information about the water vapor distribution that you can't get elsewhere. The biggest strengths of NUCAPS are identification of gradients, or of how things are changing. Additionally, NUCAPS profiles give lots of information in data-sparse regions such as over the Atlantic or Pacific Oceans. And they give information on how the atmosphere may have changed since the last radiosonde observation.
10. Vertical resolution in NUCAPS is not great. NUCAPS resolves about 6-10 layers of temperature in the troposphere, and perhaps 4-6 layers of moisture. Profiles are smooth, much smoother than radiosondes!
11. Here's a reason you might not use model data -- convective timing can be poor. Better idea: Use observations from satellite to determine the thermodynamic state of the atmosphere.
12. NUCAPS data are available in AWIPS under the Satellite Tab -- then under Suomi-NPP/NOAA-20. There, you'll see 'NUCAPS Sounding Availability' and 'Gridded NUCAPS' that you can click on. If you click on NUCAPS Sounding Availability, you'll see
13. A swath of points like this. This is a NOAA-20 swath of points. Note that there are 30 in each horizontal-ish line. The point color means something: Green Points: IR retrieval completed successfully; yellow points: IR Retrieval failed, but the microwave retrieval did not fail -- this is usually in cloudy regions ; red points: IR and microwave retrievals both failed -- this is typically in rainy regions. Note that this swath is time-stamped at 1913 UTC; these data likely showed up in AWIPS at some time between 2015 and 2030 UTC.
14. Put the NUCAPS Points over a satellite image so you can relate point color to cloudiness. Toggle between this to remind yourself!
15. Here's the plain old VIIRS image.
16. SO much data! You probably don't want to click on each point individually to ascertain what is going on -- that's laborious and tedious. But you can use PopUp SkewTs
17. PopUp SkewTs can be accessed under the Volume Tab in AWIPS.
18. Once you select PopUp SkewTs , right -click in the image and select 'NUCAPS Profiles' as what will be sampled.
19. And also turn on Sampling
20. Then when you mouse over a NUCAPS point, you'll see what the thermodynamic profile there (this case is over Indiana)
21. ...and just to the southwest
22. ...and then a bit farther south
23. ...farther south
24. ...even farther south

25. This slide just shows three points -- two green points, one red -- note how the two green points show similar information -- the one closer to the cloud edge shows conditions that are closer to saturation. The red point gives a sounding that isn't very believable.
26. Here are 4 daytime swaths over the USA (there'd be 4 nighttime swaths as well). You can see overlap north of about 40 N, and small gaps south of about 35 N. The location of these swaths shifts eastward slightly from one day to the next -- about 1/3rd of a swath width.
27. This is an example of how you might use consecutive soundings. There were two passes over PA; the westernmost column of the earlier pass and the easternmost column of the later pass overlapped. You can use the two profiles indicated to see how the atmosphere is changing in the 90 minutes.
28. The multiple passes were useful because there was a SLGT RSK on that day. This slide shows the 1700 UTC profile
29. This slide shows the 1830 UTC profile. Toggle between these slides to see how the atmosphere changed in those 90 minutes. The strength of the inversion has changed in the 90 minutes, and the LCL changed; the thermodynamic variables would have changed as well -- that's not shown. But you can use this information 90 minutes apart to get a better handle on whether convection will intensify.
30. A second case of overlapping passes over the Midwest, but this case uses gridded NUCAPS fields -- the horizontal profiles have been interpolated in the horizontal, and then -- in this case -- Total Totals indices have been computed. Note in this case how the 1747 UTC fields show strongest instability over the southern part of WI; and at 1932 UTC strong instability remains over southern WI. You can also see the impact of developing convection over northeast Iowa -- there are red points there. Note that gridded NUCAPS fields use all data regardless of the "color" of the profile point -- red, yellow or green. You might see in gridded NUCAPS fields, then, values that come from a "bad" retrieval. Keep that in mind. In this case, gridded NUCAPS showed peak instability where storm reports occurred.
31. NUCAPS have been demonstrated at HWT for a long time -- and forecasters quickly learned that the NUCAPS boundary layer. So a useful skill for a NUCAPS user in AWIPS is to learn how to modify the sounding. (Note: this is not discussed in the training, but there is a way to do this automatically for afternoon soundings; a well-mixed boundary layer that matches the surface analysis is created. Contact me if you want to learn more about that).
32. Consider this point on the west coast of FL, in a region where the temperature is near 80 and the dewpoint is near 60.
33. The sounding surface values do not match observations. There are two ways to modify the soundings. You can toggle 'EditGraph' to 'On'
34. When that's done, draggable points appear -- drag these around to make the profile better match the surface observations. (Note there's a 'Reset' button if you make an error). When you're done, toggle 'EditGraph' back to off.
35. Toggle between this and frame 34 -- see how things have changed. The LCL/LFC are different, and so are the derived parameters within the box.
36. You can also click on the 'EditData' box, and that brings up dialog boxes. Select the level you want to edit (or you can insert a level too) and change the values by typing them in.
37. The first, classic forecast problem that came from Dan Nietfeld, then the SOO in Omaha: Will showers develop as the GFS suggests?

38. Suomi NPP overflies the central US around 18 or 19z; this provides timely information on the state of the atmosphere in early afternoon. Here we have three different scenes, zooming in from North America to the Plains to WFO Omaha. Let's look at the sounding at the location circled in red.
39. Surface T/Td in this sounding match nearby METARs, so you don't have to edit it – CAPE values are low. Would you forecast showers?
40. The near-sunset visible image shows that clouds dissipated.
41. A couple days later, severe weather hit Omaha. Let's look at the sounding in the Green Box. (Note the big dewpoint gradient in this image!)
42. Modify this sounding to match METARs, and you get a SB CAPE of ~1900.
43. Some of the FORs for this sounding are likely cloudy, but some aren't.
44. Look at the point to the south – in the region of higher dewpoints. The central point is in clear air, and many of the 9 FORs for this point are also likely clear.
45. Original unmodified sounding shows CAPE of 686.
46. Modified to match the METAR and the CAPE exceeds 3095! This gradient in instability as depicted in the profiles might inform your forecasts -- you know there's an instability gradient. Will storms ride along it?
47. Here's another example of overlapping swaths. There is convection in the upper image -- over the western upper peninsula of Michigan. NUCAPS has a swath of information along Lake Michigan at 1719 UTC -- upper two soundings. Note how the northern sounding (upper left) shows something that might support convection. As you move farther south, though, into southwestern Lower Michigan (upper right), you see a much dryer sounding. You might not expect convection to develop to the south. A second overpass 90 minutes later tells a similar story. Nearly moist adiabatic along the northern edge, near the convection, and much less instability as you move to the south.
48. Some summary points. The best information from NUCAPS is moisture information in the middle troposphere. Because NUCAPS is a mid-afternoon (or midnight) data product, it provides a timely update to the 12z or 00z soundings; use it to judge how the thermodynamics of the atmosphere are changing. It's biggest use is identifying gradients, and how things might be changing with time. And if you're out over the ocean, then you have a rich source of data that is otherwise lacking.
49. Gridded NUCAPS fields are available on line at the first two sites listed here -- and NUCAPS profiles (including those from Metop B/C -- using IASI and AMSU/MHS) are available at the NOAA/OSPO site linked. If you have questions, please send me an email!