Assimilation of NUCAPS Retrieved Profiles in GSI for Unique Forecasting Applications

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Background

- SPoRT has a history of assimilating hyperspectral infrared (IR) profiles into Gridpoint Statistical Interpolation (GSI) system for regional modeling studies utilizing the Weather Research and Forecasting (WRF) model
- Traditionally hyperspectral infrared radiance data are assimilated into global operational modeling systems
- The amount of radiance data assimilated is limited due to data thinning and because radiances are restricted to cloud-free fields of view
- The number of hyperspectral infrared profiles that can be assimilated is much higher
  - Partly cloudy scenes can be assimilated
  - Do not need to depend on a complex bias correction like radiance assimilation
- Satellite profiles are traditionally assimilated as radiosonde observations and assigned radiosonde errors which are unrepresentative for satellite profiles

Experiment Setup

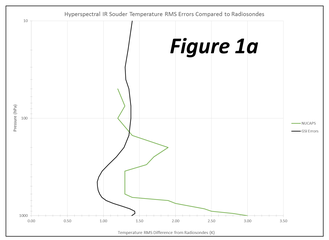
- NOAA Unique CrIS and ATMS Processing System (NUCAPS) temperature and moisture retrievals are assimilated into the GSI system to demonstrate:
  - Assimilation of hyperspectral IR profiles with appropriate error characteristics other than radiosonde error for a summer-time prefrontal convection case
  - Generation of analysis increments and changes to the analysis fields as a result of assimilation
- Community WRF version 3.6.1 and GSI version 3.3 from Developmental Testbed Center
- 3 km domain with 13 km Rapid Refresh (RAP) as boundary conditions
- Physics schemes similar to the RAP and High Resolution Rapid Refresh
- NUCAPS temperature (t) and moisture (q) profiles (+/- 3 hours of the analysis time) were appended to North American Model (NAM) prepbufr files
- This preliminary work only assimilated conventional observations and NUCAPS; no other satellite data; future work will include assimilating more satellite data and radiances

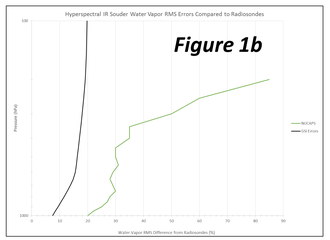
GSI Changes

- NUCAPS profiles were appended to the NAM prepbufr file with a new code to distinguish them from radiosondes
  - Source code changes were not needed to assimilate the profiles
  - Changes were made to tables in the fix directory to assimilate the new data with appropriate error values
- The global_convinfo file contains prepbufr observation types and parameters for gross error checks
  - Added observation type t, q for code 179
- The nam_errtable.r3dv contains the errors for each prepbufr observation type for 33 vertical levels from 1100 hPa to 0 hPa
  - NUCAPS t, q RMS errors from Nalli et al. (2013) were added for observation type 179

GSI NUCAPS Assimilation Results

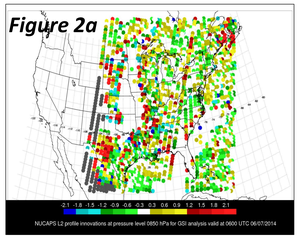
- The default radiosonde errors (black line) in GSI are generally smaller than the Nalli et al. (2013) NUCAPS RMS errors for temperature (***Fig. 1a***) and water vapor (***Fig. 1b***)
- Hyperspectral IR profiles, especially temperature, have higher error values near the surface and tropopause

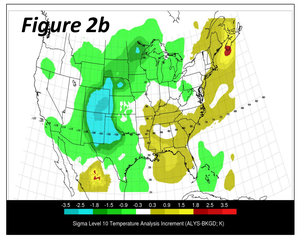


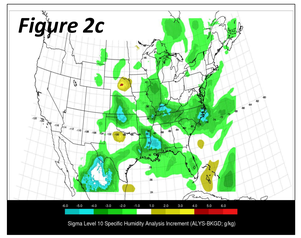


- Assigning appropriate error values can eliminate potential spurious innovations and analysis increments

- ***Figure 2a*** shows the locations and color coded innovations where the NUCAPS profiles were assimilated at 850 hPa.
- Yellow/red (green/blue) regions represent locations where individual profiles are warmer (cooler) than the final temperature analysis, gray locations were rejected by GSI
- Since innovations represent the observations – background ***Fig. 2a*** shows some profiles cool the temperature analysis by more than -2.0 K and others warm the analysis by more than 2.0 K

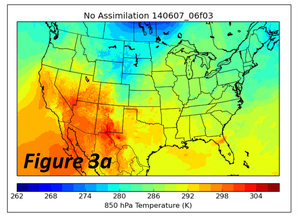


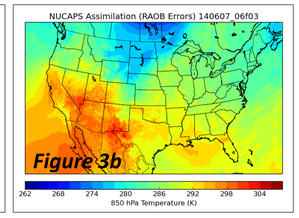


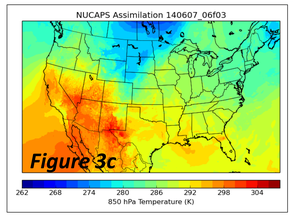


- Analysis increments show how much and where the background fields have been modified by assimilating observations
- 850 hPa temperature analysis increments (***Fig. 2b***) show the new analysis is as much as 3.5 K cooler in the West, behind the cold front and ~1 K warmer in the Southeast in the warm sector
- 850 hPa moisture analysis increments (***Fig. 2c***) show multiple regions in the domain where the new analysis is more than 2.0 g/kg drier

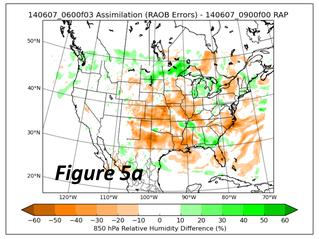
WRF NUCAPS Assimilation Results

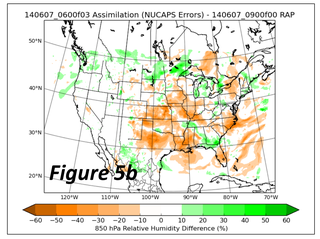






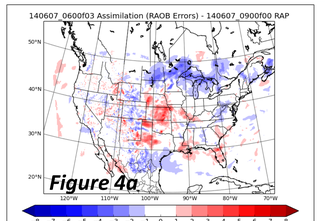
- Comparison of ***Fig. 3a, 3b, and 3c*** show colder 850 hPa temperatures in the Upper Midwest and subtle warming in the Midwest and Southeast when NUCAPS profiles are assimilated
- Only subtle changes are apparent in 850 hPa temperature between experiments that assimilate NUCAPS profiles with RAOB error (***Fig. 3b***) and NUCAPS errors (***Fig. 3c***)

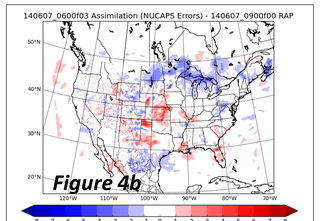




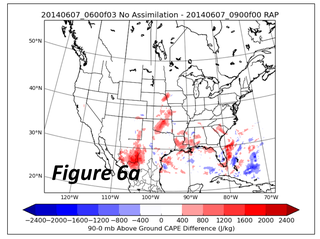
- 850 hPa Relative Humidity Figures are not shown, but more drying occurs at low levels when assimilating NUCAPS profiles with subtle differences between assimilating profiles with RAOB and NUCAPS Errors
- **Figures 5a** and ***5b*** show less drying occurs (relative to 13-km RAP analysis) when profiles are assimilated with NUCAPS errors.

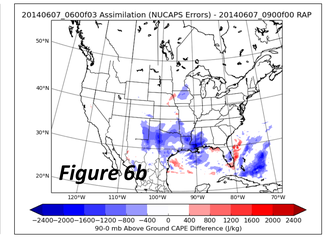
- Assimilating NUCAPS profiles changes the t and q analysis fields which impact ultimately forecasting stability indices, such as CAPE, important for forecasting severe weather





- Model output was re-gridded to 13-km and compared to the RAP analysis
- Differences are smaller and the forecasted field is closer to the RAP analysis when assimilating profiles with NUCAPS errors (***Figs. 4a and 4b***)





- The magnitude of CAPE relative to the 13-km RAP analysis is higher with no data assimilation (***Fig. 6a***)
- CAPE is under-forecasted when assimilating NUCAPS profiles (***Fig. 6b***) and the differences are slightly smaller when utilizing NUCAPS Errors instead of RAOB Errors

Summary & Future Work

- Hyperspectral IR profiles can be assimilated in GSI as a separate observation other than radiosondes with only changes to tables in the fix directory
- Assimilation of profiles does produce changes to analysis fields and evidenced by:
  - Innovations larger than +/- 2.0 K are present and represent where individual profiles impact the final temperature analysis
  - The updated temperature analysis is colder behind the cold front and warmer in the warm sector
  - The updated moisture analysis is modified more in the low levels and tends to be drier than the original model background
- Analysis of model output shows:
  - Differences relative to 13-km RAP analyses are smaller when profiles are assimilated with NUCAPS errors
  - CAPE is under-forecasted when assimilating NUCAPS profiles, which could be problematic for severe weather forecasting
- Refining the assimilation technique to incorporate an error covariance matrix and creating a separate GSI module to assimilate satellite profiles may improve results