The Impact of the Assimilation of Hyperspectral Infrared Retrieved Profiles on Advanced Weather and Research Model Simulations of a Non-Convective Wind Event

NASA POSTDOCTORAL PROGRAM
Administered by Oak Ridge Associated Universities

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NASA SPoRT

The Problem

- Tropopause folds are identified by warm, dry, high-potential vorticity, ozone-rich air and are one explanation for damaging non-convective wind events
- Could improved model representation of stratospheric air and associated tropopause folding improve non-convective wind forecasts and high wind warnings?
- The goal of this study is to assess the impact of assimilating hyperspectral infrared sounders from Atmospheric Infrared Sounder (AIRS), Infrared Atmospheric Sounding Interferometer (IASI), and Cross-track Infrared and Microwave Sounding Suite (CrIMSS) on forecasting stratospheric air

Background

- Currently, AIRS and IASI radiances are assimilated in the operational NAM
- Cloud clearing, error checking, and data thinning limit the number of radiances assimilated
- Radiance data contain limited information about the vertical temperature and moisture structure of the atmosphere and are restricted to cloud-free fields of view
- Hyperspectral IR profiles can be assimilated in some partly cloudy scenes and can be assimilated as RAOBs (and be assigned RAOB error) without the use of a computationally expensive radiative transfer model

Experiment Setup

- Developmental Testbed Center Gridpoint Statistical Interpolation System (GSI) v. 3.0 and Advanced Research Weather Research and Forecasting (ARW) Model v. 3.3
- Forecast cycling mimicking operational NAM

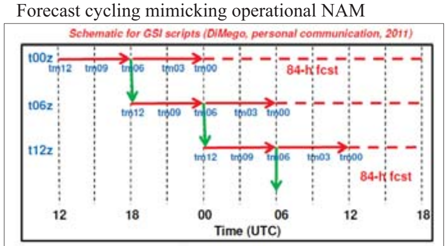

Figure 1. Schematic for forecast cycling and data assimilation with SPoRT scripts that run GSI and ARW.

- Initialized with GFS data
- 12-km domain with 35 vertical levels
- Scheme choices follow operational NSSL WRF

Control Run Data Assimilation:
- Satellite: AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
- Conventional Observations in NCEP prebufr files

Experiment Run Data Assimilation:
- Satellite: AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
- Conventional Observations in NCEP prebufr files
- **AIRS, IASI, CrIMSS temperature and moisture profiles**

Experiment Analysis

- Figs. 2 - 6 show the locations and innovations of hyperspectral IR profiles assimilated at 300 hPa during tm12 to tm00 GSI cycles for the 0000 UTC 09 February 2013 experimental model run
- The greatest number of profiles were assimilated during the tm09, tm06, and tm00 GSI cycles
- Innovations (Analysis – Background) for the experiment simulation show yellow/red (green/blue) locations where the individual profiles increased (decreased) the temperature analysis field
- During the tm06 GSI cycle, a significant number of profiles had a positive impact on the model temperature analysis field (Fig. 4)
- Any missing locations are due to the presence of thick clouds. (Figs. 4 and 6) Thick clouds limited the number of profiles assimilated over the region of interest during the tm00 cycle

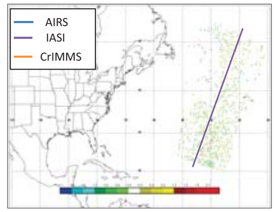

Figure 2. 300 hPa Innovations for assimilated hyperspectral IR profiles at cycle tm12 from 0000 UTC 09 Feb 2013 (valid 1200 UTC 08 Feb 2013)

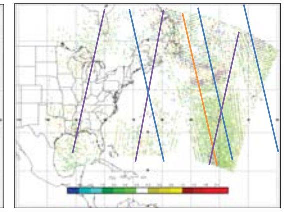

Figure 3. 300 hPa Innovations for assimilated hyperspectral IR profiles at cycle tm09 from 0000 UTC 09 Feb 2013 (valid 1500 UTC 08 Feb 2013)

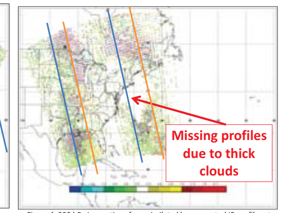

Figure 4. 300 hPa Innovations for assimilated hyperspectral IR profiles at cycle tm06 from 0000 UTC 09 Feb 2013 (valid 1800 UTC 08 Feb 2013)

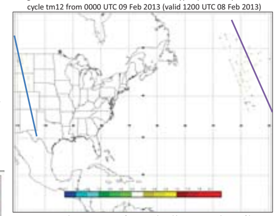

Figure 5. 300 hPa Innovations for assimilated hyperspectral IR profiles at cycle tm03 from 0000 UTC 09 Feb 2013 (valid 2100 UTC 08 Feb 2013)

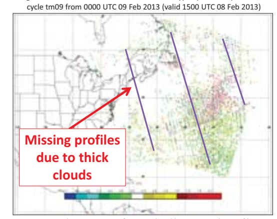

Figure 6. 300 hPa Innovations for assimilated hyperspectral IR profiles at cycle tm00 from 0000 UTC 09 Feb 2013 (valid 0000 UTC 09 Feb 2013)

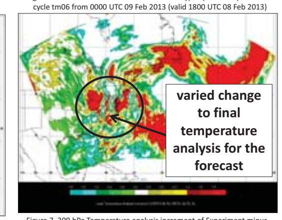

Figure 7. 300 hPa Temperature analysis increment of Experiment minus Control during cycle tm00 for 0000 UTC 09 February 2013 simulations

- The 300 hPa temperature Analysis Increment shows the impact of assimilating the hyperspectral profiles (Fig. 7)
- The analysis increment is calculated by the difference of the Experiment analysis and the Control analysis
- Even though there were missing profiles during the tm00 cycle over the region of interest (circled in Fig. 7), the cumulative effect of cycles still provided information to update the final temperature analysis
- The moisture Analysis Increment showed the most impact in the lower levels (Fig. not shown)

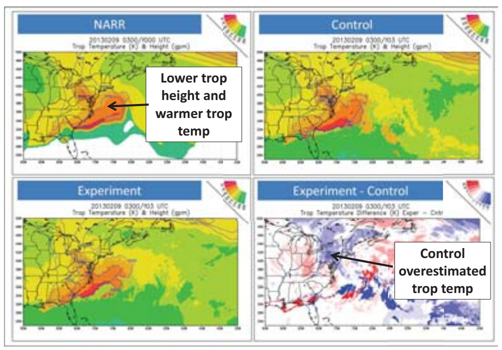

Figure 8. 0300 UTC 09 February 2013 Troposphere temperature (K) and height (gpm, blue contours)
Upper Left: NARR; Upper Right: 3-hr forecast from 0000 UTC 09 February 2013 Control Simulation, Lower Left: 3-hr forecast from 0000 UTC 09 February 2013 Experiment Simulation, Lower Right: Tropopause temperature difference (K) for Experiment minus Control

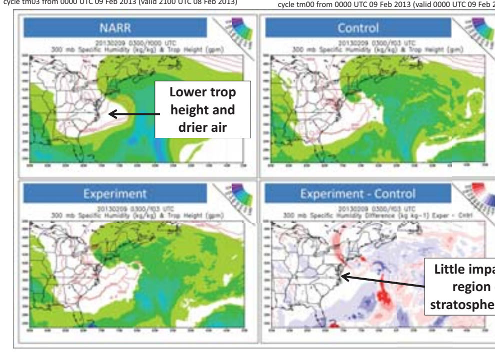

Figure 9. 0300 UTC 09 February 2013 300 hPa Specific Humidity (kg/kg, shaded) and tropopause height (gpm, red contours) Upper Left: NARR, Upper Right: 3-hr forecast from 0000 UTC 09 February 2013 Control Simulation, Lower Left: : 3-hr forecast from 0000 UTC 09 February 2013 Experiment Simulation, Lower Right: 300 hPa Specific humidity difference (kg/kg) for Experiment minus Control

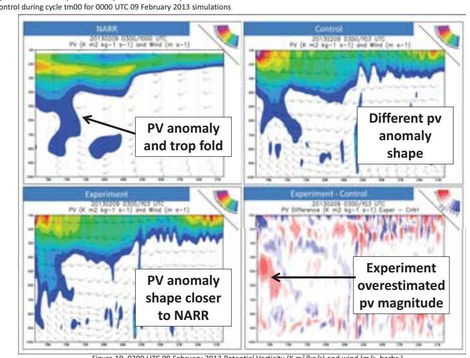

Figure 10. 0300 UTC 09 February 2013 Potential Vorticity (K m^2/kg/s) and wind (m/s, barbs)
Upper Left: NARR, Upper Right: 3-hr forecast from 0000 UTC 09 February 2013 Control Simulation, Lower Left: : 3-hr forecast from 0000 UTC 09 February 2013 Experiment Simulation, Lower Right: Potential Vorticity difference (K m^2/kg/s) from Experiment minus Control

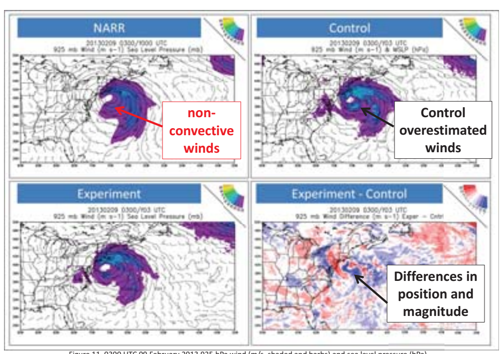

Figure 11. 0300 UTC 09 February 2013 925 hPa wind (m/s, shaded and barbs) and sea level pressure (hPa)
Upper Left: NARR; Upper Right: 3-hr forecast from 0000 UTC 09 February 2013 Control Simulation; Lower Left: : 3-hr forecast from 0000 UTC 09 February 2013 Experiment Simulation; Lower Right: 925 hPa wind difference (m/s) for Experiment minus Control

- Fig. 8 shows warm stratospheric air and low tropopause height in the vicinity of the non-convective winds
- Only subtle differences are seen in the troposphere temperature and height fields, but the Control overestimated the tropopause temperature in the region of stratospheric air
- Moisture profiles had little impact in dry, upper level regions and more impact in the lower levels (Fig. 9)
- The Experiment more closely resembled the shape of the tropopause fold (Fig. 10), however the magnitude was overestimated
- Strong cold conveyor belt winds wrap around the north side of the low pressure and non-convective winds south of the low pressure center (Fig. 8), the magnitude of the Experiment winds were closer to the NARR analysis, but displaced

Summary

- Assimilation of AIRS, IASI, and CrIMSS hyperspectral resulted in analysis increments of greater than +/-3°C in regions surrounding the thick clouds associated with the storm system of interest
- Overall, the assimilation of hyperspectral profiles improved the representation of temperature characteristics of stratospheric air and the shape of the tropopause fold, but had little impact on moisture characteristics in upper level dry regions
- Since changes in the near-surface wind field may be related to assimilation of temperature and moisture at low levels, an experiment that only assimilates upper level profiles will isolate whether changes to the upper-level representation of stratospheric air change the near-surface wind field