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

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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**?

(Danielson 1968)

(adapted from Martínez-Alvarado et al. (2010) and Clark et al. (2005).)
The Goal

• The goal of this study is to **assess** the **impact of assimilating** Hyperspectral Infrared (IR) **profiles** on forecasting **stratospheric air, tropopause folds**, and associated **non-convective winds**
  – AIRS: Atmospheric Infrared Sounder
  – IASI: Infrared Atmospheric Sounding Interferometer
  – CrIMSS: Cross-track Infrared and Microwave Sounding Suite

*Temperature Profile errors ~1K/km
*Water Vapor Profile errors ~10-15%/1-2 km layer
*Vertical Resolution: ~1-2 km
*Horizontal Resolution: ~45-50 km
Background on Data Assimilation

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

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

<table>
<thead>
<tr>
<th>Type</th>
<th>Control</th>
<th>Experiment</th>
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<tr>
<td>MHS</td>
<td>N18, N19, MetOp-A</td>
<td>N18, N19, MetOp-A</td>
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<tr>
<td>HIRS</td>
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<td>Sounder</td>
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<td>AIRS, IASI, CrIMSS</td>
<td>L2 T and q profiles</td>
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<td>Conventional</td>
<td>Soundes, Aircraft, SatWinds, RadWinds, GPSRO, METAR, BUOY</td>
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Compared results to 32-km North American Regional Reanalysis interpolated to 12-km
GSI Performance

- Profiles assimilated at 300 hPa during GSI cycles for the 0000 UTC 09 February 2013 experimental model run
- Innovations (Observation – Background) show yellow/red locations where the individual profiles should increased the temperature analysis field
- Thick clouds limited the number of profiles assimilated over the region of interest during the tm09, tm06, and tm00 cycles

Transitioning unique data and research technologies to operations
GSI Performance

- 300 hPa Temperature Analysis difference shows the impact of assimilating the Hyperspectral IR profiles.
- Even though there were missing profiles during the tm00 cycle over the region of interest, the cumulative effect of cycling still provided information to update the final temperature analysis.
- Red regions represent where the Experiment was warmer than the Control and the final analysis was increased.
- The Moisture Analysis Increment showed the most impact in the lower levels.

*Analysis increment is the analysis minus background.
*This graphic is the experiment 300 hPa temperature analysis minus control 300 hPa temperature analysis.
Experiment Analysis

- Strong cold conveyor belt winds wrap around the north side of the low pressure and non-convective winds south of the low pressure center
- Magnitude of the Experiment winds were closer to the NARR analysis, but displaced
- How does the potential vorticity anomaly compare to NARR?
Experiment Analysis

- The Experiment more closely resembled the shape of the tropopause fold, however the magnitude was overestimated.
- What does skew-t analysis reveal about the vertical structure and winds?
Experiment Analysis

- Both the control and experiment were more saturated in the low-levels and had drier upper-levels.
- A higher, shallow inversion layer in the control allowed more vertical transport of momentum and produced higher winds.
- The lower, deeper inversion layer in the Experiment limited vertical transport of momentum, and led to forecasted winds closer to the NARR’s magnitude.

Control:
- Deeper saturated layer
- Higher, shallow inversion layer

Experiment:
- Shallow saturated layer
- Lower, deeper inversion layer
Summary & Future Work

• Assimilation of AIRS, IASI, and CrIMSS profiles resulted in **analysis increments of greater than +/-3°C** in regions surrounding the thick clouds associated with the storm system of interest in the experiment assimilating the full profiles.

• Overall, the assimilation of Hyperspectral IR profiles **improved** the representation of the shape of the **tropopause fold** and magnitude of the **925 mb winds**.

• Changes in **stability** appear **more important to forecasting the near-surface wind field** than accurately representing the **tropopause fold**.

• Since the profiles were too saturated in the low-levels, **assimilating the Hyperspectral IR profiles** with appropriate **error values**, other than that of RAOB’s, could **improve** the near-surface representation of the profiles.