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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22nd Conference on Numerical Weather Prediction

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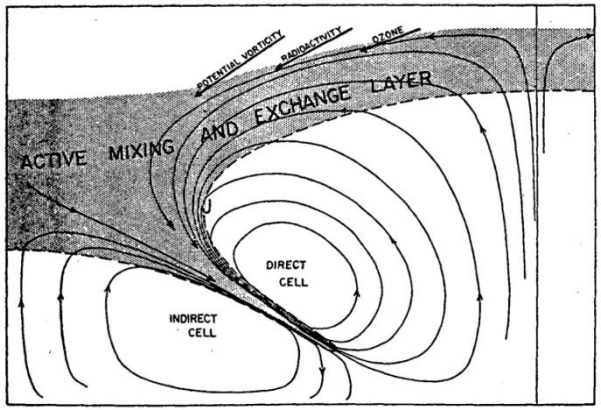
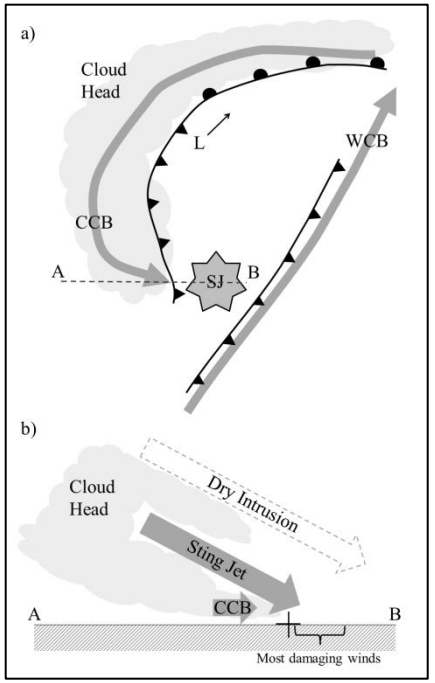
The Problem

- **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

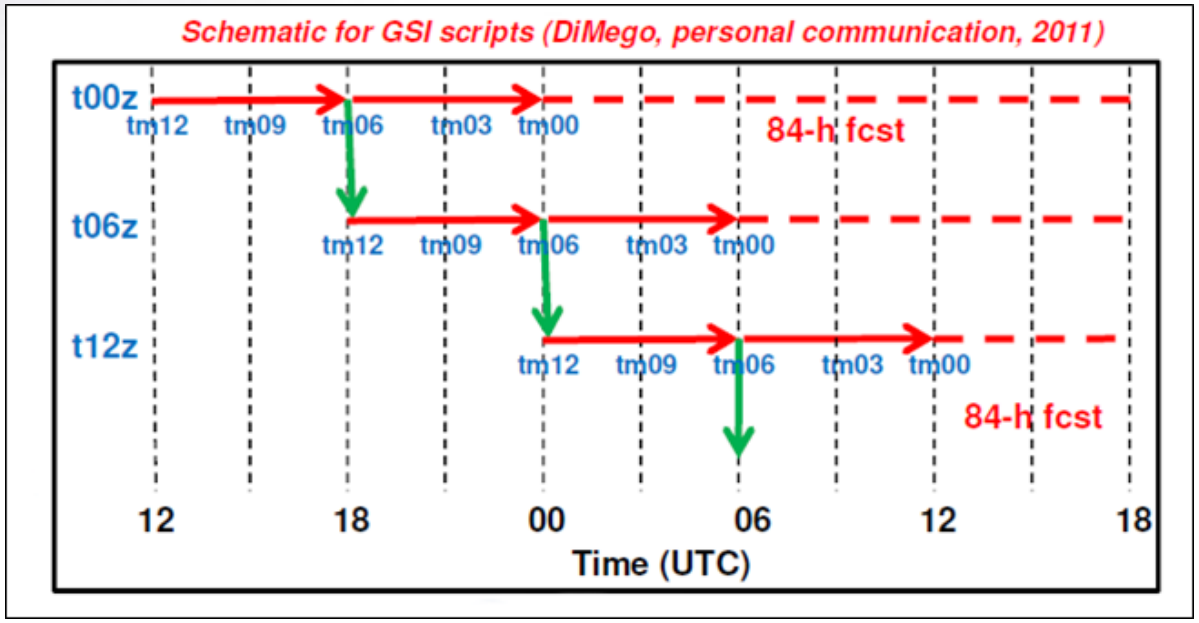
*Horizontal Resolution: ~45-50 km

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 scene**s 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:

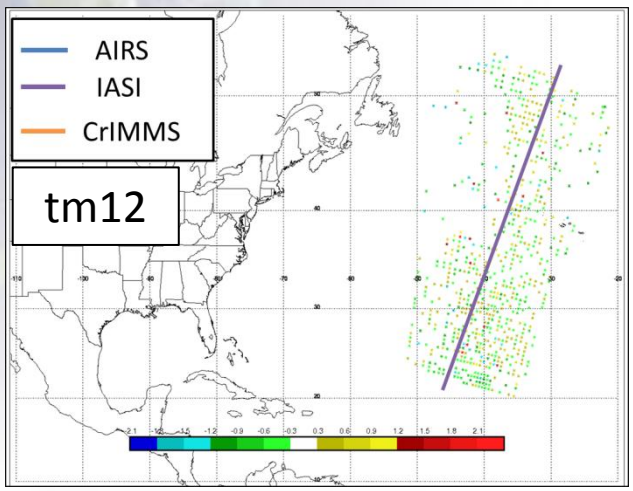
- Satellite: AMSU, HIRS, MHS, GOES Sounder, GPSRO, radar winds
- Conventional Observations in NCEP prebufr files
- **AIRS, IASI, CrIMSS temperature and moisture profiles**

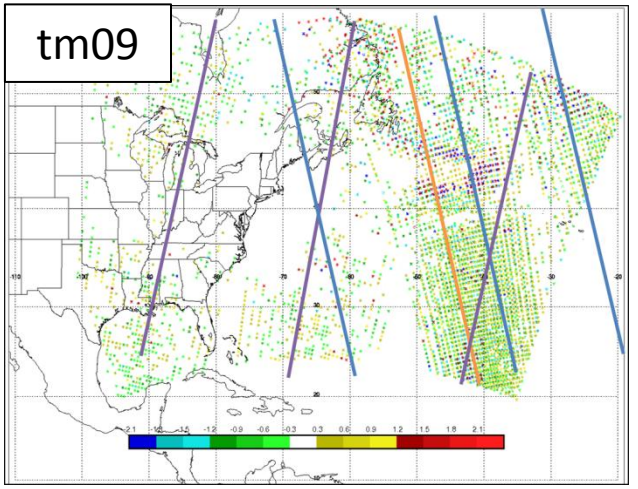
Type	Control	Experiment
AMSU-A	N15, N18, N19, MetOp-A, Aqua	N15, N18, N19, MetOp-A, Aqua
MHS	N18, N19, MetOp-A	N18, N19, MetOp-A
HIRS	N17, N19, MetOp-A	N17, N19, MetOp-A
Sounder	GOES13, GOES15	GOES13, GOES15
AIRS, IASI, CrIMSS		L2 T and q profiles
Conventional	Soundes, Aircraft, SatWinds, RadWinds, GPSRO, METAR,BUOY	Soundes, Aircraft, SatWinds, RadWinds, GPSRO, METAR,BUOY

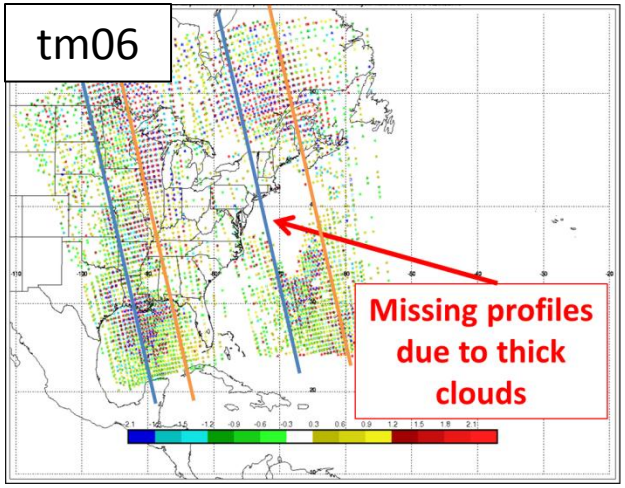
Compared results to 32-km North American Regional Reanalysis interpolated to 12-km

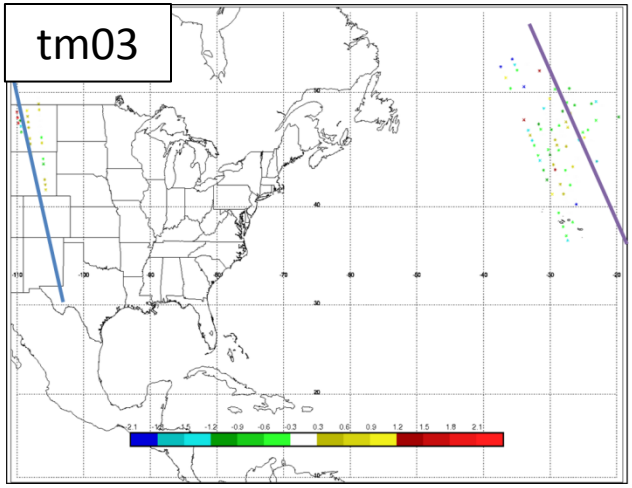
GSI Performance

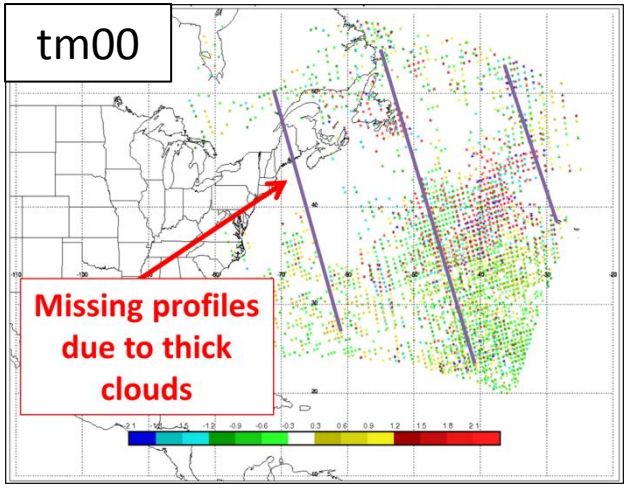
- Profiles assimilated at 300 hPa during GSI cycles for the 0000 UTC 09 February 2013 experimental model run
- Innovations (Observation – Background) show yellow/red locations where the individual profiles should increased the temperature analysis field
- Thick clouds limited the number of profiles assimilated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





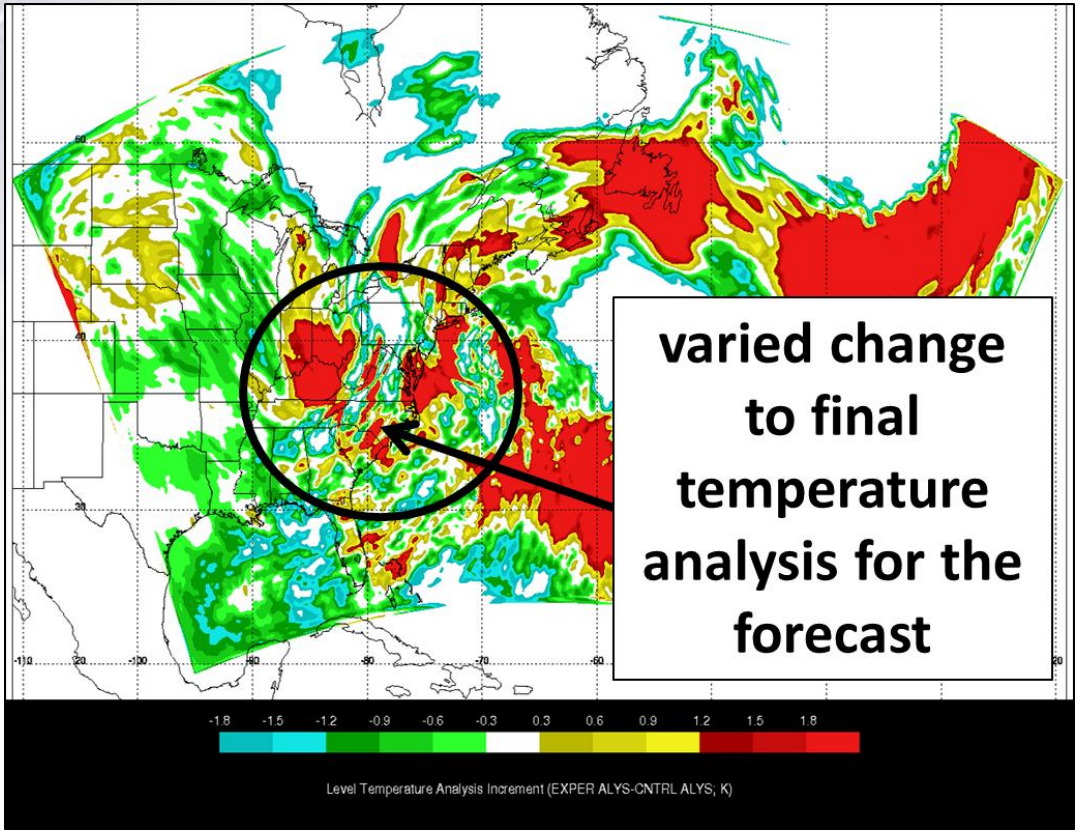






GSI Performance

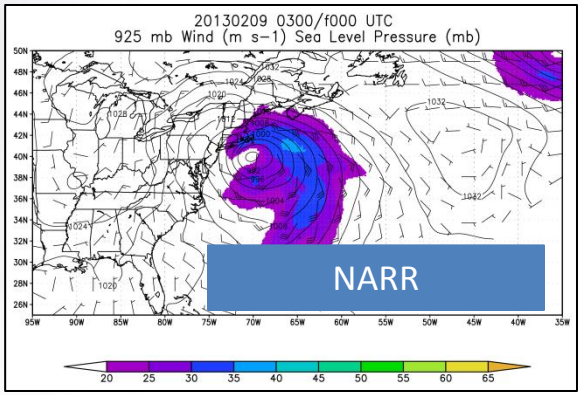
- 300 hPa Temperature Analysis difference shows the impact of assimilating the Hyperspectral IR profiles
- Even though there were missing profiles during the tm00 cycle over the region of interest, the cumulative effect of cycling still provided information to update the final temperature analysis
- 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

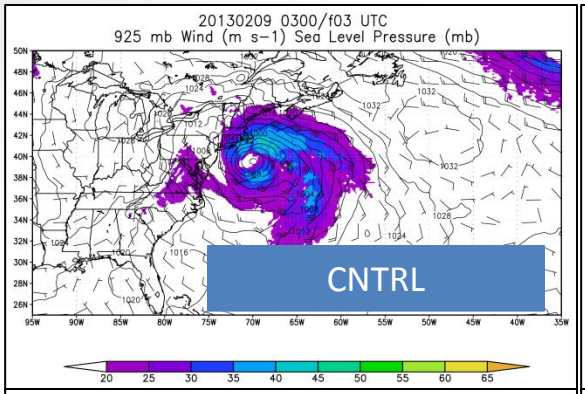


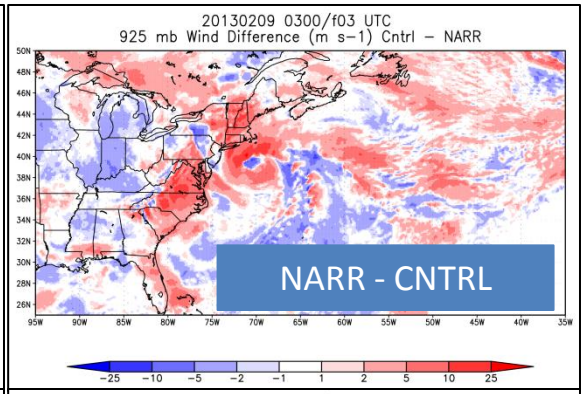
- *Analysis increment is the analysis minus background
- *This graphic is the experiment 300 hPa temperature analysis minus control 300 hPa temperature analysis

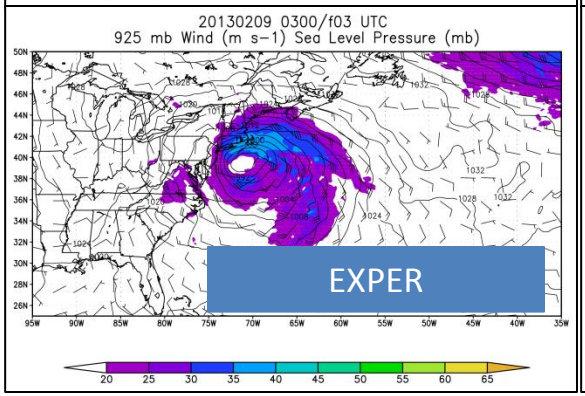
Experiment Analysis

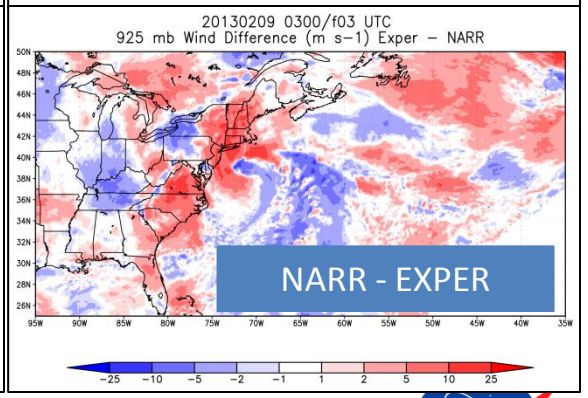
- Strong cold conveyor belt winds wrap around the north side of the low pressure and non-convective winds south of the low pressure center
- Magnitude of the Experiment winds were closer to the NARR analysis, but displaced
- How does the potential vorticity anomaly compare to NARR?





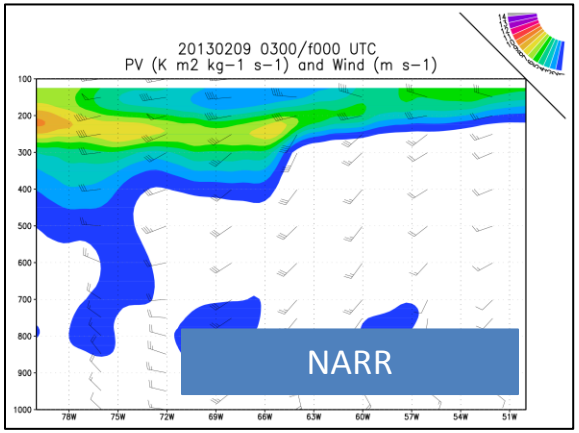


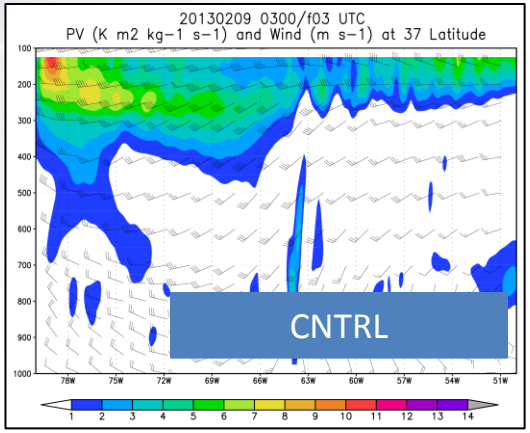


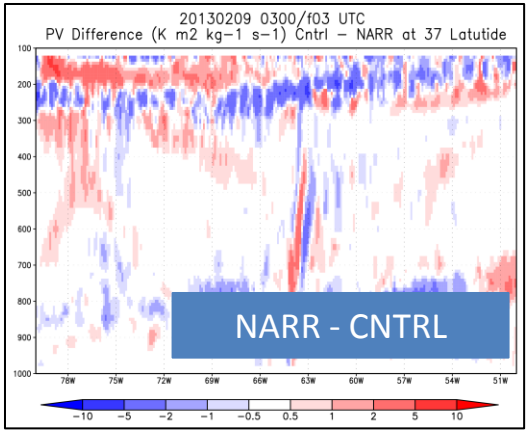


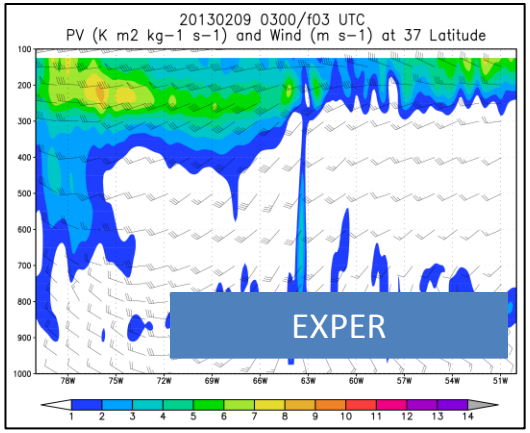
Experiment Analysis

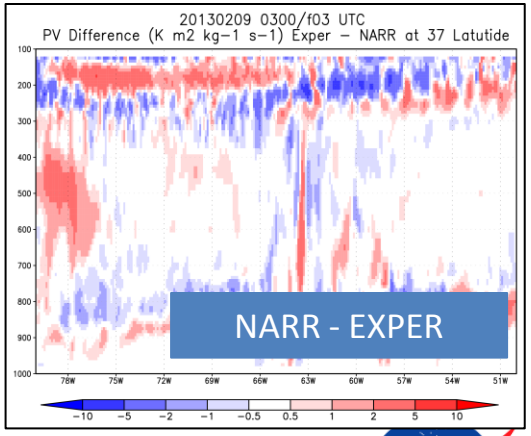
- The Experiment more closely resembled the shape of the tropopause fold, however the magnitude was overestimated
- What does skew-t analysis reveal about the vertical structure and winds?





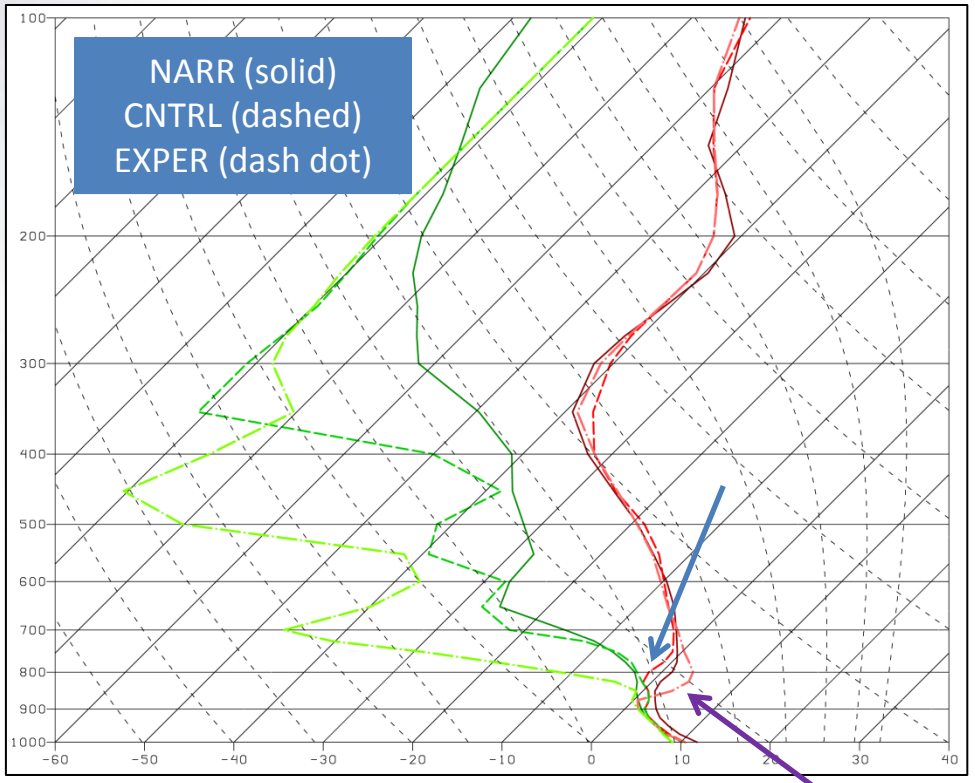


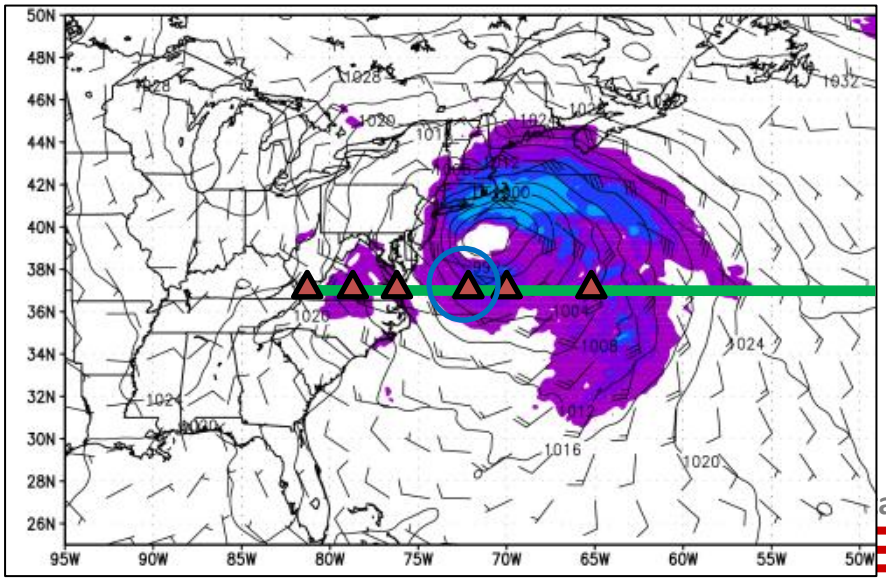




Experiment Analysis

- 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**