NOAA/NESDIS Cooperative Research Program (CoRP) 9th Symposium

Improve Hurricane Sandy forecasts with hyperspectral infrared sounder data assimilated

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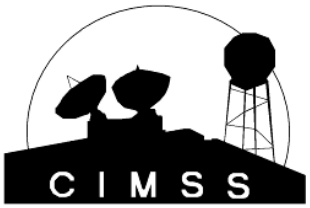
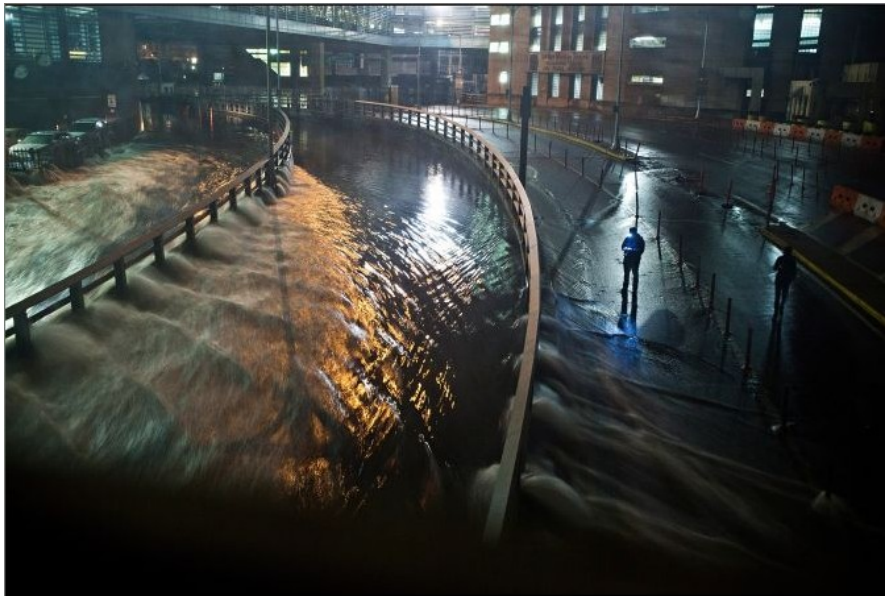


Introduction

- The Atmospheric Infrared Sounder (AIRS) is the first of a new generation of high spectral resolution infrared sounder with 2378 channels.
- Because forecast skill is dependent on the quality of the information that is assimilated into the forecast model, AIRS sounder data are expected to improve weather forecasts (Prunet et al., 1998).
- The AIRS radiance data have already been successfully assimilated in the global model and used in the operational NWP system both at NCEP and ECMWF (Le Marshall et atl. 2006;McNally et al., 2007)
- However, the data assimilation for the regional model is still a big challenge.
- Retrievals can be an important source of information for nowcasting applications and for validation of model analyses and forecast (Goldberg et al., 2003).

- **Challenge and Motivation**



- How to use the hyperspectral infrared sounder data in regional model?
- What is the impacts of hyperspectral infrared sounding data on the forecasts of hurricanes?

- **Method and Equations**

3D-VAR approach

The cost function is defined as (Wu et al. 2002)

$$J = \frac{1}{2}(x_a - x_b)^T B^{-1}(x_a - x_b) + \frac{1}{2}(Hx_a - o_o)^T O^{-1}(Hx_a - o_o) + J_c$$

Where:

x_a: Analysis fields
x_b: Background fields
B: Background error covariance matrix
H: Observation operator
o_o: Observations
O: observation error covariance
J_c: constraint terms (eg. Dynamical constraint, moisture constraint)

- **Method and Equations**

$$J = (x_a - x_b)^T B^{-1}(x_a - x_b) + (Hx_a - o_o)^T O^{-1}(Hx_a - o_o) + J_c$$

Define analysis increment $(\Delta x =)x = x_a - x_b$

$$J = x^T B^{-1} x + (H(x + x_b) - o_o)^T O^{-1}(H(x + x_b) - o_o) + J_c$$

Assuming H is a linear operator, then

$$J = x^T B^{-1} x + (Hx - (o_o - Hx_b))^T O^{-1}(Hx - (o_o - Hx_b)) + J_c$$

Define observation innovation as o$= o_o - Hx_b$

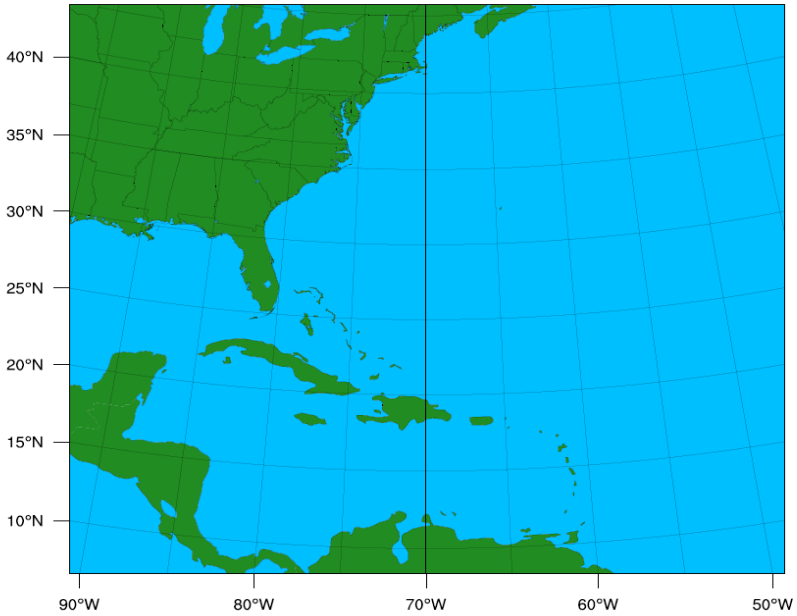
$$J = x^T B^{-1} x + (Hx - o)^T O^{-1}(Hx - o) + J_c$$

- **Experiment Design**

Hurricane Sandy

- Tropical Storm (22/18z—24/06z)
- Hurricane (24/12z—26/18z)
- Tropical Storm (27/00z—27/06z)
- Hurricane(27/12z—29/18z)

WPS Domain Configuration



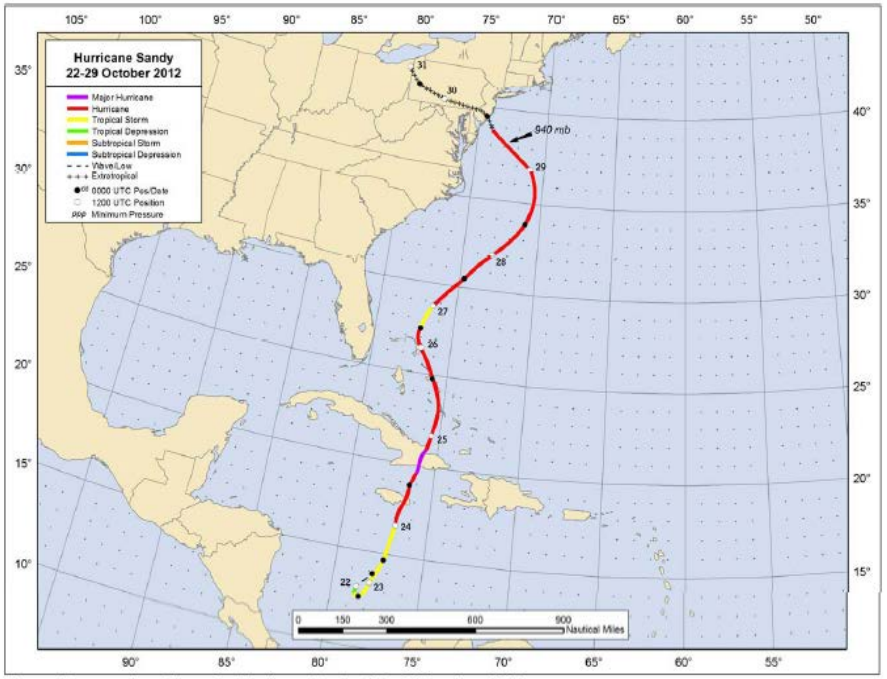
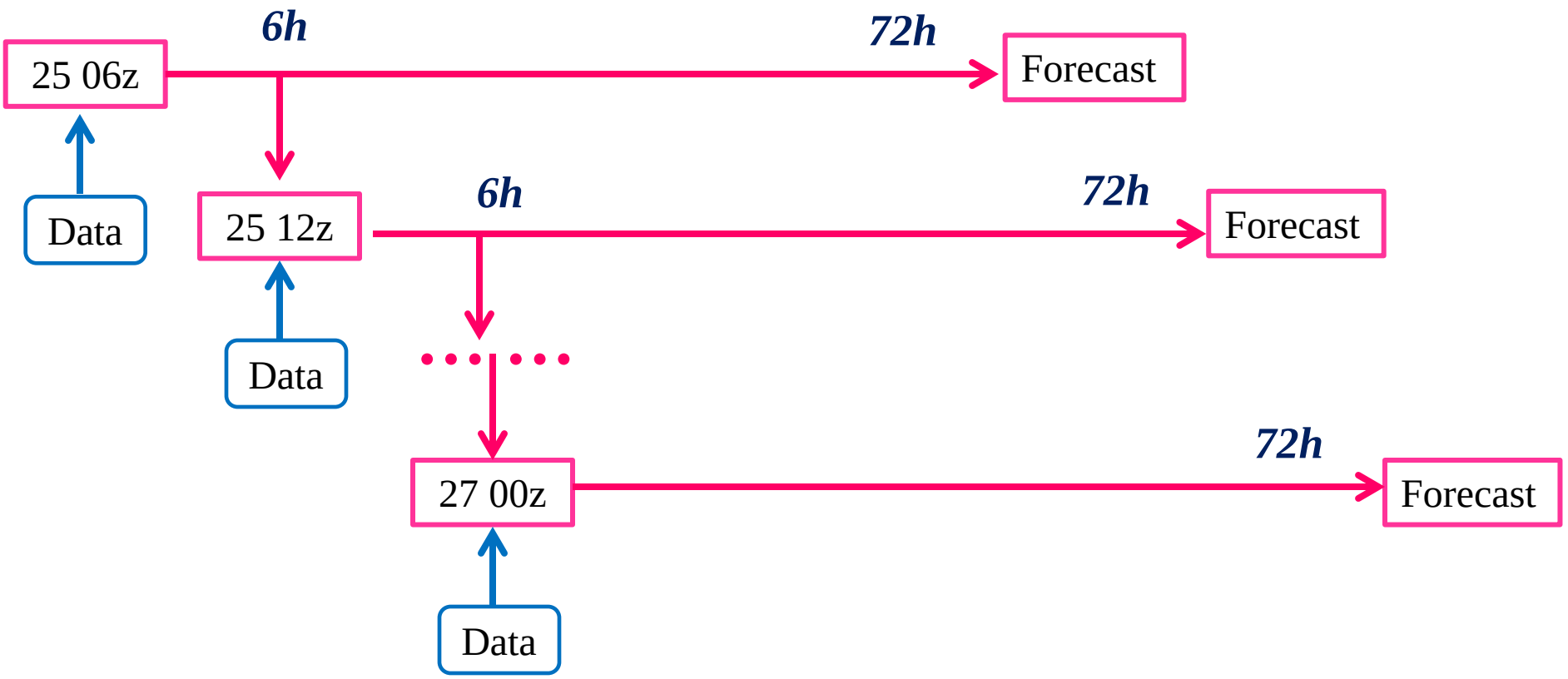


Fig from Tropical Cyclone Report (E. S. Blake et al)

Simulations

- Horizontal Resolution: 12km
- Vertical levels: 35 levels
- From 1000hPa to 10hPa
- Assimilation: 25/06z—27/00z
- Forecasts: 72hr

- **Experiment Design**



8 groups of experiments **2012-10-25-06z to 27-00z**

Window time: -1.5hr to +1.5hr

- **Experiment Design**

➢ **Conventional data**

Radiosonde
Aircraft
Wind Profiler
Surface Land (Synoptic, Metar)
Surface Marine (Ship, Buoy, C-man, Platform)

➢ **AMSUA**

Aqua: channels 6,8-13;
Metop-A: channels 1-6, 8-13, 15;
NOAA_n15: channels 1-10, 12,13,15;
NOAA_n18: channels 1-8, 10-13, 15;

➢ **AIRS SFOV sounding data**

Physical Retrieval for the hyperspectral infrared radiances(Li et al, 2007)
From 200hPa to 700hPa of temperature profiles

• Experiment Design

➢ Assimilation System

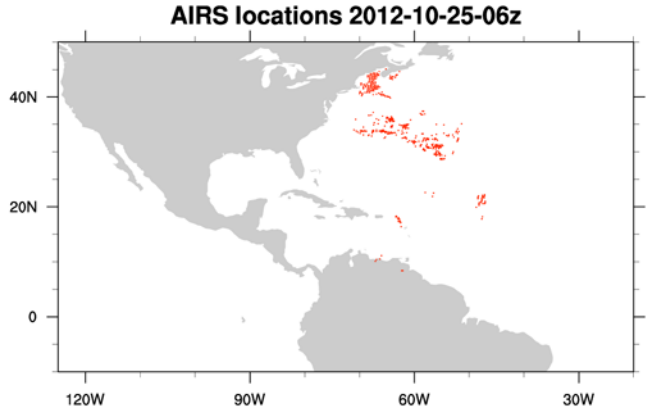
Developmental Testbaed Center | DTC
The Community Gridpoint Statistical Interpolation (GSI) V3.0
GSI is developed by National Center for Environmental Prediction (NCEP)
It could be run for both global and regional models.
http://www.dtcenter.org/

➢ Modeling System

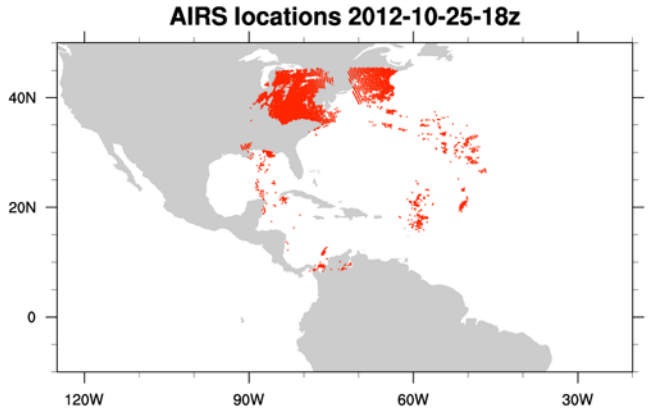
Weather Research and Forecasting (WRF) model
Advanced Research WRF (ARW) V3.2.1
WRF is developed by the National Center for Atmospheric Research (NCAR)
It is a mesoscale numerical weather prediction system.
http://www.mmm.ucar.edu/wrf/users/

- **Data Assimilation**

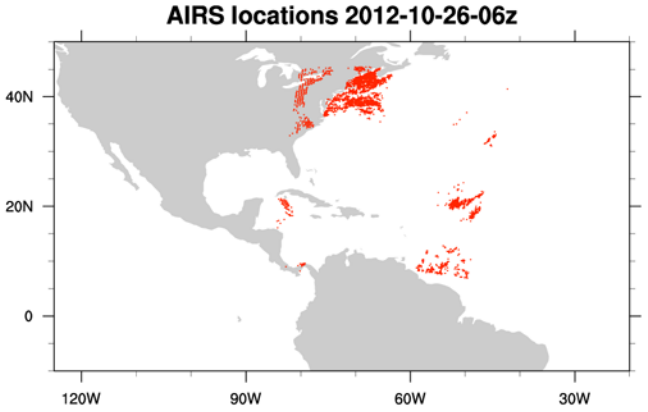
AIRS data locations under clear sky



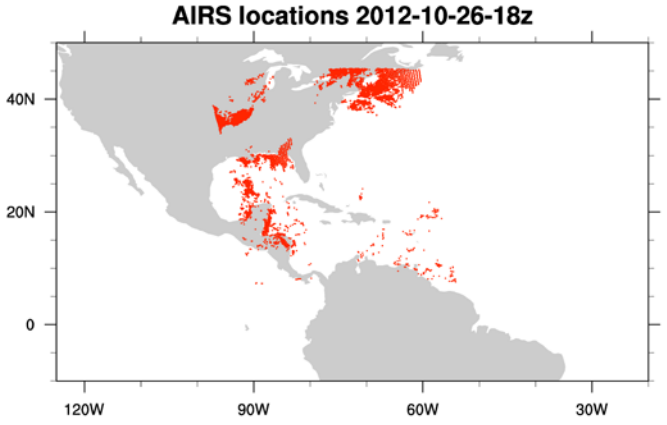
N = 14,328



N = 125,539

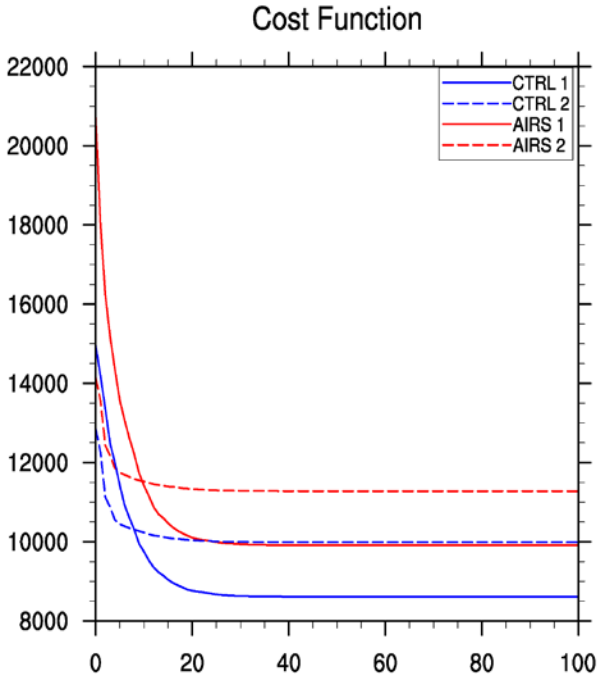


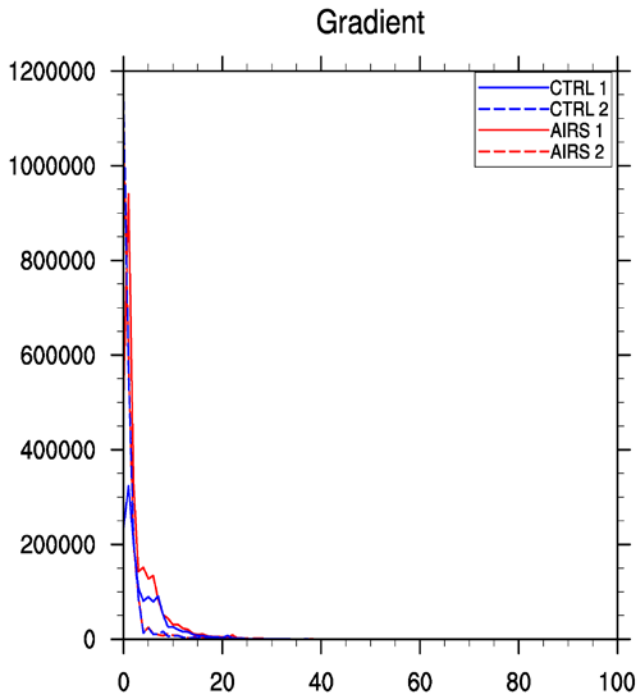
N = 61,479



N = 106,839

- **Data Assimilation**





Both cost function and gradient decrease rapidly within the first 20 iterations for the first and second outer loop.

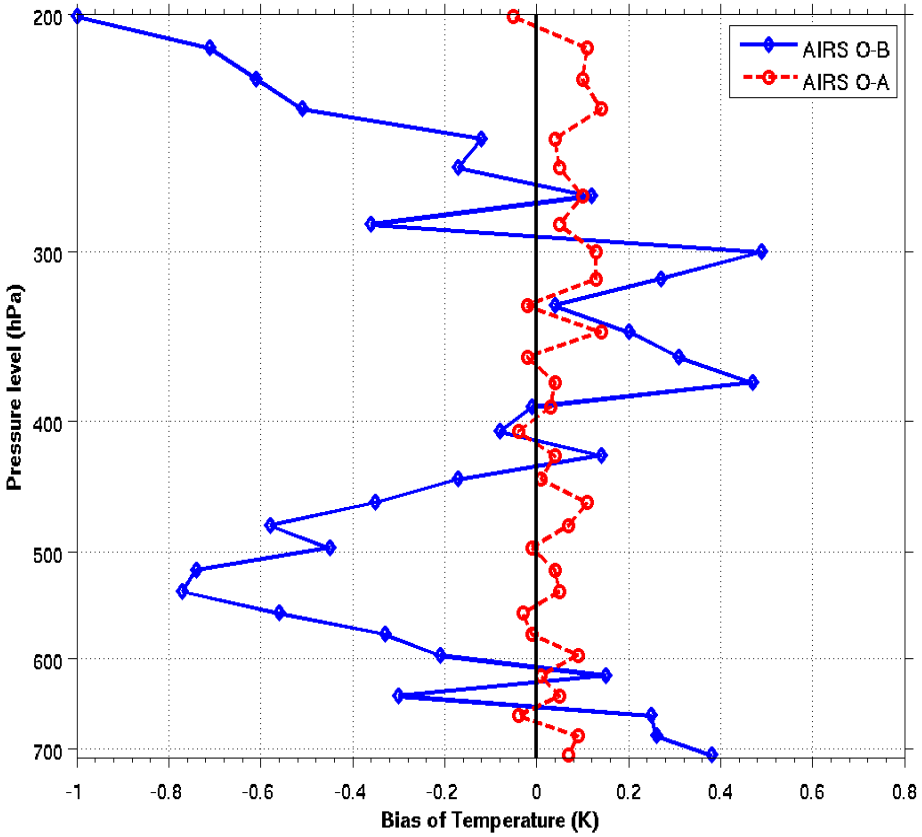
- **Data Assimilation**

O: Observations
B: Background (first guess) field
A: Analysis field

O-B: Observation innovation
O-A: Distance between observations and analysis

O-A is much smaller than O-B at every level, which represents that the AIRS sounding data fit good with the background field, and is well used in the assimilating process to help decrease the distance between the observations and analysis fields.

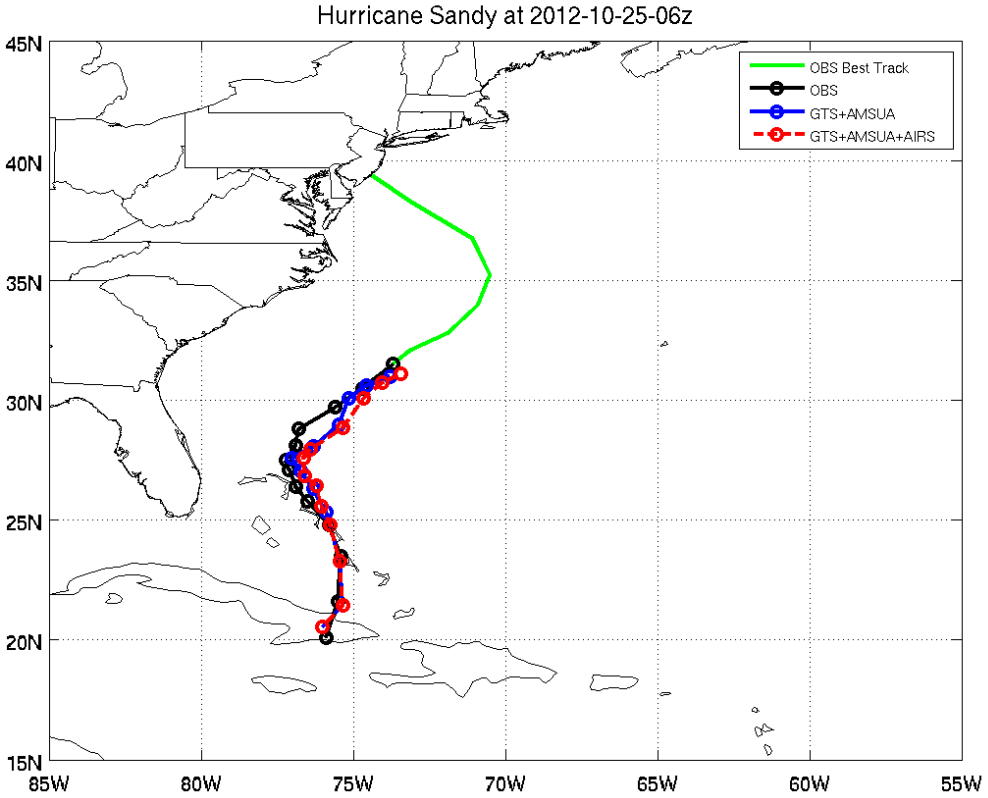
AIRS sounding data analysis



- **Forecasts Analysis**

Hurricane Sandy (2012) – 72 hours track forecasts

From 06z, 25 Oct 2012 to 00z 30 Oct 2012

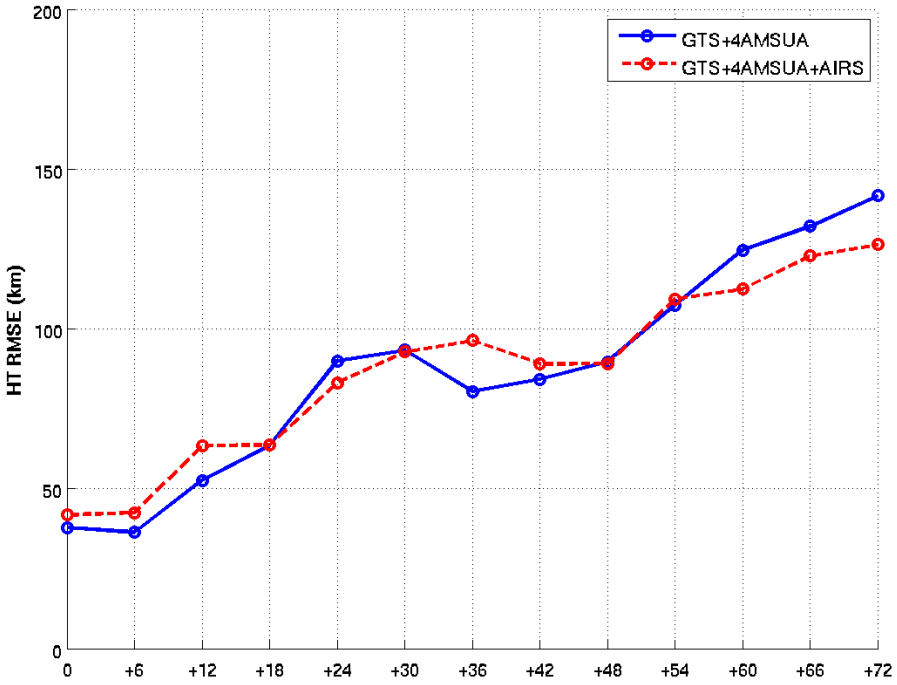


At 26 06z, Sandy moved to the northwest direction.

GTS+AMSUA+AIRS is nearer to the best track

- **Forecasts Analysis**

RMSE of hurricane track [km]



The statistical results of the 8 experiments for 72 hour forecasts

For the first 16hr, GTS+AMSUA is slightly better. But for the long term run, especially after 48hr, GTS+AMSUA+AIRS shows smaller RMSE of hurricane track.

- **Summary and Future Work**

  - Based on the quality control, conventional data, AMSUA and AIRS SFOV sounding data (200hPa to 700hPa) are used in GSI, the data assimilation model. WRF ARW model is used as the forecast model, which makes the 72hr forecasts for Hurricane Sandy (2012).

  - The cost function and gradient shows the first 20 iterations for the first and second outer loop decrease rapidly.

  - The temperature innovation (O-B) of AIRS are between -1K to 0.8K, the observation minus analysis (O-A) are between –0.1K to 0.2K, represents that the AIRS sounding data fit good with the background field, and is well used in the assimilating process to help decrease the distance between the observations and analysis fields.

  - The forecasts with GTS+AMSUA and GTS+AMSUA+AIRS for Hurricane Sandy are studied, the results of RMSE of hurricane track indicates that For the first 16hr, GTS+AMSUA is slightly better. But for the long term run, especially after 48hr, GTS+AMSUA+AIRS shows smaller RMSE of hurricane track.

- **Future Work**

  - The impacts of AIRS sounding data on the structures of hurricanes will further study.
  - And more hurricane case will be simulated to illustrate the impacts of AIRS sounding data on forecasts the hurricane track.
  - Assimilation of water vapor information will be studies in the future.

Thank you!