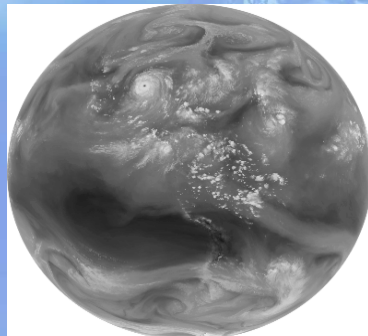
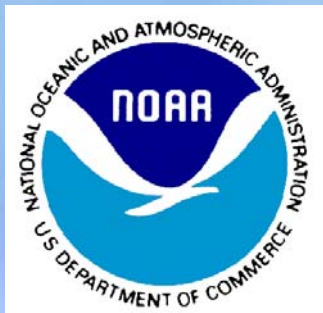


High impact weather nowcasting and short range forecasting using future geostationary advanced IR sounding data

Jun Li[&], Tim Schmit[#], Steve Goodman[@], Jim Gurka[@],
and CIMSS colleagues

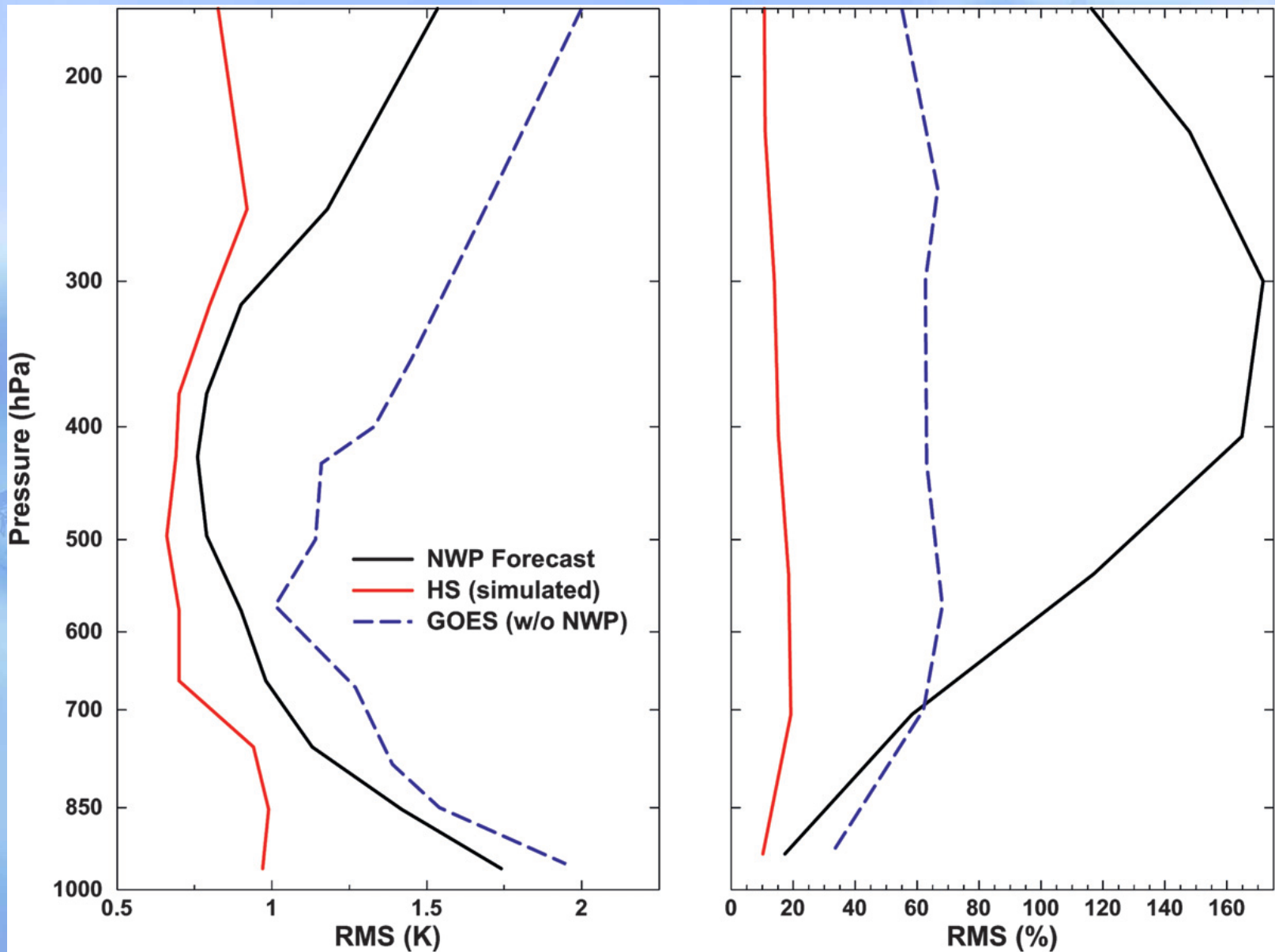
[&]CIMSS/UW-Madison
[#]STAR/NESDIS
[@]GOES-R Program Office

EUMETSAT Nowcasting and Short Range Forecast Workshop
26 – 28 April 2010, Madrid, Spain



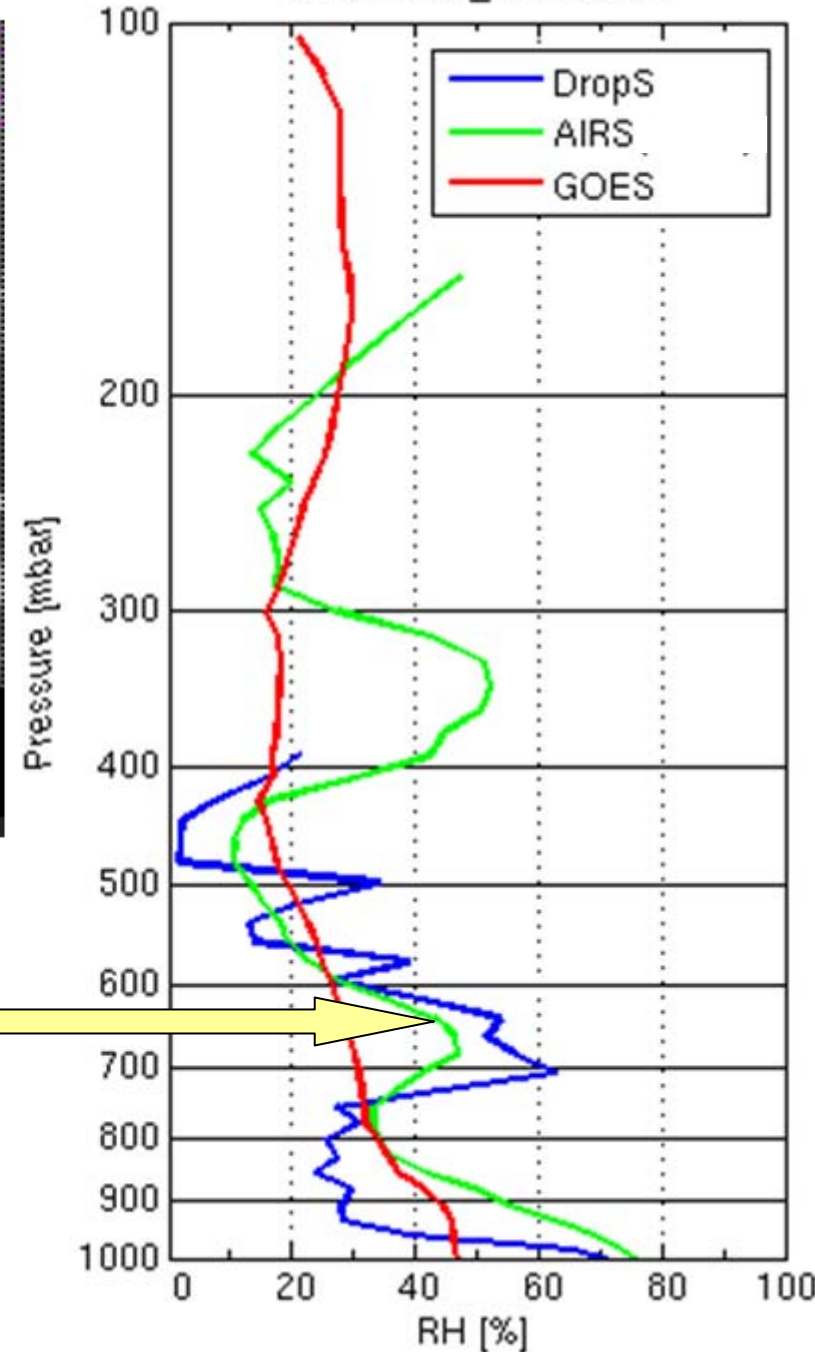
Outline

- **Why geostationary advanced IR soundings are important to nowcasting and short range forecasting?**
 - The unique value of a high temporal, high spatial and high spectral resolution IR sounder on severe weather nowcasting by depicting atmospheric vertical moisture structure, instability and inversion.
 - Assimilation of high spatial resolution advanced IR radiances/soundings in regional numerical weather prediction model
- **How to apply geostationary advanced IR soundings to high impact weather nowcasting and forecasting?**
 - Using advanced sounding products before the storm development for warning
 - GEO advanced IR radiance/sounding data can be used to improve short-range forecast through regional assimilation/forecasting system (e.g., WRF/VAR, WRF/DART)
- **To identify tropopause penetrating clouds and estimate precipitation (rain rate)**

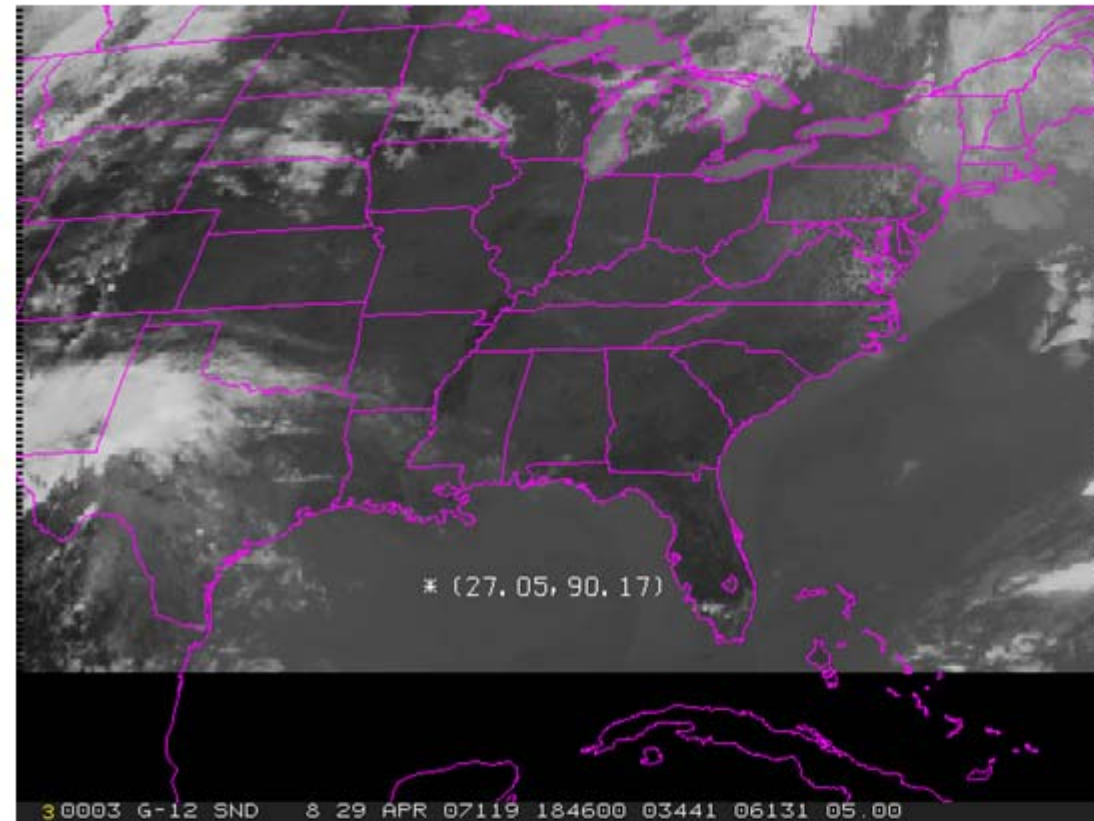


The (left) temperature and (right) water vapor mixing ratio percentage RMSEs for forecasts (black), GOES real soundings (blue), and HS (e.g., HES like) simulated soundings (red).

D20070429_185109.dat



AIRS SFOV Relative Humidity (RH) sounding depicts the vertical structure while the GOES sounding (independent of FCST) has limited vertical information

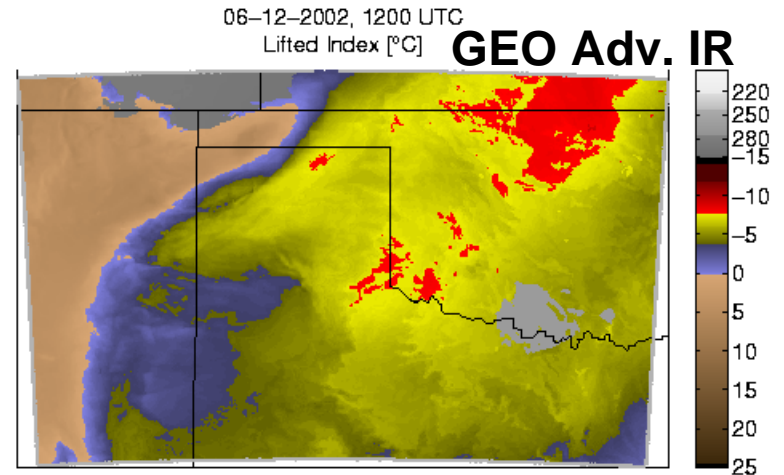
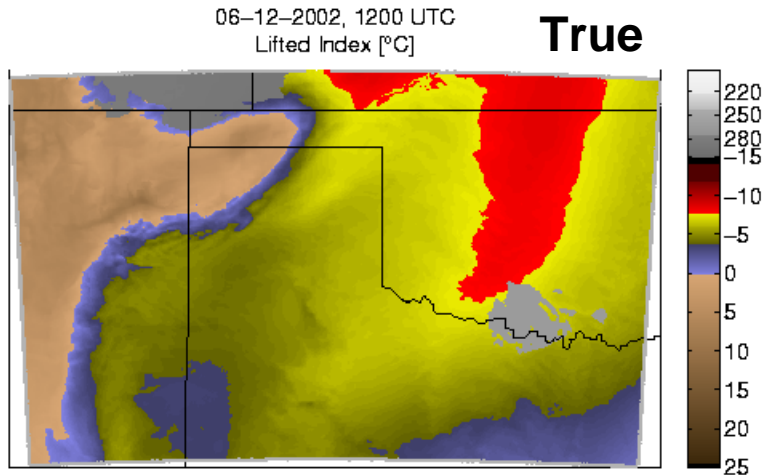


GEO advanced IR sounder simulation for HIW

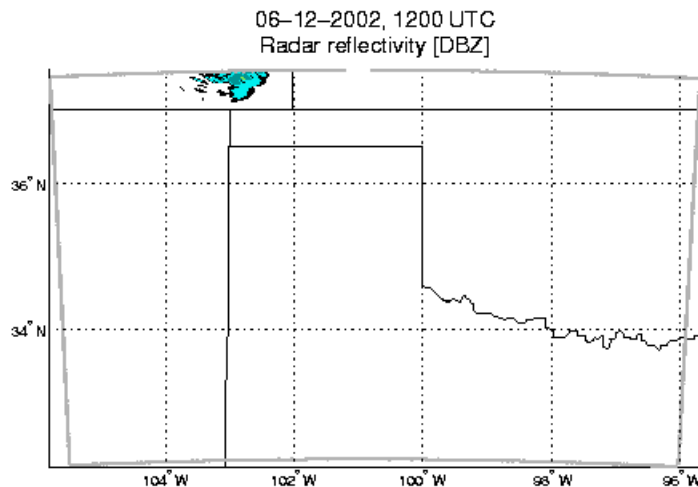
– an application to severe storm warning

- IHOP (2002) case has been used to simulate the GEO advanced IR sounding system as well as radar observations. High spatial and temporal resolution WRF model output is used as truth in the simulation. RUC forecast is also used in comparisons.
- The GEO advanced IR sounder represents a dramatic new capability for earlier warnings of severe weather, 4 – 8 hours earlier than the radar observation, current GOES Sounder or the regional forecast model

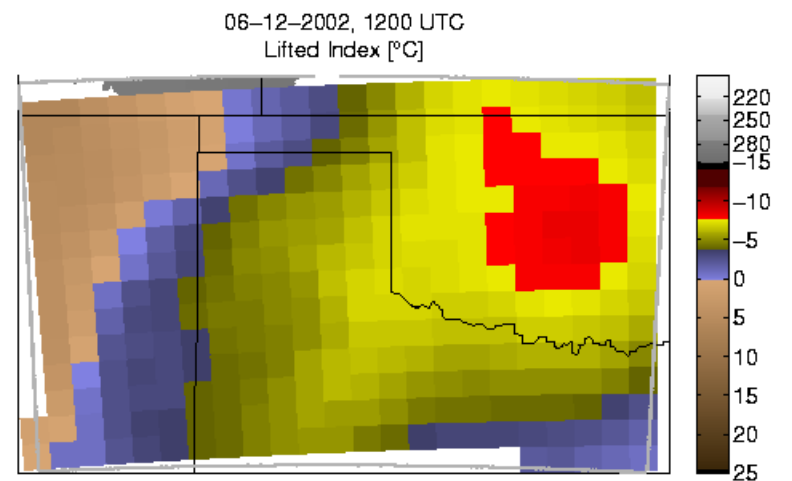
Demonstration of GEO advanced IR sounder for storm nowcasting



Red = extreme instability



Simulated Radar

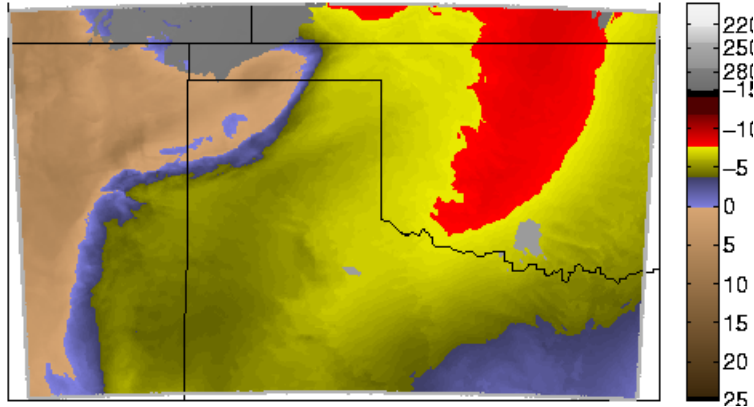


RUC forecast

HES/IRS provides needed instability and warning information hours earlier than regional forecast (+3-4 hrs) and Radar (+8 hrs)

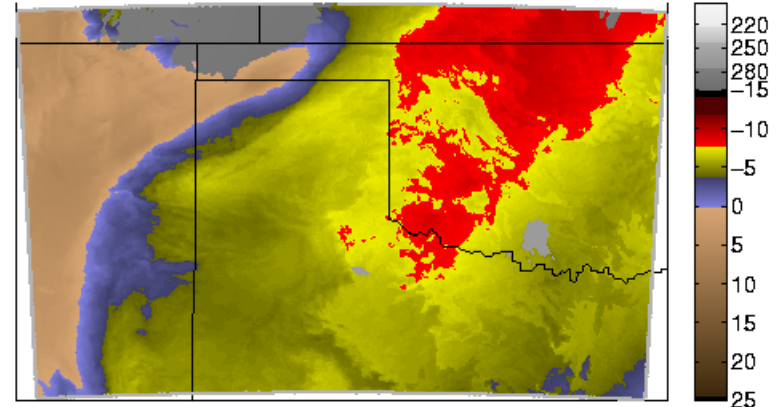
True

06-12-2002, 1300 UTC
Lifted Index [°C]



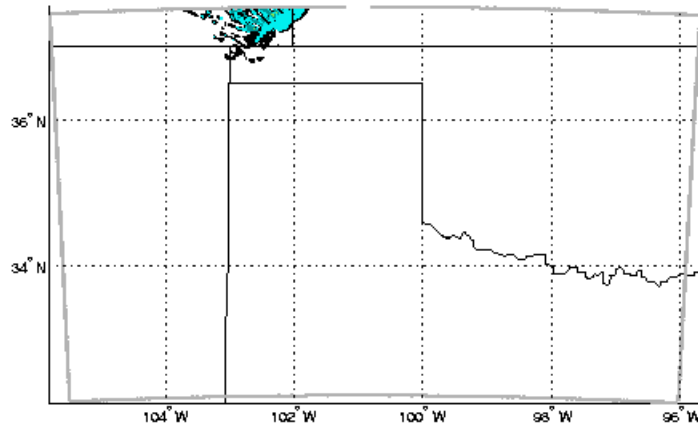
GEO Advanced Sounder

06-12-2002, 1300 UTC
Lifted Index [°C]



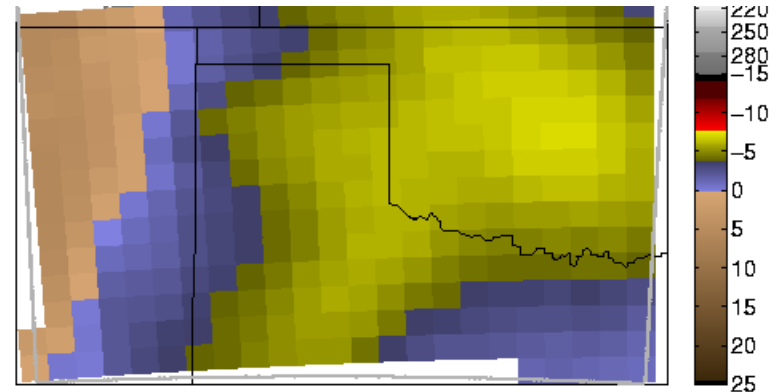
Extreme instability indicated

06-12-2002, 1300 UTC
Radar reflectivity [DBZ]



Simulated Radar

UW/CIMSS



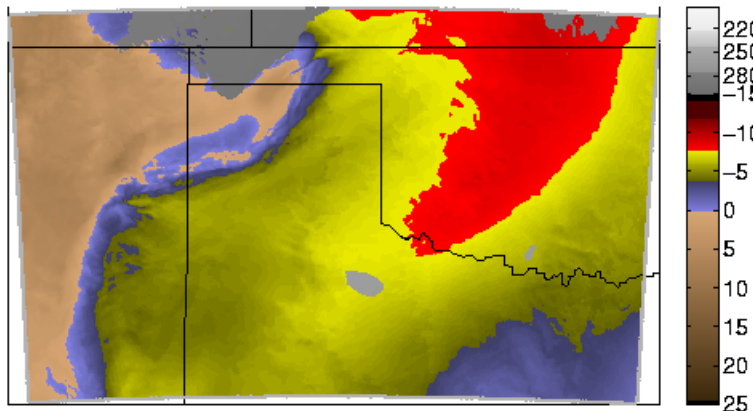
RUC Forecast

UW/CIMSS

1300 UTC

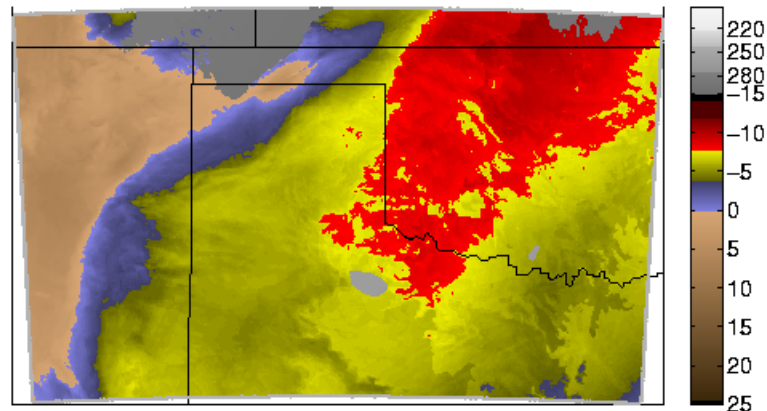
True

06-12-2002, 1400 UTC
Lifted Index [°C]

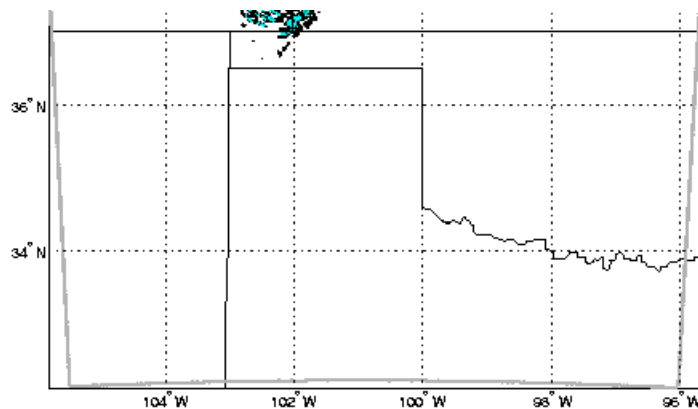


GEO Advanced Sounder

06-12-2002, 1400 UTC
Lifted Index [°C]

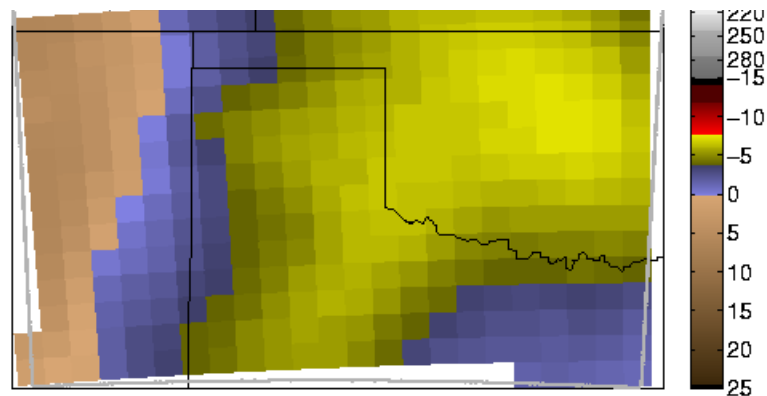


UW/CIMSS



Simulated Radar

UW/CIMSS



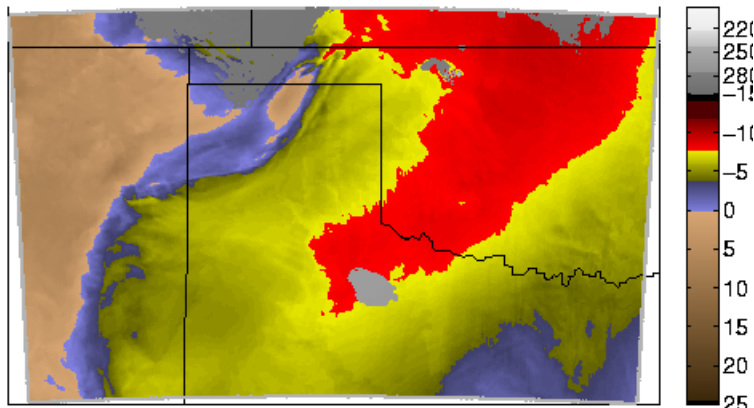
RUC Forecast

UW/CIMSS

1400 UTC

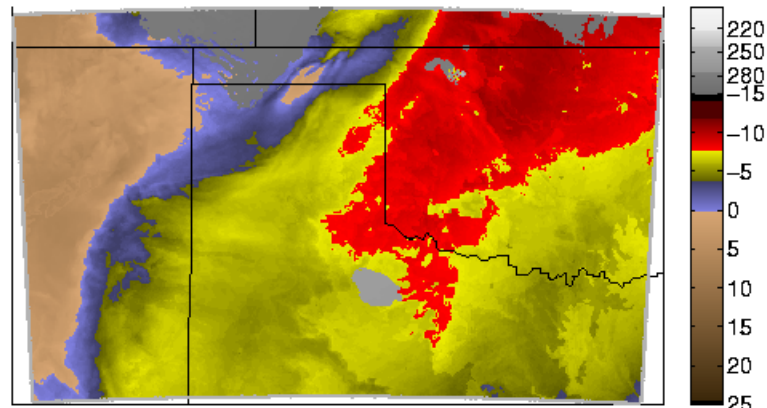
True

06-12-2002, 1500 UTC
Lifted Index [°C]

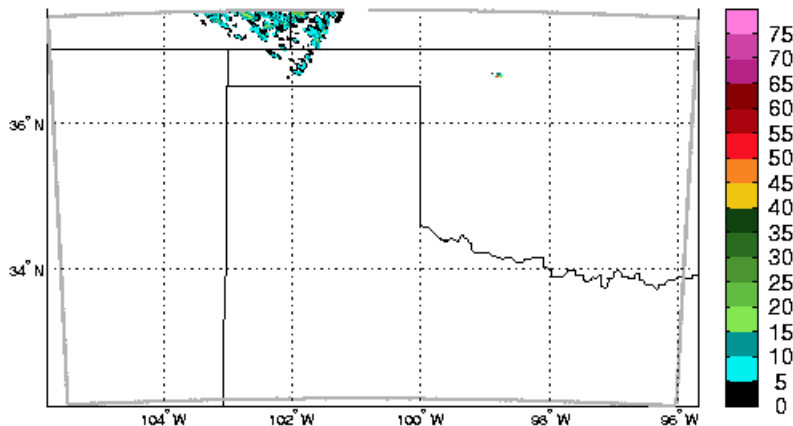


GEO Advanced Sounder

06-12-2002, 1500 UTC
Lifted Index [°C]

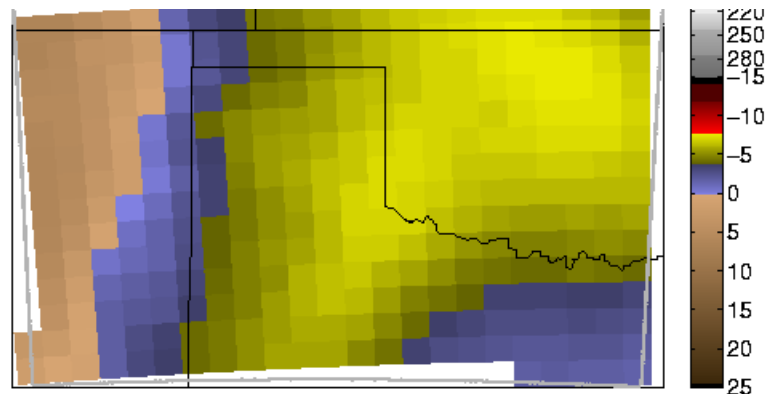


06-12-2002, 1500 UTC
Radar reflectivity [DBZ]



Simulated Radar

UW/CIMSS



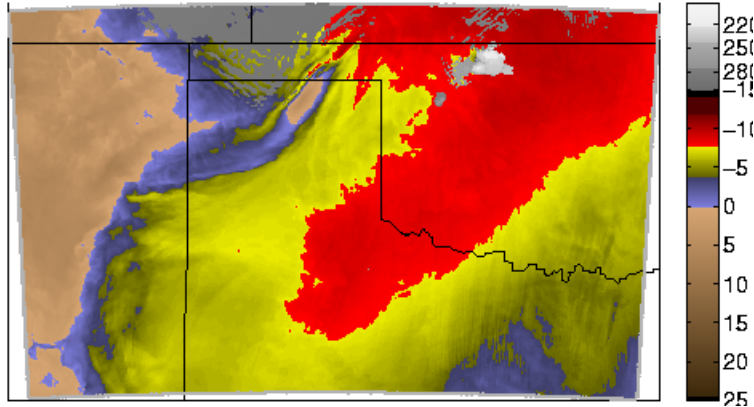
RUC Forecast

UW/CIMSS

1500 UTC

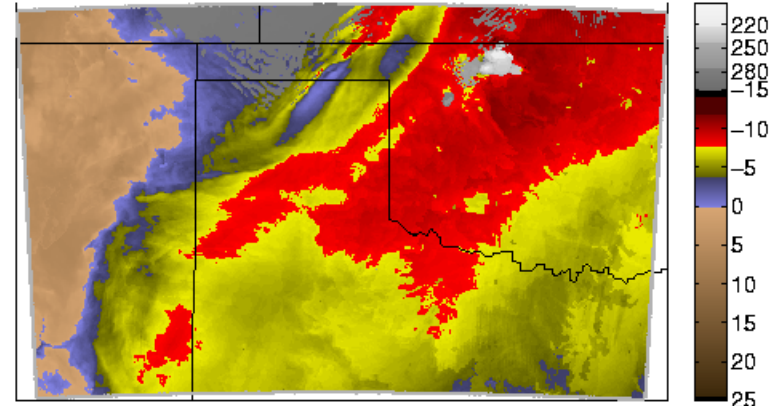
True

06-12-2002, 1600 UTC
Lifted Index [°C]

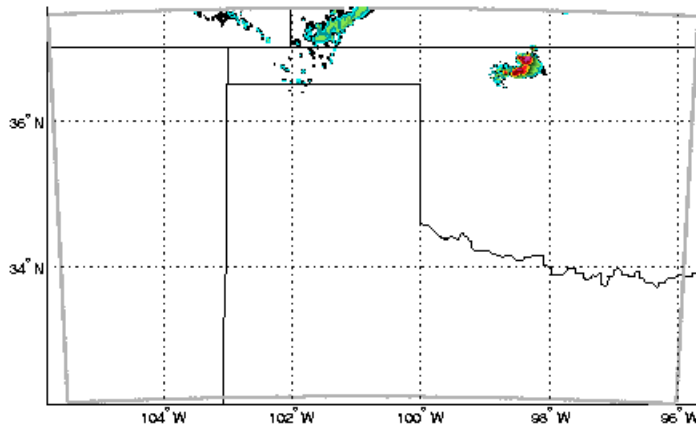


GEO Advanced Sounder

06-12-2002, 1600 UTC
Lifted Index [°C]

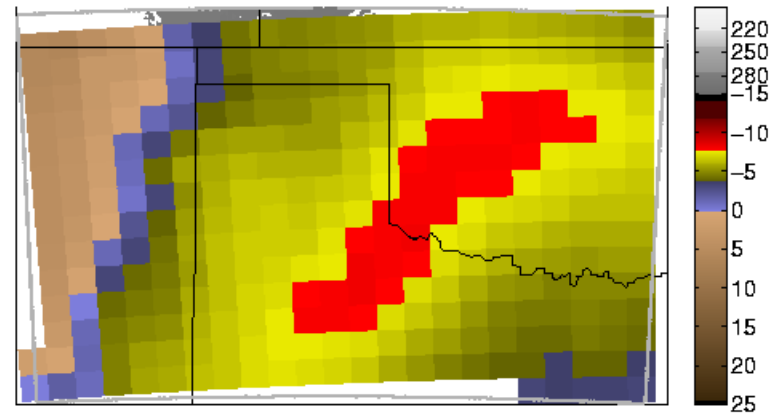


06-12-2002, 1600 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 1600 UTC
Lifted Index [°C]



RUC Forecast

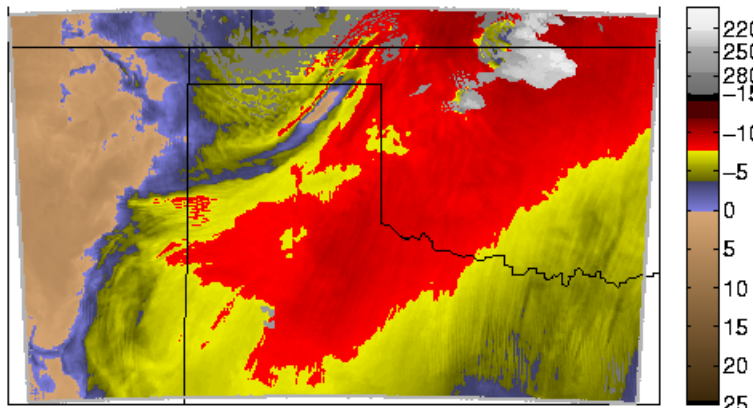
*Start to see extreme instability
3 hours later*

UW/CIMSS

1600 UTC

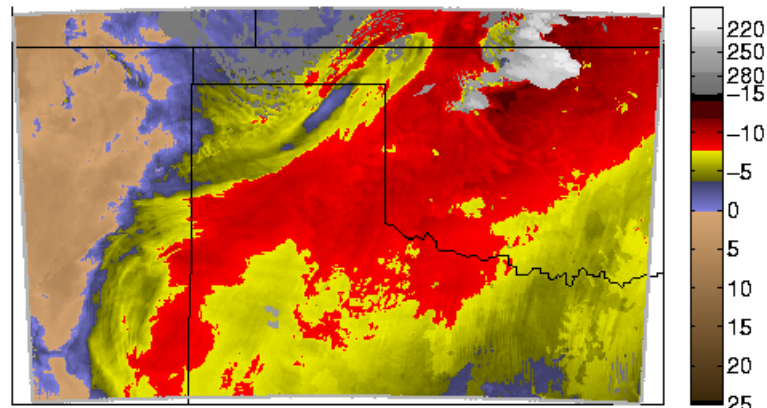
True

06-12-2002, 1700 UTC
Lifted Index [°C]

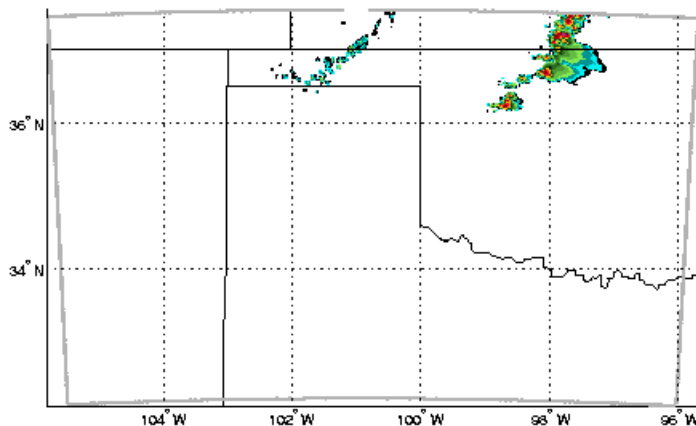


GEO Advanced Sounder

06-12-2002, 1700 UTC
Lifted Index [°C]

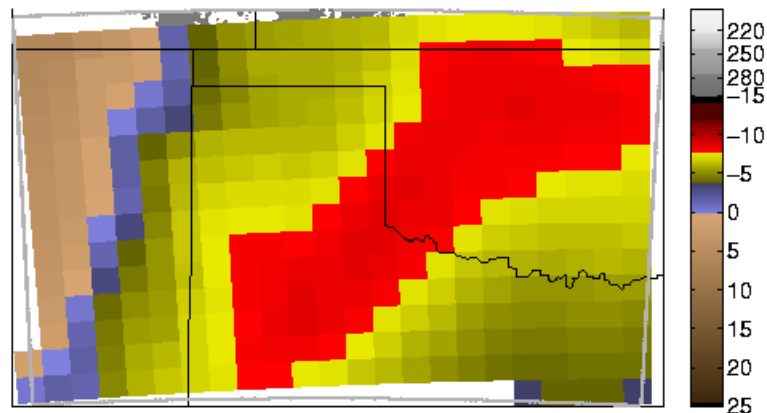


06-12-2002, 1700 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 1700 UTC
Lifted Index [°C]



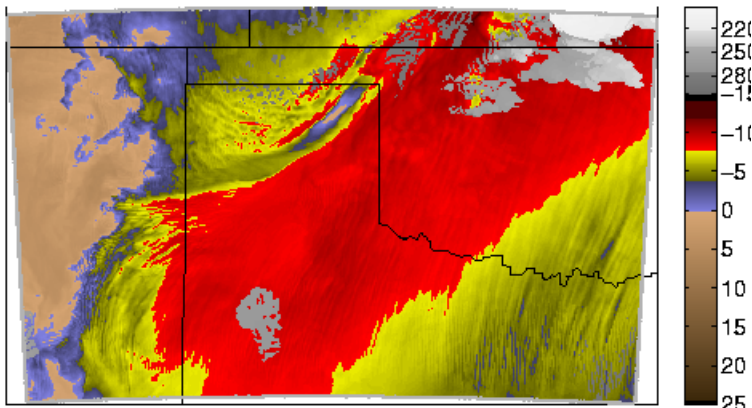
RUC Forecast

UW/CIMSS

1700 UTC

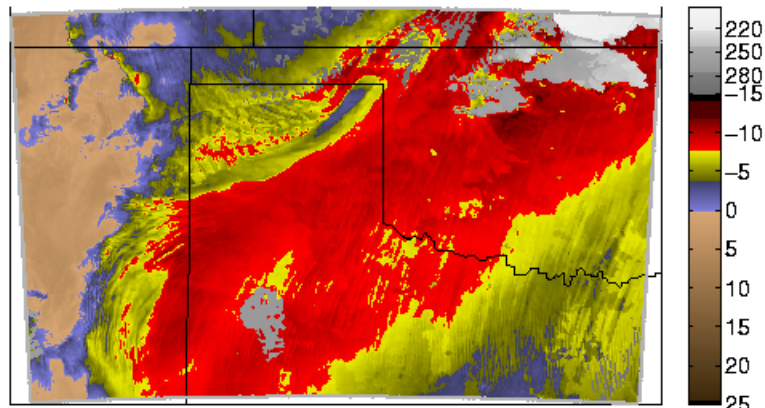
True

06-12-2002, 1800 UTC
Lifted Index [°C]

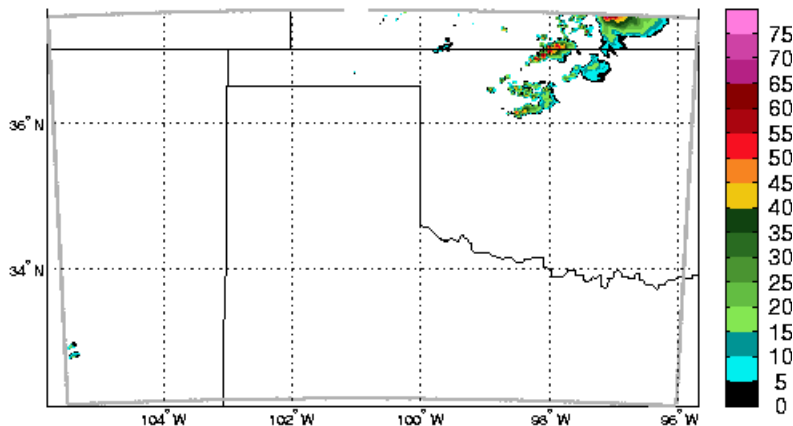


GEO Advanced Sounder

06-12-2002, 1800 UTC
Lifted Index [°C]

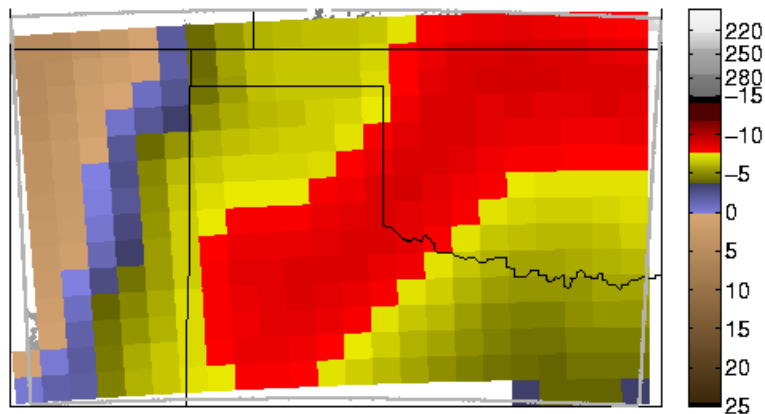


06-12-2002, 1800 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 1800 UTC
Lifted Index [°C]



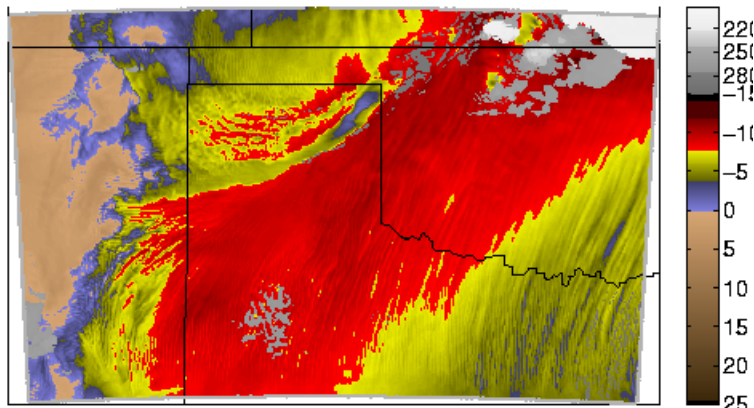
RUC Forecast

UW/CIMSS

1800 UTC

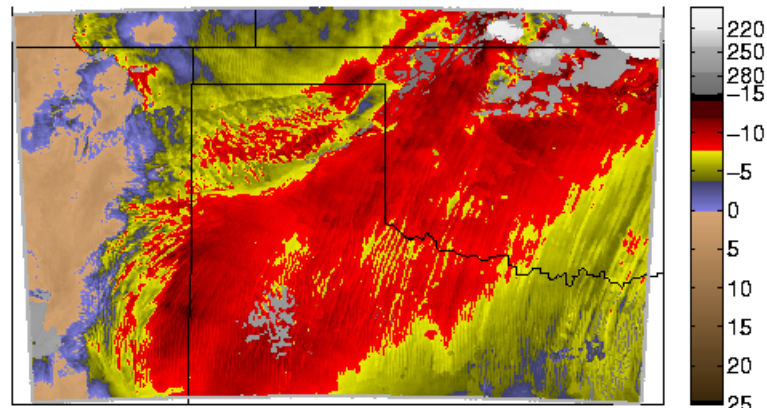
True

06-12-2002, 1900 UTC
Lifted Index [°C]

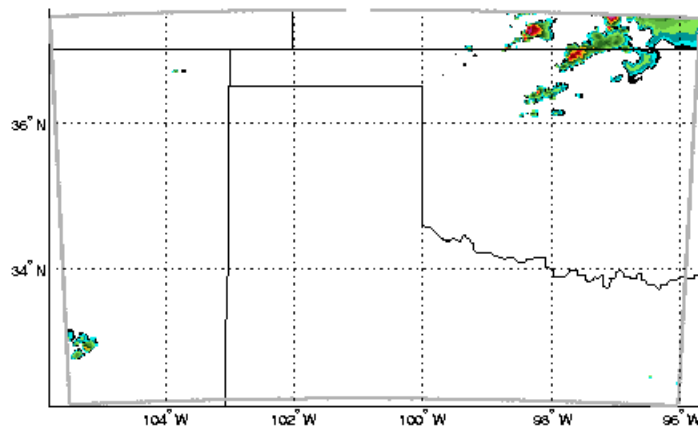


GEO Advanced Sounder

06-12-2002, 1900 UTC
Lifted Index [°C]

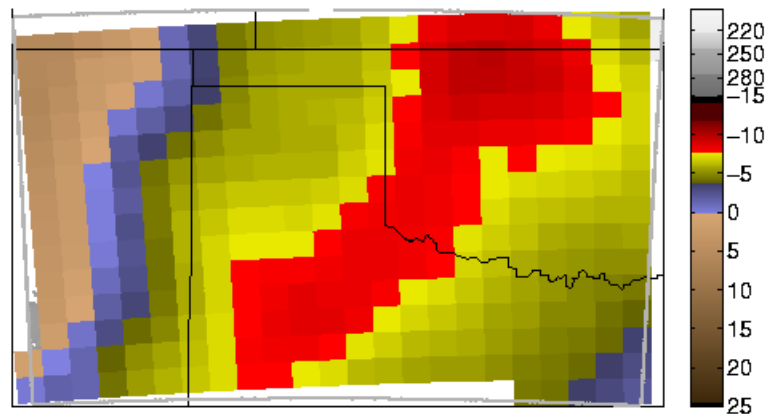


06-12-2002, 1900 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 1900 UTC
Lifted Index [°C]



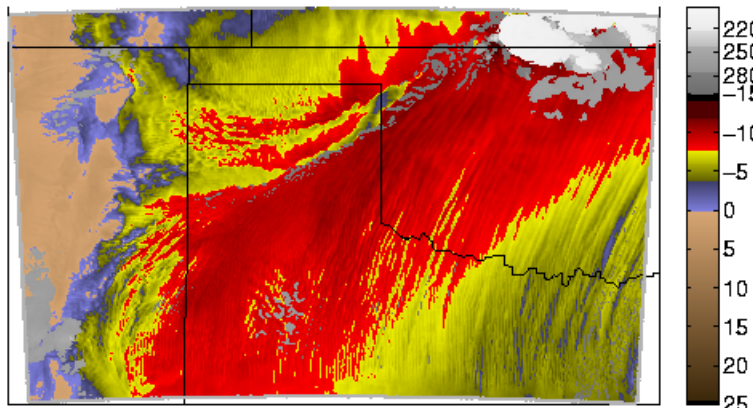
RUC Forecast

UW/CIMSS

1900 UTC

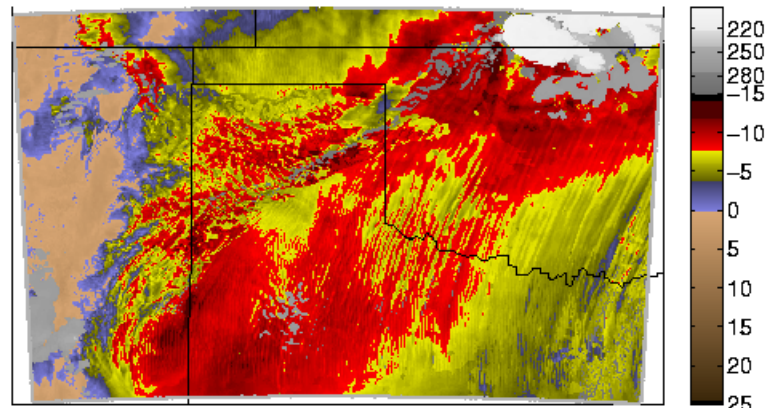
True

06-12-2002, 2000 UTC
Lifted Index [°C]

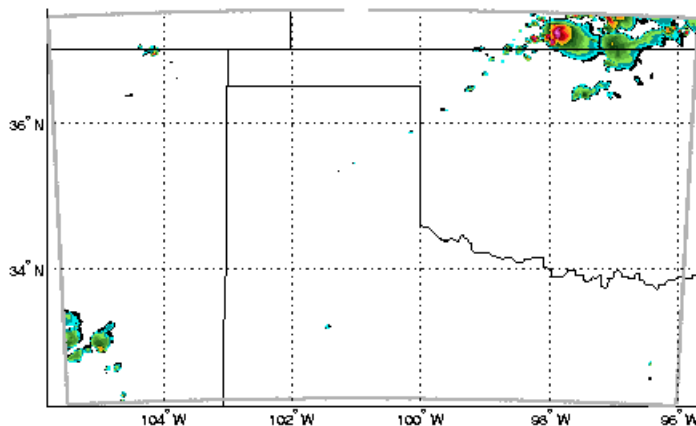


GEO Advanced Sounder

06-12-2002, 2000 UTC
Lifted Index [°C]

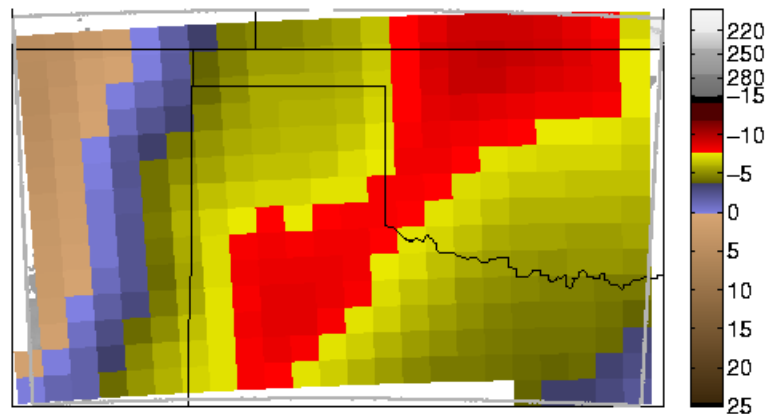


06-12-2002, 2000 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 2000 UTC
Lifted Index [°C]



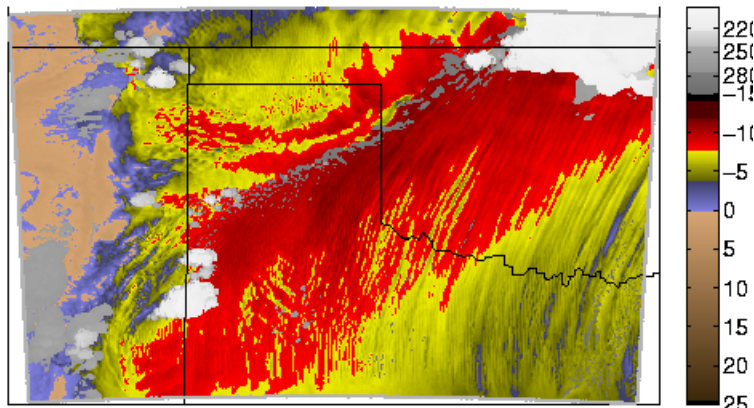
RUC Forecast

UW/CIMSS

2000 UTC

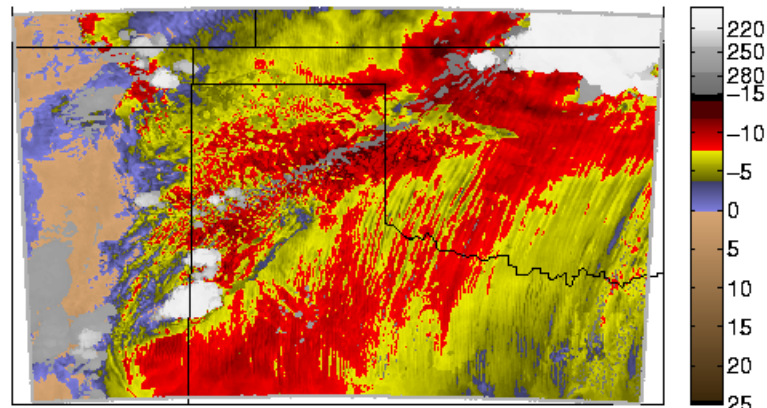
True

06-12-2002, 2100 UTC
Lifted Index [°C]

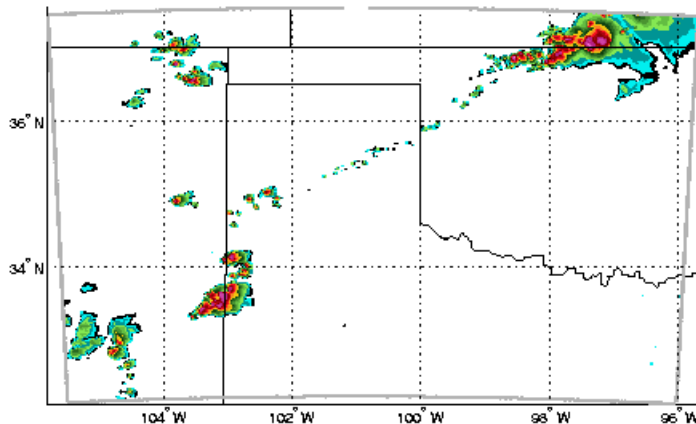


GEO Advanced Sounder

06-12-2002, 2100 UTC
Lifted Index [°C]

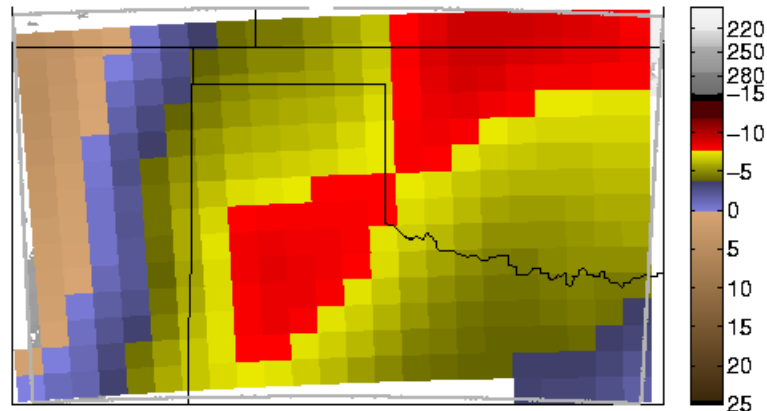


06-12-2002, 2100 UTC
Radar reflectivity [DBZ]



Simulated Radar

06-12-2002, 2100 UTC
Lifted Index [°C]



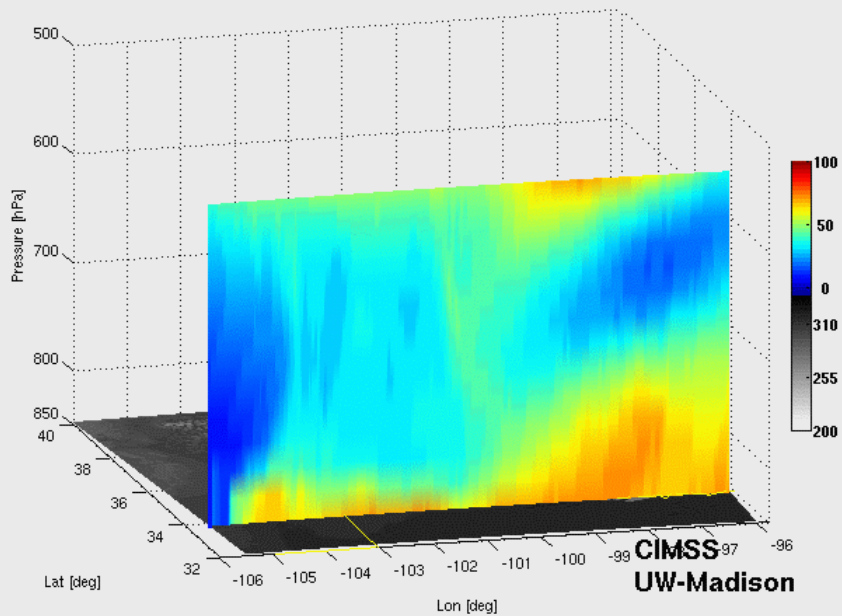
RUC Forecast

*Rain line shows in
radar 8 hours later*

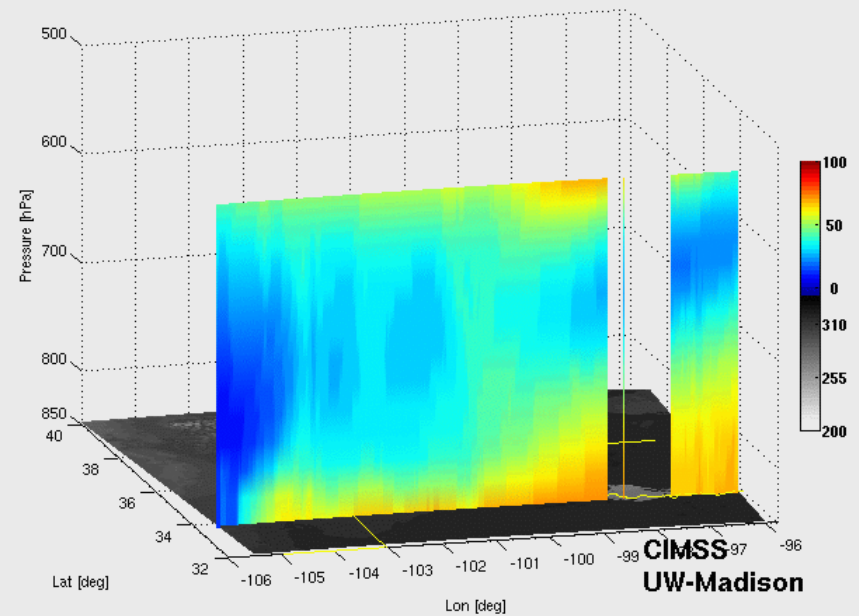
UW/CIMSS

2100 UTC

12 June 2002 1200 UTC Relative Humidity [%]



12 June 2002 1200 UTC Relative Humidity [%]

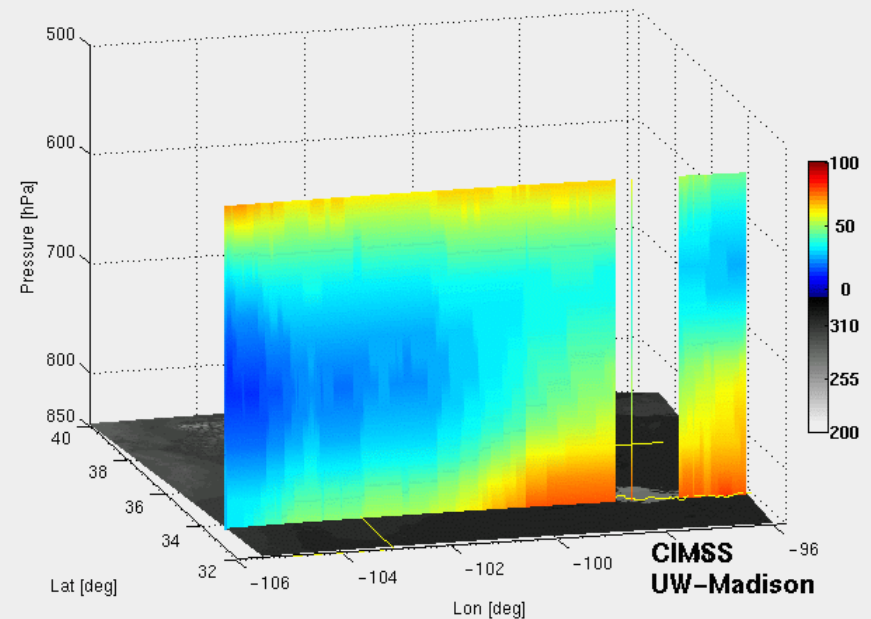


True

GEO
Advanced
Sounder

GOES-R
ABI

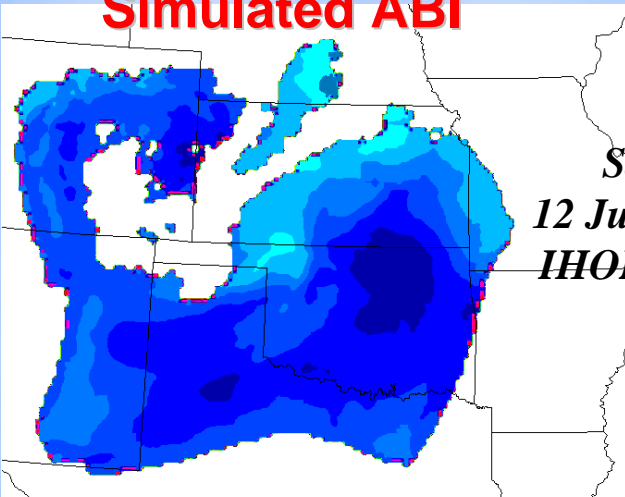
12 June 2002 1200 UTC Relative Humidity [%]



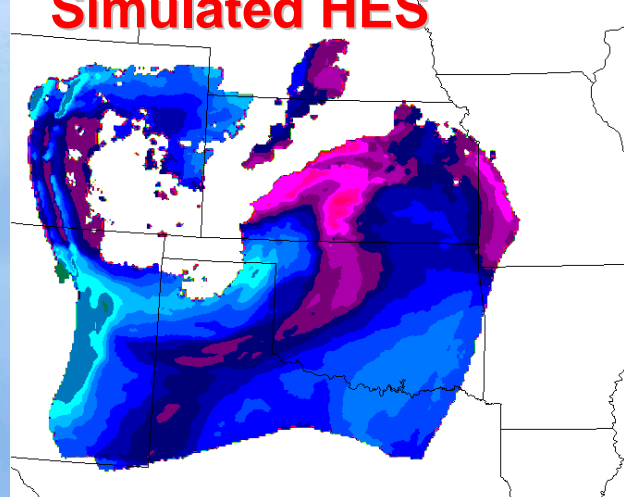
New Nearcasting Approach Demonstrates Power of Sounder

5-hour Nearcast for 2000 UTC using Equivalent Potential Temperature (Theta-E)

Simulated ABI



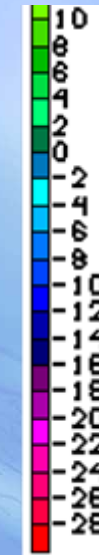
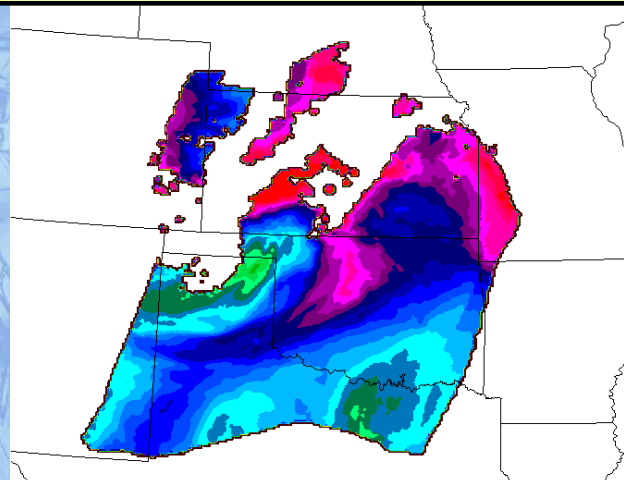
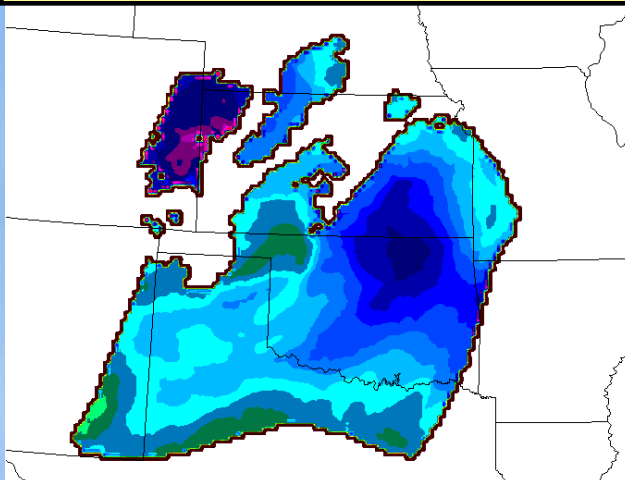
Simulated HES



*Same
12 June 2002
IHOP OSSE*



Strong, localized low-level Theta-E gradients seen by HES, not ABI
(enhanced vertical resolution gives HES much higher sensitivity to low level moisture)



Vertical Theta-E Differences (500-800 mb) indicate where instability
(large negative) supports severe deep convection

CIMSS
Nearcasting

multi-layered
observations
projected
forward in
time along
Lagrangian
trajectories
(using winds
from RUC)

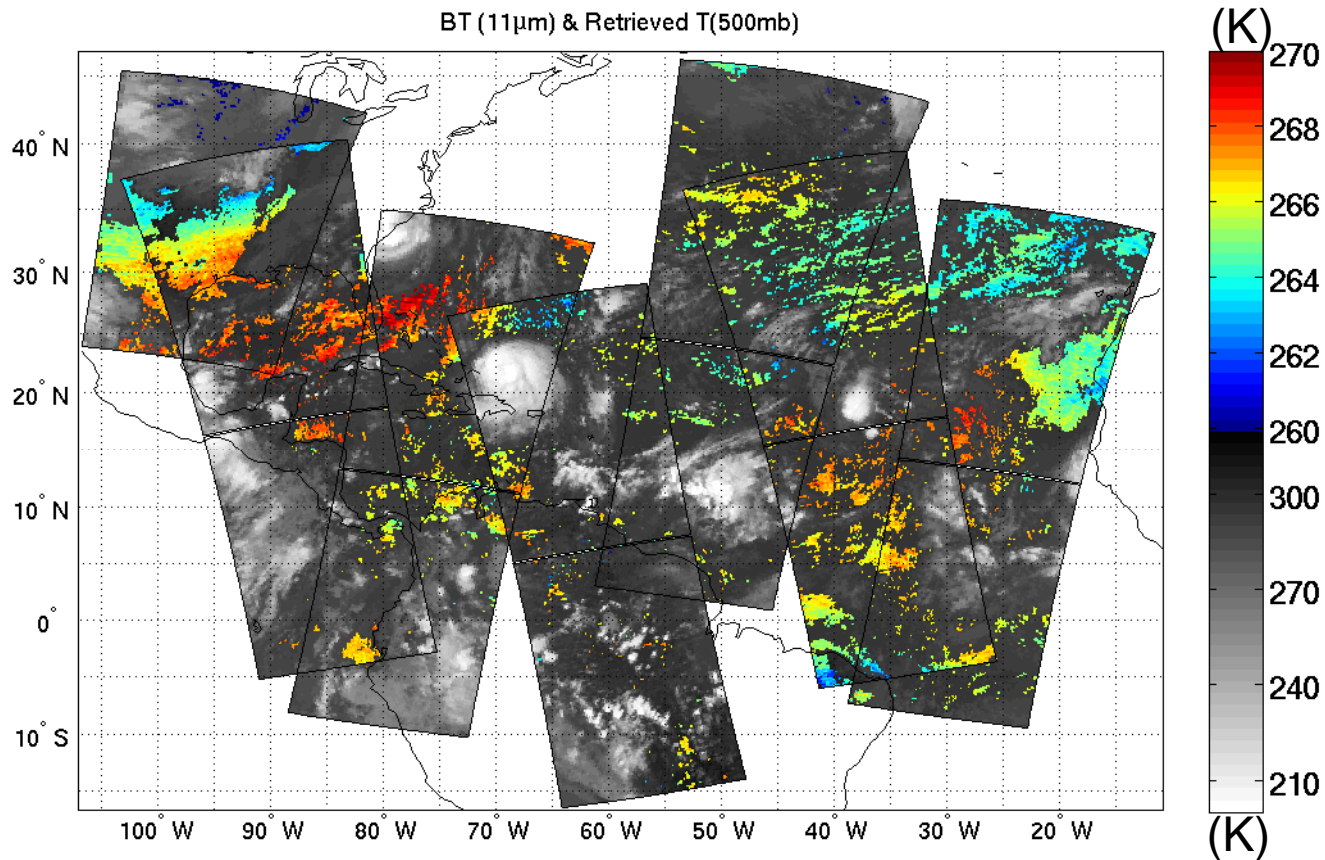
Robert Aune
(NESDIS)

17
Ralph Petersen
(UW-SSEC/CIMSS)

Using AIRS as proxy for regional hurricane/typhoon assimilation

- Full spatial resolution temperature and moisture profiles (13.5 km at nadir) from AIRS derived with CIMSS hyperspectral IR Sounding Retrieval algorithm (CHSR) have been used for Hurricane Ike (2008) and Typhoon Sinlaku (2008) assimilation and forecast.
- The full spatial resolution AIRS soundings show positive impact on hurricane/typhoon track and intensity both in assimilation and forecast using the WRF/DART system with 36 km spatial resolution.
- Full spatial resolution AIRS soundings significantly improve the definition of the typhoon vortex in the analysis and the forecast of the rapid intensification for Typhoon Sinlaku (2008).
- Full spatial resolution AIRS water vapor profiles improve temperature, moisture and wind forecast in regional NWP model in our study.

Retrieved 500mb temperature (2008.09.06 – Used in assimilation)

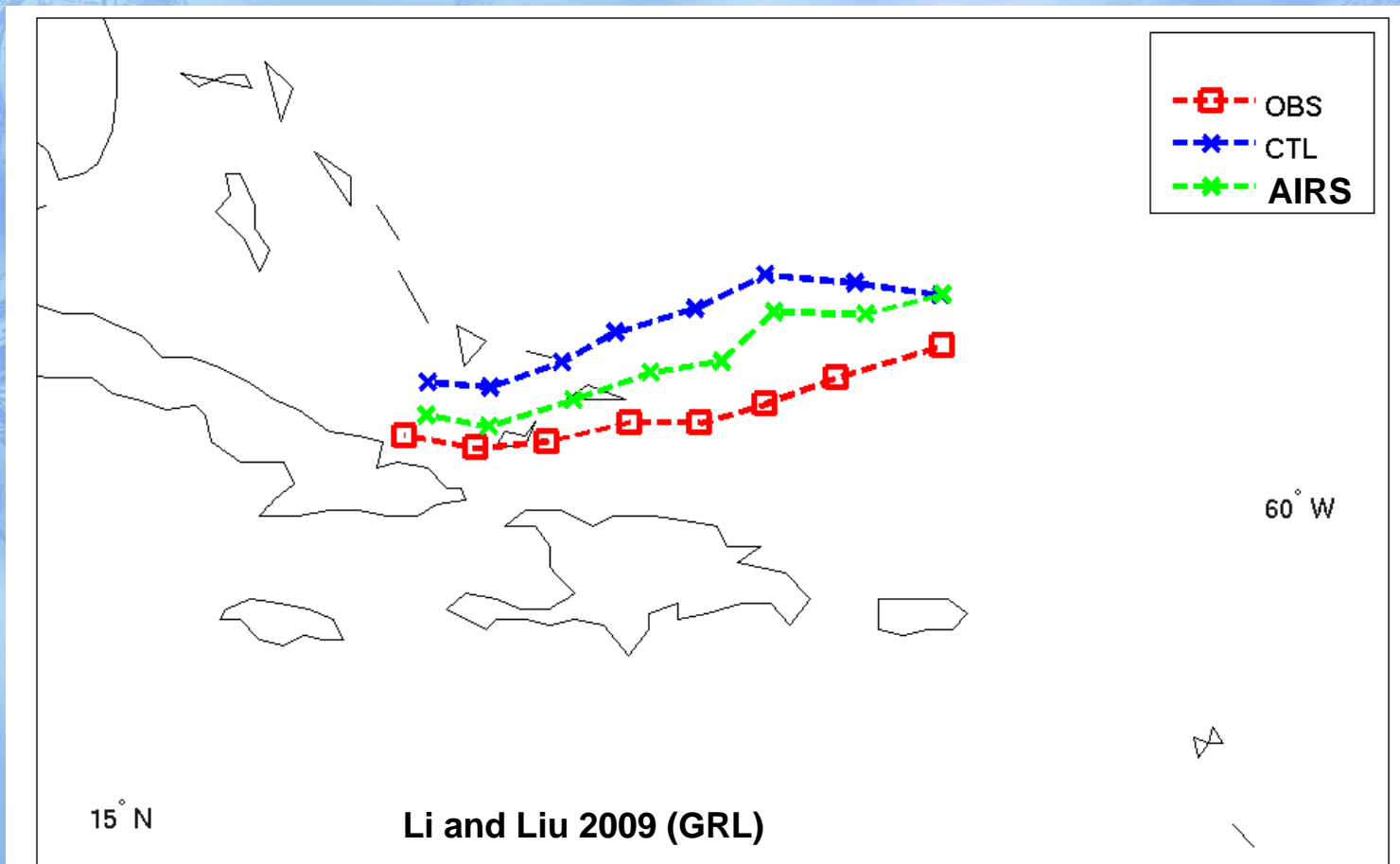


CIMSS/UW

Clear sky AIRS SFOV temperature retrievals at 500 hPa on 06 September 2008, each pixel provides vertical temperature and moisture soundings.

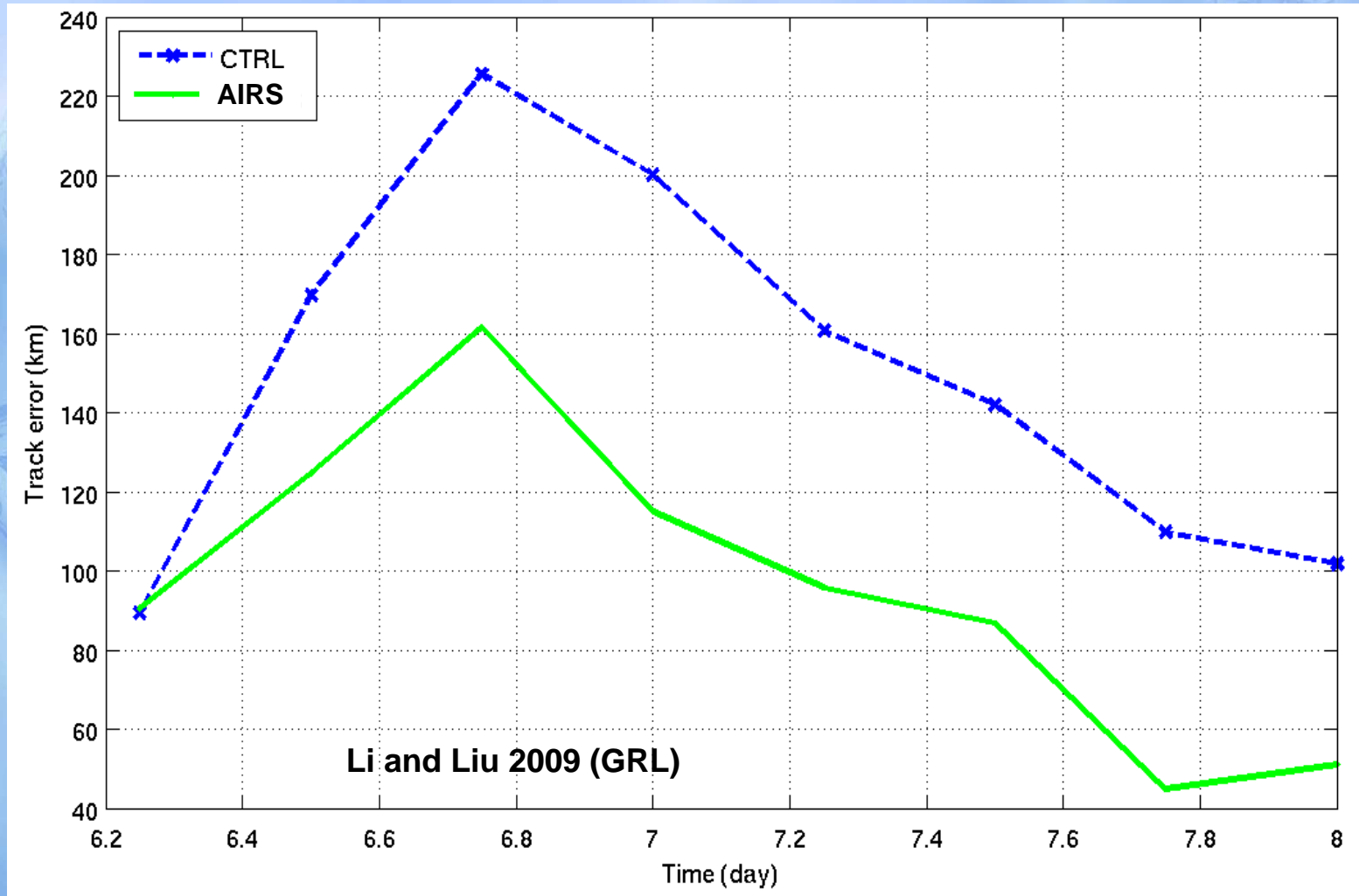
Tracks of ensemble mean analysis on Hurricane IKE

CTL Run: Assimilate radiosonde, satellite cloud winds, aircraft data, and surface data.



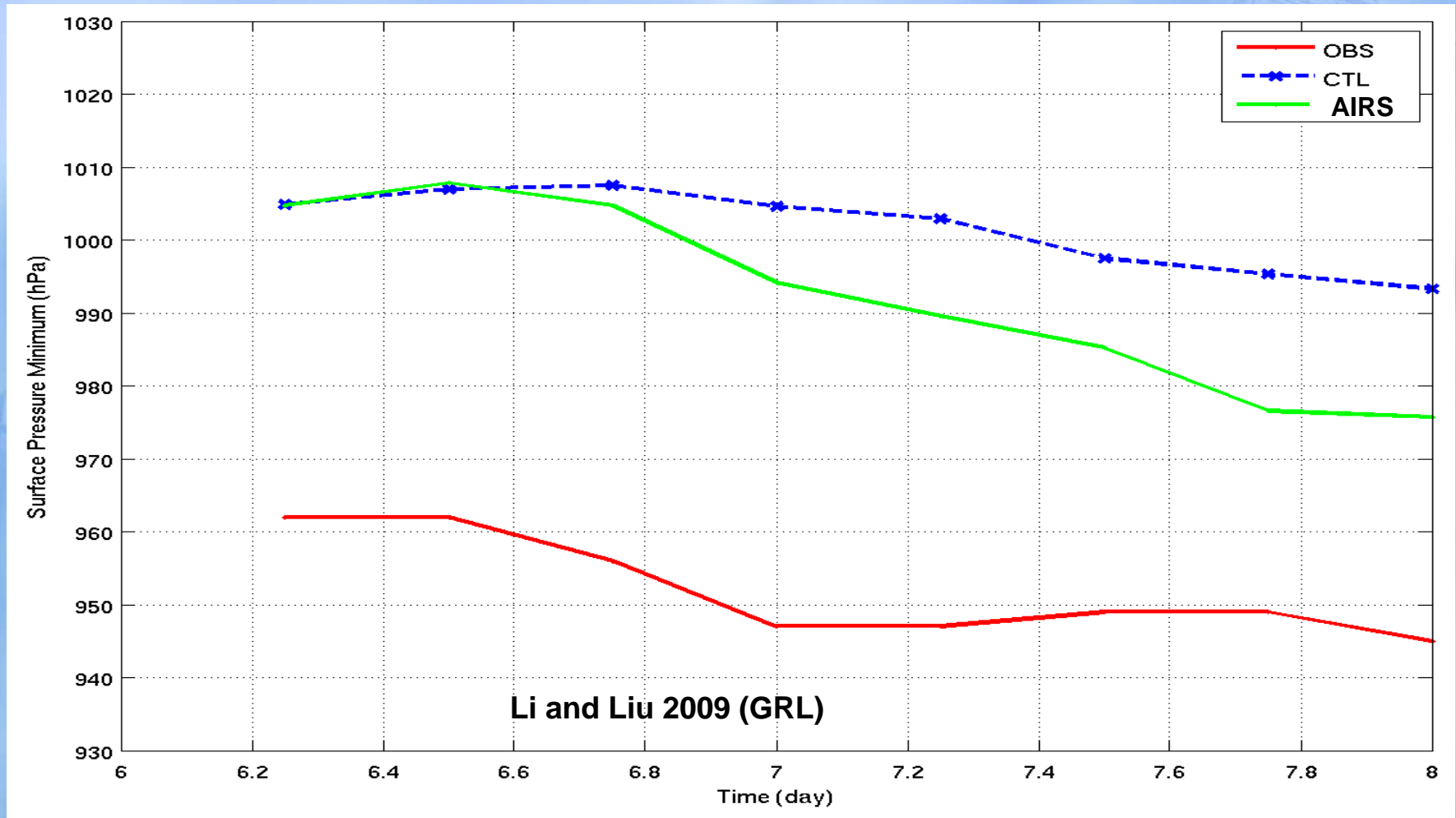
Analysis from 06 UTC 6 to 00UTC 8 September 2008

Track errors of on Hurricane IKE



Analysis from 06 UTC 6 to 00UTC 8 September 2008

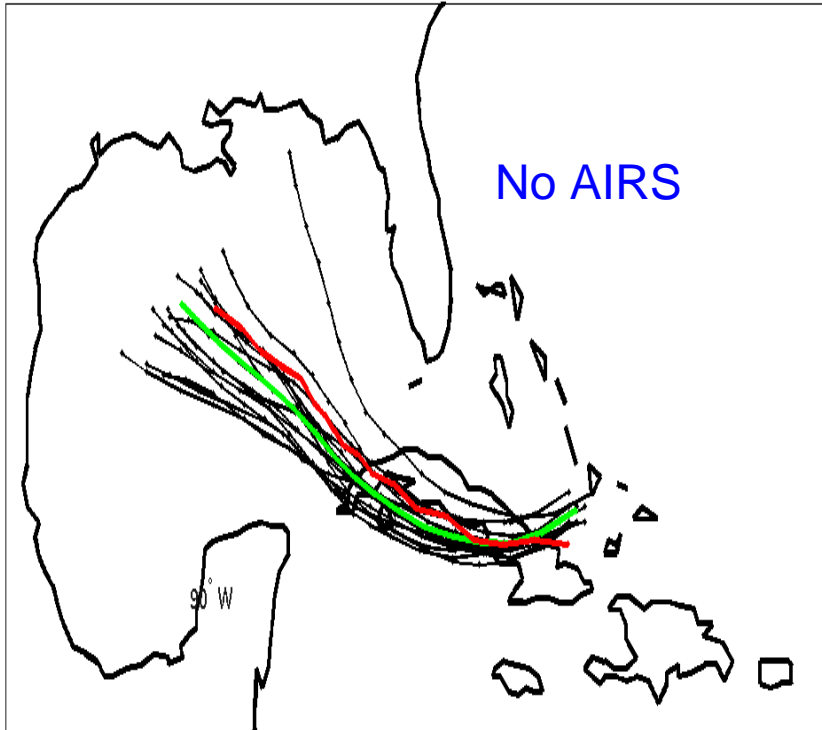
Sea level pressure (SLP) intensity on Hurricane IKE



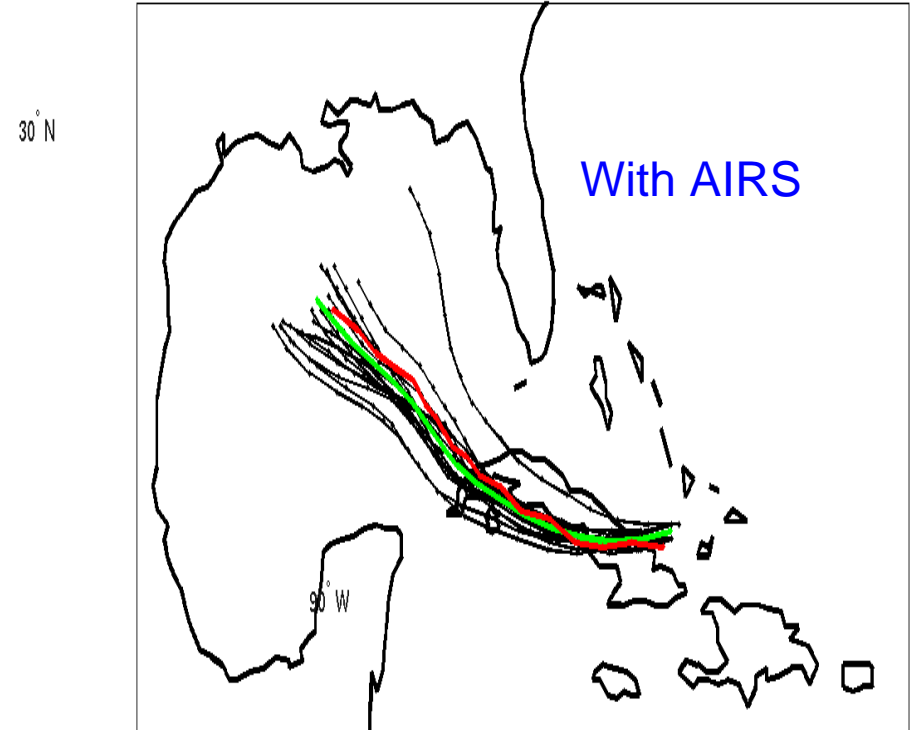
Analysis from 06 UTC 6 to 00UTC 8 September 2008

Tracks of 96h forecasts on Hurricane IKE

Ensemble forecasts from 00UTC 8 Sept, CTL



Ensemble forecasts from 00UTC 8 Sept, AIRS

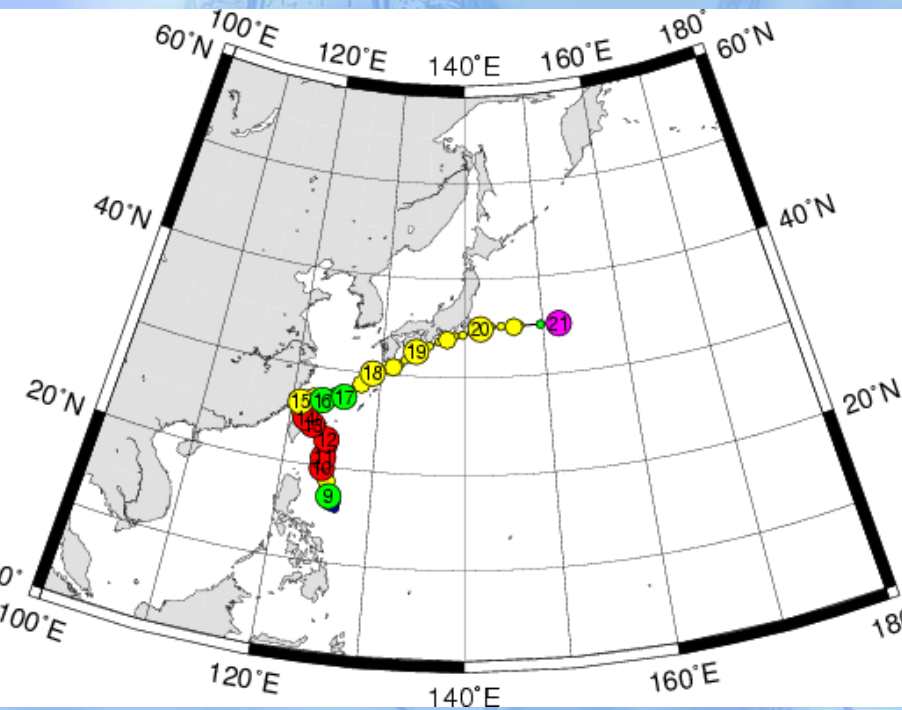


Li and Liu 2009 (GRL)

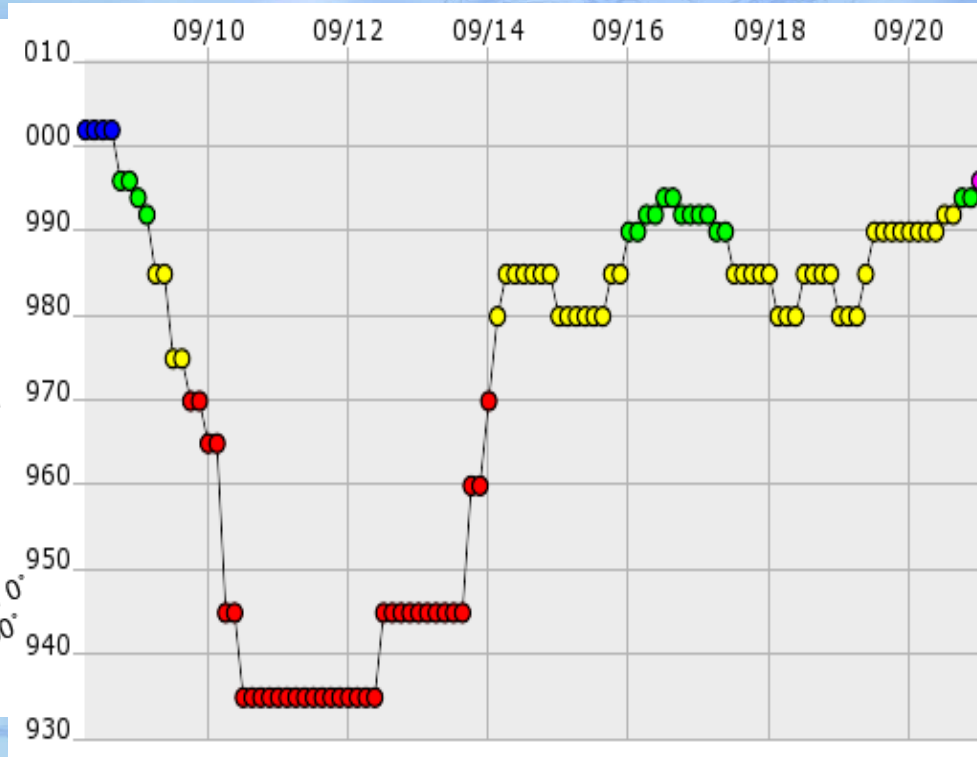
15° N

Forecasts start at 00 UTC 8 September 2008
(Red line is observation, green line is forecast)

Typhoon Sinlaku (2008) Fact

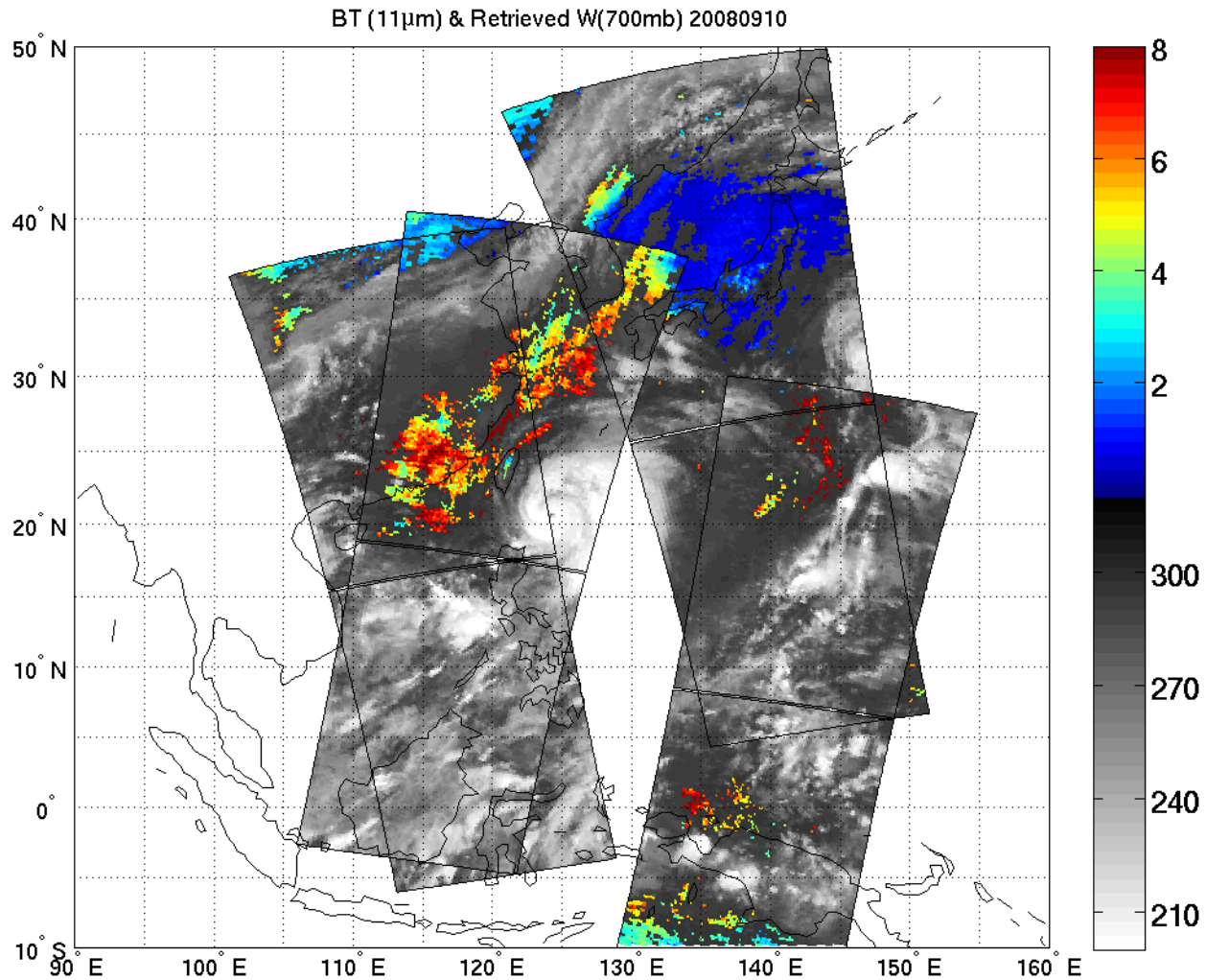


Sinlaku path



Sinlaku intensity (SLP)

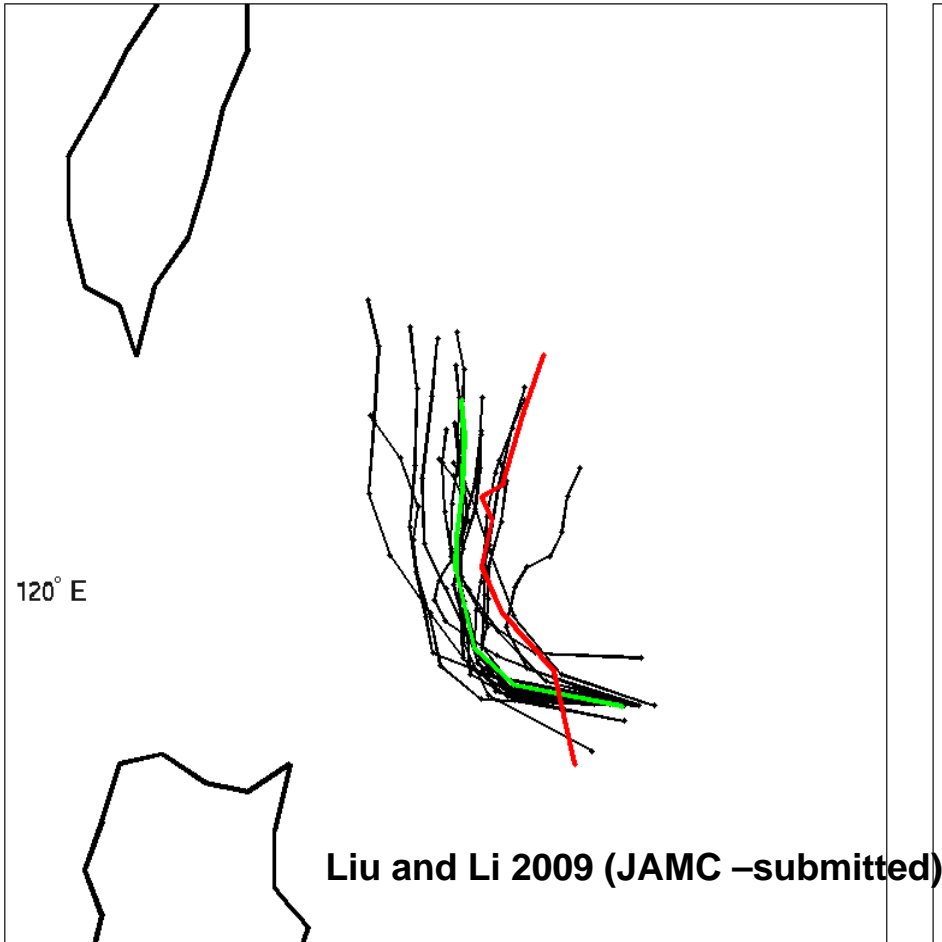
Rapid intensification is observed



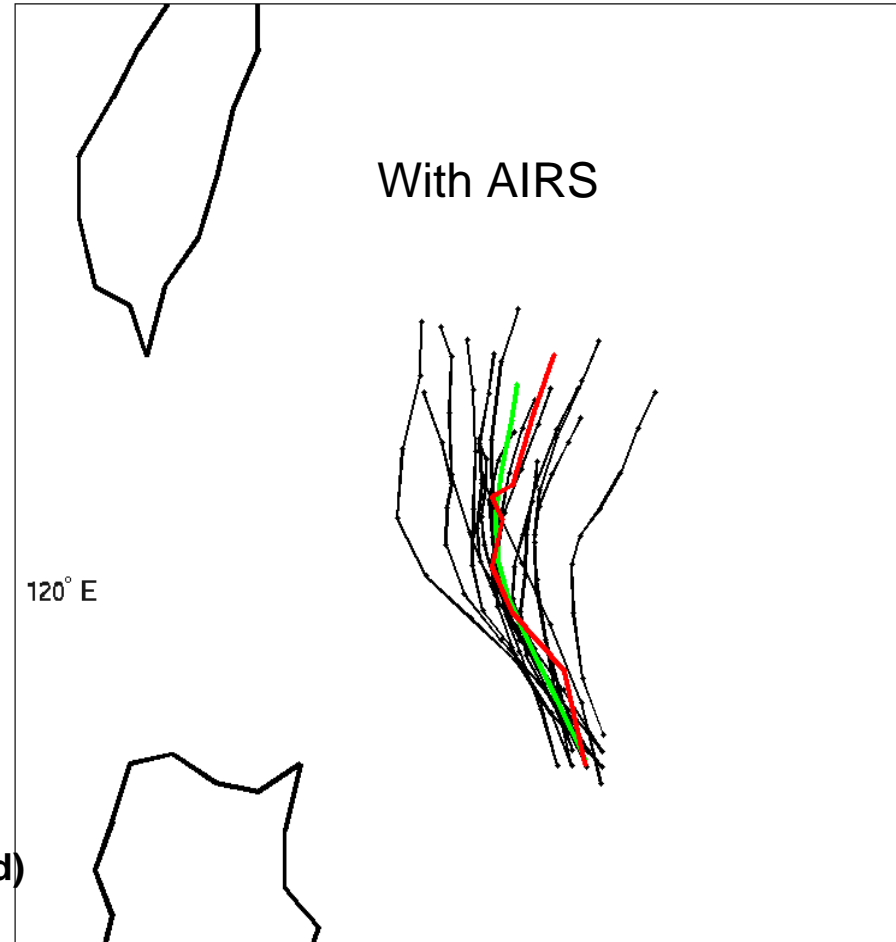
700 hPa water vapor mixing ratio (g/kg) (Sinlaku – 2008). **GEO** can provide more clear sky data with frequent observations !

Tracks of 48h forecasts on Sinlaku (2008)

Ensemble forecasts from 12UTC 9 Sept, CTL

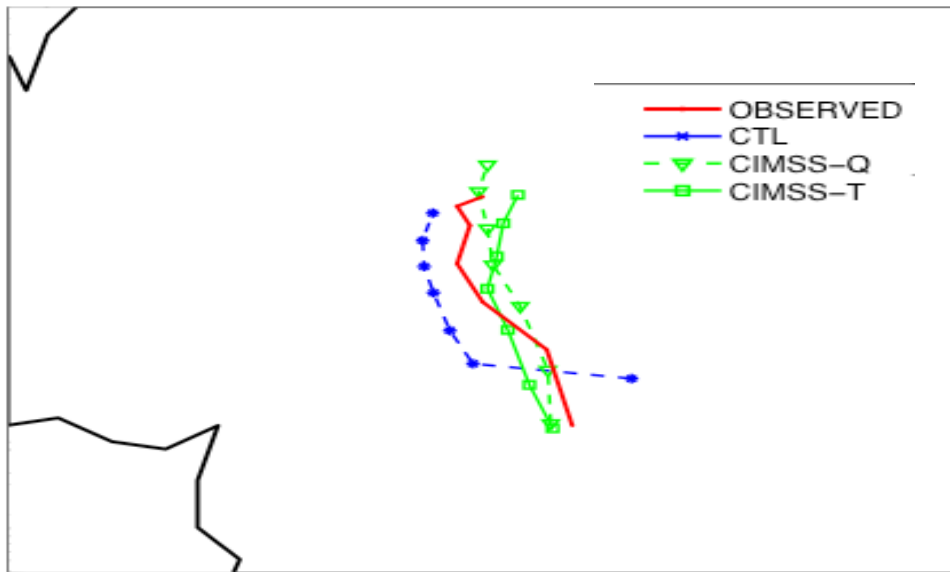


Ensemble forecasts from 12UTC 9 Sept, CIMSS

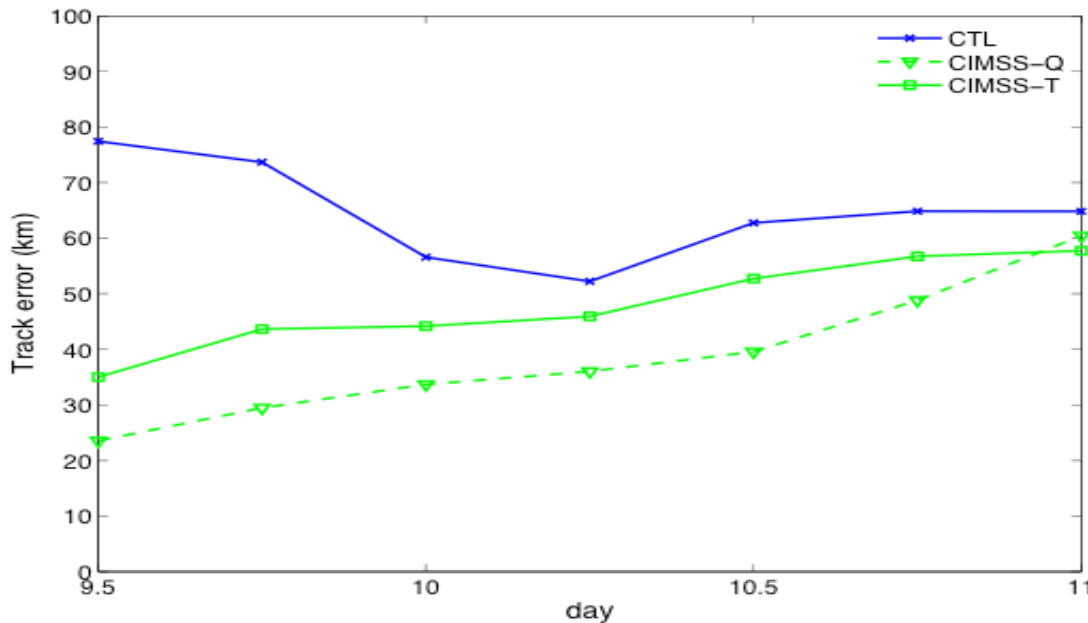


Forecasts start at 12 UTC 9 September 2008
(Redline is observation, green line is forecast)

36 hours forecast from 12UTC September 9, 2008



Impact of AIRS on Typhoon Sinlaku (2008) track forecast with full spatial resolution temperature soundings and moisture soundings, respectively.

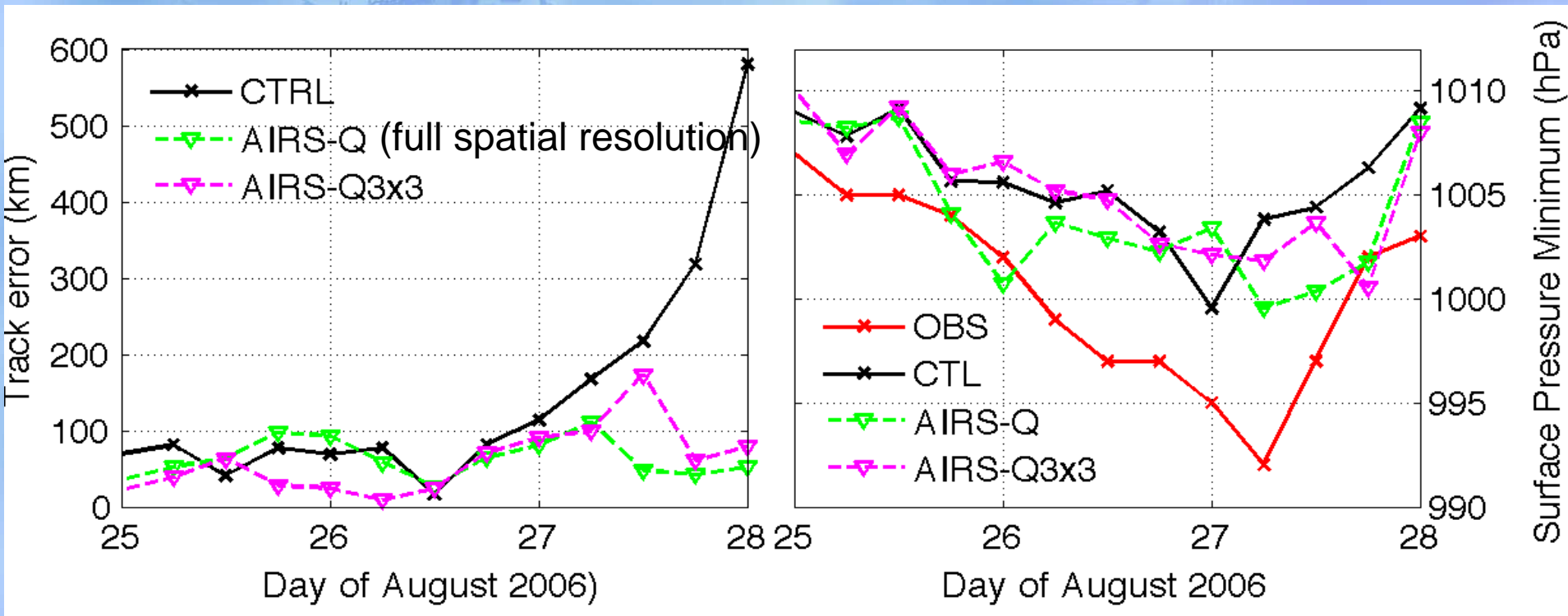


Typhoon Sinlaku (2008) track forecast error with AIRS full spatial resolution temperature soundings and moisture soundings, respectively.

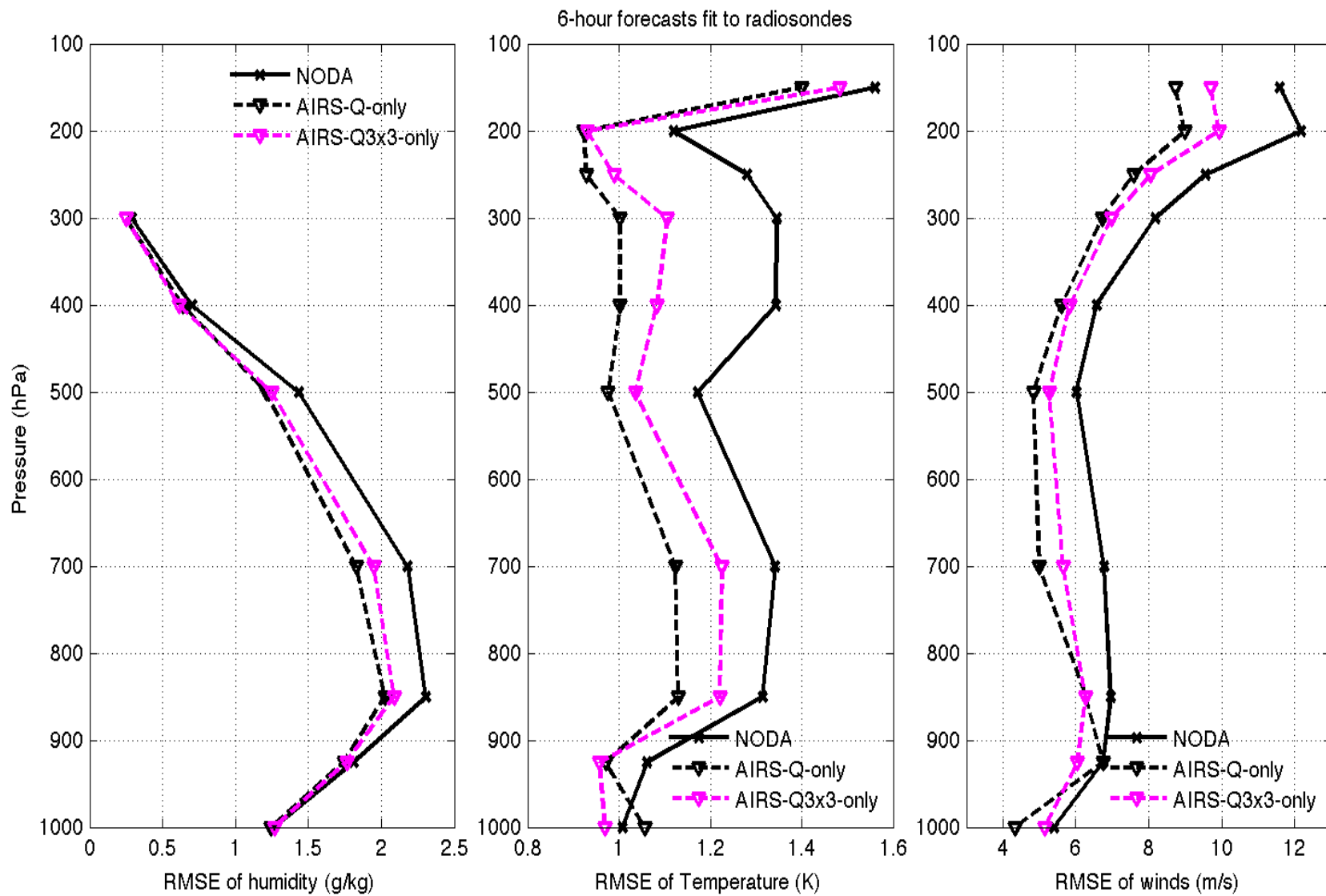
Ensemble mean analysis on Hurricane Ernesto (2006)

CTL run: Assimilate radiosonde, satellite cloud winds, aircraft data, and surface data.

Analyses of Ensemble Mean, 25-28, 00Z, August 2006)



Comparisons between 6-hour forecasts and radiosondes (00 UTC, 22-28, August 2006, Hurricane Ernesto 2006)



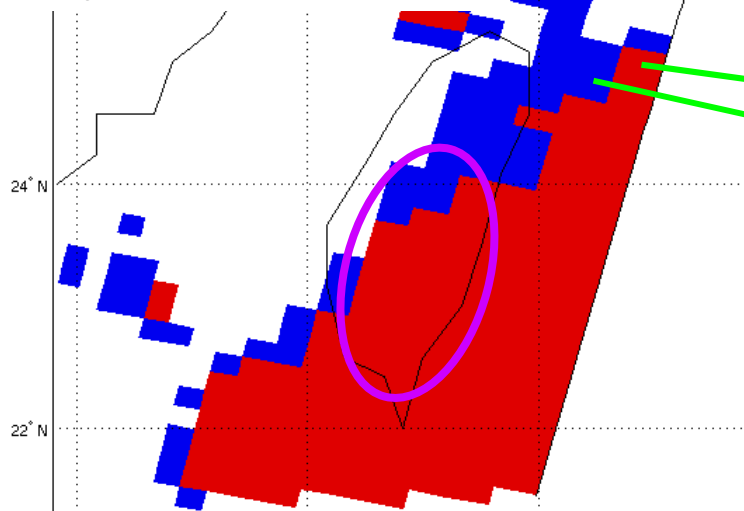
AIRS Q-only: 13.5 km

AIRS Q 3x3 -only: 40 km

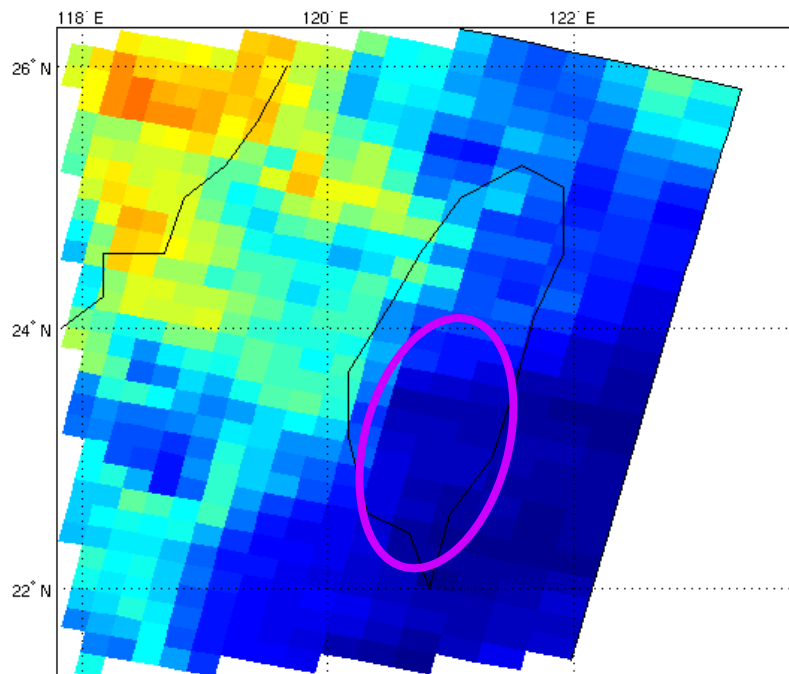
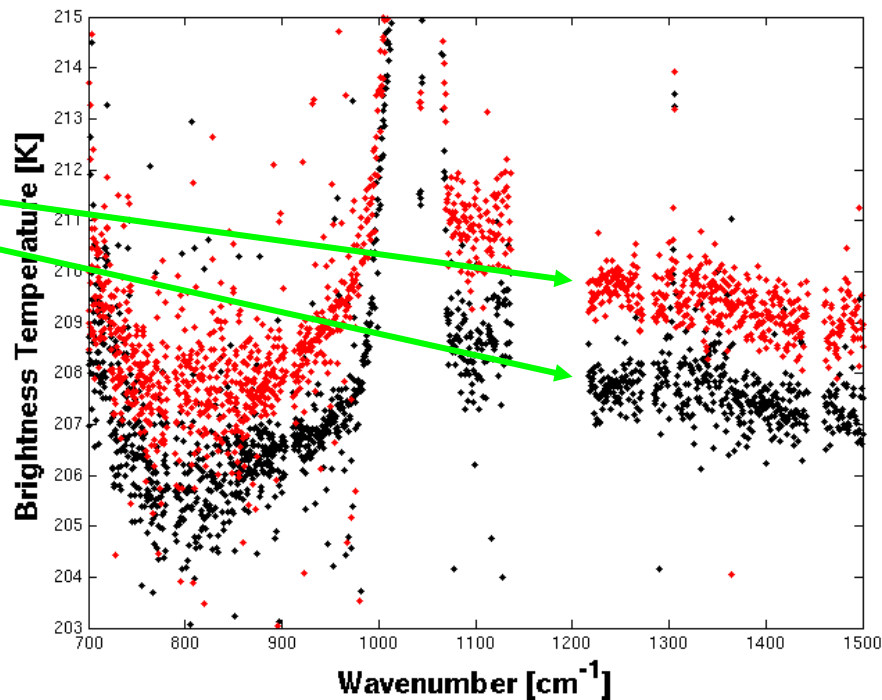
Tropopause Penetrating Cloud (TPC) with Advanced Sounder Measurements

- Broadband method for cold cloud detection
- Advanced sounder method for TPC
 - High spectral resolution
 - Online/Offline technique
- Combining advanced IR sounder and imager for precipitation estimate (rain rate)

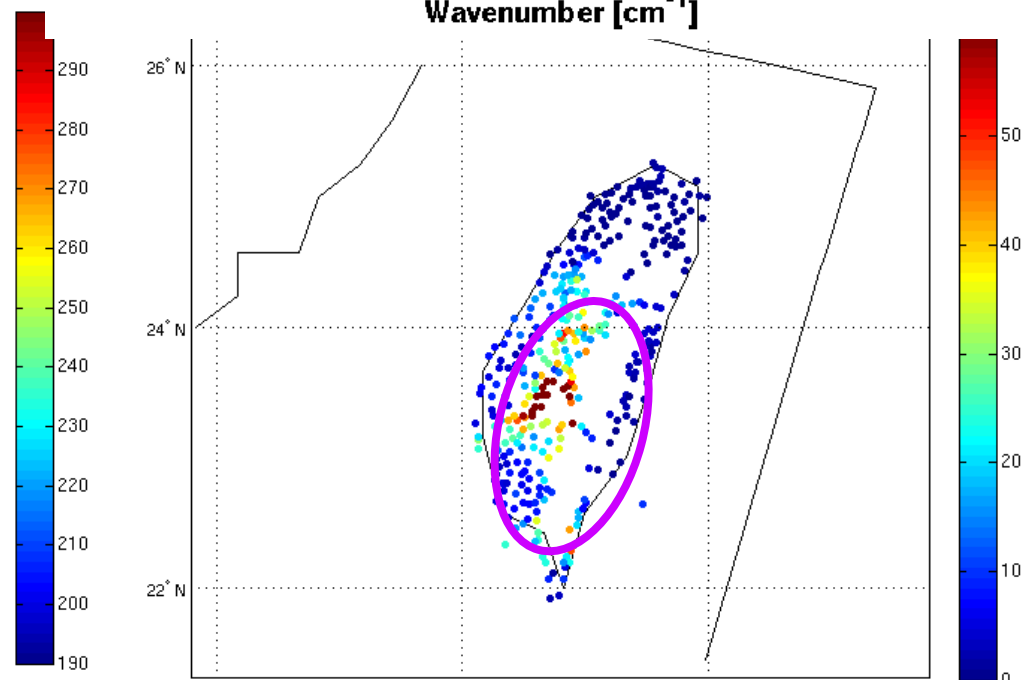
Typhoon Morakot 2009, Heavy rainfall from TPC!



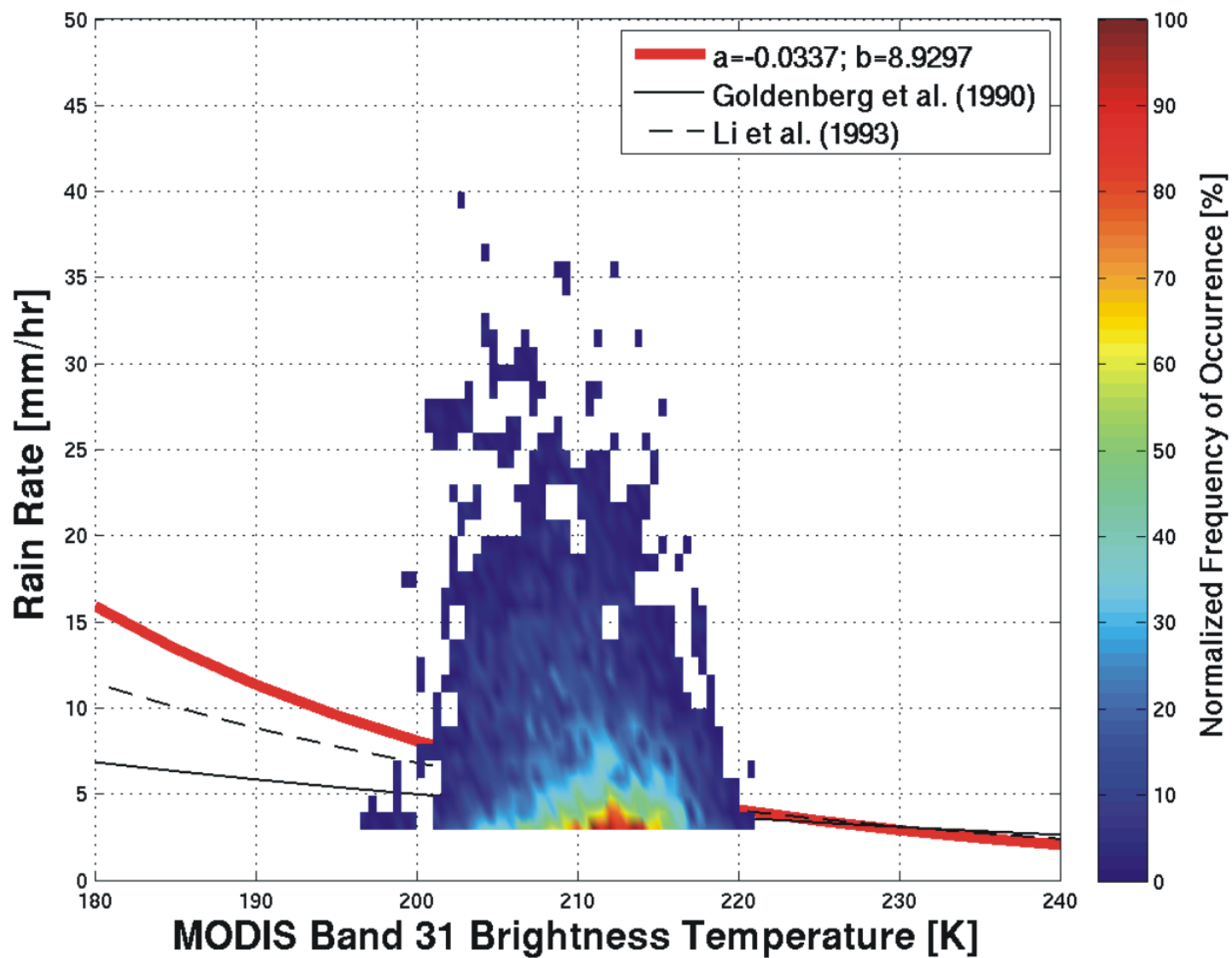
2009/08/08 AIRS Granule183 TPC



2009/08/08 AIRS Granule183 911.235 cm^{-1} BT [K]



2009/08/08 19Z Rainrate [mm/hr]



Scatter between the hourly rainfall rate [mm/hr] and the collocated MODIS 1-km pixels 11 μm (Band 31) BT [K] within the identified TPC with AIRS. The least square regression fit lines are overlaid.

Summary

- The advanced geostationary sounder represents a dramatic new, and unmatched capability for earlier warnings of severe weather
- The proxy with full spatial resolution AIRS soundings show positive impact on hurricane/typhoon track and intensity both in assimilation and forecast using the WRF/DART system.
- Geostationary advanced IR sounder has unique capability on depicting tropopause penetrating clouds and provide evolution of quantitative precipitation.
- Advanced GEO soundings also offer information on vertical atmospheric motion and trace gases.

References

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- Schmit, T. J., J. Li, S. Ackerman, J. Gurka, 2009: High-Spectral- and High-Temporal-Resolution Infrared Measurements from Geostationary Orbit, *Journal of Atmospheric and Oceanic Technology*, 26, 2273 - 2292.
- Liu, H., and J. Li, 2009: An Improvement in Forecast of Rapid Intensification of Typhoon Sinlaku (2008) Using Clear Sky Full Spatial Resolution Advanced IR Soundings, *Journal of Applied Meteorology and Climate* (in press)