Satellite Sounder Data Assimilation for Improving Alaska Region Weather Forecasts

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2014 NOAA Satellite Science Week
March 10-14, 2014

Outline

1. Motivation
2. Experiment Methods
3. Results
4. Conclusions and Discussion
5. Future work
6. Acknowledgements
7. References

Motivation

1. Short-term numerical model forecasts are extremely important (e.g. traffic control, emergency management, etc). GINA is developing a regional numerical model (GINA-WRF) to deliver high-quality, short-term weather forecast products for National Weather Forecast Offices in Alaska.

2. Data assimilation is used to improve short-term numerical weather forecasts. Data assimilation has proven to be very useful in improving both global and regional numerical weather predictions (NWP).

3. Alaska lacks conventional observation data, but receives a lot of polar-orbiting satellite passes compared to the lower 48 states. This data can significantly improve weather forecasts for Alaska.

4. Retrieved profile data from the Atmospheric Infrared Sounder (AIRS) and Cross-track Infrared Sounder (CrIS) are assimilated into the GINA-WRF model.

5. Evaluate data assimilation forecast results.

Experiment Methods

- GINA-WRF covers all the Alaska region. It is configured as two domains with a 18-km coarse domain and a 6-km nested domain.
- A single experiment includes three 48-hour forecasts produced with various configurations of GINA-WRF runs. Each configuration executes GINA-WRF three times with analysis time T-12, T-6, and T-0. Table 1 illustrates the experimental configurations.
- The three configurations are:
  - control run (CNTL)
  - AIRS data assimilation run (AIRS)
  - CrIS data assimilation run (CrIS)
- Only high-quality AIRS/CrIS retrieval profiles are used in the data assimilation.
- 48-hour forecasts over one month are used to evaluate the forecasts that are produced by each model configuration in the experiment.

Table 1 Experiment configurations

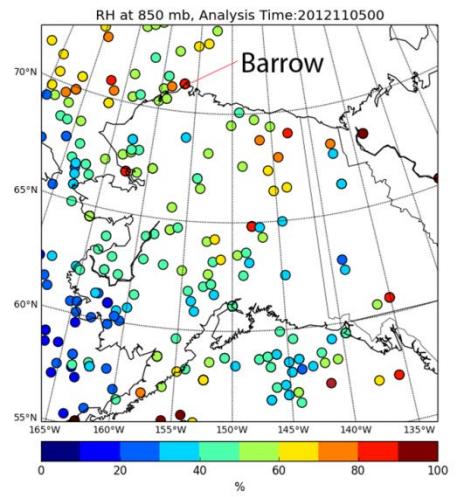
	CNTL	AIRS	CrIS
T-12	GFS forecast at T-12 ↓ WRF forecasts 6 hours ↓ 6-hour forecast		
T-6	WRF forecasts 6 hours ↓ 6-hour forecast	Do AIRS DA at T-6 ↓ AIRS DAout at T-6 ↓ WRF forecasts 6 hours ↓ 6-hour forecast	Do CrIS DA at T-6 ↓ CrIS DAout at T-6 ↓ WRF forecasts 6 hours ↓ 6-hour forecast
T-0	WRF forecast 48 hours ↓ 48 hour forecasts	Do AIRS DA at T-0 ↓ AIRS DAout at T-0 ↓ WRF forecasts 48 hours ↓ 48 hour forecasts	Do CrIS DA at T-0 ↓ CrIS DAout at T-0 ↓ WRF forecasts 48 hours ↓ 48 hour forecasts

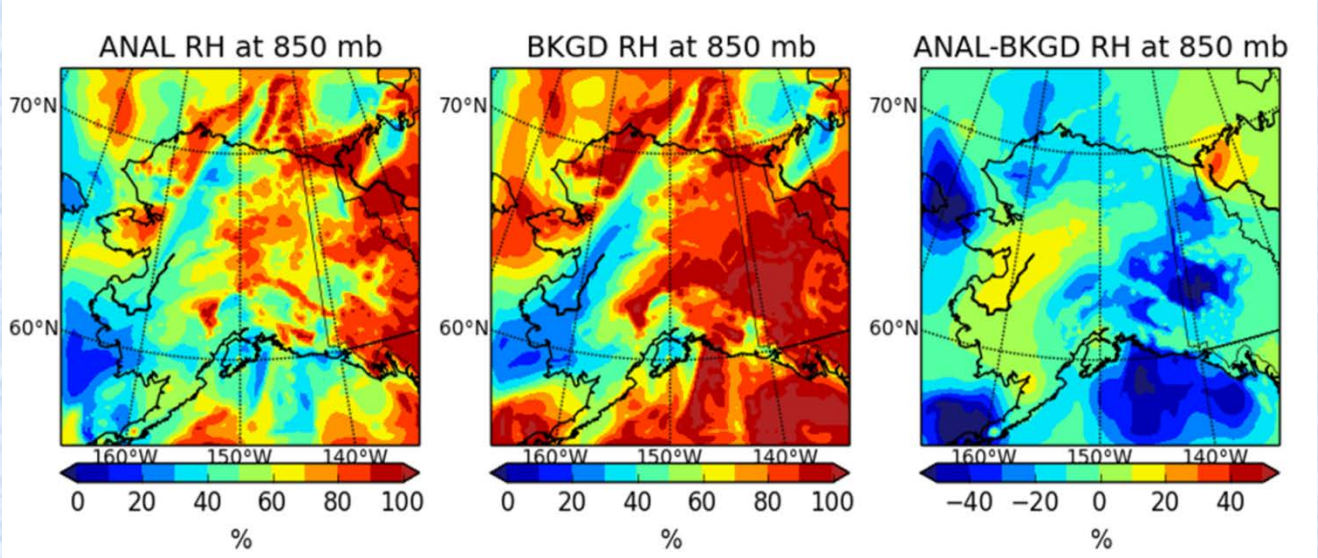
Evaluation Methods

- Utilize conventional observational data as ground truth.
- Utilize Model Evaluation Tools (MET) to match WRF-output grids with observational data points for each pressure level.
- Utilize the normalized standard deviation (NSTD), RMSE, and correlation coefficients (CC) between forecast and observation data to evaluate the forecasts for each configuration in the experiment.
  - NSTD and CC measure the amplitude and phase variation between forecast and observation data, respectively; NSTD/CCs close to 1 indicate better forecasts. RMSE measures the error between forecast and observation data; smaller RMSEs indicate better forecasts.

Results

1. AIRS/CrIS retrieval profiles do impact the initial fields.





AIRS/CrIS sounder data are filtered to provide the highest quality for data assimilation. The typical number of AIRS/CriS data points assimilated changes with altitude. For a Nov. 5, 2012, 00 Z case study, there was sufficient AIRS data at 850 mb to modify the background field. Differencing the analysis and background fields illustrates that AIRS data does modify the initial conditions in many regions. For example, the RH at 850 mb over Barrow (radiosonde site 70026) is adjusted.

2. Data assimilation outputs at T-6

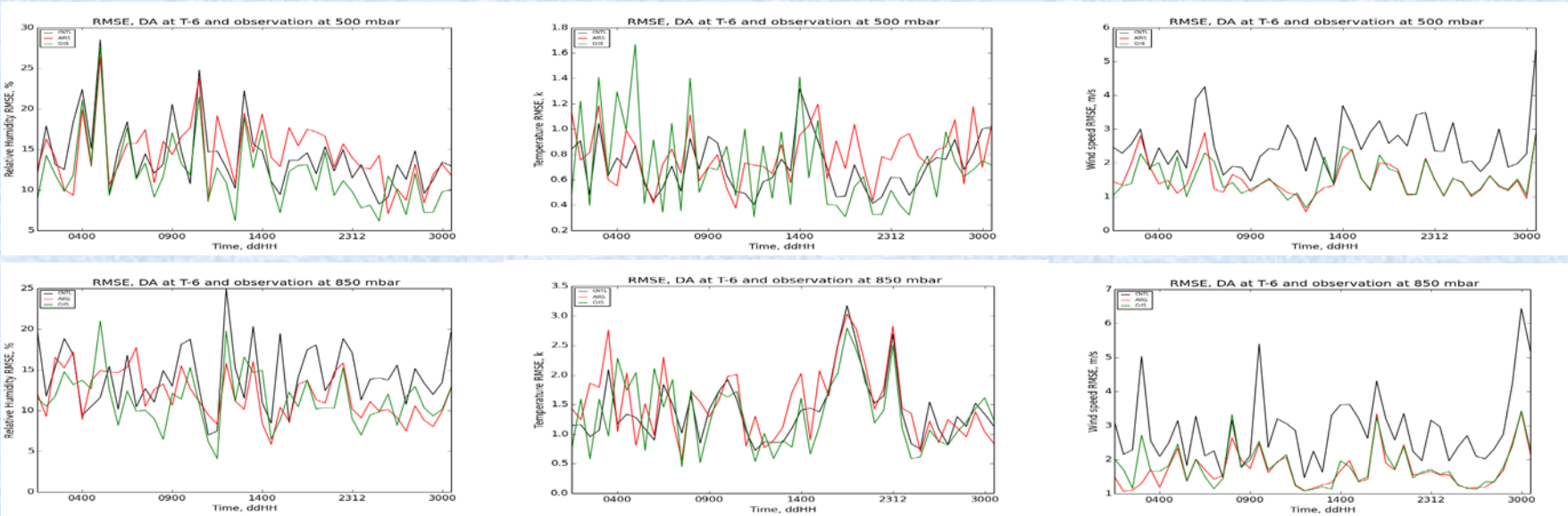
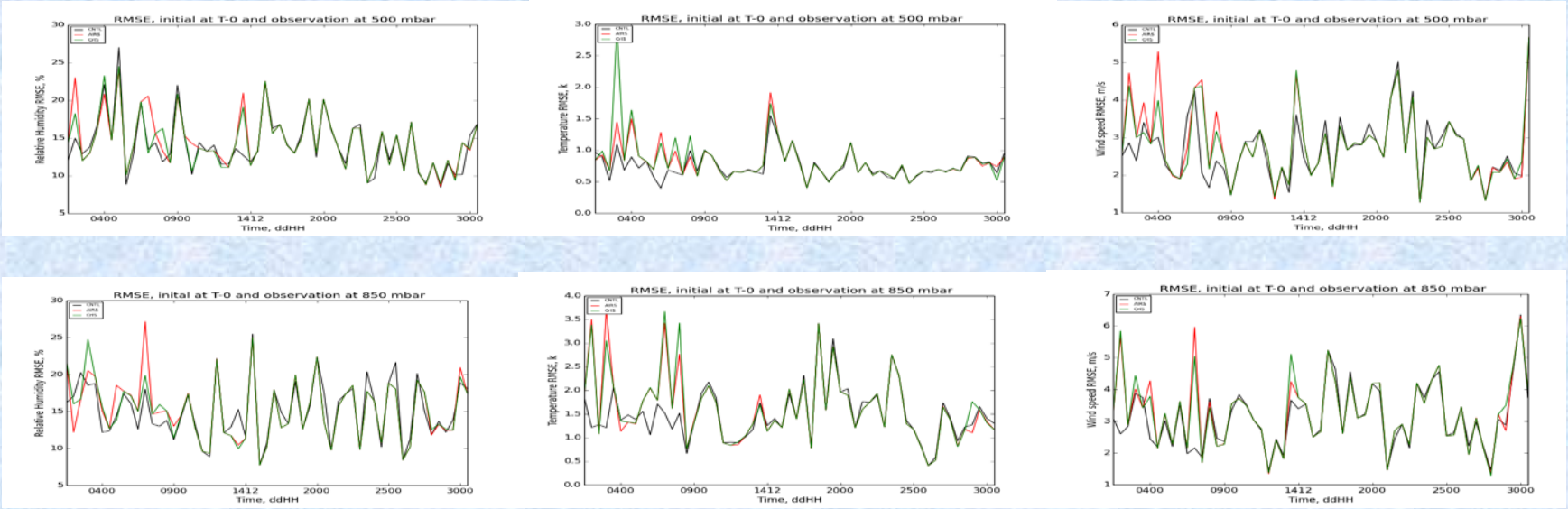


Table 2 Statistical results for DA at T-6

WIND	CNTL,500	AIRS,500	CRIS,500	CNTL,850	AIRS,850	CRIS,850
RMSE	2.633	1.567	1.574	2.995	1.770	1.843
CORR	0.948	0.982	0.980	0.870	0.956	0.951
NSTD	0.966	0.993	0.992	0.987	0.970	0.963

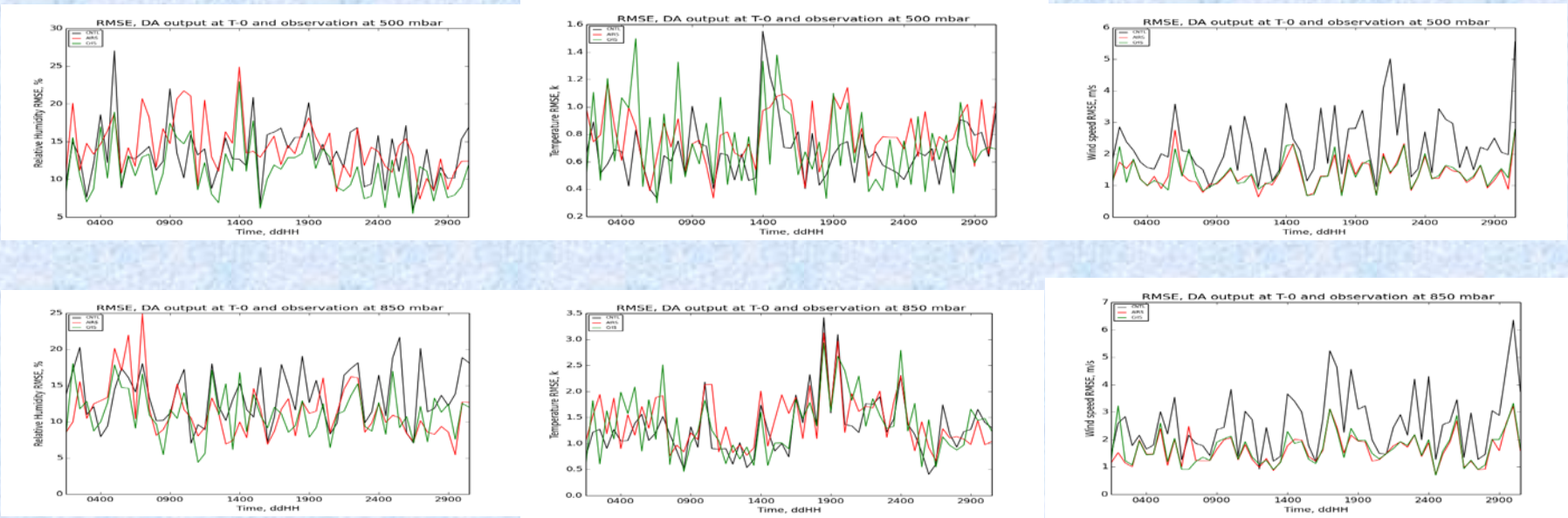
AIRS and CrIS data assimilations improve the initial wind fields in both pressure levels. They have consistently positive impacts on relative humidity fields at 850 mbar from day 13 to 30. Temperature fields do not significantly improve with AIRS/CrIS data assimilation.

3. 6-hour forecasts at T-6 for each experiment configuration



The 6-hour forecasts at T-6 have similar RMSE magnitudes from day 13 to 30 for each configuration (CNTL, AIRS, CrIS). This indicates that AIRS/CrIS data assimilation may not have significant impacts for longer forecasts.

4. Data assimilation outputs at T-0



As shown in the this figure, AIRS/CrIS data assimilation at T-0 significantly improves the initial wind field. There is also positive impact on RH at 850 mbars. The temperature field is not improved by data assimilation. Data assimilation at T-0 has the same impact on initial fields as that at T-6. Assimilating data at T-0 and T-6 performs consistently, and gives us the confidence to say that data assimilation indeed improves the initial conditions within the WRF model.

5. 6-hour forecasts at T-0

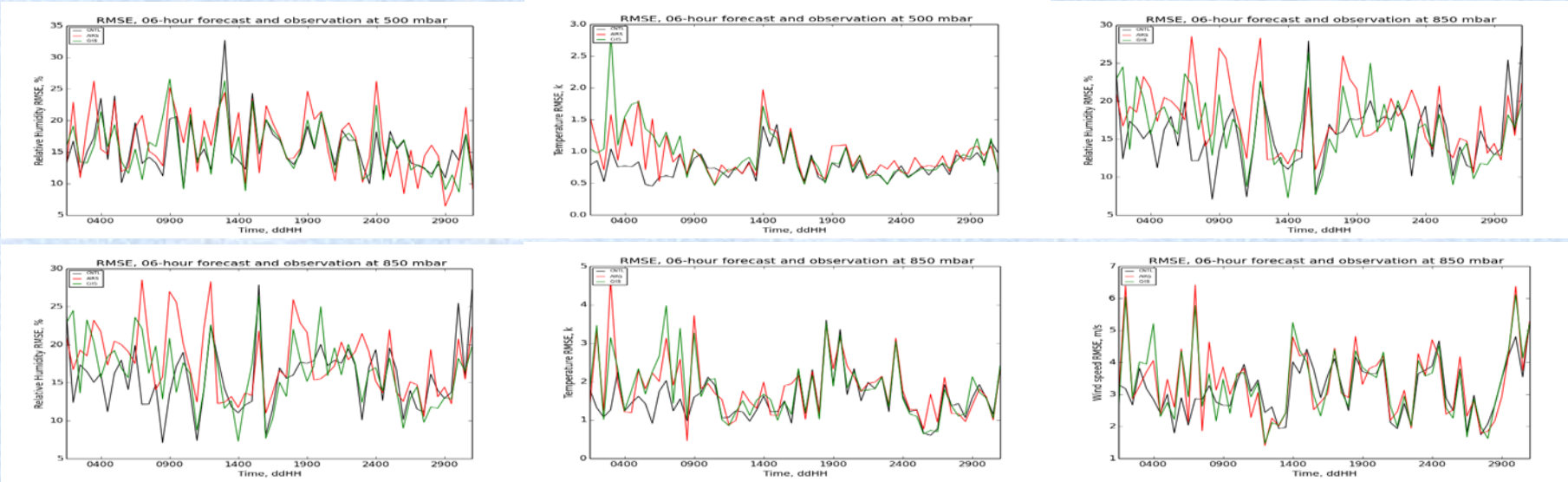


Figure 5 Comparison of 6-hour forecast results from three modes of run at T-0

6-hour forecasts from AIRS/CrIS runs show both positive and negative impacts over a one-month period. Even if the wind field was significantly improved in the initial condition, the 6-hour forecast wind field does not respond. This indicates that the WRF model forecasts are not responding to data assimilation over longer time scales. One possible reason is insufficient data available for the assimilation; the modifications are localized in time, and these modifications do not produce strong impacts over the whole domain.

Conclusions and Discussion

1. Data assimilation does modify initial conditions. The magnitude of modification varies with altitude and physical parameter. The wind speed fields were most greatly improved. Relative humidity forecasts were somewhat improved, while the temperature forecasts did not change significantly with data assimilation.

2. Data assimilation impacts on WRF forecasts were not long lasting. There was some impact on the 6-hour forecast results, but the impact was not consistent. No impact from data assimilation was found in the 48-hour forecasts.

3. We do not have enough observational data to do these comparisons, and this may impact the confidence in our statistical analysis.

4. We introduce satellite sounder data twice during the course of a complete forecast. The data may be too coarse compared with the initial grid data. As the result, the data assimilation is not impacting the forecasts significantly.

Future work

1. Assimilate data every 3 hours, increasing the number of data assimilation times from 2 to 4 in a complete forecast period. Does the additional sounder data improve the forecasts?

2. Use ensemble data assimilation technology to improve the GINA-WRF model forecasts.

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Acknowledgements

- This work was supported by the NOAA High Latitude Proving Ground with funding from the GOES-R and JPSS program offices.

- The University of Alaska Fairbanks' International Arctic Research Center and Arctic Region Supercomputing Center provided computation resources for this study.

- Thank our colleagues Scott Macfarlane and James Long for their technical support, and Don Morton and Melissa Kreller for their scientific suggestions.

Thank you !