# Data assimilation improves model forecast for cold air aloft in Alaska region

Jiang Zhu[1], E. Stevens[1], E. Weisz[2], K. Nelson[3], T. Heinrichs[1], J. Cherry[1], and D. Broderson[1]
[1]GINA, University of Alaska, [2], CIMSS/SSEC/UW-Madison [3] NOAA Center Weather Service Unit in Anchorage, AK

## Introduction

The Geographic Information Network of Alaska (GINA) at the University of Alaska began to study satellite data assimilation for the WRF model two years ago. Atmospheric Infrared Sounder (AIRS) and Cross-track Infrared Sounder (CrIS) profile data were assimilated into a customized regional WRF model called the GINA-WRF. Initial results showed sounder profile data assimilation (DA) improves the WRF model's analysis and forecast. The improvement is localized in space and limited in time. In this poster, AIRS/CrIS sounder profile vs. AIRS/CrIS radiance DAs are compared in terms of RMSE between DA and control runs. One case study of cold air aloft and a one-month statistical study are presented here. Both control and DA runs forecast cold air aloft very well. Of 4 DAs, AIRS profile and CrIS radiance DAs have a positive impact on the WRF short-term forecast, but AIRS radiance and CrIS profile DAs do not improve the forecast.

## Experiment methods and data

The GINA-WRF is setup to cover mainland Alaska at 18 km grid resolution. The optimized model physical parameterizations and treatments for the Alaska and Arctic region (Zhang et al. 2013) were employed. The experiment covers the period of Jan. 30, 00Z to Mar. 01, 18Z of 2014.

Table 1. Five running modes of GINA-WRF for first forecast

| Mode/Time | T-12 h | T-6 h | T h |
|---|---|---|---|
| CNTL | Run WPS with GFS output, run WRF to produce 6 hours of forecasts | Run WRF with 6-hour forecast from CNTL T-12h to produce 6 hours of forecasts | Run WRF with 6-hour forecast from CNTL T-6h to produce 48 hours of forecasts |
| AIRSP | Get output from CNTL WPS at T-12h, do AIRS profile DA, run WRF to produce 6 hours of forecasts | Do AIRS profile DA with 6-hour forecast from AIRSP T-12h, run WRF to produce 6 hours of forecasts | Do AIRS profile DA with 6-hour forecast from AIRSP T-6h, run WRF to produce 48 hours of forecasts |
| CrISP | Follow the same steps as AIRSP, except using CrIS profile data | | |
| AIRSR | Follow the same steps as AIRSP, except using AIRS radiance data | | |
| CrISR | Follow the same steps as AIRSP, except using CrIS radiance data | | |

Table 1 summarizes the 5 running modes of GINA-WRF for the first forecast. The experiment includes a cycling forecast every 6 hours after the cold-start of the first forecast. GDAS conventional observation data plus best quality AIRS/CrIS retrieved profile data (as determined by Pbest in AIRS and QF5_CrIMSSEDR for CrIS) and AIRS/CrIS radiance from GDAS are used as inputs for the four 3D-Var GSI data assimilation schemes. The performance of DAs is evaluated against point observations in terms of root-mean-square error (RMSE). The point observations come from the GDAS-prepared BUFR files (gdas1.tCCz.prepbufr.nr). MET tools are used to match the grid output of WRF with point observations.

## Results from the case study of February, 2014

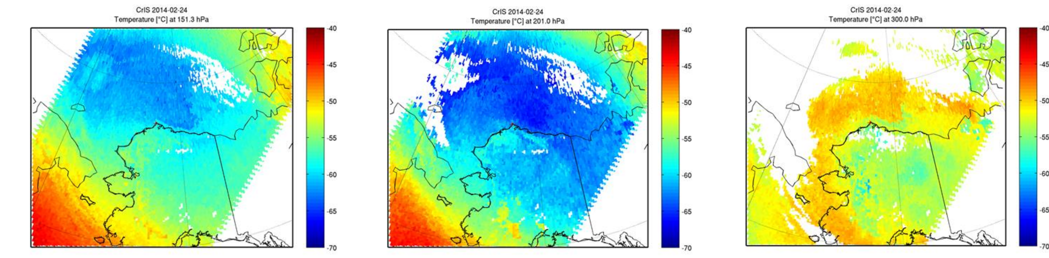

Figure 1 Cold air aloft shown in CrIS sounding data

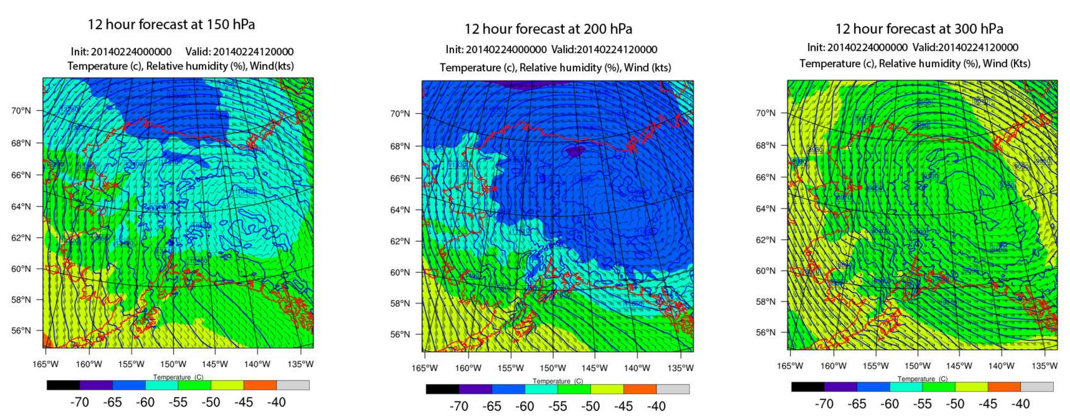

Figure 2 12-hour forecast with AIRS profile 3D-Var GSI data assimilation. Three panels show cold air mass from 300 to 150 mbar over northern coastal region of Alaska.

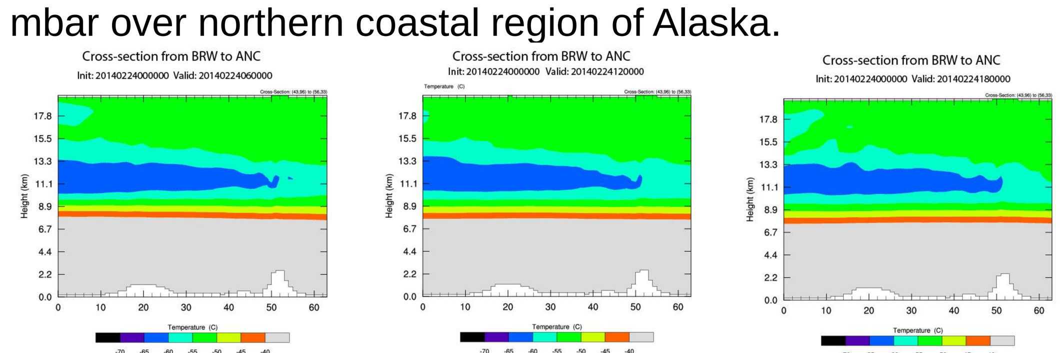

Figure 3 Cross section views from Barrow to Anchorage of forecasts at analysis time 2014022400.

Prediction of cold air aloft (below -60C) is critical for the Alaska aviation industry. Cold air aloft over the northern coastal region of Alaska on February 24, 2014 was captured by CrIS sounding data. CrIS sounding data show that the vertical extent of the cold air over Barrow is from 250 to 150 mb (Figure 1).

This cold air mass was predicted in the 12-hour forecast by GINA-WRF with AIRS profile data assimilation at analysis time 2014022400 (Figure 2). The horizontal extent of the cold air mass predicted in the 12-hour forecast matches the CrIS sounding data very well at every pressure level (Figures 1 and 2).

The 6, 12, and 18-hour forecasts at analysis time 2014022400 (Figure 3) show that the cold air mass hangs over the flight line from Barrow to Anchorage all day long. The vertical extent of the cold air mass over Barrow is from around 9.7 to 13.3 km, which is about 250 to 150 mb. The comparison of CrIS sounding data to the 12-hour forecast indicates that the GINA-WRF model with AIRS profile data assimilation can predict the critical phenomena.

## Results from monthly statistics

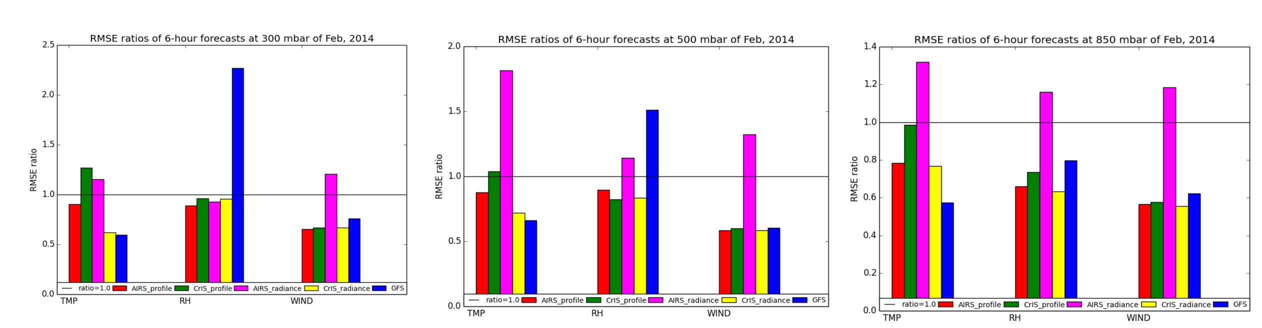

Figure 4. Three variables analyses RMSE ratios for Feb, 2014

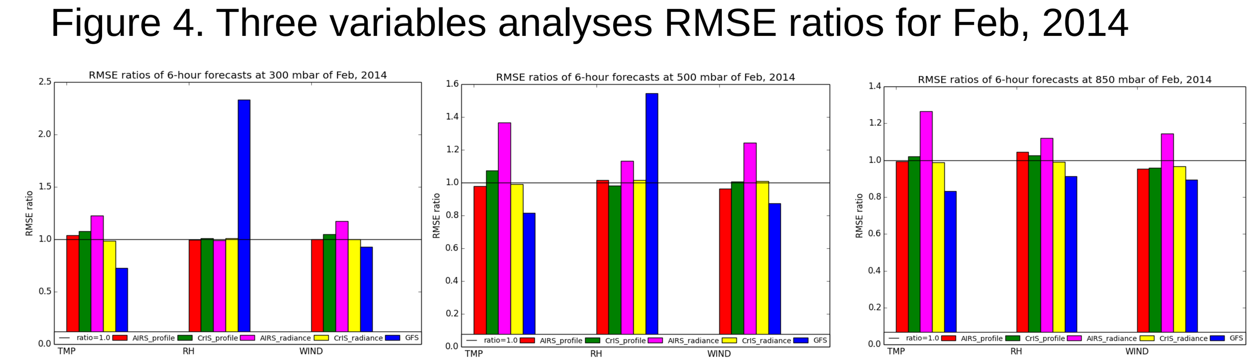

Figure 5. Three variables 6-hour forecasts RMSE ratios for Feb, 2014

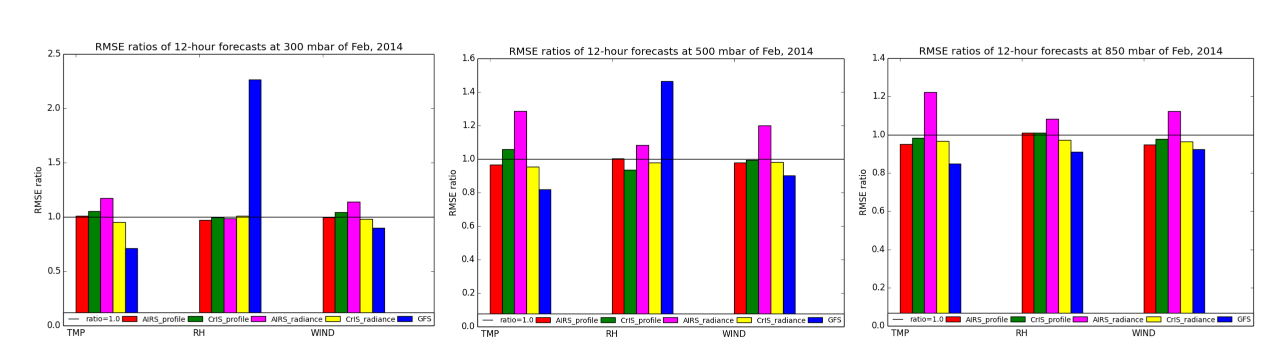

Figure 6. Three variables 12-hour forecasts RMSE ratio for Feb. 2014

Root-mean-square error (RMSE) measures the differences between values predicted by a model and the values actually observed. RMSE ratio is defined as RMSE of a DA run divided by the RMSE of a control run. An RMSE ratio less than 1 indicates that the DA run improves the analysis or forecast.

The GFS RMSE ratio (Blue) indicates the relative humidity is less accurate than the control run results, although the temperature and wind are more accurate than the control run results. The grid resolution of GFS (0.5 degree) is too coarse for regional weather forecasting.

The RMSE ratios of temperature, relative humidity, and wind speed analyses for the month of Feb. 2014 are shown in Figure 4. The median temperature, relative humidity, and wind speed RMSE ratios are 0.90, 0.89 and 0.65 for the AIRS profile DA (Red) and 0.77, 0.83 and 0.67 for CrIS radiance DA (Yellow), respectively. Figure 4 shows that both the AIRS profile and CrIS radiance DA schemes improve the analyses of these three variables at all pressure levels, whereas the AIRS radiance DA does not improve the analyses.

RMSE ratios of 6 and 12 hour forecasts from five running modes of GINA-WRF do not show significant improvement (Figures 5 and 6). AIRS profile (Red) and CrIS radiance (Yellow) DAs produce similar RMSE as the control run. In contrast, the AIRS radiance DA produces even greater RMSE values than the control run.

## Conclusions

1. GINA-WRF with AIRS profile DA can accurately forecast cold air aloft over Alaska region.
2. AIRS profile and CrIS radiance data assimilation improve the analyses of the GINA-WRF. They also improve the forecast, but the improvement is localized and time-dependent.
3. AIRS radiance and CrIS profile DA do not positively impact GINA-WRF model output.

## Literature cited

Jiang Zhu, E. Stevens, B. T. Zavodsky, X. Zhang, T. Heinrichs, and D. Broderson, 2013: Satellite Sounder Data Assimilation for Improving Regional NWP Forecasts in Alaska. Poster. 49th AMS annual meeting, Feb. 4-8, Atlanta, Georgia, USA.

Bradley T. Zavodsky, Shih-Hung Chou, and Gary J. Jedlovec, 2012: Improved Regional Analyses and Heavy Precipitation Forecasts With Assimilation of Atmospheric Infrared Sounder Retrieved Thermodynamic Profiles. IEEE Trans. Geosci. Remote Sens., 50(11), 4243-4251

Zhang, X., J. Zhang, J. Krieger, M. Shulski, F. Liu, S. Stegall, W. Tao, J. You, W. Baule, and B. Potter (2013), Beaufort and Chukchi Seas Mesoscale Meteorology Modeling Study, Final Report. U.S. Dept. of the Interior, Bureau of Ocean Energy Management, Alaska OCS Region, Anchorage, AK. OCS Study BOEM 2013-0119. 204 pp.

Model Evaluation Tools Version 4.1 (METv4.1) User's Guide 4.1. Developmental Testbed Center, Boulder, Colorado, USA.

## 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 resource for this study.

Thank our colleagues Scott Macfarlane and James Long for their technical support and Don Morton for his scientific support.

## Future investigation

Realize a 4D-Var data assimilation scheme for the GINA-WRF.