Satellite Sounder Data Assimilation for Improving Regional NWP Forecasts in Alaska

Jiang Zhu[1], E. Stevens[1], B. T. Zavodsky[2], X. Zhang[3], T. Heinrichs[1], and D. Broderson[1]
[1]GINA, University of Alaska, [2]Marshall Space Flight Center, NASA, [3] IARC, University of Alaska

Introduction

Data assimilation has proven to be very useful in improving both global and regional numerical weather prediction (NWP) (e.g. Goldberg et al. 2003, Zavodsky et al. 2012). While Alaska suffers from a sparse density of surface observations, it benefits from a large number of polar-orbiting satellite passes compared to the lower 48 states. How to utilize polar orbit satellite data to improve NWP performance is of particular interest in Alaska. The Geographic Information Network of Alaska (GINA) at the University of Alaska is conducting a study on satellite data assimilation for the WRF model. Retrieved profile data from the Atmospheric Infrared Sounder (AIRS) and Cross-track Infrared Sounder (CrIS) are assimilated into a customized regional WRF model called the GINA-WRF. Normalized standard deviation and correlation analysis are applied to evaluate performance of the data assimilation in a 48-hour and a one-month weather forecast. The ultimate goal of the research is to provide improved real-time, short-term forecasts for Alaska.

Data and methods

The GINA-WRF is setup to cover the entire Alaska area (Figure 1 and 2). The optimized model physical parameterizations and treatments for the Alaska and Arctic region (Zhang et al. 2013) were employed. Every 6 hours the model is cold-start initialized with GFS data, and assimilation cycles are performed to get updated initial conditions for the WRF forecast (see Table 1). GDAS conventional observation data plus best quality AIRS/CrIS retrieved profile data (as determined by Pbest in AIRS and QF5_CrIMSSEDR for CrIS) are used as inputs for the GSI data assimilation scheme. Three sets of forecasts were produced: Control (CNTL), AIRS data assimilation (AIRS), and CrIS data assimilation (CrIS).

Table 1. Mode of GINA-WRF Run

Mode/Analysis Time	T-12 Z	T-6 Z	T Z
CNTL	Cold start	Cycle	Cycle
AIRS	Cold start	Cycle AIRS DA	Cycle AIRS DA
CrIS	Cold start	Cycle CrIS DA	Cycle CrIS DA

Results from the three experiments are compared against point observation data using matched pairs selected by the Model Evaluation Tools (MET). One 48-hour forecast at analysis time 2012110500 is picked as a case study. Normalized standard deviation (NSTD) and correlation coefficient (CC) are calculated to quantitatify the impact of data assimilation.

Results

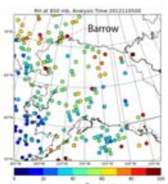

Fig.1 AIRS RH data at 850 mb

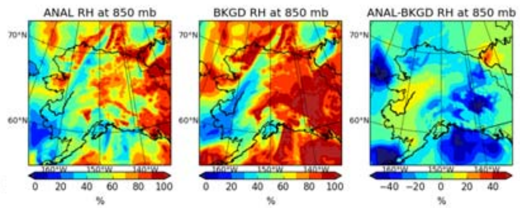

Fig.2 RH analysis and background at 850 mb

AIRS/CrIS sounder data are filtered for the best quality for data assimilation. The number of best quality data changes with altitude. In the case of Nov. 5, 2012, 00 Z, enough high quality AIRS data at 850 mb are used to adjust the background field (Fig.1). Analysis, background, and the difference in Figure 2 demonstrates that AIRS data modify the initial condition in many areas. For example, RH at 850 mb over Barrow (radiosonde site 70026) is adjusted and is picked as a case study.

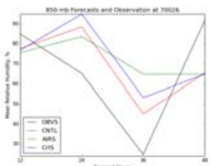

Fig.3. Comparison of 48 hours forecasts of RH with different DA and Observation

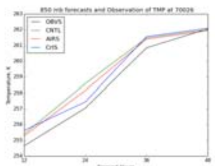

Fig.4. Comparison of 48 hours forecasts of TMP with different DA and Observation

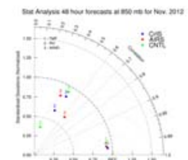

Fig.5. Statistical Analysis of 48 hours forecasts

48-hour forecasted and observed RH and temperature at Barrow are shown in Figures 3 and 4, respectively. Figure 3 shows that the 48-hour relative humidity forecasts from both the AIRS and CrIS runs are more close to observation than the forecasts from the CNTL run in terms of the variation pattern. Figure 4 shows that the 48-hour temperature forecasts from the AIRS and CrIS runs are closer to the observation values than those from CNTL run. Statistical analysis for the case is shown in Figure 5. NSTD and CC measure the amplitude and phase variation between forecast and observation data, respectively. Data points close to REF where both NSTD and CC are equal to 1 in the Tylor Diagram represent the most significant improvement in the GINA-WRF's performance. The relative humidity forecast is improved very much in this case. Additional investigation at other points in the domain indicates that significant improvement in GINA-WRF model performance only occurs where the difference between the analysis and background is large.

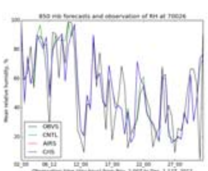

Fig.6. Monthly 24-hour forecasts for RH

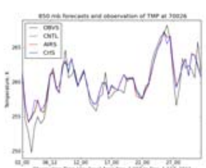

Fig. 7. Monthly 24-hour forecast for TMP

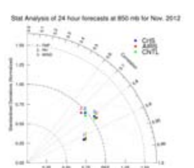

Fig.8. Statistics results of monthly 24-hour forecasts

The modification of data assimilation against background varies with location and analysis time. Figures 6 and 7 depict the 24-hour forecasts of relative humidity and temperature at 00Z and 12Z for the entire month of November, 2012. They demonstrate that AIRS/CrIS forecasts at some analysis times are improved, but some times are not, and also that the AIRS and CrIS forecasts are very similar. Figure 8 shows that AIRS/CrIS forecasts do not introduce systematic errors but improve the forecasts where and when the AIRS/CrIS data are most different from the background fields.

Conclusions

1. Both AIRS and CrIS sounder profile data assimilation improve the WRF model forecast. The improvement is localized and time-dependent.
2. Different weather variables experience different degree of improvement by data assimilation. Relative humidity presents more improvement than temperature.
3. AIRS and CrIS sounder data assimilation schemes have similar performance in terms of improvement of forecast.

Literature cited

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Future investigation

1. Use reanalysis data as "ground truth" to evaluate the forecasts to overcome the problem of coarse-resolution point observations in Alaska.
2. Conduct statistic analysis for forecasts over one year to evaluate how satellite sounder data assimilation impacts the accuracy of regional weather forecast models.