AIRS/CrIS Sounding Profile Data Improves Short-term Weather Forecast in Alaska

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Introduction

Improving numerical model short-term forecasts for Alaska by using satellite data is a goal of the Geographic Information Network of Alaska (GINA). In a previous study (Zhu et al. 2015), we compared the Atmospheric Infrared Sounder (AIRS) against the Cross-track Infrared Sounder (CrIS) profile and radiance data assimilation (DA). We found that AIRS profile and CrIS radiance DAs improve the Weather Research and Forecasting (WRF) short-term forecast, but AIRS radiance and CrIS profile DAs do not improve the forecast. In this study, we compared data assimilation schemes with the AIRS profile against the NOAA Unique CrIS/ATMS Processing System (NUCAPS) profile and evaluated these two data assimilation schemes in terms of the root mean square of error (RMSE) between forecasts and observations. The study showed that AIRS and NUCPAS profile data assimilation schemes have similar performance in term of impact on the short-term forecast.

Experiment, Data, and Evaluation Method

The GINA-WRF covers 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 period is November 17, 00Z to December 16,18Z, 2014. Every 6 hours GINA-WRF does a complete forecast run in three modes: control (CNTL), the AIRS profile DA (AIRSP), and the NUCAPS profile DA (NUCAPSP). A complete forecast run of a mode includes a cold start for T-12, a cycling run for T-6, and forecast run for T, where T is the analysis time. The 3D-Var GSI data assimilation scheme is realized in both the AIRSP and NUCAPSP modes.

GDAS conventional observation data plus best quality AIRS retrieved profile data (determined by Pbest in AIRS) is assimilated in AIRSP, whereas NUCAPSP mode uses GDAS plus NUCAPS profiles with best quality (determined by Quality_Flag in NUCAPS).

Temperature, dew point, and wind speed at 300, 500, and 850 mbar pressure levels are used to evaluate the forecasts. Forecasts over the experiment period are paired with observations by MET tools (DTC, 2013). Root-mean-square error (RMSE) measures the differences between forecast and observation data. RMSE is composed of mean bias (RMSEa) and centered pattern RMS difference (RMSEb), and $RMSE^2=RMSEa^2+RMSEb^2$ (Taylor, 2001). RMSEa measures the overall bias and RMSEb measures the variation between the forecasts and the observations. The variation can be further divided into amplitude and phase variation. RMSEs, RMSEa, and RMSEb together reveal insights into the quality of the different forecasts.

Results

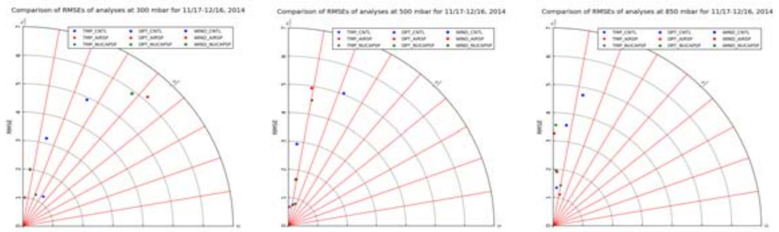

Fig. 1. RMSEs of analyses for 11/17-12/16, 2014.

Because $RMSE^2=RMSEa^2+RMSEb^2$, the relation can be presented in a polar coordinator plot. RMSE is the distance between point to origin, RMSEa is the projection of RMSE to x axis, and RMSEb is the project of RMSE to y axis. Figure 1 presents the RMSEs of analysis temperature, dew point, and wind speed at three pressure levels. It shows that AIRSP and NUCAPSP improve the analyses in similar ways: wind speed shows the most improvement at all three pressure levels; the improvement of dew point occurs at middle and lower atmosphere; and temperature shows the least improvement. The DAs improve the forecast by decreasing of the variation of the differences, not overall biases.

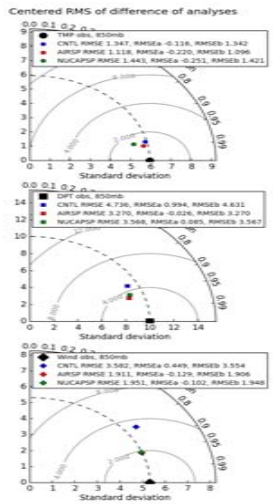

Fig.2. Centered RMS difference of wind analyses at 850 mbar for 11/17-12/16, 2014.

The variation (RMSEb) is decided by standard deviations and correlation of forecasts and observations. The relationship of the four quantities is that $RMSEb^2=fcststd^2+obsvstd^2-2*fcststd*obsvstd*corr$, where corr is the linear correlation coefficient between forecast and observation. This relationship can be shown in a Taylordiagram (Taylor, 2001). Figure 2 illustrates the variation of difference of wind analyses at 850 mbar over period of 11/17-12/16, 2014. We already knew that DAs significantly improve the wind forecast at 850 mbar, and that the improvement mainly comes from decreasing variation as shown in Figure 1. The bottom panel of Figure 2 clearly shows that DAs significantly decrease the RMSEb by raising the correlation.

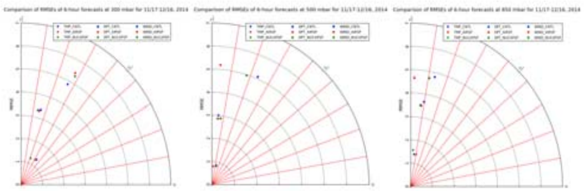

Fig.3. RMSEs of 6-hour forecasts for 11/17-12/16,2014

As shown in Figure 3, there are only limited improvements in 6-hour forecasts by data assimilation. 3D-var data assimilation can significantly impact the analyses, but the impact on 6-hour forecasts is very limited.

Conclusions

1. AIRS and NUCAPS profile data assimilation yield similar improvement in the short-term forecast.
2. The improvement varies between the physical variables. Wind speed gets the most improvement.
3. Analysis modified by DA produces a higher correlation with observation. This is the key factor to improve the forecast.

Literature cited

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Future

Investigate impact of improved data assimilation on an annual time scale.