Effect of AMSU-A observation and adjusted AMSU-A observation error covariance in global model

Sung-Min KIM, Hyun Mee KIM*, Dae Hui KIM

Department of Atmospheric Sciences, Yonsei University, Seoul, Republic of Korea

INTRODUCTION

- The adjoint-based observation impact can simultaneously evaluate the observation impact for all dataset, with lesser computation compared to observation system experiments, by using the adjoints of data assimilation and forecast system.
- In this study, the impact of observation on the forecasts is evaluated by using the adjoint-based method in a global modeling and analysis system. In addition, this study calculated the forecast sensitivity to error covariance parameters for July 2012, and proposed the adjusted error covariance by using the multiple linear regression. The modified error covariance was applied to the forecast trajectory during August 2012, and the forecast errors using the modified error covariance were evaluated in the observation space.

METHODOLOGY

1. Forecast Sensitivity to Observations (FSO)

(Baker and Daley 2000)

$$\frac{\delta e}{\delta \mathbf{y}} = \mathbf{K}^T \mathbf{M}^T \frac{\delta e}{\delta \mathbf{x}^f}$$

2. Forecast Sensitivity to error covariance parameters (FSR)

(Daescu and Todling 2010)

Perturbed background and observation error covariances are represented as follow:

$$\delta \mathbf{B} = \delta s^b \mathbf{B}, \quad \delta \mathbf{R} = \delta s_i^o \mathbf{R}$$

$$\frac{\delta e}{\delta s^b} = [\mathbf{y} - h(\mathbf{x}_a)]^T \frac{\delta e}{\delta \mathbf{y}} \quad \frac{\delta e}{\delta s_i^o} = [h_i(\mathbf{x}_a) - \mathbf{y}_i]^T \frac{\delta e}{\delta \mathbf{y}_i}$$

3. Nonlinear Forecast Error Reduction (FER) and its approximation

$$(1)\ \delta e^{nl} = (\mathbf{x}^{fa} - \mathbf{x}_t)^T \mathbf{C} (\mathbf{x}^{fa} - \mathbf{x}_t) - (\mathbf{x}^{fb} - \mathbf{x}_t)^T \mathbf{C} (\mathbf{x}^{fb} - \mathbf{x}_t)$$

$$(2)\ \delta e^{approx} \approx \frac{\delta R}{\delta \mathbf{y}} (\mathbf{y} - h(\mathbf{x}_b)) \quad (3)\ \delta e^{approx} \approx \left(\frac{\delta e}{\delta s_b}, \frac{\delta e}{\delta s_i^o} \right)^T (\delta s_b, \delta s_i^o)$$

- **Scalar**

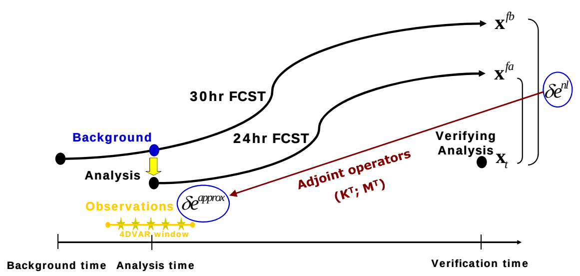
e Forecast aspect (Response function).
δs^b Background error covariance adjustment parameter.
δs_i^o Observation error covariance adjustment parameter.

- **Vector or matrix**

$\mathbf{y}$ Observation.
$\mathbf{x}_a$ Analysis.
$\mathbf{x}_b$ Background.
$\mathbf{x}_t$ True state (Verifying analysis).
$\mathbf{M}^T$ Adjoint of Perturbation Forecast (PF) model.
$\mathbf{C}$ Energy norm matrix.
$\mathbf{K}^T$ Adjoint of data assimilation system.
$\mathbf{R}$ Observation error covariance matrix.
$\mathbf{B}$ Background error covariance matrix.
h Observation operator.

EXPERIMENTAL DESIGN

➢ **Schematic of forecast sensitivity to observations in the KMA UM 4DVAR system.**



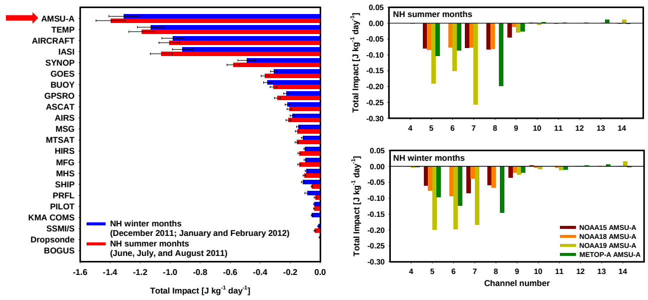
CONCLUSION

- Using the adjoint-based forecast sensitivity to observations (FSO), the contribution of observation to the forecast can be investigated. As a result of investigating the contribution of observation to the 24 hr forecast using the Korea Meteorological Ministration (KMA) operational global model, the contribution of ATOVS AMSU-A to the global forecast was the largest, and followed by the SONDE, AIRCRAFT, and IASI. The contribution of the AMSU-A radiance data varied with channels, in which the contribution of channel number 5-8, retrieved the temperature in the troposphere, was the largest.
- Using the FSO, the forecast sensitivity to error covariance parameters (FSR) was calculated for July 2012. The adjusted error covariances were calculated using the multiple linear regression of the sensitivity data of July 2012, and then applied to calculate the forecast error reduction for August 2012. The multiple linear regression method diagnosed that the background error covariance needs to be inflated by 30%, whereas most of the observation error covariances need to be deflated. Because both FSO and FSR for AMSU-A data were large, the observation error covariance of AMSU-A was reduced in the experiment (ADJ_COV experiment). The forecasts using the reduced AMSU-A observation error covariance show better results compared to the operational forecasts (CTL experiment) in the observation space.

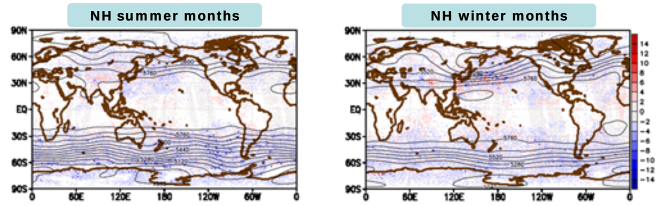
RESULTS

Time-averaged statistics stratified by each observation type and AMSU-A channel in the globe

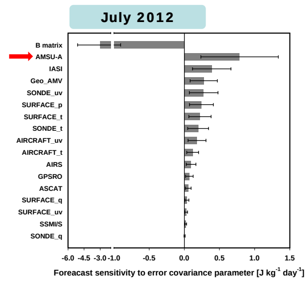
❖ **Approximation of nonlinear FER (i.e., Observation impact)**

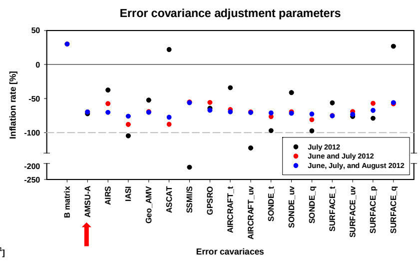


Horizontal distribution of AMSU-A observation impact

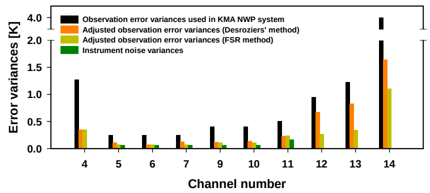


FSR and Error covariance adjustment parameters





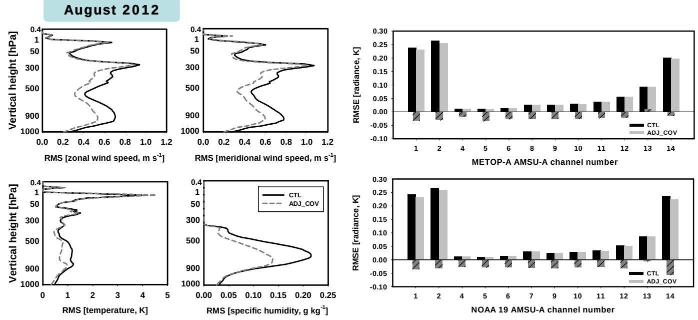
AMSU-A observation error variances



<Averaged inflation rate>

FSR method	Desroziers' method
-72.38%	-62.04%

Verification (RMSE) with respect to SONDE and AMSU-A observation



CTL: 24hr forecast error before adjusting AMSU-A observation error covariance.
ADJ_COV: 24hr forecast error after adjusting AMSU-A observation error covariance.

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Daescu, D. N., and R. Todling, 2010: Adjoint sensitivity of the model forecast to data assimilation system error covariance parameters. *Quart. J. Roy. Meteor. Soc.*, **136**, 2000–2012.

*** Corresponding author: Hyun Mee Kim, Dept. of Atmospheric Sciences, Yonsei University, email: khm@yonsei.ac.kr**