All-sky data assimilation in the KIM LETKF system

Han-Byeol Jeong[1,2], Sihye Lee[1], In-Hyuk Kwon[1], Adam Clayton[1], Myoung-Hwan Ahn[2]
Korea Institute of Atmospheric Prediction Systems (KIAPS)[1]
Department of Climate and Energy Systems Engineering, Ewha Womans University[2]
(hbjeong@kiaps.org)

1 Background

- "**All-sky**": Assimilate **all observations** directly as radiances, whether they are for clear, cloudy or precipitating scenes.
- Expected to give a number of benefits to weather forecasting
  1) Mass, wind and humidity in the presence of cloud
  2) Improved modelling of cloud and precipitation
- Currently, KIAPS is developing all-sky radiance assimilation techniques for the Hybrid-4DEnVar system (Lee et al. 2020).
- First of all, it is necessary to build knowledge about the **flow dependent** ensemble background error covariances provided by the KIM ensemble.
- Here, successful utilization of the **all-sky assimilation framework** in the LETKF stand-alone system is demonstrated with the **preliminary evaluation of the performance**.

2 Data and Method

1. **Forecast model that represents cloud and precipitation**
   : Korean Integrated Model (**KIM**) v3.7 – 4 Hydrometeors (q_c, q_i, q_s, q_r) and cloud fraction
2. **Fast observation operator that considers cloud and precipitation**
   : **RTTOV-SCATT** v13.0
3. **Observations :** Microwave Humidity Sounder (**MHS**)
4. **Observation error model:** Quadratic function of **symmetric cloud amount** (C_{SYM})

$$\mathrm{SI} = (\mathrm{TB}_{90} - \mathrm{TB}_{150}) + 35.6 - 0.139 \times \theta_{zen}, \qquad C_{SYM} = (\mathrm{SI}_{\mathrm{obs}} + \mathrm{SI}_{\mathrm{bkg}})/2$$

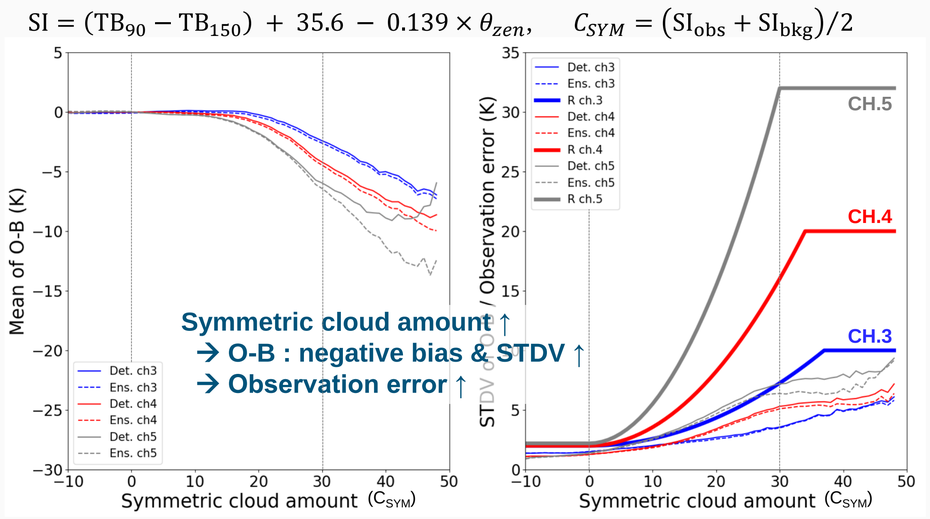
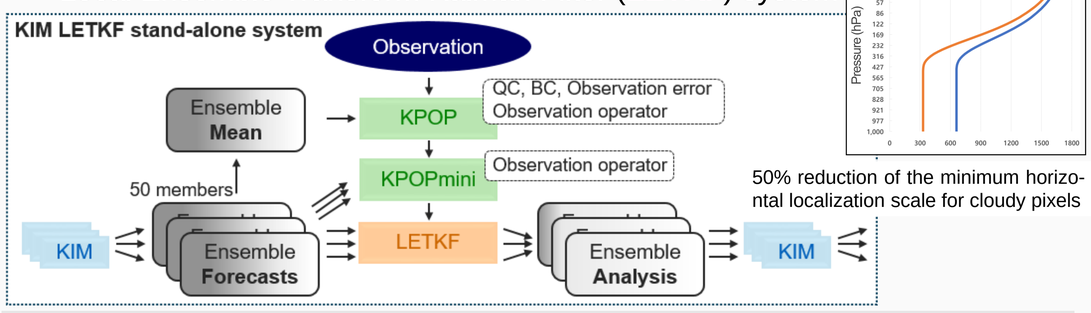


Figure 1. Mean (left) and standard deviation (STDV) (right) of background departure (O-B) binned as a function of C_{SYM}. The solid and dashed lines indicate the deterministic and ensemble background. In the right panel, thick solid lines show the observation error.

5. **Data assimilation system that can handle non-linearity**
   - Local Ensemble Transform Kalman Filter (**LETKF**) system



50% reduction of the minimum horizontal localization scale for cloudy pixels

Figure 2. Flow chart of KIM-LETKF stand-alone cycling system.

3 Results

Table 1. Cycle experiment design for MHS all-sky assimilation.

Periods	20 June – 31 July 2021 (42 days) (First 5 days excluded from analysis)	
Resolution	Horizontal: ~50 km, Vertical: L91 (model top: 1 Pa)	
Observations	Sonde, Surface, Aircraft, GPSRO, AMV, scatwind, AMSU-A + MHS	
Experiments	**CTL**	**MHS clear-sky**
	EXP	**MHS all-sky**

Figure 3. Spatial distribution of observation number (left), mean O-B (middle), and STDV of O-B (right), for the CTL and EXP experiment.

- **The number of used observation increased**, especially in the tropics and the southern hemisphere between 45˚S and 60˚S.

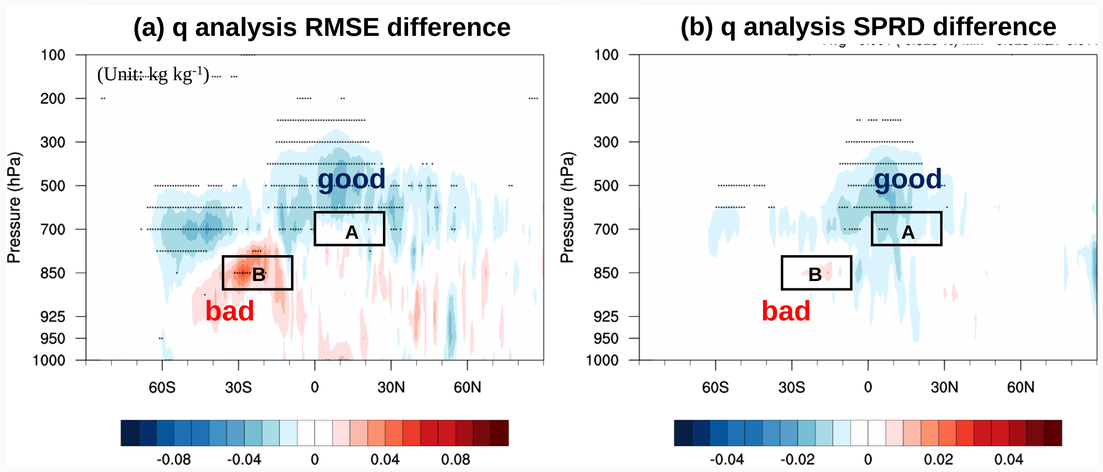


Figure 4. Zonal mean (a) analysis RMSE, and (b) ensemble spread differences (EXP-CTL) for specific humidity (q) during the period from 25 June to 31 July. Blue areas indicate beneficial impact. RMSE is calculated against ECMWF IFS analysis.

Area-averaged statistics

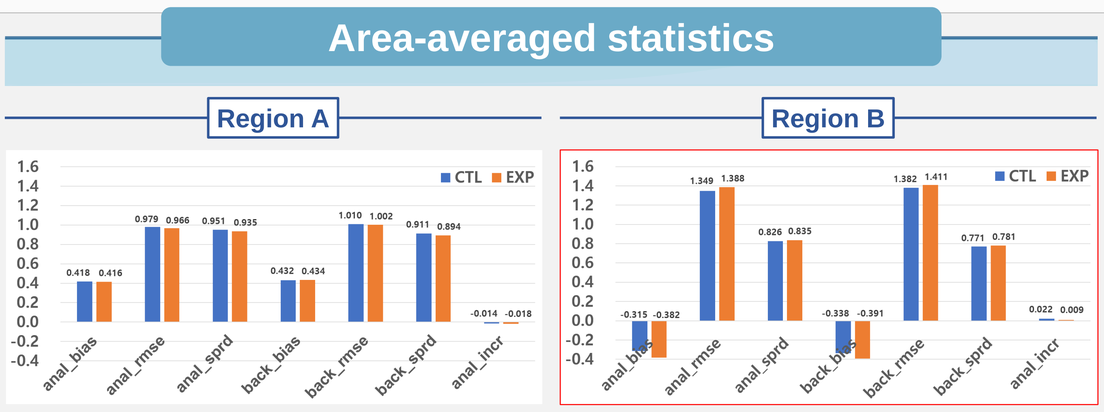


Figure 5. Comparison of q bias, RMSE, and ensemble spread of analysis and background between CTL (blue) and EXP (orange) during the period from 25 June to 31 July. The left and right panels show the area-averaged statistics for region A and B, respectively.

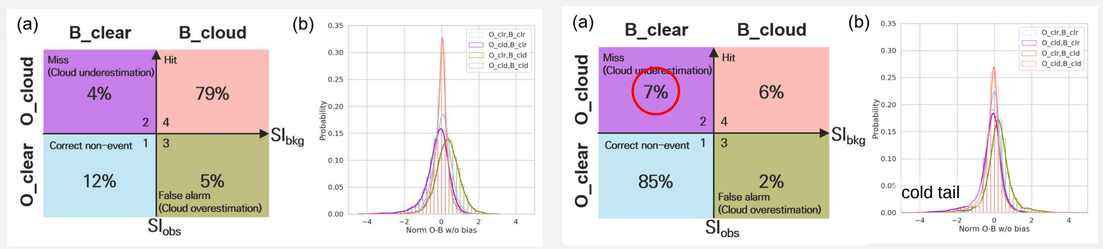
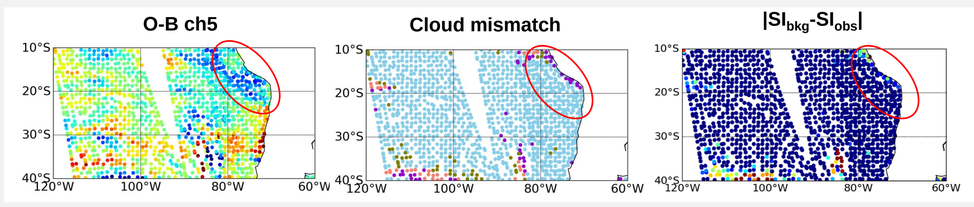


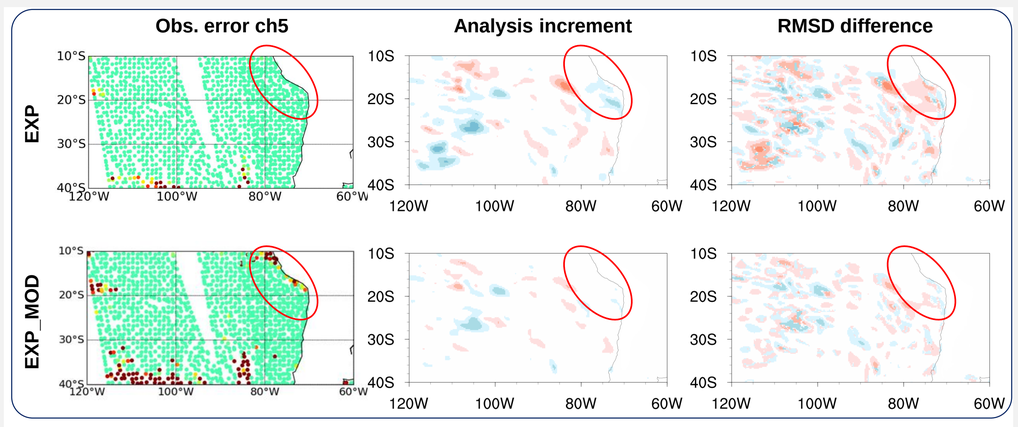
Figure 6. (a) Percentages of MHS channel 5 observations in the O_clear/B_clear (sky-blue), O_cloud/B_clear (violet), O_clear/B_cloud (green) and O_cloud/B_cloud (pink) groups. (b) O-B histograms for each group, with O-B normalized by observation error.

MHS only test (case: 00Z 20 June 2021)

- **MHS channel 5 in the region B**



- **Sensitivity to observation error**



Cloud mismatch (O_cloud/B_clear)
EXP : small observation error → large analysis increment → degradation
EXP_MOD : large observation error → small analysis increment → no degradation

4 Summary and Conclusion

"Evaluation of MHS all-sky data assimilation in the KIM-LETKF system"
- Increase of the number of used observations by a factor of about 2.
- Globally improvement in q field, except in some SH regions near 850 hPa.

"Check area-averaged statistics – region B"
- Check cloud mismatch (O_cloud/B_clear)
  - Normalized O-B : Gaussian distribution with residual cold bias (cold tail).
  - Degradation reduced by increasing the observation error.

→ **It seems to be better to use all-sky pixels more conservatively in the cloud mismatch regions.**

The 24th International TOVS Study Conference (ITSC-24)
16–22/03/2023, TromsØ, Norway