All-sky assimilation of MHS in the Korea Integrated Model (KIM) system

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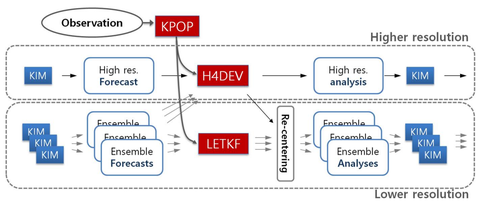
Introduction

- All-sky microwave radiance assimilation system has been developed in the Korea Integrated Model (KIM) analysis system. A system development methodology for assimilating cloud and precipitation-affected satellite radiances has been developed in accordance with the ECMWF approach (Geer et al., 2014). There is no cloud or precipitation control variable, but in the minimization, cloud and precipitation are diagnosed from the dynamical and humidity fields every time-step including the first.
- In this study, the clear-sky and all-sky contributions to the assimilation of Microwave Humidity Sounder (MHS; channel frequencies around the 183 GHz) are separated. Especially, we try to understand the processes that raises to large errors under cloudy conditions.

Semi-operational KIM system

❖ **KIM v3.2:** Global numerical weather prediction system
- resolution: N240 (~12 km), L91 (~80 km)

❖ **Hybrid 4D-EnVar, LETKF**
- resolution: N60L91 (VAR), N60L91 (Ensemble)
- state variables: winds, density, potential temperature, mixing ratio
- control variables: stream function, unbalanced temperature and surface pressure, unbalanced velocity potential, pseudo-RH
- observation: SONDE, SURFACE, AIRCRAFT, GPS-RO, AMSU-A, ATMS, MHS (land masking), SAPHIR, IASI, CrIS, CSR, AMV, Scatwind, TC Bogus, SSMIS



Thanks to In-Hyuk Kwon

Observation operator

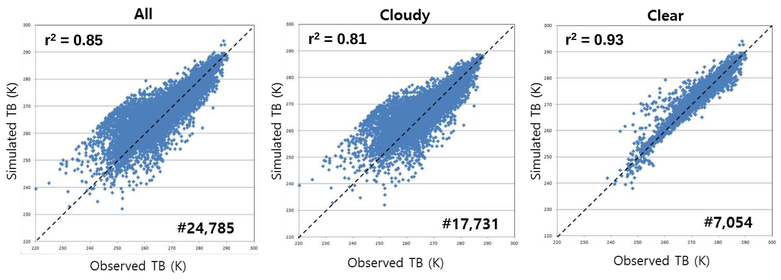
❖ **RTTOV-SCATT v11.3** (Bauer et al., 2006; Geer et al., 2009)
- Cloud types: cloud water, ice, rain, snow (bulk hydrometer optical properties)
- Fractional cloud cover: hydrometer weighted average overlap
- Scattering calculation: delta-Eddington approach

RTTOV_SCATT cloud variables	KIM cloud variables
cc : nlevels of cloud cover (0-1)	**cldrad** : cloud fraction at radiation module (0-1)
clw : nlevels of cloud liquid water (kg/kg)	**qcmps + qccps** : cloud liquid water (kg/kg)
ciw : nlevels of cloud ice water (kg/kg)	**qimps + qicps** : cloud ice content (kg/kg)
rain : nlevels of rain (kg/kg)	**qrmps** : rain water content (kg/kg)
sp : nlevels of solid precipitation (kg/kg)	**qsmps** : snow content (kg/kg) * snapshot으로 출력

* Subgrid representation with effective cloud fraction (C):
- $TB_{total} = C \times TB_{cloudy} + (1-C) \times TB_{clear}$
- $TB_{total} - TB_{clear} = C\,(TB_{cloudy} - TB_{clear})$
  Hydrometer effect

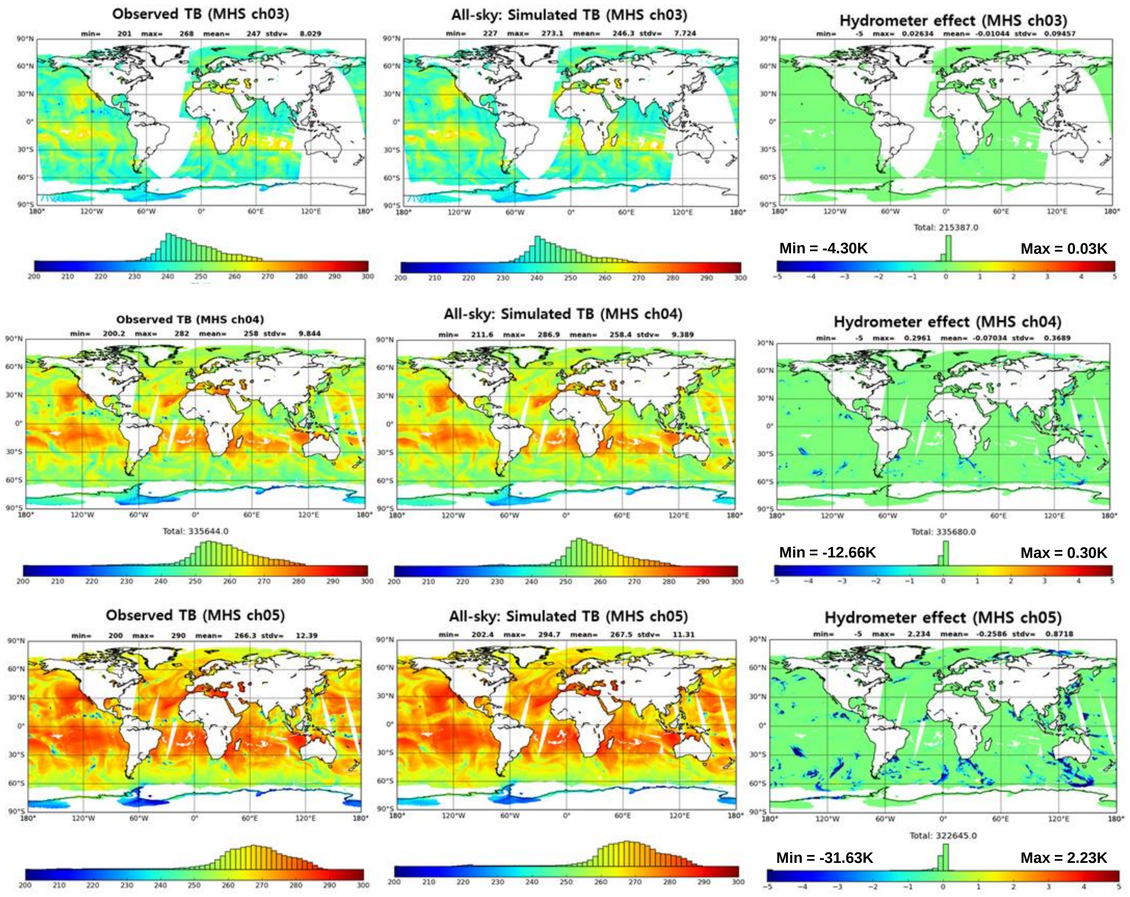
All-sky assimilation of MHS in the KIM

❖ **Observed TB vs. Simulated TB** (MHS ch05 @ 2018070206 UTC)

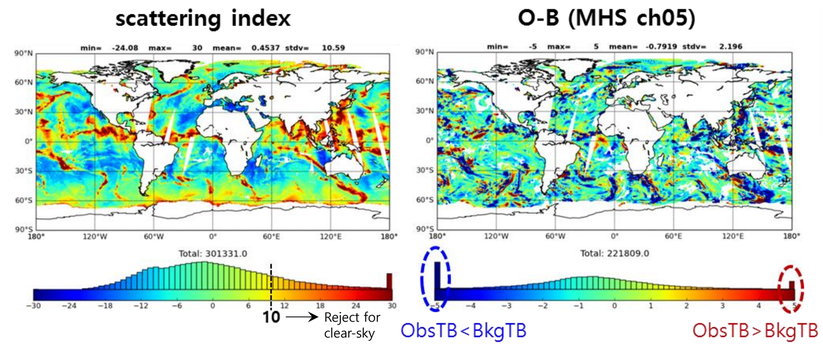


In the clear-sky samples, there is a strong correlation between the observations and model (r^2 = 0.93), compared to that of cloudy samples (r^2 = 0.81).

Although global distributions of water vapor are well represented in the simulated brightness temperature (TB), the hydrometer in the Tropical and mid-latitude regions appears to be worse.



❖ **Scattering index**

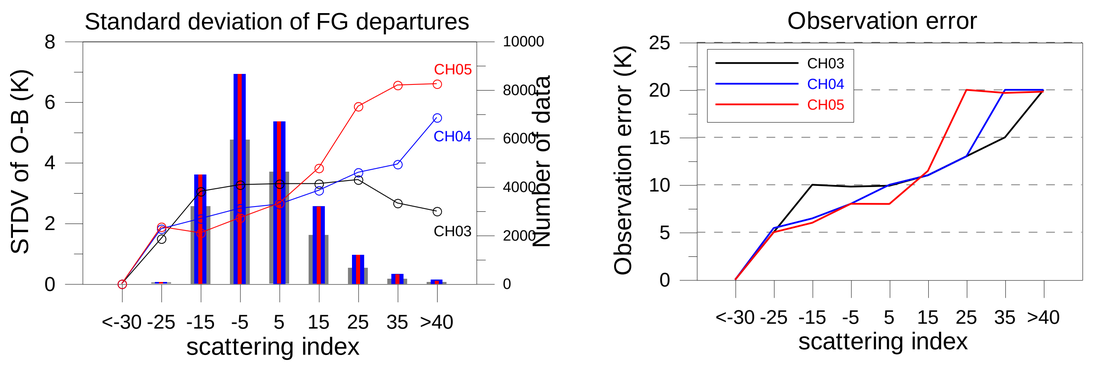


Scattering Index (SI) = (TB_{89GHz} - TB_{150GHz}) – (-39.2010 + 0.1104θ),
θ is zenith angle
Doherty et al. (2012)

Simply, SI can detect the scattering signal from heavy cloud or precipitation over ocean.

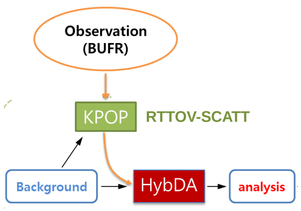
TBs at 183 GHz are strongly depressed by scattering from cloud, precipitation and ice particles.

❖ **Observation error for all-sky assimilation**

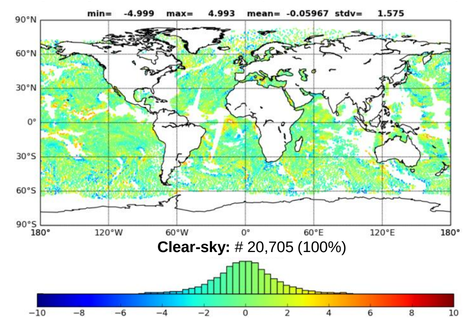


- SI is used to examine the errors in First Guess (FG) departures as a function of cloud and precipitation.
- Generally, observation errors are determined by FG departures of more than three times standard deviation.
- Increased errors in cloudy areas to reflect the difficulty of modeling and increased dynamic range of TBs in cloudy conditions (Geer and Bauer, 2011).

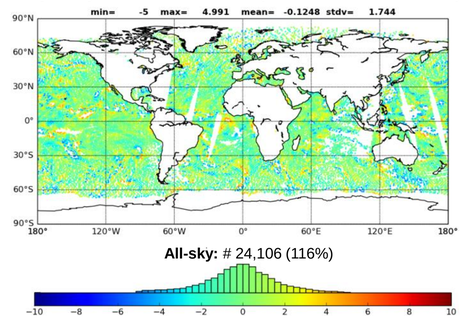
❖ **Single cycle experiment** (2018070206 UTC)
- Control (CTL) : semi-real time operational KIM v3.2
- Experiment (EXP) : same as CTL but for all-sky assimilated MHS
- Verification: ECMWF IFS analysis from 1˚x1˚



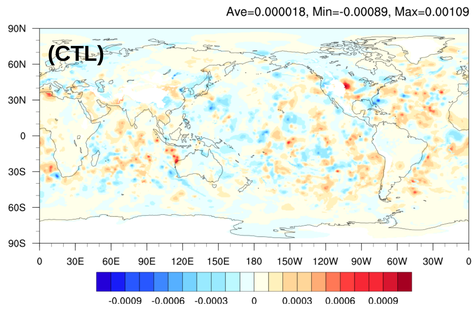
(CTL) MHS ch05: O-B (after bias correction)



(EXP) MHS ch05: O-B (after bias correction)

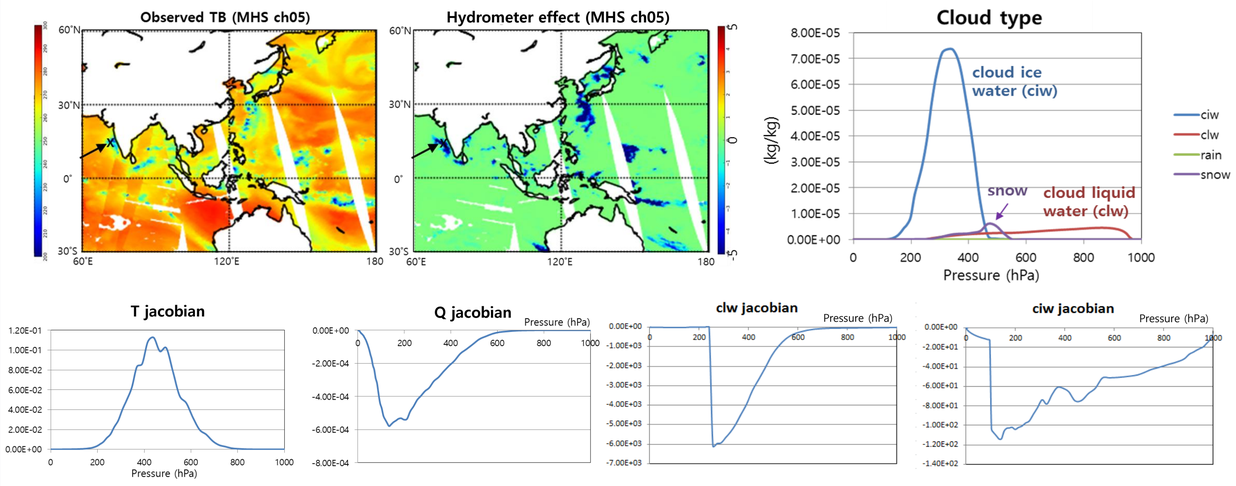


Q Analysis Increment at 850 hPa



→ After HybDA, both experiments show very similar results (e.g., increments of temperature and humidity) (not shown)

❖ **Single observation test** (16.2115˚N, 69.4769˚E)



The peak of humidity Jacobian at cloudy pixels are closely matched of that of cloud ice water (ciw). However, the magnitude of cloud liquid water (clw) Jacobian is larger than that of ciw.

Summary

- All-sky assimilation framework at KIM has been implemented with microwave-sounding radiances from MHS. The observation operator for all-sky assimilation is RTTOV-SCATT v11.3.
- The agreement between FG and observations in clear-sky is good. However, cloudy samples with the ice or water clouds show worse correlations, with large observation errors.
- Preliminary results of all-sky assimilated MHS are not remarkable. Hopefully, this observation gives significant improvements to dynamical forecast scores along with benefits to humidity fields.