Benefit of Assimilating All-sky Microwave Radiances on Precipitation over East-Asia

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1 Introduction

- East Asia is strongly influenced by the monsoon, resulting in complex cloud and precipitation patterns. However, numerical weather prediction (NWP) models often struggle with forecast accuracy due to uncertainties in radiative transfer processes involving clouds and precipitation.
- Effectively incorporating satellite radiance observations through all-sky data assimilation is expected to improve our understanding of cloud and precipitation processes, ultimately enhancing the initial conditions of NWP models.
- This study aims to assess the impact of all-sky data assimilation on weather prediction and propose an optimal assimilation strategy to improve the Korean Integrated Model (KIM) forecast performance in regions affected by clouds and precipitation.

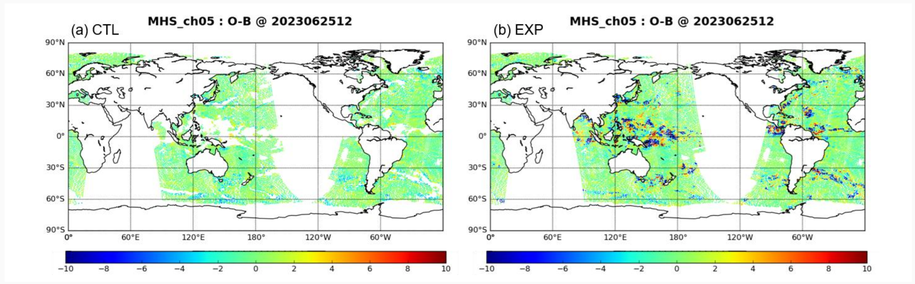
2 Method

Preprocessing for clear-sky and all-sky radiance data

	Clear-sky	All-sky
Observation operator	RTTOV v13.0	RTTOV-SCATT v13.0
Cloud screening	Mixture of TPWC, CLW and SI	None
Bias correction	Scan-angle bias correction and airmass bias correction	Same as clear-sky, but using clear pixels
Outlier check	O-B check using constant threshold	O-B check using cloud dependent threshold
Observation error	Constant	Symmetric error model as a function of cloud predictor (SI)

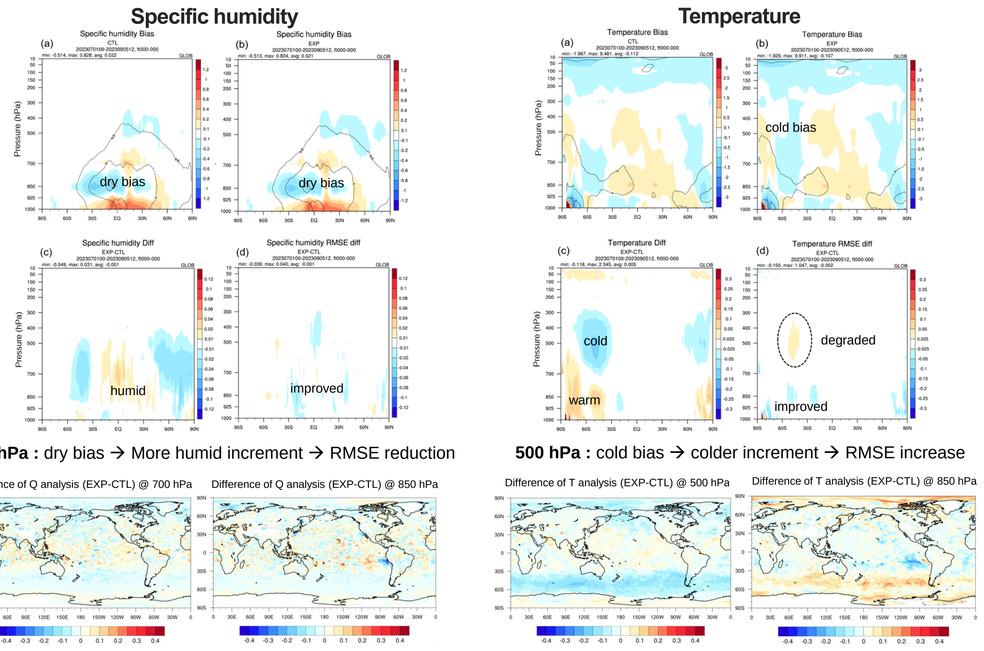
KIM cycling experiment

- KIM v4.0 (25 km) + Hybrid 4D-EnVar (50 km)
  - **CTL:** Operational observations (clear-sky radiance assimilation)
  - **EXP:** Same as CTL but for all-sky radiance assimilation for MHS and MWHS-2
- Cycling period: 2023062512 UTC ~ 2023090512 UTC
- Verification: IFS analysis remapped to 0.25˚ x 0.25˚ resolution



3 Results

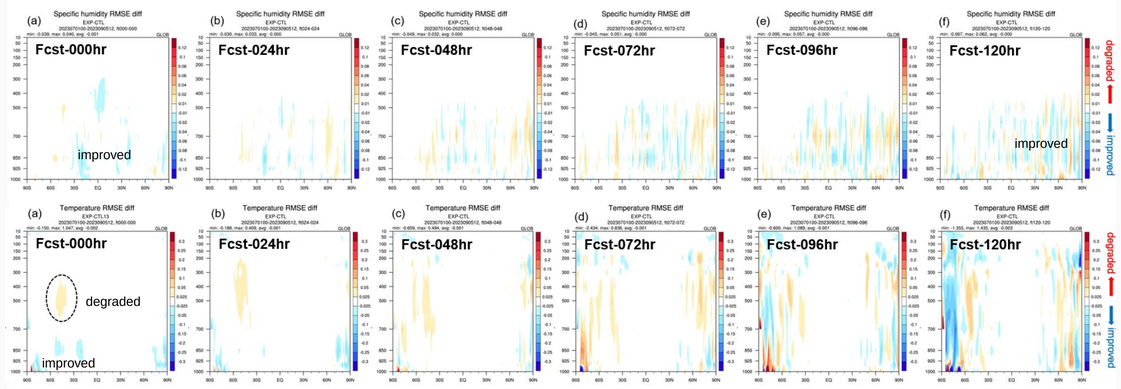
Analysis Impact



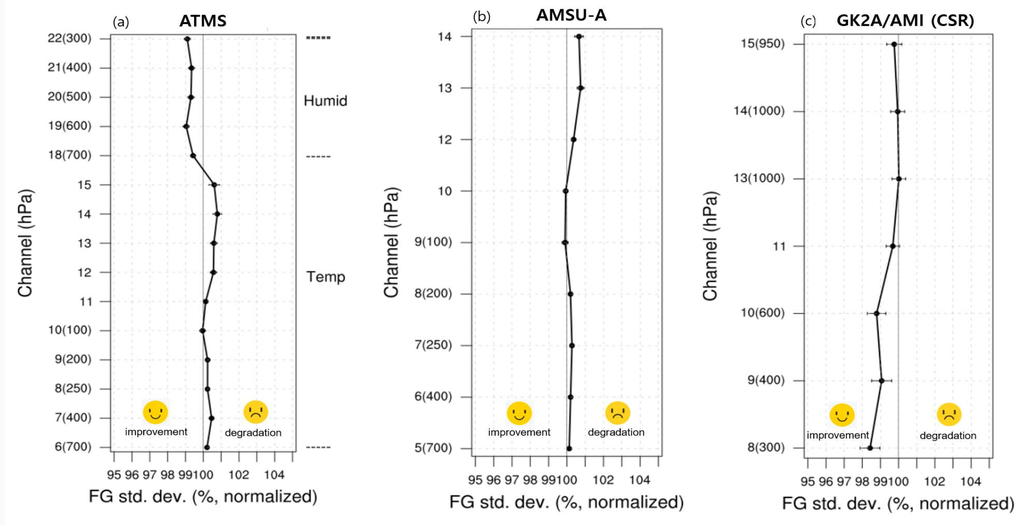
850 hPa : dry bias → More humid increment → RMSE reduction

500 hPa : cold bias → colder increment → RMSE increase

Forecast Impact

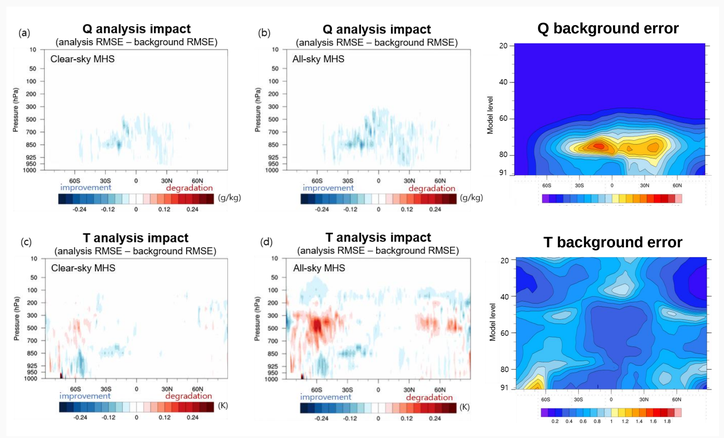


Observation Verification



The standard deviation of the water vapor channels decreased, while that of the temperature channels increased.

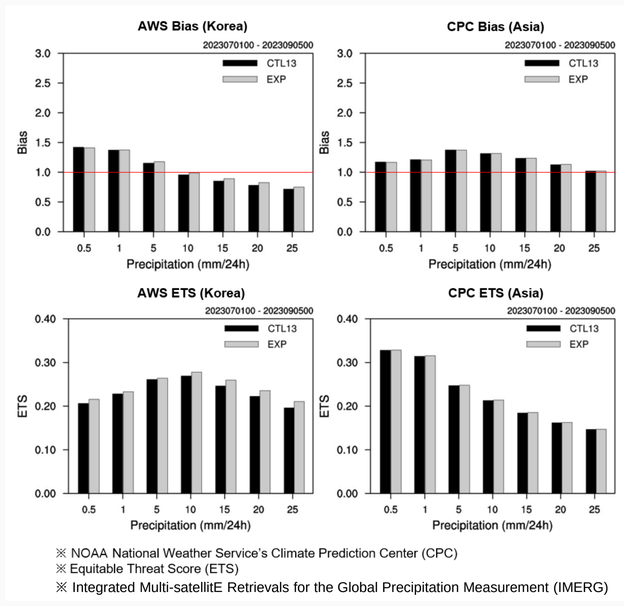
MHS alone assimilation



The Q increments are larger in the low latitudes, while the T increments are more pronounced in the mid-latitudes.

In regions with a large standard deviation of the background error covariance, the analysis increments for each variable become significantly larger.

Precipitation Verification

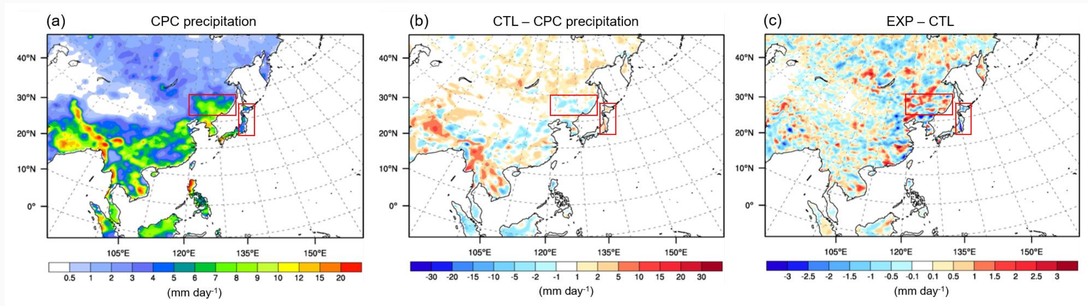


※ NOAA National Weather Service's Climate Prediction Center (CPC)
※ Equitable Threat Score (ETS)
※ Integrated Multi-satellitE Retrievals for the Global Precipitation Measurement (IMERG)

The precipitation forecast for Korea and Asia has been enhanced, reduced bias and improved ETS.

Both heavy precipitation (northern Manchuria) and light precipitation (central Japan) have improved.

Oceanic precipitation forecasts have also improved through IMERG verification (not shown).



4 Summary

- The KIM has been enhanced to **assimilate all-sky radiance** from microwave humidity sensors (**MHS and MWHS-2**) using Hybrid-4DEnVar.
- The assimilation of all-sky radiance incorporates additional observations in tropical regions, leading to increased moisture increments and **reduced humidity analysis errors** in dry-biased tropical areas. This improvement in the initial humidity field over the tropics gradually **propagates to the mid-latitudes during the forecast.**
- The **degradation of the initial temperature field** resulting from all-sky radiance assimilation is more pronounced in the **mid-latitudes** and propagates poleward during the forecast.
- The improvement of the low-latitude humidity initial field through all-sky radiance assimilation contributes to the **enhancement of precipitation forecasts** in Korea and Asia.

ECMWF workshop on data assimilation: initial conditions and beyond, Bonn, Germany, 9–10 April 2025.