Validation of cloud simulation in Korean Integrated Model (KIM)

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1 Introduction

- ✓ KIAPS developed a new global NWP model in 2020, for operational medium-range weather predicion. And KIAPS' new mission, is expanding its forecast range to sub-seasonal one with relevent couplings.
- ✓ Cloud in NWP Models is a major source of error connected to various scales of weather and climate phenomena.
- ✓ This study evaluates cloud and hydrometeor simulated by KIM with reanalysis and observations

2 Methodology

➢ Korean Integrated Model, KIM

KIM	
Dynamic core	Non-hydrostatic
Grid, resolution	Cubed sphere grid 100~8km, L91
Physics*	**KIAPS physics package**
Data assimiluation	Hybrid 4D enVAR
Couple models('2026)	NEMO, SI3, Noah MP

Physics components in KIM

- RRTMK Radiation(modified RRTMG)
- Noah-LSM
- Shin-Hong PBL (scale aware YSU)
- SAS based unifed CPS-SCV
- WSM5 (single moment 5 hydrometers)
- Prognostic cloudiness (Tiedtke PROGC)

➢ Evaluation focus and data used

Main concerns in cloud evalution	Model and reference data	
	KIM variables	Reference
A. Cloud cover and radiation fluxes	cld(cloud cover), surface SW/LW flux	ERA5, ISCCP-H, Calipso ERA5, CERES-EBAF
B. Diurnal cycles of clouds	cld	ERA5, ISCCP-H 3 hourly
C. Hydrometeors structure	qc, qi (grid + subgrid)	ERA5, CloudSat
D. Sensitivies in horizontal resolution	cld, qc, qi(grid + subgrid)	

➢ Experimental designs for KIM simulation (version 3.7)

EXP1. Seasonal simulations for JJA, DJF 2011-2020
- 100 km resolution, initialized ERA5 atm. & sfc.
- 120 day integration (1 month spin-up) with daily observed SST, seaice (OSTIA)
- 5 ensemble with time lag

EXP2. Mediuim-range forecast without data assimilation
- 100, 50, 25, 12 km resolution initialized ERA5 atm. & sfc.
- 10 day forecast from every 00 UTC in Jul 2010, 2015, 2017 & Jan 2017

3 Results

A. Total cloud cover and surface radiation fluxes

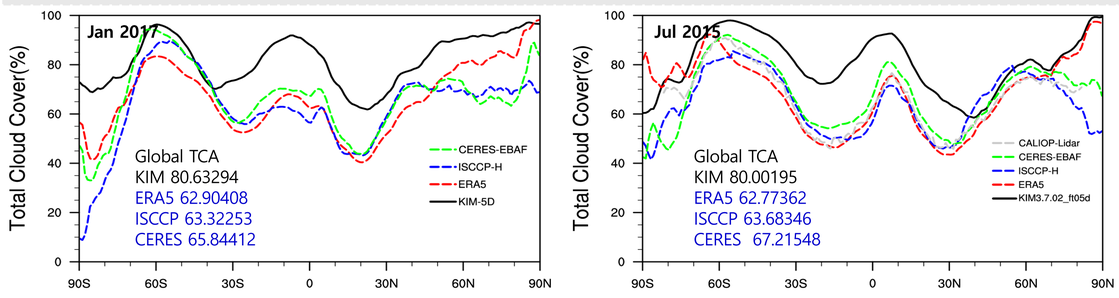

Fig 1. Mean cloud cover(zonal mean): KIM 5D forecast (25km), ERA5, ISCCP, CERES, Caliop

- KIM shows significant overestimation in cloud cover, while reference clouds agree on each other except polar regions

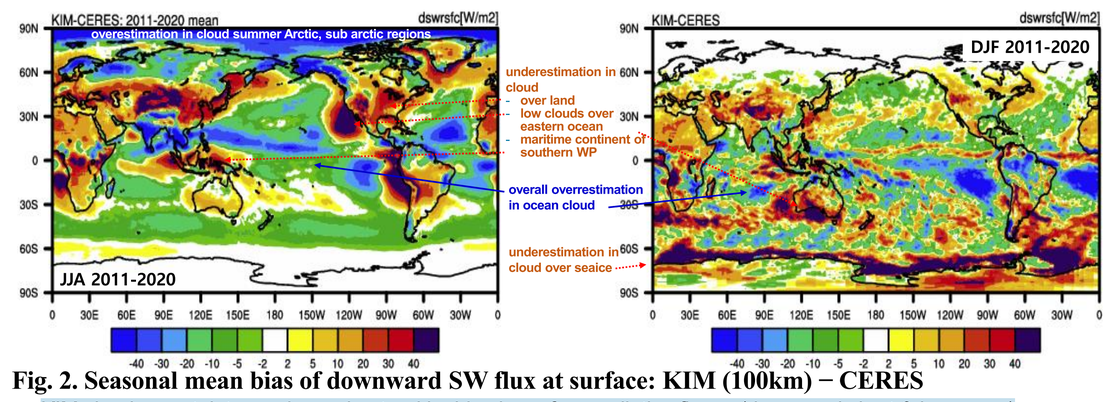

Fig. 2. Seasonal mean bias of downward SW flux at surface: KIM (100km) − CERES

- KIM cloud uncertainty can be understood by bias in surface radiative fluxes (downward short & longwave)

B. Diurnal cycles of clouds and hydrometeors

❖ **Data process for diurnal change at local time zone**

Model, OBS 3 hourly (UTC) → linear interpolation hourly (UTC) → hourly data at local time zone (LST)

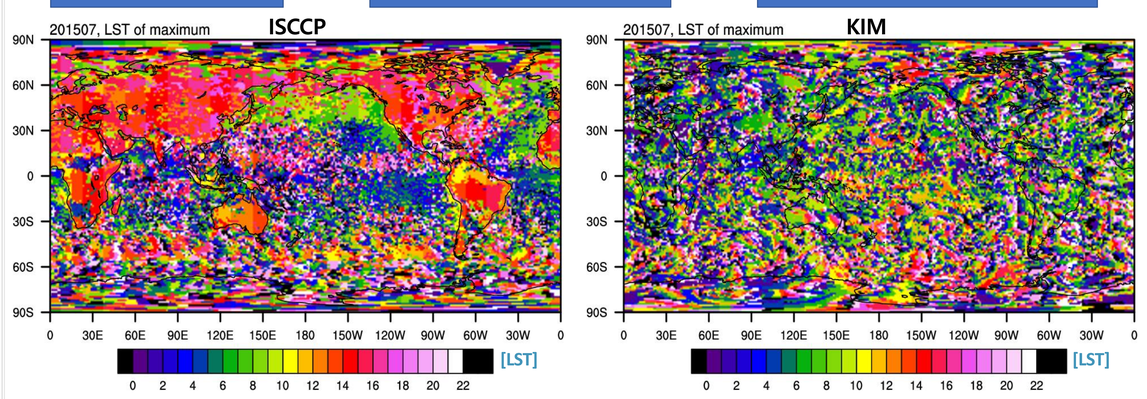

Fig. 4. Diurnal peak in TCLD (in local time): KIM 5D forecast (25km) vs ISCCP (Jul 2015)

Fig. 4. Observated clouds have various diurnal cycles
- afternoon peak over land, deep convective ocean cloud
- early monrning peak in overall tropics~subtropics ocean
- morning peak over mid-latitude ocean
- KIM CLD fails to capture it properly

CLD vs. hydrometeors

Fig. 5. KIM hydrometeors (grid + subgrid) show diurnal cycles which is not shown in the TCLD pattern.
- Subgrid hydrometeors contributes diurnal changes of clouds (not shown)
- KIM CLD needs more consistency with hydrometeors

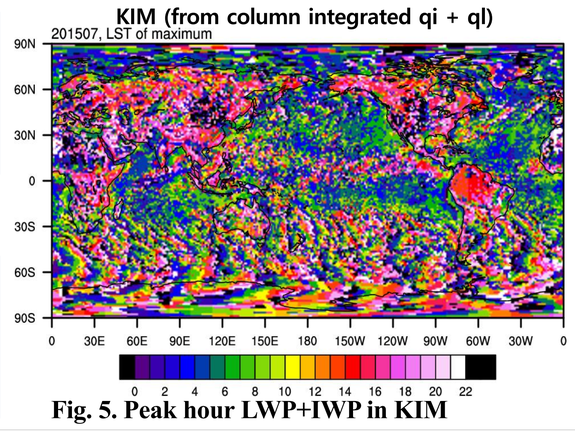

Fig. 5. Peak hour LWP+IWP in KIM

C. Vertical structures of hydrometeors: KIM, ERA5 vs CloudSat

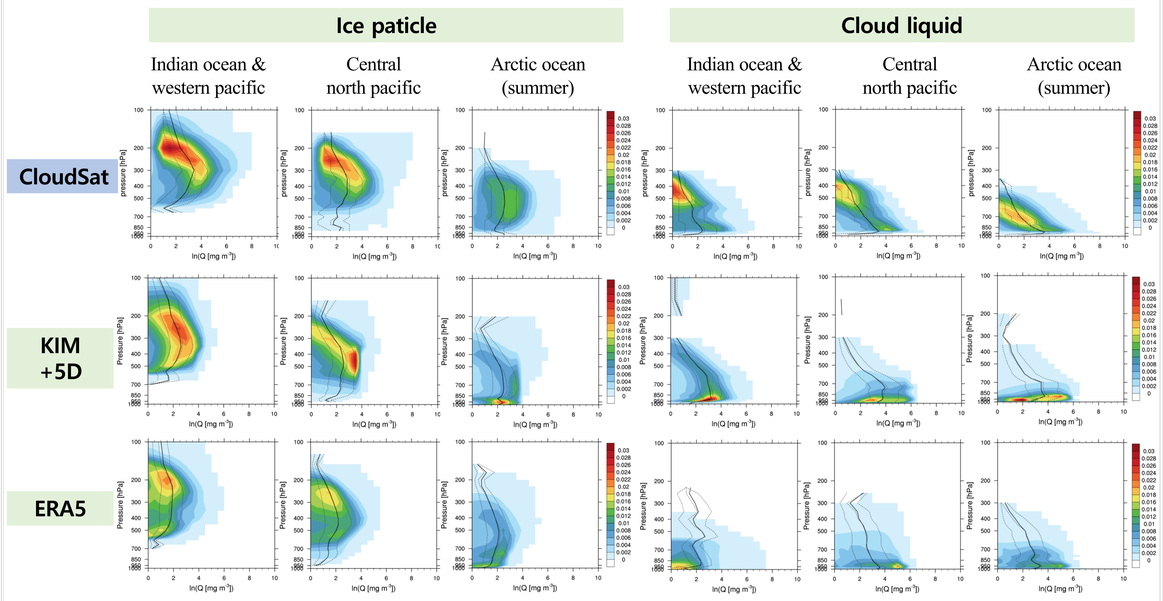

Fig. 3. Contoured frequency by altitude diagram (CFAD) collected for different regions (Jul 2010)

- KIM simulates cold cloud peaks at the lower level with larger mass concentration for tropical and mid-latitude clouds
- KIM overestimates low level liquid clouds significantly
- Both KIM and ERA5 show different structures of hydrometors in summer Arctic clouds with observation

❖ Further evaluation will be followed using a cloud simulator (COSP with KIM output is under development)

D. Resolution sensitivities in cloud simulations

❖ **Horizontal resolution and time step for sensitivity test (only to dx)**

	NE045 (~100km)	NE090 (~50km)	NE180 (~25km)	NE360 (~12km)
Default	200s	100s	50s	
Exp	25s	25s	25s	25s

Sensitivity to dt

→ Sensitivity only to dx

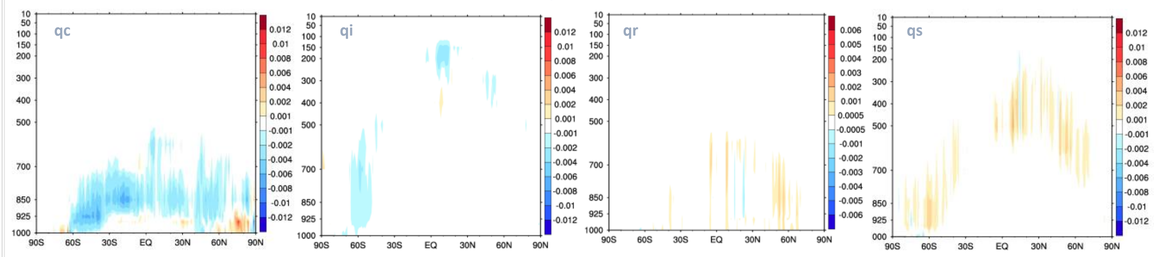

Fig. 6. Difference between NE360-NE180 in sub-grid + grid hydrometeor contents (g/kg)

- Ice (qi) and liquid cloud (qc) decrease with increase in resolution, while rain (qr) and snow (qs) increases
- It is mainly attributed to grid scale process (MPS) sensitivity, and affects cloud radiative forcing

4 Summary

- ✓ Cloud and hydrometeors simulated by KIM is evaluated with reanalysis and various observations
- ✓ KIM cloud cover is highly overesimated and show inconsistency with hydrometeors, suggesting the necessity of revision in the cloud scheme
- ✓ The diurnal cycle and vertical structure of KIM cloud/hydrometor show difference with observation, which can be sources of systematic bias
- ✓ Hydrometeors and clouds are quite sensitive to the horizontal resolution and the time step

6th WGNE workshop on systematic errors in weather and climate models, Reading, UK, 31 Oct – 4 Nov 2022