Evaluation of cloud hydrometers from Korean Integrated Model (KIM) using multi reanalysis products and satellite observations

Akkisetti Madhulatha[1], Rae-Seol Park[1], Jung-Yoon Kang[1], Tae-Hun Kim[1], and Song-You Hong[1]

[1]Korea Institute of Atmospheric Prediction Systems

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Abstract

Validation of cloud hydrometeors simulation from the global models is important issue as it pertains to the accuracy of climate predictions. In this study, the cloud hydrometeor data from Korean Integrated Model (KIM) is validated using different Reanalysis (ERAI, ERA5, and MERRA) and Satellite Observations (Cloudsat). In ERA5 products, cloud snow water and rain water are also available. Satellite observations are gridded to compare with model simulations. Cloud liquid water (Qc), Cloud snow water (Qs), Cloud ice water (Qi), Cloud rain water (Qr), Vapour mixing ratio (Qv) for January (dry) and July (wet seasons) of 2017 are considered for validation. BIAS and RMSE are calculated for comparison. To understand the vertical distribution of hydrometeors, contour frequency altitude diagrams (CFADs) are plotted. Early validation of KIM hydrometeors shows the reasonable estimate of different hydrometeors with KIM model showing more Qc at surface, more Qv at upper levels. The vertical structure of Qi has showed significant bias at upper levels with model showing large ice values at higher levels. ERAI and ERA5 products has showed distinct pattern of Qi due to different configurations. More Qs at upper levels is also evident in model simulations. Combined distribution (Qc+Qi) of KIM at lower (upper) levels is more comparable with ERA5 (MERRA) products. Further, Qr distribution shows underestimation at the equator and over estimation at the latitude belts. To examine the contribution of different physics modules related to the bias, the hydrometeors from cumulus, microphysics and shallow convection are also analyzed separately. Accuracy of KIM simulated cloud hydrometeors against different products and possible causes for biases will be discussed in the conference.

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Akkisetti Madhulatha[1,*], Rae-Seol Park[1], Jung-Yoon Kang[1], Tae-Hun Kim[1] and Song-You Hong[1]

a.madhu@kiaps.org, madhulatha11@gmail.com

Affiliation: Korea Institute of Atmospheric Prediction Systems (KIAPS), Seoul, South Korea

Introduction

- Validation of cloud hydrometeors simulation from the global models is important issue as it pertains to the accuracy of climate predictions.
- KIM (Hong et al., 2018) hydrometeors are validated using different reanalysis ERA5 (https://cds.climate.copernicus.edu),
- ERAI (https://www.ecmwf.int) MERRA (https://goldsmr5.gesdisc.eosdis.nasa.gov and CLOUDSAT (www.cloudsat.cira.colostate.edu) observations.
- All products are remapped and gridded to model resolution for comparison.
- Qc,Qs,Qi,Qr,Qv for January (dry) and July (wet) seasons 2017 are considered. Qs, Qr are available only in ERA5.
- Various statistics : Normalized Probability Distribution Functions (PDF's), BIAS, Mean, RMSE, Contoured Frequency Altitude Diagrams (CFADs) are constructed.
- CLOUDSAT observations of cloud ice are also processed for January 2017.
- Identifying the biases related to hydrometeors by evaluating with different Reanalysis, satellite observations is important for model development particularly for KIM Physics update and also effect of assimilation strategies (all sky (ERA5)/ clear sky (ERAI and dependency on ingestion of different observations on model simulations.

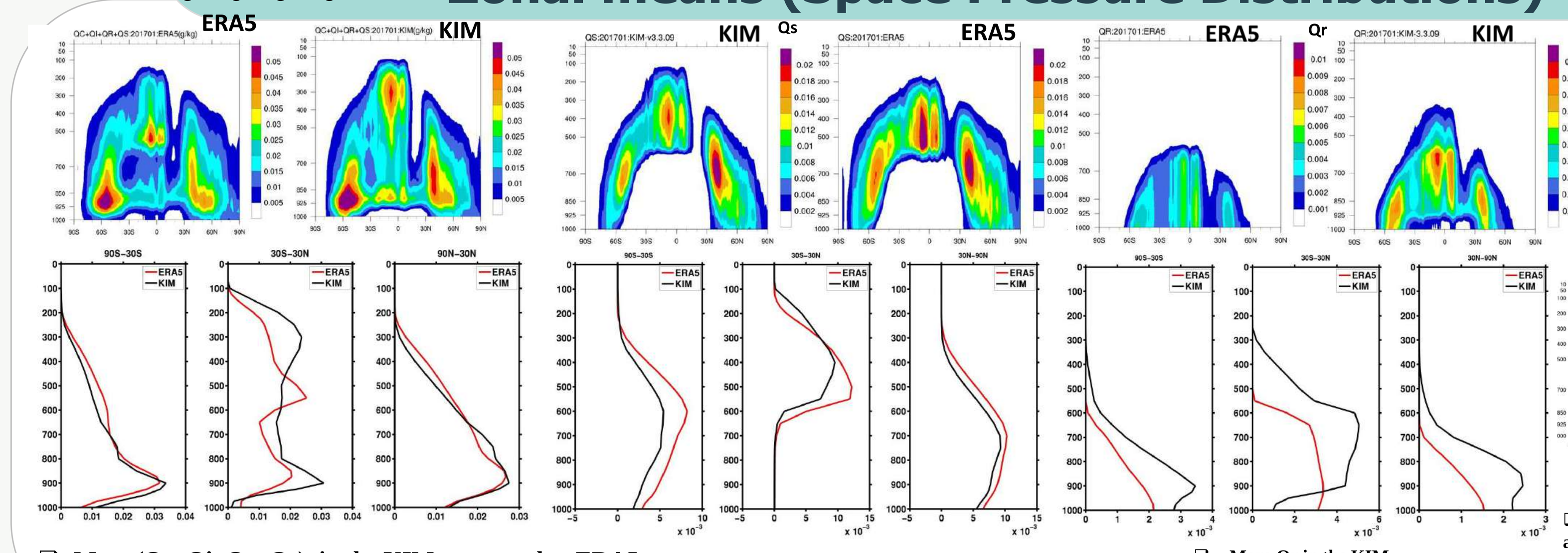
Reanalysis Products

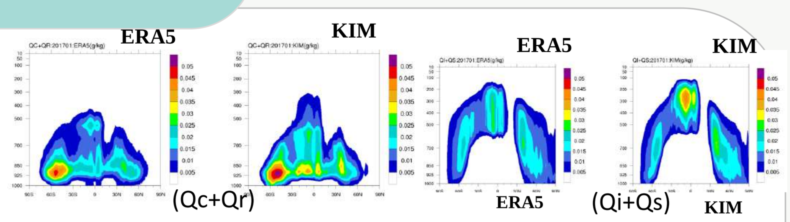
	ERA Interim	ERA5	MERRA
Period covered	1979-present	1950-present	1980-present
Assimilation system	IFS Cycle 31r2 4D-Var	IFS cycle 41rs-4DVar	GOES 5.12.4Variatio
Spatial resolution	79 km globally, 60 levels to 0.1hPa	31 km globally, 62 km for the Ensemble Data Assimilation (EDA), 137 levels to 0.01 hpa	~50 km
Output frequency temporal resolution	6 hourly analysis fields	Hourly analysis fields	1-hourly
Input Observations	As in ERA-40 and from GTS	In addition, various newly reprocessed data sets and recent instruments that are not ingested in ERA-Interim	NASA GMAO
Satellite Data	RTTOV-7, clear-sky, 1d-Var rainy radiances	RTTOV-11, All-sky for various components	CRTM
Spatial grid type	Reduced Gaussian	Reduced Gaussian	Cubed Sphere

KIM Physics

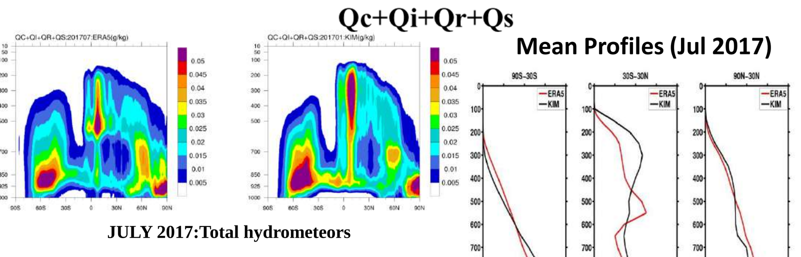
Physics Schemes	KIM 3.2.11 to KIM 3.3.02/V3.3.09
Cumulus parameterization (CPS)-KSAS Han et al. (2016); Kwon and Hong (2017)	Revision of Co for Overshooting layer modification
Shallow convection (SCV) Hong and Jang (2018)	Modification of C0 in SCV
Cloud microphysics (MPS)-WSM6 Hong et al. (2004)	add qrmps, qrcps, and qrscv for all-sky radiance (KIM only) (no update)
Radiation (RAD)-RRTMK Baek (2017)	improved optical properties of dust by including the effect of Earth curvature
Cloudiness (CLD) Park et al. (2016)	-
Vertical diffusion (PBL) Shin and Hong (2015), Lee et al. (2018)	Wmax options for gray zone
Aerosol chemistry (AER) 3D aerosol data	-
Orographic gravity wave drag (GWDo) Choi and Hong (2015)	-
No-mountain gravity wave drag (noGWDo) Choi and Hong (2015)	-
Land surface layer (LSM) Koo et al. (2017, 2018)	MODIS Type dependent emissivity (Minor revision in LSM)
Kim and Hong (2010)	Mixing ratio to specific humidity in latent heat flux over oceans.

(Qc+QI+QR+QS) distribution (ERA5)
Zonal means (Space Pressure Distributions)





- Both liquid and solid hydrometeors are over estimated in KIM compared to ERA5.



JULY 2017:Total hydrometeors

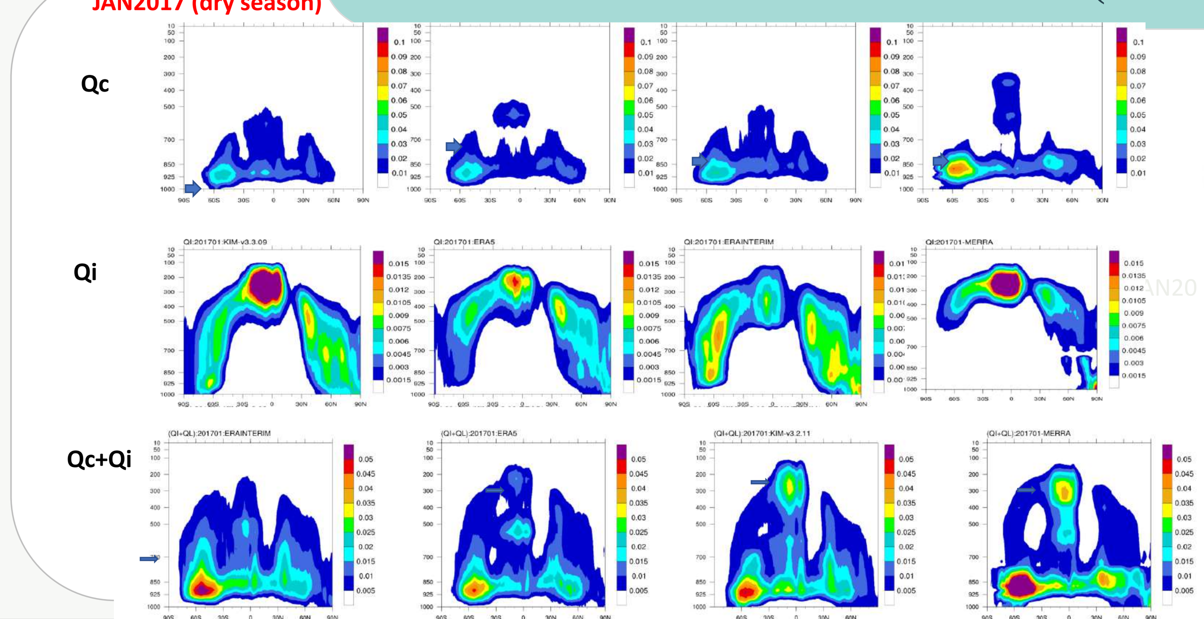
- Over different regions, KIM total hydrometeors are overestimated compared to ERA5 for July 2017.
- In NH, underestimated in KIM.

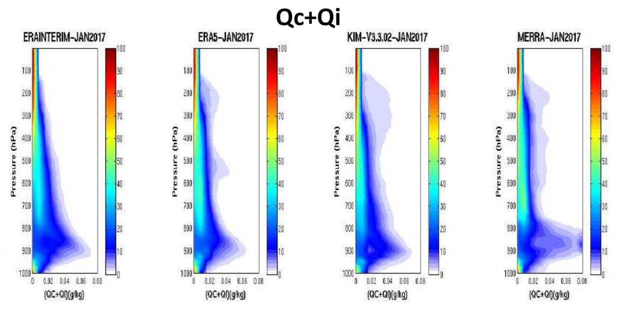
- More (Qc+Qi+Qr+Qs) in the KIM compared to ERA5.
- Qs and Qr are available in ERA5 but not in other products.
- Less Qs in the KIM
- More Qr in the KIM

KIM:V3.3.09

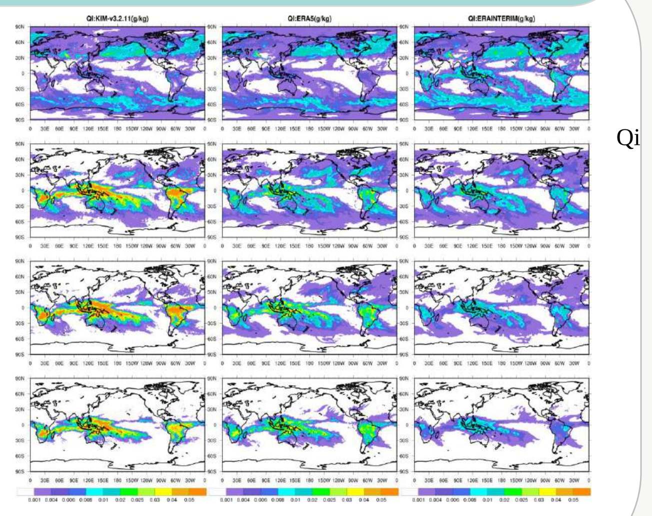
QI,QC zonal means (ERA5/ERAI/MERRA) Spatial distribution (Qi) and Contoured Frequency Altitude Diagrams (CFADS) , Qr spatial distribution

JAN2017 (dry season)



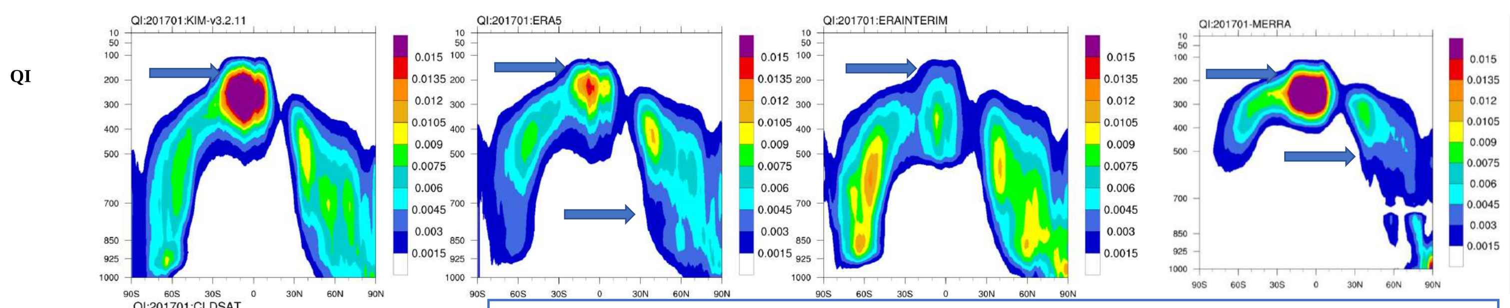


- CFADS clearly shows the differences in vertical variation of QI+QC between the products.
- QI+QC: From KIM are more comparable ERA5(MERRA) at lower (upper) levels.

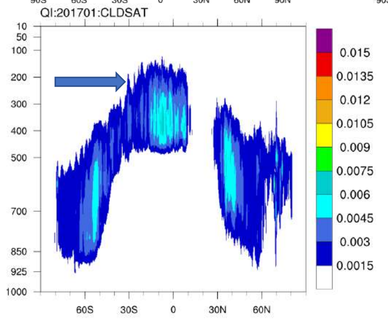


- Varied distribution of Qi is evident between the ERA5/ERAI.

Qice: Cloudsat data
Quality control :Height to Pressure levels conversion

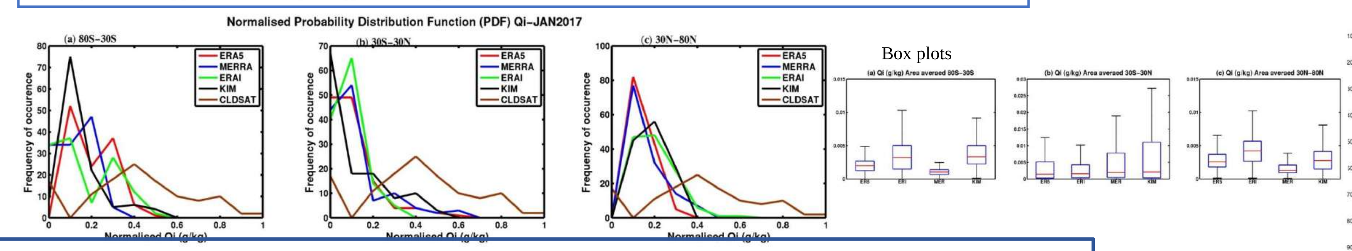


JAN2017

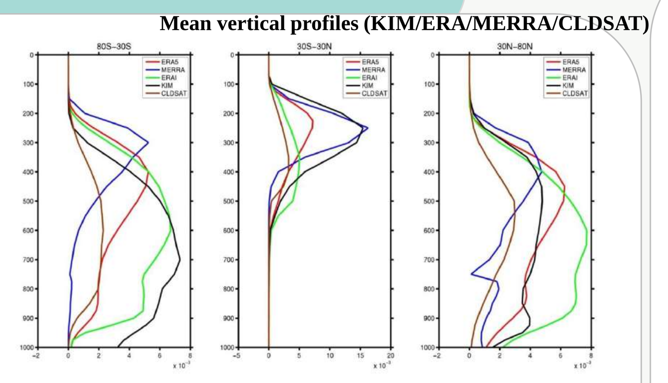


2C-ICE.P1_R05 for Jan 2017 is processed.

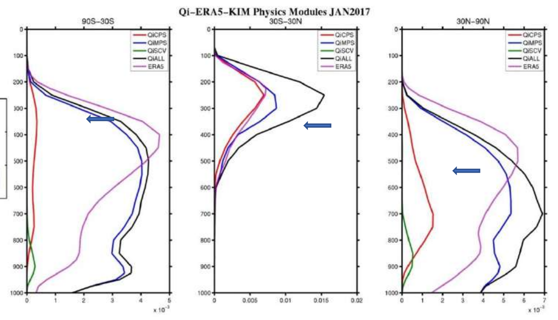
- Conversion from height levels to pressure levels to compare with model data.
- Scale height H=RT/Mg, R=Gas Constant=8.314, M=Mean Molecular mass
- Temperature and pressure levels from cloudsat are taken to calculate the pressure levels
- Hydrostatic approximation (dp/dz=gp) , $P=P_0exp(-z/H)$



Mean vertical profiles (KIM/ERA/MERRA/CLDSAT)



- Mean vertical profiles from different products showed varied distribution.

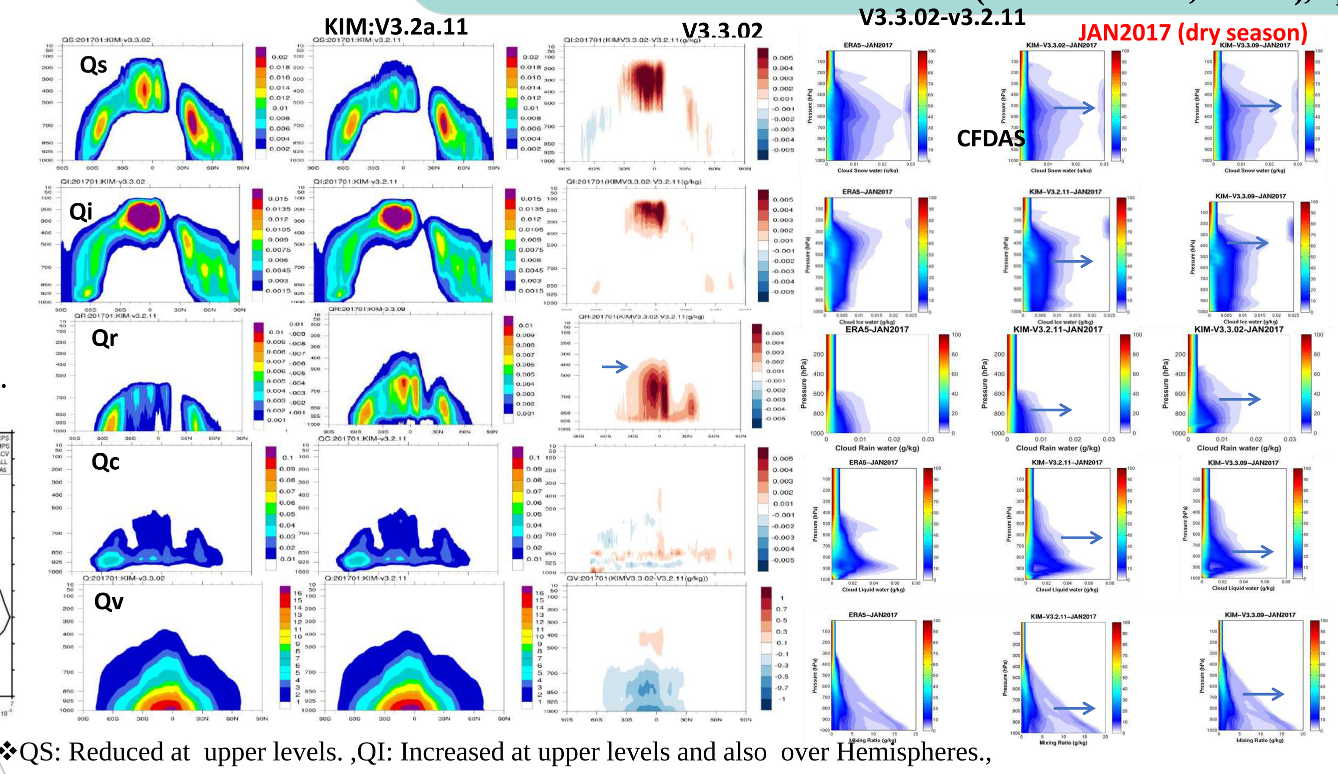


- As there are differences in order between the products, normalized PDFs are considered.
- Statistical analysis shows that Over NH (KIM/ERA5), Tropics (KIM/MERRA), SH (KIM/ERA) are closer.
- Overall mean vertical correlation (not shown here) is more in ERA5 in NH/SH.
- Even though magnitude of Qi is different but Cloudsat observations also shows less qi which has to be taken into consideration.
- Box plots analysis shows the distribution of lower and upper ranges of Qi over different regions , consistency between KIM/Reanalysis products.

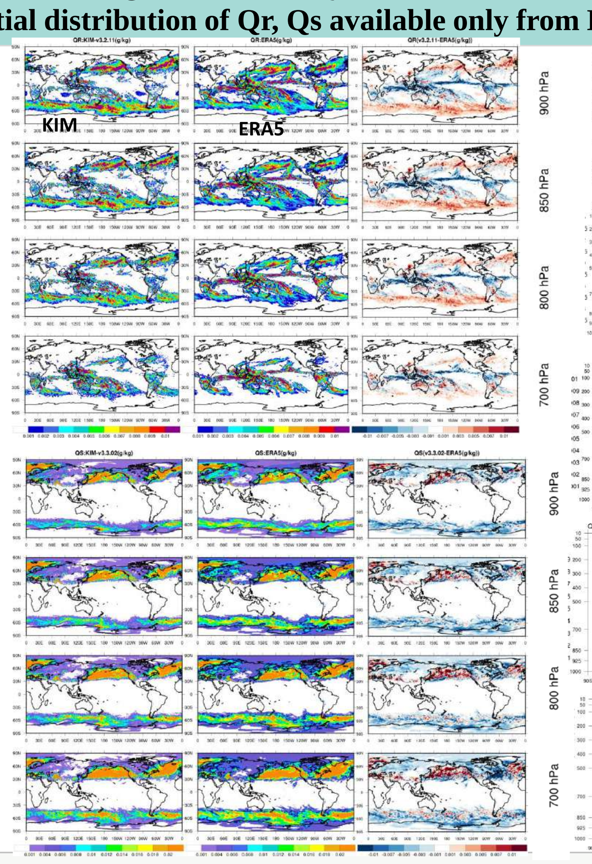
- Qi from different physics modules shows that Qimps contributed for higher values of Qi over different regions.

Versions Updates and change in different hydrometeors
(V3.2.11-V3.3.02,V3.3.09), Spatial distribution of Qr, Qs available only from ERA5

JAN2017 (dry season)

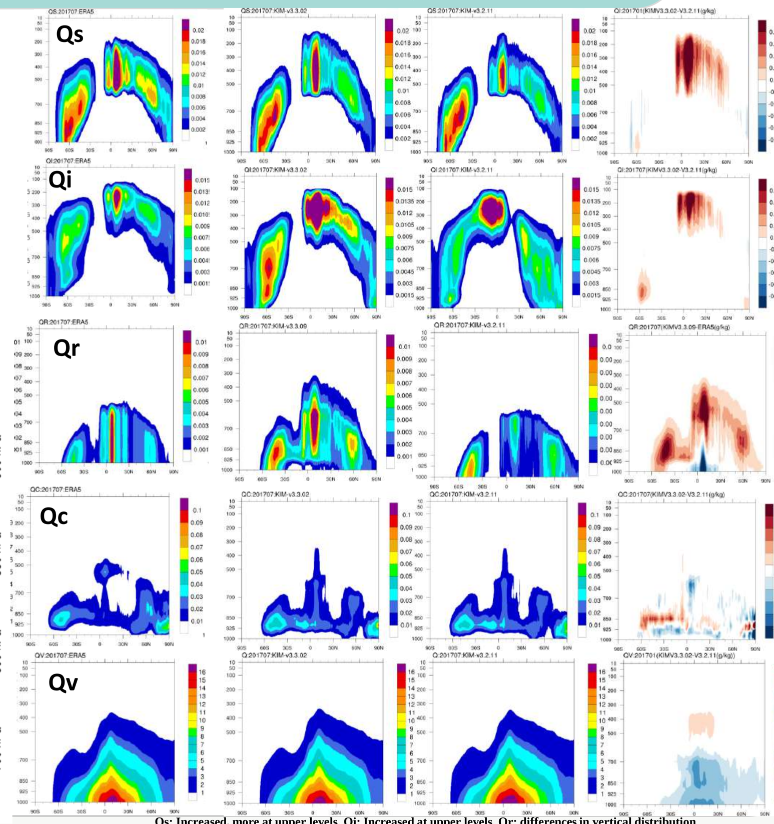


- QS: Reduced at upper levels. ,QI: Increased at upper levels and also over Hemispheres.,
- QR: Increased , differences in vertical distribution. Qc: Reduced at lower/upper levels. Qv: Reduced at lower levels.



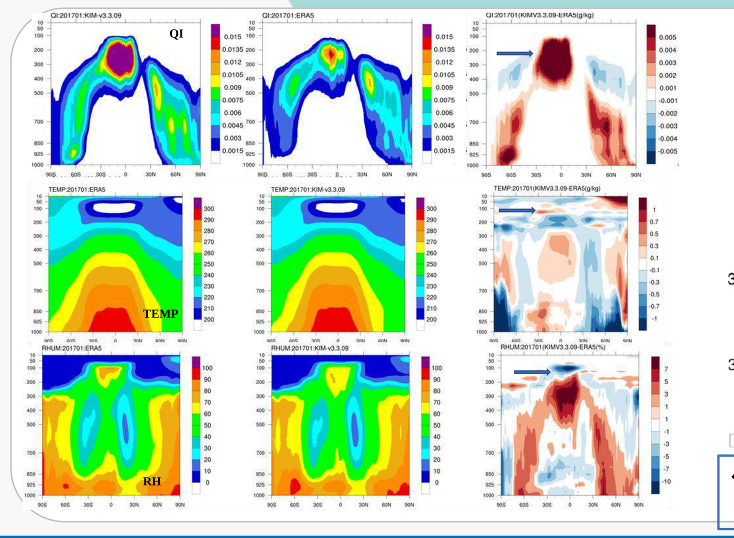
- Typical pictures (right) showing spatial distribution of Qr, Qs available only inERA5/

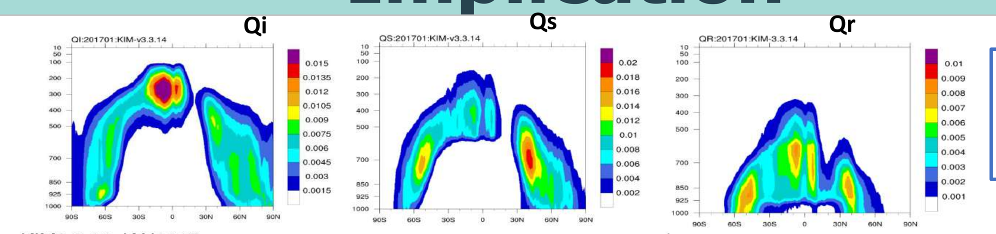
JUL2017 (wet season) V3.3.02-v3.2.11



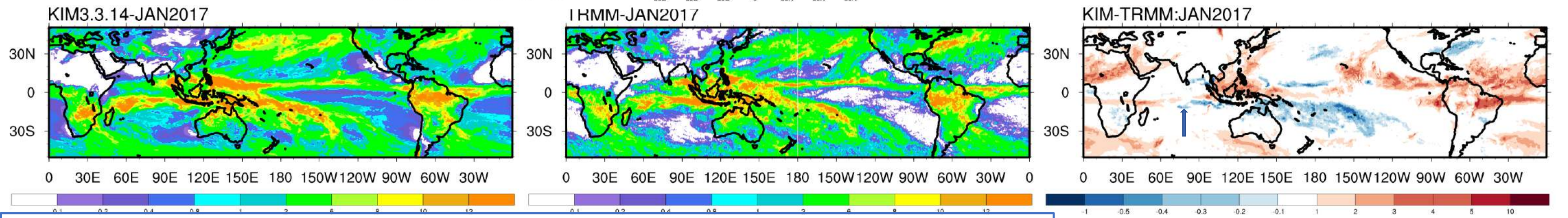
Qs: Increased, more at upper levels. Qi: Increased at upper levels. Qr: differences in vertical distribution
Qc: Differences at 925, 850 hpa levels. Qv: Decreased at lower levels.

Implication





- More Qi at Upper levels (tropics) – Less Temperature –More RH and it affects the hydrological cycle and Precipitation distribution.
- More Qi implies-Deep convective clouds –More Rainfall.
- From V3.309 to V3.3.14 Qi is further reduced. Major update in cps (optimist ion of decaying rate of auto conversion parameter) V3.3.14.



- Further KIM V3.5 version with updated Physics (microphysics, Radiation) updates and assimilation (all-sky and other updates) and dynamics are in progress.
- Bias in rainfall is reduced with reduction in Qi.

Summary and Remarks

- To validate the cloud hydrometeors from KIM model, various reanalysis ERA5/ERAI/MERRA and Satellite Observations (Cloudsat) are considered.
- Early validation of KIM hydrometeors shows reasonable estimate of different hydrometeors with KIM model showing more Qc at surface, more Qv , Qi at upper levels, and less Qs and more Qr.
- Total hydrometeor distribution shows more hydrometeor content in KIM compared to ERA5 due to more ice at upper levels and more rain at lower levels.
- Among the hydrometeors, Qi has showed the distinct pattern between KIM, different reanalysis and satellite products.
- KIM Qi is matching with ERA5 (in NH), MERRA(Tropics), ERATNTERIM (SH).
- The difference between ERA5/ERAI related to Qi distribution can be attributed to physics modules and all sky /clear sky assimilation strategies in former.
- Cloudsat observations also showed less Qi at upper levels.
- Different reanalysis products has showed distinct pattern based on different configurations like physics, assimilation methodologies, use of observations ingested.
- Verification of KIM hydrometeors from different products provided feedback for the Model development work particularly physics update to identify the possible causes for the biases and improve model physics options.
- Along with physics, main difference of Qi at upper levels between ERA5/ERAI could be due to all-sky assimilation method. The impact of all sky assimilation on Qice at upper levels needs to be examined.
- Among the cloud hydrometeors, Qice from KIM model and different reanalysis products has showed distinct pattern over tropics at the upper levels., the best reanalysis to be relied for comparing the model hydrometeors and possible biases between reanalysis products has to be investigated. Quality control of satellite observations is also important.

- Evaluation of cloud hydrometeors from Reanalysis and satellite products is important to physics and assimilation updates in KIAPS to support the KIM model development. Best reanalysis suitable for the KIM model needs to be investigated as it depends on many factors and analysis of more satellite observations is necessary.

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