Effect of single and double moment microphysics schemes and change in CCN, latent heating rate structure associated with severe convective system over Korean Peninsula

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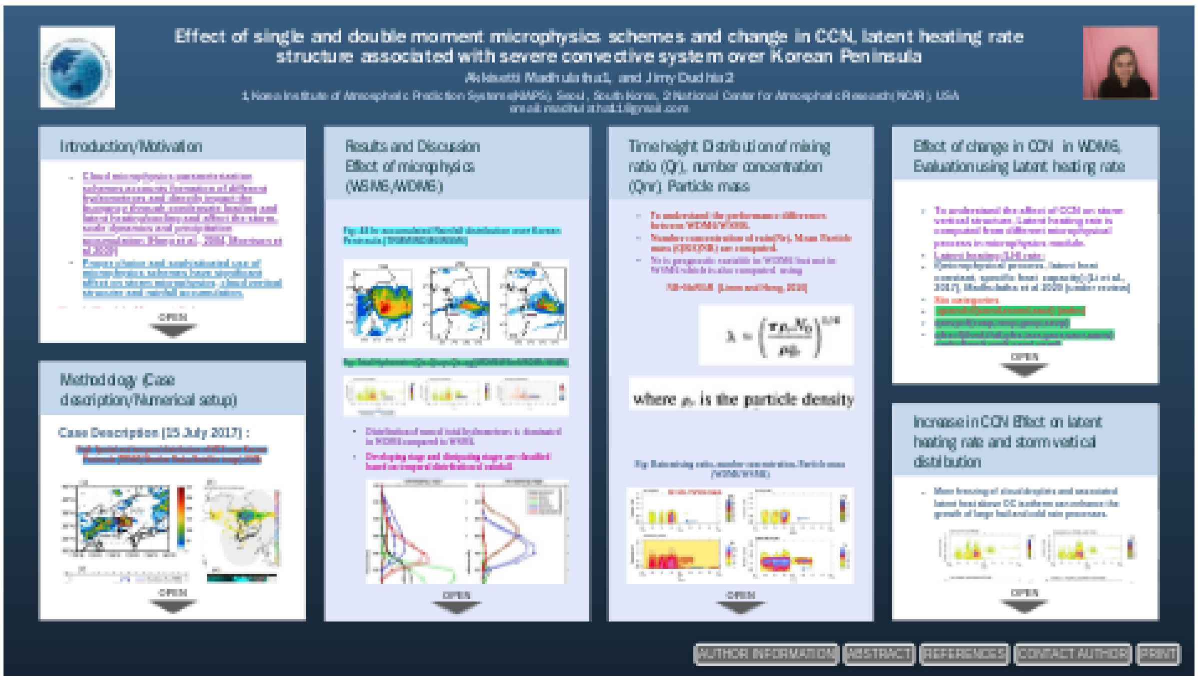
November 22, 2022

Abstract

Cloud microphysics plays important role on the storm dynamics. To investigate the impact of advanced microphysics schemes, using single and double moment (WSM6/WDM6) schemes, numerical simulations are conducted for a severe convective system that formed over the Korean Peninsula. Spatial rainfall distribution and pattern correlation associated with the convective system are improved in WDM6. During developing stage of the system, the distribution of total hydrometeors is larger in WDM6 compared to WSM6. Along with mixing ratio of hydrometeors (cloud, rain, graupel, snow and ice),number concentration of cloud and rainwater are also predicted in WDM6. To understand the differences in vertical representation of cloud hydrometeors between the schemes, rain number concentration (Nr) from WSM6 is also computed using particle density to compare with Nr readily available in WDM6.Varied vertical distribution, and large differences in rain number concentration, rain particle mass are evident between the schemes. Inclusion of number concentration of rain and cloud, CCN along with mixing ratio of different hydrometers have improved the storm morphology in WDM6. Inorder to investigate the cloud-aerosol interactions, numerical simulation has been conducted using an increase in CCN(aerosol) in WDM6 which has shown an improved rainfall distribution with intense hydrometer distribution. The latent heating (LH) rates of different phase change processes (condensation, evaporation, freezing, melting, sublimation and deposition) are also computed using various transformation rate terms in the microphysics modules. It is inferred that the change in aerosol has increased the LH of evaporation and freezing and affected the warming and cooling processes, cloud vertical distribution and subsequent rainfall.

Effect of single and double moment microphysics schemes and change in CCN, latent heating rate structure associated with severe convective system over Korean Peninsula



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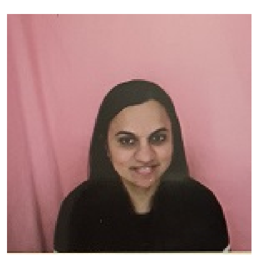


PRESENTED AT:

INTRODUCTION/MOTIVATION

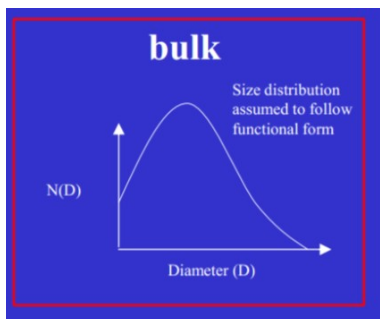
- **Cloud microphysics parameterization schemes accounts formation of different hydrometeors and directly impact the buoyancy through condensate loading and latent heating/cooling and affect the storm-scale dynamics and precipitation (Hong et al., 2004, Morrison et al 2009).**

- **Proper choice and sophisticated use of microphysics schemes have significant affect on storm microphysics, cloud vertical strucutre and rainfall accumulation.**

<u>Single/Double Moment Schemes:</u>

- **Bulk Microphysics schemes assumes size distribution function for each hydrometeor type and predict one or more moments of that distribution.**

Fig 1: Bulk Microphysics scheme overview



WSM6/WDM6

- **Prognostic water substance include (Qv,Qc,Qi,Qs,Qr,Qg) for both WDM6 and WSM6, additionally prognostic number concentration for cloud, rain (Nc, Nr) along with Cloud Condensation nuclie (CCN) in WDM6.**
- **Initial CCN (100 cm-3) in WDM6**
- **Particle size distribution**
- **WDM6:**
- **(Qc,Qr)=Gamma distribution**
- **Qi,Qs,Qr,Qg=Exponential**
- **WSM6: All Exponential Distribution**

Table 1: WSM6/WDM6 formulation

(Lim and Hong, 2010)

Nr Size distribution	WSM6 WDM6	$N_R\lambda_R\exp[-(\lambda_R D_R)]$ $N_R\lambda_R^2 D_R\exp[-(\lambda_R D_R)]$
Nc size distribution	WSM6 WDM6	Constant value with Nc=3X10^8 m^{-3} $n_c(Dc) = 3N_c\lambda_c^3 D^2_C\exp[-(\lambda c Dc)^3]$

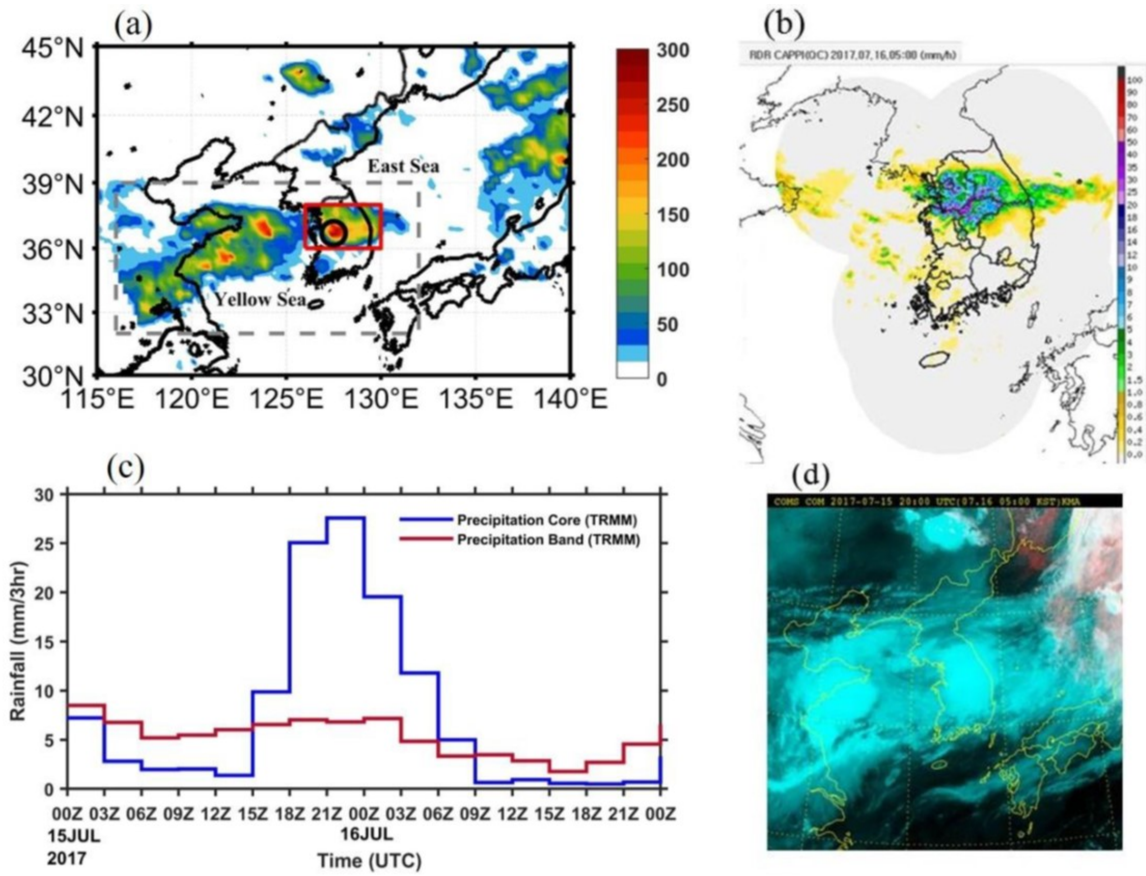
objective:

Effect of single (WSM6) and double moment (WDM6) microphysics schemes on simulation of MCS formed over Korean Peninsula.

METHODOLOGY (CASE DESCRIPTION/NUMERICAL SETUP)

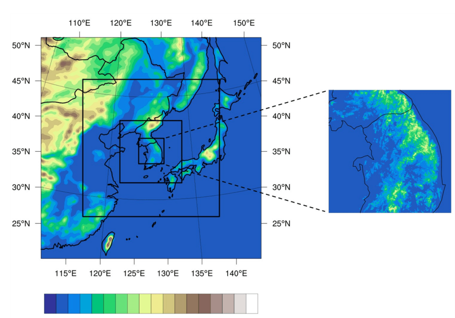
Case Description (15 July 2017) :

Fig2: Spatial and temporal distribution of MCS over Korean Peninsula (TRMM),Weather Radar/Satellite image)-KMA



- **Korean Peninsula has received rainfall related to the MCS propagation which typically develop over Yellow sea, move eastward, and affect the 124 Korean Peninsula during Changma season (Chen et al., 1999).**
- **Present study concentrates on Precipitation core of MCS where the system passed over Korean Peninsula**

Fig3: Nested Domain Configuration



WRF/KIM Physics (Hong et al., 2018)

- **Resolution(27/9/3/1km), Timestep(72,24,8,2s)**
- **Microphysics (WDM6/WSM6)**
- **Experiments with change in CCN in WDM6.**

- **Pbl (Shin and Hong, 2015)**
- **Scale aware cumulus scheme**
- **Rainfall evaluation (TRMM)**

RESULTS AND DISCUSSION
EFFECT OF MICROPHYSICS (WSM6/WDM6)

Fig: 48 hr accumulated Rainfall distribution over Korean Peninsula (TRMM/WDM6/WSM6)

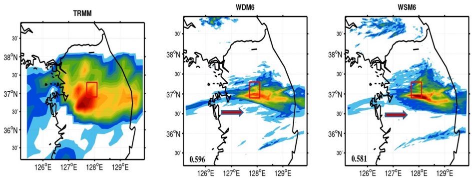
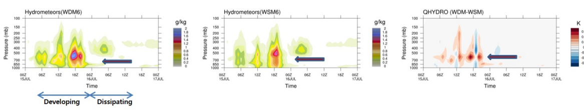


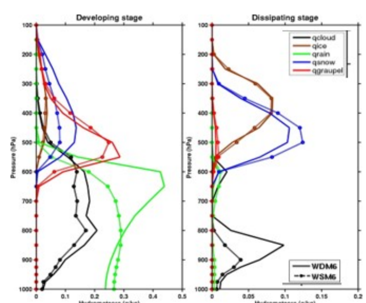
Fig: Total Hydrometer (Qc+Qi+qr+Qs+qg)(WDM6/WSm6/WDM6-WSM6)



- **Distribution of sum of total hydrometeors is dominated in WDM6 compared to WSM6.**

- **Developing stage and dissipating stages are classified based on temporal distribution of rainfall.**

Fig: Mean Distribution of Hydrometeors



- **Mean Distribution of sum of total hydrometeors is dominated in WDM6 compared to WSM6.**
- **Developing stage: all hydrometeors dominant in WDM6.**
- **Dissipating stage: qi, qs, qr, qg (qc) are (is) dominant in WSM6 (WDM6).**

TIME HEIGHT DISTRIBUTION OF MIXING RATIO (QR), NUMBER CONCENTRATION (QNR), PARTICLE MASS

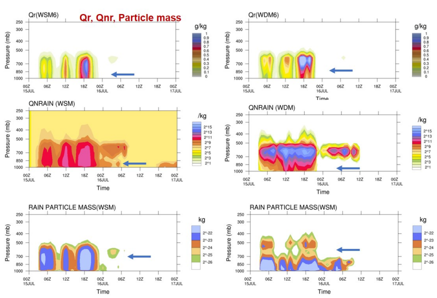
- **To understand the performance differences between WDM6/WSM6.**
- **Number concentration of rain(Nr), Mean Particle mass (QR/QNR) are computed.**
- **Nr is prognostic variable in WDM6 but not in WSM6 which is approximated using particle density**

NR=NoR/λR (Limm and Hong, 2010)

$$\lambda = \left(\frac{\pi \rho_r N_0}{\rho q_r}\right)^{1/4}$$

Density of rain is utilised.

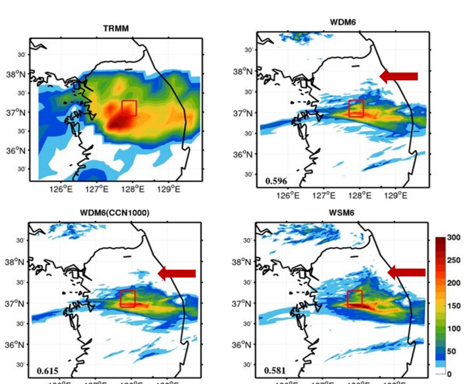
Fig: Rain mixing ratio, number concentration, Particle mass (WDM6/WSM6)



- **Varied vertical distribution, large differences in rain particle mass developing/dissipating stages (WDM6/WSM6).**
- **Inclusion of number concentration, CCN along with mixing ratios have improved the storm morphology over different stages in WDM6.**
- **Excessive Nr plays important role in determing precipitation.**

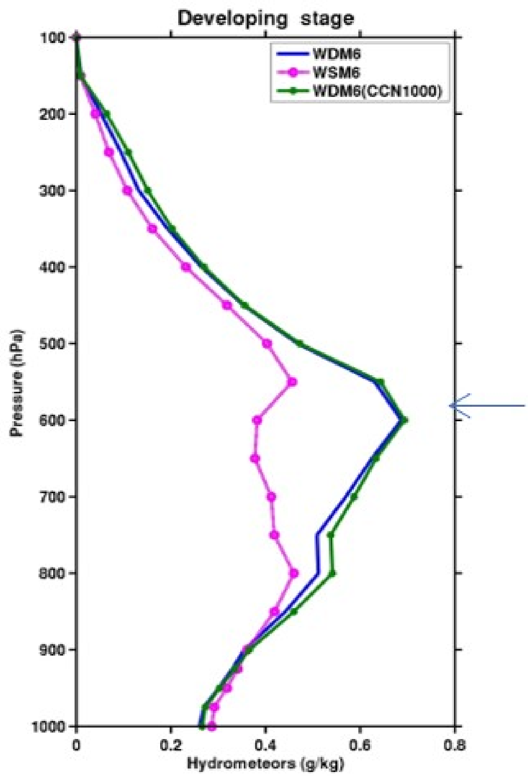
Effect of change in CCN in WDM6:

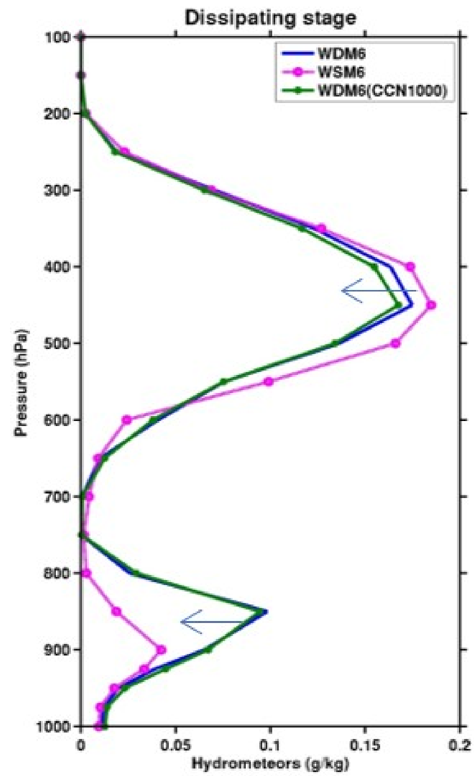
Fig: Spatial Distribution of rainfall and mean distribution of total and indiviudal hydrometeors

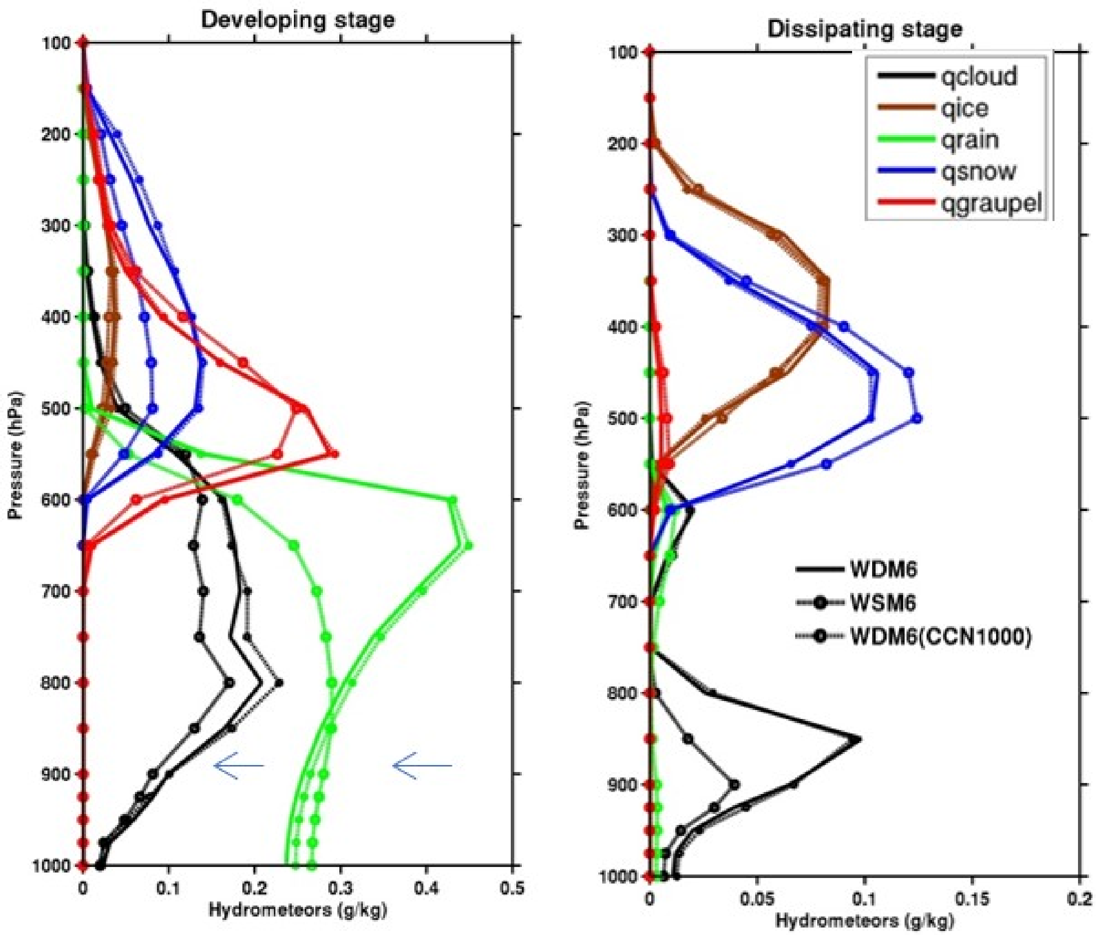


- **Increase in CCN in WDM6 has improved the rainfall simulation with improved pattern correlation.**

Fig: Mean Hydrometeor content (top panel) individual hydrometeors (bottom panel) (WDM6,WDM6_CCN,WSM6)







- **More hydrometeor content is noticed with increase in CCN.**

EFFECT OF CHANGE IN CCN IN WDM6, EVALUATION USING LATENT HEATING RATE

- **Aerosol distributions can influence cloud droplet size distributions, warm and cold rain processes and inturn affect the mixed phase regions.**
- **To understand the effect of CCN on storm vertical structure, Latent heating rate is computed from different microphysical process in microphysics module.**

Latent heating (LH) rate:

- **f(microphysical process, latent heat constant, specific heat capacity) (Li et al., 2017), Madhulatha et al 2020 (under review)**
- **Six categories**

condensation, evaporation,

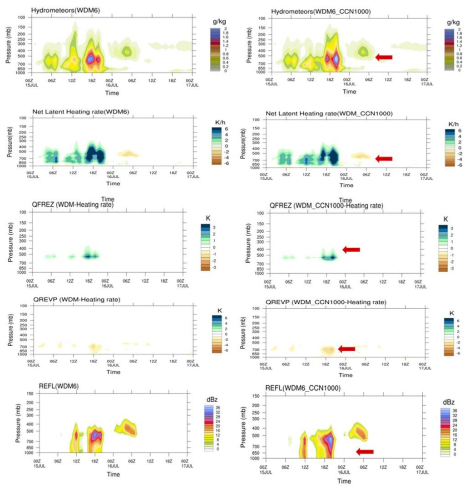
freezing,melting

sublimation,deposition

Various microphysical transformation terms (lim and Hong, 2010) from WDM6 and WSM6 microphysics module are considered for calculation.

DISCUSSION:

Fig: Vertical distribution of cloud features



- **More freezing of cloud droplets and associated latent heat above OC isotherm can enhance the growth of large hail and cold rain processes.**
- **Increased freezing and evaporation (with ccn raise)**

INCREASE IN CCN=MORE HYDROMETEOR CONTENT=AFFECT LATENT HEAT DISTRIBUTION-WARM AND COLD RAIN PROCESS=RAINFALL

Conclusions:

- **Sensitivity of single and double moment schemes on simulation of MCS is investigated.**
- **Distribution of different hydrometeors is dominant in WDM6 compared to WSM6.**
- **Varied distribution in rain number cocnentration, rain particle mass.**
- **Inclusion of number concentration, CCN along with mixing ratios might have contributed for the improved storm morphology over different stages of the MCS.**
- **Change in CCN affected the warming and cooling process.**

Acknowledgements:

- **This work has been carried out through the R&D project on the development of global numerical weather prediction systems of the KIAPS, funded by the KMA.**
- **NCAR(WRF Model).**
- **NCAR NCEP (TMPA observations)**
- **Analysis tools: NCL (https://www.ncl.ucar.edu/ (https://www.ncl.ucar.edu/)), MATLAB,GRADS**

THANKS TO ALL VIEWERS

SPECIAL THANKS TO AGU 2020 CONVENERS

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