Impact of a two-moment bulk microphysics scheme on precipitation forecast in the JMA regional model

Masahiro Sawada (Numerical Prediction Development Center, Japan Meteorological Agency), msawada@met.kishou.go.jp

Introduction

As JMA's NWP strategic plan toward 2030, heavy precipitation disaster prevention is one of the priority objectives. To achieve this, there is still considerable room for improvement in predicting the precise timing and location of heavy precipitation by developing the related physical schemes in numerical prediction model. The aim of this study is to investigate the impacts of the microphysics scheme sophistication, such as warm-rain 2-moment, on rainfall forecast and its feasibility as an operational model.

Model outline and experimental setting

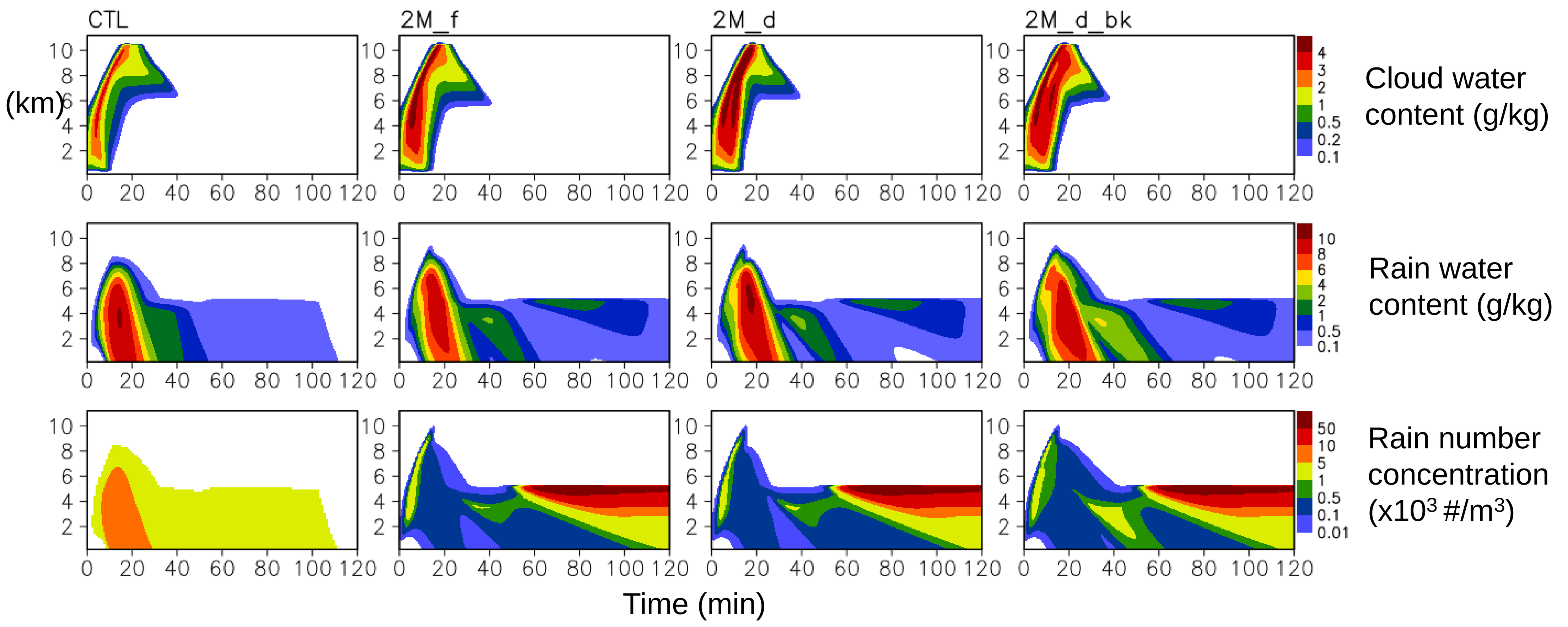
JMA regional model: ASUCA (Ishida et al. 2022)
Microphysics: 1-moment (Ikuta et al. 2020) for control experiment
Grid spacing: 2 km horizontal resolution, 76 vertical layers
Forecast hours: 10 h
Period: 2020.7.2~7.15, 4 times/day(6 hourly)
Initial/boundary condition: Local analysis/Mesoscale model forecast

Forecast domain: 3160x2600 km^2

Names	Warm rain	Drop size distribution/shape parameter	Raindrop collection efficiency
CTL	1-moment	$N_r(D_r) = N_{0r}\exp(-\lambda_r D_r)$	$E_{rcol} = 1$
2M_f	2-moment (Cohard & Pinty 2000)	$N_r(D_r) = N_{0r} D_r^{\alpha_r}\exp(-\lambda_r D_r)$, $\alpha_r = 5$	$E_{rcol} = \begin{cases} 1 & (\overline{D_r} < D_{th}) \\ \exp[-2.5\times10^3(\overline{D_r} - D_{th})] & (D_{th} \le \overline{D_r} < 2mm) \\ 0 & (2mm \le \overline{D_r}) \end{cases}$ $D_{th} = 0.6mm$ (Cohard & Pinty 2000)
2M_d		$\alpha_r = \begin{cases} 6\tanh[c_1(D_m - D_{eq})]^2 + 1, D_m \le D_{eq} \\ 30\tanh[c_2(D_m - D_{eq})]^2 + 1, D_m > D_{eq} \end{cases}$ $c_1 = 4mm^{-1}, c_2 = 1mm^{-1}$ D_m: mean volume diameter, $D_{eq} = 1.1mm$ (Seifert 2008)	
2M_d_bk			$E_{rcol} = \begin{cases} 1 & (\overline{D_r} < D_{th}) \\ 2 - \exp[2300(\overline{D_r} - D_{th})] & (D_{th} \le \overline{D_r} < 2mm) \end{cases}$ $D_{th} = 0.5mm$ (Verlinde & Cotton 1993) $E_{rcol} < 0$ indicates raindrop breakup.

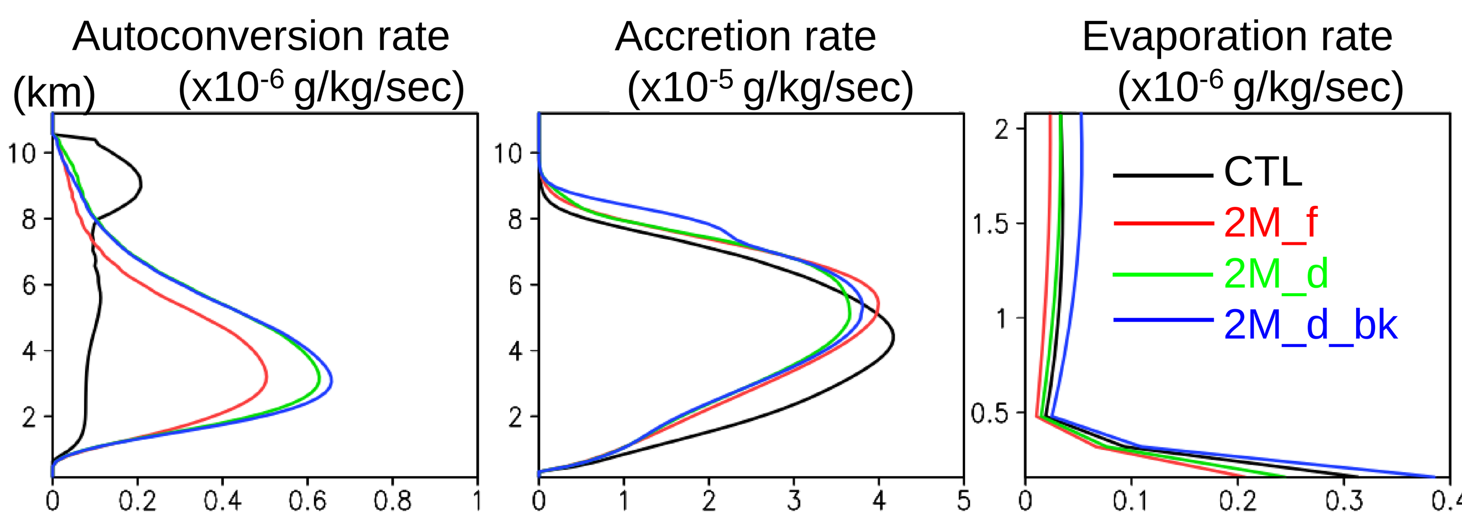
KiD (Kinematics driver model)

- KiD: 1-d column model (Shipway and Hill, 2012)
- Case: deep2, transient test of a deep convective environment



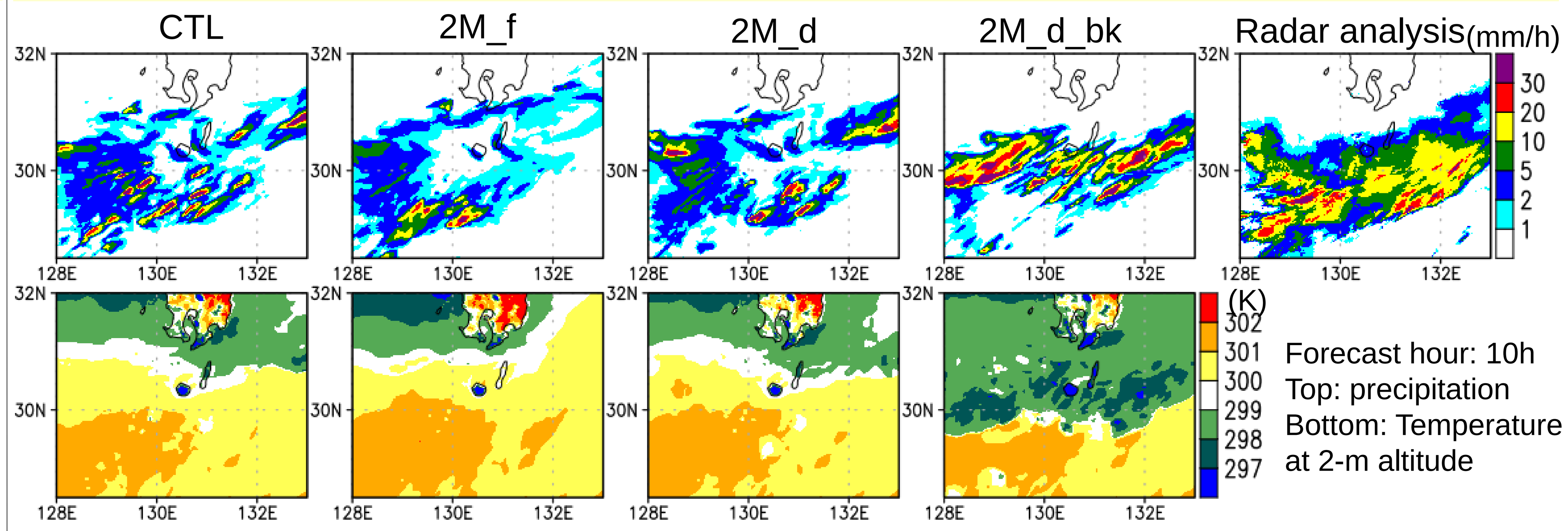
- Cloud water content increased in the experiments with 2-moment scheme.
- The weak precipitation lasted longer in the experiments with 2-moment scheme.
- Number concentration of rain (Nr) increased at the cloud top and around the melting layer in the experiments with 2-moment scheme, resulting from the size sorting. Nr increased in 2M_d_bk compared to 2M_f and 2M_d.

Time-averaged profile between 5-65 min.



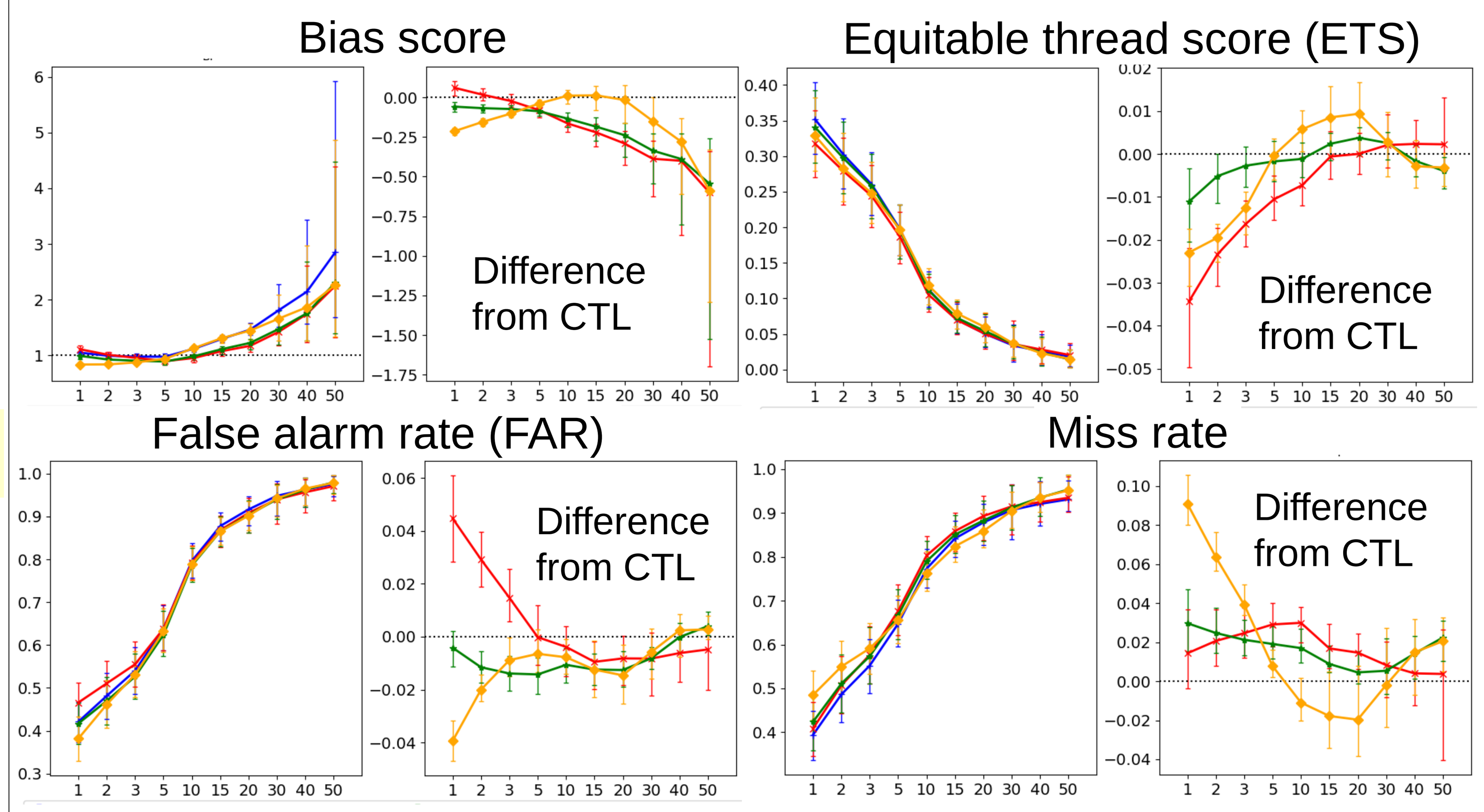
- Autoconversion rate: CTL had a top heavy profile while 2-moment schemes had bottom heavy profile.
- Accretion rate: CTL > 2M_f > 2M_d_bk > 2M_d
- Evaporation rate: 2M_d_bk > CTL > 2M_d > 2M_f

Real case: 2020.7.8.04 UTC –Baiu front–



- In CTL, scattered precipitation cells were formed along the Baiu front but these were not organized into the band along the front.
- 2M_f could not reproduce the rainband system along the Baiu front and expanded weak precipitation area. The low temperature area (cool color region, indicates cold pool) were narrow compared with CTL.
- 2M_d formed the scattered, heavy precipitation cells, similar to CTL.
- 2M_d_bk formed the heavy precipitation band with northward deviation from the actual band location. The band formation/maintenance seemed to be related to cold pool.

Statistical verification with regard to radar analysis



Note: to compare the same condition, initial condition is the same among the experiments. However, 2-moment scheme needs number concentrations (Nc & Nr) at initial. Forecast skill will change if Nc & Nr generated in local analysis system are used.

- 2-moment scheme tends to decrease bias score especially for 30 mm/h compared with CTL.
- In 2M_f, FAR increased for less than 3 mm/h, decreasing ETS.
- In 2M_d, FAR was reduced and the ETS degradation was mitigated compared with 2M_f.
- Enhancement of raindrop breakup further decreased FAR and increased miss rate for weak precipitation. Reduction of miss rate for 10-20 mm/h resulted in the increase of ETS.

Summary

- Warm-rain 2-moment scheme in microphysics is implemented to ASUCA.
- The precipitation forecast got worse in the 2-moment scheme with fixed shape parameter (2M_f), especially weak precipitation due to the increase of false alarm. This may indicate the parameters in the 2-moment scheme need to be optimized for operational use.
- Introduction of diagnostic shape parameter (2M_d) improved weak precipitation forecast by reducing false alarm.
- The raindrop breakup (2M_d_bk) had a large impact on precipitation forecast. This seemed to be caused by cold pool activity associated with the evaporative cooling of raindrop.

Future work

- Verification with radar/satellite data using simulator.
- Further development of rain processes (breakup, evaporation).
- Consideration of other physics development to avoid compensation error.

Acknowledgement

We gratefully acknowledge all the colleagues developing ASUCA. This participation in the 3rd PAN-GASS meeting is supported by JST Grant Number JPMJPF2013 ("ClimCORE").