A scale-aware convective parameterization scheme developed at KIAPS

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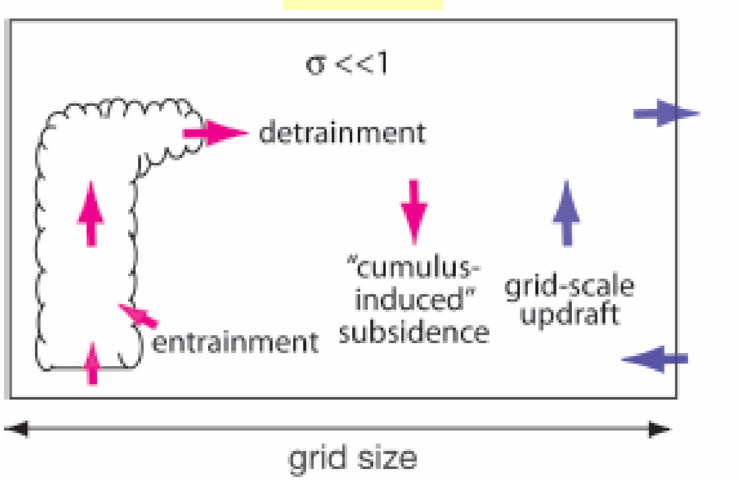
Contents

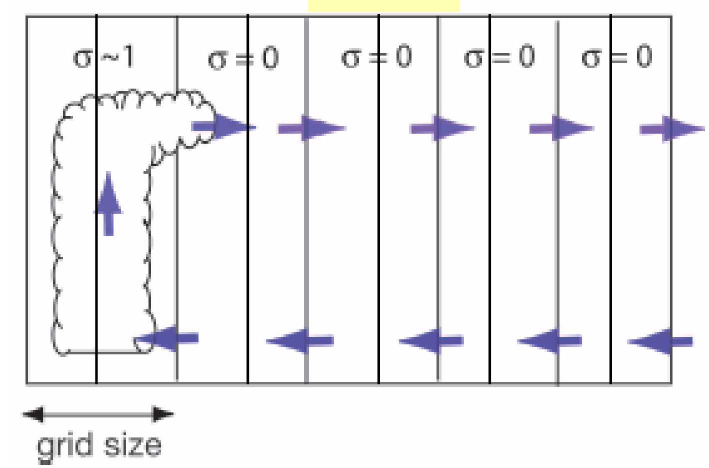
Background

GCM



Grid size is much bigger than convection cell

CRM

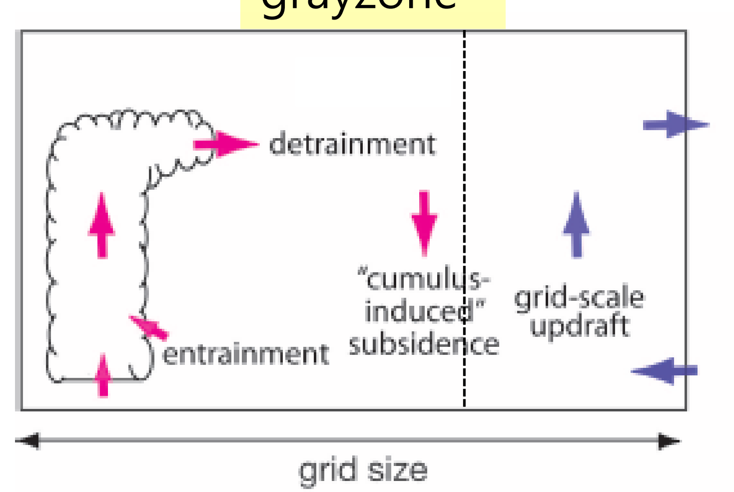


Grid size is smaller than convection cell

σ = Ac/Ag

convection area: Ac
grid box area: Ag

grayzone



CPS grayzone

σ is getting bigger with Δx getting smaller
When σ not negligible: need to adjust CPS

→ σ dependent CPS

Arakawa et al (2011)

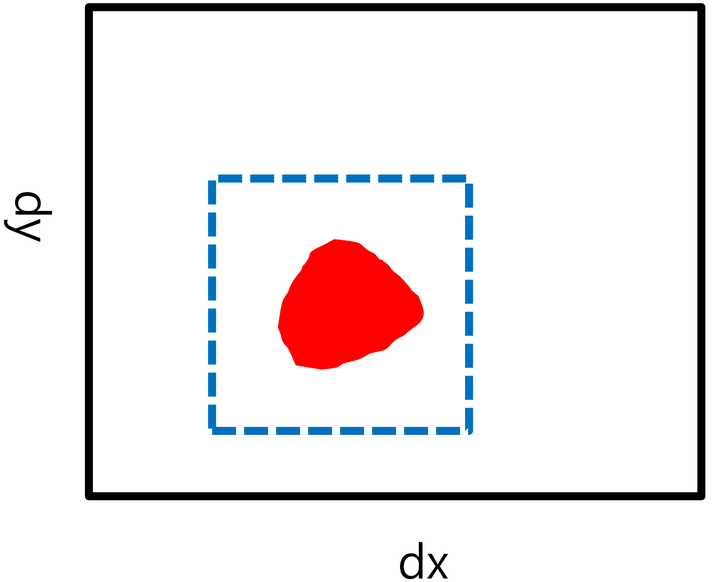
Overview of concept/current grayzone CPSs

Arakawa and Wu (2013)

$$\overline{w'\varphi'} = (1-\sigma_u)^2 \left(\overline{w'\varphi'}\right)_E$$

$$\sigma_u = \frac{\left(\overline{w'\varphi'}\right)}{\frac{\delta w \delta \varphi}{(1-\sigma_u)^2} + \left(\overline{w'\varphi'}\right)_E}$$

Pan et al (2014) $\sigma_u = \frac{\overline{w}}{w_c}$



Overview of concept/current grayzone CPSs

Grell and Freitas (2014) and Han et al (2017)

$$\sigma_u = \frac{3.14 R_c^2}{A_{grid}}\ ,\ R_c = \frac{0.2}{\varepsilon},\ A_{grid} = dx^2$$

Zheng et al (2016)

$\tau = \frac{H}{W}\ \beta(dx)$ Slight modification of Bechtold(2008) with some other changes

τ: Convective adjustment time scale $\beta = (1 + ln\frac{25}{dx})$

Han et al (2017) demonstrated that the method suggested by Arakawa and Wu(2014) and Pan et al(2014) do not work properly due to

1. smaller $\bar{w}$ even in fine horizontal resolution
   (e.g. $\sigma_u \sim 0.1$ or less at dx=2km)
2. uncertainties of determining key parameters in the current CPSs

Method

With grid getting finer (bigger σ)

→ less active sub-grid convection
weaker sub-grid convection

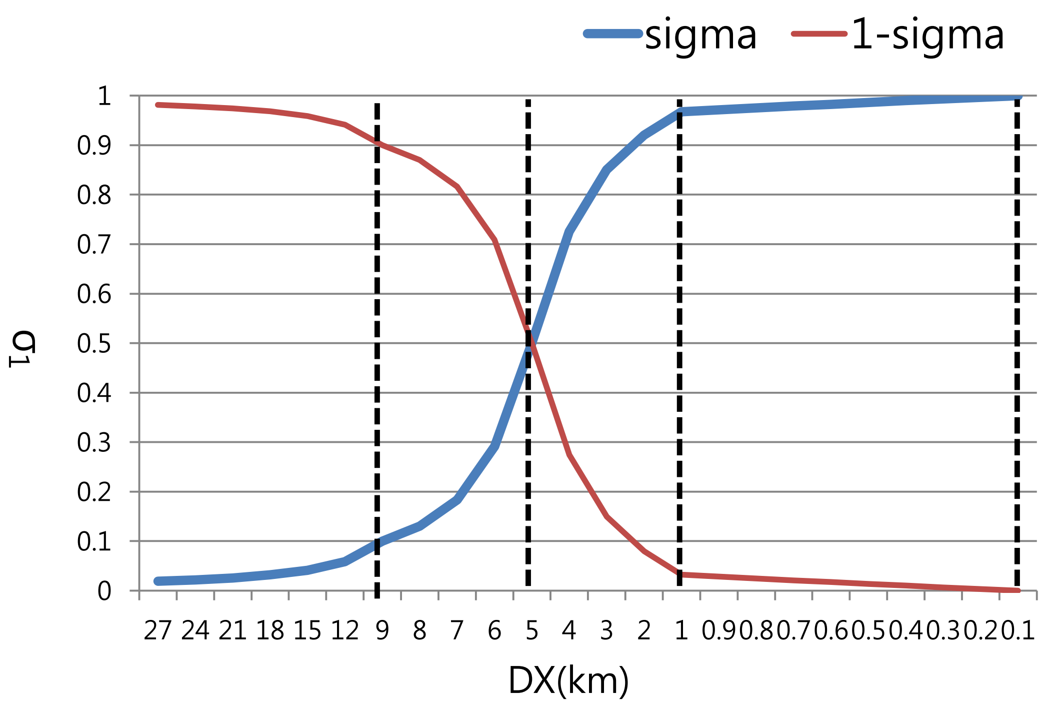
Three modifications are made:

1. **Cloud-base mass flux is proportional to $(1 - \sigma)^2$**

    derivation from Arakawa and Wu(2013)

2. **Convective trigger is proportional to $(1 - \sigma)$**
3. **Convective cloud water detrainment to grid is proportional to σ**

Define convective fractional area (σ_1)



Δx	σ_1
9 km	0.1
5 km	0.5
1 km	0.97
0.1km	1.0

$$\sigma_1 = 1 - \frac{1}{\pi}\left\{\tan^{-1}\left[\sigma_{con}\left(\Delta x - \Delta x_{5km}\right)\right] + \frac{\pi}{2}\right\}$$

Adapted from Hong and Pan (1998, MWR)

$$\text{where} \quad \sigma_{con} = \frac{\tan(0.4\pi)}{\Delta x_{5km} - \Delta x_{1km}}$$

e.g. dx=1km

Trigger and CB mass flux are 3% and 1% of the original SAS value

Detrainment is 97% of the original value

Define convective fractional area (σ_2)

Pan et al (2014)

$$\sigma_2 = \frac{\bar{w}}{w_c}$$

$\bar{w}$: grid point vertical velocity

w_c: convective vertical velocity averaged from cumulus bottom to top

Revised cloud base mass flux $\overline{\omega'\varphi'} = (1-\sigma_1)(1-\sigma_2)\overline{\omega'\varphi'}_E$

For trigger and detrainment, only σ_1 is used

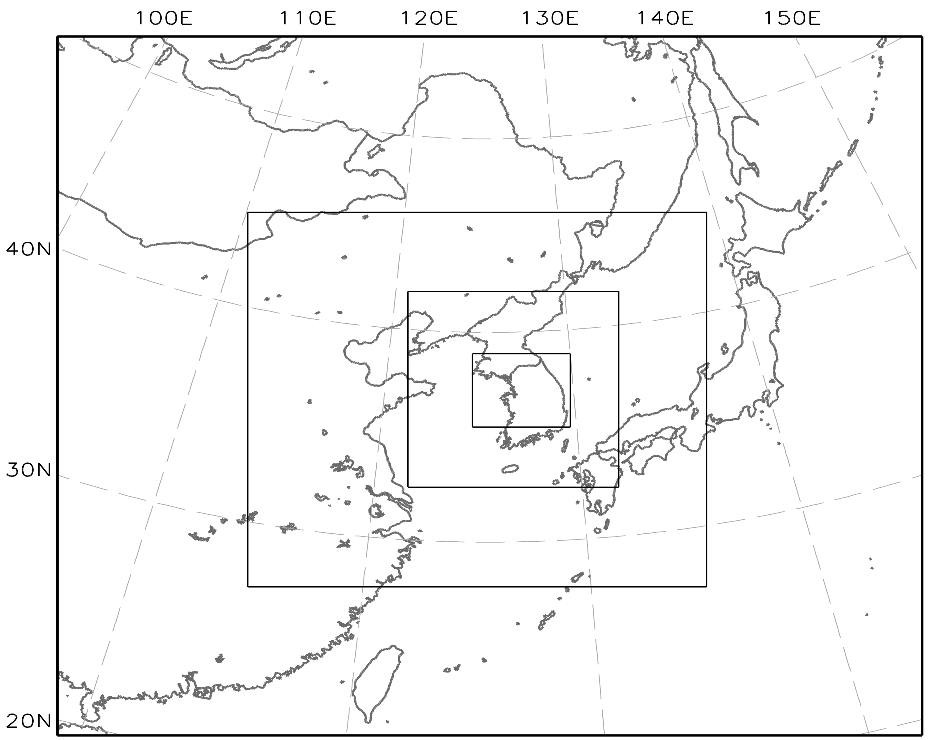
The sensitivity tests conducted showed, the combination of σ_1 and σ_2 to modify the cloud base mass flux worked the best not σ_1 or σ_2 alone

Experimental Design

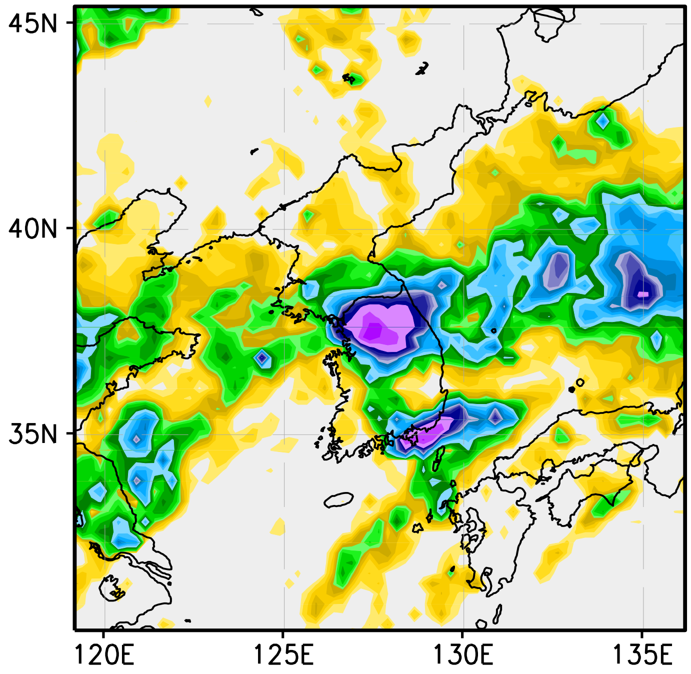
EXP	Description
OSAS	NCEP GFS SAS without scale-awareness 27-9-3-1km all with CPS
NOCP	As in ORIG but no CPS in 3-1km
GSAS	Modified SAS for scale-awareness CIN, mass flux, and detrainment
GCIN	Only active scale-awareness CIN
GCMF	Only active scale-awareness mass flux
GDTR	Only active scale-awareness detrainment

WRF ARW, one-way nest (27-9-3-1km), SAS, WSM5, YSU, NOAH, RRTMG

Model domain (27-9-3-1km)



TMPA rainfall 2612-2712UTC



Initial, boundary condition: NCEP FNL 1°X1°

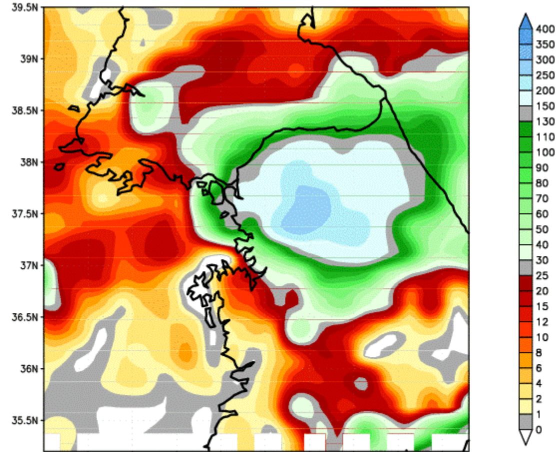
Initial time: 2011 July 26 0000UTC +48hr forecast

Result shown 24hr accumulated rainfall from July 2612UTC to 2712UTC

Results

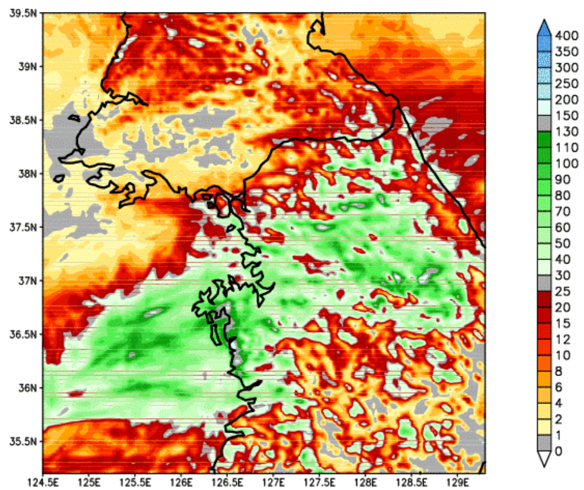
24-h acc. Precipitation at 12UTC 27 July 2011 (dx=3km)

Observed Precip (TMPA)



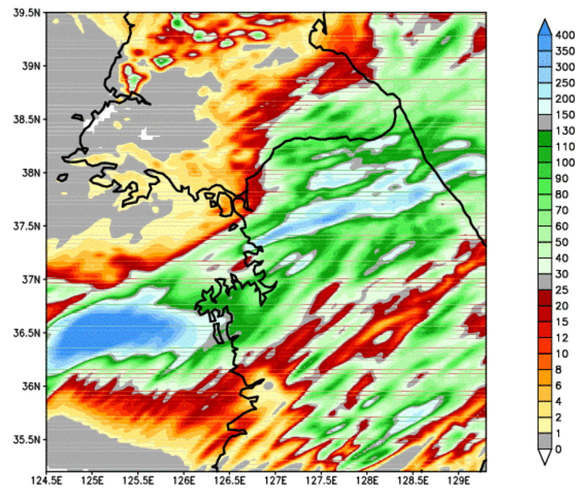
Max. rainfall: 442.3mm

Max. rainfall: 190.6mm



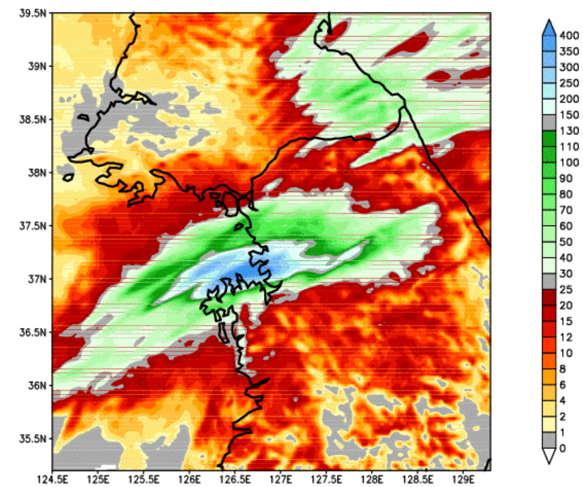
OSAS

Max. rainfall: 665.4mm



NOCN

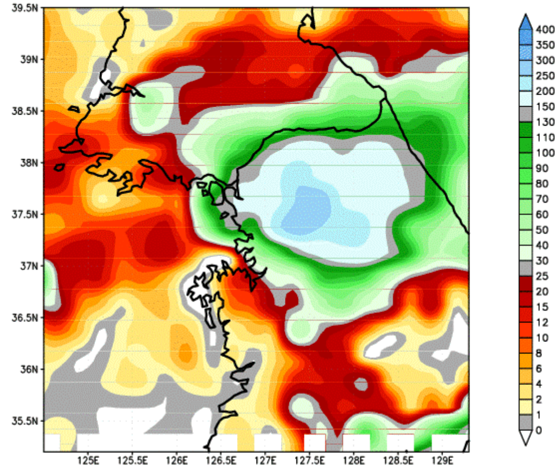
Max. rainfall: 477.2mm



GSAS

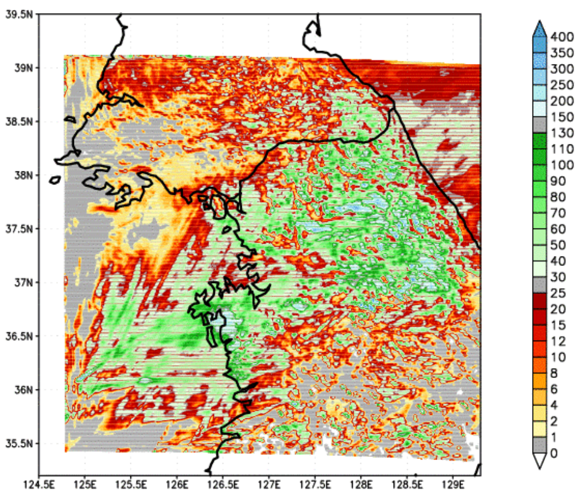
24-h acc. Precipitation at 12UTC 27 July 2011 (dx=1km)

Observed Precip (TMPA)



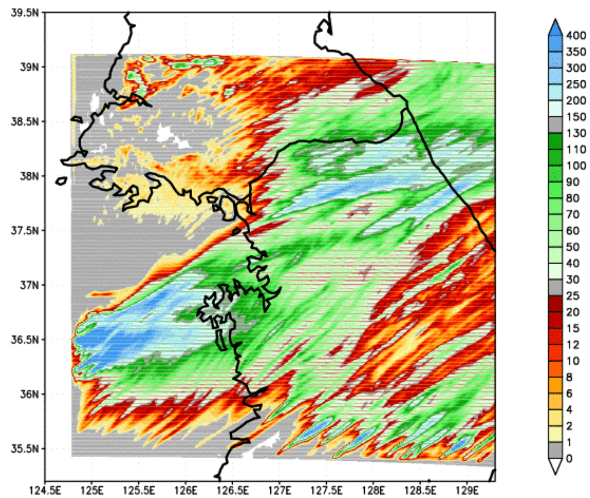
Max. rainfall: 442.3mm

Max. rainfall: 788.8mm



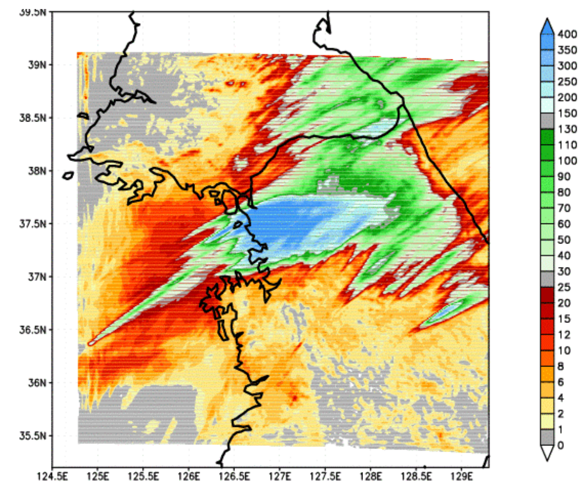
OSAS

Max. rainfall: 2168.6mm



NOCP

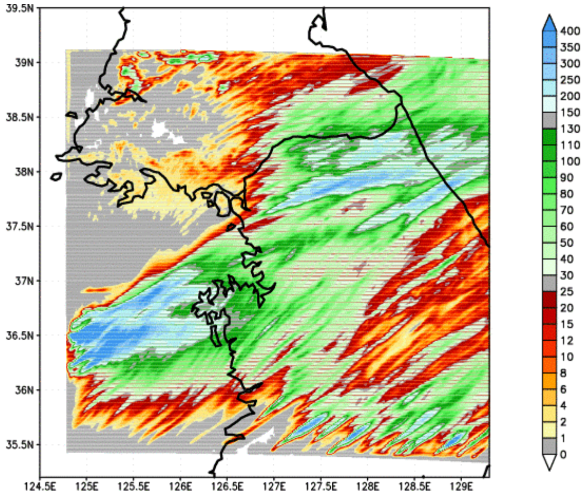
Max. rainfall: 765.3mm



GSAS

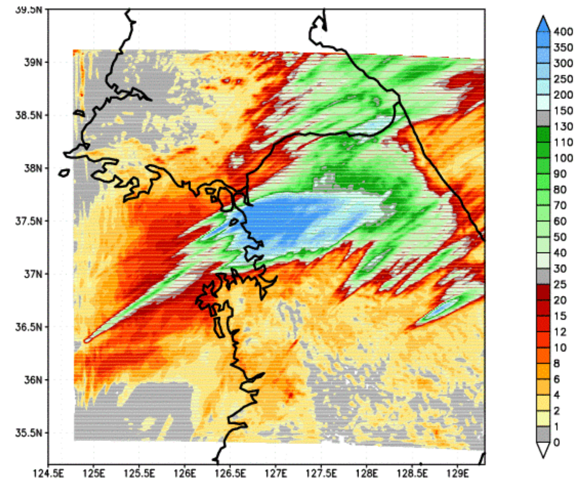
The role of CPS in dx=1km

Max. rainfall: 2168.6mm

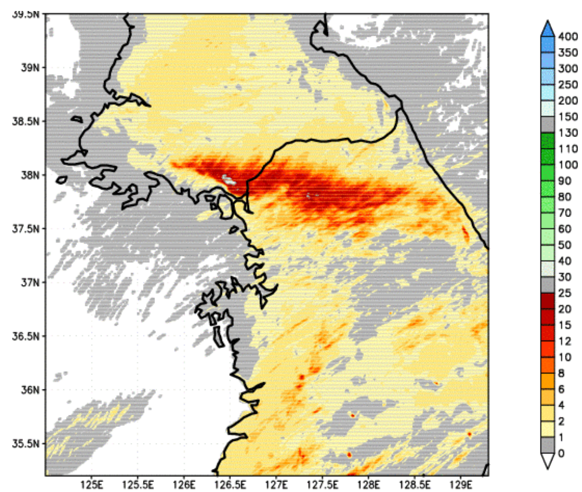


NOCP

Max. rainfall: 765.3mm



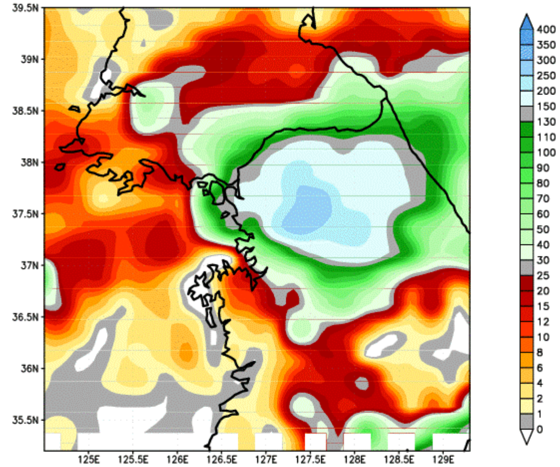
GSAS



Rainfall from GSAS CPS

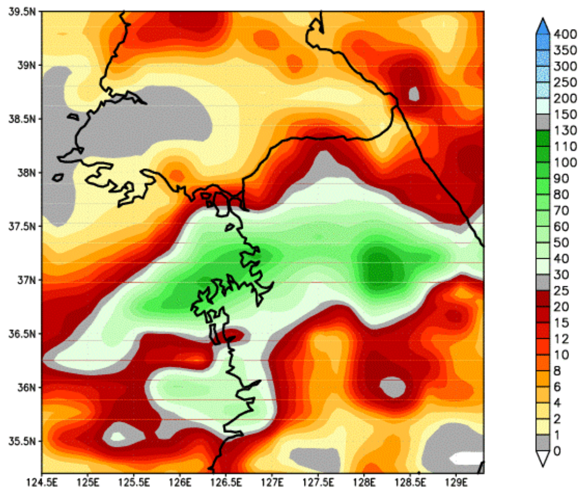
24-h acc. Precipitation at 12UTC 27 July 2011 (dx=27km)

Observed Precip (TMPA)



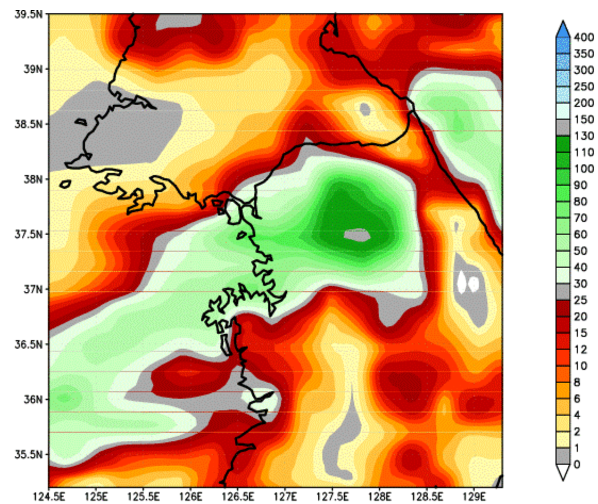
Max. rainfall: 442.3mm

Max. rainfall: 117.1mm



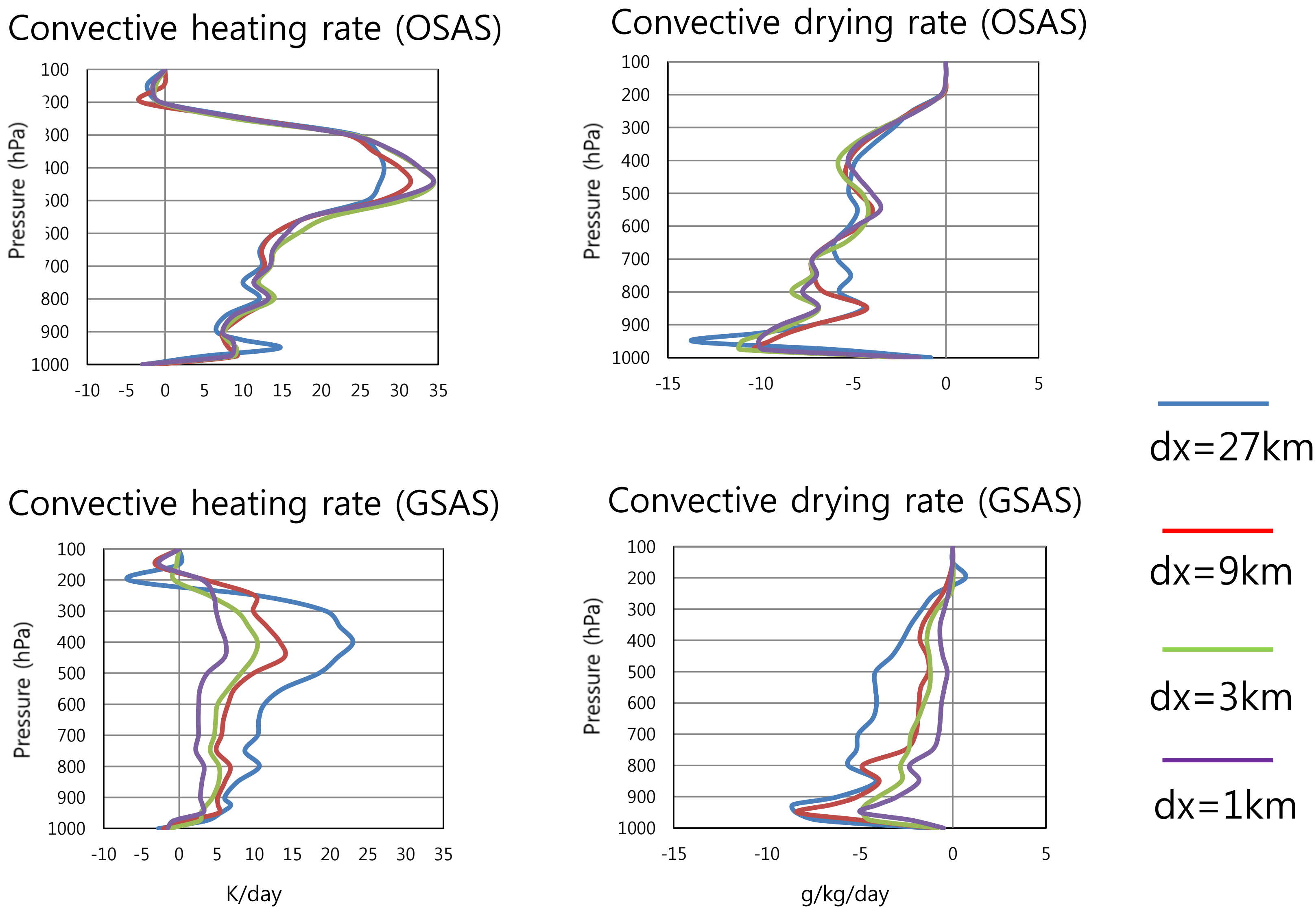
OSAS

Max. rainfall: 136.2mm

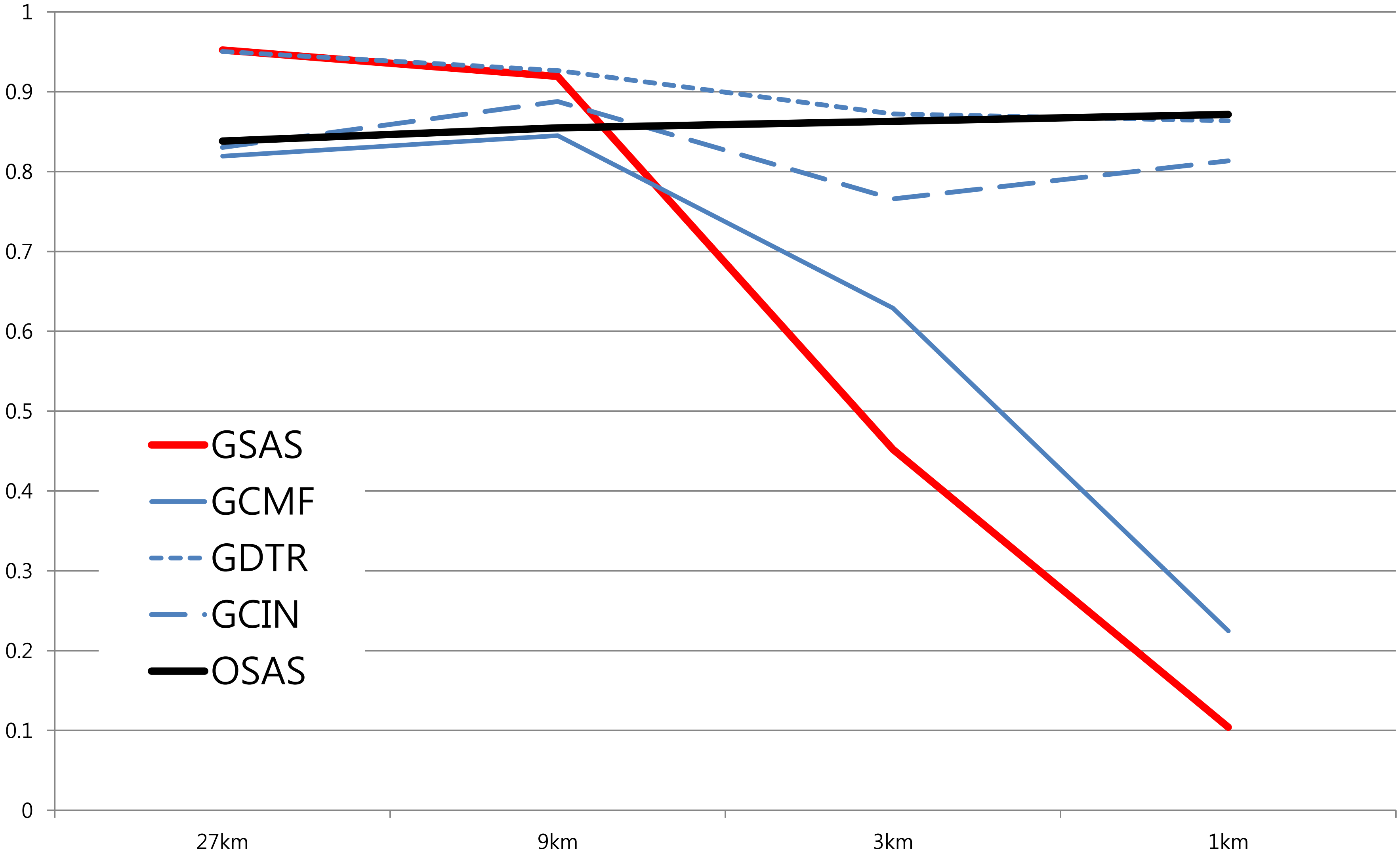


GSAS

Vertical profiles of convective heating and drying over main rainfall area

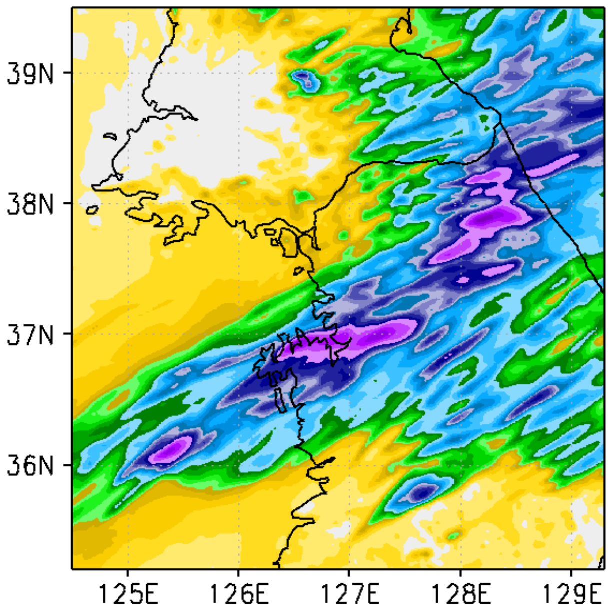


Convective rainfall ratio $\left(= \frac{convective\ rain}{total\ rain}\right)$

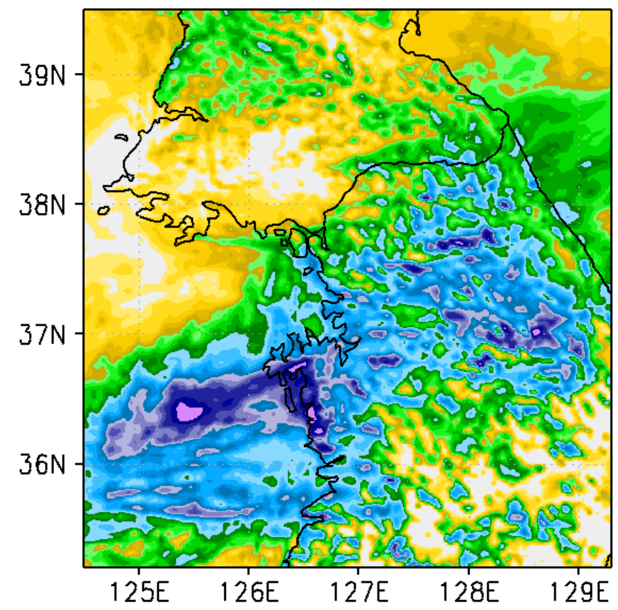


Results of using only σ_1 and σ_2 for mass-flux adjustment at dx=3km

$(1-\sigma_1)^2 \cdot CMF$, total rainfall

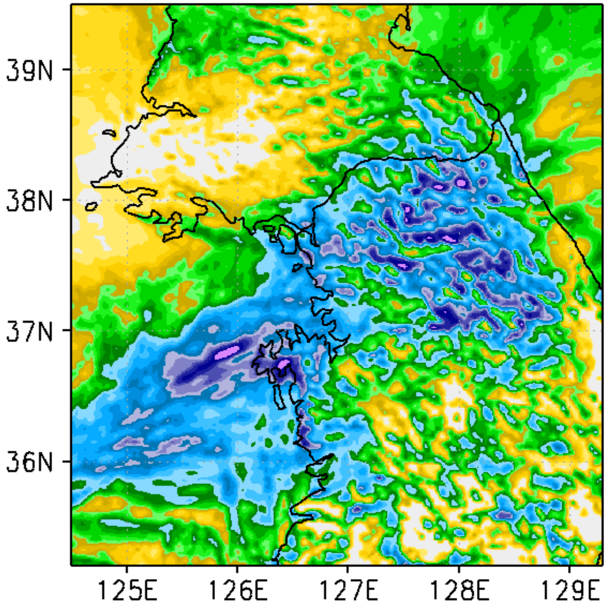


$(1-\sigma_2)^2 \cdot CMF$, total rainfall

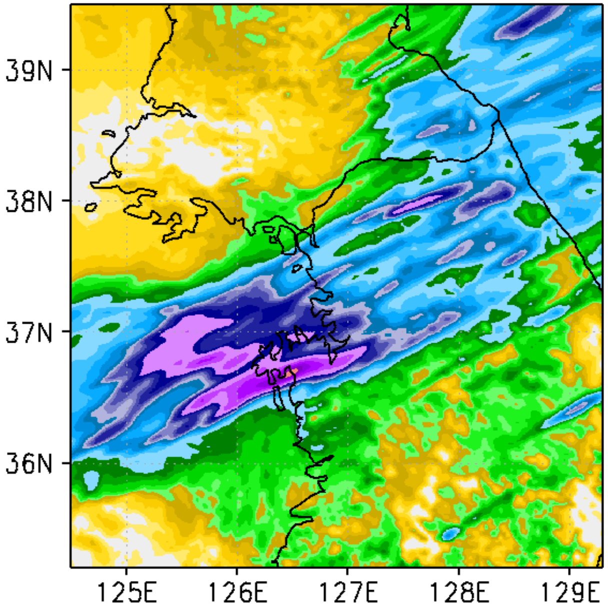


Sensitivity of lateral boundary impacts

OSAS with GSAS BDY, total rainfall



GSAS with OSAS BDY, total rainfall

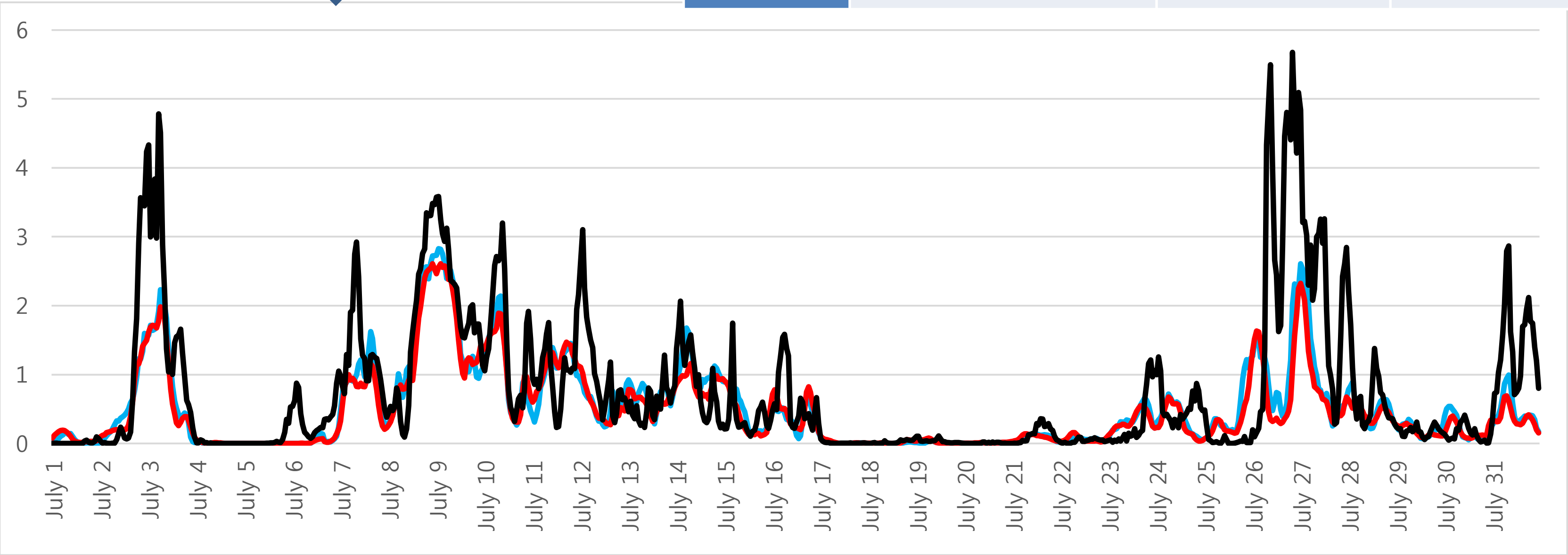


One-month simulation Results (July 1 – 31 2011)

Verification score

Experiments	RMSE	PC	Category	ETS	FAR
NOCP	31.59	0.55	<5mm	0.37	**0.28**
			10mm	0.36	0.29
			15mm	0.35	0.30
			20mm	0.33	0.31
			25mm	0.31	0.34
GSAS	**29.52**	**0.61**	<5mm	**0.38**	031
			10mm	**0.39**	**0.27**
			15mm	**0.38**	**0.24**
			20mm	**0.36**	**0.24**
			25mm	**0.32**	**0.28**

Total rainfall time series



Summary and Conclusion

1. Model resolution depend SAS scheme (GSAS) proposed in this study seems working better than original scheme over all model resolution ranges (1km to 27km)
2. Three parameters modified in this study show different effects on model resolutions. Modification of detrainment impacts mostly to lower resolution simulation (9-27km), while cloud base mass flux change improves higher resolution regimes (1-3km)
3. The original SAS scheme does not show the much sensitivity of convective rain ratio (CRR) over grid resolution, GSAS show steady decreases of CRR with finer resolution (95% at 27km, 10% at 1km)

Summary and Conclusion

5. The uses of two different convective fractional areas seems to complement each other's weakness
6. The sensitivity results show that the modifications on CPS is greater impacts on the simulation results that lateral boundary effects

Change of perspective on grayzone CPS(?)

▶ smart way to perturb sigma (function of PDF and/or dx)

▶ revisit Quasi-Equilibrium assumption (especially dx is small)

▶ grid mean value vs. it's deviation → grid resolution becomes finer, then CPS scheme acts like subgrid turbulence scheme


Korea Institute of Atmospheric Prediction Systems
:Beyond the limit of the modern science and technology
Thank you
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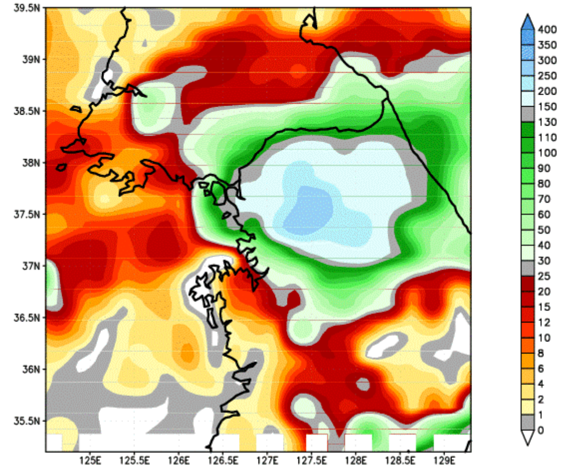
ATMOSPHERIC PREDICTION SYSTEMS

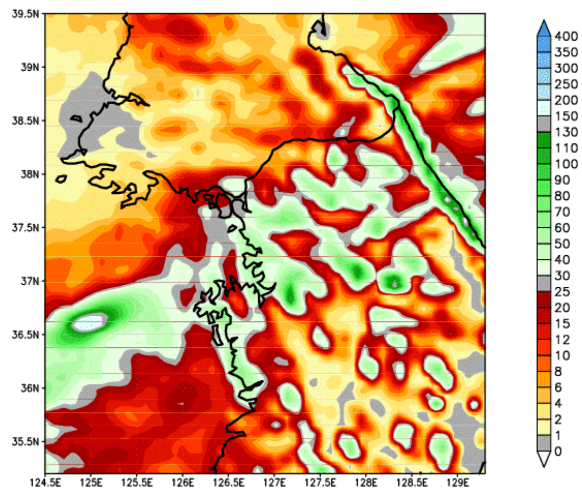
24-h acc. Precipitation at 12UTC 27 July 2011 (dx=9km)

Observed Precip (TMPA)



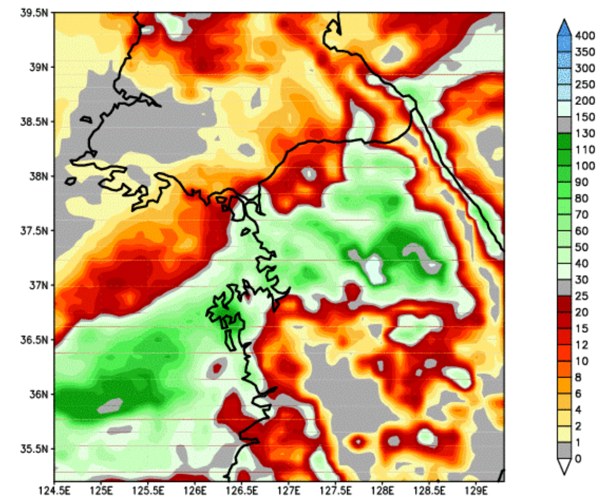
Max. rainfall: 442.3mm

Max. rainfall: 135.2mm



OSAS

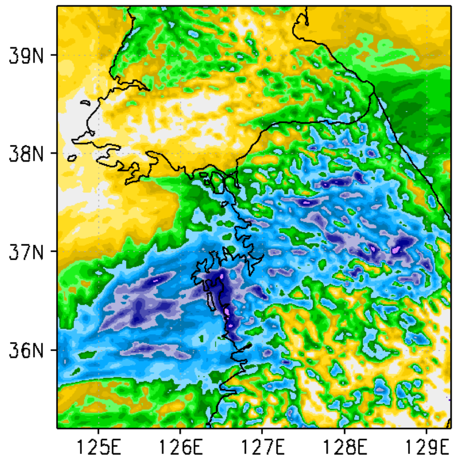
Max. rainfall: 197.0mm



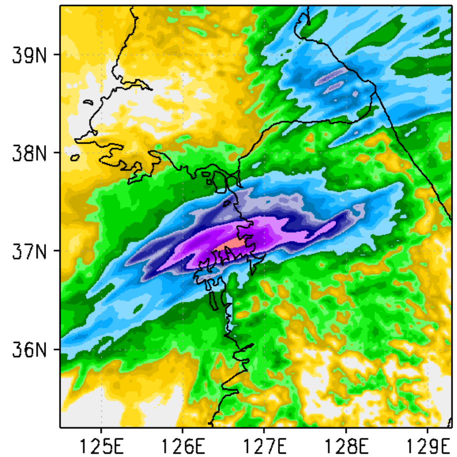
GSAS

Sensitivity results at dx=3km

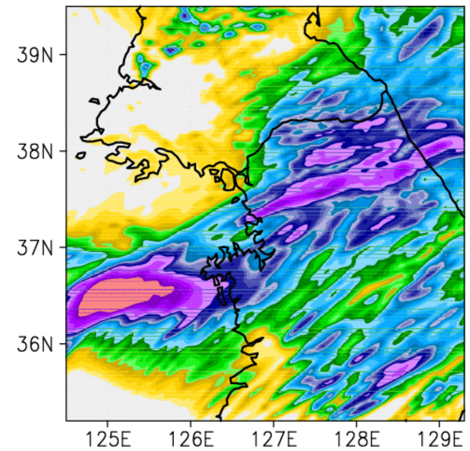
OSAS; total rainfall



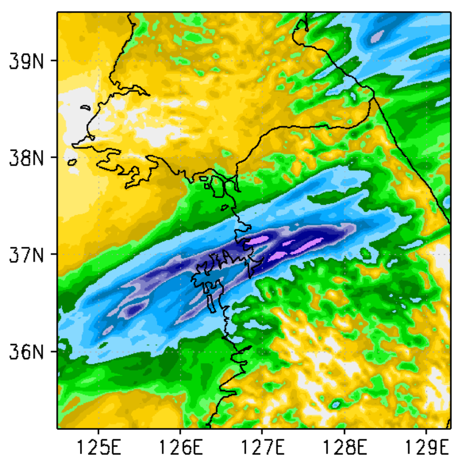
GSAS; total rainfall



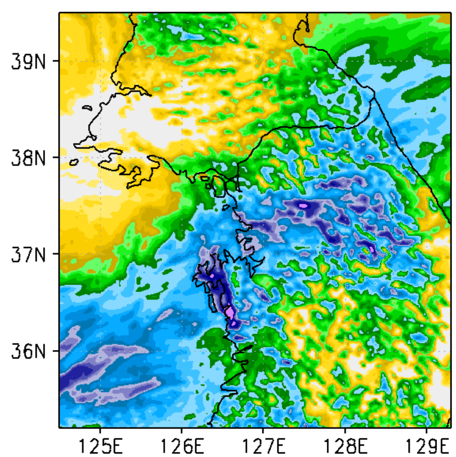
NOCP; total rainfall



GCMF; total rainfall



GDTR; total rainfall



GCIN; total rainfall