Impact of Dynamical downscaling on the improvement of short term precipitation prediction by using Cloud Microphysics Data Assimilation System (CMDAS)

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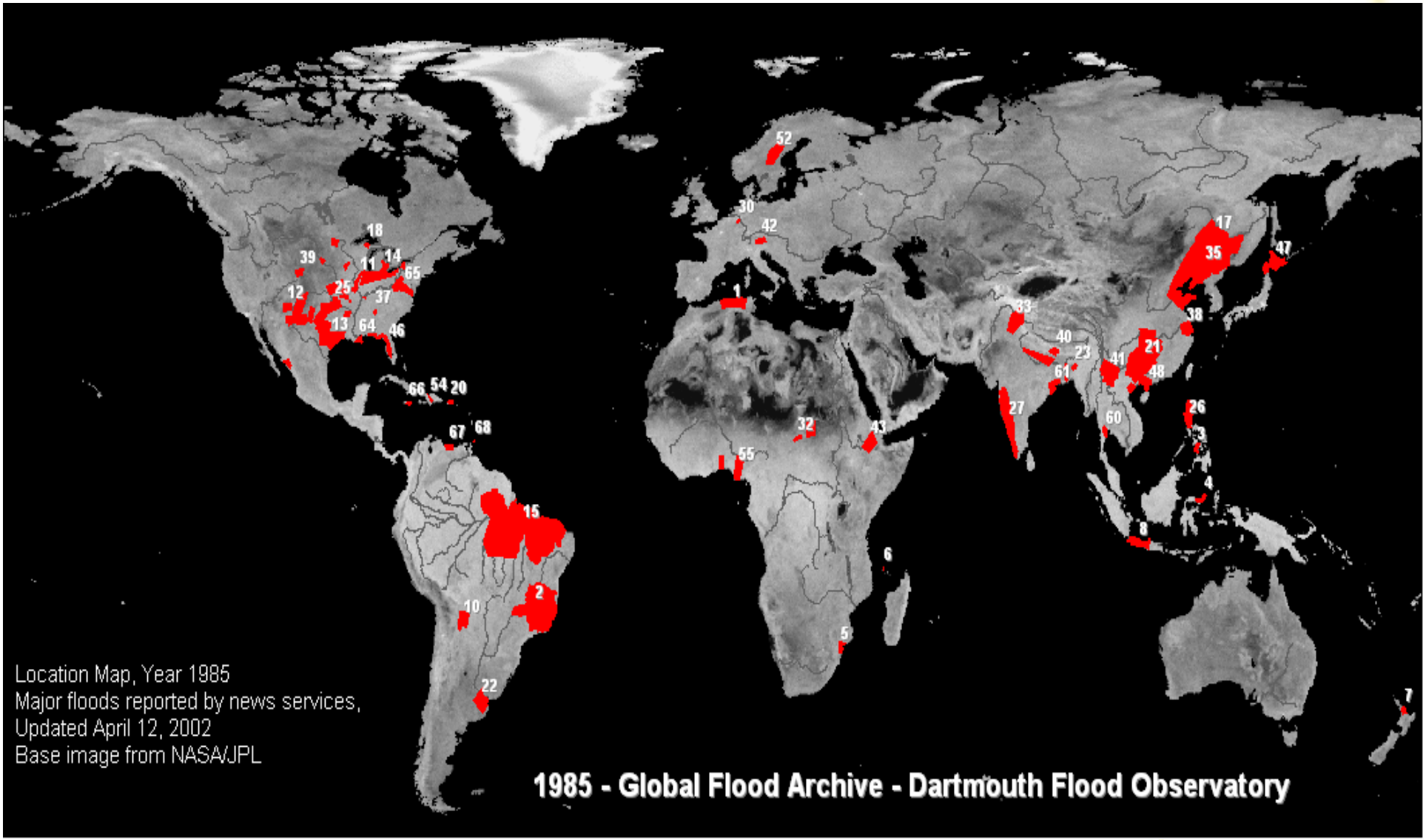
Presentation Outline

- Introduction & Problem statement
- Progressive Scientific Initiatives
- Motivation
- Cloud Microphysics Overview
- Cloud Microphysics Data Assimilation System Methodology
- Case Studies
- Precipitation Prediction by ARPS
- Conclusions

- Frequency of Torrential Rainfall and flooding



Problem Statements

- Convective storms →many sizes, produce hazardous weather events. Various isolated storms organized → Larger clusters of storms → Mesoscale Convective Systems (MCSs).

- Due to problems with initial conditions and convective parameterization schemes, most operational models are unreliable for predicting MCSs.

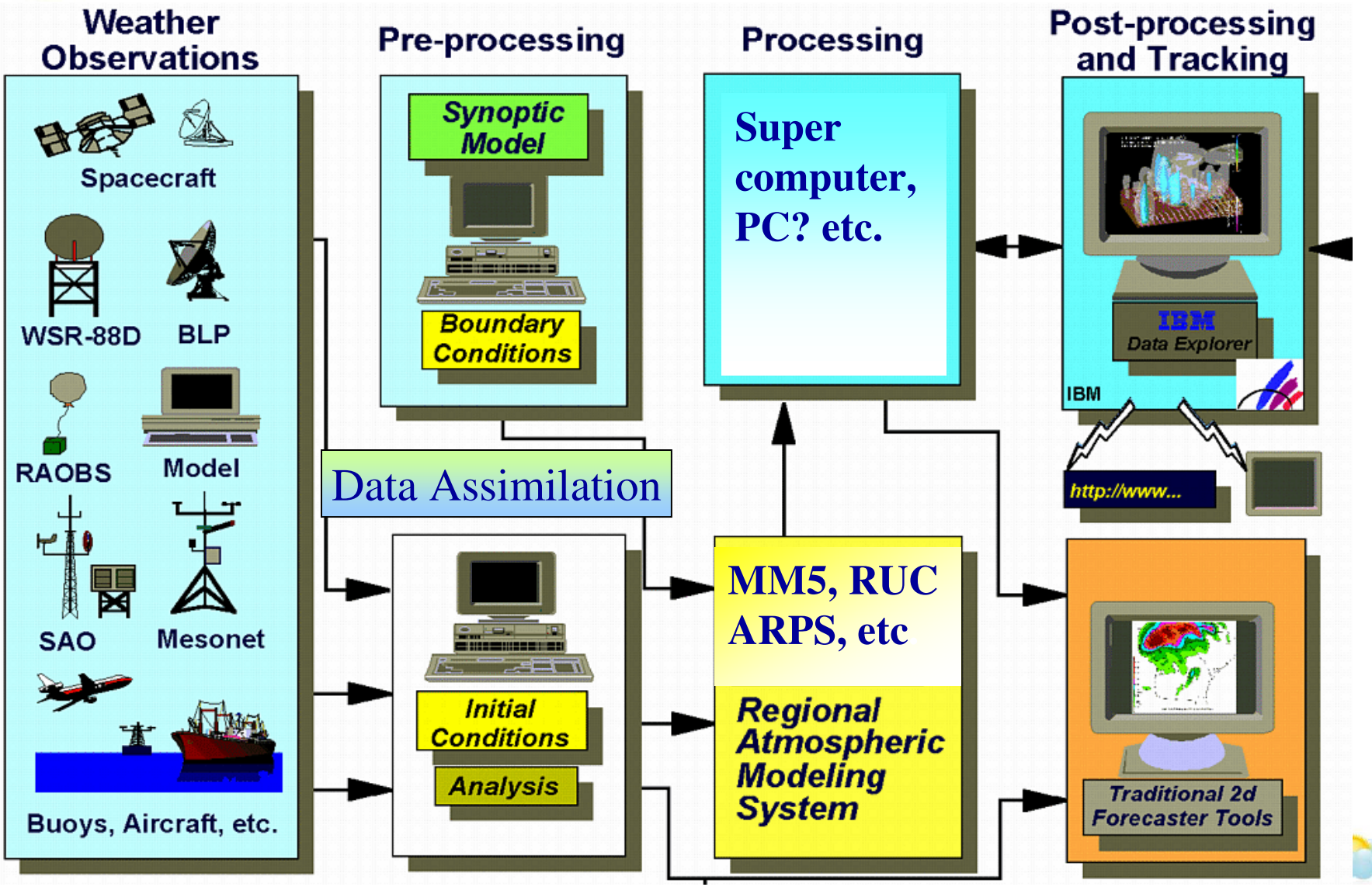
- Most NWP Models have difficulty for Pcep. predicting:
  - Total precipitation amount
  - Convective system evolution
  - Timing and location of convection initiation
  - Lack of understanding of cloud microphysics

How can a forecaster use NWP to predict MCSs?

- Higher resolution
- Look for favorable synoptic and mesoscale patterns in NWP products
- Look for predicted buoyancy
- Be alert for synoptic positioning/timing errors and any known model biases
- Watch for predictions of unrealistic looking precipitation “bull's-eyes” due to convective parameterization limitations

- But in spite of all that intellectual precautions, Precipitation →most difficult forecast parameter→ in NWP. Improvements in numerical modeling→ Reduction in forecast errors→ Winds, temperature, sea level pressures and geo-potential heights→ But progress in precipitation prediction →bit slow.

These problems could be addressed by Cloud Microphysics Data Assimilation by using Satellite data for better understanding of cloud microphysics processes & improved predictability of weather.



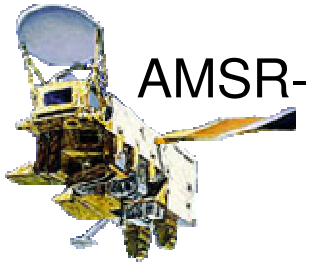
Progressive Scientific Initiatives

Development of Cloud Microphysics Data Assimilation System (CMDAS)

→ To retrieve reasonable cloud distribution by modifying the cloud properties over the ocean by AMSR-E data

Validation of CMDAS & CMDAS Products

Case Studies



AMSR-E

Short range Precipitation Prediction

Motivations

- Output of NWP →Use as a initial step but can't rely on the prediction results of rainfall and CLWC. Therefore, by combining the model output and satellite observations, more reliable CLWC information & precipitation prediction can be made.

- By using GDAS output as IC of the mesoscale model & Satellite data, IC→ finer grid scale model→ more reliable precipitation prediction for local area→Ultimately contribute to unguaged basins.

- By having better precipitation prediction, we can safe the human lives by having confidence on flood forecasting and river water managements.

GDAS: Global Data Assimilation System IC: Initial Condition

CMDAS Methodology

Non-hydrostatic Model Output

(Initial Guess)

Cloud Parameters Update

Model Operator
(Cloud Microphysics)

Observation Operator
(RTM) (Tb_{mod})

Tb_{obs}

Cost (J)= (Tb_{mod} - Tb_{obs})^2

Global Minimization Scheme
(Shuffled Complex Evolution)
Duan et al, 1992

IF J_{min}

No

Yes

Optimized
Initial
Condition

Precipitation Prediction by
ARPS

Theoretical distributions of assimilated Variables

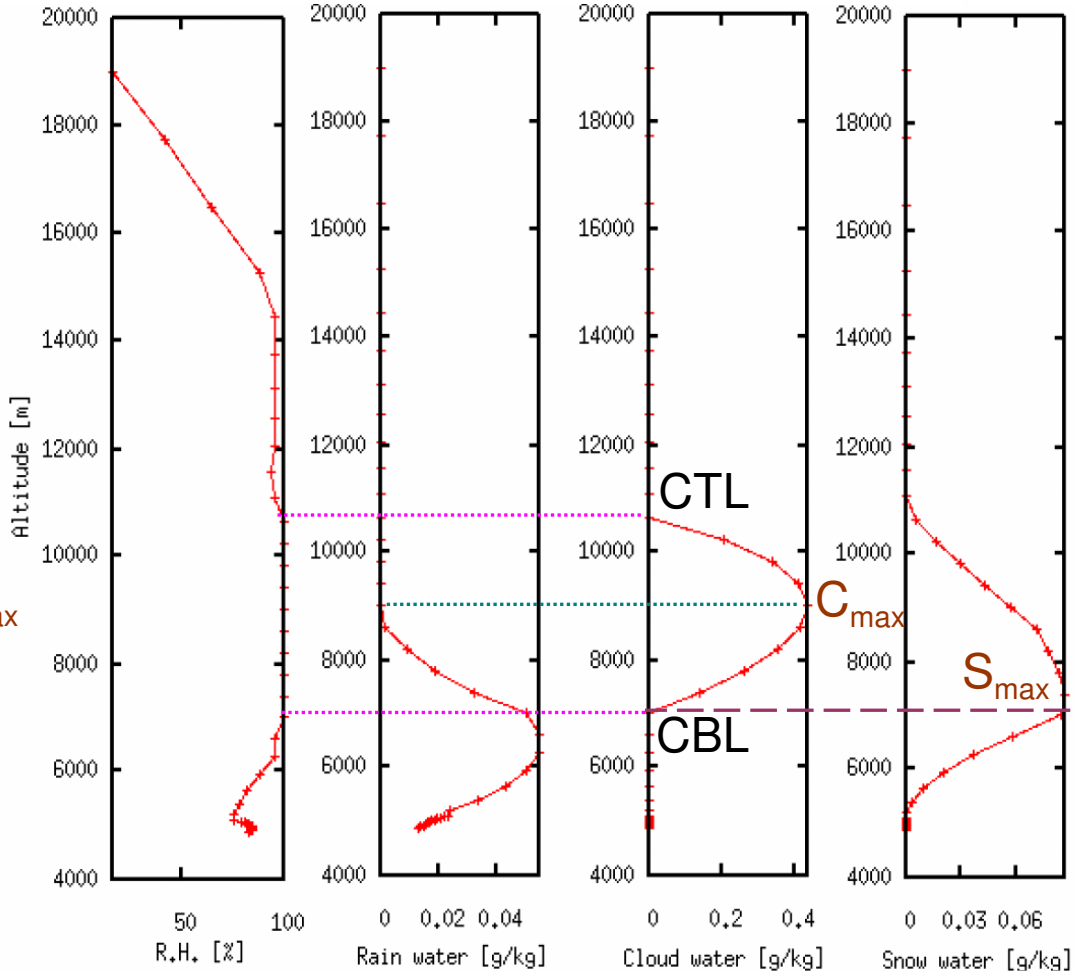
Assumptions:

IWV: Air_{sat} i.e R.H =100% [cloud Region]

ICLWC: Parabolic Distribution with Max. CLWC at center of cloud .

IRW : Skewed profile of ICLWC, rain drops formation start from C_{max}

ISW : Snow formation starts from CT reaching to S_{max} at CBL.



Cloud Microphysics Data Assimilation System (CMDAS) Methodology

Non-hydrostatic Model Output

(Initial Guess)

Cloud Parameters Update

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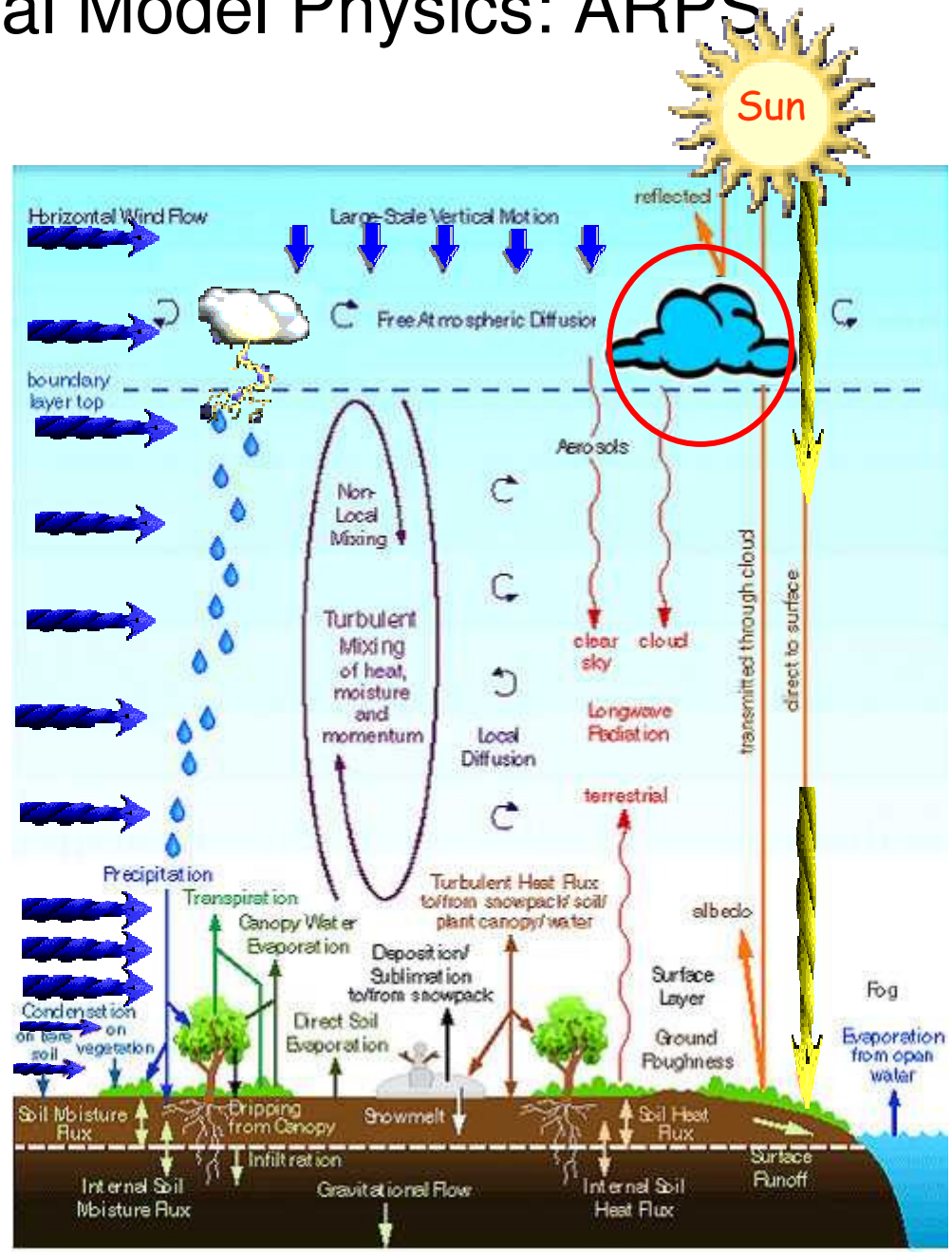
Optimized
Initial
Condition

Precipitation Prediction by
ARPS

Numerical Model Physics: ARPS



CMDAS Methodology

Non-hydrostatic Model Output (Initial Guess)

Cloud Parameters Update

Model Operator (Cloud Microphysics)

Observation Operator (RTM) (Tb_{mod})

Tb_{obs}

Cost (J)= $(Tb_{mod} - Tb_{obs})^2$

Global Minimization Scheme (Shuffled Complex Evolution) Duan et al, 1992

IF J_{min}

No

Yes

Optimized Initial Condition

Precipitation Prediction by ARPS

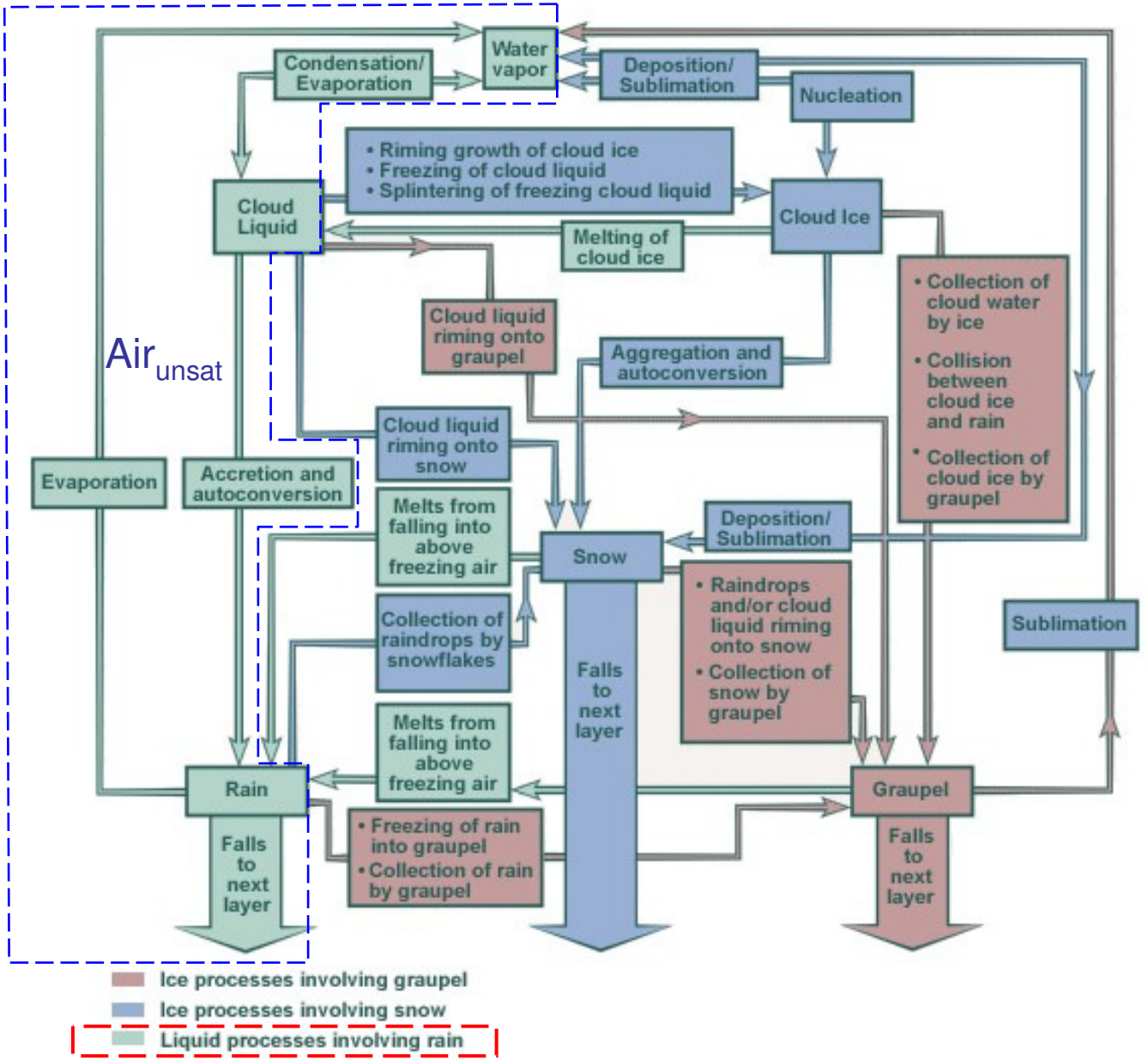
Cloud Microphysics

- Clouds form due to cooling of large parcels of air to a temperature below their dew point. These large scale processes are referred as "Cloud Dynamics".

- Cloud droplets usually form & evolve to form precipitation due to much smaller scale processes occurring on the order of particle size → "Cloud Microphysics".

Cloud Microphysics

Warm Rain Microphysics



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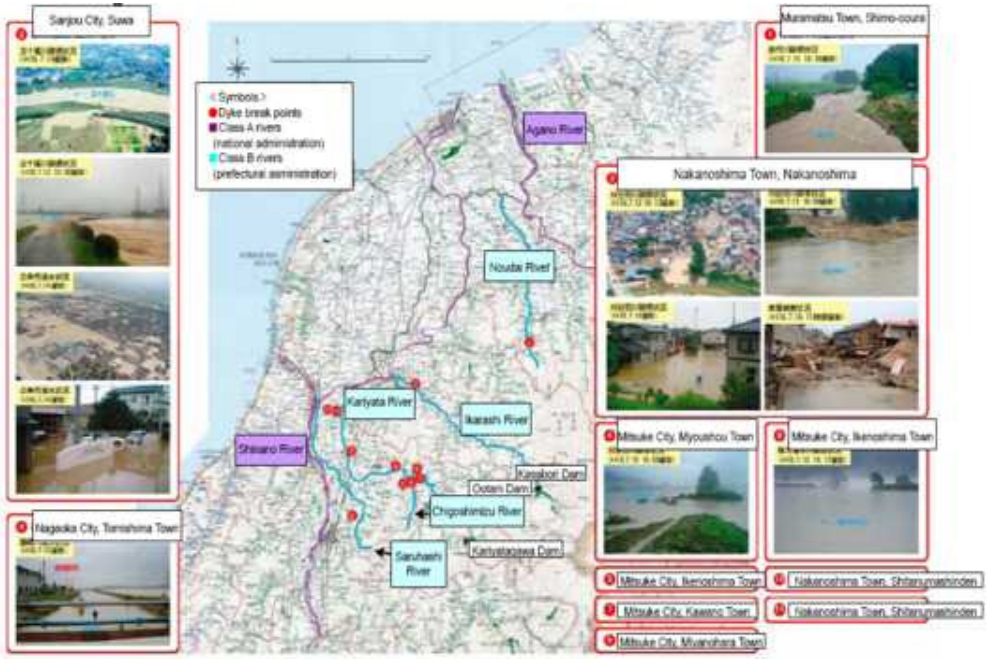
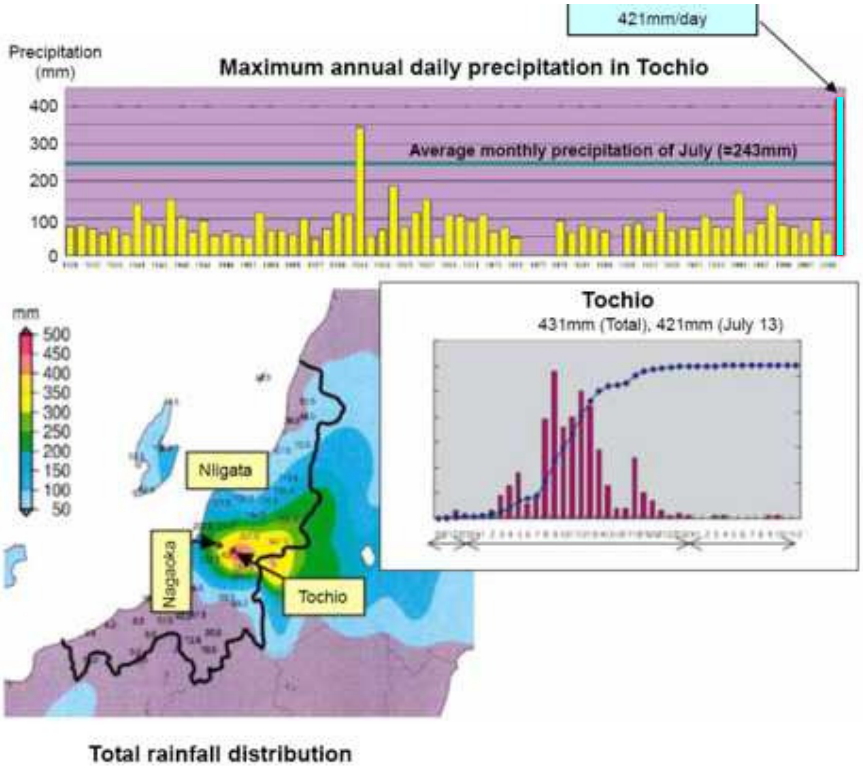
Niigata Extreme Event

- In 12th July 2004, a Baiu-front from the Japan Sea to the Niigata area was activated by warm and moist air blowing from the South caused by Record breaking number of typhoons without losing their force over Japan.

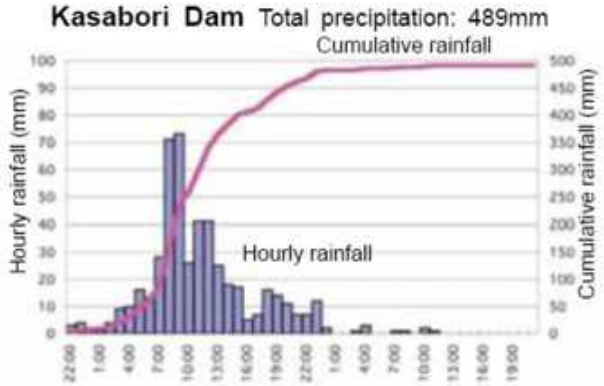


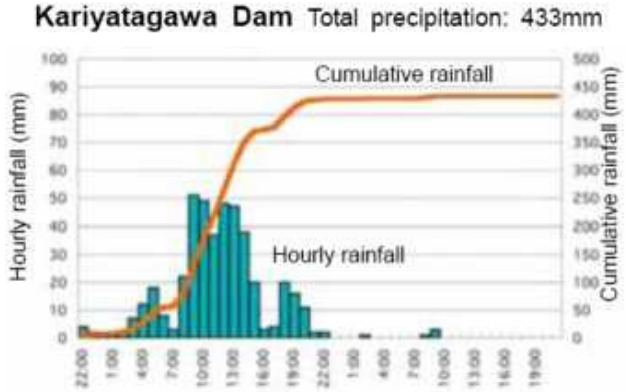
- Daily Torrential precipitation of 13 July reached 421 mm in Tochio City, nearly twice the average monthly precipitation of July in Tochio (243 mm).

- Historical Regional heavy rainfall



Total rainfall distribution

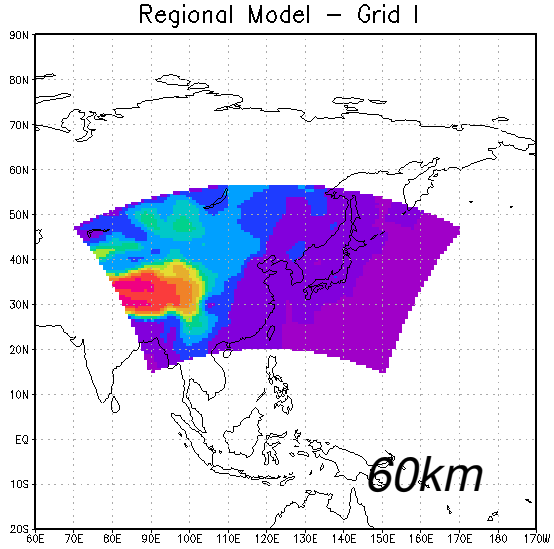


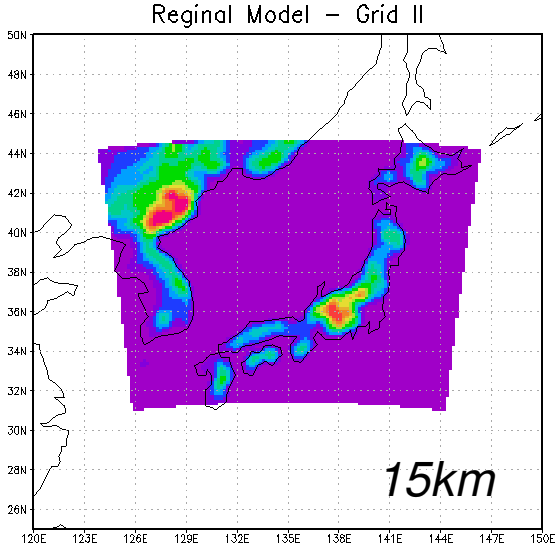


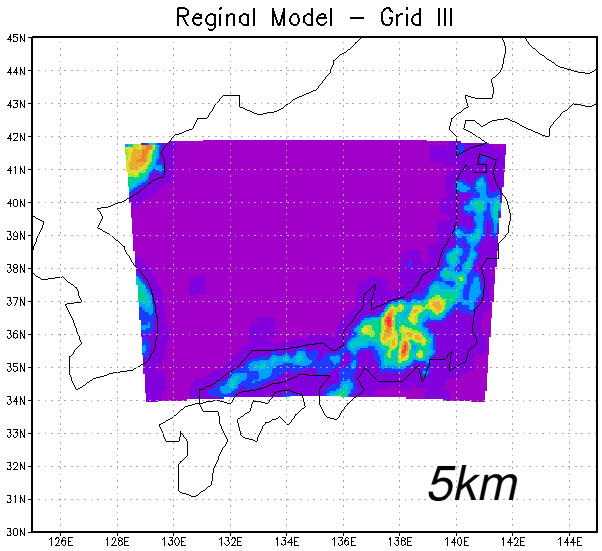
Experimental Design of Niigata Flood (ARPS)

Event	Niigata Heavy Rainfall (12^{th} July ~ 13^{th} July 2004)
domain	600 km × 600 km × 20km
horizontal grid size	5000 m
vertical grid size	5000 m
Resolution	60, 15, 5 Sq. Km
integration time	48 hrs
time increment	10 sec for model integration
Initial/Boundary condition	GFS (Global Forecast System) analysis (1x1)
Cloud microphysics	Lin Ice scheme
CPS	Kain-Fritch

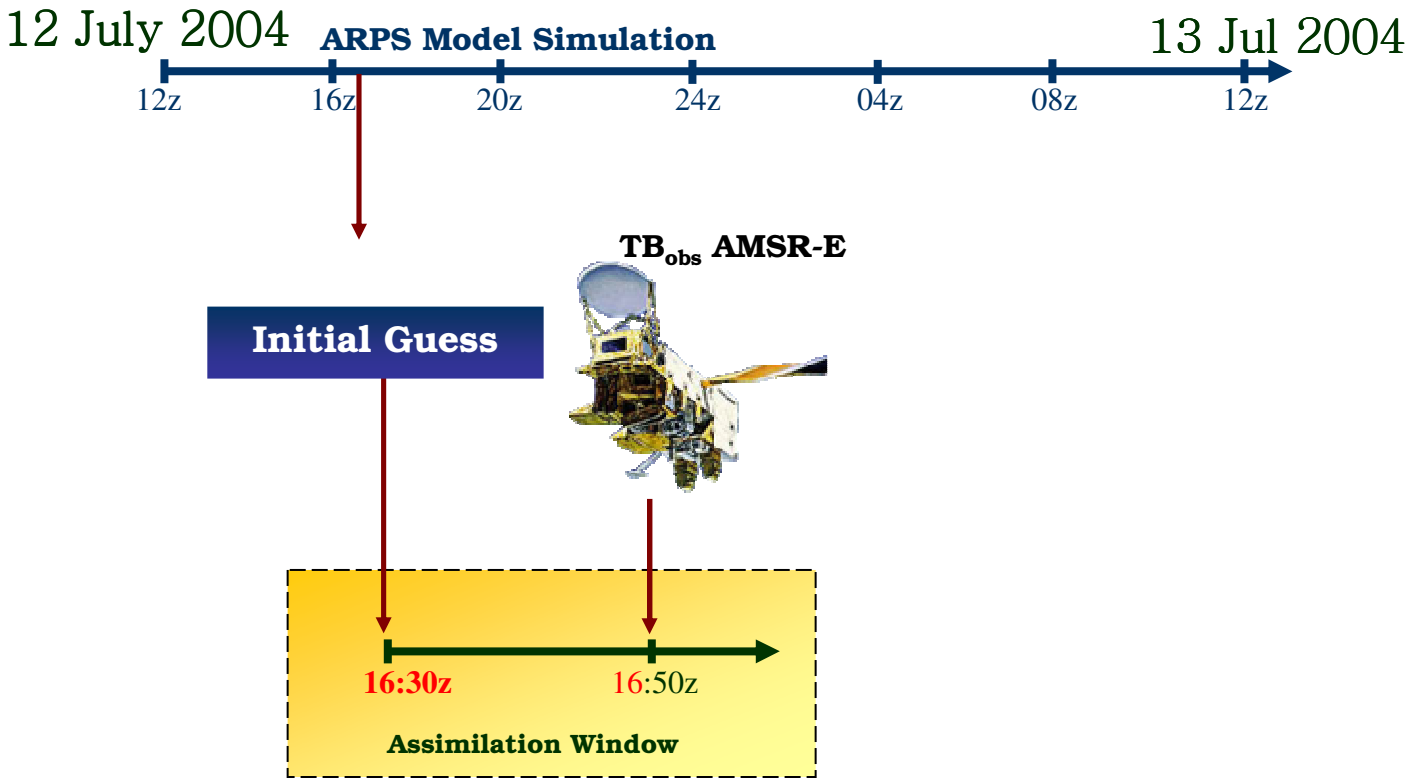
Model Setup

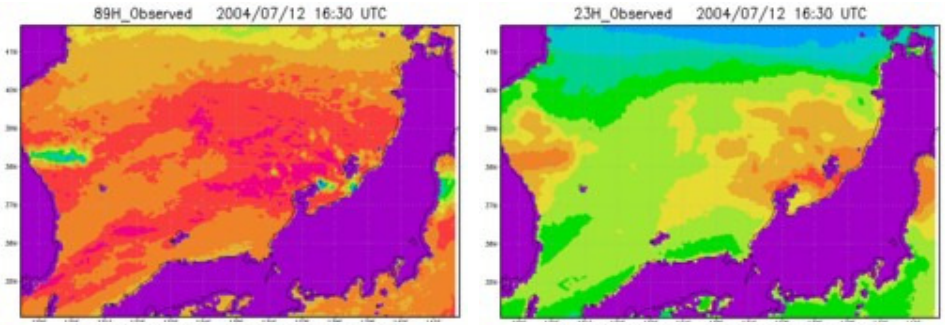

Regional Model – Grid I
90N
80N
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
60E 70E 80E 90E 100E 110E 120E 130E 140E 150E 160E 170E 180 170W
60km


Reginal Model – Grid II
50N
48N
46N
44N
42N
40N
38N
36N
34N
32N
30N
28N
26N
120E 123E 126E 129E 132E 135E 138E 141E 144E 147E 150E
15km

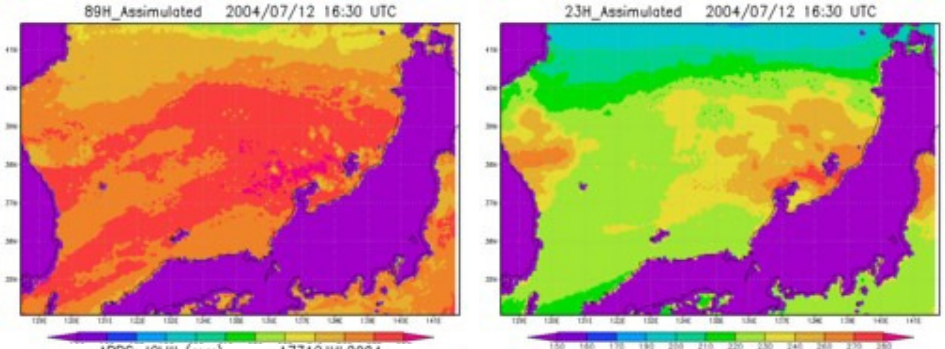

Reginal Model – Grid III
45N
44N
43N
42N
41N
40N
39N
38N
37N
36N
35N
34N
33N
32N
31N
30N
126E 128E 130E 132E 134E 136E 138E 140E 142E 144E
5km

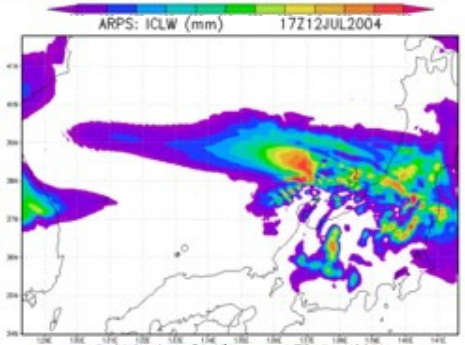
Practical Approach

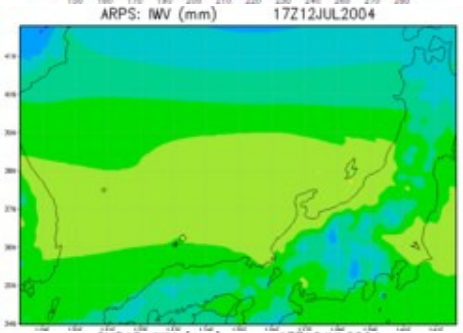


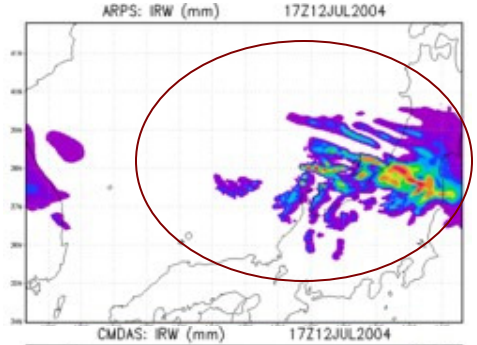

89H_Observed 2004/07/12 16:30 UTC

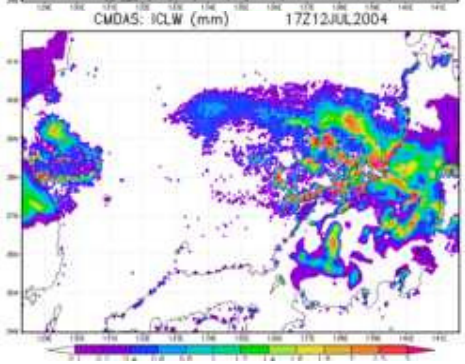
23H_Observed 2004/07/12 16:30 UTC

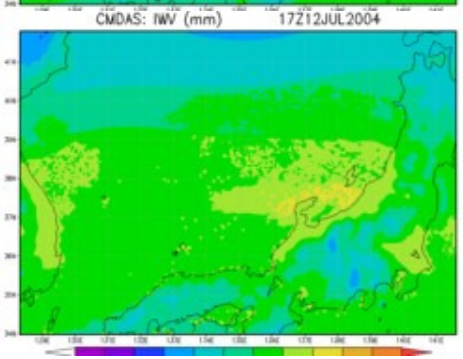

89H_Assimulated 2004/07/12 16:30 UTC
23H_Assimulated 2004/07/12 16:30 UTC

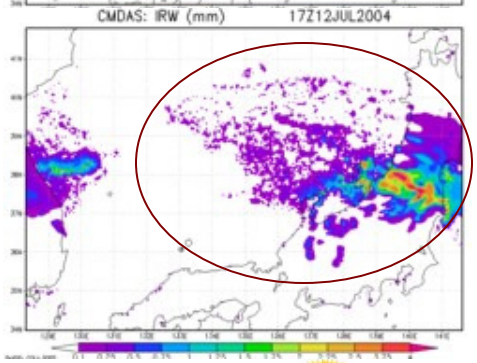

ARPS: ICLW (mm) 17Z12JUL2004


ARPS: IWV (mm) 17Z12JUL2004

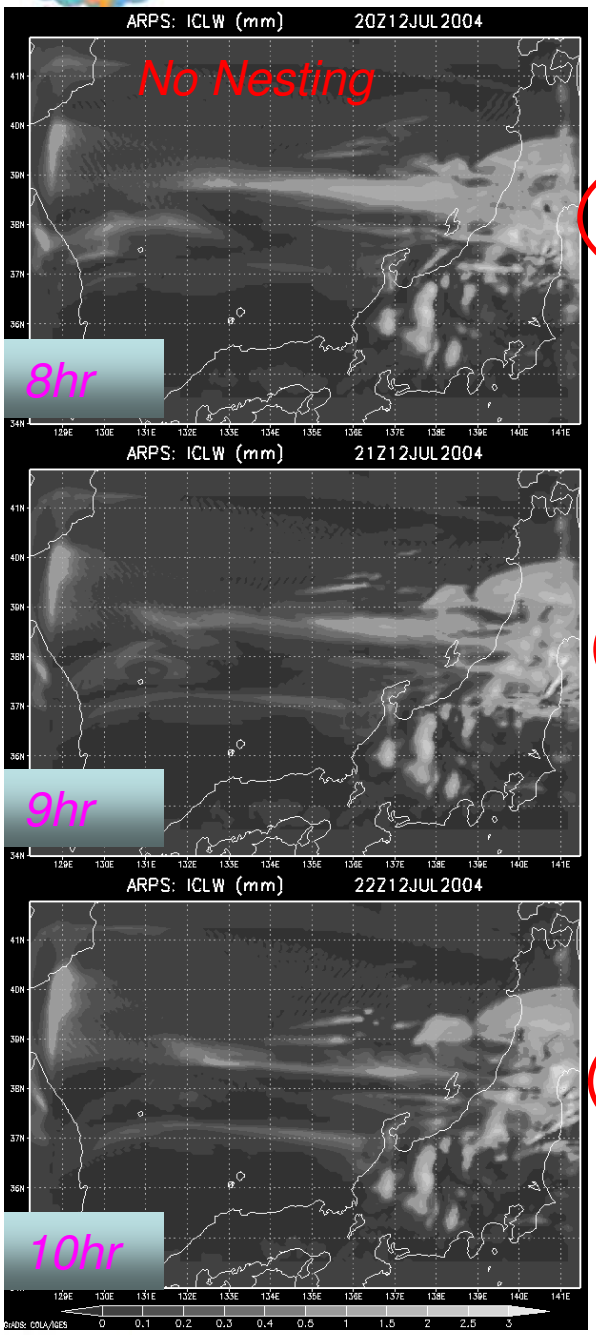

ARPS: IRW (mm) 17Z12JUL2004

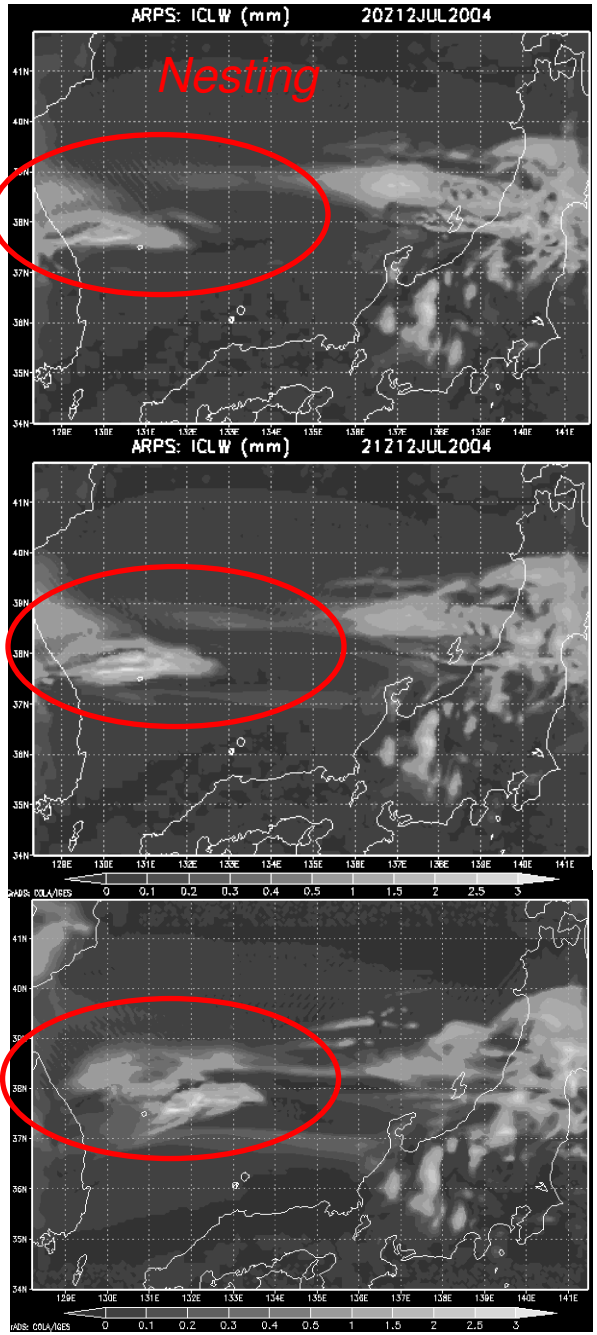

CMDAS: ICLW (mm) 17Z12JUL2004

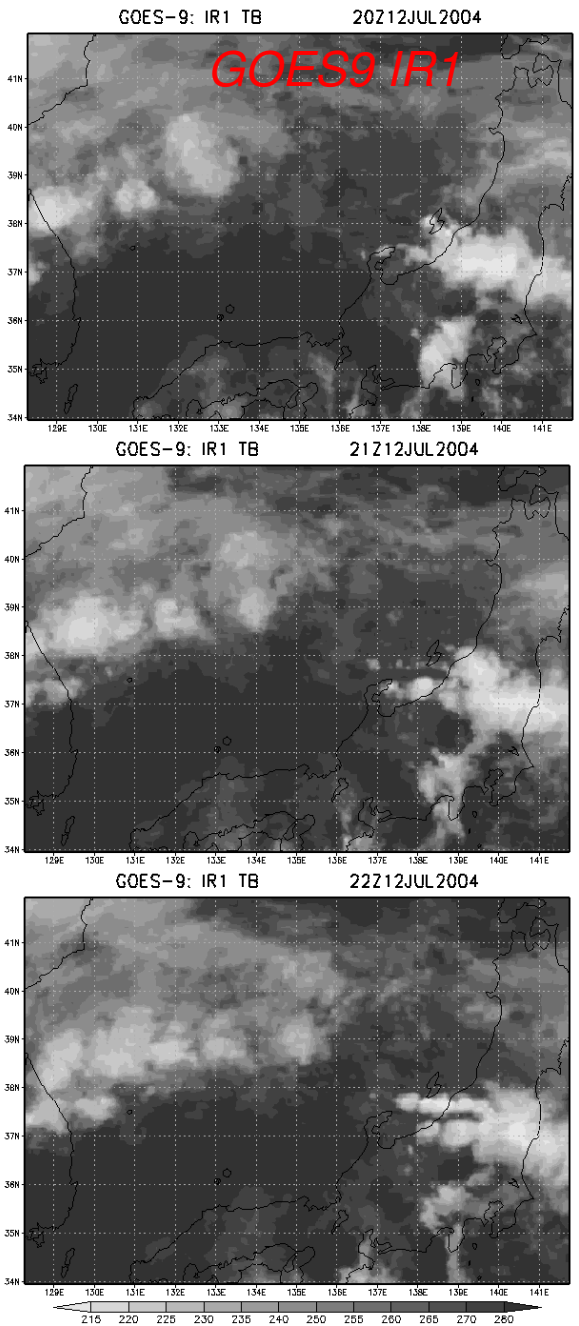

CMDAS: IWV (mm) 17Z12JUL2004

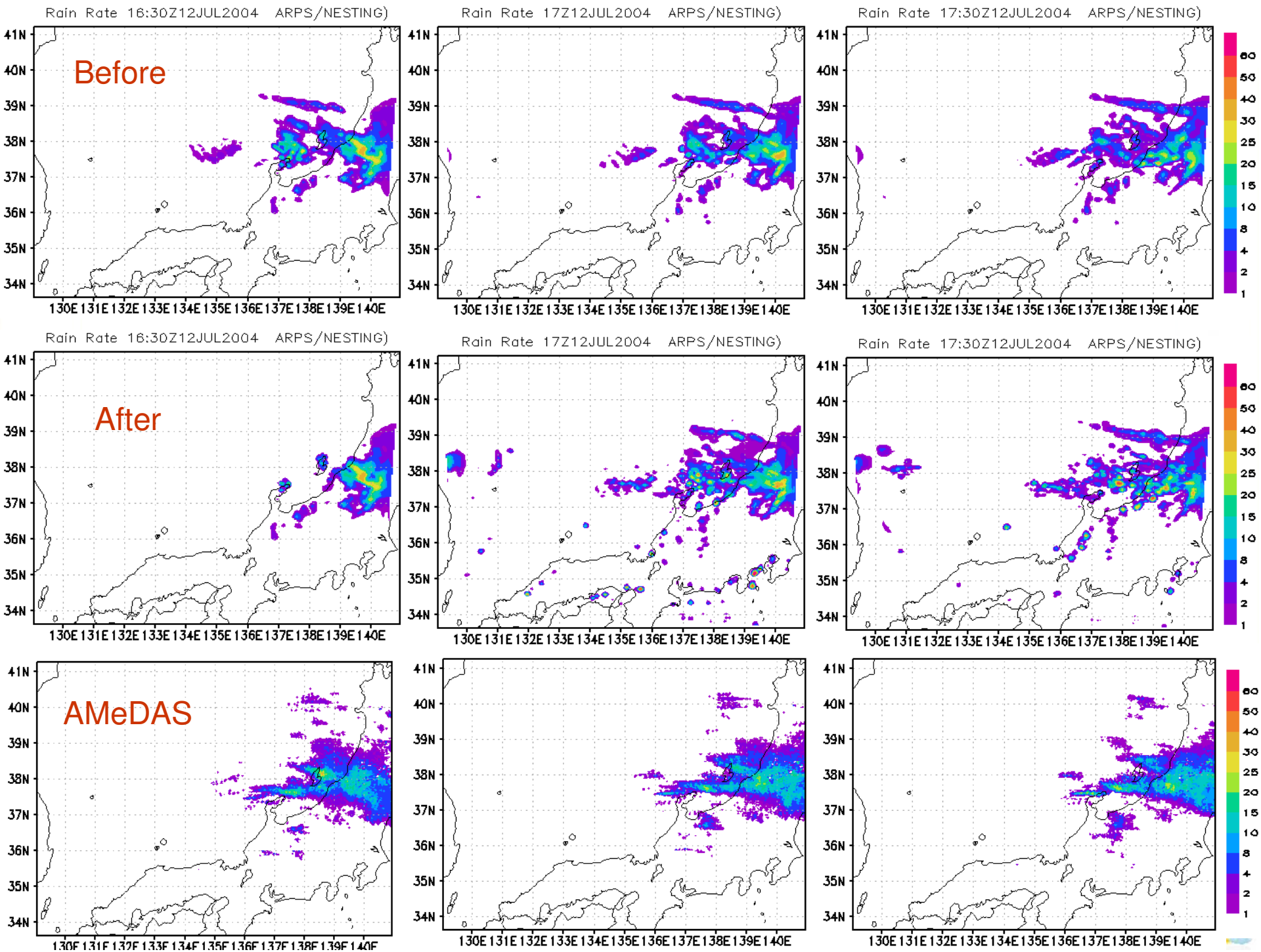

CMDAS: IRW (mm) 17Z12JUL2004

Nesting Vs No Nesting








Rain Rate 16:30Z12JUL2004 ARPS/NESTING)
Rain Rate 17Z12JUL2004 ARPS/NESTING)
Rain Rate 17:30Z12JUL2004 ARPS/NESTING)
Before
Rain Rate 16:30Z12JUL2004 ARPS/NESTING)
Rain Rate 17Z12JUL2004 ARPS/NESTING)
Rain Rate 17:30Z12JUL2004 ARPS/NESTING)
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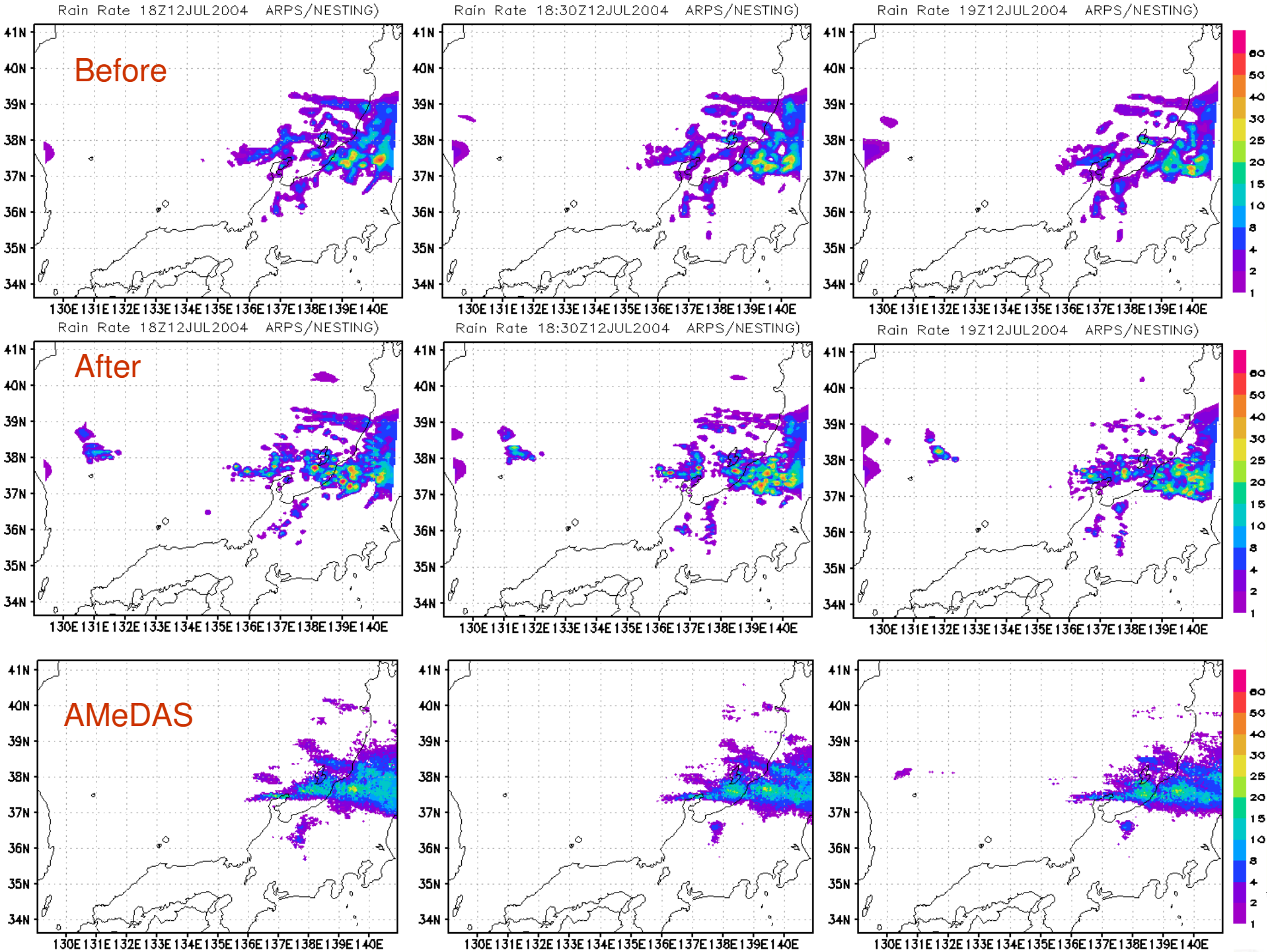
Rain Rate 18Z12JUL2004 ARPS/NESTING)
Rain Rate 18:30Z12JUL2004 ARPS/NESTING)
Rain Rate 19Z12JUL2004 ARPS/NESTING)
Before
Rain Rate 18Z12JUL2004 ARPS/NESTING)
Rain Rate 18:30Z12JUL2004 ARPS/NESTING)
Rain Rate 19Z12JUL2004 ARPS/NESTING)
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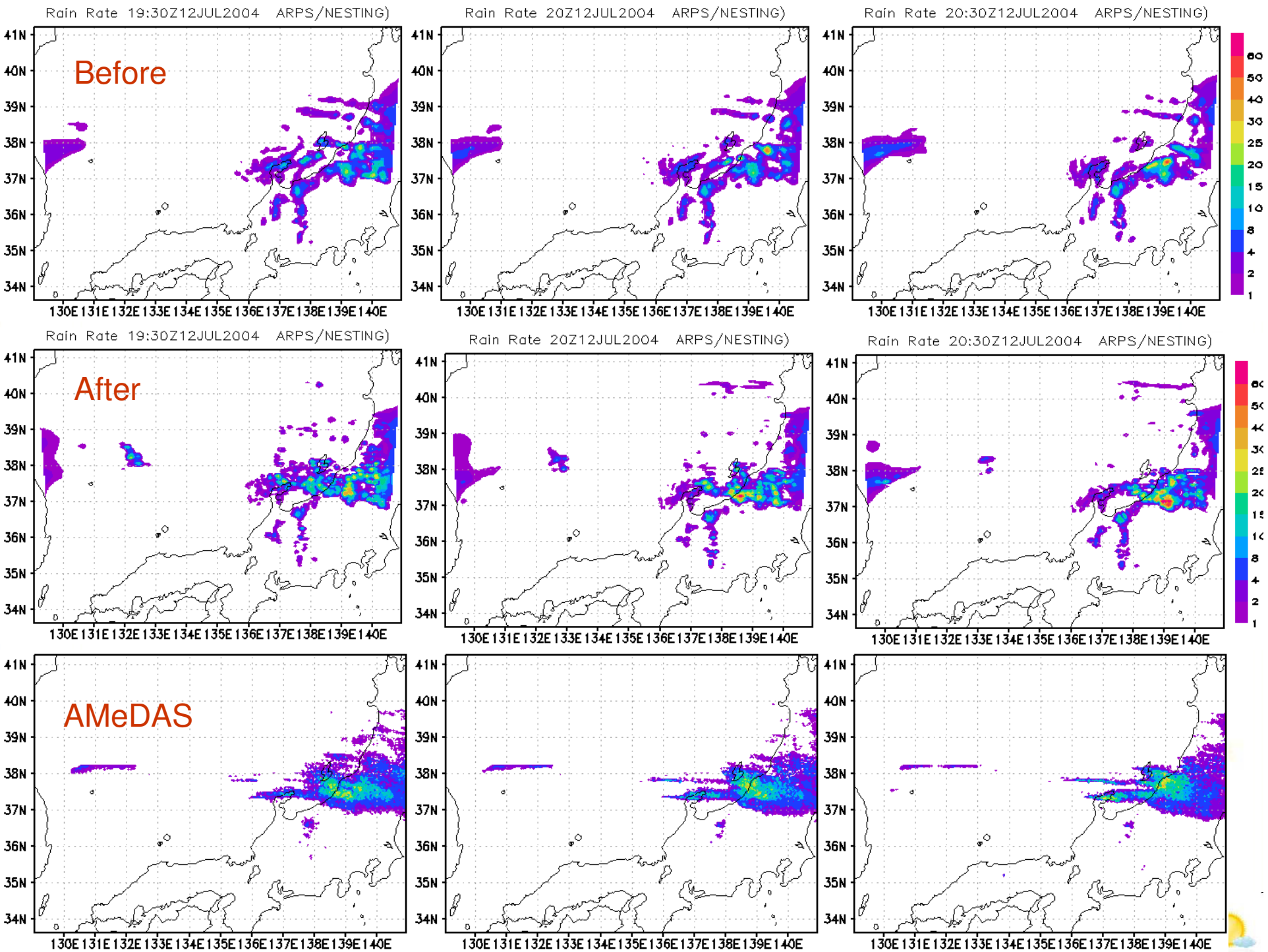
Rain Rate 19:30Z12JUL2004 ARPS/NESTING)
Rain Rate 20Z12JUL2004 ARPS/NESTING)
Rain Rate 20:30Z12JUL2004 ARPS/NESTING)
Before
Rain Rate 19:30Z12JUL2004 ARPS/NESTING)
Rain Rate 20Z12JUL2004 ARPS/NESTING)
Rain Rate 20:30Z12JUL2004 ARPS/NESTING)
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130E 131E 132E 133E 134E 135E 136E 137E 138E 139E 140E
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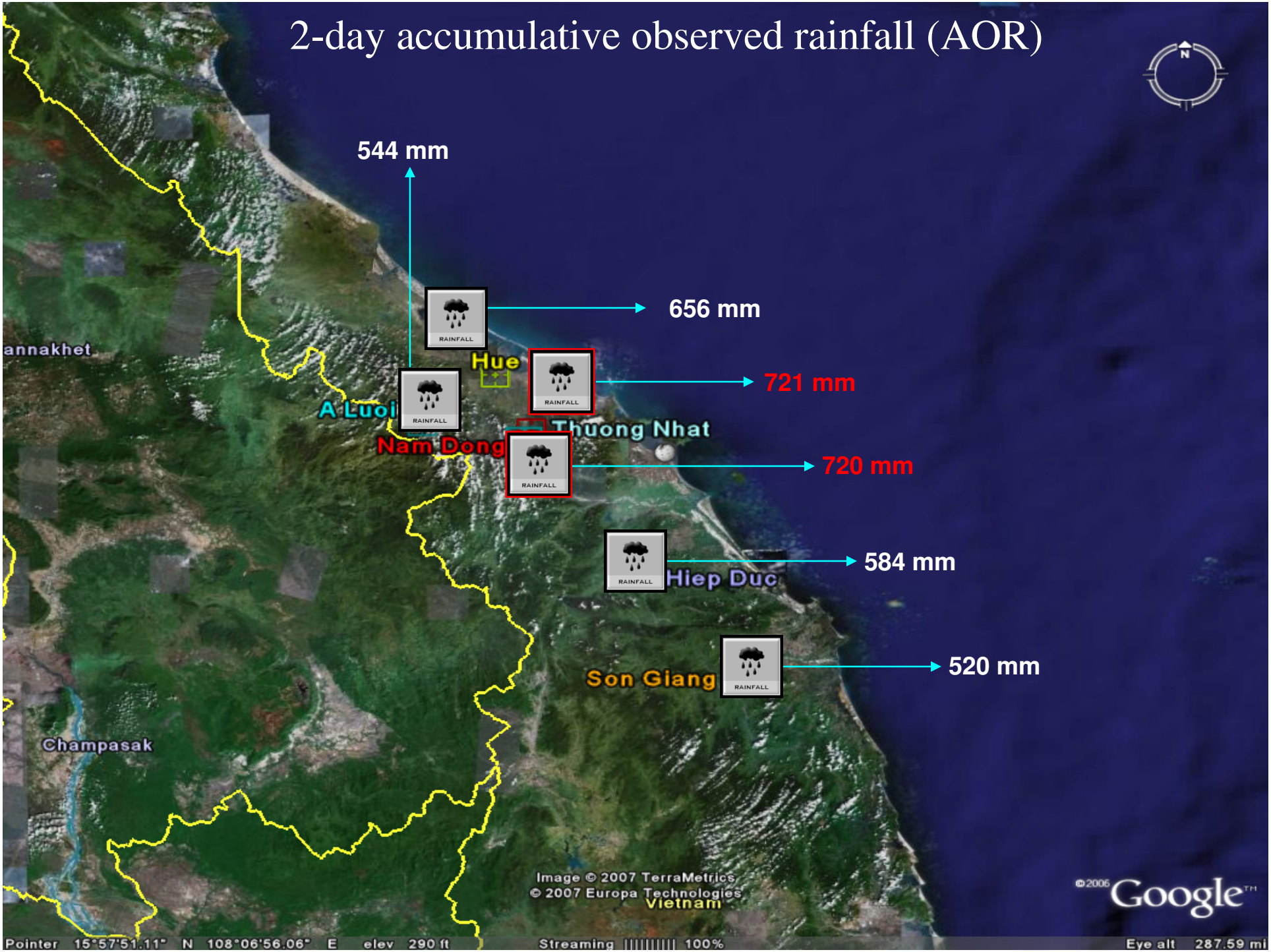
Vietnam Extreme Event

- Band of topographically-forced convective clouds occurred north of 15^{o}N in the Truong Son Mountains→ Propagated northward off the mountains towards the coast

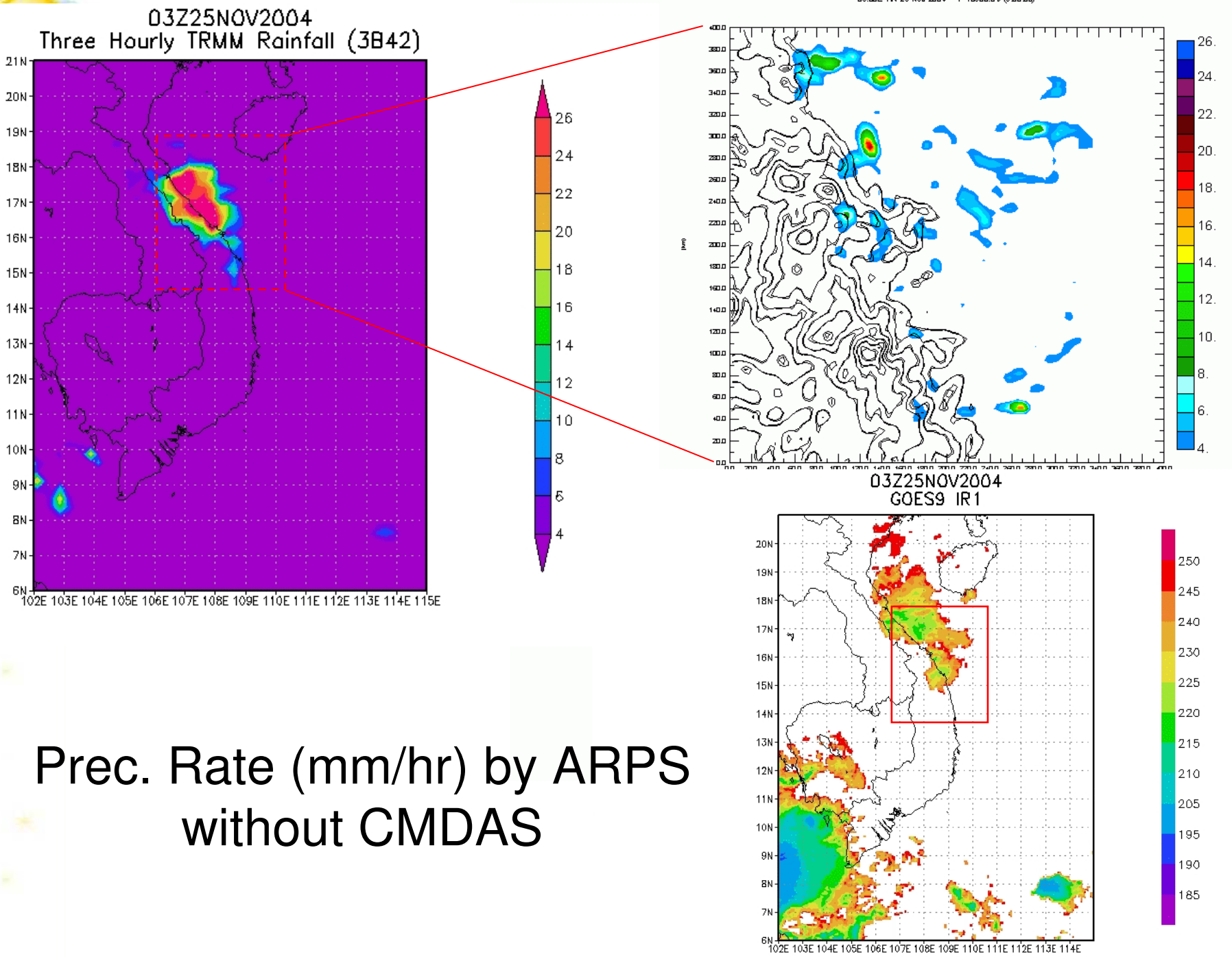
- From 24 to 26 November 2004 an extreme heavy rainfall event occurred in the mountainous provinces of central Vietnam, resulting in flooding along local rivers and severe human and property damage.

2-day accumulative observed rainfall (AOR)



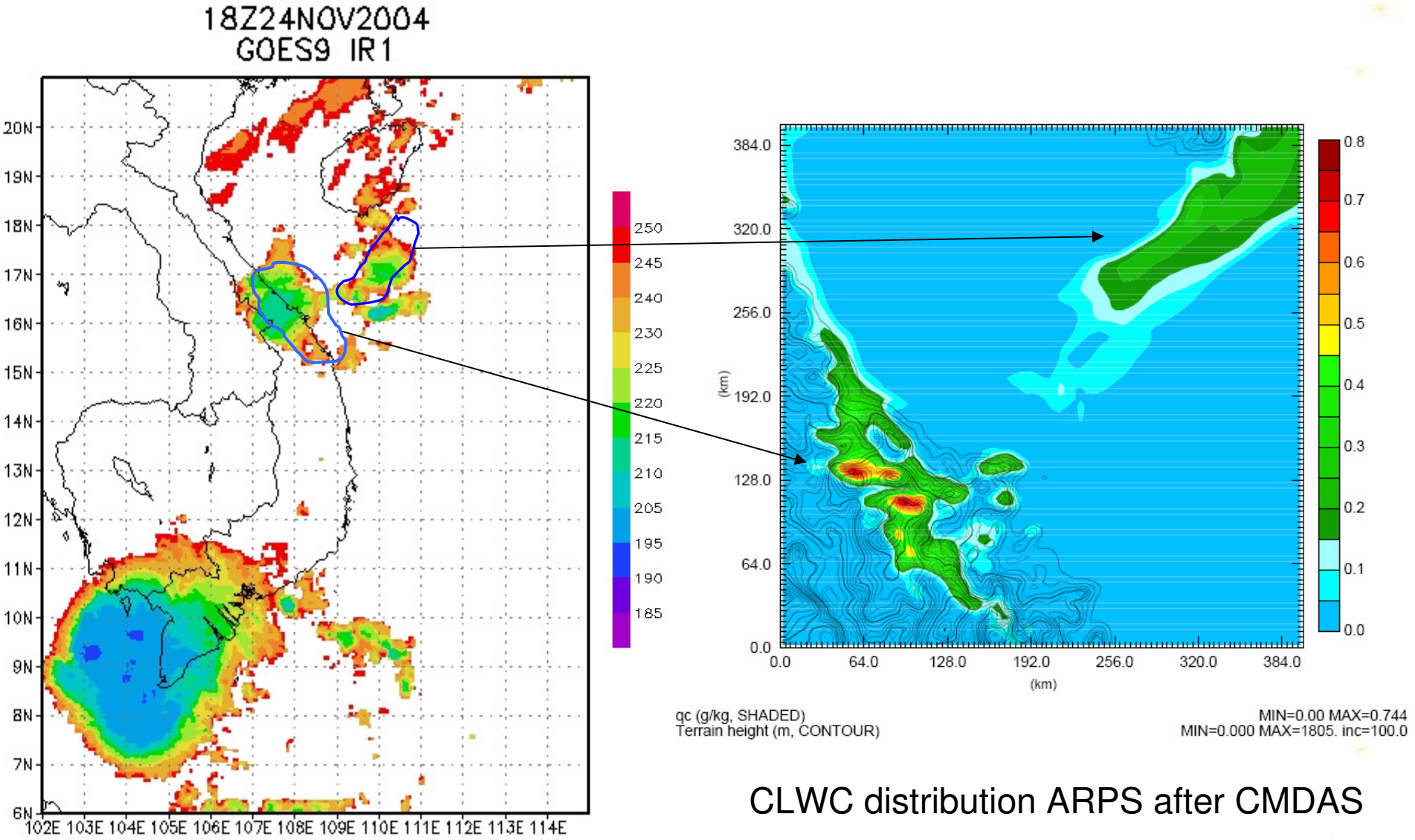
Experimental Design of Vietnam Flood (ARPS)

Event	Vietnam Heavy Rainfall (24^{th} Nov ~ 26^{th} Nov 2004)
domain	400 km × 400 km × 20km
horizontal grid size	4000 m
vertical grid size	4000 m
grid numbers	103 × 103 × 53
integration time	36 hrs
time increment	3 sec for model integration
Initial/Boundary condition	GFS (Global Forecast System) analysis (1x1)
Cloud microphysics	Lin Ice scheme
CPS	WRF Kain-Fritch

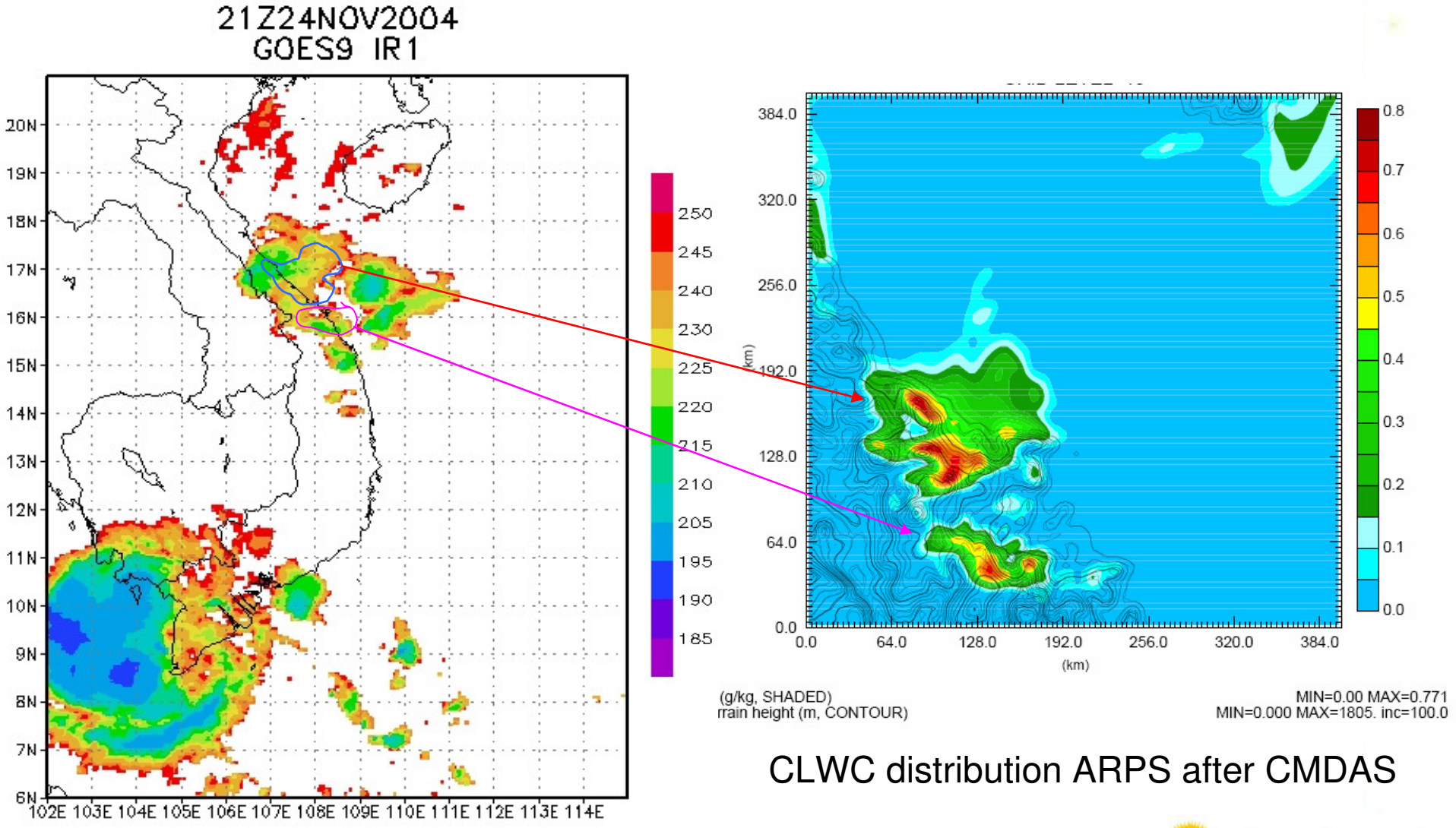


Prec. Rate (mm/hr) by ARPS without CMDAS

ARPS with New Initial Conditions:

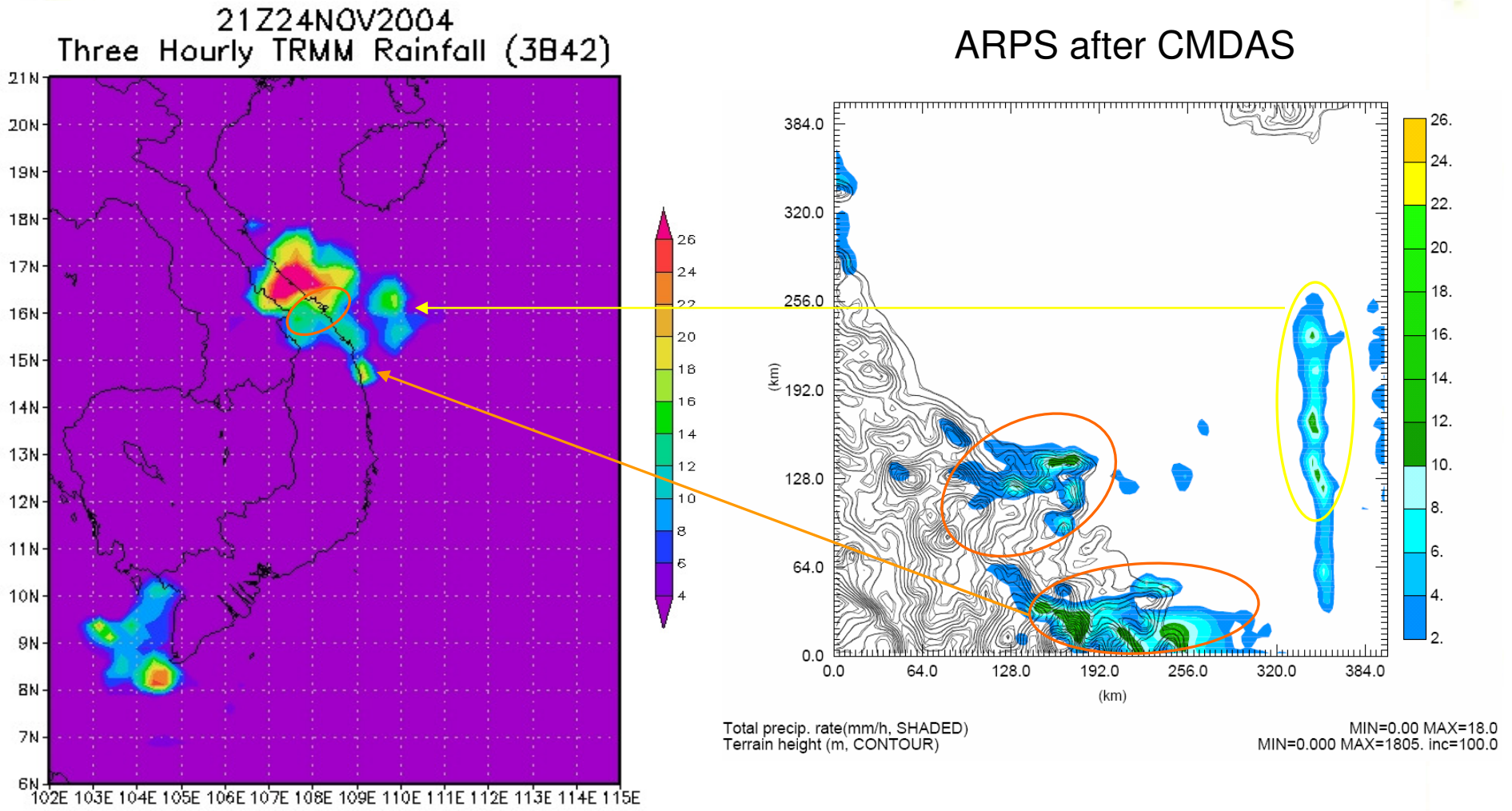


CLWC distribution ARPS after CMDAS



CLWC distribution ARPS after CMDAS

Precipitation rate by ARPS



Conclusive Remarks

- Dynamical downscaling could be able to improve the short term precipitation predcition by improving BCs which come from GCMs
- Assimilated brightness temp. and integrated parameters show good agreement with observation
- Forecasting with improved initial conditions shows agreement in the beginning, however the generated cloud system by CMDAS seems dying later on.

  → Cloud dynamics play important role to keep the energy to develop the cloud system further more.
- Unable to predict the Niigata heavy rainfall event, even with dynamical downscaling → due to NCEP reanalysis data → Need better BC data
- Precipitation rate Analysis: For initial 6 hrs, ARPS with new IC from CMDAS gives comparable precipitation spatial and temporal distribution with AMeDAS radar rain rate values (Niigata Extreme Event case).
- The spatial and temporal distribution & over/under-estimation displacement of precipitation over Vietnam area by ARPS → maybe due to uncertain/lack of low level convergence to support the continued growth of the initial and split updraft.

Thanks for your efforts by facilitating us with better water resources management !!