A QPF experiment using VDRAS, WRF and data observed in 2008 SoWMEX IOP#8

Yu-Chieng Liou[1], Sheng-Lun Tai[1]
Shao-Fan Chang[1] and Juanzhen Sun[2]

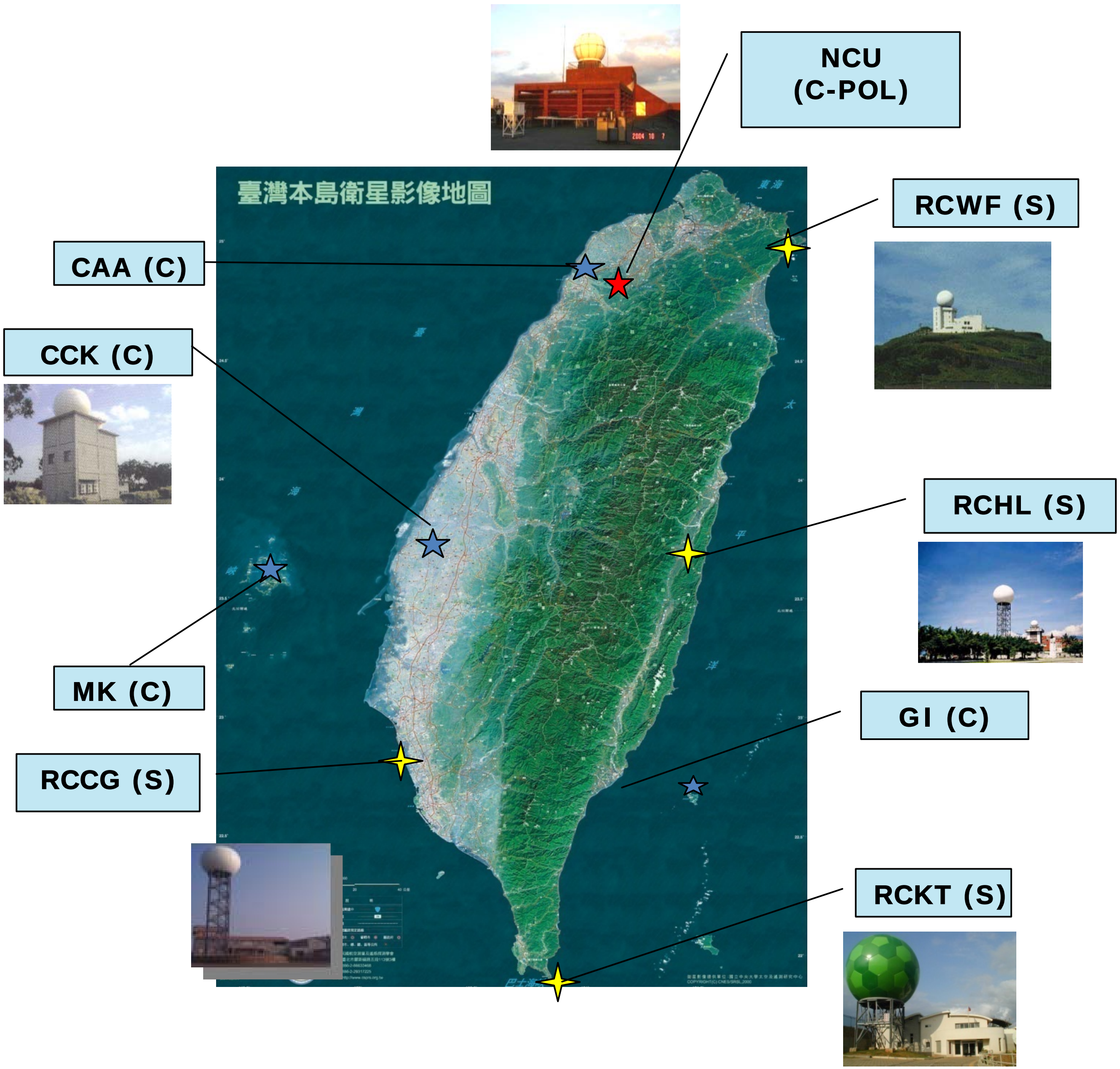
Institute of Atmospheric Physics, NCU, Taiwan
National Center for Atmospheric Research, USA

Outline

- Research Purpose
- Brief introduction of VDRAS
- Brief introduction of the selected real case
- VDRAS analysis fields
- Senstivity of rainfall to background fields
- VDRAS + WRF to improve QPF
- Summary and future work

- **Radar can observe meso- and convective scale weather systems with high spatial (< 1.0 km) and temporal (< 10 min) resolutions.**
- **Methods (3DVAR, 4DVAR, EnKF) for radar data assimilation to improve NWP have been developed for the past 2 decades. (Gal-Chen 1987; Lin et al. 1993; Crook 1994; Weygandt et al. 2002; Synder and Zhang 2003, Sun 2005; Xiao et al. 2005; Hu et al. 2006)**

Taiwan Ground-Based radar network



3 dual-pol.
6 Doppler

- **Variational Doppler Radar Analysis System (VDRAS): Developed at NCAR, a cloud-resolving model, equipped with 4DVAR adjoint model, can assimilate Doppler radar data (Sun and Crook 1997, 1998).**

- **Applied in 2000 Sydney Olympic game for real-time wind analysis (Crook and Sun 2002, 2004).**

- **Applied in prediction of a flood in Colorado (Warner et al. 2000)**

- **Applied in IHOP_2002 for QPF of a squall line in U.S. continent (Sun and Zhang, 2008).**

- **Provide frequent real-time analysis fields in 2008 Beijing Olympic (Sun et al. 2010)**

First time to apply VDRAS in Taiwan & nearby area to test its QPF skill

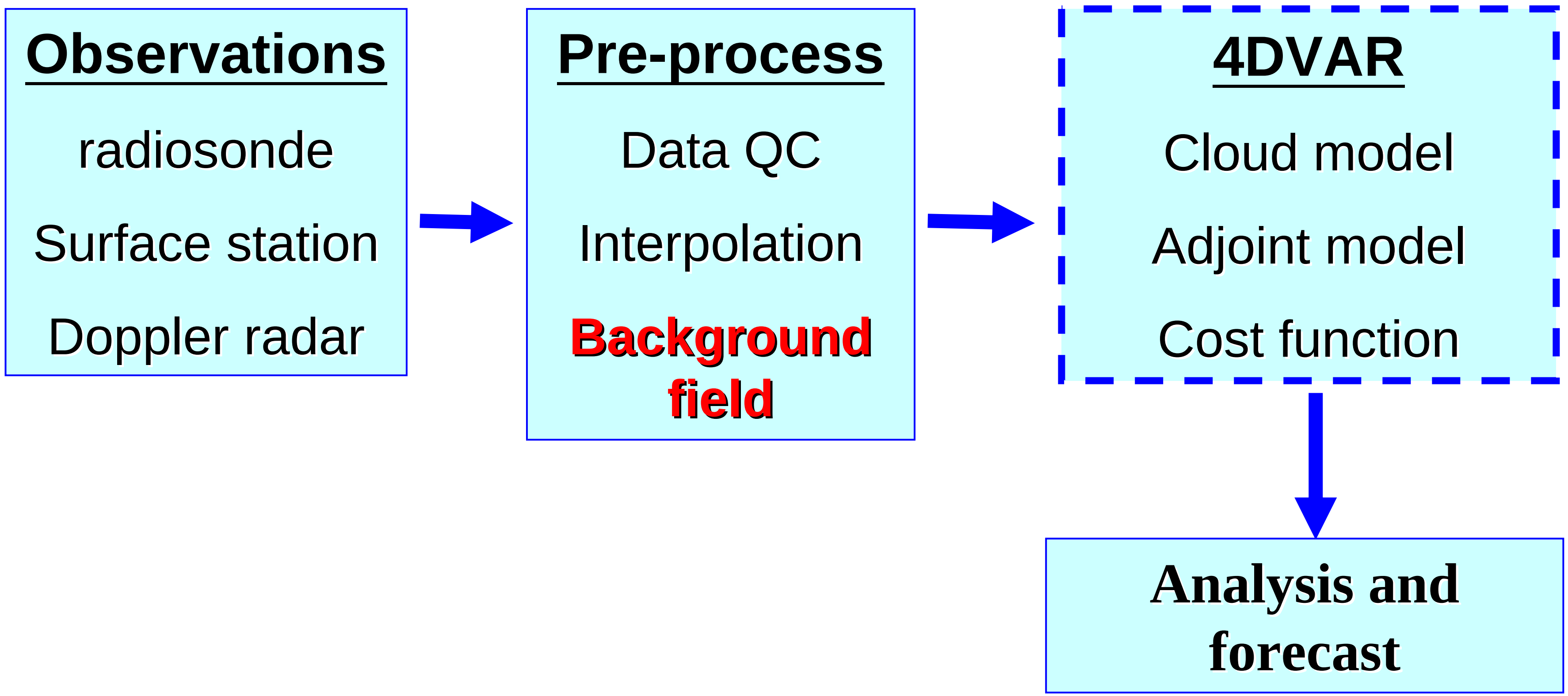
Challenges:

(a) **Complex topography: VDRAS does not resolve terrain.**

(b) **Surrounding oceans: limit in-situ observations.**

VDRAS

Variational Doppler Radar Analysis System

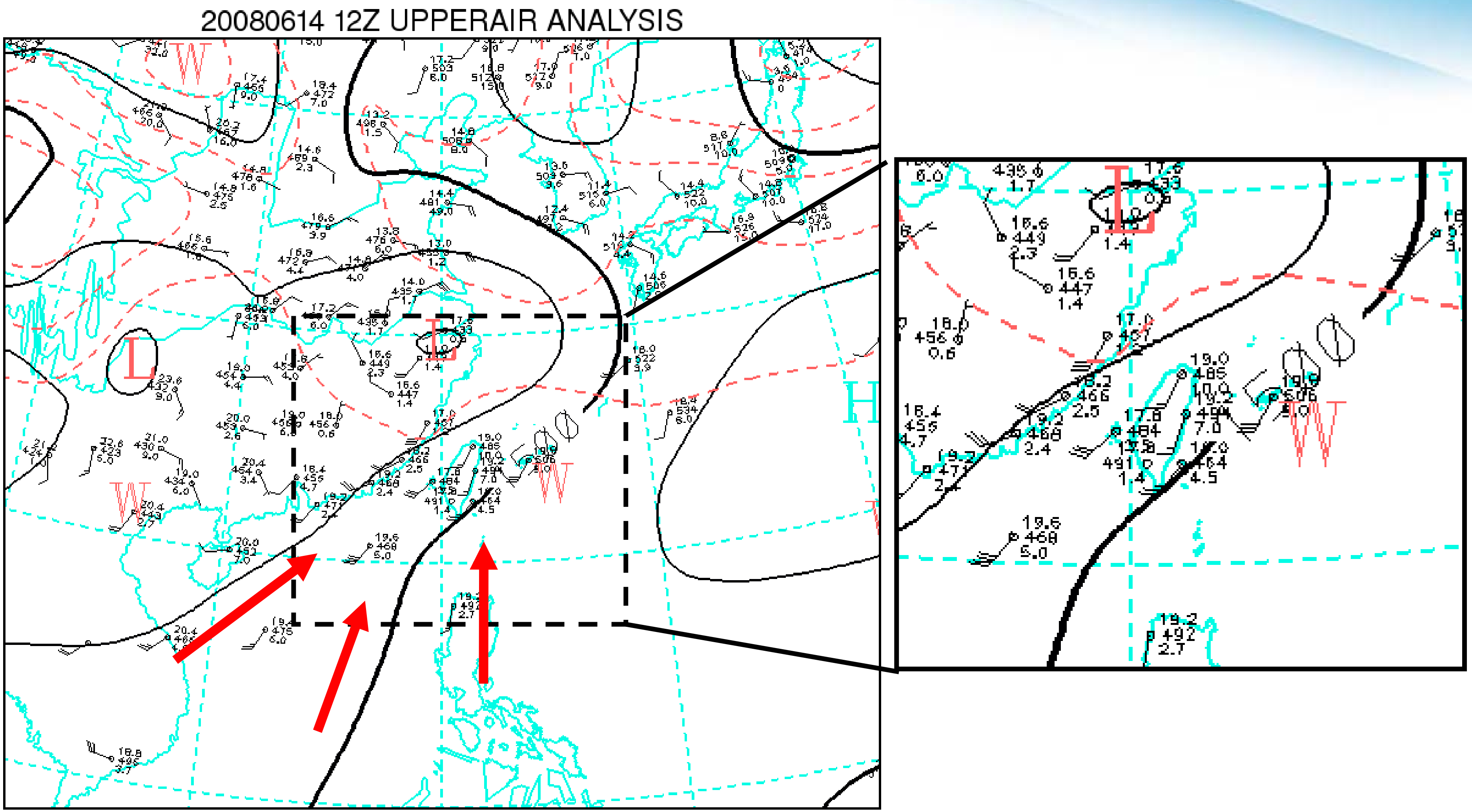


Case study

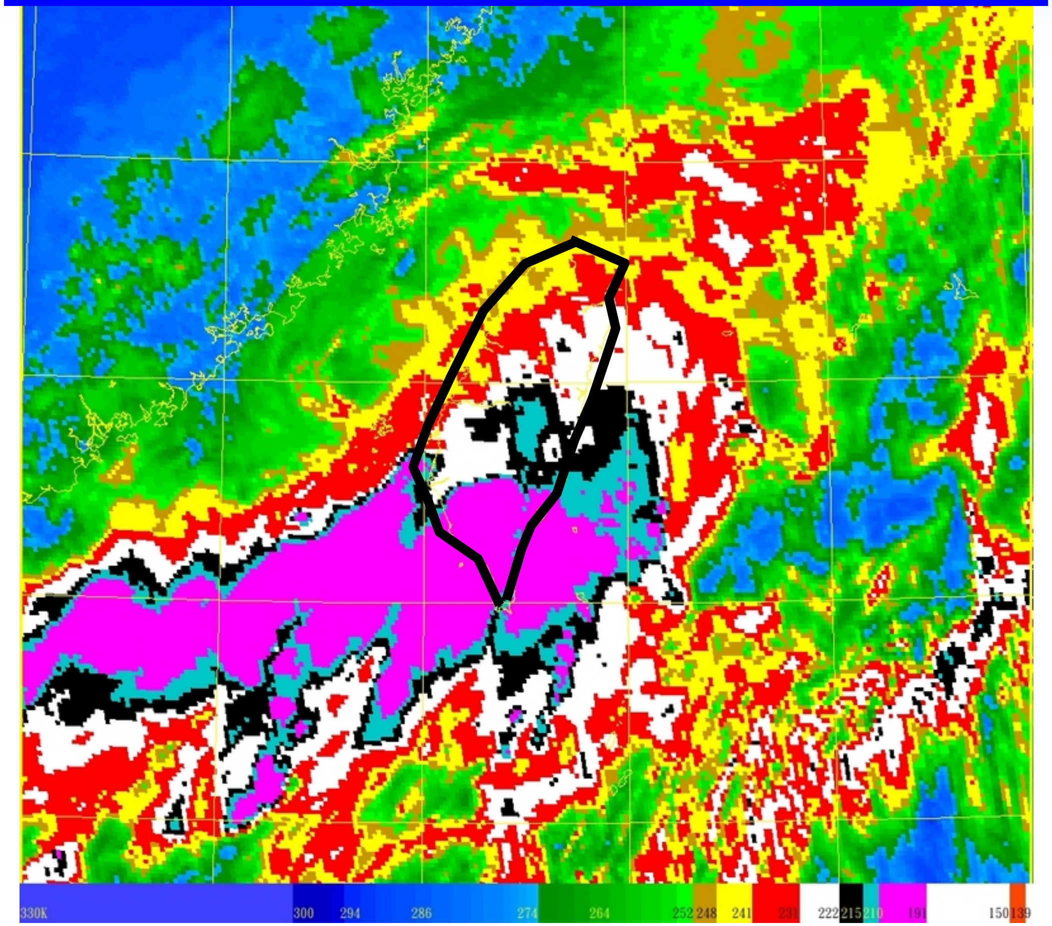
- 2008 SoWMEX/TiMREX
- IOP8: 6/14 00 UTC to 6/17 00 UTC
- Mei-Yu Front
- Assimilation experiment:

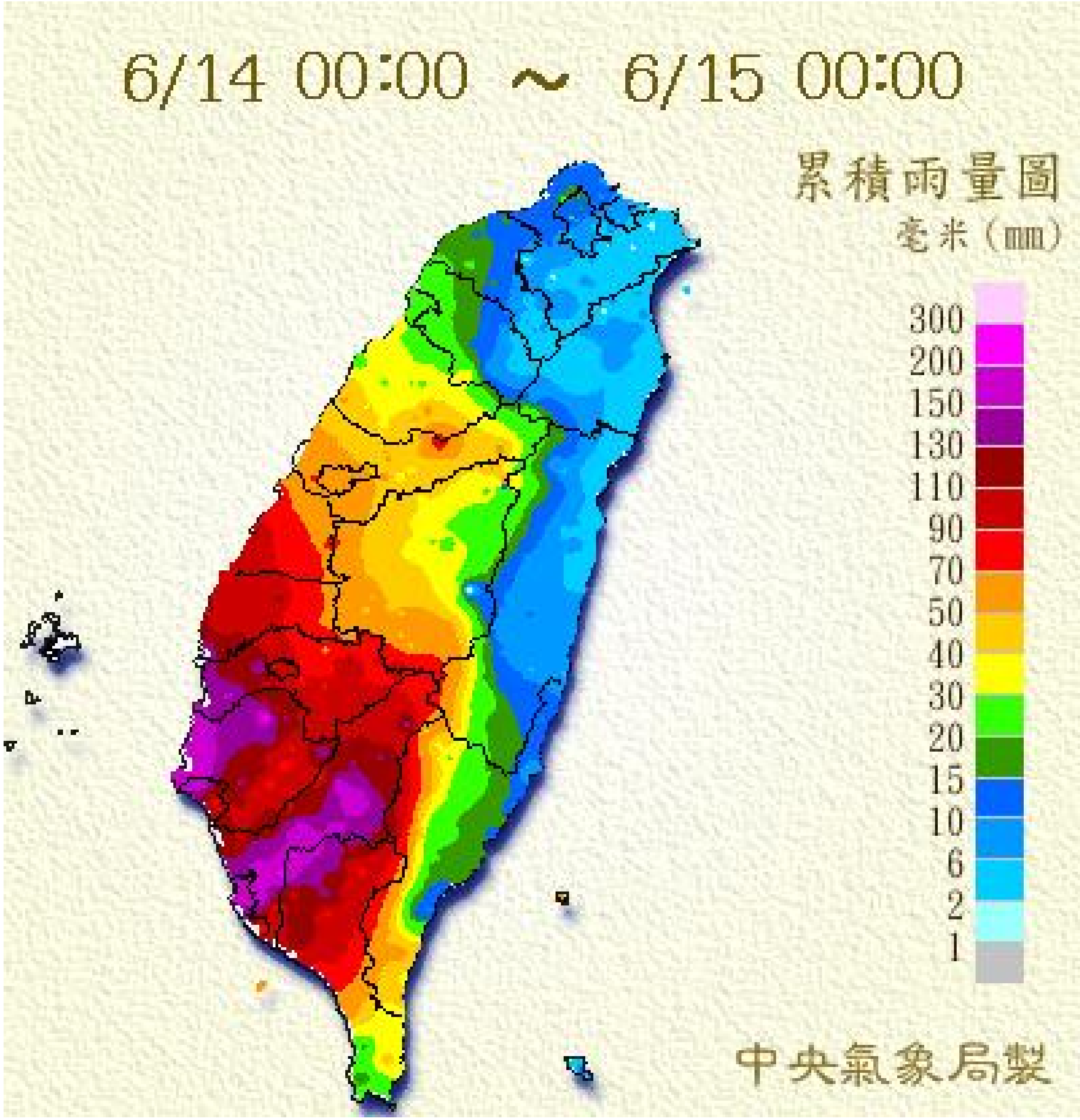
  6/14 1046 UTC to 1354 UTC

6/14 1200UTC 850hpa weather map

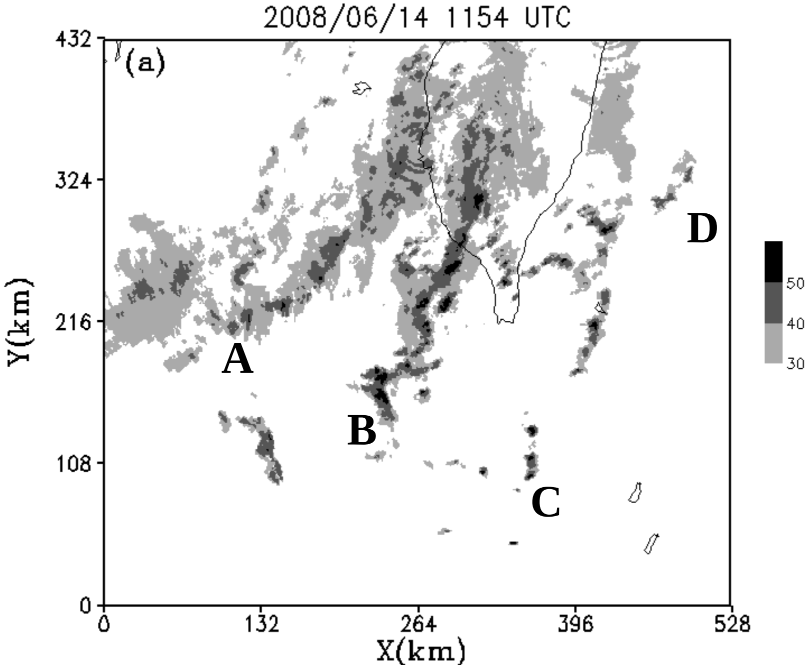


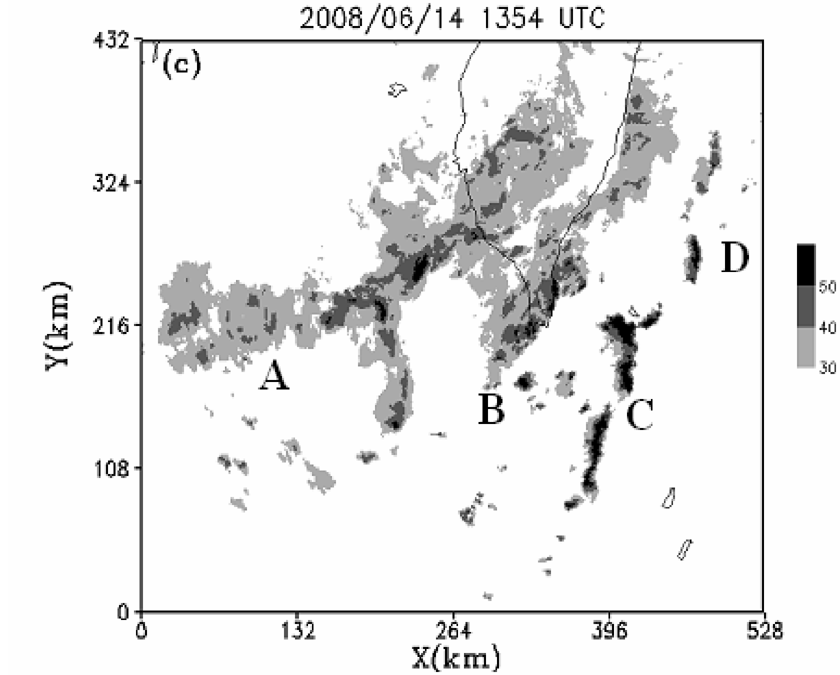
6/14 1130 UTC IR Satellite Image

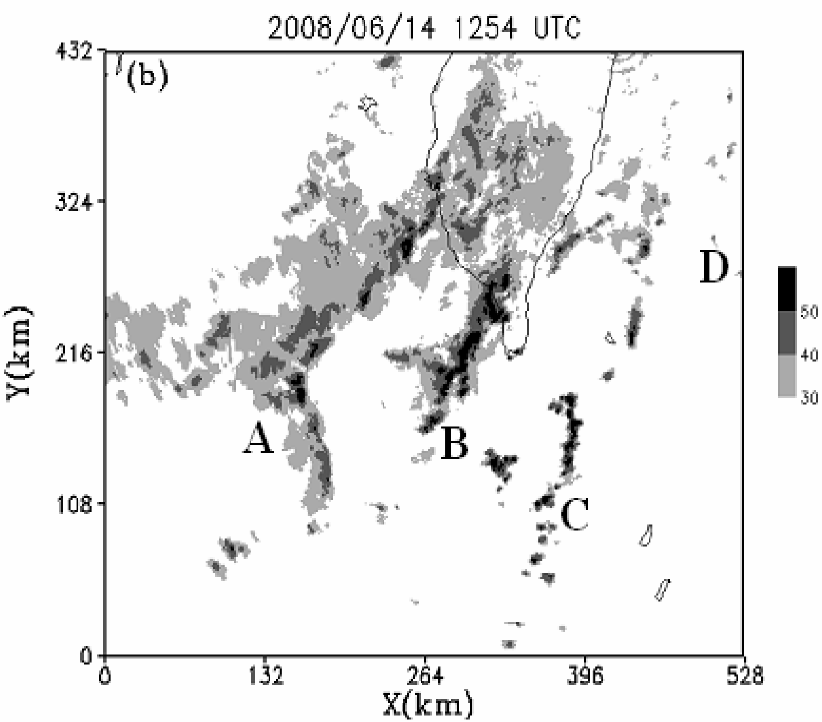




24-hour accumulated rainfall (torrential rain > 200 mm/day)



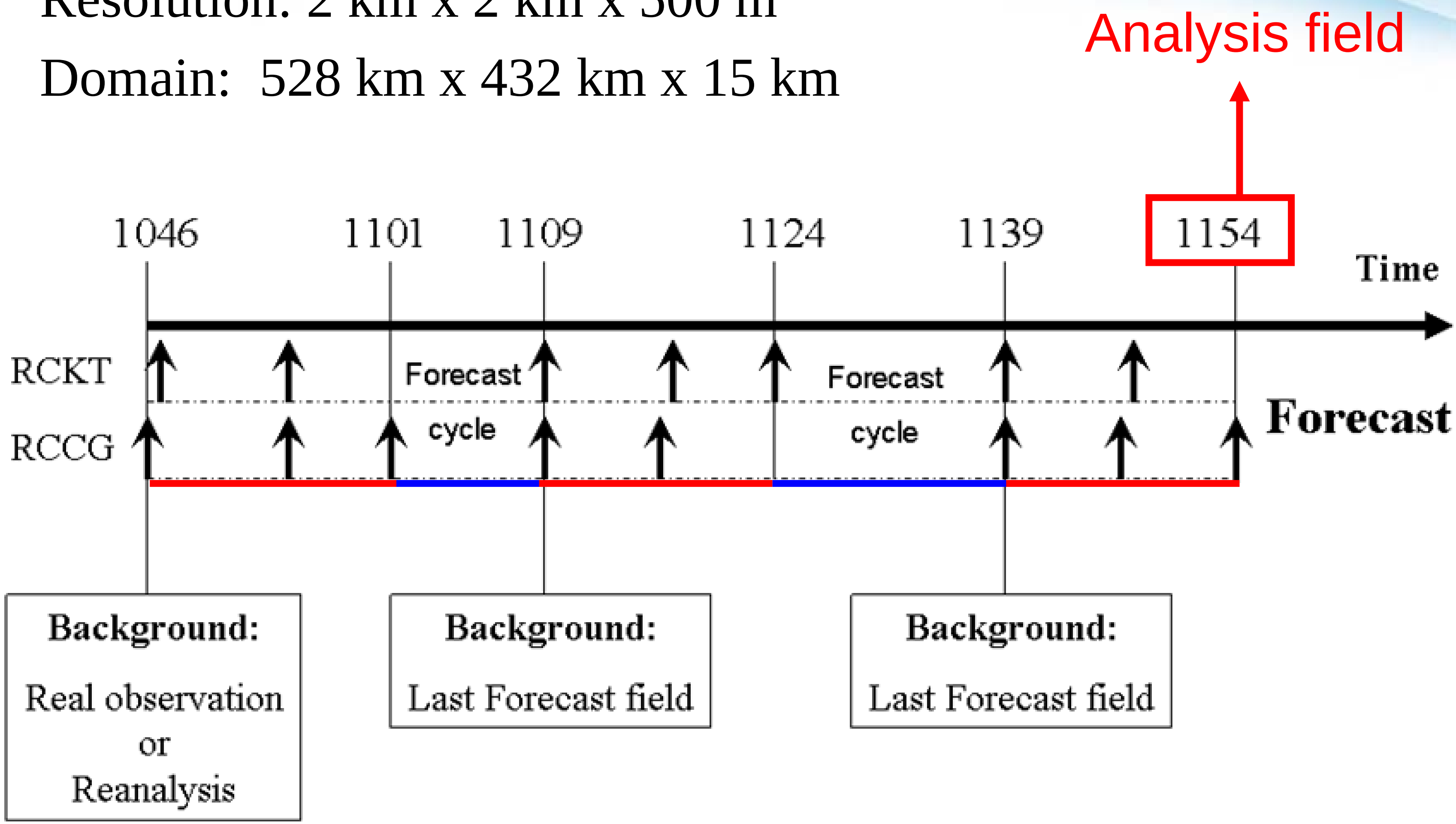


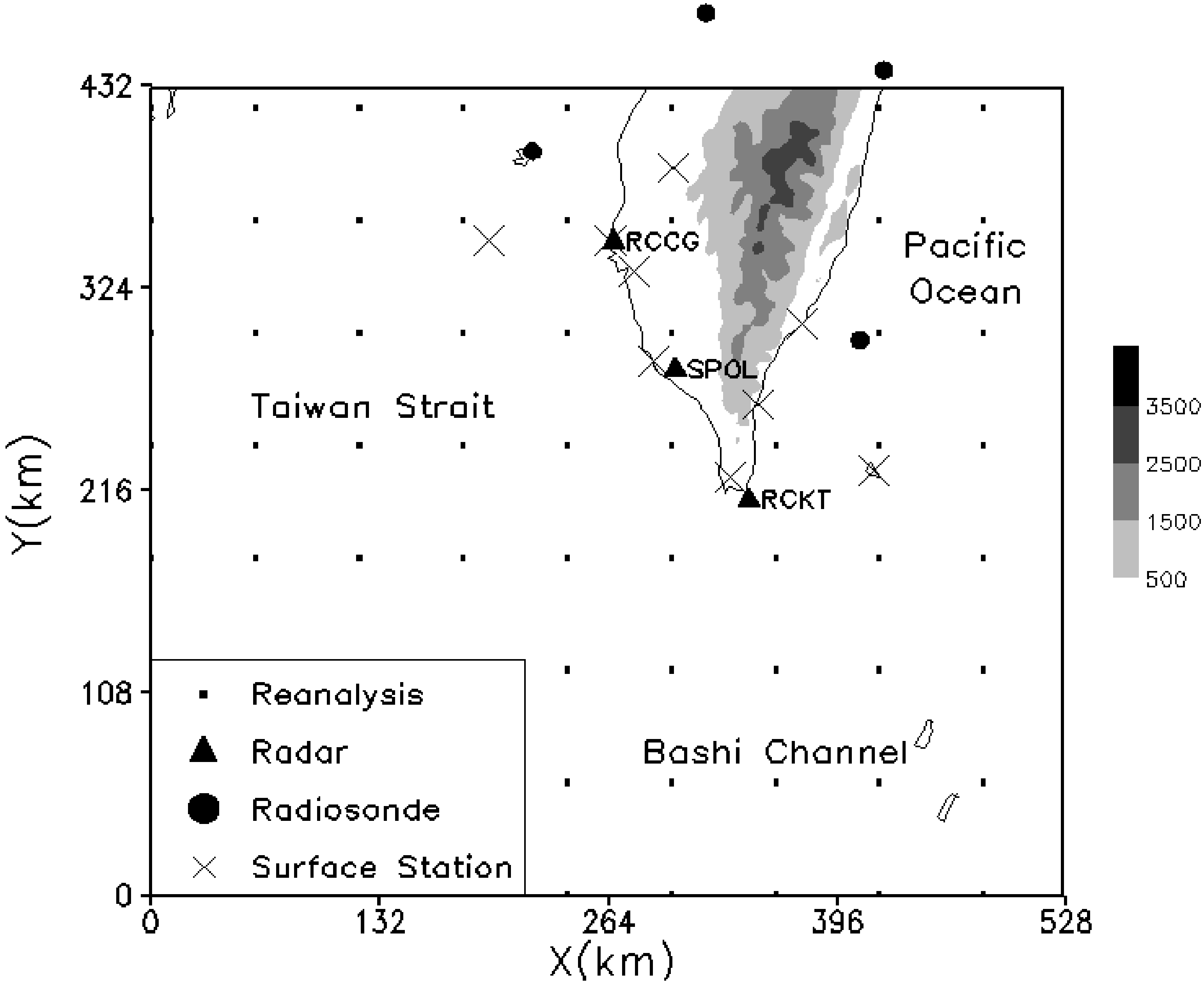


Mosaic radar CV

Assimilation strategy

- Grid points: 264 x 216 x 30
- Resolution: 2 km x 2 km x 500 m
- Domain: 528 km x 432 km x 15 km





432
324
216
108
0
Y(km)
0
132
264
396
528
X(km)
RCCG
SPOL
RCKT
Pacific Ocean
Taiwan Strait
Bashi Channel
Reanalysis
Radar
Radiosonde
Surface Station
3500
2500
1500
500

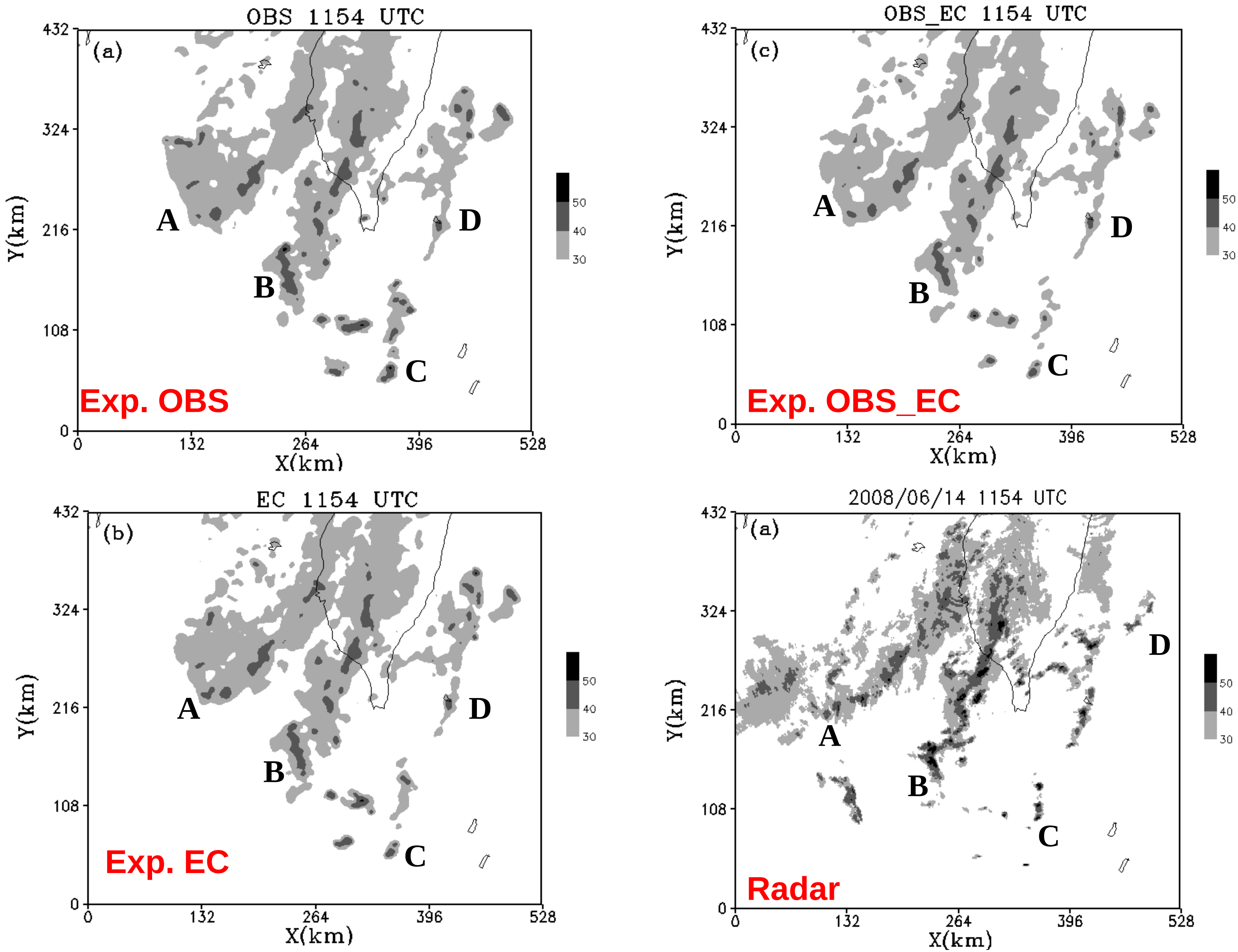
Fig. 2

Impacts of background fields on the VDRAS analysis field (at UTC 1154)

Experiment OBS (in-situ obs. only)

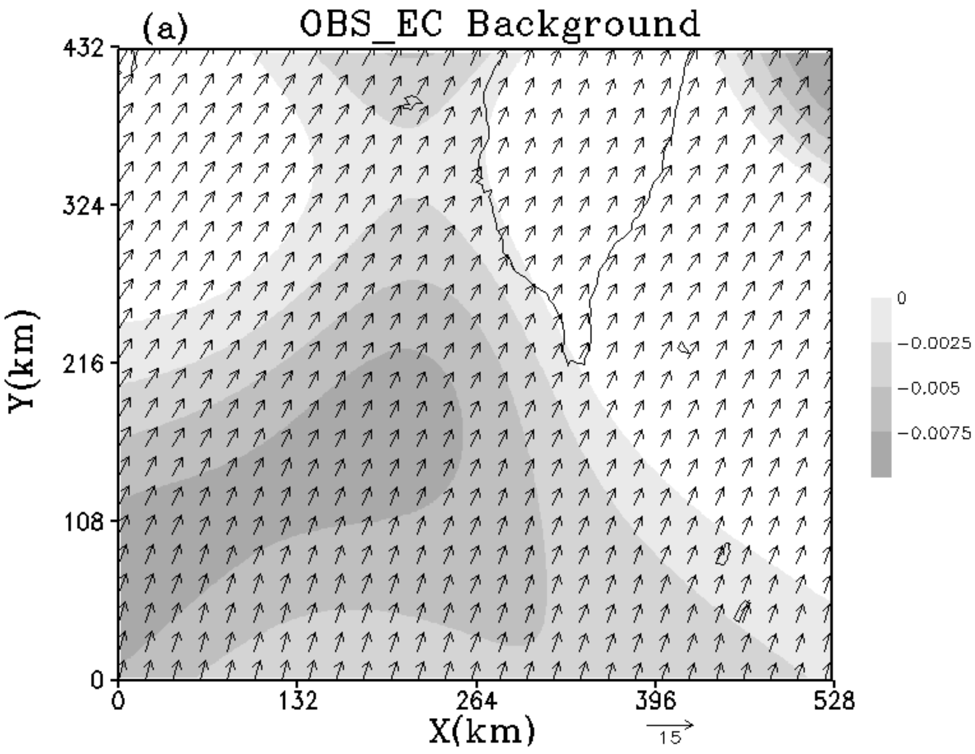
Experiment EC (reanalysis from ECMWF only)

Experiment OBS_EC (Both)

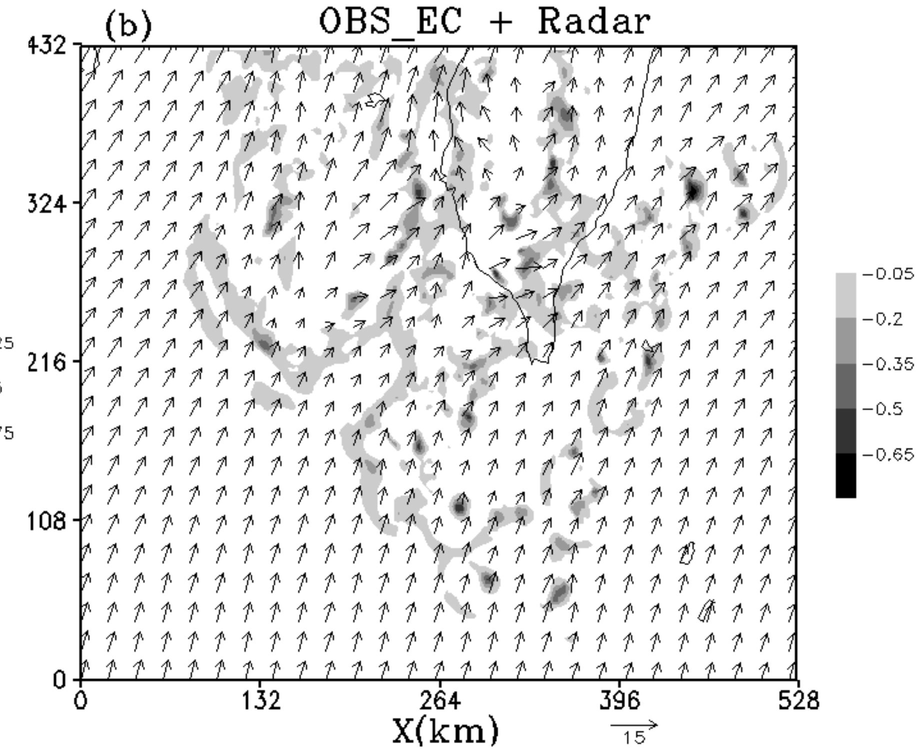


OBS 1154 UTC
(a)
Exp. OBS
OBS_EC 1154 UTC
(c)
Exp. OBS_EC
EC 1154 UTC
(b)
Exp. EC
2008/06/14 1154 UTC
(a)
Radar
A
B
C
D
X(km)
Y(km)
30
40
50

Convergence field before and after Radar data assimilation



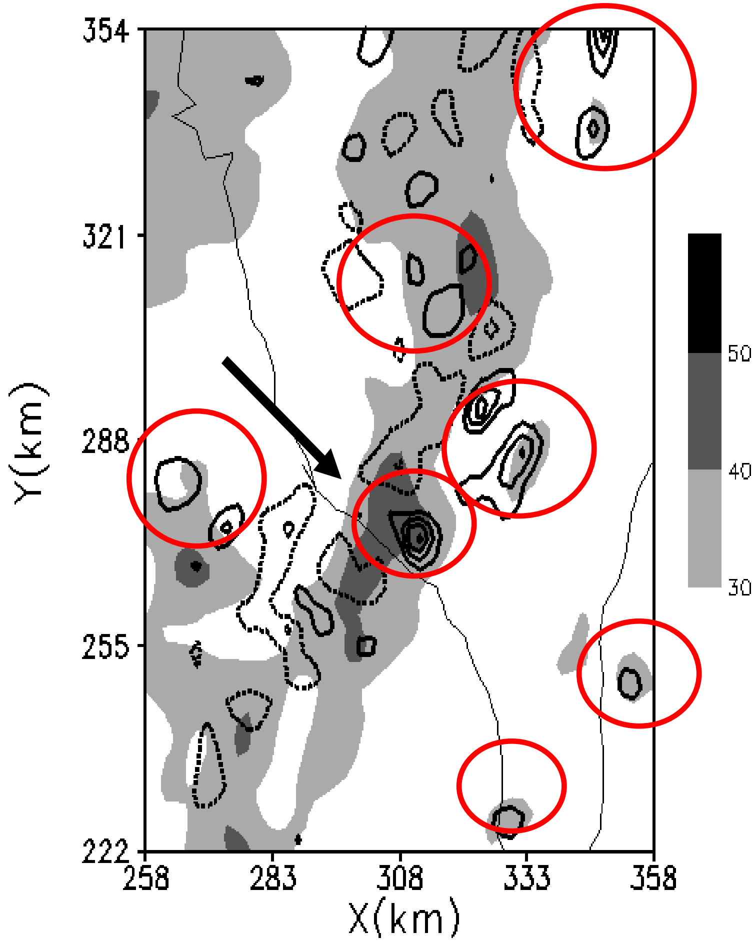
Before



After

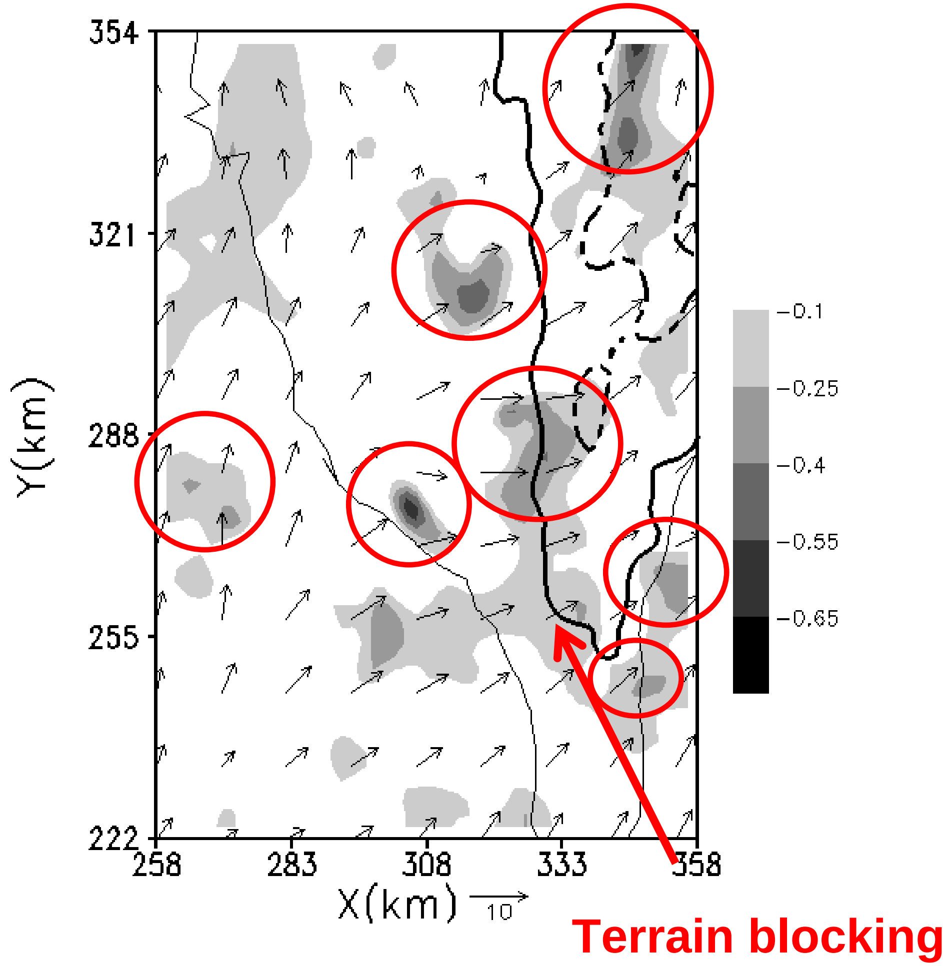
More small scale features (Intensity Increases 100 times)

W (contour)
dbz(shading)



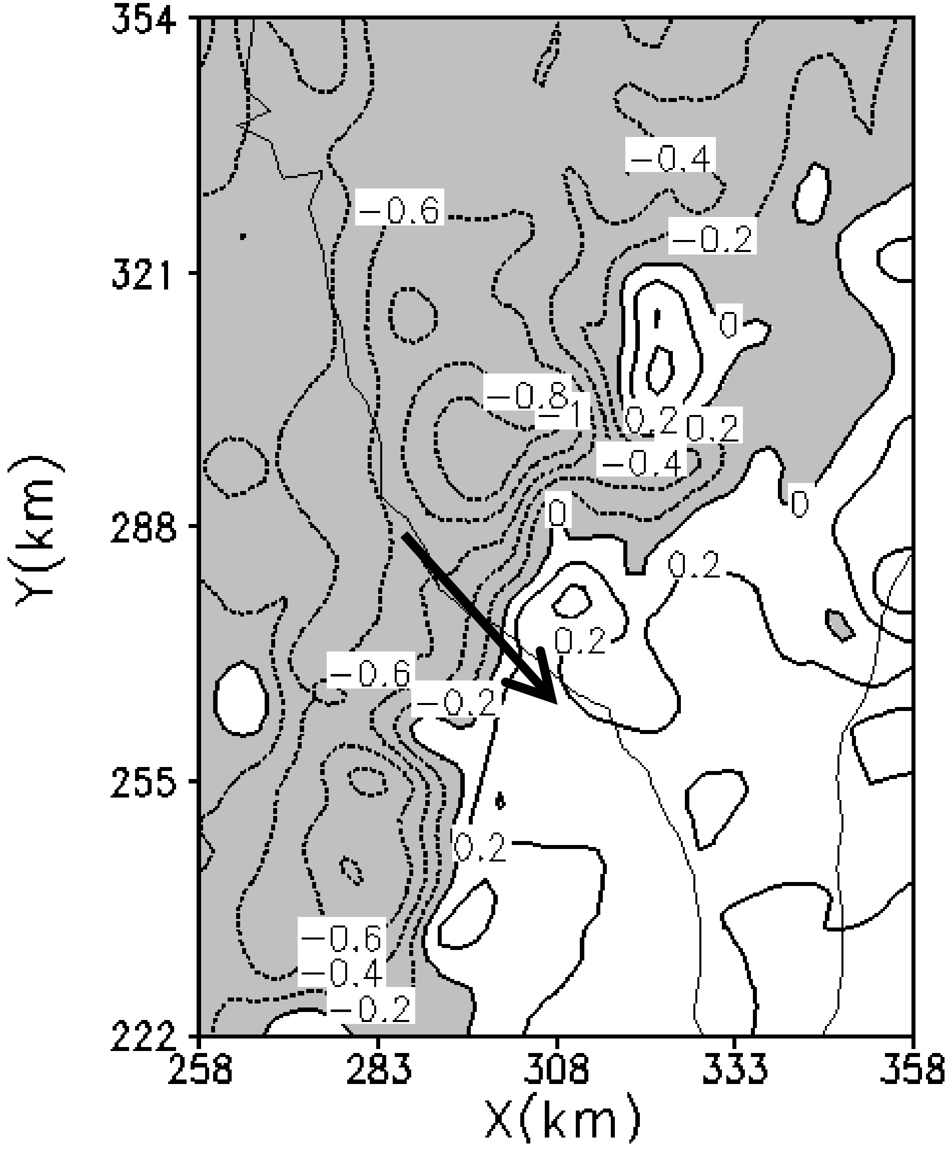
Z= 1.25 km

Convergence (shading)
Thin line: coastal line
Thick line: 500 m terrain
Thick dash line: 1000 m terrain



Z= 0.25 km

Perturbation temperature



Cold pool behind the leading edge

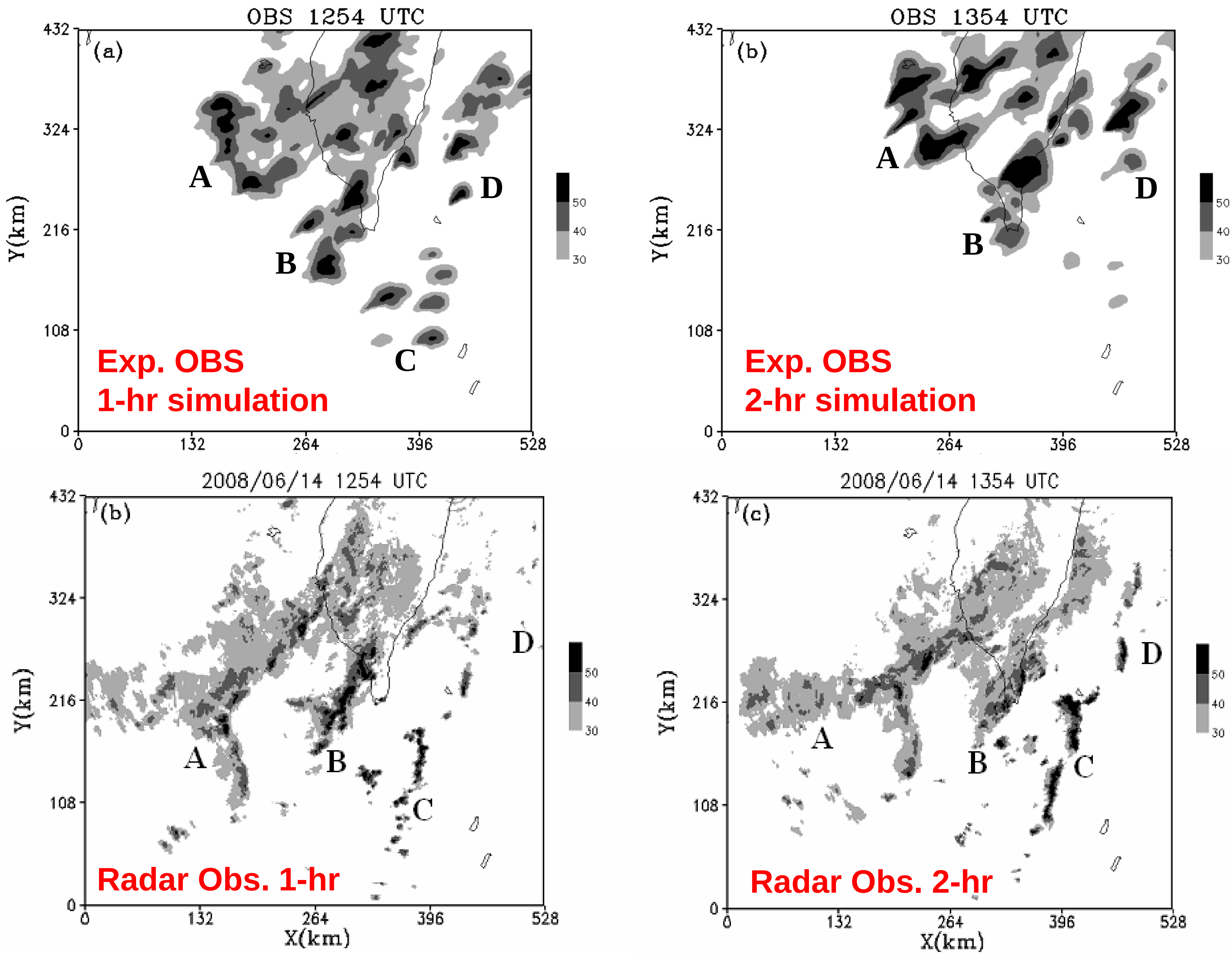
(1) VDRAS can retrieve reasonable kinematic and thermodynamic features after assimilating radar data.

(2) VDRAS can reflect the topographic effects, although it does not resolve the terrain explicitly.

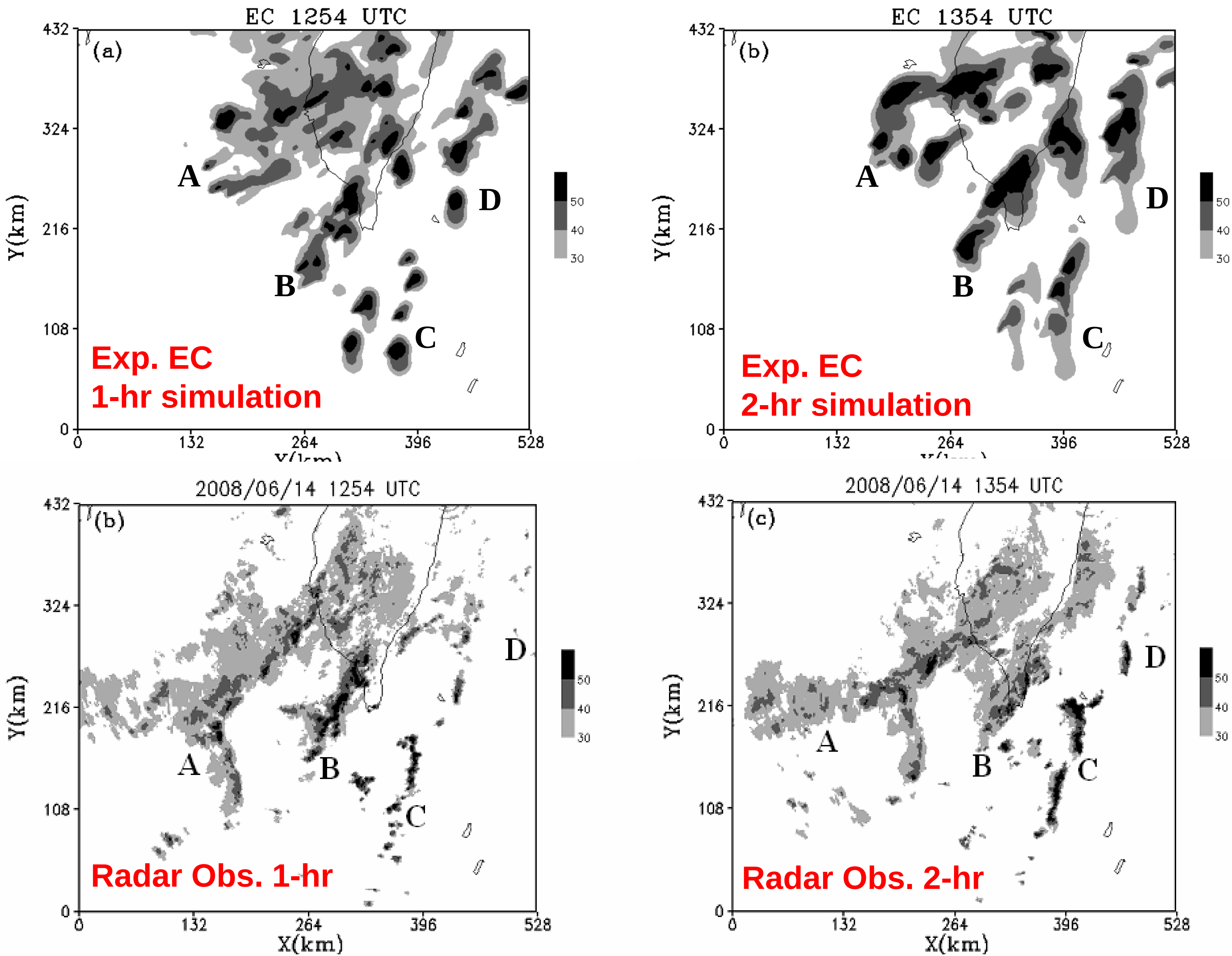
VDRAS simulation:

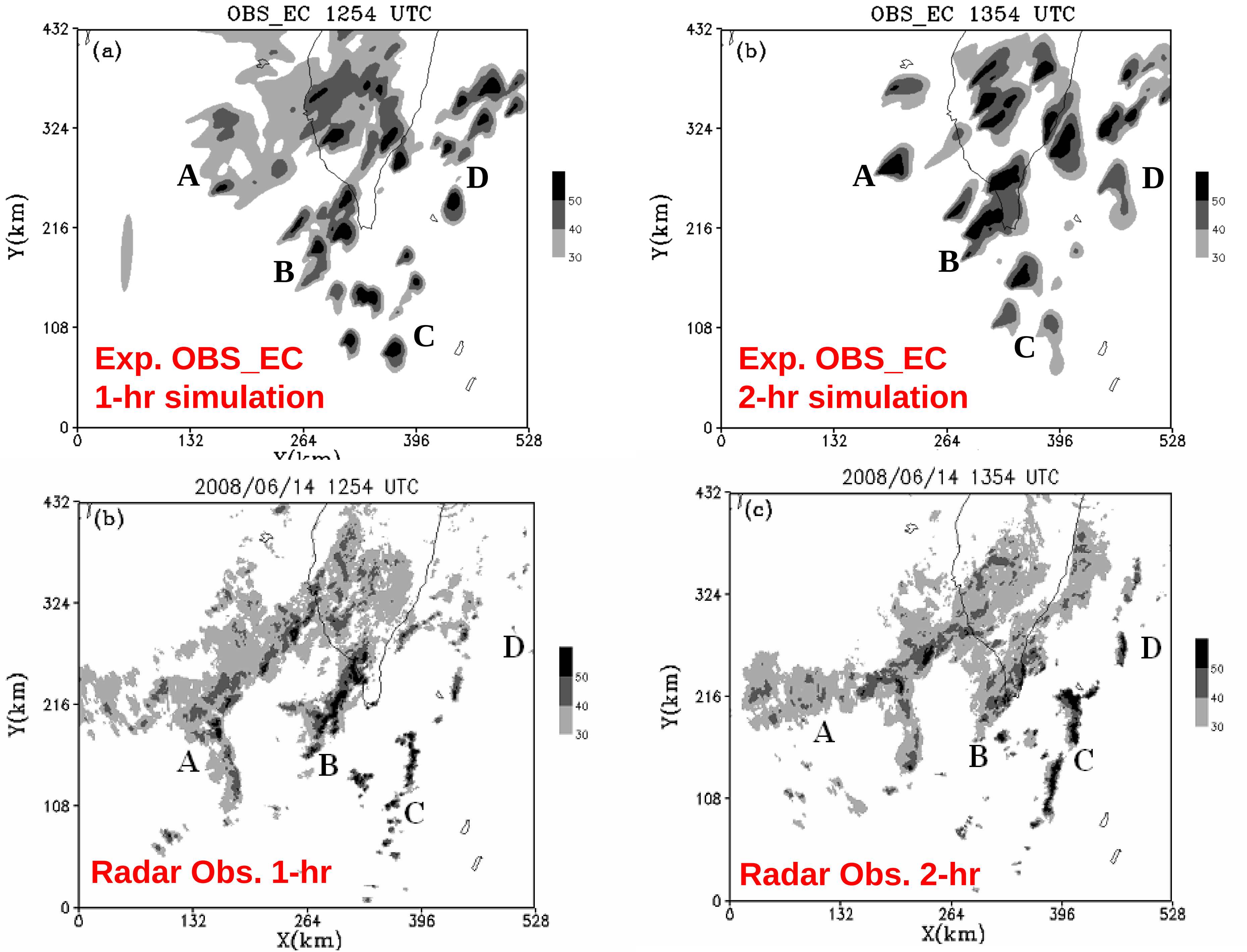
Sensitivity of model forecasts to different background fields

Experiment OBS (in-situ obs. only)
Experiment EC (ECMWF only)
Experiment OBS_EC (Both)

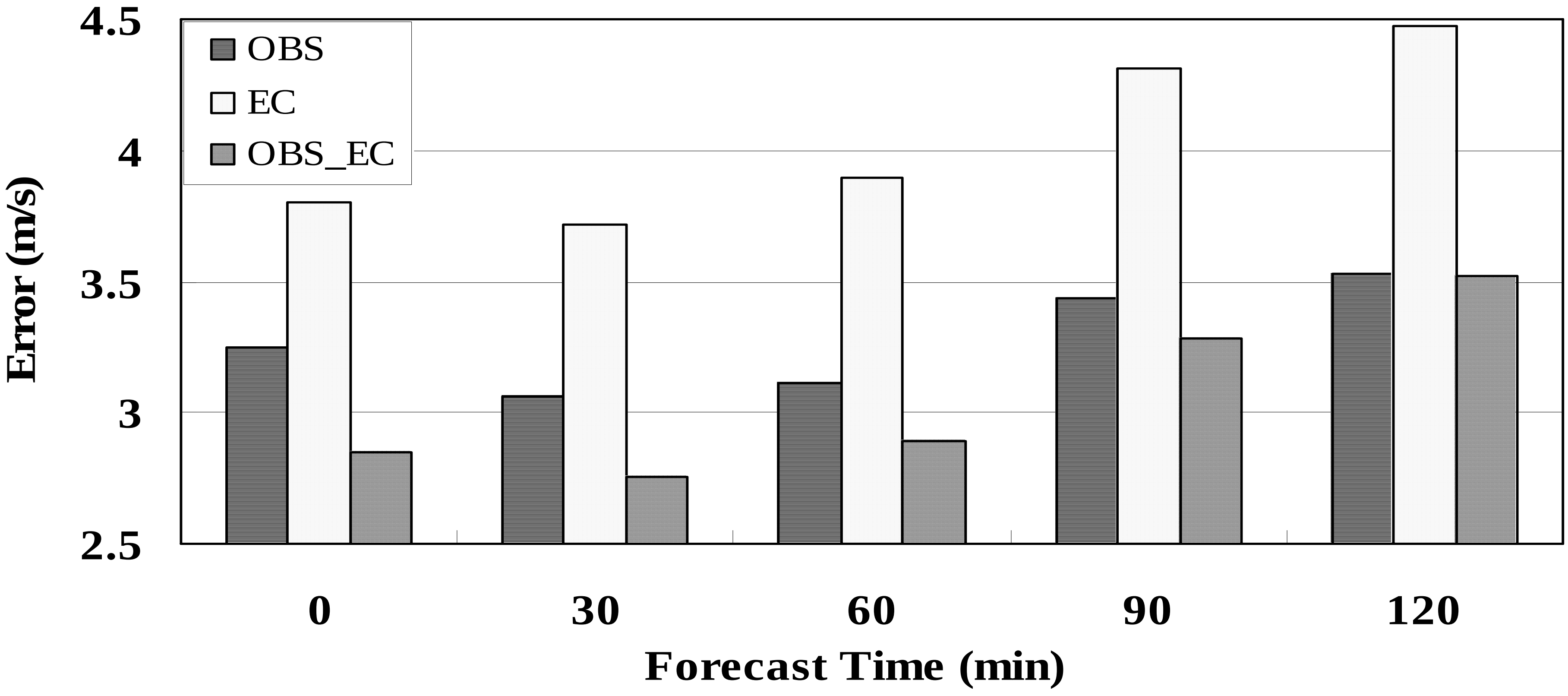


OBS 1254 UTC
(a)
A
B
C
D
Exp. OBS
1-hr simulation
OBS 1354 UTC
(b)
Exp. OBS
2-hr simulation
2008/06/14 1254 UTC
(b)
Radar Obs. 1-hr
2008/06/14 1354 UTC
(c)
Radar Obs. 2-hr
Y(km)
X(km)
0
108
216
324
432
132
264
396
528
30
40
50

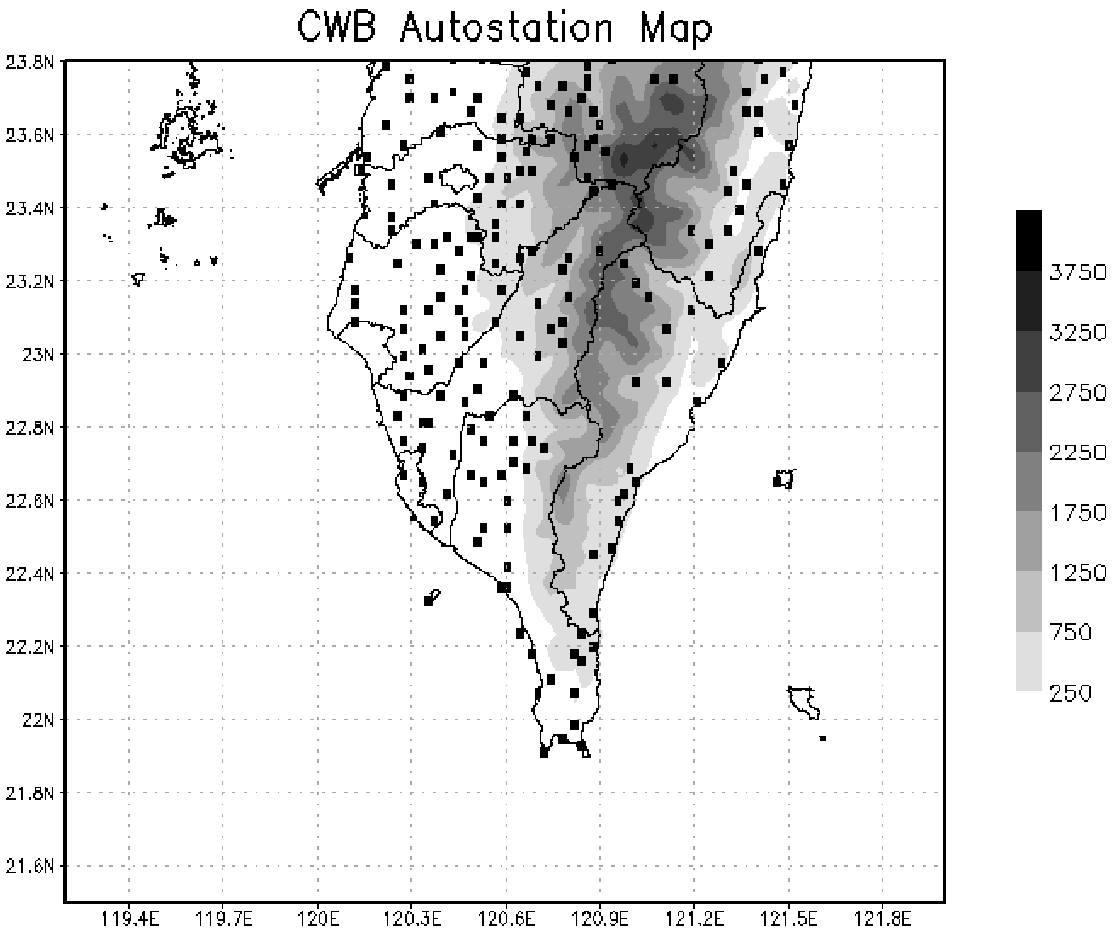

EC 1254 UTC
(a)
A
B
C
D
Exp. EC
1-hr simulation
EC 1354 UTC
(b)
Exp. EC
2-hr simulation
2008/06/14 1254 UTC
(b)
Radar Obs. 1-hr
2008/06/14 1354 UTC
(c)
Radar Obs. 2-hr
Y(km)
X(km)
0
108
216
324
432
132
264
396
528
30
40
50


OBS_EC 1254 UTC
(a)
A
B
C
D
Exp. OBS_EC
1-hr simulation
OBS_EC 1354 UTC
(b)
A
B
C
D
Exp. OBS_EC
2-hr simulation
2008/06/14 1254 UTC
(b)
A
B
C
D
Radar Obs. 1-hr
2008/06/14 1354 UTC
(c)
A
B
C
D
Radar Obs. 2-hr
Y(km)
X(km)
50
40
30

Root-mean-square error of predicted radial wind from OBS, EC, OBS_EC (verified against S-POL)



Surface rain gauge



Evaluation of QPF

$$\mathrm{ETS} = \frac{\mathrm{H} - \mathrm{R}}{\mathrm{F} + \mathrm{O} - H - R}$$

H: Correct forecast

F: # positive forecast

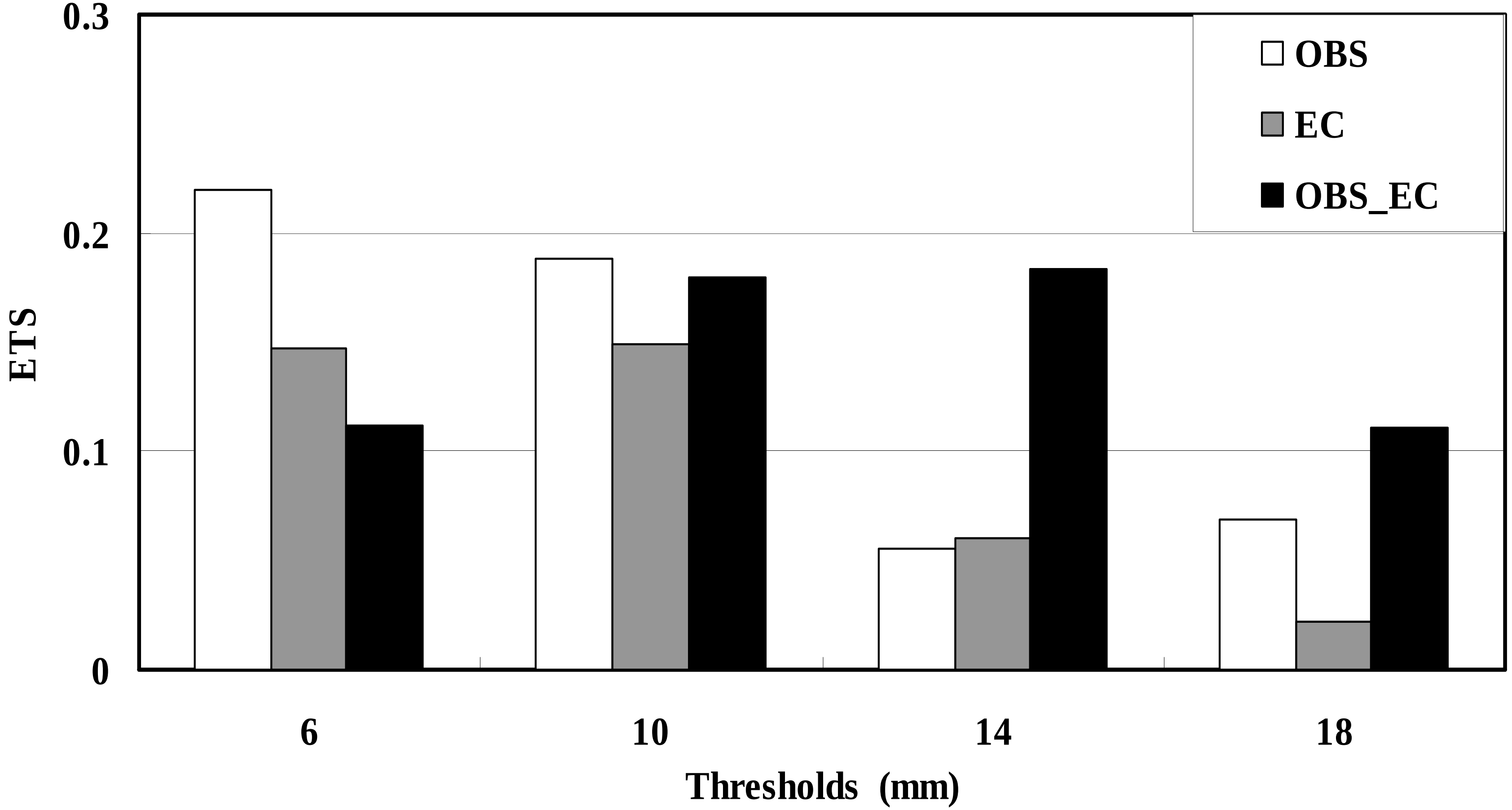
O: # observed event

R: # hit by chance

(2) RMSE of the 2-hr accumulated rainfall amount

(3) Spatial correlation coefficient (SCC)

ETS of predicted 2-h accumulated rainfall from Exp. OBS, EC, OBS-EC



SCC and RMSE of rainfall from Exp. OBS, EC, OBS_EC

	OBS	EC	OBS_EC
SCC	0.38	0.29	0.43
RMSE (mm)	7.9	9.6	8.5

Comparison among OBS, EC, OBS_EC

(1) ETS: EC < OBS and/or OBS_EC

(2) Rainfall (RMSE in mm):
OBS (7.96) < OBS_EC (8.50) < EC(9.64)

(3) SCC: OBS_EC(0.43) > OBS (0.38) > EC(0.28)

(4) Wind field is better predicted in OBS_EC

(5) Convection C disappeared in OBS, but well simulated in OBS_EC

(6) OBS_EC is considered the best.

Simulation by VDRAS alone
ETS : 0.1 ~ 0.2

No terrain.

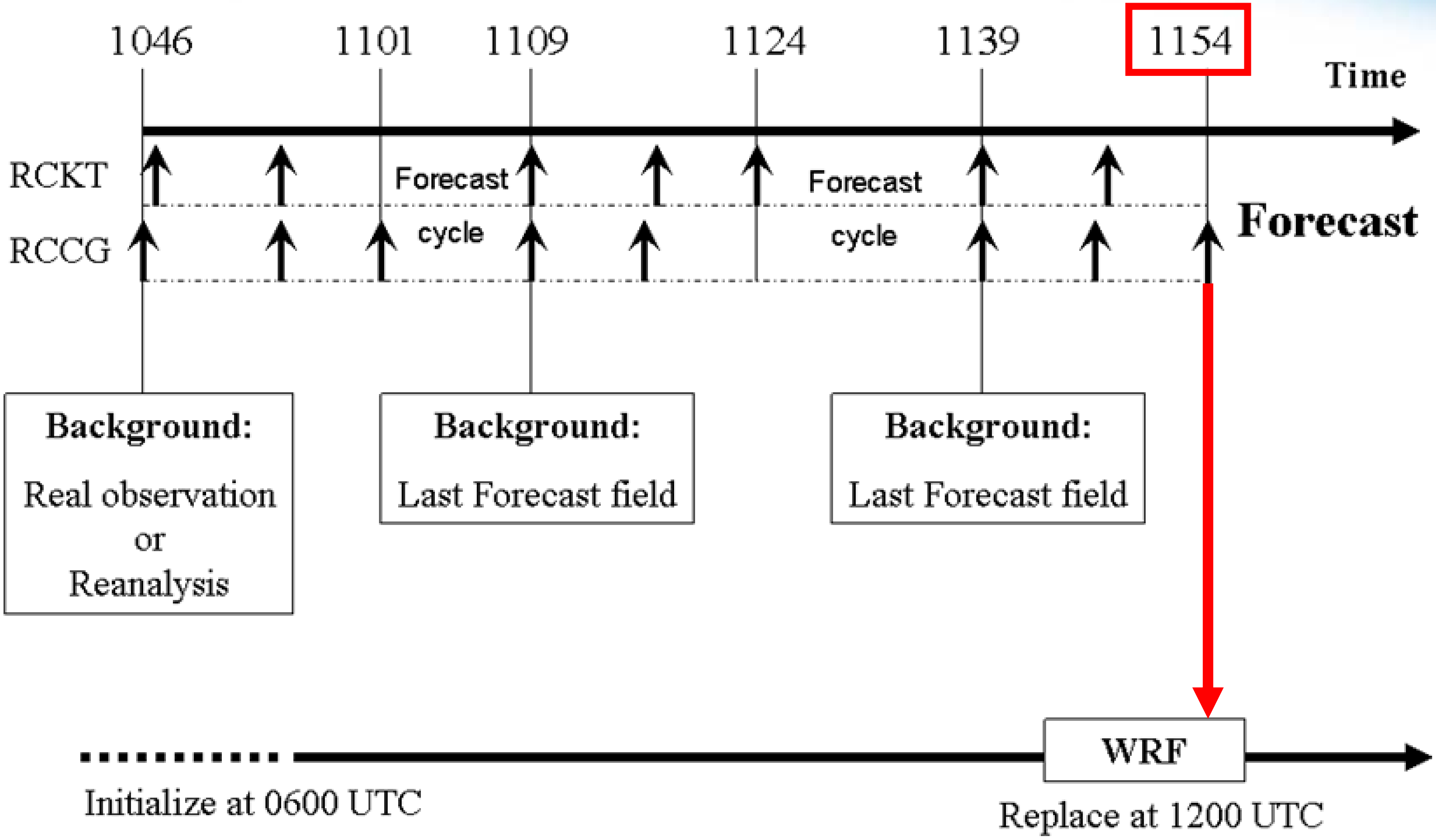
Needs to make further improvement.

VDRAS + WRF

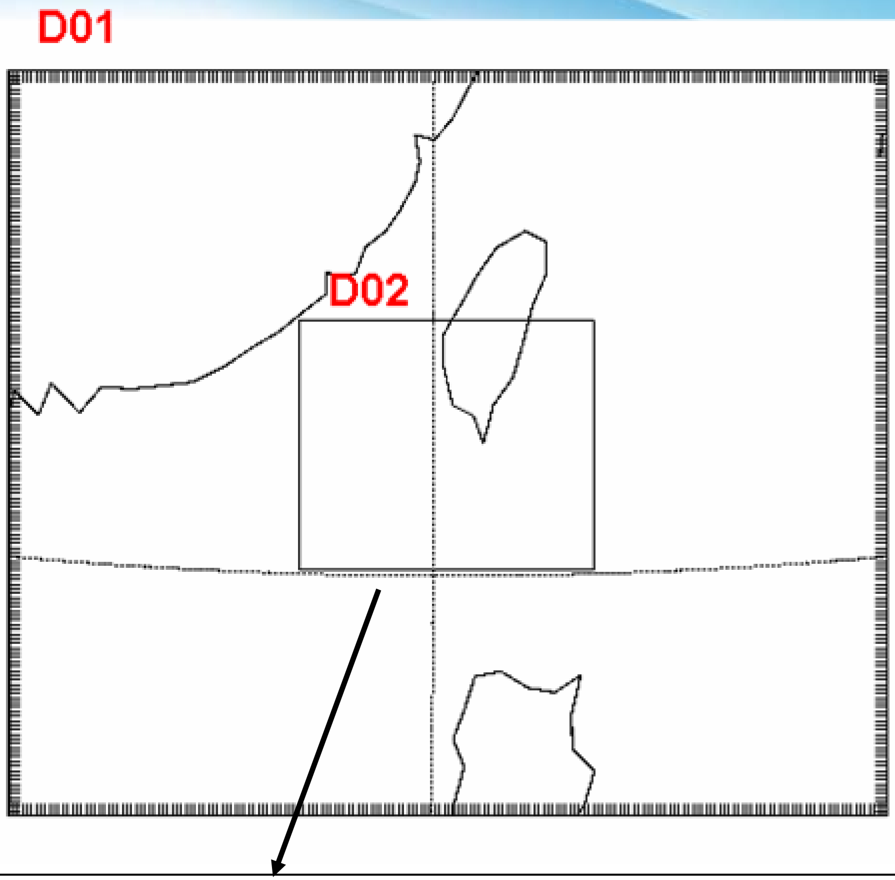
Why?

	VDRAS	WRF
Terrain	No	YES
Microphysical scheme	Kessler Warm rain (vapor, cloud, rain)	Lin et al. (1983) (vapor, cloud, rain, ice, snow, graupel)
Horizontal grid	Arakawa-C	Arakawa-C
Vertical grid	Flat surface	Follow-terrain

Experiment Design



VDRAS merged with WRF



Horizontal: D02 = VDRAS

Vertical: Interpolation by least square fitting

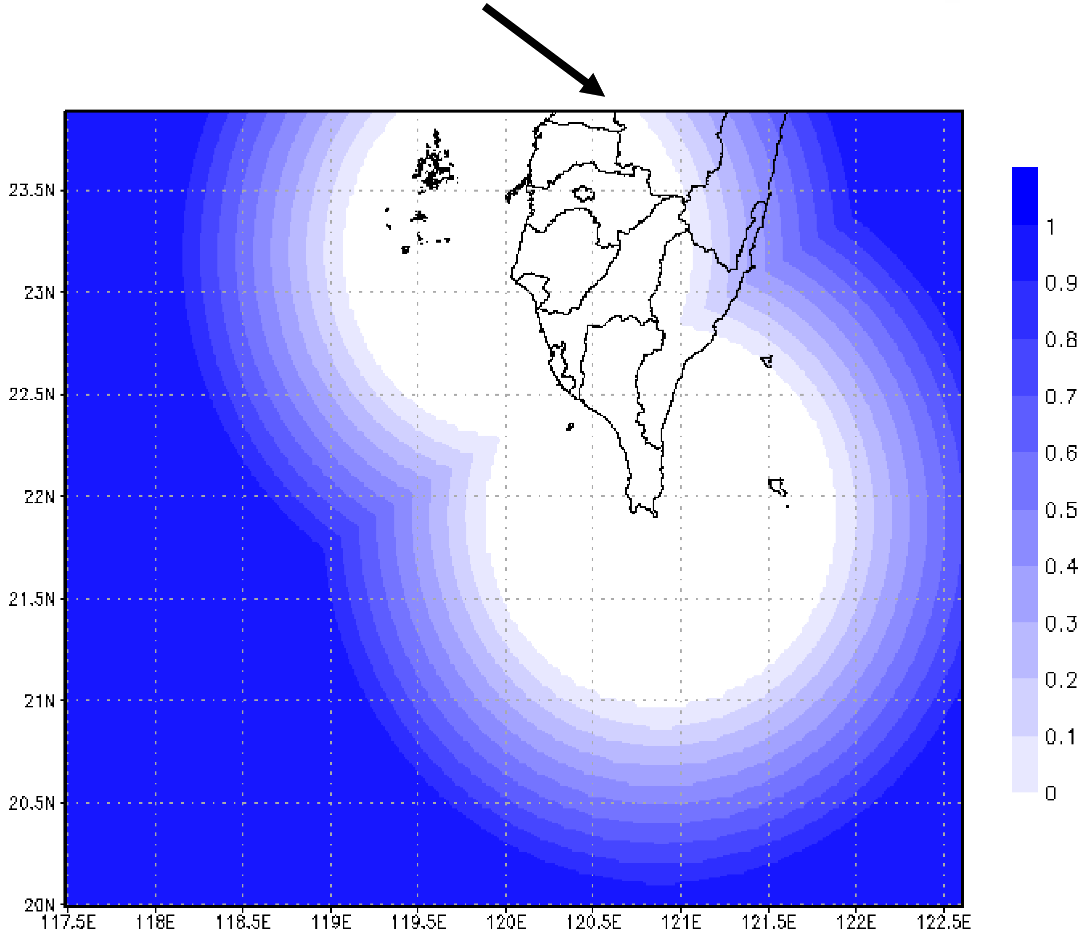
Two-way interactions allowed between D01 and D02

How to merge two models?

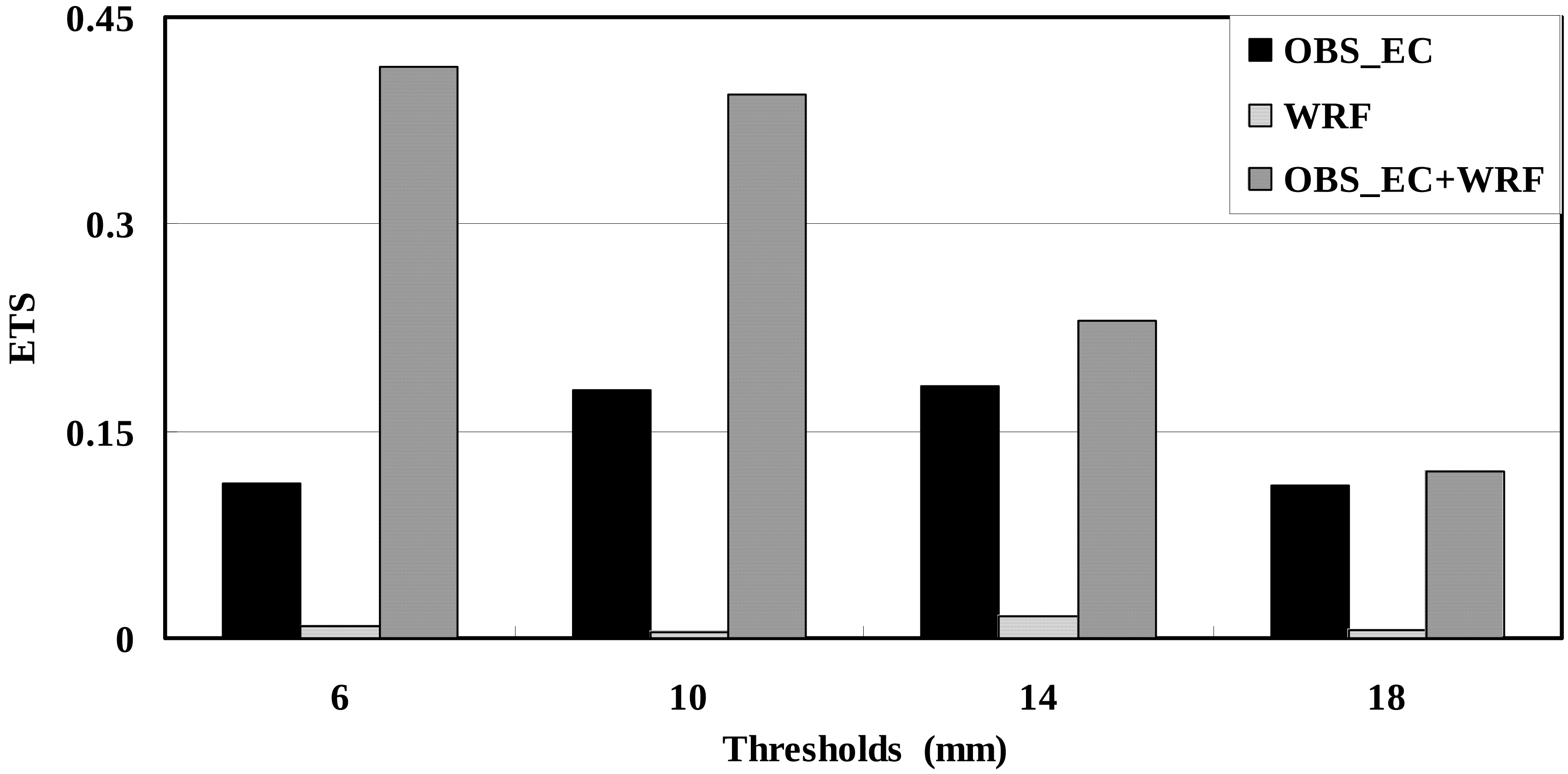
- u, v, w, θ', qv, qr, qc

  → a weighted average of VDRAS and WRF

- qi, qs, qg set to zero.

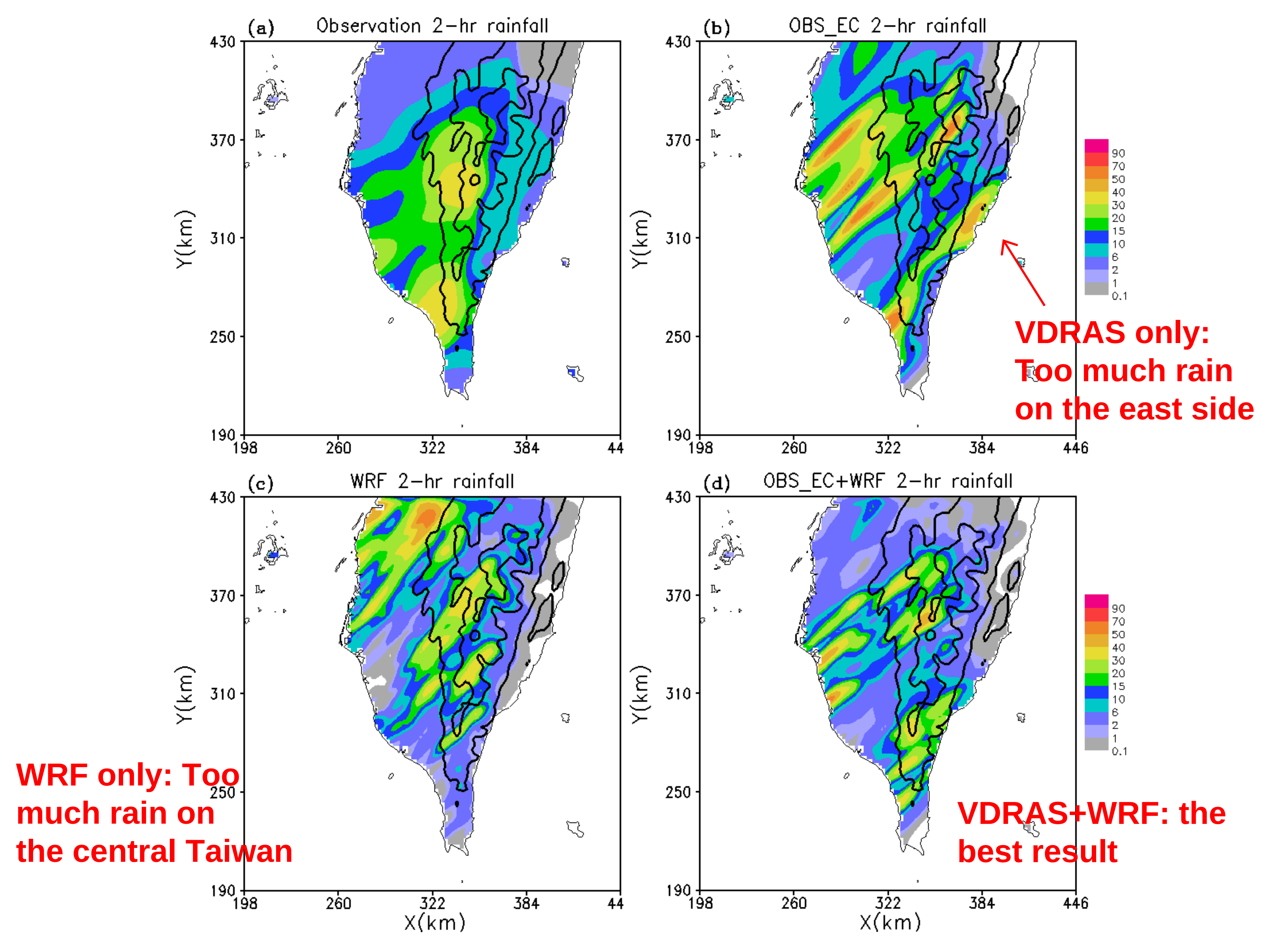


Weighting coefficient for WRF



RMSE (mm):OBS_EC+WRF (5.4) < OBS_EC (8.5) < WRF(10.0)

SCC :OBS_EC+WRF (0.68) > OBS_EC (0.43) > WRF(~ 0)



(a) Observation 2-hr rainfall
(b) OBS_EC 2-hr rainfall
(c) WRF 2-hr rainfall
(d) OBS_EC+WRF 2-hr rainfall
Y(km)
X(km)
430
370
310
250
190
198
260
322
384
446
90
70
50
40
30
20
15
10
6
2
1
0.1
VDRAS only: Too much rain on the east side
WRF only: Too much rain on the central Taiwan
VDRAS+WRF: the best result

Summary

- After assimilating radar data, VDRAS can provide reasonable analysis fields, even on terrain.
- If VDRAS is used alone for forecast, the background field better be a combination of in-situ observations and re-analysis data (or from a mesoscale model).
- Merge VDRAS with WRF improve the QPF skill significantly (radar data to VDRAS, terrain by WRF).
- This research provides a possible alternative to apply VDRAS in other regions with similar geographic condition and observational limitations.

Future work

- **More sophisticated way to merge VDRAS and WRF (e.g., variational adjustment)**
- **Add ice phase and terrain directly into VDRAS.**
- **Assimilate more radar data from MK, CCK, GI, S-POL.**

Thanks for attention!