冰相微物理對四維變分都卜勒雷達分析系統(VDRAS)於短時定量降雨預報之影響研究

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Outline

- **V**ariational **D**oppler **R**adar **A**nalysis **S**ystem (**VDRAS**)
- Ice-phase microphysics and squall line simulation
- Experiment results
  - -Observation System Simulation Experiments (OSSEs)
  - -Real case study
- Summary

Introduction

- Doppler radar observation with high resolution
  → convective scale research

- Data assimilation technique
  → proper initial conditions for NWP

- Developing radar data assimilation
  → improve the quantitative precipitation forecast (QPF) in Taiwan

- 3DVar、4DVar、EnKF　or　Hybrid

VDRAS

(Variational **D**oppler **R**adar **A**nalysis **S**ystem**)**

- Developed by Dr. Sun and Crook, NCAR

- cloud model with **4DVar** radar data assimilation
  →assimilate Doppler radial wind and reflectivity
  →retrieve 3D winds, thermodynamic field and microphysics
  →numerical forecast

-Field projects :

- Sydney 2000; Beijing 2008 Forecast Demonstration Project
- Severe Thunderstorm Electrification and Precipitation Study (STEPS)
- International H_2O Project (IHOP_2002)
- 2008 Southwest Monsoon Experiment (SoWMEX)

- **Original warm-rain process**

  q_r : rain water

  q_c : cloud water

  q_v : vapor

-No terrain version in this study (Cartesian coordinate)

■Cost function

$$J = (\mathbf{x}_o - \mathbf{x}_b)^{\mathrm{T}} \mathbf{B}^{-1} (\mathbf{x}_o - \mathbf{x}_b) + \sum_{\sigma,t} [\eta_v (V_r - V_r^o)^2 + \eta_q (q_r - q_r^o)^2] + J_p$$

Background term

Observation term

J_p: Penalty term

$\mathbf{X_0}$: model variables (u, v, w, θ_l , q_r , q_t)

$\mathbf{X_b}$: background information from the other sources (ex: another model, surface station, sounding)

B : covariance matrix of the background error

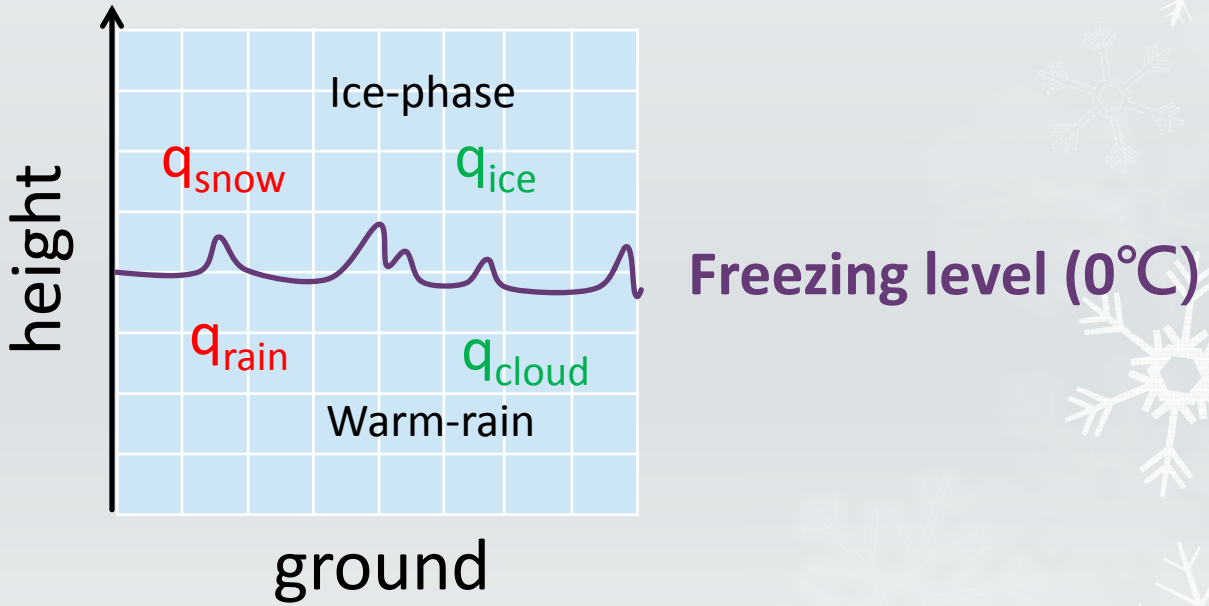
V_r^o , Z : observations of the **radial velocity** and **reflectivity**

Vr - (u,v,w) Relation: $v_r = \frac{x - x_r}{r} u + \frac{y - y_r}{r} v + \frac{z - z_r}{r} (w - V_T)$

Z - q_r Relation: $q_r = \frac{1}{\rho} 10^{[(Z-43.1)/17.5]}$

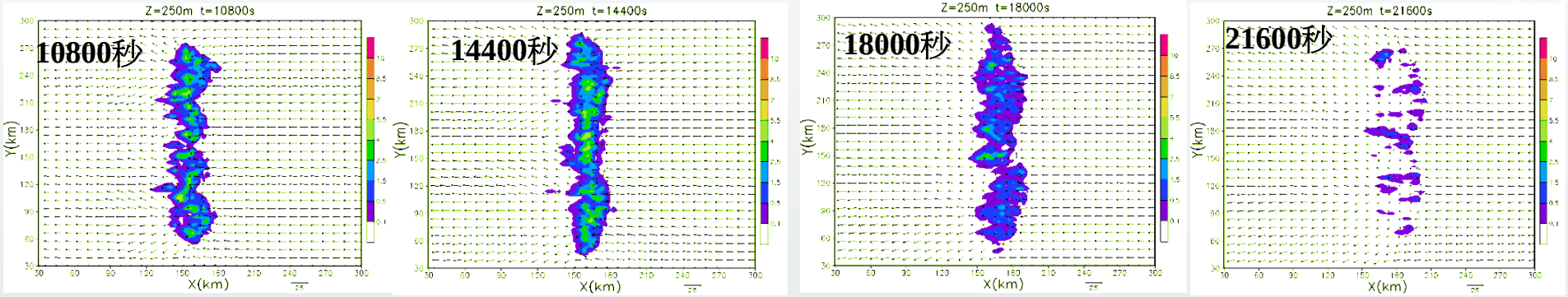
Ice-phase microphysics

- Kessler warm-rain + ice-phase (Dudia, 1989; Hong et.al., 2004) (Simple ice scheme/WSM3)
- No supercooled cloud ; No super warmed snow or ice crystals
- Storing snow/rain ($q_{r,s}$) in one array and cloud/ice ($q_{c,i}$) in another

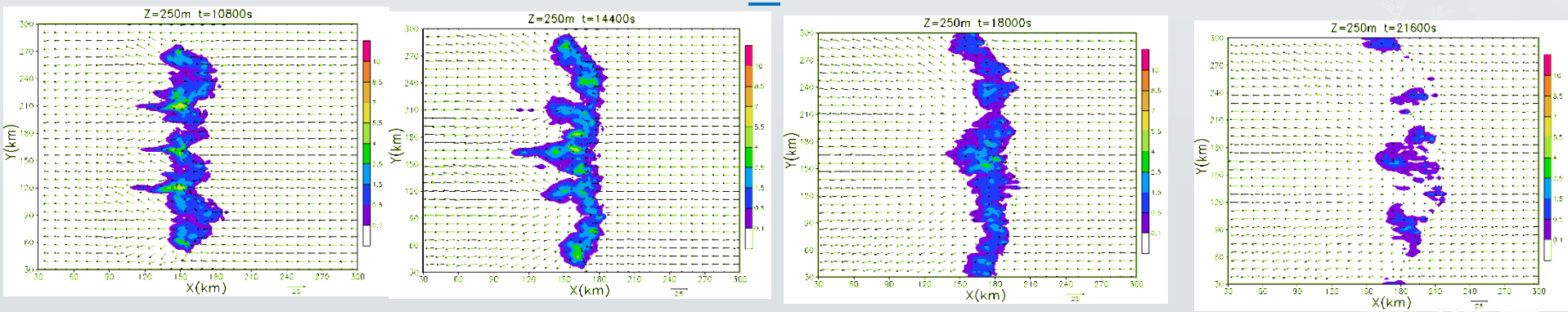


Squall line simulation

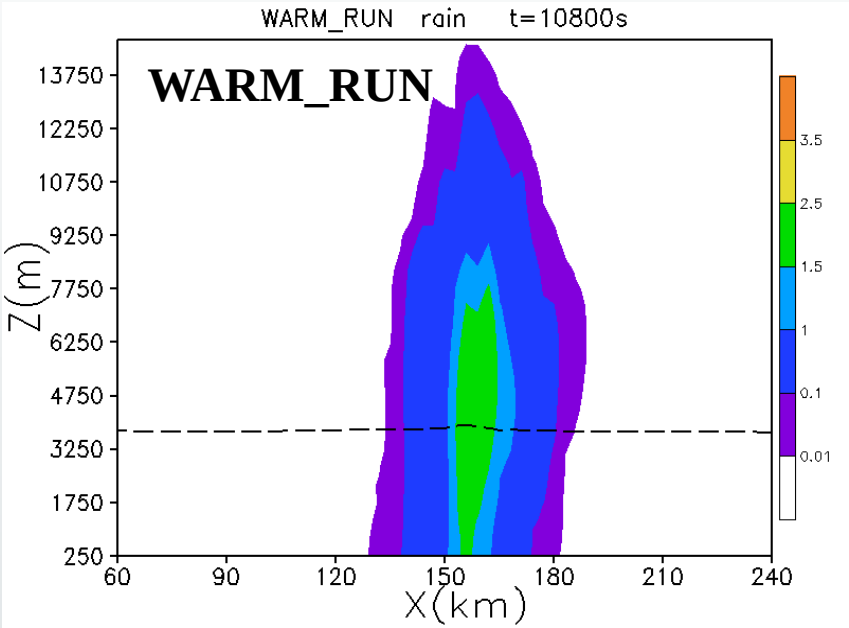
WARM_RUN

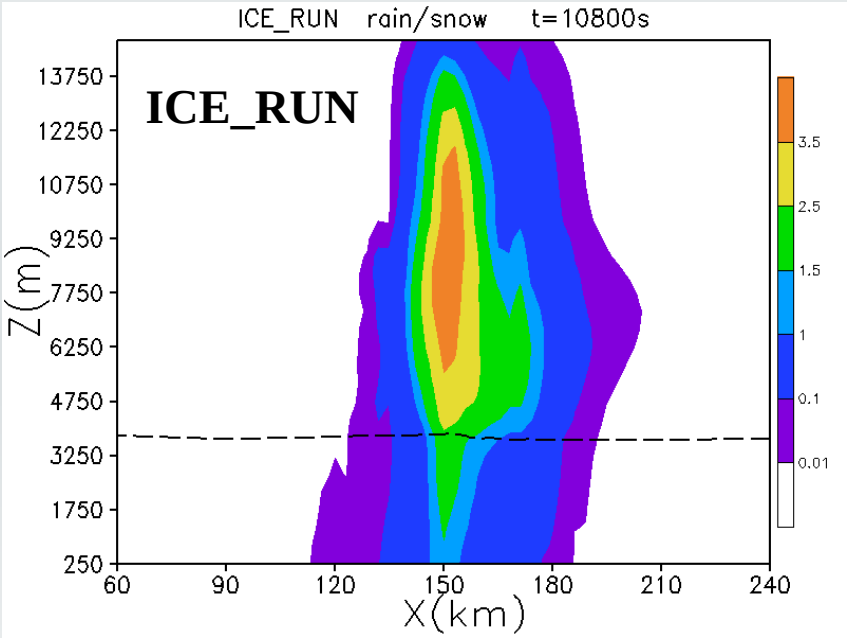


ICE_RUN

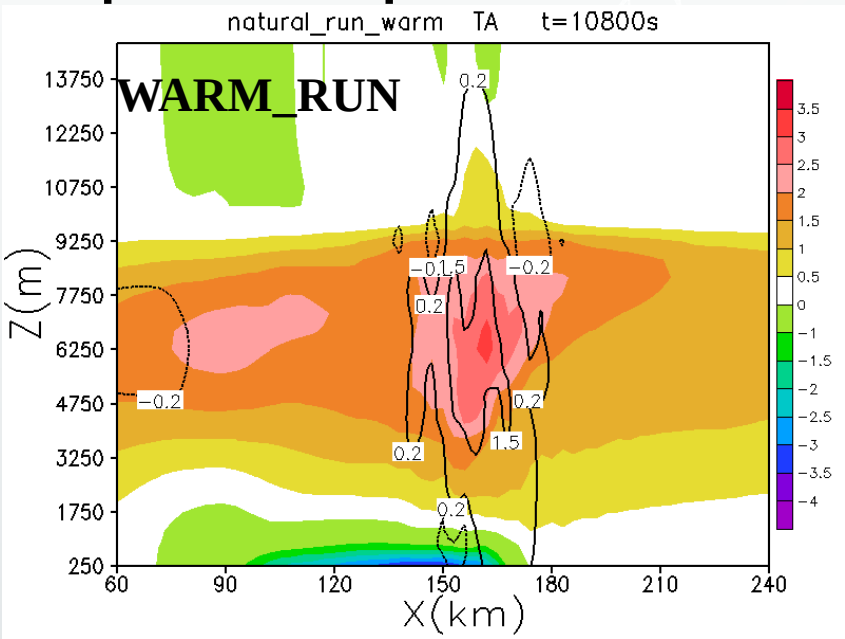


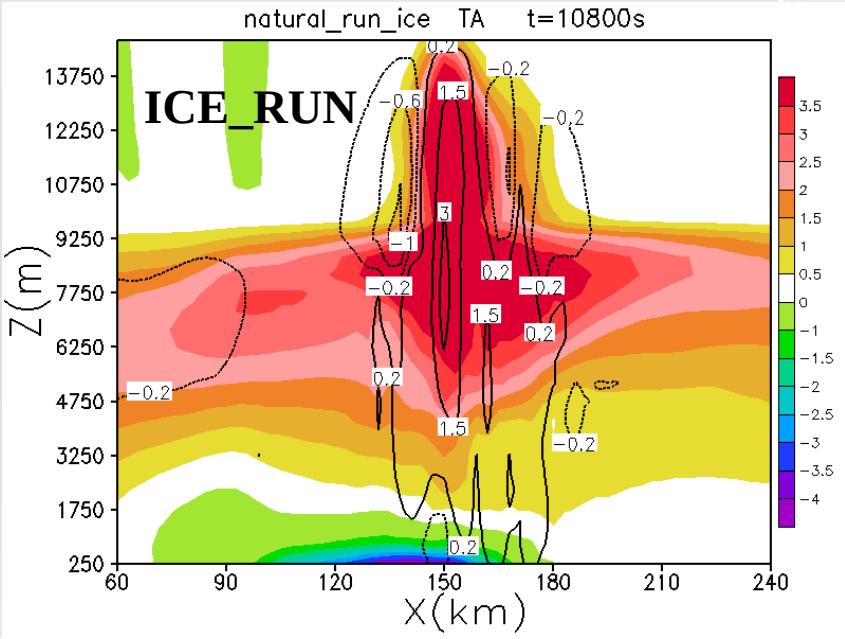
Line-averaged rain/snow water mixing ratio





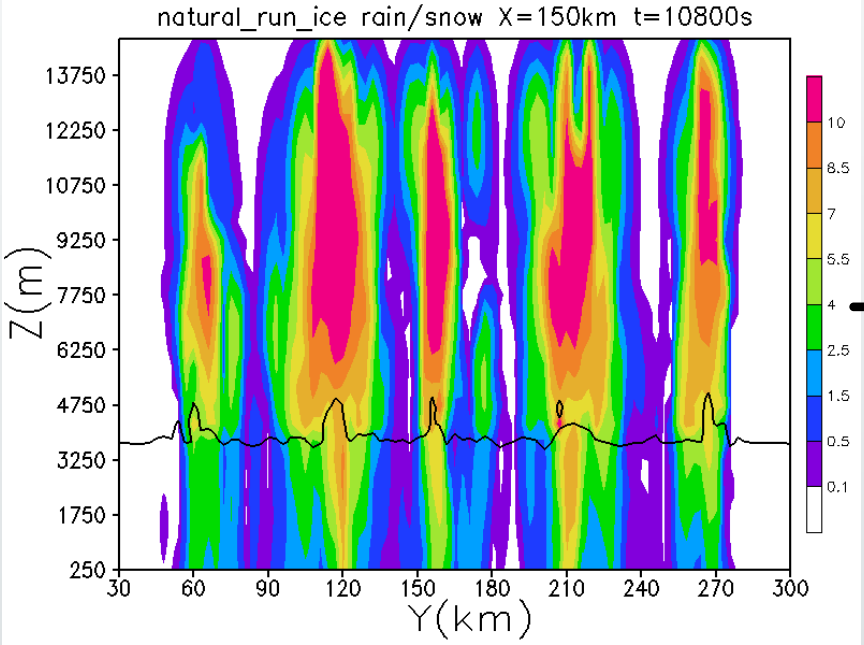
Vertical velocity (contour); temperature perturbation



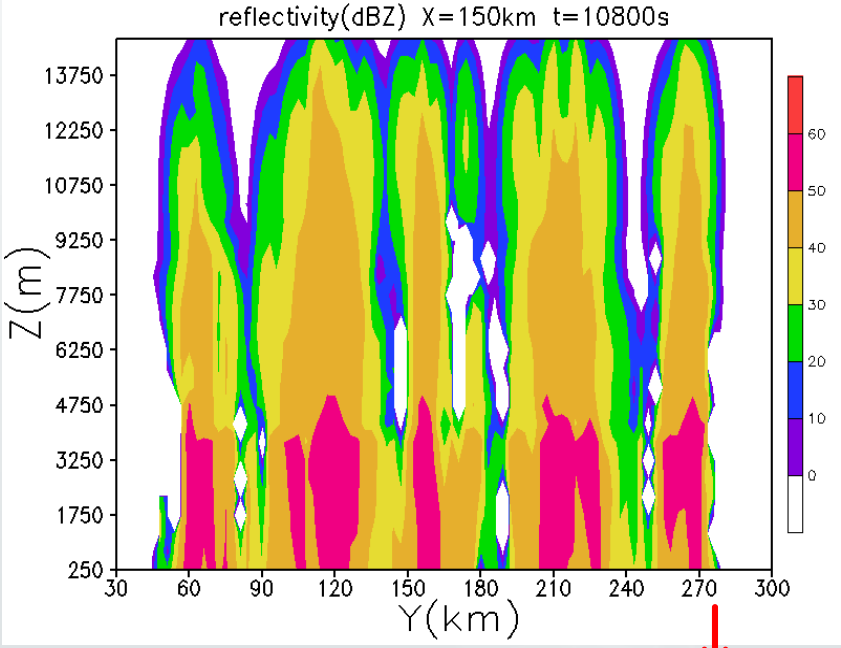


OSSEs

True_Run (ICE_RUN)
rain/snow water ($q_{r,s}$)



Simulated reflectivity (dBZ)



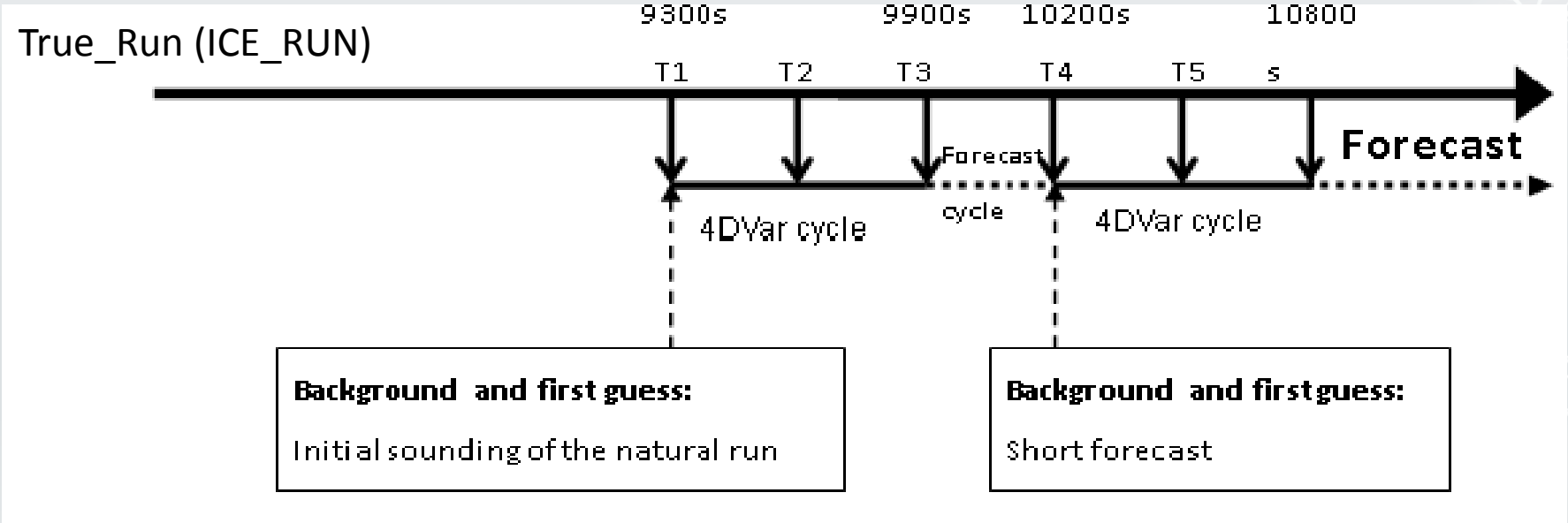
$$\text{rain}: Z = 43.1 + \log_{10}(\rho q_r)^{17.5}$$

$$\text{snow}: Z = 31.1 + \log_{10}(\rho q_s)^{17.5}$$

$$J_o = \sum_{\sigma,t}[\eta_v(V_r - V_r^o)^2 + \eta_q(q_{r,s} - q_{r,s}^o)^2]$$

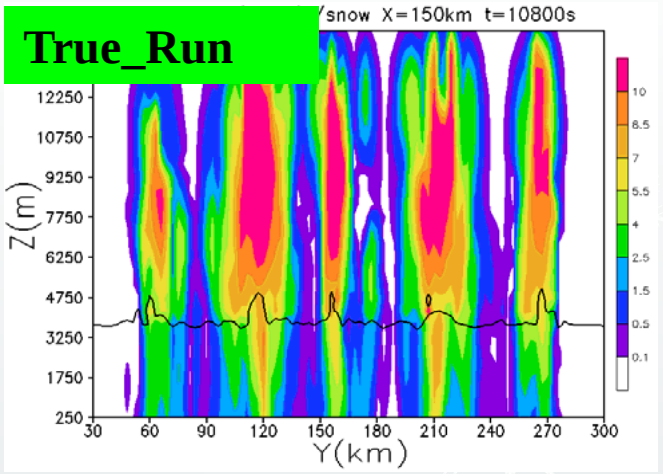
In real world:
Don't know the real freezing level.

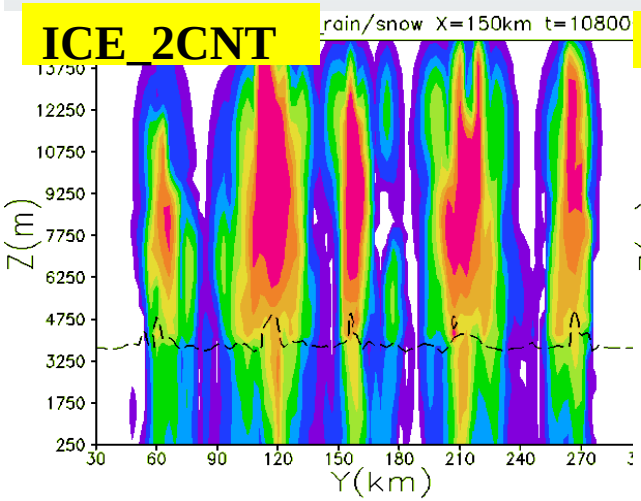
Experiment	Description
ICE_2CNT	referred freezing level from True_Run
WARM_2C	Only Warm-rain process
ICE_2C	referred freezing level: 1st cycle → initial field (sounding) 2nd cycle → short forecast

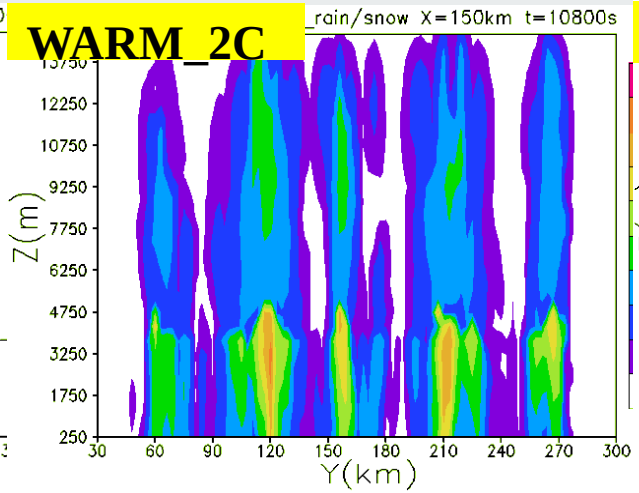


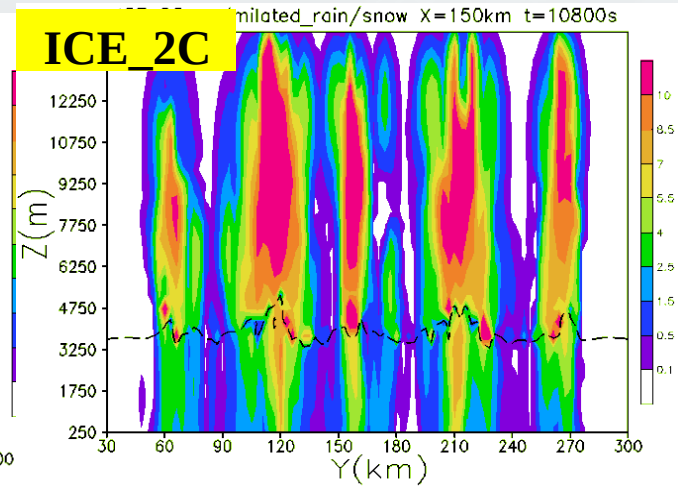
Observed (ready for assimilation) rain/snow mixing ratio (10800 s)

$$J_o = \sum_{\sigma,t} [\eta_v (V_r - V_r^o)^2 + \eta_q (q_{r,s} - q_{r,s}^o)^2]$$

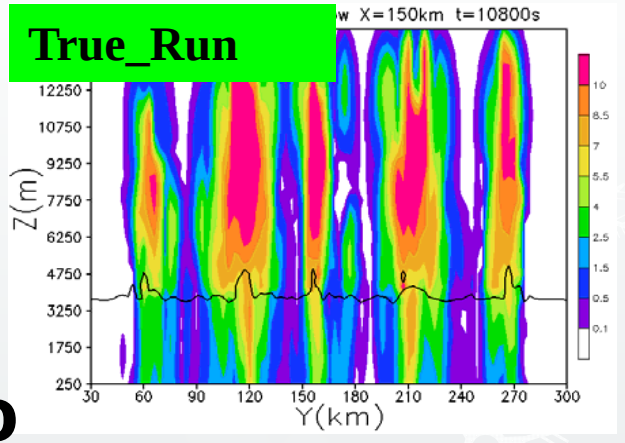


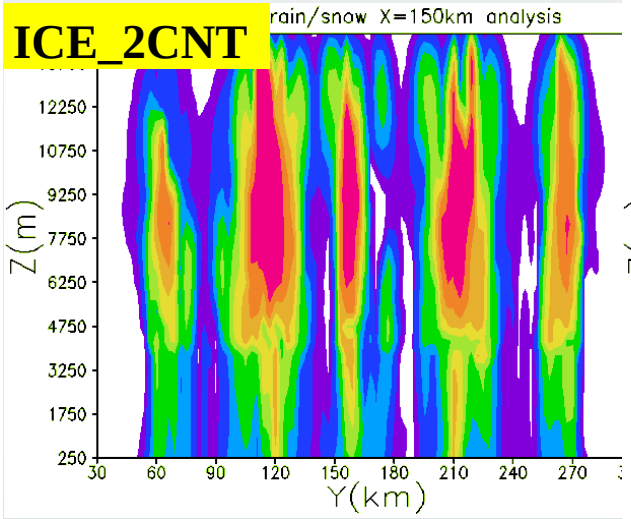


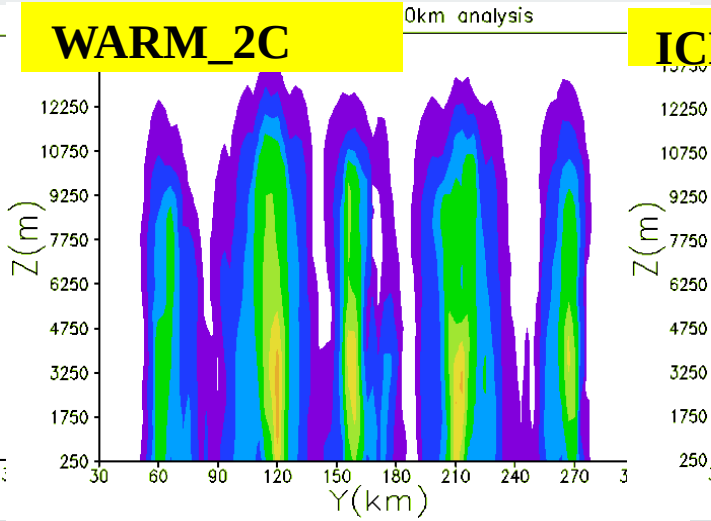


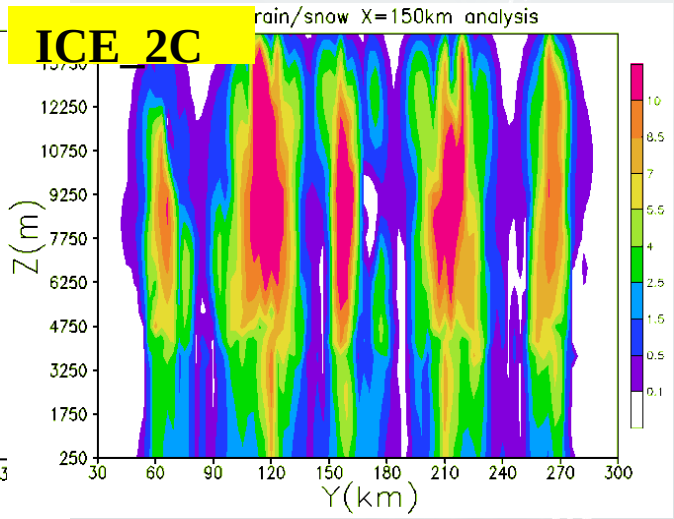


Analysis field (10800 s) : rain/snow water mixing ratio



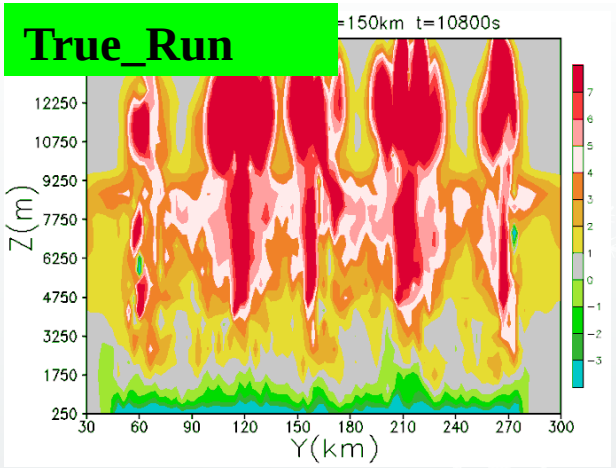




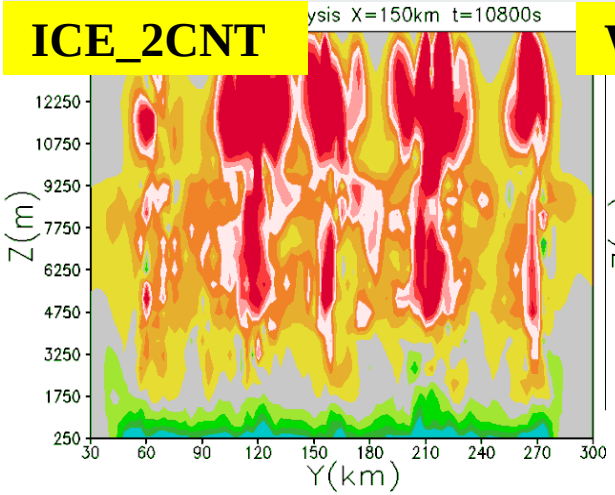


Analysis field (10800 s) : temperature perturbation

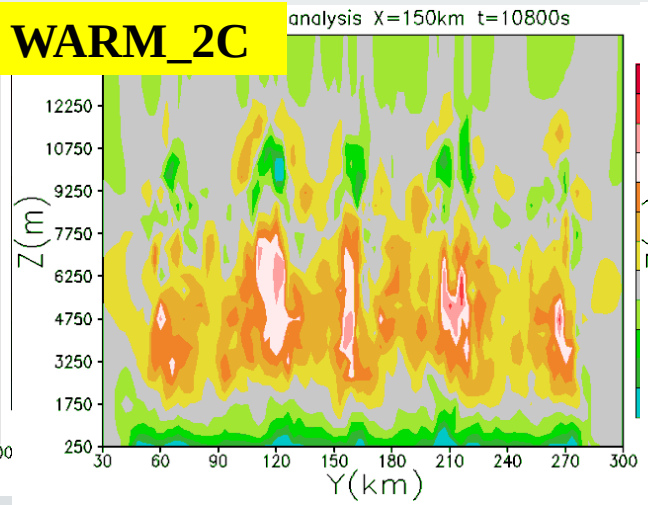
True_Run



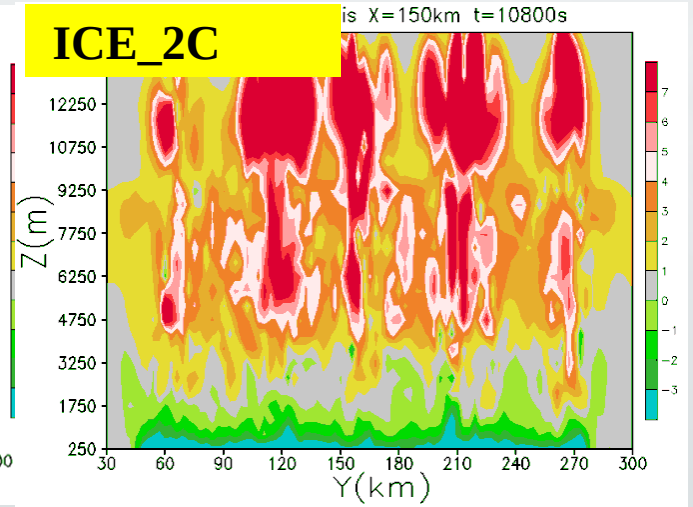
ICE_2CNT



WARM_2C

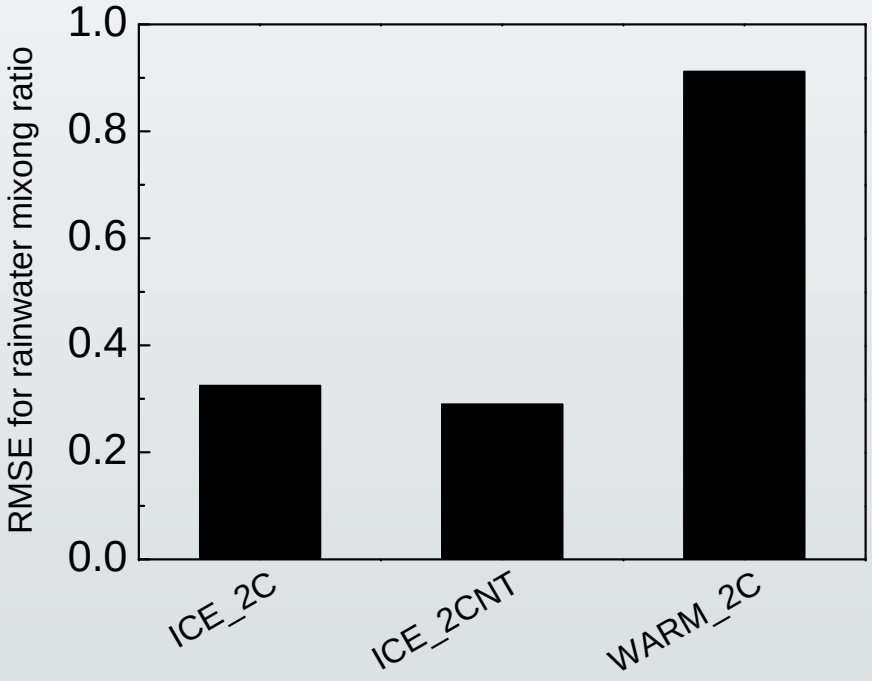


ICE_2C

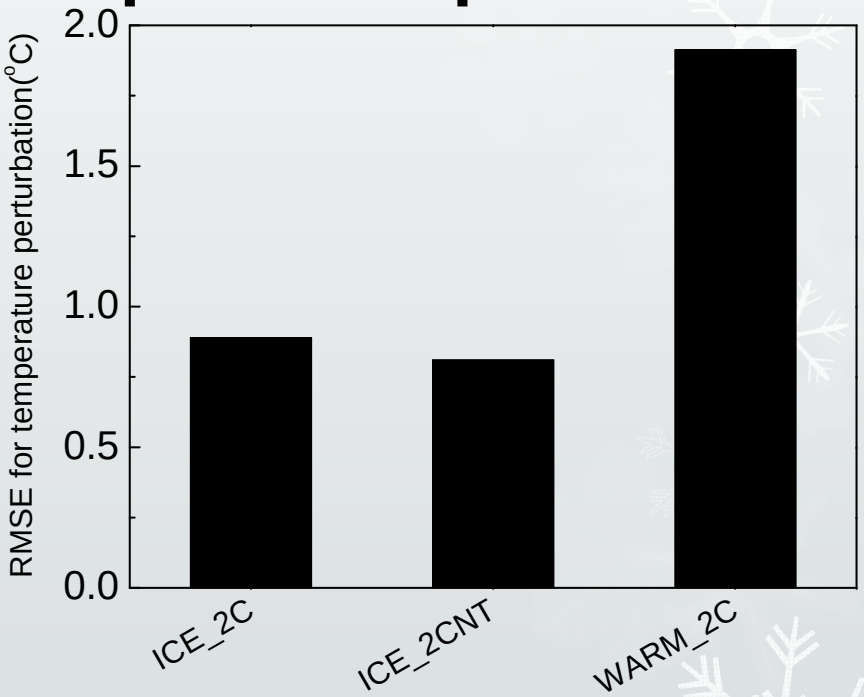


Root-mean-square error (analysis at 10800s)

rain/snow mixing ratio

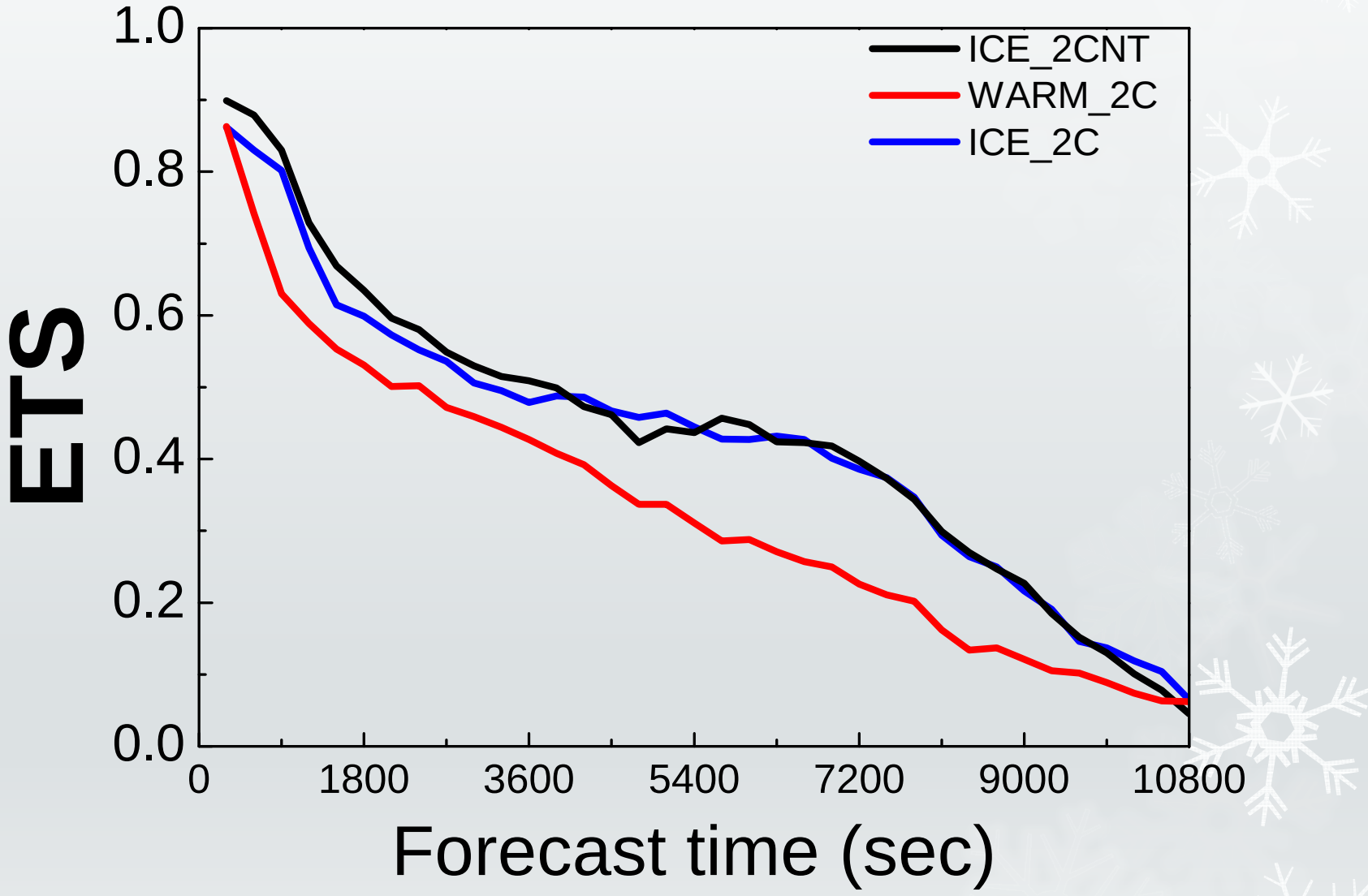


temperature perturbation



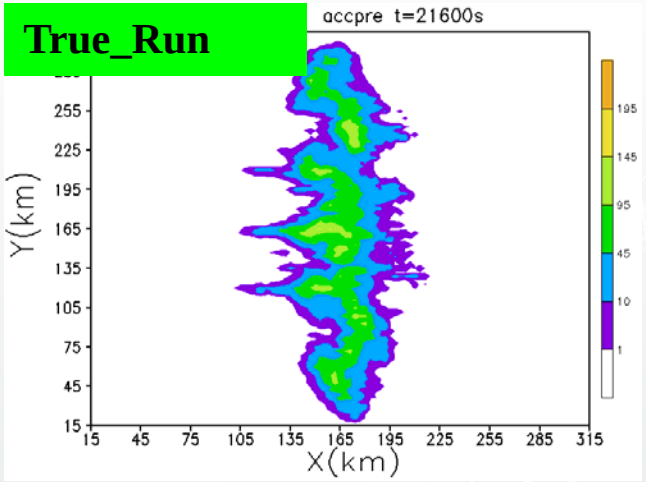
Rain fall forecast skill : Equitable Threat Score (ETS)

ETS threshold : 1.25mm $(5min)^{-1}$

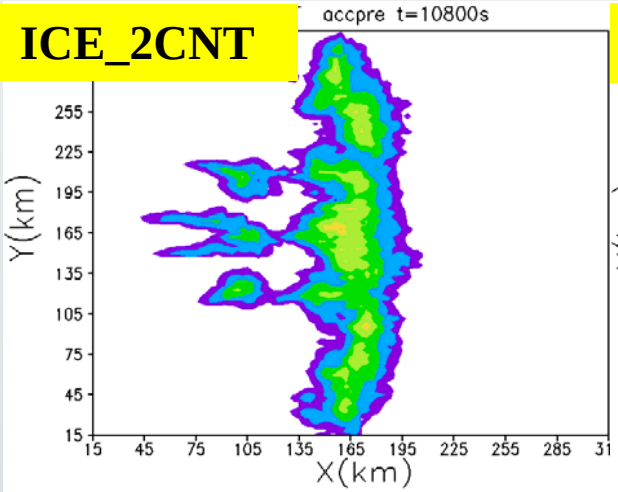


3 hours accumulated rain fall

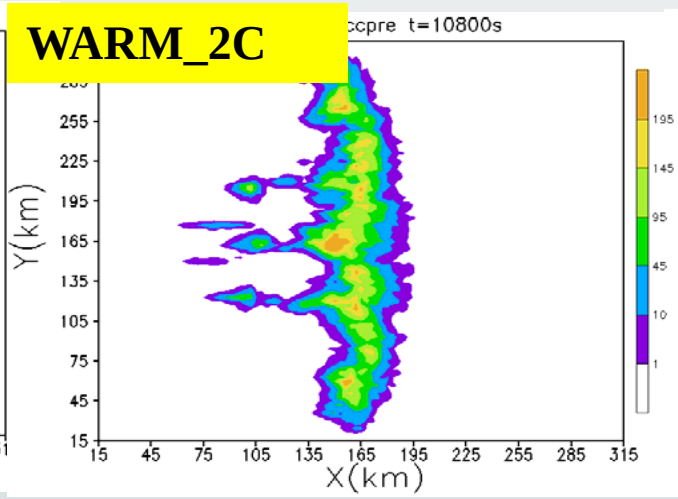
True_Run



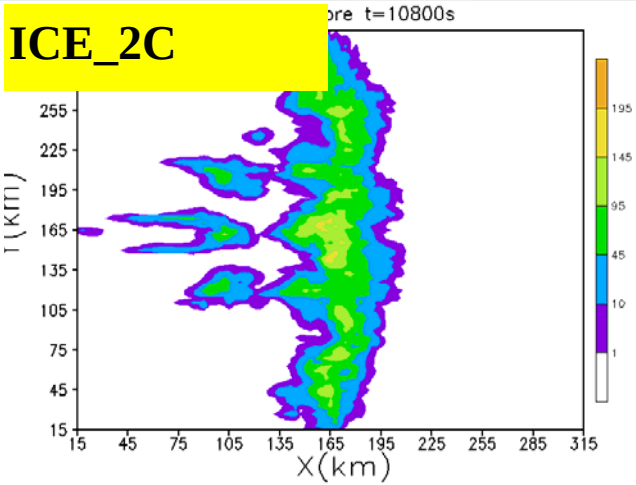
ICE_2CNT



WARM_2C



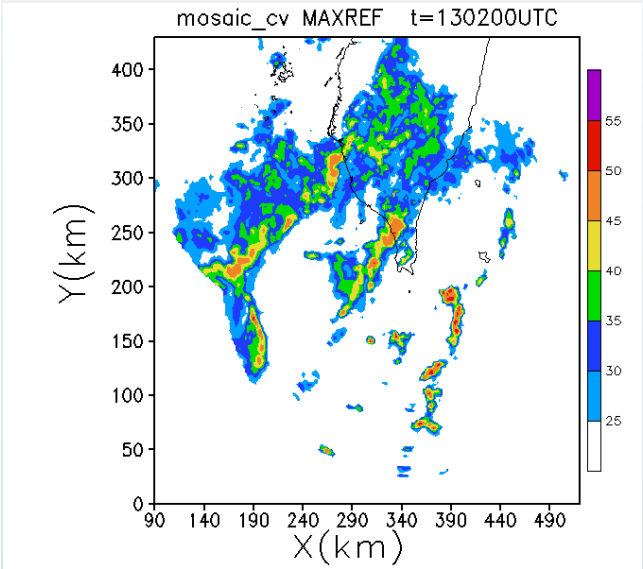
ICE_2C



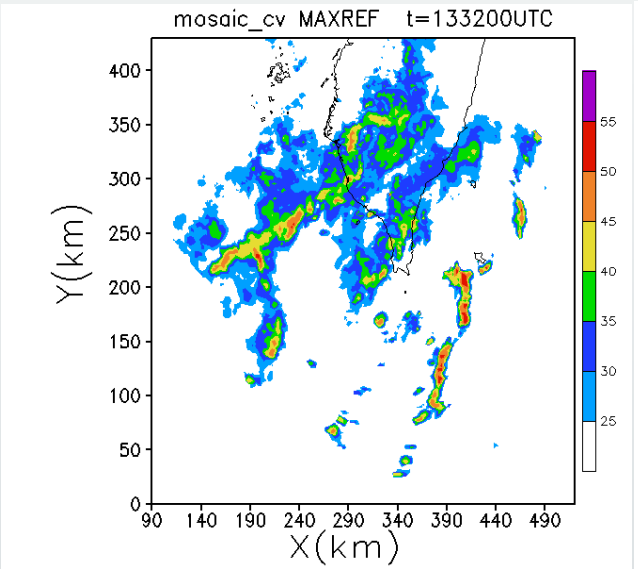
Real case

2008 SoWMEX IOP #8 June/14

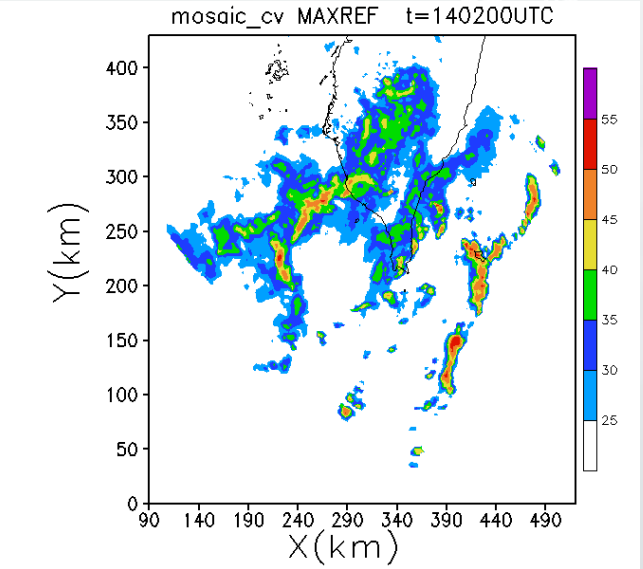
1302UTC

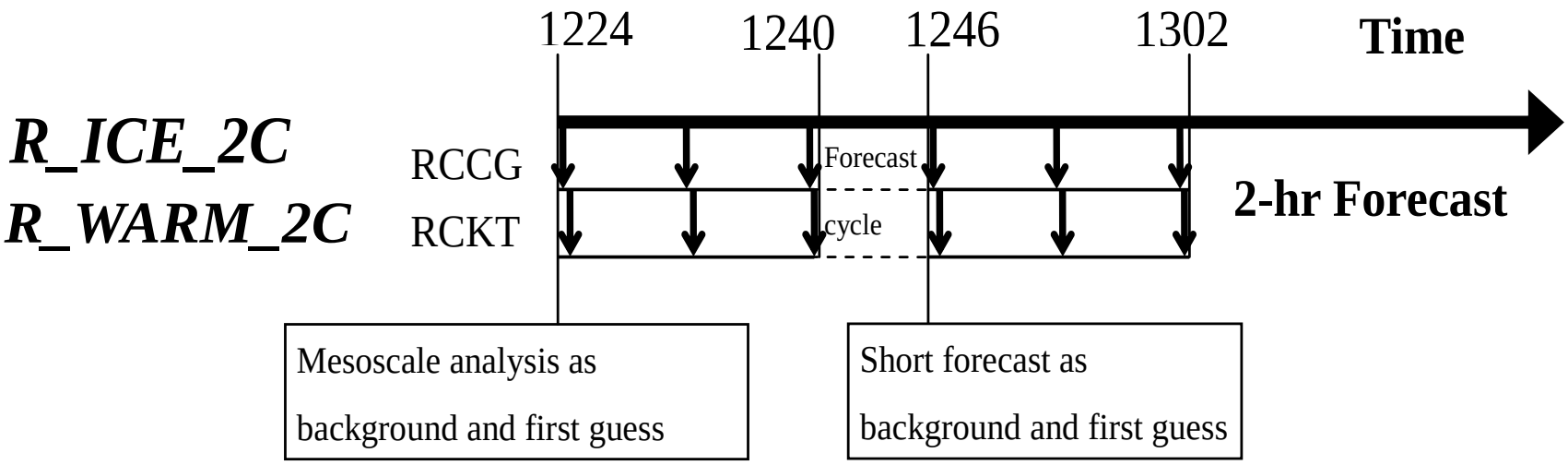


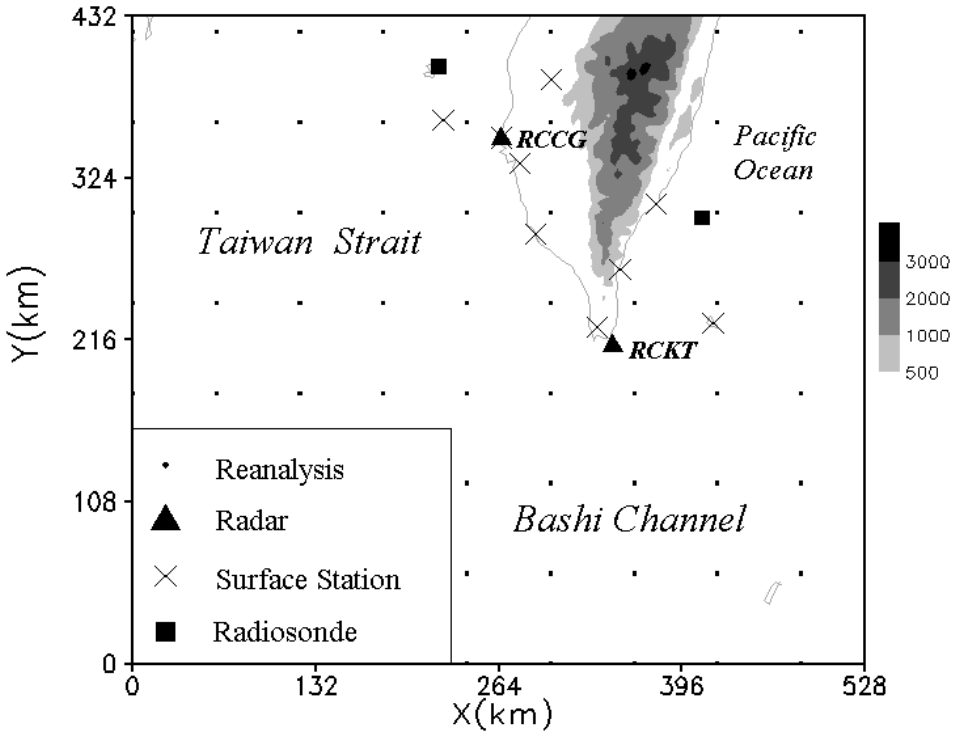
1332UTC



1402UTC



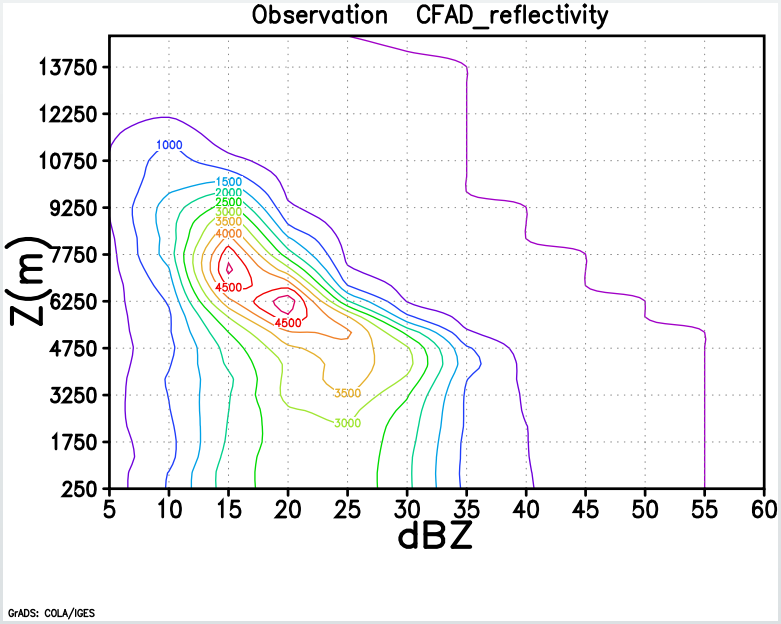

1224
1240
1246
1302
Time
R_ICE_2C
R_WARM_2C
RCCG
RCKT
Forecast
cycle
2-hr Forecast
Mesoscale analysis as background and first guess
Short forecast as background and first guess


432
324
216
108
0
Y(km)
0
132
264
396
528
X(km)
RCCG
RCKT
Pacific Ocean
Taiwan Strait
Bashi Channel
3000
2000
1000
500
Reanalysis
Radar
Surface Station
Radiosonde

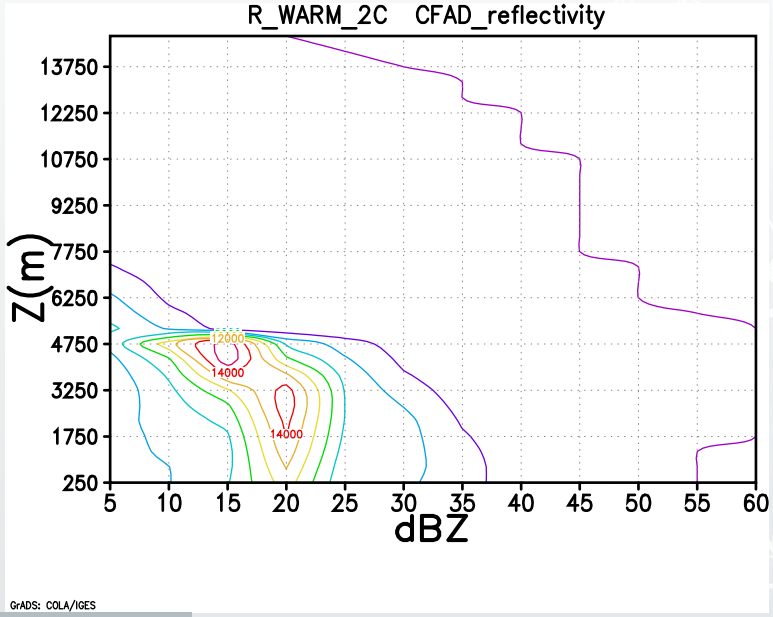
CFAD from reflectivity

1302UTC (analysis)

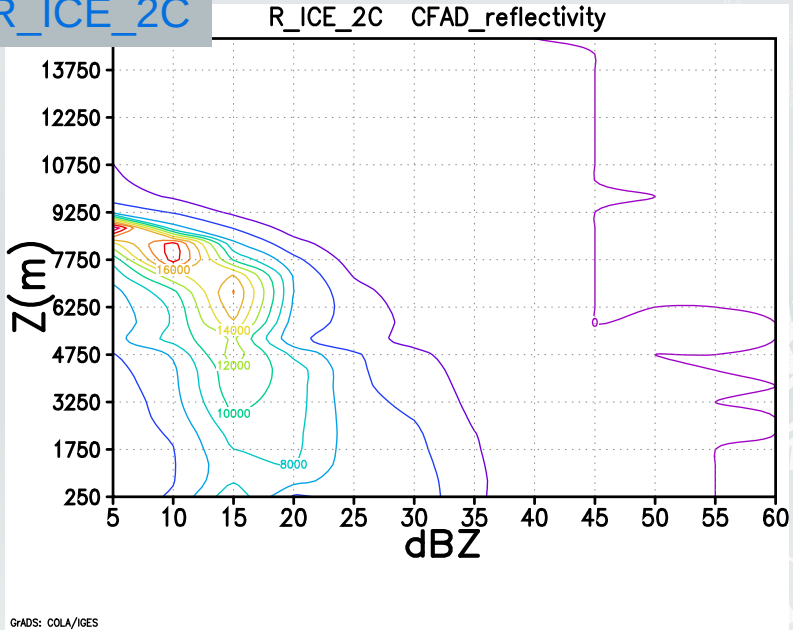
Observation



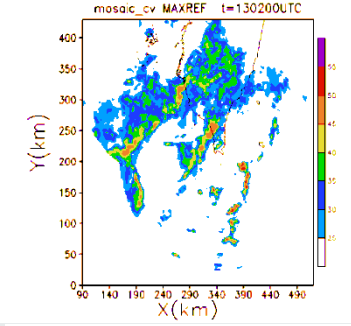
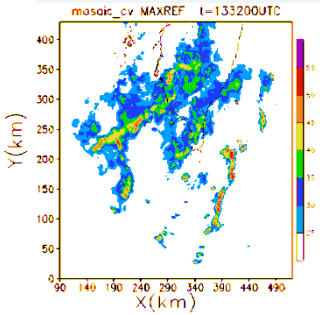
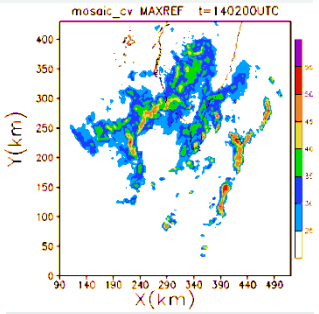
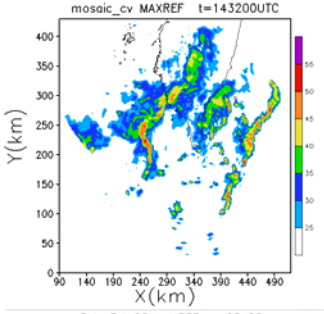
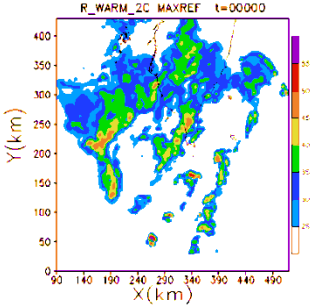
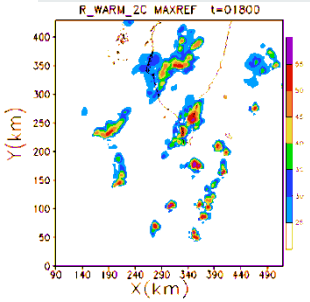
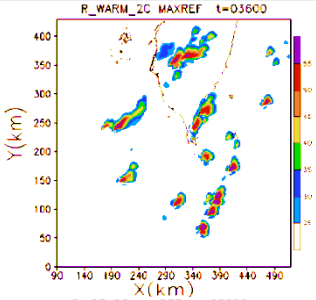
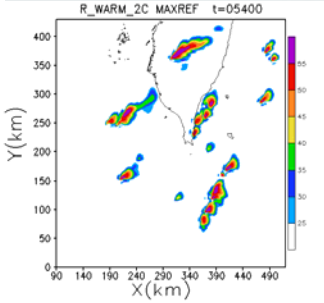
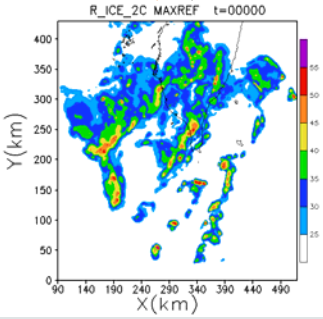
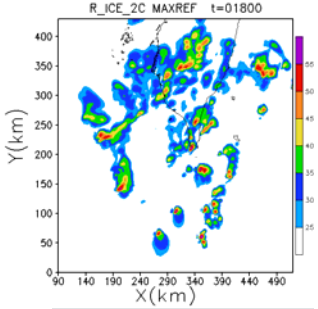
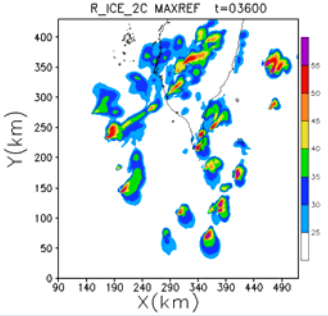
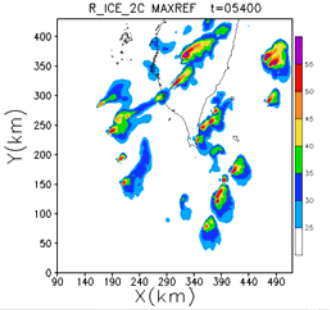
R_WARM_2C



R_ICE_2C

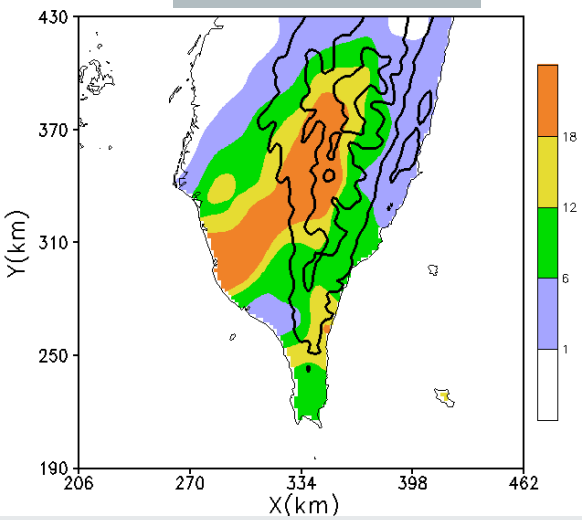


Maximum reflectivity

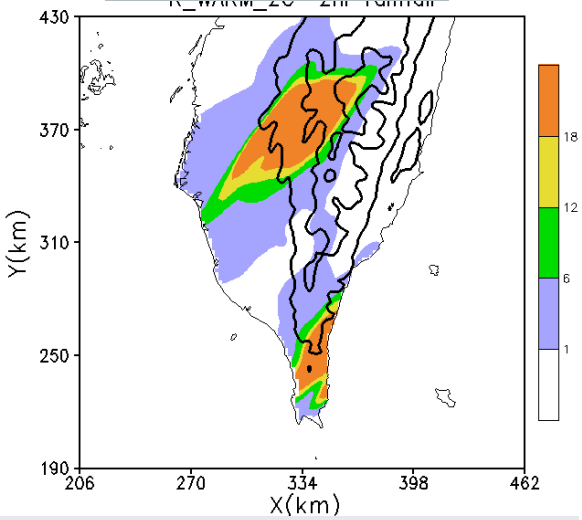
	1302UTC (analysis)	1332UTC (30 min)	1402UTC (60 min)	1432UTC (90 min)
Observation				
R_WARM_2C				
R_ICE_2C				

2-hr accumulated rain fall

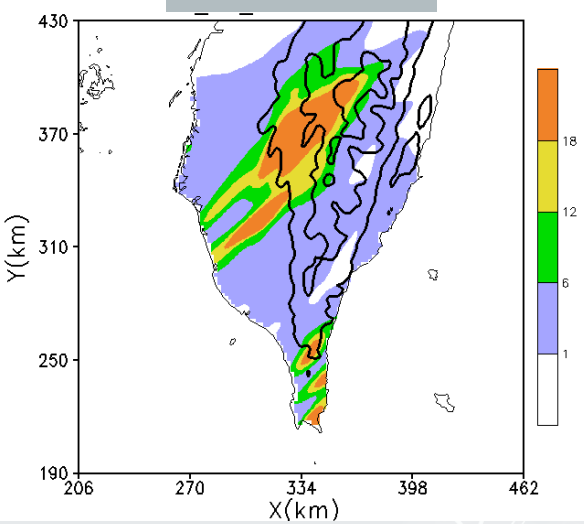
Observation

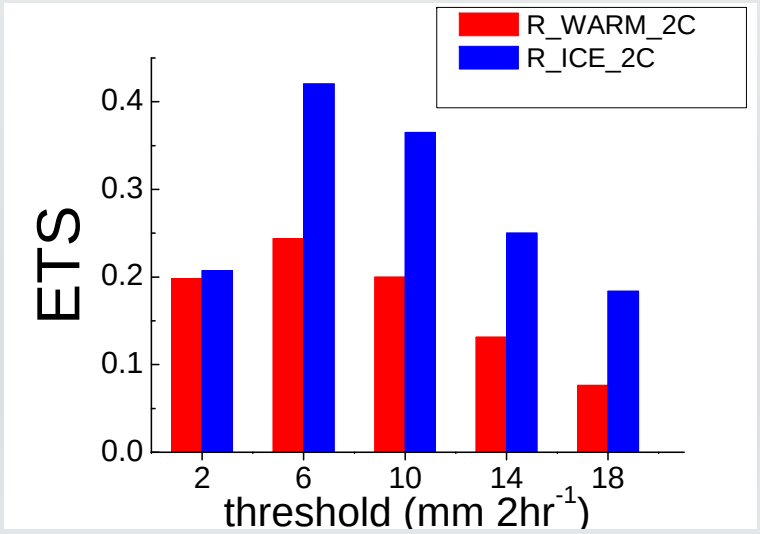


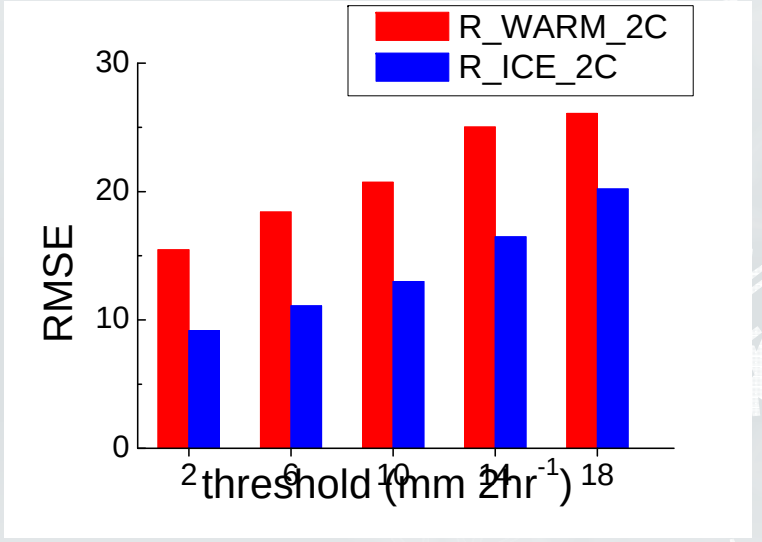
R_WARM_2C



R_ICE_2C







R_ICE_2C better than R_WARM_2C

Summary & Future work

- Using ice phase microphysics scheme can simulate strong heating and upward vertical velocity.
- The retrieved snow water is underestimated while only including warm-rain process.
- Ice-phase microphysics improves the QPF.
- More real cases.
- Combine with VDRAS_terrain version.

Thanks for your attention.