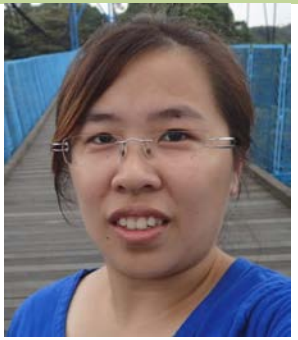
對流尺度預報誤差特性分析
與
資料同化影響評估



鍾高陞, 陳立昕, 柯靜吟

Dept. of Atmospheric Sciences
National Central University

Acknowledgement: 廖宇慶教授、楊舒芝教授

2016 Conference on
Weather Analysis and Forecasting
Oct. 6th, 2016

Outline

1. Introduction and motivation
2. Case study and setup
3. Results of forecast error structures
4. Summary

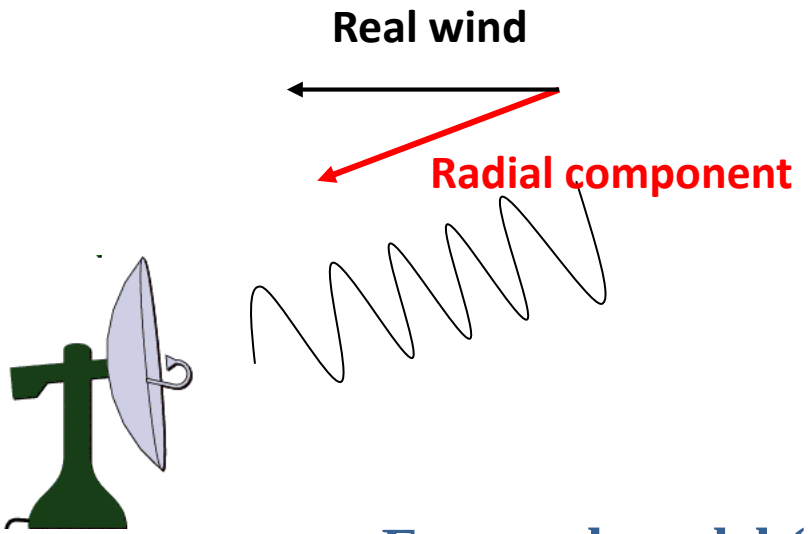
Introduction

Data assimilation at convective scale:

Challenge :

- High temporal and space variability
- No simple balances can be used
- Observing system: measurements (e.g. radar network)

  are not direct model variables (U,V,W,P,T)



Radar observations
(Doppler wind, reflectivity)

To Initialize
Numerical Weather Prediction
(U,V,P,T…)

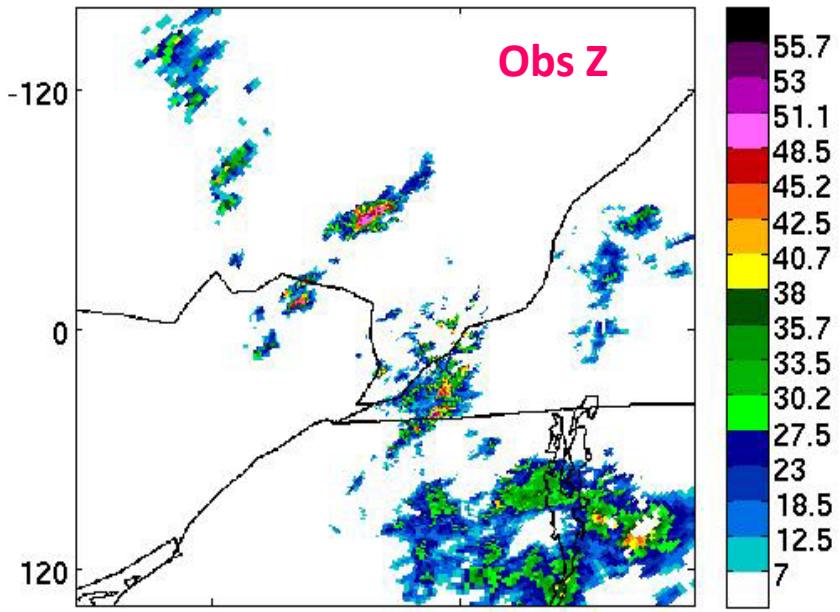
Forward model (observation operator)

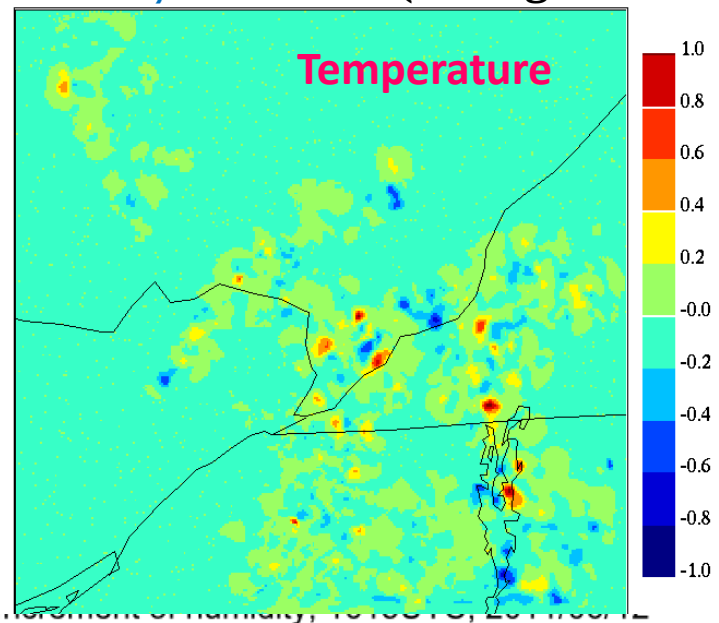
$$V_r = u\frac{x}{r} + v\frac{y}{r} + (w + V_t)\frac{z}{r}, \quad Z = 43.1 + 17.5\log(\rho q_r).$$

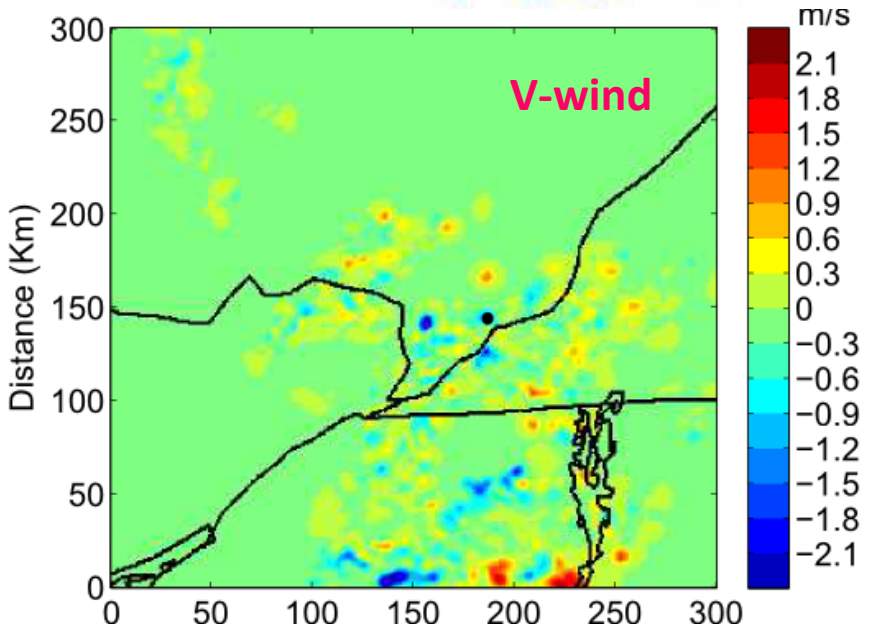
By using Canadian HREnKF and assimilating Vr from single Doppler radar

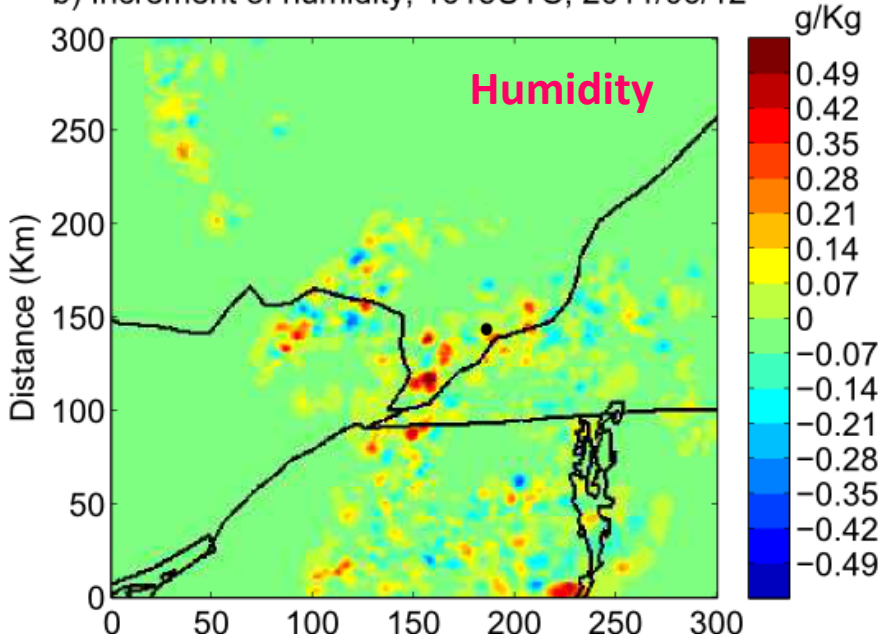
Is it able to propagate information to other control variables?

Localized convection on June 12, 2011 (Chang et al. 2014)





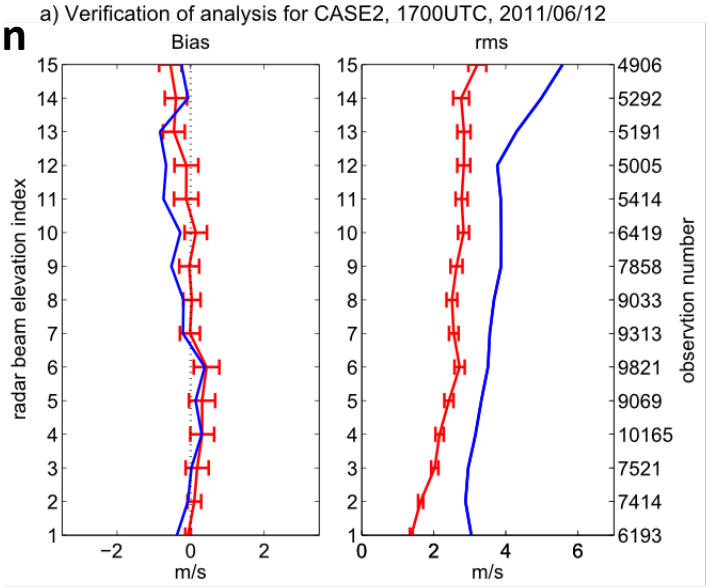




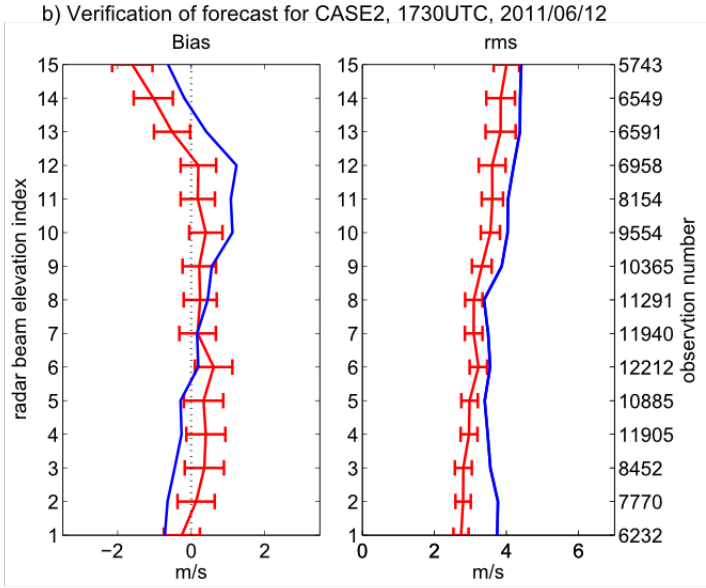
Verification of radial wind for very short-term forecacst (0-90 min)

Localized convection on June 12, 2011

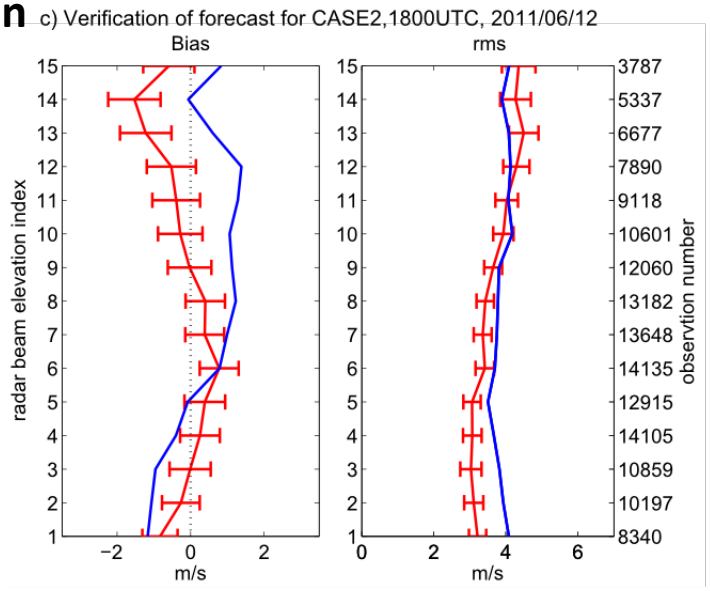
00-min



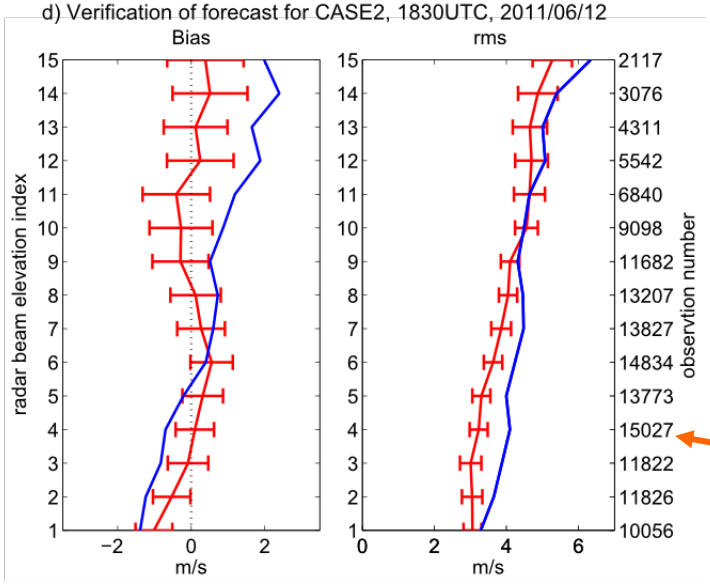
30-min



60-min



90-min

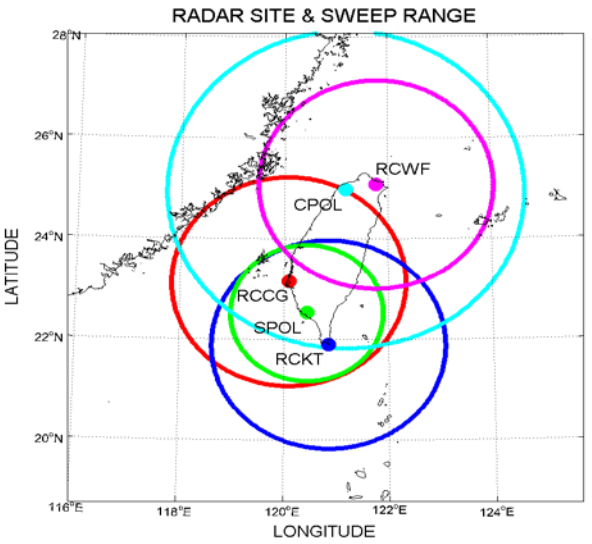


No data Thinning

Bias and rms of analysis of control run
Ensemble mean of bias and rms of analysis or forecast
Ensemble standard deviation of bias and rms of analysis or forecast

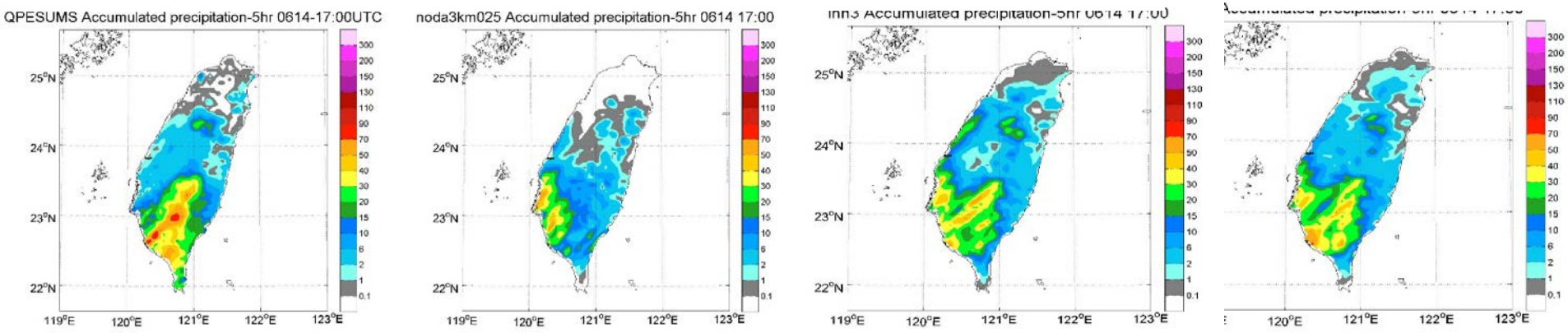
➢ Assimilating Vr and Z of radar network in Taiwan [3-km] (Prof. Yu-Cheing Liou and Shu-Chih Yang)

WRF-LETKF Radar Assimilation System
WLRAS (Tsai et al 2014)
Assimilating both radial wind and reflectivity
Case study on 2008/06/14-15 SoWMEX IOP8



5-hr accumulated precipitation

◆ observation ◆ No DA ◆ 1-hr DA ◆ 2-hr DA

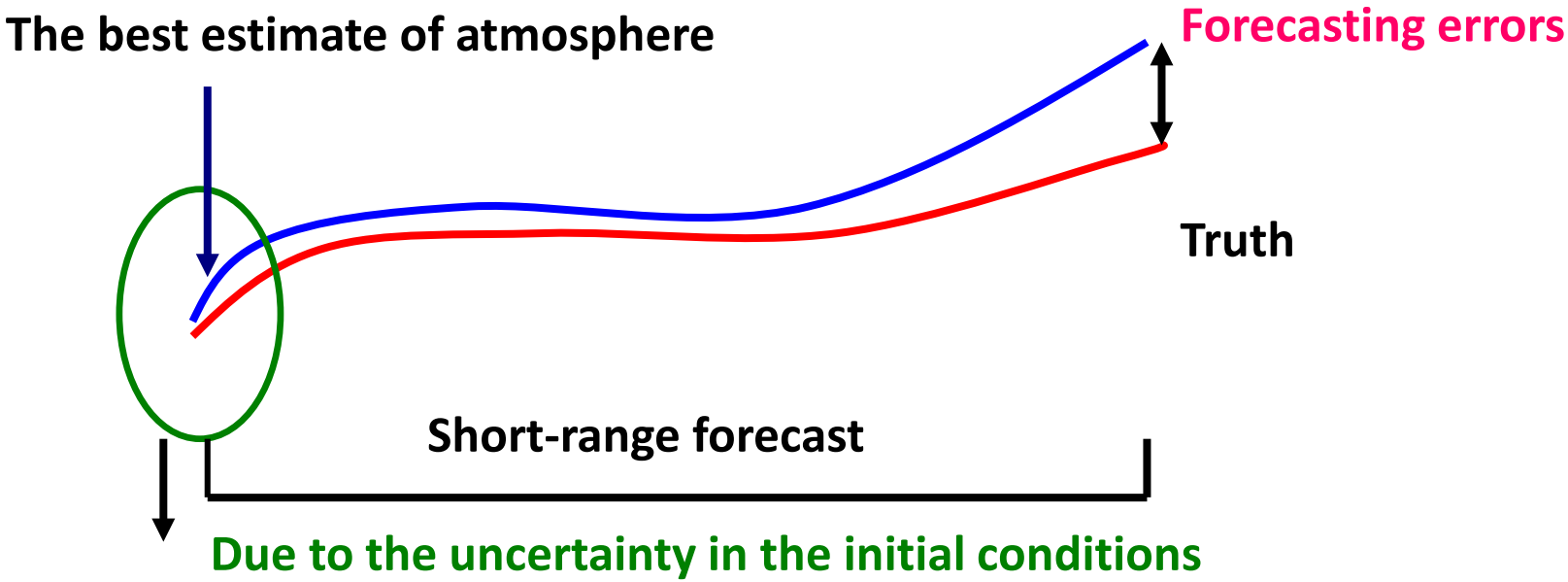


Q: By assimilating radial wind and reflectivity of radar network , why we still need a longer assimilation window to improve QPF?

[Motivation]

Definition and methodology

What is the forecast (background) errors?



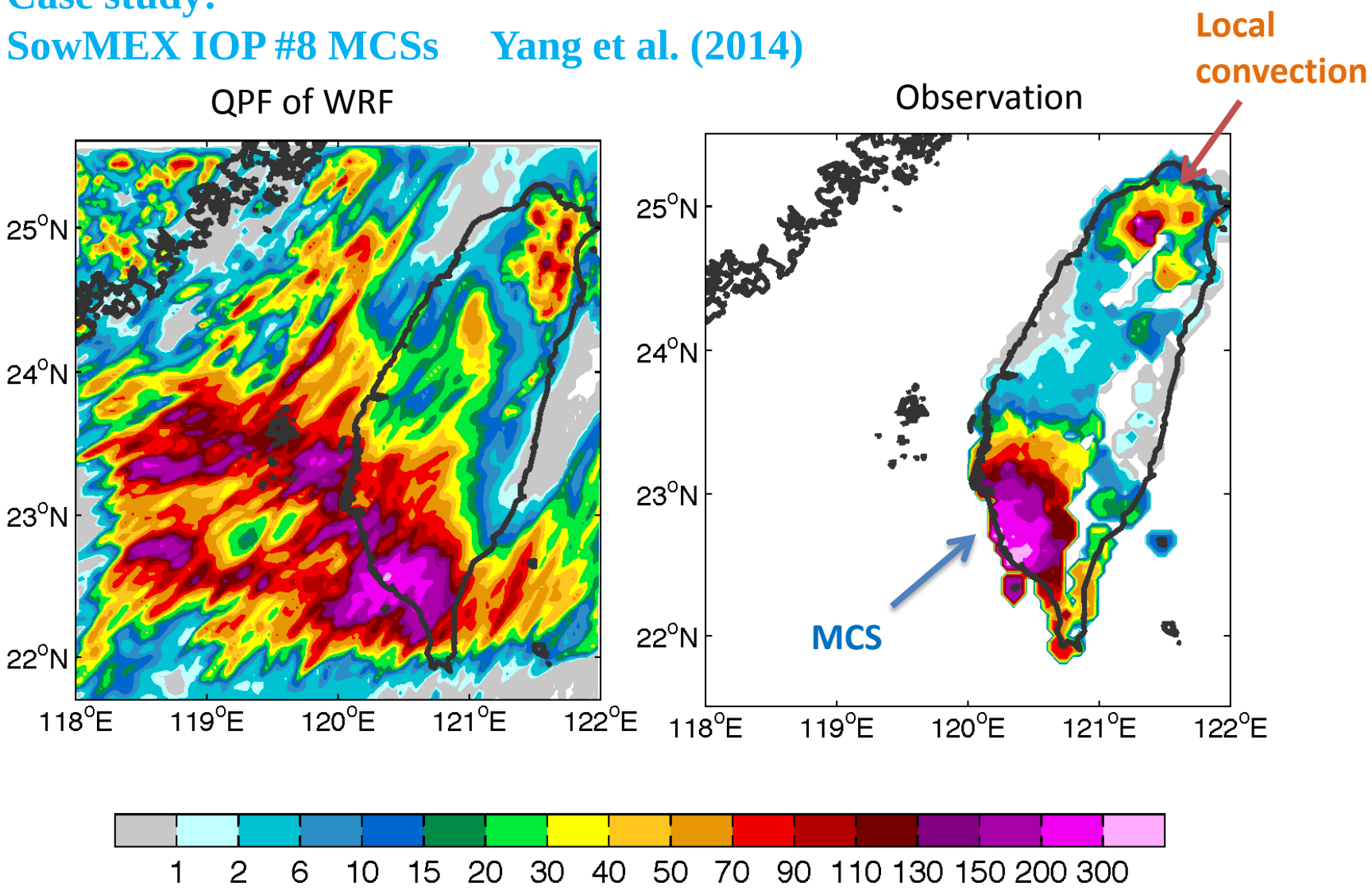
- **In data assimilation:**

The "optimal" analysis fields can be obtained only if the statistics of the background and observations errors can be accurately describe.

EnKF DA system → Ensemble scheme →
Examine the forecast errors at convective scale → Variance, Correlation

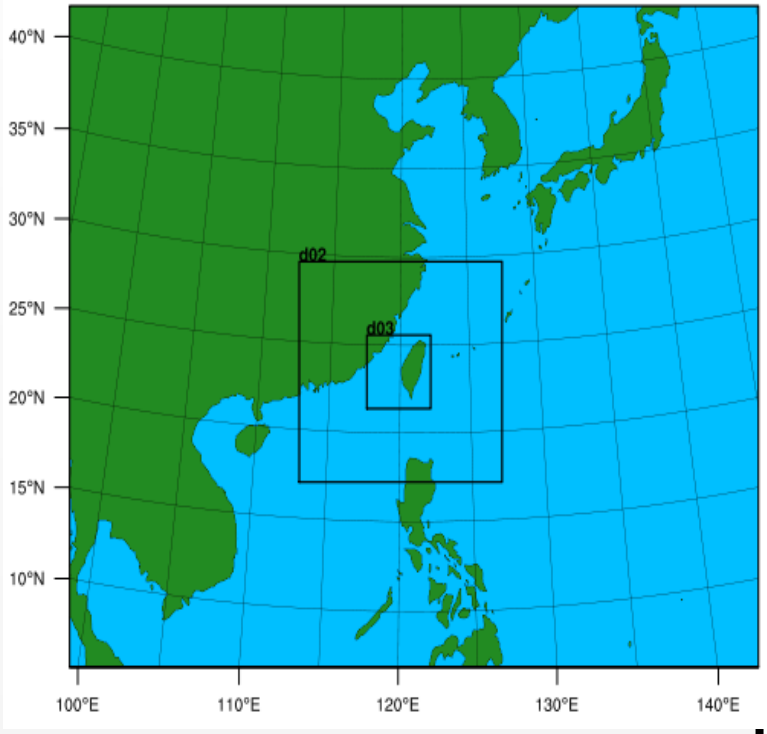
Examine Forecast error at convective scale Over Taiwan area (Island, Ocean and Terrain)

Case study:
SowMEX IOP #8 MCSs **Yang et al. (2014)**



Model configuration

Model Version	WRF 3.2.1
Domains	D01(27-km) 180×150 D02(9-km) 160×150 D03(3-km) 150×150 27 layers, top at 50 hPa
Physical Parameterizations	Longwave Radiation: RRTM scheme Shortwave Radiation: Dudhia scheme PBL: YSU scheme Cumulus: G-D ensemble scheme Microphysics: GCE scheme
Initial Time	1200 UTC 15^{th} Jun., 2008
Initial Condition	WRF-LETKF analysis ensemble (conventional data, AMV, GPS-RO)
Ensemble Members	72

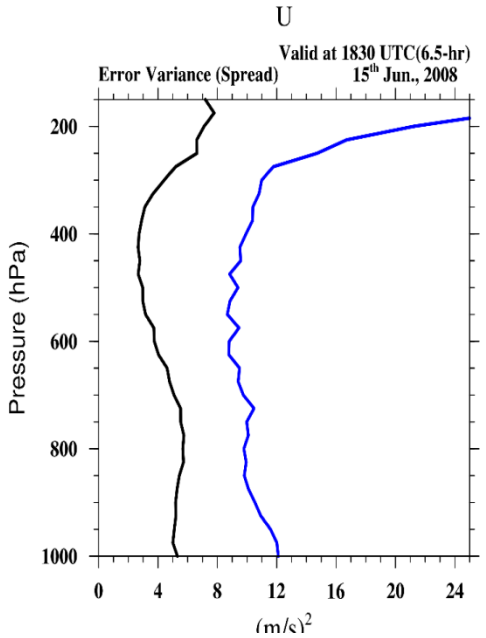


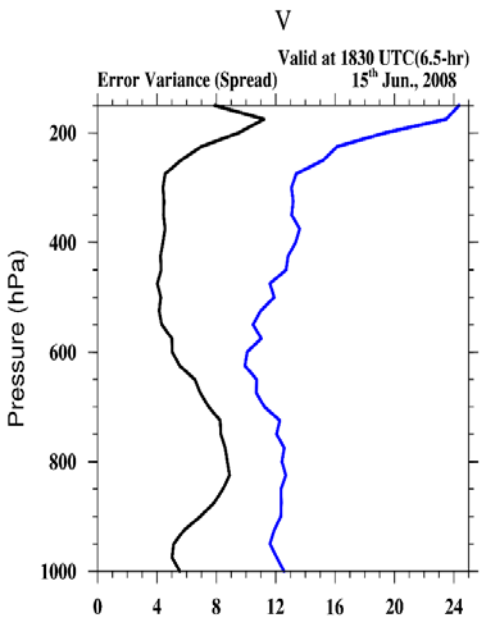
Yang et al. (2014)

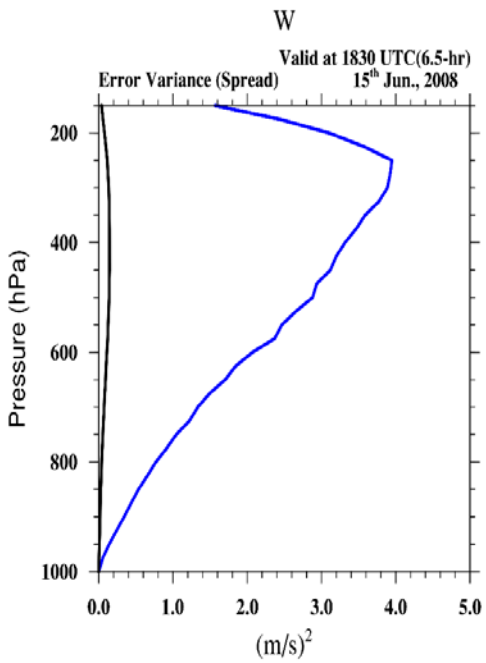
Variance: D2(9km) vs. D3(3km)

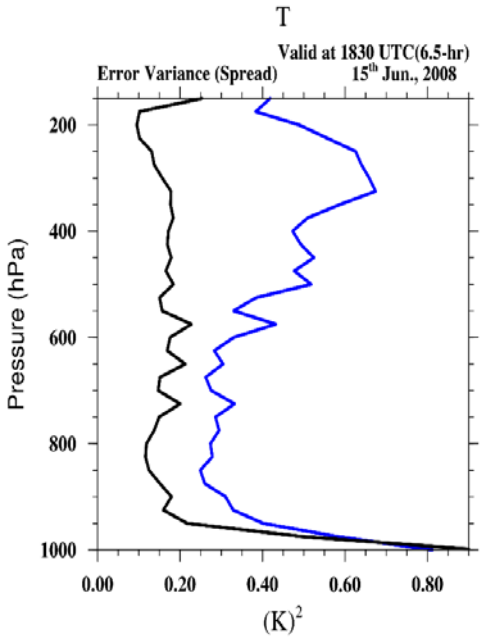
D2(9-km)

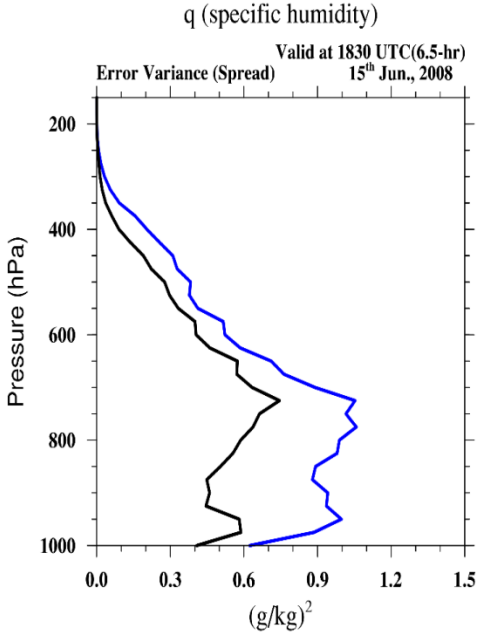
D3(3-km)











Higher model resolution is associated with larger background errors

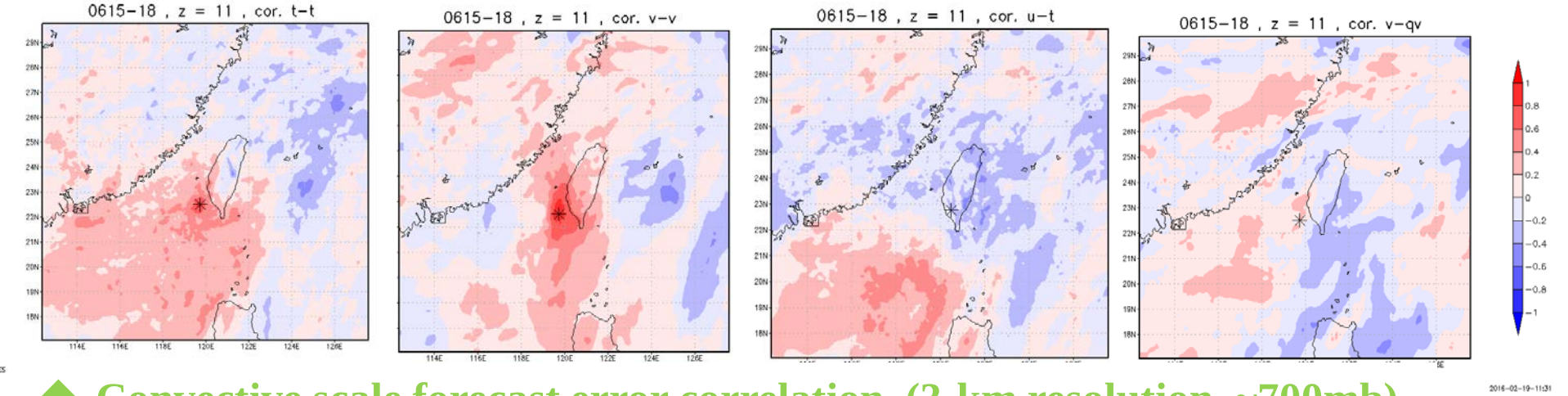
↓

Capture the smaller-scale weather features

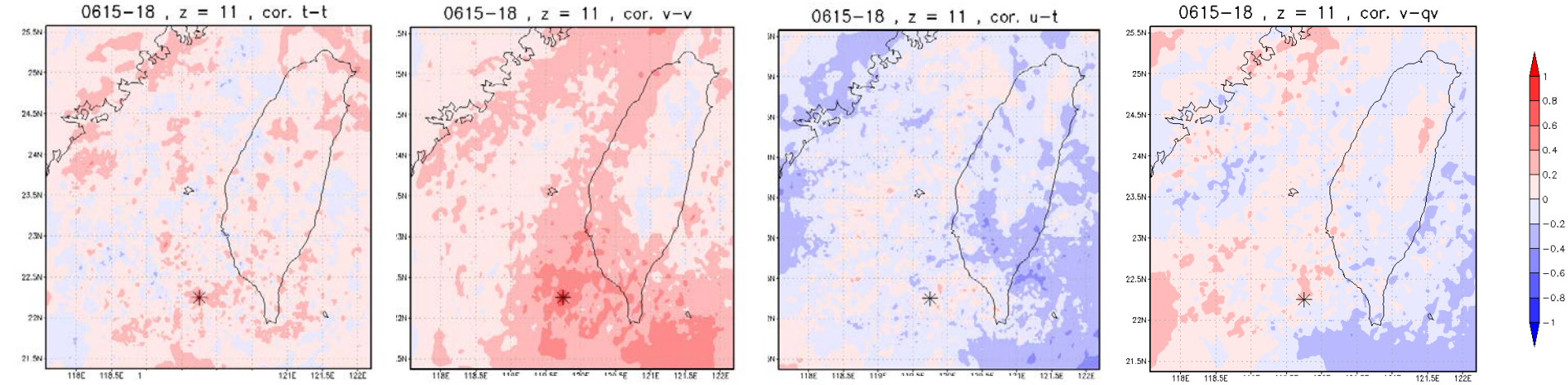
Large uncertainty is good for data assimilation

Error Correlation: D2(9km) vs. D3(3km)

◆ Mesoscale forecast error correlation (9-km resolution, ~700 mb)



◆ Convective scale forecast error correlation (3-km resolution, ~700mb)

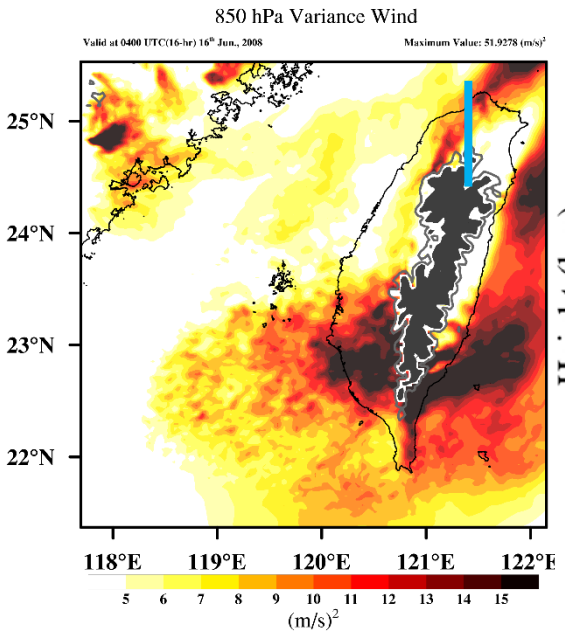


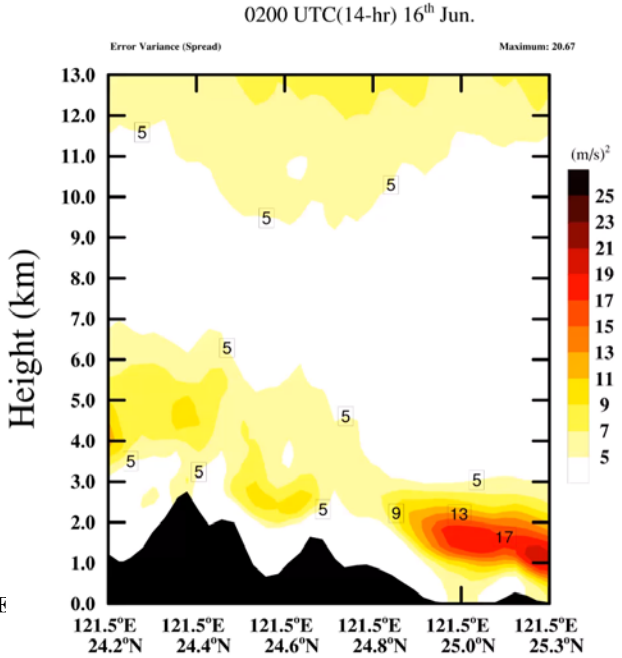
T-T **V-V** **U-T** **V-qv**

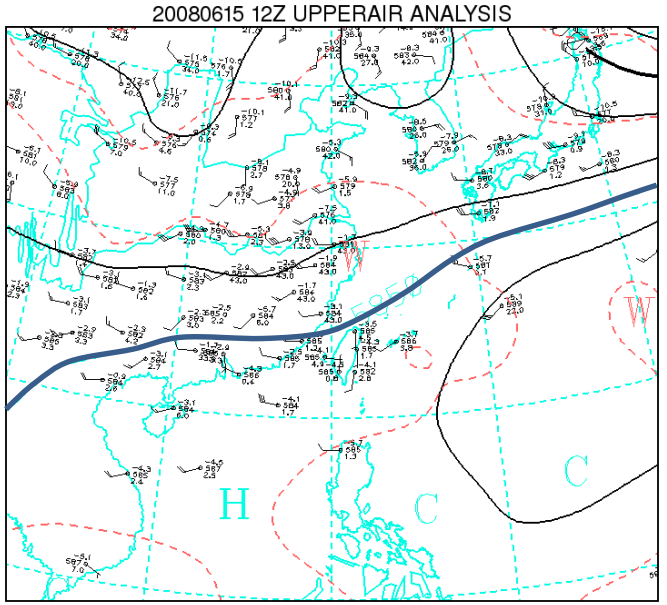
- ***Less strong / very local correlations between control variables at convective scale***
- ***Multi-scale information***

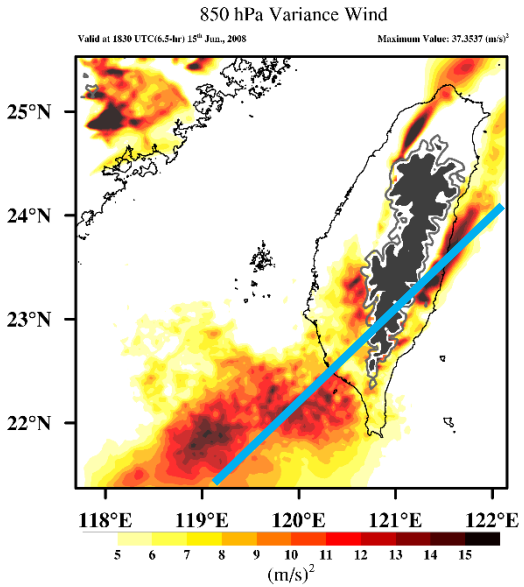
Now, focus on 3-km resolution (convective scale)

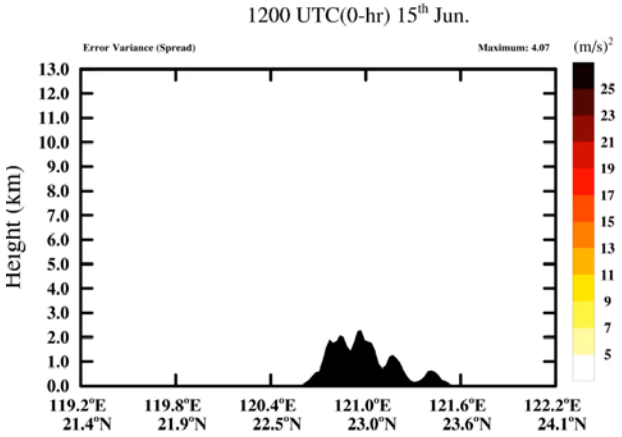
Variance (uncertainty) in time

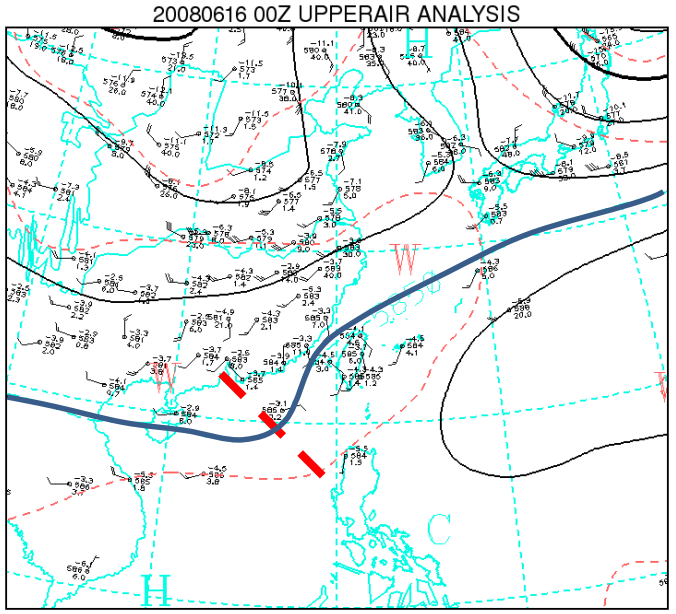












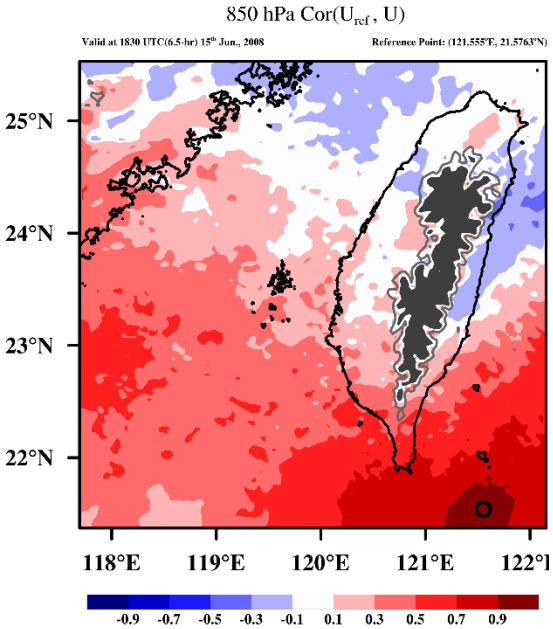
Error of Auto Correlation (850 mb)

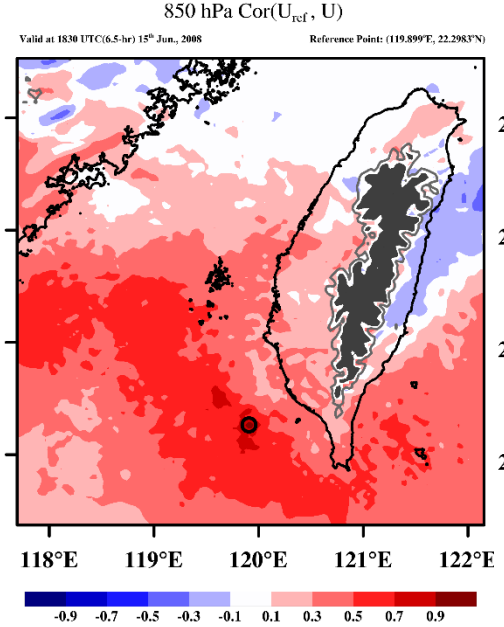
Non-precip

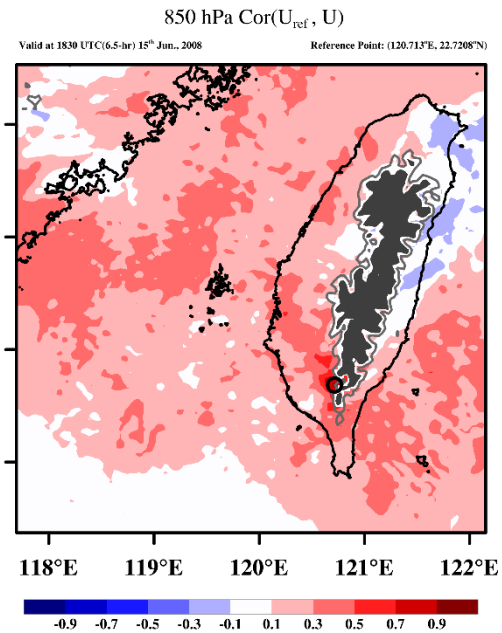
Sea

Land

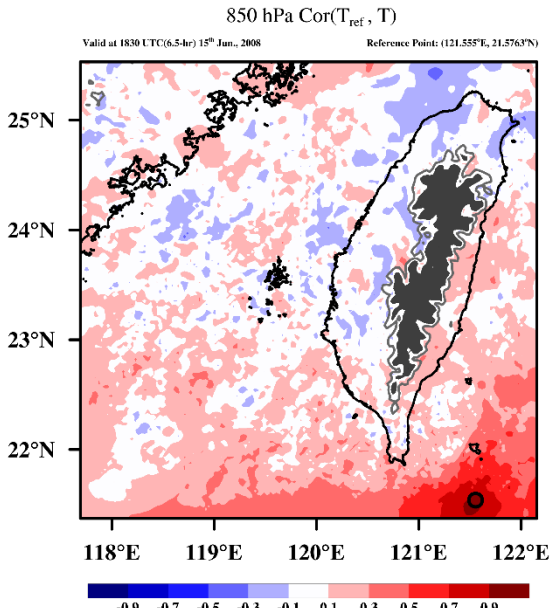
U

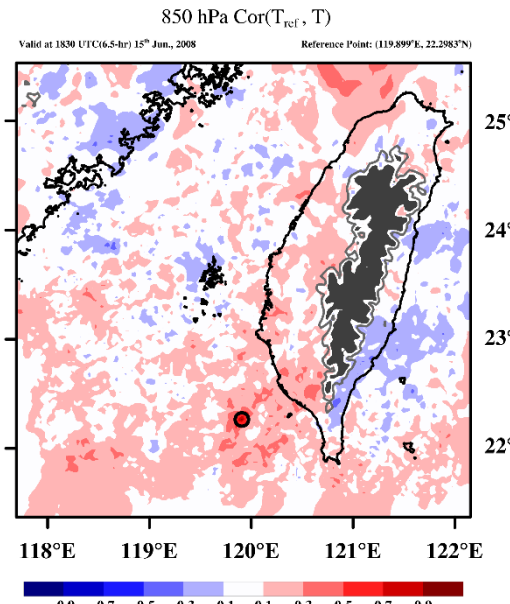


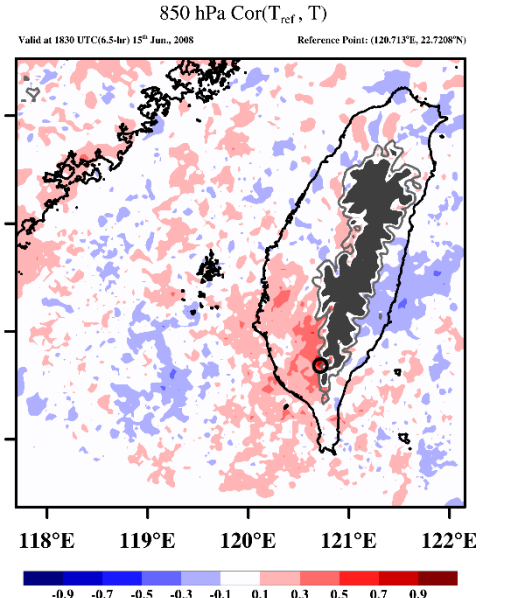




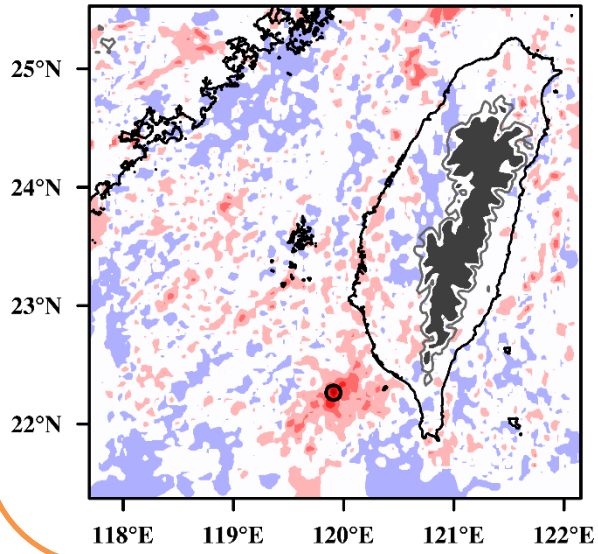
T



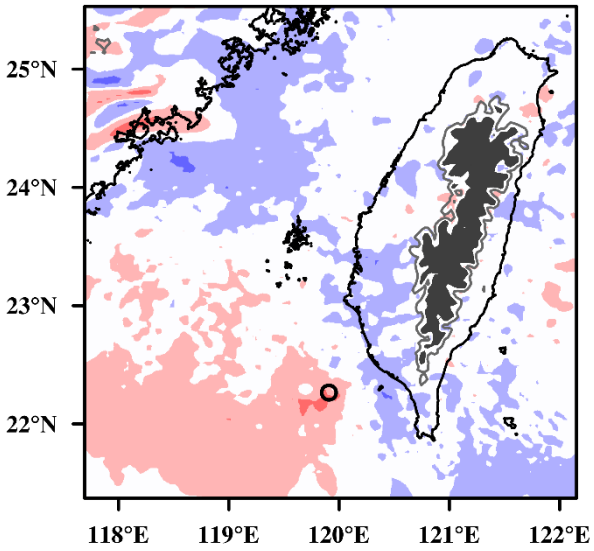




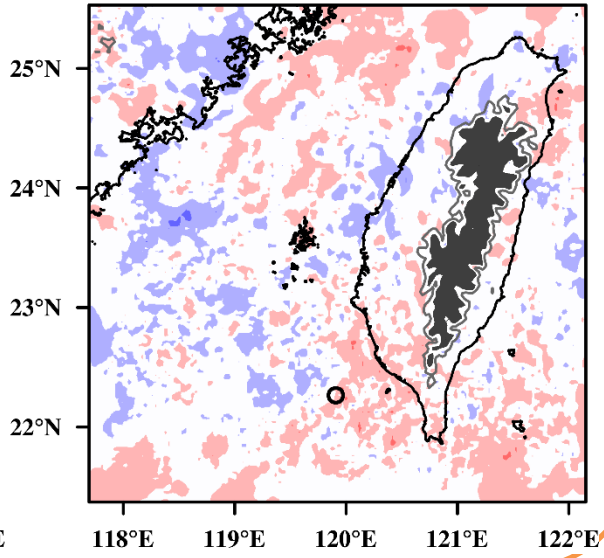
qr-qr auto-correlation



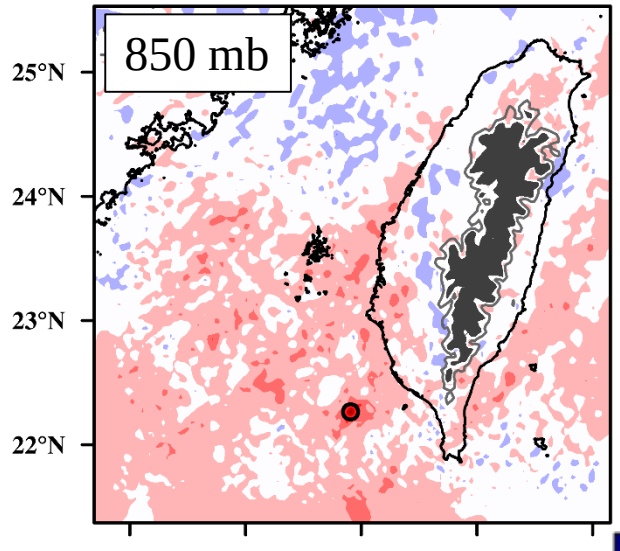
qr-U cross-correlation



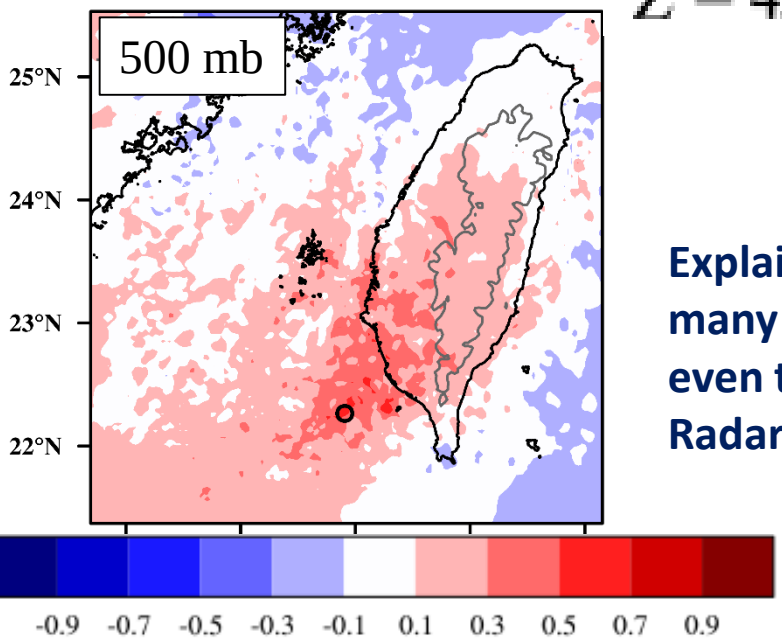
qr-T cross-correlation



qv-qv auto correlation



T-qv cross-correlation

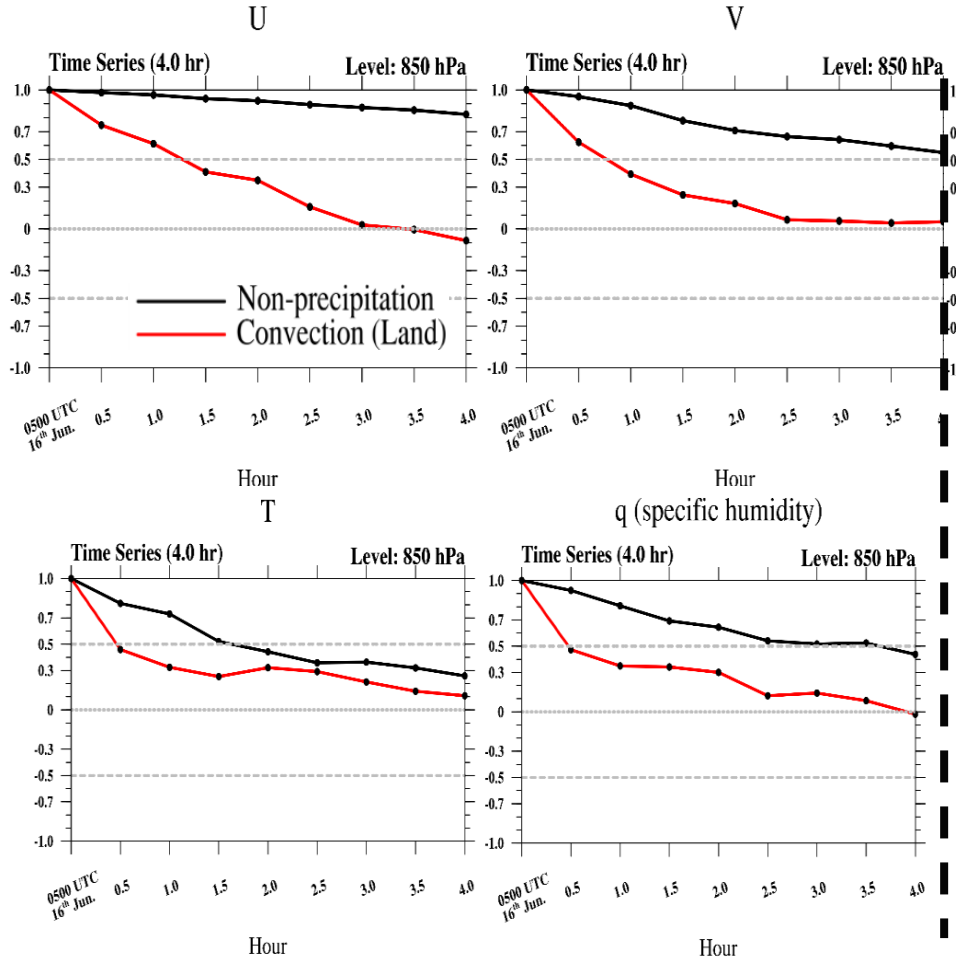


$$Z = 43.1 + 17.5 \log(\rho q_r)$$

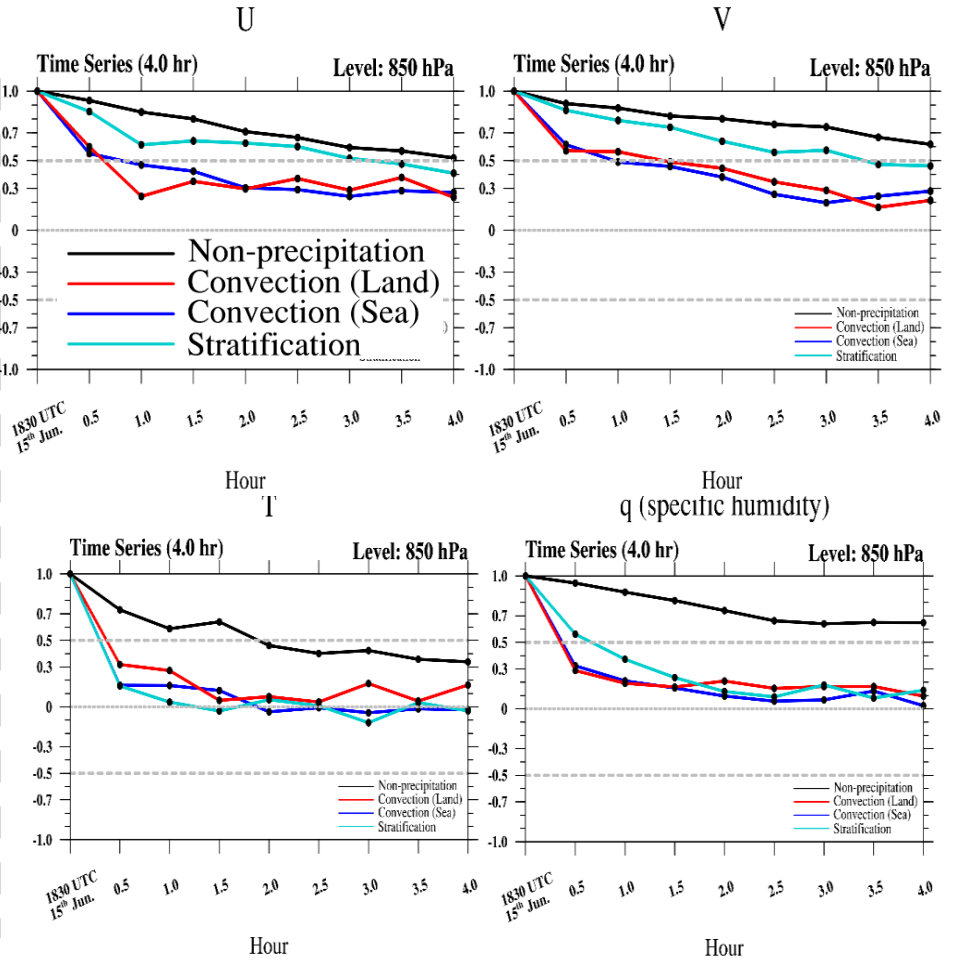
Explain why we need many cycles in DA even though with Radar network observations

Error Correlation in Time

Localized convection



MCS



Summary

- **By assimilating radar radial wind observations, it is able to modify other control variables (temperature and humidity fields). However, it may take many cycles to have significant modifications.**

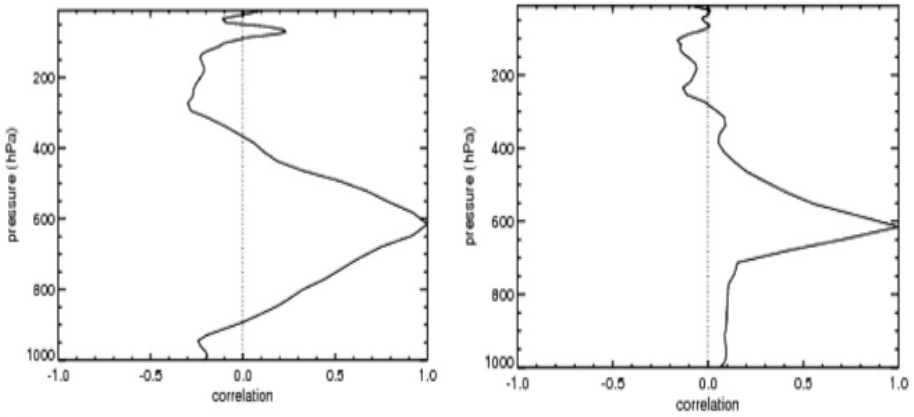
- **The forecast errors at convective scale shows that:**
  1) model of high resolution is associated with larger uncertainties;
  2) multi-scale situation is both showed in variance and correlation
  3) less strong correlation / very localized between control variables, especially for rain mixing ratio (qr);
  4) the correlation drops quickly in time, so frequent assimilation of radar observation is necessary.

- **If we want to reduce the cycling process and obtain the new analysis rapidly, high-density observations of temperature / humidity are needed. (remote sensing, meso-net, radiometer)**


Thank you for your attention!
Any questions?

Chung et al. 2013

(a) Non-Precipitation (b) Precipitation



(c) Precipitation

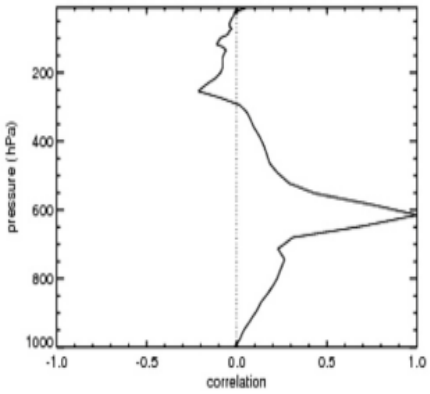
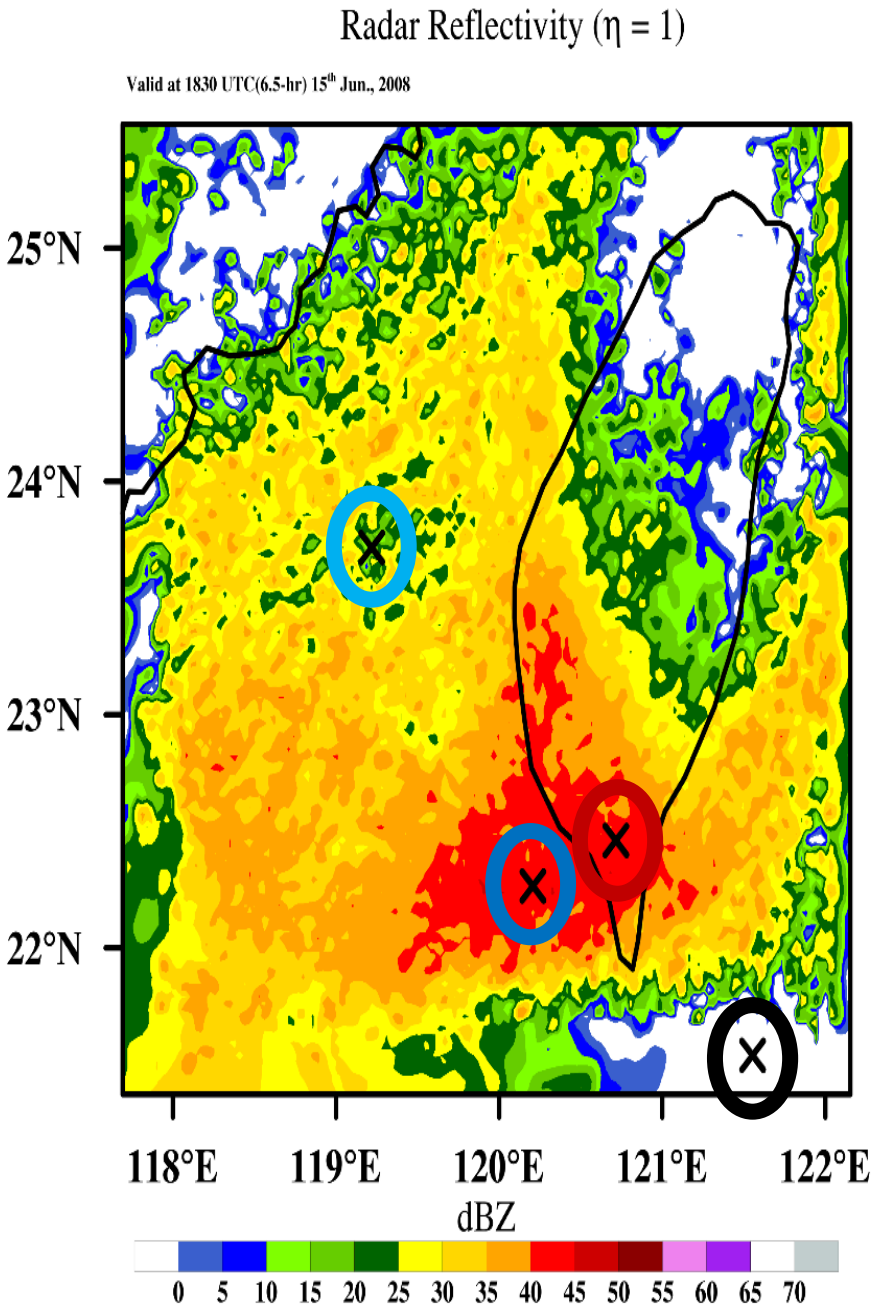


FIG. 12. Vertical error correlation of temperature of 30-min forecast in (a) subdomain 7, (b) subdomain 24, and (c) subdomain 10. The vertical error structure is computed at approximately 600 hPa and averaged in each subdomain (3600 pixels).



Background Error Correlation

The threshold for the smallest significant correlations.(Houtekamer and Mitchell 1988)

$$\overline{(\rho - \hat{\rho})^2} = \frac{1}{N}(1-\rho^2)^2 \approx \frac{1}{N}(1-\hat{\rho}^{\,2})^2 .$$

ρ: true correlation; $\hat{\rho}$: estimated correlation from N sample pairs.

$$\rho \approx \hat{\rho} \pm [\frac{1}{N}(1-\hat{\rho}^{\,2})^2]^{1/2}$$

(e.g.) $0.5 \pm [\frac{1}{72}(1-0.5^2)^2]^{0.5} \Rightarrow [\mathbf{0.412}, 0.588]$

$0.7 \pm [\frac{1}{72}(1-0.7^2)^2]^{0.5} \Rightarrow [\mathbf{0.640}, 0.760]$