Study on data assimilation to improve precipitation forecasts

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1. Background and purpose
2. Improved DA scheme
3. Comparison of PR Z observation with model

1. Background

JMA

- Various satellite data have been assimilated to generate accurate initial states of Numerical Weather Prediction (NWP)
- However, use of cloud/precipitation-affected data is limited
  - Complex processes, high nonlinearity and non Gaussianity
  - While some cloud/precipitation-affected radiances have been assimilated in NWP centers, no space radars have been used
- Aonashi & Eito (2011) developed EnVAR+DEC data assimilation (DA) system
  - Successfully assimilated cloud/precipitation-affected TMI radiances
  - But some issues were found
    - 1. Sampling errors
      - Small ensemble members, especially for precipitation event
    - 2. Gravitational noise generated in DEC
    - 3. Limited observations

EnVAR: Ensemble-based VARiational method
DEC: Displacement Error Correction

Purpose

JMA

- Generate better initial states and forecasts by developing an advanced DA system and assimilating cloud/precipitation observations

- 1. Improve EnVA+DEC DA system
  - Reduce sampling errors in EnVA
  - Suppress gravitational noise by developing a smoothing term in the variational method in DEC
- 2. Assimilate new observation
  - PR and DPR vertical profiles

EnVA+DEC (Aonashi & Eito 2011)

- DEC
  - Preprocessing to correct displaced error d using a variational method

$$J_d = \frac{1}{2}(Y - H(\bar{X}^f(\vec{d})))^t R^{-1}(Y - H(\bar{X}^f(\vec{d})))\} + |\vec{d}|^2 / 2\sigma_d^2$$

- EnVA
  - An ensemble-based variational method
    - Estimate flow-dependent error covariance
    - Need no adjoint models
    - Handle non-linearity
  - Analysis variable Ω is defined in ensemble forecast error subspace $P_e^{f/2}$

$$J_x = 1/2(\vec{X} - \bar{X}_f)P_f^{-1}(\vec{X} - \bar{X}_f) + 1/2(Y - H(\vec{X}))R^{-1}(Y - H(\vec{X}))$$

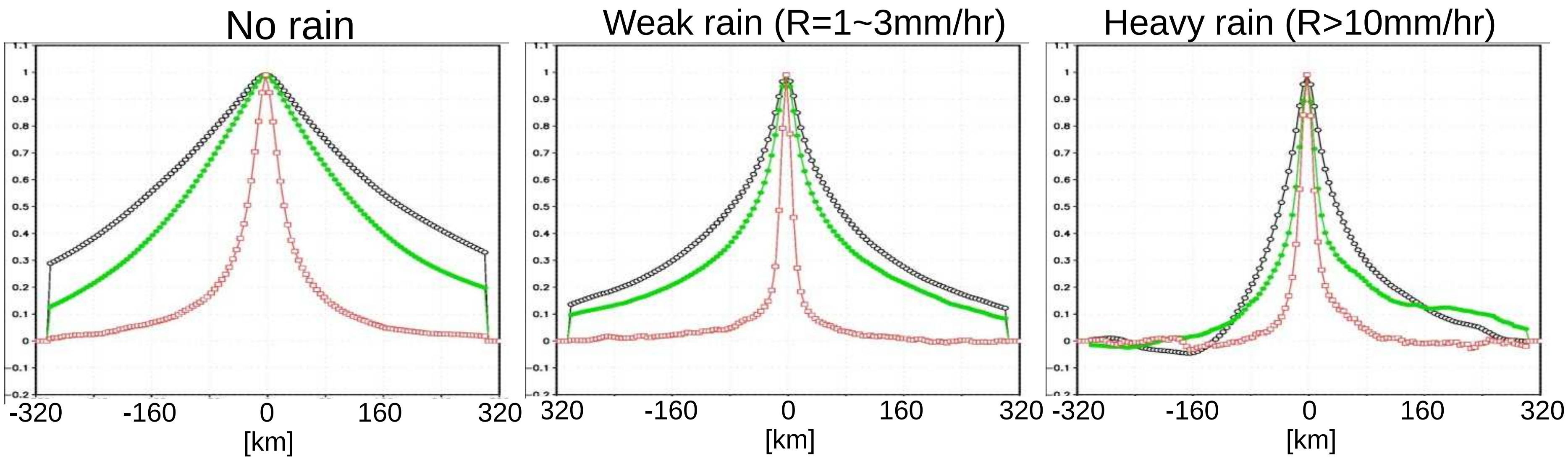
$$\vec{X} - \bar{X}^f = P_e^{f/2} \circ \Omega \qquad P_e^{f/2} = [\vec{X}_1^f - \bar{X}^f, \vec{X}_2^f - \bar{X}^f, ,,, \vec{X}_N^f - \bar{X}^f]$$

  - Spatial localization is applied to forecast error covariance $P_f = P_e^f \circ S$

Improve EnVA (1/2): 2-scale analysis variables

- Horizontal scale varies for variables and rain condition
- Separate analysis variables into large-scale mode and local mode according to horizontal correlation scale
  - Large-scale mode : U,V, quasi-RH, potential temperature
  - Local mode : precipitation-related variables and departure of the large-scale mode from the spatial average

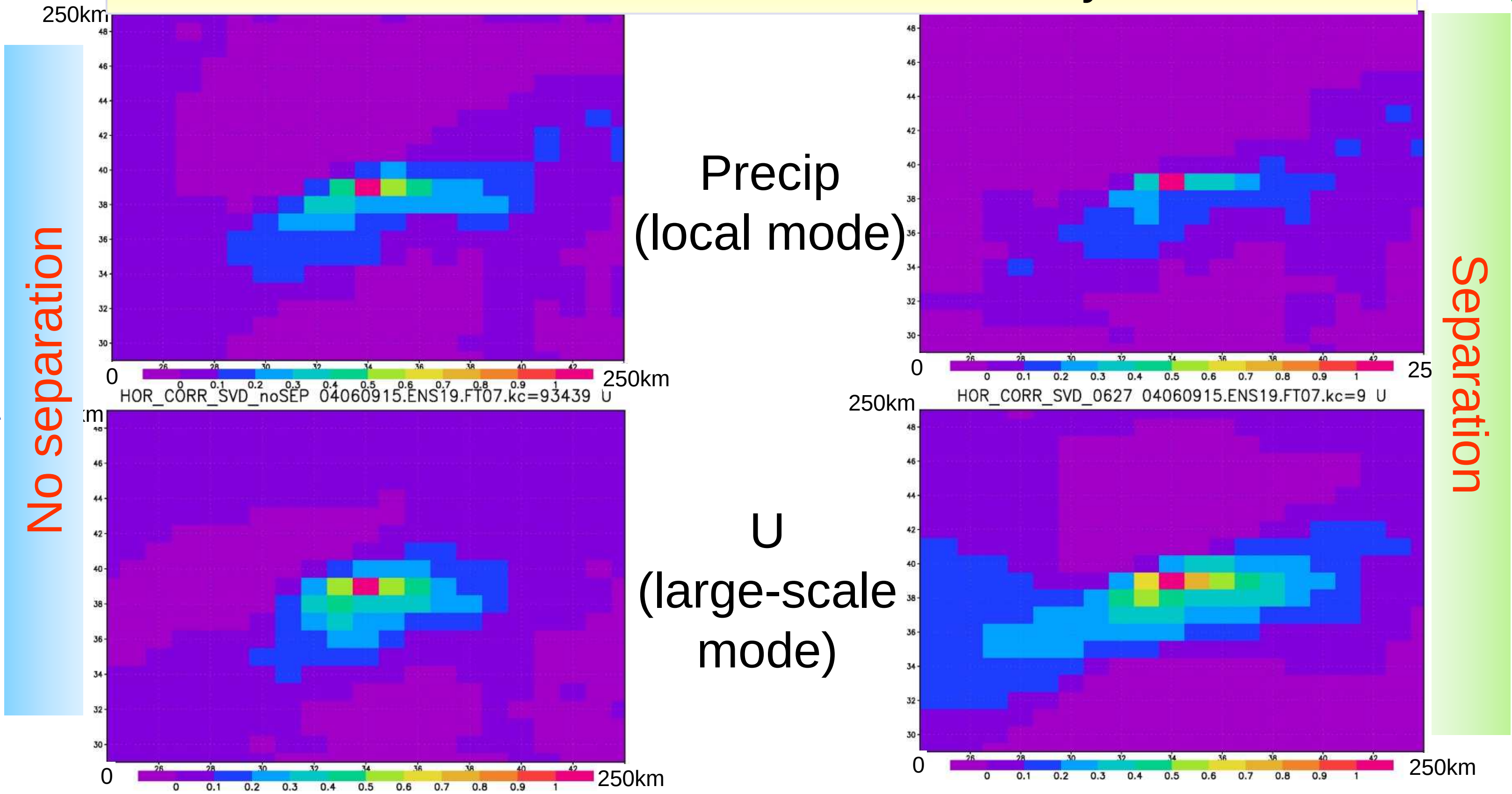
Horizontal correlation of ensemble forecast errors for
U (m/s), quasi-RH (%), W (m/s)



Horizontal correlation of 2-scale analysis variables

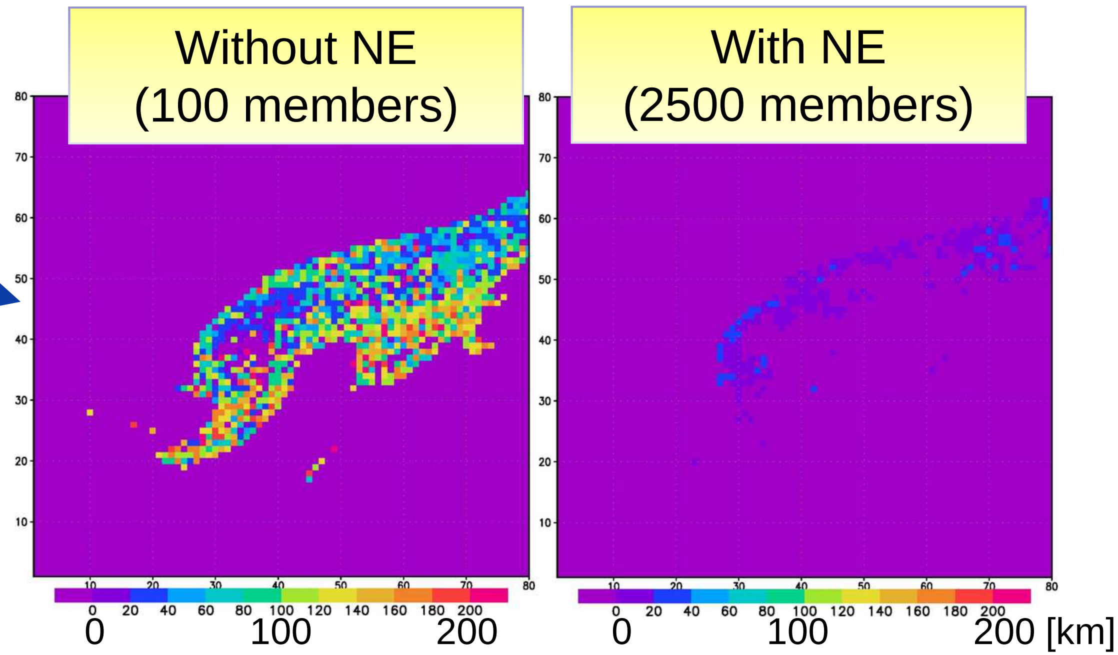
- Without separation, both variables have moderate scale
- With separation, local variable (precipitation) reasonably shows smaller scale while others show larger scale.

Horizontal correlation estimated in heavy rain area



Improve EnVA (2/2)
Neighboring ensemble (NE)

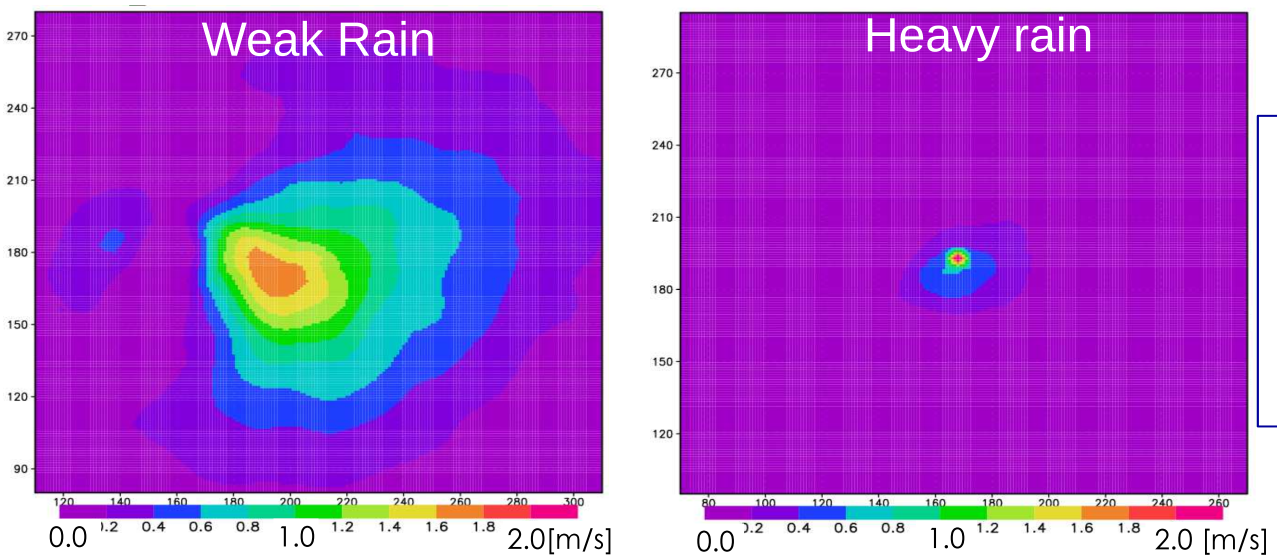
- Adopting spectral localization (Buehner and Charron, 2007) creates spatially shifted versions of ensemble members to calculate the forecast error covariance.
  - Increased ensemble members reduce sampling errors although effective spatial scale is compromised.
- NE within up to s=5 grids (=5x5 ensemble) successfully reduced averaged distance with high correlation of precipitation



Averaged distance for precipitation horizontal correlation > 0.5 in the case of typhoon

Evaluation of the new EnVA using OSSE

- The new EnVA (2-scale analysis variables and NE) was tested by assimilating simulated RAOB and surface precipitation.
- OSSE results showed
  - Analysis increment with reasonable scale variation according to precipitation conditions.
  - Precipitation analysis well agrees with truth.



Analysis increment of U (m/s) at 1460 m generated by assimilating pseudo-RAOB.

3. Assimilate PR & DPR

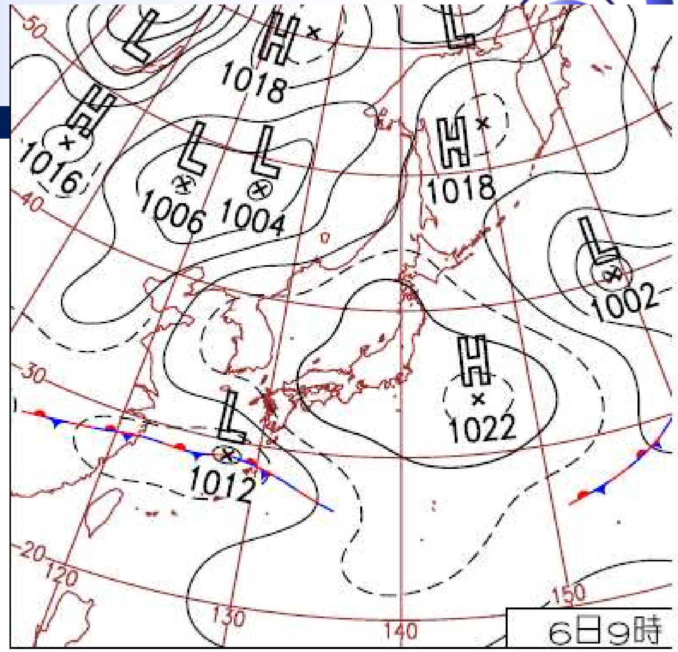
- Investigate the viability and impact of Z or precipitation profiles
  - Exploit vertically-resolved precipitation-related information

  .

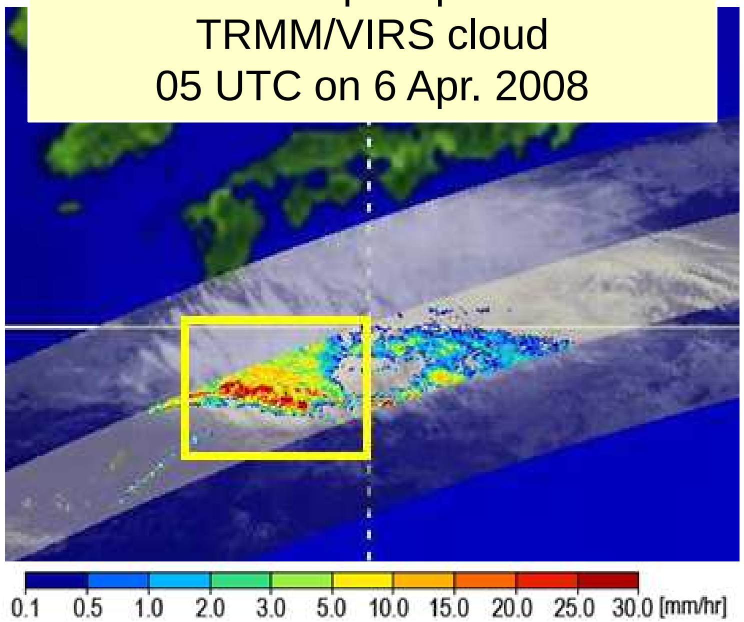
- As the 1st step, we are comparing PR observation (Z) with model simulation
  - JMA-NHM (Saito et al. 2006) + Joint-simulator (Hashino et al. 2013)
  - Needed to develop quality control procedures in DA
  - Help to verify model cloud microphysics
    - Contribute to model improvement

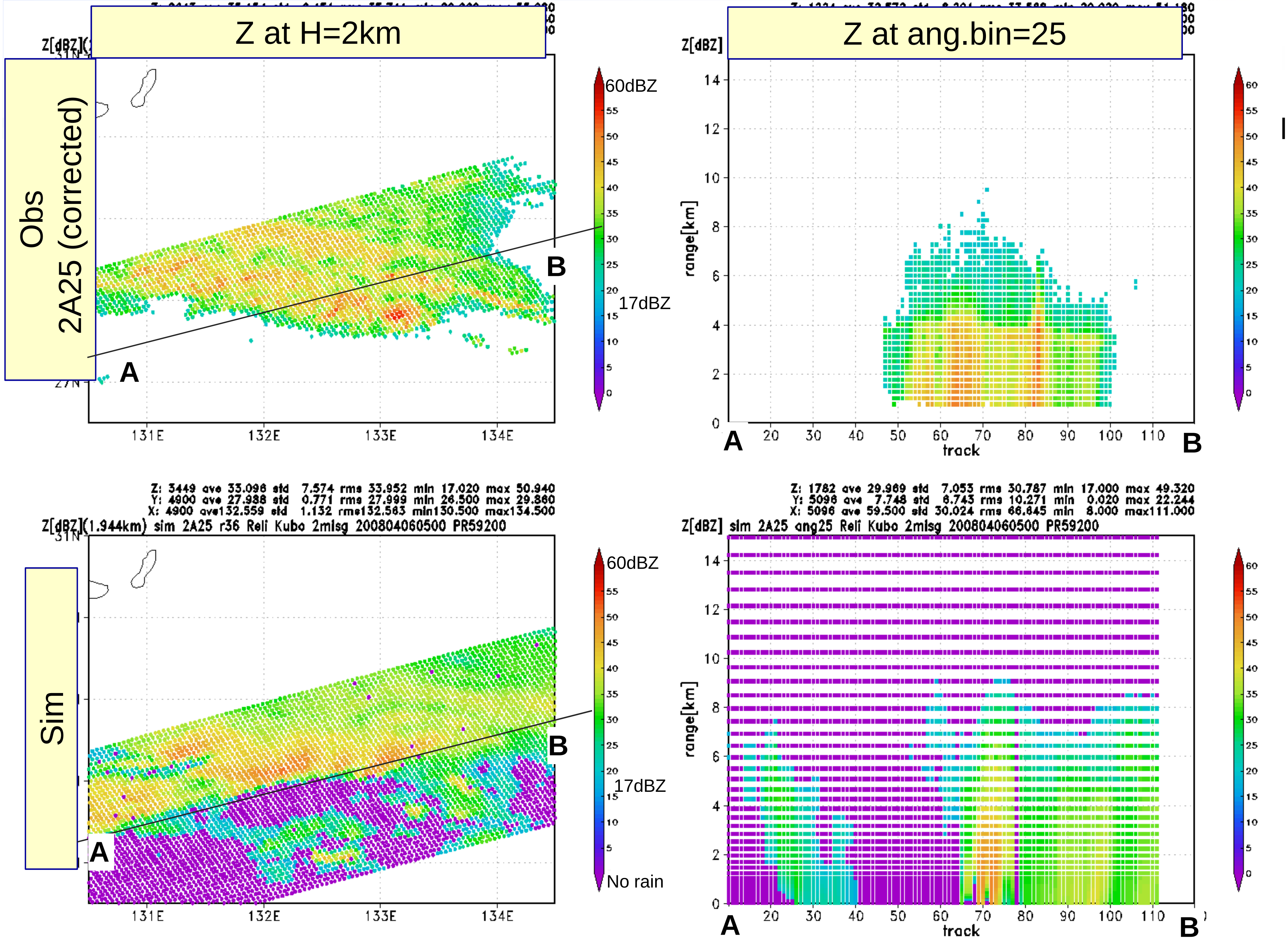
Comparison result 1

- Model : JMA-NHM
  - 5km, 50 layers, 151x151 grids
  - Initial: 00UTC on 6 April 2008, 5-h forecast
- Observation :TRMM/PR (ver.7)
  - 2A25 (attenuation-corrected Z)
  - 1C21 (No corrected Z)
  - Used when “rain certain” in ”reliab” flag
- Simulator : Joint-simulator (Ver201308)
  - Nearest neighborhood interpolation to observation point
  - Turn off bright band calculation function



TRMM/PR precipitation &
TRMM/VIRS cloud
05 UTC on 6 Apr. 2008




Z at H=2km
Z at ang.bin=25
Obs
2A25 (corrected)
Sim
Z[dBZ]
60dBZ
17dBZ
No rain
range[km]
track
A
B
131E
132E
133E
134E
Z: 3449 ave 33.096 std 7.574 rms 33.952 min 17.020 max 50.940
Y: 4900 ave 27.988 std 0.771 rms 27.999 min 26.500 max 29.860
X: 4900 ave132.559 std 1.132 rms132.563 min130.500 max134.500
Z[dBZ](1.944km) sim 2A25 r36 Reli Kubo 2misg 200804060500 PR59200
Z: 1782 ave 29.969 std 7.053 rms 30.787 min 17.000 max 49.320
Y: 5096 ave 7.748 std 6.743 rms 10.271 min 0.020 max 22.244
X: 5096 ave 59.500 std 30.024 rms 66.845 min 8.000 max111.000
Z[dBZ] sim 2A25 ang25 Reli Kubo 2misg 200804060500 PR59200

CFAD (Contoured Frequency by Altitude Diagram)