Study on data assimilation to improve precipitation forecasts

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Background

- Various satellite data have been assimilated to generate accurate initial states of Numerical Weather Prediction (NWP)
- However, cloud/rain-affected data from satellite have been underused in the data assimilation
- Space-based precipitation radars
  - Provide global vertical precipitation information over the both land and ocean
  - Complement ground based radars and space-based passive sensors
  - Assimilation study is limited (Benedetti et al. 2005)

Objective

- Objective
  - Assimilate GPM-Core/DPR and/or TRMM/PR to improve precipitation analysis and forecasts

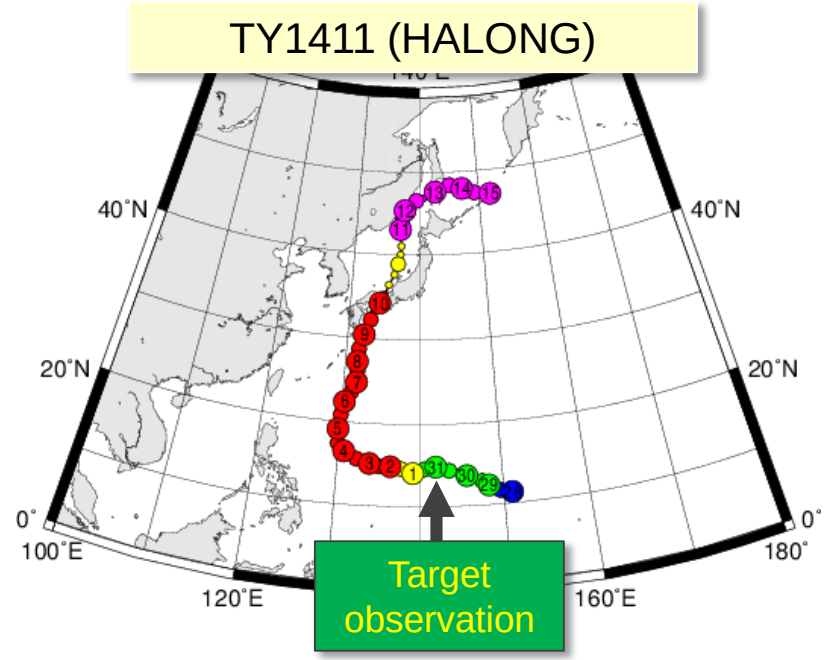
- Specific objectives
  - 1. Compare PR/DPR observations with model simulation
    - → Understand characteristics of obs/model/simulator to develop QC, obs.error, and (if necessary) BC
    - → Also help model development
  - 2. Improve the ensemble-based variational (EnVA) data assimilation system
    - Aonashi and Eito (2011) showed effectiveness and problem of EnVA
  - 3. Assimilate PR/DPR and evaluate analysis and forecast accuracy

Content

- 1. Compare GPM-Core/DPR Ze observation and JMA-NHM simulation
- 2. Evaluate the improved EnVA with Observing System Simulation Experiment (OSSE)
- 3. Extend EnVA to include PR/DPR Ze
  - Include a radar simulator and develop quality control (QC) procedures

1. Comparison of DPR observation and JMA-NHM simulation

- Target : Typhoon T1411 (Halong)
- GPM-core/DPR:
  - 2ADPR (NS and HS), attenuation corrected reflectivity factor (Ze)
  - Remove data with Ze<14 dBZ and clutter-flagged
- NWP model
  - JMA-NHM : Operational meso-scale model of JMA since 2004 (Saito et al. 2006)
    - Cloud variables: Qc, Qi, Qr, Qs, Qg, Ni, N_S, Ng
  - 2-h forecast from 00 UTC 31 July, 2014
  - 5 km res., 401x401 grids, 50 layers
- Radar simulator
  - Joint-simulator (Hashino et al. 2013)
  - Include a slant-path effect in calculation of input profile
  - Remove simulation with Ze<14 dBZ

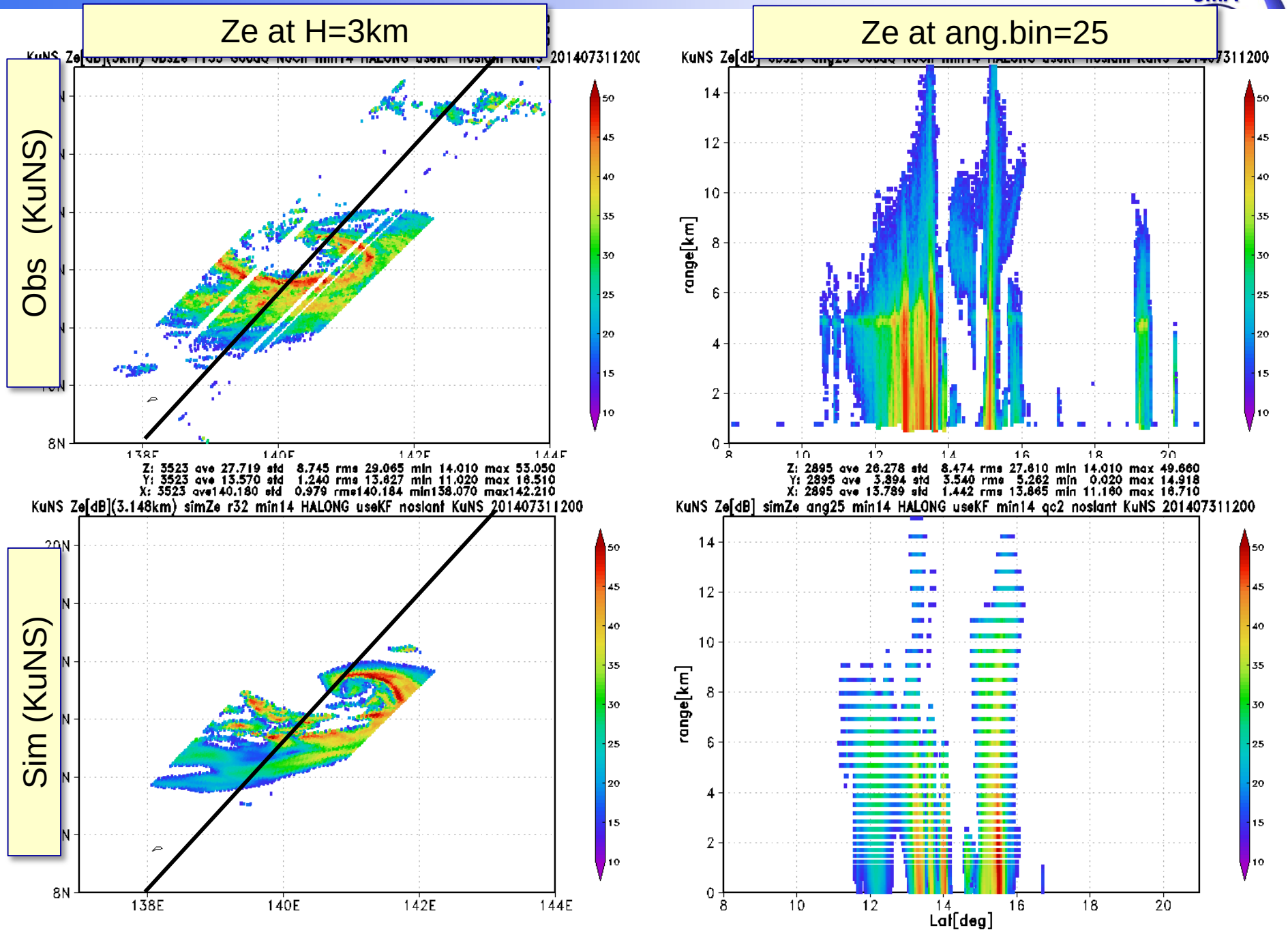


Ze at H=3km

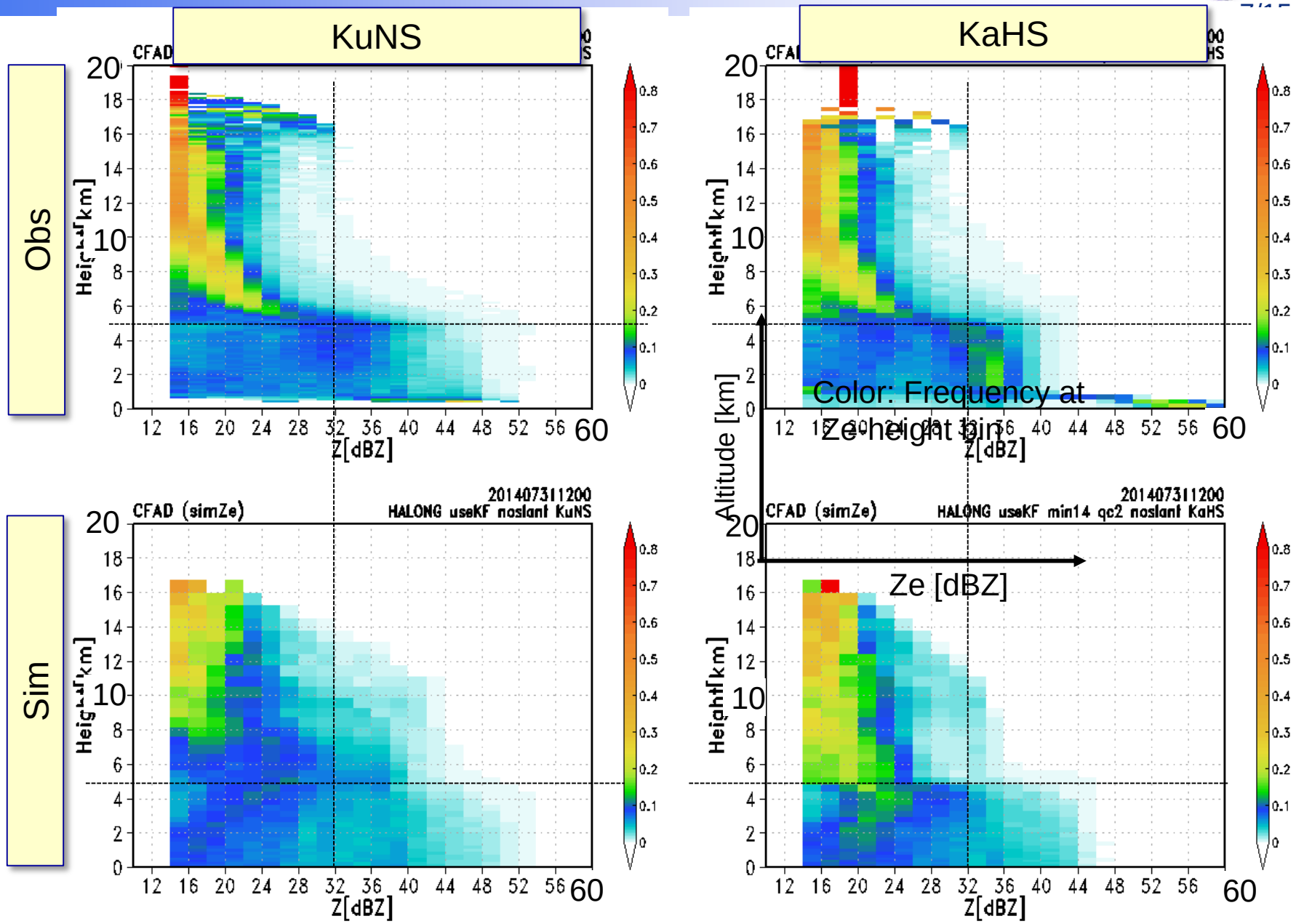
Ze at ang.bin=25

Obs (KuNS)

Sim (KuNS)



CFAD (Contoured Frequency by Altitude Diagram)



2. Evaluate the improved EnVA

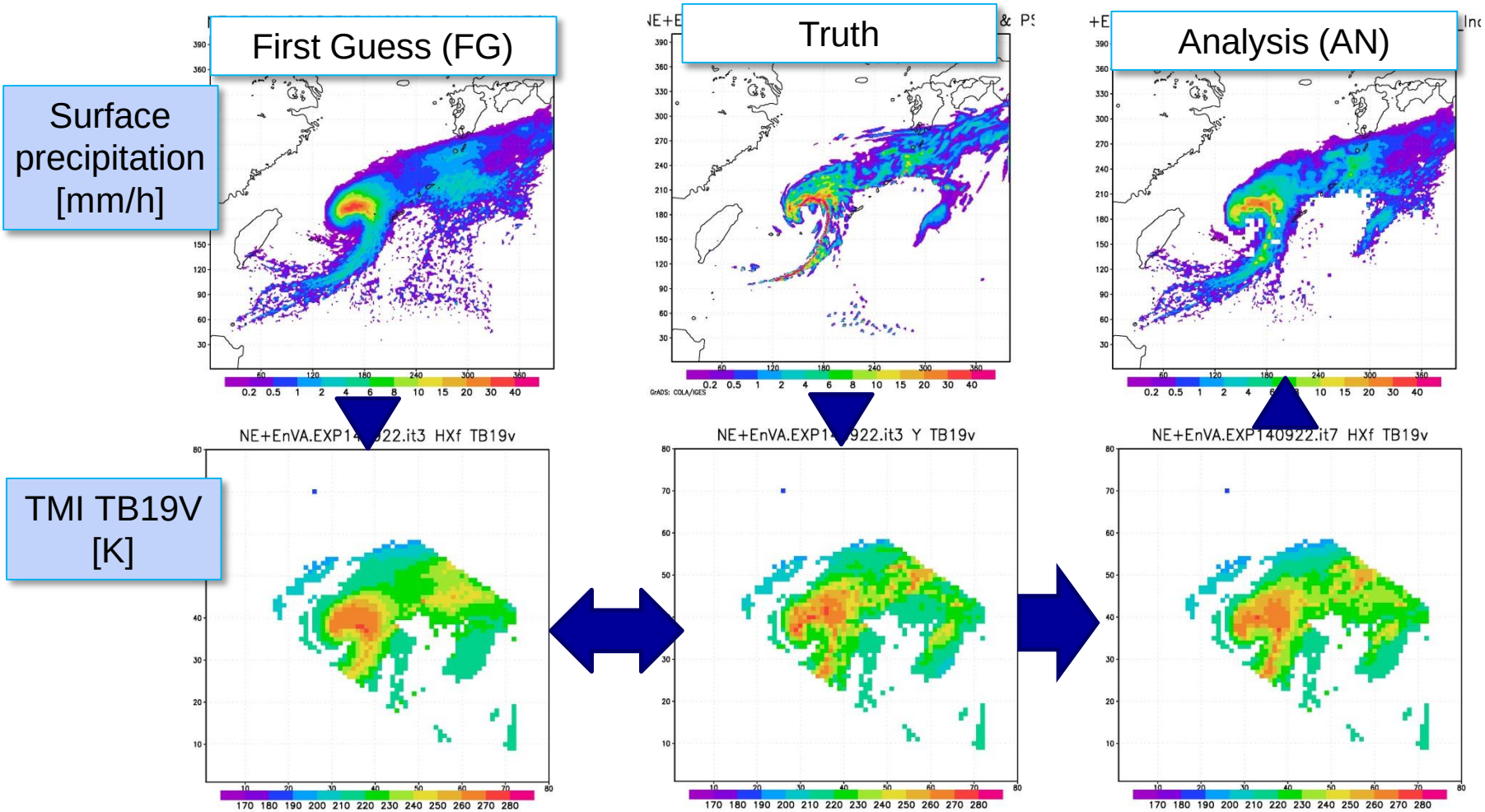
- EnVA: Ensemble-based Variational scheme (Aonashi and Eito 2011)
  - Minimize a cost function in ensemble forecast error subspace (Lorenc 2003)
  - $J(x) = J(\Omega) = \left(x - \overline{x^f}\right)^T \mathbf{P^{-f}} \left(x - \overline{x^f}\right) + (y - H(x))^T \mathbf{R^{-1}} (y - H(x))$

    $x - \overline{x^f} = P_e^{f/2} \circ \Omega \qquad P_e^{f/2} = \left(x_1^f - \overline{x^f}, x_2^f - \overline{x^f}, , , , x_N^f - \overline{x^f}\right)$

    $\mathbf{P^f} = \mathbf{P_e^f} \circ \mathbf{S}$: $\mathbf{S}$ spatial localization
- Improve EnVA to reduce sampling errors with
  - Neighboring Ensemble (NE) approach based on spectral localization (Buehner and Charron, 2007) in addition to an adaptive spatial localization
  - Dual scale analysis variables dependent on horizontal scale
    - Separate precip/W and U/V/RH/PT/Ps

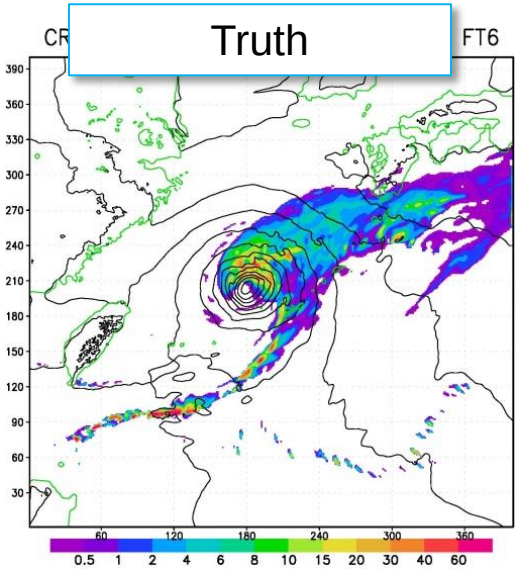
EnVA OSSE (Observing System Simulation Experiment)

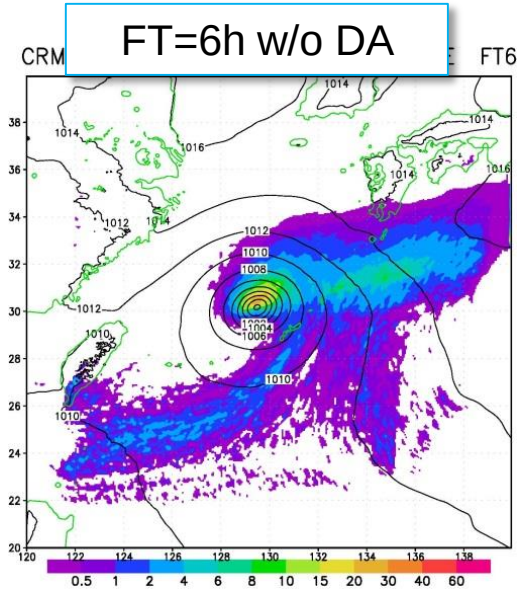
- Assimilate TMI TB synthetic data created from truth field
- EnVA: 100 members, 5x5 NE → 2500 NE members
- Typhoon T0404 (Conson) : 22 UTC 9 June, 2004

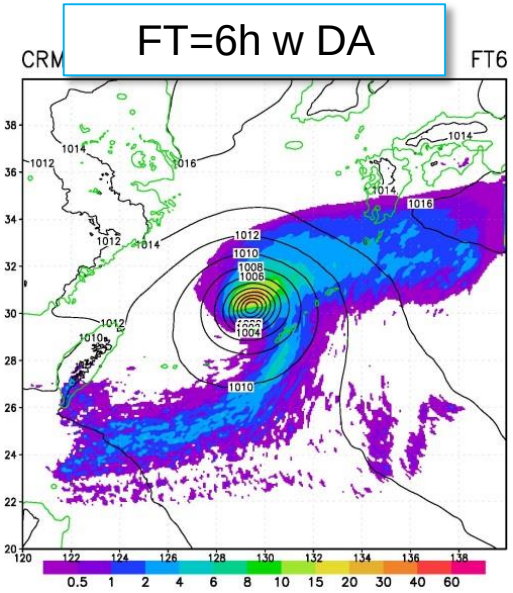


EnVA OSSE : 6-h forecast

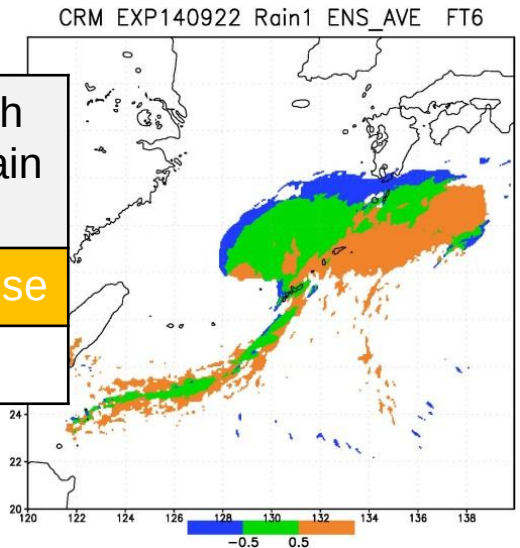
Surface precipitation [mm/h]

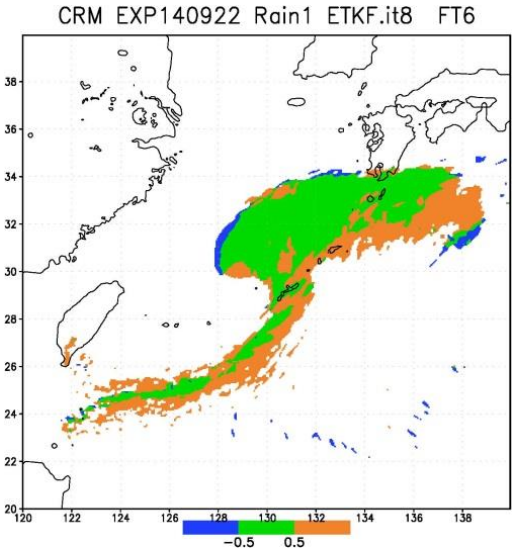






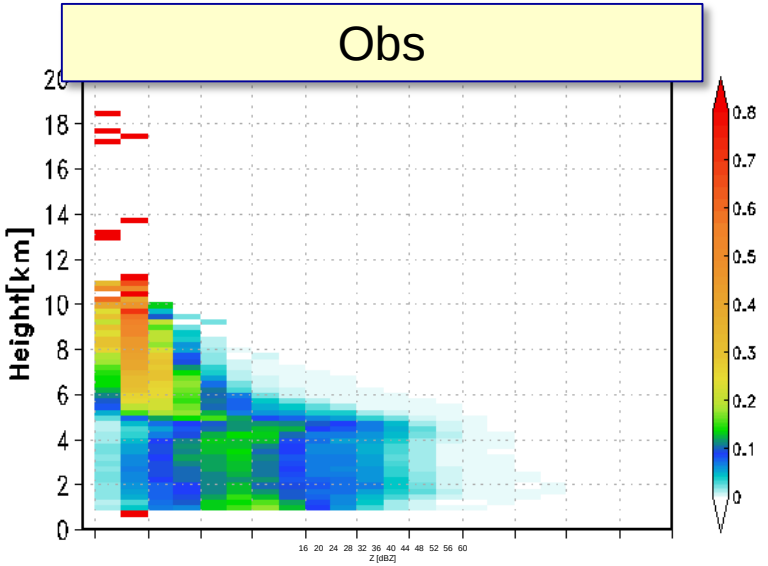
Area classification with rain>1mm/h	Truth Rain	Truth No rain
Forecast Rain	○Good!	× False
Forecast No rain	× Miss	

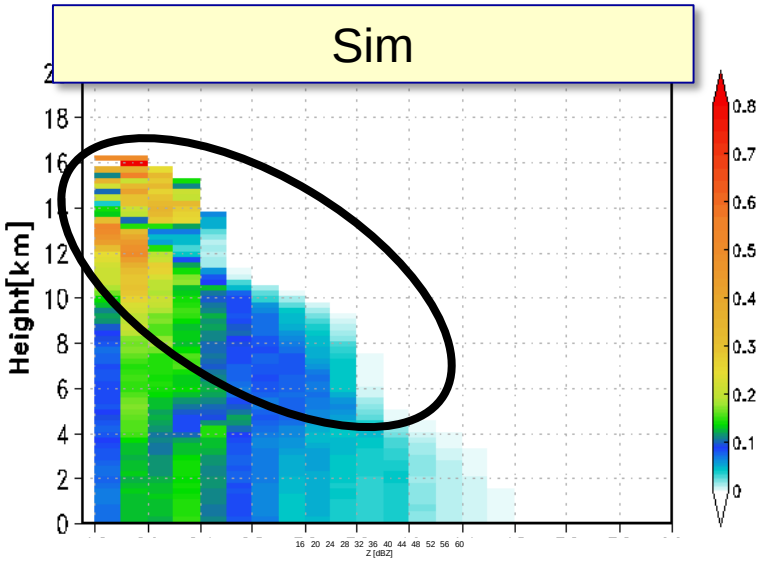




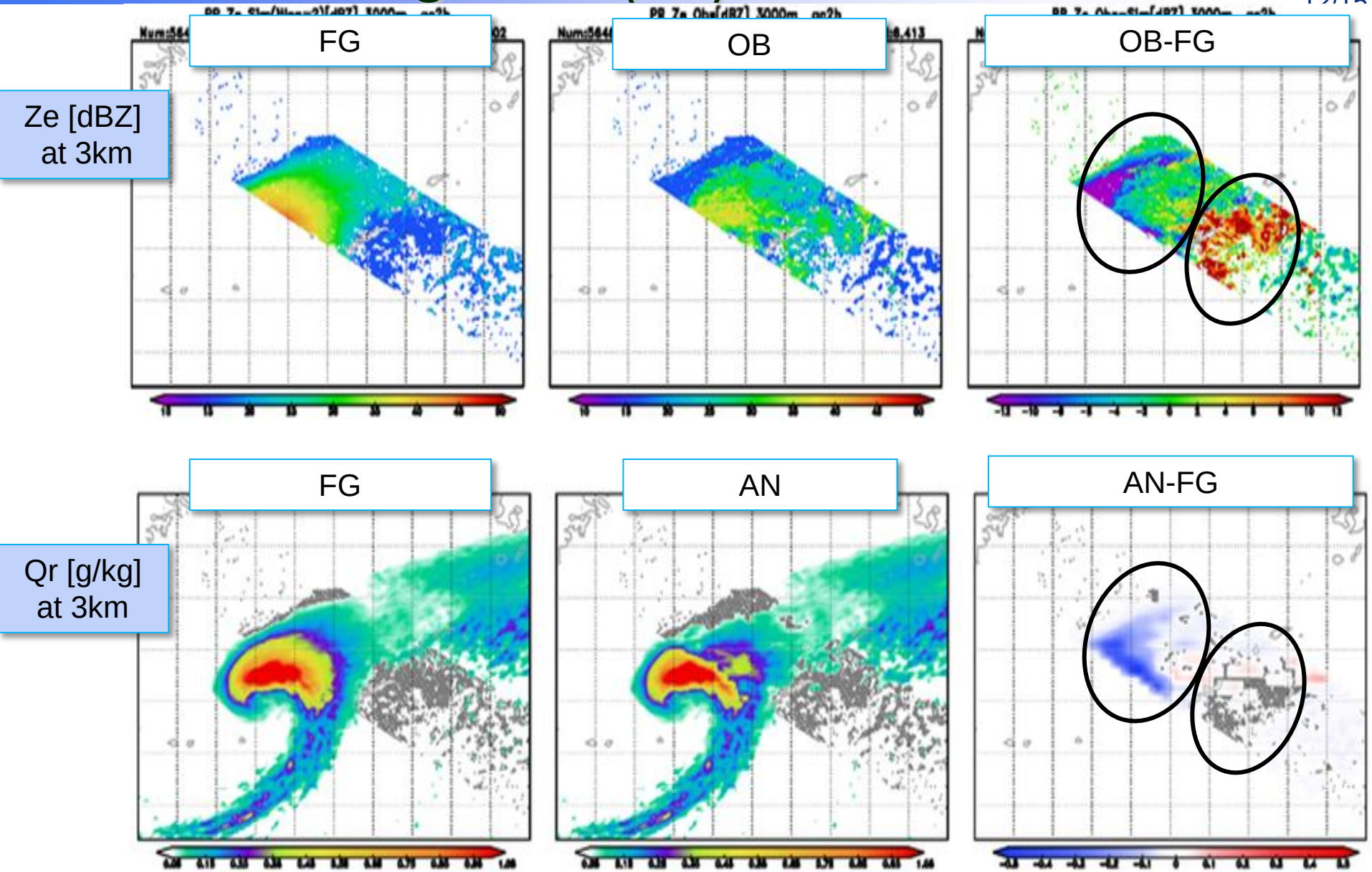
3. Extend EnVA to include PR/DPR Ze

- Observation (OB)
  - TRMM/PR 2A25 attenuation corrected Ze
- Pre-processings
  - QC (Quality Control) procedures reject data
    - Above and in bright band
    - Affected by ground clutter
    - Over land
    - When both OB and FG have no rain (<17dBZ)
    - Having large OB-FG
      - FG: Ze simulated from model first-guess (FG)
  - Observation error = 2dBZ





Assimilation result : Ze and rain mixing ratio (Qr)



Summary and plans

- Comparison of GPM-core/DPR with model simulation
  - JMA-NHM overestimates Ze from ice particles and shows unclear bright band
  - Ze overestimation by ice is alleviated in Ka relative to Ku.
- Evaluate the improve EnVA
  - OSSE shows improved EnVA properly assimilates precipitation-affected radiance of TMI
- Extend EnVA to include PR/DPR
  - Include Joint-simulator and develop QC procedures
  - Preliminary assimilation test shows reasonable change in Qr and Ze according to the difference observation and first guess

- Plan
  - Assimilate DPR Ze in the improved EnVA
  - Improve a Displacement Error Correction (DEC) scheme
  - Evaluate analysis and forecast by including DPR in the improved EnVA

- Thank you for your attention