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31st AMS hurricane conf.

Displaced Ensemble variational assimilation to incorporate MWI TBs into a CRM for Typhoon Conson

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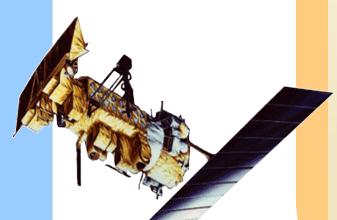
GPM(Global Precipitation Measurement)

TRMM
TMI
PR

Aqua
AMSR-E

ADEOS-II
AMSR

DMSP
SSM/I



NOAA AMSU-B

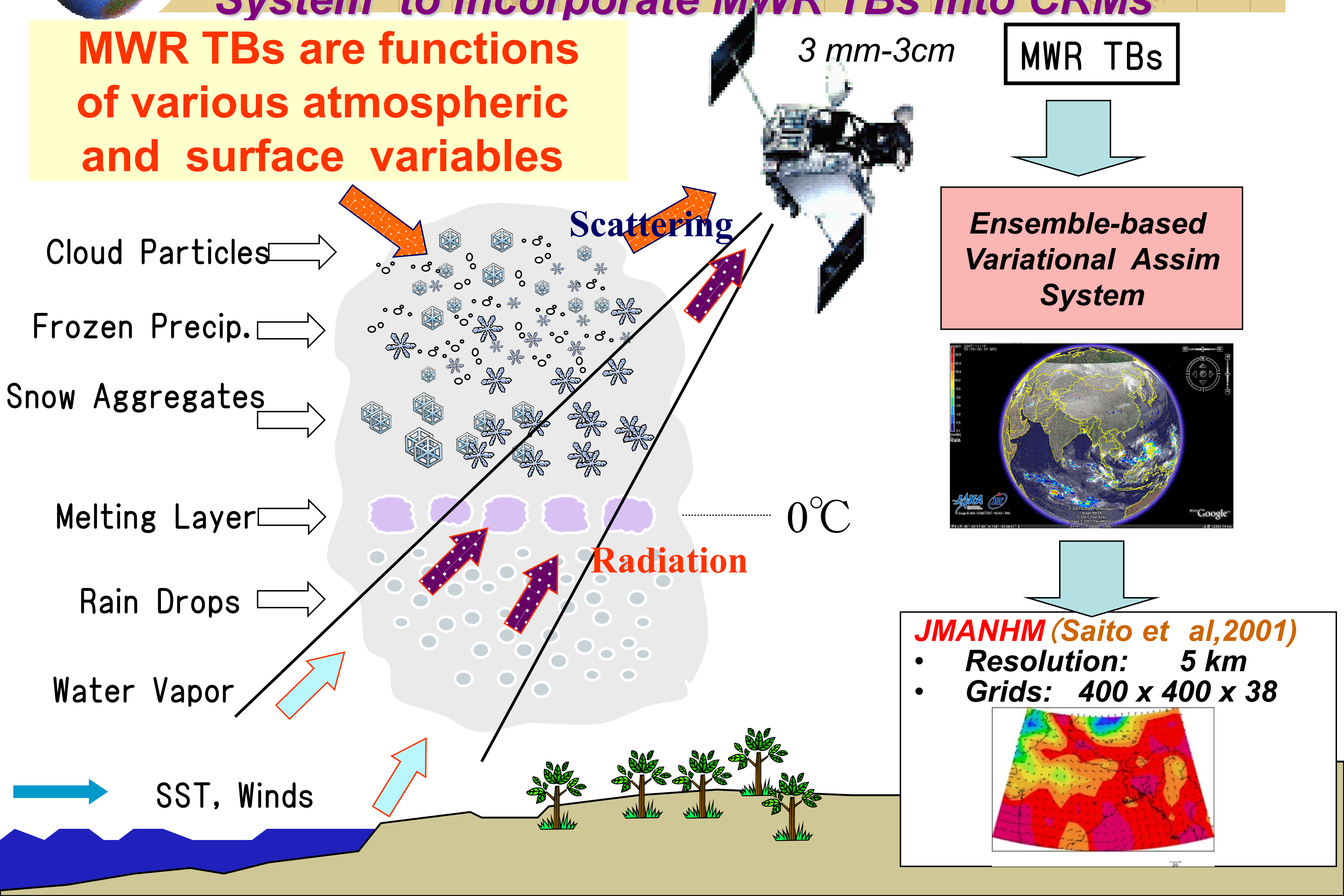
Constellation Satellites
Microwave radiometers

Core Satellite
Dual frequency Precipitation Radar
GPM Microwave Imager

Concept of GPM

GOAL: Ensemble-based Variational Assimilation System to incorporate MWR TBs into CRMs

MWR TBs are functions of various atmospheric and surface variables



OUTLINE

- Introduction
- Ensemble-based Variational Assimilation (EnVA)
  - Methodology
  - Problems in EnVA for CRM
- Displacement error correction (DEC)+EnVA
  - Methodology
  - Application results for Typhoon CONSON (T0404)
- Summary

EnVA: min. cost function in the Ensemble forecast error subspace

- Minimize the cost function with non-linear Obs. term.

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

- Assume the analysis error belongs to the Ensemble forecast error subspace （Lorenc, 2003):

$$\vec{X} - \overline{X}^f = \mathrm{P_e^{f/2}} \circ \Omega \qquad \Omega = [\vec{\mathrm{w}}_1, \vec{\mathrm{w}}_2, ,,,,, \vec{\mathrm{w}}_\mathrm{N}]$$

$$P_e^{f/2} = [\vec{X}_1^f - \overline{X}^f, \vec{X}_2^f - \overline{X}^f, ,,, \vec{X}_N^f - \overline{X}^f]$$

- Forecast error covariance is determined by localization

$$\mathrm{P^f} = \mathrm{P_e^f} \circ \mathrm{S}$$

- Cost function in the Ensemble forecast error subspace:

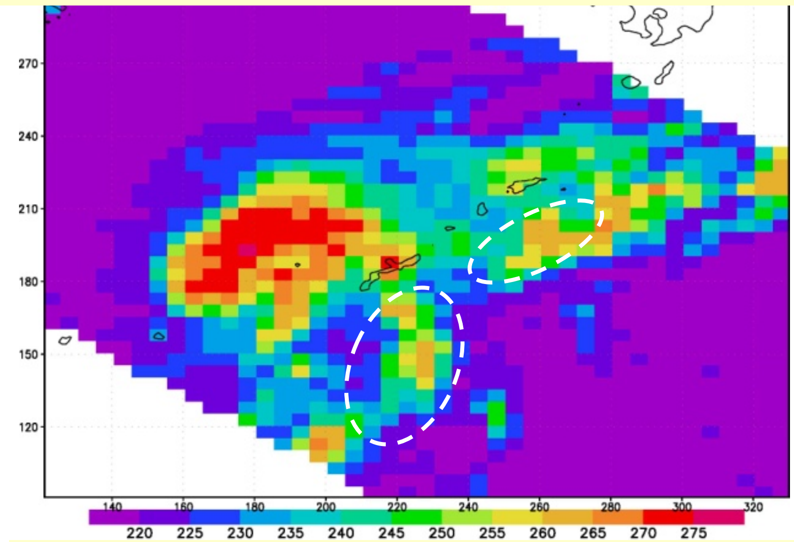
$$J(\Omega) = 1/2\, trace\{\Omega^t S^{-1} \Omega\} + 1/2\{H(\vec{X}(\Omega)) - Y\}^t R^{-1}\{H(\vec{X}(\Omega)) - Y\}$$

Problem in EnVA (1): Displacement error

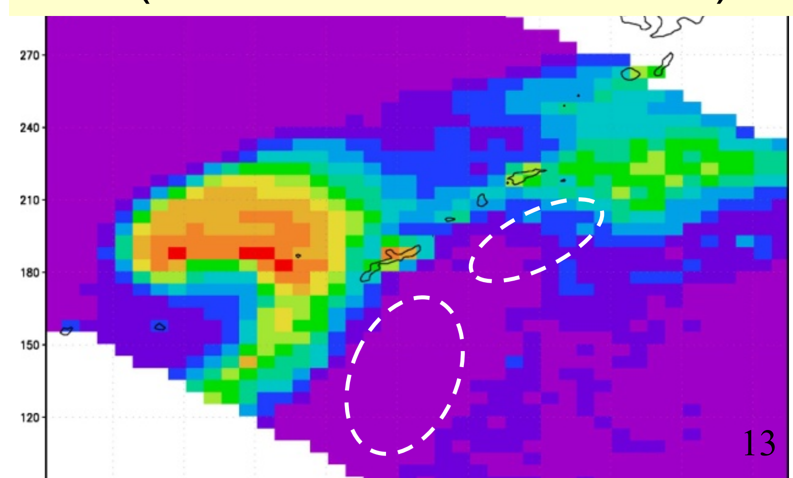
- Large scale displacement errors of rainy areas between the MWI observation and Ensemble forecasts

- Presupposition of Ensemble assimilation is not satisfied in observed rain areas without forecasted rain.

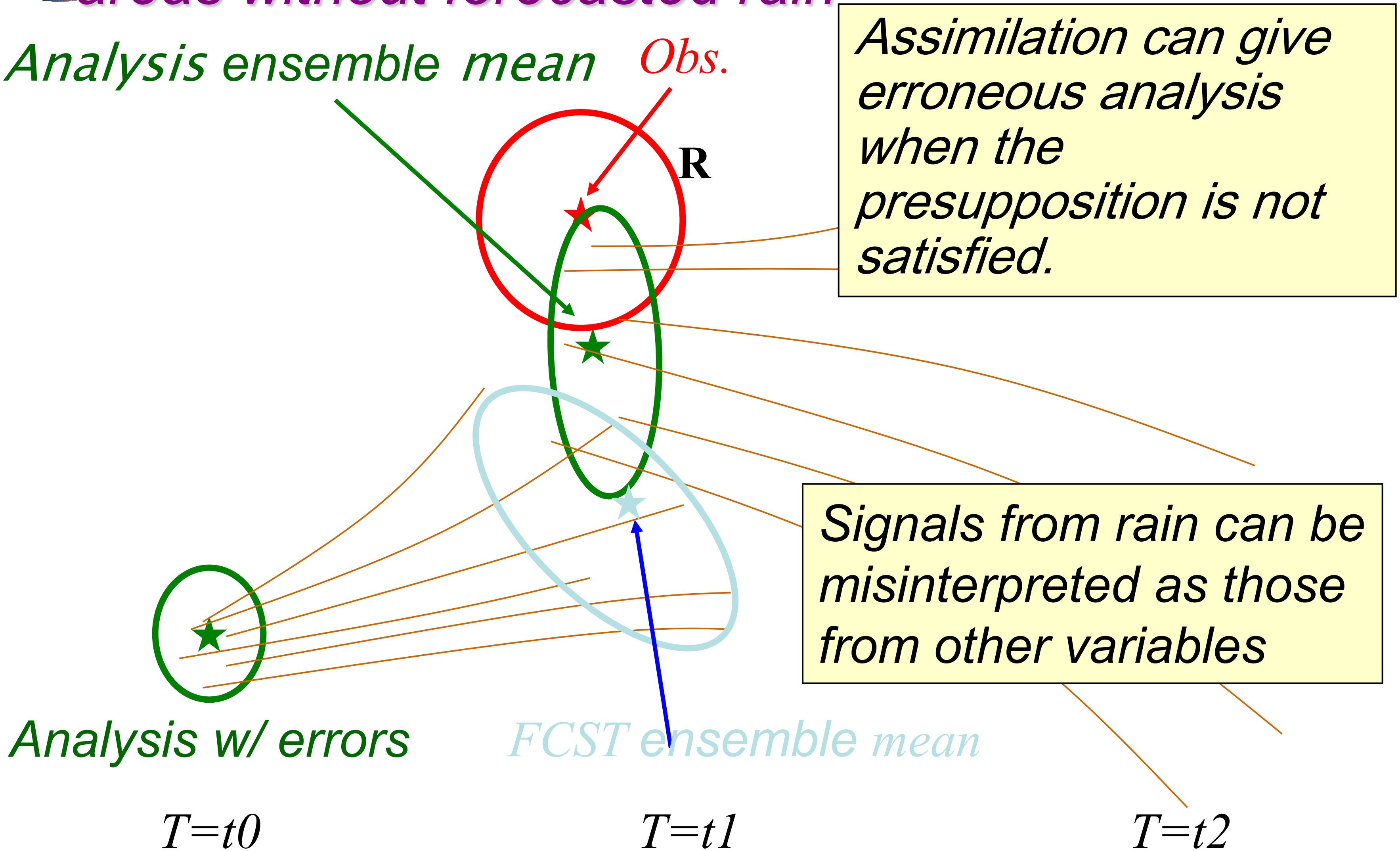
TMI *TB19v* (2004/6/9/22UTC)



Mean of Ensemble Forecast
(2004/6/9/15UTC FT=7h)



Ensemble-based assimilation for observed rain areas without forecasted rain



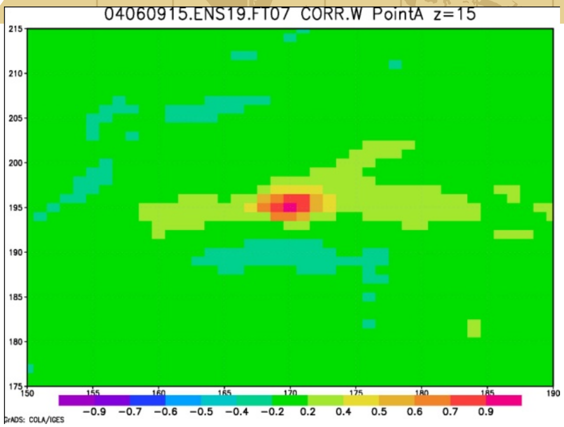
Displacement error correction is needed!

Problem in EnVA (2): Sampling error

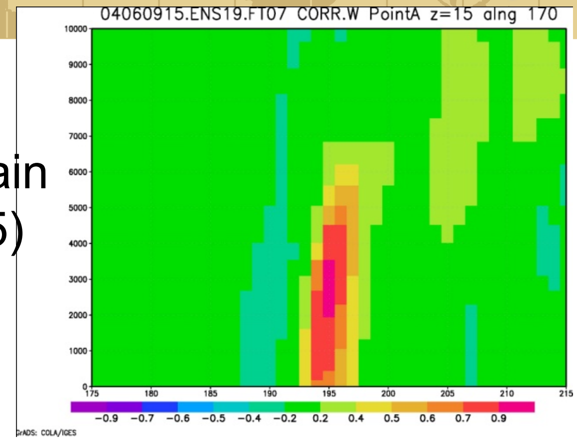
Forecast error corr. of W (04/6/9/15z 7h fcst)

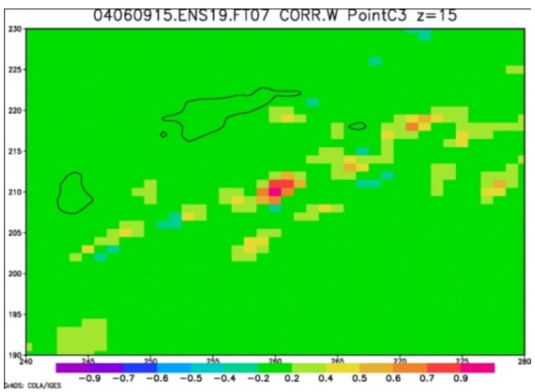
200 km

200 km

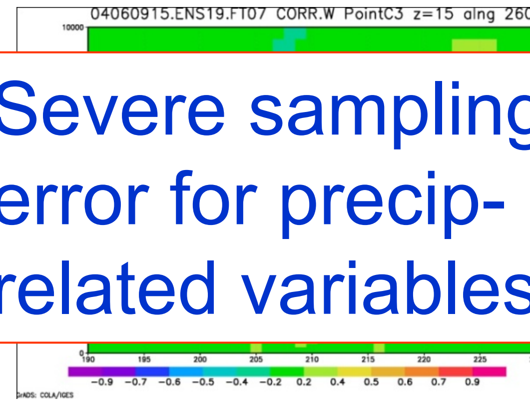


Heavy rain
(170,195)

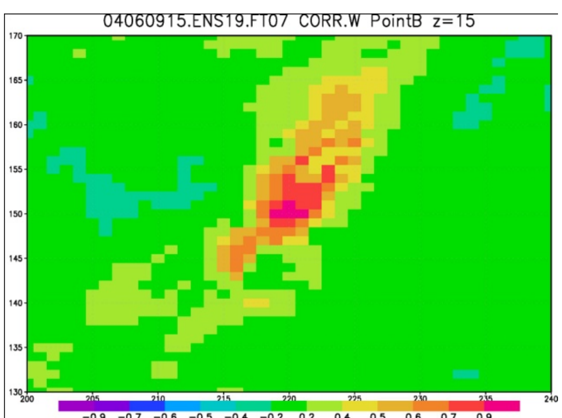




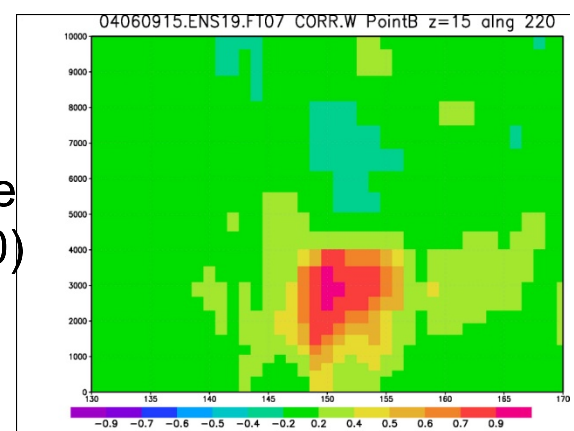
Weak ra
(260,210



Severe sampling error for precip-related variables



Rain-free
(220,150)



Displacement error correction (DEC)+EnVA

- Methodology
- Application results for Typhoon CONSON (T0404)
  - Case
  - Assimilation Results
  - Impact on precipitation forecasts

Displaced Ensemble variational assimilation method

In addition to $\vec{X}$, we introduced $\vec{d}$ to assimilation.

The optimal analysis value maximizes ：

$$\arg\max P(\vec{X}, \vec{d} \mid Y, \overline{X}^f)$$

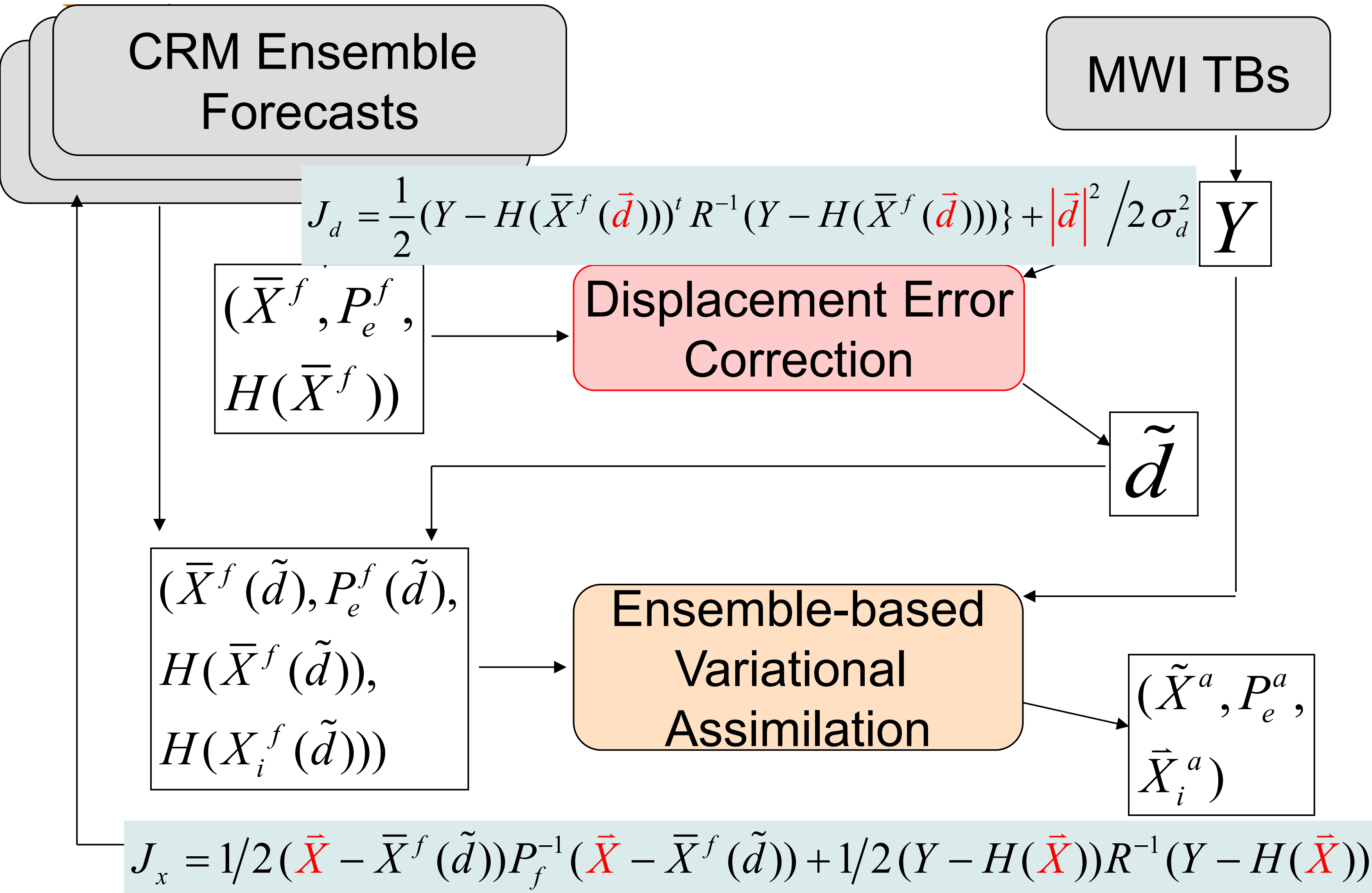
$$P(\vec{X}, \vec{d} \mid Y, \overline{X}^f) = P(\vec{d} \mid Y, \overline{X}^f) P(\vec{X} \mid \vec{d}, Y, \overline{X}^f)$$

Assimilation results in the following 2 steps:

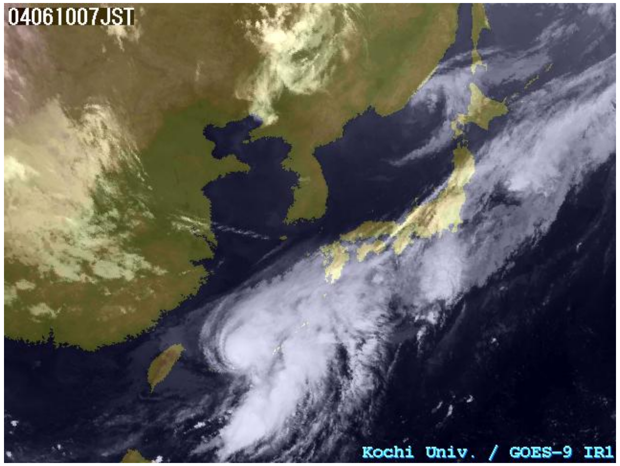
1) DEC scheme to derive $\vec{d}^a$ from $P(\vec{d} \mid Y, \overline{X}^f)$

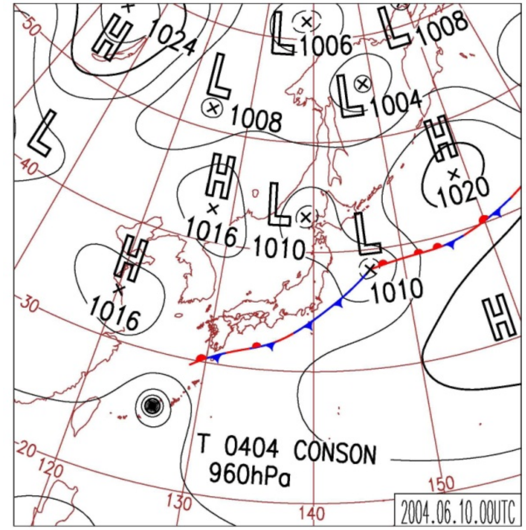
2)EnVA scheme using the DEC Ensembles to derive $\vec{X}^a$ from $P(\vec{X} \mid \vec{d}^a, Y, \overline{X}^f)$

Assimilation Procedures



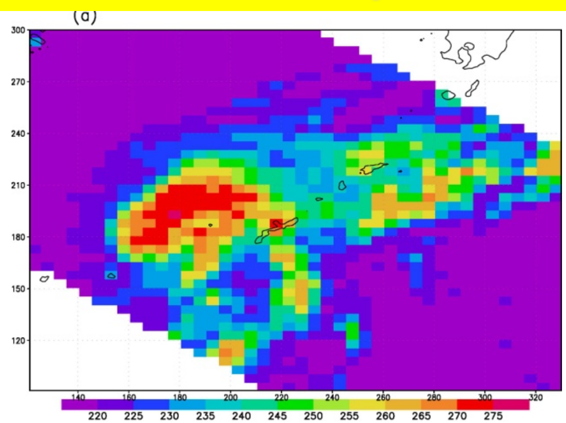
Case (2004/6/9/22 UTC) TY CONSON

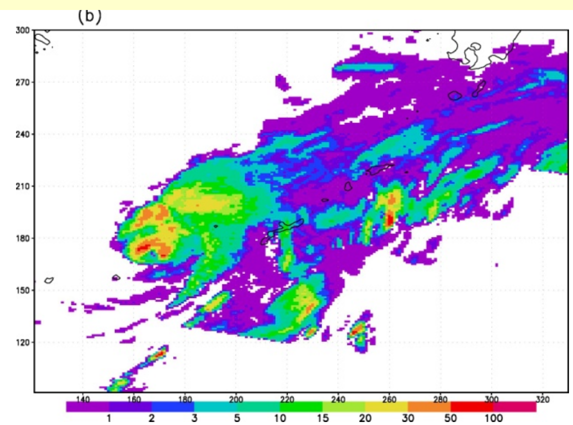




Assimilate TMI TBs (10v, 19v, 21v) at 22UTC

RAM (mm/hr)





CRM Ensemble Forecasts & RTM

CRM: JMANHM (Saito et al,2001)

- Resolution: 5 km
- Explicitly predict hydrometeors

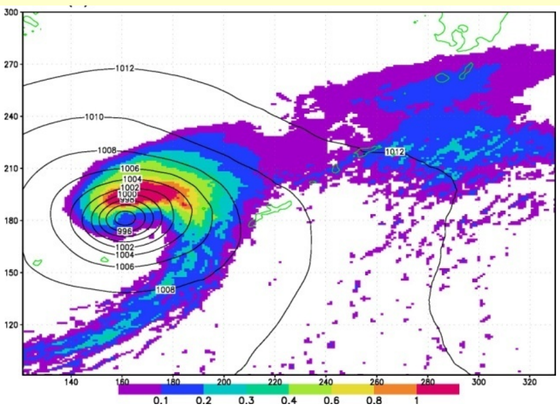
Ensemble forecasts

- 100 members started with perturbed initial data at 04/6/9/15 UTC (FG)
- Geostrophically-balanced perturbation (Mitchell et al. 2002) plus Humidity

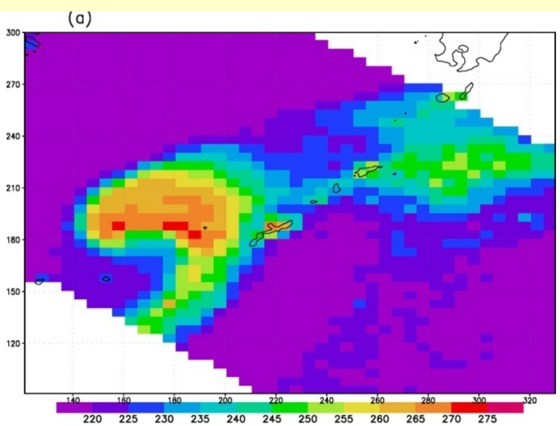
RTM: Guosheng Liu (2004)

- Plane-parallel model (4stream approx.)
- Mie Scattering (Sphere)

Ensemble mean (FG)
Rain mix. ratio

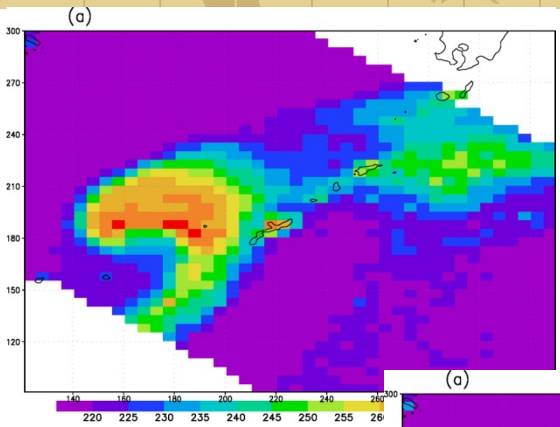


TB19v cal. from FG

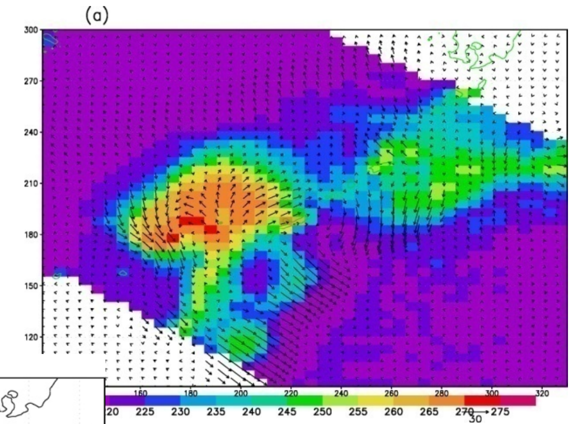


TB19v from TMI and CRM outputs

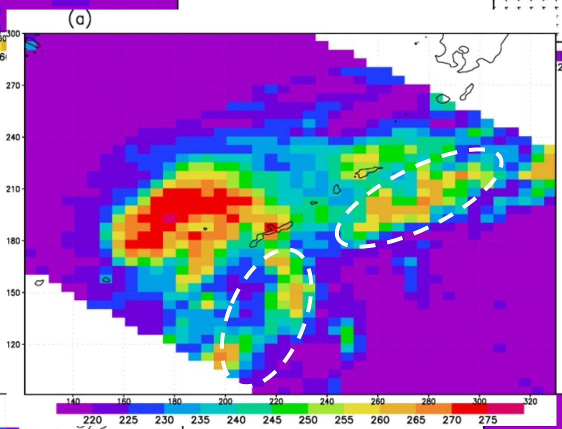
FG : First guess



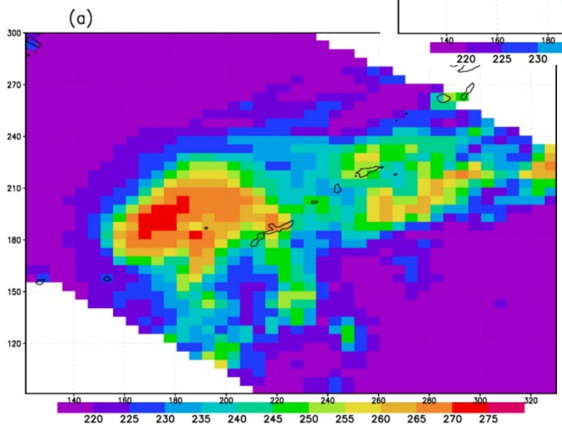
DE : After DEC



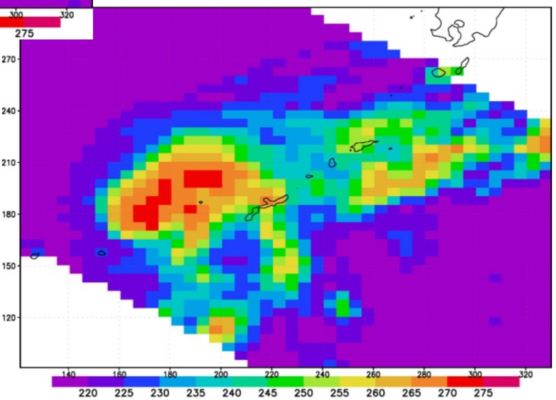
TMI



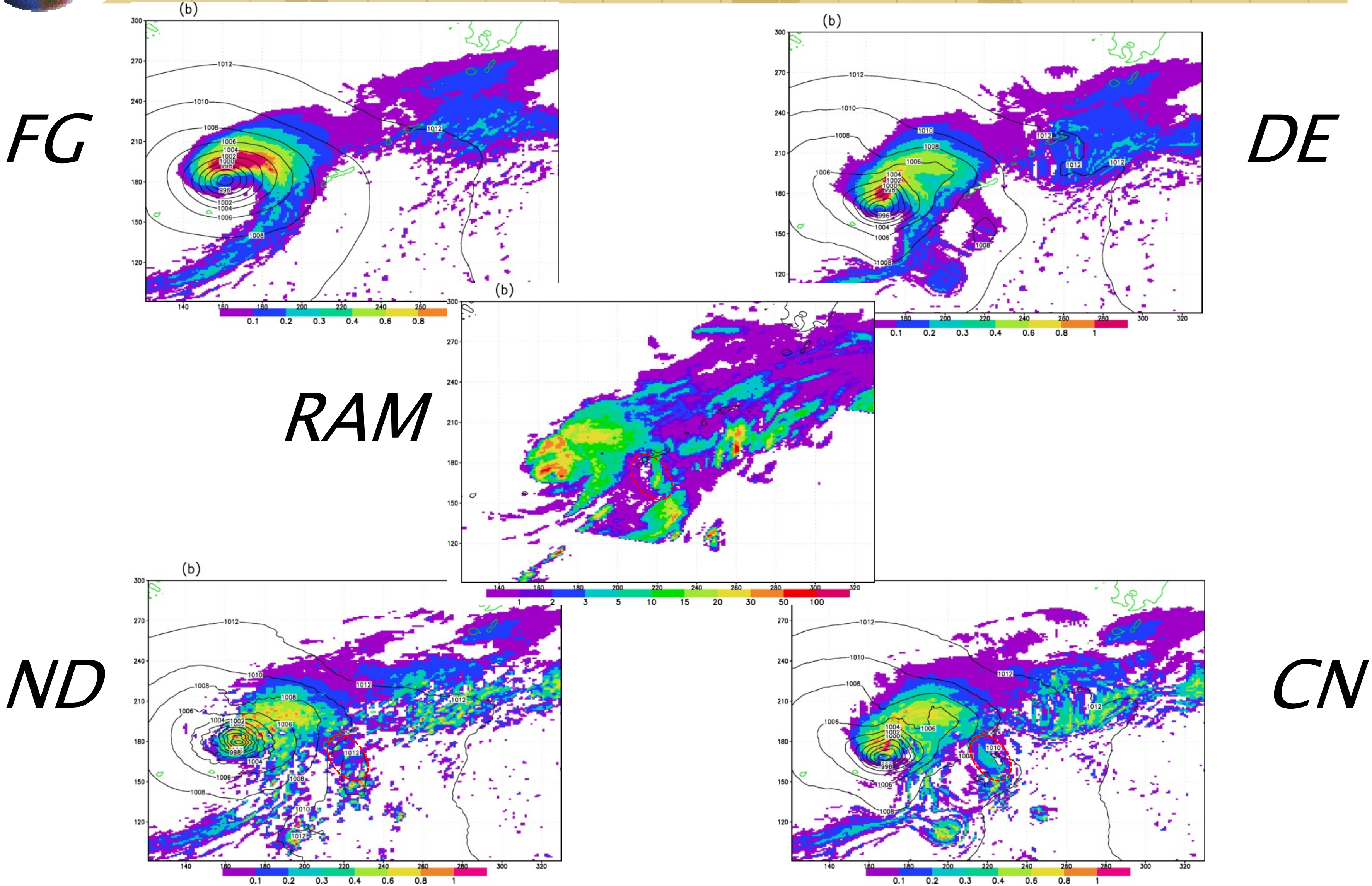
ND: NoDE+ EnVA



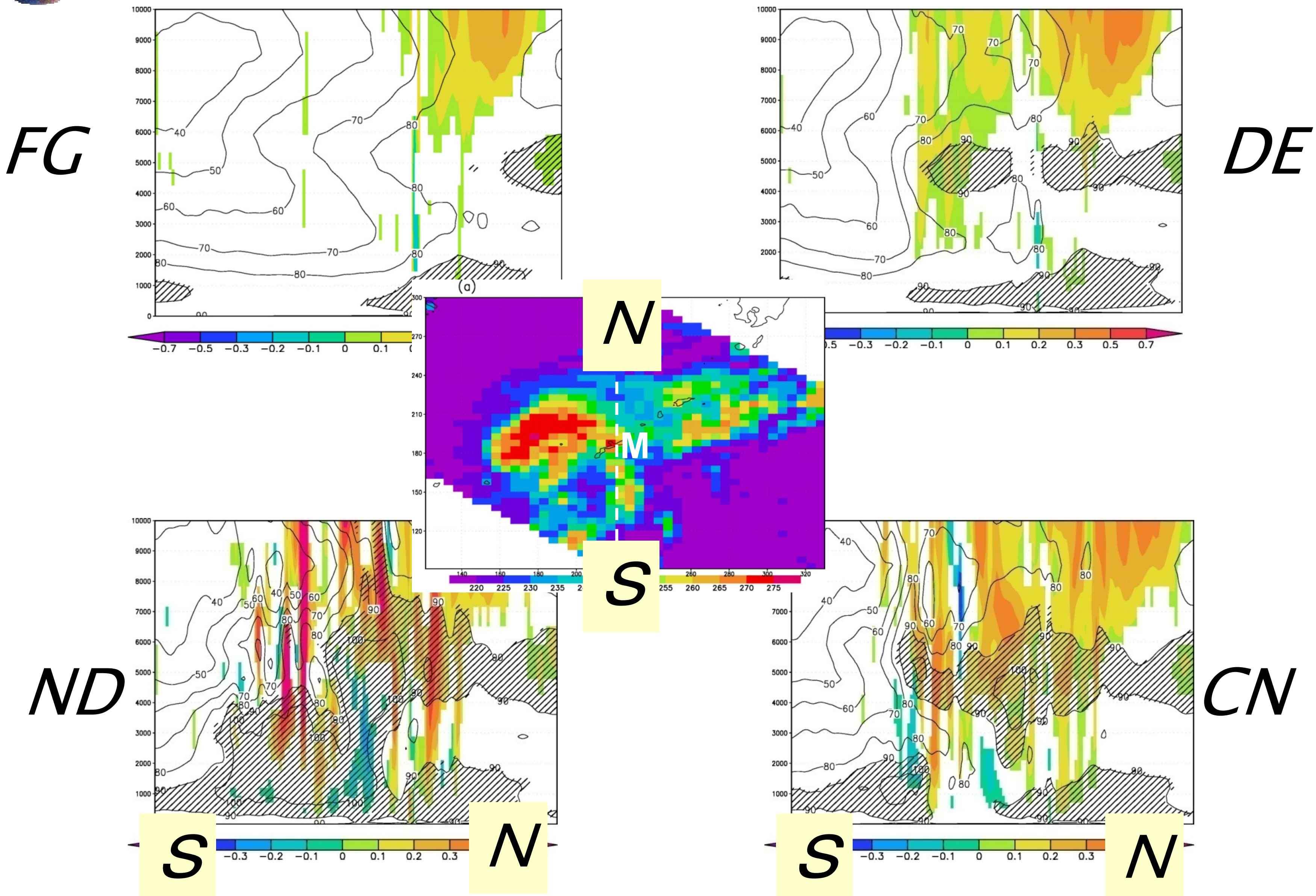
CN : DE+ EnVA



RAM and Rain mix. ratio analysis (z=930m)

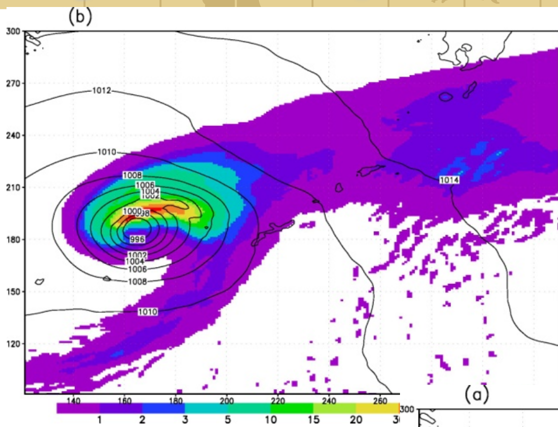


RH(contours) and W(shades) along N-S

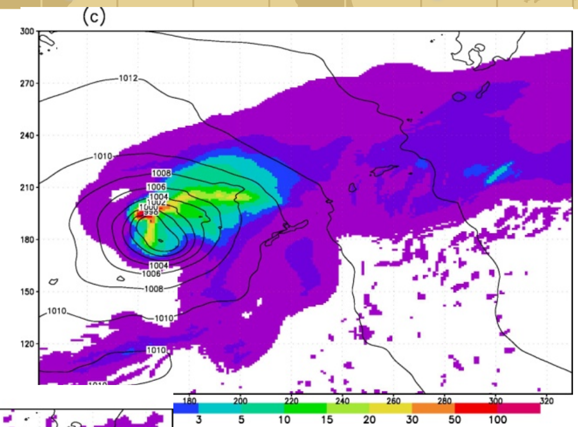


Hourly Precip. forecasts (FT=0-1 h) 22-23Z 9t

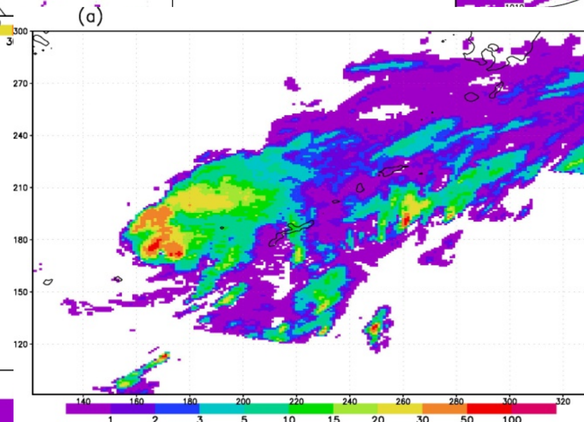
FG



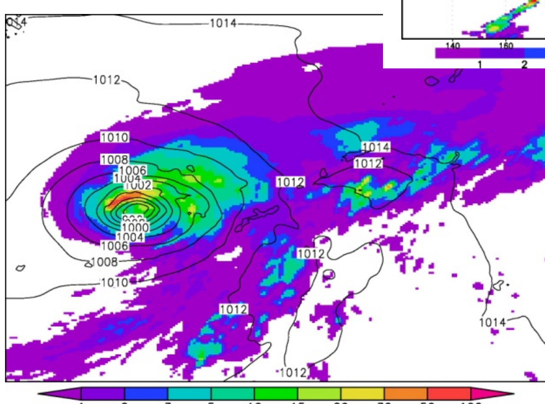
DE



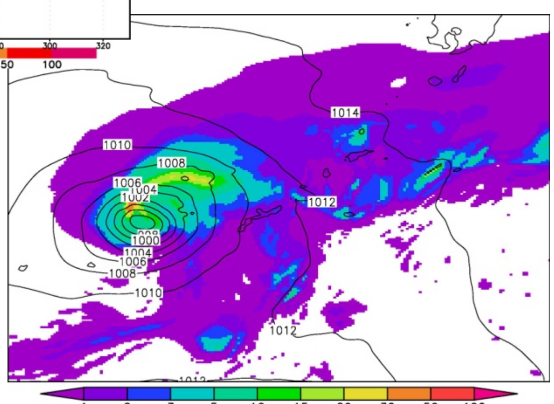
RAM



ND

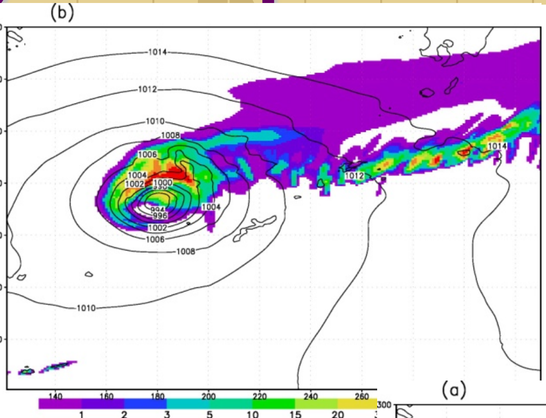


CN

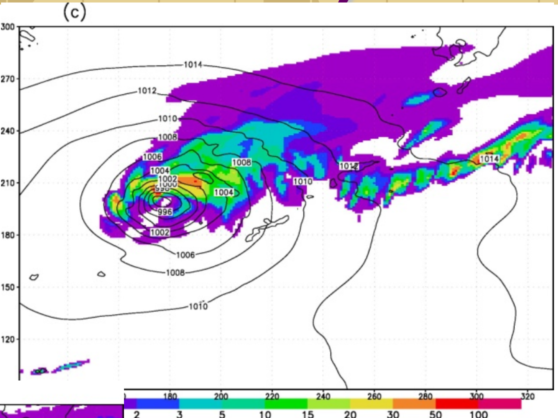


Hourly Precip. Forecasts (FT=3-4 h) 01-02Z 10th

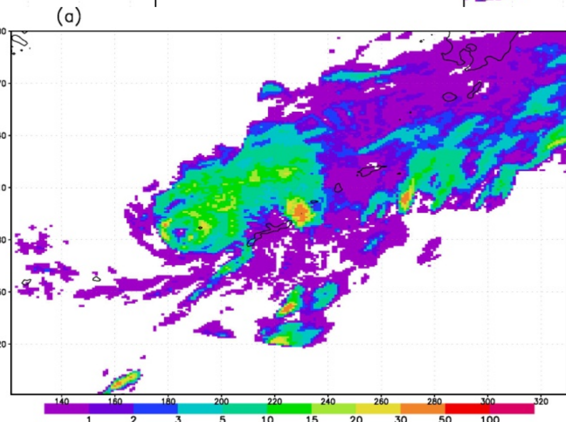
FG



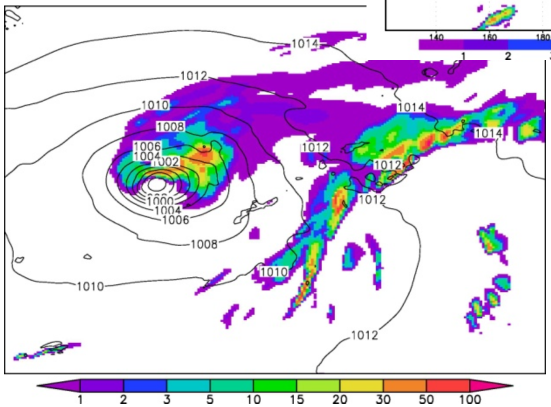
DE



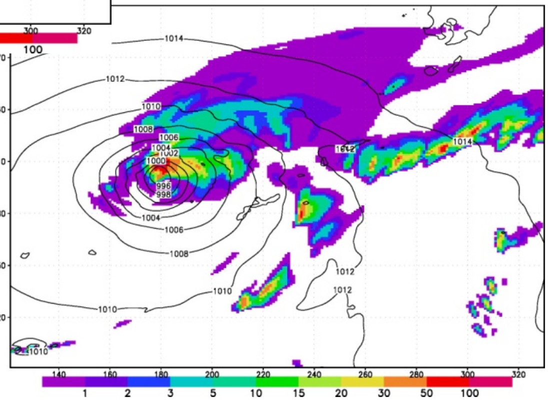
RAM



ND



CN



Summary

- Ensemble-based data assimilation can give erroneous analysis, particularly for observed rain areas without forecasted rain.
- We developed an ensemble-based assimilation method that uses Ensemble forecast error covariance with displacement error correction.
- The application results (T0404) showed that the assimilation of TMI TBs alleviated the large-scale displacement errors and improved precip forecasts.
- The scheme also avoided misinterpretation of TB increments due to precip displacements as those from other variables.

Thank you for your attention.

End