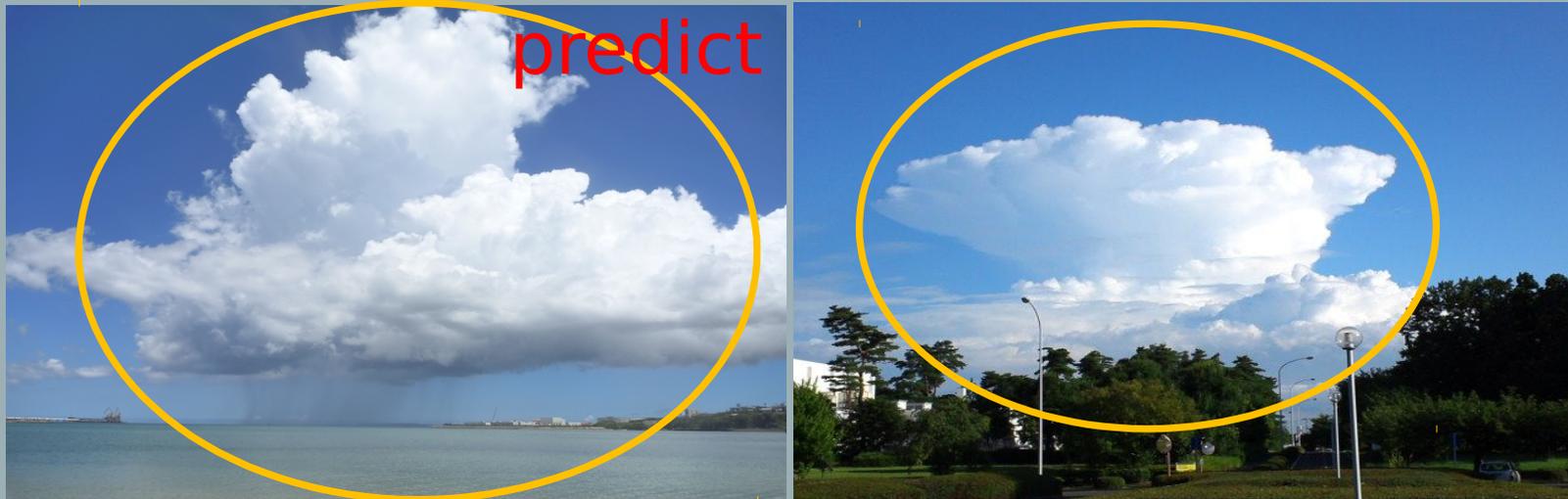


DEVELOPMENT OF
A STORM-SCALE PARTICLE FILTER
FOR INVESTIGATING PREDICTABILITY OF
CONVECTION INITIATION AND DEVELOPMENT

Difficult to
predict



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Genta Ueno

The Institute of Statistical Mathematics

Many thanks to
Drs. Seko, Hotta,
Yokota, and

DIFFICULT TO PREDICT?

Answer: Low predictability

Two types of prediction
Zhang

(Lorenz 1996; F.

Next question:

**What is indeed the source of chaos
in convective storms?**

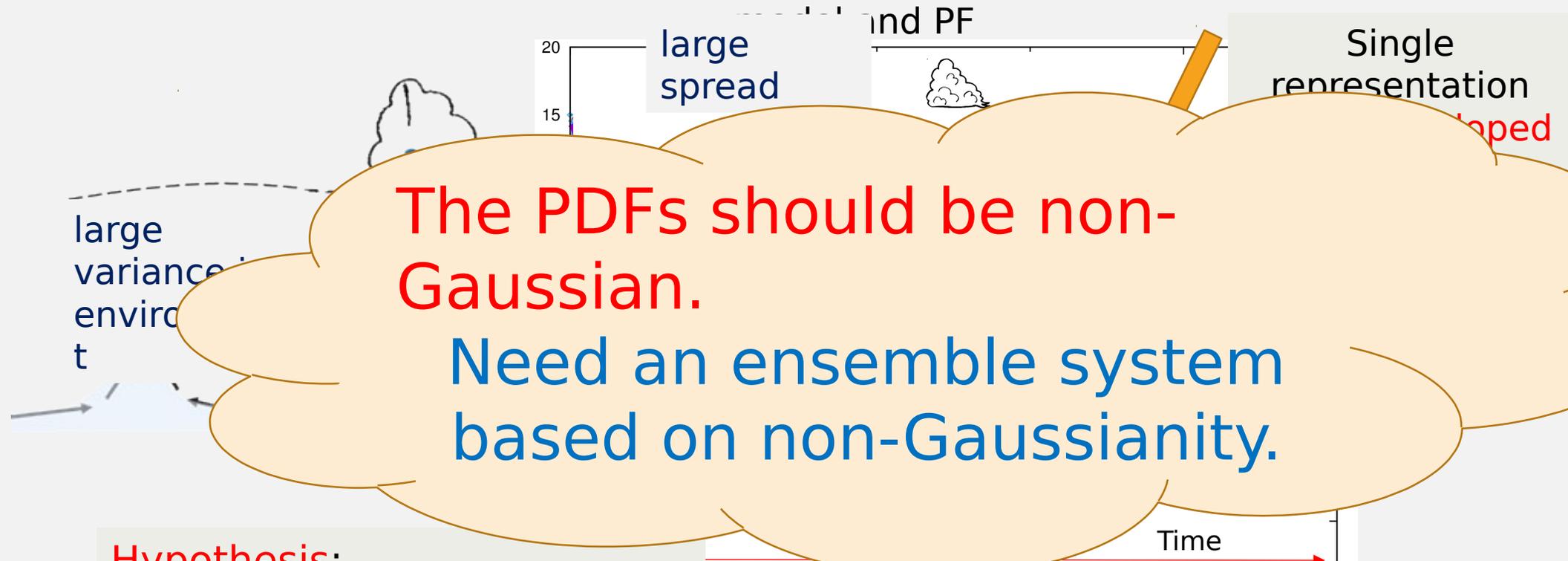
Chaos = Strong nonlinearity

**→ Investigate it using an ensemble
system dealing with nonlinearity!**

Prac

CONCEPT OF THE STUDY

Trajectories of 100 particles predicted and filtered by Lorenz



The PDFs should be non-Gaussian.

Need an ensemble system based on non-Gaussianity.

Hypothesis:

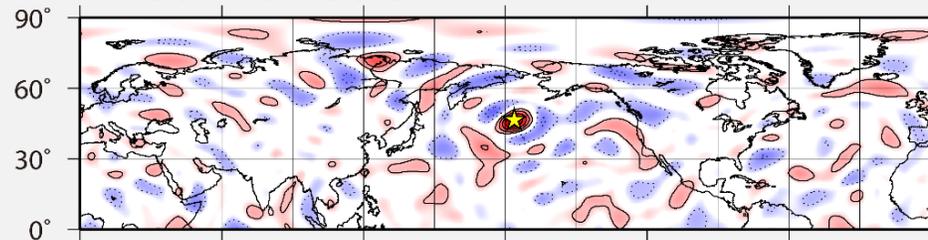
It will be observed large spread of the particles in environmental fields before the CI.

- Two groups at the initial stage of the Cb:
- highly developed Cb or low developed Cu
 - Earlier or later developed

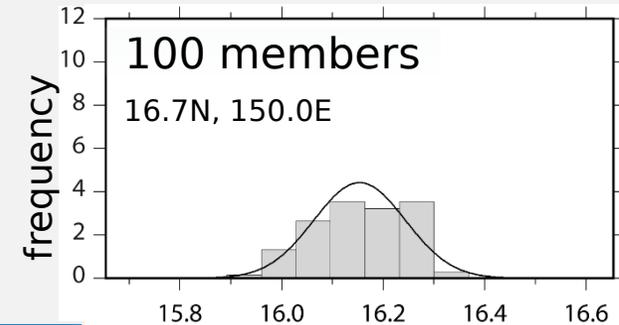
NON-GAUSSIAN PDF

- Miyoshi et al. (2014) successfully implemented 10240-member LETKF with the SPEEDY model (T30/L7).

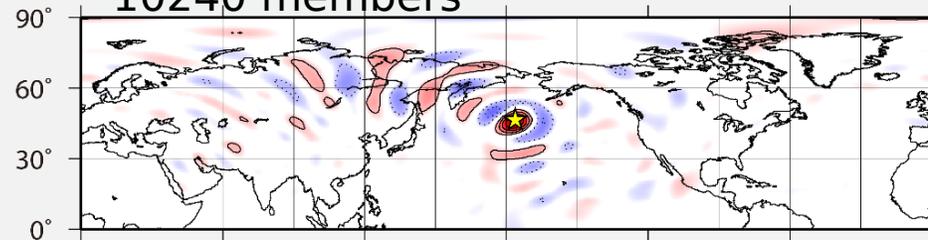
Auto-correlations for Q from  at 00 UTC 17 January.
100 members



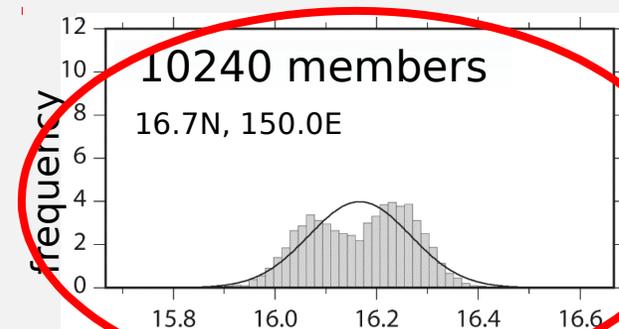
Specific humidity [g/kg] at a single grid point



10240 members



Sampling noise reduced



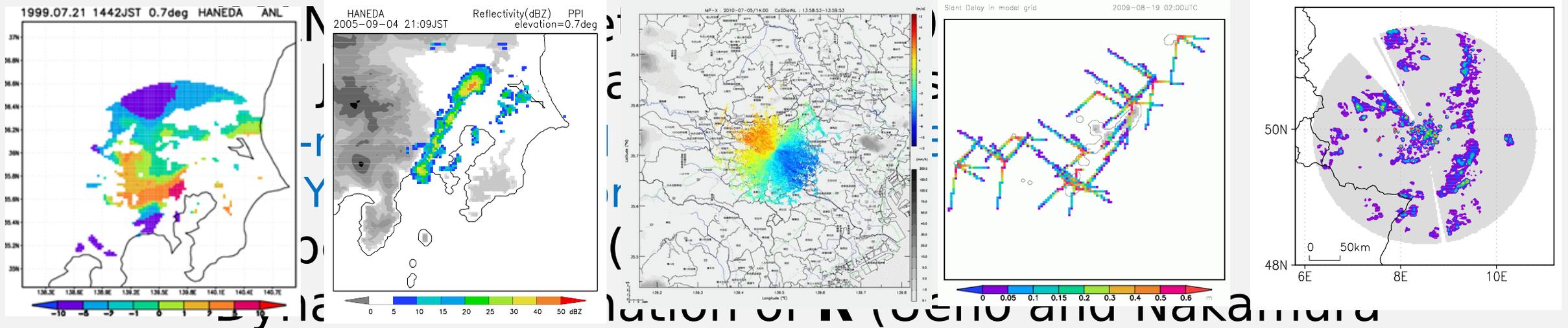
Bimodal PDF likely related to precipitation area

High-precision probabilistic representation

Courtesy of Miyoshi and

NHM-PF

- Sampling Importance Resampling (SIR) filter



2016)

see [Poster 4.1: Genta Ueno: Bayesian estimation of the observation-error covariance matrix in ensemble-based filters](#)

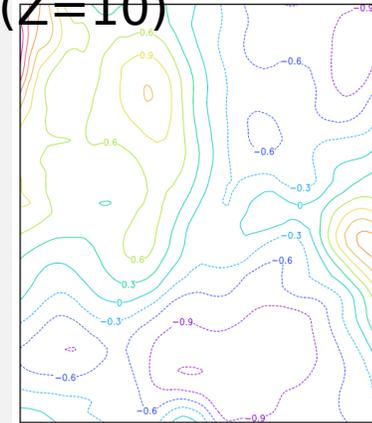
- Advanced observational operators developed for NHM-4DVAR (Kawabata et al. 2007; 2011; 2014a; 2014b; 2018)

RF(RANDOM FIELD) PERTURBATION AS SYSTEM NOISE

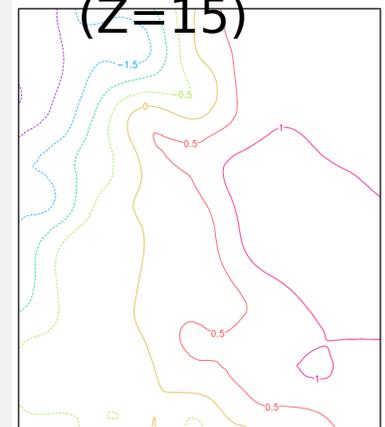
Magnusson et al. (2009)

- 12-h forecasts by JMANHM were performed for 20 days initialized both at 00 and 12 UTC.
- Output 3 hourly
- A set of forecast were randomly chosen to make a difference field.
- Variables of RF are 3-dimensional wind, potential temperature, water vapor, cloud water, and cloud ice.
- Horizontal averages were set to ZERO at every vertical layer.
- Running mean with 5x5 grids to avoid spiky noise.

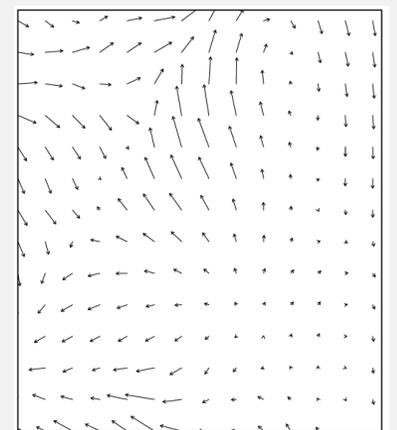
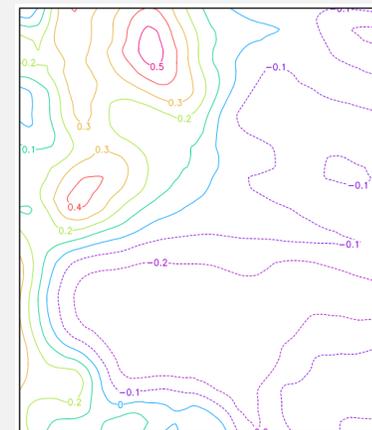
Water vapor
(Z=10)



PT
(Z=15)

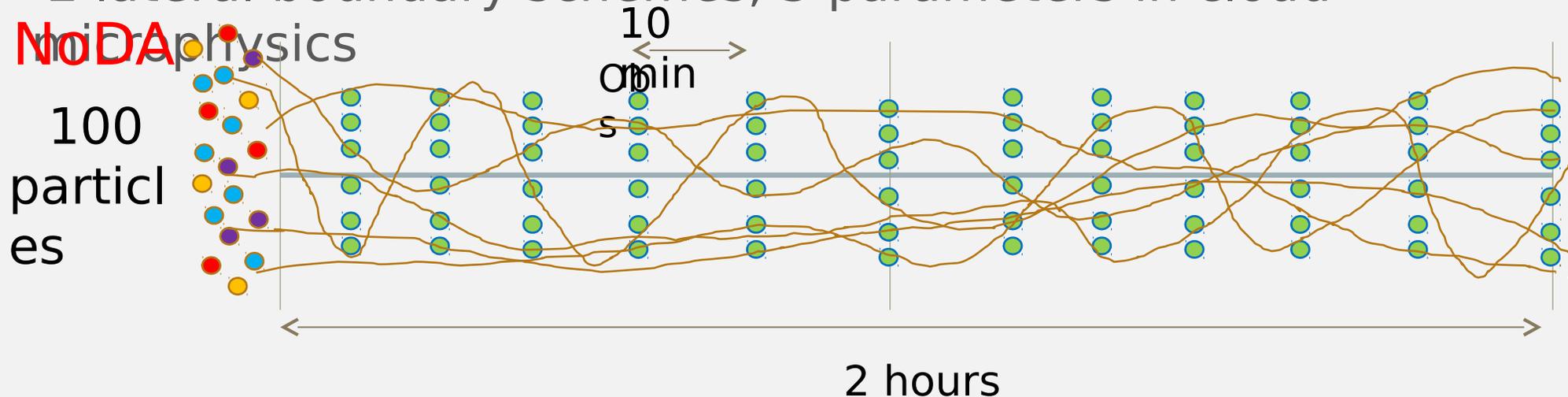


Cloud water (Z=10) Wind (Z=5)

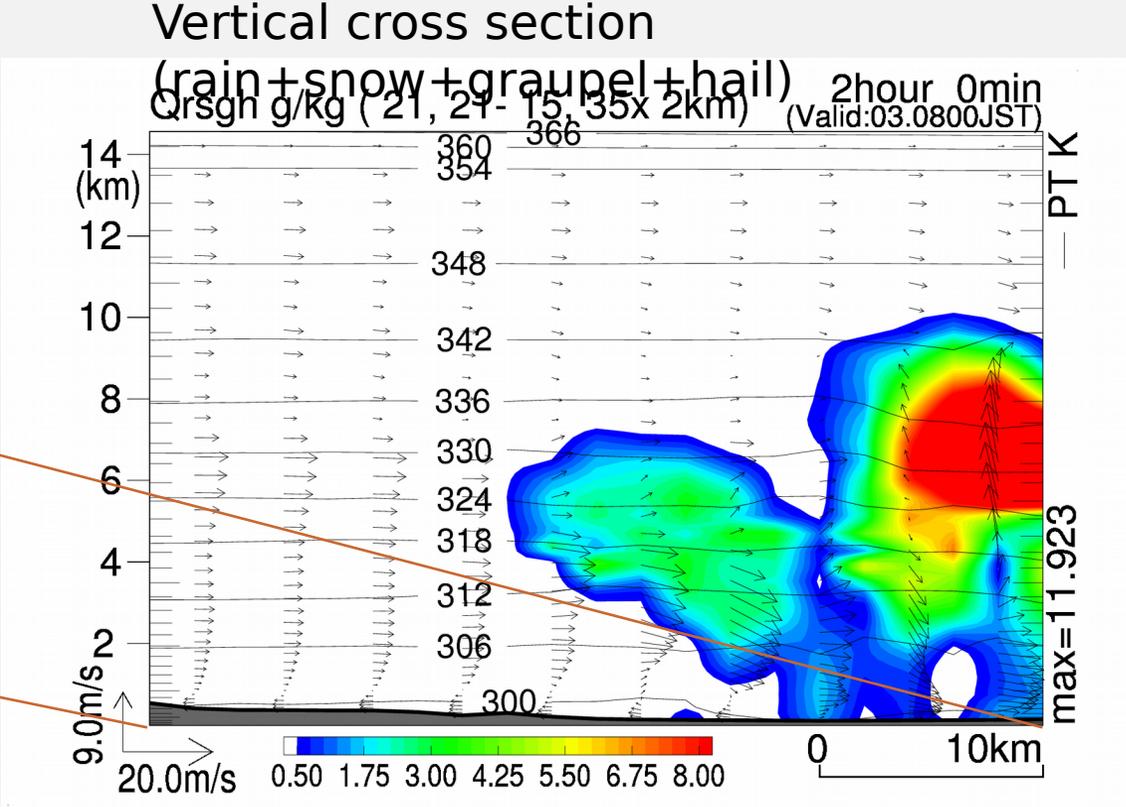
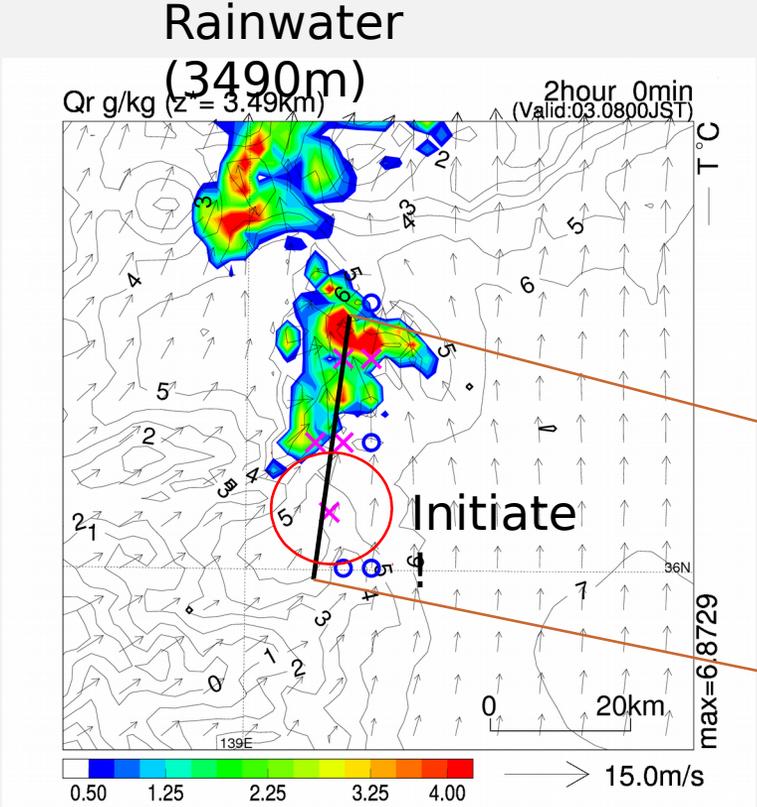


DESIGN OF OSSE

- **100 particles** from LETKF (50 members) and LAF (two different analysis time)
- 48x48x50 grids at **2 km** grid spacing
- 2-h assimilation with observations at every **10 min**
- 8 sets of parameter (model switch) ensemble:
2 lateral boundary schemes, 3 parameters in cloud



NATURE RUN & OBSERVATION NETWORK



Observations (truth with Gaussian noise)

X (pseudo radar): mixing ratio of rainwater (6 points at 15, 25, 35th layer)

O (surface obs): wind, potential temperature, mixing ratio

RESULT: PARTICLES WITH WEIGHT ALONG WITH TIME STEP

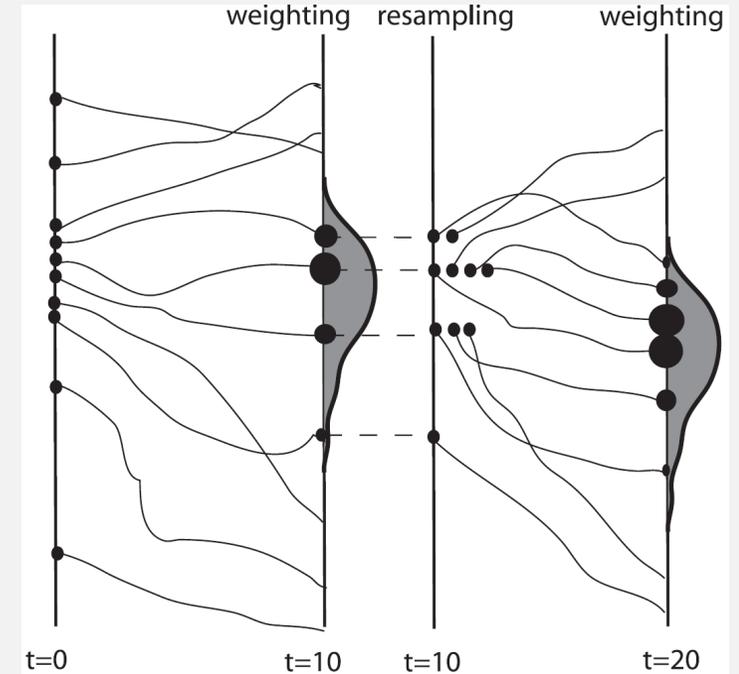
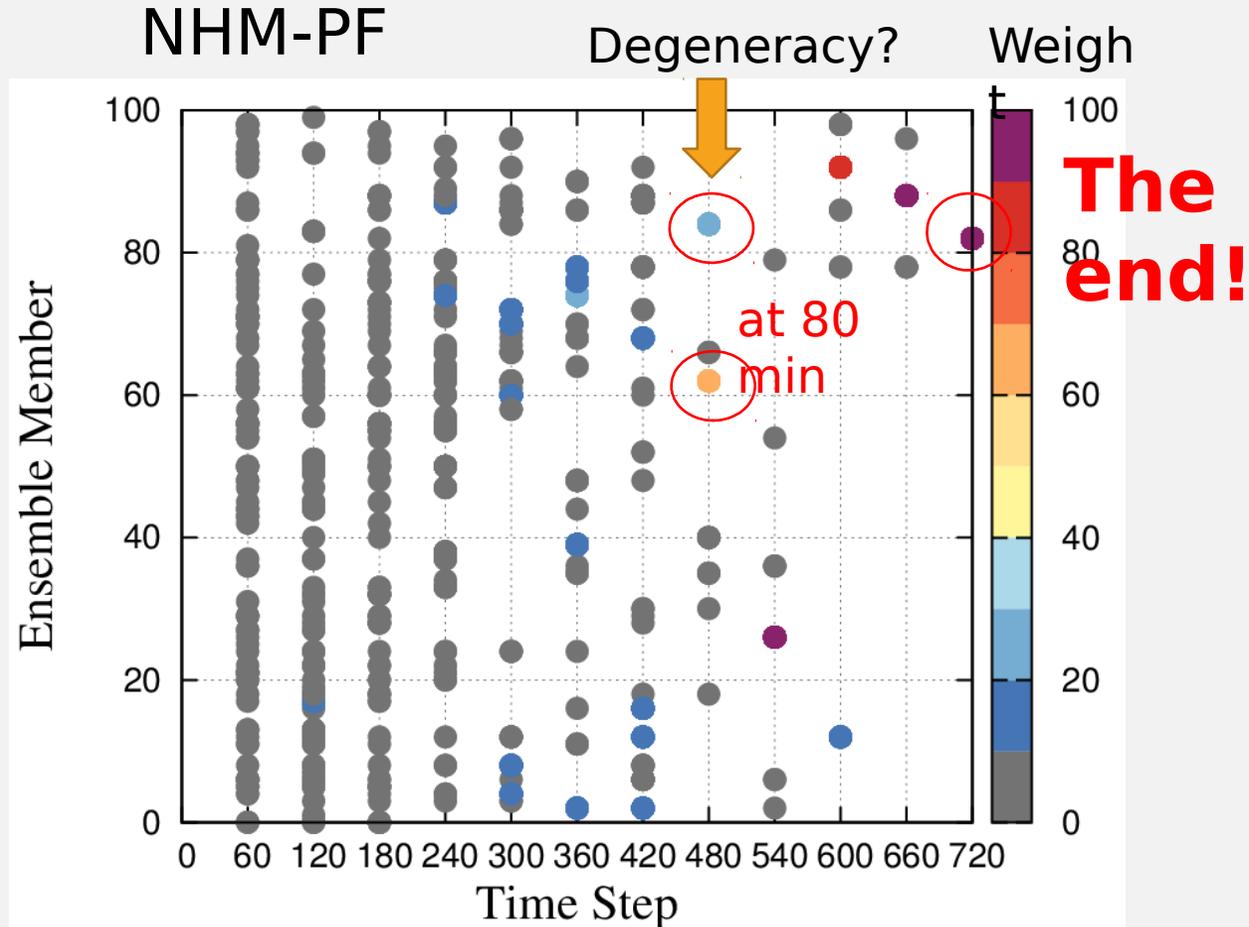
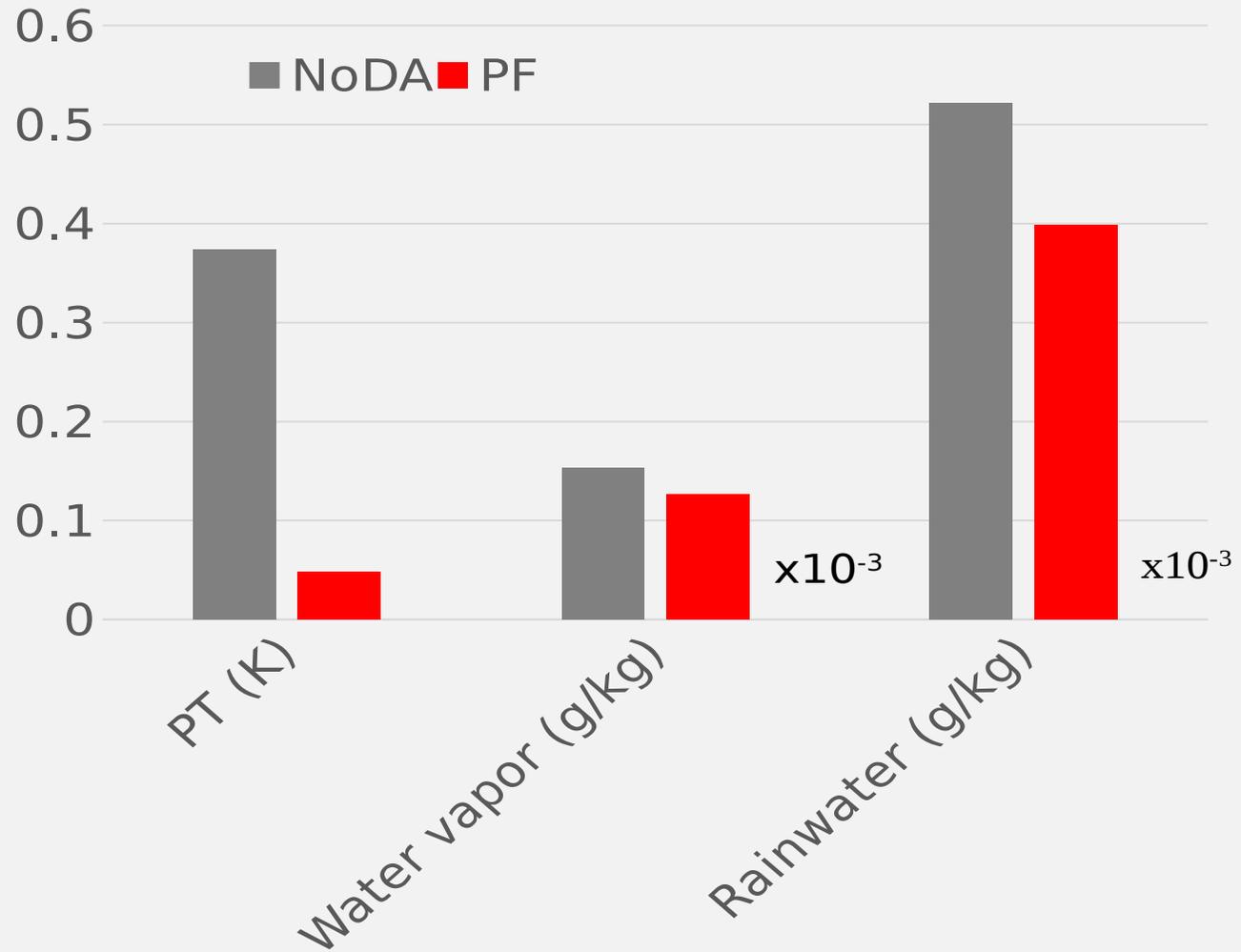


Fig. 2 of P. J. van Leeuwen (2009, MWR)

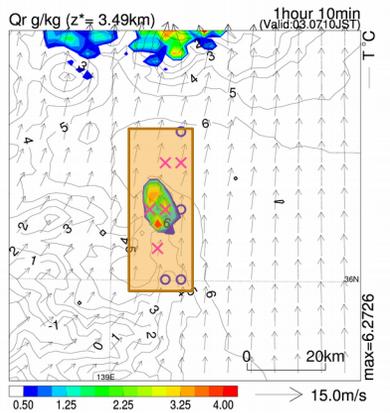
RESULT: RMSE AGAINST OBSERVATIONS



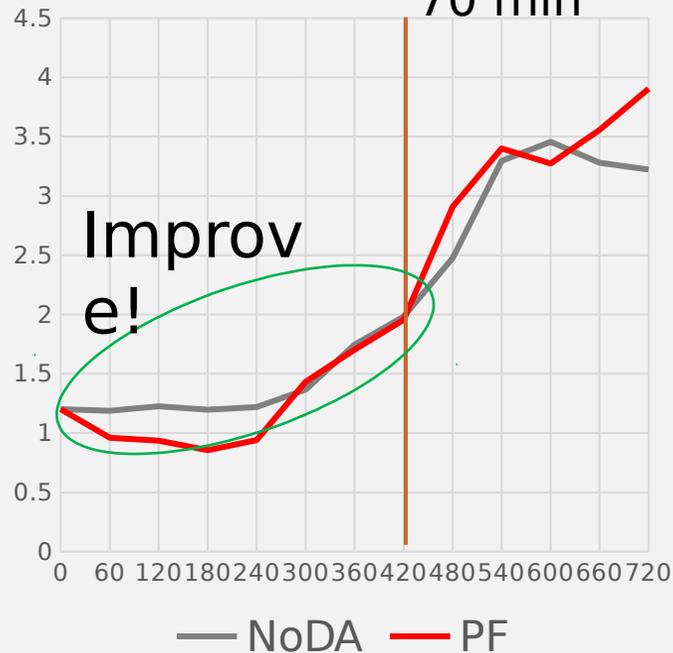
RESULT: RMSE AGAINST NATURE RUN

(grid to grid, over rain region)

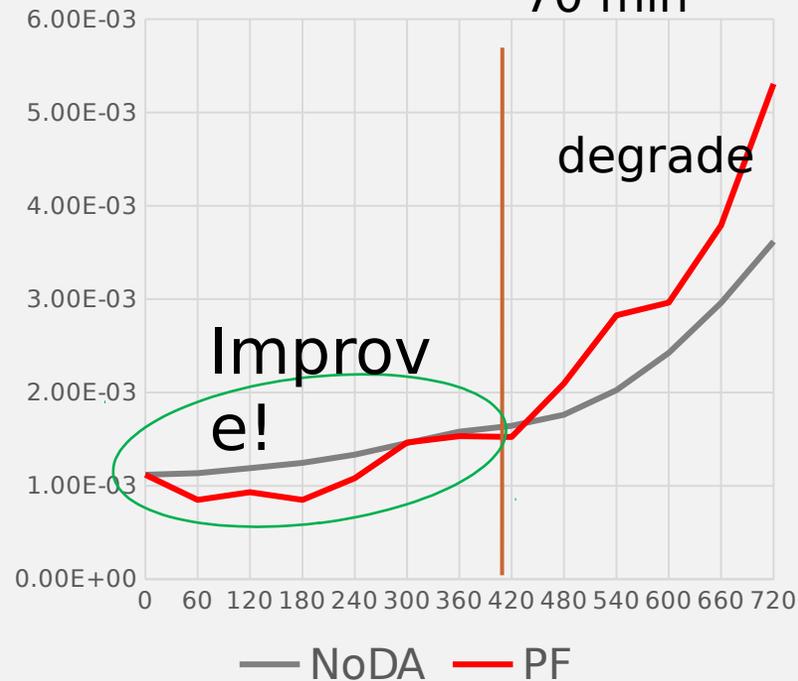
Degeneracy at 80 min affects the worse score.



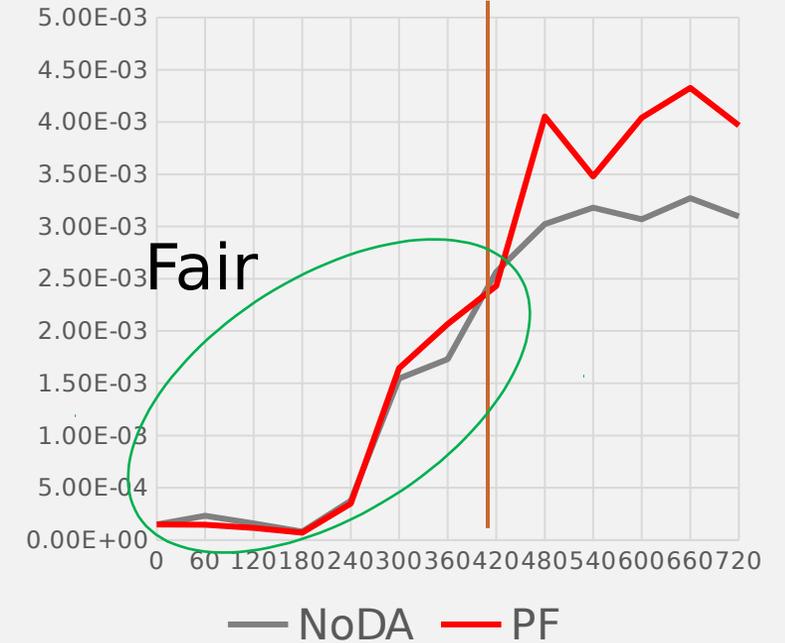
Potential temperature 70 min



Water vapor 70 min



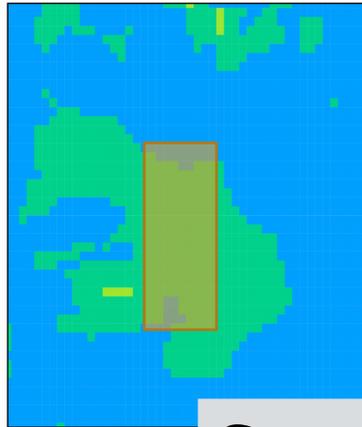
Rainwater70 min



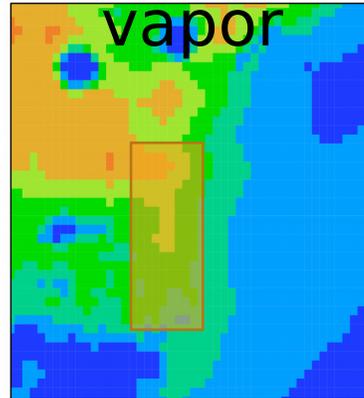
RESULT: SPREAD AT 70 MIN

PF

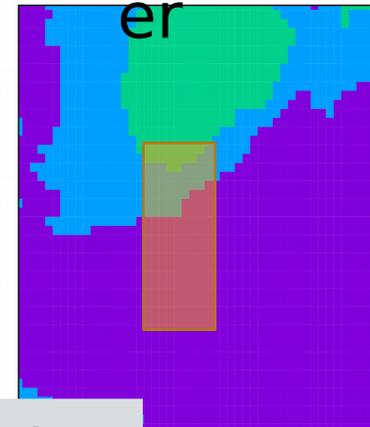
PT



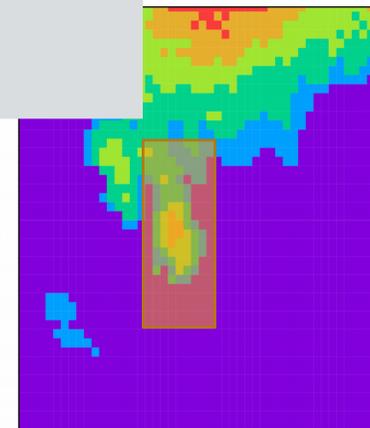
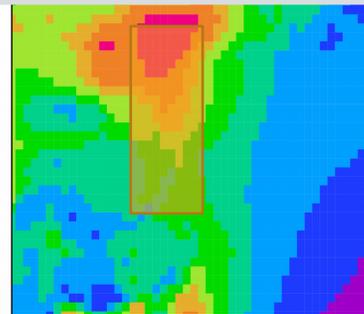
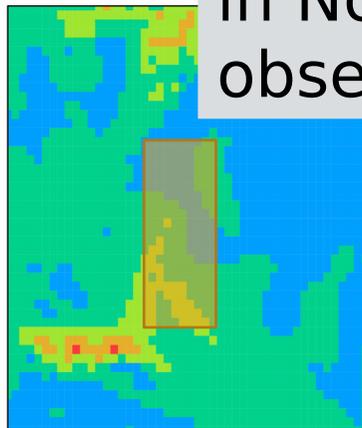
Water
vapor



Rainwat
er



NoDA



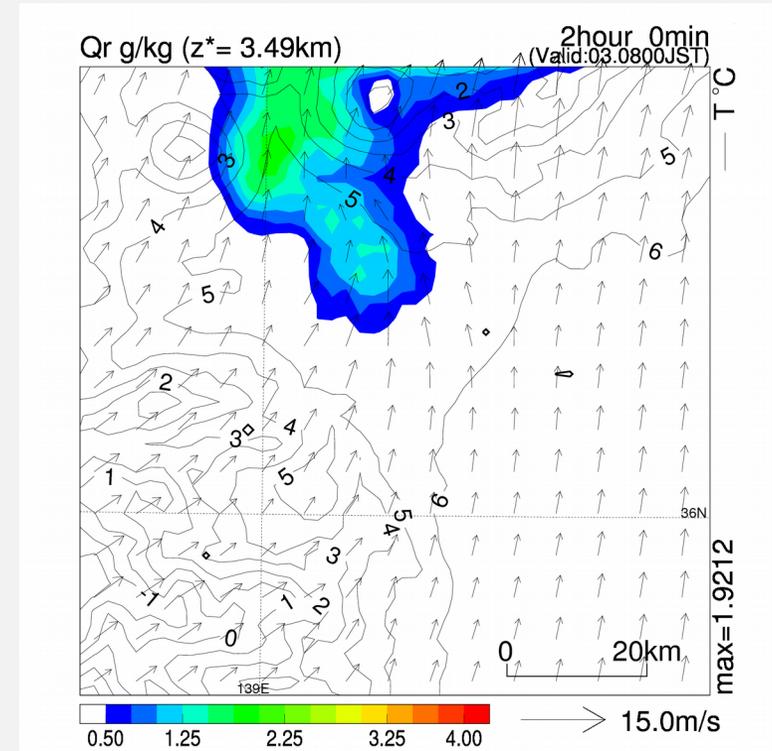
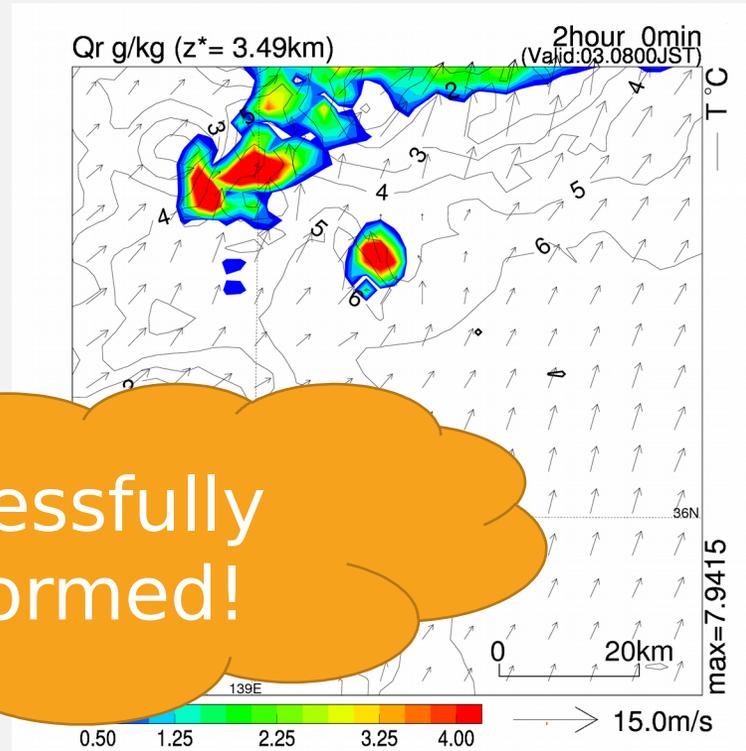
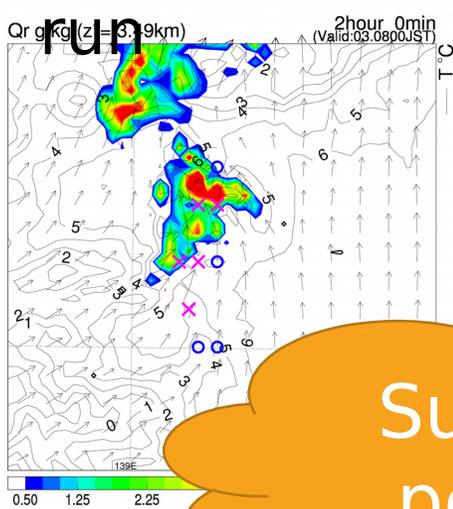
Spreads in PF are smaller than that in NoDA especially over the observation and rain area.

RESULT: ENSEMBLE MEAN (RAINWATER)

PF

NoDA

Nature
run



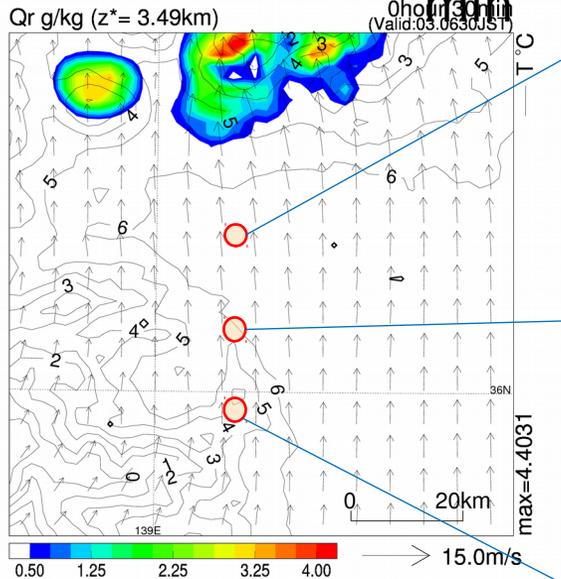
Successfully performed!

Intensity and horizontal scale of Cb core were significantly improved by NHM-PF.

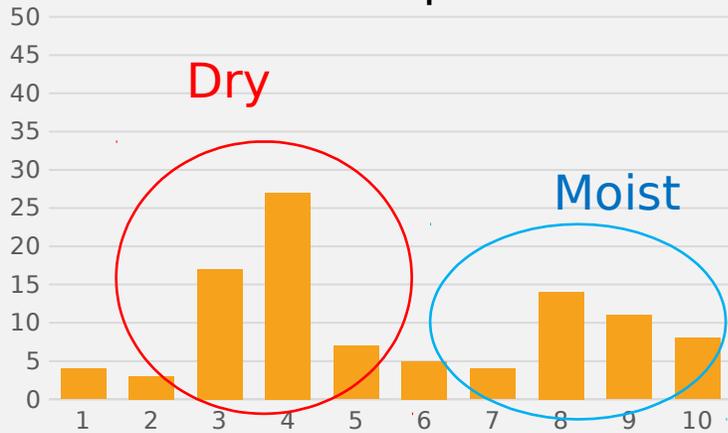
PDF (Z = 20)

30 min

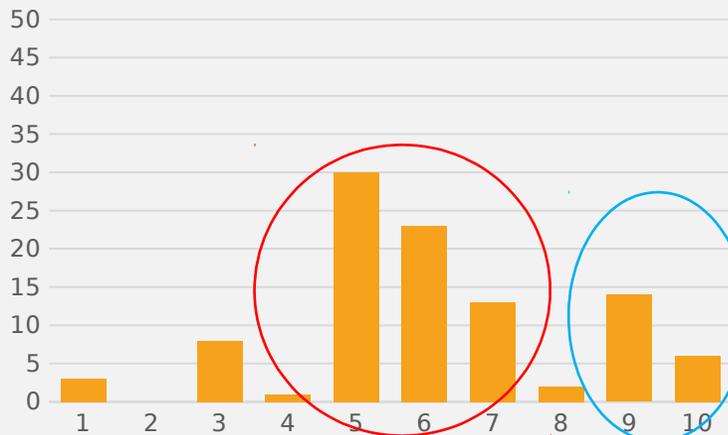
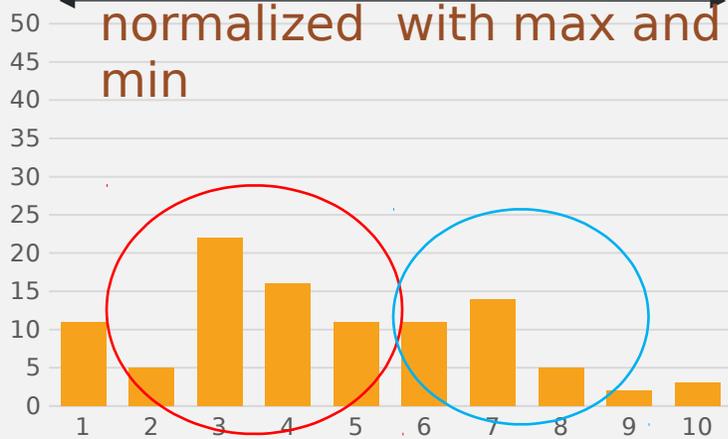
min



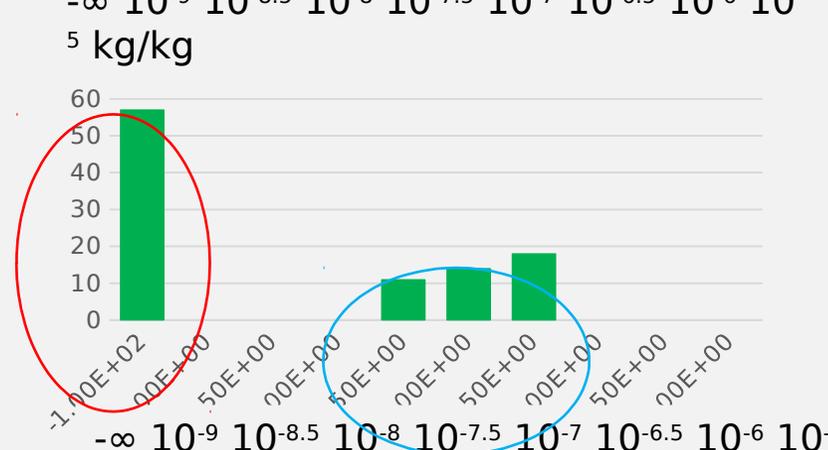
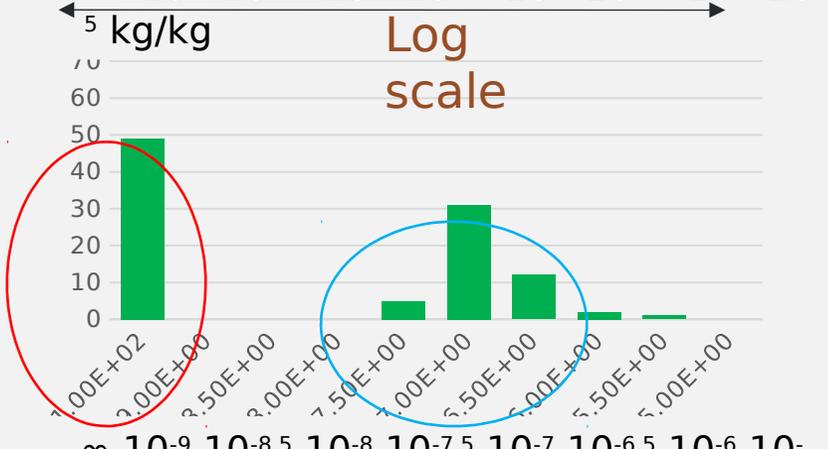
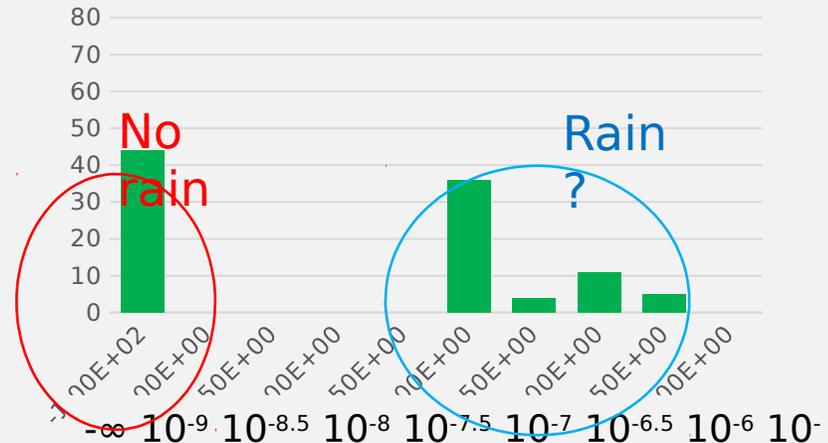
Water vapor



normalized with max and min



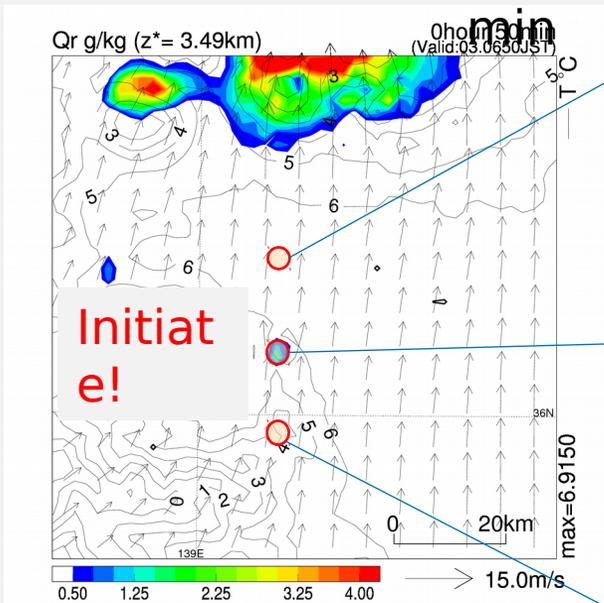
Rainwater



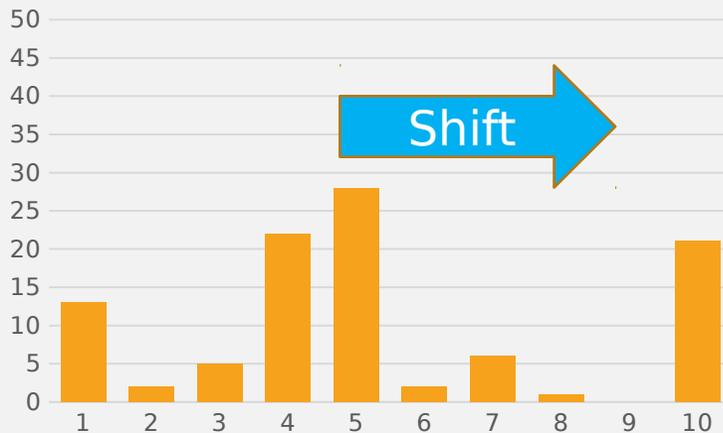
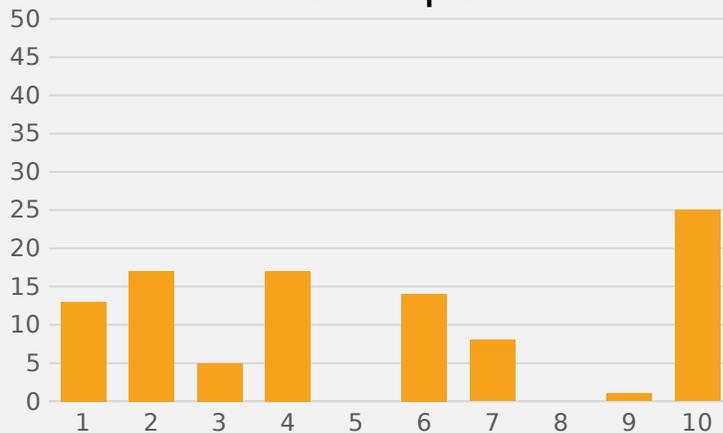
PDF (Z = 20)

50

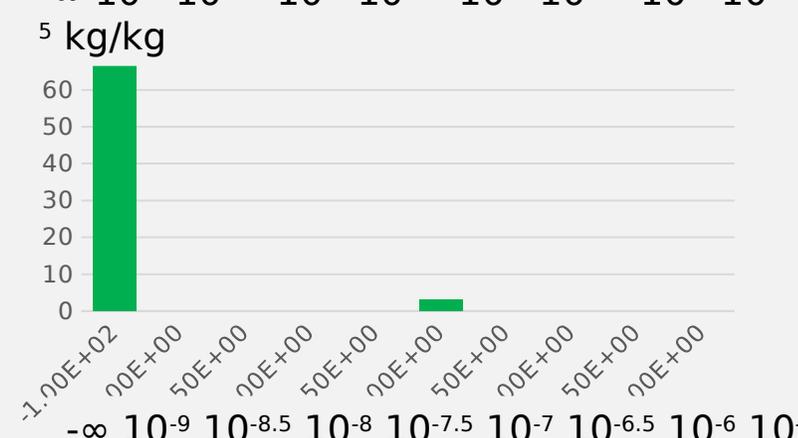
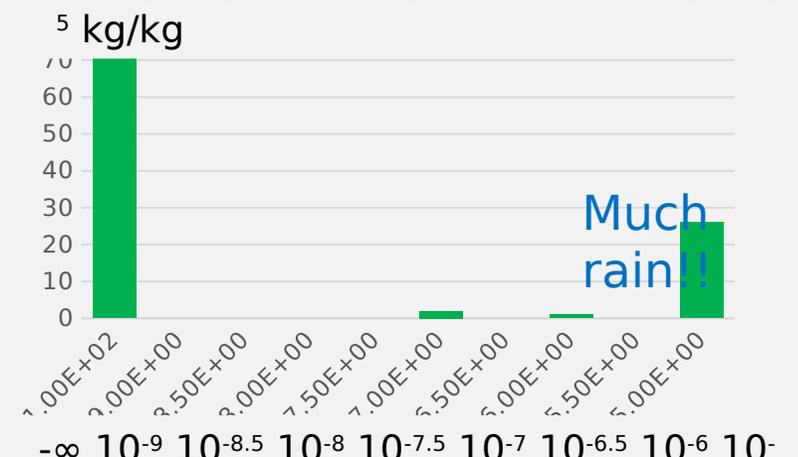
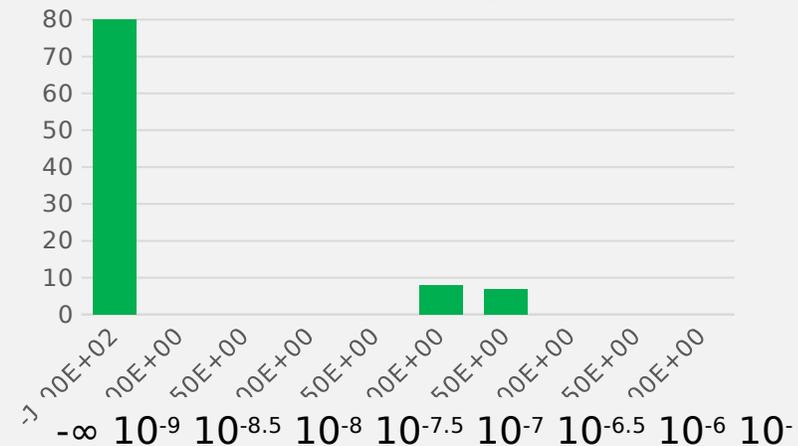
min



Water vapor

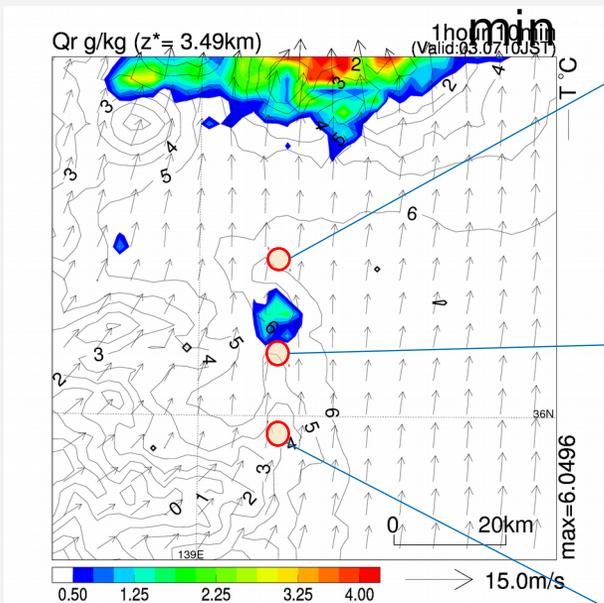


Rainwater

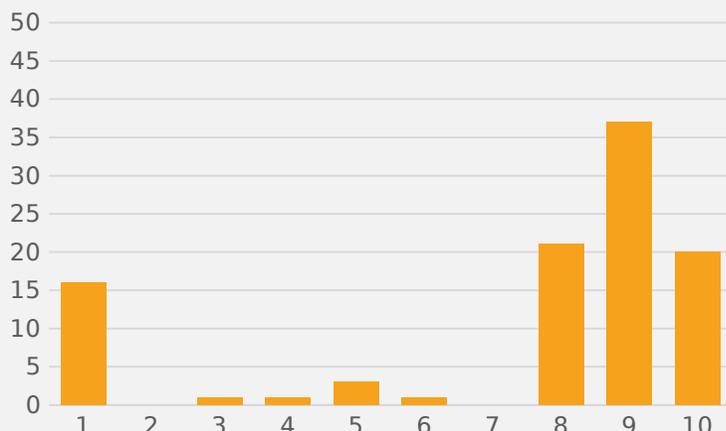


PDF (Z = 20)

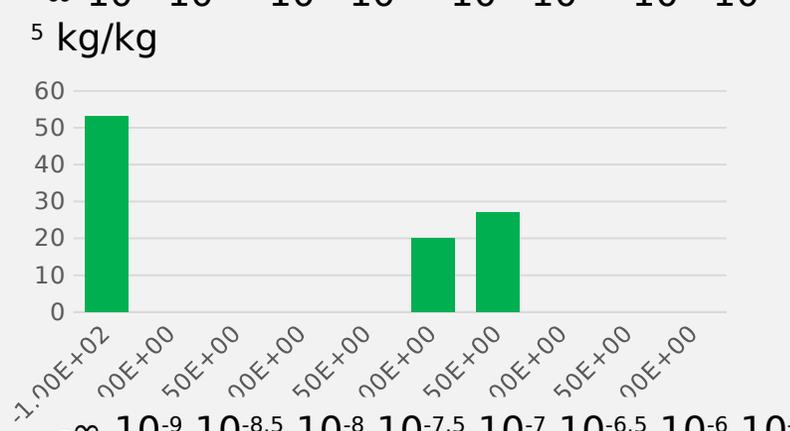
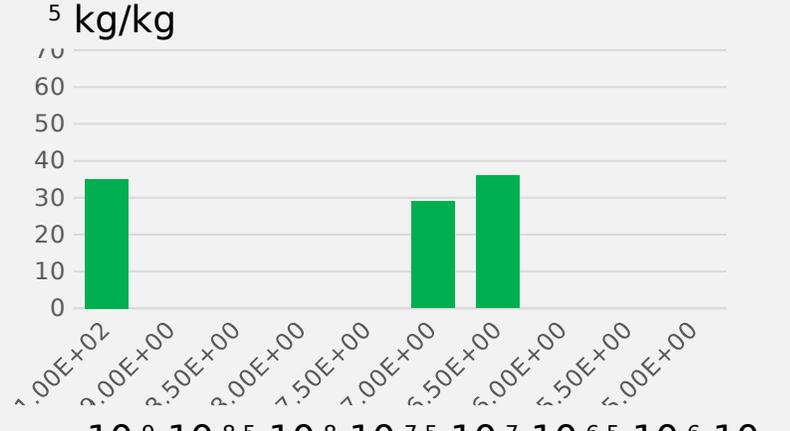
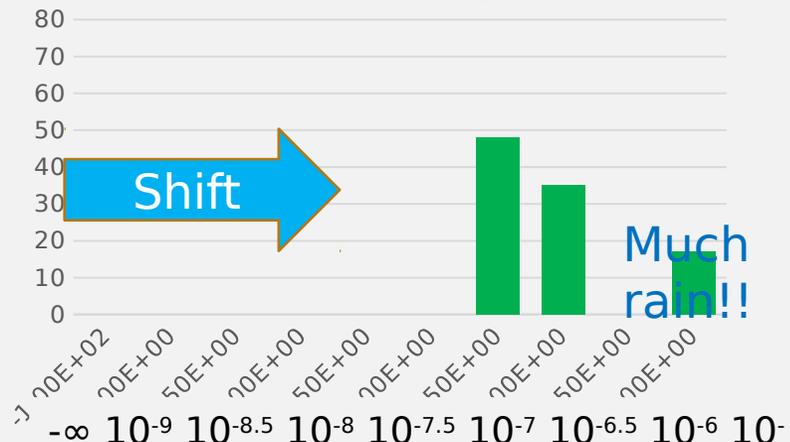
70 min



Water vapor



Rainwater



SUMMARY

- To investigate predictability on Cb and/or thunderstorms, we need nonlinear and non-Gaussian DA system.
- A particle filter with JMANHM (**NHM-PF**) was developed.
- Horizontal resolution of NHM-PF is 2-km and advanced obs. operators for NHM-4DVAR are implemented.
- RF perturbation and parameter (model switch) ensemble were applied in OSSE.
- **NHM-PF was successfully performed** at least by 70 min: RMSEs and spread reduced, and the thunderstorm in the model was enhanced.
- Multimodal PDFs were seen over the rain region as well as the inflow regions.
- Next step: Enhance the number of particles up to ????

Thank you for your attention.