Data assimilation experiments of refractivity data obtained by JMA-operational Doppler radar

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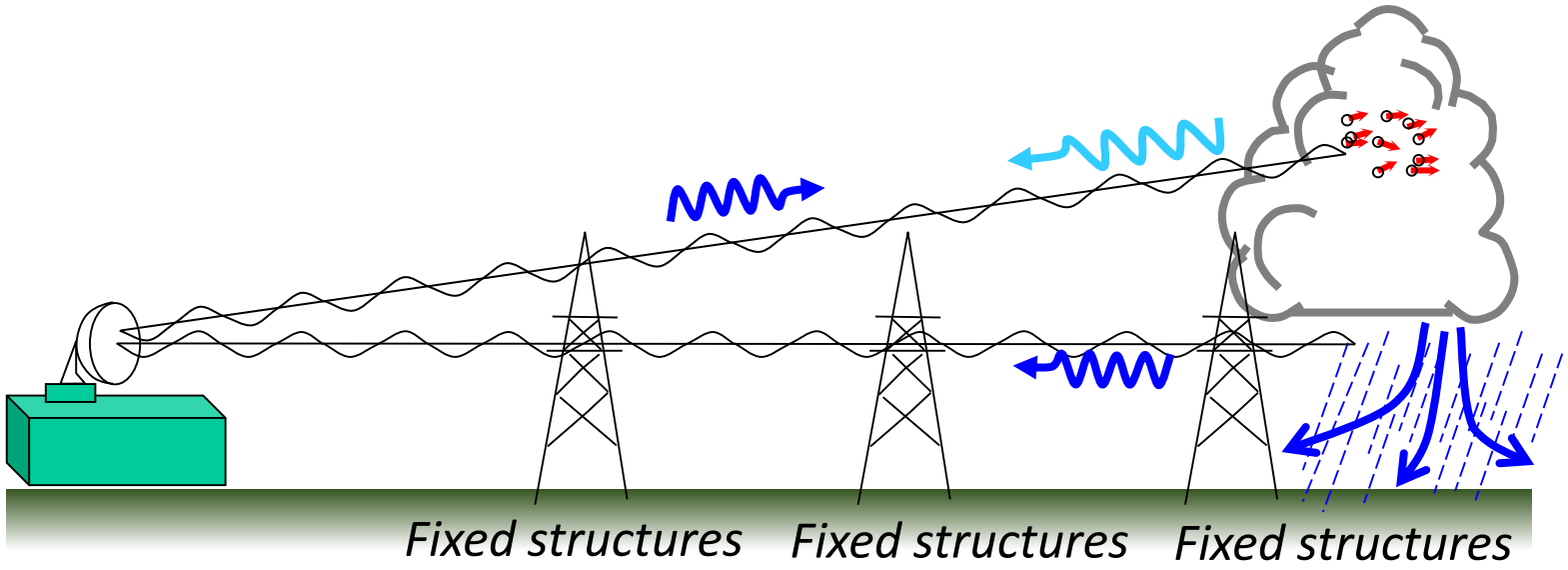
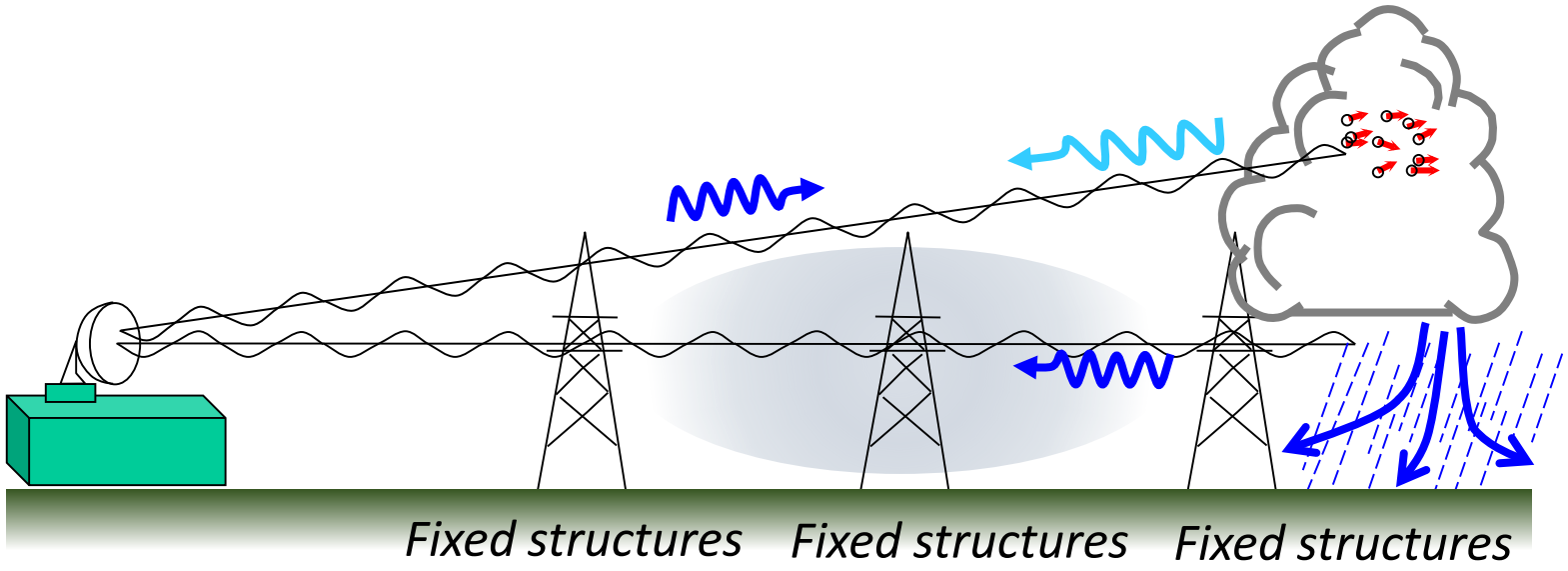
What does radar observe?



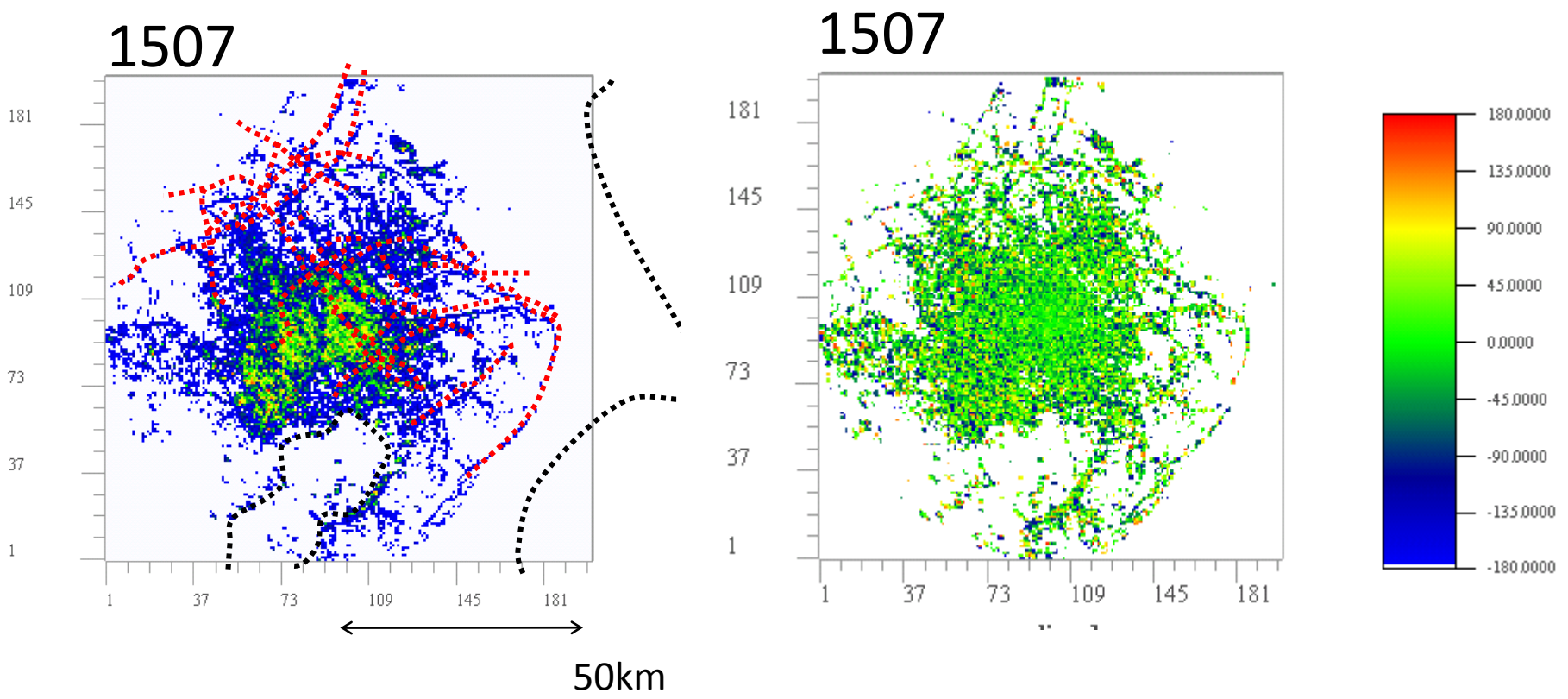
- **Reflectivity and radial wind:**
  Signals reflected from water substances are used.
- **How about water vapor?**
  Signal is not reflected from water vapor.
  Signals reflected from fixed structures were used for the data.

What does radar observe?



- Signals reflected from fixed structures were delayed by water vapor. (Signal delays become longer in humid and colder air.)
- The principle of estimation of water vapor is the same as ‘GPS Meteorology’.

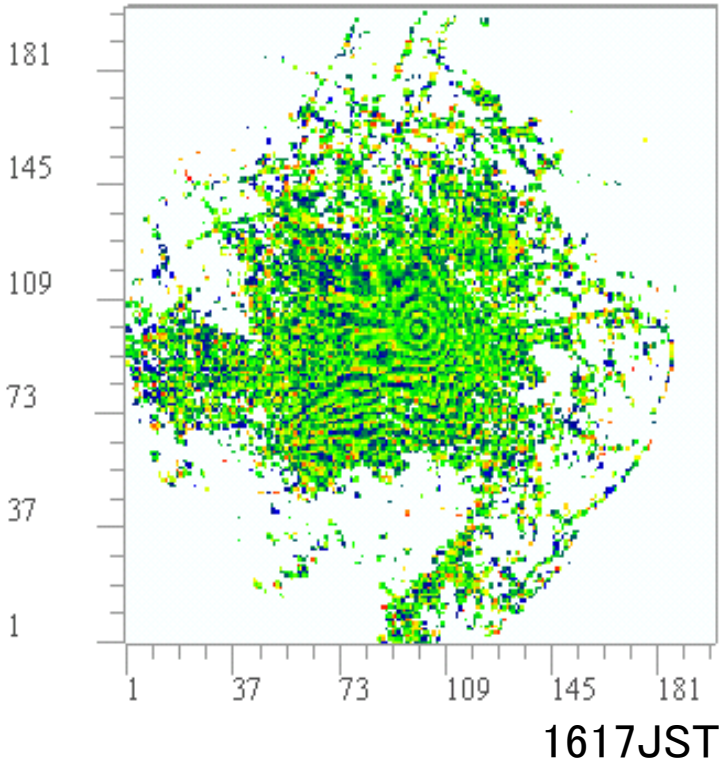
Distributions of fixed structures and of absolute values of phase



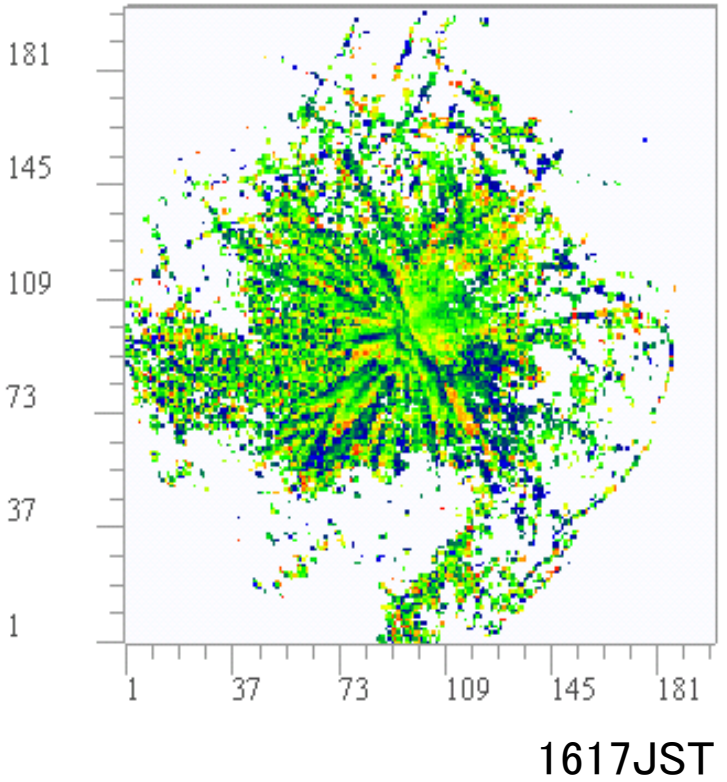
- Several lines reflected from electric power supply towers are seen (red lines in the left graphic).
- Phase values are randomly distributed.

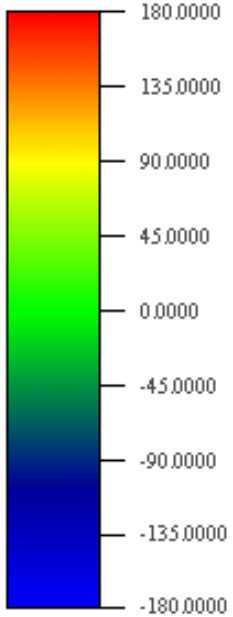
Increment of phase

1 hour Increment



10 minute Increment



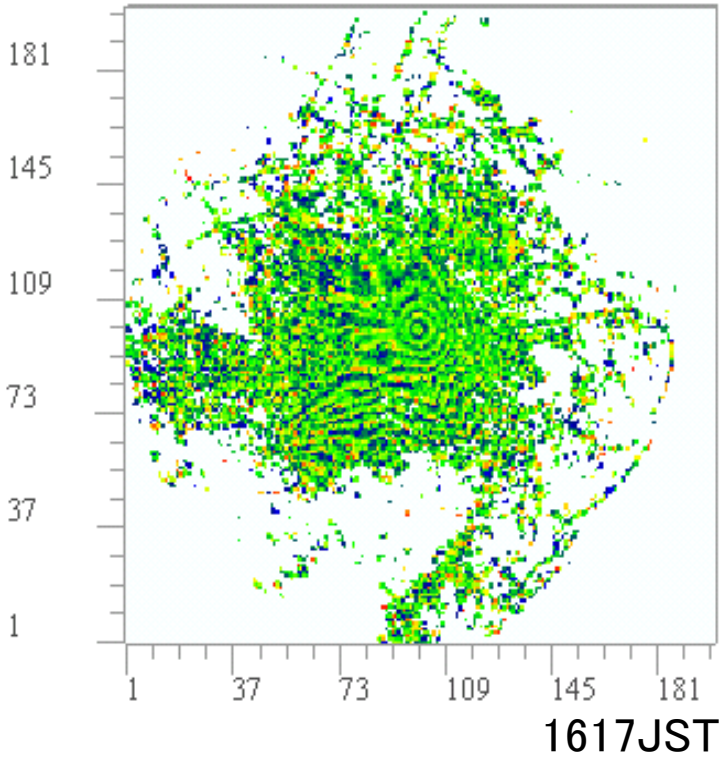


- **10 minute Increment**

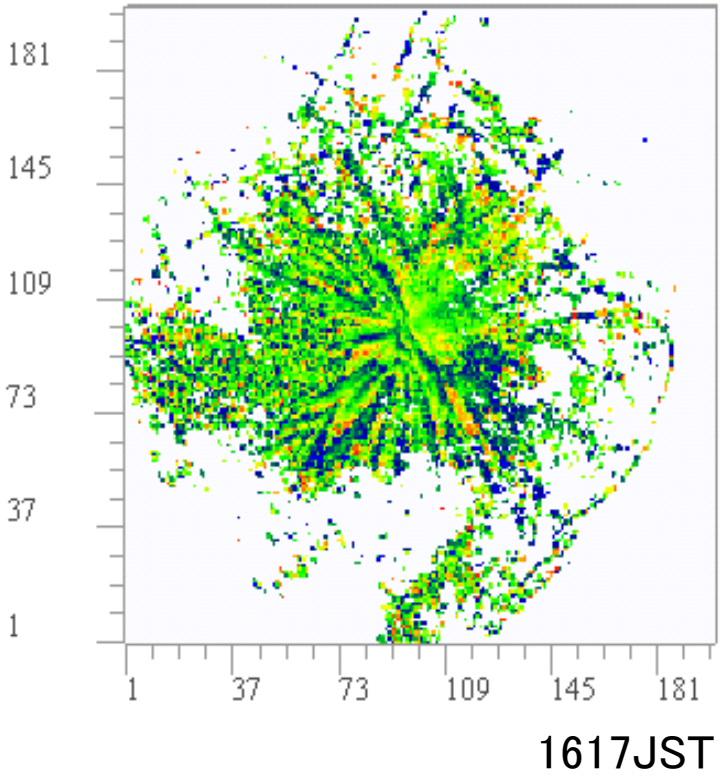
Because radio-waves reflected from the fixed structures far from radar site are affected by the large fluctuation of water vapor near the radar site, a radiative pattern appeared

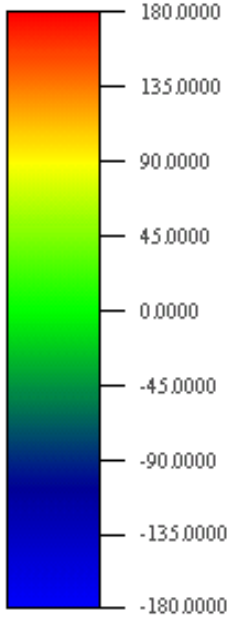
Increment of phase

1 hour Increment



10 minute Increment

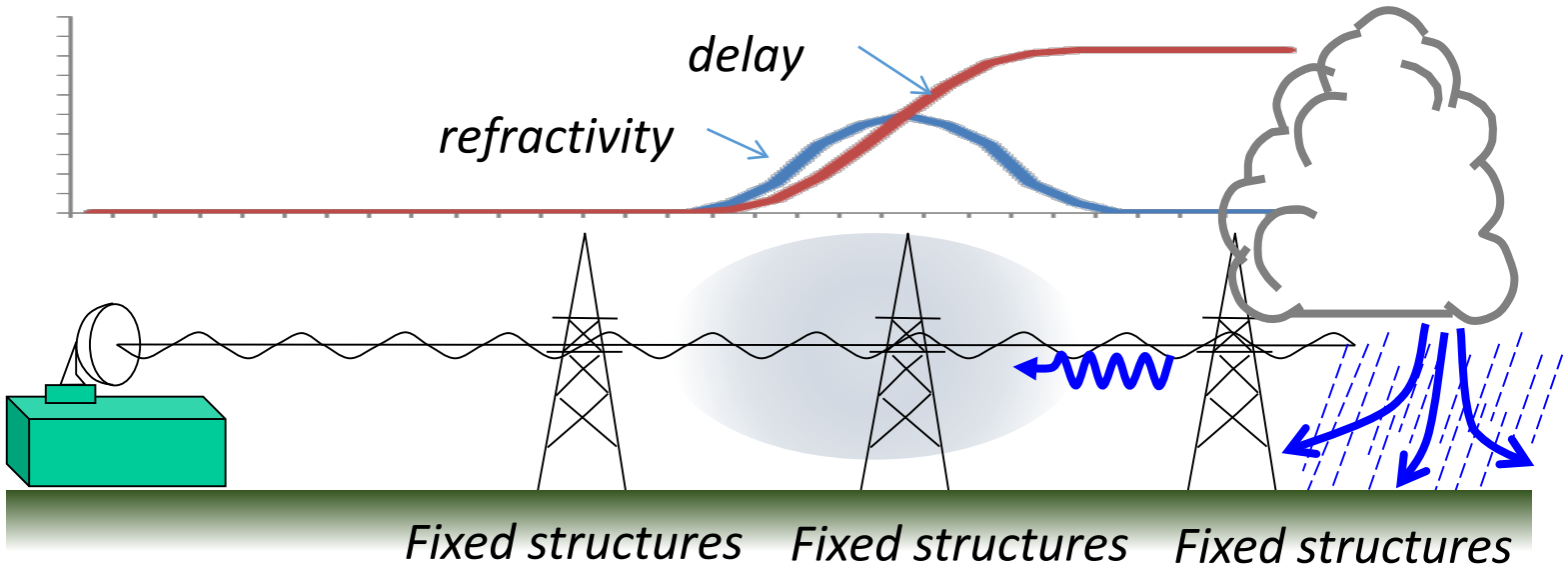




- **1 hour Increment**

Due to a long period, phase exceeds ±180 deg. several times during 1 hour. Ring shaped distribution appeared.

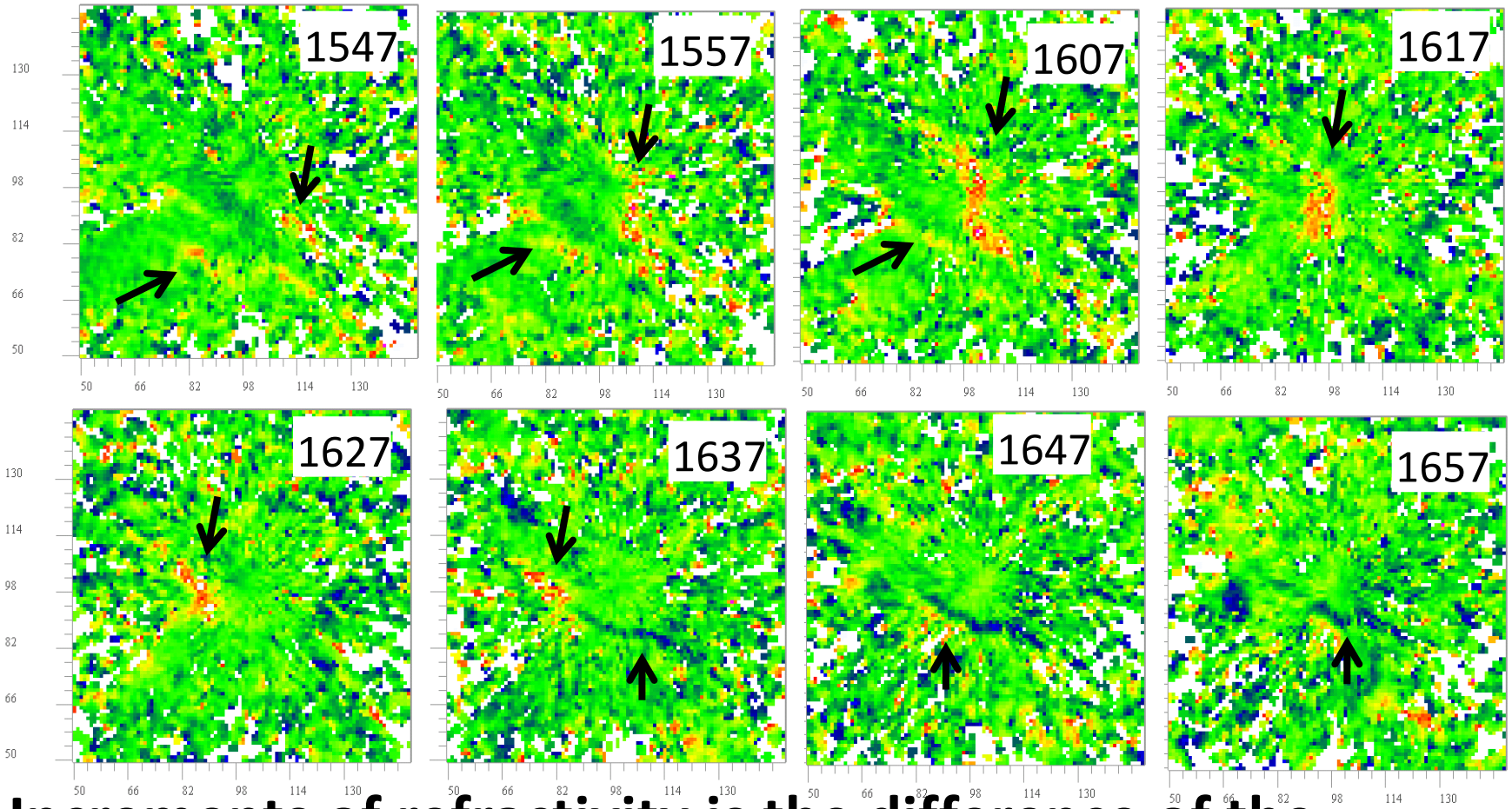
Temporal increment of refractivity



- Delays are increased more when radio waves pass a high refractivity area. Namely, the delay is the sum of the refractivity along the path of radio wave.
- Delay is the sum of refractivity along the path.

  => The horizontal increment of delay is the refractivity.
- Temporal increment of delay is the temporal increment of the refractivity along the path.

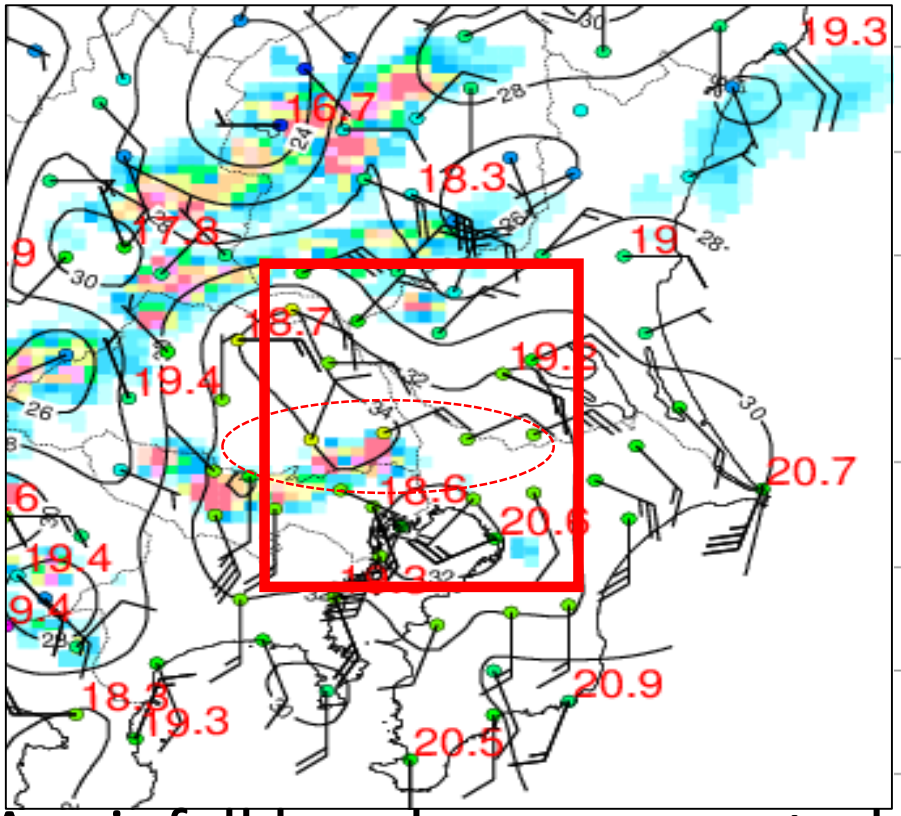
Temporal variations of refractivity



- Increments of refractivity is the difference of the increments of the delay along the radial direction.
- Large increment areas moved smoothly. This variation shows that these increments were caused by atmosphere.

Rainfall at 16 JST

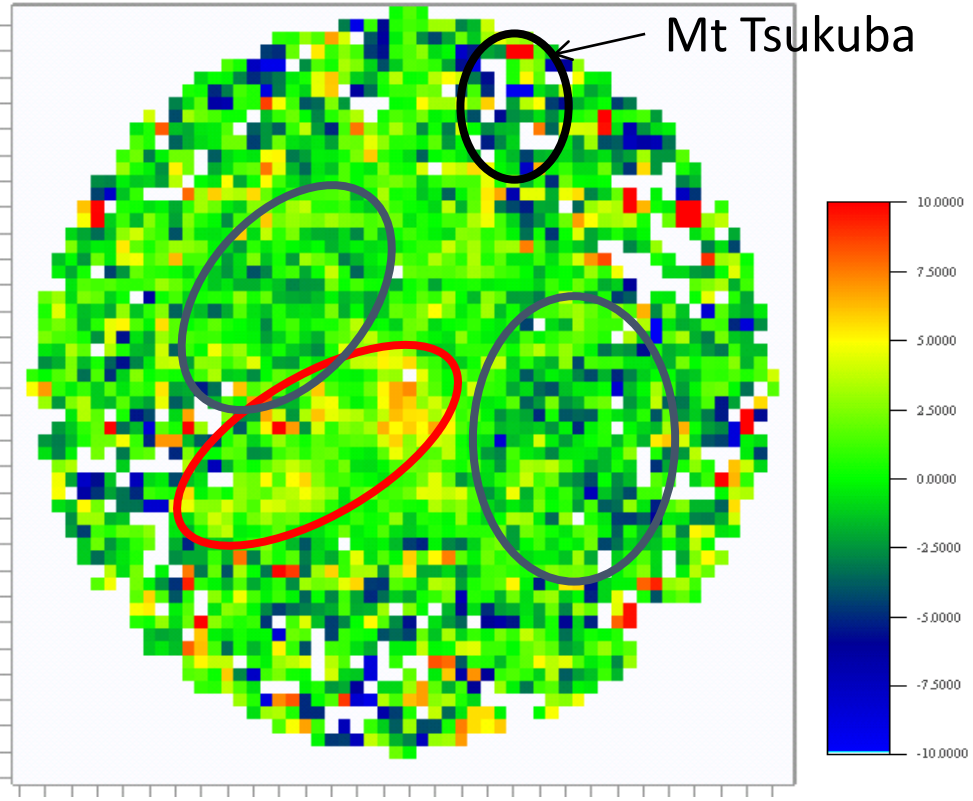
2008年8月4日16時



- A rainfall band was generated in Tokyo by the convergence of low level airflows.
- An easterly flow existed just on the eastern side of Tokyo.

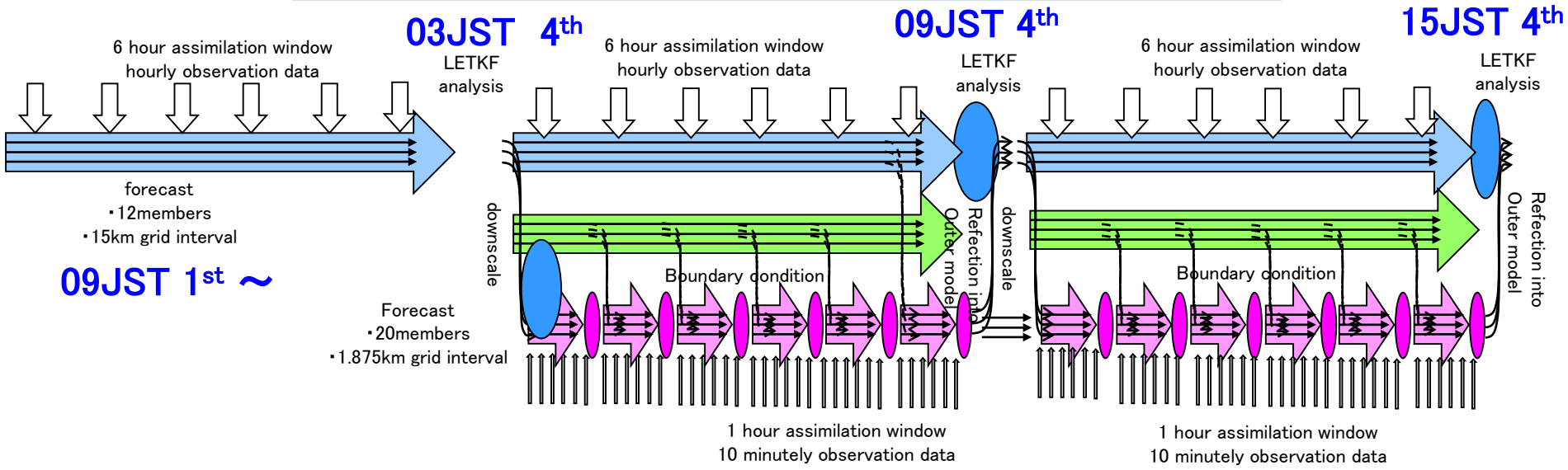
Variation of refractivity

16:00－16：10

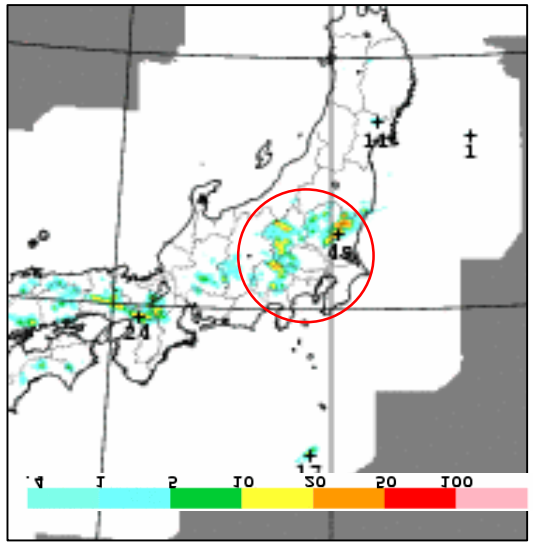


- Refractivity was increased near the radar site where the airflows were converged, and decreased on the eastern and northwestern sides.

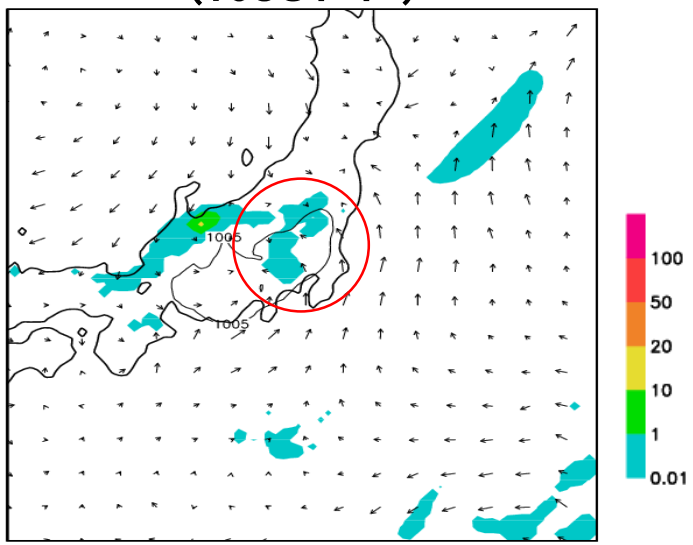
Nested LETKF system



Observation (15JST)

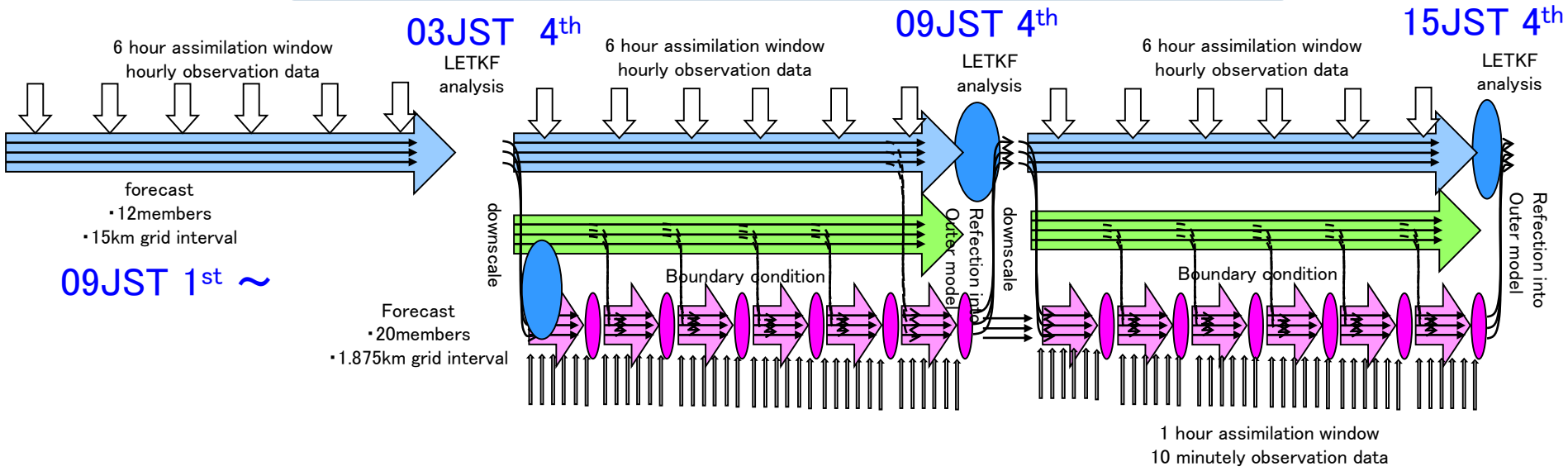


Ensemble mean of Outer LETKF (15JST 4th)

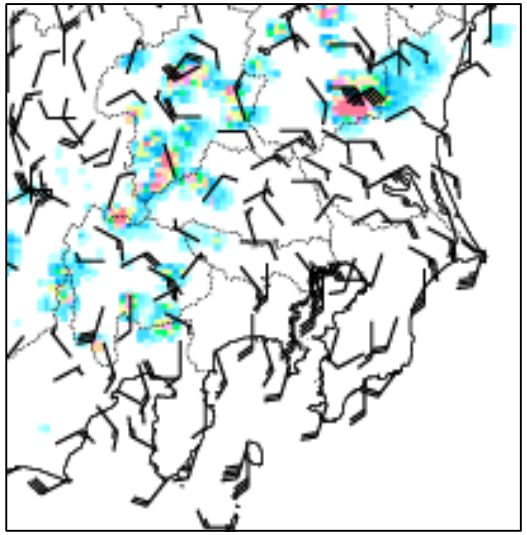


Rainfall regions over the mountainous area was reproduced by Outer LETKF.

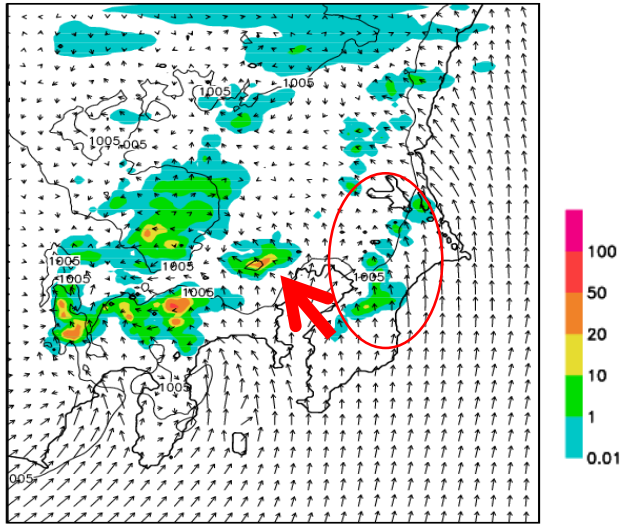
Nested LETKF system



Observation (15JST)



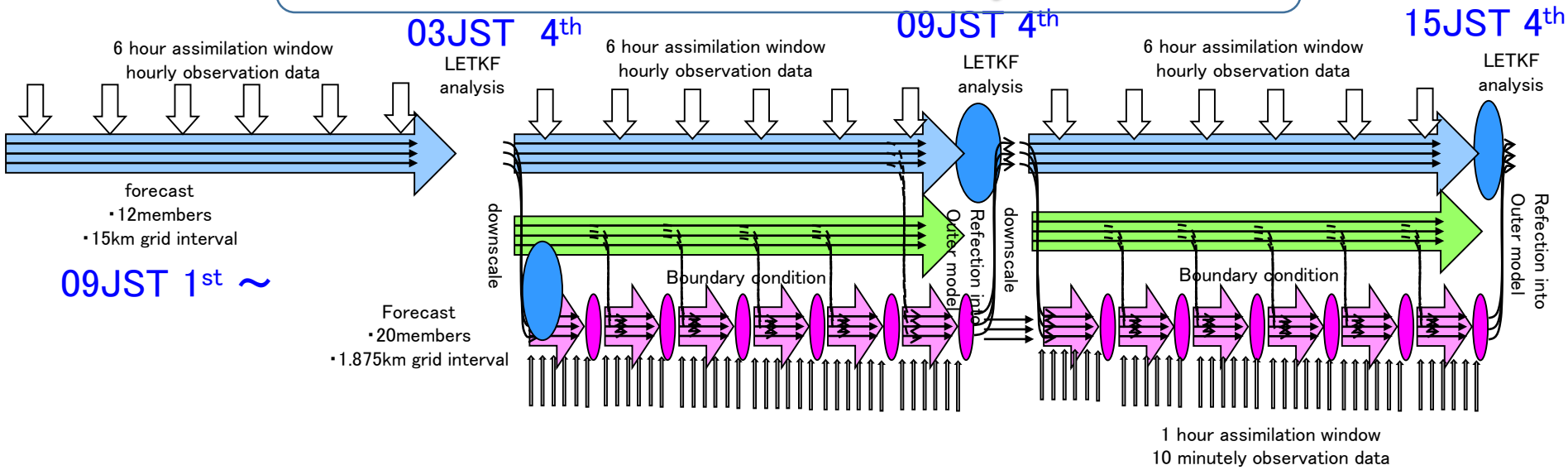
Ensemble mean of Inner LETKF (15JST 4th)



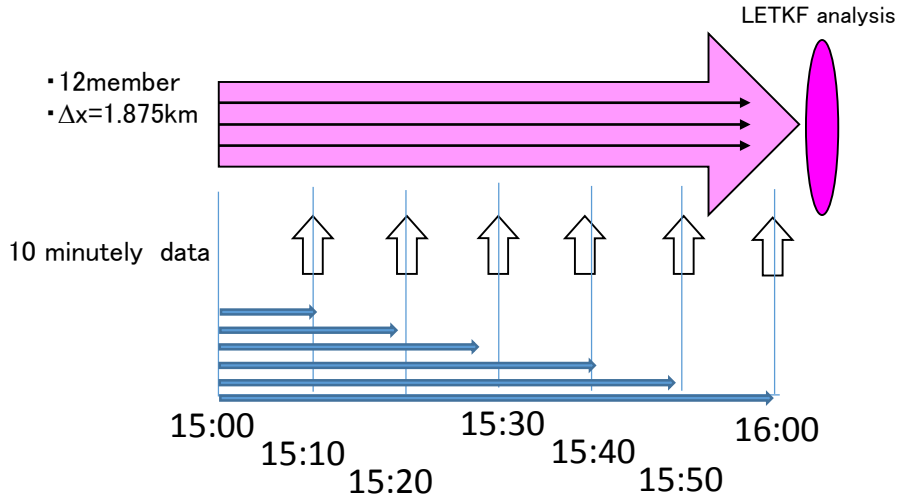
Rainfall regions that were not observed were generated on the eastern side of Tokyo (red circle).

Rainfall band in Tokyo was reproduced by Inner LETKF.

Nested LETKF system



Temporal variation of refractivity was assimilated in Inner LETKF



Observation data was produced by adding the temporal variation to the analyzed value of 15 JST.

Observation data was used in Inner LETKF because the refractivity had information of a few ten kilometer scale variations

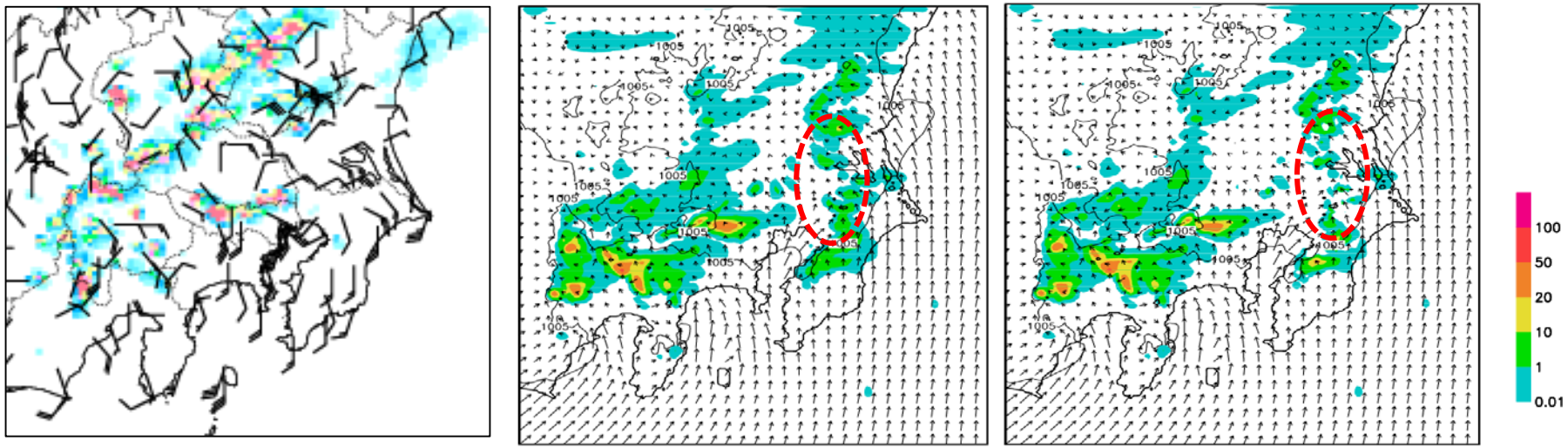
Height of observation data was assumed to be 60 m, which is the height of the radar.

Comparison of the assimilation results
Impacts of refractivity data

Observation 16JST

Ensemble mean 16JST
w/o refractivity data

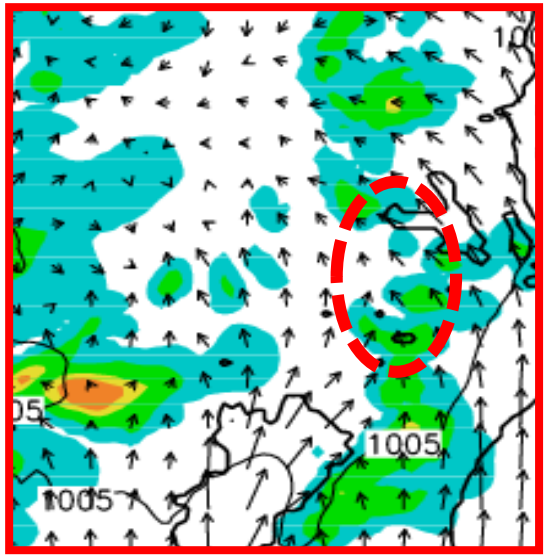
Ensemble mean 16JST
with refractivity data



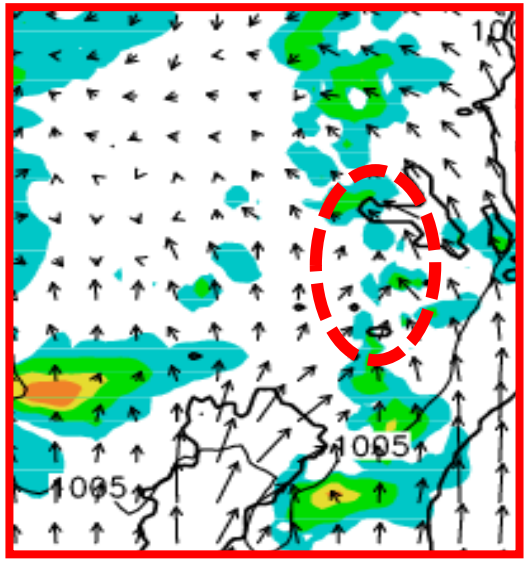
- When refractivity data was not assimilated, the rainfall regions that were not observed (indicated by red circles) were generated on the eastern side of Tokyo.
- When refractivity data was assimilated, rainfall regions on the eastern side of Tokyo became weaker (indicated by red circle) .

Comparison of the assimilation results
Impacts of refractivity data

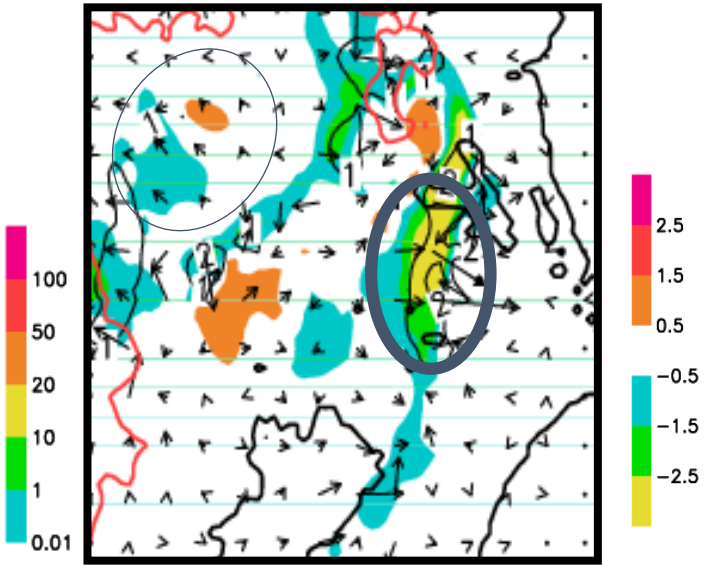
Ensemble mean 16JST
w/o refractivity data



Ensemble mean 16JST
with refractivity data



Difference of water vapor,
temperature and horizontal wind
between two analyzed fields



- When refractivity data was assimilated, rainfall regions became similar to the observed ones.
- Predicted rainfall became weaker, because water vapor was reduced by adding the refractivity to the assimilation data.

Summary

- Information of water vapor (refractivity) is obtained from Doppler radar data.
- Refractivity data is expected to increase the accuracy of forecasts of local heavy rainfalls by improving initial conditions.
- The number of case studies should be increased to improve the estimation methods and assimilation methods of the refractivity.