Impact of Doppler Lidar radial wind data assimilation to a localized heavy rainfall event

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Cloud Resolving Nonhydrostatic 4D-Var Assimilation System（NHM-4DVAR）

Model (not incremental)

- Forward : JMANHM (JMA operational mesoscale model)
  (Full model with 3-ice cloud microphysics)
- Adjoint : Dynamical core, Warm rain, Lateral boundary conditions

Horizontal resolution

- 2km

Observations

- Doppler radial wind (Kawabata et al. 2007) and
  reflectivity (Kawabata et al. 2011) by Doppler Radar,
  GPS precipitable water vapor(Kawabata et al. 2007),
  GPS zenith total delay, GPS slant total delay (Kawabata et al. 2013),
  Wind profiler, surface wind, surface temperature,
  Virtual temperature profile by RASS, Doppler Lidar radial wind

Doppler Radar vs. Doppler Lidar

Radar observes:

reflectivity and radial winds

inside cumulonimbus

by rain drops

using radio waves.

Lidar observes:

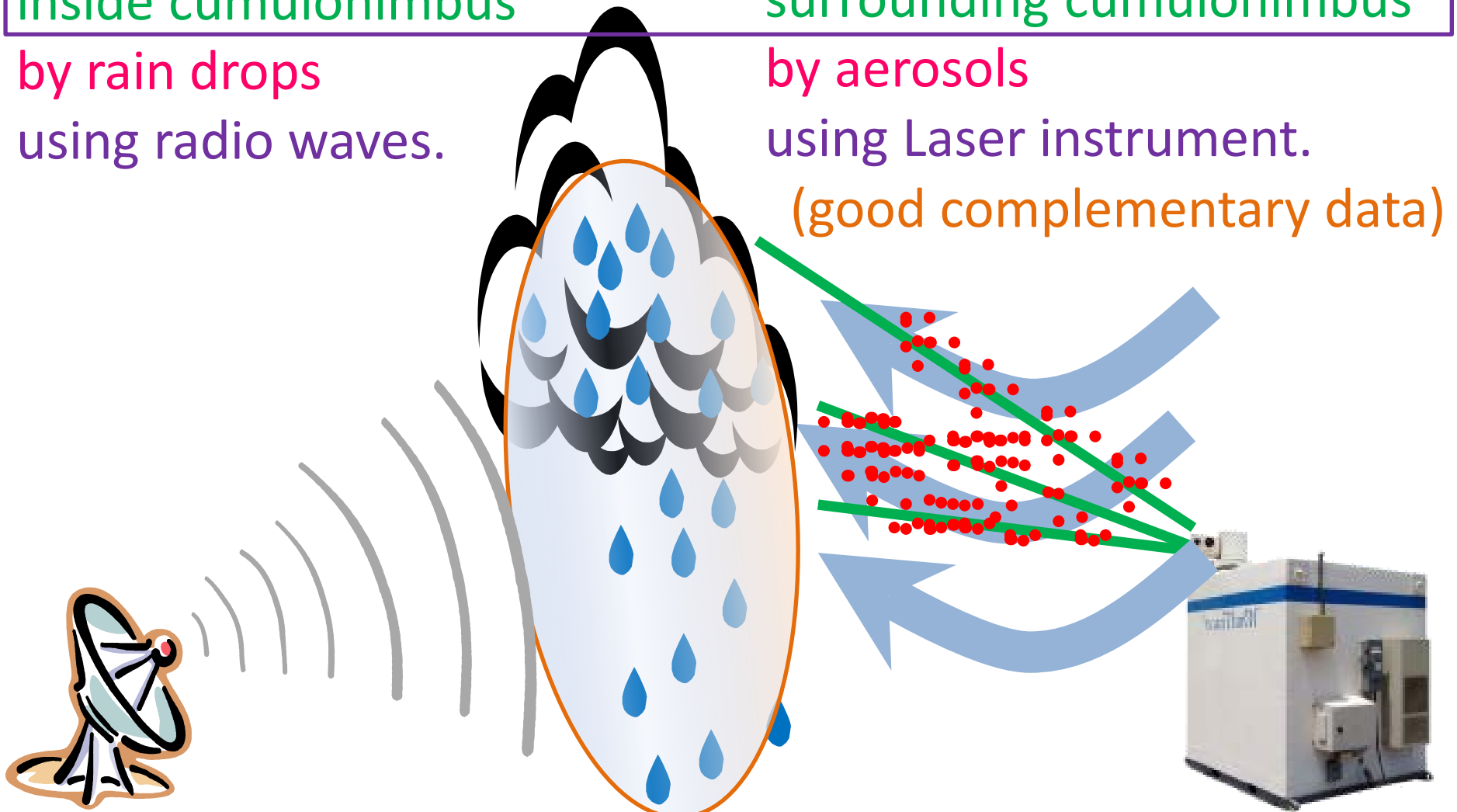
radial winds

surrounding cumulonimbus

by aerosols

using Laser instrument.

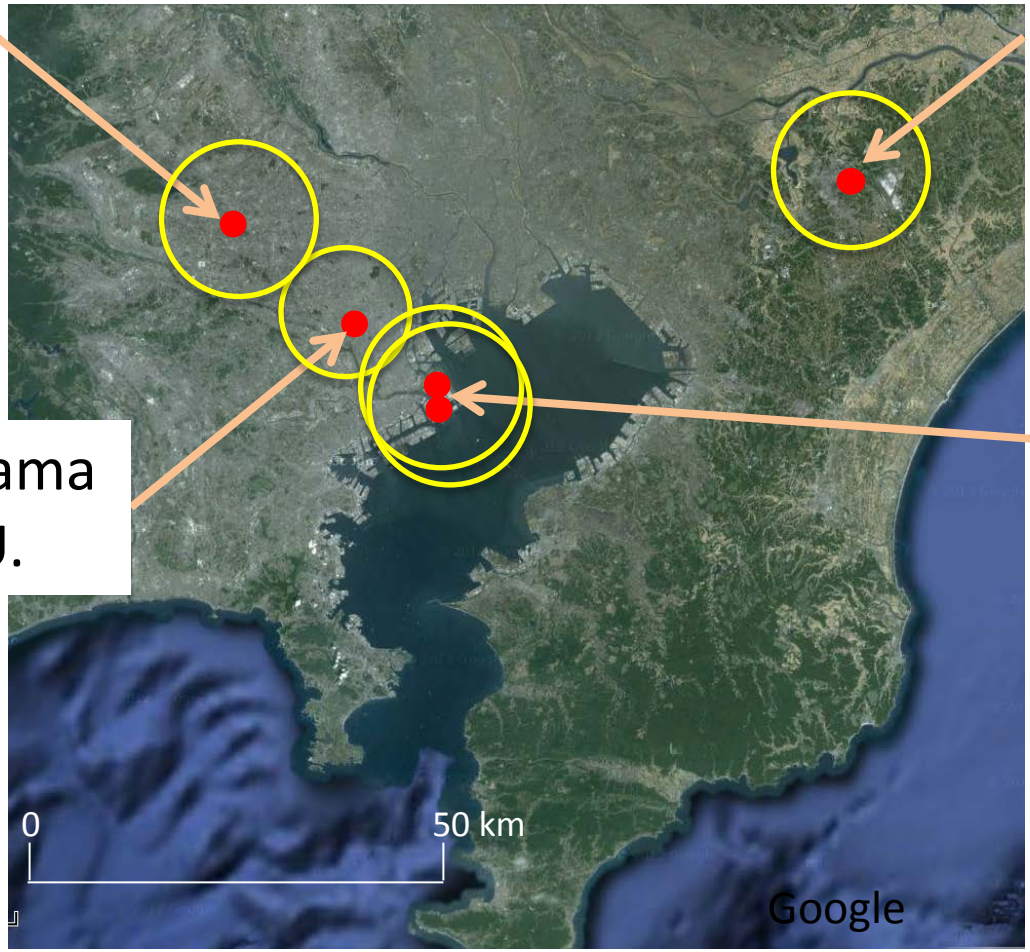
(good complementary data)



Four Doppler Lidars in west Tokyo

One at Koganei by NICT (used in this study).

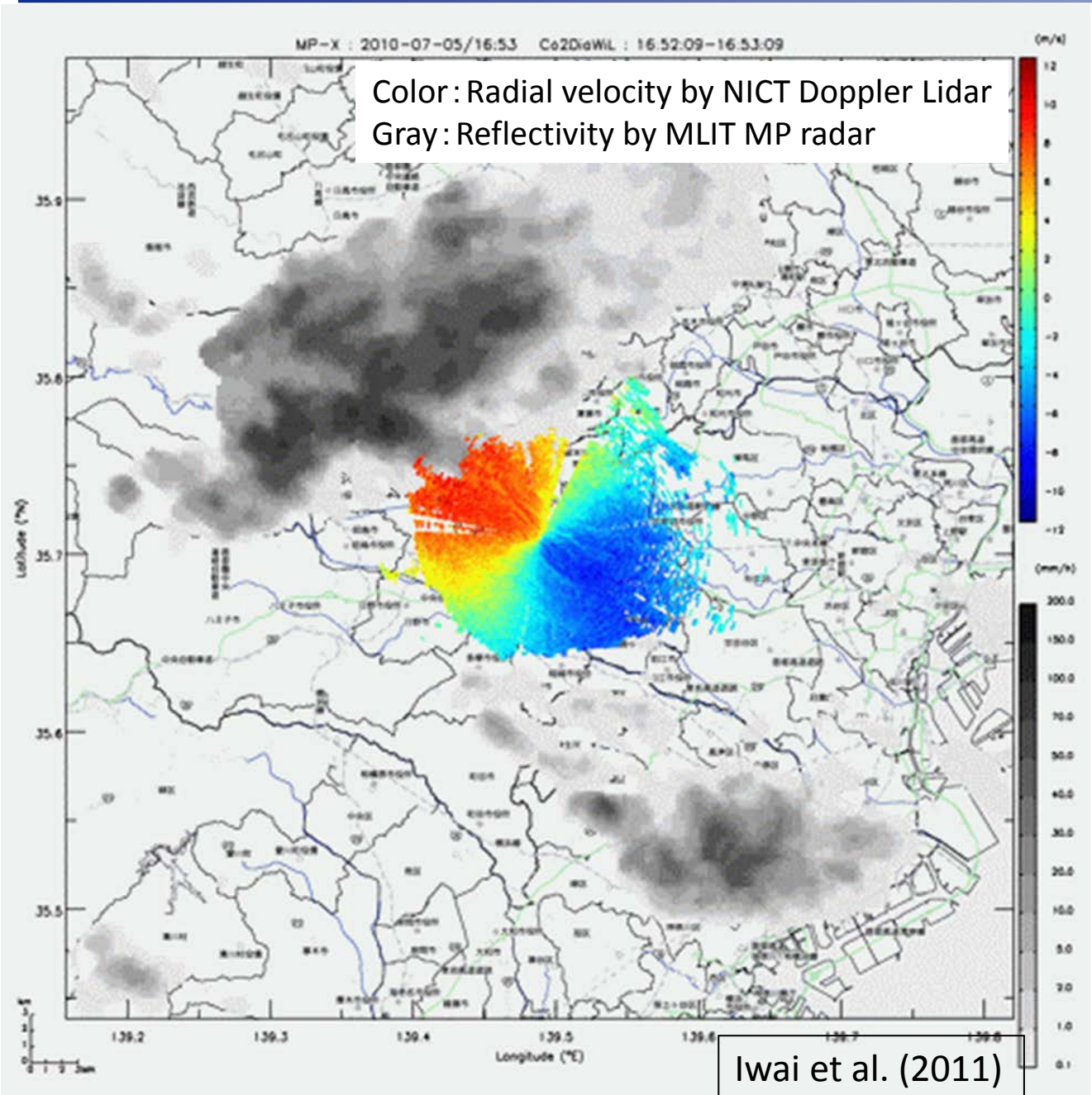
Narita airport as JMA operational instrument.



One at Ookayama by Hokkaido U.

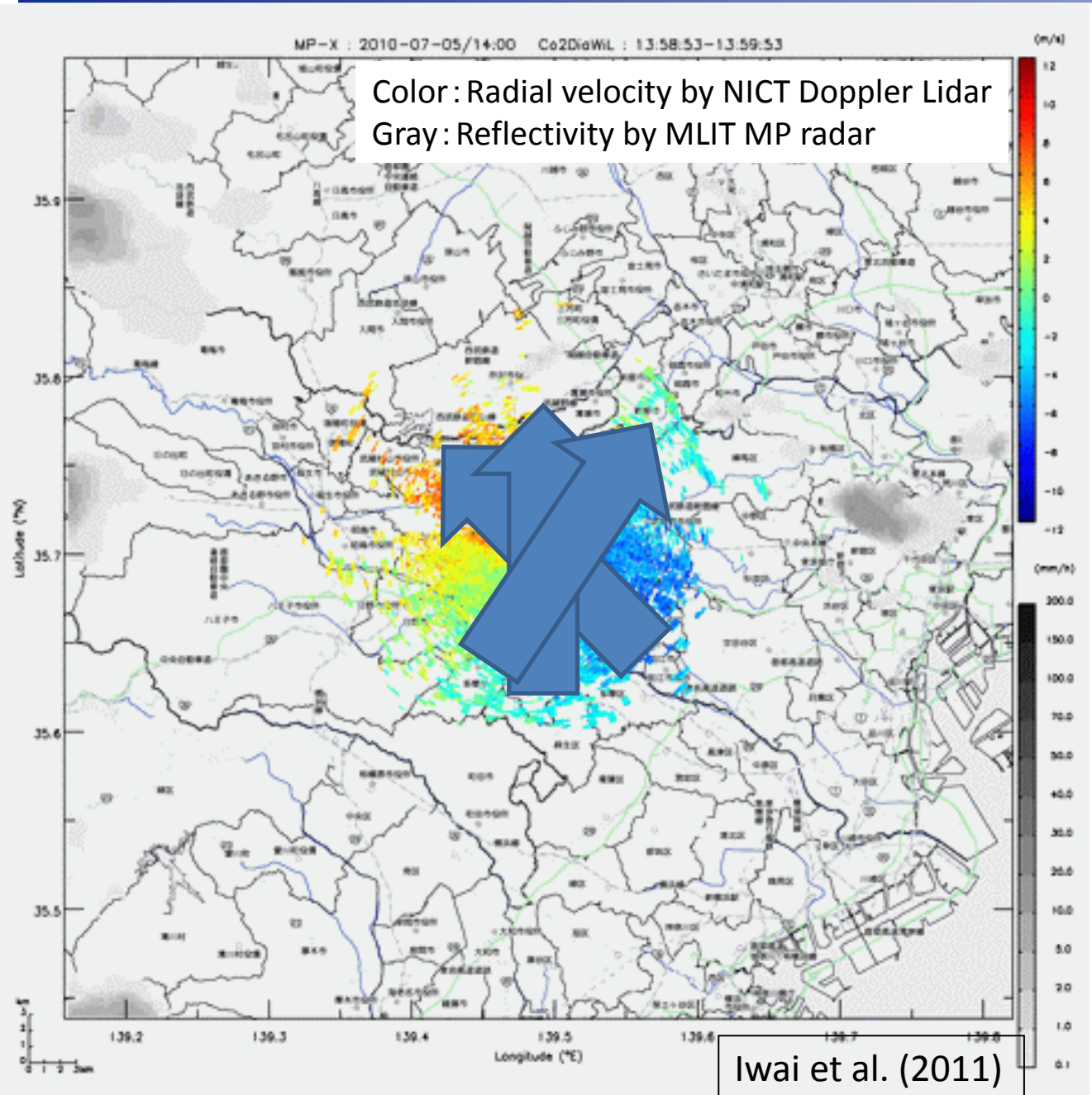
Two at Haneda airport as JMA operational instruments.

Precipitation and observed radial winds; 2010 July 5 14:00 – 21:25 JST



Iwai et al. (2011)

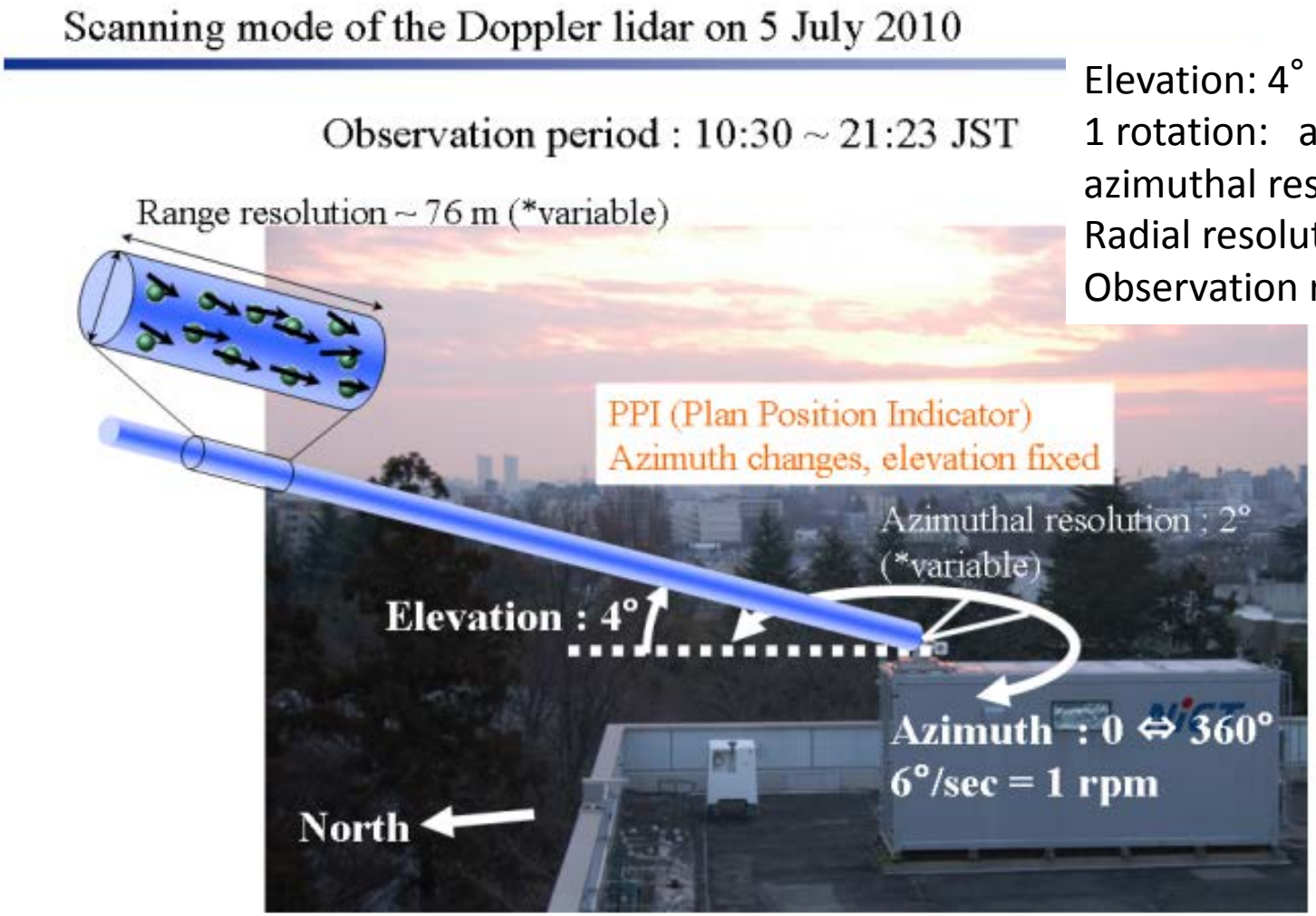
Precipitation and observed radial winds; 2010 July 5 14:00 – 21:25 JST



Iwai et al. (2011)

1. Lidar observed south-easterly wind the direction of which represented that of the environmental wind field.
2. When cumulonimbus came near the Lidar, wind speed became strong.
3. The wind direction changed to southerly.
4. After the cumulonimbus passed by, the direction changed to south-south-westerly, finally back to south-easterly.

NICT Doppler Lidar at Koganei

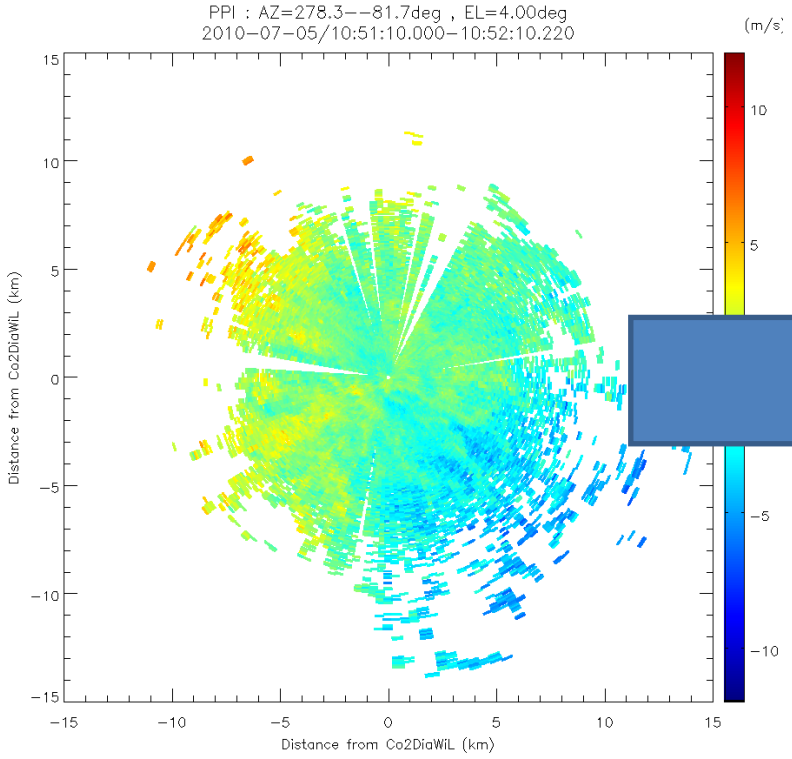


Elevation: 4°
1 rotation: about 1 min
azimuthal resolution: about 2°
Radial resolution: about 76 m
Observation range: 10–20 km

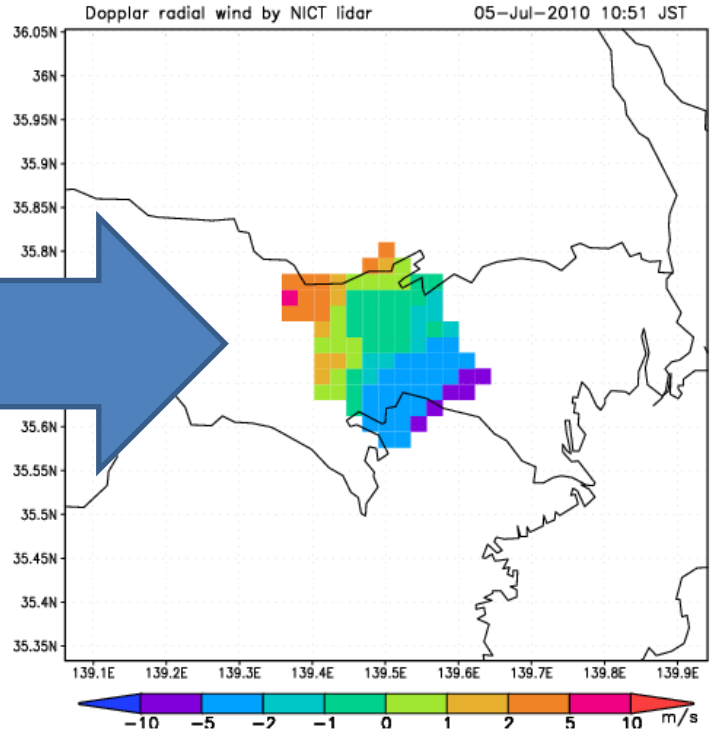
(Iwai, 2011)

Super Observation

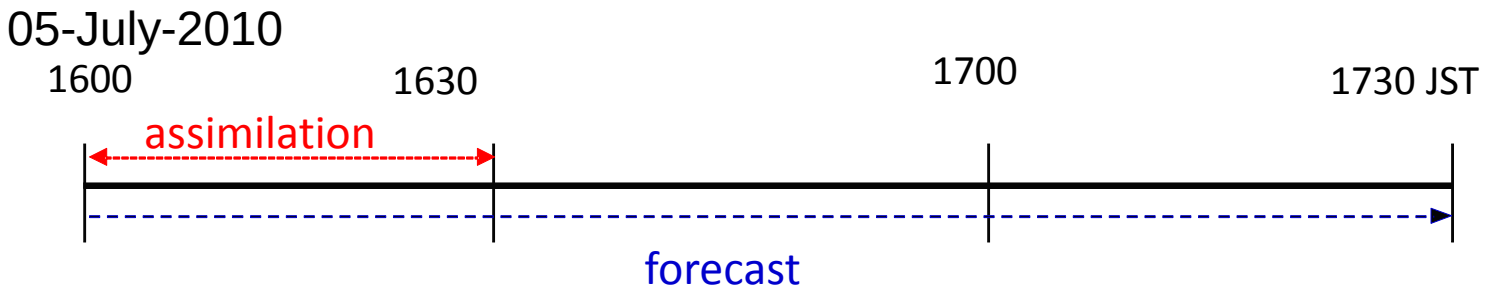
Observation



Super Obs which high-dense observations are interpolated into model grids.



4D-Var Experiment for Lidar data



Observations

CTL
- **GPS Precipitable water vapor every 10 min**
- **Radar reflectivity every 1 min**
- **Radial winds by Doppler Radars every 1 min**
- **Radial winds by Doppler Lidar every 1 min**

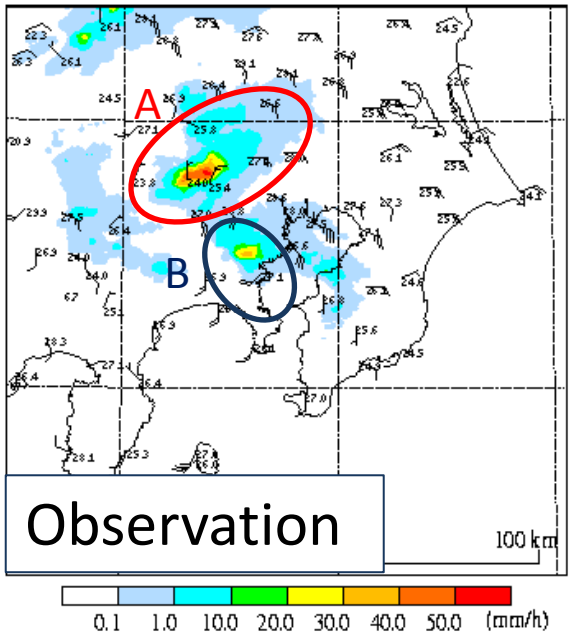
LDR

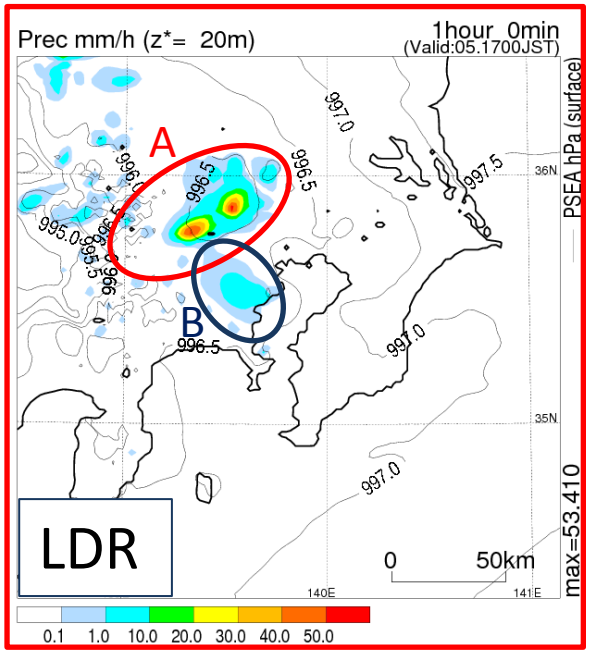
- **No Observation** → **NoDA**

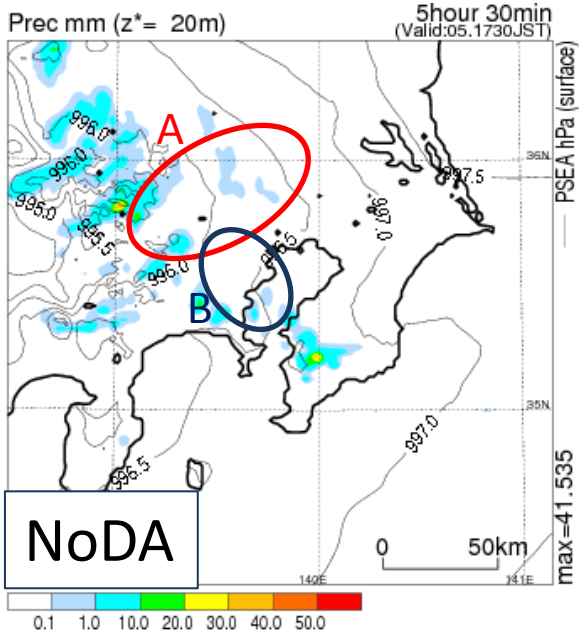
First guess

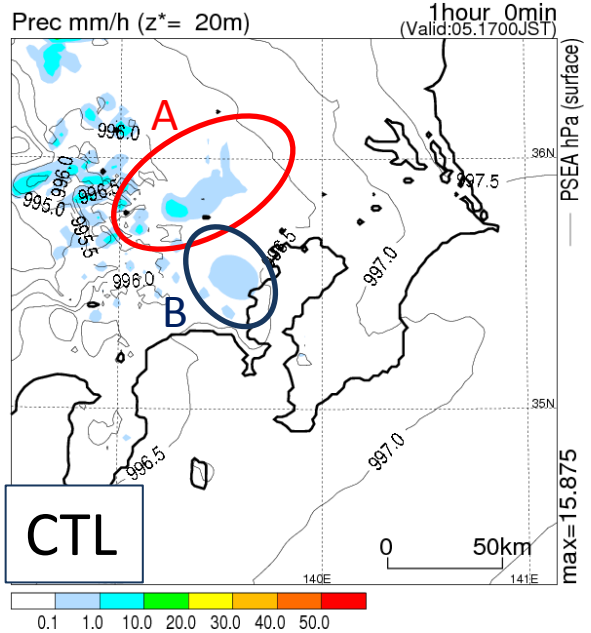
- **Downscaling from JMA NHM initiated with JMA meso analysis**

1-h rainfall in OBS, NoDA, CTL, LDR







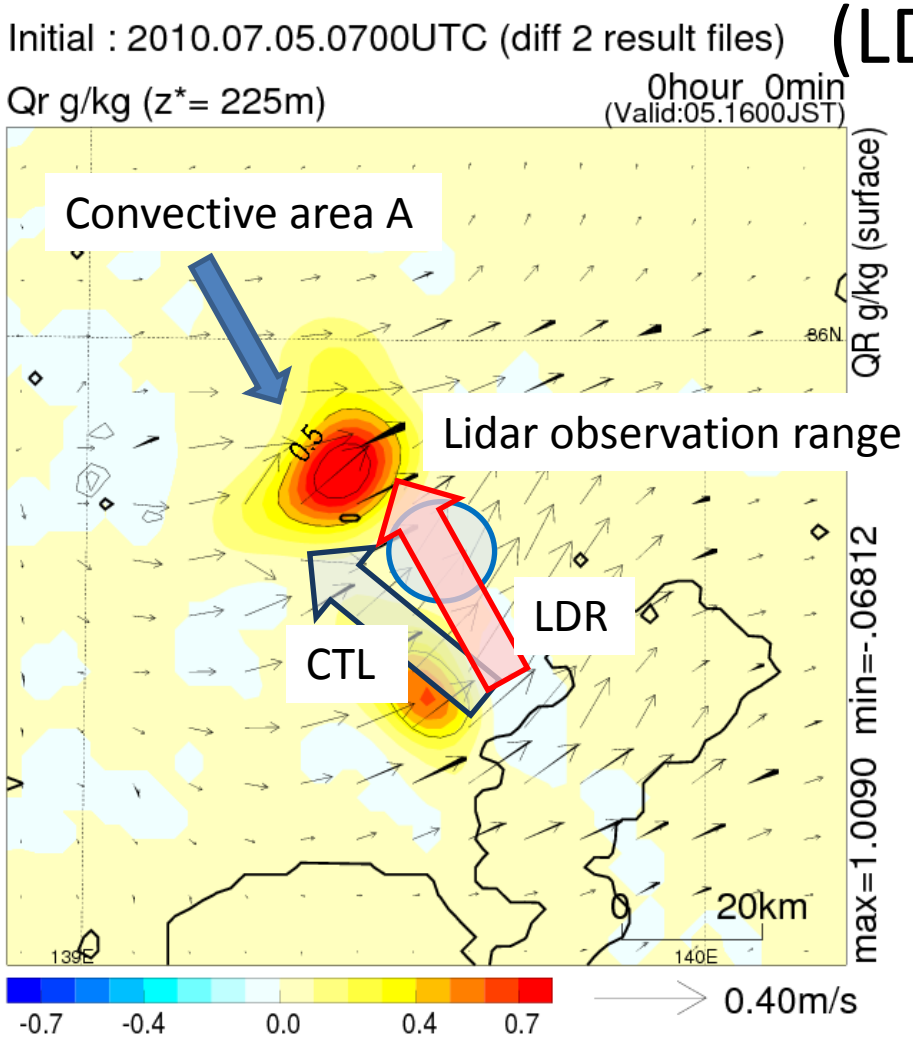


In NoDA, no strong convective areas.

In CTL, similar rainfall regions (A, B) appear but their intensity is weak (< 10 mm h^{-1}) compared with Observation.

In LDR, both convective areas of A and B are reproduced well with the maximum rainfall intensity of 53 mm h^{-1}.

Differences of wind vector and water vapor (LDR – CTL) z=225m FT=0



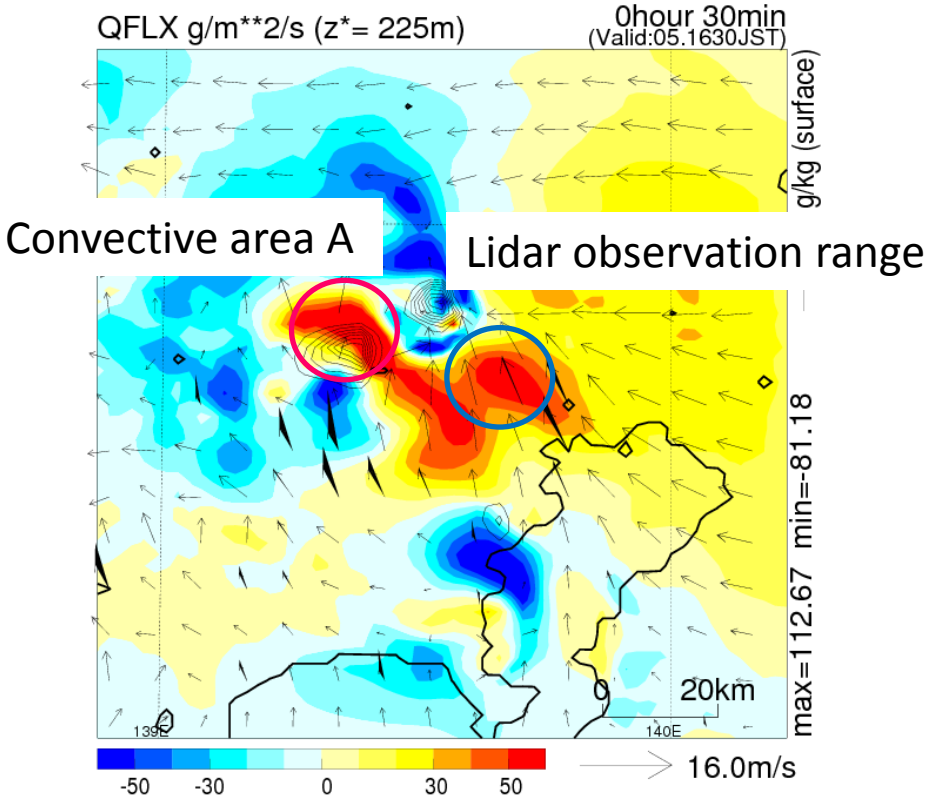
Vectors: difference of horizontal wind vectors between LDR and CTL
Colored shades: mixing ratio of rain water

Differences of wind vectors are distributed around Lidar observation range.

Mixing ratio of rain water in the convective area A increases in LDR.

The wind direction of the inflow to the cumulonimbus is changed southerly after the assimilation of Doppler Lidar observations.
→ Effective water vapor transportation

Difference of water vapor flux (LDR - CTL)
z = 225 m, FT=30min



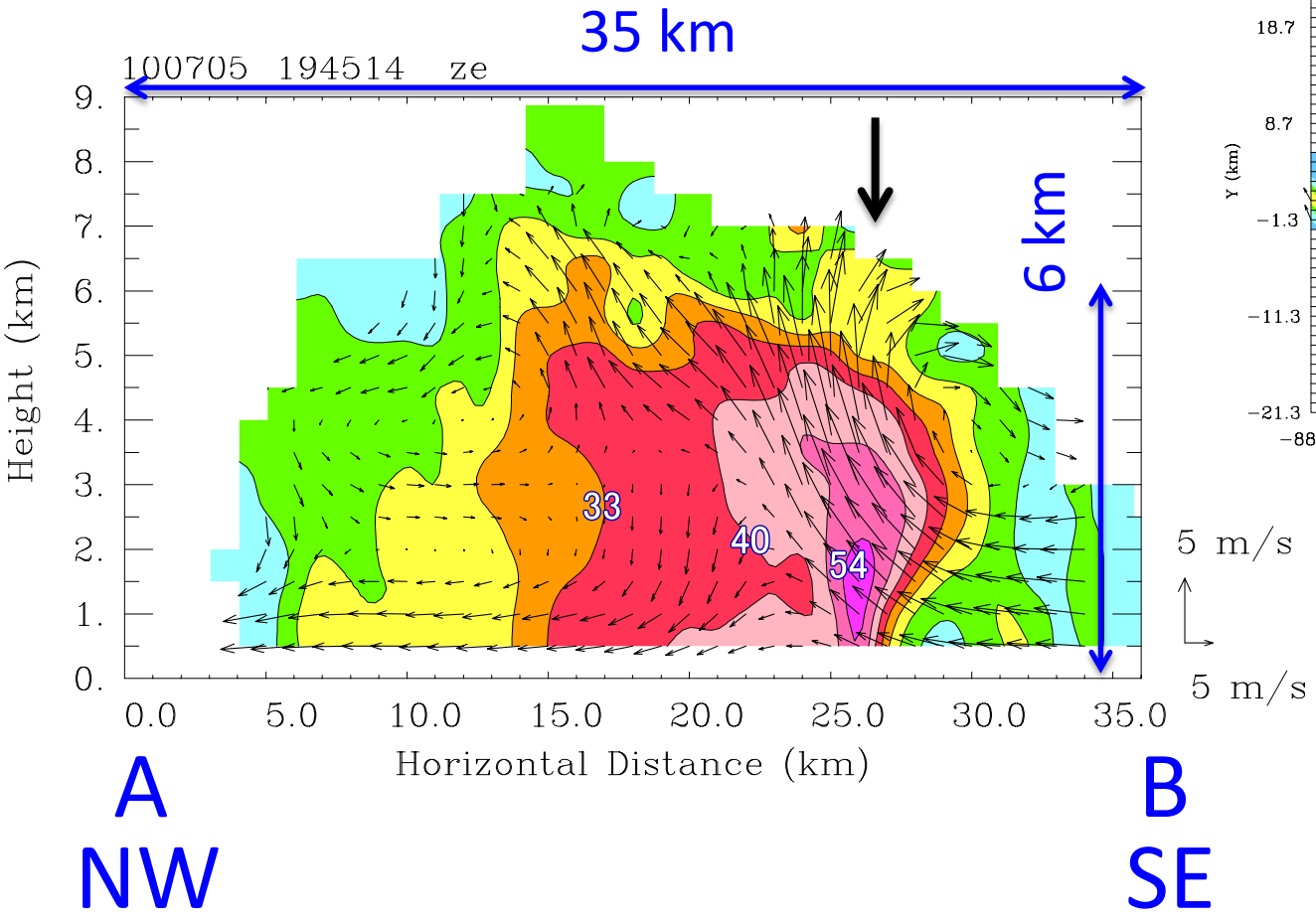
Vectors: Horizontal wind vectors at 225 m height in LDR.
Colored shades: Difference of water vapor flux between LDR and CTL.

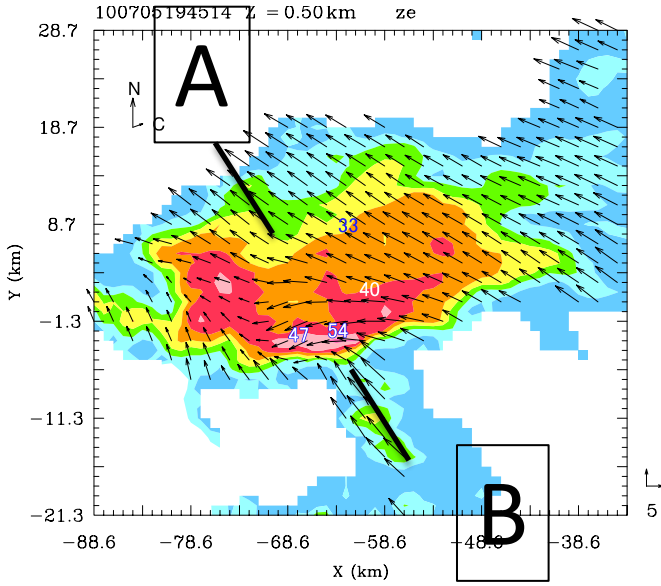
The difference of wind direction provides the difference of water vapor flux.

Water vapor inflows to the cumulonimbus more in LDR than in CTL. This difference intensified rainfall A in LDR.

Analysis of Radar Observation

Mature stage (1945 JST)





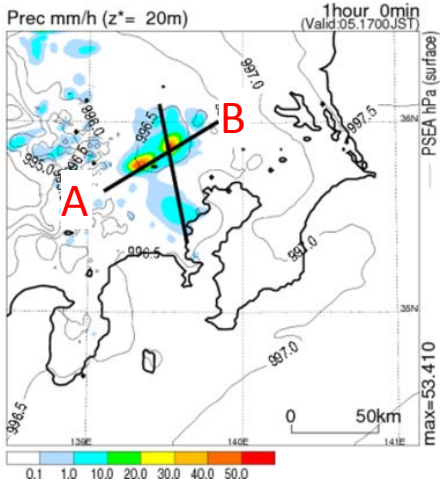
Position of the vertical cross-section

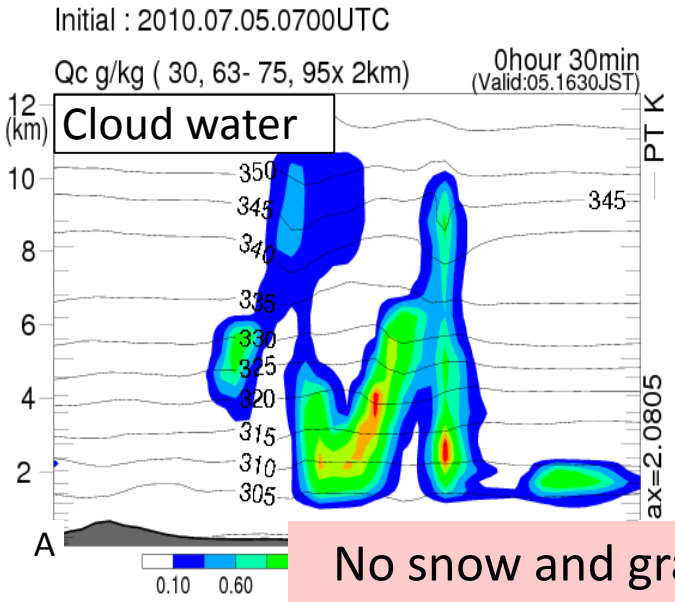
Arrows: vector representation of system-relative horizontal wind and vertical component

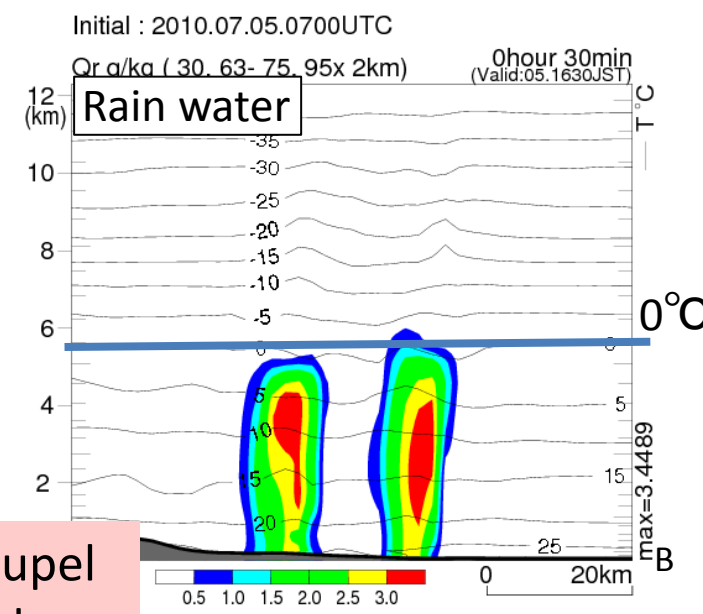
Courtesy of Dr. Yamada (MRI)

Analysis of the cumulonimbus in LDR

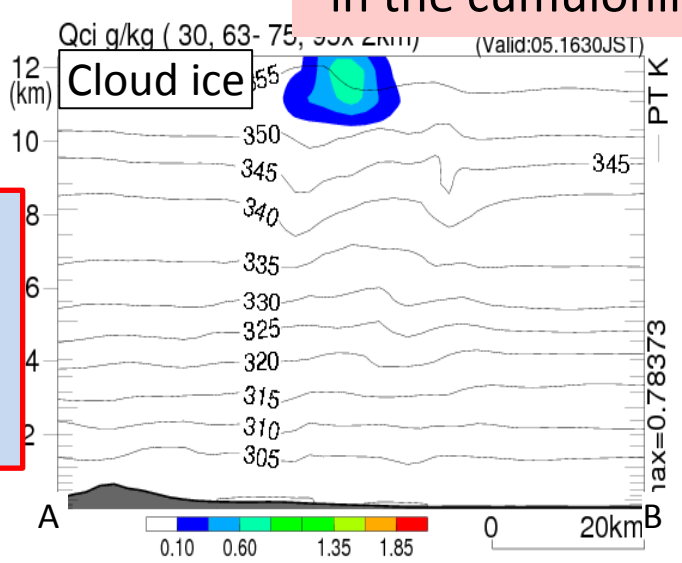
Vertical cross-section of water substances (FT=30min)

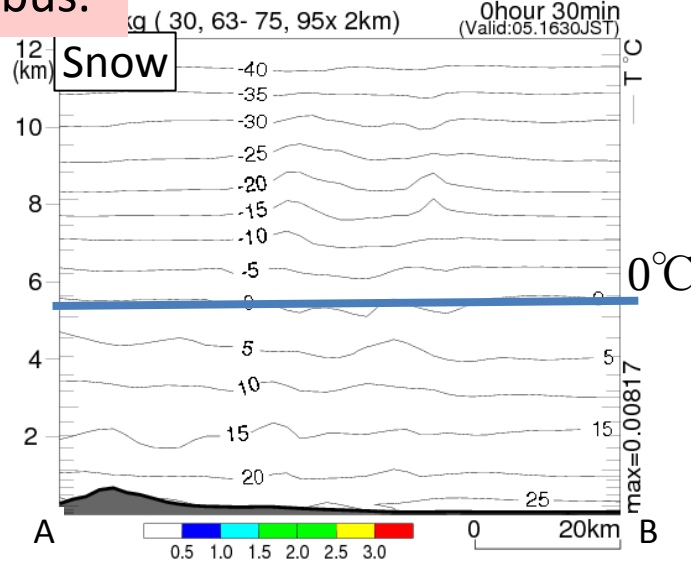






No snow and graupel in the cumulonimbus.





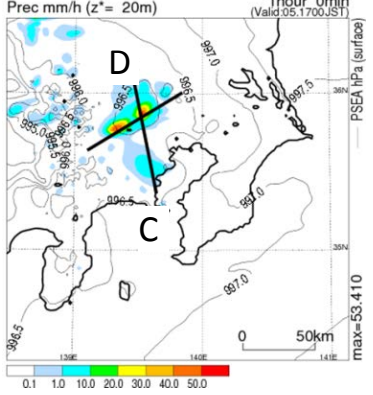
The heavy rainfall was produced without ice phase (warm rain).

Contours : potential temperature

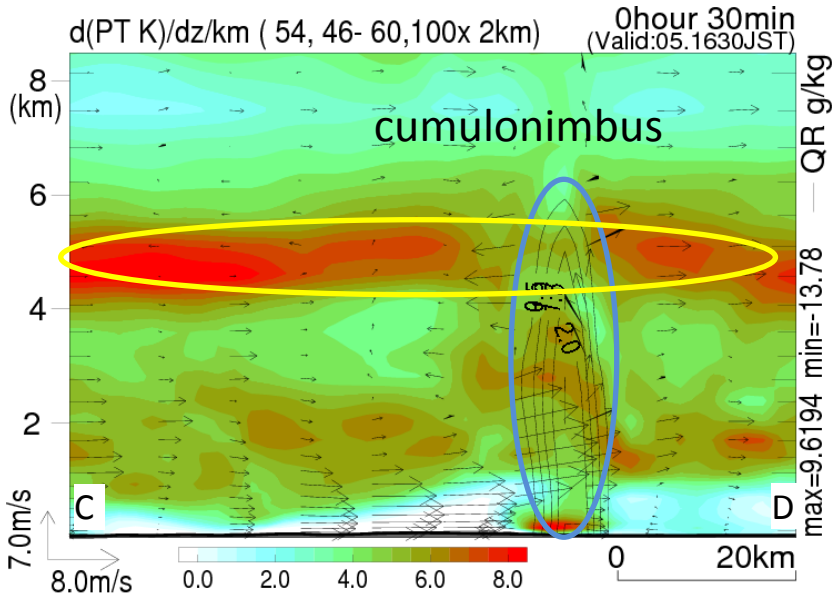
Contours : temperature

Analysis of the cumulonimbus in LDR

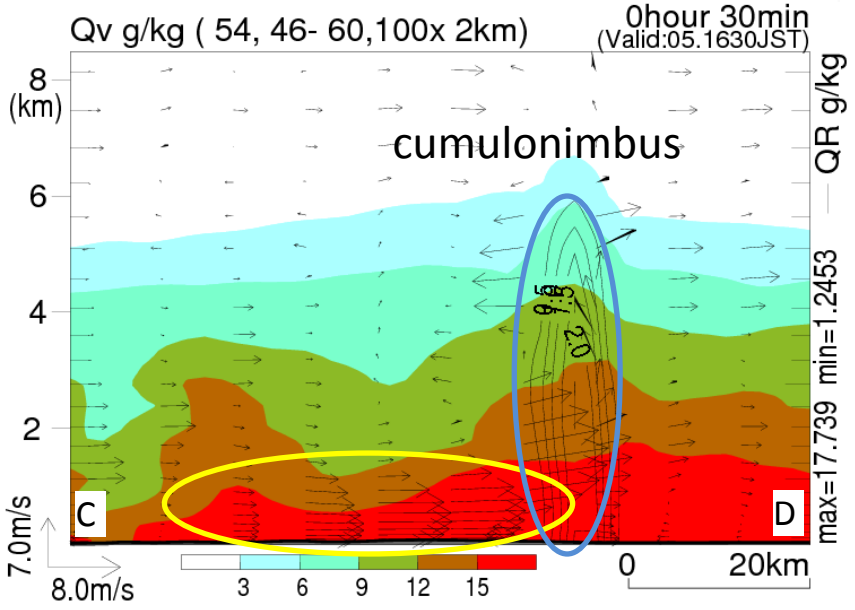
Vertical cross-section of water vapor and stable layer (FT = 30 min)



Color shade: dtdz
Contour: mixing ratio of rain water



Color shade: water vapor
Contour: rain water



Q. Why warm rain?

A. Stable layer.

Since there was a stable layer at 5-km height, the cumulonimbus did not develop over the freezing level.

Q. Why such intense rainfall?

A. Large flux of water vapor.

Very humid air over 10 g kg^{-1} inflowed to the cumulonimbus with the strong sea breeze over 10 m s^{-1}.

Summary

- Data assimilation experiment was conducted on the Itabashi heavy rainfall event using NHM-4DVAR.
- Assimilated observations are radial wind by Doppler Lidar, radial wind by Doppler Radar, radar reflectivity, and GPS precipitable water vapor.
- By assimilating Doppler Lidar data, the intense rainfall region was forecasted similar to the observation.
- Because of the stable layer, the cumulonimbus did not developed over the freezing level.
- Large water vapor flux induced the heavy rainfall.