Radar data assimilation for tornadic thunderstorm observed on 6th May 2012 around TSUKUBA city using CReSS-3DVAR-IAU system

The objective of this study:
To investigate the predictability of the tornadic supercell storm using dense radar network data In Tokyo metropolitan region And CReSS-3DVAR-IAU with 1km resolution

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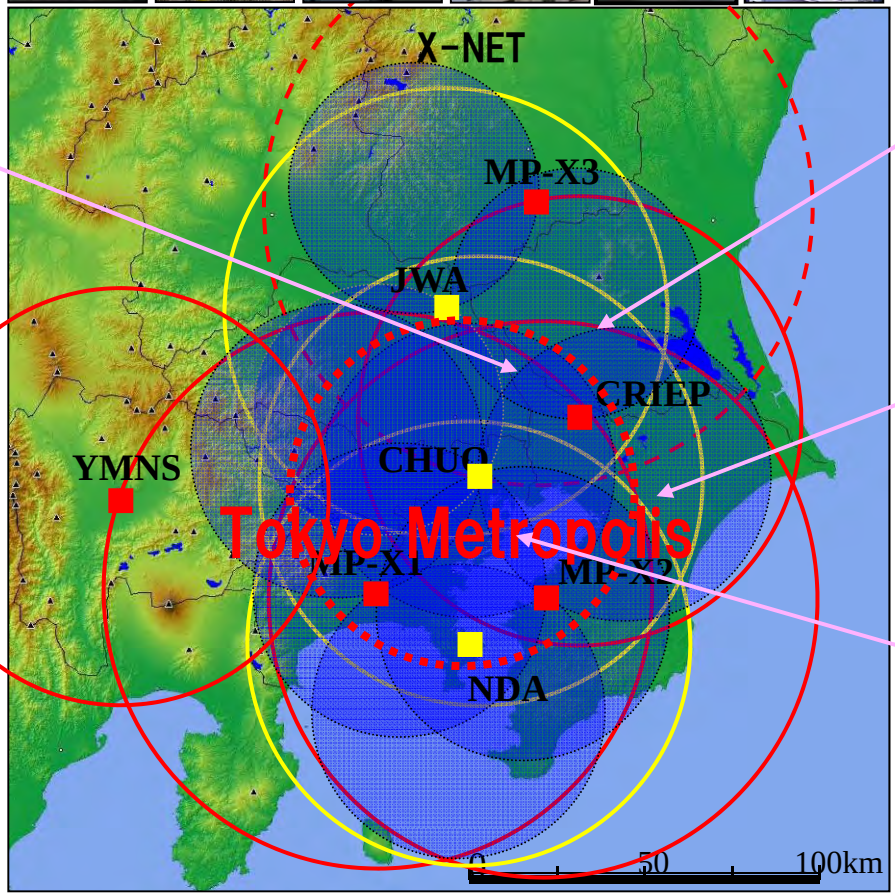
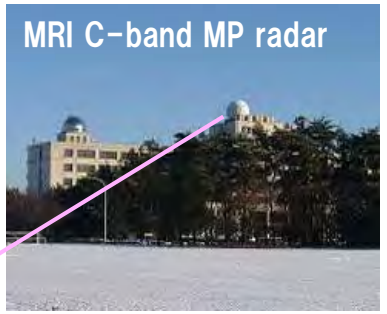
Real-time estimation of 3D wind in TOMACS

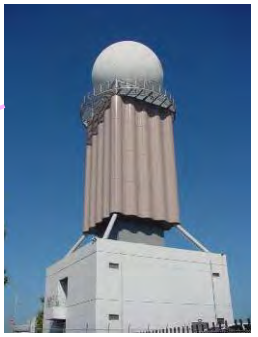
Research/operation weather radars concentrate in the Tokyo Metropolitan Area: X-NET (5 X-band MP radars and 3 Doppler radars), two X-band MP radars of River Bureau, MRI C-band MP radar and 3 JMA C-band operational Doppler radars.



M. Maki of NIED and X-NET Group

JMA Kashiwa C-band Doppler radar

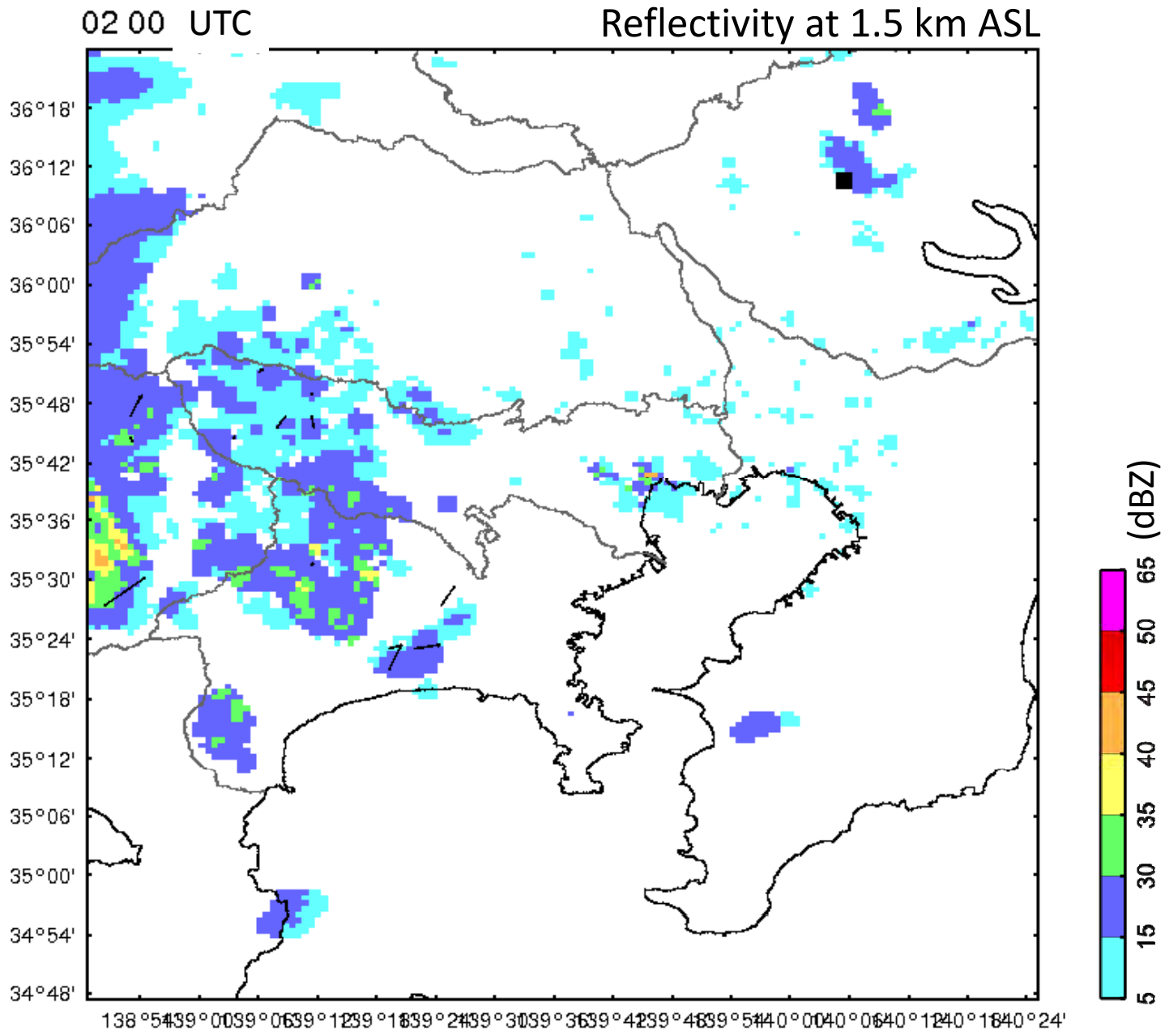




JMA Narita Airport C-band Doppler radar

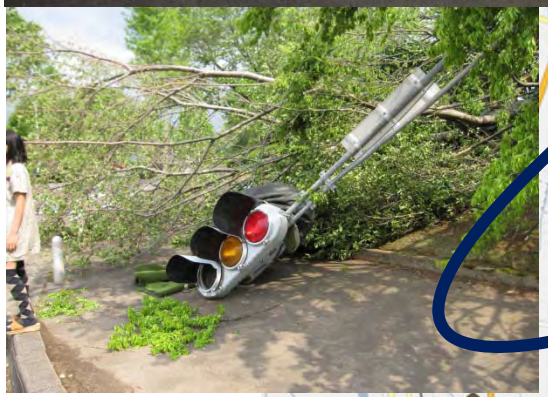
JMA Haneda Airport C-band Doppler radar

Real-Time 3D wind analysis using X-NET



Tornado damage on May 6th 2012 in Tsukuba

The most severe Tornado damage (Fujita scale was F3) in Japan was observed on 6th May 2012 . More than 30 people was injured, and a 14 year's-old boy was killed. The tornado path length was 17 km.



Damage report

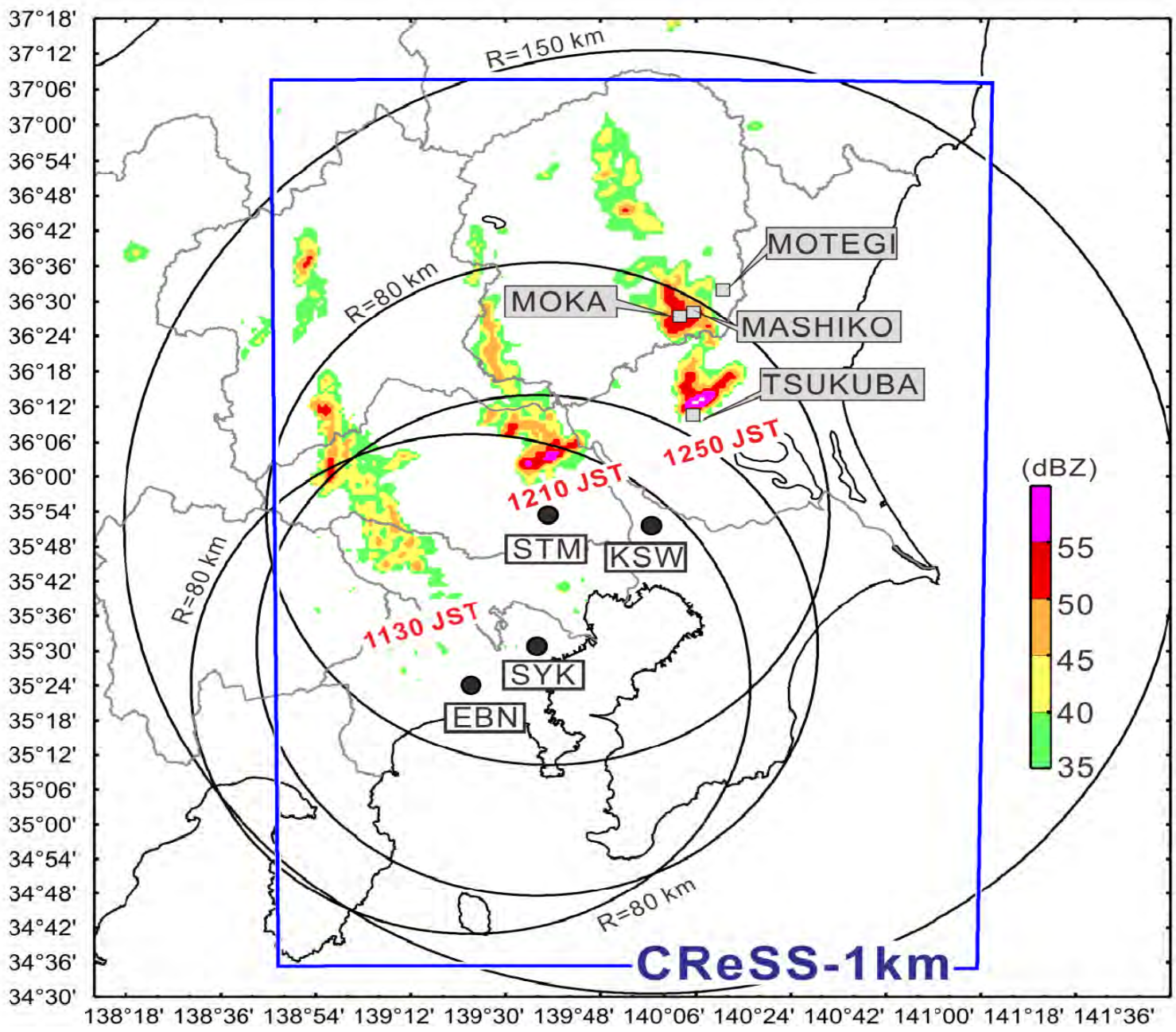
Radar range and simulation domain

Radar

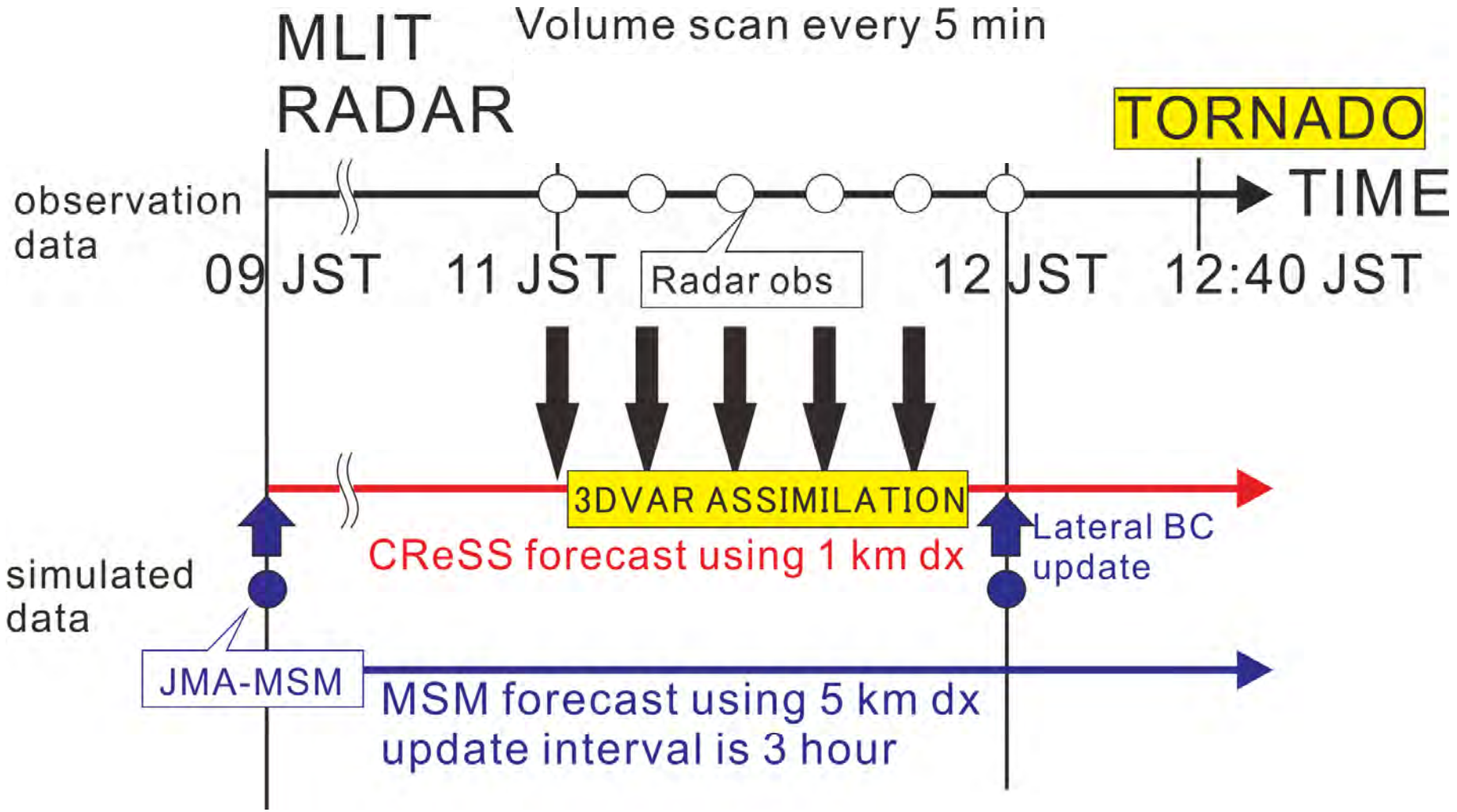
- NIED X-band Dual-Pol (EBN) (dt = 5 min)
- MLIT X-band Dual-Pol (STM,SYK) (dt = 5min)
- JMA C-band (KSW) Doppler (dt = 10min)

Numerical model

- CReSS ver3.2
  dx = 1 km
  dz = 200-500m



CReSS -3DVAR with Incremental Analysis Update (IAU)



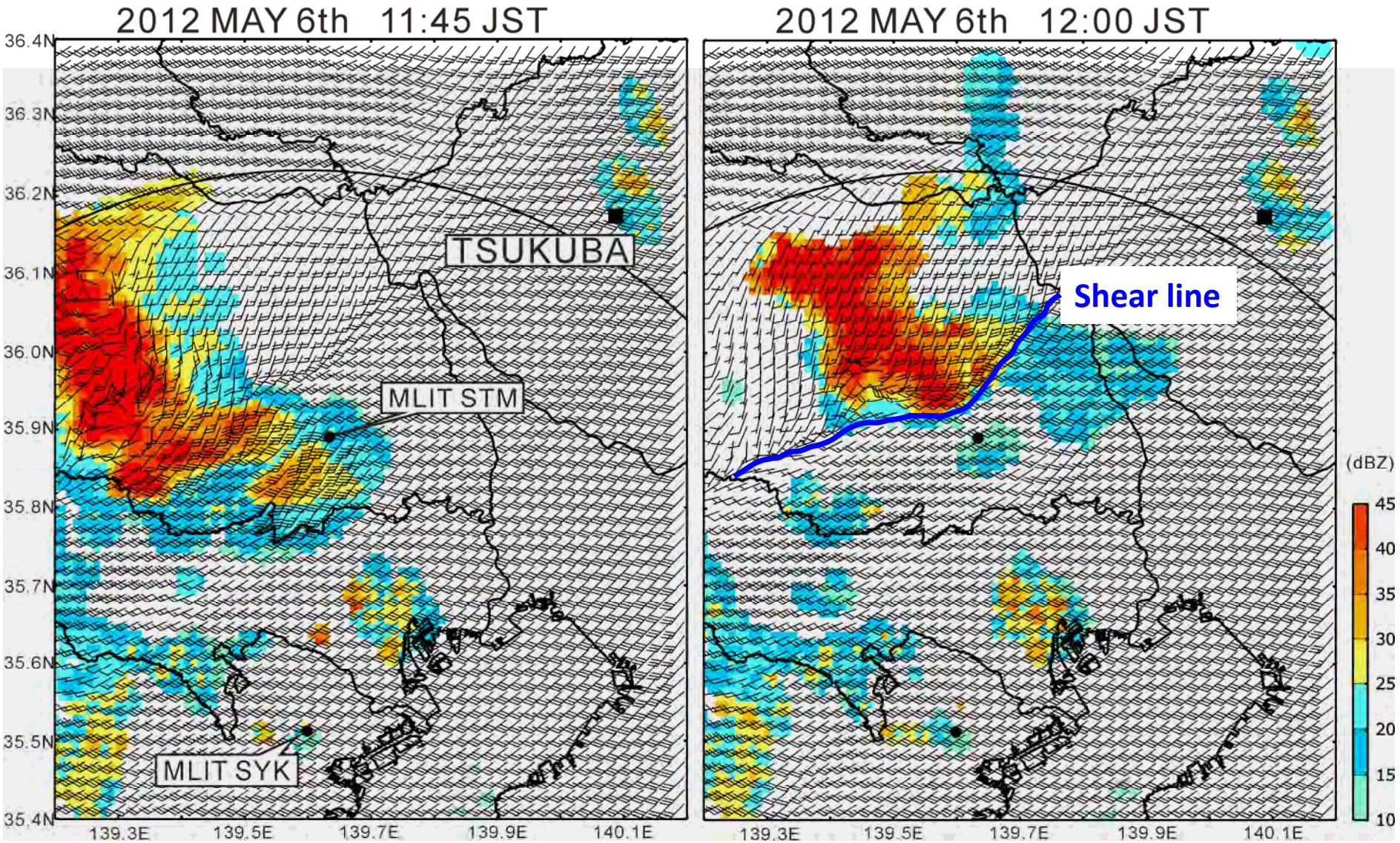
CReSS3DVAR assimilates radial velocity from radar network every 5 min.

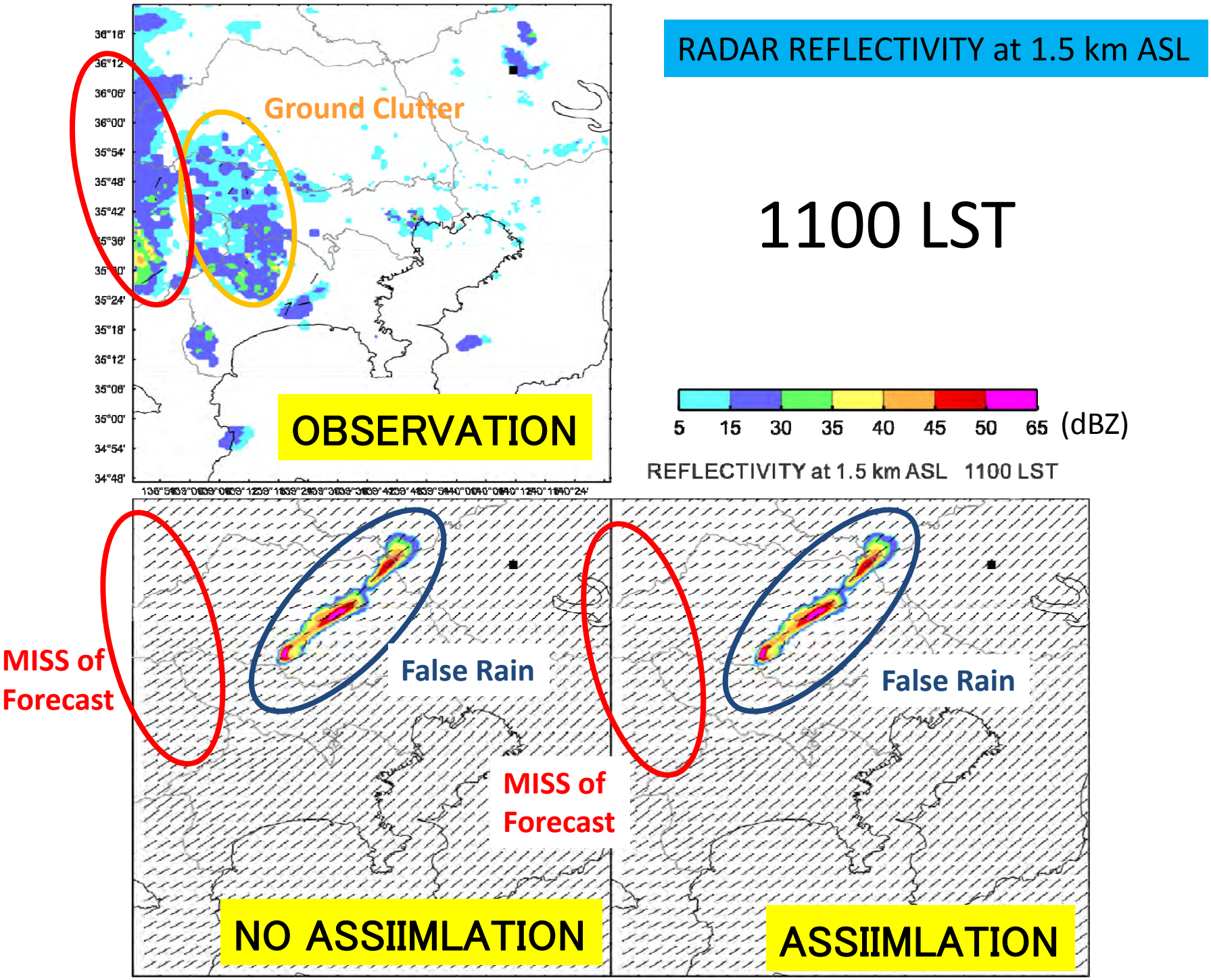
Increment of wind velocity is evaluated at the observation time.

The incremental of wind velocity is assimilated using nudging scheme.

Objective analysis (3DVAR) for wind field at a height of 1km

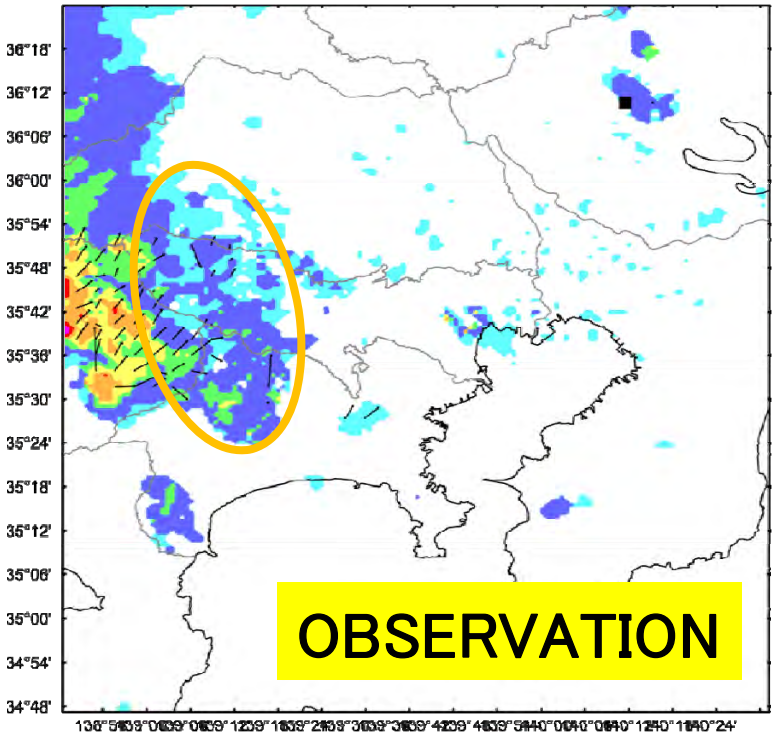
Radar reflectivity and analyzed wind field by 3DVAR-IAU



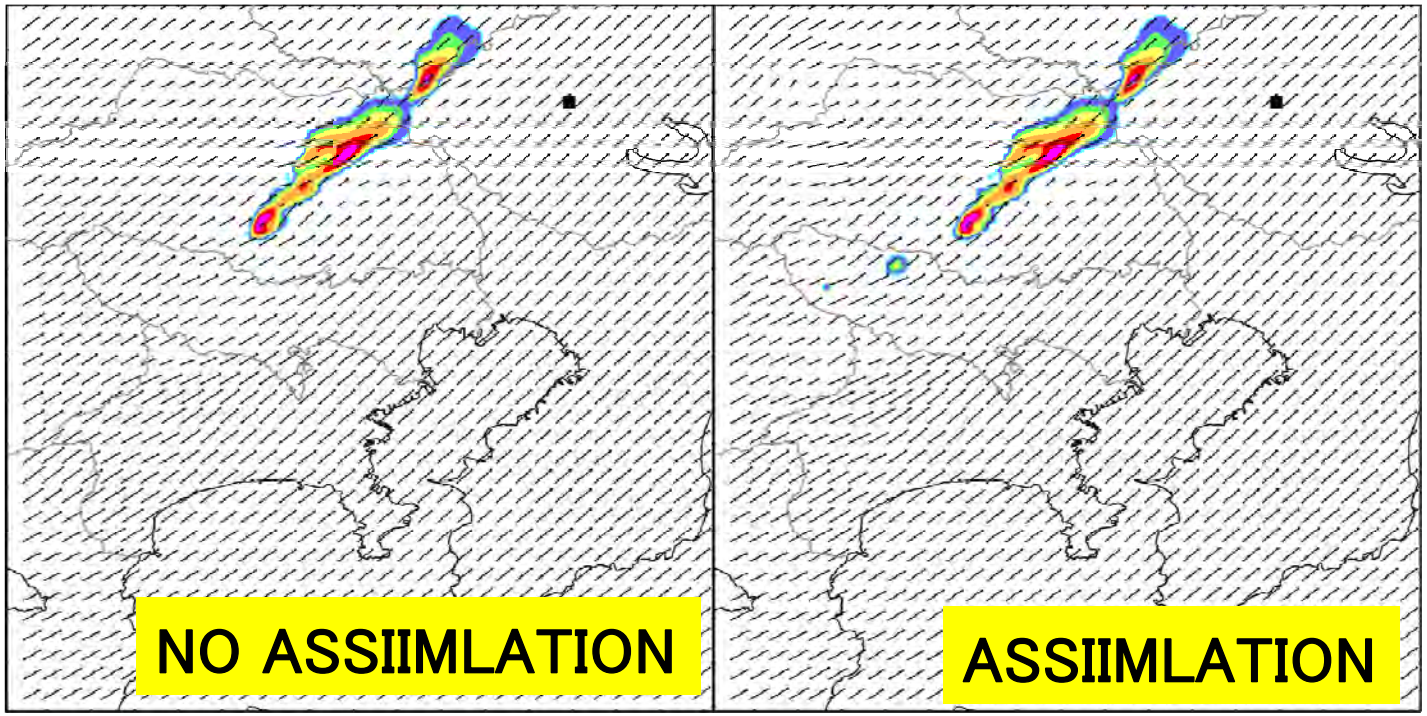

RADAR REFLECTIVITY at 1.5 km ASL
1100 LST
Ground Clutter
OBSERVATION
5 15 30 35 40 45 50 65 (dBZ)
REFLECTIVITY at 1.5 km ASL 1100 LST
MISS of Forecast
False Rain
False Rain
MISS of Forecast
NO ASSIIMLATION
ASSIIMLATION

RADAR REFLECTIVITY at 1.5 km ASL

1110 LST

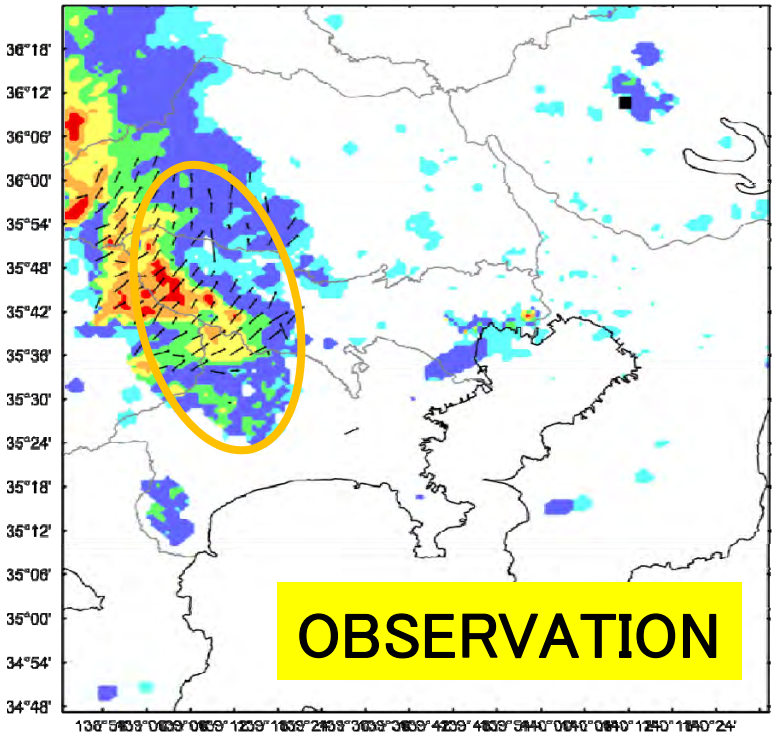


REFLECTIVITY at 1.5 km ASL 1110 LST

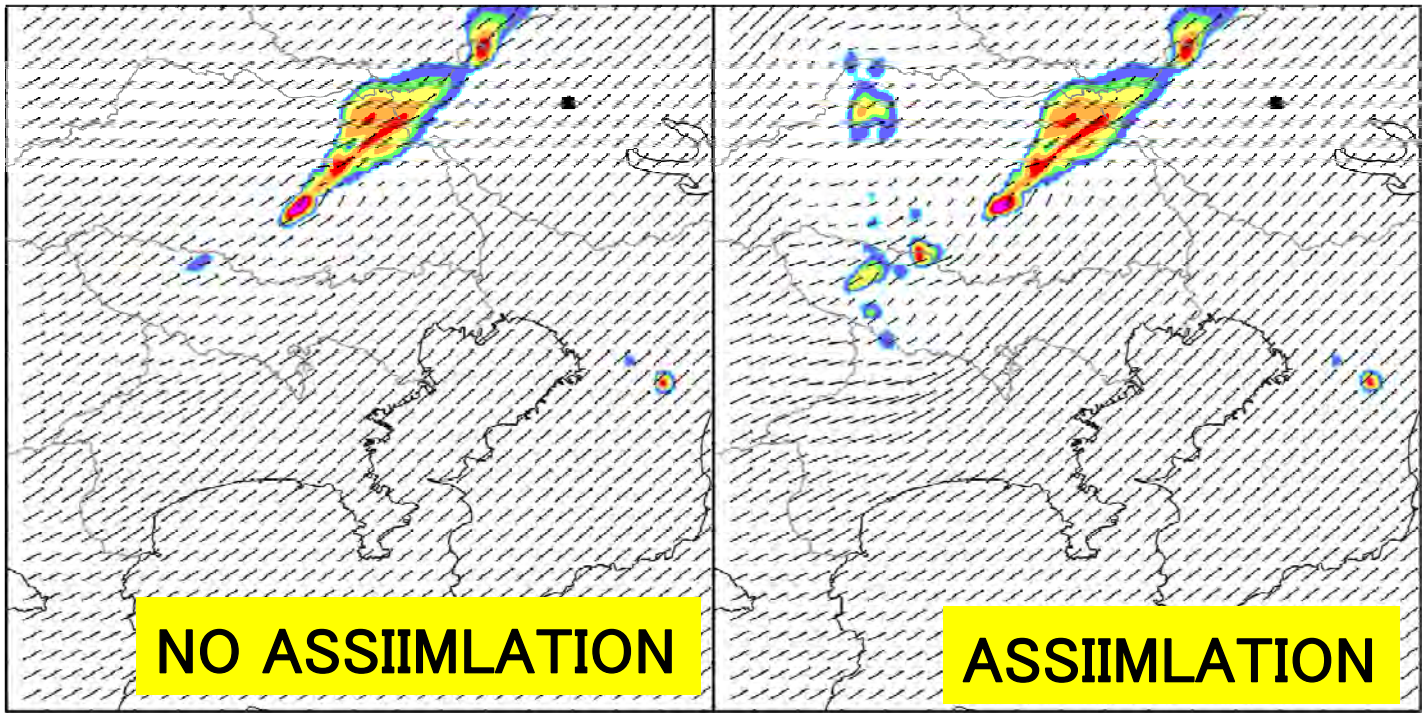


RADAR REFLECTIVITY at 1.5 km ASL

1120 LST

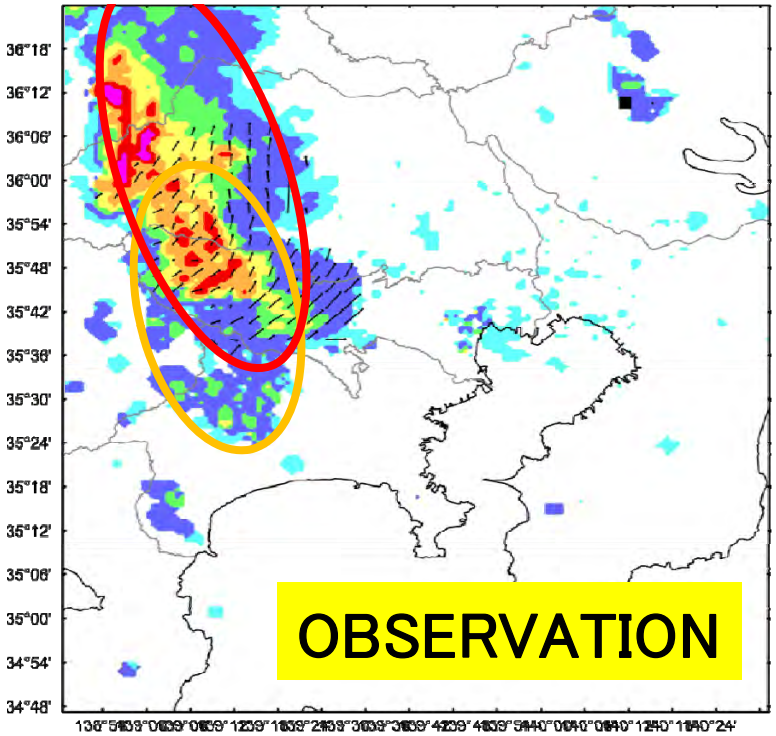


REFLECTIVITY at 1.5 km ASL 1120 LST

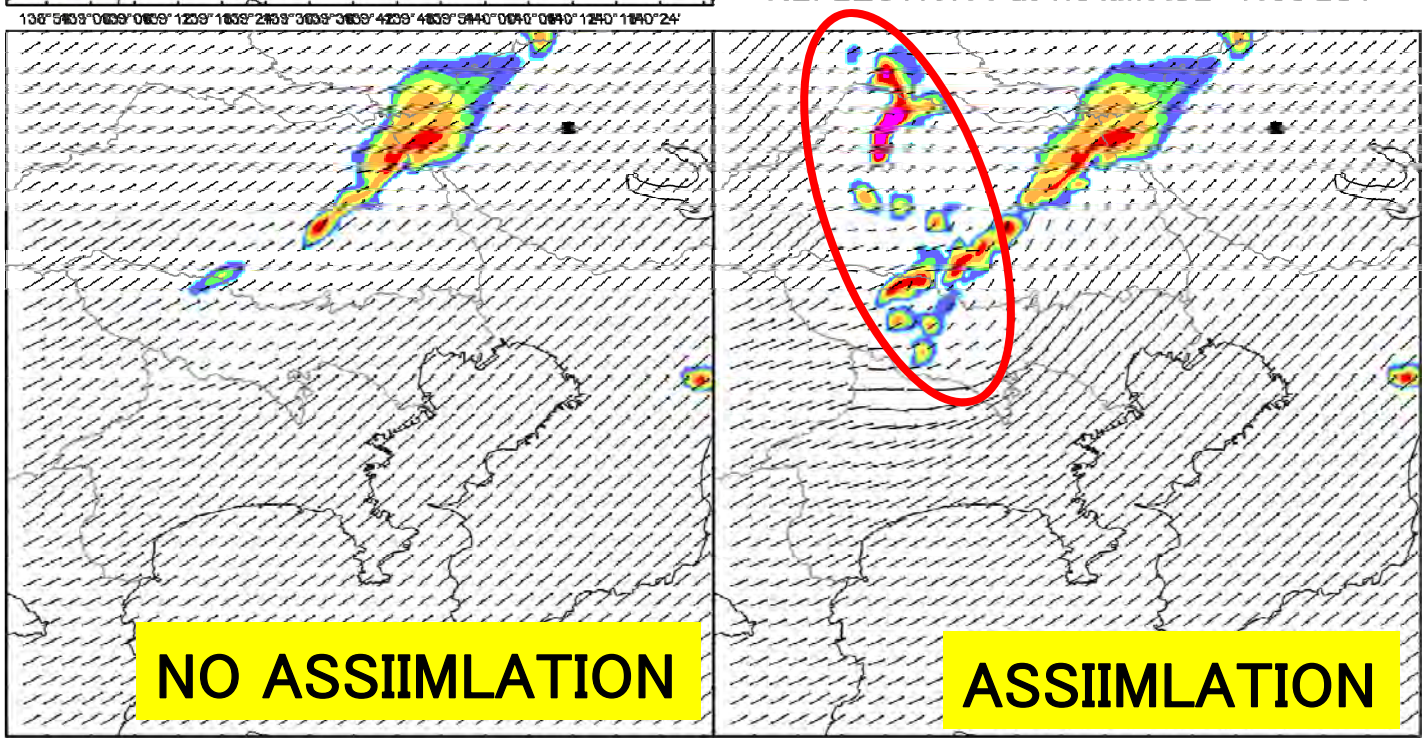


RADAR REFLECTIVITY at 1.5 km ASL

1130 LST

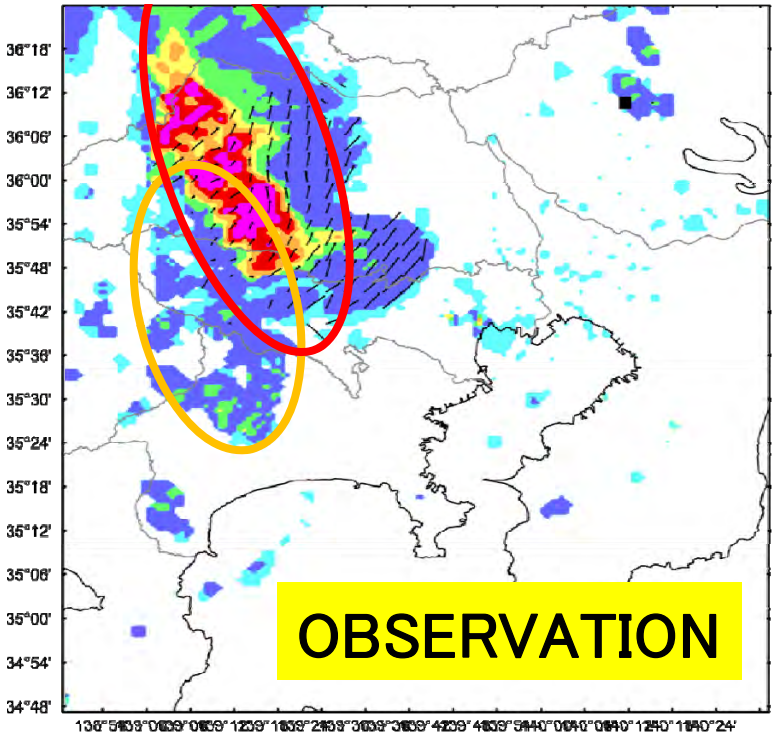


REFLECTIVITY at 1.5 km ASL 1130 LST

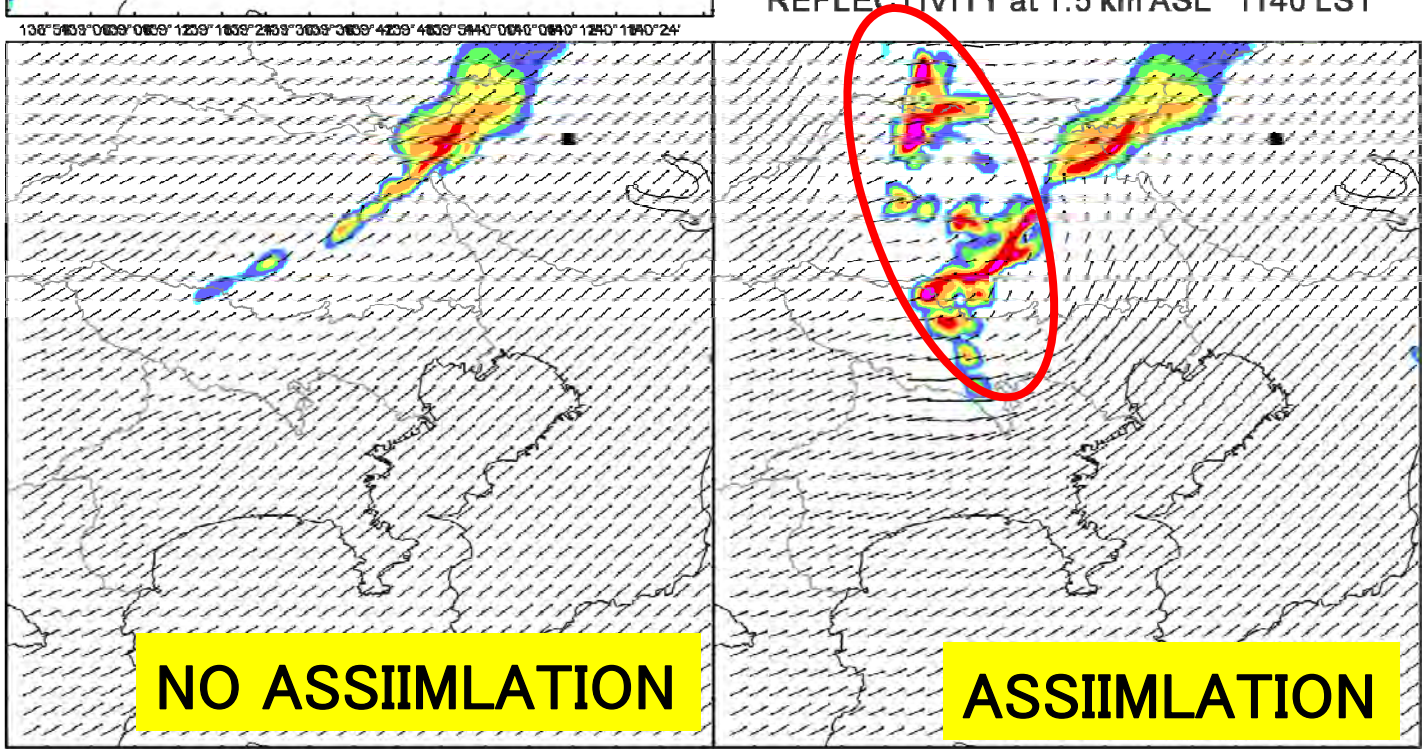


RADAR REFLECTIVITY at 1.5 km ASL

1140 LST

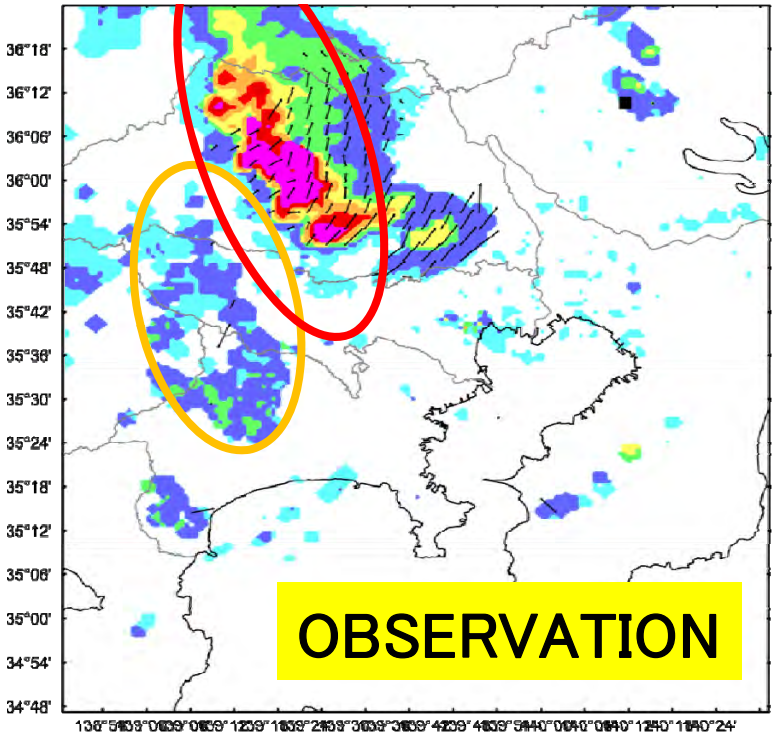


REFLECTIVITY at 1.5 km ASL 1140 LST

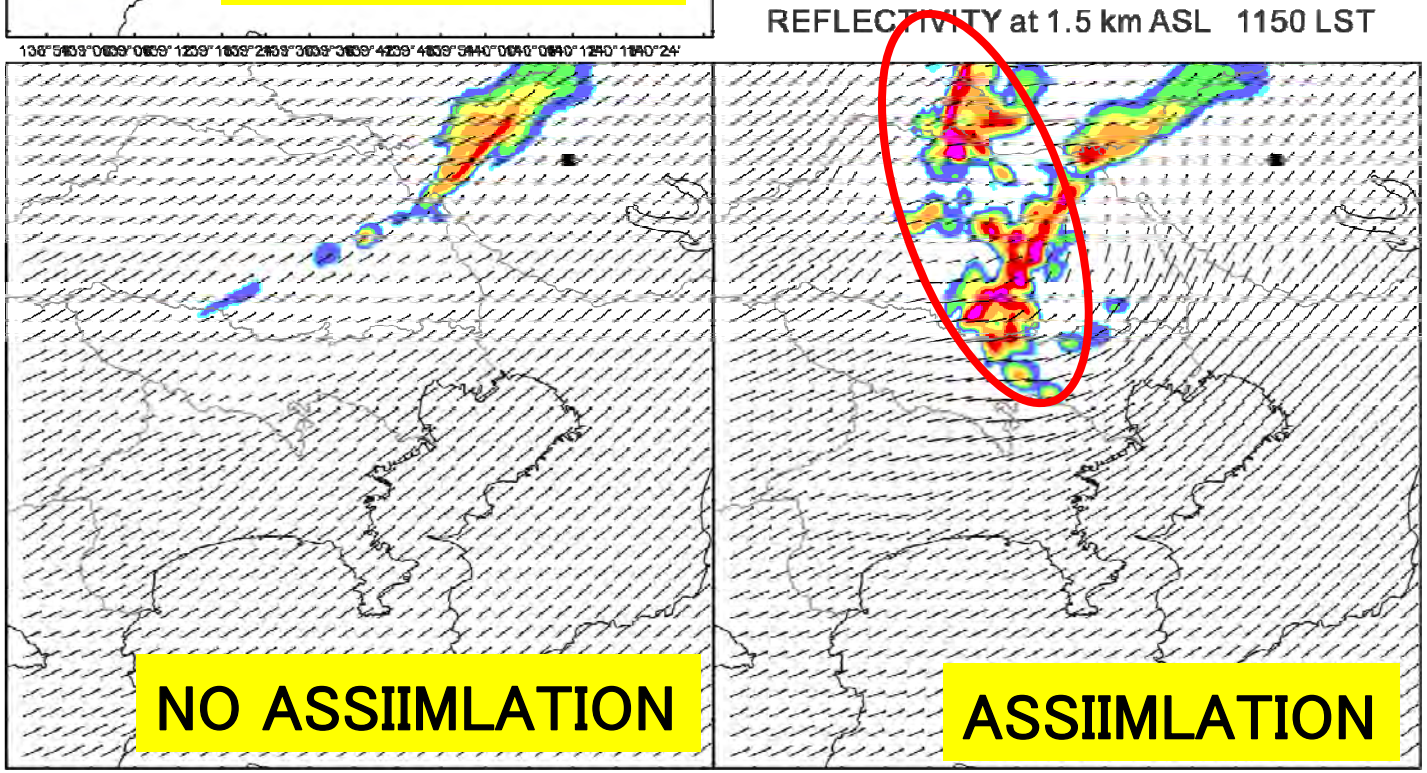


RADAR REFLECTIVITY at 1.5 km ASL

1150 LST

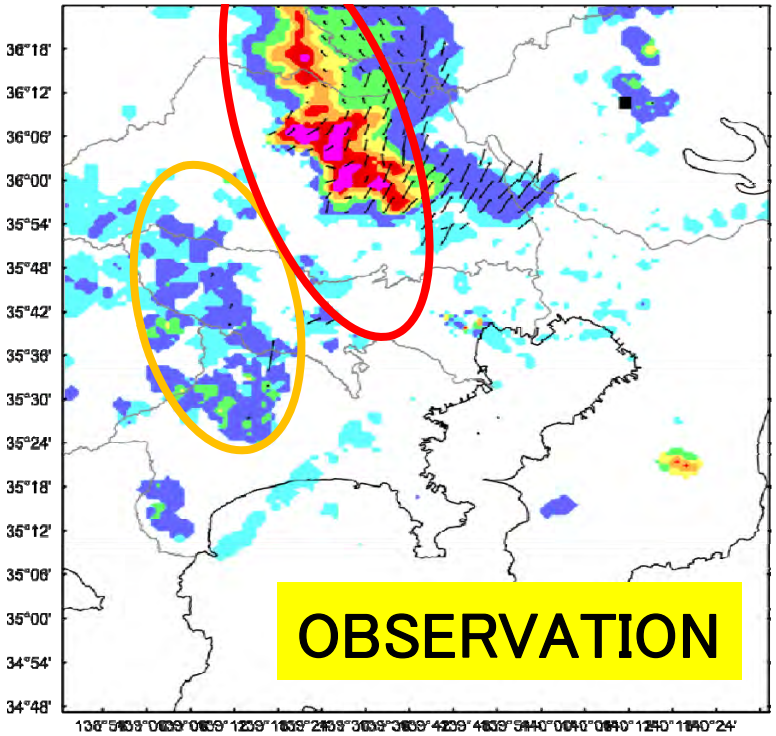


REFLECTIVITY at 1.5 km ASL 1150 LST

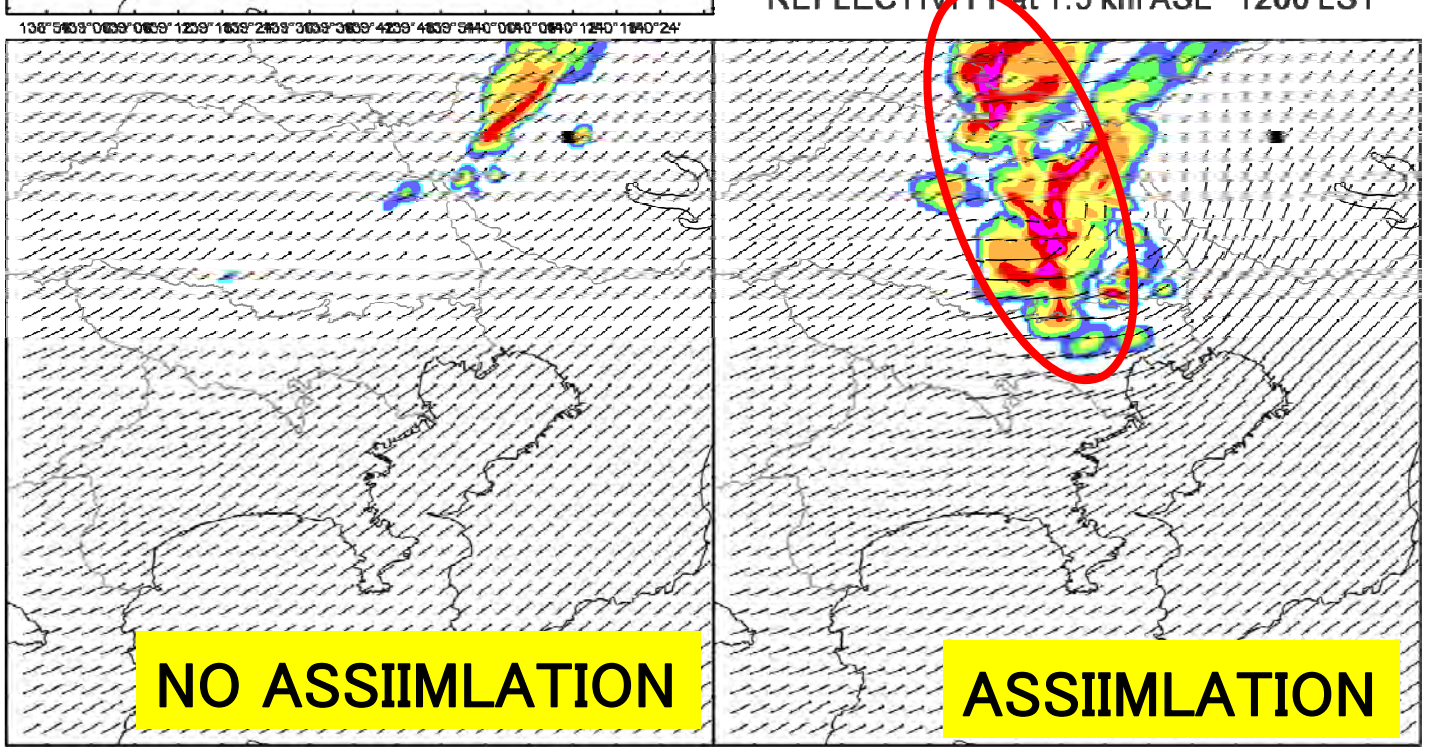


RADAR REFLECTIVITY at 1.5 km ASL

1200 LST

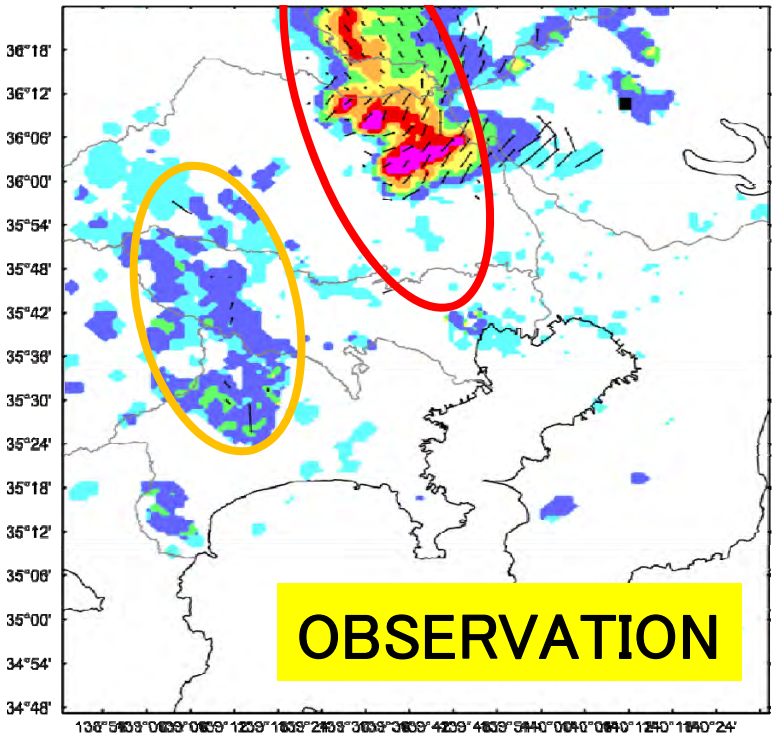


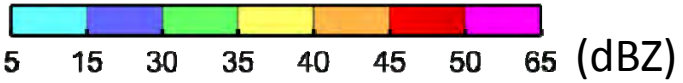
REFLECTIVITY at 1.5 km ASL 1200 LST



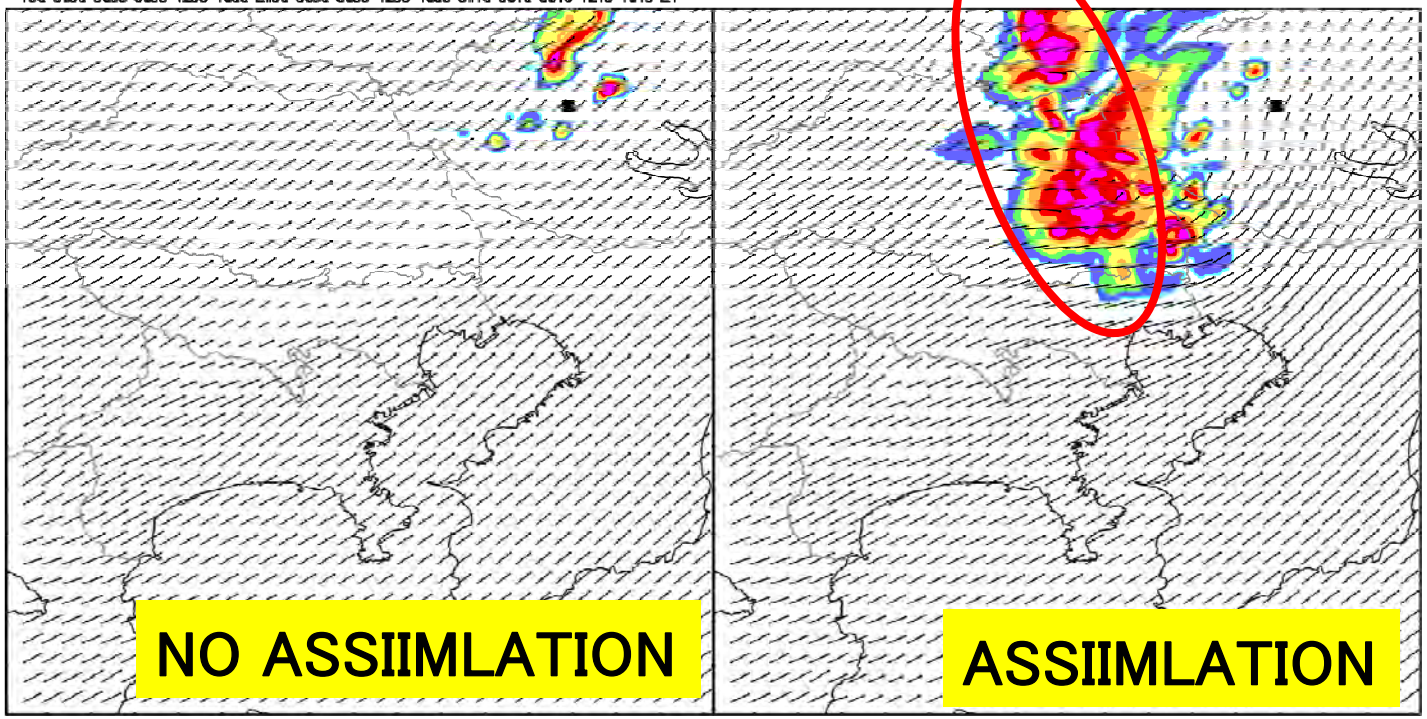
RADAR REFLECTIVITY at 1.5 km ASL

1210 LST



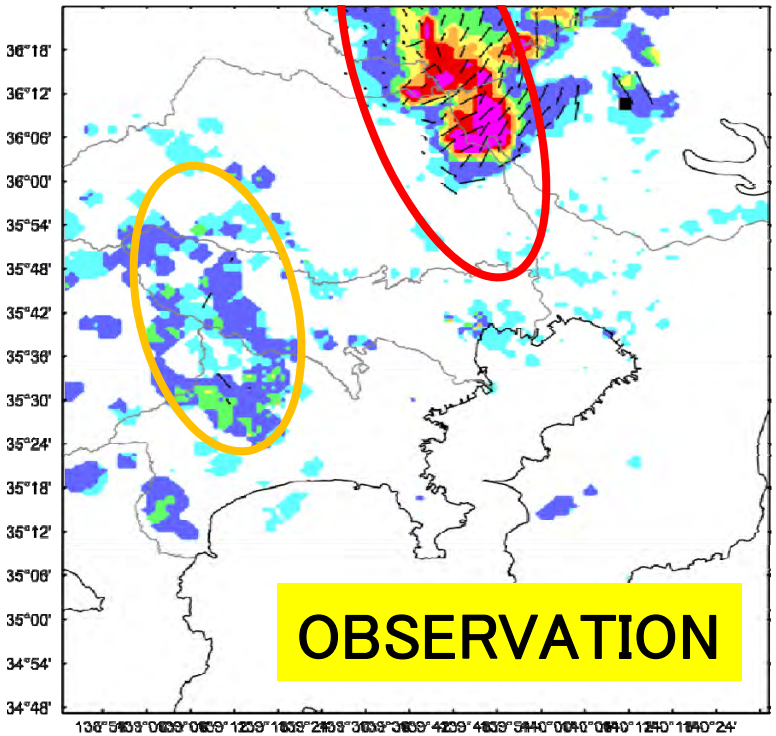


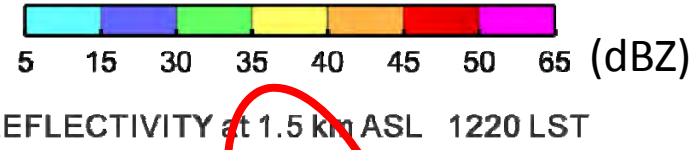
REFLECTIVITY at 1.5 km ASL 1210 LST

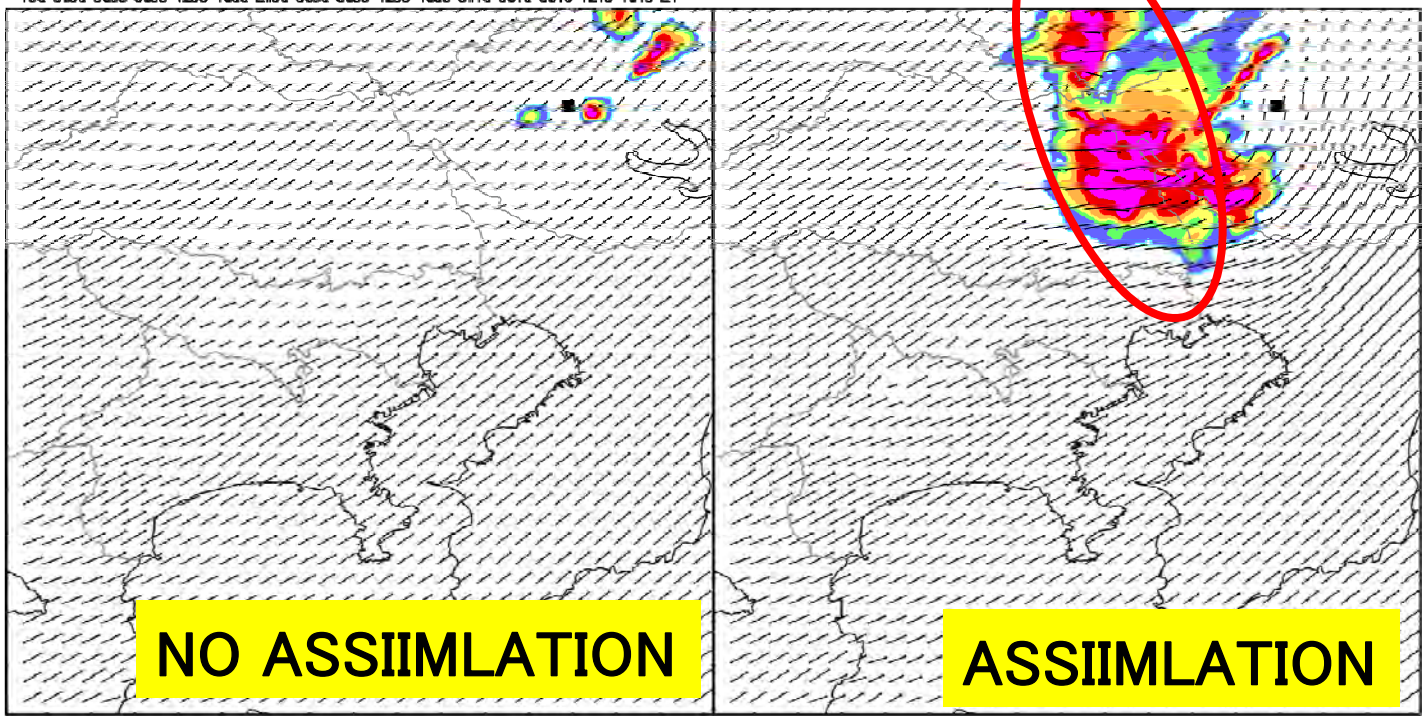


RADAR REFLECTIVITY at 1.5 km ASL

1220 LST

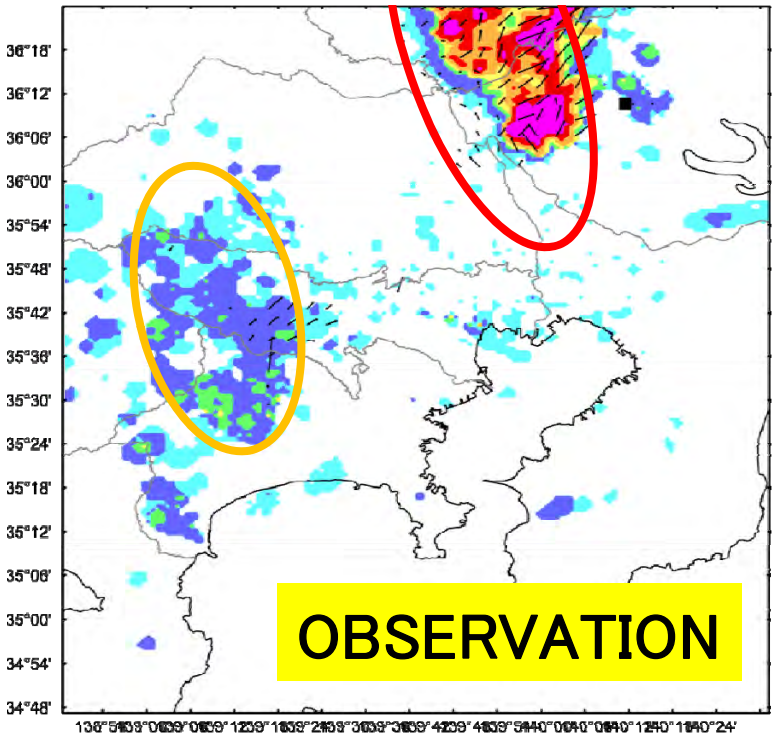


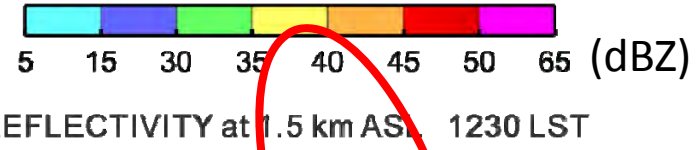


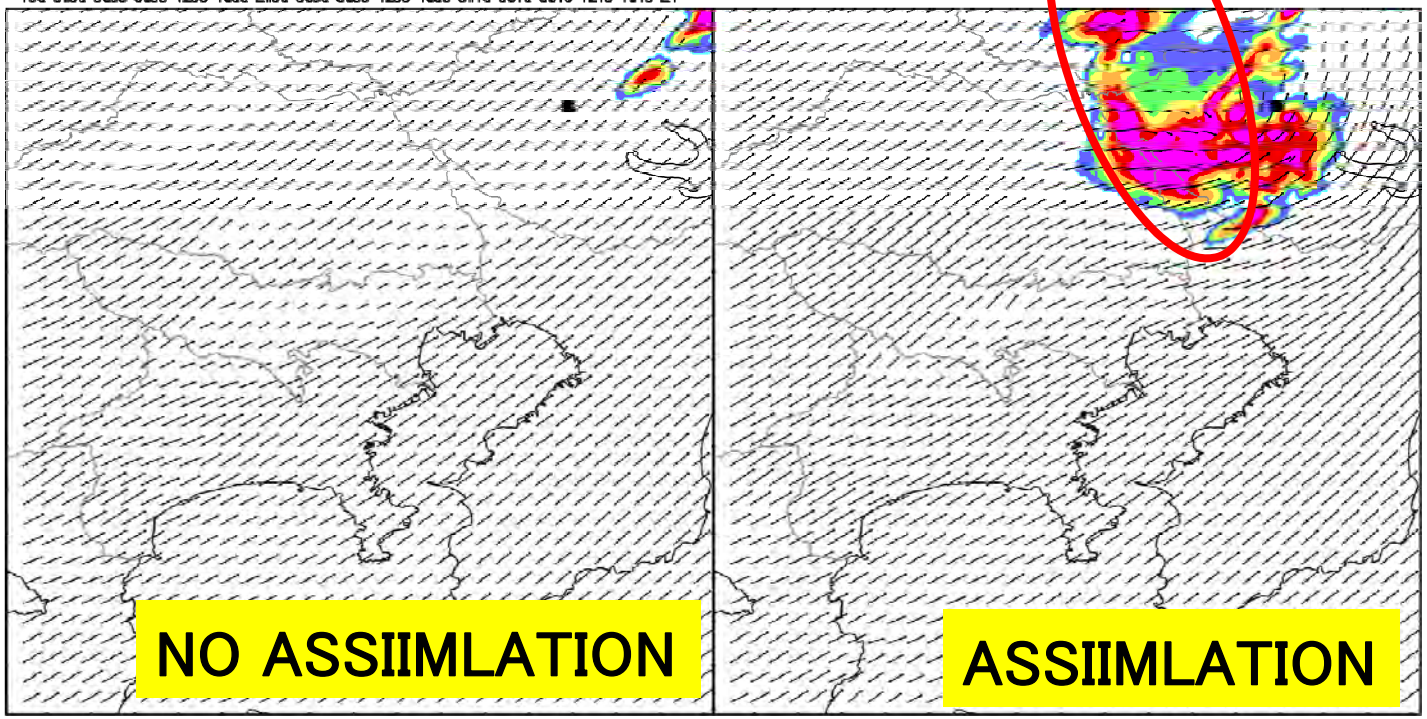


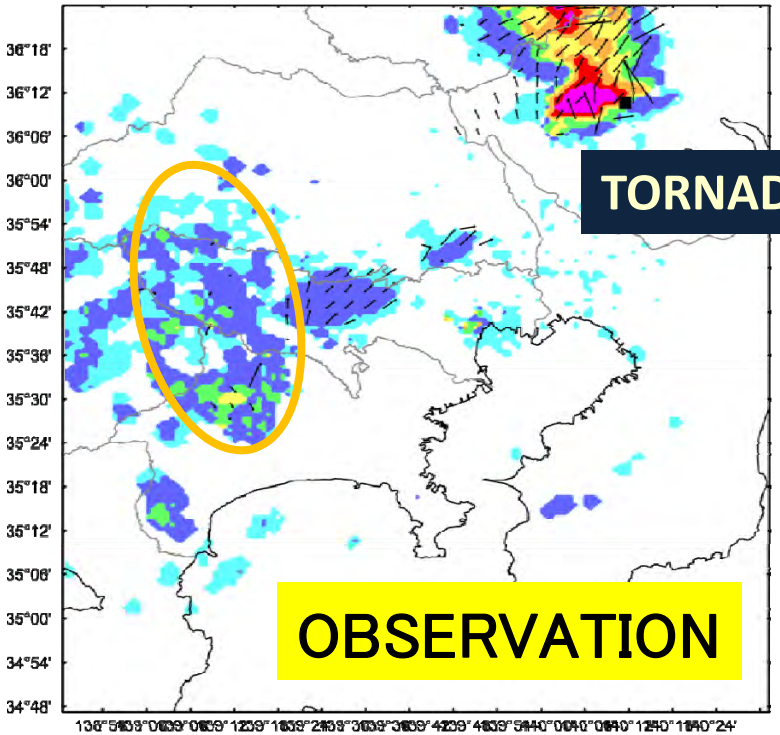
RADAR REFLECTIVITY at 1.5 km ASL

1230 LST







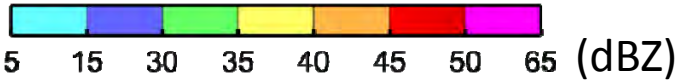


RADAR REFLECTIVITY at 1.5 km ASL

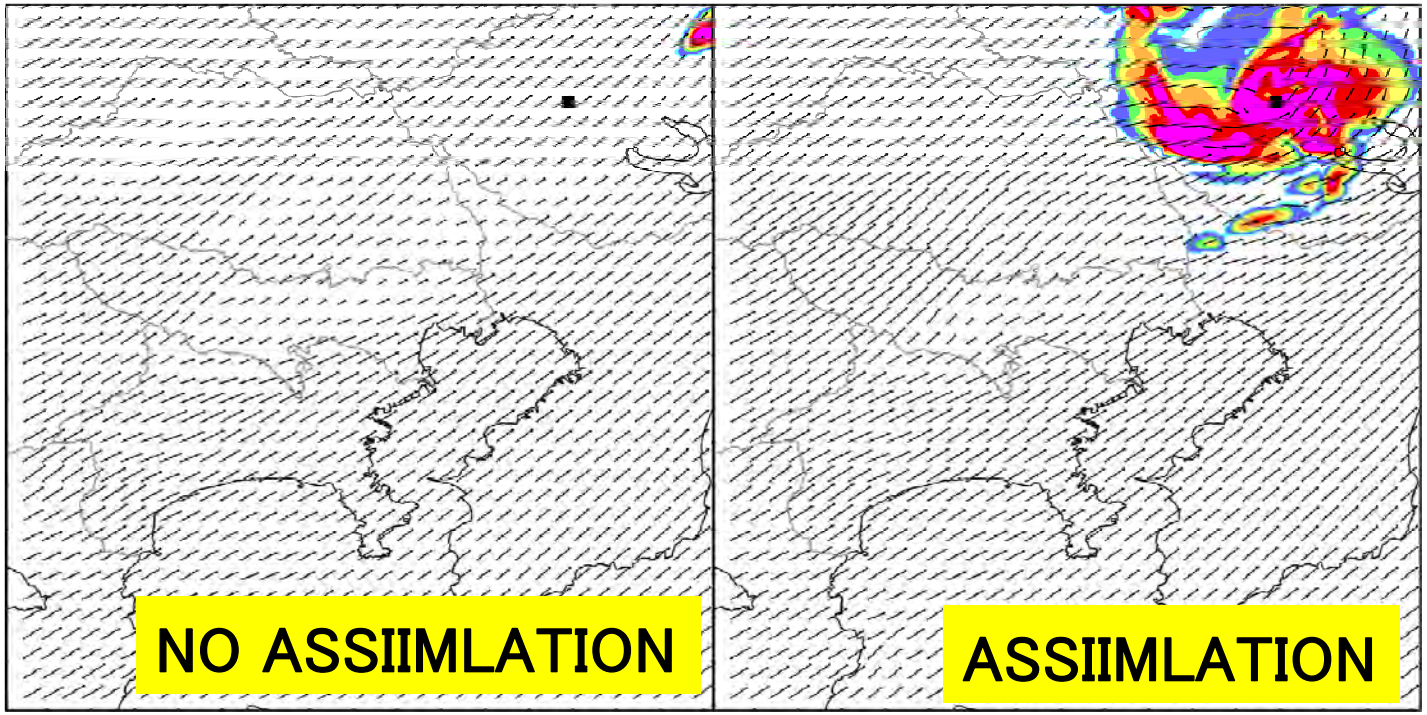
TORNADO touch-down !!

1240 LST

OBSERVATION



REFLECTIVITY at 1.5 km ASL 1240 LST

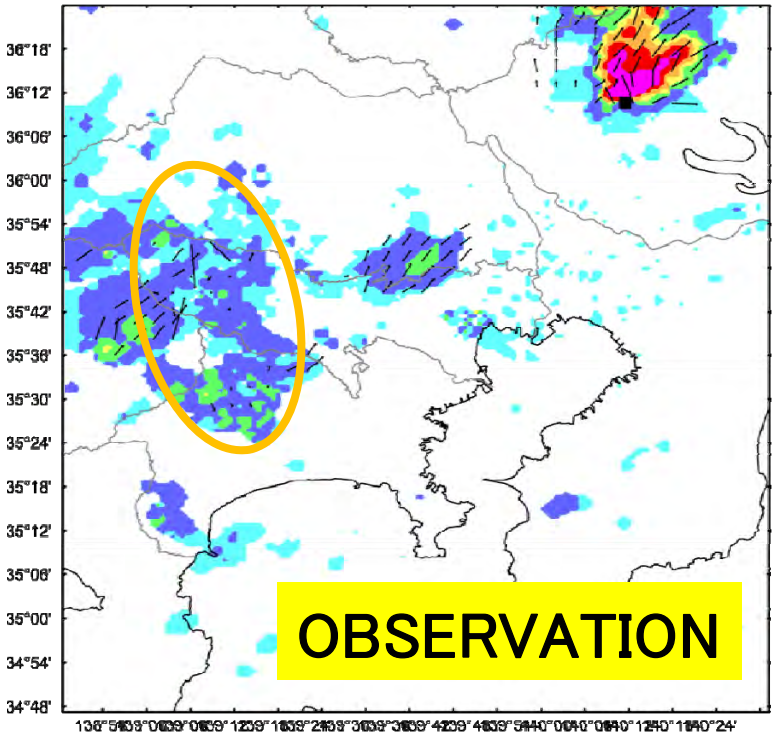


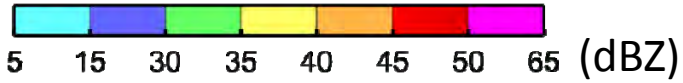
NO ASSIIMLATION

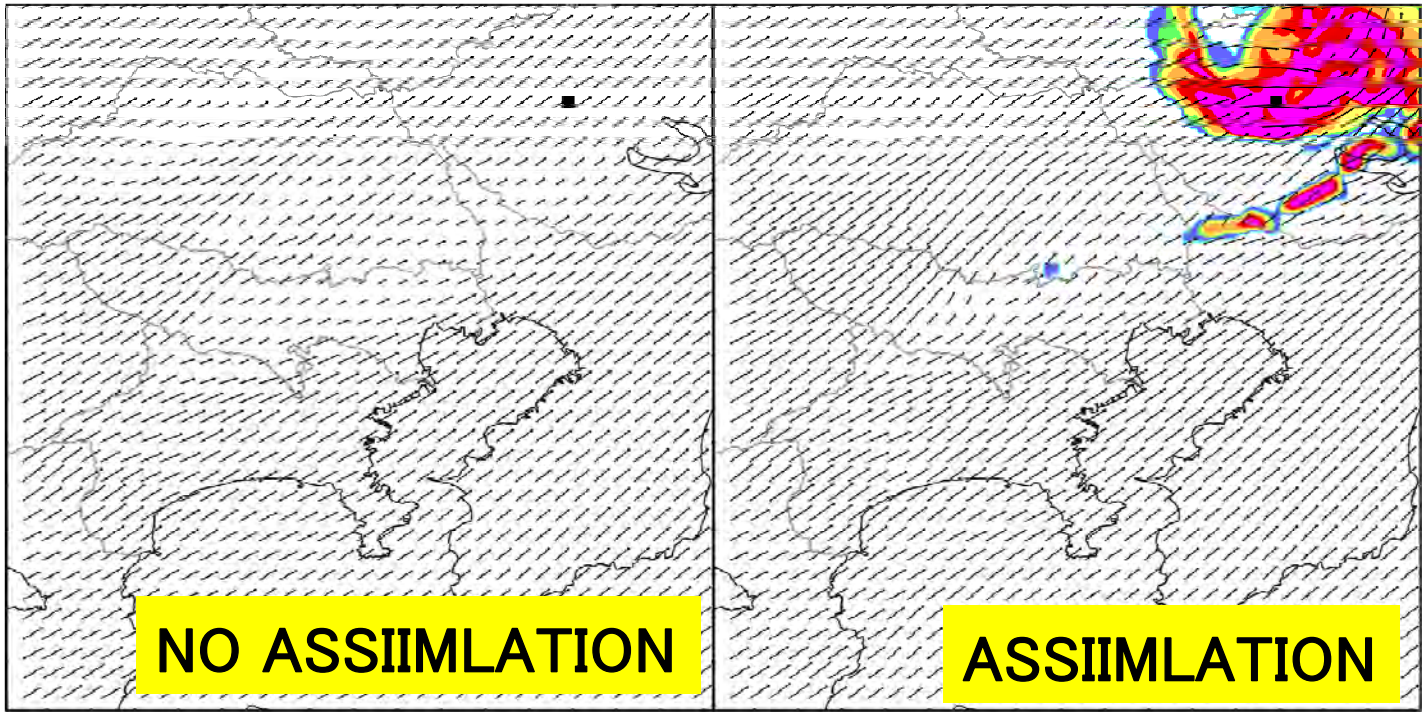
ASSIIMLATION

RADAR REFLECTIVITY at 1.5 km ASL

1250 LST



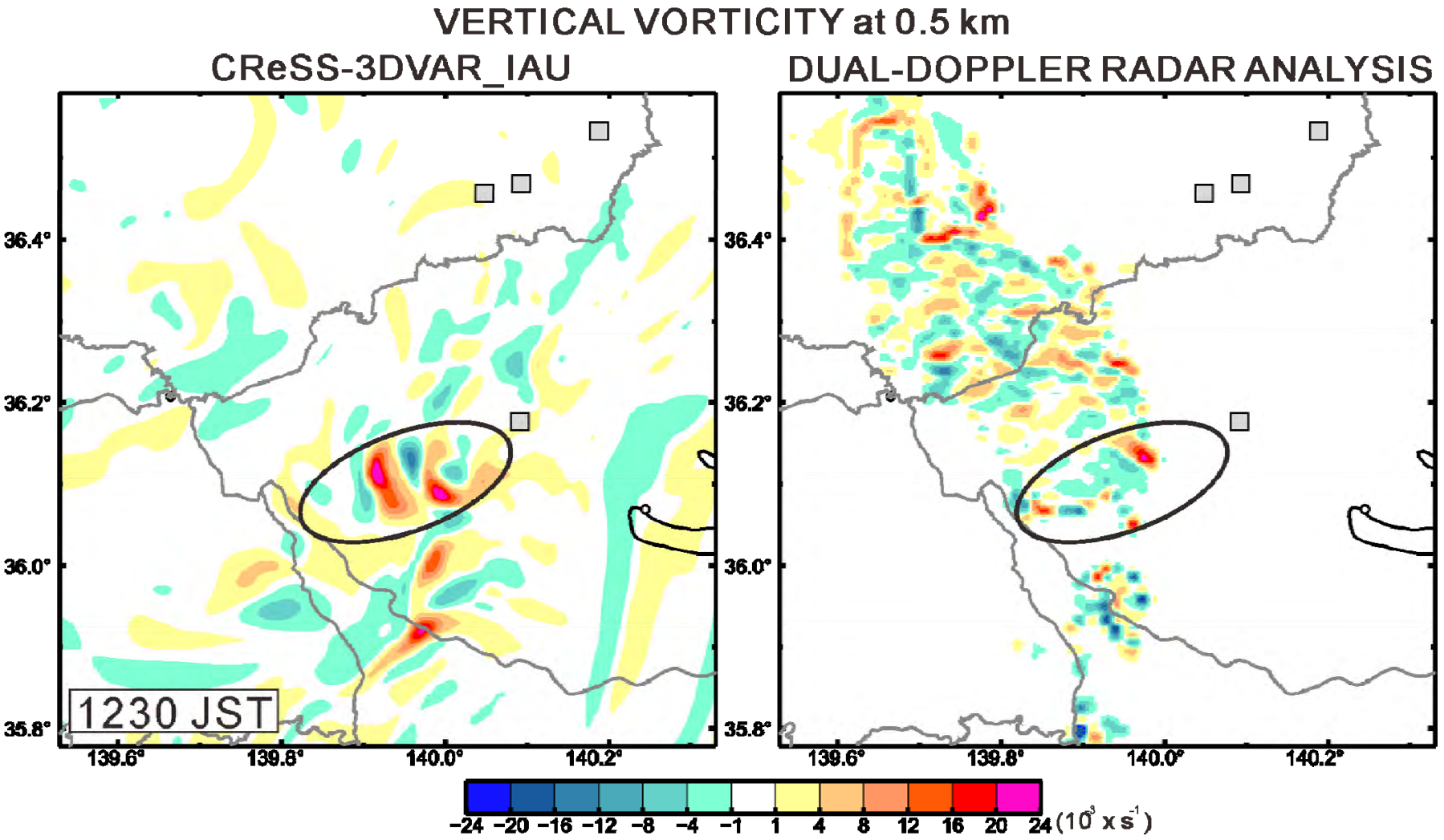


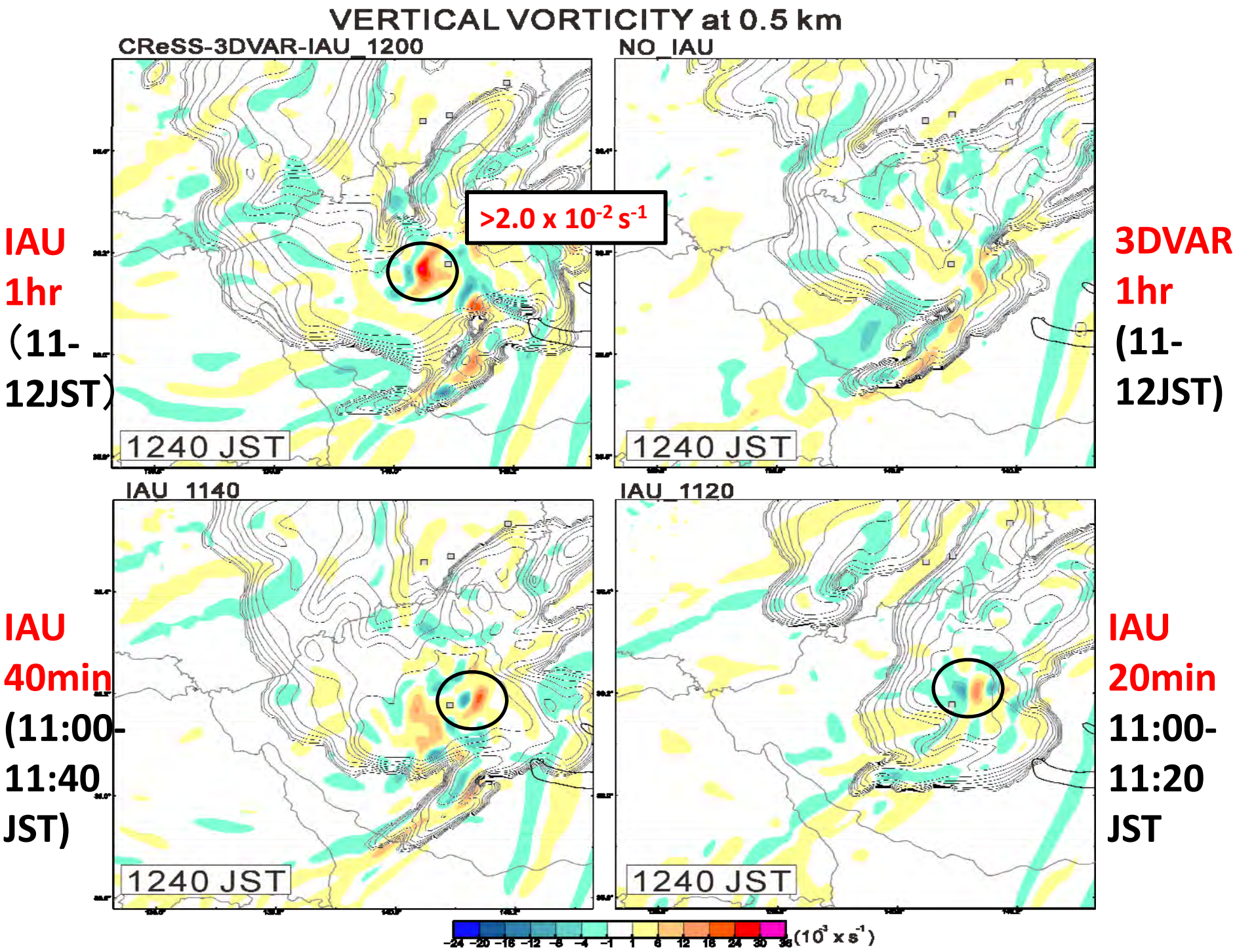


Vertical vorticity at a height of 0.5 km at 1230 JST

CReSS

Dual-Doppler Analysis




VERTICAL VORTICITY at 0.5 km
CReSS-3DVAR-IAU_1200
NO_IAU
>2.0 x 10-2 s-1
IAU 1hr (11-12JST)
3DVAR 1hr (11-12JST)
1240 JST
1240 JST
IAU_1140
IAU_1120
IAU 40min (11:00-11:40 JST)
IAU 20min 11:00-11:20 JST
1240 JST
1240 JST
-24 -20 -16 -12 -8 -4 -1 1 6 12 18 24 30 36 (10-3 x s-1)

Summary

- We investigated the predictability of tornadic storm observed on 6th May 2012 at Tsukuba city using 3DVAR-IAU assimilation with X-band dual-polarimetric radar network data in Tokyo Metropolitan region.

- Radial velocity from 4 radars were assimilated from 11:00 to 12:00 JST (40 minutes before the tornado-"touch down").

- Incremental Analysis Update (IAU) scheme (11-12 JST assimilation window) successfully simulated **strong vertical vorticity > 2.0 x 10^{-2} s^{-1}** around 12:40-12:50 JST

- IAU scheme using shorter assimilation window (40 min or 20min) also successfully simulated **strong vertical vorticity > 1.5 x 10^{-2} s^{-1}**

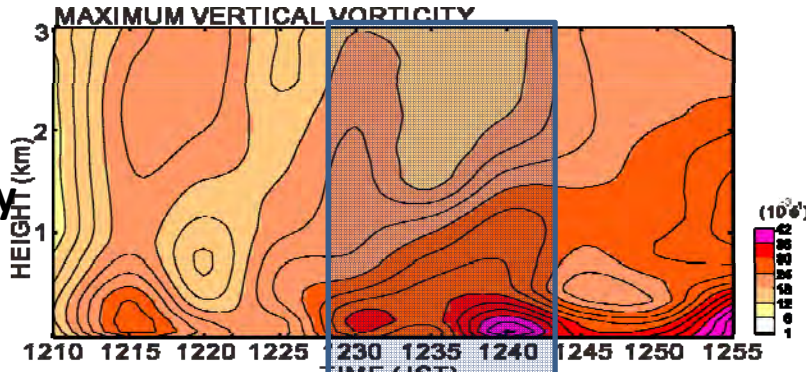
- 3DVAR without IAU simulated much weaker vertical vorticity.

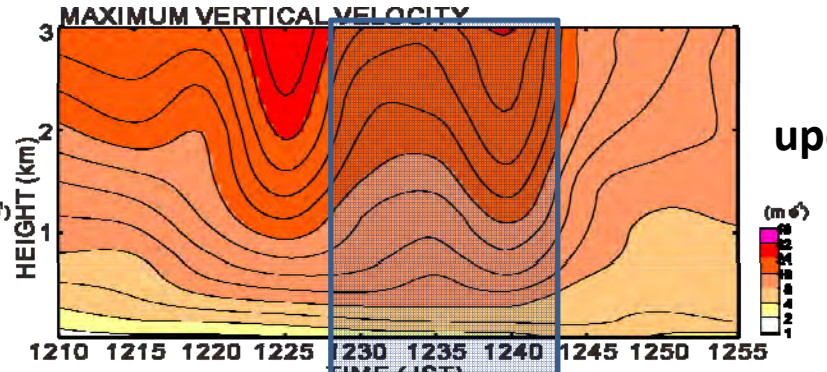
Vorticity Analysis

$$\frac{\partial \omega}{\partial t} = -\left[u\frac{\partial \omega}{\partial x} + v\frac{\partial \omega}{\partial y} + w\frac{\partial \omega}{\partial z}\right] + \left[\varepsilon\frac{\partial w}{\partial x} + \varphi\frac{\partial w}{\partial y}\right] + \omega\frac{\partial w}{\partial z}$$

advection tilting stretching

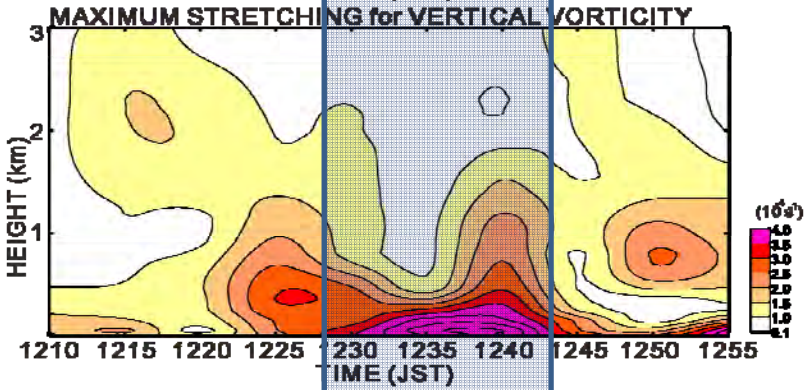
Vertical Vorticity

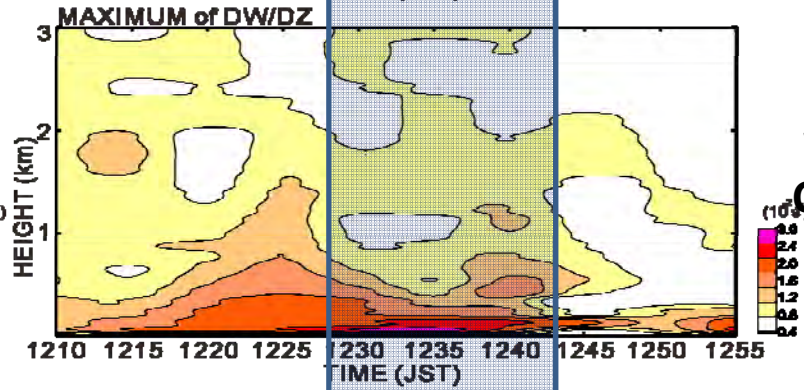




updraft

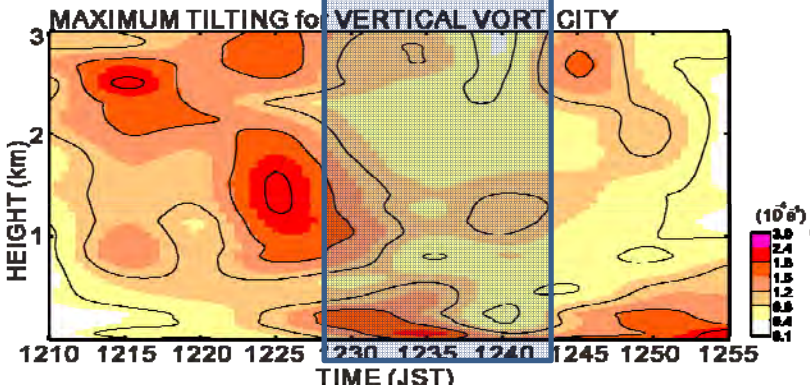
stretch

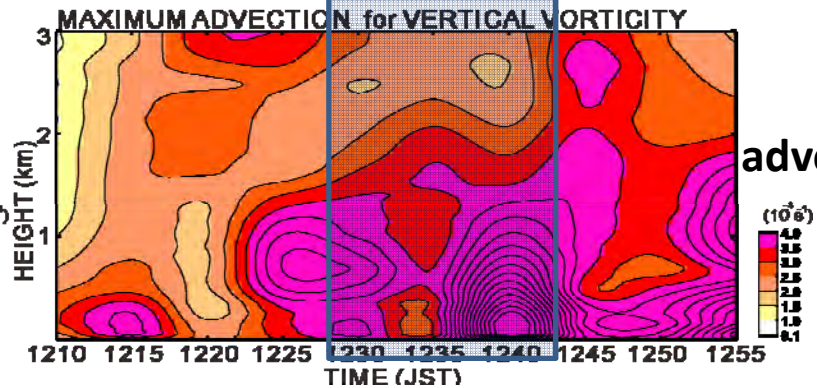




wind Conv.

Tilt





advection