Assimilation Experiment on a Local Heavy Rainfall Event Using Doppler Lidar Observations

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Abstract

A cloud resolving 4D-Var system was applied to a local heavy rainfall event occurred on 5 July 2010 in the west of Tokyo.

In the control assimilation experiment (CTL), radial wind field by meteorological Doppler Radars and GPS precipitable water vapor data were assimilated, while in the test experiment (LDR), radial winds by Lidar were assimilated furthermore.

Comparative experiments show that the LDR forecast reproduces better the observed distribution and intensity of rainfall than the CTL forecast. Difference of zonal wind fields between CTL and LDR suggests that the low level wind modified by the Lidar data assimilation is important to obtain this result.

Heavy rainfall event

- Itabashi Heavy Rainfall (05-July-2010)
- Radar observes: reflectivity and radial winds by rain drops inside cumulonimbus using radio waves.
- Lidar observes: radial winds surrounding cumulonimbus by aerosols using Laser instrument. (good complementary data)

- NHM-4DVAR is a cloud-resolving nonhydrostatic 4D-Var data assimilation system based on the JMA Nonhydrostatic Model (NHM), to investigate the mechanism of heavy rainfall events induced by mesoscale convective systems (MCSs).

Model

- Forward model: NHM (full nonhydrostatic model)
- Adjoint, tangent linear model: Dynamic frame work
- Cloud microphysical process (Warm rain)
- Lateral boundary conditions

Control variables

- Wind (u,v,w), surface pressure, potential temperature, nonhydrostatic pressure, total water, relative rain water, pseudo relative humidity (for lateral boundary)

Observational data

- radial wind by Doppler Lidar, GPS precipitable water vapor, GPS zenith total slant delay, GPS slant total delay, surface wind, surface temperature
- Horizontal resolution : 2 km

Assimilation system, Doppler Lidar and Rainfall event

- NICT Doppler Lidar (used in this study)
- Super observation
- Assimilation method for Doppler Lidar
- Radar and surface data are provided by Japan Meteorological Agency, GPS data by the Geospatial Information Authority of Japan.

References


Other references


Four Doppler Lidars in west Tokyo

- Narita airport as JMA operational instrument.
- Haneda airport as JMA operational instruments.
- One at Ookayama by Hokkaido U.
- NICT Doppler Lidar (used in this study)

Assimilation method for Doppler Lidar

Super observation

Rapid increase of water level

• Initiated around 1500 JST in west of Tokyo.
• At 1800 JST, strengthened around NICT observation site.
• At 2000 JST, strengthened again around Itabashi.
• Move to Chiba prefecture around 2100 JST.
• Lifetime: 6h, horizontal scale: 30km

Water level of Shakujii River

- Rapid increase of water level
- Super observation
- Observation
- Assimilation method for Doppler Lidar
- Super observation
- Radar and surface data are provided by Japan Meteorological Agency, GPS data by the Geospatial Information Authority of Japan.
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.
The reproduced cumulonimbus consists of warm rain cloud, and this characteristic feature is consistent with the radar observational analysis by Yamada (2012).

What are keys for the successful result?
The successful result is given by improvements of “water vapor field” by GPS assimilation and “advection of water vapor” by Lidar assimilation.

Analysis of the cumulonimbus in LDR
Vertical cross-section of water vapor and stable layer (FT = 30 min)

Q. Why warm rain?
A. Stable layer
Since there existed a stable layer at 5-km height, the cumulonimbus hardly developed over the freezing level.

Q. Why such intense rainfall?
A. Large flux of water vapor, Very humid air over 15 g kg⁻¹ inflowed to the cumulonimbus with strong sea breeze over 10 m s⁻¹.