AS06-A008

Structure of Heavy Precipitation System in Gifu Prefecture, Japan, on 15 July 2010

Mariko Oue, Koichi Inagaki, Taro Shinoda, Takeharu Kouketsu, Tadayasu Ohigashi, Masaya Kato, Kazuhisa Tsuboki, and Hiroshi Uyeda

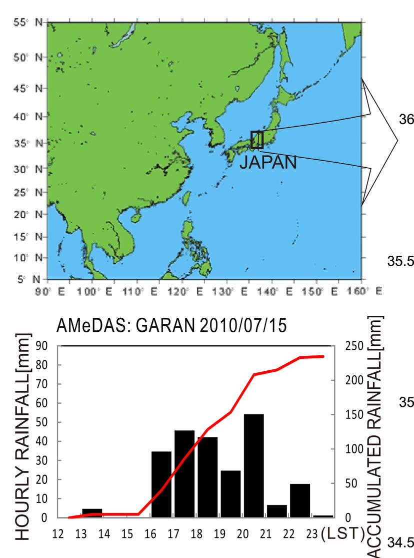
Hydrospheric Atmospheric Research Center, Nagoya University, Nagoya

*e-mail: oue@rain.hyarc.nagoya-u.ac.jp

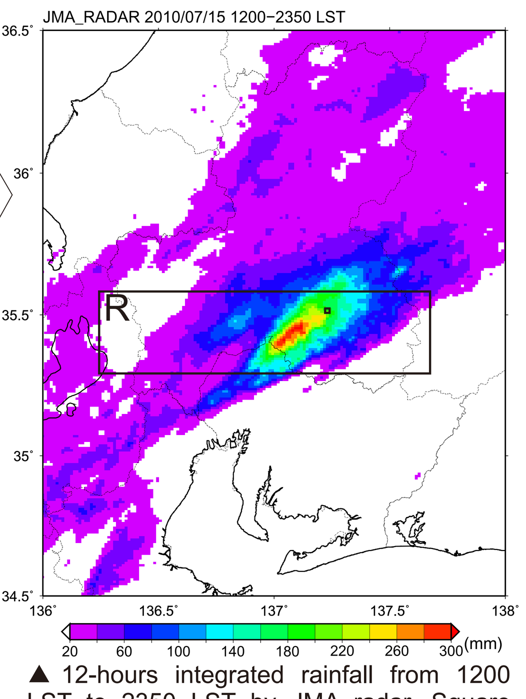
INTRODUCTION

In the Baiu period from June to July in Japan, precipitation systems sometimes provide heavy rainfall. Several papers reported importance of convective cells developing in humid environments for heavy rainfall in precipitation systems. Roles for convective cells developing in humid environments in heavy precipitation systems are not known totally and are worth investigating.

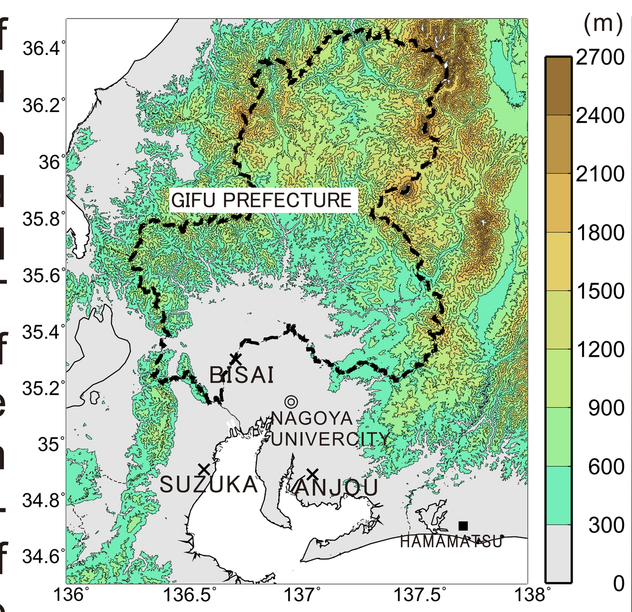
On 15 July 2010, the end of the Baiu period, linear-shaped precipitation systems formed in Gifu prefecture of Japan and provided very heavy rainfall between 1600 and 2330 LST (LST = UTC + 9). Purpose of this study is to clarify structure of the heavy precipitation systems focusing on movements and developments of convective cells constituting the system.



▲ Hourly rainfall (bar) and accumulated rainfall (red line) at Garan.



▲ 12-hours integrated rainfall from 1200 LST to 2350 LST by JMA radar. Square indicates a raingauge point.

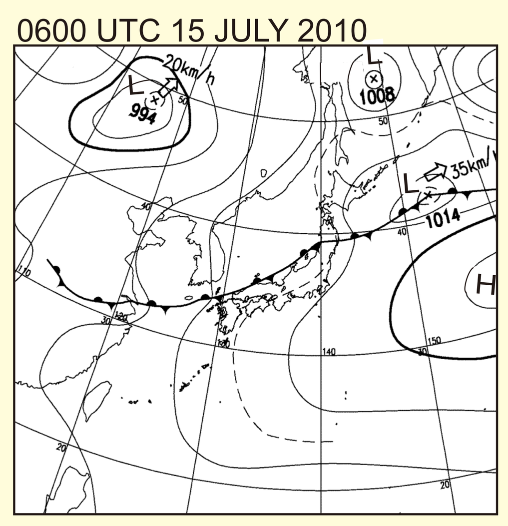


▲ Cross marks show locations of MLITX Radars (Anjou, Bisai, and Suzuka). Open circle shows Location of Nagoya University's radar. Square shows Sounding Observation site (Hamamatsu).

DATA

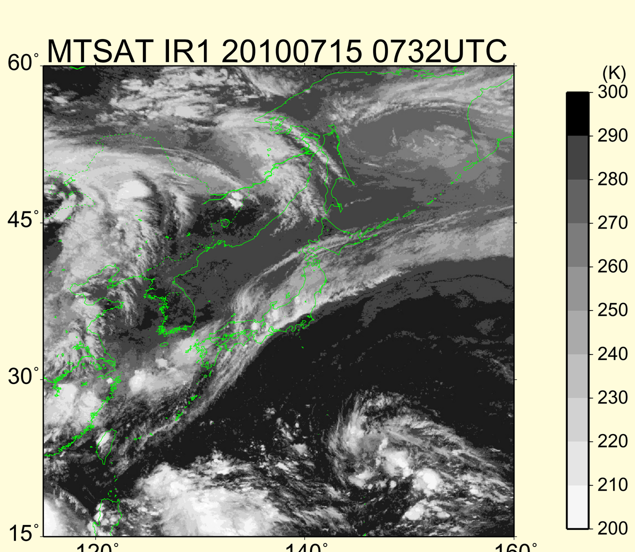
- X-band polarimetric radars installed by Ministry of Land, Infrastructure, Transport and Tourism (MLITX; Anjou, Bisai, Suzuka)
  Plan position indicator (PPI) volume scan: 15 elevations, 5-minutes interval, and 60-km observation range for each radar
  → Constant altitude PPI of radar reflectivity (Zh) and Doppler velocity (CAPPI; 1km × 1km × 0.25km)
  → Doppler radar analysis using CAPPI
- Nagoya University's X-band polarimetric radar (NUPOL)
  Range height indicator (RHI)
- C-band radar of Japan Meteorological Agency (JMA)
- JMA Mesoscale Model
- Meteorological satellite
- Raingauges of Automated Meteorological Data Acquisition System (AMeDAS)

ENVIRONMENT



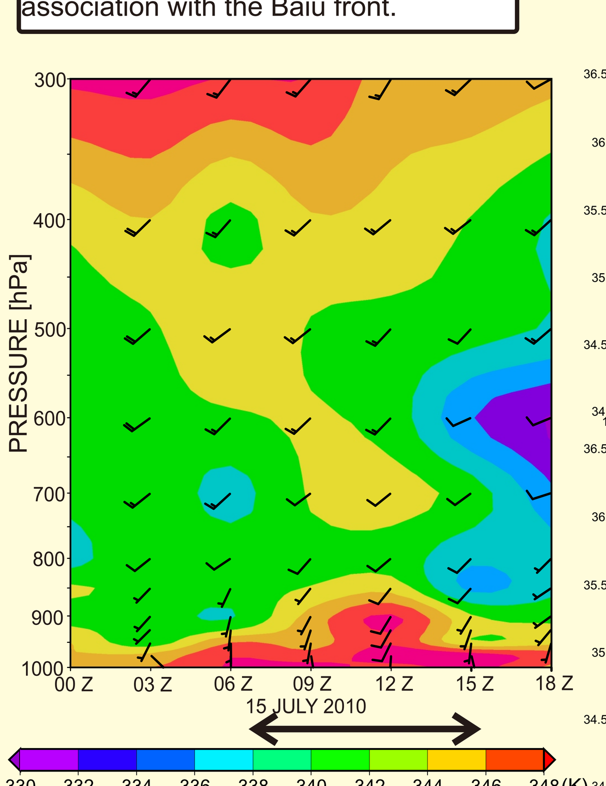
▲Weather map of 0600 UTC 15 July 2010.

The precipitation system developed in association with the Baiu front.

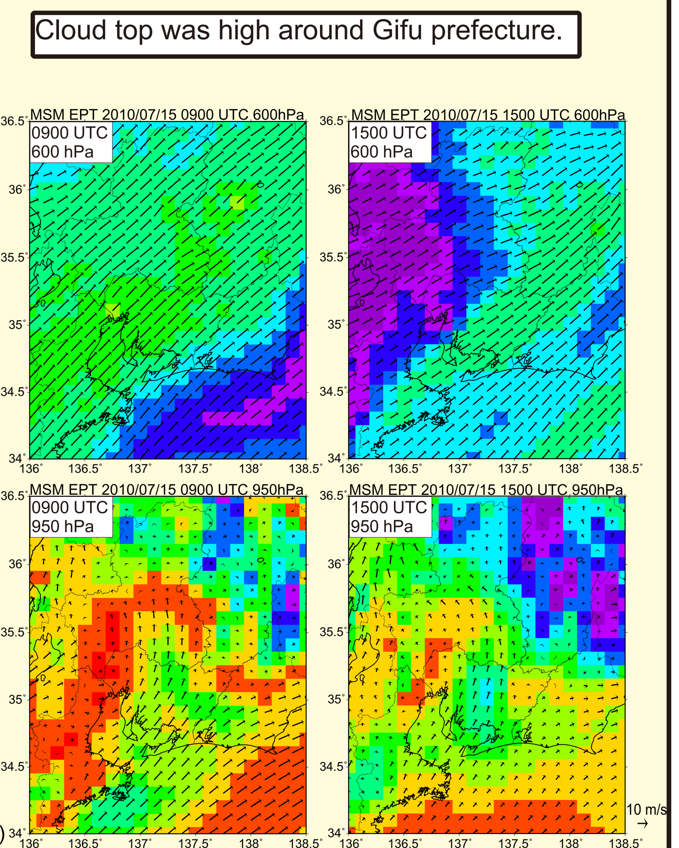


▲Satellite image (IR1) of 0730 UTC 15 July 2010.

Cloud top was high around Gifu prefecture.



▲Height-time cross section of equivalent potential temperature (θ e) around latitude of 35.2 and longitude of 137.0 by MSM. An arrow indicates duration of precipitation.



▲Horizontal distribution of θ e (shade) and horizontal wind (vectors) by MSM. Left panels show 0900 UTC 15 July 2010, and right panels show 1500 UTC 15 July 2010. Top row shows level of 600 hPa, and bottom row shows level of 950 hPa.

High-θ e air continuously inflowed from south or southwest at low altitudes below 900 hPa. Convective instability was maintained.

The south-southwesterly wind at low altitudes broke down after 1500 UTC, and low-θ e air mass flowed at middle altitude.

The low-θ e air mass probably caused that a precipitation system moved eastward.

Acknowledgments

Authors appreciate Dr. Shingo Shimizu of National Research Institute for Science and Disaster Prevention (NIED). He provided a program for dual Doppler radar analysis in this study. Authors also thank Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and Dr. Takeshi Maesaka who provided data of MLIT's X-band polarimetric radar.

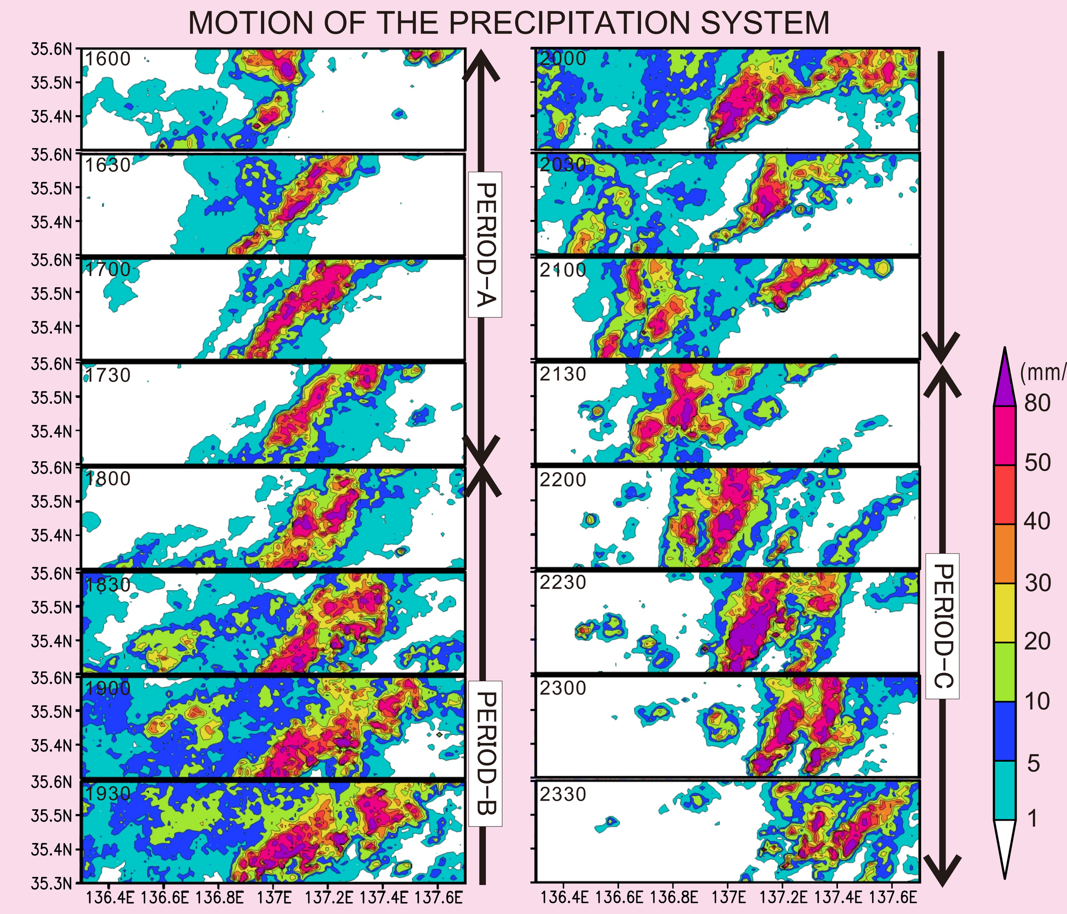
SUMMARY

Structure of precipitation systems providing heavy rainfall on 15 July 2010 was clarified as follows.

- High-θ e air continuously flowed in low altitudes from south, and convective instability was maintained.
- 1600-1800 LST: A linear-shaped precipitation system had a direction from southwest to northeast and stayed. Convergence line caused by inflow of south-southwesterly wind maintained. Convective cells formed over the system and moved to northeast, which was same as a direction of the system.
- 1800-2130 LST: The precipitation system had a direction from west-southwest to east-northeast. Convergence line that was caused by inflow of south-southwesterly wind maintained. Convective cells formed to the south of the system and moved toward north-northeast.
- 2130-2350 LST: Another precipitation system had a direction from southwest to northeast and moved toward east. Convective cells formed at the leading side of the system and moved toward northeast.
- Each cell developed by inflow of southerly wind below 2 km ASL and moved toward northeast by southwesterly wind at middle altitude. Cells locally developed to high altitude (30-dBZ echo-top over 6 km ASL). Graupel existed and contributed heavy rainfall.

PRECIPITATION SYSTEM

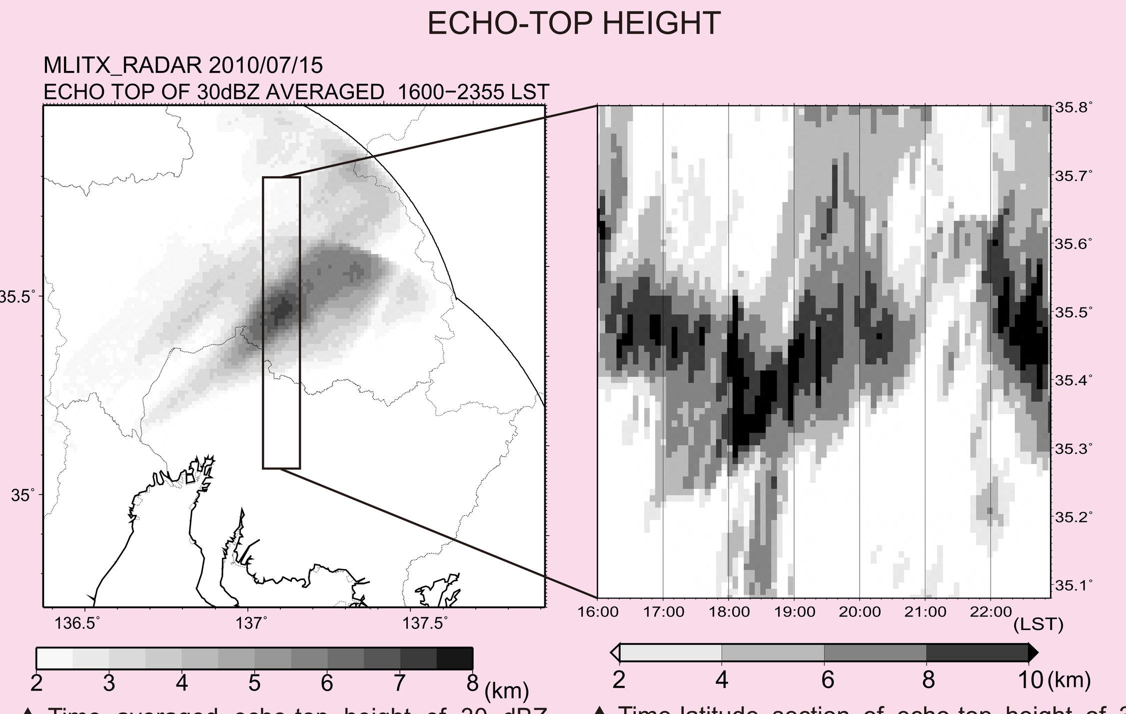
MOTION OF THE PRECIPITATION SYSTEM



▲Time series of rain intensity by JMA radar over a region R in above panel.

Duration of the rainfall is divided into three periods:
PERIOD-A: a linear-shaped precipitation system had direction from southwest to northeast and almost stayed;
PERIOD-B: the precipitation system had direction from west-southwest to east-northeast and almost stayed;
PERIOD-C: another precipitation system directed from southwest to northeast propagated toward east.

ECHO-TOP HEIGHT

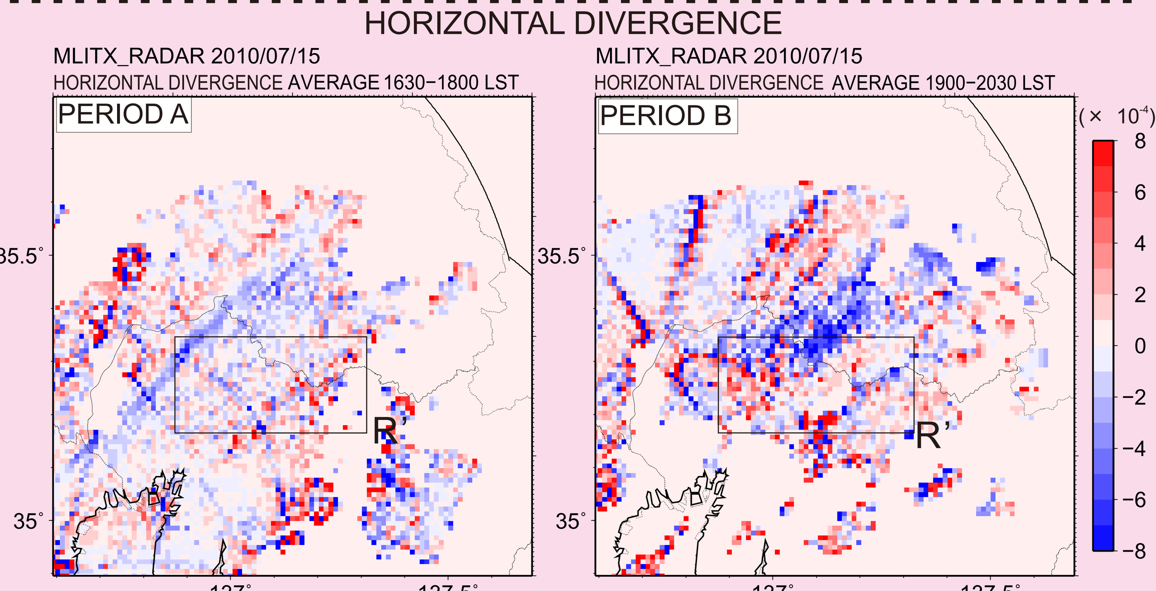


▲ Time averaged echo-top height of 30 dBZ between 1600 LST and 2355 LST for each grid having 30 dBZ in Zh at 2 km ASL in CAPPI of MLITX.

▲ Time-latitude section of echo-top height of 30 dBZ between 137.05 and 137.15 in longitude (10-km width). Values shown in this figure are longitudinally averaged using CAPPIs of MLITX.

Localized precipitation was provided by precipitation cells developing to high altitude (30-dBZ echo-top over 6 km).

HORIZONTAL DIVERGENCE

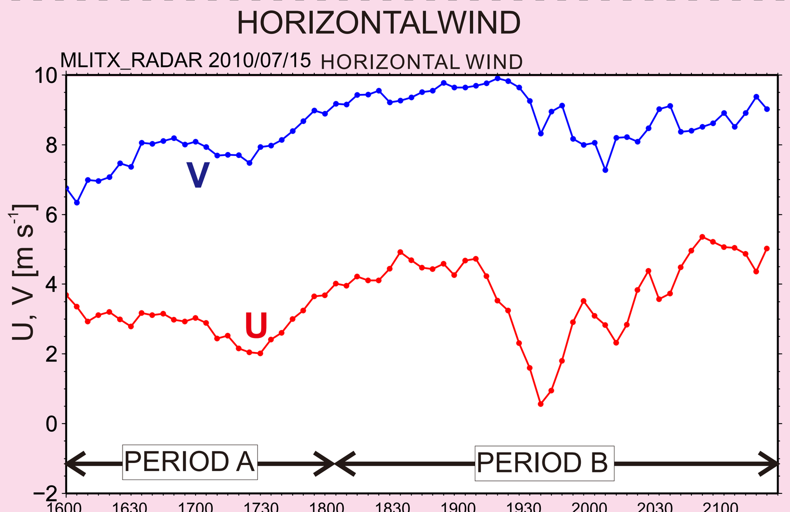


▲Time average of divergence at 2 km ASL between 1630 LST and 1800 LST (left; period A) and 1900 LST and 2030 LST (right; period B).

PERIOD A,B: Convergence zone was maintained at the same place along the precipitation system during each period.
A: Convective line was sharp and had a direction from southwest to northeast.
B: Convective line had a direction from west-southwest to east-northeast.

Stationary convergence zone caused the maintenance and staying of precipitation system during period A and period B.

HORIZONTALWIND



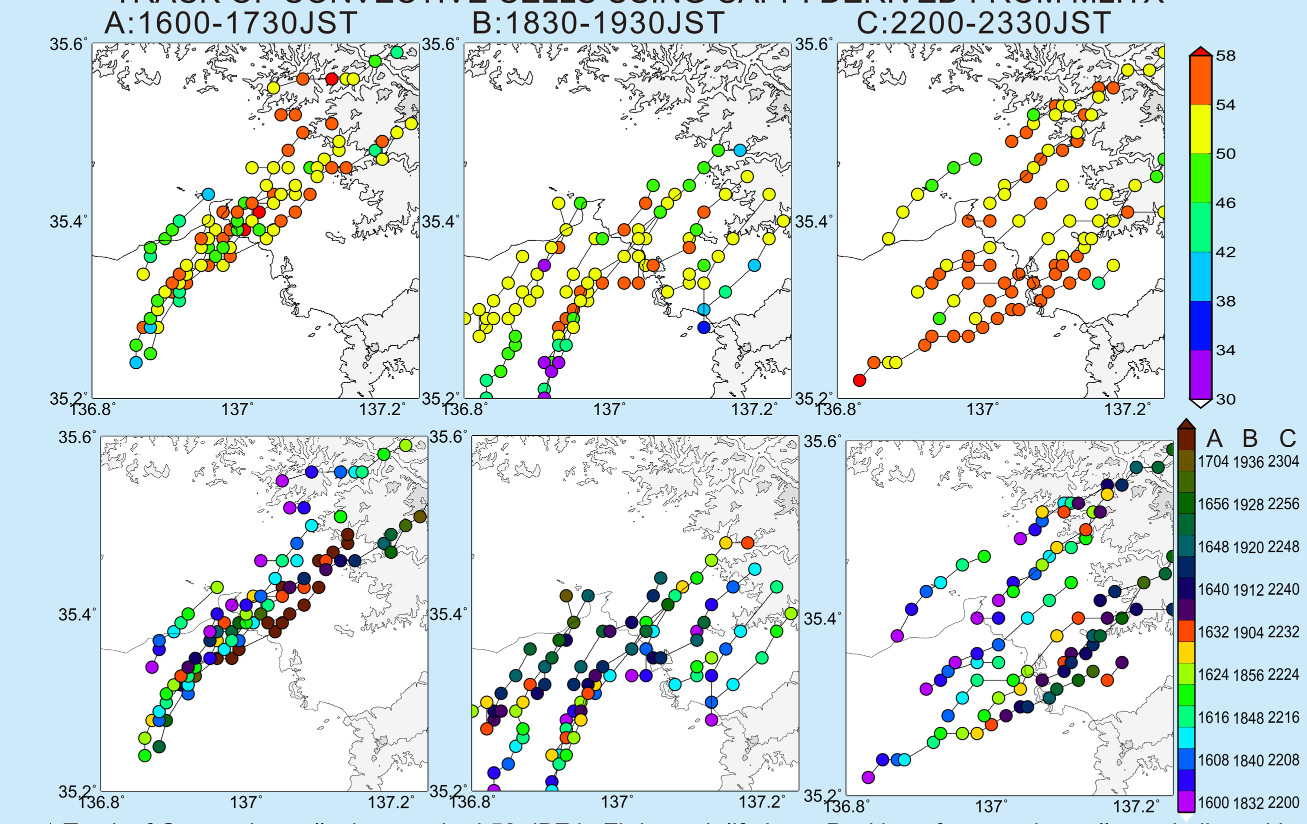
▲ Time series of horizontal wind averaged over a region R' shown above figure. Red line indicates east-west component, and blue line indicates north-south component. The region indicates inflow area toward a precipitation system.

During period B, inflow was stronger, or u-component was weaker.

Stronger wind with large north-south component possibly caused both of the linear-shaped precipitation system and the sift of direction of the convergence line from period A to period B.

CONVECTIVE CELLS

TRACK OF CONVECTIVE CELLS USING CAPPI DERIVED FROM MLITX



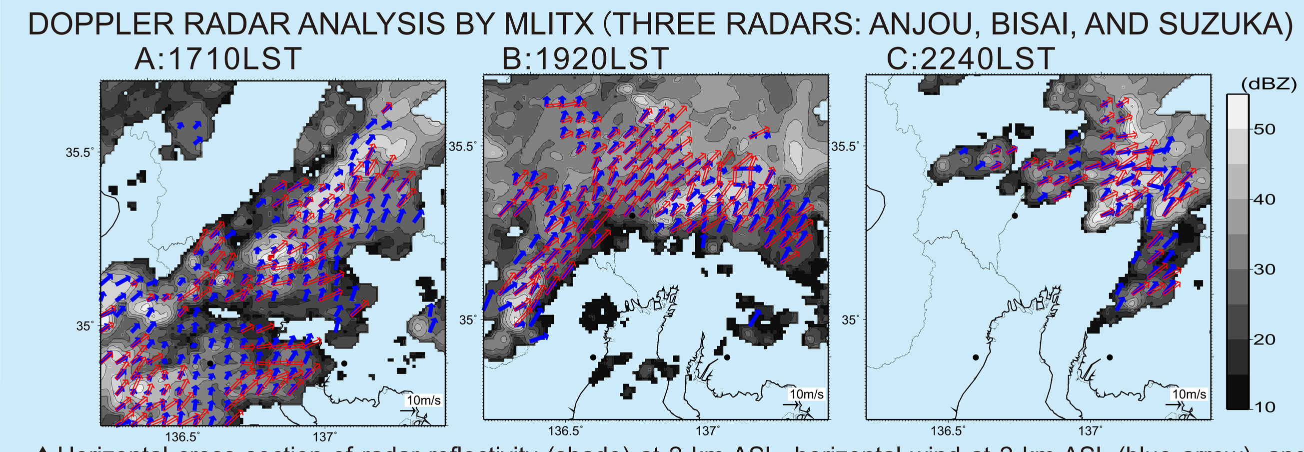
▲Track of Convective cells that reached 50 dBZ in Zh in each lifetime. Position of convective cells are indicated by circles. Each of the same convective cells is connected by solid lines each cell. Color scales indicate radar reflectivity in top row and time in bottom raw. Left panels show 1600-1730JST, middle panels show 1830-1930JST, and right panels show 2200-2300JST. CAPPIs derived from MLITX are used for tracking of cells every 4 minutes.

Moving speed of cells

	East-west component	North-south component	Number of cell
A	6.5 m/s	5.8 m/s	17
B	6.5 m/s	9.5 m/s	16
C	9.0 m/s	6.2 m/s	14

A: Cells developed along the precipitation system directed from southwest to northeast and moved toward northeast. Direction of cell's movement is the same as direction of the system.
B: Cells with large reflectivity aligned from west-southwest to east-northeast. Each cell developed to the south of the system and moved toward east-northeast.
C: Cells developed at the leading side of a precipitation system moving toward east.

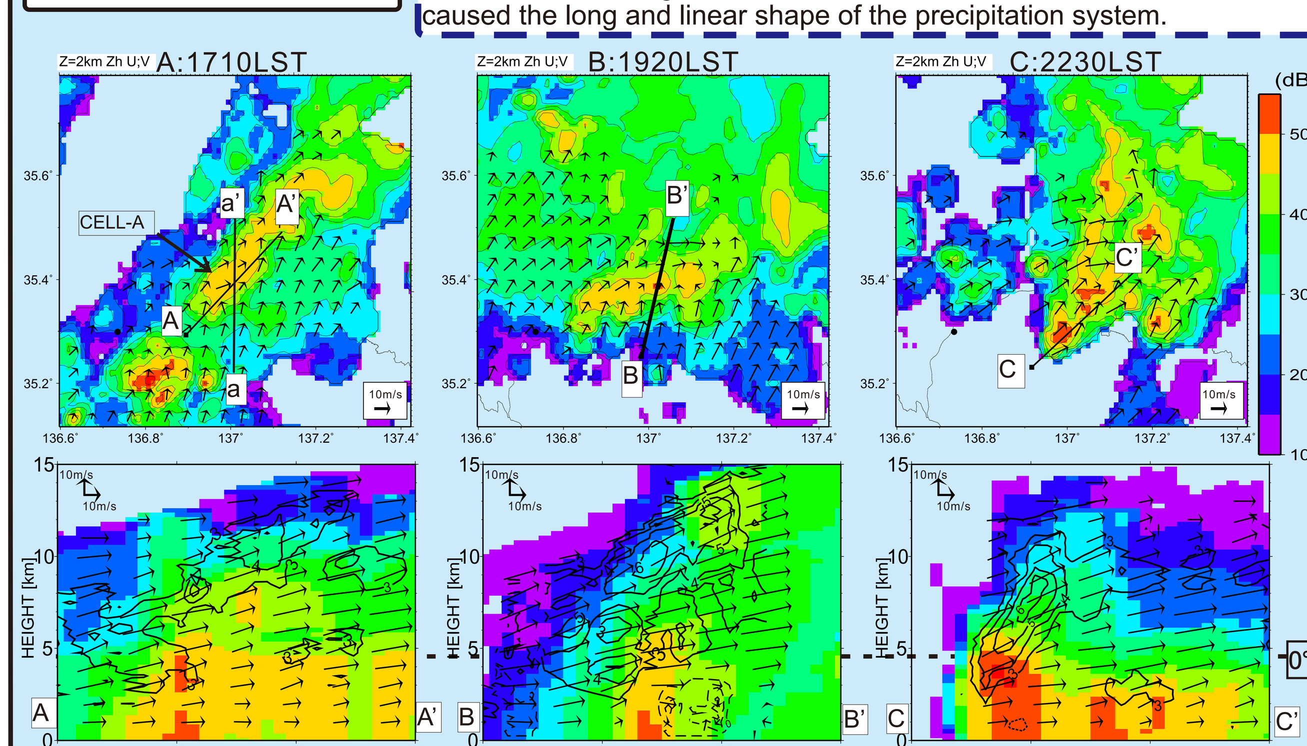
DOPPLER RADAR ANALYSIS BY MLITX (THREE RADARS: ANJOU, BISAI, AND SUZUKA)



▲Horizontal cross section of radar reflectivity (shade) at 2 km ASL, horizontal wind at 2 km ASL (blue arrow), and horizontal wind at 5 km ASL (red arrow) for (left)1710 LST, (middle)1920 LST, and (right)2240 LST.

There was a large wind shear between low altitudes below 2 km and middle altitudes.

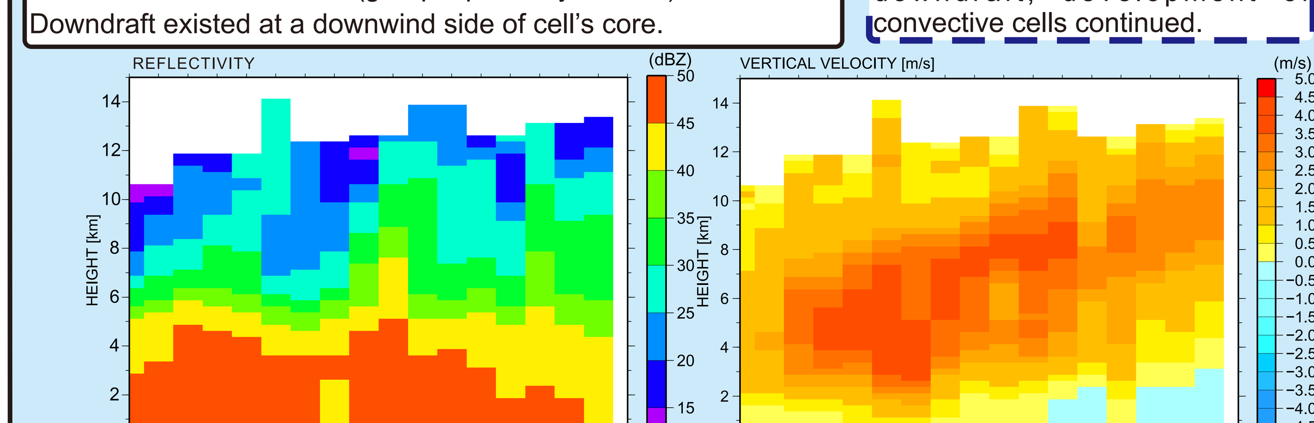
Cells developed by inflow from south-southwest below 2 km and moved by southwesterly wind at middle altitude. For period A, matching of direction of convergence line with direction of wind at middle altitudes caused the long and linear shape of the precipitation system.



▲ Top panels show horizontal cross section of radar reflectivity (shade) and horizontal wind (arrow) at 2 km ASL. Bottom panels show vertical cross section along lines indicated top panels. Arrow in bottom panels shows wind along each section, and solid contour and dashed contour show updraft every 1 m s⁻¹ and down draft every 1 m s⁻¹, respectively. Left is 1710 LST, middle is 1920 LST, and right is 2230 LST.

Convective cells developing to high altitude provided heavy rain.
Core of updraft tilted to downwind. Large reflectivity over 30 dBZ existed above 0°C altitude (graupel probably existed).
Downdraft existed at a downwind side of cell's core.

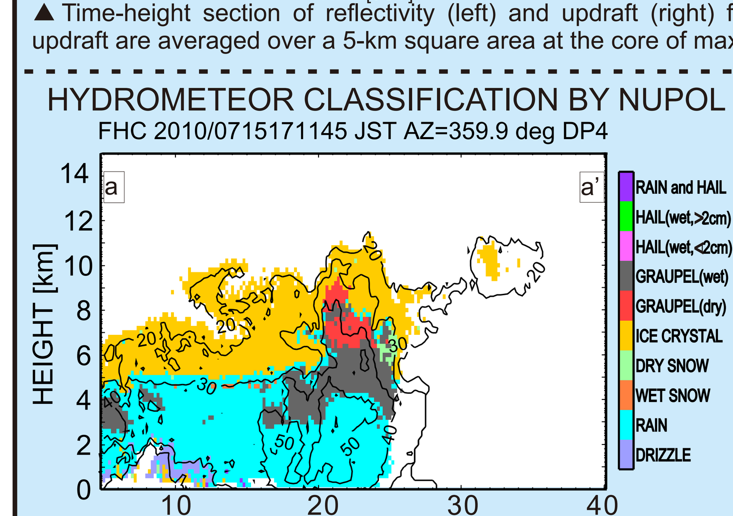
Because inflow of southerly wind at low altitudes was not blocked by downdraft, development of convective cells continued.



▲ Time-height section of reflectivity (left) and updraft (right) for cell-A indicated in above panel. Reflectivity and updraft are averaged over a 5-km square area at the core of maximum reflectivity at 2-km ASL every 0.25 km height.

First half of the lifetime, updraft existed at low altitudes. With an increase of altitude of updraft's core, echo top increased.
Graupel existed near the core of updraft in the latter half.

HYDROMETEOR CLASSIFICATION BY NUPOL



Ascending force was enhanced by release of latent heat due to growth of ice particles.

◀ Hydrometeor classification derived from NUPOL's RHI (1711 LST) along a-a' indicated in upper panel. Classification method advanced by Liu and Chandrasekar (2000) is introduced. Contour shows radar reflectivity from 20 dBZ every 10 dB.