WSN16, 25th, July 2016, Chinese University of Hong Kong

Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS): Lessons and outcome

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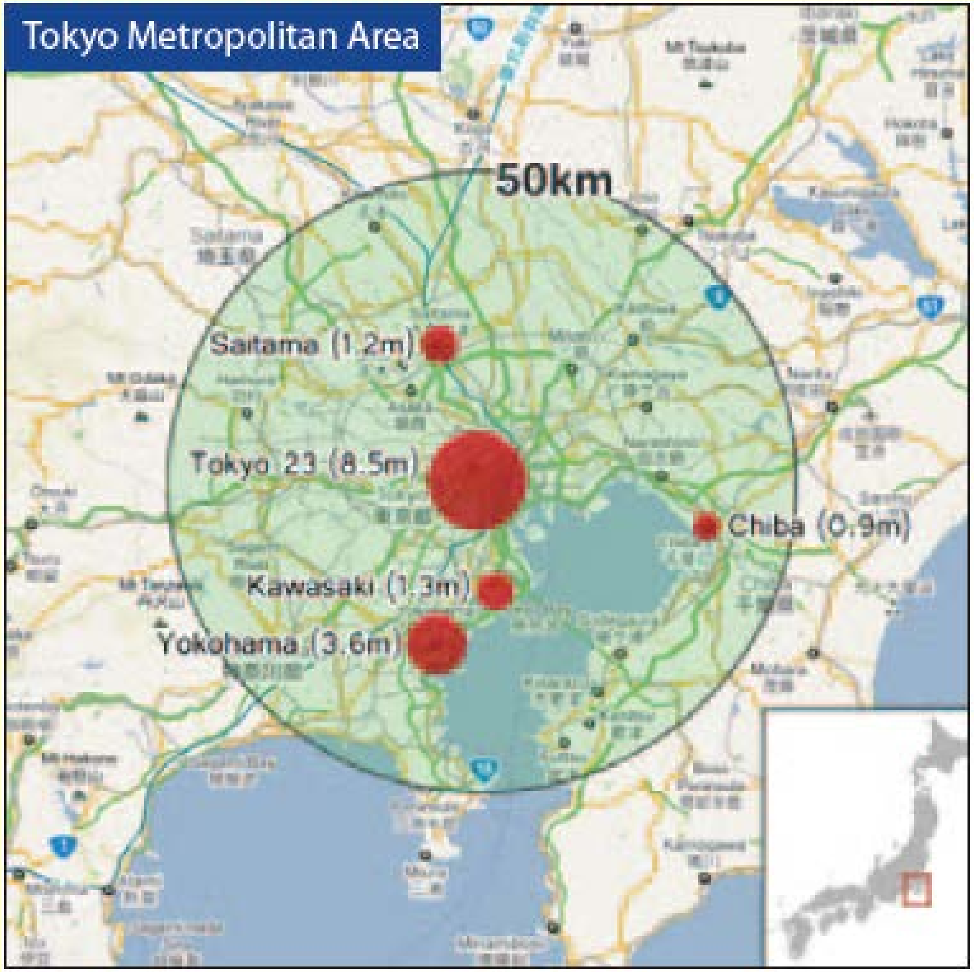
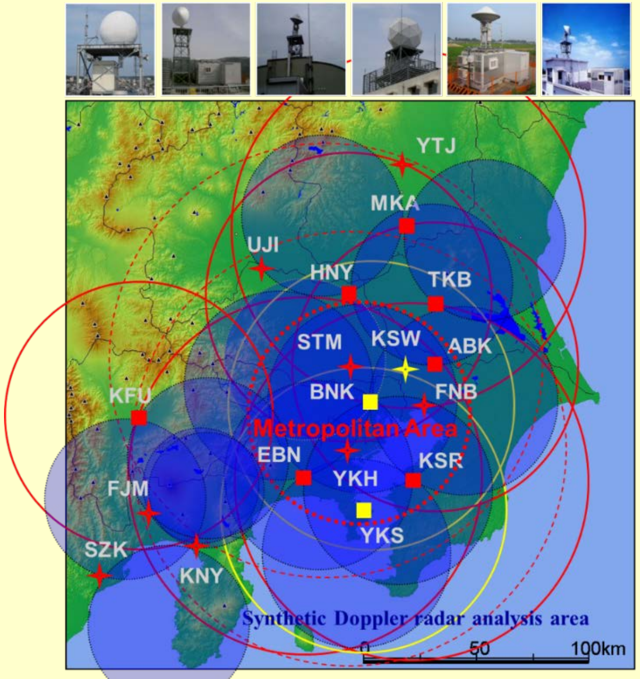
Tokyo Metropolitan Area

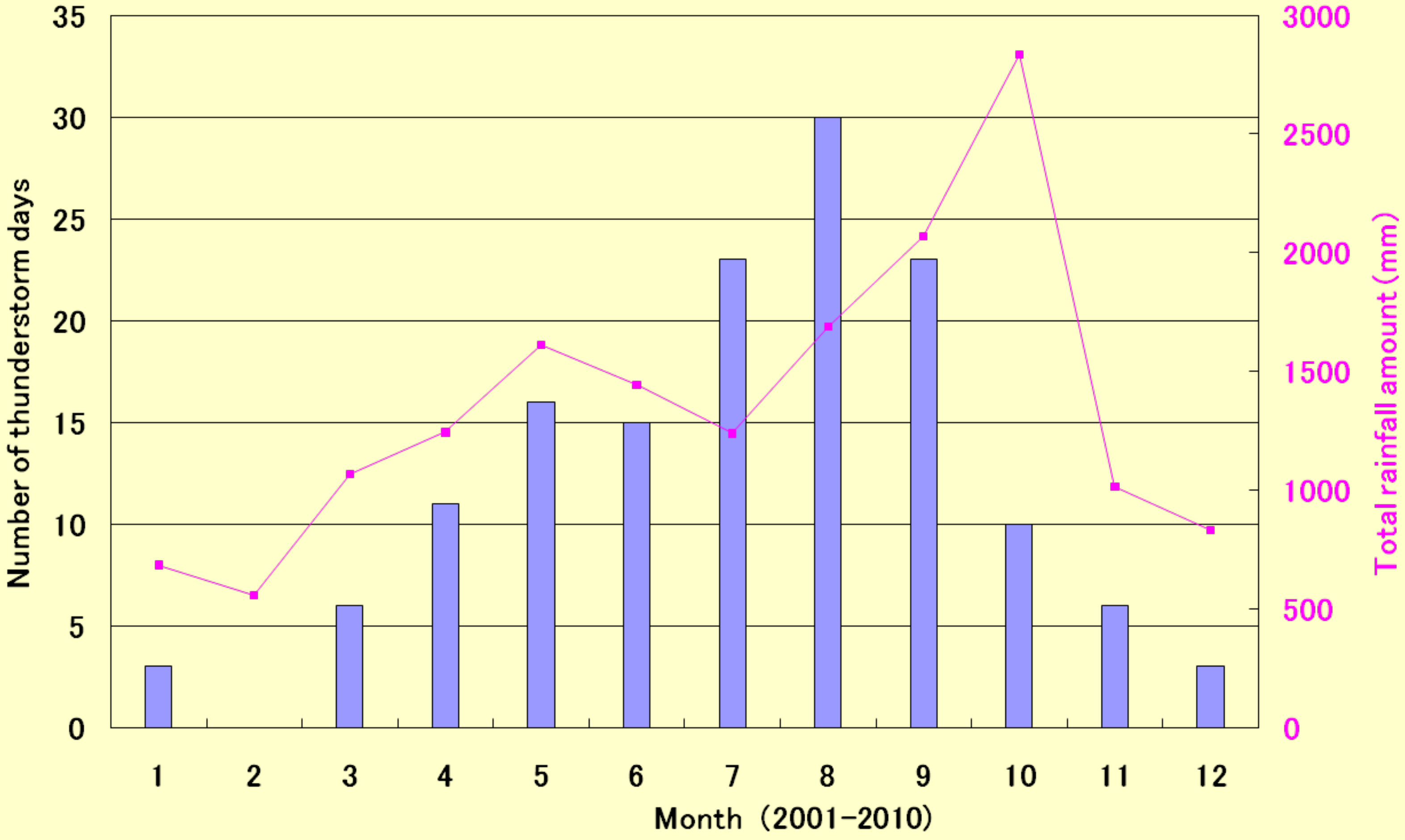


- The 50 km area surrounding Tokyo
- 30 million population
- Covered by dense observations by JMA, MRI, MLIT, NIED and GSI.



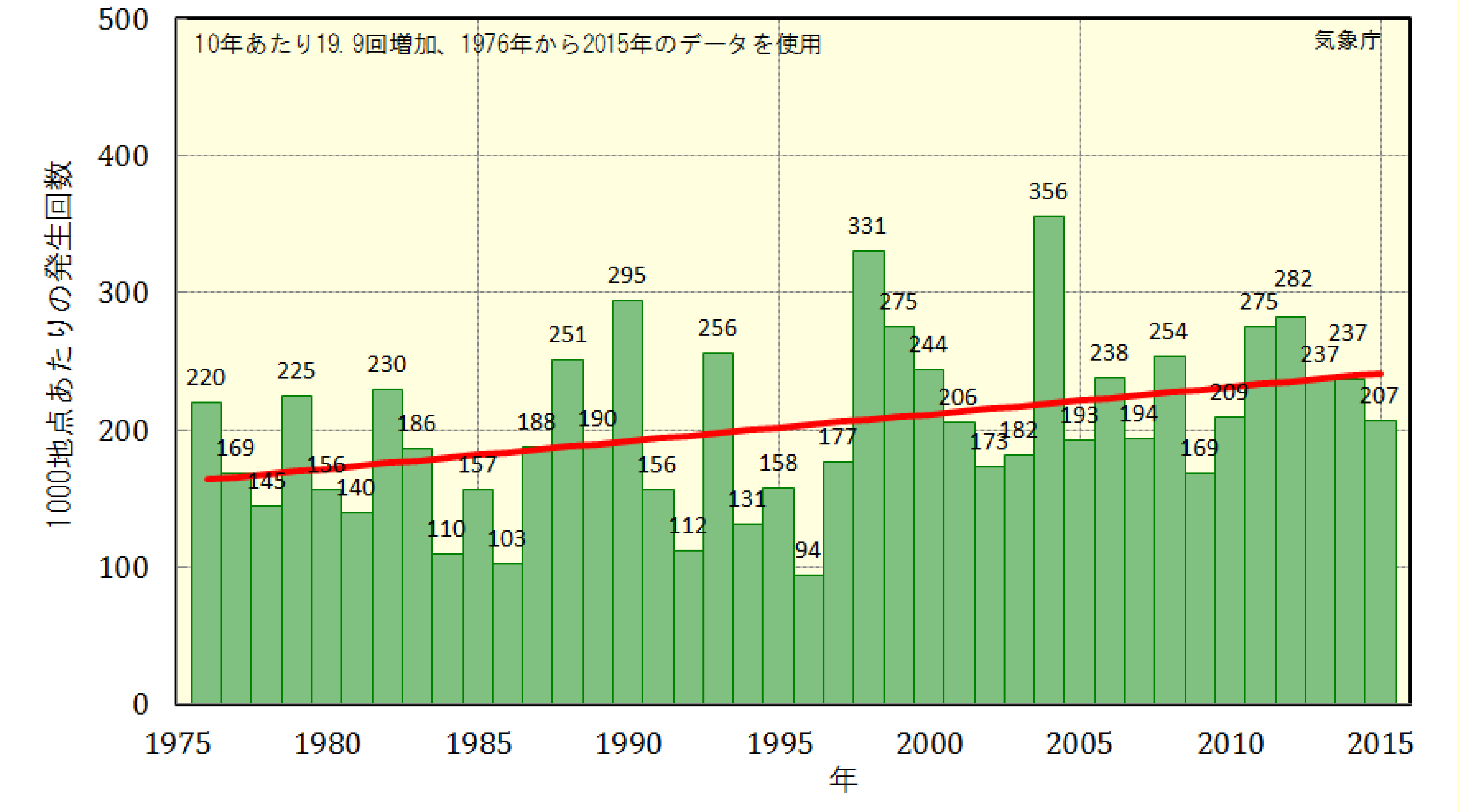
X-band network by NIED and collaborative institutions

Number of monthly thunderstorm days and total rainfall amount in the latest 10 years in Tokyo



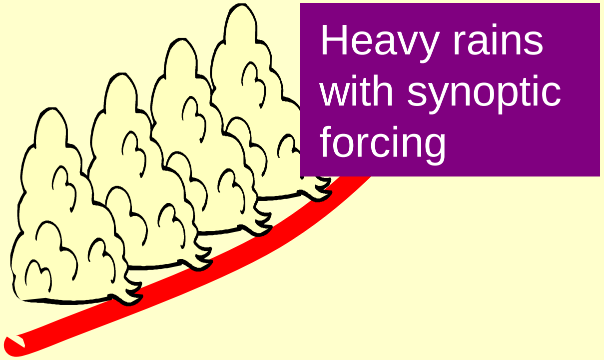
After Ishihara (2012)

Number of annual intense rains over 50 mm/h per 1,000 AMeDAS points in the latest 40 years

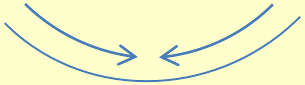


After JMA website

Predictability of local heavy rainfalls

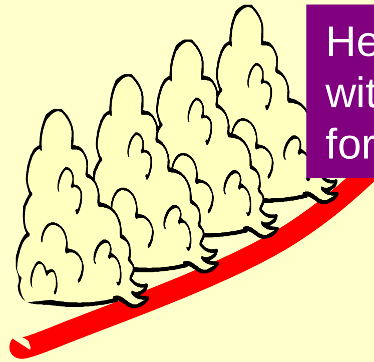


Orographic/synoptic forgings make local heavy rainfall predictable



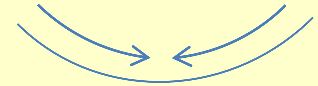
Predictability of local heavy rainfalls

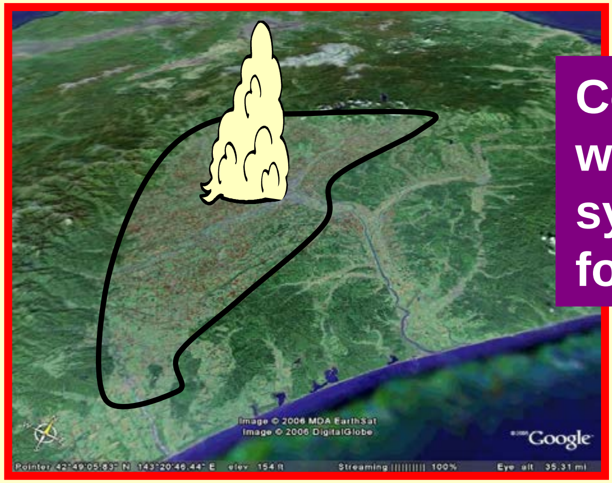
Heavy rains with orographic forcing



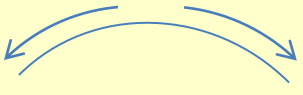
Heavy rains with synoptic forcing

Orographic/synoptic forgings make local heavy rainfall predictable





Convective rains without strong synoptic/orographic forcing

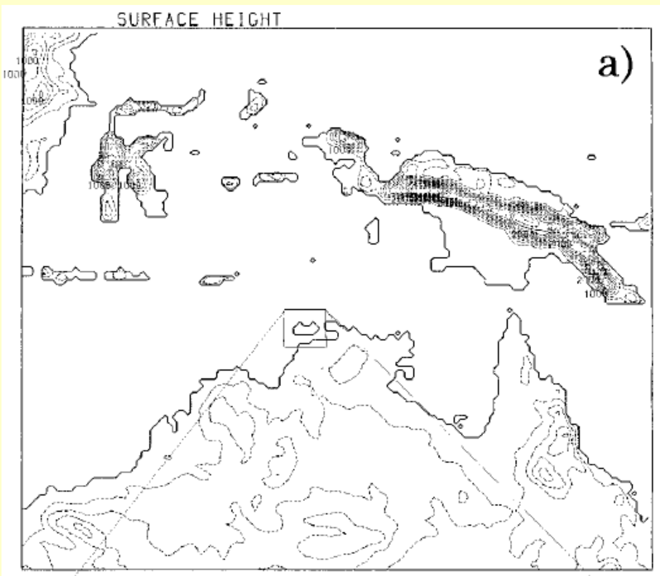


・・very difficult to keep a lead time due to

- small spatial/temporal scales
- sensitive to small perturbations in initial conditions

Maritime Continent Thunderstorm Experiment (MCTEX)

Nov. – Dec. , 1995 by BMRC, NCAR, CSU, MRI., .. (Keenan et al. 2000, BAMS; Saito et al. 2001, MWR)



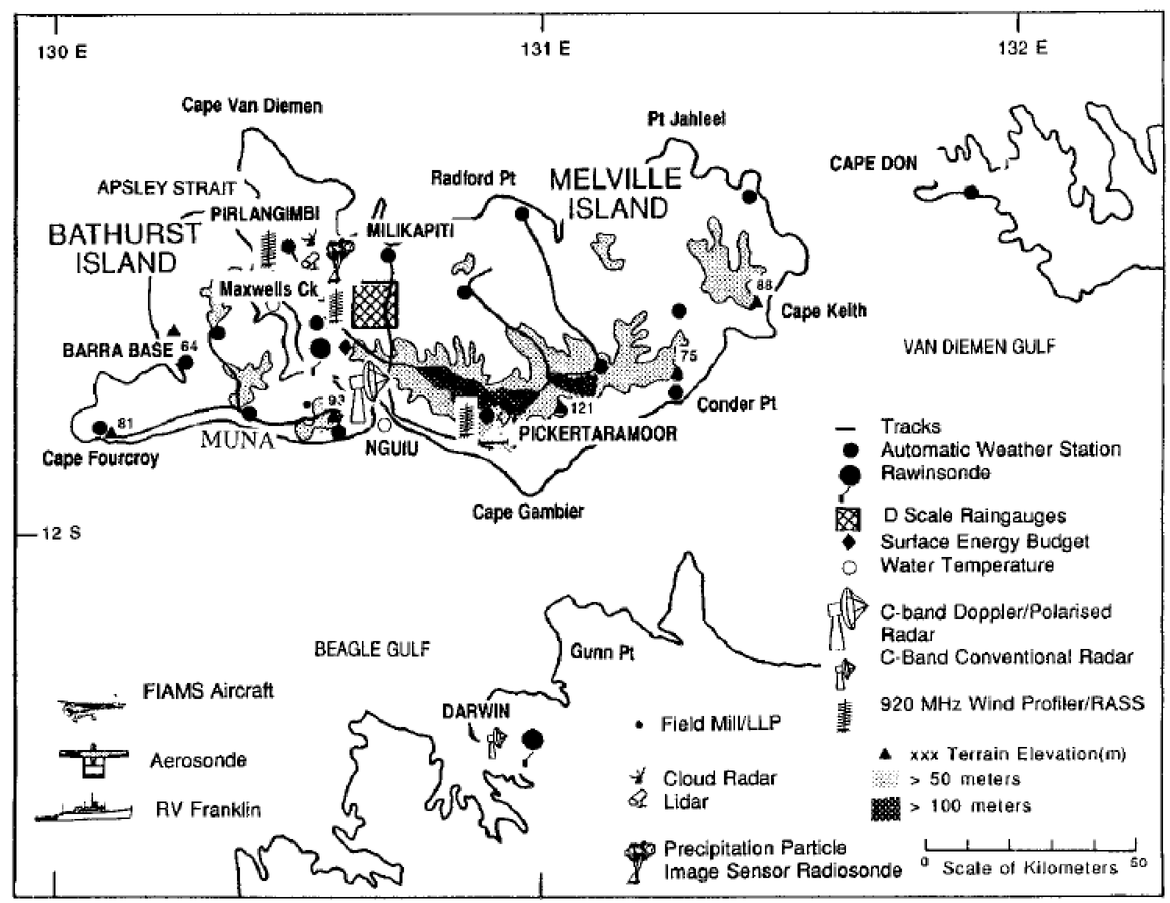


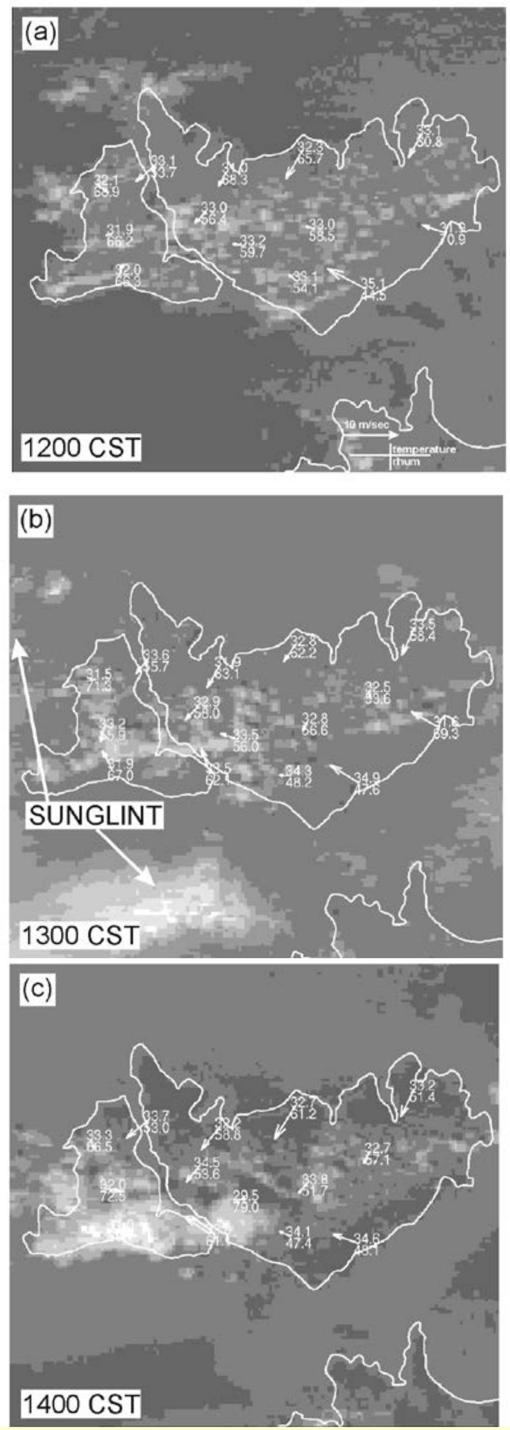
FIG. 1. Orographic features of the Tiwi Islands and the MCTEX observational network.

Diurnal evolution of convection on 27 Nov 1999

- Horizontal convection in morning, and sea-breeze front along the coast.
- Shallow clouds associated with the Rayleigh-Benard convection, inland.
- Cloud merger along the east-west line-shaped convergence zone.
- Explosive growth of deep convection after the merging stage.

Left: Visible GMS image on 27 November 1995.

Right: Schematic view based on a numerical simulation by 1 km NHM.



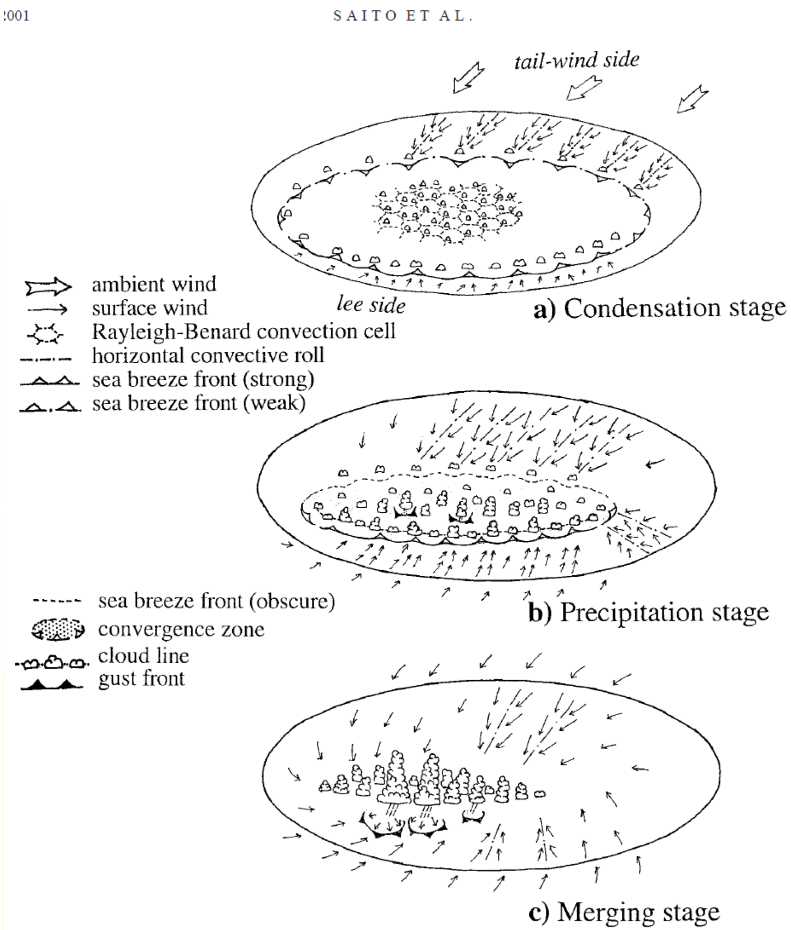
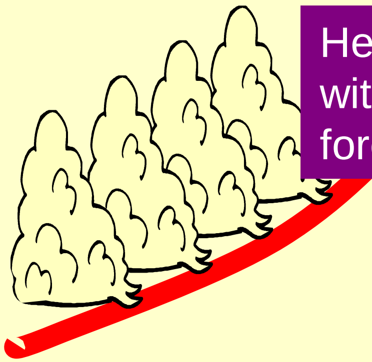


FIG. 19. Schematic representation of a conceptual model showing stages in the diurnal evolution of tropical island convection. (a) Condensation stage. (b) Precipitation stage. (c) Merging stage.

Saito et al. (2001)

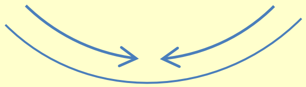
Predictability of local heavy rainfalls

Heavy rains with orographic forcing



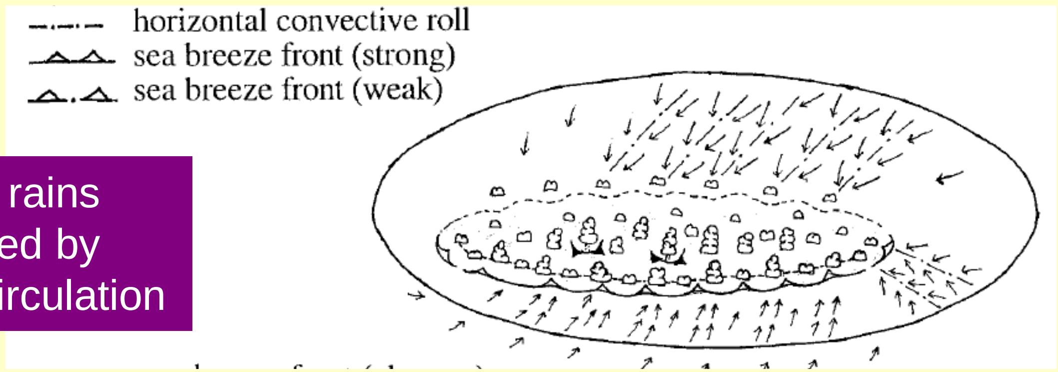
Heavy rains with synoptic forcing

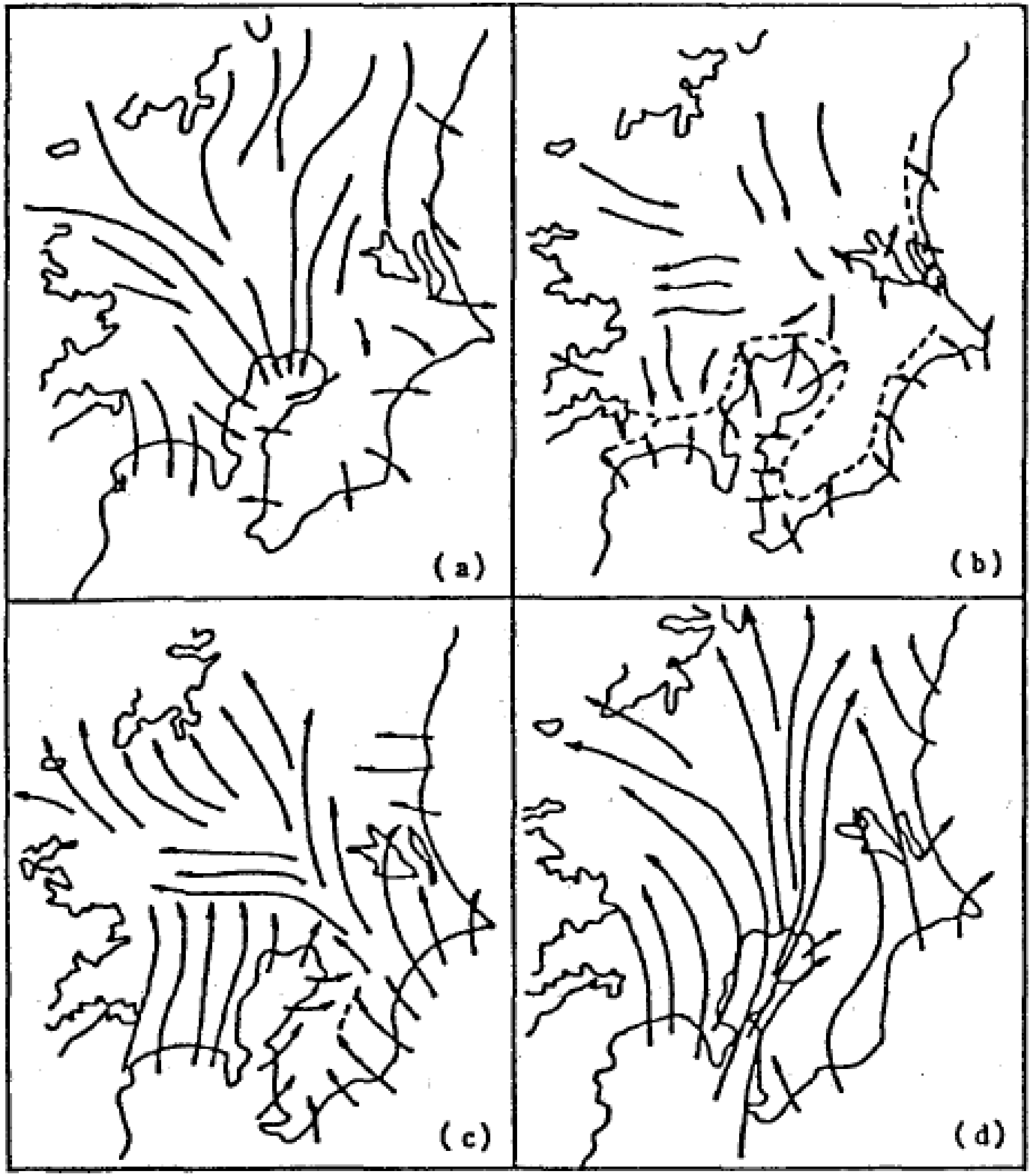
Orographic/synoptic forgings make local heavy rainfall predictable



Land-Sea distribution may improve predictability of deep convection

Heavy rains triggered by local circulation

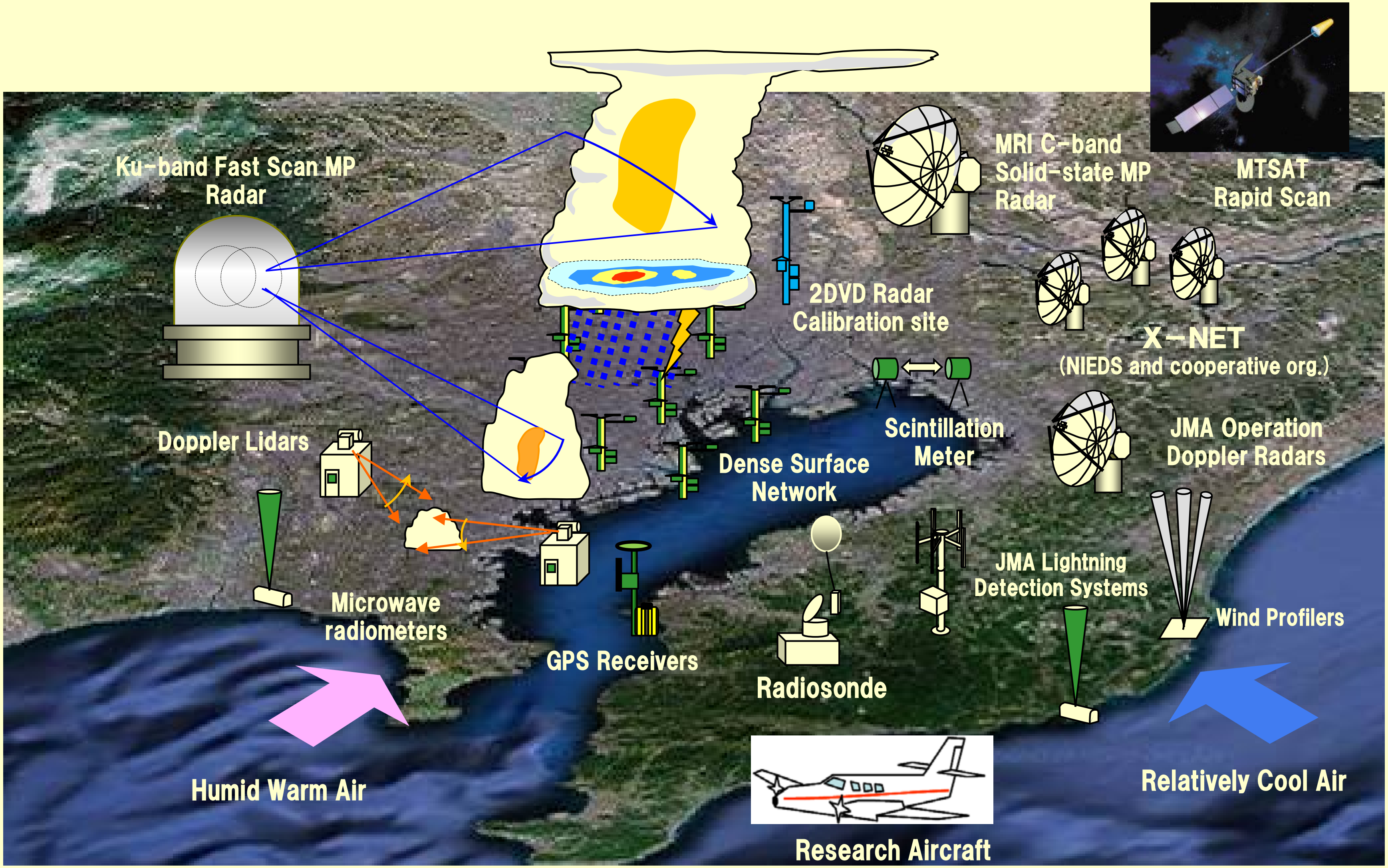




Typical daily change of surface wind circulation over the Kanto district (Kawamura 1977)

TOMACS

A field campaign in the Tokyo metropolitan area with a dense observation network was conducted by MRI, NIED and 12 research organizations for the summers of 2011-2013.



Targets and Instruments

Target			Instruments: Campaign	Instruments: Operational
Environment/ Boundary layer	Troposphere	Temperature, Water vapor, Wind	Radiosonde MWR GPS（Tokyo Bay Area）	Radiosonde GPS (GEONET) UHF Wind Profiler
	Boundary Layer		Unmanned Aerial Viecle Doppler Lidar	
		Vertical Heat Flux	Scintillometer	—
	Surface	Temperature, Wind, Rain, Td, Pressure	High spaciotemporal surface meteorological network	AMeDAS
Convection	**Image (VIS, IR)**		**Web Cameras**	**JMA MTSAT (Rapid Scan Imager)**
	High Spaciotemporal 3-D strucuture of rain intensity		**Ku-band Fast Scan Radar**	**—**
	3-D Precipitation, Wind, and Polarimetric Parameters		**X-NET (X-band Polarimetric) C-band Polarimetric Radar**	**MLIT X-band Polarimetric Radar JMA C-band Doppler Radar**
	Vertical distribution of raindrop size		**Micro Rain Radar**	**—**
	Surface Drop size distribution, rainfall amount		**Disdrometer (2DVD, Optical) AWS**	**Rainguage Networks (AMeDAS, MLIT, Local Government)**
	Lightning		**Transportable lightening Inst.**	**JMA LIDEN**

WWRP RDP proposal

In July 2013, a part of the project was endorsed as a RDP of WWRP.

WWRP RDP Science Plan: Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS)

Proposers:

T. Nakatani[1], Y. Shoji[2], R. Misumi[1], K. Saito[2], N. Seino[2], H. Seko[2], Y. Fujiyoshi[3] and I. Nakamura[4]

Institutions

[1] National Research Institute for Earth Science and Disaster Prevention

[2] Meteorological Research Institute

[3] Hokkaido University

[4] Toyo University

1. Project Summary

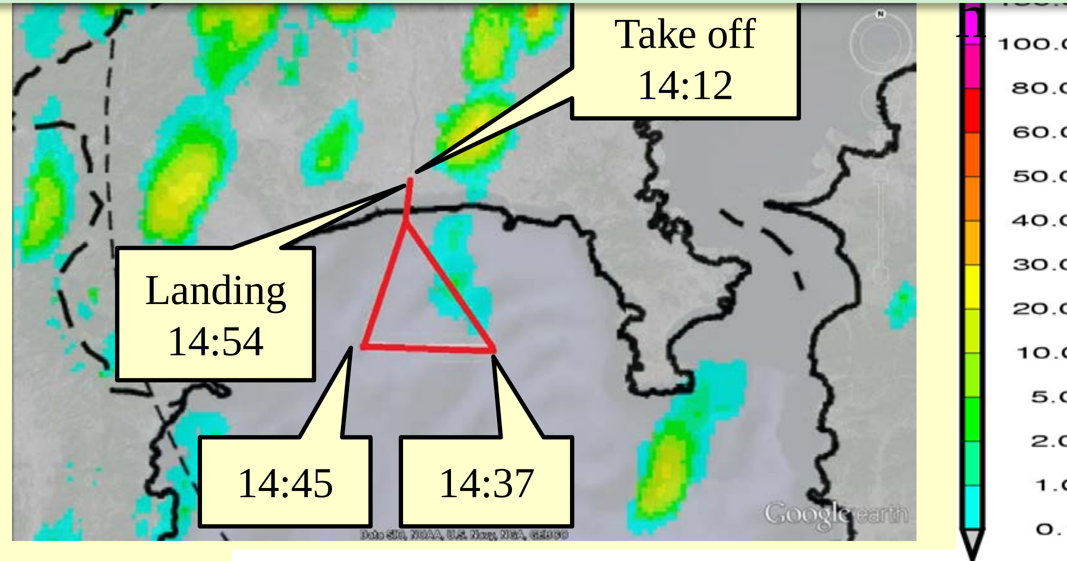
An unprecedented dense observation campaign and relevant modeling and societal studies have been conducted since April 2010 by the National Research Institute for Earth Science and Disaster Prevention (NIED), Meteorological Research Institute (MRI), and more than 25 national institutions and universities in Japan that target local high-impact weather (LHIW) in the Tokyo metropolitan area. The objectives of the project, the Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS), include the 1) elucidation of the mechanism of LHIW in urban areas (e.g., local torrential rain, flash flood, strong wind, lightening), 2) improvement of nowcasting and forecasting techniques of LHIW, and 3) the implementation of high resolution

http://www.wmo.int/pages/prog/arep/wwrp/new/documents/Doc4_6_TOMACS_RDP_proposal_20130704.pdf

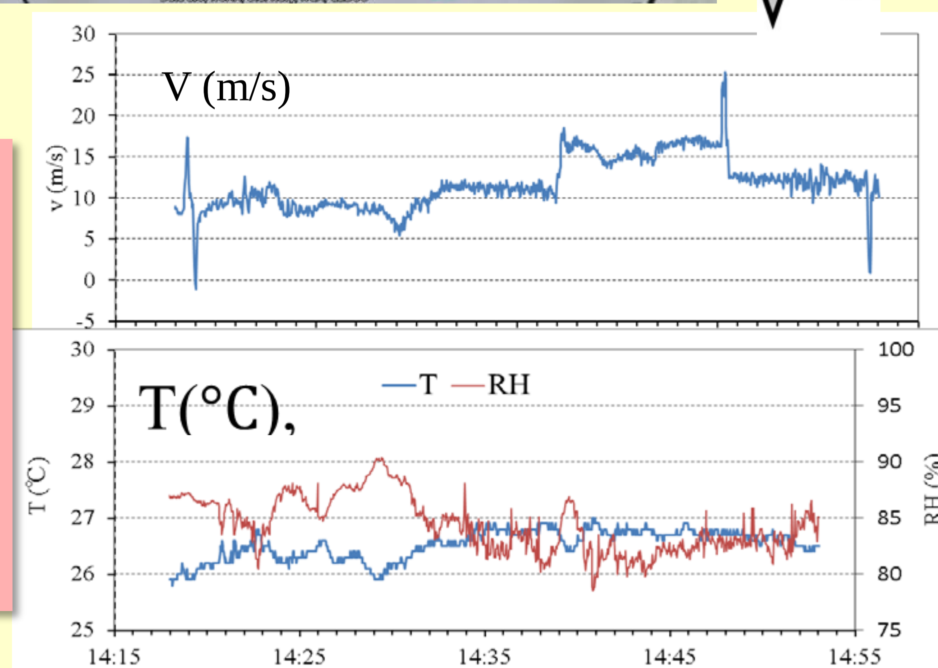
RDP: Participants and Counterparts

Country	Institution	Participant	Theme	Counterpart
Australia	Bureau of Meteorology (BOM)	A. Seed	Nowcasting (STEPS)	NIED
Brazil	Sao Paulo Univ.	A. Pereira	Nowcasting Urban modeling	MRI
Canada	Environment (EC)	S. Belair P. Joe	Urban modeling Nowcasting	MRI, NIED
Germany	(HU)	V. Wulfmeyer	Data assimilation, LES and lidar obs.	MRI
Korea	Pugyon National Univ. (PNU)	D.-I. Lee	Disdrometer observation	NIED, Kagoshima Univ.
France	UANPE	D. Schertzer	Precipitation	Kagoshima Univ. ,NIED
USA	NCAR	J. Sun	Storm scale data assimilation	CRIEPI
USA	Colorado State Univ. (CSU)	V. Chandrasekar	Dallas-Fort Worth testbed	NIED, Kagoshima Univ.

Environment / Boundary Layer (3)
UAV observation experiment



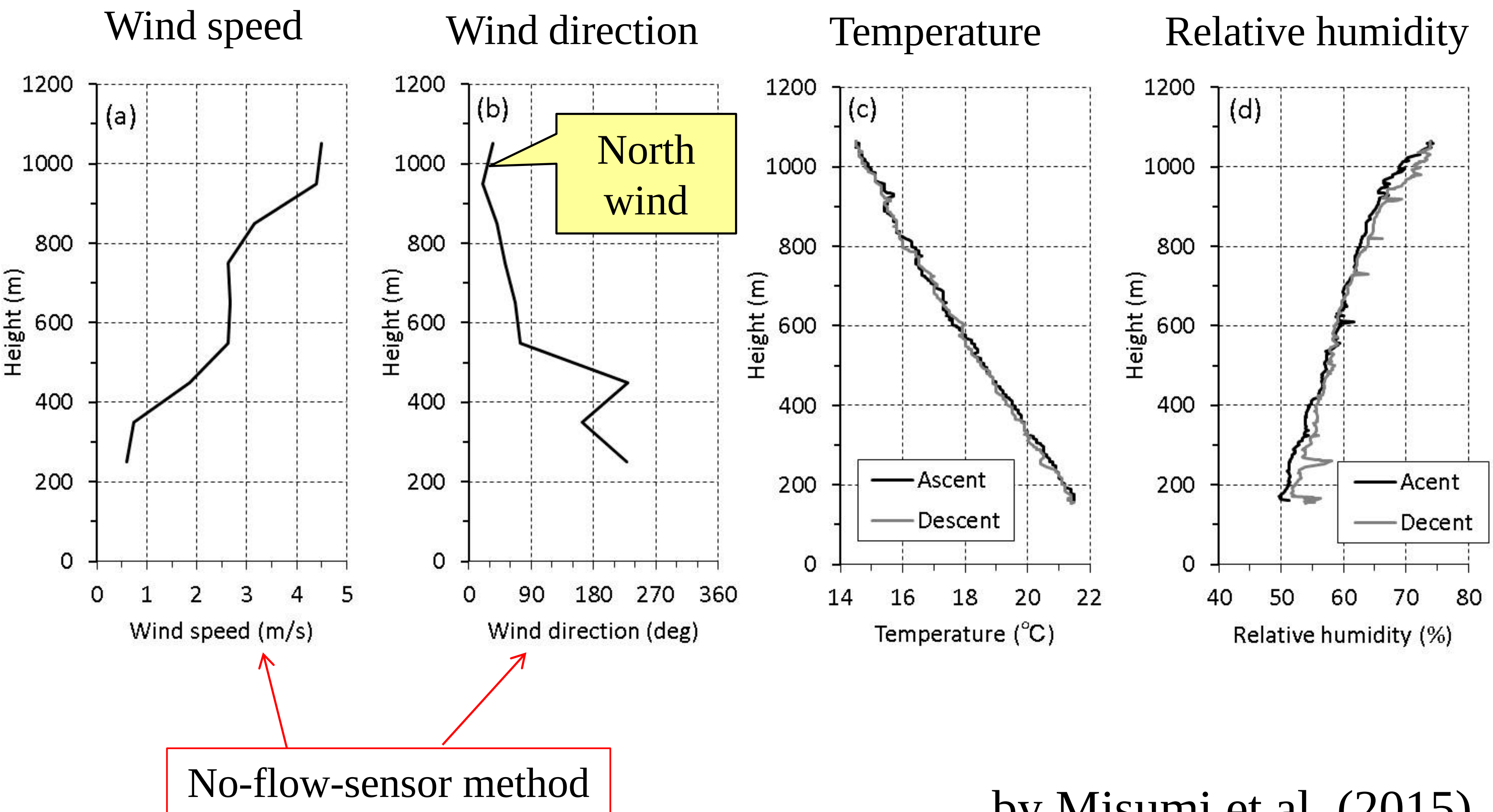
Feasibility experiment of UAV (unmanned aerial vehicle) for observation of BL was conducted by NIED over the Sagami Bay. The UAV is a twin-engine aircraft, 4.6 m in width, 35 kg in weight. Its cruising speed is 100-120 km/h with a 4-hour flight duration.



Vertical profiles at the point A

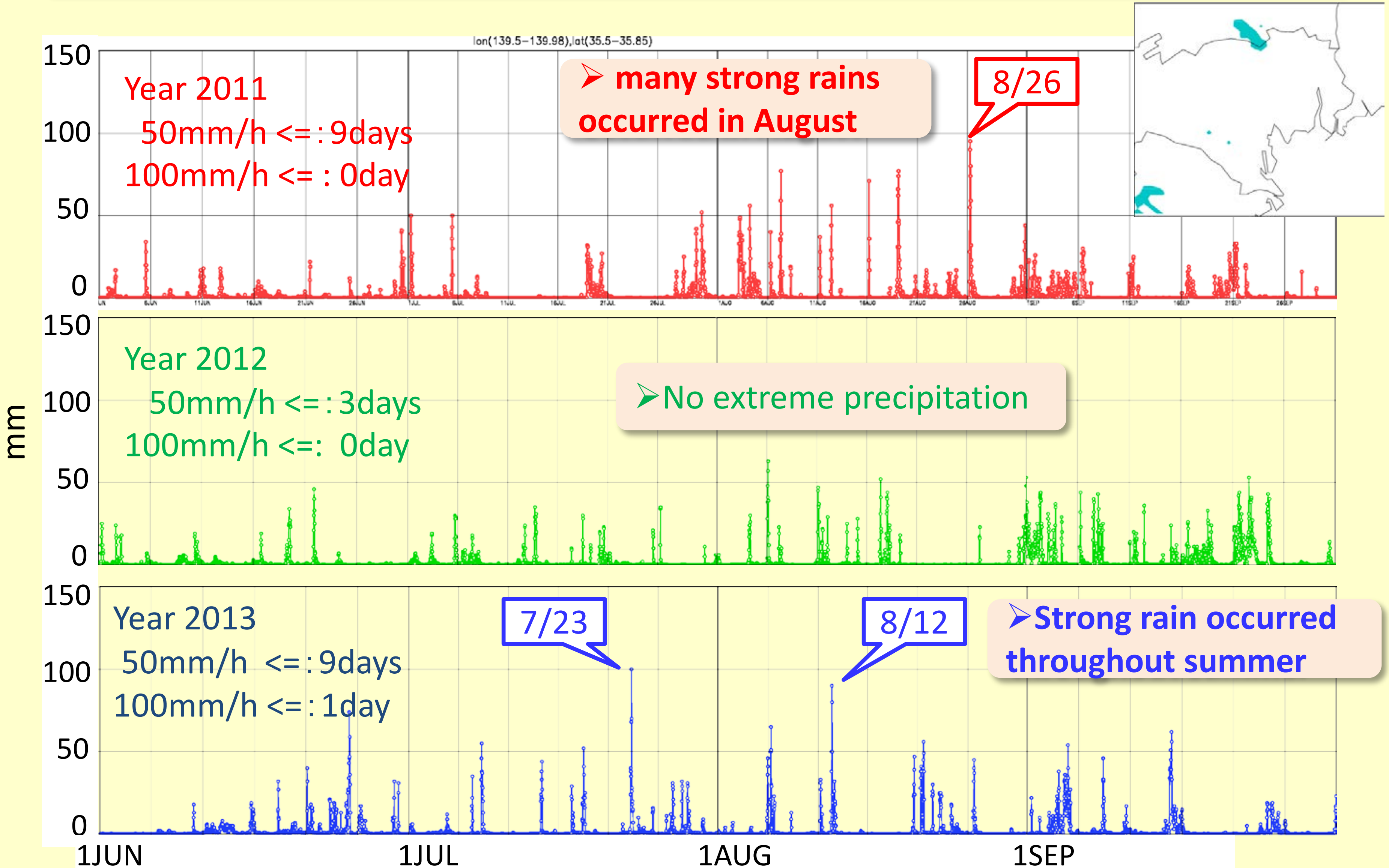
Vertical profiles observed by the UAV

(14:00-14:20 JST on 18 September 2014)



by Misumi et al. (2015)

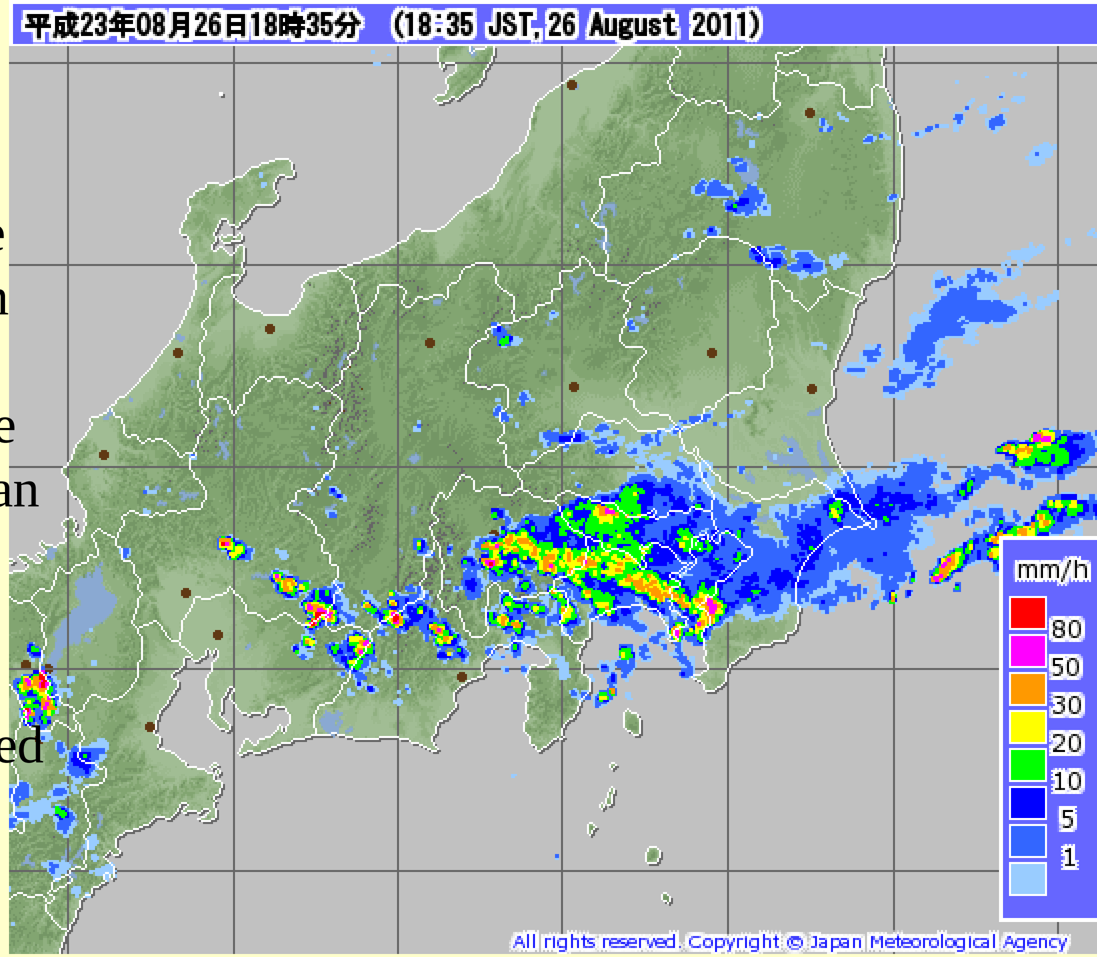
Maximum 1 hour precipitation during TOMACS IOP

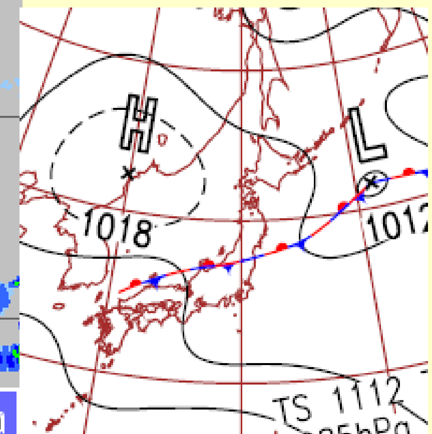


Local heavy rainfall on 26 August 2011

On 26th August 2011, a mesoscale convective system developed in the western part of the Tokyo metropolitan area.

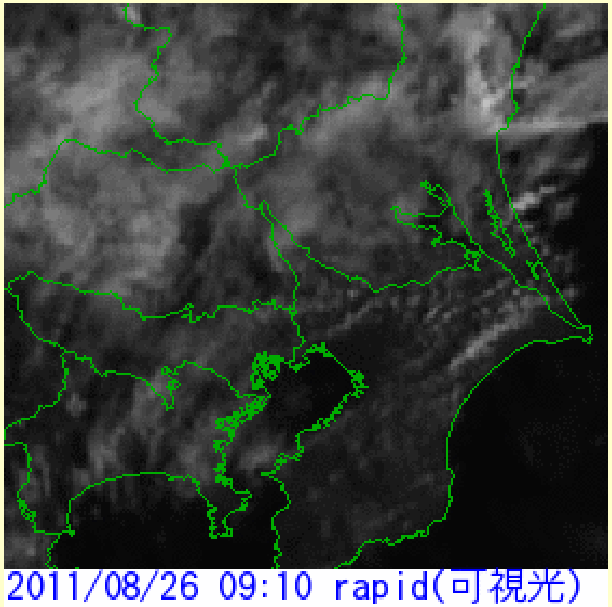
Local heavy rainfall over 90 mm/h was observed in Tokyo and Kanagawa prefectures.

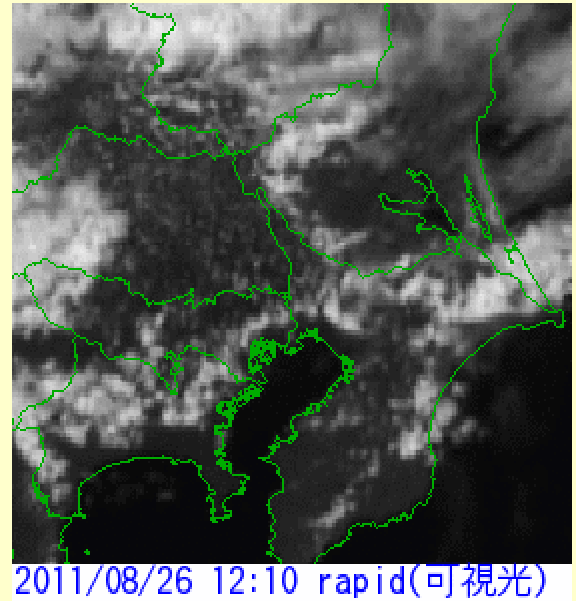


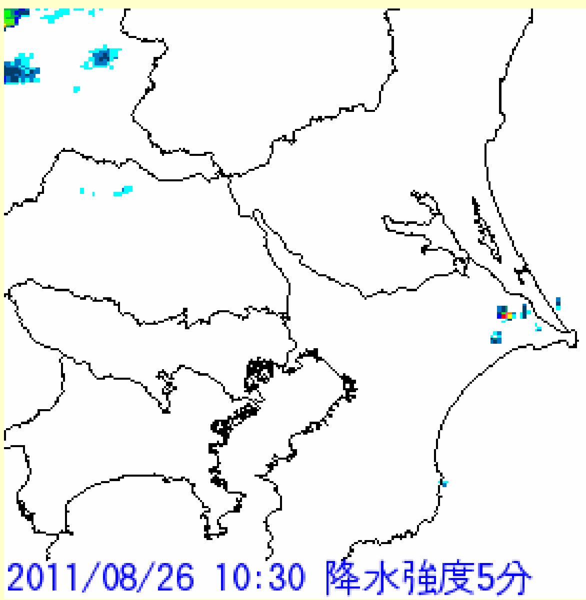


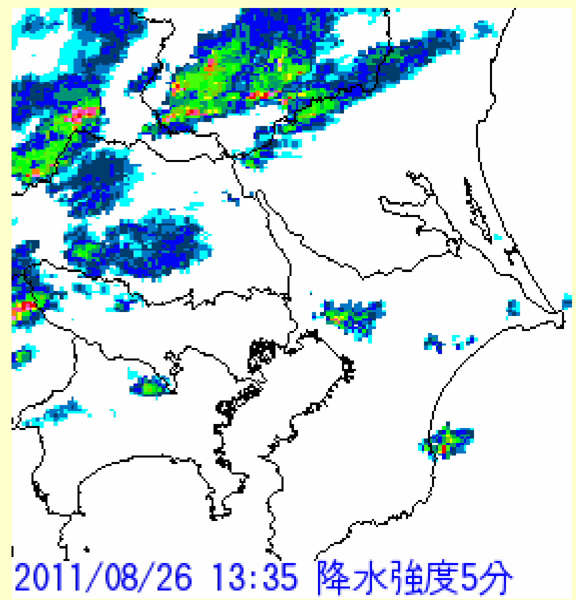
Rainfall intensity from 1615 to 1835 JST by JMA nowcasting on 26 August 2011

MTSAT-1R rapid scan (Tanaka 2012)





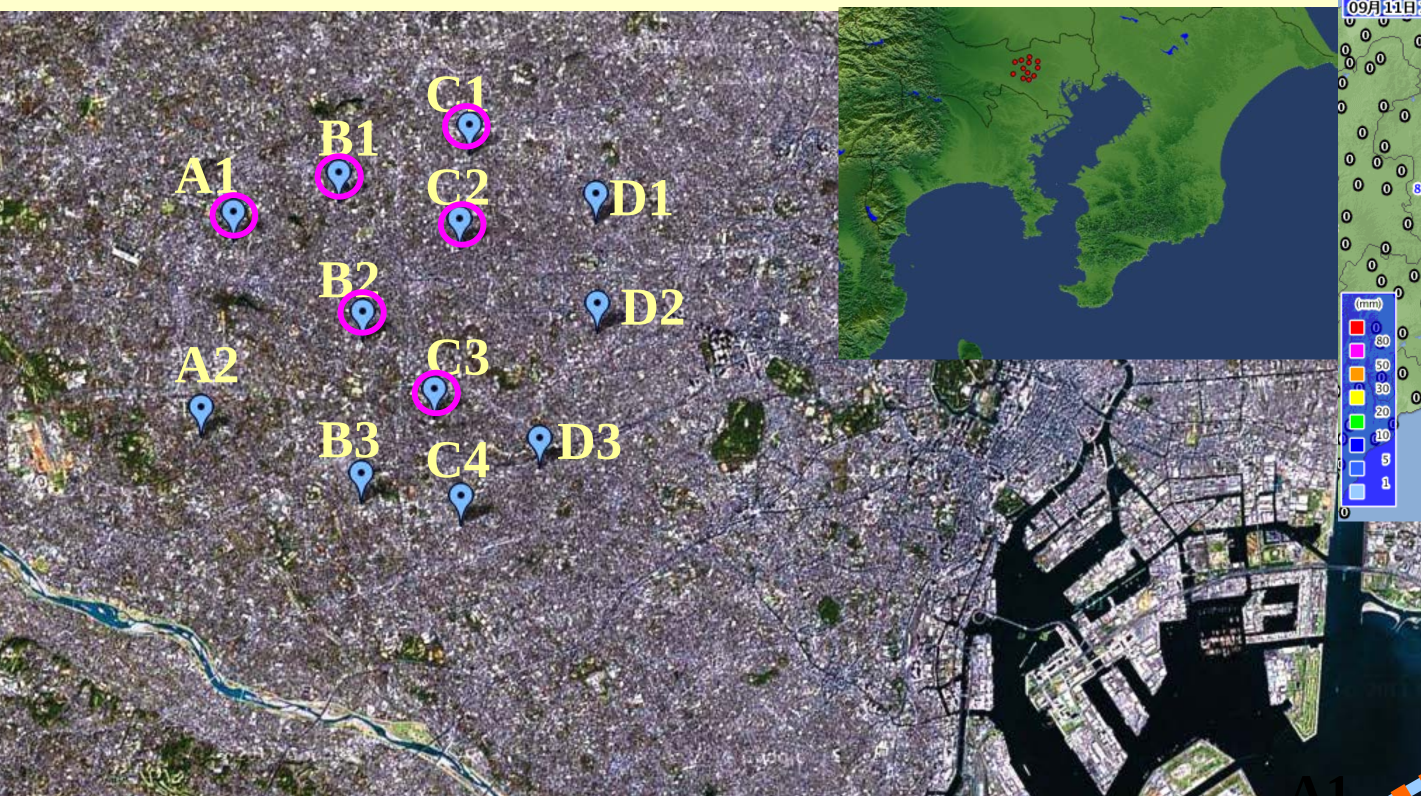


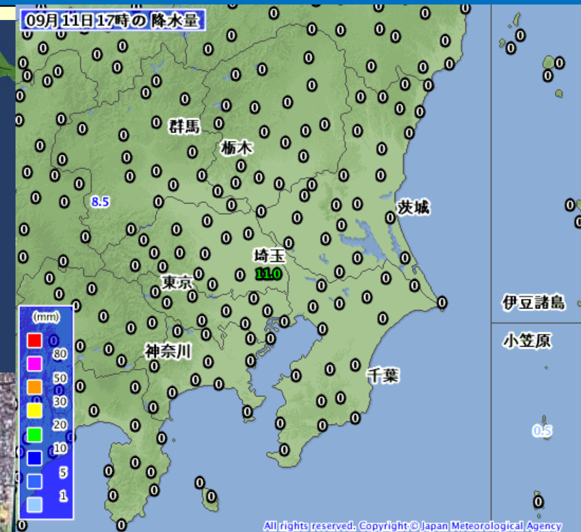


Misocyclone accompanied by MCS on 26 Aug 2011

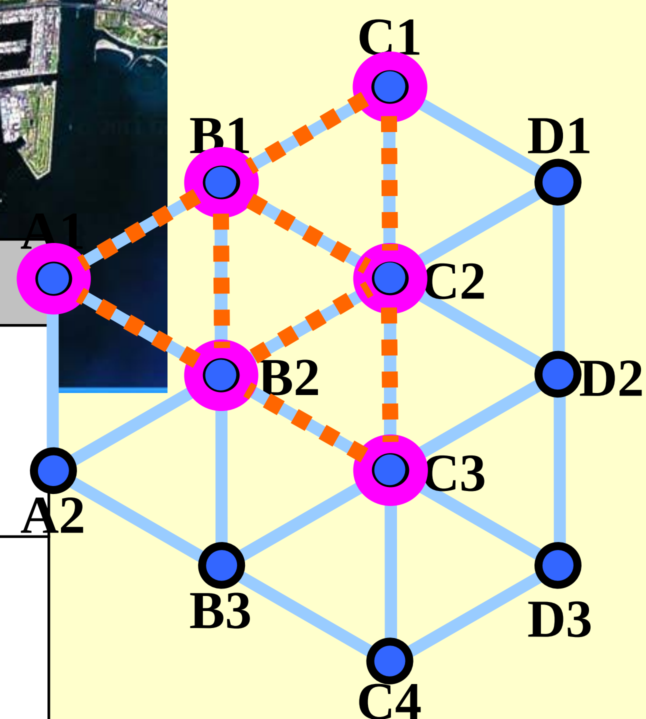
Youtube animation

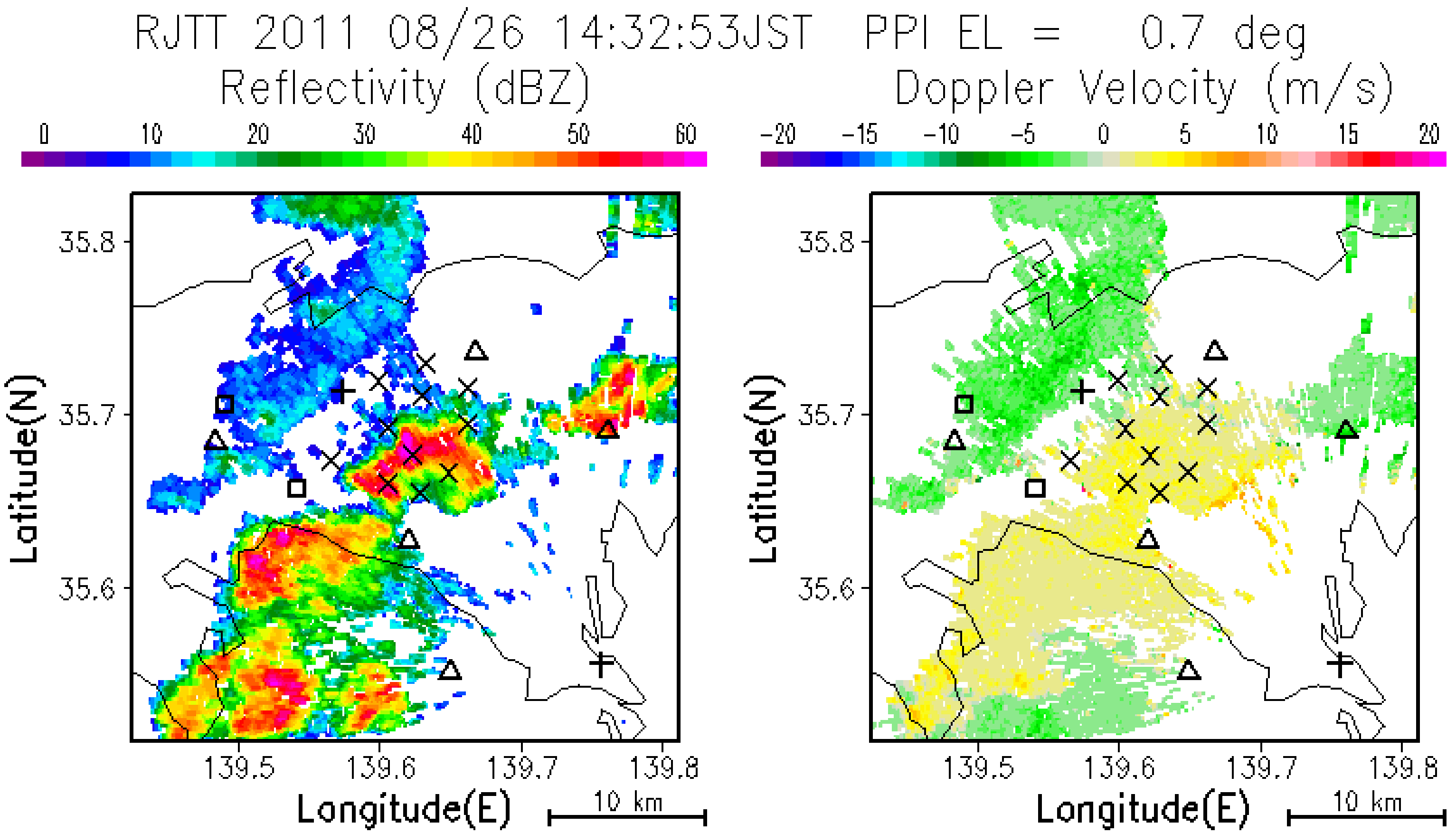
High-resolution AWS network





System	Number	Measurements	Observation intervals
Weather Transmitter WXT520 (Vaisala)	12	Surface weather data	1 second for wind direction and speed 10 seconds for temperature, humidity, pressure, and precipitation
Laser-based optical disdrometer (OTT PARSIVEL®)	6	Drop size and velocity in precipitation Rain fall intensity	10 seconds





by S. Saito (2012)

Publication

SOLA, 2013, Vol. 9, 153−156, doi:10.2151/sola.2013-034

A Case Study of the Merging of Two Misocyclones in the TOMACS Field Campaign Area of Tokyo on 26 August 2011

Sadao Saito, Kenichi Kusunoki, and Hanako Y. Inoue
Meteorological Research Institute, Tsukuba, Japan

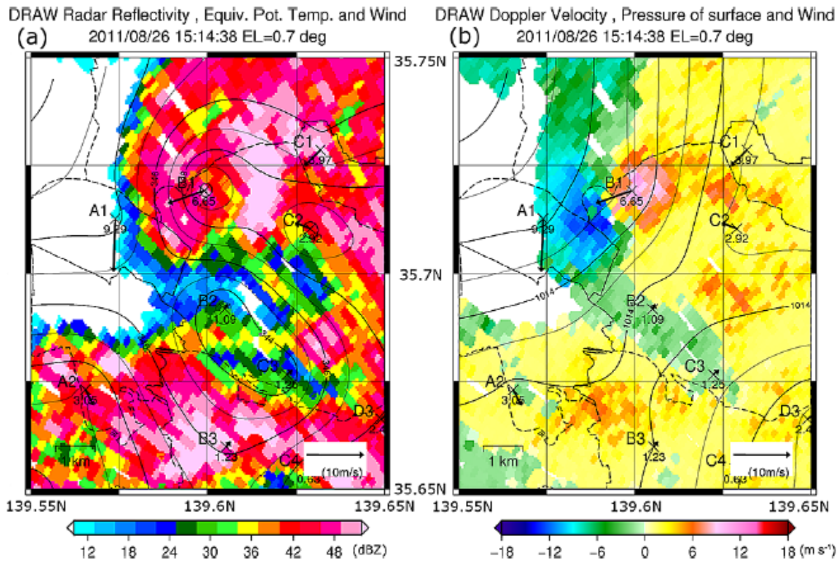


Fig. 4. (a) DRAW radar reflectivity (color shading), wind speed and direction (vectors), and equivalent potential temperature (contours) and (b) DRAW Doppler velocity (color shading), wind speed and direction (vectors) and sea level corrected pressure (contours) in the area of the Ground Network at 15:14 JST. Contour intervals are at 1 K in (a) and 0.2 hPa in (b). Crosses show the locations of Ground Network stations A1−3, B1−3, and C1−3.

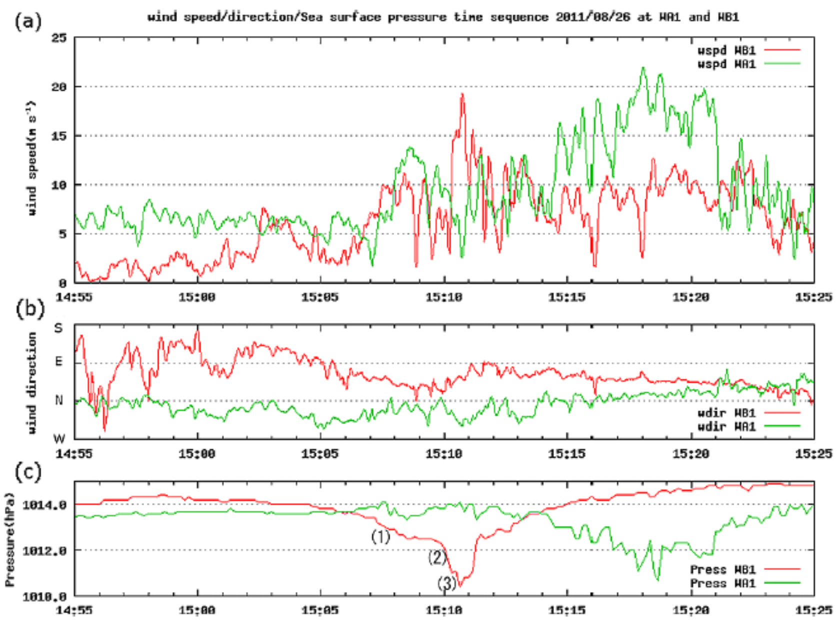
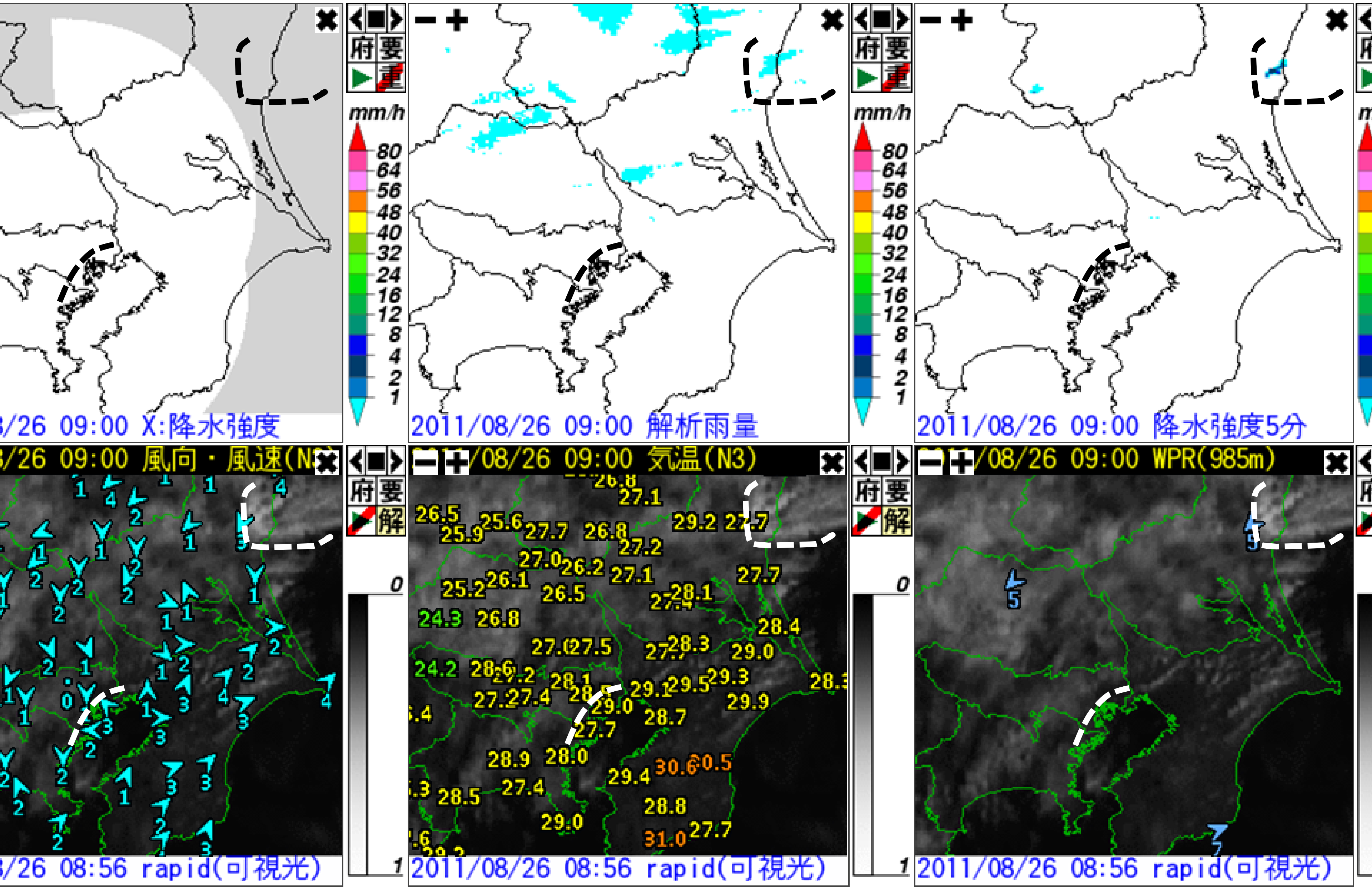
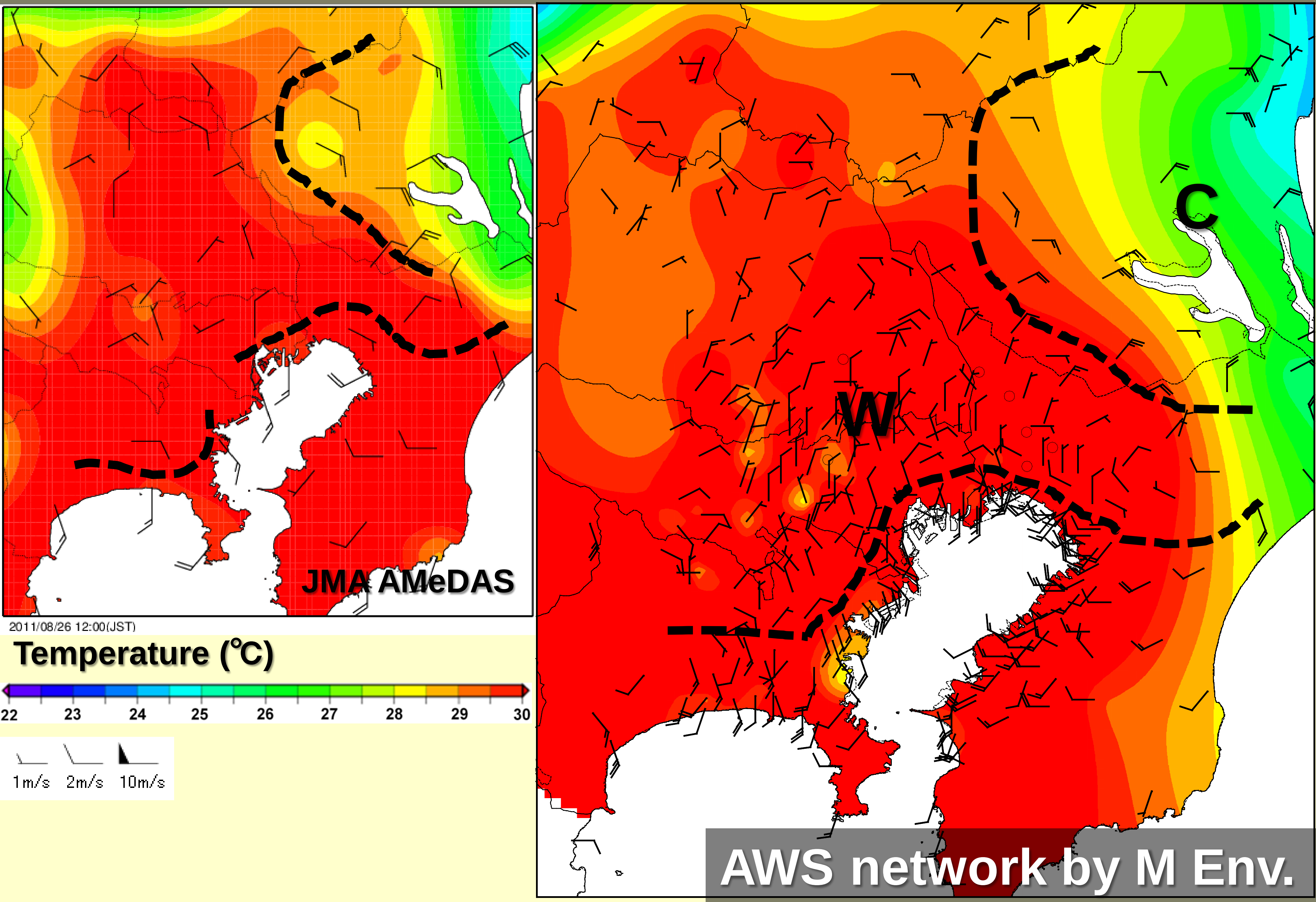


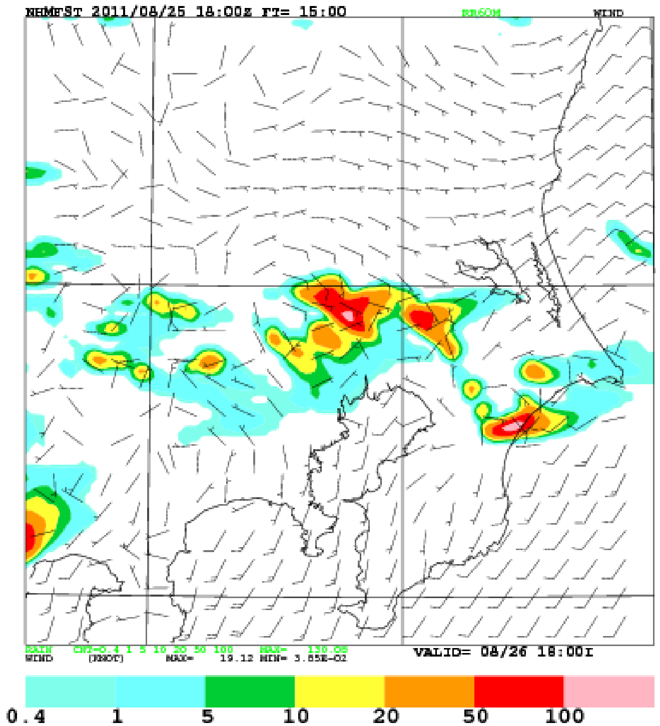
Fig. 6. Time series of (a) wind speed, (b) wind direction, and (c) sea level corrected pressure at stations B1 (red lines) and A1 (green lines) from 14:55 to 15:25 JST. See the text for the explanation of numbers (1), (2), and (3).

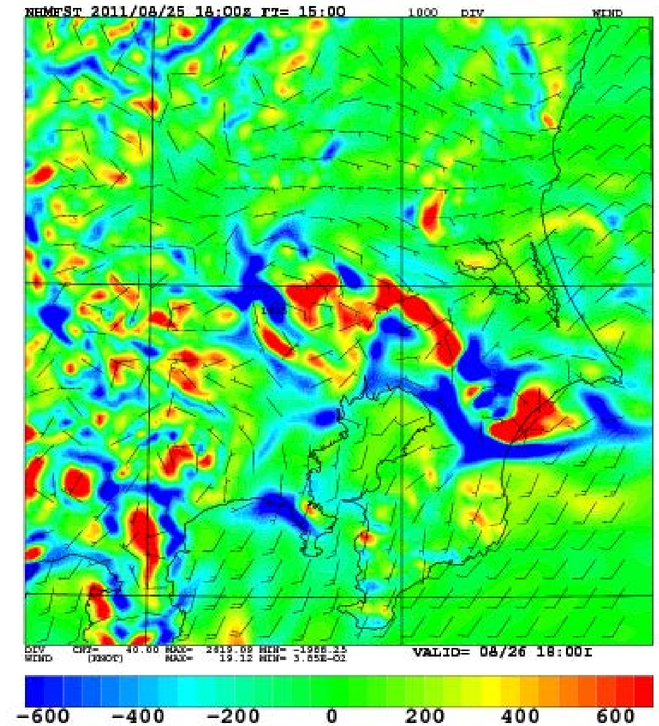


MTSAT-1R rapid scan

2011.08.26 12JST / AMeDAS vs Soramame







Surface wind and 1h precipitation for 10-18 JST by p04 MSV

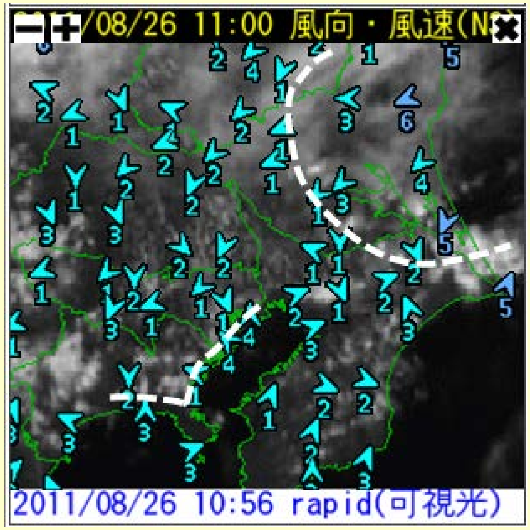
Horizontal convergence at 1000 hPa and surface wind for 10-18 JST by p04 MSV

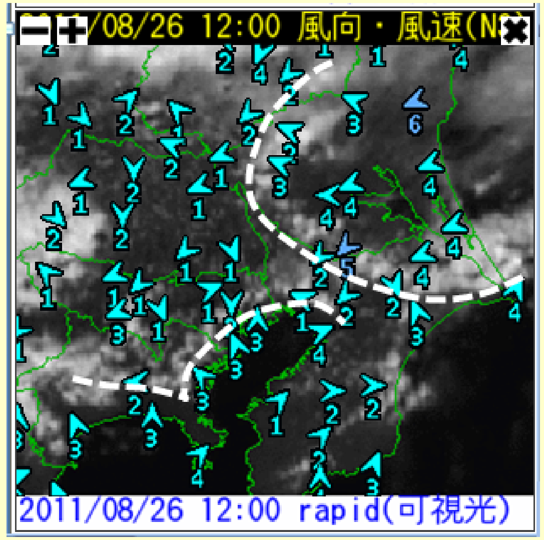
Cloud resolving simulation using JMA-NHM and its mesoscale SV

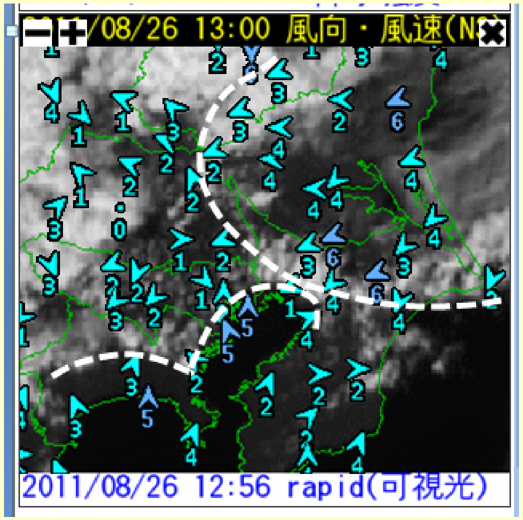
Saito et al. (2016)

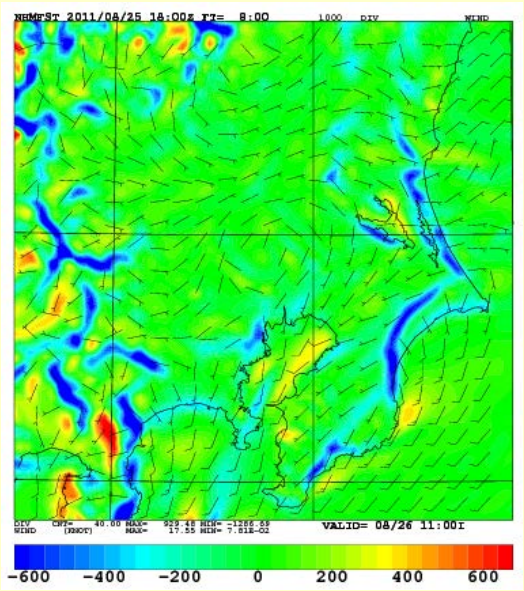
Comparison with observation

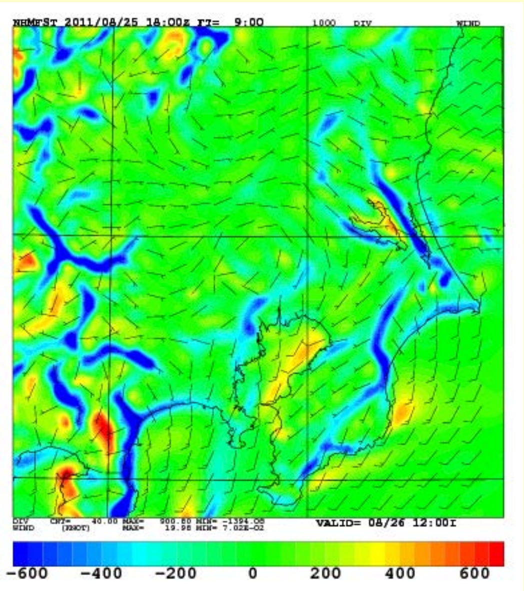
Saito et al. (2016)

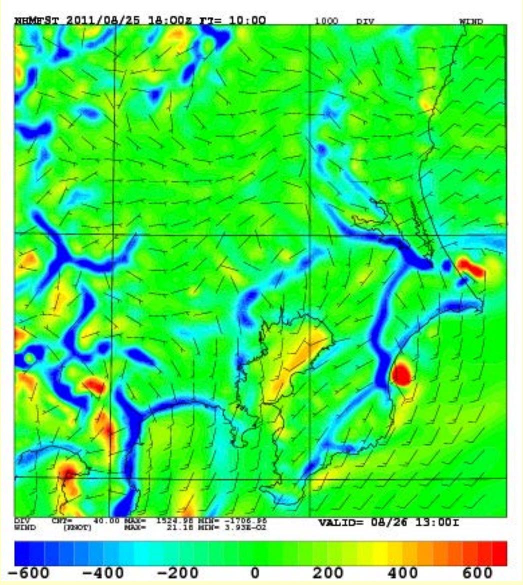


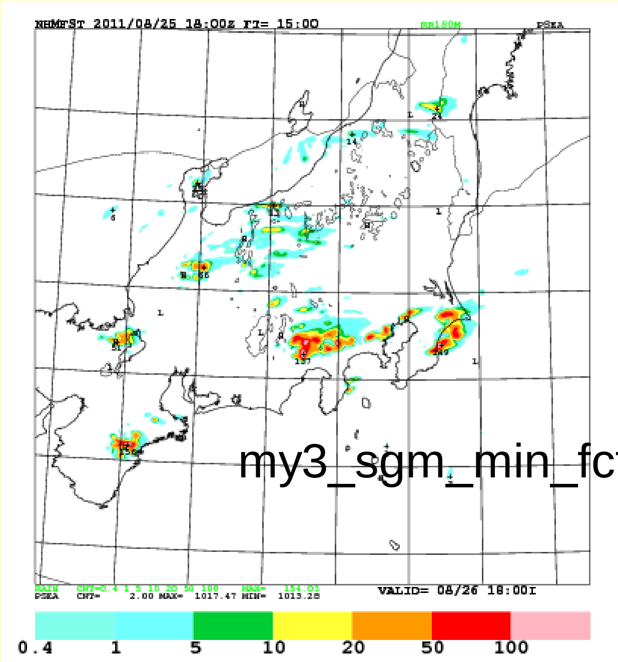












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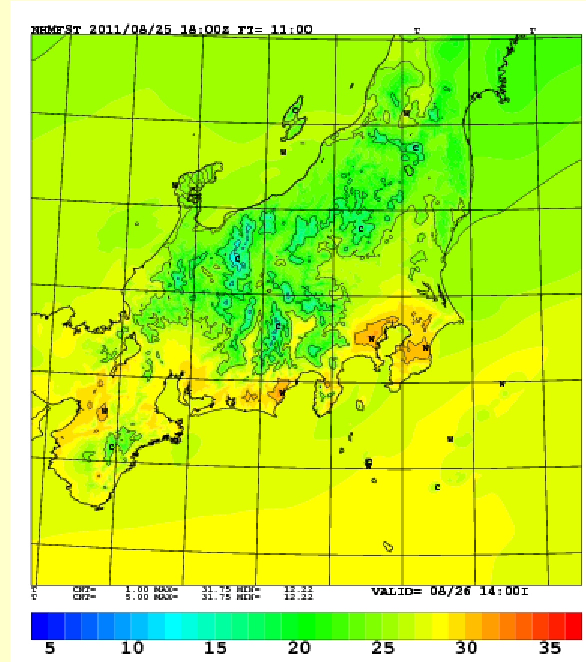
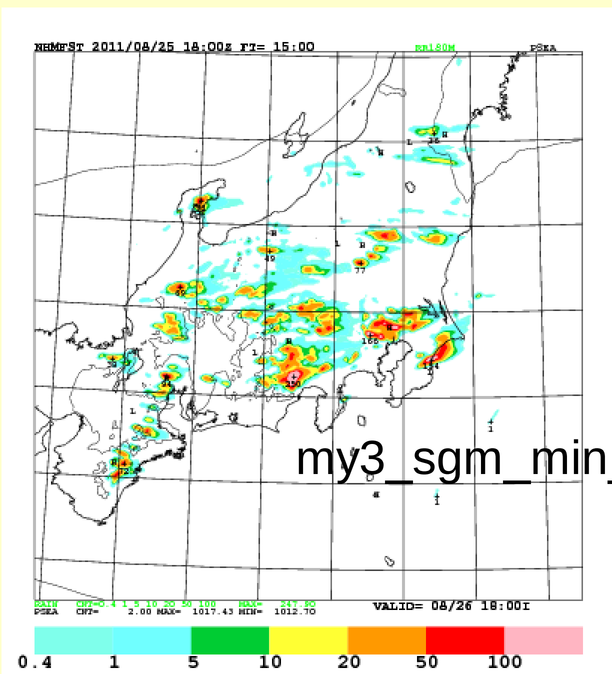


05UTC surface temperature



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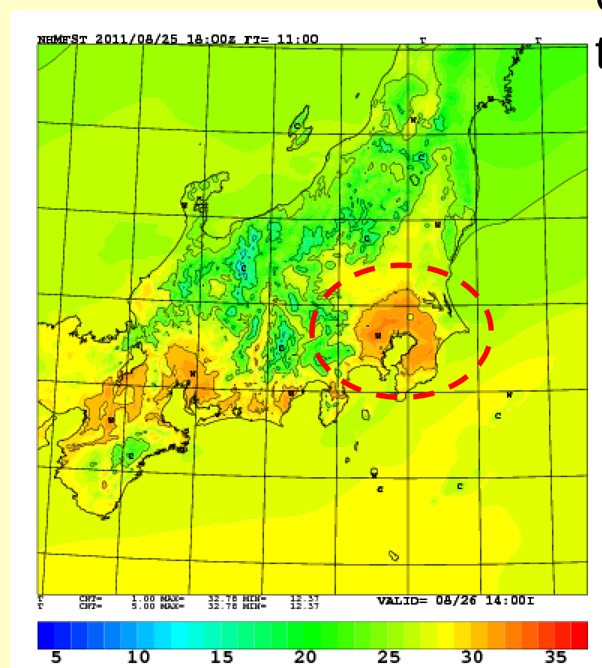
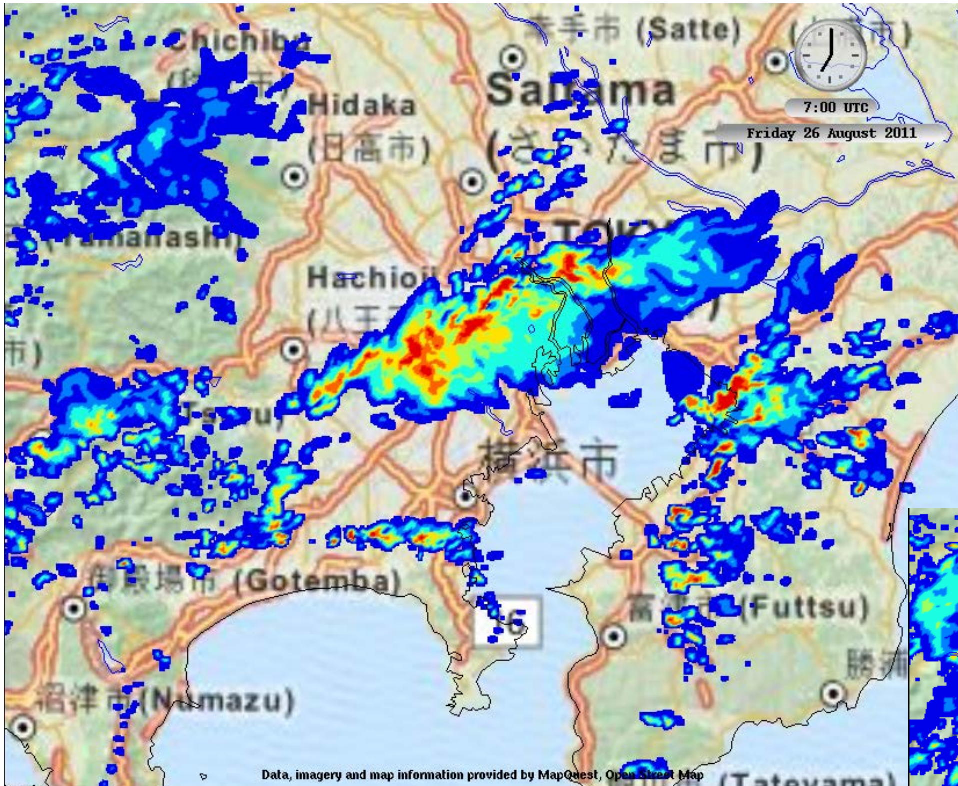


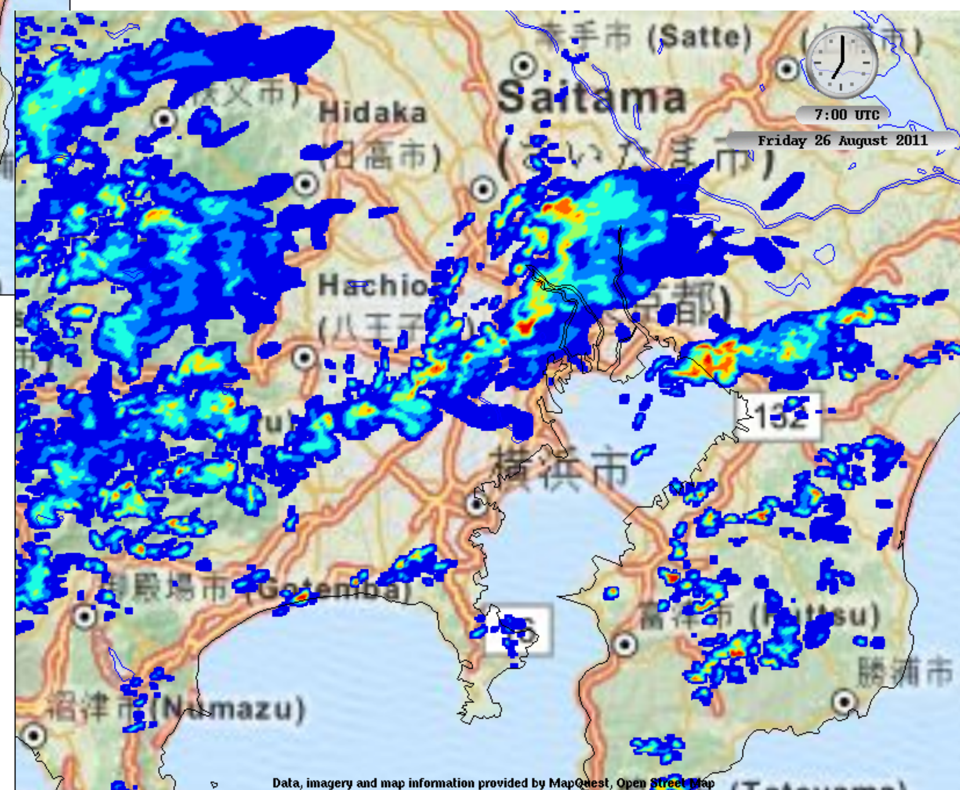
Surface temperature increased by reducing lower limit of σ, due to decrease of cloud amount.

Impact of Urbanization



EC's GEM 500 m simulation by Bélair et al. (2015)

Without URBAN (no TEB)



CONTROL RUN – with URBAN

19-h Forecast
Valid at 1600 JST
26 Aug. 2011

Data Assimilation System in TOMACS

	System Name	Institute in Charge
1	Cloud Resolving NHM-4DVAR system	Meteorological Research Institute
2	Local Ensemble Transform Kalman Filter (LETKF)	Meteorological Research Institute
3	CReSS 3DVAR System	NIED
4	NCAR VDRAS	Central Research Institute of Electric Power Industry, NCAR

Overview of TOMACS

An unprecedented dense observation field campaign for local HIWs and boundary layer was conducted for Tokyo metropolitan area in the summers of 2011-2013.

Observation data are archived and data handling tools are developed for domestic and international participants.

The project has been endorsed as a RDP of WWRP for 2013-2016 as an international testbed for local HIWs by deep convection and boundary layer physics.

Researches for mesoscale NWP and nowcasting, and data assimilation intercomparisons were conducted.

Lessons and outcome

- Mesoscale convective systems (MCS) occurred without synoptic forcing are triggered by a convergence by sea breezes.
- The position of MCS triggering is determined by synoptic wind direction and sea breeze interaction.
- Surface heating and urban effect play important roles, which suggests importance of aerosols to determine the radiation and cloudniness.
- Detailed structure and evolution of MCSs were observed by the field campaign.
- Storm scale data assimilation showed availability of dense observation and feasibility of dynamical very short range forecast of precipitation.
- Cloud resolving ensemble prediction showed feasibility of probabilistic forecast of local HIWs with a lead time.

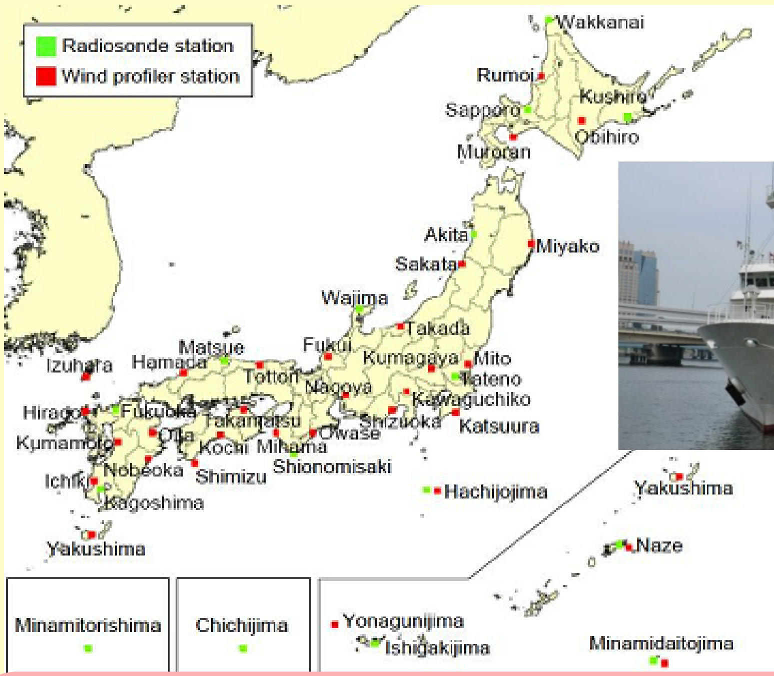
→ A special issue of JMSJ on TOMACS will be published in 2017.

Thank you

Environment / Boundary Layer (1)
Radiosonde

Operational

Radiosonde stations (■) and wind profilers (■) of JMA.



Operational upper-air observation is performed through 16 RAOB stations twice a day (00 and 12 UTC).
JMA's research vessel occasionally performs such observation.

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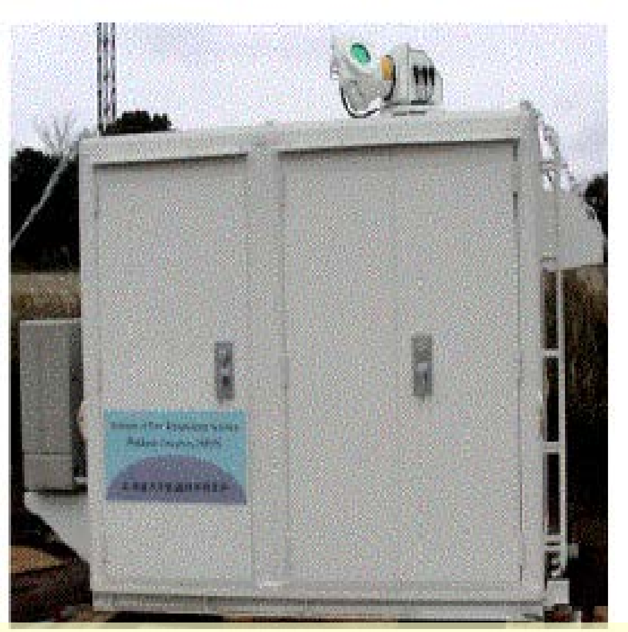
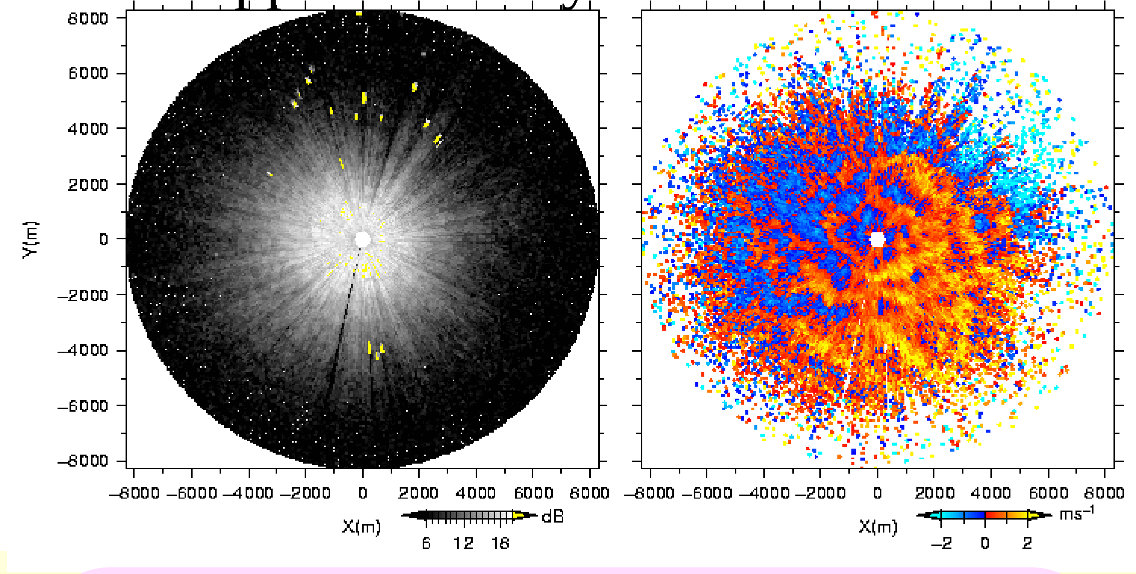
RAOBs are carried out at several sites in the Tokyo Metropolitan Area to capture the atmospheric environment for heavy rainfall.

Environment / Boundary Layer (2)
Doppler Lidar

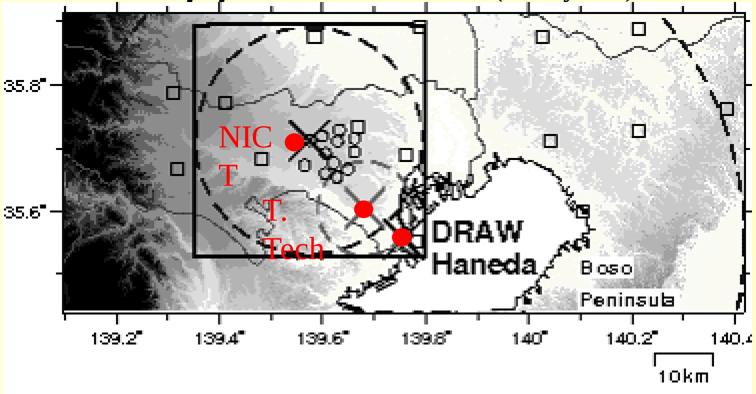


SNR

Doppler Velocity

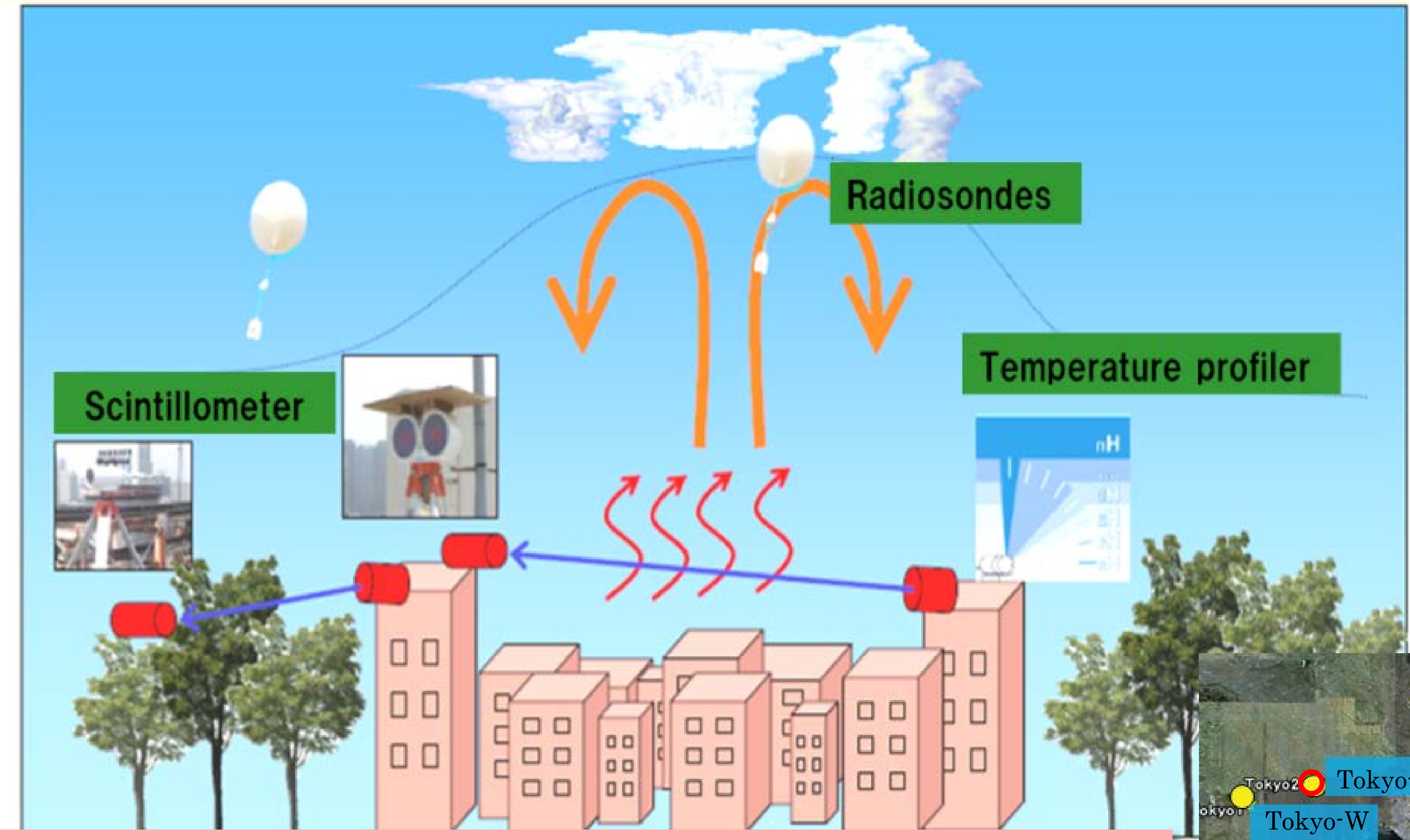


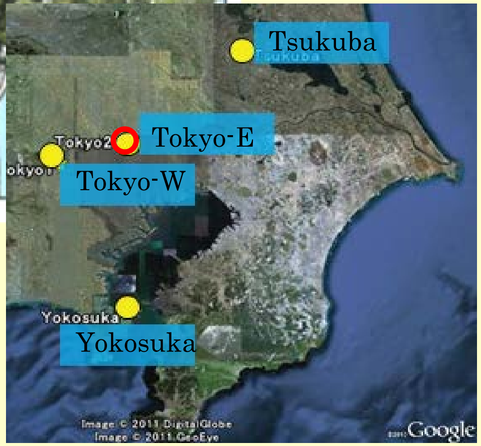
Doppler Lidar *(Ookayama)*



Two research Doppler Lidars (NICT and Hokkaido University), as well as the JMA operational Doppler Lidars at the Haneda airports, are operated to observe the behavior of sea breeze fronts and air flow in the atmospheric boundary layer prior to the initiation of convection.

Environment / Boundary Layer (3)
Scintilometer

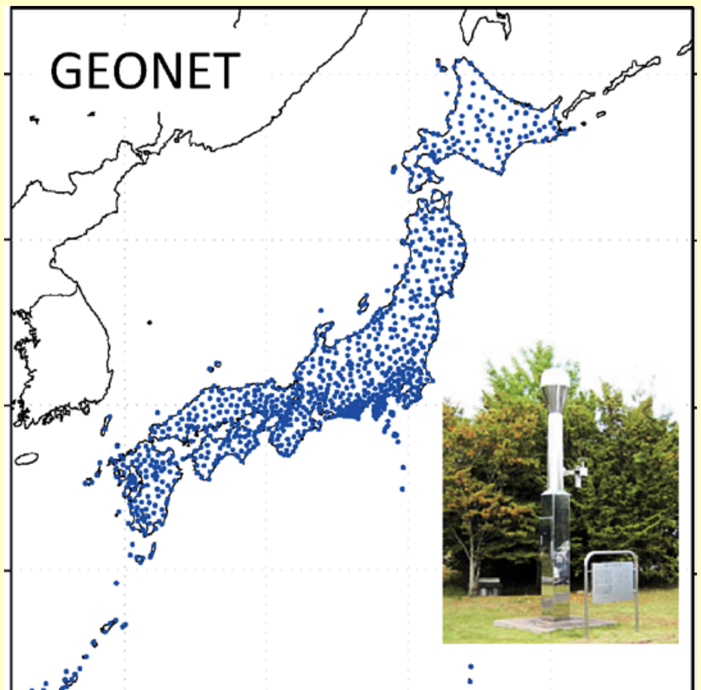




To evaluate the surface heat budget in an urban area, sensible heat flux measurements with a large aperture scintillometer have been conducted in the Itabashi Ward of Tokyo.

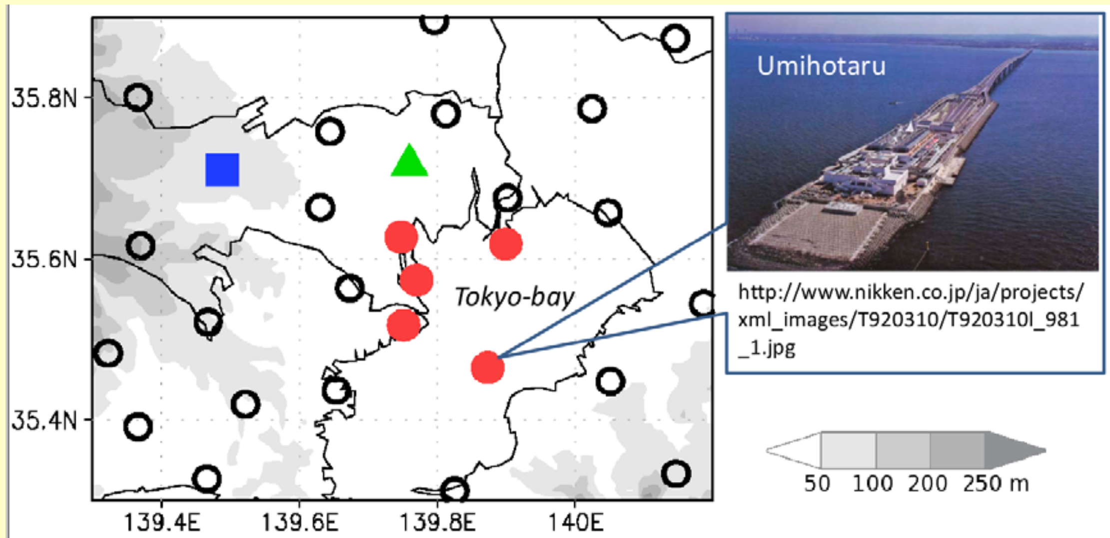
Environment / Boundary Layer (4)
GPS/GNSS

Operational



The Geospatial Information Authority of Japan (GSI) operates the nationwide ground-based GPS earth observation network (GEONET) with more than 1,200 GNSS stations.

TOMACS

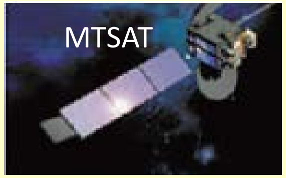


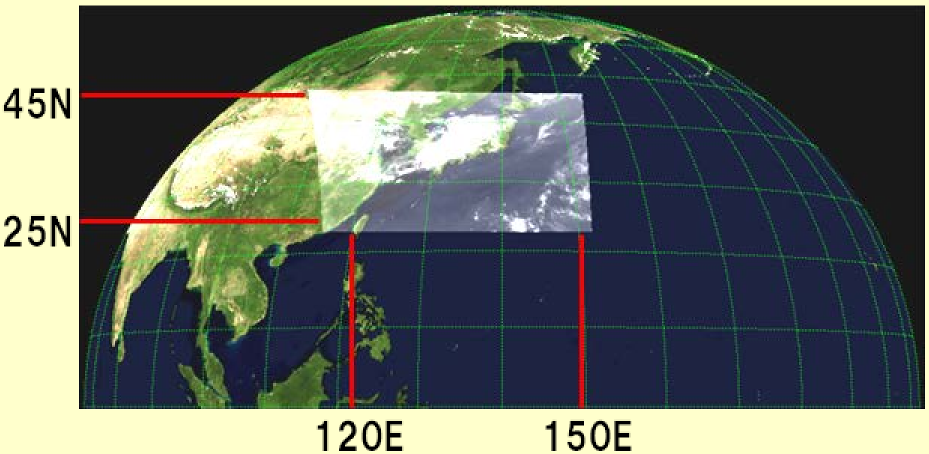
GPS/GNSS stations in Tokyo area

●: TOMACS, ○: GEONET,
■: IGS(KGNI), ▲: Earthquake Research Institute/ University of Tokyo

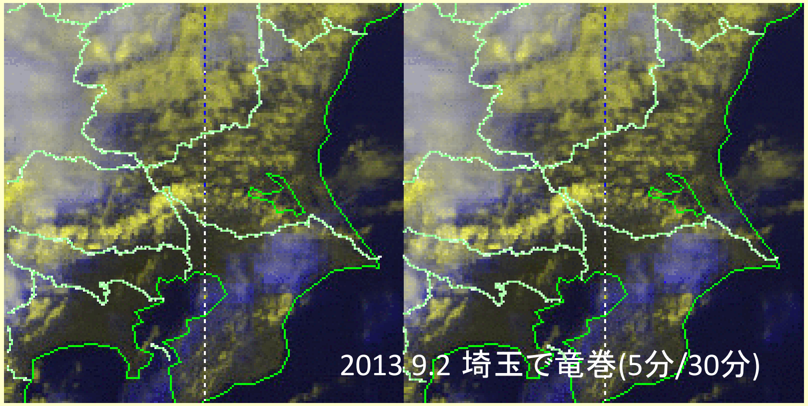
Five receiver sets have been installed in the eastern region of the Tokyo metropolitan area to increase the spatial resolution of the GNSS. One of the stations is located on an artificial island in Tokyo Bay

Convection (1)
MTSAT Rapid Scan





Tornado case on 2 Sep. 2013

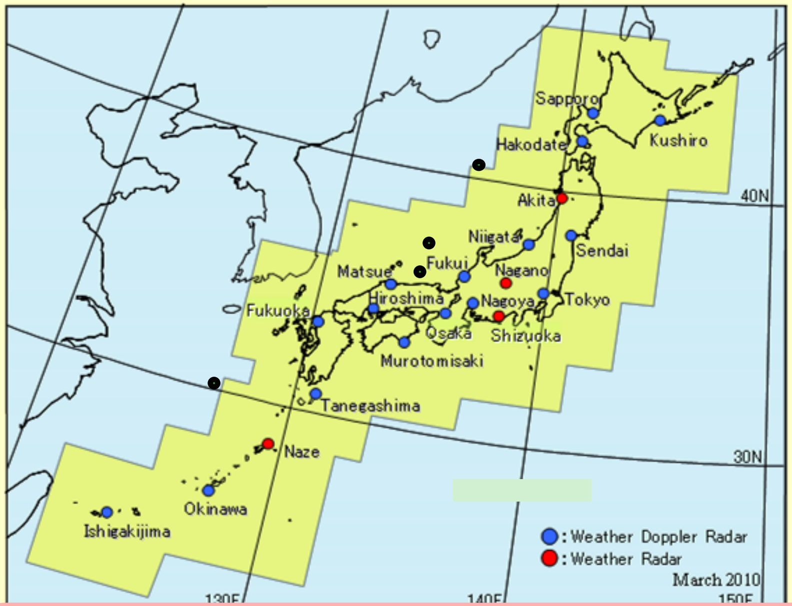


Test operations of JMA Geostationary Satellite (MTSAT; Himawari) rapid scans began in the summer of 2010. Since the summer of 2011, visible and IR images have been captured every 5 minutes.

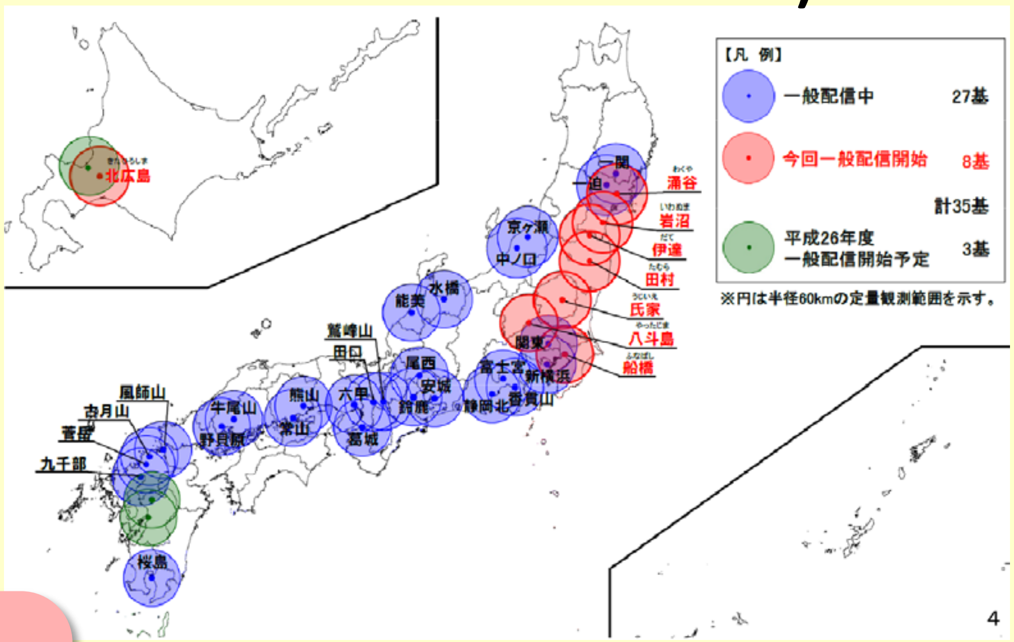
The rapid scan images elucidate rapid development of convection on a tornado case on 2 Sep. 2013.

Convection (2)
Nationwide Radar Network

Doppler weather radar network of JMA



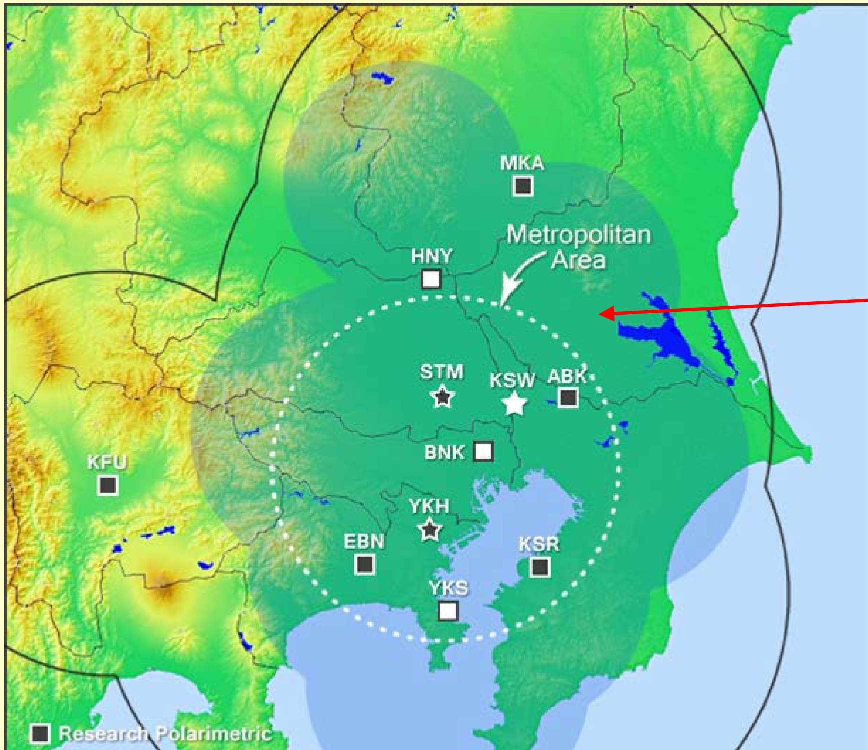
XRAIN
(MLIT's X-band polarimetric Radar Information Network)



JMA operates a network of 20 C-band Doppler weather radars across Japan.
Nine aviation weather offices also operate Doppler radars.

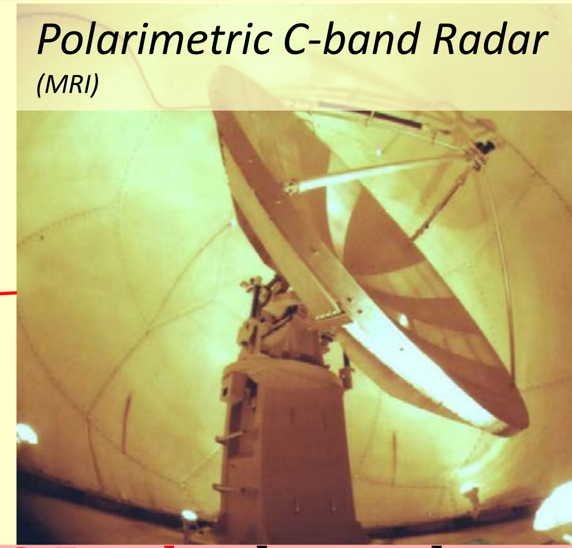
As of November 2013, 35 radars are in the operational phase, and three more will begin their operational tests in 2014.

Convection (3)
Advanced Radar Network



X-NET is an advanced X-band research radar network that has been implemented by the NIED and several universities and research institutes.

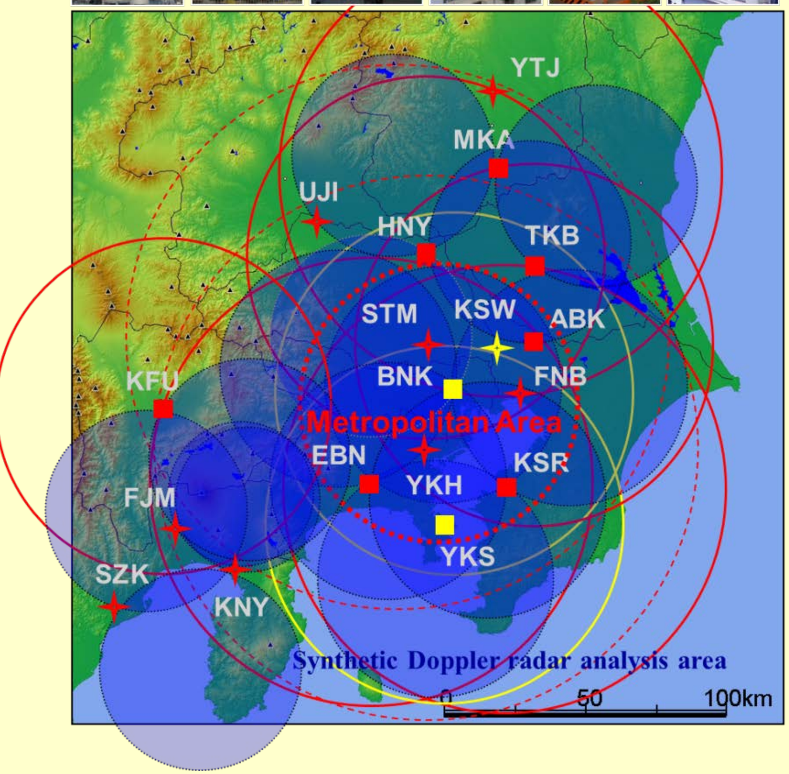
NIED: National Research Institute for Earth Science and Disaster Prevention



Polarimetric C-band Radar
(MRI)

MRI C-Band radar employs two solid-state transmitter units to simultaneously emit horizontally and vertically polarized waves. The high stability of the radio waves generated by the solid-state transmitters enables the radar to make polarimetric observations with high time-resolution and reliability.

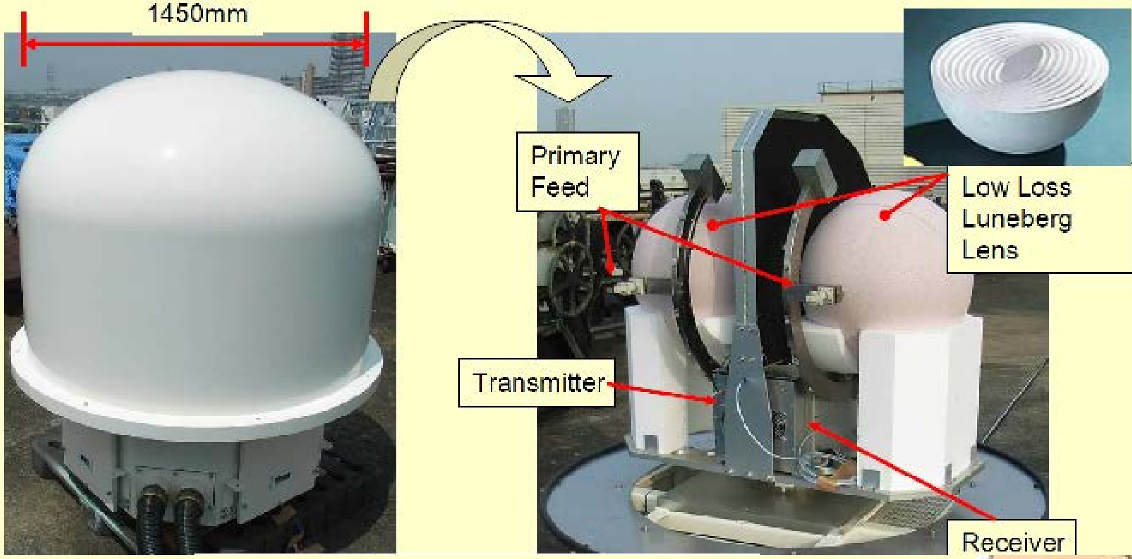
X-NET (X-band Radar Network)

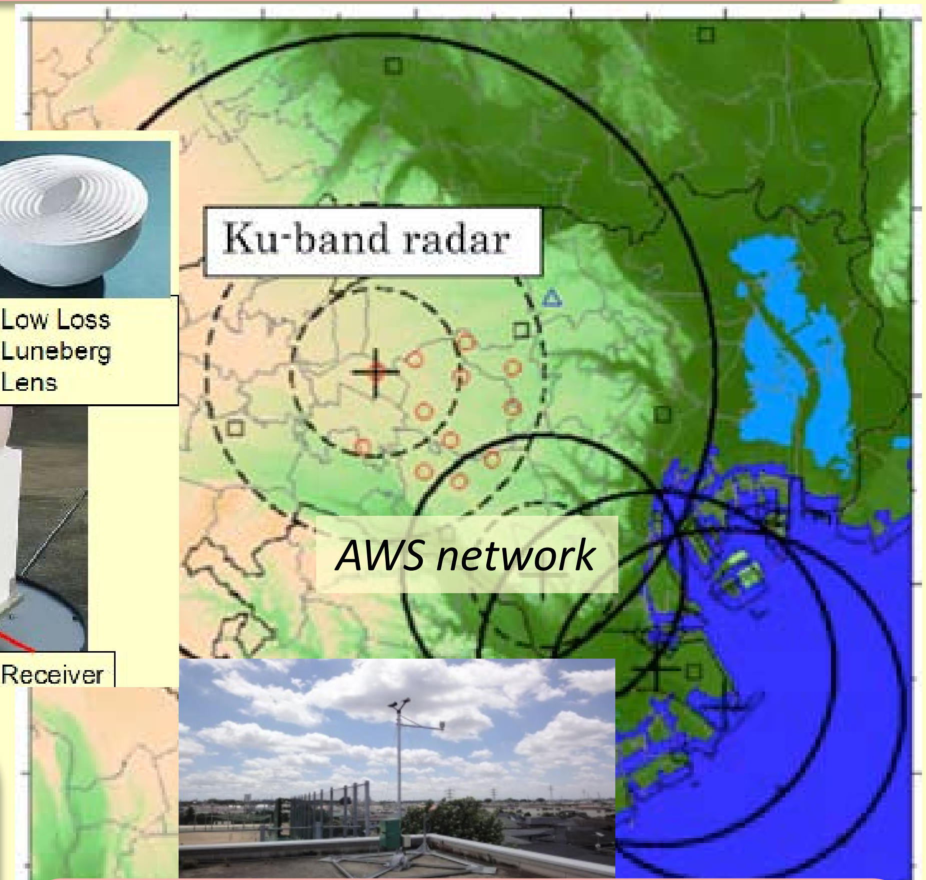


X-NET works operationally to provide input data of Nowcast systems.

Institute	Obs. interval	Num. of elev. angles	Obs. mode
National Defense Academy of Japan	5min.	14	Continuous obs.
Chuo Univ	10min.	14+RHI	Continuous obs.
Yamanashi Univ	5min.	12	Continuous obs.
Central Research Institute of Electric Power Industry	5min.	15	as needed
JWA	5min.	15+RHI	
NIED Ebina	5min.	12+RHI	Continuous obs.
NEID Kisaradu	5min.	12+RHI	Continuous obs.

Convection (4)
Fast-scan Radar and Dense AWS Network





A Ku-band "fast scan" radar was developed by Osaka University and Sumitomo Electric Industries in order to obtain a 3-D structure of a cumulonimbus cloud every 1 min. The radar has been operated at Seikei University in Musashino-shi, Tokyo.

A network of 12 AWS stations with 3 km resolution was set up eastward of the Ku radar observation area.