Observations and numerical simulations for TOMACS urban heavy rainfall cases

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Introduction

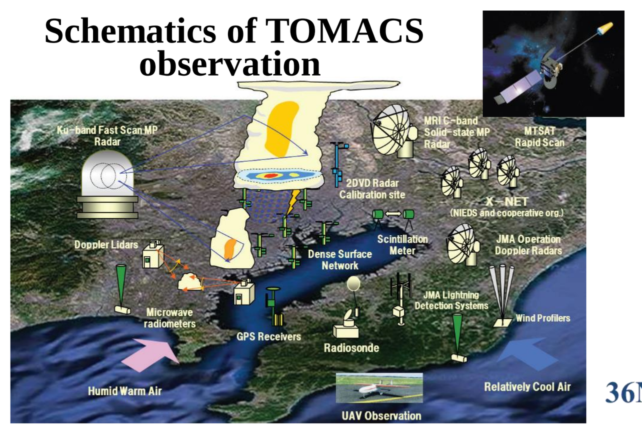
Toward better understanding, monitoring, and prediction of urban severe weather

It is recognized that large cities with populations of several million people are inherently vulnerable to severe weather, such as torrential rain, flash flood, lightning, and tornados. Recent increase in the occurrence of heavy rainfall, which may be due to global warming, can cause extensive damages to large cities. Thus, better understanding, monitoring, and prediction systems of extreme weather is required.

To address these issues, "Tokyo Metropolitan Area Convection Study for Extreme Weather Resilient Cities (TOMACS)" has been launched in 2010. TOMACS aims 1) to understand the processes and mechanisms of extreme weather, using dense meteorological observation networks designed in the Tokyo metropolitan district, 2) to develop monitoring and prediction system of extreme phenomena (MPSEP), and 3) to evaluate efficacy of MPSEP by means of social experiments in collaboration with related government institutions, local governments, private companies, and residents.

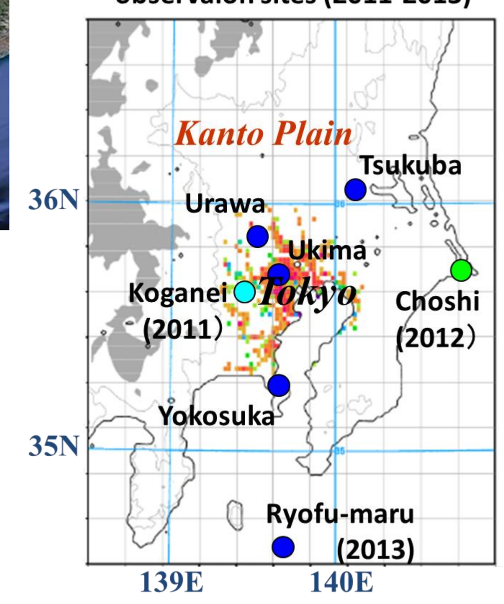
Field campaign of TOMACS has been conducted in 2011-2013 (mainly summer seasons) . Activities of convective system in Tokyo and surrounding areas were captured with Radar network, dense AWS and disdrometer network, radiosonde, GPS monitoring network of water vapor, and urban surface flux monitoring using scintillometer, as well as operational observation system of the Japan Meteorological Agency (JMA). TOMACS has been endorsed as Research and Development Project (RDP, 2013-2016) of the World Weather Research Programme (WWRP) of the World Meteorological Organization (WMO).

Schematics of TOMACS observation



In the present study, we investigated two cases of thunderstorm developed in Tokyo. Intensity and spatial extension of precipitation were quite different between the two cases. Formation processes of convective systems and vertical profiles of temperature/moisture were examined using data of conventional observation, radiosonde soundings , and numerical simulations using Non-hydrostatic model (NHM, Saito et al., 2006) of JMA with 2 km grid spacing.

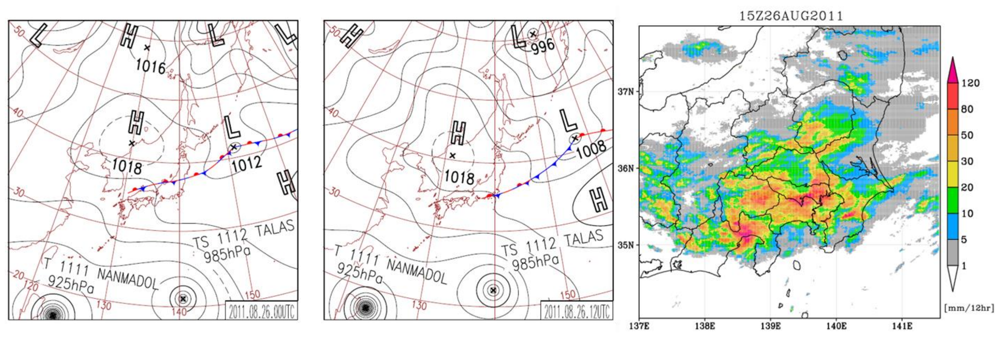
TOMACS radiosonde observaion sites (2011-2013)

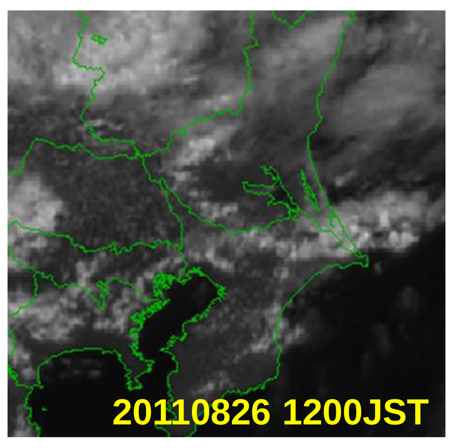


Results

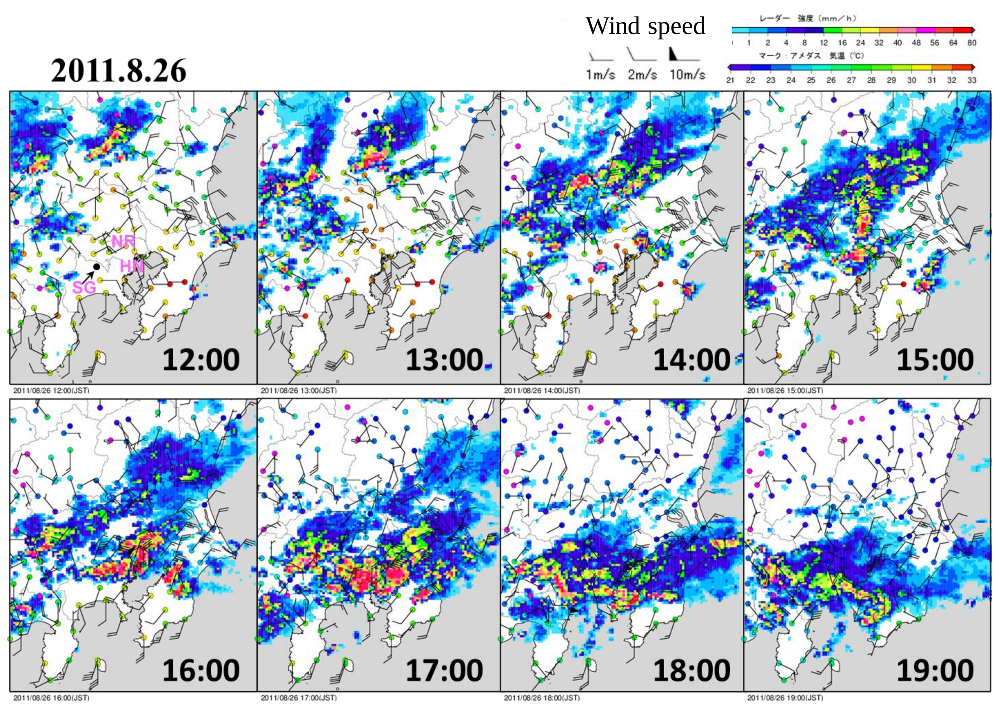
Observation

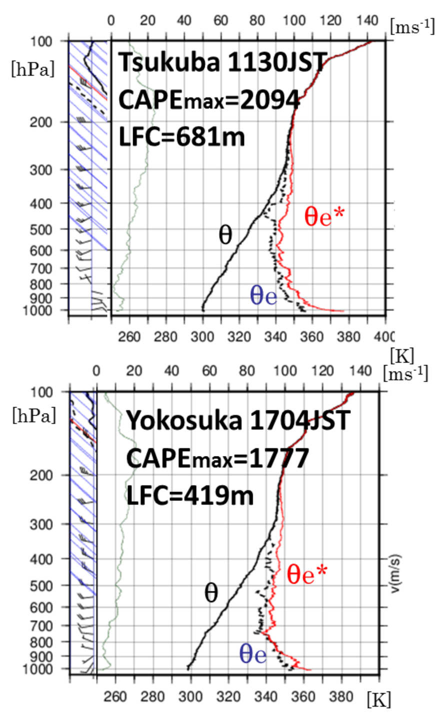
Case1 26 August 2011



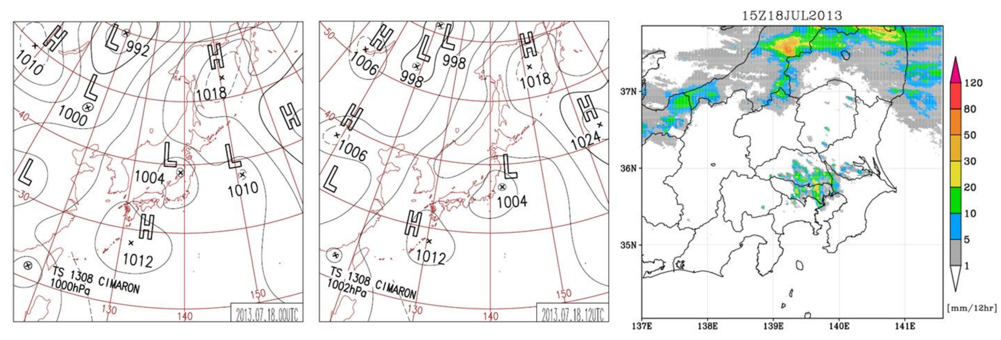


- One of the severest thunderstorms in the TOMACS observation period
- Hourly precipitation: 94mm/hr at Sagamihara (SG in the figure below), 90.5 mm/hr at Nerima(NR), 82 mm/hr at Haneda(HN) at around 1600JST
- GMS rapid scan captured formation of arc-shaped cloud at the leading edge of easterly flow

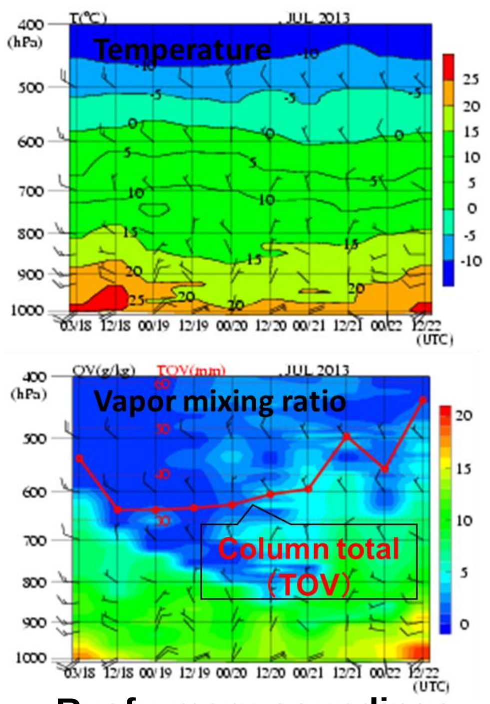




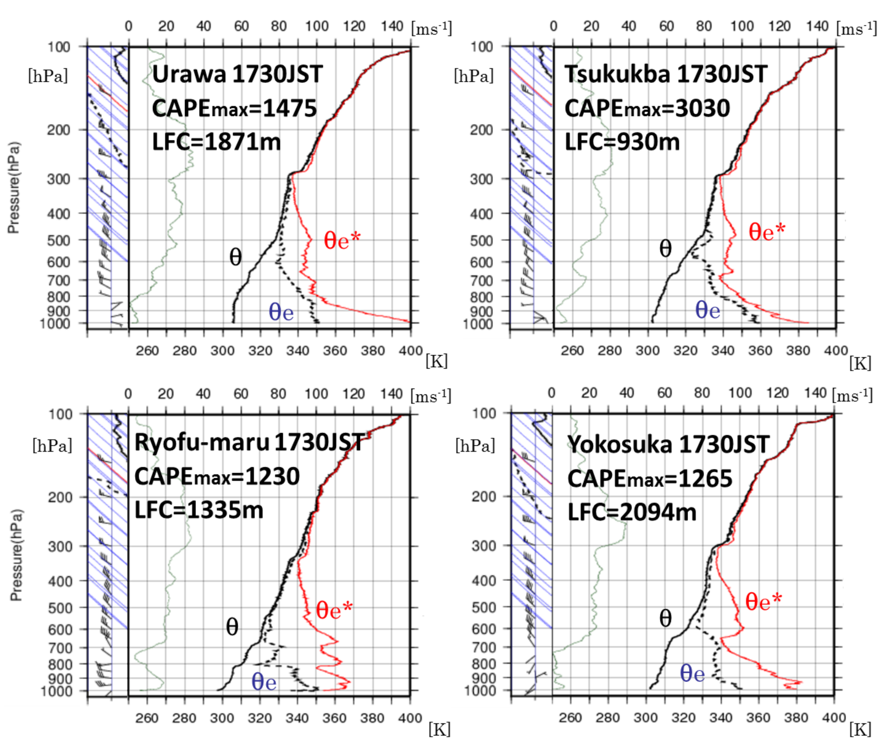
Case2 18 July 2013

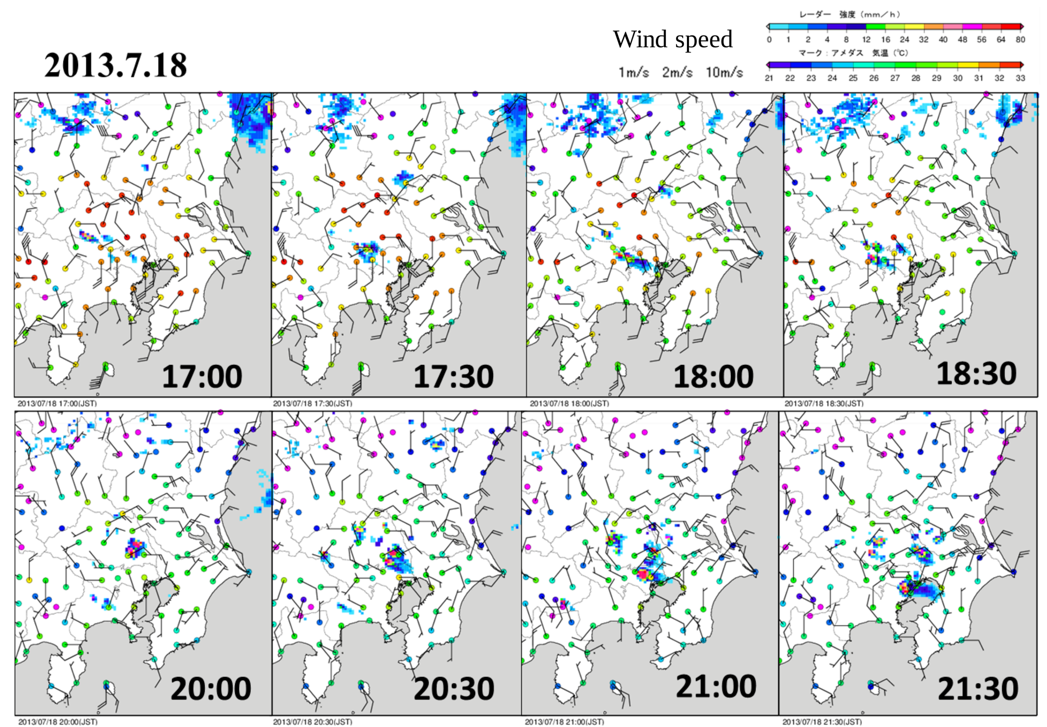


- Both precipitation amount and area were smaller than in case1
- Maximum daily precipitation in Tokyo area was 50mm/day (Radar-raingauge analysis)
- Five-days upper-air soundings at JMA Ryofu-maru observation ship to the south of Tokyo revealed increase in water vapor in (or prior to) precipitation events



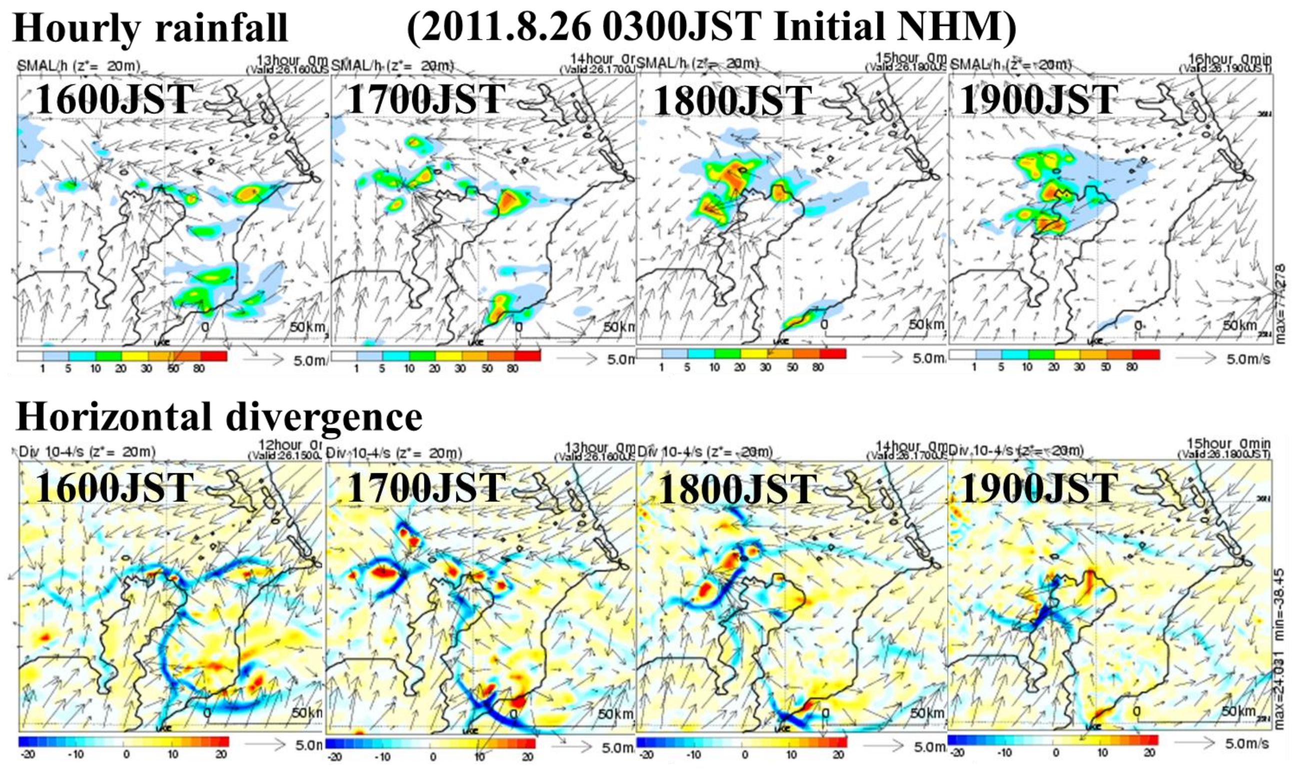
Ryofu-maru soundings





Simulation

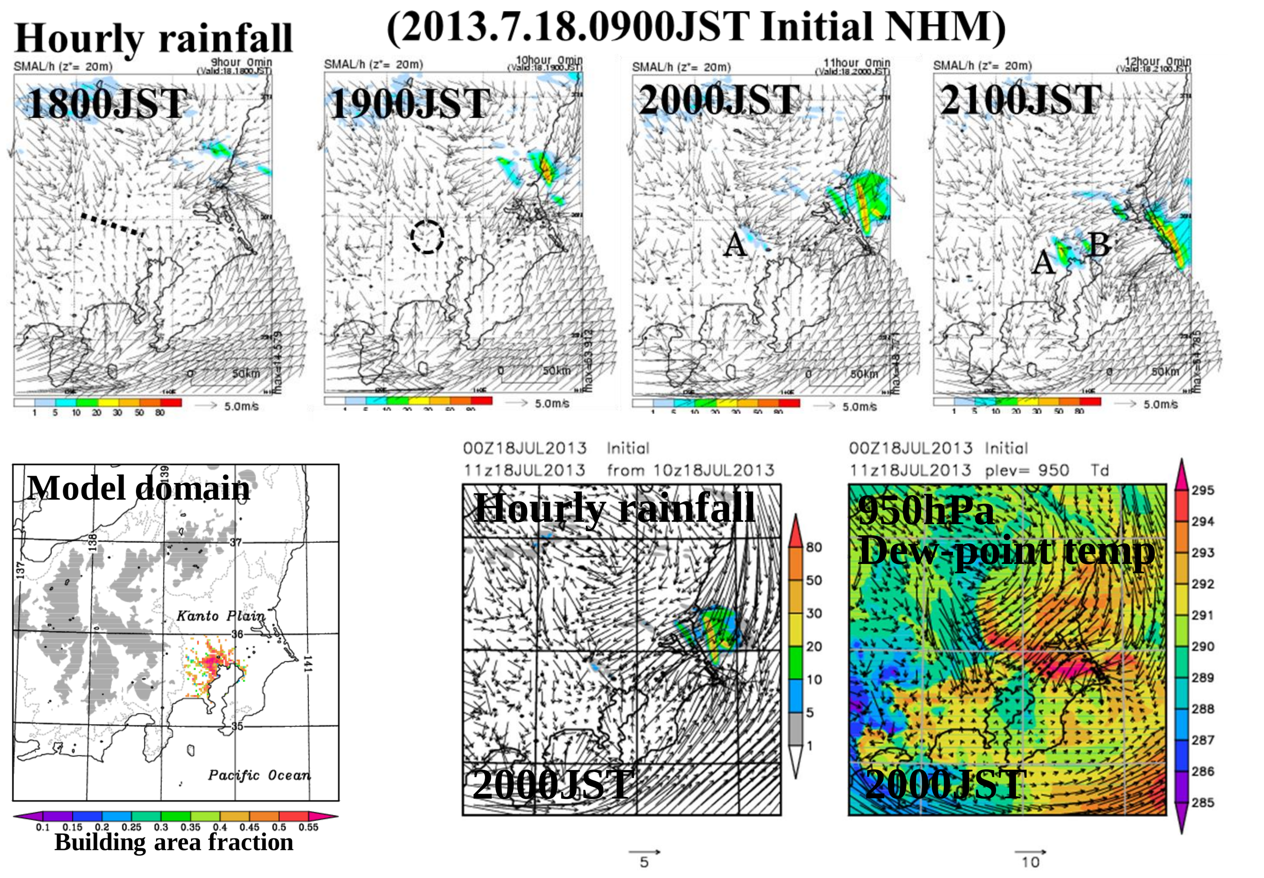
Hourly rainfall (2011.8.26 0300JST Initial NHM)



NHM specifications

Governing equations	Fully compressible, non-hydrostatic
Discretization	Grid point method, z*-coordinate
Treatment of advection	4th order flux form, advection corrected
Map projection	Lambert conformal projection
Topography	GTOPO30
Cloud microphysics	Bulk scheme with ice phase predicting qv, qc, qr, qi, qs, qg
Cumulus parameterization	Not used when DX <= 2 km
Turbulent closure	Improved MY3(Nakanishi and Niino, 2006)
Cloud radiation	Kitagawa (2000)
Clear sky radiation	Yabu, Murai and Kitagawa (2005)
Clouds in radiation processes	Partial condensation scheme
Surface flux	Beljaars and Holtslag (1991)
Urban canopy	SPUC (Aoyagi and Seino, 2011)

Hourly rainfall (2013.7.18.0900JST Initial NHM)



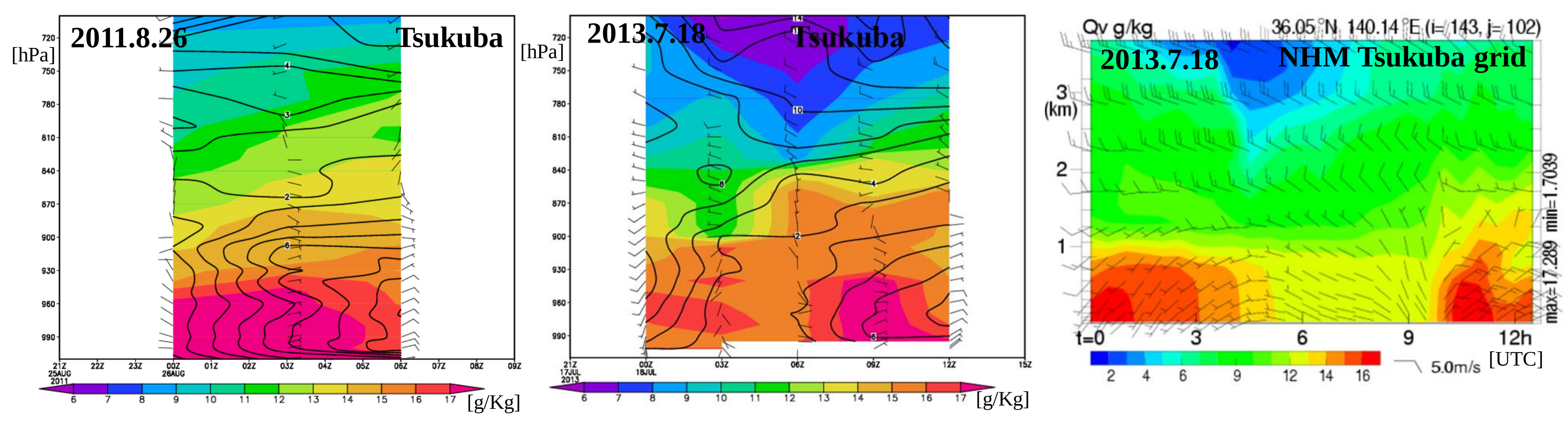
Discussion

Similarities and differences between cases

In both of the two cases, the easterly flow extending from the eastern coast of the Kanto plain plays an important role for the formation of convective cloud in Tokyo and surrounding areas, in addition to the southerly flow developed in the southern part. Fujibe et al.(2002) points out that formation of the easterly and southerly inflow (E-S wind pattern) is one of the suitable conditions for the development of local convective system in Tokyo in summer season. The present observations captured typical structure of the wind field and other atmospheric conditions for the heavy rainfall, including an increase of water vapor content at the head of the easterly flow observed in the 18 July 2013 case.

In these cases, a synoptic stationary front moving southward from the northern part of Japan or a low pressure system passing north of the Kanto region is likely to promote formation of the easterly flow. However, contributions of other possible formation factors, such as cold outflow from proceeding precipitations, should be further examined.

As shown in the right table, stability indices in the 26 August case seem not so extreme compared with the other case. However, thickness of the easterly wind layer was larger and the E-S flow pattern developed earlier, which may lead to the severe thunderstorm.



Comparison of indices (largest/smallest observed)

Index	26AUG2011	18JUL2013
CAPEmax	2090 (Tsukuba)	3030 (Tsukuba)
θe(500m)-θes(500hPa)	-12 (Tsukuba)	-13 (Tsukuba)
LFC [m]	419 (Yokosuka)	884 (Tsukuba)
Surfaceθe(500m)	355 (Yokosuka)	359 (Tsukuba)
Surface temperature [K]	32 (Tokyo)	31 (Tokyo)
Southerly wind speed [m/s]	7.5 (Yokosuka)	6.7 (Yokosuka)
Northerly wind speed [m/s]	7.0 (Tsukuba)	6.9 (Tsukuba)
Thickness of northerly wind layer [m]	1813	1130

References

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Acknowledgements

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