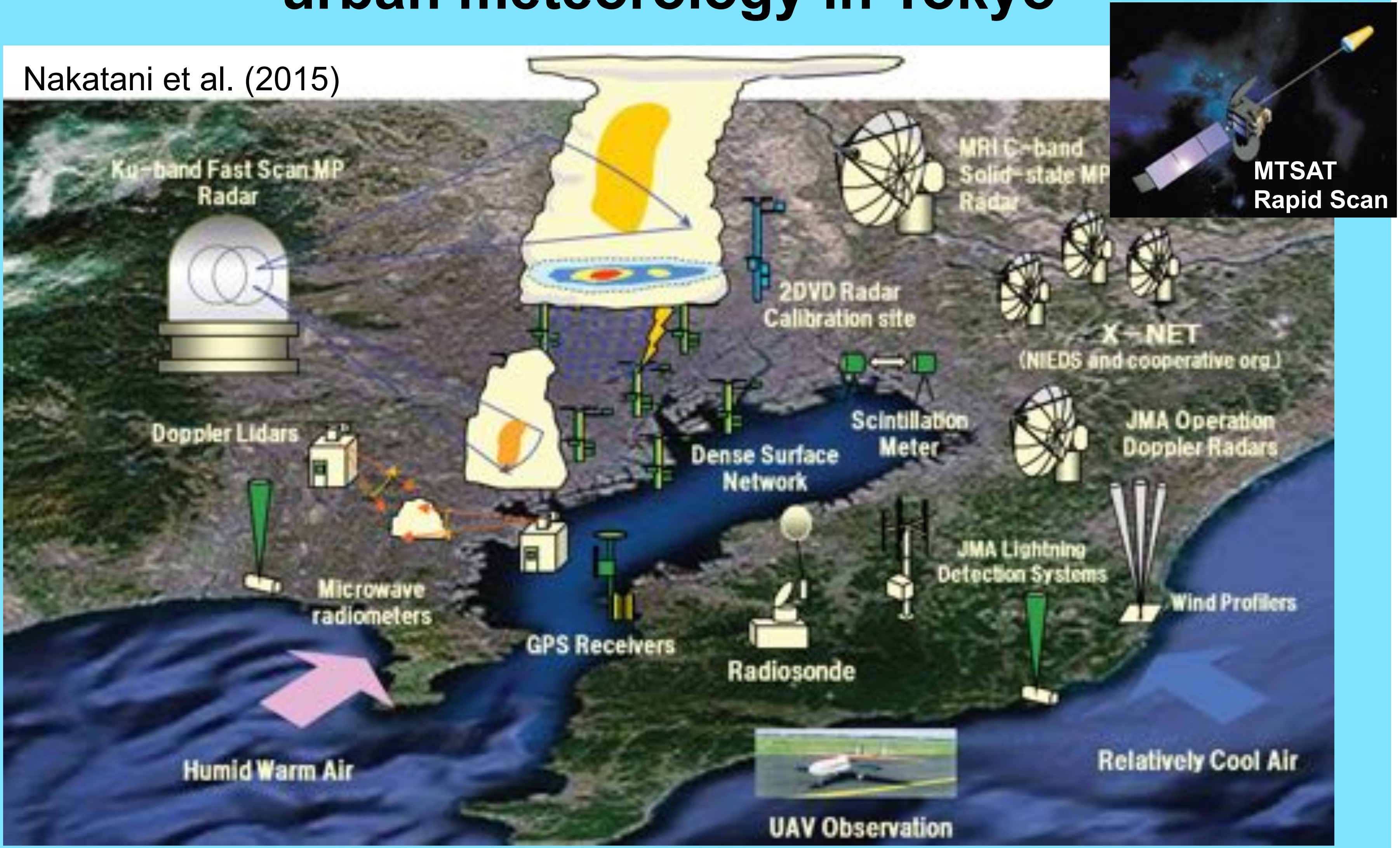
IWAQFR 2017

Observations and numerical modeling study of urban meteorology in Tokyo


Nakatani et al. (2015)

http://mizu.bosai.go.jp/wiki2/wiki.cgi?page=TOMACS

Radiosonde observations in TOMACS

Aim

To capture atmospheric environment of the heavy rainfall in higher space/time resolution than usual

To understand urban boundary-layer processes and its role for the formation and development of convective system

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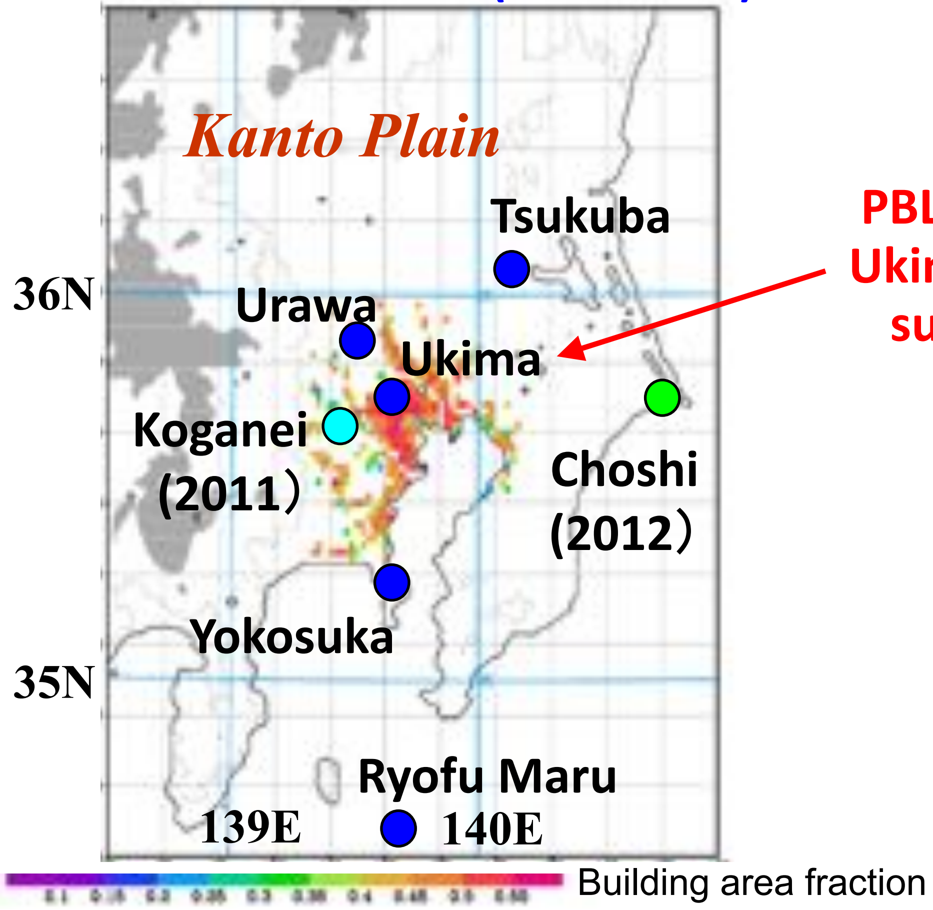
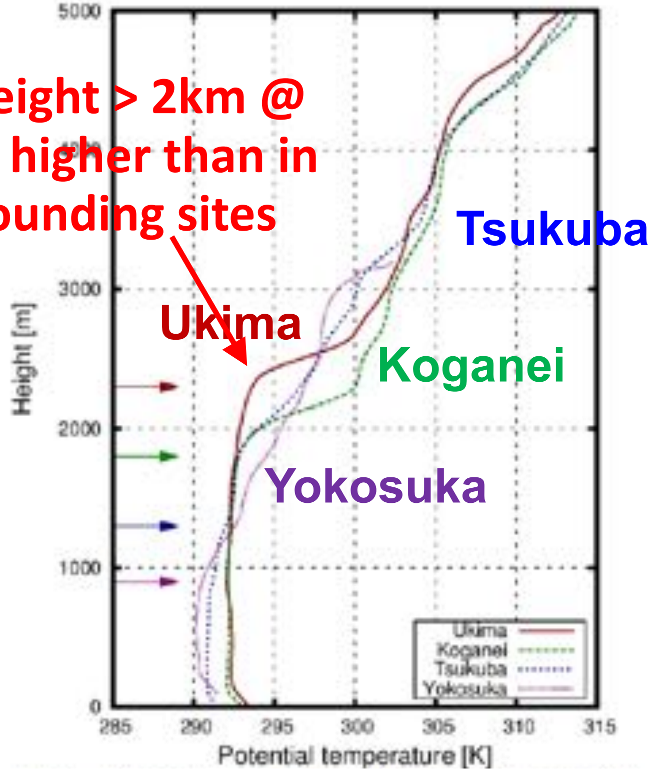
Observation sites (2011-2013)



Potential temperature profile 15JST 4OCT2011 (Sugawara et al., 2015)

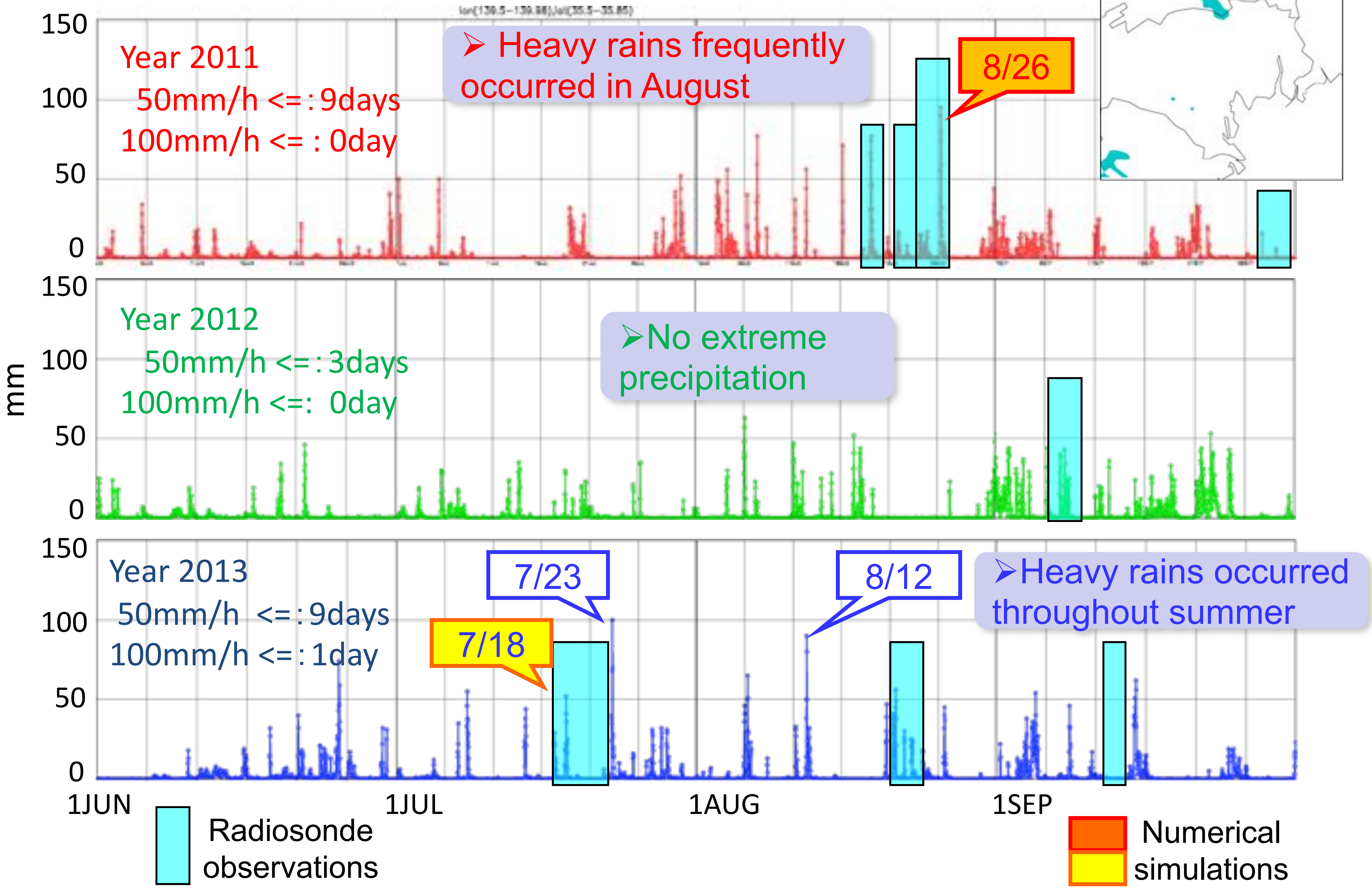


PBL height > 2km @ Ukima higher than in surrounding sites

Heavy rain activities in central Tokyo 2011-2013

Shoji (2017)

Area-maximum hourly precipitation



Year 2011
50mm/h <= : 9days
100mm/h <= : 0day

➢ Heavy rains frequently occurred in August

Year 2012
50mm/h <= : 3days
100mm/h <=: 0day

➢ No extreme precipitation

Year 2013
50mm/h <= : 9days
100mm/h <= : 1day

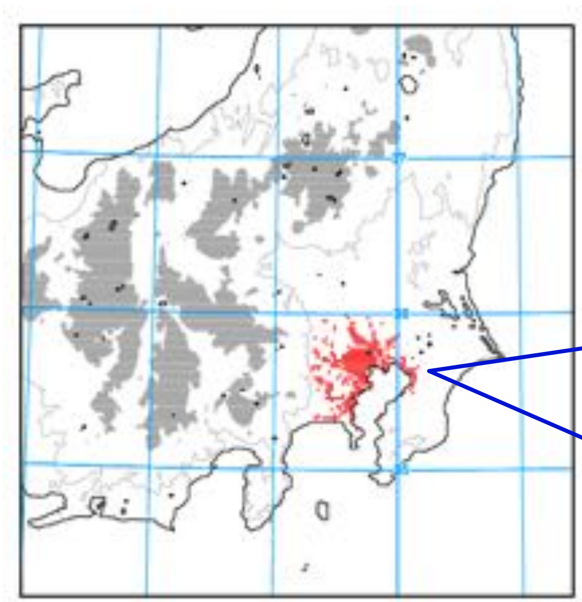
➢ Heavy rains occurred throughout summer

Radiosonde observations

Numerical simulations

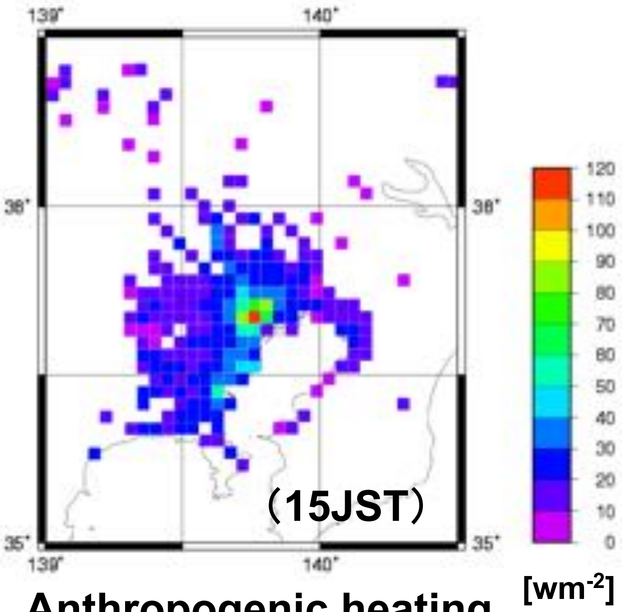
Experimental design

Model：　Non-Hydrostatic Model of JMA (Saito et al. 2006)
　　　　SPUC urban canopy scheme (Aoyagi Seino, 2011)
Initial/Boundary condition：JMA Mesoscale Analyses
Domain：Central Japan dX=2km 200x200x50 grids
Cloud microphysics：Bulk scheme with ice phase
Turbulent closure :　Improved MY3(Nakanishi Niino, 2006)



🟥：SPUC - applied grid

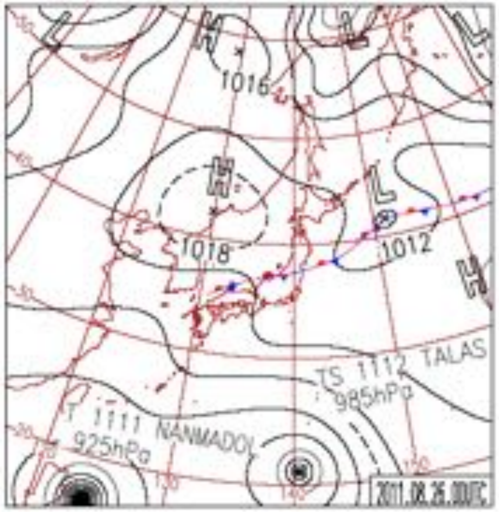
・SPUC is worked at grids where more than 80% of the grid area is categorized into urbanized land use

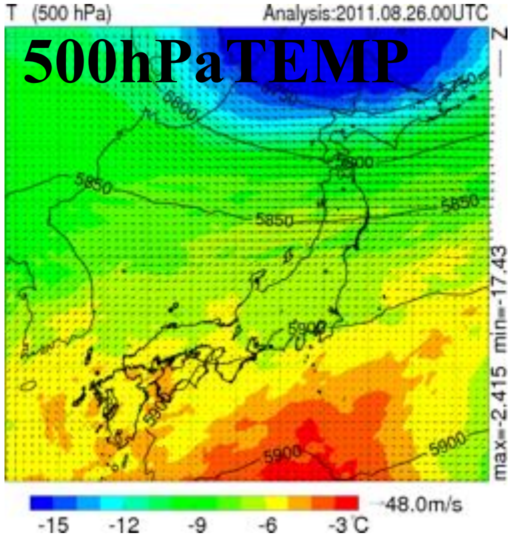


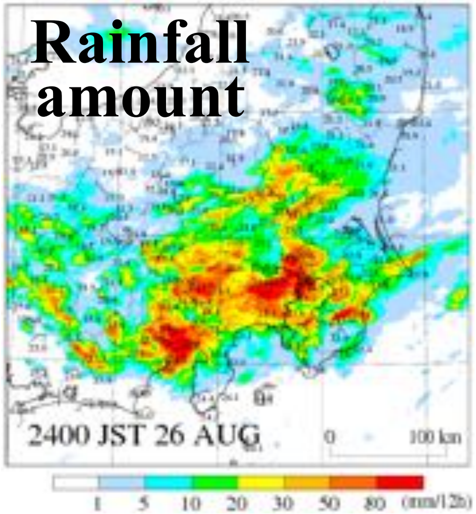
Anthropogenic heating
(Senoo et al., 2004)

Synoptic overview in two heavy rain events in Tokyo

26AUG 2011

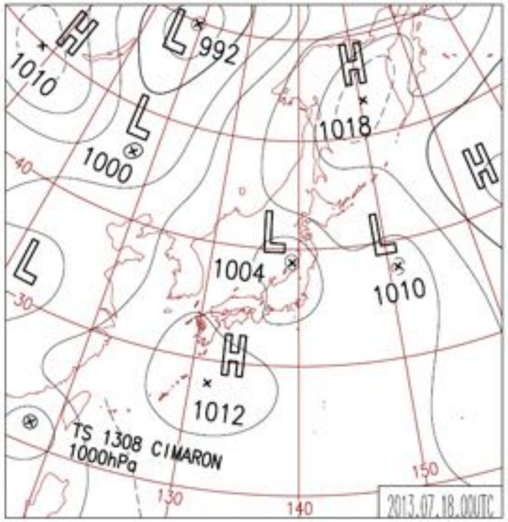


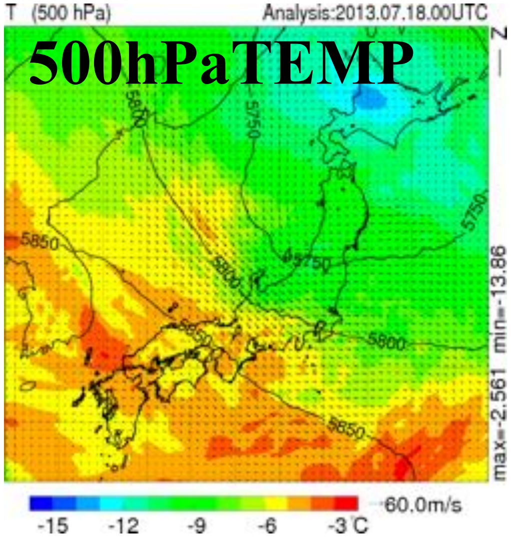


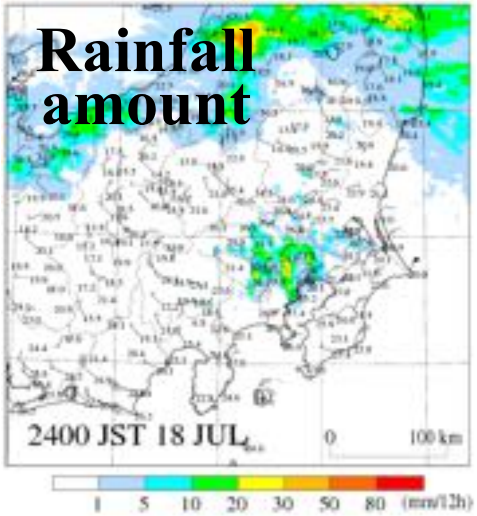


Extremely severe storm in wide area

18JUL 2013

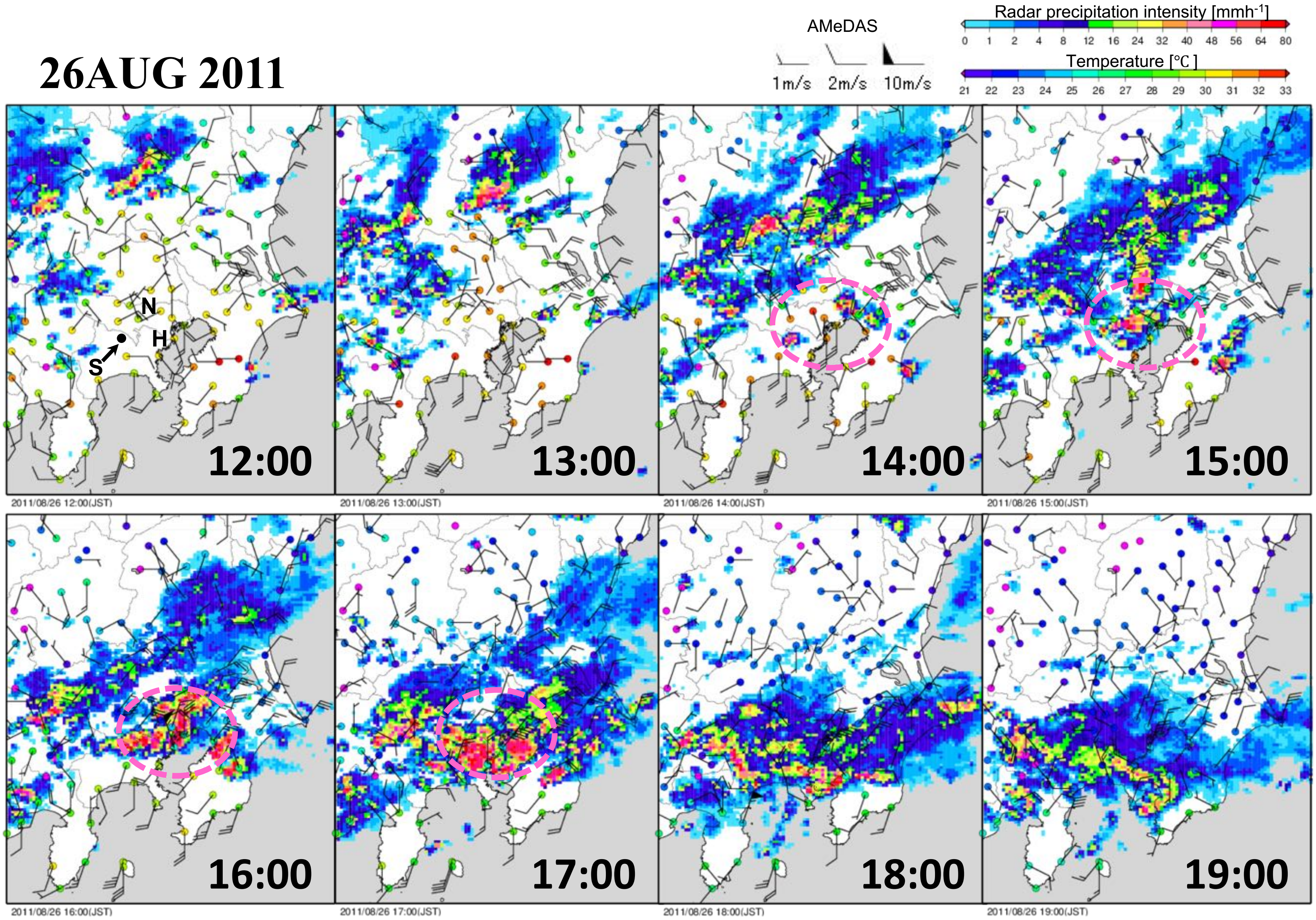




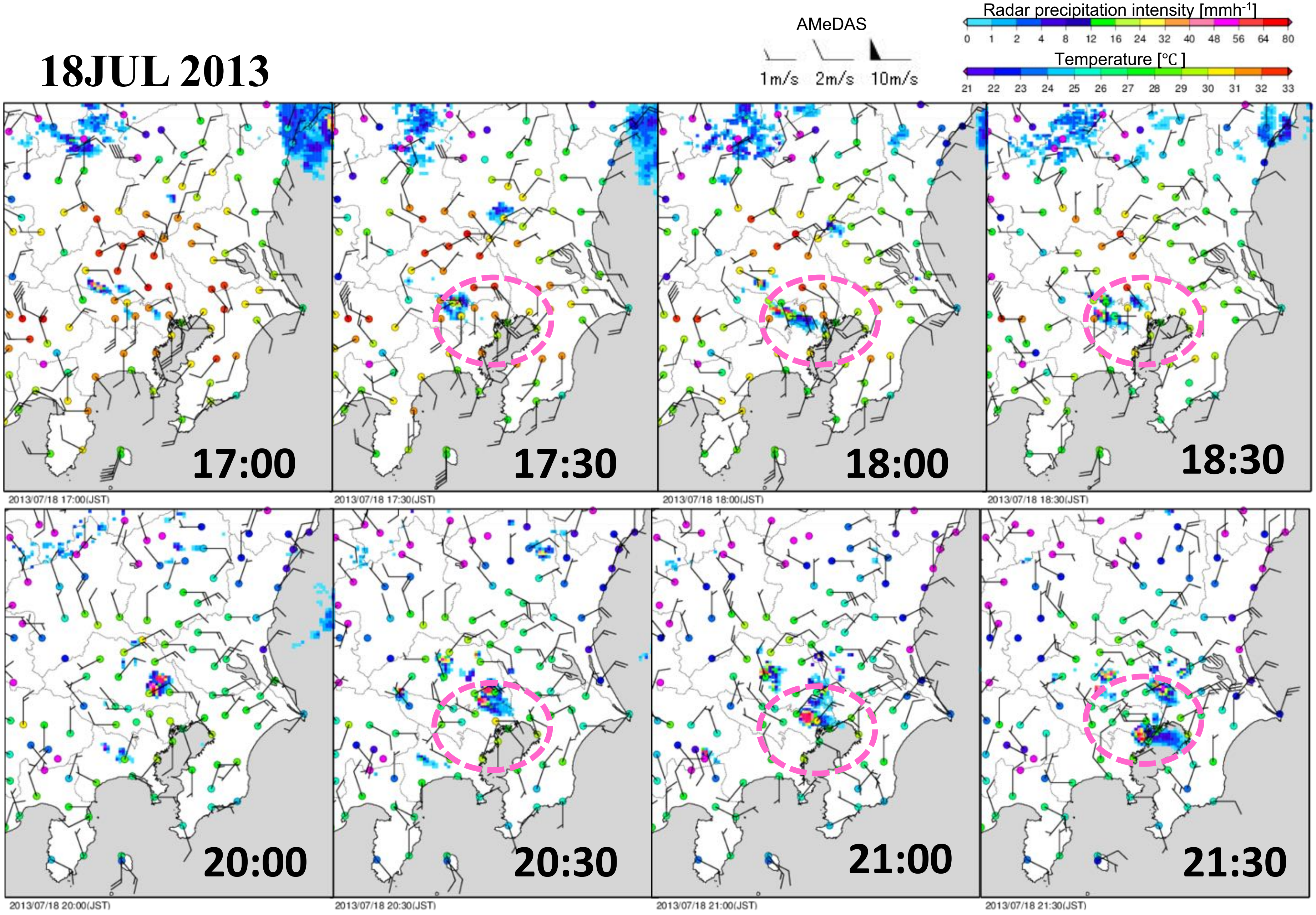


Thunder-storm in limited area

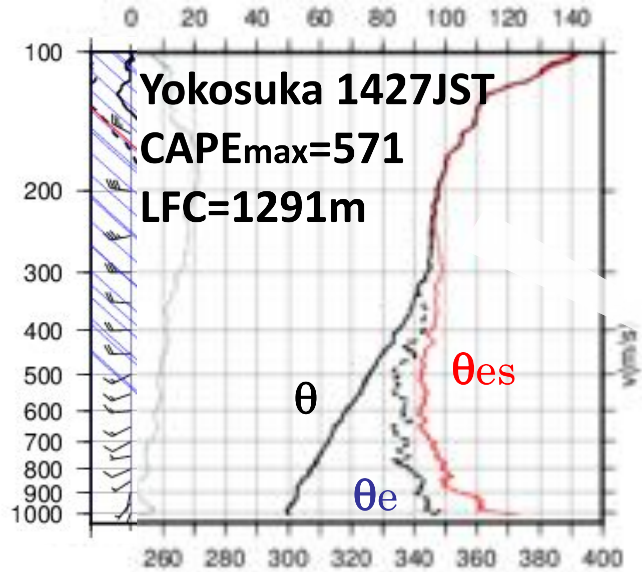
Surface and Radar observations 26 August 2011

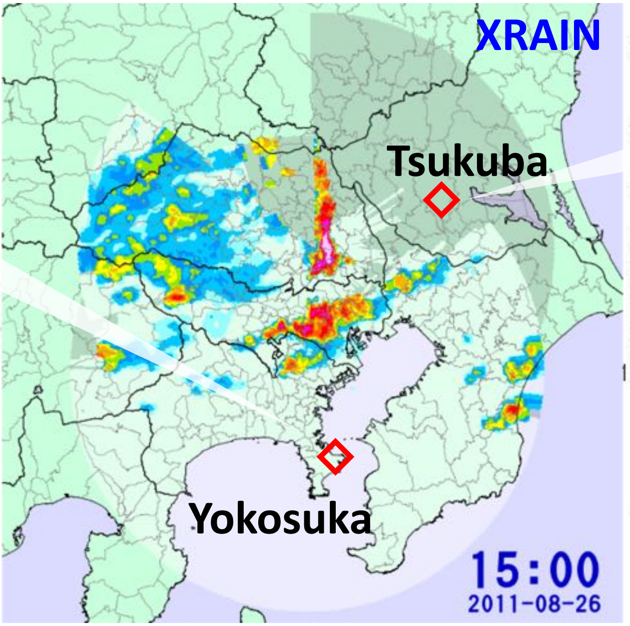


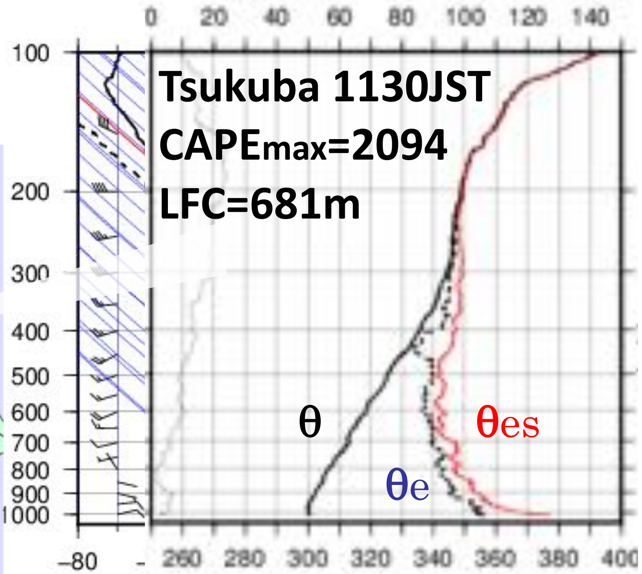
Surface and Radar observations 18 July 2013

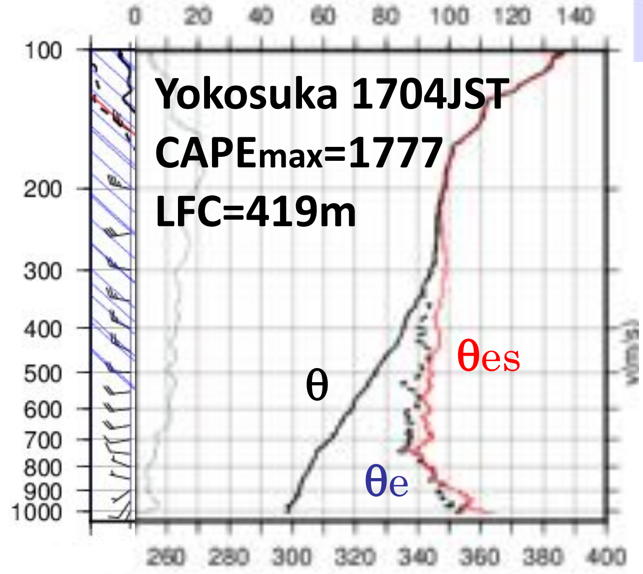


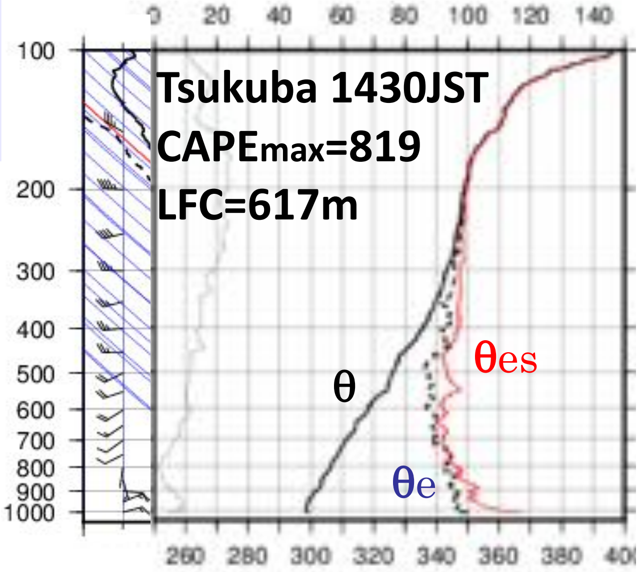
26 August 2011 severe storm case







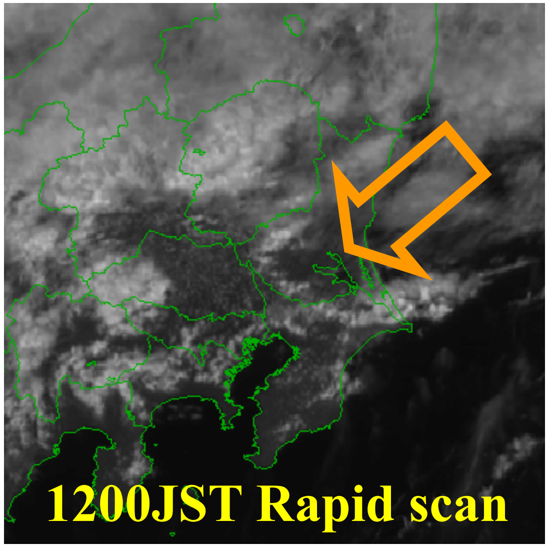


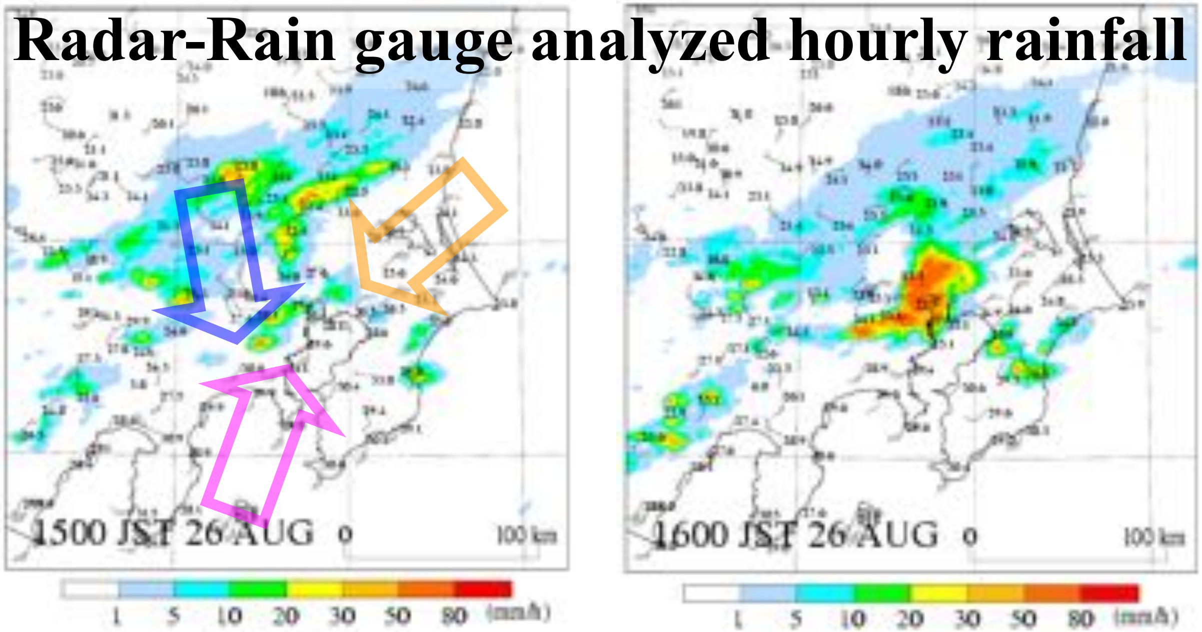


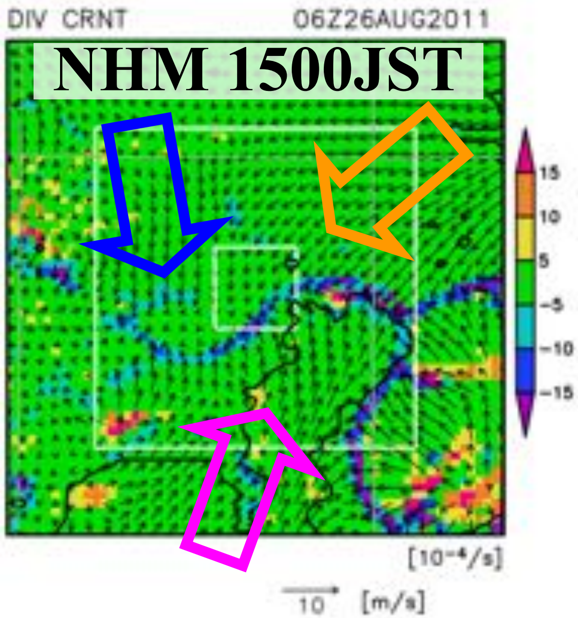
In this case, radiosonde observations took place at two sites: Tsukuba to the northeast of Tokyo and Yokosuka to the south of Tokyo, and environmental conditions for the storm formation were obtained.

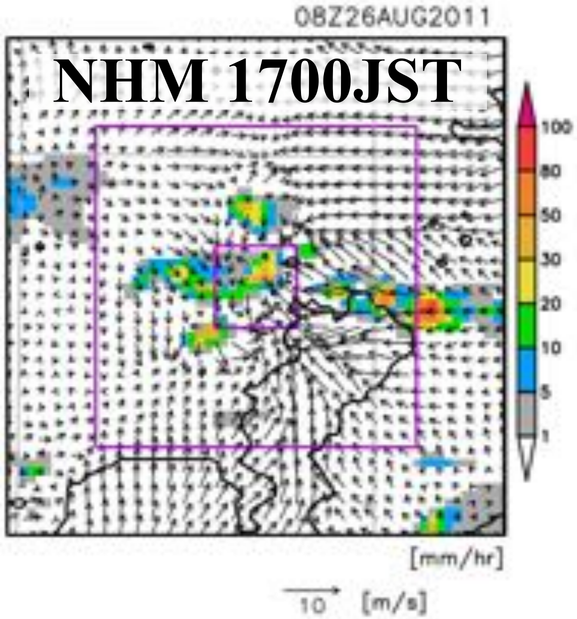
Soundings at Tsukuba show that a stability index CAPE was high at around noon and decreased later.
On the other hand, at Yokosuka, CAPE increased in the evening.

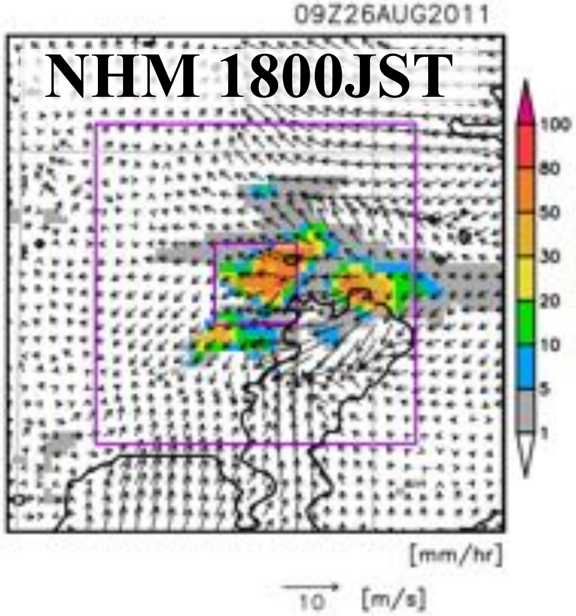
26 August 2011：Mesoscale flow structure


1200JST Rapid scan


Radar-Rain gauge analyzed hourly rainfall


NHM 1500JST

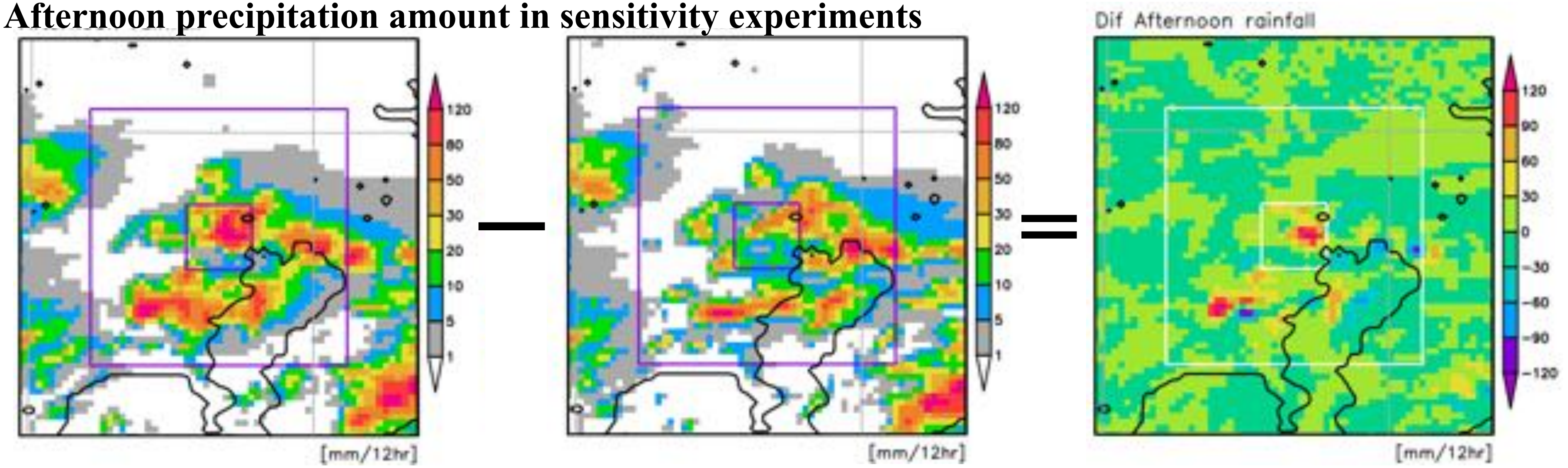

NHM 1700JST


NHM 1800JST

26 August 2011: Impact of urbanization

Current urban (Highly-urbanized)　　**Less-urbanized**　　**Difference**

Afternoon precipitation amount in sensitivity experiments



One of the questions in urban climate is how the urban processes and urban heat island influence on the rainfall in this big city.

To investigate the point, virtually less-urbanized experiment has been carried out, in addition to the current urban experiment, and the simulated precipitations were compared.

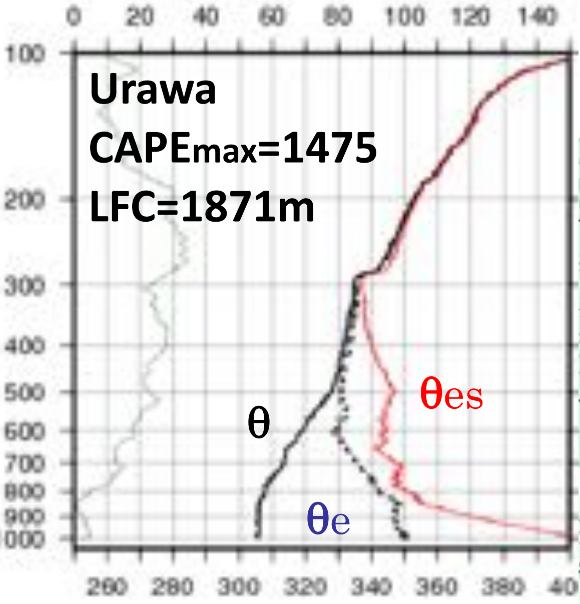
⬇

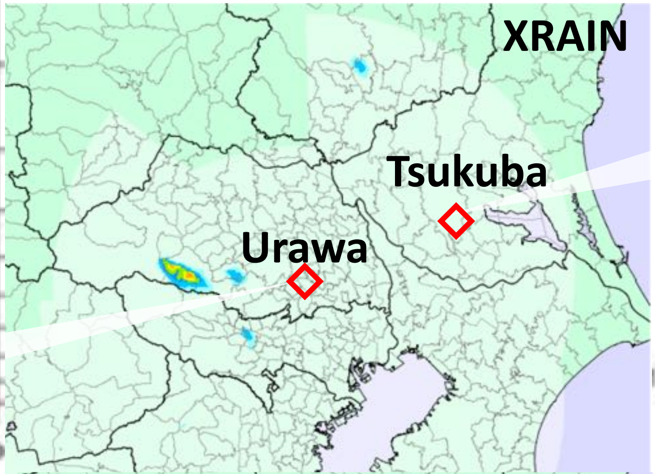
Current urban experiment resulted in a larger amount of rainfall in the central Tokyo area.

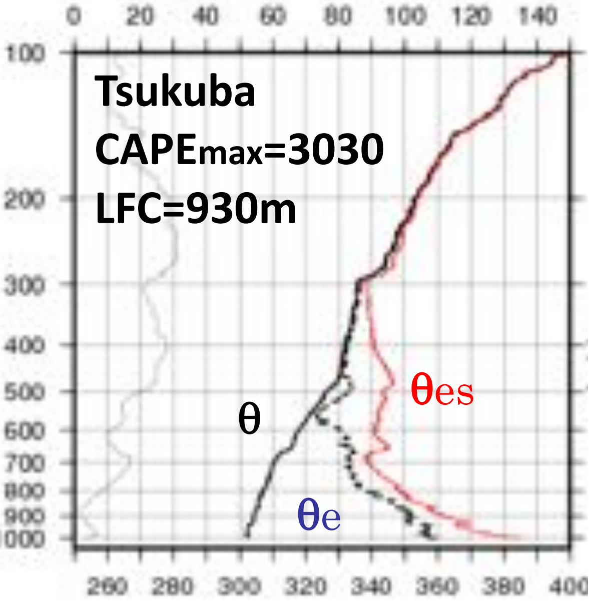
Further comparison with the two experiments suggests that the intensified convergence and ascending motion due to urban temperature rise can cause precipitation increase in central Tokyo.

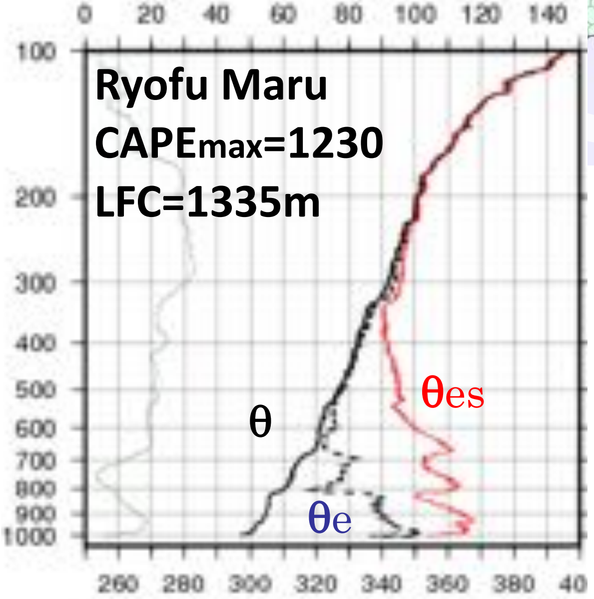
18 July 2013 case

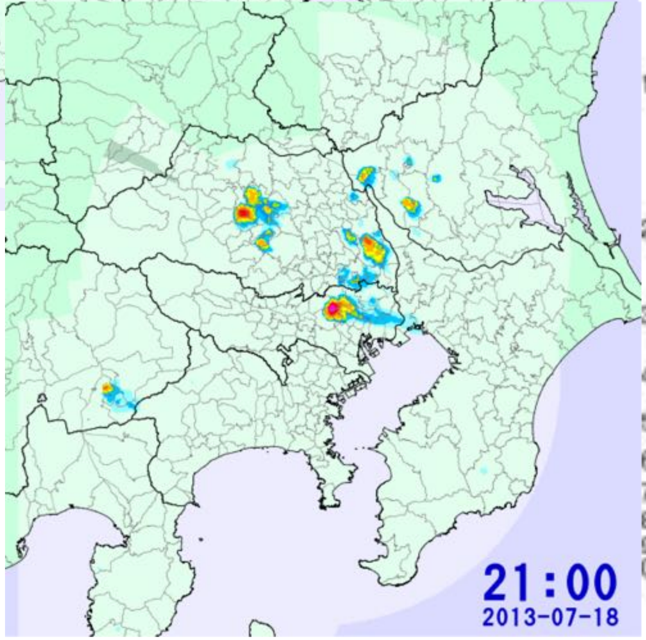
18JST 18July 2013 soundings

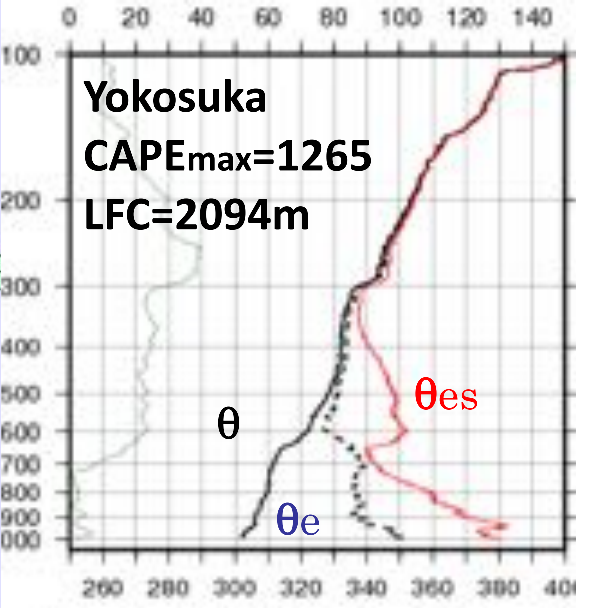






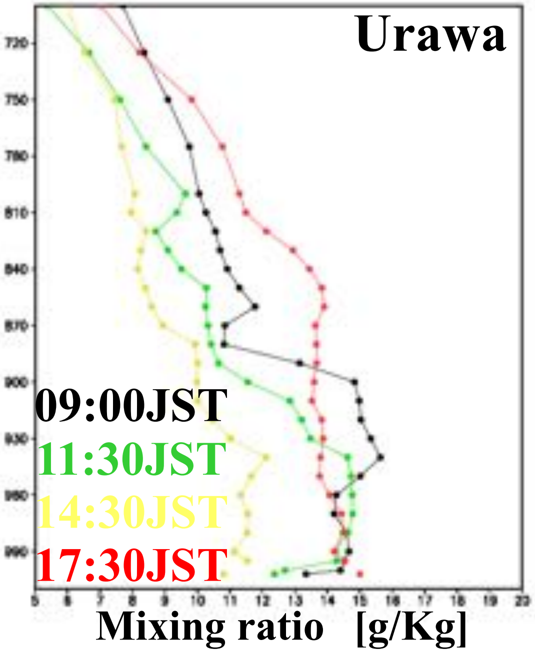


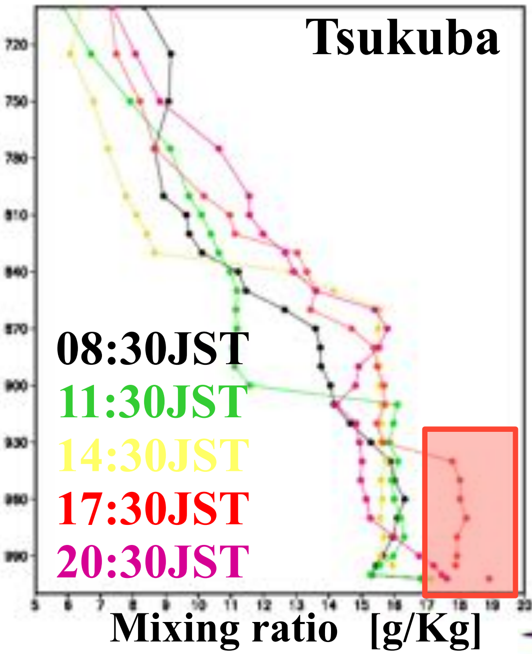


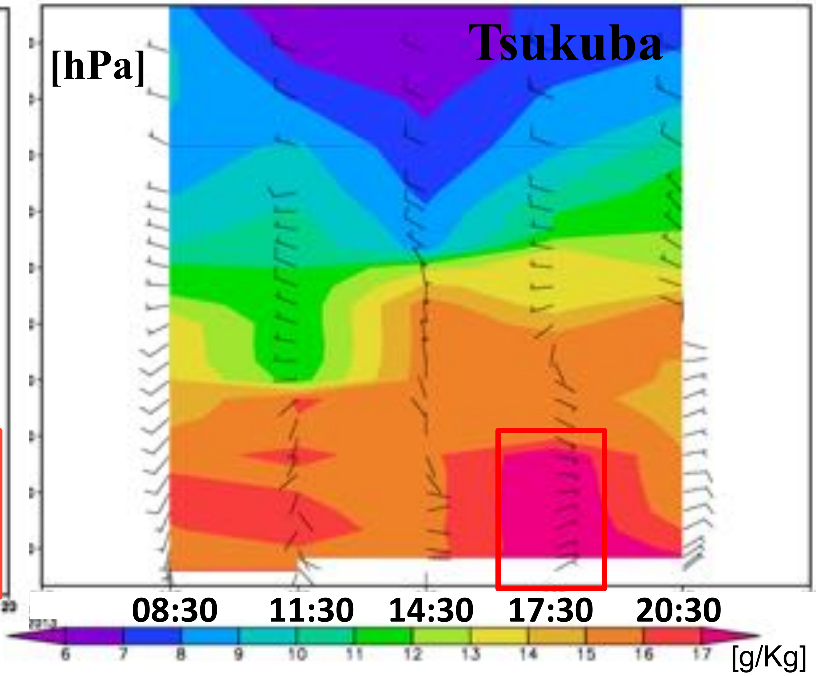


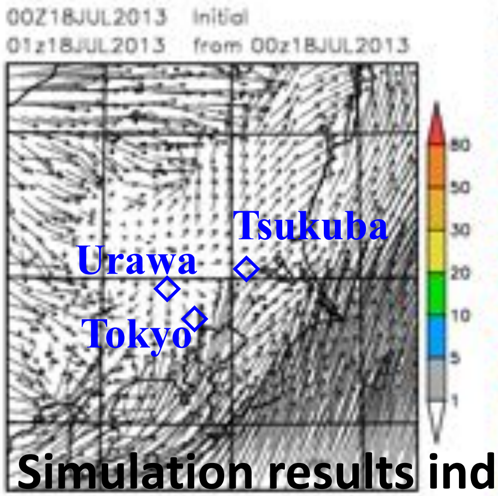
Low-level wind and moisture variation 18JUL2013

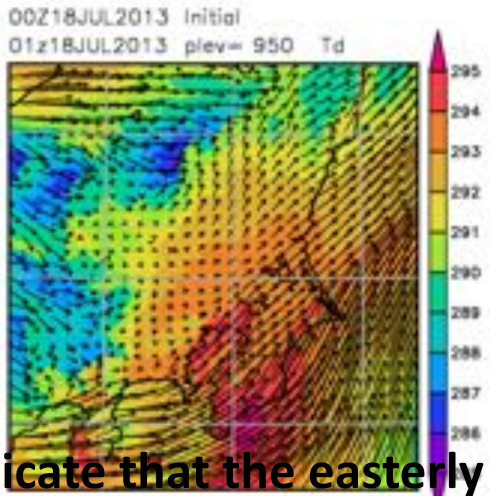
Observed profiles of vapor mixing ratio and time-height section











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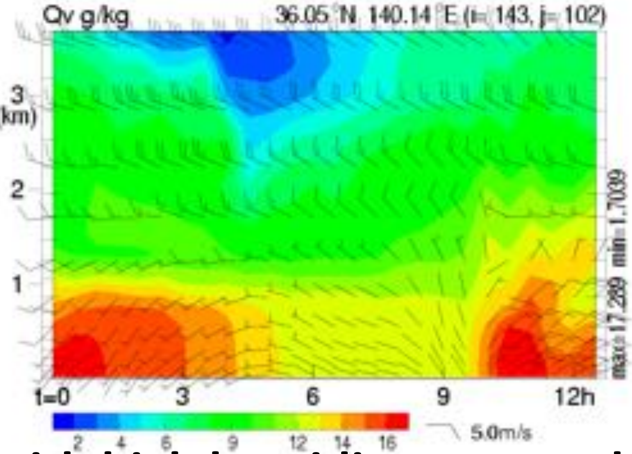
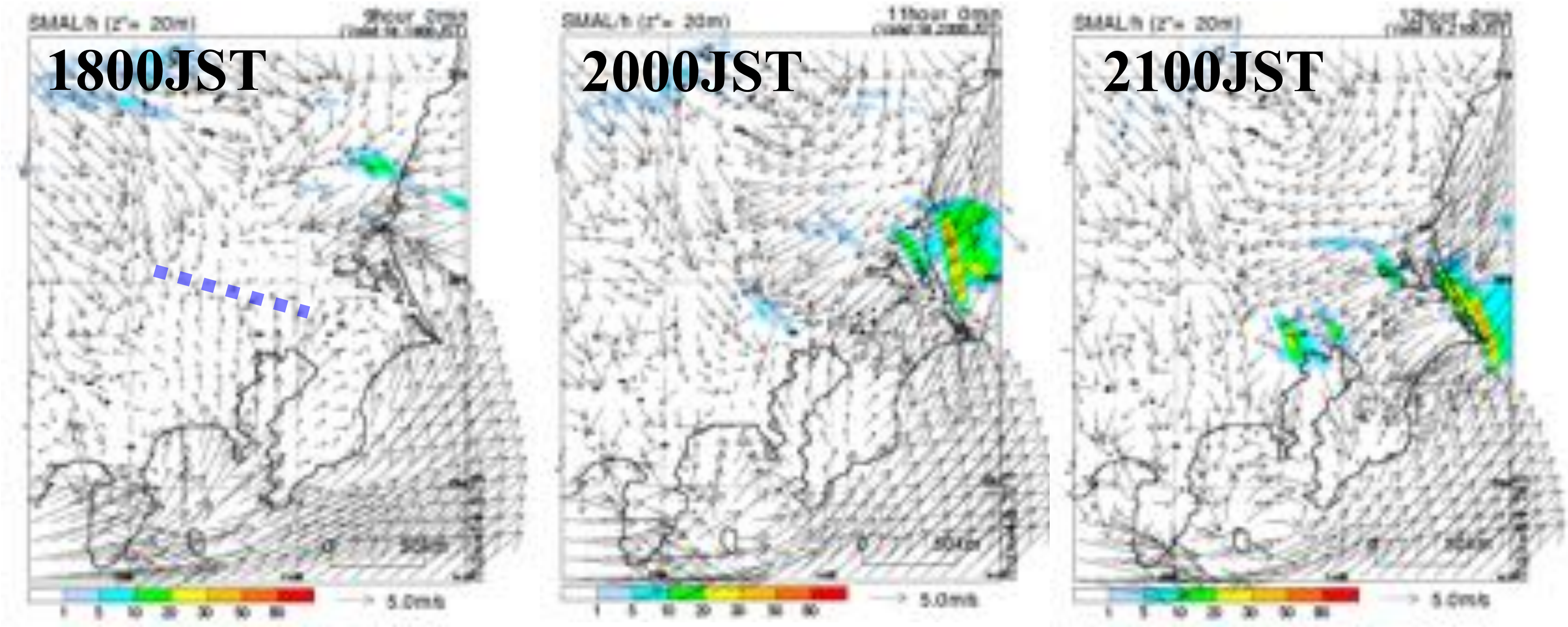


Simulation results indicate that the easterly flow with high humidity zone at the leading edge passed over Tsukuba in the evening and approached Tokyo.

Simulation results for 18 July 2013 case

NHM hourly rainfall



Surface wind field was basically well simulated, but onset of evening precipitation near Tokyo was delayed in the model.

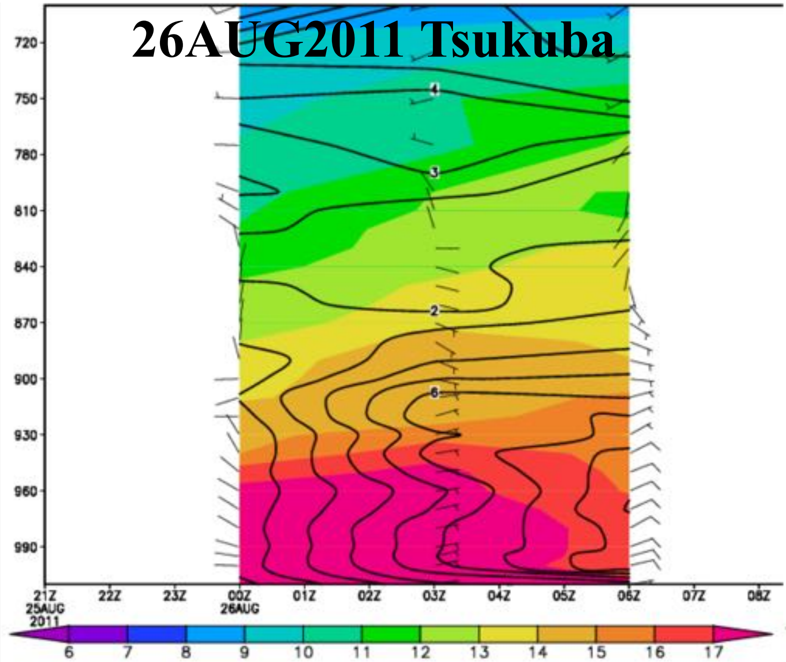
Rainfall in the nighttime was realistically simulated.

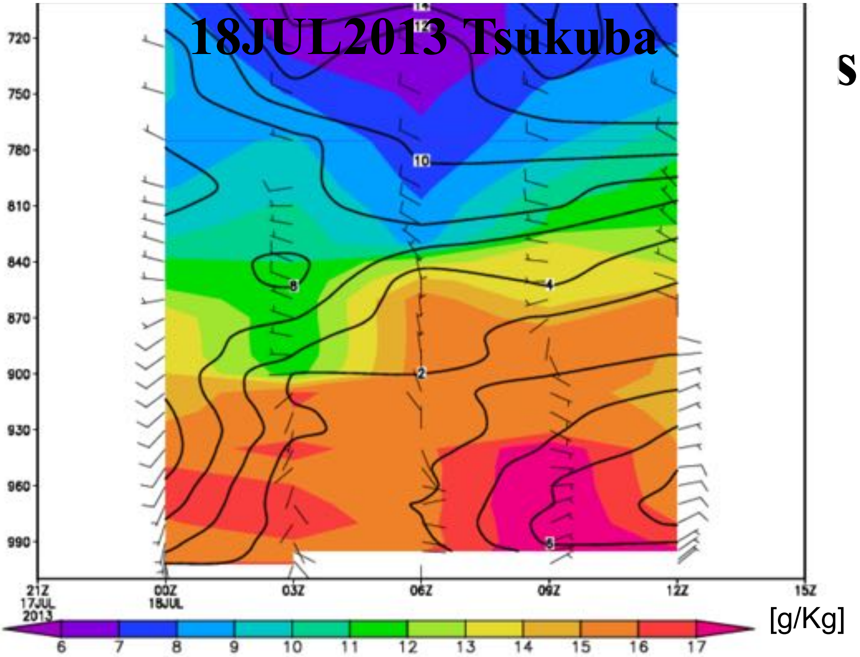
Development of both southerly and easterly inflow was found in this case , as well as in the August 2011 case.

Model results suggest that the extension of the humid easterly contributed to the formation of the nighttime thunderstorm.

Comparison between the two cases

To discuss what was extreme in the 26AUG2011 case, several indices in the two cases evaluated from the observation are summarized in this table





Easterly wind speed [m/s]	7.0 (Tsukuba)	6.9 (Tsukuba)
Thickness of easterly layer [m]	1813	1130
Relative humidity (500hPa) [%]	75(Yokosuka)	38 (Tsukuba)

Since model results show that the convergence between mesoscale inflow triggered cloud formation in Tokyo, greater thickness of the easterly inflow may play a key role for the active convective system development.

However we cannot say so far how extreme the thickness was.

→ Further observations are needed to clarify the variability of the wind field.

Summary

Radiosonde observations and numerical simulations in TOMACS well capture urban boundary-layer structure and atmospheric environmental conditions of convective rainfall events.

Well-developed easterly and southerly inflow leading to distinct convergence characterized the wind field in heavy rainfalls. Evolution of the easterly inflow is likely a key factor for the development of the convective systems.

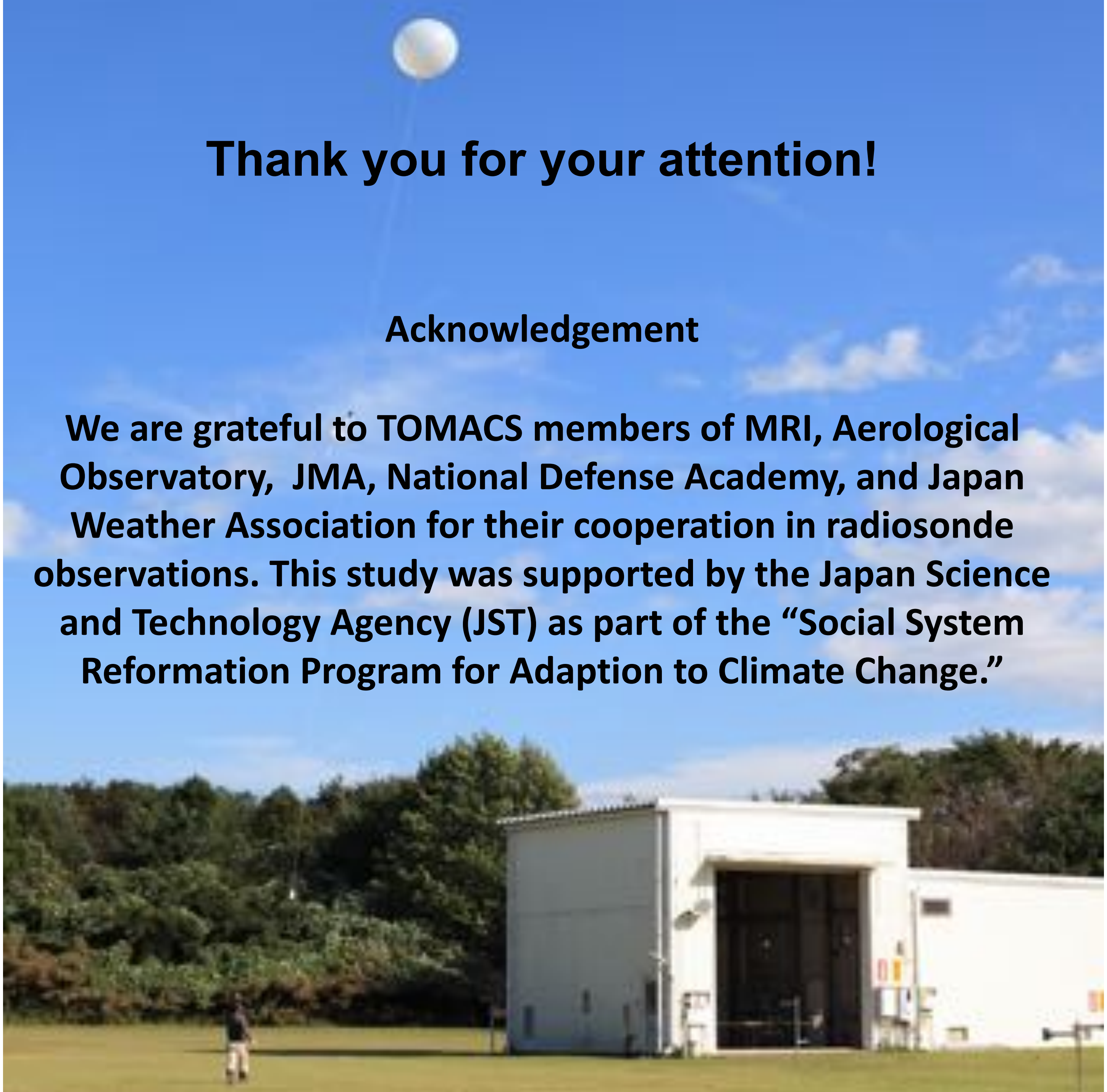
As for urban forcing, simulations suggest that increased urban effect generally intensify the precipitation in Tokyo

Ongoing/future works

Understanding mesoscale wind variability particularly of easterly

Utilizing new assimilation data for improving spatial variability in near-surface humidity (e.g. data obtained by local governments)

Sub-km resolution simulation to understand convective initiation process and for applications for human comfort



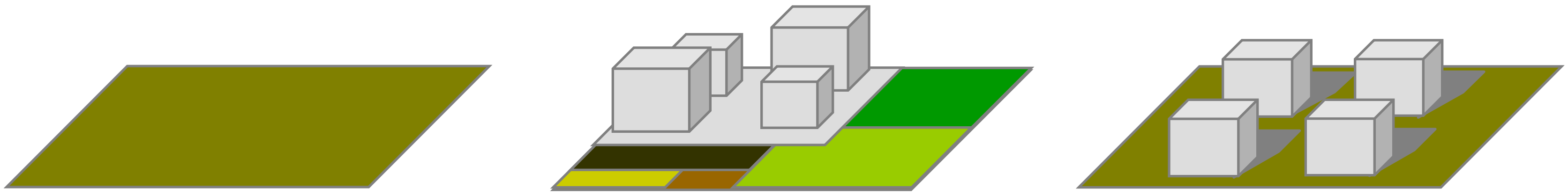
Thank you for your attention!

Acknowledgement

We are grateful to TOMACS members of MRI, Aerological Observatory, JMA, National Defense Academy, and Japan Weather Association for their cooperation in radiosonde observations. This study was supported by the Japan Science and Technology Agency (JST) as part of the "Social System Reformation Program for Adaption to Climate Change."

supplement

Square Prism Urban Canopy scheme



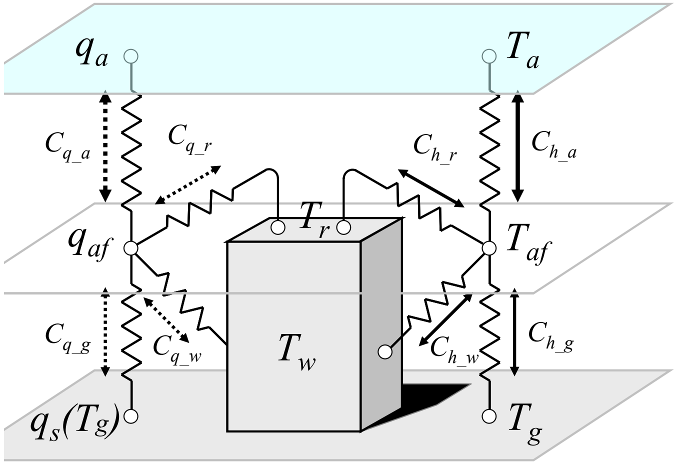
SLAB

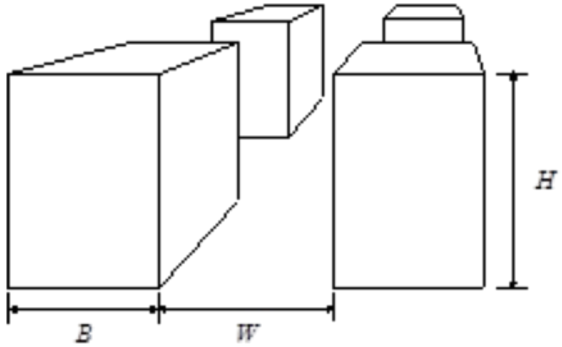
Grid-averaged surface properties based on 100m-mesh 11 categories land-use data

SPUC

Heat, moisture, radiation exchanges between canopy elements and atmosphere are considered

- Regular array of buildings
- Aspect ratio H/B = 0.5 is used
- Precipitation trapping taken into account
- Anthropogenic heating (Senoo et al, 2004)





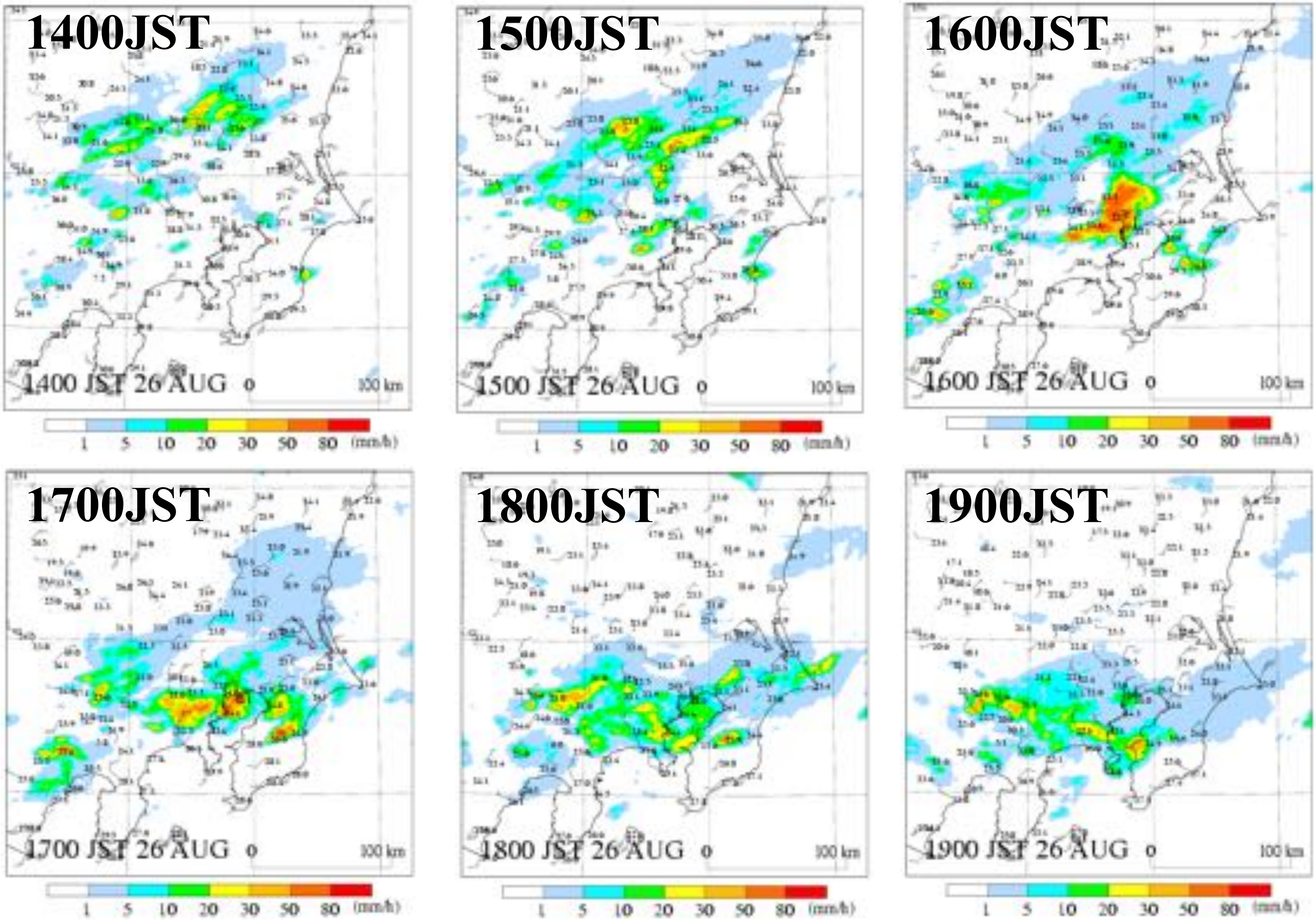
Aoyagi and Seino (2011)

Specifications of NHM (Saito et al., 2006, 2007)

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 for dx < 4 km**
Turbulent closure	**Improved MY3(Nakanishi & 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 scheme (Aoyagi and Seino, 2011)**

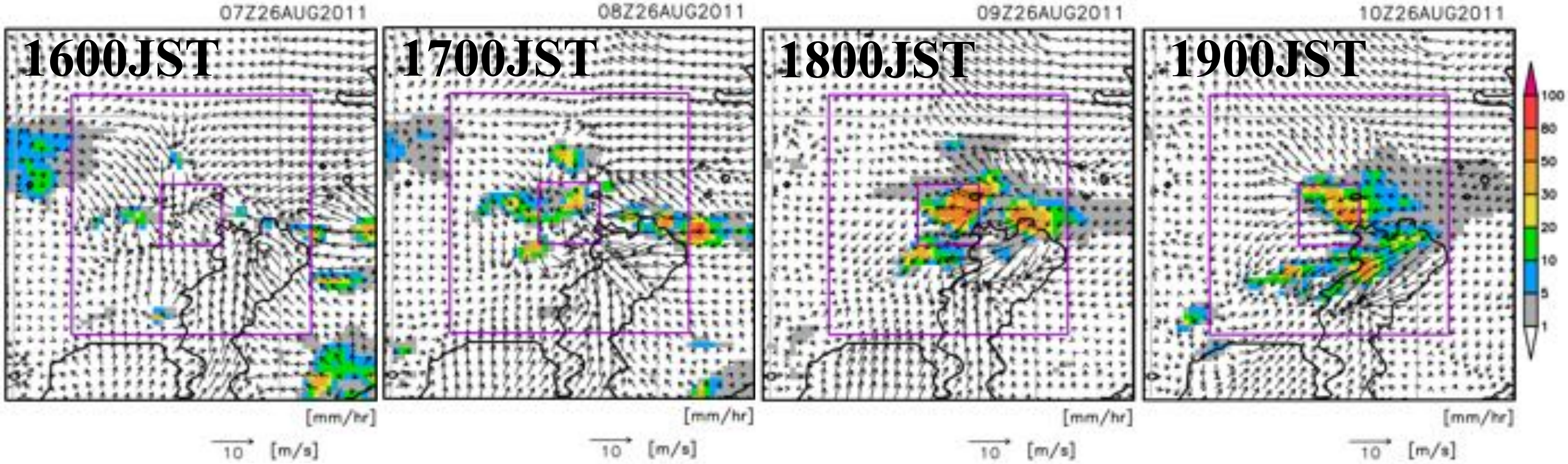
Observed hourly precipitation: 26 August 2011

Radar-rain gauge analyzed precipitation **2011.8.26 1400-1900JST**

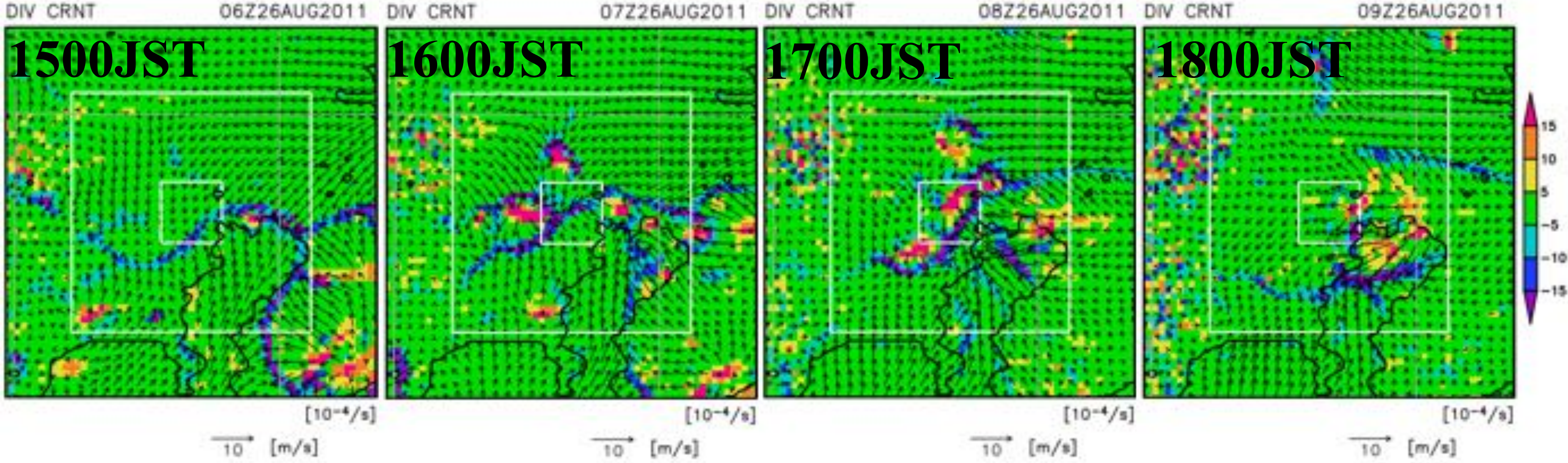


Simulated hourly precipitation: 26 August 2011

Hourly precipitation



Surface divergence (Blue color: convergence)



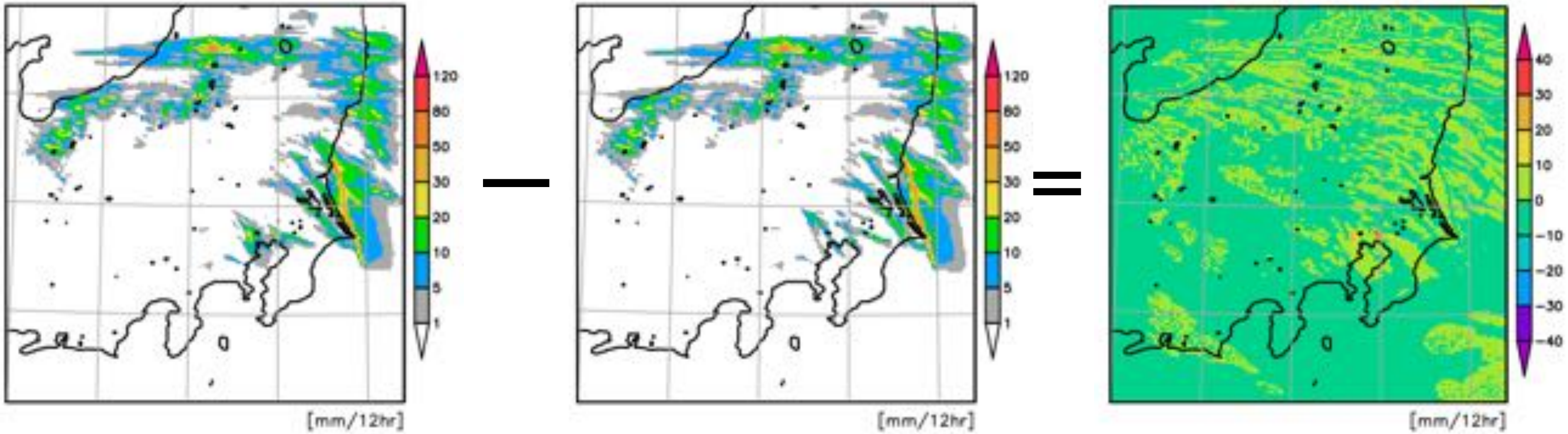
18 July 2013: Impact of urbanization

Current urban (Highly-urbanized)

Less-urbanized

Difference

Afternoon precipitation amount in sensitivity experiments



Further detailed discussions for urban impact on precipitation are made in Seino et al. (2017, accepted in Urban Climate)

XRAINの特徴

参考資料

- XRAINは、XバンドのMP（マルチパラメータ）レーダを用い、高精度・高分解能で、ほぼリアルタイムで配信することが可能。

1. 高分解能（Xバンドの特性）

- Xバンドレーダは、Cバンドレーダに比べ**波長が短く、高分解能な観測**が可能。（Xバンド：8～12GHz、Cバンド：4～8GHz）

2. 高いリアルタイム性（MPレーダの特性）

- 2種類の偏波（水平・垂直）を送信することで、**雨粒の形状等を把握し、雨滴の扁平度等から雨量を推定。**
- 地上雨量計による補正を行わずに、**高精度な雨量データをほぼリアルタイムで配信**することが可能。

3. 雨滴の移動方向・移動速度の観測が可能（ドップラー機能）

- ドップラー機能により、雨滴の移動方向と移動速度を把握することで、降雨予測等への活用が期待。

XRAIN全景（能美サイト）

レーダアンテナ（埼玉サイト）

2種類の波を送信

雨粒形状の変化を把握

国交省XRAIN（XバンドMPレーダネットワーク）:
X-band polarimetric（multi parameter） RAdar Information Network

http://www.mlit.go.jp/report/press/mizukokudo03_hh_000786.html