Tokyo Metropolitan Area Convection Study (TOMACS)

Kazuo Saito
Meteorological Research Institute, Japan

with courtesy of

M. Maki and R. Misumi
National Research Institute for Earth Science and Disaster Prevention (NIED)

Meteorological Research Institute (MRI)

Y. Fujiyoshi, Y. Takahashi and S. Watanabe
Hokkaido University

and

M. Ishihara
Aerological Observatory
Threat Score (TS) in MSM  Mar.2001-Jul.2011

Threat Score 5mm/3h 20km verif. grid for FT=3-15

- TS
- TS12M

Nonhydrostatic model

Meso4DVAR

10km to 5km

Nonhydrostatic 4DVAR

GPS TPWV

Radar Reflectivity

Heavy rains with synoptic forcing

Heavy rains with orographic forcing

- relatively predictable in the current mesoscale NWP up to a point

Convective rains without strong synoptic/orographic forcing

- difficult to predict due to
  - small horizontal/temporal scales
  - sensitive to small perturbations in initial conditions
Example of orographic heavy rainfall

Radar-AMeDAS Observed rainfall 03-06 UTC, 19July 2011

MSM prediction FT=21 03-06 UTC, 19July 2011

A strong typhoon (T201106 Ma-on) hit western Japan and record breaking 851mm rainfall was observed in one day (19 July 2001). MSM model accurately predicted the orographically forced rainfall.
Example of frontal local heavy rainfall

Radar-AMeDAS Observed rainfall
03-06 UTC, 29July 2011

MSM prediction FT=15
03-06 UTC, 29July 2011

A stationary front brought 527 mm heavy rainfall in one day. MSM forecasts were accurate for this event.
Example of unforced local heavy rainfall

Several convective cells yielded 50 mm per hour local heavy rainfalls at several locations. MSM failed to predict these local heavy rainfalls.
"Social System Reformation Program for Adaption to Climate Change"
Strategic Funds for the Promotion of Science and Technology (JST/MEXT)
Social Experiments on Extreme Weather Resilient Cities

Core Research Institutes:
◆ National Research Institute for Earth Science and Disaster Prevention (NIED)
◆ Meteorological Research Institute (MRI)
◆ Toyo University

Collaboration with 23 organizations:
Background

Large cities are inherently vulnerable to severe weathers such as torrential rainfall, lightning, and tornados. The number of occurrences of urban heavy rainfall has been increasing, which may be due to the global warming.

The present research project aims to understand the process and mechanism of extreme weather using dense meteorological observation networks designed in the Tokyo metropolitan area, to develop the monitoring and predicting system of extreme phenomena and to implement social.
The number of thunderstorm days in Tokyo

10-year average
The number of monthly thunderstorm days and total rainfall amount in the latest 10 years in Tokyo
Many types of deep convection are generated in the warm season in the Tokyo Metropolitan area.

Subject 1: Field Experiments TOMACS

【Meteorology】
To obtain new insight on mechanisms of extreme weather
(1) Development of new technologies
(2) Field campaign in the Tokyo area
(3) Statistical analysis

New observation facilities
Field campaign in the Tokyo Metropolitan area
Understanding the mechanism

Subject 2: Early Detection and Prediction System

【Engineering】
Developments collaborating with end users
(1) Extreme weather nowcasting methods
(2) Development of test-beds of nowcasting systems
(3) Extreme weather database

Subject 3: Social Experiments

【Sociology】
Evaluation and adaption the developed nowcasting system
(1) Social experiments in rescue services, risk management, infrastructure and education
(2) Recommendations for extreme weather resilient cities

to Issue More Accurate and Adequate Warning

to Evaluate and to Adapt the Nowcasting Systems

Many types of deep convection are generated in the warm season in the Tokyo Metropolitan area.
Subject 1: Field Experiments TOMACS

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New observation facilities
Field campaign in the Tokyo Metropolitan area
Understanding the mechanism
TOMACS (Tokyo Metropolitan Area Convection Study) with a dense observation network by MRI, NIED and 12 research groups in the summers of 2011–2013, as testbed for deep convection.
Research/operation weather radars concentrate in the Tokyo Metropolitan Area: X–NET (5 X–band MP radars and 3 Doppler radars), two X–band MP radars of River Bureau, MRI C–band MP radar and 3 JMA C–band operational Doppler radars.
The X-NET data is classified from the level 0 to 4 according to the level of processing managed.

**Level 0:** Raw radar data recorded with an original format of a radar company.

**Level 1:** Raw data after the format conversion to NetCDF.

**Level 1.5:** Radar data after fundamental corrections such as attenuation correction and unfolding of Doppler velocity data.

**Level 2:** “Basic” product such as rain rate, wind speed.

**Level 3:** “Advanced” data such as VIL, areal rainfall, etc.

**Level 4:** “Predicted” data of precipitation and wind.

An Example of the level 2 products of X-NET. Time change of rainfall and wind distribution at the height of 1km when a cold front passed over the Kanto region on Feb 18, 2011.
The Ku-band FM-Chirp fast scan MP radar developed by the Osaka University and Sumitomo Electric Industries is used to observe very high-resolution structure of thunderstorms. A full volume scan is made by 1 minute intervals, and reflectivity, Doppler velocity and polarimetric parameters are obtained at 10m intervals.

T. Ushio of Osaka University
O. Suzuki of MRI
Preliminary observation in Tsukuba, Ibaraki

18:30JST, 11 Aug. 2011

Reflectivity: 3D

Doppler velocity: vertical cross section

Tsukuba

Kakioka: 114.5mm/h (19:12JST)

Reflectivity: vertical cross section
Two research Doppler lidars are operated in the experiment in addition to four JMA operational Doppler lidars in the Haneda and Narita airports, to observe the initiation of convection and behaviors of sea breeze fronts.

Lidar of Hokkaido University (Y. Fujiyoshi and M. Kawashima)
- 1.54 μm eye-safe laser
- 20km of maximum range
- 25m resolution

PPI of the Lidar of National Institute of Information and Communications Technologies (NICT) on 5 July 2010, just before initiation of thunderstorms

NICT Team
Doppler lidar PPI (EL: -0.5deg.) 2011/8/9 8:14-8:55JST (Day-time)

Microwave radiometer

Doppler lidar PPI (EL: -0.5deg.) 2011/8/9 22:14-22:55JST (Night-time)

Time-height cross-section of temperature 2011/7/2000UTC ~ 8/10 2300UTC
TOMACS: UAV airplane
To capture atmospheric environment for heavy rainfall/urban PBL structure

- Use of UAV for atmospheric observation.
- Observation of environments for initiation/development of local heavy rainfalls.
  1. Vertical profiles in/around the urban area.
  2. Convergence of easterly and southerly airflows.
TOMACS: Sonde Observation

To capture atmospheric environment for heavy rainfall/urban PBL structure

Risk assessment: Utilization of sonde trajectory simulation

Sonde falling area is predicted in advance to reduce accident owing to sonde falling over urbanized area.

Observation sites

Sonde sounding
Tsukuba 03UTC 26AUG2011
26AUG2011 Thunderstorm case
Boundary layer observation

Relationship between sensible heat flux from the surface and the initiation of convection will be studied using scintillation meters, radiosondes, temperature profilers, wind profilers.

H. Sugawara of National Defense Academy
N. Seino of MRI
NICT Team (Y. Murayama, S. Satoh, S. Ishii, H. Iwai and R. Oda)
### System Specifications

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

Laser-based optical disdrometer
(OTT PARSIVEL®)

Example of observed 10 min precipitations on August 26, 2011
In addition to 14 GPS receivers by the GPS Earth Observation Network System (GEONET of the Geospatial Information Authority of Japan, 6 GPS receivers have been installed in the Tokyo Metropolitan area.

Rapid scan of JMA Geostationary Satellite MTSTAT with every 5 minutes will be provided.

Y. Shoji of MRI

I. Osaka and Y. Izumikawa of JMA Met Satellite Center

Additional GPS receiver stations
- GEONET stations

MTSAT
Rapid scan area

Precipitation intensity (mm/h)
TOMACS: GPS Observation
For monitoring of water vapor variation

- KNAN: Tokyo Univ. of Marine Science and Technology
- KHJM: Oota Incineration Plant
- KWSK: Kawasaki Harbor Joint Government Building
- URY: Urayasu City Clean Center
- UMHT: Umi-hotaru PA

- Five new GPS sites are installed in addition to GEONET.
- Online data acquisition at four stations except for UMHT.
- Solar–powered energy supply at UMHT.
Analysis Example:
Small scale convective systems on 27 July 2011.

PWV sequence from 16:00 to 21:00 UTC derived from TOMACS GPS sites.

Newly installed GPS sites capture small scale water vapor variation under the convective activity.

Japan standard time is +9 h against UTC.
High-resolution monitoring of thunderclouds by the High Precision Telescope on the RISING-2 micro satellite

A photo of cumulonimbus cloud over Africa taken from ISS

A few 100 m resolution image provides the approximate location of a tower, but a 5 m resolution is required to identify the exact evolution.

Junichi Kurihara, Yukihiro Takahashi, and *Shigeto Watanabe
Graduate School of Science, Hokkaido University, Japan
**RISING-2 satellite**

- 50-kg 3-axis satellite made and operated by Hokkaido Univ. and Tohoku Univ.
- development and fabrication already completed and **to be launched in 2013 (not fixed)**
- Low earth, sun-synchronized polar orbit
- passing over Japan 2 or 3 times/day (20min each) in daytime

**High-resolution telescopic imaging system**

- can be pointed to any direction
- 3CCD for R,G, B and 1CCD with tunable filter for 650-1000nm (selectable) with FWHM 20 nm
- resolution: 5 m/pixel @ 700km alt. in nadir direction
Subject 2: Development of monitoring and prediction system for extreme phenomena

(1) Improvement of forecast techniques
(MRI, NIED, JMA, JWA, Kyoto Univ.)

(2) Monitoring and prediction system (NIED, JWA, NILIM, ENRI)

(3) Database of extreme phenomena (NIED)

End users
- Fire department
- Local governments
- Railroad companies
- Students

- For water rescue
- For risk management
- For social infrastructure
- For education
<table>
<thead>
<tr>
<th><strong>1) Improvement of forecast techniques</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Very short-range forecast (~5 minute)</strong></td>
</tr>
<tr>
<td><strong>Nowcasting (~1 hour)</strong></td>
</tr>
<tr>
<td><strong>Data assimilation and numerical forecast (~6 hours)</strong></td>
</tr>
</tbody>
</table>
• IOP in 2011 (25-29 July and 18-24 August)

• Presentation at AOGS2011 (Taipei), EMS2011, ISEC2011(OU), WMO workshop (Boulder), KJC joint conference (Pusan)

• International workshop at NIED with approx. 10 invited speakers in October (or November) 2012

• Data policy:

  Open for project participants.

  Probably, will be open for collaborative partners/registered users including scientists in foreign institutions

• Data format/archiving

  Try for archiving with unified format such as NetCDF with various levels (Level 1-3)
Comments/Advise?

- Science Plan and HP: only in Japanese at this stage
- Five countries: impossible for the filed campaign
- International Scientific Advisory Board?
- Some institutions may have interest in observation data
- Schedule for proposal to CAS JSC meeting (March 2012?)
The Next-Generation Supercomputer ‘K’ has been constructed by RIKEN at Kobe. http://www.nsc.riken.jp/index-eng.html
Fujitsu SPARC64™ VIIIfx, 8 cores, 128 Gflops x 80,000
First place in the LIMPACK benchmark TOP500 list in June 2011 with 8.162 Pflops and a computing efficiency ratio 93.0%. Whole system is complete in 2012.
Field 3: Global Change Prediction for Disaster Prevention

Subject 1: Projection of tropical cyclones in climate change by a cloud resolving global model (NICAM)

Subject 2: Prediction of heavy rainfalls by a cloud resolving NWP system

JAMSTEC and AORI, University of Tokyo

MRI and JMASTEC

To show a feasibility of the dynamical and probabilistic prediction of local heavy rainfalls in the scale of local municipalities by a cloud resolving ensemble NWP system (hourly, 1-2 km, 50-100 members)
Thank you
Research Subject 1: Studies on Extreme Weather with Dense Meteorological Observations

To understand the initiation, development, and dissipation processes of convective precipitation, and to clarify the mechanism of localized heavy rainfall which potentially causes natural disasters such as flooding and land slide, a variety of cumulus activities are studied by dense research and operational meteorological observation networks in the Tokyo Metropolitan Area, numerical experiments, and statistical analysis of environmental conditions preferable for extreme weather.
Research Subject 2: Developments of the Early Detection and Prediction System of Extreme Weather

The aim of the second research subject is to establish the “Monitoring and Prediction System of Extreme Phenomena (MPSEP)” which can process real-time data of the dense meteorological observation networks and predict localized heavy rainfalls and strong winds. Information from the MPSEP is utilized in social experiments described in the third research subject. It is also aim of the research subject to establish database of the extreme weather which is useful for planning disaster countermeasures.
Research Subject 3: Social experiments on extreme weather resilient cities

The aim of the third research project is to validate the effects of the MPSEP on disaster prevention and the reduction of damage in these situations through field tests of the MPSEP in four different disciplines: Emergency deployments, river managements, infrastructures, and educations. Before implementing social experiments, surveys on appropriate information and effective means of transmitting information will be done in each experimental field to make the MPSEP suitable for practical use.
### Specifications of Ku-band radar

![Low Loss Luneberg Lens](image)

#### System

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Frequency</td>
<td>15.75GHz</td>
<td></td>
</tr>
<tr>
<td>Operational Mode</td>
<td>Spiral, Conical, Fix</td>
<td></td>
</tr>
<tr>
<td>Band Width</td>
<td>80MHz (max)</td>
<td>15.71GHz - 15.79GHz</td>
</tr>
<tr>
<td>Modulation</td>
<td>FM sharp</td>
<td></td>
</tr>
<tr>
<td>Coverage</td>
<td>Az : 360° / El : 90°</td>
<td></td>
</tr>
<tr>
<td>Resolution (Az/El)</td>
<td>3°(min)</td>
<td></td>
</tr>
<tr>
<td>Resolution (Range)</td>
<td>5m (min)</td>
<td>variable</td>
</tr>
<tr>
<td>Resolution (Time)</td>
<td>1min./scan</td>
<td></td>
</tr>
</tbody>
</table>

#### Antenna

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Gain</td>
<td>36dBi</td>
</tr>
<tr>
<td>Beam Width</td>
<td>3°</td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
</tr>
<tr>
<td>Cross Polarization</td>
<td>25dB (min)</td>
</tr>
<tr>
<td>Antenna Noise Temp.</td>
<td>75K (typ.)</td>
</tr>
</tbody>
</table>

#### Transmitter Receiver

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitted Power</td>
<td>10W (max)</td>
</tr>
<tr>
<td>Duty Ratio</td>
<td>0% ~ 100%</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>2dB (max)</td>
</tr>
</tbody>
</table>

#### Signal Processing

<table>
<thead>
<tr>
<th>Items</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>D/A</td>
<td>170MHz - 14bit IQ 2ch</td>
</tr>
<tr>
<td>A/D</td>
<td>170MHz - 14bit IQ 2ch</td>
</tr>
<tr>
<td>Range Gate</td>
<td>32k (max)</td>
</tr>
<tr>
<td>IPP</td>
<td>variable</td>
</tr>
</tbody>
</table>
JAVAD GrAnt-G3T

Receiver and Data Communication Equipment

www.shimz.co.jp/tw/works/11tra/4.html

- Sampling: 1 Hz
- Elevation cut off: 0 degree
- Online data acquisition (except for UMHT): 1hly
In order to characterize and validate localized heavy rain and associated small-scale severe thunderstorms near the surface, the surface weather stations were distributed in the study area. We have installed 12 weather transmitter (WXT520; Vaisala) and 6 laser-based optical disdrometers (OTT PARSIVELR) at intervals of 3 kilometers in the area.

The installation sites are a municipally-owned waterworks and an apartment house as well as high schools, where each device will be mounted on the top of a steel pole as high as 5 meters. The WXT520 observation intervals are 1 second for wind direction and wind speed, and 10 seconds for temperature, humidity, and pressure. The optical disdrometer measures drop size (DSD) and fall velocity distribution during the interval of 10 seconds, which are important for the understanding of localized heavy rain development. These data can be also used to calculate rain fall intensity and equivalent reflectivity to compare to radar data. The observation data are to be sent to the computer in the Institute via the Internet.
<table>
<thead>
<tr>
<th>Target</th>
<th>Parameter</th>
<th>Instruments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environments</td>
<td>T, wind, water vapor in the Troposphere</td>
<td>Research aircraft</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiosonde stations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>GPS receivers</td>
</tr>
<tr>
<td>Boundary layer</td>
<td>Air flow</td>
<td>Doppler Lidars</td>
</tr>
<tr>
<td></td>
<td>Vertical heat flux</td>
<td>Scintillometer</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radiation measurement</td>
</tr>
<tr>
<td>Surface</td>
<td>T, wind, rain (partially Td, P)</td>
<td>High-resolution surface network</td>
</tr>
<tr>
<td></td>
<td></td>
<td>JMA AMeDAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>River Bureau rain gauges</td>
</tr>
<tr>
<td>Cumulus</td>
<td>Images of cumulus</td>
<td>MTSAT rapid scan imager</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Web cameras</td>
</tr>
<tr>
<td>Thunderstorms</td>
<td>Fast-scan, high-resolution 3D reflectivity/velocity</td>
<td>Ku-band fast scan radar</td>
</tr>
<tr>
<td></td>
<td>3D reflectivity/velocity</td>
<td>X−NET Doppler radars</td>
</tr>
<tr>
<td></td>
<td>Polarimetric parameter</td>
<td>X−Net MP radars</td>
</tr>
<tr>
<td></td>
<td>Distribution of raindrops</td>
<td>2D−Disdrometer</td>
</tr>
<tr>
<td></td>
<td>Lightning</td>
<td>JMA Lightning Detection System</td>
</tr>
</tbody>
</table>
Five strategic fields (2011-2015)

Field 3

- Life Science & Medicine
- New materials & Energy
- Earth Sciences
- Next generation Engineering
- Matter & Universe

Core institute

- RIKEN: Life science Community
- JAMSTEC: Earth science Community
- Institute for Industrial Science U. Tokyo: Engineering Community
- Center for Comp. Science U. Tsukuba: Basic science Community


Ukawa (2010)