International Training Workshop on Natural Disaster Reduction Sep. 26–30, 2016

Study for Meteorological Hazard Mitigation

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Super Typhoon Yolanda

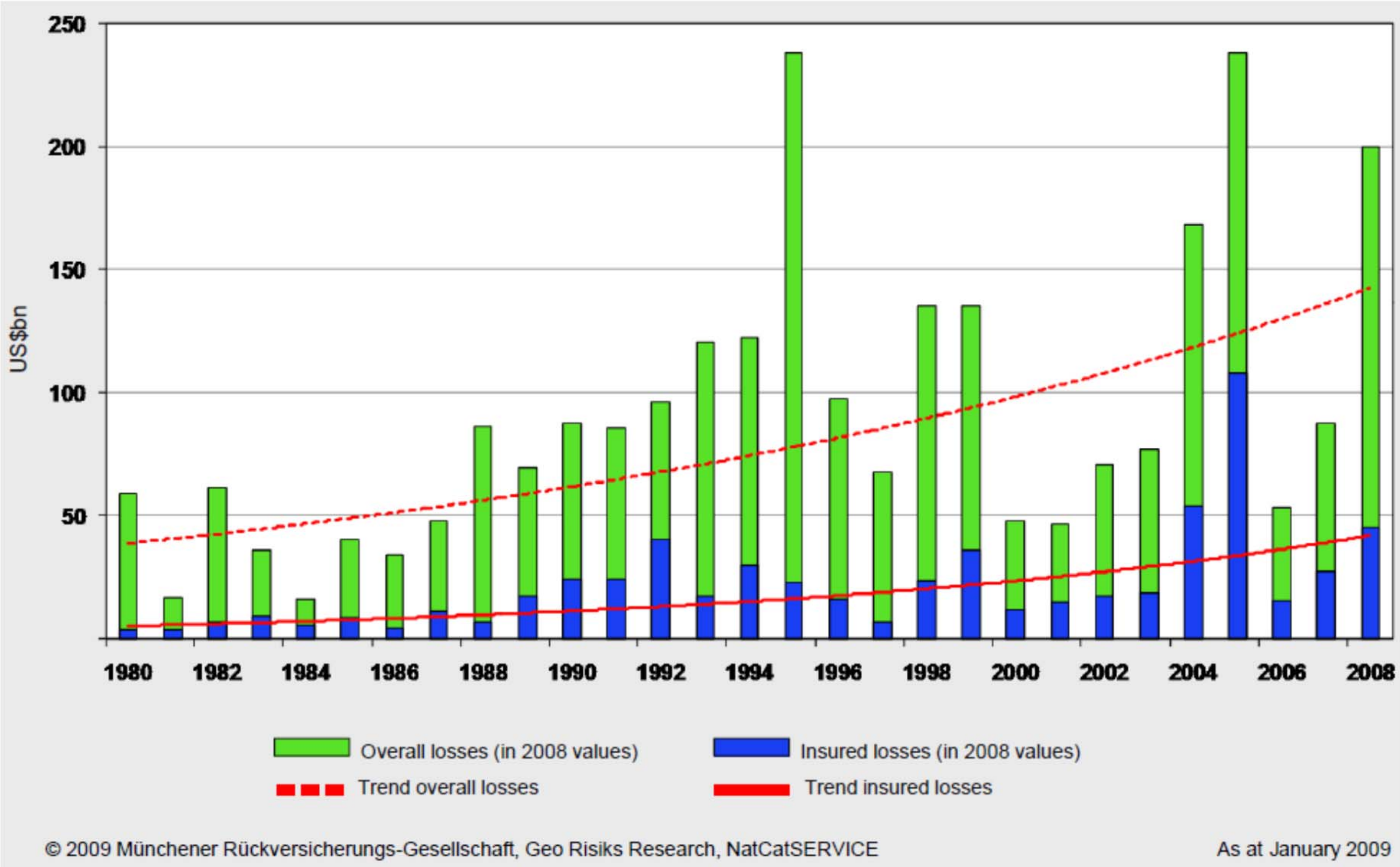
Severe Storm in Tokyo

Outline

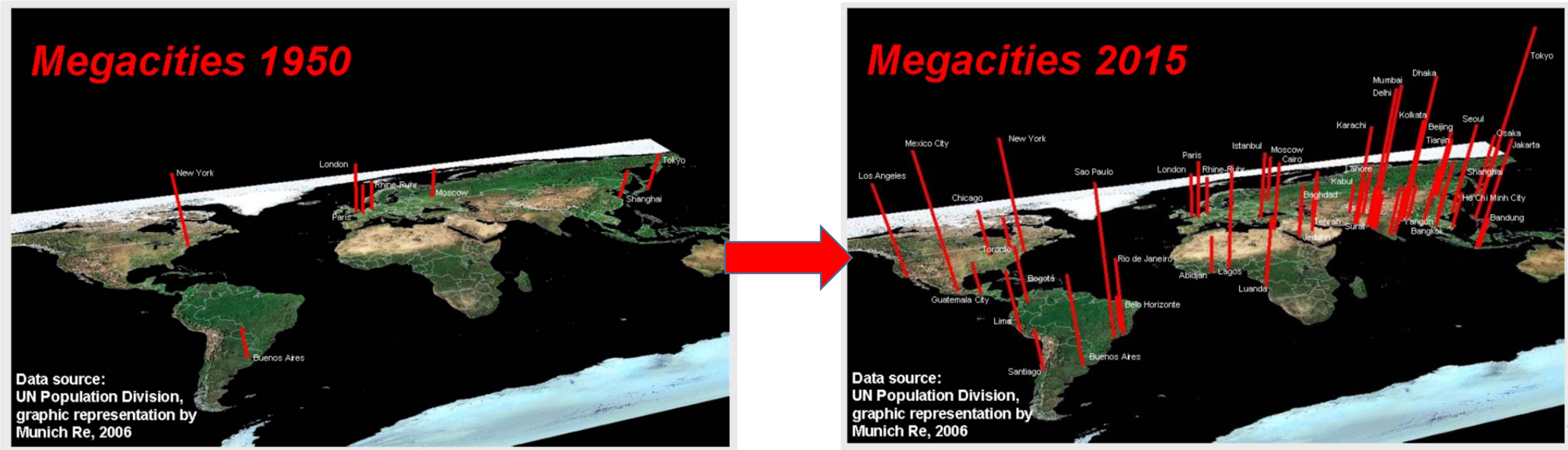
- Introduction
  - Trend of natural disasters
- Method for assessment of maximum storm surge
- Monitoring system for short-term severe weather
- Summary

Global Natural Disasters 1980－2009

Overall and insured losses with trend



Reason for the increasing trend of natural disaster:
- Change in our society: An increase in Megacities!



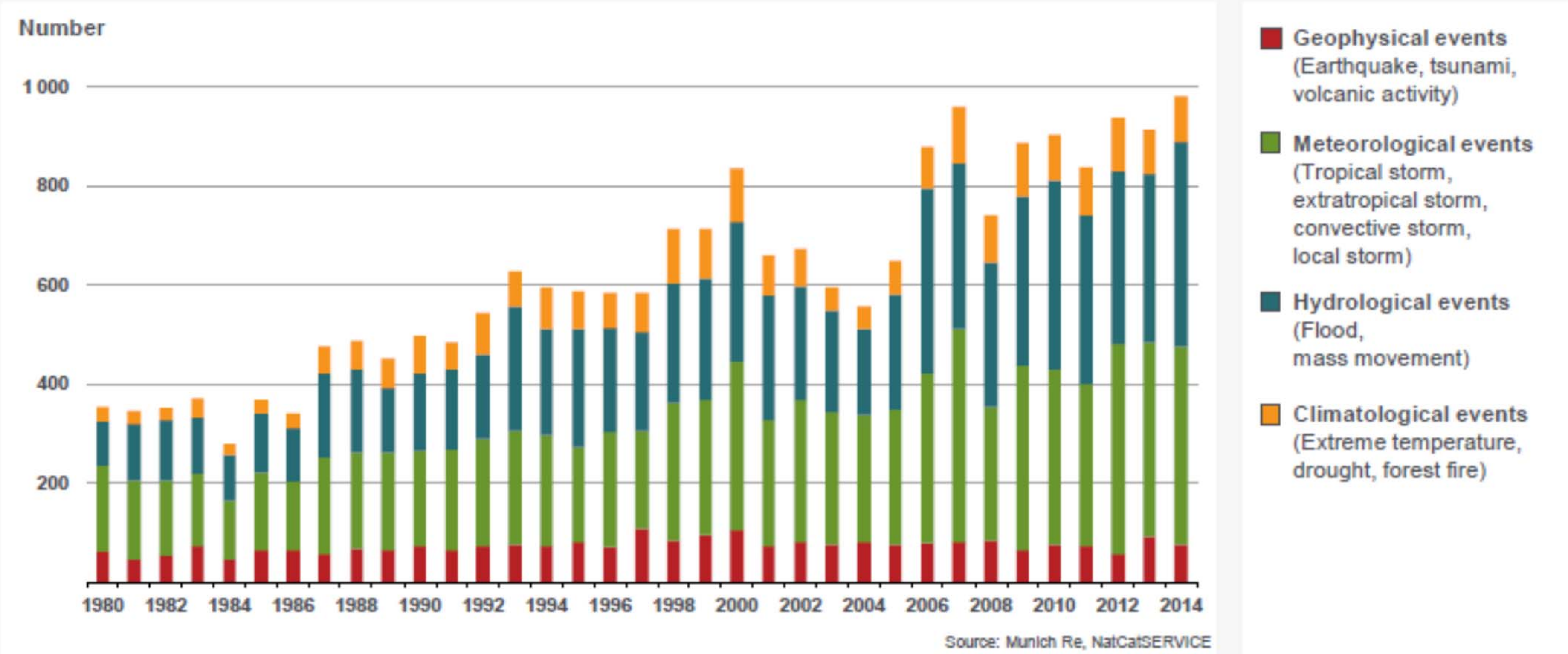
- ✓ Rise in population is remarkable over coastal areas
- ✓ Improvement of living standards
- ✓ Vulnerability of societies and technologies to natural hazards

NatCatSERVICE

Loss events worldwide 1980 – 2014

Number of events

Munich RE



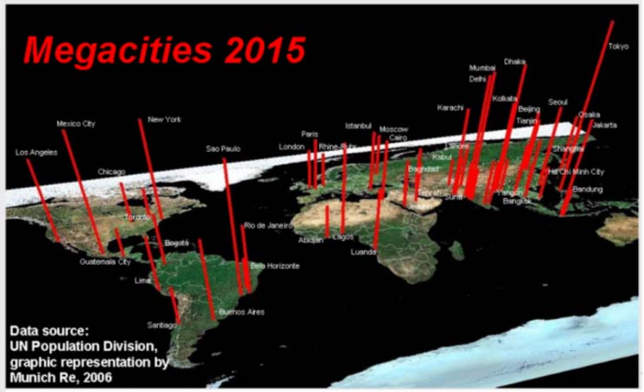
Source: Geo Risks Research, NatCatSERVICE – As at January 2015

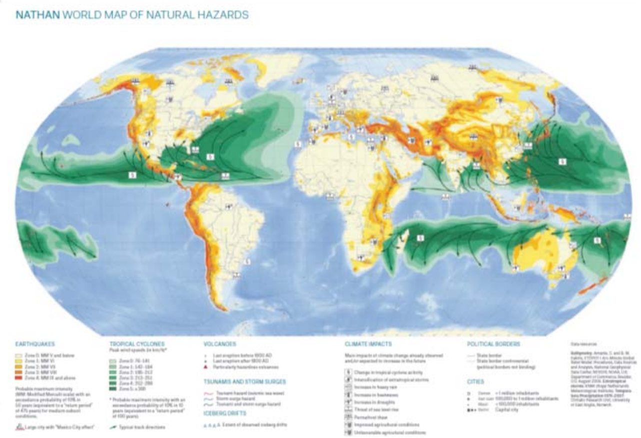
An increase in loss due to hydro-meteorological events is remarkable!

Major Natural Disasters in Asia 1980—2008

Costliest catastrophes: insured losses

Period	Event	Affected Area	Losses (US$m, original values)		Deaths
			Overall losses	Insured losses	
26.-28.9.1991	Typhoon Mireille (No. 19)	Japan	10.000	7.000	62
6.-8.9.2004	Typhoon Songda (No.18)	Japan, South Korea	9.000	4.700	41
22.-25.9.1999	Typhoon Bart (No. 18)	Japan, Republic of Korea	5.000	3.500	29
17.1.1995	Earthquake	Japan, Kobe	100.000	3.000	6.430
22.9.1998	Typhoon No. 7/8 Vicki and Waldo	Japan	3.000	1.600	18
19.-21.10.2004	Typhoon Tokage (No.23)	Japan	2.300	1.300	80
22.8.-2.9.2004	Typhoon Chaba (No.16)	Japan, Guam	2.000	1.200	16
10.1.-13.2.2008	Winter damage	China	21.100	1.200	129
16.-19.9.2006	Typhoon Shanshan - No.13	Japan, Republic of Korea	2.500	1.200	10
11.-19.9.2000	Typhoon Saomai, floods	Japan, South Korea	1.500	1.050	25





Typhoon is one of the major drivers causing natural disasters.

Assessment of Typhoon-induced Storm Surge

- Tropical Cyclones (TCs) have a greatest potential for loss of human life and economic damage, due to strong winds, heavy precipitation, landslide and storm surges associated with them.
- It is expected that the frequency of intense tropical cyclone might increase in future.
- It is necessary to perform risk assessment for new-kinds of tropical cyclone hazards because risk assessment is vital to government disaster preparedness programs (DPP).
- We have developed the model for assessment of maximum storm surge.

General consensus assessment of the numerical experiments for TC intensity

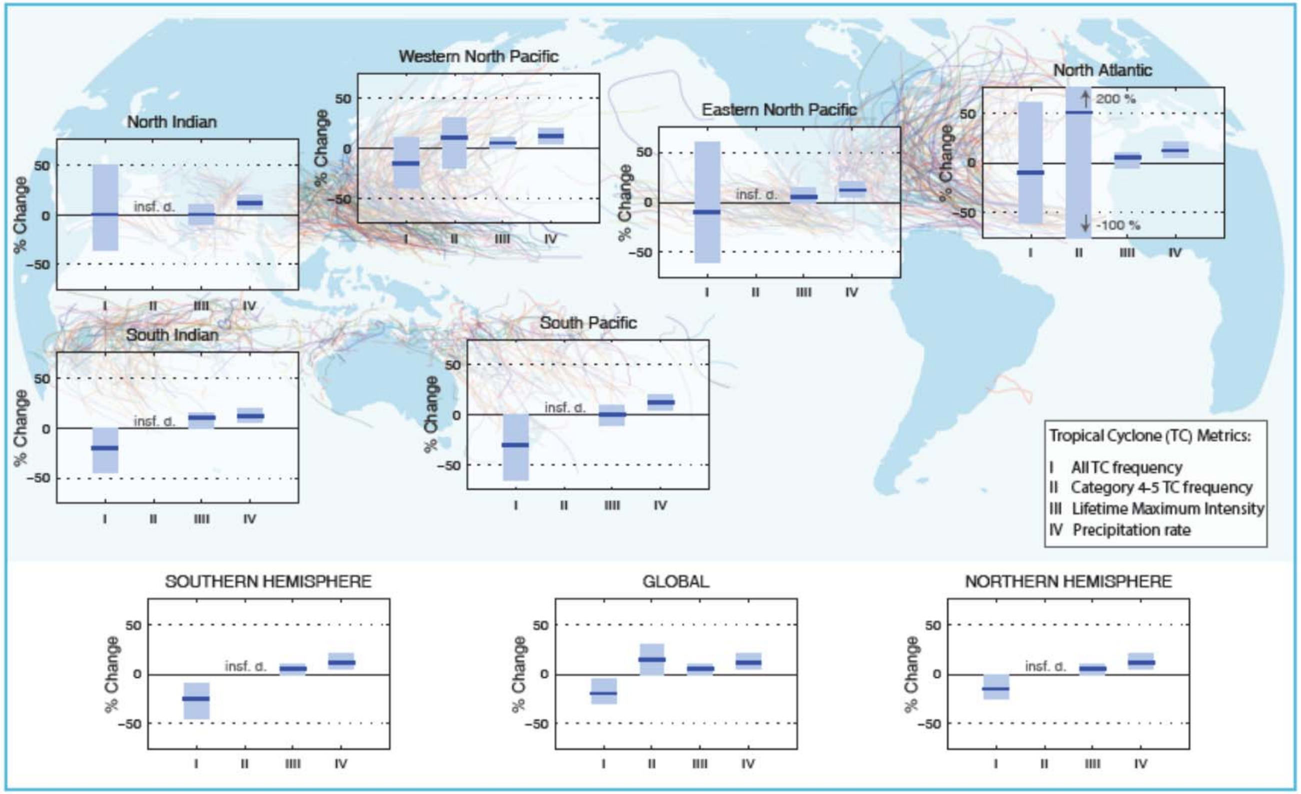


Figure 14.17 | General consensus assessment of the numerical experiments described in Supplementary Material Tables 14.SM.1 to 14.SM.4. All values represent expected percent change in the average over period 2081–2100 relative to 2000–2019, under an A1B-like scenario, based on expert judgement after subjective normalization of the model projections. Four metrics were considered: the percent change in (I) the total annual frequency of tropical storms, (II) the annual frequency of Category 4 and 5 storms, (III) the mean Lifetime Maximum Intensity (LMI; the maximum intensity achieved during a storm's lifetime) and (IV) the precipitation rate within 200 km of storm centre at the time of LMI. For each metric plotted, the solid blue line is the best guess of the expected percent change, and the coloured bar provides the 67% (*likely*) confidence interval for this value (note that this interval ranges across –100% to +200% for the annual frequency of Category 4 and 5 storms in the North Atlantic). Where a metric is not plotted, there are insufficient data (denoted 'insf. d.') available to complete an assessment. A randomly drawn (and coloured) selection of historical storm tracks are underlain to identify regions of tropical cyclone activity.

Assessment of Typhoon-induced Storm Surge

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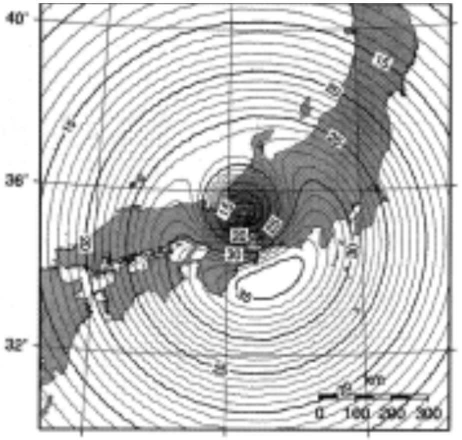
- It is expected that the frequency of intense tropical cyclone might increase in future.

- It is necessary to perform the assessment for new-kinds of tropical cyclone hazards because risk assessment is vital to government disaster preparedness programs (DPP).

- We have developed the model for assessment of maximum storm surge, because storm surge could cause natural catastrophes.

Tropical cyclone model for assessment of storm surge

Wind: Empirical Parametric Model



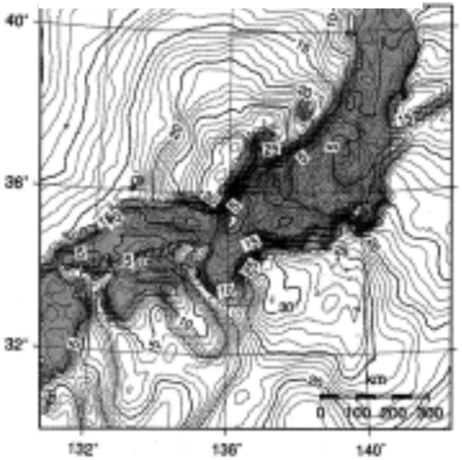
$$p = p_c + \Delta p \exp\left(-r_m / r\right)$$

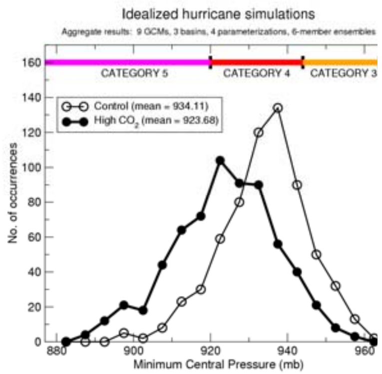
$$\frac{{V_{gr}}^2}{r_t} + fV_{gr} = \frac{1}{\rho}\frac{\partial p}{\partial r}$$

$$\frac{1}{r_t} = \frac{1}{r}\left(1 + \frac{C}{V_{gr}}\sin\alpha\right)$$

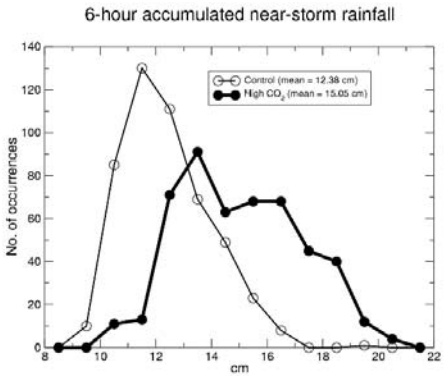
- ✓ The empirical tropical cyclone model cannot simulate actual asymmetric structures in a landfall tropical cyclone, often leading to large errors in storm surge forecasting.
- ✓ Current methods of tropical cyclone risk assessment are based on history, which is too short and which may not be a good guide to the future under global warming.

Wind: Analysis





Max Wind : 4%/℃

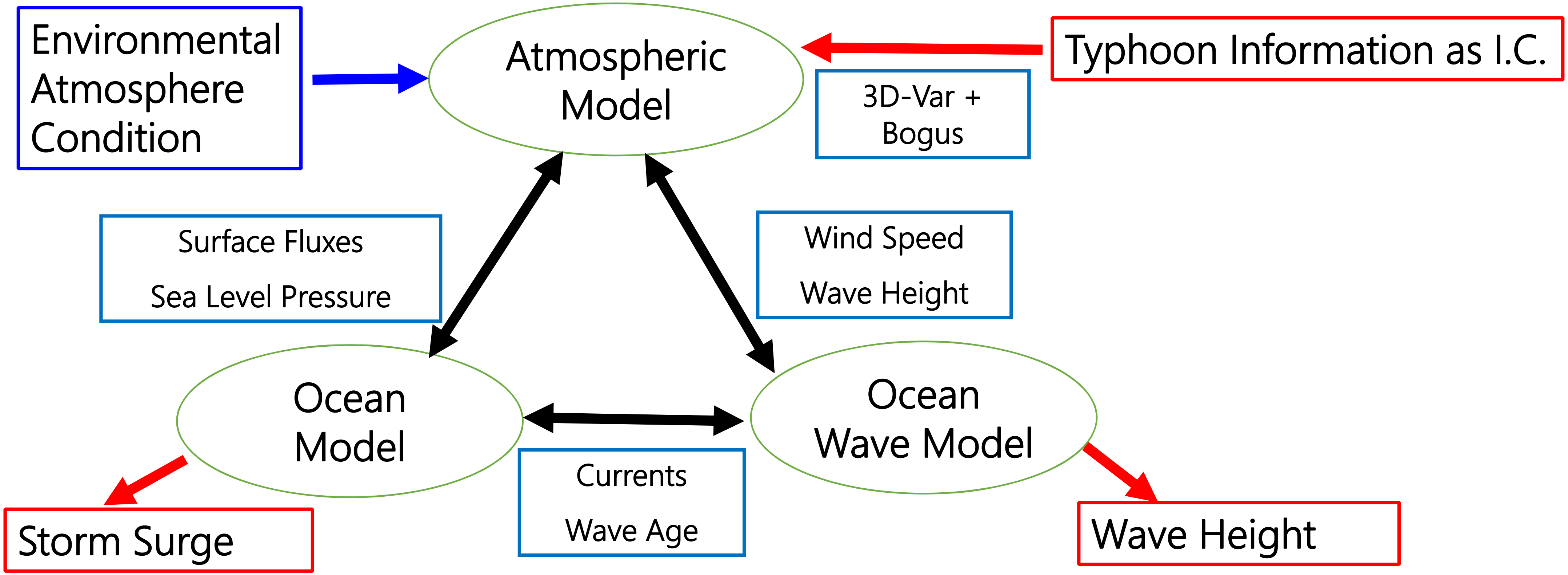


Intense Rainfall: 12%/℃

Can We Use Physics to Improve Tropical Cyclone for Risk Assessment?

From Knutson and Tuleya (JC2004)

Maximum Storm Surge Assessment Model

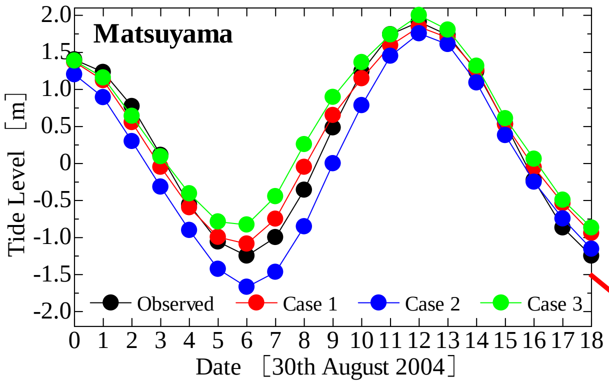


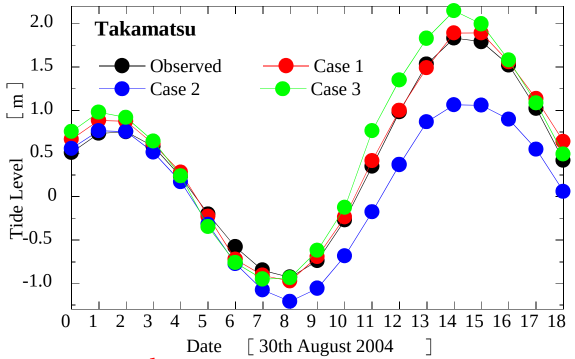
The model incorporated with bogus scheme can estimate storm surge under any scenario, taking account of physics such as topographic effect, air-sea interactions and climate changes.

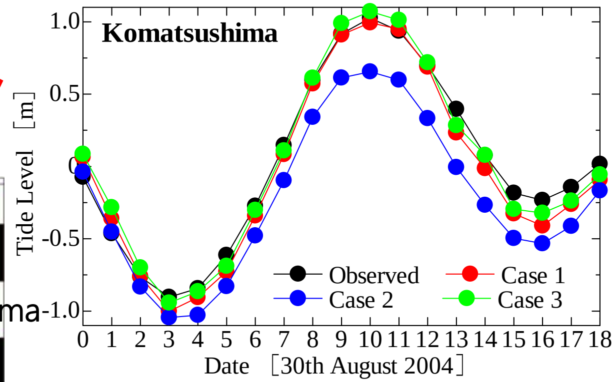
Validation（Typhoon Chaba 2004）

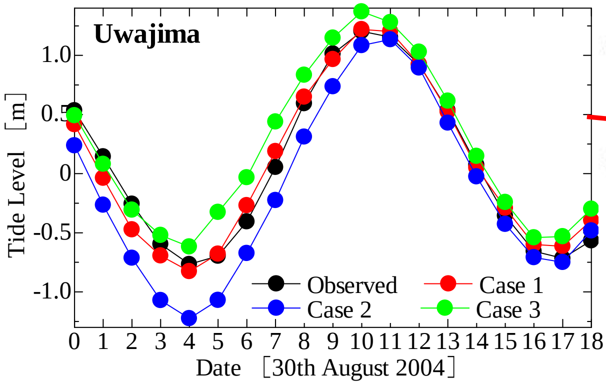
- Case 1:Coupled Model
- Case 2:Empirical Parametric Model
- Case 3：Coupled Model but different Ocean

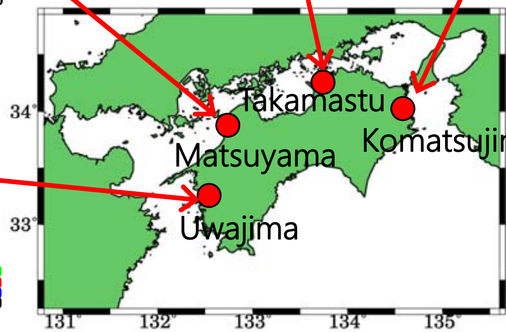
Takamastu







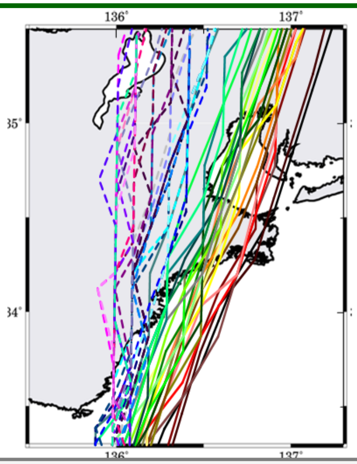


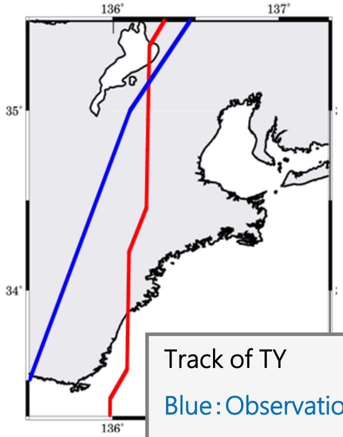


The model is doing a good job for both storm surge and tide level at all stations!

Possible maximum storm surge induced by Isewan Typhoon (Typhoon Vera)

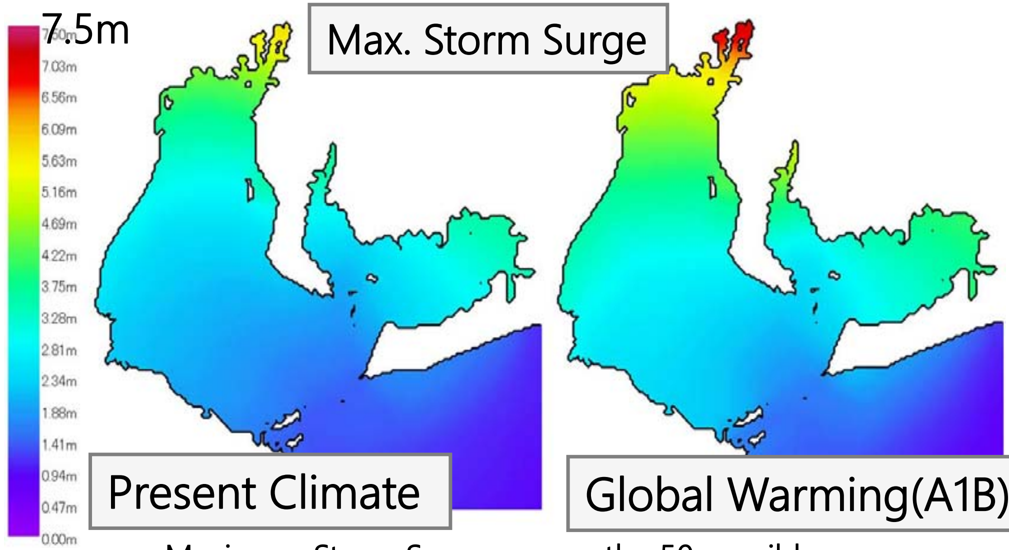
Isewan Typhoon was the strongest and deadliest typhoon on record to make landfall on Japan.





Track of TY
Blue : Observation
Red : Maximum

The 50 possible maximum typhoons are initialized on the different positions.



Present Climate

Global Warming(A1B)

Maximum Storm Surge among the 50 possible maximum typhoons

These method would be useful for assessment of impacts of storm surge by the possible maximum typhoons under both the present and future climate conditions.

- ✓A maximum storm surge recorded in history : 3.5 m (Sep. 1959).
- ✓A maximum storm surge even under present climate if the typhoon takes a different track : 5.6m
- ✓ A maximum storm surge under future climate : 6.9 m
- ✓Several infrastructures : 4.8m

Monitoring system for short-term severe weather

- Much attention has been paid to recent increases in severe weather, in particular, extreme intense rainfall, that often causes natural disasters such as landslide and urban floods.

- It is difficult to observe localized heavy rainfall and severe wind with less than 10 km scale in real time by conventional methods.

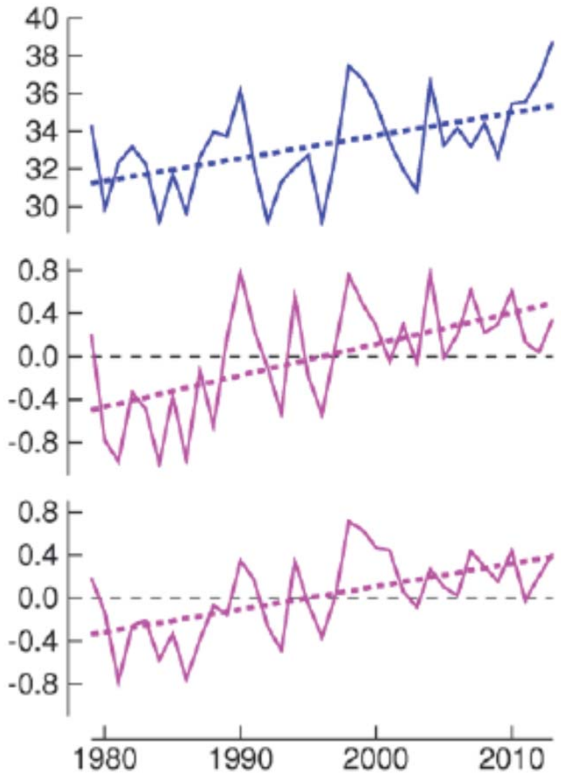
- Toward the mitigation of natural disasters induced by localized heavy rainfall, we have developed the new-observing systems.

Recent trend of precipitation, air temperature, and sea surface temperature in Japan

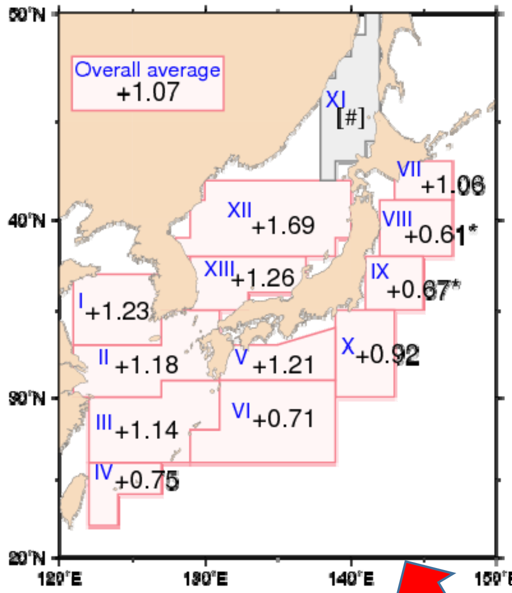
Maximum daily precipitation averaged over the weather stations in Japan

Deviation of annual mean air temperature averaged over the weather stations in Japan

Deviation of annual mean sea surface temperature averaged over the oceans around Japan



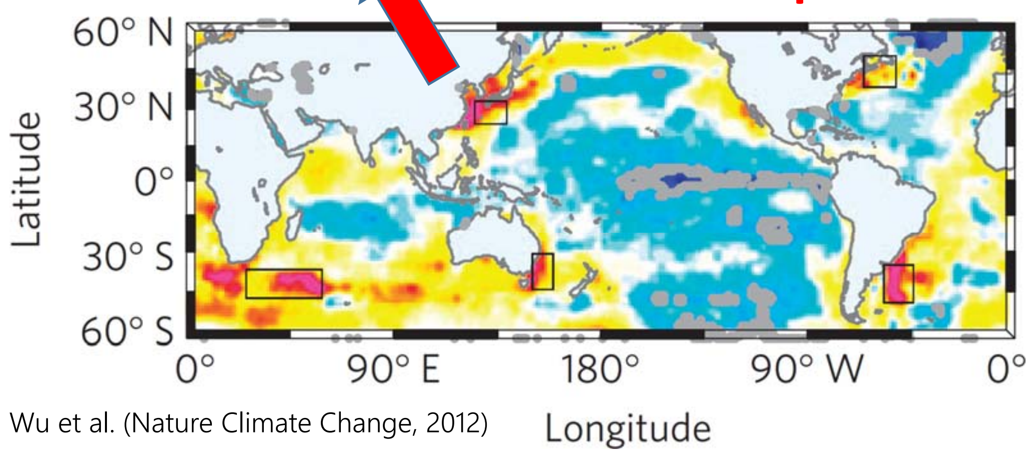
From Fujibe (2015)



From JMA

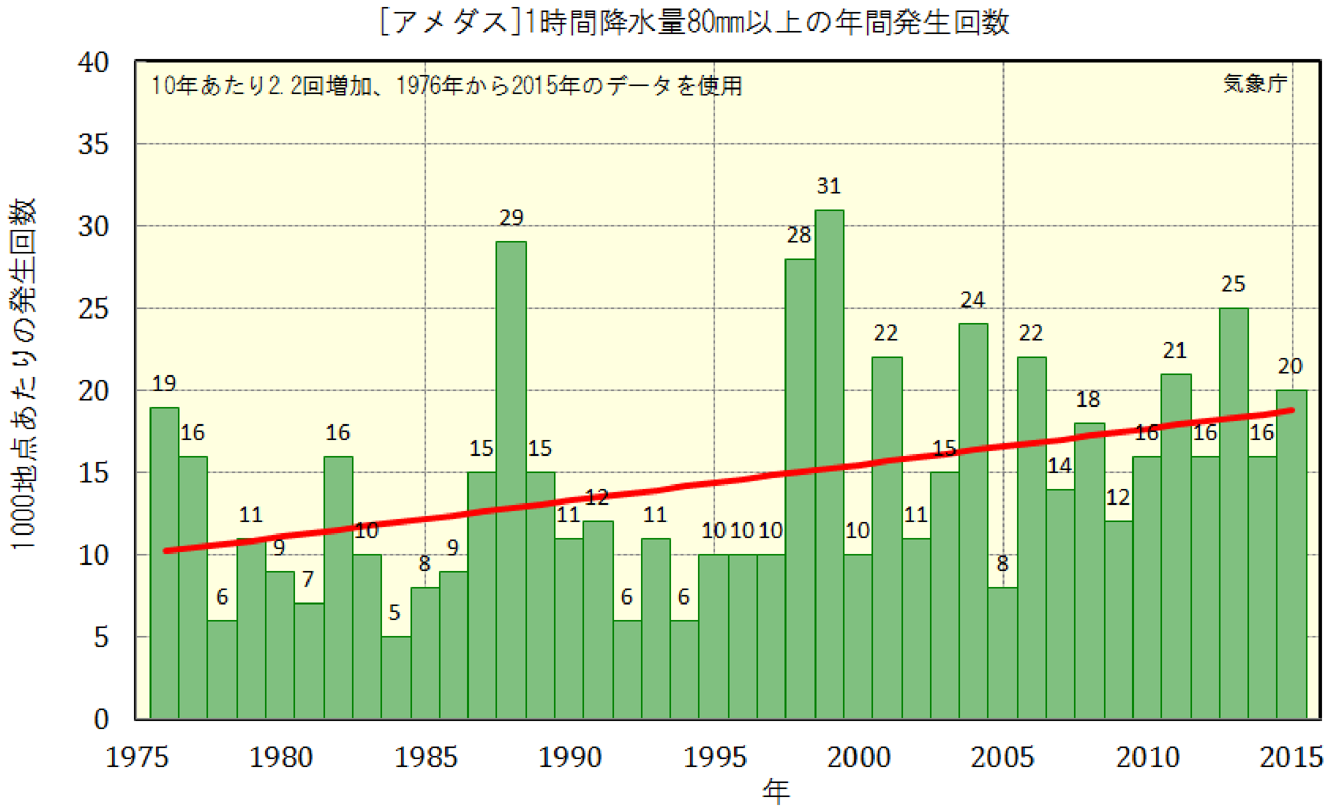
Trend of annual mean sea surface temperature over the oceans around Japan is the largest among the world oceans past 100 years.

Hot Spots!



Wu et al. (Nature Climate Change, 2012)

Frequency of intense hourly rainfall events more than 80 mm/h over the weather stations in Japan.



From JMA

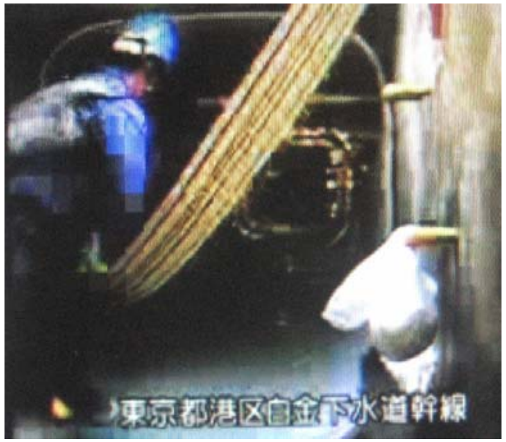
An increasing trend of extreme rain is found not only in maximum daily precipitation but also in frequency of intense hourly precipitation events.

Extreme rainfall in 2008

Disaster in the drainage occurred in Zoshigaya, Tokyo, caused by heavy rainfall on 5 August 2008

5 workers were killed in drainage by rising flow associated with localized heavy rainfall which developed rapidly within 10~20 min.

http://www.asahi.com

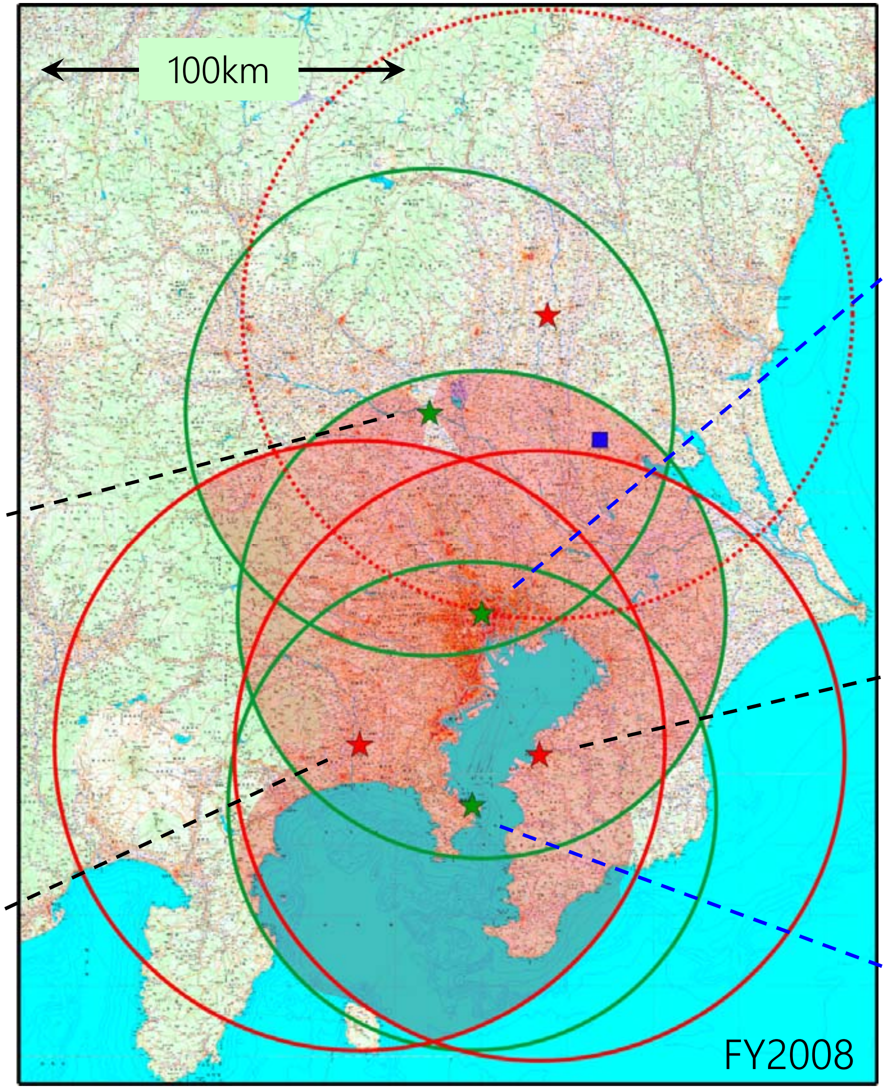


Radar Network in the Metropolitan Tokyo Area (X-NET)

● MRI
● CRIEPI

JWA (Hanyu)

NIED MP-X (Ebina)



Circle: obs. range, shade: wind synthesis area

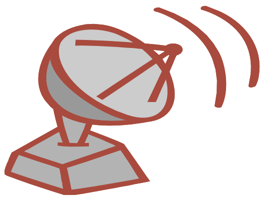
Chuo U. (Tokyo)

NIED X-DOP (Kisarazu)

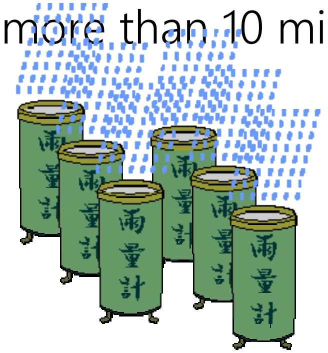
NDA (Yokosuka)

How to make a rainfall map

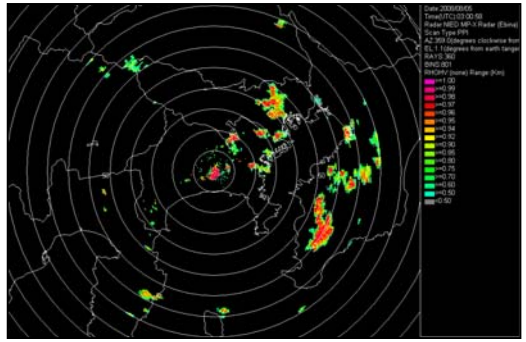
1) Traditional way (takes more than 10 minutes)



Radar observation

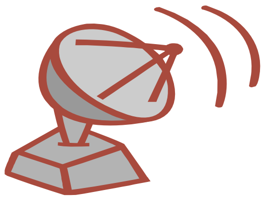


Correction by rain-gauges

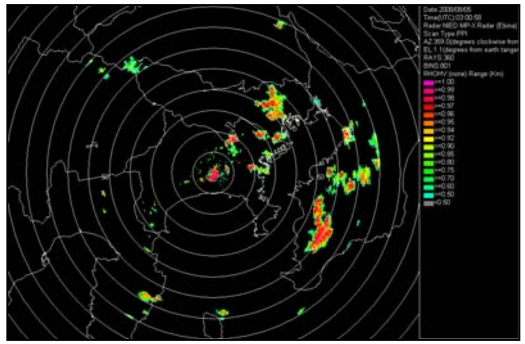


Rainfall map

2) Multi-parameter radar (takes less than 1 minute)



Radar observation

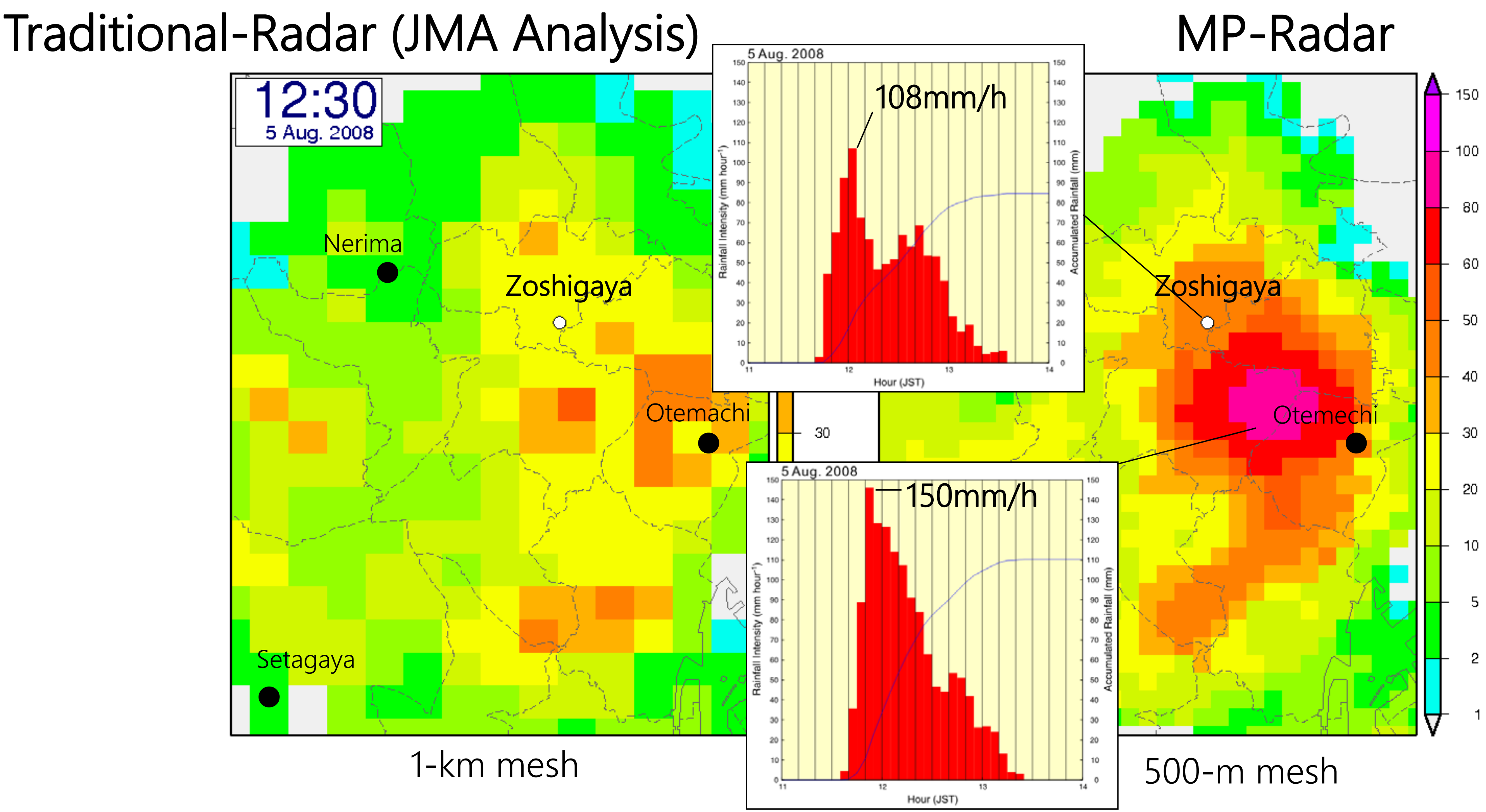


Rainfall map

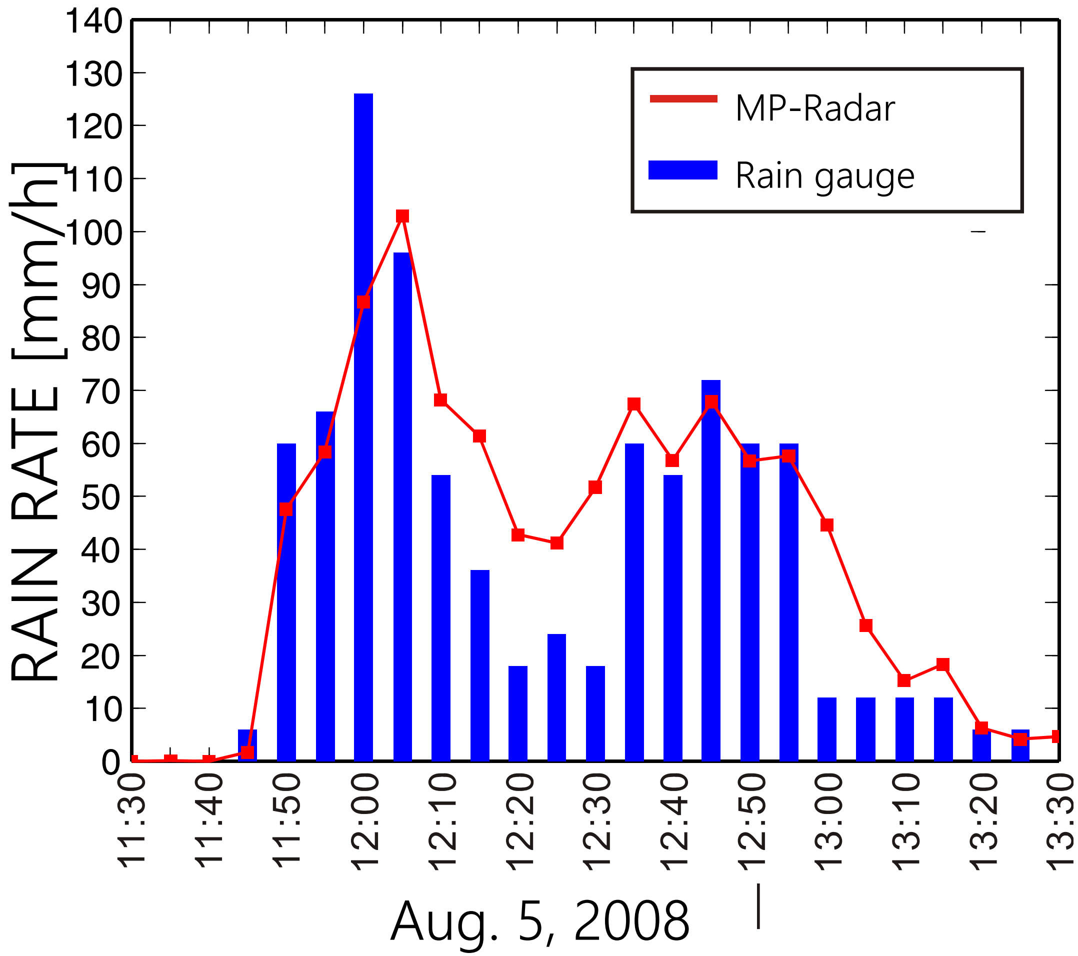
MP Radar can observe precipitation with accuracy without the delay of correction!

Comparison of 1-hr Rainfall Amount (11:30 to 12:30)

Accident occurred in the drainage about 11:40JST



Comparison of 5-min Rain Rate of MP Radar with Rain Gauge

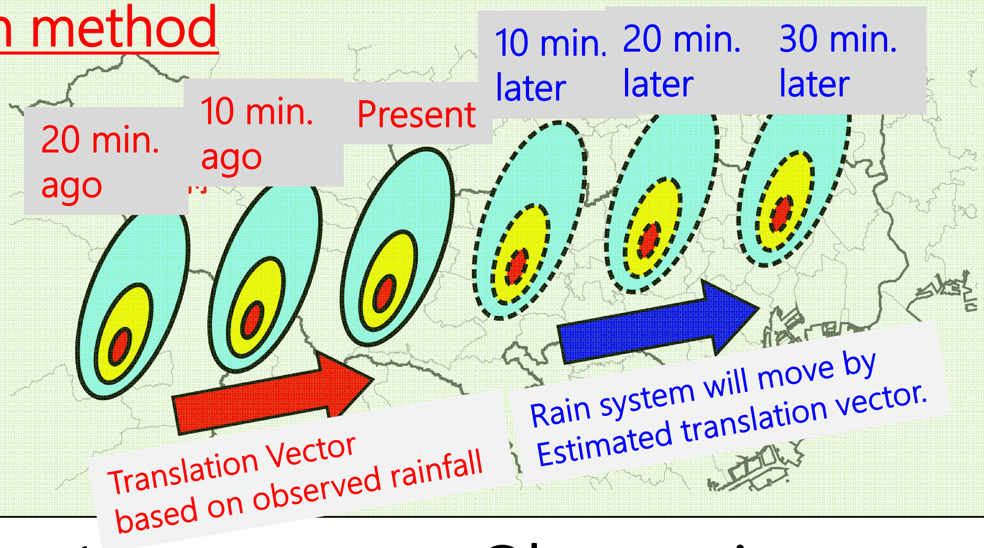


@Otemachi near Zoshigaya

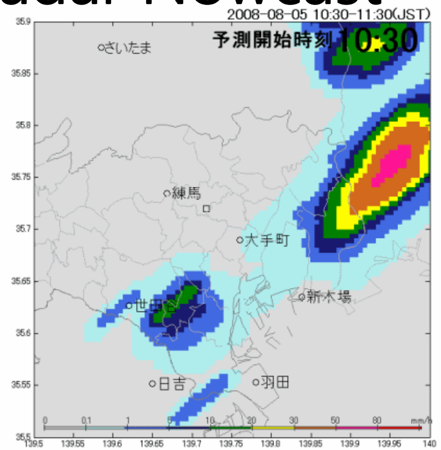
MP radar **well captures the intense rainfall actually observed by rain-gauge.**

Possibility of 1-hr. nowcast (30-min. forecast) of rainfall

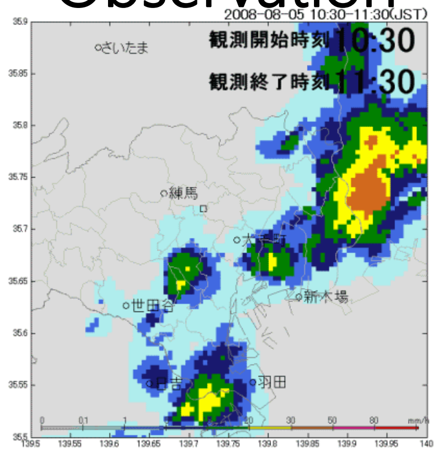
①Extrapolation method



MP-Radar Nowcast



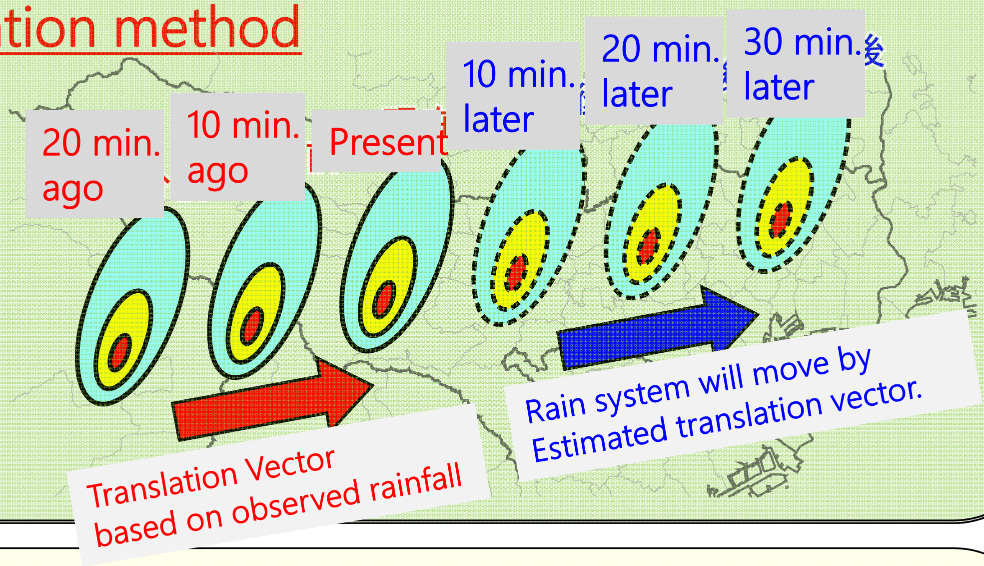
Observation



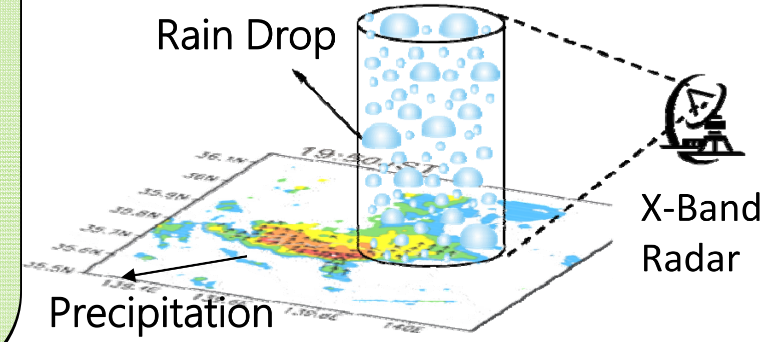
500-m mesh, 10-min int.

Another nowcast method : VIL

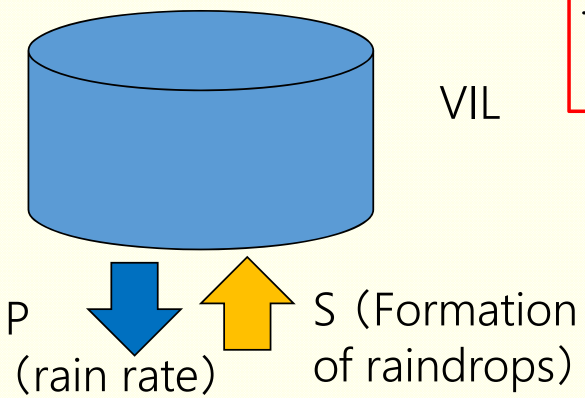
① Extrapolation method



Vertically integrated liquid-water content (VIL)



② VIL method

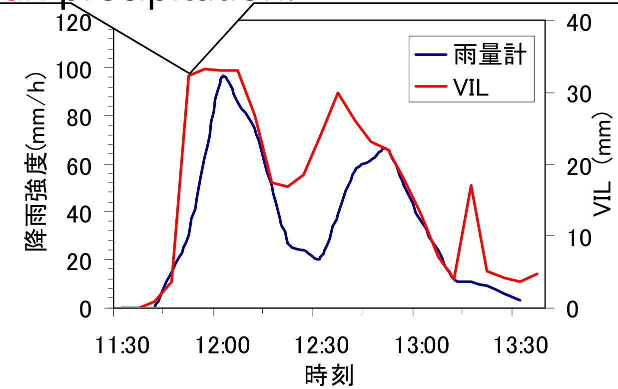


$$\frac{d(VIL)}{dt} = S(t) - P(t)$$

$$S(t) = \frac{VIL(t) - VIL(t - \Delta t)}{\Delta t} + P(t)$$

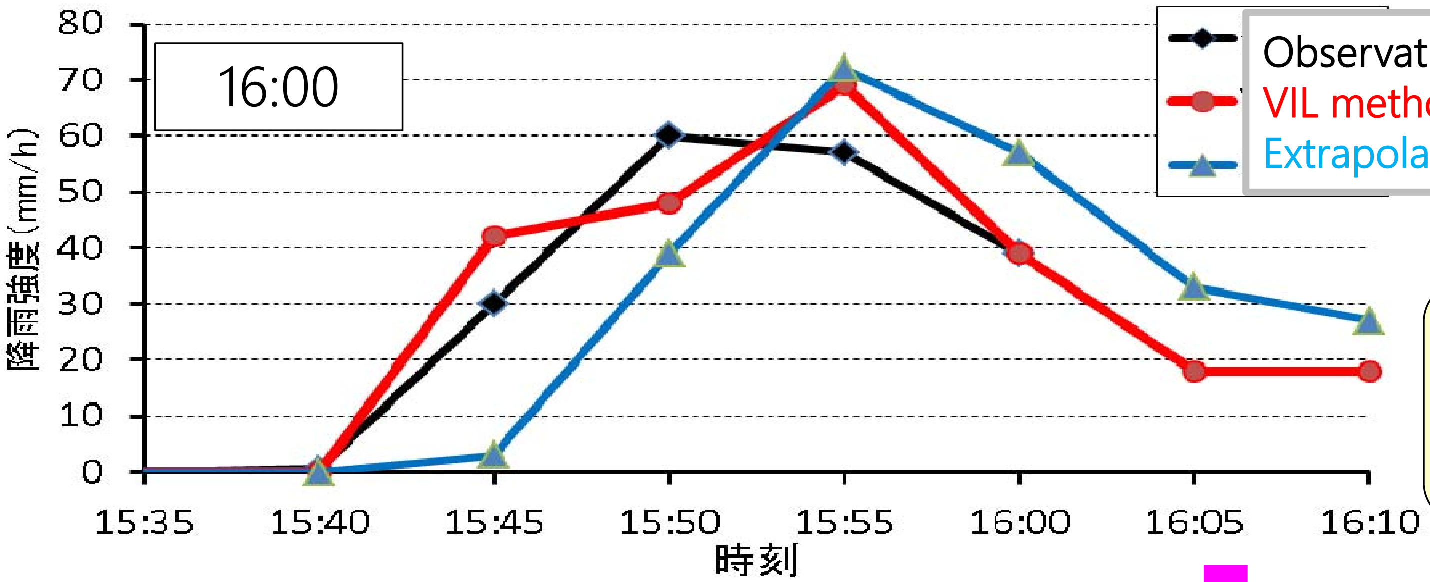
$$VIL(t) = \alpha P(t) + \beta$$

VIL tends to increase 10 minute earlier than precipitation!

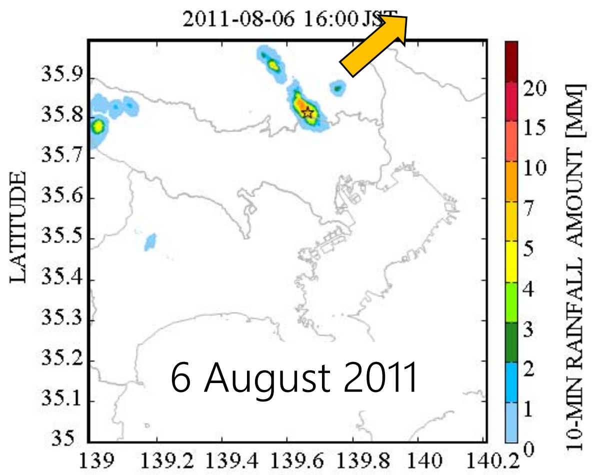


Relationship between VIL and Rain rate on August 5, 2008, at Zoshigaya in Tokyo.

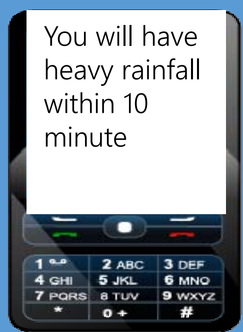
Comparison of nowcast of precipitation by VIL method



✓ VIL method improves the forecast of beginning of rainfall



Information via smart phones



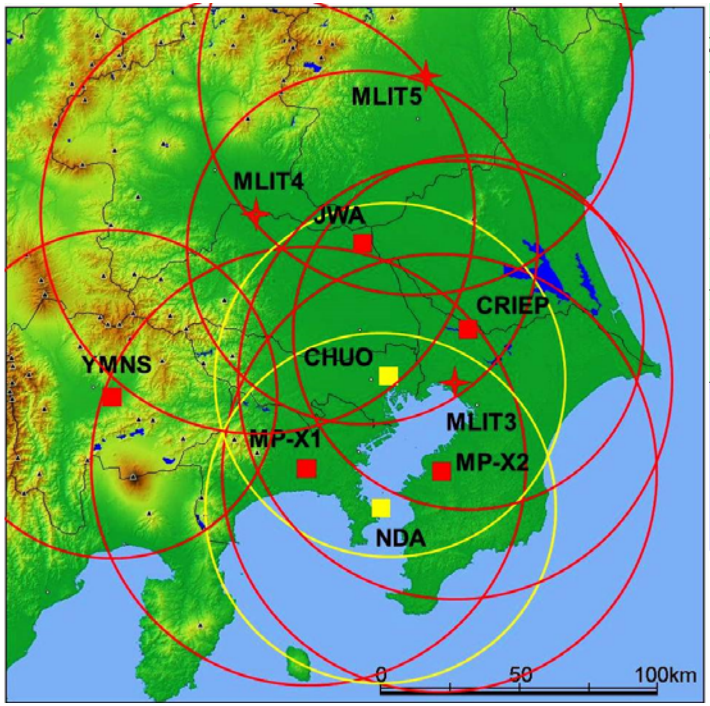
Heavy rain early warning !
Stay or Go ?

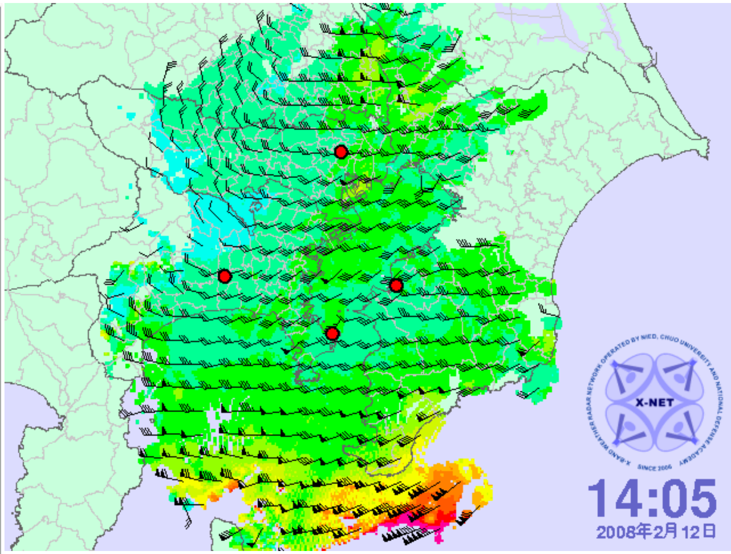
Summary

- We are faced with an increase in natural disaster. The increase is related to
  - Change in Society
  - New levels of weather extremes – Lacking experience in new kinds of hazards
- These could have potentially bring the new kinds of weather risks and more intense natural catastrophes.

- Further studies for both prospective hazard modelling and development of observing system would be required for meteorological hazard mitigation.

Estimation of wind distribution using X-band radar network



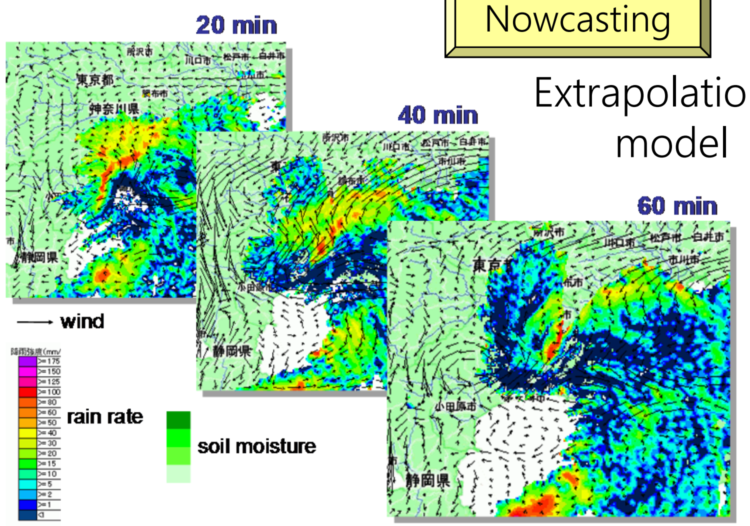


Radar can estimate not only precipitation but also wind fields using principle of Doppler effect

Monitoring

Nowcasting

Extrapolation & model



Is the nowcast of strong wind possible?
Can we catch wind burst / tornado ?

This is an ongoing big challenge!

Thank you