高知大学
Kochi University

Advances in Stormwater Management: Fusion of Numerical Modelling and Internet of Things

2023-09-19, Water New Zealand Association Webinar

Yoshihiro Shibuo, Kochi University

Presentation Outline

- ❑ Introduction
- ❑ Integrated Urban Flood Modelling
- ❑ Application of Internet of Things
- ❑ *Big Data in Earth Sciences*
- ❑ Fusion of Numerical Modelling & IoT
- ❑ Summary

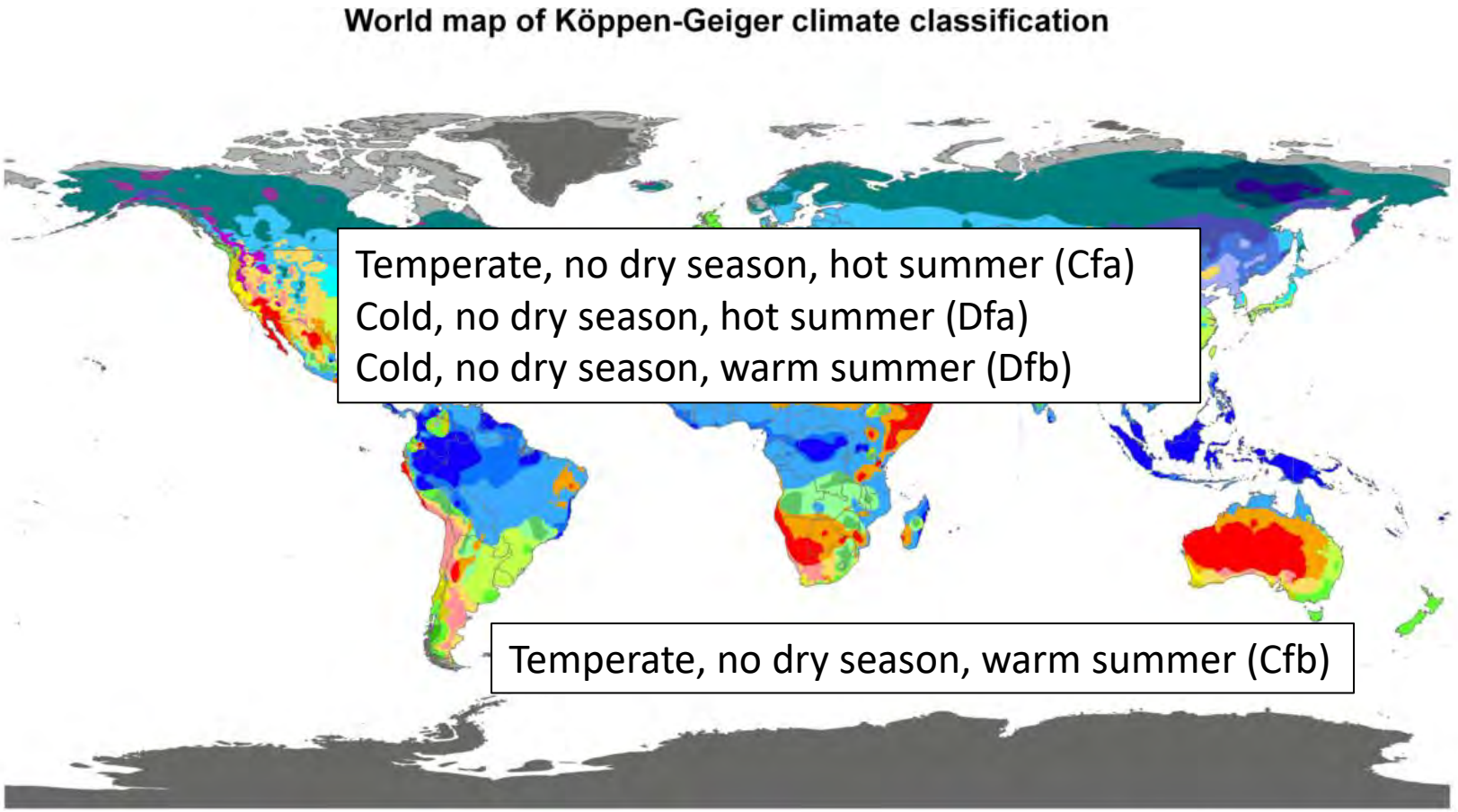
Advances in Stormwater Management

Introduction

Physical Geography

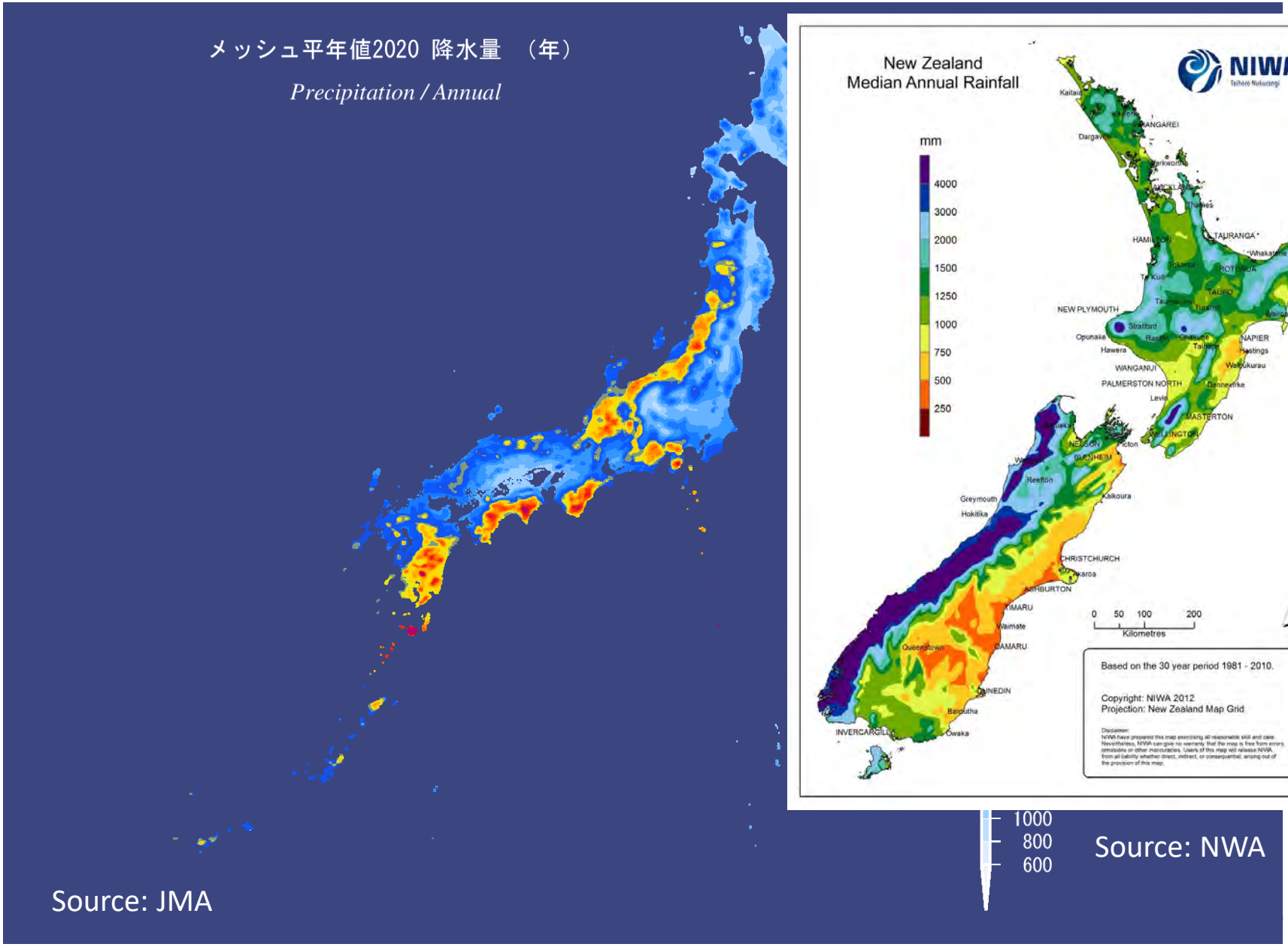
Source: GSI, Japan

Climate Classification

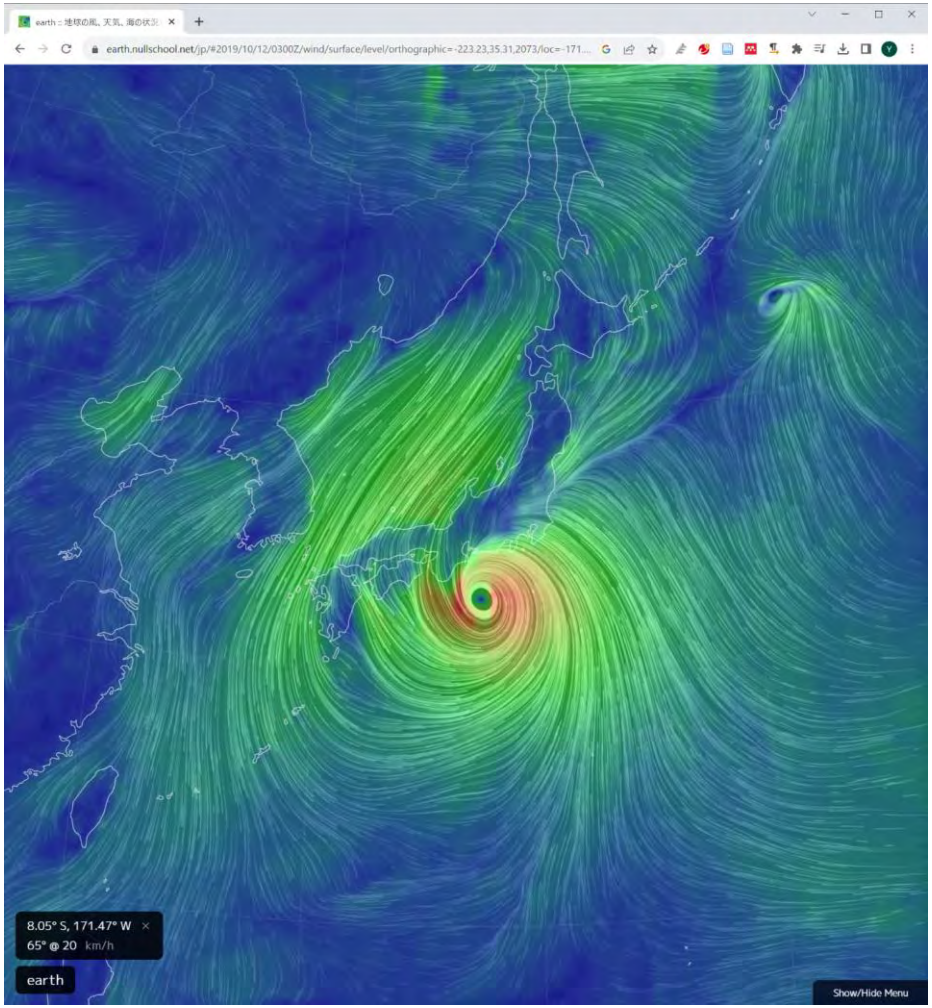


THE UNIVERSITY OF MELBOURNE

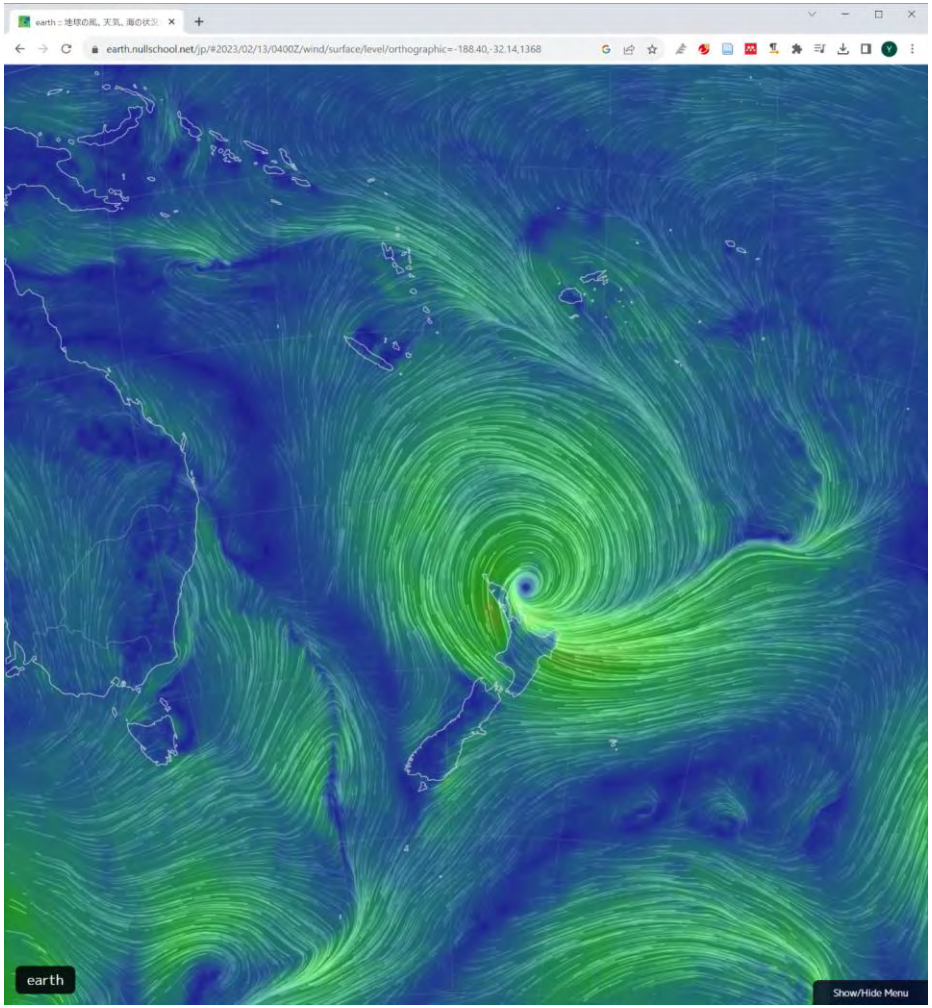
Average Annual Precipitation



Typhoons and Cyclones



Typhoon Hagibis, 2019



Cyclone Gabrielle, 2023

Source, null earth

Recent Example Cases: Typhoon Hagibis, 2019

台風第19号
（ハギビス、(Hagibis)）

Category 5: Super typhoon

Typhoon #19

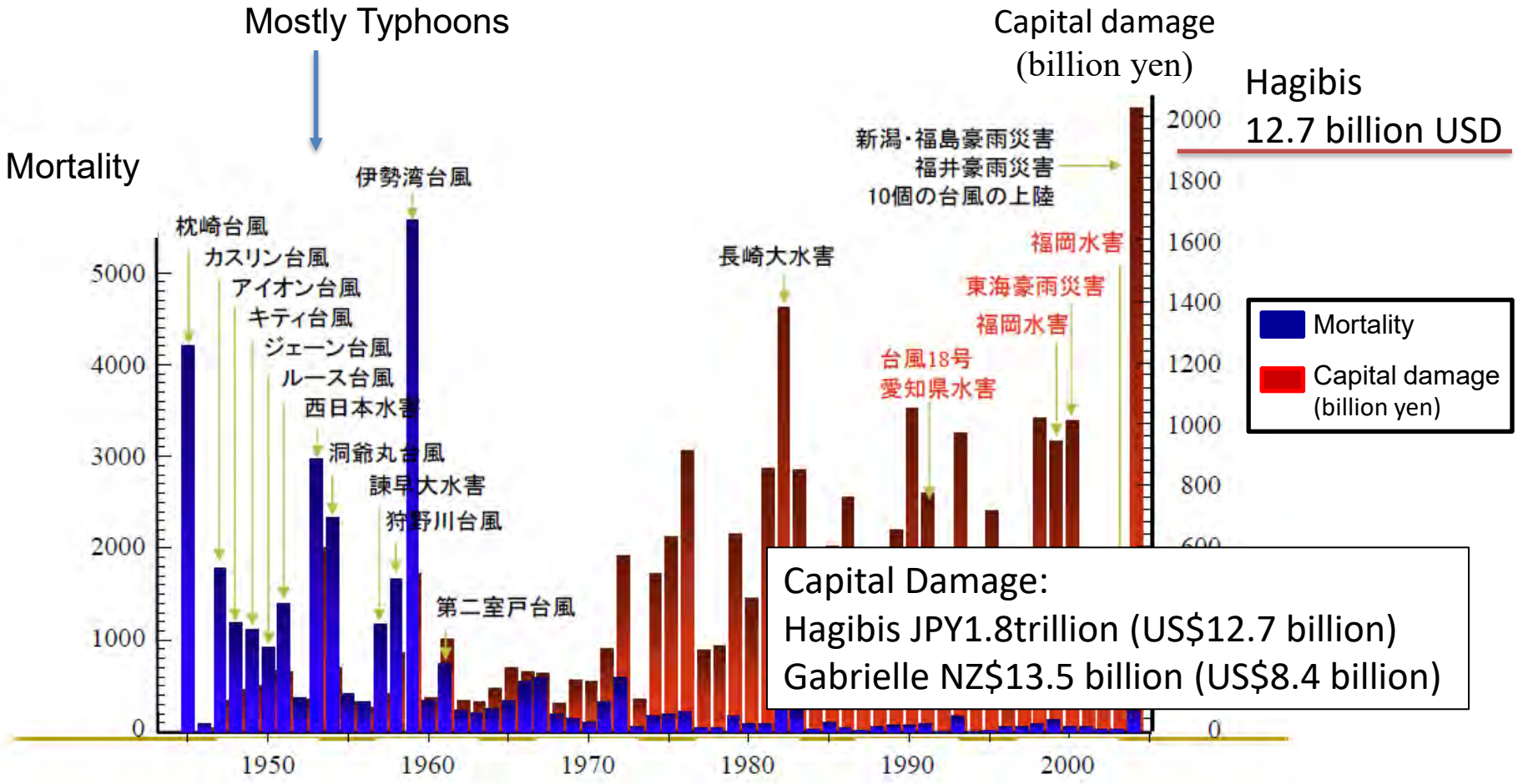
Occurrence period :Oct.6, 3:00 - Oct. 13, 12:00
Life span: 7 days 9 hours

Typhoon #19: Water erupts from manholes.
Inundation in Hachioji, Tokyo (Oct. 12, 2019)

https://www.youtube.com/watch?v=7Cwy5NNjLUc

Mortality and Capital Damage by Disasters

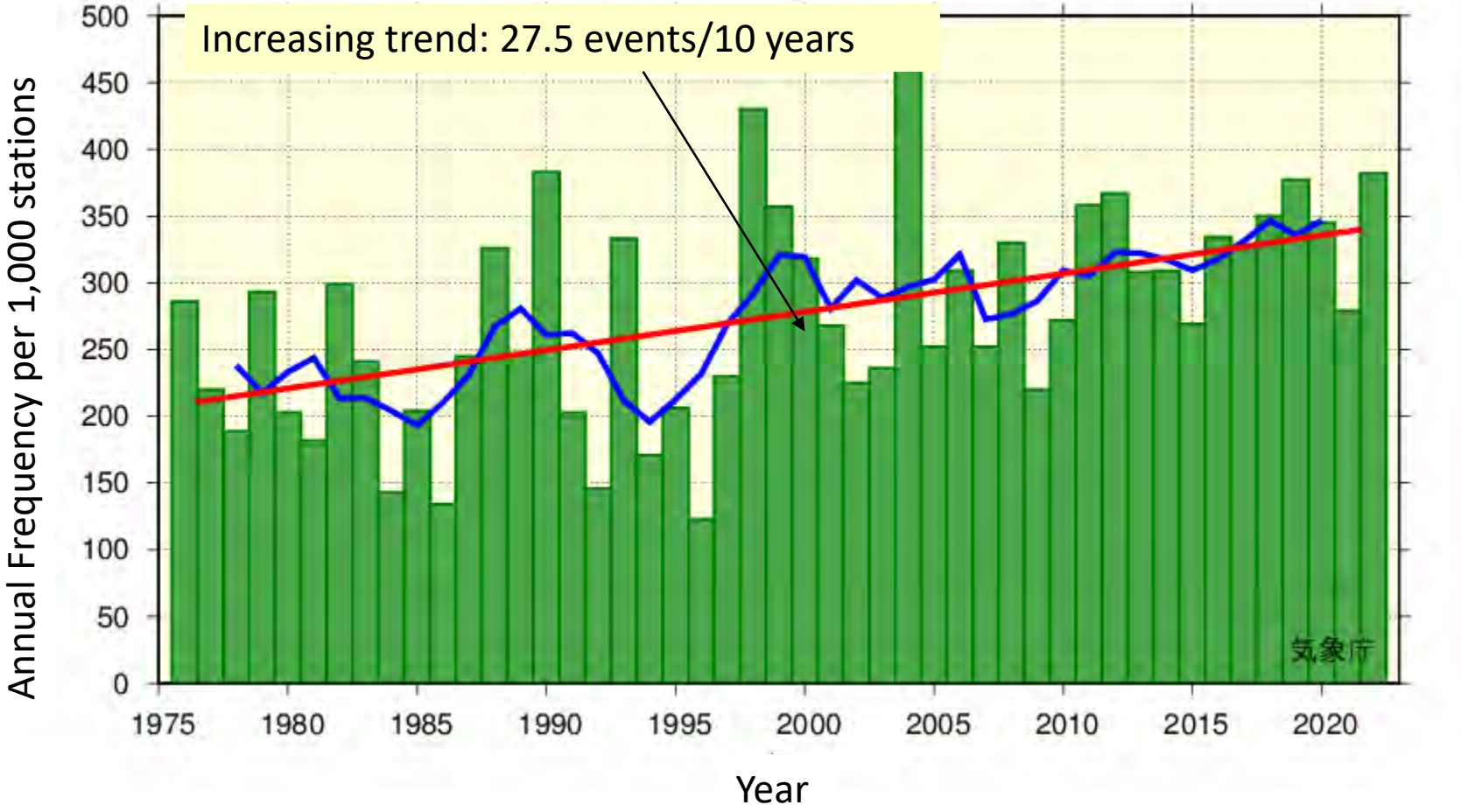
Mortality has decreased by various measures, but capital damage keep increasing



(http://www.salagrande.net/tominaga.pdf)

Trends in Torrential Rainfall in Japan

Frequency of rainfall event with intensity ***more than 50mm/hr***

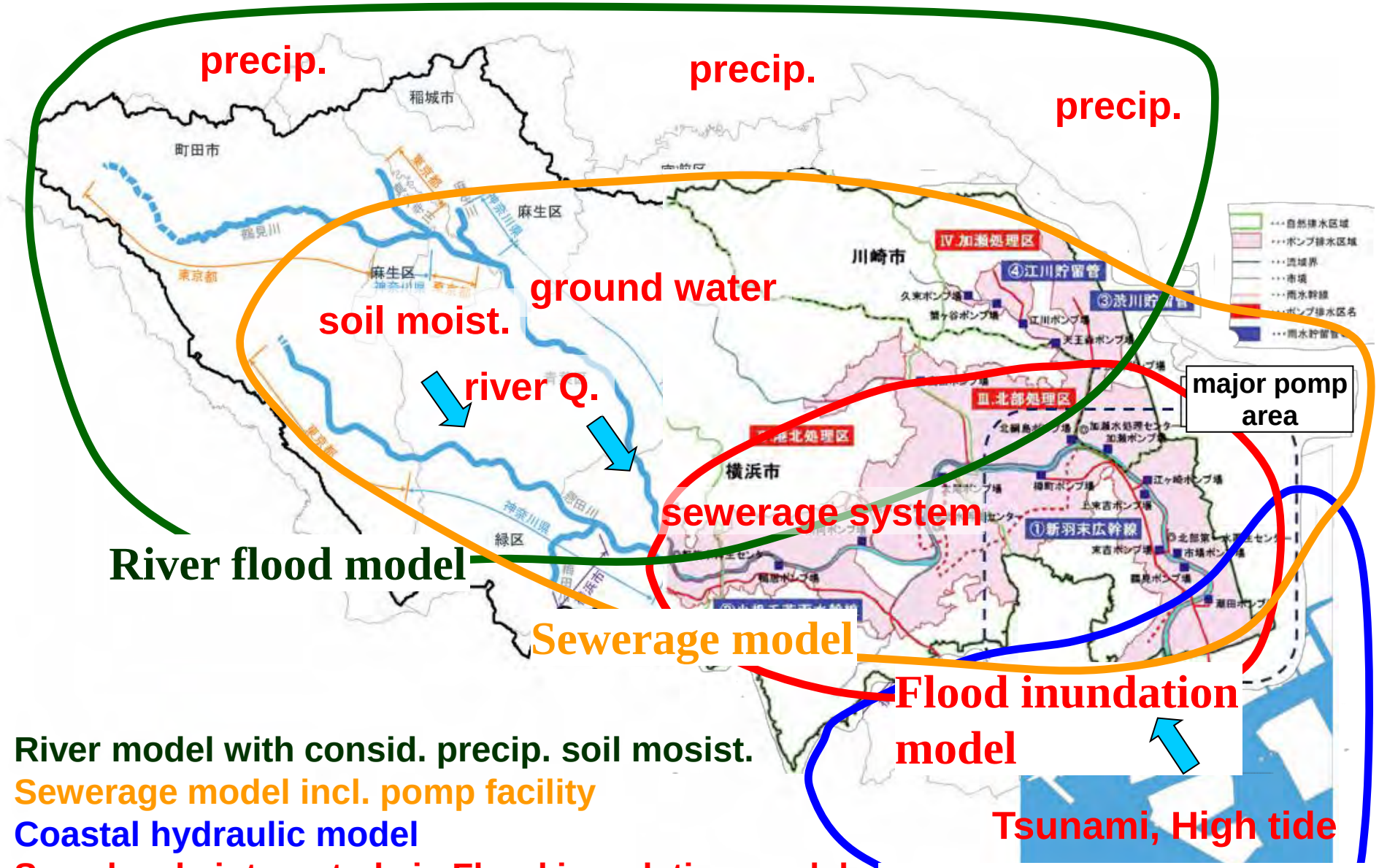


Source, JMA

Advances in Stormwater Management

Integrated Urban Flood Modelling

Flood contributing factors and sub-models



River model with consid. precip. soil mosist.

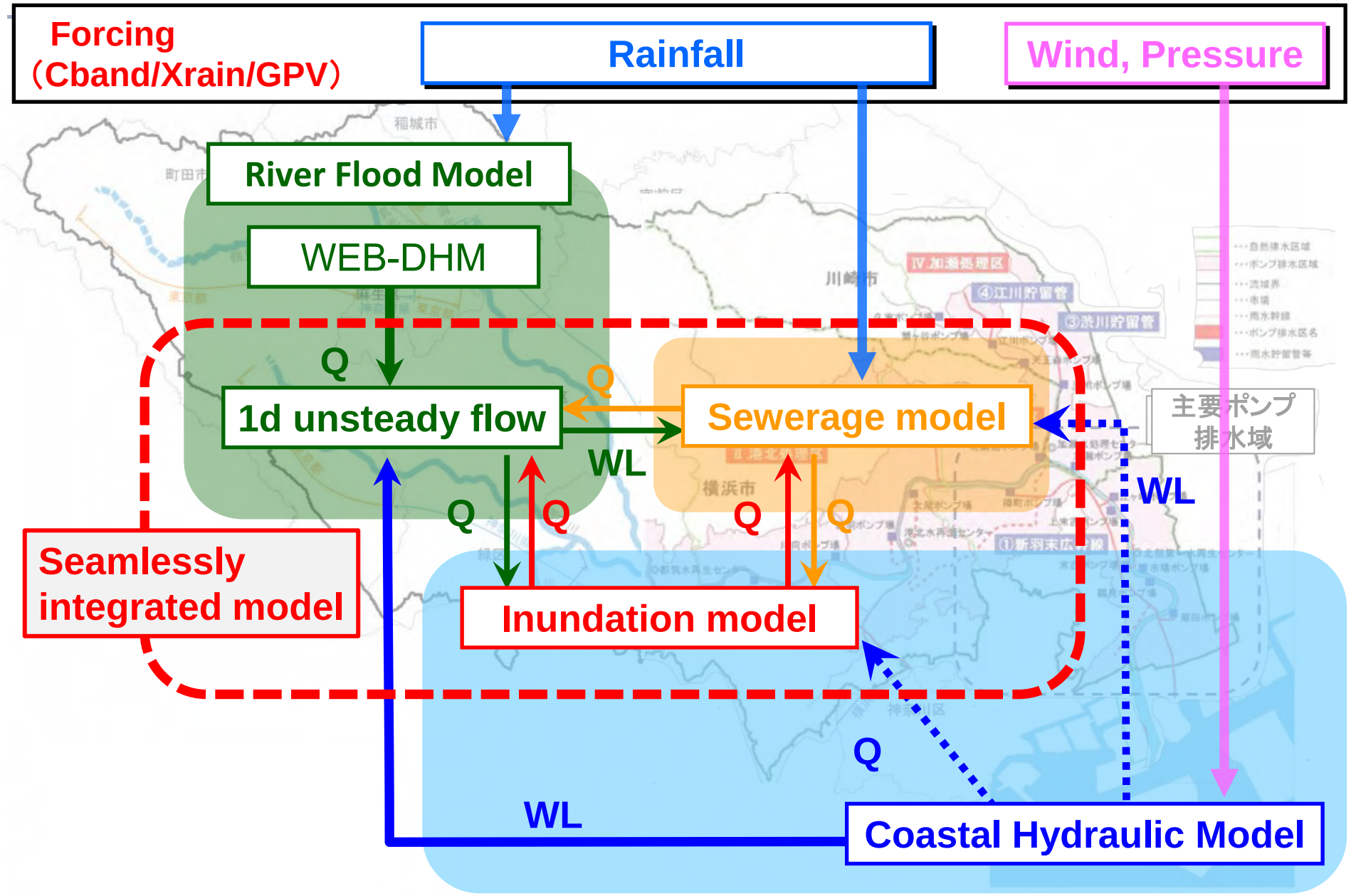
Sewerage model incl. pomp facility

Coastal hydraulic model

Seamlessly integrated via Flood inundation model

→Realize real-time integrated flood forecast

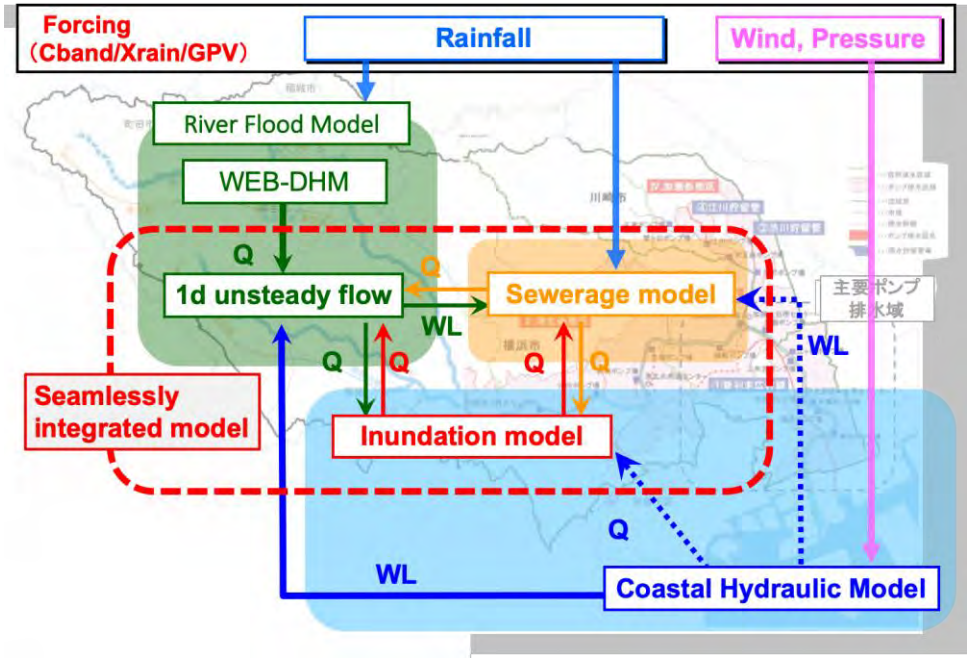
Schematic Image of Seamlessly Integrated Model



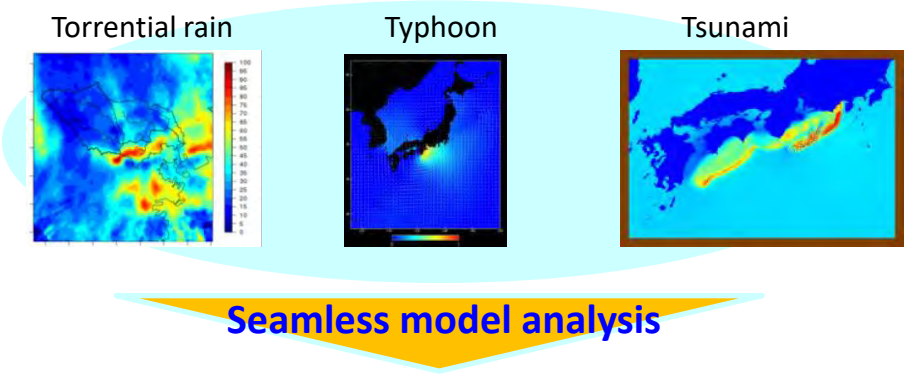
Integrated urban flood simulation model

The “Seamless Model”

Real-time analysis of urban flood using a simulation model that integrates elements of river, sewerage systems and coastal hydraulics.



Sanuki et al., J-JSCE Ser. B1 (Hydraulic Engineering) (2016)



Rapid and integrated water hazard prediction

Water level and flow rate in river
Water level in drainage pipes and pump discharge
Fluvial (River) flood and Pluvial (Surface) flood

Multi-purpose retarding basin


Source: Keihin River Office


Source: Keihin River Office

Nippa Suehiro Stormwater Storage Pipe

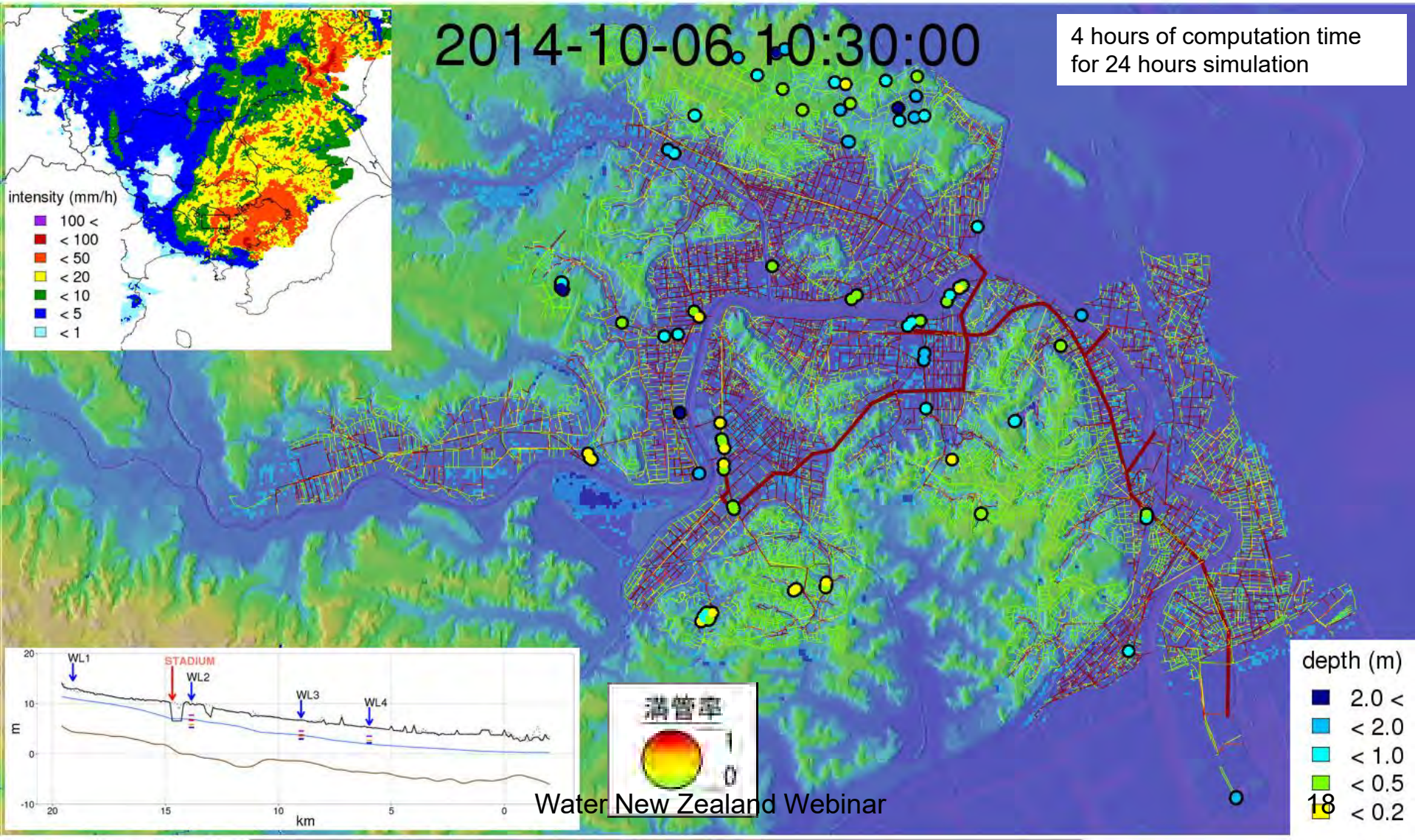
Source: Yokohama city

Nippa Suehiro Stormwater Storage Pipe

Inside the pipe

Model Application to Typhoon 18, 2014

Typhoon 18 in 2014: 360 mm of cumulative rainfall with 50mm/hr intensity



Model Application to Typhoon 18, 2014

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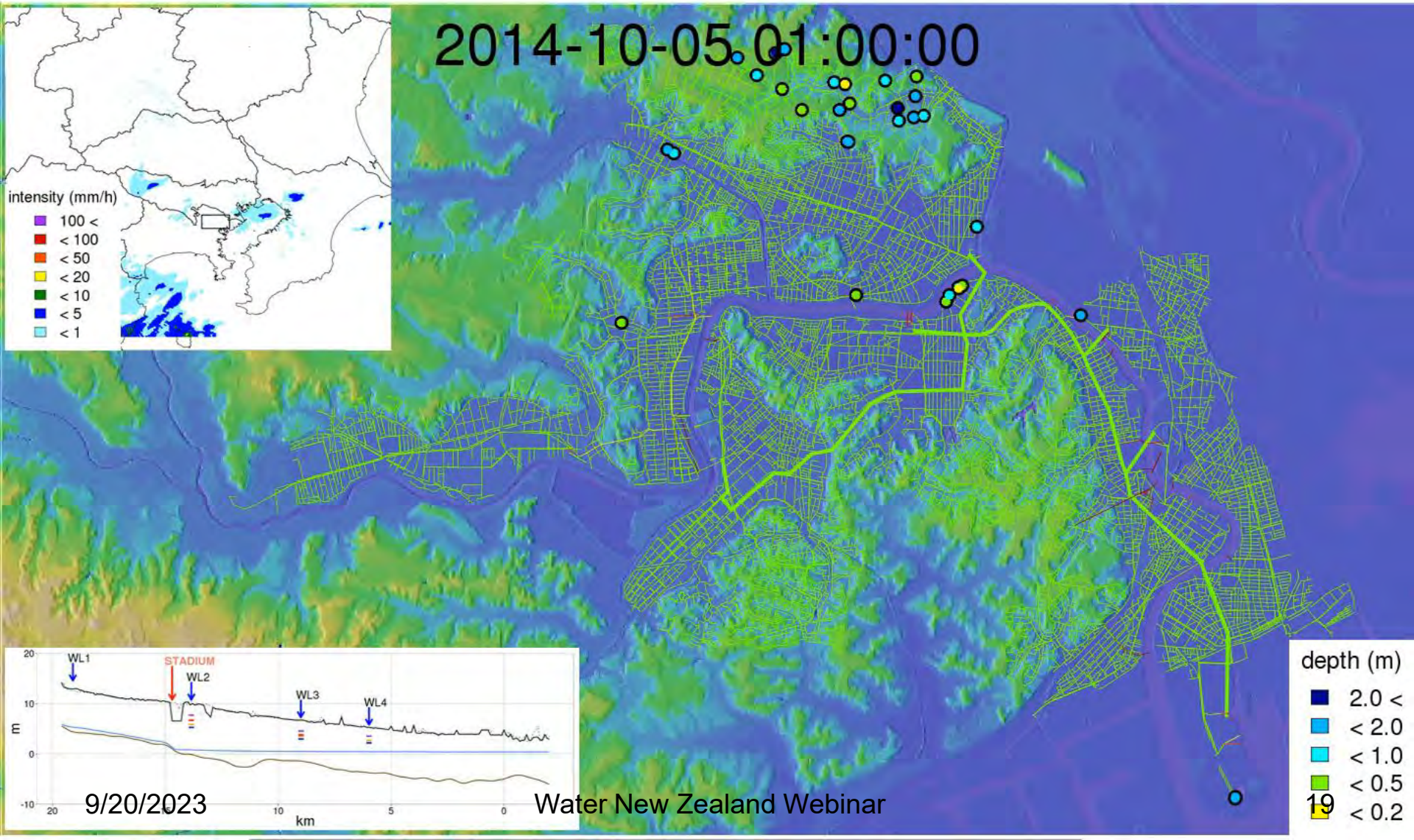
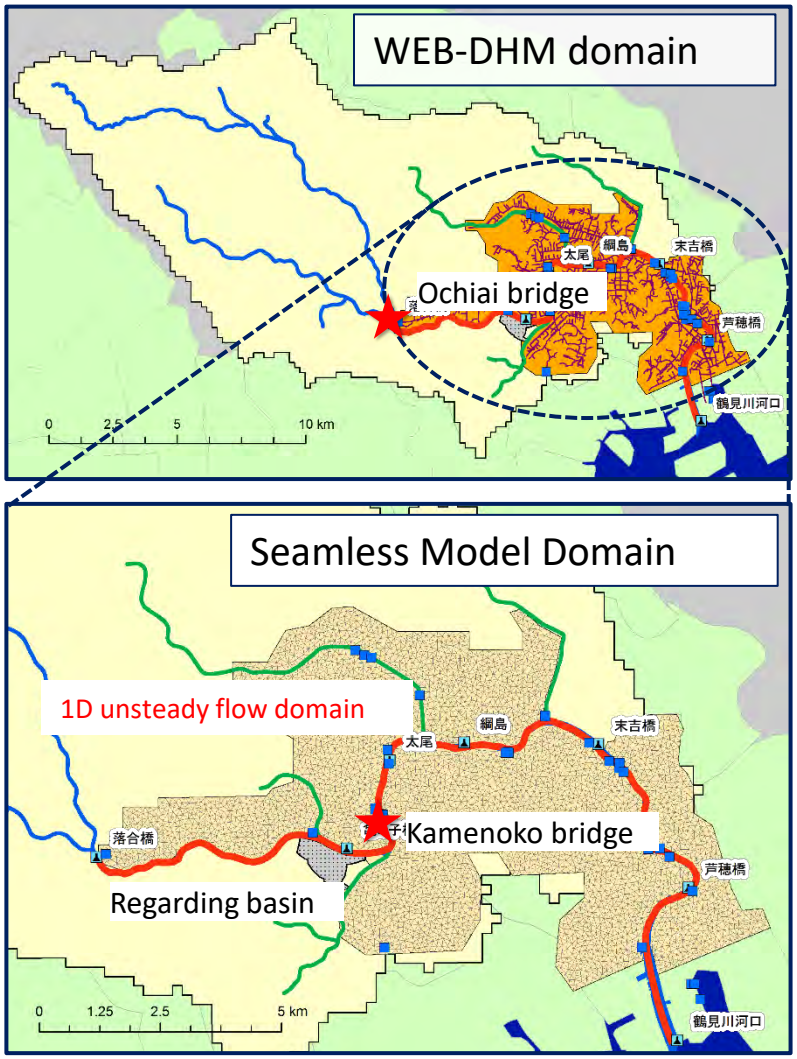
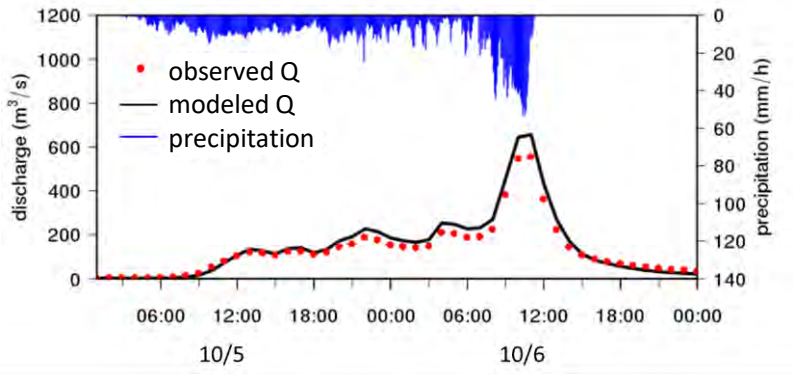
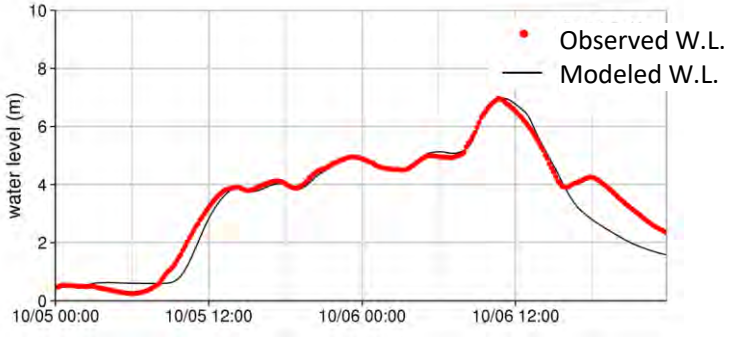


Model Validation: Rivers and Flood Control Facilities





WEB-DHM discharge at Ochiai bridge



Seamless model water level at Kamenoko bridge

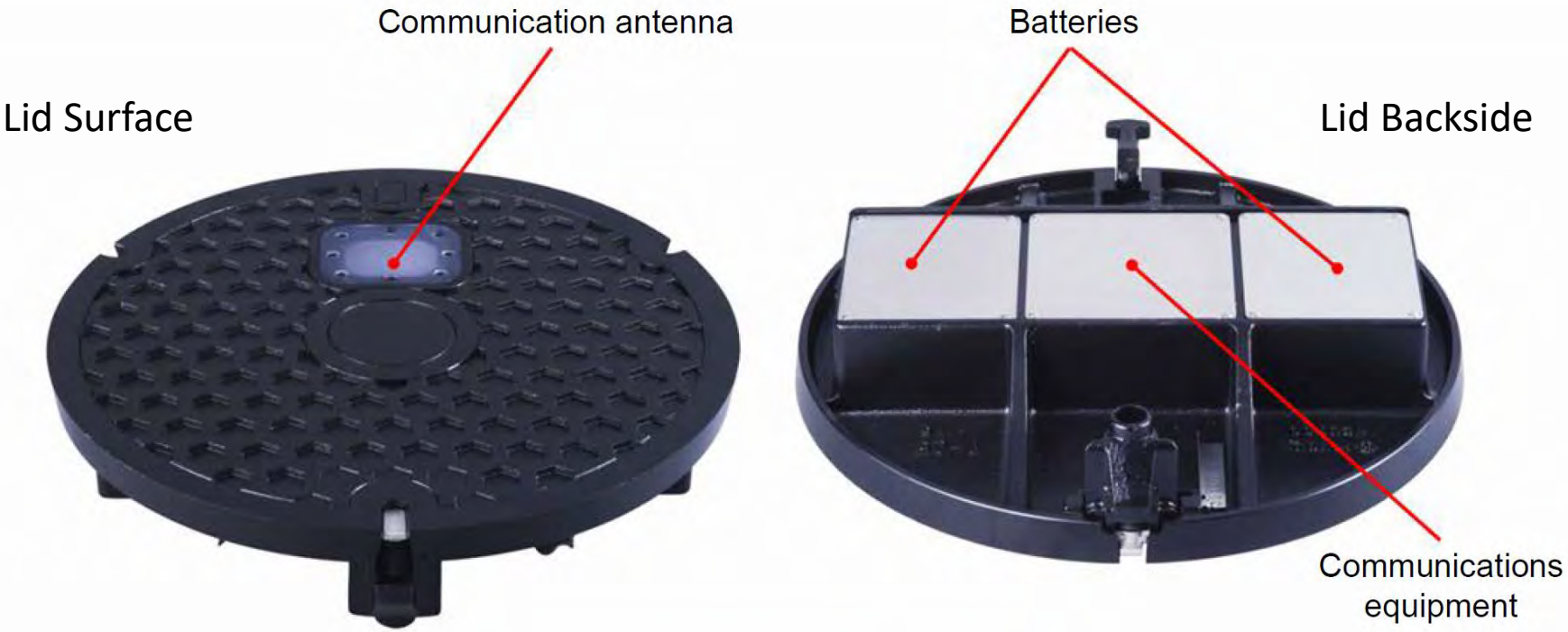
Modeled Flood Control Volumes

	Observed (m^3)	Model (m^3)
Retarding Basin	1,536,000	1,785,000
Storm water Retention Pipe	380,000	388,800

Advances in Stormwater Management

Application of Internet of Things

Realtime Water Level Monitoring in Stormwater Drainage



Smart Manhole Cover

* Smart Manhole Cover was jointly developed by Tokyo Metropolitan Sewerage Service Corporation, Hinode Ltd., and Meiden Corporation.

Meiden Coorp.

Examples of Smart Manhole Cover Installation

Confluent type sewage pipe (ϕ300mm), water level

Sewage bypass pipe (ϕ1,100 mm), flow (commercial power reception)

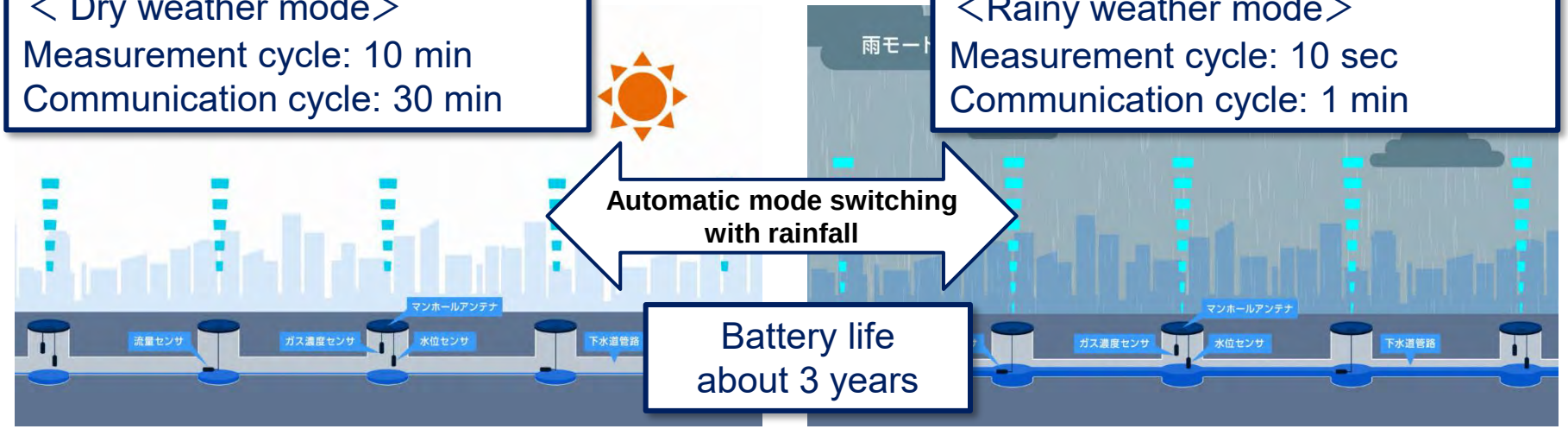
Meiden Coorp.

Features of Smart Manhole Cover

- Manhole with a communication device, an antenna with a built-in battery on the backside of manhole lid, serving as IoT
- Automatic switching function responding to wet and dry weathers for prolonging battery life

＜ Dry weather mode＞
Measurement cycle: 10 min
Communication cycle: 30 min

＜Rainy weather mode＞
Measurement cycle: 10 sec
Communication cycle: 1 min



Battery life about 3 years

Antenna

Lid Surface

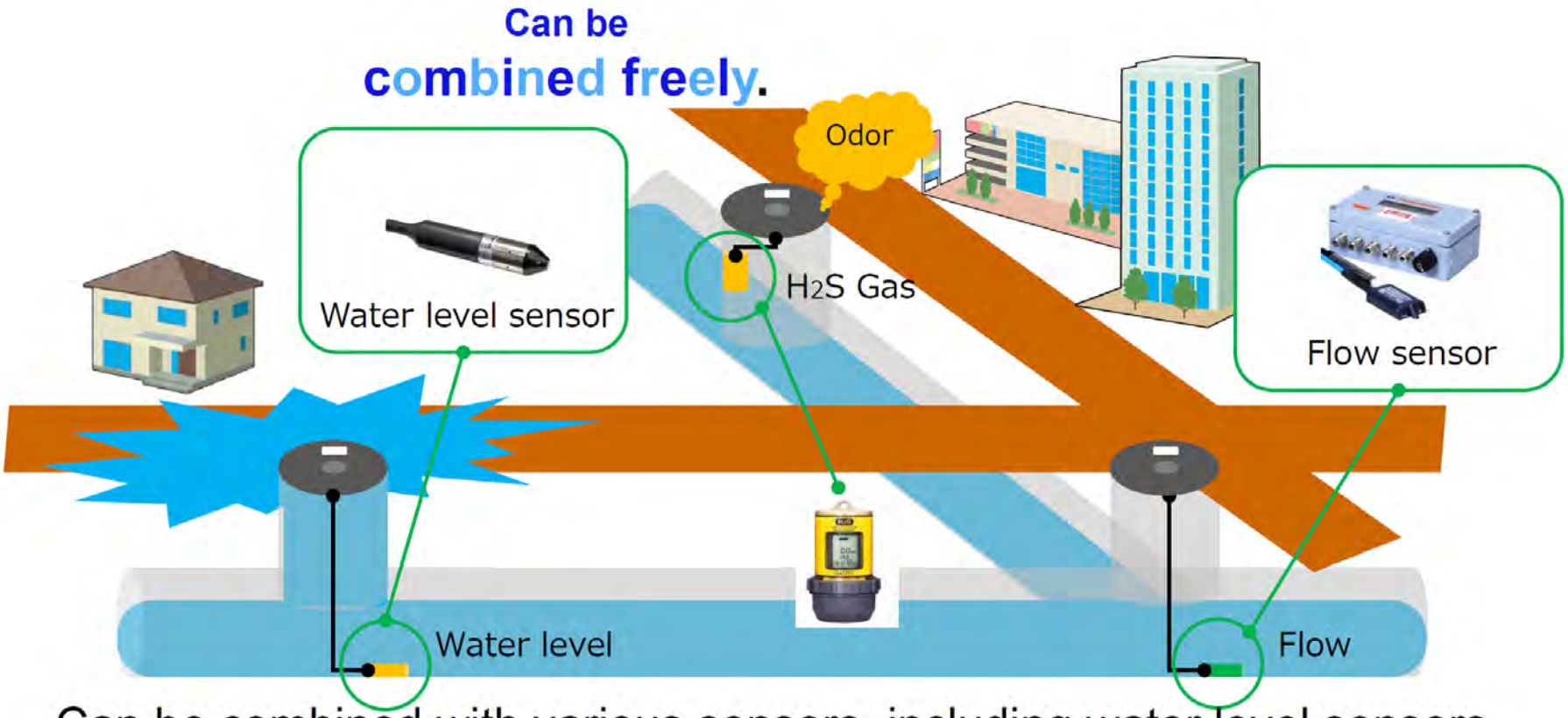
Battery

Lid Backside

Meiden Coorp.

Communication device

Features of Smart Manhole Cover

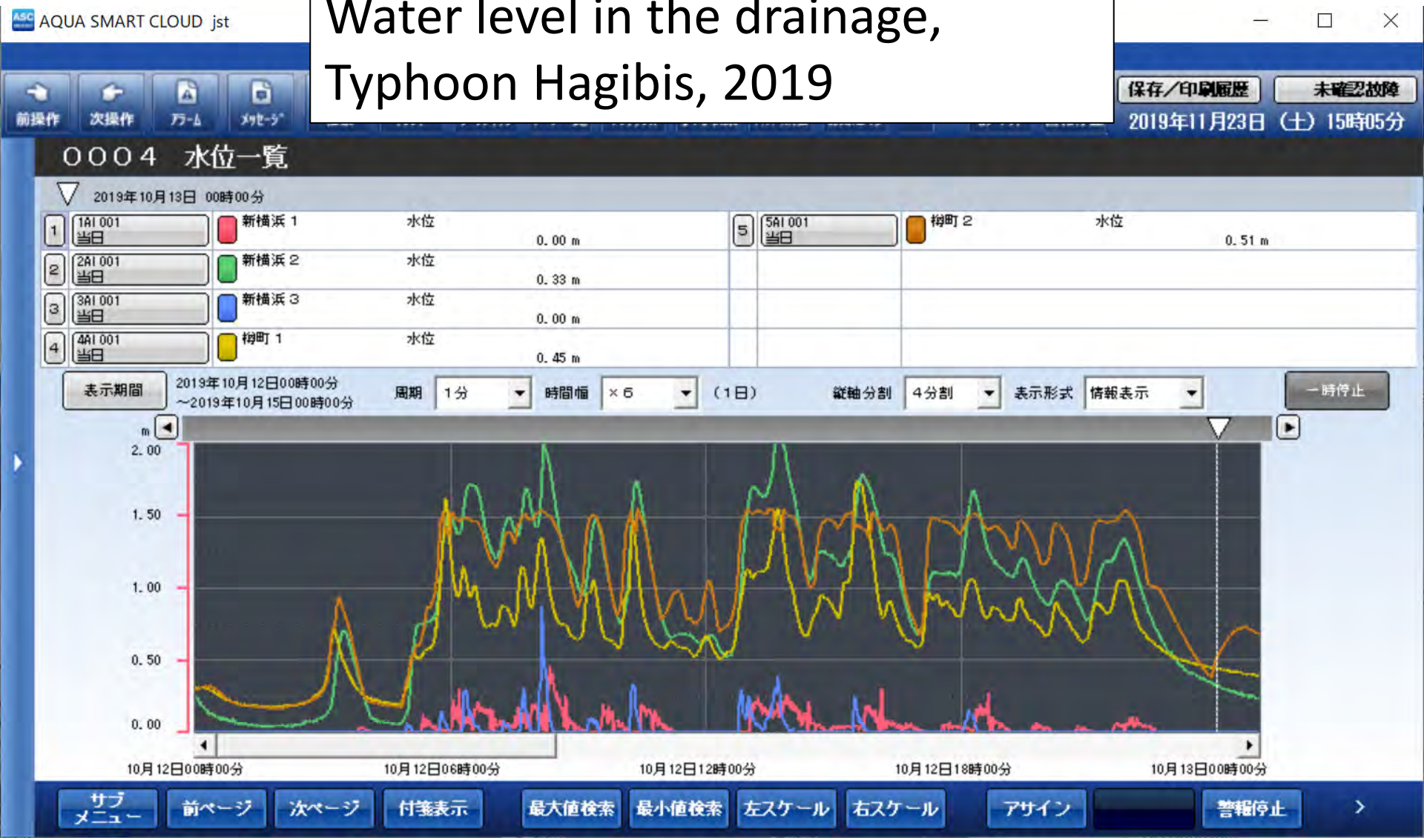


Can be combined with various sensors, including water level sensors.

Meiden Coorp.

Observed Water Level on Cloud file server,

Water level in the drainage, Typhoon Hagibis, 2019



Advances in Stormwater Management

Big Data in Earth Sciences

INTEGRATED

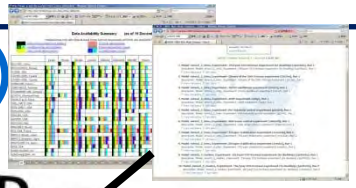
Ground observation data

Marine observation data

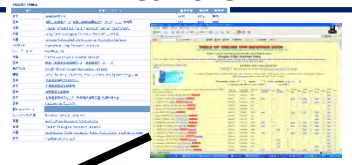
Satelite data

simulation

WCRP CMIP3



MetBroker



INTEGRATED

Prototype of Data Integration & Information Fusion Core System

Application Layer

User Apps. | User Apps. | User Apps. | User Apps. | User Apps.

Common Infrastructure Software Layer

- Visualizer(w display wall)
- Discovery Work Flow Assist
- Data Quality Manager
- Data Transformer
- Data Crawler
- ETL
- Data Mingrator
- Data Navigator
- Meta Data Manger

Data Management layer

- DB management system

File System Layer

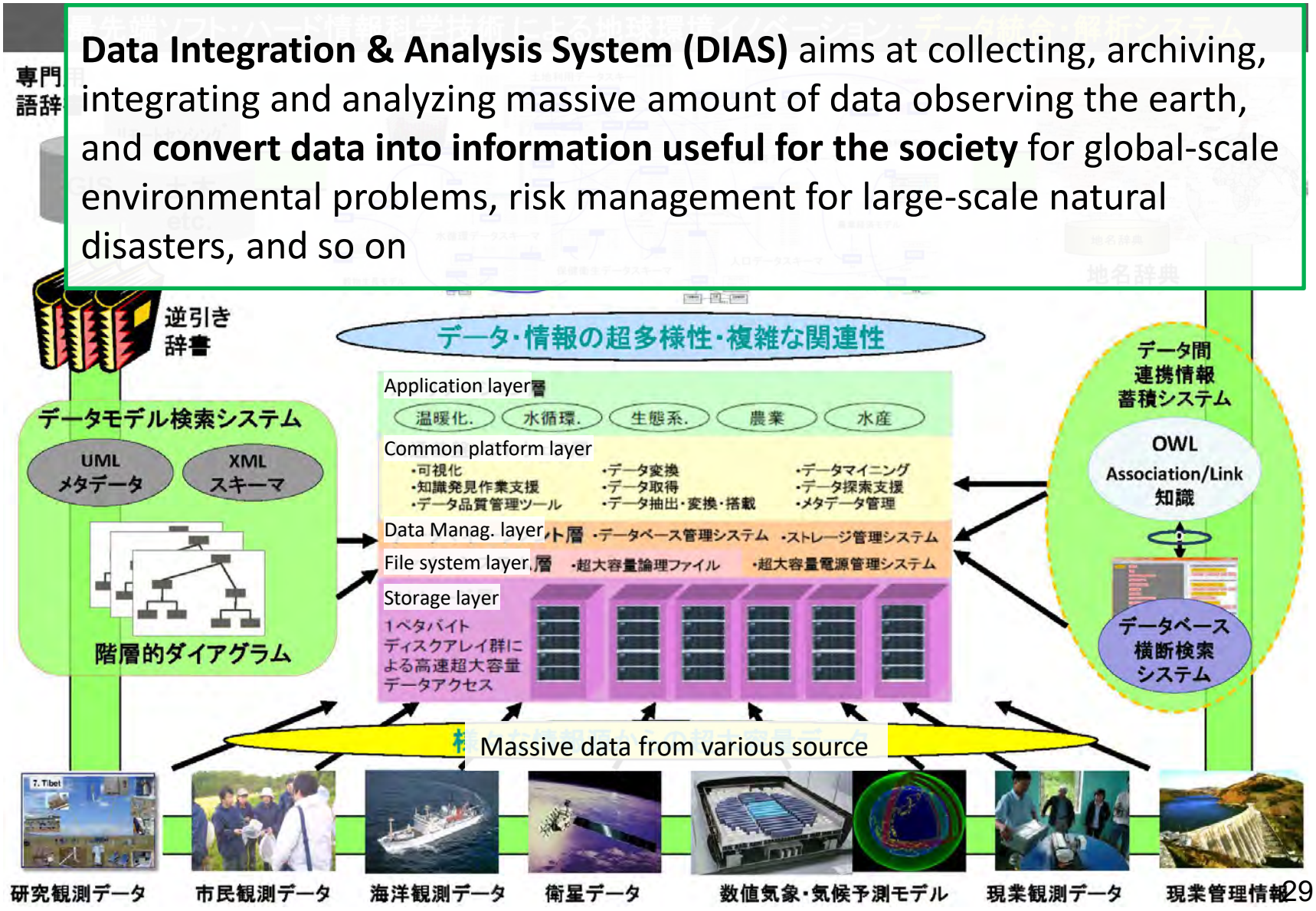
- PB scale logical file
- Storage management
- Power management

Storage Layer

Disk Arrary Cluster

Data Integration and Analysis System (DIAS)

Data Integration & Analysis System (DIAS) aims at collecting, archiving, integrating and analyzing massive amount of data observing the earth, and **convert data into information useful for the society** for global-scale environmental problems, risk management for large-scale natural disasters, and so on



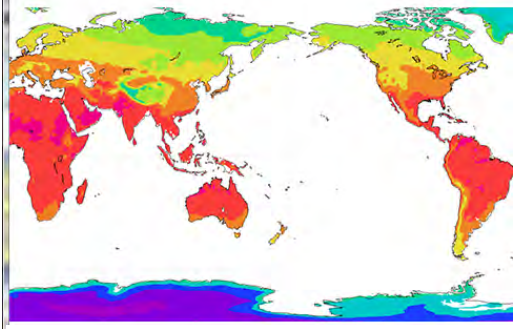
Data Set Examples

最先端ソフト・ハード情報科学技術 による地球環境イノベーション：データ統合・解析システム

GCM Output

DIAS Data Integration and Analysis System Program

CMIP5 Data Analysis System

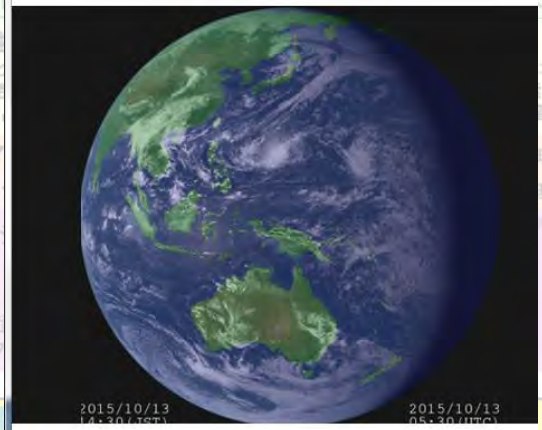


Some examples include but not limited to
CMIP3: 34TB
CMIP5: 1.6PT

Himawari 8

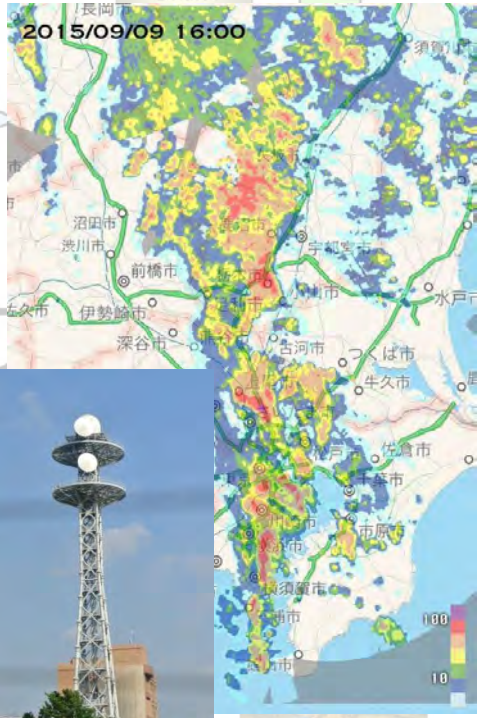
DIAS Data Integration and Analysis System Program

Latest Himawari-8 Images



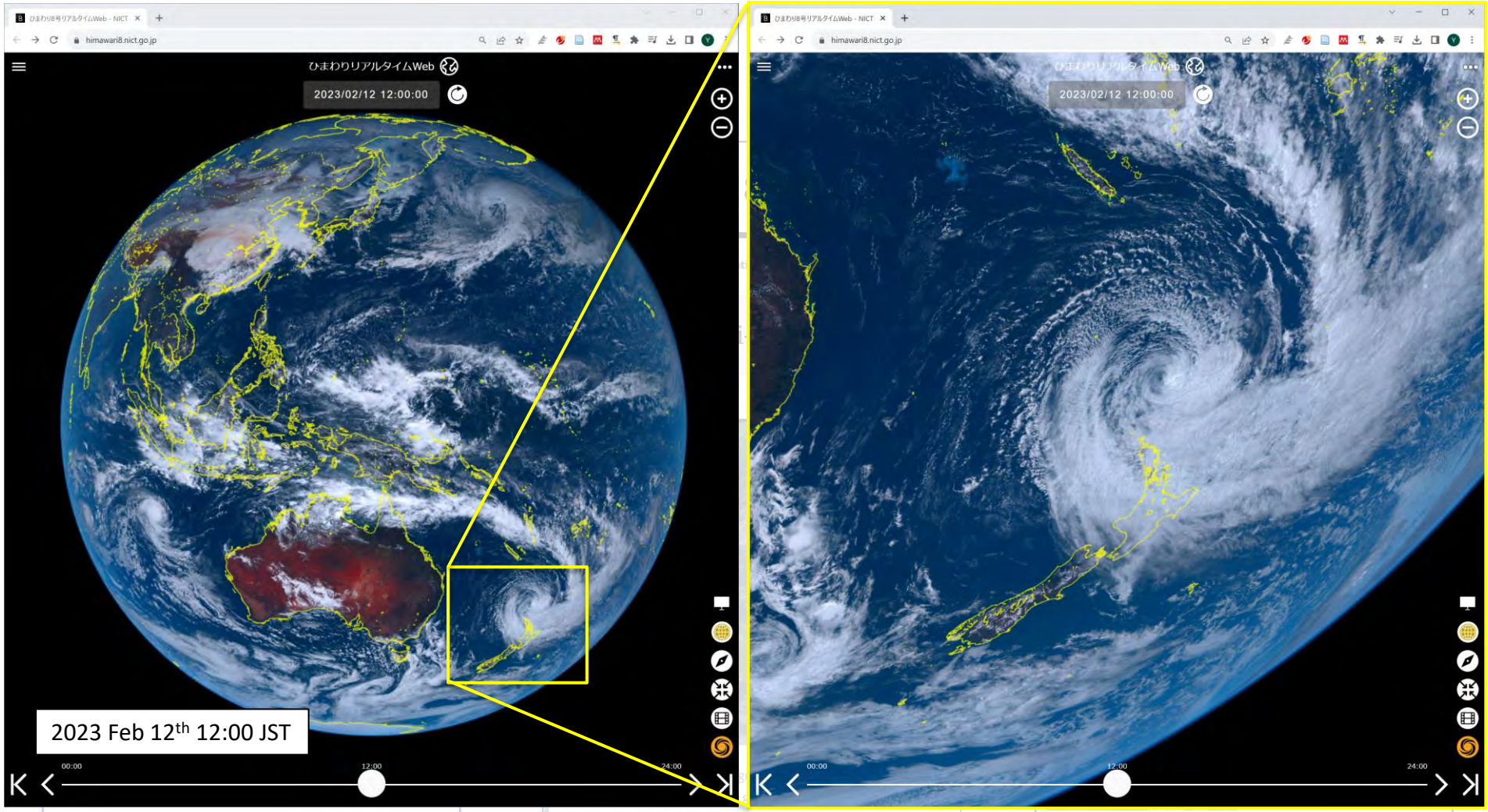
The Latest Himawari-8 Images page provides still images and animations
visual and infrared sensors of the geostationary weather satellite Himaw
the-minute movements of typhoon and clouds online.

Real-time Rainfall



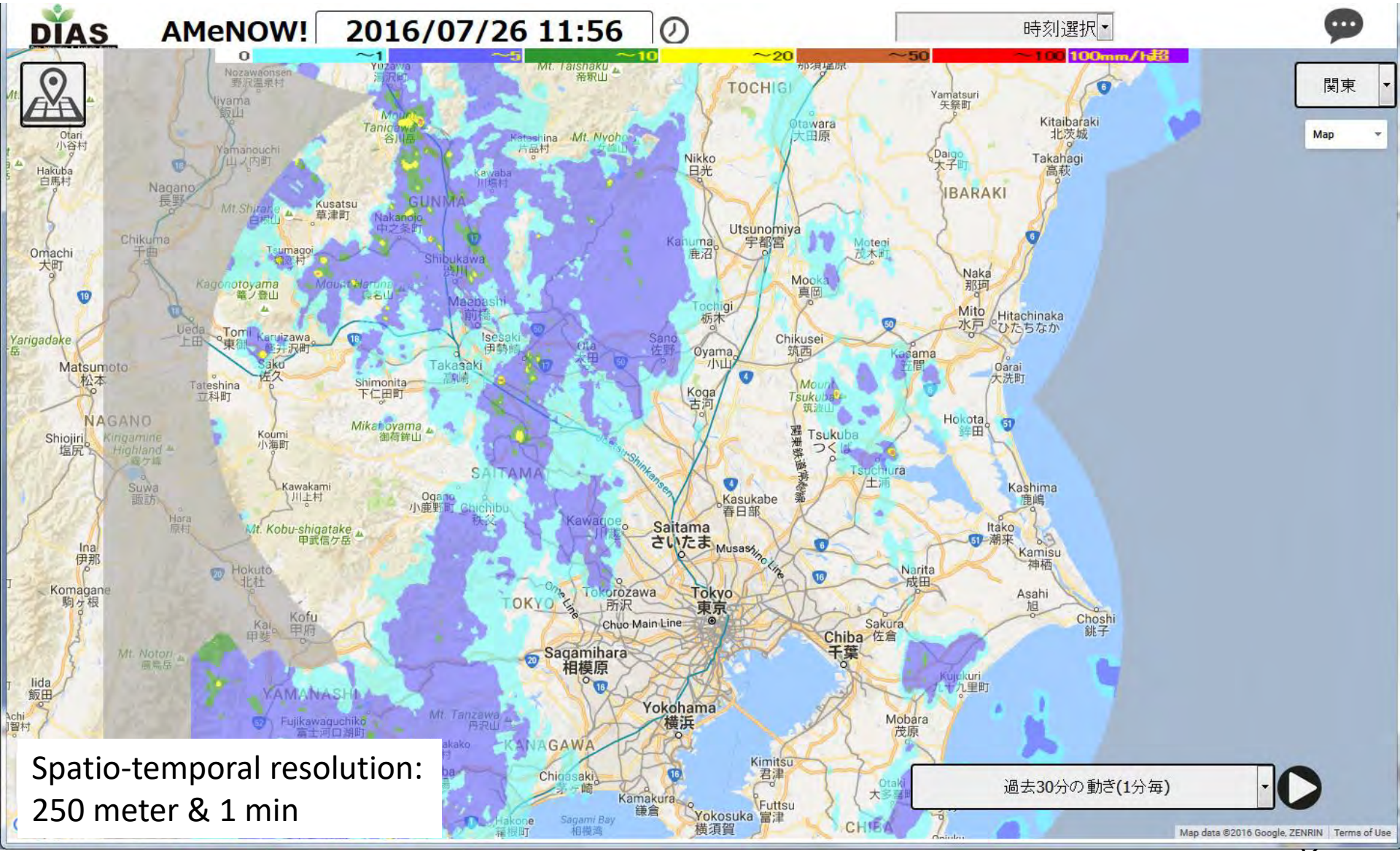
研究観測データ　市民観測データ　海洋観測データ　衛星データ　数値気象・気候予測モデル　現業観測データ　現業管理情報

Satellite Imagery by Himawari



Cyclone Gabrielle, 2023

X band Multi-Parameter Radar



Spatio-temporal resolution:
250 meter & 1 min

DIAS as Information Fusion Reactor

More than 10 PB of data storage

Value Creation from Information Explosion
(Large and Diverse Information)
Information Fusion Reactor
By Prof. Kitsuregawa

Supporting Decision Making in Stormwater Management by Integrating Big Data and Hydrological Modeling

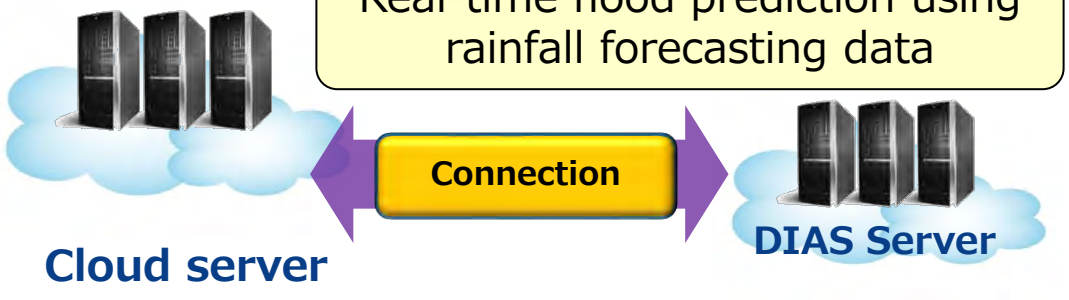
Advances in Stormwater Management

Fusion of Numerical Modelling & Internet of Things

Real-time water level sensing and Flood Prediction

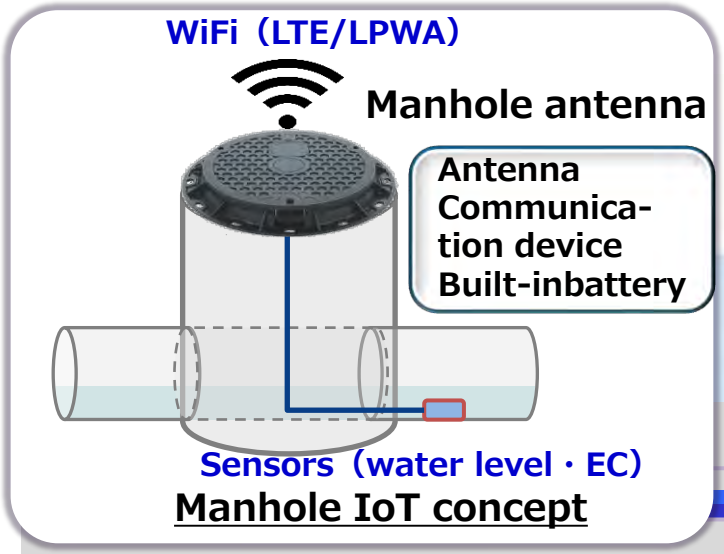
Integration of rainfall and water level monitoring information

Real-time flood prediction using rainfall forecasting data



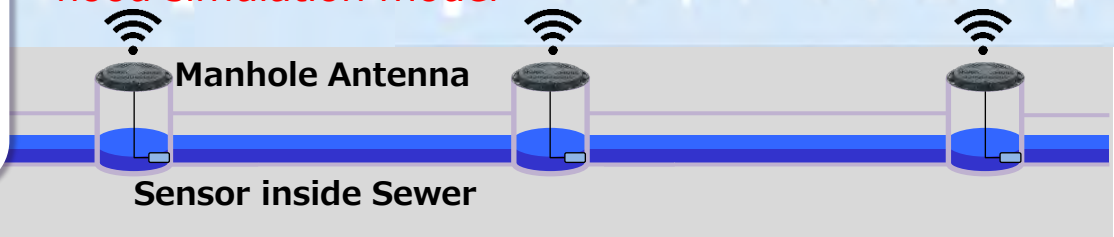
- Cloud server management system
- Data integration system on rainfall and monitoring information

Collection



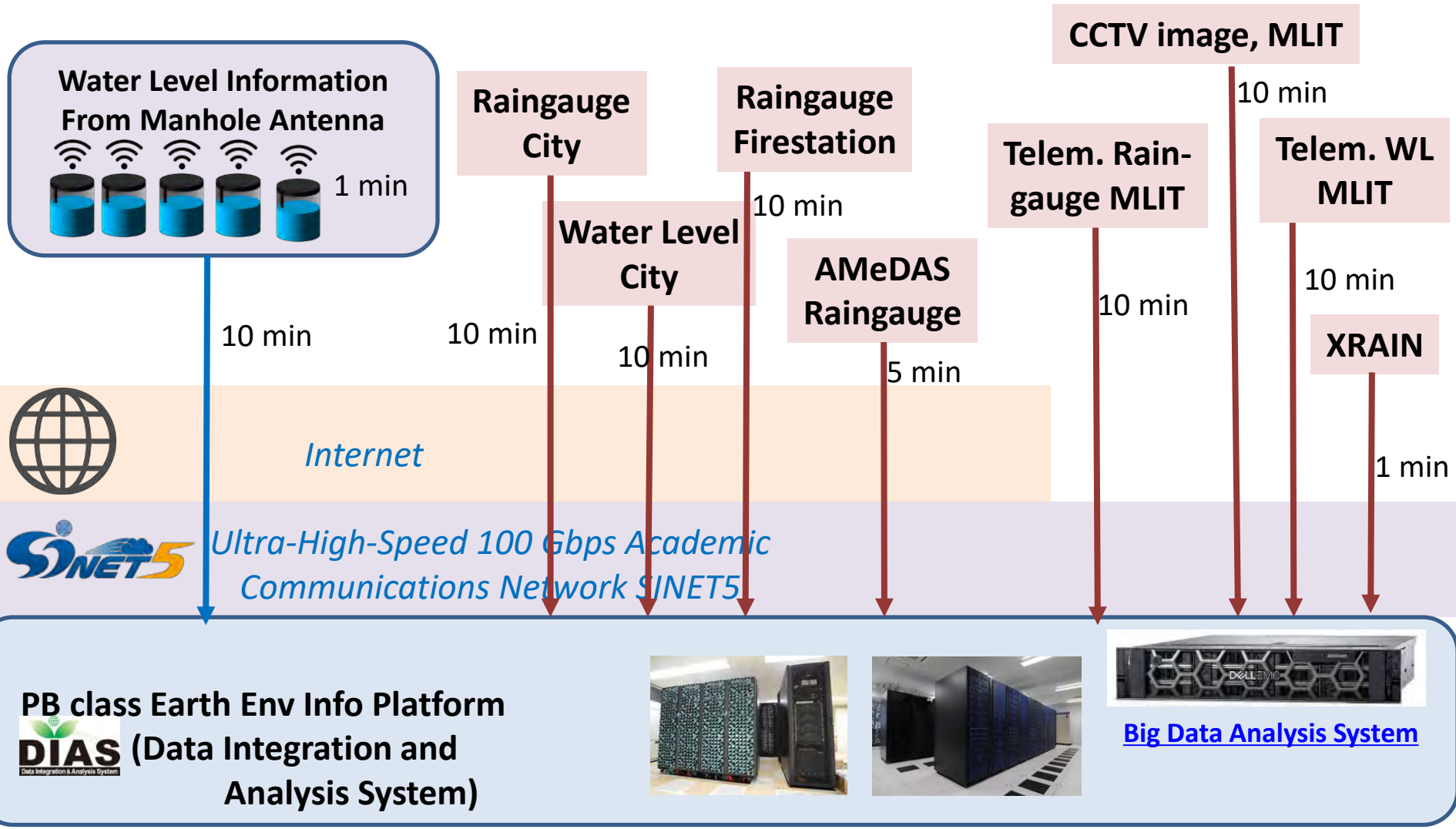
・Monitoring data applied to data assimilation of flood simulation model

Real-time sensing of water level in drainage pipes



・**Real-time sensing of water level in drainage pipe using manhole IoT**
・**Water level monitoring system with wireless network combined with LTE / LPWA**

Big Data Management on DIAS



Application to Recent Flood Events

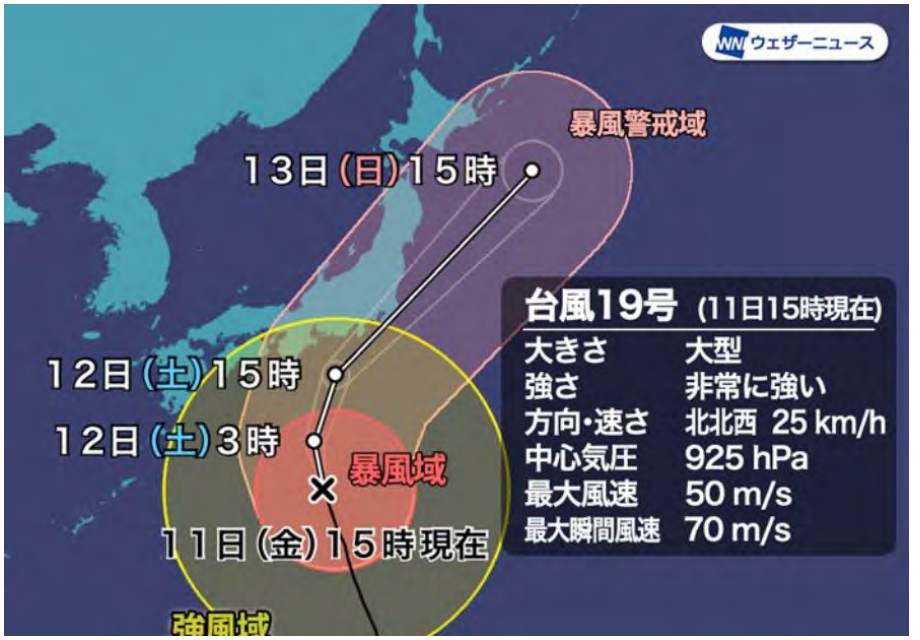
September 2019
Typhoon #15 (FAXAI)

177.5mm@Yokohma (72.0mm/hr Intensity)

https://weathernews.jp/s/topics/201909/070125/

October 2019
Typhoon #19 (HAGIBIS)

221mm@Yokohma (27.5mm/hr Intensity)

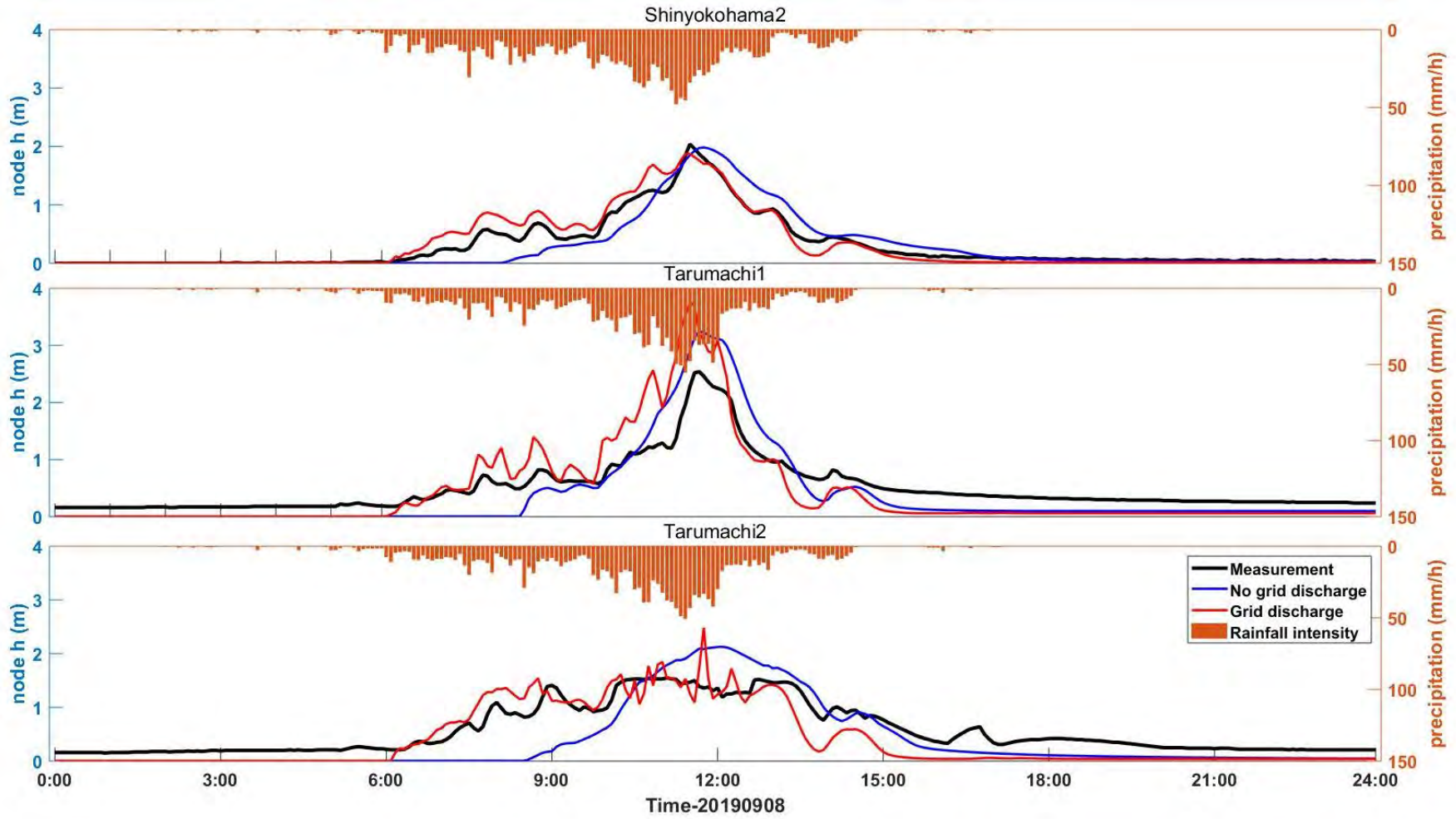


https://weathernews.jp/s/topics/201910/110185/

Model Validation: Water Level in Drainages

Typhoon #15 :FAXAI

Improve accuracy by tuning model parameters

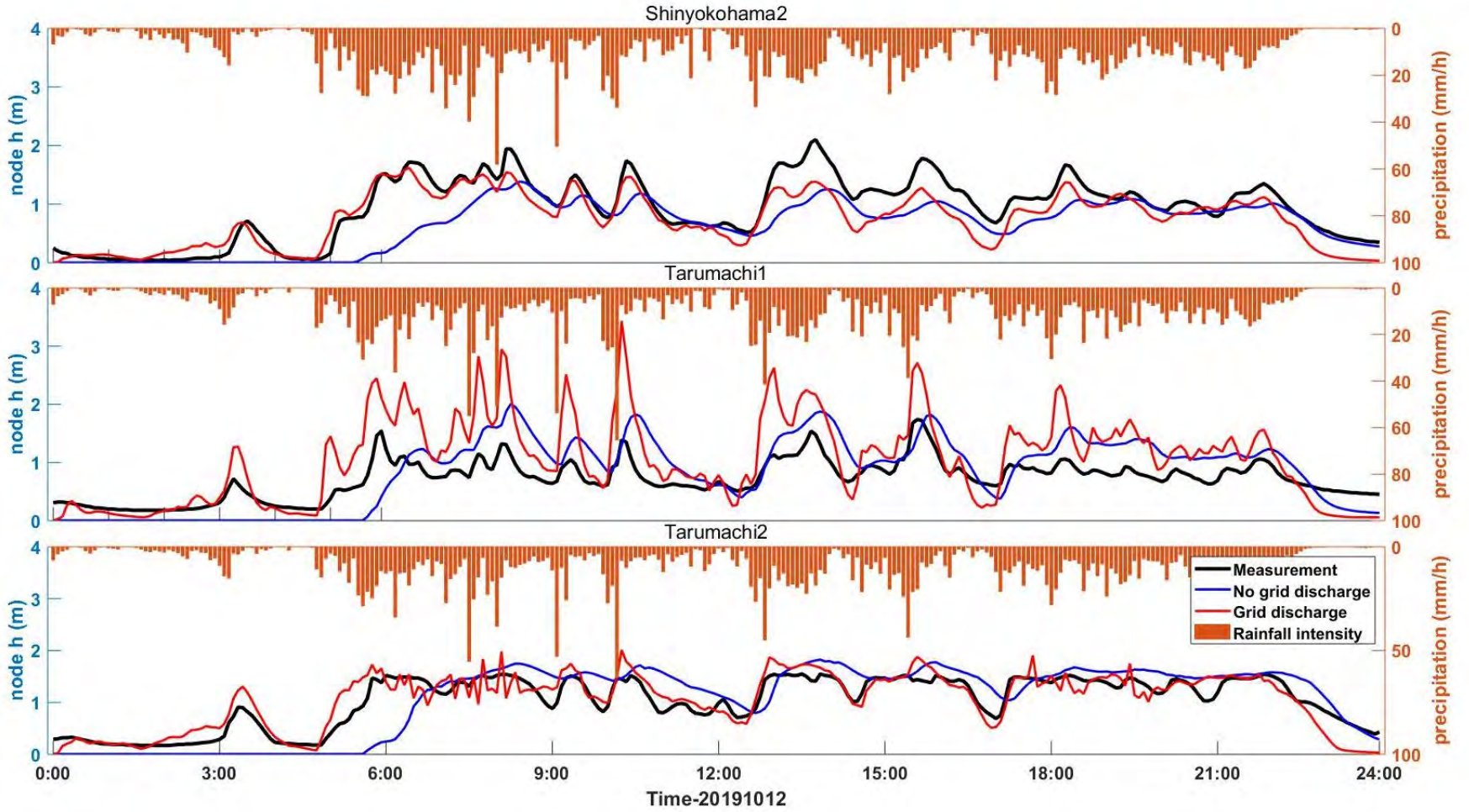


(Wu et al., 2022)

Model Validation: Water Level in Drainages

Typhoon #19 :HAGIBIS

Improve accuracy by tuning model parameters



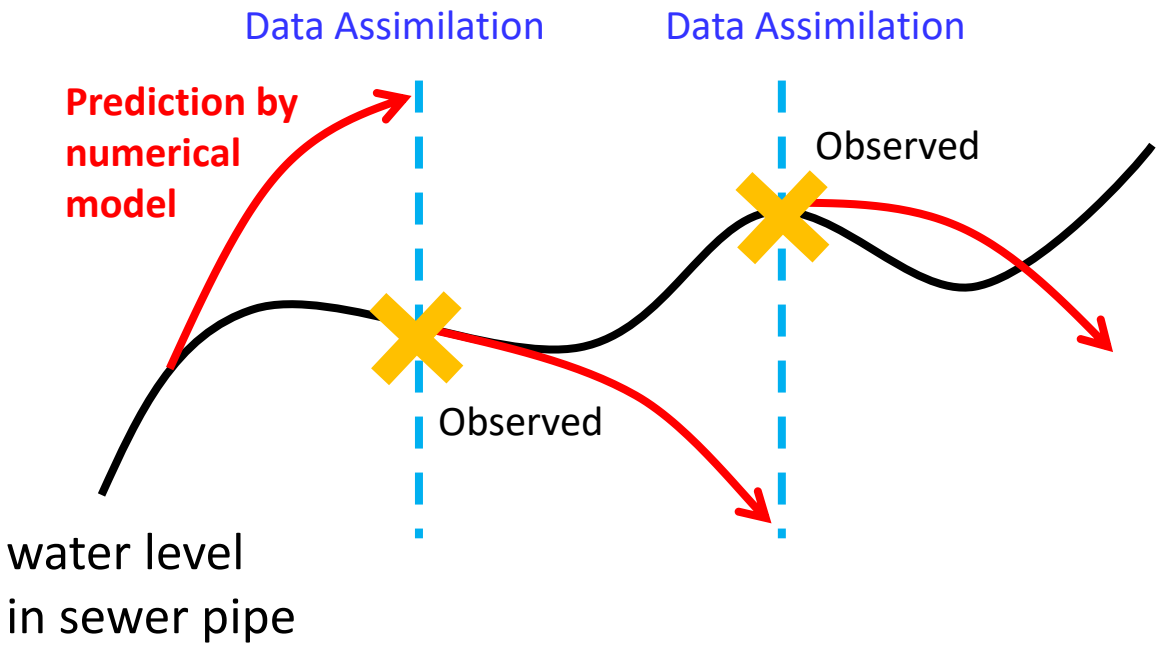
(Wu et al., 2022)

Introduction of Data Assimilation method

Establishment of urban flood prediction model integrating data assimilation method using rainfall forecast information

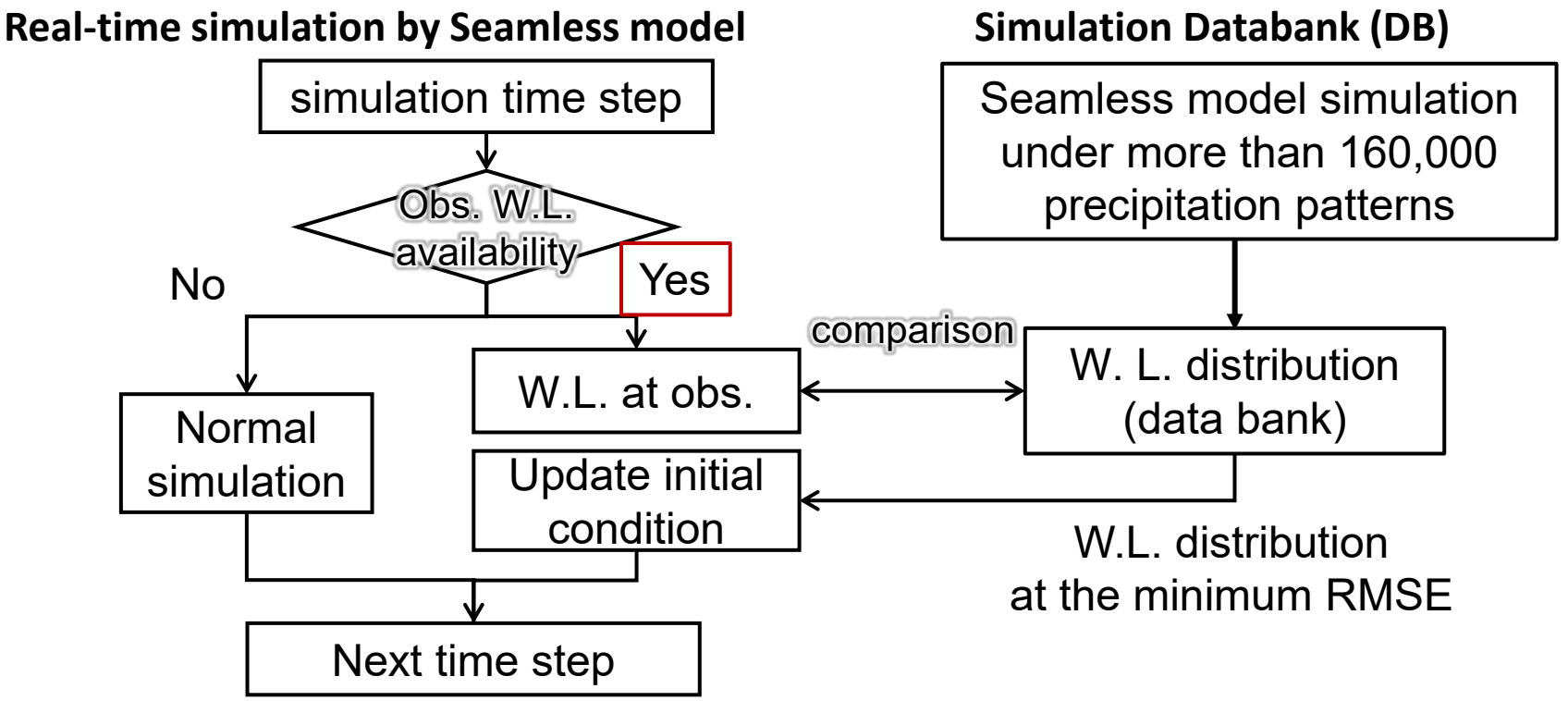
- *In order to predict the urban flooding due to torrential rainfall, we introduce data assimilation method which inputs actual observation value and performs real-time simulation.*

- *Data assimilation integrates observed information into numerical simulation allowing to explain better explanation of the physical status.*
- *This method can improve the model forecast accuracy.*



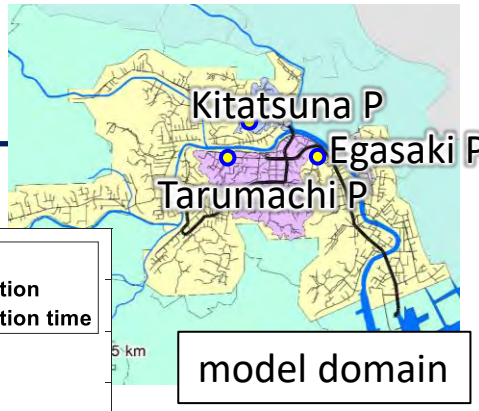
Databank-based Data Assimilation

- *We developed a new Data Assimilation method, in which water level distribution are replaced with the simulation set with least RMSE in DB.*
- *Water level distribution in the sewer network are simulated in advance with numerous numbers of hypothetical precipitation patterns for DB.*

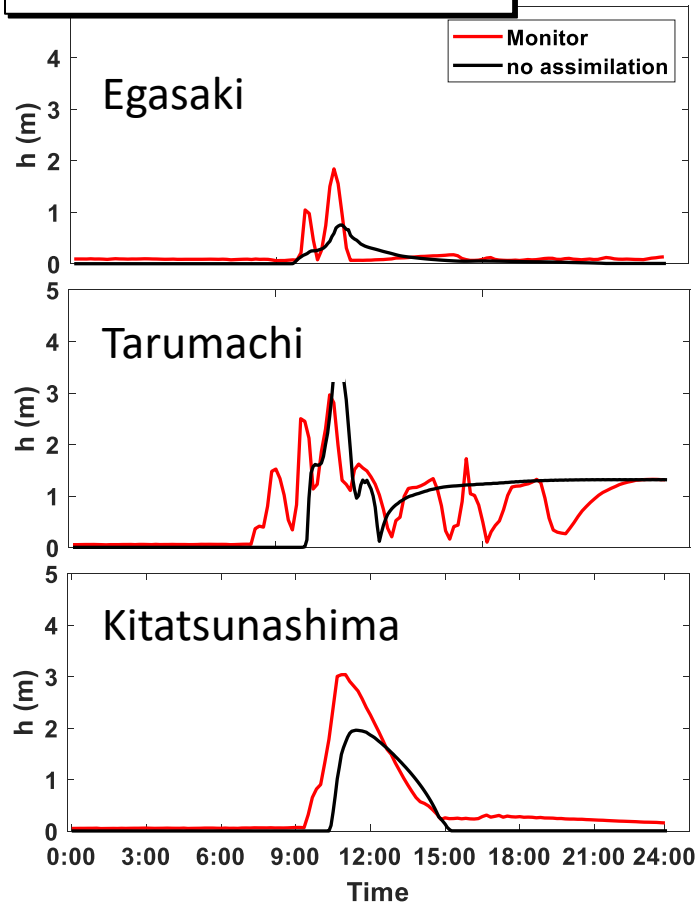


(Shituo et al., 2019)

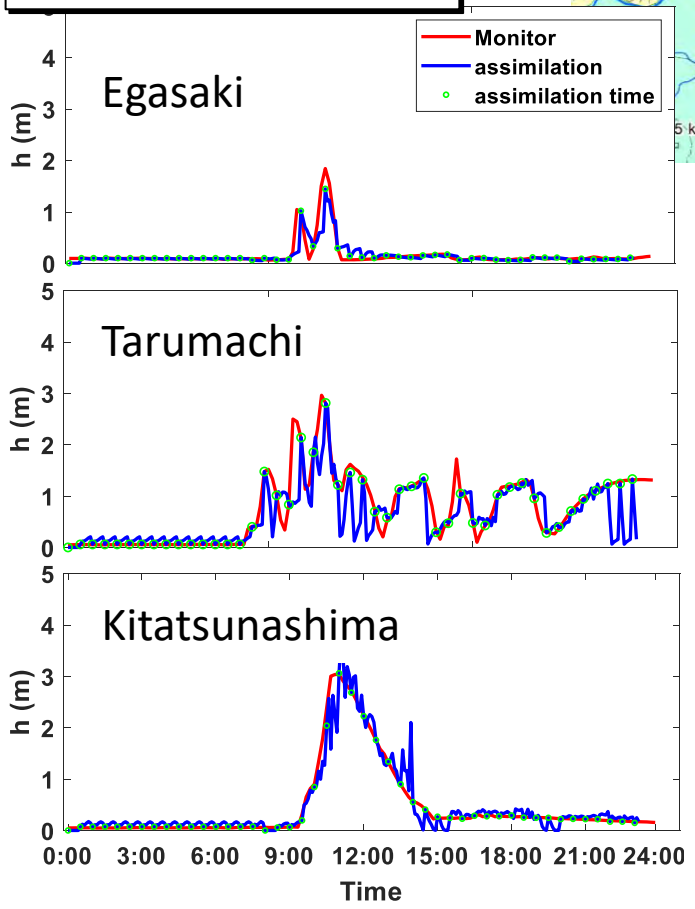
Validation of the Model



Without Data Assimilation



With Data Assimilation



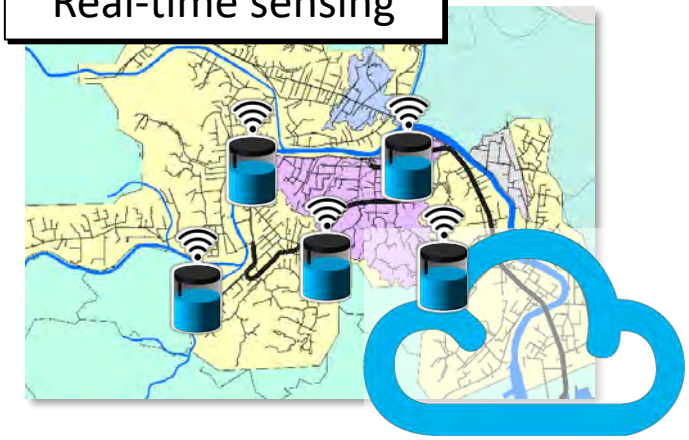
- ✓ Data assimilation at every 30min improved accuracy drastically
- ✓ Hydrographs with multiple flood peaks was difficult to reproduce, but now possible with data assimilation

(Shituo et al., 2019)

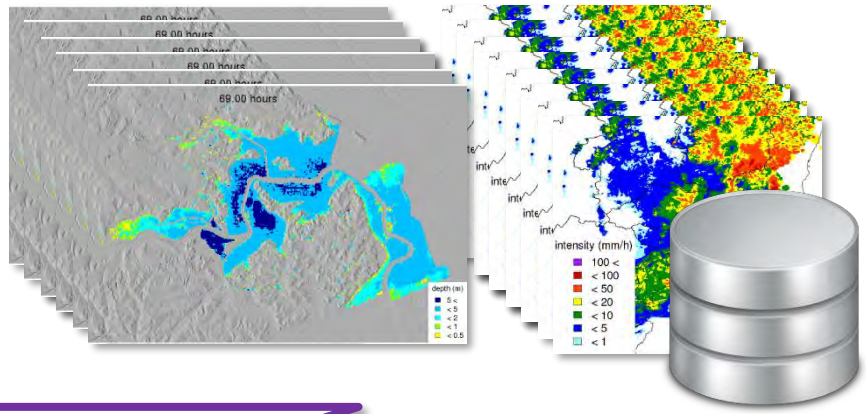
Fusion of Real-time Sensing and Numerical Modelling

- ✓ Real-time data in sewer pipe senor gives opportunity to extract most plausible physical status from numerous simulation scenarios, prepared in advance
- ✓ High speed and high accuracy sewer network modeling is now realized

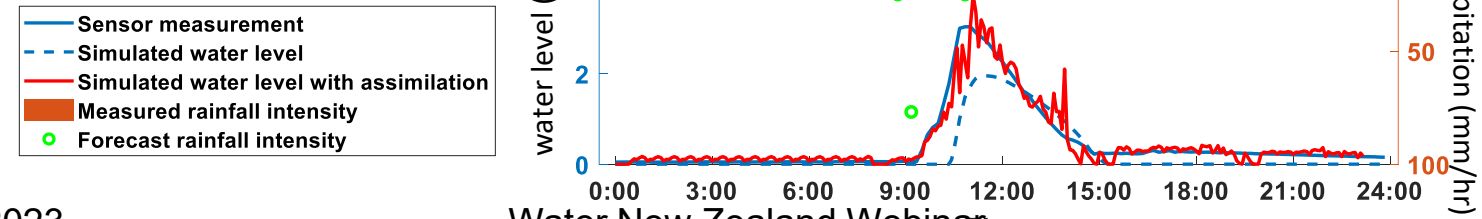
Real-time sensing



Simulation Databank

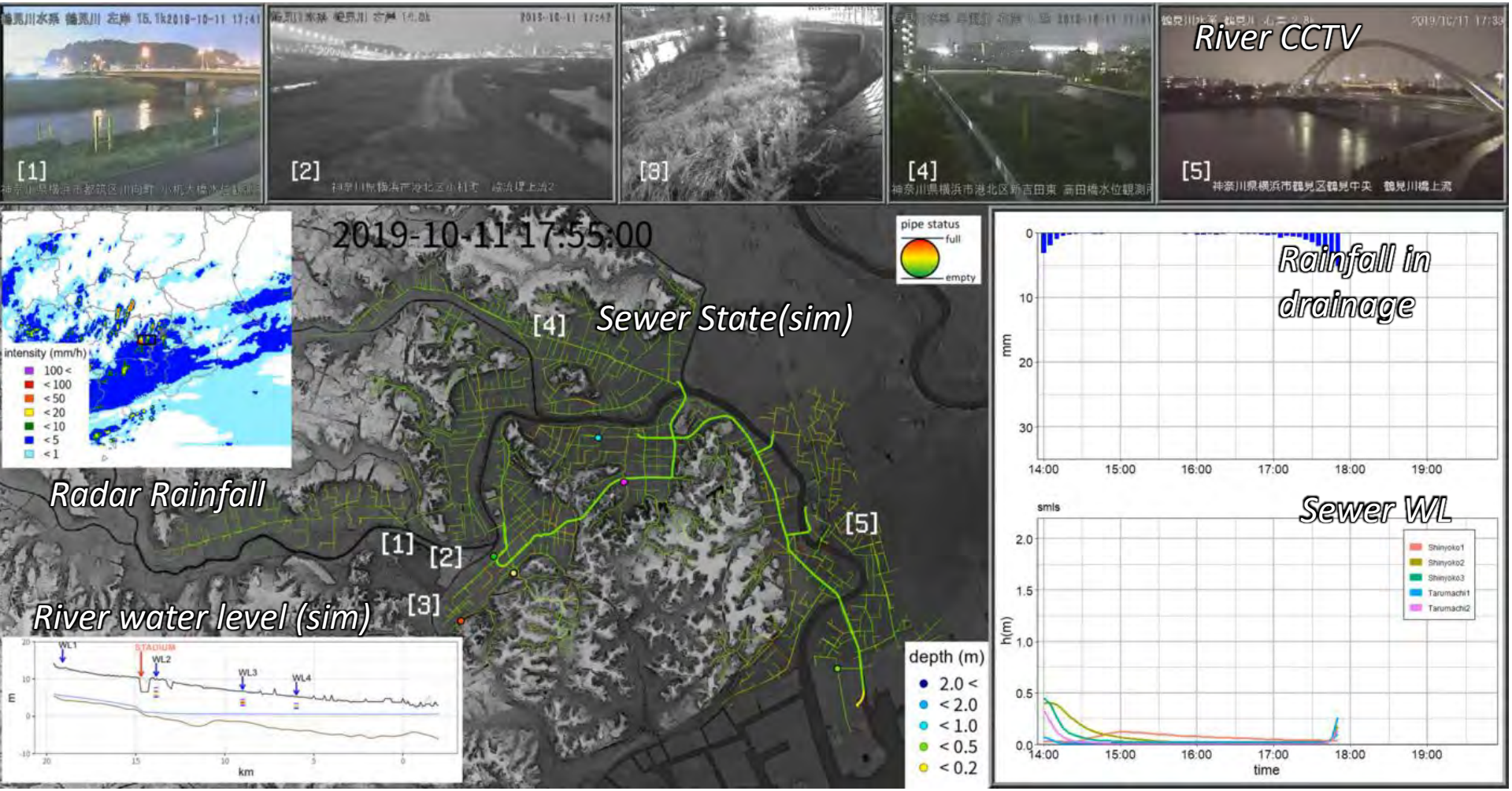


Databank-Based Assimilation



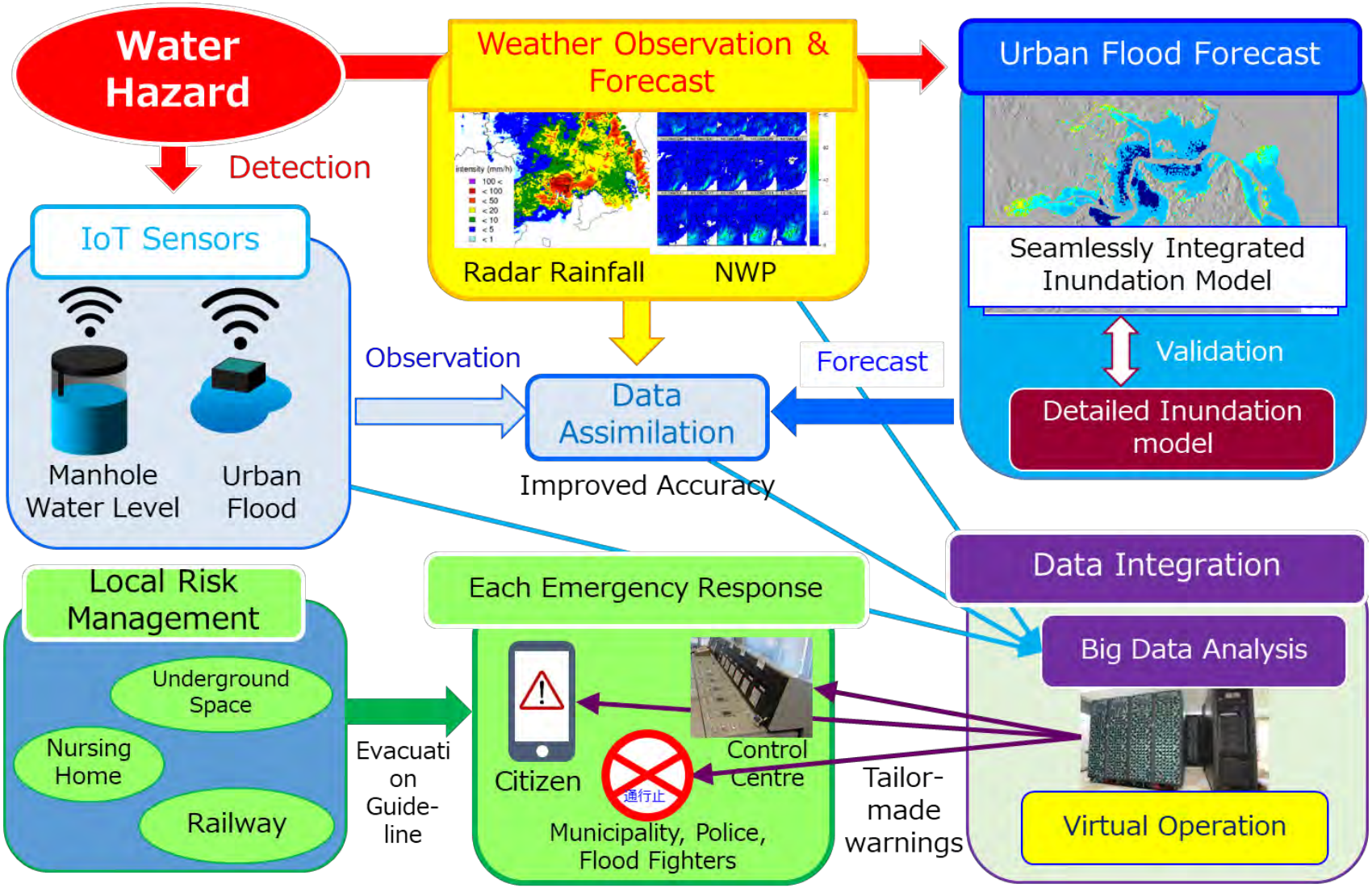
Example Use of Big Data for Flood Countermeasure

Integrated Flood analysis against Typhoon Hagibis, 2019



(Shituo et al., 2021)

Real-time Prediction and Control of Urban Flood Risk



Advances in Stormwater Management

Summary

Summary

- ✓ Importance of maximum use of available countermeasures both structural and non-structural
- ✓ Integrated urban flood modeling against river flooding, urban flooding, and storm surge
- ✓ Use of Big Data to create information wisdom
- ✓ Real-time sensing in unmonitored drainage network by manhole IoT
- ✓ Real-time data provides opportunity to improve forecast accuracy through Data Assimilation
- ✓ Fusion of numerical modelling and IoT for realization of real-time countermeasure against urban flooding

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Provision of Data and Research Field

- Keihin river office bureau
- Yokohama City

Majority of the presented works were conducted at the Department of Urban engineering, the University of Tokyo

Selected References

Y. Shibuo and H. Furumai, Advances in Urban Stormwater Management in Japan: A Review, *J. Disaster Res.*, Vol.16 No.3, pp. 310-320, 2021. https://doi.org/10.20965/jdr.2021.p0310

C. Saito, M. Nakashima, R. Kawaguchi, Urban Flood Disaster Monitoring Services by Using Manhole with Built-in Antenna (Smart Manhole Cover), MEIDEN REVIEW Series Vol.176, No.2, 2019. https://www.meidensha.co.jp/rd/rd_02/rd_02_02/rd_02_02_08/rd_02_02_05_01/pdf/Review_176_03_web_190603.pdf

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