Practical Application of Weather Radar Information in Japan

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Today, I am talking about…

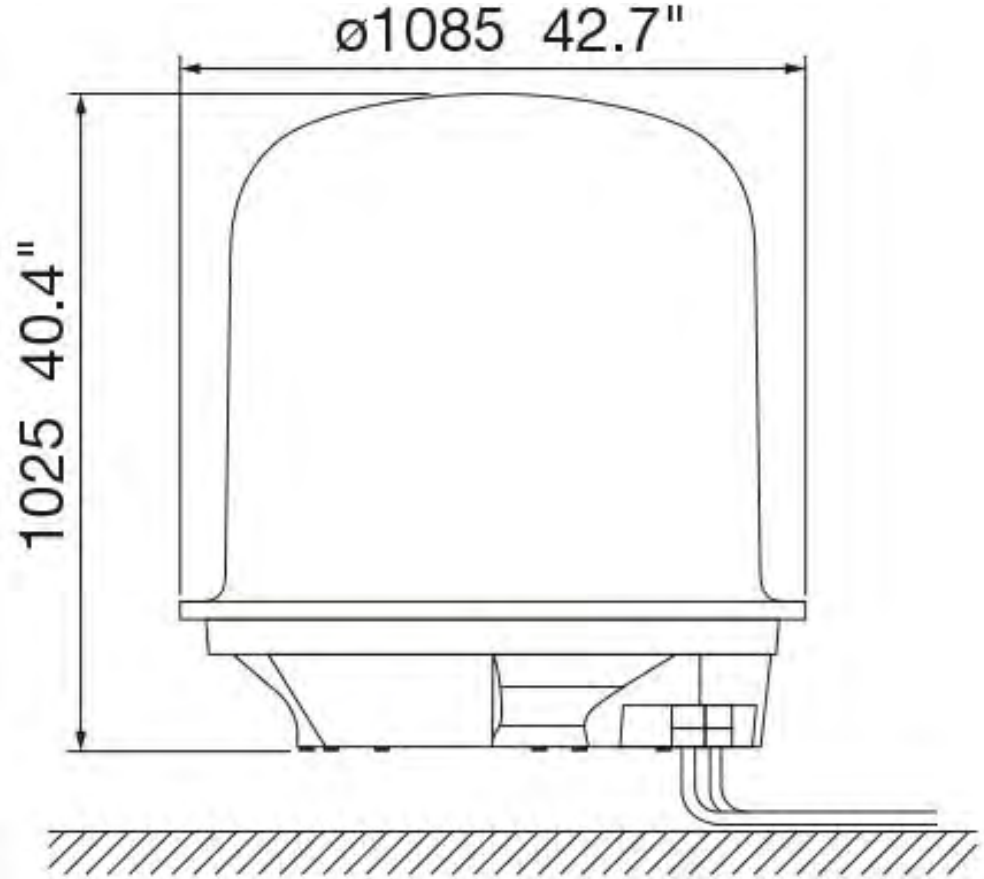
- development of mini radar and its application
- QPE comparison between X-MP and non-MP
- Small river discharge calculation
- Citizens' evacuation at frequently inundated area
- Sewage water management

Mini-Radar Development

FURUNO

Maritime electric manufacture,
Making many vessels' radar for navigation

Small but full function Multi-Parameter Doppler Radar

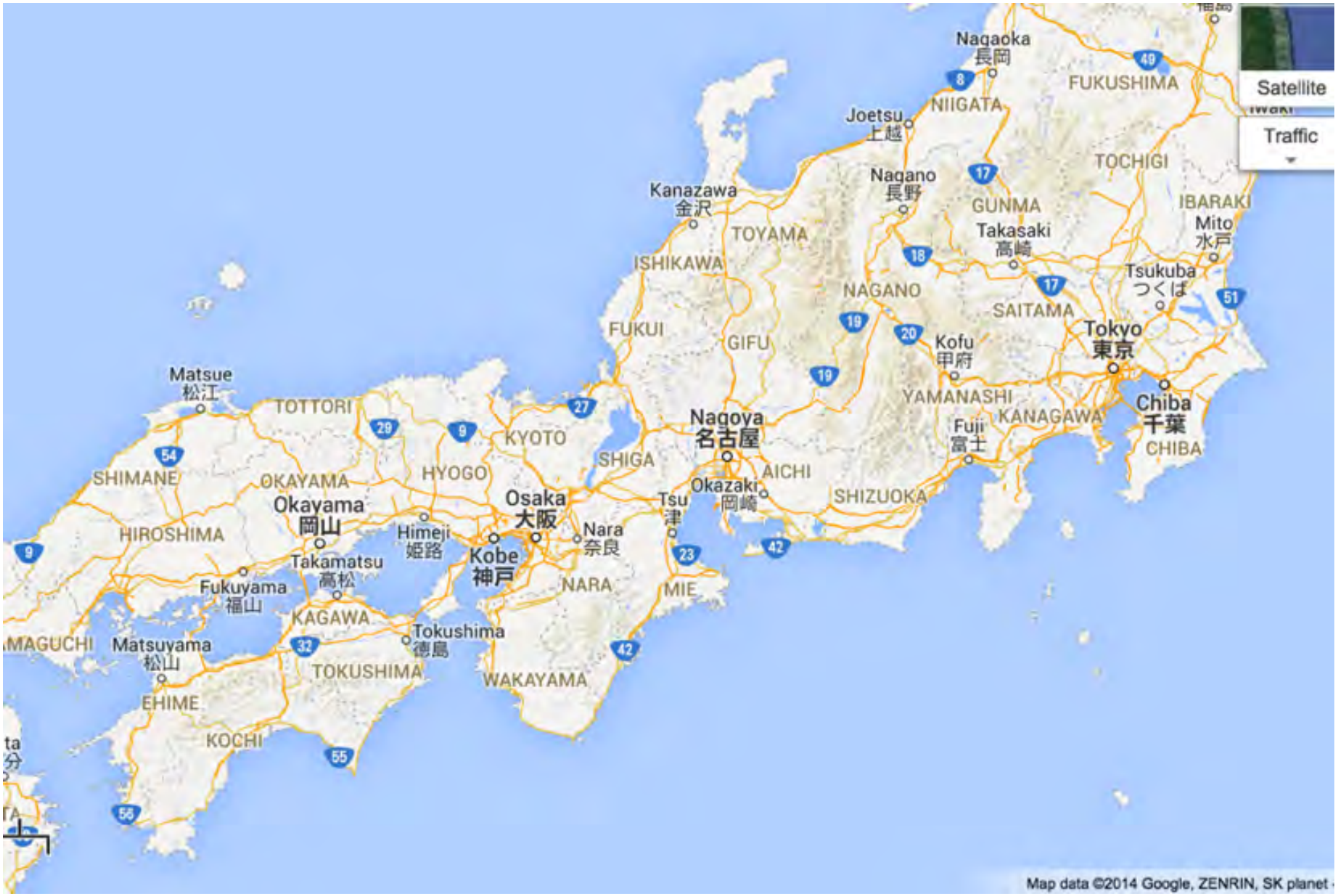


WR-2100

https://www.furuno.com/en/systems/meteorological-monitoring/

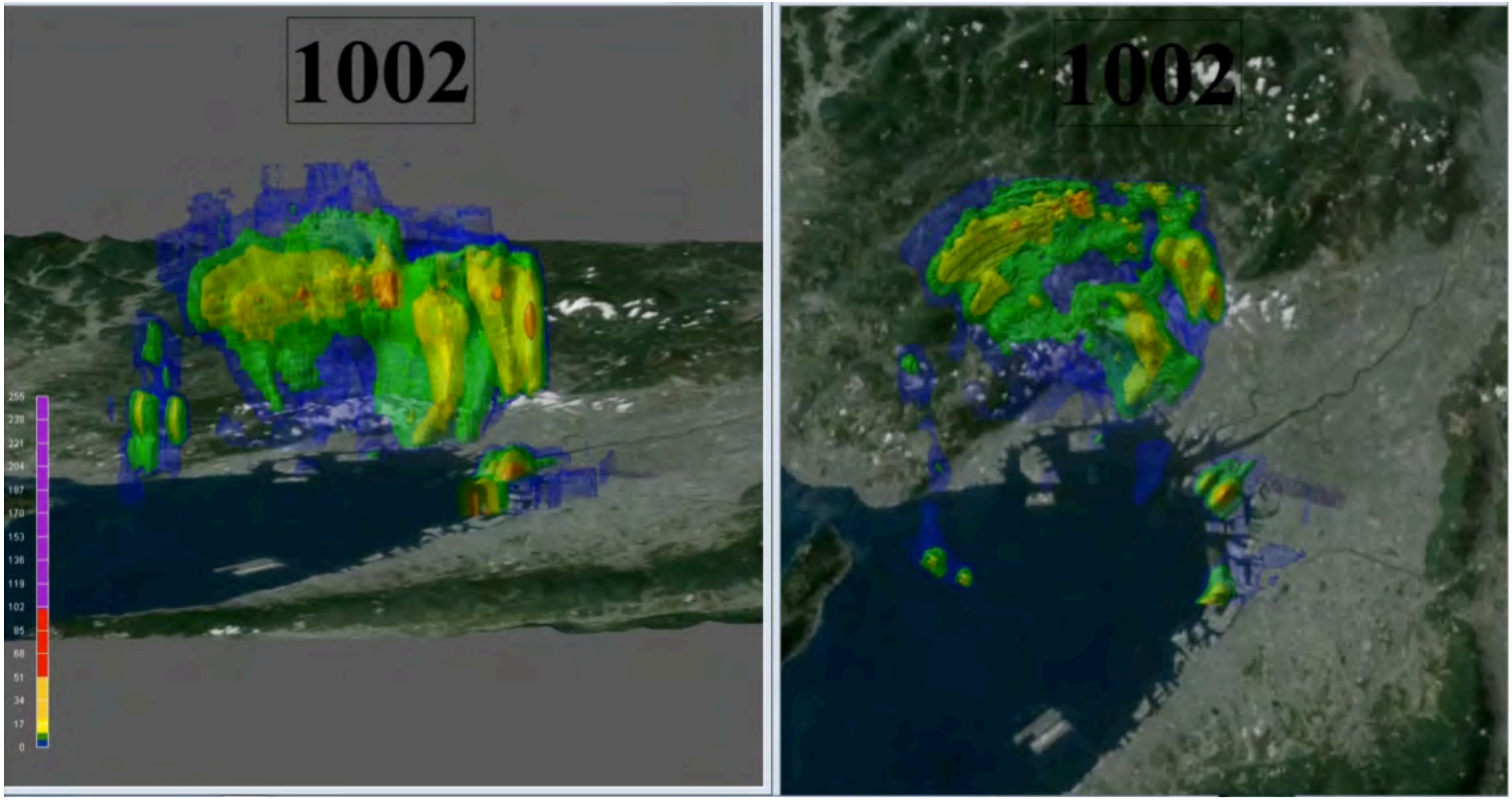
Please take a look at the resolution of

WR2100


Satellite
Traffic
Nagaoka
長岡
FUKUSHIMA
NIIGATA
Joetsu
上越
Nagano
長野
TOCHIGI
GUNMA
IBARAKI
Kanazawa
金沢
TOYAMA
Takasaki
高崎
Mito
水戸
ISHIKAWA
NAGANO
Tsukuba
つくば
SAITAMA
FUKUI
GIFU
Kofu
甲府
Tokyo
東京
Matsue
松江
TOTTORI
YAMANASHI
KANAGAWA
Chiba
千葉
Nagoya
名古屋
Fuji
富士
KYOTO
SHIGA
CHIBA
SHIMANE
HYOGO
AICHI
OKAYAMA
Okazaki
岡崎
SHIZUOKA
Osaka
大阪
Okayama
岡山
Tsu
津
HIROSHIMA
Himeji
姫路
Nara
奈良
Kobe
神戸
Takamatsu
高松
Fukuyama
福山
NARA
MIE
KAGAWA
Tokushima
徳島
Matsuyama
松山
TOKUSHIMA
WAKAYAMA
EHIME
KOCHI
Map data ©2014 Google, ZENRIN, SK planet

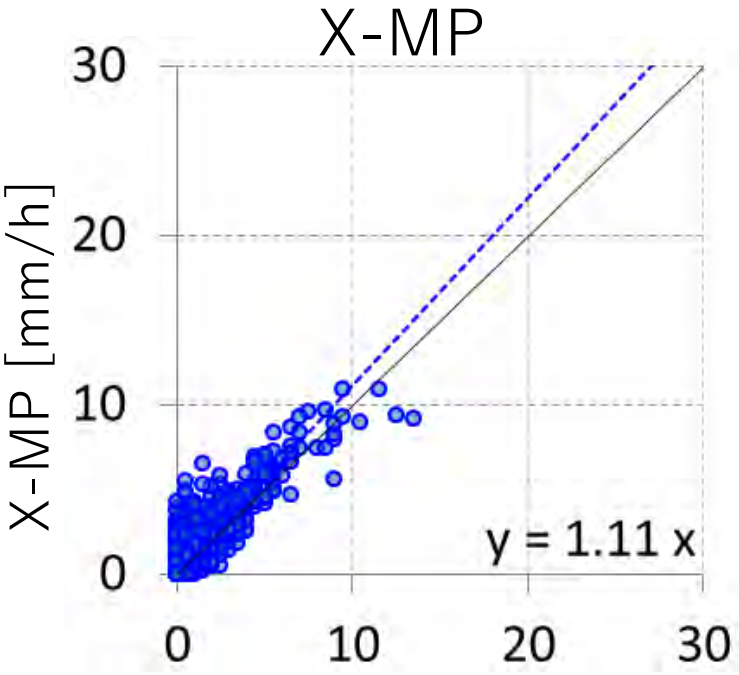

Takasago
高砂市
Kakogawa
加古川市
Takarazuka
宝塚市
Nishinomiya
西宮市
Ashiya
芦屋市
Kobe
神戸市
Akashi
明石市
Kobe Port
神戸港
Kobe Airport
神戸空港
Sakaisenboku Port
堺泉北港
Osaka Bay
大阪湾
Hannan Port
阪南港
Kansai International Airport
関西国際空港
Awaji
淡路市
Sumoto
洲本市
Minamiawaji
南あわじ市
Sennan
泉南市
Hannan
阪南市
Kishiwada
岸和田市
Kaizuka
貝塚市
Izumi
和泉市
OSAKA
Toyonaka
豊中市
Ibaraki
茨木市
Hirakata
枚方市
Suita
吹田市
Neyagawa
寝屋川市
Osaka
大阪市
Daito
大東市
Ikoma
生駒市
Higashiosaka
東大阪市
Sakai
堺市
Matsubara
松原市
Fujiidera
藤井寺市
Habikino
羽曳野市
Tondabayashi
富田林市
Kawachinagano
河内長野市
Yamatokoriyama
大和郡山市
Sakurai
桜井市
Kashihara
橿原市
Gose
御所市
Mount Kongō
金剛山
Gojo
五條市
Hashimoto
橋本市
Kinokawa
紀の川市
Wakayama
和歌山市
Iwade
岩出市
Kainan
海南市
Mt Koyasan
高野山
Satellite
Traffic
Map data ©2014 Google, ZENRIN

Osaka Bay　L: Bird’s eye View R: Plain View

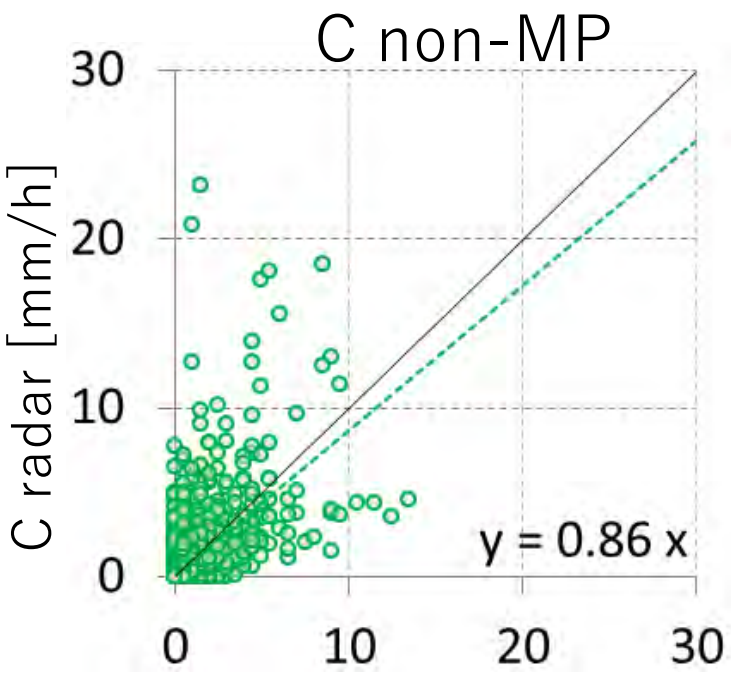


Osaka Bay　L: Bird’s eye View R: Plain View

Quantitative Precipitation Estimation QPE



Raingauge [mm/h]
Correlation coefficient 0.86
RMSE 0.21



Raingauge [mm/h]
Correlation coefficient 0.65
RMSE 0.32

Quick Explanation

Relationship between Z and R

drop size distribution

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$

Rain Rate[mm/hr]

$$R = \int_0^{\infty} N(D) \frac{\pi}{6} D^3 w(D) dD$$

Radar reflectivity factor

$$Z = \int_0^{\infty} N(D) D^6 \, dD$$

Quick Explanation

drop size distribution

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$

Rain Rate[mm/hr]

$$R = \int_0^{\infty} N(D) \frac{\pi}{6} D^3 w(D) dD$$

Radar reflectivity factor

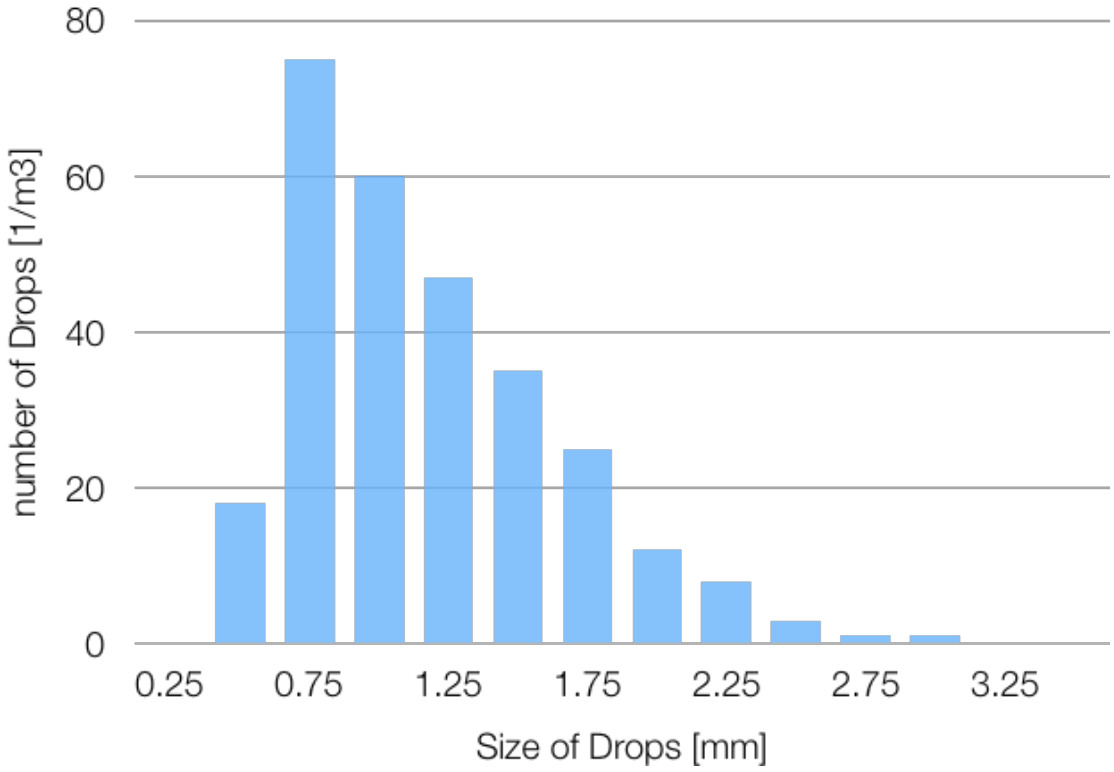
$$Z = \int_0^{\infty} N(D) D^6 \, dD$$

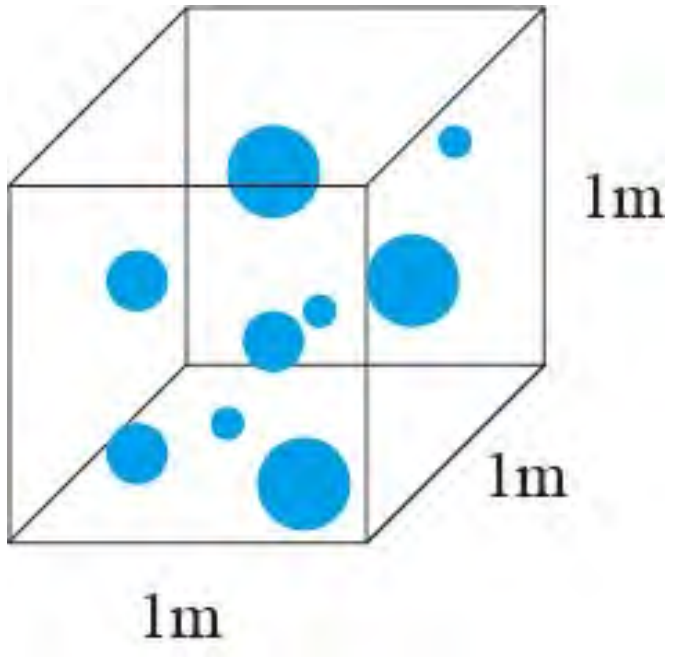
Z-R relationship

$$Z = BR^{\beta}$$

Quick Explanation

N(D) number concentration, drop size distribution

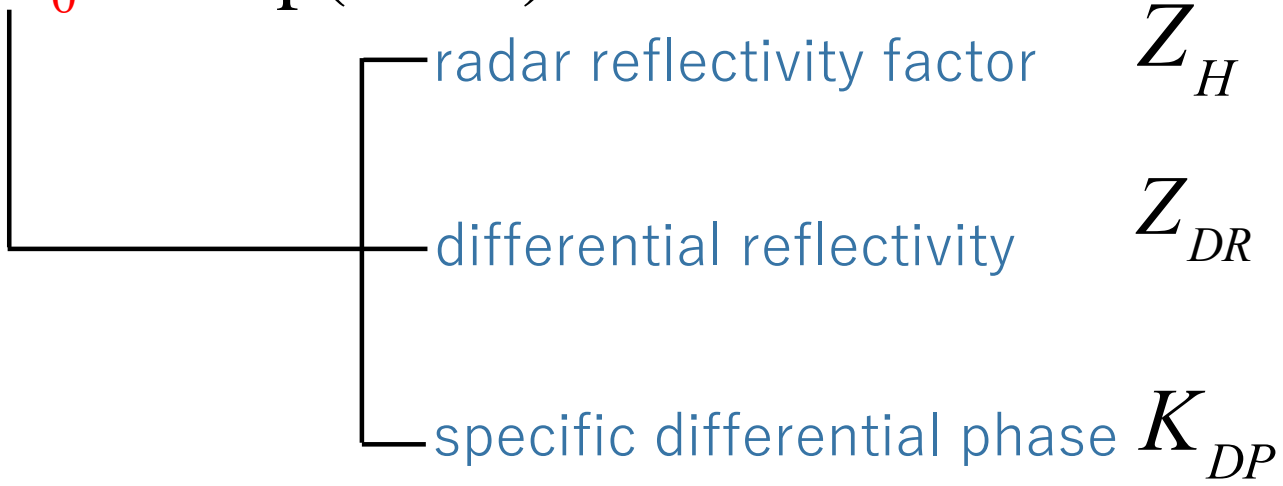




Quick Explanation

Three size parameters are solved by three radar parameter

$$N(D) = N_0 D^{\mu} \exp(-\Lambda D)$$



Quick Explanation

In situ observation

Takahashi (1976), Suzuki (2007)

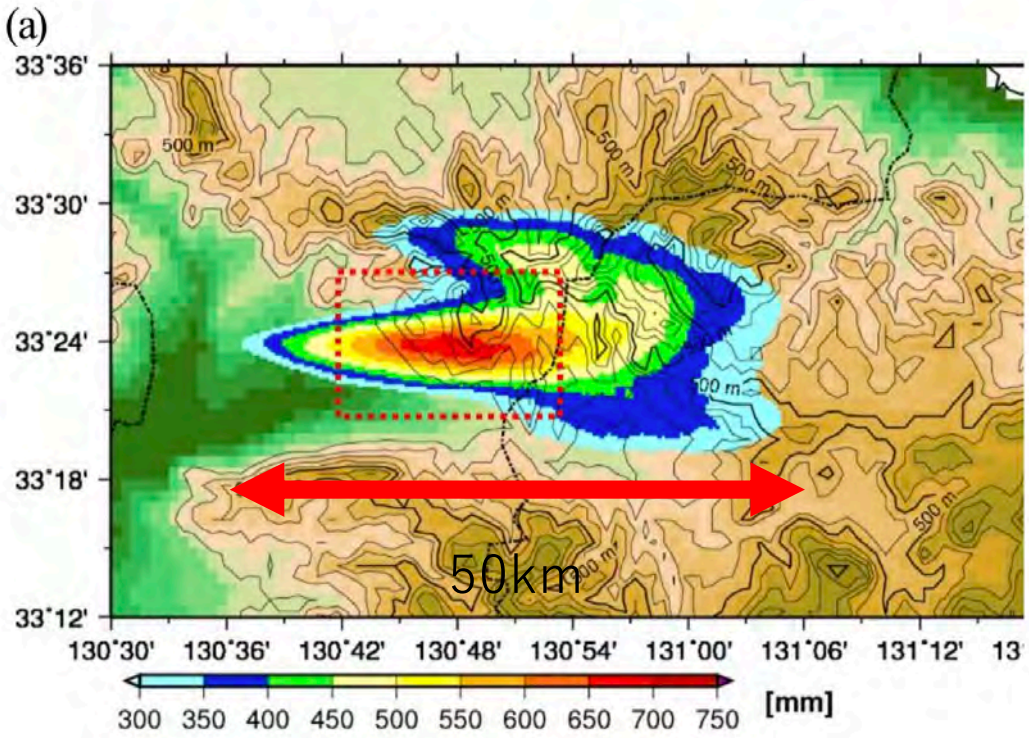
rain drop

snow flake

Quick Explanation

This kind of fundamental scientific research gave a lot of advantage to understand radar, weather and their application

Discharge Calculation from Radar in small rivers



Left: Nakakita and Yamaguchi (2018)
http://www.dpri.kyoto-u.ac.jp/web_j/publication/other/20180330_kyusyu.pdf

Right: Mainichi News papers (2017.7.12)
https://mainichi.jp/graphs/20170712/hpj/00m/040/001000g/12

Discharge prediction in small rivers

Advantage

- Radar rainfall is given at each grid point (cells)
- It is suitable to cell distributed rainfall runoff simulation.
- The error generated by radar during QPE process may be eliminated during integration for runoff simulation.
- Lag of rainfall observed by radar and rain falls on ground will be implicitly included in parameter of runoff simulation

Disadvantage

- Systematic error of higher altitude area like mountain because of higher elevation angle

Small river close to Kobe (Syukugawa)

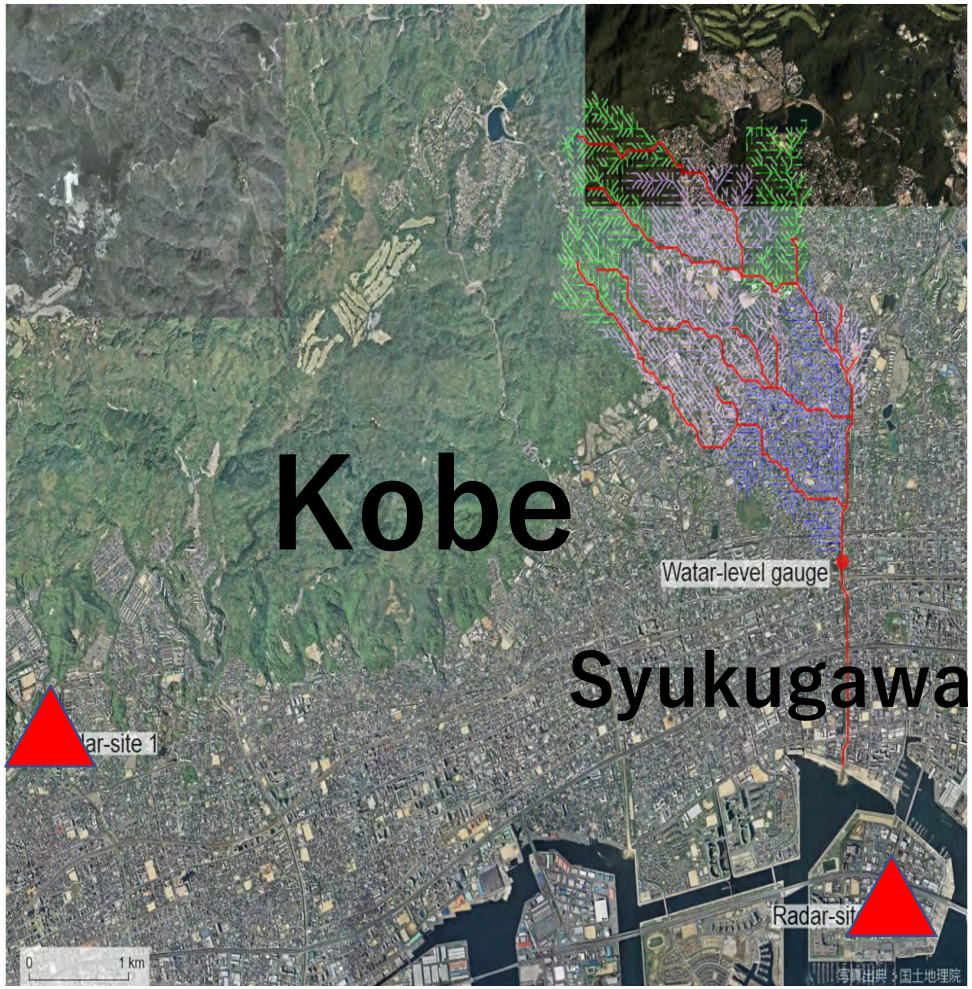
- Discharge estimation by using X-MP radar

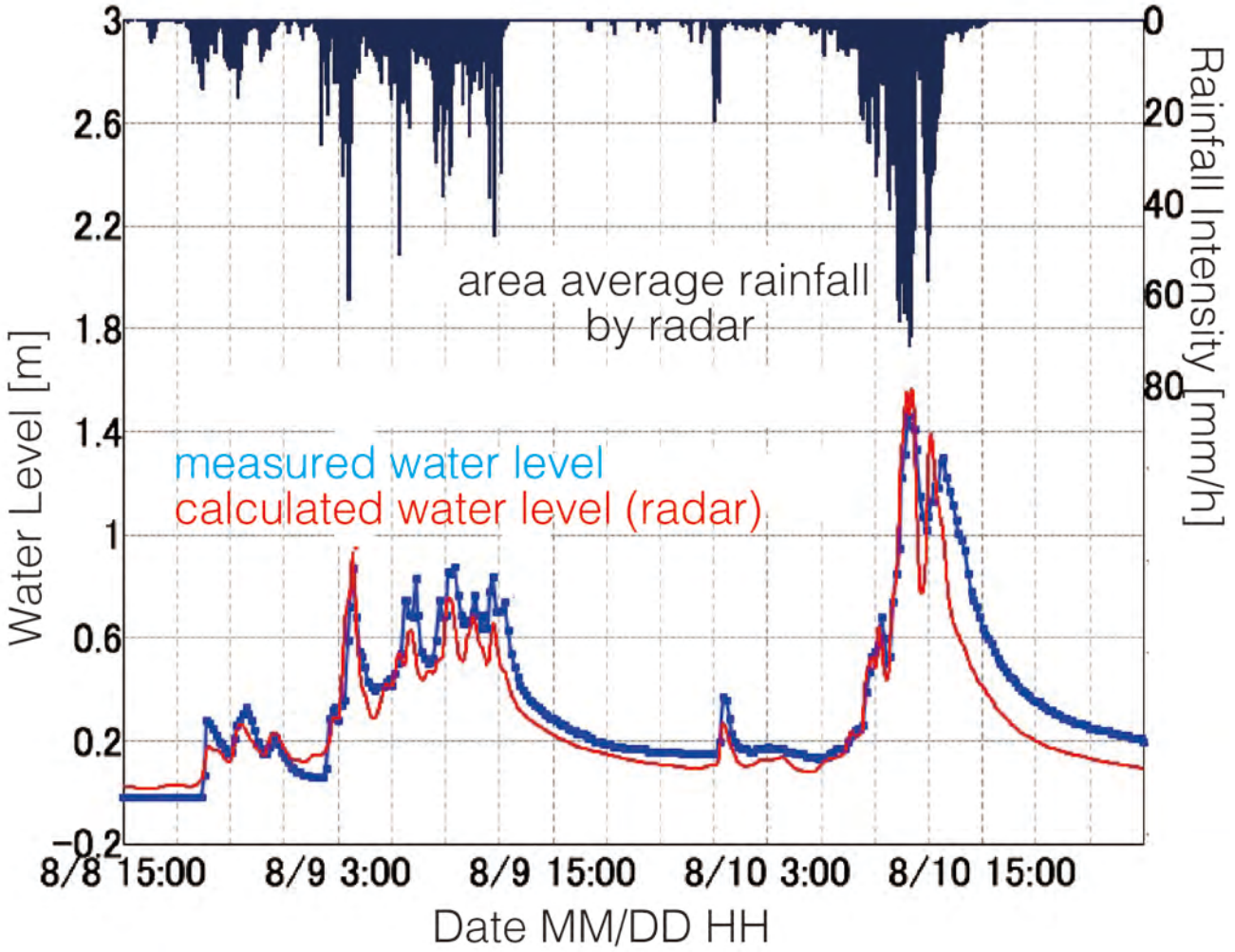
Ishigaki, Takaki, Oishi, Nakakita (2015): Estimation of water level by using high resolution radar in urban small river, JMS meeting in spring

Target

- Syukugawa river: 8 km^2
- August 8-10, 2014
- Typhoon No11
- Discharge calculation: GeoHyMos (Shiiba, Tachikawa, et al. 2010)
- Residential area, Forests, Mountain
- Rainfall is given by two radars

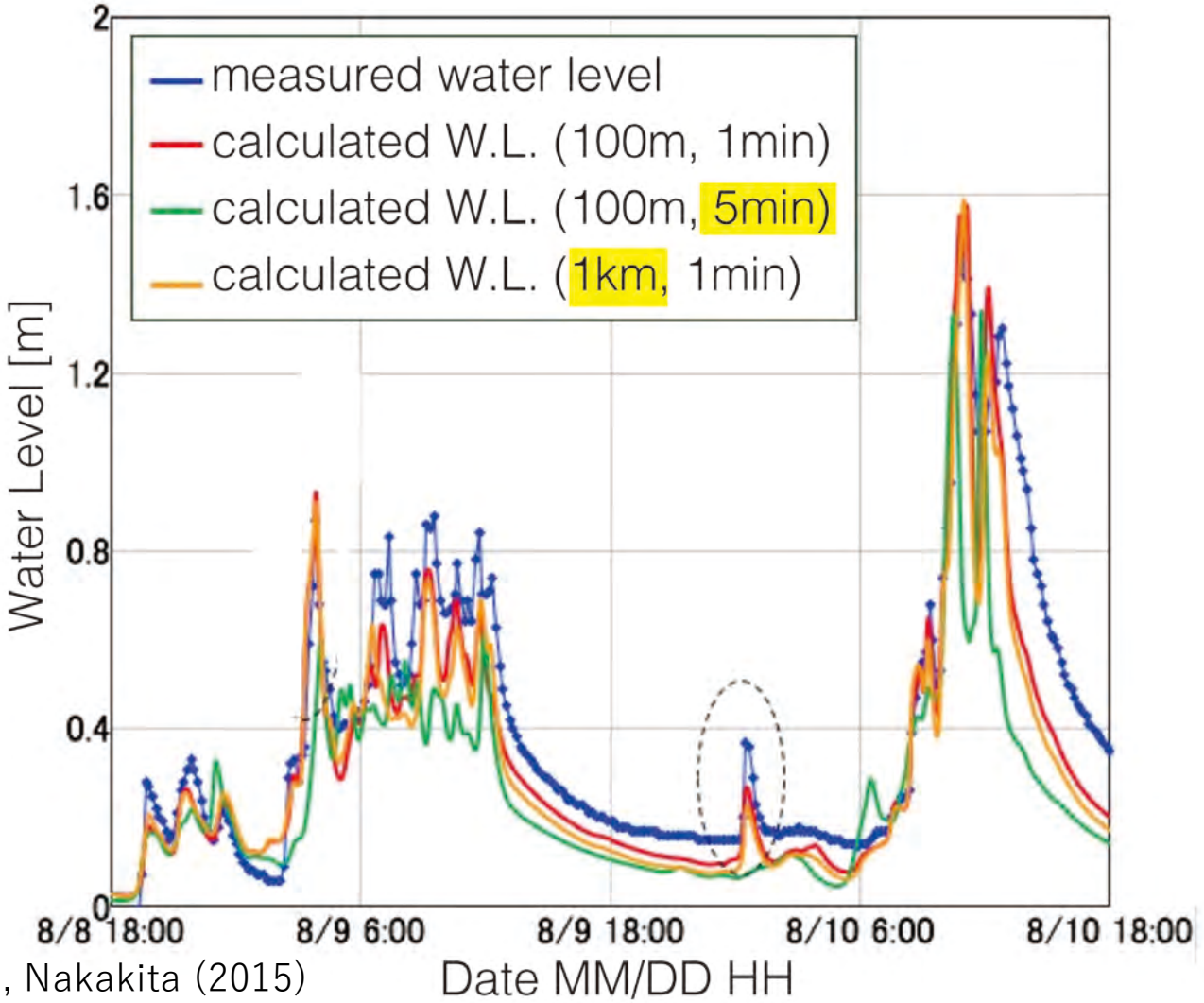
Ishigaki, Takaki, Oishi, Nakakita (2015)



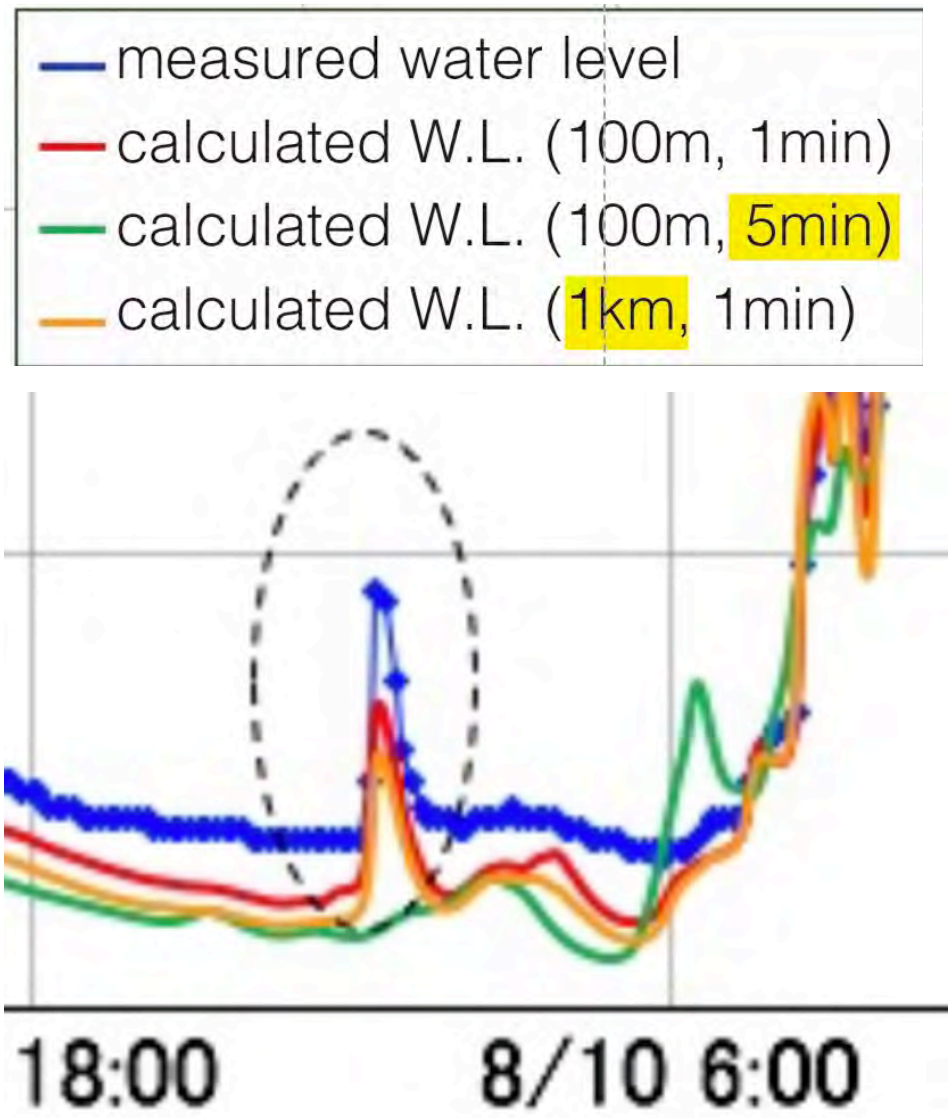


Ishigaki, Takaki, Oishi, Nakakita (2015)

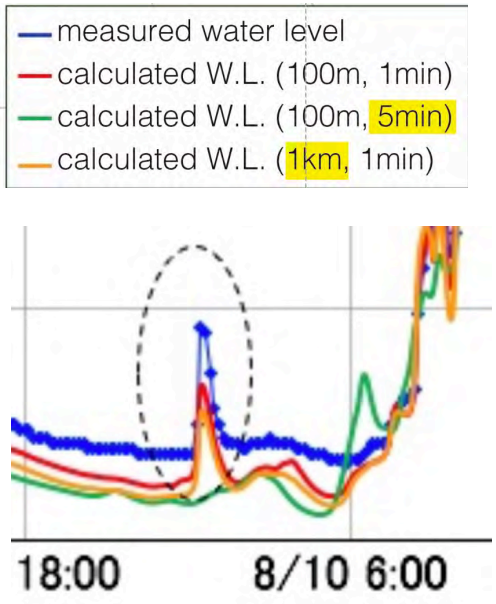
Whether temporal resolution or spatial resolution is more important?



Ishigaki, Takaki, Oishi, Nakakita (2015)



Ishigaki, Takaki, Oishi, Nakakita (2015)



Temporal resolution is important for small river discharge calculation.

1min is better than 5min.

Ishigaki, Takaki, Oishi, Nakakita (2015)

Radar and Deep learning

Figures of methods are in the URL.

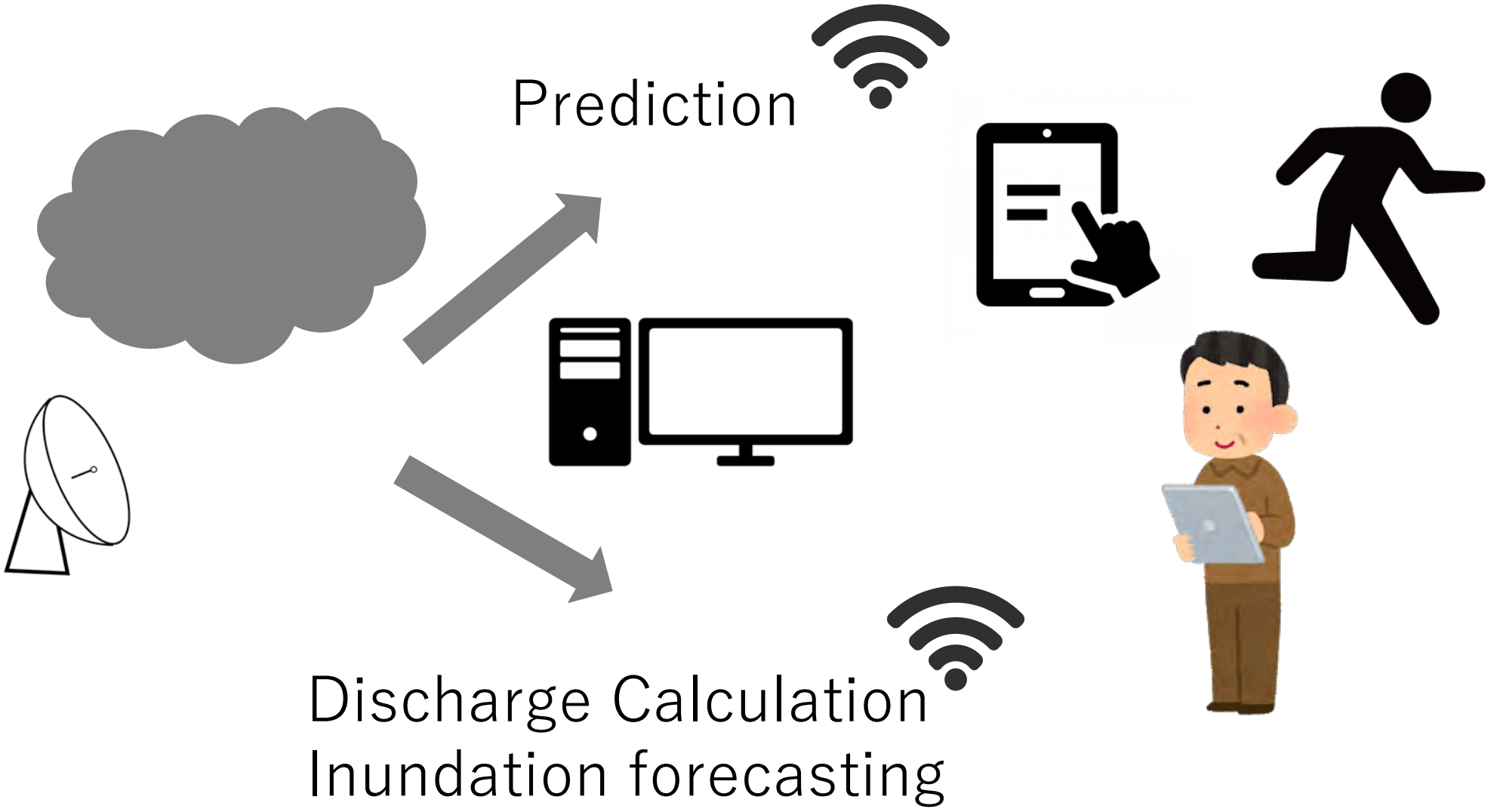
Fusamae and Shimamoto (2018) MLIT article
http://www.qsr.mlit.go.jp/useful/n-shiryo/kikaku/kenkyu/h30/04/4_03(18).pdf

Research results figures are in the URL.

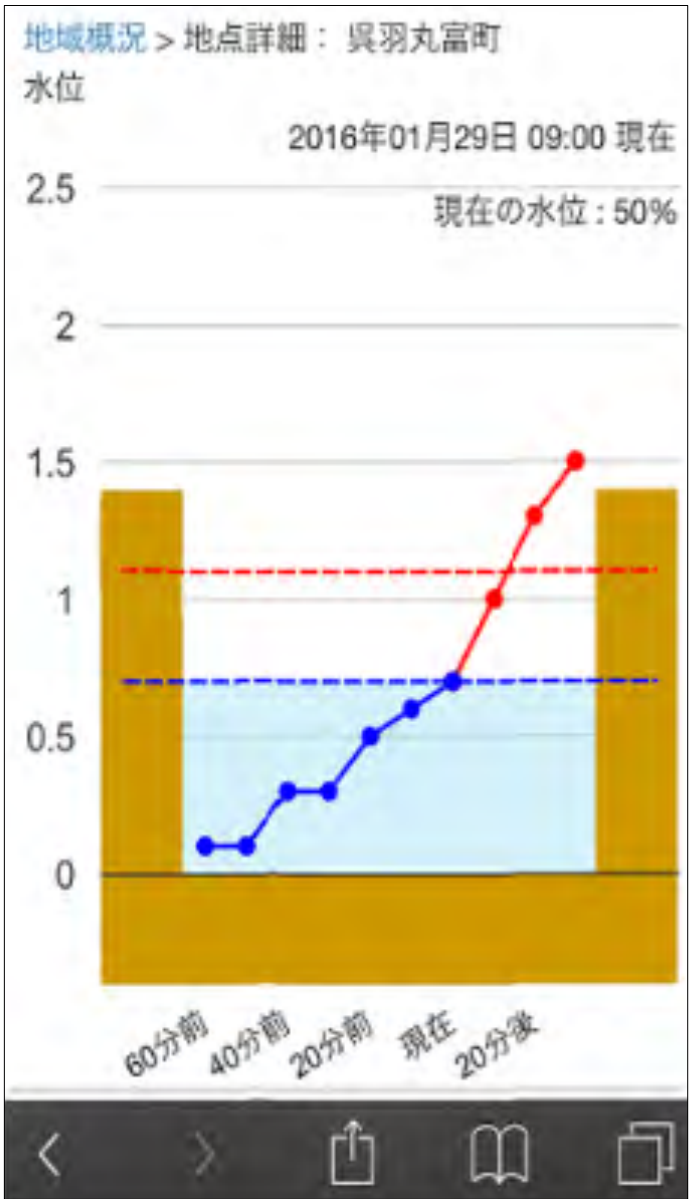
Fusamae and Shimamoto (2018) MLIT article
http://www.qsr.mlit.go.jp/useful/n-shiryo/kikaku/kenkyu/h30/04/4_03(18).pdf

Information sharing with citizens

- Tablet computer
- Local citizens who suffered from inundation for many years


Prediction
Discharge Calculation
Inundation forecasting

Display image



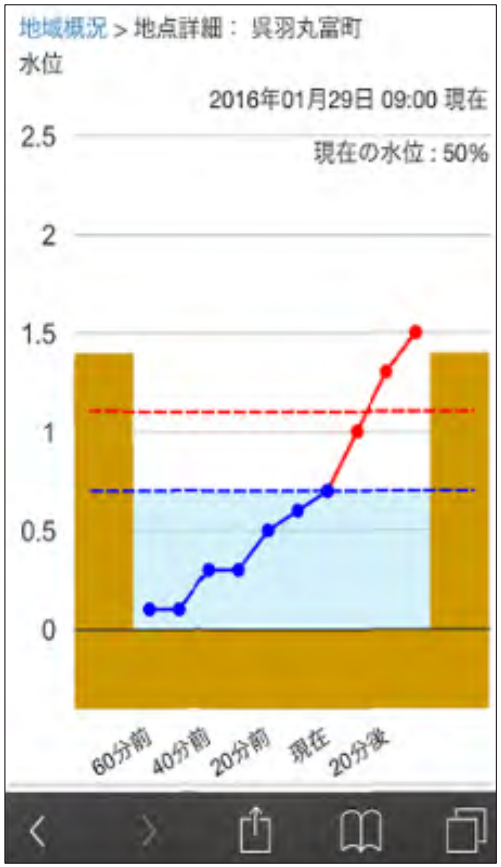
Water level at a point in the river

Previous

Forecasts

Display image

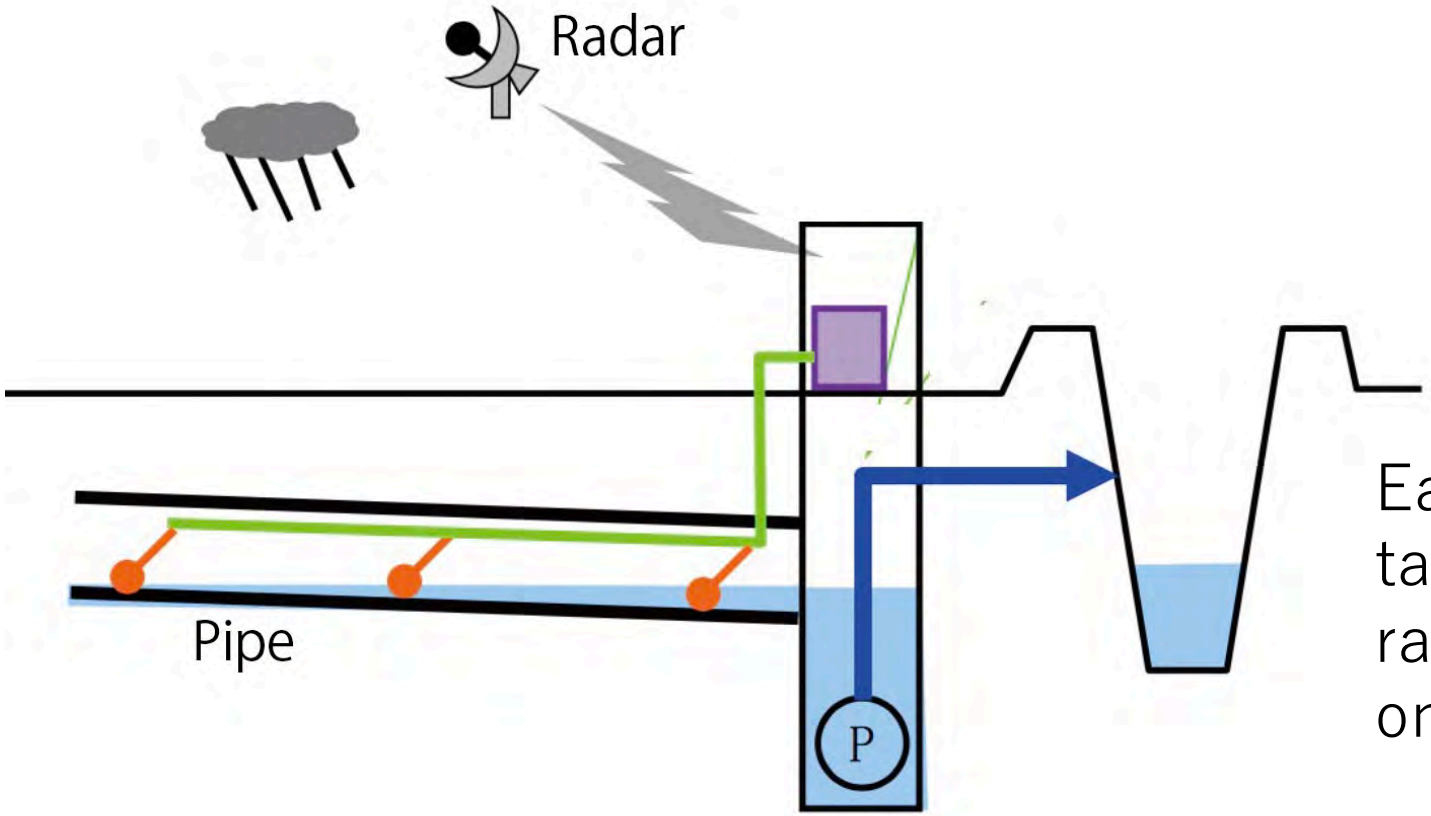
Inundation Forecast done by precise sewage pipe flow calculation


地域概況 > 地点詳細： 呉羽丸富町
水位
2016年01月29日 09:00 現在
現在の水位：50%
2.5
2
1.5
1
0.5
0
60分前
40分前
20分前
現在
20分後


地域概況 > 浸水予測マップ
浸水深 0~15cm（道路冠水）
浸水深15~45cm（床下浸水）
浸水深45cm以上（床上浸水）
別画面表示

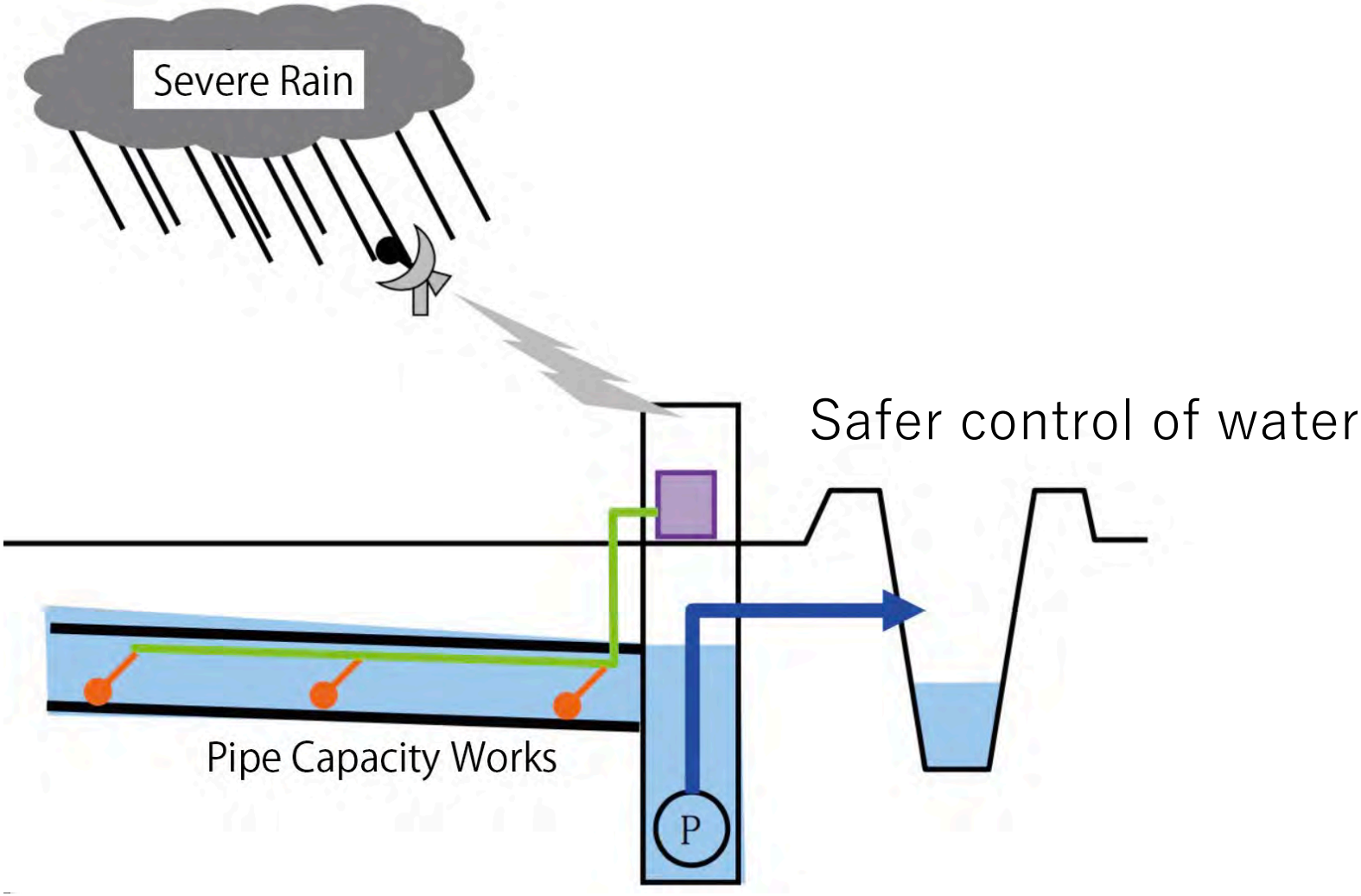

小川やため池が…
多発する“記録的大雨”
都市に潜むリスク
LIVE
クロ現＋
奈良
撮影　視聴者
内水氾濫

Sewage Water Management with Radar

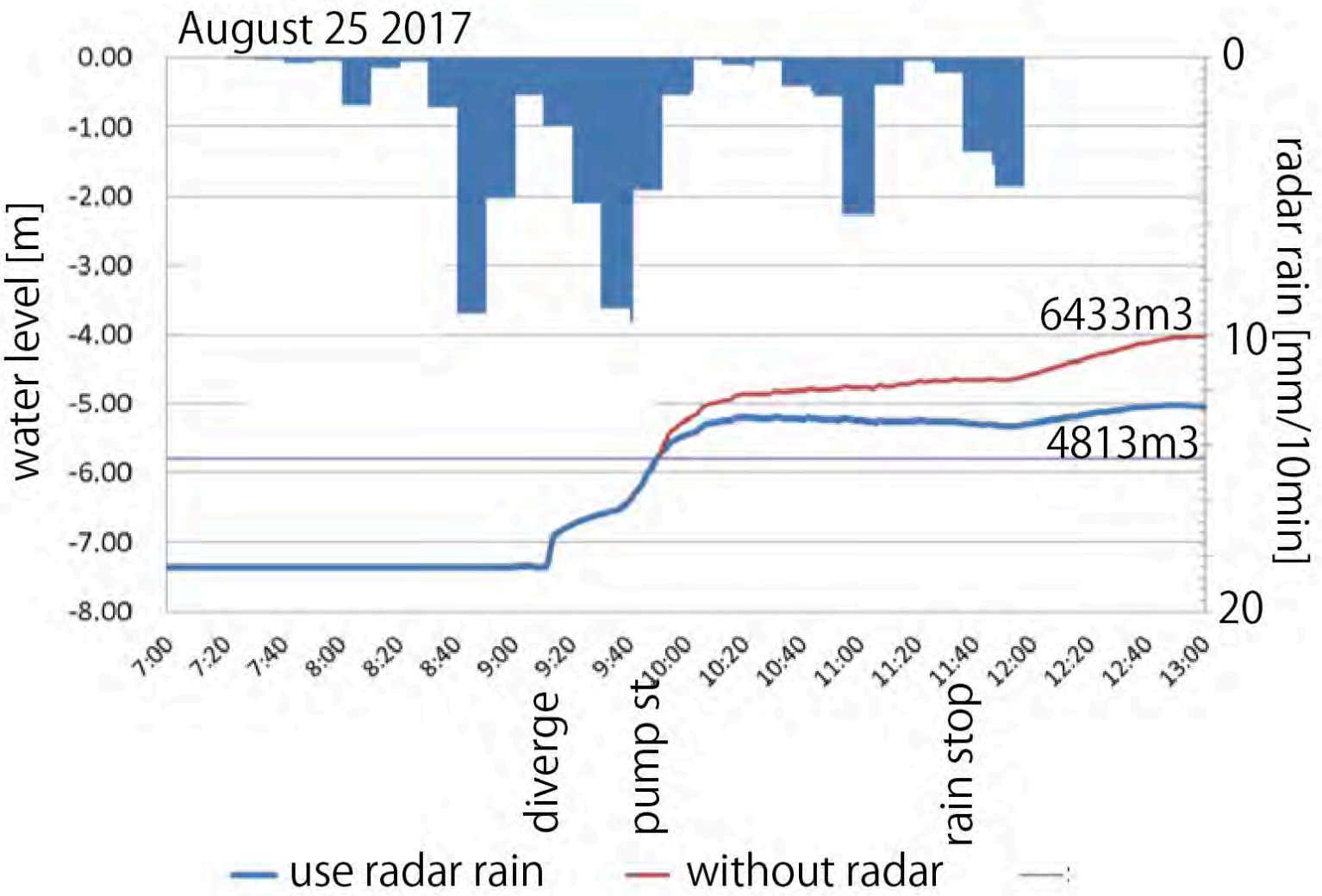


Earlier action was taken before severe rain was observed on the ground

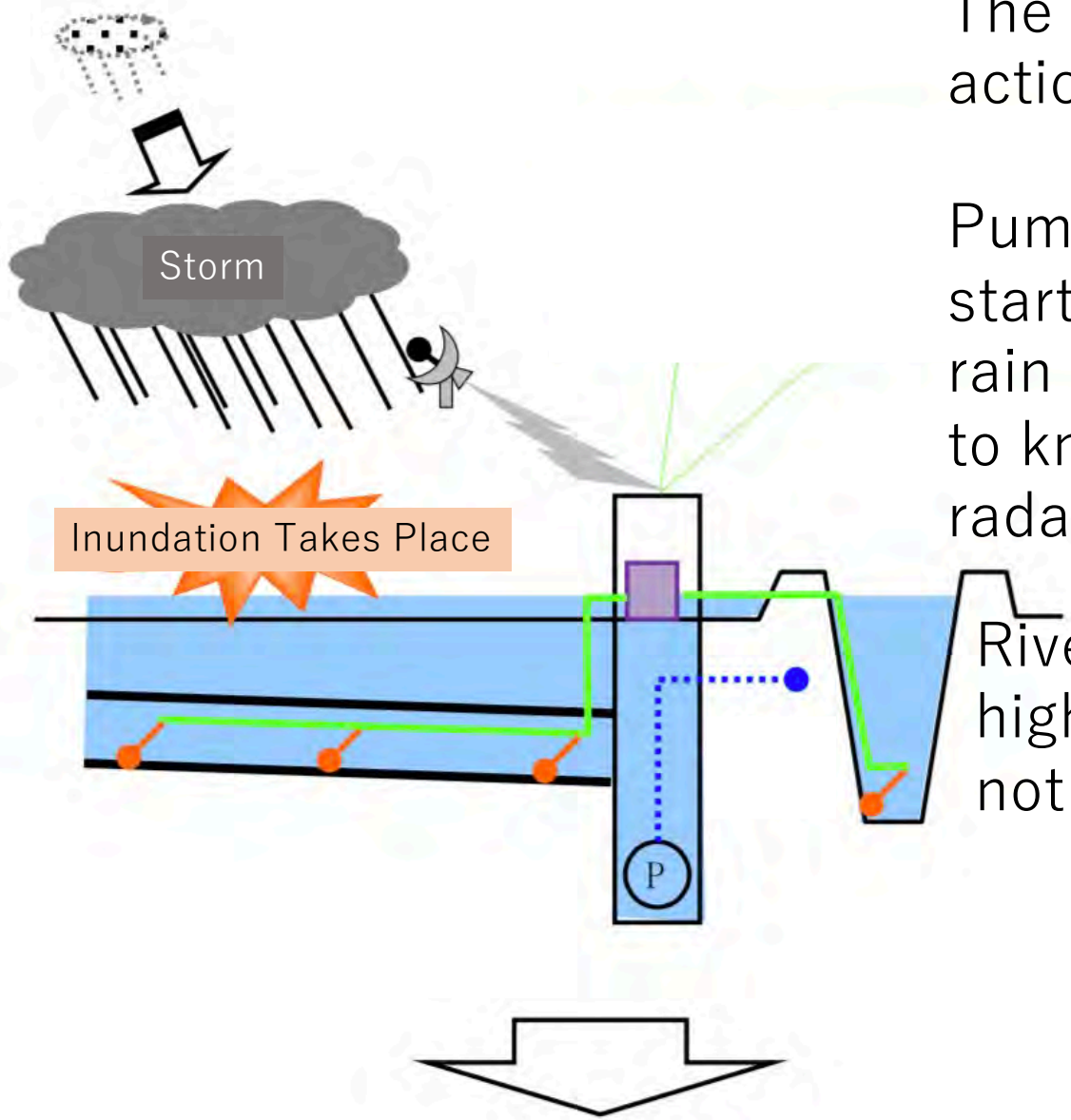
TECHNICAL NOTE of National Institute for Land and Infrastructure Management No.998 March 2018



TECHNICAL NOTE of National Institute for Land and Infrastructure Management No.998 March 2018


August 25 2017
water level [m]
radar rain [mm/10min]
0.00
-1.00
-2.00
-3.00
-4.00
-5.00
-6.00
-7.00
-8.00
0
10
20
6433m3
4813m3
7:00
7:20
7:40
8:00
8:20
8:40
9:00
9:20
9:40
10:00
10:20
10:40
11:00
11:20
11:40
12:00
12:20
12:40
13:00
diverge
pump st
rain stop
use radar rain
without radar

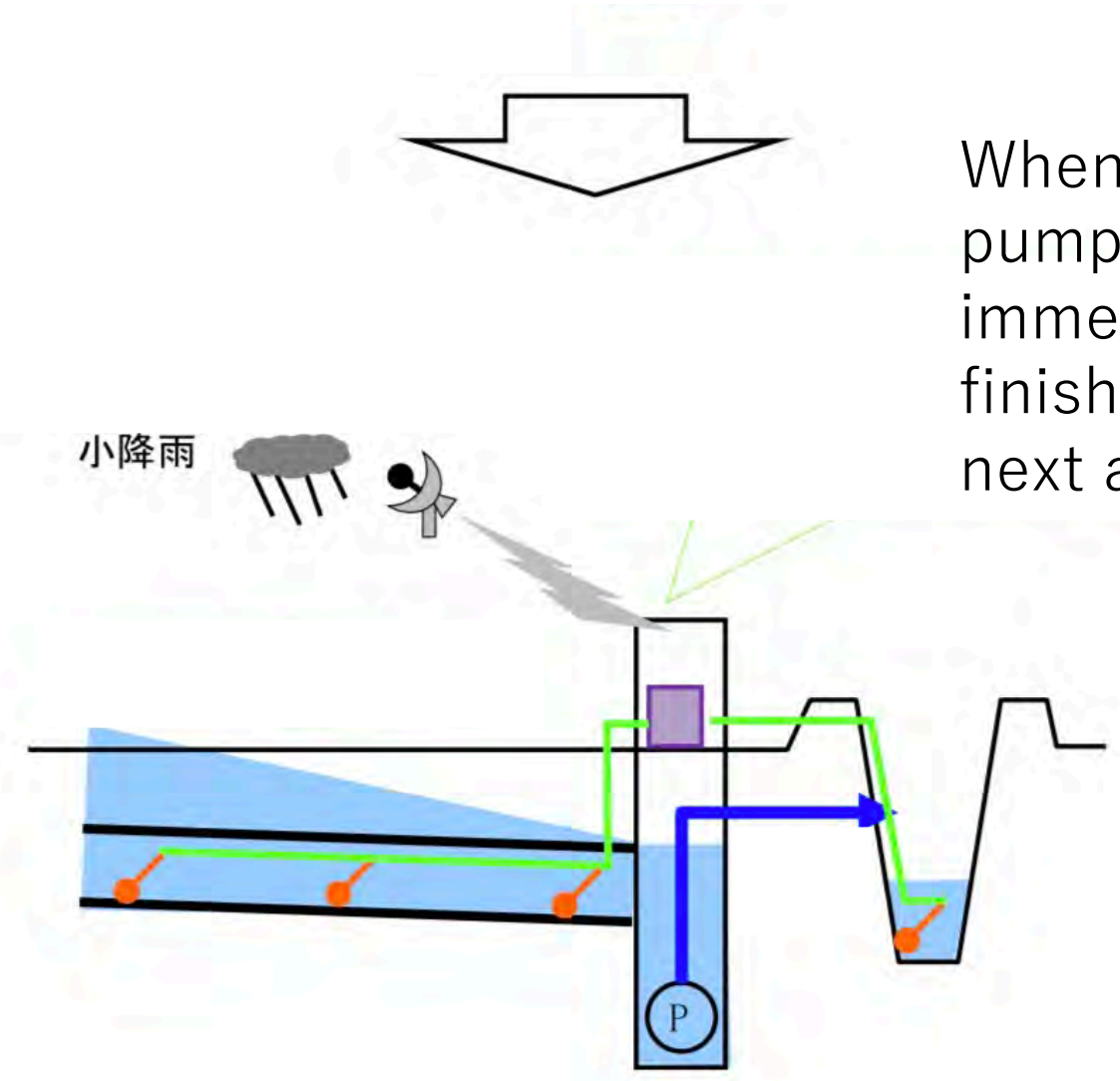
Prediction of stop raining



The other earlier action

Pump is ready to start during severe rain that is difficult to know without radar

River water level is high and pump does not start operation.



When it stop raining, pump started immediately and it finish inundation for next action

Summary

- QPE, small river discharge, citizens' evacuation, sewage water management
- Application: objectives, targets, targets requirements
- Resolution: temporal resolution
- Necessity:

People did not know what they want before they get.