Real-time Impact-based Tsunami Forecast Facility
Contribution to EW4ALL & Tsunami Ready

Shunichi KOSHIMURA

koshimura@tohoku.ac.jp

Deputy Director, International Research Institute of Disaster Science, Tohoku University

CTO, RTi-cast, Inc. (Private-based Tsunami Forecast Provider)

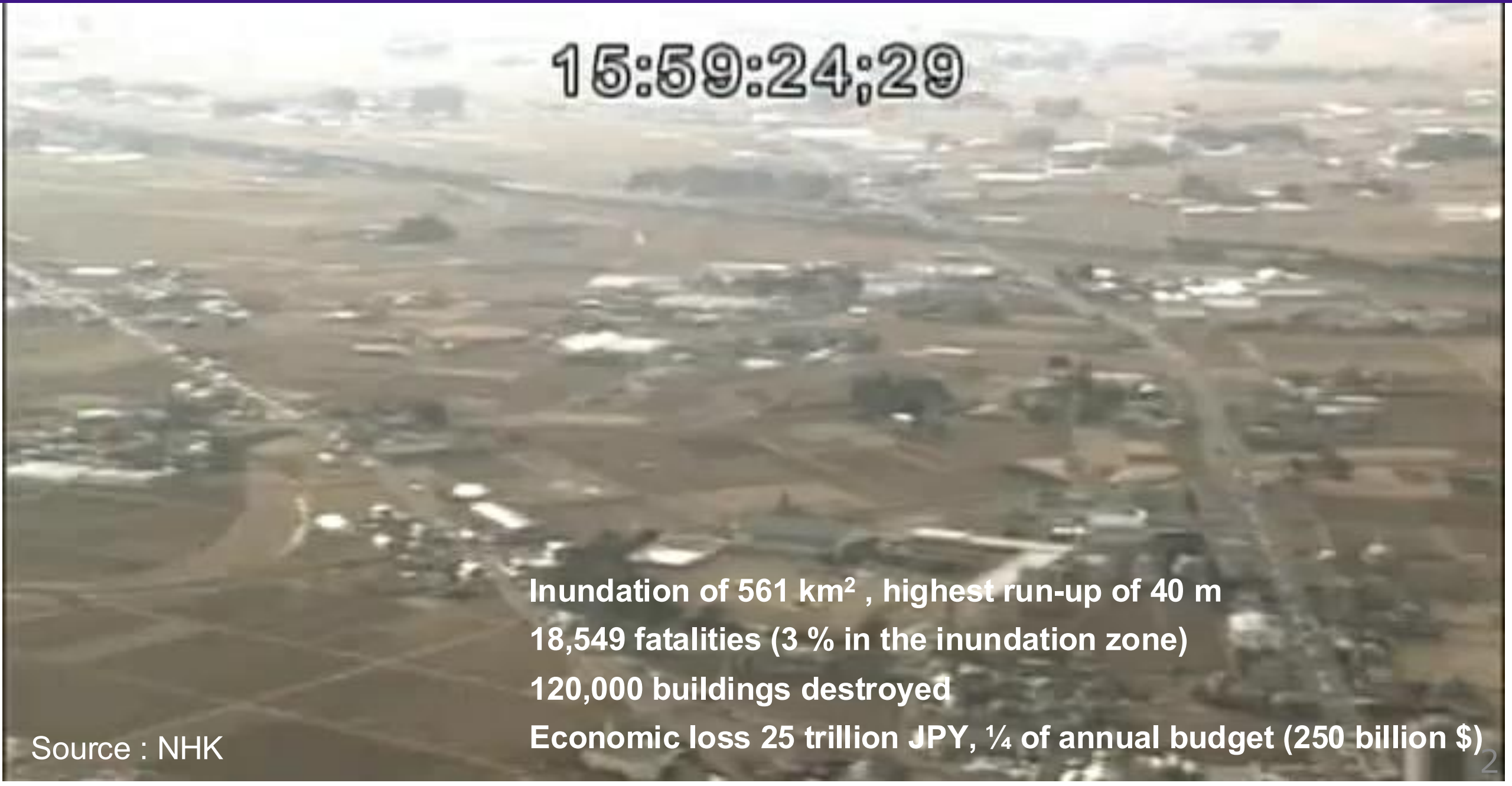
TOHOKU UNIVERSITY

TOHOKU UNIVERSITY IRIDeS International Research Institute of Disaster Science

RTi-cast

TsunamiCast

The 2011 Great East Japan Earthquake Tsunami



Inundation of 561 km^2 , highest run-up of 40 m

18,549 fatalities (3 % in the inundation zone)

120,000 buildings destroyed

Economic loss 25 trillion JPY, ¼ of annual budget (250 billion $)

Source : NHK

THE ROYAL SOCIETY PUBLISHING | All Journals | Brought to you by Tohoku University | Sign in | Search

Home | Content | Information for | About us | Sign up | Propose an issue

PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A

MATHEMATICAL, PHYSICAL AND ENGINEERING SCIENCES

You have access

Check for updates

View PDF

Tools | Share

Cite this article

Section

Abstract

1. Introduction

2. Pre-2011 paradigm

3. Response to the 2011 event

4. Post-tsunami reconstruction outlook

5. Conclusion

Authors' contributions

Competing interests

Funding

Acknowledgements

Footnotes

Research article

Response to the 2011 Great East Japan Earthquake and Tsunami disaster

Shunichi Koshimura and Nobuo Shuto

Published: 28 October 2015 https://doi.org/10.1098/rsta.2014.0373

Abstract

We revisited the lessons of the 2011 Great East Japan Earthquake Tsunami disaster specifically on the response and impact, and discussed the paradigm shift of Japan's tsunami disaster management policies and the perspectives for reconstruction. Revisiting the modern histories of Tohoku tsunami disasters and pre-2011 tsunami countermeasures, we clarified how Japan's coastal communities have prepared for tsunamis. The discussion mainly focuses on structural measures such as seawalls and breakwaters and non-structural measures of hazard map and evacuation. The responses to the 2011 event are discussed specifically on the tsunami warning system and efforts to identify the tsunami impacts. The nation-wide post-tsunami survey results shed light on the mechanisms of structural destruction, tsunami loads and structural vulnerability to inform structural rehabilitation measures and land-use planning. Remarkable paradigm shifts in designing coastal protection and disaster mitigation measures were introduced, leading with a new concept of potential tsunami levels: Prevention (Level 1) and Mitigation (Level 2) levels according to the level of 'protection'. The seawall is designed with reference to Level 1 tsunami scenario, while comprehensive disaster management measures should refer to Level 2 tsunami for protection of human lives and reducing potential losses and damage. Throughout the case study in Sendai city, the proposed reconstruction plan was evaluated from the tsunami engineering point of view to discuss how the post 2011 paradigm was implemented in coastal communities for future disaster mitigation. The analysis revealed that Sendai city's multiple protection measures for Level 2 tsunami will contribute to a substantial reduction of the tsunami inundation zone and potential losses, combined with an effective tsunami evacuation plan.

Details | References | Related | Figures

This Issue

28 October 2015
Volume 373, Issue 2053

Theme issue 'Tsunamis: bridging science, engineering and society' compiled and edited by Utku Kanoglu, Vasily Titov, Eddie Bernard and Costas Synolakis

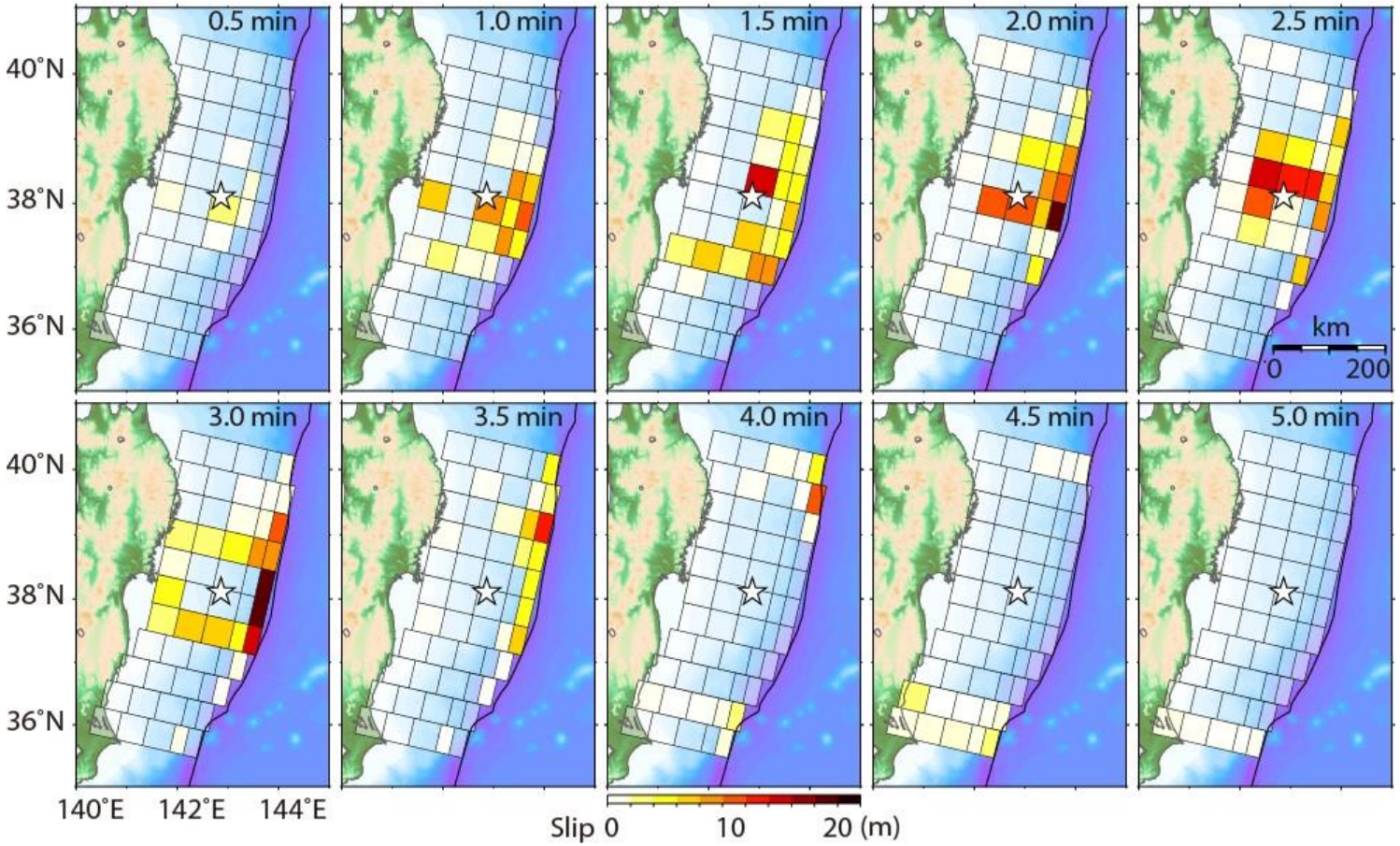
Article Information

DOI: https://doi.org/10.1098/rsta.2014.0373
Published by: Royal Society
Print ISSN: 1364-503X
Online ISSN: 1471-2962

History:

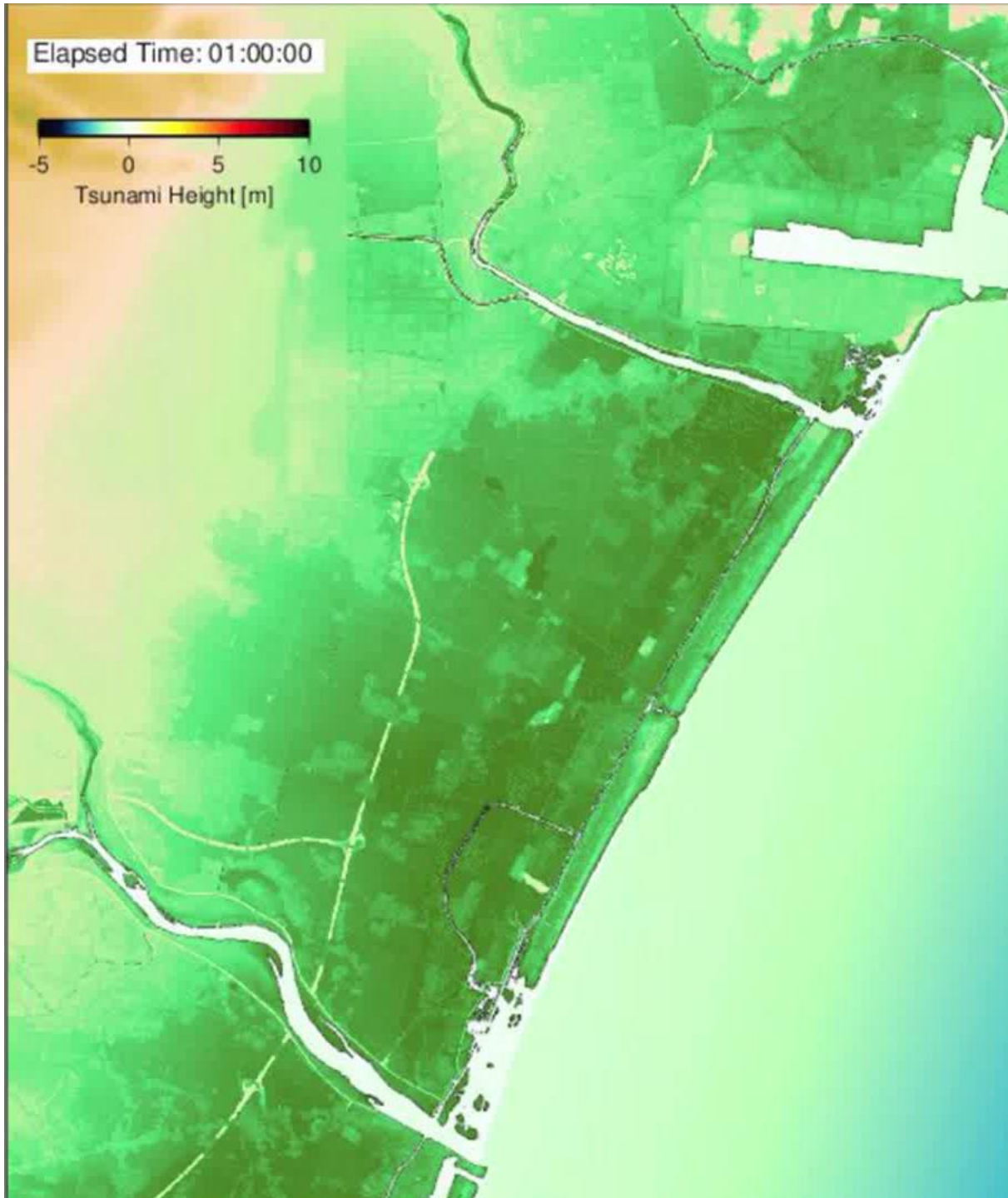
Manuscript accepted 28/05/2015
Published online 28/10/2015
Published in print 28/10/2015

Koshimura and Shuto, Response to the 2011 Great East Japan Earthquake and Tsunami disaster, Philosophical Transactions A, 373(2053), 2015. https://doi.org/10.1098/rsta.2014.0373

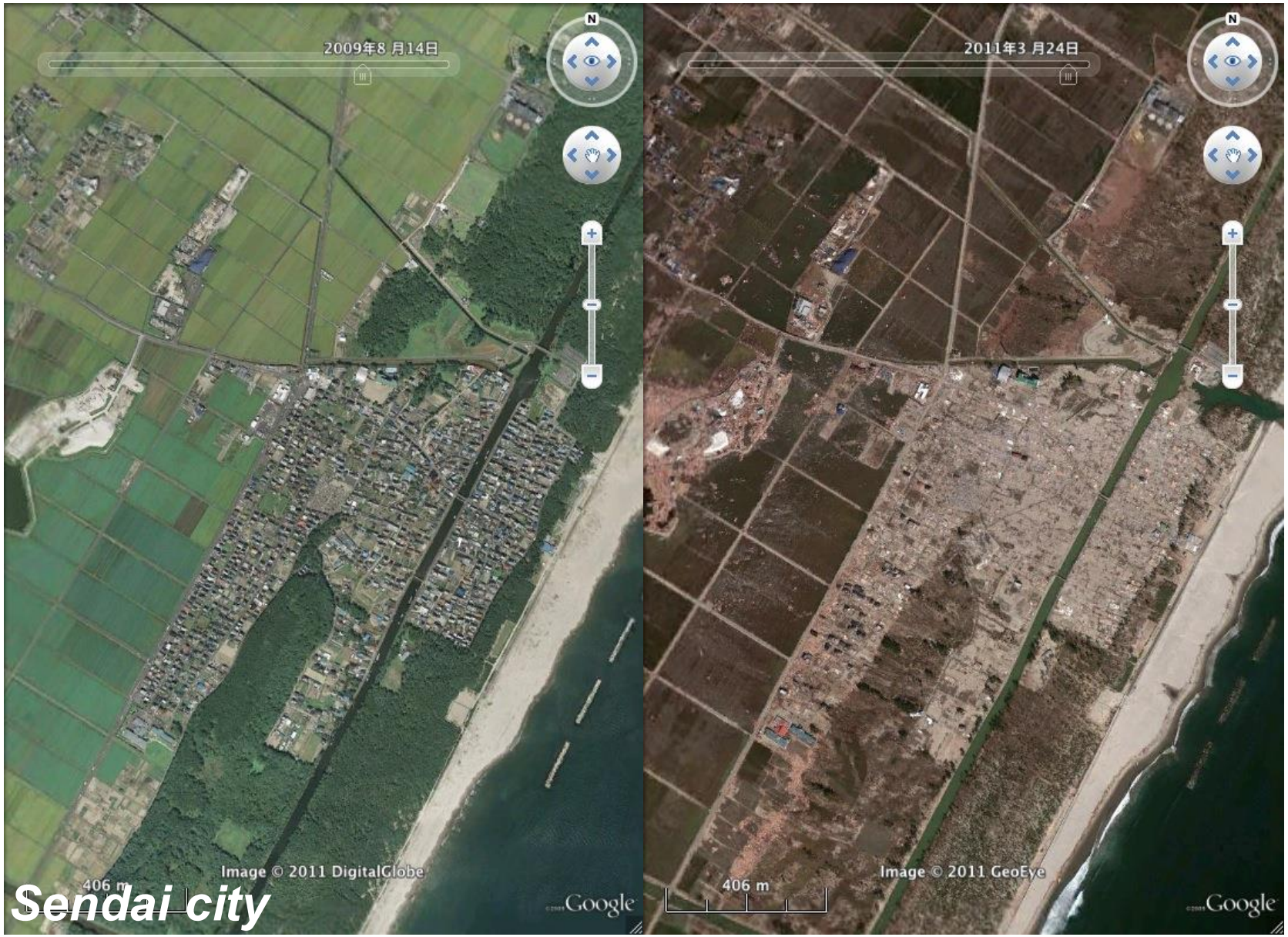


Fault rupture process (Satake et al., 2013)

The 2011 Tsunami in Sendai

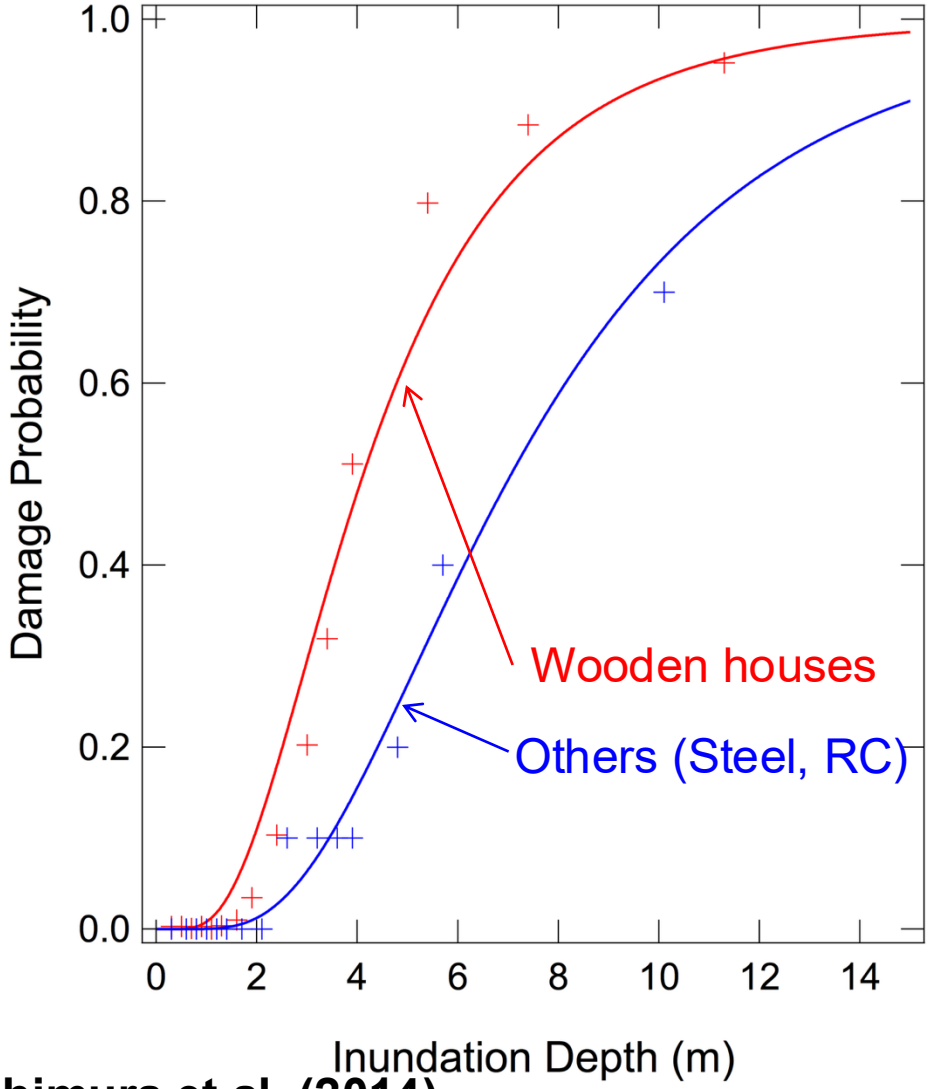


Devastated coastal communities

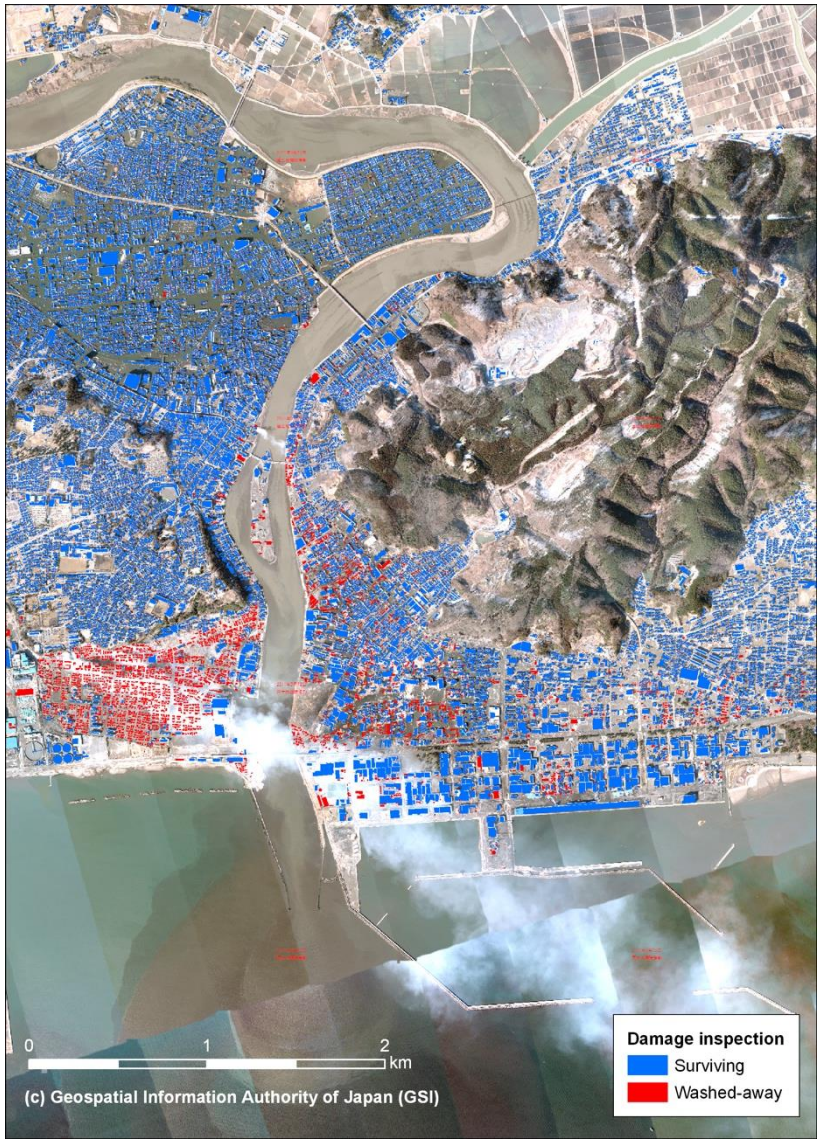


Sendai city

Structural Vulnerability
Tsunami Fragility Curve



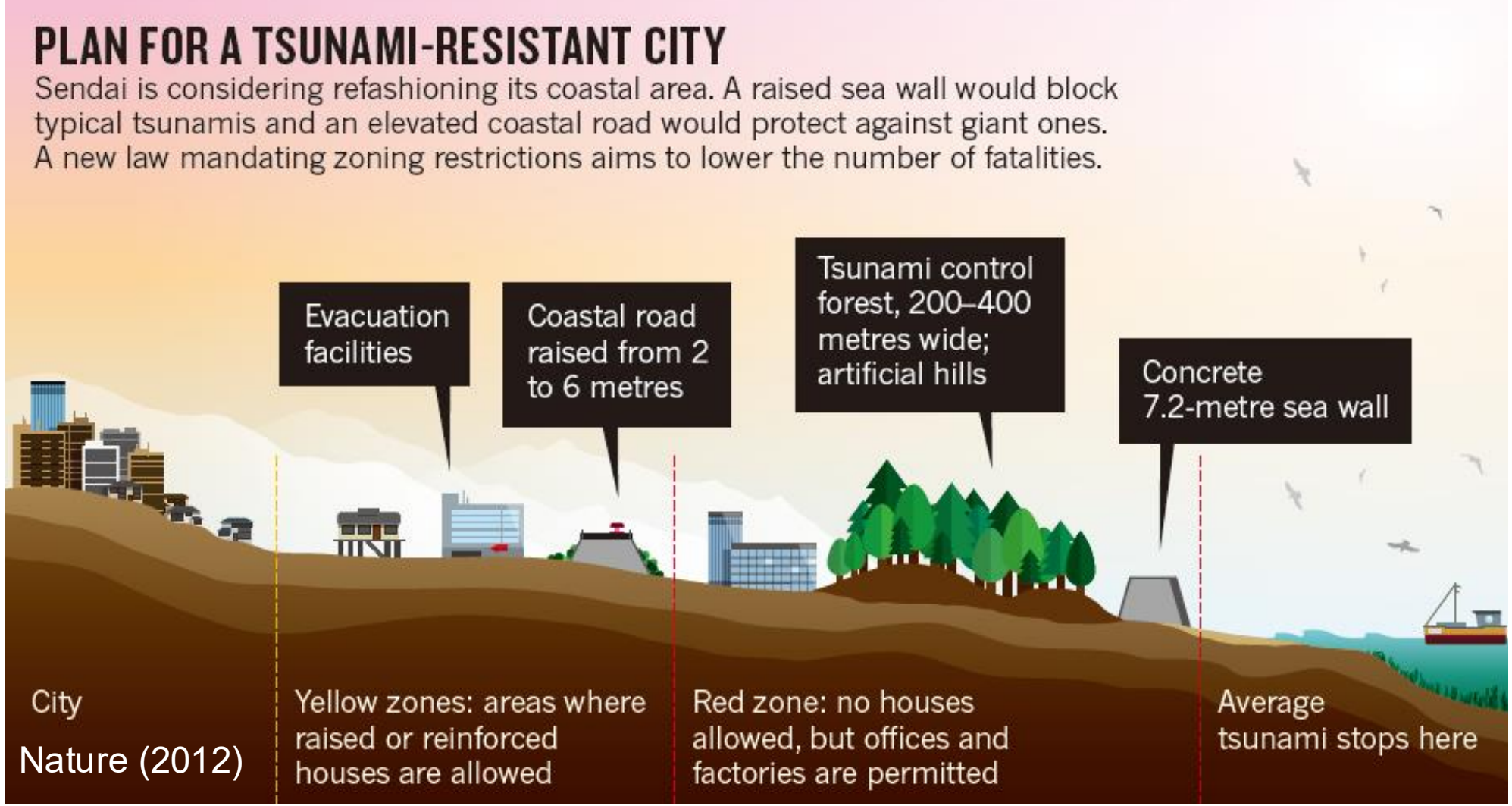
Koshimura et al. (2014)



Paradigm Shift of Coastal Protection

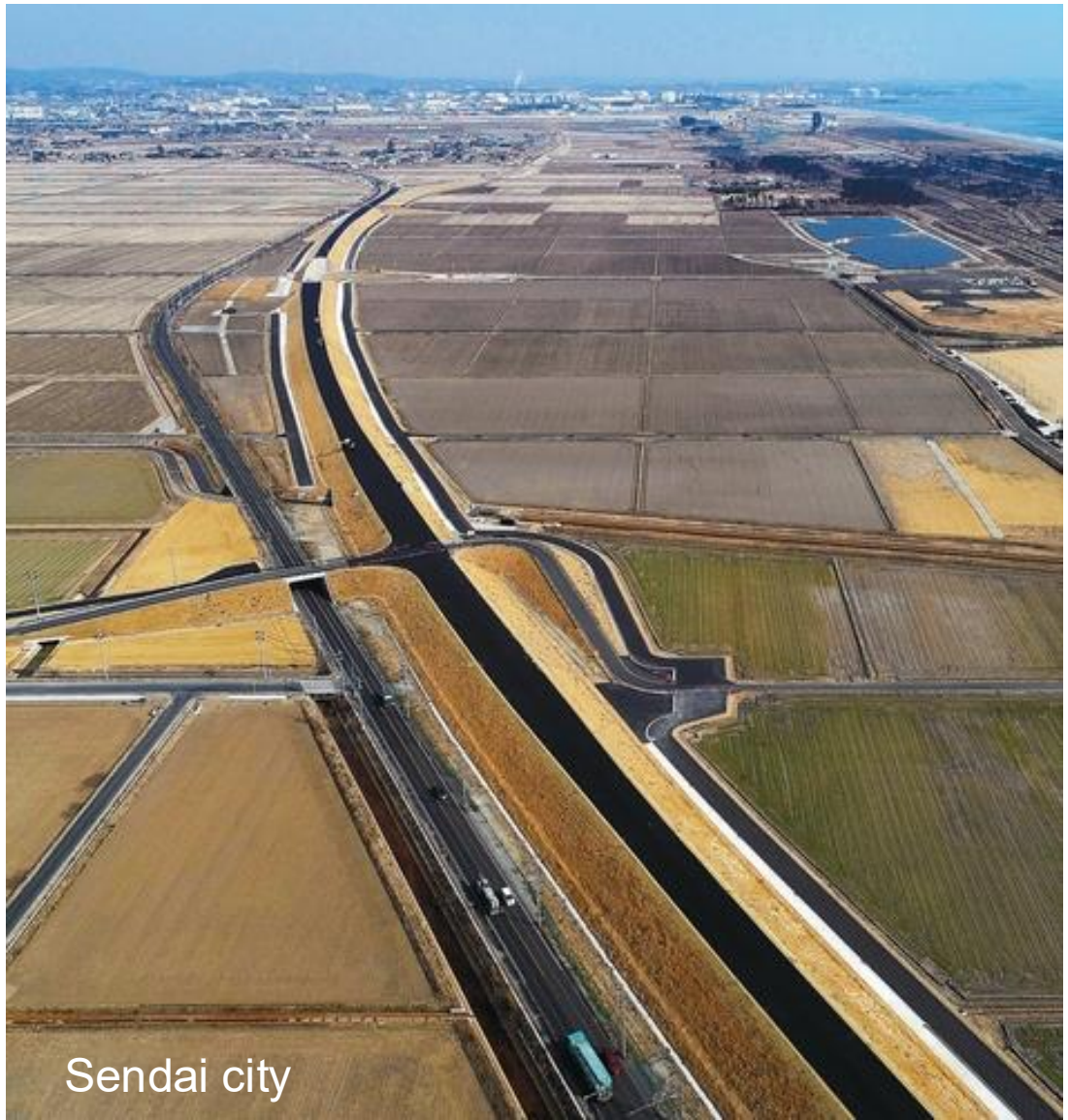
- **Prevention Level (Level 1, 150-year tsunami)** : prevent tsunamis from penetrating inland to protect lives and properties (or economic activities). **Applying to sea wall design.**
- **Preparedness/Mitigation Level (Level 2, extreme tsunami)** : reduce the losses with comprehensive measures ; coastal protection, urban planning, evacuation and public education. **Applying to all tsunami disaster management plans (hazard maps, use management)**.

Sendai city's reconstruction plan
Multiple protection to minimize losses



Nature (2012)

The elevated prefectural road (10 km)
Height : 6m, Width 30 m (120 million $)



Cycle of Understanding Disaster Processes

Forecasting Consequences

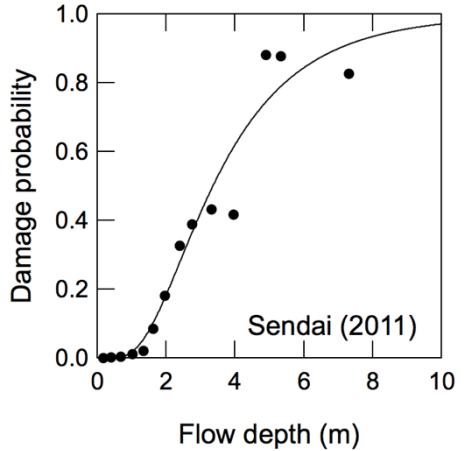
IMPACT
LOSS
CONSEQUENCE

=

HAZARD × EXPOSURE × VULNERA
BILITY

Learning from Consequences

Mechanism, Causality, Correlation



Real-time Impact-based Tsunami Forecast Facility
Contribution to EW4ALL & Tsunami Ready


UNDRR
UN Office for Disaster Risk Reduction
After a disaster,
early assessment
of the damage
can save lives.

Standard Tsunami Warning Messages (JMA)

	Estimated maximum tsunami height	
	Numerical announcement	Expression in the case of the massive earthquake
Major Tsunami Warning	10 m < *h*	Huge
	5 m < *h* ≤ 10 m	
	3 m < *h* ≤ 5 m	
Tsunami Warning	1 m < *h* ≤ 3 m	High
Tsunami Advisory	0.2 m ≤ *h* ≤ 1.0 m	—

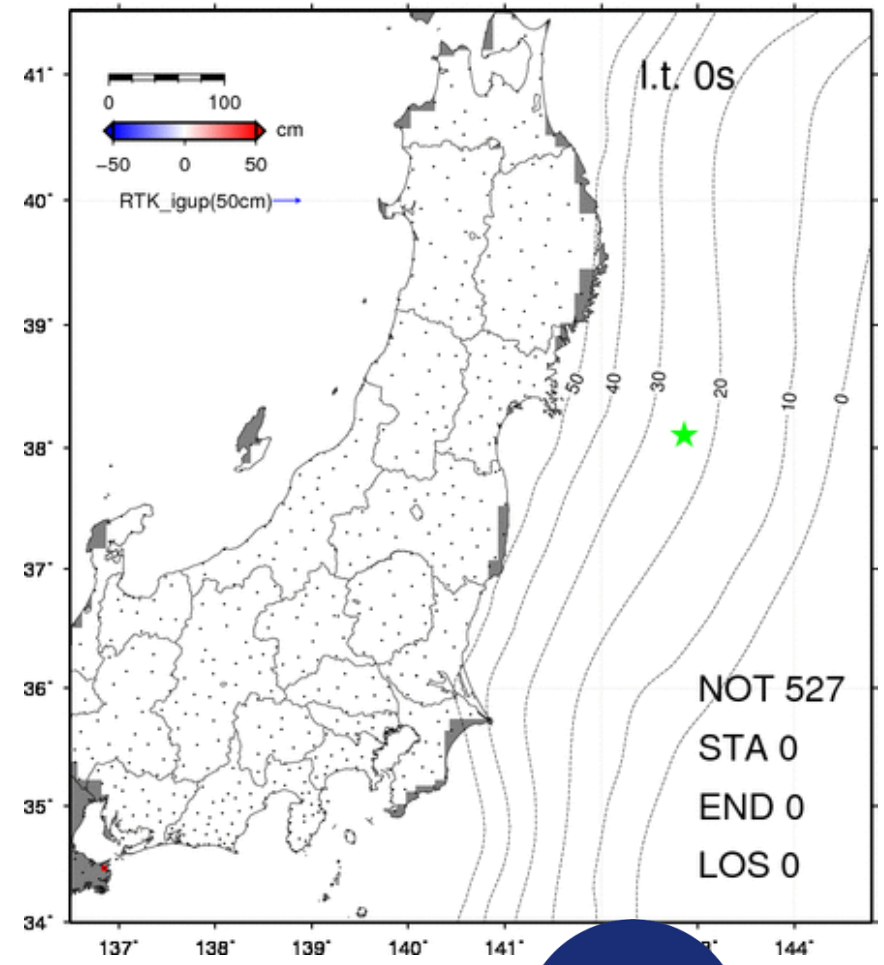
- **Rapid estimation of coastal tsunami height**
- **Pre-computed tsunami propagation model database**

No inundation forecast information is provided

TsunamiCast
Operational GNSS-based Tsunami Inundation Forecast

Supercomputer

RTi-cast



TsunamiCast

Value of TsunamiCast
Real-time Tsunami Inundation and Damage Forecast

~minutes

~hours

~days

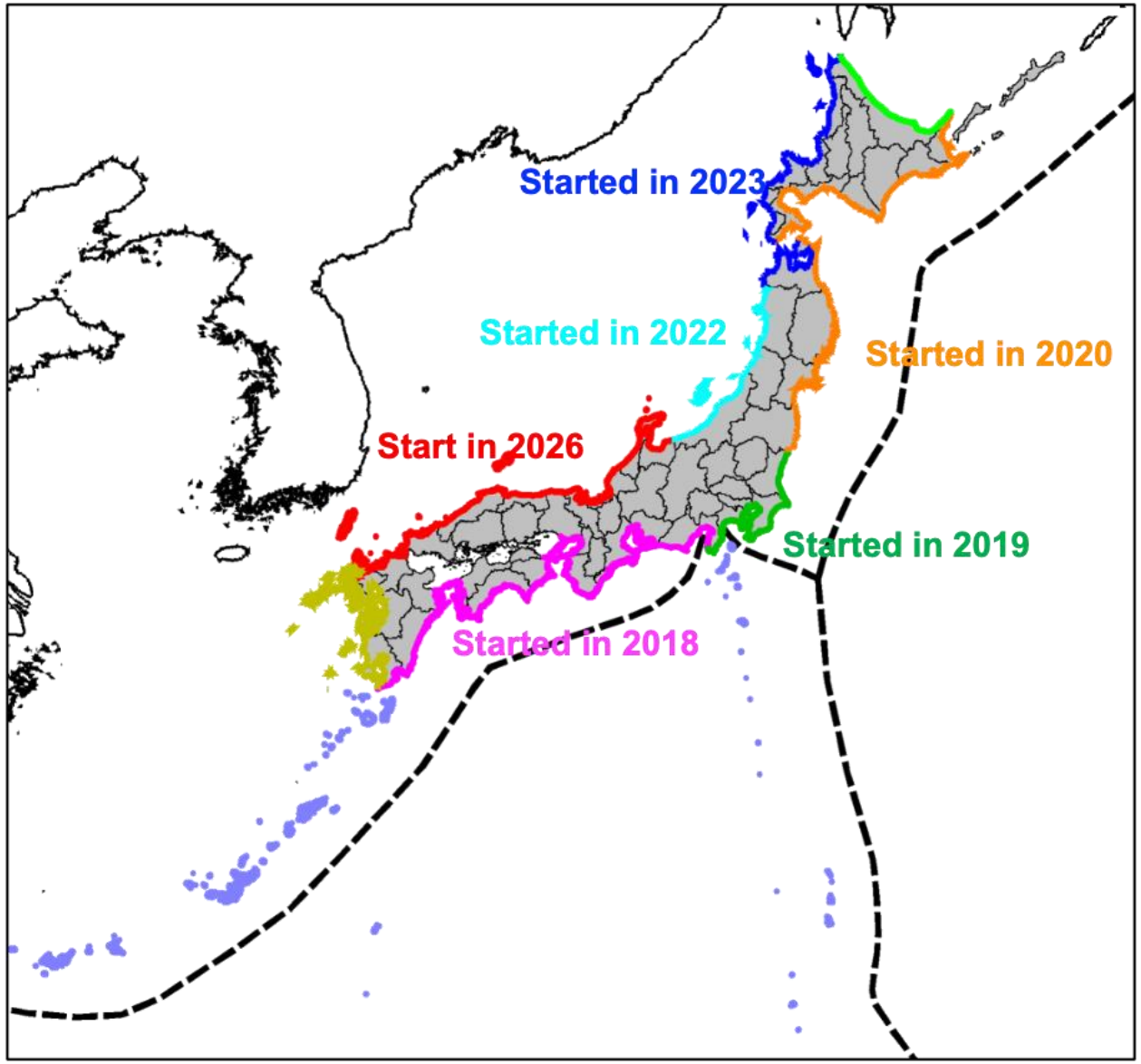
Supporting Resilience – Reduce Loss and Recover Quickly

- How extensive does the tsunami penetrate? (Where is the safe place?)
- How many people are exposed?
- How many structures/infrastructures are damaged?
- How extensive disaster relief activities should be deployed?
- How much losses?

RTi-cast was approved by JMA in March 2024, as a unique private-based tsunami forecast provider to support disaster response of specified users (not general public).

TsunamiCast

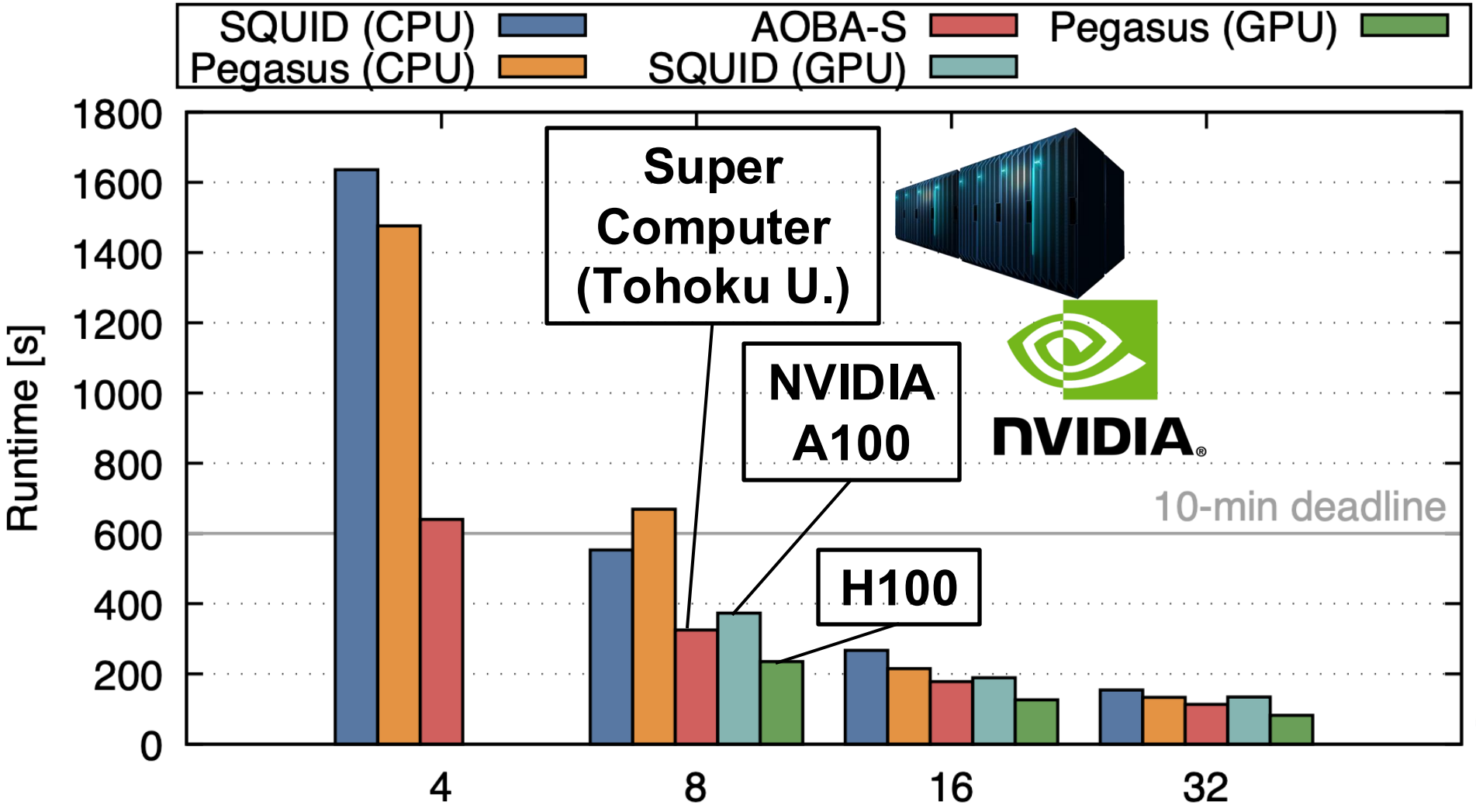
Nation-wide Impact-based Tsunami Forecast for Cabinet Office of Japan and Prefectural Government



RTi-cast

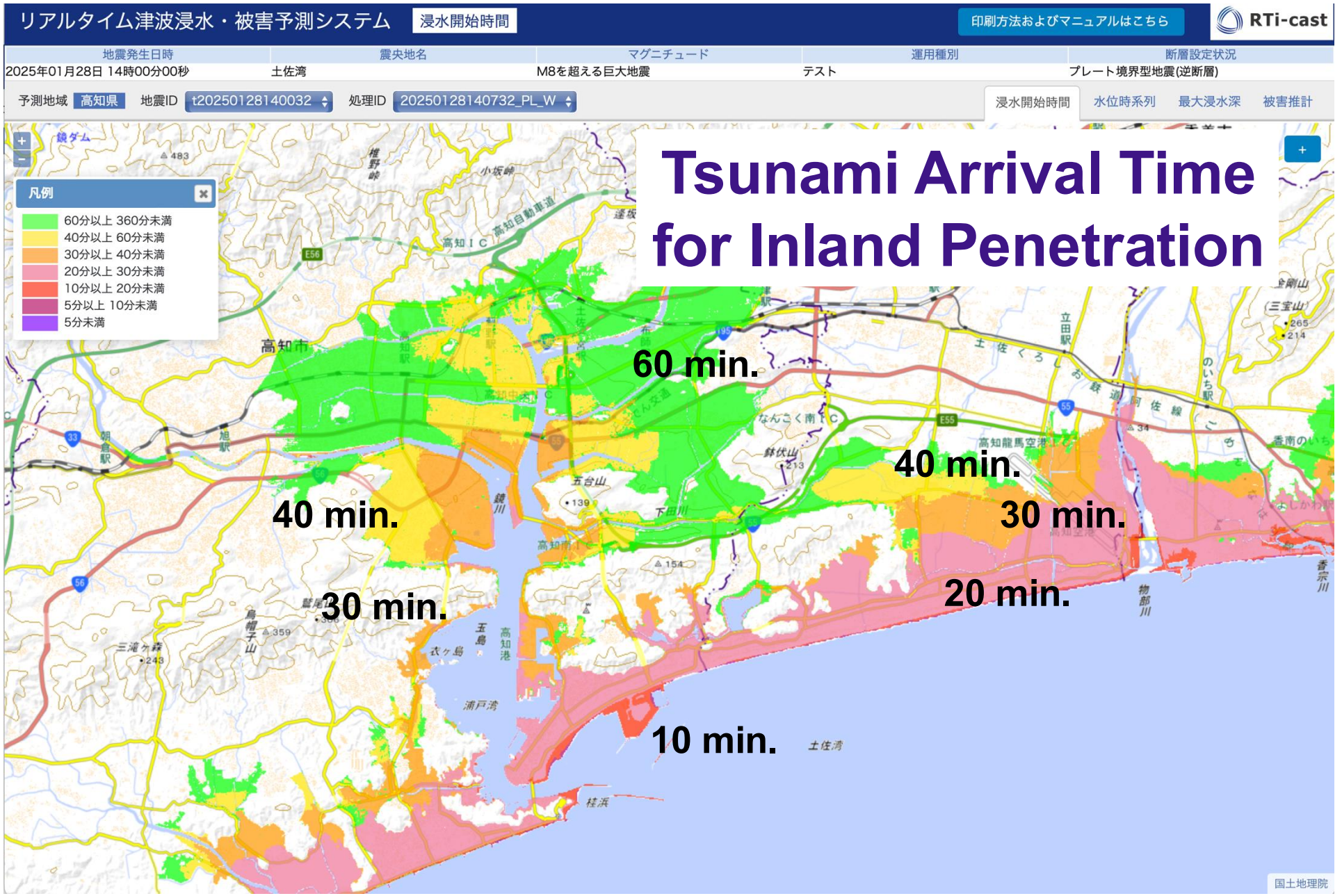
TsunamiCast

Performance of TsunamiCast for Diverse Users
Time to Complete 6-hour Forecast with 10m resolution



Takahashi et al. (2024)

TsunamiCast Products



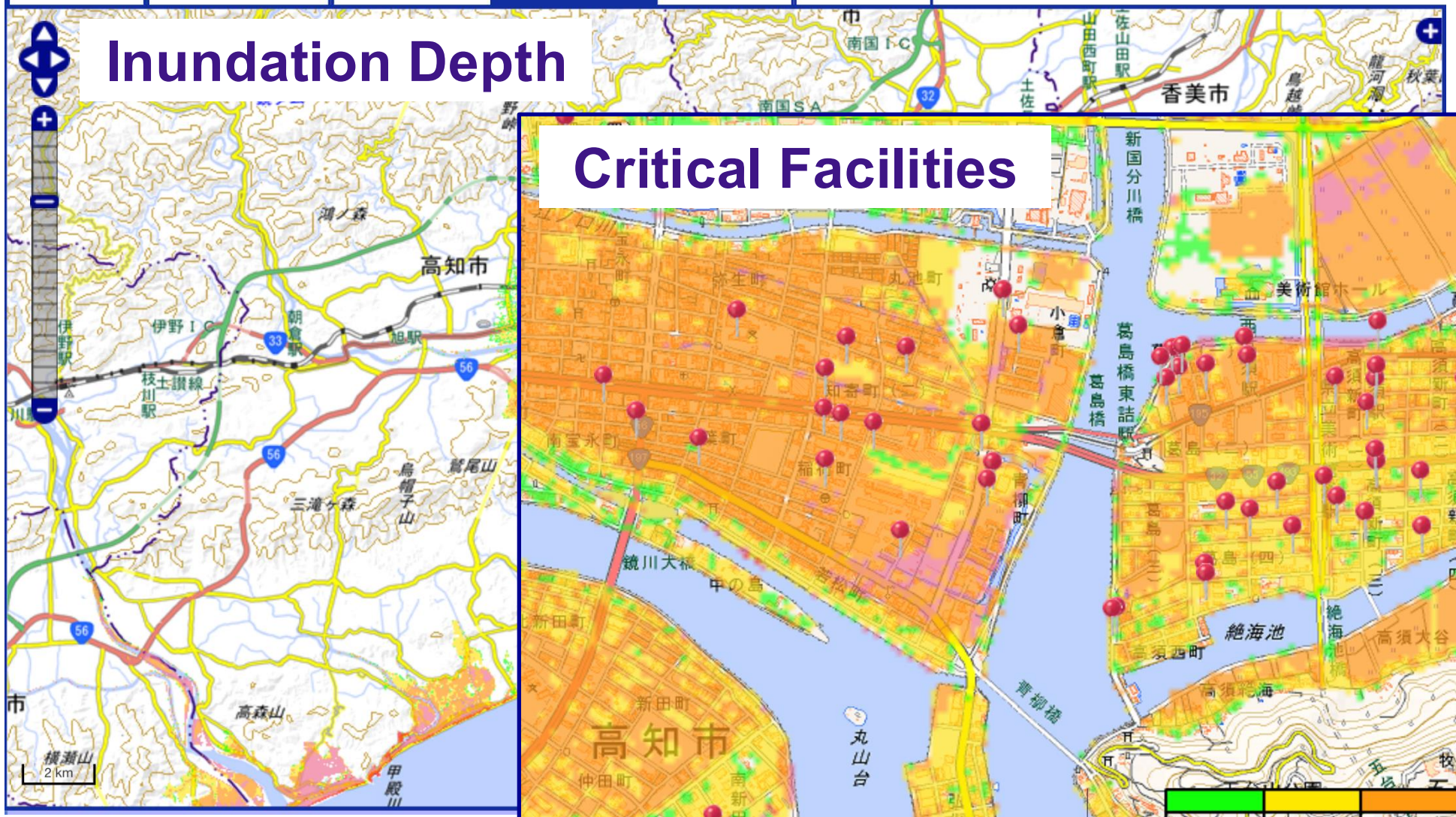
TsunamiCast

TsunamiCast Products

到達時間 | 浸水開始時間 | 水位時系列 | 最大浸水深 | 最大水位 | 被害推定

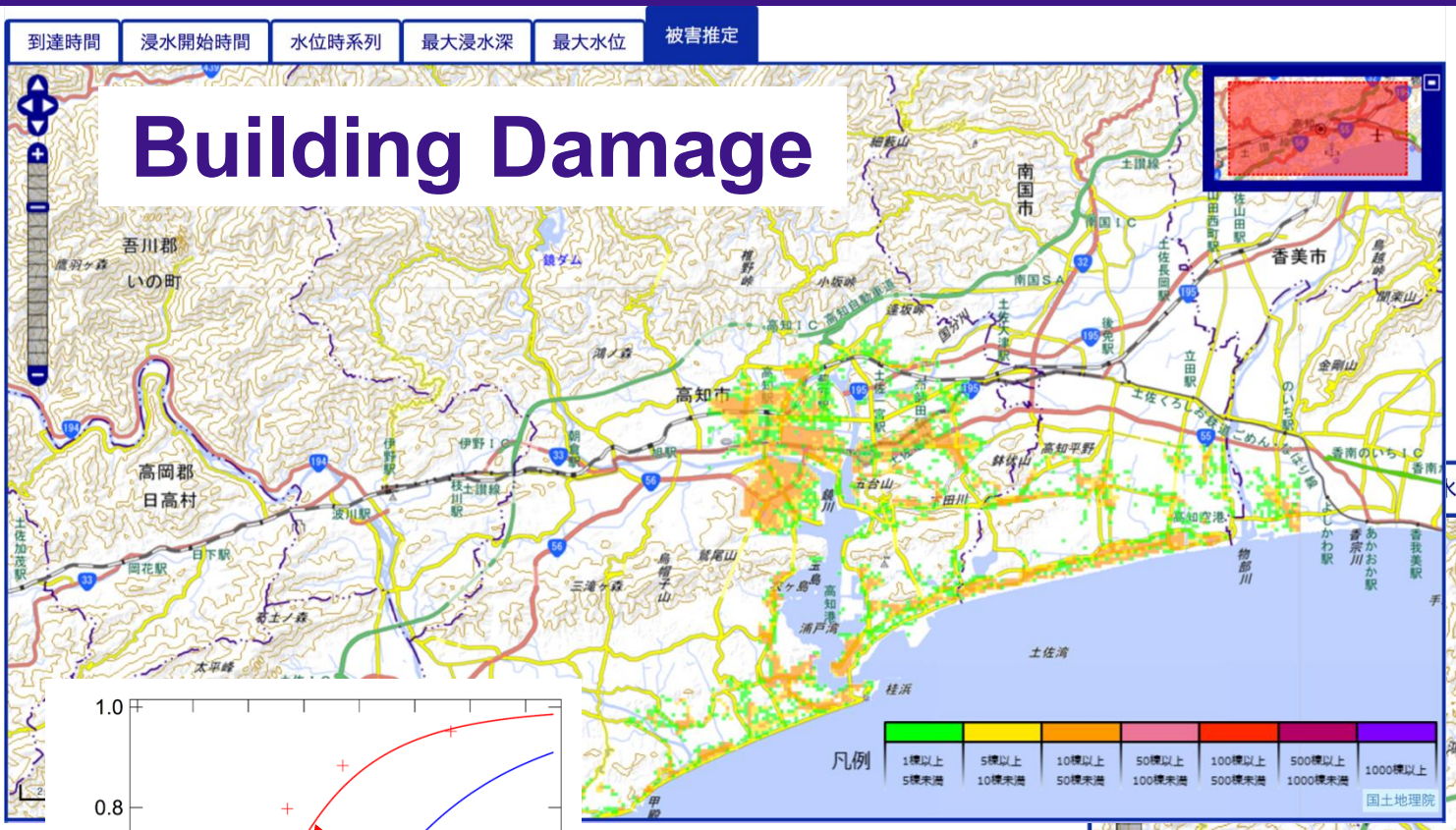
TsunamiCast

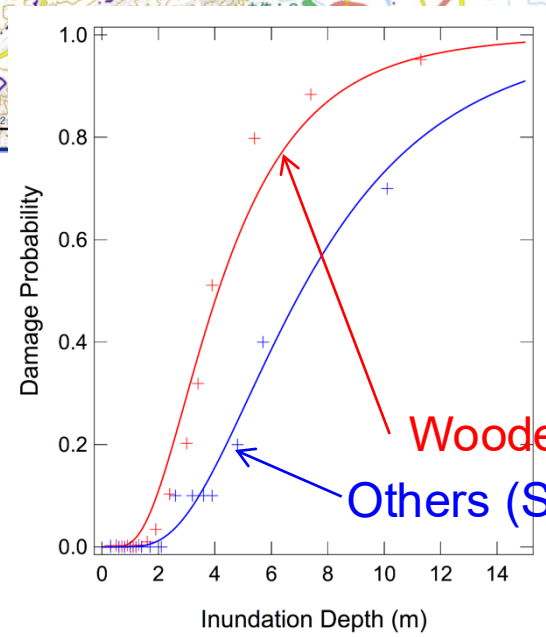
Inundation Depth



Critical Facilities

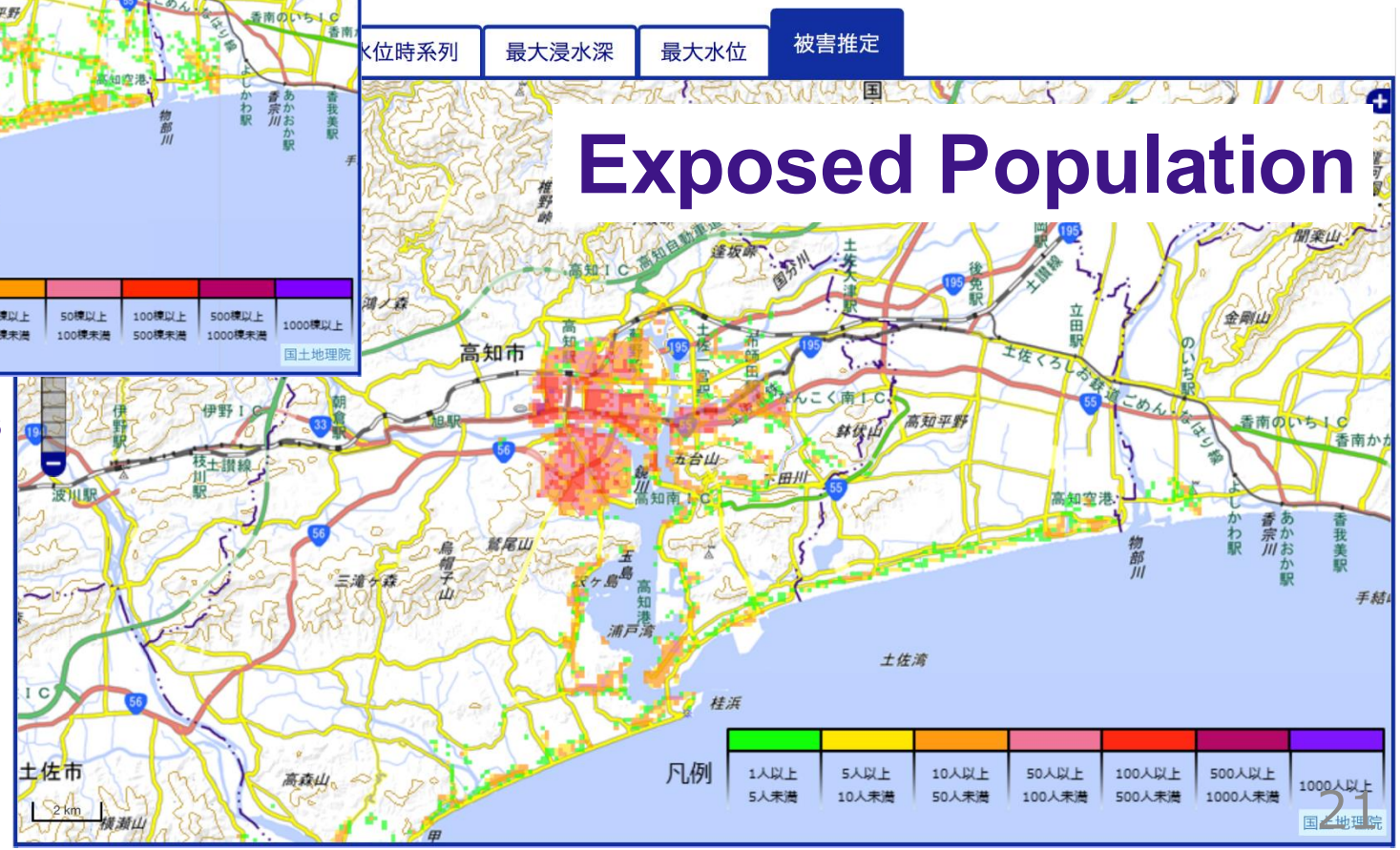
TsunamiCast Products





Tsunami Fragility Curves

Koshimura et al. (2014)



Digital Twin

Probabilistic Tsunami Hazard and Risk Analysis
Towards Disaster Risk Reduction and Resilience
2025, Pages 543-559

Chapter 24 - Digital twin paradigm for coastal disaster risk reduction and resilience

Shunichi Koshimura [1 2 3], Nobuhito Mori [4], Naotaka Chikasada [5], Keiko Udo [3], Junichi Ninomiya [6], Yoshihiro Okumura [7], Erick Mas [1 2 3]

Show more

+ Add to Mendeley Share Cite

https://doi.org/10.1016/B978-0-443-18987-6.00024-5 ↗

Get rights and content ↗

Abstract

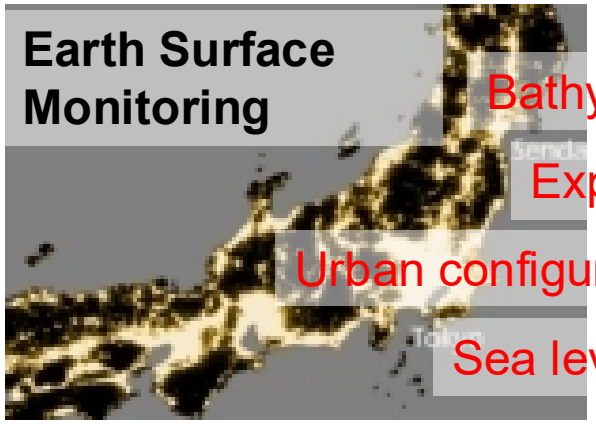
Coastal digital twin (CDT) is a new research and practice paradigm in coastal science and engineering to enhance disaster resilience. The components of CDT have three functionalities. One is the transformation from “Data” to “Information” by integrating “Sensing” and “Monitoring.” The second is “Modeling” and “Inference” by using available data and information. The third is “Policy Design” to gain implications and decide “Policies” for optimal “Practices” to enhance social resilience. The fusion of these components and the feedback loop in a cyber-physical system is the key to gaining knowledge and insights for optimal solutions in the physical world.

Koshimura et al. (2025) "Digital twin paradigm for coastal disaster risk reduction and resilience", 543-559, 2024.
https://doi.org/10.1016/B978-0-443-18987-6.00024-5
in K. Goda, R. D. Risi, A. R. Gusman, I. Nistor, eds, Probabilistic Tsunami Hazard and Risk Analysis Towards Disaster Risk Reduction and Resilience, 460p.

Digital Twin (Koshimura et al., 2025)

Disaster Response

Earth Surface Monitoring



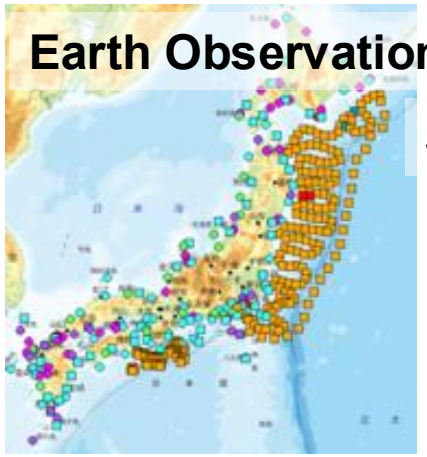
Bathy/Topo

Exposure

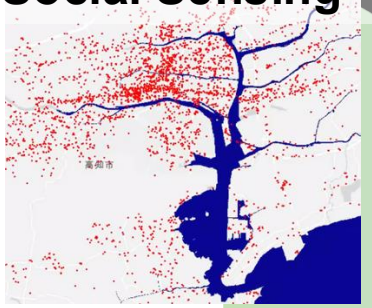
Urban configurations

Sea level rise

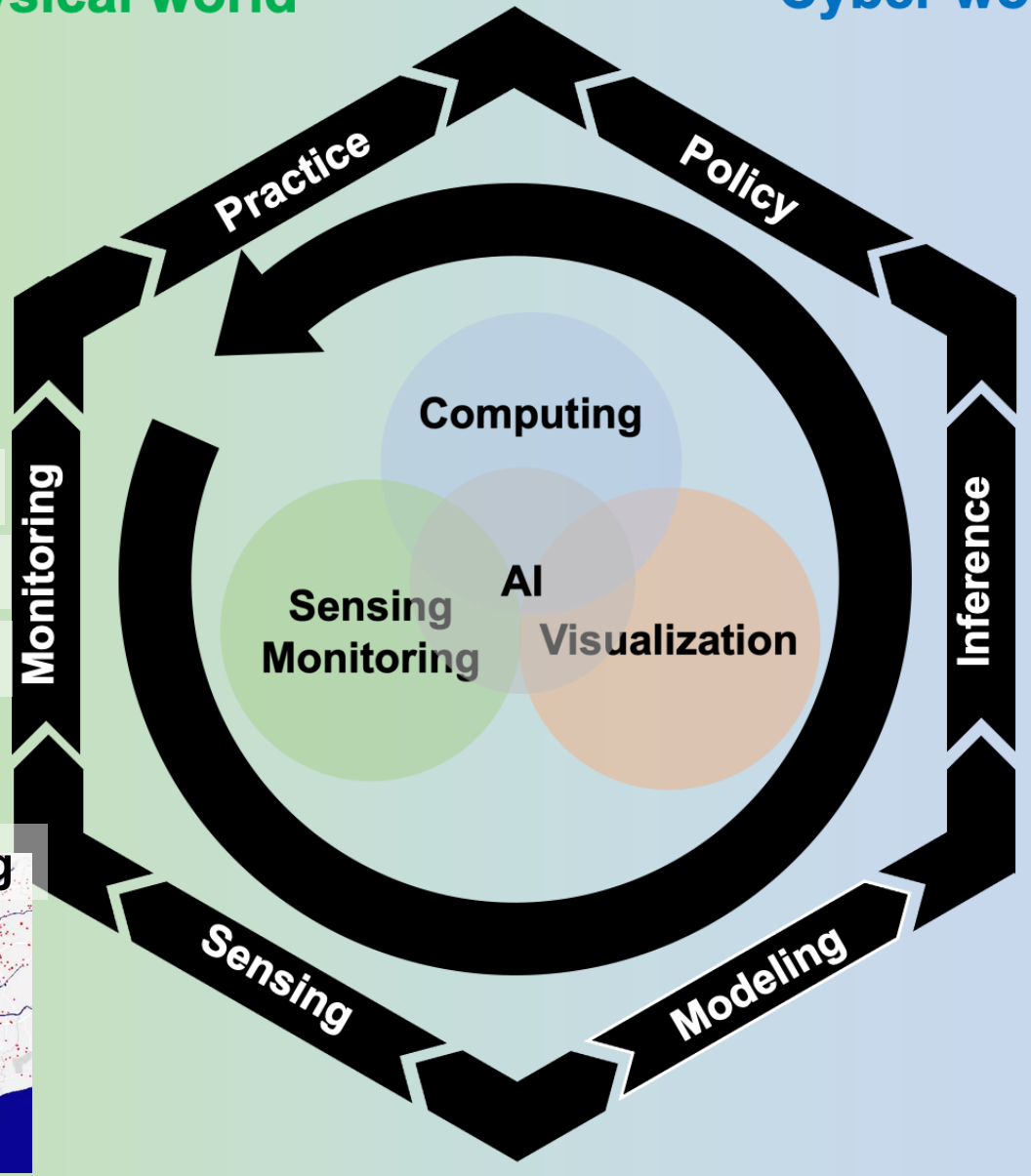
Earth Observation



Social Sensing

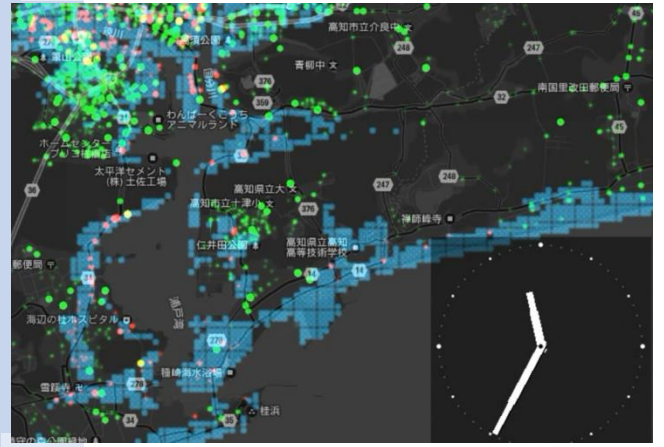


Physical world **Cyber world**

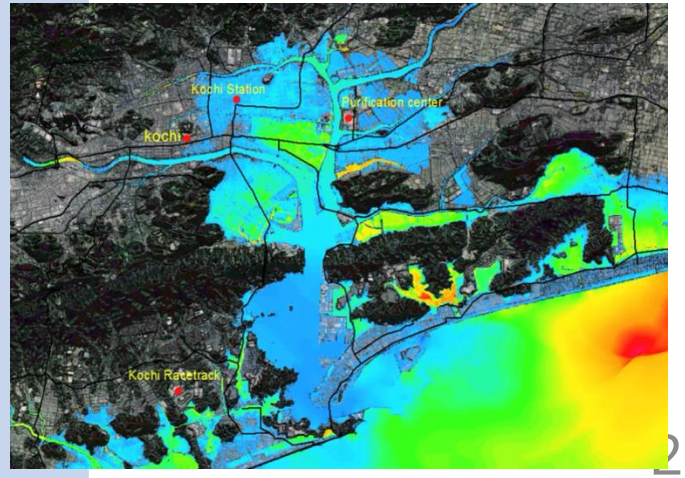


Policy Design
Adaptation
Strategies

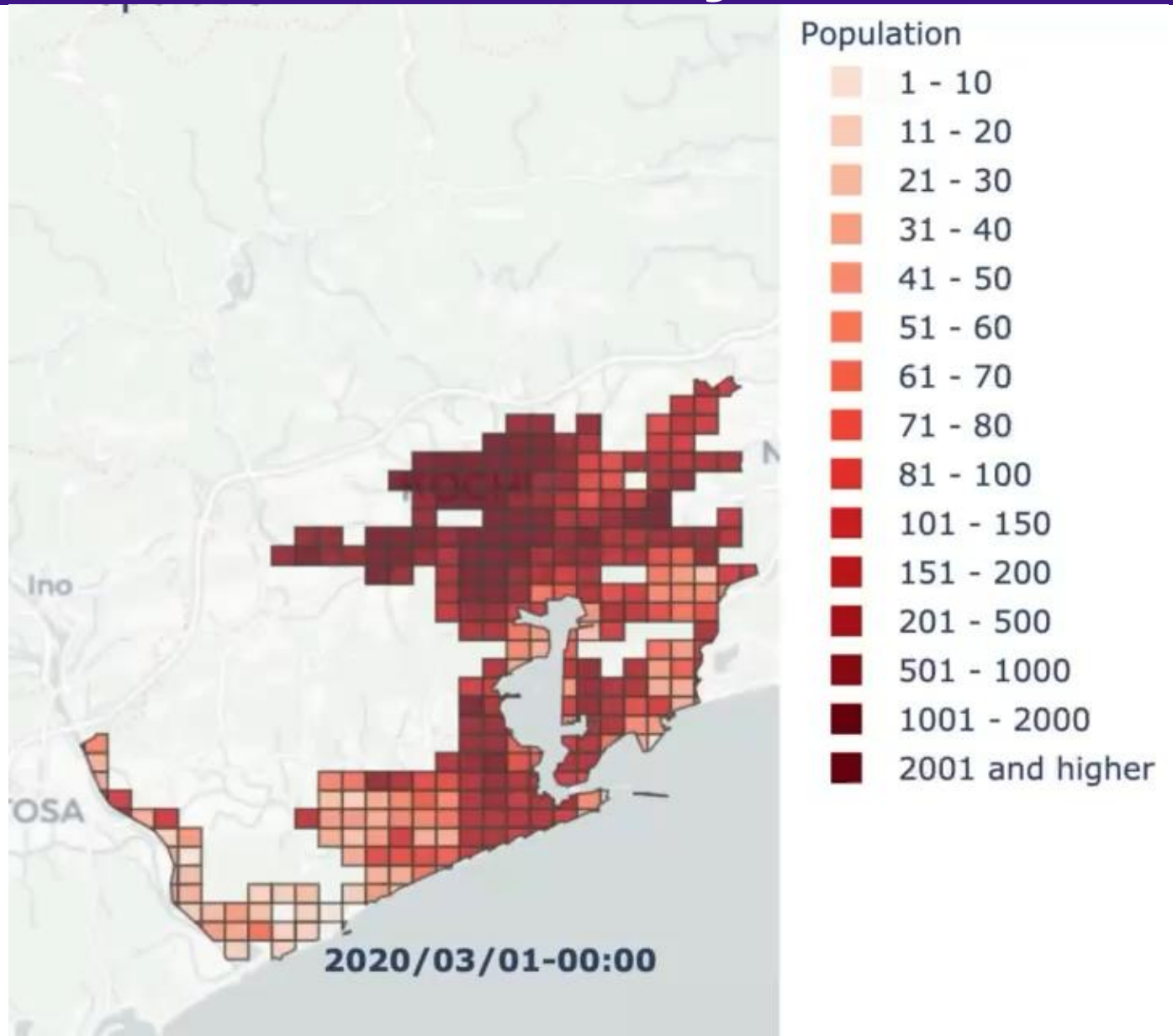
Exposure/Consequences



Hazard Forecasts/Scenarios

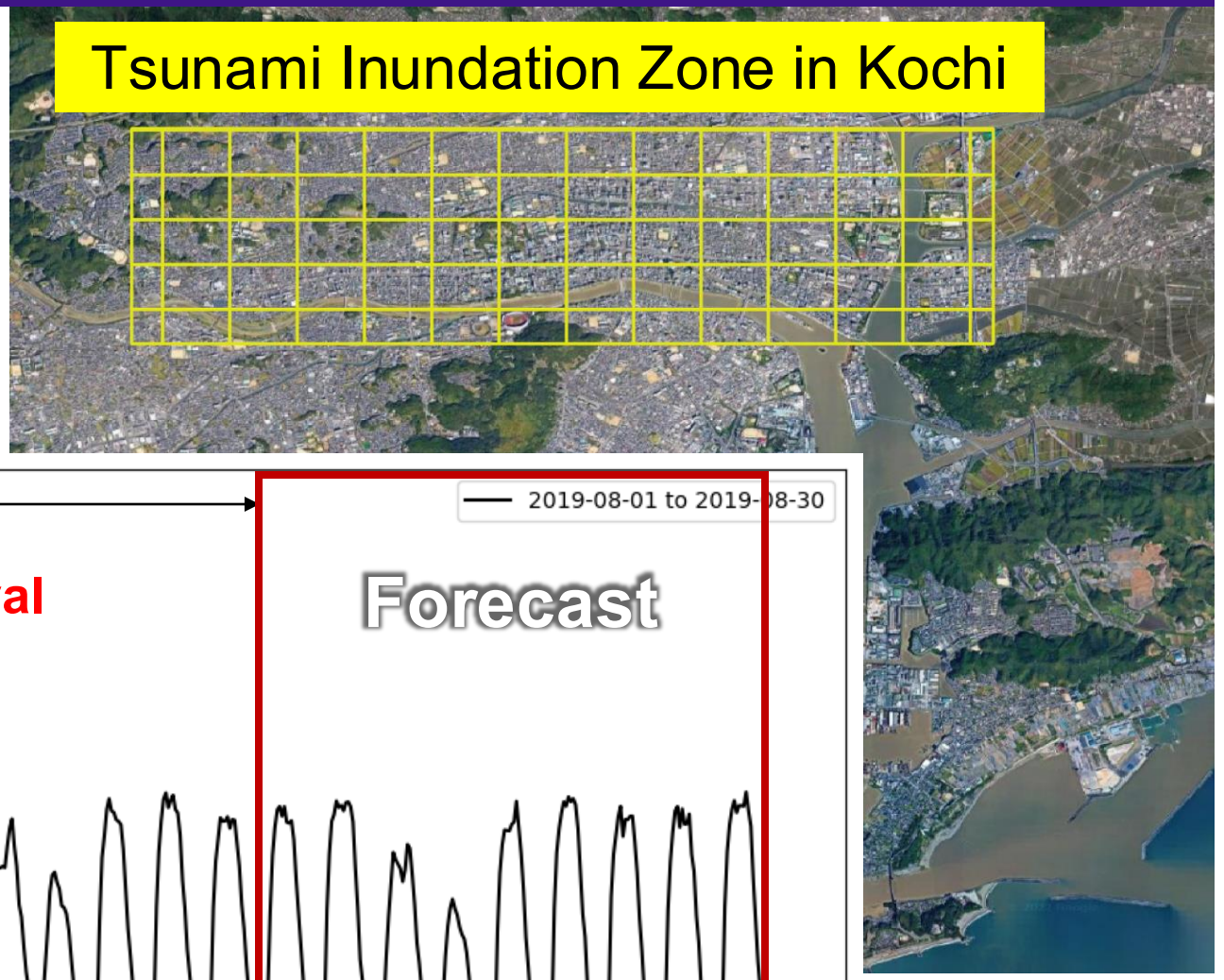


Real-time Exposure Estimates
Docomo Mobile Statistics, Every Hour, Every 500 m

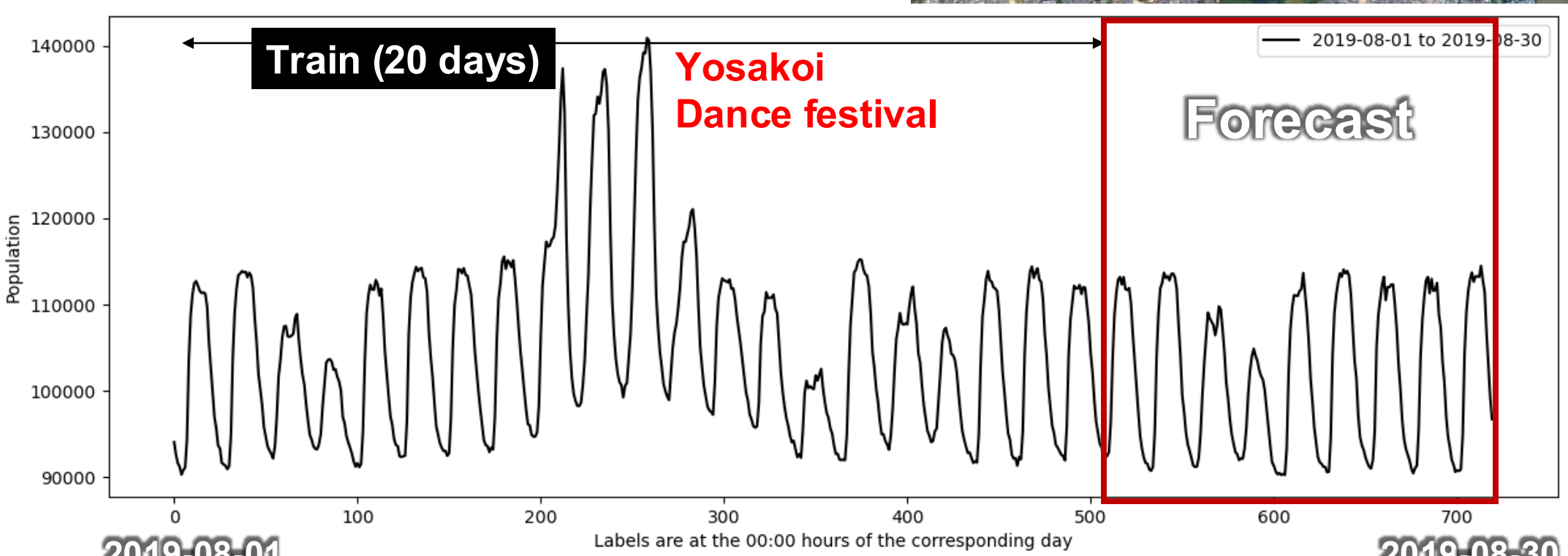


docomo InsightMarketing

Short-term Population Forecast



Time series of Population [2019-08-01-30]

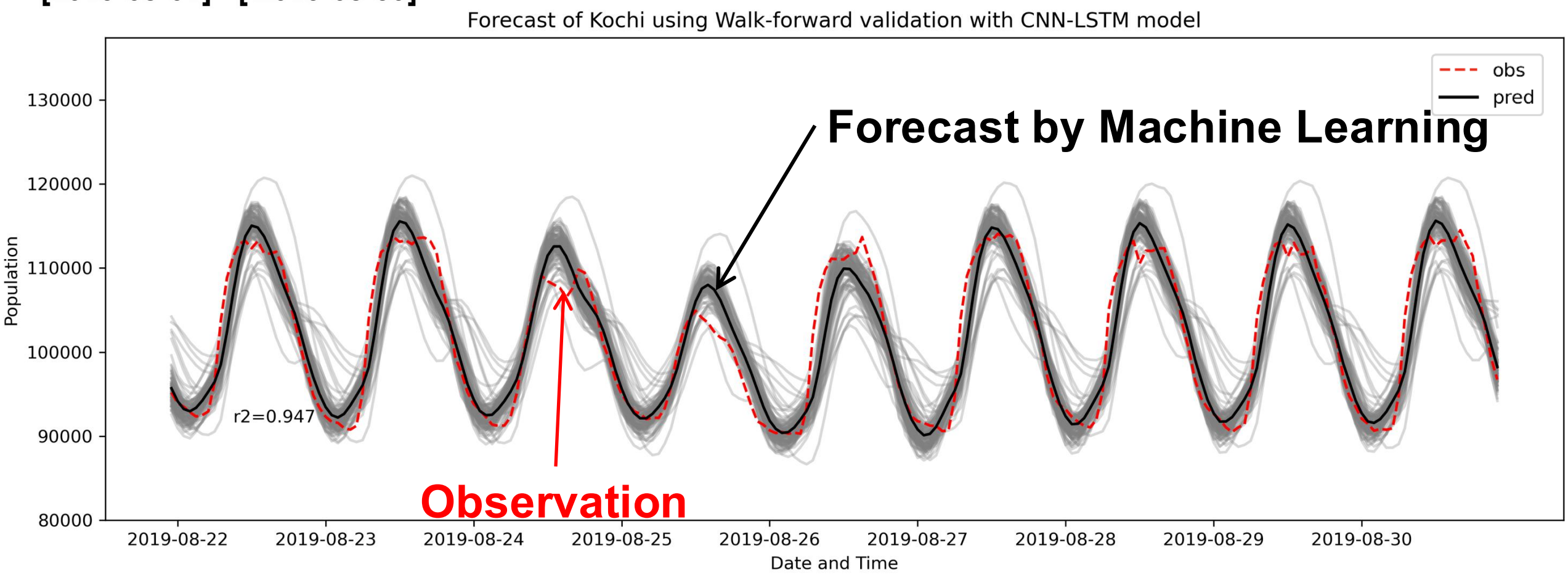


Short-term Population Forecast

KOCHI-SHI

[2019-08-01] - [2019-08-30]

Time series of Population



Progress in Disaster Science
Volume 25, January 2025, 100396

Multiple hazards and population change in Japan's Suzu City after the 2024 Noto Peninsula Earthquake

Shohei Nagata [a], Erick Mas [a], Yuriko Takeda [a], Tomoki Nakaya [b c], Shunichi Koshimura [a]

Show more

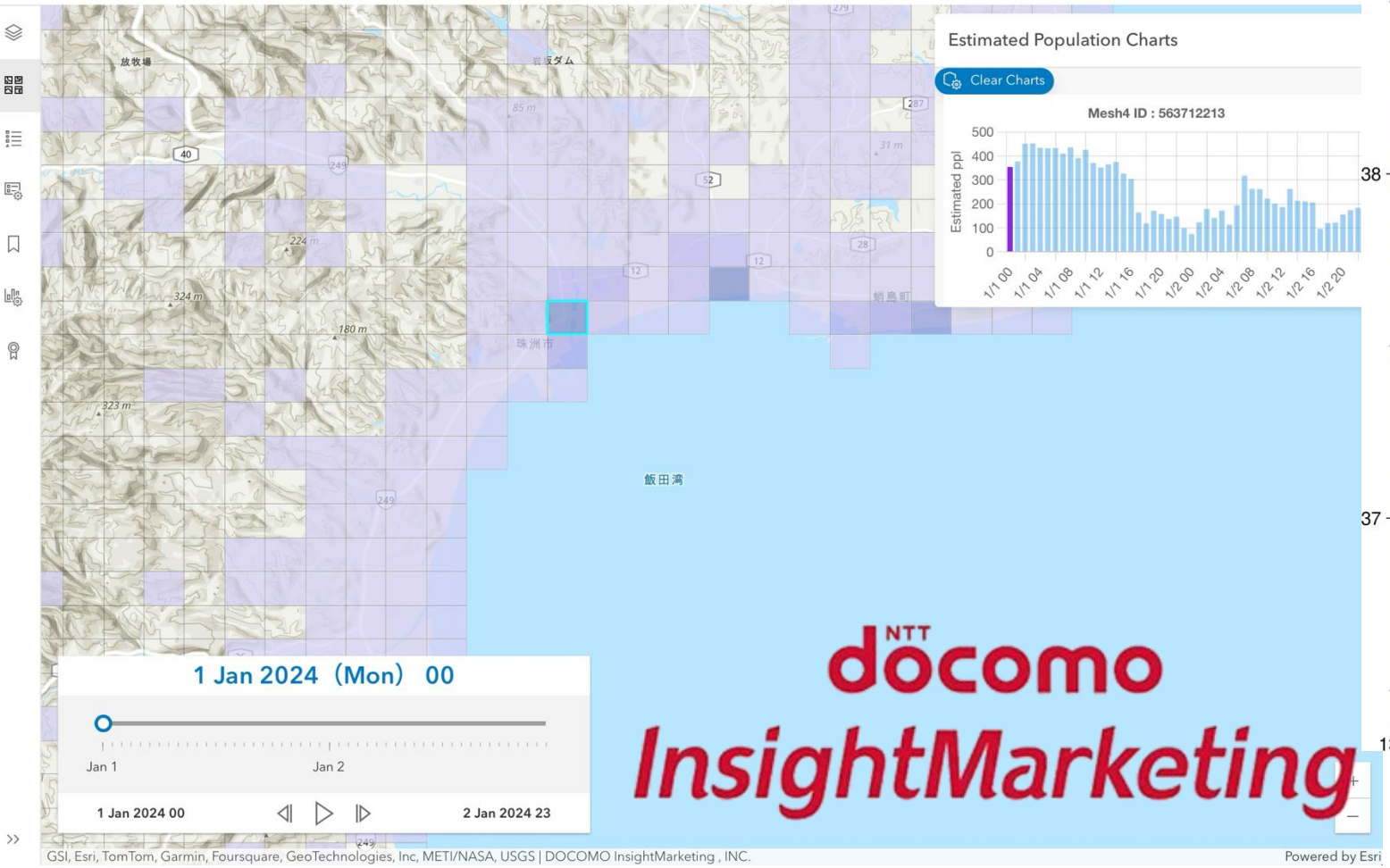
+ Add to Mendeley Share Cite

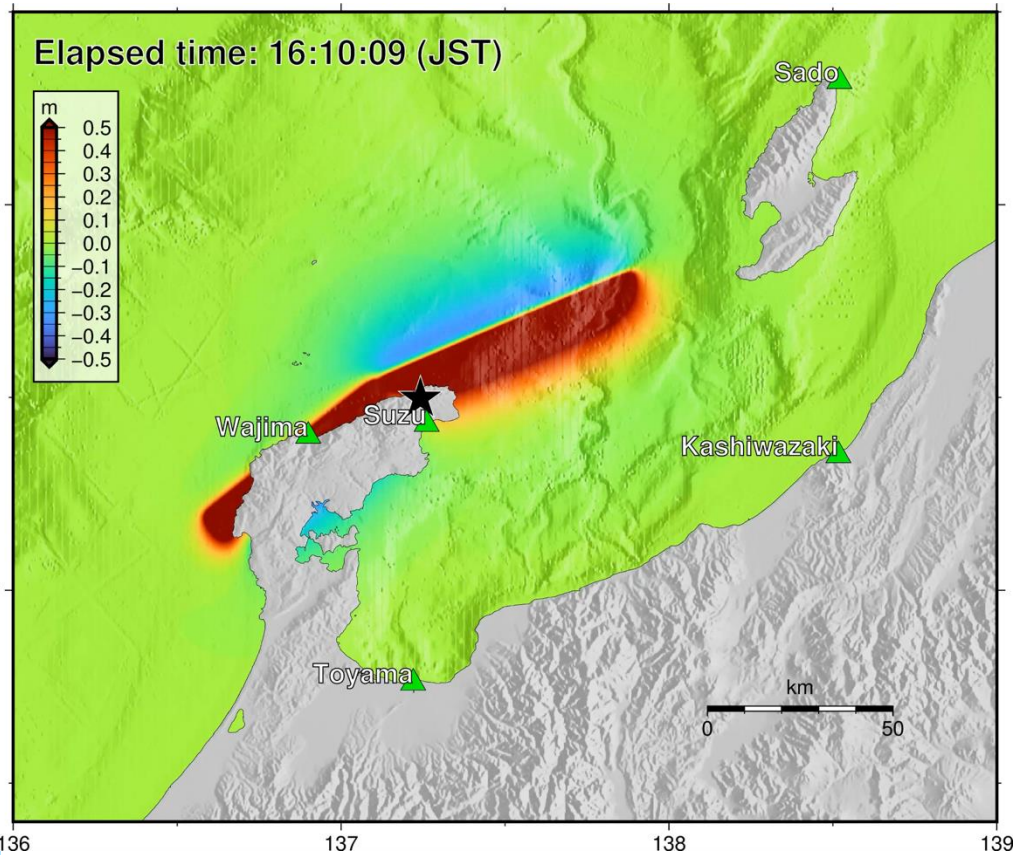
https://doi.org/10.1016/j.pdisas.2024.100396

Get rights and content

Real-time Exposure Mapping
The 2024 Noto Peninsula Earthquake Tsunami

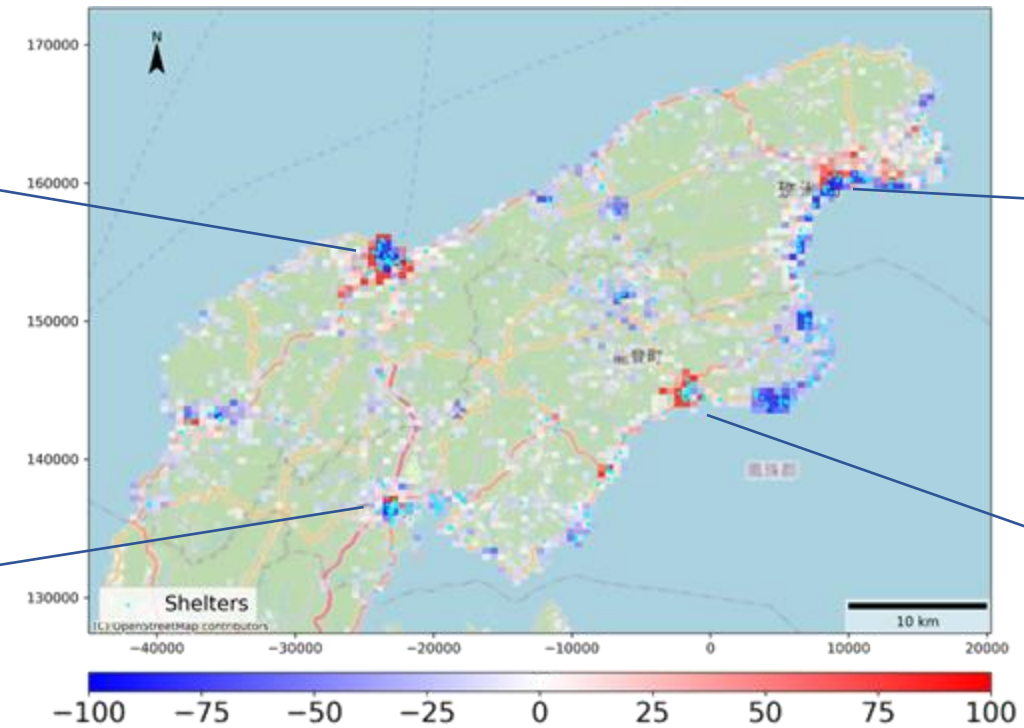
Mobile Spatial Statistics Viewer - IRIDeS, Tohoku University





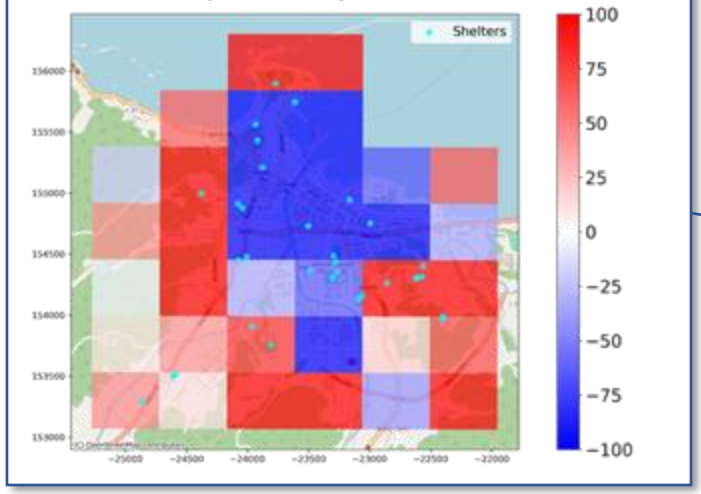
Population Change after the Earthquake
The 2024 Noto Peninsula Earthquake Tsunami

Population changes before (15:00-16:00) and after (16:00-17:00)

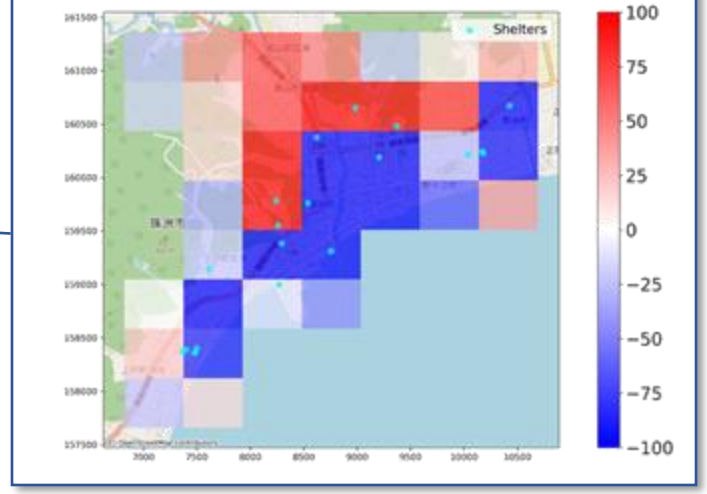


100 pers. decrease ← 0 → 100 pers. increase

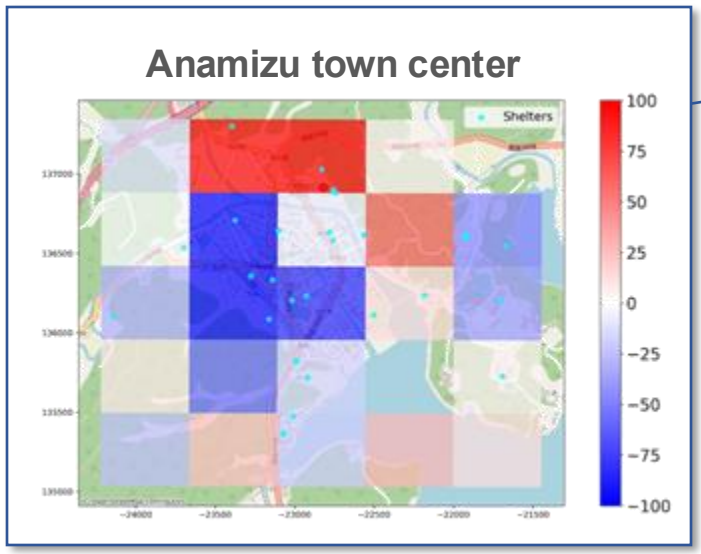
Wajima city center



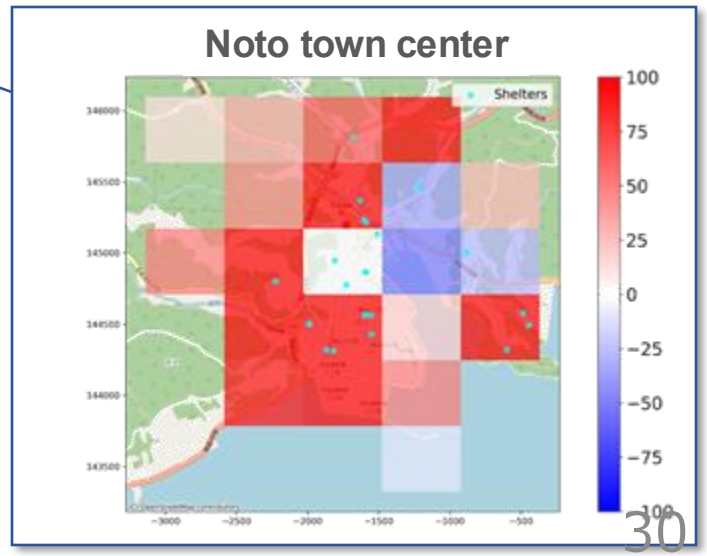
Suzu city center



Anamizu town center

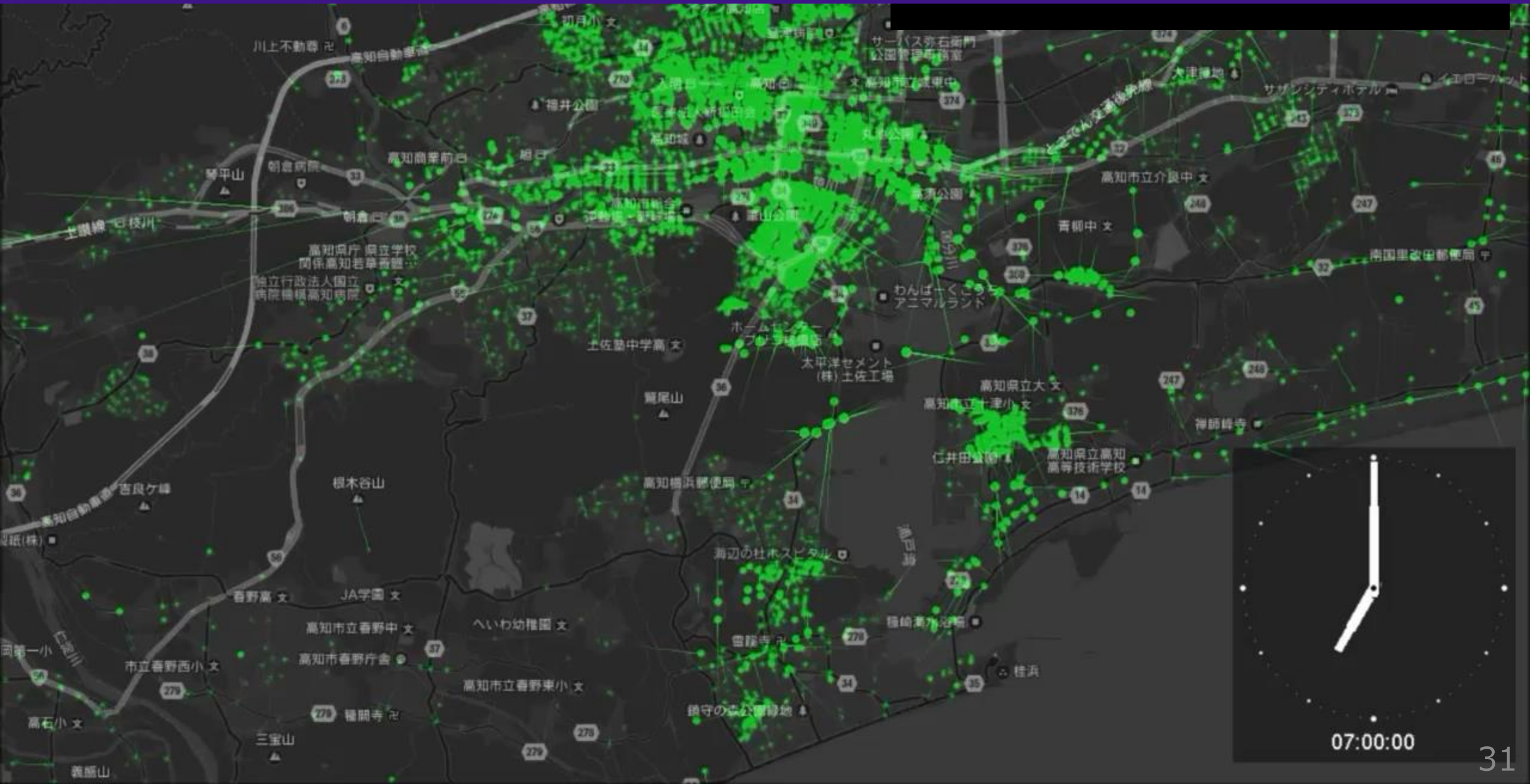


Noto town center



- Declining population trend in coastal mesh
- Population growth trend in the inland mesh

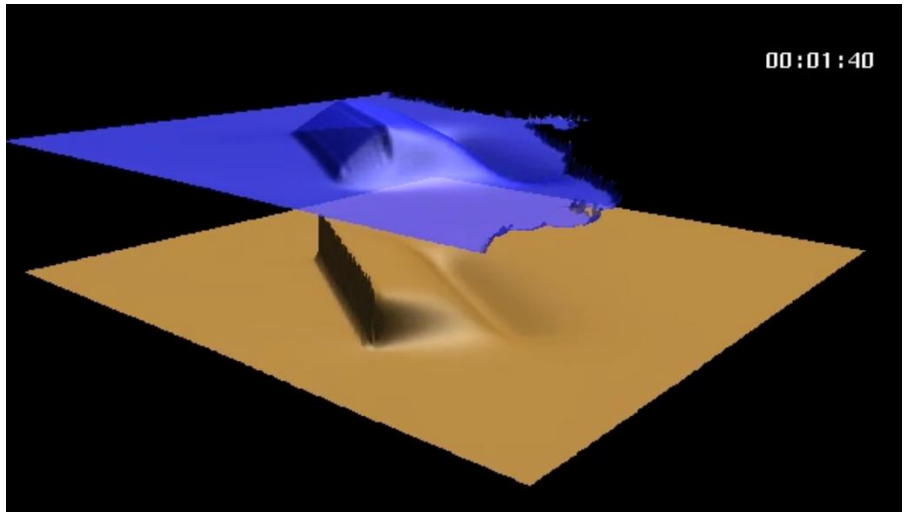
Future of Tsunami Digital Twin : Personalized Alert



Expanding TsunamiCast Capability Towards Global Real-time Impact-based Tsunami Forecast Facility

Full Cloud-based Real-time Tsunami Inundation Forecast

Rapid determination of tsunami source model + **Urgent computing capability (HPCI)** + **Web-based map products**



New Partnership
(AWS-Tohoku U.)

ArcGIS Online

TsunamiCast Products for Global Agendas

Partners

- High-resolution bathy/topo data
- Liaison with users

Standard Forecast Products

- Tsunami arrival time on land
- Inundation depth
- Building damage
- Exposed population

TsunamiCast

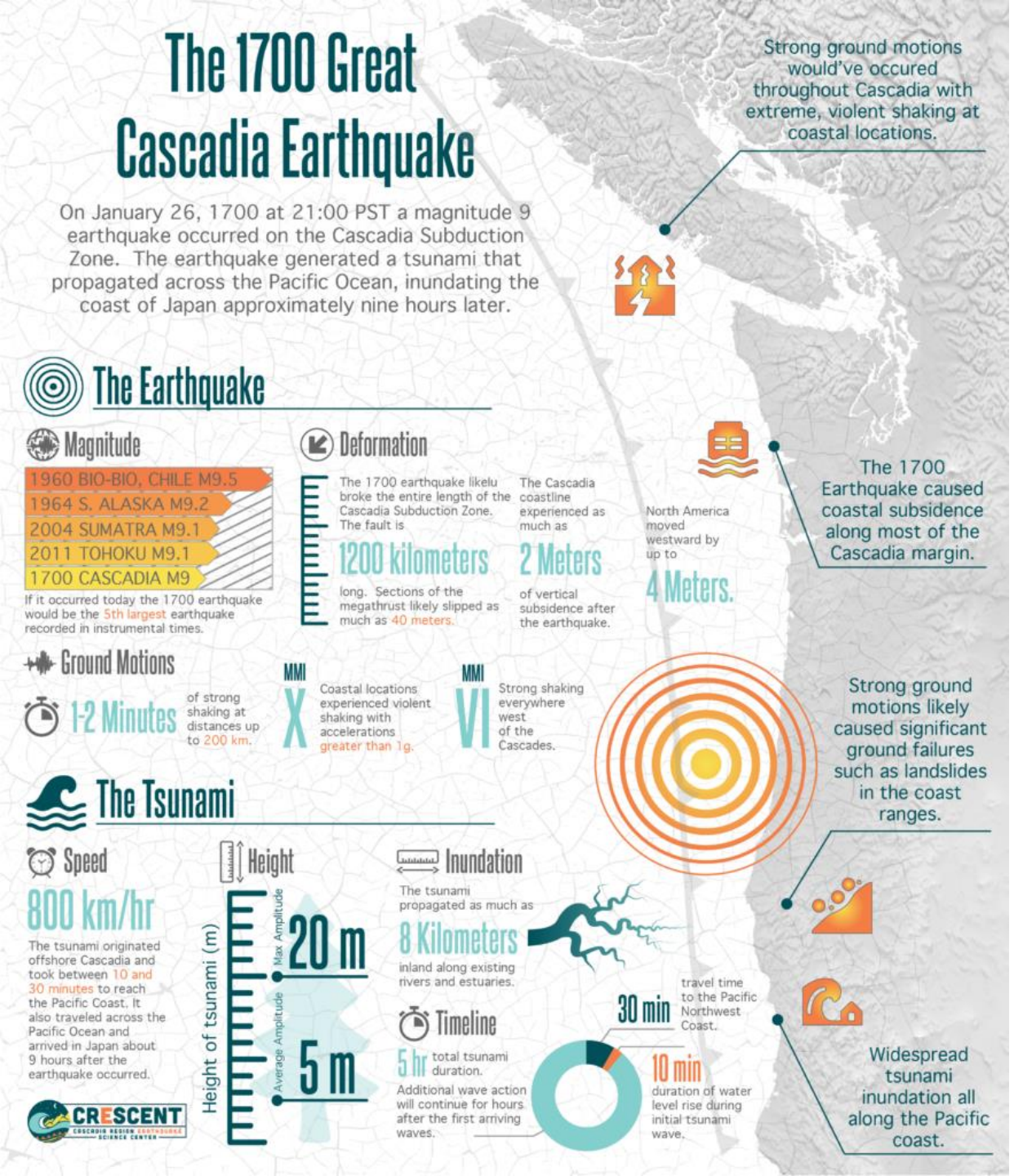
Products for Tsunami Ready

Tsunami Ready

- Tsunami hazard assessment
- Tsunami evacuation plan
- Emergency response plan

Products for Early Warnings 4 All

- Tsunami inundation forecasting
- Dissemination & Communication
- Emergency response



Collaborators in US

EARTH SCIENCE APPLIED SCIENCES

Leveraging Earth Observation Data and Products to Create a Comprehensive Tsunami Loss Estimation Platform - Impacts in a Changing Climate -

UNIVERSITY OF OREGON

PI Diego Melgar

Brendan Crowell

ImageCat

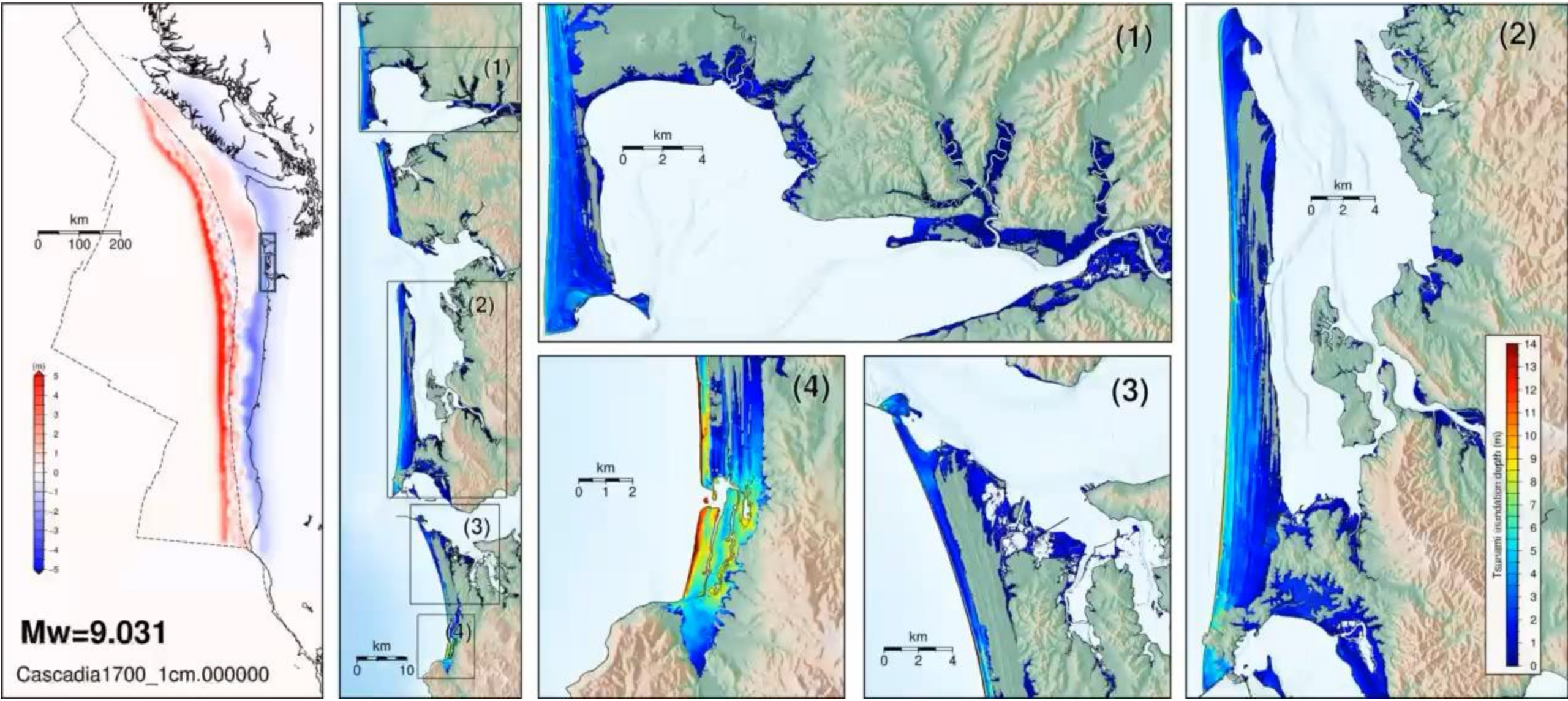
Ron Eguchi

Shunichi Koshimura

TOHOKU UNIVERSITY

RTi-cast

Cascadia Tsunami Scenarios



What We Propose ?

Real-time Impact-based Tsunami Forecast Facility

Cost-effective solution to promote cooperation **to develop new products and services** to help **accelerate EW4ALL and Tsunami Ready**.

”Endorse private sectors to accelerate the achievements of EW4ALL”, says Prof. Dwikorita Karnawati (Head of BMKG)

Sendai Framework for Disaster Risk Reduction 2015 - 2030

Investing in disaster risk reduction for resilience to fill the gap between the science and practice of tsunami inundation forecast.

United Nations