

## Lessons learned from the 2011 Tohoku earthquake and tsunami for the mitigation in the future

Fumihiko Imamura, Prof. and director  
of International Research Institute of  
Disaster Science(IRIDeS),  
TOHOKU University

One of investment for future risk



# March 11, 2011 disaster and IRIDeS

- March 11, 2011 disaster
  - Worst disaster in history from triple tragedy
    - JPY 16.9 trillion (\$210 billion)
    - e.g. JPY 6.5 trillion(\$81 billion ) for Hurricane Katrina
  - Uncovered limitations of modern science and technology
    - Large-scale disaster impacts can't be prevented
    - Need longer time horizons for better understanding; importance of referencing ancient documents and geological evidence
  - Holistic approach is needed to respond to mega-scale disasters
    - Need wider spatial horizons for getting enough cases and experiences : International cooperative research

# IRIDeS: A new institution in a disaster stricken area

- Principle:

- Promote world's leading research on natural disasters through:

- learning from the Tohoku earthquake and tsunami;
    - contributing to the regional recovery; and
    - set an international paradigm on disaster management studies

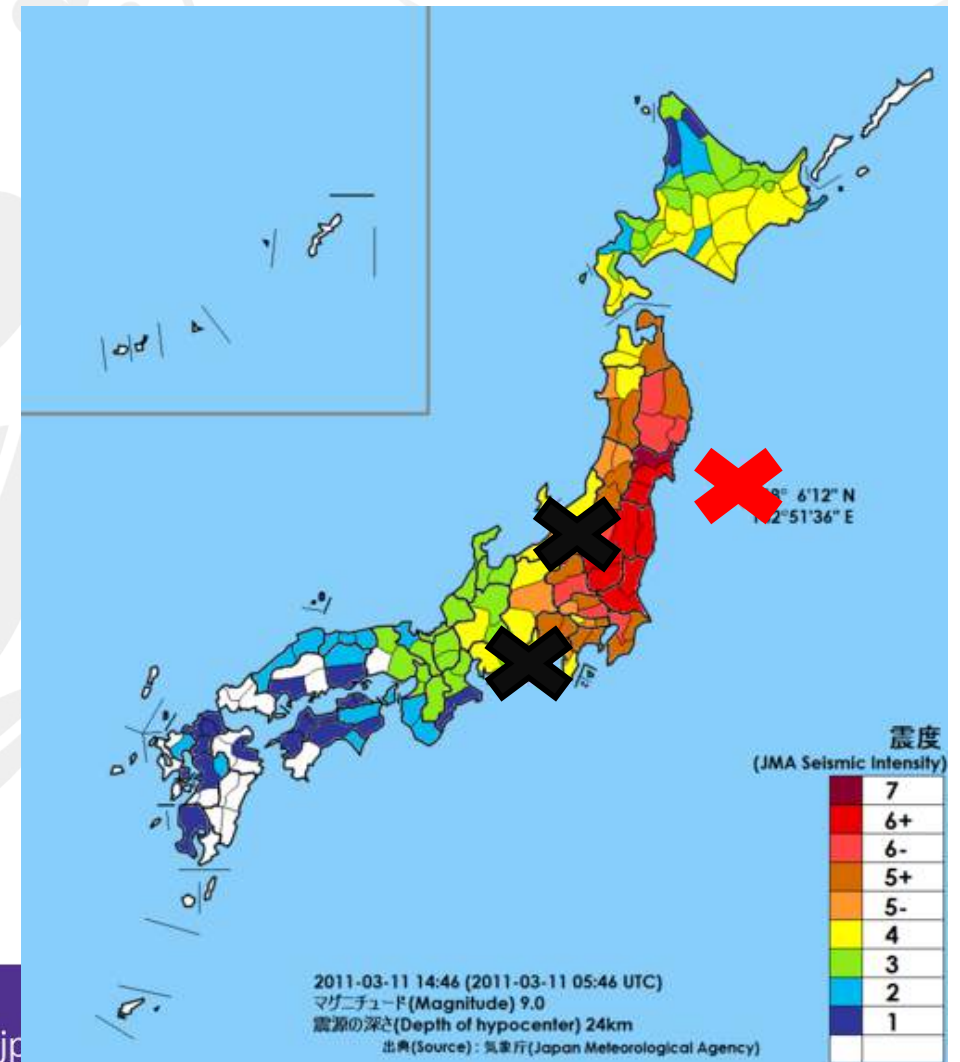


# Unfolding the 3.11 event:

## Triple Tragedy and Damages

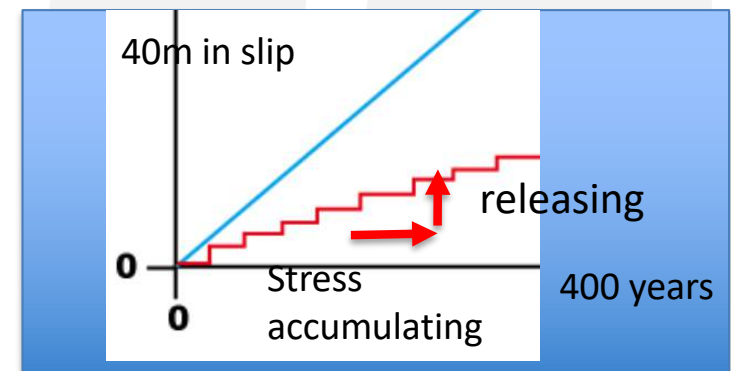
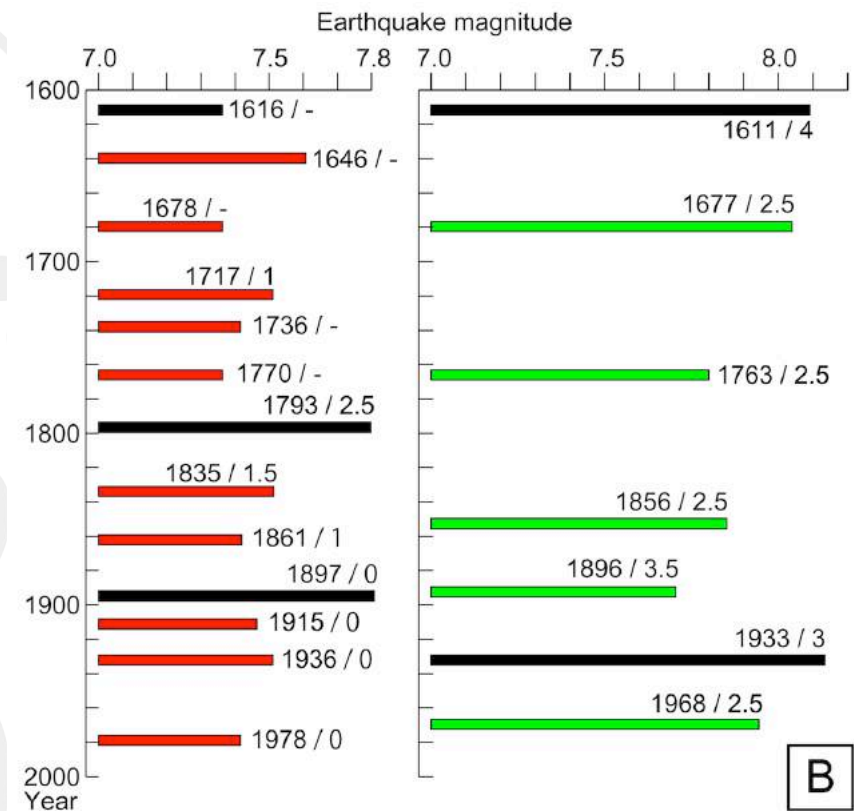
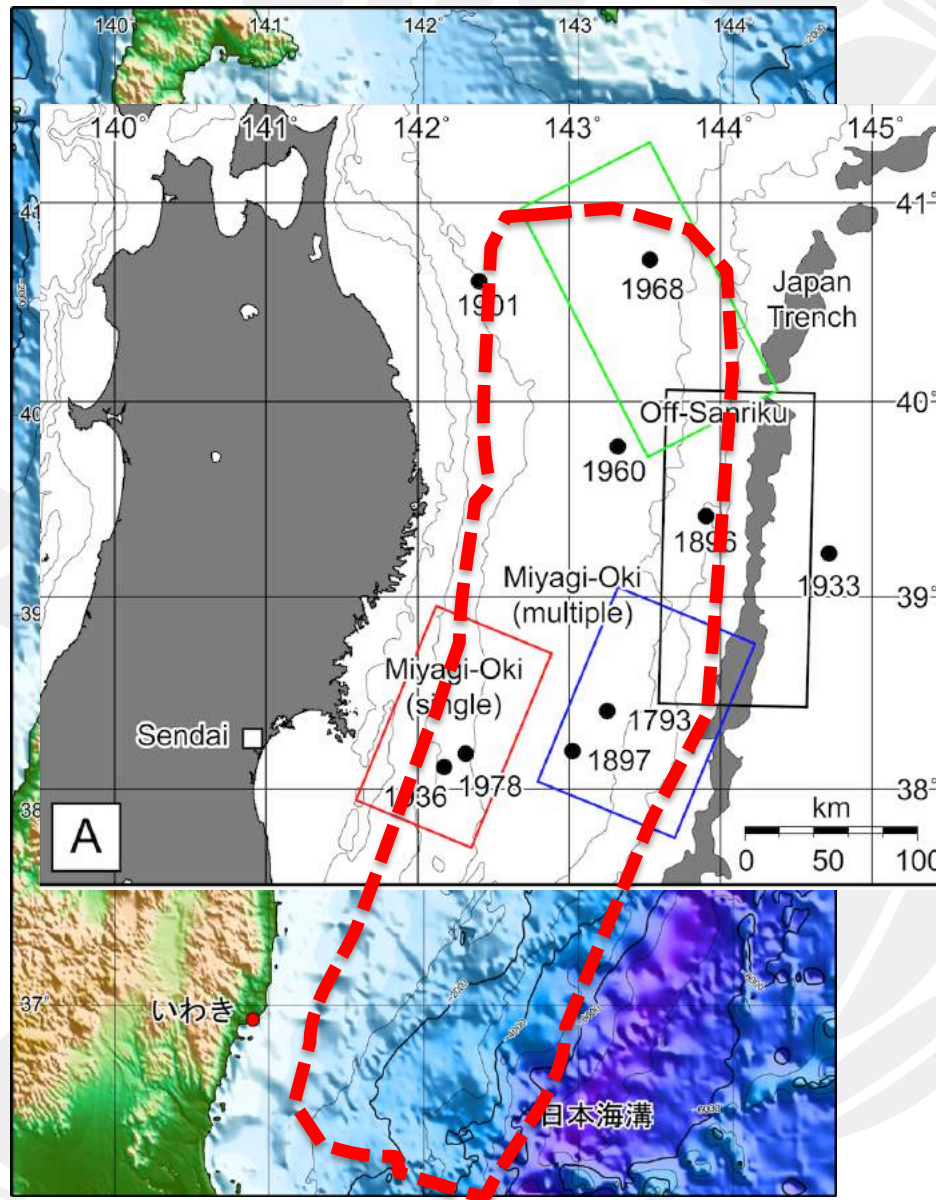
- **Triple Disasters: ONE – The Earthquake**

- Time: March 11, 2011, 2:46pm
- Scale: Mw 9.0  
(4th largest in the world since 1900 (USGS))
- In 5 days: 2 additional Mw 5+ earthquakes (black X)
- In a month: 400 + aftershocks continues





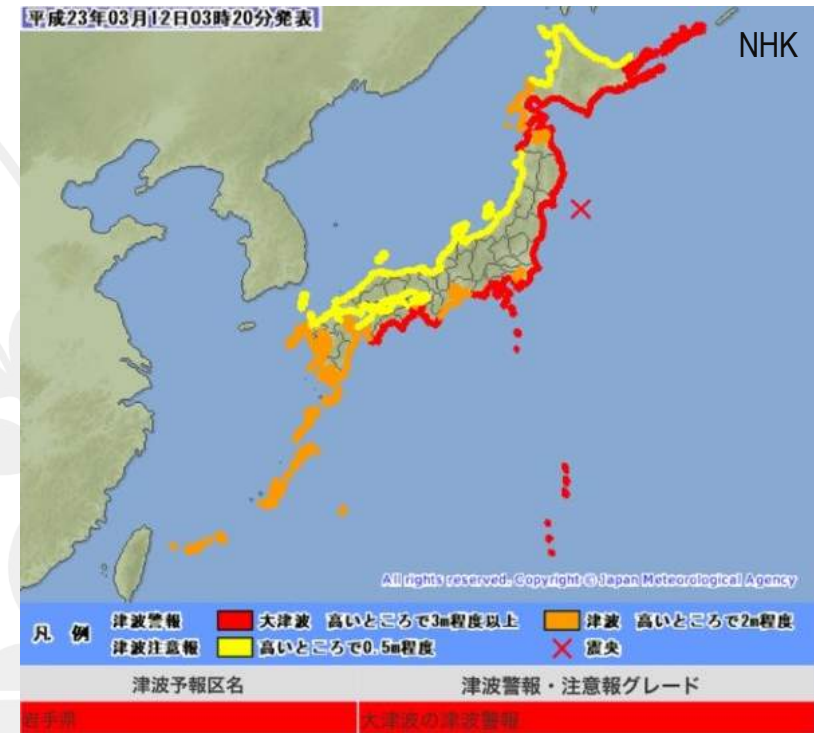
# Historical tsunamis in Tohoku for 400 years and the 2011 Tohoku Eq.



- T.Hatori, Distributions of Seismic Intensity and Tsunami of the 1793 Miyagi Oki Earthquake, Northeastern Japan, *Bulletin of Earthquake Research Institute, University of Tokyo*, **62**, 297-309 (1987).

- Triple Disasters: **TWO – Tsunamis**

- Tsunami evacuation order and warning, immediately after – all around coastal Japan
- Time reaching the coast: less than 20-30 min
- 7 tsunamis in the first 6 hrs after the shock, continue for 2 days



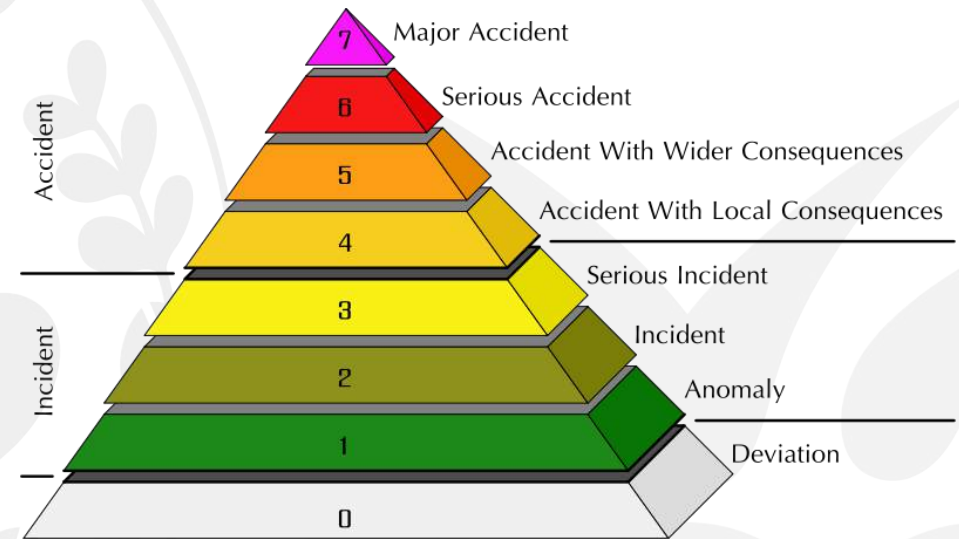
- According to the information:
  - Highest wave recorded: 9.3m
  - Highest run up-height : 35 m
  - Farthest inland reached: 8km



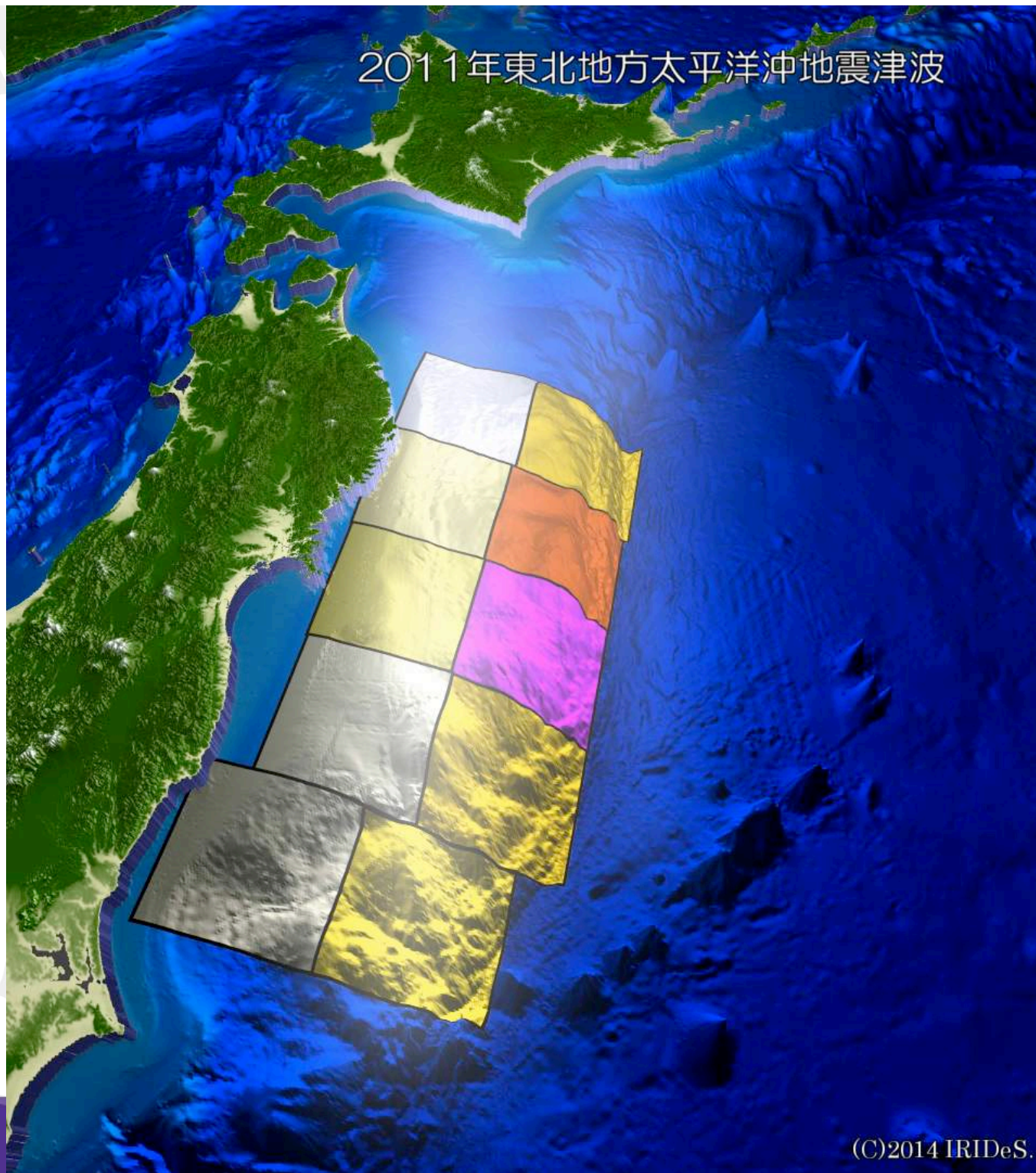
- Triple Disasters:

## THREE – Nuclear Power Plant Failure

- One of the worst nuclear incident, triggered by the earthquake and tsunami
- Temporarily assessed as level 7 on INES
- Emergency state is still on-going



# 2011年東北地方太平洋沖地震津波





# Other damages

- Inundated area: 560km<sup>2</sup>
- Liquefaction
- Fire





# Tsunami Warning (JMA,2010) Non-structural measure

## Time Sequence to Issue Earthquake Information and Tsunami Warning

Earthquake

Earthquake Early Warning

Tsunami Warning

Seismic Intensity Information

1.5min.

2~3min.

Tsunami Information

(Estimated Tsunami Heights and Arrival Times)

Earthquake Information

(Hypocenter and Magnitude)

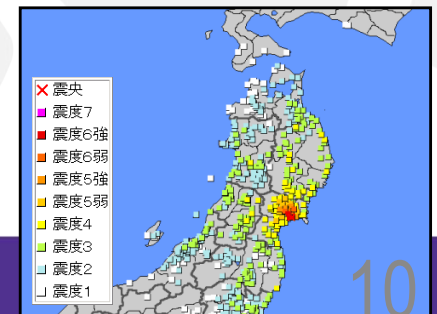
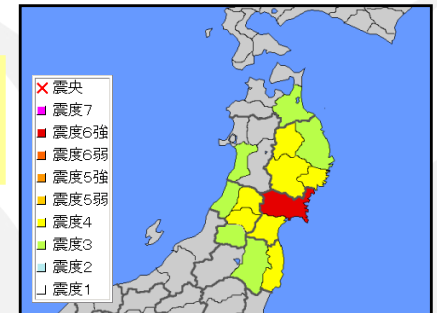
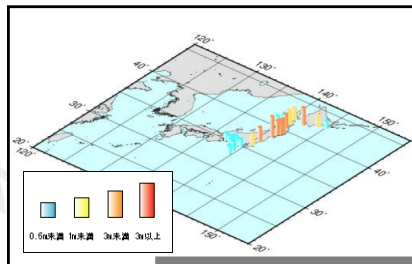
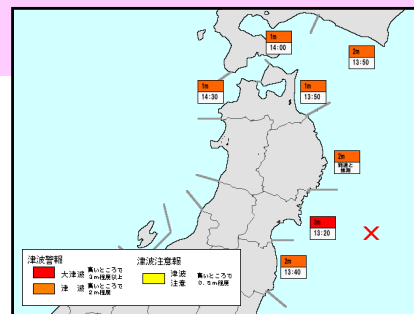
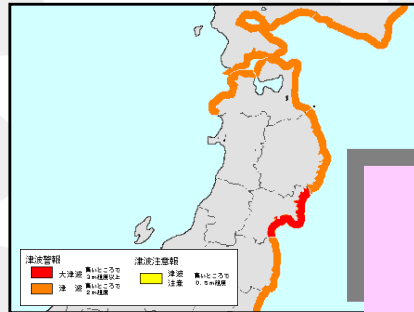
Earthquake and Seismic Intensity Information

5min.

Seismic Intensity Information at each Site

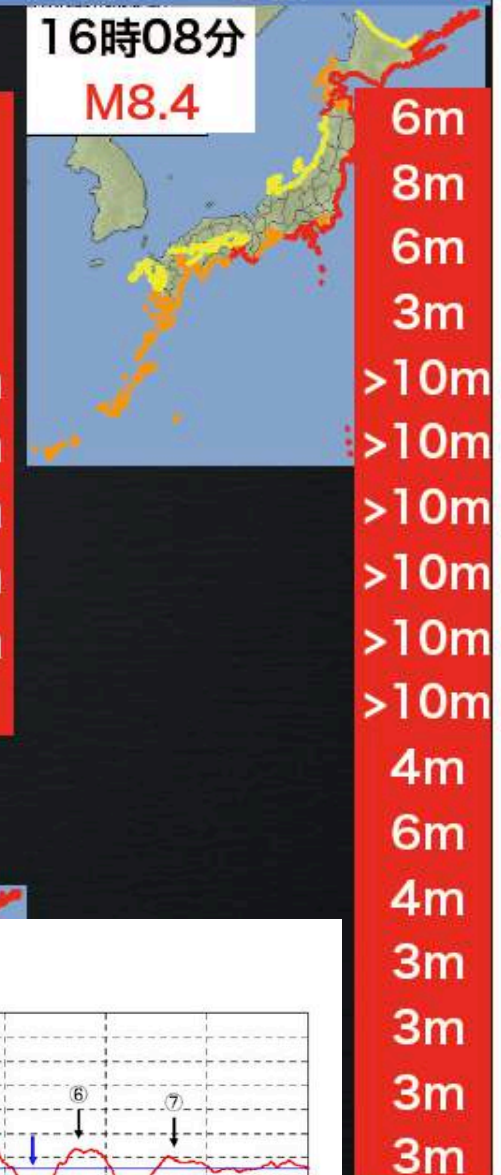
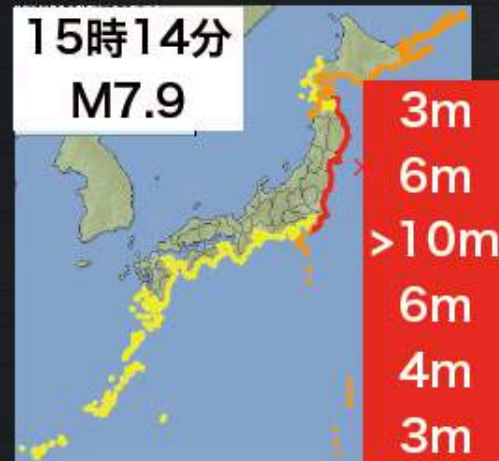
Tsunami Information

(Observed Tsunami Heights and Arrival Times)

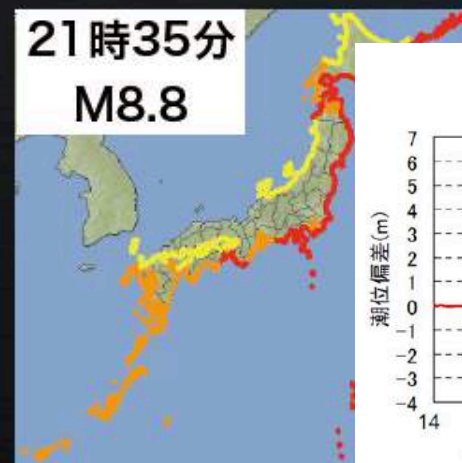


地震発生：3月11日14時46分頃，M9.0

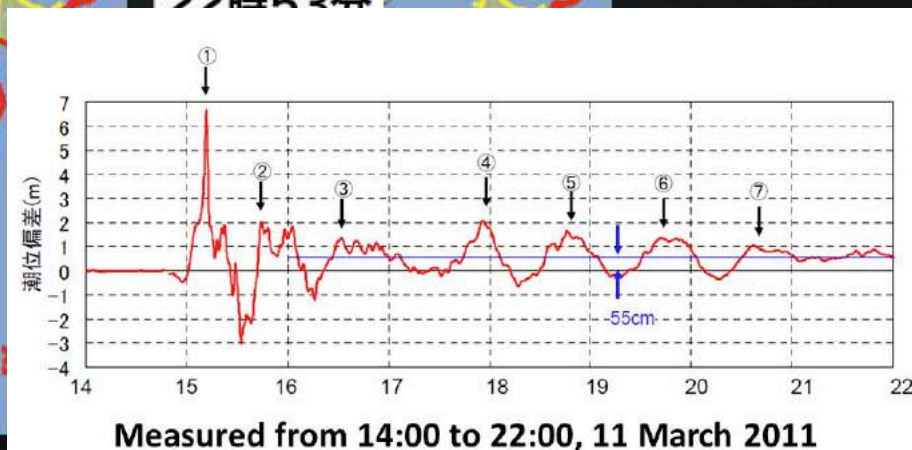
津波警報 大津波 高いところで3m程度以上 津波 高いところで2m程度  
津波注意報 高いところで0.5m程度 震央



JMA Tsunami information updated on 11 March 2011  
1<sup>st</sup> issue only 3 min. after the Eq. , but warning underestimated the wave height and impact, reducing the effectiveness of evacuation



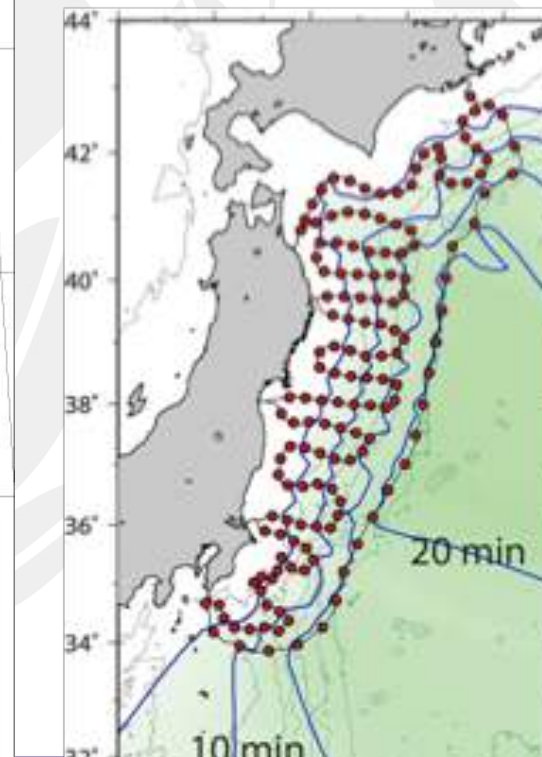
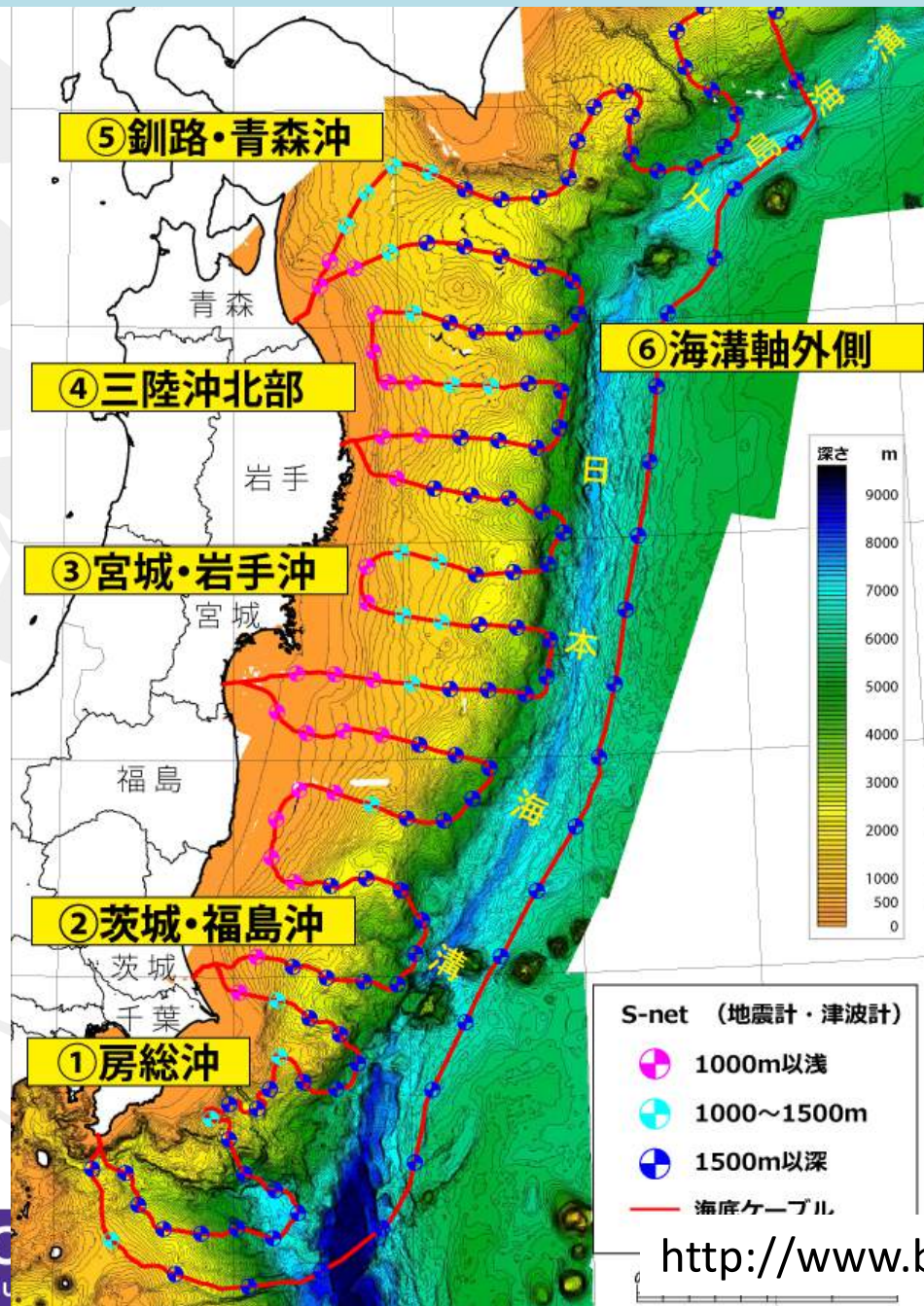
22時52分





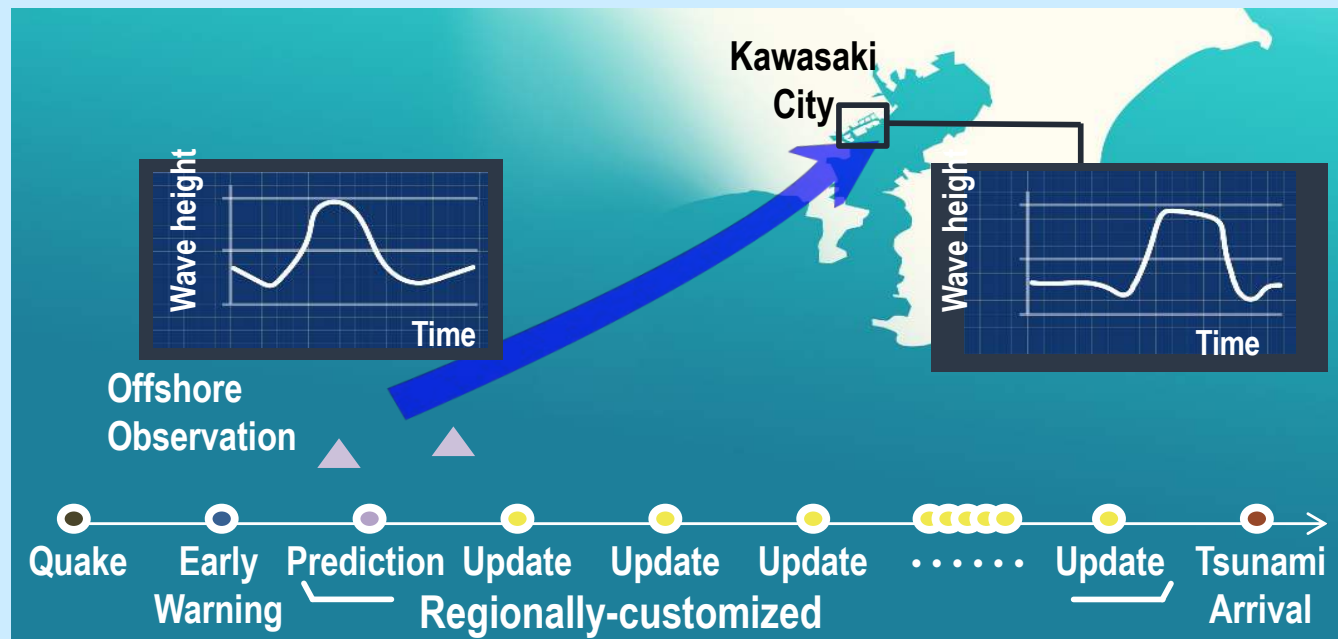
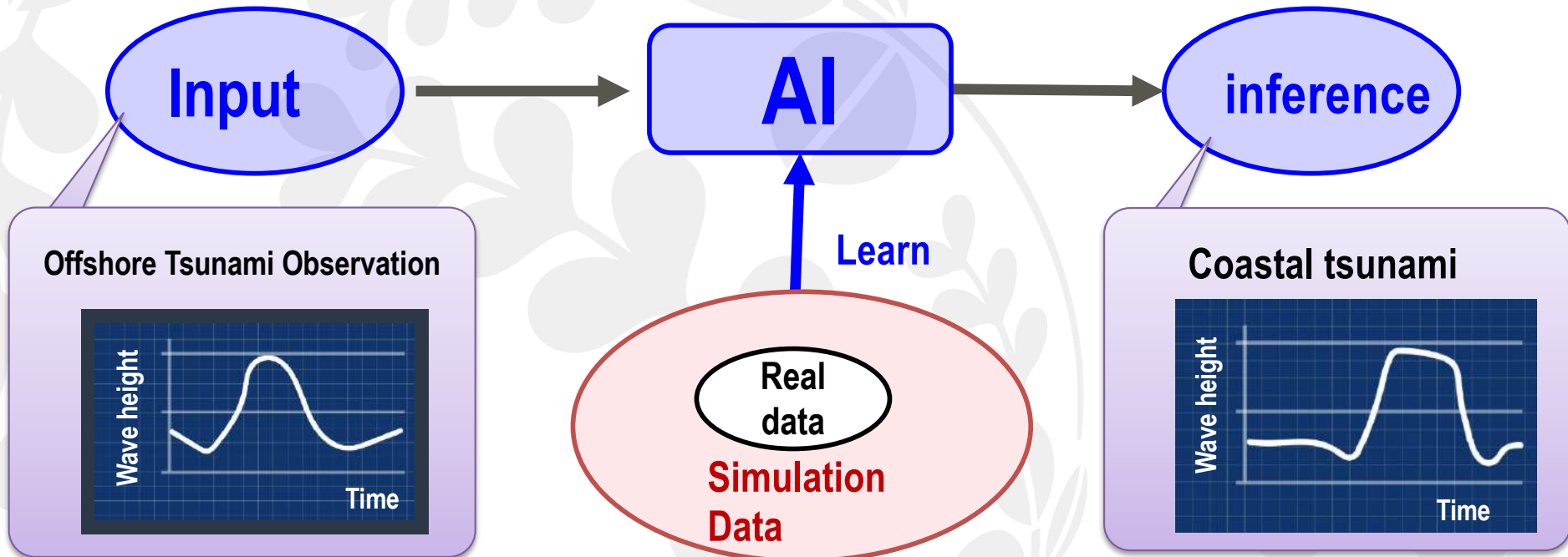
# Improvement of earthquake/tsunami observation in real time

- More stations to detect tsunamis shortly



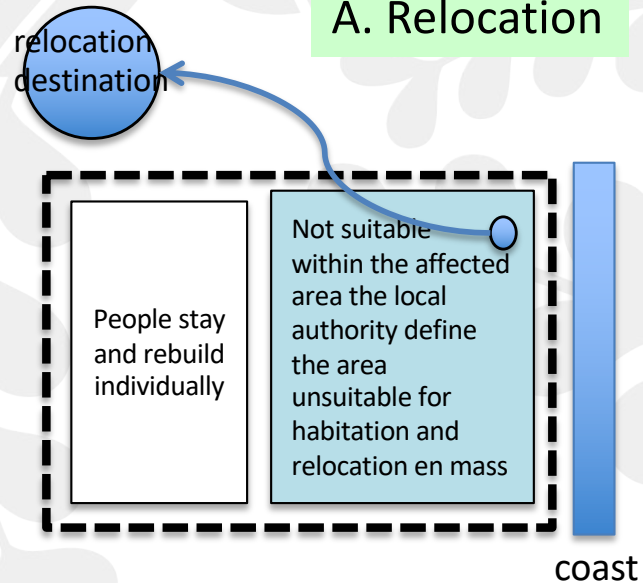
<http://www.bosai.go.jp/inline/tsunami/tsunami01.html>

# Applying a new way; Instant tsunami prediction based on AI

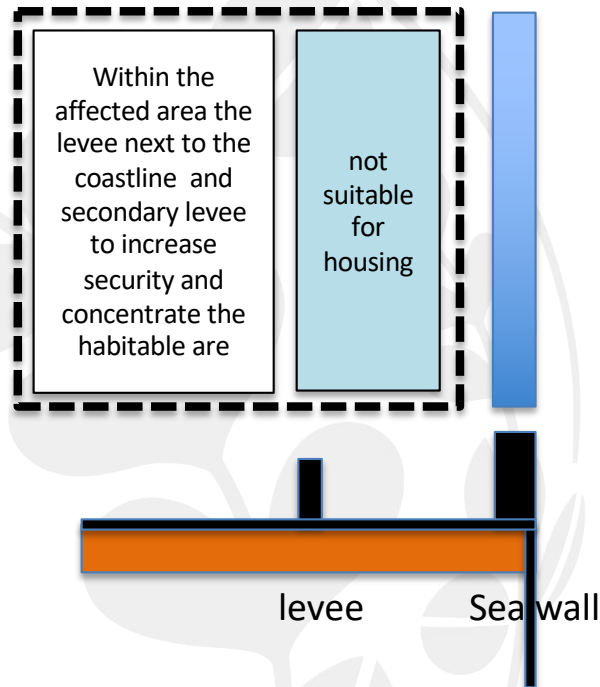




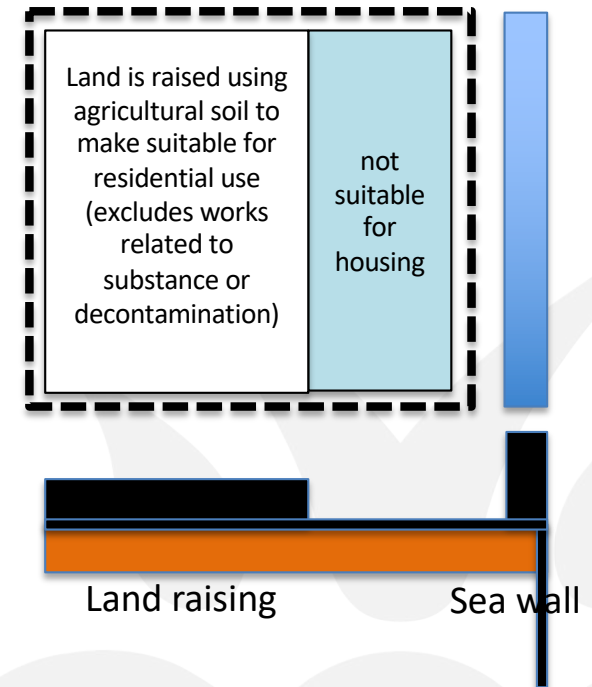
### A. Relocation



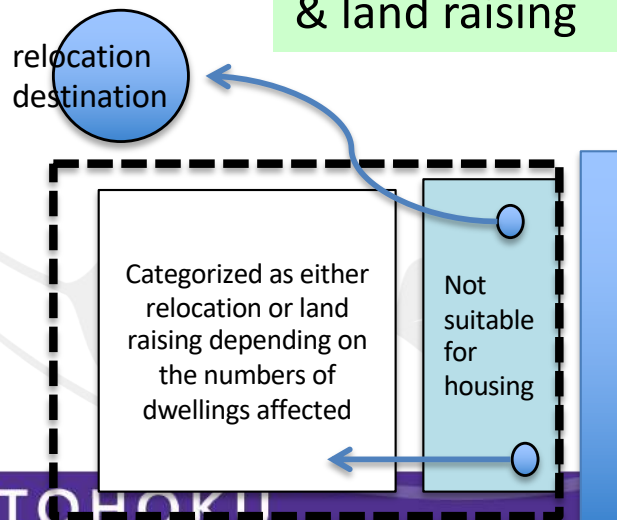
### B. Aggregation on site



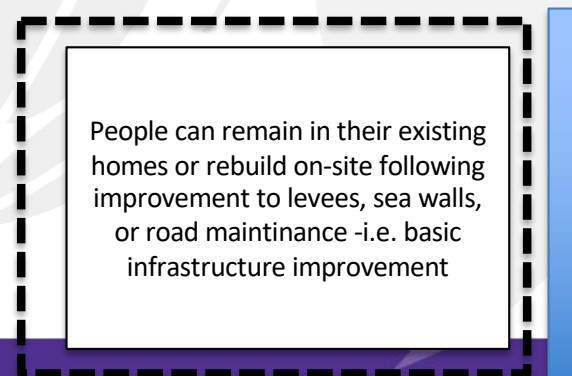
### C. Land raising



### D. Relocation & land raising

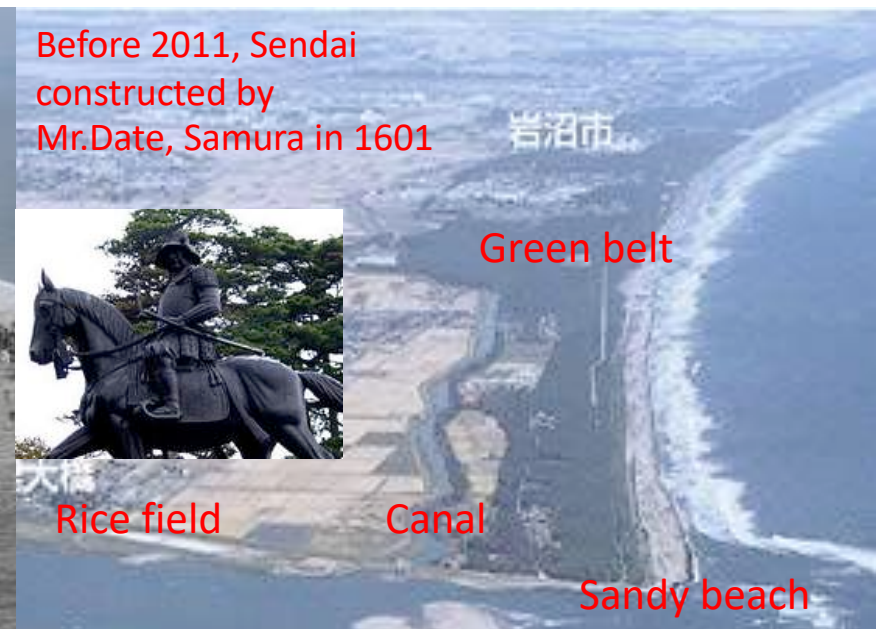
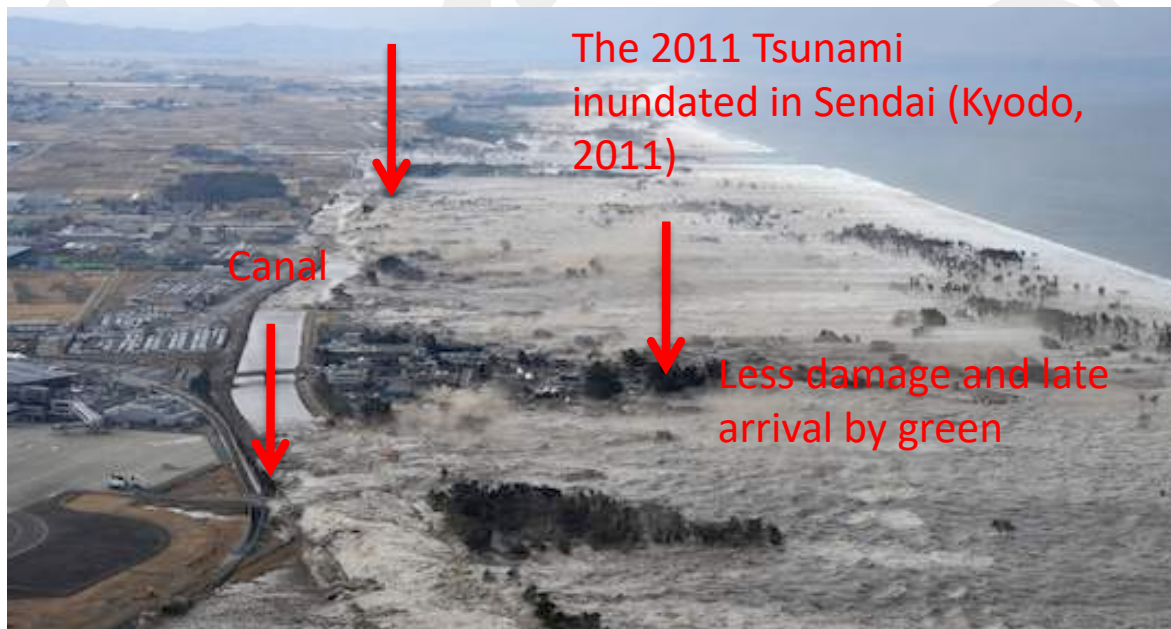


### E. On site with defence facilities





# Multi-layers Protection for Resilient City

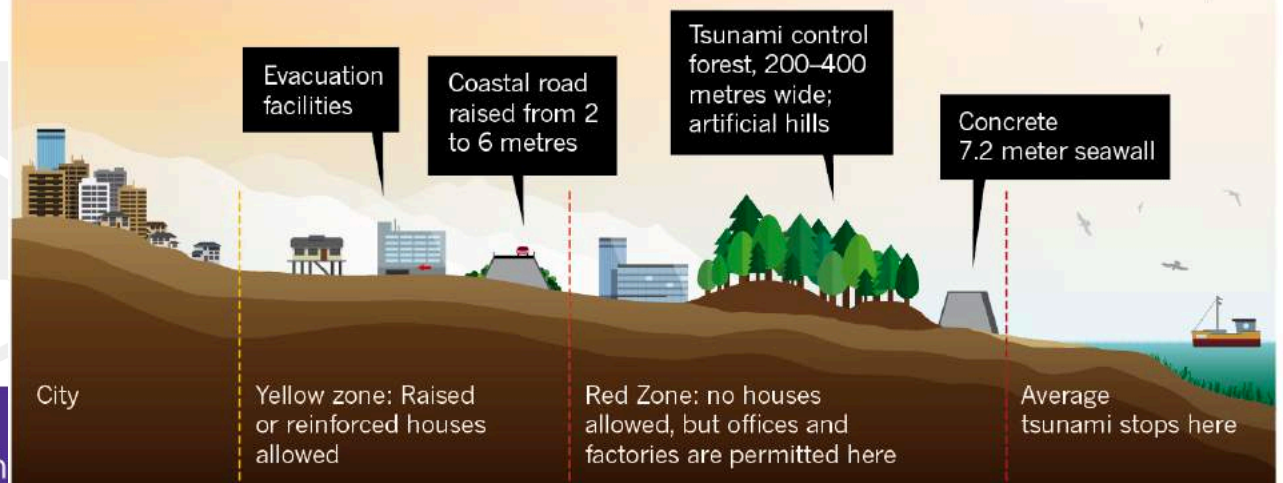


Only two shrines were damaged among 100 with 1,000 years history in the affected area

## PLAN FOR A TSUNAMI-RESISTANT CITY

Sendai is considering refashioning its coastal area. A raised seawall would block typical tsunamis and an elevated coastal road would protect against giant ones. Zoning restrictions would lower the number of fatalities.

Cyranoski (Nature, Vo.483, 2011)



# Fundamental Strategy for Tsunami Disaster Measures

## Tsunami level 1

- Aim to ensure protection of human lives, assets and national land (coastal line), etc against comparatively frequent tsunami (50 -150 years) on the basis of constructing coastal protection facilities.
- Conduct technical development and improvement of structures so that they cannot be easily broken even when the tsunami height exceeds the design level.

## Tsunami level 2

- Aim to prevent as much human damages as possible against maximum tsunami level by “Integrated Protection” combining structural and non-structural measures such as land use regulation, building code and emergency/evacuation procedures.



# 'Build Back Better' Approach in Reconstruction Projects In Sendai

Restoration of damaged residential areas



Disaster reconstruction municipal housing



Evacuation stairs



Farmland reclamation



Tsunami evacuation facility



Restoration of a wastewater treatment plant



Coastal embankment



Elevated roads





# Remarks

## - the 2011 Great East Japan Earthquake and tsunami

- "Triple Disaster": multi-hazards of earthquake, tsunami and NPP accident
- Underestimate of tsunami warning and the Limits of Hazard Maps => Improving real time observation
- A New Approach to Countermeasures: Experience and Enhancement => Level 1 and 2, multi-layers protection for resilient city