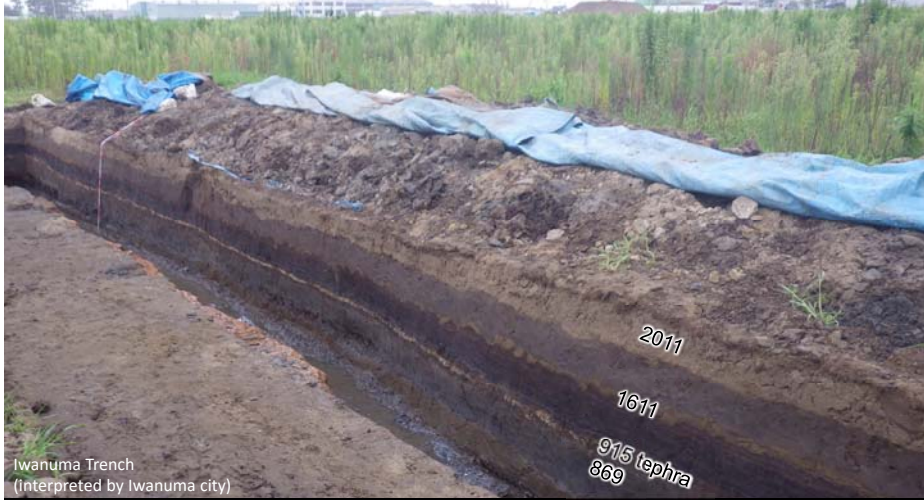


Geological and historical evidence of paleotsunami



Iwanuma Trench
(Interpreted by Iwanuma city)

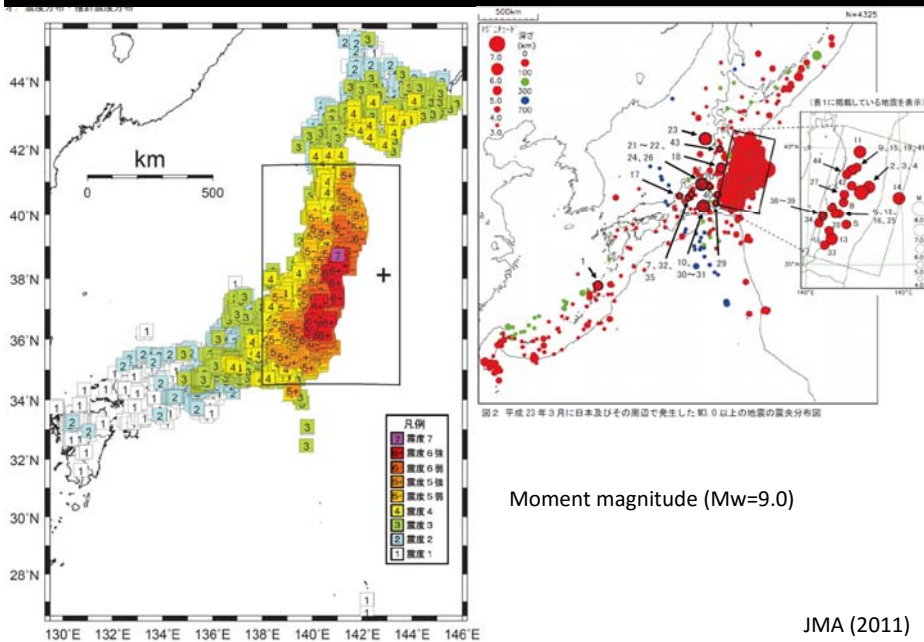
Kazuhisa Goto
(International Research Institute of Disaster Science, Tohoku University)

Geological evidence of paleotsunami in Tohoku

Huge boulders deposited by the 2011 Tohoku-oki tsunami



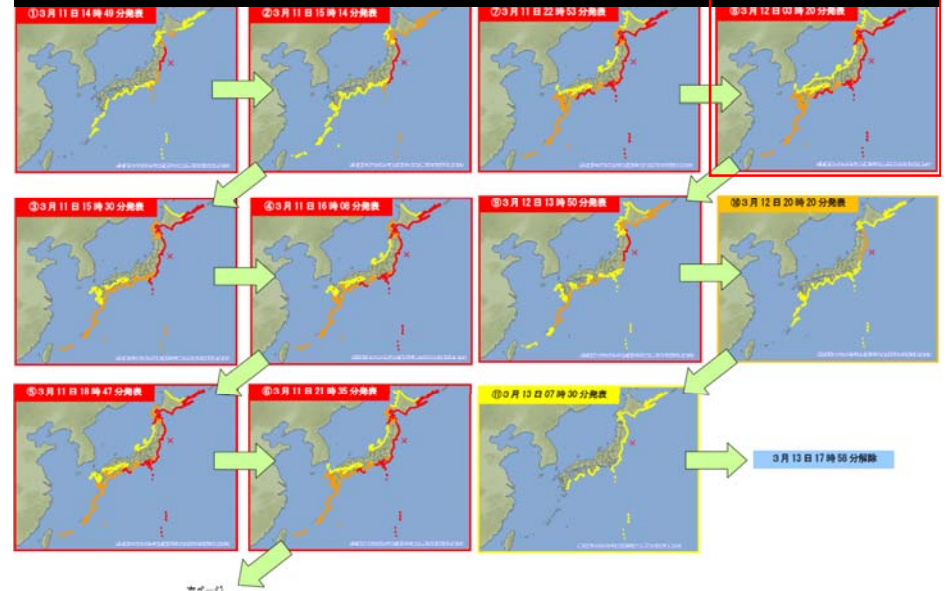
Mw=9.0 earthquake on 11 March 2011



Moment magnitude (Mw=9.0)

JMA (2011)

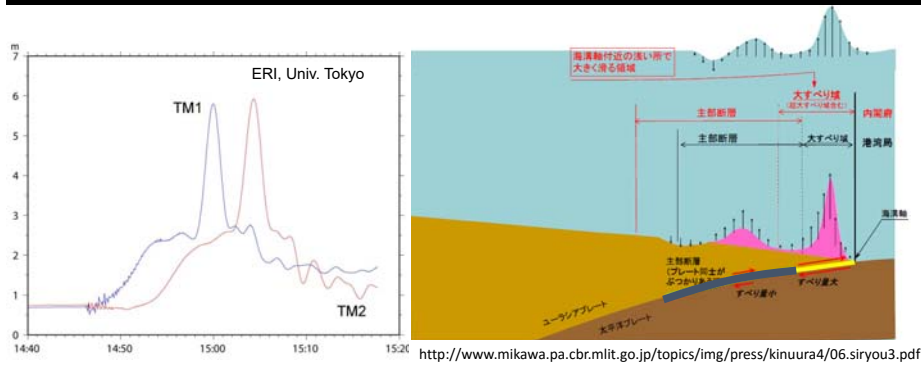
Tsunami warning issued on 11 March 2011



JMA (2011)

Red and orange: tsunami warning
Yellow: attention

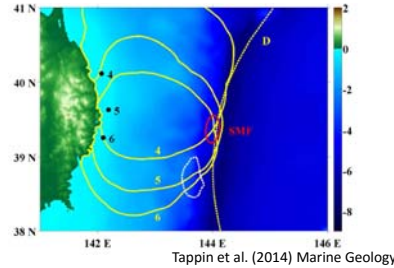
Tsunami generation mechanism



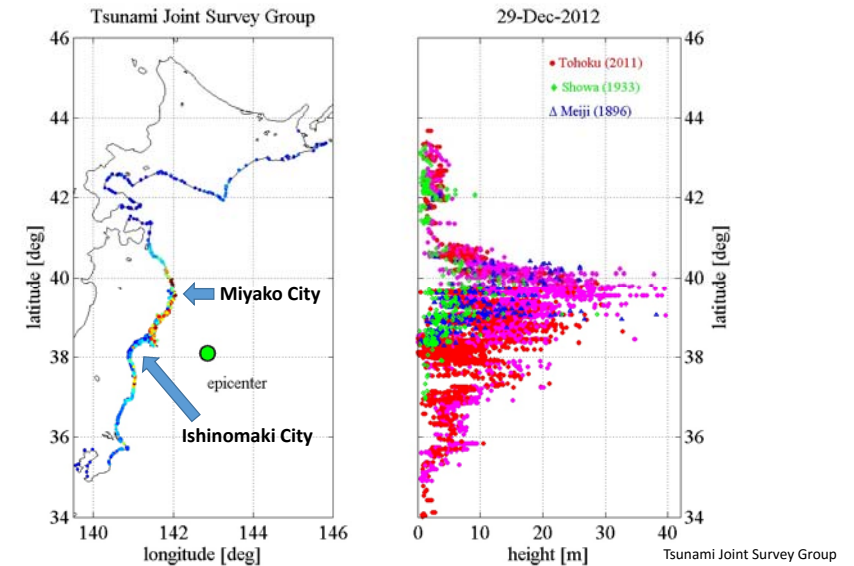
■ Extremely large slip along the shallow plate boundary (near trench axis)

(e.g., Satake et al., 2011).

■ Submarine landslide(s) was the additional source of tsunami at Sanriku coast (Tappin et al., 2014) ?



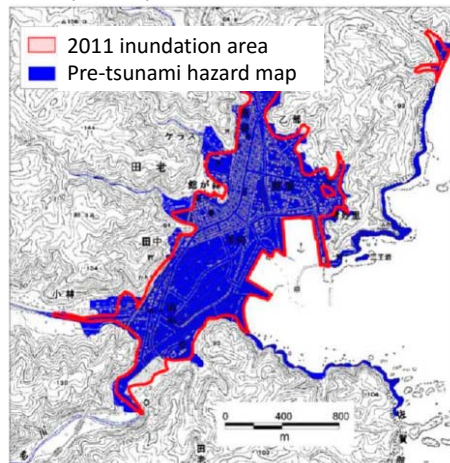
2011 Tohoku-oki tsunami heights



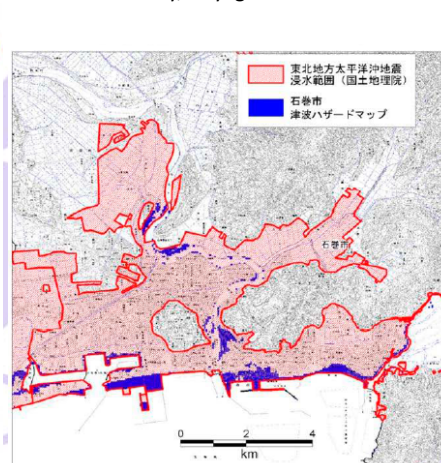
Very high run-up, but northern people experienced similar size of tsunamis past 120 years.

Pre-2011 tsunami risk assessment

Tsunami hazard map and 2011 inundation area at Miyako City, Iwate Prefecture



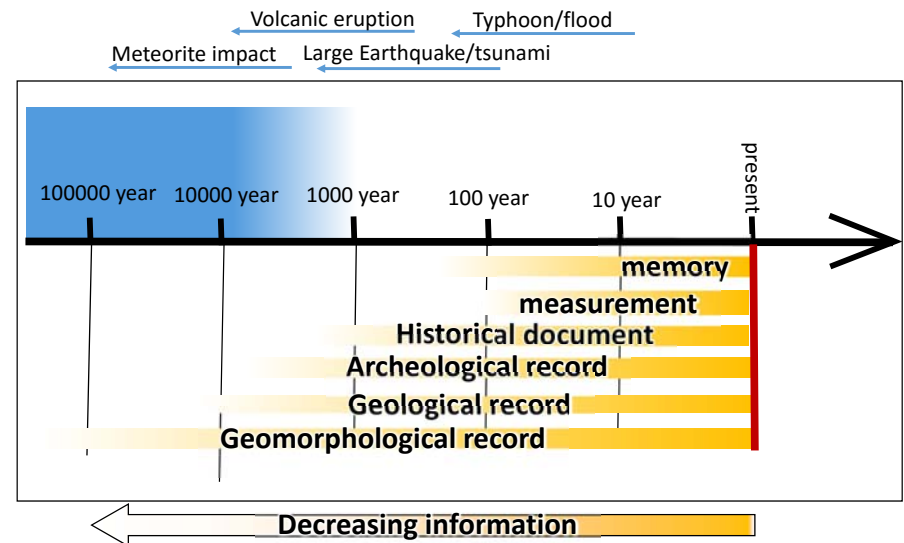
Tsunami hazard map and 2011 inundation area at Ishinomaki City, Miyagi Prefecture



Modified after CDMC (2011)

Large difference of the tsunami hazard maps in areas prepared before the 2011 event

How to know past hazard/disaster?

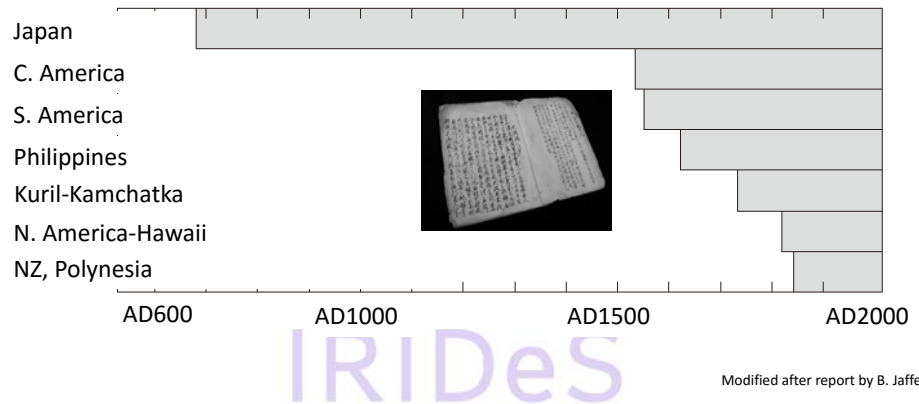


Modified after J. Komatsubara

Evidence of paleotsunami decreases to the past

Historical record

Historical documents describe detail of earthquake and tsunami and consequent damages.



Some countries have legend and/or oral tradition of tsunamis.

Geological evidence of paleotsunami

Major objectives of the paleo-tsunami research are

- estimation of the long-term tsunami recurrence interval.
- estimation of the inundation area, flow height, and magnitude of earthquake.

for the tsunami risk assessments.

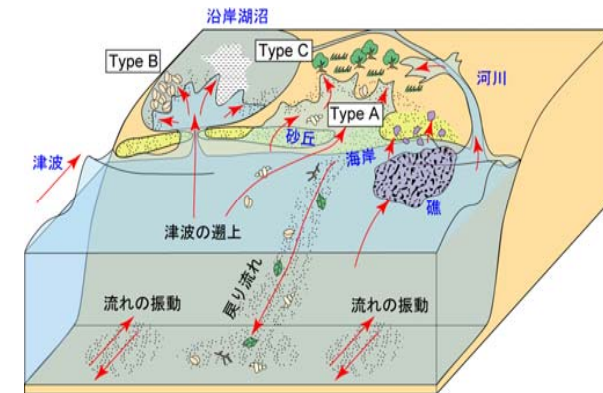
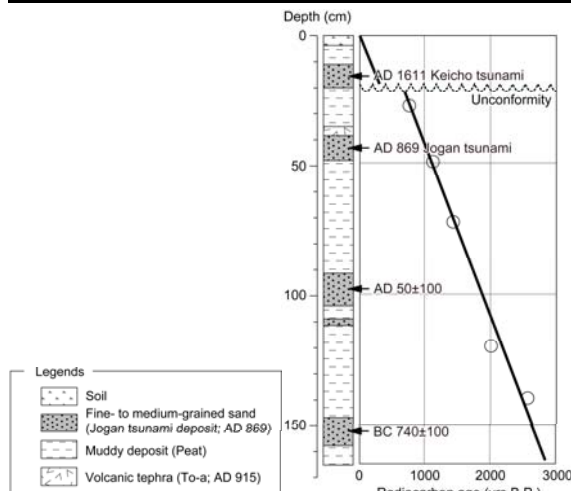


Image of the tsunami sediment transportation (Sugawara et al., 2008)

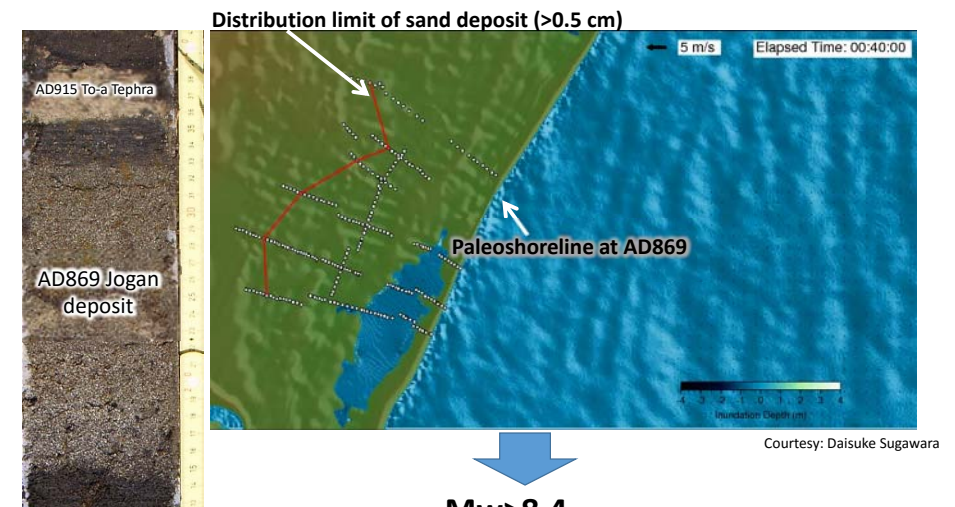
Tsunami recurrence estimated from tsunami deposit in Sendai



Minoura and Nakaya (1991), Sugawara et al. (2012)

Few hundred to thousand years interval.

Estimating magnitude of the AD869 Jogan earthquake



Courtesy: Daisuke Sugawara

Mw>8.4

It was not considered in the hazard map before the 2011 event

- Tsunami inundated at least 3-4 km from the paleo-shoreline (e.g. Abe et al., 1990).
- Few hundred to thousand years recurrence interval (e.g. Minoura and Nakaya, 1991).

New policy for the tsunami risk assessment

Outline of the Report of the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunami
Based on the Lessons Learned from the "2011 off the Pacific coast of Tohoku Earthquake"

Objectives

- The other experiences and tough lessons experienced must be permanently passed on as a testament linking the past, the present and the future, and as wisdom for the building of disaster-resilient nation and communities.
- Based on the report, the national government is expected to perform necessary revisions of Japan's overall earthquake and tsunami countermeasures and pour every effort into enhancing disaster management measures for the future, thus fully fulfilling the fundamental government role of protecting the lives and property of the nation's citizens.

Characteristics of the earthquake and tsunami damage and principles for tsunami to be used for future hazard assumptions

Characteristics and verification of the damage caused by the 2011 off the Pacific coast of Tohoku Earthquake

- Coexisting human and material damage caused by the mega earthquake and tsunami
- Unforeseeable magnitude 9.0 earthquake
- Off-diagonal assumptions were far removed from the actual hazard, disaster management measures excessively dependent on coastal protection facilities, and tsunami warnings that fell below the actual tsunami height, etc. **rebuild disaster management measures in its entirety according to reflections and the lessons learnt**

Principles on selecting earthquakes and tsunamis for development of disaster management measures

- Examine the largest-possible mega earthquakes and tsunamis from every possible angle.
- Select earthquakes and tsunamis for hazard assumption based on scientific knowledge such as analysis of ancient documents and surveys of tsunami deposits and coastal topography.
- Enhance researches on seismology, geology, archaeology and history in a comprehensive manner.

Principles for future tsunami hazard assumptions for developing tsunami countermeasures

- Future hazard assumptions will require two levels of tsunamis
- Largest-possible tsunamis with extremely low possibility of occurrence but devastating once they occur

Future directions for earthquakes and tsunamis

Disaster prevention

- For the largest possible tsunamis, implement structural measures, sea or evacuation, such as preparation of escape route, in accordance with
- The fundamental step in protecting human life from tsunamis is evacuation as a strong or extended sheltering is left.
- In communities where tsunamis strike directly, community development in communities where topographical conditions or the scale of sea use and evacuation are thoroughly examined with consideration to factors such as
- Preparation of a topographic and elevation of risks for with
- Improvement of tsunami evacuation routes and evacuation actions in accordance with the review of tsunami warnings or
- Improvement and strengthening of tsunami warnings and in delivering tsunami warnings, every possible tool including local disaster notice profiles, "Sag" etc. should be utilized, and responses to power to local government buildings need to be examined.
- Improvement and strengthening of earthquake and tsunami improve the accuracy of tsunami prediction by enhancing the observation system, design and data base system.
- Designation of tsunami evacuation buildings and development of tsunami evacuation routes, tsunami evacuation buildings integration with community development, with regard to tsunami evacuation criteria need to be examined.
- Development of rules of conduct for guiding residents to protective research and analysis needs to be made regarding evacuation routes of conduct will be stipulated with regard to disaster management the disaster area.

Damage reduction

- Review of damage scenario methods and the factors considered based on the Great East Japan Earthquake. The damage or the Great East Japan Earthquake will be examined for quantitative assessment of the effectiveness of promoting disaster management measures.
- Develop several scenarios including a worst-case scenario that assumes the maximum damage occurs, by assuming different circumstances such as the time of the day or meteorological conditions.
- Systematic efforts to make buildings resistant to earthquakes and strengthening of awareness raising activities
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Towards the future

Cabinet Office, Government of Japan

The Japanese government made a new guideline for tsunami disaster prevention plans in December 2011, and recommended that local governments prepare for the "maximum possible earthquakes and tsunamis".

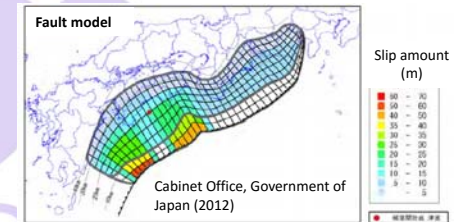
Maximum possible.... How large and how to estimate?

Historical and geological evidence tell us approximate return period and size of the rupture area of the fault.

- ✓ Magnitude of each seismic event is uncertain.
- ✓ Geological and historical researches take long time...
- ✓ Tsunami may not be generated only by the fault rupture (e.g. submarine landslide).

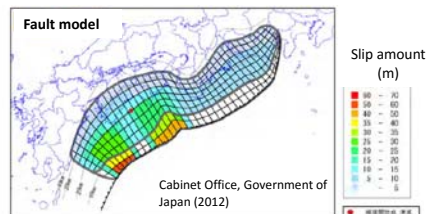
Nankai Trough

- Many big cities (Osaka, Nagoya, Tokyo)
- 1300 years historical record
- 100-200 years interval of large event
- 1707 event was the largest (Mw=8.6~8.7)
- Many geological evidence



In 2012, national government reported Mw=9.1 earthquake as the possible maximum event along the Nankai Trough. Tsunami run-up height will be approx. 30 m in maximum. Human and economic losses will be 320,000 peoples and 220 trillion JPY (Asahi newspaper).

Maximum possible.... How large and how to estimate?

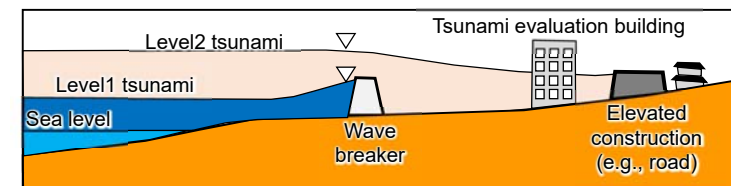


1. "The slip amounts were estimated based on the knowledge of 2004 Sumatra earthquake, 2010 Chilean earthquake, and 2011 Tohoku earthquake (CDMC, 2012)".

2. "It is very difficult to estimate the recurrence interval or timing of occurrence of this maximum possible earthquake and tsunami (CDMC, 2012)".

1. Do local governments need to prepare for such event?
2. Is this really the maximum? Overestimation or underestimation?

Post-2011 policy for the tsunami countermeasure



- **Level 1 tsunami:** One that occurs frequently every few tens of years to a hundred or more years. The estimated tsunami height is the basis for construction of shore protection facilities.
- **Level 2 tsunami:** One that occurs with an extremely low frequency, but generating severe damage once it occurs. Shore protection facilities are probably insufficient to protect against a tsunami of this size. Saving human life is, therefore, the top priority, and hence so an awareness campaign including disaster education is highly recommended.