



東北大学

# Historical review of tsunamis in Tohoku District and brief review of tsunami disasters in the Great East Japan Earthquake

14 March 2012  
International Symposium on Earthquake & Tsunami  
Disaster Reduction -Learning from the Great East Japan Earthquake-  
Fumihiko Imamura, Prof. Tsunami Eng,  
DCRC, Tohoku Univ.



- Historical earthquake and tsunami hazard/disaster
- Earthquake and tsunami recorded in Tohoku Area
- Tsunami damage from Great East Japan Earthquake
- Toward reconstruction and future implication

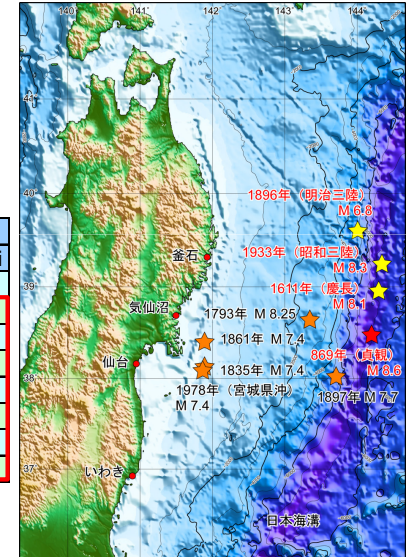


# Historical Tsunami recorded in Tohoku

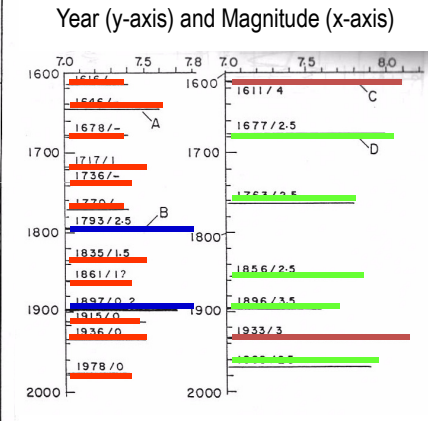
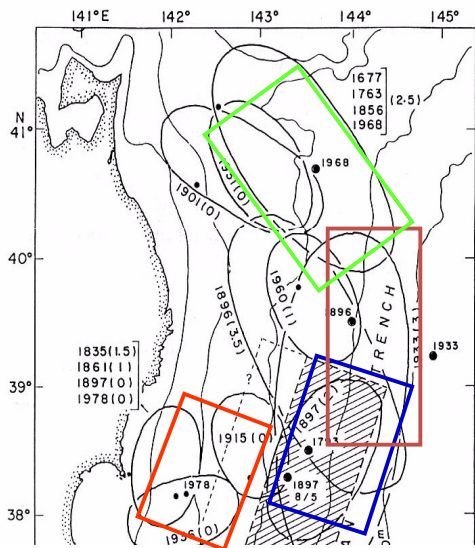
- Tsunami struck mainly Sanriku coast
- Fewer records in Miyagi and Fukushima coast
- Large Tsunamis occurred by events closer to the Japan Trench
- Small Tsunamis by off-the-coast Miyagi

Occurrence Date		Magnitude	
Western Calender	Japanese Calender	EQ	Tsunami
13 July, 869	貞観11年 5月26日	8.6	4
2 Dec, 1611	慶長16年10月28日	8.1	3
17 Feb, 1793	寛政 5年 1月 7日	8.25	2
20 July, 1835	天保 6年 6月25日	7.4	2
21 Oct, 1861	文久 1年 9月18日	7.4	1
15 June, 1896	明治29年	6.8	4
3 Mar, 1933	昭和 8年	8.3	3
12 Jun, 1978	昭和53年	7.4	0

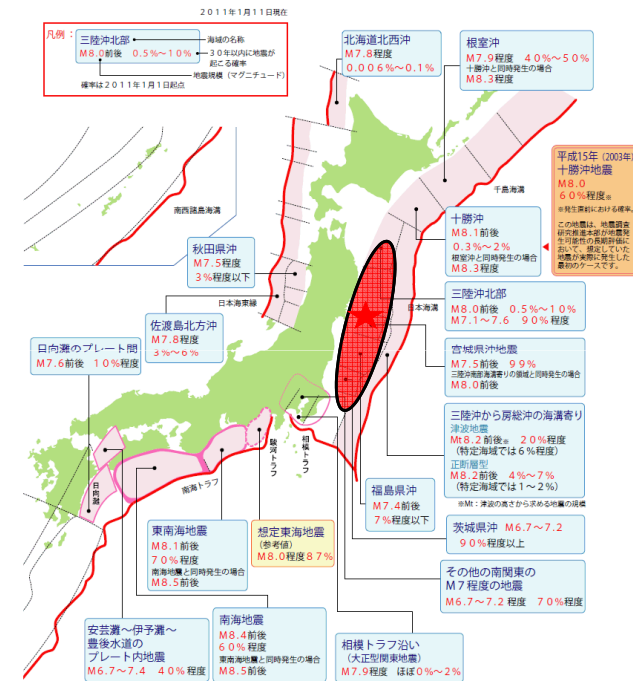
Above: Historical Tsunami observation hitting Tohoku Pacific coast.  
Right: Wave source, based on Watanabe 1985.



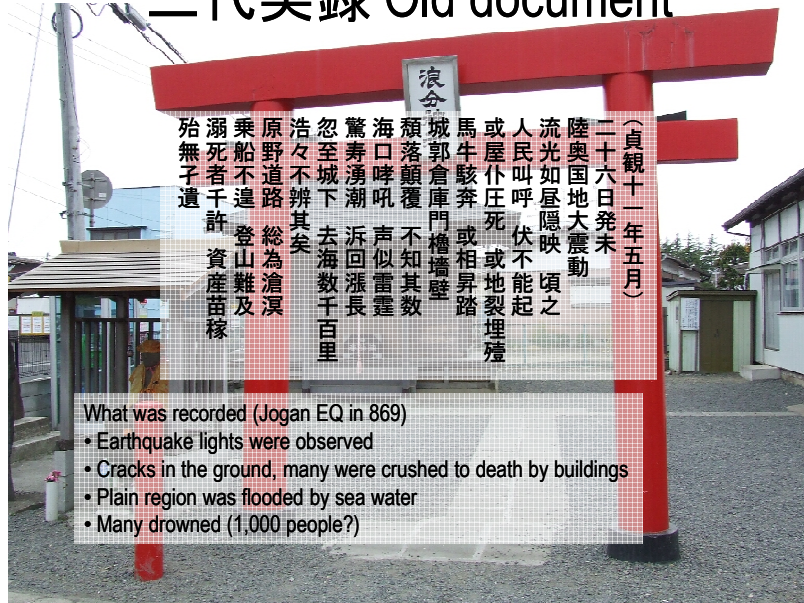
# Historical Earthquake and Tsunami in Off-the-Coast Sanriku and Miyagi



Off-the-coast Miyagi EQ occurs once in 37 years

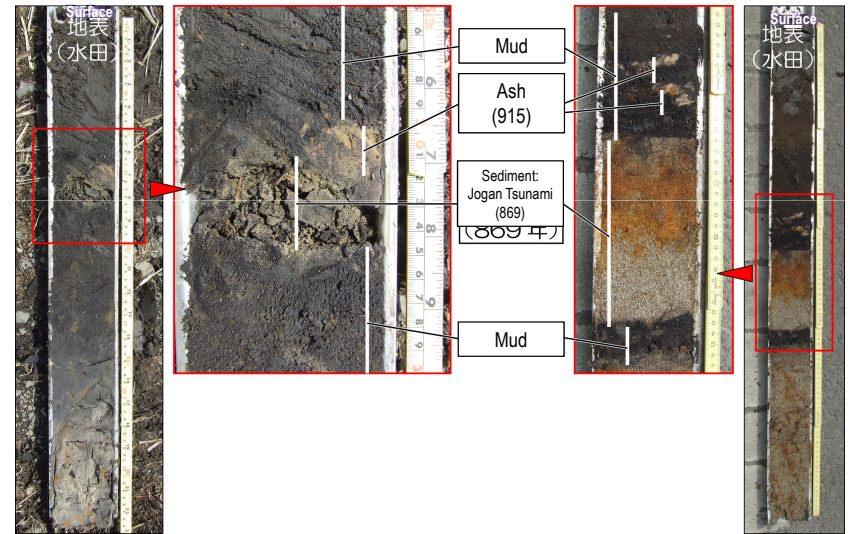


# 三代実録 Old document

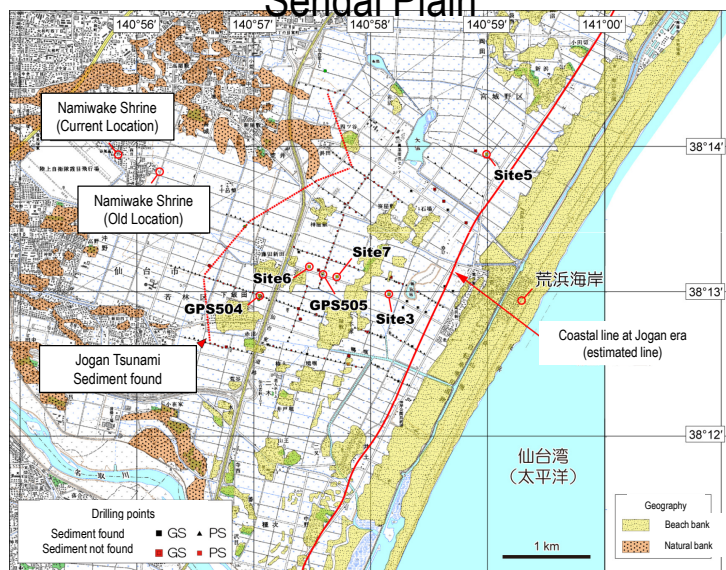


# Tsunami Sediment by Drilling

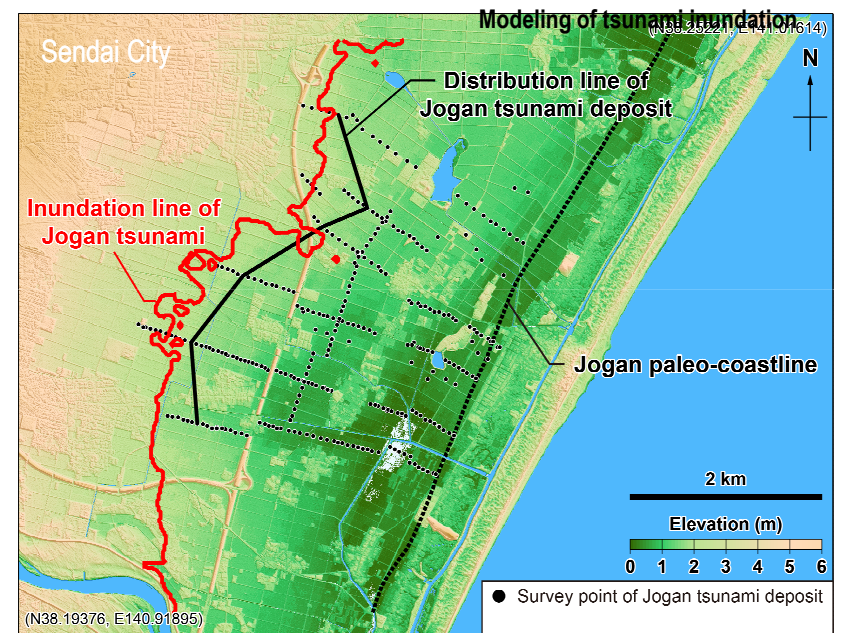
two layers; volcano ash and tsunami sand



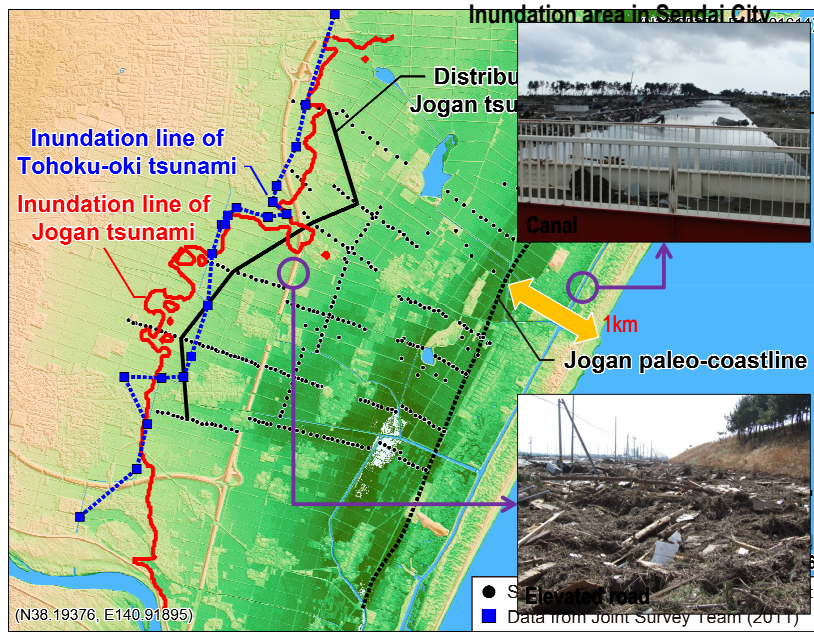
# Distribution of 869 Jogan Tsunami Sediment in Sendai Plain



# Estimation of the event size (3)



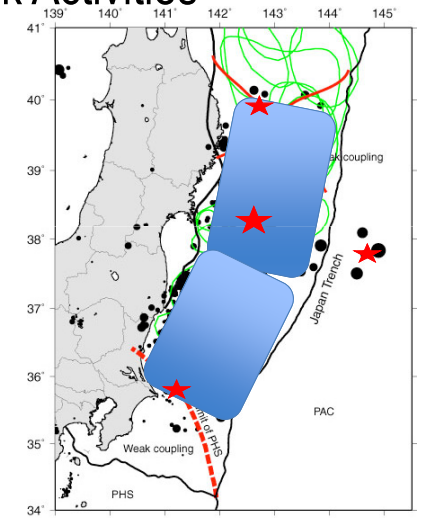
Comparison to Tohoku-oki event (1)



NH13G-08: Sugawara et al.

# The Mainshock and Aftershock Activities

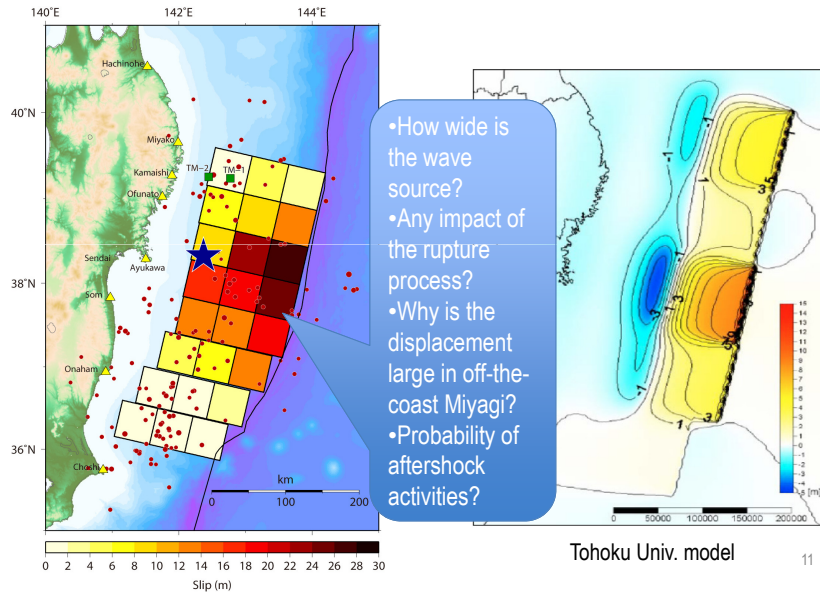
- Mainshock : M9.0 (14:46)  
500km x 200km  
The largest in size recorded
- Immediately after
  - Off-the-coast Sanriku M7.5 (15:08), Off-the-coast Ibaraki M7.3 (15:15), Japan Trench M7.4 (15:25)
- Aftershock activities
  - Fukushima, Ibaraki, Boso
  - Lasting aftershock activities
  - Stress transfer?



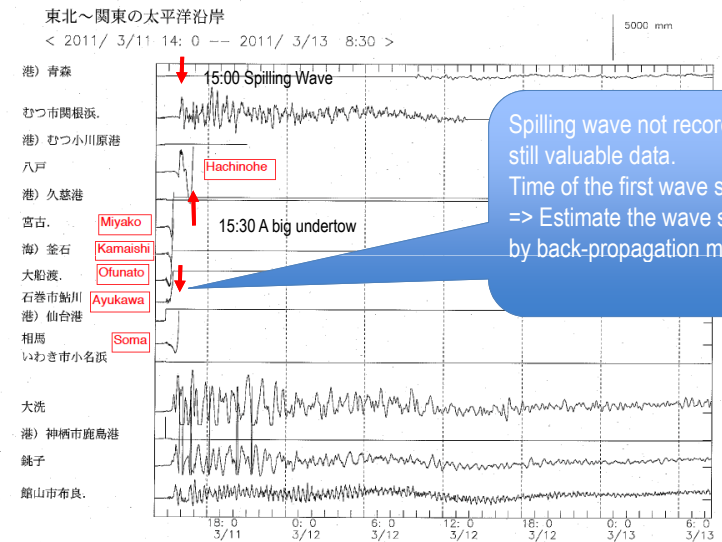
Uchida, Tohoku University  
[http://www.aob.geophys.tohoku.ac.jp/info/topics/20110311\\_news/index.html](http://www.aob.geophys.tohoku.ac.jp/info/topics/20110311_news/index.html)

## Example of faults model for tsunami (Fujii&Satake,2011 & Tohoku Univ.model)

[http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami\\_ja.html](http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami_ja.html)



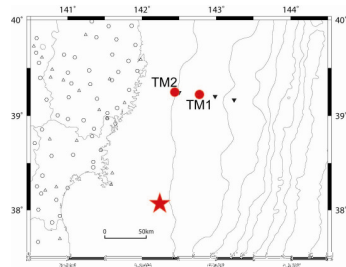
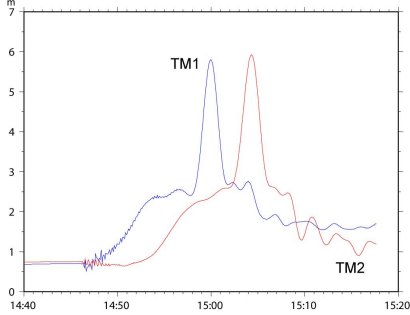
## Tsunami observed in Coastal Areas (JMA)



Source: JMA

Off-the-coast Tsunami Observation (Tsunami obs. off-the-coast Kamaishi + GPS Wave Gauge)

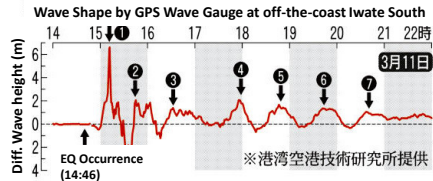
2011/3/11 14:40~15:20



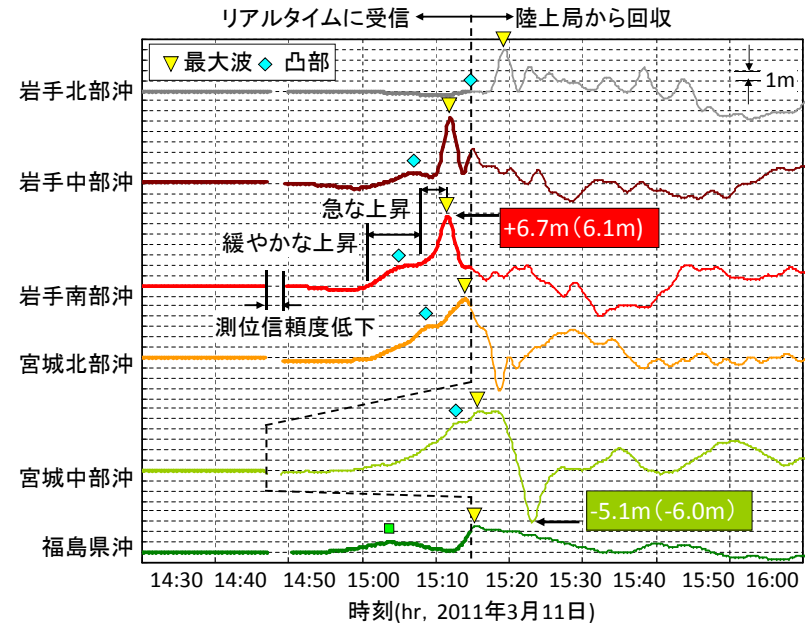
Primary wave arrived at 11:45 to TM1 (closer to Japan Trench), and the first wave with 7cm height struck in 7min later. TM2 (closer to the coast) observed wave with similar wave length in 4min later.

Primary wave arrived at 14:46 to TM1 (closer to Japan Trench), and the first wave with 3.5m height struck in 7min later. TM2 (closer to the coast) observed wave with similar wave length in 4min later.

Earthquake Research Institute, The University of Tokyo



第1波の「緩やかな上昇」と「急な上昇」



Casualties

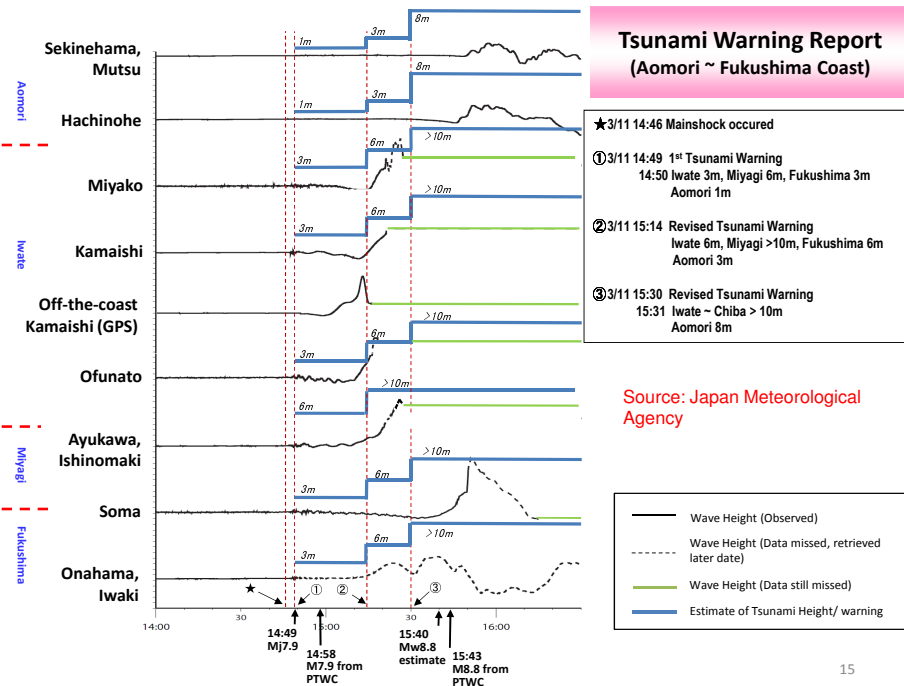
- The number of casualties continues to rise. The Government has confirmed 10,102 people have died. Still 17,053 missing on March 26. It has already exceeded that the 1995 Great Hanshin Awaji (Kobe) Earthquake.

As of 8:00 am March 26 2011

Prefecture	Killed	Missing	Refugees
Iwate	3,092	4,878	43,728
Miyagi	6,097	6,237	86,927
Fukushima	855	5,934	86,308
Others	58	4	29,146
<b>Total</b>	<b>10,102</b>	<b>17,053</b>	<b>246,109</b>

Source: The Emergency Disaster Response Headquarters

=> 15,400 killed and 7,700 missing on 22 June



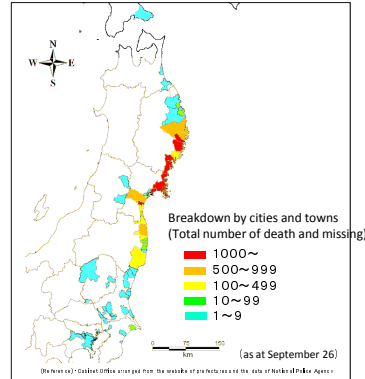
## Human Loss and Building Damage

Table 1: Earthquake and tsunami caused the tremendous degree and extent damage; as 12 prefectures.

<b>Human Loss</b>	death: 15,811, missing: 4,035 (as at September 26)
<b>Building Damage</b>	Collapsed: 117,542 buildings, Partially destroyed: 177,192 buildings (as at September 26)
<b>Applicable Disaster Relief Act</b>	241 cities (10 prefectures) (※including 4 cities applied on the northern Nagano earthquake)

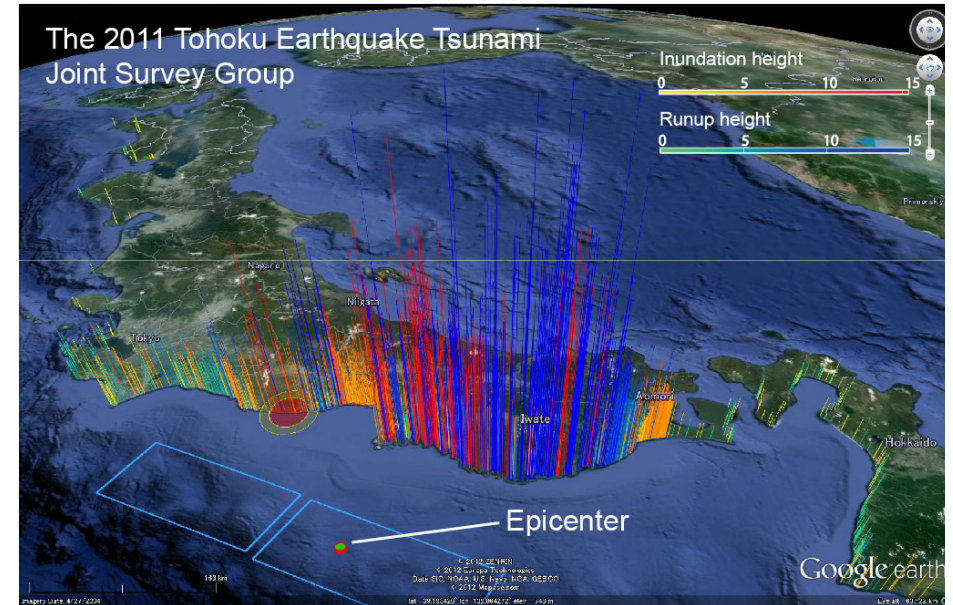
Breakdown by prefecture (death, missing, collapsed buildings) (as at Septem 23)

Prefecture	death	missing	Collapsed Buildings
Hokkaido	1	0	0
Aomori	3	1	307
Iwate	4,664	1,651	21,209
Miyagi	9,477	2,141	75,391
Yamagata	2	0	37
Fukushima	1,604	239	17,740
Tokyo	7	0	0
Ibaraki	24	1	2,799
Tochigi	4	0	262
Gunma	1	0	0
Chiba	20	2	797
Kanagawa	4	0	0
<b>Total</b>	<b>15,811</b>	<b>4,035</b>	<b>117,542</b>

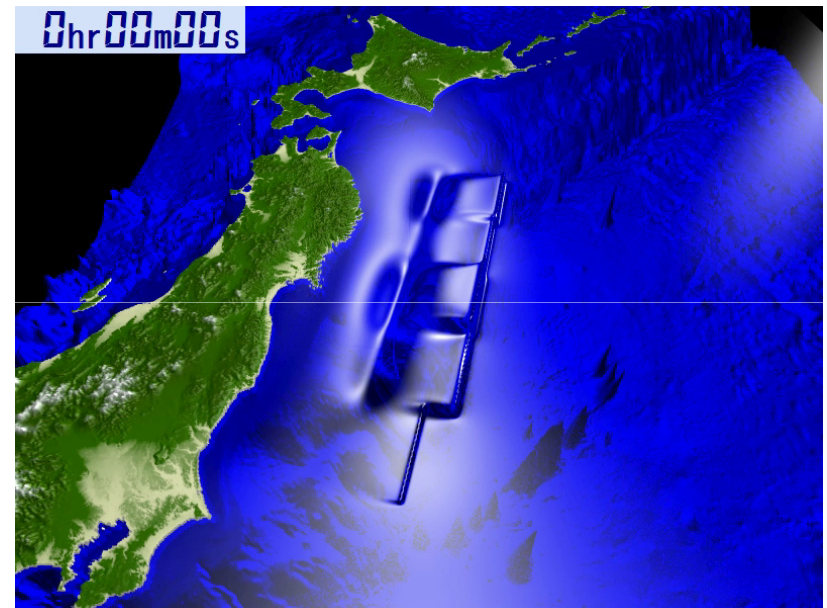
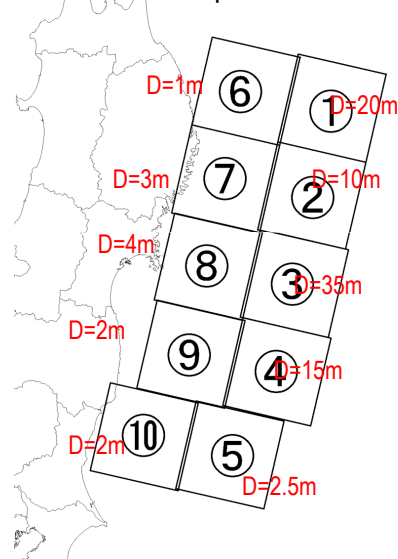
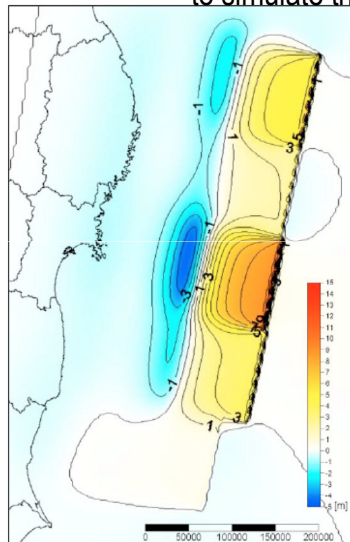


(Reference)  
 \*Human Loss and Building damage: The data of National Police Agency (September 23, 2011)  
 \*Applicable Disaster Relief Act: Ministry of Health, Labour and Welfare "Relevant information of the Great East Japan Earthquake in 2011: Cities applied Disaster Relief Act". \*About application of Disaster Relief Act on the northern Nagano earthquake"

これまでの調査結果  
 参加: 約100名  
 測点: 約400点(1ヶ月) => 現在4,000点



### Tohoku Univ. model Vers.1.0 to simulate the inundation and runup



# Characteristic of Tsunami Damage

- Huge amount of inundation (443km<sup>2</sup>)+ destructive wave force
- Directly and indirectly: Floating of debris, ships, cars and tanks
- # cars disposed 230K, # ships disposed 19K
- Secondary loss: Fire following, salt water damage
- Changes in geography

東北各県の漁船の被災状況

県登録漁船	被災漁船	
宮城	13,770	12,023
岩手	9,872	516
福島	14,304	5,726
計	38,919	19,238



# Tsunami Countermeasures

- **Structures**; sea wall, break water, dike, controlling forest, started in 1930's and 1960 after Chilean tsunami
- **Non-structures**; Tsunami warning, Evacuation building, Education and awareness, monuments

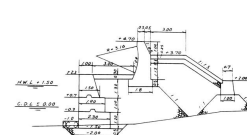


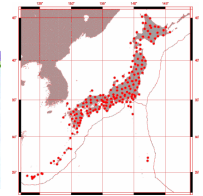
Fig. 2. Dual purpose structure (composite type tsunami wall).

Photo 2. Typical fishing village (Ryoishi), on the Sanriku coast.

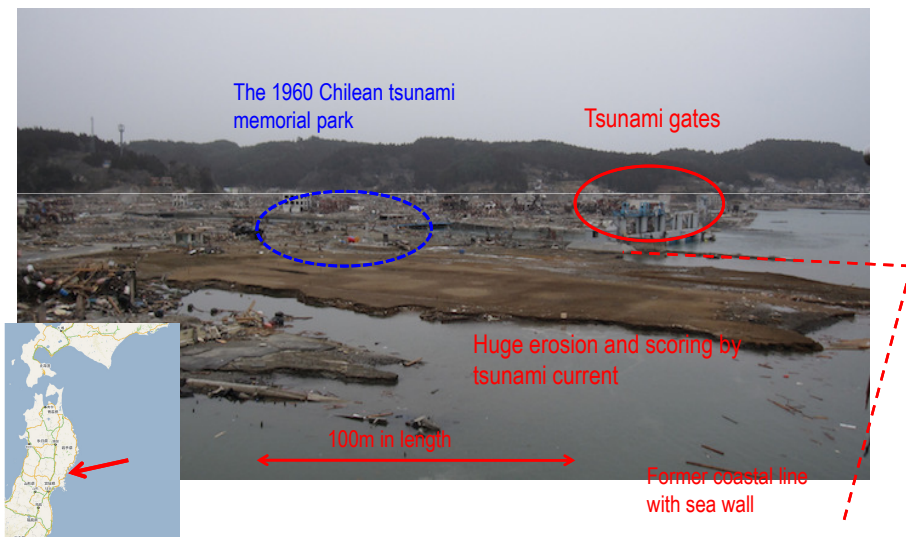
Sea wall protecting the fishery harbor



JMA Earthq.&Tsunami monitoring &Tsunami Forecasting system to provide information



# Change topography, erosion, destruction on the gates and sea wall at Minami-Sanriku, Miyagi

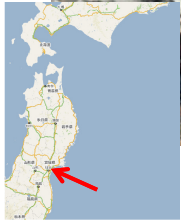


# Destruction on the coastal villages and rail at Higashi Mastushima, Miyagi



# The tsunami attacking Sendai area

15:56 JT on March 11



(共同通信) [http://www.boston.com/bigpicture/2011/03/massive\\_earthquake\\_hits\\_japan.html](http://www.boston.com/bigpicture/2011/03/massive_earthquake_hits_japan.html)

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# The tsunami attacking Sendai area

15:58 JT on March 11



(共同通信) [http://www.boston.com/bigpicture/2011/03/massive\\_earthquake\\_hits\\_japan.html](http://www.boston.com/bigpicture/2011/03/massive_earthquake_hits_japan.html)

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# The 1st Tsunami Struck Sendai Plain

15:56, 11 March



(Source: Mainichi Shimbun) [http://www.boston.com/bigpicture/2011/03/massive\\_earthquake\\_hits\\_japan.html](http://www.boston.com/bigpicture/2011/03/massive_earthquake_hits_japan.html)

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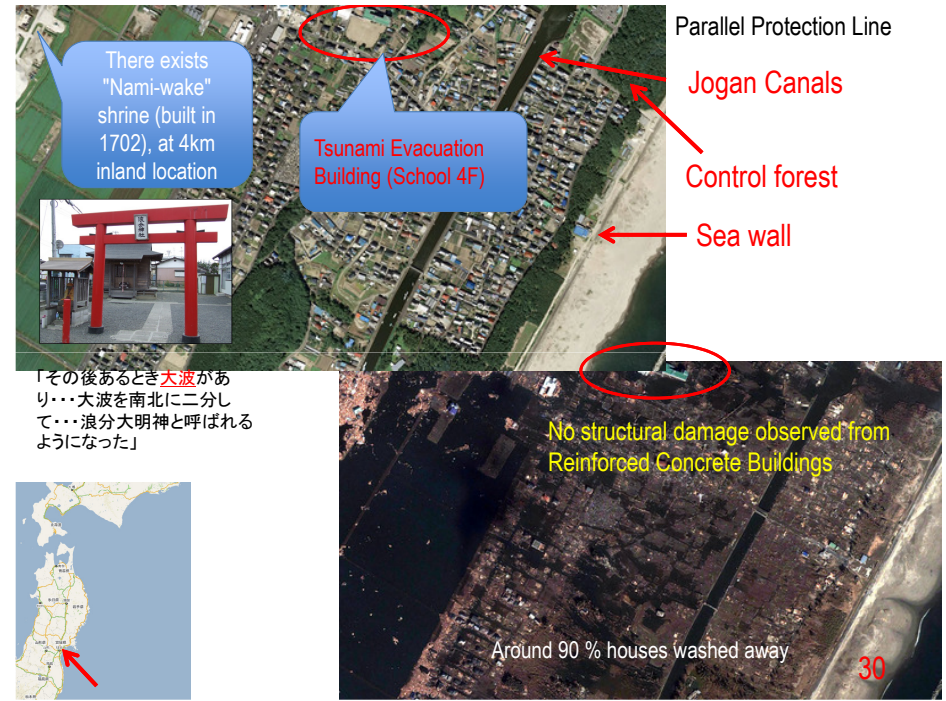
# The 1st Tsunami Struck Sendai Plain



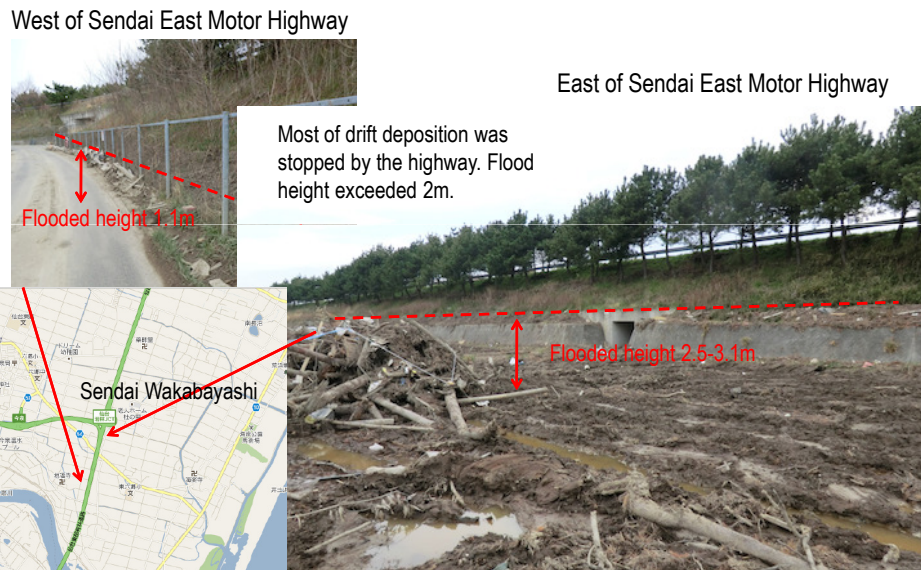
(Source: Mainichi Shimbun) [http://www.boston.com/bigpicture/2011/03/massive\\_earthquake\\_hits\\_japan.html](http://www.boston.com/bigpicture/2011/03/massive_earthquake_hits_japan.html)

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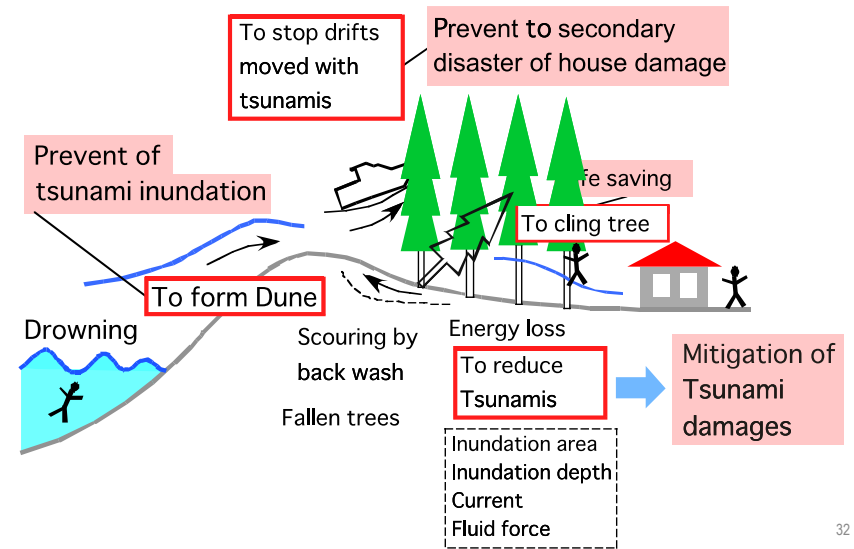
# Drifted Fuel Tank (Asahi, Kessenuma)



# High way reduced tsunami



# Several functions of coastal forest in Japan (Harada & Imamura, 2003)





## Immediate Actions

- Anticipate aftershocks and induced quakes (Normal slip event in off-the-coast Sanriku, or aftereffect stress transfer to circumjacent faults)
- Effective removal and usage of debris and drift deposition brought by the quake and tsunami
- Geographic displacement along the coast, a remedial measure to cope with long-term threat to increased flooding
- Quantitative data collection and analysis for land use and zoning plan: areas and height flooded, hydrodynamic force, damage status.

## Mid to Long-term Actions

- Assuming seismic events and tsunamis to cope with, and emergency management in case unanticipated.
- Review and revision of the Coastal Safety Fundamental Plan: rebalance between physical mitigation and enhanced communication: information sharing, evacuation, and public awareness.
- Quantitative seismic hazard analysis based both on probable maximum and probabilistic approaches and disseminate results to wider public
- Contribution to the Headquarters for Earthquake Research Promotion, reflection to the Central Disaster Council
- Considerations to relocation, land use plan based on historical quakes and tsunamis
- Long-term reconstruction and development
- Better understanding of historical tsunami events: Jogan Tsunami in 869 and Keicho Tsunami in 1611

## Next Steps

- Better scientific understanding of tsunami mechanism
- Collection of insights and scientific data for mitigation
- Field survey of historical quakes and reporting back
  - => Archiving for collective use
- Outreach activities and offering expertise
  - Collaboration and alliance amongst institutions for better networking
  - Support reconstruction work with local community
- Tohoku University Focus Research Project: Reconstruction and community rehabilitation initiatives
- <http://www.dcrc.tohoku.ac.jp/archive/>

Thank you for your attention

Knowing risk  
Reducing risk &  
Living at risk