Ocean bottom data

The observation record of the ocean bottom pressure gauge. At around 14:46, the ground motion of the earthquake (M9) reaches the pressure gauge and at TM1 (coast-side), the sea level is gradually rising from that point.

The sea level rose 2 m, and after 11 minutes, the level went drastically up to 3m, which makes 5 m of elevation in total. At TM2: located 30km toward the land, a same elevation of sea level was recorded with 4 minutes delay from TM1.

釜石沖海底ケーブル式地震計システムで観測された海面変動
東京大学地震研究所

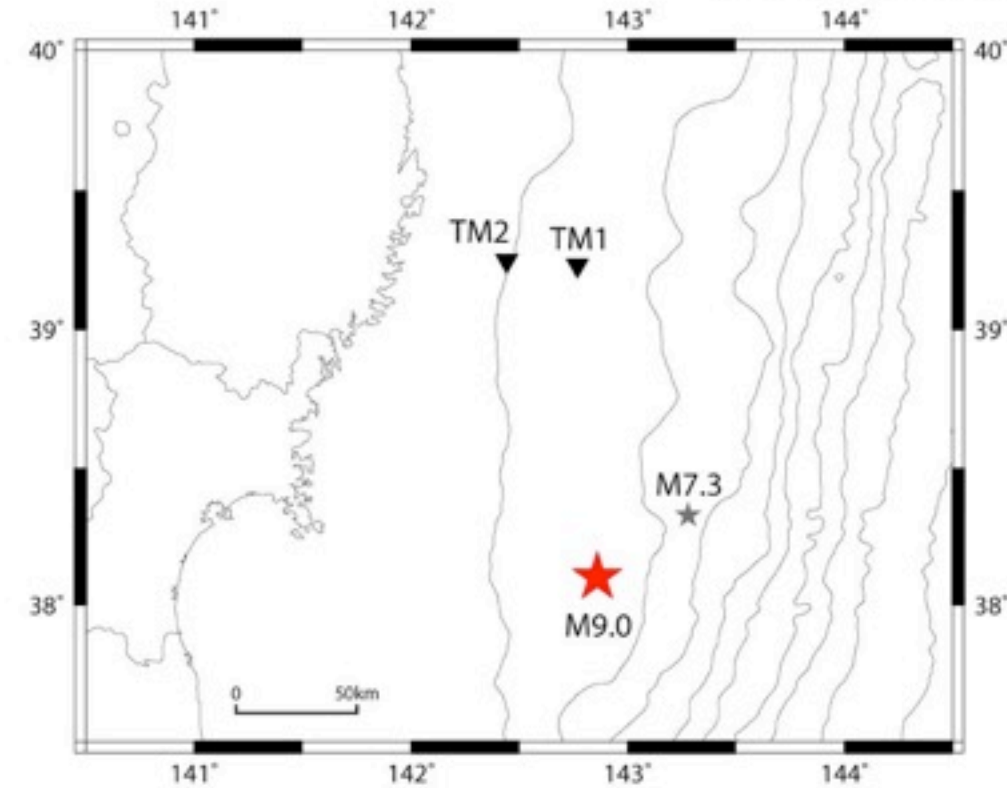


図１　釜石沖ケーブル式海底水圧計の位置

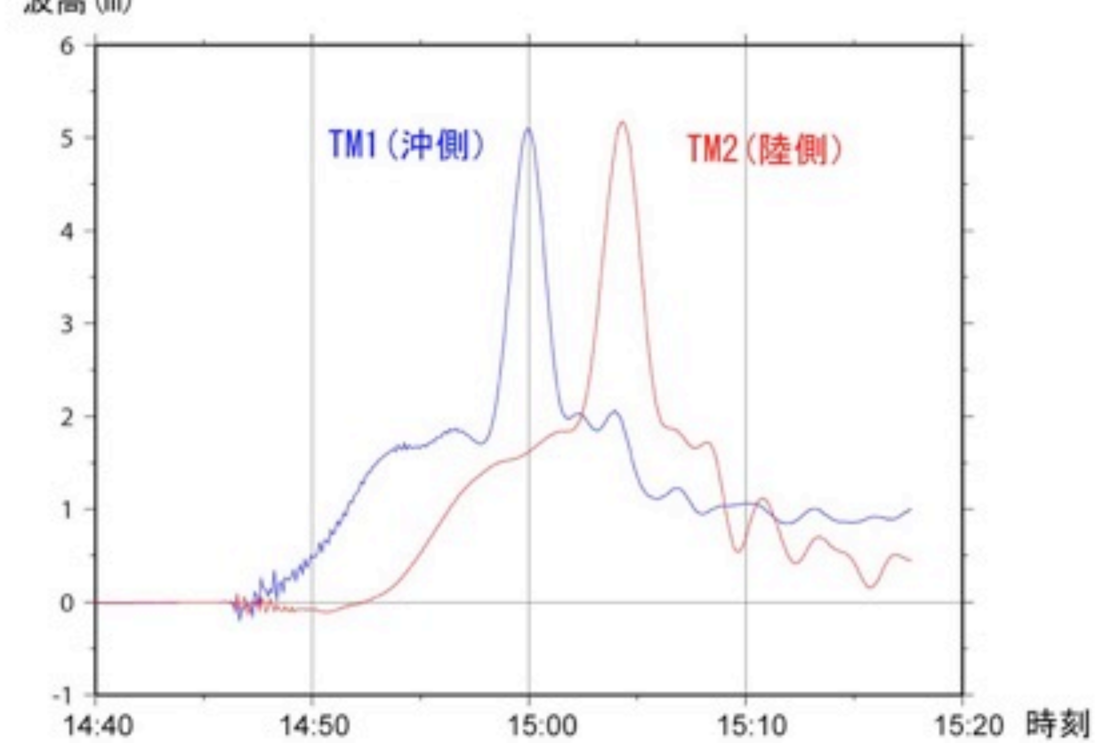
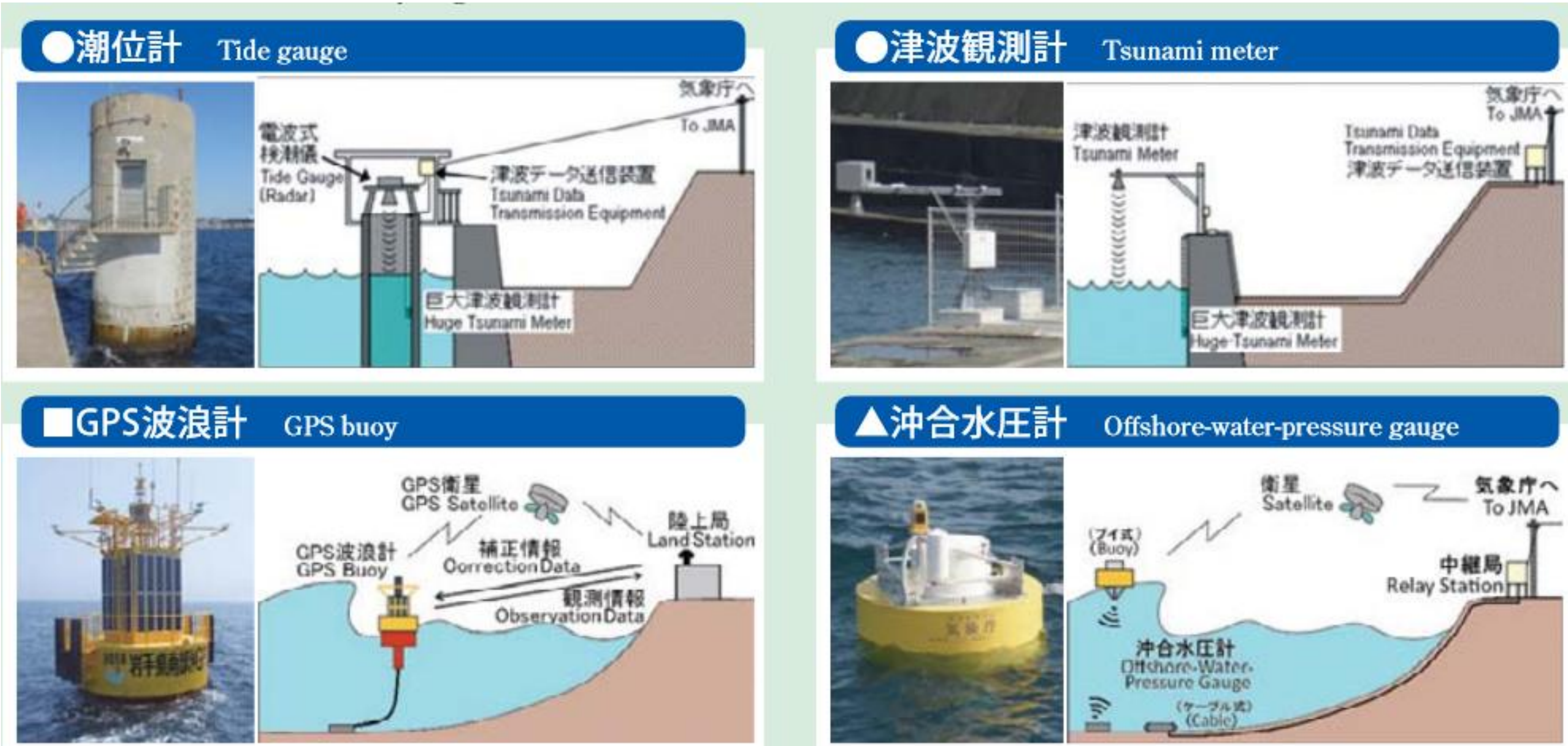


図２　海底水圧計の観測記録。14時46分頃、本震(M9.0)の振動が水圧計に伝わり、TM1(海寄り)では、その時から徐々に海面が上昇している。約２m上昇し、約11分後にはさらに約3m急激に上昇し、合計約5m海面が上昇した。約30km陸寄りに設置されているTM2では、TM1から約4分遅れて同様の海面上昇を記録した。

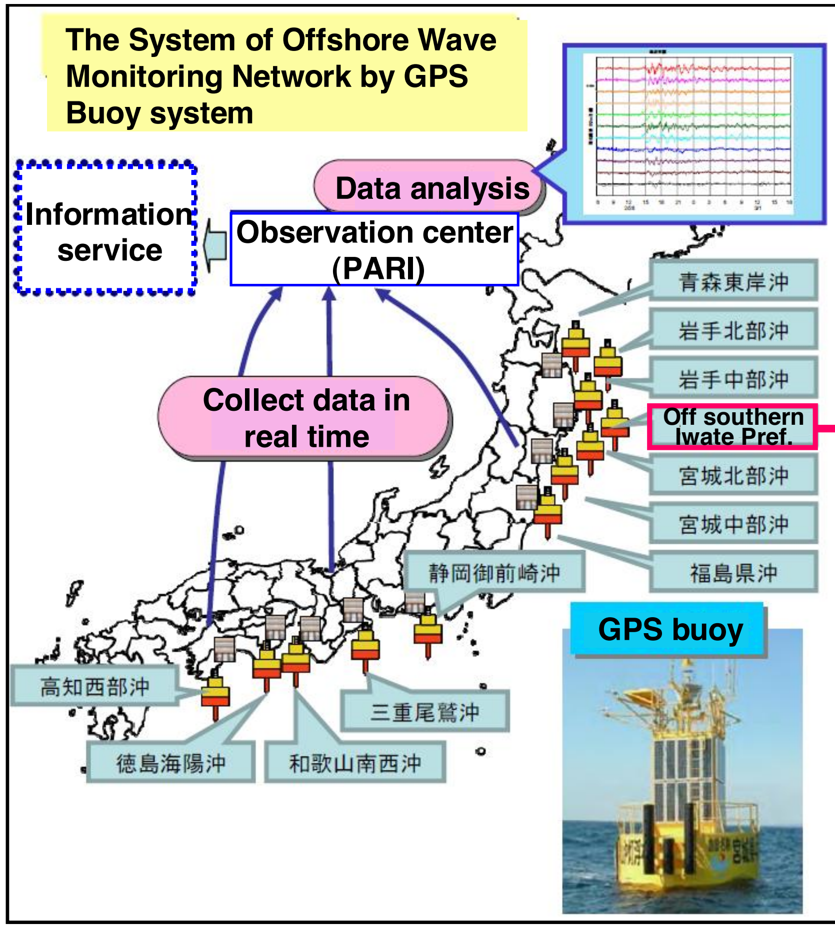
Tsunami measurements



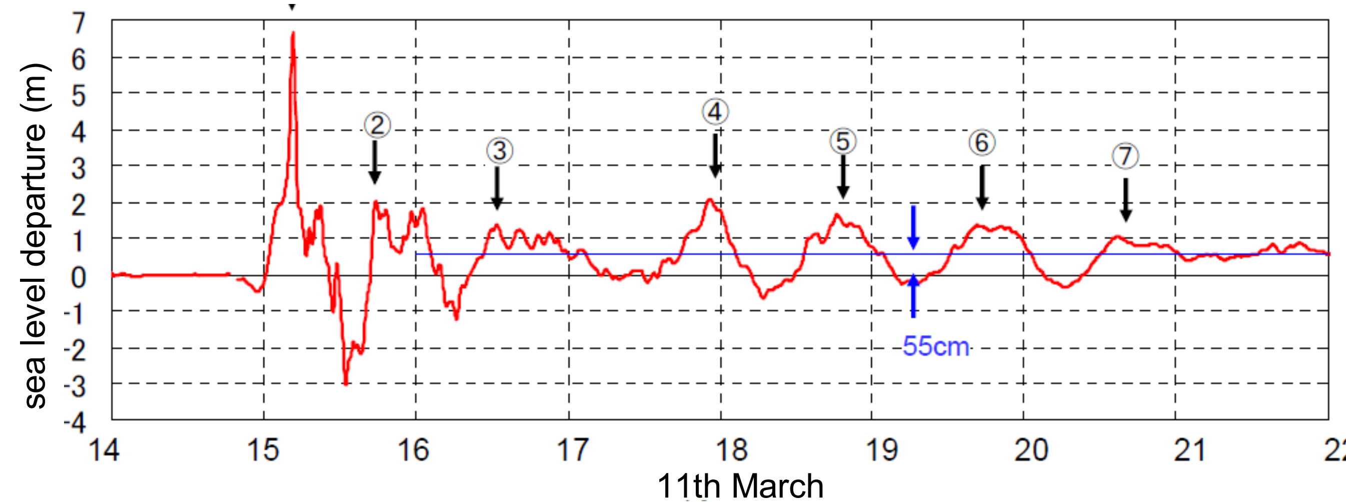
Tide gauges and tsunami meters are used to observe sea levels and tsunamis in coastal areas. When a very large tsunami with heights exceeding the measurement range of these instruments is generated, huge-tsunami meters are used. GPS buoys are installed offshore to detect tsunamis promptly, and offshore-water-pressure gauges are installed farther offshore to help clarify the situation of tsunamis in their early stages.

http://www.data.jma.go.jp/svd/eqev/data/en/guide/tsunamiinfo.html

Tsunami wave characteristics

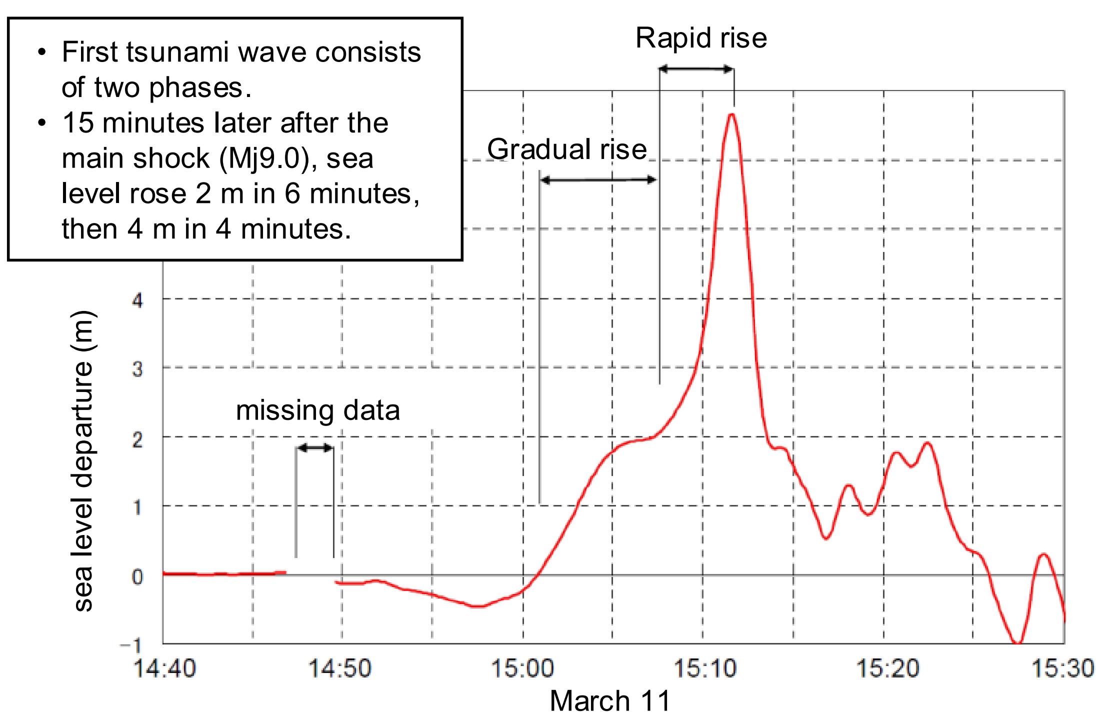


Tsunami waveform record from GPS buoy data off southern Iwate Pref. (204m off Kamaishi)

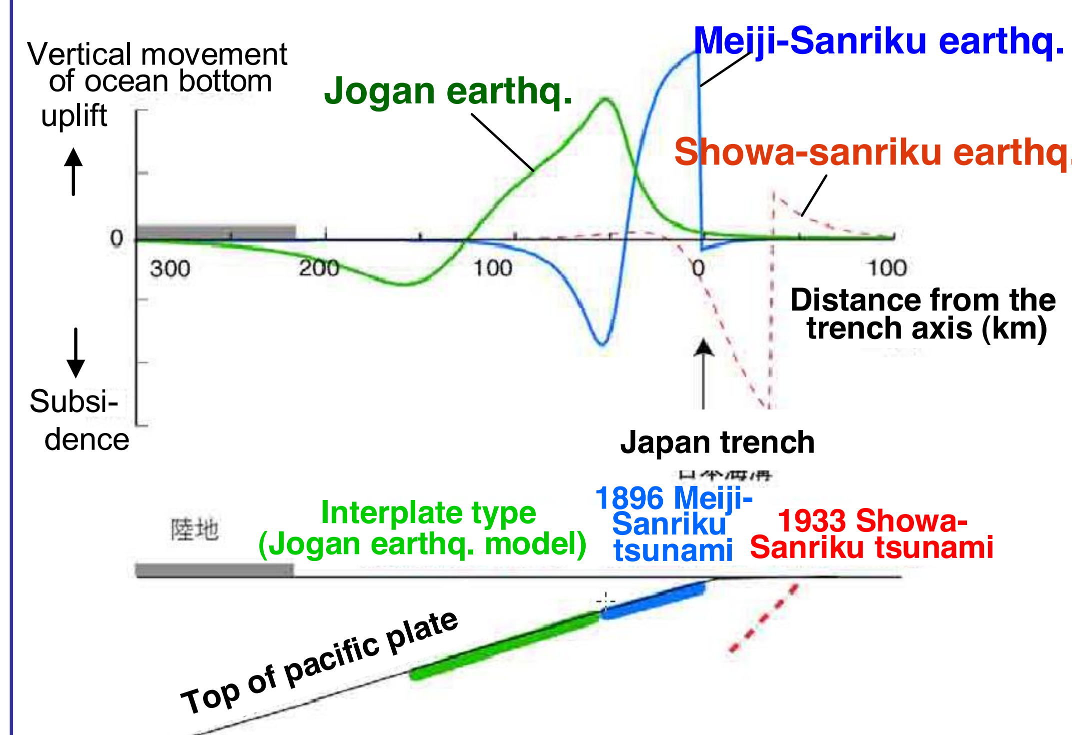


- The maximum wave height was 6.7 m (first wave) off southern Iwate Pref. at 15:12.
- First tsunami wave was extremely high.
- Wave period
  First to third tsunami wave: irregular period
  Fourth to seventh tsunami wave: about 50 minutes period
- Total amount of rose in average sea level were 55 cm after the earthquake.

Reference: Independent Administrative Institute Port and Airport Research Institute

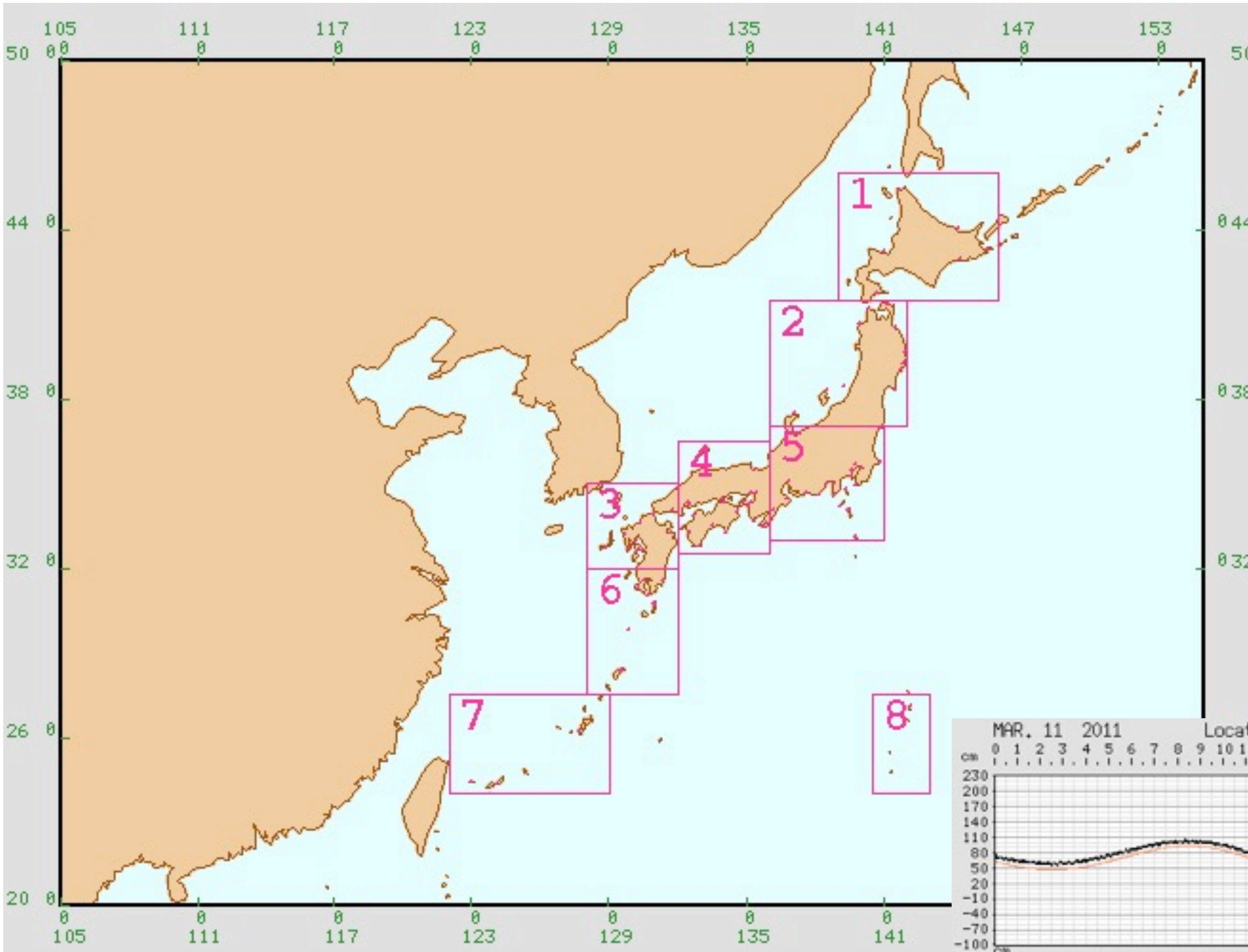


Reference: Independent Administrative Institute Port and Airport Research Institute



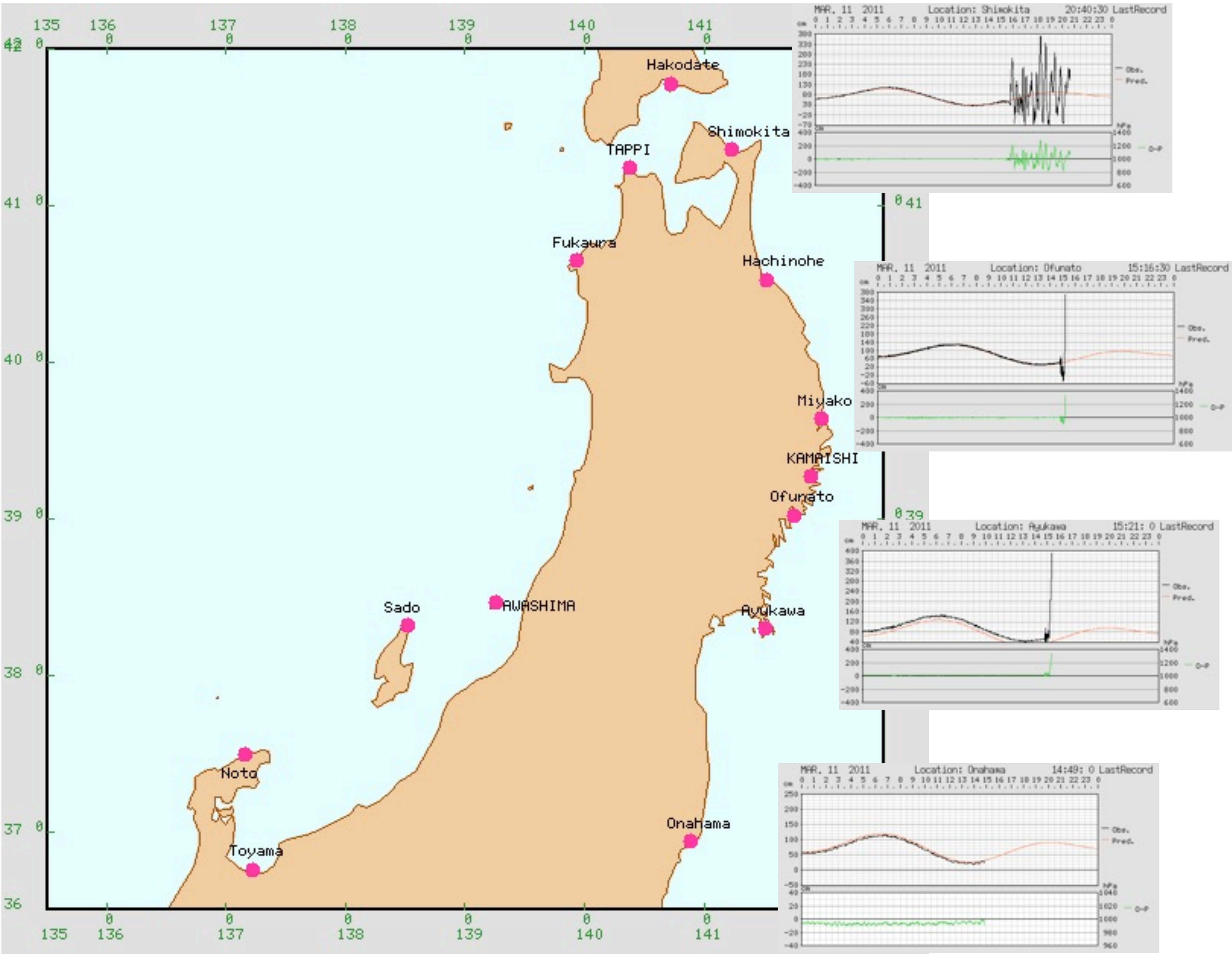
Reference : Satake (2011) Paper preparing for NIED meeting on Apr.17.

Tsunami data



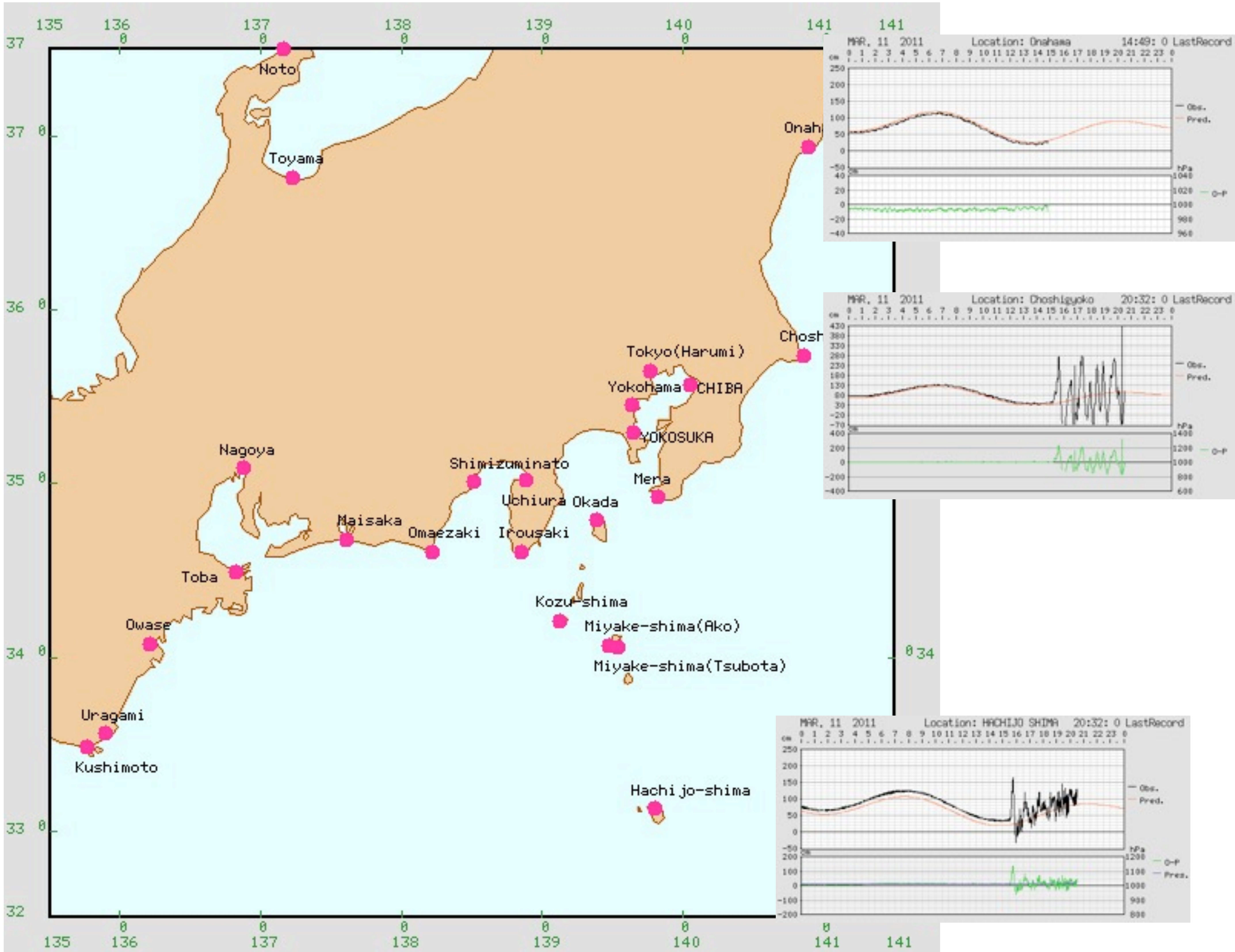
http://www1.kaiho.mlit.go.jp/KANKYO/TIDE/real_time_tide/sel/index_e.htm

Tsunami data



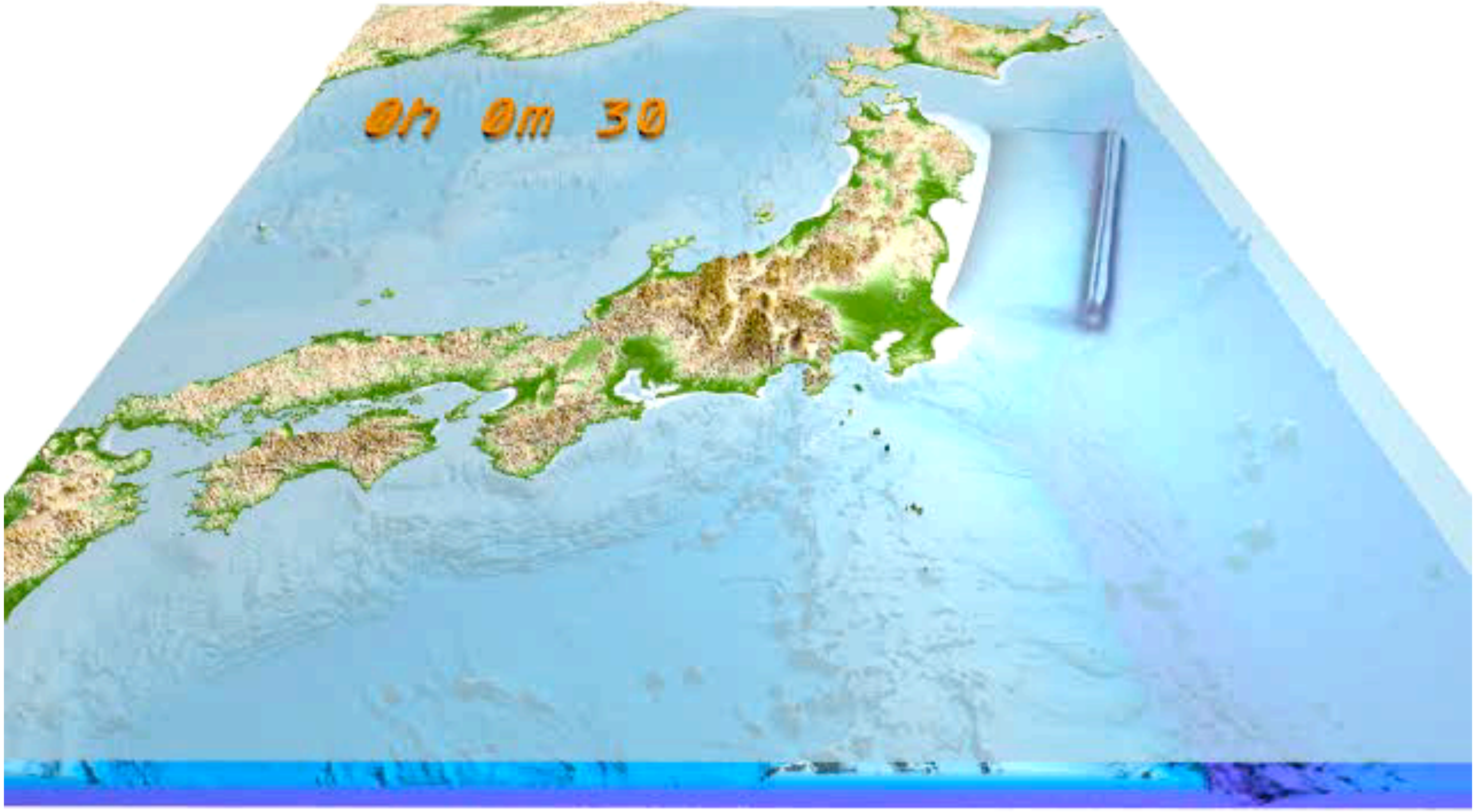
http://www1.kaiho.mlit.go.jp/KANKYO/TIDE/real_time_tide/sel/index_e.htm

Tsunami data - DART buoys



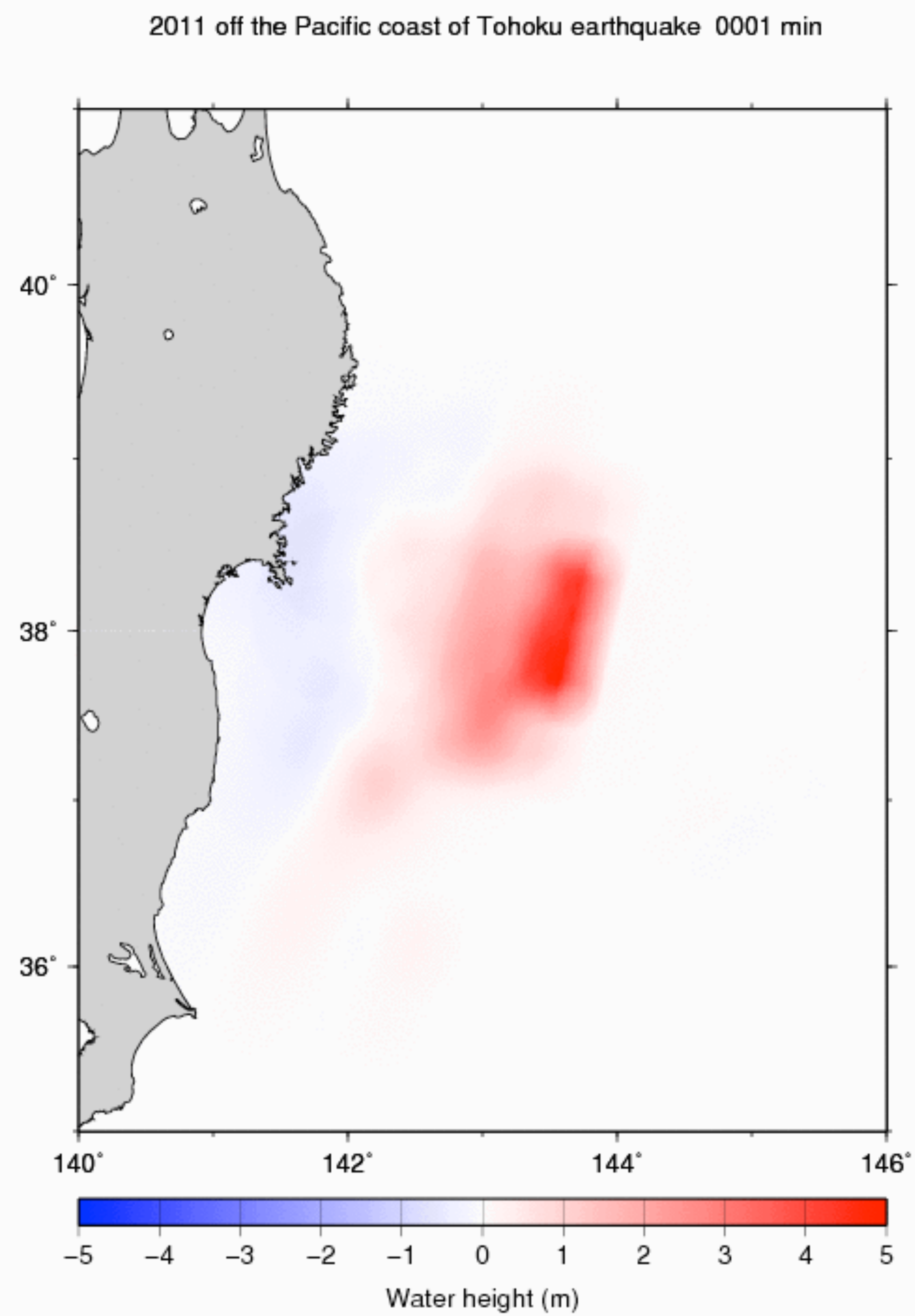
http://www1.kaiho.mlit.go.jp/KANKYO/TIDE/real_time_tide/sel/index_e.htm

Tsunami animation: time scales...



"Earthquake Research Institute, University of Tokyo, Prof. Takashi Furumura and Project Researcher Takuto Maeda"

Tsunami data and simulations: source

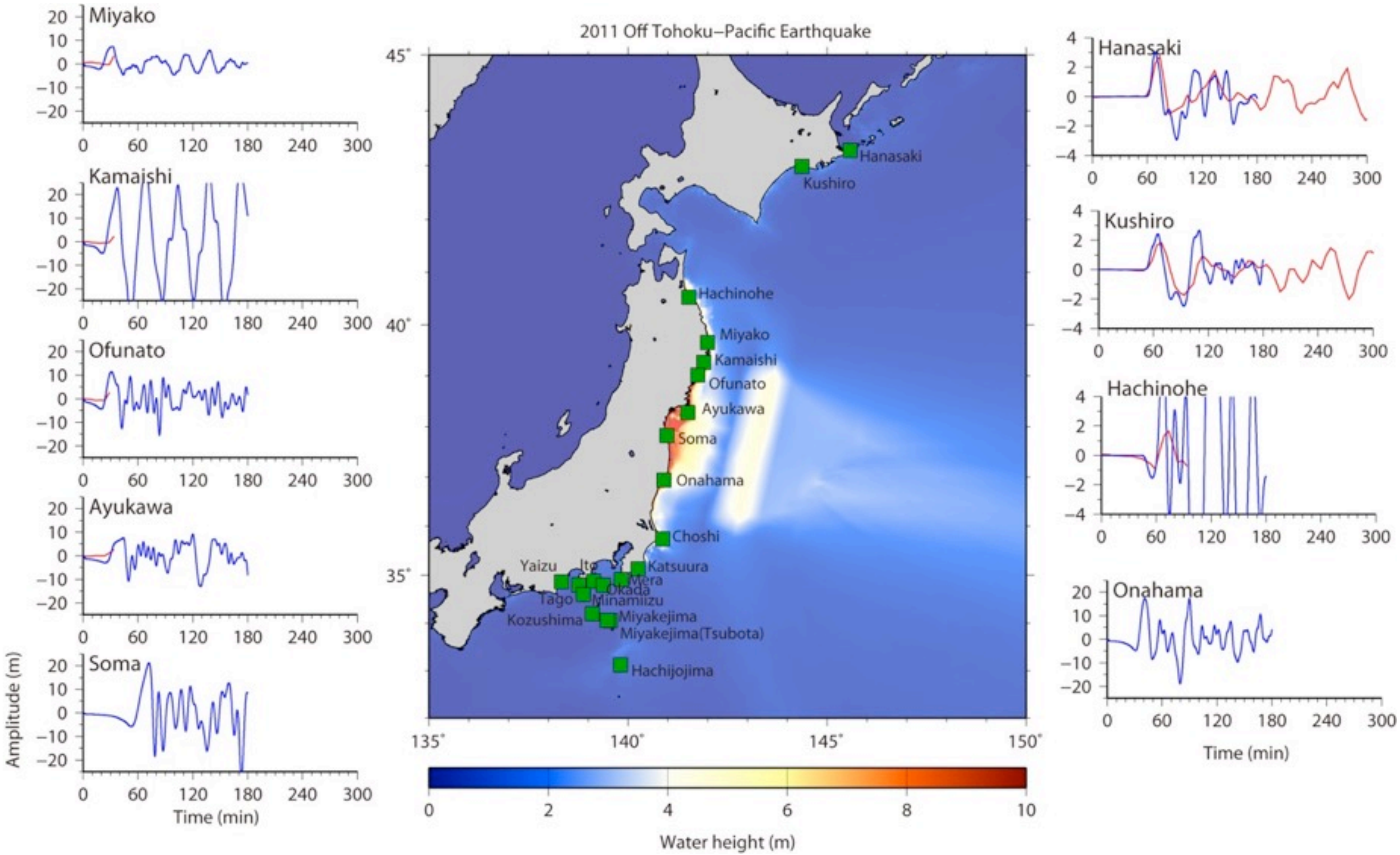


Tsunami Propagation

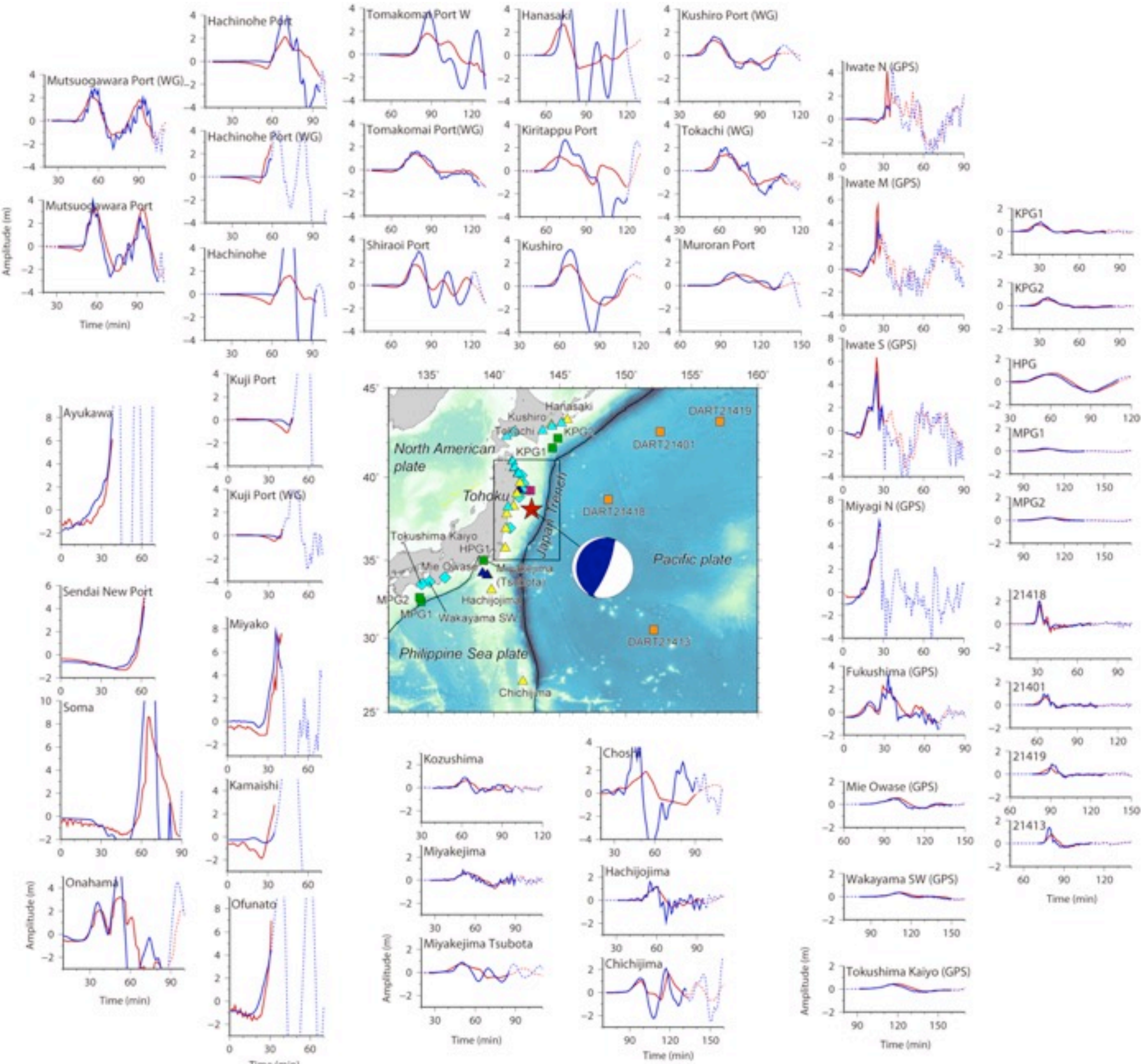
The red color means that the water surface is higher than normal sea level, while the blue means lower.

by Yushiro Fujii (IISEE, BRI) and Kenji Satake (ERI, Univ. of Tokyo)
http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami_inv.html

Tsunami data and simulations



Tsunami data and simulations: source

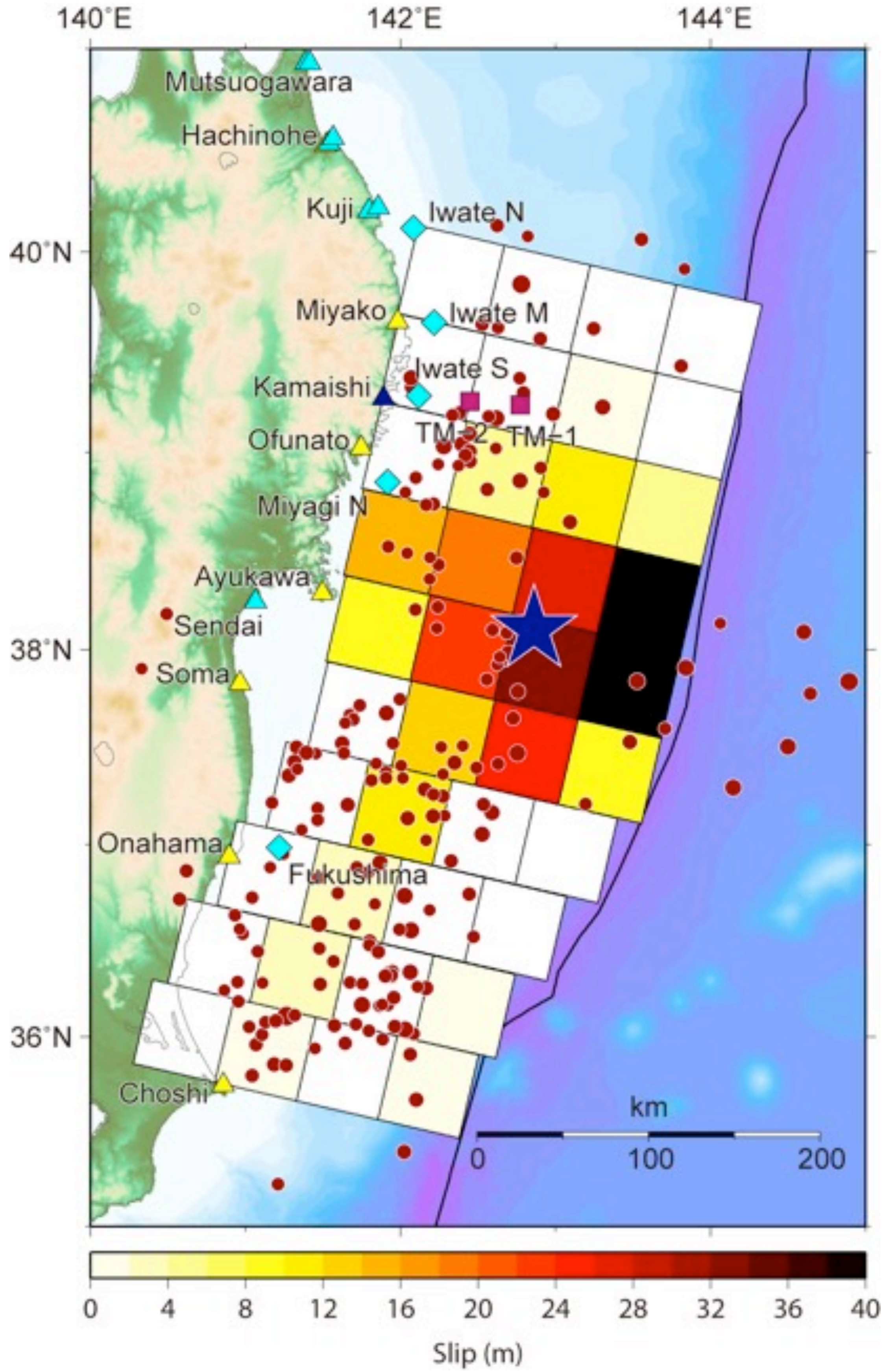


Simulated Tsunami around Japanese coasts

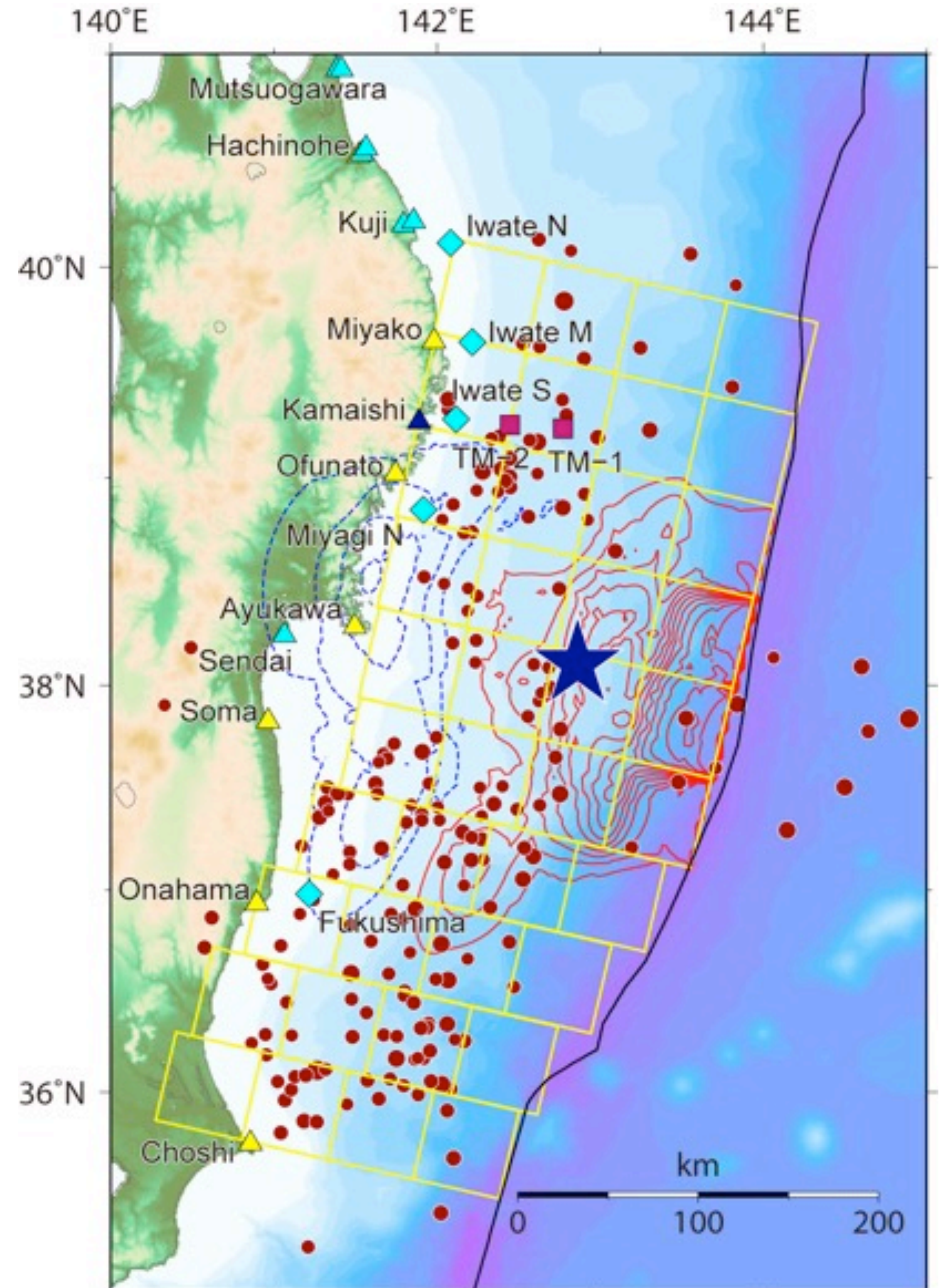
Red and blue lines indicate the observed tsunami waveforms at Japanese tide gauges and ocean bottom tsunami sensors and synthetic ones, respectively. Solid lines show the time windows used for inversion.

by Yushiro Fujii (IISEE, BRI) and Kenji Satake (ERI, Univ. of Tokyo)
http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami_inv.html

Tsunami data and simulations: source



Slip distribution on the fault mode



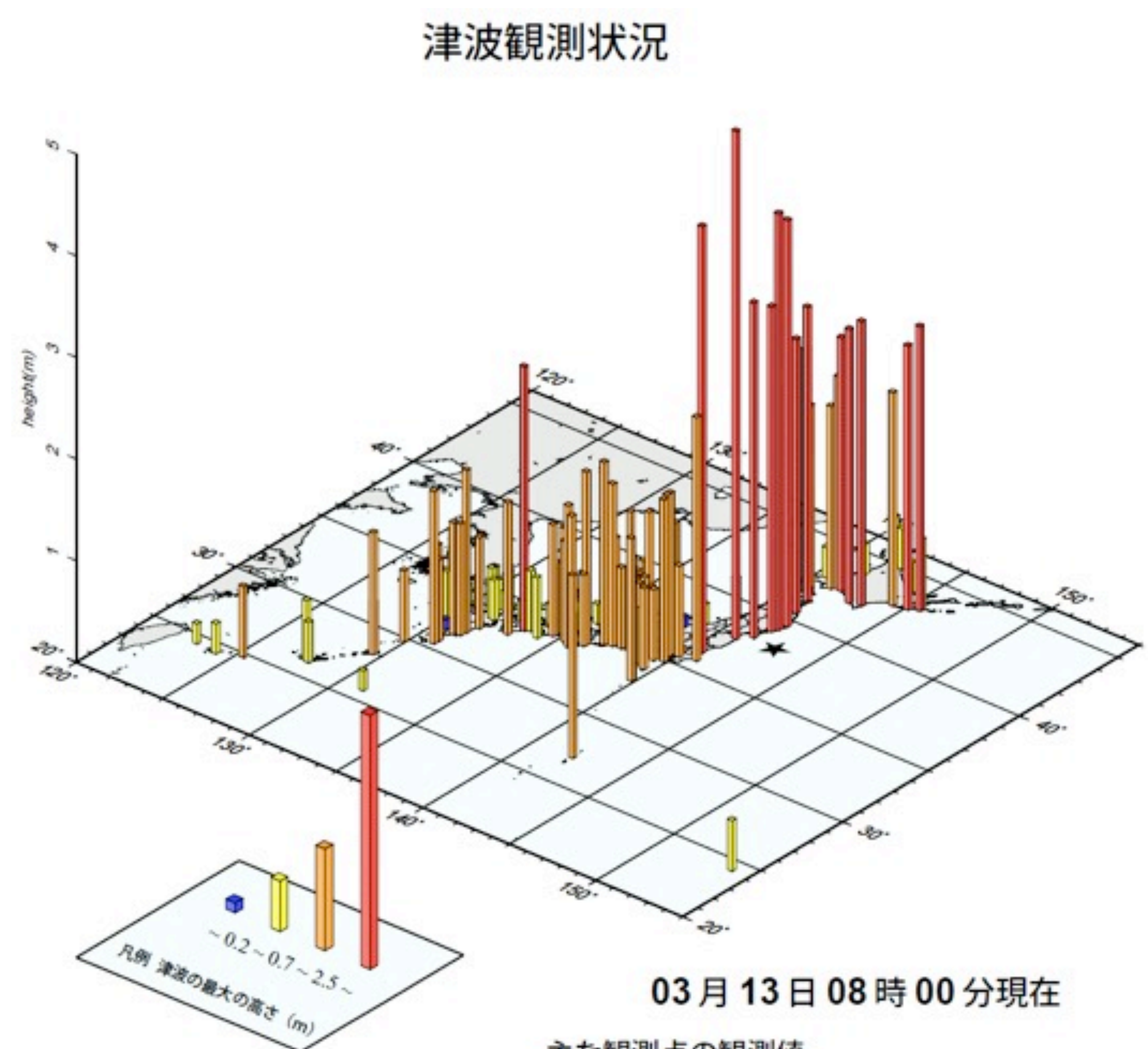
Calculated seafloor deformation due to the fault model

by Yushiro Fujii (IISEE, BRI) and Kenji Satake (ERI, Univ. of Tokyo)
http://iisee.kenken.go.jp/staff/fujii/OffTohokuPacific2011/tsunami_inv.html

Distribution of tsunami heights

Figure from the Headquarters for Earthquake Research Promotion
(at March 13)

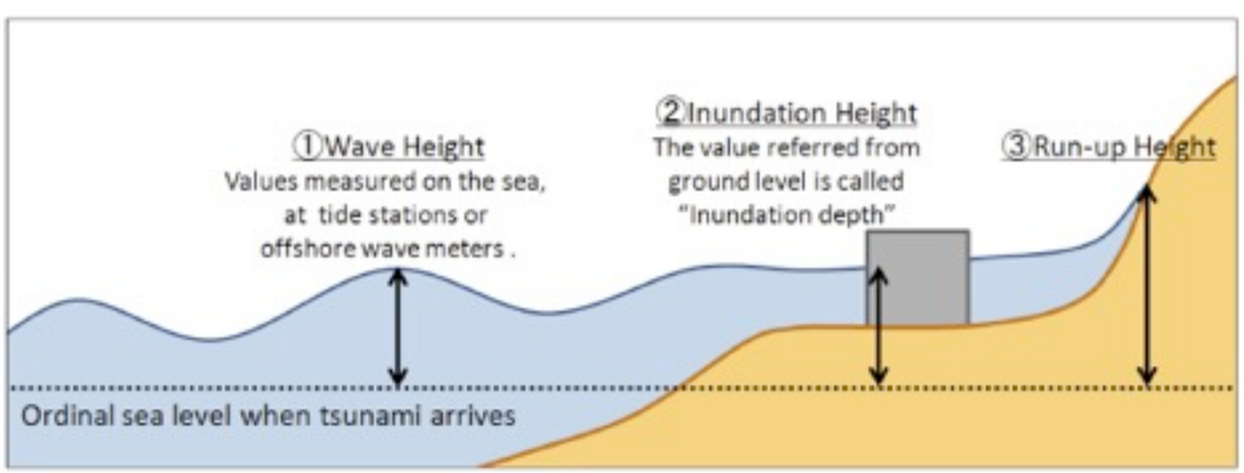
http://www.jishin.go.jp/main/index-e.html



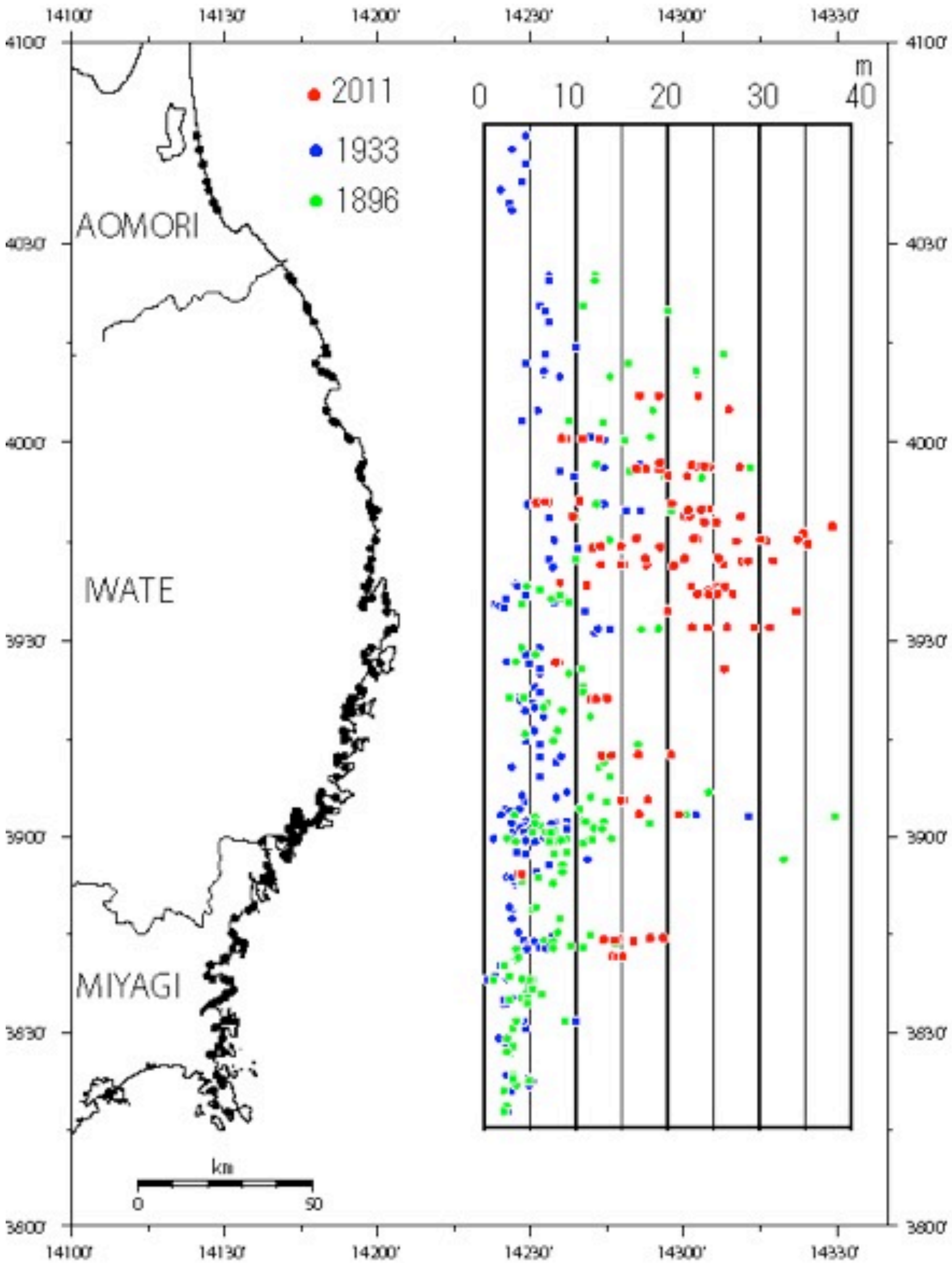
主な観測点の観測値

	第一波			最大波	
相馬	11日 14時 55分	押し	0.3m	11日 15時 50分	7.3m以上
大洗	11日 15時 15分	押し	1.8m	11日 16時 52分	4.2m
釜石	11日 14時 45分	引き	0.1m	11日 15時 21分	4.1m以上
宮古	11日 14時 48分	押し	0.2m	11日 15時 21分	4.0m以上
石巻市鮎川	11日 14時 46分	押し	0.1m	11日 15時 20分	3.3m以上
大船渡	11日 14時 46分	引き	0.2m	11日 15時 15分	3.2m以上
むつ市関根浜	11日 15時 20分	引き	0.1m	11日 18時 16分	2.9m
根室市花咲	11日 15時 34分	引き	微弱	11日 15時 57分	2.8m
十勝港	11日 15時 26分	引き	0.2m	11日 15時 57分	2.8m以上
浦河	11日 15時 19分	引き	0.2m	11日 16時 42分	2.7m

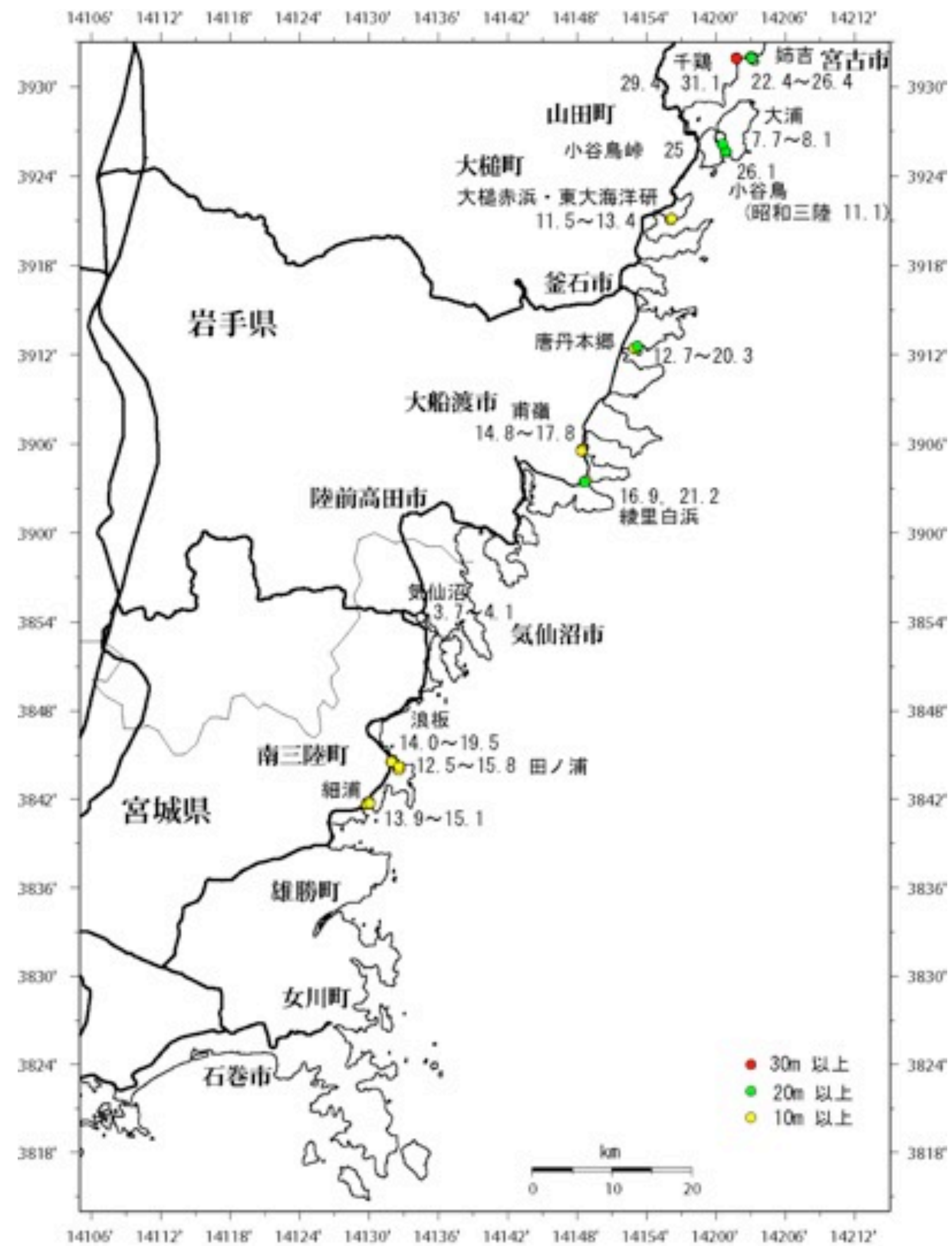
気象庁作成



Distribution of tsunami heights



Northern sanriku – comparison with the tsunami in Meiji period and Showa period



Southern Sanriku

By: Dr.Tsuji, Dr.Satake, Project Researcher: Ishibe, Project Researcher: Nishiyama

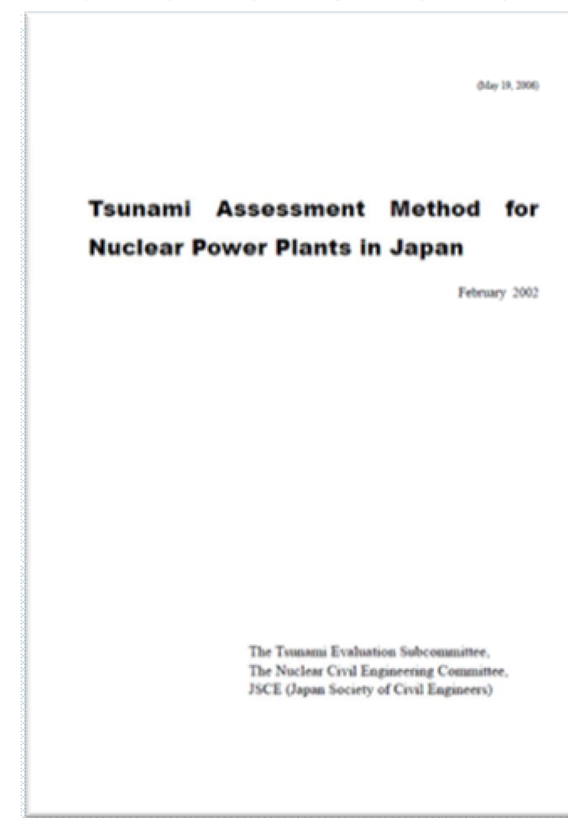
Tsunami Assessment method for NPP in JSCE, Japan

The TSUNAMI EVALUATION SUBCOMMITTEE,
Nuclear Civil Engineering Committee, JSCE

Masafumi Matsuyama (CRIEPI)

History of TES

- Phase I 1999-2000
  The maximum and minimum water levels by deterministic method
  → "Tsunami assessment method for NPP in Japan」（2002）"
- Phase II 2003-2005
  Probabilistic Tsunami Hazard Analysis for the max. and min. water levels
  Numerical simulation of nonlinear dispersion wave theory with soliton fission and split wave-breaking
  Tsunami wave force on breakwater
- Phase III 2006-2008
  Topography change due to tsunami
  Development of probabilistic Tsunami Hazard Analysis
- Now → Phase IV 2009-2011
  Revising of 「Tsunami assessment method for NPP in Japan」


(May 19, 2006)

Tsunami Assessment Method for Nuclear Power Plants in Japan

February 2002

The Tsunami Evaluation Subcommittee,
The Nuclear Civil Engineering Committee,
JSCE (Japan Society of Civil Engineers)

Niigata meeting, November 2010
http://www.jnes.go.jp/seismic-symposium10/presentationdata/3_sessionB.html

Tsunami Assessment method for NPP in JSCE, Japan

The TSUNAMI EVALUATION SUBCOMMITTEE,
Nuclear Civil Engineering Committee, JSCE

Masafumi Matsuyama (CRIEPI)

Deterministic method (2002)
Main flow chart

Sub flow 1

Verification of fault model(s) and numerical calculation system on the basis of historical tsunami(s)

↓

Sub flow 2

Estimation of the design water levels on the basis of **parametric study** in terms of basis tsunamis

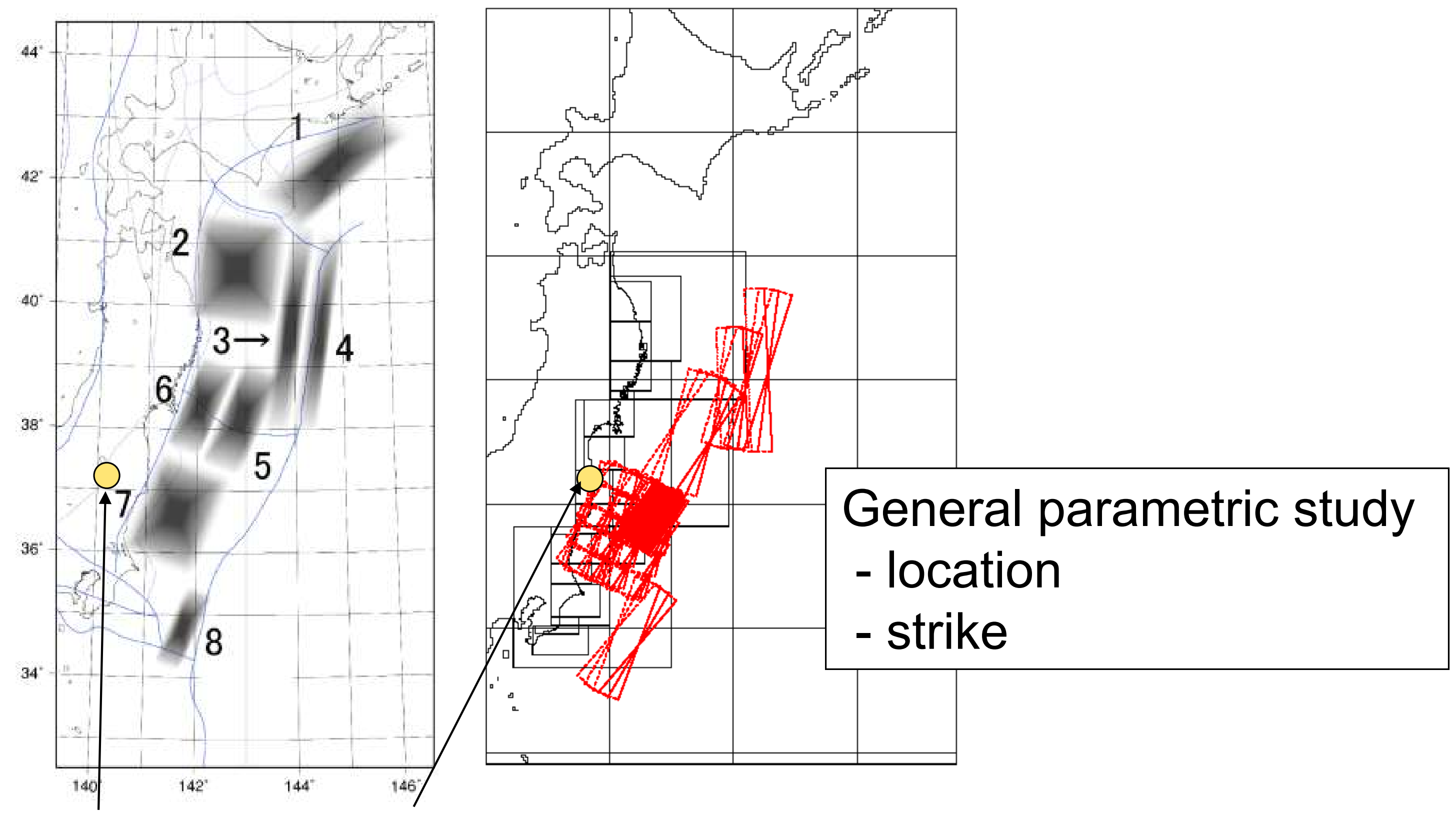
↓

tide → Design high water level / Design low water level

↓

End

General parametric study in the near field

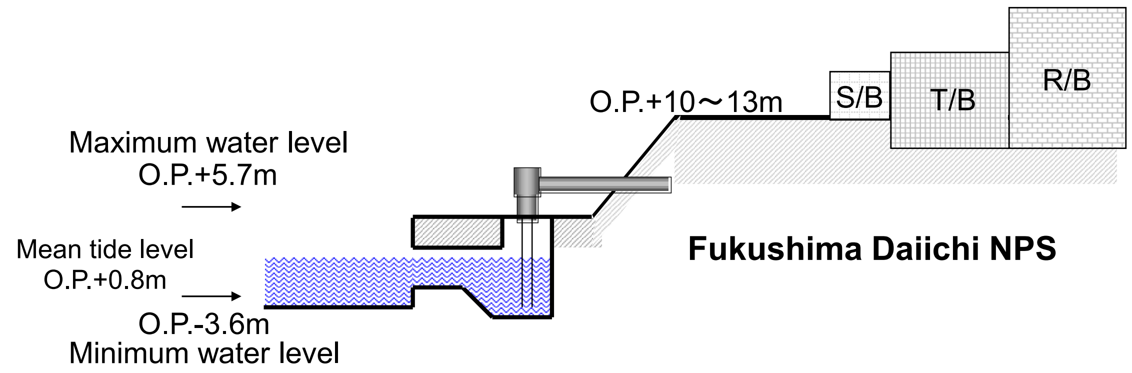


Fukushima Daiichi NPS

東京電力

Summary of Evaluation

Maximum water level = 4.4m + O.P.＋1.3m = O.P.+5.7m
Minimum water level = -3.6m – O.P.±0.0m = O.P.-3.6m



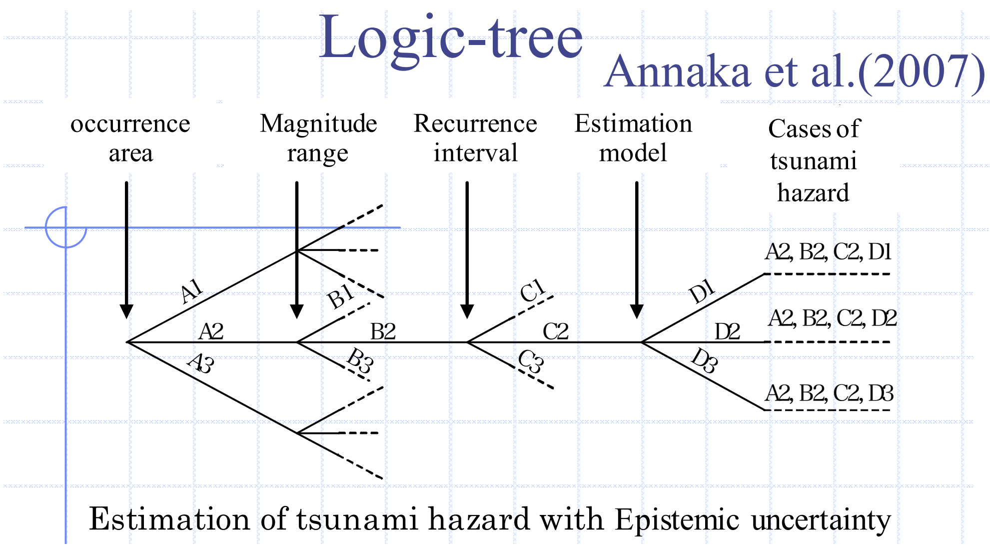
We assessed and confirmed the safety of the nuclear plants based on the JSCE method which was published in 2002.

Niigata meeting, November 2010
http://www.jnes.go.jp/seismic-symposium10/presentationdata/3_sessionB.html

Tsunami Assessment method for NPP in JSCE, Japan

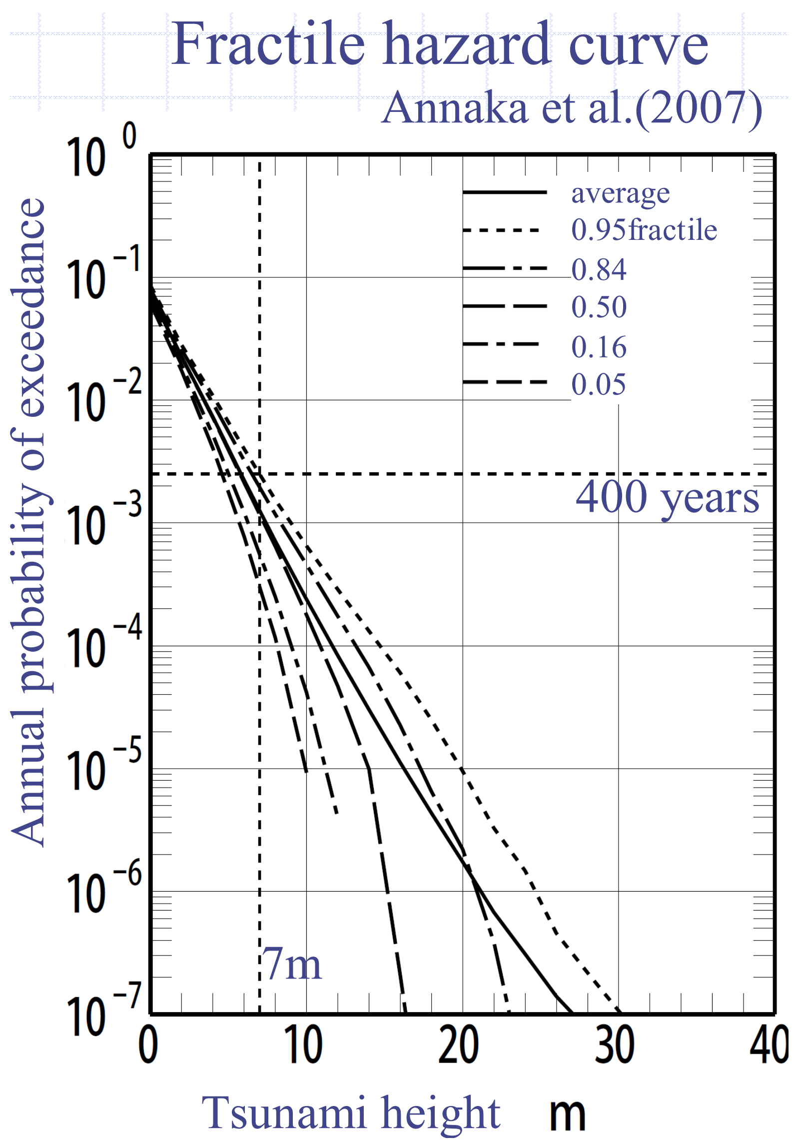
The TSUNAMI EVALUATION SUBCOMMITTEE,
Nuclear Civil Engineering Committee, JSCE

Masafumi Matsuyama (CRIEPI)



Probabilistic Tsunami Hazard Analysis (PTHA)

- Probabilistic estimation of tsunami risk
  - Estimation of the <u>deterministic</u> design tsunamis
- Considering uncertainties in estimation
  - Errors in fault parameters
  - Errors in the numerical calculation system (numerical simulation, topography data)
  - Incomplete knowledge and data about the earthquake process



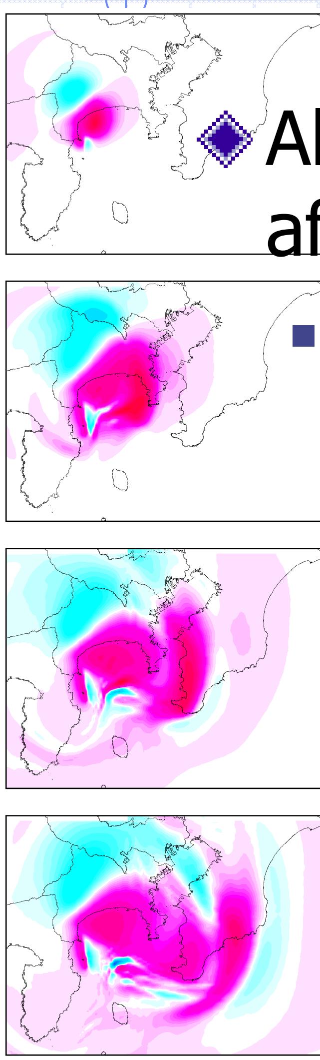
Niigata meeting, November 2010
http://www.jnes.go.jp/seismic-symposium10/presentationdata/3_sessionB.html

Tsunami Assessment method for NPP in JSCE, Japan

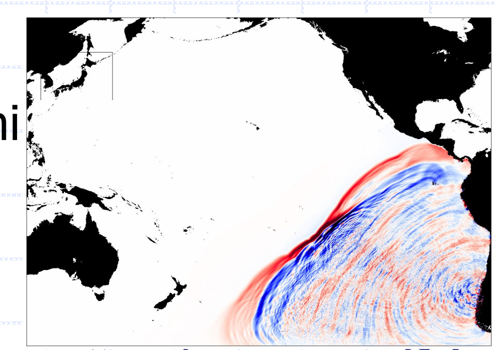
The TSUNAMI EVALUATION SUBCOMMITTEE,
Nuclear Civil Engineering Committee, JSCE

Masafumi Matsuyama (CRIEPI)

A brief review of recent activities



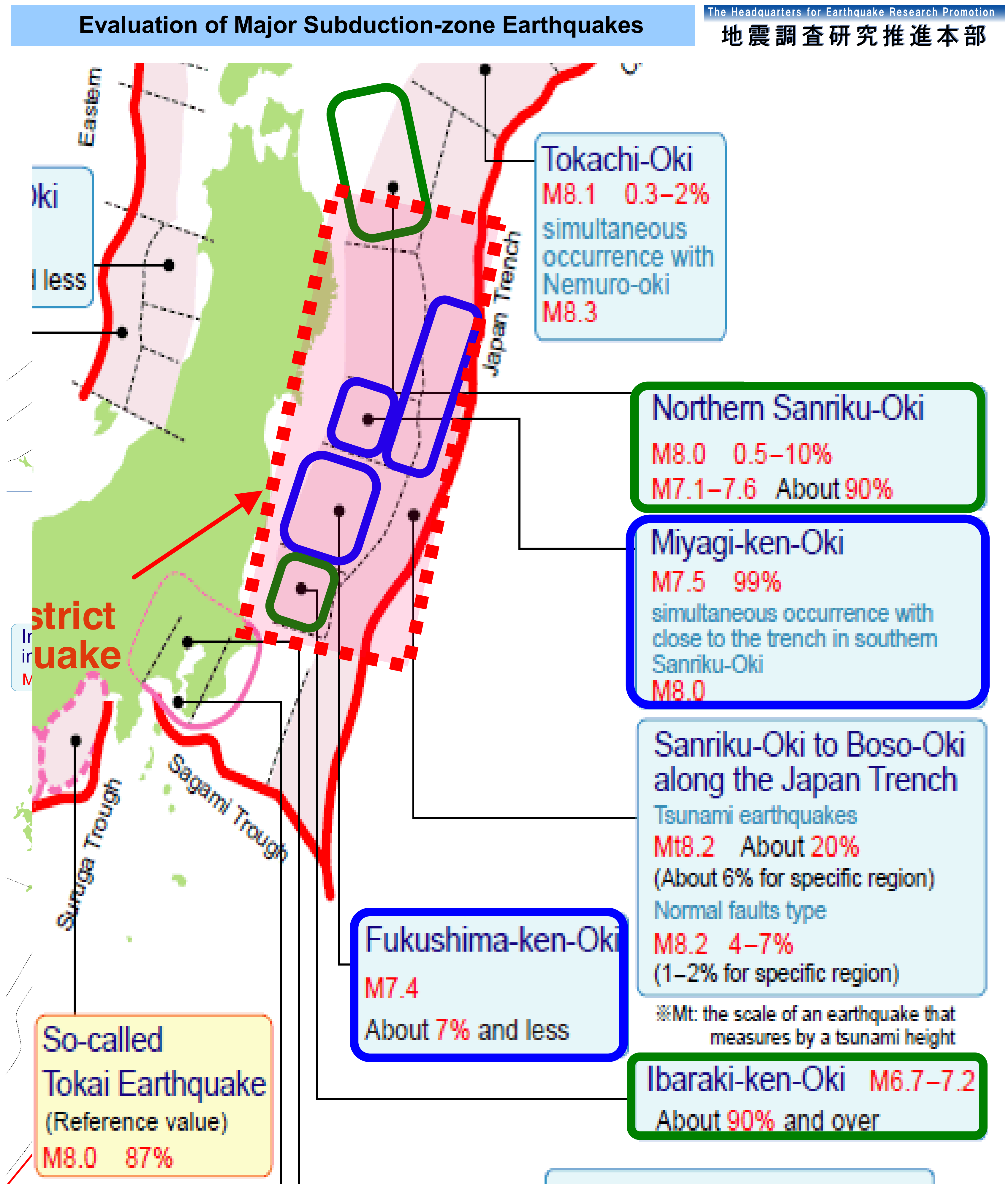
- Almost ten years have passed after tsunami manual released.
  - Recent advances and new knowledge
    - Tsunami source model (fault model)
      - Re-evaluation of historical tsunami faults
      - Spatial inhomogeneity in terms of slip
    - Numerical simulation
      - New simulation method of crustal motion (GMS, Grand Motion Simulator by NIED*)
      - New simulation method of far field tsunami
        - Nonlinear dispersion theory



*National Research Institute for Earth Science and Disaster Prevention, Japan

Niigata meeting, November 2010
http://www.jnes.go.jp/seismic-symposium10/presentationdata/3_sessionB.html

Expectations...

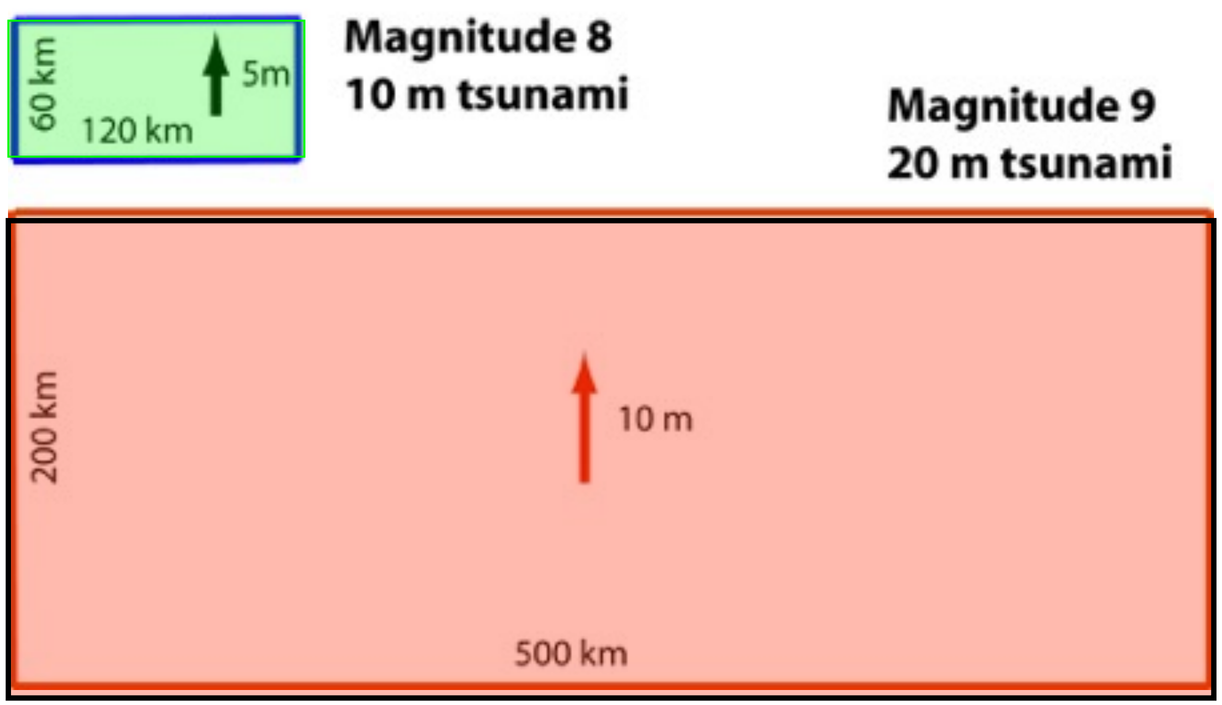


"Estimated magnitude and long-term possibilities within 30 years of earthquakes on regions of offshore based on Jan. 1, 2011."

"Estimated magnitude and long-term possibilities within 30 years of earthquakes on regions of offshore based on Jan. 1, 2008."

Reality...

Planning assumed maximum magnitude 8 Seawalls 5-10 m high



Tsunami runup approximately twice fault slip

M9 generates much larger tsunami

Stein, S. and E. Okal, The size of the 2011 Tohoku earthquake needn't have been a surprise, EOS, 92, 227-228, 2011.

Sea gate in Hachinohe

http://minkara.carview.co.jp/userid/405365/car/375387/1923923/photo.aspx

Sea gate (9.3 m high)

http://ja2xt.mu-sashi.com/Numazu5.htm

Sea walls

Sea wall with stairway evacuation route used to protect a coastal town against tsunami inundation in Japan.

Photo courtesy of River Bureau, Ministry of Land, Infrastructure and Transport, Japan.

Elevated platform used for tsunami evacuation that also serves as a high-elevation scenic vista point for tourist.

Okushiri Island, Japan. Photo courtesy of ITIC

Deepest breakwater in Kamaishi (Iwate)

Tsunami walls...

The 2.4 km long tsunami wall in Miyako, Iwate Prefecture, was destroyed. The 6 m, 2 km long, wall in Kamaishi, Iwate Prefecture, was overwhelmed but delayed the tsunami inundation by 5 minutes.

The 15.5 m tsunami wall in Fundai, Iwate Prefecture, provided the best protection, but it is good to know that the original design was only 10 m. The village mayor fought to make it higher from information in the village historical records.

The biggest problem is that tsunami walls may give a false sense of security and other preparedness measures may NOT be undertaken.

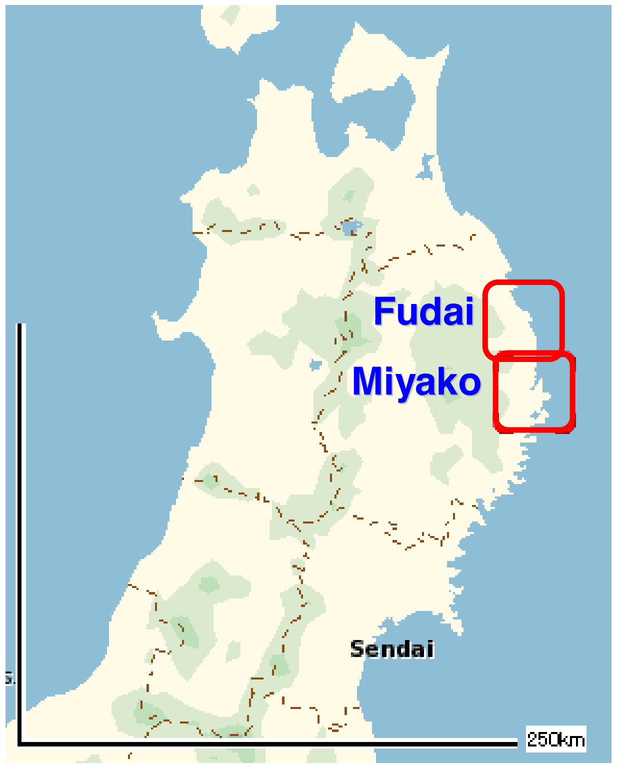
Woody Epstein, 2011

Sea wall at Fudai

49 foot sea wall:
completed in 1967; floodgates were added in 1984.

Following the 1896 Meiji tsunami, village mayor Kotoku Wamura pressed for a seawall at least 15 meters high, often repeating the tales handed down to him growing up: that the devastating tsunami was 15 meters.

Miyako and Fudai...



The 10m-high seawall was destroyed in Taro district, Miyako city, Iwate Pref.

The 15.5m-high seawall was undestroyed in Otabe district, Fudai village, Iwate Pref.

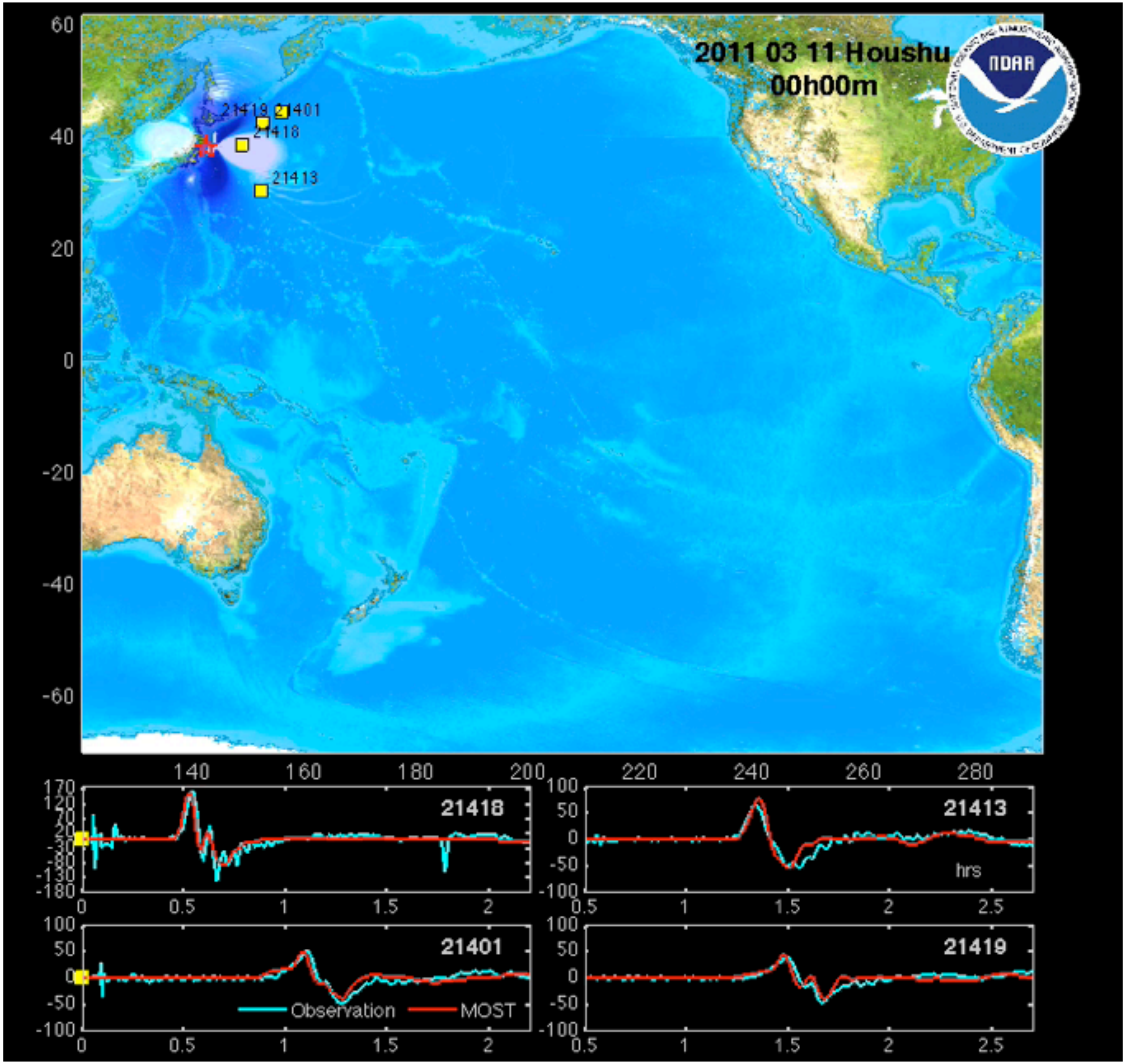
Fig. III-1-16 Difference of seawall heights resulting in different consequence.

A photo from the village's point of view (i.e. facing the coast)

A photo from a viewpoint of facing the village taken at the spot slightly below the stone monument

Tsunami stones
(Tsunami-seki)

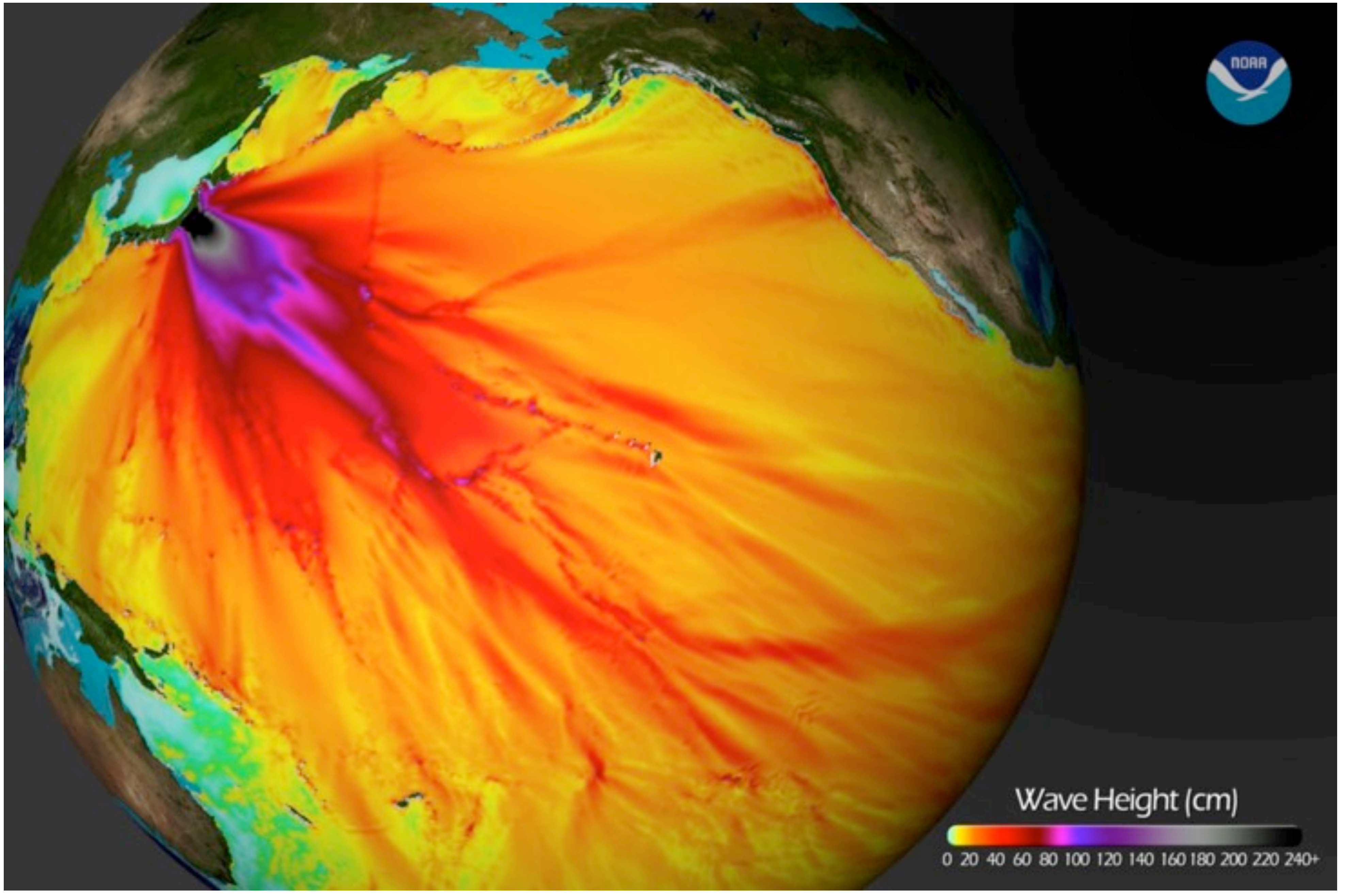
Tsunami animation - NOAA



https://www.ngdc.noaa.gov/hazard/11mar2011.html

Propagation forecast

A tsunami propagation forecast model contours the forecasted maximum wave amplitudes (in cm) from the tsunami detailing the tsunami energy propagation.



This led to a Pacific wide tsunami warning being issued.

Tsunami warning - NOAA

severe Widespread Warning, Watch, or Advisory in Effect
Click here to read the latest tsunami message.

All Regions | Pacific Ocean | Hawai'i | Indian Ocean | Caribbean Sea

Message pacific.2011.03.11.103059

Tsunami Information

Message Time:	11 Mar 2011 10:30 UTC
Message Num:	6
Message Text:	click to read
Message Type:	a Widespread Tsunami Warning is in Effect
Warning:	Japan, Russia, Marcus Is., N. Marianas, Guam, Wake Is., Taiwan, Yap, Philippines, Marshall Is., Belau, Midway Is., Pohnpei, Chuuk, Kosrae, Indonesia, Papua New Guinea, Nauru, Johnston Is., Solomon Is., Kiribati, Howland-baker, Hawaii, Tuvalu, Palmyra Is., Vanuatu, Tokelau, Jarvis Is., Wallis-futuna, Samoa, American Samoa, Cook Islands, Niue, Fiji, New Caledonia, Tonga, Mexico, Kermadec is, Fr. Polynesia, Pitcairn, Guatemala, El Salvador, Costa Rica, Nicaragua, Antarctica, Panama, Honduras, Chile, Ecuador, Colombia, Peru
Watch:	
ETAs / Obs:	measurements

Earthquake Information

	Preliminary (PTWC)	Official (USGS)
Origin Time:	11 Mar 2011 05:46 UTC	11 Mar 2011 05:46 UTC
Magnitude:	8.9 Mwp (reviewed by PTWC)	7.9
Latitude:	38.3° N	38.3° N
Longitude:	142.4° E	142.4° E
Depth:	24 km (14.9 mi)	24.4 km (15.2 mi)

Location: Near East Coast of Honshu Japan

More Info.: updated earthquake information from the USGS NEIC