2020.11.6
第4回国際津波防災学会総会
4thGeneral Assembly Meeting

International Tsunami Disaster Prevention Society (ITDPS)

1923年関東地震時における海底地すべりの発生可能性と津波波源分析

Possibility of submarine landslide and analysis of tsunami source in 1923 Great Kanto earthquake

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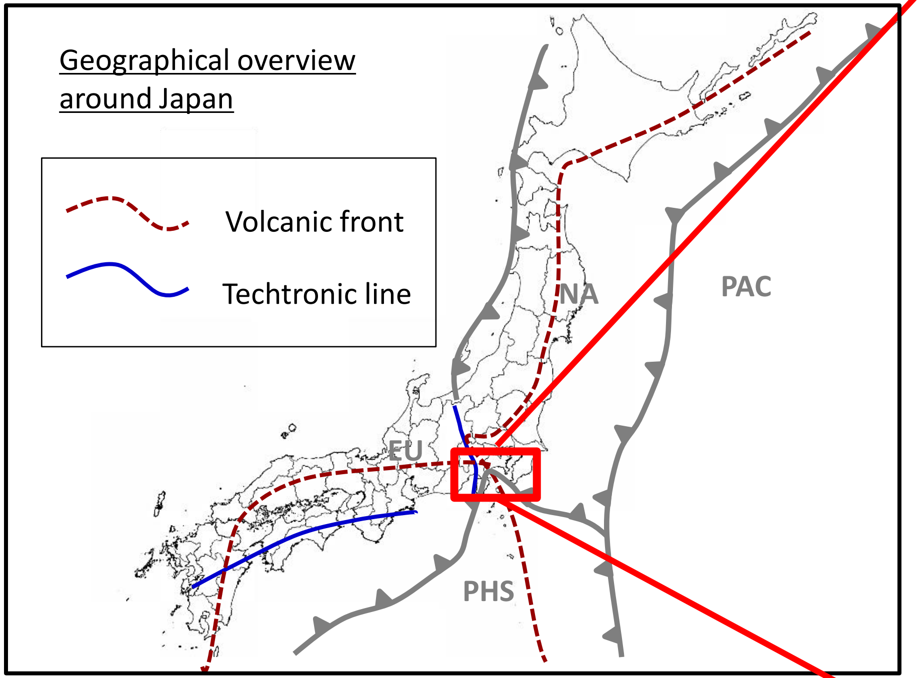
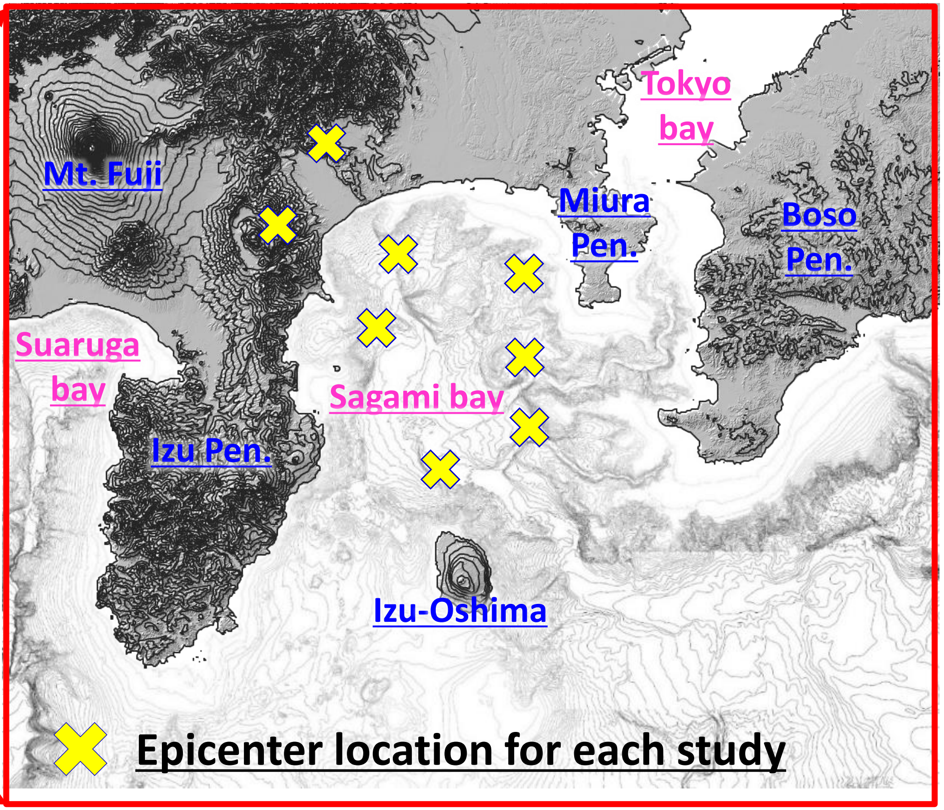
/Port and Airport Research Institute(PARI), Japan

1923年大正関東地震津波について/1923 Kanto earthquake tsunamis

- September 1, 1923, Magnitude：7.9-8.1(Mj)
- 死傷者数（Casualties）：105,385人（行方不明者含）→2011 tsunamis：24,585人（警視庁）
- 日本の災害史上最悪のイベント /One of the huge damage event in Japan



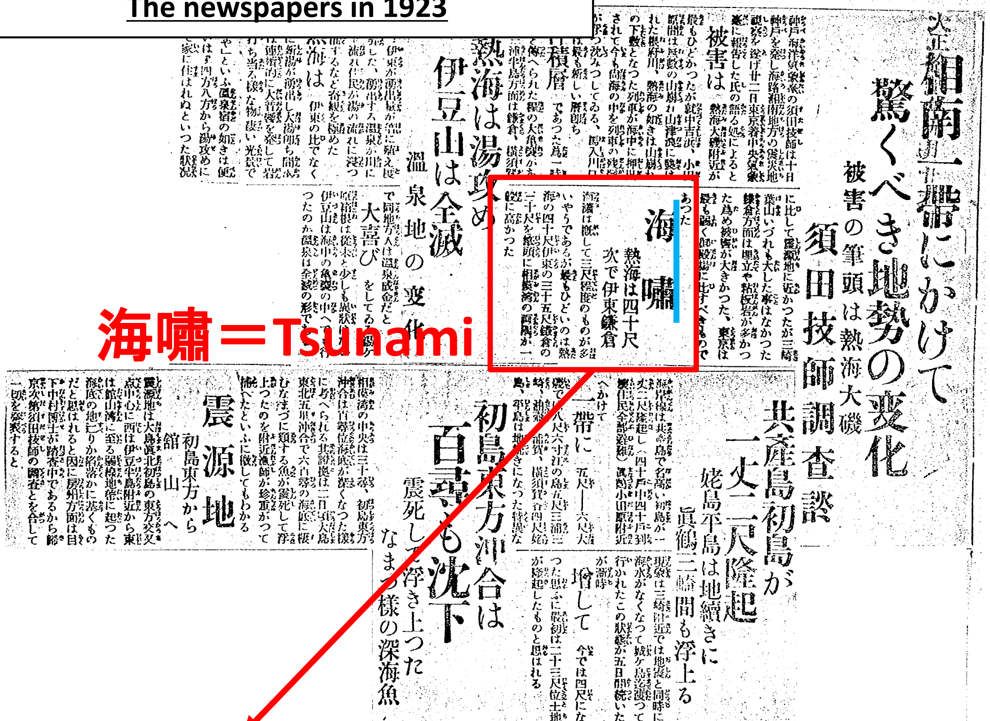


Imamura(1924), Turner(1927), Utsu(1979), Matsuzawa(1928), Gutenberg, Richter(1954), Usami(1966), Kanamori, Miyamura(1970), Hamada(1986)

1923年大正関東地震津波について/1923 Kanto earthquake tsunamis

The newspapers in 1923

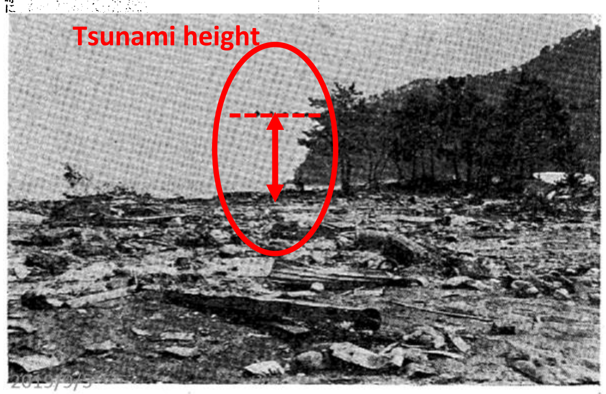
ref : http://www.herpl.adep.or.jp/


相模湾一帯にかけて驚くべき地勢の変化
被害の筆頭は熱海大磯
須田技師調査談
共産島初島が一丈二尺隆起
姥島平島は地続きに 真鶴二瞬間も浮上る
初島東方沖合は百尋も沈下
震死して浮き上つた なまづ様の深海魚
震源地 初島東方から館山へ
伊豆山は全滅 温泉地の変化
熱海は湯攻め
海嘯 熱海は四十尺 次で伊東鎌倉

海嘯＝Tsunami

熱海（Atami）	: 40尺≒12m
伊東（Ito）	: 30尺≒9m
鎌倉（Kamakura）	: 35尺≒10m

A huge tsunami attacked in Atami and Kamakura



Kamakura, Yuigahama

Ref: Kamakura Citizens Net, http://www.kcn-net.org/oldnew/index.html

1923年大正関東地震津波について/1923 Kanto earthquake tsunamis

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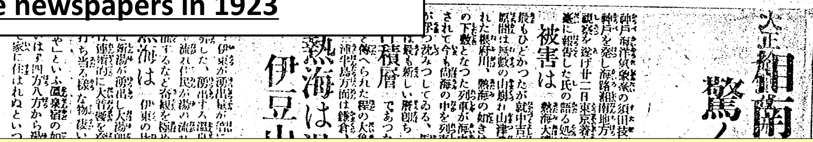
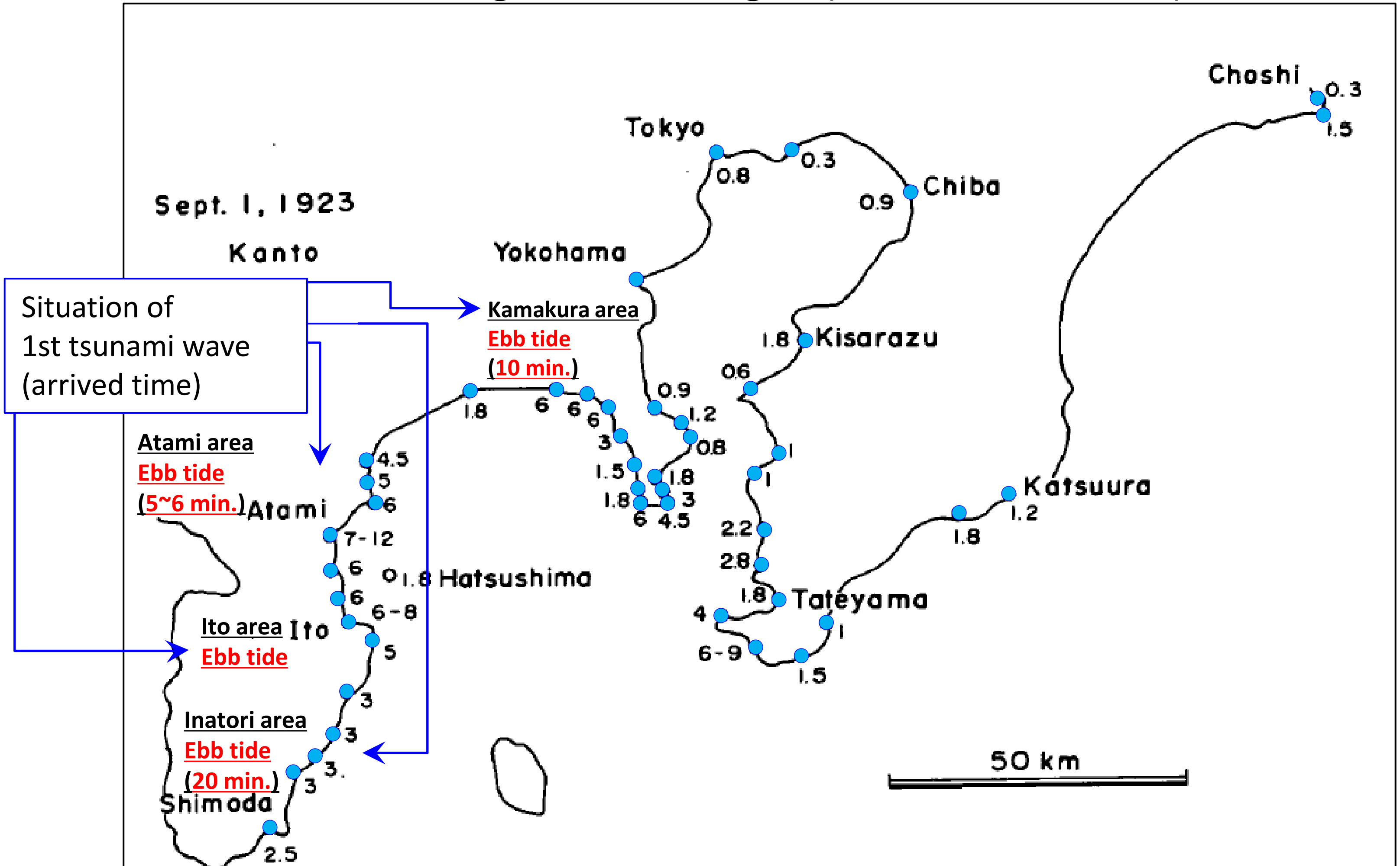


A huge tsunami attacked in Atami and Kamakura

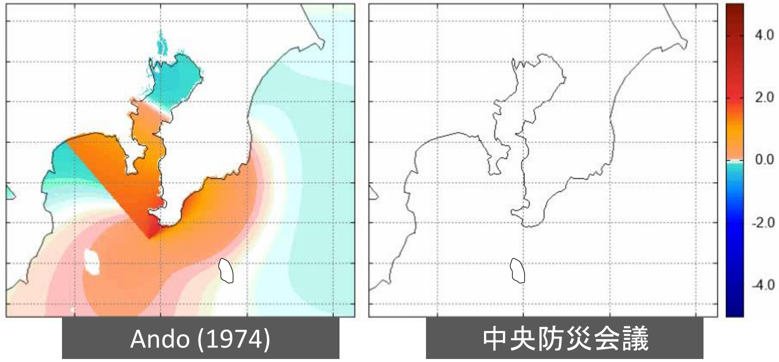
Ref: Kamakura Citizens Net, http://www.kcn-net.org/oldnew/index.html

Recording tsunami heights(Hatori et al., 1979)

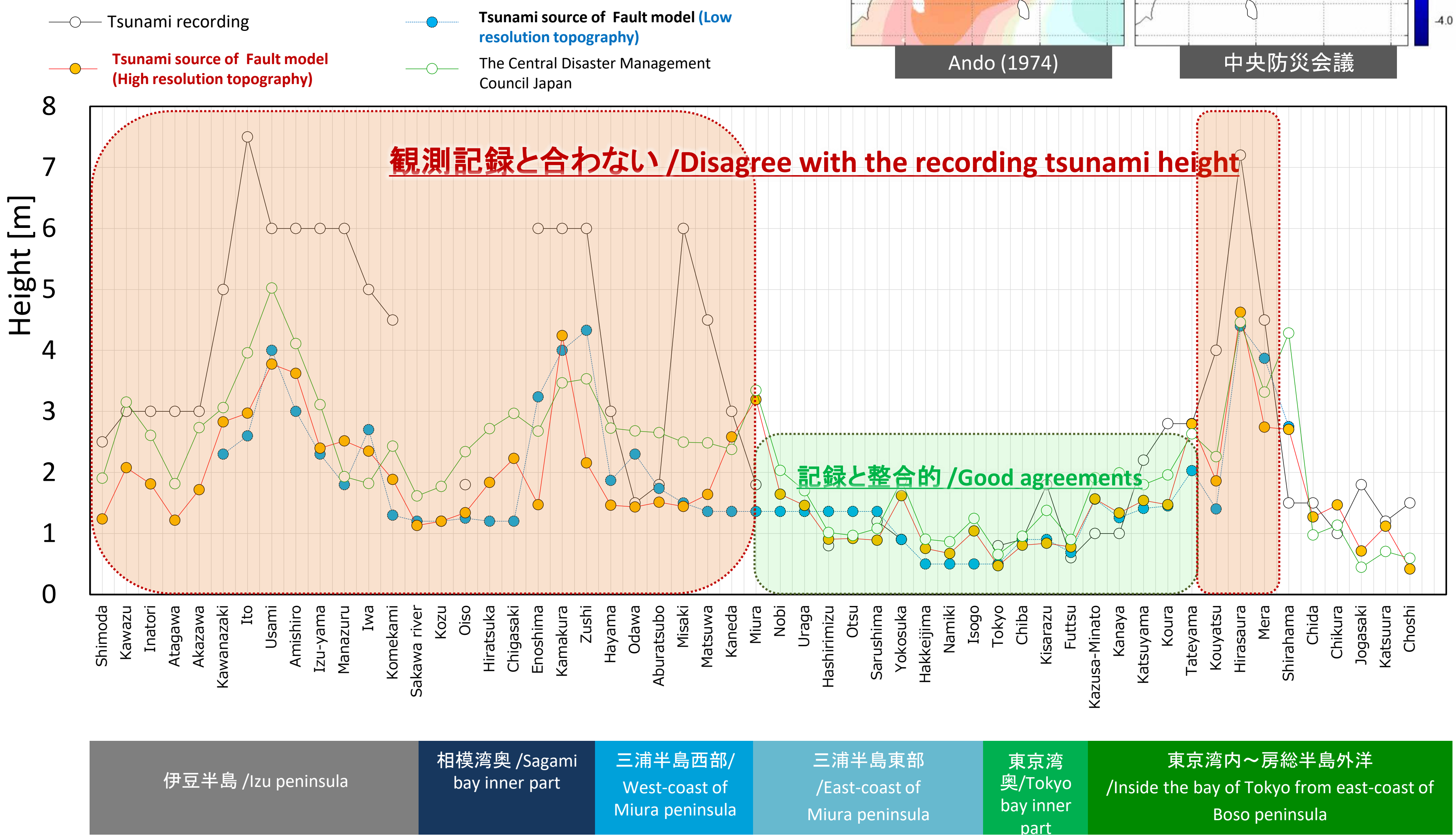


羽鳥ら(1979):関東地方の津波, 津波ディジタルライブラリィ, http://tsunami-dl.jp/document/170

各断層モデルに基づく再検証/ Recalculation based on each fault model

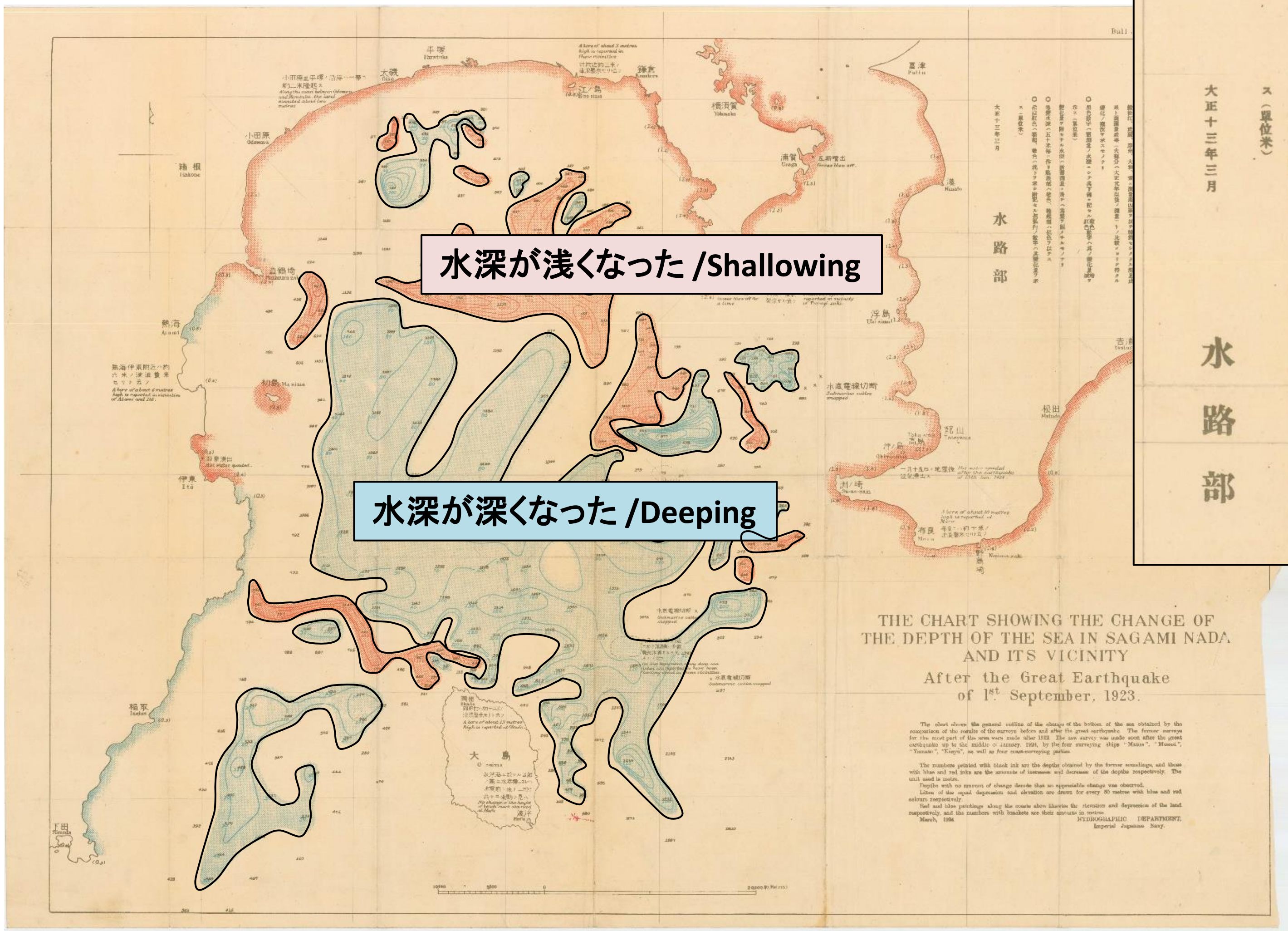


各地点の津波高の比較 /MAXIMUM TSUNAMI HEIGHT

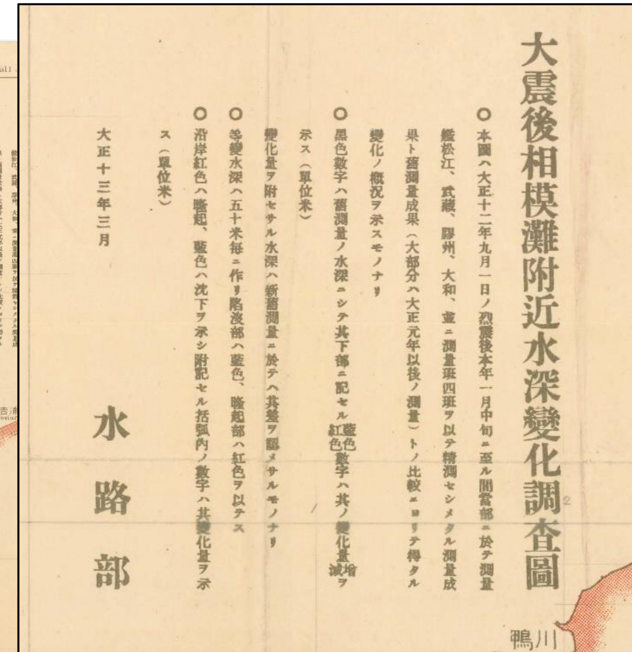


相模湾/東京湾口の海底地形変化
The depth change of Sagami bay and Tokyo bay

関東地震1923年による相模湾の水深変化
/The depth change in Sagami bay due to the 1923 Great Kanto earthquake

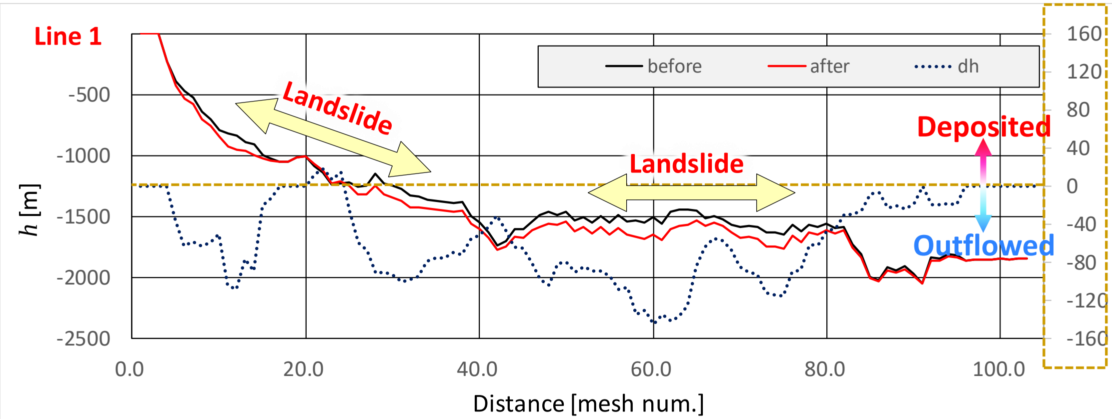


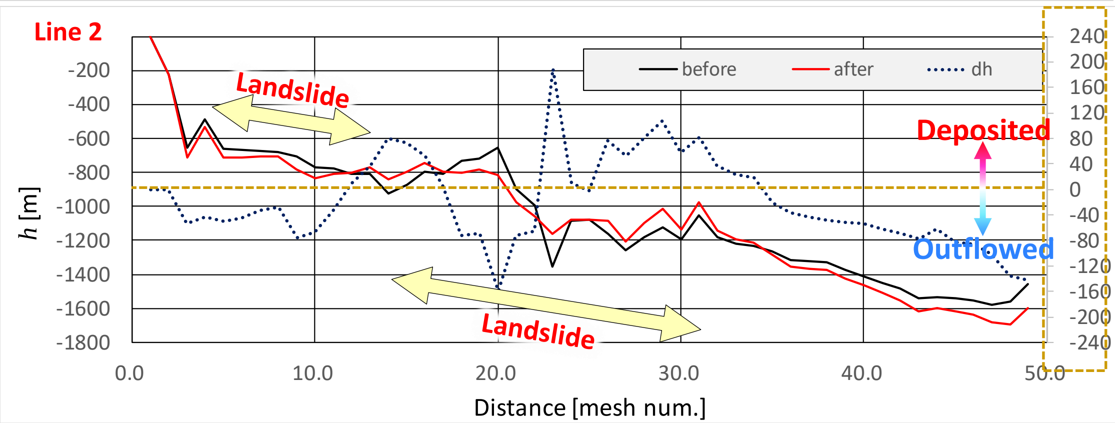
Hydrographic department, Imperial Japanese Navy(1924):
The chat showing the change of the depth of the sea in Sagami-Nada and its Vicinity

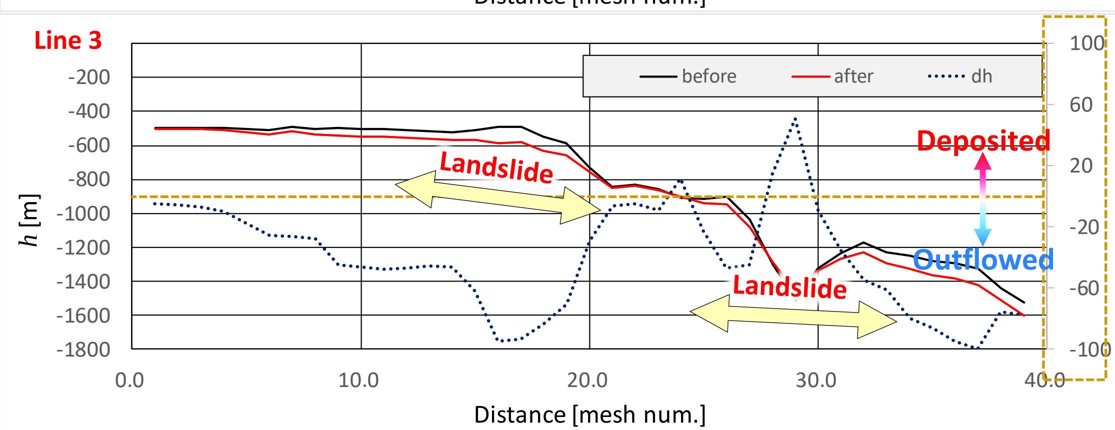


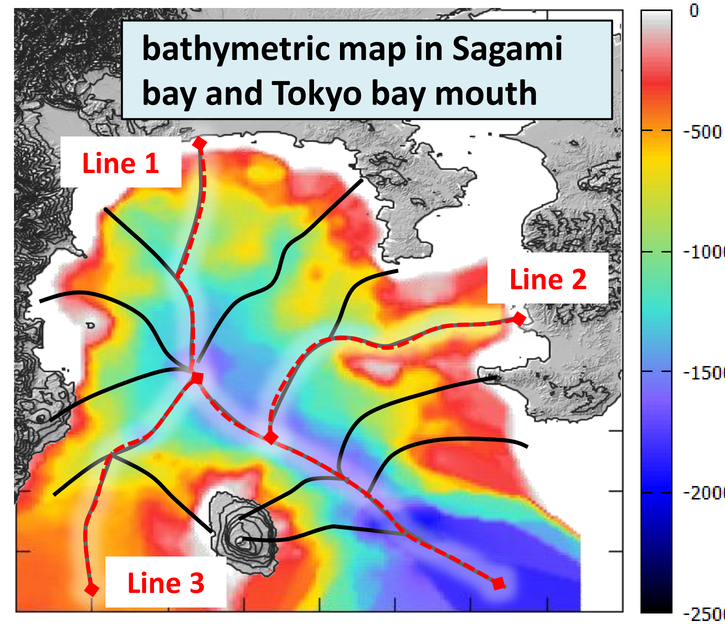
National Institute of Maritime, Port and Aviation Technology
Port and Airport Research Institute (PARI)

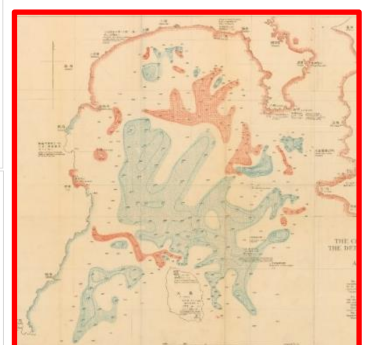
相模湾/東京湾口の海底地形変化
The depth change of Sagami bay and Tokyo bay

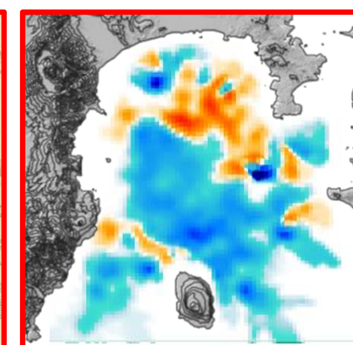






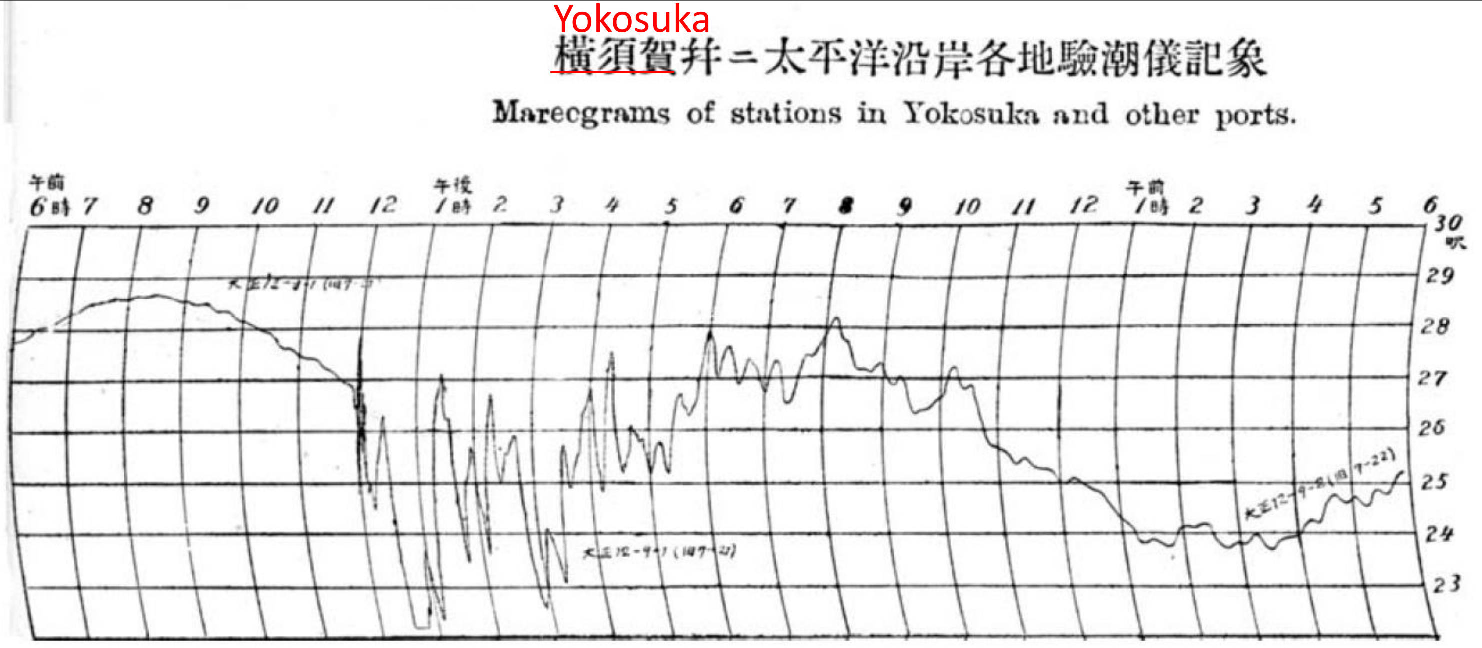






水深変化記録は、海底地すべりと仮定すると整合的
/The depth change can be well explained if it is caused by submarine landslides.

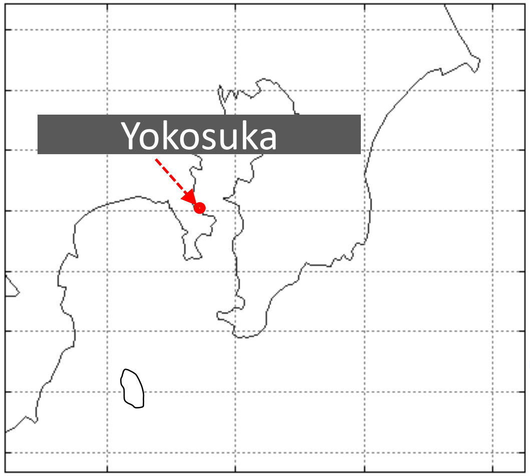
横須賀験潮儀で観測された1923年関東津波の記録
Recording tsunami height in time series of 1923 Kanto tsunami at Yokosuka



Yokosuka

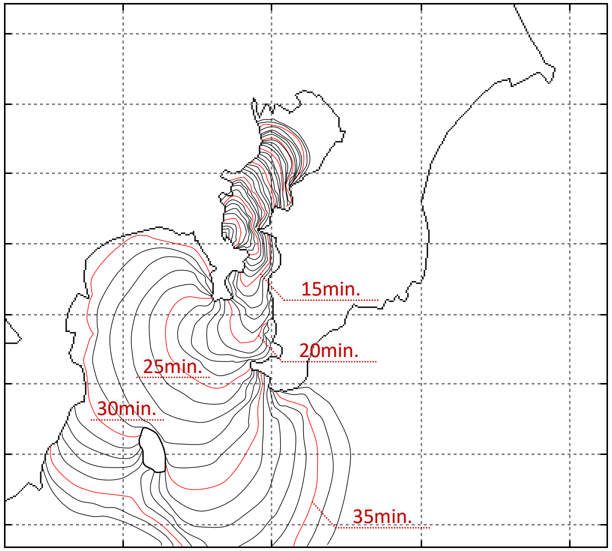
図３－24　横須賀海軍工廠の検潮所で記録された津波［震災予防調査会，1926 に基づく］

ref：内閣府，http://www.bousai.go.jp/kyoiku/kyokun/kyoukunnokeishou/rep/1923_kanto_daishinsai/pdf/1923--kantoDAISHINSAI-1_06_chap3.pdf

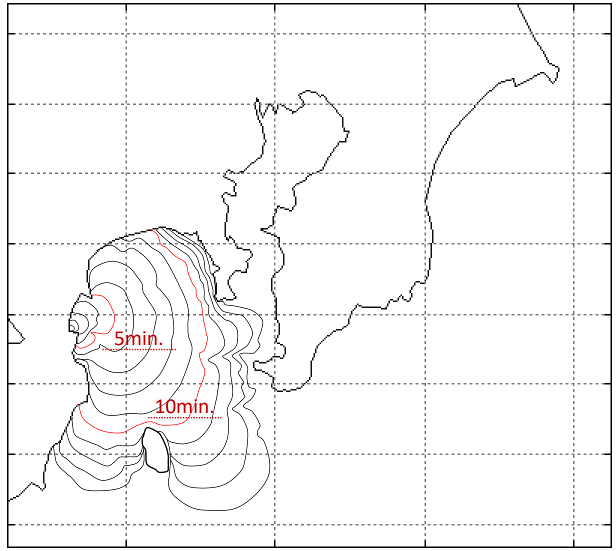


津波波源位置の逆解析
/Inversion calculation of tsunami source

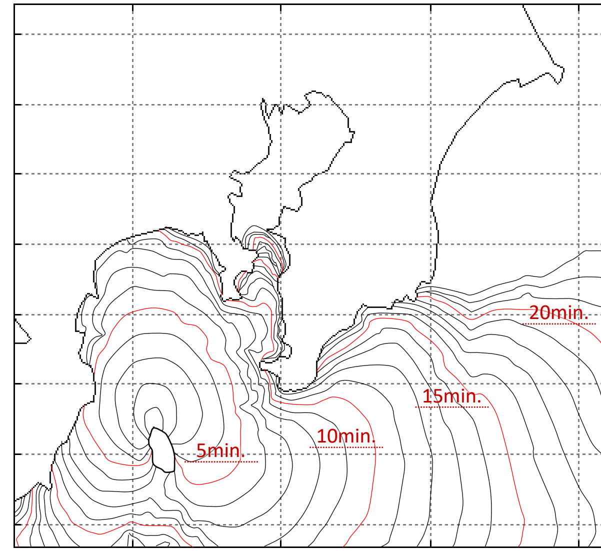
Yokosuka



Atami



Izu-Ohsima



各沿岸地点の記録と整合的な津波伝播時間の交点を
見つけ出せれば、津波の波源を抽出できるのでは？

Legend

- Every 1 min. (black line)
- Every 5 min. (red line)

解析結果
/Simulation results

各地点の記録 /Records of each point

熱海 /Atami

Tsunami height is approx. 7-12m, after earthquake 5-6 min.

真鶴 /Manazuru

Tsunami height approx. 6m, after earthquake 5-6 min.

鎌倉 /Kamakura

Tsunami height approx. 6m, after earthquake 10-13 min.

下田～川奈崎南部 /South of Kawanazaki to Shimoda

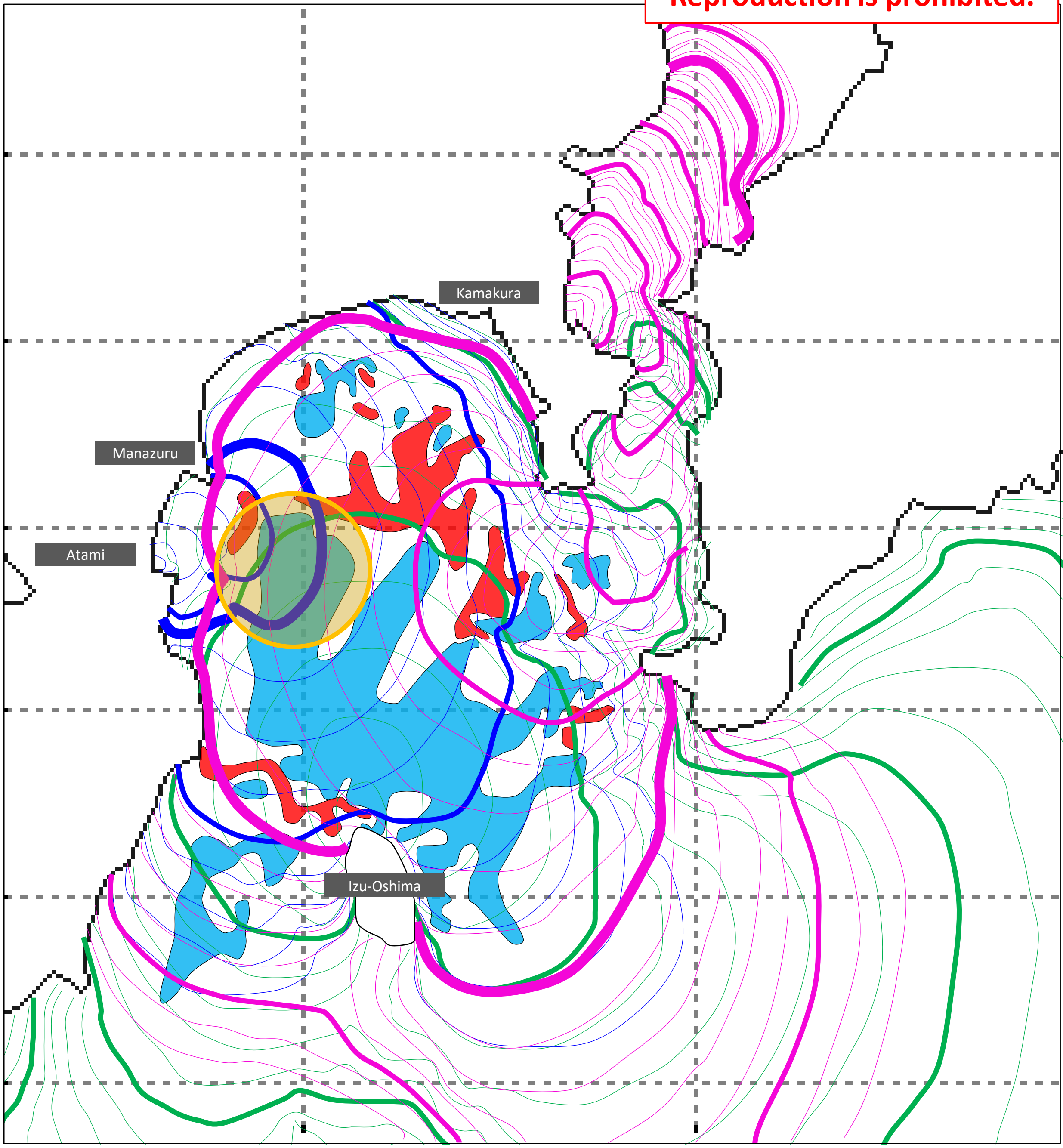
Tsunami height is approx. 1.8-2.1 m, after earthquake 20 min.

伊豆大島 /Izu-Oshima

Tsunami height approx. 13m

Legend

Thin line	Every 1 min.
Medium line	Every 5 min.
Thick line	Recording



Terminal velocity of submarine landslide (Lovholt, et al., 2015)

Eq.(1)

$$U_{\mathrm{term}} = \sqrt{\left(\frac{\rho_{\mathrm{s}}}{\rho_{\mathrm{w}}} - 1\right)\frac{2gz(\sin\theta - f\cos\theta)}{C_{\mathrm{F}}}}$$

The liner shallow water wave celerity

Eq.(2)

$$c = \sqrt{\frac{gd\tanh(\pi h/d)}{\pi}}$$

Tsunami height due to the submarine landslides (Harbitz, 1992)

Eq.(3)

$$\Delta h_{\mathrm{f}} = \frac{z}{\cosh(\pi h/d)}\frac{c}{c-U}$$

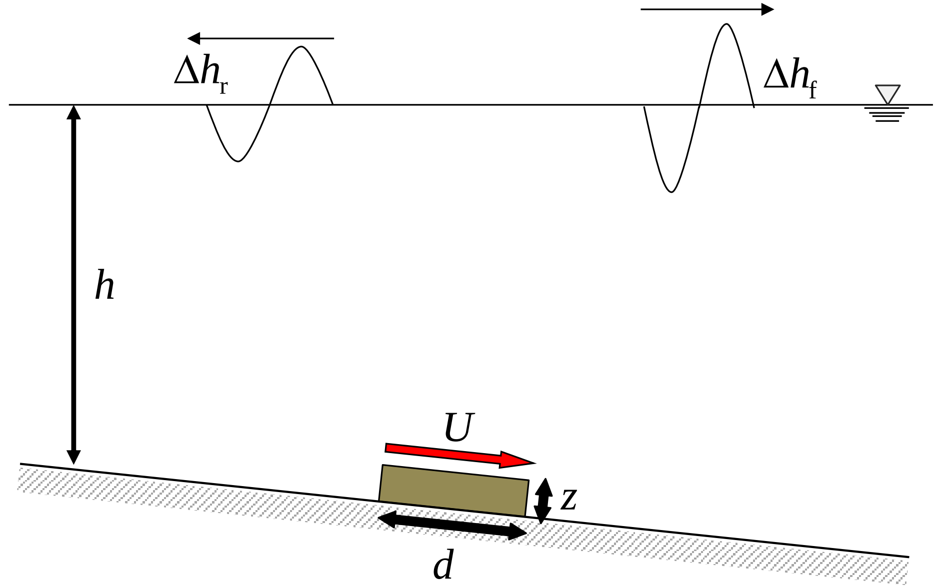
Eq.(4)

$$\Delta h_{\mathrm{r}} = \frac{z}{\cosh(\pi h/d)}\frac{c}{c+U}$$

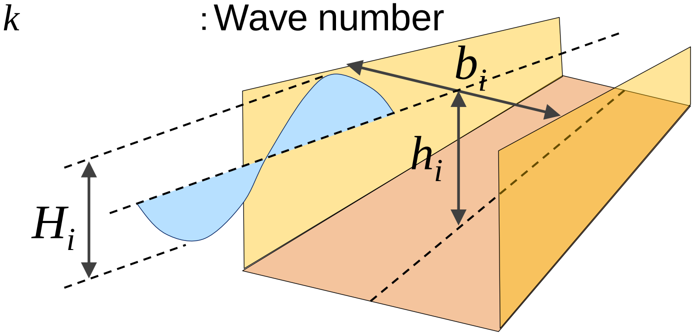
Green's law

Eq.(5)

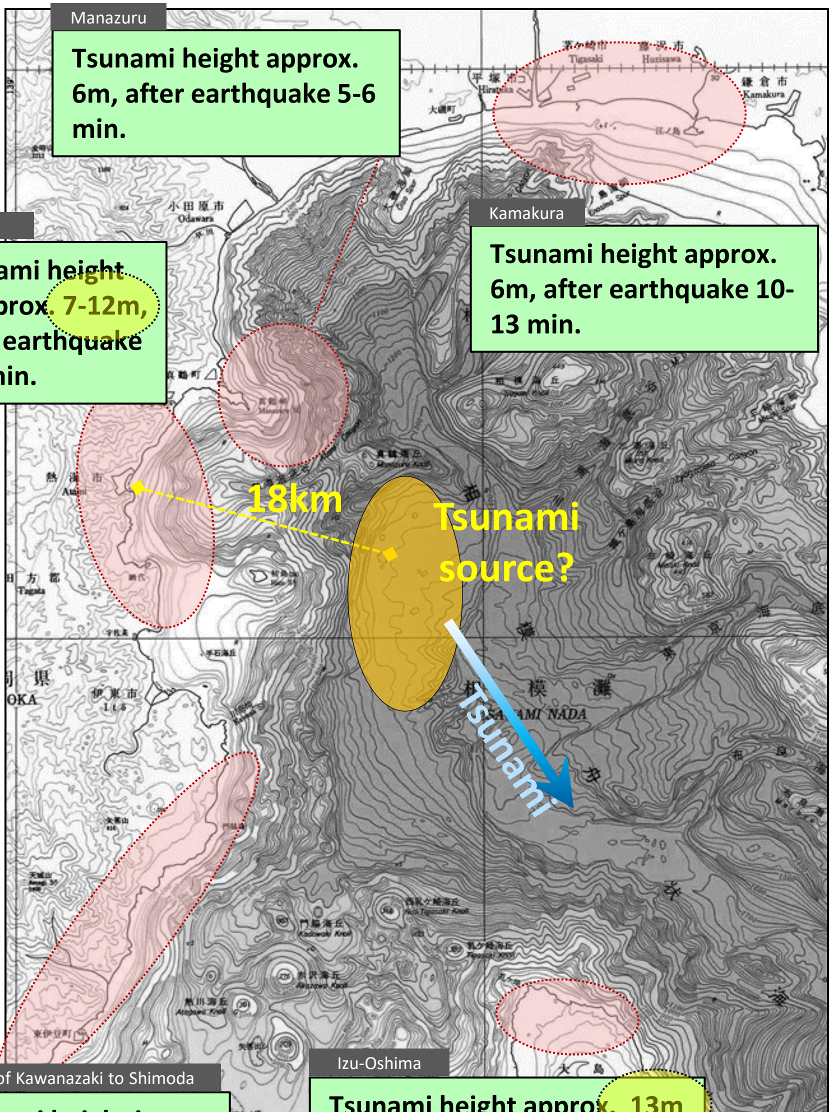
$$\frac{H_2}{H_1} = \left(\frac{b_1}{b_2}\right)^{1/2}\left(\frac{h_1}{h_2}\right)^{1/4}$$



ρ_{s}, ρ_{w}	: Density of sediment and sea water
θ	: seabed angle
C_{F}	: Surface friction coefficient
f	: Coulomb friction coefficient
Δh_{f}, Δh_{r}	: Wave height (hr)
Z	: Landslide thickness
d	: Landslide length
h	: Water depth
$U \fallingdotseq U_{\mathrm{term}}$	: Landslide velocity
g	: Gravitational acceleration
k	: Wave number



Submarine landslide tsunami can qualitatively explain wave phase, arrival time and wave height



Manazuru
Tsunami height approx. 6m, after earthquake 5-6 min.

Atami
Tsunami height is approx. 7-12m, after earthquake 5-6 min.

Kamakura
Tsunami height approx. 6m, after earthquake 10-13 min.

South of Kawanazaki to Shimoda
Tsunami height is approx. 1.8-2.1 m, after earthquake 20 min.

Izu-Oshima
Tsunami height approx. 13m

C_F	0.0019	-	Parameters of Storegga slide in Harbitz(1992)
f	0.005	-	
θ	0.37	deg	
ρ_s	1.7×10^3	kg/m³	
ρ_w	1.1×10^3	kg/m³	
g	9.8	m/s²	
d	1000.0	m	Estimated from depth change
z	83.18	m	
h	1420.0	m	Topography data
U_{term}	26.43	m/s	Eq.(1)
C	55.84	m/s	Eq.(2)
h_f	1.82	m	Eq.(3)
h_r	0.65	m	Eq.(4)
Atami H_2	12.65	m	Eq.(5), b1=100m, b2=1000m, h1=1m, h2=1420m
Izu-Oshima H_2	11.2	M	Eq.(5), h1=1m, h2=1420m

Reproduction of further concrete tsunami needs to be carried out using detailed geological data.

まとめ/Conclusion

- 本研究は、高精度の海底地形を用いて、1923年の関東地震津波について再検証した /This study reverified the tsunamis of 1923 Kanto earthquake using high accuracy seafloor topography.
- 断層モデルで計算された津波高さは地形データ精度や地盤変動量が向上したものの、津波記録との差が認められた /Tsunami height calculated by the fault model disagree with the recording tsunami height in spite of improving calculation accuracy.

- 現在の海底地形データとの比較から、地震前後で観測された地形変化は海底に沿って対応していることを確認した /We confirmed that the bathymetric changes which observed before and after the 1923 Kanto Earthquake corresponded to the submarine valleys of the Sagami Bay from the analyzing of comparison with the current submarine topographic data.

- 1923年津波の発生メカニズムを海底地すべりによるものを考慮した場合、単純な海底地すべり波源モデルを用いて検証したところ、相模湾内の真鶴岬沖における、海底地すべり波源は、地形変化による浅水変形と収斂効果を考慮すると定性的に津波の高さを説明出来得ることを確認した /The mechanism of 1923 Kanto tsunami event is a high possibility reason due to the submarine landslide. We estimated tsunami scale using simple model considering the tsunami mechanism is submarine landslides. The tsunami arrival time and the location of tsunami source induced by submarine landslide in Sagami Bay were qualitatively consistent with the recording tsunami height by considering the characteristics of the shallow-water deformation and the tsunami convergence.

今後の展望/Future works

• 海底地すべり津波波源の精査	Consideration of the tsunami sources caused by submarine landslides
• 詳細な津波数値シミュレーション	Detail numerical calculation for tsunamis
• 海底地盤調査	Subseafloor survey
• 記録（時系列）との比較の仕方	How to compare the recording tsunami height in time series

ご清聴ありがとうございました

THANK YOU FOR KIND ATTENTION