TSUNAMI HAZARD AND RISK ASSESSMENT

(INPUT OF LARGEST M9 CLASS EVENTS)

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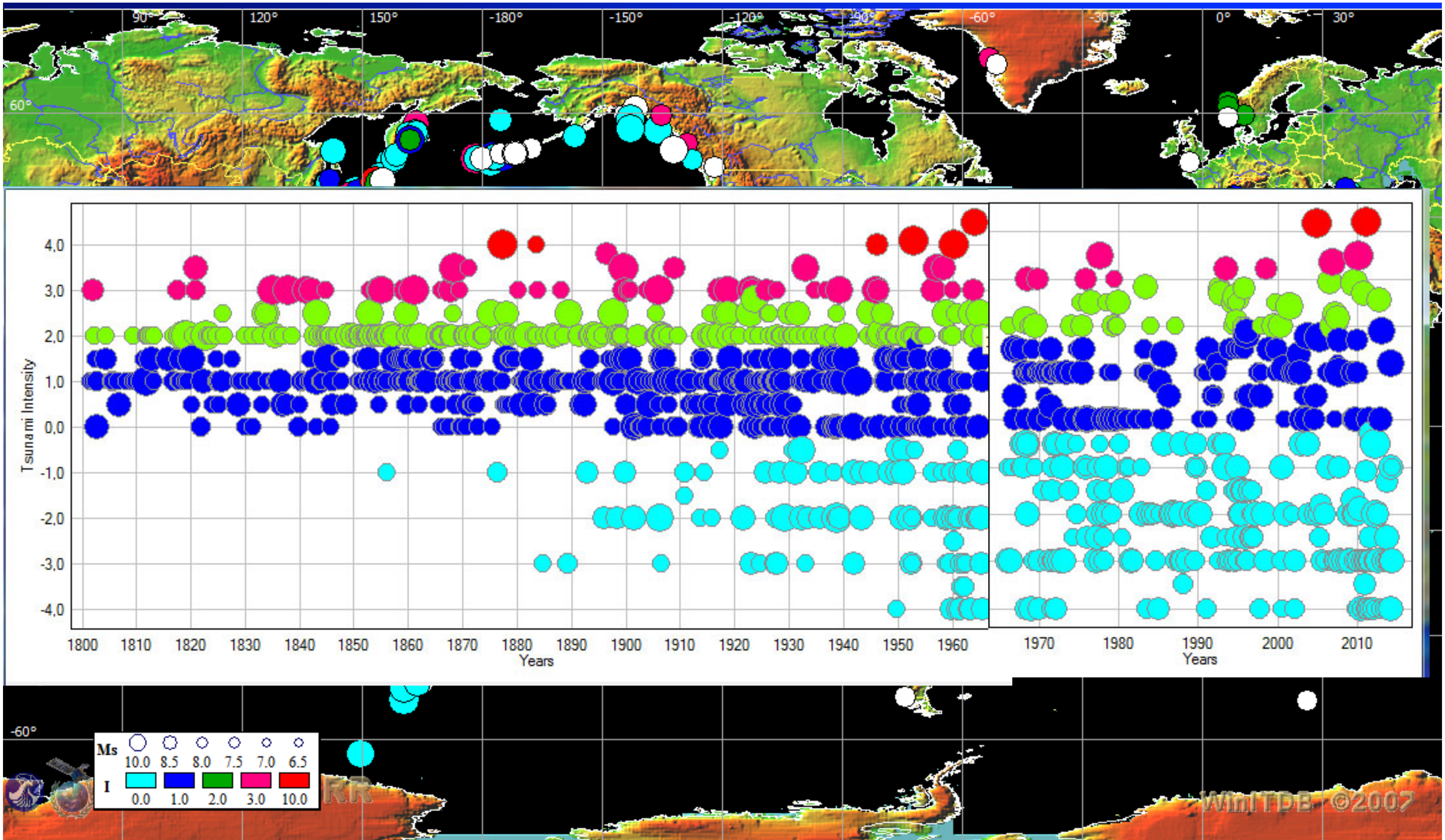
My own milestones

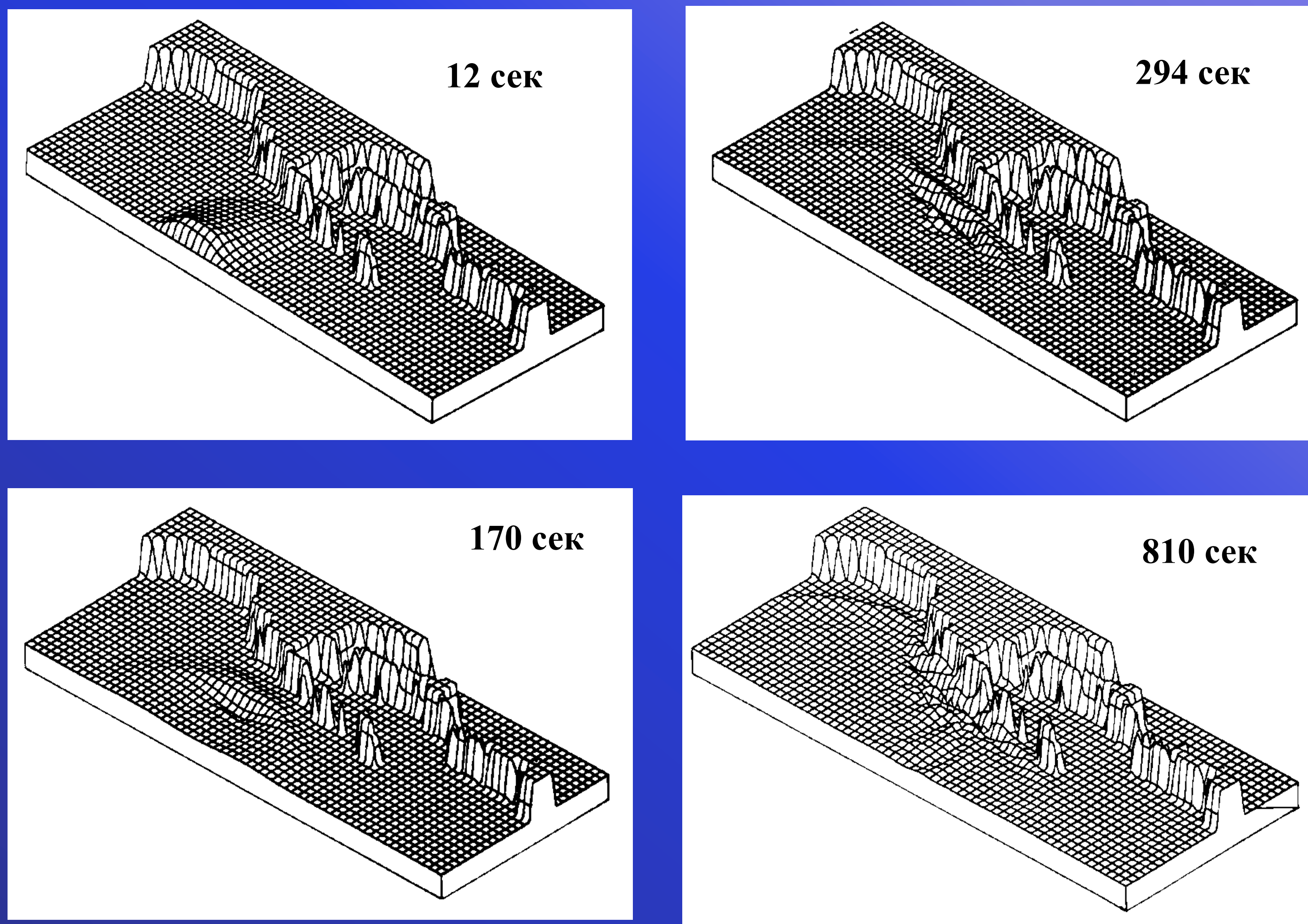
40-year anniversary: 1975 July – E.Bernard's visit to Novosibirsk. Beginning of numerical modeling of tsunami in USA and USSR and joint efforts in bottom tsunami recording

30-year anniversary: 1985 July– my first participation in ITSU-XII, Sidney, BC, Canada

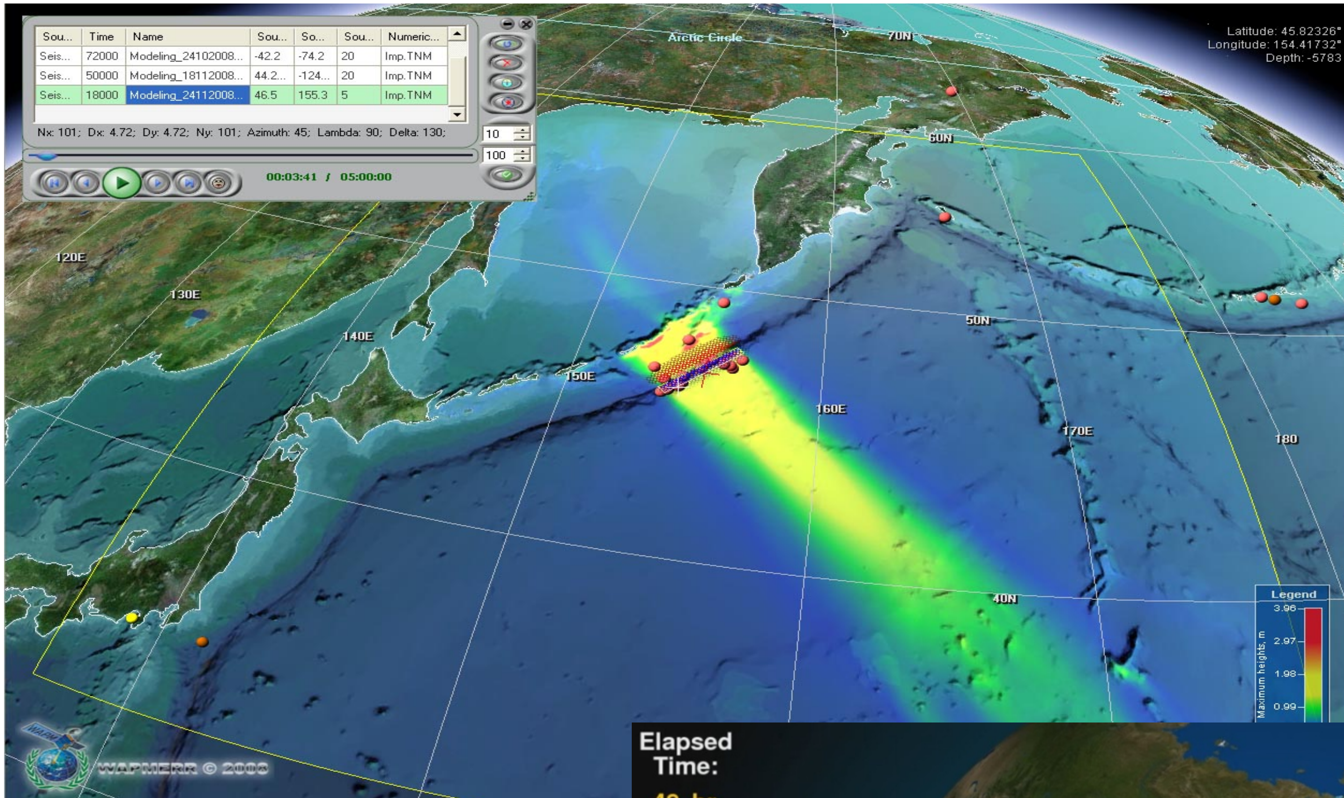
25-year anniversary: 1990 June – the first paleotsunami field trip in Kamchatka



452 tsunamigenic events (20% of the ~2250 total historical tsunamis) occurred in the Word ocean during 1965-2015 including 2 trans-oceanic mega-tsunamis – 2004 Indian Ocean and 2011 Tohoku – and 5 tsunami-earthquakes (of 14 known so far).

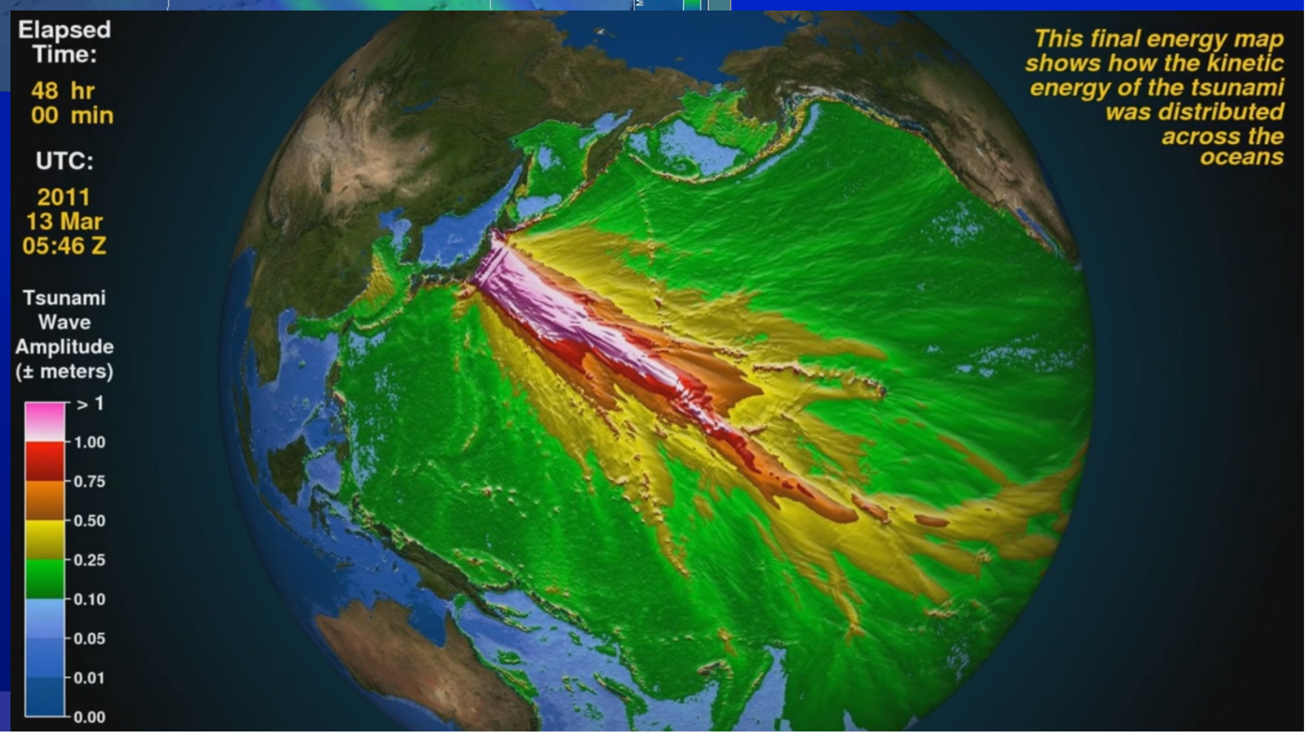


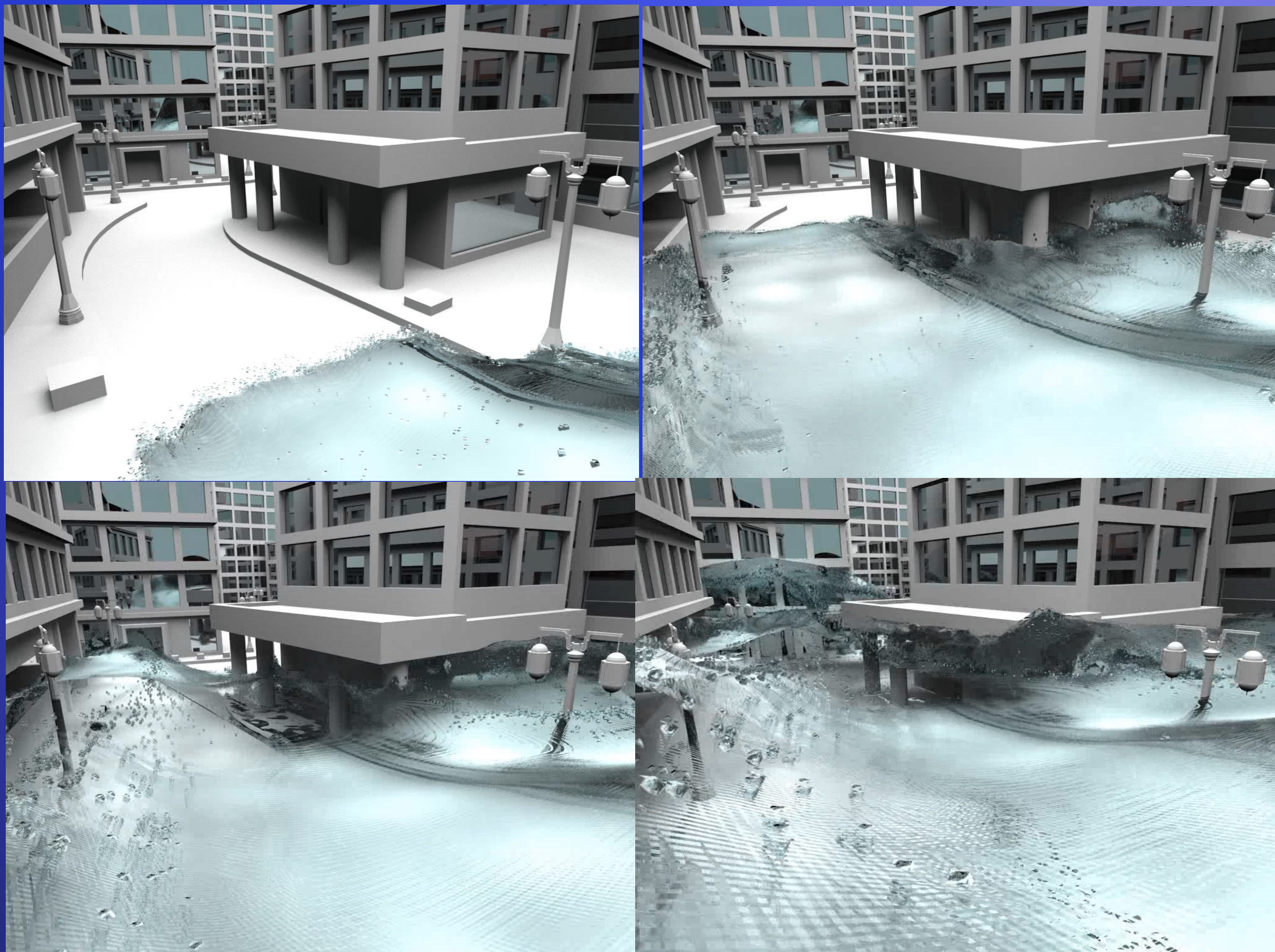
Numerical modeling and paper-ink plotter vizualization of the Nemuro-oki tsunami of June 17, 1973 made on the main-frame BESM-6 computer in TL/ICMMG in 1978



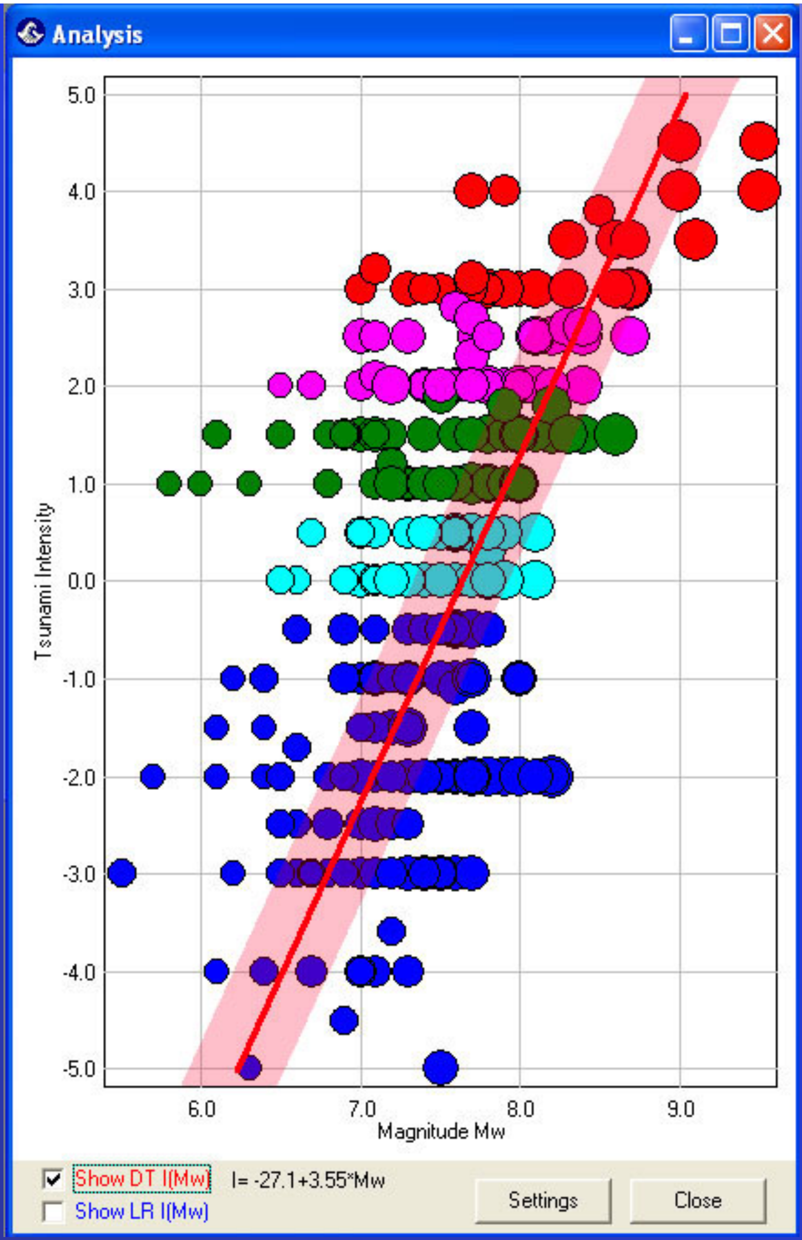
WAPMERR-TL/ICMMG Pacific-wide modeling and 3D vizualization of the Mw8.4 Simushir tsunami of November 15, 2006 in central Kuriles

PTWC global modeling and 3D vizualization of the Mw9.0 Tohoku tsunami of March 11, 2011 in the World Ocean





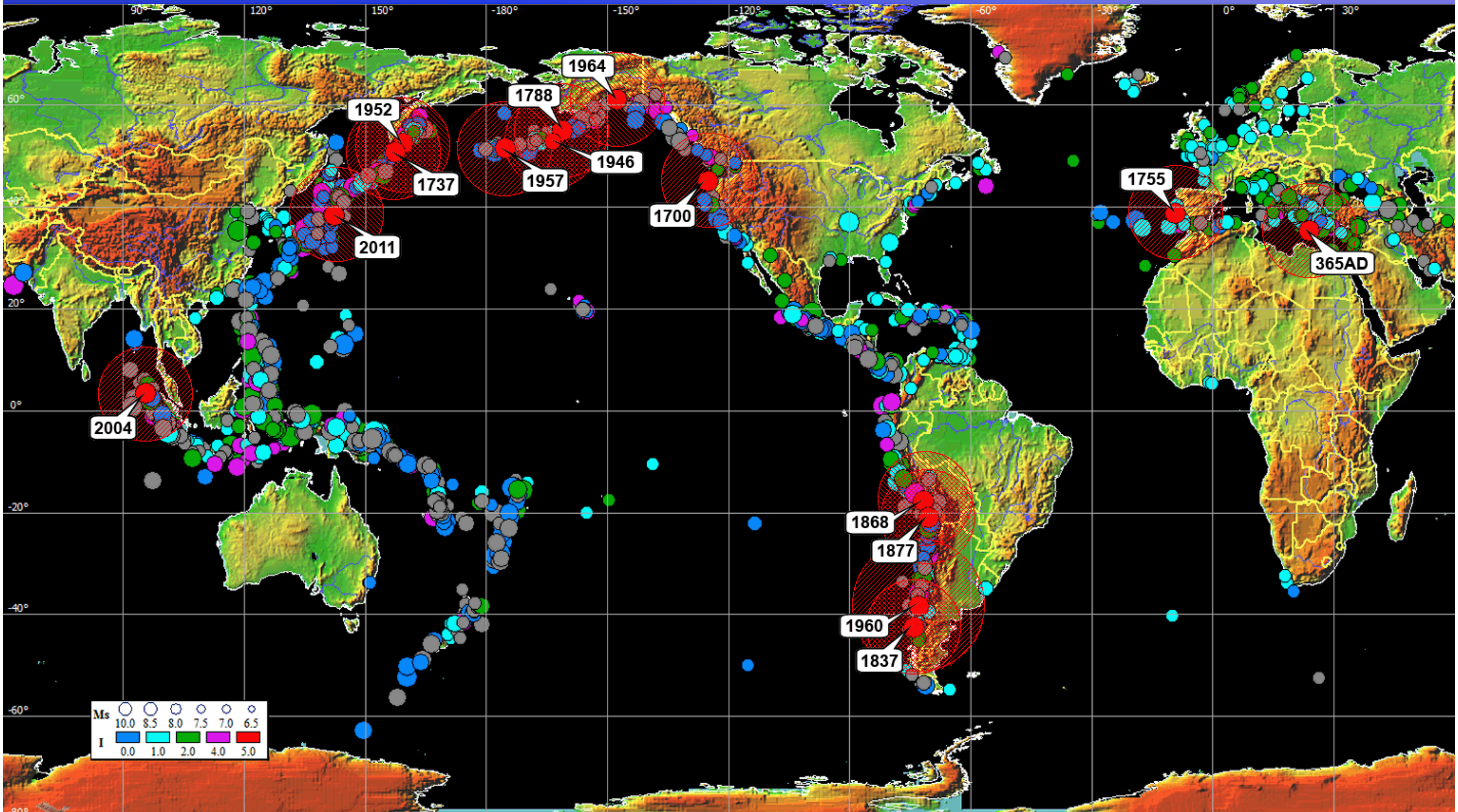
Numerical modeling of tsunami run-up within full 3D Navier-Stokes model (ICM RAS, 2011)



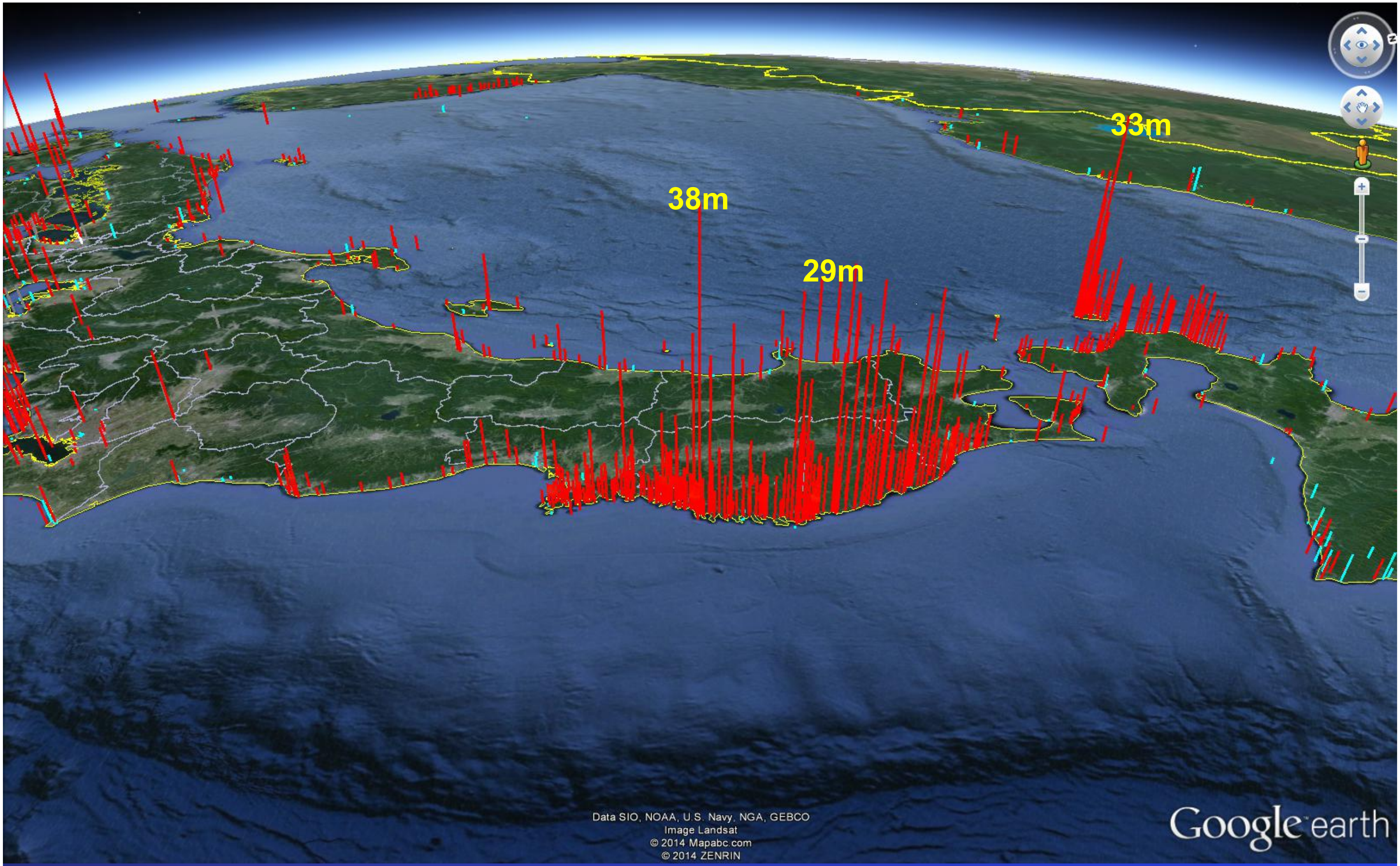
Dependence of tsunami intensity I (on Soloviev-Imamura scale) on Mw magnitude (on the right) of submarine earthquake occurred since 1900 in the World Ocean

Three groups of largest tsunamis of the World Ocean
(compared by different parameters)

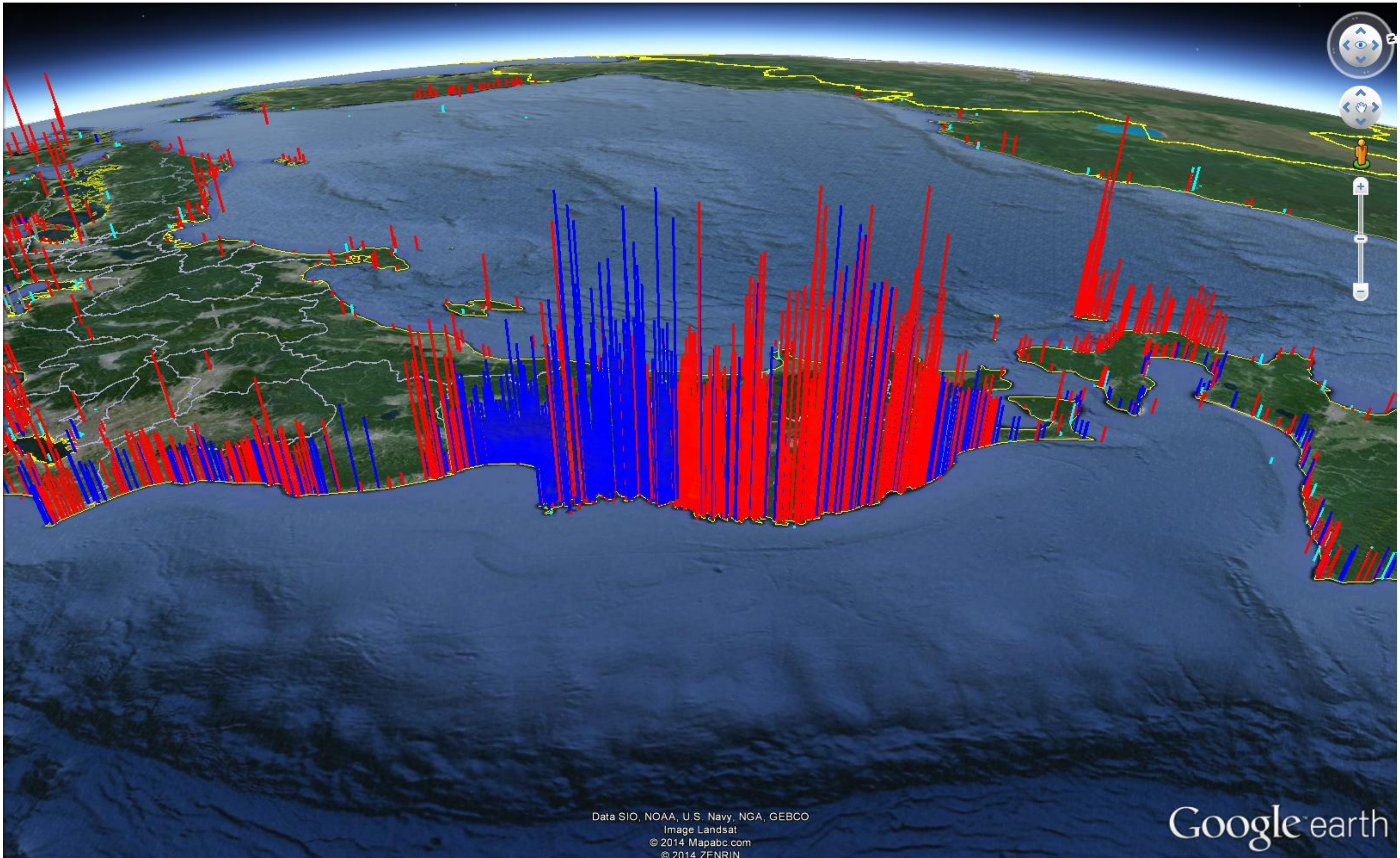
14 trans-oceanic tsunamis, (H > 5m at D > 5000km) N - number of run-ups	Top-15 tsunamis with highest run-up, sorted by H_{max}	Top-15 tsunamis with largest fatalities, sorted by N_{FAT}
365AD Crete N= 5	525m 1958 Lituya Bay	226,898 2004 Sumatra
1700 Cascadia N= 5	250 m 1963 Vajont Dam	36,417 1883 Krakatau
1737 Kamchatka N= 5	150m 1936 Lituya Bay	30,000 1707 Nankaido
1755 Lisbon N=49	120m 1854 Lituya Bay	27,122 1896 Sanriku
1788 Aleutian N= 3	88m 1788 Aleutians	26,000 1498 Enshunada
1837 Chile N= 23	85m 1771 Ishigaki Is.	18, 497 2011Tohoku
1868 Chile N= 115	80m 1674 Indonesia	15,000 1741 Osima
1946 Aleutians N= 549	70m 1936 Norway	13.486 1771 Ishigaky Is.
1952 Kamchatka N= 340	68m 1964 Alaska	12,000 1952 Kamchatka
1957 Aleutians N= 326	63m 1737 Kamchatka	10,000 1755 Lisbon
1960 Chile N= 1193	62m 1934 Norway	10,000 1765 Guanzhou
1964 Alaska N= 423	55m 2011 Tohoku	5,233 1703 Boso Pen.
2004 Sumatra N=1,026	51m 2004 Sumatra	5,000 1605 Nankaido
2011Tohoku N=5,570	42m 1946 Aleutians	4,376 1976 Philippines
	40m 2000 Greenland	3,000 1854 Nankaido



Map of historical tsunamigenic events in the World Ocean. Sources of 2250 events occurred from 2000 BC to 2012 are shown. Color represent the tsunami intensity on Soloviev-Imamura scale. Large red circles highlight the M9 class mega-events resulted in trans-oceanic tsunamis



Historical run-up distribution along the coast of Honshu before 11.03.2011



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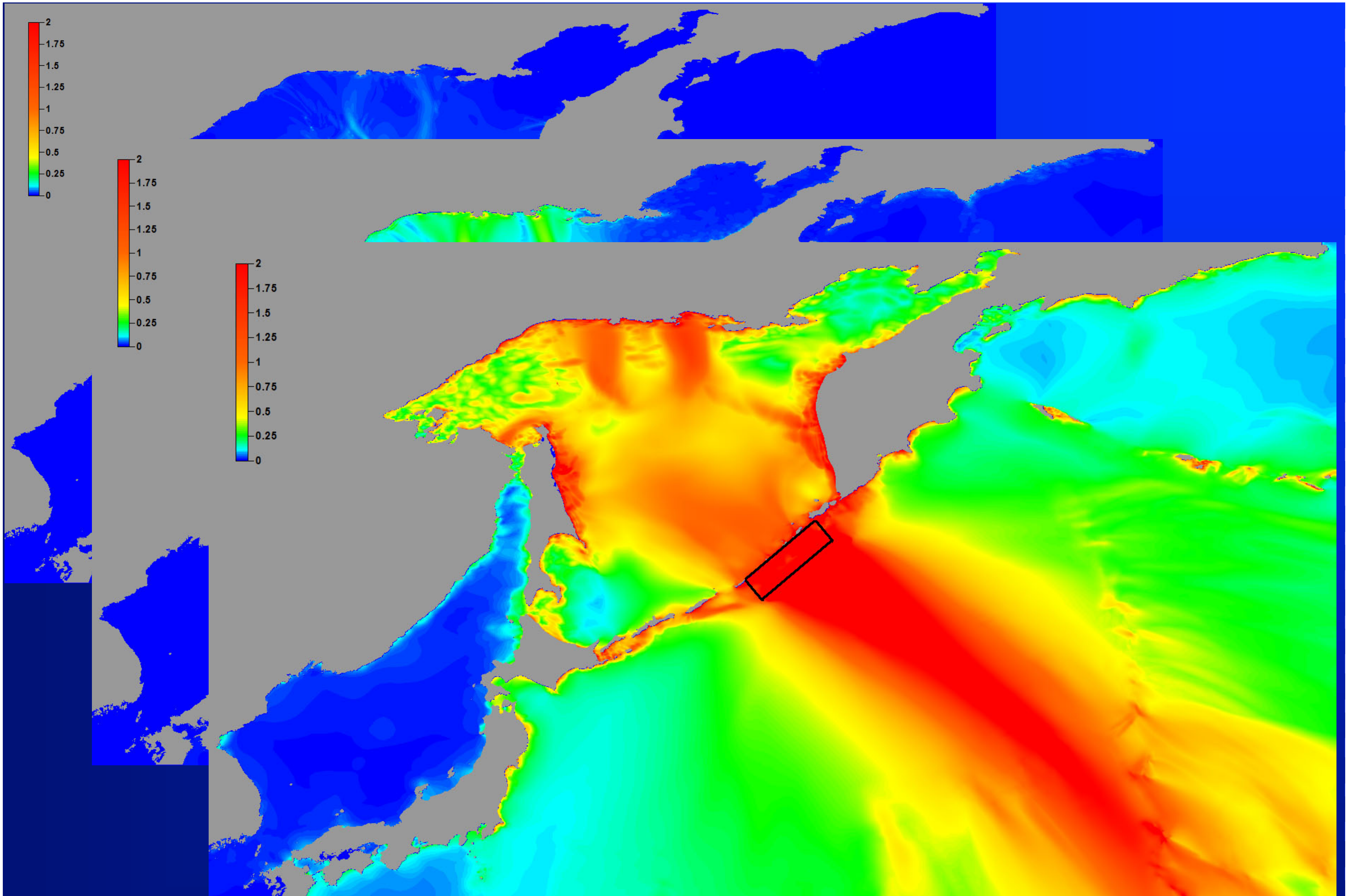
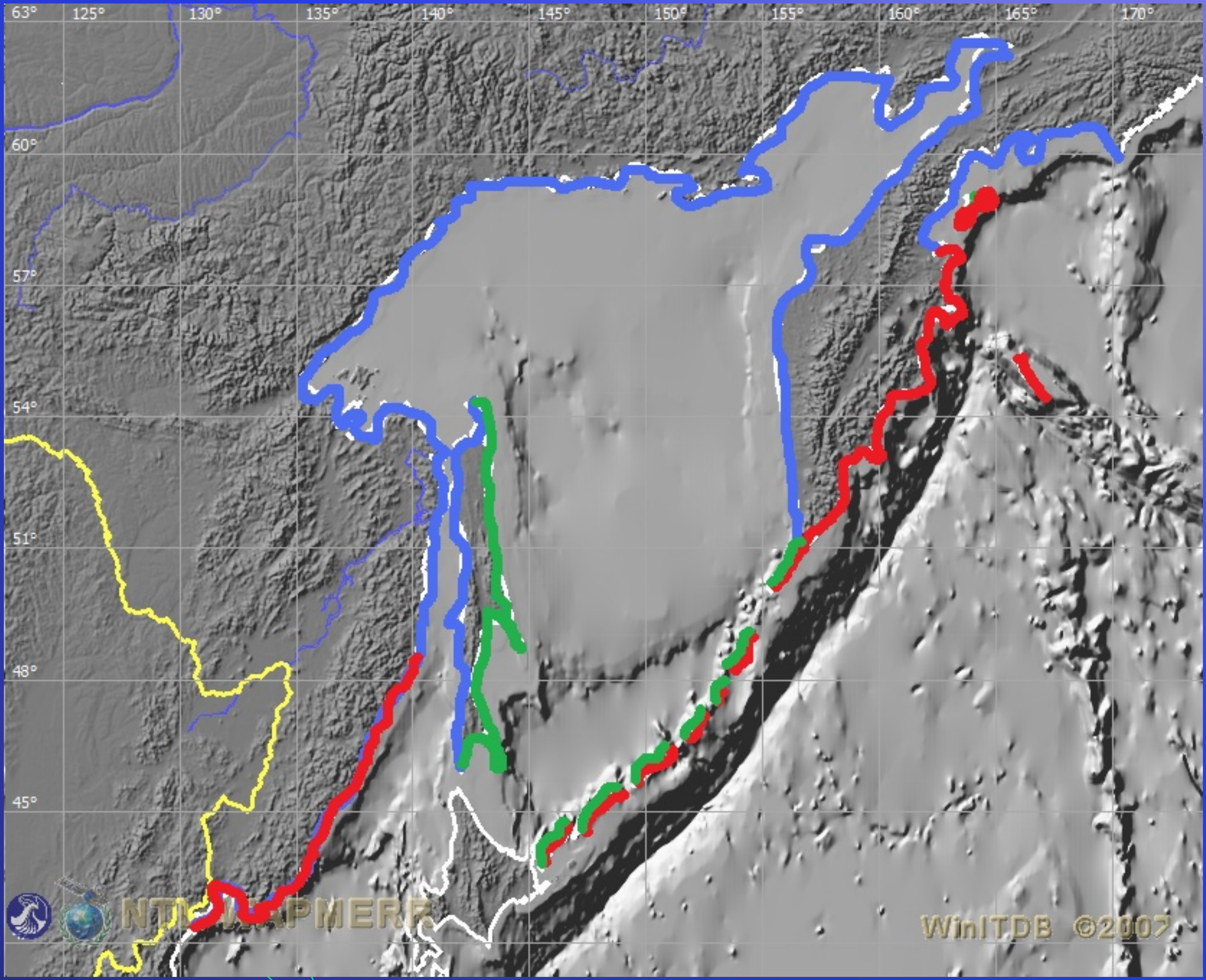


Tsunami propagation modeling in the Kuril-Kamchatka region for Mw=7.8, 8.4, 9.0 sources



Parts of Far East coast with predominant input into tsunami hazard from local earthquakes (red color), from far-field sources (blue color), and mixed input (green color)

General formula for calculation of tsunami risk is

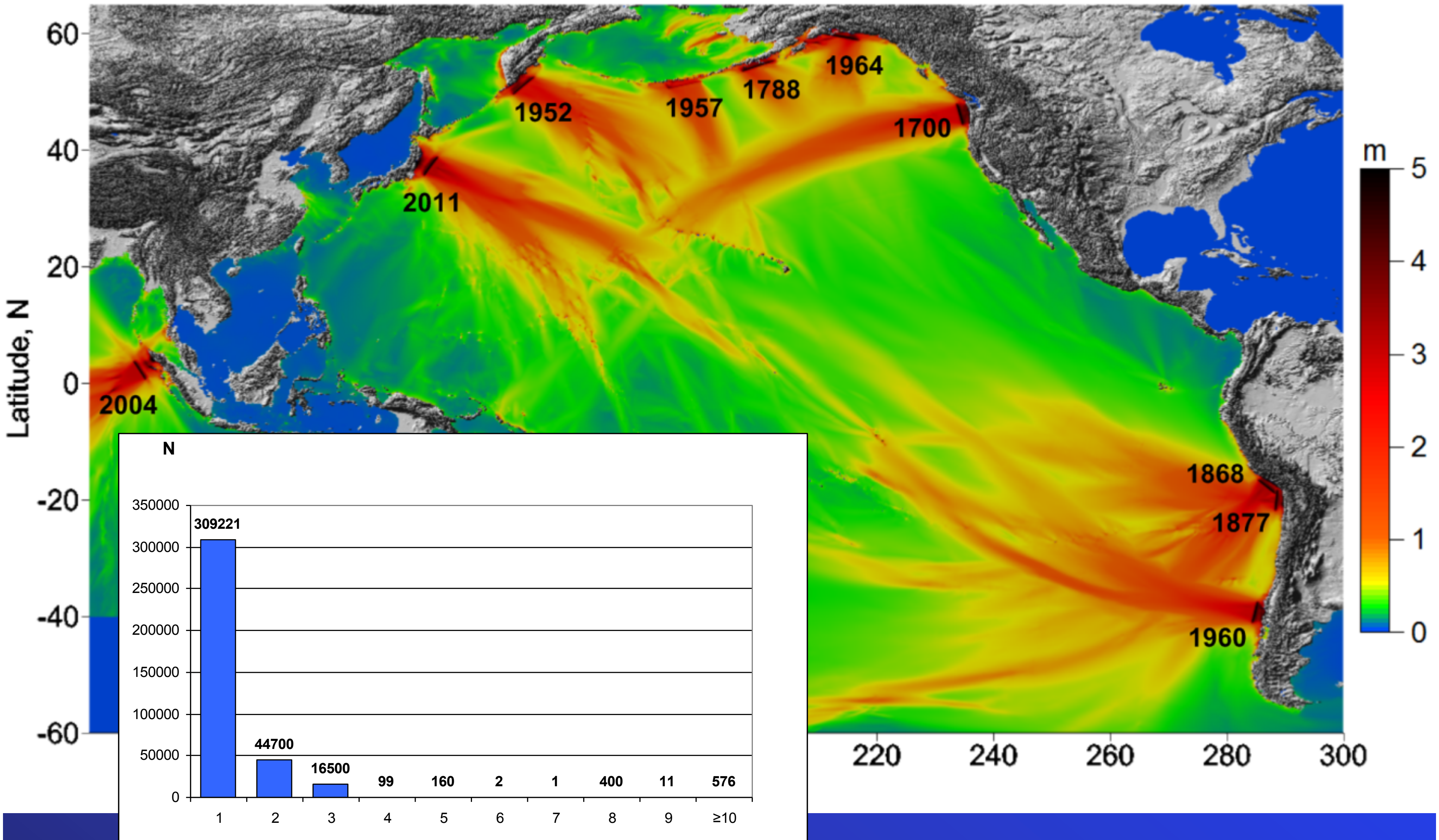
$$R = H * V * C,$$

where R – risk, H –hazard, V – vulnerability, C- cost

In this formula, the Expert System can contribute to calculation of H value, i.e. probability of exceedence of any selected run-up value for a given period of time

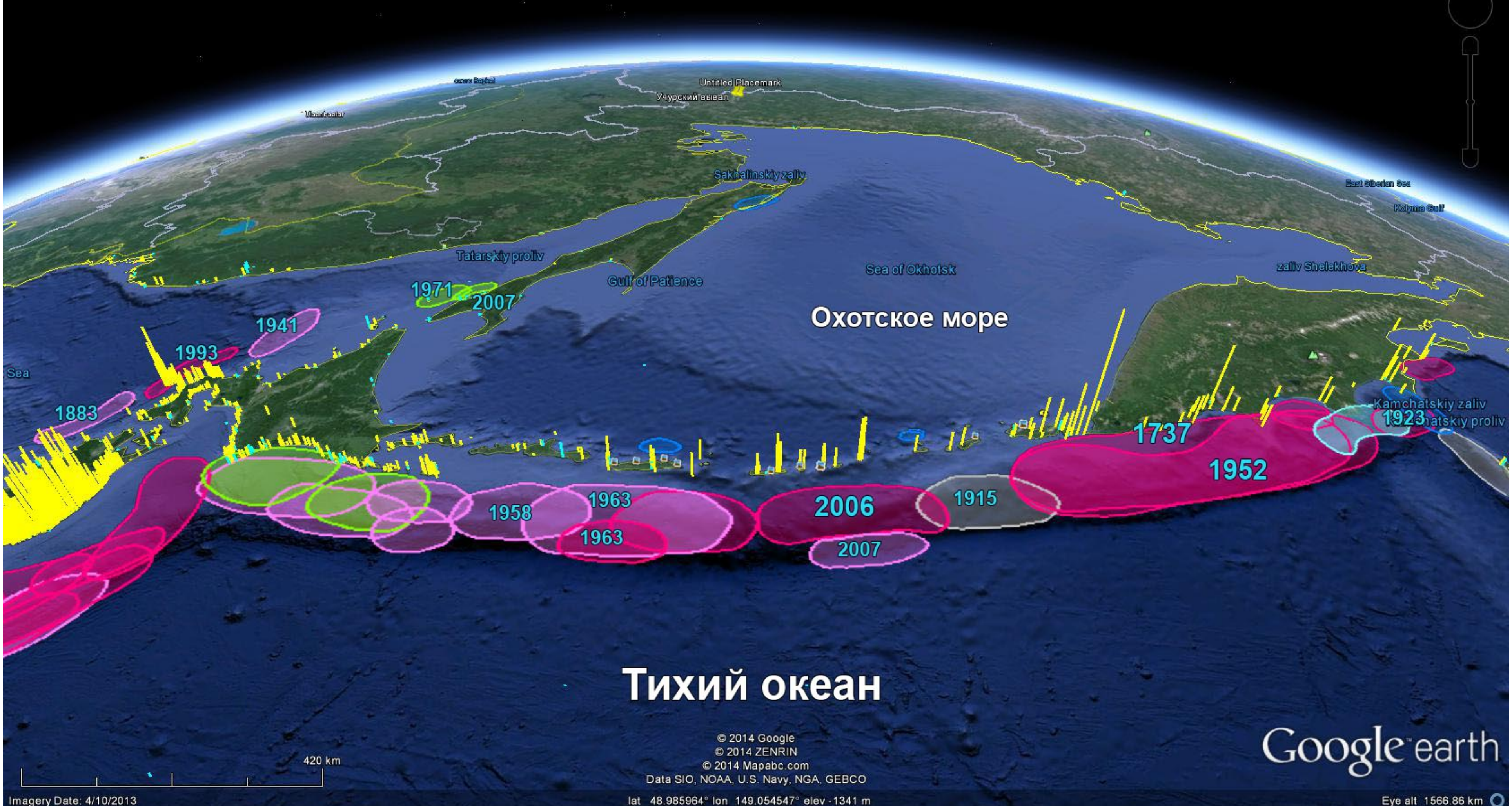
Basic steps involved in the tsunami hazard calculation by this approach are:

- Selection of a geographical area
- Retrieval of historical run-ups
- Calculation of the recurrence function
- Calculation of the "hazard curve"

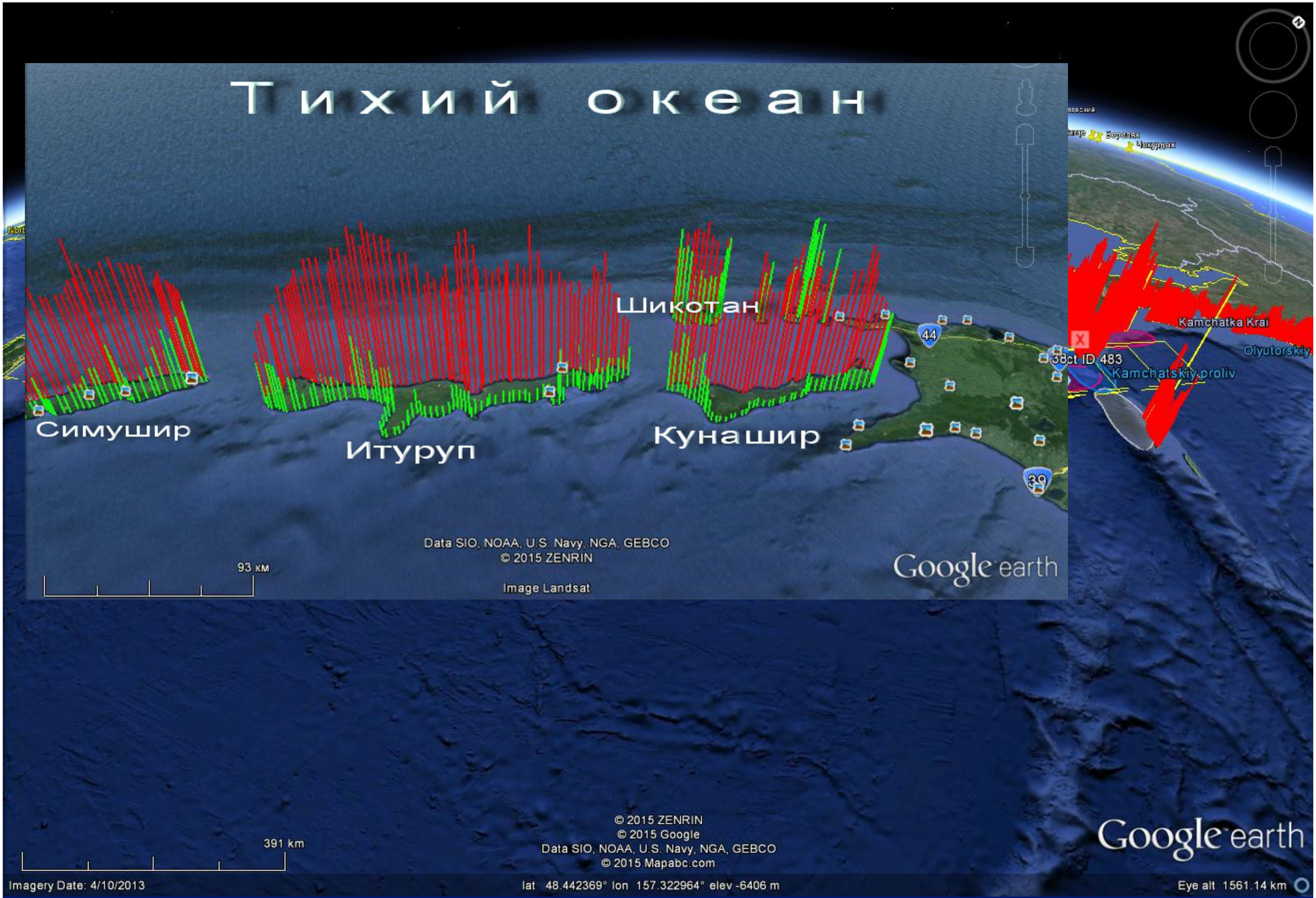


Energy flux for trans-oceanic mega-tsunamis historically known. Insert figure – distribution of fatalities over the tsunami propagation time (up to 85% fatalities occur during the first hour).

Last confirmed tsunami fatalities in Russia were in 1952 (>10,000)



Source map and historical tsunami heights in Kuril-Kamchataka region from 1737 to 2015

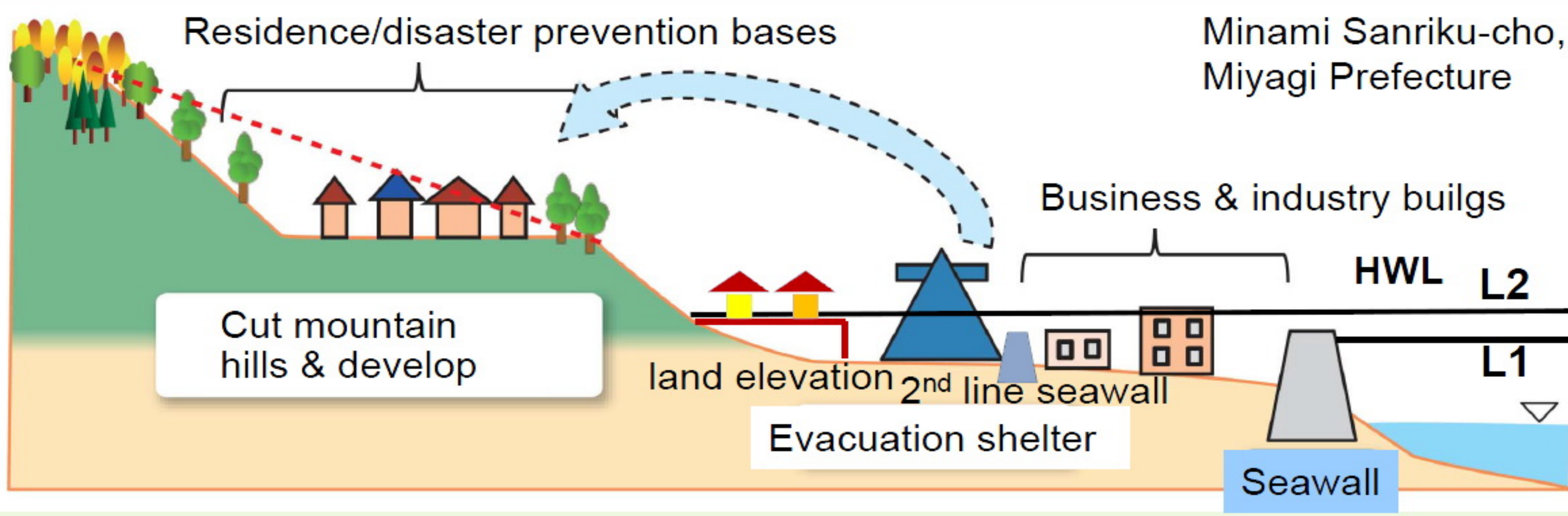


Historical tsunami heights in the Kuril-Kamchata region , 1737-2014 and results of mofdeling for Mw=9.0. model sources

Reconstruction principles in Tohoku
(Central Disaster Management Council, 28 Sept 2011)

Two levels Approach

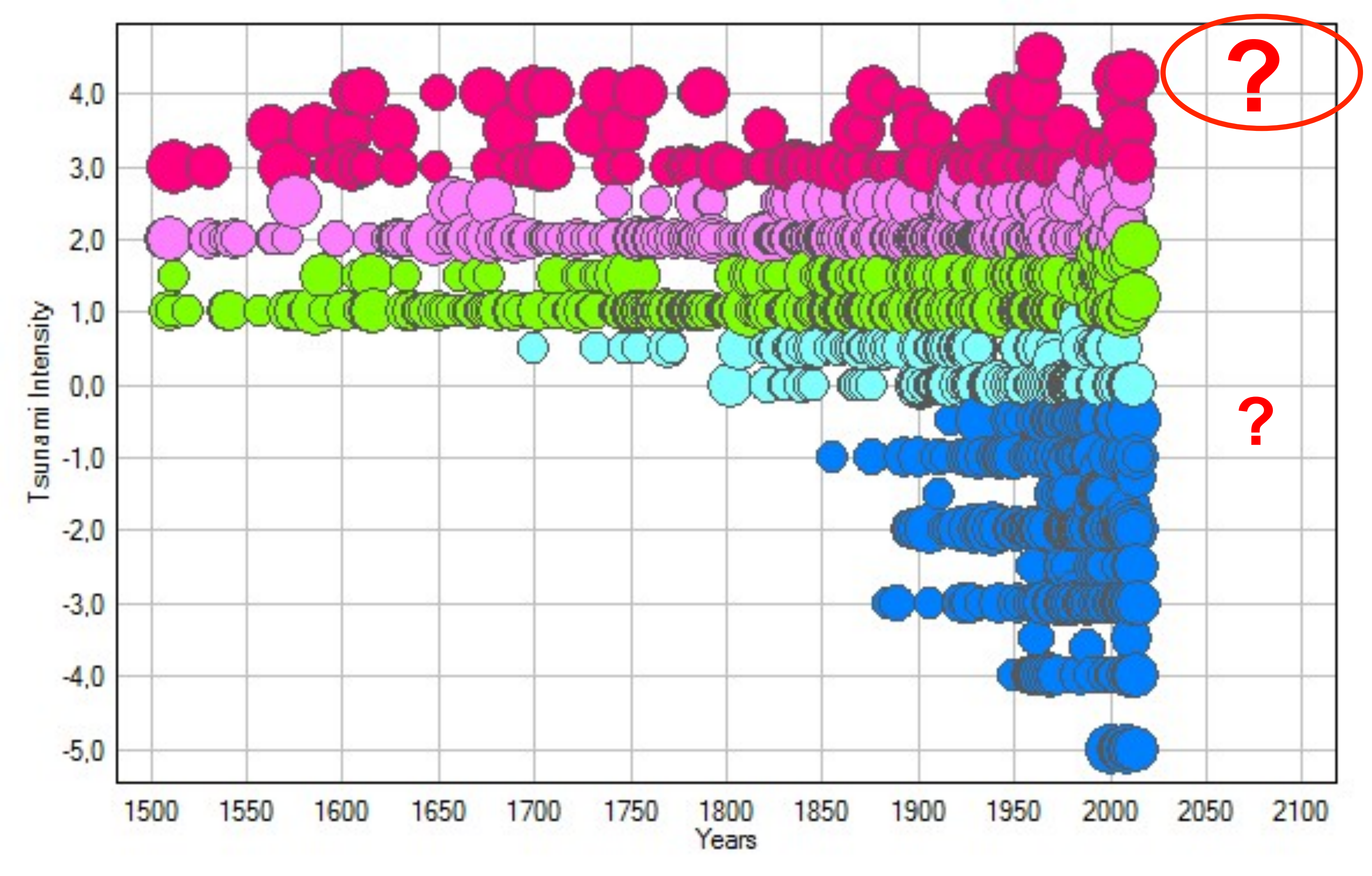
Level 1 Tsunami (Frequent scale: 50-150 years)
Life, properties & livelihood
- Sea walls, dikes, highways:



Level 2 Tsunami (Maximum scale: 1000 years) Life
- Move to higher lands
- Tall buildings to evacuate
- Landuse (park, factories, farmland; commercial/business, residential areas)

ICHARM

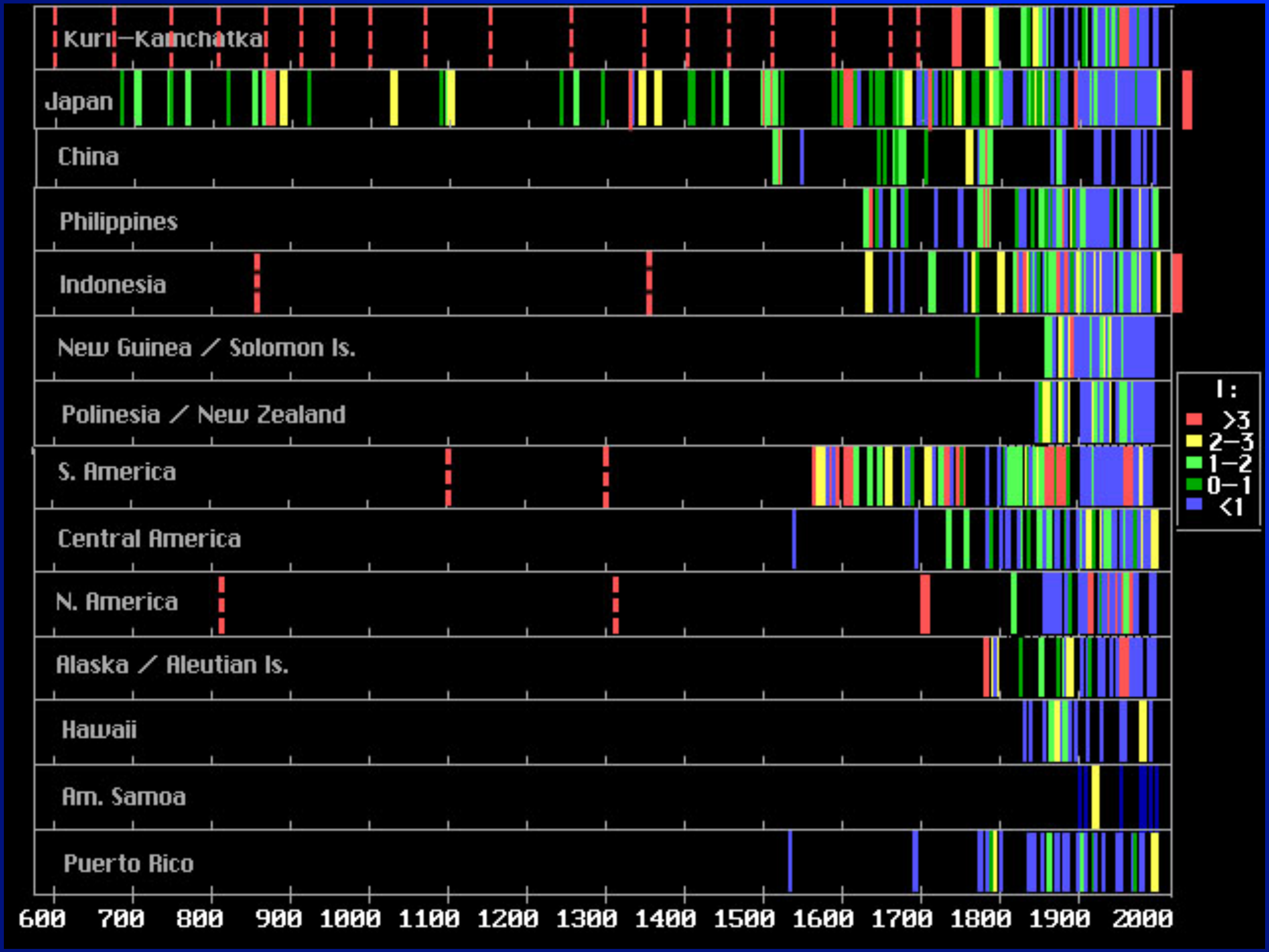
New paradigm in tsunami hazard mitigation in Japan – two-level strategy in tsunami hazard management (Takeuchi, 2013)



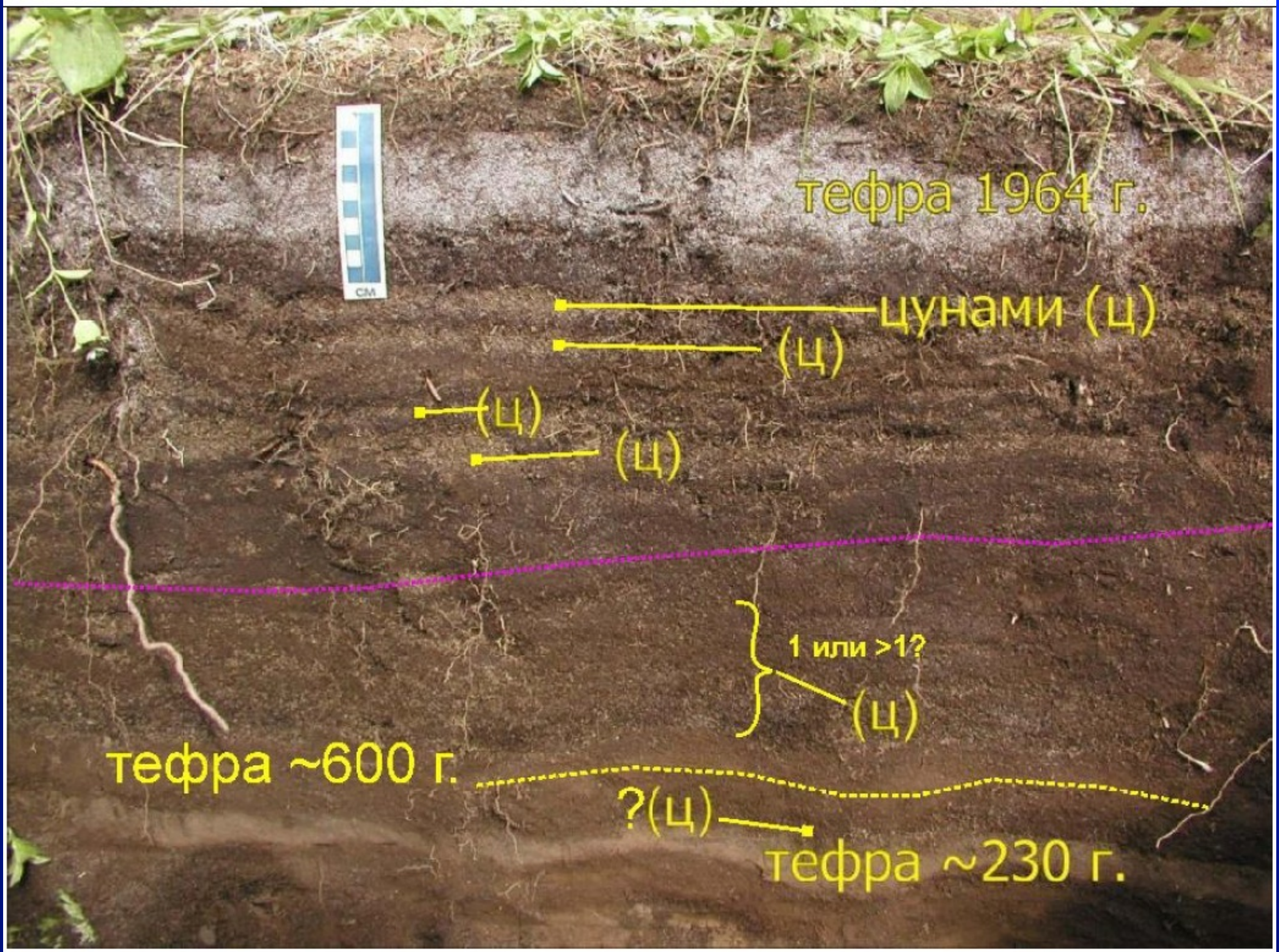
PTHA is actually prediction of the future (seismotectonic process) for some extended period of time (100 – 1000 years)

- "Those who have knowledge do not predict.
- Those who predict do not have knowledge"
- *Lao Tsu, 4 century BC*

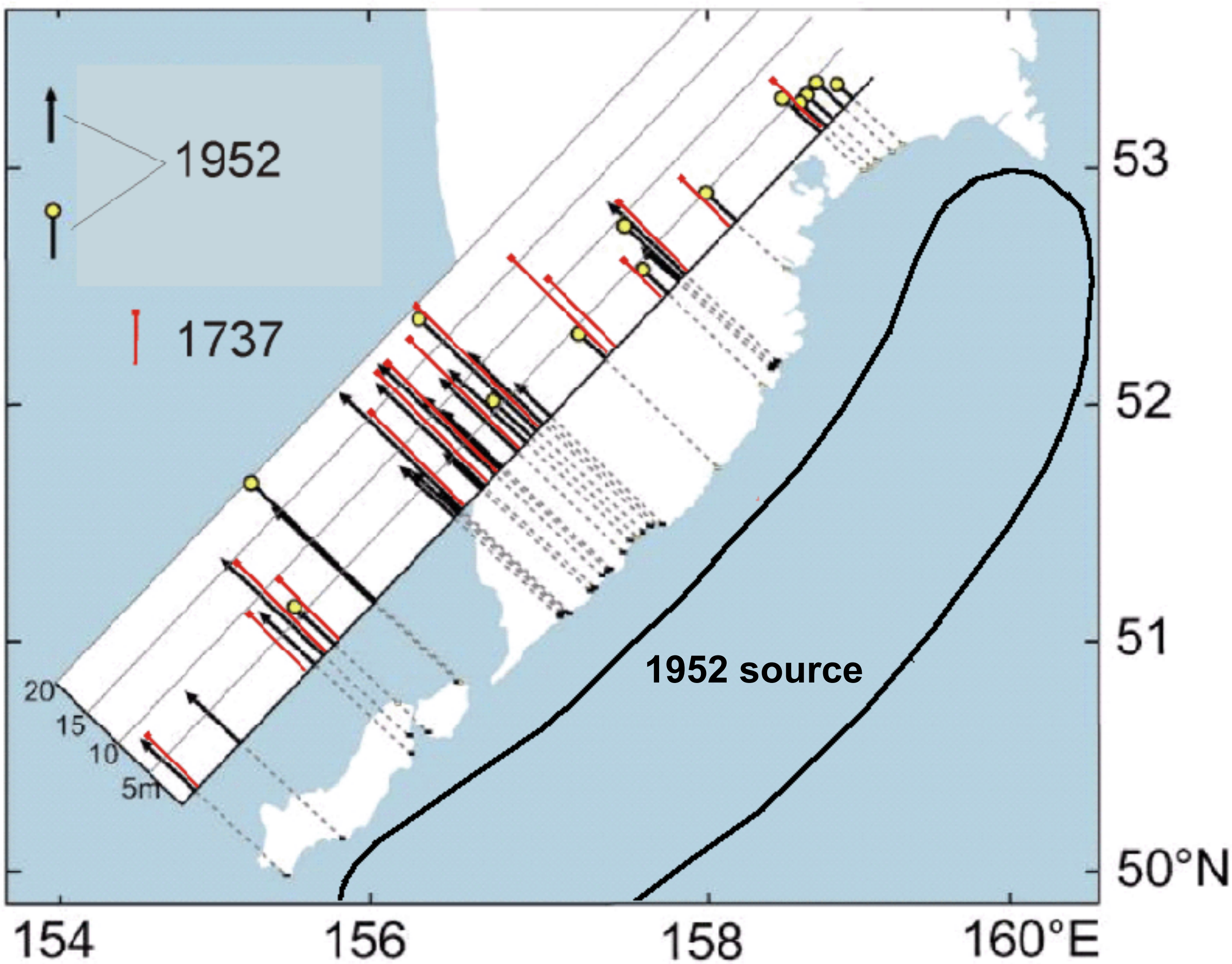
- "If you want to know what will happen, look first at what has already occurred"
- *Niccolo Machiavelli*



A comparative length and completeness of regional tsunami catalogs in the Pacific. Each vertical line corresponds to a single tsunamigenic event with color representing the tsunami intensity on Soloviev-Imamura scale. Average length is 424 years.



Tsunamigenic sand layers in the cross-section made at the altitude of 20.5 m on the Kamchatskiy Cape (Pinegina, 2014)



Restored (by paleo-geological tracing) run-up heights of the 1737 and 1952 tsunamis along the Paramushir – Kamchatka east coast (Pinegina, 2014)

Important key points

- Trans-oceanic tsunamis resulted from M9 class subduction earthquakes gives the major input in overall tsunami hazard (<1% of events responsible for >50% of all fatalities).
- They produce high (>10m) run-ups over extended portion (~1000km) of coastline and constitute major hazard for the coast of marginal seas
- With few exceptions (1896 Sanriku, 1946 Aleutians) the magnitude value Mw=9.0 looks like a threshold for generating of trans-oceanic tsunamis
- Geological methods of paleotsunami tracing is indispensable tool for long-term tsunami hazard assessment and needs to be used in all regions

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