TSUNAMI DAMAGE SURVEY

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About me

Yoshinori Shigihara

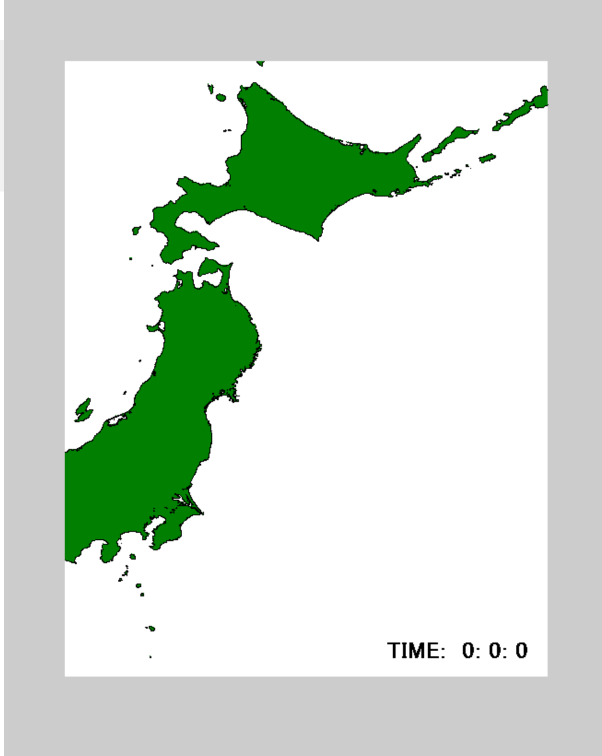
Assistant Professor

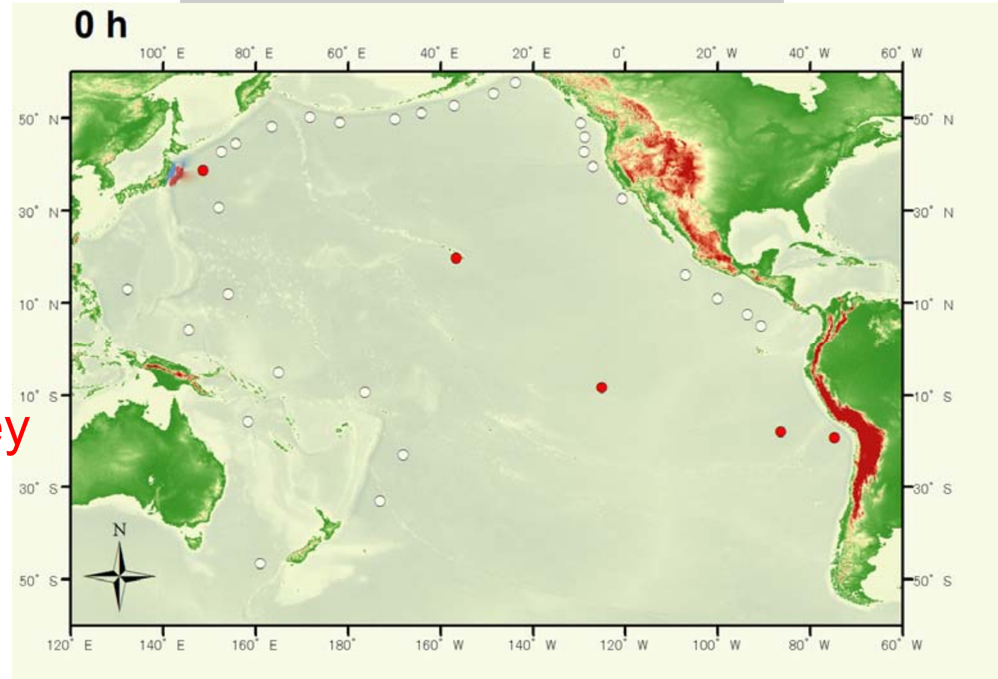
- Graduate school of Tohoku University (2001-2003)
- National Defense Academy (2004-)

Research Interests

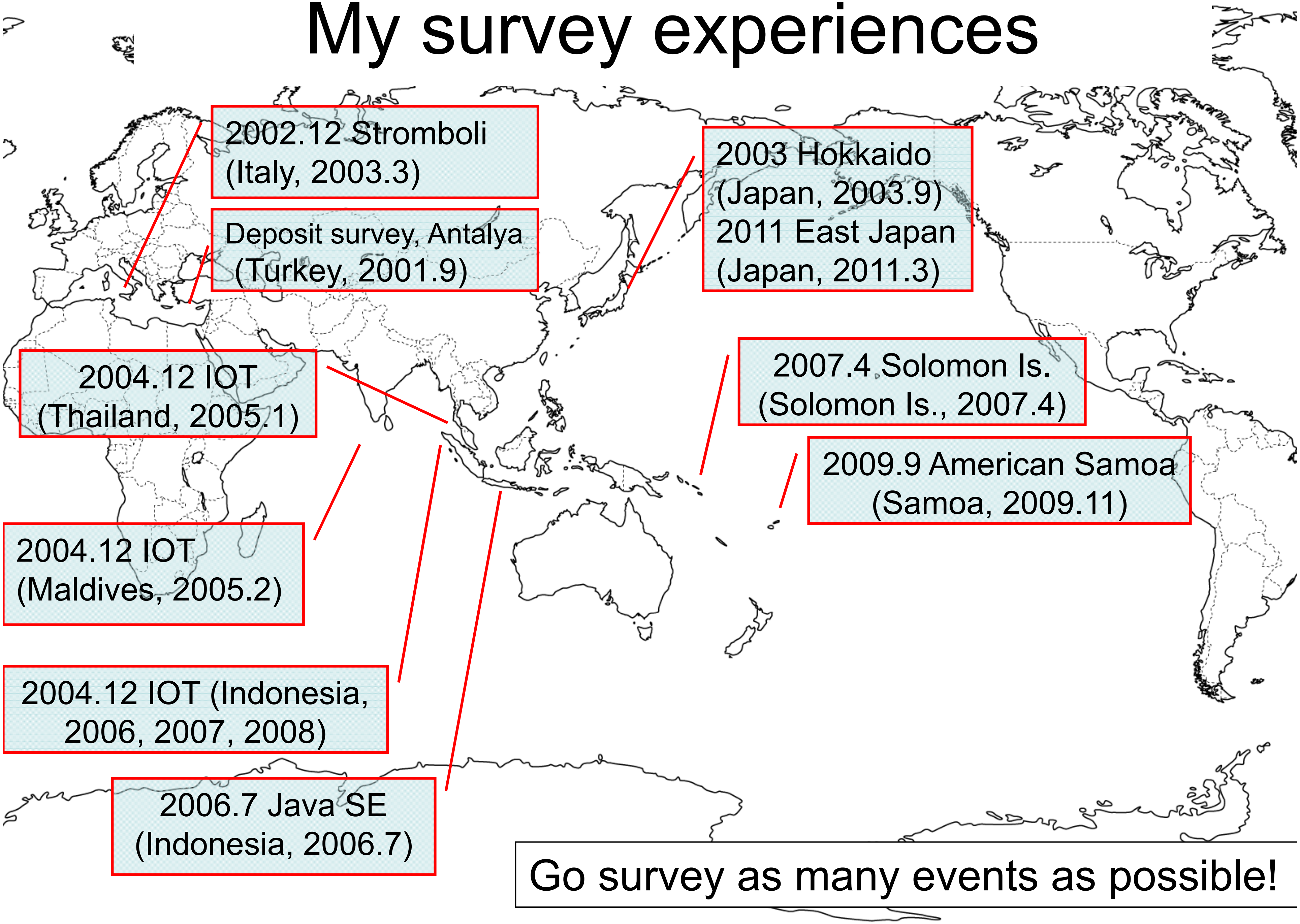
- Numerical modeling of tsunami from generation to inundation
- Estimation of wave force acting on structures
- Modeling of drifting debris due to tsunamis

Laboratory experiment and field survey are important to understand tsunami physics.





My survey experiences

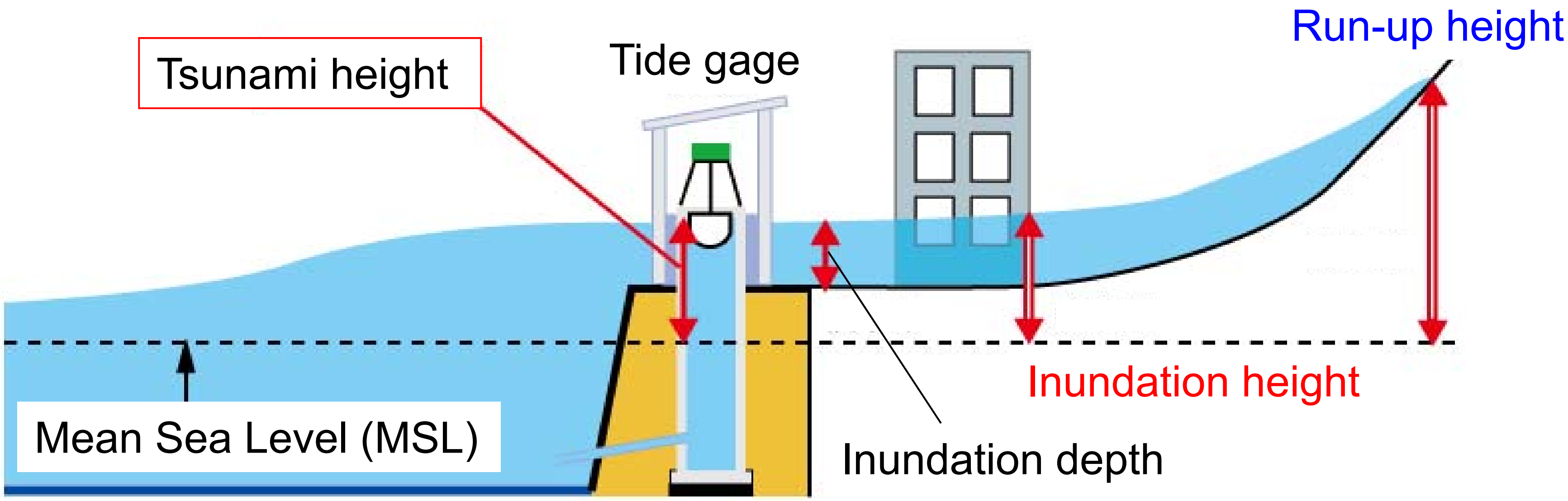


Go survey as many events as possible!

Outline

1. Self-introduction
2. Examples of tsunami damages
   – Human damage
   – Structure
     • Building
     • Bridge
   – Infrastructure
   – Fishery and agriculture
   – Coastal erosion
3. Survey method and theory
   – Camera and GPS
   – Level survey
     • Equipment
     • Field note
   – Tide-level adjustment
4. Matters to be attended in field survey
   – Variety of tsunami trace
   – Selection of tsunami trace
   – Reliability
5. Method of leveling & Exercise

Definition of Tsunami Height



- Tsunami height: vertical distance from MSL to water surface
  - Run-up height : ground level where tsunami stops finally
  - Inundation height : vertical distance to trace-mark on obstacle

- Inundation Depth (ID) : From ground to interest point

* Important factor for the structure design against tsunami
(ex. wooden houses will be washed away if ID > 2m)

Website from Japan Meteorological Agency(JMA)

Examples of Tsunami Trace

Inundation height

Watermark on wall of building

Run-up height

Borderline of debris on ground

Example of tsunami damages

-Human damage of 2004 Indian Ocean Tsunami-

	death	missing
Indonesia	126,602	94,638
Sri Lanka	38,938	4,100
India	10,749	5,640
Thailand	5,305	2,932
Maldives	82	26
Malaysia	69	5
Myanmer	61	
Bangladesh	2	
East Africa	137	
Total	181,945	107,341

- Information from Reuters, 27 March 2005
- UN predicted that the death toll might be more than 300,000.

Casualties by historical tsunamis in Japan

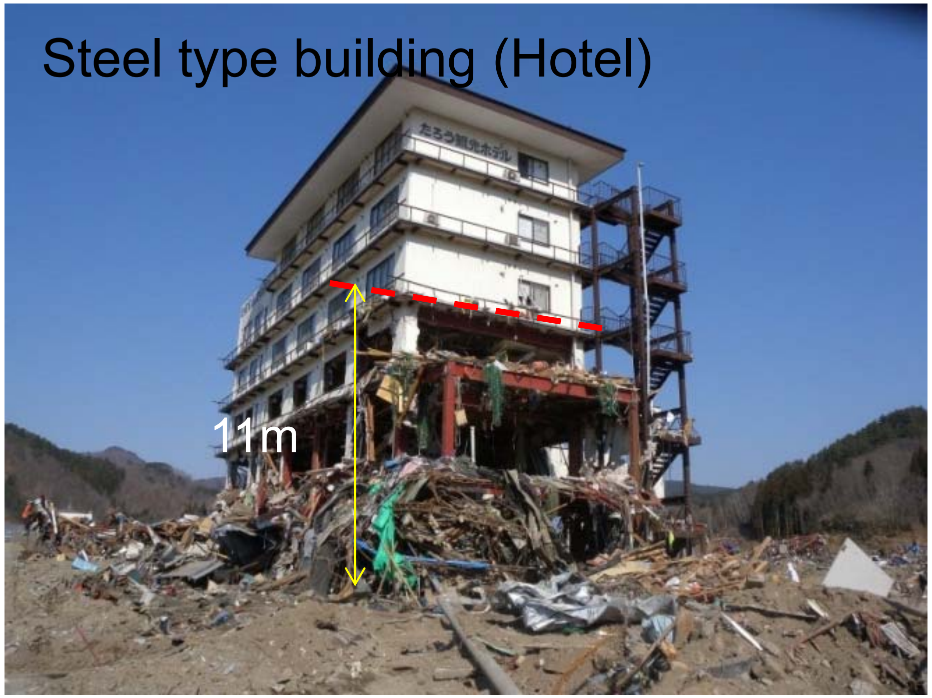
	death	missing	note
2011 East Japan	15,844	3,450	Data of Jan. 6, 2011
1993 Hokkaido Nansei-oki (Okushiri)	202	28	The main cause was the tsunami.
1983 Japan Sea	104		100/104 were killed by the tsunami.
1960 Chili	119	20	
1946 Showa Nankai	1,330	102	This record may be inaccurate, because of the confusion just after Word War II.
1944 Showa Tonankai	998		
1933 Showa Sanriku	1,552	1,542	
1923 Kanto	More than 100,000		Death toll was more than 100,000. But the major cause was the earthquake and the fire.
1896 Meiji Sanriku	21,753		
1854 Ansei Tokai & Nankai	Huge		Death toll was believed as more than 10,000. We do not have an accurate nationwide data. The major cause might be the tsunami.
1707 Ho-ei	Huge		
1703 Genroku	Huge		
1611 Keicho Sanriku	Huge		
1605 Keicho	Huge		

HUMAN DAMAGE

- Death toll depends on the condition of natural phenomena and the condition of human society
  - Condition of tsunami
    - Attack time: Morning? Noon? Night?
    - Magnitude: If the tsunami is very small, no one is killed and injured by the tsunami. If tsunami height is greater than 2-3m, the casualties increases suddenly. The tsunami flow with 70cm depth can kill the human. If the tsunami is very great, there is the possibility that most residents are killed by the tsunami.
  - Condition of human society (Vulnerability)
    - High population on low-lying area
    - Lack of protection (coastal structure)
    - Lack of information, education and leadership

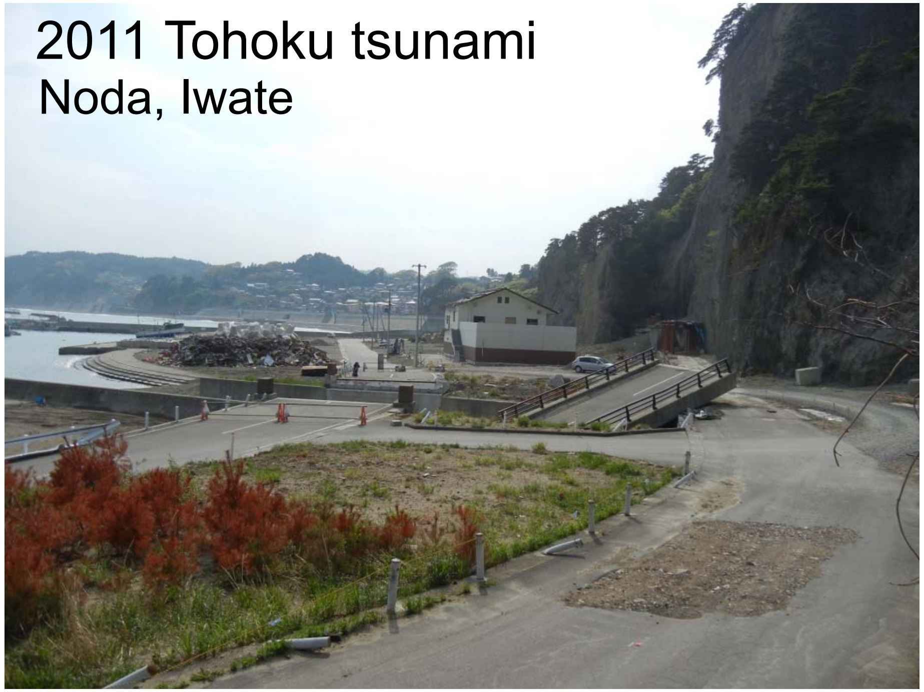
Damage of buildings

2011 Tohoku tsunami in Miyako Taro, Iwate Pref.

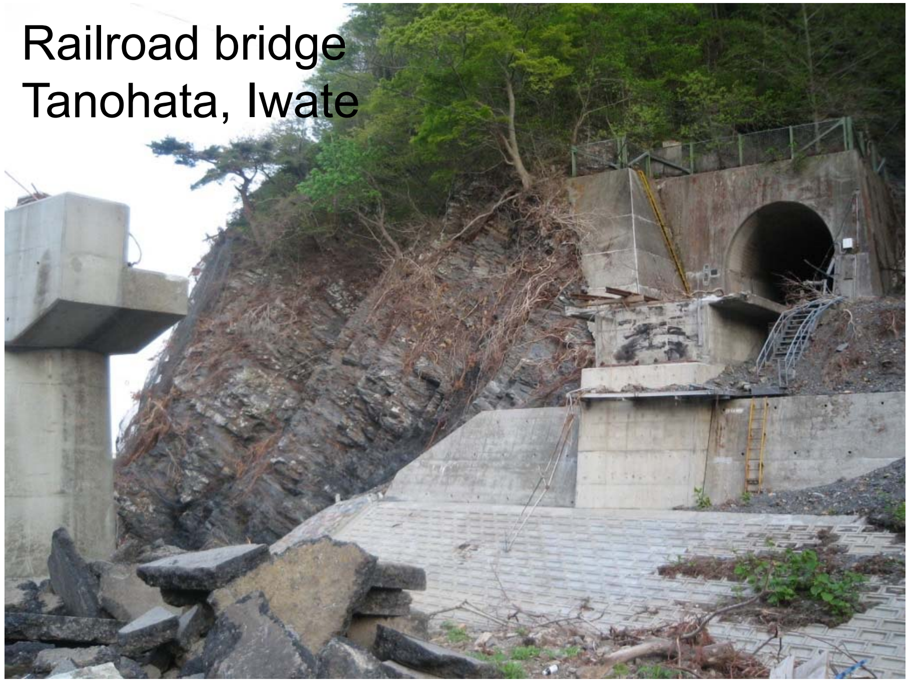


Damage of bridges

- Wash away girders
- Shut off traffic
- Lift force might be significant effect to the mechanism of damage



IOT 2004; Banda Aceh, Indonesia



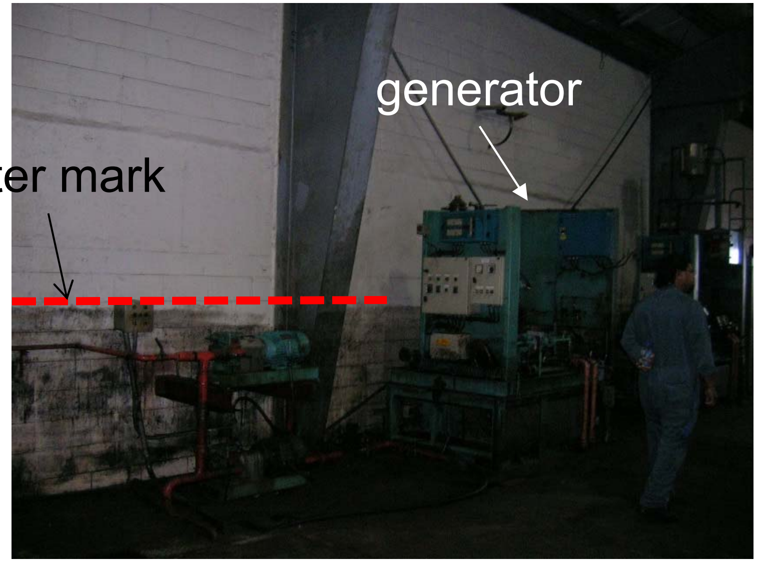
Seawall failure due to breaking wave impact and scouring due to tsunami backwash

Damage by 17 July 2006 Java Tsunami, Pangandaran, Indonesia

Damage of Infrastructure

Once facilities are inundated,(ex. generators, water-purify tanks) all system must be shutdown.

Steam power plant



Pago Pago, American Samoa.
2009 Samoa Tsunami

Sewage plant

2011 Tohoku Tsunami; Sendai, Japan

Damage in agriculture

Damage of rice field by 2011 Tohoku Tsunami; Sendai, Japan

- Serious damage to the crops
- Injury from salt water
- A lot of debris
- Need long term for recover

Survey method and theory

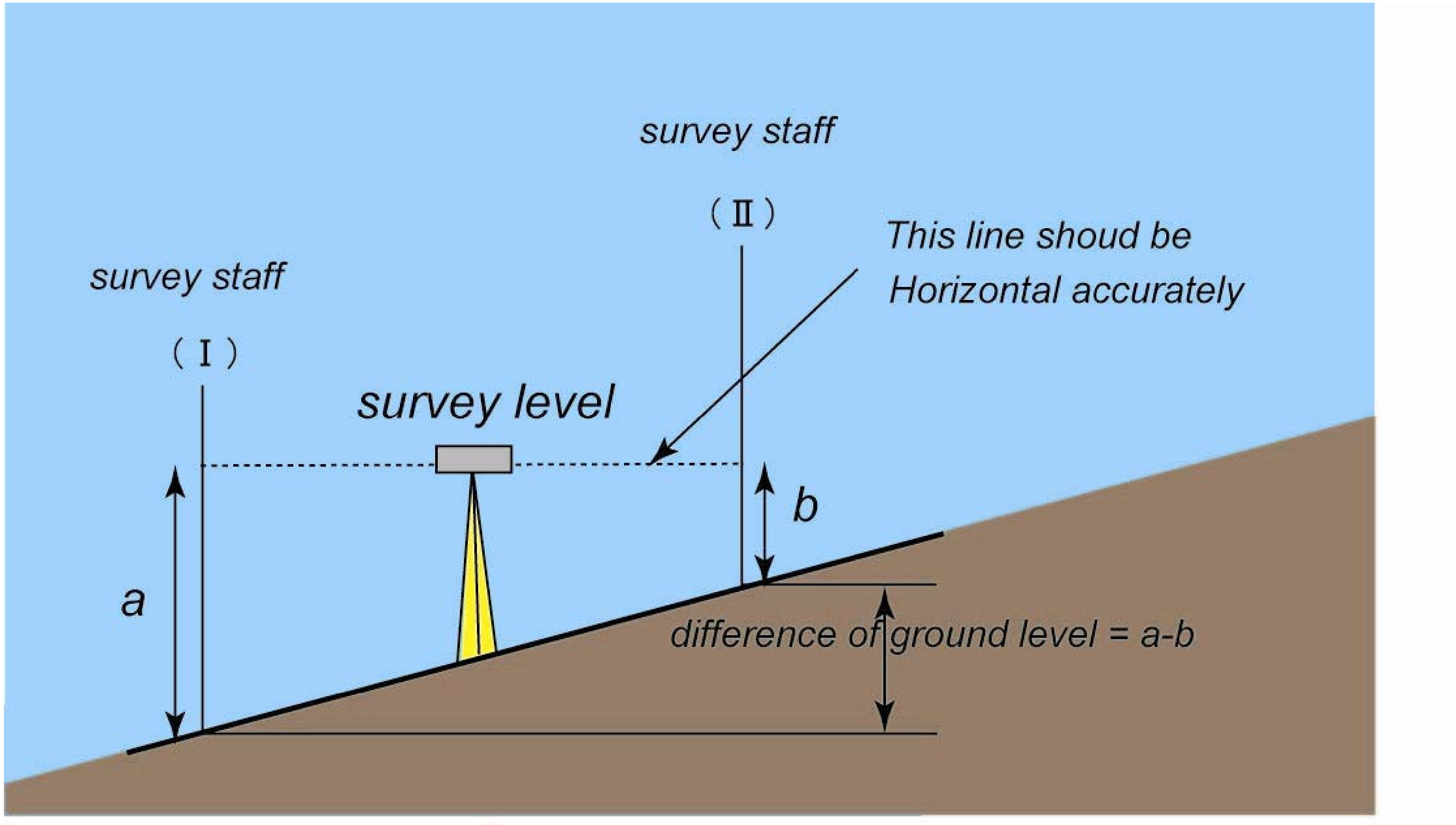
To analyze the tsunami effect,,,

- We need to know
  - tsunami height (flow depth, water level,,)
  - tsunami arrival time
  - tsunami direction
  - flow velocity
  - wave period
  - number of waves
- We need to get
  - tide/wave gage record
  - satellite info
  - measurement and interview in post-tsunami survey

Post-Tsunami Survey

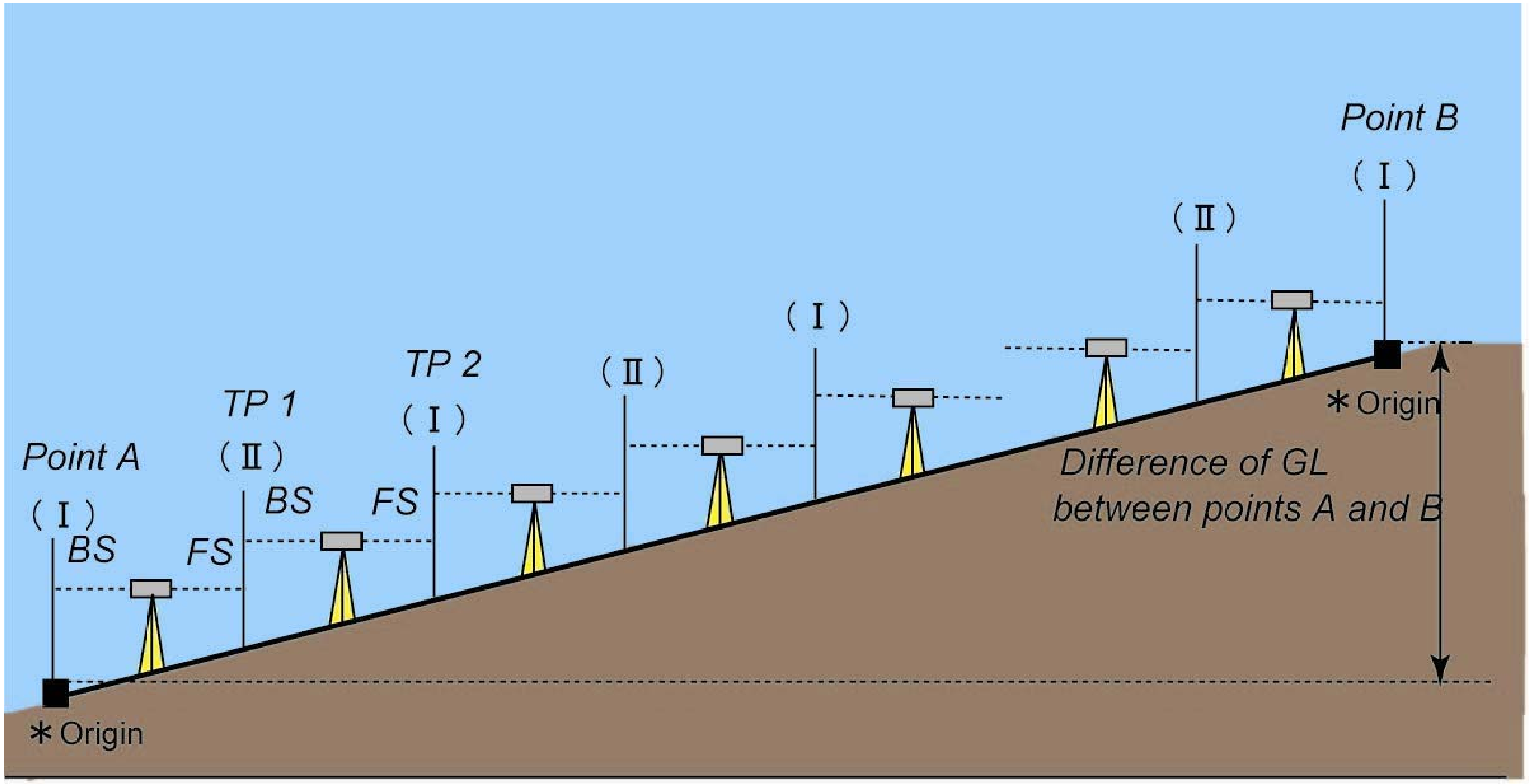
- Low-density Wide-area measurement
  - Camera, watch, hand-held GPS
    - Map datum of GPS: Take care!
    - Camera with a built-in GPS is convenient.
  - **Leveling**
    - Accuracy of hand-held GPS is several-meters to ten-several-meters in horizontal, and several-meters to several-tens-meters in vertical. Horizontal accuracy is enough, but vertical one is not. Thus we should use leveling for vertical measurement.
- High-density Narrow-area measurement
  - Topographical survey

Principle of level survey



- If you have a survey staff and you can keep your eye horizontal, you can measure the difference of ground level easily.
- To see a survey staff horizontally, we use ‘automatic level’ or ‘hand level’. Recently, ‘laser distance meter’ is used frequently.

Principle of level survey



Difference between ground level of point A and that of point B

= ∑Back Sight - ∑Fore Sight

Team minimum = 1 level-man + 1 staff-man (2 persons)

Equipment for level survey

- **Automatic level**
  - Accurate
  - Heavy, Big → time to pass the immigration
  - Staff-man should stand on the target point.
- **Hand level**
  - Inaccurate; but surprisingly accurate if you become skilled
  - Light and Small
  - Pole-man should stand on the target point.
- **Laser distance meter**
  - Inaccurate; but the total error may be less than 20cm (in the case of general distance)
  - Main equipment is similar in weight and length, but the legs are not required. (But the legs are useful)
  - It is not necessary that staff-man stand on the target point. You can directly survey the height.

Automatic level

1. Setup the legs as horizontally as possible
2. Attach the survey level to the head of the legs
3. Be the leveling bubble in the circle using the footscrews of the level
4. Centre the vertical cross-hair on the levelling staff and clamp the telescope
5. Focus onto the staff, and read the scale to 1mm

Hand level

1. Center the leveling bubble. You can look at the leveling bubble in the right-half.
2. Focus onto the pole, and read the scale to 1cm.

Note 1: You should not read the scale of the staff. You should use a red-white pole with 20cm scale. The important thing is to keep it horizontal.

Note 2: The instrument height is the height of your eye.

Laser distance meter

- Look at the target, using the sight scope
- Push the bottom, and read the display

Note: A vertical vibration of hand possibly provide a fatal error.

Tide-level adjustment (1)

- The level of tsunami trace is often measured from the sea level.
- We should consider the tide. The sea level at the survey may be different from that at the tsunami.

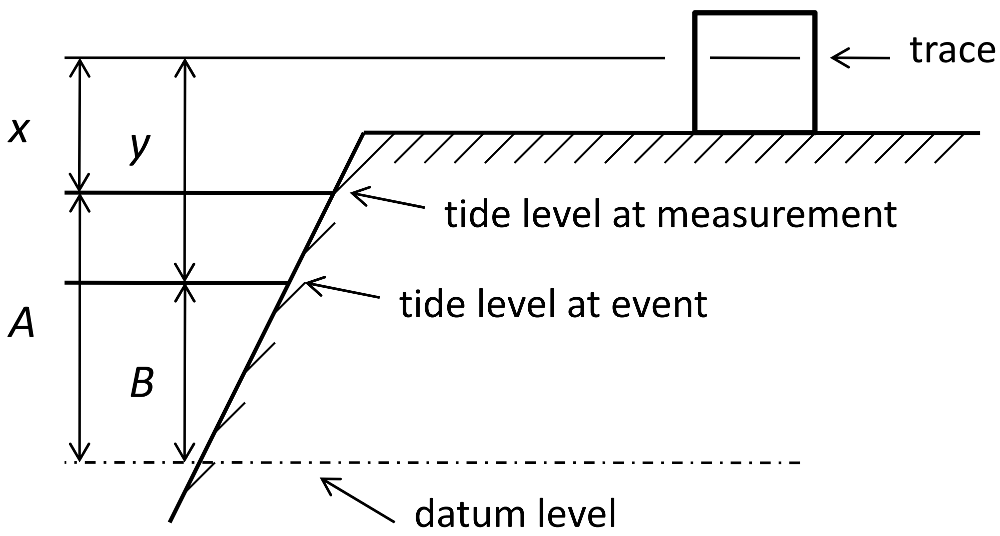
x = measured height of the trace from the sea level

A = tide level at the measurement

y = actual height of the trace

B = tide level at the event

$$y = x + A - B$$

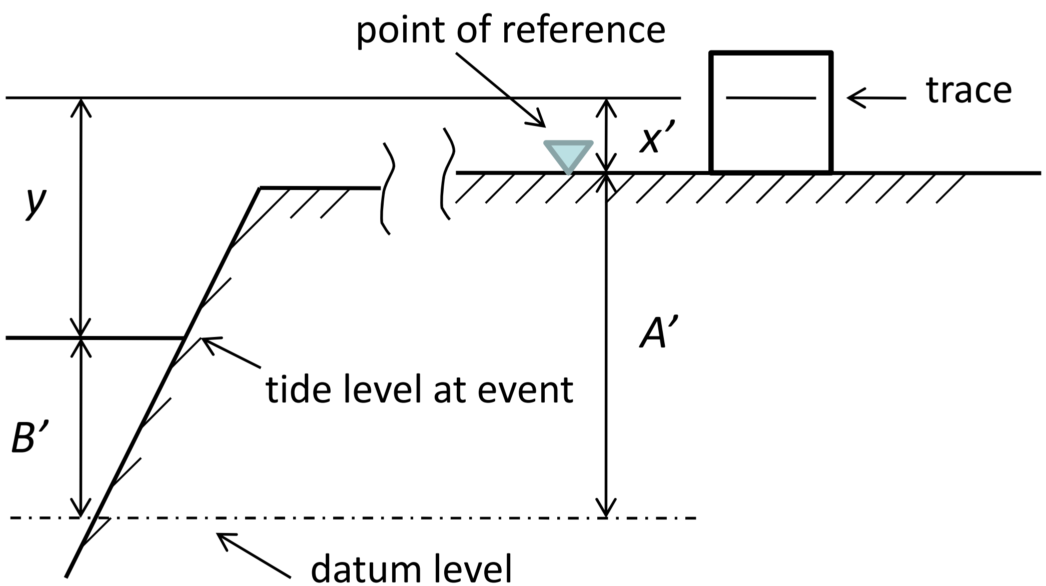


Tide-level adjustment (2)

- Sometimes the trace height is measured from some point whose elevation is already known.
- Note that the reference point elevation on a map is not always evaluated from the local sea level.

$$y = x' + A' - B'$$

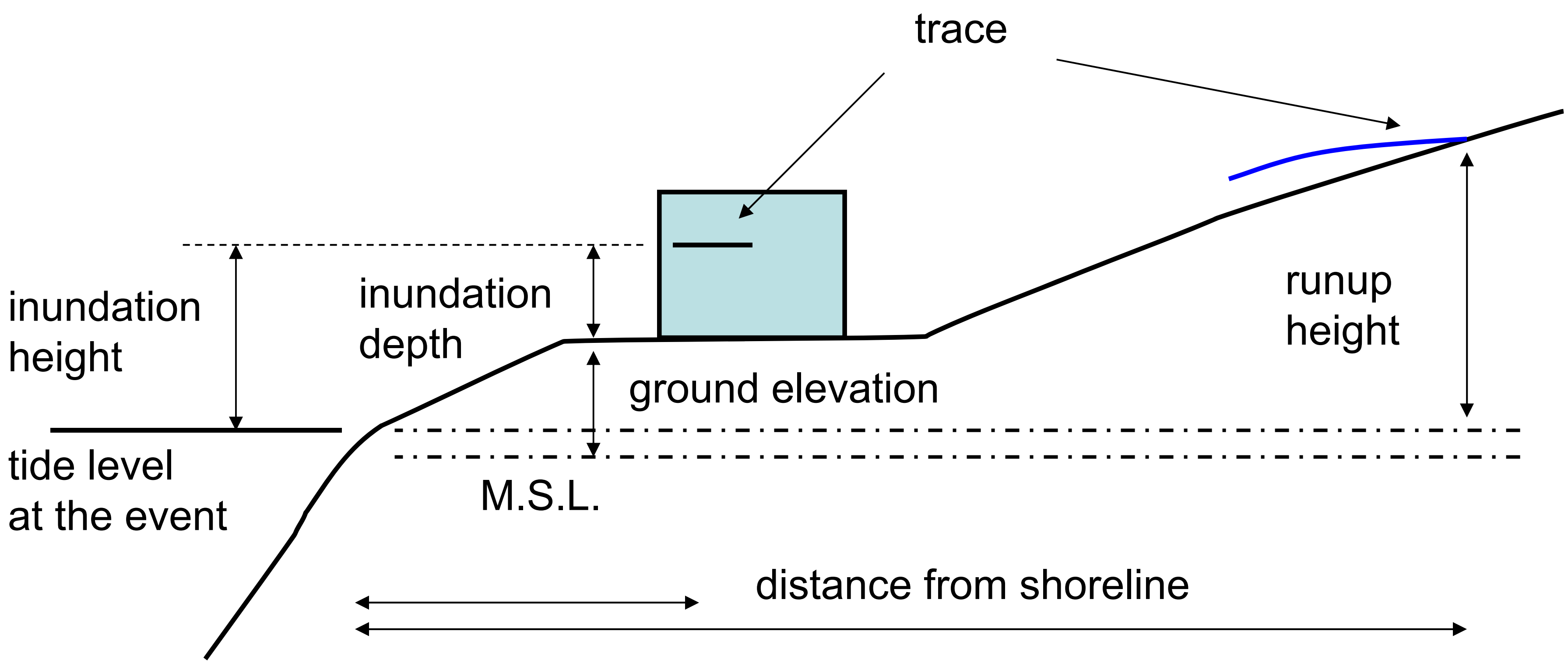
x' = measured height of the trace from the reference point (=ID)
A' = elevation of the reference point
B' = tide level at the event from the same datum level as *A'*.



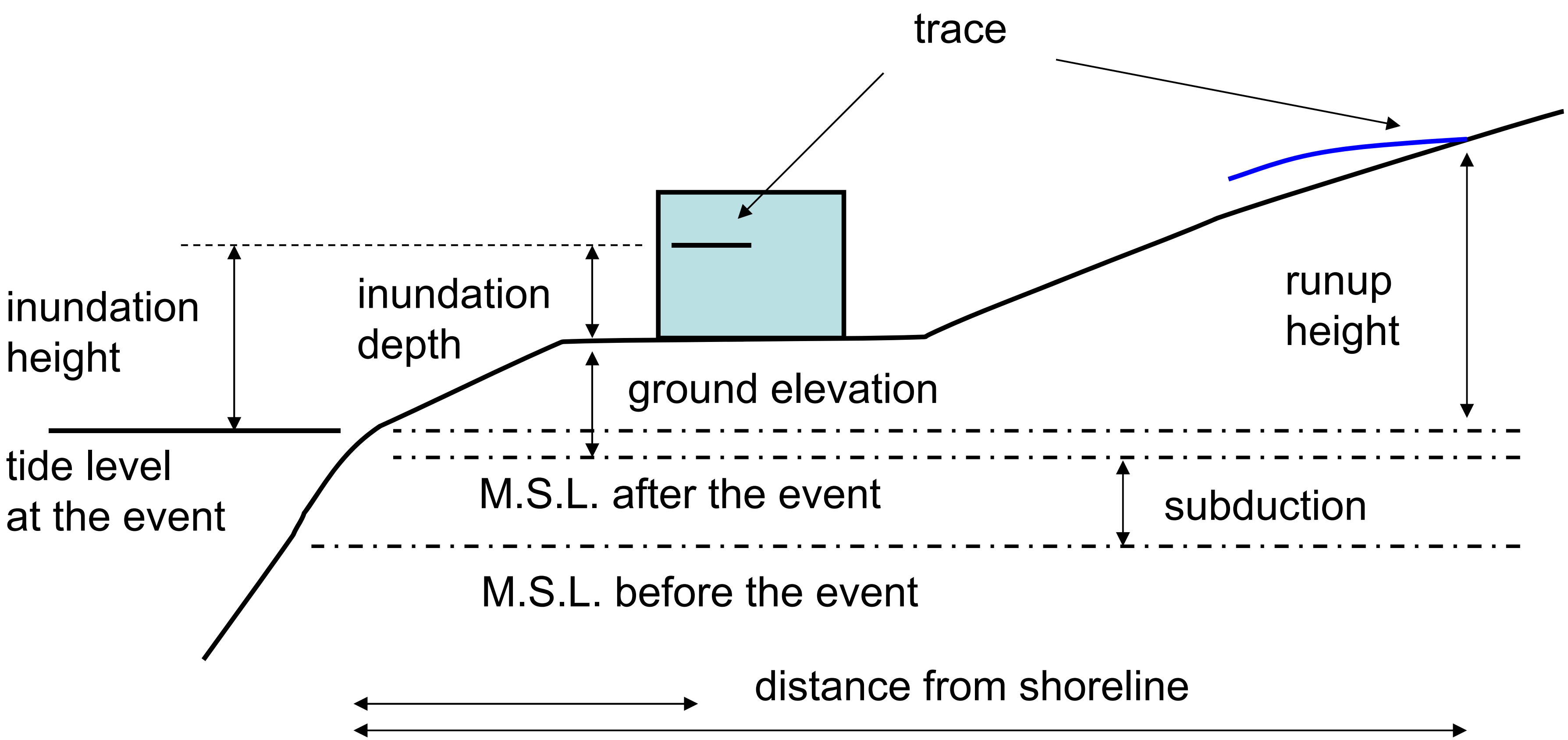
Tide-level adjustment (3)

- Of course, if $x >> |A-B|$, this adjustment is not so important. However, if x and $|A-B|$ has same order of magnitude, it is important to consider this adjustment.
- B (B')(=tide level at the event) is not always equal to the tide level at the tsunami arrival time. If the trace was left by the 3rd wave, B (B') should be the tide level at the 3rd wave.
  - This difference is not so important in many cases. However, for a case that tide level varies very rapidly, or for a case of far-field tsunami that continues several-tens hours, it is important to know when the water elevation reached the maximum. In such a case, the trace is often left by a wave at high tide, and the trace is not a record of the maximum wave.
- In addition to the tide, we should take care the subduction/uplift of ground by earthquakes.

Definition (without subduction/uplift)



Definition (with subduction/uplift)



Matters to be attended in field survey

Required information in Table(1)

- point number
- site name
  - (country, region and location name)
- location
  - (latitude, longitude)
- ground elevation
- trace height
- distance from shoreline
- classification
  - (runup or inundation)
- kind of measured target
  - (e.g. water mark inside the house, broken branch and so on)
- measurement time
- tide at measurement
- tide at the event
- trace height after tide level adjustment
- note
- reliability
- measuring person’s name

Required information in Table(2)

- In Note, we expect that the situation of trace is described
  - direction of trace
    - If the measured target is the water mark adhered on building's wall, the direction of wall is important to understand the physical meaning of the data. (ocean side? inland side? or inside?)
  - consistency with other traces
  - surrounding topography
  - etc.

Required information in Table(3)

- Reliability definition (following the tradition from 1960 Chilean Tsunami)
  - A: high. Trace is clear, AND, measurement is accurate.
  - B: moderate. Trace is not clear but reliable water level can be obtained by evident of resident, surrounding situation etc., AND, measurement is accurate.
  - C: low. Even if trace is clear, it is thought as abnormal height. Or else measurement error is large (e.g.) because distance from shoreline is very long.
  - D: lowest. Trace is not clear and distinguishable (e.g.) because of typhoon.
- In general, the accuracy is affected the following two factors.
  - Error caused by selection of trace
    - If trace is not clear, error is large.
    - We should select the trace of which we could understand the clear physical meaning. Broken branch is not desirable.
  - Error caused by measurement itself
    - Distance from shoreline, equipment

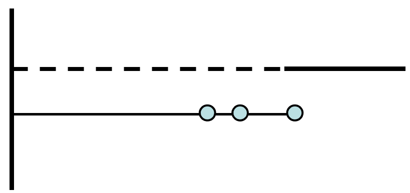
		Selected measurement-target			
		Clear trace	Point by eyewitness evidence	Clear but special point	Unclear trace
Error of measurement	Small	A	B	C	D
	Large	C	C	C	D

Required information in Table(4)

- When the trace height was measured from the sea level, the tide level adjustment is required. The information on tide level adjustment should be noted in the table.
  - Measurement time
  - Tide level at the measurement
  - Assumed tsunami arrival time (arrival time of the wave that left the trace)
  - Tide level at the tsunami
  - Reference of tide level (M.S.L. is desirable. If not possible, it necessary to write the used reference clearly.)
- (If necessary,) To avoid confusing, add country-code to point number, e.g. TH-23, ID-11. Two or three characters provided in ISO 3316 is used as country code.
  - Indonesia=ID：IDN, Sri Lanka=LK：LKA, Thailand=TH：THA, India=IN：IND, Maldives=MV：MDV

How to draw Figure

- It is recommended to plot on plane map.
  - Trace number should be entered
    - e.g. [TH-12] 5.4
  - If special attention is necessary, add some mark
    - e.g. [ID-15] 7.2 (*)
  - Example at Google Earth : http://www.nda.ac.jp/~fujima/TMD/
- If bar graph is used, pay attention to:
  - All data should not be drawn on the same figure, if classification, reliability, distance from coastline are quite different.
  - Pay attention not to hide low trace-height data
    - e.g.



Example: Use of Google Earth

- Figures with arbitrary scale can be made automatically by using Google Earth.
- Very easy to distribute the integrated data. kmz file is only a text file. Automatic download is available by using ‘network link’ in Google earth.
  - If you have Google Earth, please add ‘network link’ to: http://www.nda.ac.jp/cc/users/fujima/TMD/Tsunami_Measurement_Data.kmz
  - At present, data obtained by Japanese teams are stored in the database. This work was carried out with support of Tsunami Technical Committee, Asian Civil Engineering Coordinating Council (ACECC).

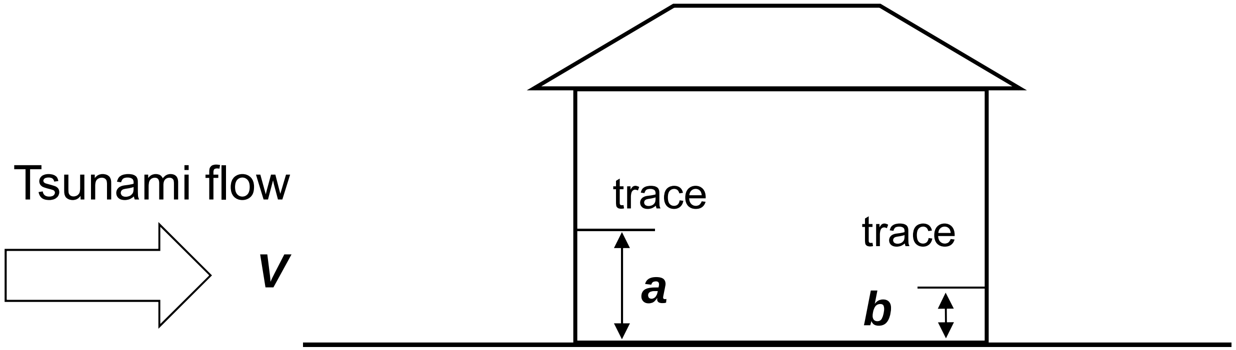
http://www.nda.ac.jp/cc/users/fujima/TMD/
Tsunami_Measurement_Data.kmz

View database by Google Earth

Note on ‘Placemark’ on image of Google Earth

- If Name of Placemark is 4.2 R, for example, the runup height after tide-level adjustment is 4.2m at the position of Placemark icon.
- If that is 3.5 I, the inundation height after tide-level adjustment is 3.5m at the position of Placemark icon.
- If that is 6.6 *, 6.6m has another special meaning that is not runup height and inundation height. For example, (1) that is the height of structure, (2) that is only a reference data, (3) we could not understand the data type (runup or inundation), and so on.

Estimation of velocity by Matsutomi



- If the tsunami direction is clear, and you obtain the trace height at the front of the building, ***a***, and that at the rear of the building, ***b***, you can roughly estimate the flow velocity, ***V***, based on the principle of Pitot tube.

$$V = \sqrt{2g(a-b)}$$

- Okamoto and Matsutomi (2009) modified the relation through their hydraulic experiments as follows:

$$V = 0.6\sqrt{2g(a-b)}$$