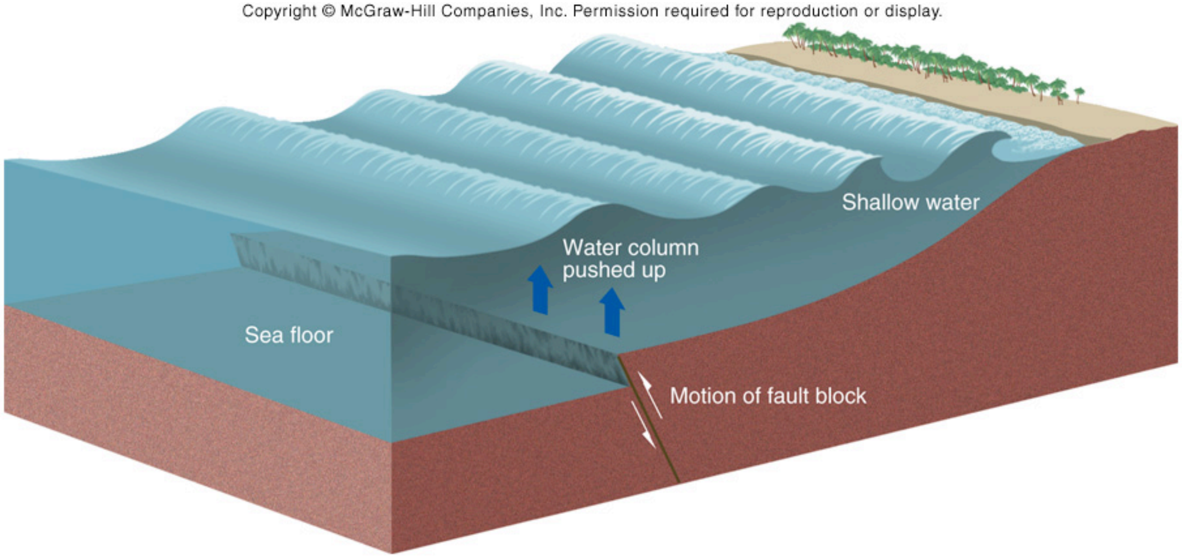
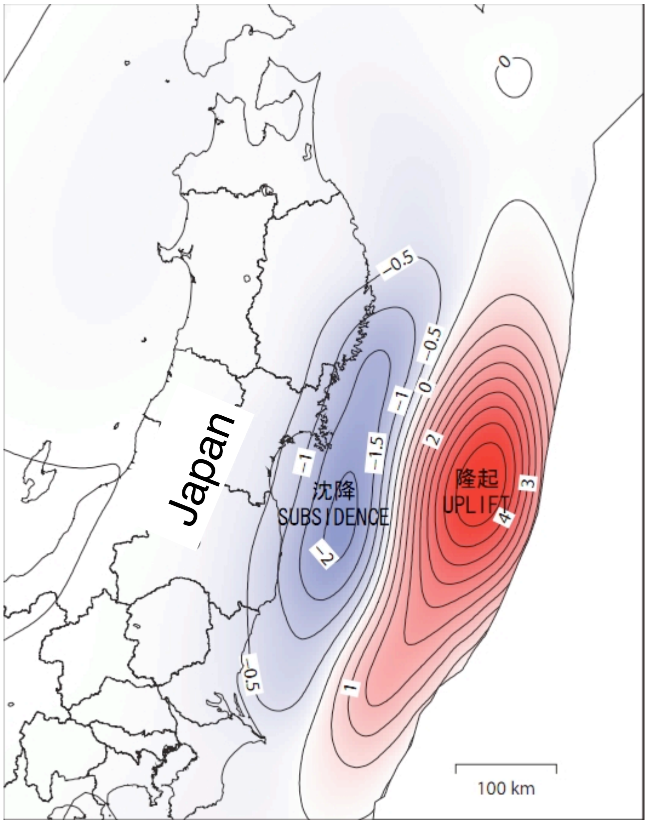
TSUNAMIS

- “tidal wave” a misnomer: NOTHING to do with tides (origin of name...)
- caused by submarine earthquakes, landslides, or eruptions
- about two destructive ones per year in the Pacific ocean - one ocean-wide tsunami every 10-12 years
- gently sloping shore and bays focus the tsunami and allow it to move far inland

How a tsunami starts





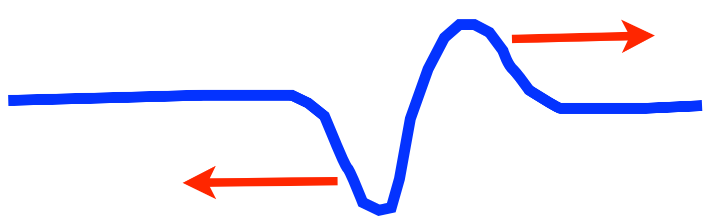
March 11, 2011 Japan earthquake seafloor uplift and subsidence

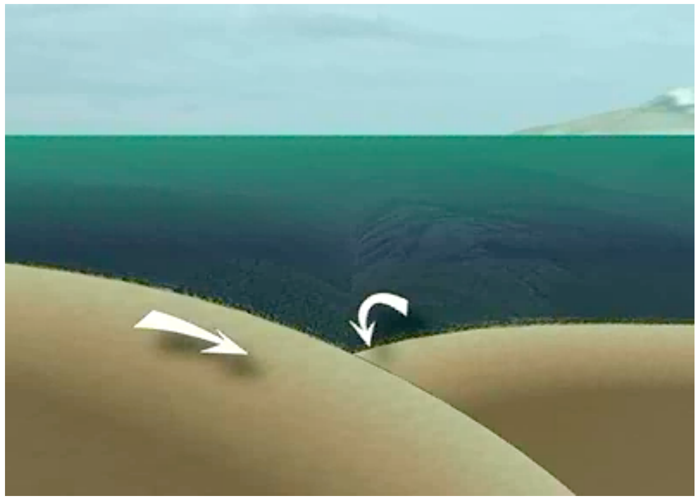
dimensions of seafloor uplift/ subsidence region?

amplitude of seafloor uplift and subsidence?

toward Japan
trough hits first
(water recedes first)

toward western North America crest hits first

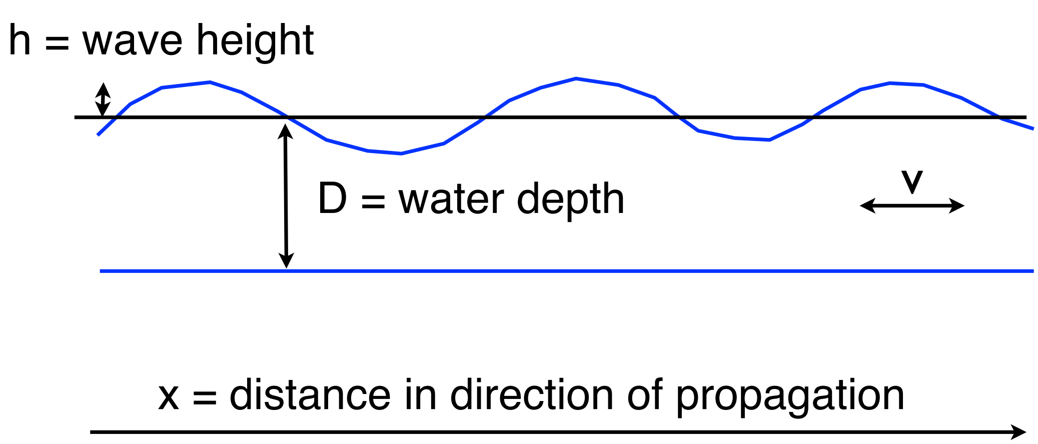




Miho Aoki, University of Alaska-Fairbanks Art Department, University of Alaska-Fairbanks

“Shallow water equations”: assume all motion is horizontal (because wavelength is longer than ocean depth and wave height is small)

v = velocity of the water sloshing back and forth as the wave passes through



(not drawn to scale)

Mass conservation:

$$\frac{\partial h}{\partial t} = -\frac{D\partial v}{\partial x}$$

Momentum conservation (Force balance):

$$\frac{\partial v}{\partial t} = -\frac{g\partial h}{\partial x}$$

These can be combined to get a wave equation:

$$\frac{\partial^2 h}{\partial t^2} = gD\frac{\partial^2 h}{\partial x^2}$$

refer to class handout here

$$\frac{\partial^2 h}{\partial t^2} = gD\frac{\partial^2 h}{\partial x^2}$$

What is this an equation for?
That is, what is it telling us?

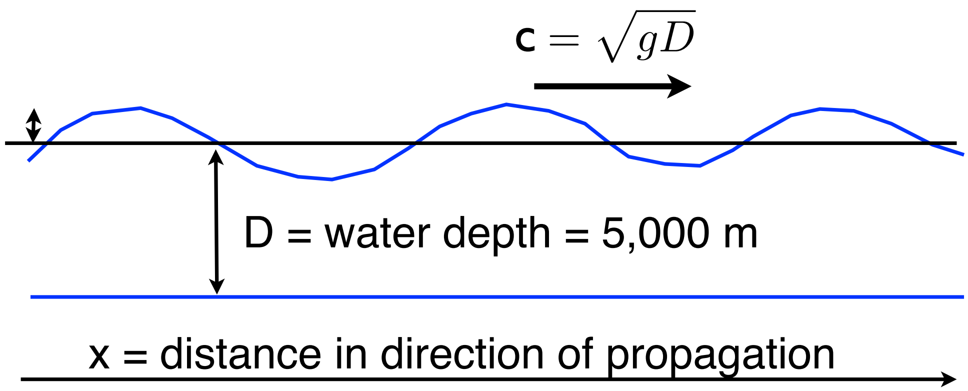
$cos(x - ct)$ is a solution to this equation, as long as $c = \sqrt{gD}$
so is $sin(x - ct)$

You can tell by taking derivatives of both sides and plugging them into the equation at the top of this slide.

The solutions are *sinusoidal waves that are moving with a velocity of c in the x direction*.

$g = 10\ m/s^2$

h = wave height (set by tsunami earthquake uplift) = 1m
wavelength (set by tsunami earthquake uplift area's width) is 500 km (for example)



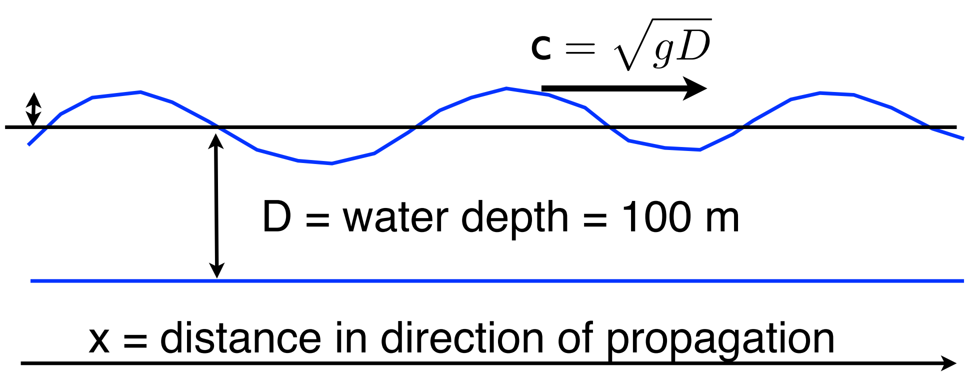
(1) How fast in the open ocean?

(2) wave period (peak to peak)?

(will you notice in a boat?)

$g = 10\ m/s^2$

h = wave height (set by tsunami earthquake uplift) = 1m
wavelength (set by tsunami earthquake uplift area's width) is 300 km (for example) in open ocean



How fast as you get closer to the shore?
100m? 10m?

(wave period stays the same, so wavelength gets shorter)

It turns out that energy transmission by a water wave is proportional to wave speed times wave height^2

Energy is conserved (assume none is being put in or removed by other means) so:

$$\frac{h_{shallow}}{h_{deep}} = \sqrt{\frac{c_{deep}}{c_{shallow}}}$$

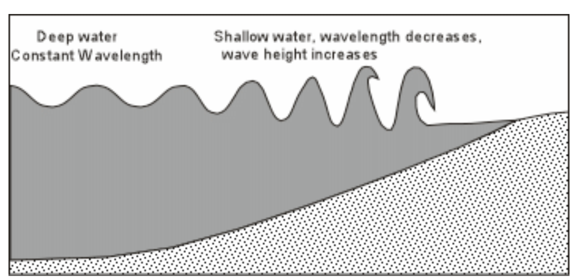
What is the tsunami wave height h where the water is 10 m deep?

Note: wave may be slowed more by drag of the seafloor as it approaches the coast. This can make it taller.

How fast can you run?

Usain Bolt - about 10.4 m/s

Tsunami - several m/s



water rises by 10 m in 20 minutes then retreats (another 20 minutes) then rises again...

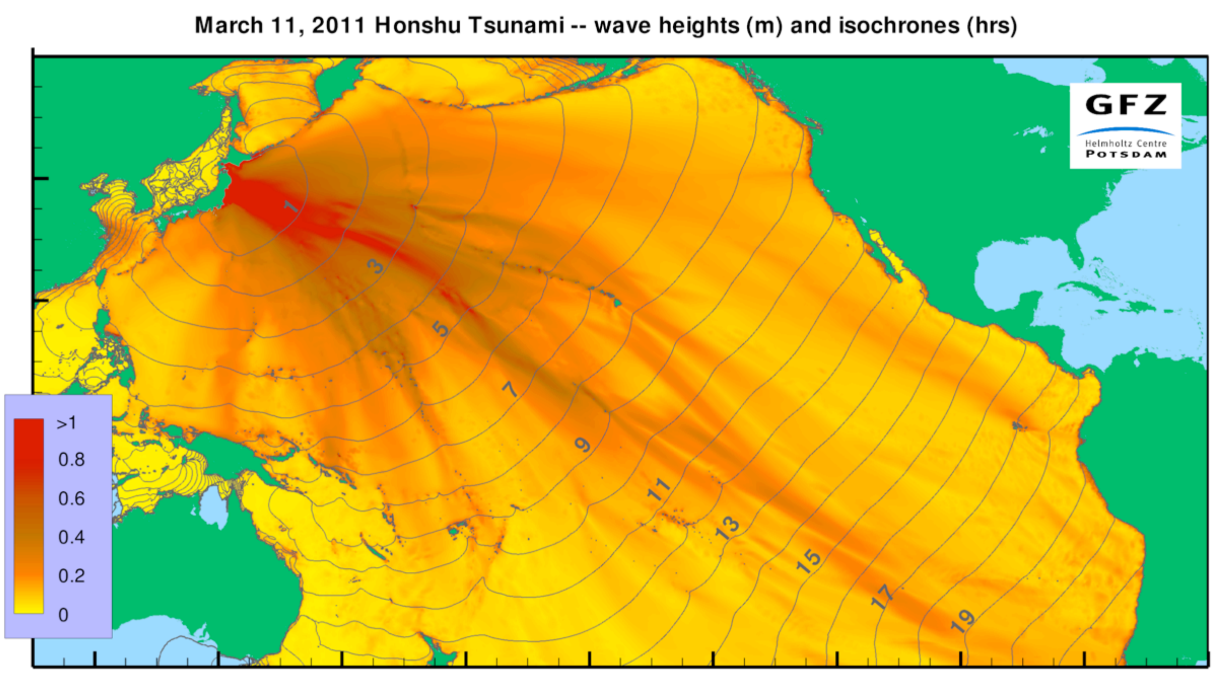
water may either retreat first or advance first, depending on where you are

several waves can hit over hours, the biggest may not be the first

nearly flat land surface means inundation inland several km (3-4 km in Japan)

Tsunami simulations

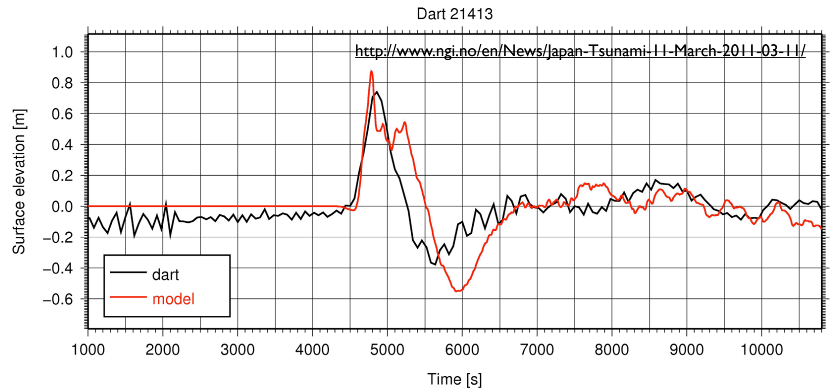
- 2D flow
- realistic ocean bathymetry
  (waves refract and reflect)
- correct initial condition (seafloor uplift pattern)
- accurate at predicting height and arrival time
  (used to generate tsunami warnings)

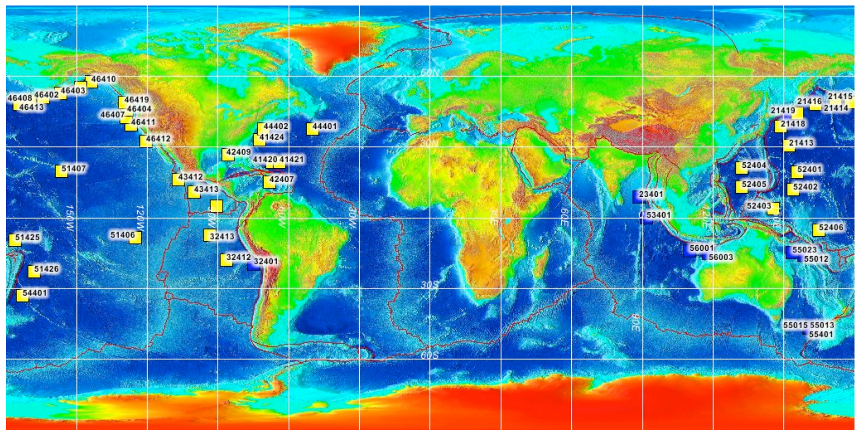

March 11, 2011 Honshu Tsunami -- wave heights (m) and isochrones (hrs)
>1
0.8
0.6
0.4
0.2
0
1
3
5
7
9
11
13
15
17
19

Comparing models with data on the open ocean

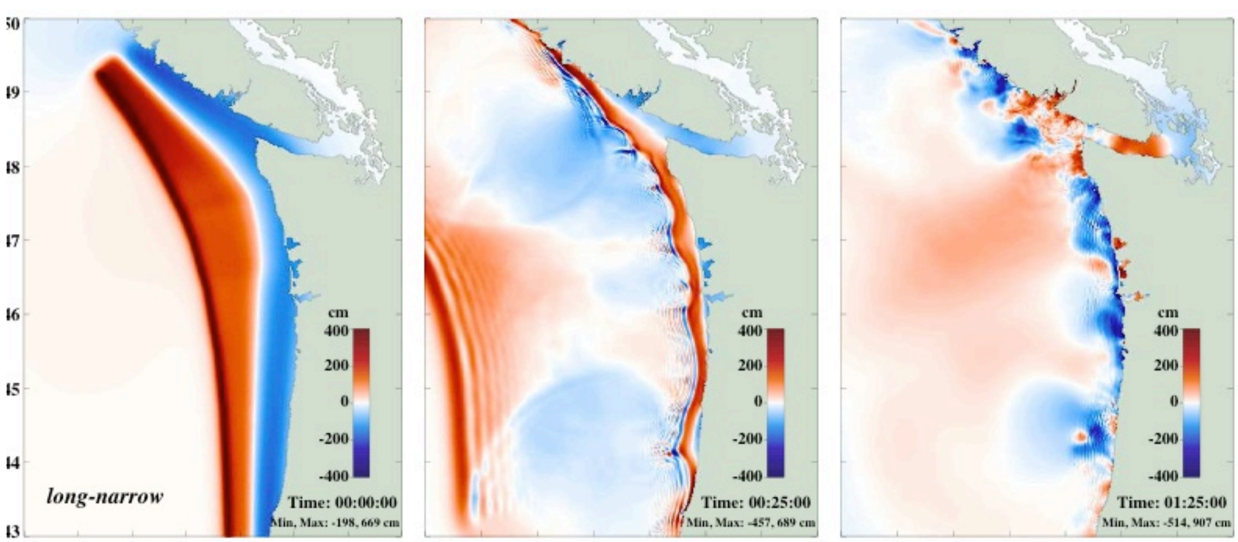
DART buoys

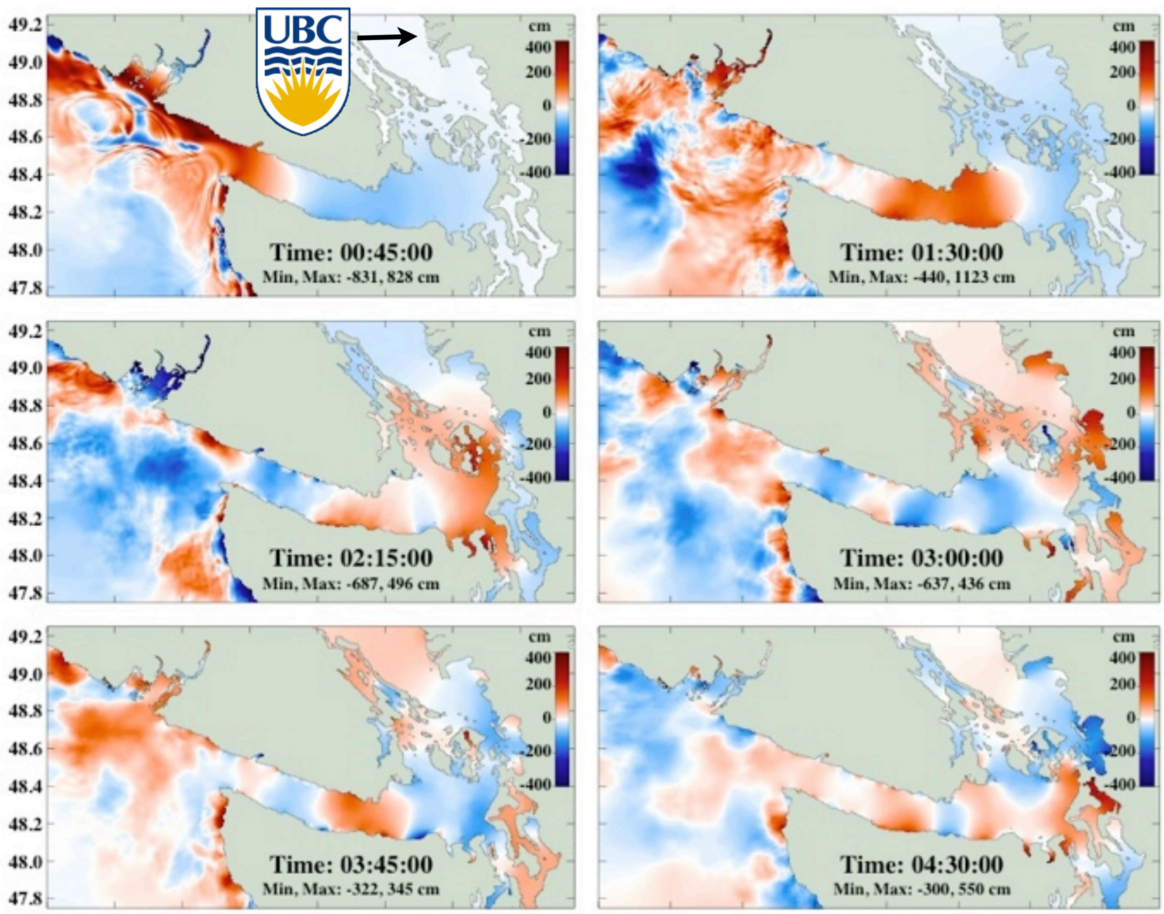
Deep-ocean Assessment and Reporting of Tsunamis





Magnitude 9 earthquake tsunami model by J. *Cherniawsky et al. 2007 (National Resources Canada, Sydney BC)*





Maximum wave heights (modeled M 9 Cascadia earthquake)