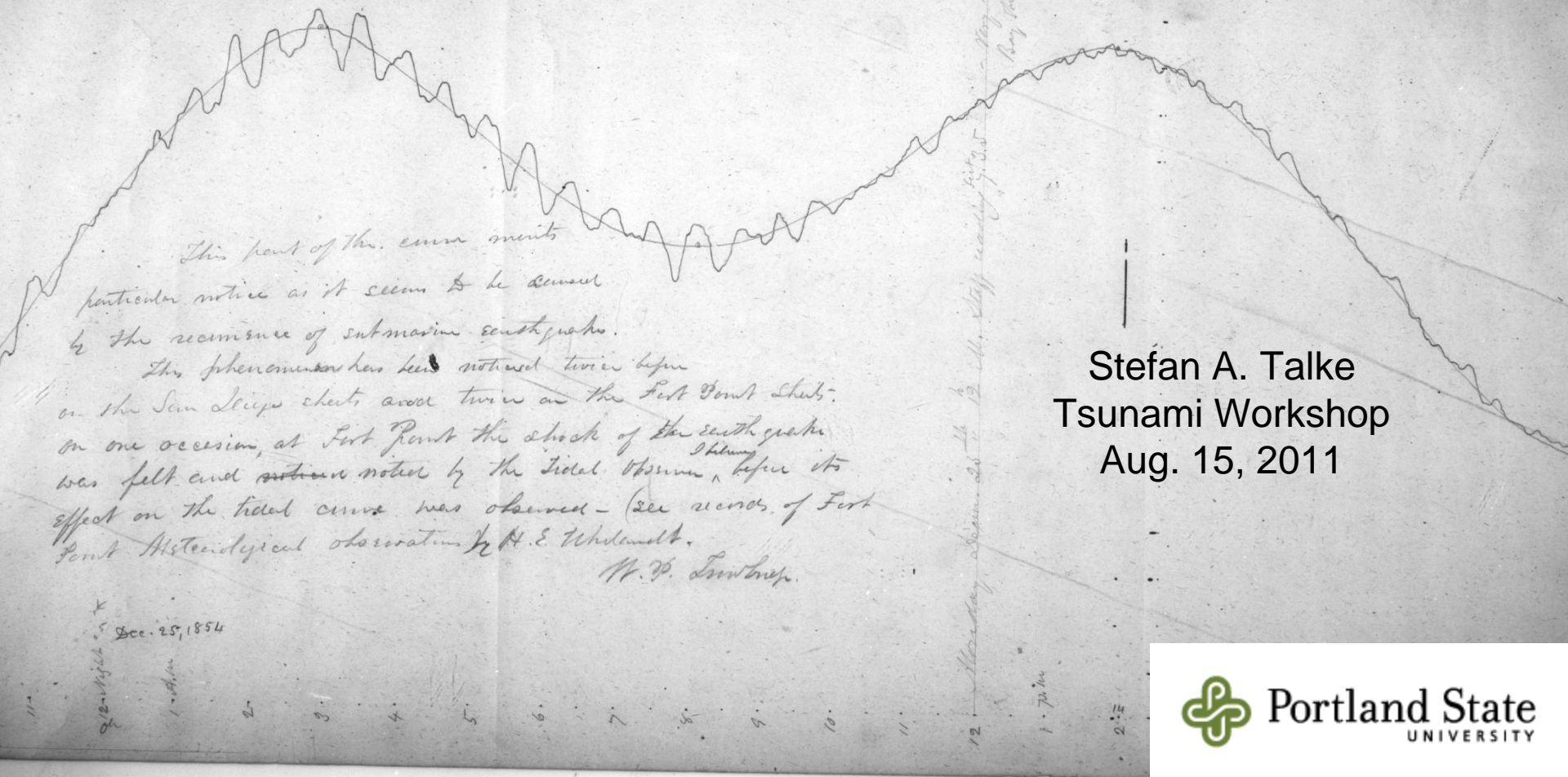


# Historical Tsunamis on the Columbia River



Stefan A. Talke  
Tsunami Workshop  
Aug. 15, 2011

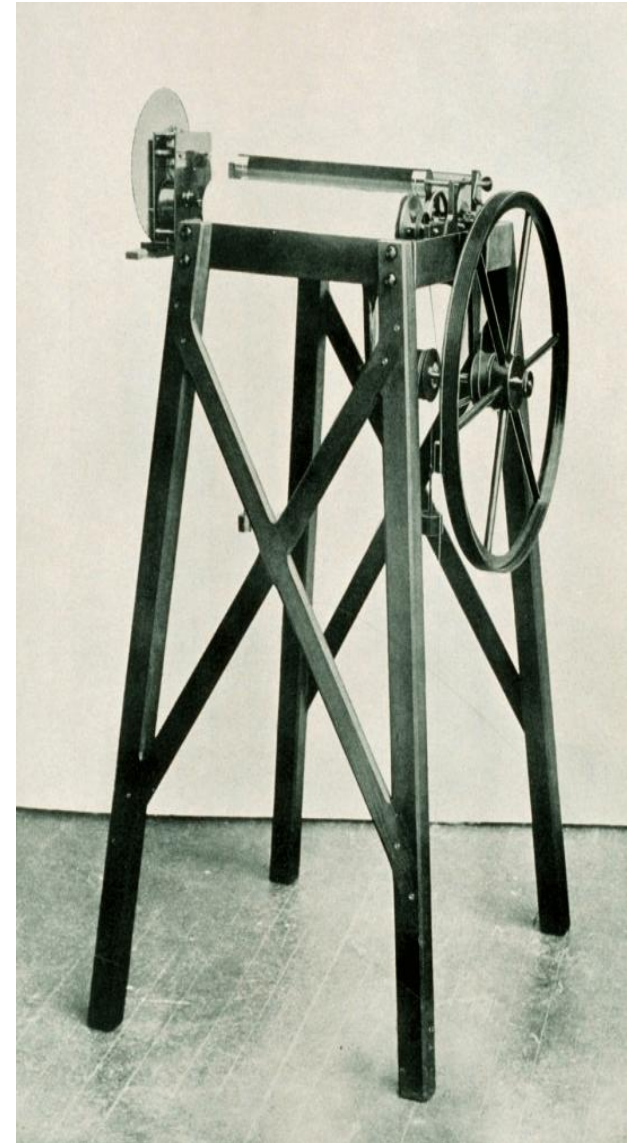
# Tsunami Measurements: Background



Historically, tsunamis have been measured on tide gauges.

--In fact, the first tsunami ever measured was in San Diego (see previous), San Francisco, and Astoria in 1854

→ Much of the early tide data is virtually forgotten (except, in many cases, by Tsunami researchers).



Saxton Tide Gauge



# Background

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So.... What is the history of tsunami measurements on the Columbia?

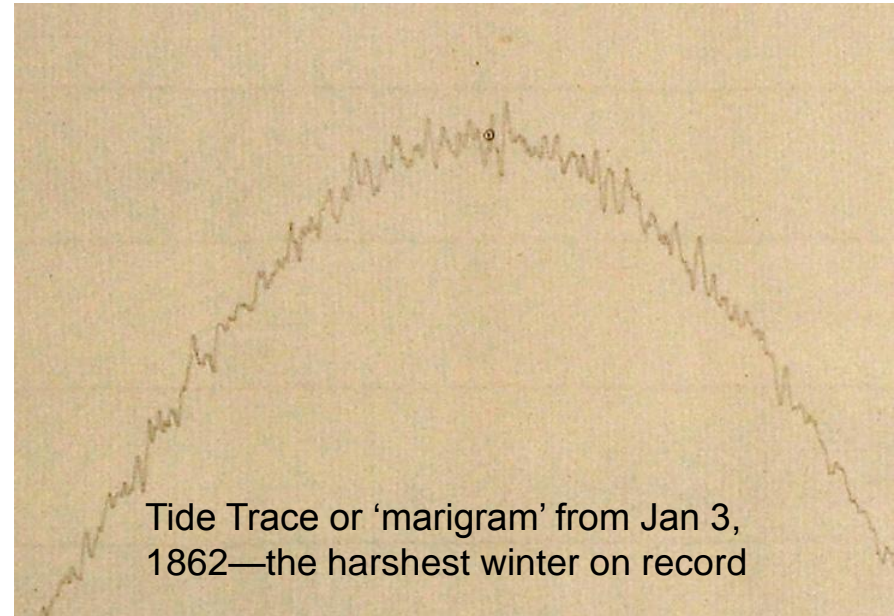
As part of an NSF project, 'Secular Changes in Pacific Tides' (Jay, Zaron, and Talke), we are attempting to increase the record length of tide data

We have found documentation for:

- 1853-1876: Astoria (US Coastal Survey)**
- 1883-1899: Astoria (Army Corps)**
- 1899-1907: Ft. Stevens (Army Corps)**
- 1925-present: Astoria Tongue-Point**

▫At various times, as many as 20 gauges have been deployed on the Columbia (e.g., in the 1940s). In 1964, **5 gauges measured the tsunami from the Great Alaskan Earthquake**

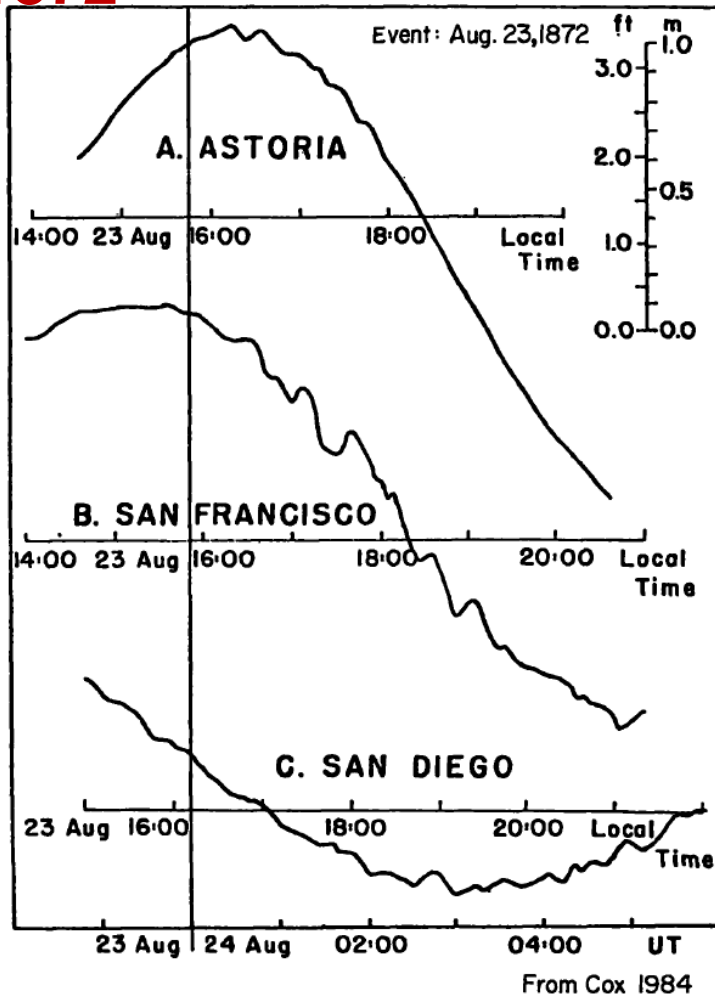
→What tsunamis have been measured—and the data retained—on the Columbia?



Tide Trace or 'marigram' from Jan 3, 1862—the harshest winter on record

# Overview of talk

1872



By nature, tsunamis are intermittent

--So, a big challenge and difficulty is—how does one calibrate and validate models?

One strategy—look into the historical record

What follows is a catalog of tsunami waves, including one just recently re-discovered.

--Likely excludes some tsunamis (e.g., 1868, any between 1884-1907)

Cautionary note, however: One cannot step into the same river twice. The Columbia is much different today than when all the historical tsunamis occurred

# 1700: The “Orphan Tsunami”

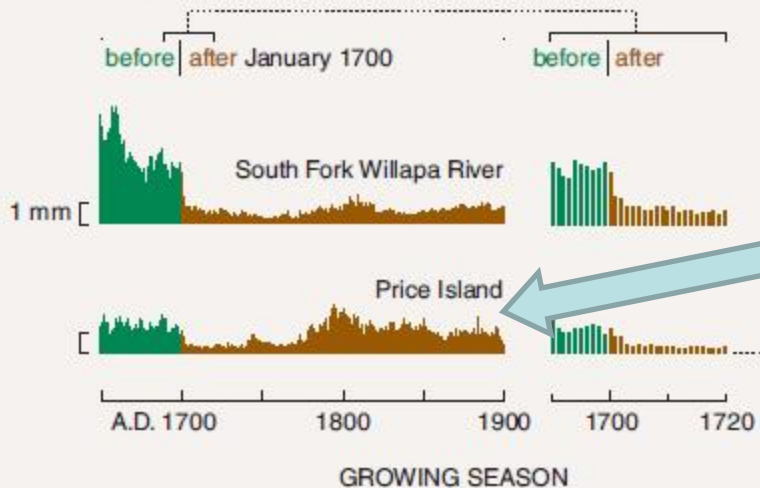
--Tree Ring analysis has recently shown evidence that a tsunami devastated the PNW in 1700 (e.g., Jacoby, 1997)

→ Widespread subsidence from subduction earthquake of M. 9.0 caused tree stress/death



## ▲ Signs of stress in surviving Sitka spruce

### RING WIDTHS OF TWO SURVIVORS



Price Island, 1994

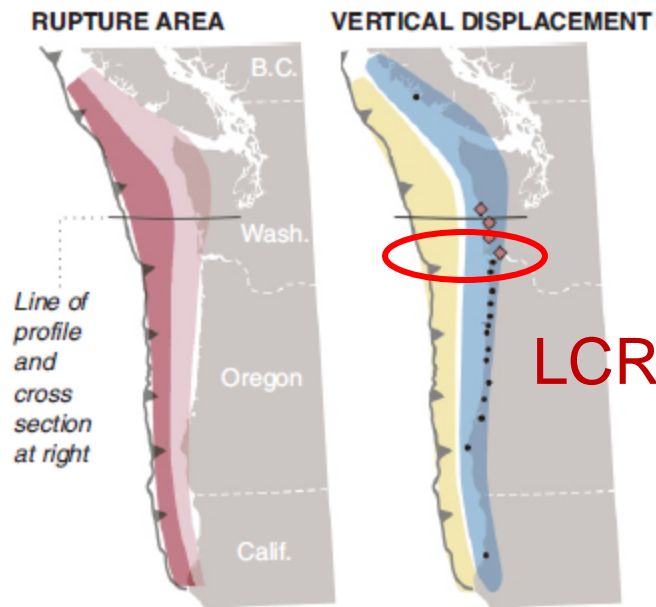
Figures from Atwater et al., 2005

### SURVIVORS' GROVE, COLUMBIA RIVER

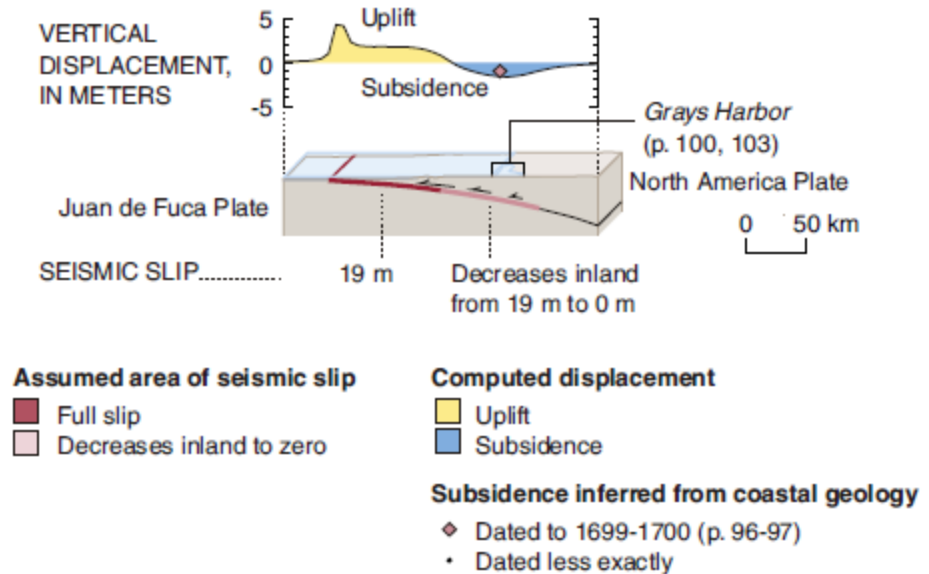


# 1700: The “Orphan Tsunami”

Rupture and deformation from a hypothetical 1700 earthquake



Figures from Atwater et al., 2005



## Observations:

- (1) Complex uplift and subsidence pattern. How do details of this convulsion affect the tsunami that is generated?
- (2) The subsidence stretches into the estuary and river. Hence, does one need to consider what happens to river flow and/or the tidal wave propagating up the river?
- (3) These are just model results. The archeological record suggests subsidence all the way to the Willamette, based on location of Native American villages



# Krakatoa

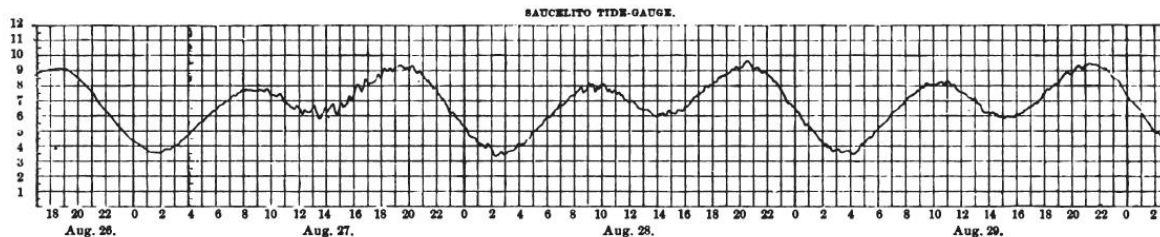
Krakatoa: Volcanic Eruption in Sunda Straits, Indonesia, on Aug. 27, 1883

Loudest sound in history. Was heard in Perth and the middle of the Indian Ocean (Rodriguez Island), 3000 miles away

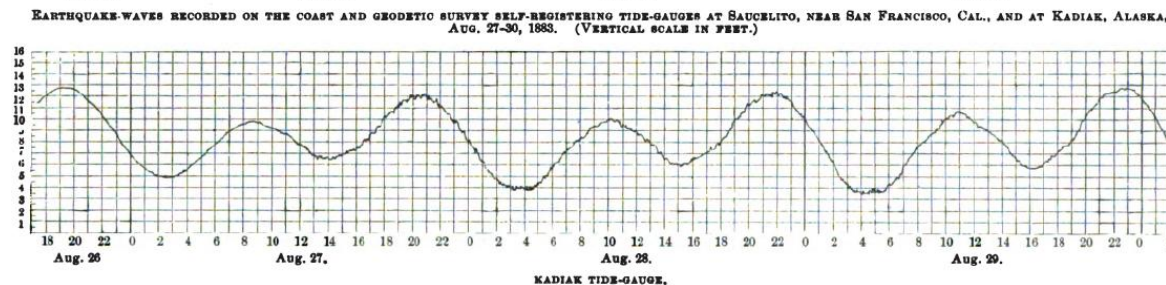
-- It was the atmospheric pressure variations that are thought to have caused the tsunami waves in the Pacific and Atlantic Oceans... Worldwide, 30 tide gauges measured a tsunami.



Krakatoa, Aug. 27 1883

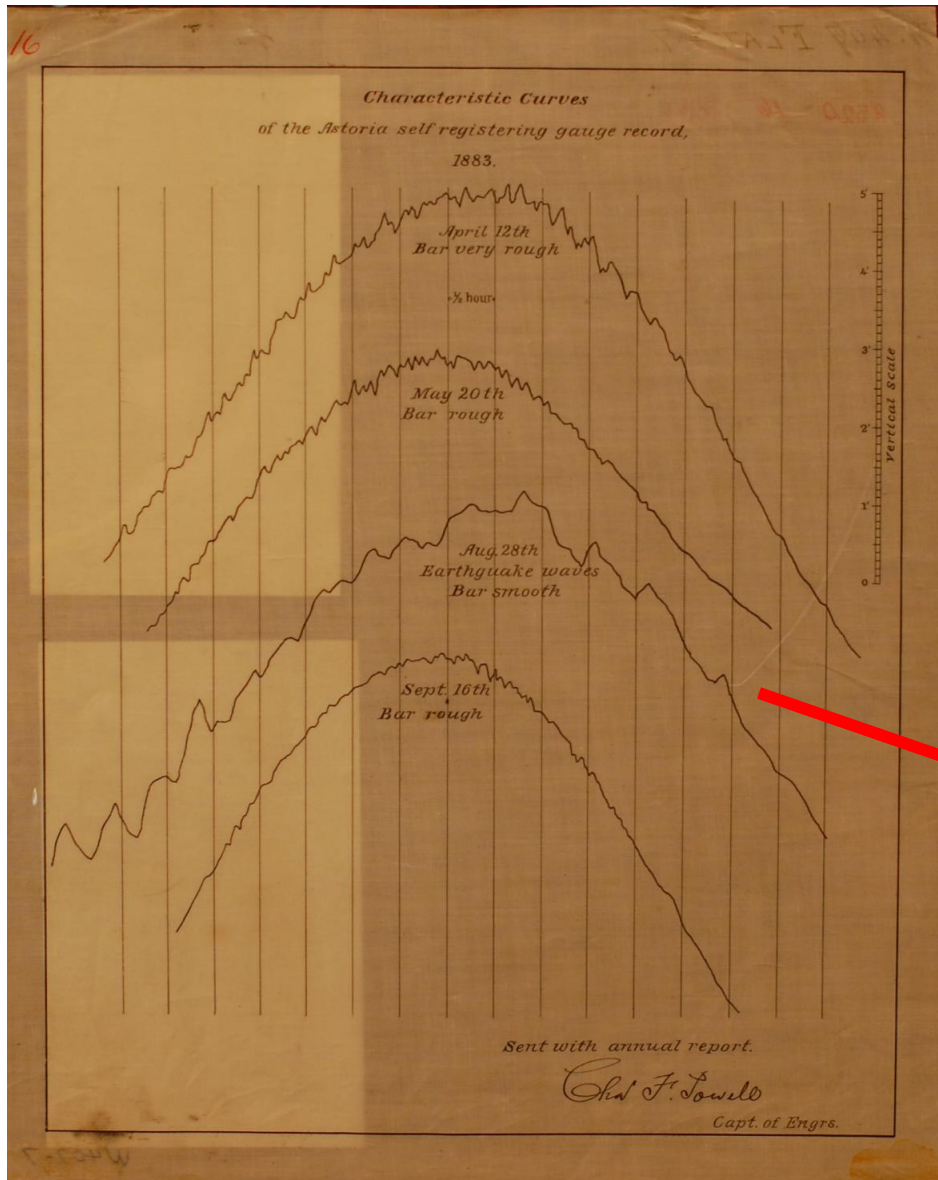


SF Bay



Kodiak Island

# Krakatoa



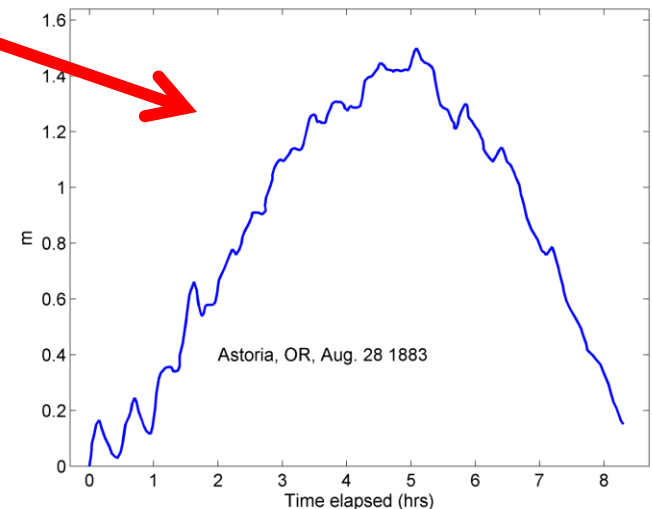
From Army Corps Annual Report, 1884

We have recently recovered  
a marigram trace from Astoria

It has never been analyzed  
since 1884.

Magnitude ~ 20 cm

\*Such marigrams show that  
even a remote signal  
propagates 20km or more  
up-estuary.





# Other Tsunamis

Kamchatka Earthquake, 1952: Magnitude 8.2

181

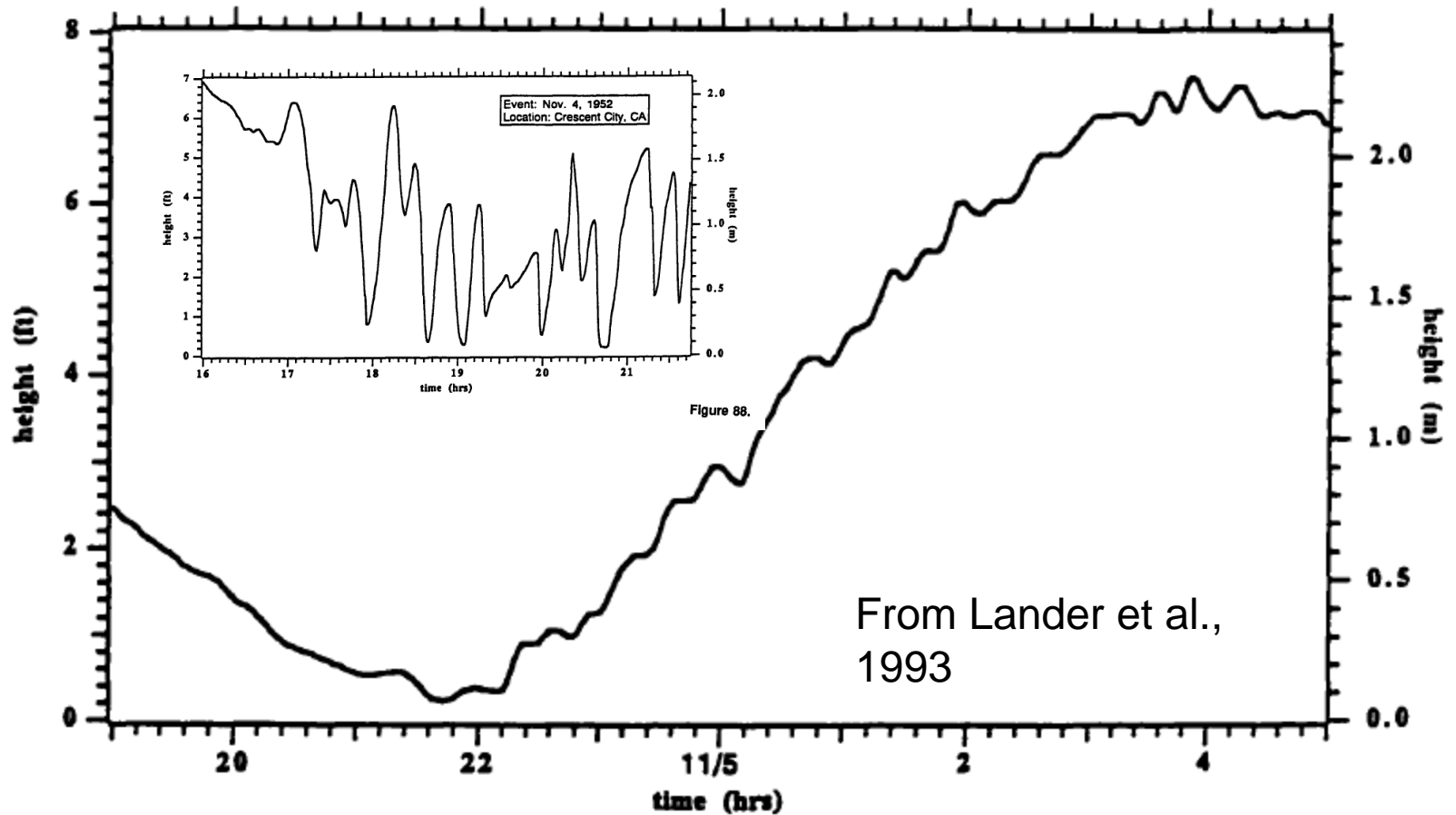
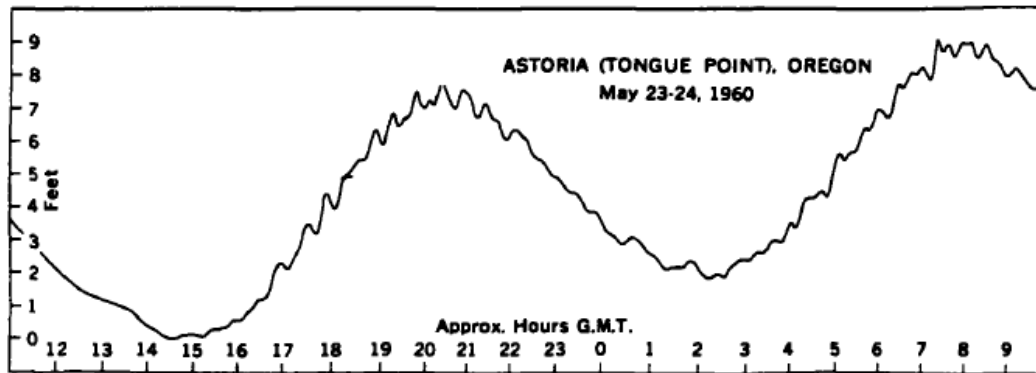


Figure 87.

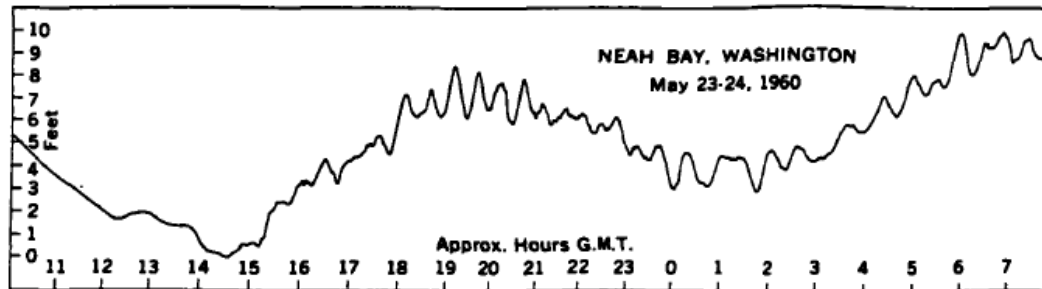
From Lander et al.,  
1993

# Other Tsunamis

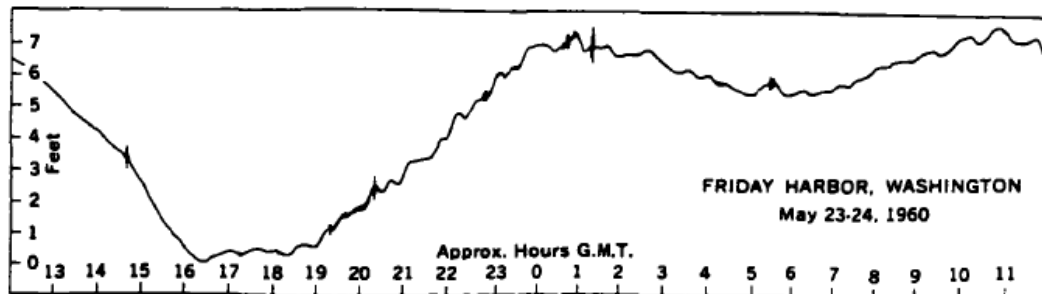
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Chilean Earthquake  
May 23, 1960  
Magnitude 8.6



Note that Astoria waves  
(max 0.5 ft) are  $\sim \frac{1}{2}$  the  
size of the more open  
coast station at Neah  
Bay (max 1.2 ft)

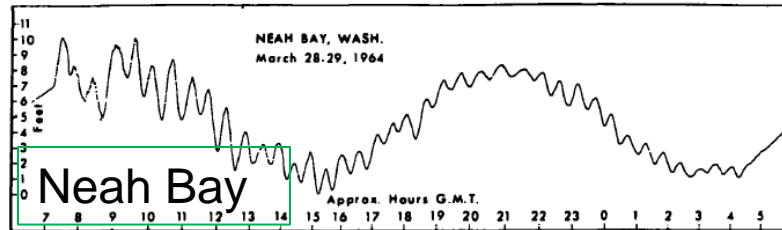


→ Constraint on  
decay of waves?

Berkman and Symons (1964)

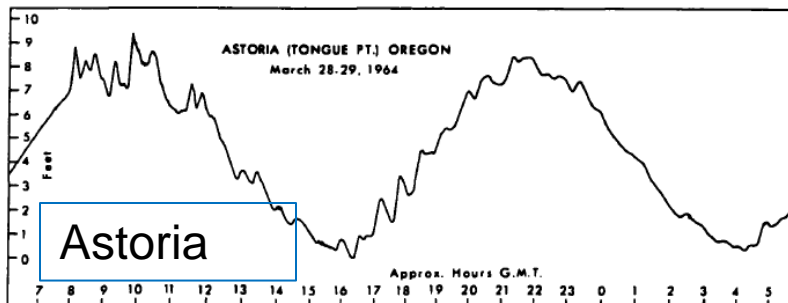
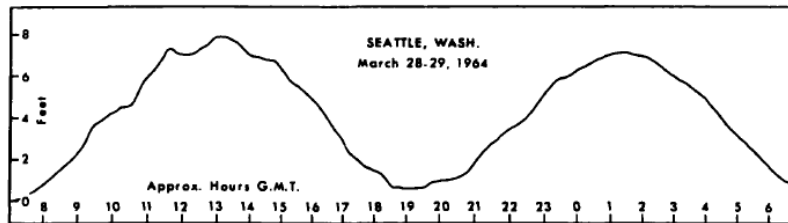
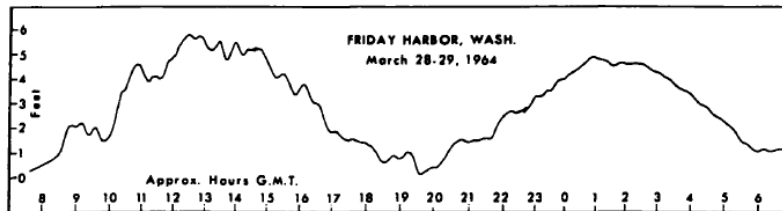
From Lander et al.,  
1993

# Other tsunamis



Great Alaskan Earthquake,  
March 28 1964

Magnitude 8.4

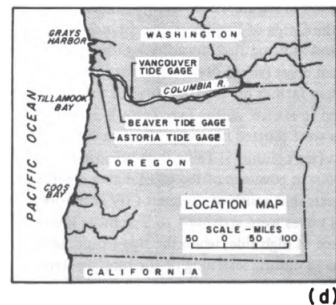
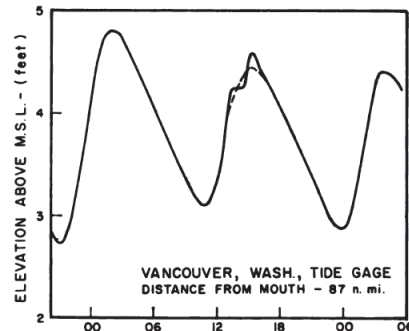
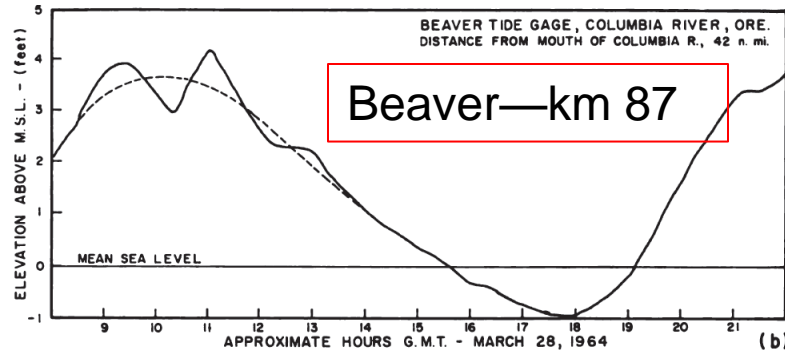
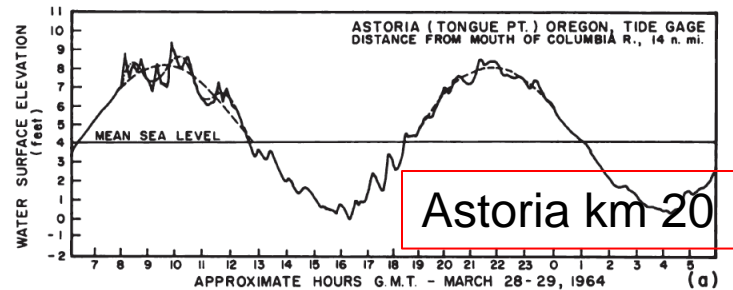


Note amplitudes of several feet—  
Probably largest tsunami ever  
recorded in Astoria



# The Great Alaskan Tsunami on the Columbia

170 TSUNAMIS



River, showing progression of the tide wave and

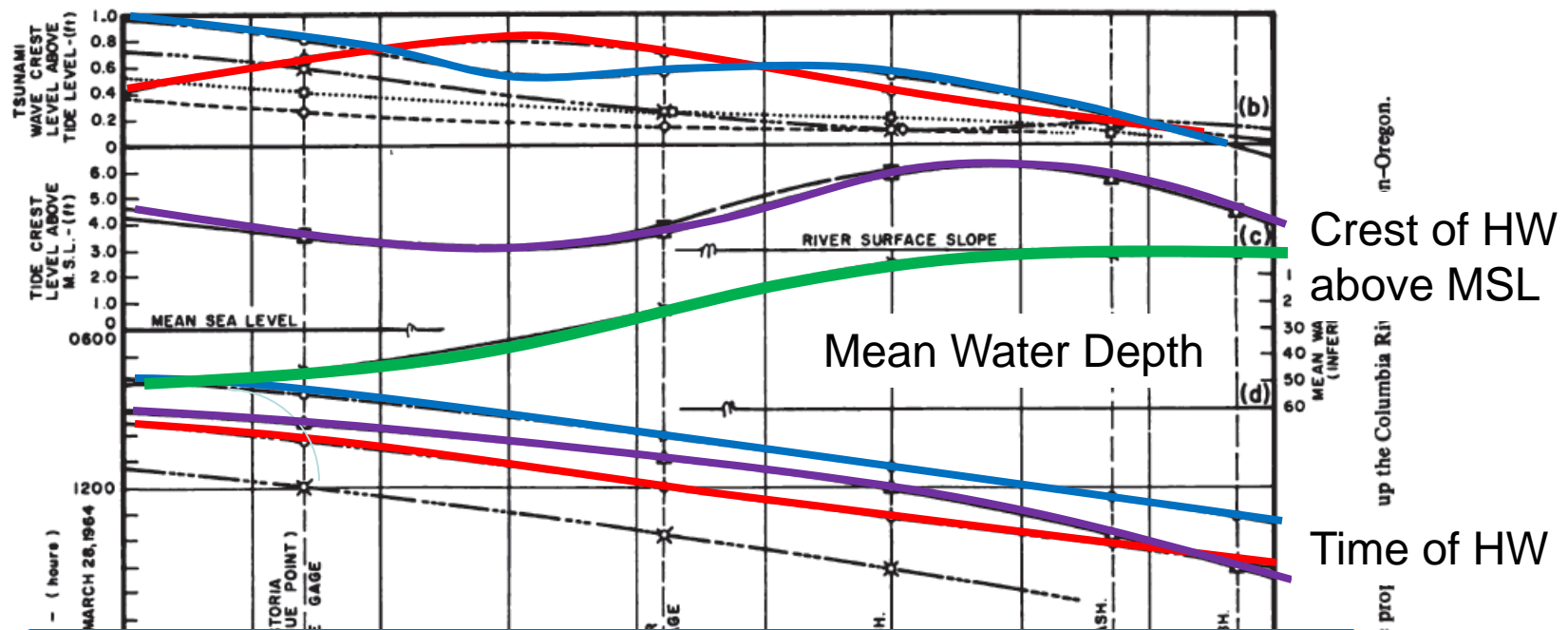
The 5 gauges that measured this tsunami provide the only spatial data that we have found—to date—on the propagation of a tsunami up the Columbia

The tsunami was still 1 foot large in Beaver, and was measured in Vancouver, WA.

However, the location (if it still exists) of the original data from 4 out of the 5 gauges is unknown

# The Great Alaskan Tsunami on the Columbia

EFFECTS OF THE TSUNAMIS: AN ENGINEERING STUDY



n-Oregon.

Crest of HW above MSL

up the Columbia Ri

Time of HW

FIGURE 128 Analysis of tsunami wave prop

1<sup>st</sup> Tsunami Wave: Propagates just ahead of High Water (i.e., at end of flood)

--No attenuation in height between km 87 and km 111

2<sup>nd</sup> Tsunami Wave: Occurs just after HW (beginning of ebb)

--Wave height actually increases between Astoria and km 87

→ The tidal phase matters!

# Discussion

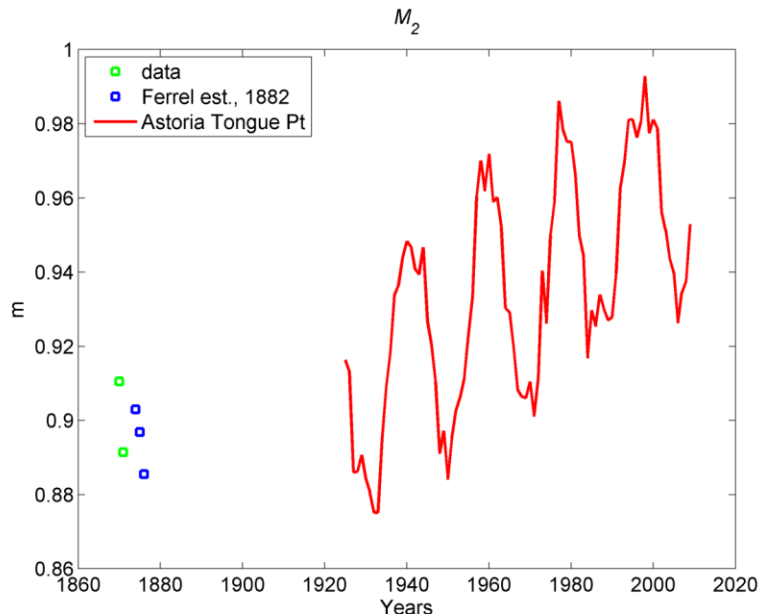
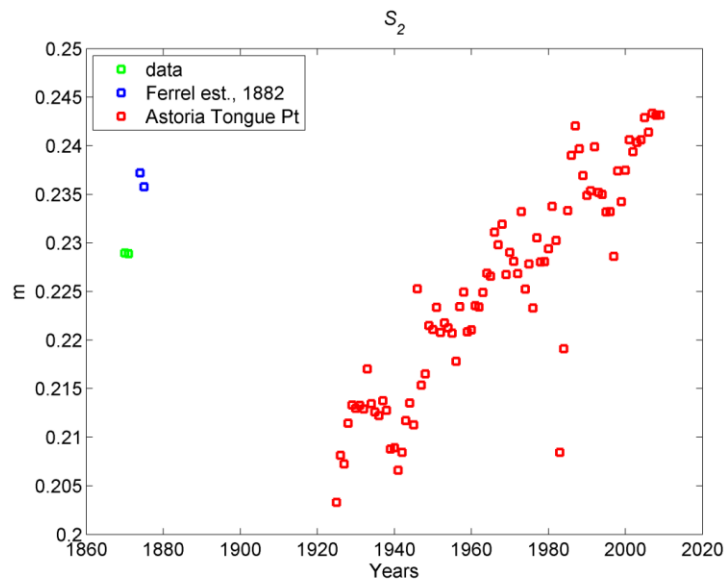
So... Does this mean we can use historical data—especially the 1964 tsunami—to constrain and validate our models?

Sort of...

Since 1960, the  $S_2$  constituent has increased ~5% at Astoria

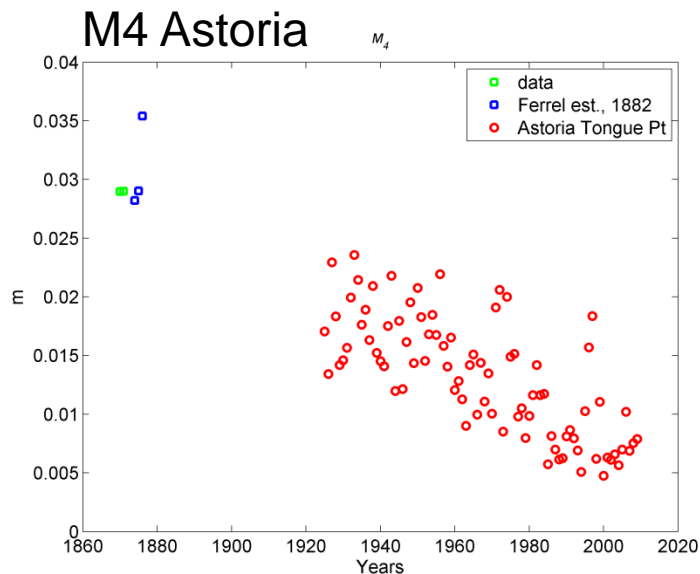
Similarly, since 1925, the  $M_2$  constituent has increased ~5% at Astoria

The Lower Columbia River has been greatly changed in the past 150 years. This can be observed in the tidal signal, in particular.





# What has changed? Friction



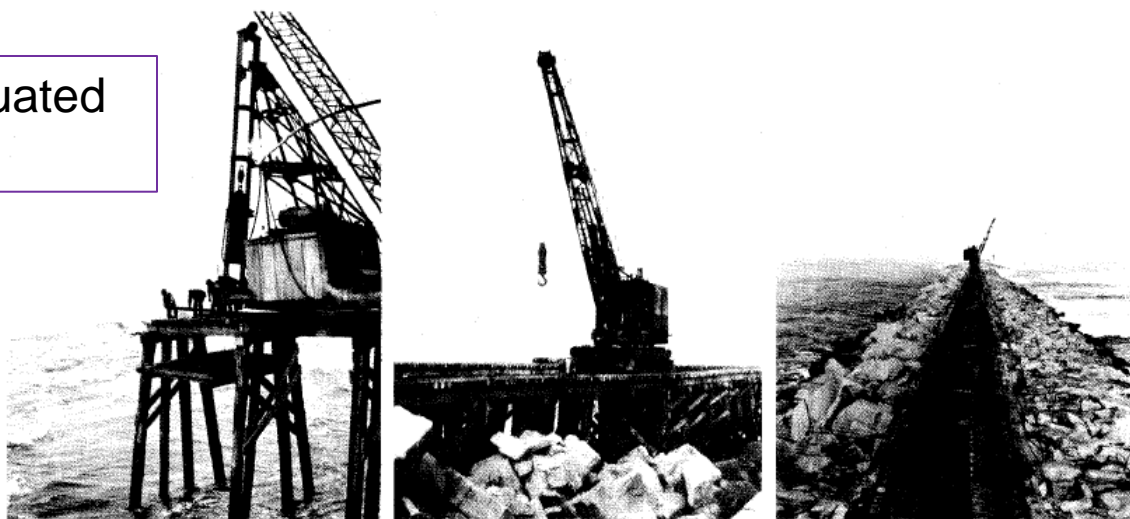
M4 plot for Astoria—using 5 years of 19<sup>th</sup> century data— shows that generation of non-linear ‘overtides’ has greatly decreased (even since 1960)

→A primary cause for decreasing friction is increased river depth (dredging)

→Decreased River flow also contributes

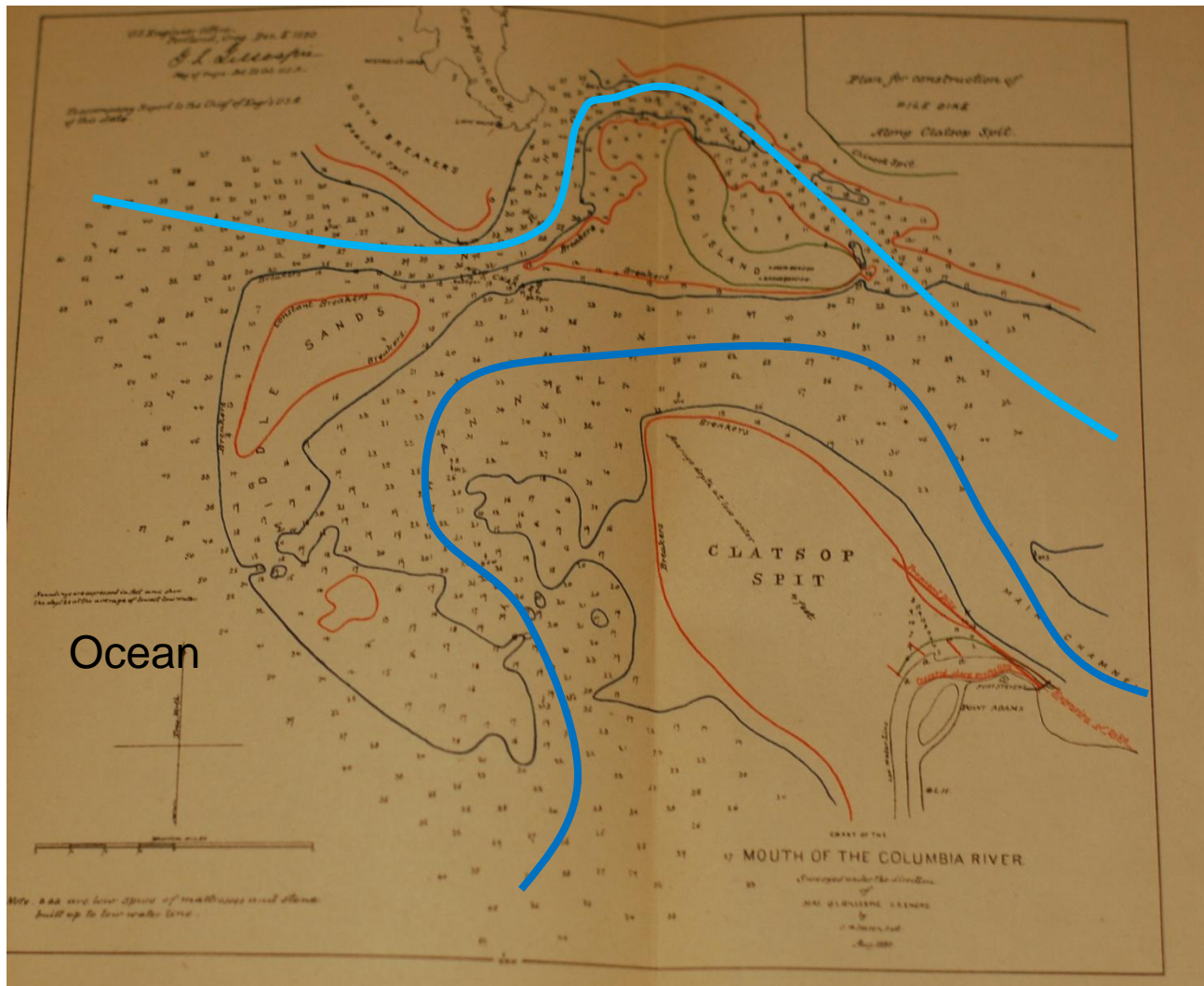
Would a tsunami today be attenuated much less?

Construction of the Columbia River jetties, 1880's



# Consider again a Cascadia type event

If we could determine wave run-up from the 1700 event— say, geologically— would/could it be used as an indicator of the next M9.0 event?

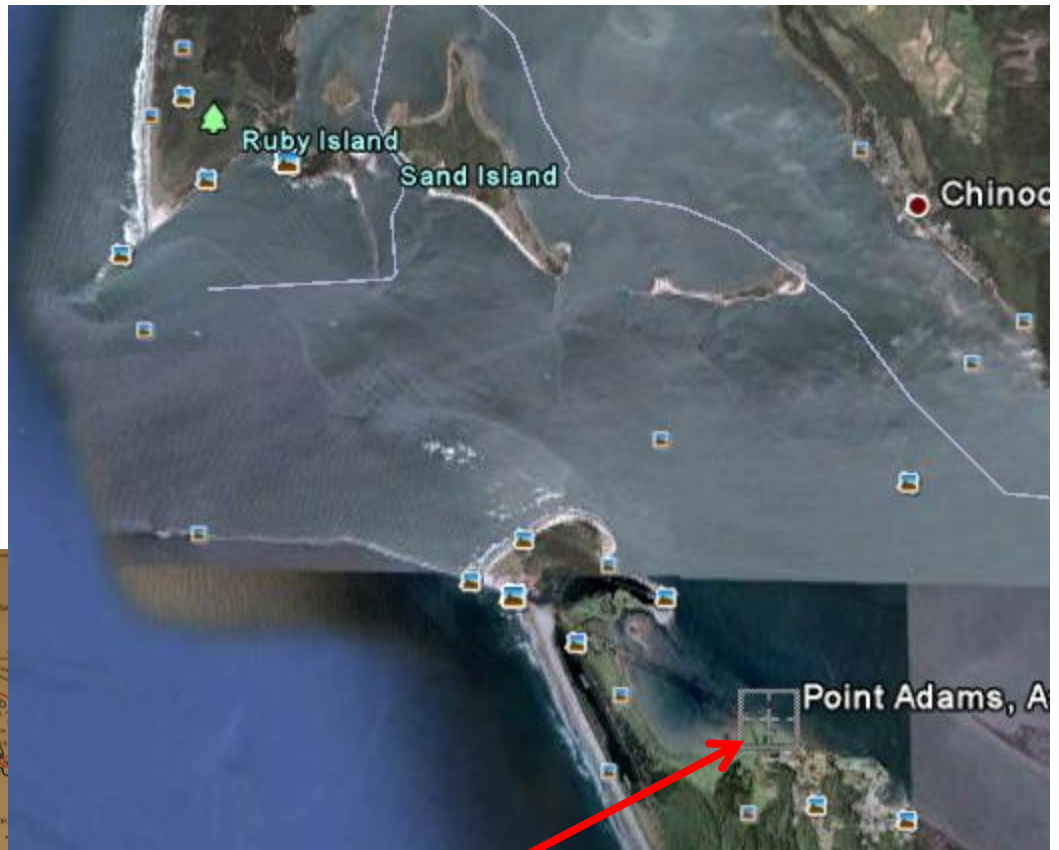


Red = Sand

Blue = Channel

→ Two Channels at entrance at time of Krakatoa!!

Map of Columbia River Bar—Army Corps, 1882



Change has been large...

Proceed with caution.



