Tsunami Hazard Mitigation Guidance for the Maritime Community

George R. Priest, Oregon Dept. of Geology and Mineral Industries Presentation to Mapping and Modeling Subcommittee, National Tsunami Hazard Mitigation Program.

August 20, 2014

Maritime Advisory Committee (MAC) February 4, 2014 Meeting

Attendees

- Allan, Jonathan, DOGAMI
- Blake, Wade, NOAA
- Caraveo, Bryan, USN
- Chuck, Walter, Port of Newport, OCZMA
- Clark, Randy, USCG
- Fryer, Gerard, NOAA
- Gately, Kara, NOAA
- Kirby, James, U Del
- Madin, Ian, DOGAMI
- McCall, Dylan, USCG
- McMullen, Scott, OFCC, OPAC
- Miller, Kevin, CA
- Nicolsky, Dmitry, U Alaska
- Priest, George, DOGAMI
- Rizzo, Althea, OEM
- Springer, Christopher
- Stimely, Laura, DOGAMI
- Thompson, Terry, Lincoln Co.,
- Walsh, Tim, WA DNR
- Wilson, Rick, CA
- Zhang , Joseph, VIMS

Invited but did not attend

- Burnette, Eric, Port of Portland
- Cheung, Kwok Fai, Hawaii
- Goldfinger, Chris, OSU
- Huerfano Moreno, Victor, PR
- Jordan, Dan, Columbia River Bar Pilots
- Lopez, Alberto, PR
- Lynett, Pat, USC
- Mercado, Aurelio, PR
- Stansfield, Todd, USN (Bryan Caraveo sat in)

Added during post-meeting review loop

- Corcoran, Patrick, OSU Sea Grant Extension
- Hildenbrand, Kaety, OSU Sea Grant Extension

SUMMARY OF MARITIME GUIDANCE

Distant Tsunamis

- **Warning**:
  NOAA broadcasts
- **≥ 4 hours to take action**
- **Offshore**: go to **>30 fathoms;**
  Guidance during event: USCG
- **Tied to dock**:
  - Check with local officials
  - Explore options in advance (e.g. go upriver? Out to sea?)
- **On Land**:
  - Go to evacuation site
  - Wait until local officials say it is safe to return.

Local Tsunamis

- **Warning**:
  - Ground shaking
  - Ocean roar
  - Water receding or surging
- **10 minutes to take action**
- **Offshore**: go to **>100 fathoms;**
  Guidance during event: USCG
- **Tied to dock** or **on land**:
  - Go to evacuation site
  - Wait until local officials say it is safe to return.
- Plan to be out to sea for days with nearby ports out of commission (fuel, food, etc.).

WHAT TO KNOW ABOUT TSUNAMIS

Tsunami Dangers

A tsunami is a series of waves, usually caused by an earthquake beneath the sea floor. As tsunamis enter shallow water near land, they increase in height and can cause great loss of life and property damage.
For boaters, tsunami dangers also include:

- Sudden water-level fluctuations
- Grounding of vessels as water level suddenly drops
- Capsizing from incoming surges (bores), complex coastal waves, and surges hitting grounded boats
- Strong and unpredictable currents that can change direction quickly
- Eddies/whirlpools
- Drag on large-keeled boats
- Collision with other boats, docks, and debris

Tsunami Types and Warnings

LOCAL TSUNAMIS are caused by great earthquakes near the Oregon coast and will strike in 10 to 30 minutes. The earthquake is the warning for a local tsunami. Be alert for natural warning signs:

- Onshore
  - Strong ground shaking for minutes
  - Loud ocean roar
  - Water receding unusually far, exposing the sea floor
  - Water surging onshore faster than any tide
- Offshore
  - You may feel the earthquake through the hull of your boat
  - You could see a rapid and extreme shift in currents and simultaneous changes in wind wave heights

Smaller **DISTANT TSUNAMIS** are caused by great earthquakes far away from the Oregon coast and will strike four hours or more after the earthquake. Be alert for warning statements and natural warning signs:

- Sign up to receive notifications from the National Tsunami Warning Center, which issues two types of warnings for Oregon boaters:
  - **Advisories:** Peak tsunami wave heights of 1 to 3 feet are expected, indicating strong and dangerous currents can be produced in harbors
  - **Warnings:** Tsunami wave heights could exceed 3 feet, indicating very strong, dangerous currents and inundation of dry land is anticipated
- Contact your harbormaster or emergency services office to find out what notifications you can sign up for locally
- Listen for warnings from sirens or announcements from airplanes and from the media
- Heed natural warnings such as a loud ocean roar or rapid changes in sea level or currents

Tsunamis Can Trick You

- The first surge may not be the last or the largest
- It is not unusual for tsunami surges to continue for 12 hours
- Dangerous currents can persist in harbors for 60 hours or more
- The National Tsunami Warning Center forecasts how long dangerous conditions persist

WHAT TO DO TO PREPARE

Are you prepared for a great earthquake and tsunami to strike, rendering ports, fuel supplies, and other infrastructure inaccessible?

For more information on how to better prepare, check with:

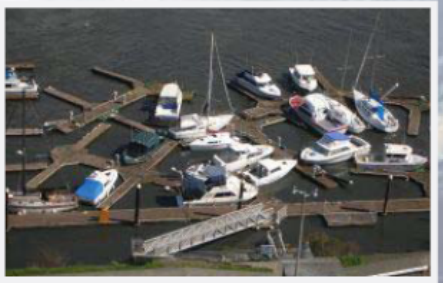
- Harbor masters and port captains
- US Coast Guard contacts
- State and local emergency managers
- National Tsunami Warning Center: www.wcatwc.arh.noaa.gov
- Oregon Department of Geology and Mineral Industries – download evacuation maps: www.oregontsunami.org
- National Weather Service – sign up for alerts: www.weather.gov/emailupdates/
- Weather Forecast Offices
  - Medford www.wrh.noaa.gov/mfr/
  - Portland www.wrh.noaa.gov/pqr/
- Oregon Emergency Management: www.oregon.gov/OMD/OEM/
- NOAA: www.tsunami.gov
- Federal Emergency Management Agency: www.ready.gov/tsunamis
- Centers for Disease Control: www.bt.cdc.gov/disasters/tsunamis
- Red Cross: www.redcross.org

Support provided by the National Tsunami Hazard Mitigation Program, NOAA Award Number NA13NWS4670013

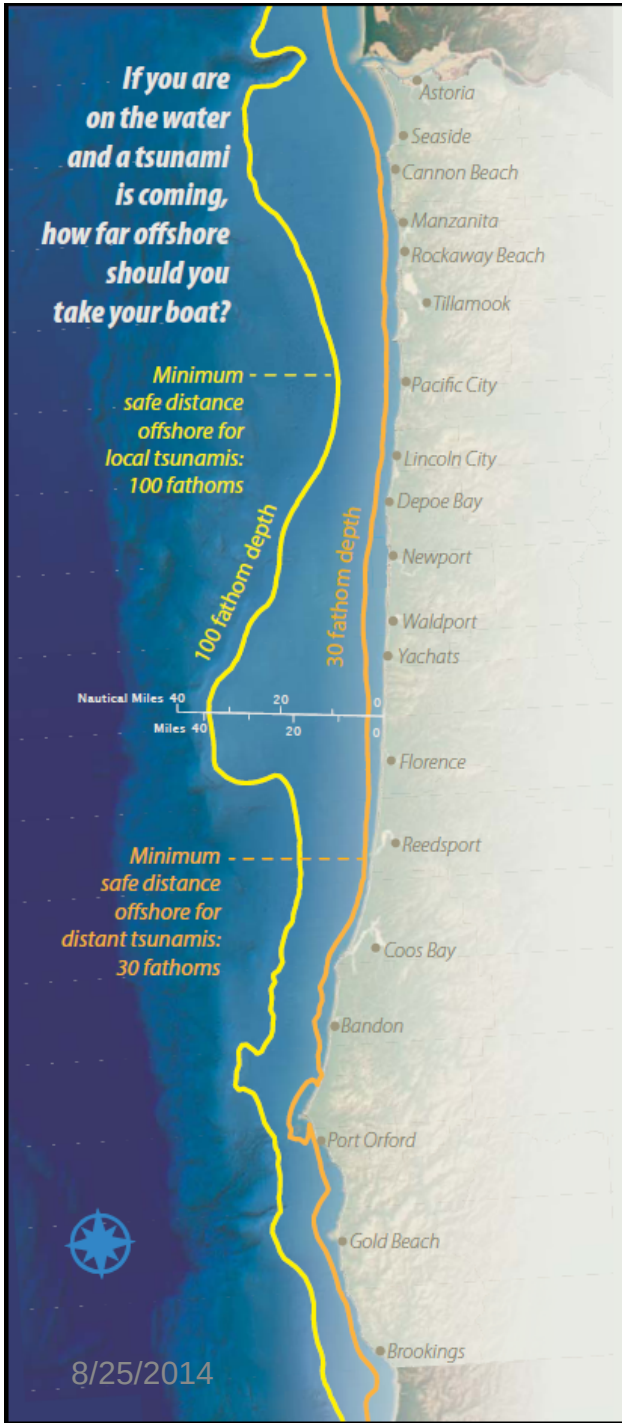
TSUNAMI!

WHAT OREGON BOAT OWNERS NEED TO KNOW

Port of Brookings, Ore., following wave surges from the March 11, 2011 tsunami off the coast of Japan. Photo: Jamie Francis/The Oregonian



Marina damage near Chetco River, Ore., following wave surges from the March 11, 2011 tsunami off the coast of Japan. Photo: U.S. Coast Guard



WHAT TO DO WHEN A TSUNAMI STRIKES

What to do depends on what type of tsunami occurred and where you are

Distant Tsunamis

You generally have at least 4 hours after the distant earthquake to take action.

If you are on the water

- Check with the US Coast Guard (USCG) before taking any action. If advised that offshore evacuation is an option and this option looks practical for your vessel, proceed to a staging area **greater than 30 fathoms (180 ft)**. If conditions do not permit, dock your boat and get out of the tsunami evacuation zone.

If you are on land or tied up at the dock

- Your choices are to a) evacuate out to sea beyond 30 fathoms, b) leave your vessel and evacuate out of the distant tsunami inundation zone, or c) go upriver. DO YOUR HOMEWORK before the event to understand how practical these options are for the largest distant tsunamis that might strike your area. Check with local authorities and www.oregontsunami.org for information.
- Check with local authorities before taking any action. Most distant tsunamis are small enough that it is safer to keep your boat docked. Congestion in the waterway or among those trying to pull boats out with trailers can create serious problems. Sea and weather conditions may be more dangerous than the tsunami! Get yourself out of the tsunami evacuation zone.

After the tsunami

- **If in an offshore staging area**, check with the USCG for guidance before leaving the staging area; conserve fuel by drifting until you know what actions you need to take.
- **If in an onshore assembly area**, check with local authorities for guidance before returning to the inundation zone.

BROADCASTS DURING A TSUNAMI EVENT

USCG will issue Urgent Marine Information Broadcasts on CH 16, and additional information will be available from NOAA Weather Radio.

Local Tsunamis

You have only ~10 minutes to take action, so have a plan ahead of time that includes a quick way to release commercial fishing gear so your boat is not dragged down by currents; have least 3 days of food, fuel, and water.

If you are on the water

- **At less than 100 fathoms (600 ft):** (1) Stop commercial fishing operations immediately, (2) free the vessel from any bottom attachment (cut lines if necessary), and (3) if you can beach or dock your boat and evacuate on foot within 10 minutes of a natural warning, then this is your best chance. If that is not possible, head to greater than 100 fathoms, keeping in mind the following:
  - Proceed as perpendicular to shore as possible.
  - Sail directly into wind waves, keeping in mind that wind waves opposed by tsunami currents will be greatly amplified.
  - Maintain as much separation as possible from other vessels.
  - Synchronize movements with other vessels to avoid collisions.
- **At greater than 100 fathoms:** If you are in deep water but not quite 100 fathoms, head to deeper water. If you are already at greater than 100 fathoms, then you are relatively safe from tsunamis, but deeper water is safer from tsunami currents and the amplification of wind waves by those currents.

If you are on land or tied up at dock

- **Evacuate out of the tsunami evacuation zone.** You don't have time to save your boat and could die if you try to do so.

After the tsunami

- **If in an offshore staging area,** check with the USCG for guidance before leaving the staging area; conserve fuel by drifting until you know what actions you need to take.
- **If in an onshore assembly area,** check with local authorities for guidance before returning to the inundation zone.
- **Do not return to local ports** until you have firm guidance from USCG and local authorities.
  - Local ports will sustain heavy damage from a local tsunami and may not be safe for days, weeks or months.
  - If at sea, check to see if you can reach an undamaged port with your current fuel supply and watch for floating debris or survivors that may have been washed out on debris.
  - If at sea, consider checking with USCG about your role in response and recovery.

Maritime Tsunami Dangers

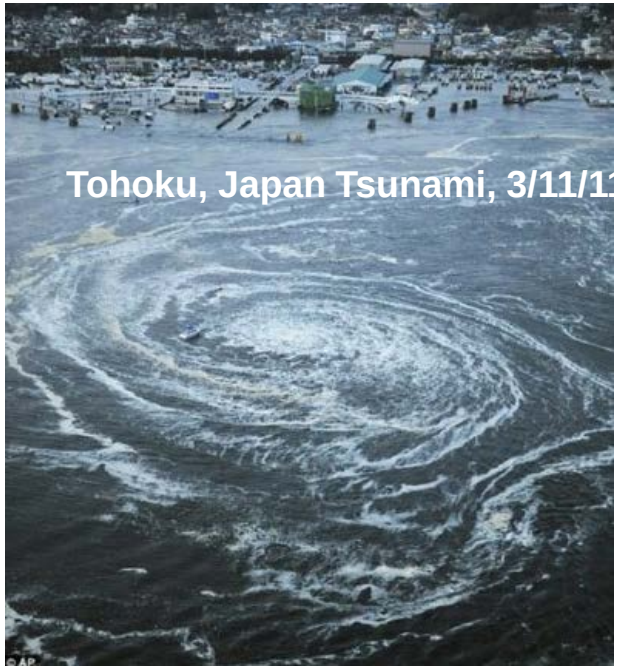
- High velocity currents
- Wind wave amplification by tsunami currents
- Rapidly reversing velocity
- Minimum flow depth (grounding of vessels)
- Debris field from withdrawing tsunamis & currents
- Tsunami wave steepness (only very close to shore)
- Vorticity (whirlpools)

Shear Flow/Vorticity

Vorticity >0.1 = very strong shear

<u>EXPLANATION OF VORTICITY UNITS</u>:
Vorticity =|dv/dx-du/dy| where
dv = change of north velocity,
du = change of east velocity
dx= change of distance east
dy = change of distance north

Example: 0.01 units of 1/sec = velocity changing 1m/sec over 100-m distance



Source of picture: http://news.nationalgeographic.com/news/2011/03/pictures/110311-tsunami-earthquake-japan-hawaii-science-world-waves/#/japan-tsunami-earthquake-hits-northeast-whirlpool_33139_600x450.jpg

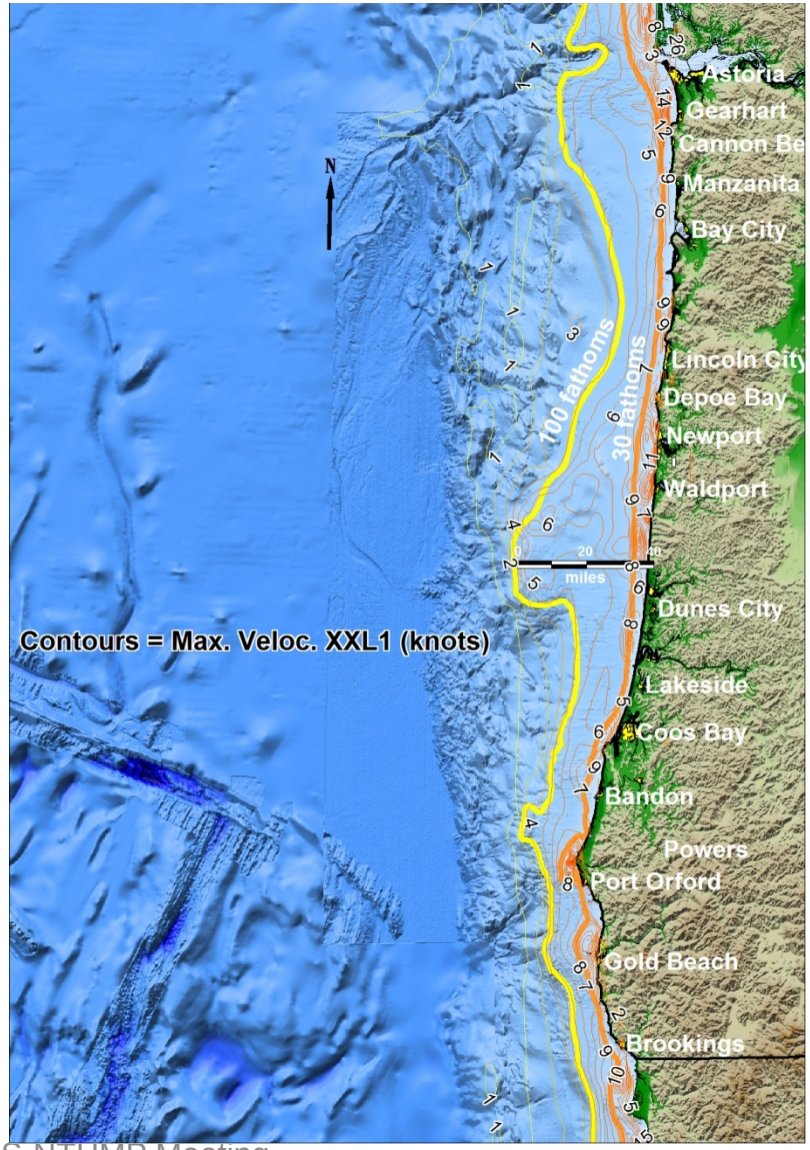
Thresholds

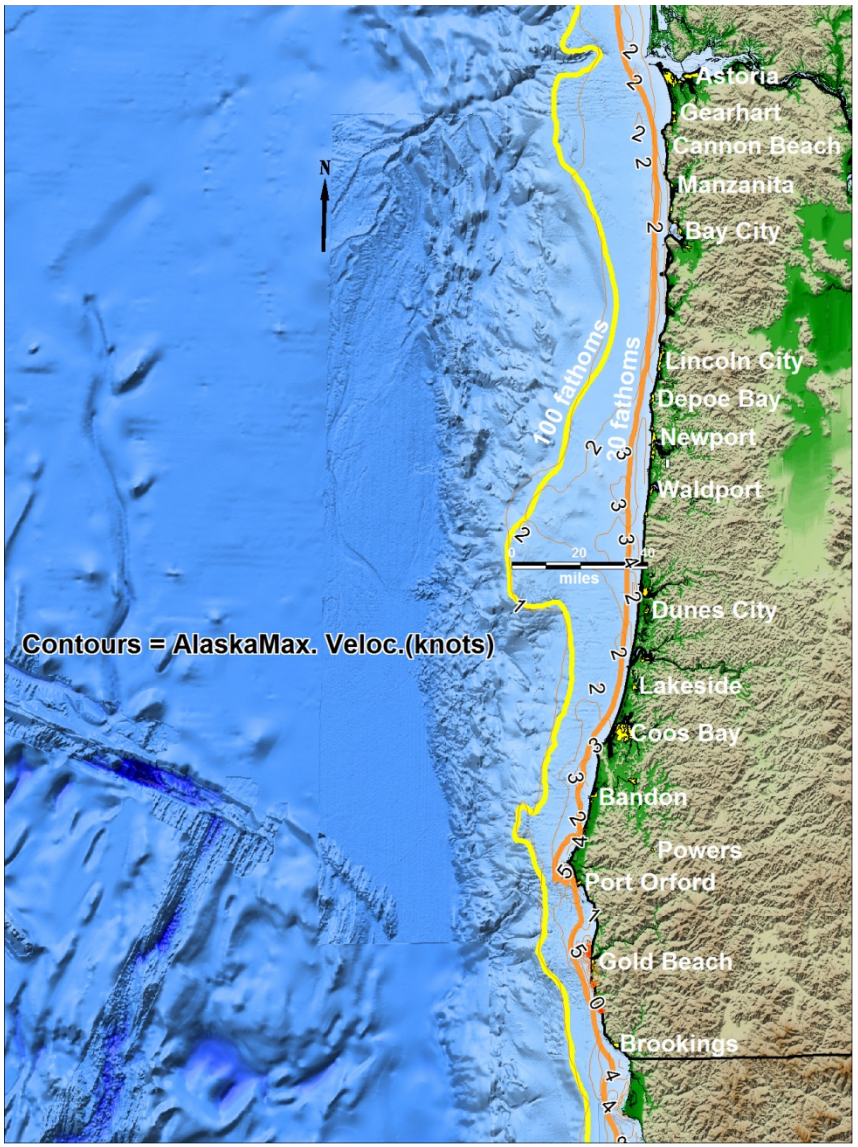
Vorticity, Minimum Flow Depth, Velocity, Wind Wave Amplification

- Velocity threshold **>3 knots** = damaging in open ocean?
  - Without wind waves
  - With wind waves
- Minimum flow depth threshold = **~50 ft**
  - Max. displacement of aircraft carrier ~40 ft
  - Are there larger vessel displacements?
- Threshold vorticity
  - **>0.1** for very strong shear
  - Could be as low as **>0.01** for any shear
- Wind waves amplified to the point of breaking

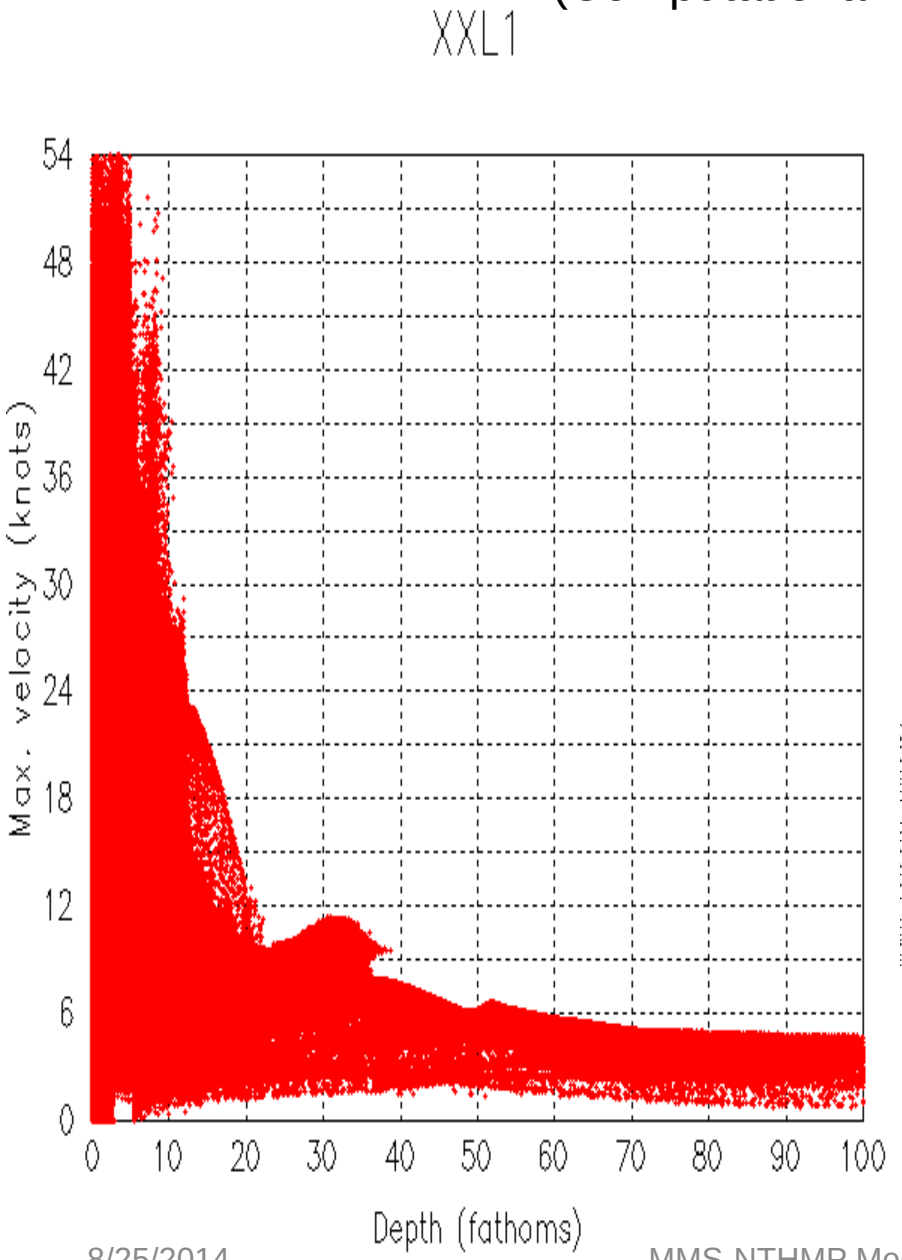
How far offshore do dangerous (>3 knots) tsunami current velocities persist?

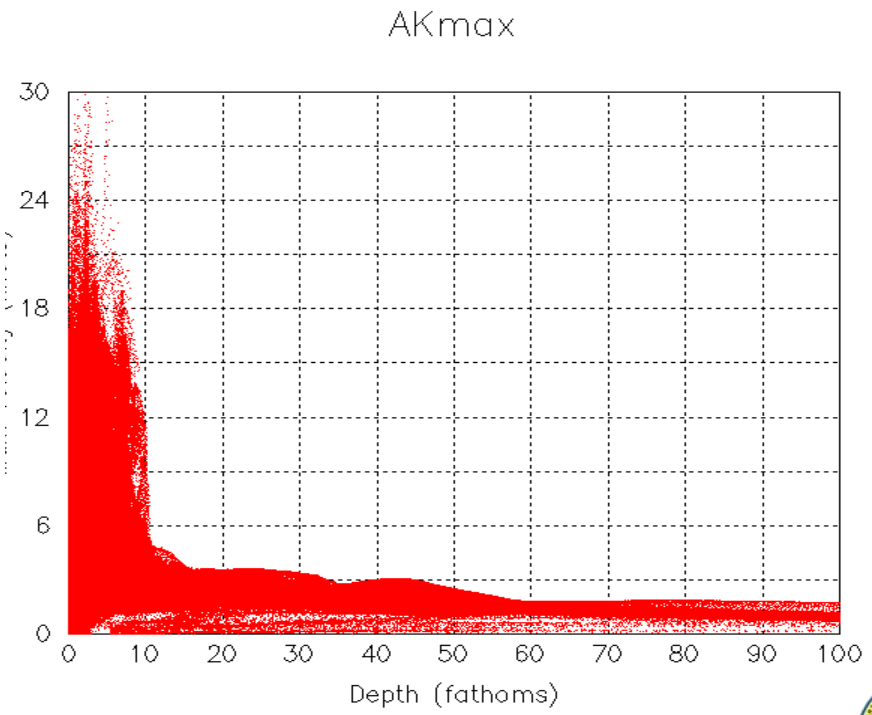
Alaska and Cascadia Maximum Velocities -Whole Coast (from 2011 preliminary coarse grid simulation)





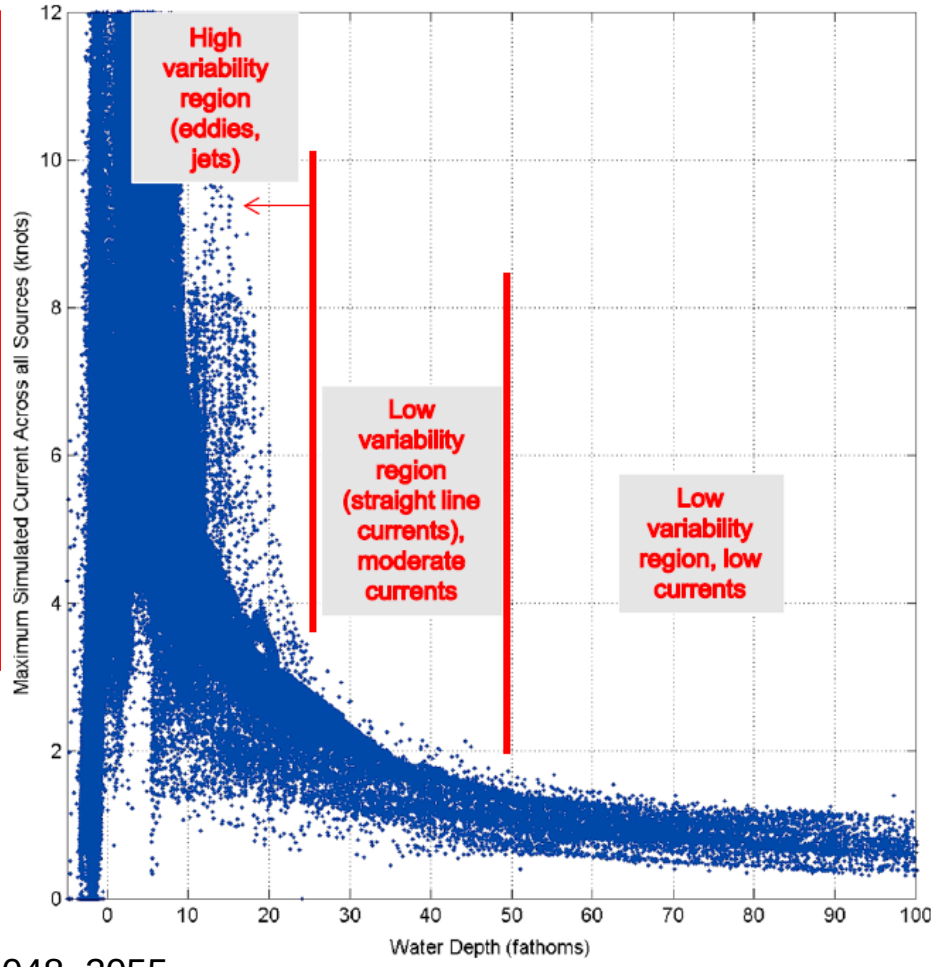
Velocity versus Depth - Central Oregon Coast (Computational Points for Grid B)





Distant Tsunami "Safe Depth" = 30 Fathoms in Crescent City Study

It is found that maximum tsunami currents of less than 1 knot (0.5 m/s) are expected at a depth of 100 fathoms (~180 m). Large variations in the possible maximum current exist to a depth of approximately 25 fathoms (~45 m), indicating that this is the greatest depth that large eddies or jets might extend to. Depths greater than 30 fathoms (~55 m) will in general be safe, particularly for dispersed or larger vessels.



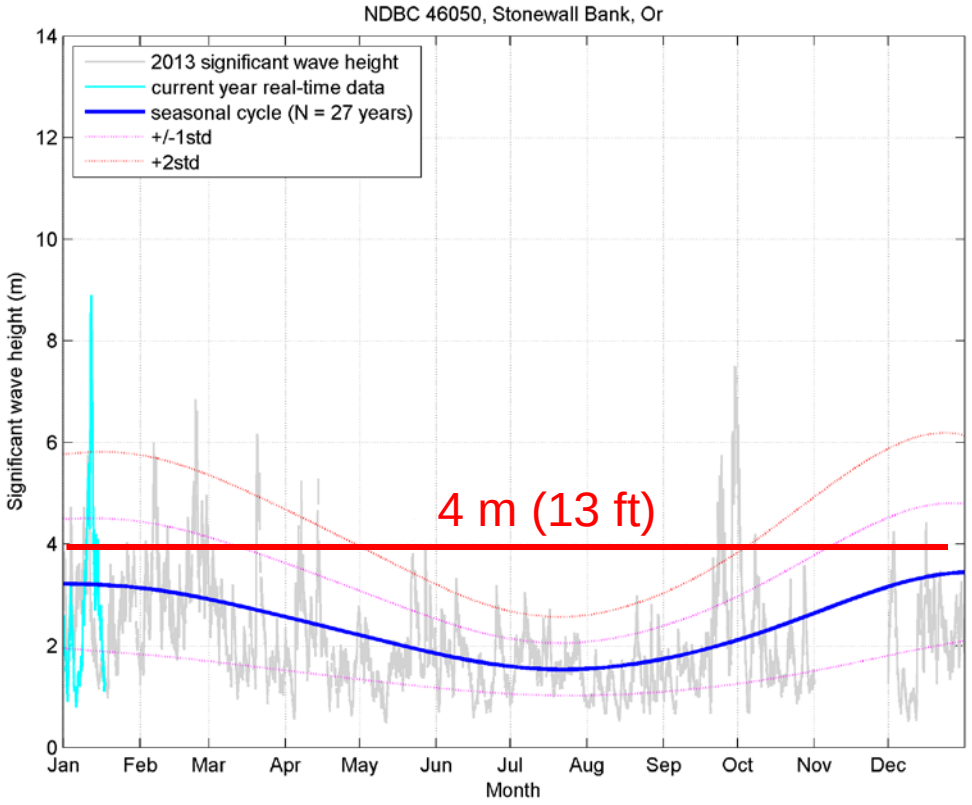
1 fathom = 1.8 meters = 6 feet

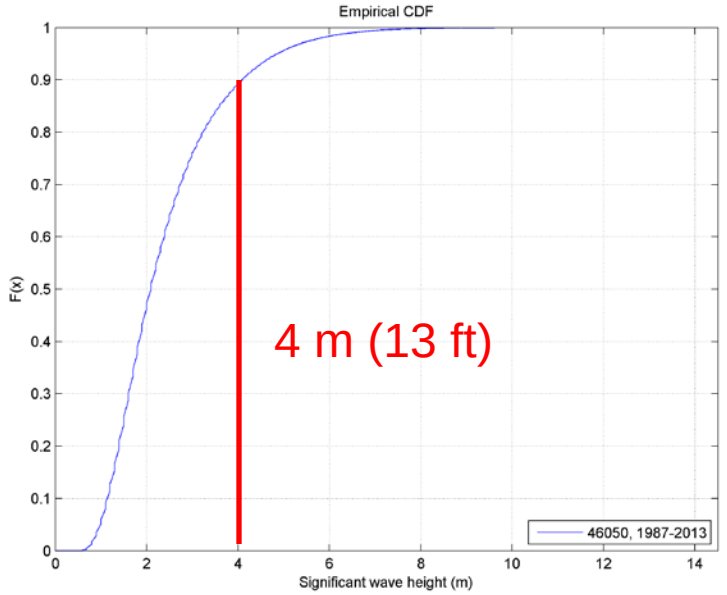
Source: Lynett et al. (2014) Geophys. Res. Lett., 41, 2048–2055

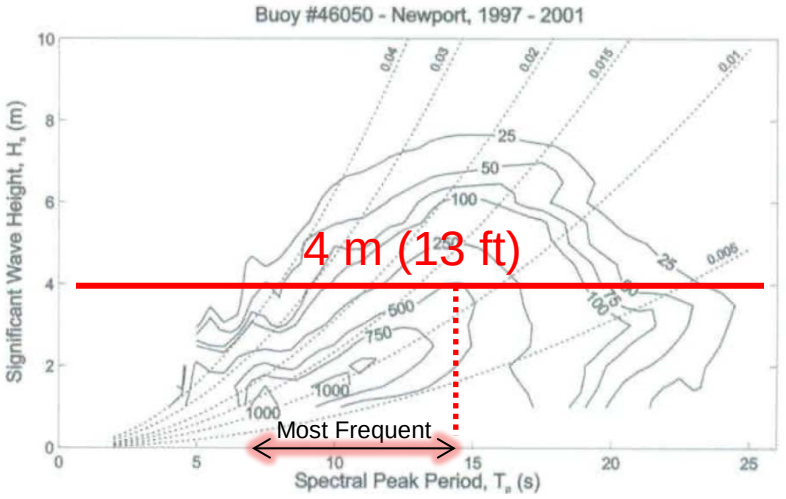
What about amplification of wind waves by tsunami currents?

- Currents opposed to wind waves can significantly amplify wave height.
- How much amplification occurs for “typical” PNW wind waves for reasonable tsunami currents?

Wave Data – Central Oregon(Stonewall Bank)



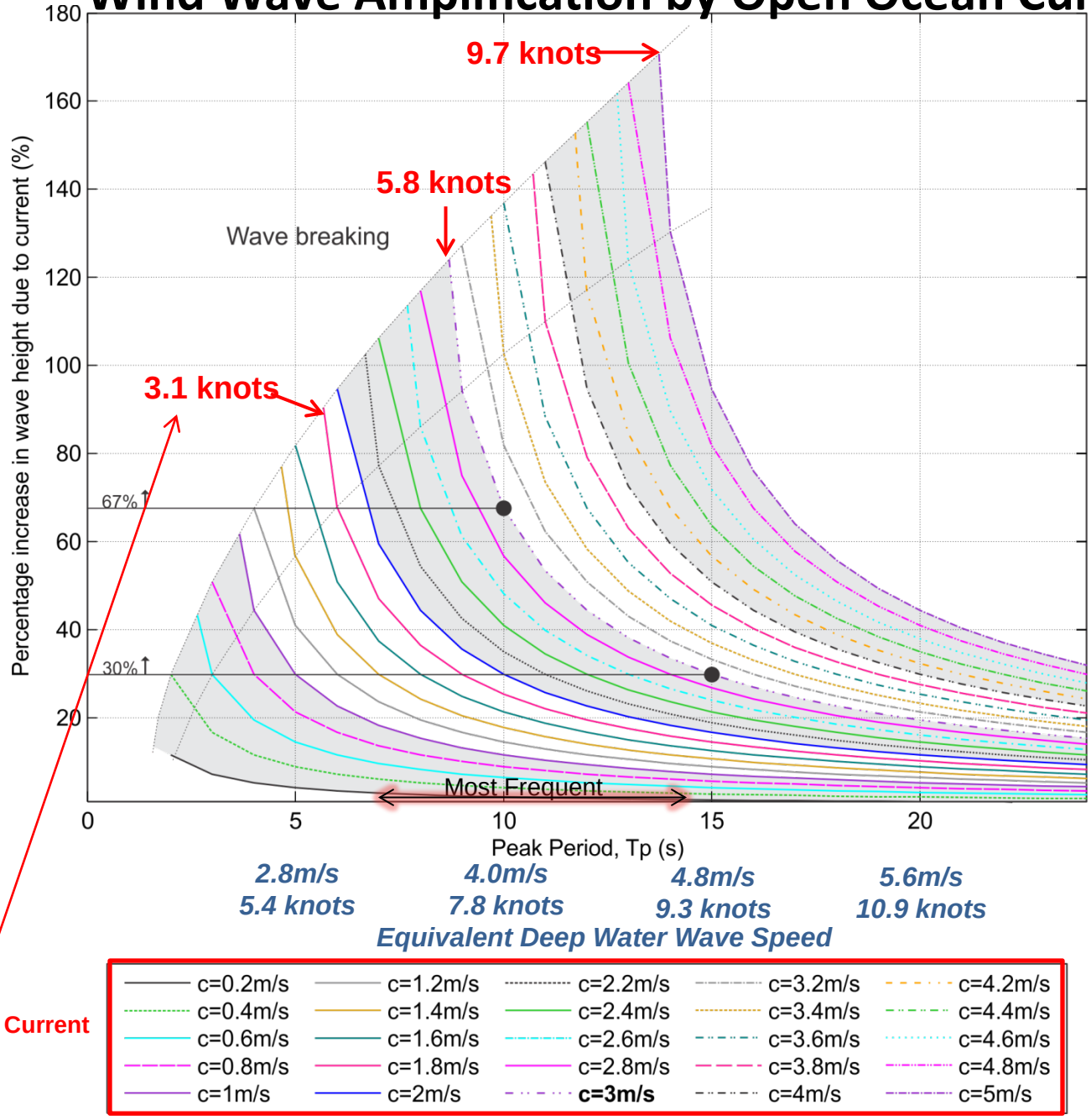




Significant wave height = average of highest 1/3 of waves

Scatter diagram for 1998-2002 (Allan and Komar, 2006)

Wind Wave Amplification by Open Ocean Currents



C = Tsunami Current

NOTE:
Most frequent PNW wave periods for 1998-2002 are **7-14 seconds**
(see scatter diagram of Allan and Komar, 2006)

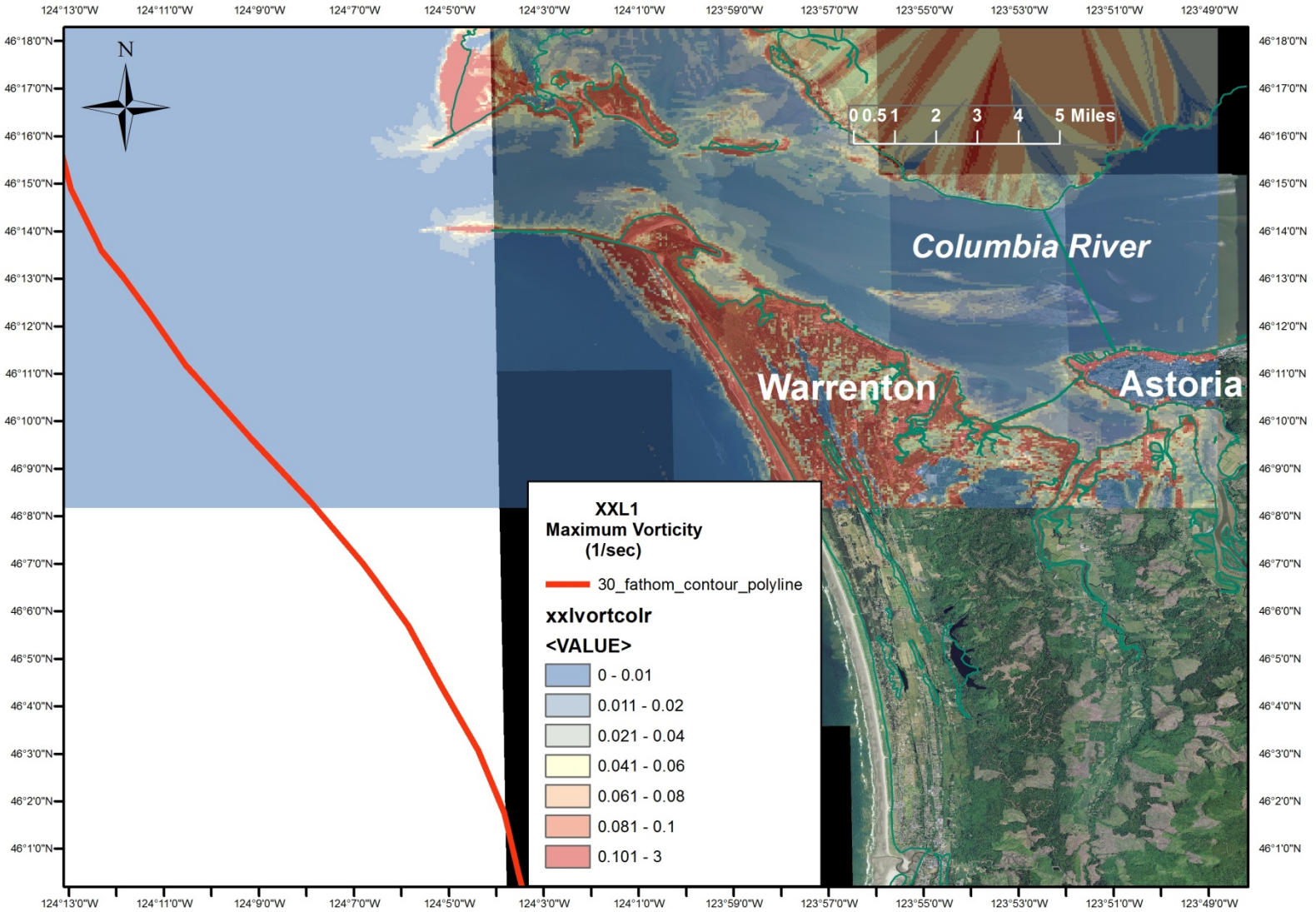
Wind Wave Amplification

- Large amplification occurs when current speed is close to opposing wind wave speed.
- Small, slow waves are thus highly amplified by even small currents.
- Higher speed tsunami currents that occur closer to shore amplify more wave sizes.
- Wave breaking for periods of 7-14 s, the most frequent PNW wind wave periods:
  - ~3-knot currents cause all wind waves ≤ 7 s to break; sig. wave ht. of 7-s waves are mostly 1 m but <4 m
  - ~6-knot currents cause all wind waves ≤ 9 s to break; sig. wave ht. of 9-s waves are mostly 1-2 m but <6 m
  - ~10-knot currents cause all wind waves ≤14 s to break; sig. wave ht. of 14-s waves are mostly 2-5 m but <7.5 m
    (**Note**: wave breaking is preceded by wave height amplification on the order of 50-170%; ~14 sec is the most frequent period for significant wave height of 13-ft (4-m) on the PNW scatter diagram; 90% of PNW waves have significant wave height ≤ 4 m over 27 years of observations;).
- Since XXL produces currents >3-4 knots at ≤ 100 fathoms, there will be widespread steep and breaking waves under typical PNW wind conditions; the same is true for AKmax at <30 fathoms.

Next Step for Maritime Planning

Detailed Guidance for Harbors Emphasis on Distant Tsunamis

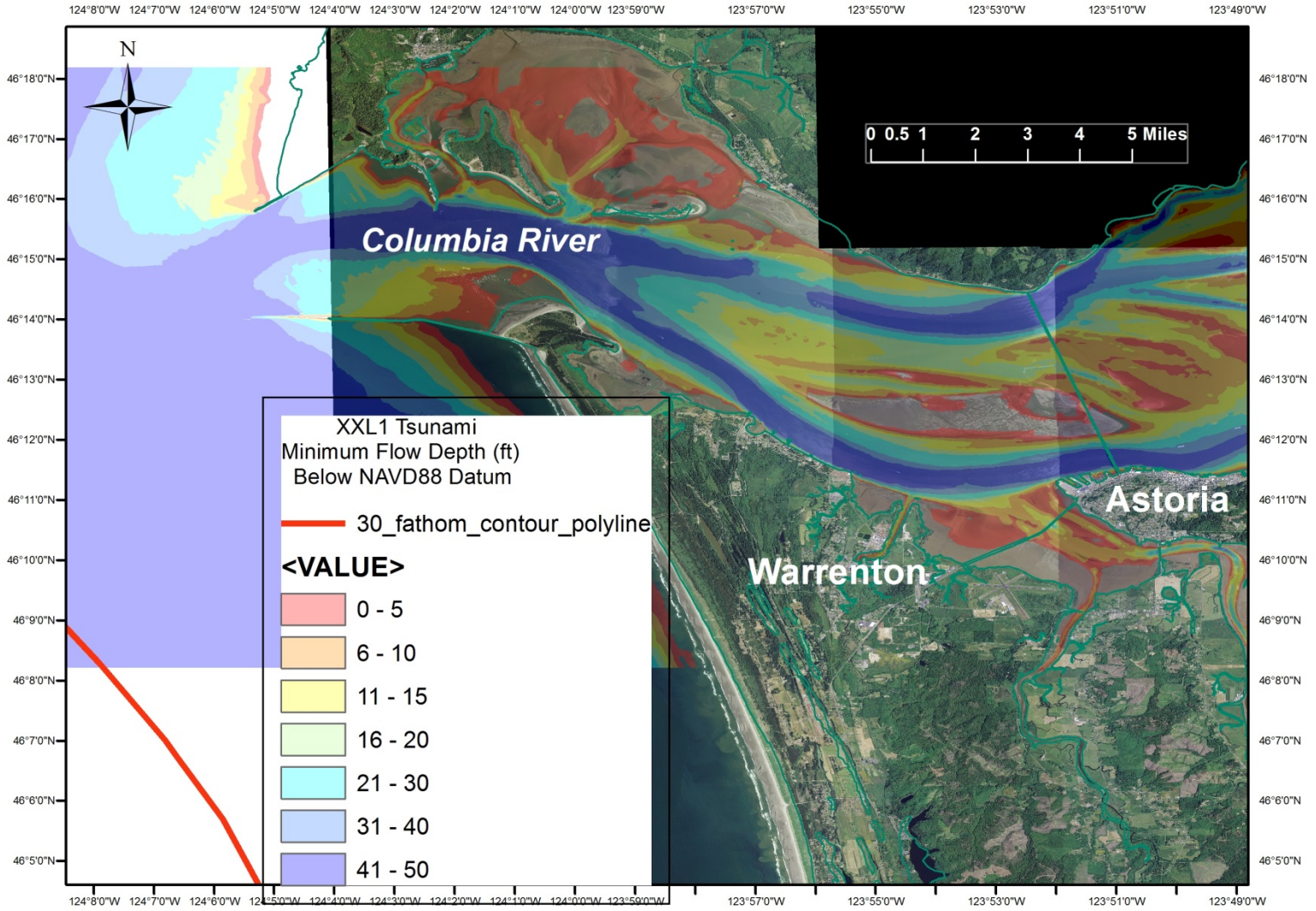
XXL1 Cascadia
Maximum Vorticities at Columbia River



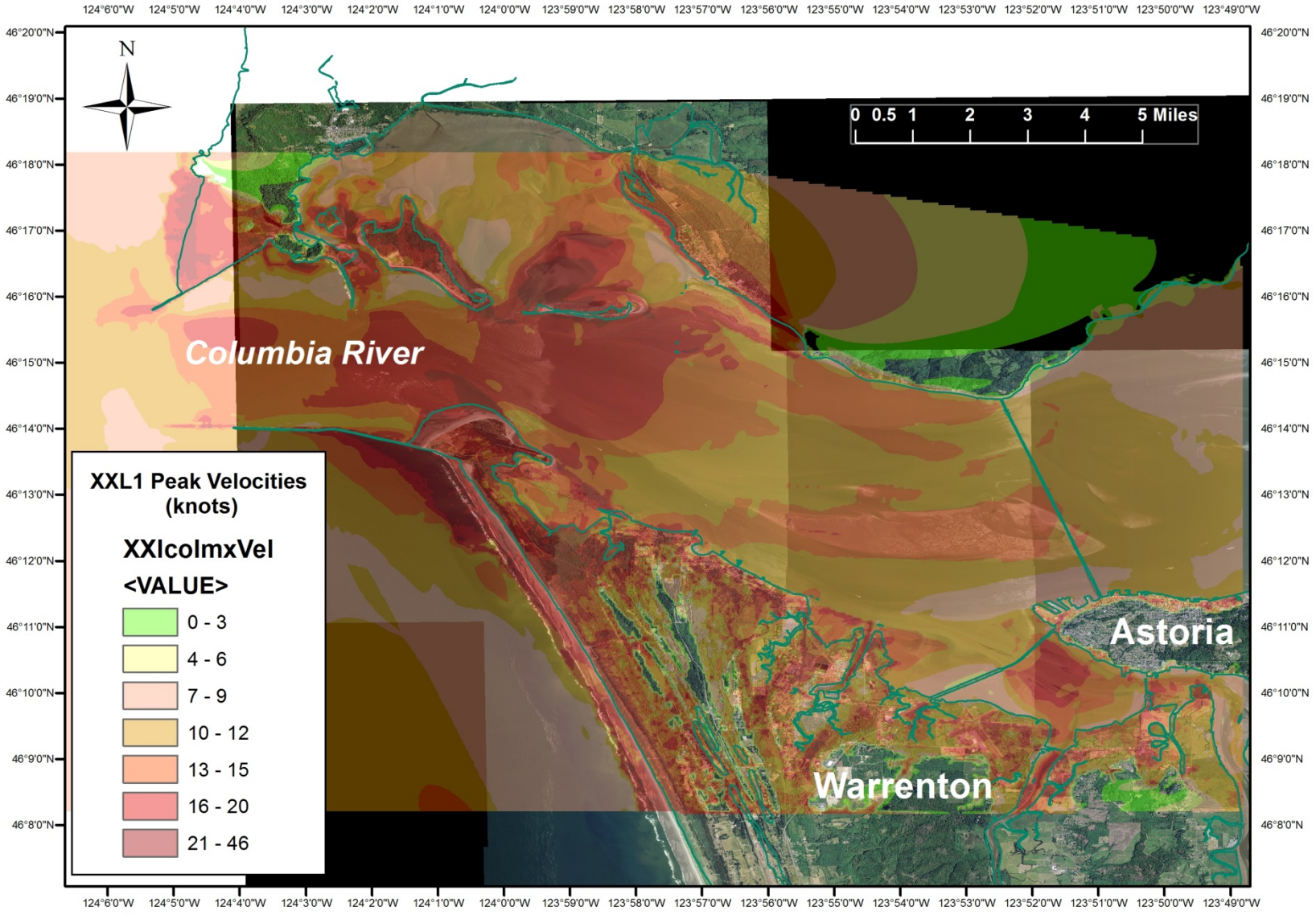
XXL1 Cascadia

Minimum Flow Depths – Columbia River

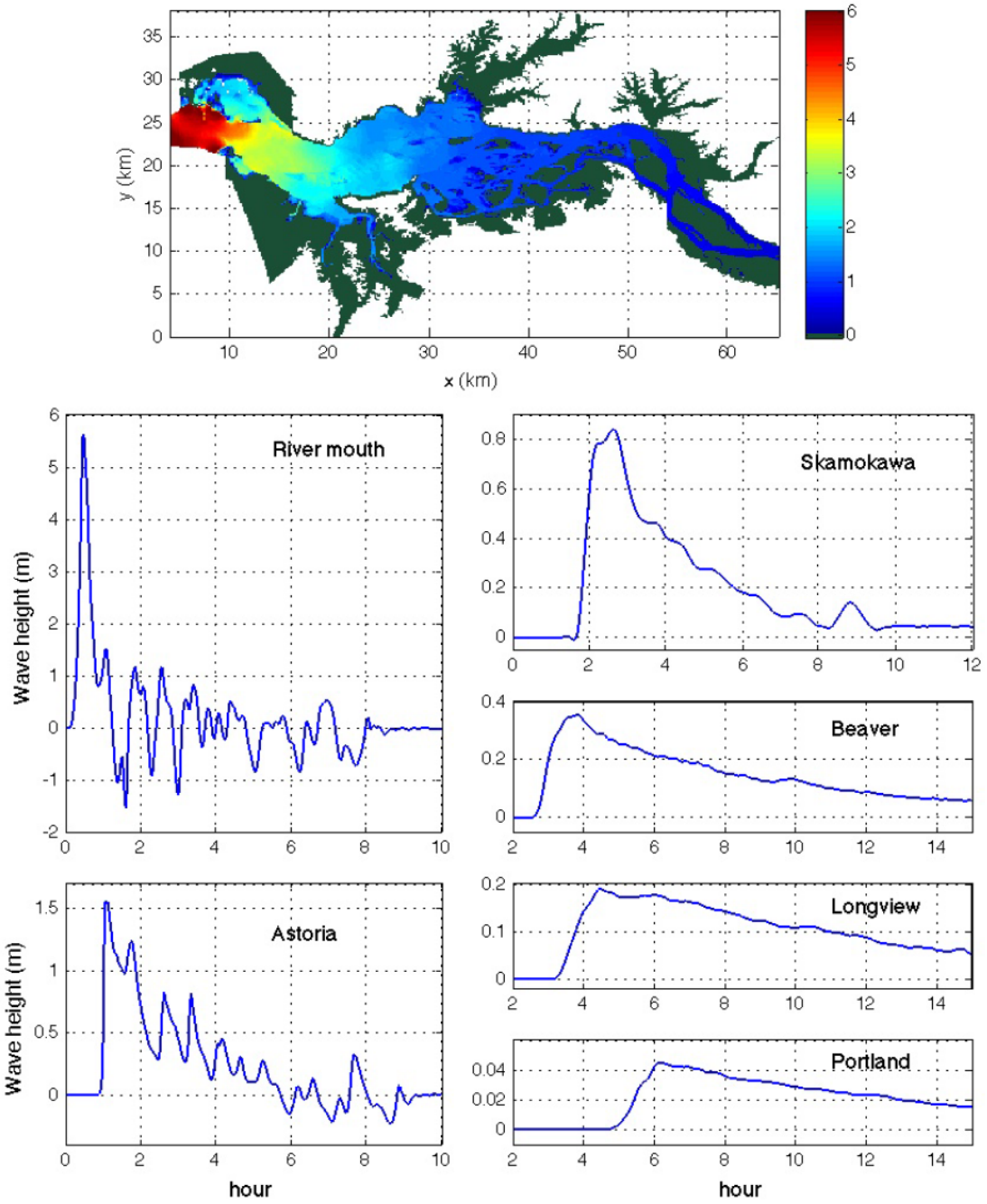
(~40-50 ft = maximum ship displacement)



XXL1 Peak Velocities – Columbia River

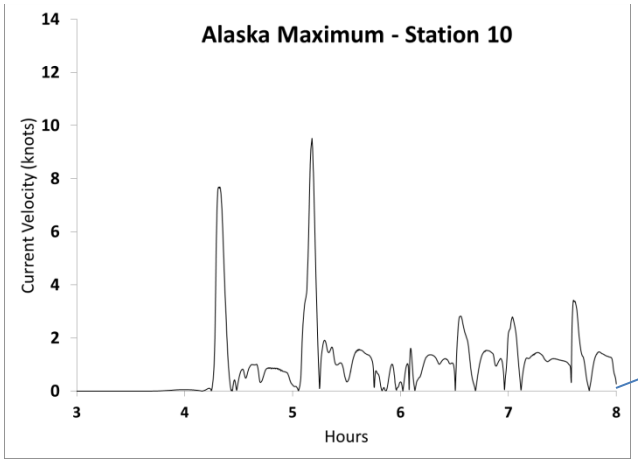


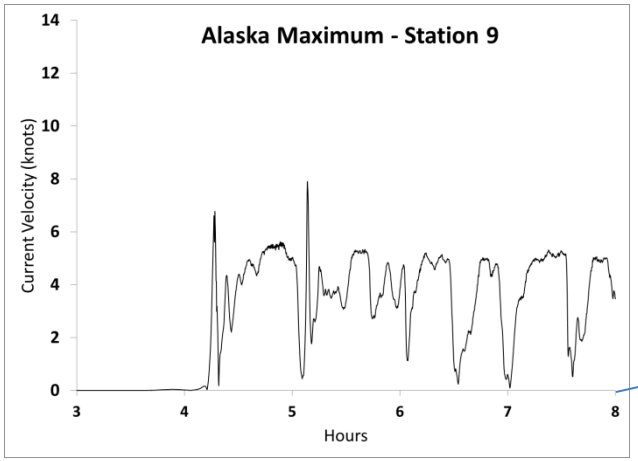
Upstream dissipation of a **5.6-m (18-ft) Cascadia Tsunami** from the mouth of the Columbia River to Portland (Yeh et al., 2011)

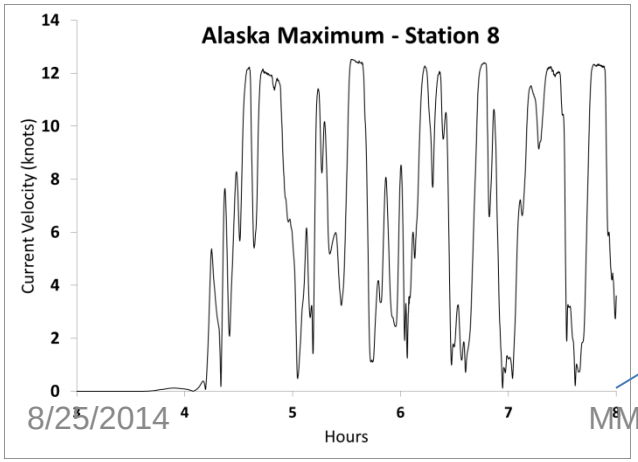


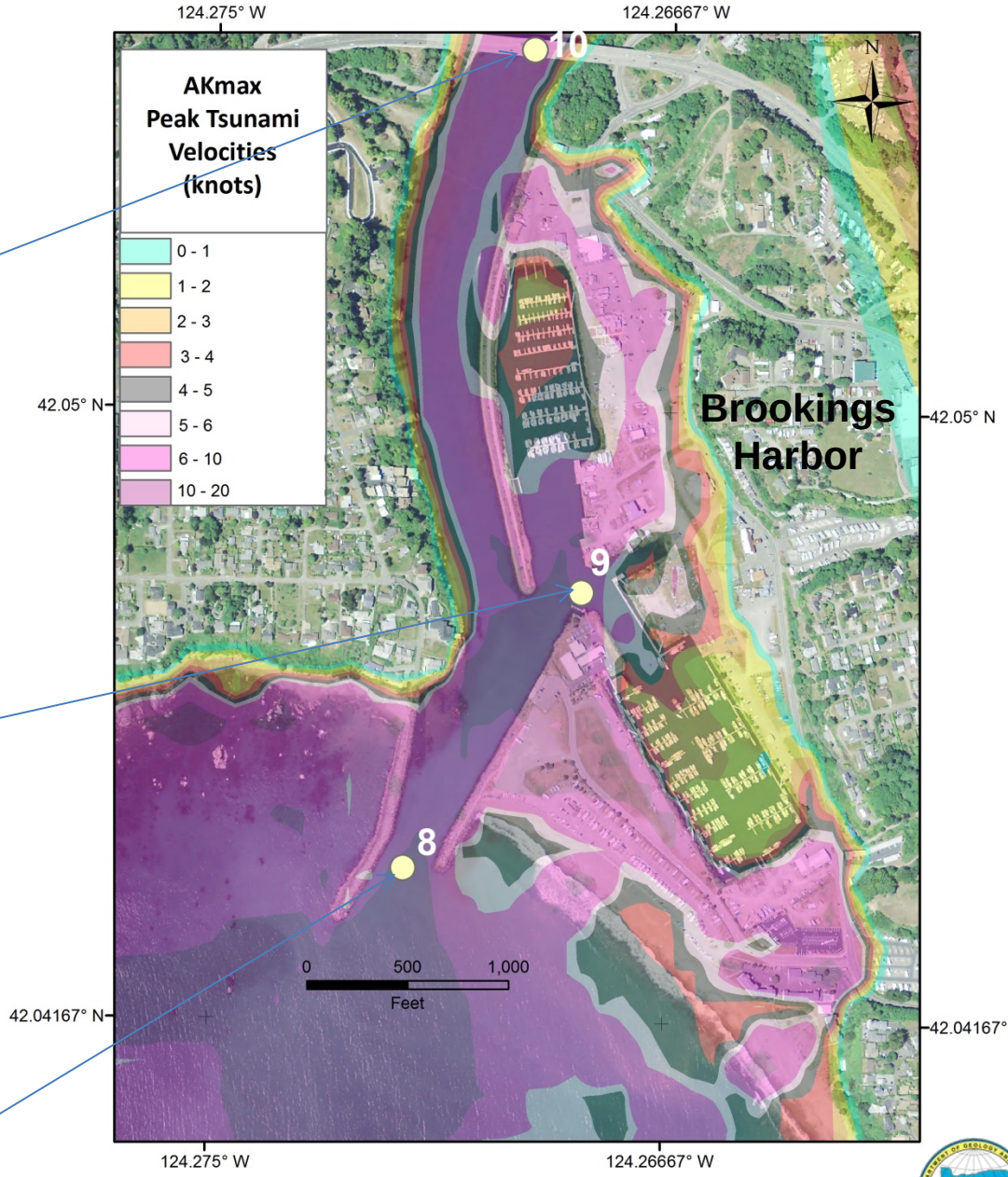
Cascadia tsunamis completely overwhelm small ports at the coast but maximum-considered distant tsunamis may not.

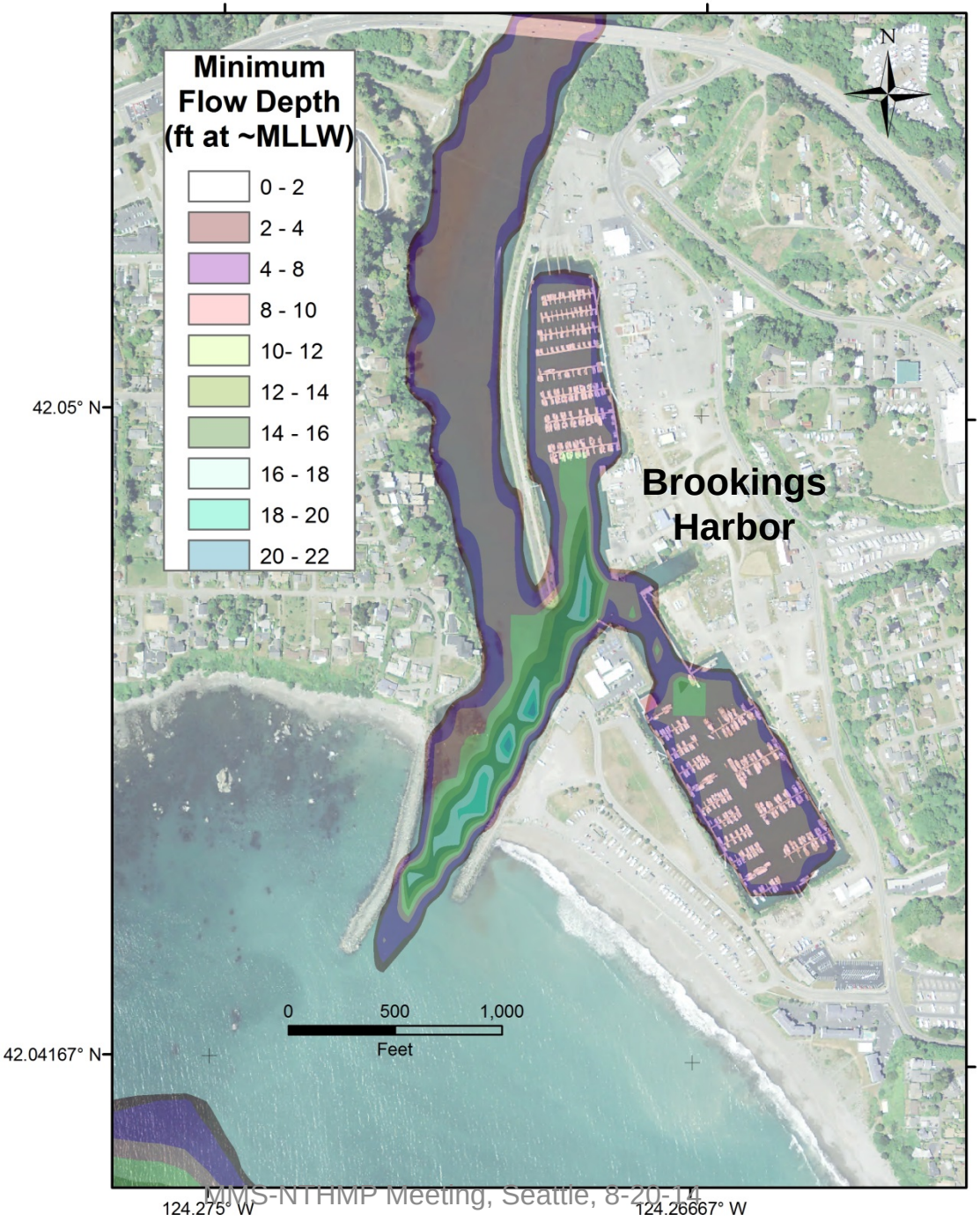
Example:
Brookings Harbor, Southern Oregon

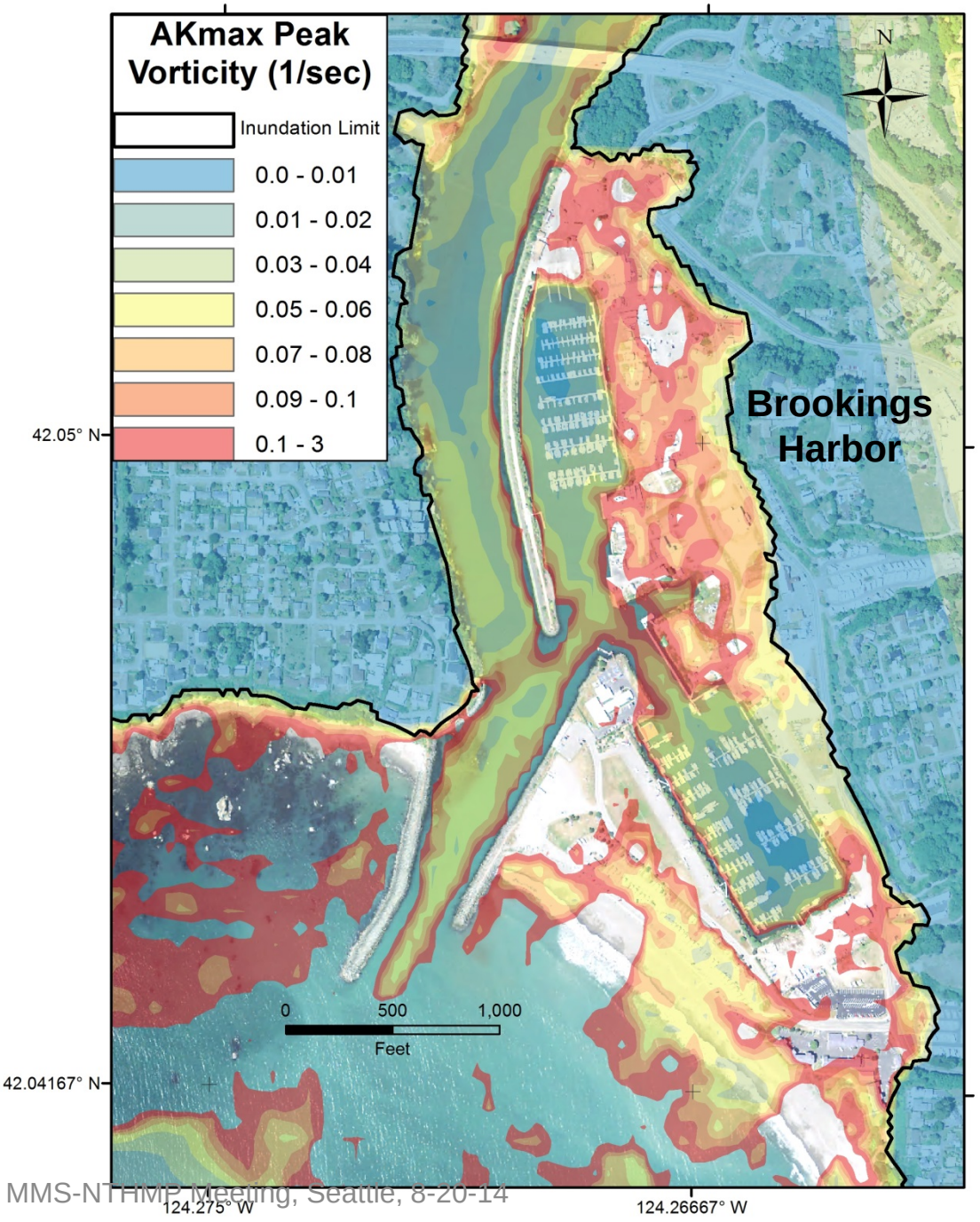

Alaska Maximum - Station 10
Current Velocity (knots)
Hours


Alaska Maximum - Station 9
Current Velocity (knots)
Hours


Alaska Maximum - Station 8
Current Velocity (knots)
Hours


124.275° W
124.26667° W
42.05° N
42.04167° N
AKmax
Peak Tsunami
Velocities
(knots)
0 - 1
1 - 2
2 - 3
3 - 4
4 - 5
5 - 6
6 - 10
10 - 20
10
9
8
Brookings
Harbor
N
0
500
1,000
Feet


Minimum
Flow Depth
(ft at ~MLLW)
0 - 2
2 - 4
4 - 8
8 - 10
10- 12
12 - 14
14 - 16
16 - 18
18 - 20
20 - 22
N
Brookings
Harbor
0
500
1,000
Feet
42.05° N
42.04167° N
124.275° W
124.26667° W


AKmax Peak Vorticity (1/sec)
Inundation Limit
0.0 - 0.01
0.01 - 0.02
0.03 - 0.04
0.05 - 0.06
0.07 - 0.08
0.09 - 0.1
0.1 - 3
N
Brookings Harbor
42.05° N
42.04167° N
0
500
1,000
Feet
124.275° W
124.26667° W