Lessons Leaned from Past Tsunamis - Upstream Operational Shortcomings

Dr. Charles McCreery
Director, PTWC, USA NOAA

No Common Sense for Tsunamis

- **Tsunamis are Not Common - Often 1st Time**
  - For individuals at risk
  - For government officials that must respond (incl. TWCs)
- **Tsunamis Can Be Learned From**
  - Tsunami wave characteristics from physics / models
  - Human response behavior from social science
- **Each Tsunami is Unique**
- **Warning / Response Planning Needs Imagination.**
  - What situations might occur?
  - How to prepare/respond based on best science?
  - Procedures recorded in SOPs
- **Learn from the Past to Improve Future Response**

Recent Tsunamis to Learn From

- **Since 1975 - 119 tsunamis > 1m, 42 deadly**
- **Since 2004 - 14 deadly tsunamis (9 in the Pacific Ocean, 5 in the Indian Ocean)**
  - Dec 2004 Indian Ocean (230,000 lives)
  - Jul 2006 Java (668 lives)
  - Apr 2007 Solomon Islands (52 lives)
  - Sep 2009 Samoa (192 lives)
  - Oct 2010 Mentawai (400 lives)
  - Feb 2010 Chile (156 lives)
  - Mar 2011 Japan (16,000 lives)
  - Feb 2013 Solomon Islands (10 lives)
  - Jan 2022 Tonga (6 lives)
- **What have we learned for early warning?**

September 1992 Nicaragua Tsunami

- Ms=7 earthquake off the coast of Nicaragua
- Very little shaking along the coast
- Little or no tsunami expected, but
- Large tsunami struck – 116 lives lost

Lessons Learned

- Slow Earthquake
- Use Mw, not Ms
- Use slow discriminant
- Not always shaking
- Not that uncommon – ‘06 Java, ‘10 Mentawai

New Guinea Tsunami - Jul 1998

- Mw 7.1 earthquake – no tsunami expected, but
- Large tsunami impact – 2200 lives lost
- Probable cause was undersea landslide triggered by the earthquake

Lessons Learned

- Tsunami possibility after any large earthquake
- Roar from the sea may be only real warning

Sumatra Tsunami - Dec 2004

- Mw 9.2 earthquake – size not known for 4 hours
- Rupture direction and extent only known later
- Unrecognized hazard – nothing like this expected
- End-to-end alerting not possible

Lessons Learned

- Use new methods to measure huge quakes
- Techniques to quickly gauge rupture area
- Expect 1000-yr event
- Use forecast models
- End-to-end alerts

Japan Tsunami – Mar 2011

- Mw 9.0 earthquake – that big was not expected
- First alert in 3 min, but earthquake size and forecast tsunami impacts too small
- Human behavior – some did not evacuate

Lessons Learned

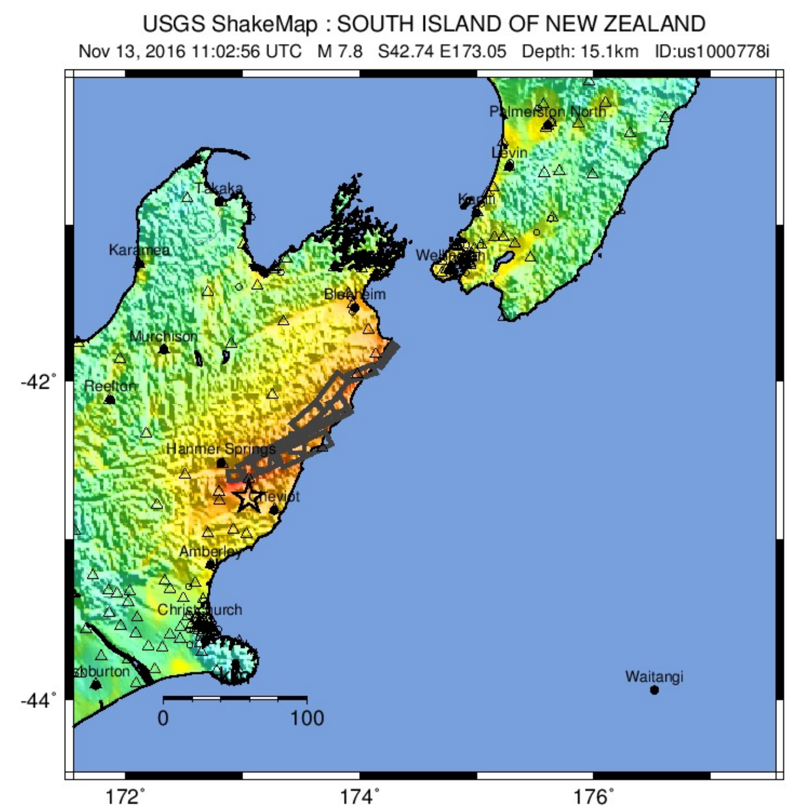
- Expect 1000-yr event
- Conservative first alert message
- Study/address how to motivate right actions

New Zealand Tsunami – Nov 2016

- Mw 7.8 earthquake – epicenter inland
- New Zealand and PTWC evaluated as no tsunami threat
- Complex rupture – main slip 200km to north
- 7m tsunami occurred

Lessons Learned

- Assume conservative earthquake source size
- Conservative first alert message
- Sea level gauges detect

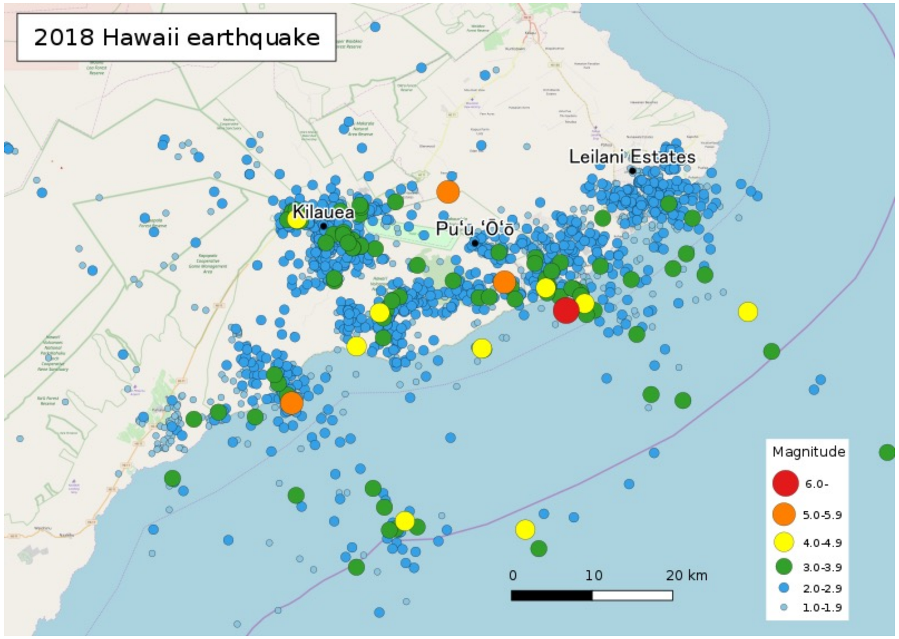


Hawaii Tsunami – May 2018

- Mw 6.9 earthquake – minimum PTWC threshold for a local tsunami warning
- PTWC initial Mw was 6.0, then 6.4, then 6.9
- 0.4 m tsunami observed on nearest gauge

Lessons Learned

- Used to relying on ml
- Special application of Mw required
- Better to wait a few extra minutes to get it right



In Conclusion…

- Every tsunami is unique and can provide new information to improve early warning
- The problem is dynamic – technologies for detection, evaluation, forecasting, and alerting keep changing
- Coastal vulnerabilities change with increasing coastal populations and infrastructure
- We must continue to share our knowledge and experiences to improve the system

Thank You

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