

# Agenda

8:00 Tsunami Overview

8:30 Tsunami Forecast **Modeling** and Discussion

9:15 Tsunami Hazard Assessment and Discussion

10:00 *Break*

10:15 Tsunami **Measurements**: Tour and Discussion

11:30 Tsunami Forecast System Demonstration

12:15 Tsunami Wrap-up

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# Tsunami Overview



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***Pacific Marine Environmental Laboratory***  
***August 28, 2008***

# Relevance

- NOAA Research Plan

**Improve NOAA's understanding and forecast capability in coasts, estuaries, and oceans**

**3-5 Year Milestone: Improve tsunami warnings with emphasis on run-up inundation and reducing false alarms**

# Tsunami Accomplishments

- Developed, tested, and transferred 2 generations of tsunami measurement technology (DART) to operational NOAA (NWS)

**IMPACT** - Real-time data available for experimental forecasts and DART technology has become the national & international standard

- Patented, licensed, and trademarked the measurement technology

**IMPACT**- New jobs in U.S.(\$2.7M in sales)

- Developed, tested, and are transferring tsunami modeling technology to operational NOAA (NWS)

**IMPACT**- First generation of tsunami forecast products to become operational in 2009, becoming international standard for forecasting

- Built capacity for Indian Ocean nations through PMEL/UW certification course and PMEL modeling training program

**IMPACT**-180 scientists trained: Indian Ocean nations have tsunami warning capabilities based on PMEL standards in measurement and modeling technologies: others to follow through United Nations organizations and bi-lateral agreements

# Outline

- Historical Context of Tsunami Research
- Deep Ocean Tsunami **Measurement** Technology
- Tsunami Forecast **Modeling** Technology
- International Capacity Building
- Summary

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# Brief History of PMEL Tsunami Research

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- 1965- Alaska and Chile tsunamis leads to formation of Joint Tsunami Research Effort (NOAA/University of Hawaii)
  - 1975- Hawaii local tsunami leads to local tsunami warning system with earthquake activated alarms in each county of Hawaii
  - 1980 – First National Tsunami Research Plan: NOAA –measurements, NSF-modeling
  - 1981 – Begin DART development using bottom pressure sensor
  - 1986 – First deep ocean tsunami detected ( not real-time)
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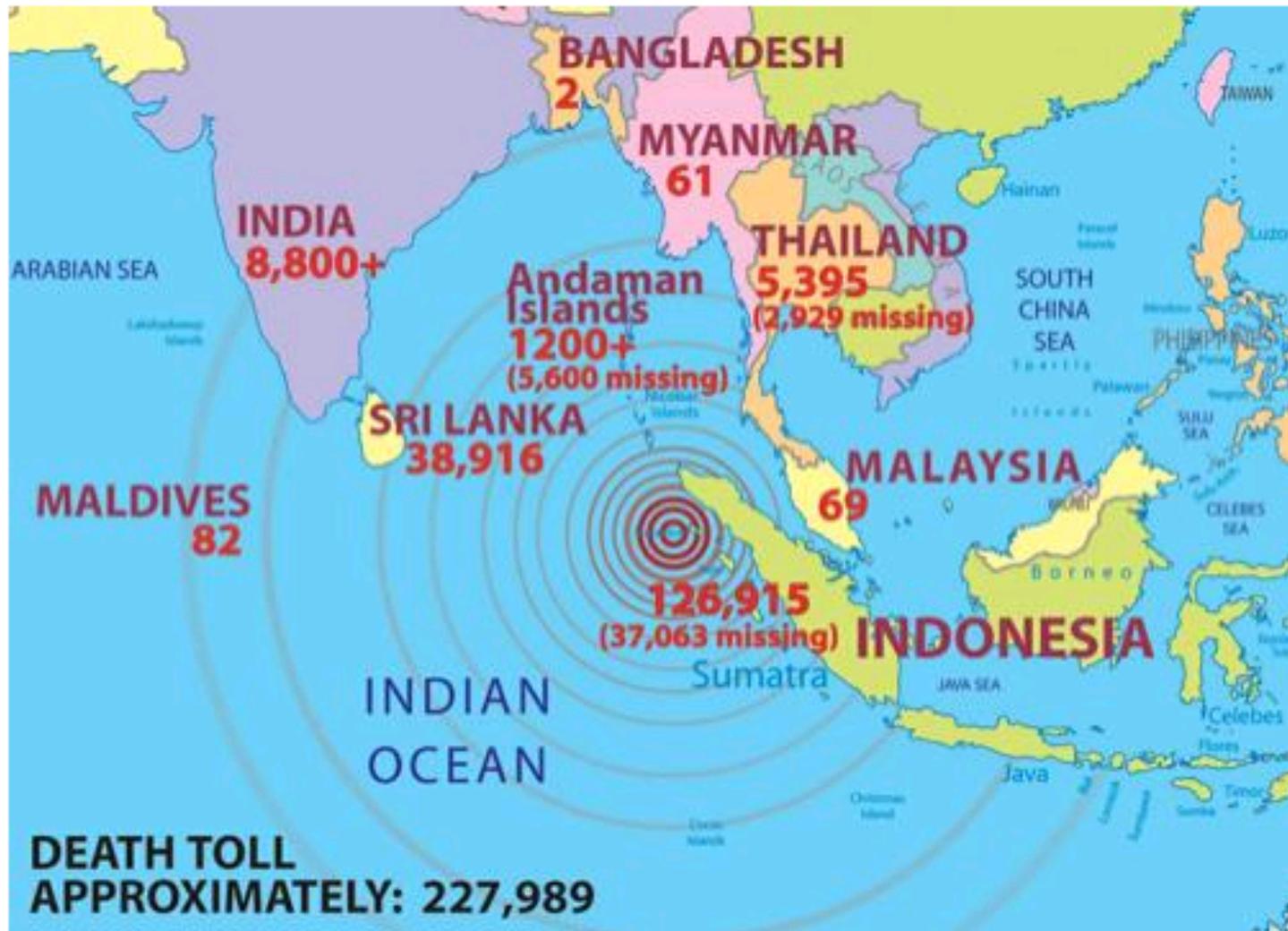
- 1992- California earthquake/tsunami identifies West Coast threat to local tsunami
  - 1997- National Tsunami Hazard Mitigation Program founded, **tsunami forecast requested by States**, begin forecast modeling
  - 2001- DART experimental array completed (6 buoys)
  - 2003- DART I transferred to NDBC, 1st experimental tsunami forecast using deep ocean real-time tsunami **measurements** & inundation **model**
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- 2004- Indian Ocean tsunami kills 237,000, \$26M supplemental funds to strengthen U.S. tsunami warning system (centerpiece- PMEL developed tsunami technology)
- 2005- DART II Transferred to NDBC, publish book Tsunami Resilience, begin development of tsunami education program, measurement standards established
- 2006- Tsunami Act passed, 2<sup>nd</sup> experimental tsunami forecast
- 2007- 3<sup>rd</sup>-8<sup>th</sup> experimental tsunami forecasts, DART patent approved, first license, model standards published
- 2008 – DART II operational array completed (U.S. 39 buoys), Australia, Chile, Indonesia, and Thailand participate (44 total), DART/ETD passed operational testing

# Center of Excellence in Disaster Management and Humanitarian Assistance

## Emergency Report : September, 2005



**Damage \$13.6B : Displaced 1,100,000**

# Ten Deadliest Natural Disasters on Record

<b>Rank</b>	<b>Event</b>	<b>Location</b>	<b>Death Toll</b>
1	1931 Yellow River flood	China	1-4 million
2	1887 Yellow River flood	China	900,000 - 2 million
3	1970 Bhola cyclone	Bangladesh	500,000 - 1 million
4	1938 Yellow River flood	China	500,000-900,000
5	1556 Shaanxi earthquake	China	830,000
6	1839 India cyclone	India	300,000
7	1642 Kaifeng flood	China	300,000
8	1976 Tangshan earthquake	China	242,000
9	2004 Indian ocean tsunami	Indian Ocean	237,000
10	1138 Aleppo earthquake	Syria	230,000

By Comparison 2005 Hurricane Katrina in the U.S. killed 1,033 people.

# US Response = \$950M

- Defense: Relief = \$250M
- State (USAID): Reconstruction = \$660M  
(\$16M for IO tsunami warning system)
- Commerce (NOAA): Warnings= \$26M
- Interior (USGS): Seismic upgrade = \$13M
- NSF: Research surveys = \$1M

# US Response (Policy)

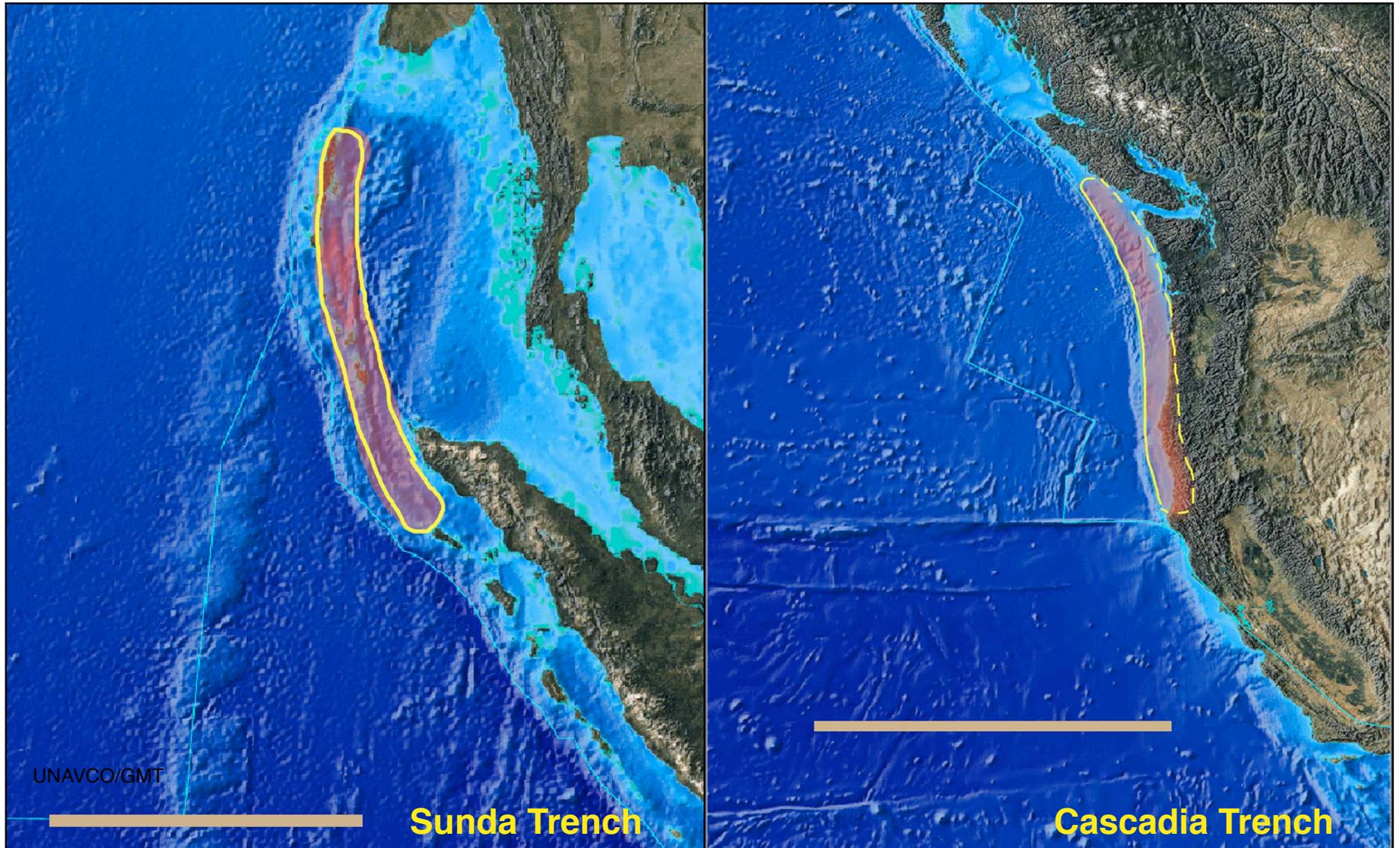
Tsunami Warning and Education Act  
(Authorizes \$129M for FY08-12)

1. Tsunami Warning: NOAA (65%)
2. Tsunami Mitigation: States/NOAA (27%)
3. Tsunami Research: NOAA (8%)
4. International Capacity Building: NOAA (0%)

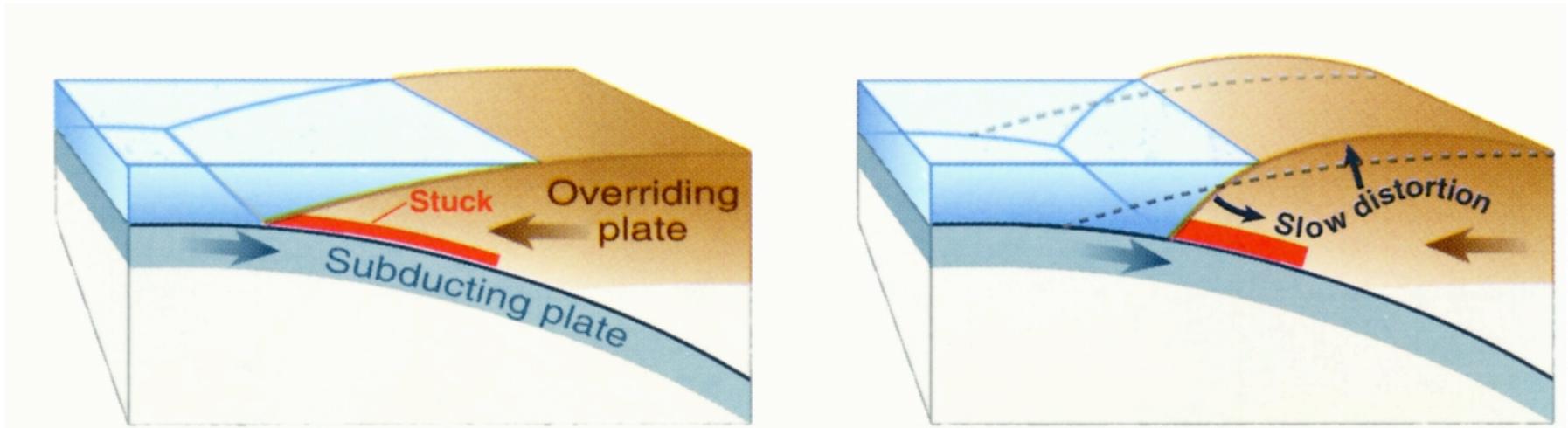
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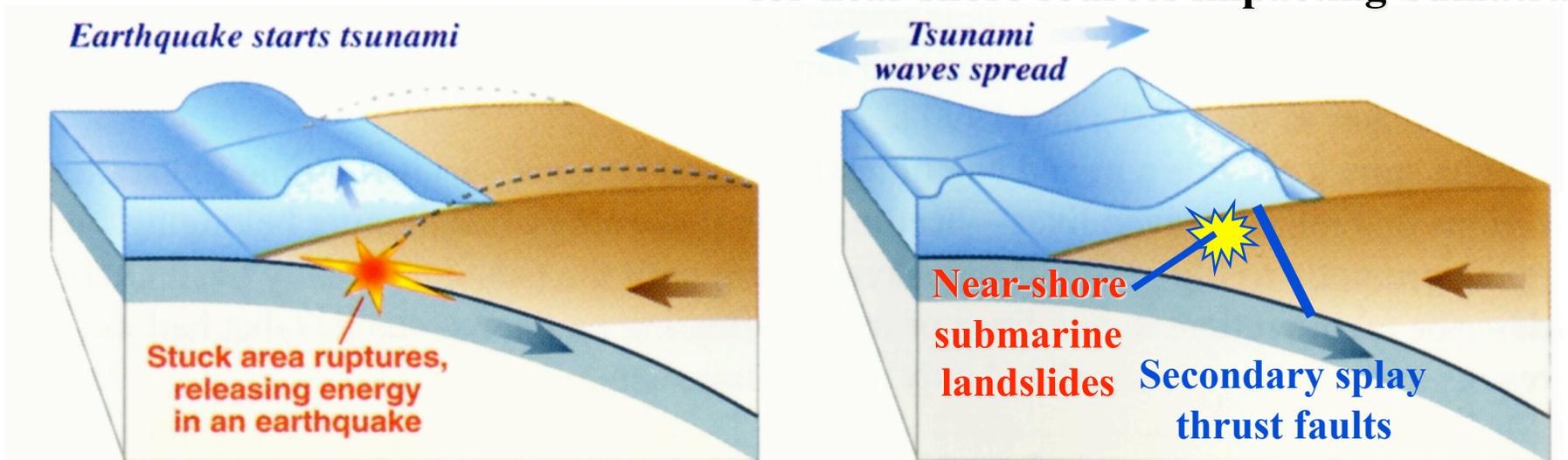
# Lessons for the United States



## Tsunami Generation From Giant Earthquake Subduction Zones (Generic)

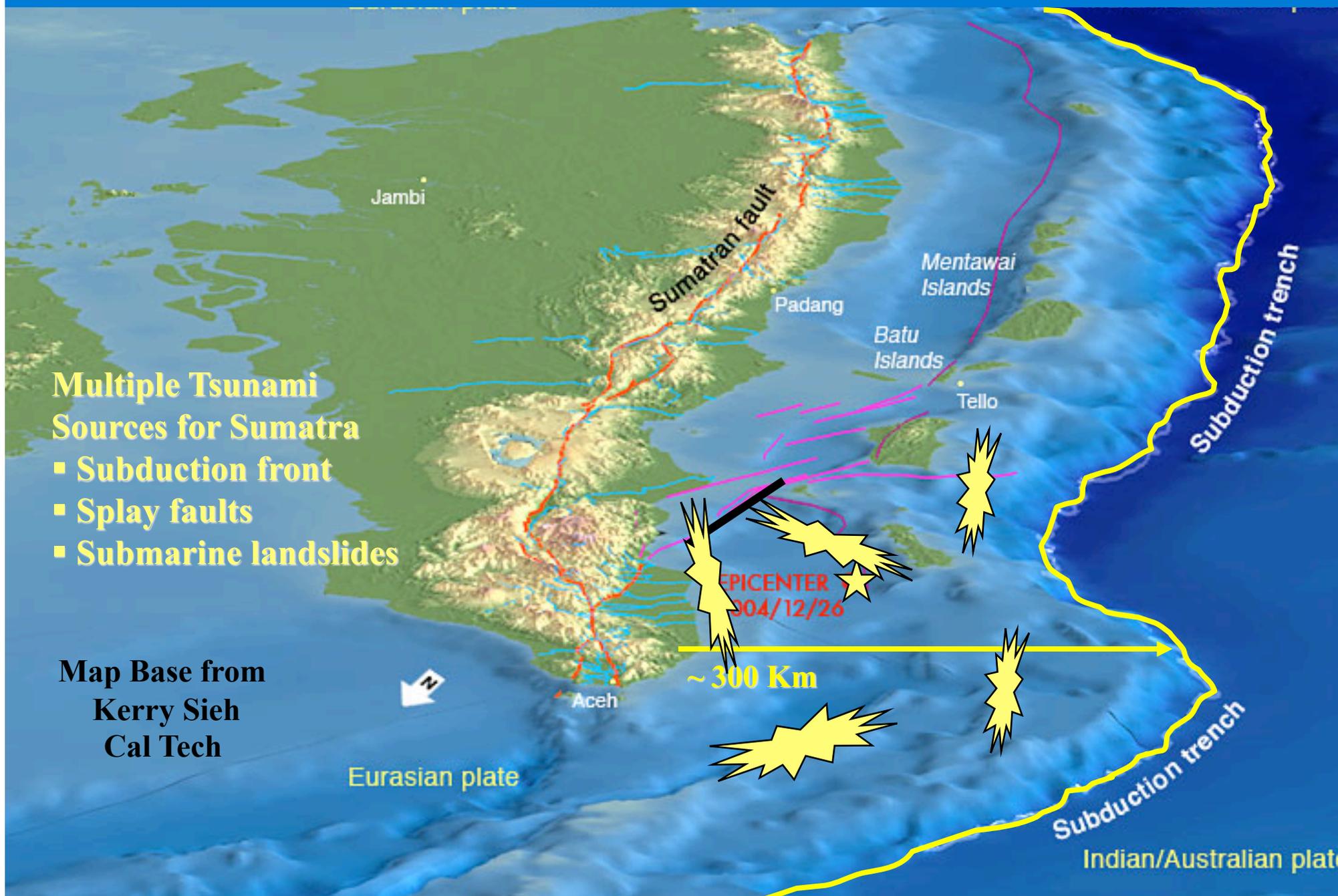


### Alternate tsunami source interpretations for near shore sources impacting Sumatra



Modified from Atwater,

# Sumatra



Tsunami is a set of long ocean gravity waves caused by any large, abrupt disturbance of the ocean surface.

*Example*

# Corollary

Earthquake information ALONE is **insufficient** to determine the tsunami's destructiveness

# Criteria

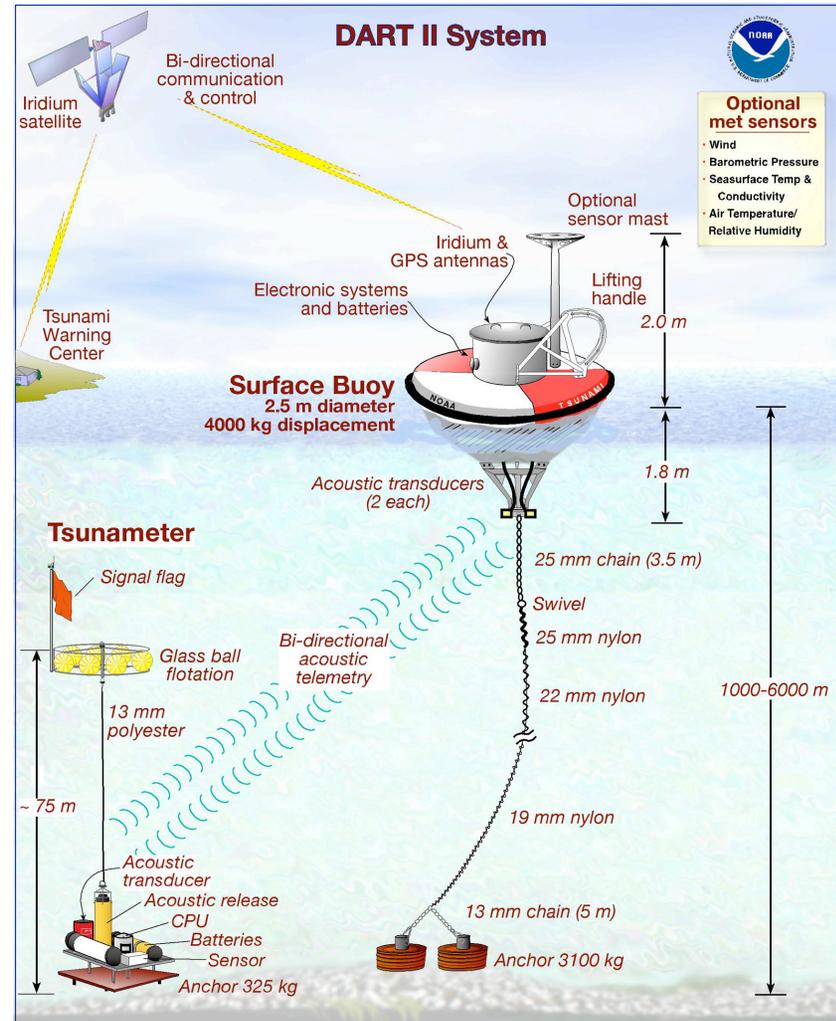
- Measurement type: amplitude over time
- Accuracy: 0.5 cm
- Sample rate: 1 minute or less
- Processing speed: within 2 minutes
- Availability: within 5 minutes, globally

Tech/Criteria	Type	Accuracy	Rate	Processing	Availability
DART					
GPS Buoy		X			X
CODAR	X	X	X	X	X
Sat. Altimeter		X		X	X
Sat. Scatt.	X	X	X	X	X
ADCP	X	X	X	X	X
E/M voltage	X	X	X	X	X
Acoustic	X	X		X	X
Cabled BPR					X

# DART II

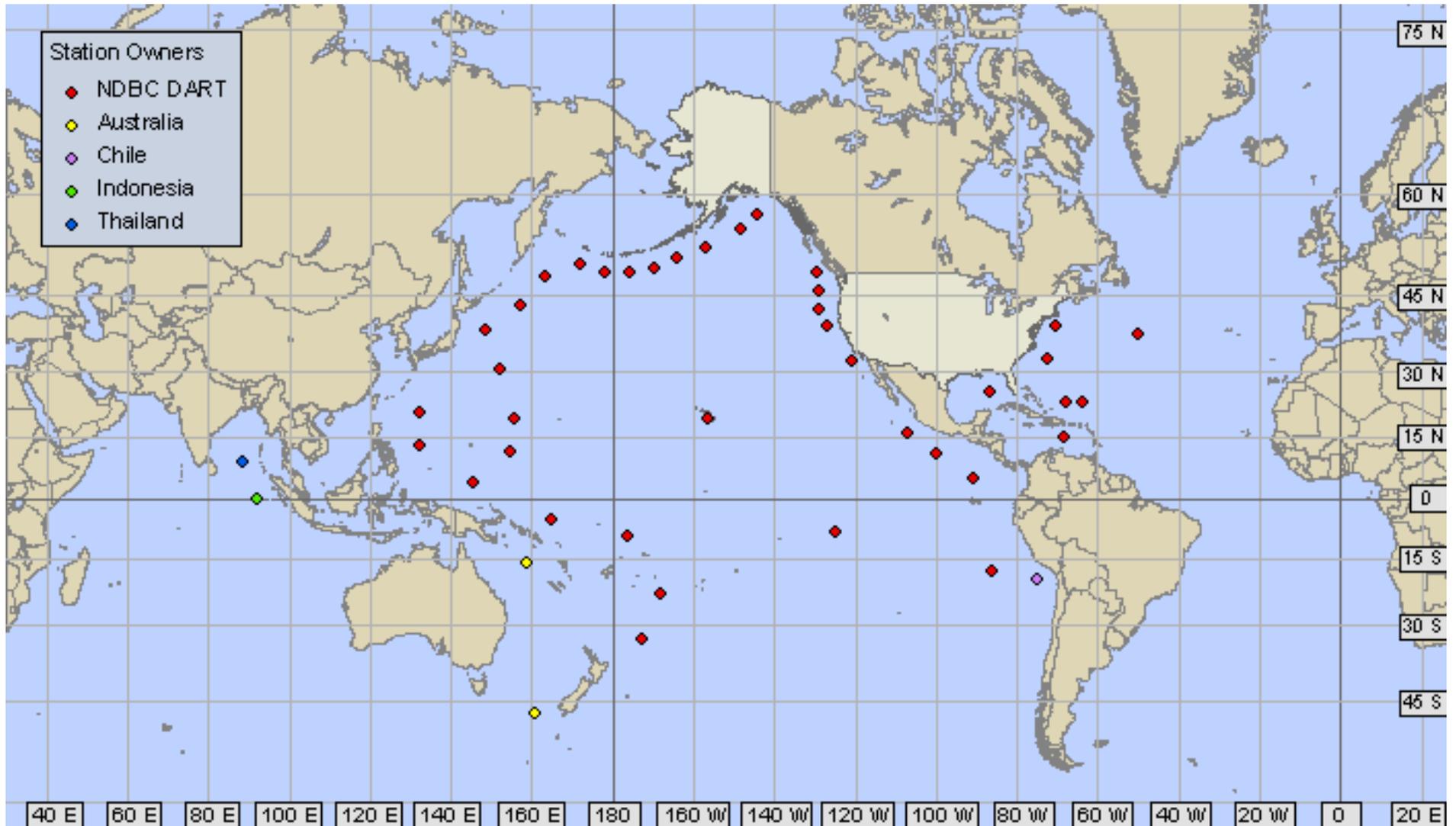
Key technologies:

- Bi-directional coms
- Tsunami Detection Algorithm
- Backup systems
- Worldwide deployable
- Plug-in to existing warning center infrastructure
- Optional meteorological sensors



**DART**<sup>®</sup> tsunami technology

# Global DART Station Array (July 2008)



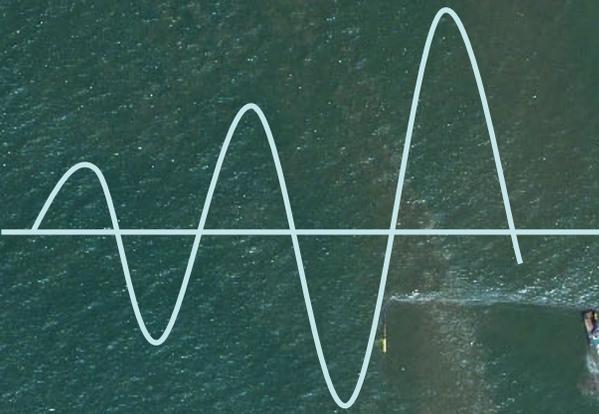
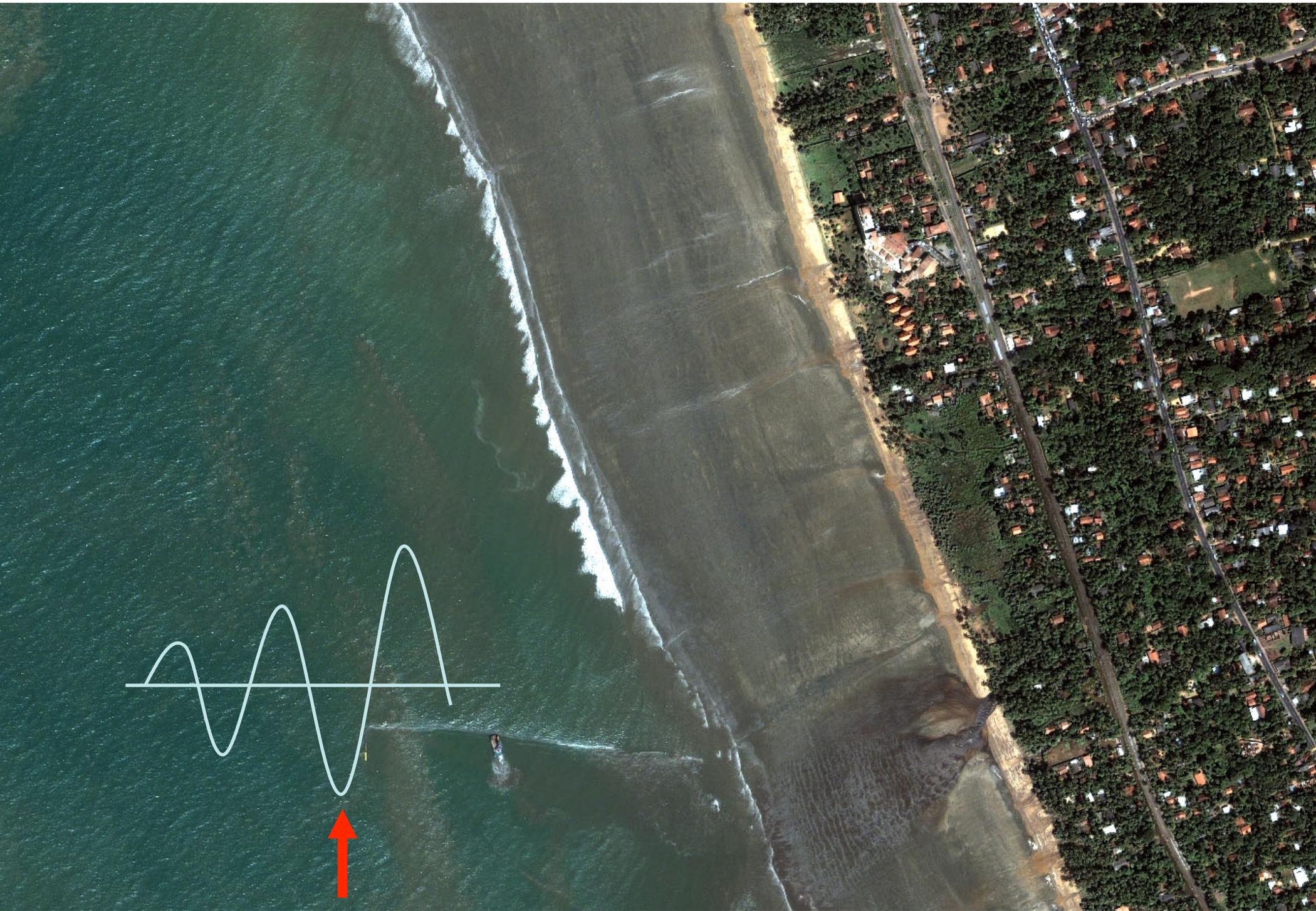
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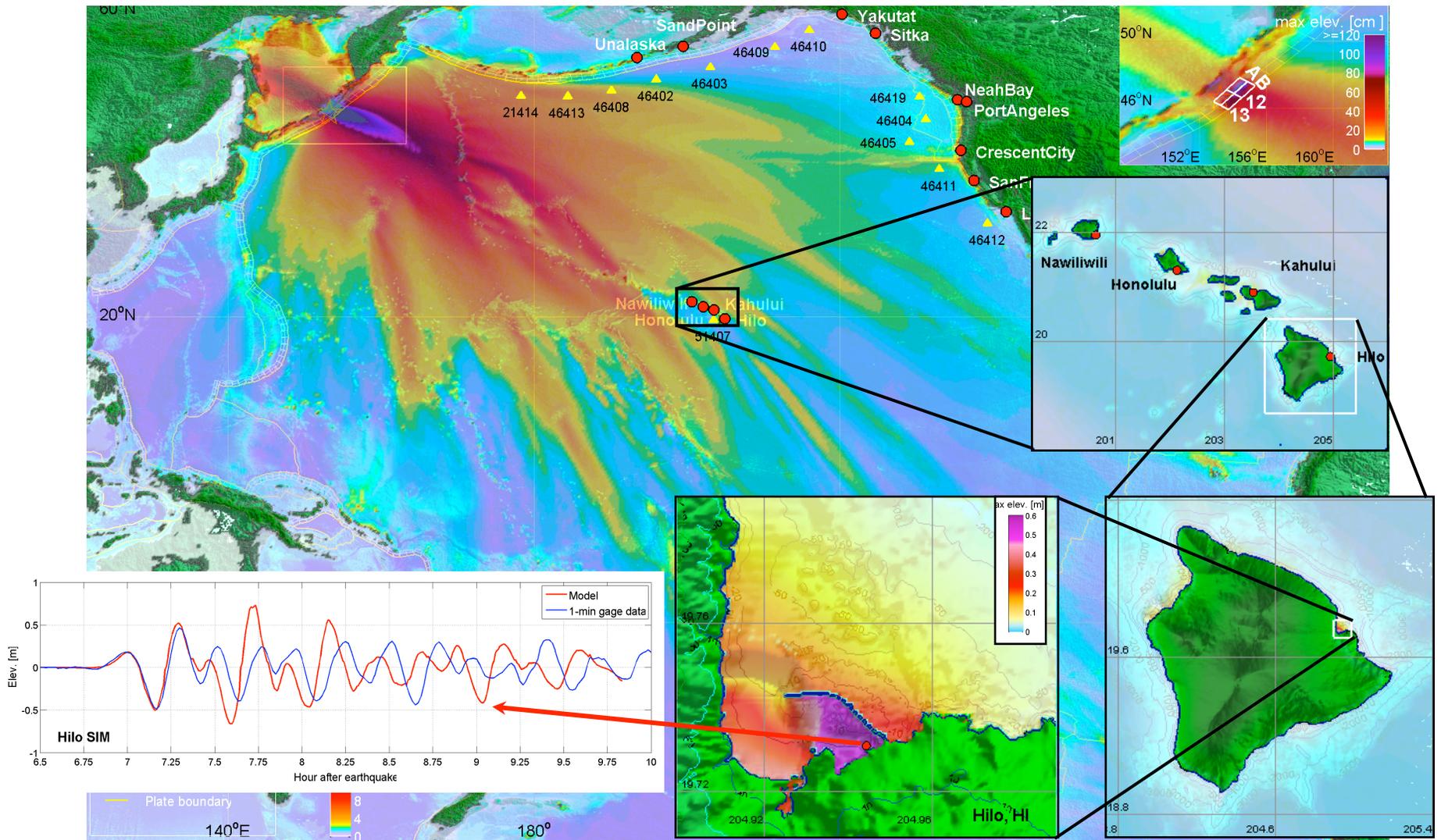






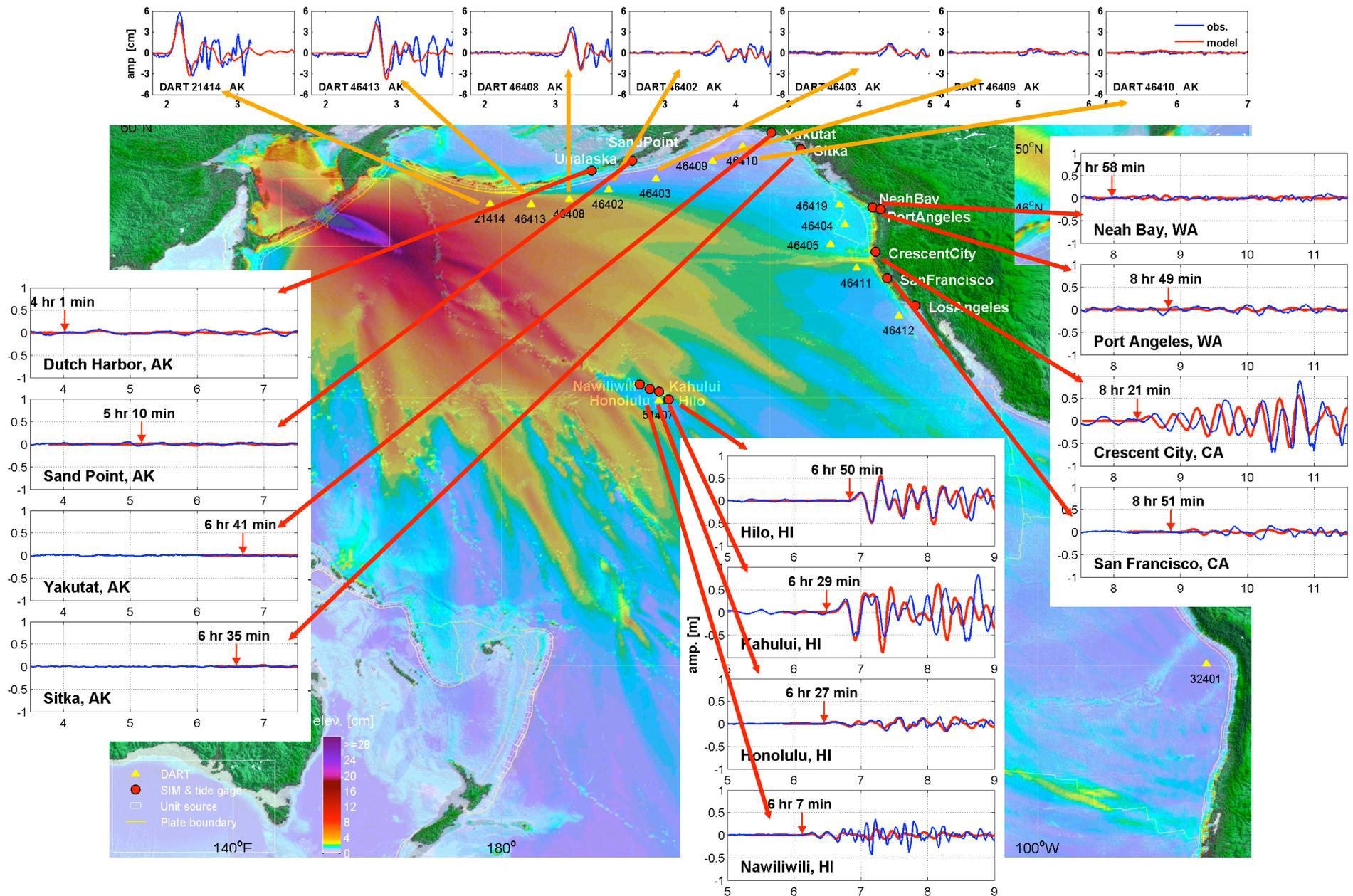


# The 15 Nov 2006 Central Kuril Tsunami

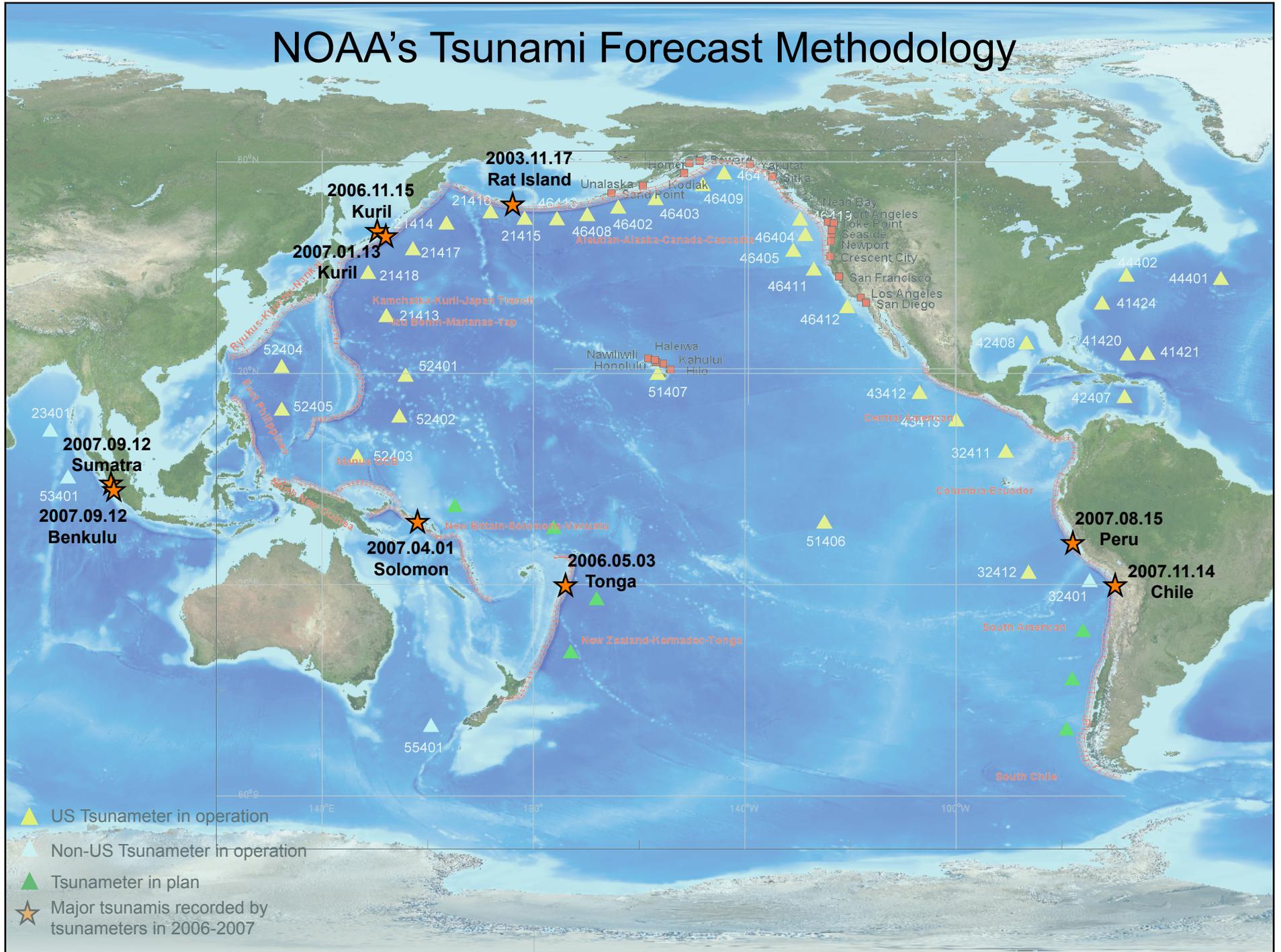


**Propagation Animation**

# The Nov. 15, 2006 Kuril Is. Tsunami -- forecast modeling



# NOAA's Tsunami Forecast Methodology



# Modeling Accomplishments

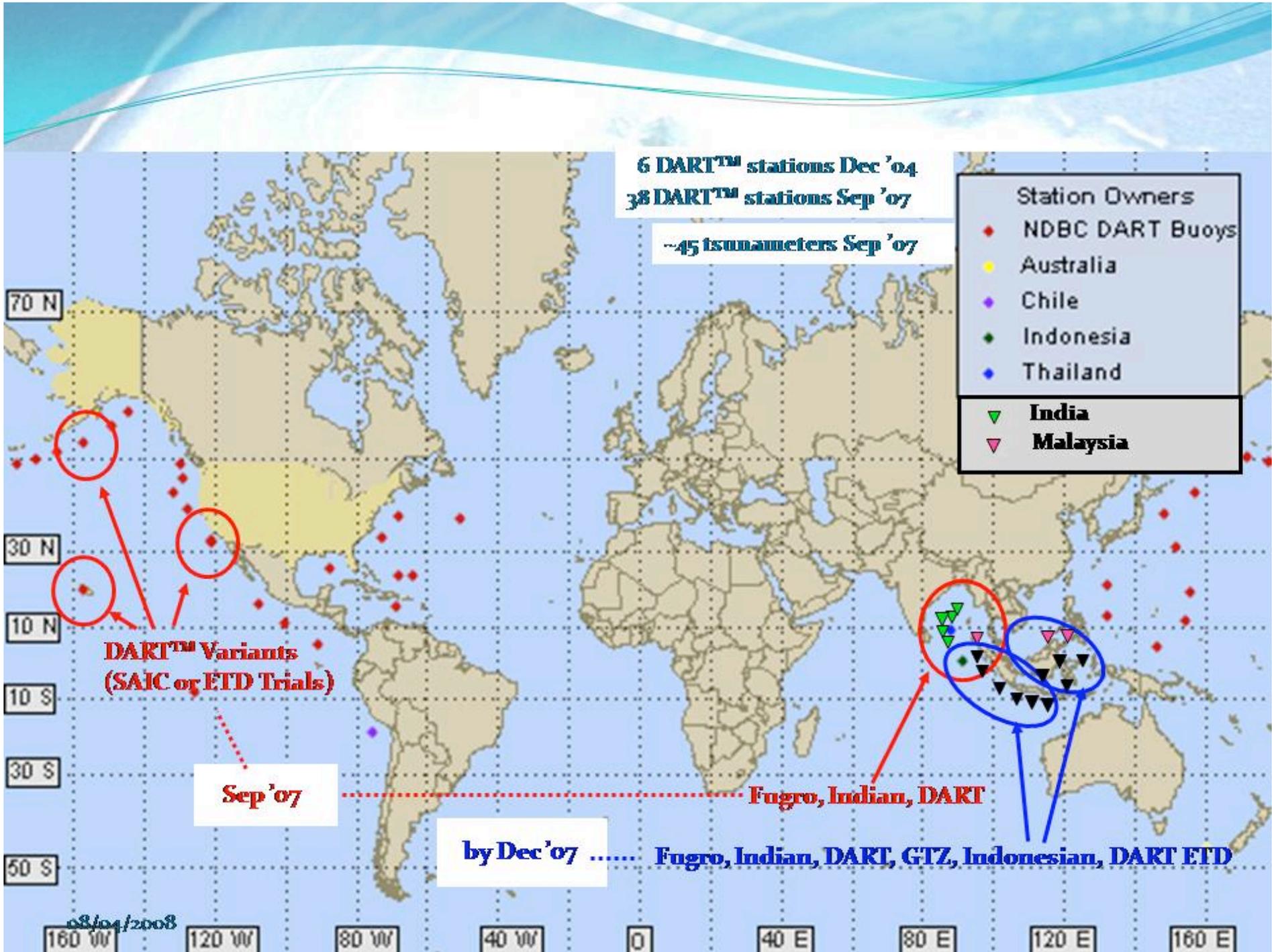
- Constructed propagation data base of over 1000 potential global sources
- Constructed 30 inundation forecast models for use in site specific forecasts
- Developed an implementation plan for transitioning forecast system to National Weather Service

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# Tsunami **Measurement** International Leadership

- DART system description publicly available after Sumatra tsunami
- Concept copied and adopted by 4 commercial firms and 3 national efforts
- Founding member of IOC-International Tsunameter partnership (standards, tech transfer, etc)
- MOUs and tech transfer agreements:
  - NOAA-NDBC
  - Australia (Bureau of Meteorology)
  - Indonesia (BPPT)
  - Chile (SHOA)



# International Tsunameter Partnership



## Countries

**India**

**Thailand**

**Malaysia**

**Indonesia**

**Australia**

**USA**

**Germany**

**Chile**

## **SUPPLIERS**

**Fugro Oceanor**

**Sonardyne**

**Envirtech**

**SAIC**

**Lighthouse R&D**

**SeaBird**

# Tsunami **Modeling**

## International Leadership

### United Nations (UNESCO) group for Indian Ocean Tsunami Warning System

1. Develop inundation maps for the coastal communities of the Indian Ocean region within 10 years
2. Develop source scenarios for inundation mapping
3. Model standards, scenarios and benchmarks to be available on the website
4. Training to include short-term and long-term strategies

# Tsunami Modeling Training

Sponsored by USAID, AusAID, UNESCO/IOC, EC, SHOA

## Indian Ocean

62 Scientists  
20 Countries

## Europe

25 Scientists  
9 countries

## Pacific

13 Scientists  
5 countries

## Totals

100 Scientists  
34 countries



# **Tsunami Certificate Program University of Washington Seattle, Washington**



# International Capacity Building

- **Tsunami Measurements**

1. PMEL developed DART technology adopted by Indian Ocean Nations ( through UN organization)
2. UN organization established International Tsunameter Partnership (Governments & Private Sector) to establish standards and provide mechanism for technology transfer

- **Tsunami Modeling**

1. PMEL modeling standards adopted by Indian Ocean nations
2. Modeling Training Program developed by PMEL and taught to 100 Indian, Pacific, and Atlantic Ocean scientists

- **Tsunami Education- Certification Program**

PMEL/University of Washington developed world's first certification course and certified 80 scientists from Indian Ocean

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# Summary

- **Quality:** National and International standards for tsunami measurement and modeling are based on PMEL developed technology
- **Relevance:** New generation of tsunami forecasting is the first major upgrade of NOAA's Tsunami Warning Products in almost 40 years.
- **Productivity:**
  1. **Measurement:** DART technology developed, tested for operational use, transitioned to NOAA operations , patent & license in place, new jobs in private sector
  2. **Modeling:** Tsunami forecast system developed with 30 site specific inundation models, tested by real-time experimental forecasts, published results
  3. **Education:** Established tsunami science and preparedness certification program

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