



UNITED STATES DEPARTMENT OF COMMERCE  
NATIONAL OCEANIC AND  
ATMOSPHERIC ADMINISTRATION



# NOAA/NWS Tsunami Program

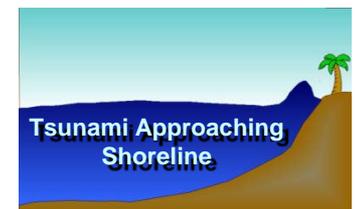
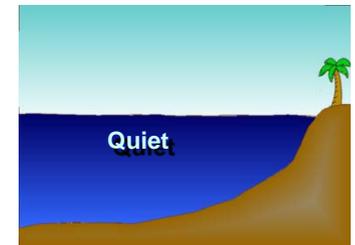
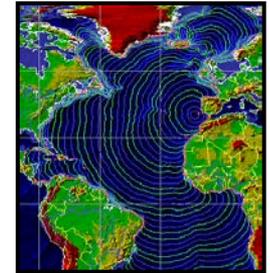
Mike Angove  
NOAA/NWS Tsunami Program Lead

NTHMP Annual Meeting  
February 2016



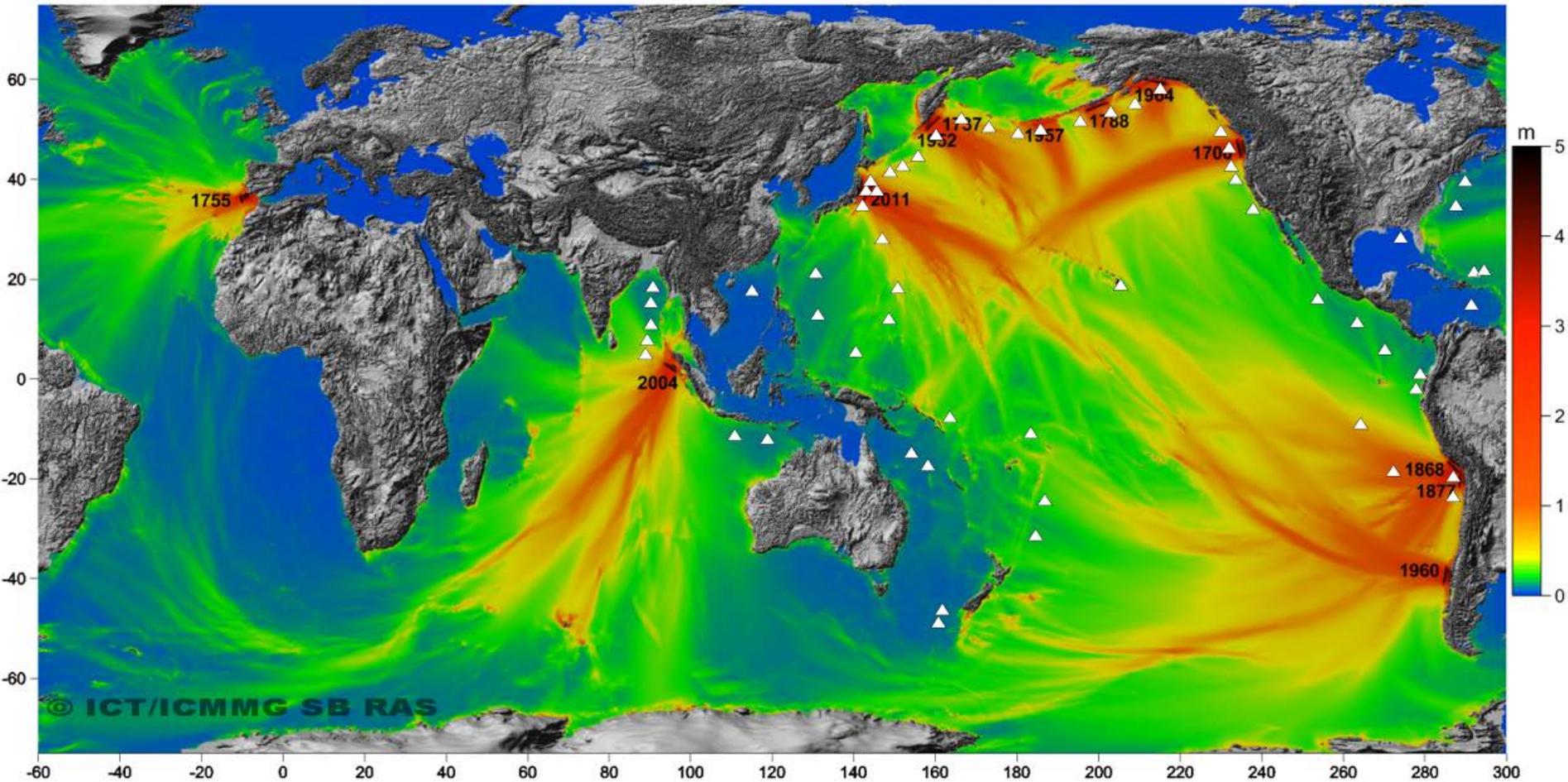
# What Is a Tsunami?

- Series of *shallow water waves* generated in the *deep ocean* by:
  - Large undersea earthquakes,
  - Undersea landslides,
  - Undersea volcanic activity,
  - certain-weather-related phenomena, and meteorites
- In the deep ocean, tsunamis move up to 600 mph and may only be a few inches high at the surface
- At coasts, water and energy are focused into a series of powerful waves





# DART Locations and Historical Mega-Tsunamis





# U.S. Tsunami Warning System





# Detection and Observation

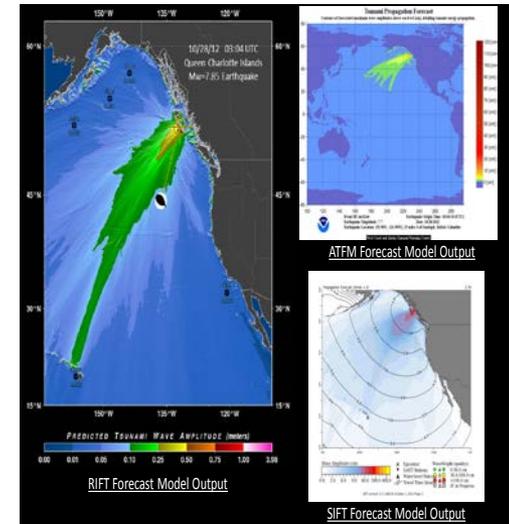
- Seismic Networks
  - Alaska, Hawaii, Caribbean
- Sea-Level Networks
  - 39 Deep-Ocean Assessing and Reporting of Tsunamis (DART) observation systems
    - National Data Buoy Center
  - Coastal sea-level stations
    - Center for Operational Oceanographic Products and Services (188)
    - Tsunami Warning Centers (21)





# Forecasting and Warning

- National Tsunami Warning Center
- Pacific Tsunami Warning Center
- Pacific Marine Environmental Laboratory (models)
- National Centers for Environmental Information (coastal elevation and historical archive)



National Tsunami Warning Center, Palmer, Alaska

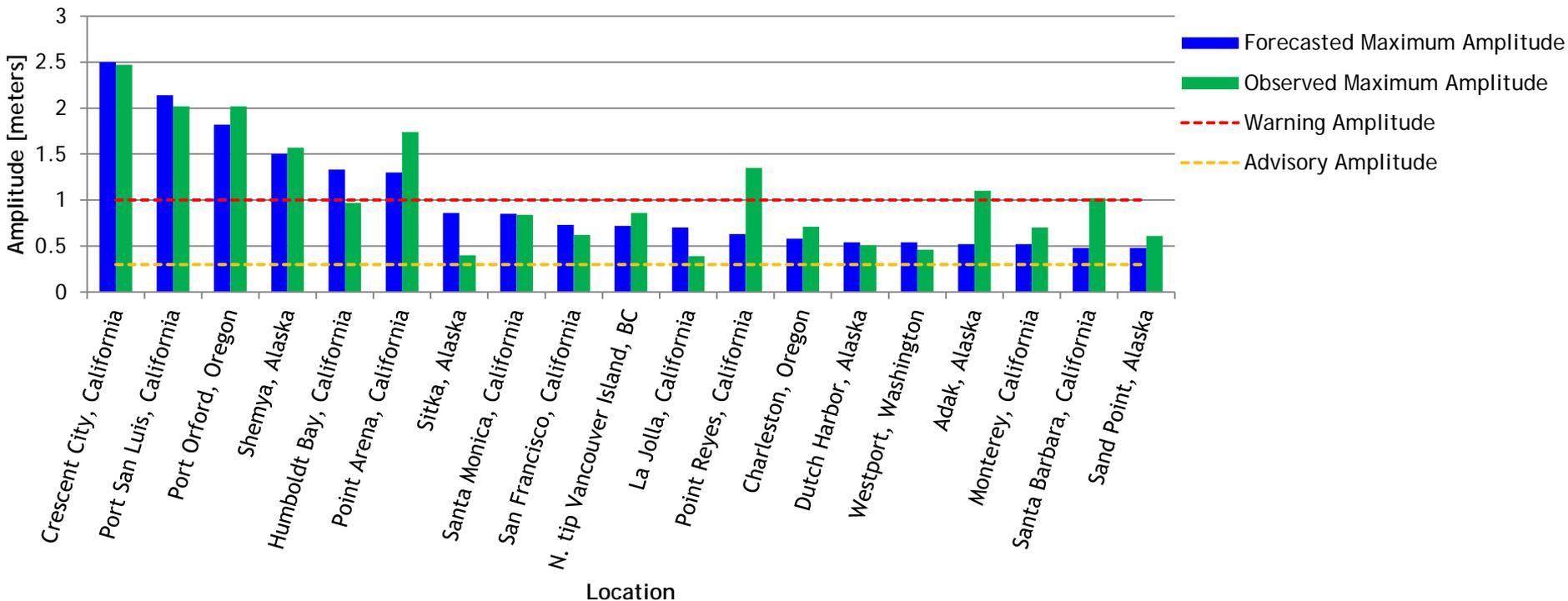


Pacific Tsunami Warning Center (at the NOAA Daniel K. Inouye Regional Center), Honolulu, Hawaii



# Japan 2011 Tsunami Forecast and Observed Wave Heights

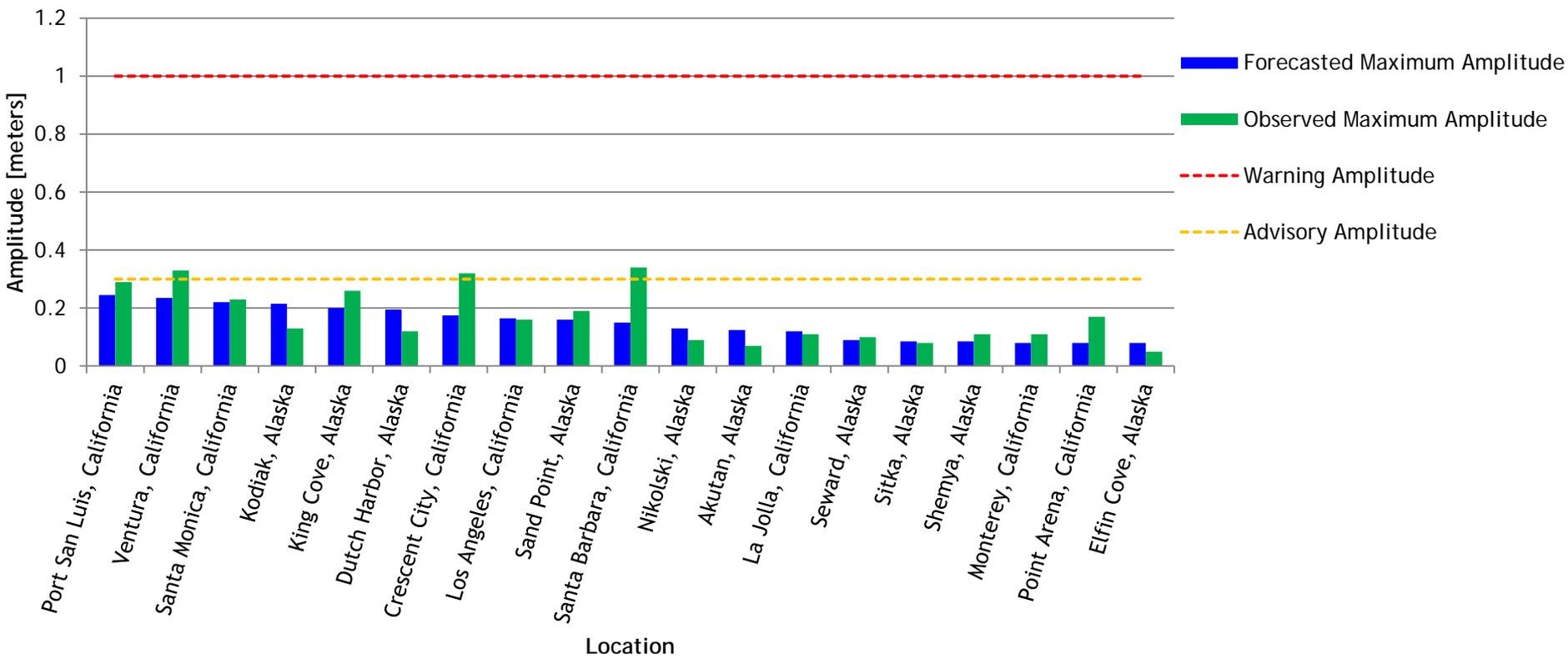
## Maximum Tsunami Amplitudes March 11, 2011 - Honshu, Japan





# Chile 2015 Tsunami Forecast and Observed Wave Heights

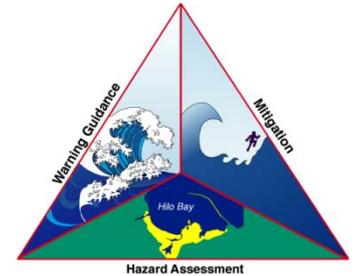
## Maximum Tsunami Amplitudes September 16, 2015 - Chile





# Preparedness and Mitigation

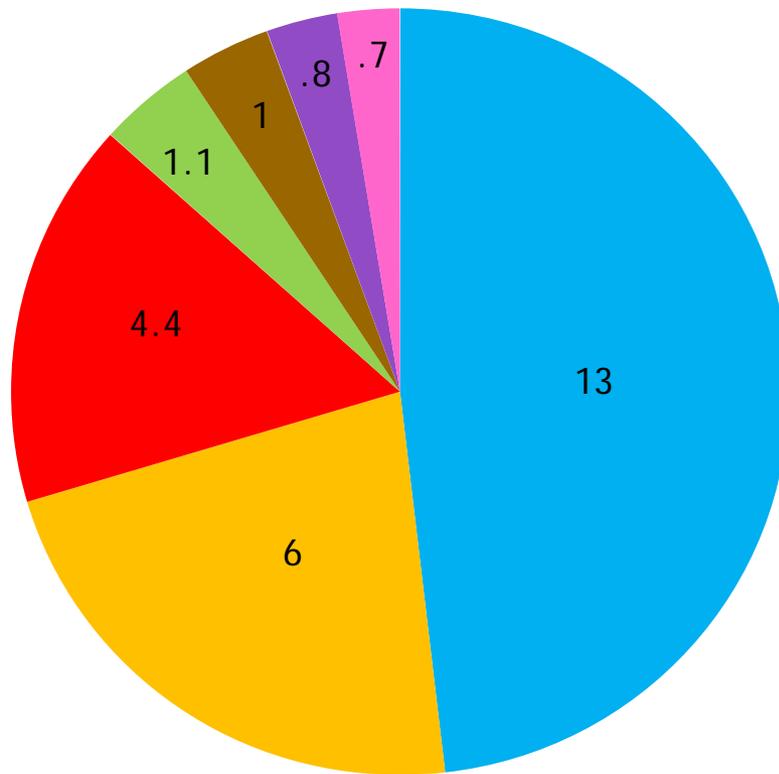
- National Tsunami Hazard Mitigation Program
  - NOAA, Federal Emergency Management Agency, U.S. Geological Survey, 28 states and territories
- TsunamiReady Program
  - 190 U.S. communities
- Weather Forecast Offices





# FY15 Budget (ROM)

## FY15 Appropriations: \$27M



- Sea Level Observations Operations & Maintenance
- State Partner Grants
- Tsunami Warning Center Operations
- Research and Development
- Dedicated Preparedness & Mitigation Activities (ITIC/CTWP)
- National Centers for Environmental Information
- Program Support & Administration



# Research and Development

Priority				Operational Need	FY16 Research Efforts	Operational Sponsor
CTWP	ITIC	NTWC	PTWC			
1		1	1	<b>Impact-based DSS</b>	1. Operationalize <u>Tweb</u> <ul style="list-style-type: none"> <li>• Evacuation lines/maps overlay</li> <li>• Dissemination tool</li> </ul> 2. International forecast guidance 3. Exercise scenarios 4. Guidance for addressing very large, infrequent tsunami events 5. Hazard level based on scenario runs using <u>ComMIT</u> (SIMS/country developed grids/available grids)	1. NTWC/PTWC  2. ITIC 3. CTWP 4. CTWP 5. ITIC
		2	2	<b>Improved assimilation of EXISTING data to constrain tsunami source</b>	1. Assimilate existing cabled observing data 2. Assimilate coastal stations into SIFT 4.0 3. GPS/GNSS 4. DEM (NCEI recurring)	1. NTWC/PTWC  2. NTWC/PTWC 3. NTWC/PTWC 4. NTWC/PTWC
		3	3	<b>Accurate near-real-time tsunami detection and measurement</b>	1. DART 4G 2. GPS Shipping (FY14-16) 3. FO Cabling (OBS PPA) 4. HF Radar	1. NDBC 2. PTWC 3. ? 4. NTWC
		4	4	<b>Accurate coastal tsunami model forecasts for any source and any AOR coastline</b> OR Near-real-time tsunami detection and measurement for source determination and/or forecast validation OR Improved tsunami forecasts	1. SIM (NCTR recurring) 2. Incorporate tsunami amplitude into storm surge/tide forecasts and vice versa 3. Drive SIMS from RIFT 4. Currents/ duration	1. NTWC/PTWC 2. ?  3. PTWC 4. NTWC/PTWC



# GNSS Earthquake Source Model

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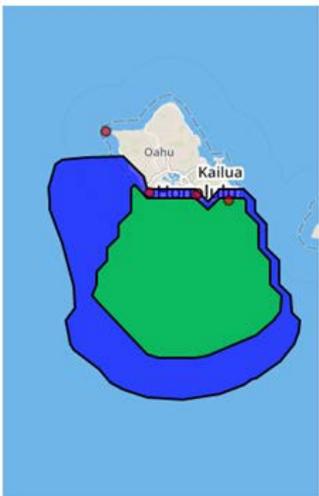
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Running in real-time on a fixed fault surface





# HF Radar



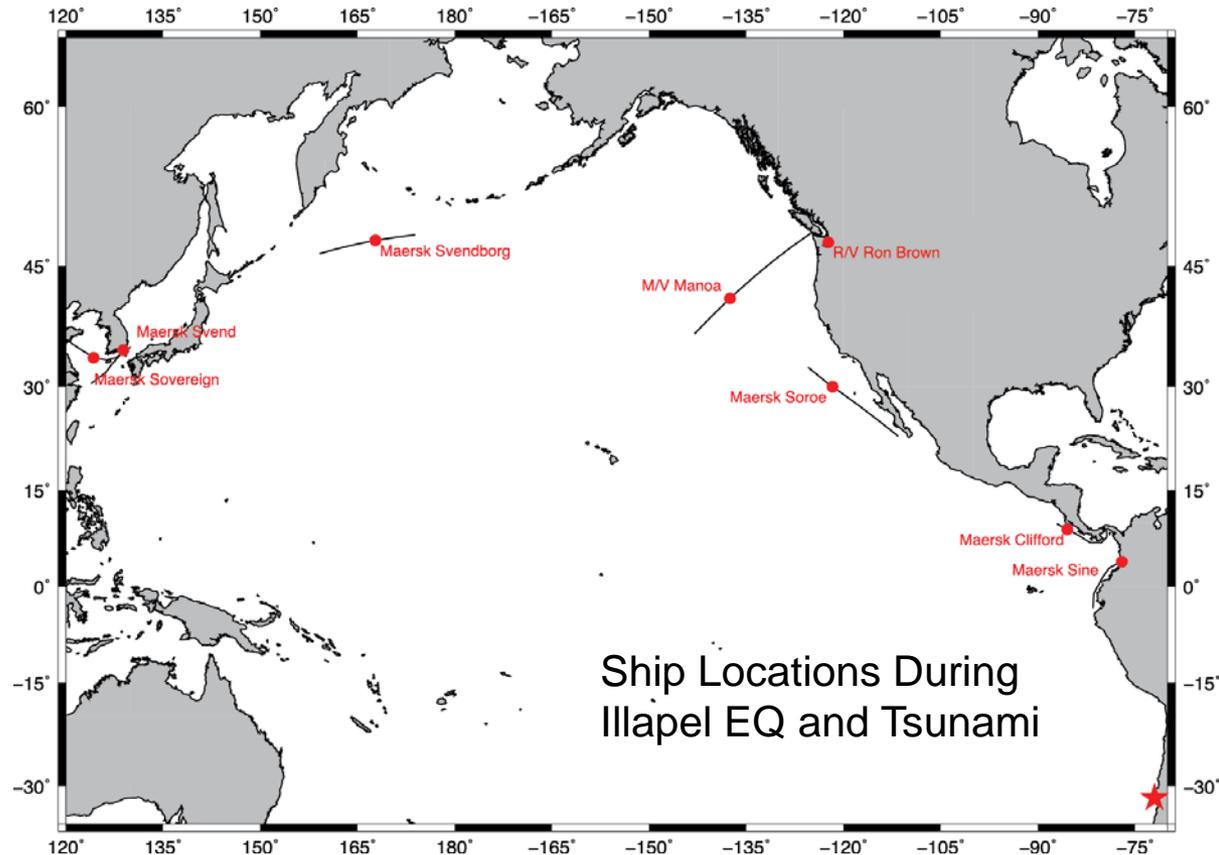
4000 m		1000 m		500 m		200 m	
Height (cm)	Orbital Velocity (cm/s)						
10	0.5	14	1.4	17	2.4	36	7.9
20	1.0	28	2.8	34	4.7	71	15.7
50	2.5	71	7.0	84	11.8	178	39.4
100	4.9	141	14.0	168	23.5	356	78.7

Detection Possible
  Detection Most Likely



# Ship-based Tsunami Detection and Characterization

- **8 ships operating at the time of the Illapel tsunami**
- **3 ships in the open ocean**
- **Performance was in line with our initial expectations of the system**





# International Commitment—IOC

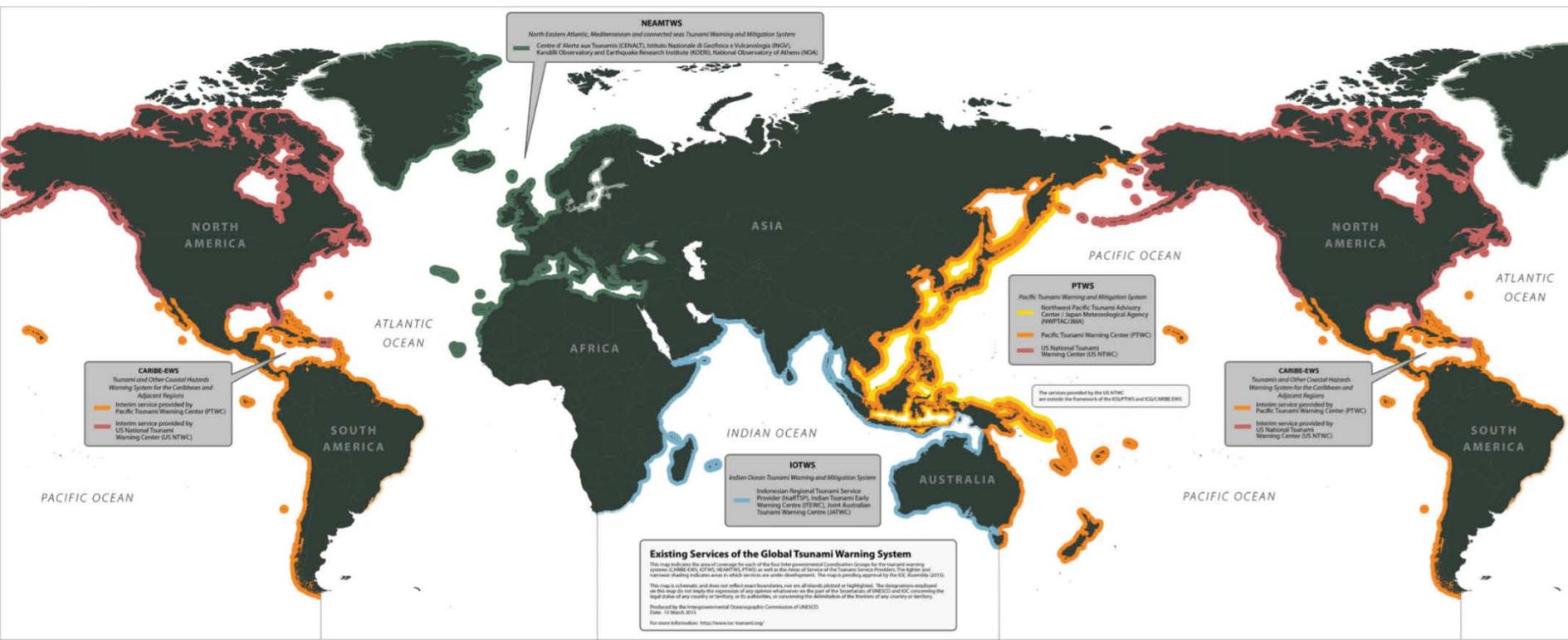
NOAA supports the UN's Intergovernmental Oceanographic Commission's coordinated tsunami warning and mitigation systems in the Pacific and Caribbean, providing forecast and observation guidance and education and preparedness services:

- Pacific Tsunami Warning Center
- International Tsunami Information Center
- Caribbean Tsunami Warning Program
- National Weather Service Headquarters





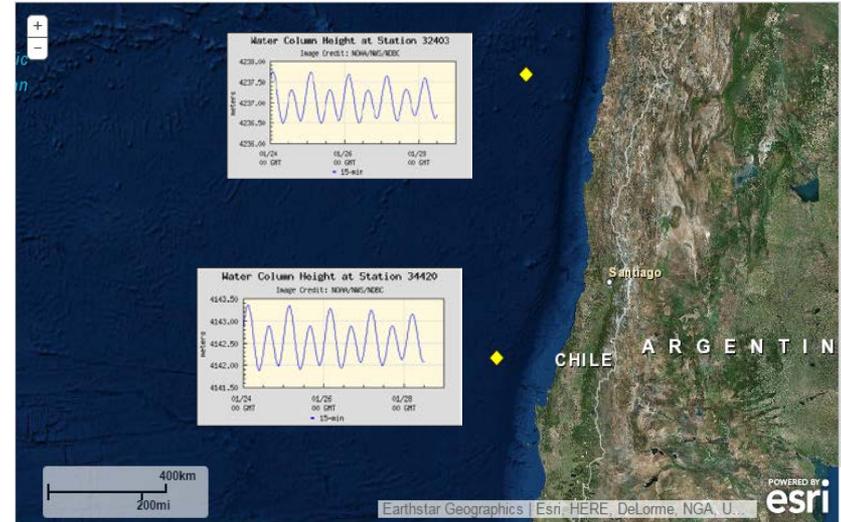
# Global Tsunami Warning System





# International Cooperation— Bilateral

- Chile—DART 4G



- UK—Tide gauges (Anguilla, Turks and Caicos)
- EC—codify alerting agreement



**U.S. National Oceanic and Atmospheric Administration  
National Weather Service  
Pacific Tsunami Warning Center, Honolulu, Hawaii**

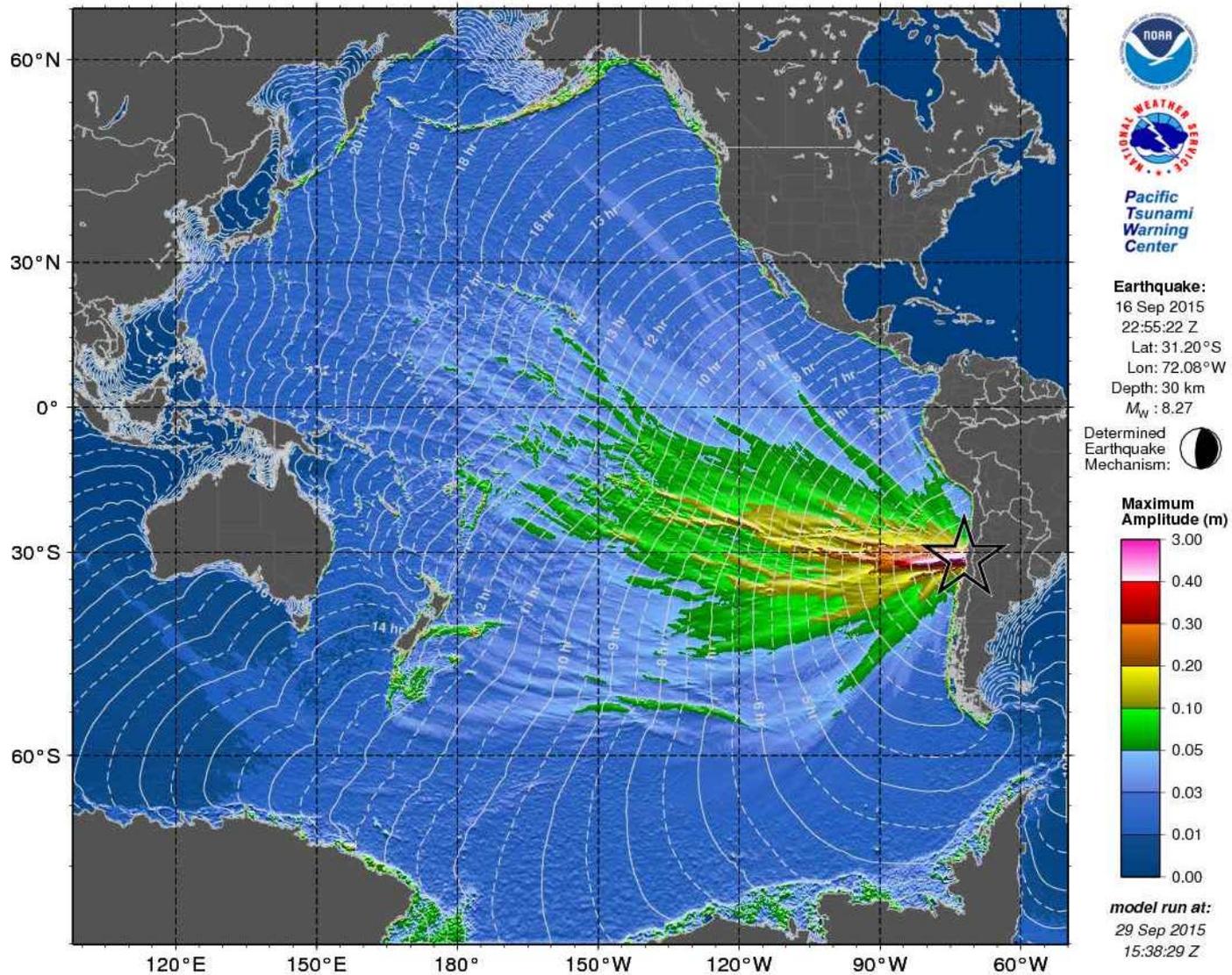


# **Chile Tsunami of September 16-17, 2015**

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**Charles McCreery  
Director, PTWC**

# Ocean Forecast





# Summary of Forecast and Observations

PLACE	FORECAST	ALERT	MAXIMUM ON GAUGE
Chile	>3 m	N/A	4.72 m (Coquimbo)
Fr. Polynesia	1-3 m	N/A	1.40 m (Nuku Hiva)
Peru	0.3-1 m	N/A	0.52 m (Callao)
Ecuador	0.3-1 m	N/A	0.18 m (Baltra)
Japan	0.3-1 m	N/A	0.80 (Kuji)
Russia	0.3-1 m	N/A	0.44 m (Shikotan Is.)
Hawaii	0.3-1 m	Advisory	0.85 m (Hilo)
West Coast	0.3-1 m	Advisory	0.33 m (Ventura)
Am. Samoa	0.3-1 m	Advisory	0.63 m (Pago Pago)
Guam/CNMI	<0.3 m	None	<0.03 m (Apra Harbor)

# Summary of Casualties and Damages (Earthquake and Tsunami)



- ❑ All major effects happened in Chile
- ❑ Over 1 million were evacuated from the coast
- ❑ 13 deaths and 14 injuries (most or all from earthquake)
- ❑ 6 persons missing as of 24 September
- ❑ 55 persons in shelters
- ❑ 13427 without housing
- ❑ 816 homes destroyed
- ❑ 1011 homes uninhabitable
- ❑ Most tsunami damage around Coquimbo and Tongoy
- ❑ Most earthquake damage around Salamanch and Illapel



# Coquimbo Sea Level Gauge (+4.72 m)



Photo Courtesy of SHOA



# Multiple Ships Aground at Coquimbo



Photo Courtesy of SHOA



# Keys to Success

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- Sirens  
Dense, “Unmistakable”
- Wireless Alerts  
Get to everyone with a phone
- Posture  
Take threat seriously



# New for FY16

- PPA transition at NWS HQ
  - TSU \$\$ Part of Analyze, Forecast and Support (AFS) Portfolio
  - Increased flexibility for NWS Director to fund according to priority v. program area
- IT Modernization of TWC Operational System (update)
- NTHMP Deliverables as NWS AOP Milestones
- Consolidation of Caribbean TSU Forecasts (Domestic and International) under PTWC
- Meteotsunami Operational Protocol
- TWERA



# Q&A

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NOAA/NWS Deputy Tsunami Program Manager  
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Christa Rabenold  
NOAA/NWS Tsunami Program Mitigation Specialist

<http://www.tsunami.gov>



**Program Information and Highlights**

**G**

**Lead:**  
 Michael Angove, Program Lead

**Scope:**

- 1) Provide policy/procedural oversight and recommend resource allocation to support TSU forecast, warning and mitigation capability
- 2) Perform duties as UNESCO/IOC US Tsunami National Contact in support of the US Permanent Representative to the IOC
- 3) Manage tsunami-related RDT&E activities
- 4) Administrate National Tsunami Hazard Mitigation Program (NTHMP)

**Estimated Benefits:**

- 1) Accurate and timely tsunami detection forecast and warnings
- 2) Meet NOAA's IOC commitments for tsunami forecast and warning
- 3) Balanced and operationally relevant R&D program
- 4) Community tsunami resilience through mitigation efforts such as TsunamiReady™ and NTHMP activities

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**Scheduling**

FY16 Milestones	Date	Status
Alerting infrastructure (e.g., sirens) installed for 15 additional Tsunami-vulnerable U.S. communities via NTHMP grants.	Q4	On track. Contracts awarded USVI. Delivery Pending
Tsunami inundation maps created for five (5) Gulf Coast and five (5) East Coast communities.	Q4	On track. Gulf coast done. East Coast Pending
10 new TsunamiReady™ Communities recognized	Q4	On track. 2 New FY16 as of 31 Jan

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**Issues/Risks**

**None.**

***Note: TSU NSP is dependent on CP to field the next-generation TWC Operational System (TOPS). Recent schedule re-baselining limits risk to tsunami forecast and warning capability, however additional delays could impact TWC operations.***

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**Finances**

Travel	\$ 164,349
Printing	\$ 6,000
Support Contract	\$ 365,826
Supplies	\$ 3,000
NTHMP Grants	\$ 6,000,000
<u>Tsunami R&amp;D</u>	<u>\$ 2,500,000</u>
<b>Total</b>	<b>\$ 9,039,175</b>

**Obligation Status**

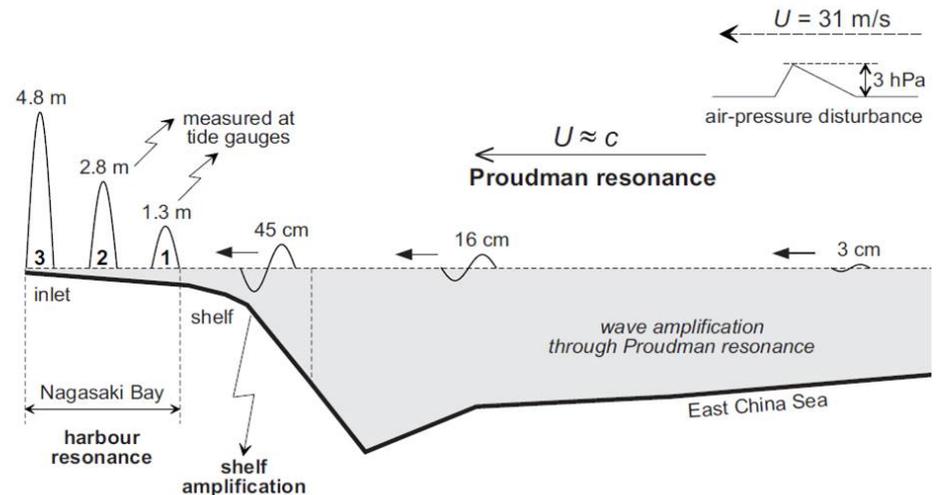
On track

**Execution Status**

On track

# Meteotsunamis

- Tsunami-like waves of meteorological vs. seismic origin
- Formation dependent on intensity, direction, and speed of disturbance over water at appropriate depth
- NOT same as storm surge



Source: Monserrat, Vilibić, Rabinovich; Nat. Hazards Earth Syst. Sci., 6, 2006



# 2013 Animation

## Tsunami Forecast Model Animation of the 13 June 2013 Atlantic Meteotsunami



**RIFT** Model by Dailin Wang  
Animation by Nathan Becker  
*NOAA/NWS/Pacific Tsunami Warning Center*



<https://www.youtube.com/watch?v=ykABRe5Yt3c>



# MT Challenges

- Forecasting—Meteotsunami (MT) formation tightly constrained by depth, translational speed of disturbance, and direction; requires extremely accurate mesoscale forecast
- Detection—Even if MT forms, network of observation systems not dense enough to detect MT disturbance
- Messaging—Potential for confusion with wind-driven storm surge and normal seiche activity



# MT Proposed Protocol

- WFOs monitor medium-range numerical weather prediction (NWP) to ID candidate disturbances
- WFO contact National Tsunami Warning Center (NTWC) if candidate disturbance within ~24hrs of formation to discuss
- WFO include potential for MT in Area Forecast Discussions and/or Special Weather Statements
- Inside 12 hours, NTWC will monitor tsunami detection networks; DART buoys placed in event mode, coastal gauges closely monitored
- If detection made, NTWC will alert local WFOs and provide *estimates* of amplitude and travel time to coastal locations
- WFOs may issue alerts if warning criteria met(e.g., coastal flood warning)

