

Developing Real-time
Tsunami Forecast for US
coasts.
(Challenges and Solutions)

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NOAA Center for Tsunami Research
Pacific Marine Environmental Laboratory
Seattle, WA

Tsunami Forecast:

use models to predict site-specific impact



Forecast Challenge 1:

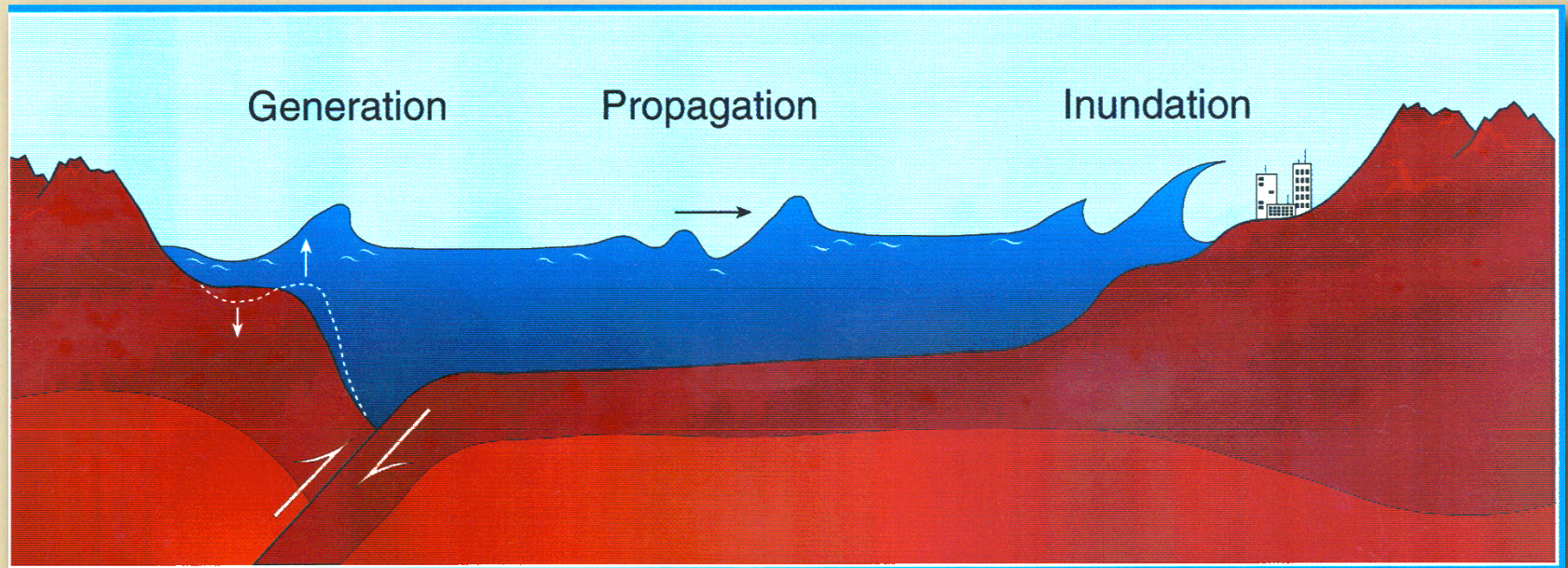
Can models reproduce details of tsunami impact?

2004 Sumatra tsunami in Thailand



Can models provide useful timely forecast?

Tsunami Modeling Stages



Model Sources



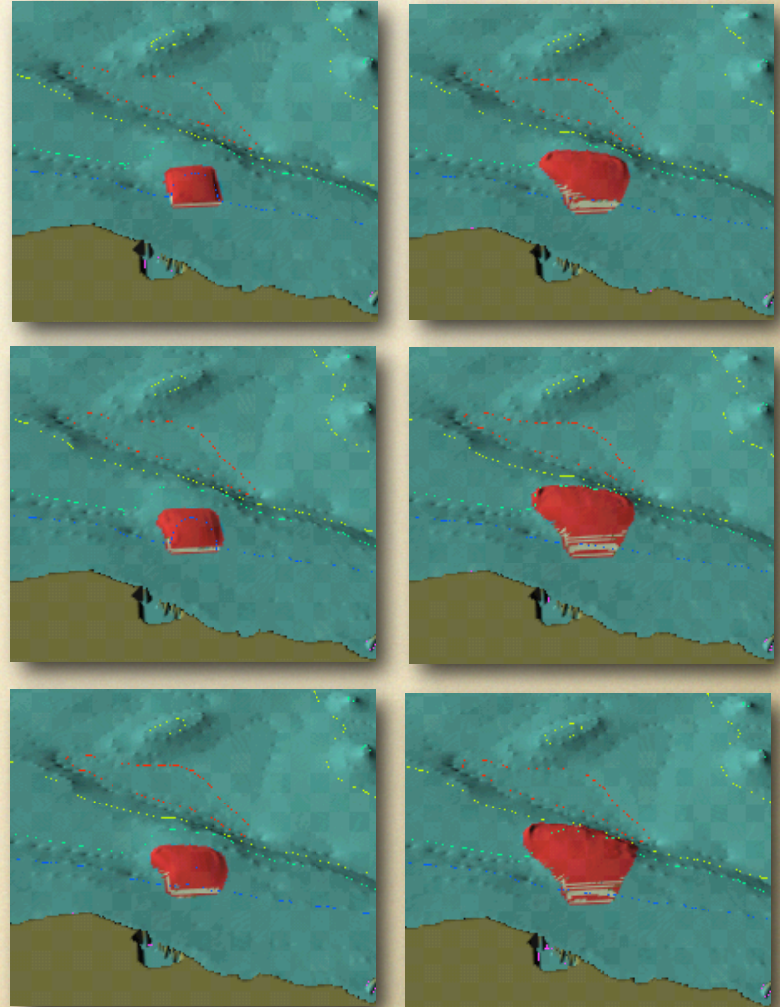
Seismic source

June 10, 1996

Andean Island tsunami

Source Parameters:

Mw	7.9
Length	140km
Width	70km
Strike	260
Dip	20
Rake	108
Slip	2m

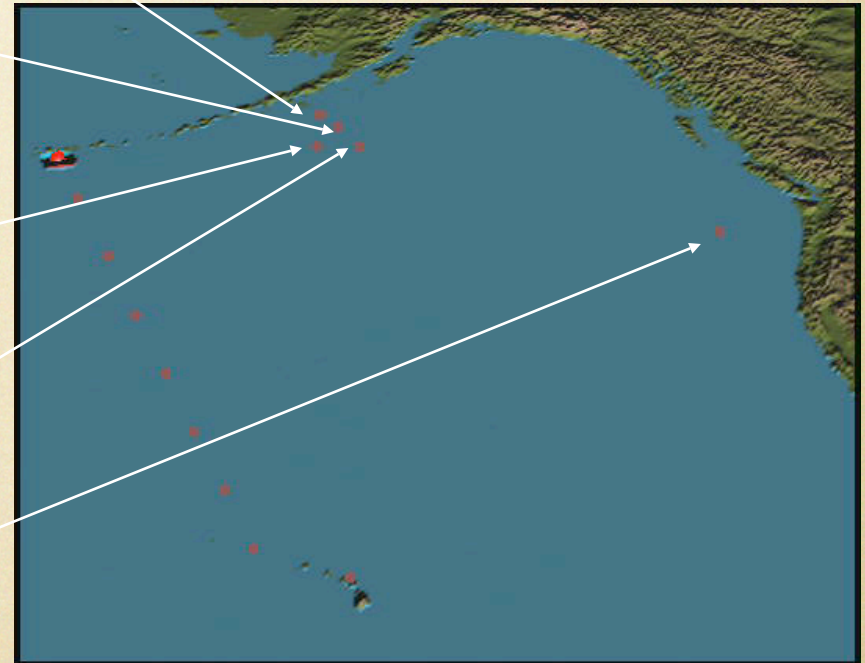
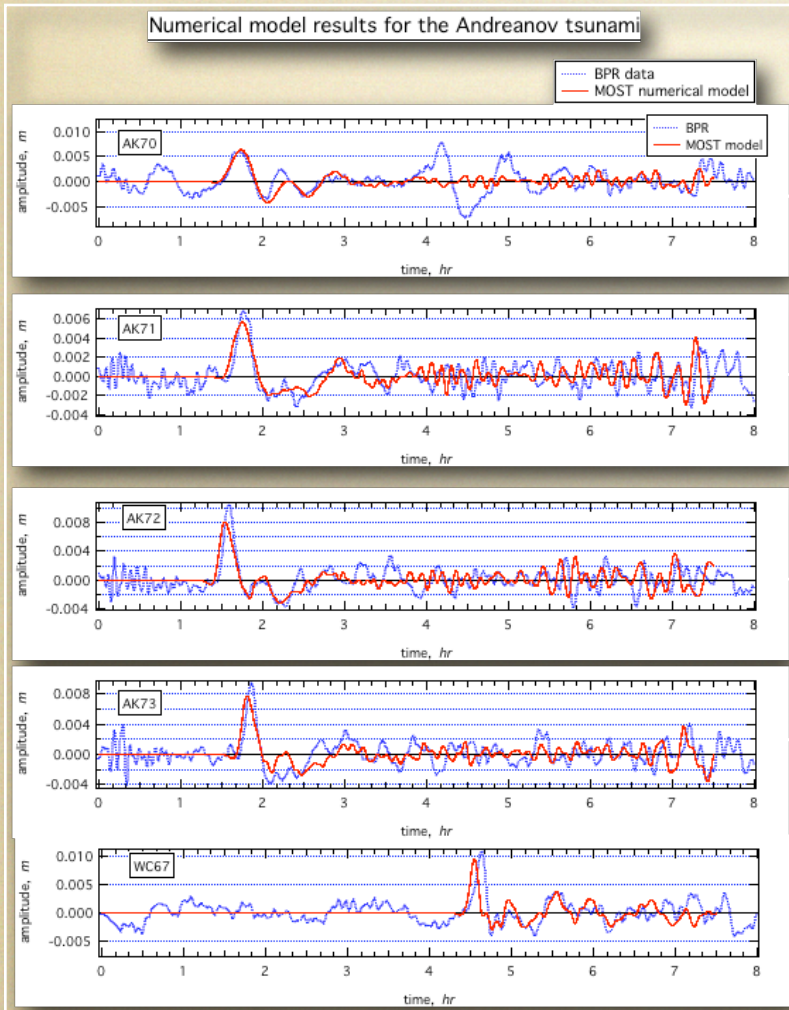


Landslide source

1998 Papua New Guinea tsunami

Propagation model testing

*June 10, 1996 Andreanov tsunami
Simulation (MOST model)*



Inundation model



Simulation of the Aonae inundation

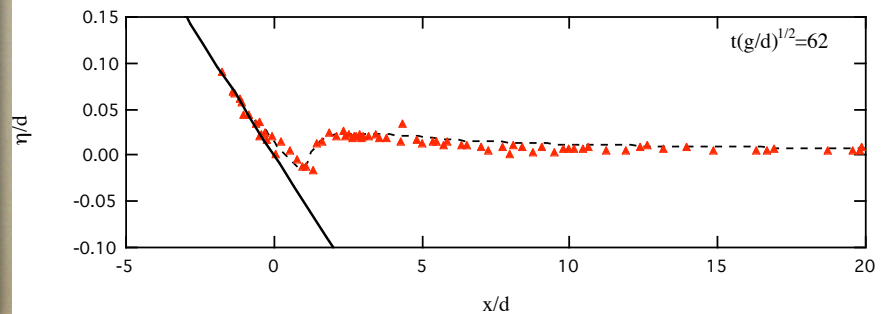
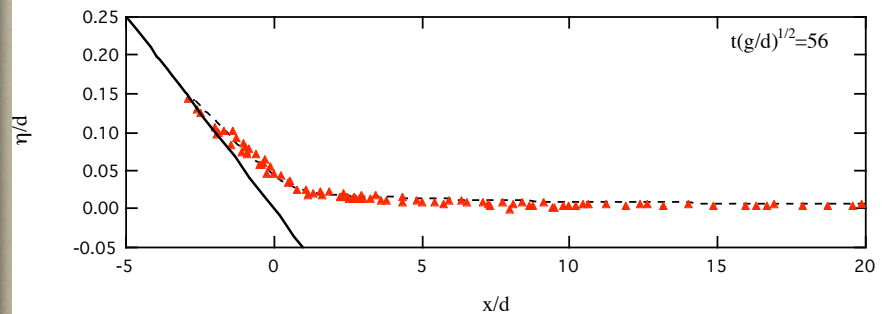
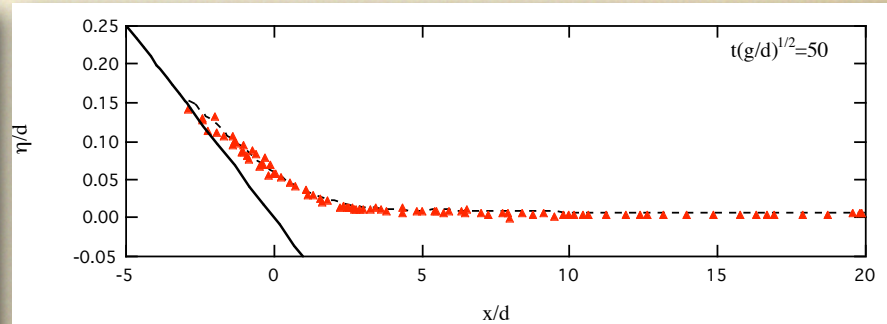
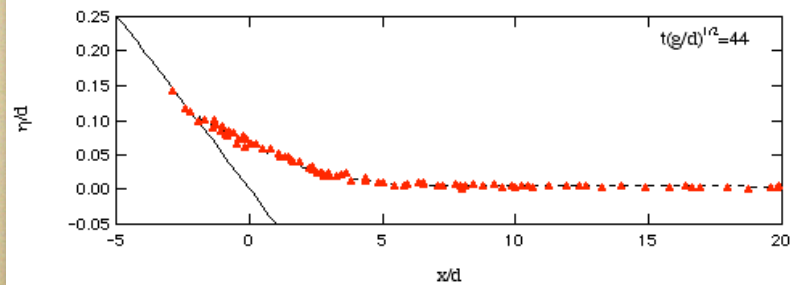
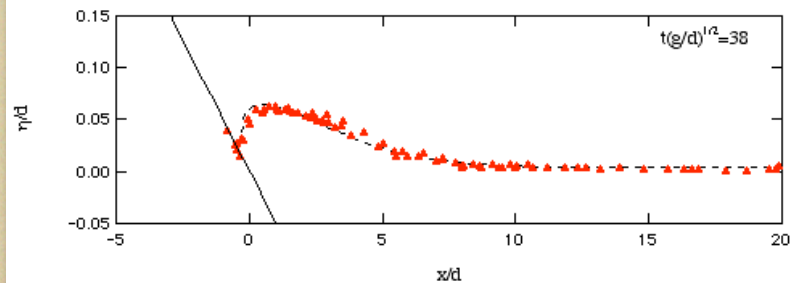
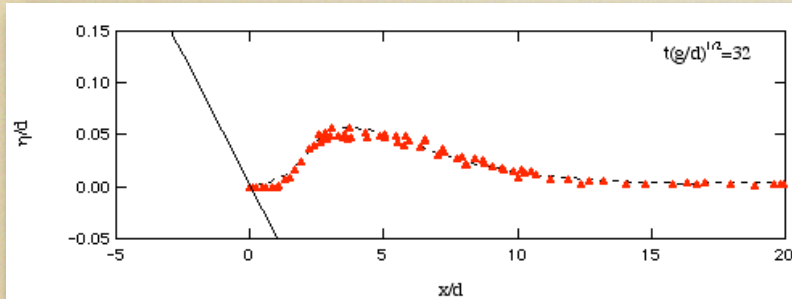
(1993 Okushiri tsunami)



MOST Validation

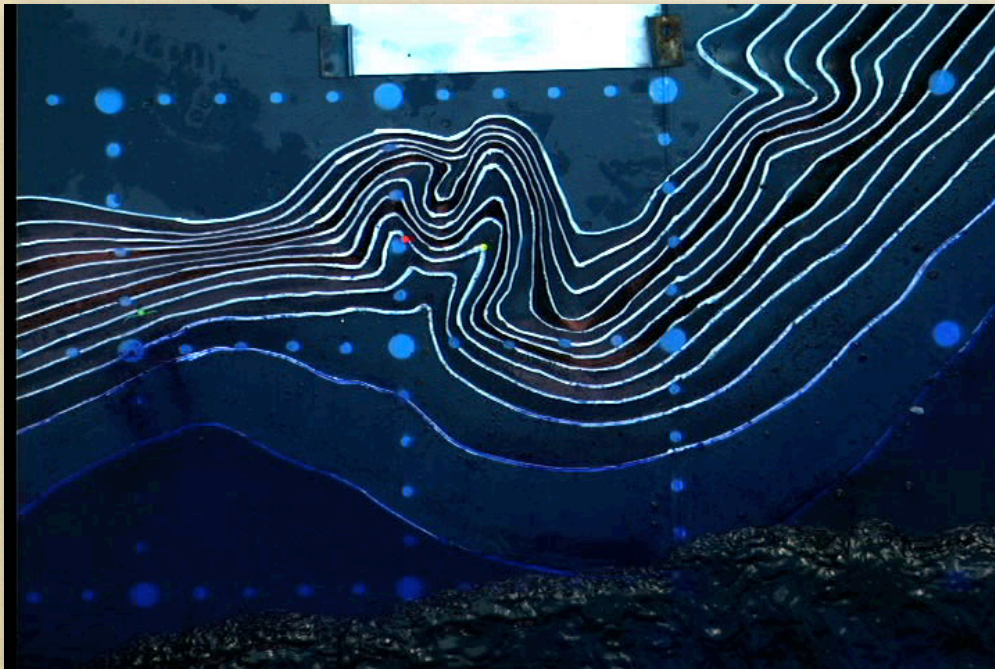
Solitary wave runup on plain beach $H/d = 0.04$

Titov, V.V., and Synolakis, C.E. , 1998, Numerical modeling of tidal wave runup. Journal of Waterway, Port, Ocean and Coastal Engineering, 124 4), 157 – 171.

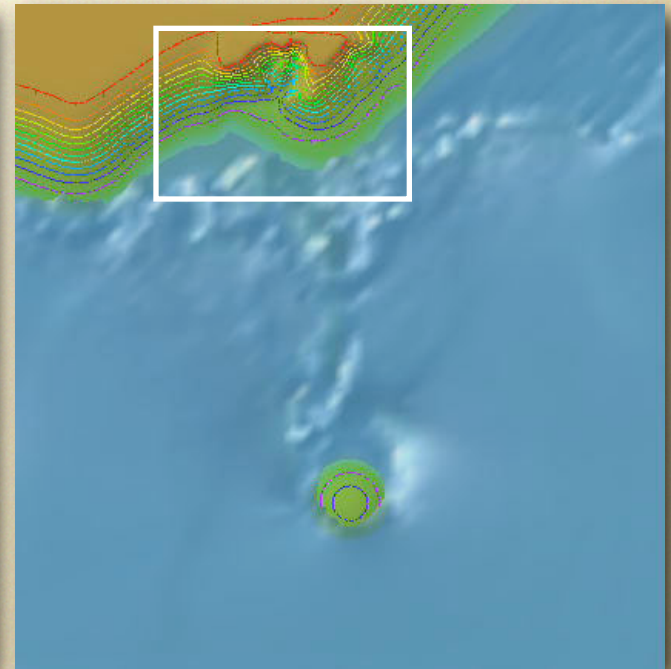


MOST validation

Catalina Workshop Benchmarks (Liu *et al.*, 2006)



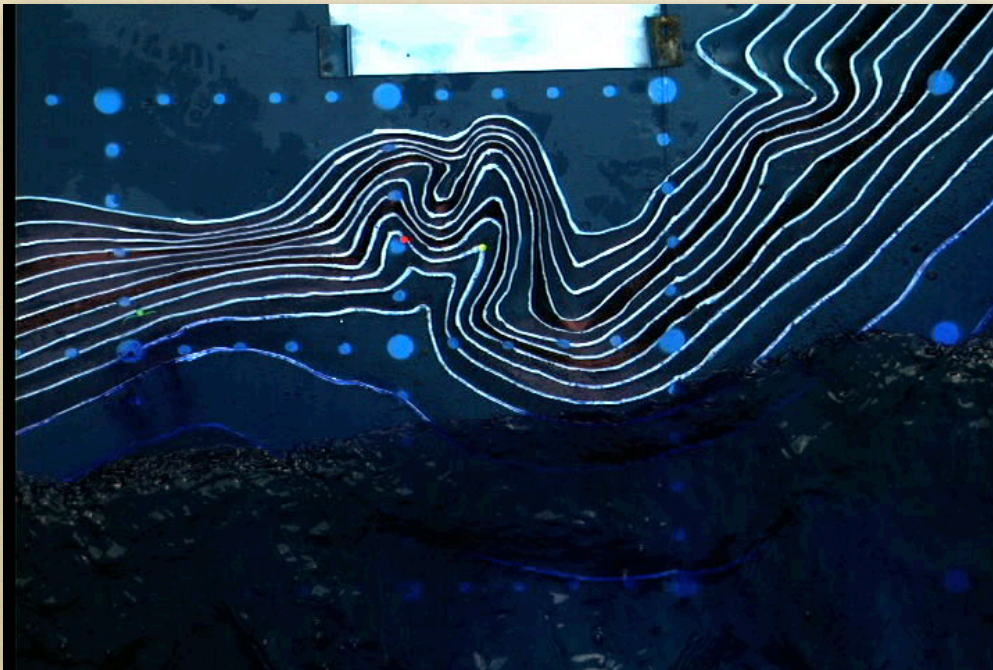
Wave tank experiment



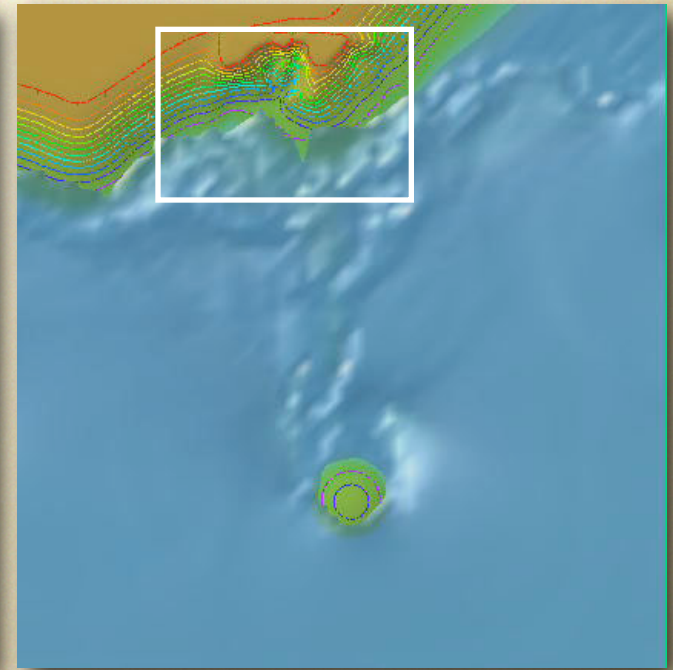
MOST model

MOST validation

Catalina Workshop Benchmarks (Liu *et al.*, 2006)



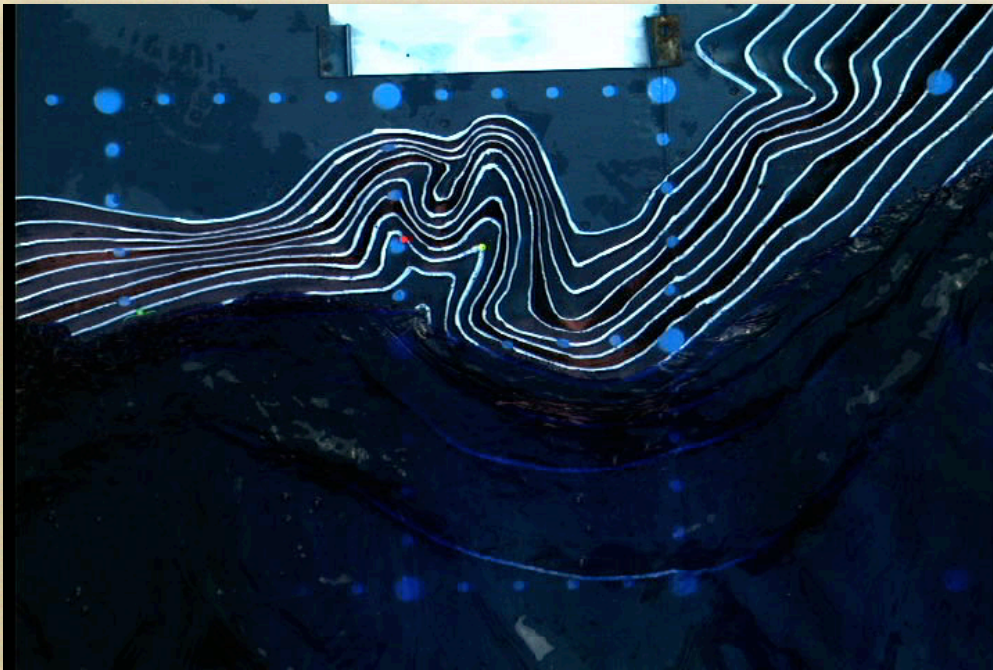
Wave tank experiment



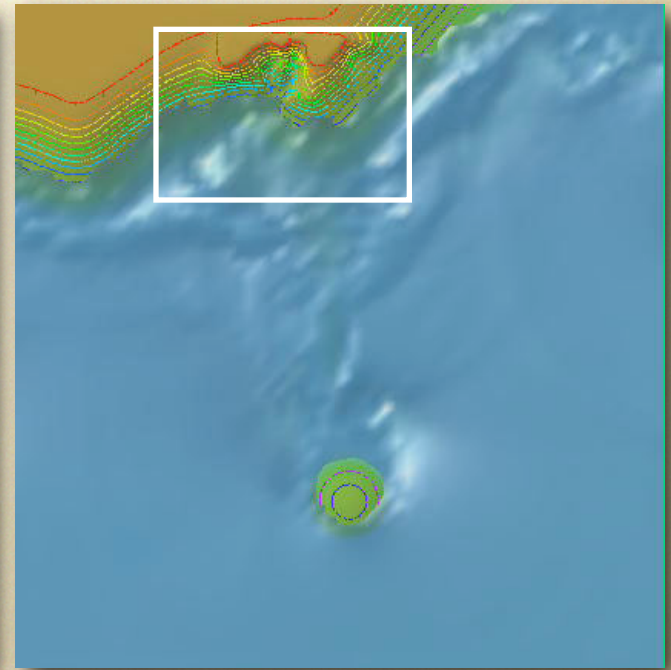
MOST model

MOST validation

Catalina Workshop Benchmarks (Liu *et al.*, 2006)



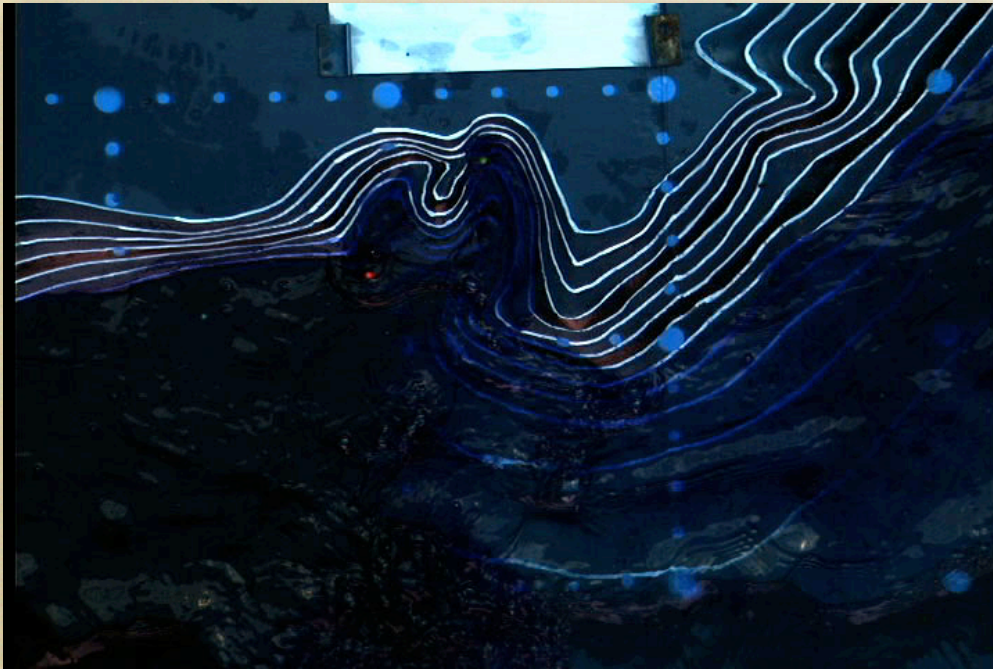
Wave tank experiment



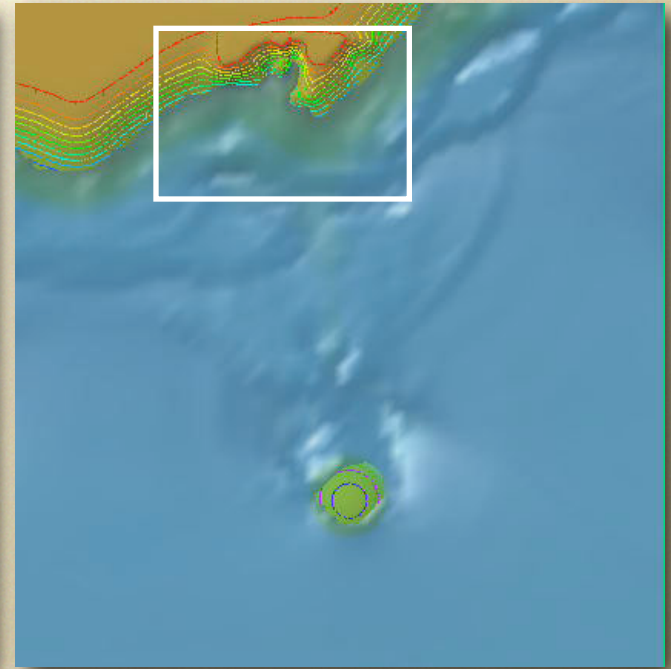
MOST model

MOST validation

Catalina Workshop Benchmarks (Liu *et al.*, 2006)



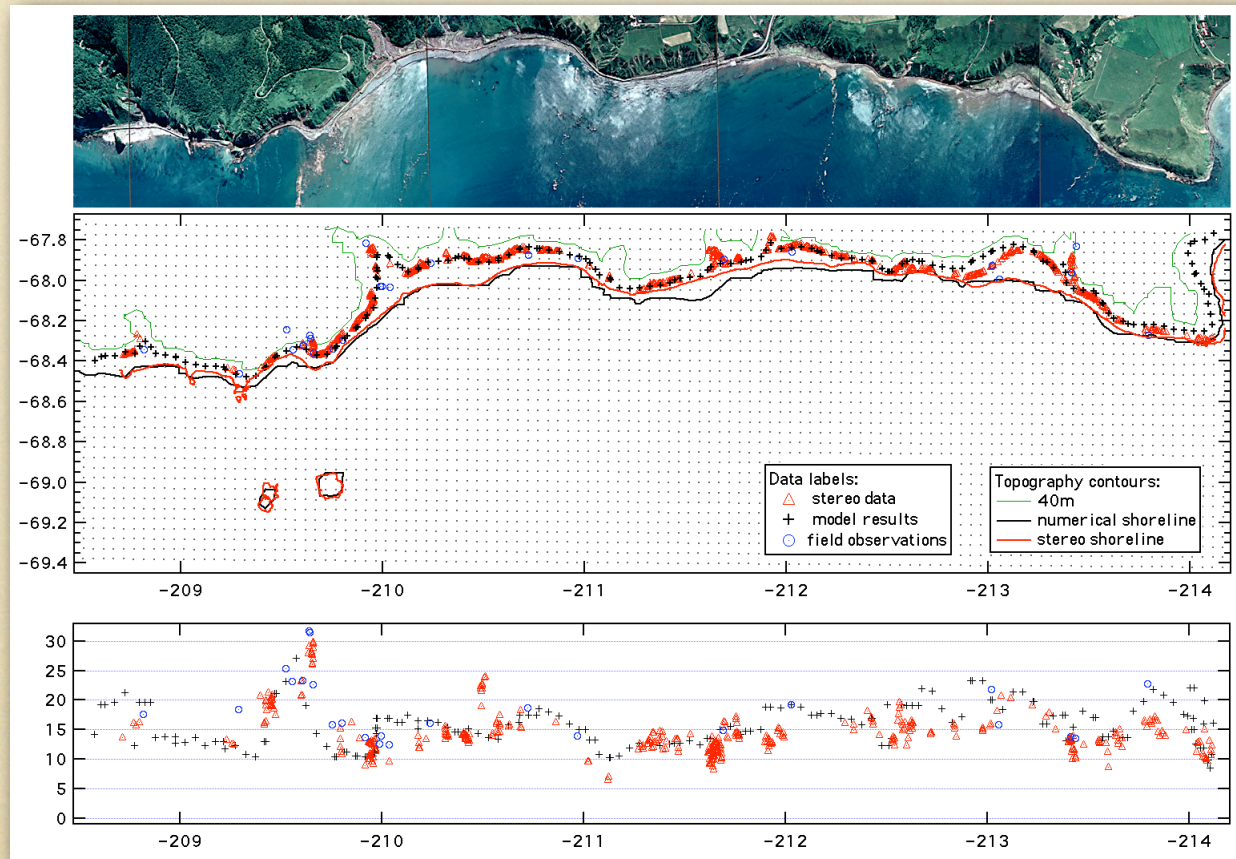
Wave tank experiment



MOST model

MOST validation

Okushiri simulation compared with field data



Forecast Challenge 2:

Can models provide useful timely forecast?



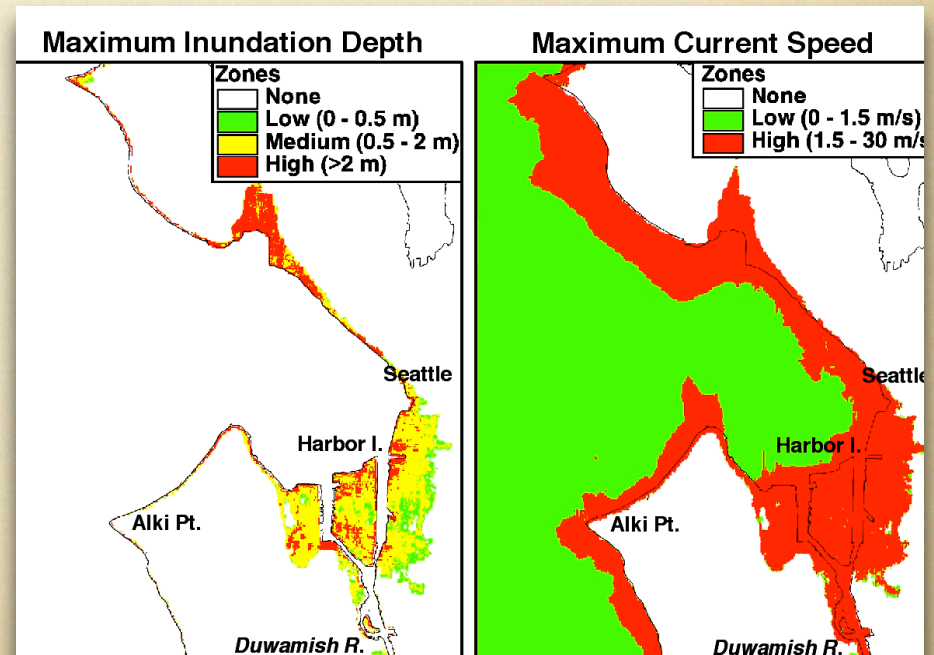
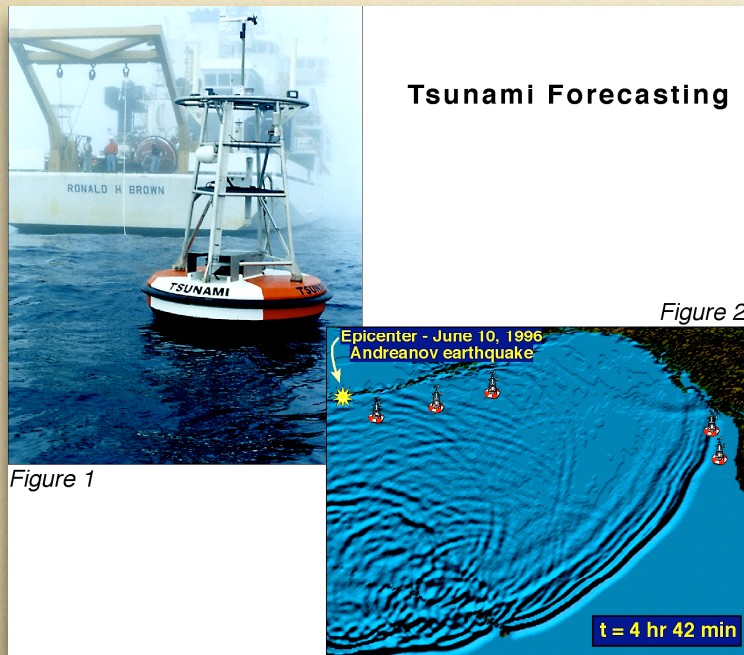
Tsunami Forecasting

Short-Term

(Real-time, during the event)

Long-Term

(Community inundation maps)



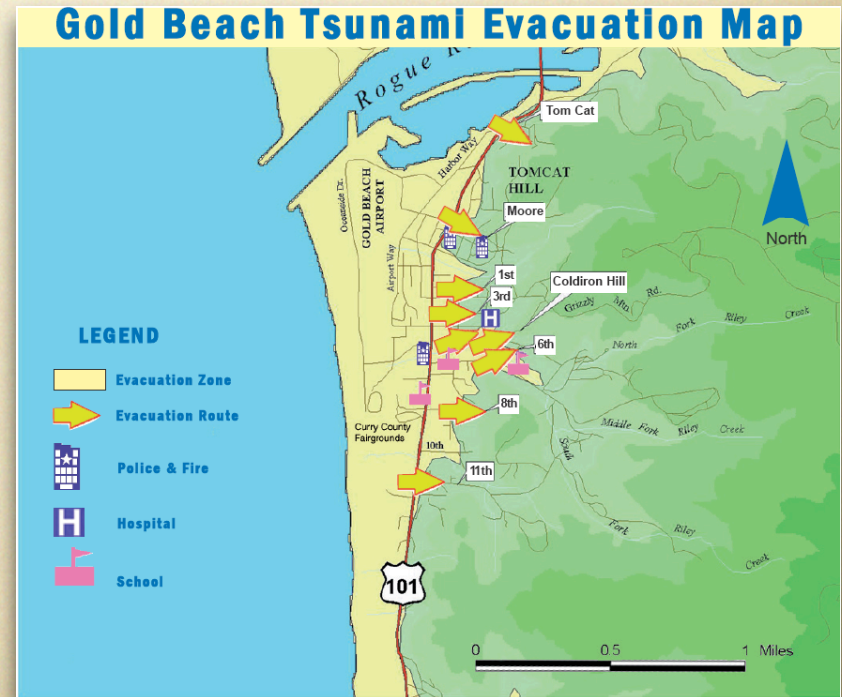
Tsunami Inundation Mapping

Apply:

- High-resolution model
- deterministic worst-case scenario

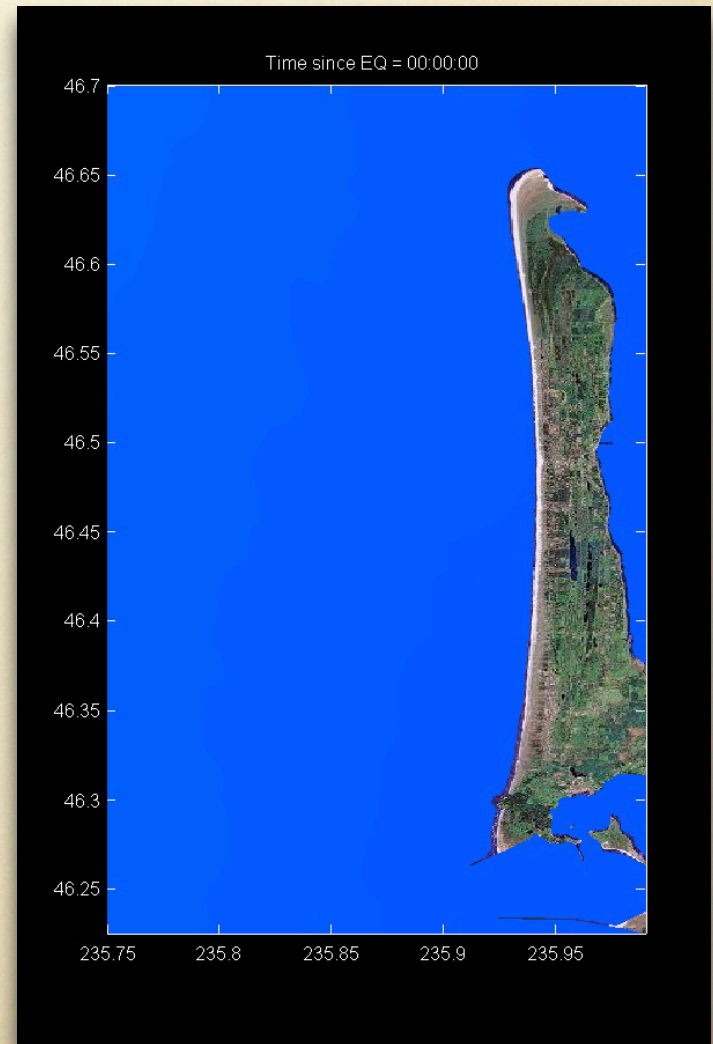
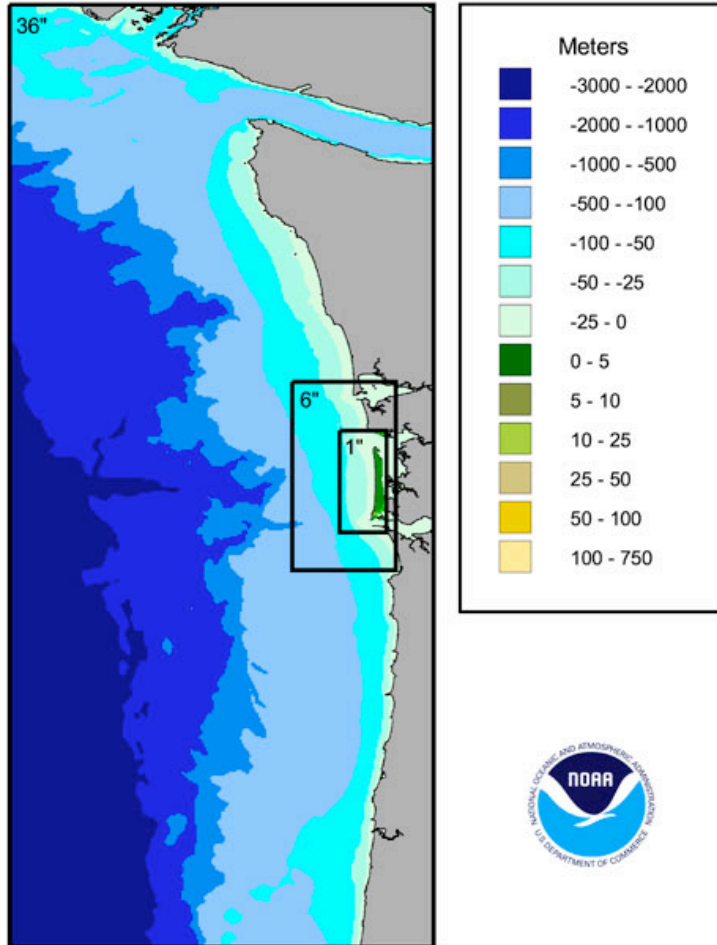
Produce:

- Tsunami inundation maps
- Evacuation maps

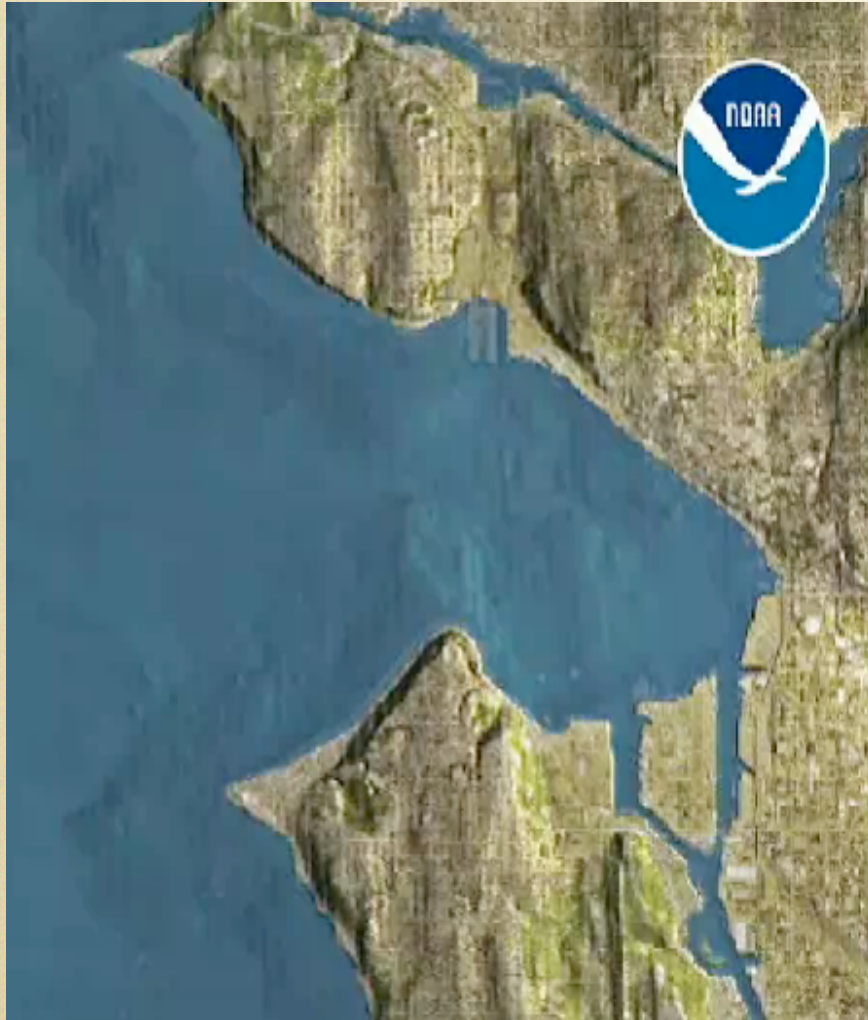


Modeling for Mapping

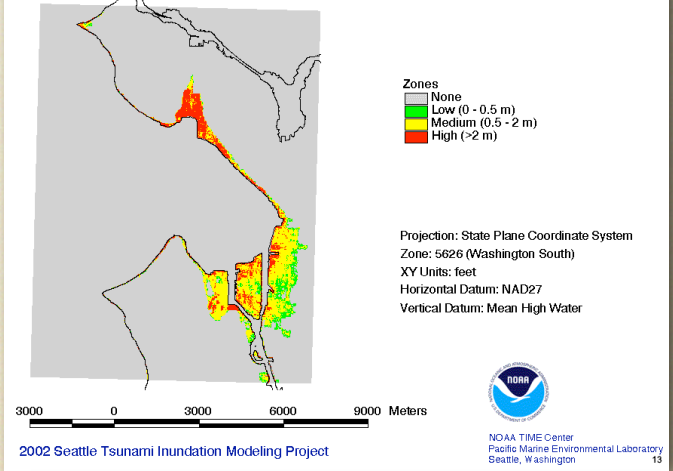
Long Beach, Washington - Modeling Grids



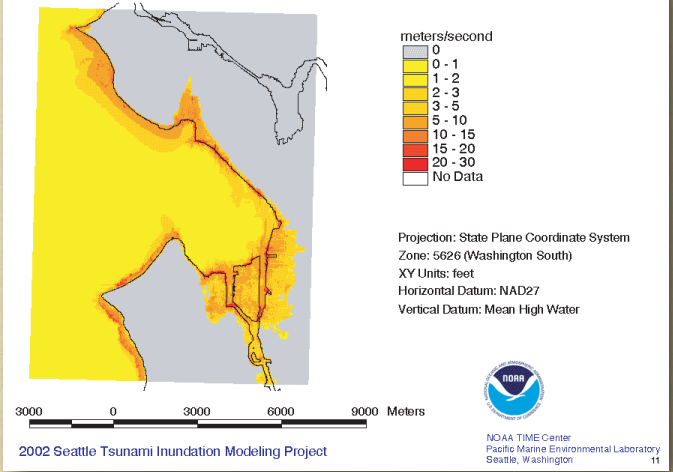
Scientific Products:



Maximum Inundation Depth Zones



Maximum Current Speeds



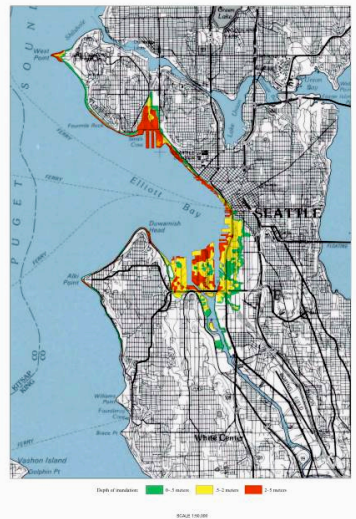
State Products: Inundation Map



Tsunami Hazard Map of the Elliott Bay Area, Seattle, Washington: Modeled Tsunami Inundation from a Seattle Fault Earthquake

by
Timothy J. Walsh*, Vasily V. Titov†, Angie J. Venturato‡, Harold O. Mofjeld‡, and Frank J. Gonzalez*
2003

* Washington Division of Geology and Earth Resources, 4307 15th Avenue, NW, WA 98147-5801, Seattle, WA
† Washington State University, P.O. Box 342500, Pullman, WA 99164-2500, Pullman, WA
‡ NOAA West Coast Pacific Marine Environmental Laboratory, 2215 Central Expressway, Seattle, WA 98101-5040



INTRODUCTION

The City of Seattle and the National Oceanic and Atmospheric Administration (NOAA) are pleased to present the results of this study. This map provides information on potential tsunami inundation depths from a future earthquake on the Seattle Fault. The National Oceanic and Atmospheric Administration (NOAA) is pleased to present the results of this study. This map provides information on potential tsunami inundation depths from a future earthquake on the Seattle Fault.

THE SEATTLE FAULT

Geological studies have shown the Seattle Fault to be an active strike-slip fault in the western United States. The Seattle Fault extends for about 30 kilometers through the city of Seattle, Washington. It is considered one of the most hazardous faults in the Pacific Northwest region.

MAP LOCATION

Population	Depth (m)	City
0.5	1.0	1
1.0	1.5	2
1.5	2.0	3
2.0	2.5	4
2.5	3.0	5
3.0	3.5	6
3.5	4.0	7

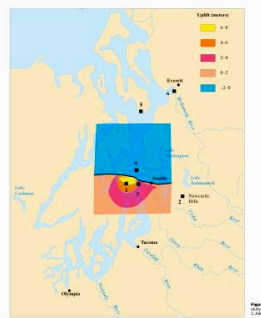


Figure 3. Study area showing the location of the Seattle Fault. The Seattle Fault extends for about 30 kilometers through the city of Seattle, Washington. It is considered one of the most hazardous faults in the Pacific Northwest region.

Figure 4. Coastal inundation depths (meters) from a Seattle Fault earthquake. This map shows the modeled inundation depths from a future earthquake on the Seattle Fault. The color scale ranges from 0.5 meters (green) to 4.0 meters (red). Major roads and landmarks are labeled.

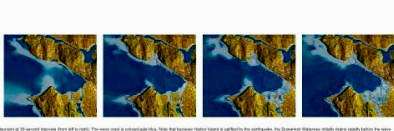


Figure 5. Aerial photographs showing inundation depth contours overlaid on the terrain.

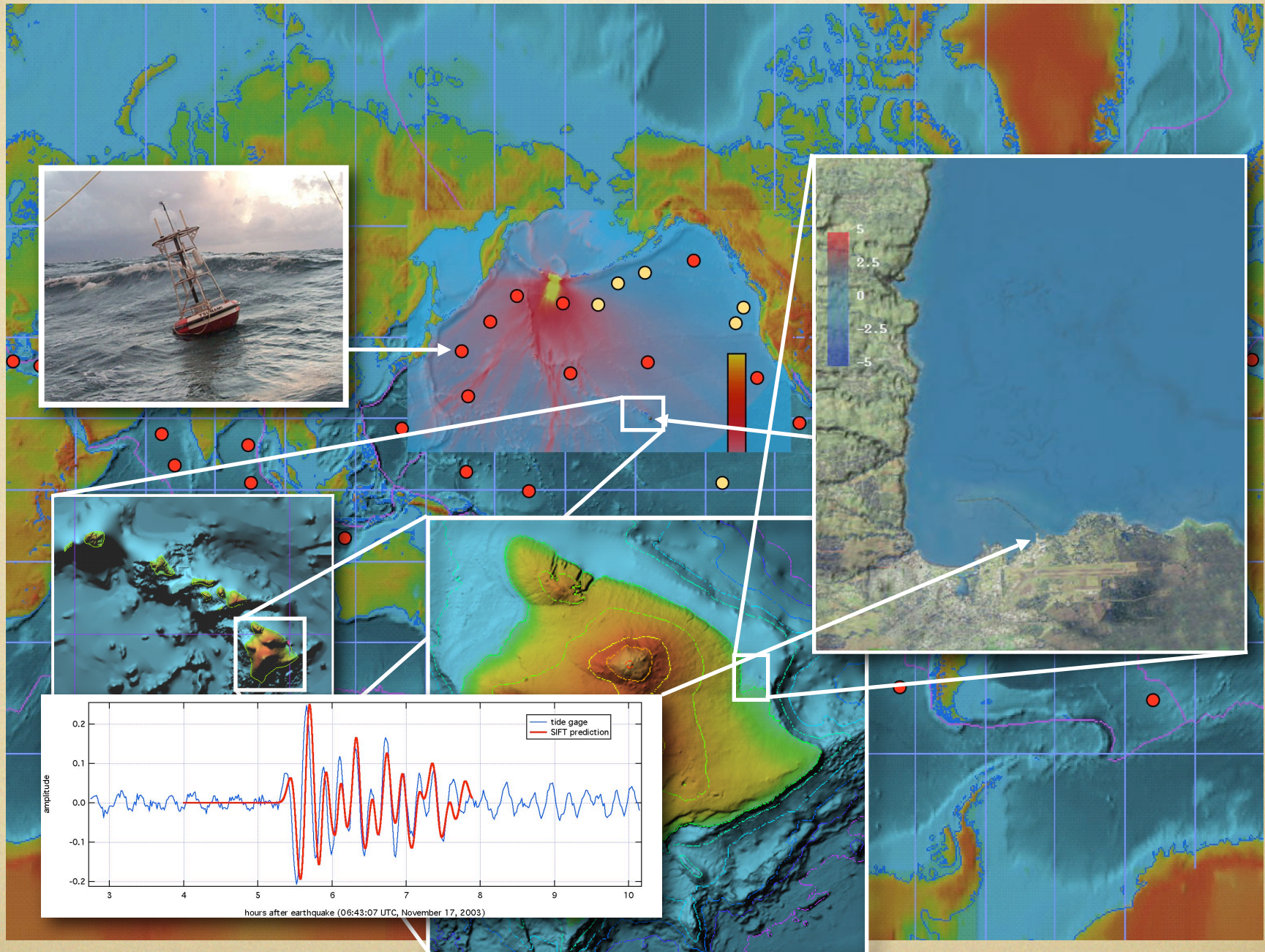
Tsunami Hazard Zone

IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

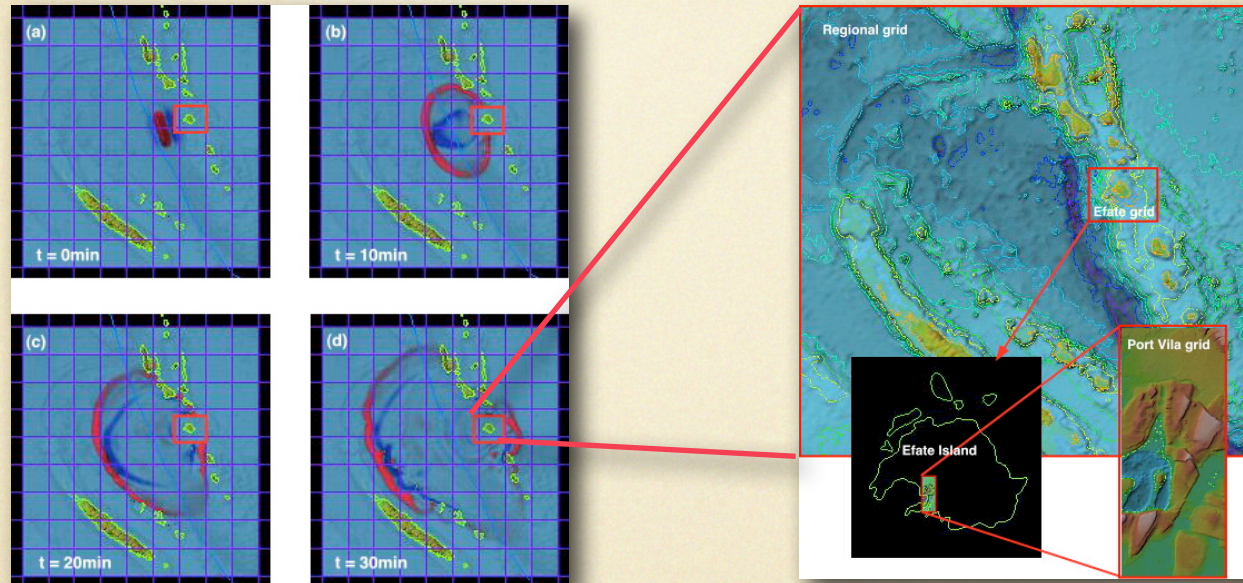
Small circular logo with text: Washington State Department of Geology and Earth Resources

This phenomenon is not "natural" (see NOAA 2002) as a result of flooding over a period of minutes (only) caused by the displacement of water. Experience with tsunamis and tsunamigenic areas is very limited. This is not a drill. You should be prepared to evacuate if you are in an area at risk. This information is provided for informational purposes only and should not be used as the sole basis for evacuation planning. For more information, visit www.wa.gov/dnr.

NOAA Tsunami Forecast



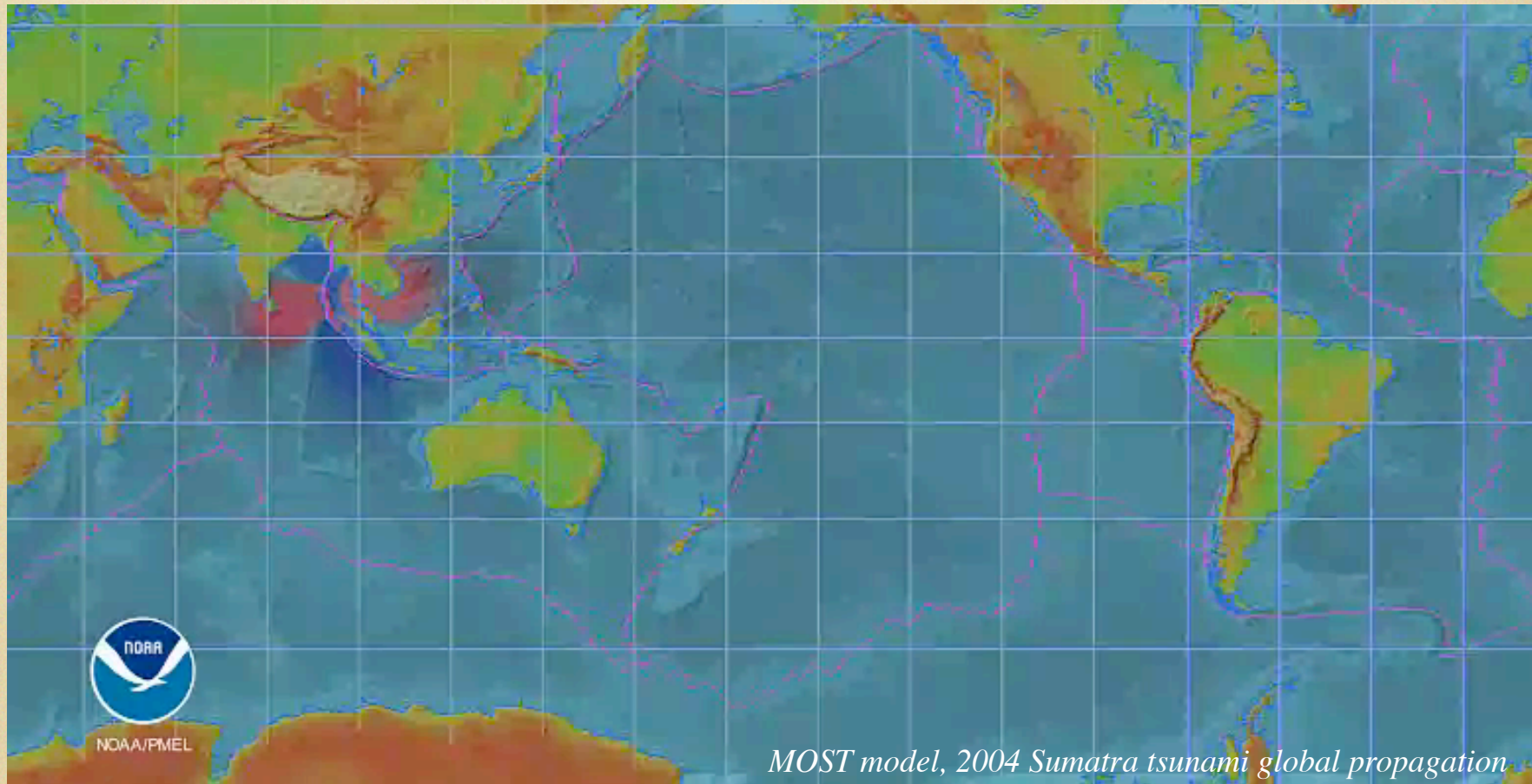
High-resolution model



Port Vila, Vanuatu. Hypothetical Mw8.1 tsunami

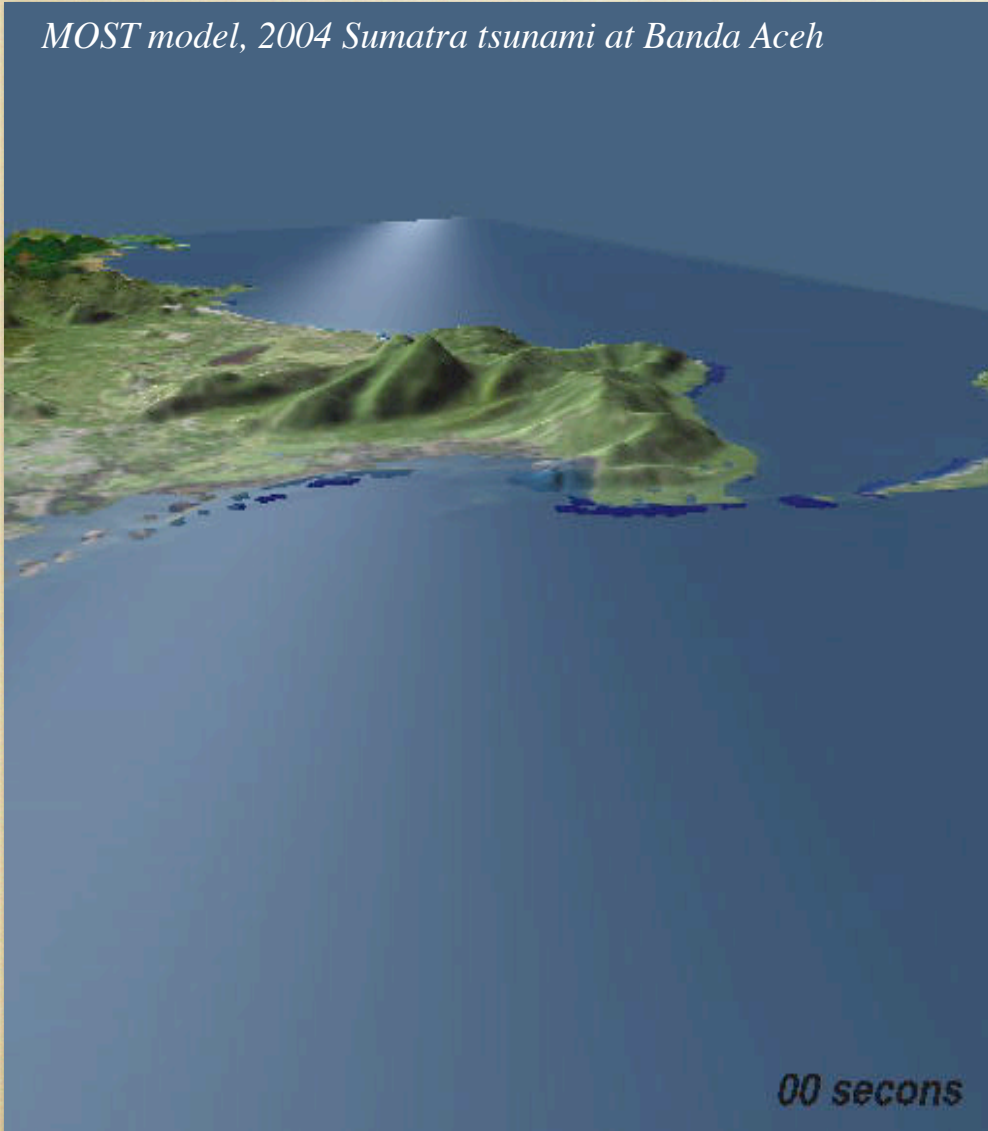


Sumatra 2004: Propagation model

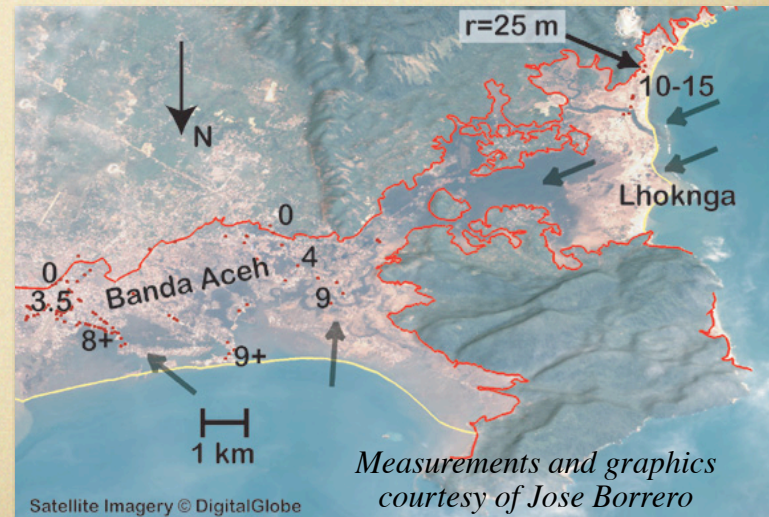
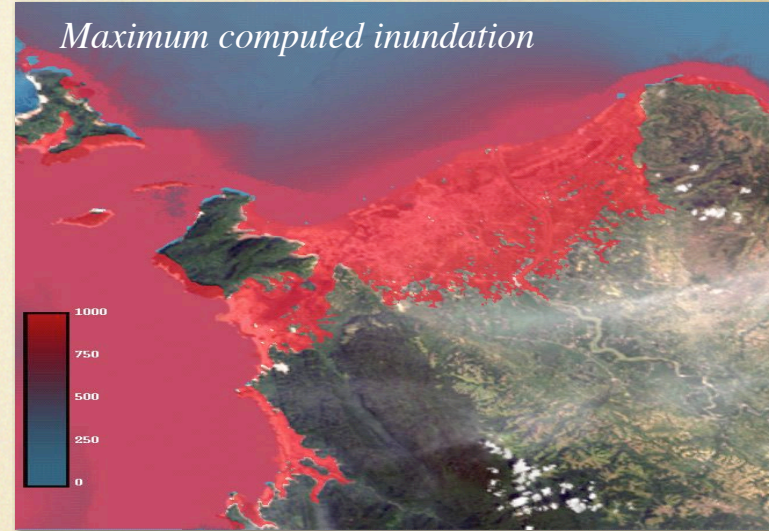


Sumatra 2004: Inundation Model

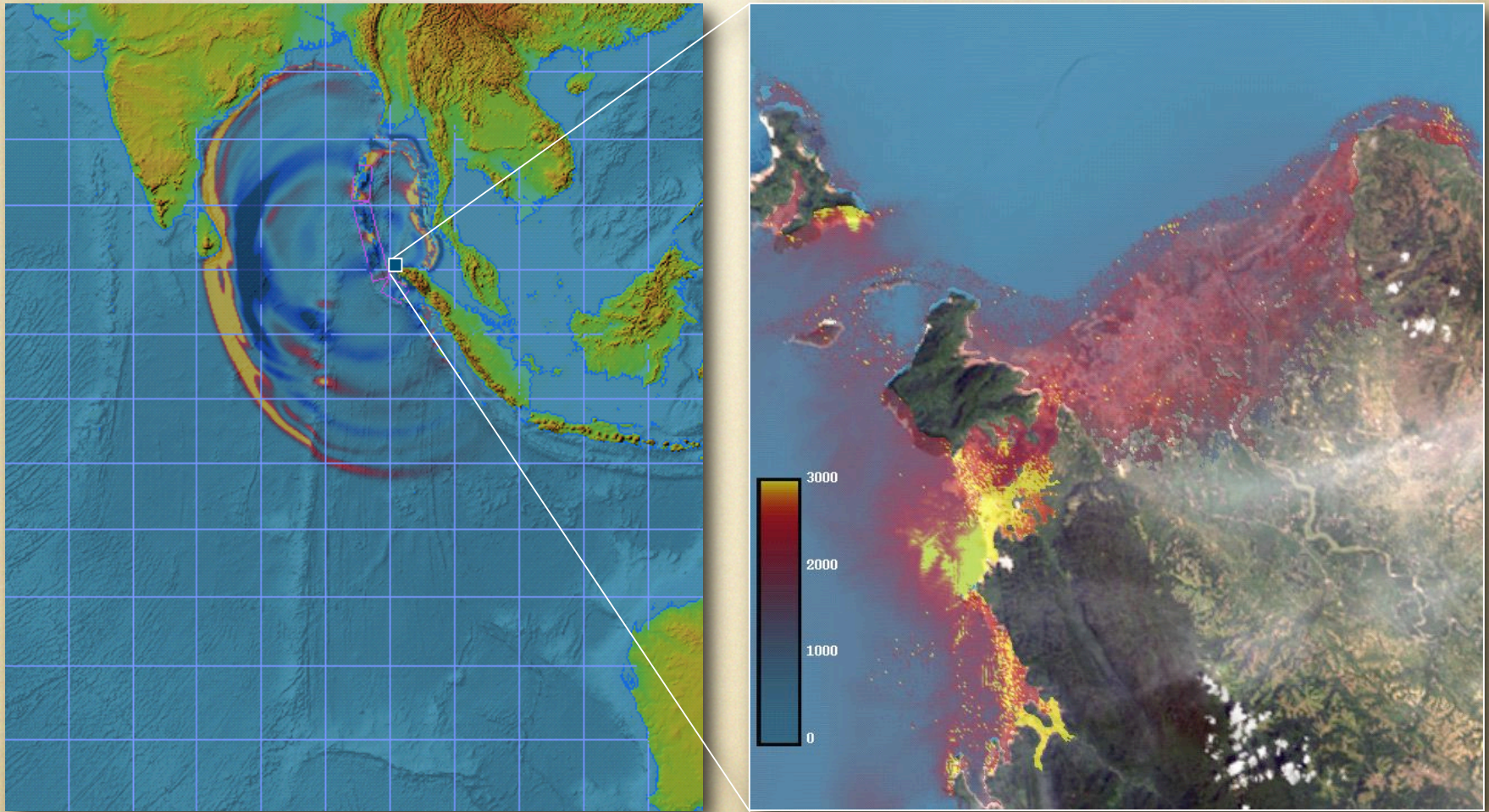
MOST model, 2004 Sumatra tsunami at Banda Aceh



Maximum computed inundation



Test for Tsunami Forecast



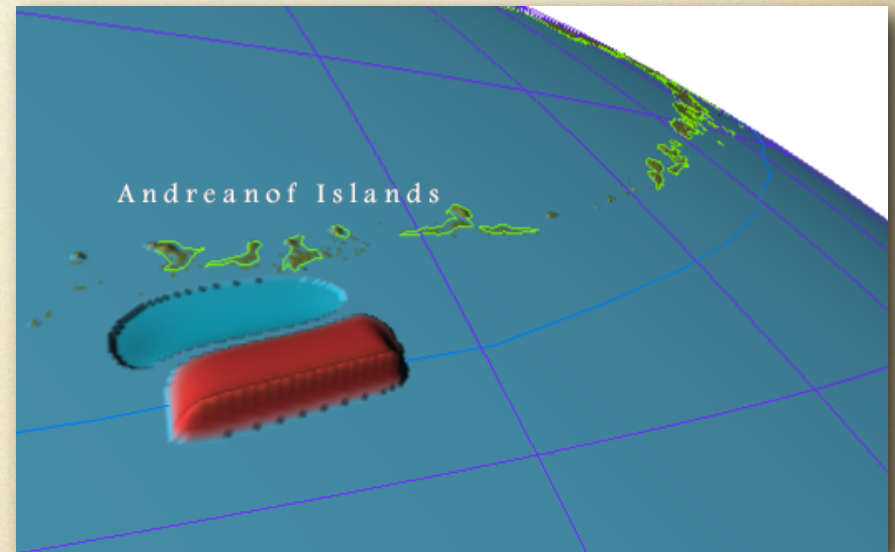
Challenge 3: Source definition

June 10, 1996

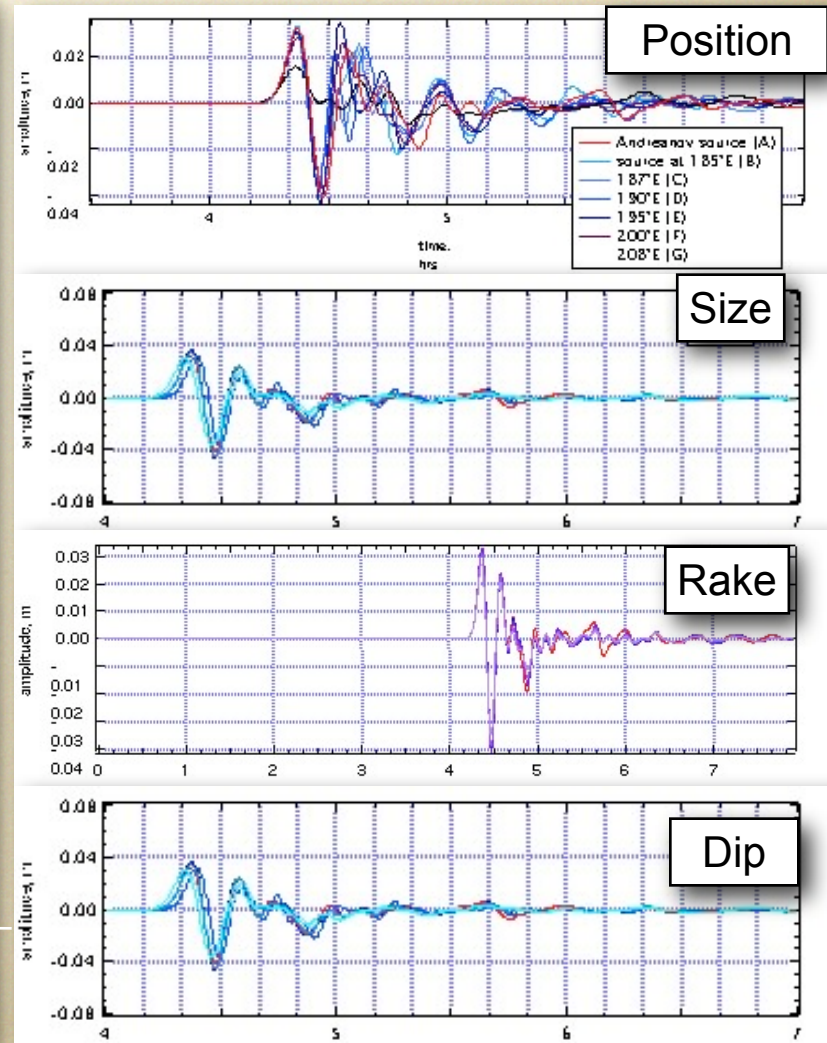
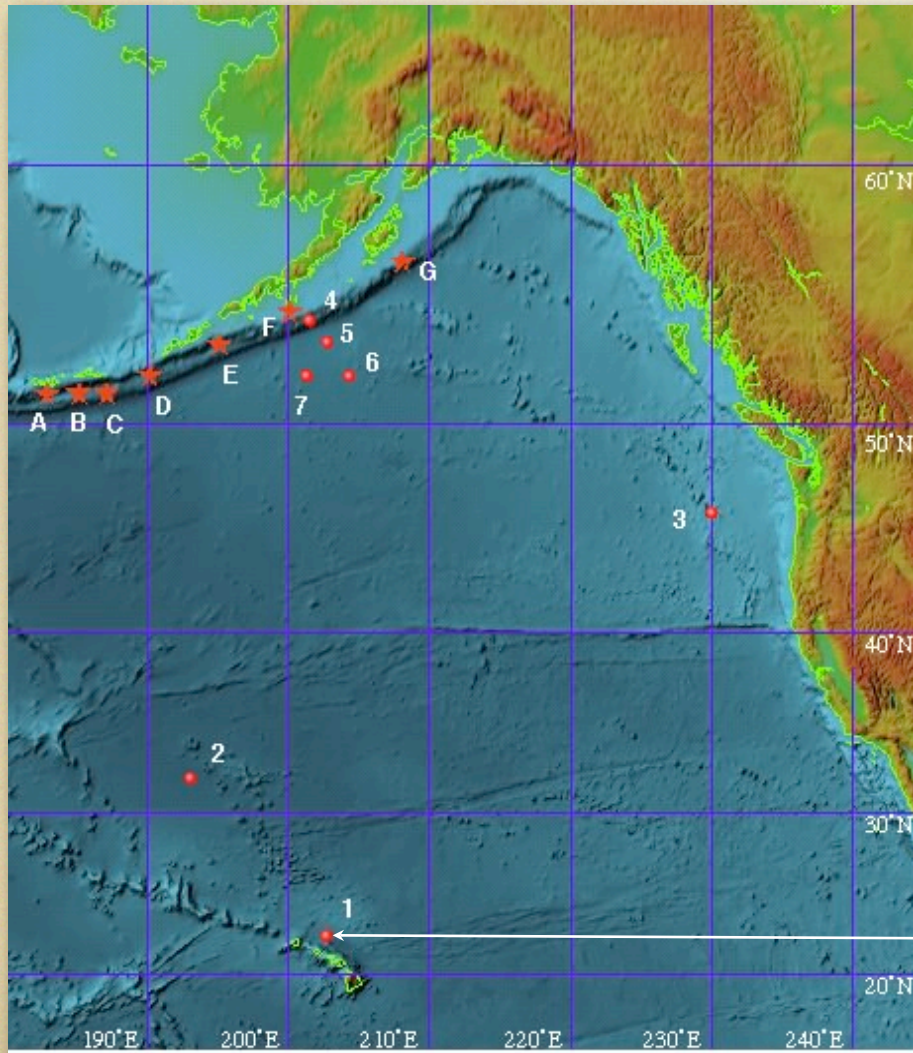
Andreanov Island tsunami

Source Parameters:

Mw	7.9
Length	140km
Width	70km
Strike	260
Dip	20
Rake	108
Slip	2m



Source Sensitivity Study



Source Sensitivity Study

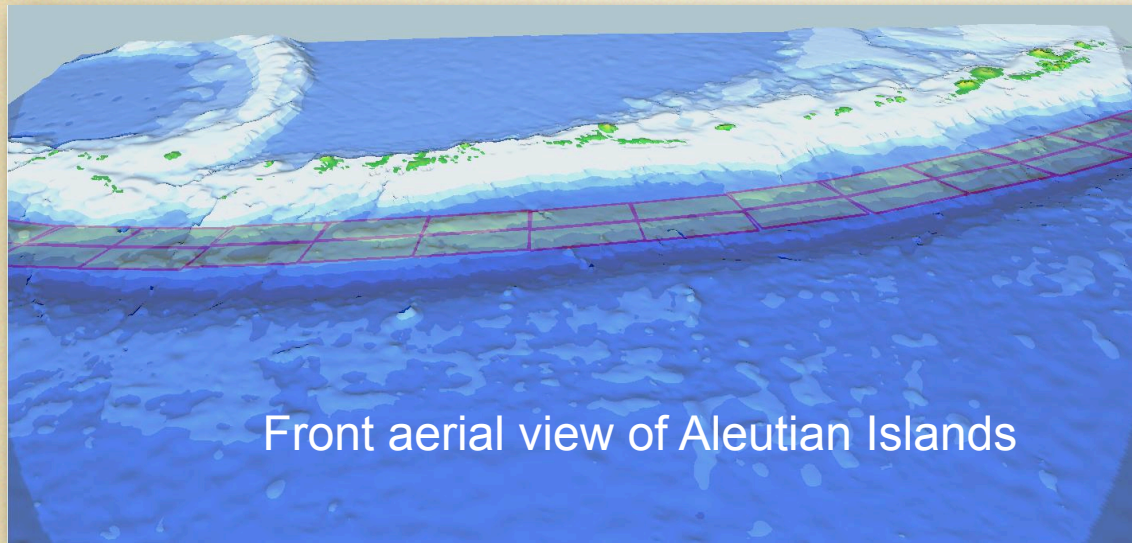
Titov, V. V., H.O. Mofjeld, F.I. González and J.C. Newman, 1999, Offshore forecasting of Alaska-Aleutian Subduction Zone tsunamis in Hawaii, NOAA Tech. Memo. ERL PMEL-114, 22pp.

The sensitivity study for AASZ earthquake demonstrates that the offshore tsunami characteristics weakly depend on STRIKE, DIP, SLIP and SIZE (if the Moment kept constant by adjusting slip amount). Hence, the leading tsunami waves generated by AASZ earthquakes are characterized in the far field mainly by earthquake magnitude and location.

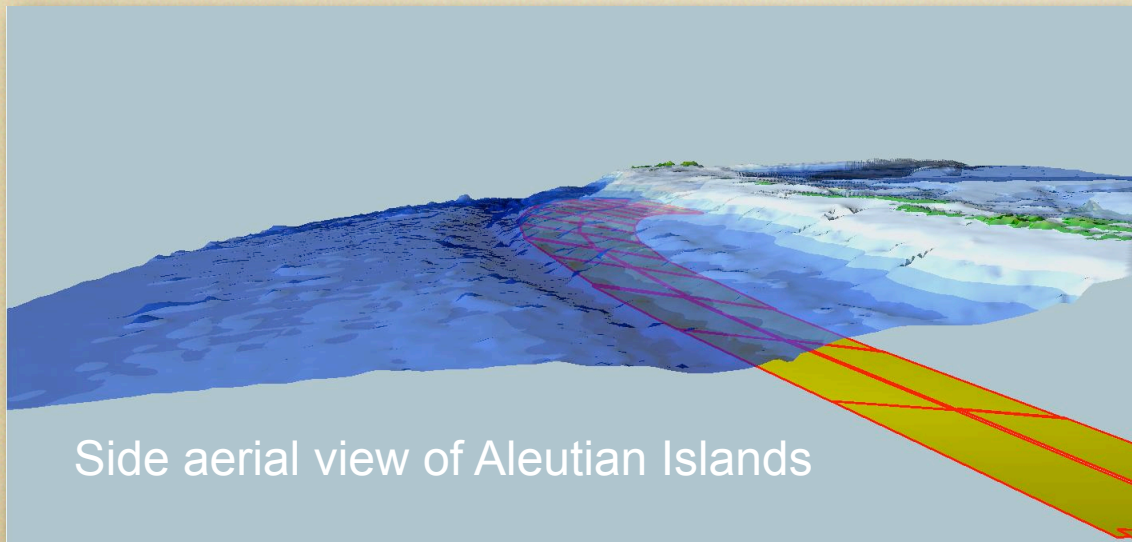
Forecast Methodology

- Linear propagation database
- Linear combinations model arbitrary source
- Source correction using DART
- Inundation estimates with non-linear model

Propagation Model Database



Front aerial view of Aleutian Islands



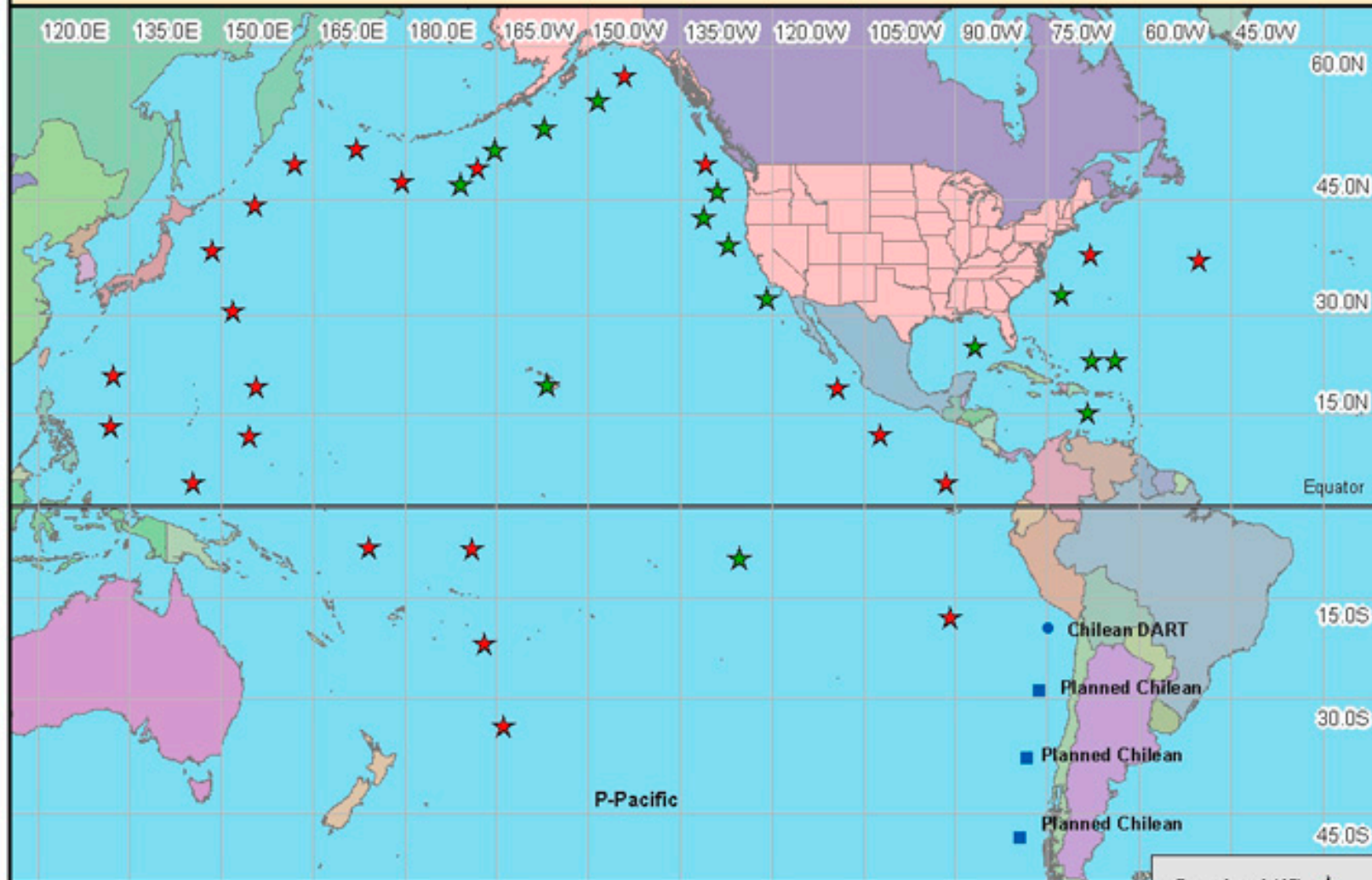
Side aerial view of Aleutian Islands

Unit Sources:

- 100km × 50km faults
- Placed along subduction zones and known tsunamigenic faults
- Aligned to fit known fault geometries

DART LOCATIONS - CONCEPTUAL PLAN

(As of April 17, 2006)



Completed (15) ★
Planned (24) ★
Total Network (39)

Stand-by Inundation Model

SIM development

Reference Model

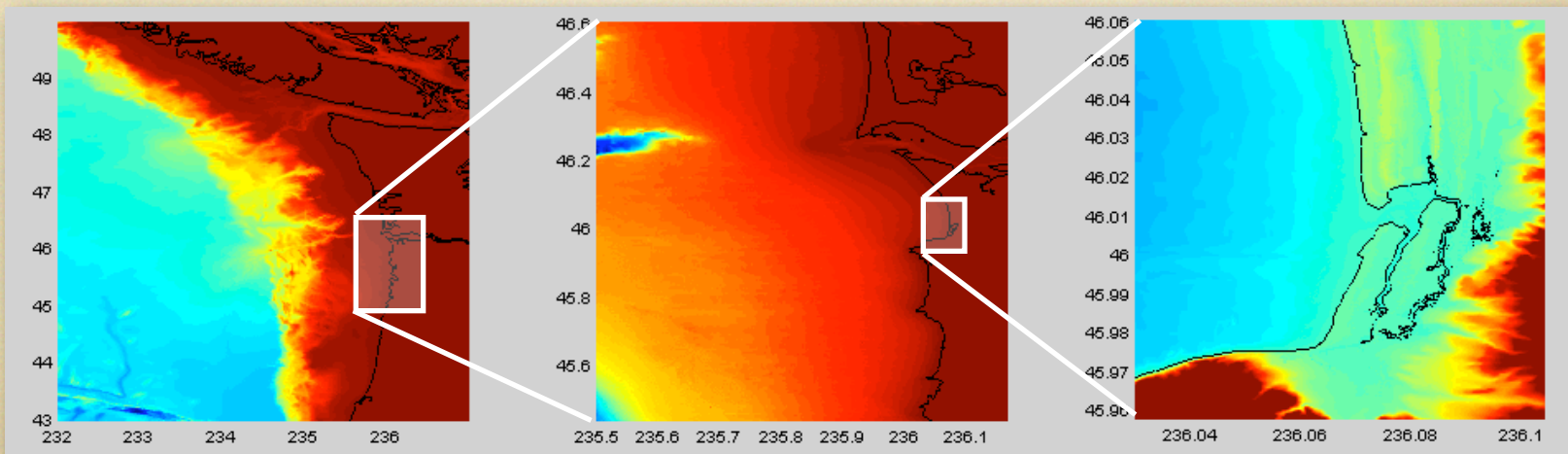
Use best available bathy-topo data. Identification of vital assets within the fine resolution inundation grid. Major population centers. Vital Infrastructure: Roads, Airports, Hospitals....



A. Resolution: 36" x 36"

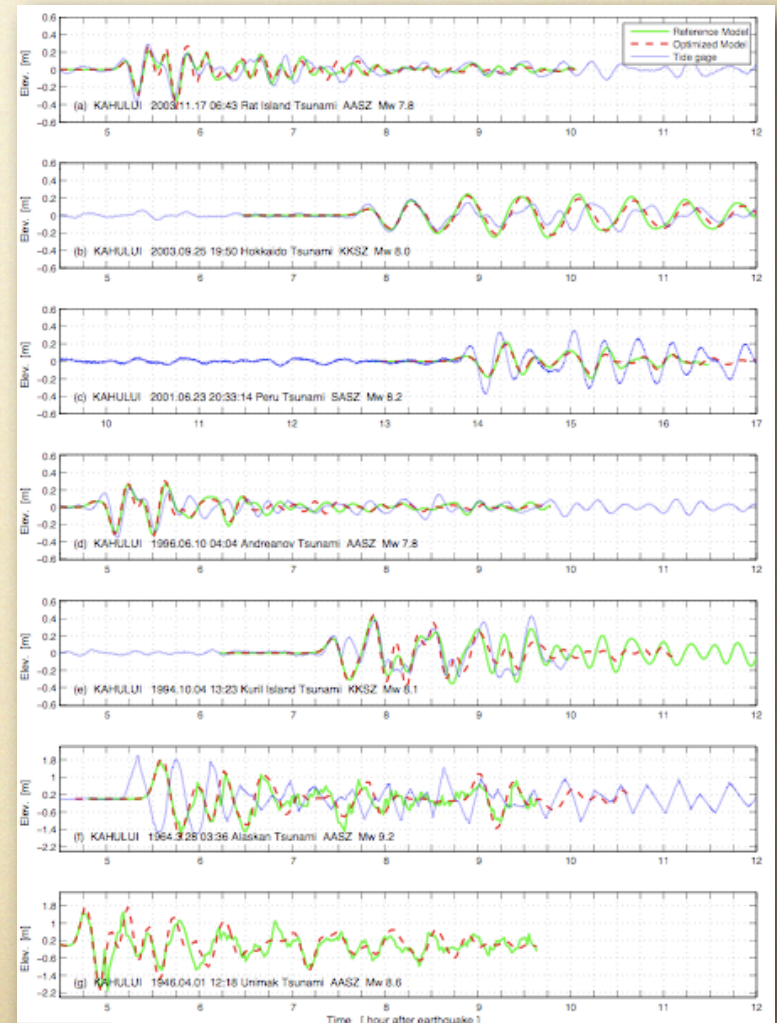
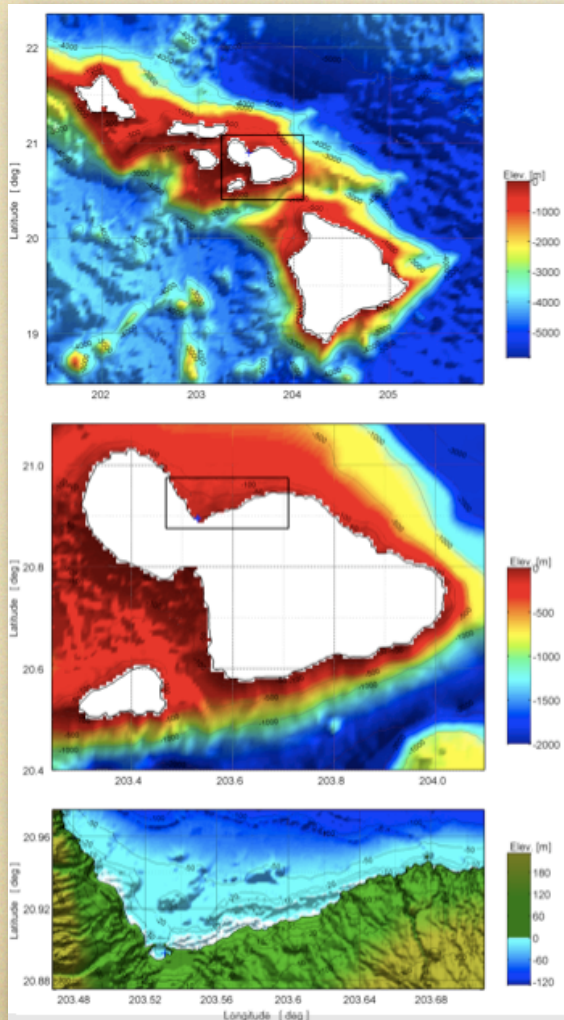
B. Resolution: 6" x 6"

C. Resolution: 1/3" x 1/3"



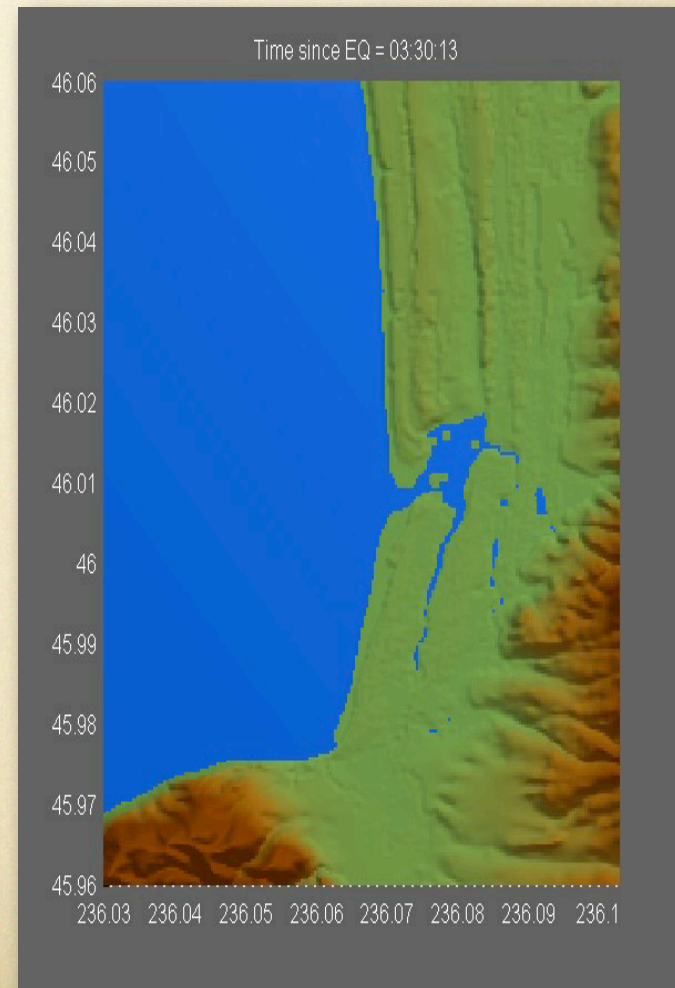
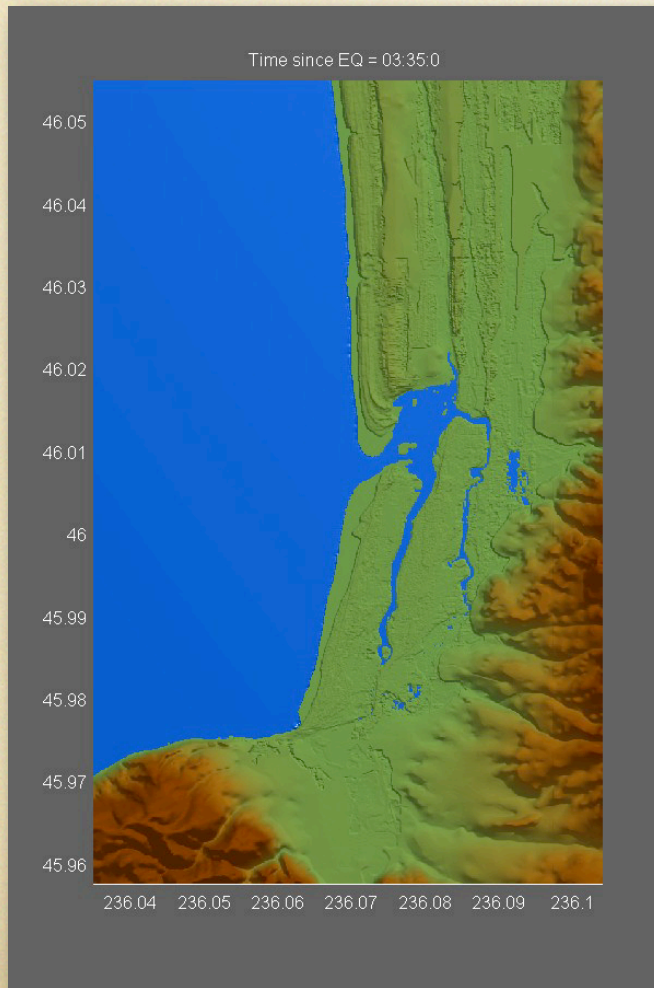
Optimize for speed

Monitor Speed vs. Accuracy by comparison with Reference Run.

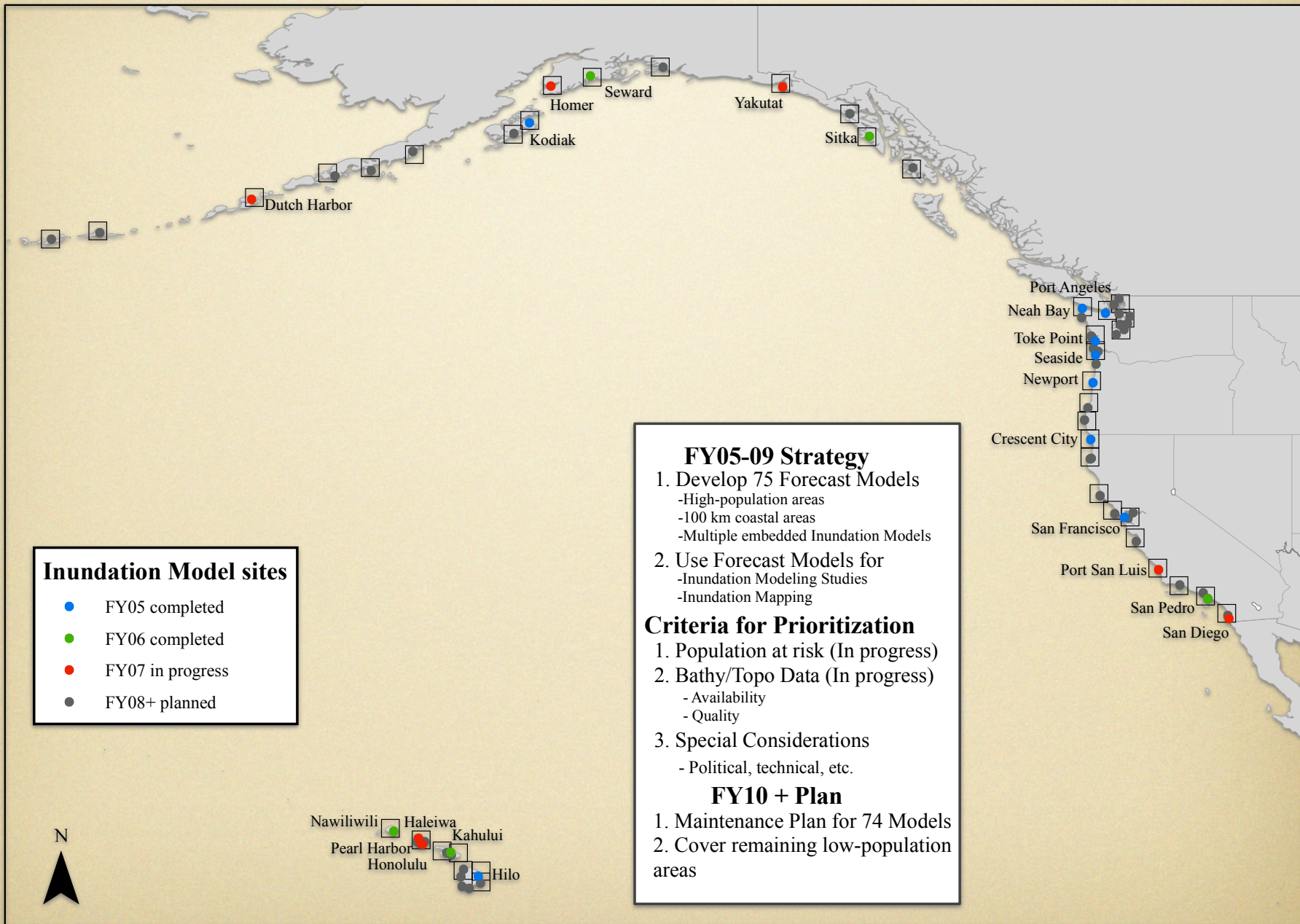


Reference vs Optimized

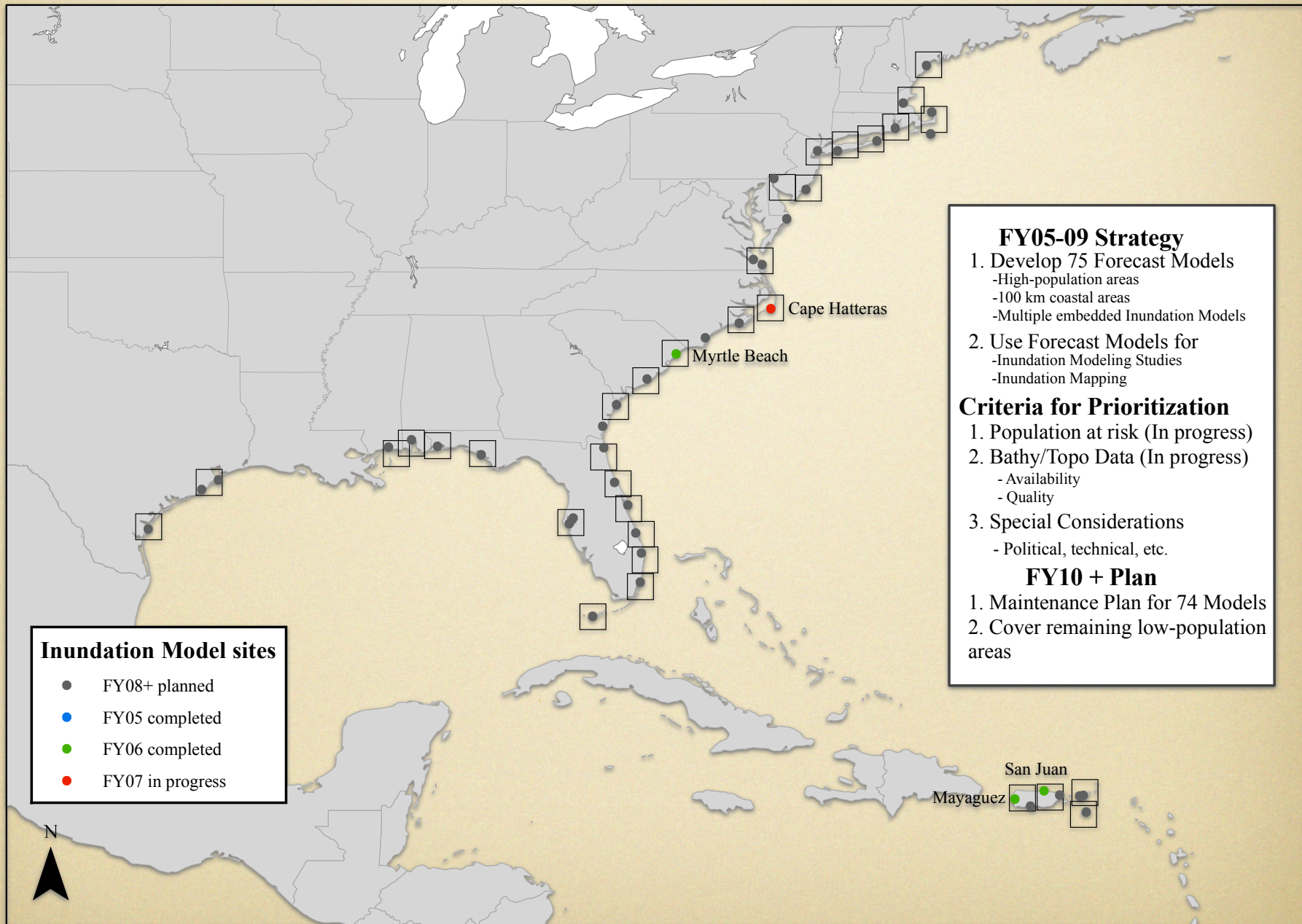
Comparison of the Reference Model (5.2 hours) and SIM (10 mins)



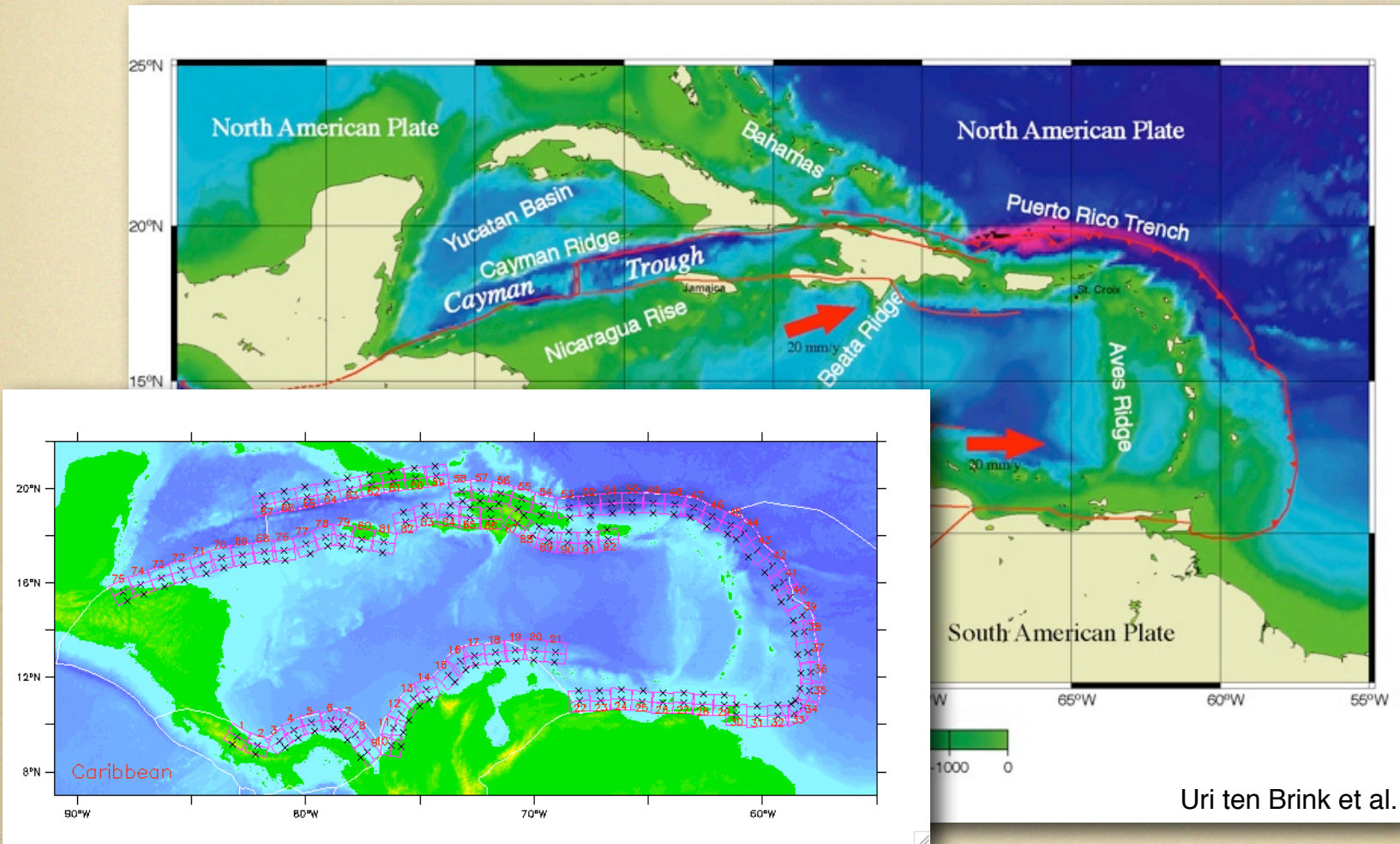
NOAA Tsunami Forecast Modeling and Mapping



NOAA Tsunami Forecast Modeling and Mapping

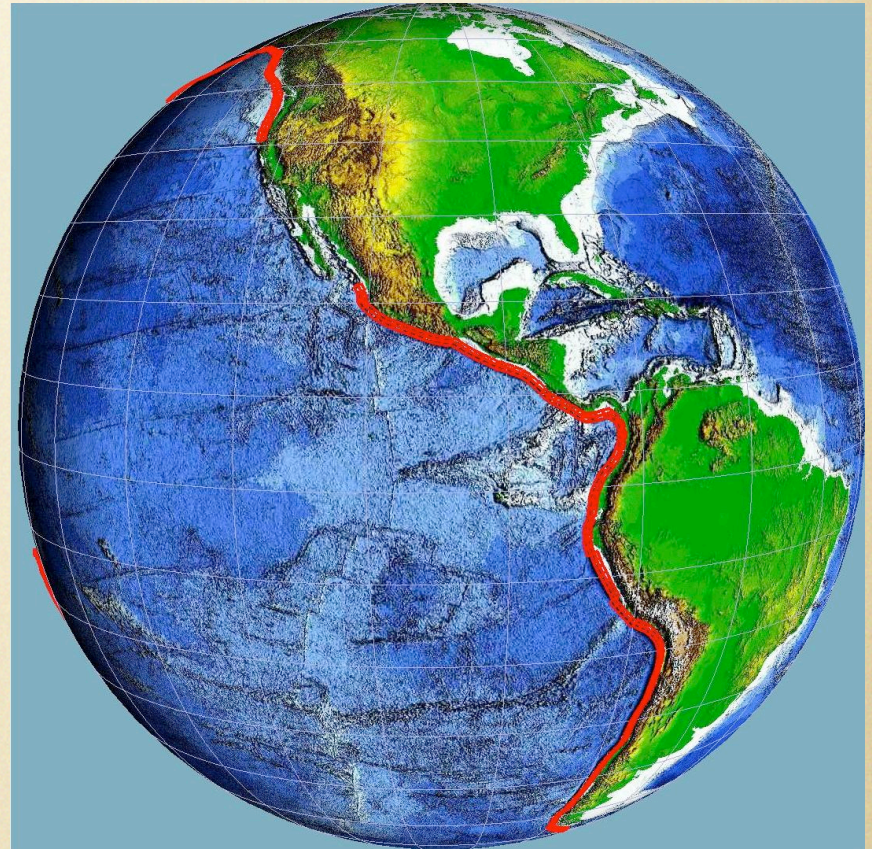
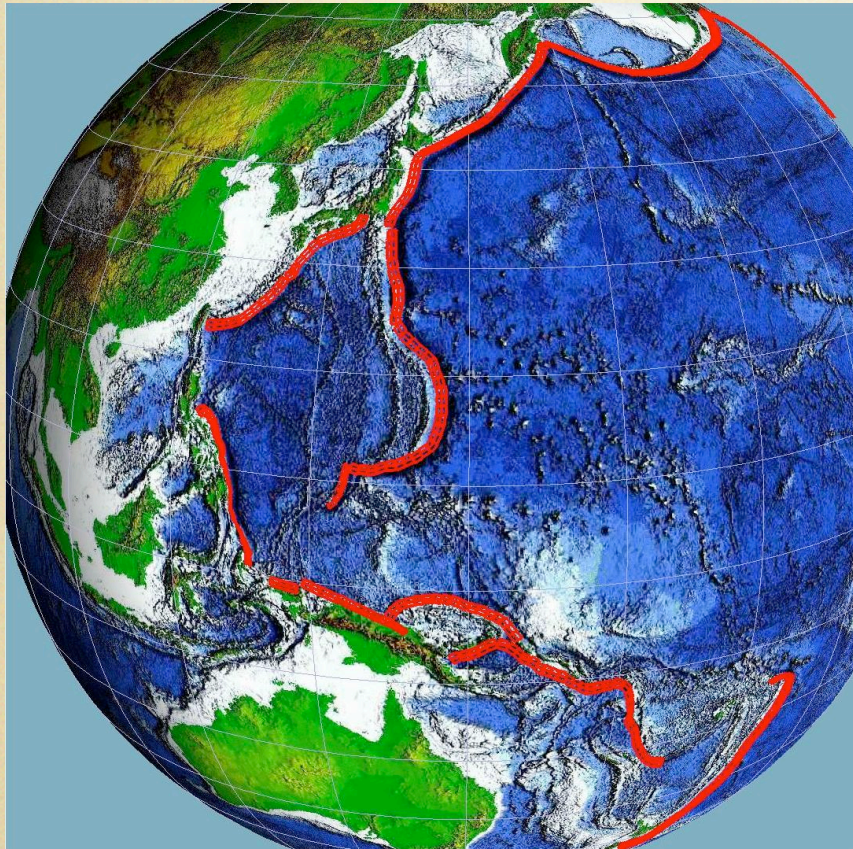


Propagation Model Database



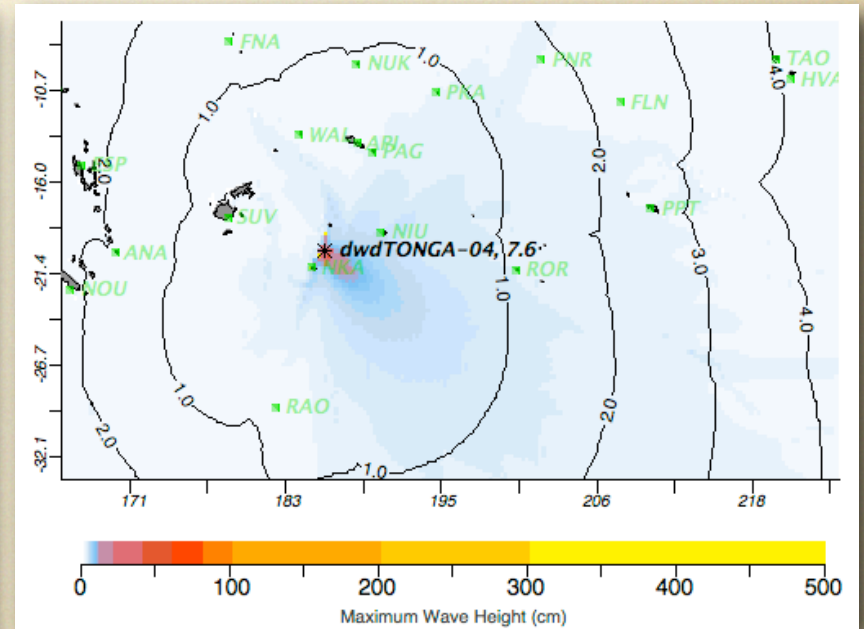
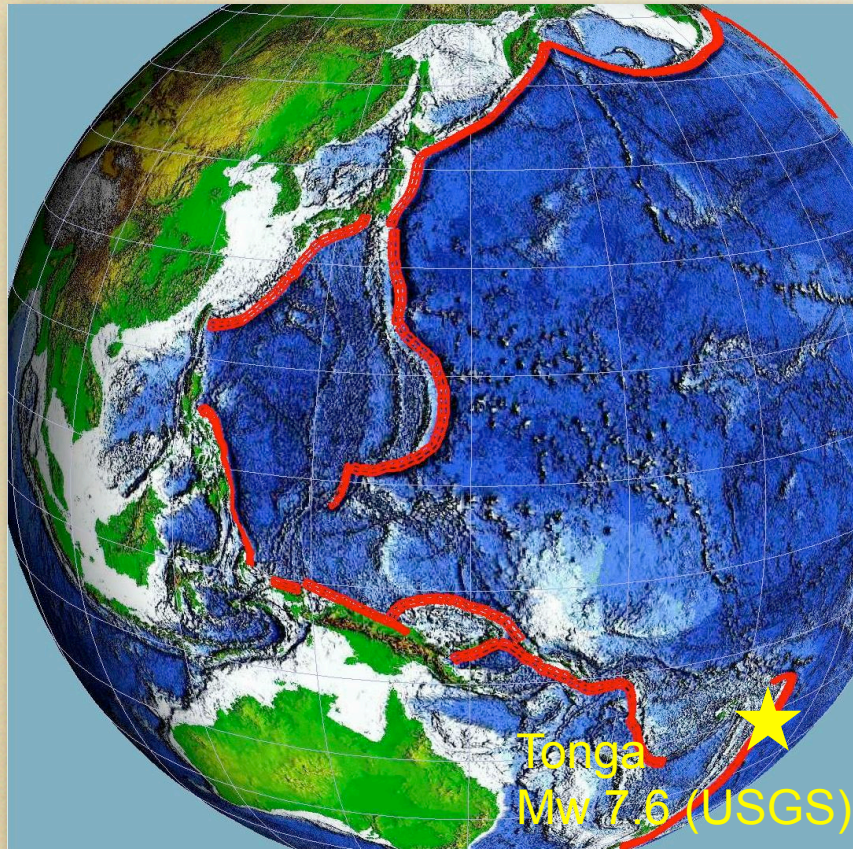
Pre-computed tsunami propagation scenarios for 182
“Unit sources”

Propagation Model Database



Pre-computed tsunami propagation scenarios for 1258
“Unit sources” for Pacific and Atlantic

Propagation Model Database



At Niue tide gage
Forecast: 36.6 cm
Observed: 42 cm.

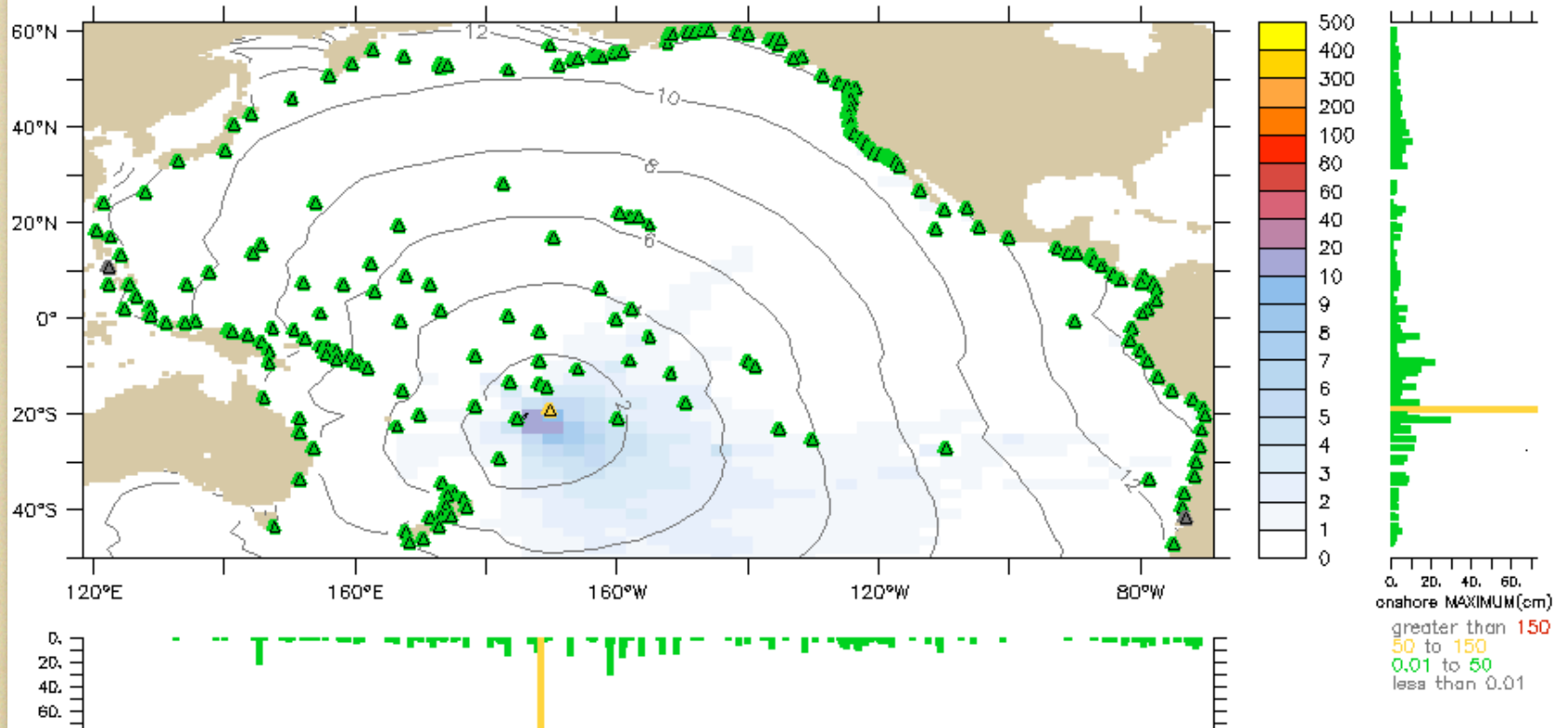
May 3, 2006 Tonga tsunami test

Tonga Tsunami Forecast

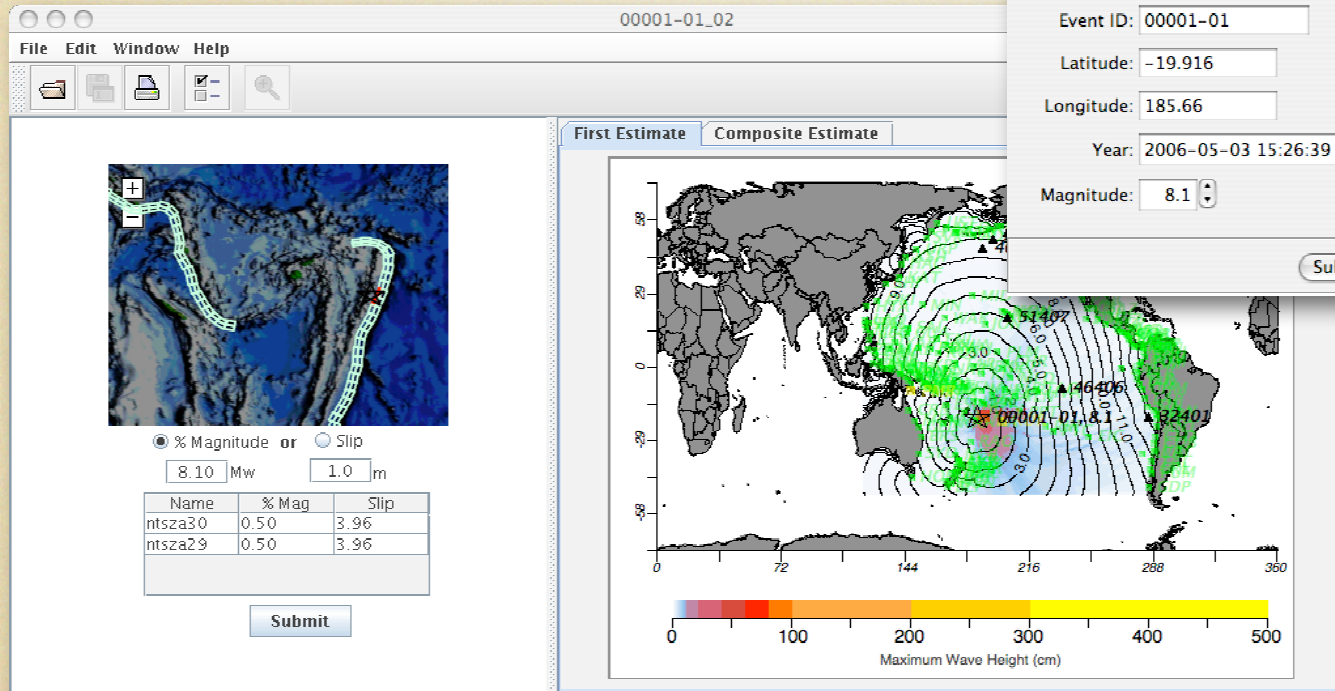
Short-term Inundation Forecasting for Tsunami (SIFT)

Maximum Wave Crest Height(cm) & First Wave Travel Time(hrs)

Source: New Zealand-Kermadec-Tonga Mw 7.8, 2.81*a29



Tonga Tsunami Forecast



Test Event Creation

Event ID: 00001-01 (XXXXX-XX)

Latitude: -19.916 (-90 to +90)

Longitude: 185.66 (0 to +360)

Year: 2006-05-03 15:26:39 (yyyy-MM-dd hh:mm:ss) UTC

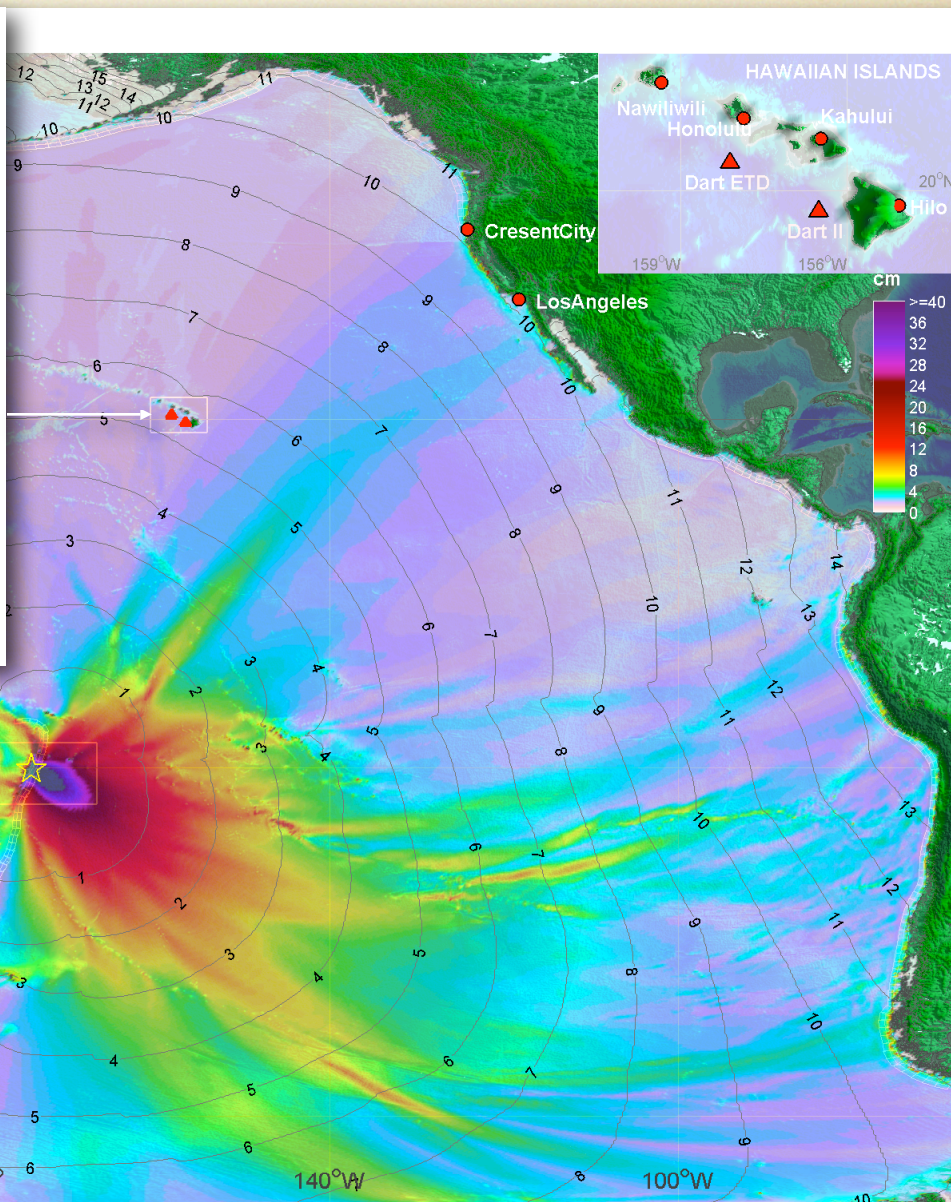
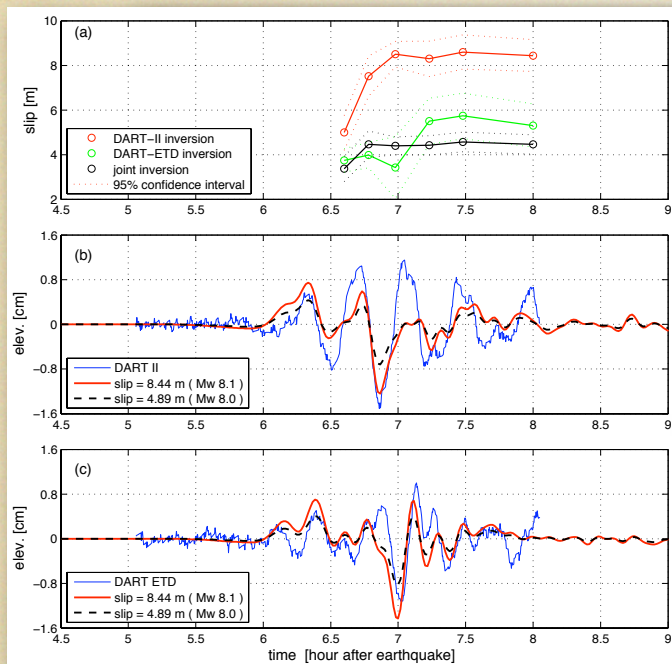
Magnitude: 8.1 (Mw X.X)

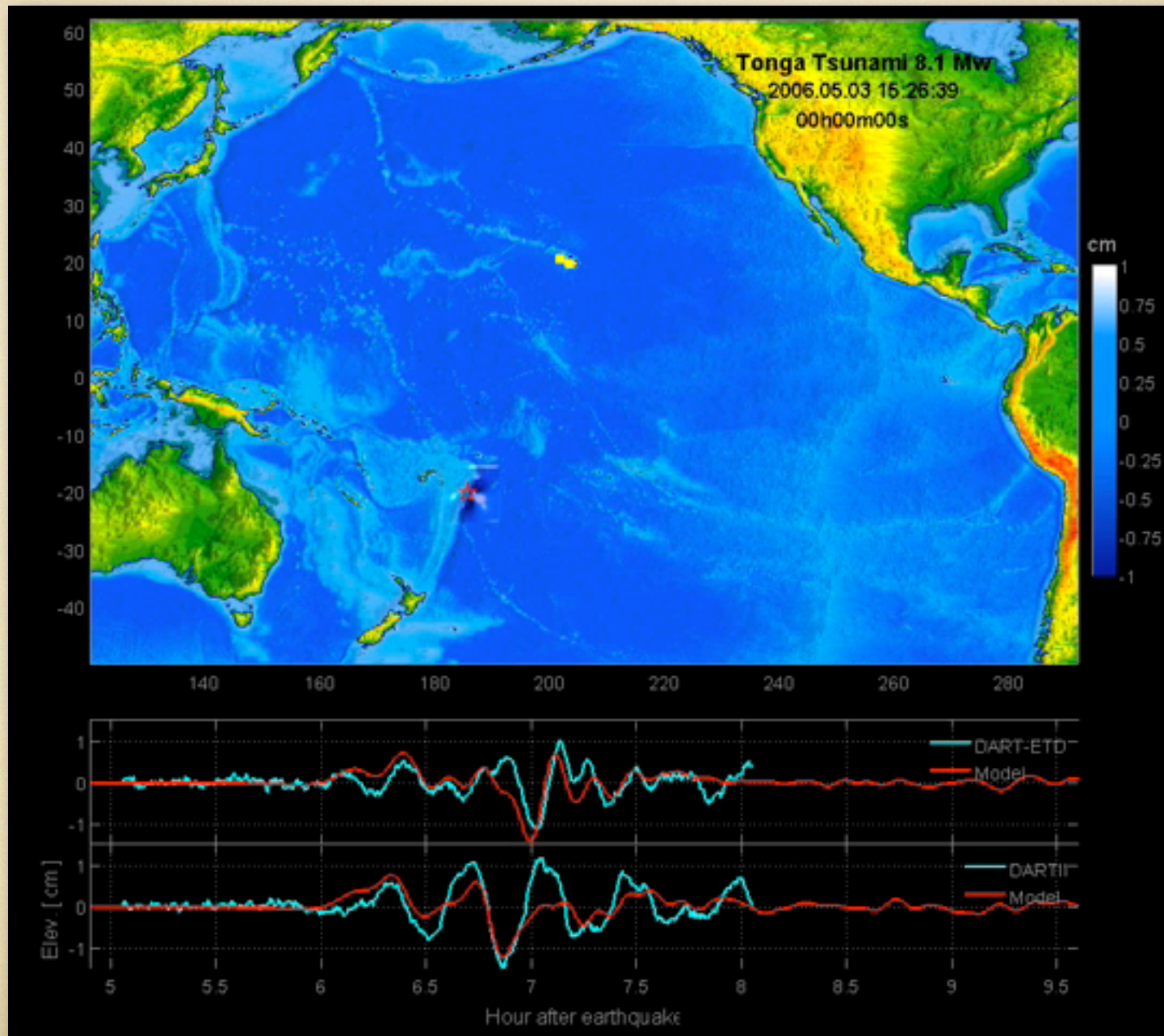
Submit Event

Code	Arrival Time (UTC)	Local Time	Count	Amplitude (cm)	Location	Rgn.
NIU	15:26:39 UTC 03 May 2006	04:26:39 NUT 03 May 2006	00:00	162.0	Niue Is, Niue	0
NKA	15:26:39 UTC 03 May 2006	04:26:39 TOT 04 May 2006	00:00	17.4	Nukualofa, Tonga	0
PAG	15:33:39 UTC 03 May 2006	04:33:39 SST 03 May 2006	00:00	23.6	Pago Pago, American Samoa	0
API	15:39:39 UTC 03 May 2006	04:39:39 SST 03 May 2006	00:00	10.4	Apia, Samoa	0
WAL	15:44:39 UTC 03 May 2006	03:44:39 WFT 04 May 2006	00:00	13.7	Wallis Is, Wallis-Futuna	0
SUV	15:51:39 UTC 03 May 2006	03:51:39 FJT 04 May 2006	00:00	20.5	Suva, Fiji	0
PKA	16:06:39 UTC 03 May 2006	06:06:39 CKT 03 May 2006	00:00	27.3	Pukapuka Is, Cook Islands	0
RAO	16:07:39 UTC 03 May 2006	04:07:39 NZST 04 May 2006	00:00	15.5	Raoul Is, Kermadec Is	0

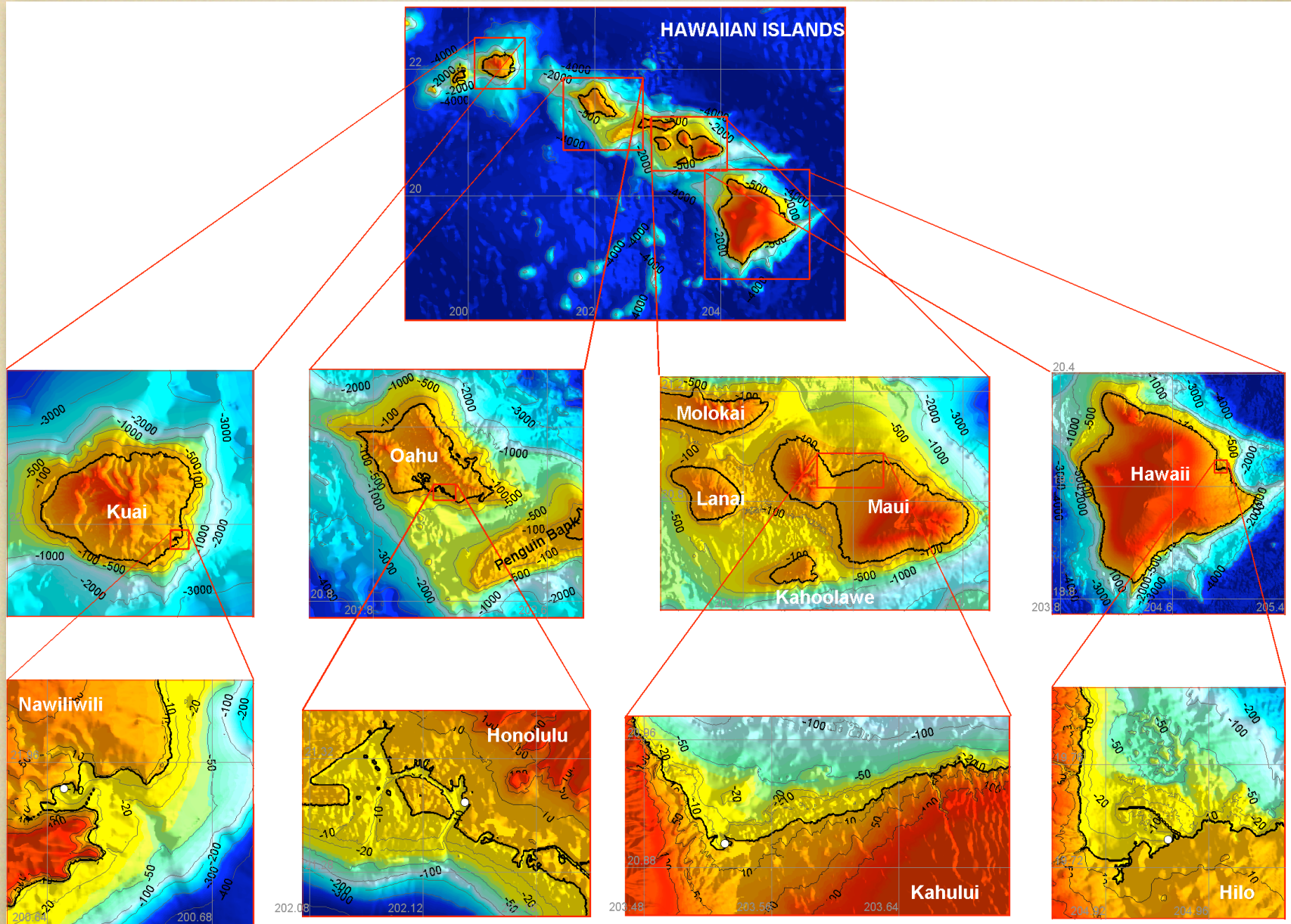
Event Time: 15:26:39 UTC 03 May 2006 Elapsed Time: 166:30 Event ID: 00001-01 Magnitude: 8.1 Location: 185.7,-19.9

Data assimilation test

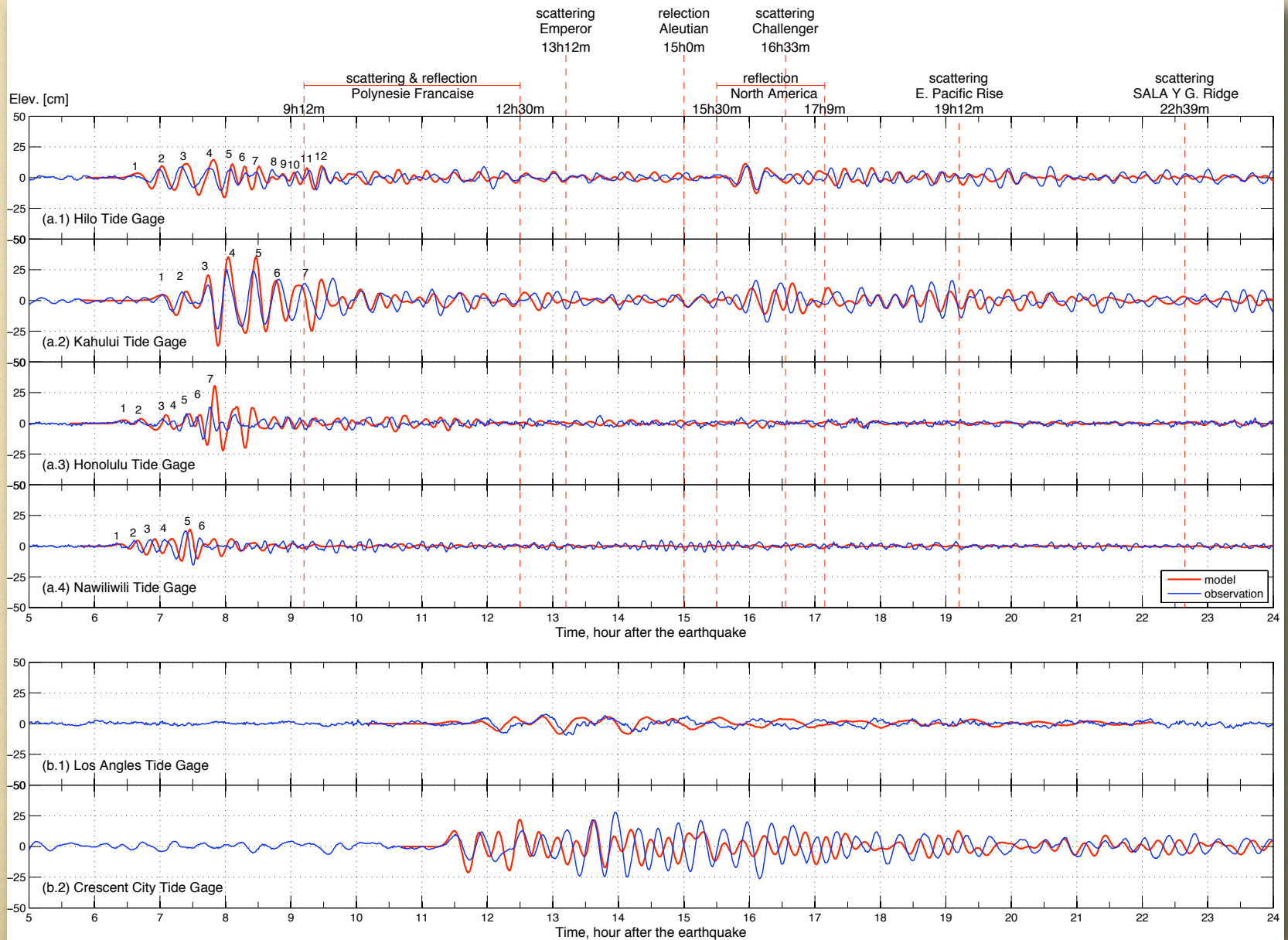




Forecast models test



Forecast models test



Thank You!

Questions?