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Update to Tsunami Guidance: Future Reactor Siting

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Meeting Agenda: Proposed Update of SRP 2.4.6

- Introductory Remarks
- Tsunami Basics and Reactor Siting
- Proposed Update to SRP 2.4.6
  - Overview of SRP 2.4.6
  - Tsunami Sources
  - Tsunami Propagation and Runup
  - NRC Research to Characterize Tsunami Hazard for the East and Gulf Coasts
- Opportunity for Public Comment and Discussion
- Meeting Summary and Adjournment

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Introductory Remarks

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Tsunami Basics and Reactor Siting

Tsunami literally means harbor wave. These waves are generated in a body of water when its bed is rapidly displaced on a massive scale.

- Small Amplitude, but very deep down to the bottom
- Very Long Wavelength
- Unnoticed at Sea
- Shoreline may recede (trough) or rise (crest)
- Rising shoreline / large waves threat to facilities
- Receding shoreline may expose intake structures

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Probable Maximum Tsunami

The PMT is defined as that tsunami for which the impact at the site is derived from the use of best available scientific information to arrive at a set of scenarios reasonably expected to affect the nuclear power plant site taking into account sparsity and uncertainty of historical events….. appropriate phenomena….and combinations of effects……

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Overview of SRP 2.4.6 (2007 Ed.)

- Title Change from Previous Version
- Review Areas, Procedures and Acceptance Criteria
  - Historical data
  - Probable Maximum Tsunami
  - Tsunami Propagation Models
  - Wave Runup, Inundation, and Drawdown
  - Hydrostatic and Hydrodynamic Forces
  - Debris and Water-Borne Projectiles
  - Effects of Sediment Erosion and Deposition
  - Other Site-Related Evaluation Criteria
  - Additional Information for 10CFR 52 Applications

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Overview of SRP 2.4.6 (2007 Ed.) (Continued)

- Areas of Review (continued)
  - Review Interfaces
    - SRP 14.3.1 (Site Parameters Tier 1)
    - SRP 2.4.10 (Flood Protection Measures)
    - SRP 9.2.5 (Ultimate Heat Sink)
    - Geophysics/Seismic – Tsunami / Like Waves
    - SRP 2.3.6 (Proposed) DC Parameter Envelope

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Overview of SRP 2.4.6 (2007 Ed.) (Continued)

- Acceptance Criteria
  - Based on the Following Regulations
    - 10 CFR 100
    - 10 CFR 100.10(c) for Applications Before 1/10/97
    - 10 CFR 100.20(c) Applications after 1/10/97
    - 10 CFR 100.23(d) Applications after 1/10/97
    - 10 CFR 50, GDC 2
    - 10 CFR 52.17(a)(1)(vi) for ESP Applications
    - 10 CFR 52.79(a)(1)(iii) for COL Applications

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Overview of SRP 2.4.6 (2007 Ed.) (Continued)

- Acceptance Criteria (continued)
  - Guidance Documents
    - RG 1.27 Ultimate Heat Sink …..
    - RG 1.29 Seismic Design Classification
    - RG 1.59 Design Basis Floods …..
    - RG 1.102 Flood Protection ….
  - Data: NOAA, National Geophysical Data Center
  - Regulatory Guides & best current practice

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Overview of SRP 2.4.6 (2007 Ed.) (Continued)

- Statements for Evaluation Findings
  - CP, OL, and COL Reviews
  - ESP Reviews
  - Design Certification Reviews
- Implementation
  - 10 CFR 50 & 52 Applications
  - Exceptions for Acceptable Alternative Method

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NRC Tsunami Guidelines

- Tsunami hazard at a site:
  - Distance, location & site elevation
  - Historical data
  - Many hazard elements
    - Flooding, drawdown, coastal erosion, hydrodynamic effect on reactor safety

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NRC Tsunami Guidelines (continued)

- Tsunami hazard at a site (continued):
  - Site vulnerability
    - Choosing hazard elements for site
  - Resources: NOAA, US Corps of Engineers
  - Planning for high quality application

Probable Maximum Tsunami

- It may be represented by a set of scenarios reasonably expected to affect a nuclear power plant site.
- These scenarios take into consideration
  - appropriate combinations of the effects of normal and accident conditions with the effects of the natural phenomena.
  - safety functions to be performed.

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US Historical Tsunami Records

- Tsunamis were induced by
  - Earthquake **(71%)**
  - Landslides triggered by earthquakes **(13%)**
  - Landslides **(10%)**
  - Volcano Eruptions **(2%)**
  - Others **(4%)**

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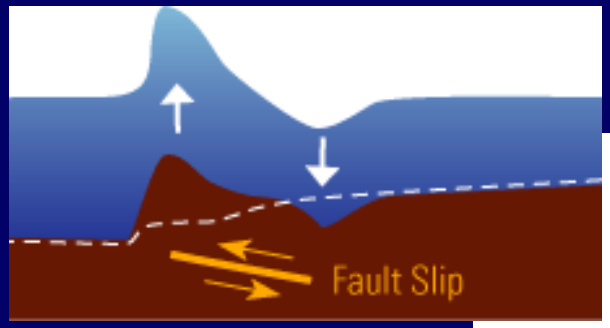
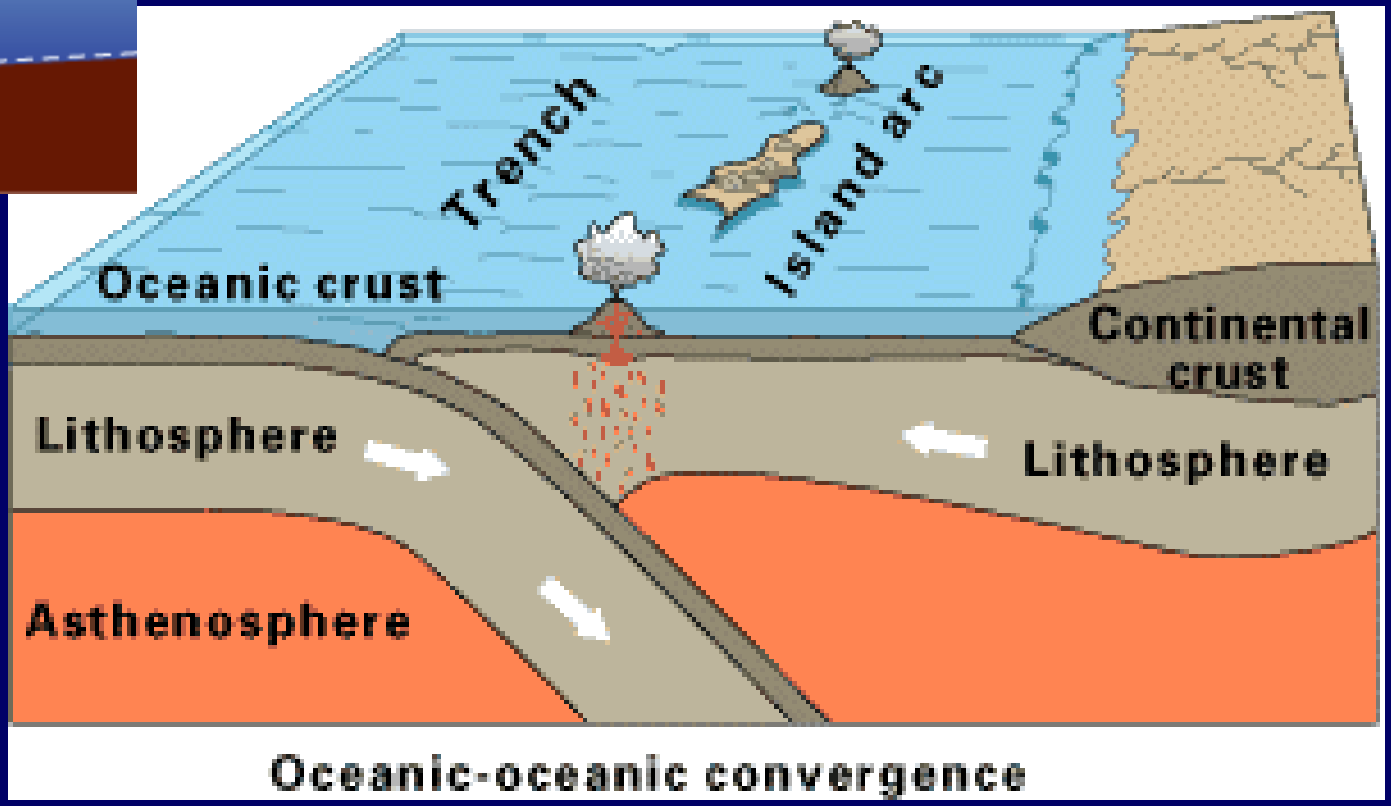
Earthquake Triggered Tsunami





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Earthquake Triggered Tsunami (Continued)

- Local and remote seismic sources
  - Maximum Magnitudes, focal depth, fault dimension, orientation, displacement and the potential sea floor relocating volume
- Tectonic settings
  - Subduction zones (inter-plate thrust)
  - Out-rise normal faults, back-arc thrusts, deep intra-slab events
  - Strike-slip faults

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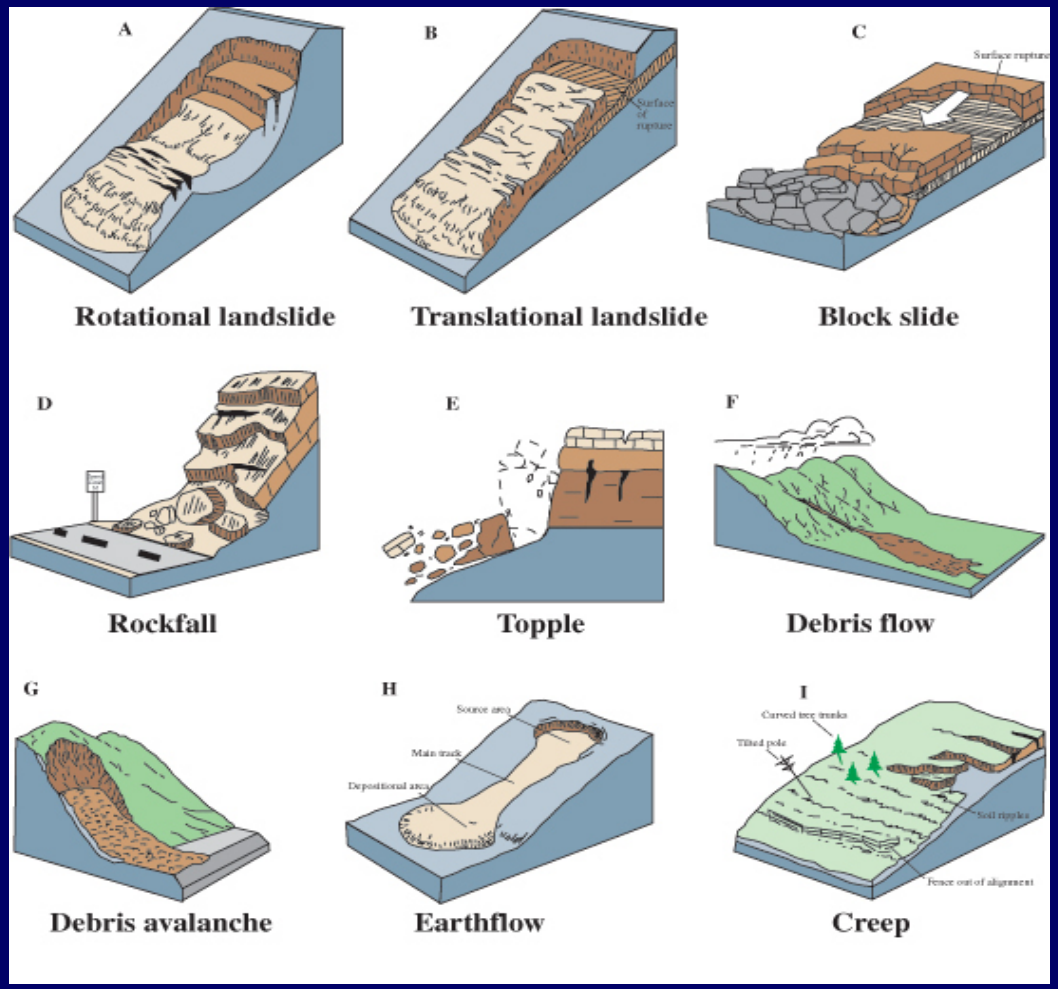
Earthquake Triggered Tsunami (Continued)

- Return period of the earthquakes associated with a specific tectonic setting
  - Historical data
  - Paleotsunami studies
- Tsunami earthquakes
  - Latest Japan studies indicate tsunami earthquake concept

Landslide Triggered Tsunami

- Submarine Landslides
  - Types: slides, topples, spreads, falls and flows.
  - Important parameters: slide volume distribution and time history (slide acceleration and speed).
- Subaerial Landslides
  - Geographically limited

Landslide Triggered Tsunami (Continued)



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Volcano Activity Triggered Tsunami

- Submarine Volcano Eruptions
  - Pyroclastic flows
  - Caldera collapses
  - Explosive eruptions
  - Debris avalanche and flank failures

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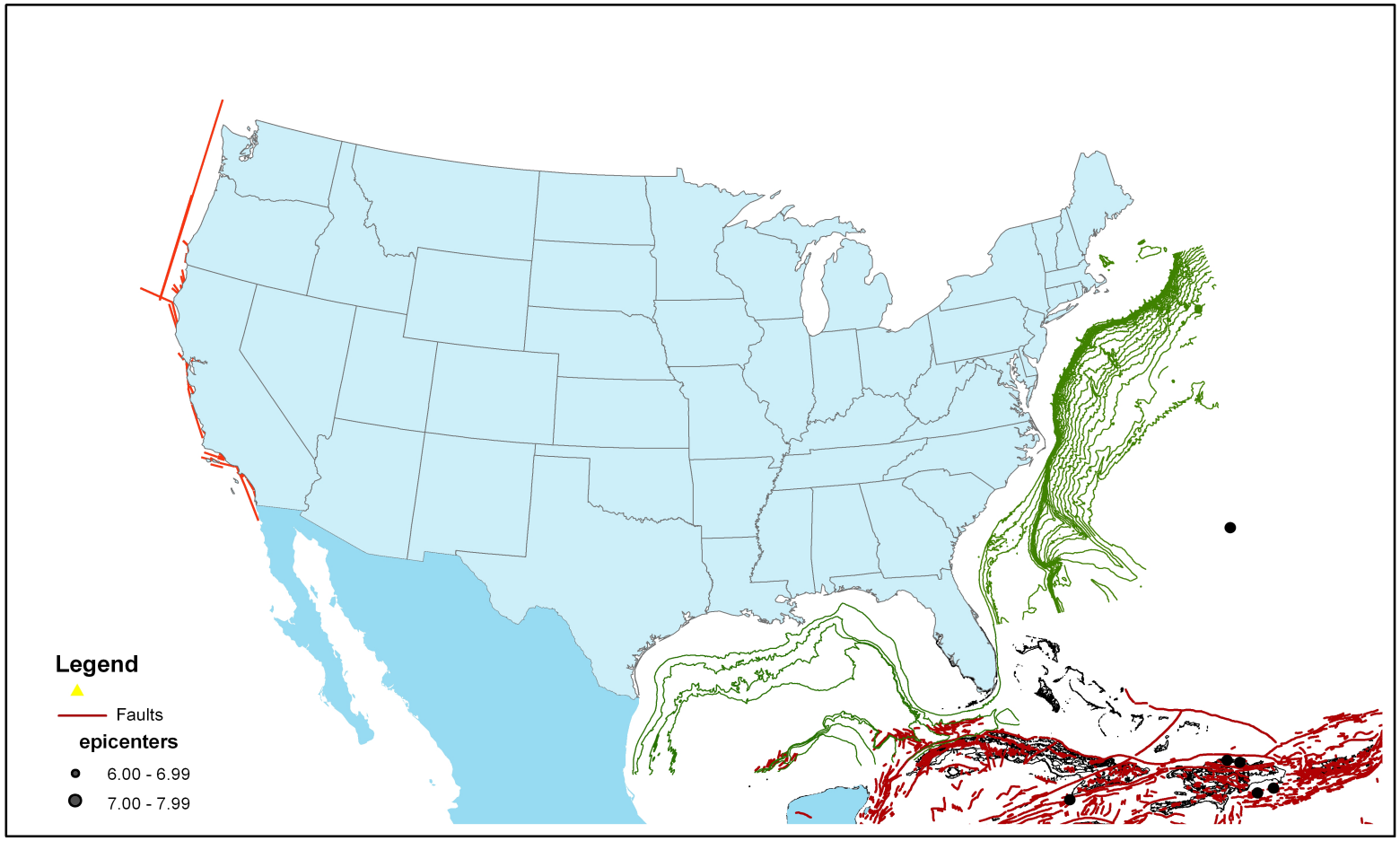
Some Tsunami Sources In East and Gulf Coasts



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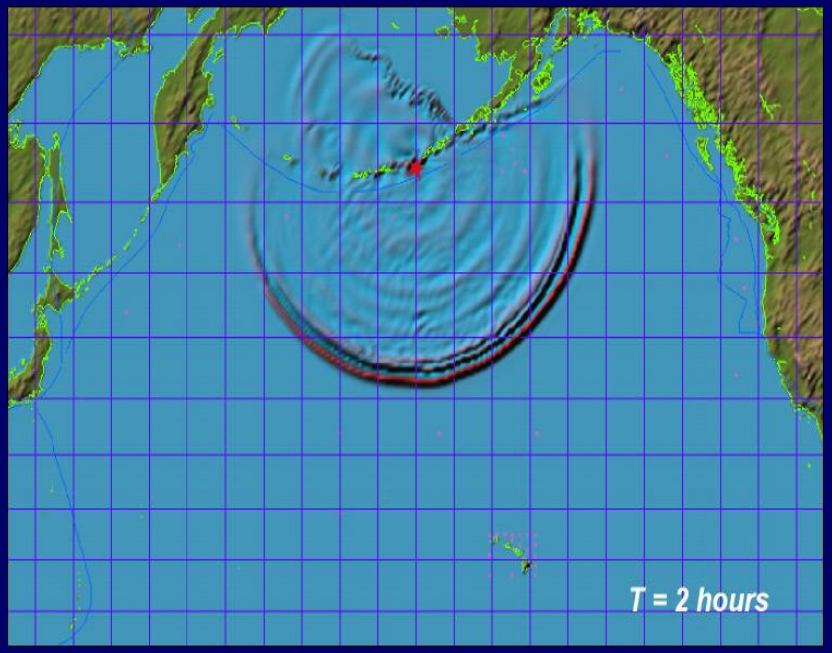
Interacting With Others

- Investigations for tsunami sources should be coordinated with Geology and Seismology related investigations.

Tsunami Propagation and Run-up

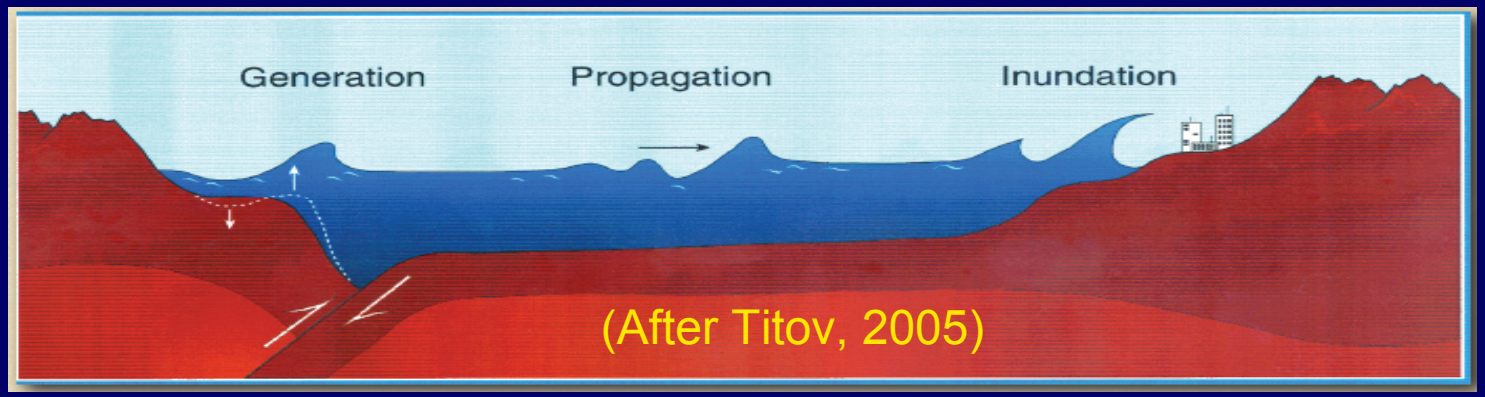
- Concept
- Theories
- Initial & Boundary Conditions
- Parameters & Bathymetry
- Models
- Source of Information



Tsunami Propagation
(from NOAA/PMEL)

Concept

- Wave formation
- Wave propagation: far-field or near-field
- Wave Run-up: inundation and drawdown:
  - Definition: the max. vertical extent of wave up-rush on a beach above the still water level.



Wave Propagation Theory

- Linear long-wave theory
  - For small h/D ratio, use unsteady +pressure terms
- Non-linear long-wave (shallow water wave) theory
  - Unsteady +pressure +advection terms, consider steep slope & eddy viscosity
- Dispersive wave theory
  - Applied when the curvature of tsunami wave increases with propagation
  - Wave dispersion + vertical acceleration

*** Theory used depends on the specific site

*** Should include the Coriolis force and adopt a spherical coordinate system for far-field tsunami

*** Use a 2-D model in general, but 3-D models for (i) a steep slope, or (ii) a small valley acts as a maximum run-up point

Initial Conditions

- The amount of vertical slip of the sea bottom
- Duration of fault movement
  - Assume an instantaneous displacement as a conservative scenario
- Setting the initial conditions
  - Initial water surface is still, and initial water flux is set to zero
  - Then, apply the vertical slip distribution of the sea bottom

(After Titov, 2005)

Boundary Conditions (BC)

- Offshore BC:
  - Free, open boundaries on offshore and both sides
- Onshore BC:
  - Complete reflection condition
  - Run-up front boundary – allow water flux
- Overflow BC:
  - Breakwater, sea dike, seawall revetment

Numerical Modeling

- Model area may be determined based on:
  - The location of tsunami source region
  - Horizontal scale of tsunami
  - Characteristics of submarine and coastal topography
  - Protection structures, etc.
- Spatial mesh grid:
  - The wavelength of a tsunami varies from several hundreds km at offshore to water depth at onshore, thus for the mesh sizes to get accurate computational results
- Key parameters:
  - Fractional coefficients for sea and inundation areas
  - Eddy viscosity coefficient
  - Set a minimum water depth
  - Computing time step

Potential Sources of Data

- Bathymetry data as appropriate:
  - 5-Minute Gridded Earth Topography Data by NOAA/NGDC (1988) for far-field tsunami
  - 2-Minute Gridded Earth Topography Data
  - Use nautical chart, coast guard maps, USACE data for near-field tsunami
- Topographic data in the inundation area:
  - USGS topography maps or DEMs, others
  - Need past topographic data for simulating historical tsunamis

Potential Approaches

- Simple Analytical Equations
  - I-D wave run-up and overtopping
  - USACE's "Tsunami Engineering (1980)"
  - USACE's "Coastal Engineering Manual (2005)"
- Physical Scale Models
  - Example: Diablo Canyon used a 1:45, 80 ftx120 ft scale model to estimate the harbor and breakwater influences on tsunami to confirm analytical model
- Examples of Numerical Models
  - MOST (Method Of Splitting Tsunami, by Titov and Synolakis):
  - TUNAMI-N2 model by Tohoku Univ.
  - U. of Alaska's model
  - ADCIRC finite element model by Baptista and Myers, and others

Sources of Information

- Website
  - http://nctr.pmel.noaa.gov/model.html
  - http://www.ngdc.noaa.gov/mgg/inundation/
  - http://www.usgs.gov/hazards/tsunamis/
  - http://www.tsunamiwave.info/
  - http://chl.erdc.usace.army.mil/chl.aspx?p=s&a=ResearchAreas;20

- Some Technical Publications
  - Camfield, F., "Tsunami Engineering", U.S. Army Corps of Engineers, Coastal Engineering Research Center, Special Report No. 6, Ft. Belvoir, VA, 1980
  - USACE, " Coastal Engineering Manual", EM-1110-1100, Coastal and hydraulic laboratory, U.S. Army Corps of Engineers, 2005
  - JSCE, "Tsunami Assessment Method for Nuclear Power Plants in Japan", Japan Society of Civil Engineers, 2002.
  - Gonzalez et al., "Seaside Oregon Tsunami Pilot Study – Modernization of FEMA Flood Hazard Maps", Tsunami Pilot Study Working Group, Joint NOAA/USGS/FEMA Special Report, 2006
  - Gonzalez et al., "Scientific and Technical issues in Tsunami hazard Assessment for Siting of Nuclear Plants", Draft Report, Science Review Working Group, 2006

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NRC Research to Characterize Tsunami Hazard for the East and Gulf Coasts

Purpose of Research Program:

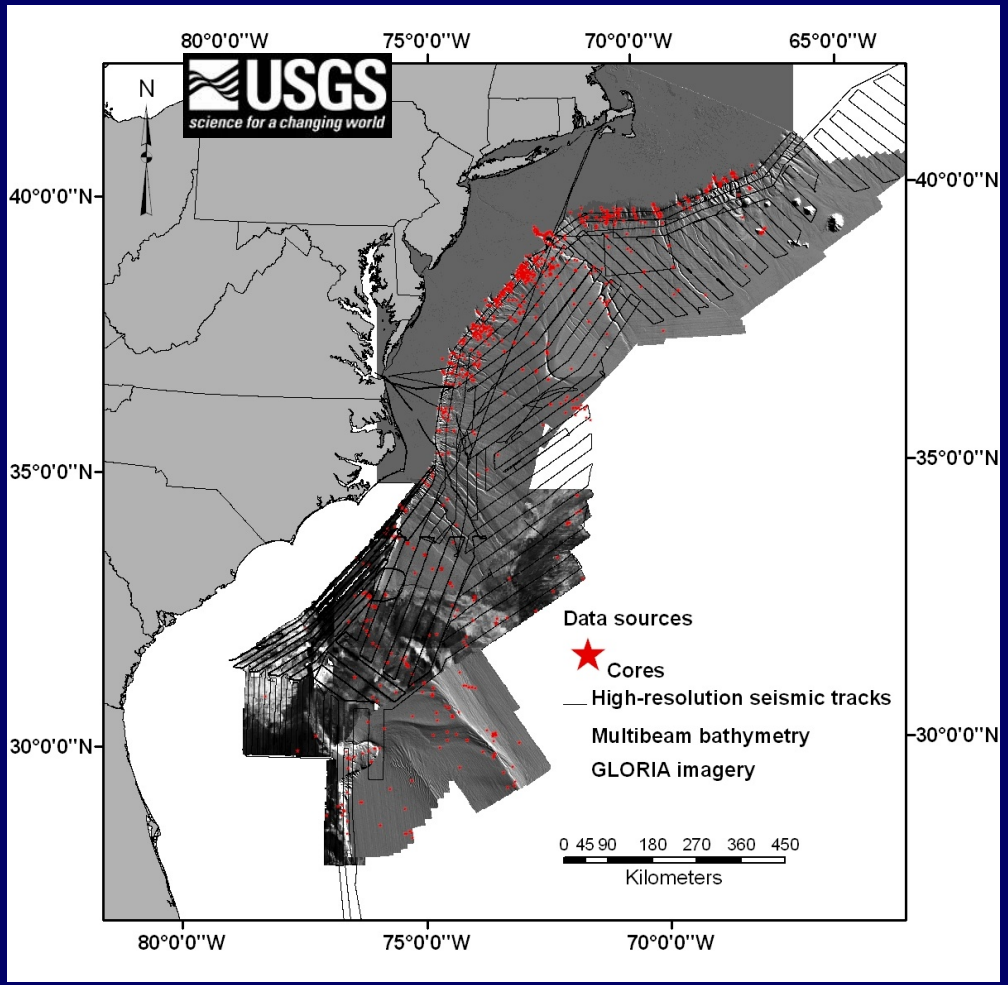
- To develop a source database for review of NPP applications
- To provide characterization of sources for NOAA tsunami modeling
- To investigate potential impact of landslides on tsunami hazard for the east and gulf coasts
- To develop probable maximum tsunami (PMT) using probabilistic tsunami hazard analysis (PTHA) in the long term

NRC Tsunami Research Program

- Research program is composed of two parts:
  - Current work with the USGS focused on developing a tsunami source database (seismic and landslide)
  - Database expected May 2007
  - Future work with NOAA will model the impact of the sources in the database

USGS Study

- Historic information of landslide-induced tsunamis
- Analysis of geophysical maps of coasts
- Analysis of available offshore soil/rock cores
  - Separation of events
  - Dating of events
  - Characterization of soil types prone to slides
- Assessment of known seismic sources



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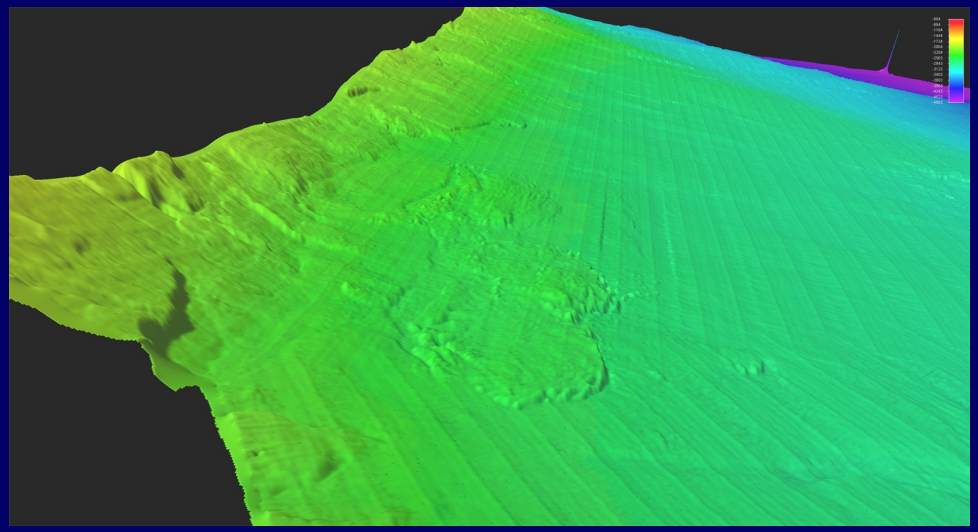
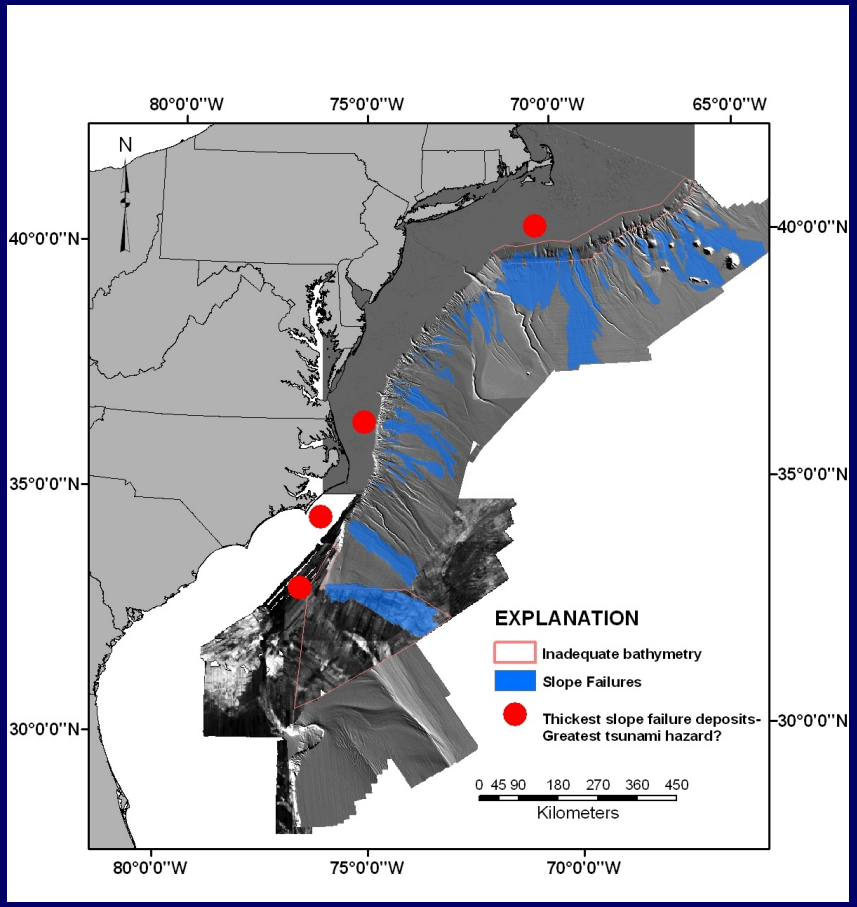
Difficulties include:

- Changes in sea level
- Separating multiple events
- Dating events
- Understanding source regions





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science for a changing world

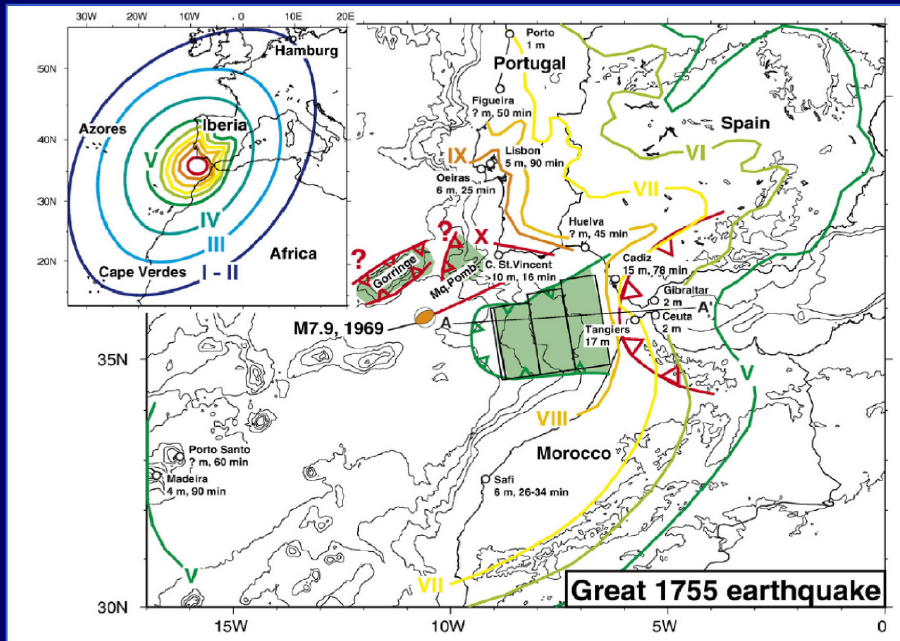
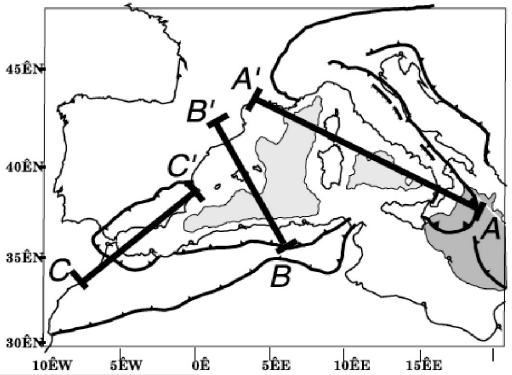
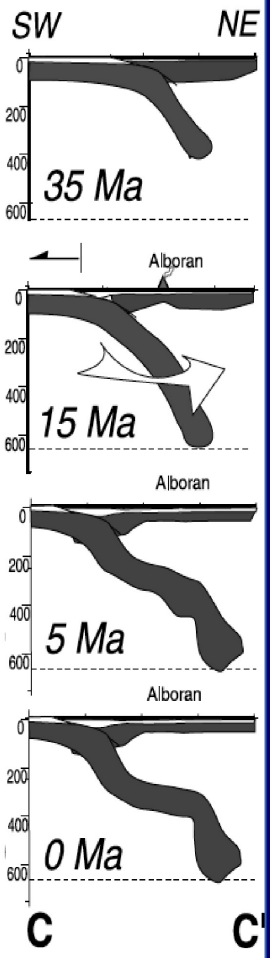


Fig. 1. Isoseismal map of the 1755 earthquake (after Martinez-Solares et al., 1979; Levret, 1991). Inset shows entire felt zone in NW Africa, western Europe and the NE Atlantic (after Johnston, 1996). Bathymetry shown as 1000 m contours (Sandwell and Smith, 1997). The 1969 Cape St. Vincent earthquake occurred on the N60E trending Horseshoe Fault. Historically reported tsunami arrival times and amplitudes are given for cities in the study area (Baptista et al., 1998a).

Gutcher et al., 2006



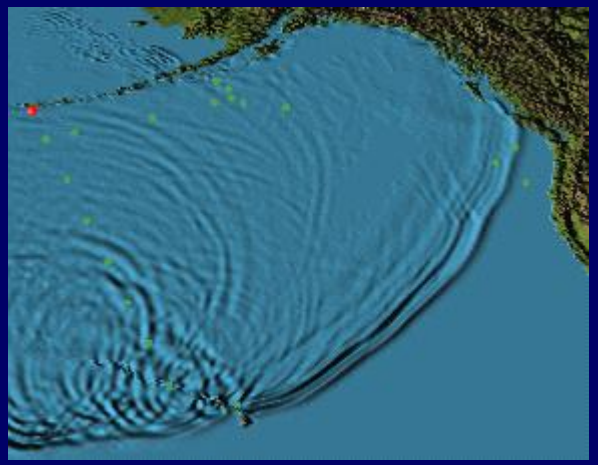


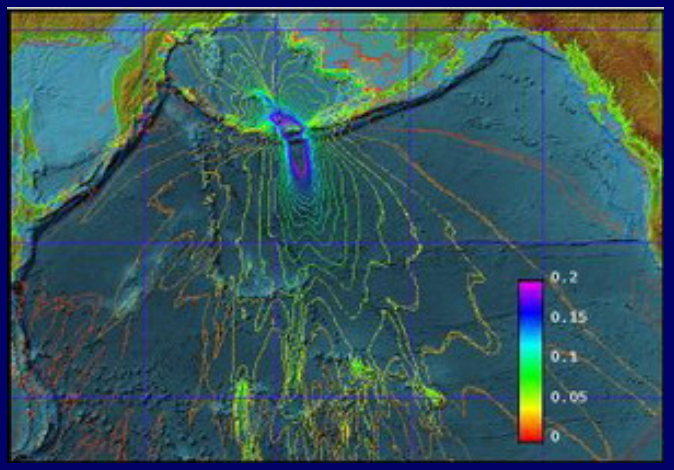
Faccenna et al., 2004

A Mediterranean subduction zone propagating into the Atlantic Ocean: A possible source for the 1755 Lisbon earthquake

Next Step: NOAA Modeling

- NOAA to use UGSG source information to add landslide capability to global (MOST) model
- NOAA modeling addresses “linear” part of PMT and PTHA analyses
- Site-specific inundation modeling performed separately





NRC Tsunami Guidance Development Summary

- Tsunami hazard review update is a comprehensive effort
- Includes SRP and application format update
- Includes technical studies
- Coordinated with National Plan
- Includes research plan to develop source database and PTHA

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NRC Tsunami Guidance Development Summary (continued)

- The draft SRP 2.4.6 is on ADAMS 1-17-2007
- SRP update by March 31, 2007
- PNNL NUREG/CR March 31, 2007
- Importance of prior planning
- Consideration of tsunami hazard element affecting reactor safety

Update to
Tsunami Guidance: Future Reactor Siting

Comments and Discussion

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Update to
Tsunami Guidance: Future Reactor Siting

Meeting Adjourned