TWC Operations: Limitations and Challenges

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TWC LIMITATIONS

- **Why Is There Need to Know Limits?**
  - Helps Guide SOP Development
  - Helps Foster Realistic Expectations

- **Seismic:** Real-time Earthquake Source Characterization

- **Tsunami:** Detection, Forecasting (travel time, wave heights and periods)

- Alert Dissemination
Limitations of Seismic Analysis

- Speed of Initial Analysis Depends On
  - Density of Seismic Network
  - Type and Quality of Seismic Stations
  - Speed of Data Transmission
  - Speed of Seismic Processing
  - Confidence in Result

- Elapsed Time to Initial EQ Parameters
  - 2-5 min with Regional Network
  - 5-15 min with Global Network
Accuracy of Hypocenter (Location / Depth)

- Bias - nearby stations only on one side
- Latitude, Longitude error not so critical
- But depth critical to tsunamigenesis
- Depth constraint poor (especially if shallow)
- Hypocenter is only the point of initial rupture
- Tsunamigenic earthquakes have large source
Limitations of Seismic Analysis

- **Accuracy of Earthquake Magnitude**
  - Rapid methods underestimate great events
  - Magnitude is a very limited representation of earthquake size
  - No magic threshold for tsunamigenesis
Limitations of Seismic Analysis

- **Anomalous Events**
  - Slow earthquakes
    - Traditional magnitudes underestimate
    - Enhanced tsunami potential
  - Landslide tsunamis
    - Smaller earthquake triggers landslide
    - Landslide generates tsunami
    - 1998 Papua New Guinea, Mw=7, >2000 casualties
  - Splay faults
    - Splay fault rupture accompanies main rupture
    - Tsunami generated closer to shore
Slow Earthquake: 2006 Java Tsunami

- Little apparent ground motion
- Large surf, so no clues in ocean behavior
- Death toll 730
Limitations of Seismic Analysis

- **Finite Faults**
  - Fault rupture over large area
  - Amount of slip varies along fault
  - Depth of ruptured fault varies
  - Tsunamigenesis varies
  - Important near the earthquake
  - Not so important for distant tsunami
  - Finite fault analysis too slow for local warning
Fault areas of some famous earthquakes

<table>
<thead>
<tr>
<th>Year</th>
<th>Location</th>
<th>Moment ($10^{27}$ dyne-cm)</th>
<th>Mw</th>
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</thead>
<tbody>
<tr>
<td>1960</td>
<td>Chile</td>
<td>2000</td>
<td>9.5</td>
</tr>
<tr>
<td>1964</td>
<td>Alaska</td>
<td>800</td>
<td>9.2</td>
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<tr>
<td>1906</td>
<td>San Francisco</td>
<td>10  15</td>
<td>7.9</td>
</tr>
<tr>
<td>1946</td>
<td>Nankai</td>
<td>15  15</td>
<td>8.1</td>
</tr>
<tr>
<td>1944</td>
<td>Tonankai</td>
<td>10  15</td>
<td>8.1</td>
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<tr>
<td>2003</td>
<td>Tokachi-oki</td>
<td>9</td>
<td>7.9</td>
</tr>
<tr>
<td>1995</td>
<td>Kobe</td>
<td>0.3</td>
<td>6.9</td>
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</tbody>
</table>

2004 Sumatra
$400 \times 10^{27}$ dyne-cm
Mw 9.3

from James Mori, DPRI
Complicated Slip Distributions

1999 Chi-Chi, Taiwan Earthquake from James Mori, DPRI
Sea Level Measurements are Critical for:

- Tsunami Detection (Yes or No)
- Tsunami Measurement (Arrival Time, Amplitude, Period, Duration)
- Constraining/Tuning Tsunami Forecast
Limitations of Tsunami Detection

- **Speed of Sea Level Measurements**
  - Tsunami must travel to gauge
    - Depends upon density of gauge network
    - 15 min to >1 hr typical to first gauge
  - Tsunami wave must pass gauge
    - Wave periods are 5 to 60 min
    - Need at least ¼ of wave
    - Tsunami is a series of waves
    - Maximum may not be first wave
  - Gauge must transmit data
    - Typically every 5-15 min
Limitations of Tsunami Detection

- **Type of Sea Level Measurements**
  - **Coastal Gauge**
    - Most common
    - Signal highly modified by coastal effects
    - May be destroyed by large tsunami
  - **Deep Ocean Gauge**
    - Less common
    - Most expensive
    - Pure tsunami signal to constrain forecast
Limitations of Tsunami Forecasting

- **Estimated Arrival Time Forecast**
  - Based on initial seismic analysis
  - Point source or assumed finite fault

- **Initial Threat Level Forecast**
  - Based only on initial seismic analysis and general geophysical/oceanographic constraints
  - Least accurate

- **Sea Level Constrained Forecast**
  - Too late for local tsunami
  - Deep ocean measurements best constraint
  - More accurate
Tsunami Travel Times from Small Source
Tsunami Travel Times from Large Source
Limitations and Challenges (1)

- Real-time forecasting is of limited use for local warning. Self-evacuation might be the only way to avoid the loss of lives.

- Real-time forecast is only as good as the EQ parameters. Initial EQ mag can be easily off by 0.2 or more, resulting in a factor of two difference in wave amplitude.

- Method used for determining coastal forecast (Green’s law) amplitude can underestimate harbor resonances and overestimate for small islands. The extent of inundation/flooding cannot be determined from the RIFT forecast.
Limitations and Challenges (2)

- How to make accurate forecast for coastal regions with a wide continental shelf (Thailand, Australia, etc.). Ultra fine resolution might not be feasible in real time. Couple with inundation models or using nested grids to refine coastal forecast?

- Real-time DART inversion is not yet available for RIFT but it is desirable.

- Landslide model (currently simply slump model)

- Asteroid Tsunami

- Meteorological tsunamis
Limitations of Tsunami Forecasting

- **Historical Comparisons**
  - Historical record is very short and incomplete in most areas
  - No repeat events
  - May be okay to identify coastal sensitivities
Limitations of Messages / Dissemination

- **Message Content**
  - Should be simple and to the point
  - Should contain key information
    - Situation Evaluation and Summary
    - Seismic Parameters
    - Predicted Threat Level
    - Estimated Tsunami Wave Arrival Times
    - Key Tsunami Wave Measurements
    - Recommended Actions
  - Tied to SOPs and trigger SOP actions
**Limitations of Messages / Dissemination**

- **Message Dissemination**
  - Disseminate by reliable methods
    - After initial warning, commercial phone lines may go down so no voice or fax
    - Other comms may be out due to earthquake damage
  - Disseminate to responsible 24x7 offices
  - Messages must be recognized and acted upon immediately
Thank You

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