Earthquake Characteristics and Finite Fault Processes: Diagnostics for Tsunamigenic Potential

Alaska is characterized by high seismicity due to the active subduction of the Pacific Plate beneath the North American Plate (~5 to 7 cm/year) and is the most seismically active region in the United States. Great Alaska coastal and Aleutian Seismic Zone earthquakes tend to produce major tsunamis in Alaska, Hawaii, and the west coast of North America. When (not whether) major earthquakes occur, Alaska's coastlines can expect to be flooded within as little time as 15 minutes. The threat does not stop there, as these tsunamis are likely to propagate across great distances with devastating effects on Hawaii and the west coast of the United States as well.

To improve our tsunami and earthquake observations and modeling, Alaska Earthquake Information Center (AEIC) personnel are participating in the National Tsunami Hazard Mitigation Program with NOAA, FEMA, USGS, and the five western states. Observational research will be conducted to improve the quality and quantity of tsunami observations, including both seismic and water wave observations.

Earthquake research is focussed on improving the scientific understanding, and technology, to rapidly evaluate earthquake source parameters that have bearing on the production of tsunamis, i.e., location, source depth, magnitude, sense of motion on the fault, and the rupture extent. Knowing this information will allow us to assess the physical source size for the amount of water displacement due to motions of the sea floor. In the case of a large earthquake, the important quantity for a source that has significant spatial dimensions is the distributed earthquake source area, not the exact point estimate reported as the high frequency hypocenter. Analysis methodologies based on broadband waveforms will open up new opportunities to design earthquake parameter determination schemes for large earthquakes with finite source dimensions. (See Figure 1.)

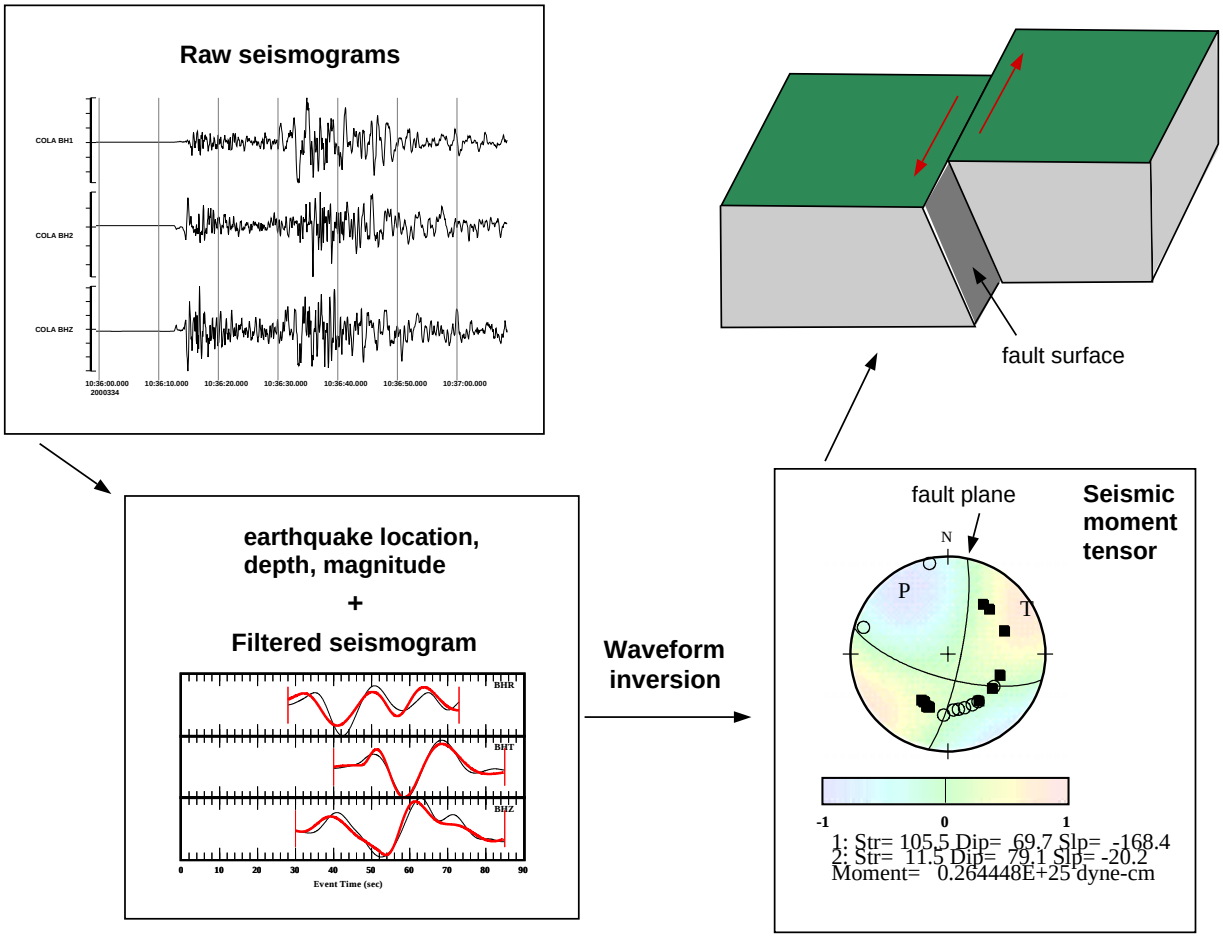

Figure 1. Inversion of the seismic waves for the earthquake source parameters.

Many large and great earthquakes have a very complicated rupture history, which strongly effects the generation of tsunami waves. A good example of this behavior is the 1964 Prince William Sound earthquake. With a rupture length of 800 km there was a large variability of slip on the fault surface ranging from a few meters to over 20 meters and thus a large effect on tsunami generation. (See Figure 2.) The region with the most substantial slip, known as an asperity, is believed to be a strong region on the fault in which most of the strain is accumulated and the largest displacements occur during an earthquake. When a large earthquake occurs in a particular segment of the arc, it will most likely be the asperities in that region that will produce the largest displacements. Knowing the locations of these asperities is a substantial benefit to earthquake and tsunami hazards.

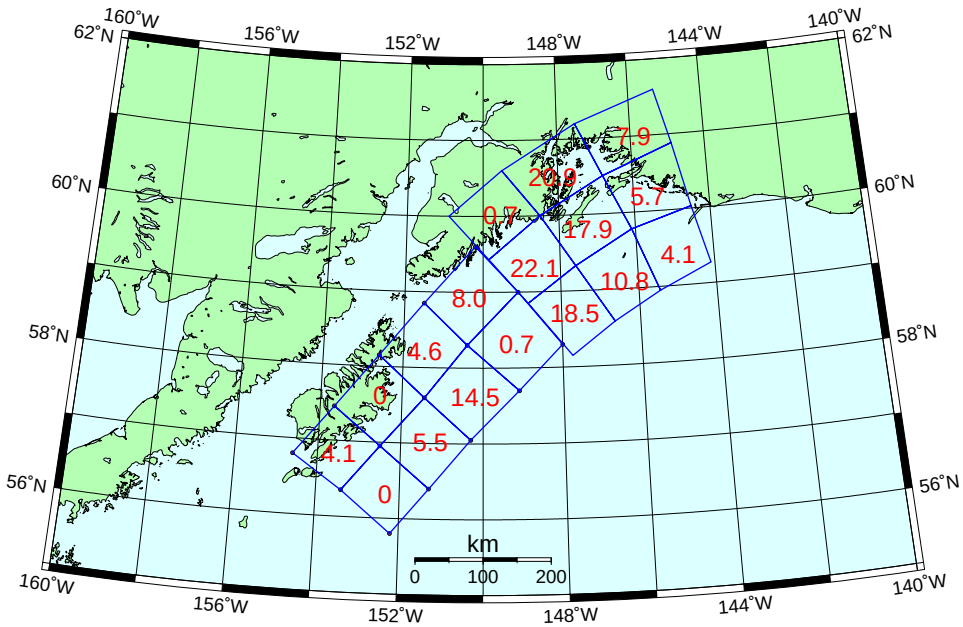

Figure 2. Slip distribution of the 1964 Great Alaska Earthquake.

In the past, the computation of the moment release rate (i.e., source time function) during an earthquake, and finally the detailed determination of slip distribution on a finite faults, has been fairly time consuming and has not been possible on a real time basis. With the help of faster computers and more importantly, real and near-real time data from high quality broadband stations, it is now possible to determine the source time function in near-real time. Simple calculations using the source duration and seismic moment from the source time functions lead to a gross average slip on the fault, in addition to an indication of fault complexity (i.e. multiple ruptures, etc.). This type of information could greatly help produce realistic estimates of tsunami heights and travel times which could be used in hazard assessment.

Given the moment tensor parameters, the source time function, the distributed moment release rate, and the precise location of the earthquake allows for an integration of the seismology results directly into the computation of the tsunami water wave propagation. These parameters are the necessary inputs for determining the distribution of the amplitudes of the “tsunami Green’s Functions” as being developed by NOAA/PMEL efforts and the AEIC inundation team. Once asperities are properly mapped, improved segmentation can be defined for the greens function approach to the tsunami propagation calculation, and the estimated tsunami source amplitudes from the seismological calculations will be straight forward.