Instrumentation for sea level and tsunami measurements

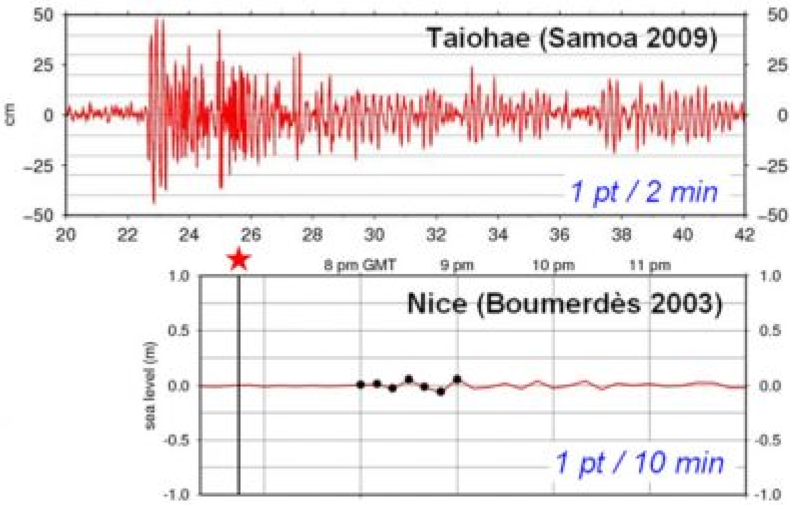

Figure 1: Evolution of the sampling quality of tsunami sea level measurements recorded on tide gauges. Top: tsunami arrival about 4 h after the Samoan earthquake (magnitude 8.1, 2009), recorded in Taiohae (Nuku Hiva Island, Marquesas Islands). Bottom: tide gauge in Nice following the Boumerdès earthquake (magnitude 6.8, 2003). In 2003, the Nice tide gauge had too loose temporal sampling (10 min of integrated data for 5 min) to record the tsunami correctly [Source: © CEA]

On the coast, tide gauges were originally designed to measure ocean tides. They could measure the tsunami waves arriving in the port where the instrument is installed. Historically made up of floats, today they are essentially lidar sensors aiming at the water surface (below).

Historically recorded on rolls of paper, the devices moved to digital recordings at the end of the 20th century. Time sampling to record tides with periods of about 12 hours was, however, often insufficient to record tsunami waves of small period. In the Pacific, the devices installed before 2004 for tsunami measurements were already capable of correctly reproducing the tsunami waveform (see figure below).

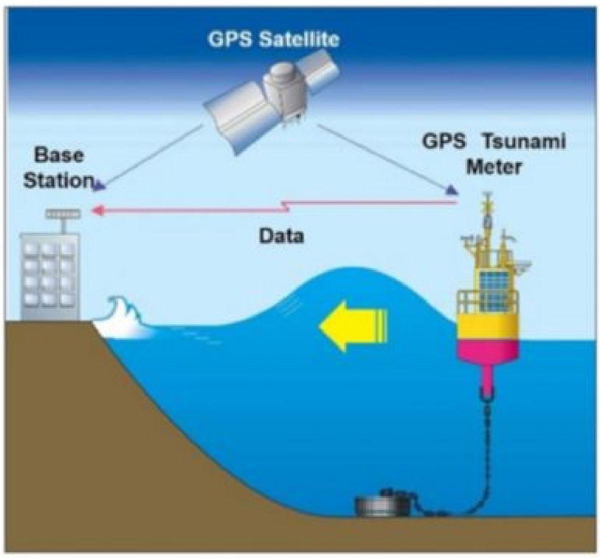

Figure 2. Schematic diagram of sea level measurement using GPS buoys [Source: https://www.hitachizosen.co.jp/english/products/products029.html]

GPS sensors deployed on buoys near the coasts also allow the measurement of tsunami heights at the time of its amplification. Japan has equipped its coasts since the 1990s. These buoys (see below), whose data have been analysed in real time since the end of the 2000s, made it possible to increase the warning level in 2011.

Pressure sensors deployed on the ocean floor were invented by the Americans in the 1980s (DART buoys, [Deep ocean Assessment and Reporting of Tsunamis]) could rapidly measuring a tsunami wavepropagation, with centimetric resolution, and sending the data via satellite via a buoy. Such sensors are also deployed on multi-instrument **submarine cables**, for example off the coast of Japan (below).

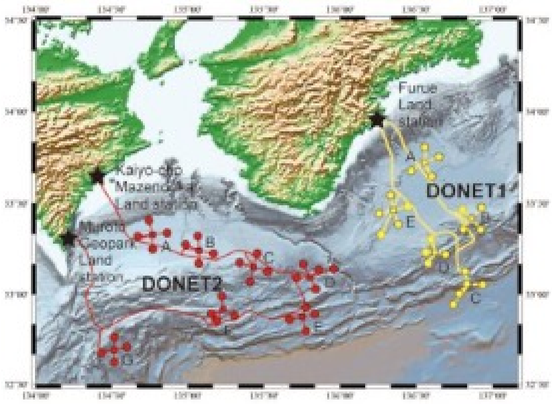

Figure 3. Deployment of multi-instrument submarine cables off Japan. These data are now analysed in real time. [Source: https://www.jamstec.go.jp/donet/e/donet/donet2.html]

Finally, satellite data can be used to hazard map areas (optical, radar) and, rarely, give an indication of the water height at sea (altimetry). The analysis of the variation of the total electronic content of the ionosphere (by GNSS sensors or satellites) can also show the coupled tsunami propagation in the upper layers of the atmosphere, as for earthquakes.
