A Lagrangian Tsunami Observation System Using GPS Buoys and/or Ships

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1. Characteristics of a Horizontal Displacement during a Tsunami

A tsunami is characterized as a long wave when a horizontal wavelength is much larger than the depth of the ocean. A horizontal displacement (HD) of a tsunami exceeds a vertical displacement (VD) by more than a factor of ten. Also, the HD is constant throughout the ocean column. For example, in the case of a tsunami having a VD of 1m in an area 4000m in depth within a period of 30 minutes and wavelength of 356km, the HD is theoretically 14.2 m. It means that any water particle associated with this tsunami undergoes a substantial HD of 30m within the period.

2. Principle of a Lagrangian Tsunami Observation System

Such an HD as stated above can be discriminated if we install GPS technology upon a buoy and/or a ship. That is, it may be possible to trace their position by sampling one second intervals, calculating the HD successively with an accuracy of 1m. Also, when an earthquake occurs, the responsible tsunami center usually issues basic seismological parameters such as seismic center, magnitude and characteristics of a fault, as well as an estimated tsunami height and propagation time for each area.

When a tsunami propagates into an area, an HD of GPS buoy and/or ship will be affected mainly by three components. One is a short period component of several seconds due to ocean waves. The second component may be an ocean current, which is considered to be stationary and linear for one hour or so. The third component is due to the tsunami which has some periodic or transient change with an order of 10 minutes. So, it may be possible to extract the tsunami by filtering the other components and by using the seismic information in a time series of the HD of GPS buoy and/or ship. Consequently, we may observe a tsunami by noting not the VD but the HD of the ocean column with using GPS buoy and/or ship. We call this method HDPP (Horizontal Displacement with Predominant Period).

3. Preliminary Experiments and Analysis

In order to estimate a feasibility of this Lagrangian system, several experiments upon GPS single-positioning were performed at an airport and a port, respectively. Also, an analysis for KGPS on a ship was done. At Yonagunijima Airport, GPS (JAVAD, Lexon-GD) was tested by carrying antenna along NW-SE direction about 25m there and back for several minutes (the upper figure after Sakai et. al). Another experiment was done at Hitachi Port. GPS buoy (NovAtel engine and a Sensorsystem antenna) was draught manually there and back for about ten minutes along WSW-ENE direction for about 40m (the lower figure). These experiments show that the position of GPS can be traced with an accuracy of 1m or so. On the other hand, a wake of a ship (Japan Coast Guard) determined by KGPS shows very fine displacement in three dimensions with an order of 1 cm. These results seem to show promise for the development of an early forecast system, as well as a tool in order to record tsunamis.