Development of Analytical Technique for Observation of Ocean Bottom Crustal Deformation

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We are developing a system for observation of ocean-bottom crustal deformation by using GPS/Acoustic techniques. In the system, we determine the position of a vessel by Kinematic GPS method and measure distances between the vessel and the benchmarks by acoustic ranging. Then we can determine the position of the benchmarks. We have installed several benchmark units to carry out a continuous monitoring of ocean floor crustal deformation in two regions, Suruga Bay and Kumano basin. Each benchmark unit consists of three transponders with certain space distributions. We have carried out the measurement for test study for about 3 years. Quality of the obtained data improved from the middle of 2004 in Kumano Basin and from 2005 in Suruga Bay by reduction of the noise due to the vessels and improvement of installation of the instruments. We can now determine the weight center of the three benchmarks with accuracy of plus and minus 5 cm. In Kumano basin, we detected 20 cm south-southeastward co-seismic movement between two observations before and after a M7 class earthquake [Tadokoro et al. 2005, JEPS]

In our analysis, we assumed that the sound velocity was constant for a given interval and changes between different intervals. This was on the basis that the sound velocity changes by smooth curve with time. We estimated velocity correction coefficient for the each interval and the positions of the three benchmarks simultaneously. In determining the length of interval, longer interval should be suitable for modest velocity change and shorter interval should be suitable for a steeper change. We determined the length of the interval by following procedure. At first we divided the measurement into halves and determined the positions and correction coefficients with various length of the interval for the both halves. Secondly we adopted the length of the interval with which the positions of the benchmarks are determined the closest between two halves. The problem of this criterion is that we adopt wrong positions by error when the both determined positions have the same bias against real position.

So now we are developing a new analysis method using Bayesian approach. We used cubic B-spline functions [Barnhill and Riesenfeld,1974] as basis functions to express the smooth curve of velocity change and determined their coefficients to obtain the best fit curve uniquely and objectively. The smoothness of the coefficients was represented by second order derivative. We searched the hyper parameter which gives the most suitable smoothness on the basis of a Bayesian Information Criterion (ABIC).

To evaluate the performance of the this method and to compare it with present method, we carried out a synthetic experiment. We made synthetic travel-time data using certain velocity models and proper accidental errors with actual vessel positions. We resolved locations of the benchmark units.

The results suggested that the solutions of the benchmarks were better than the solution using the previous method. Degree of the improvement depends on the degree of given accidental errors of acoustic travel-time. According to the synthetic experiment, our observation can achieve better accuracy than the actual measurement achieved. One problem is that the best solutions which give the positions nearest to the given ones do not give the smallest ABIC. The smallest ABIC is given with a hyper parameter which makes the curve rougher in some degree than the best one. We will investigate the cause of this bias and then apply this method to actual data.