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FMM Application to the Slip Response Function Used in EQ Cycle Simulations in a Semi-infinite Elastic Medium.

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At subduction zones, earthquake cycle simulations have recently been executed to understand a variety of slip modes observed in plate interfaces and provided some information on the future earthquakes. For better understanding and getting useful information, it is important to estimate the distribution of frictional propaerties in plate interfaces. To estimate frictional parameters, however, we need a large number of iterations in simulation.
Usually, we need to divide the modeling plate interface into N cells. The cycle simulations require the amount of computation of $O(N^2)$, in evaluating the products of a slip response function matrix and a slip (rate) vector. If the cell size is smaller and the larger regions are analyzed, N becomes larger. Then the memory size is larger, and it takes usually much time to execute iterative simulations. Therefore we need to develop the faster computational method with less memory size to perform iterative simulations for estimating frictional parameters in a large scale region such as the Nankai and the Sumatra and also in a region with very heterogeneous frictional parameters in a variety of spatial scales which requires much smaller cells around meters.

Fast Multipole Method (FMM) is an effective method to compute the N-body interaction problem fast. The contributions from the distant bodies are computed together, and the ones from nearby bodies directly. Putting together the contributions from distant bodies is achieved by making expansion of distance with associated Legendre function. This method has been frequently applied to the problems such as in electromagnetic fields and in astronomy.
FMM realizes the fast computation with O(N). Also the computation memory size becomes small. In order to develop a rapid computation method in the cycle simulation, we evaluated the applicability of FMM in this study.

Application of FMM to the elastostatic crack problem at homogeneous 3D infinite medium is described in detail in Yoshida et al. (2001). We tried to develop FMM expansion in a homogeneous semi-infinite elastic medium. The equation contains the term which we cannot expand. However, about the stress of the dip-direction, when taking the dip angle 0, or when dip angle is not zero but the slip has strike components, we can apply FMM with high accuracy. When the dip angle is not zero and the slip has dip-components, the term which cannot be expanded has the contribution rather large. In this case, we cannot compute with high accuracy with this way.

The subduction zones take the dip-angle of about 20 degrees and the slip has dip-components. In this case, when we neglect the term which we cannot expand, the accuracy compared with the stress computed with Okada (1992) is less good, whereas it is improved than using infinite-solution instead of semi-infinite-solution.

Then, we need to consider another method in this case. Fukuyama et al. (2009) developed a method of computing the stress in a semi-infinite medium at a dynamic rupture simulation, using the infinite-slip response function. According to them, in our quasi-static simulation, we add the

computation of displacements at the Earth's surface, where the stress is free, due to slips on the plate interface. Then we can apply FMM in an infinite medium to the semi-infinite problem even at subduction zones. Compared to the case of applying approximate FMM into semi-infinite medium, this method takes more time, but can get better accuracy. And, in addition, we can treat the complicated geometry of the sea-bottom close to the trench or the trough.

Keywords: earthquake cycle simulation, Fast Multipole Method