PRELIMINARY MODELING OF GLOBAL SEISMIC WAVE PROPAGATION IN THE WHOLE MARS.

G. Toyokuni[1], Y. Ishihara[2] and H. Takenaka[3], [1]NIPR (10-3 Midori-cho, Tachikawa, Tokyo 190-0013, Japan; toyokuni.genchi@nipr.ac.jp), [2]NAOJ (2-12 Hoshigaoka, Mizusawa, Oshu, Iwate 023-0861, Japan; ishihara@miz.nao.ac.jp), [3]Kyushu Univ. (6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan; takenaka@geo.kyushu-u.ac.jp).

Introduction: We construct a numerical scheme to calculate probable global seismic wave propagation for the whole Mars models.

Observation of reliable marsquake and direct estimation of Martian inner structure from such data has been one of the most attractive topics in planetary science for decades. The data from Viking 2 seismometer emplaced on the surface of Mars in the Utopia Planitia region in 1976 is the only observation of marsquakes up to now although, unfortunately, a possible small seismic event was detected during the five months of operation [1]. This episode and much other estimation had shown that Mars is less seismically active than the Earth, but recent study using Martian surface pictures revealed topography suggesting that Mars is still rumbling [2]. Currently, preparation for the Japanese next Mars exploration mission MELOS is progressing, which contains a plan to install broad-band seismometers on Mars' surface [3].

On the other hand, indirect estimation of Martian inner structure has been attempted using various pieces of information such as cosmochemical data derived from the SNC meteorites, and planetophysical data including the moment of inertia, the topography, the gravity field, and the Love number. Especially, Sohl and Spohn [4] had proposed two end-member standard Mars models named "model A" and "model B" of density and seismic wavespeeds distribution in radial direction constructed in order to satisfy certain values of the polar moment of inertia factor and the bulk chondritic Fe/Si ratio, respectively (Figure 1).

Looking back on investigation history of the Earth's interior, our knowledge has been enhanced by mutual progress of observation and numerical methods. Increased enthusiasm for Mars exploration in recent years strongly requires developing a method for numerical modeling of global seismic wave propagation based on our current knowledge of Martian inner structure.

Methodology: We have been developing numerical schemes using the finite-difference method (FDM) for accurate and efficient modeling of global seismic wave propagation through realistic Earth models with lateral heterogeneity. In spite of the ongoing increase of computational performance, full 3-D simulation of global seismic wavefields is still a challenge and far from being a routine tool for investigating the Earth's inner structure using, for example, the waveform inversion. Therefore, in the field of global seismology, a traditional method called axisymmetric modeling has often been employed, which solves the 3-D elastodynamic equation in spherical coordinates on a 2-D cross section of the Earth including a seismic source and receivers under assumption that the structural model is axisymmetric with respect to the axis through the source. It can perform the global waveform modeling with a similar computation time and memory as for 2-D modeling with consideration of full 3-D geometrical spreading although serious drawbacks are involved: structures are restricted to be axisymmetric due to the assumption.

We have succeeded in extending the conventional axisymmetric modeling to treat realistic asymmetric structures and moment-tensor point sources keeping its efficiency [5, 6]. For more realistic simulations, we then enhanced the computation accuracy adopting the so-called effective grid parameters which enables us to accurately consider position of material discontinuity inside the FD grid cell [7], introduced anelastic attenuation [8], and solved problems related to the center of the Earth which is a singularity of wave equations in spherical coordinates [9]. The resulting scheme can provide accurate computations of global seismic wavefields excited from an asymmetric source and propagate through arbitrary heterogeneous, attenuative structures over the Earth's center, with a

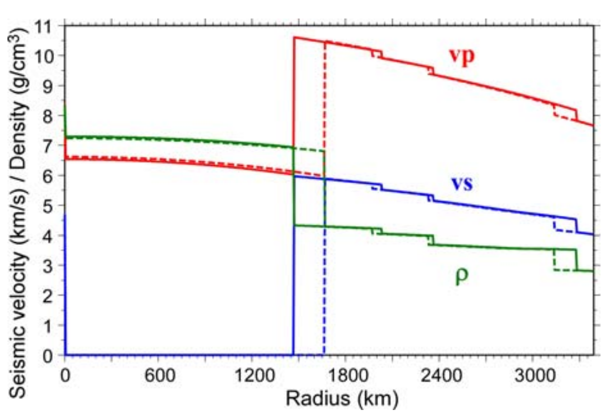

Figure 1. Radial distribution of seismic velocities and density for model A (solid curve) and model B (dotted curve) [4].

small computation requirement comparable to the 2-D modeling. This time we applied our scheme to Martian structure models. Since the radius of Mars is nearly half of the Earth's radius, modeling of Martian global seismic wave propagation requires less computational resources than for the Earth with the same frequency band.

Numerical Examples: As a preparatory stage, we calculate synthetic seismograms for the model A and model B proposed by Sohl and Spohn [4]. Referring to the PREM [10], simple anelastic attenuation is imposed onto these two models with Q for the bulk modulus $Q\kappa$=60000 at all depths, and Q for the shear modulus $Q\mu=\infty$ for the liquid core and $Q\mu$=600 for other regions. We put a 30 km-depth seismic source of a simple dip-slip mechanism with non-zero moment-tensor components of $M_{13}=M_{31}=M_0$ since the most likely seismic events on Mars are considered to be analogous to intraplate oceanic earthquakes due to lithospheric cooling [11]. This time we employ a source time function as a phaseless bell-shaped pulse with width of 60 s which is sufficient for current target frequency range of observation by the MELOS [3].

Figure 2 indicates snapshots of global seismic wave propagation at 3500 s after excitation for models A and B. Large differences between the two Mars models are crust thickness and depth of the core-mantle boundary (CMB): the Model B has thicker crust and shallower CMB. At around the opposite side of the source position, we can clearly see that the model differences strongly affected on rows of surface waves which have already passed through the antipodal point and are traveling toward the epicenter. The surface wave for the model A contains longer coda waves due to the shallower crust.

Recent study using topography and gravity measured by the Mars Global Surveyor had revealed hemispherical variation of crustal thickness [12]. Our scheme can easily treat such lateral heterogeneities. In the presentation, we will show other numerical examples using probable laterally heterogeneous Mars structure models.

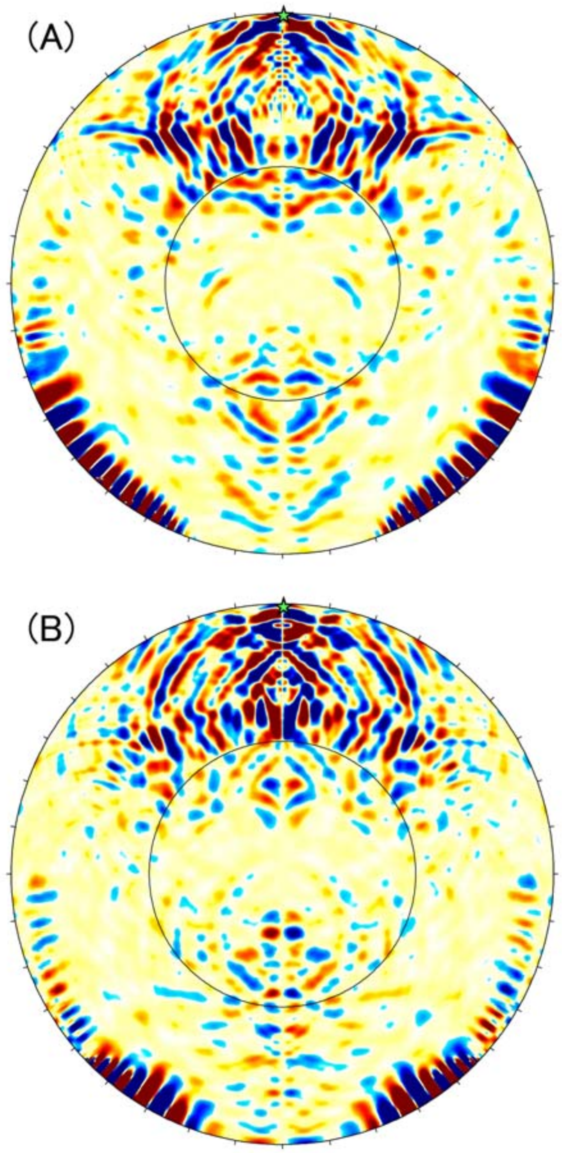

Figure 2. Snapshots of the global seismic wave propagation for the model A (top), and model B (bottom) at 3500 s after excitation. Red and blue denote relatively large positive and negative values of radial component of the particle velocity. The borders of the models are the free surface and the CMB. The source location is indicated by green star.

References: [1] Anderson D. L. et al. (1977) *JGR, 82(28),* 4524–4546. [2] Ferrill D. A. et al. (2004) *GSA Today, 14(10),* doi:10.1130/1052-5173. [3] Kurita K. et al. (2009) *JPGU Meeting 2009,* Abstract #P142-002. [4] Sohl F. and Spohn T. (1997) *JGR, 102(E1),* 1613-1635. [5] Toyokuni G. et al. (2005) *GRL, 32, L09305,* doi:10.1029/2004GL022180. [6] Toyokuni G. and Takenaka H. (2006) *Earth Planets Space, 58,* e29-e32. [7] Toyokuni G. and Takenaka H. (2009) *CAGEO, 35,* 635-643. [8] Toyokuni G. and Takenaka H. (2008) *AGU Fall Meeting 2008*, Abstract #S13A-1785. [9] Toyokuni G. and Takenaka H. (2009) *AGU Fall Meeting 2009*, Abstract #S32A-03. [10] Dziewonski, A. and Anderson, D. L. (1981) *PEPI, 25,* 297-356. [11] Golombek M. P. (1994) *LPSC XXV,* 441-442. [12] Zuber M. T. et al. (2000) *Science, 287,* 1788-1793.