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3D Earth Structure Study since 1980s

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Up until about 1980, the focus of structure study has mainly on the improvement of one-dimensional (1D) structure of the Earth. Use of body waves, surface waves and free oscillation data led to a good, global 1D earth model around 1980, such as PREM (Dziewonski and Anderson, 1981), from which we still get benefit because it remains to be a good reference model for deep structure. Research efforts since then have continuously improved our understanding of three-dimensional (3D) structure and have given us many insights on the deep earth processes in our dynamic earth. We will briefly review the history of development for 3D earth models and discuss current prospects for new developments in the next few years.

When we look back and examine the developments in the past 20-25 years, we note that new developments were always associated with new data and/or new ways of looking at data (analysis). Perhaps the oldest and most powerful has been traveltime delays for body waves. Analyses of ISC data (e.g., Fukao et al., 1992; van der Hilst et al., 1996) and digital waveform data (e.g., Grand, 1994) led us to important (and controversial) questions on the fate of subducting slabs. Analyses of anisotropy also played an important role as they are related to mantle flow ; two approaches for anisotropy, S-wave splittings approach (e.g., Silver, 1996) and surface wave azimuthal anisotropy (e.g., Tanimoto and Anderson, 1985), are now routinely applied for new dense array data to elucidate mantle flows in?various regions. Another powerful approach is the receiver functions (e.g., Phinney, 1964; Owens, 1986) that can identify sharp discontinuities and are now playing an important role in understanding the detailed subduction zone dynamics (e.g., Kawakatsu and Watada, 2007). All approaches have been constantly improving with new flux of data and are helping us to understand the detailed dynamical processes.

What are then happening right now and where are we going in the next few years? In addition to further (incremental) developments of the above ideas, I would argue that the use of seismic noise and array type data analyses will lead us to new developments in seismic structure.

Use of the Green function approach, first introduced to seismology by Campillo and Paul (2003), is clearly making impact for retrieving crustal and mantle structures. There is no question that the upper mantle will be revised from the use of noise in a few years. However, there are still controversial aspects in the technique, especially on accuracy of waveforms (e.g., Tsai, 2009). Careful analysis is clearly required before including such data for structure retrieval. Undoubtedly, there will be many efforts on this question to resolve these problems.

Array analyses of seismic data have been around since late 1960s but opportunities for the application of this technique dramatically increased over the last 10 years, as there are so many dense installation of seismographs. In some cases, combination of noise data and array analysis is giving us a new approach. For example, it is now possible to track hurricanes in the ocean by array analysis and P-waves from such sources seem to be useful for teleseismic structure study. In many cases, sources are in the ocean away from plate boundaries and thus provide rare seismic signals from oceanic sources, complementing natural earthquake data.

Keywords: three dimensional structure, seismic wave, tomography, mantle dynamics, crustal dynamics