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論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Long Period Teleseismic Phase Picking Based on Machine Learning and Seismic Structure of the Earth ’ s Mantle
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

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（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Departmen of, Graduate major in	地球惑星科学 系 地球惑星科学 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 理学 ）
学生氏名： Student's Name	Jun Su	指導教員（主）： Academic Supervisor(main)	Prof. John W. Hernlund
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文800語程度）
Thesis Summary (approx.800 English Words)

This thesis explores the novel use of machine learning techniques in enhancing the understanding of the Earth's mantle structure through seismology. The Earth's mantle, extending from just beneath the crust to the outer core, is crucial for understanding geodynamic processes, such as plate tectonics and geomagnetism. Traditional seismic methods face challenges due to the sheer volume of seismic data generated by global seismic networks. Machine learning (ML), with its capacity to handle large datasets and identify complex patterns, offers a new approach to overcoming these challenges in global seismology. This study addresses longstanding questions of thermochemical heterogeneity and wavefront healing effect in interpreting seismic observation for mantle structure by utilizing ML and other advanced computational tools to process vast amounts of seismic data efficiently and accurately.

Early seismic tomographic models were actualized by digital teleseismic travel time observation of the first-arriving seismic primary (P) and secondary (S) waves, simplifying the wave propagation within the Earth as an infinitely narrow ray. These early techniques, while groundbreaking, were limited in their ability to resolve fine-scale structures due to their reliance on simplified assumptions and limited data types. With the development of high-quality digital broadband seismic networks, seismic tomography has made significant strides. The integration of various seismic phases has enhanced model resolving power, and the advent of full waveform inversion (FWI) has revealed complicated structures and phenomena. Despite these advancements, the computational intensity of FWI remains a significant challenge. The inversion process requires tremendous computational resources for accurate forward modeling of the seismic wavefield and iterative inversion to minimize the misfit between observed and synthetic waveforms.

This thesis leverages machine learning techniques to tackle these challenges, focusing on developing a scalable, robust, and statistical phase picker that can handle large-scale seismic datasets with high precision and efficiency. The novel ML architecture of Transformer is capable of understanding the context of arrival phases in the waveform data through its hierarchical attention mechanism, which significantly improves the detection and measurement of seismic wave arrival compared to previous ML methods. This ability has proven particularly valuable in creating comprehensive earthquake catalogs and seismicity maps by effectively detecting smaller events with weaker signals near the seismic stations or on a regional scale. Nevertheless, this thesis is the first study focused on a global scale for long period P and S wave arrivals to shed light on the nature(s) of large-scale structure such as large low shear velocity province (LLSVP) and subducted slabs.

This thesis introduces the Global Long-wavelength Body-wave Catalog (GLoBoCat), which demonstrates the efficacy of the ML phase pickers in accurately selecting both P and S arrivals without requiring a predefined velocity model or synthetic waveform calculation. The GLoBoCat, combining mutual P and S long period arrivals in the same source-receiver pairs, serves as a valuable resource for comparing with its high frequency counterparts and developing better-informed thermochemical models of the Earth's interior. Our hypothesis tests completely rule out the alternative explanation of uncoupled change between P and S velocities with wavefront healing effect or relative resolution for the first time, suggesting that variations in both temperature and composition/phase are required to explain the seismological observation for the lower mantle. Additionally, the probability of ML picking results is also estimated, allowing further applications of modern statistical inversion methods, such as Bayesian inference and Physics-Informed Neural Networks (PINNs), to utilize the vast amount of data across the globe and derive a probabilistic, meshless, four-dimensional description of the Earth' s interior.

This thesis provides an interpretive tool for velocity structure in seismic tomography, as we call "cross-filtering," by utilizing singular value decomposition (SVD). We obtain resolution operators for P and S waves and apply one resolution to the other tomographic model to map the uncoupled change in P and S velocities. The result shows that the significant differences in P and S velocities cannot be explained by coverage alone and mark a few volume percent of the mantle to be large uncorrelated moduli province (LUMP). We investigate the possible nature of LUMP by discussing mineral physics in two geodynamic scenarios of primordial material and recycled slab. We also examine the primordial material case by implementing tomographic filtering to the mantle convection models and comparing them with the seismic observation.

備考 ： 論文要旨は、和文2000字と英文300語を1部ずつ提出するか、もしくは英文800語を1部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (English) or 1copy of 800 Words (English).

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