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Associate Professor Junosza-Szaniawski
Deputy Research Director
Institute of Geophysics
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Dear Dr Junosza-Szaniawski,

Thank you for the invitation to serve as a reviewer for the Habilitation of Dr. Andrzej Górszczyk. I am pleased to be able to provide my assessment of his submitted and thematically related body of post-doctoral work entitled "Seismic methods for the reconstruction of high-resolution regional geological models and their application to various types of data from the Nankai subduction zone in Japan". I have carefully read the summary of his scientific accomplishments and the four accompanying papers, which were all published in highly ranked international journals; Journal of Geophysical Resarch (JGR): Solid Earth is particularly well regarded in North Amnerica and beyond. I assess the work of Dr. Górszczyk to be of a very high quality that exceeds the level required for award of the Habilitation degree.

Dr. Górszczyk has focussed primarily on the development of cutting-edge algorithms related to the extraction of quantitative elastic properties from various types of active source seismic data using full waveform inversion (FWI), but he has also devoted significant effort to the interpretation and understanding of the higher resolution results available using these techniques. Though the mathematical framework for FWI was first presented in the 1980s, the method was at first not widely adopted due to its high computational cost and the requirement for seismic data acquired with high spatial sampling. With the increase in available computing resources over the last two decades, however, use of FWI has grown rapidly, particular in the hydrocarbon exploration industry. Software for the forward modelling and various inversion approaches have been developed by several workers, but the practical success of the method with noise-contaminated field data depends on the solution of

challenging problems, particularly the selection of the starting model for the necessarily iterative inversion. By initially working with Stephane Operto, one of the long-established leaders in theoretical FWI, and the SEISCOPE consortium, Dr Górszczyk has been able to make important improvements to the algorithmic approach, which is why his 2021 paper was highlighted by the Editor of Journal of Geophysical Research, and he has also extracted valuable new insights into the Nankai subduction zone that are greatly valued by his collaborators at the Japan Agency for Marine Earth Science and Technology (JAMSTEC).

The work presented by Dr. Górszczyk for his Habilitation represents a logical sequence of related developments over a period of approximately six years, beginning with significant improvement of the acoustic frequency domain inversion FWI codes originally developed by Dr Operto and the use of a novel approach incorporating slope tomography into the estimation of the starting model. The choice of the starting model remains critically important in FWI, because if this model is too different from the actual model the inversion will be unsuccessful, and produce a misleading result. Many workers derive the starting model using first arrival tomography (FAT), because these refractions can be easily identified, but unfortunately such FAT models are often insufficiently accurate to drive a higher resolution FWI towards the correct final model. Dr Górszczyk's addition of slope tomography aims to fit the apparent velocities of arrivals as wells their times in order to better constrain the final model, bringing it closer to a model that can be used for FWI. Many algorithm developers are content to demonstrate their methods on synthetic datasets, but Dr Górszczyk chose the more difficult challenge of a field dataset from the Nankai subduction zone. The higher resolution of Dr Górszczyk's final velocity model relative to the starting model is clear, but the accuracy of the final model is often more difficult to assess. By using this velocity model to depth migrate the multichannel reflection survey acquired coincident with the wide-angle ocean-bottom seismometer (OBS) survey, Dr Górszczyk has shown the close correspondence between two results derived by different methods from different datasets (prestack depth migration vs. FWI), and been able to reveal the location of the subduction megathrust and the overlying splay faults that flatten into it. It's important to note that acoustic FWI yields the P wave velocity found in these structures, which is important for understanding their geological and petrophysical properties, e.g. pore pressure.

Due to their great importance, estimation of the starting model and modification of the FWI methodology are areas of very active current research, both in industry and academia, with many different approaches developed and tested with mixed results. Dr Górszczyk has made a valuable contribution by using Graph-Space Optimal Transport to improve the convexity of the FWI objective function in carefully selected time windows such that it has a well-defined global minimum and no local minima that result in convergence to an incorrect result. The significance of this work is that it is, in theory, possible to avoid the problem of finding the starting model, because (almost) any starting model will produce convergence to the desired result. The successful use of a 1-D starting velocity model for 2-D FWI, after careful modification of the algorithm, of both a complex synthetic dataset and the Nankai OBS field dataset is a dramatic and impressive result, which is why it was highlighted by the Editor of JGR: Solid Earth. Dr Górszczyk's generation of the sophisticated 3-D anelastic parameter model of a subduction zone is also important, because it provides a sophisticated model that can be used to evaluate the limitations of different FWI methods in a controlled fashion, for example acoustic inversion of anelastic datasets and 2-D FWI of data from a 3-D subsurface model.

Dr Górszczyk carried out much of his methodological and algorithmic development work in cooperation with members of the internationally recognised SEISCOPE consortium at Geoazur in the south of France and the Université de Grenoble, with whom he clearly has very strong working relationships. The crustal-scale OBS field survey from the Nankai subduction zone is one of the few academic datasets amenable to FWI, and by collaborating with scientists at JAMSTEC, he gained access to these data and worked with experienced researchers there on interpretation of his higher resolution results. Dr Górszczyk has clearly established himself as an internationally recognised researcher, which augurs well for his future work at the Institute of Geophysics.

Dr Górszczyk has been successful in obtaining the funding to establish his research group and support student(s) at the Institute of Geophysics. He maintains strong collaborations with some of the most esteemed scientists in his field. His work is at the cutting edge of crustal seismology, and at a similar level to the top early career international researchers in his field. I can say that without a doubt, Dr Górszczyk has a very impressive, high quality body of post-doctoral work, and his focused efforts on developing and improving the FWI methodology has significantly advanced the field.

Sincerely,

Andrew J. Calvert
Professor
Department of Earth Sciences