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Geoscientific Model Development Discussions
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# *Interactive comment on* "GO_3D_OBS – The Nankai Trough-inspired benchmark geomodel for seismic imaging methods assessment and next generation 3D surveys design (version 1.0)" *by* Andrzej Górszczyk and Stéphane Operto

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Rie Nakata

The manuscript describes about novel model development efforts based on the authors' previous works in the eastern Nankai Trough. The paper is well written and mostly easy to follow. The developed model will be useful for the community including the model developing methodologies. I found two components are missing:



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Discussion paper

i) comparisons of waveforms to observed ones : are the waveforms representative enough? , ii) comparisons with drilling efforts or onshore proxy sites for physical properties. Some discussions will be useful.

**Dear Rie,**

**Thank you for your positive assessment of our work and for your constructive comments. Please find hereafter our answers.**

**Best regards**
**The authors**

It is fine to build a model with a focus on multiparameter FWI – but slightly differs from title (imaging). You start FWI as "velocity building" which is typically different from "imaging". You may want to clarify these points and perhaps add "FWI" in abstract. Can the authors discuss if we can simulate 3D reflection dataset (as in Kumano) using the model and test various imaging methods too? Are the grid sizes etc sufficient?

**In the context of this study, imaging should be understood as any procedure for estimating the earth's rock parameters from seismic data - including traveltime tomography, migration-based velocity analysis, migration and full waveform inversion. This term has therefore a broader meaning than what is typically behind the "imaging" term referring to migration-like techniques only, which are mostly used in exploration geophysics. We will put more emphasis on this terminology issue in the manuscript to prevent misunderstanding and distinguish velocity model building techniques from migration techniques in addition to all-at-once**

**approaches as full waveform inversion.**
**Simulating 2D or 3D reflection dataset with a 25m grid interval to test migration techniques is of course possible. In fact, we already did some tests in 2D using a profile of the GO_3D_OBS geomodel (AGU abstract Sambolian(2019), SEG abstract Alashloo(2020)). On the original grid (25 m) with acoustic approximation, accurate and stable modeling is possible up to frequencies 15 Hz - 20 Hz (depending on the accuracy order of the stencil). To allow higher frequency content or elastic modeling, one may need to resample the model on a finer grid. We decided to define the original model version using 25 m grid to avoid extremely large volume of the files containing the model (132 GB per parameter using 25 m grid)**

There are numerous drilling efforts in the subduction zones and field sampling in proxy sites, including those off the Kumano-nada region of the Nankai trough. The physical properties (and so on) should reflect the results. Please add comments on how your model leverage these efforts.
Eastern Nankai?: Kingston's work is off Kumano and thus not eastern Nankai. As your structural model significantly depends on his work, I suggest to remove specific reference to "eastern" and add references of Kumano too.
The authors describe very lightly about applicability to other subduction zone studies. How much does the model applicable and what sense? Is the model applicable to erosional margins? Or the procedure used to build a model? Adding more references is also important.

**We agree that drilling provides useful information about the physical properties of the subsurface. This information, however, can rapidly change between nearby drilling sites across the same margin (for example a single segment of the Nankai Trough) and is mainly shallow (down to**

**~1 km below the sea floor). Moreover, the resolution of the drilling logs is much higher compared to the scale of the structures that we incorporate in the model.**
**As mentioned by the second reviewer, we were referring too specifically to the eastern-Nankai Trough region in the original manuscript, while our overall goal is to provide a representative complex crustal-scale benchmark model of subduction zones by gathering useful information from different areas (while maintaining geological consistency). Therefore, we want to stress that our goal is not to build a geomodel of a specific area.**
**Accordingly, we indirectly take benefit from drilling information through the Brocher's relations, which gather informations from different geological environments coming from either numerous field or laboratory measurements. This allows us to combine geological features from different subduction zones (including Kumano accretionary prism interpreted by Kingston - we will mention Kumano-nada region in the manuscript) with the aim to make the structure as realistic and complex as possible. However, the scales and shapes of those structures are necessarily modified and therefore they cannot represent accurately the subduction zone of a specific area.**
**At the beginning of Section 2.1 *Geological features* we write:**
**"*The overall geological setup of our model is mainly (but not only) inspired by the features interpreted in the Nankai Trough area. However, these structures can be also found in different margins around the world combined in various configurations. Therefore, our model is not intended to replicate a particular subduction zone and its related geology for geodynamic studies of the targeted region. On the contrary, it was designed to comprise broad features one may encounter in these tectonic environments.*"**
**The purpose of this study is therefore to provide a realistic crustal-scale**

**geomodel to test any seismic imaging methods that may be useful at this scale (tomography, any kind of migration, FWI) and related issues as survey design, high-performance computing issues etc. etc. We choose subduction zone for its geological complexity, the associated variations of the physical parameters, and the fundamental issues related to the better understanding of the structural factors controlling the rupture process of a megathrust earthquake at seismogenic zones. Recent imaging works performed by ourselves in this setting provide us the initial guidelines and inspiration to perform this study. We afraid that it might inappropriate to study a particular erosional margin with our geomodel, although some other inferences regarding e.g. resolution analysis of FWI from wide-angle OBS data or crosstalk between parameters during multi-parameter inversion, might remain valid to first order. Indeed, nothing prevents building such an erosional margin model or any other model for specific studies using the approaches we presented in the manuscript.**

are there specific problems encountered in previous FWI/imaging works apart of scaling issues? For example, as seen in Park et al (2010) and addressed in Kamei et al. (2012), low velocity zones were problematic for MVA and subsequent earthquake fault imaging was really a problem (perhaps blank accretionary prisms) – the authors rightly mention "trapped" waves etc. Adding imaging/inversion issues for (specific) important geological features will be helpful (and if they are incorporated into).
"deep" targets: what do you mean by deep targets? Perhaps you can be more specific?

**Of course, the dimension of the target is one issue - especially from the high-performance computing (HPC) viewpoint (indeed, each user can extract any target from the full model to focus on specific areas of the**

**model). In the manuscript, we review several methodological issues that could be investigated with our model: optimal survey design and sparsity-promoting regularisation to deal with sparse acquisitions; initial velocity model building for FWI; detrimental effects of out of plane wavefield propagation during 2D imaging; nonlinearity of the FWI and design of robust misfit function to mitigate cycle skipping, resolution analysis, multi-parameter imaging, ... On the structural side, we try to incorporate most of the geological features at different scales that have been documented in subduction zones, including underplating of crustal sheets, complex thrusts and folds in the accretionary wedge, thrusts with damaged zones, steep and mild faults in the subducting oceanic crust, sedimentary basins, thin subduction channel with heterogeneous lateral properties, duplex, ridges etc. Those structures, which should generate wavefields whose anatomy is similar to those recorded in the field, can raise different challenges depending on the applied technique, acquisition design and physics approximation.**
**Thank you for bringing our attention to "deep targets". We shall be more specific. By deep we mean the targets which cannot be precisely reconstructed using the data acquired with typical streamer length - $\sim$6 km. We edit the manuscript to be more precise.**

Great to see a range of different modeling efforts. Some motivational statements will be helpful: Why do these modeling important? Are you recommending to generate 3D (visco-)elastic spectral-element waveforms and apply a method of imaging/inversion? Are you going to make these waveforms available as "datasets" as done by BP/Chevron etc?

**Thank you for this suggestion. We will underline the importance of**

**different modeling approximation.**
**In Section 4.5 *Further development* we mention:**
***"On the other hand, generating accompanying dataset for the current models can further broaden its impact. Possible dataset could include sparse 3D and dense 2D OBS deployments, as well as corresponding streamer data. Such dataset could be directly use for a given type of processing."***
**Therefore, it is true that we plan to release such open-access datasets in the future. We already did some tests with 2D OBS and 2D MCS data - including modeling, depth-migration and acoustics, visco-acoustic and elastic FWI techniques. We need to check very carefully the accuracy of the wavefield simulations for different physics before making datasets, preferably OBS and MCS, available for the community. We need also to define several representative targeted area (2D and 3D) in terms of location and dimension such that a user can select the most suitable one for his study (which can be geologically- or methodologically-driven).**

Interwoven OBS gathers are nice, but some of the authors descriptions are difficult to follow (esp. 2D vs 2.5D vs 3D) unless scrutinizing those plots. The authors should add arrows (e.g. Pn waves or representative off-planer waves). Also it would be easier to understand "complexity" if the authors show 2.5D snapshots along with 3D snapshots.
Please add amplitude spectrum and amplitude-vs-offset curves to show the spectra esp. for pure vs visco acoustic simulations to quantitatively display the discrepancies.
Please add comments on whether/how much the modeled waveforms represent the observed waveforms (e.g. in eastern Nankai) to convince the model is representative.
A word for choosing spectral element at the start of section 3.3 will be beneficial rather than at the end.

**We augment the figures to make them more exhaustive. We also provide the insight into example of the field OBS gather.**
**Considering all of the pros and cons of the spectral element modeling engine, we decide to use the SEM46 code developed in the framework of the SEISCOPE project since it allows us to perform elastic modeling in marine environment with a high accuracy and an adaptive mesh, while avoiding the detrimental staircase effects of the finite-difference method at the sea bottom.**

The authors discuss about benefits to FWI/tomography/acquisition. How does the model help imaging? How the model help bridging imaging and tomography gaps?

**In the Introduction, we mention how high resolution velocity reconstruction methods like FWI applied to the OBS data can produce the background velocity models for the migration of the MCS reflection data. Moreover, the high-resolution FWI models can be jointly interpreted with the reflectivity section making the interpretation more valid (Górszczyk et al. 2019). Therefore, establishing robust FWI approaches for the processing of OBS data using synthetic tests can mitigate the resolution gap between tomography and migration.**

small scale perturbations "disk-shaped structural elements": what do these who geologically? What do they need to overlap?

**We use the primitive disk-shaped SE with variable magnitude, since it is easy to control its spatial-scale ratios. This gives a certain level of control on the size and the shape of the final small-scale perturbations. They**

**overlap to avoid introduction of artificially looking disc shaped anomalies. Through their dense spatial positioning and stacking, we obtain a random/noisy background perturbations as presented in Figure 6a.**

Figure 1: Is the figure necessary? I do not know if any outside FWI community understands the figure without further expanding the descriptions. The manuscript is about model not FWI. I think the figure is unnecessary.

**We agree that Figure 1 might be addressed to the FWI expert. However, since the manuscript is also about how to use the model to assess methods and design survey geometry, we believe it makes sense to mention the theoretical guidelines that may be followed to perform this assessment. Therefore, we keep the Figure 1 as it is.**

Figure 2: Add meanings of the lines in Figure 2a in the caption.

**We edit the caption.**

Figure 5: Perhaps add a vertical profile?

**We present vertical inline profiles.**

Figure 6: c-f: what are numbers on the top left? "Red/blue colours indicate: : :" is difficult to follow.

**We edit the caption.**

RMS: is not defined.

**We explain the abbreviation.**

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