Dear Editor,

We are glad to receive the review report and would like to express our sincere thanks to you and the reviewers. Without the constructive comments from the reviewers, the quality of this manuscript cannot be significantly improved. All the comments and suggestions have been carefully considered to revise the manuscript. Detailed reply to all comments and the associate manuscript modifications are given below.

Comments from the reviewer #1

1. First, as I said in my initial review, I'm still confused as to why the model being used has so many seemingly extra processes unrelated to the problem at hand. For example, why was sediment and the processes of erosion and sedimentation included? Why was plasticity included if faulting and fracturing are not important to the system evolution? Why was melt transport and crustal accumulation included? My general question regarding the all of the above is "what is the goal of adding these processes and how do they affect (or not) the results?" Most importantly, in the current draft the authors do not demonstrate how the above processes affect their results. I suppose that it is possible that all of these are essential to the problem the authors are examining. Yet, even if they do not affect the results, I think the authors should demonstrate this to the reader – otherwise the paper ends up being difficult to interpret with certainty.

Reply: The reviewer questioned our model with "extra processes". We appreciate this comment, but we disagree with the reviewer. We disagree that a simplified model is better than a sophisticated model. Actually, the "extra processes" (e.g., sedimentation/erosion, plasticity, and melt processes) used in our model are the basic elements in the sophisticated numerical codes in the geodynamic community. Our mode is deal with large scale geodynamic processes (i.e., plume migration and mid-ocean ridge spreading), and some of the processes as the reviewer mentioned may not be the first-order controls, but they are important and one should not exclude. For instance, we keep sediments above the crust, because it represents the real geological background since the ocean crust is indeed covered by sediments.

Although we do not emphasize faulting and fracturing which are related to plasticity, we do see the effect of plasticity in the oceanic plate above the arising plume (through strain rate field). Furthermore, the processes of melt transport and crustal accumulation are important features of plume-lithosphere interaction in our models. Specifically, oceanic plateau or thickened crust is formed near the ridge when the plume flows to the ridge, whereas molten plume is hardly extracted when plate drags plume away.

2. With the melting process, equations 12 and 13 show that conservation of mass (volume) for an incompressible material is only being obeyed globally and not locally. Locally, on a given grid element or node, when mass is removed and moved elsewhere this will violate div(v) = 0 at that point. I think it would be useful for the author's to acknowledge this in their model set up and to discuss how using a compressible formulation might affect the solution (or not) and what evidence supports their assertion.

Reply: The melt extraction in the model is definitely mass-conservative, as has been applied in previous modeling works (Gerya et al., 2015; Gülcher et al., 2020).

3. The plume head appears to be nearly always pinned at the minimum viscosity of the model – could the authors comment on this and explain why they did not try larger plume viscosities (or lower plume T)? It seems that the viscosity contrasts are going to be very important for the behavior of the plume material.

Reply: *Thanks for the advice. In fact, we had systematically tested the influence of plume temperature on plume-ridge interaction, and found that plume temperature affects model evolution in the following ways. Firstly, plume temperature influences the rate of plume rise. Secondly, higher plume temperature can increase the molten plume material, leading to more intense interaction between the mantle plume and the lithosphere, resulting in a lot of magmatic activity. But in general, increasing or decreasing the plume temperature does not directly change the model type in the parameter plot (Fig. 8).*

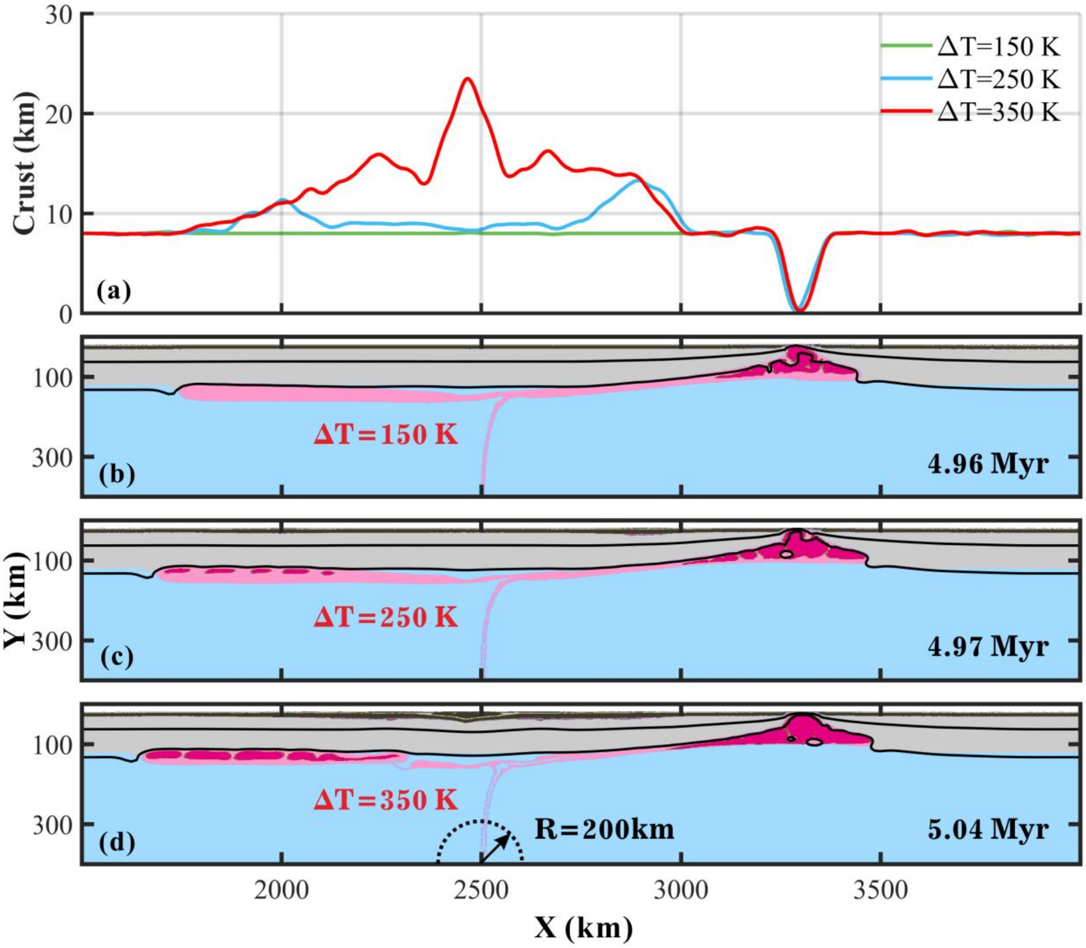

Figure 1. Model evolution of ridge-ward plume flow with different plume temperatures shown by (a) crust and sediment thickness, (b) composition.

4. Figure 3b-a. Can the author's explain why the models exhibit a long lived plume tail. The author's describe the impetus for their plume as a semi-circular heat patch at 660 km depth. Yet, looking at figure 3 there is compositionally "plume" material for >8 Myr. I'm a bit surprised about this. Shouldn't the material have buoyantly risen above its initial depth by this point?

Reply: *In our model setup, the plume initially exists as a semicircle heat patch, driven upward by the excess temperature. When the model evolves by 8 Myr, the whole mantle plume has risen below the plate, and a very small portion of plume material maintain in deep. This may be due to the deep mantle circulation that causes a little material remained in the deep. But the total amount of plume material is conserved throughout the evolution. There is no continuous supply of material from the deep* *mantle to the plume. In fact, as the model evolves over time, residual plume tail material will rise beneath the plate eventually.*

5. A discussion of likely plume head size given our knowledge of mantle parameter space would be useful here. What is a likely radius of a plume head in the mantle? What would be the expected range?

***Reply**: We appreciate this comment. The radius of the plume in the mantle can be roughly measured from seismic tomography. Based on finite-frequency tomography, Montelli(2004) present evidence for the existence of deep-mantle thermal convection plumes and reveals the plume has a radius of 100 km to 400 km. Besides, in previous simulation studies on mantle plumes, the reference range of plume radius is also within the range of 0 ~ 300 km. As a result, We believe that the plume radius parameter used in the model is reasonable.*

Minor comments:

Line 296: "massive melting and crust production" is very vague and not quantifiable. Please either replace with numbers from the model or simply state that melting and crustal production occur within the model.

***Reply:** We have made revision in the main text (line 219).*

Line 582 – "gird" should be "grid"

***Reply:** We have made revision in the main text (line 414).*

Comments from the reviewer #2

1. lines 479-481: “ Therefore, the effects of plume size are not a good candidate to explain the notable difference between the Atlantic and Pacific in terms of plume-ridge interaction mode.“ There is a discrepancy between Fig. 1b and this sentence. Figure 1b shows that plume buoyancy is an important factor in ridge-ward or plate-drag motion of plume. Based on Fig. 1b, plumes with low buoyancy flux (small plumes) favours plume-ridge interaction. Is the data in Fig. 1b based on observations? Why does it differ from Fig. 11b which indicates negligible effect of plume buoyancy?

Reply:

Thanks for your suggestions. Indeed, the plume buoyancy flux data used in the fig.1b and fig.11b are the same. The buoyancy fluxes of mantle plumes refer to the Hoggard(2022), which is calculated from the topographic swell volume, and considers both the decay of buoyancy through time and the differential motion between asthenospheric buoyancy and the overlying plate. Based on Fig.1b, it is true that plumes with low buoyancy flux tends to interact with nearby ridge. However, it is also worth noting that these small plumes tend to be very close to ridge. Indeed, figure 11 shows that when the mantle plume is close enough to the ridge, even the mantle plume with small buoyancy can flow to the ridge. This also shows that apart from the buoyancy flux of mantle plume, distance also plays a very important role in the effect of plume-ridge interaction, which is consistent with our simulation results.

2. Lines 357-363: I believe cooling of the plume in the time scale of authors model (~7 Myrs) is not a good explanation for plate drag mode of plumes with large plume-ridge distance. Plume sustains hot in such a time scale as it can be seen in e.g. Figure 7. I think the main reason for plate drag in the case of distant plumes is the mantle plume flux which is not large enough to allow the plume materials to reach the ridge (due to the large plume-ridge distance). This is the same for small sized plumes.

Reply: *Thanks for your comments. We agree with you. We believe that the first-order factor for plate drag models is the mantle plume flux or plume size, which we have* *discussed in section 3.4.1. Indeed, when plume uprises with large flux, plume material can still flow into the ridge even at a large plume-ridge distance (Fig.6). Indeed, we discuss the effect of thermal cooling of plume in section 3.4.2, aiming to reveal that the plume-ridge distance can also affect the plume-ridge interaction. Larger distance forms lower pressure gradient between the plume and ridge, and it takes longer time for plume flowing to the ridge, leading to the cooling of plume and plume viscosity increased. In fact, chances are that the plume may sustain hot in the first Myrs after ponding the lithosphere.*

Other minor specific comments:

- Line 42: what is "on-axis and off-axis plume"

Reply: *Thanks for your comments. The "on-axis and off-axis plume" mean ridge-centered and off-ridge plume. We reword this sentence in introduction section.*

- Lines 60-61: "The distribution of hotspots with classified as plume-ridge interaction (ridge-ward spreading) vs. no interaction (plate-drag spreading) also still remains enigmatic. " This sentence is not clear.

Reply: *Thanks for your advice. We reword this sentence in introduction section.*

- Lines 64-65 : What is "horizontally propagating viscous finger"? I suggest to briefly explain it in paratheses here.

Reply: *Thanks for your advice. We reword this sentence in the manuscript.*

- Line 296: Replace "The" by "the"

Reply: *We have made revision in the main text.*

- Line 19: "Slow spreading rates" should be added here.

Reply: *We have made revision in the main text .*

- Line 20: "Large plume-ridge distance" should be added here.

Reply: *Thanks for you comments. We have made revision in the main text.*

- Line 398: "The transition from ridge-ward (positive γ) to plate-drag (negative γ) flow" In Figure 9, the orange curve (with spreading rate of 30 cm/yr) has positive γ but its deformation mode (based on Table S1) is plate-drag.

Reply: *The orange curve in fig. 9 (M58: half spreading rate of 30 mm yr-1, an initial plume head radius of 150 km, and an off-axis distance of 1000 km) should be classified as plate drag flow. The spreading fraction γ is positive at first, but turns to negative rapidly due to drag of moving plate. Actually, there is no plume material flowing into the ridge.*

- In Fig. 5 thickness of lithosphere is more than 200 km but in Figs. 3-4 lithosphere is thinner!

Relpy: *Thanks for your comments. The Y-axis tick in Fig.5 were labeled incorrectly. We have modified the tick in Fig.5.*

- Line 527: It should be fast spreading rates.

Relpy: *Thanks for your comments. We have made revision in the main text.*