General comments Reviewer 1 – Cynthia Ebinger

- **Comment:** Zwaan and Schreurs utilize fully scaled analogue models to investigate the role of rotational stresses on the continental-scale spatial evolution of rift zones, with comparison to rifting patterns in East Africa. The models explore a range of co-eval rift initiation geometries, and then track the time evolution of strain for comparison with the modern geometry of active rift zones in parts of E Africa. The models ignore rifting in the offshore SE rift branch in oceanic lithosphere east and southeast of the Rovuma block, and the SW branch that continues perhaps as far west as Angola around the San block.

    - **Reply:** As we now describe clearer in the new version of the manuscript, we implement the **active** plate boundaries for the East African Rift north of the Somalia-Nubia rotation axis, as specified in e.g. Saria et al. (2014) (and in Stamps et al. 2021 too). As such we do include the boundaries of the Rovuma plate in two of our models (A and D), and the eastern boundaries of this plate (which undergo very limited deformation in nature) do in fact show some limited activation in our model D. The latter part is a limitation that is addressed in the text.
    - The SW branch is not included in our models since it is not part of the active plate boundaries as defined by Saria et al. (2014) and Stamps et al. (2021).
    - Note that these southernmost parts of the East African Rift are situated close to the Nubia-Somalia rotation pole, which makes their individual motion rather complex. In our study we focus on the system north of this rotation pole, which is affected by the rotation of the Somalian plate. As such, potential plates further to the south-east (the existence and importance of which are debated) are not included in our models.

- **Comment:** My major concern with the paper is the reliance on outdated structural models based on coarse satellite imagery, and lacking information from seismicity and geodesy that shows modern plate motions. Specifically, the papers cited for the role of pre-existing basement shear zones are all based on satellite imagery and lack the 3rd dimension – the dip of structures. Likewise, the age of some lineaments mapped in these publications remains speculative (e.g., Chorowicz, 2005), and papers utilizing displacement of data strata should only be considered.

    - **Reply:** In our models we implemented the main **active** East African Rift System plate boundaries as proposed by recent authors e.g. Saria et al. (2014), but also in Stamps et al. (2021). This was perhaps not sufficiently clear in the manuscript, and we have now expanded the discussion of weaknesses in East Africa.
    - We do not believe that the dip of structures is of much importance regarding the scale of our study. We aim at modelling the activation of weaknesses and the localization of rifting along the active East African Rift System plate boundaries. The exact type of weakness is of limited important: what is important is that a rift basin forms.

- We agree that the age of the different basins along the East African Rift System remains speculative, as we did point out in our manuscript. We have however expanded the discussion and have added more details on timing of rifting in the introduction as well.
- We do not fully follow the final part of the last sentence.

- **Comment:** The comparisons with data in Section 4.15 as well as model constraints need to be re-thought, and omission of processes (e.g., magmatism, GPE, etc) need to be clearly articulated.

    - **Reply:** We assume the reviewer refers to section 4.2 (“General model limitations”) here and have added the suggested processes to the discussion. As specified above, we base our modelling study on the present-day tectonic situation, and explore how rotational motion of the Somalian plate, together with localization of deformation along weaknesses in the lithosphere, can lead to the development of the structures seen in present-day East Africa.

Suggested literature:

- **Comment: Seismicity:**

    - (Lindenfeld, M., Rümpker, G., Link, K., Koehn, D., & Batte, A. (2012). Fluid-triggered earthquake swarms in the Rwenzori region, East African Rift—Evidence for rift initiation. Tectonophysics, 566, 95-104
    - Lavayssière, A., Drooff, C., Ebinger, C., Gallacher, R., Illsley-Kemp, F., Oliva, S. J., & Keir, D. (2019). Depth extent and kinematics of faulting in the southern Tanganyika rift, Africa. Tectonics, 38(3), 842-862
    - Ebinger, C. J., Oliva, S. J., Pham, T. Q., Peterson, K., Chindandali, P., Illsley-Kemp, F., ... & Mulibo, G. (2019). Kinematics of active deformation in the Malawi rift and Rungwe Volcanic Province, Africa. Geochemistry, Geophysics, Geosystems, 20(8), 3928-3951
    - Weinstein, A., Oliva, S. J., Ebinger, C. J., Roecker, S., Tiberi, C., Aman, M., ... & Fischer, T. P. (2017). Fault-magma interactions during early continental rifting: Seismicity of the M agadi-N atron-M anyara basins, A frica. Geochemistry, Geophysics, Geosystems, 18(10), 3662-3686
    - Zheng, W., Oliva, S. J., Ebinger, C., & Pritchard, M. E. (2020). Aseismic deformation during the 2014 M w 5.2 Karonga earthquake, Malawi, from satellite interferometry and earthquake source mechanisms. Geophysical Research Letters, 47(22), e2020GL090930)

- **Comment: and geodetic strain from active plate motion and time-averaged strains:**

    - (e.g., DeMets, C., & Merkouriev, S. (2021). Detailed reconstructions of India–Somalia Plate motion, 60 Ma to present: implications for Somalia Plate absolute motion and India–Eurasia Plate motion. Geophysical Journal International, 227(3), 1730-1767

- Stamps, D. S., Kreemer, C., Fernandes, R., Rajaonarison, T. A., & Rambolamanana, G. (2021). Redefining east African rift system kinematics. Geology, 49(2), 150-155;
- Knappe, E., Bendick, R., Ebinger, C., Birhanu, Y., Lewi, E., Floyd, M., ... & Perry, M. (2020). Accommodation of East African rifting across the Turkana depression. Journal of Geophysical Research: Solid Earth, 125(2), e2019JB018469
- Birhanu, Y., Bendick, R., Fisseha, S., Lewi, E., Floyd, M., King, R., & Reilinger, R. (2016). GPS constraints on broad scale extension in the Ethiopian Highlands and Main Ethiopian Rift. Geophysical Research Letters, 43(13), 6844-6851
- Viltres, R., Jónsson, S., Ruch, J., Doubre, C., Reilinger, R., Floyd, M., & Ogubazghi, G. (2020). Kinematics and deformation of the southern Red Sea region from GPS observations. Geophysical Journal International, 221(3), 2143-2154.)

- **Reply:** We kindly thank the reviewer for the suggested literature, and have cited some of these works where appropriate.

- **Comment:** The authors cite decades-old papers to quote a N to S younging, inferring a N-S propagation of rifting throughout the EAR. Yet, the only two sectors of the EAR confirming that pattern are the Eastern rift in Kenya and N Tanzania, and the southern Malawi rift. The MER appears to have propagated from S to N, and the very poorly date Western rift may have initiated near the Rungwe volcanic province, and propagated both N and S from there (e.g., Roberts, E. M., Stevens, N. J., O'Connor, P. M., Dirks, P. H. G. M., Gottfried, M. D., Clyde, W. C., ... & Hemming, S. (2012). Initiation of the western branch of the East African Rift coeval with the eastern branch. Nature Geoscience, 5(4), 289-294.). See also Daly MC, Green P, Watts AB, Davies O, Chibesakunda F, and Walker R (2020) Tectonics and Landscape of the Central African Plateau, and their implications for a propagating Southwestern Rift in Africa. Geochemistry, Geophysics, Geosystems. e2019GC008746. For information on the SW rift zone.

    - **Reply:** The comments are not fully clear, but we believe we can answer here:
    - The evolution of the (various parts of the) East African Rift remains a matter of debate, as we point out in the manuscript. In our study we propose a scenario for this evolution, based on the present-day structures / plate boundaries and the rotation of the Somalian plate. Any deviations from the general pattern we see should then be addressed. We now made sure that this discussion is more extensive, using the highly useful feedback provided by the reviewer.
    - Regarding the propagation of the Main Ethiopian Rift (MER) propagation: this seems a topic of debate (e.g. Bonini et al. 2005; Corti 2009), and is now better discussed in the text, as is the development of the other rift segments.
        - Note however, that there is quite some discussion about the ages of the rift segments, and our model findings are generally in quite good agreement with recent work (e.g. Macgregor, 2015).

- The Western Rift actually propagates in both directions (north and south) in our models, which is in fact in agreement with what the reviewer suggests.

Other major concerns are as follows:

- **Comment:** The EAR formed above one or more mantle plumes, and topographic relief within the region is > 1000 km. How do the authors include GPE? If not, tell the reader that it is ignored.

    - **Reply:** The impact of mantle plumes or gravitational potential energy (GPE) is not included in our study. Instead we use a simple set-up to explore the effect rotational rifting due to the rotation motion of the Somalian Plate would have on the evolution of the East African Rift System. We do now address this in the discussion as a potential reason why some of the East African Rift System evolution (as expressed at the surface) could deviate from what the fully rotation-induced rift system (as is simulated in our models would generate). That is, rift initiation timing in the shape of deformation at the Earth's surface could potentially be different, but it is not expected to affect the large-scale rift (deformation) patterns we observe nowadays, which do fit the behaviour of our model C quite well.

- **Comment:** Likewise, parts of the study area have experienced 2+ km of magmatic underplate and have strain accommodated by magma intrusion. Since this is not included, tell the reader and consider the consequences.

    - **Reply:** We do indeed not include magmatic underplating in our models. As suggested by Buck (2004 and 2006), magmatism may promote the localization of deformation. This could impact rift timing and was already mentioned, but is now better explained in the discussion.

- **Comment:** Parts of the study area are underlain by cratonic roots that are 70 km thicker than surrounding areas. Since this is not considered, tell the reader and consider the consequences.

    - **Reply:** It is true that the thickness and rheology of the lithosphere can have a strong impact on the timing of rifting and its expression at the surface. This is now addressed in the text. However, the moment rifting is active along a weakness, plates are in motion and the individual thickness of the different (micro-plates) surrounding these weaknesses is not that important anymore.

- **Comment:** On what basis did the authors choose these models? Without careful consideration of the timing of diachronous rifting data, choice of models could be biased to outdated and inaccurate information.

    - **Reply:** This question is not very clear. We are testing different weakness geometries, based on the situation in the East African Rift System. We believe that the general pattern in our model C fits very nicely with the patters seen in recent GPS analyses (both Saria et al. 2014 and Stamps et al 2021). Overall, the models nicely show alternative scenarios of East African Rift System evolution that could have emerged if other weaknesses/rift patterns were developed.

- We have now modified the text to better explain the reader what the basis for this modelling study was: we took current plate boundaries as provided by Saria et al. (2014) and Stamps et al. (2021), and combined these with the rotation of the Somalian plate to better understand their impact on the evolution of the East African Rift System.

Minor comments

- **Comment:** Segments is generally used to describe a single fault-defined basin unit, whose length depends on the strength of the plate.

    - **Reply:** We believe that the use of "rift segment" is quite ok here.

- **Comment:** Line 48 - Strike slip faulting happens in accommodation zones and may reactivate a variety of basement sttructures, but overall, the rift structures form irrespective of basement structures. Please don't list my name there.

    - **Reply:** We have rewritten the introduction and the Ebinger et al. 1989 reference is not cited in this context anymore.

- **Comment:** Line 53: What do you mean by an inherited weakness? THe 'weaknesses' are highly variable in the cited papers. What about the role of variable rheology linked to plate thickness (and hence geothermal gradient), composition, pre-existing thin zones, availability of melt, not just shear zones: see Muirhead et al., 2020;

    - **Reply:** These are inherited weaknesses in the lithosphere that allow the easy localization of deformation and the nucleation of rift basins. As the reviewer points out, there are various origins of such weaknesses. We have added some more details to the text to make this clear. But in our models we use a simplified type of weakness in the shape of a "seed", and we believe this is permissible as we focus on large-scale rift patterns and aim to reproduce the arrangement of the East African Rift System.

Summary

- **Comment:** The authors have published earlier papers considering rift models, which is in part why I urge them to dig more deeply into assumptions, and to move beyond EAR mythology to factual data constraining modern plate boundary deformation, and to move past lineament analyses.

    - **Reply:** We do not fully follow what the reviewer means with "EAR mythology". It is true that we have published various papers on analogue models of continental rifting, aiming at better understanding a variety of processes. A number of these modelling papers were parameter studies, but in this manuscript we explicitly aim to apply our models to better understand a specific natural example (the East African Rift System). The result is a model-driven study, providing large-scale insights in the potential evolution of the East African Rift System as the result of the rotational motion of the Somalian plate. This is indeed the great strength of our modelling approach: we can test different scenarios and predict patterns and processes.

- We do agree that there are opportunities to strengthen the links to the natural example along the lines suggested by the reviewer and have done so in the revised text.

References:

- Bonini, M., Corti, G., Innocenti, F., Manetti, P., Mazzarini, F., Abebe, T., Pecskay, Z., 2005. Evolution of the Main Ethiopian Rift in the frame of Afar and Kenya rifts propagation. Tectonics 24, TC1007. doi:10.1029/2004TC001680.
- Corti, G., 2009, Continental rift evolution: From rift initiation to incipient break-up in the Main Ethiopian Rift, East Africa: Earth-Science Reviews, v. 96, p. 1–53, doi:10.1016/j.earscirev.2009.06.005.
- Macgregor, D., 2015..: History of the development of the East African Rift System: A series of interpreted maps through time, J. Afr. Earth. Sc., 101, 232-252, https://doi.org/10.1016/j.jafrearsci.2014.09.016