# Tomographic study of the East African Rift in Mozambique - Initial results

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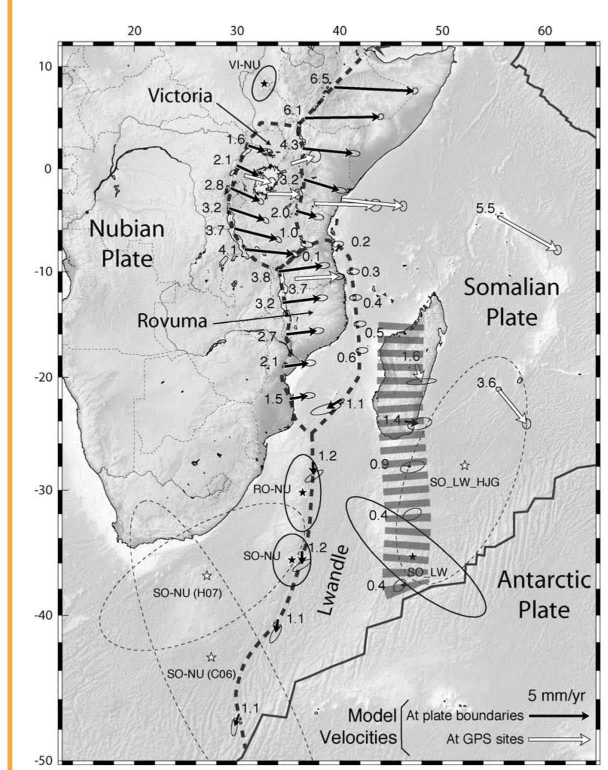
## Motivation and Goals

Over the past 20 years, extensive research has focused on the East African Rift (EAR), from the Red Sea to southern Tanzania. However, the southern tip of the EAR, in Mozambique, has not been investigated so far. In recent years, GPS data provided some indication on the plate tectonic setting [Stamps et al, 2008], and a complex system of three microplates – Victoria, Rovuma and Lwandle - was proposed to explain the extension of the Nubia-Somalia plate boundary until the Southwest Indian Ridge (Figure 1), but the limited spatial resolution of GPS geodesy in this region does not allow a detailed picture. The M7 Machaze earthquake of 2006, in central Mozambique, shed new light on the location of the rifting activity, and motivated the current work. The MOZART (MOZambique African Rift Tomography) project initiative is dedicated to the investigation of the crust and the mantle structure, in this particular region of the EAR.



Stamps et al, 2008

Figure 1. Kinematic model for the East African rift. Relative motions along plate or block boundaries are shown with black arrows, with model velocities values in mm/yr.

## MOZART project

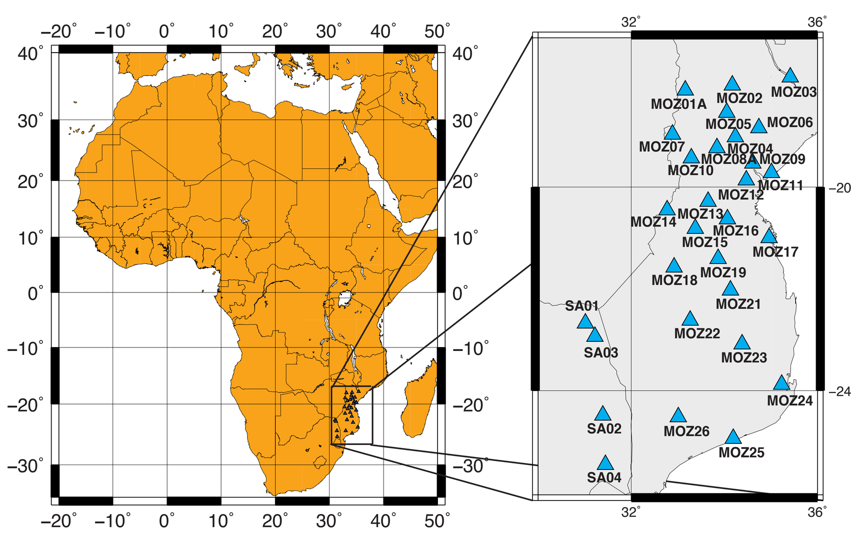


Figure 2. Map of the MOZART broadband seismic network.

As a first step towards the characterization of the 3D structure of the Mozambican sector of the plate boundary, project MOZART (funded by FCT, Lisbon, PI J. Fonseca), which started in March 2010, deployed and is currently operating during 24 months a network of 30 broadband stations (120s), loaned from the SEIS-UK equipment pool. The network has been installed in two stages (March 2011 and November 2011). In order to obtain a large coverage, the stations were spread between NE South Africa and central Mozambique (Figure 2).

This network will provide essential data to:

- the study of the distribution of local seismicity in the region;
- the mapping of crustal thickness (Moho depth) through receiver function analysis;
- the study of seismic anisotropy (shear wave splitting) in the region, and causative inherited mesoproterozoic structures;
- the construction of a tomographic velocity model for the crust and upper mantle in the region, from surface wave dispersion (using earthquake data and ambient noise) and ultimately from waveform tomography.

The integrated analysis of these results will shed unprecedented light into the geodynamic processes that are taking place in one of the least studied - and, in view of the very latest results, one of the most interesting - portions of the Earth's lithosphere.

This network provides an unprecedented volume of quality seismic data giving the opportunity to study seismic tomography.

Current work focuses on waveform comparisons between MOZART data and spectral element method synthetic seismograms. We are addressing the following questions:

- How well do global 3D and 1D Earth models explain MOZART data, given that they were built using independent data?
- How suitable are MOZART data for waveform tomography?

## Methodology

Given the recent deployment of the MOZART network, we had data available to initiate this study from March to August of 2011. Based on this, we chose two different earthquakes that occurred in this period.

We have calculated the synthetic waveforms using the spectral elements method (Komatitsch and Tromp, 1999) for two different earth models: 1D (PREM, Dziewonski and Anderson, 1981) and 3D (S20RTS, Ritsema et al., 1999 combined with CRUST2.0, Bassin et al., 2000). Both synthetics and observed waveforms were filtered for surface waves for T~100s, T~80s and T~45s. For reference we also make the comparison with the GSN station SUR, localized in South Africa. Waveform misfits are also calculated using the L2 norm misfit formula:

$$m^2 = \frac{\sum_i \left(u_i^{syn} - u_i^{obs}\right)^2}{\sum_i \left(u_i^{obs}\right)^2}$$

Initial comparisons between MOZART data and synthetics showed poor horizontal component data quality; thus, in this initial study we focus on vertical component data comparisons.

## Mw6.0 Kyrgyzstan (11th July 2011)

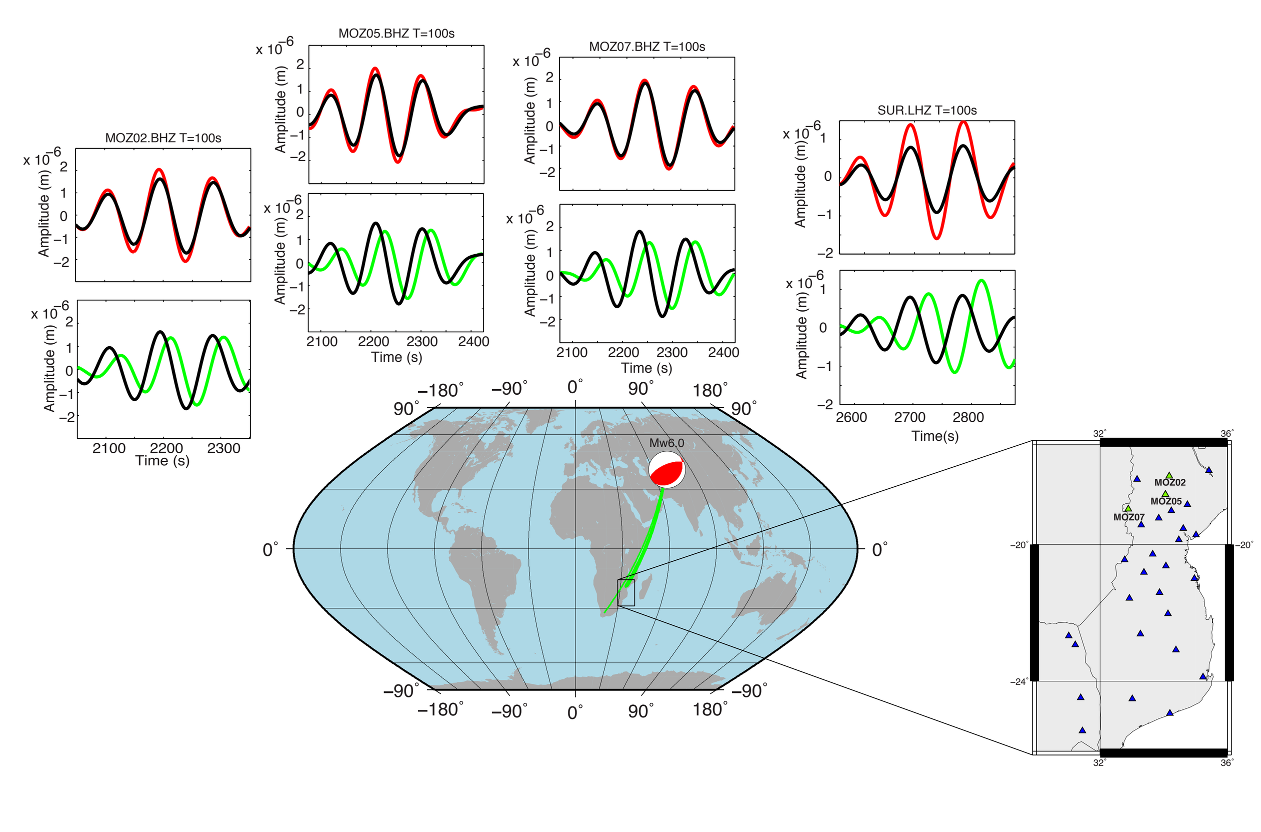


Figure 3. Surface wave (T~100s) comparisons between real data (black) and synthetic waveforms calculated using S20RTS (red) and PREM (green) as earth model respectively. We also show comparisons for the GSN station SUR, for reference.

| | S20RTS | | | PREM | | |
|---|---|---|---|---|---|---|
| | T=100s | T=80s | T=45s | T=100s | T=80s | T=45s |
| MOZART | 0.04 | 0.94 | 6.62 | 1.32 | 2.27 | 4.42 |
| SUR | 0.59 | 1.59 | 4.80 | 4.29 | 5.04 | 5.40 |

Table 1. L2-norm misfits ($m^2$) for the waveform comparisons shown in Figure 3 (T=100s) and for wave periods of 80s and 45s. MOZART misfits are average values over all the MOZART stations.

- Overall, the 3D Earth synthetics explain MOZART long-period surface waveforms fairly well, with relatively small data misfit values. Moreover, MOZART vertical component data have similar quality to SUR data. The discrepancies between data and synthetics are larger for the SUR station than for MOZART stations, highlighting limitations in the global Earth models for that specific source-receiver path.
- 1D Earth PREM synthetics lead to the poorest data fits, as this model does not explain very well the data phase.

## Mw6.6 Eastern Honshu, Japan (19th April 2011)

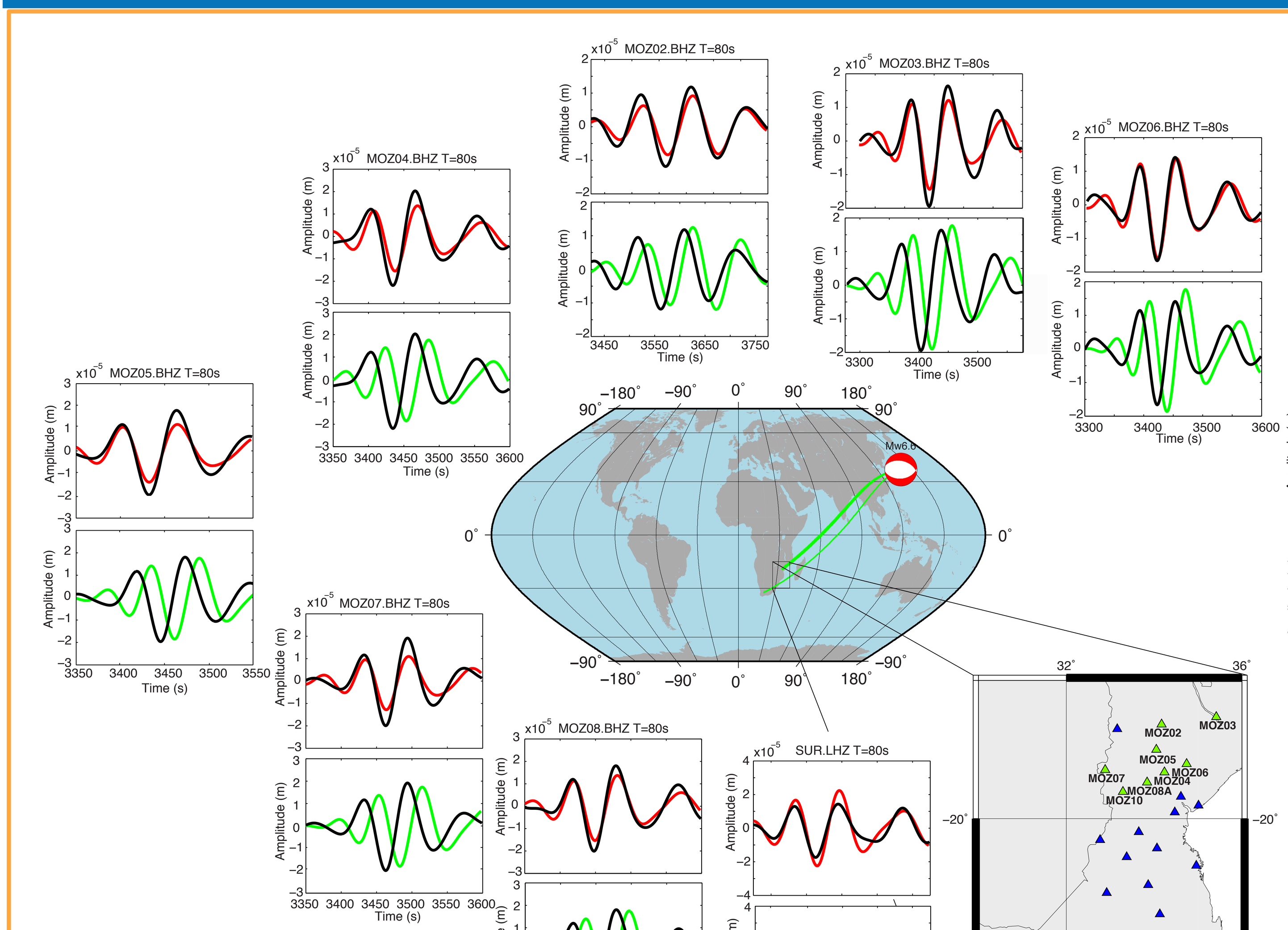


Figure 4. Surface wave (T~80s) comparisons between real data (black) and synthetic waveforms calculated using S20RTS (red) and PREM (green) as earth model respectively. We also show comparisons for the GSN station SUR, for reference.

| | S20RTS | | | PREM | | |
|---|---|---|---|---|---|---|
| | T=100s | T=80s | T=45s | T=100s | T=80s | T=45s |
| MOZART | 0.20 | 0.17 | 0.30 | 1.37 | 2.29 | 2.02 |
| SUR | 0.13 | 0.27 | 0.44 | 0.12 | 2.59 | 2.50 |

Table 2. L2-norm misfits ($m^2$) for the waveform comparisons shown in Figure 4 (T=80s) and for wave periods of 100s and 45s. MOZART misfits are average values over all the MOZART stations.

- Similar to the Kyrgyzstan earthquake, vertical component MOZART data have quality comparable to SUR data and overall the 3D Earth synthetics explain the data relatively well (despite some slight amplitude differences).
- Comparisons with PREM synthetics show, once again, larger discrepancies, notably large phase shifts between the waveforms, which lead to high misfit values.

## Conclusions

- Vertical component MOZART surface wave data seems suitable for waveform tomography studies. Horizontal component data are more limited, showing poorer quality.
- 3D Earth model synthetics explain the surface wave phases well, but are more limited at matching amplitudes, showing that there is still scope for improvement of the Earth model.
- 1D Earth PREM synthetics explain surface wave amplitudes broadly as well as the 3D Earth model, but lead to much poorer phase fits.
- In order to validate these initial results, we need to use a much larger set of earthquakes for meaningful statistical comparisons. Moreover, it will be interesting to carry out comparisons for other wave periods and for body waves.

## References

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