Intraplate Seismicity Around Rodrigues Island (Indian Ocean) From Time-Domain Array Analysis

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1. Introduction

Rodrigues Island is located at the eastern end of the Rodrigues Ridge, approximately 650 km east of Mauritius in the South-West Indian Ocean. Rodrigues Ridge connects the Reunion hotspot track with the Central Indian Ridge (CIR) and has been suggested to represent the surface expression of a sub-lithospheric flow channel. From global earthquake catalogues, the seismicity around Rodrigues Island has been generally associated with events related to the fracture zones at and off the CIR.

Here, we report on the seismicity recorded at a temporary array of ten seismic stations operating on Rodrigues Island from Sept. 2014 until June 2016 with a focus on the possible seismic activity along Rodrigues Ridge.

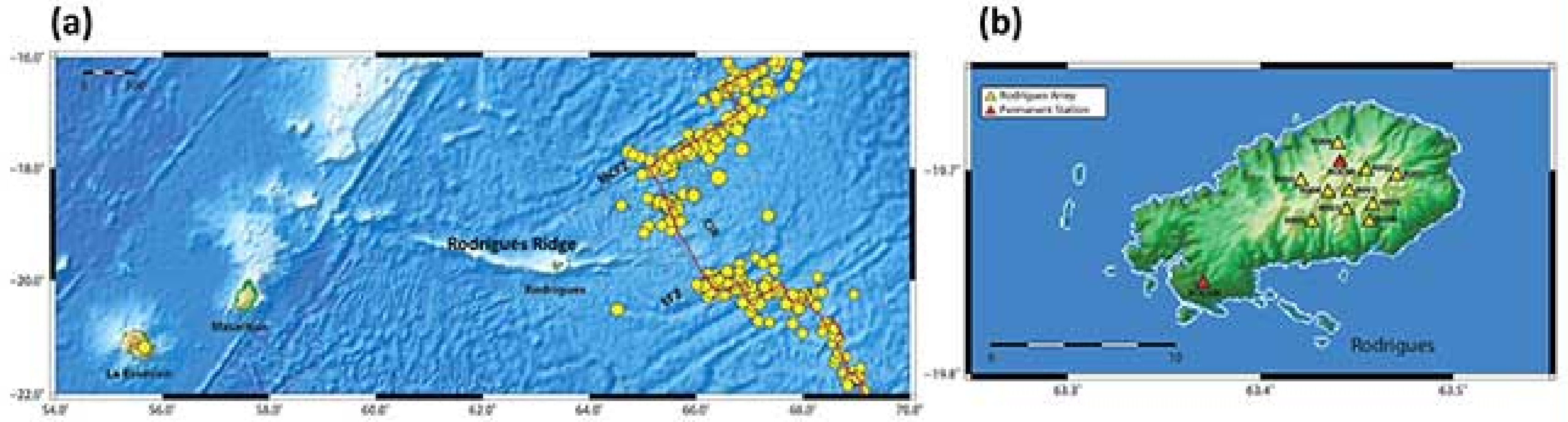


Figure 1. **(a)** Tectonic setting of Rodrigues–Central Indian Ridge (CIR) region. Event locations from the USGS catalogue (01/2000–04/2017) are shown in yellow. MCFZ: Marie-Celeste fracture zone and EFZ: Egeria fracture zone. **(b)** Locations of array stations on Rodrigues Island (yellow triangles). Red triangles denote permanent stations ROCAM and RODM. Station RODM was operational between 10/11/2010 and 07/09/2014.

2. Beamforming

The slowness and the backazimuth of an event are determined from beamforming: Assuming a plane wavefront of horizontal slowness s_0 moving across the array with an apparent velocity $v_a = 1/|s_0|$, the waveform at station j is given by

$$w_j(t) = w(t - r_j \cdot s_0), \qquad (1)$$

where r_j defines the position of the station.

For an array consisting of M stations, the beam energy is calculated from the trace amplitudes within a suitable time window defined by t_1 and t_2.

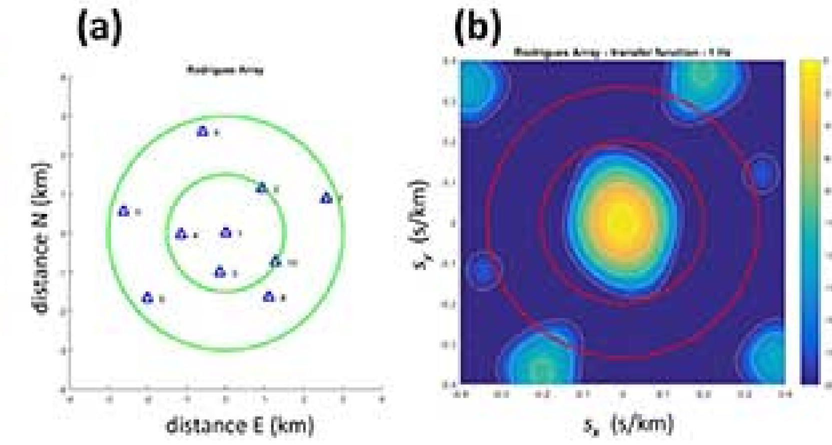
$$E = \int_{t_1}^{t_2} y^2(t)\,\mathrm{d}t = \int_{t_1}^{t_2} \left[\frac{1}{M}\sum_{j=1}^{M} w_j(t + s \cdot r_j)\right]^2 \mathrm{d}t\,, \qquad (2)$$

where s denotes the (trial) slowness for the current beam. The beam energy reaches a maximum, if $s = s_0$. The backazimuth is then obtained from $\tan^{-1}(s_{0x}/s_{0y})$.

For regional earthquakes, the slowness cannot be used to determine the epicentral distance of an event. We therefore use the arrival time difference between the S and P waves (see **Figure 4**).

3. Array analysis

Figure 2. Based on our initial estimates on earthquake distance and frequency content, the aperture of the array was set to about 5 km **(a)**. The 10 stations were arranged such as to minimize the influence of sidelobes of the array response function **(b)**.



Conventionally, array analyses are performed in the frequency domain, which is computationally advantageous as the amplitude stacking can be limited to the dominant frequency or a narrow frequency band. This approach usually requires selection of a common time window for all traces. However, in cases of significantly different arrival times of the phase to be analyzed, a large common time window has to be chosen such that the cut waveforms of individual traces may be significantly different. In the time domain, we can time-shift the traces before stacking, which is then performed within a much narrower time window. This approach ensures that only the relevant waveform is contained within the stack, provided that the correct time shift has been applied. The time-domain analysis corresponds to a broad-band frequency stack, without the described disadvantages.

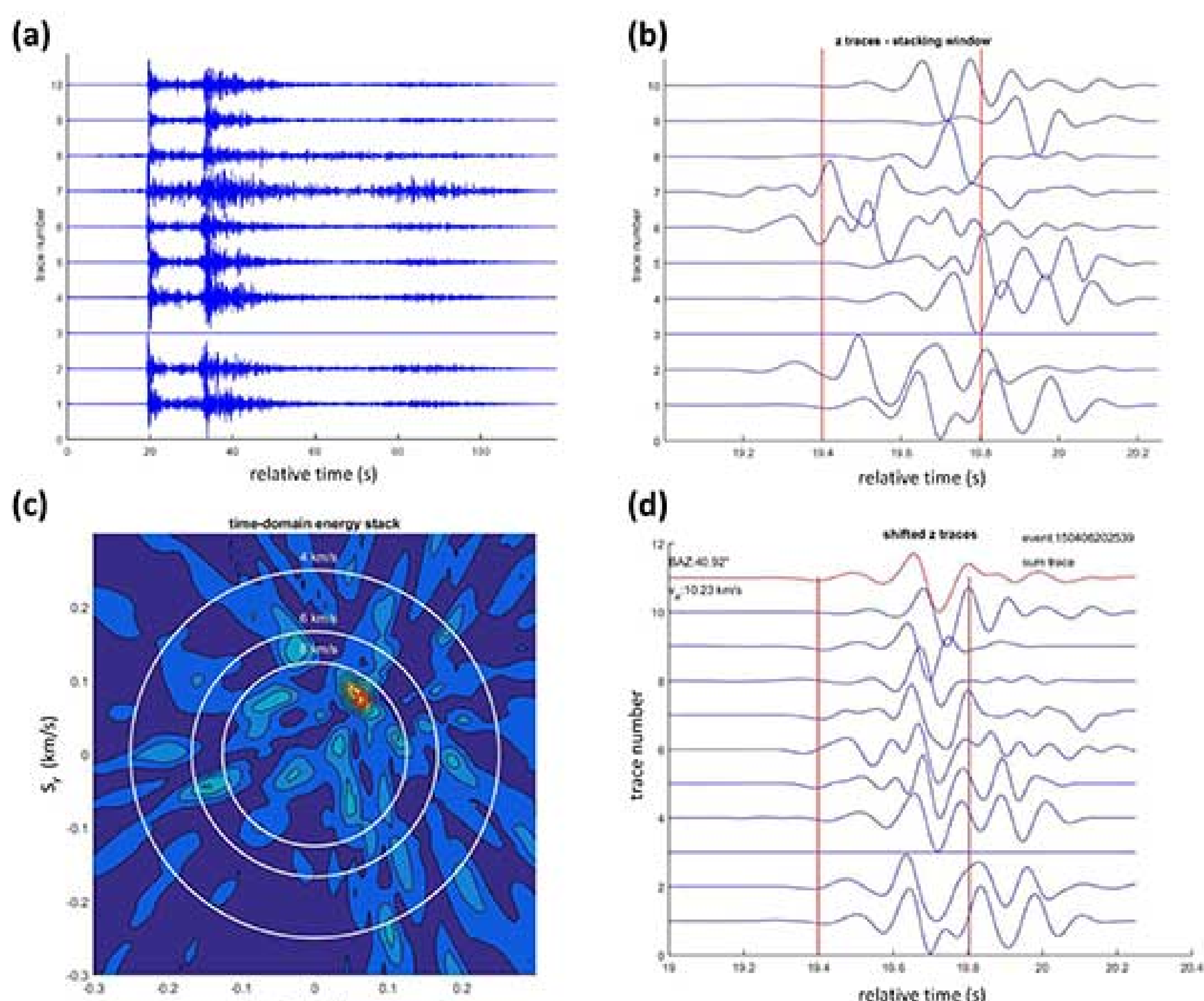


Figure 3. Array analysis of a regional event near Rodrigues. **(a)** Z-component traces; station 3 was not recording at the time of the event. **(b)** Zoom-in of the P-waveforms. After applying the time shift corresponding to a trial slowness s, traces are summed within the time window denoted by the red lines. **(c)** Beam energy as function of horizontal slowness components s_x and s_y. The maximum is marked by a red line and corresponds to the slowness s_0. White circles denote apparent velocities, v_a, of 4-8 km/s. **(d)** Shifted traces and beam (red trace) corresponding to the maximum indicated in (c). The backazimuth of this event is determined at about 41°.

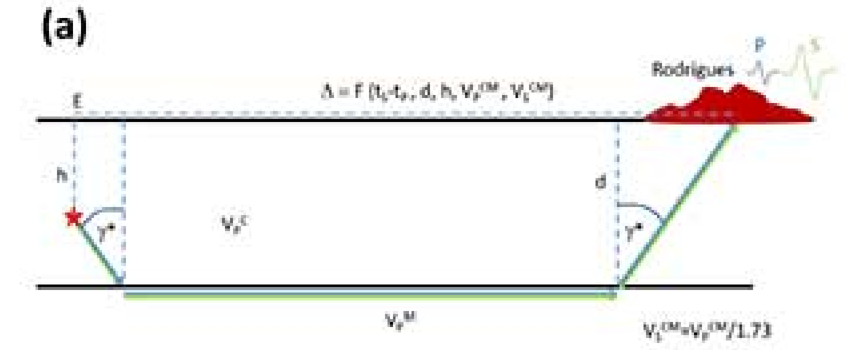
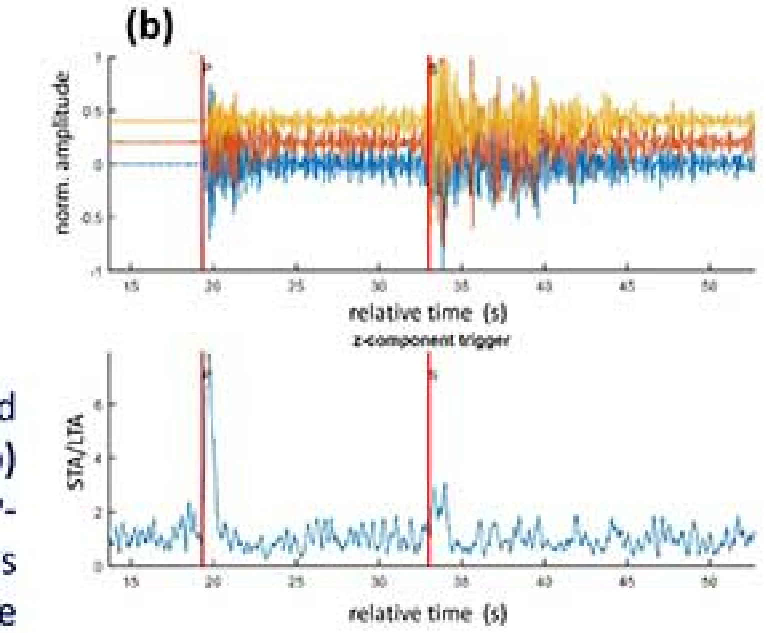


Figure 4. Epicentral distances, Δ, were estimated based on **(a)** a simple 1-D velocity model and **(b)** the travel-time differences between S- and P-wave arrivals. We assume that the earthquakes occur within the oceanic crust. After deriving the distances, local magnitudes of the events were obtained.



4. Results

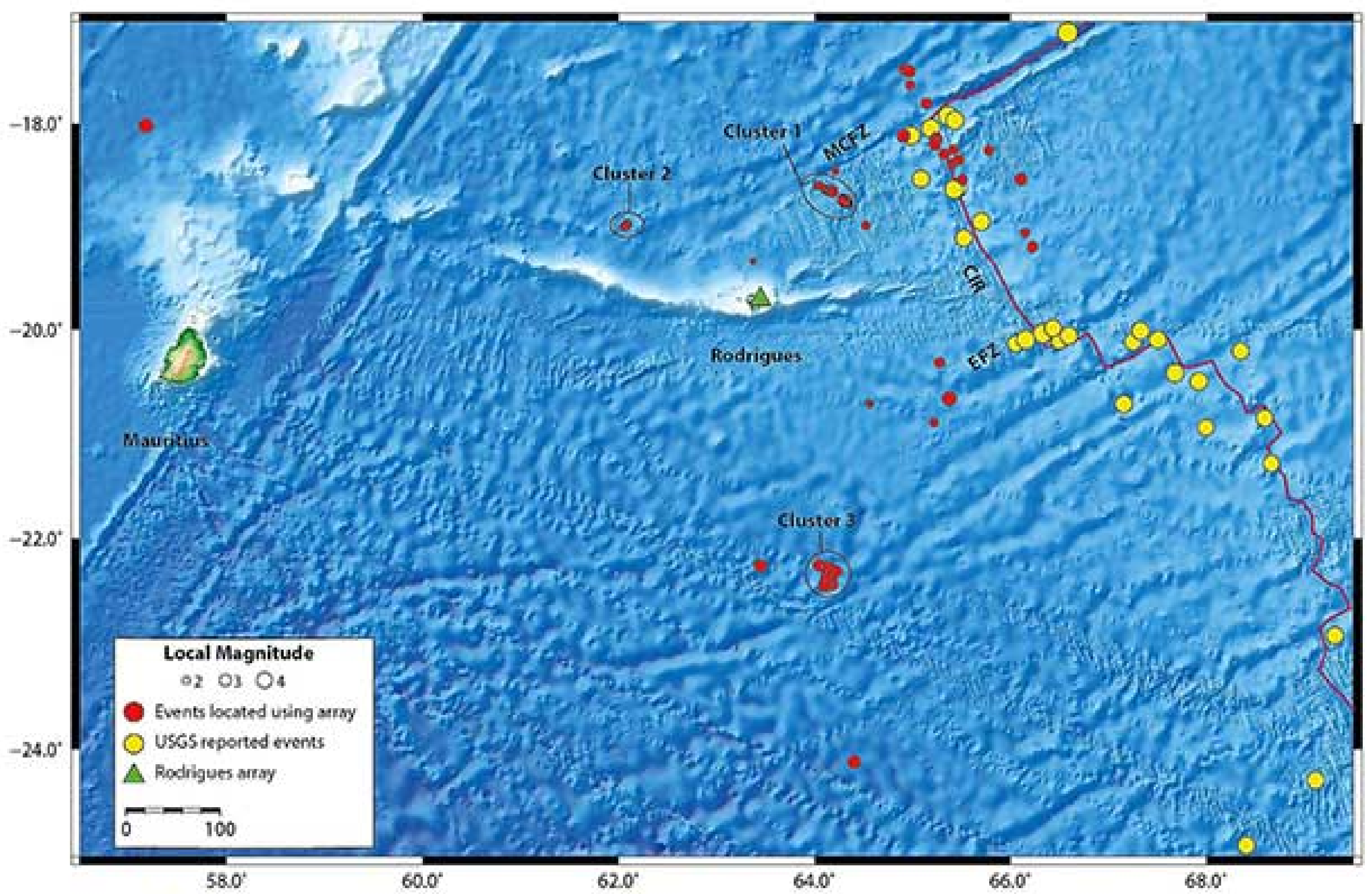


Figure 5. Locations of new events (red) detected and located using the array analysis and earthquakes from the USGS catalogue (yellow) during the same time period (from 09/2014 to 06/2016). MCFZ: Marie-Celeste fracture zone and EFZ: Egeria fracture zone.

5. Conclusions

- We detected and located **62 new events**, which were not reported by the global networks. Most of the events are located off the CIR and can be classified as **intraplate** events. Local **magnitudes** of the events varied between 1.6 and 3.7.
- Most of the events were localized in the north-east of Rodrigues at distance of about 140 km from the reference station of the array. The **Rodrigues Ridge appeared aseismic** during the period of operation.
- **Three seismic clusters** were observed around the island. A distinguishable swarm of earthquakes was observed to the west of the spreading segment of the CIR during the period from March to April 2015.