Do foreshock rates vary regionally?

Russell Azad Khan [1] Max Werner[1], Juliet Biggs[1], Ake Fagereng[2]

1 University of Bristol, School of Earth Sciences, 2 Cardiff University, School of Earth and Environmental Science

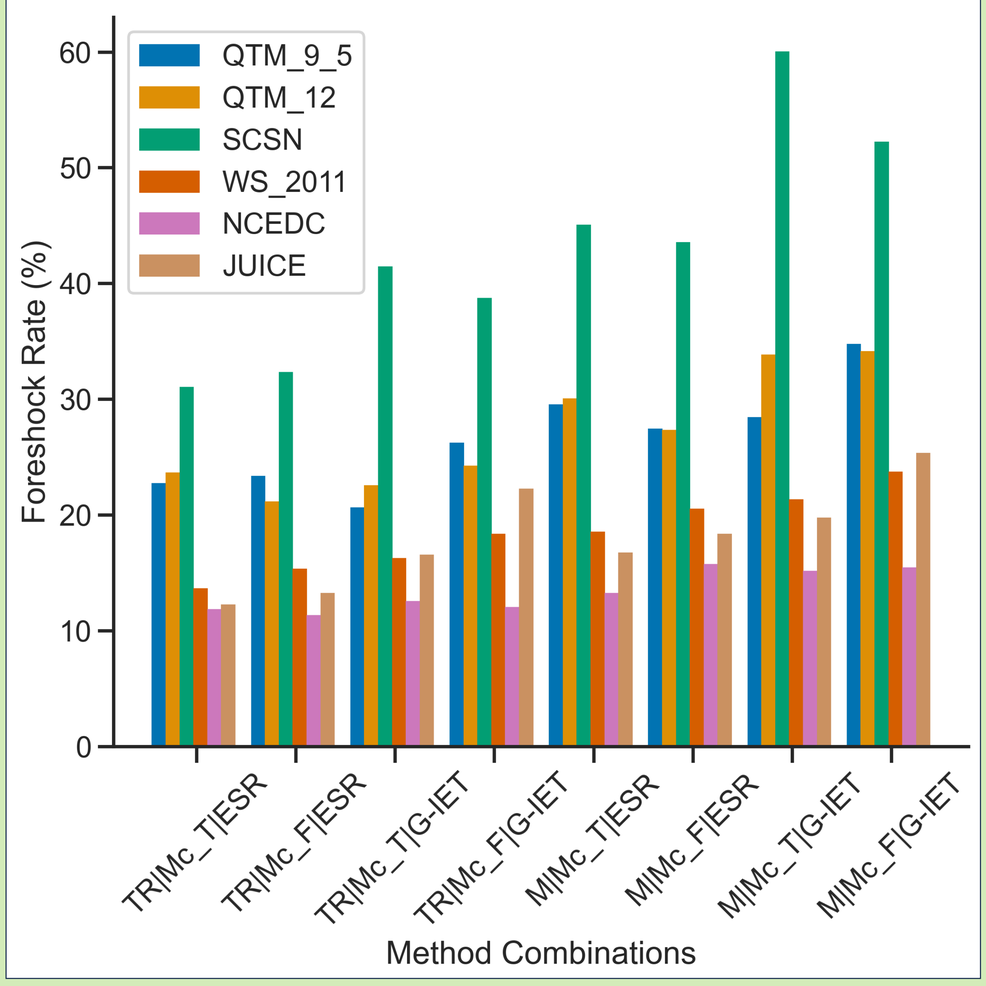
Motivation

- New data: high resolution regional earthquake catalogues (e.g. **QTM_9_5** and **QTM_12**) may allow us to see more foreshocks than in previous catalogues.
- We still do not understand what happens right before large earthquakes. A better understanding of foreshocks could improve our ability to forecast large earthquakes.

Table 1: *The regional earthquake catalogues.*

Region	Name	Earthquakes	Mc	b-value	Timespan
Southern California	QTM_9_5	1,811,362	0.0	0.69	2008-2017
Southern California	QTM_12	898,597	0.0	0.60	2008-2017
Southern California	SCSN	181,503	1.2	0.74	2008-2017
Northern California	WS_2011	513,474	1.1	0.70	1984-2011
Northern California	NCEDC	126,842	2.3	0.88	1966-2019
Japan	JUICE	1,091,640	1.1	0.73	2000-2012

Figure 1: *Regional foreshock rate results for 8 method combinations.*



Summary

- We calculate the foreshock rate (proportion of mainshocks with foreshocks) for 6 regional earthquake catalogues (**Table 1**).
- Two methods to select mainshocks: **TR** (*Trugman & Ross, 2019)*, & **M** (*Moutote et al. 2021)*.
- Two methods to select foreshocks (*van den Ende & Ampuero, 2020*): **ESR** (Empirical Seismicity Rate), & **G-IET** (Gamma inter-event times).
- Two completeness options: Earthquakes below the local completeness magnitude (Mc) removed (**Mc_T**) and not removed (**Mc_F**) from local catalogues.
- 8 Method Combinations (**TR**|**Mc_T**|**ESR**, etc.).
- Southern California (**QTM_9_5**, **QTM_12**, **SCSN**) systematically has higher foreshock rates than Northern California (**WS_2011**, **NCEDC**), and Japan (**JUICE**).
- A lower catalogue completeness magnitude (Mc) does not mean we see more foreshocks for Southern California. The **SCSN** catalogue (Mc = 1.2) has higher foreshock rates than the **QTM catalogues** (Mc = 0.0). Further work is required to find out why.

Key:

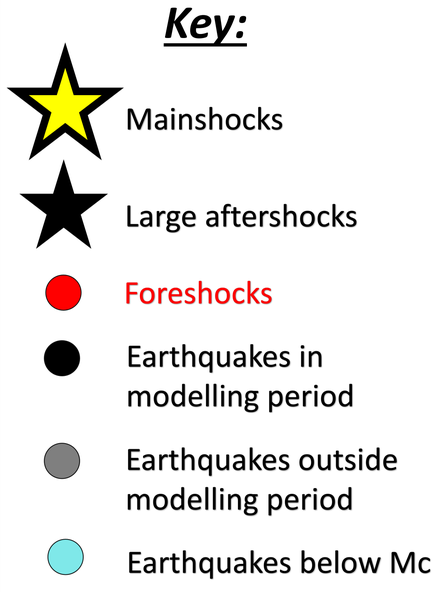


Figure 2: *An example earthquake time series showing the chosen modelling parameters.*

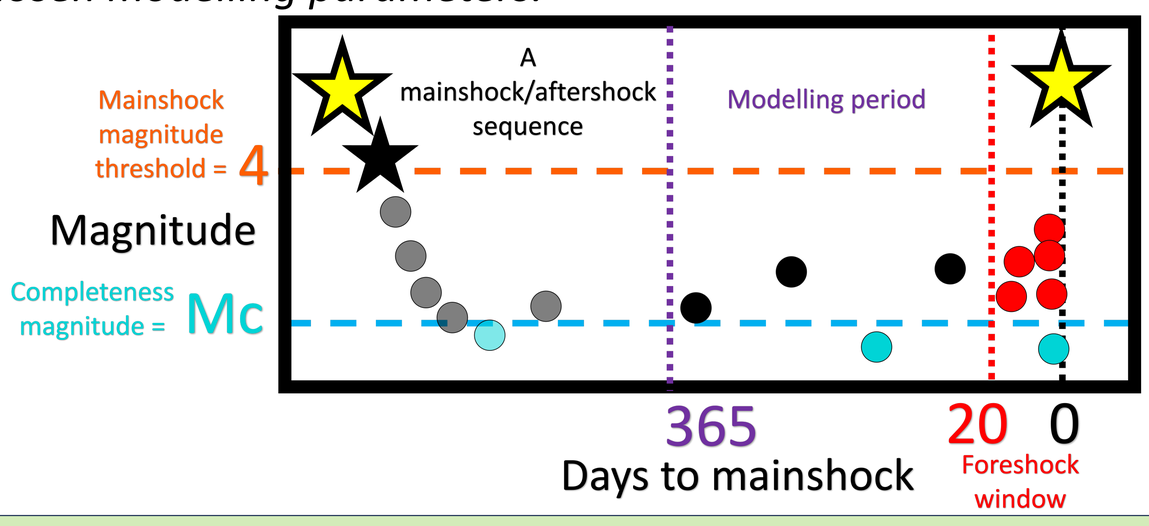
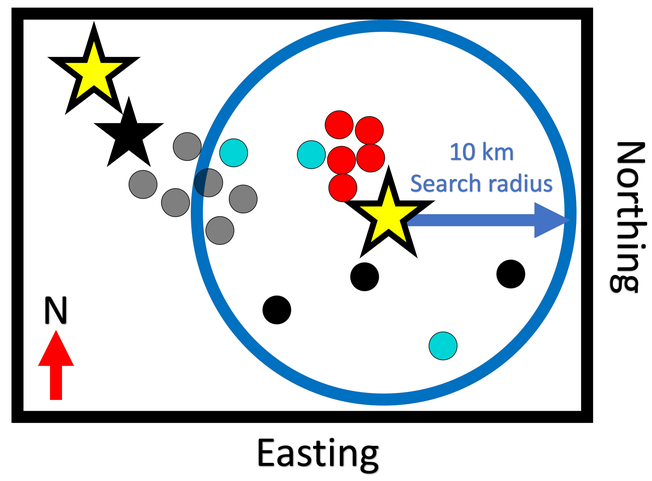


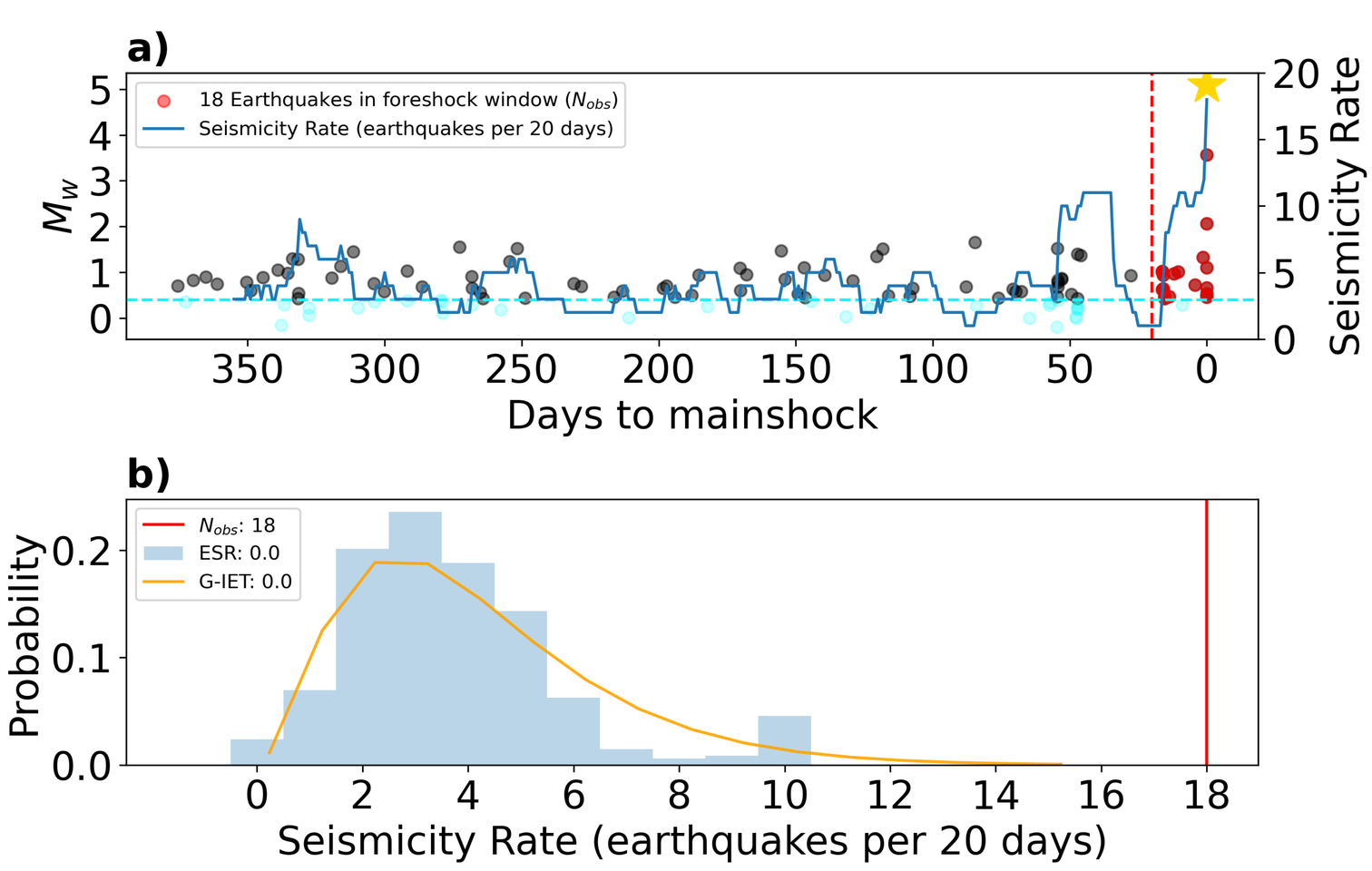
Figure 3: *A map view of the earthquakes from Fig 2.*



Methods

- We do not just call the red earthquakes foreshocks, We build seismicity rate models (**Fig 4**) and ask the question: what was the probability of seeing this many earthquakes in 20 days?
- We build seismicity rate probability models (**Fig 4**, **ERS** & **G-IET**) using earthquakes from within the search area during the modelling period (**Fig 2** & **3**). From these models we can get the probability of seeing any number of earthquakes in a 20-day period.
- A mainshock has foreshocks if the probability of seeing N_{Obs} or more earthquakes in the foreshock window is < 1% (0.01) (**Fig 4**).

Figure 4: *a) A real earthquake time series. b) Seismicity rate probability models.*



Further Questions

- How robust are the regional differences in foreshock rates with respect to different parameters?
- What could be causing regional differences in foreshock rates?
- Are foreshocks triggered by other earthquakes (cascades), or by aseismic slip, or are foreshocks swarms due to high heat flow?
- Can we use regional differences in foreshock rates to build improved earthquake forecasting models, or to better understand the physics of large earthquake nucleation?