Exploring the Predictability of Earthquake and Tsunami Hazards to People in Unstable Coastal Regions during Particular Periods of Time: were the 26 December 2004 Sumatran earthquake and tsunami tidally-triggered and hence predictable in the future (and past), here and elsewhere?

Robin Crockett, Gavin Gillmore, Paul Phillips, David Gilbertson.!

Abstract!

This poster describes the observation and quantification of tidally synchronous earthquake incidence in the period around the 26 December 2004 Sumatran earthquake / tsunami event. In addition, three other recent catalogued Indonesian earthquake/tsunami events are examined, as is the 01 April 2007 Solomon Islands event which occurred during the initial preparatory work. !

For the 26 December 2004 event, the relationship indicates earthquake inducement via ocean tidal loading of the offshore terrain and, during the ten-month period of high earthquake activity in this region, earthquake incidence associated with tidal-loading maxima was (a) 38% and (b) 86% higher than the period averages for the full and declustered earthquake catalogues respectively. A preliminary investigation of the Solomon Islands event indicates a similar relationship, although the inducement appears to be via earth tides in this case, and incidence associated with earth-tide maxima in this region was (a) 70% and (b) 50% higher than the period averages for the full and declustered major-earthquake catalogues respectively. It is concluded that the 26 December 2004 earthquake/tsunami event was tidally triggered, and the 01 April 2007 Solomon Islands also on the basis of the preliminary investigation, and hence some such events in this region might be predictable for the future and the past. However, three other Indonesian events investigated were not, with two of these displaying no tidal influence. This analytical approach seems to be effective and suggests earthquake-tsunami hazards related to variations in tidal loading are predictable for coastal communities in some tectonic and geographical settings and during the period of time studied, but not in others. Possible geological, geographical and oceanographic reasons are being examined. !

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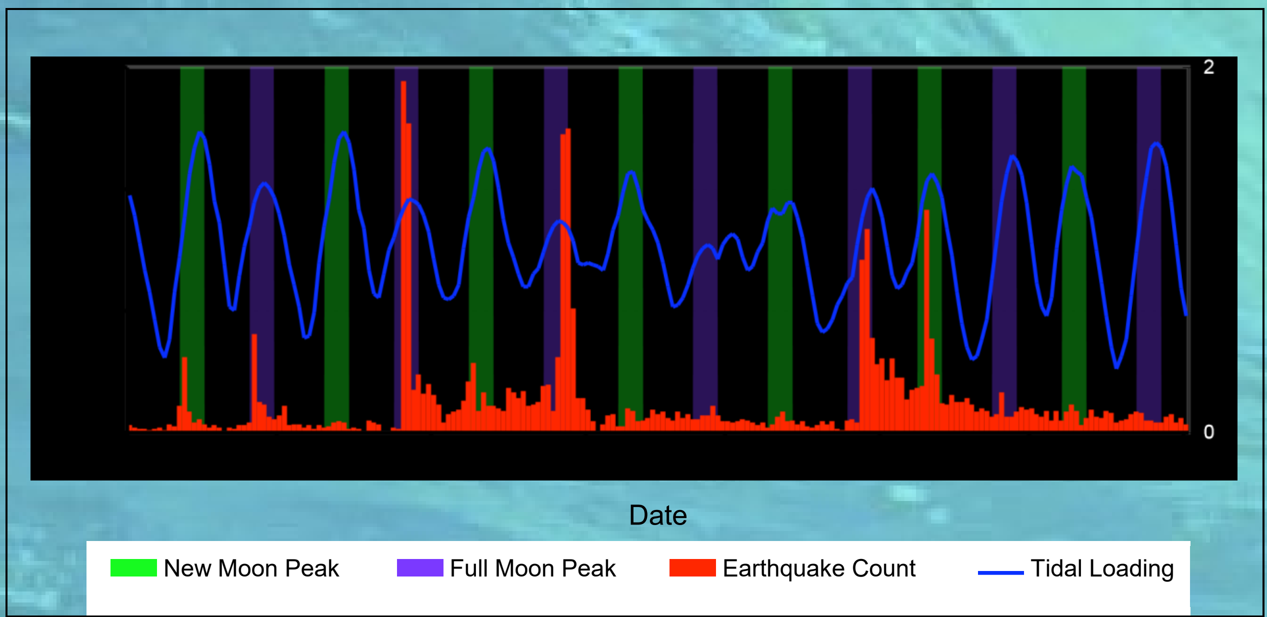

Figure 1. The Headline Picture.!

Daily earthquake frequencies with tidal variations superimposed in the Aceh area of eastern Sumatra!

Introduction!

Geoarchaeologists in coastal regions struggle with the investigations of past human activities in relation to earthquakes and earthquake triggered processes such as tsunamis. This reflects uncertainties about their identification in the geomorphic and archaeological record, and uncertainties about their triggers: the latter is the subject of this poster. The relationship between spikes in earthquake frequency and new and full moons, and the corresponding ocean tidal loading maxima of the area offshore in the Aceh area of Sumatra are clear from Figure 1.!

The spikes in earthquake frequency correspond to major earthquakes triggering aftershocks, including (a) the great earthquake of 26 December 2004 (Mw=9.0, full moon) and the associated major earthquakes of (b) 24 January 2005 (Mw=6.3, full moon 25 January), (c) 28 March 2005 (Mw=8.7, full moon 25 March) and (d) 10 April 2005 (Mw=6.7, new moon 08 April) which made international news headlines.!

Cluster analysis reveals two geographical groups – an eastern group (mid-Java eastwards) and the more important western group (mid-Java westwards, including Sumatra). Stripping out the 'aftershock noise' – declustering – reveals the major trigger-earthquakes in both geographical groups. The tidal periodicity of these earthquakes is revealed in Figure 2.!

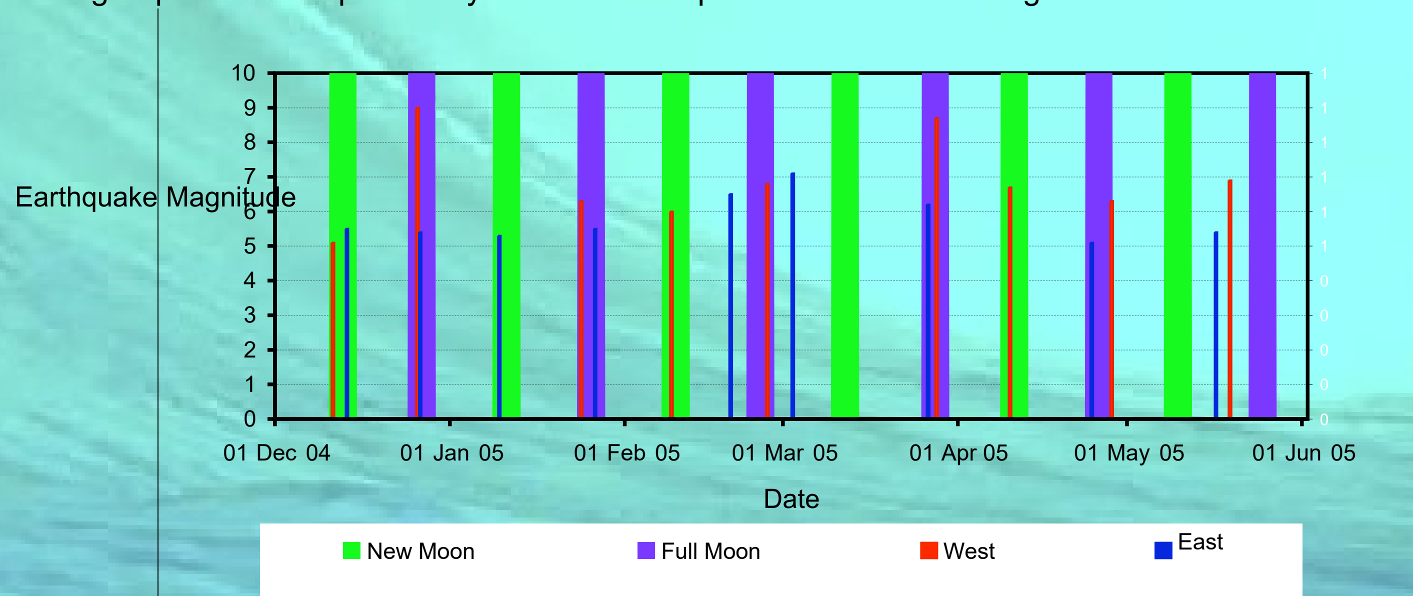

Figure 2. Tidal Periodicity of Key Major Earthquakes.!

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The major western-group earthquakes include the four ‘headline’ earthquakes noted above.!

Window Correlation.

Fourier spectra reveal frequency components corresponding to the lunar month and lunisolar fortnight, but are noisy owing to the ‘jitter’ of earthquake incidence around the tidal maxima.

Cross-correlation reveals a lunisolar-cyclic variation in correlation coefficient, but the magnitude is small owing to the dissimilarity of shape between the approximately sinusoidal tidal variation and the variable – ‘random’ – non-sinusoidal earthquake incidence.

Window-correlation is a novel, shape-independent technique under development at the University of Northampton. This technique entails windowing the earthquake catalogue according to quarter lunar-cycles centred on the new and full moons (tidal maxima) and first and third quarters (tidal minima). The earthquake-incidence totals are then calculated for the four cumulative quarter-cycles which, taking account of earthquake incidence peaks at new and full moons, can be combined to produce cumulative totals:

tidal maximum $n_{max} = n_{New} + n_{Full}$

tidal minimum $n_{min} = n_{Quarter1} + n_{Quarter3}$

The quarter-cycle windows are then offset (lagged) for these tidal references over a range of intervals and the calculations repeated to produce sequences of cumulative totals. If the catalogue does not contain any tidal-periodic behaviour then, for all offsets/lags:

$$n_{New} \approx n_{Full} \approx n_{Quarter1} \approx n_{Quarter3} \quad \text{and} \quad n_{max} \approx n_{min}$$

However, if the catalogue contains tidal-periodic behaviour, an offset/lag corresponding to the lag revealed by cross-correlation will maximise the difference $n_{max} - n_{min}$

This can be conveniently represented via the normalised ratio, *r*, which allows direct comparison between, for example, full and declustered catalogues:

$$r = \frac{n_{max}}{n_{max} + n_{min}} = \frac{n_{New} + n_{Full}}{n_{New} + n_{Full} + n_{Quarter1} + n_{Quarter3}}$$

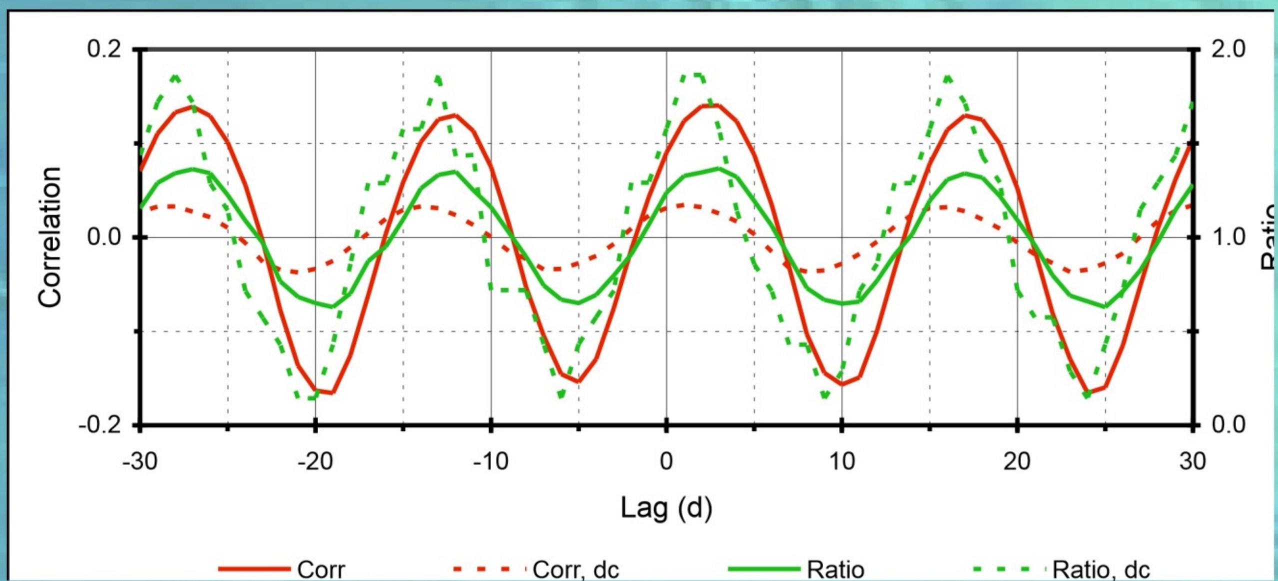

Figure 3. Cross- & Window- Correlation Output

Statistical Significance (Western Group).

The *de-facto* standard statistical test for lunar and tidal periodic behaviour in earthquake incidence is ‘Schuster’s Test’, despite its inherent liability to yield false negatives if used naively. Chi-Squared tests can also be used. Both tests can be visualised via the roseplots shown in Figure 4.

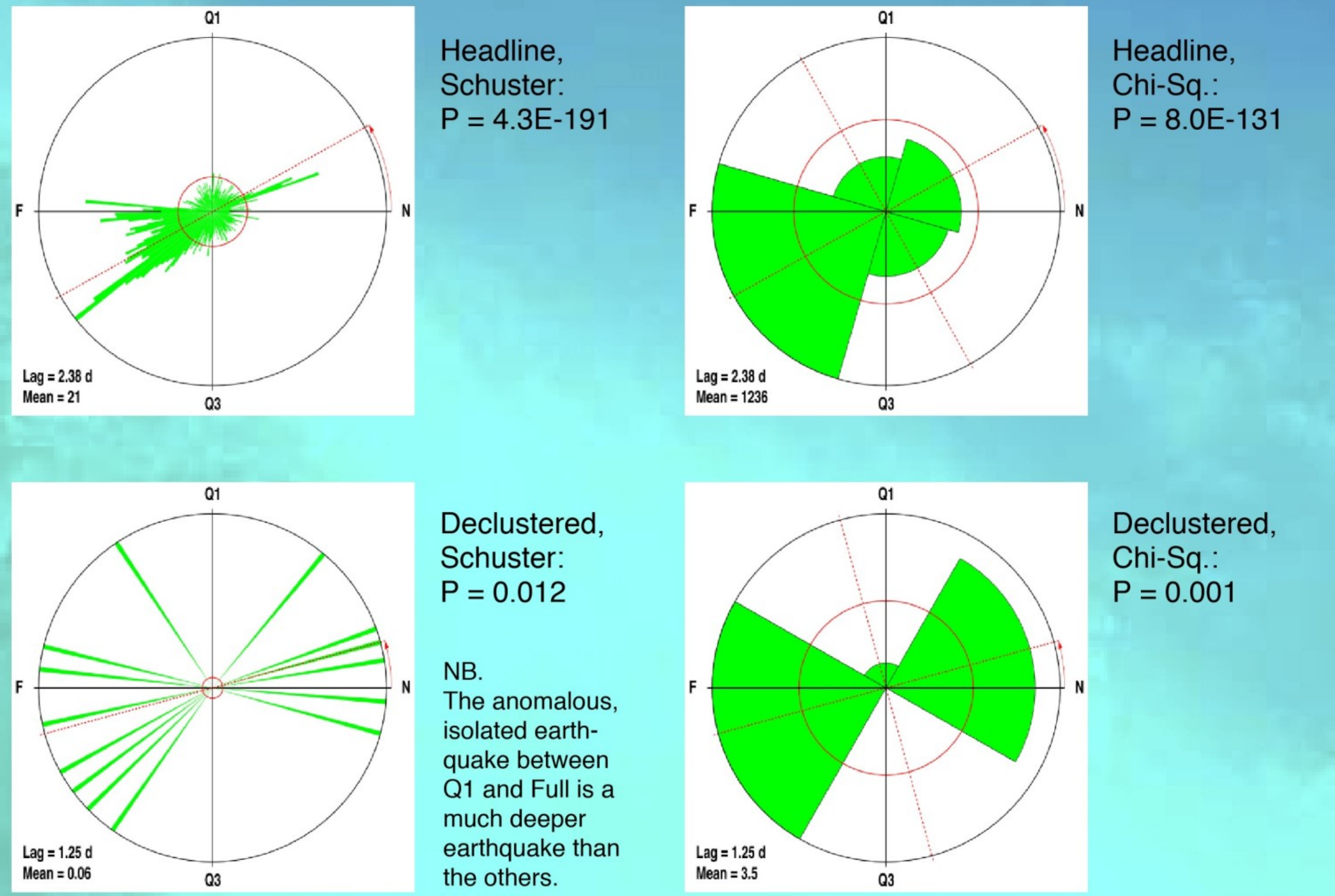

Figure 4. Roseplots and By-Chance Probabilities.

Conclusions.

Both tests reveal that the tidal-periodic incidence of earthquakes is highly unlikely to have occurred by chance. Consequently, we conclude that the Indonesian earthquake and tsunami of 26 December 2004 were most probably to some extent tidally triggered. The precise nature of the mechanism is unknown but the lag behind new/full moons corresponds to ocean tidal loading, indicating a probable role for this. This analytical approach seems to be effective and suggests earthquake-tsunami hazards related to variations in tidal loading are predictable for coastal communities in some tectonic and geographical settings and during the period of time studied, but not in others. Possible geological, geographical and oceanographic reasons are being examined.

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