From OBS Data: Acoustic Signatures of Tsunami Earthquakes in the Near-Field

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INTRODUCTION

Ever since the introduction of the term “tsunami earthquakes” by Kanamori in 1972, identification of such events has been a challenge, especially in real-time. This is due to their anomalously slow seismic rupture and long-period seismic moment (event's inefficiency in high frequencies). The former which controls tsunami potential, remains unrecognized in real-time due to the latter, since it causes the tsunamigenic character of the earthquake to be hidden from short-period waves and in particular felt accelerations.

This inability in identifying such earthquakes is accented in near-field due to the limited time in for warning the inhabitants and executing evacuation protocols.

In this study and in the context of the deployment of long-period ocean-bottom sensors (OBS) in epicentral areas, we have explored a simple but robust way of quantifying source parameters which could potentially lead to the real-time identification of tsunami earthquakes in the near field.

We use records of 2011 Tohoku aftershocks on an OBS JAMSTEC pressure sensor off the coast of Japan in the wake of the mainshock. Since seismic phases are not resolvable at short distances, we are simply introducing an integrated measurement of the pressure signal following the concept of the estimated energy of earthquakes first introduced by Boatwright and Choy (1986). After scaling to seismic moment, we compare this parameter, Ω, with other discriminants, such as Newmann and Okal's (1998) energy-to-moment ratio, Θ and Okal et al.'s (2003) T-wave parameter Γ. We also consider the duration of the pressure signal, and examine its relation to Ω.

METHOD

Earthquake energy estimation methods from body waves, similar to those introduced by Boatwright and Choy (1986) or Newman and Okal (1998) cannot be applied in near-field due to the irresolvablility of seismic phases. Therefore, due to the failure of seismic methods, we are motivated to consider the acoustic signatures of earthquakes which is routinely recorded by the hydrophone channels in the Ocean-Bottom Seismometers (OBS).

We consider an integrated measurement, Ω, the square of pressure variations divided by the bulk modulus. This is expressed in the following equation where α, ρ, and M_0 are acoustic velocity and density of water and estimated seismic moment of the earthquake. P is the amplitude of the pressure signal.

$$\Omega = \log\left(\frac{\int_{\omega_{min}}^{\omega_{max}} [P(\omega)^2]\, d\omega}{2\pi\rho\alpha^2 M_0}\right) + 30 \qquad (1)$$

The last term in Eq. (1) is a calibration constant which is chosen empirically. It should be noted that the pressure signal used in our method is empirically band-pass filtered between 0.1 Hz and 2 Hz where we have found most of the relevant energy to be focused and integrated accordingly.

DATA & PRELIMINARY RESULTS

We have applied our method to 12 months of continuous acoustic data from a JAMSTEC station sampling at 100 Hz for 40 aftershocks of the 11 March 2011 Tohoku earthquake (i.e., 41 events total) with $M_w \geq 6$. The observed frequency distribution of the data along with the frequency range of interest in our study led to an integration limit of 0.2 to 2 Hz (Fig. 1).

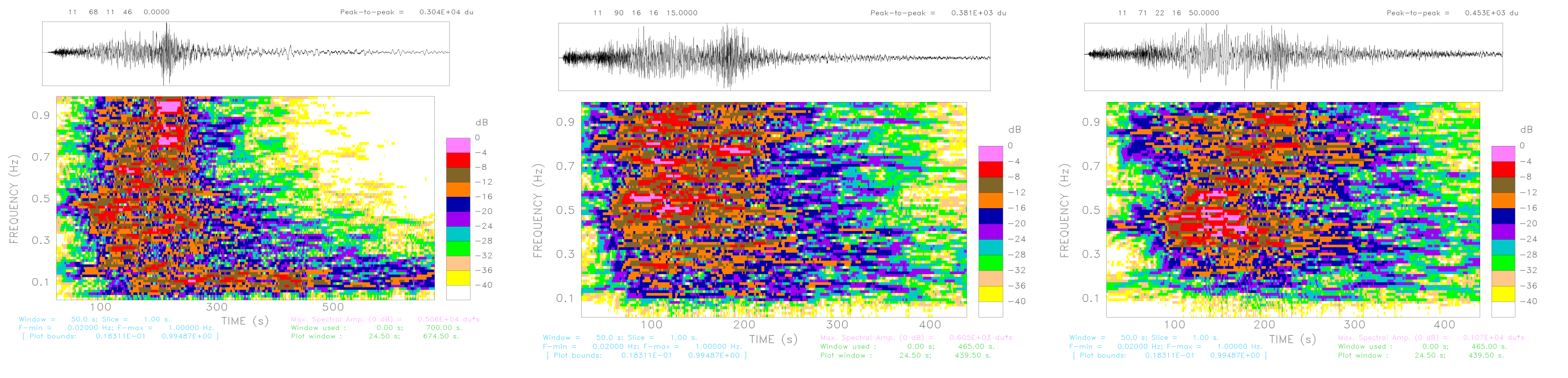


Figure 1. Examples of spectrograms for the aftershocks acoustic data.

The calculated values for Ω for the earthquakes in question are compared with Θ, and Γ, and source duration parameter, $\tau_{1/3}$ (Okal, 2013). These results are plotted in Figs. 2 & 3 respectively.

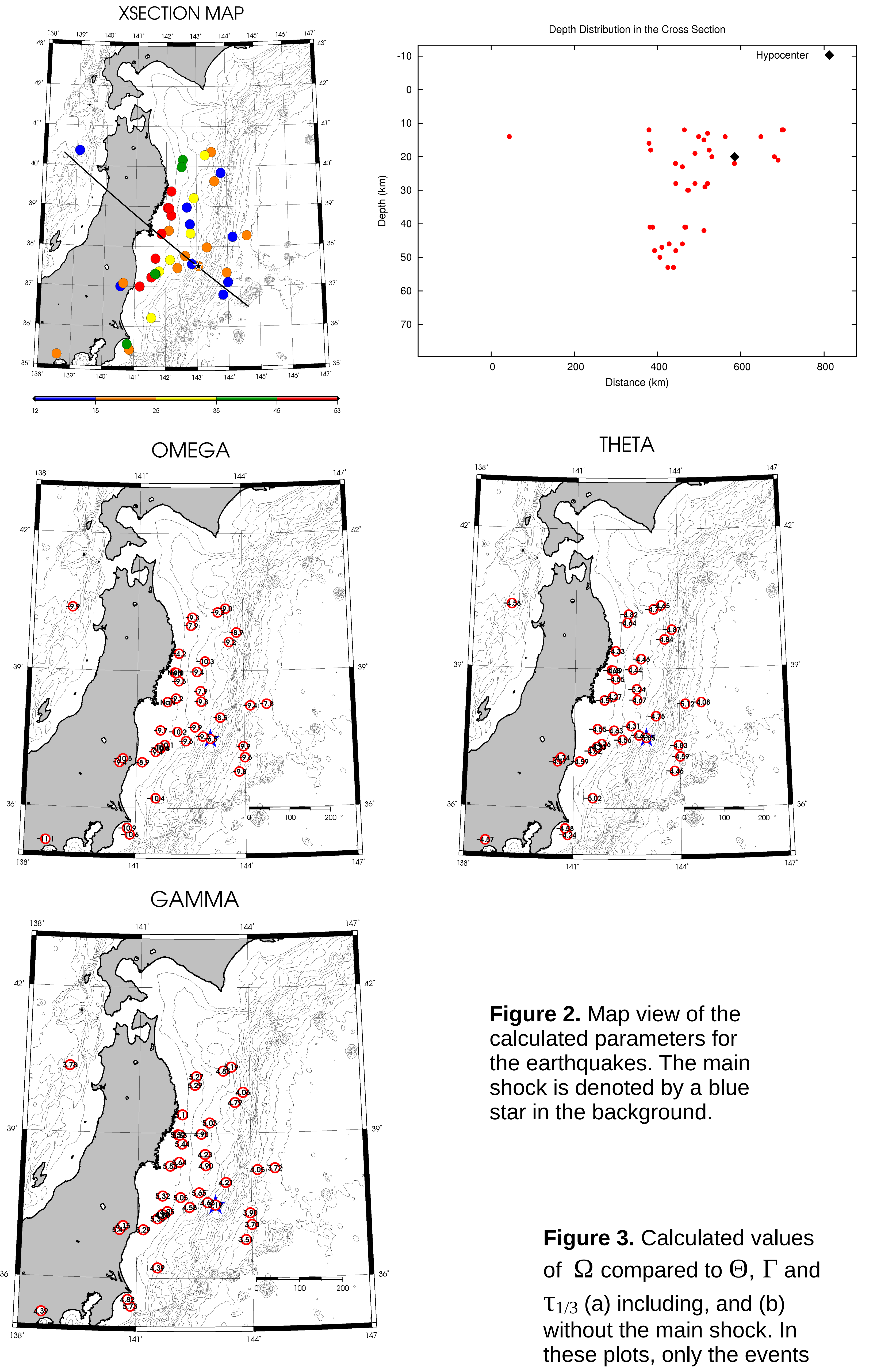
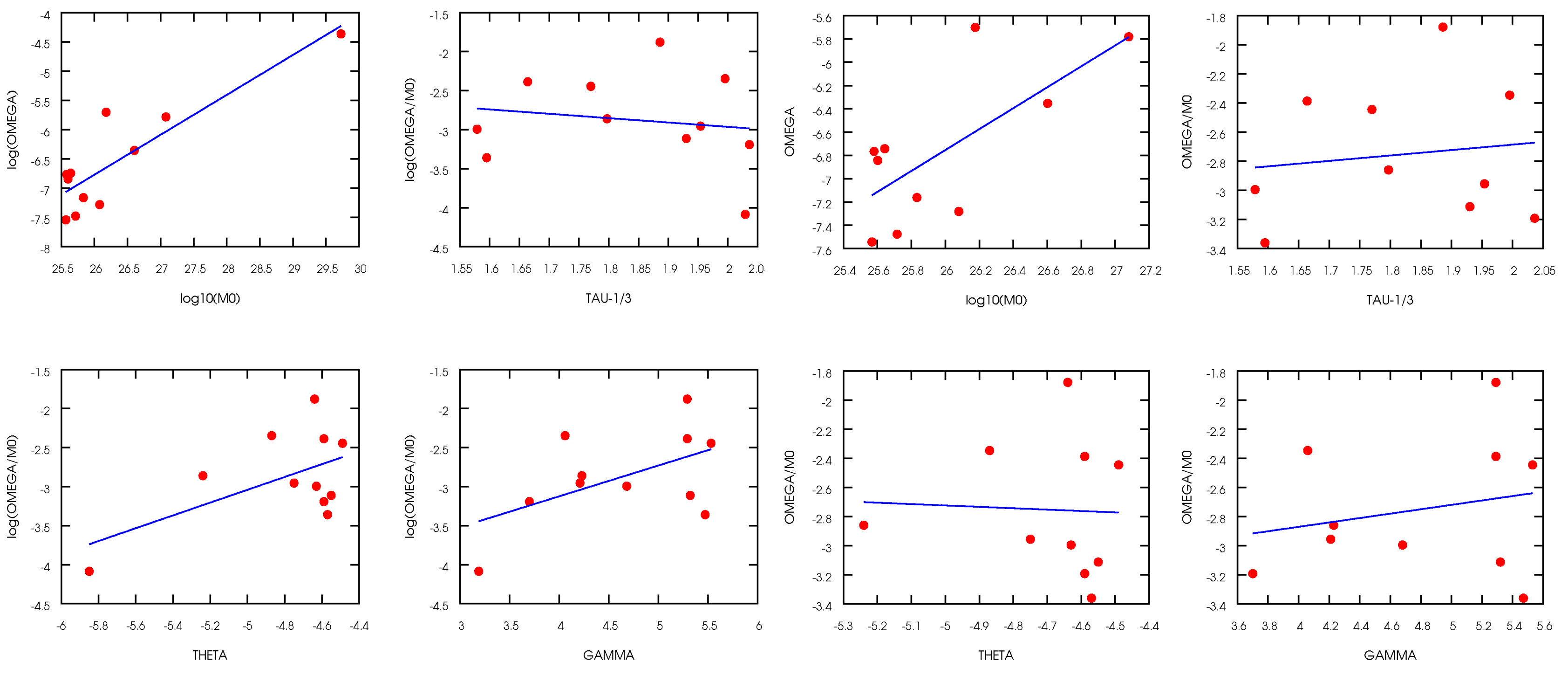


Figure 2. Map view of the calculated parameters for the earthquakes. The main shock is denoted by a blue star in the background.

Figure 3. Calculated values of Ω compared to Θ, Γ and $\tau_{1/3}$ (a) including, and (b) without the main shock. In these plots, only the events with $M_w \geq 7$ are considered.



(a) (b)

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