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Rupture imaging of large Earthquakes with a Poststack Isochrone Migration Method

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1

Summary

Rapid and robust characterization of large earthquakes in terms of their spatial extent and temporal duration is of high importance for disaster mitigation and early warning applications.

Backtracking of seismic P-waves was successfully used by several authors to image the rupture process of the great Sumatra earthquake (26.12.2004) using short period and broadband arrays ([1], [2], [3]). We follow here an approach of Walker et al. [4] to backtrack and stack broadband waveforms from global network stations using traveltimes for a global Earth model [6] to obtain the overall spatio-temporal development of the energy radiation of large earthquakes in a quick and robust way.

We present results for selected events with well studied source processes (Kokoxili 14.11.2001, Tokachi-Oki 25.09.2003, Nias 28.03.2005). Further, we apply the technique in a semi-real time fashion to broadband data of earthquakes with a broadband magnitude >= 7 (roughly corresponding to Mw 6.5). Processing is based on first automatic detection messages from the GEOFON extended virtual network (GEVN, [9]).

2

Method applied to seismograms at teleseismic distances

Individual waveforms are corrected for the radiation pattern, geometrical spreading, and attenuation. To avoid overweighting of regions with dense station networks, corrected waveforms leaving the source region in nearby ray bundles are stacked in a first processing step. Then, in a second step all first order stacks are used to form the final stack (final beam trace). The **semblance coefficients** are used as a measure of coherence [1, 2]. They are calculated within time windows of 30 s starting at the theoretical onset of the first-arrival phase (e.g. P waves, model: ak135 [3]). Time windows are subsequently shifted by 5 s over the ensemble of seismograms. Assumptions on source location and time are made (grid points). The **semblance coefficients** are calculated for all assumed hypocentres.

$$semblance = \frac{1}{M}\frac{\sum_{k=1}^{N}\left(\sum_{i=1}^{M} a_{ik}\right)^2}{\sum_{k=1}^{N}\left(\sum_{i=1}^{M} a_{ik}^2\right)}$$

When source mechanism at early detection times is missing, automatic hypocenter location information from the GEOFON detection system is used to infer on the source mechanism by employing a grid search over possible source orientation angles.

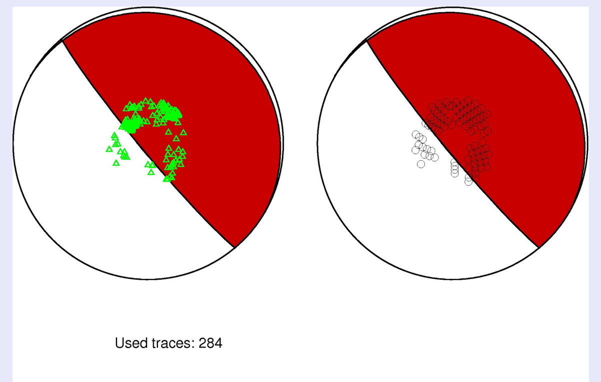
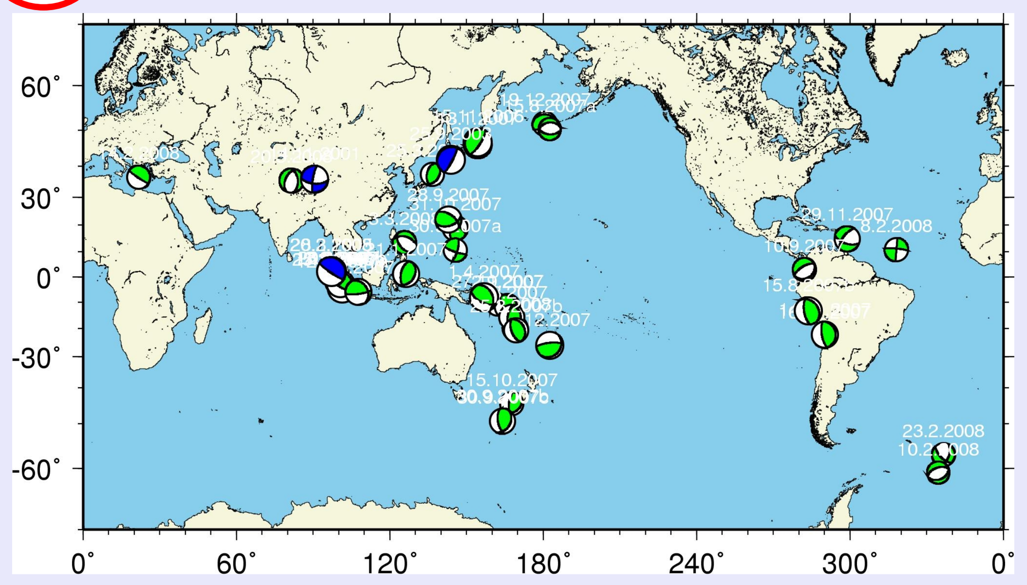


Fig. 1: Scheme to form first order beams of nearby stations for the 28.03.2005, Mw 8.7 event in Sumatra. Left: Green triangles correspond to piercing points of P waves. Right: Patches, for which waveforms are stacked.

3



The map shows the processed events (HRV CMT solutions [5]). Three events which were studied with other methods are displayed in blue color. Green color marks events which were analyzed using the broadband data of the GEVN in a semi-automatic detection driven approach. The online data were automatically quality controlled for gaps and strongly deviating average amplitude levels. Only vertical components were used.

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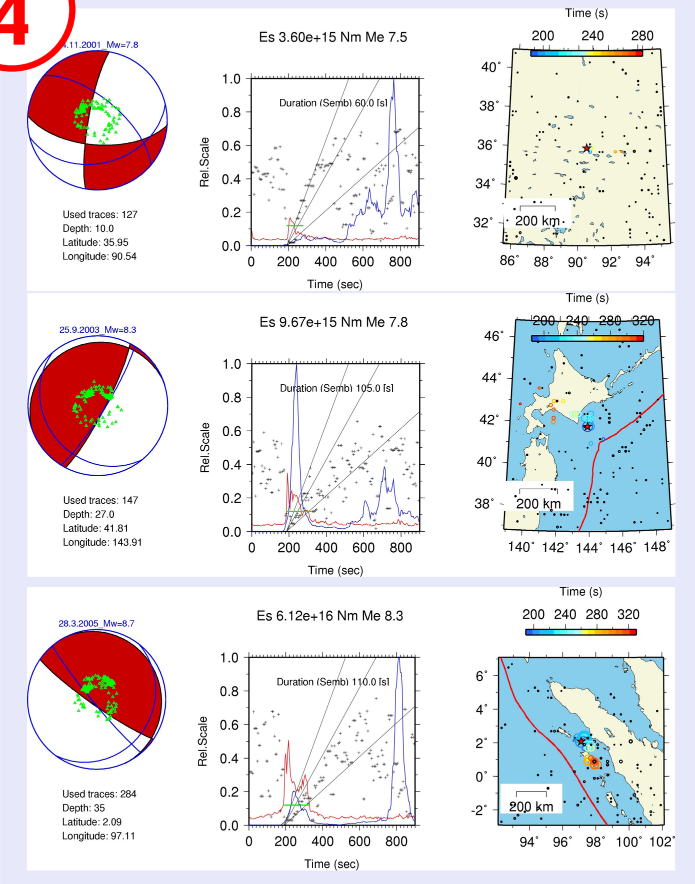


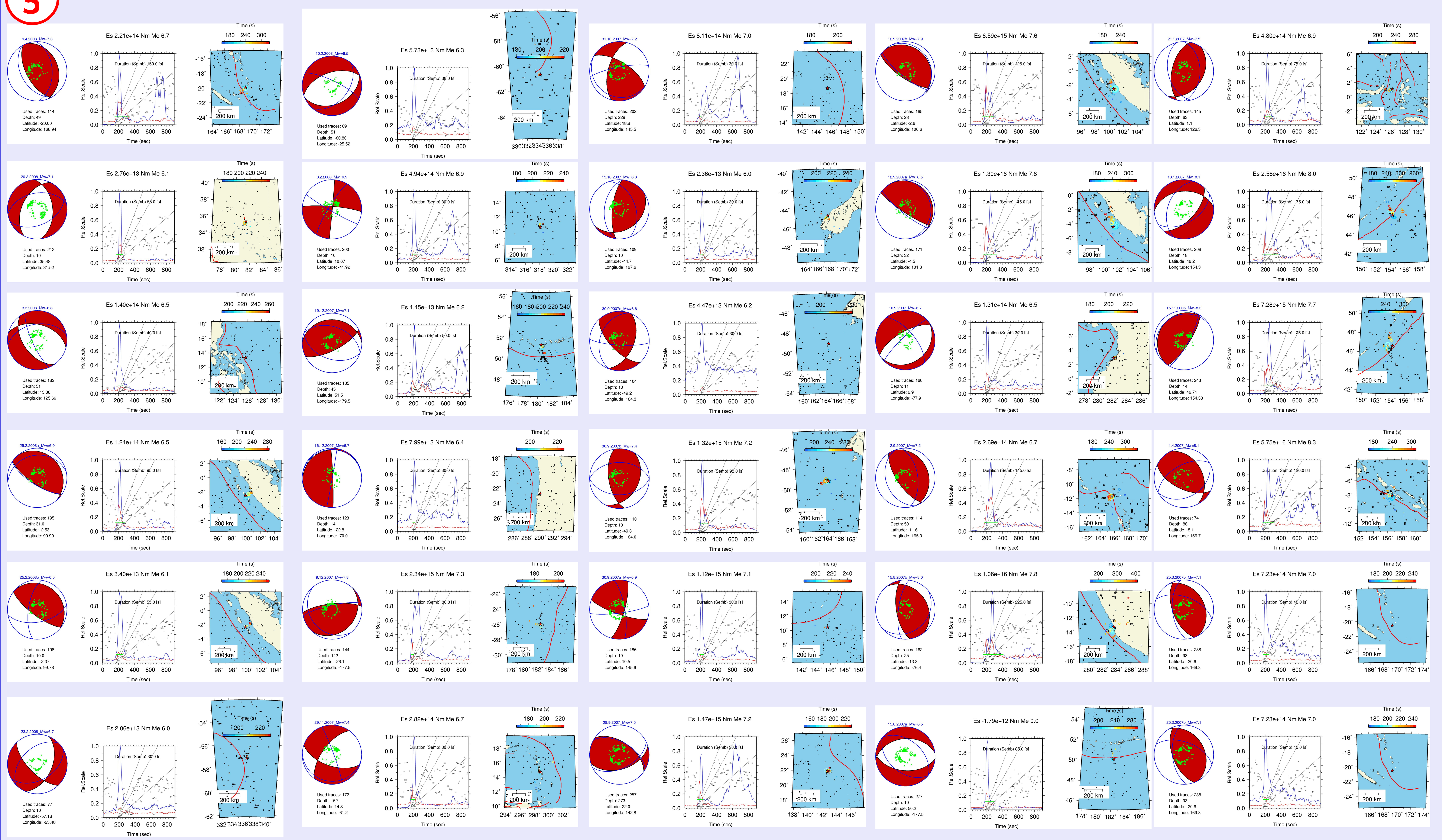
left panel: best grid search mechanism in blue
middle panel: semblance, energy, rupture duration
crosses show estimate of v_r (slopes of 1, 2 and 3 km/s)
right panel: spatio-temporal position of semblance max.

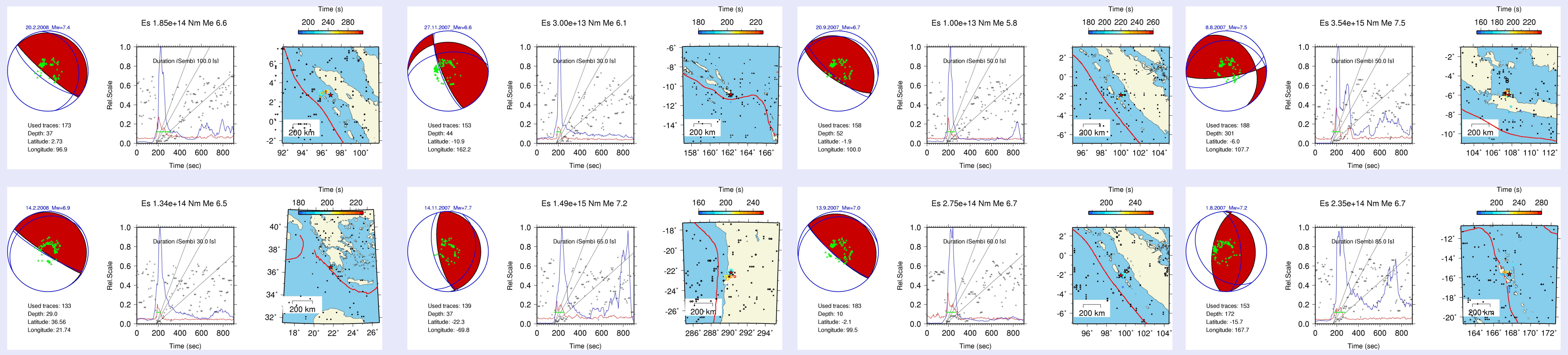
1. The Kokoxili event of 14.11.2001 was a very large strike-slip event and produced a surface rupture of up to 400 km length ([7]). While our best-fitting source mechanism (initial part of the P-wave) deviates from the average mechanism, the spatio-temporal extent of the event can be followed for more than 200 km). The average rupture velocity is near 3 km/s.

2. The Tokachi-Oki event of 25.9.2003 is the largest megathrust event in Japan which is recorded by modern instruments. Our data indicate down-dip rupture which was also found by other authors, see [8].

3. The Nias earthquake of 28.3.2005 followed the devastating Sumatra 2004 Tsunami earthquake after only 3 months. We image rupture propagation mainly to the southeast with major energy radiation beneath the islands in good correspondence with other studies, e.g. [4]. This might be an explanation for the relatively moderate Far-field-Tsunami generated by this event.

5





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