Lessons from the 2004 Sumatra earthquake and tsunami

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Abstract

The 2004 Sumatra earthquake was the largest one since 1964, and perhaps 1960. Its tsunami was the most lethal one in recorded history, and the first one to export death and destruction ocean-wide since 1964. It was also the first mega-event to occur since both the plate tectonics and information technology revolutions. We review the principal lessons this event (and to a lesser extent the subsequent earthquake on 28 March 2005) taught the scientific community.

1. Mega-earthquakes can occur in hitherto unsuspected areas. The simple concept of a maximum predictable earthquake derived as a function of plate age and convergence rate simply would not predict the 2004 event at its location, and is thus in dire need of a serious re-evaluation.
2. As large as the tsunami run-up was, it is correctly predicted in the near field by simple models based on earthquake scaling laws, and verified from numerical simulations; this serves as a further validation, if needed, of the codes used for their computations.
3. In the far field, the distribution of observed tsunami amplitudes is an excellent illustration of the directivity of the source, as introduced more than 30 years ago by Ben-Menahem and Rosenman (*J. Geophys. Res.*, **77**, 3097-3128, 1972).
4. The earthquake's T waves were recorded world-wide, in apparent violation of geometrical optics, which leads to a serious questioning of the concept of masking.
5. The tsunami was so large that it was recorded by many instruments not designed for this purpose. However, many of these records can be modeled, and thus provide new insight into the coupling between the hydrosphere, the solid Earth, and the atmosphere. In particular, satellite altimetry records can be interpreted in terms of the seismic moment of the source.
6. CTBTO hydrophones recorded the tsunami in a broad range of frequencies, and these records can be modeled successfully in the high-frequency (10 mHz) band, where they constitute, to our best knowledge, the first such observations in the far field outside the Shallow-Water Approximation (SWA). At lower frequencies, the signals are recorded but the drastic filtering of the system precludes their quantitative modeling.
7. Horizontal long-period seismometers can record the tsunami world-wide and, in the regional field, across the whole frequency band (both inside and outside the SWA). Their records can be modeled to the extent that insular horizontal seismometers could conceivably function as ancillary NOAA/DART-type mid-ocean sensors.
8. High-frequency (10 mHz) components of the tsunami wavefield can have very significant effects on distant harbors, and must be included in civil defense mitigation algorithms.
9. The failure to warn Indian Ocean communities in real time of the impeding tsunami was not so much scientific as managerial and organizational. Future efforts should be targeted primarily at developing robust communication protocols.
10. Education can and does work -- but is still sorely needed.