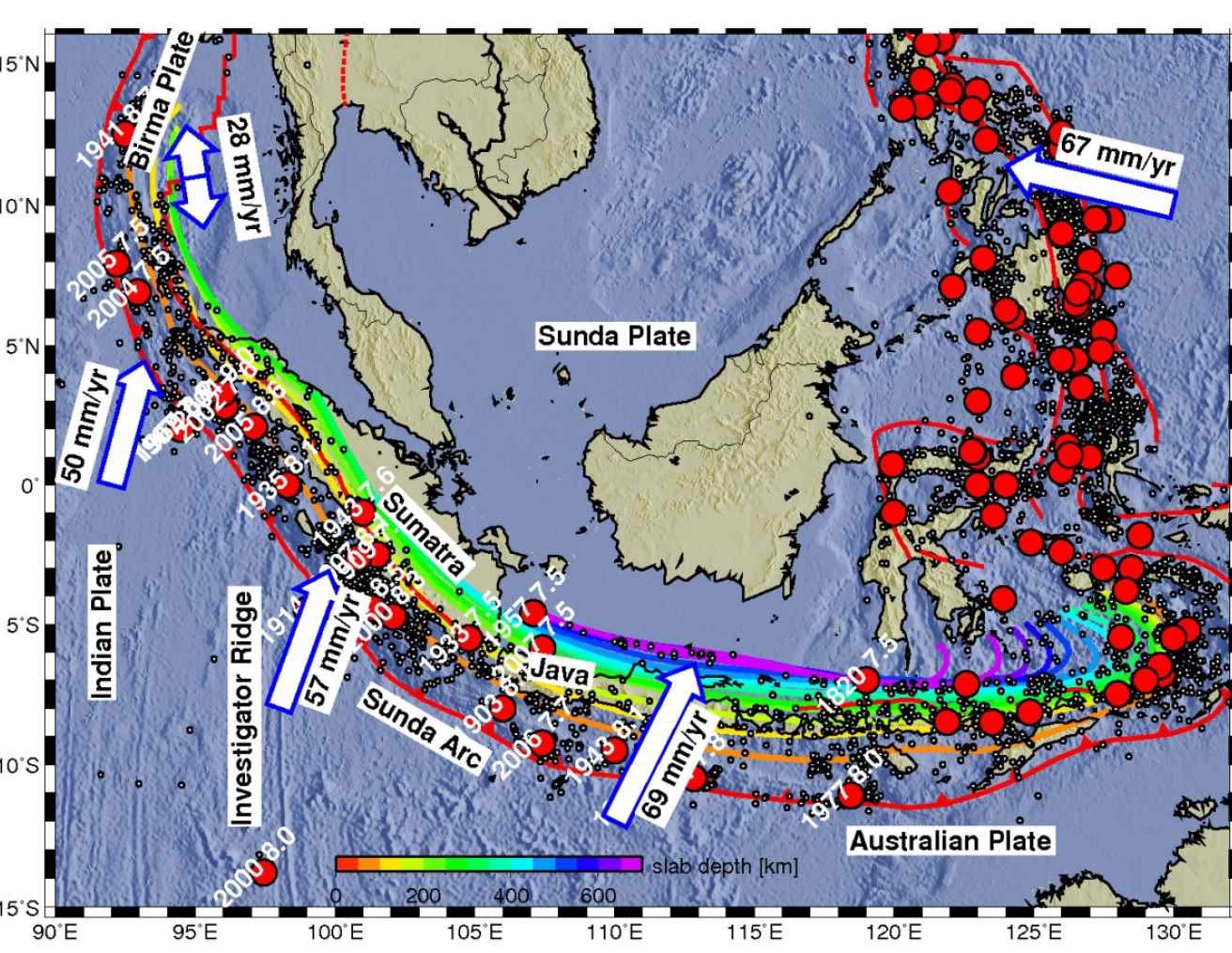


1. Introduction

Fig. 1: Map of seismicity and tectonics in the Sunda Arc region. Red circles: major earthquakes, contour lines: slab depth (RUM model). Arrows indicate plate motion.



We use seismic array methods (semblance analysis) to image areas of seismic energy release in the Sunda Arc region (Fig. 1) and world-wide. Broadband seismograms at teleseismic distances ($30^\circ \leq \Delta \leq 100^\circ$) are compared at multiple subarrays (Fig. 2) which are later combined by multiplication of their semblance maps. High semblance tracked over long time (10s of seconds to minutes) and long distances indicate locations of earthquakes. The method allows resolution of rupture characteristics for tsunami early warning and hazard mitigation:

- start and duration,
- velocity and direction,
- length and area.

The method has been successfully applied to major recent events in real time (see Sections 3-5, Refs. [1], [2], [3]). Results are found shortly after source time, visit www.geo.uni-potsdam.de/arbeitsgruppen/Geophysik_Seismologie/forschung/ruptrack.

Fig. 2: Principle of semblance analysis. Waveforms are compared within time windows defined by hypothetical source position and source time. Time and location at source are shifted to obtain resolution in space and time.

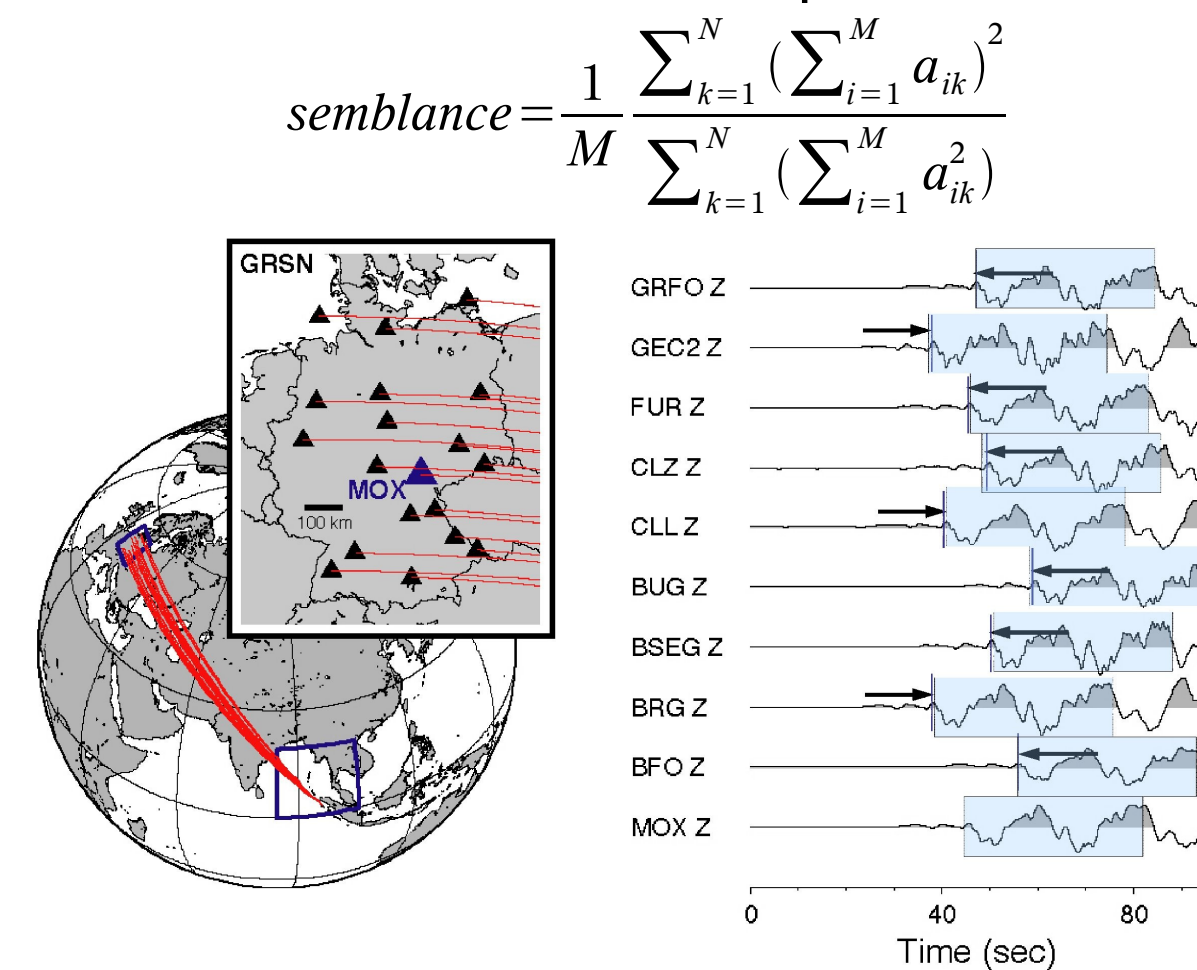
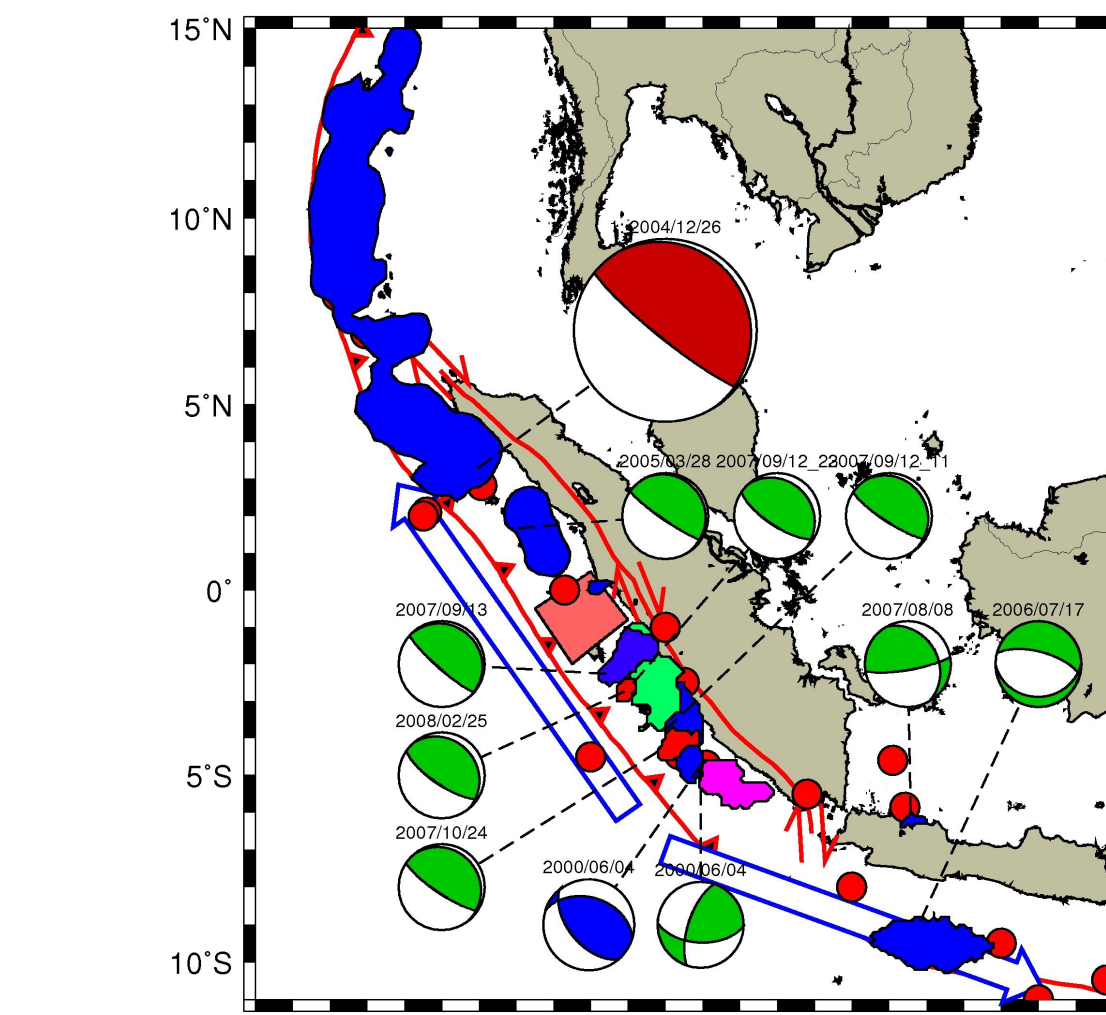
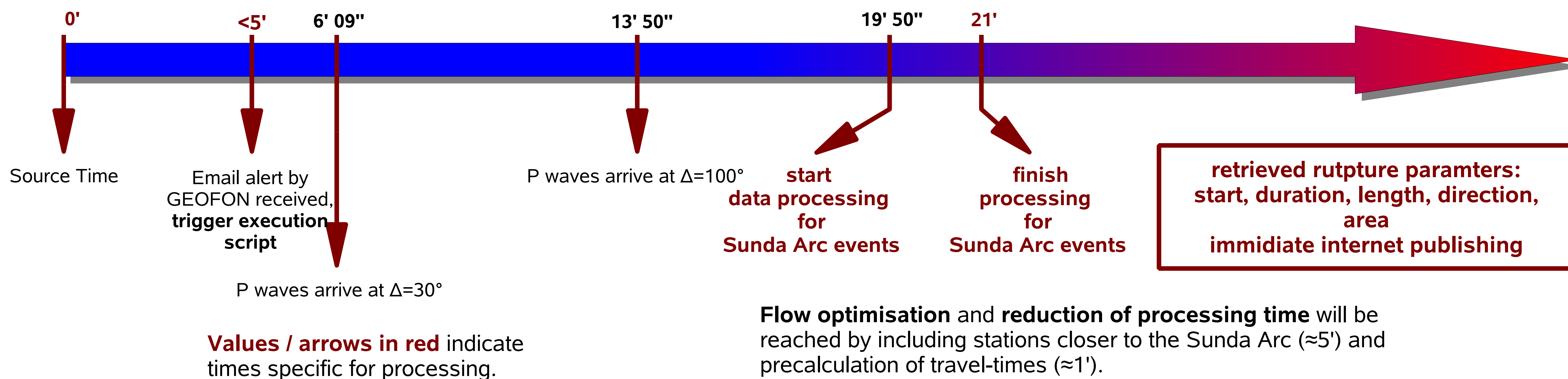


Fig. 3: Rupture areas of major Sunda Arc events since 2000 from semblance analysis. Focal mechanisms by University of Potsdam, [4], and [5].



2. Flow and Timeline of Near Real-Time Processing

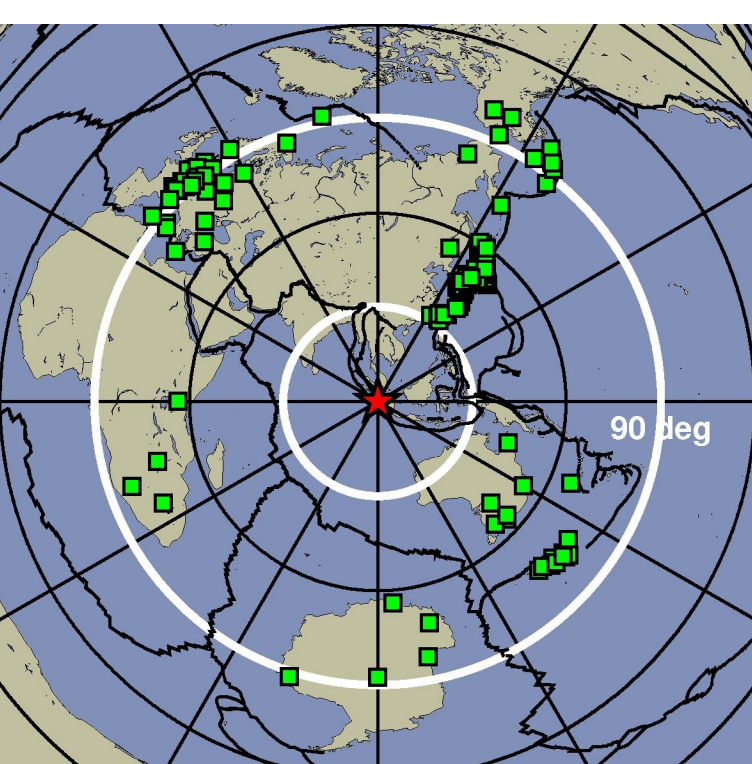


Flow optimisation and reduction of processing time will be reached by including stations closer to the Sunda Arc ($\approx 5'$) and precalculation of travel-times ($\approx 1'$). Resolution of rupture imaging may be increased by including more stations (Section 3) such as F-Net or near source seismic arrays and more sophisticated methods such as pattern recognition.

3. Manual vs. Automatic Real-Time Processing

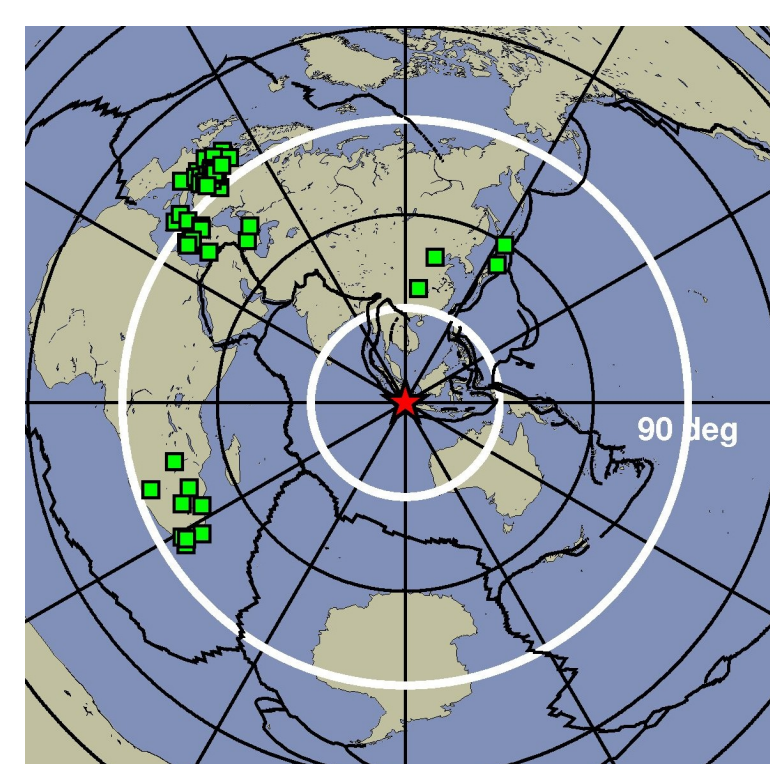
Results from manual and automatic post-processing (equivalent to real-time processing) show striking similarities of major rupture characteristics, e.g. source location, rupture direction, length, area, and velocity. During manual post-processing more than 70 Japanese F-net stations provide high image resolution. They are currently not available in real time. Stations in Australia / New Zealand were not included in automatic processing (likely polarity reversals resulting from source radiation properties).

Manual Data Processing

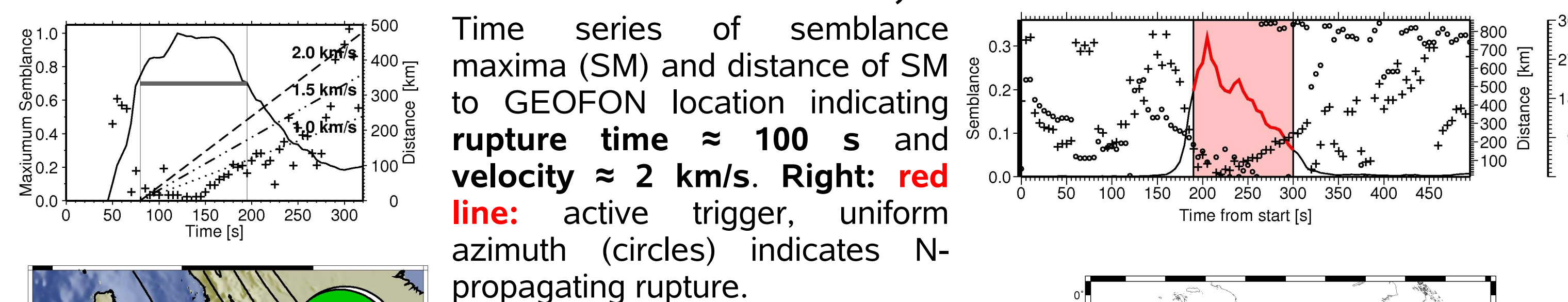


Left / right: Station distribution during manual processing / automatic real-time data processing

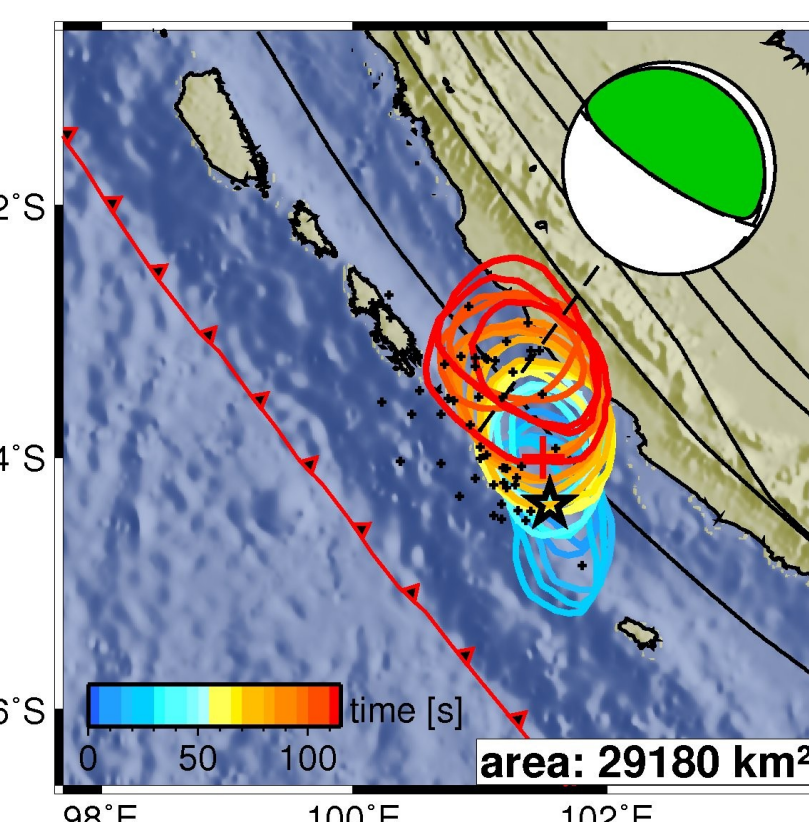
Automatic Processing



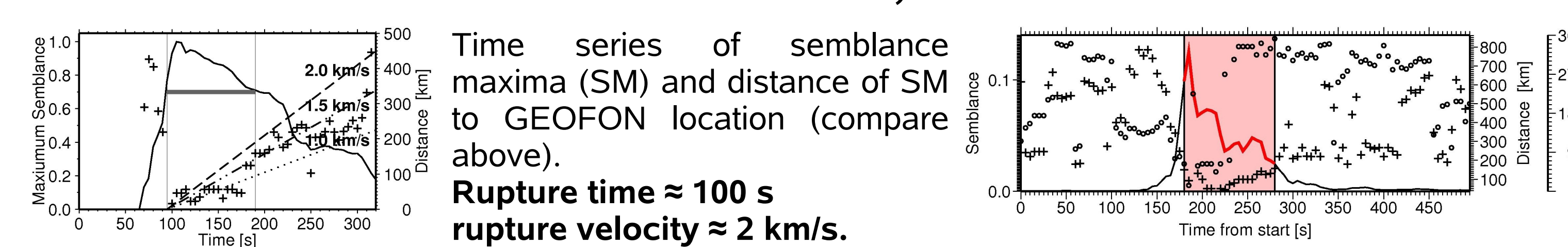
Mw8.0 on 12/09/2007, 11:10



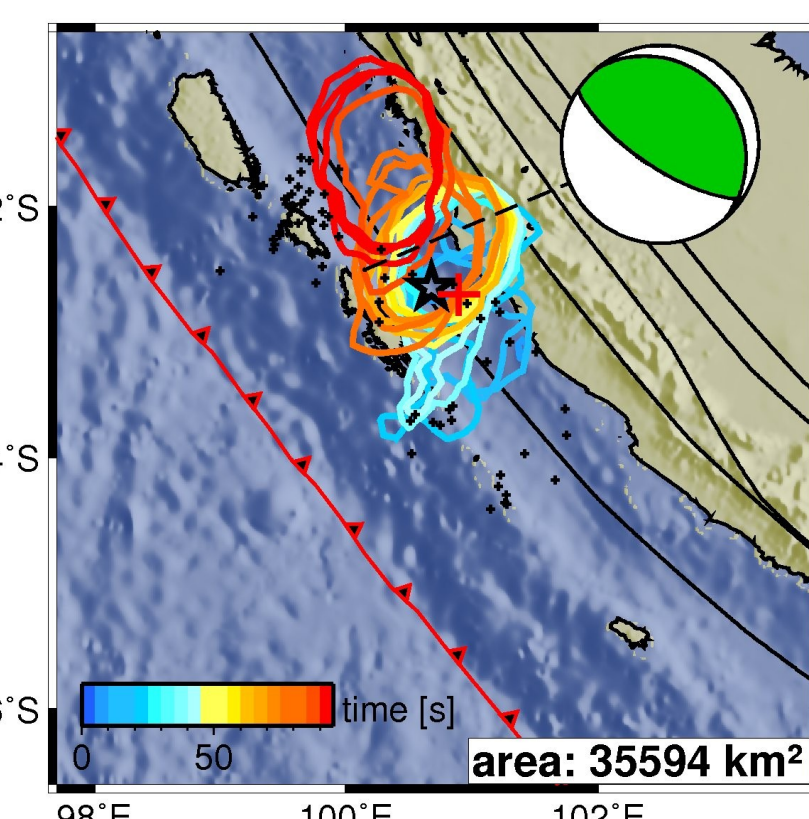
Map of semblance (contour) imaging rupture extent. Star: GEOFON epicentre. Colours represent time from source time. Right: Contours for of positive triggering (red line in semblance-time plot). Crosses: locations of semblance maxima.



Mw8.0 on 12/09/2007, 23:49

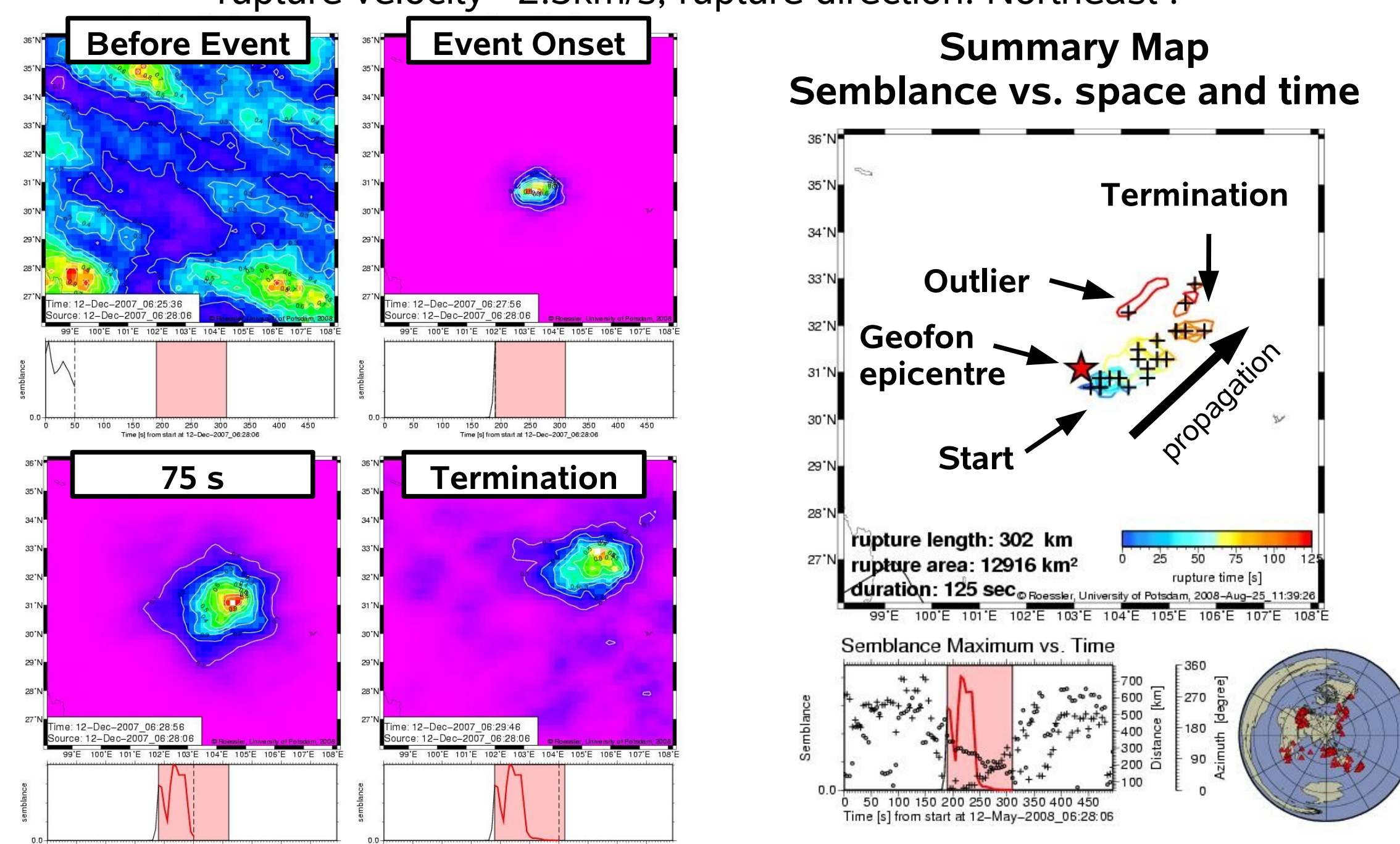


Map of semblance (contour) imaging rupture extent (compare above). Rupturing appears to be smooth. Only start and end phases are clearly resolved. Rupture lengths are similar for both processing schemes but estimated areas are quite different.



4. Example of Fully Automatic Processing

M8.0 Sichuan, China, Earthquake: 12/05/2008 at 31.1°N, 103.3°E, depth=10 km
Normalised semblance snapshots. Source duration ≈ 120 s, rupture length ≈ 300 km, rupture velocity ≈ 2.5 km/s, rupture direction: Northeast.



5. Online Publishing

For major earthquakes we present our results via internet in real-time: www.geo.uni-potsdam.de/arbeitsgruppen/Geophysik_Seismologie/forschung/ruptrack
Current magnitude threshold for processing is M5.5.

Bruchausbreitung sehr großer Erdbeben

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Institut für Geowissenschaften, Universität Potsdam

Region: Northern Sumatra, Indonesia
Herzzeit: 2004-12-26 00:58:49
Magnitude: 9.3
Epicentrum: 3.80° N | 96.20° E
Herdtiefe: 30 km
Distanz: 10708 km (6655 miles) to Potsdam
Azimut: 270.41° to Potsdam

Erklärung: Höhe und lokal konzentrierte Semblance zeigt den Ort seismischer Energieabstrahlung z.B. durch ein Erdbeben zu einer bestimmten Zeit an. Somit kann der Bruchverlauf sehr großer Erdbeben abgebildet werden. Oftmals sämtliche Verläufe der Semblance wird durch nachfolgendes Rauschen verwascht.

Wack auf das Ereignisdatum führt zum jeweiligen Ereignis. Vollständige Tabelle: www.geo.uni-potsdam.de/arbeitsgruppen/Geophysik_Seismologie/forschung/ruptrack/index.php

Origin Time [s]	Mag	Lat [N]	Long [E]	Depth [km]	Region
2008-09-11 00:20:52	7.1	42.01	143.68	30	Hokkaido, Japan Region
2008-09-09 16:52:09	7.5	13.51	167.02	126	Vanuatu Islands
2008-07-23 15:38:21	7.1	39.77	141.54	118	Eastern Honshu, Japan
2008-07-05 02:12:04	7.4	53.90	163.09	617	Sea of Okhotsk
2008-05-12 06:28:01	8.0	31.08	103.32	10	Sichuan, China
2008-02-25 06:36:34	7.4	-2.53	99.90	21	Southern Sumatra, Indonesia
2007-09-13 03:35:26	7.2	-2.17	99.57	10	Southern Sumatra, Indonesia
2007-09-12 23:49:06	8.0	3.84	103.68	26	Southern Sumatra, Indonesia
2007-08-12 11:10:26	8.0	-4.57	101.34	32	Southern Sumatra, Indonesia
2007-08-08 17:04:59	7.5	-6.07	107.73	301	Java, Indonesia
2007-08-01 17:08:58	7.2	-15.70	167.73	172	Vanuatu Islands
2007-04-01 20:40:09	7.8	-8.18	158.75	88	Solomon Islands
2007-01-21 11:27:49	7.6	-1.16	126.36	63	Northern Molucca Sea
2007-01-13 04:23:21	8.1	46.26	154.39	16	East of Kii Peninsula
2006-11-15 11:14:23	8.3	46.61	163.47	76	Kuiri Islands
2006-07-18 08:19:27	7.7	-3.28	107.42	20	South of Java
2005-03-28 16:09:36	8.6	-2.07	97.01	30	off-coast Sumatra
2004-12-26 00:58:49	9.3	3.80	96.20	30	Northern Sumatra, Indonesia

Time: 26-Dec-2004_01:05:29
Source: 26-Dec-2004_00:57:09

Acknowledgments and References
Data were provided by GEOFON, IRIS, NIED. Seismic Handler and GMT were used for seismogram analysis and plotting, respectively.
[1] Krüger, F., Ohrnberger, M., 2005, Tracking the rupture of the Mw=9.3 Sumatra earthquake over 1,150 km at teleseismic distance, Nature, 435 Res. Lett., 32
[2] Krüger, F., Ohrnberger, M., 2006, Spatio-temporal source characteristic of the 26 December 2004, Sumatra earthquake as imaged by teleseismic broadband arrays, Geophys.
[3] Rößler, D., Krüger, F., Ohrnberger, M., 2008, Rupture properties of the 2006 tsunamogenic Java earthquake seen at teleseismic distances, in review
[4] USGS: www.usgs.gov [5] Global CMT Project: www.globalcmt.org