The seismological software package SeisComP 3 and its role for tsunami early warning in southeast Asia

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GFZ
Helmholtz Centre
POTSDAM

Managing Waveform Data and Metadata for Seismic Networks
Giza, Egypt 8 - 17 November 2009

Overview

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The dilemma of December 26, 2004

Sumatra-Andaman earthquake, M_w 9.3

Tsunami causes up to 350,000 victims (sources vary) in Indonesia, Thailand, Sri Lanka, India and even Somalia

The dilemma of December 26, 2004

00:58 UTC Earthquake off the coast of northern Sumatra

OT +12 min. GFZ Potsdam (Germany) reports EQ with m_b 6.9

OT +15 min. PTWC (USA) reports M_{WP} 8.0

OT +25 min. Tsunami hits Aceh, Indonesia

OT +66 min. PTWC revises to 8.5

OT +79 min. NEIC (USA) reports M_S 8.5

OT +95 min. Tsunami hits Sri Lanka and Thailand

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OT +3 months Stein and Okal report M_W 9.3

Grossly underestimated magnitude

resulted in a misjudgement of the risk of an ocean-wise tsunami

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Lessons learned? Or not?

M_w7.7 Earthquake off Central Java 2006

Tsunami causes 700 victims

Java, July 17, 2006

08:19 UTC Earthquake off the coast of central Java

OT +2 min. BMG receives phone calls from coast

OT +5 min. BMG SMS alert, M_L 6.8 based on 8 BB stations

OT +6 min. BMG reports m_b 5.5 $\rightarrow$ non-typical earthquake

OT +12 min. PTWC observatory message, M_W 7.3

OT +17 min. PTWC bulletin #1, M_W 7.2 $\rightarrow$ regional watch

OT +21 min. 5-meter tsunami wave hits Pangandaran

OT +22 min. NEIC M_W 7.2 from body-wave moment tensor

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OT +6 hrs. GCMT solution M_W 7.7

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an accurate magnitude was not available early enough.

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The Challenge - Tsunami Warning for Indonesia

- Earthquake sources very close to affected coasts
- Tsunami traveltimes 20 . . . 40 minutes

Short tsunami travel times

require tsunami warnings within $\approx$ 5 minutes!

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The GITEWS Project

German-Indonesian Tsunami Early Warning System

- Funded by the German Ministry of Science following the 2004 catastrophe
- Funding period 2005 – 2010
- Multidisciplinary
  - **Seismology**
  - GPS
  - Buoys with OBU (GPS, seismic, pressure)
  - Tide gauges
  - Modelling
  - Integrated warning center
- Tightly integrated within IOTWS
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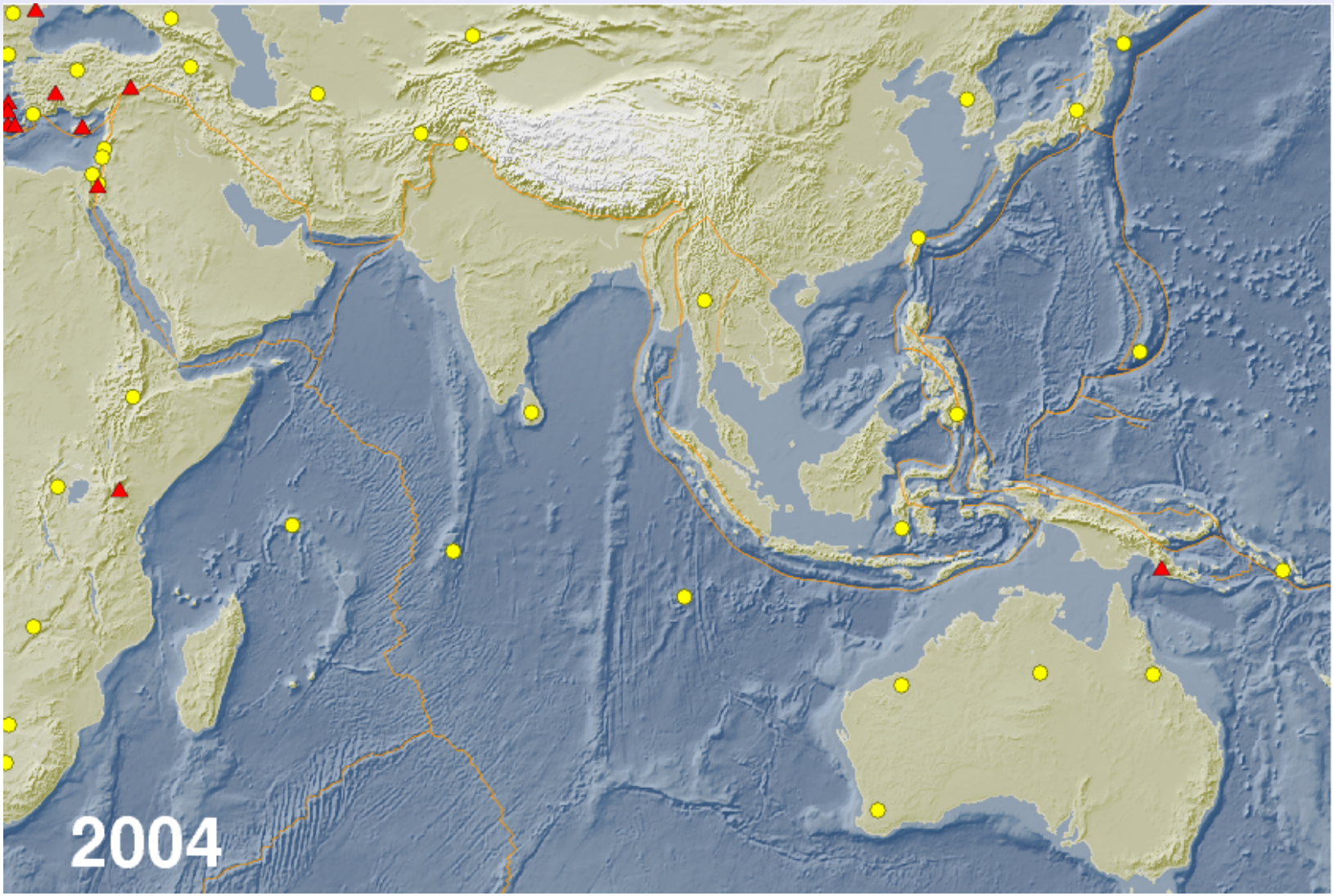
The IOTWS Seismic Network



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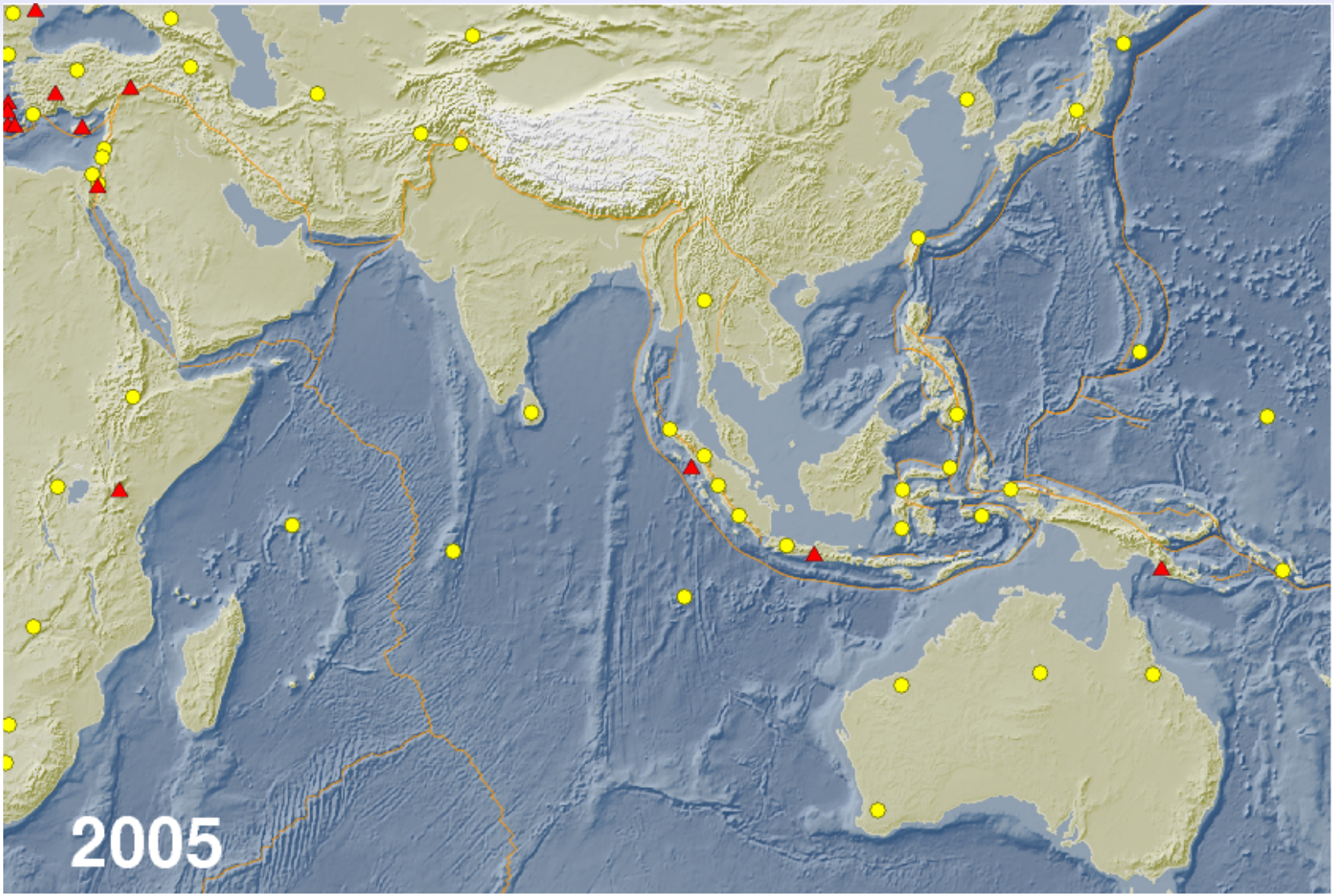

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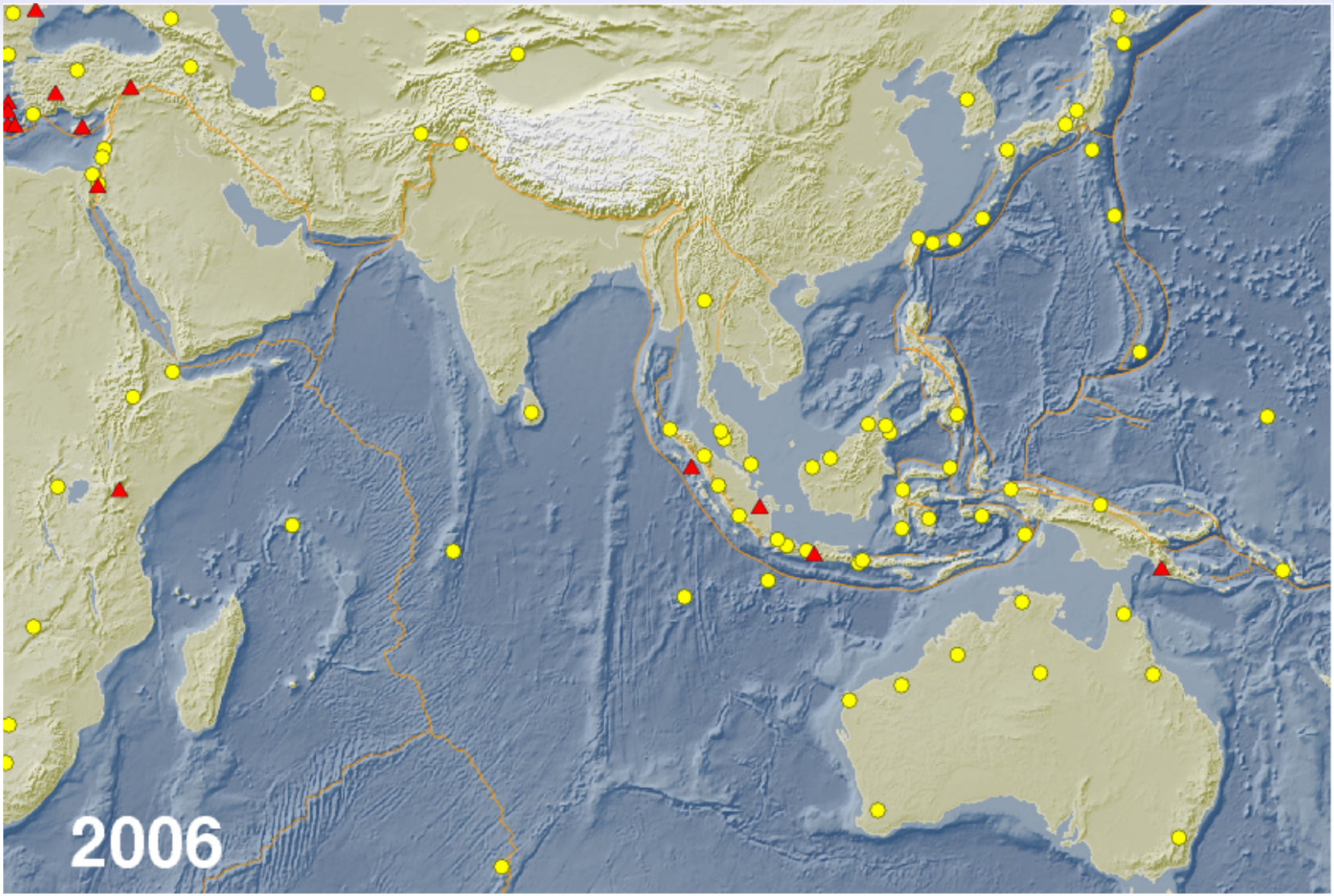

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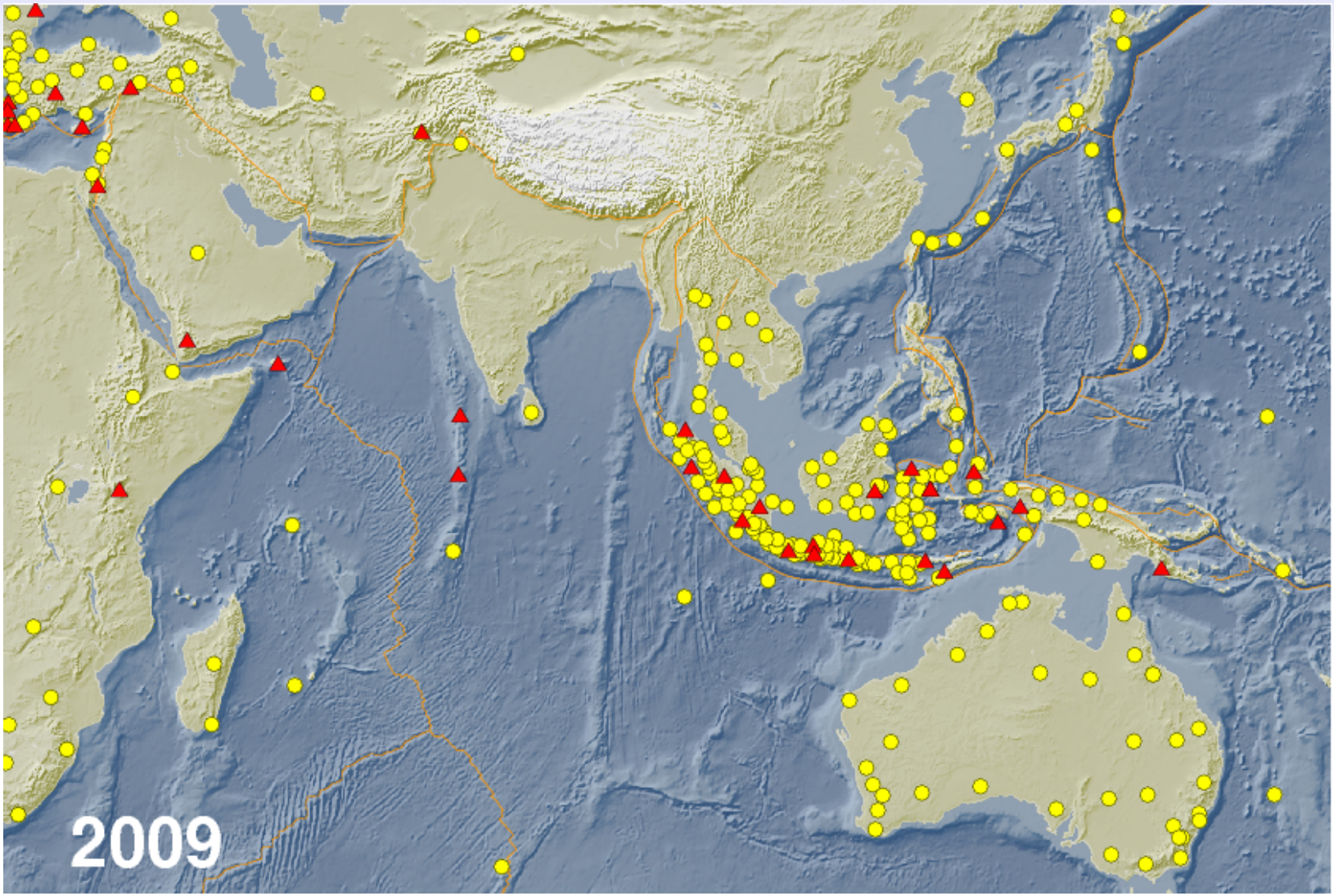

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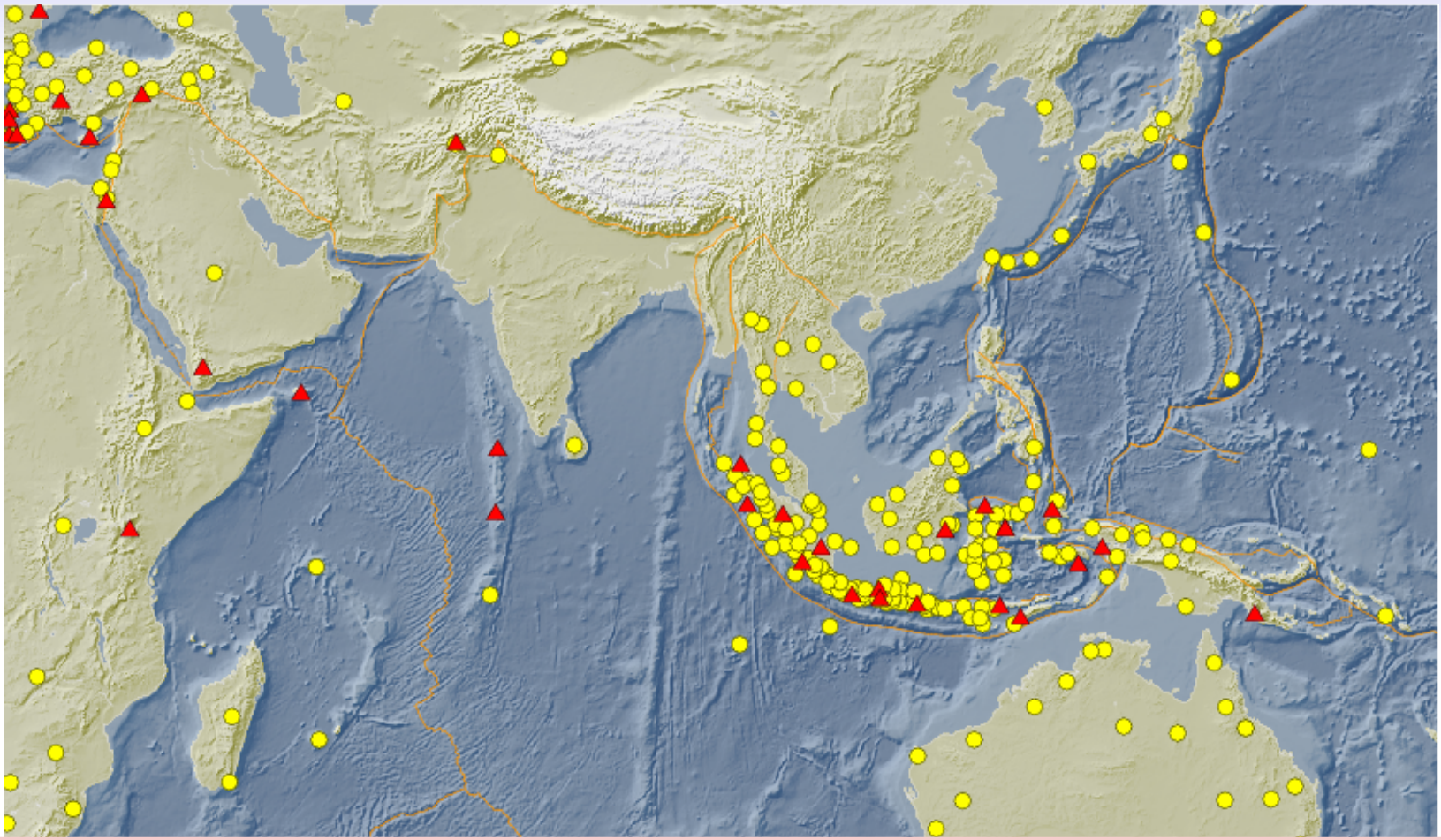

Now 143 broadband stations operational in Indonesia

Plan is to have 160 stations by 2010!

Adaption of Software to IOTWS Network

Robust data transmission

SeedLink was already available

Flexible data integration

Using SeedLink plugins (LISS, NAQS, etc., new: CD 1.1)

Automatic processing

Must be reliable enough not to require interaction (normally)

Need for fast, non-saturating magnitudes

Adoption of mB to regional distances, integration of Mwp, ...

Manual interaction

Must still be possible at any time

Existing 3rd-party software found to be inadequate

→ Start of SeisComP 3 development within GITEWS

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- Software package for seismological data acquisition, quality control and analysis in real time
- Data archiving modules
- GUIs for quick manual interaction, event visualization and state-of-health monitoring
- Emphasis on simplicity and speed. SeisComP must allow timely tsunami warnings!

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- Since 2003 (after the Algeria earthquake) development of simple automatic analysis tools
- Since 2005 (version 2) with multi-channel picker, global associator/locator, since 2006 prototype version of mB magnitude no integrated interactive analysis
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Evolution of the SeisComP software package

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- SeedLink as core protocol and software has become a de-facto standard in Europe since 2001 and is adopted world-wide
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- Since 2005 (version 2) with multi-channel picker, global associator/locator, since 2006 prototype version of mB magnitude no integrated interactive analysis
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Main features of SeisComP

- Distributed processing
- Data acquisition using SeedLink
- QuakeML data model used for storage and communication
- Automatic P picker (STA/LTA)
- Automatic global phase associator/locator
- Magnitudes implemented: ML, MJ, mb, mB, Mw(mB), Mwp
  planned: mBc, Ms(20), Ms(BB)
- GUIs for simple data quality and state-of-health monitoring and event visualization
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- Use of de-facto standards for data and parameter exchange (QuakeML, SeedLink, ArcLink)
- Written in C++ with most functionality available as library functions
- Inter-process communication between modules using TCP-based messaging to allow distributed processing
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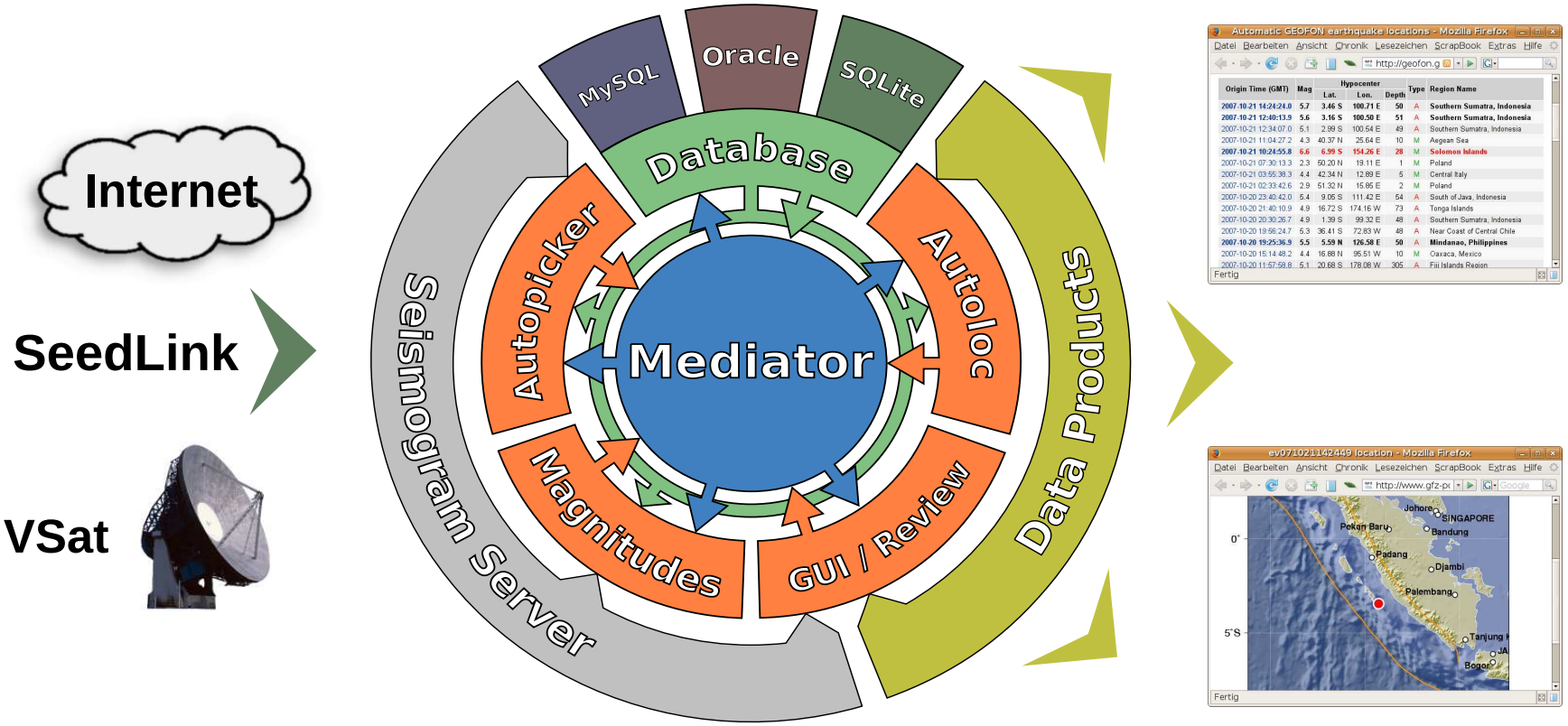

QuakeML

- Meta data object model
- Provides both XML serialization and database schema
- Extensible
- Intended for international data exchange
- Developed by ETH Zürich and GFZ Potsdam
- Contributions from NEIC, EMSC, IRIS
- Homepage: **www.QuakeML.org**
- SeisComP supports QuakeML

QuakeML

```
<?xml version="1.0"?>
<seiscomp>
  <EventParameters>
    <event publicID="ev071023233207#2" created="2007-10-23T23:35:59.687787Z">
      <preferredOriginID>or071023233207#23</preferredOriginID>
      <preferredMagnitudeID>or071023233207#23#netMag.Mw(mB)</preferredMagnitudeID>
      <description>Java, Indonesia</description>
    </event>
    <origin publicID="or071023233207#0" created="2007-10-23T23:35:46.580568Z">
      <time>
        <value>2007-10-23T23:21:39.497741Z</value>
        <lowerUncertainty>2.934</lowerUncertainty>
        <upperUncertainty>2.934</upperUncertainty>
      </time>
      <latitude>
        <value>49.328</value>
        <lowerUncertainty>13.742</lowerUncertainty>
        <upperUncertainty>13.742</upperUncertainty>
      </latitude>
      <longitude>
        <value>-157.161</value>
        <lowerUncertainty>9.491</lowerUncertainty>
        <upperUncertainty>9.491</upperUncertainty>
      </longitude>
```

Data acquisition using SeedLink

SeedLink is the data acquisition protocol in SeisComP. It features:

Uses MiniSeed format

the real-time version of SEED, which is **the** standard format for seiscmic data exchance. Data are converted to MiniSeed (and thus **homogenized**) as early as possible

Plugins for most digitizers

EarthData, Q330, Guralp, Nanometrics, ...

$\Rightarrow$ reduce dependency on hardware (and manufacturer!)

Plugins for other protocols

LISS, NAQS, Scream, ...

Robustness

automatic re-connect, priority on data completeness

Flexibility

SeedLink can be used over dialup lines, through SSH tunnels, internet connections, VSat, ...

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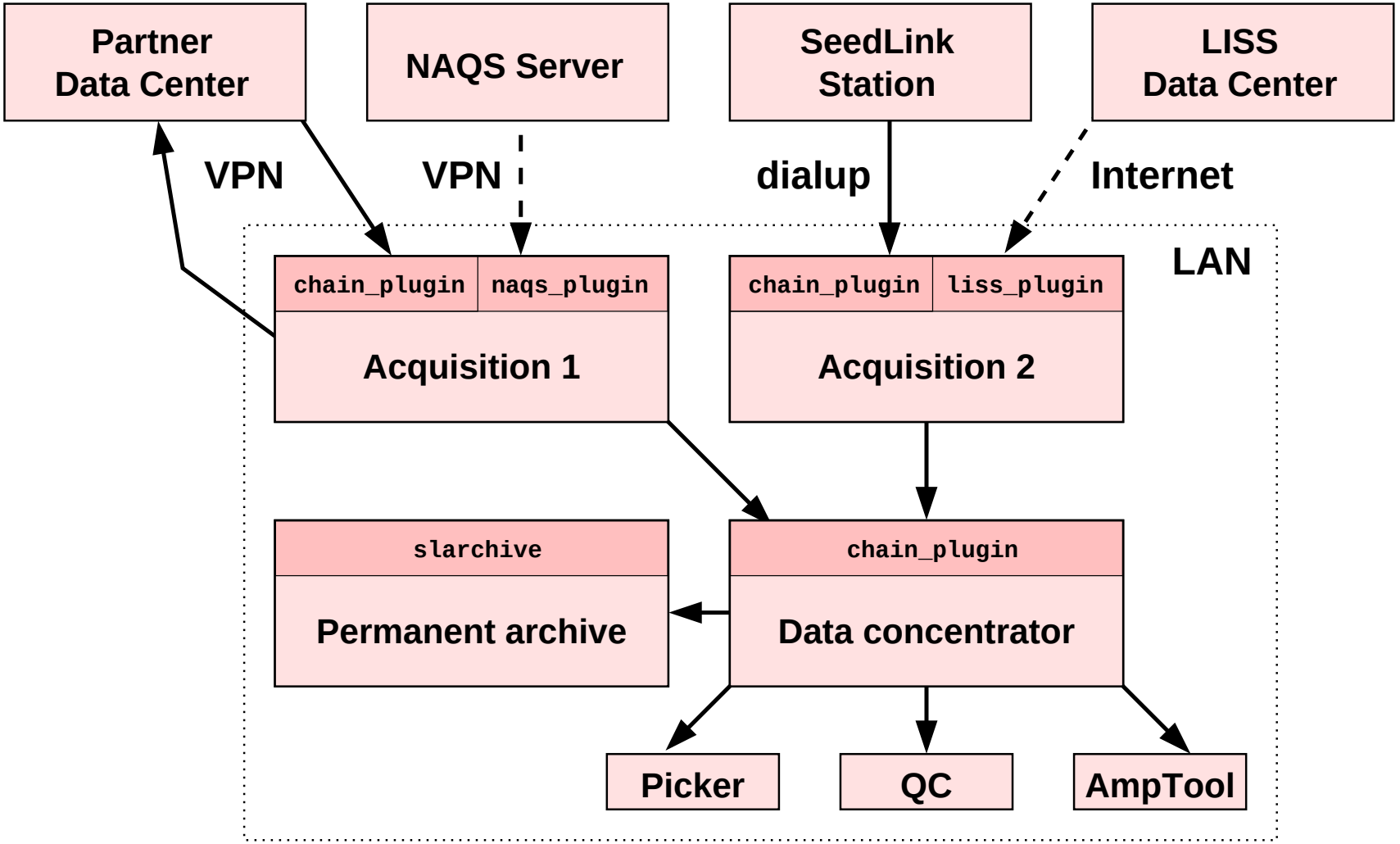
SeedLink Acquisition



Digitizer plugins

- Quanterra Q380/Q680, Q4120 and Q730
- Quanterra Q330 (UDP/IP)
- EarthData PS2400 and PS624
- Lennartz M24, PCM5800 and MARS88
- Guralp DM-24
- Kinemetrics K2
- Geotech DR24
- Nanometrics HRD24

Import/Export plugins

In addition to plugins that talk directly to a digitizer, plugins for exporting data from the following data acquisition systems are available:

- IRIS/GSN Live Internet Seismic Server (LISS)
- IRIS/IDA Near Real Time System (NRTS)
- Earthworm
- CTBTO's CD1.1
- Kinemetrics Antelope
- Nanometrics NAQS
- Guralp's SCREAM
- RefTek's RTPD

Earthworm, Antelope and NAQS can also have SeedLink clients, importing data from SeedLink (e.g. `slink2ew` for Earthworm).

Magnitudes in SeisComP

- Originally only mb and ML (SeisComP 1/2)
- For tsunami warning, quick magnitude quantification for M $\approx$ 8 and larger is needed
- SeisComP 3 uses (broadband!) mB as default magnitude for large earthquakes
- Other fast magnitudes available (Mwp) or planned (Mwpd, mBc, Mm, Mjma, ...)
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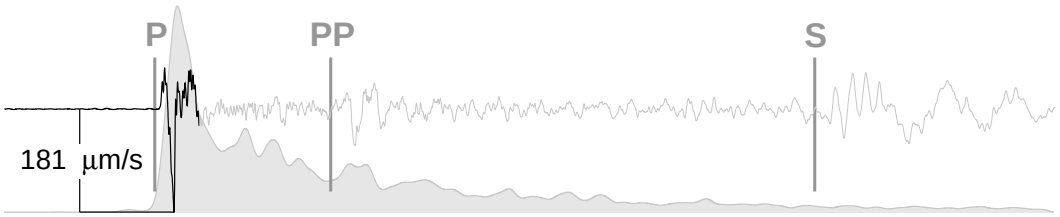
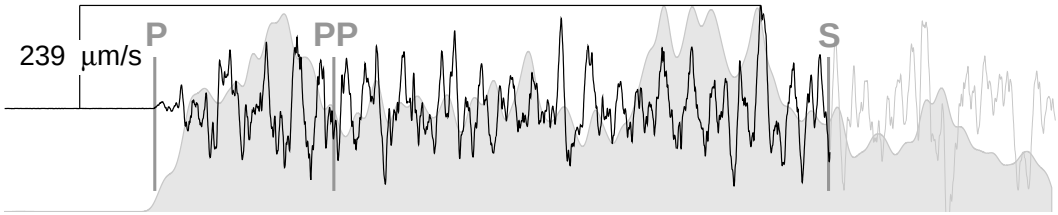
The body-wave magnitude mB

$$m_B = Q(\Delta, z) + \log \frac{V_{max}}{2\pi}$$

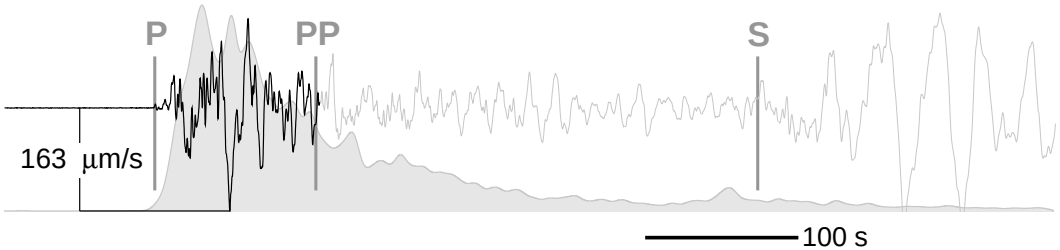
India 26 January 2001 Mw 7.6 RUE Δ=51° mB 8.2



Sumatra 26 December 2004 Mw 9.3 PMG Δ=53° mB 8.3

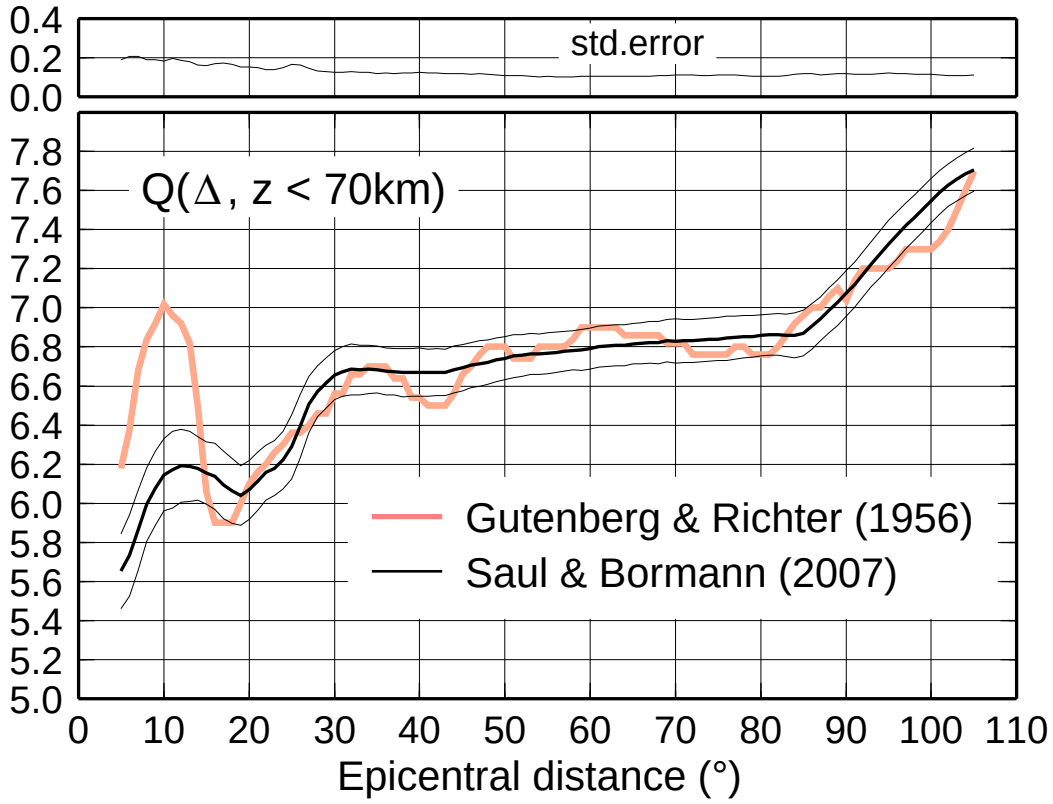


Sumatra 12 September 2007 Mw 8.4 PMG Δ=46° mB 8.1

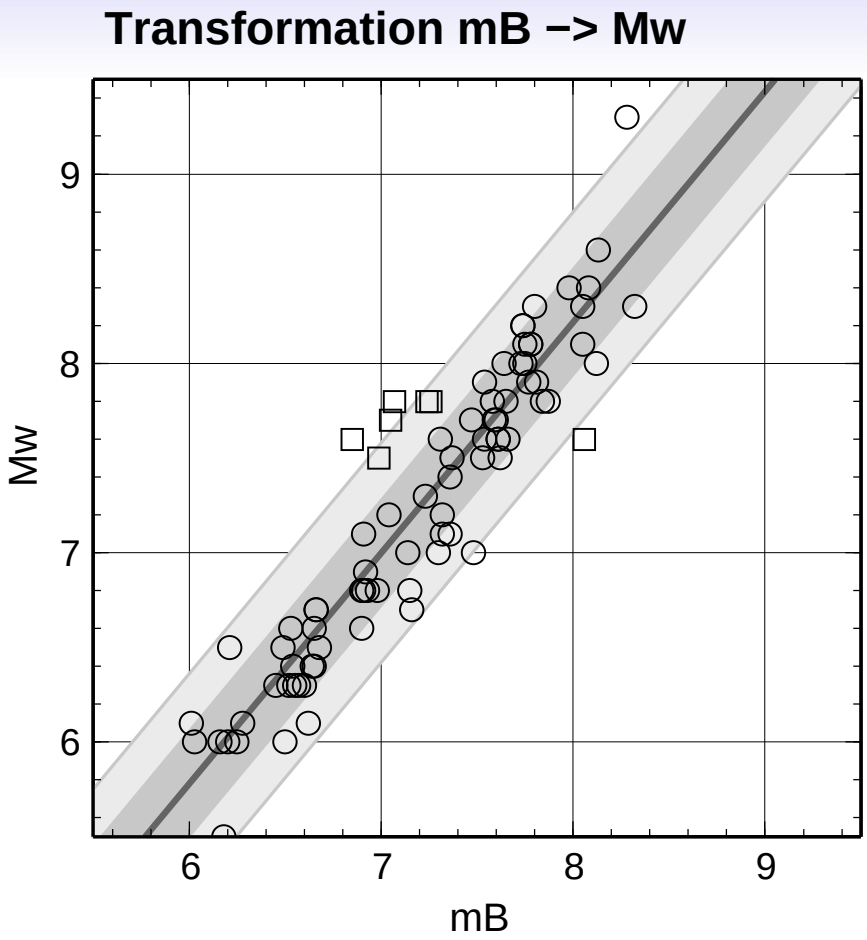


The body-wave magnitude mB

New m_B calibration function (Saul & Bormann, 2007)

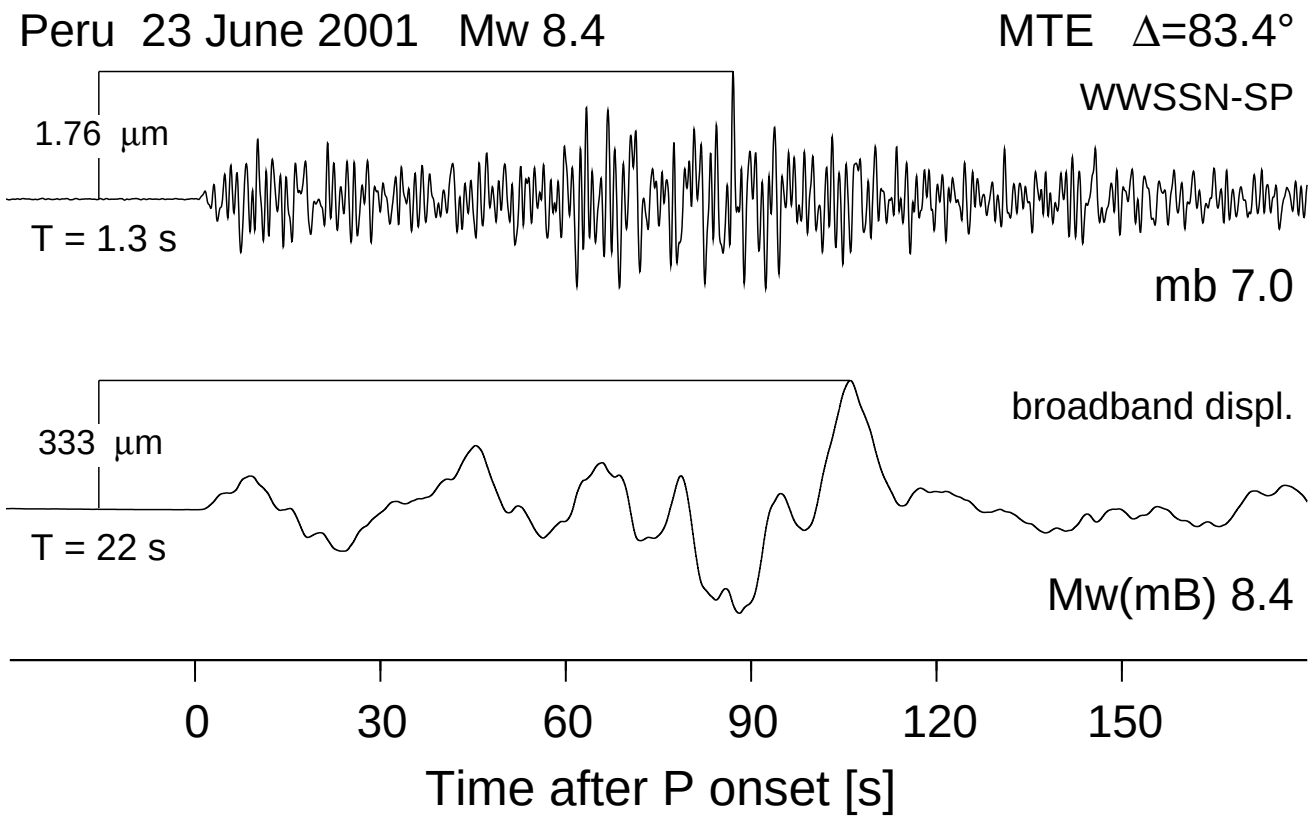


Estimating Mw from mB



$$M_W(m_B) = 1.33\, m_B - 2.36 \qquad \text{(Bormann \& Saul, 2008)}$$

Saturation of m_b



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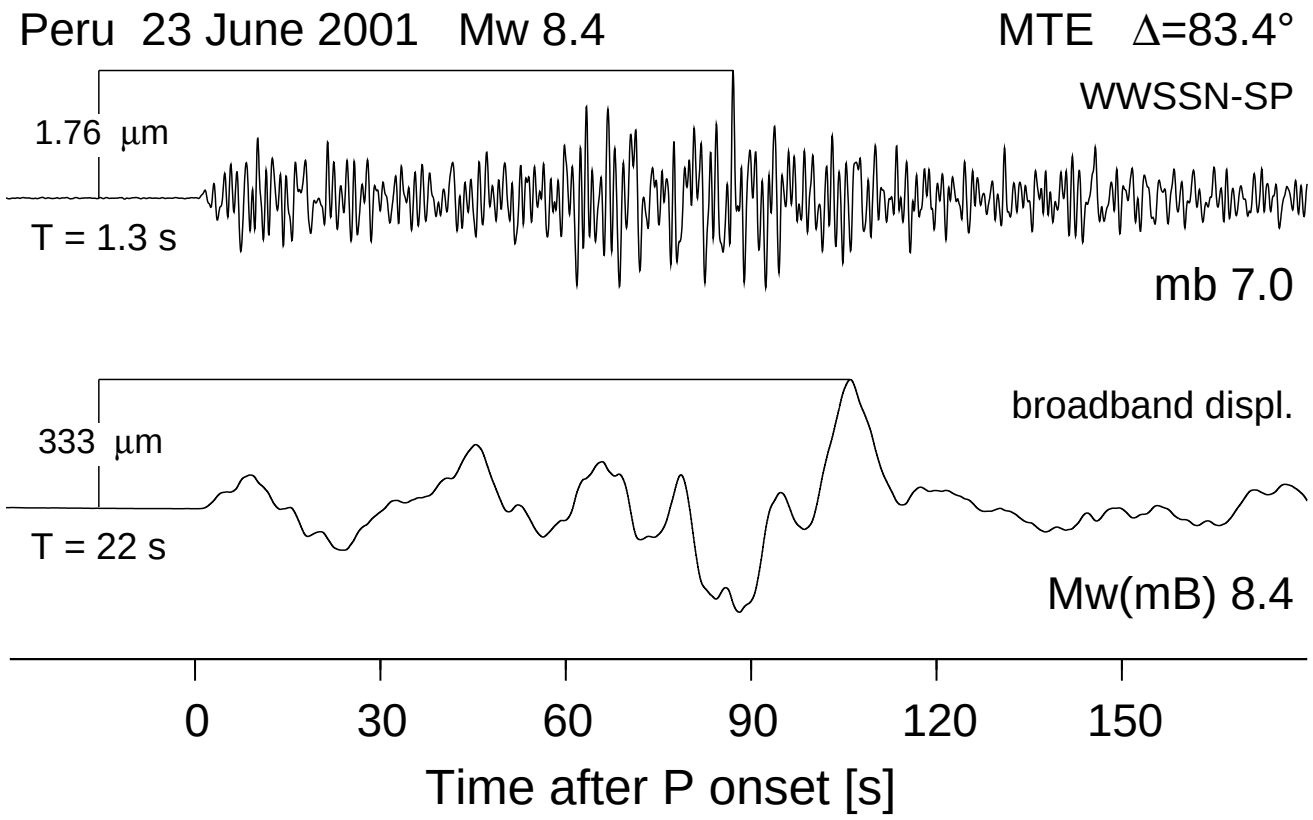
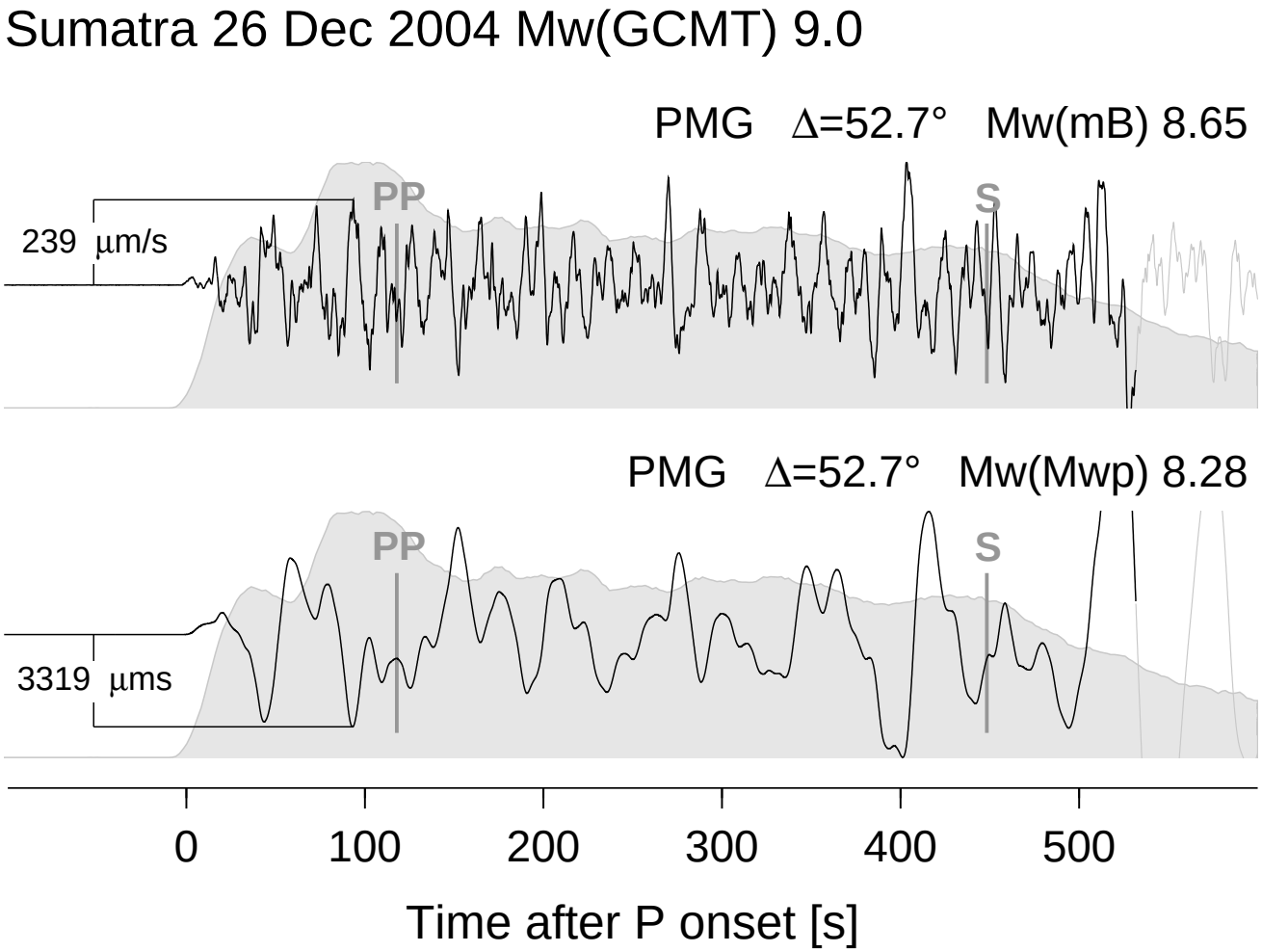


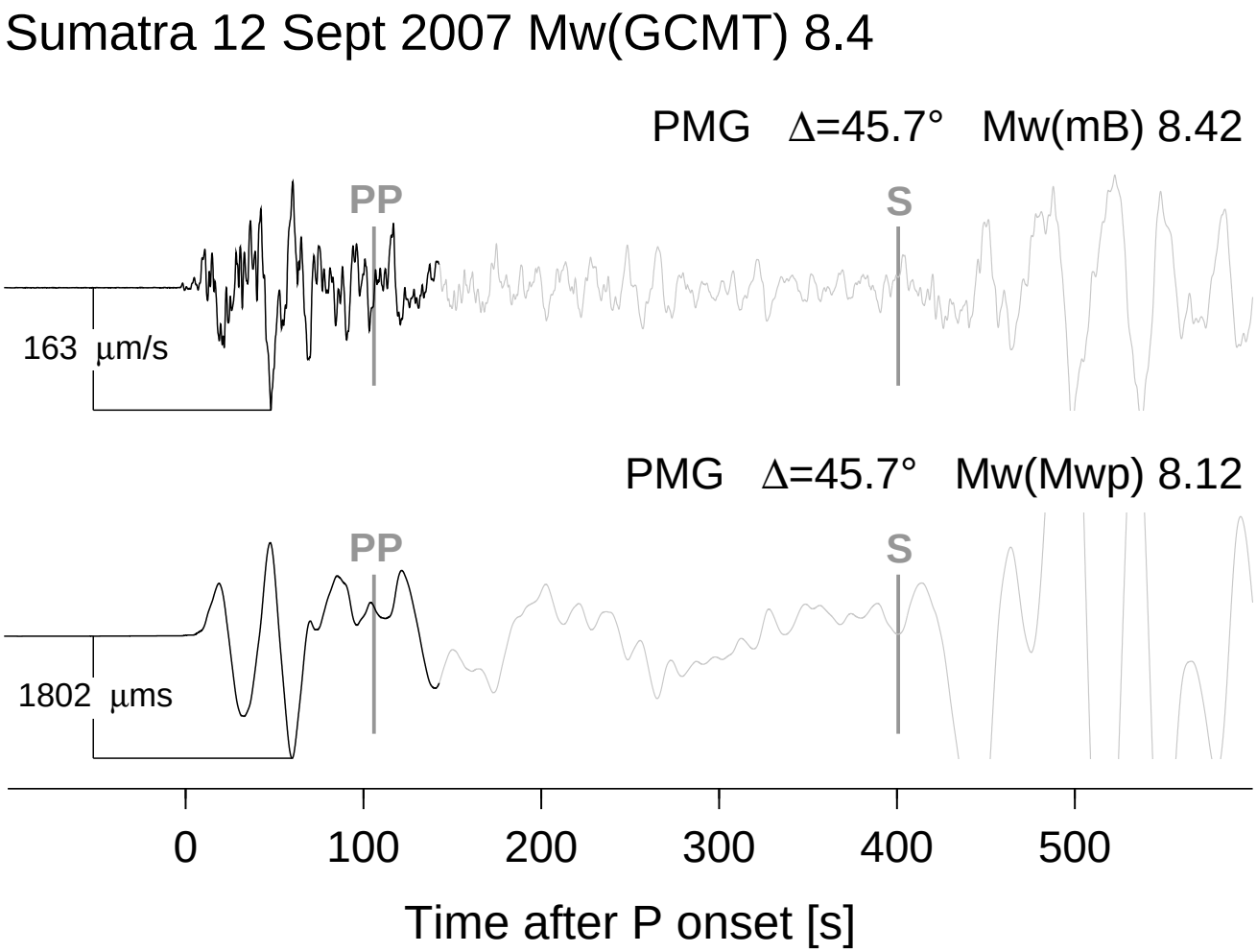
The saturation effect

may result in a magnitude underestimation of more than 3 units!

Example for Mwp and mB

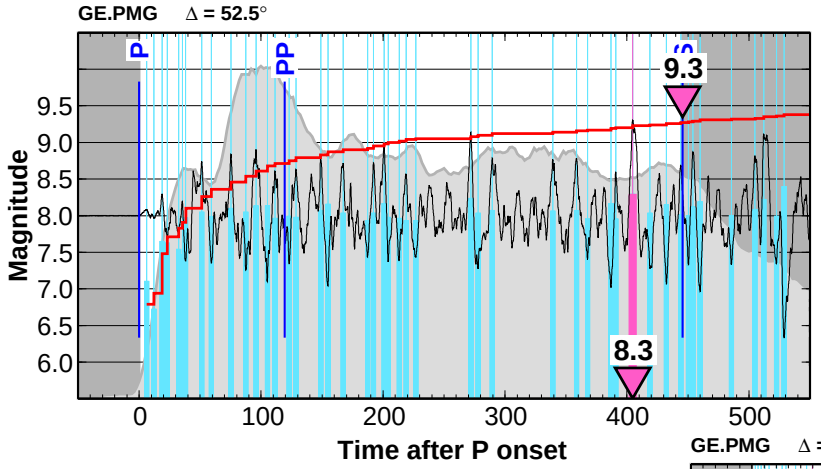


Example for Mw and mB



mBc - The new XXL magnitude

$$m_{Bc} = Q(\Delta, z) + \log \sum_i \frac{V_{max,i}}{2\pi}$$

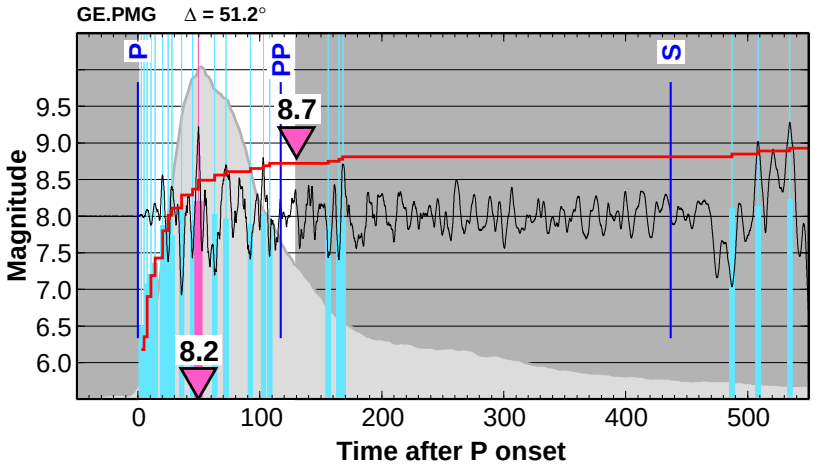


Sumatra 26 December 2004

Mw(CMT)	9.0
Mw(S&O)	9.3
mBc	9.3

Sumatra 28 March 2005

Mw(CMT)	8.6
mBc	8.7



Saul & Bormann (2007)

Software Installation at BMKG Indonesia

Provisional installation of SeisComP 2
at BMKG in July 2005 by GFZ

Installation of SeisComP 3
at BMKG in May 2007 by three GFZ experts

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SeisComP being used at BMKG

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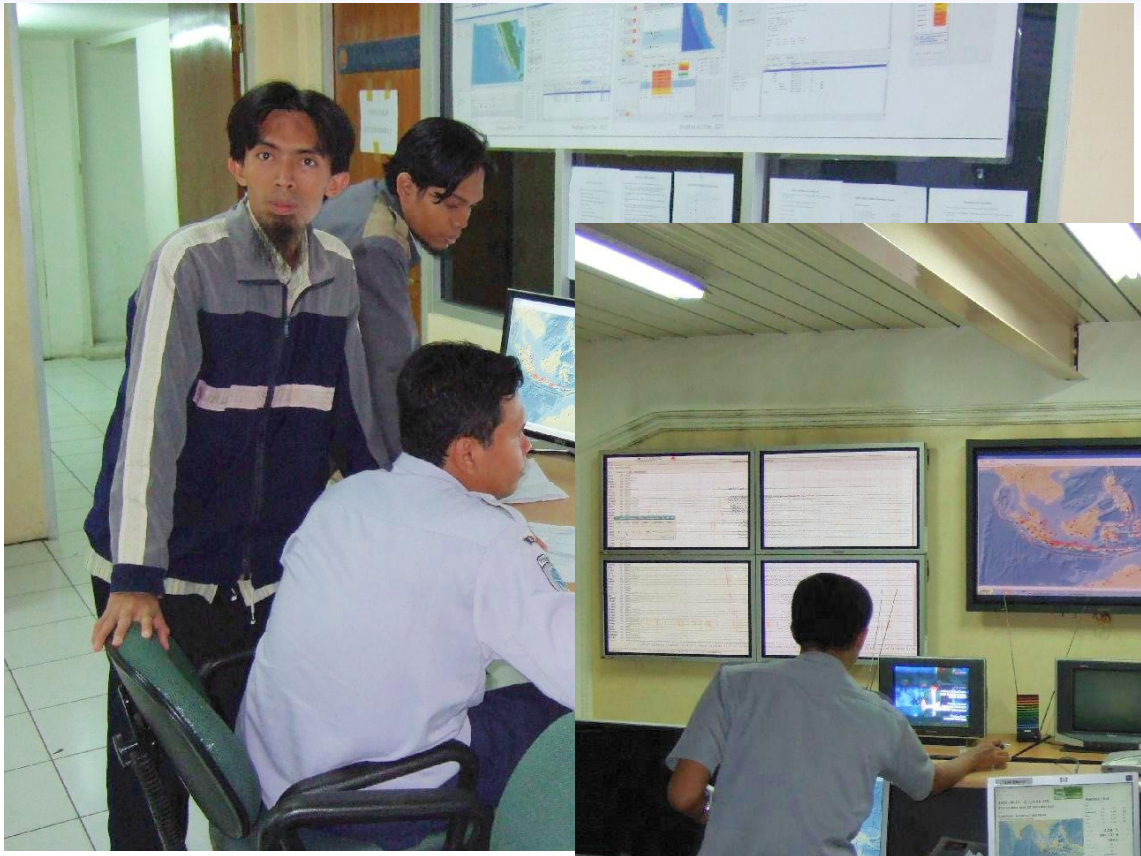
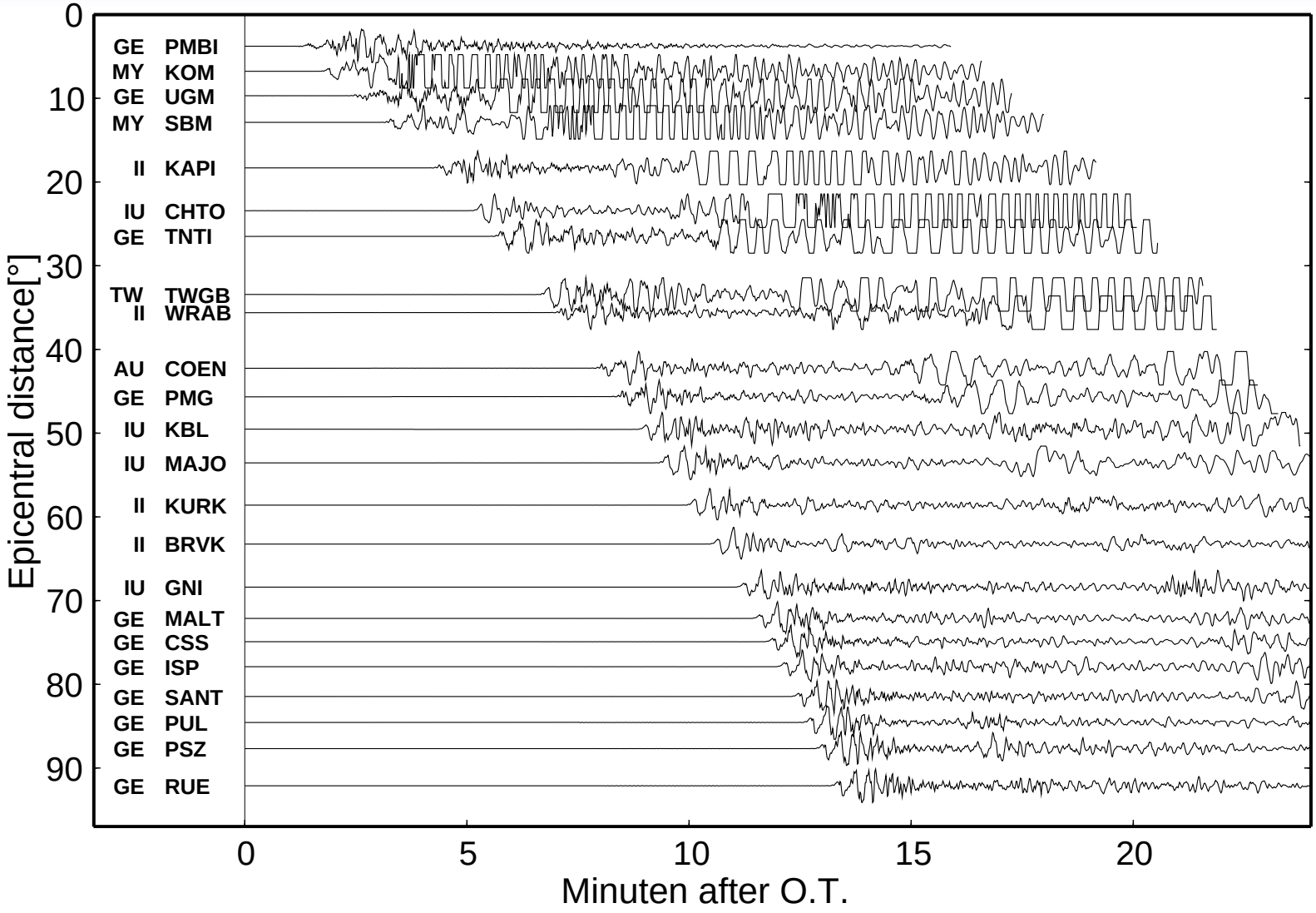


20 min. after the Bengkulu EQ!

Bengkulu Earthquake - Data example



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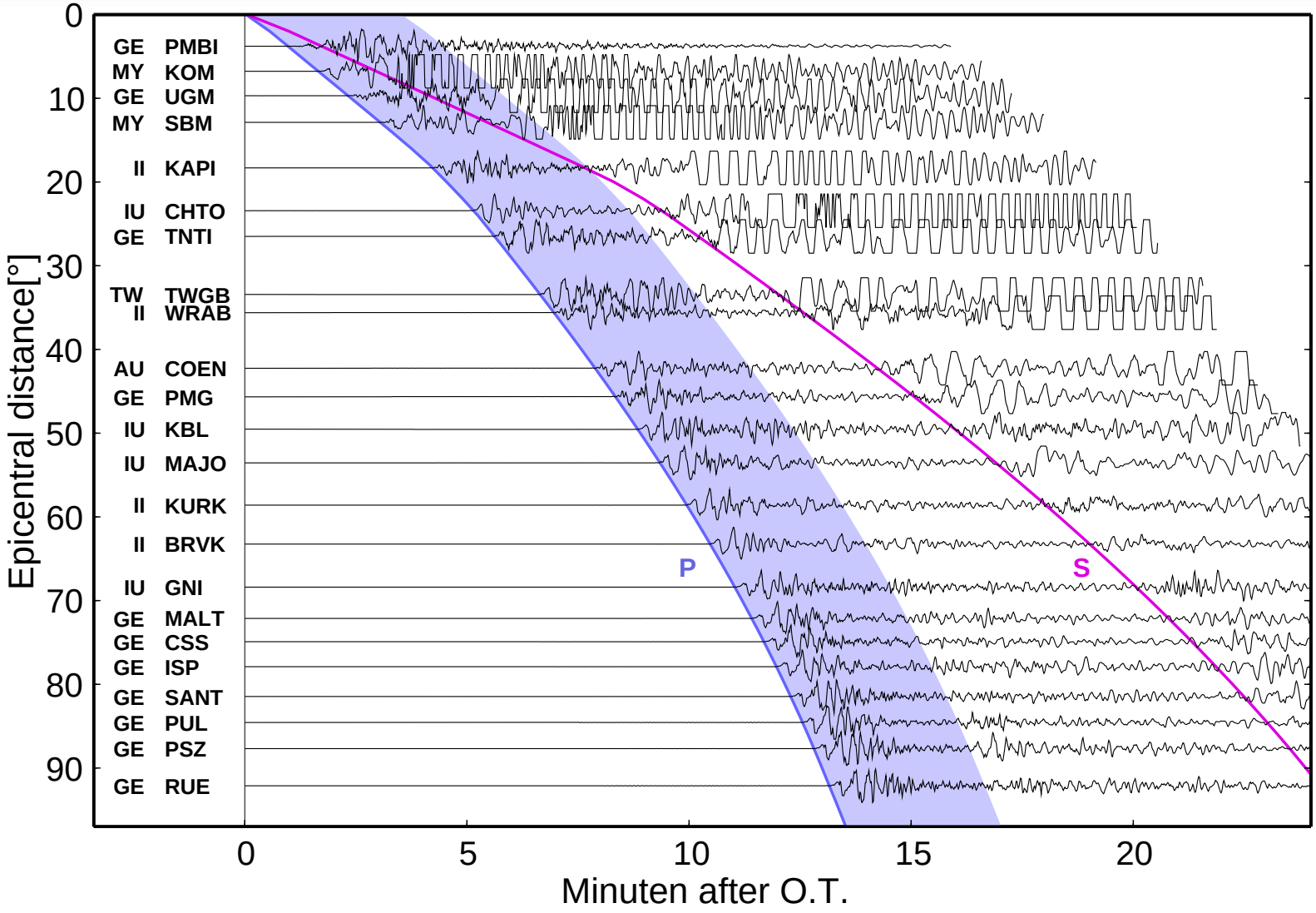

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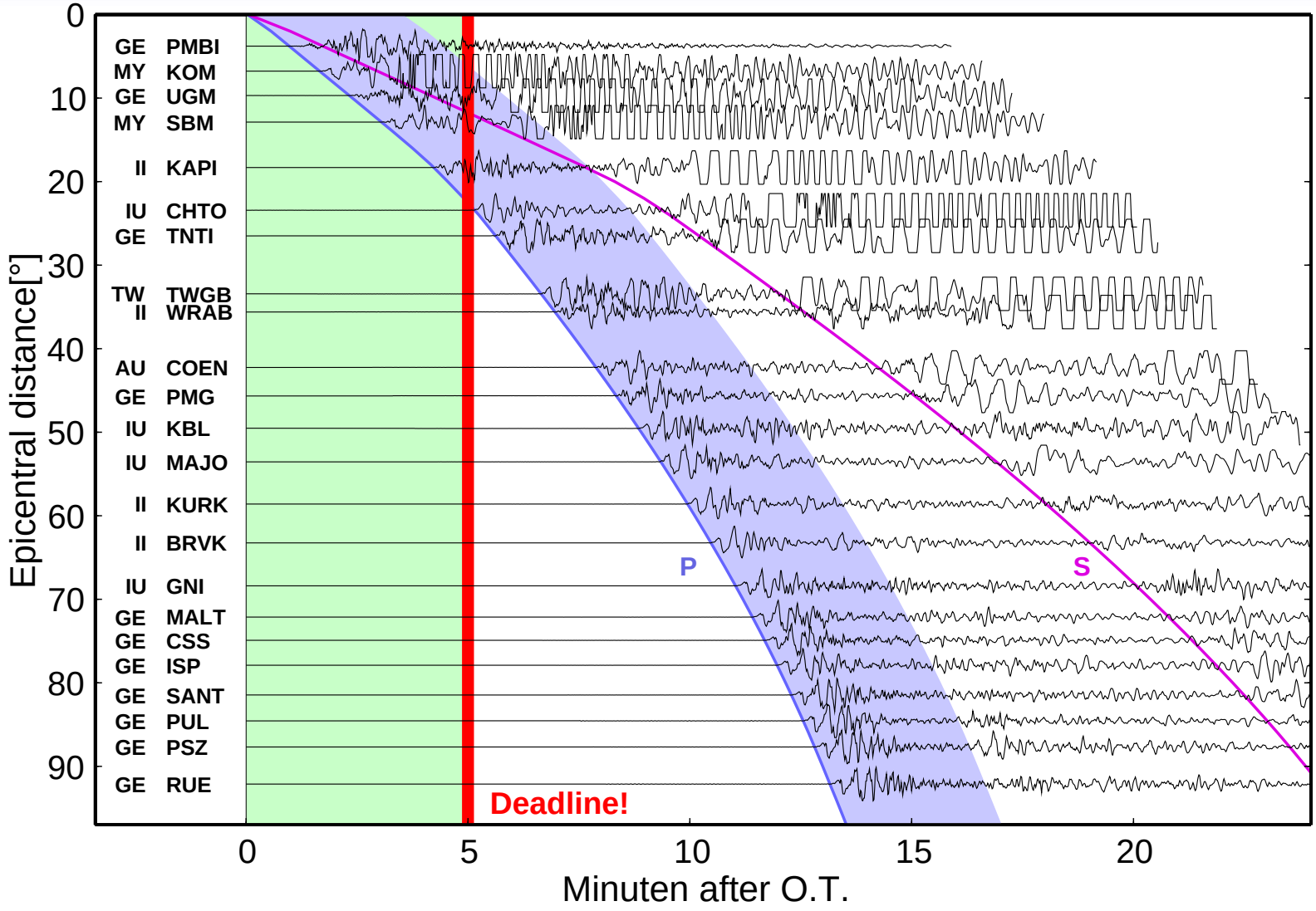

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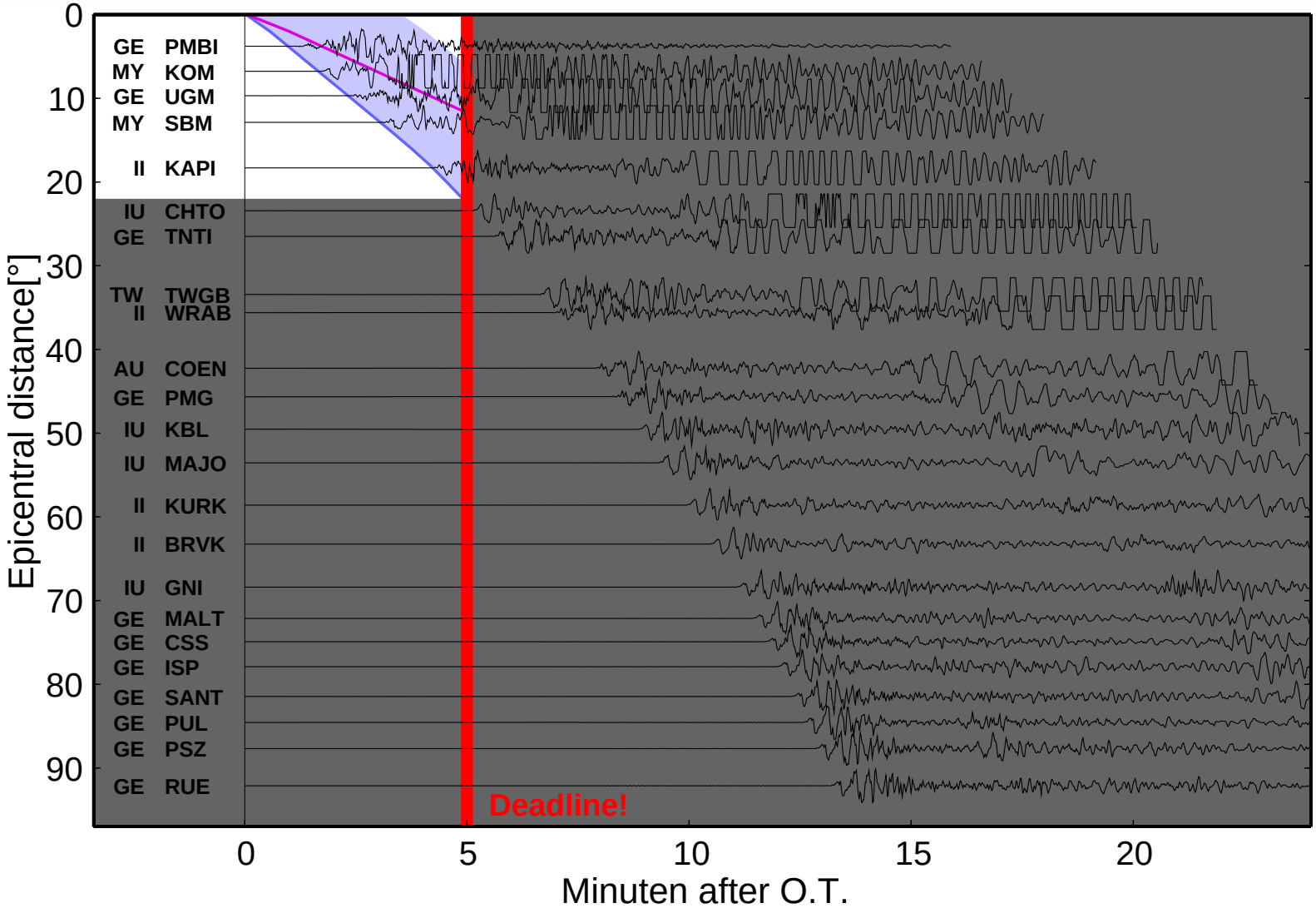
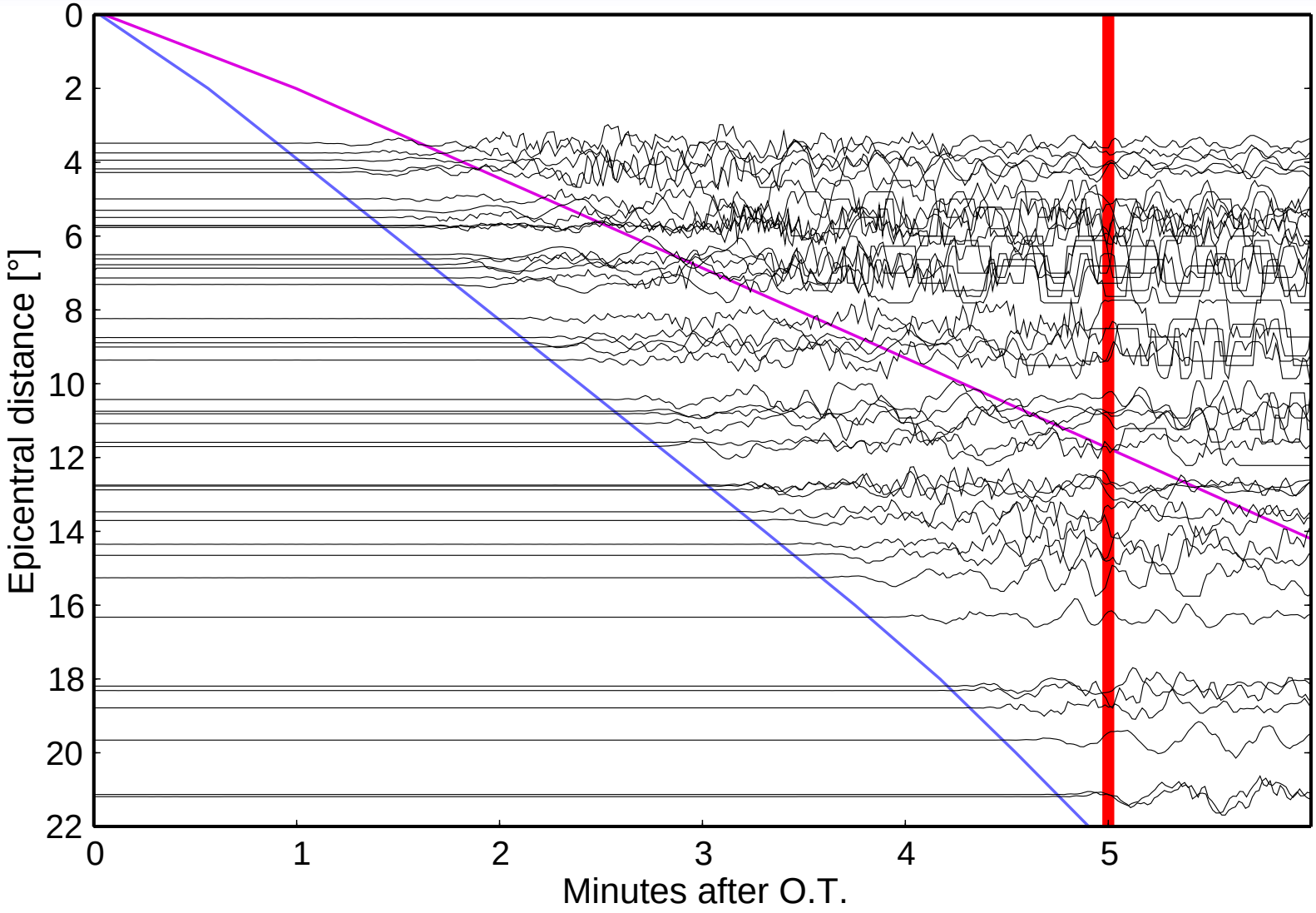


Bengkulu Earthquake - Regional data example



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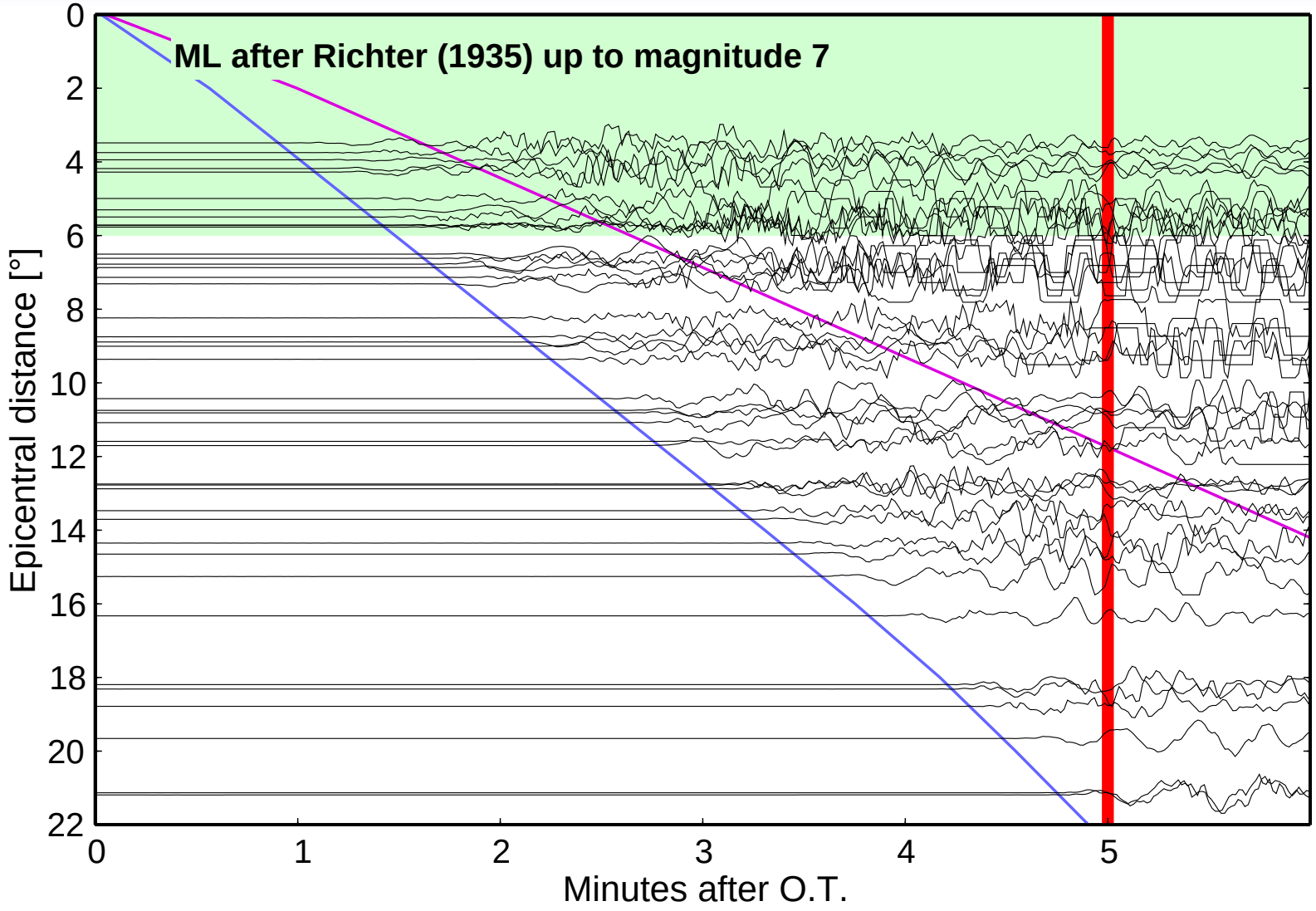

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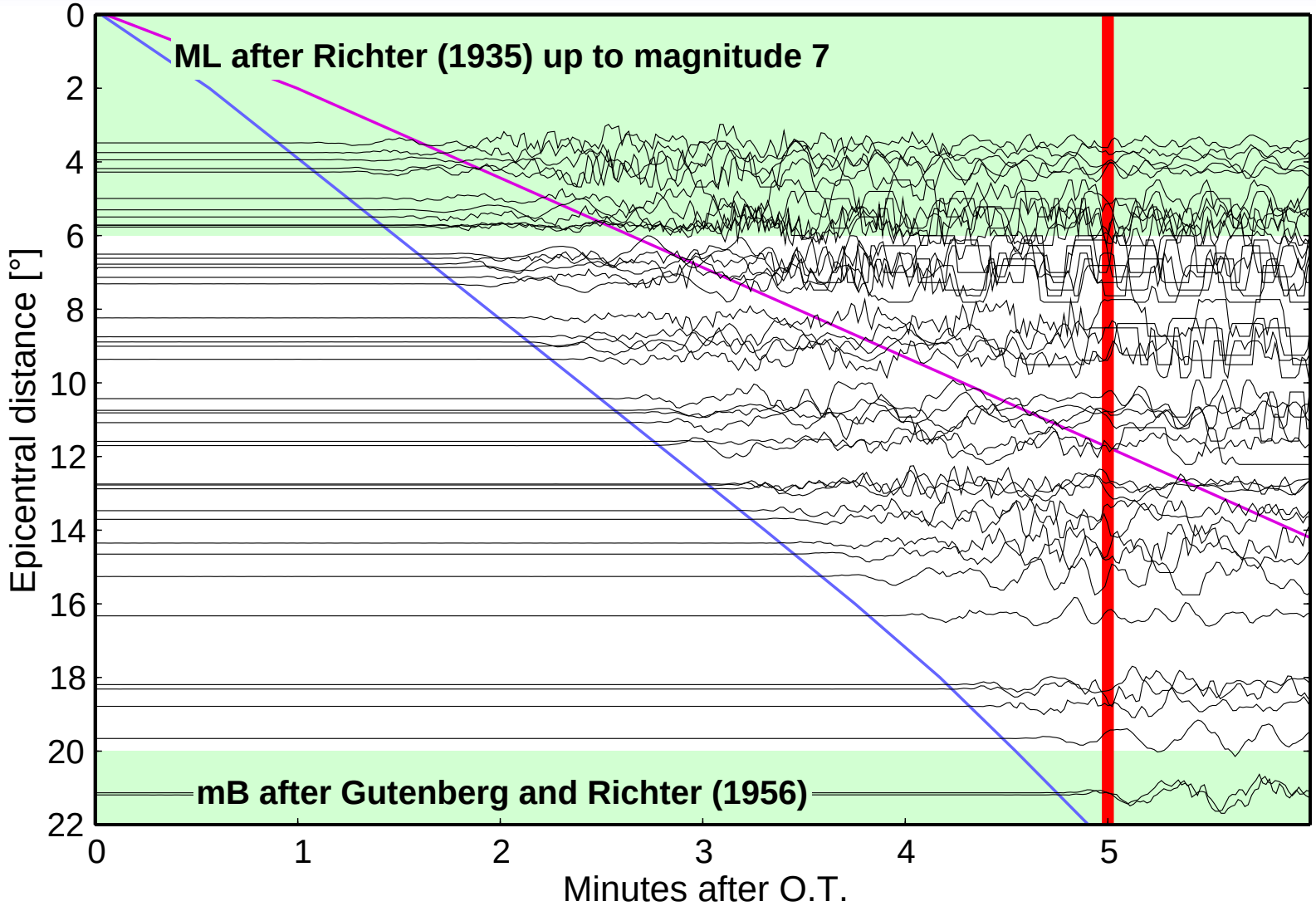
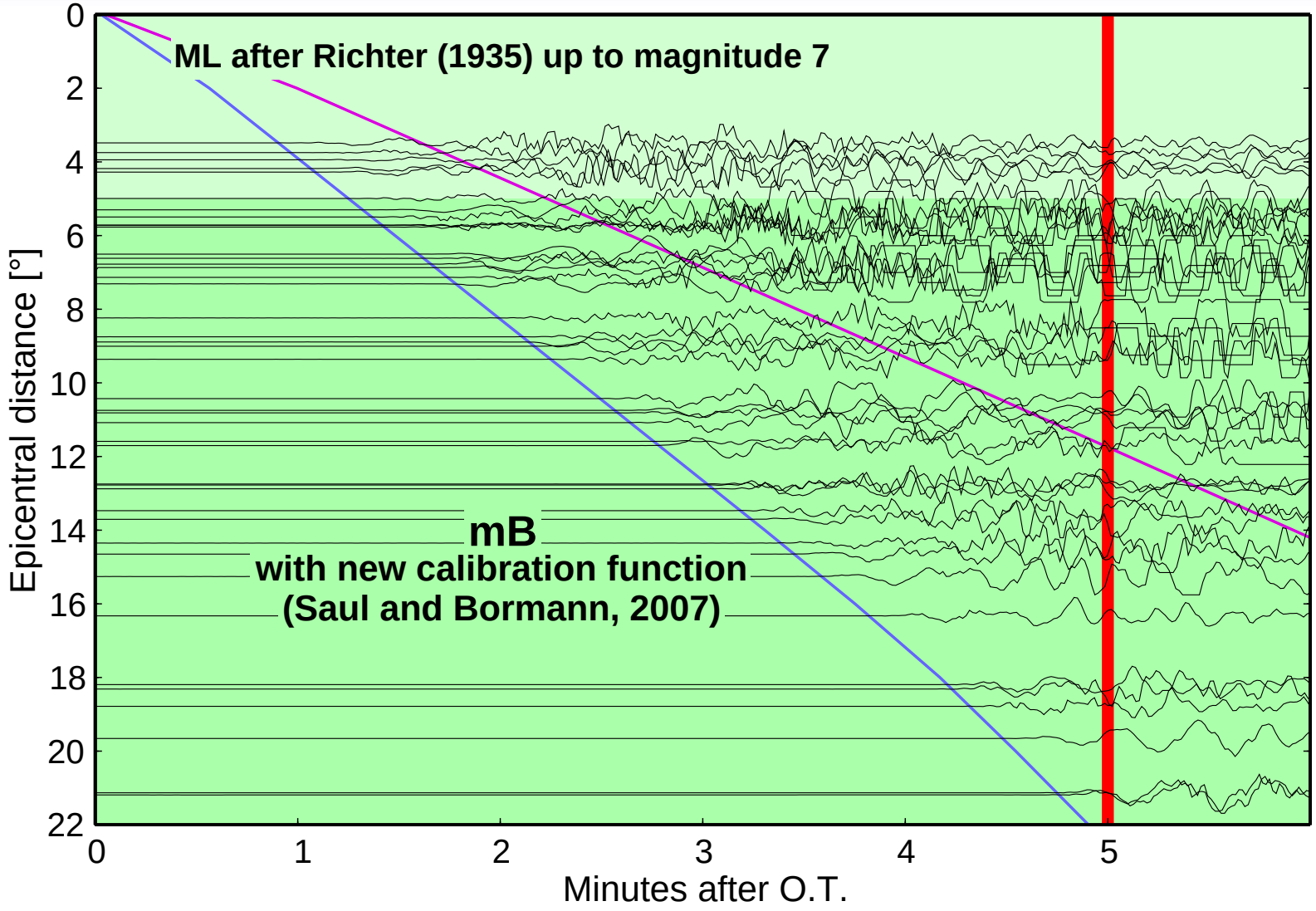


Bengkulu Earthquake - Regional data example



Timeline of the September 12, 2007, Mw 8.4 Bengkulu Earthquake

First automatic location and magnitude at BMKG

mb 7.3, depth 11 km at O.T. +2:28 min.

Stabilizing location and magnitudes at BMKG

Mw(mB) 7.9, Mwp 8.3, at about O.T. +4 min.

BMKG tsunami warning

at O.T. +4:41 min. (M 7.9)

Automatic GFZ email alert

at O.T. +6:13 min. (M 7.9, depth 10km)

PTWC tsunami watch

at O.T. +14 min. (M 7.9)

GCMT solution

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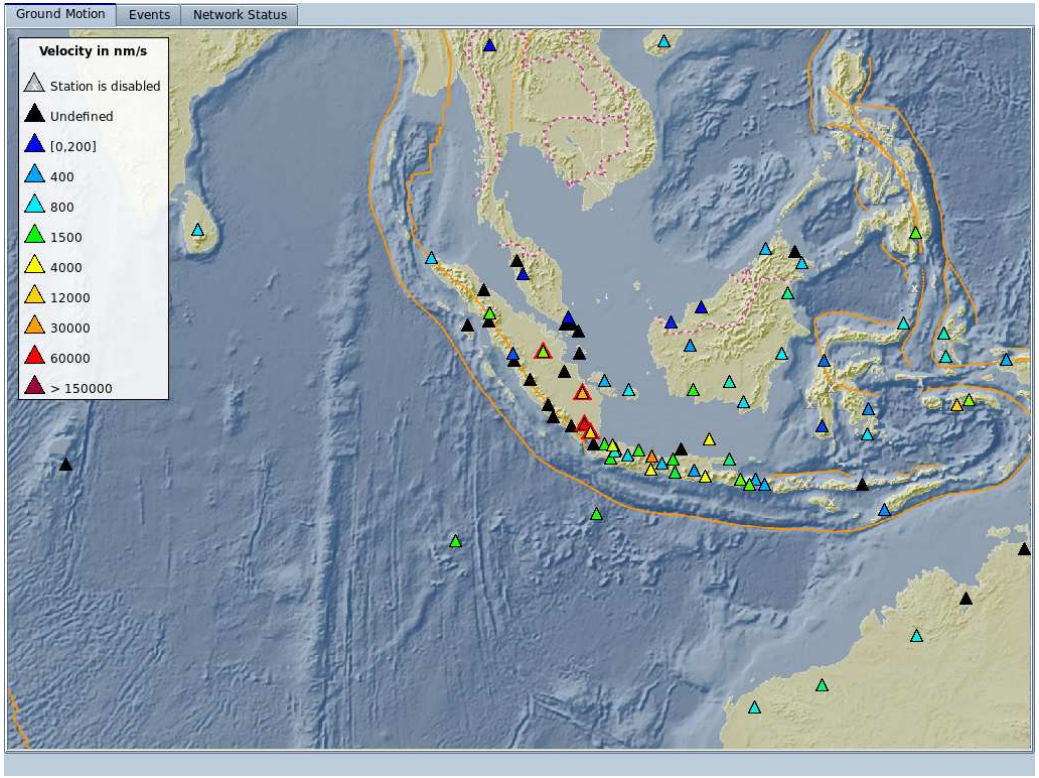
Bengkulu Earthquake - SeisComP MapView



+1 min.

From playback!

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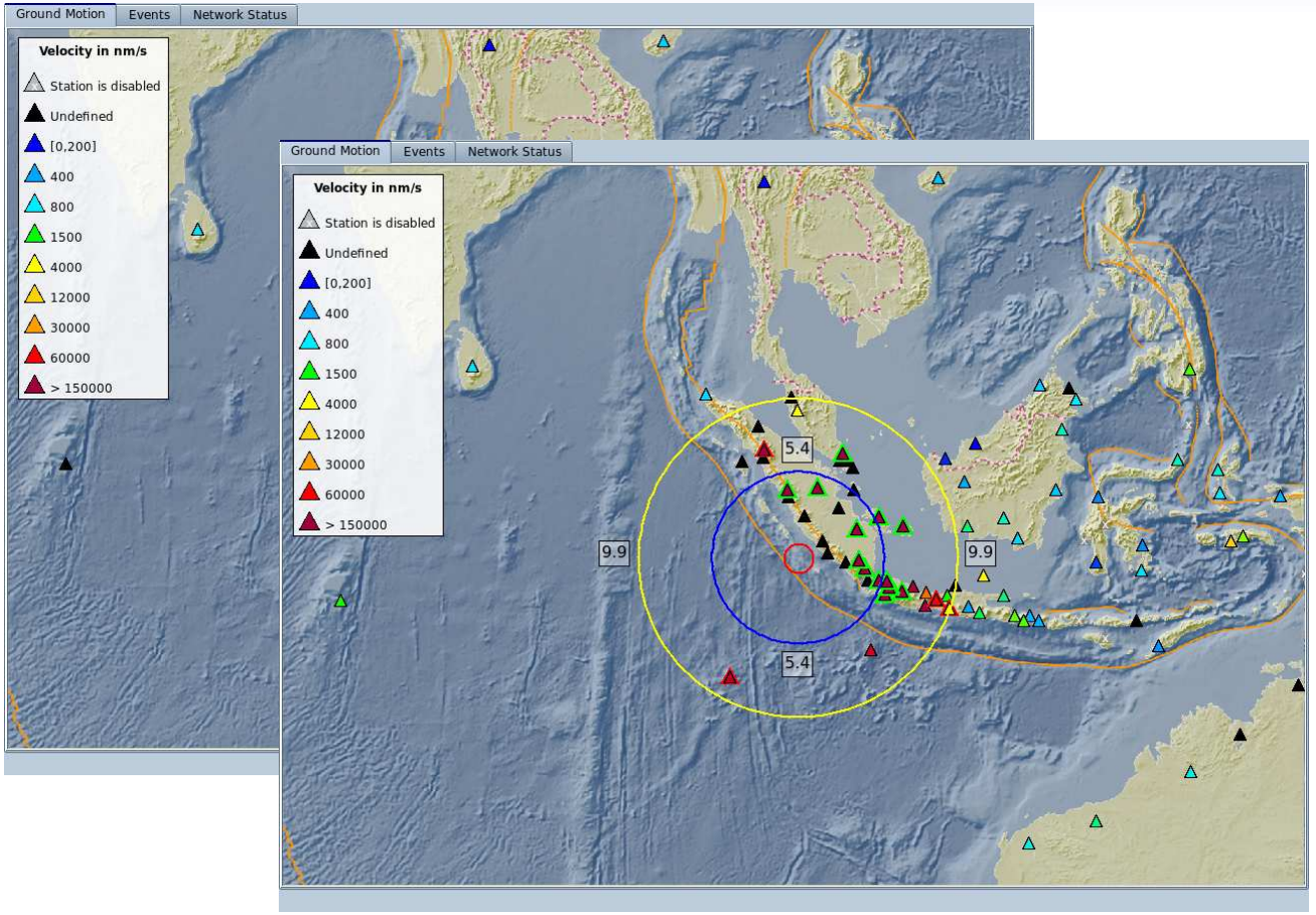
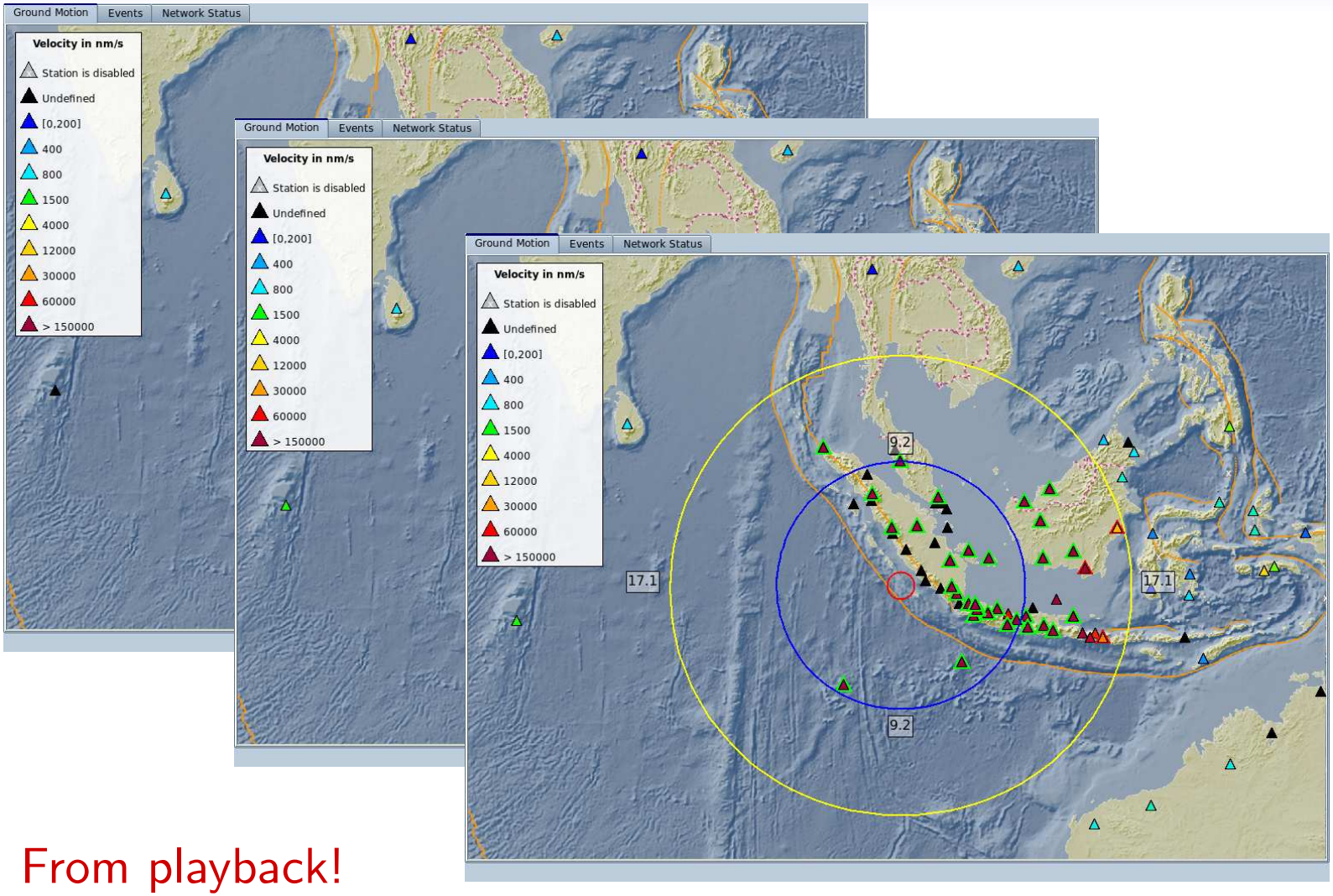


+2.5 min.

From playback!

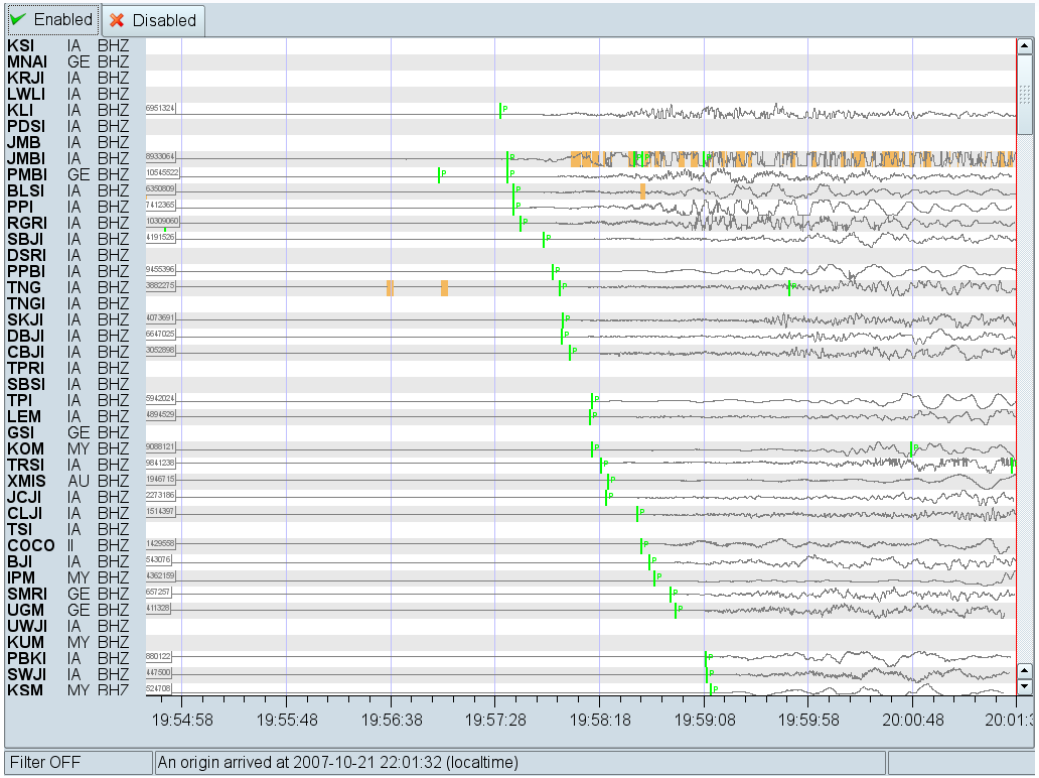
Bengkulu Earthquake - SeisComP MapView



From playback!

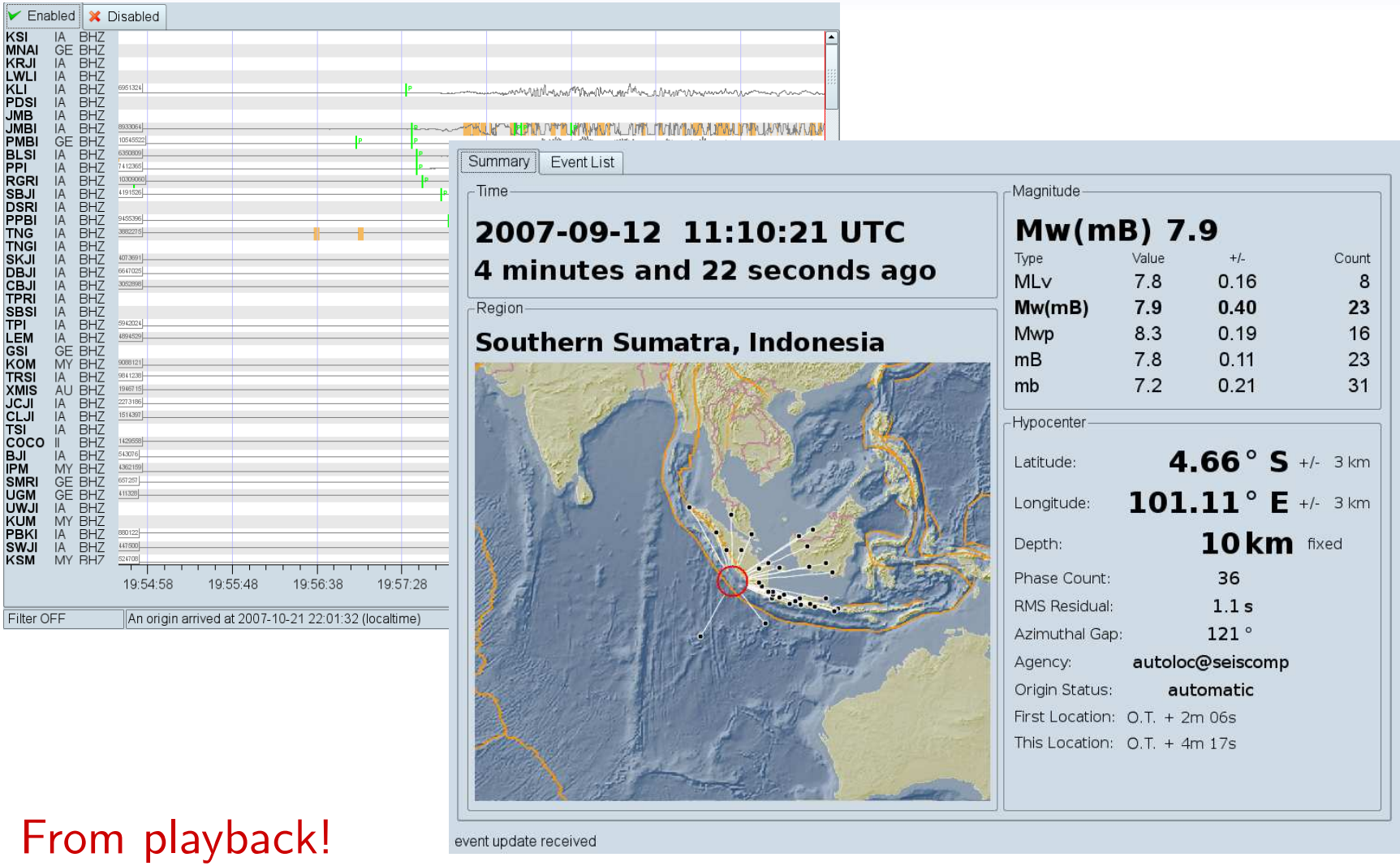
+4 min.

Bengkulu Earthquake - SeisComP GUIs



From playback!

Bengkulu Earthquake - SeisComP GUIs



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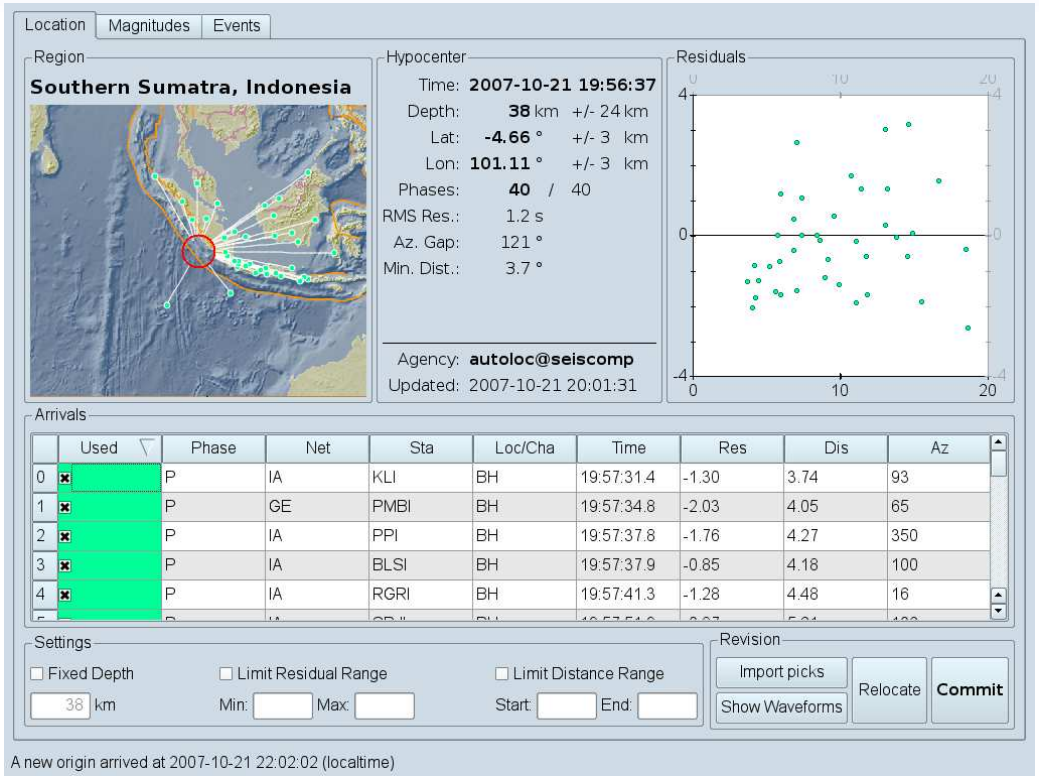

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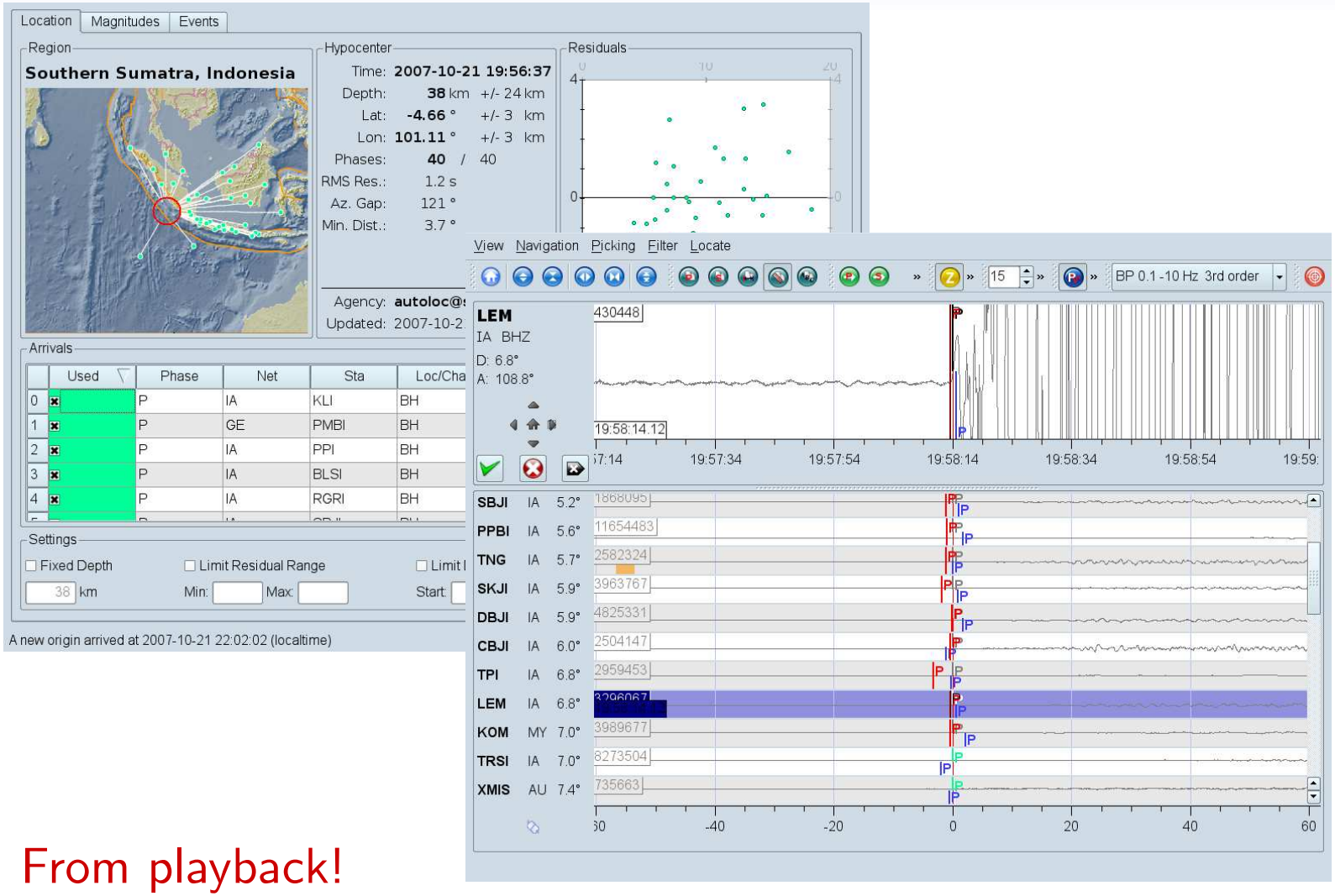

From playback!

Inauguration INATEWS/GITEWS

Jakarta, November 11, 2008

Upgrade to SeisComP at GFZ

- Since August 1st, 2007, SeisComP is used for generating automatic GFZ EQ alerts
- Fully automated alerts for all events with at least 25 P picks
- Events with less than 25 P picks are published only after manual review
- Manual review may take half a day or more, as GFZ is not a monitoring facility, no 24/7 service

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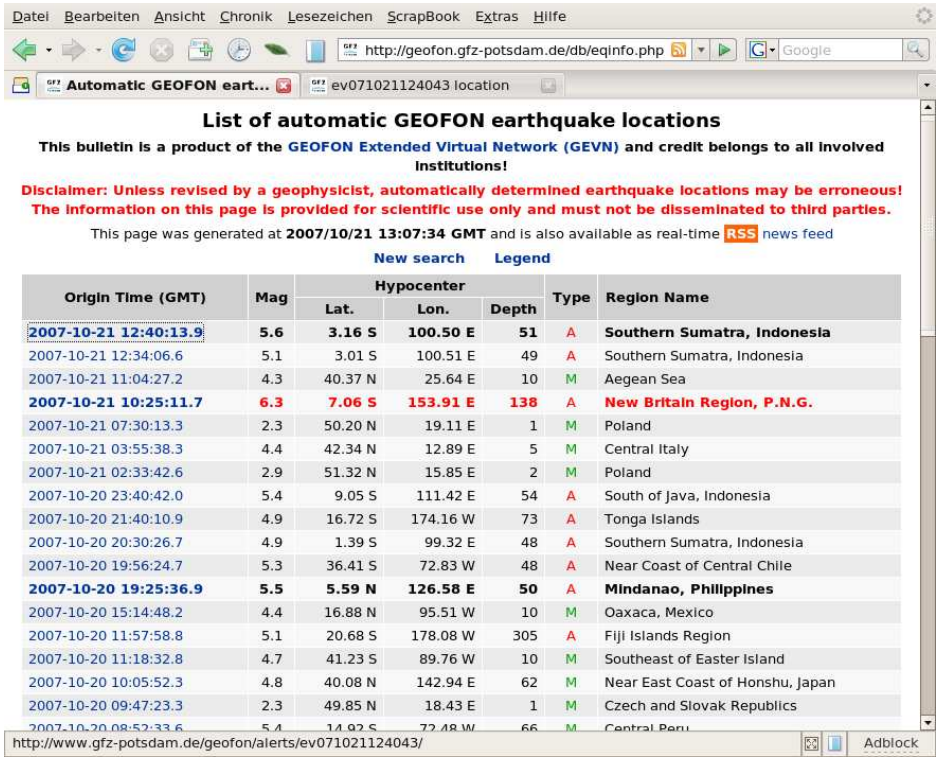
Automatic GEOFON Earthquake Locations



Datei Bearbeiten Ansicht Chronik Lesezeichen ScrapBook Extras Hilfe

http://geofon.gfz-potsdam.de/db/eqinfo.php

Automatic GEOFON eart... | ev071021124043 location

List of automatic GEOFON earthquake locations

This bulletin is a product of the GEOFON Extended Virtual Network (GEVN) and credit belongs to all involved institutions!

Disclaimer: Unless revised by a geophysicist, automatically determined earthquake locations may be erroneous! The information on this page is provided for scientific use only and must not be disseminated to third parties.

This page was generated at **2007/10/21 13:07:34 GMT** and is also available as real-time RSS news feed

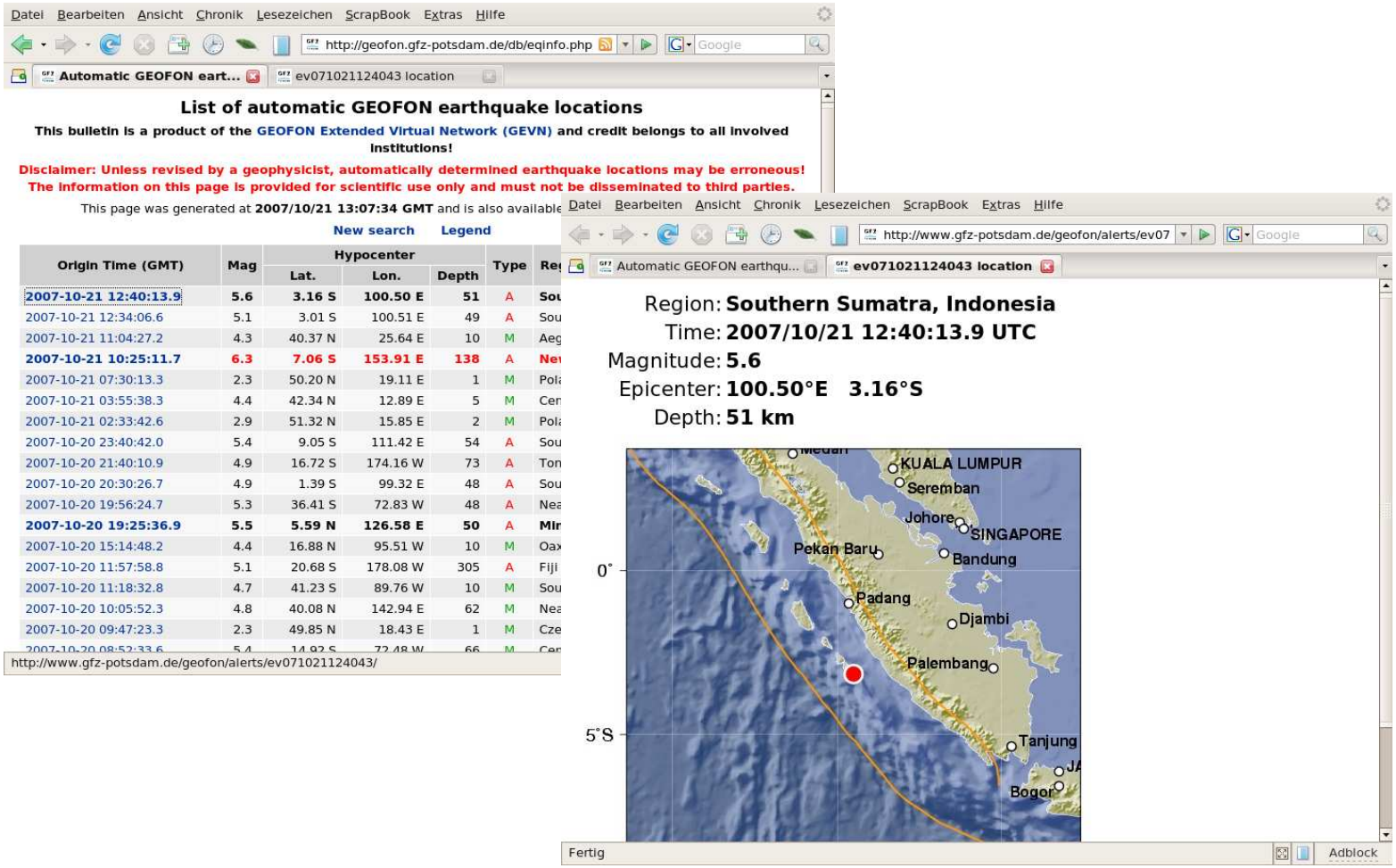
New search Legend

Origin Time (GMT)	Mag	Hypocenter			Type	Region Name
		Lat.	Lon.	Depth		
2007-10-21 12:40:13.9	**5.6**	**3.16 S**	**100.50 E**	**51**	A	**Southern Sumatra, Indonesia**
2007-10-21 12:34:06.6	5.1	3.01 S	100.51 E	49	A	Southern Sumatra, Indonesia
2007-10-21 11:04:27.2	4.3	40.37 N	25.64 E	10	M	Aegean Sea
2007-10-21 10:25:11.7	**6.3**	**7.06 S**	**153.91 E**	**138**	A	**New Britain Region, P.N.G.**
2007-10-21 07:30:13.3	2.3	50.20 N	19.11 E	1	M	Poland
2007-10-21 03:55:38.3	4.4	42.34 N	12.89 E	5	M	Central Italy
2007-10-21 02:33:42.6	2.9	51.32 N	15.85 E	2	M	Poland
2007-10-20 23:40:42.0	5.4	9.05 S	111.42 E	54	A	South of Java, Indonesia
2007-10-20 21:40:10.9	4.9	16.72 S	174.16 W	73	A	Tonga Islands
2007-10-20 20:30:26.7	4.9	1.39 S	99.32 E	48	A	Southern Sumatra, Indonesia
2007-10-20 19:56:24.7	5.3	36.41 S	72.83 W	48	A	Near Coast of Central Chile
2007-10-20 19:25:36.9	**5.5**	**5.59 N**	**126.58 E**	**50**	A	**Mindanao, Philippines**
2007-10-20 15:14:48.2	4.4	16.88 N	95.51 W	10	M	Oaxaca, Mexico
2007-10-20 11:57:58.8	5.1	20.68 S	178.08 W	305	A	Fiji Islands Region
2007-10-20 11:18:32.8	4.7	41.23 S	89.76 W	10	M	Southeast of Easter Island
2007-10-20 10:05:52.3	4.8	40.08 N	142.94 E	62	M	Near East Coast of Honshu, Japan
2007-10-20 09:47:23.3	2.3	49.85 N	18.43 E	1	M	Czech and Slovak Republics
2007-10-20 08:52:33.6	5.4	14.92 S	72.48 W	66	M	Central Peru

http://www.gfz-potsdam.de/geofon/alerts/ev071021124043/ Adblock

Upgrade to SeisComP at GFZ

Automatic GEOFON Earthquake Locations



Datei Bearbeiten Ansicht Chronik Lesezeichen ScrapBook Extras Hilfe

http://geofon.gfz-potsdam.de/db/eqinfo.php

Automatic GEOFON eart... | ev071021124043 location

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2007-10-21 11:04:27.2	4.3	40.37 N	25.64 E	10	M	Aeg
2007-10-21 10:25:11.7	**6.3**	**7.06 S**	**153.91 E**	**138**	A	**Ne**
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2007-10-21 03:55:38.3	4.4	42.34 N	12.89 E	5	M	Cen
2007-10-21 02:33:42.6	2.9	51.32 N	15.85 E	2	M	Pol
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2007-10-20 15:14:48.2	4.4	16.88 N	95.51 W	10	M	Oax
2007-10-20 11:57:58.8	5.1	20.68 S	178.08 W	305	A	Fiji
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http://www.gfz-potsdam.de/geofon/alerts/ev071021124043/

Datei Bearbeiten Ansicht Chronik Lesezeichen ScrapBook Extras Hilfe

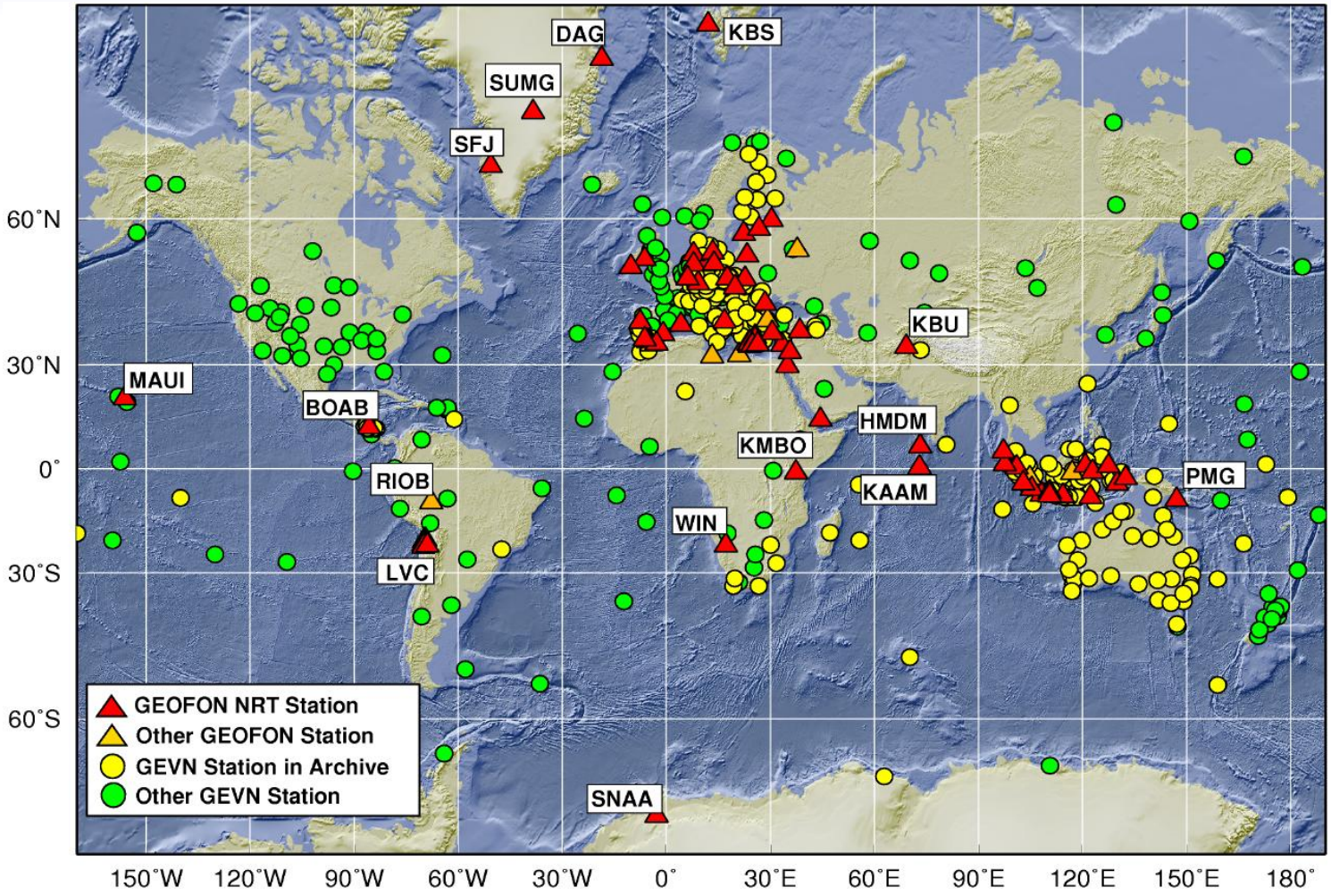
http://www.gfz-potsdam.de/geofon/alerts/ev07

Automatic GEOFON earthqu... | ev071021124043 location

Region: **Southern Sumatra, Indonesia**
Time: **2007/10/21 12:40:13.9 UTC**
Magnitude: **5.6**
Epicenter: **100.50°E 3.16°S**
Depth: **51 km**

Fertig Adblock

Seismic network used at GFZ



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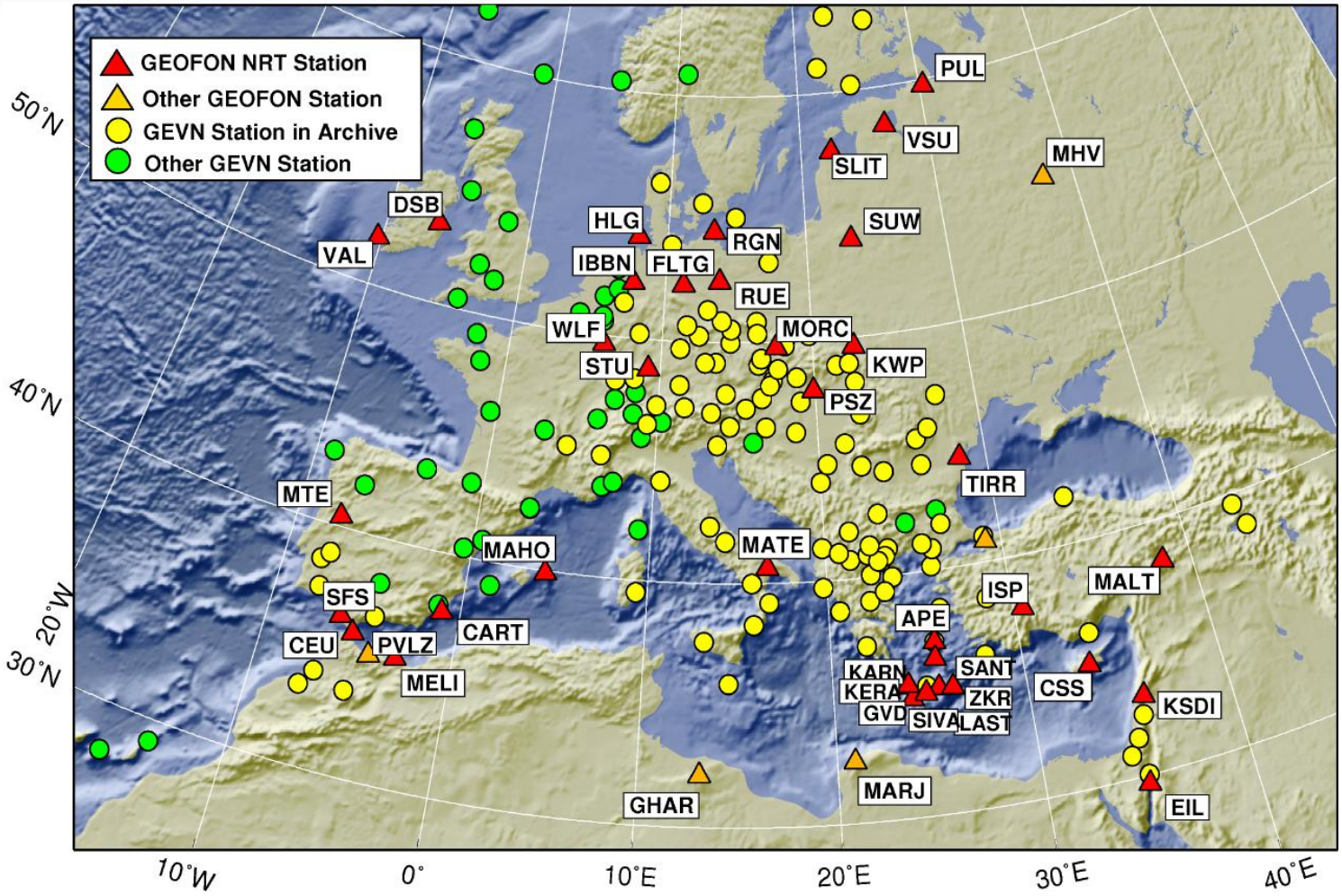

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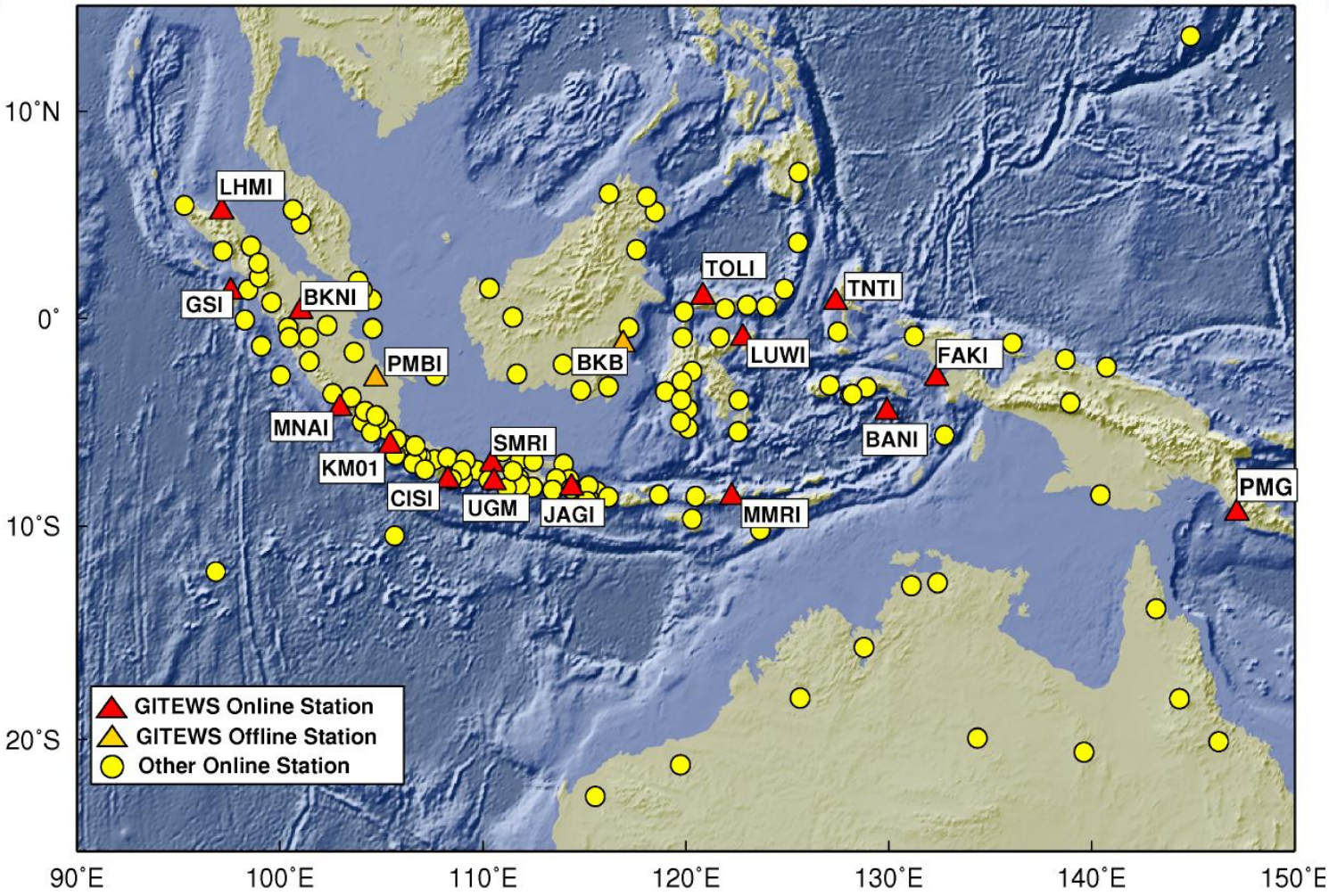
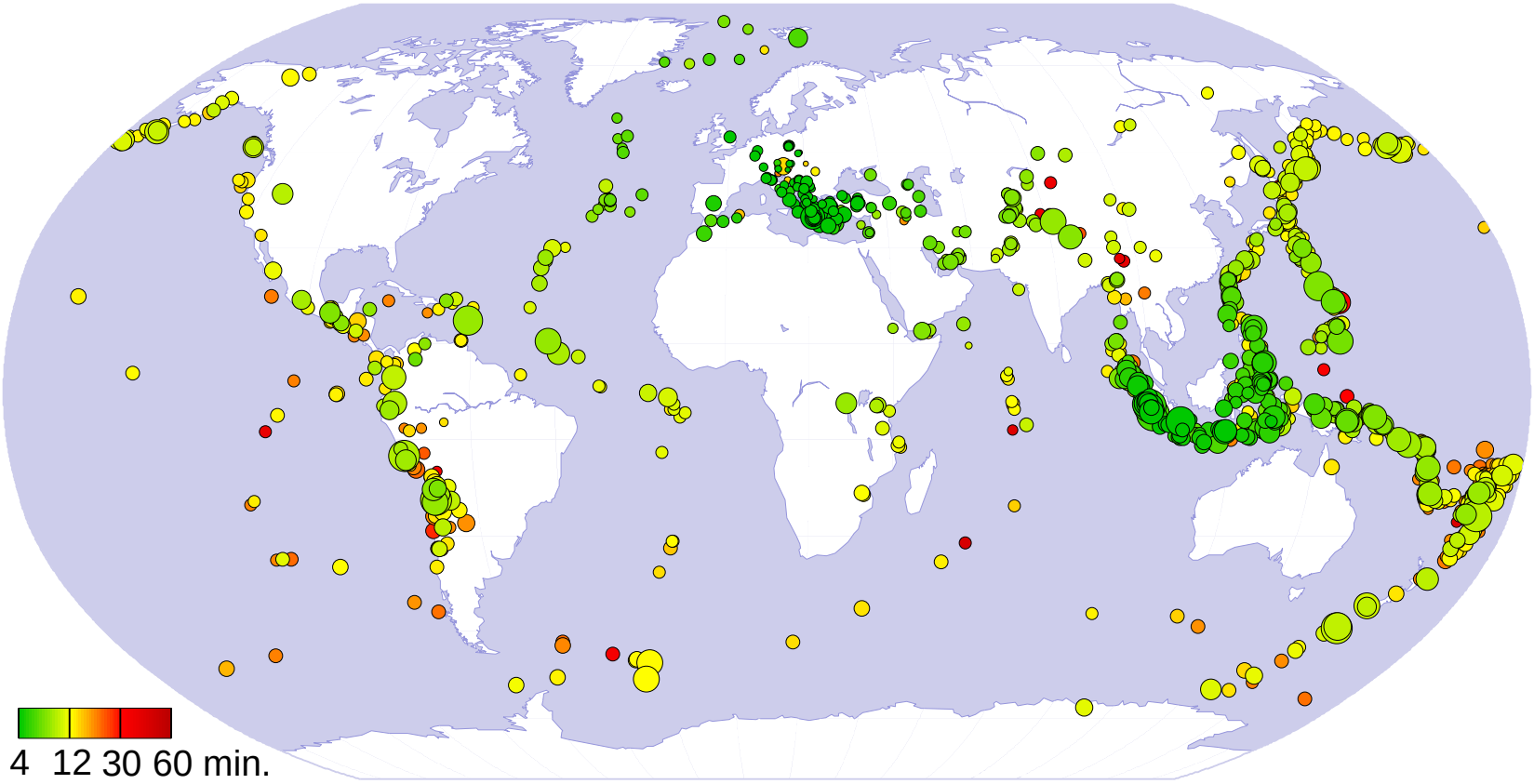


Performance of SeisComP at GFZ

Delays of automatic GFZ alerts since August 1, 2007



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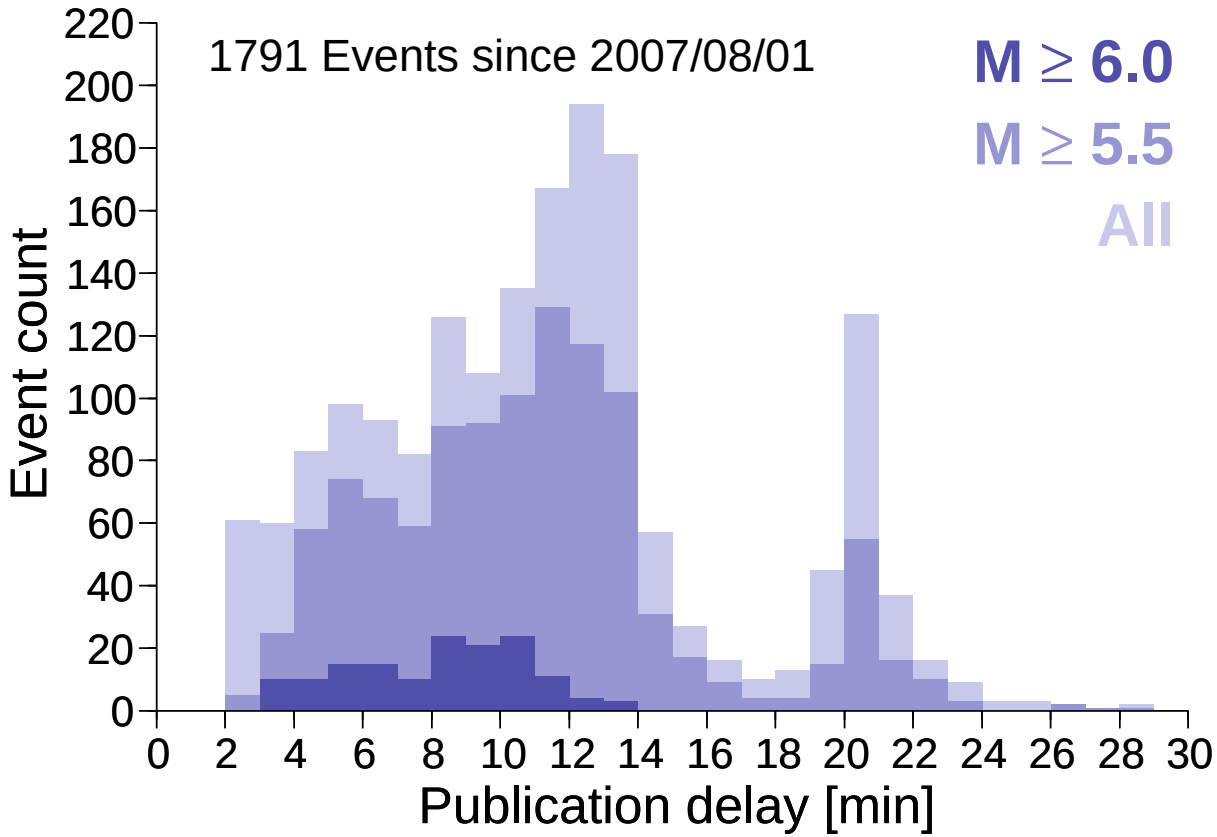
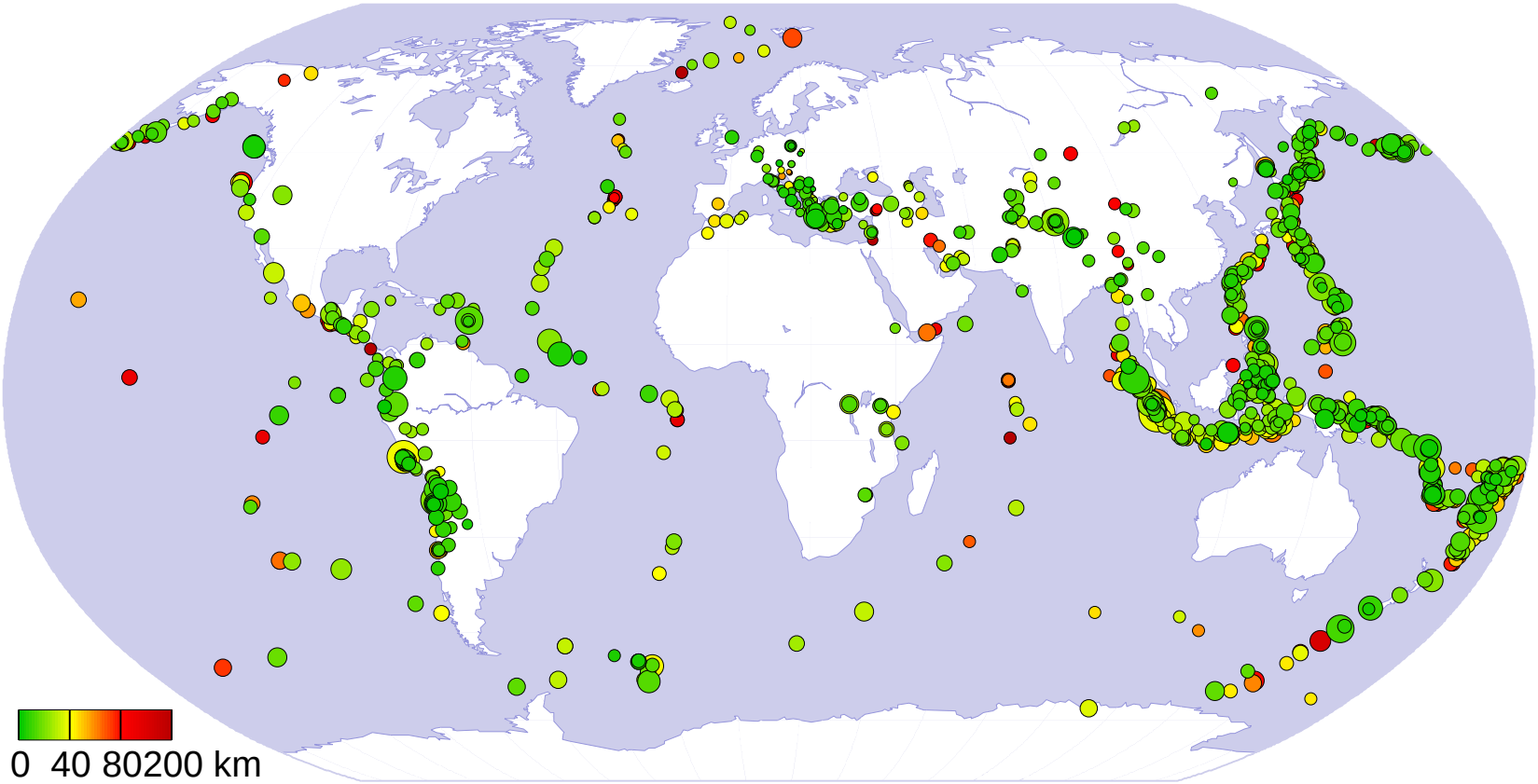


Performance of SeisComP at GFZ

Location difference of automatic GFZ alerts vs. PDEs



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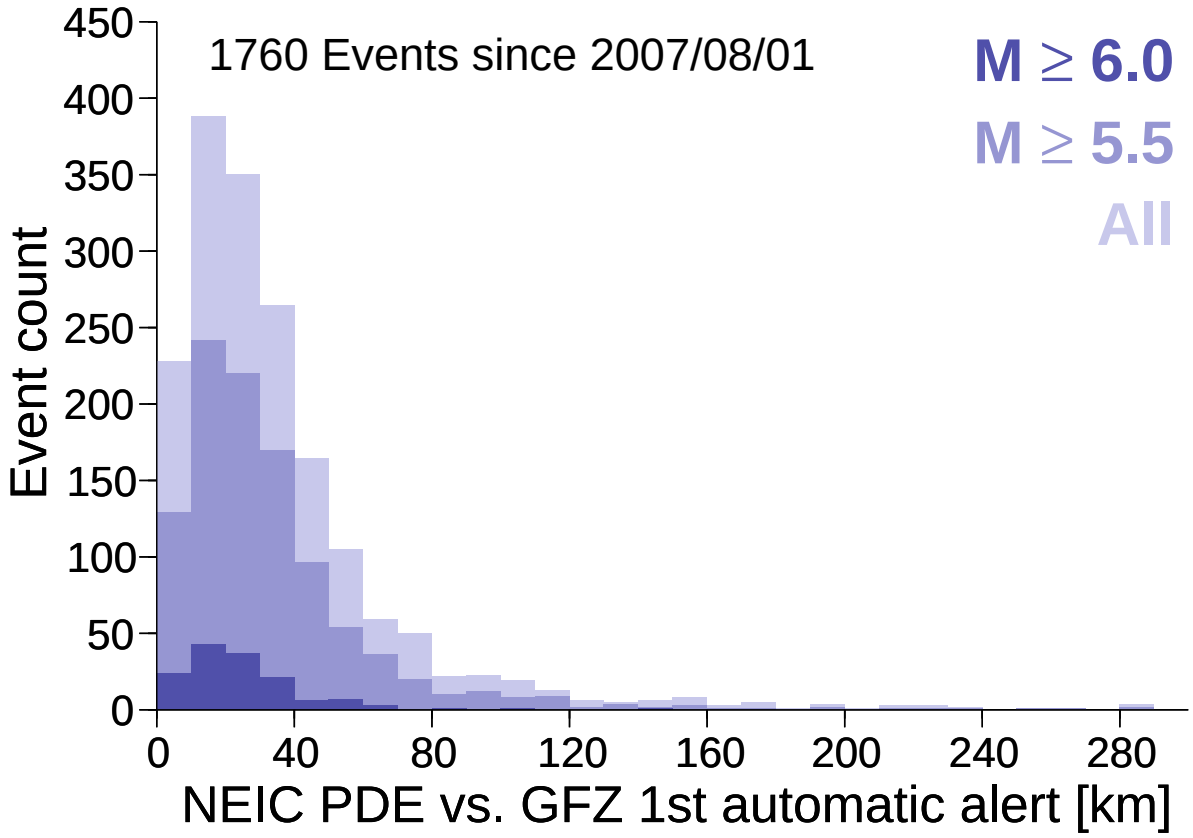

Recent achievements

SC2 legacy programs superseded by SC3 equivalents

Autopick, Autoloc, ...

Improved configuration

Convenient configuration using plain text files. Very few settings are *required*, most have reasonable defaults.

Database replication

and clean-up to avoid database congestion. Work in progress

Support for PostgreSQL

fully implemented

Messaging stability

e.g. automatic re-connect

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Currently POSIX-only, porting to MacOSX successful

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fully implemented

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e.g. automatic re-connect

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should flow back into Autoloc

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velocity models, grid optimization, ...

Magnitude calibration

required especially for MJ, ML

Faster magnitudes

by producing incremental amplitude measurements

Focal meachanisms

determined in near-real time

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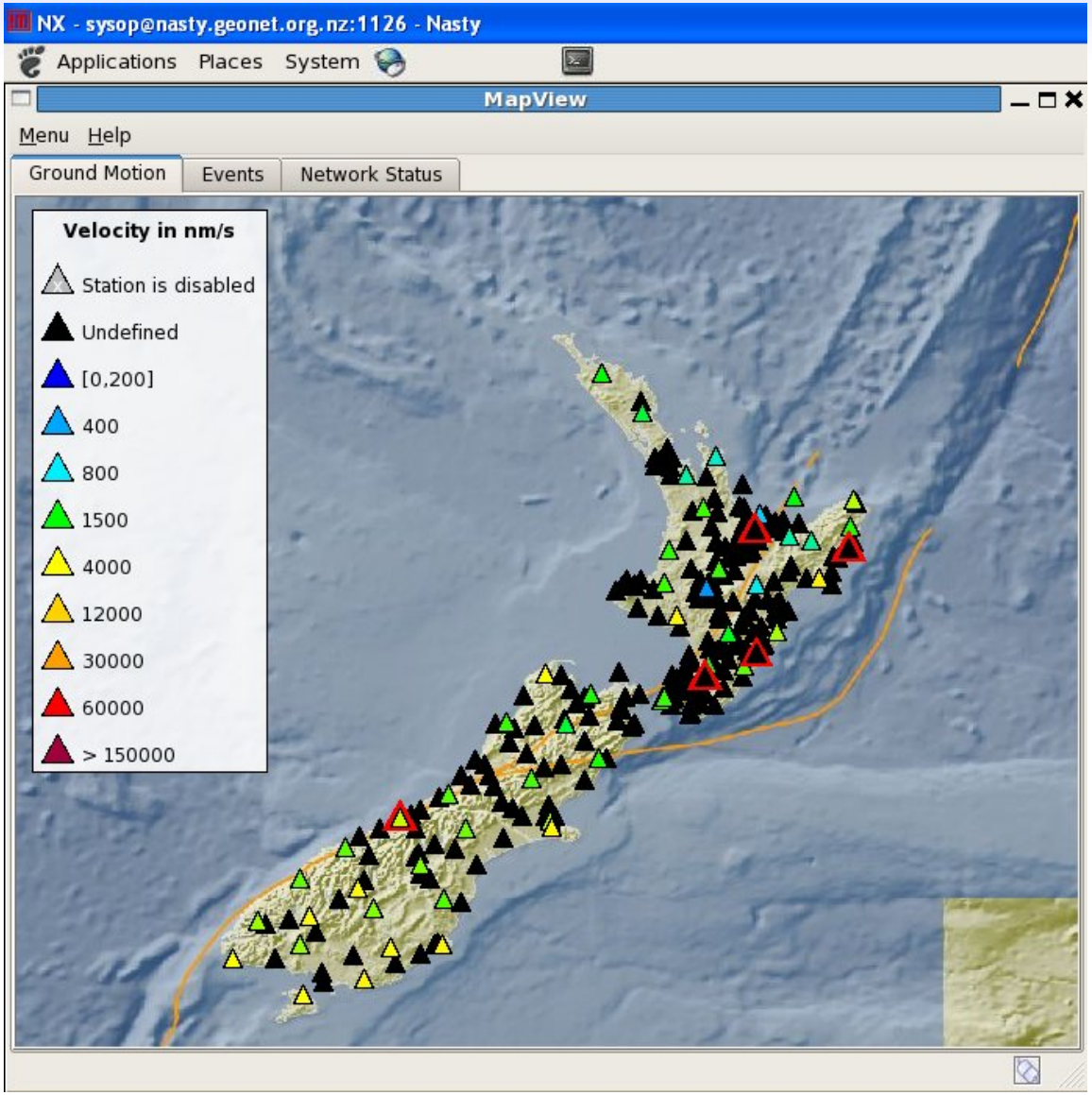
SeisComP3 in New Zealand



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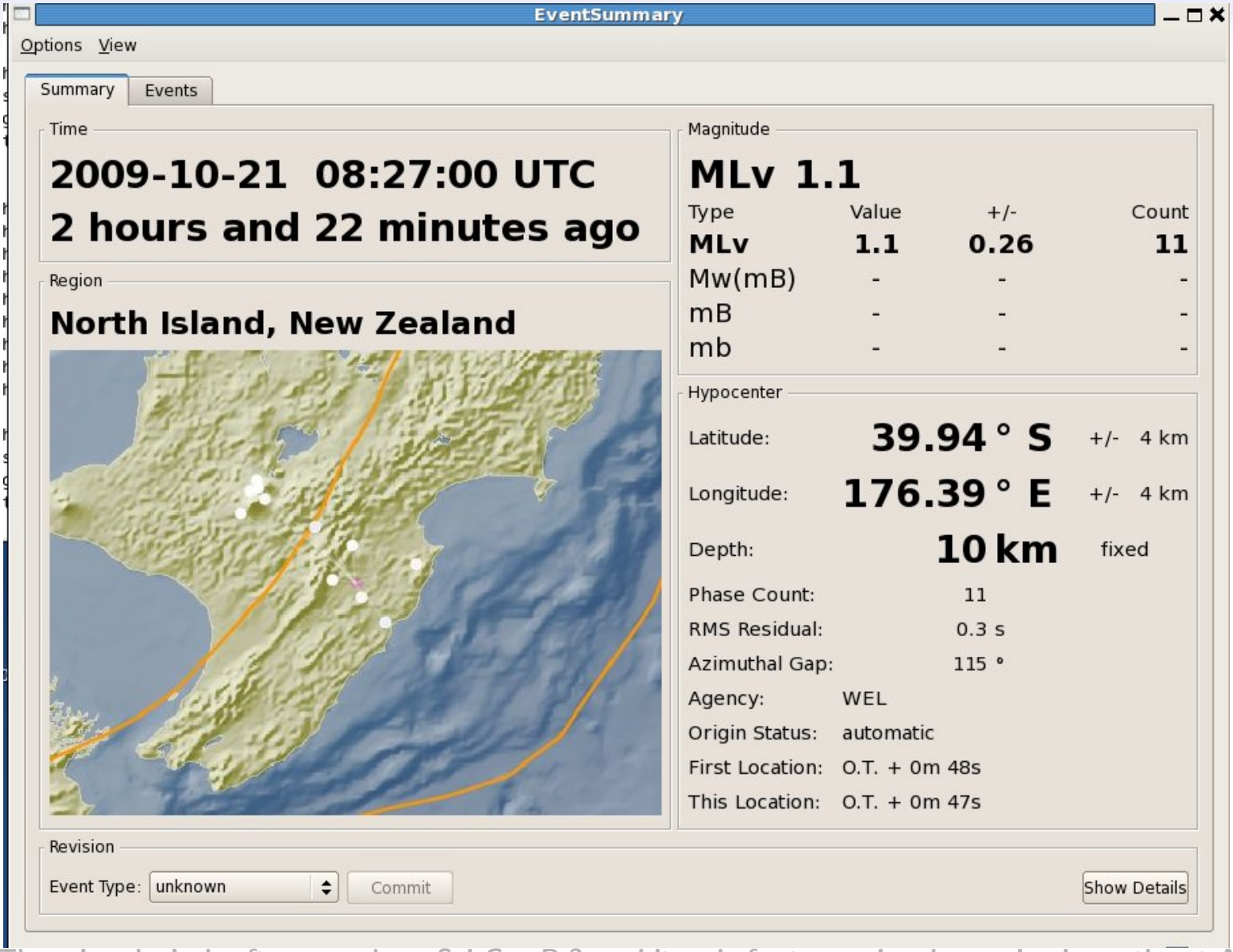

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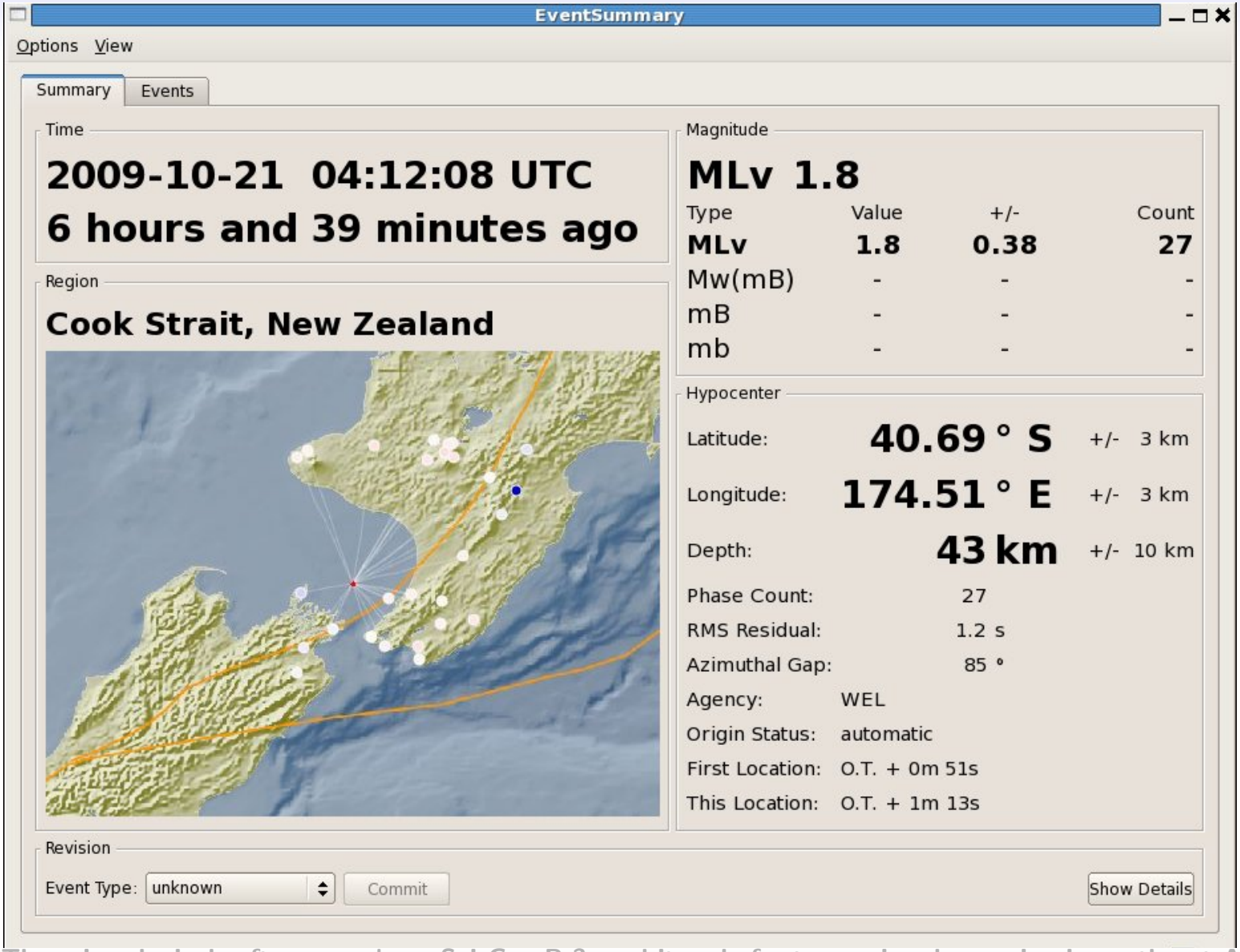

Thank You!

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