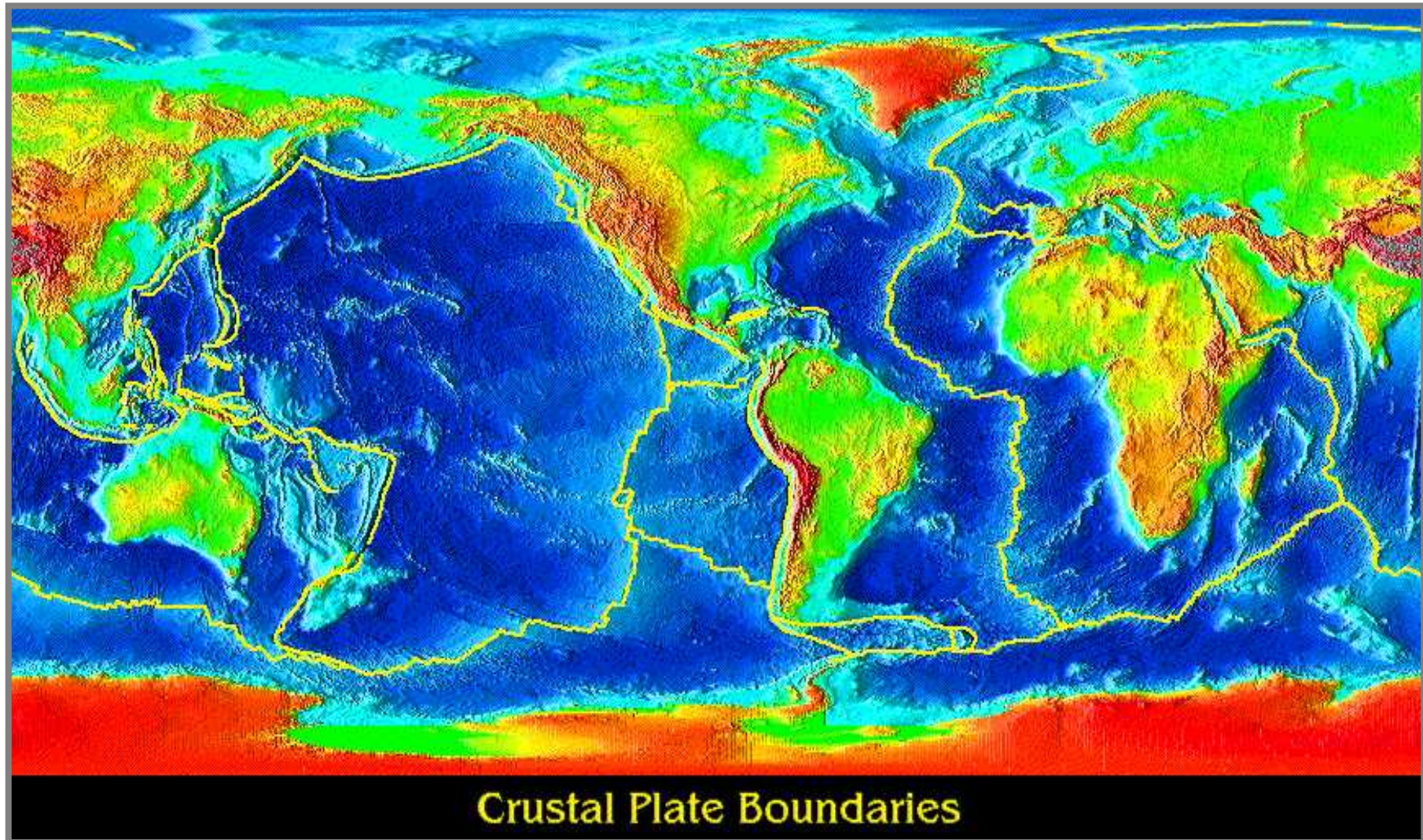


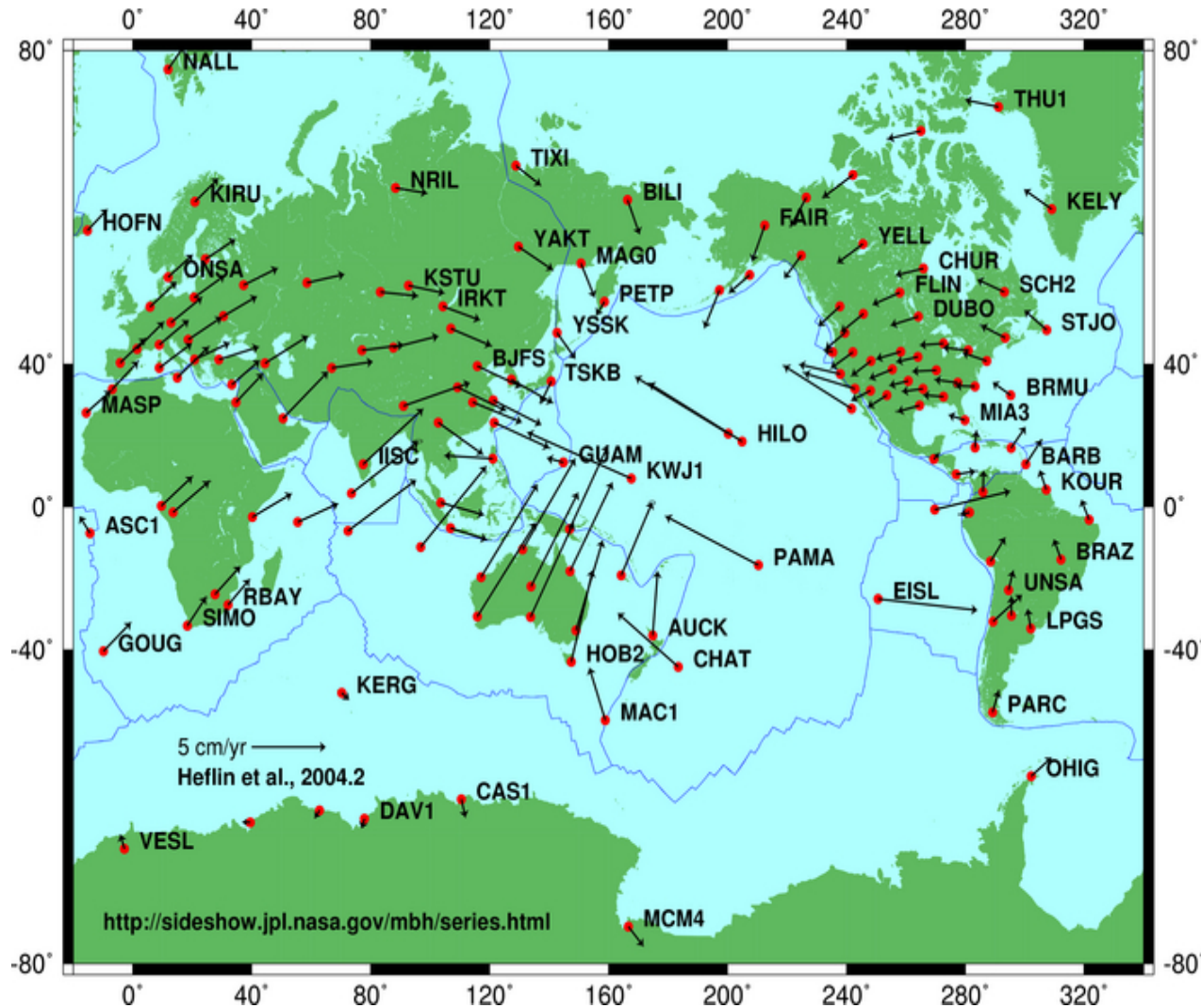


Tsunamis: Sumatra Ereignis Dezember 2004

Folien von Prof. Bunge, LMU

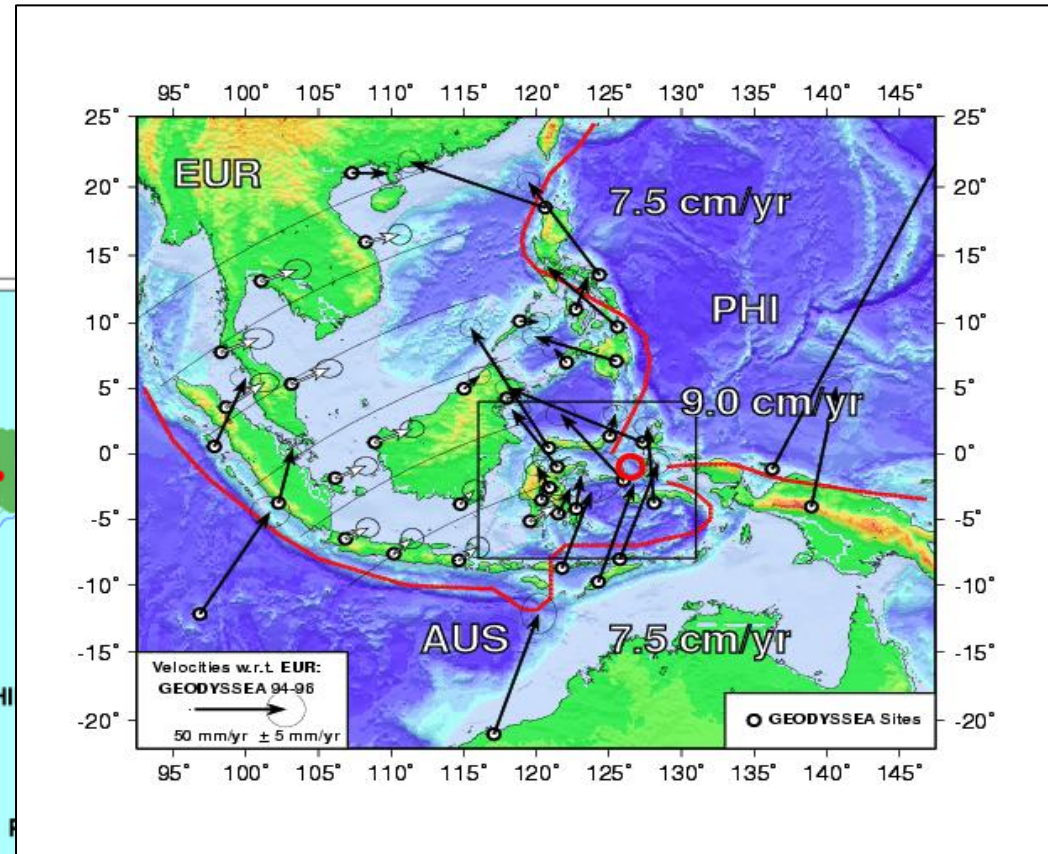
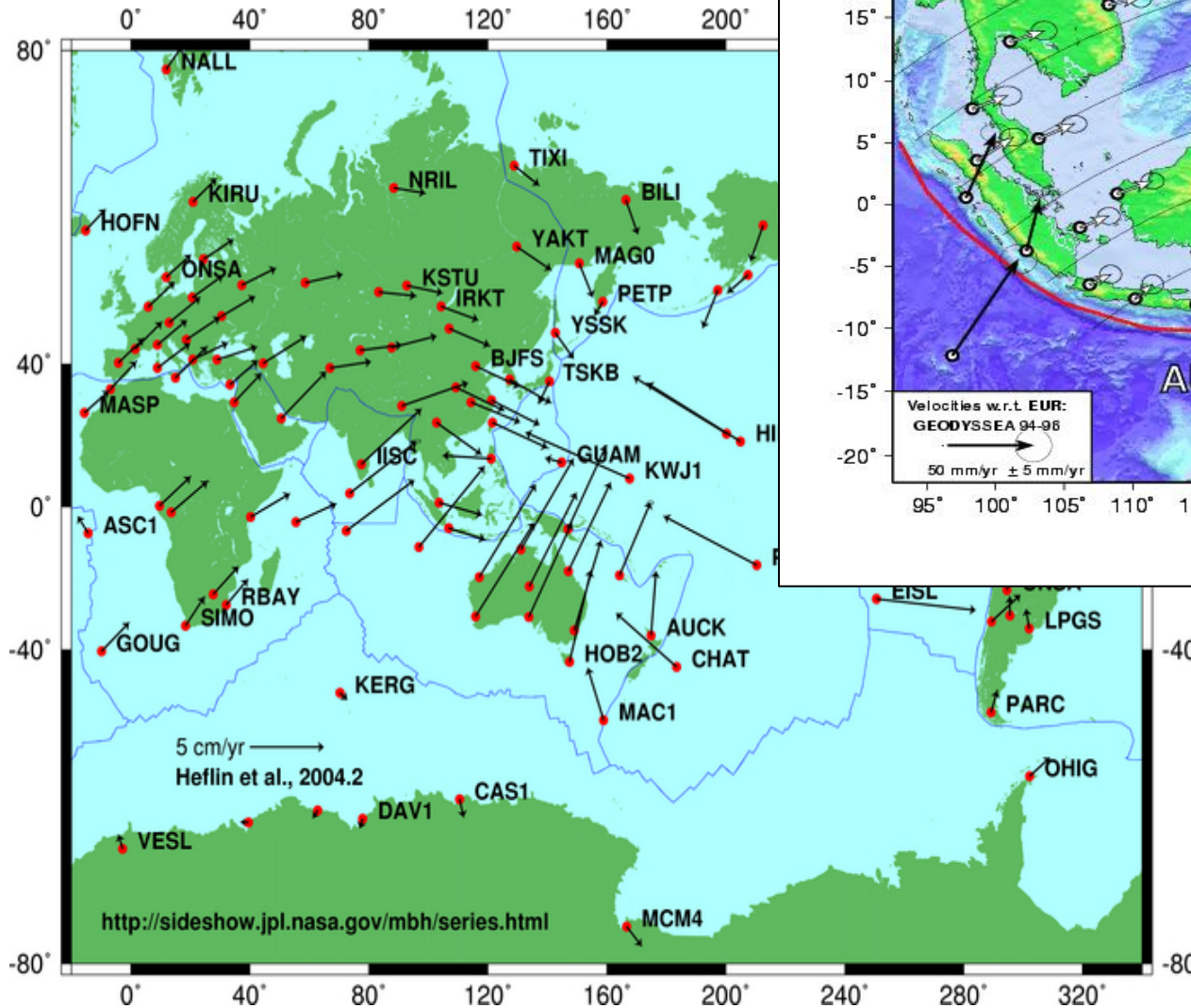
Tektonische Plattengrenzen





**Astronomische
Geodäsie mittels
Präzisionsmessungen
*Globales Positions
System (GPS)*
(TU-München)**

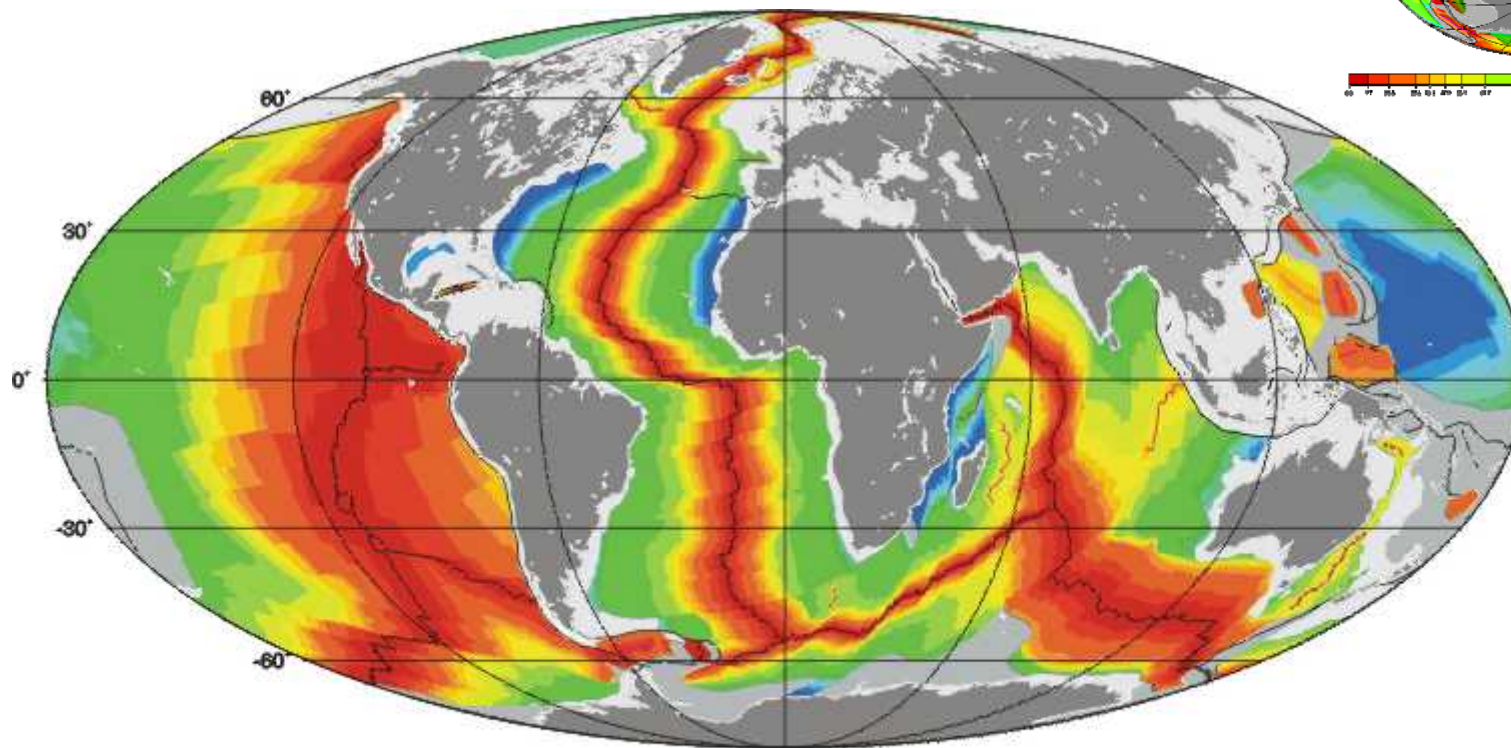
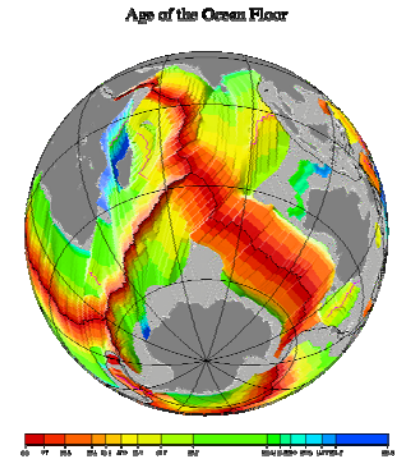
**ermöglicht heute
Echtzeitmessungen
tektonischer
Plattenbewegung**



~ 6 cm / Jahr
Plattenbewegung
um Sumatra

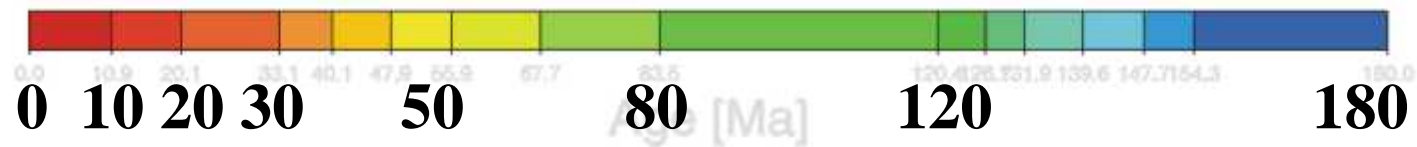
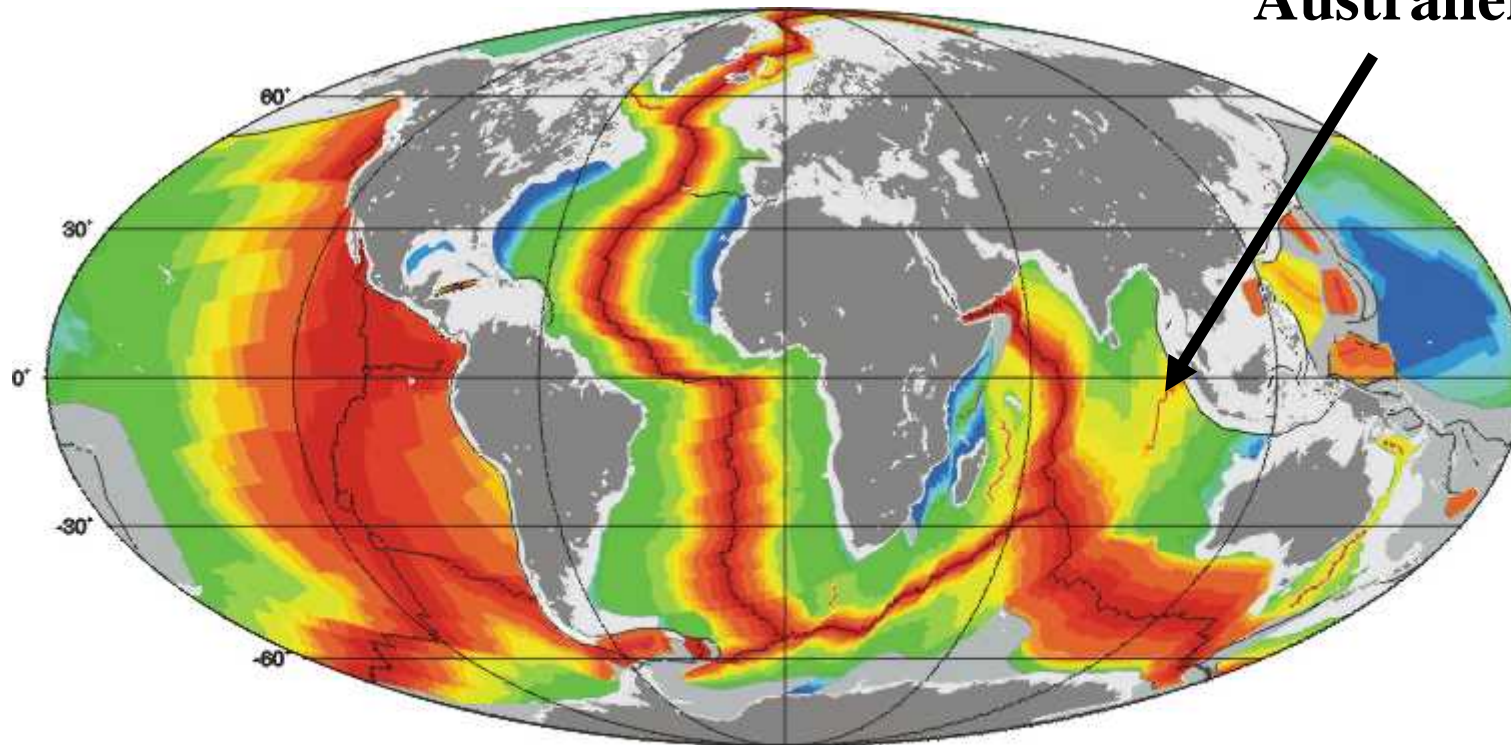
6 Meter / Jahrhundert

Jung = Rot
Alt = Blau

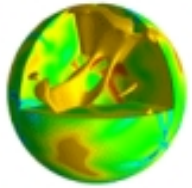


Alter des Ozeanbodens [Millionen Jahre]

**Nascente Plattengrenze
zwischen Indien und
Australien**



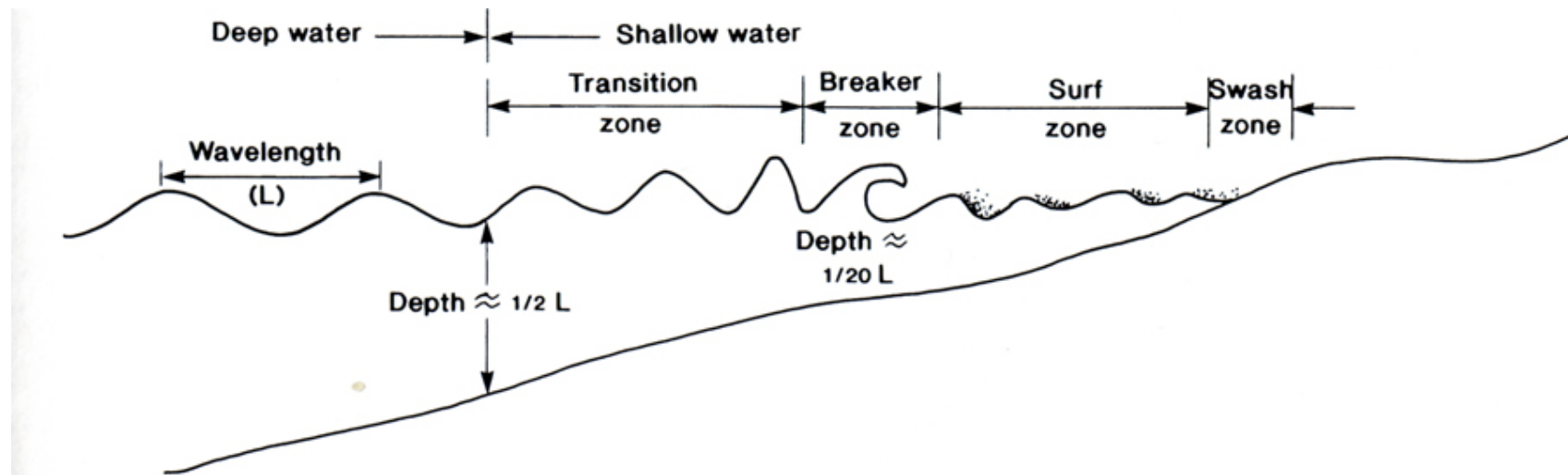
Alter des Ozeanbodens [Millionen Jahre]



Describing Ocean Waves

- **Wind Waves:** $T \sim 10\text{-}20\text{s}$ $\lambda \sim 10\text{-}600\text{m}$
- **Deep Water Velocity:** $v = \lambda/T$ ($v \sim 1\text{-}30\text{m/s}$)
- The speed of deep water waves depends on wavelength, deep water waves are **dispersive**.
- **Shallow Water Velocity:**

$$v = \sqrt{\frac{g\lambda}{2\pi} \tanh\left(\frac{2\pi D}{\lambda}\right)} \approx_{d < \frac{L}{20}} \sqrt{gD}$$



Ausbreitungsgeschwindigkeit der Tsunamiwellen

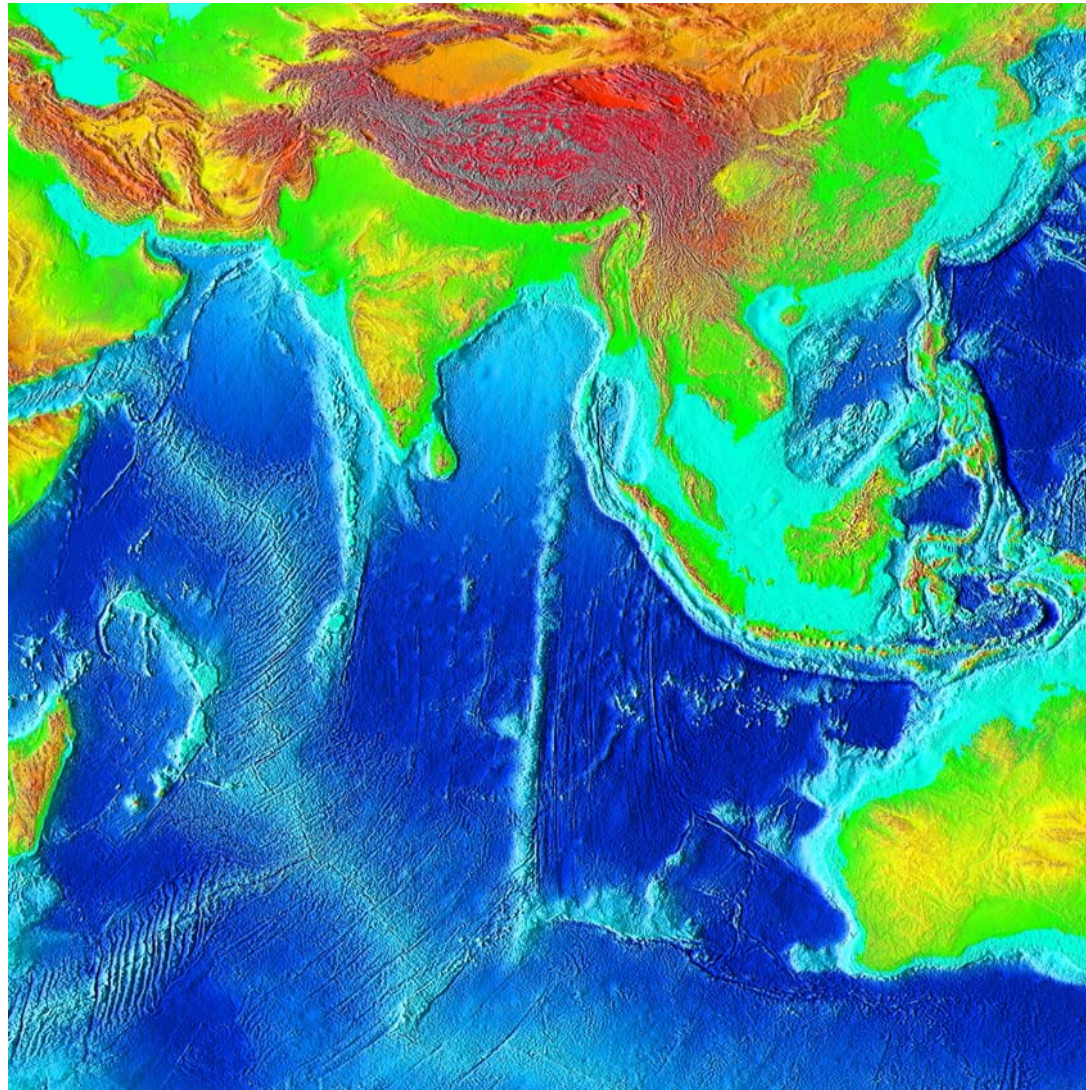
$$V = (g * h)^{1/2}$$

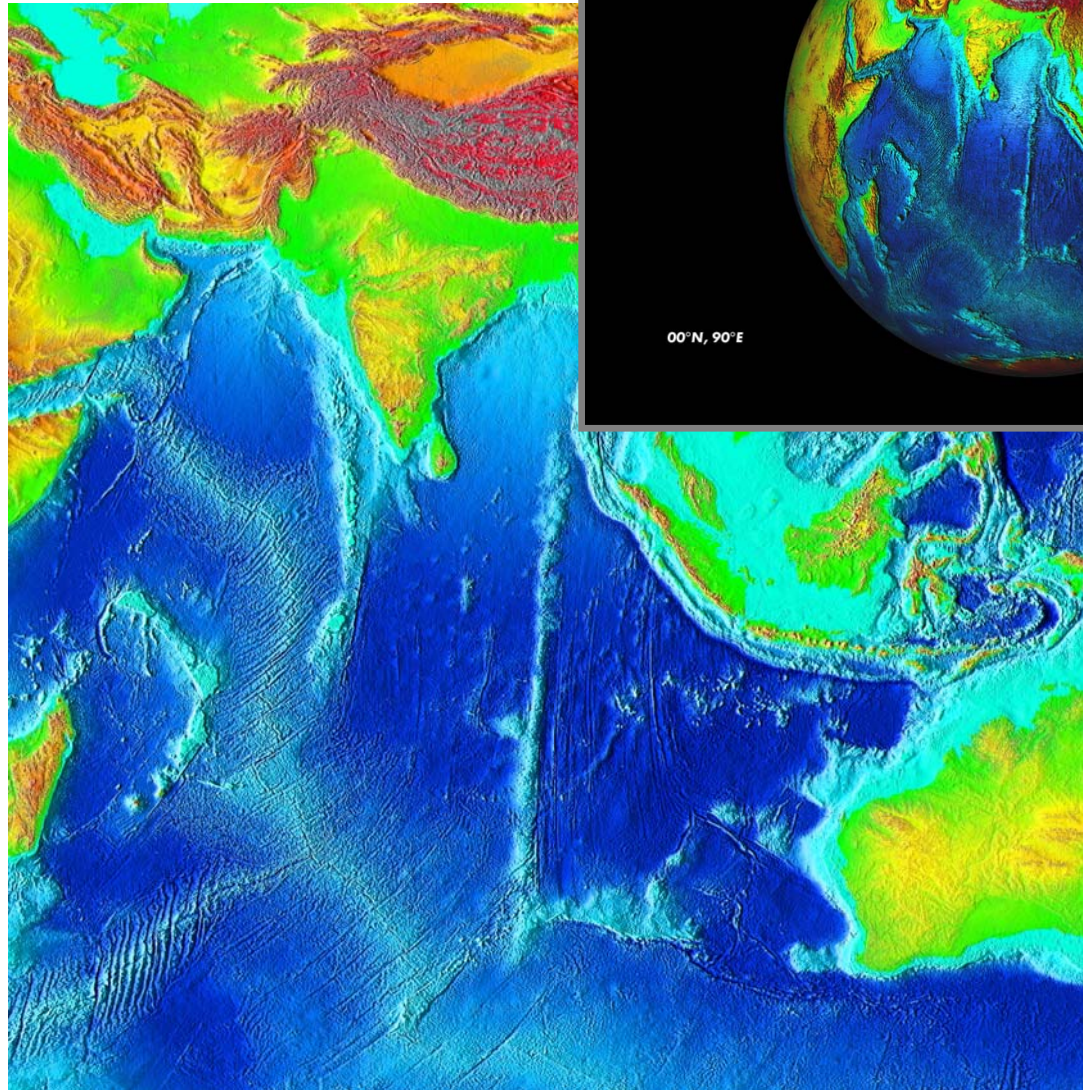
$$V = (10 \text{ m / sec}^2 * 4000 \text{ m})^{1/2}$$

$$V = (40.000 \text{ m}^2 / \text{sec}^2)^{1/2}$$

$$V = 200 \text{ m/sec} \sim 700 \text{ km/h}$$

g = Erdbeschleunigung, h = Tiefe des Ozeanbodens



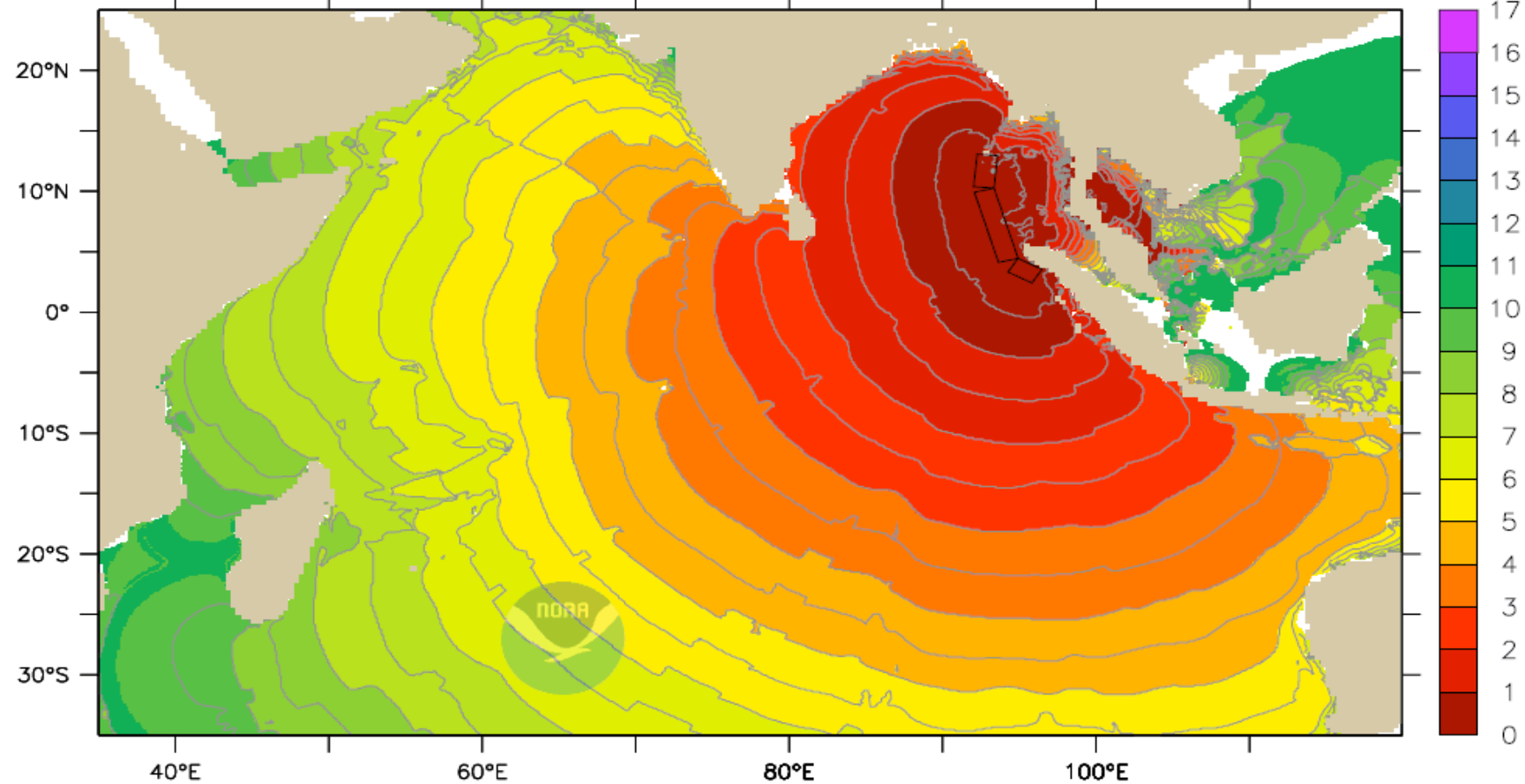


Facility for the Analysis and Comparison of Tsunami Simulations (FACTS)

Arrival Time of First Wave(hours) – 2004.12.26 Indonesian Tsunami

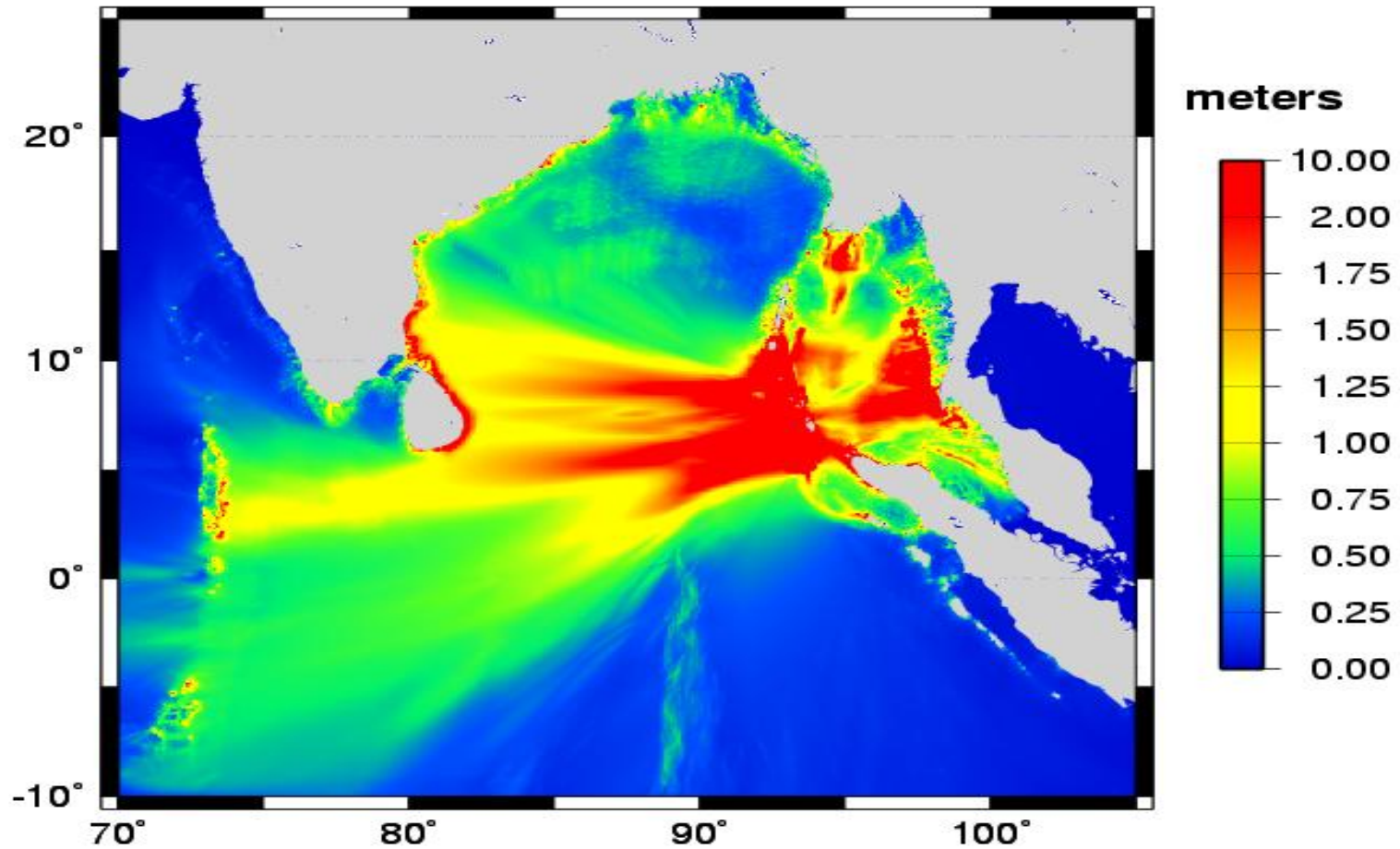
T (SECONDS) : -30 to 36030

Source: Mw 9.0 (4°N,95.7°E–20m*(200x150km),90°rake,13°dip,300°strike,5m depth)+(7.3559°N,94.1393°E–20m*(670x150km),90°rake,13°dip,345°strike,5m depth)+(11.605°N,93.4723°E–20m*(300x150km),90°rake,13°dip,365°strike,5m depth)

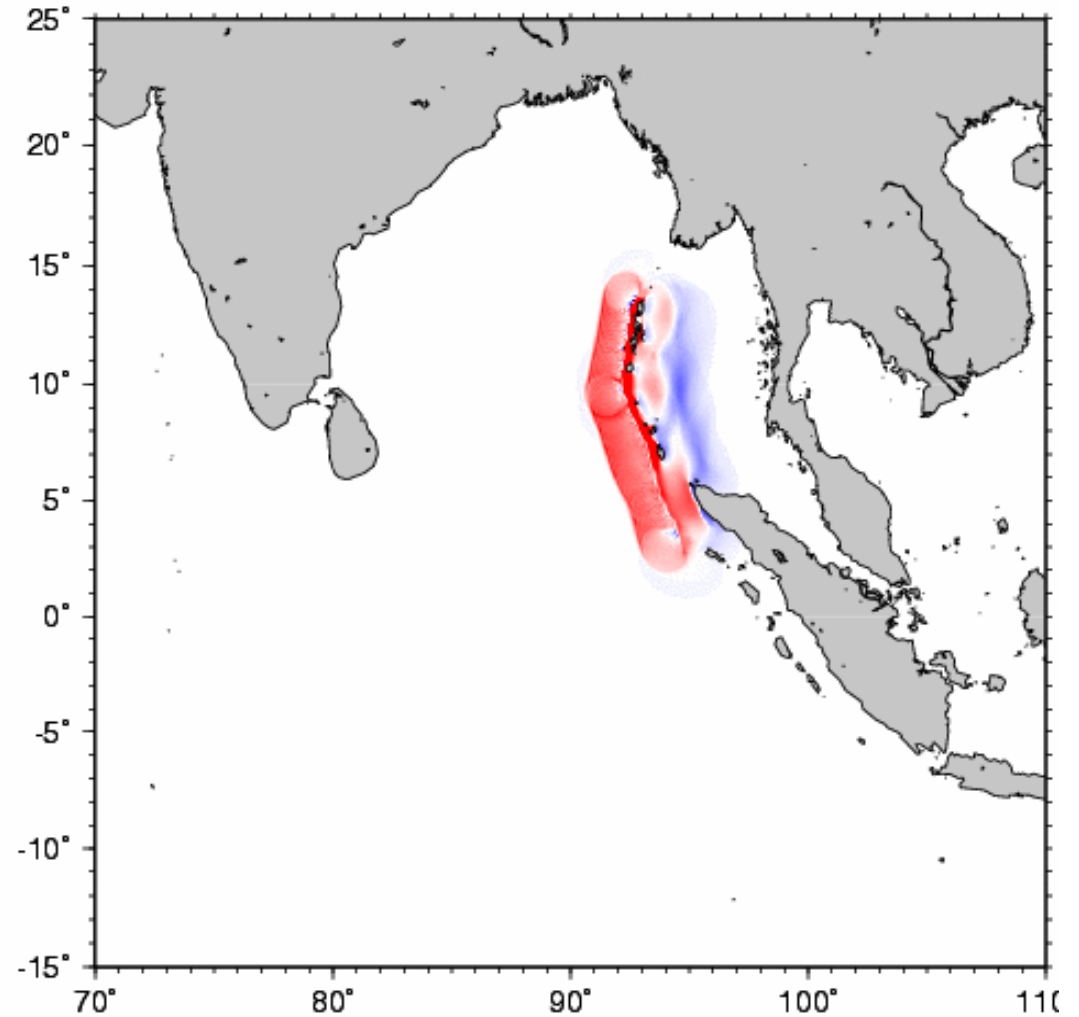
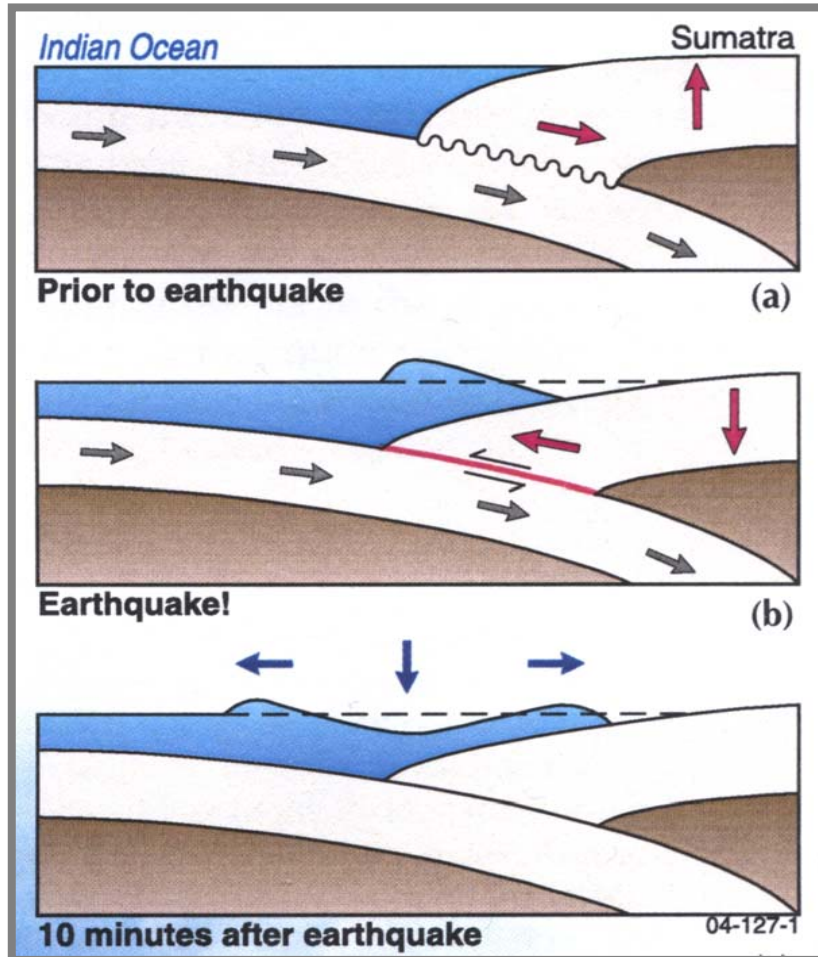


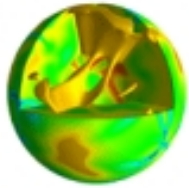
SOURCE: US Dept of Commerce/NOAA/Pacific Marine Environmental Laboratory (PMEL) http://www.pmel.noaa.gov/tsunami/indo_1204.html

Maximum water elevation



A.Piatanesi - INGV



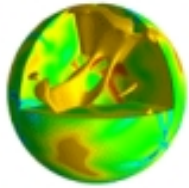


**GEO
LMU**

BANDA ACEH, INDONESIA: June 23, 2004

A satellite image of the waterfront area of Aceh province's capital city before the tsunami.





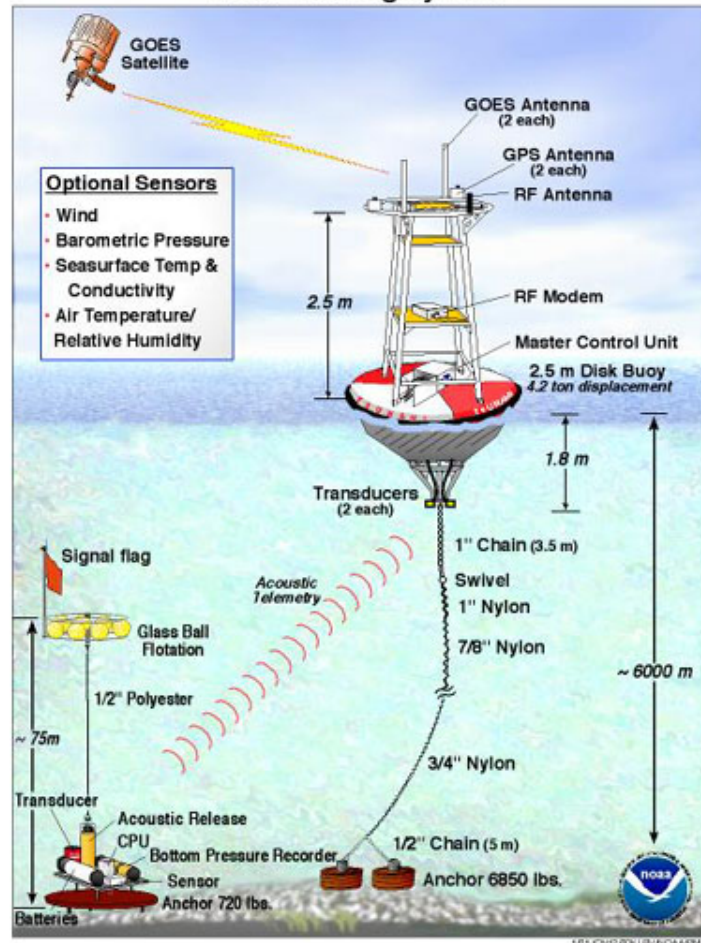
**GEO
LMU**

BANDA ACEH, INDONESIA: December 28, 2004

An image taken after the tsunami shows destroyed housing and the shoreline nearly wiped out.



DART Mooring System

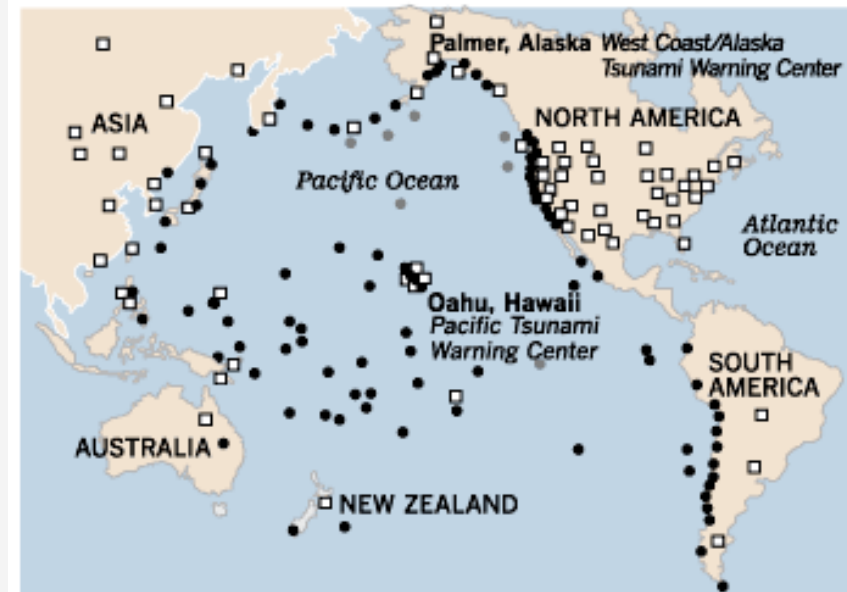


Sounding the alarm

Unlike in the Indian Ocean, the Pacific Ocean has a system to warn about tsunamis. Across the Pacific, there are hundreds of tide and seismic stations and ocean sensors that provide data about earthquakes and the potential for tsunamis.

Tsunami warning system in the Pacific Ocean

- Tide station
- Deep ocean sensor
- Seismograph station



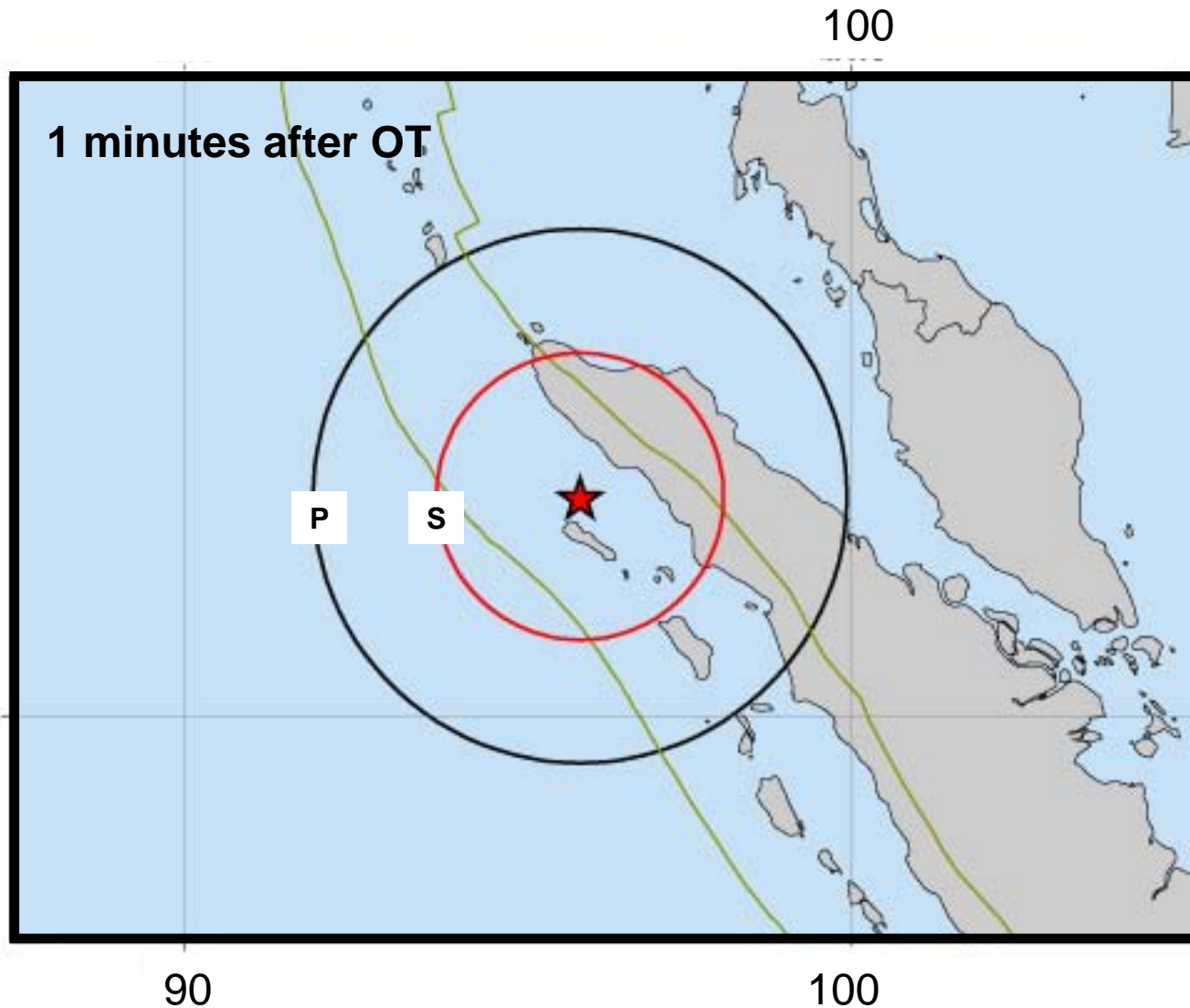
Sources: National Oceanic and Atmospheric Administration, International Tsunami Information Center

PERRY PEREZ Los Angeles Times

Sumatra Tsunami 2004



Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

People are sensing severe shaking

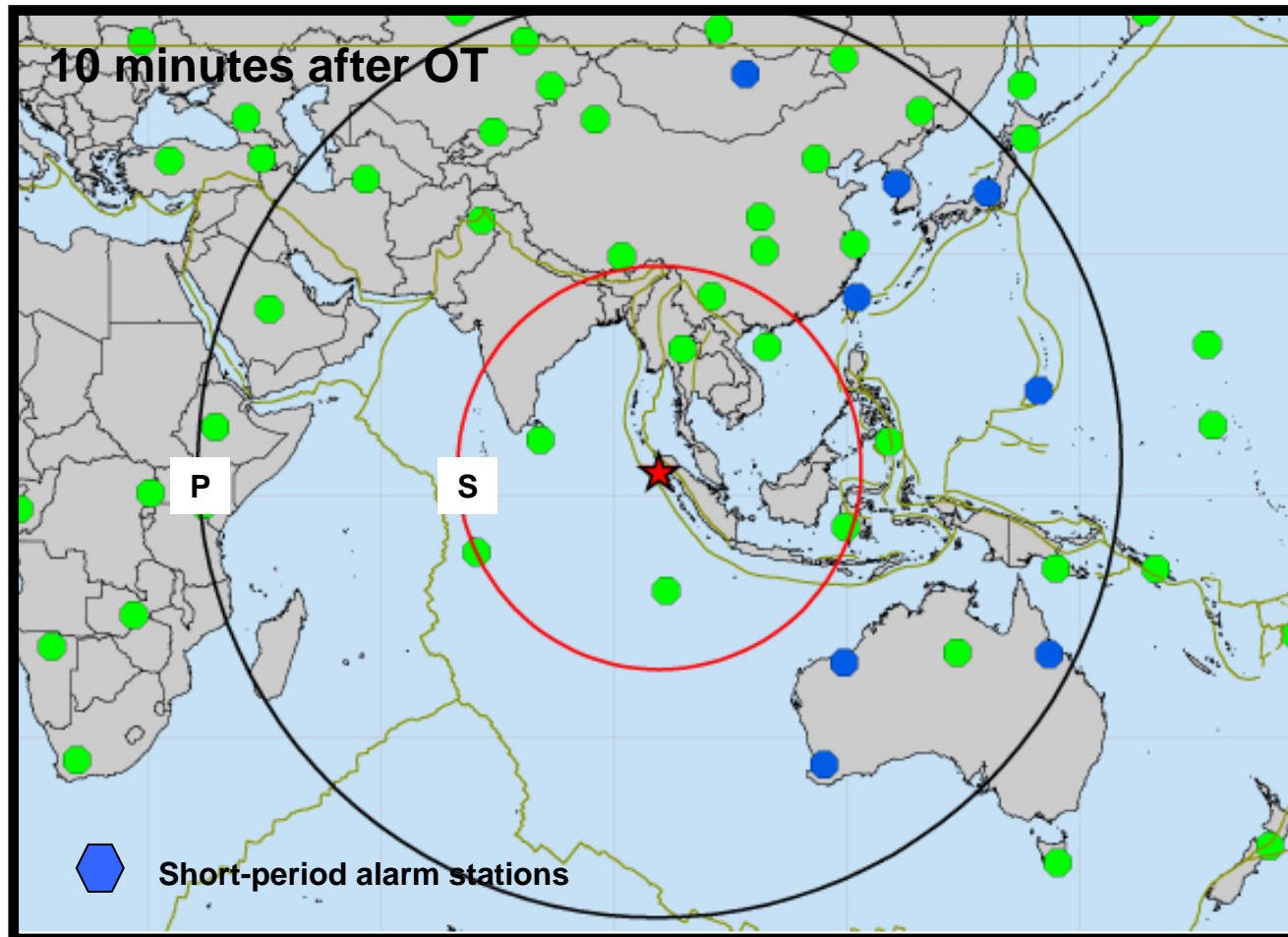
NEIC

No information regarding earthquake

PTWC

No information regarding earthquake and/or tsunami

Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

Significant structural damage in Banda Aceh

Tsunami inundation along the Sumatran coast

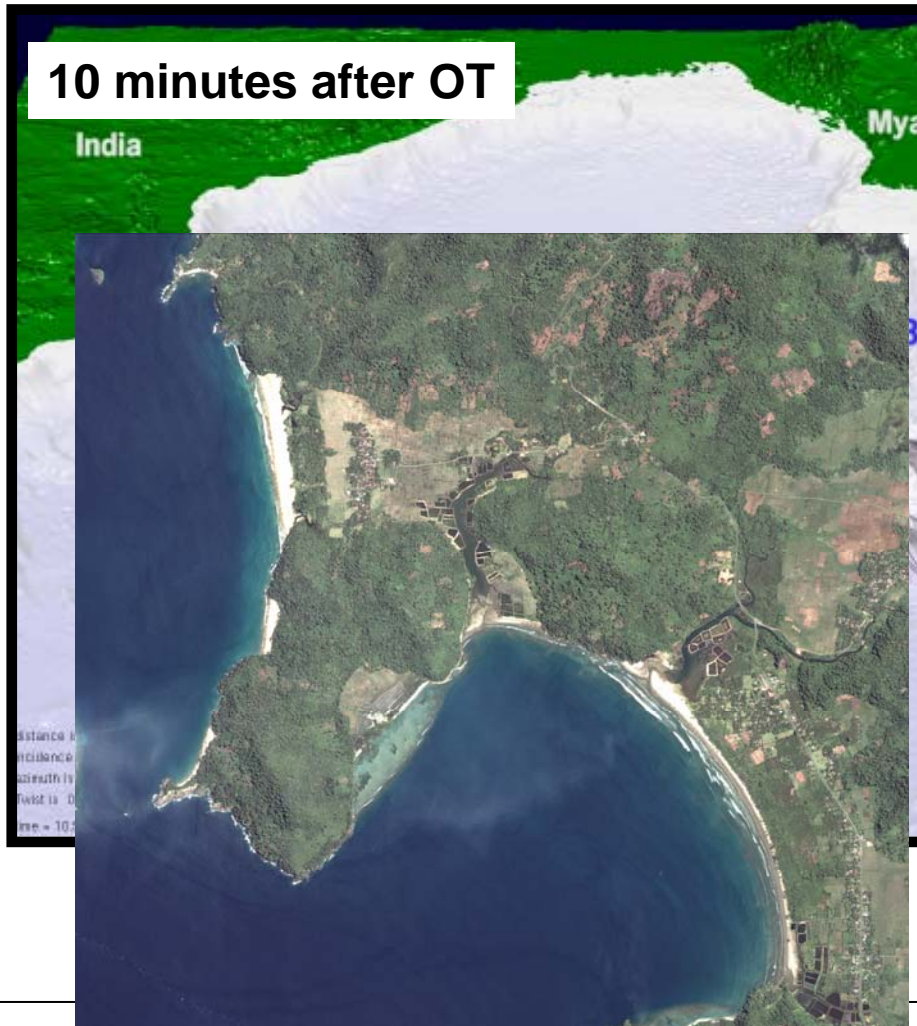
EQ is widely felt throughout the region

NEIC

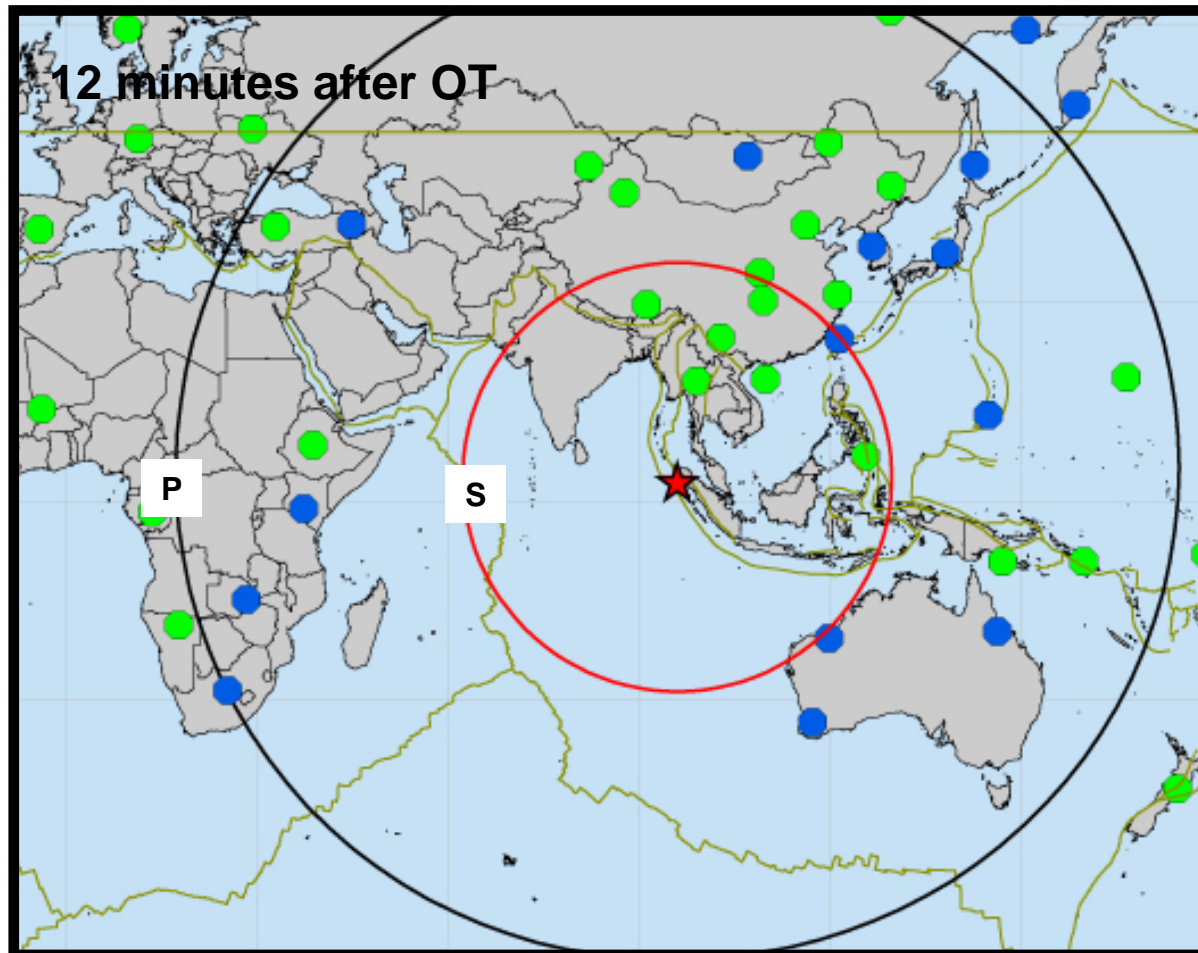
Short period alarm on eight stations in the region

PTWC

Short period alarm on western Pacific stations



Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

Tsunami inundation spreads further along the Sumatran coast

NEIC

Short period alarm on sixteen stations in the region

Mb6.2, Mwp8.2 earthquake located off the north coast of Sumatra

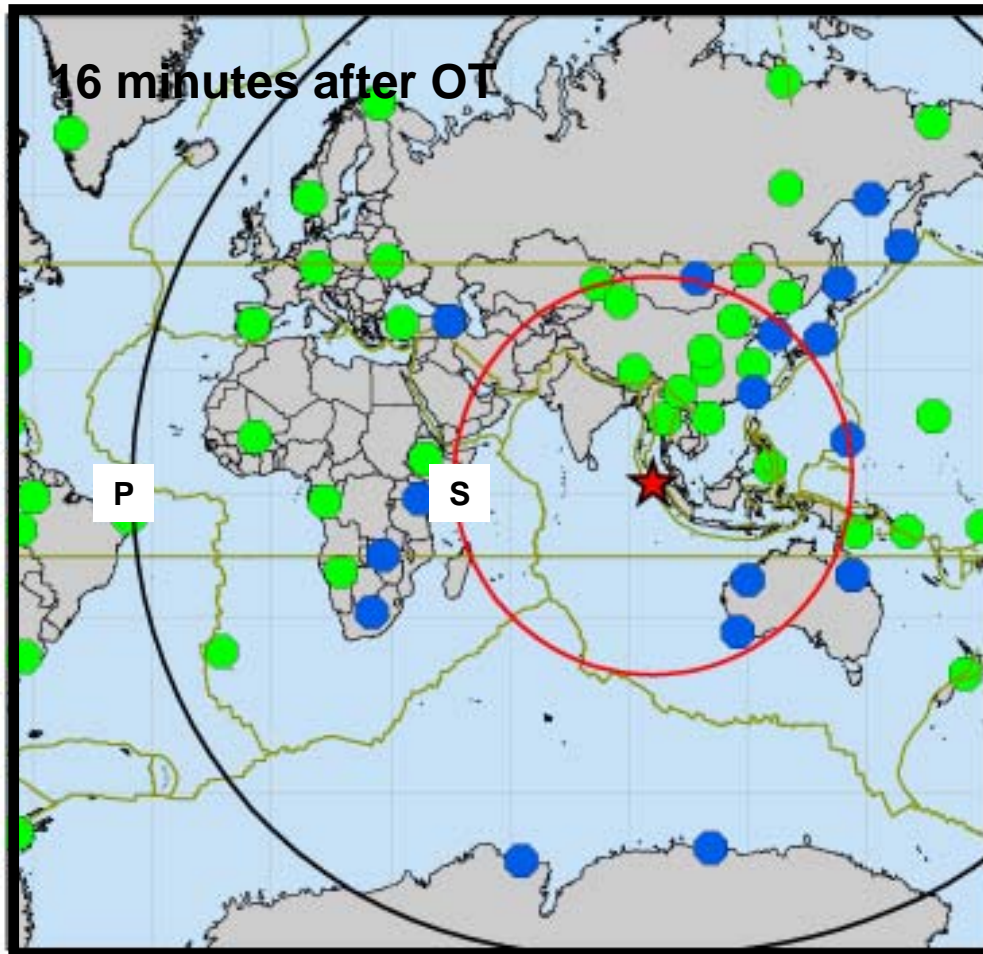
Pager notification to duty seismologists and others at NEIC

PTWC

Mwp8.2 earthquake located off the north coast of Sumatra

No tsunami advisor for the Pacific Ocean

Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

Tsunami inundation spreads further along the Sumatran coast and reaches the Nicobar Islands

NEIC

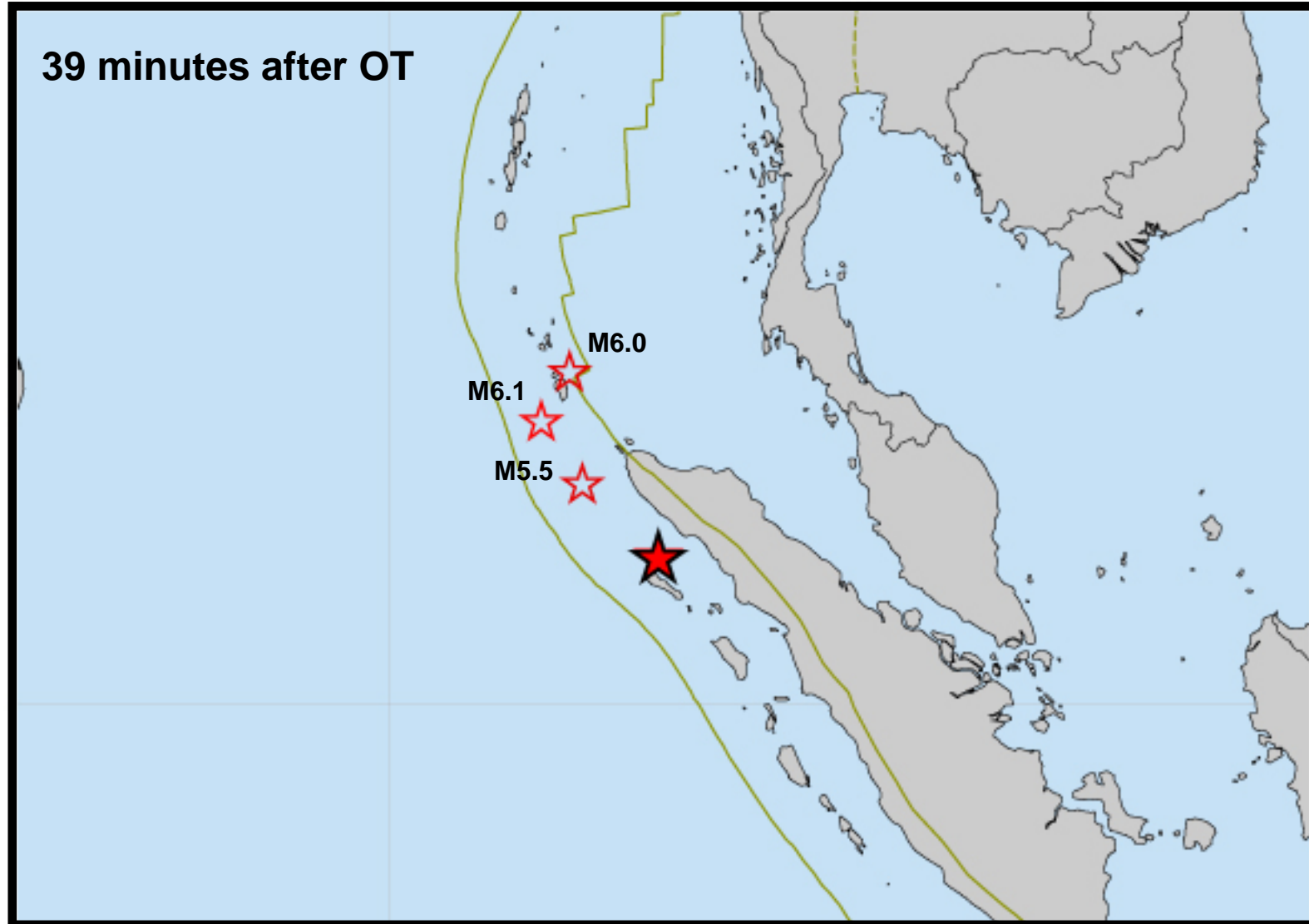
First automatic location released at NEIC

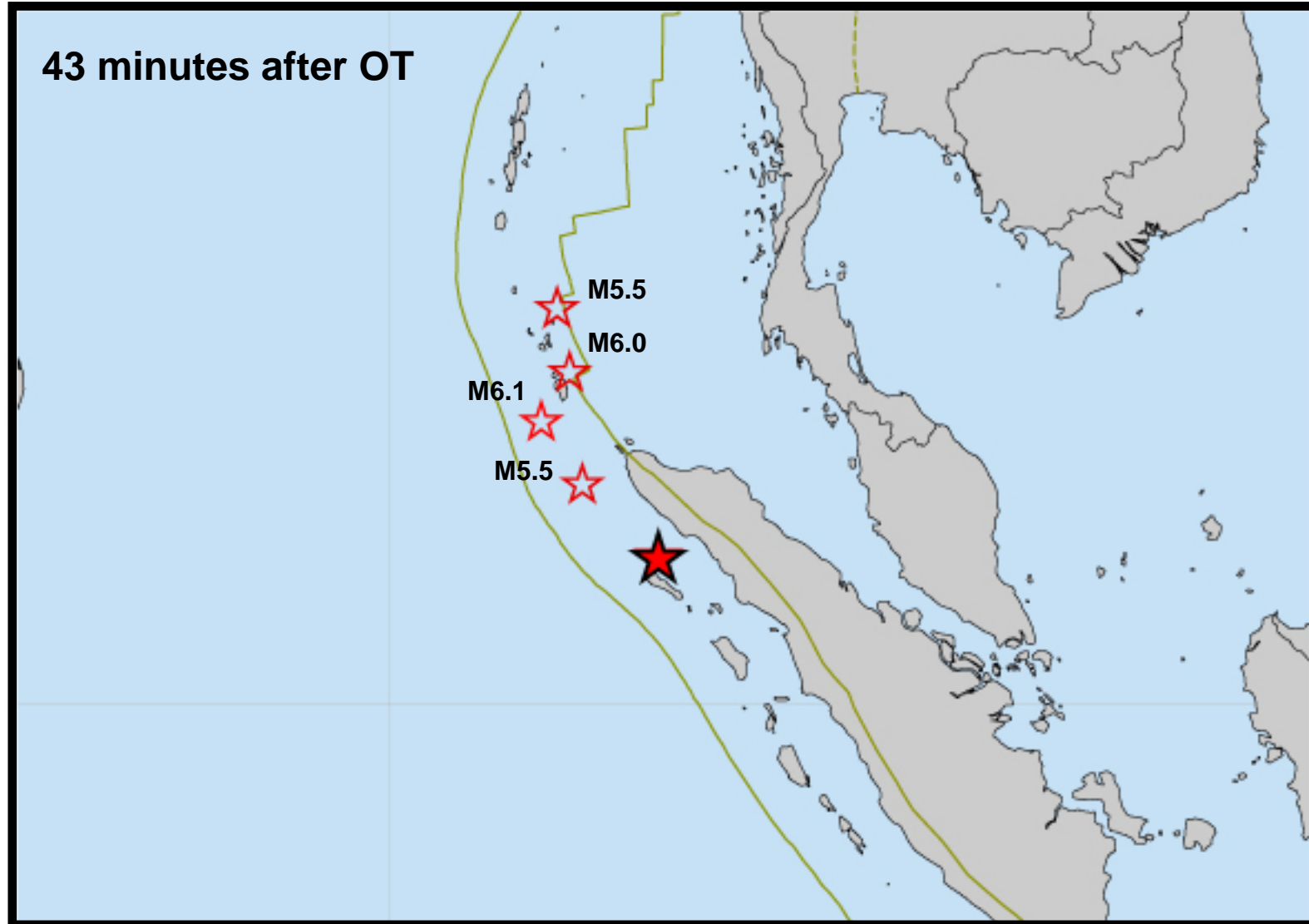
Pager notification to about 10 people in the USGS

PTWC

Confers with NEIC on the location and magnitude of the Earthquake

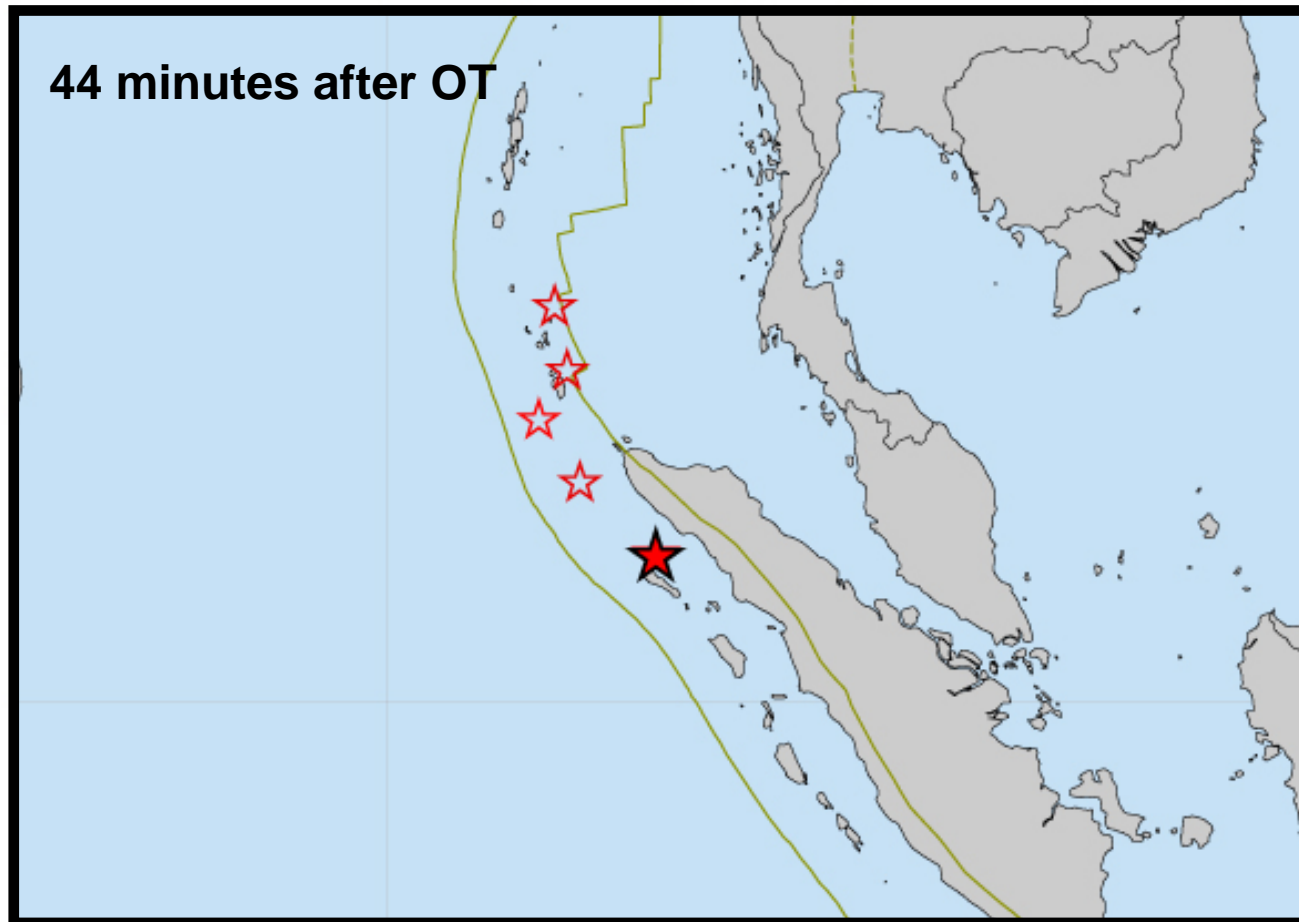
Release Tsunami Information Bulletin







Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

Tsunami is passing thru the
Nicobar Islands

NEIC

Automatic M_s magnitude is
calculated ($M_s 8.5$)

Pager notification to about 30
people in the USGS

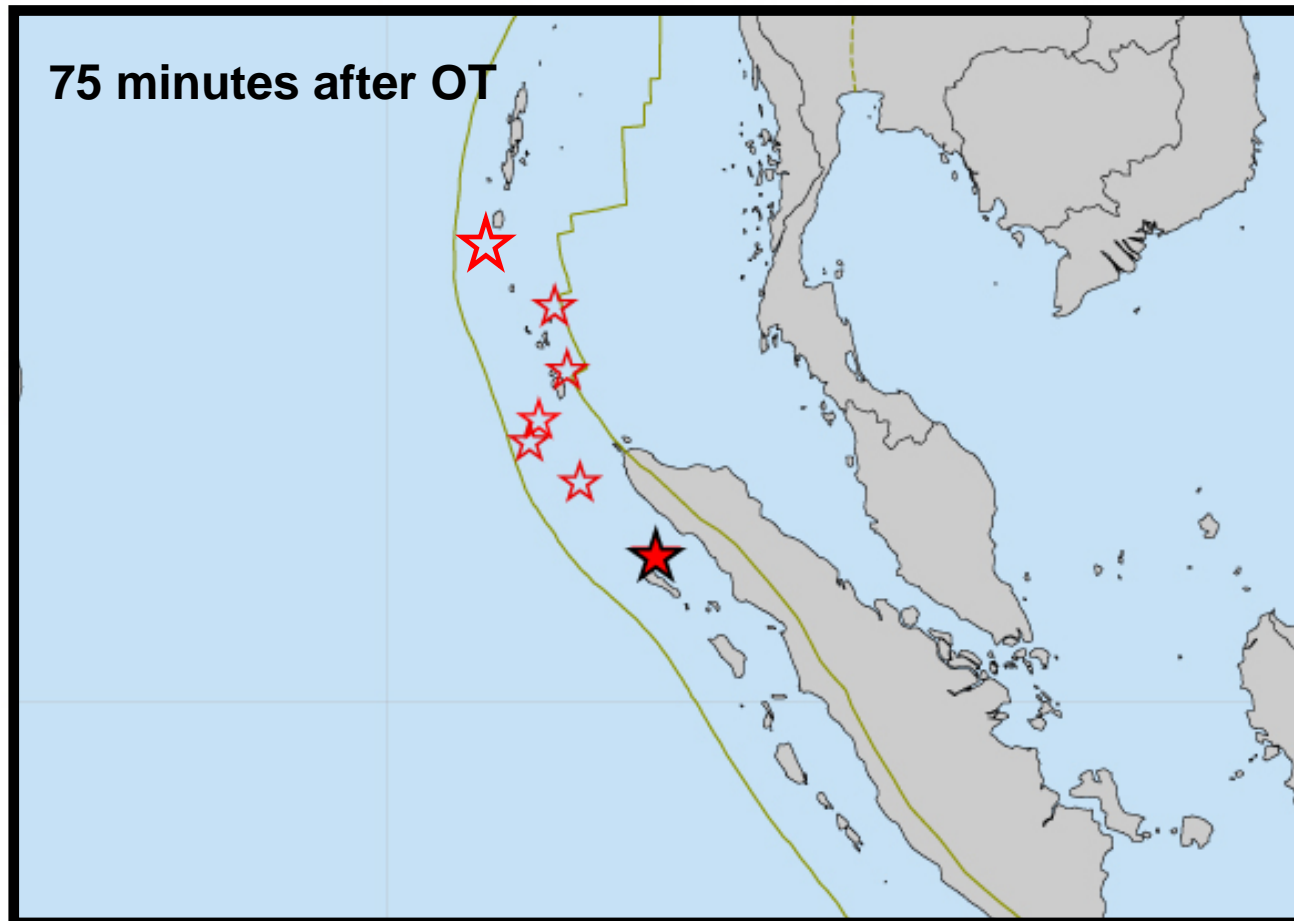
Aftershocks suggest $M_s 8.5$ is
too low

PTWC

0 Confers with NEIC on the
location and magnitude of the
earthquake

Notifies US Military on Diego
Garcia on the possibility of
an approaching tsunami

Propagation, Response and Warning Times for the M9.0 Sumatra EQ



Northern Sumatra

Tsunami reaches the Andaman Islands, approaches the Thai coast

NEIC

Releases reviewed earthquake location and magnitude (Ms8.5)

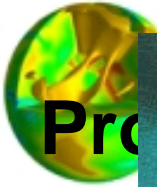
Pager notifications are sent to 25,000 people

Call down list is activated

Wire service reports of collapsed buildings in Banda Aceh

PTWC





Pro
for

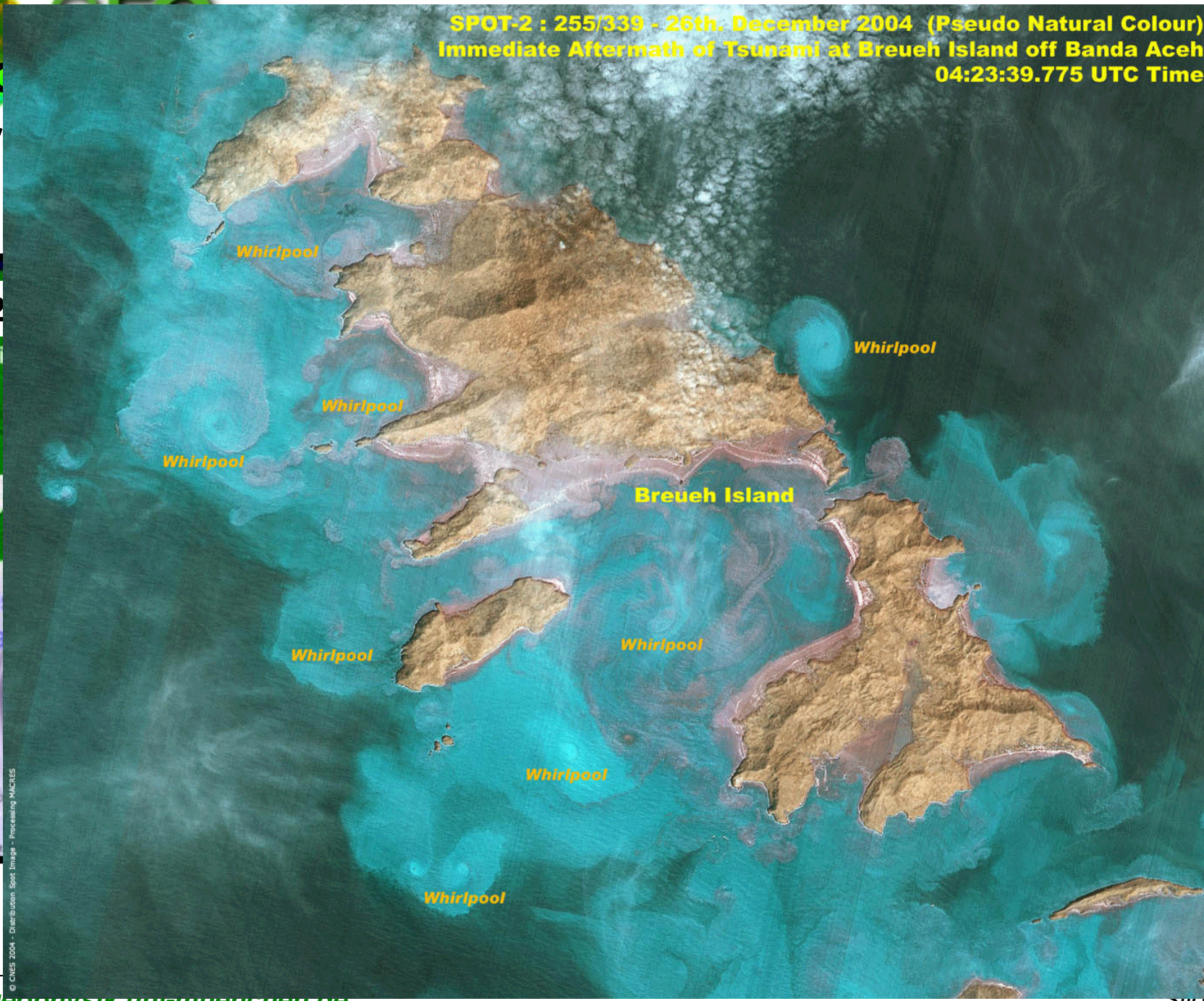
**SPOT-2 : 255/339 - 26th. December 2004 (Pseudo Natural Colour)
Immediate Aftermath of Tsunami at Breueh Island off Banda Aceh
04:23:39.775 UTC Time**

122
Indi

Wave
Sri La

Distance is 2.41
Azimuth is 43.88
Altitude is -0.00
Twist is 0.00
Scale = 122.0 mm

© CNES 2004 - Distribution Spot Image - Processing MARSIS



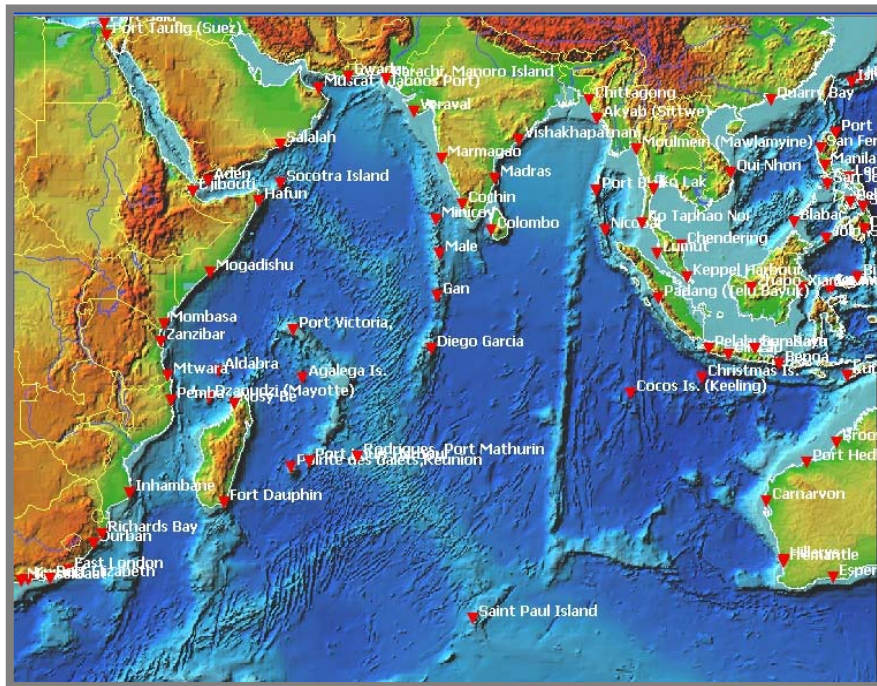
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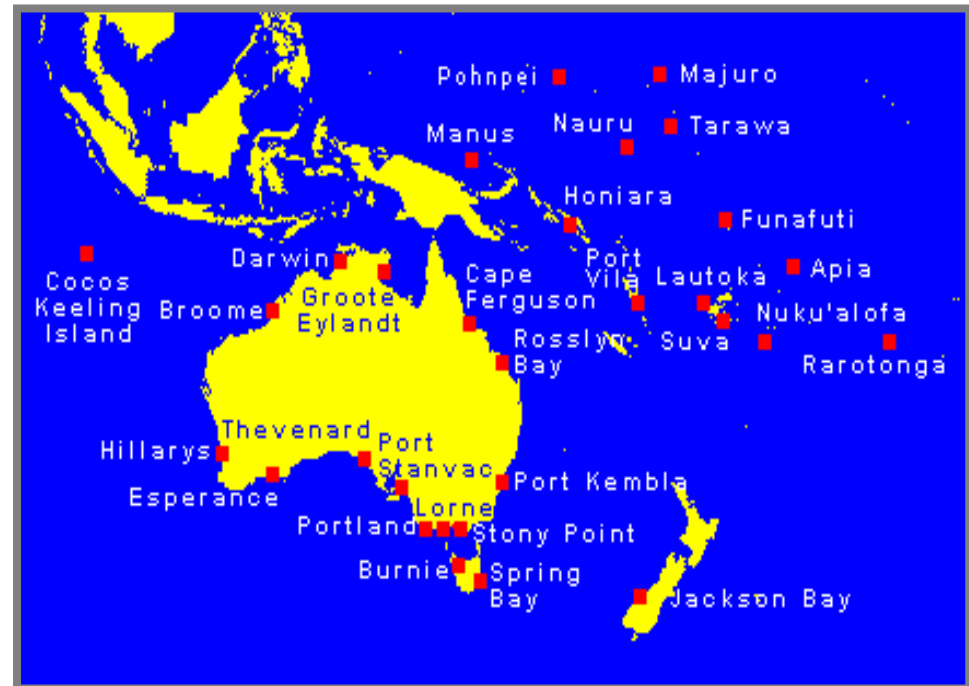
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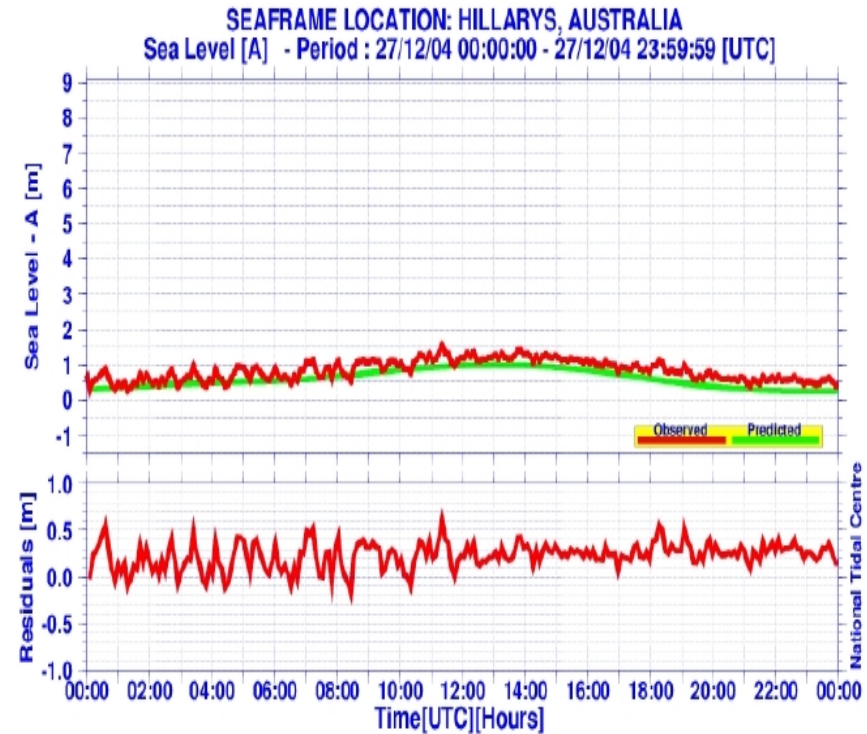
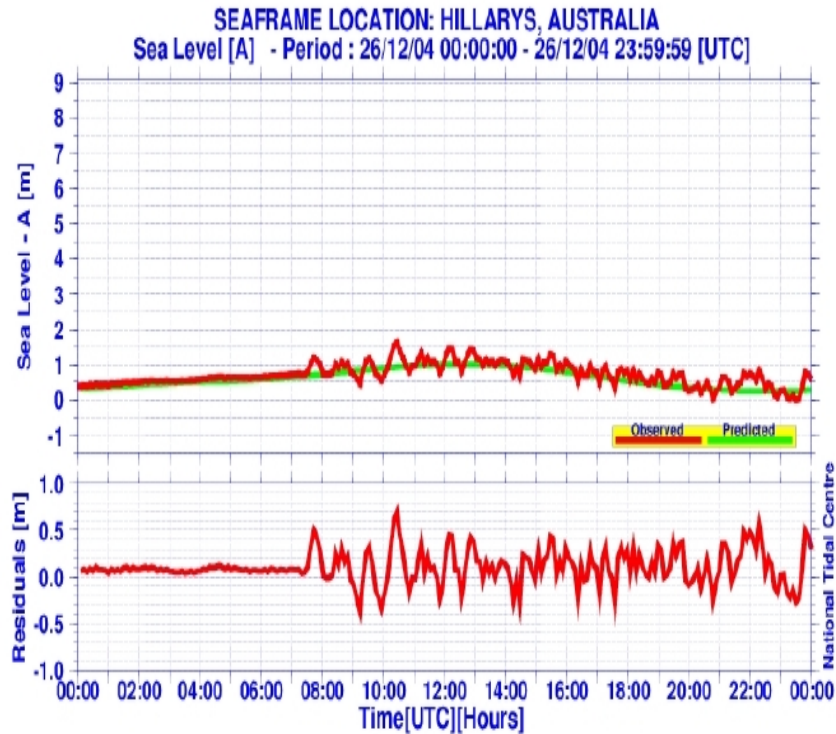


Pegel-Stationen Indischer Ozean

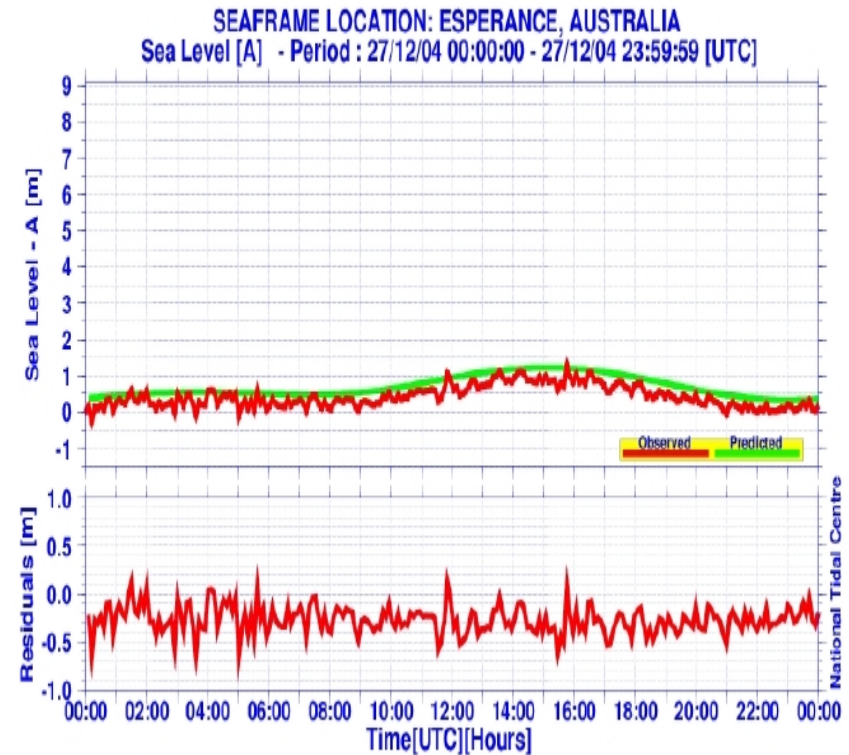
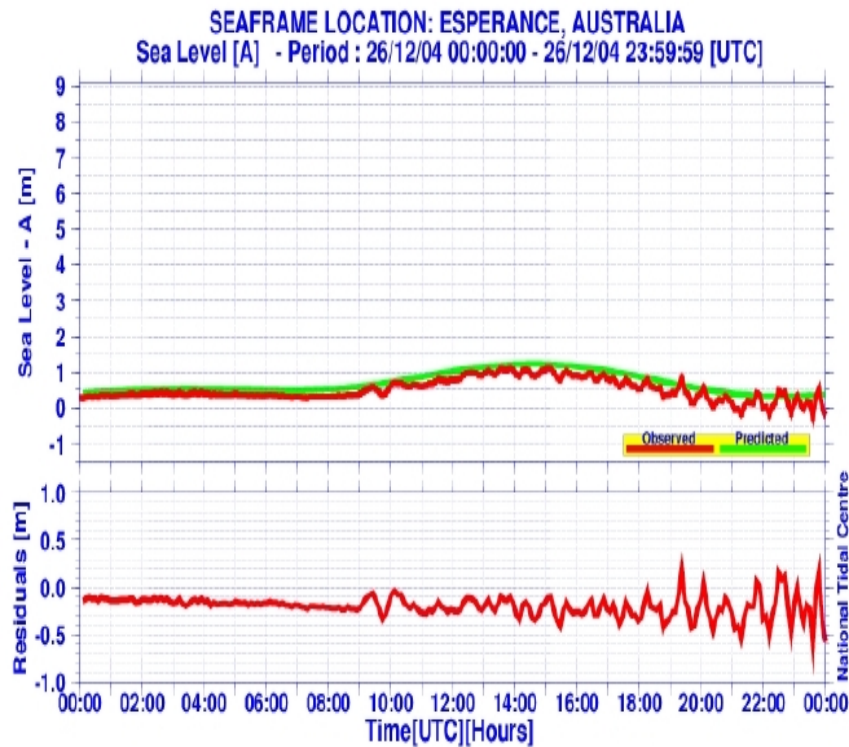


Australische Pegel-Stationen

Beobachtete Pegelstände in Hillarys (Australien) 26.-27. 12. 2004



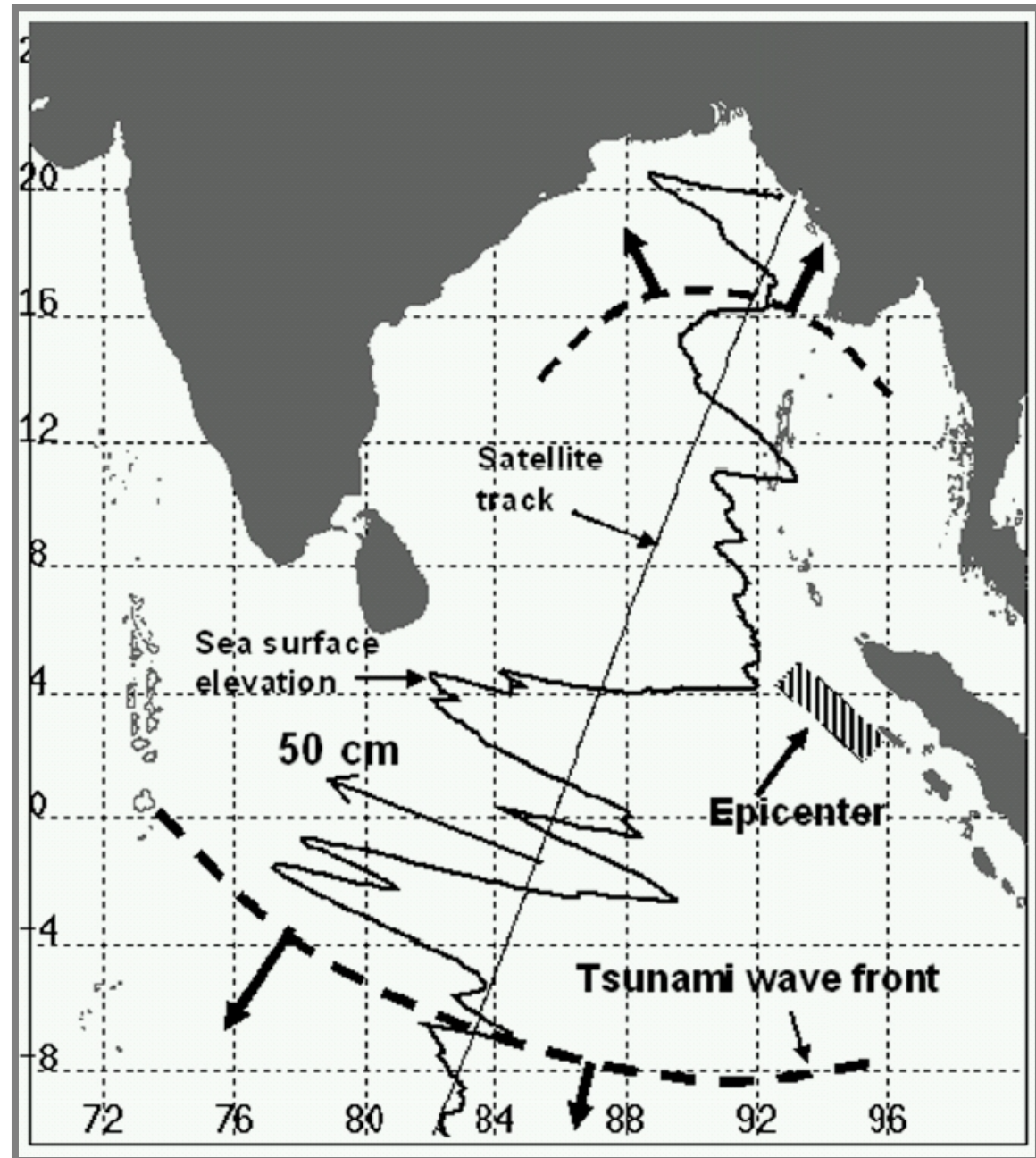
Beobachtete Pegelstände in Esperance (Australien) 26.-27. 12. 2004



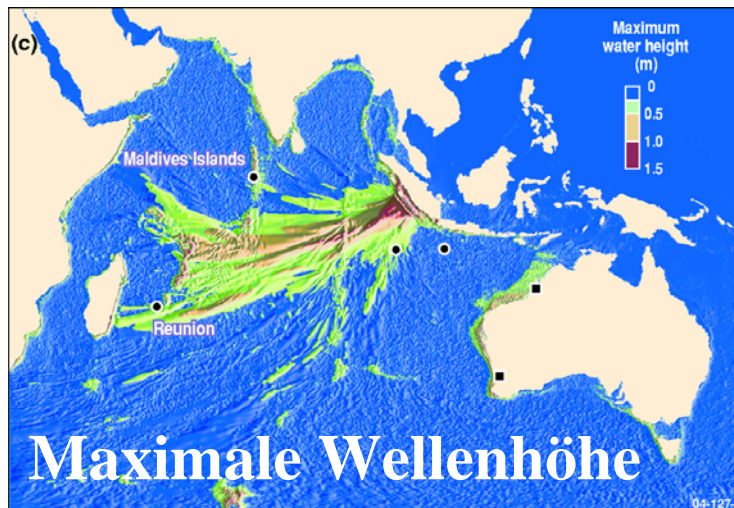
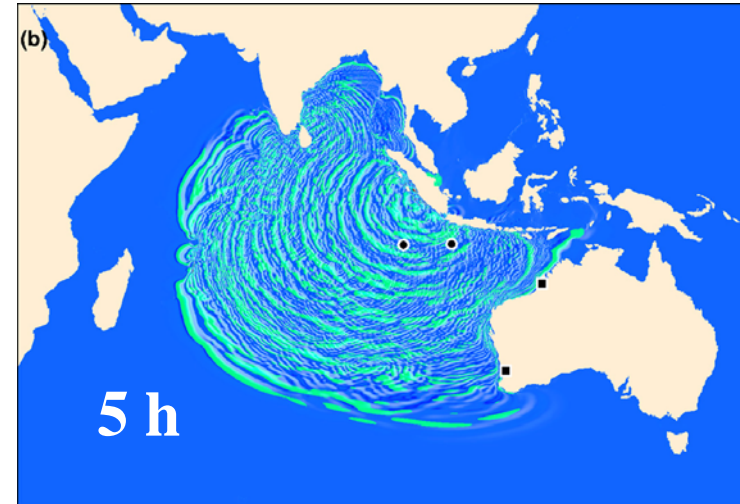
**Satellitengestützte
Echtzeitmessung
der Meereshöhe
im Indischen Ozean:**

**Beobachtung der
durchlaufenden
Tsunamiwelle**

**(Prof. Rummel,
TU München)**



Historische Tsunamis der Region



Sumatra Erdbeben 1833
Geschätzte Magnitude ~ 8-9

**Australien hervorragend
positioniert zum Aufbau
eines regionalen Warnsystems**

Weitere Informationen : World-Wide-Web



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http://www.geophysik.uni-muenchen.de/home/index.php?language=de

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Tsunami

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 MUM 01/04 II
 SZ 12/04

Geophysical Informations about Tsunamis

The 2004 December 26 Sumatran Earthquake and Tsunami

Links to Special pages

- Nature - news piece 2005 January 5
- Nature - links to tsunami information
- IRIS Special Page
- Earthquake News & Highlights
 U.S. Geological Survey, National Earthquake Information Center
- IUGG Tsunami Commission site
- NASA Earth Observatory Information and images
- Geoscience Australia - 2004 and 1833 tsunamis
- EIC Seismological Note No. 161 - Off the West Coast of Northern Sumatra Earthquake
 Yamanaka - Earthquake Research Institute, University of Tokyo
- Tide gauge and runup data from tsunami
 U.S. National Geophysica Center, NOAA
- The December 26, 2004 Earthquake Tsunami Disaster of Indian Ocean
 Japanese Research Group on The December 26, 2004 Earthquake Tsunami Disaster of Indian Ocean
- Special page of the Off Coast of Northern Sumatra Earthquake
 International Institute of Seismology and Earthquake Engineering, Building Research Institute, Tsukuba, Japan
- 2004 December 26 Tsunami
 National Institute of Oceanography, India
- Indonesia/Nicobar/Andaman earthquake
 R. Bilham, CIRES, U of Colorado
- December 26 Tsunami in Indian Ocean
 Geological Survey of Japan
- Catalog of Damaging Earthquakes in the World
 International Institute of Seismology and Earthquake Engineering, Building Research Institute, Tsukuba, Japan

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