On the Job Training on

Tsunami Inundation Modelling and Mapping and Development of Tsunami Hazards Maps for Implementation of UNESCO-IOC Tsunami Ready Pilot Sites in Madagascar, Maldives, Seychelles and Sri Lanka

Hyderabad – India, 16–21 March 2026

Historical and syntenic Scenarios using ComMIT

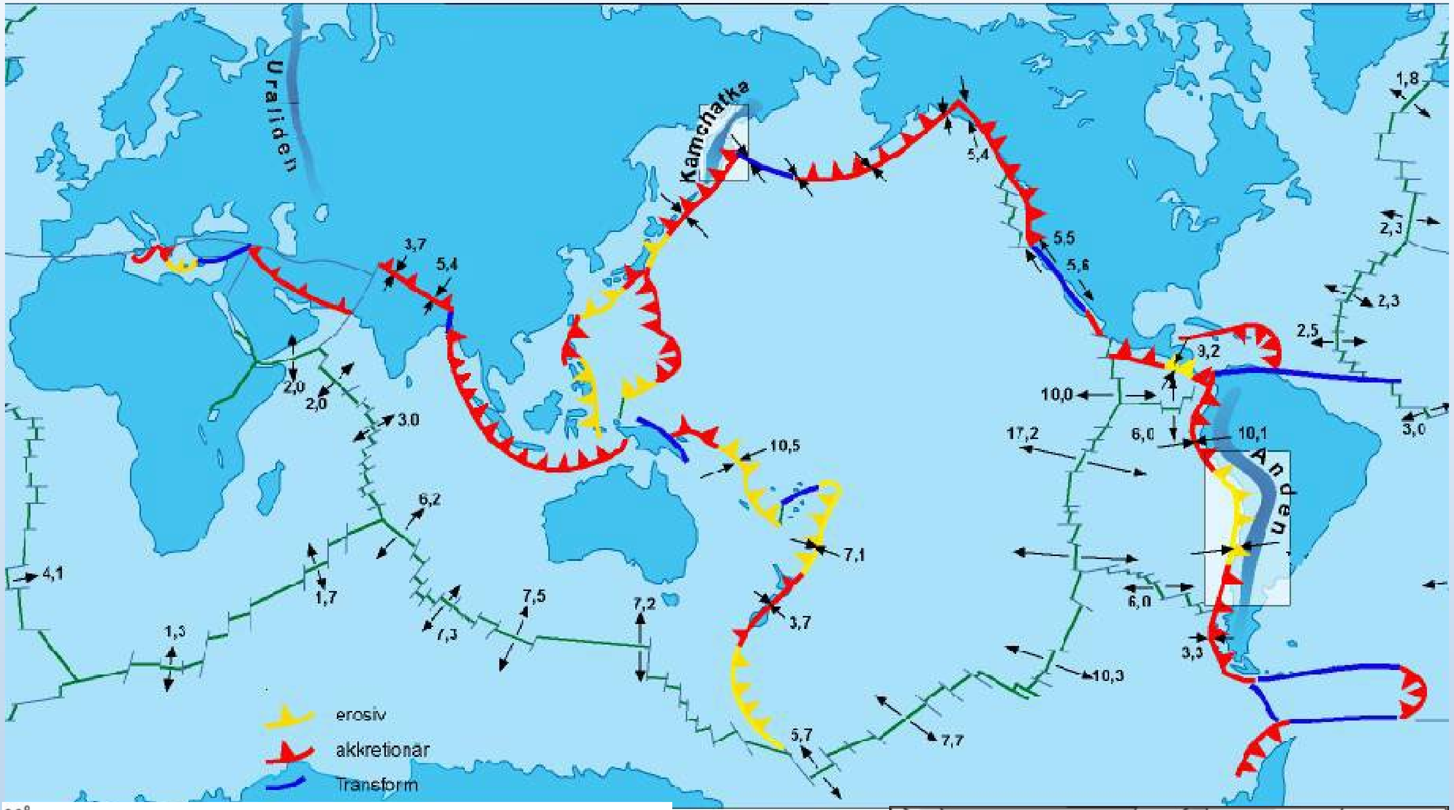
Patanjali Kumar Chodavarapu, M.S (DM), Ph.D

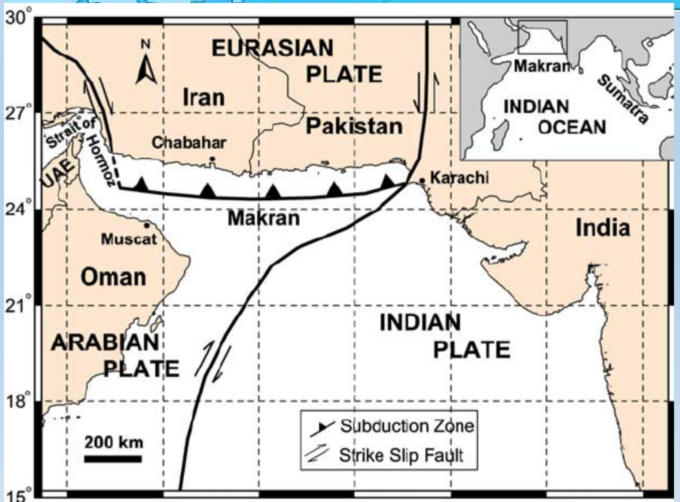
Scientist -F

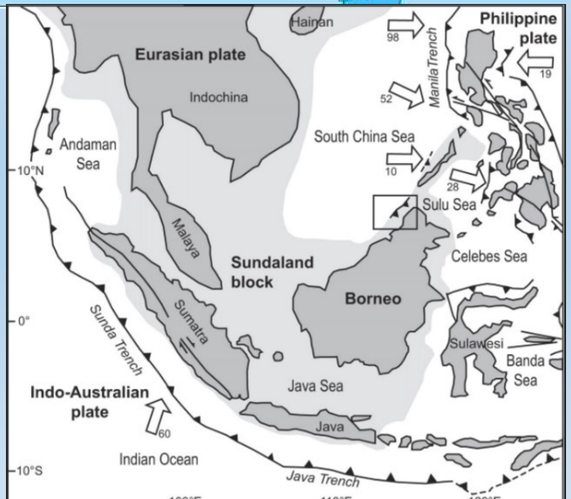
Indian National Center for Information Services (INCOIS), MoEs, Hyderabad

patanjali@incois.gov.in

Subduction Zones

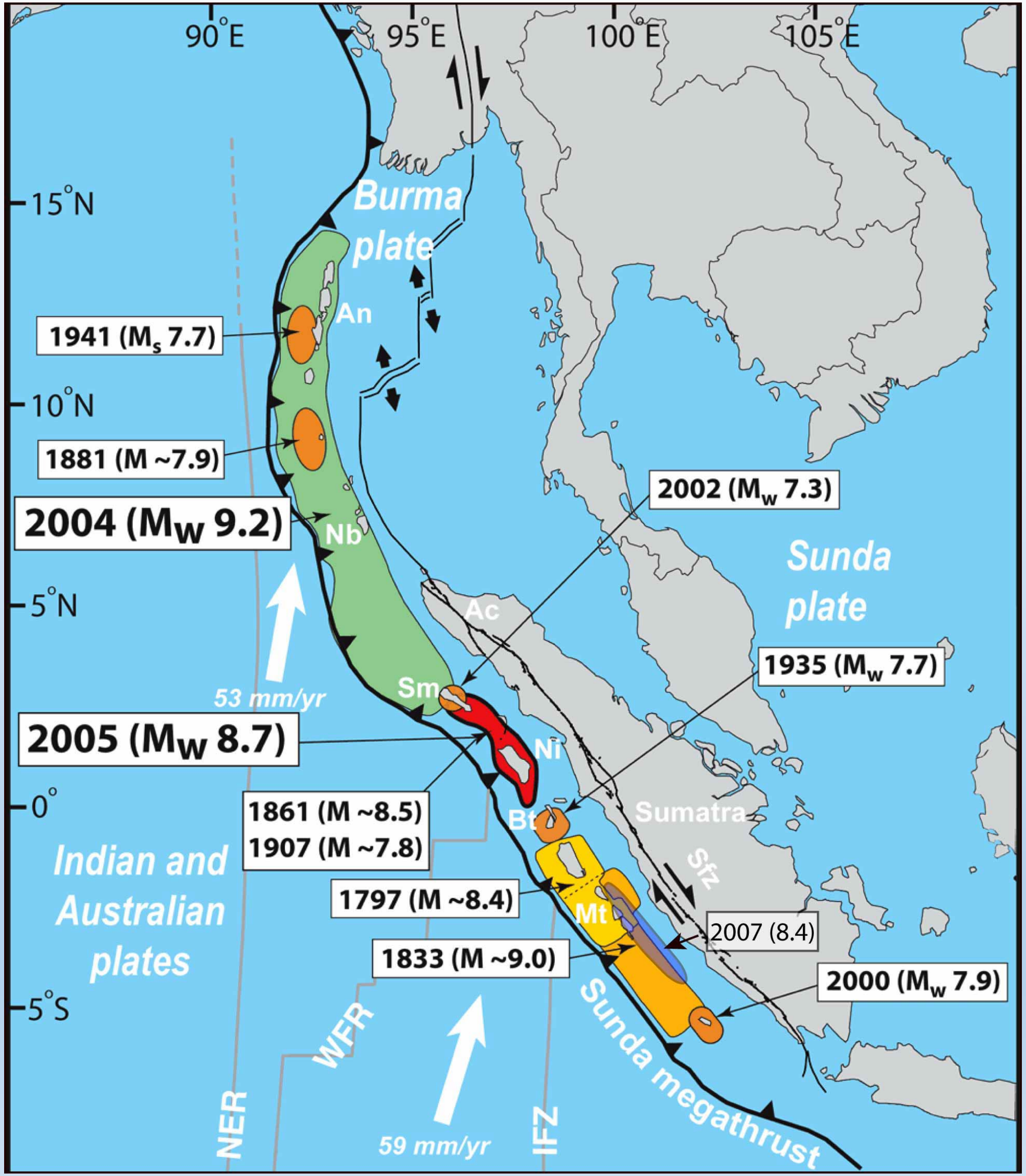






Historical Earthquakes in Sumatra

Satish Singh, 2009



Historical earthquakes in Makran

Ref: Mohammad Heidarzadeh et al 2008

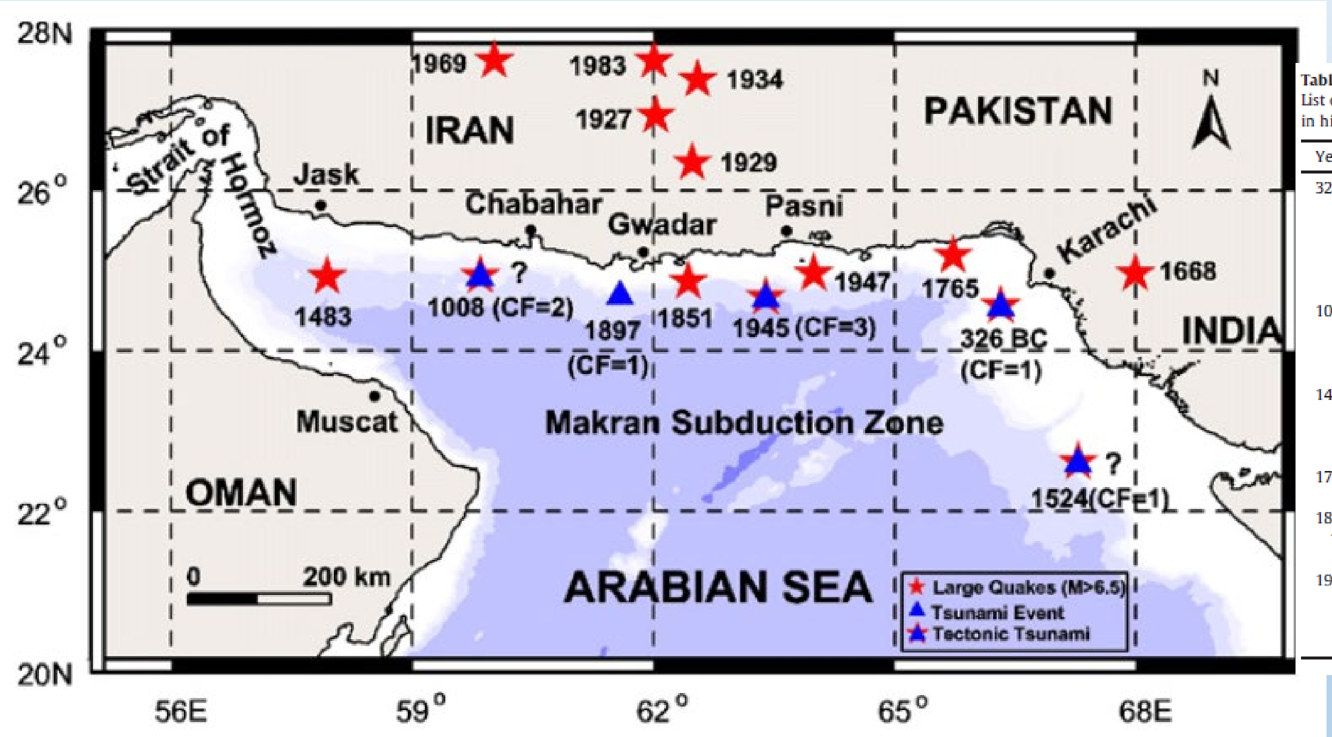
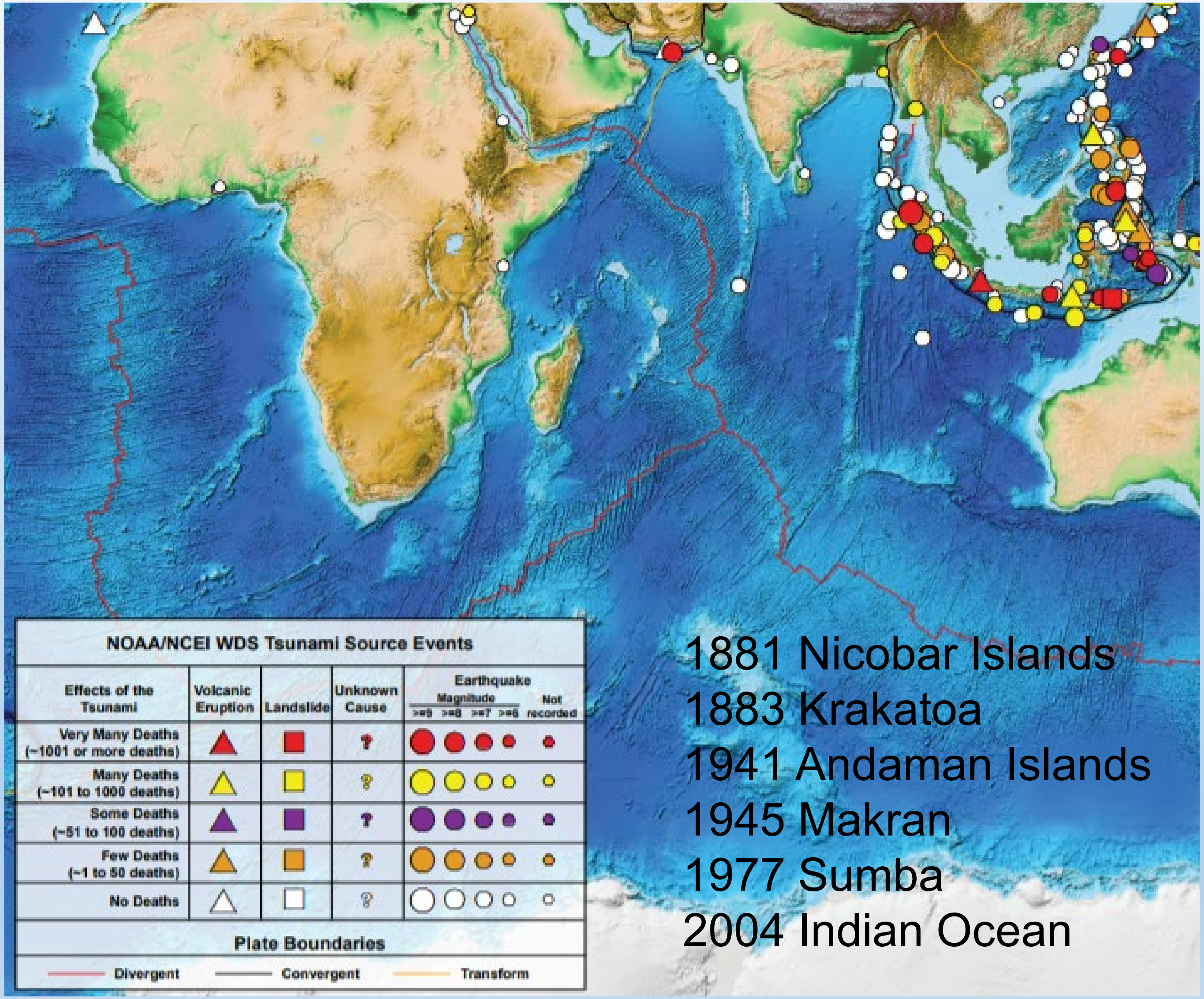


Table 1
List of large earthquakes and tsunamis around the Makran subduction zone as attested in historical records.

Year	Location	Remarks	References
326 BC	Eastern Makran near the Indus Delta	Destruction of a Macedonian fleet in Western India by huge waves is described in Greek and Indian historical records.	Murty and Bapat, 1999; Pararas-Carayannis, 2006b; Rastogi and Jaiswal, 2006.
1008 AD	Western Makran, near the strait of Hormoz	An earthquake and tsunami on the southern coast of Iran.	Ambraseys and Melville, 1982.
1483 AD	Western Makran, near the strait of Hormoz	Destructive earthquake in the strait of Hormoz, northwestern Oman was affected by the earthquake.	Quittmeyer and Jacob, 1979; Ambraseys and Melville, 1982.
1765 AD	Eastern Makran	A strong earthquake in the eastern Makran.	Quittmeyer and Jacob, 1979; Byrne et al., 1992.
1851–1864 AD	Middle part of Makran, Near Gwadar	Two great earthquakes in the middle part of Makran affected the town of Gwadar	Quittmeyer and Jacob, 1979; Byrne et al., 1992.
1945 AD	Offshore Pakistani coast near Pasni	Magnitude 8 to 8.3 tsunami wave run-up was 11 to 13 m in the near coast, claimed about 4000 lives.	Quittmeyer and Jacob, 1979; Ambraseys and Melville, 1982; Pararas-Carayannis, 2006a.

Tsunami Sources (NGDC/NOAA)



1881 Nicobar Islands
1883 Krakatoa
1941 Andaman Islands
1945 Makran
1977 Sumba
2004 Indian Ocean

Sources used for 2009 PTHA

Subduction Zone	Segment	Maximum Magnitude (Mw)		
		Historical	Low Hazard	High Hazard
Andaman-Sunda Arc	A	unknown (1762[1])	0.0	9.5
	B	9.2 (1881[2], 2004[3])	9.2	
	C	8.7 (1861,2005[4])	8.7	
	D	9.1 (1797,1833,2007[5])	9.1	
	E	7.6 (2000[5])	7.6	
	F	7.8 (1994[7],2006[8])	7.8	
	G	none	0.0	
Makran	H	unknown (1483[8])	0.0	9.1
	I	8.1 (1945[9])	8.2	
South Sandwich		none	0.0	9.0

Table 2: Summary of megthrust earthquake tsunami source zones used in the low-hazard and high-hazard maps. The three subduction zones considered are shown, along with the segmentation that was used for the low-hazard maps (see Fig. 5a). The maximum magnitude of the historical earthquakes listed in brackexts is listed in the third column. The maximum magnitudes used to generate the low-hazard and high-hazard assessments are shown in columns four and five. Where the maximum magnitude for historical earthquakes is listed as 'unknown' that indicates that a large (possibly megathrust) earthquake occurred, but its magnitude is unknown. By contrast 'none' indicates that there is no known historical occurrence of a megathrust earthquake large enough to generate a destructive tsunami. The years of historical earthquakes are indicated in parentheses with superscripts to indicate the following references: [1] Cummins (2007), [2] Ortiz and Bilham (2003), [3] Stein and Okal (2005), [4] Briggs *et al* (2005), [5]Natawidjaja *et al* (2006), [6]Abercrombie *et al* (2003), [7] Abercrombie *et al* (2001), [8]Ammon *et al* (2007), [8]Abraseys and Melville (1982), [9]Byrne *et al* (1992). These studies were used to infer the width of the megathrust seismogenic zone used in the low-hazard map, indicated as (full) or (half).

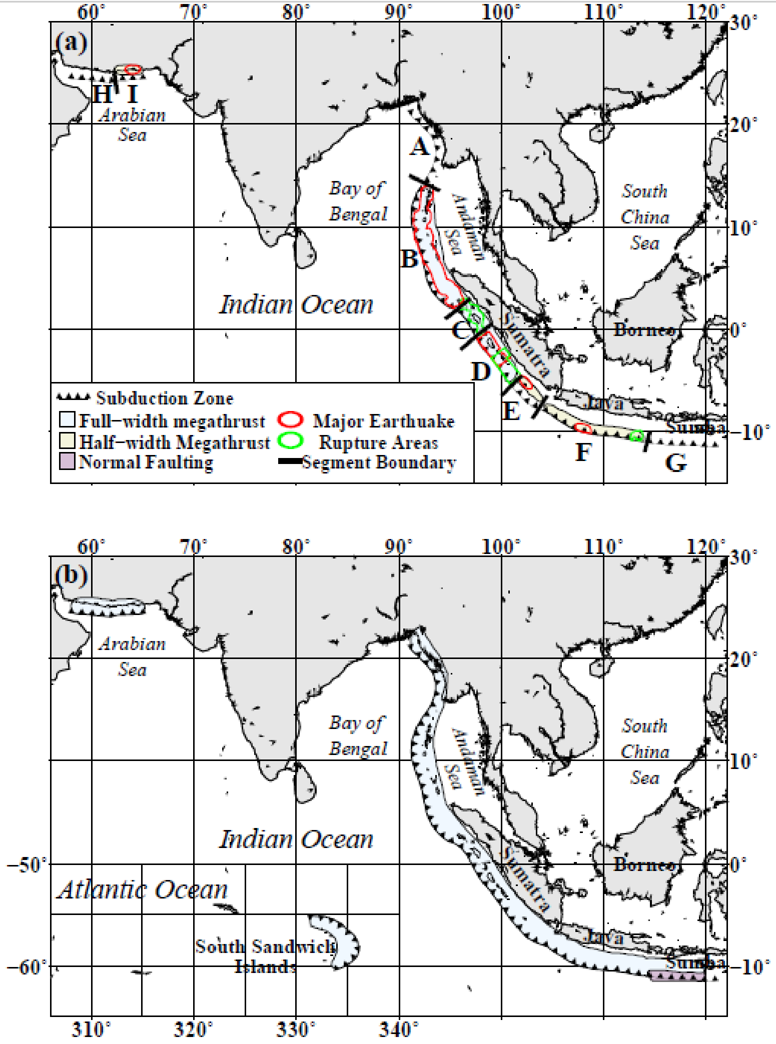


Figure 5: Map of megathrust earthquake sources of tsunami in the Indian Ocean, illustrating the source characterisation used for the low-hazard and the high-hazard maps. (a) The megathrust segmentation for the low hazard map. Also shown are the megathrust seismogenic zones characterized as "full-width" and "half-width". (b) The segmentation for the high-hazard assessment. This figure alsoincludes the South Sandwich Arc, which is a source of tsunami for the high-hazard map but not for the low-hazard one. The Puysegur subduction zone south of New Zealand was included, but made no significant contribution to the hazard along the coastlines coinsidered here. Plate boundaries from Bird (2002).

Results of Indian Ocean PTHA

Indian Ocean nation	1/2000yr tsunami amplitude (m) low	1/2000yr tsunami amplitude (m) high	Most Important Subduction Zone Segments
Bangladesh	0.5	0.6	Andaman
British Ocean Territory	1.1	1.7	Andaman, Sumatra
Burma	1.1	1.5	Andaman, Sumatra
Comoros	0.3	0.5	Makran, Andaman, Sumatra
Djibouti	0.2	0.4	Makran
India	1.9	3.1	Makran, Andaman, Sumatra
Indonesia	5.6	7.1	Andaman, Sumatra, Java and Sumba
Iran	0.3	2.7	Makran
Kenya	0.5	0.8	Andaman, Sumatra
Madagascar	1.0	2.2	Andaman, Sumatra, Java, Sth Sandwich
Maldives	2.2	3.0	Andaman, Sumatra, Makran
Mauritius	1.2	1.7	Andaman, Sumatra, Makran
Mayotte	0.3	0.4	Andaman, Sumatra, Makran
Mozambique	0.5	1.4	Andaman, Sumatra, Sth Sandwich
Oman	0.6	3.8	Andaman, Sumatra, Makran
Pakistan	0.9	2.8	Makran
Reunion	0.7	1.4	Andaman, Sumatra, Sth Sandwich
Seychelles	0.8	1.2	Andaman, Sumatra, Makran
Somalia	0.7	1.1	Andaman, Sumatra, Makran
South Africa	0.6	1.6	Andaman, Sumatra, S Sandwich
Sri Lanka	2.9	3.7	Andaman, Sumatra
Tanzania	0.5	0.9	Andaman, Sumatra, Makran
Thailand	1.9	2.6	Andaman, Sumatra
United Arab Emirates	0.1	0.8	Makran
Yemen	0.8	1.3	Makran, Andaman, Sumatra

Table 1: Summary of results for all the nations considered in the study for one particular measure of the offshore tsunami hazard, the name of country is listed in the first column. The second and third columns show the maximum tsunami amplitude with a 1 in 2000 year chance of being exceeded for any point off the Indian Ocean nation shown in the first column for the low hazard and high hazard assessments, respectively. The nations shown in red have the highest (greater than 2m maximum tsunami amplitude in the high hazard map) hazard at this return period. The nations shown in green have the lowest (tsunami amplitude is less than 1m in the high hazard map) at the 2000 year return period. The fourth column lists the subduction zones which make the greatest contribution to the 1 in 2000 year hazard for that particular nation.

- A 2000 year return period is typically the upper limit used for emergency planning because it is normally associated with a large, but still reasonably probable, event.
- Tsunami height at 100m water depth
  - Less than 25 cm is likely insignificant
  - 25 to 75 cm could cause significant localized run-up
  - Greater than 75 cm, a significant threat
- You may need to modify these as you learn more from inundation modelling
- Greens Law

Guidance for Selection of Scenarios

Selection of appropriate scenarios and magnitude may be based on the results of PTHA which provides a range of maximum tsunami amplitude with a 1 in 2000-year chance of being exceeded for each country for a low and high hazard source. The table also provides information on the subduction zone segments that contribute to tsunami hazard for each country.

Indian Ocean nation	1/2000yr tsunami amplitude (m)		Most Important Subduction Zone Segments
	low	high	
Bangladesh	0.5	0.6	Andaman
British Ocean Territory	1.1	1.7	Andaman, Sumatra
Burma	1.1	1.5	Andaman, Sumatra
Comoros	0.3	0.5	Makran, Andaman, Sumatra
Djibouti	0.2	0.4	Makran
India	1.9	3.1	Makran, Andaman, Sumatra
Indonesia	5.6	7.1	Andaman, Sumatra, Java and Sumba
Iran	0.3	2.7	Makran
Kenya	0.5	0.8	Andaman, Sumatra
Madagascar	1.0	2.2	Andaman, Sumatra, Java, Sth Sandwich
Maldives	2.2	3.0	Andaman, Sumatra, Makran
Mauritius	1.2	1.7	Andaman, Sumatra, Makran
Mayotte	0.3	0.4	Andaman, Sumatra, Makran
Mozambique	0.5	1.4	Andaman, Sumatra, Sth Sandwich
Oman	0.6	3.8	Andaman, Sumatra, Makran
Pakistan	0.9	2.8	Makran
Reunion	0.7	1.4	Andaman, Sumatra, Sth Sandwich
Seychelles	0.8	1.2	Andaman, Sumatra, Makran
Somalia	0.7	1.1	Andaman, Sumatra, Makran
South Africa	0.6	1.6	Andaman, Sumatra, S Sandwich
Sri Lanka	2.9	3.7	Andaman, Sumatra
Tanzania	0.5	0.9	Andaman, Sumatra, Makran
Thailand	1.9	2.6	Andaman, Sumatra
United Arab Emirates	0.1	0.8	Makran
Yemen	0.8	1.3	Makran, Andaman, Sumatra

Table 1: Summary of results for all the nations considered in the study for one particular measure of the offshore tsunami hazard, the name of country is listed in the first column. The second and third columns show the maximum tsunami amplitude with a 1 in 2000 year chance of being exceeded for any point off the Indian Ocean nation shown in the first column for the low hazard and high hazard assessments, respectively. The nations shown in red have the highest (greater than 2m maximum tsunami amplitude in the high hazard map) hazard at this return period. The nations shown in green have the lowest (tsunami amplitude is less than 1m in the high hazard map) at the 2000 year return period. The fourth column lists the subduction zones which make the greatest contribution to the 1 in 2000 year hazard for that particular nation.

5.17 Madagascar (low hazard)

The hazard offshore Madagascar in the low hazard assessment is much higher offshore eastern and south-eastern coasts than the western and north-western coasts (Figure 32(c)). The south-eastern coast has hazard noticably larger than the rest of the east coast. Hazard values at the 2000 year return period range from 0.1m (west coast) to 1m (southeast coast) (Figure 32(a)) and comes from both the Sumatran and Andaman zones (Figure 32(b))

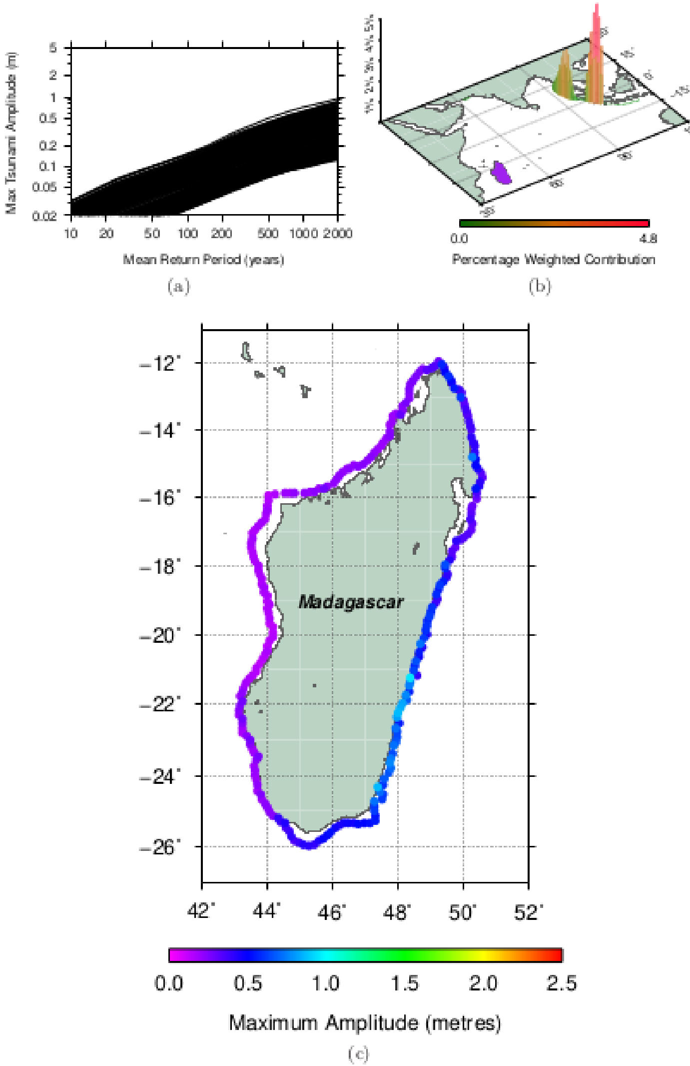


Figure 32: Madagascar:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.18 Madagascar (high hazard)

In the high hazard assessment the hazard is again much higher off the west to southwest coasts of Madagascar (Figure 33(c)). The hazard off the south and northeast coast is intermediate and that off the western coast is much smaller. At the 2000 year return period the hazard ranegs from 0.2m to 2.2m (Figure 33(a)). The hazard mostly comes from the Sunda Arc zones, but there is also a significant contribution from the South Sandwich zone (Figure 33(b)).

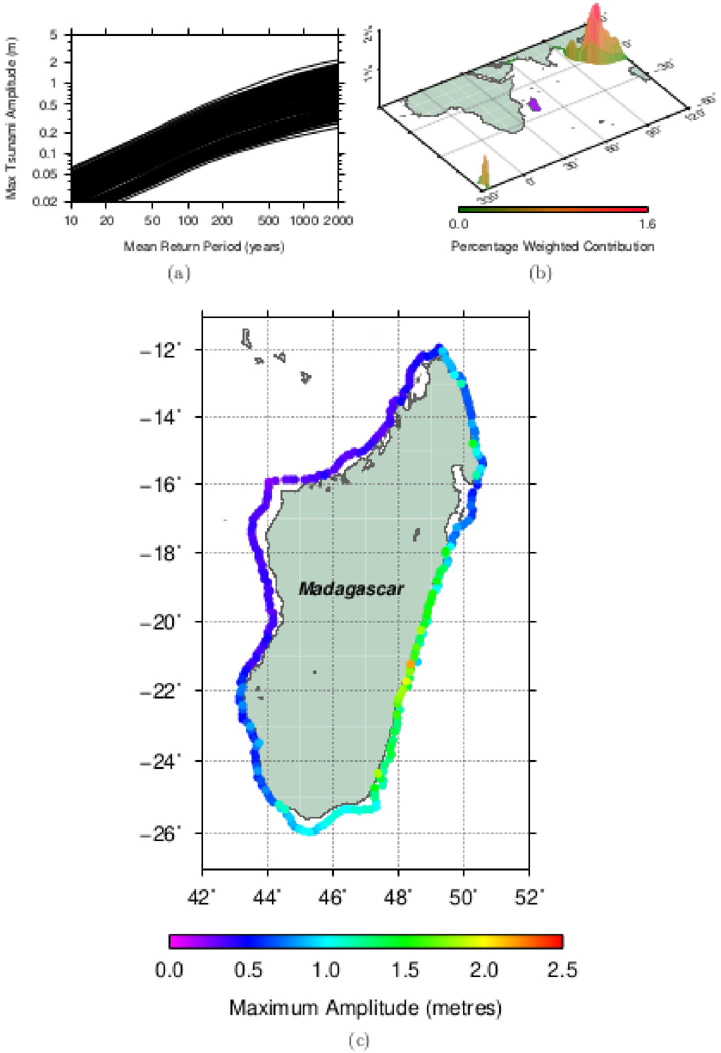


Figure 33: Madagascar:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.19 Maldives (low hazard)

The hazard offshore the Maldives in the low hazard assessment is much higher offshore the eastern coasts than the west and higher in south than the north (Figure 34(c)). The hazard at this return period comes entirely from the Andaman zone (Figure 34(b)) and ranges from 0.3m to 2.2m depending on location (Figure 34(a)).

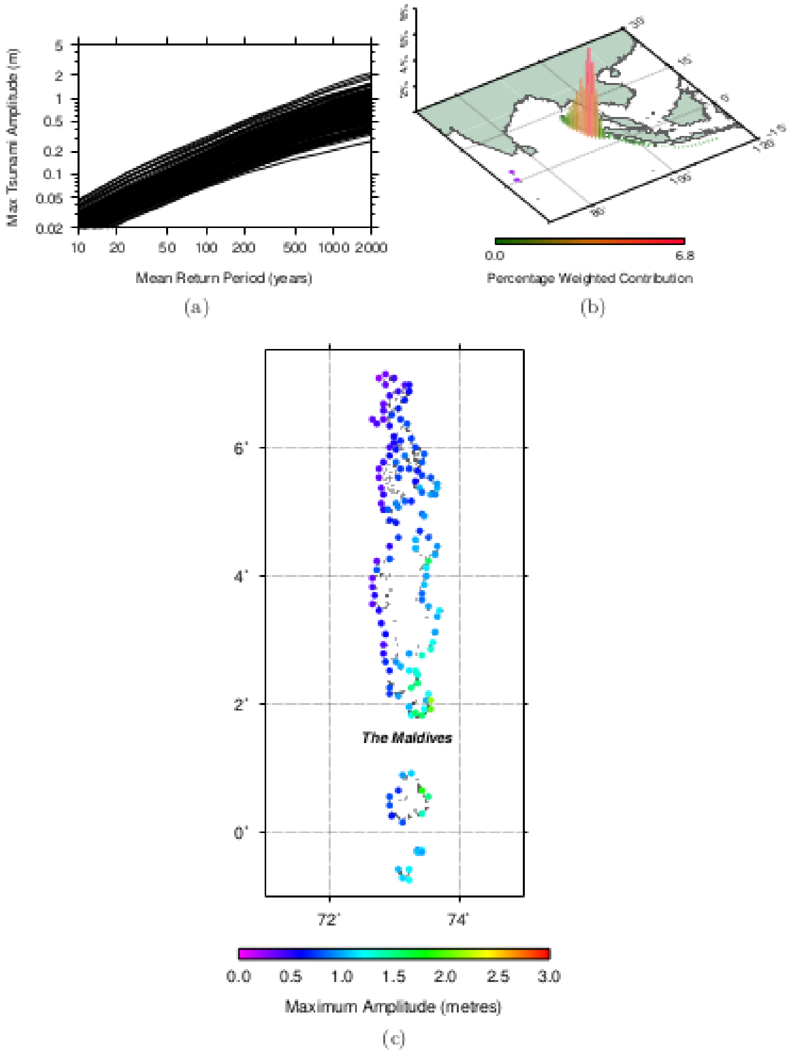


Figure 34: Maldives:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.20 Maldives (high hazard)

The distribution of hazard in the high hazard assessment of the Maldives is similar to the low hazard one (Figure 35(c)). The 2000 year hazard values range from 0.6m to 3.0m depending on which side of the chain the points are located (Figure 35(a)). Hazard again mostly originates from the Andaman zone, with a small contribution from Sumatra as well (Figure 35(b))

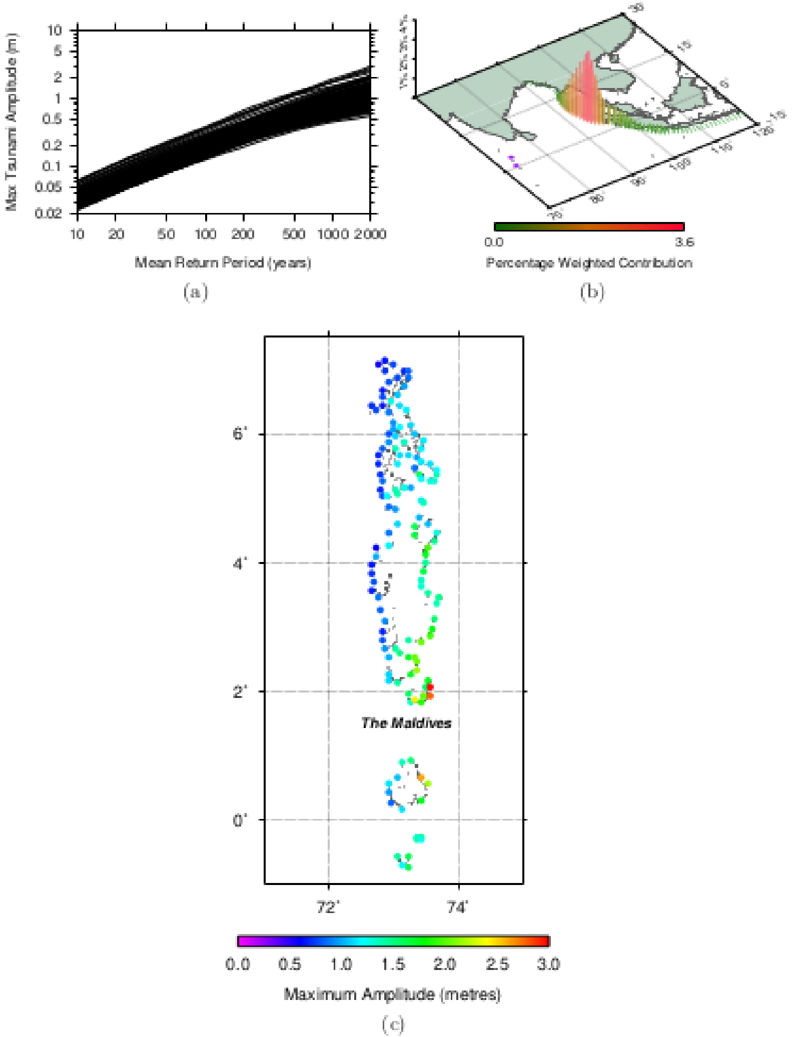
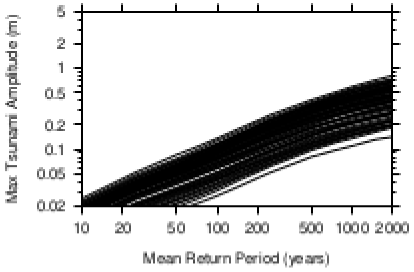


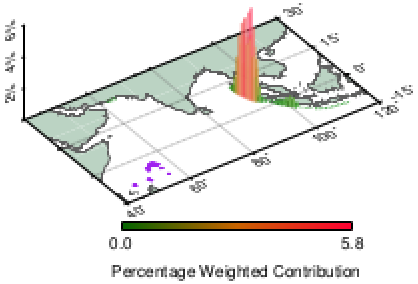
Figure 35: Maldives:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.33 Seychelles (low hazard)

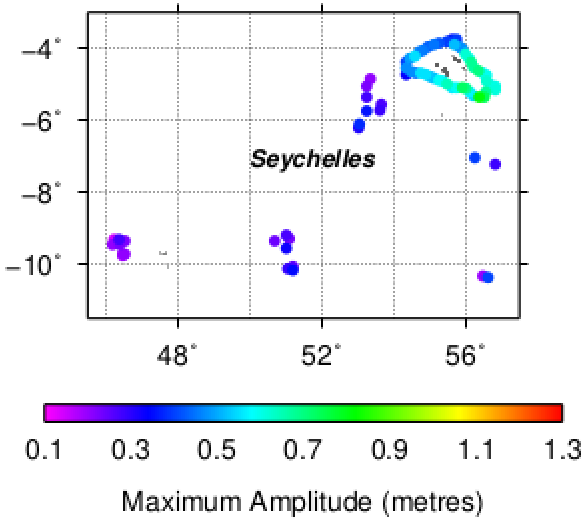
Hazard in the Seycelles at the 2000 year return period is at a maximum for the islands in the northeast part of the archipelgio (Figure 48(c)). Values range from about 0.1m to 0.8m depending on location (Figure 48(a)). The most important subduction zone for the Seycelles from this assessment is the Andaman section of the Sunda Arc, with a smaller contribution from Sumatra (Figure 48(b))



(a)



(b)

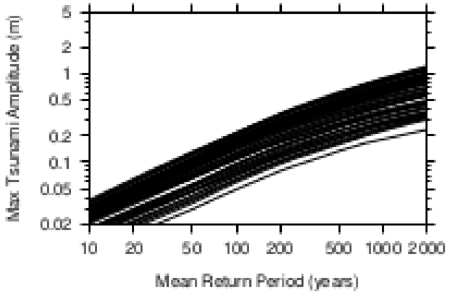


(c)

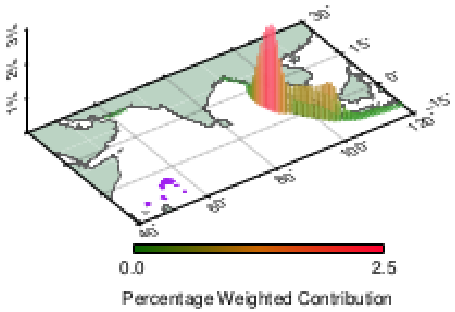
Figure 48: Seychelles:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.34 Seychelles (high hazard)

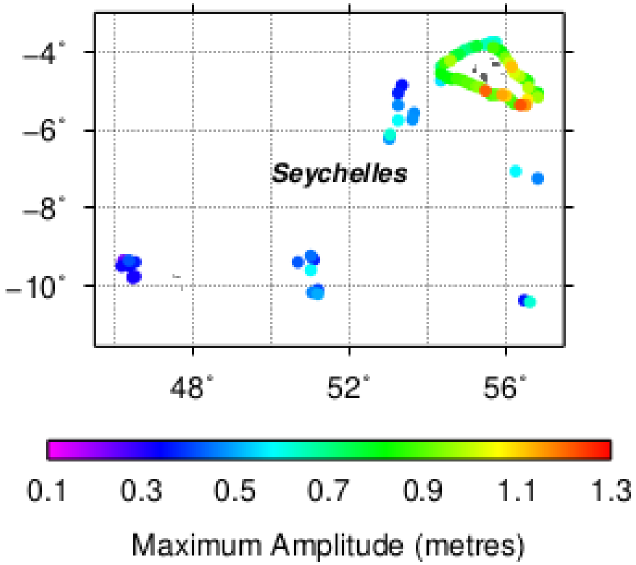
As with the low hazard assessment, the hazard offshore islands in the northeast of the Seychelles is much higher than it is for the rest of islands (Figure 49(c)). Values range from 0.2m to 1.2m at the 2000 year return period (Figure 49(a)). Most of this hazard again comes from Andaman, but there is also a strong contribution from Sumatra (Figure 49(c)).



(a)



(b)



(c)

Figure 49: Seychelles:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.39 Sri Lanka (low hazard)

The hazard offshore the eastern coasts of Sri Lanka at a 2000 year return period is much higher than offshore the western coasts of Sri Lanka which face India (Figure 54(c)). Values range from 0.4m to 3m, depending on the choice of coast (Figure 54(a)). The hazard here is naturally dominated by the Andaman zone Figure 54(b)).

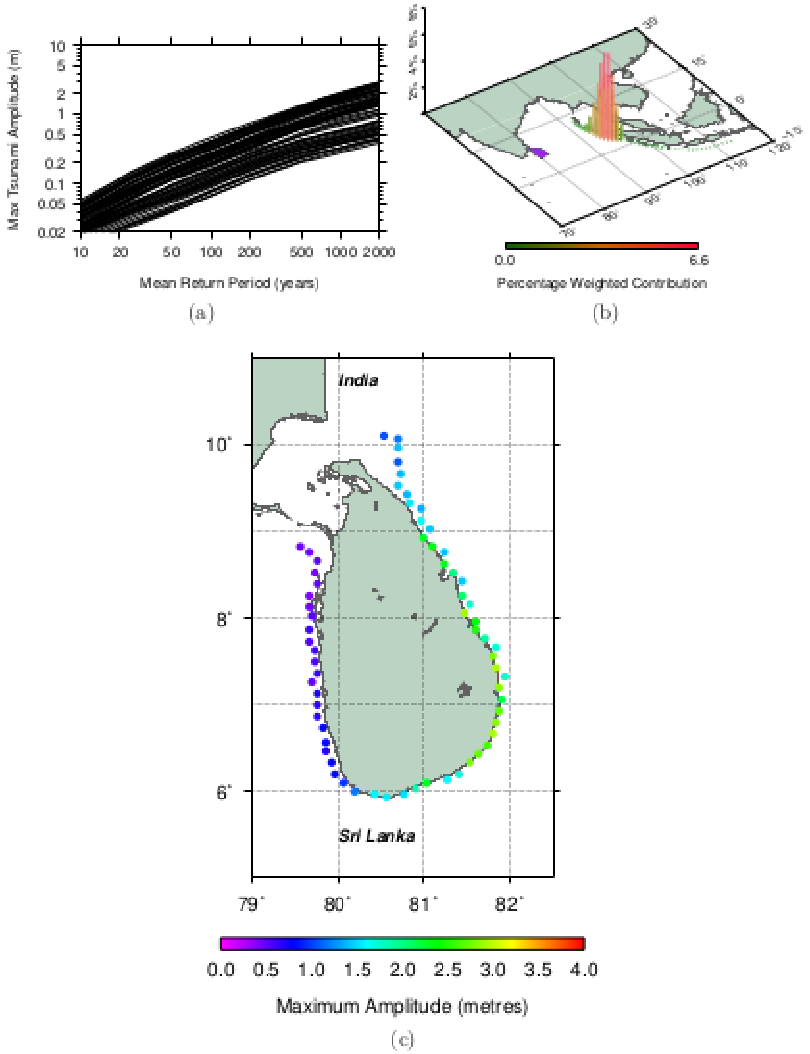


Figure 54: Sri Lanka:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.40 Sri Lanka (high hazard)

The hazard offshore Sri Lanka is again much higher off the eastern, particularly the south-east coasts, at the 2000 year return than offshore the western and northern coasts (Figure 55(c)). Values range from 0.6m to nearly 3.7m Figure 55(a)). Again, the main source of this hazard is the Andaman zone Figure 55(b)).

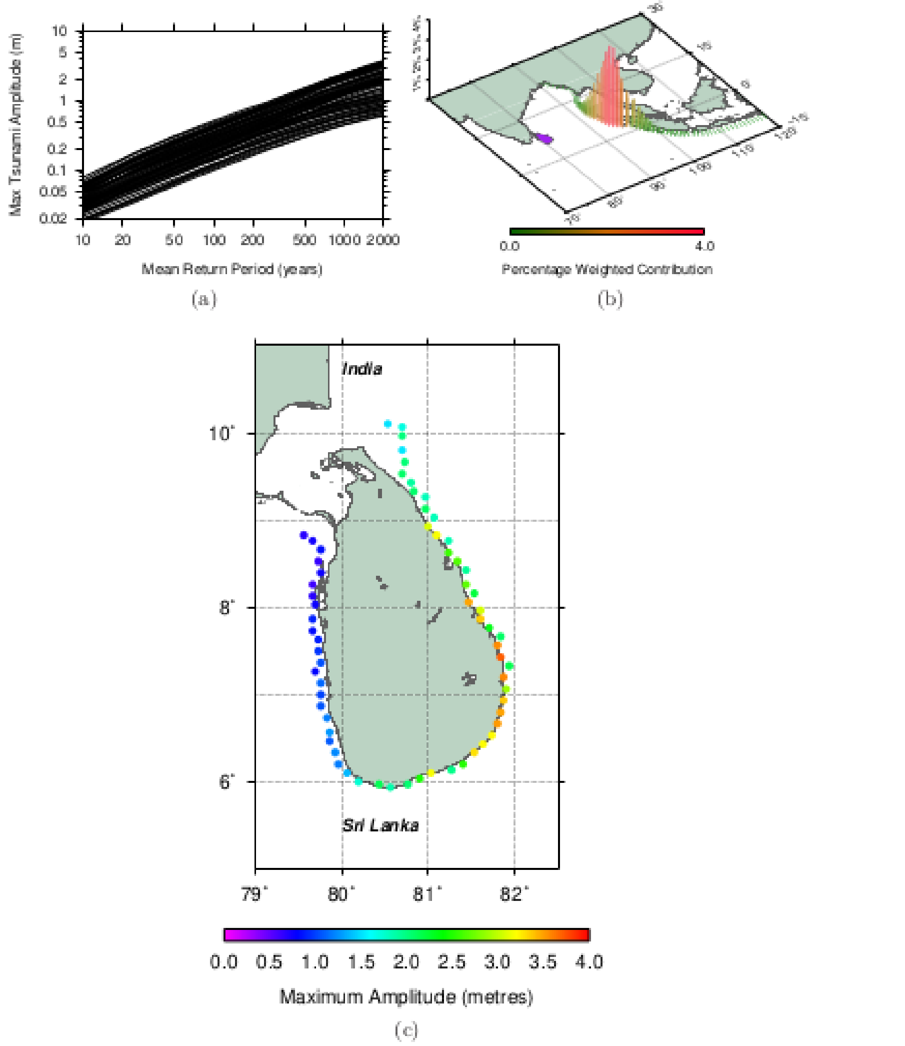
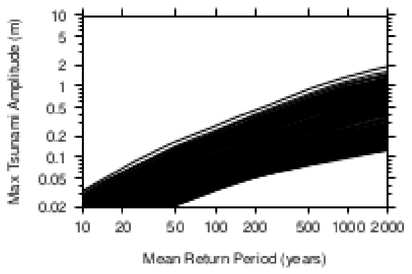


Figure 55: Sri Lanka:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

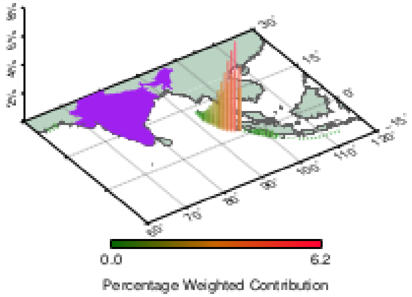
5.11 India

5.11.1 Indian Mainland (low hazard)

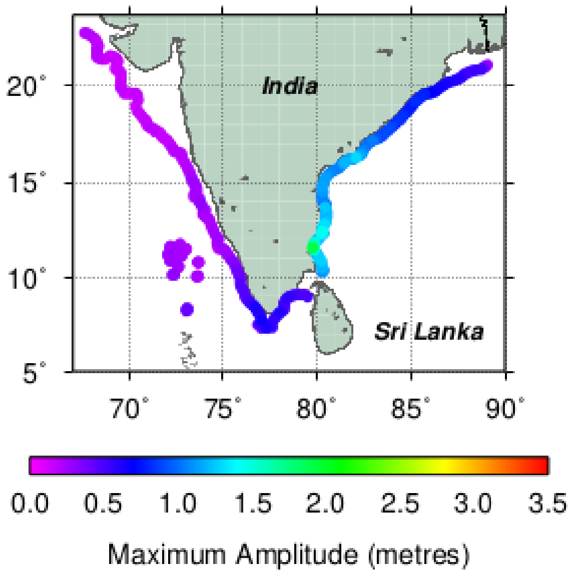
The large 2000 year maximum amplitude has a very large spread of values for mainland India. It is far higher on the east coast than on the west coast (Figure 18(c)). Values at the 2000 year return period range from 0.1m (west coast) to 1.9m (east coast). The hazard here is dominated by the southern and central Andaman zone (Figure 18(b))



(a)



(b)

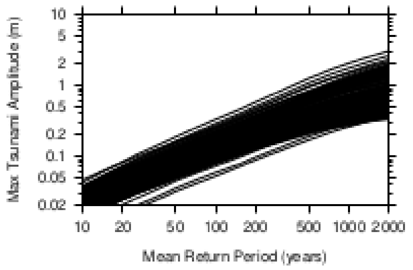


(c)

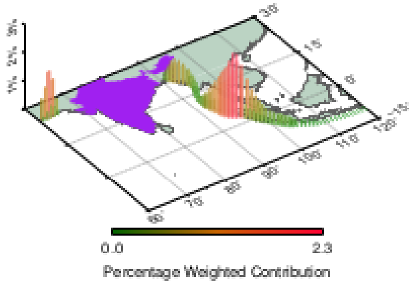
Figure 18: India:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

5.11.2 Indian Mainland (high hazard)

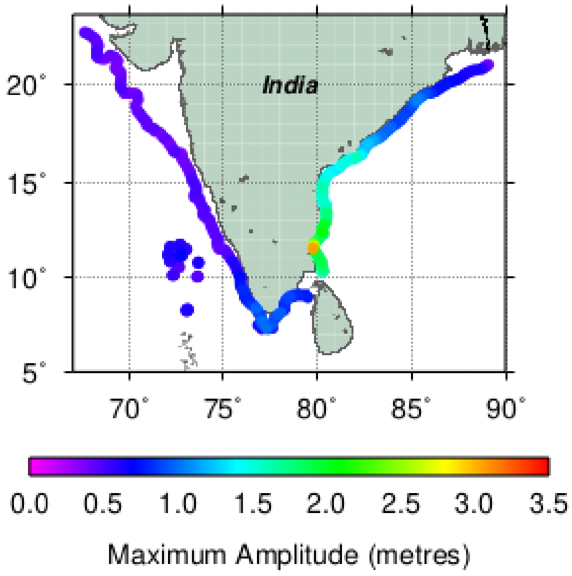
The large 2000 year maximum amplitude in the high hazard again is much higher on the east coast than the west (Figure 19(c)). The hazard ranges from over 3m (east coast) to 0.3m (west coast). The single high hazard value for the east coast in both the low and high hazard maps should be interpreted with caution as this could be due to a local bathymetric anomaly in the global bathymetry dataset used in this assessment. The deaggregated hazard map (Figure 19(b) shows that the most important zone is the Andaman, but significant contributions also come from the Arakan (east coast) and Makran (west coast).



(a)



(b)



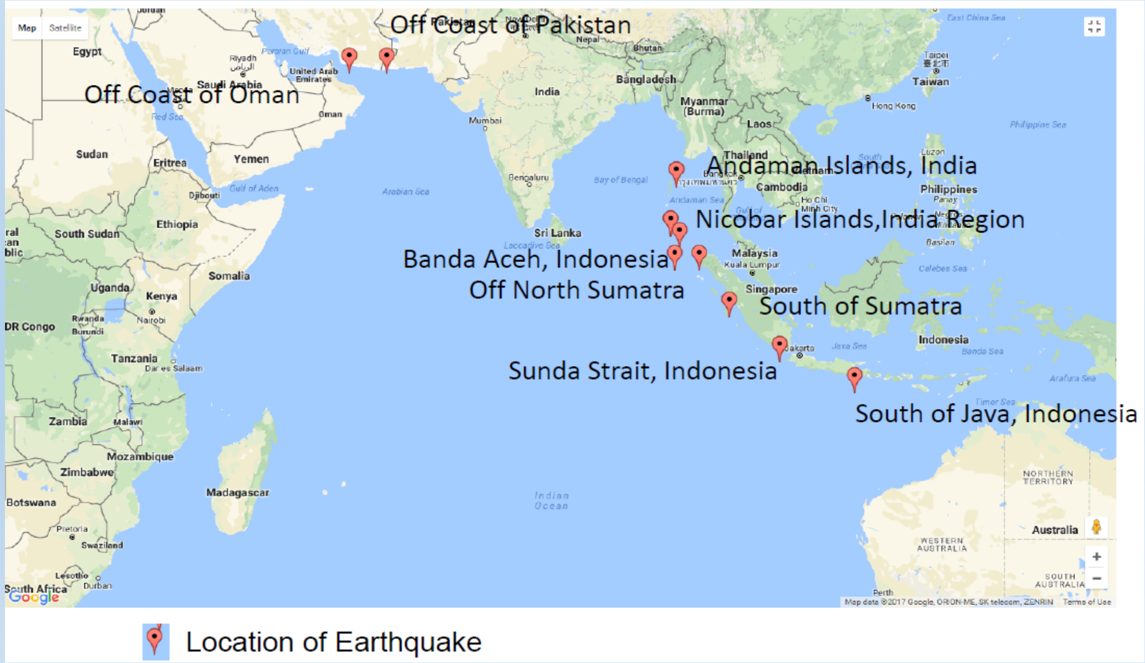
(c)

Figure 19: India:- (a) Hazard curves for all model output points. (b) National weighted deaggregated hazard. (c) Maximum amplitude at a 2000 year return period for all model output points.

Guidance for Selection of Scenarios

Each country may consider selecting 4 scenarios from the table below run inundation model using ComMIT. Based on the results of the model runs, a composite inundation line may be generated for further hazard assessment

S. No.	Latitude	Longitude	Magnitude	Region
1	24.8 N	62.2 E	9.0	Off Coast of Pakistan
2	24.8 N	58.2 E	9.2	Off Coast of Iran
3	12.65 N	93.5 E	9.0 to 9.2	Andaman Islands
4	7.2 N	92.9 E	9.0 to 9.2	Nicobar Islands
5	3.3 N	96.0 E	9.3	Banda Aceh / Off North Sumatra
6	1.93 S	99.22 E	9.2	South of Sumatra
7	6.94 S	104.7 E	9.0 to 9.2	Sunda Strait
8	10.4 S	112.8 E	9.1	South of Java



ComMIT Unit Sources for PTHA Suggested Scenarios

cut and paste into "Model->Sources from Solution/Combination"

- Off Coast of Pakistan
  Mw 9.0, mk2-7, rows a-b, alpha=14.7839
  14.7839*mk2b+14.7839*mk2a+14.7839*mk3b+14.7839*mk3a+14.7839*mk4b+14.7839*mk4a+14.7839*mk5b+14.7839*mk5a+14.7839*mk6b+14.7839*mk6a+14.7839*mk7b+14.7839*mk7a

- Off Coast of Iran
  Mw 9.2, mk4-10, rows a-b, alpha=25.284
  25.284*mk4a+25.284*mk4b+25.284*mk5a+25.284*mk5b+25.284*mk6a+25.284*mk6b+25.284*mk7a+ 25.284*mk7b+25.284*mk8a+25.284*mk8b+25.284*mk9a+25.284*mk9b+25.284*mk10a+25.284*mk10b

- Andaman Islands
  Mw 9.2, io5-12, rows a-b, alpha=22.123
  22.123*io5a+22.123*io5b+22.123*io6a+22.123*io6b+22.123*io7a+22.123*io7b+ 22.123*io8a+22.123*io8b+22.123*io9a+22.123*io9b+22.123*io10a+22.123*io10b+ 22.123*io11a+22.123*io11b+22.123*io12a+22.123*io12b

- Nicobar Islands
  Mw 9.2, io11-18, rows a-b, alpha=22.123
  22.123*io11a+22.123*io11b+22.123*io12a+22.123*io12b+22.123*io13a+22.123*io13b+22.123*io14a+22.123*io14b+22.123*io15a+22.123*io15b+22.123*io16a+22.123*io16b+22.123*io17a+22.123*io17b+22.123*io18a+22.123*io18b

- Banda Aceh, North Sumatra
  Mw 9.3, io17-24, rows a-b, alpha=31.250
  31.250*io17a+31.250*io17b+31.250*io18a+31.250*io18b+31.250*io19a+31.250*io19b+31.250*io20a+31.250*io20b+31.250*io21a+31.250*io21b+31.250*io22a+31.250*io22b+31.250*io23a+31.250*io23b+31.250*io24a+31.250*io24b

- South of Sumatra
  Mw 9.2, io24-31, rows a-b, alpha=22.123
  22.123*io24a+22.123*io24b+22.123*io25a+22.123*io25b+22.123*io26a+22.123*io26b+22.123*io27a+22.123*io27b+22.123*io28a+22.123*io28b+22.123*io29a+22.123*io29b+22.123*io30a+22.123*io30b+22.123*io31a+22.123*io31b

- Sunda Strait
  Mw 9.2, io33-40, rows a-b, alpha=22.123
  22.123*io33a+22.123*io33b+22.123*io34a+22.123*io34b+22.123*io35a+22.123*io35b+22.123*io36a+22.123*io36b+22.123*io37a+22.123*io37b+22.123*io38a+22.123*io38b+22.123*io39a+22.123*io39b+22.123*io40a+22.123*io40b

- South of Java
  Mw 9.1, io44-49, rows a-b, alpha=14.7839
  14.7839*io44b+14.7839*io44a+14.7839*io45b+14.7839*io45a+14.7839*io46b+14.7839*io46a+14.7839*io47b+14.7839*io47a+14.7839*io48b+14.7839*io48a+14.7839*io49b+14.7839*io49a

Thank you