

Impact of the December 26, 2004 South Asian Tsunami observed with Satellite Remote Sensing Imagery

by

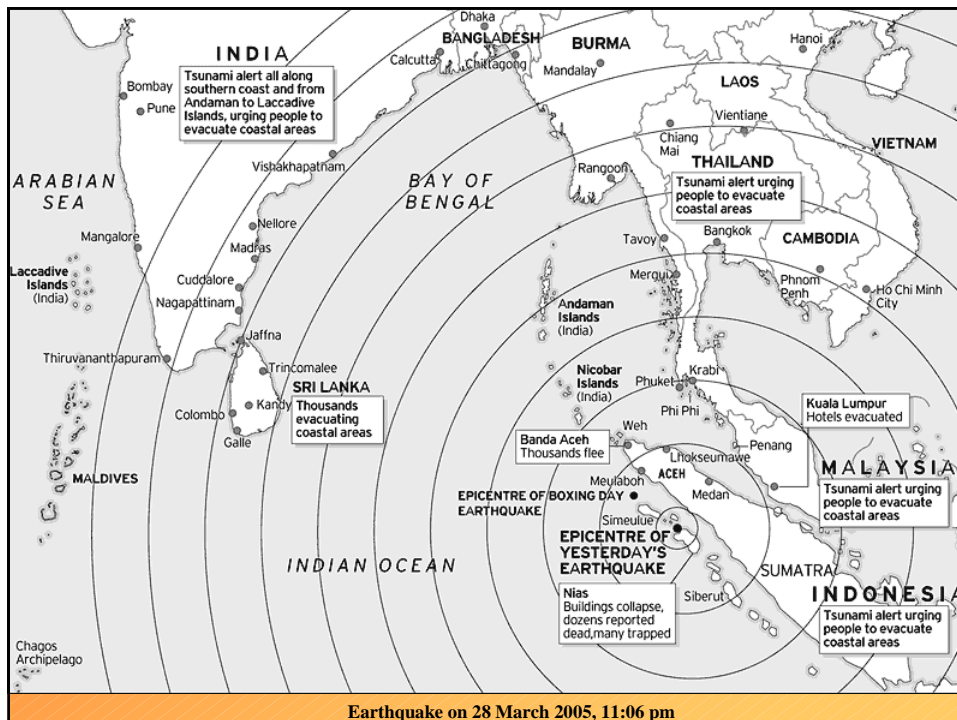
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LSB-SISV Seminar – 2 April 2005



2004 Boxing Day Tsunami (*Chronology: Time in GMT*)

- **0059:** Earthquake occurred off the west coast of Sumatra (95.78E, 3.30N), measured 9.0 on the Richter Scale.
- **0100:** Earthquake hits several cities in Indonesia, Malaysia.
- **0107:** Earthquake signals triggered alarm at the Pacific Tsunami Warning Center, but underestimated to be 8.0 on Richter Scale.
- **0110:** Tsunami hits west coast of Sumatra, 10 – 15 minutes after the earthquake.
- **0230:** Tsunami hits Sri Lanka, 1 hour 30 minutes after the earthquake.
- **0245:** Tsunami hits Phuket and neighbouring coastal areas of Thailand, 1 hour 45 minutes after the earthquake.
- **0400:** Tsunami hits Maldives, 3 hours after the earthquake.
- **0945:** Tsunami hits east coast of Africa, 8 hours 45 minutes after the earthquake.



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2004 Day Tsunami

- **Coastal Inundation:** Tsunami runup of 40 m (S/W coast of Aceh) and inland penetration of 5 km are reported. Runup of 5 m reported along Indian coast.

- **Death Toll:**

Indonesia:	234,271
Sri Lanka:	30,957
India:	16,389
Thailand:	5,395
Maldives:	82
Malaysia:	68
Myanmar:	61
Bangladesh:	2
Somalia:	298
Tanzania:	10
Kenya:	1
Total:	287,534

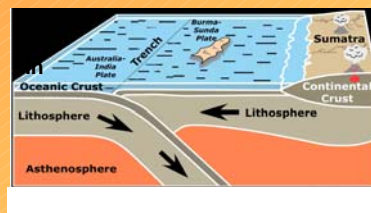




Subduction Zone

West of Sumatra, the India Plate slips under the Burma Micro-Plate/Sunda Plate, at a rate of about 6 cm/yr.

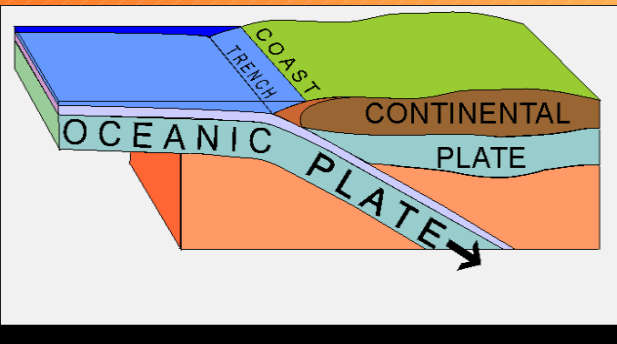
This forms a subduction zone which is prone to earthquakes.



Subduction Zone and Earthquake

At a subduction zone, the two plates generally tend to stick together. The relative motion creates an increasing strain in the upper plate, and suddenly, rupture occurs at some point. The upper plate bounces back, and we have an earthquake. The vibrations spread out through the earth crust, and are picked up by seismographs all over the world. The rupture at one point releases the stress there, but the neighbouring areas are now under more severe stress, and they may yield, causing a sequence of quakes. This is the reason we have aftershocks following an earthquake.

If the earthquake occurs under the sea, the continental plate bouncing back will give a big push to a large volume of water, setting up a tsunami.

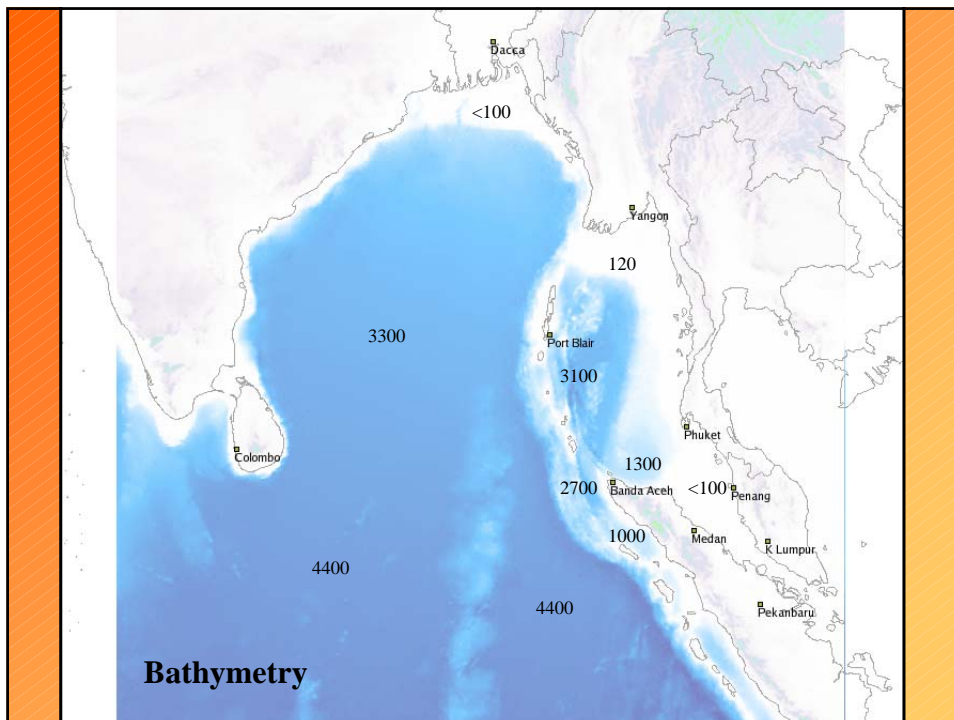
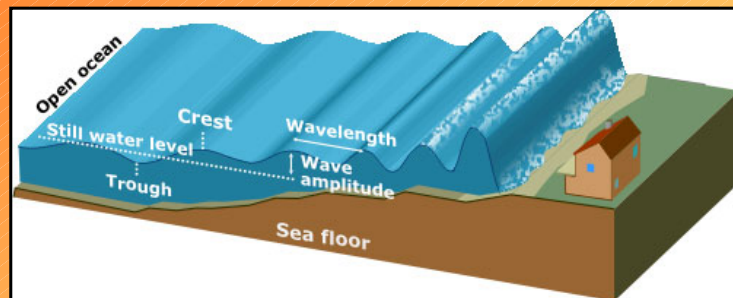


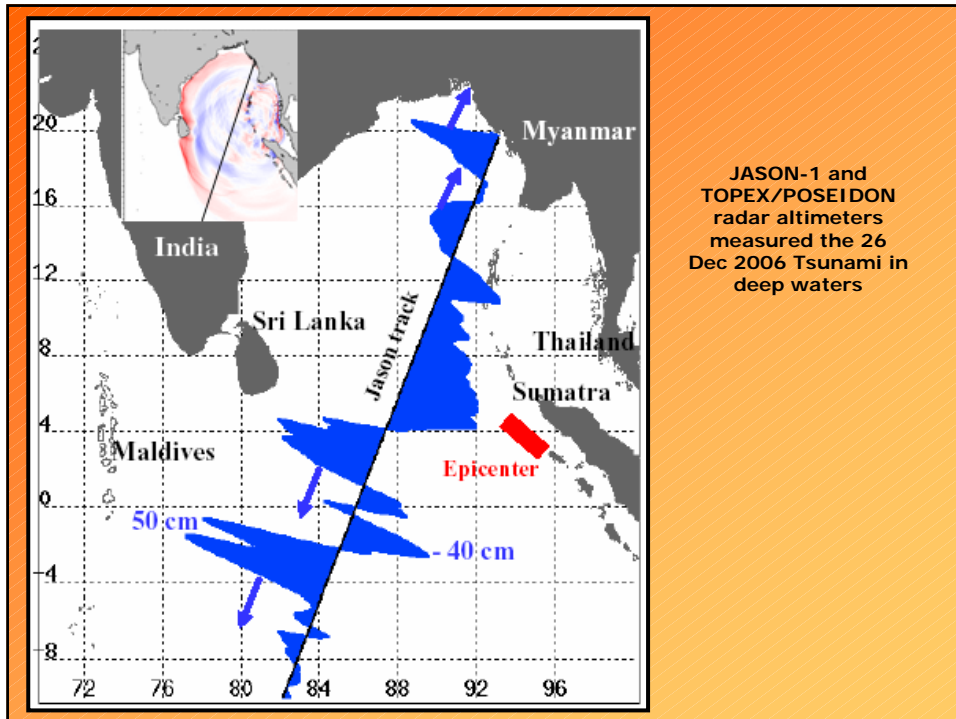
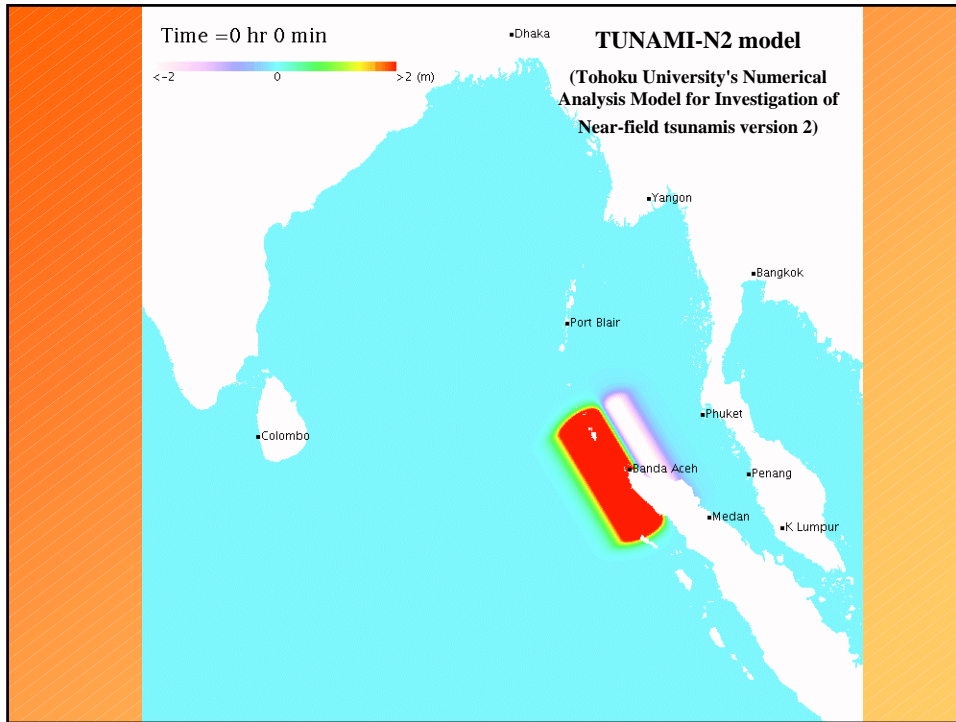
Tsunami risk is high if:

- Earthquake > 8.0.
- Earthquake occurs at shallow depth.
- Earthquake occurs deep in the sea.
- Earthquake causes up/down movement of the seafloor.

Tsunami

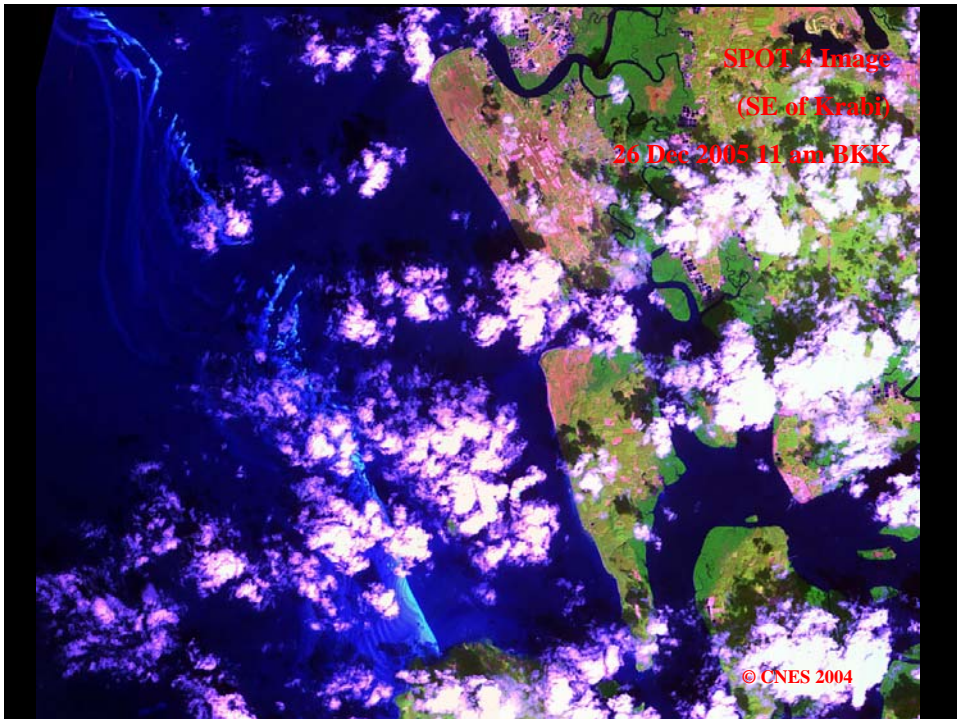
- Tsunami travels at very high speed in deep ocean. The speed is approximately given by \sqrt{gh} where g is the gravitational acceleration and h the depth of the ocean. For an average ocean depth of 4000 m, the speed will be about 700 km per hour. This is the speed of aircraft.
- Tsunami are hardly noticeable in the ocean (height < 1m), tsunami undergoes a transformation as it advances into shallow waters.
- Since the wave speed is proportional to the square root of the water depth, the waves ahead slow down while the waves behind catch up. This leads to shortening of the wavelength and the growth of the wave height.
- The wave height increases approximately as $h^{-1/4}$. A 1-m tsunami wave from deep ocean (6000 m) will grow to a height of 5 meters when it moves into shallow water of 10 meter depth.





Satellite Images

(Modis, SPOT 5, IKONOS)







Banda Aceh



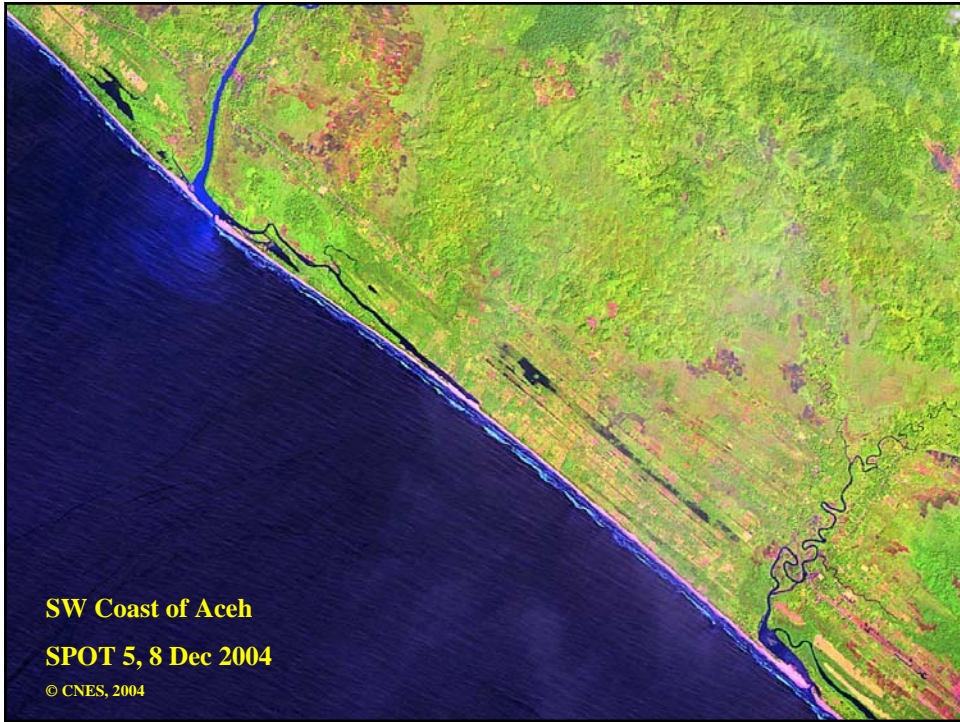
Banda Aceh

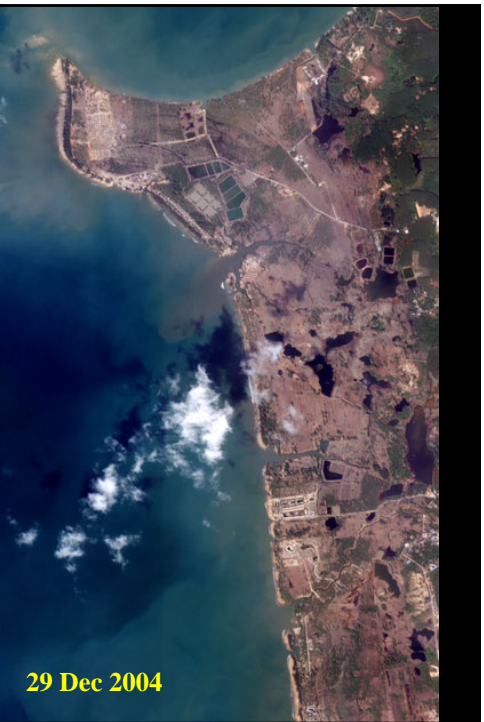














**Blue Village
Pakarang Resort**

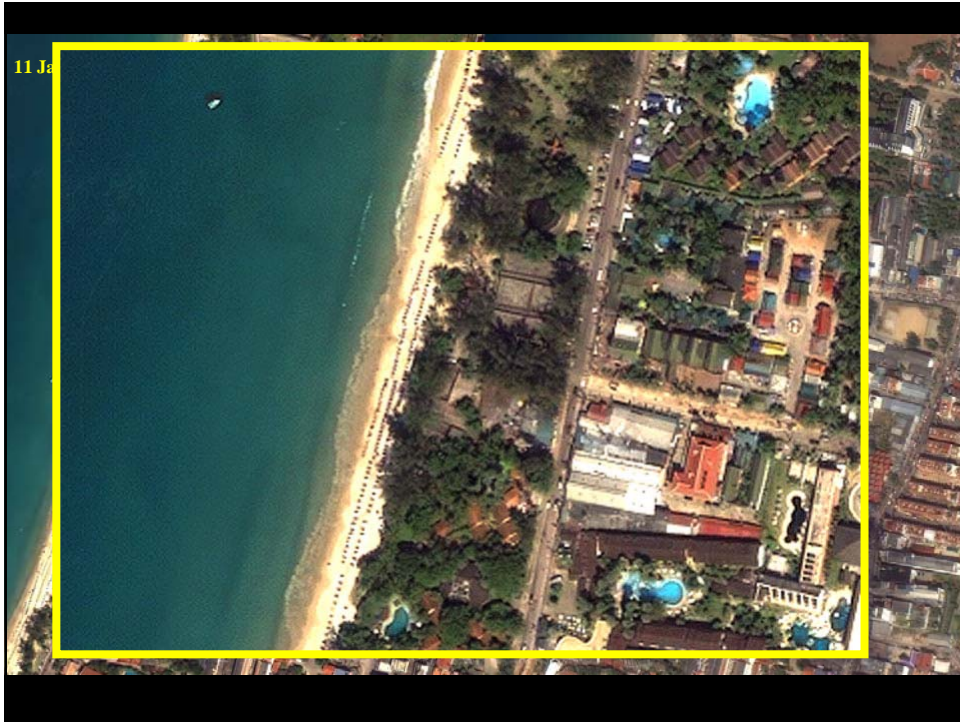


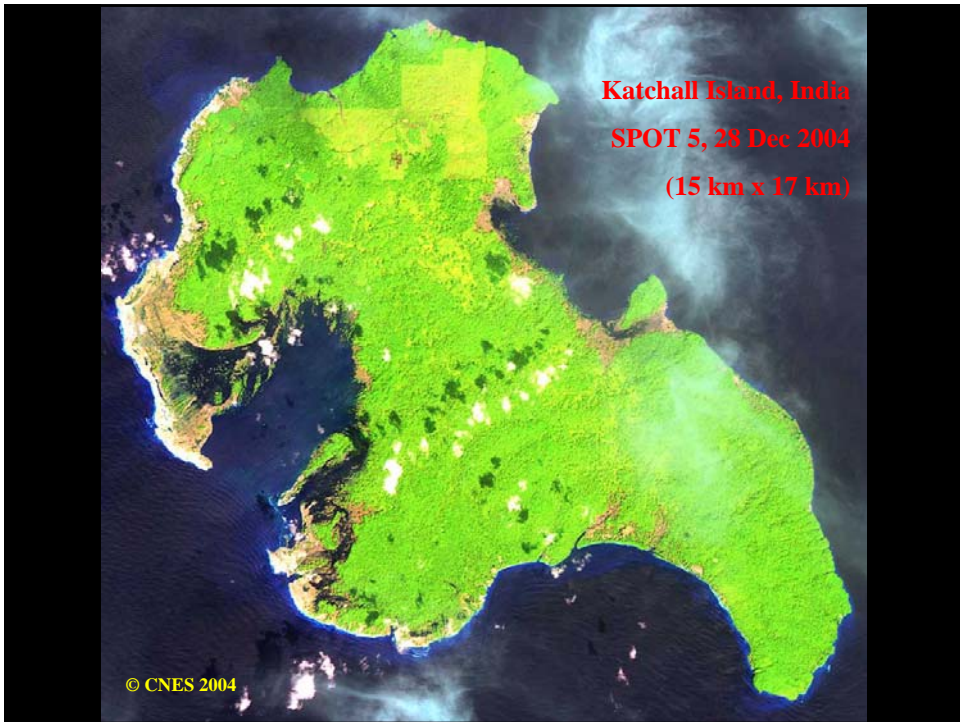
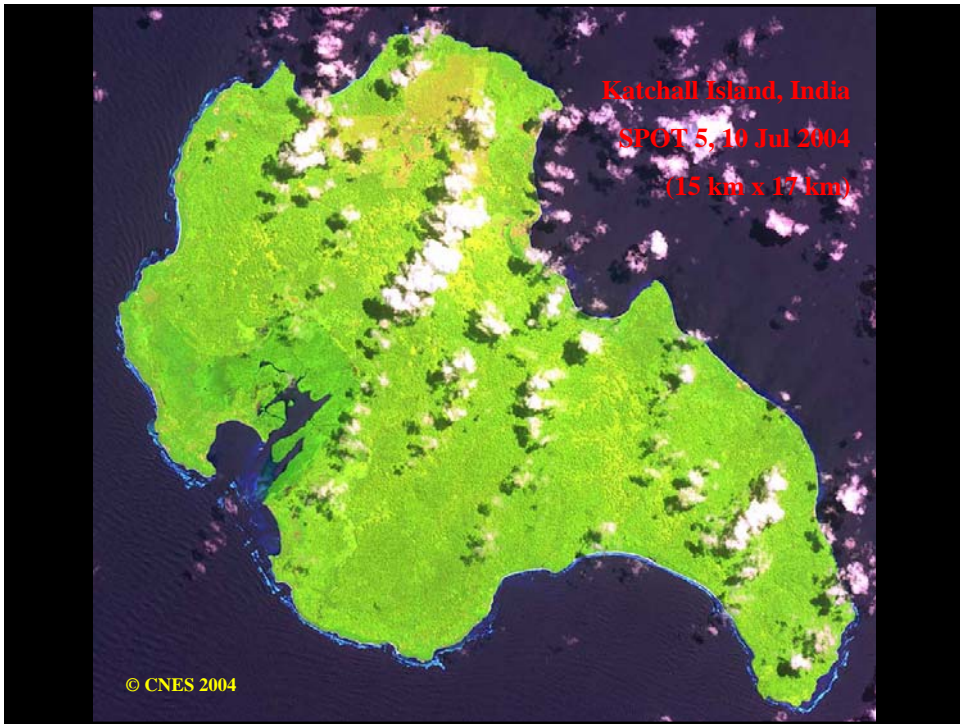
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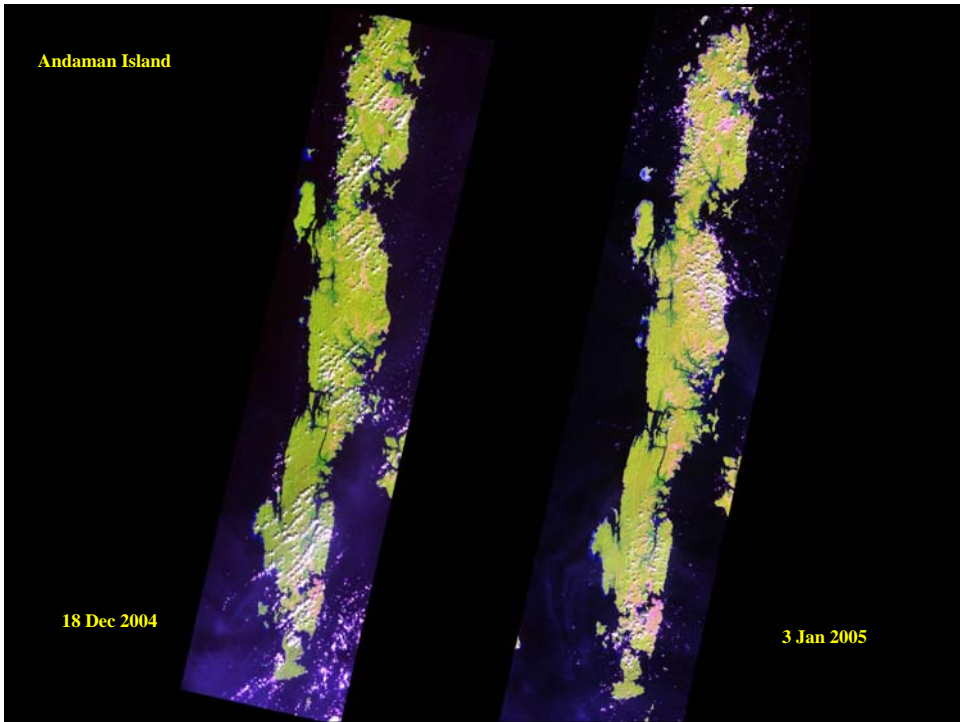
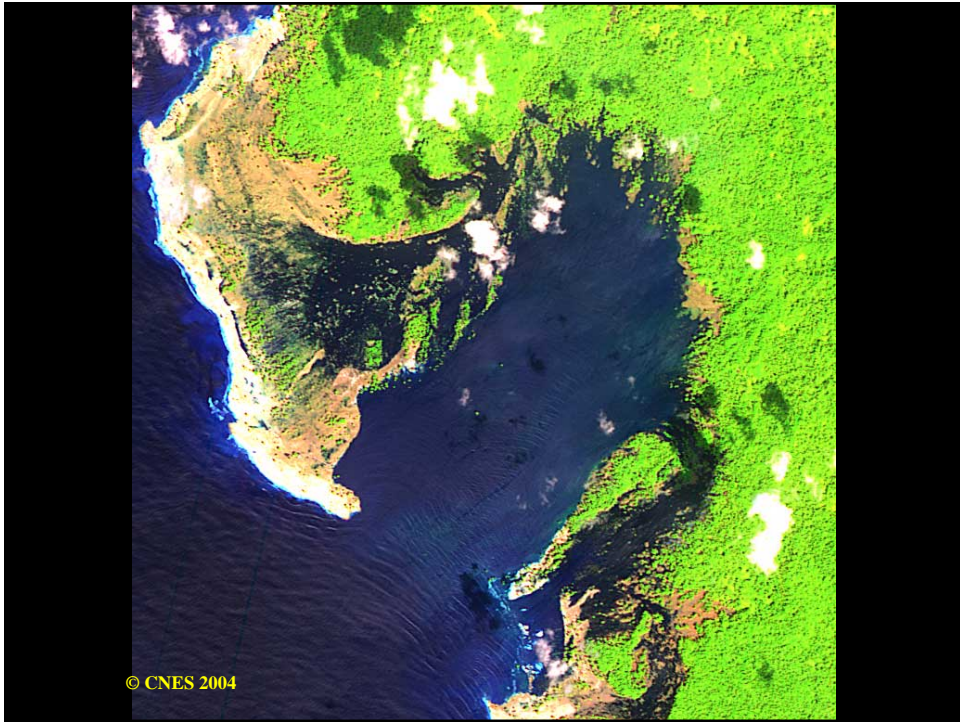


A fly-through of Khao Lak beach (IKONOS + SRTM)

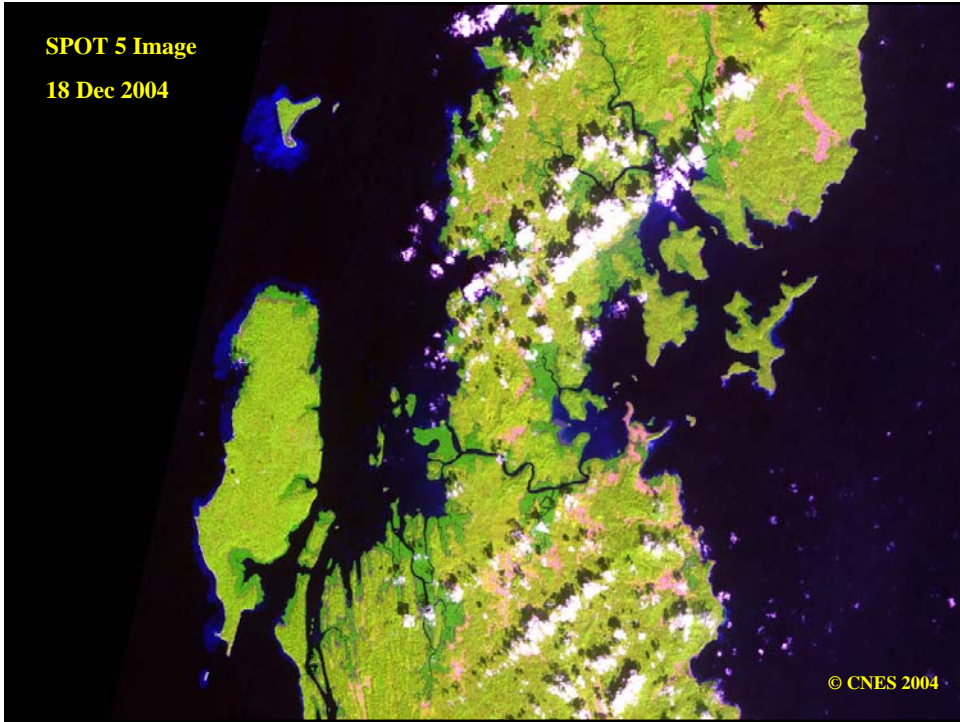




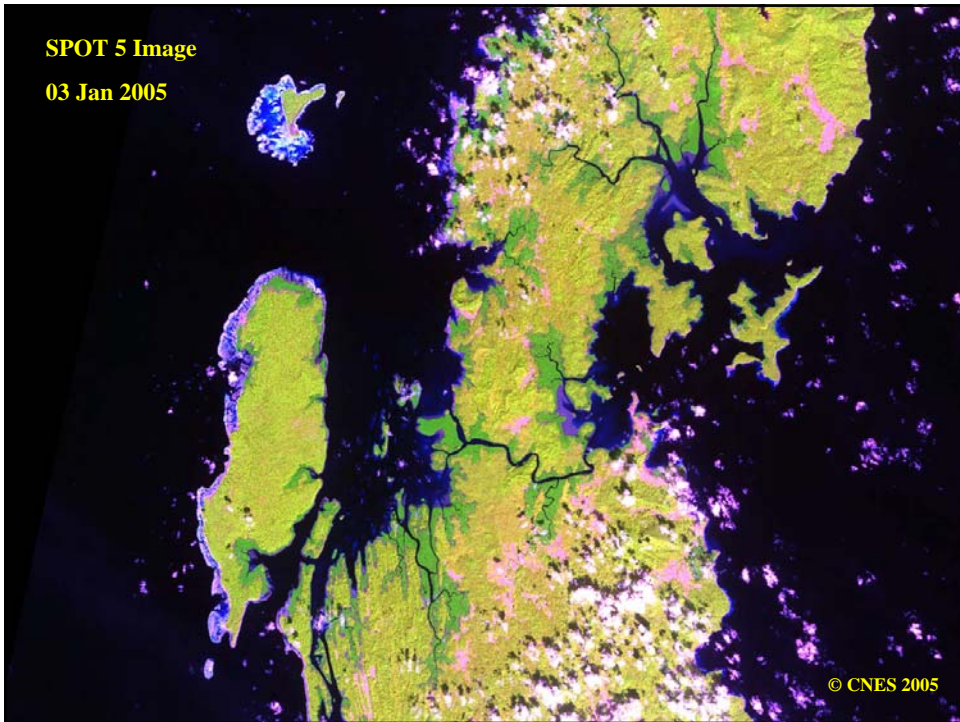




SPOT 5 Image
18 Dec 2004



SPOT 5 Image
03 Jan 2005



The 26 December 2004 quake was registered at 9.0 on Richter scale, the biggest in 40 years. The magnitude of the quake in the night of 28 March 2005 was recorded between 8.5 and 8.7, but (according to various monitoring agencies) caused only a slight wave.

The USGS reported that a tide gauge near the Cocos Islands in the eastern Indian Ocean recorded a "small" tsunami (wave of 10 inches to 20 inches). The agency said no major tsunami was observed near the epicenter of the earthquake.

Why do some earthquakes spawn tsunamis that kill thousands while others hardly stir a ripple on the ocean surface?

"That's one of the mysteries of seismic science," said spokeswoman for the U.S. Geological Survey (USGS).

"We are hoping that with an increase in the seismic [monitoring] system ... around the world, [we] will be able to determine why some offshore earthquakes cause tsunamis and some don't."

CNN.com – 28 March 2005

"I'm baffled an earthquake this size didn't trigger a tsunami near the epicenter," said a geophysicist at the Pacific Tsunami Warning Center, which is operated by NOAA

AP Science – 29 March 2005



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Thank You