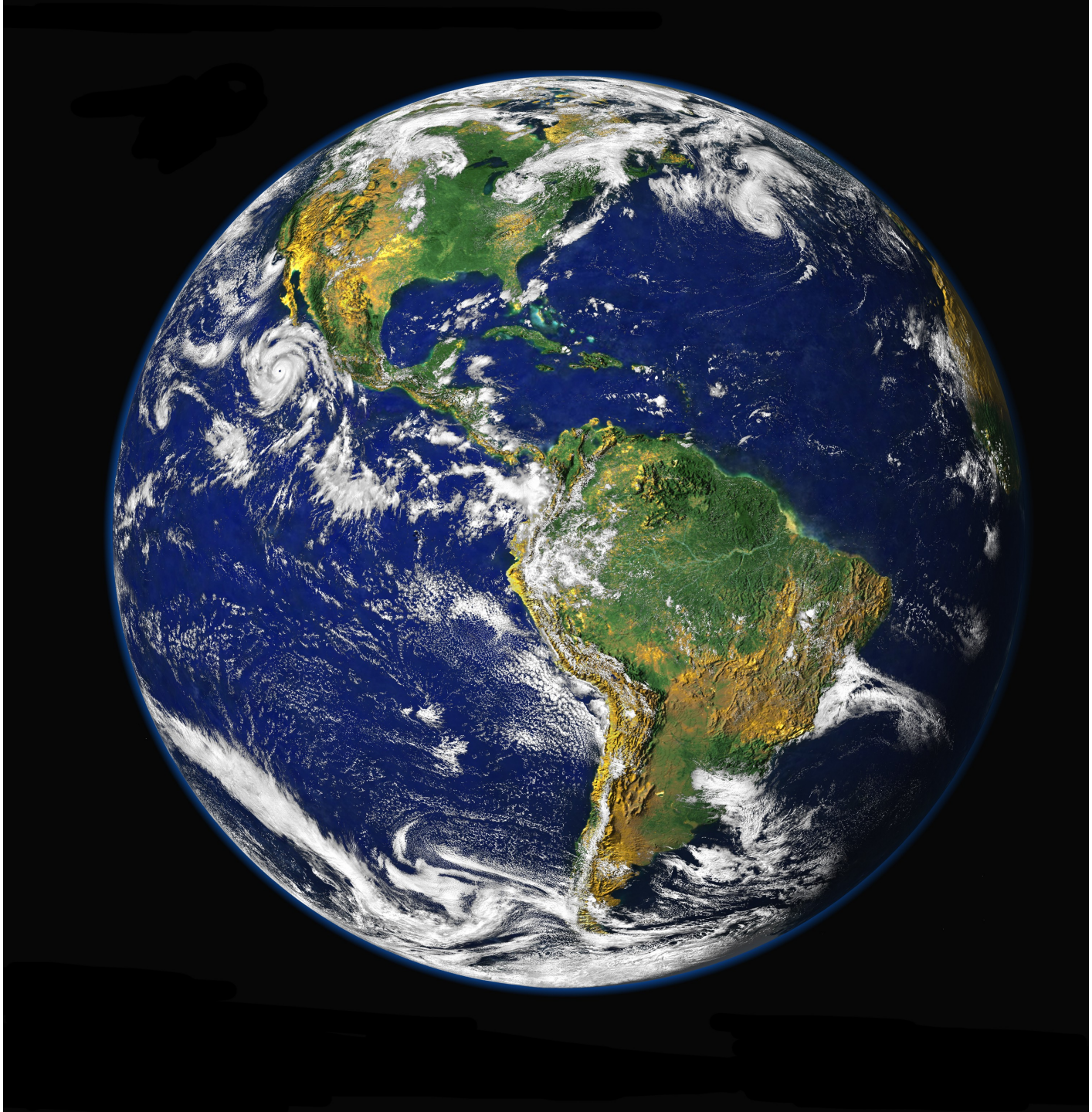
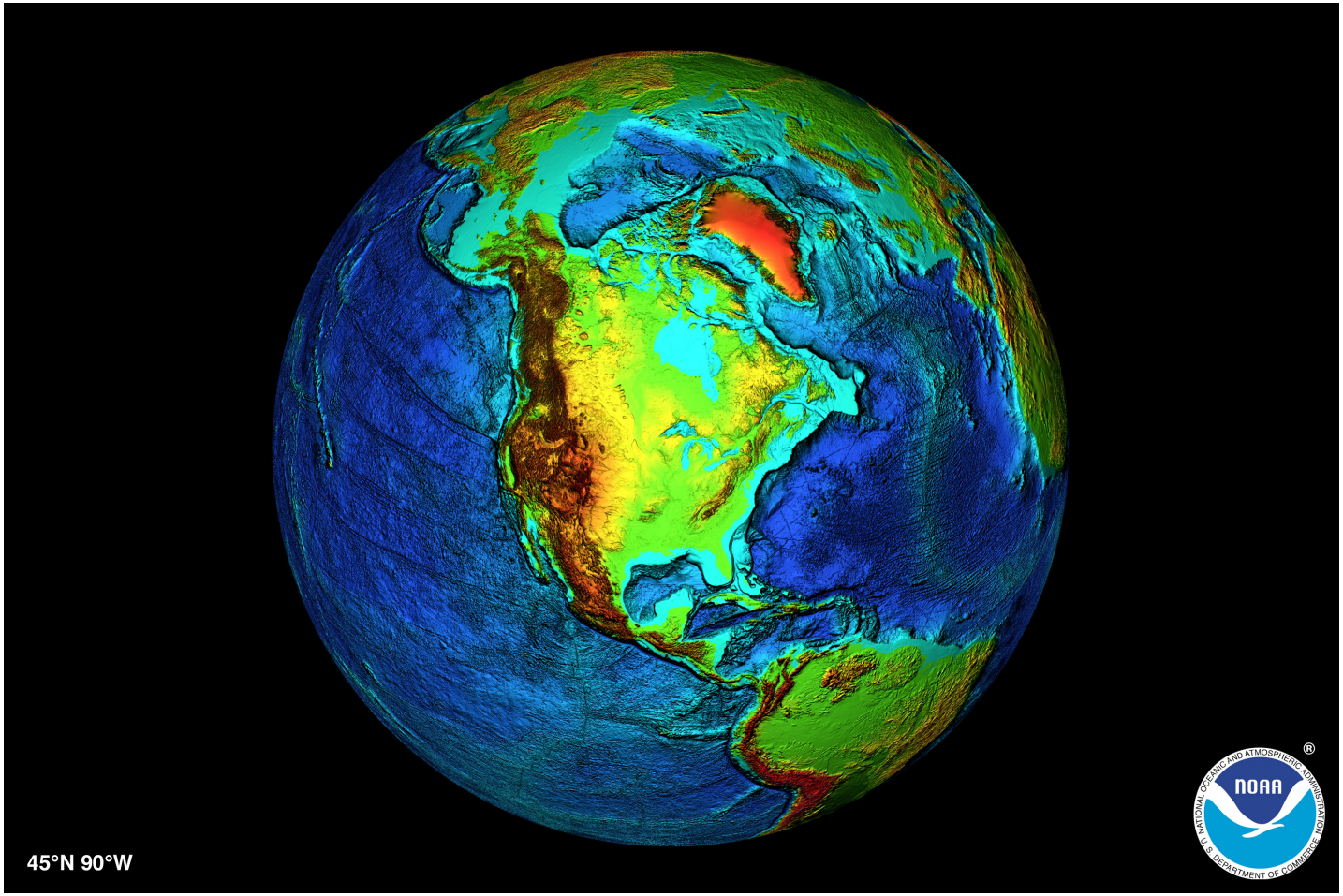
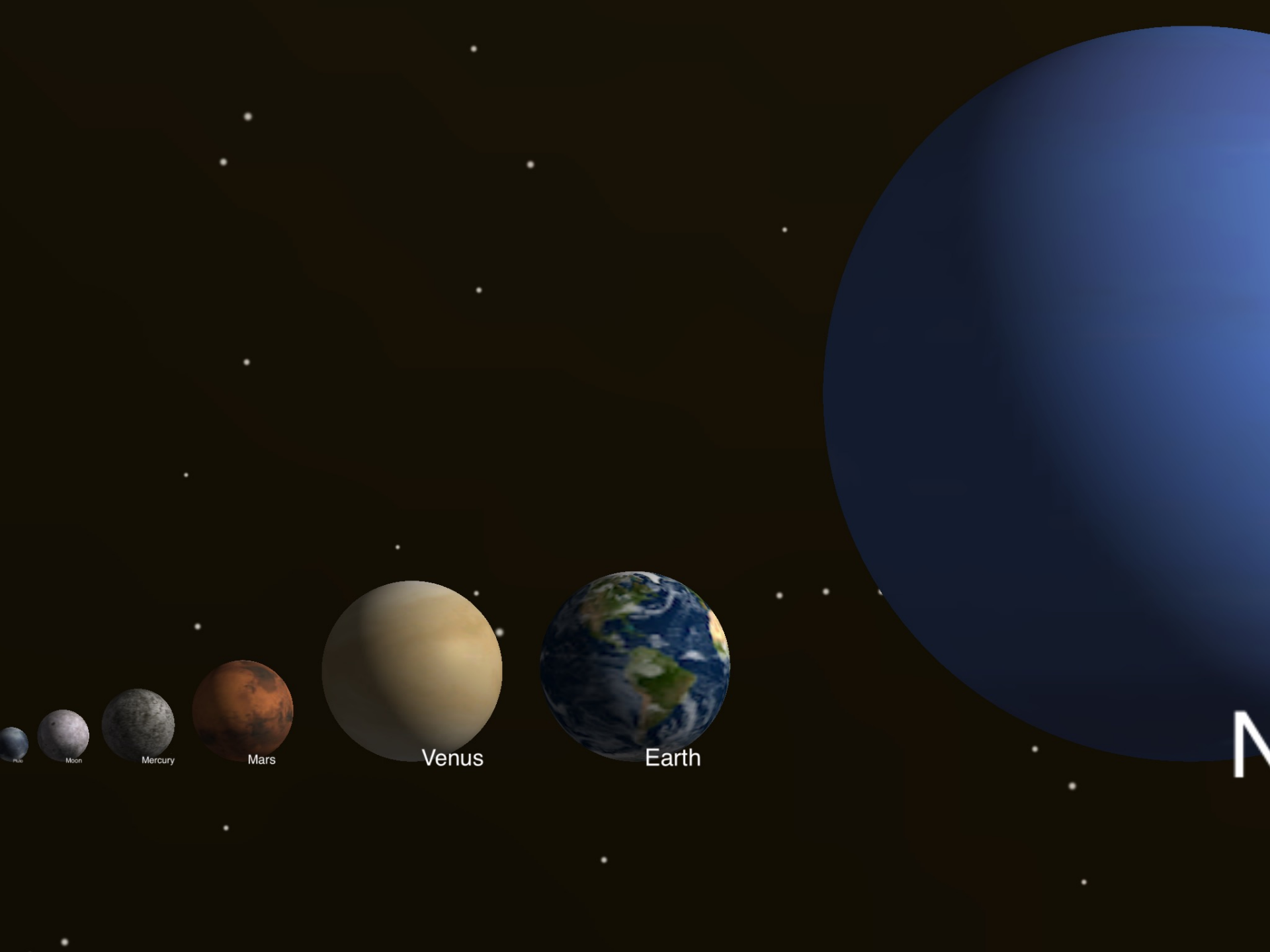
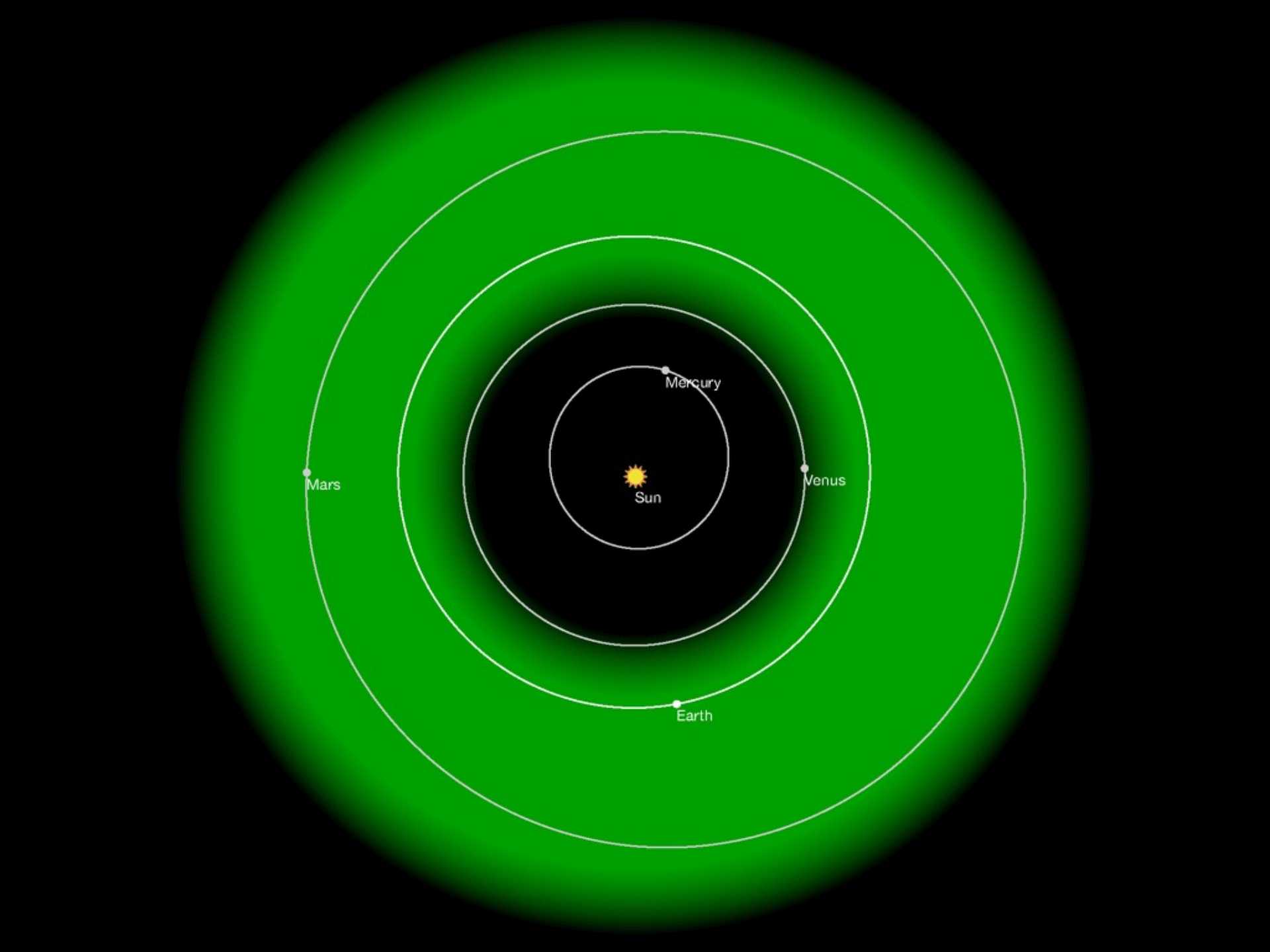


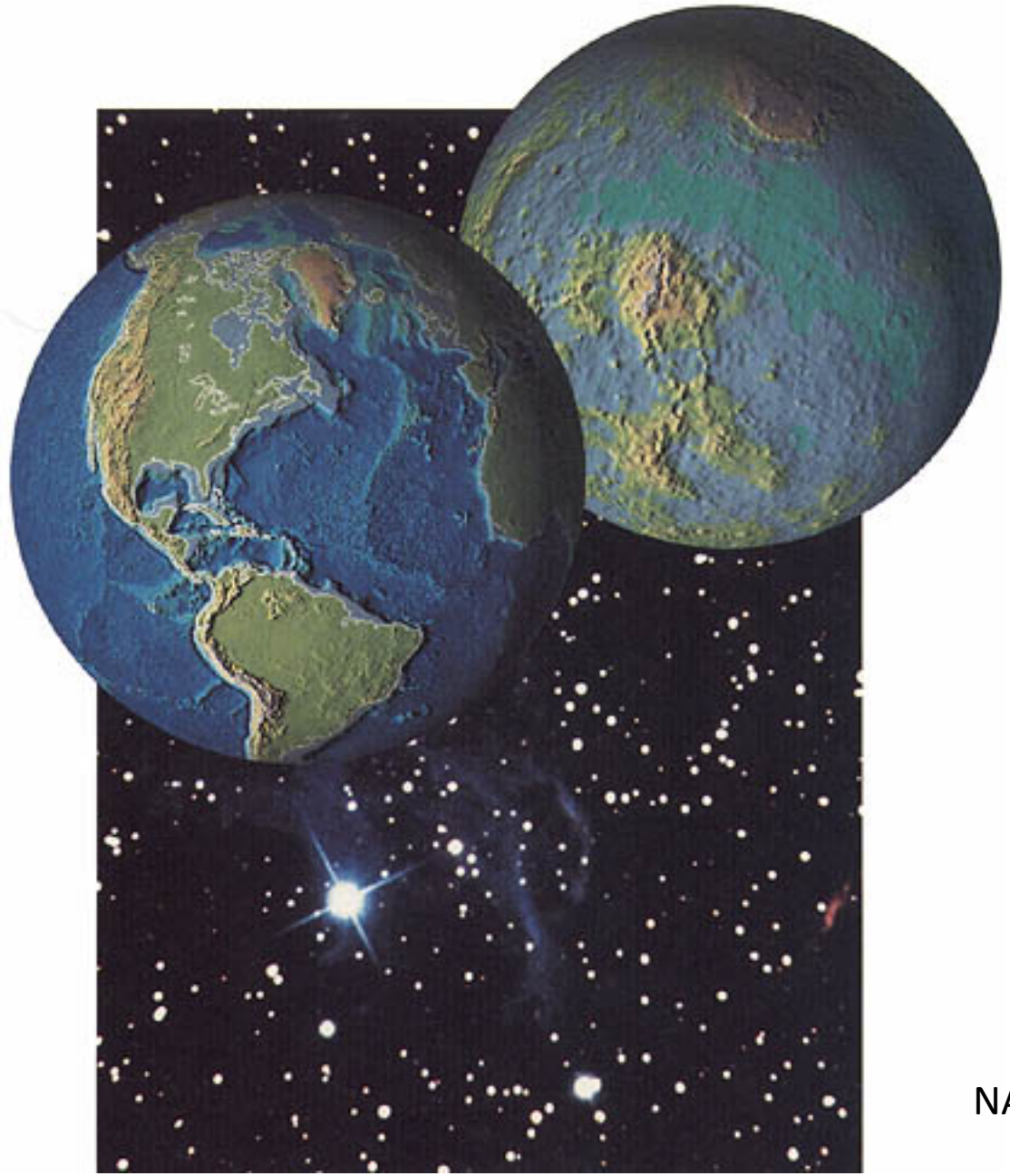
nasa



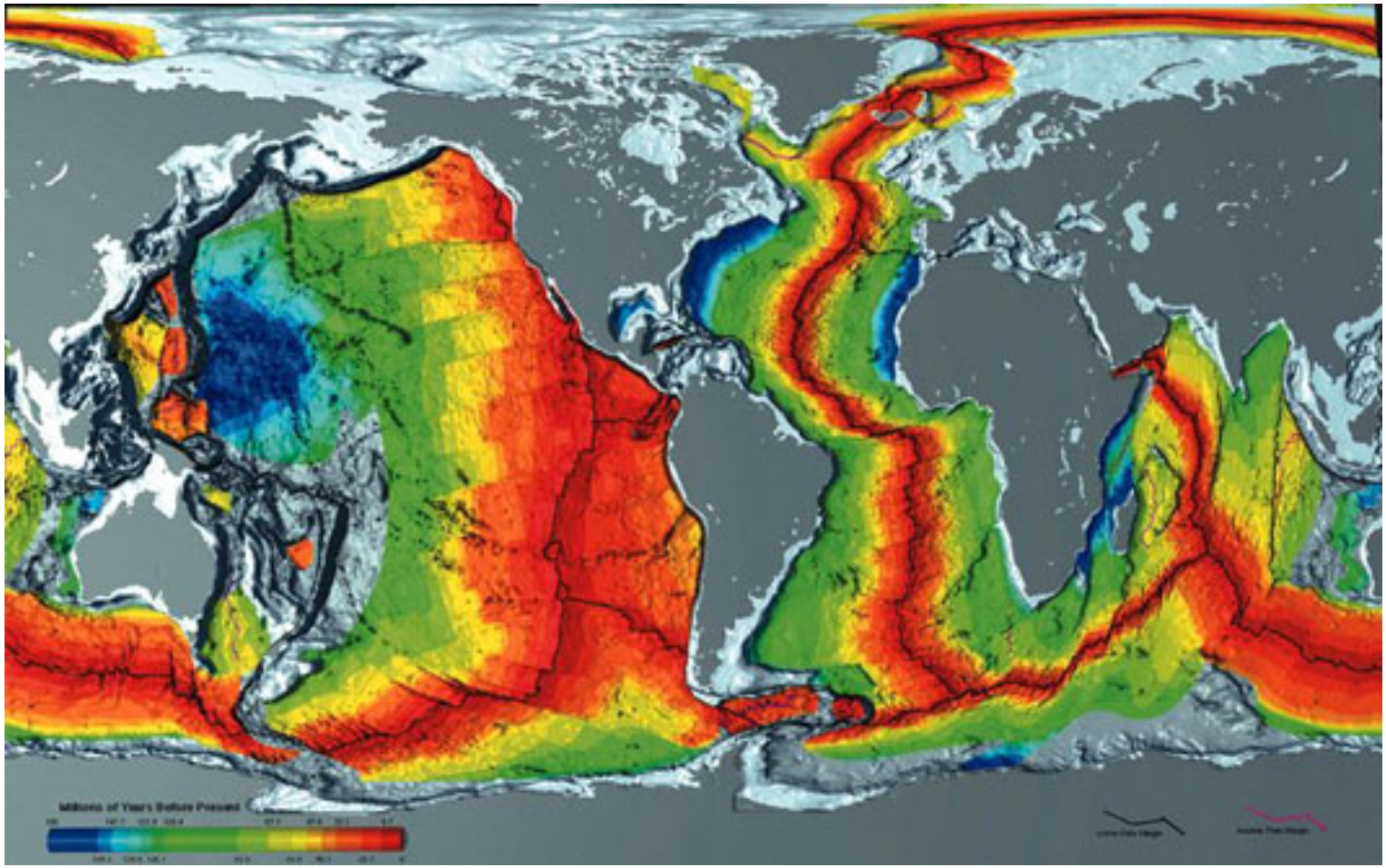
http://www.ngdc.noaa.gov/mgg/global/relief/SLIDES/JPEGfull/Slide01.jpg


Moon
Mercury
Mars
Venus
Earth

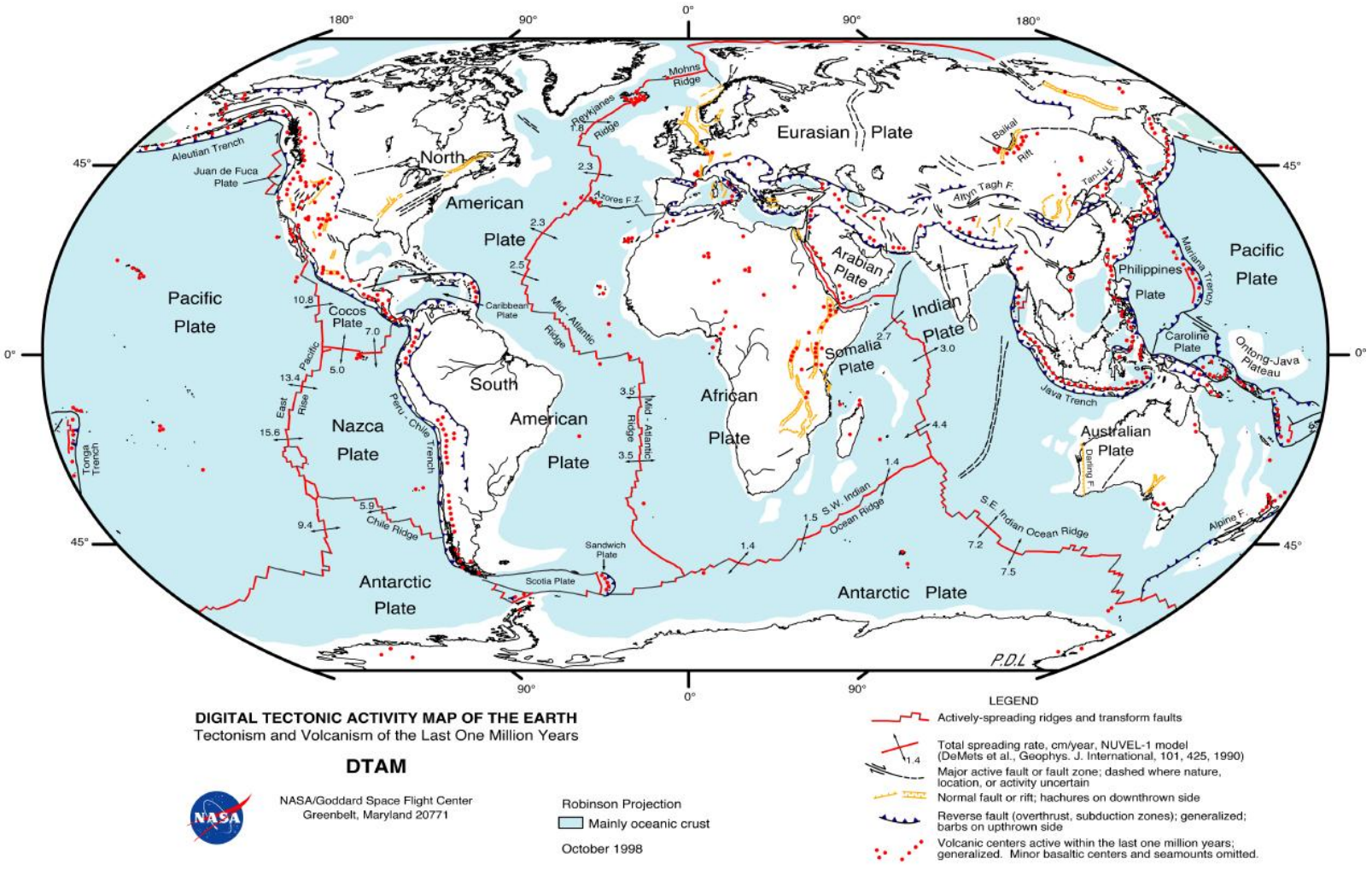

Mercury
Venus
Earth
Mars
Sun



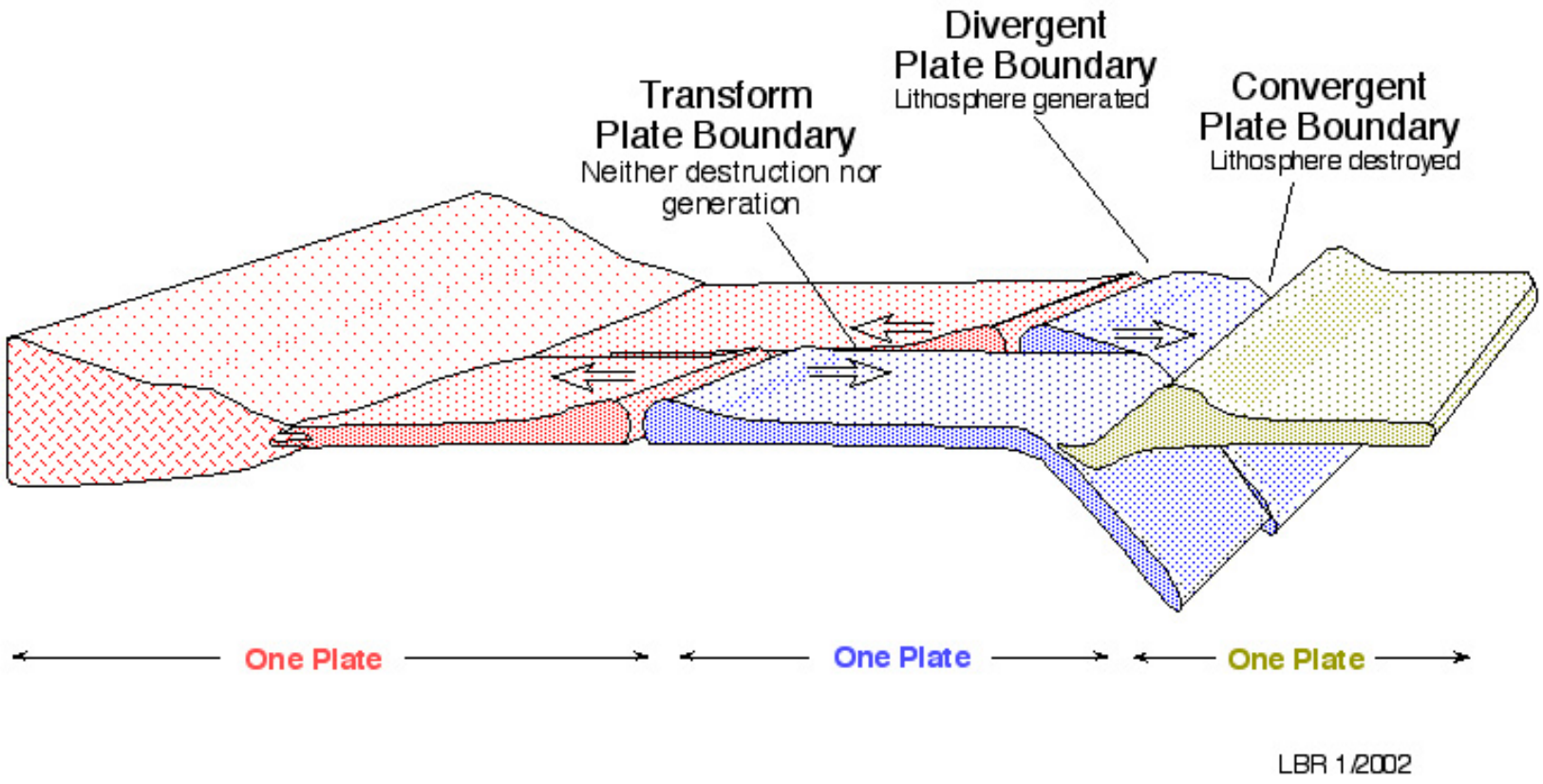
NASA



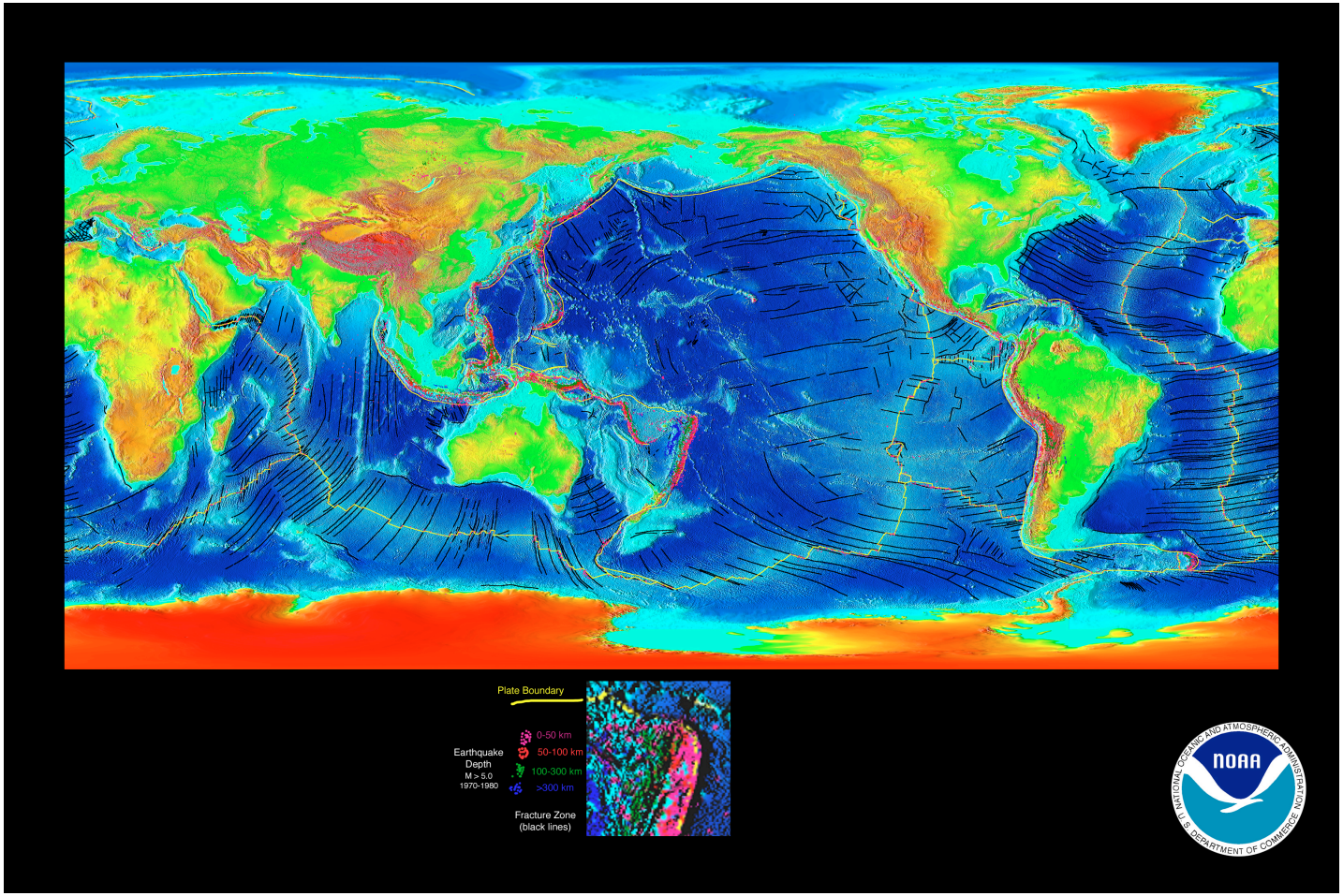
http://www.eoearth.org/images/158799/Tectonic_plates_age.jpg



http://www.globalchange.umich.edu/globalchange1/current/lectures/evolving_earth/tectonic_map.jpg



http://www.gly.uga.edu/railsback/1121PlateTectonicsGen2.jpeg



http://www.ngdc.noaa.gov/mgg/global/relief/SLIDES/JPEGfull/Slide18.jpg

Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

USGS

Japan was struck by a magnitude 9.0 earthquake off its northeastern coast Friday. This is one of the largest earthquakes that Japan has ever experienced.

In downtown Tokyo, large buildings shook violently and there is severe flooding due to a tsunami generated by the earthquake.

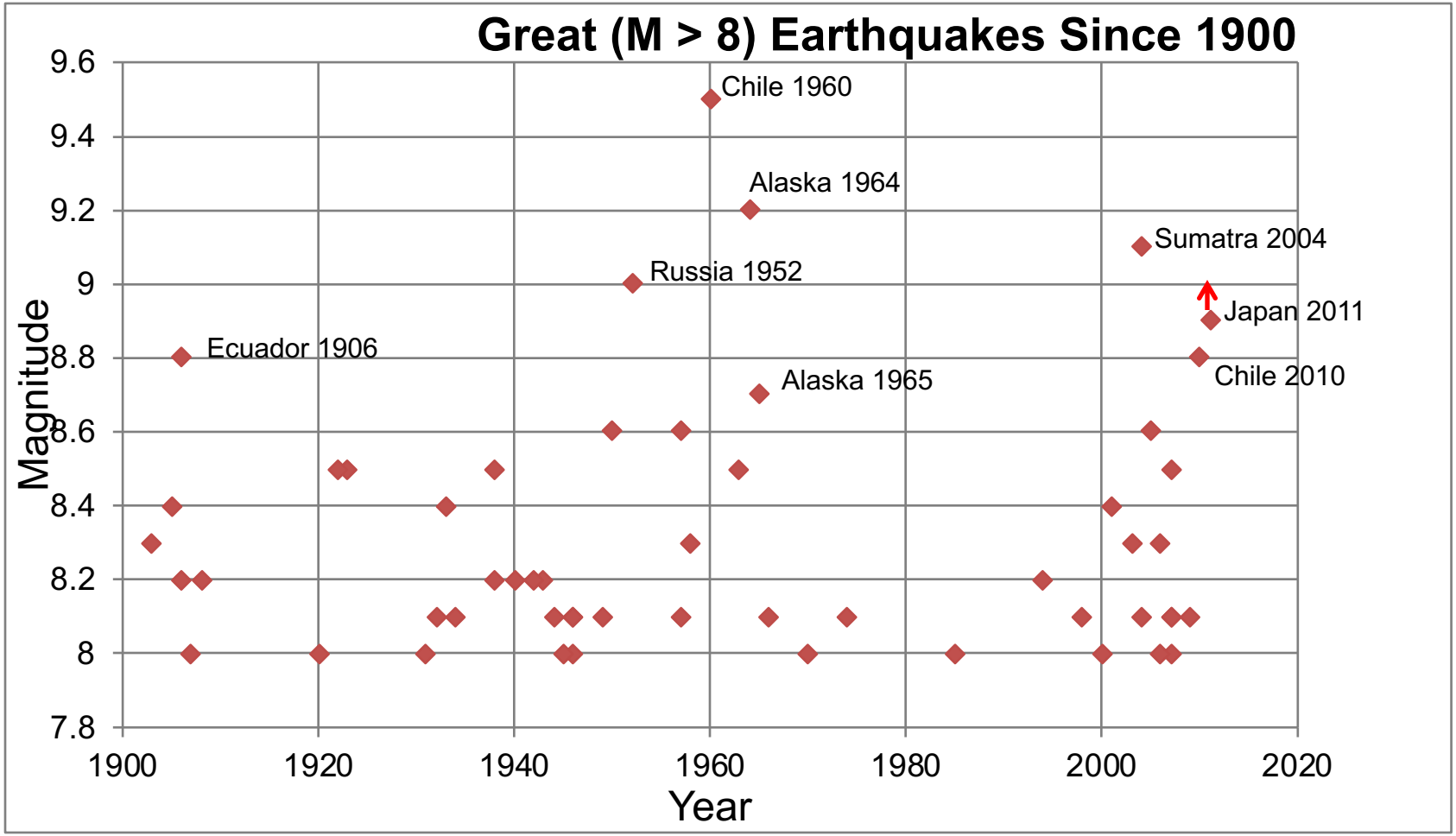
Part of houses swallowed by tsunami burn in Sendai, Miyagi Prefecture (state) after Japan was struck by a strong earthquake off its northeastern coast Friday, March 11, 2011.

New York Times

Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

Globally, this is the 4th largest earthquake since 1900.

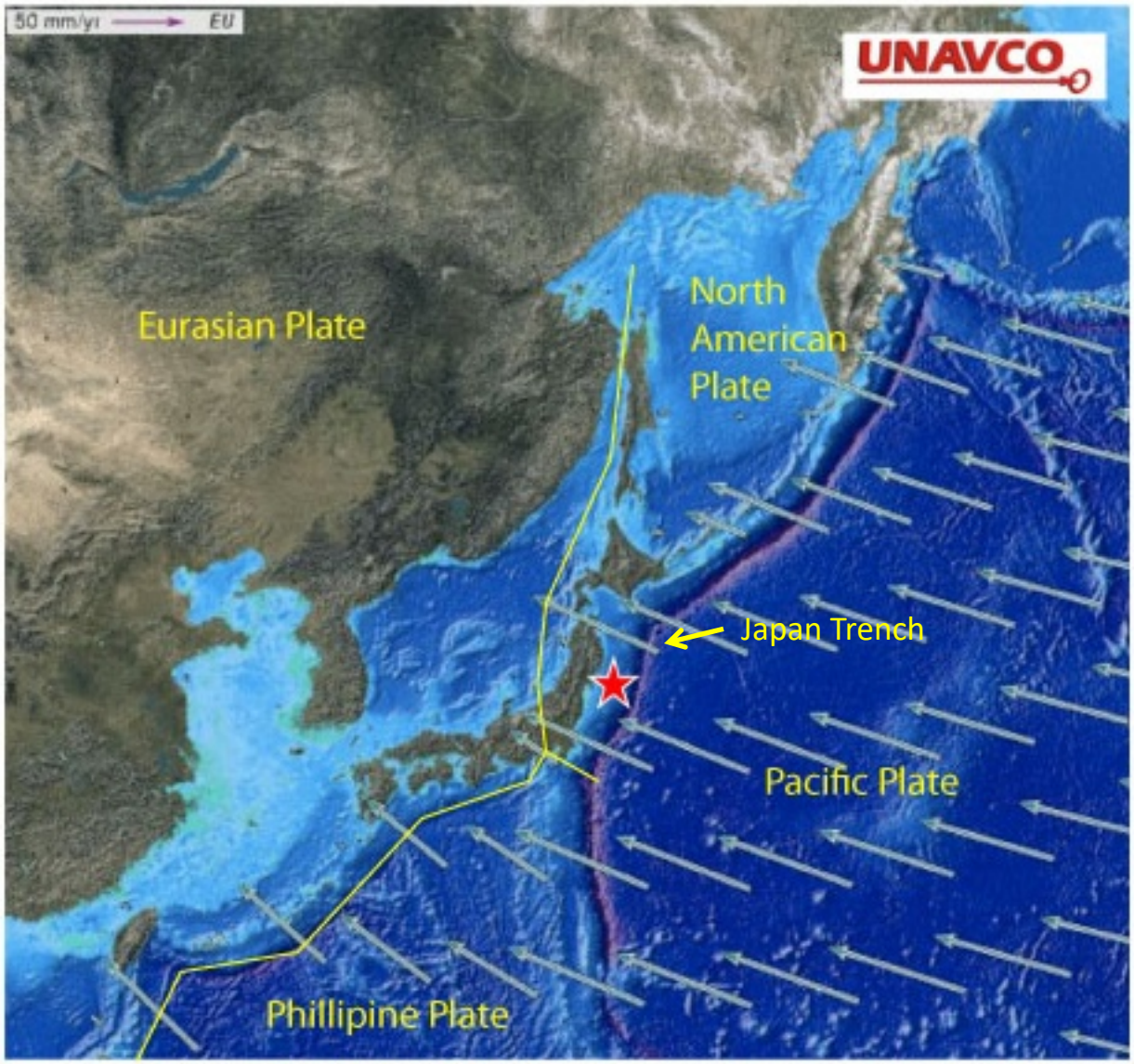


Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

This earthquake was the result of thrust faulting along or near the convergent plate boundary where the Pacific Plate subducts beneath Japan.

This map also shows the rate and direction of motion of the Pacific Plate with respect to the Eurasian Plate near the Japan Trench. The rate of convergence at this plate boundary is about 83 mm/yr (8 cm/year). This is a fairly high convergence rate and this subduction zone is very seismically active.

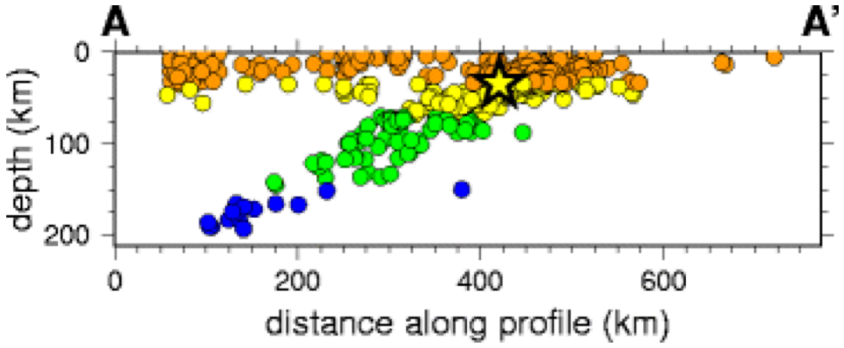


Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

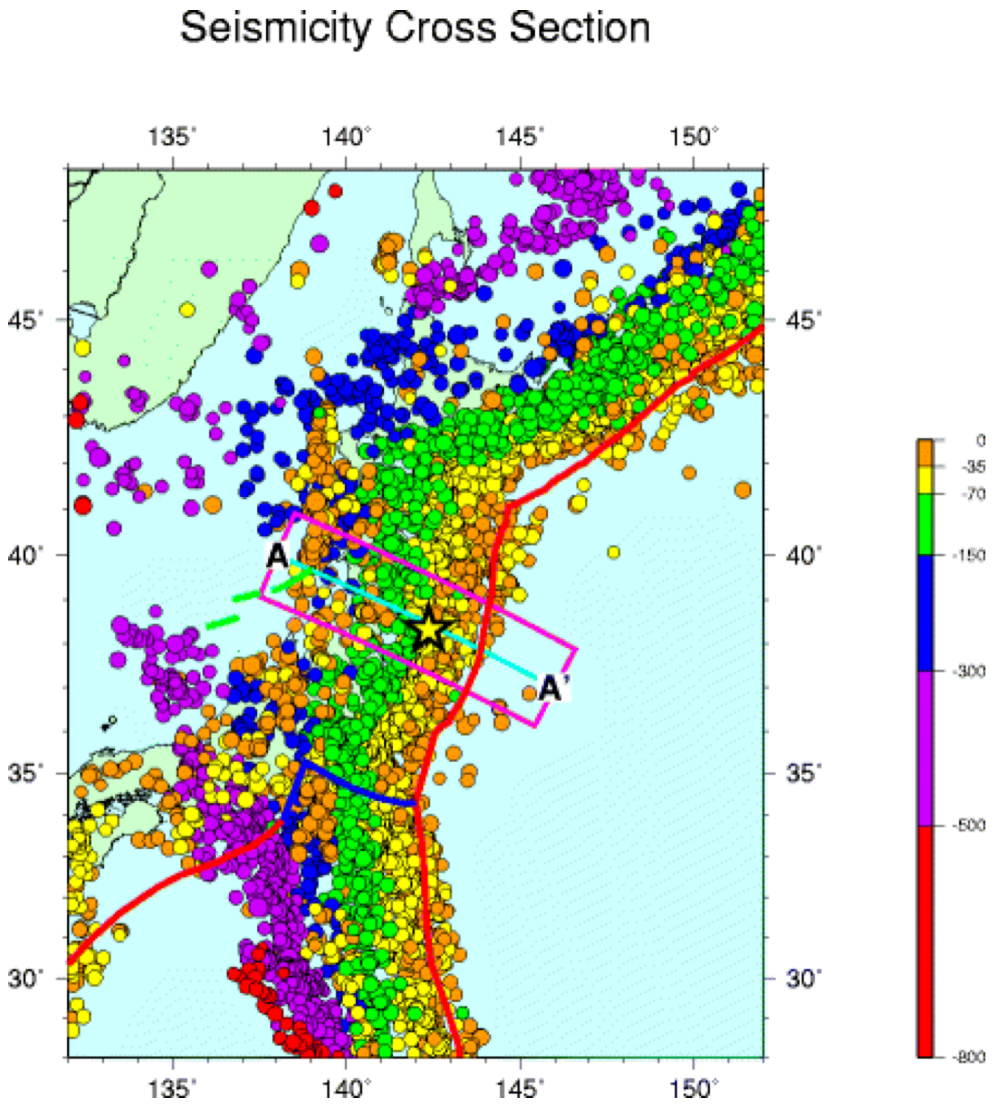
Friday, March 11, 2011 at 05:46:23 UTC

The map on the right shows historic earthquake activity near the epicenter (star) from 1990 to present.

As shown on the cross section, earthquakes are shallow (orange dots) at the Japan Trench and increase to 300 km depth (blue dots) towards the west as the Pacific Plate dives deeper beneath Japan.



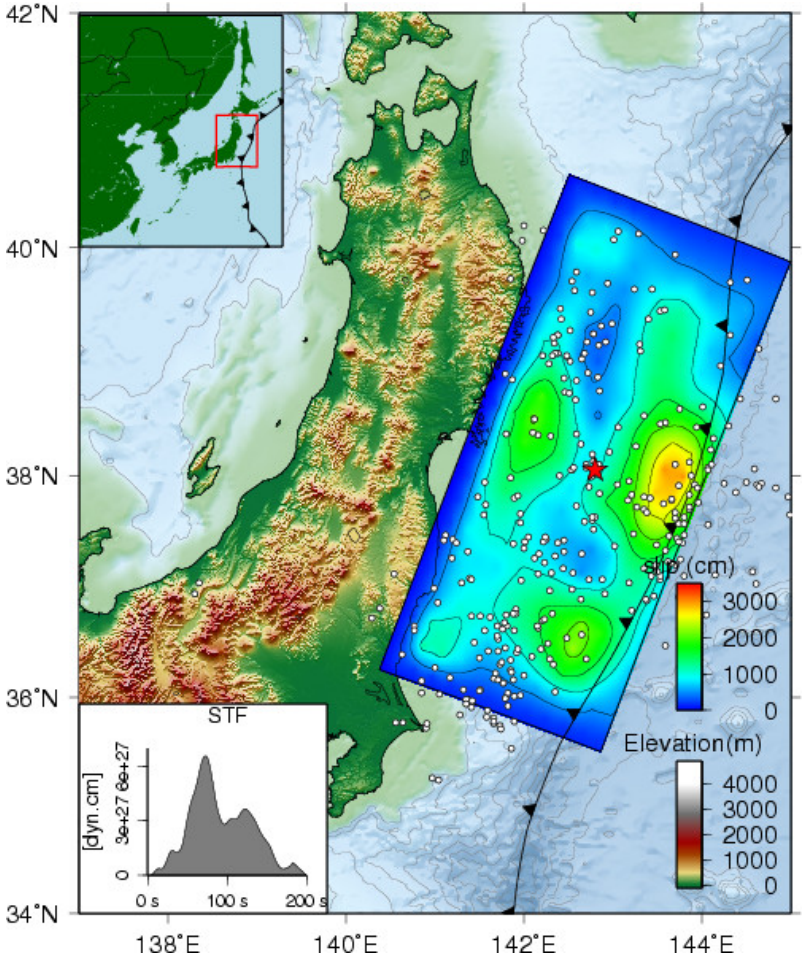
Seismicity Cross Section across the subduction zone showing the relationship between color and earthquake depth.



Images courtesy of the US Geological Survey

http://www.tectonics.caltech.edu/slip_history/2011_tohoku-oki-tele/

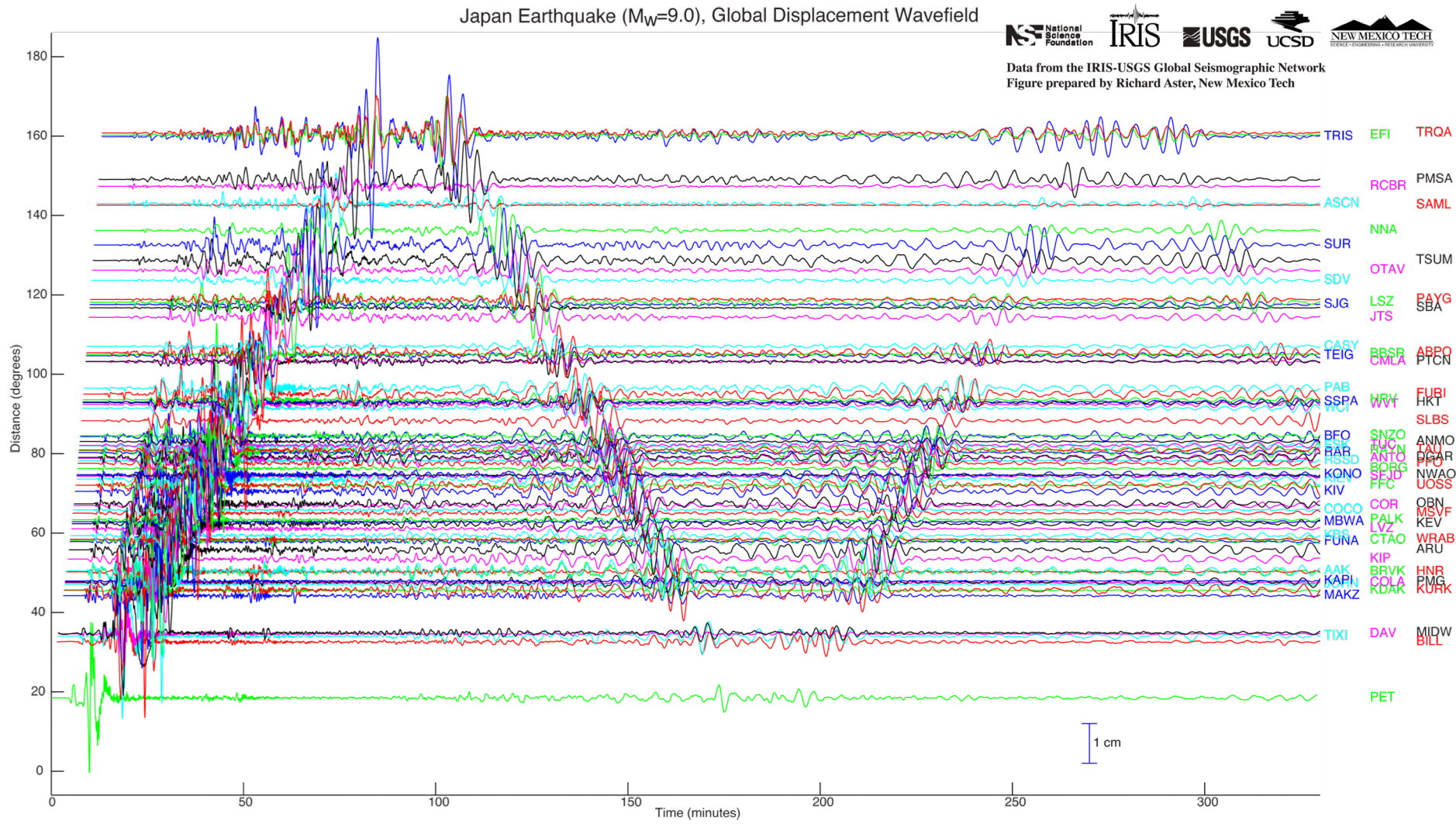
Shengji Wei
(Caltech)
Anthony Sladen
(Geoazur-CNRS)



Magnitude 9.0 NEAR THE EAST COAST OF HONSHU, JAPAN

Friday, March 11, 2011 at 05:46:23 UTC

Seismic waves recorded around the world.



IRIS Teachable Moments

Magnitude 7.8 NEPAL

Saturday, April 25, 2015 at 06:11:26 UTC

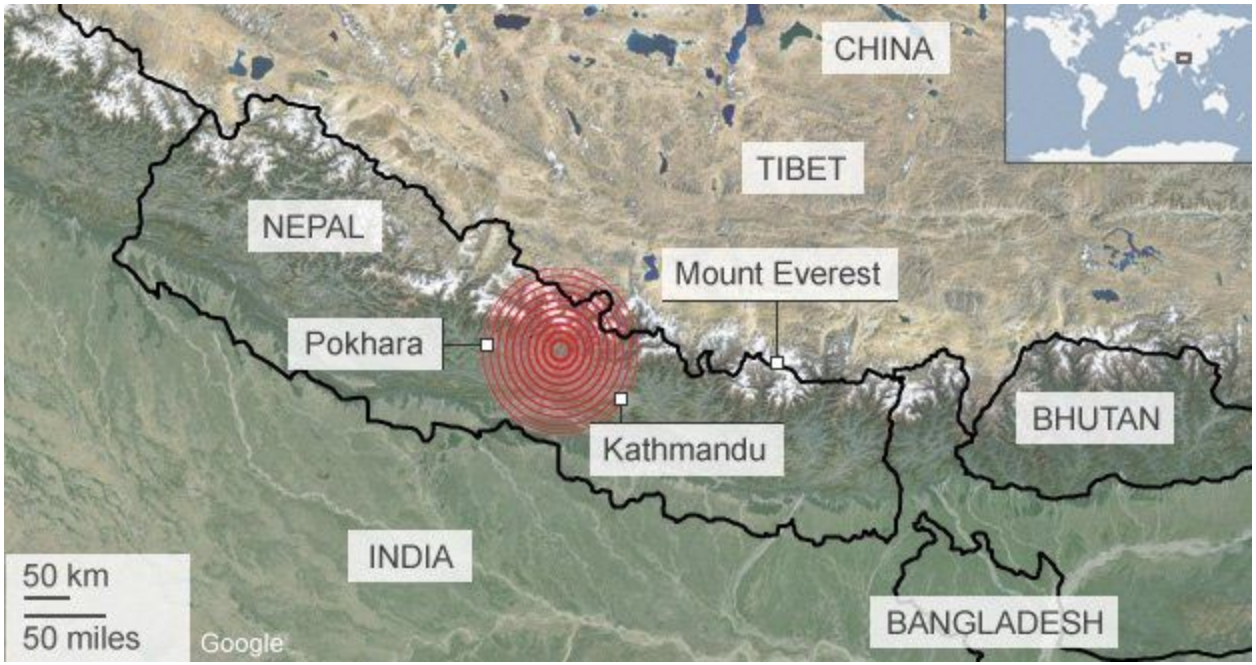
A magnitude 7.8 earthquake occurred with an epicenter 77 km (48 miles) northwest of Kathmandu, the capital city of Nepal that is home to nearly 1.5 million inhabitants. The earthquake flattened homes, buildings and temples, causing widespread damage across the region and killing more than 2,300 and injuring more than 5,000.

Rescue workers remove debris as they search for victims of earthquake in Bhaktapur near Kathmandu, Nepal. A major earthquake shook Nepal's capital and the densely populated Kathmandu Valley before noon Saturday, causing extensive damage with toppled walls and collapsed buildings, officials said.

(AP Photo/Niranjan Shrestha)

Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

The earthquake centered outside Kathmandu, the capital, was the worst to hit Nepal in over 80 years. It destroyed swaths of the oldest neighborhoods of Kathmandu and severely damaged three Unesco World Heritage sites. The earthquake was strong enough to be felt all across parts of India, Bangladesh, China's region of Tibet and Pakistan.



Reports of damage and injuries are still being confirmed. The situation is unclear in remote areas which remain cut off or hard to access. Many mountain roads are damaged or blocked by landslides.

Image courtesy of the BBC

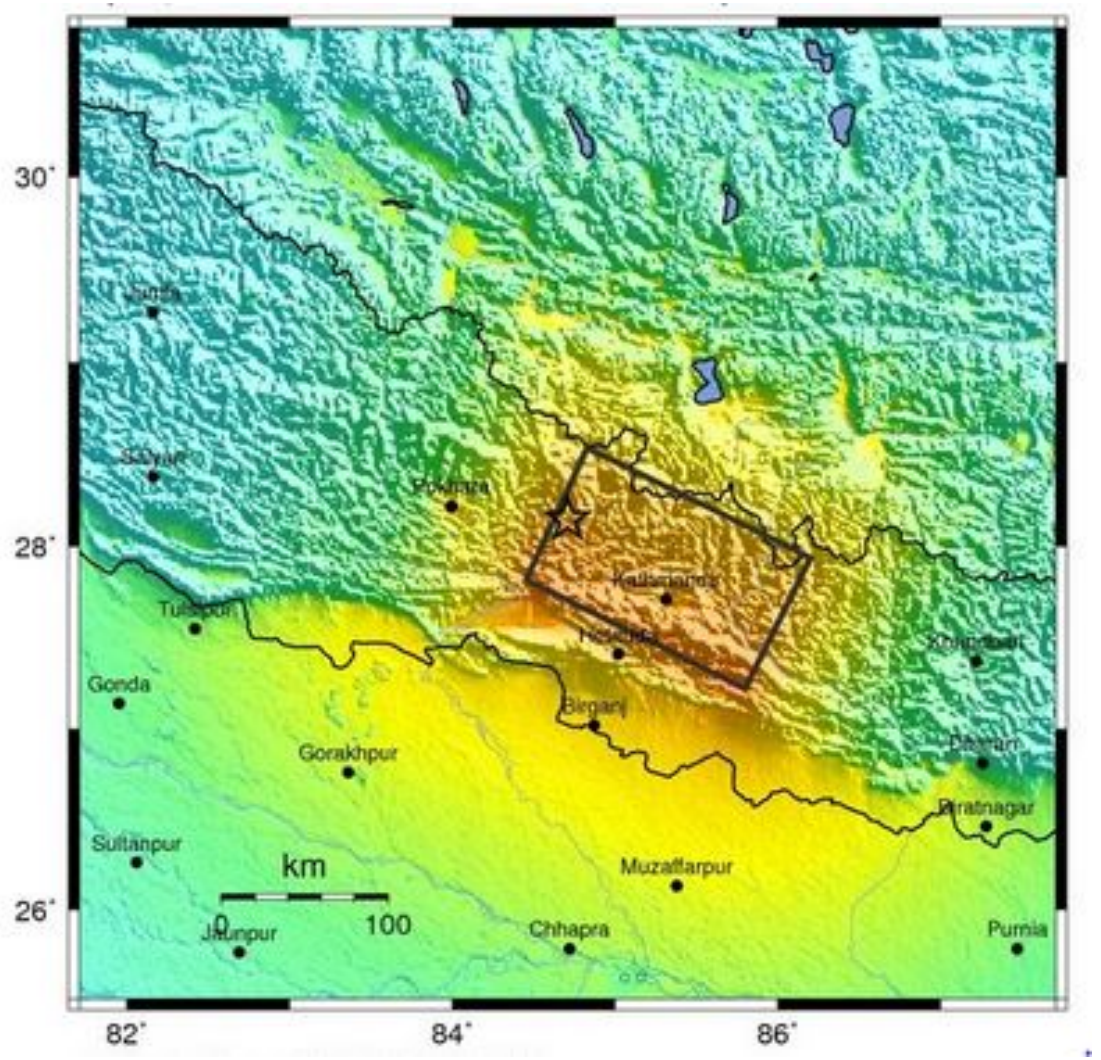
Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

Shaking Intensity

The Modified Mercalli Intensity (MMI) scale depicts shaking severity. The area nearest Katmandu experienced very strong to severe shaking.

Modified Mercalli Intensity	Perceived Shaking
X	Extreme
IX	Violent
VIII	Severe
VII	Very Strong
VI	Strong
V	Moderate
IV	Light
II-III	Weak
I	Not Felt

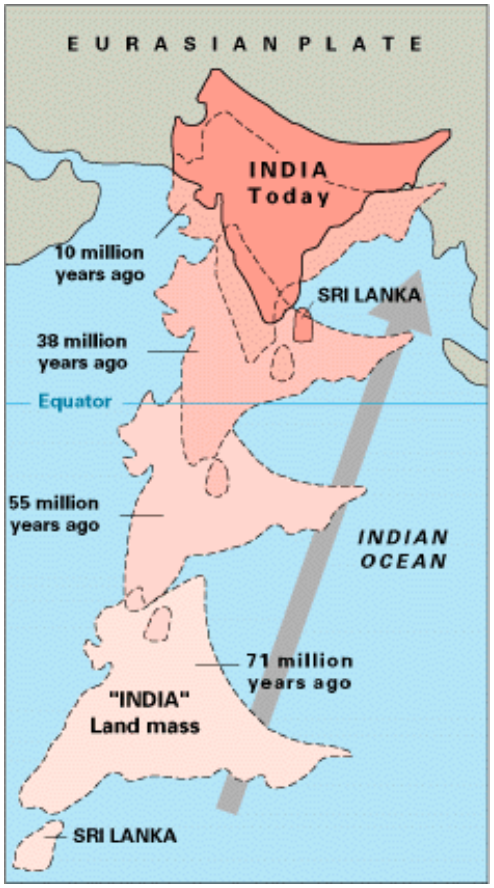
Image courtesy of the US Geological Survey



USGS Estimated shaking Intensity from M 7.8 Earthquake

Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

The earthquake activity in Nepal is caused by the ongoing continent-continent collision between India and Asia. That collision has produced the Himalaya Mountains and the Tibetan Plateau. The collision zone wraps around the northwest promontory of the Indian continent in the Hindu Kush region of Tajikistan and Afghanistan then extends to the southeast through Nepal and Bhutan.

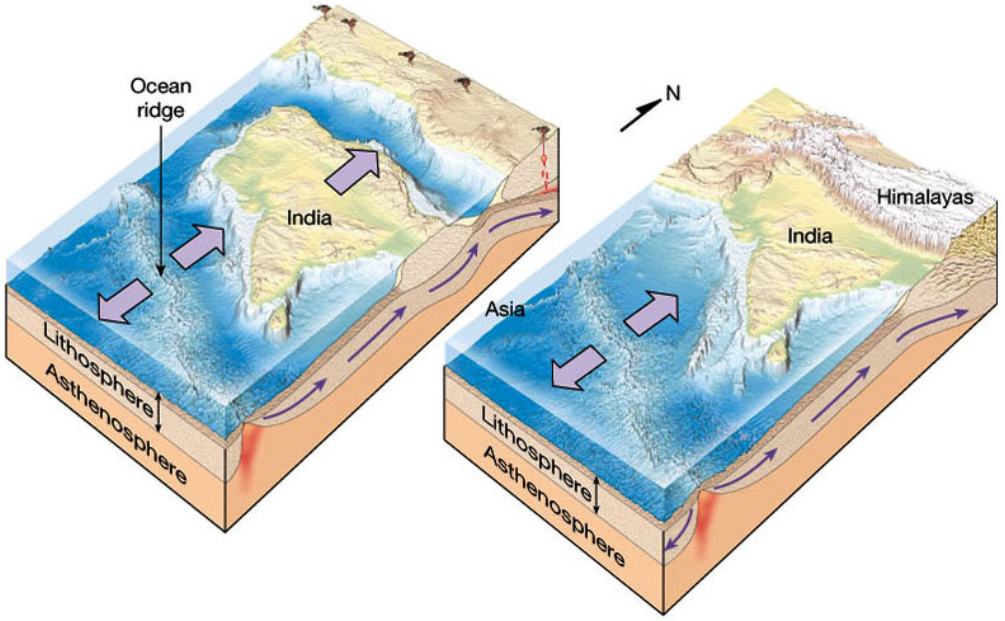


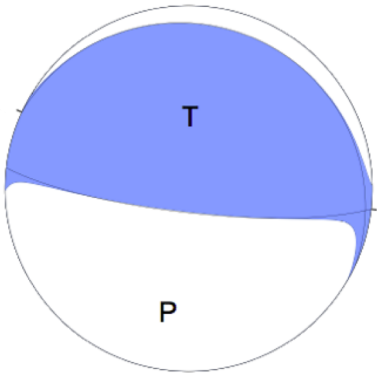
The motion of India into Asia is essentially perpendicular to the Himalaya Mountains in Nepal. So thrust faulting earthquakes are the most common kind of earthquake in the central Himalayan region.

Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

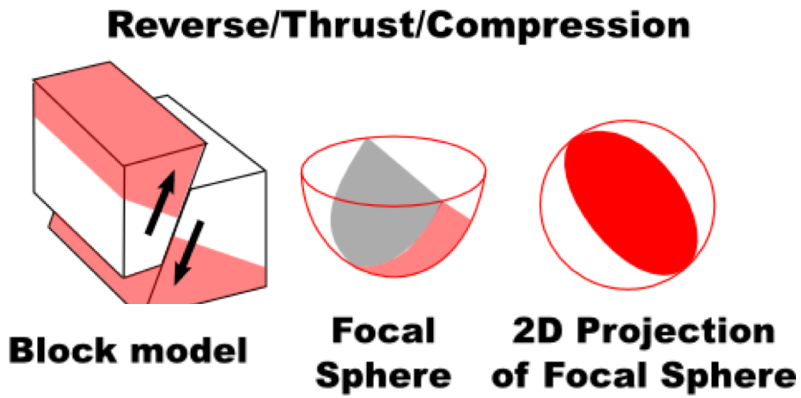
This earthquake occurred as the result of thrust faulting between the subducting Indian Plate and the overriding Eurasian Plate to the north.

At the location of this earthquake the Indian Plate is converging with Eurasia at a rate of 45 mm/yr towards the north-northeast, driving the uplift of the Himalayas and the Tibetan Plateau.

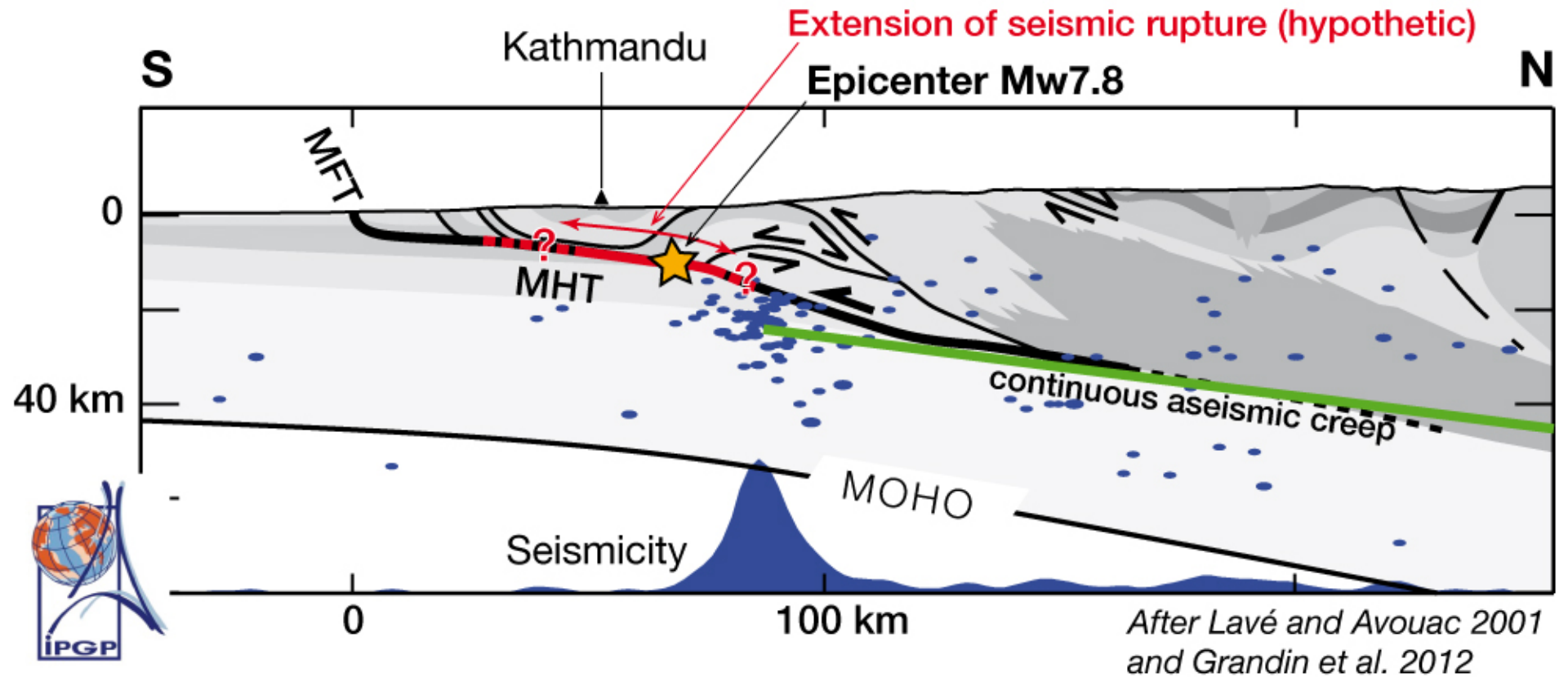




USGS Centroid Moment Tensor Solution



The tension axis (T) reflects the minimum compressive stress direction.
The pressure axis (P) reflects the maximum compressive stress direction.

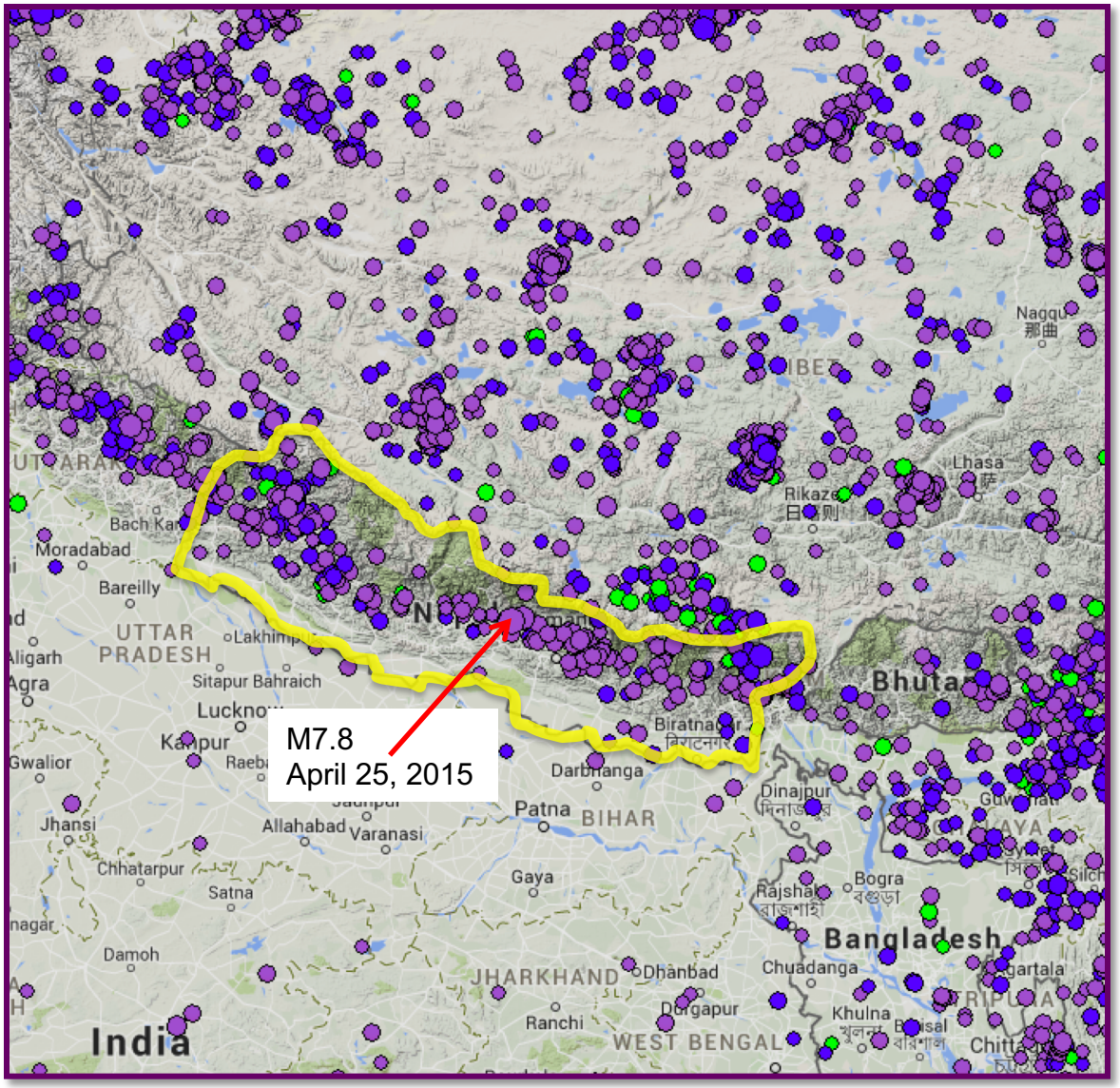


http://www.ipgp.fr/en/central-nepal-earthquake-april-25th-2015

Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

This map shows epicenters of earthquakes since 1990 (>M4) within the India – Asia collision zone. Note the belt of earthquakes along and south of the Himalaya Mountains sweeping through Nepal (yellow outline).

Four earthquakes ≥M6 have occurred within 250 km of the April 25 earthquake over the past century. The largest included a M6.9 in August 1988 and a M8.0 in 1934 which severely damaged Kathmandu. The 1934 earthquake is thought to have caused around 10,600 fatalities.



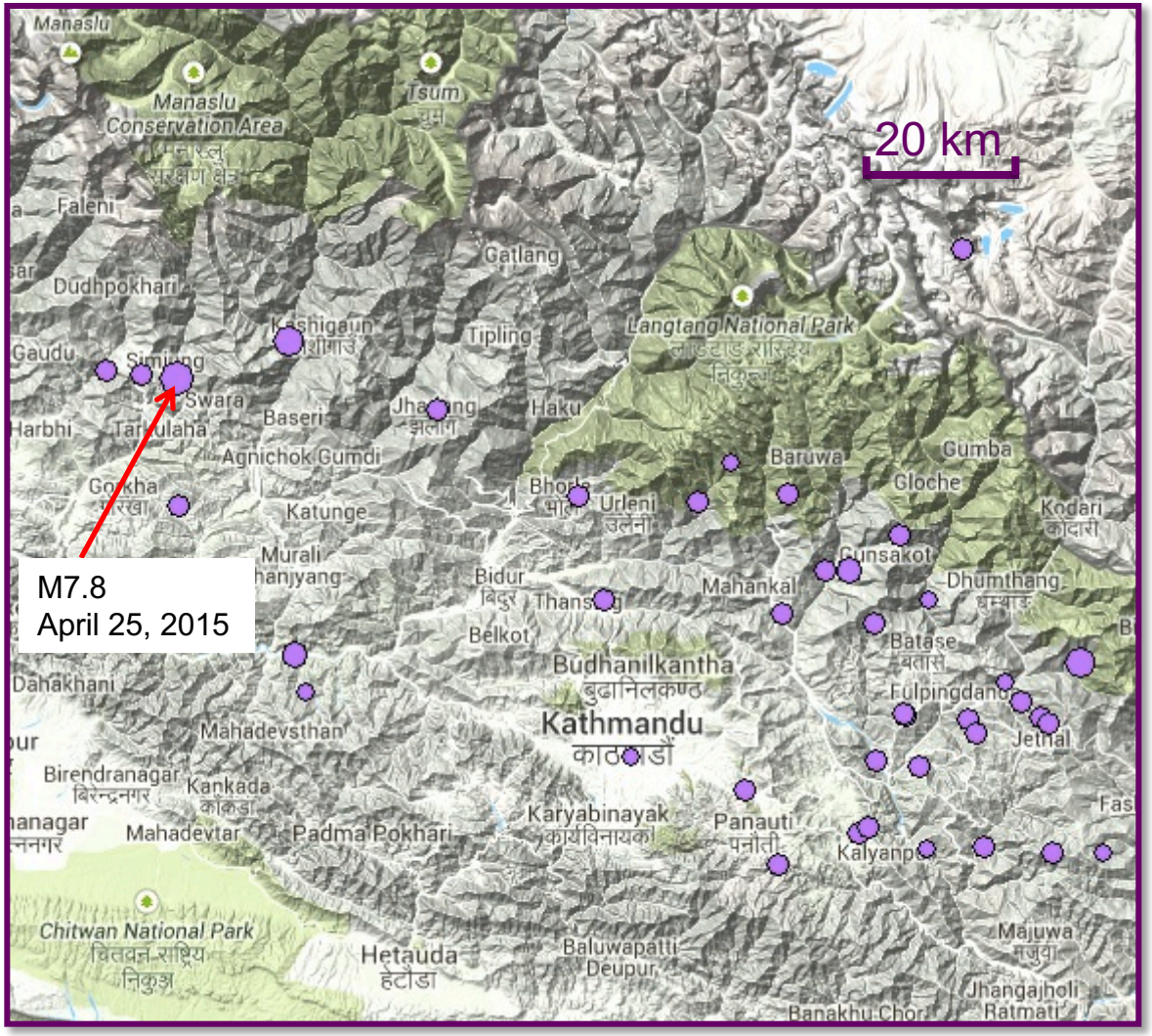
Map created using the IRIS Earthquake Browser: *www.iris.edu/ieb*

Magnitude 7.8 NEPAL
Saturday, April 25, 2015 at 06:11:26 UTC

This map shows the magnitude 7.8 earthquake (mainshock) and the distribution of 40 aftershocks of magnitude 4 or larger that occurred over the following 27 hours.

The aftershock distribution outlines the rupture zone of the mainshock. The rupture during the mainshock initiated beneath the epicenter and propagated toward the southeast.

On the next slide, a map of fault displacement during the earthquake is superimposed on this same map.

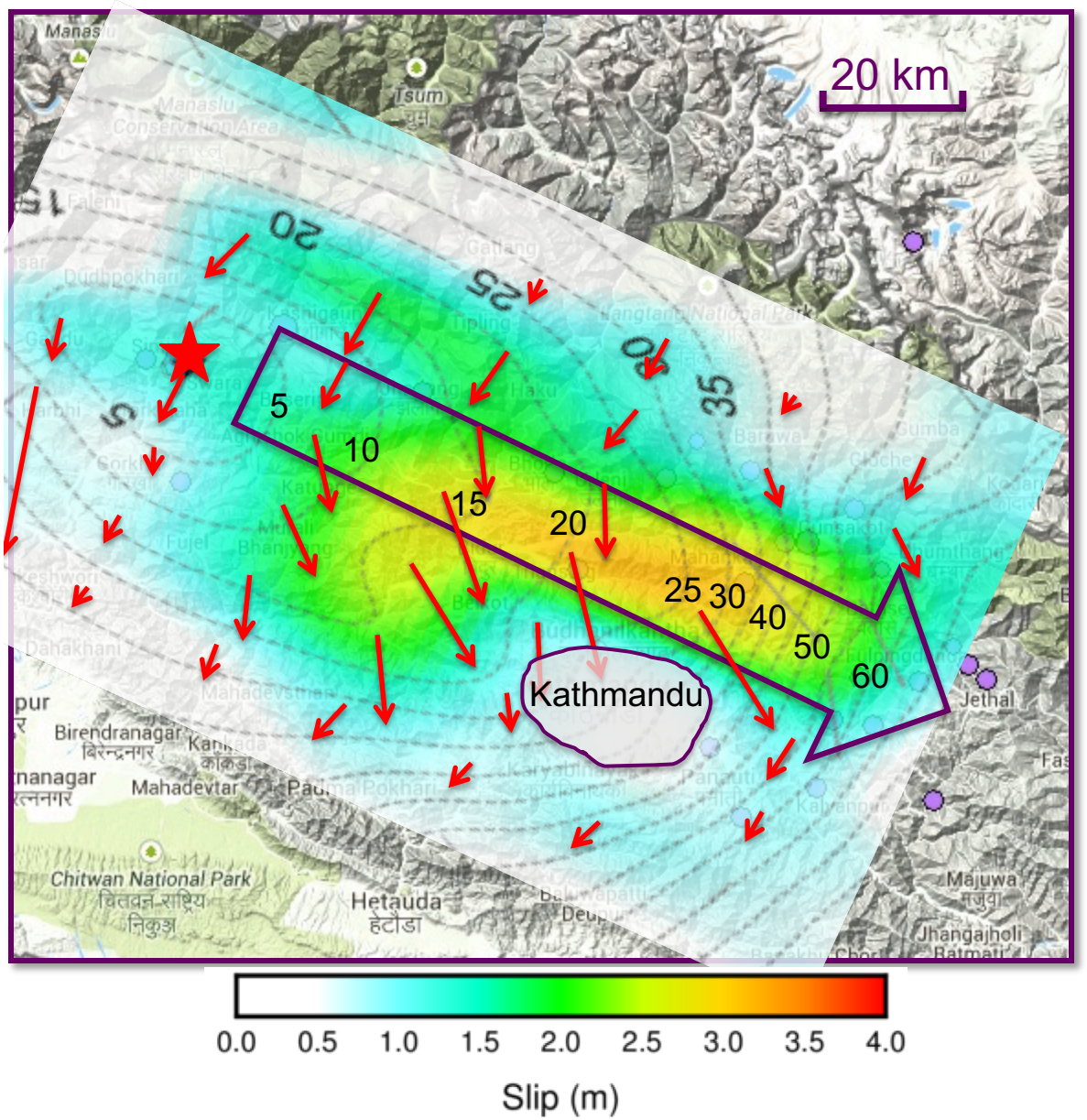


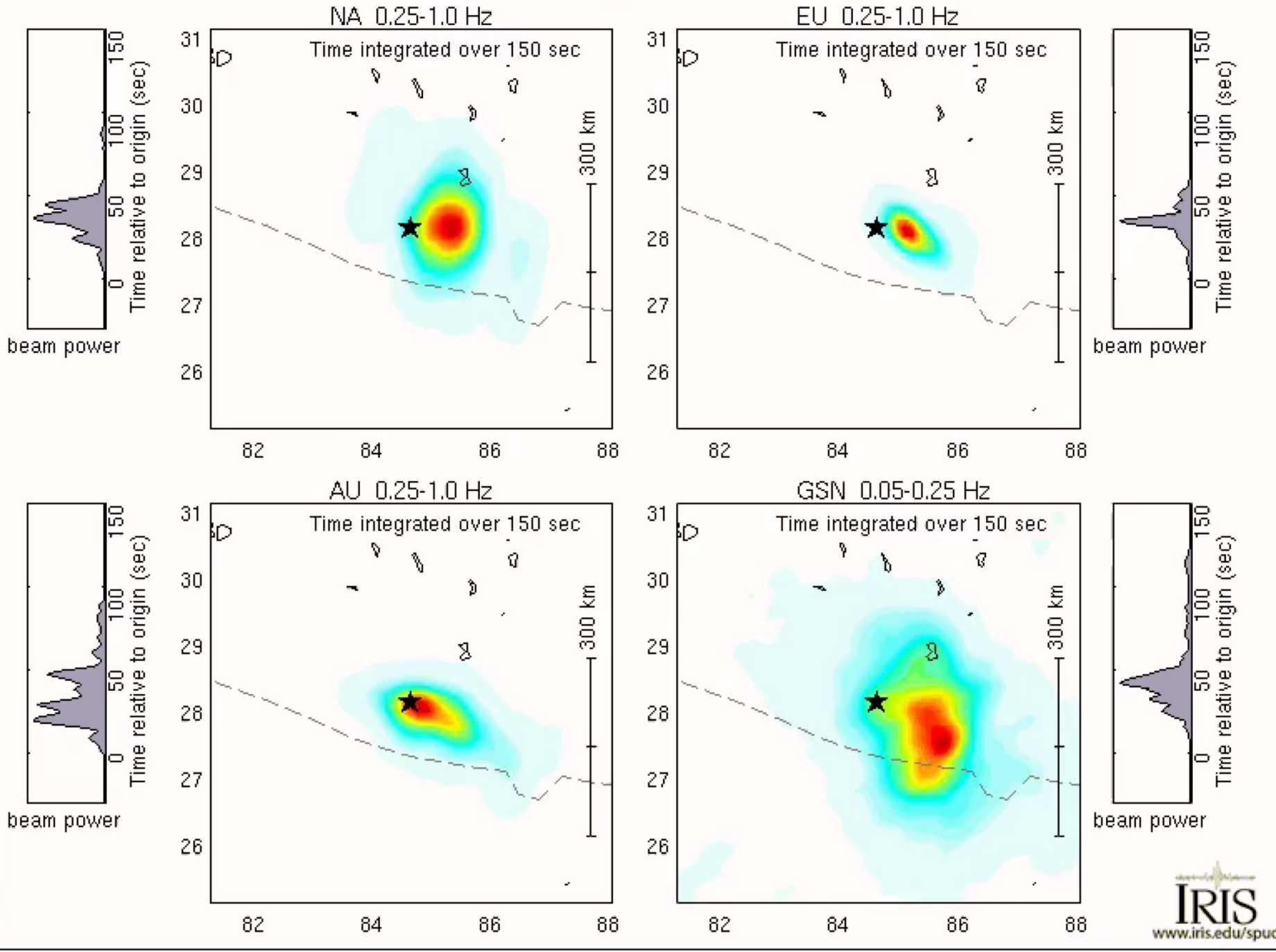
Map created using the IRIS Earthquake Browser: *www.iris.edu/ieb*

Magnitude 7.8 NEPAL

Saturday, April 25, 2015 at 06:11:26 UTC

This map shows fault displacement during this earthquake. The red star is the epicenter while the purple arrow shows the direction of rupture propagation towards the southeast. Contours show the rupture front in 5 second increments after rupture initiation. Small red arrows show the direction and amount of motion of the rocks above the fault with respect to the rocks below the fault. The amount of slip is shown by color of shading. Maximum fault displacement of about 3 meters occurred in the rupture zone about 20 km north of Kathmandu.

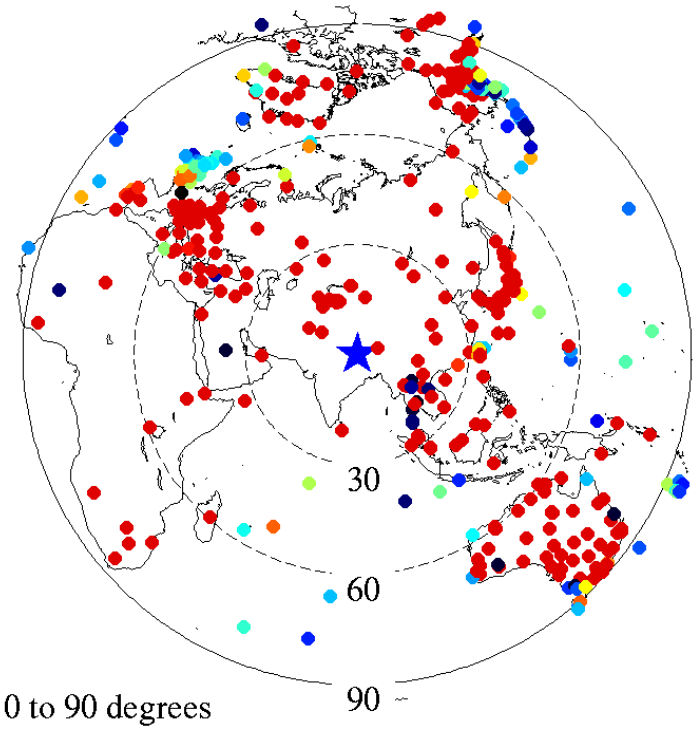



2015/04/25 06:11 M7.9 Z=15km Data
NA 0.25-1.0 Hz
EU 0.25-1.0 Hz
AU 0.25-1.0 Hz
GSN 0.05-0.25 Hz
Time integrated over 150 sec
300 km
beam power
Time relative to origin (sec)
0
50
100
150
26
27
28
29
30
31
82
84
86
88
IRIS
www.iris.edu/spud

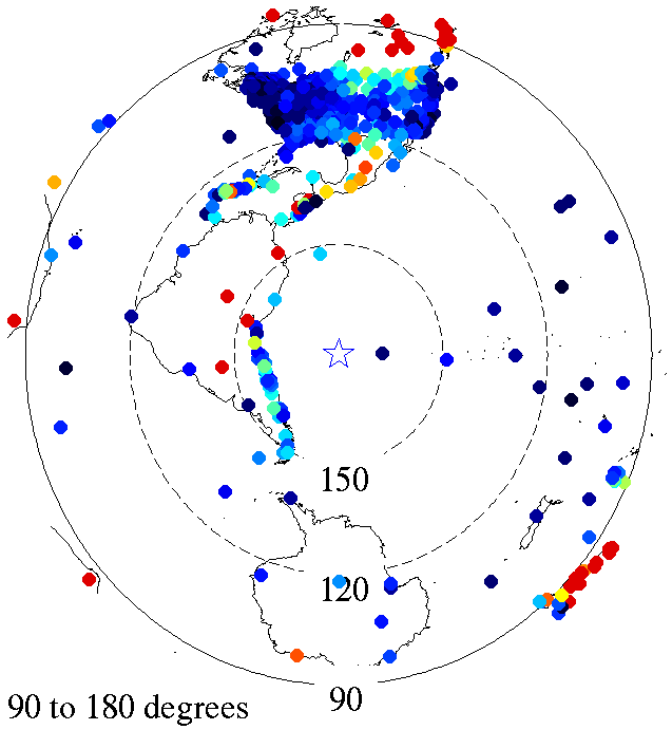
Signal to noise ratio map for all BHZ data at IRIS 0.3to1.0Hz

NEPAL

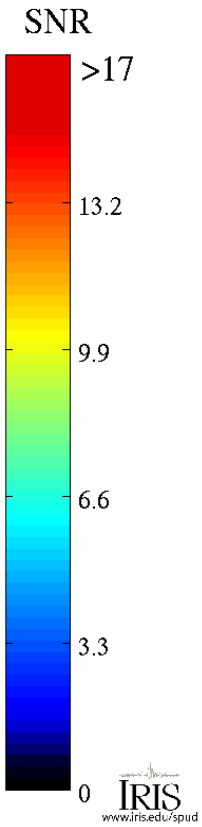
2015/04/25 06:11:25 M7.9 Z=11.9km Lat=28.1654 Lon=84.7251



0 to 90 degrees



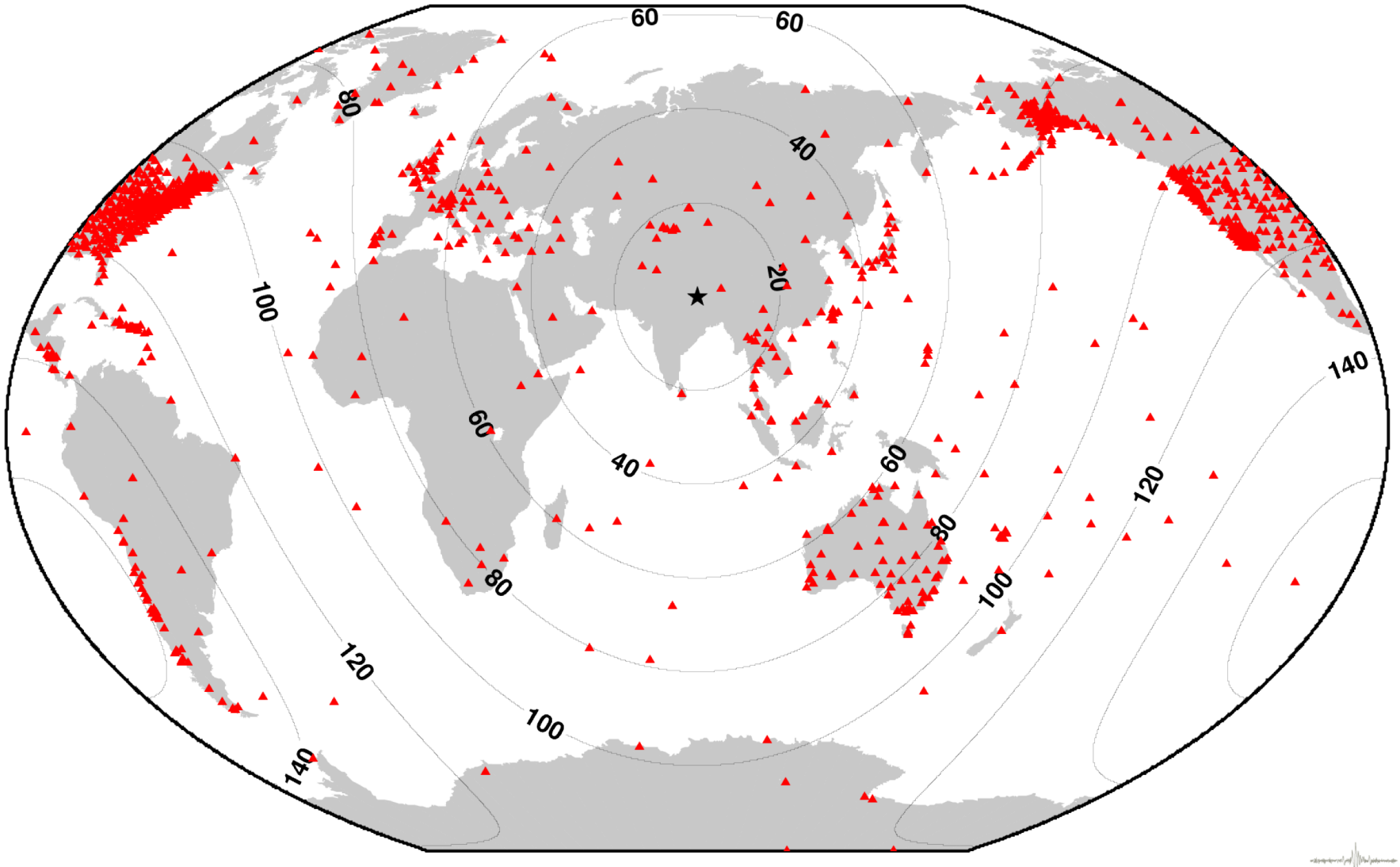
90 to 180 degrees



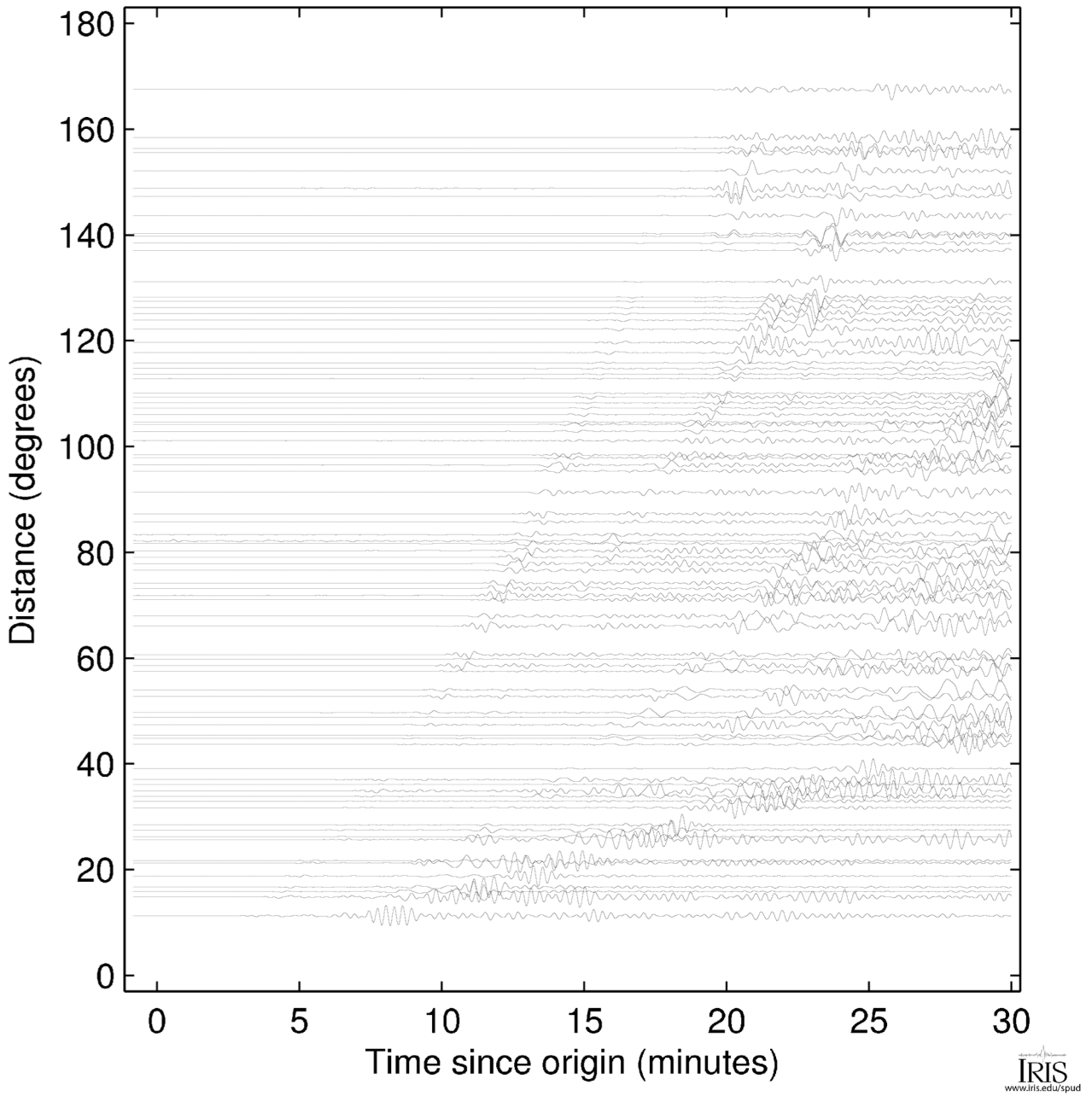
IRIS
www.iris.edu/spud

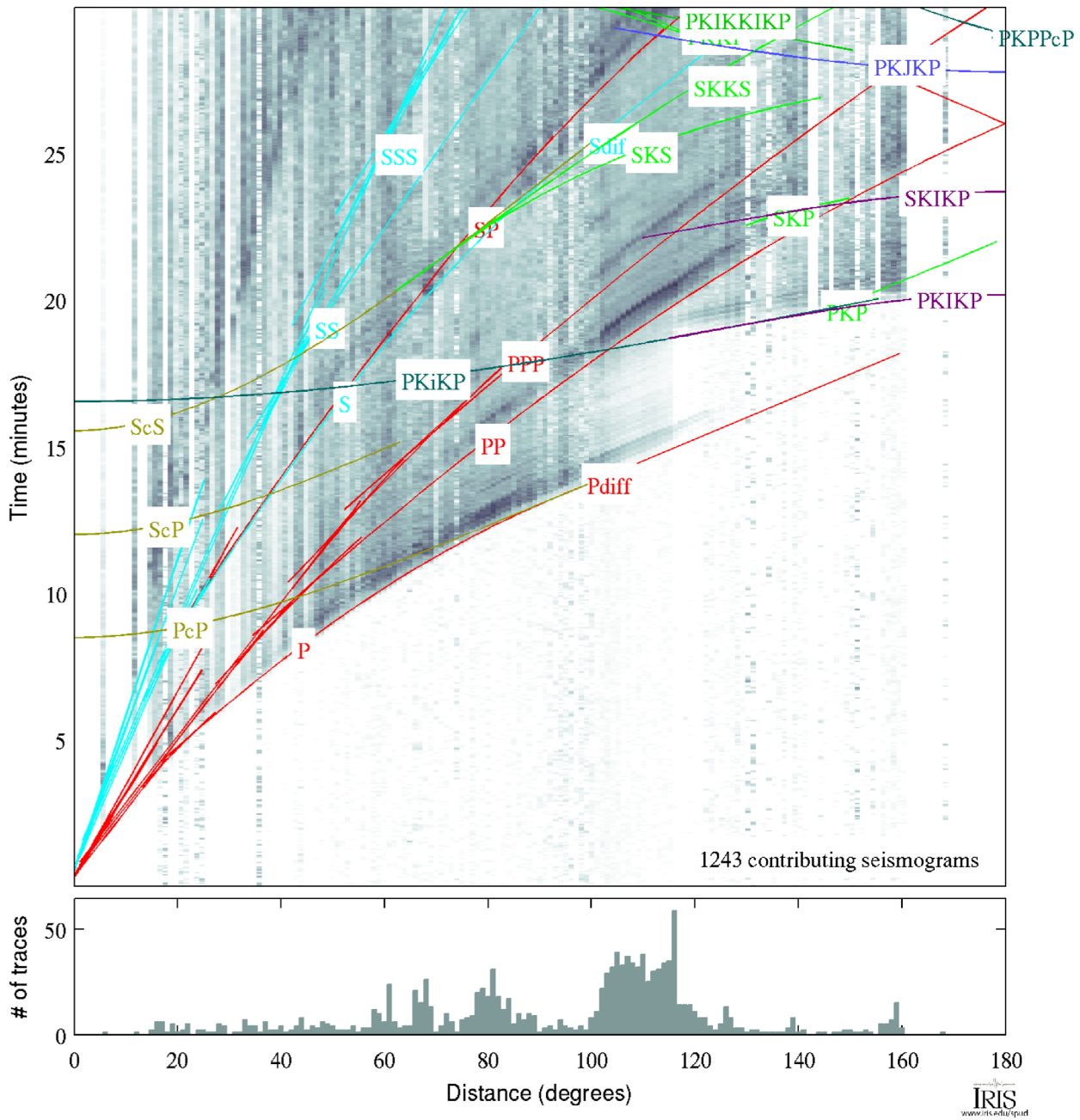
Broadband stations

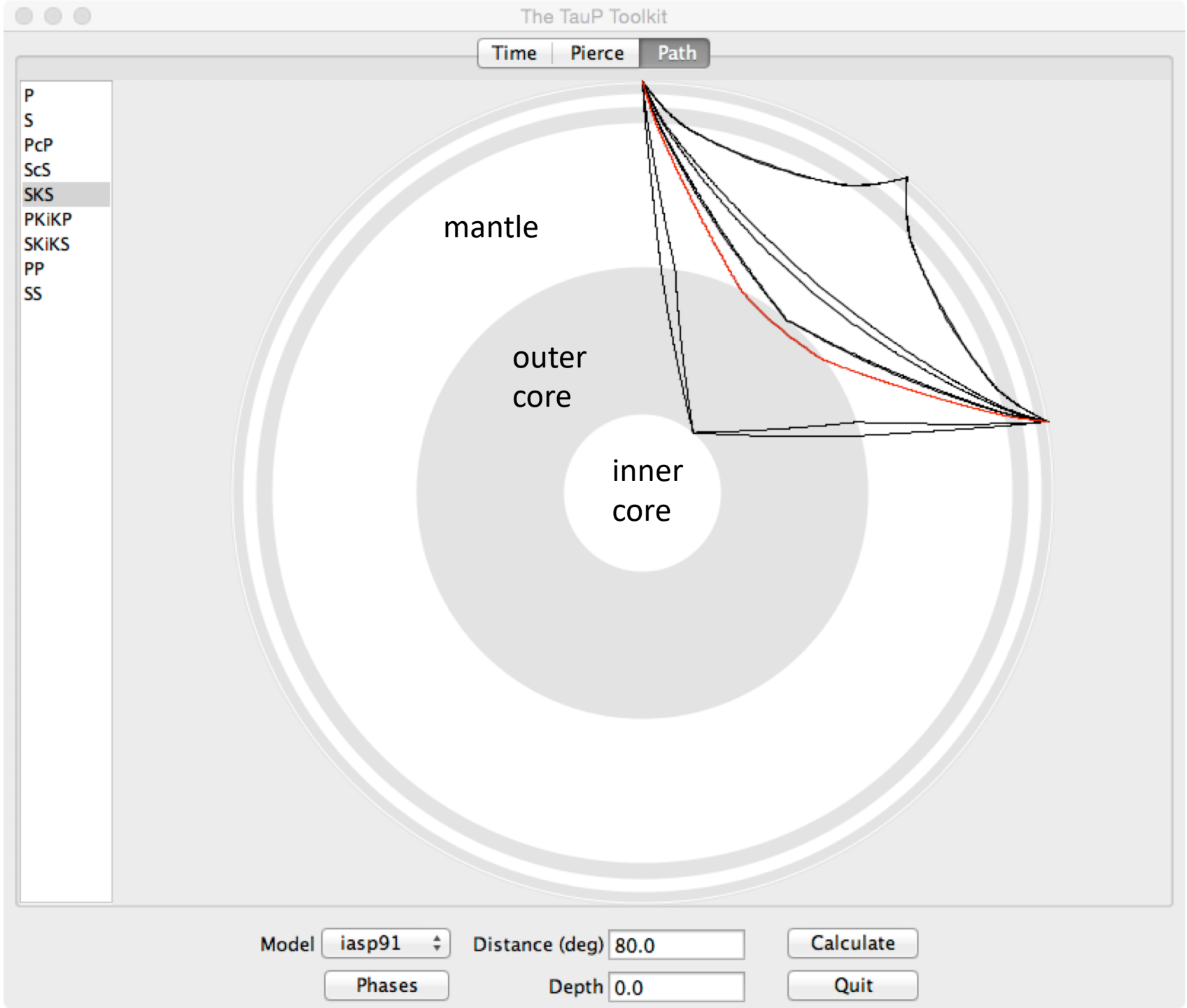
2015/04/25 06:11:25 M7.9 Z=11.9km Lat=28.1654 Lon=84.7251
NEPAL

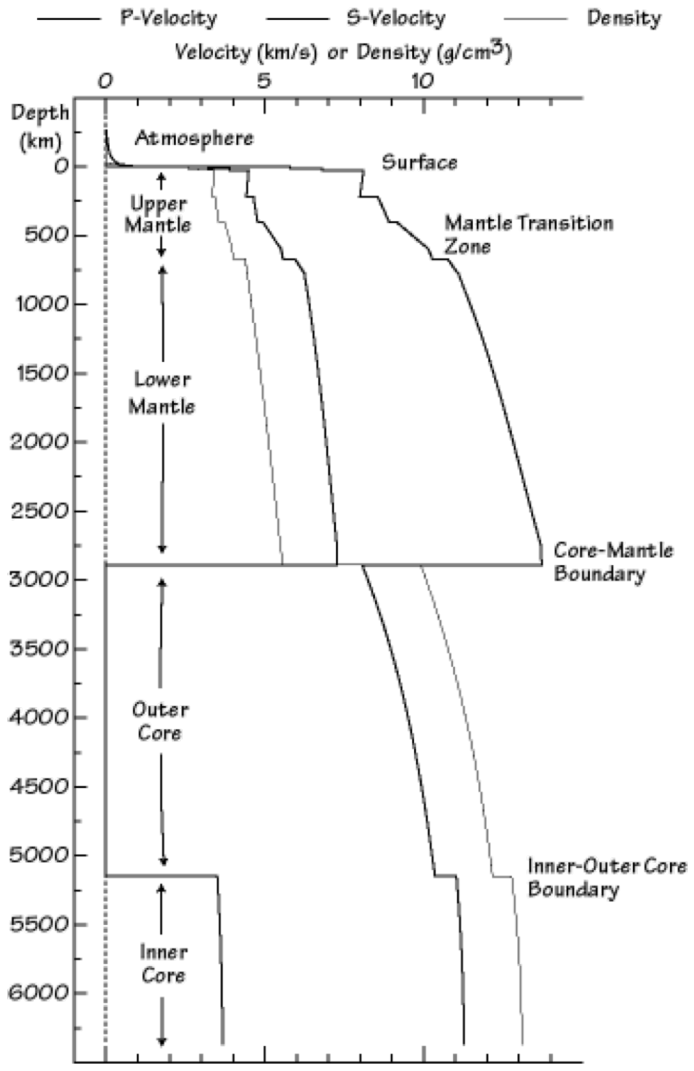


IRIS
www.iris.edu/spud


GSN data combed and aligned on origin 0.01to0.05Hz BHZ
NEPAL
2015/04/25 06:11:25 M7.9 Z=11.9km Lat=28.1654 Lon=84.7251
Distance (degrees)
0
20
40
60
80
100
120
140
160
180
0
5
10
15
20
25
30
Time since origin (minutes)
IRIS
www.iris.edu/spud


Distance binned envelope stacks 0.1to0.5Hz BHZ
2015/04/25 06:11:25 M7.9 Z=11.9km Lat=28.1654 Lon=84.7251
NEPAL
PKIKKIKP
PKPPcP
PKJKP
SKKS
SSS
Sdiff
SKS
SKIKP
SP
SKP
PKIKP
PKP
SS
PPP
PKiKP
S
ScS
PP
Pdiff
ScP
PcP
P
1243 contributing seismograms
Time (minutes)
25
20
15
10
5
# of traces
50
0
0
20
40
60
80
100
120
140
160
180
Distance (degrees)
IRIS
www.iris.edu/spud


The TauP Toolkit
Time
Pierce
Path
P
S
PcP
ScS
SKS
PKiKP
SKiKS
PP
SS
mantle
outer
core
inner
core
Model
iasp91
Distance (deg)
80.0
Calculate
Phases
Depth
0.0
Quit



http://eqseis.geosc.psu.edu/~cammon/HTML/Classes/IntroQuakes/Notes/Images_specific02/prem.gif

Moment Tensor for MW 7.9 (GCMT) NEPAL

Centroid Event

Date-Time (UTC):	2015-04-25 06:11:58
Location:	NEPAL
Latitude, Longitude:	27.910 °, 85.330 °
Magnitude:	7.9 MW
Depth:	12.0 km
Author:	Global CMT Project
Catalog, Contributor:	GCMT, GCMT

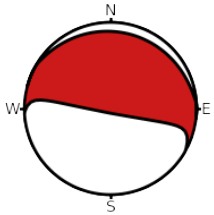
Event

Date-Time (UTC):	2015-04-25 06:11:25
Location:	NEPAL
Latitude, Longitude:	28.231 °, 84.731 °
Magnitude:	7.8 MWW (US)
Depth:	8.2 km
Author:	US
Catalog, Contributor:	NEIC PDE, NEIC COMCAT
Related Products:	

CMT Details

Event ID	C201504250611A
Timestamp:	S-20150713124123
CMT Version:	Final
NDK Version:	V10
Reference Catalog:	PDEW
Source	Zero Trace
Moment Rate Fn:	TRIHD
Half Duration:	21.3
Depth Determination:	FIX
Scalar Moment	8.386 e+27 (dyne-cm)

Focal Mechanism



Moment Tensor (Exponent: 27)

Component	Value	Error
Mrr	1.76	0.004
Mtt	-1.82	0.004
Mpp	0.058	0.004
Mrt	8.04	0.042
Mrp	-1.51	0.049
Mtp	0.475	0.003

Principal Axes (Exponent: 27)

Name	Azimuth	Plunge	Length
T	10	51	8.302
N	101	1	0.166
P	191	39	-8.471

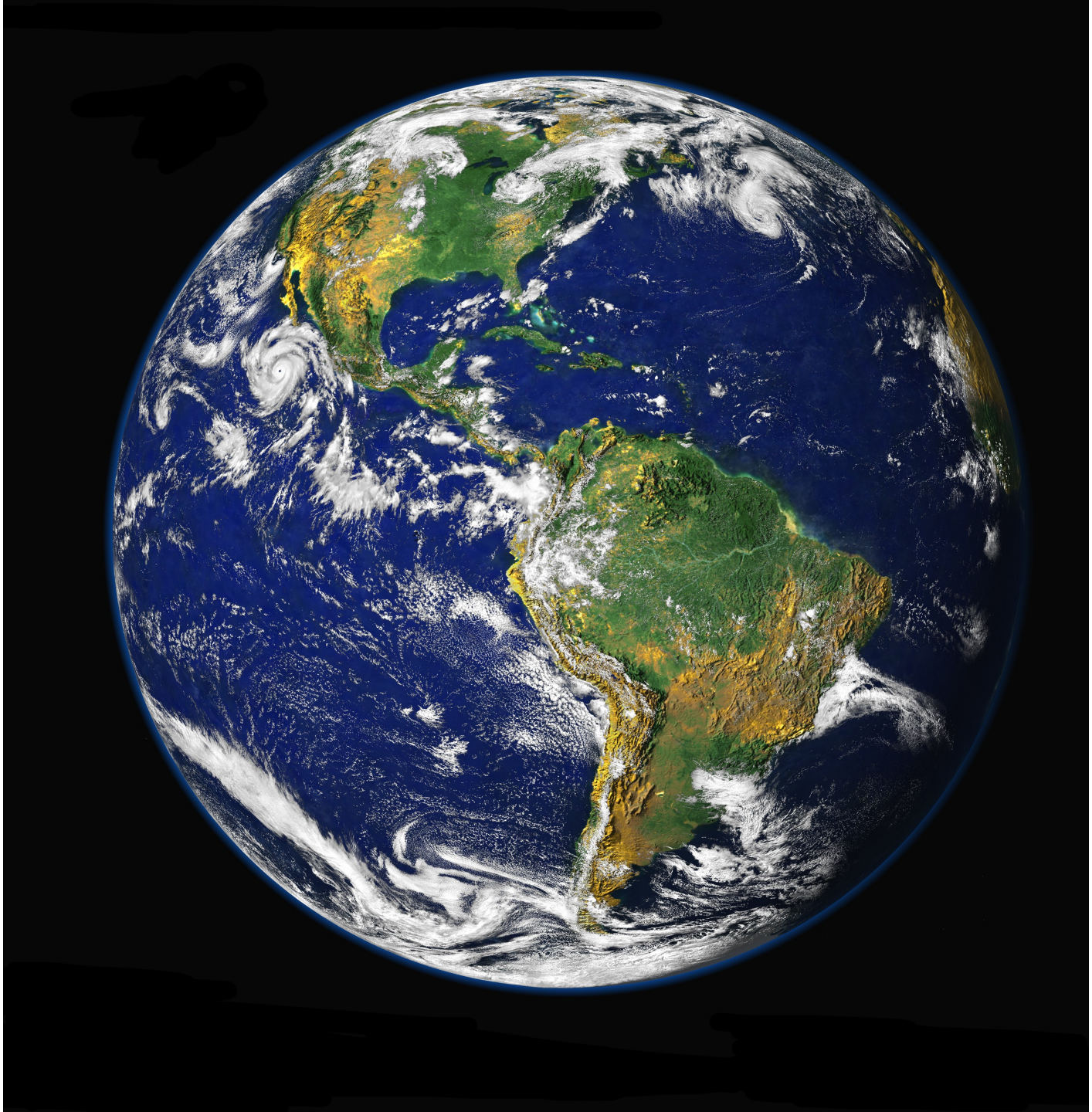
Nodal Planes

Name	Strike	Dip	Rake
NP1	287	6	96
NP2	101	84	89

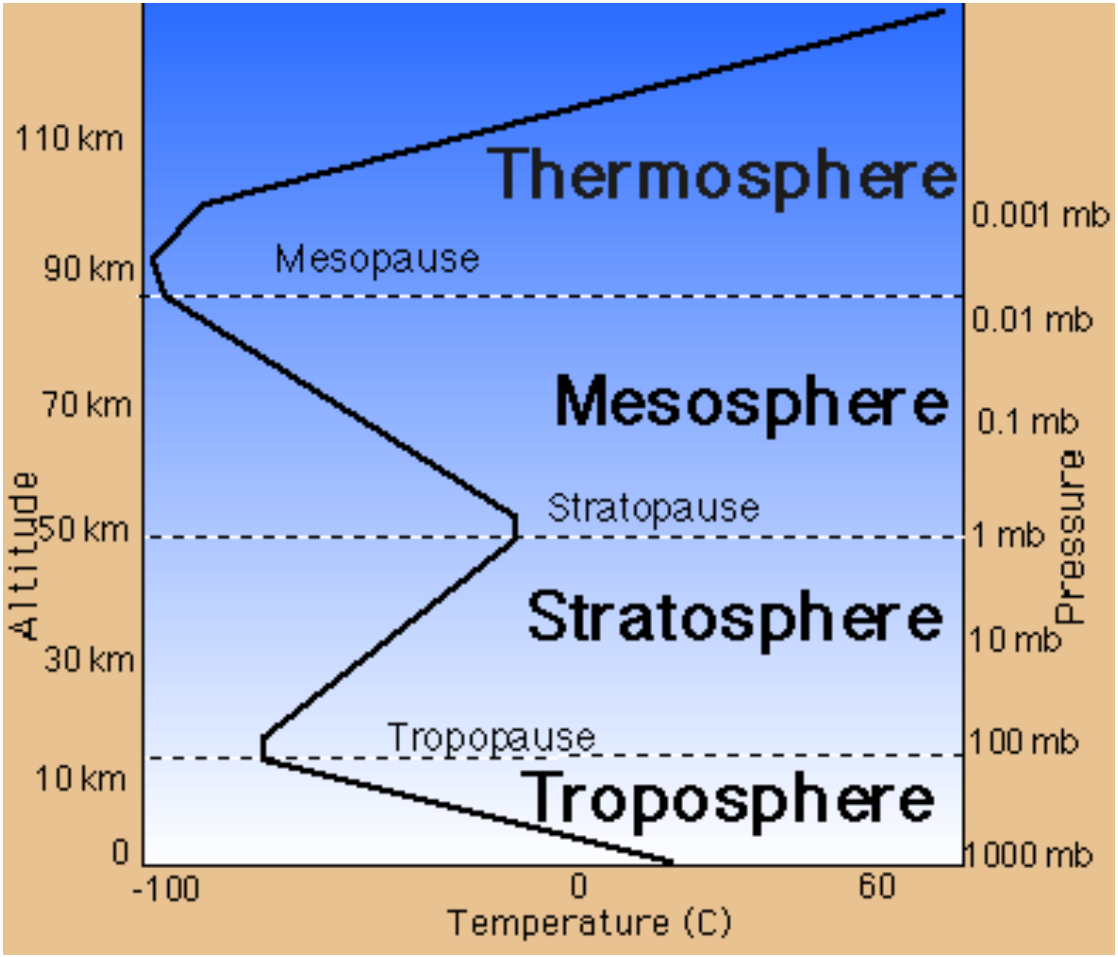
Data Used in Inversion

Type	Stations	Components	Shortest Period
Body Waves	174	469	50
Mantle Waves	172	480	150
Surface Waves	160	380	50

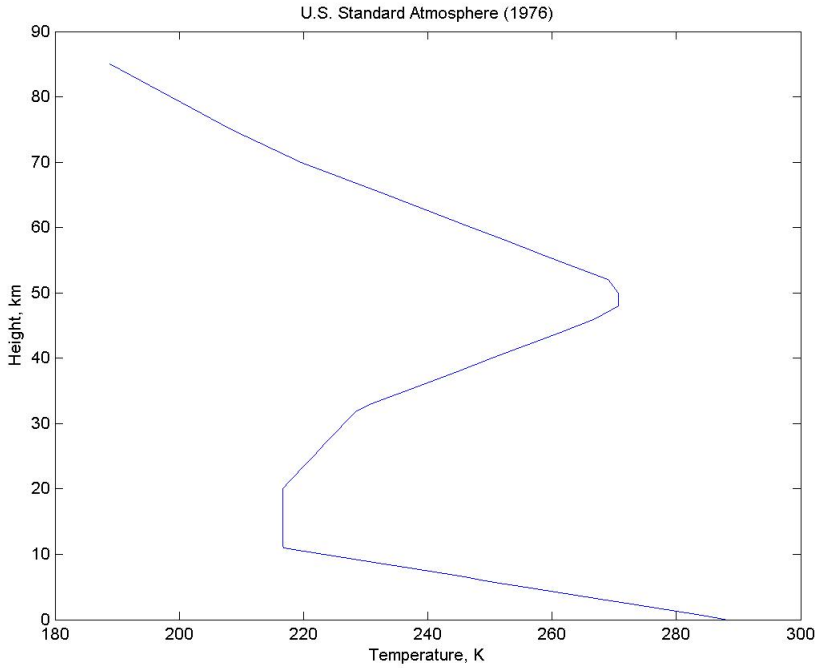
Event Location

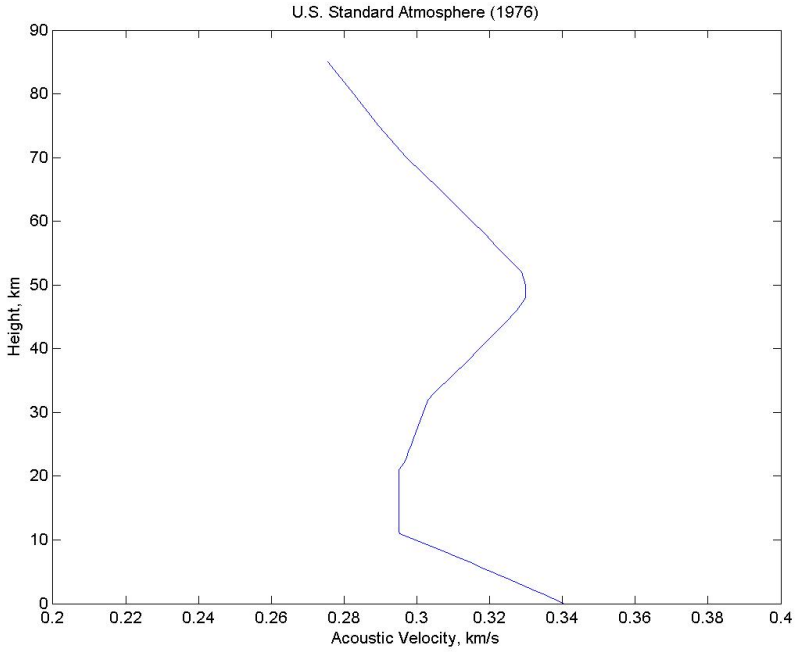


nasa



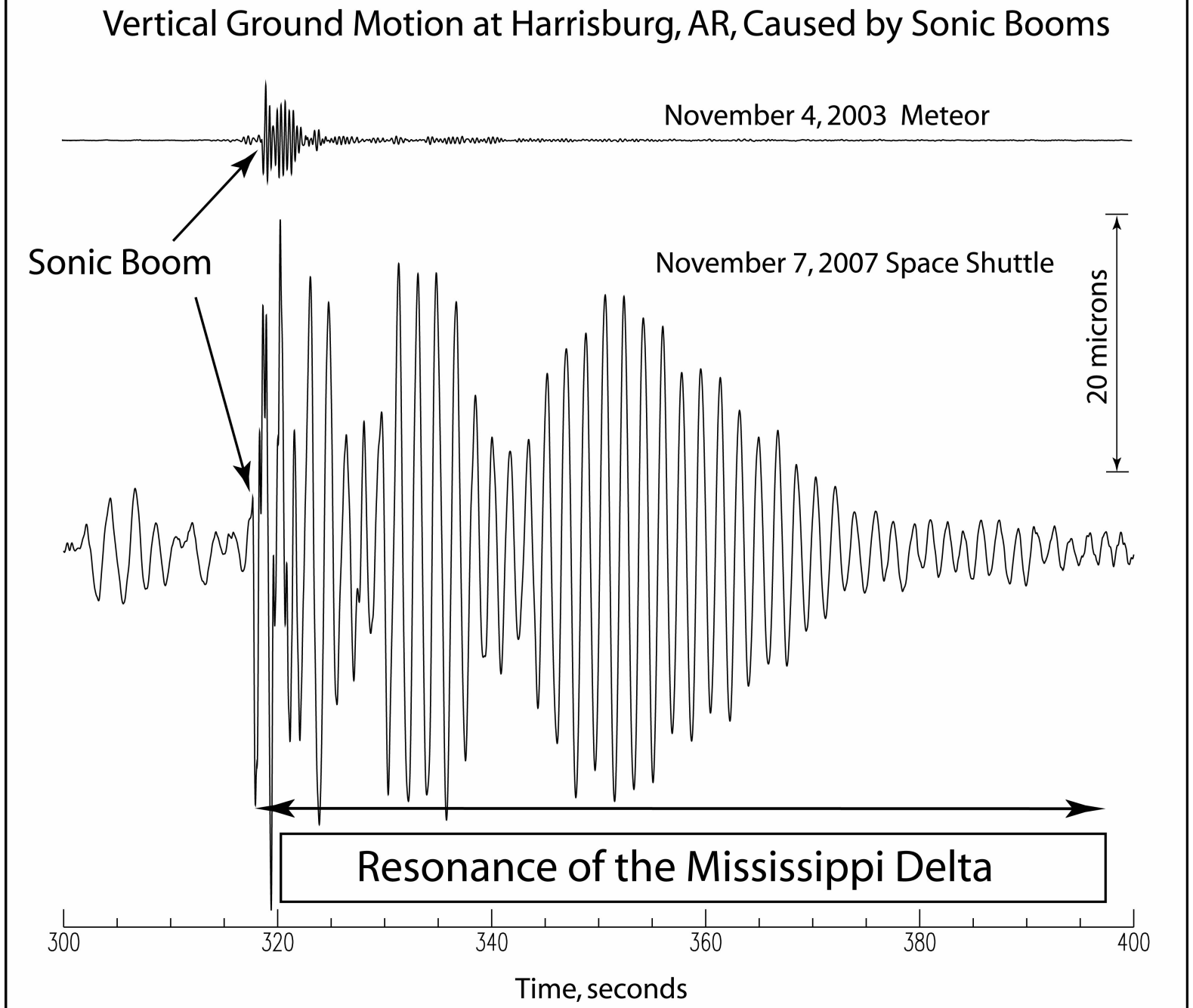
http://teachertech.rice.edu/Participants/louviere/Images/profile.gif

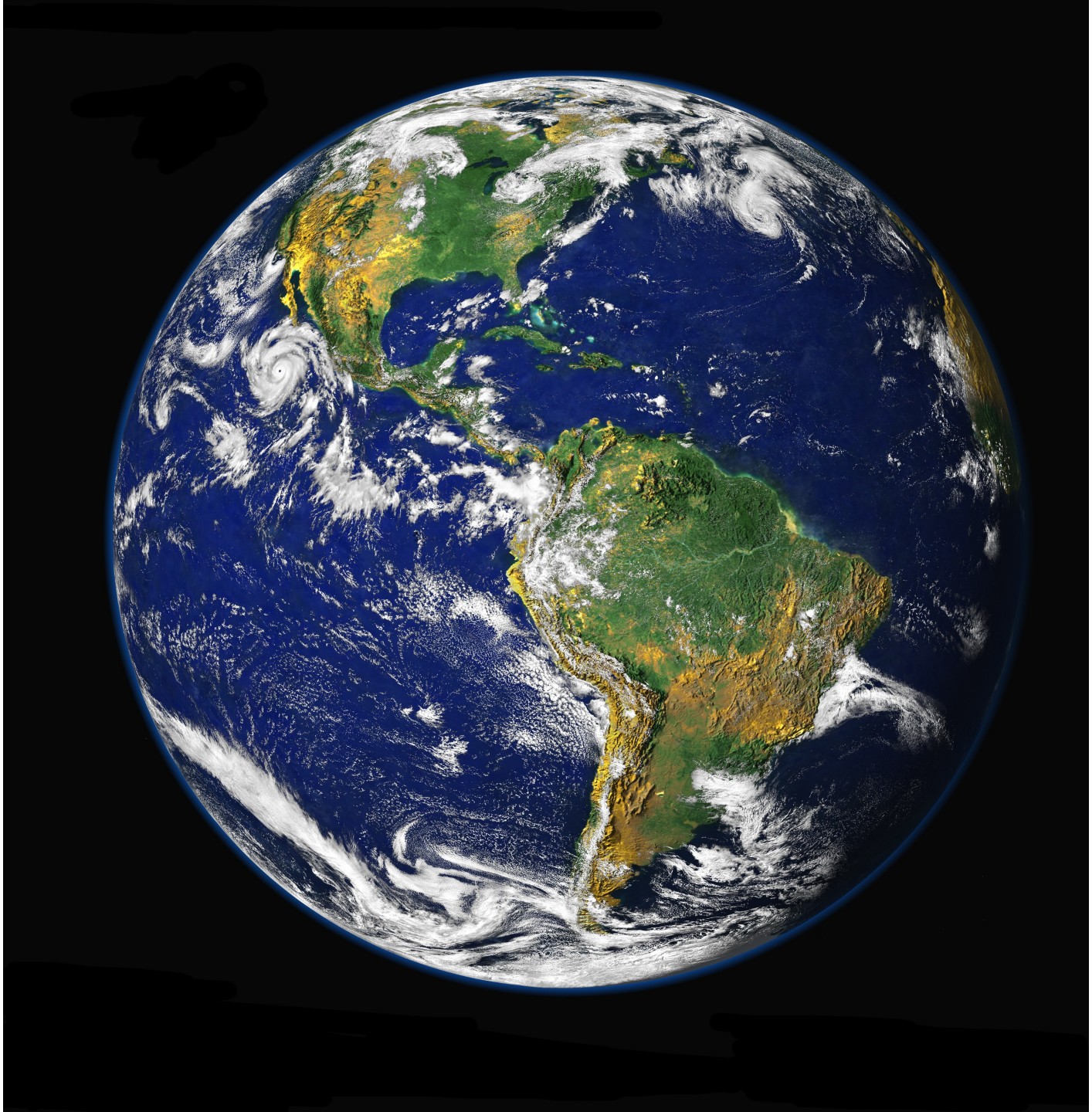




$$c_{eff} = \sqrt{\gamma_g RT} + \hat{n} \cdot \vec{u}$$

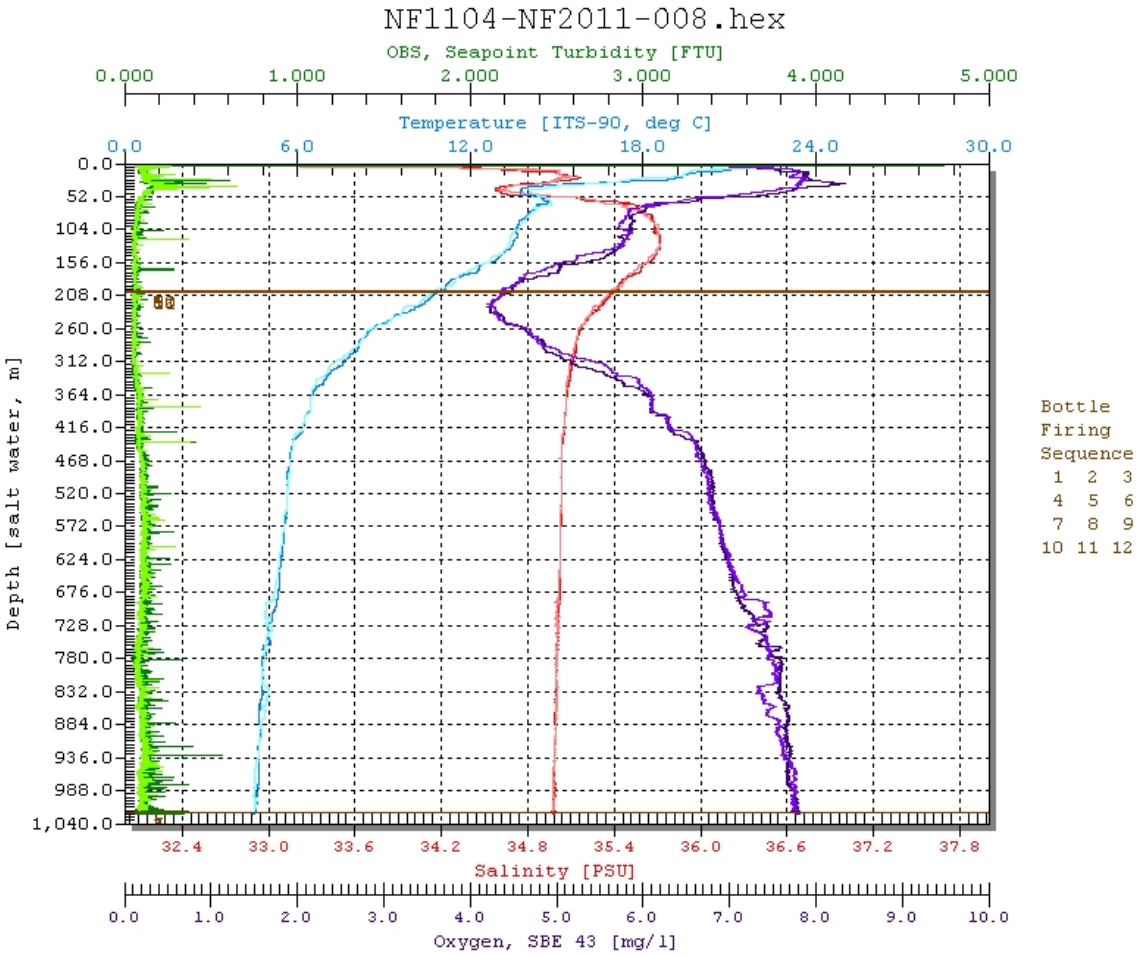
where $\vec{u}$ is wind direction


Vertical Ground Motion at Harrisburg, AR, Caused by Sonic Booms
November 4, 2003 Meteor
Sonic Boom
November 7, 2007 Space Shuttle
20 microns
Resonance of the Mississippi Delta
300
320
340
360
380
400
Time, seconds

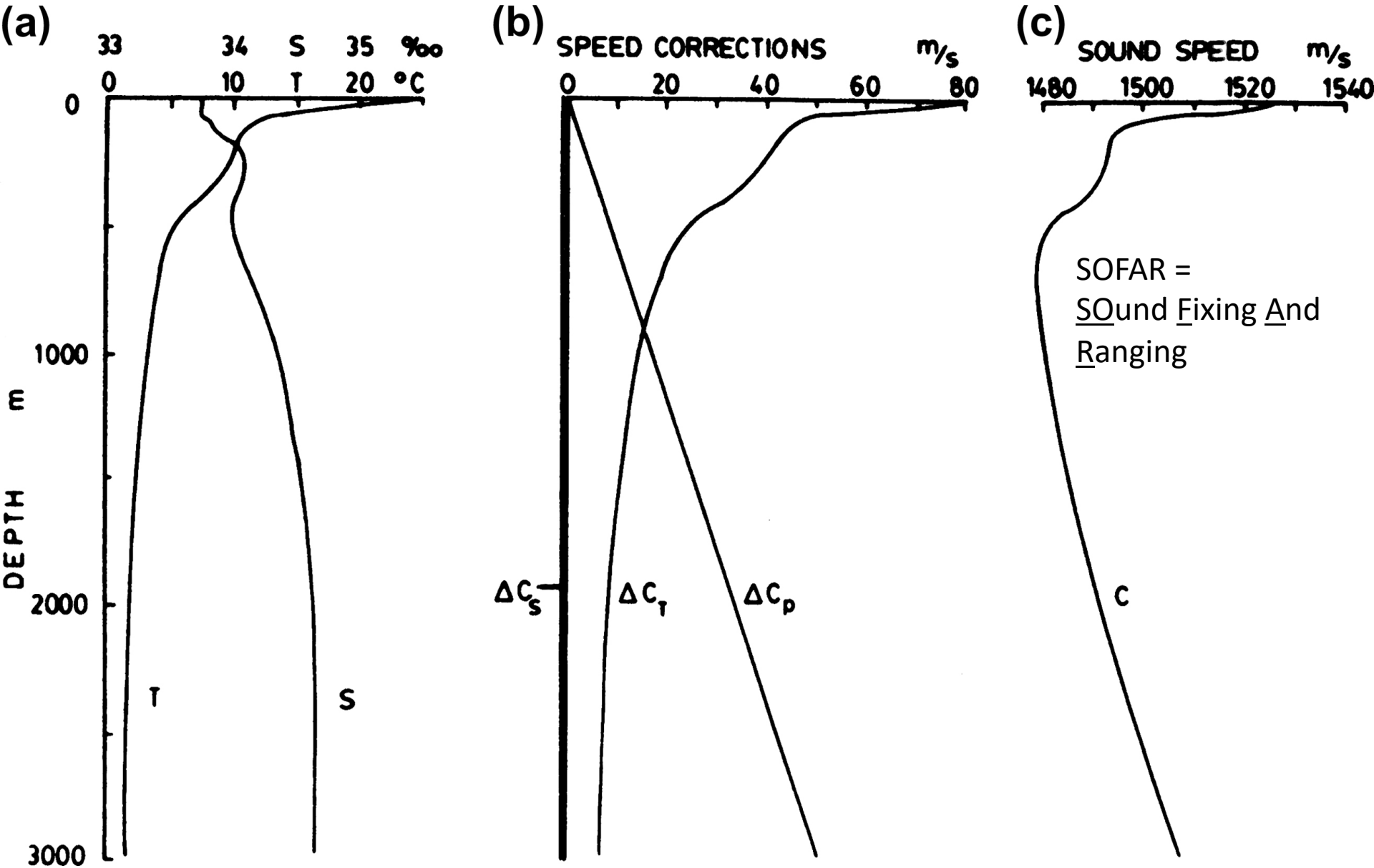


nasa

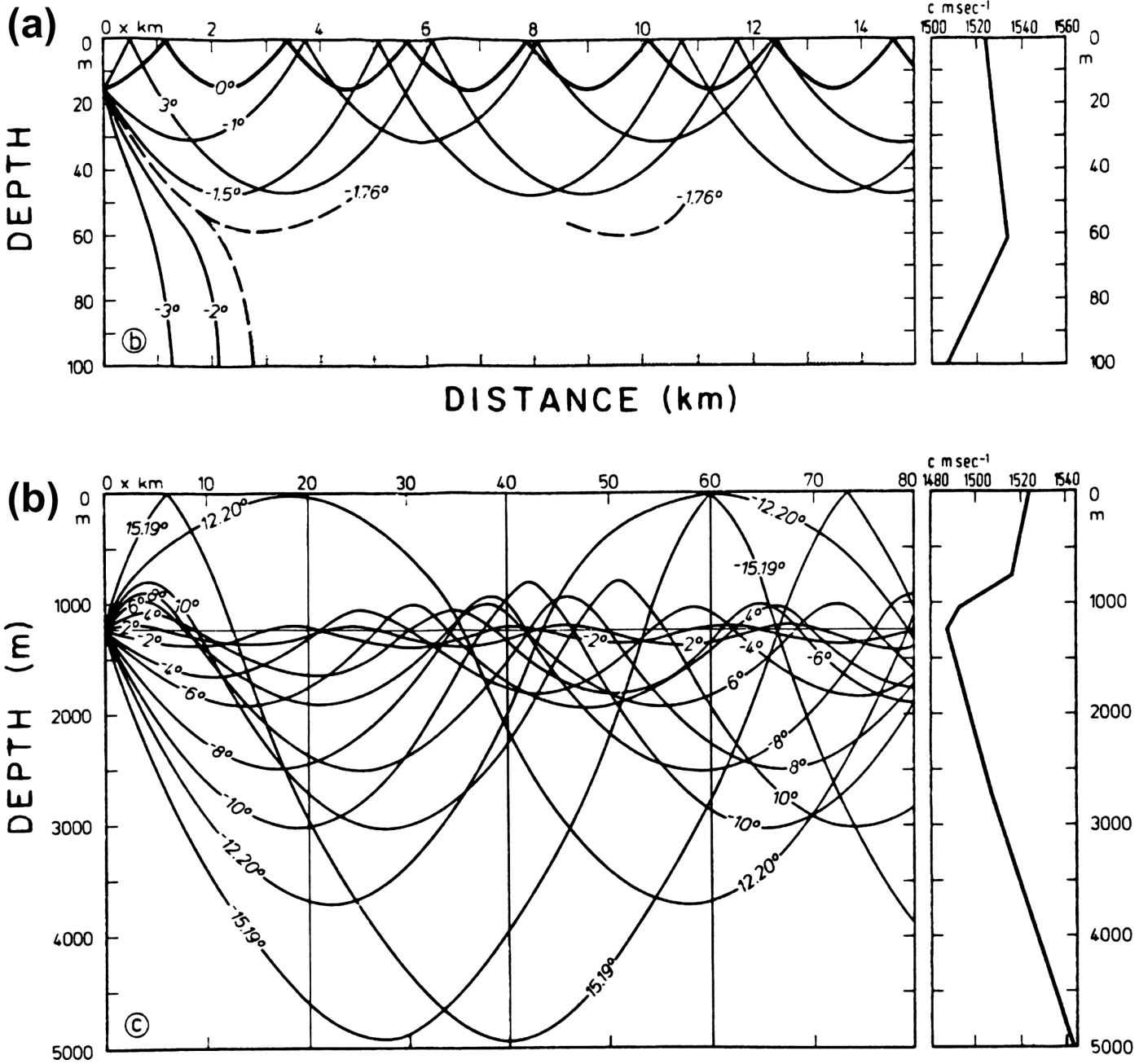
Ocean Velocity Structure



http://deepwatercanyons.files.wordpress.com/2011/06/nf1104-nf2011-008.jpg



http://booksite.academicpress.com/DPO/gallery/ch03/003007ac_full.jpg



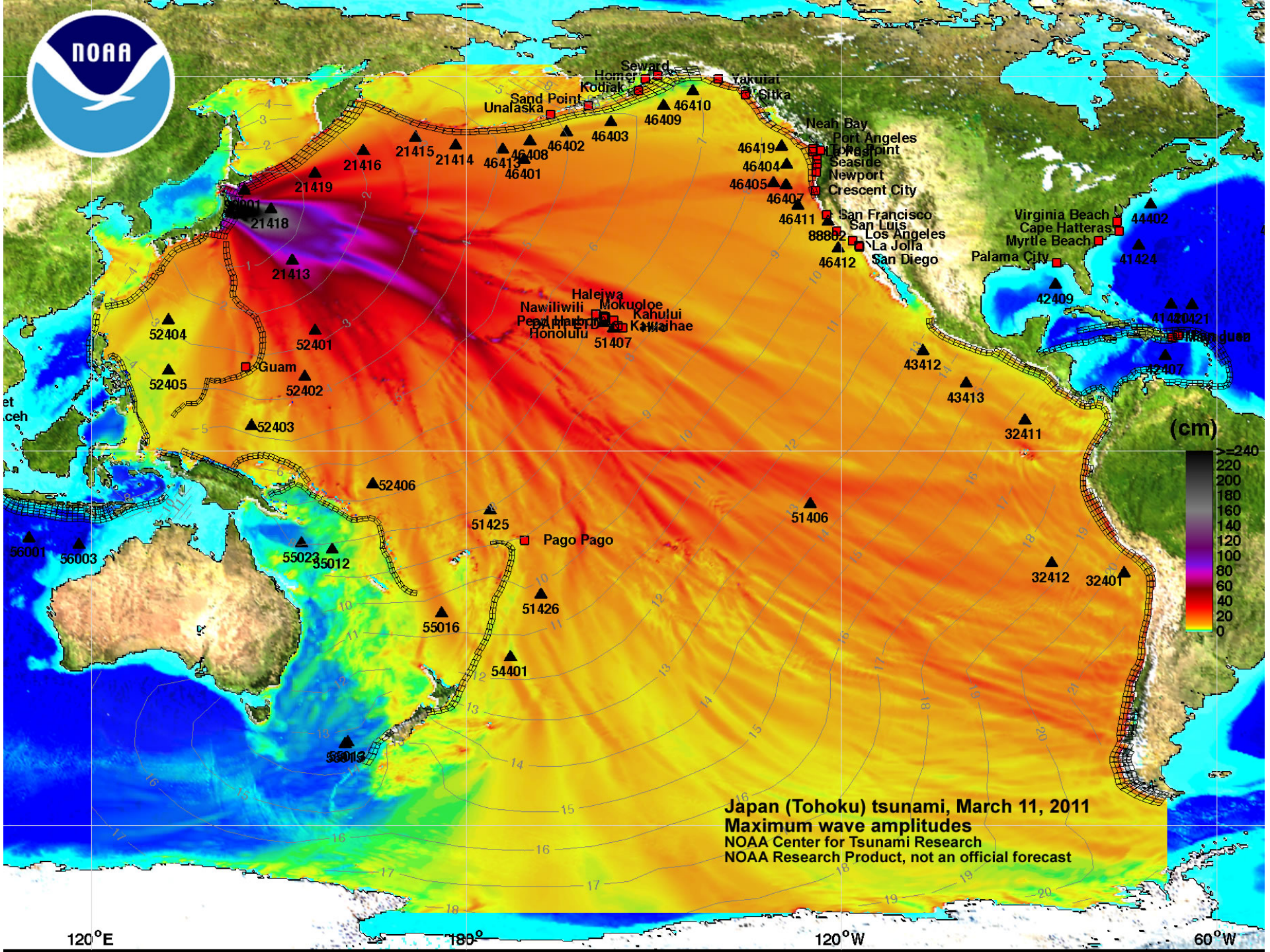
http://booksite.academicpress.com/DPO/gallery/ch03/003008ab_full.jpg

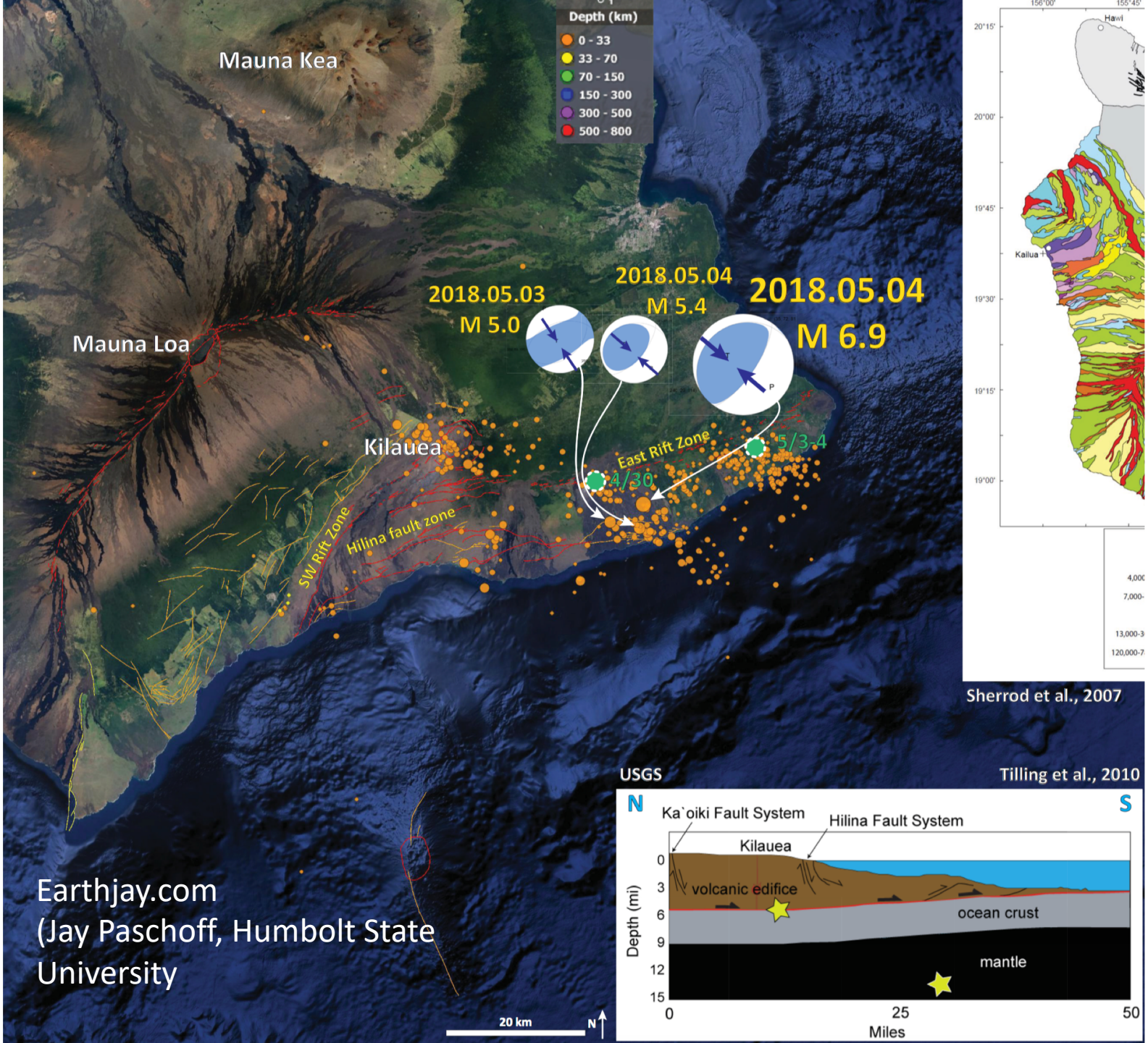
Show only before

Show only after

Before: Waves breech an embankment in Miyako, Iwate prefecture, on March 11, 2011. (Toru Yamanaka / AFP/Getty Images).

After: Jan. 16, 2012. (Toru Yamanaka / AFP/Getty Images)


Seward
Homer
Kodiak
Yakutat
Sitka
Sand Point
Unalaska
46410
46409
46403
46402
46408
46401
21415
21414
21416
21419
21418
21413
46419
46404
46405
46407
46411
88882
46412
Neah Bay
Port Angeles
Seaside
Newport
Crescent City
San Francisco
San Luis
Los Angeles
La Jolla
San Diego
Virginia Beach
Cape Hatteras
Myrtle Beach
Palama City
44402
41424
42409
41420
41421
42407
43412
43413
32411
32412
32401
Halejwa
Nawiliwili
Mokuoloe
Kahului
Honolulu
51407
52404
52401
52405
Guam
52402
52403
52406
51425
Pago Pago
51406
56001
56003
55023
55012
55016
51426
54401
55013
(cm)
>=240
220
200
180
160
140
120
100
80
60
40
20
0
Japan (Tohoku) tsunami, March 11, 2011
Maximum wave amplitudes
NOAA Center for Tsunami Research
NOAA Research Product, not an official forecast
120°E
180°
120°W
60°W


Depth (km)
0 - 33
33 - 70
70 - 150
150 - 300
300 - 500
500 - 800
Mauna Kea
Mauna Loa
Kilauea
2018.05.03
M 5.0
2018.05.04
M 5.4
2018.05.04
M 6.9
East Rift Zone
4/30
5/3-4
SW Rift Zone
Hilina fault zone
20 km
N
Earthjay.com
(Jay Paschoff, Humbolt State University
Sherrod et al., 2007
USGS
Tilling et al., 2010
N
S
Ka`oiki Fault System
Hilina Fault System
Kilauea
volcanic edifice
ocean crust
mantle
Depth (mi)
0
3
6
9
12
15
0
25
50
Miles

Zhigong Peng, Georgia Tech