

# **National seismological network & real time earthquake monitoring**



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***Ministry of Earth Sciences***

***New Delhi-110003***

***Indo-Taiwan Workshop on “Earthquake Early Warning  
System”***

***(16-19 January 2013)***

# MANDATE

**As a nodal agency of Govt  
the primary role of IMD is to  
provide information on  
earthquake occurrences  
in and around India  
in least possible time  
for effective management of**

**EARTHQUAKE & TSUNAMI  
DISASTERS**

### **Earthquake Monitoring:**

- Real time seismic monitoring on 24X7 basis.
- Country-wide network of 82 seismological observatories - Real time data receipt, processing and information dissemination system through SMS, FAX, email, IVRS and Website. ([www.imd.gov.in](http://www.imd.gov.in) ).
- Includes 17-stations for early warning of tsunamis and two V-SAT based telemetry clusters in Delhi and Northeast India.

### **Seismological Services:**

- Seismological data compiled, processed, analyzed and archived systematically.
- Monthly National Seismological Bulletins prepared.
- Analog seismograms are scanned and vector digitized.
- Earthquake data / seismicity reports of specific regions shared with various user agencies and research community.
- Training programs/ refresher courses in Seismology conducted regularly.

### **Research & Development:**

- R&D studies for better understanding of Crust and upper Mantle structure, earthquake source characteristics, earthquake precursor studies, etc.
- Bilateral collaboration with international agencies.

# **ORGANIZATIONS OPERATING SEISMIC STATIONS / NETWORKS**

## **India Meteorological Department - National agency**

- **National Geophysical Research Institute, Hyderabad**
- **Wadia Institute of Himalayan Geology, Dehradun**
- **Regional Research Laboratory, Jorhat**
- **Institute of Seismological Research, Gandhinagar**
- **Bhaba Atomic Research Centre, Mumbai**
- **Indian Institute of Geomagnetism, Mumbai**
- **Geological Survey of India, Kolkatta**
- **National Institute of Rock Mechanics, Kolar**
- **Central Scientific Instruments Organisation, Chandigarh**
- **Centre for Earth Science Studies, Tiruvananthapuram, etc.**
- **Maharashtra Engineering Research Institute**
- **Gujarat Engineering Research Institute**
- **Sardar Sarovar Narmada Nigam Ltd.**
- **Narmada Valley Development Authority**
- **Kerala State Electricity Board, etc**
- **IITs – Roorkee / Kharagpur**
- **Manipur University, Imphal**
- **Indian School of Mines, Dhanbad**
- **Kurukshetra University**
- **Kumaun University, etc.**
- **...**



# ***IMD'S NETWORK EXPANSION***

## **Pre-instrumental era- (Prior to 1900):**

1898 : FIRST SEISMOLOGICAL OBSERVATORY SET UP AT KOLKATTA.

## **Early Instrumental era- (1900-1963):**

~1947 : **FIVE** OBSERVATORIES.

~1950 : **EIGHT** OBSERVATORIES.

~1960 : **FIFTEEN** OBSERVATORIES.

## **Modern instrumental era- (1964 –1995):**

1964 : FOUR WWSSN EQUIPMENT INSTALLED.

~1970 : **EIGHTEEN** OBSERVATORIES.

1978 : SRO EQUIPMENT INSTALLED AT SHILLONG.

1980 : **FORTY FIVE** OBSERVATORIES.

1991 : FOUR DIGITAL STAND-ALONE SYSTEMS INDUCTED.

## **Digital era- (1996- ):**

1996 : DIGITAL SEISMIC SYSTEMS (**10+14** GSN STANDARD) INDUCTED.

2001 : DIGITAL TELEMETRY NETWORK (**16**) AROUND DELHI.

2007 : REAL TIME SEISMIC MONITORING NETWORK (**17**) FOR TSUNAMIS.

2011 : REAL TIME SEISMIC MONITORING NETWORK (**20**) FOR NE INDIA.

# **A TOTAL OF 82 STATIONS IN OPERATION**

# Seismicity of India and it's Neighborhood

( $M \geq 5.0$ ; 1505- June, 2011)

## RECENT EVENTS

Sikkim (2011), 6.9, **77**

Pakistan (2005), 7.4, **1309**

Sumatra (2004), 9.3, **16389**

Bhuj (2001), 7.7, **13805**

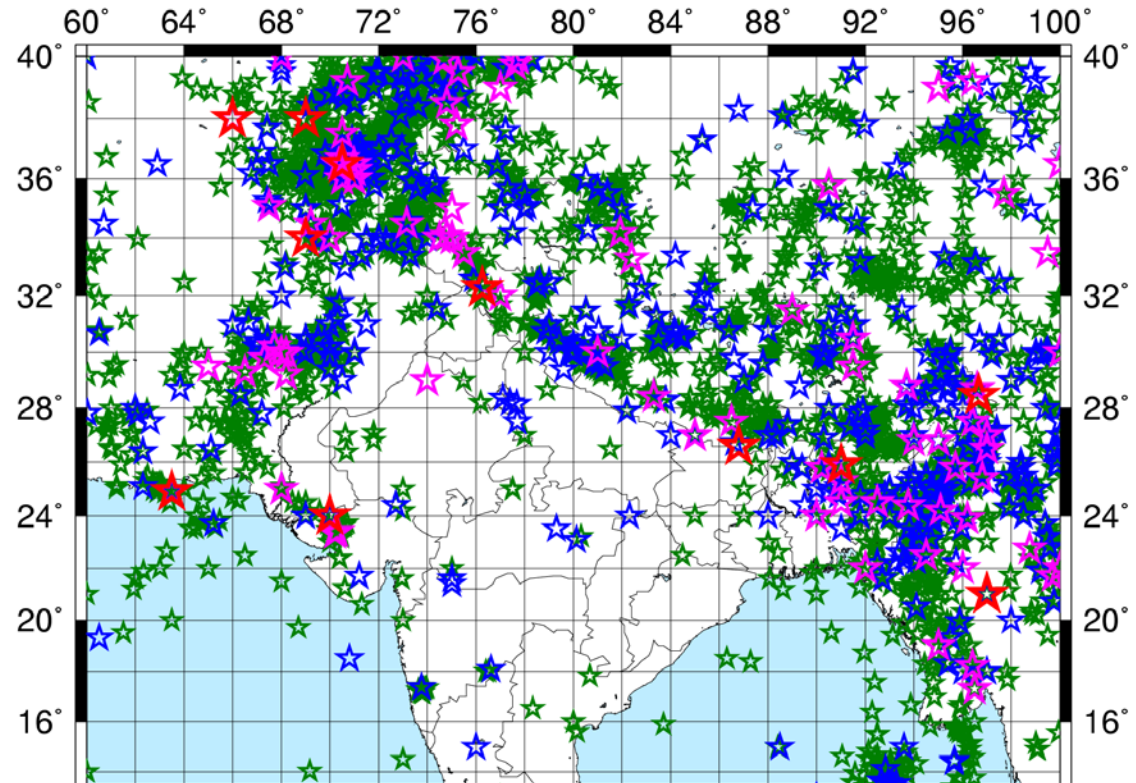
Chamoli (1999), 6.8, **103**

Jabalpur (1997), 6.0, **39**

Latur (1993), 6.3, **7601**

Uttarkashi (1991), 6.6, **769**

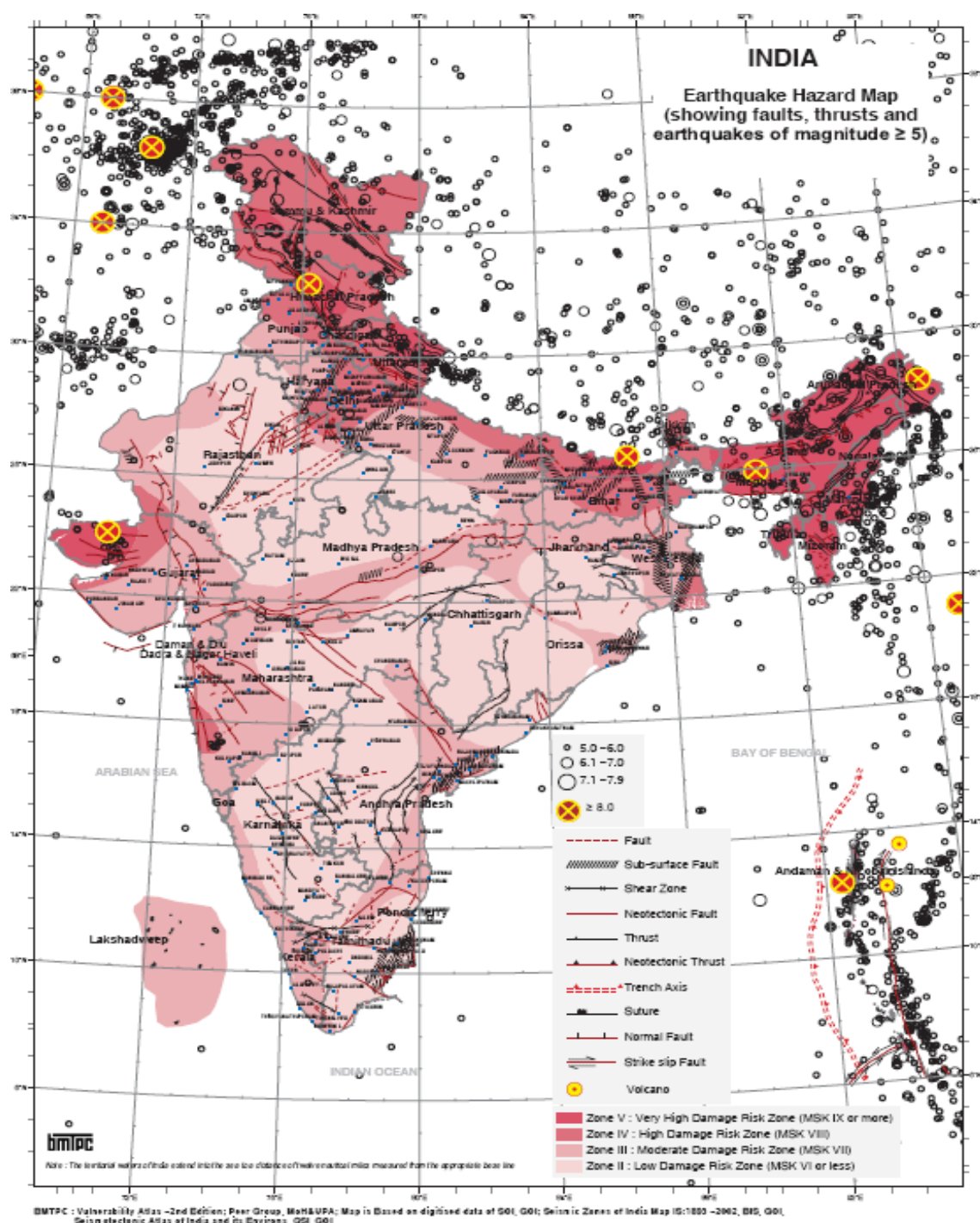
(Casualties in India: 40K+)



# ***SIGNIFICANT EARTHQUAKES IN AND AROUND INDIA***

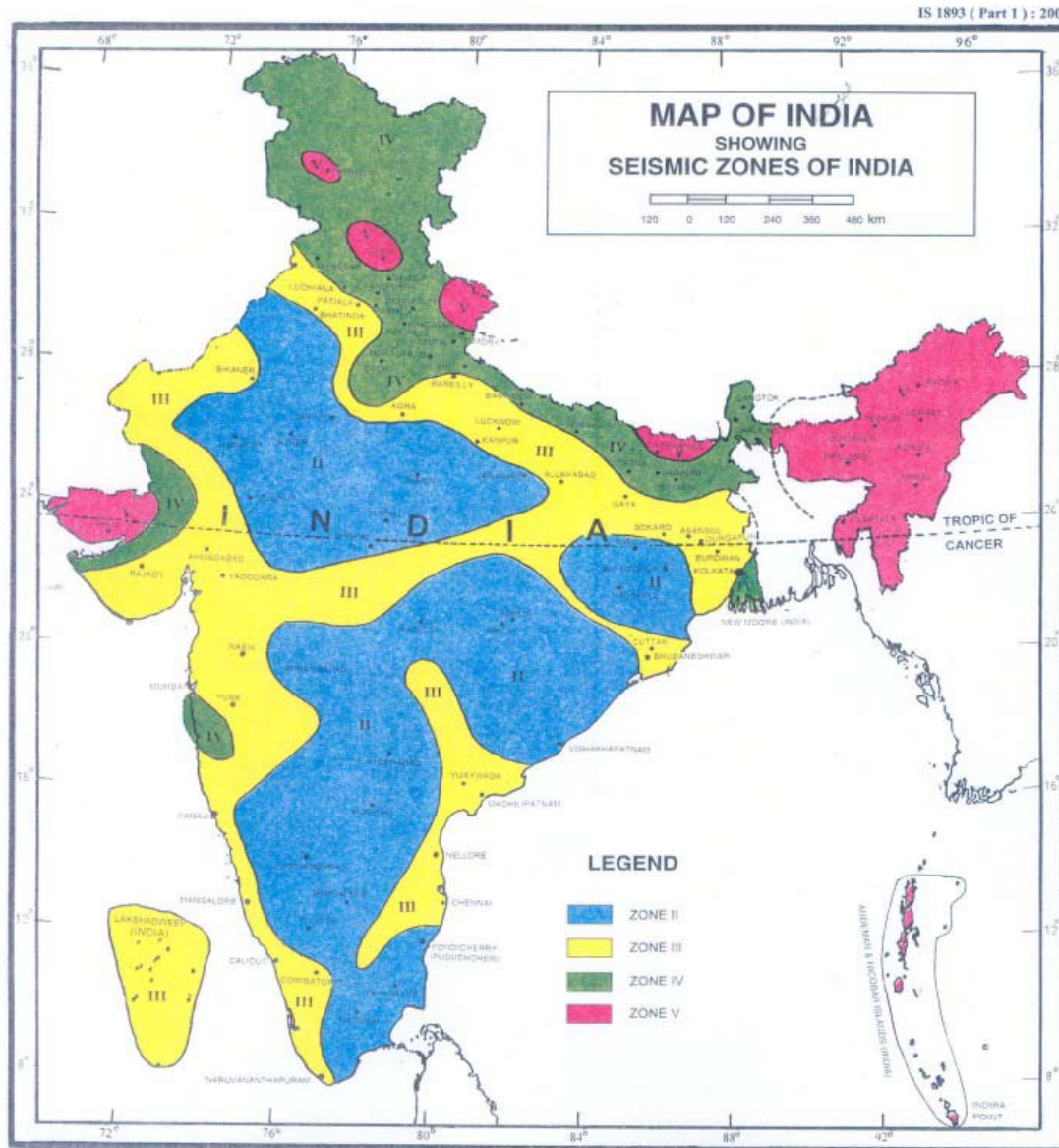
	Date	Epicentre		Region	Mag.
		Lat (°N)	Long (°E)		
1	1819 Jun 16	24.0	70.0	KUTCH, GUJARAT	8.0
2	1869 Jan 10	24.5	92.5	NEAR CACHAR, ASSAM	7.5
3	1885 May 30	34.1	74.8	SOPORE, JAMMU & KASHMIR	7.0
4	1897 Jun 12	25.9	91.0	SHILLONG PLATEAU	8.7
5	1905 Apr 4	32.3	76.3	KANGRA, HIMACHAL PRADESH	8.0
6	1918 Jul 8	24.5	91.0	SRIMANGAL, ASSAM	7.6
7	1930 Jul 3	25.8	90.2	DHUBRI, ASSAM	7.1
8	1934 Jan 15	26.6	86.8	BIHAR-NEPAL BORDER	8.3
9	1941 Jun 26	12.4	92.5	ANDAMAN ISLANDS	8.1
10	1943 Oct 23	26.8	94.0	ASSAM	7.2
11	1950 Aug 15	28.5	96.7	ARUNACHAL PRADESH-CHINA BORDER	8.5
12	1956 Jul 21	23.3	70.2	ANJAR, GUJARAT	7.0
13	1967 Dec 11	17.4	73.7	KOYNA, MAHARASHTRA	6.5
14	1975 Jan 19	32.4	78.5	KINNAUR, HIMACHAL PRADESH	6.2
15	1988 Aug 6	25.1	95.1	MANIPUR-MYANMAR BORDER	6.6
16	1988 Aug 21	26.7	86.6	BIHAR-NEPAL BORDER	6.4
17	1991 Oct 20	30.7	78.9	UTTARKASHI, UTTARAKHAND	6.6
18	1993 Sep 30	18.1	76.6	LATUR-OSMANABAD, MAHARASHTRA	6.3
19	1997 May 22	23.1	80.1	JABALPUR, M.P.	6.0
20	1999 Mar 29	30.4	79.4	CHAMOLI, UTTARAKHAND	6.8
21	2001 Jan 26	23.4	70.3	BHUJ, GUJARAT	7.7
22	2004 Dec 26	3.3	96.1	OFF WEST COAST OF SUMATRA	9.3
23	2005 Oct 8	34.5	73.1	MUZAFFARABAD	7.6
24	2011 Sep 18	27.8	88.1	SIKKIM-NEPAL	6.9

# EARTHQUAKE HAZARD & FAULT MAP





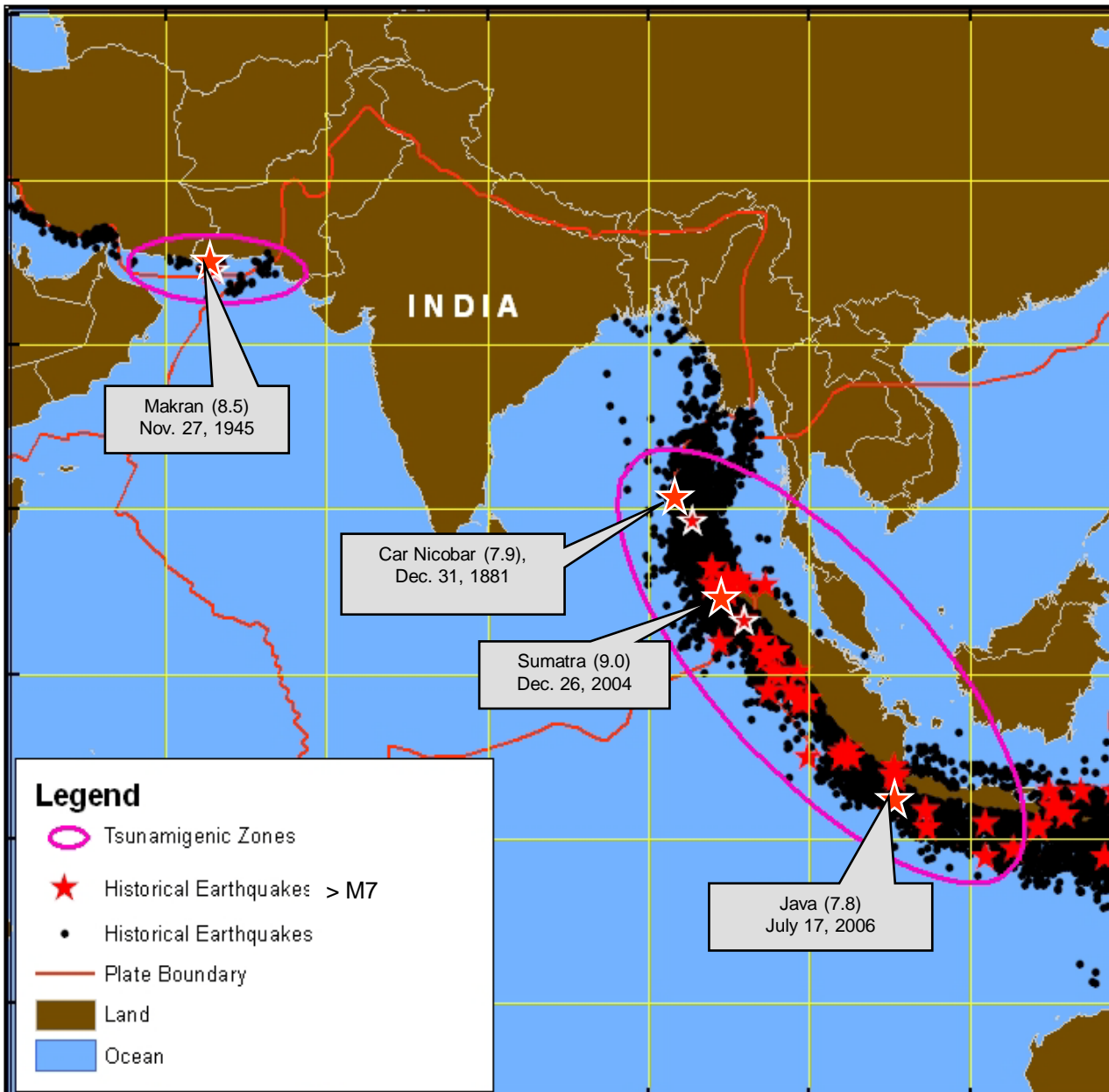
# Seismic Zoning Map of India



Seismic Zone	MMI PGA(g)	Area (%)
<b>V (VERY SEVERE)</b>	<b>≥IX 0.49</b>	<b>12</b>
<b>IV (SEVERE)</b>	<b>VIII 0.25</b>	<b>18</b>
<b>III (MOD.)</b>	<b>VII 0.20</b>	<b>27</b>
<b>II (LOW)</b>	<b>≤VI 0.19</b>	<b>43</b>

NOTE : Towns falling at the boundary of zones demarcation line between two zones shall be considered in High Zone.

# Tsunamigenic earthquake sources



Tsunamis are primarily caused due to large undersea earthquakes, with magnitude more than ~7.0, focal depth less than 30.0 km and vertical movement of blocks.

Possible tsunamigenic earthquake sources are shown by ellipses.

Earthquakes with slow rupture velocities are also most efficient tsunami generators.

75% of earthquake energy is released in the circum-Pacific belt, along which 900 tsunamis are reported in 20<sup>th</sup> Century.

20% in the Alpine-Himalayan belt, along which 6 tsunamis are reported in 20<sup>th</sup> Century.

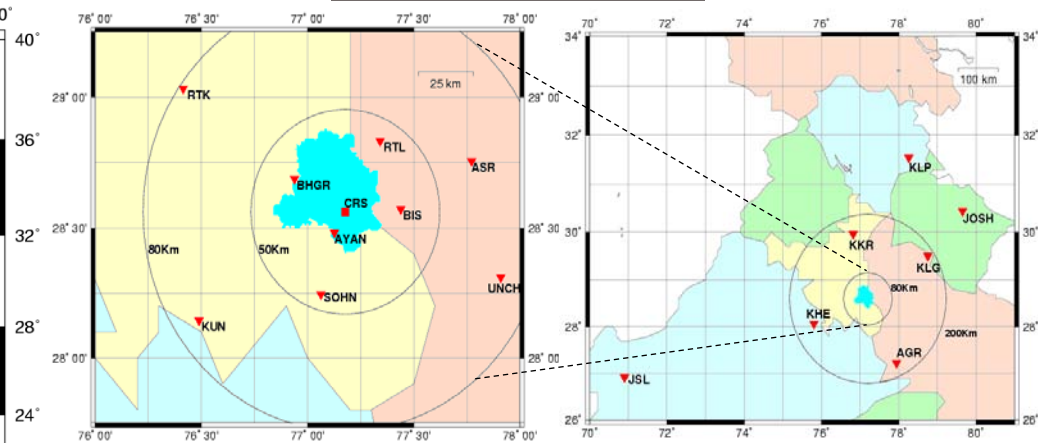
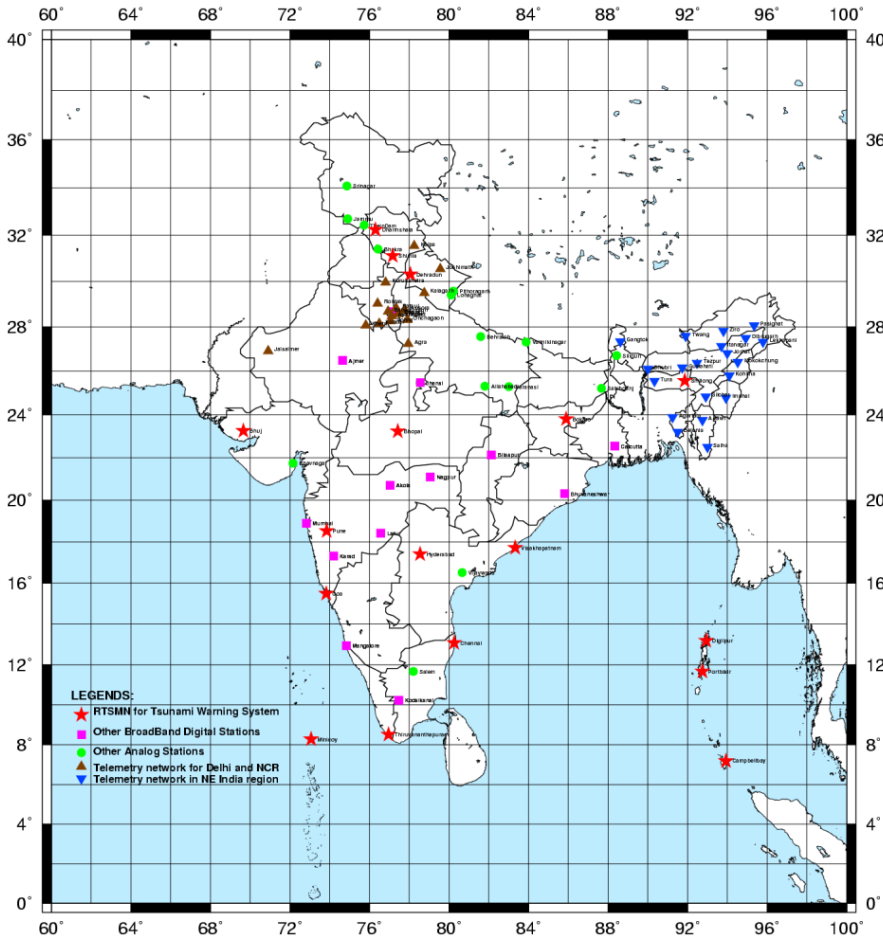
## Historical Tsunamis in India:

12 Apr, 1762 (BoB EQ) – 1.8 M  
31 Dec, 1881 (Car Nicobar EQ)  
27 Aug, 1883 (Krakatoa) – 2 M  
26 Jun, 1941 (Andaman EQ)  
27 Nov, 1945 (Makran EQ) – 12 M  
26 Dec, 2004 (Sumatra EQ)

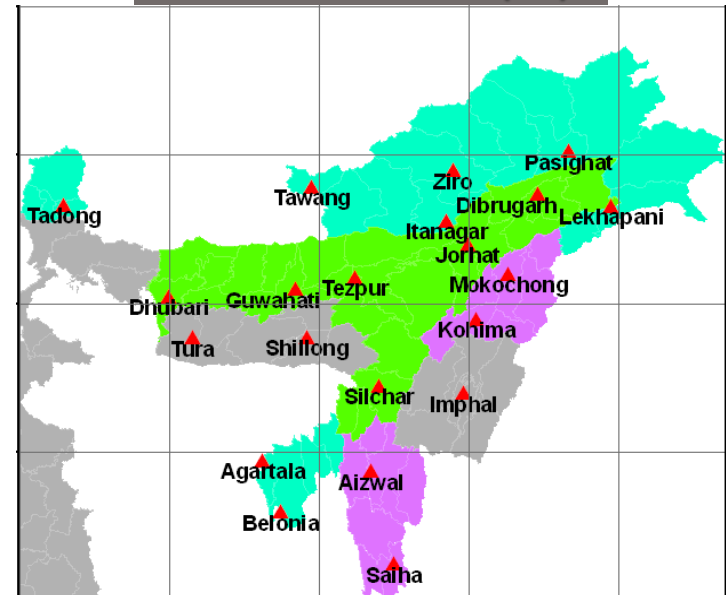
**Landslides, Volcanoes & Meteor Impacts can also generate Tsunamis.**

# National Seismic Network (82)

## Delhi (16)

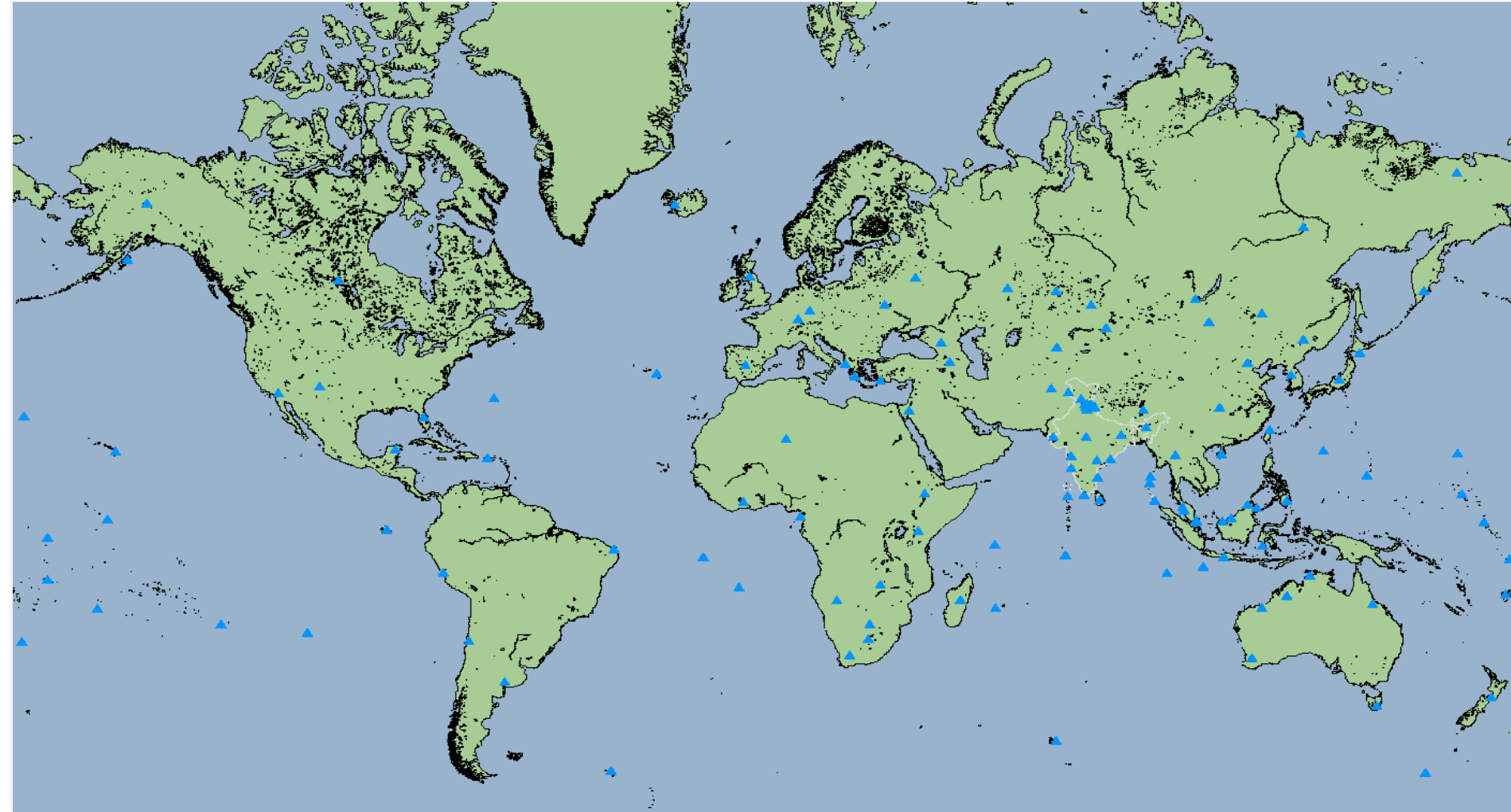


## Northeast India (20)



**Digital: 66 & Analog :16**

# Real Time Seismic Monitoring Network (RTSMN)



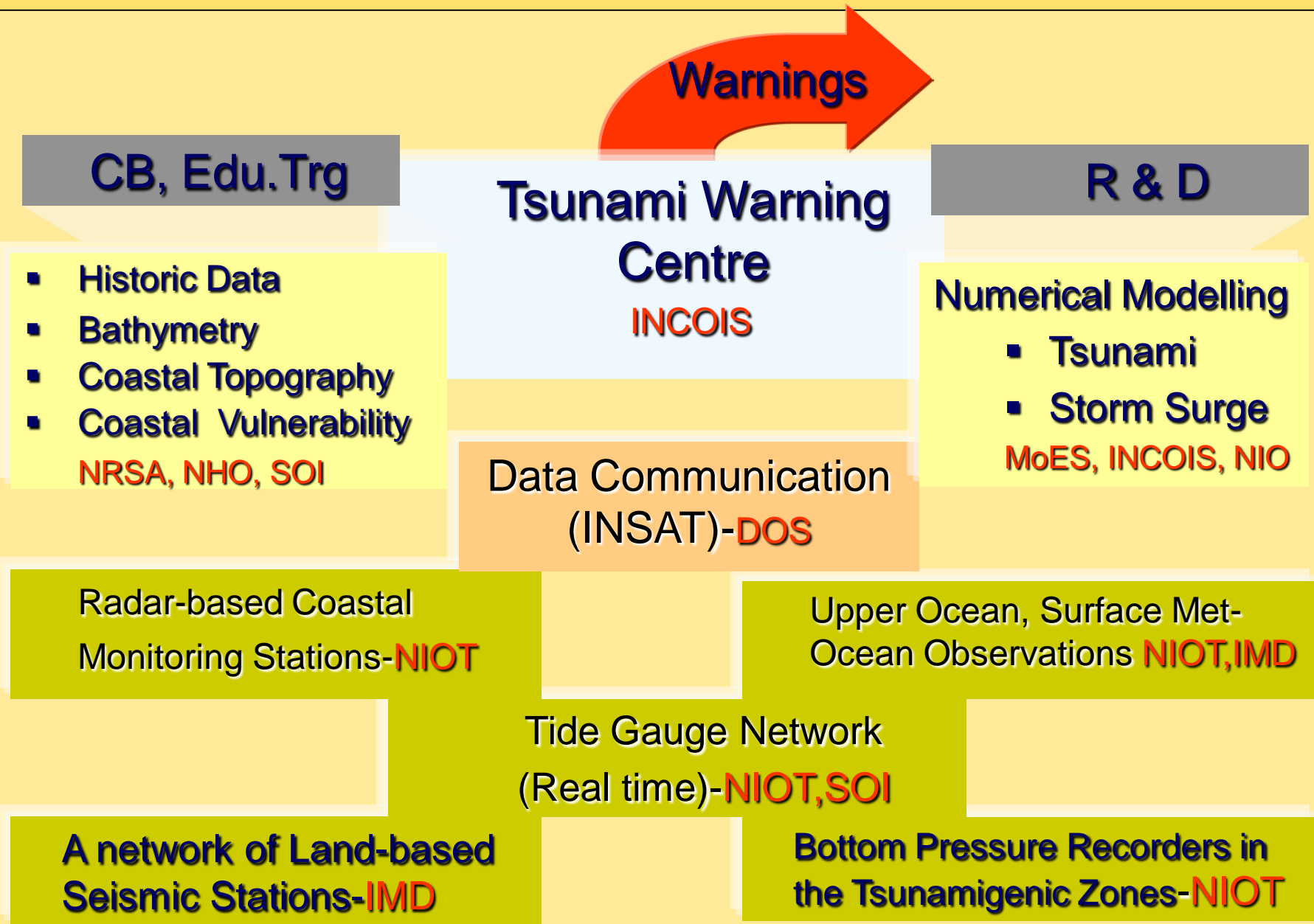
***~100 IRIS stations configured under RTSMN system***

**Transmission of continuous seismic waveform data**

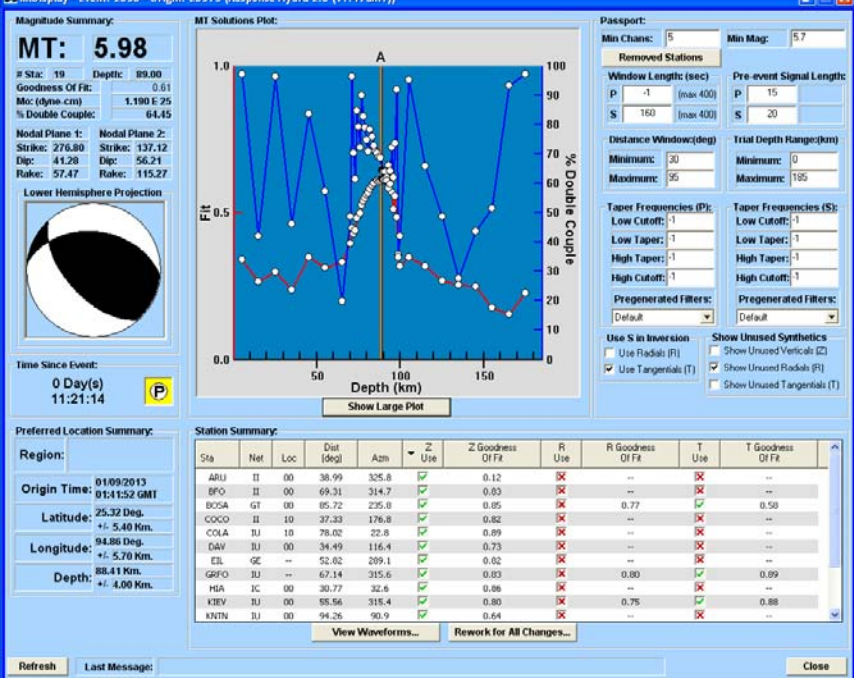
**of three seismic stations - Portblair, Minicoy and Shillong to  
Incorporated Research Institutions of Seismology (IRIS), Washington, USA.**



# Indian Tsunami Early Warning System (ITEWS) at INCOIS, Hyderabad



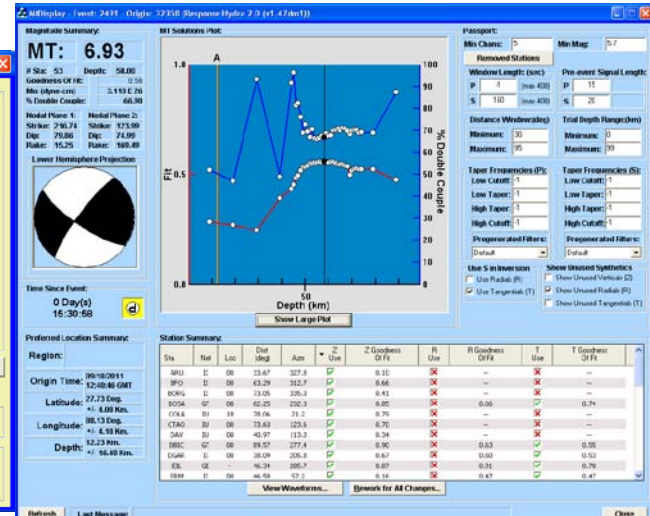
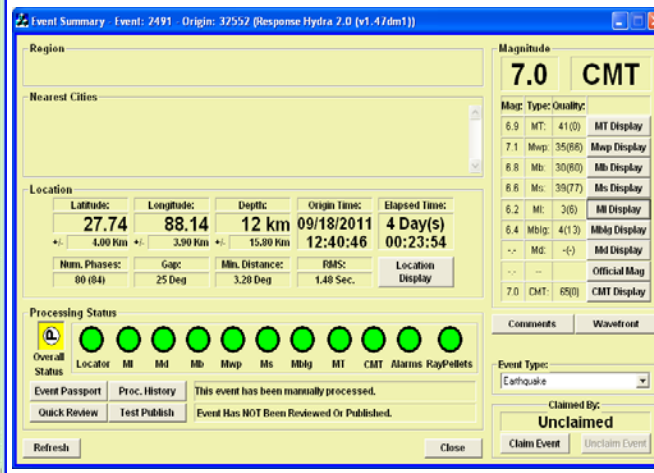
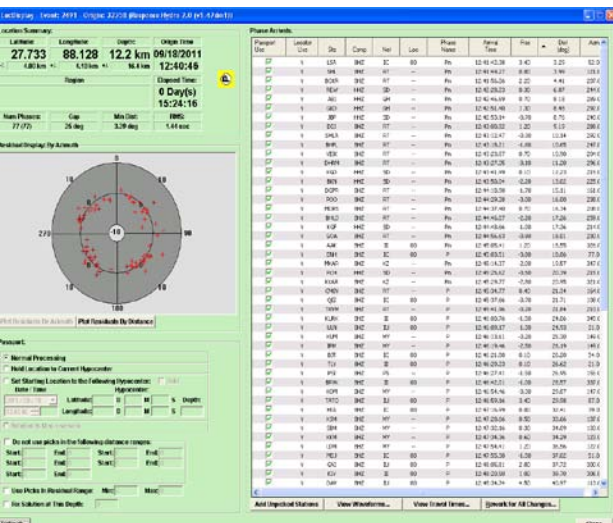
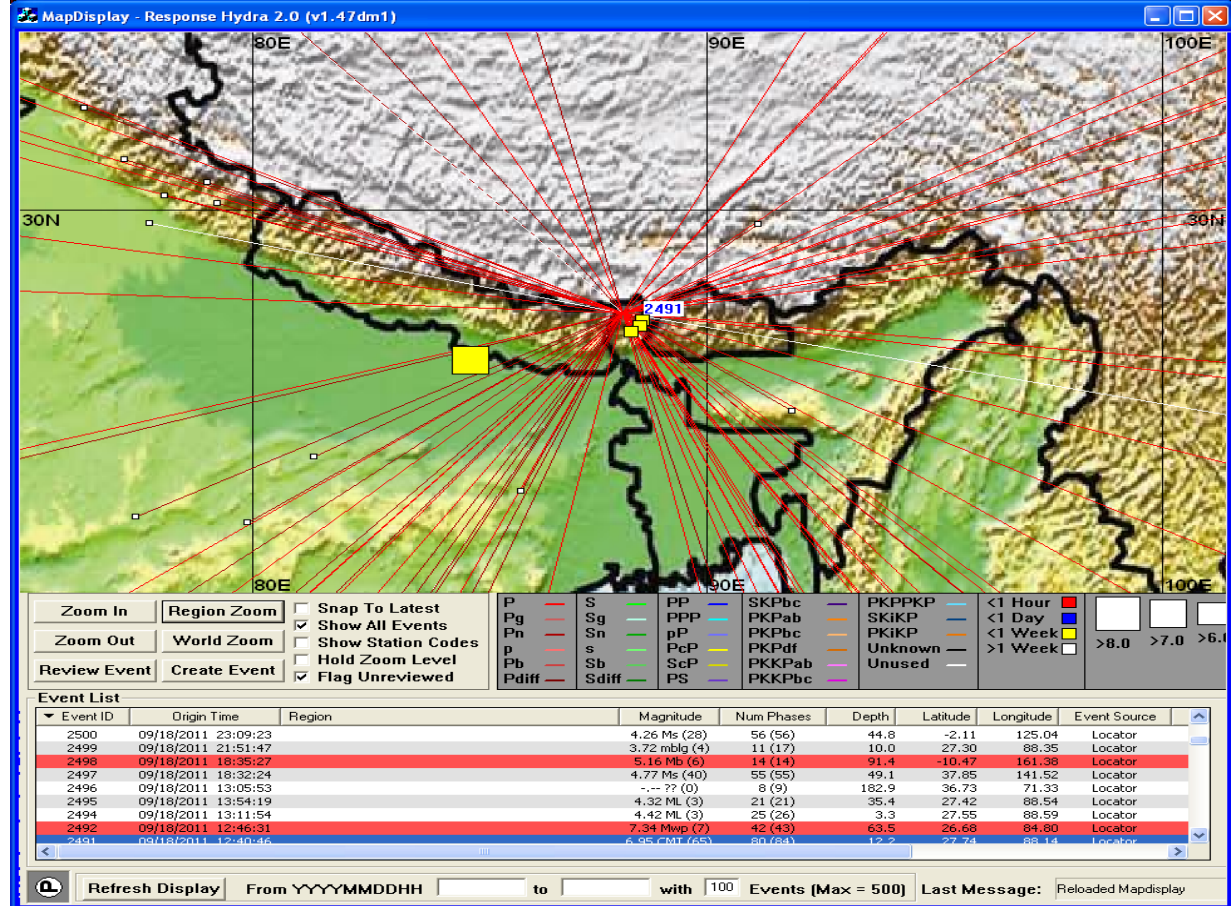
**Epiceentre: 25.4° N & 94.9° E**  
**Region: Myanmar-India**  
**border region**





# Sikkim earthquake

**Date: 18/09/2011**  
**Time: 18:11 hrs (IST)**  
**Magnitude: 6.8**  
**Focal depth: 10 Km**  
**Epicentre: 27.7° N & 88.2 ° E**  
**Region: Sikkim-Nepal Border**  
**Reporting in 4 min. (SMS-I)**

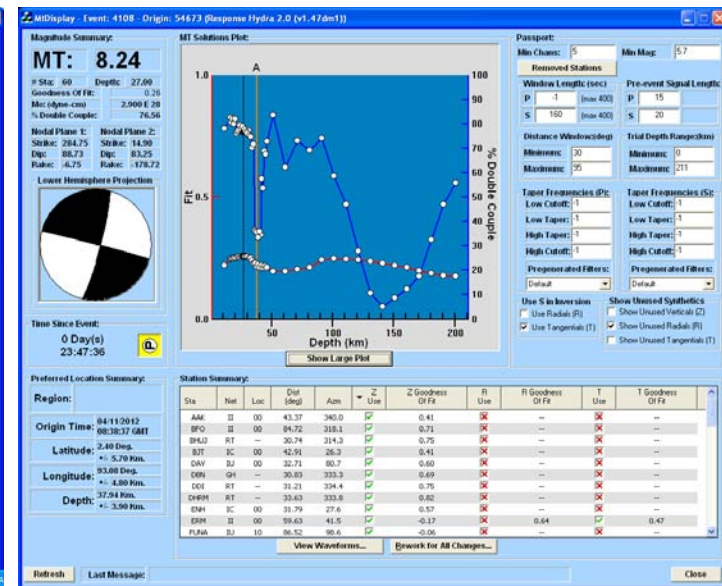
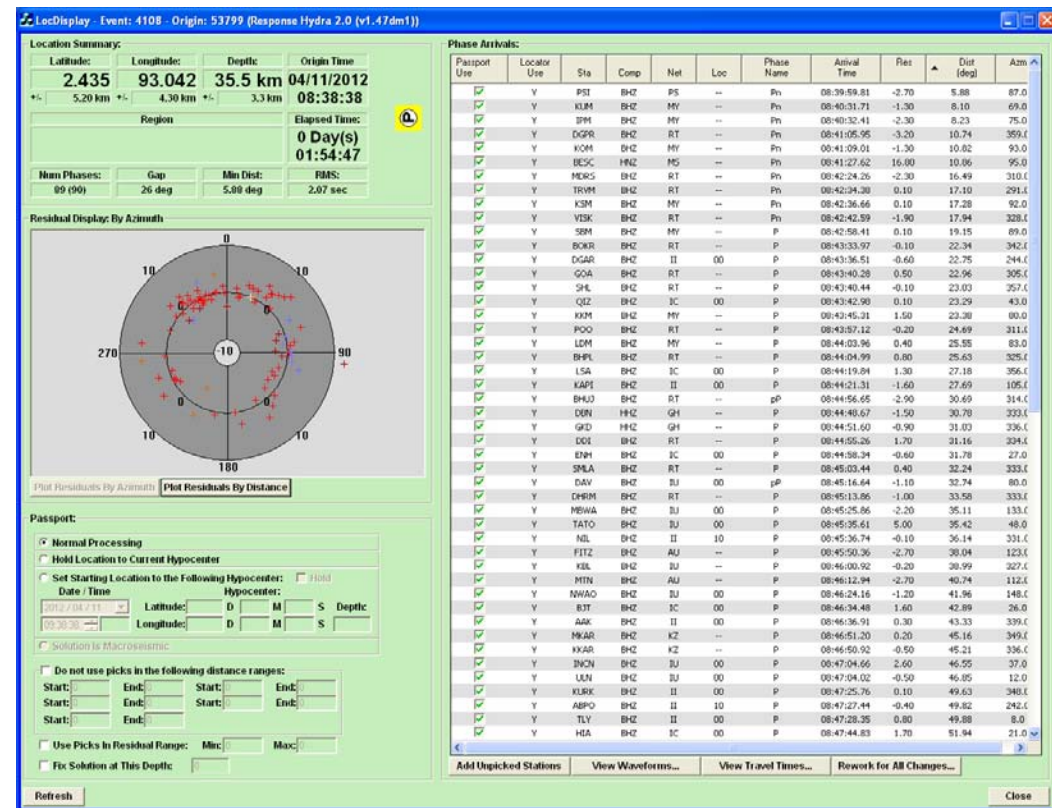
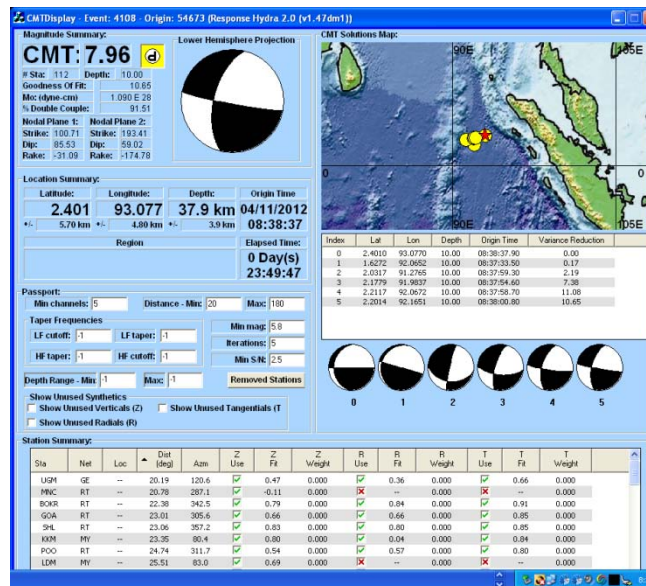
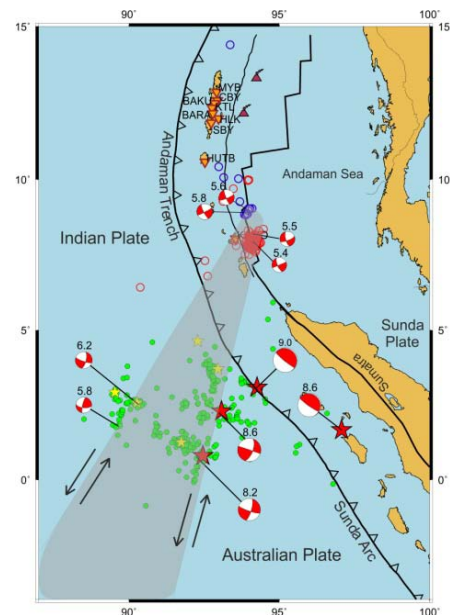




# Sumatra earthquakes of 11<sup>th</sup> April, 2012

Time: 14:09 hrs (IST)  
Magnitude: 8.5  
Focal depth: 10 Km  
Epicentre: 2.3° N & 93.0° E  
Region: off west coast of northern Sumatra  
Time of report: SMS level-I in ~6 minutes

Time: 16:13 hrs (IST)  
Magnitude: 8.1  
Focal depth: 18 Km  
Epicentre: 0.8° N & 92.4° E  
Region: off west coast of northern Sumatra  
Time of report: SMS level-I in ~7 minutes



# M:4.5 earthquake of 19<sup>th</sup> Aug 2012 in Northeast India

## FocalMechanism

Latitude: **26.82 ° N**

Longitude: **92.54 ° E**

Depth: **33 km**

Moment: **7.77E+15 Nm**

Mw: **4.5**

Misfit: 0.28

CLVD: 0.01

Phase Count: 15

Min dist: 1.0 °

Max dist: 3.0 °

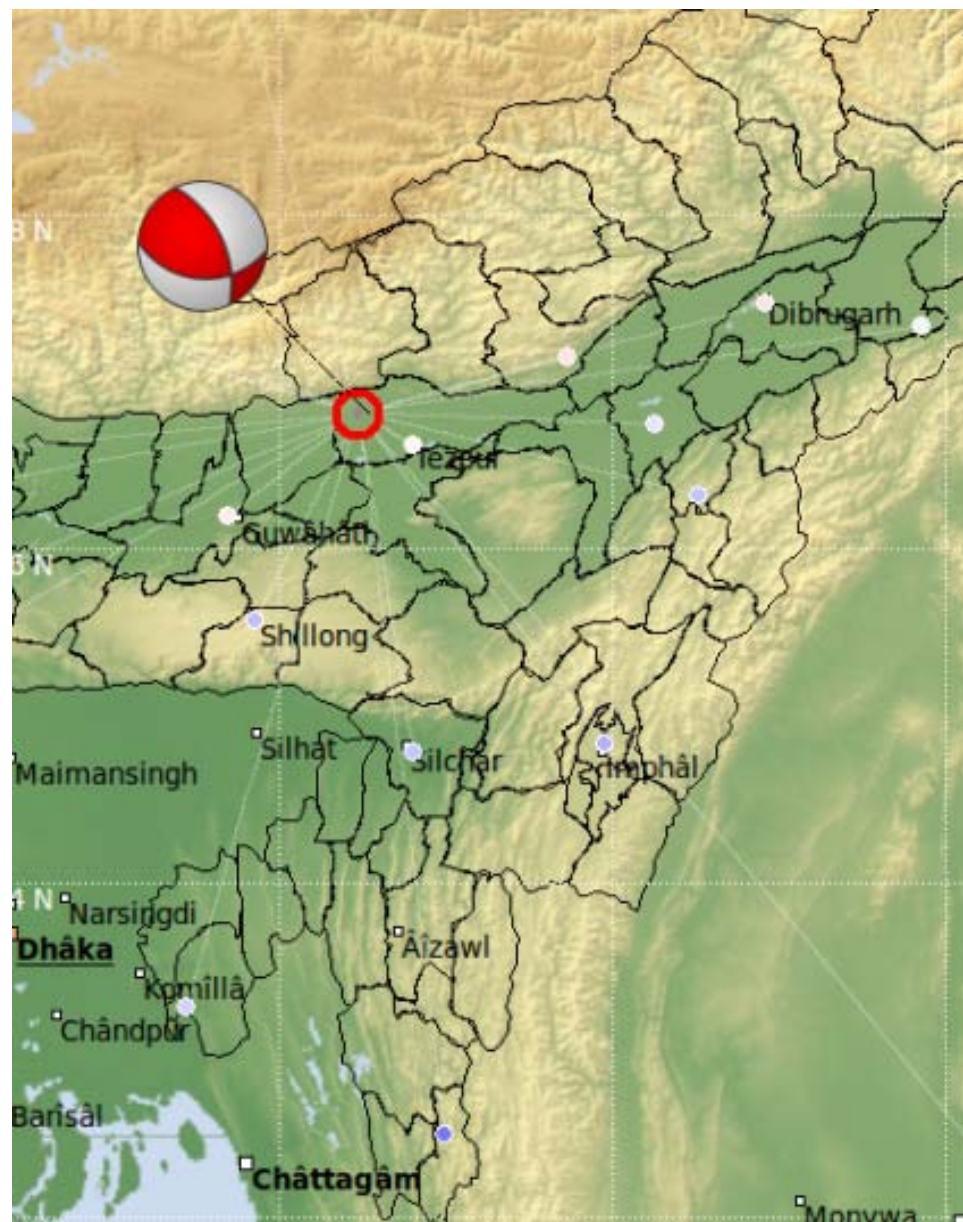
Nodal planes: S: 93, D: 46, R: 38

S: 334, D: 63, R: 129

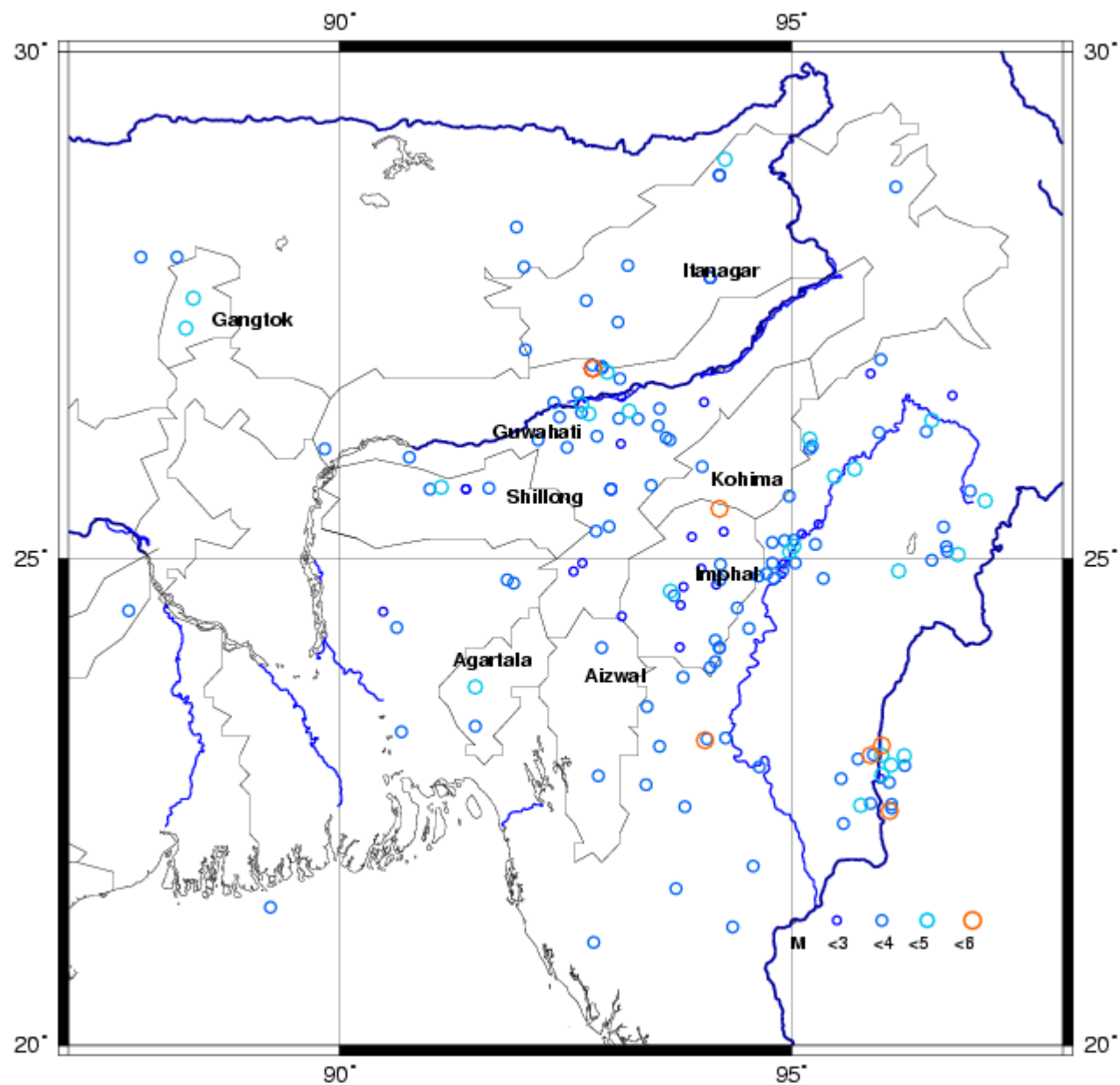
Type: centroid

Agency: IMD

Status: automatic







Seismicity in north east India from July – Dec 2012


# IMD / RTSMN WEBSITE

Athena - Web Browser

File Edit View Go Bookmarks Tools Window Help

Back Forward Reload Stop <http://192.168.5.86:8080/> Search Print

Home Bookmarks Java Desktop System Sun Microsystems



## भारत मौसम विज्ञान विभाग

## India Meteorological Department

Powered by Nanometrics Athena

[Earthquakes](#) [Catalog](#) [Log In](#) [v.1.0.0](#) [RSS Feed](#) [View in Google Earth](#)

**Date**

From:  Today 7d This Month Last Month

To:  30d 60d 90d YTD Last Year

**Magnitude**

Min:  Max:

Type:

**Location**

From:

To:

**Depth**

Min:  Max:

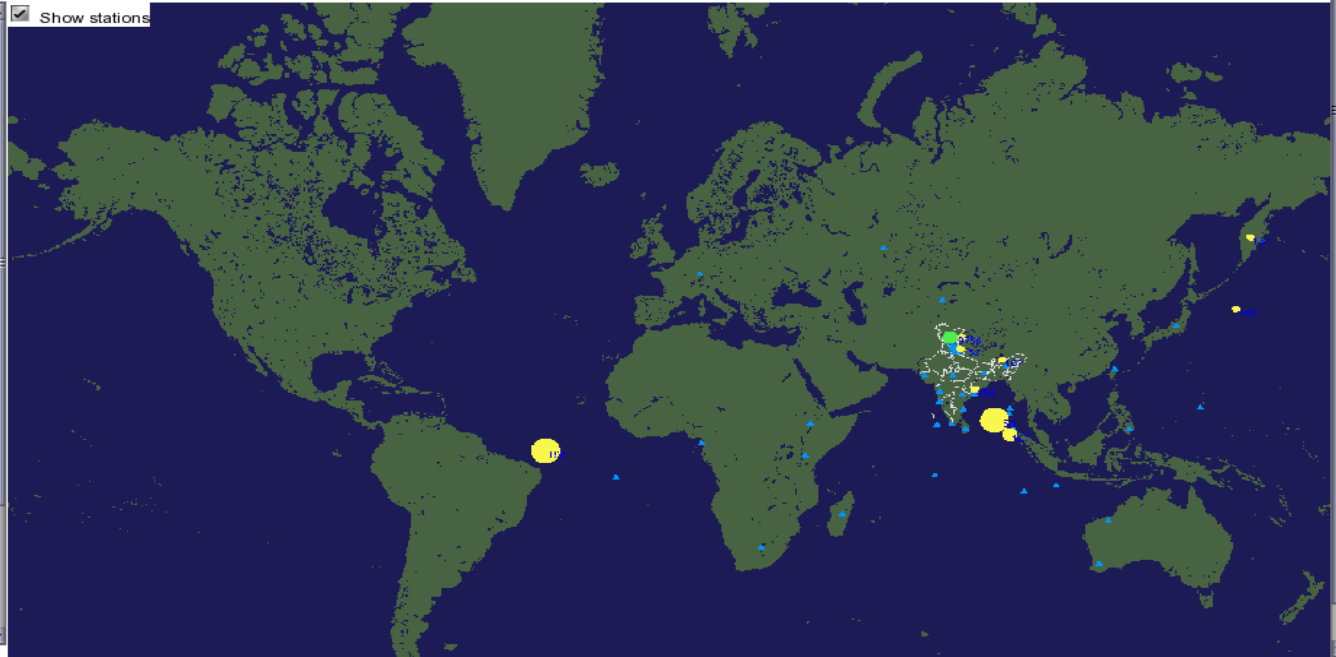
**Count**

Search

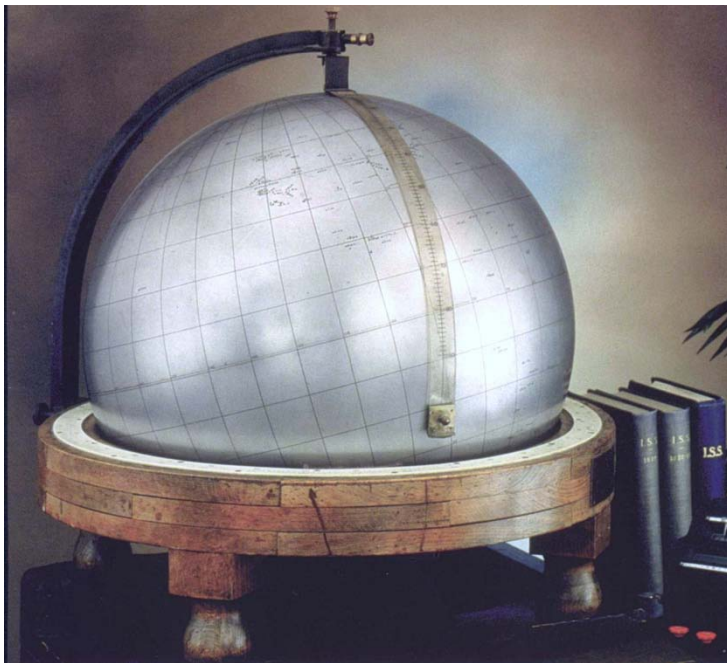
### Recent Earthquakes

	Time	Depth	Magnitude
●	2008-05-23 21:17:23.8500 33.64°N, 76.56°E 7 km from Abring, Jammu and Kashmir, India	6.2 km	3.9 ML
●	2008-05-23 19:35:48.2500 0.30°N, 33.65°W	15.0 km	6.2 Mb
●	2008-05-23 17:46:34.1700 5.44°N, 92.84°E	60.1 km	4.6 Mb
●	2008-05-23 17:24:51.0100 33.65°N, 79.74°E 18 km from Wüjiang, Xizang, China	10.0 km	
●	2008-05-23 03:27:36.2900 40.58°N, 154.53°E	600.0 km	
●	2008-05-23 03:27:11.5900 55.43°N, 158.54°E 34 km from Aginskiy, Kamtsjatka, Russia	346.0 km	
●	2008-05-22 17:42:12.1900 30.59°N, 79.28°E 13 km from R?nsi, State of Uttarakhand, India	27.5 km	2.1 Md
●	2008-05-22 17:39:46.9500 27.55°N, 90.82°E 6 km from Bumtang Tang, Bhutan	0.4 km	2.5 ML

☒ Show stations



Launch Mon May 26, 11:15:27 Athena - Web Browser



# IMD'S DATA GETS INCORPORATED IN THE BULLETINS OF INTERNATIONAL SEISMOLOGICAL CENTRE (ISC)

## ISCNEWS

January to June 2010 [www.isc.ac.uk](http://www.isc.ac.uk)

New data and funds, special projects and meetings



The latest updates, news and activities from the ISC

India Meteorological Department



The India Meteorological Department (IMD) of the Ministry of Earth Sciences of the Government of India has been a Member of the ISC for many tens of years. Yet the size of Earth Science programmes in India has changed a great deal since the IMD first joined the ISC in 1971. Following the decision of the Ministry of Earth Sciences, the IMD substantially increased its membership contribution and joined the group of ISC's largest supporters that also includes the US, UK, Japan, Russia and China.

The ISC greatly appreciates the help and advice of Prof. Harsh Gupta (Vice-President of IUGG), Dr Brijesh K. Bansal (Ministry of Earth Sciences) and Dr R.S. Dattatrayam (Director of Seismology Division, IMD) who have played vital roles in this important development.

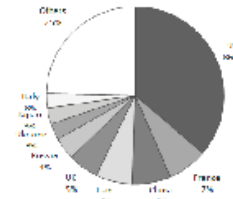
The India Meteorological Department continues with its always timely contribution of seismic bulletin data where seismic arrivals from many stations are included on a regular basis. Seismic networks in India are growing at fast rate and we hope that the IMD will continue providing these data to the ISC. We are also expecting that the IMD would be able to start contributing preliminary bulletin data soon after events occur prior to sending its finally reviewed data.



National Science Foundation  
WHERE DISCOVERIES BEGIN

The United States National Science Foundation (NSF) is not a regular Member of the ISC though it has contributed a substantial share of funding since the ISC outset in early 1960s. In recent years the ISC has submitted formal proposals to the NSF every four years. One of the previous ISC Directors, Ray Willeman, was particularly skilled at writing convincing and focused proposals and subsequent Directors have followed his lead. The most recent proposal was submitted in July 2009. This proposal, covering the period from mid-2010 to mid-2014, has now been granted in full. The overall amount committed by the NSF represents an increase compared to the last few years. The grant includes supporting regular ISC operations for four years but in addition two add-on projects were highly regarded by the reviewers and have also been funded.

The first of the two add-on projects is to set up an ISC database and website backup at IRIS DMC in Seattle. This development will create a fall-back facility in case of temporary loss of ISC service similar to that narrowly avoided during the Big Thatcham Floods in 2007. It will address concerns about the speed of the Bulletin web queries as well as provide the IRIS DMC with up-to-date access to the ISC Bulletin hypocentres that are currently used (based on the contents of the ISC CDs) to serve waveform requests related to specific seismic events. The NSF grant will pay for the cost of the server at IRIS DMC, the cost of the initial trip to Seattle for the ISC DB Administrator to make an initial setup at IRIS as well as managing the backup remotely thereafter.



Web-based use of the ISC Bulletin by researchers from different countries in the last 10 years

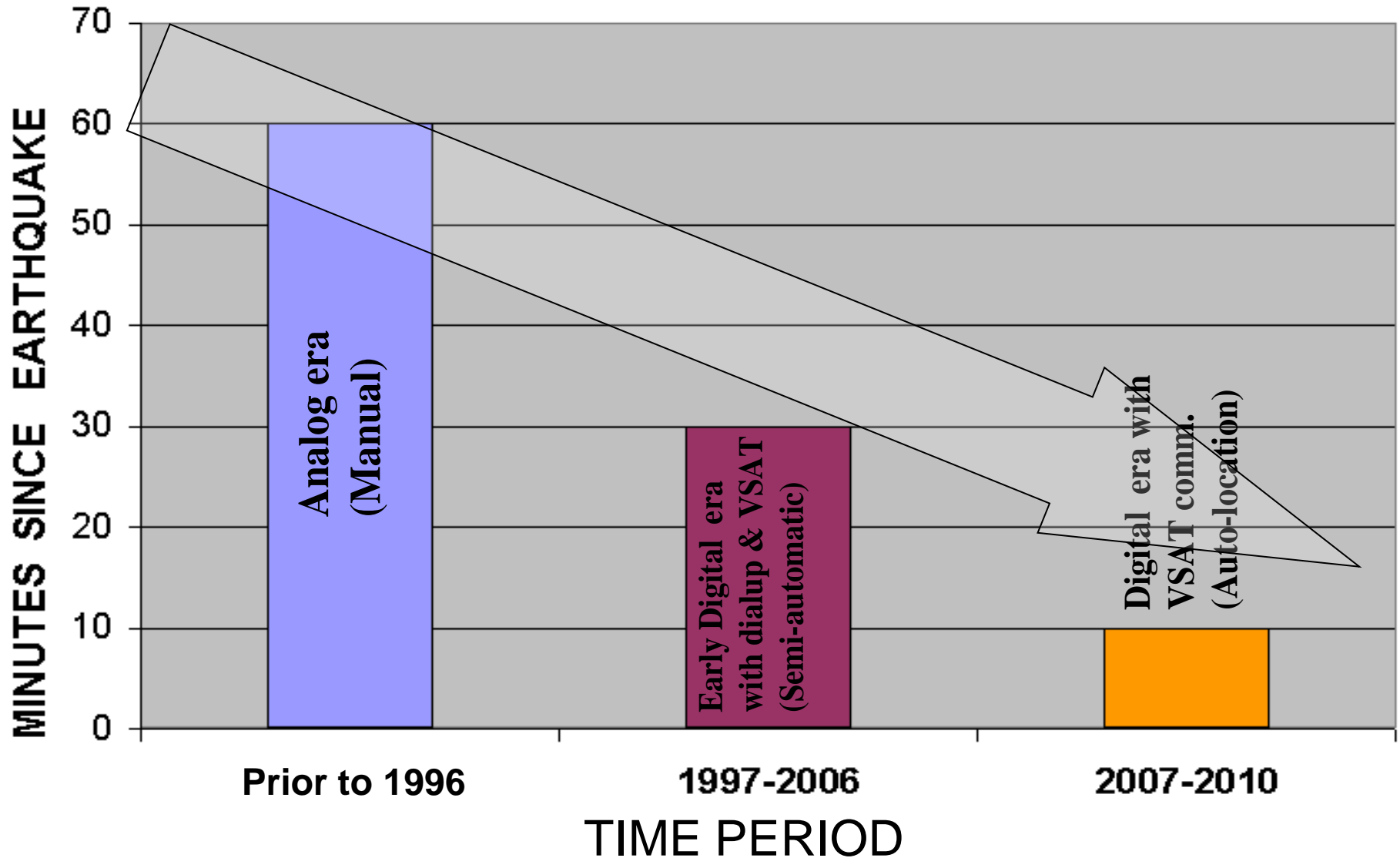
The second add-on project will pay for an additional member of staff for four years, providing a welcome boost to the task of re-building the entire ISC Bulletin for 1960-2009. This project has already started based on additional funding committed for improving the ISC services by Japan, China and India. NSF's support is invaluable in making sure that this development is completed in four years rather than eight as originally planned. The work will include:

- re-computing the ISC hypocentre solutions using the ak135 velocity model and newly developed location algorithm;
- re-computing ISC magnitude estimates using better averaging and outlier removing technique and providing magnitude uncertainties for the first time;
- adding previously unavailable surface wave magnitudes for years 1960-1977, courtesy of GEM project;
- identifying and where possible filling gaps in original bulletin reports from networks;
- adding new datasets from scientific experiments and temporary deployments, especially those involving OBS;
- running modern consistency checks on the entire bulletin and correcting identified blunders in the Bulletin.

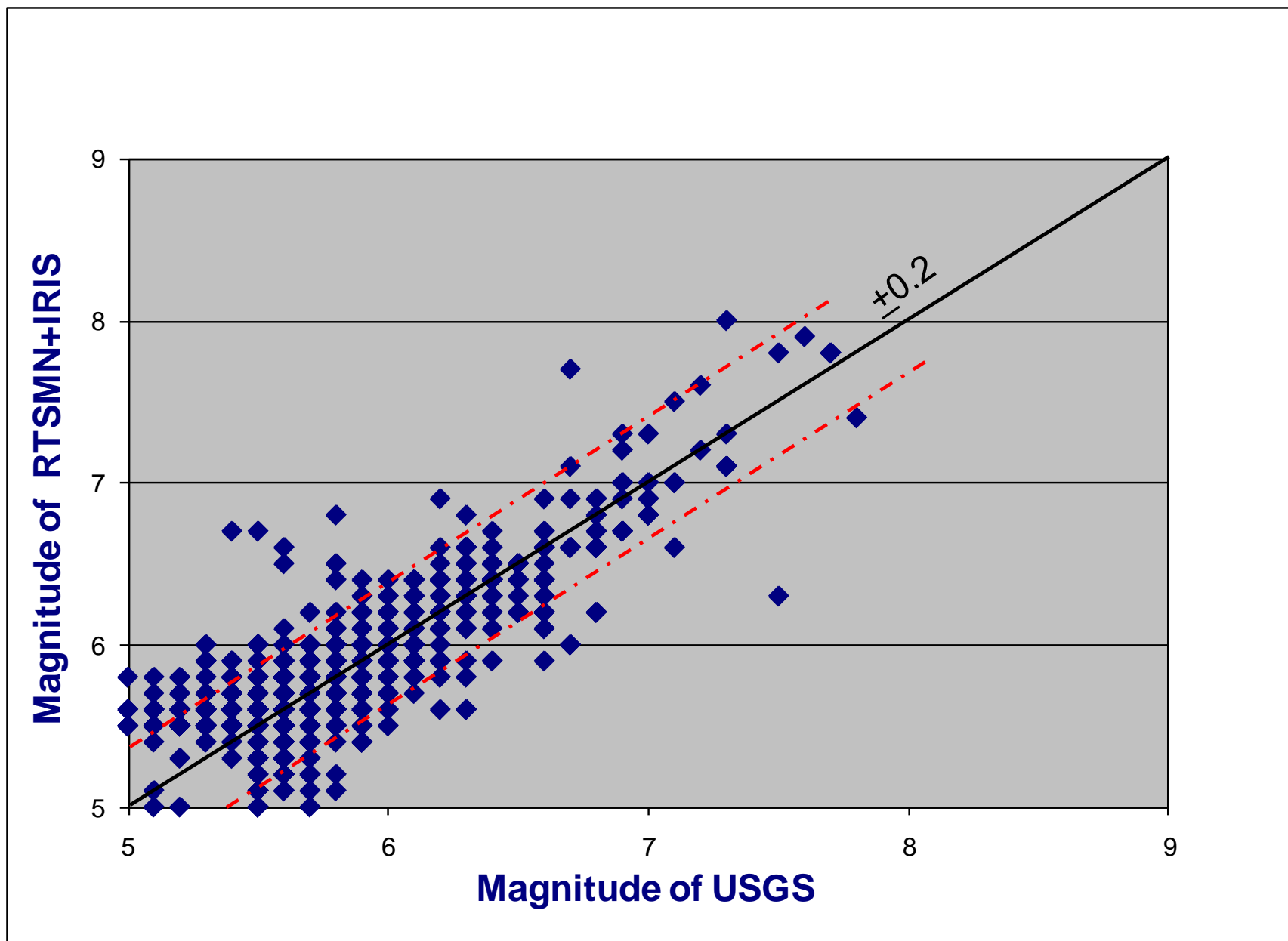
This project will produce a large scale update to the flagship ISC product that is widely used in many fields of geophysical research.



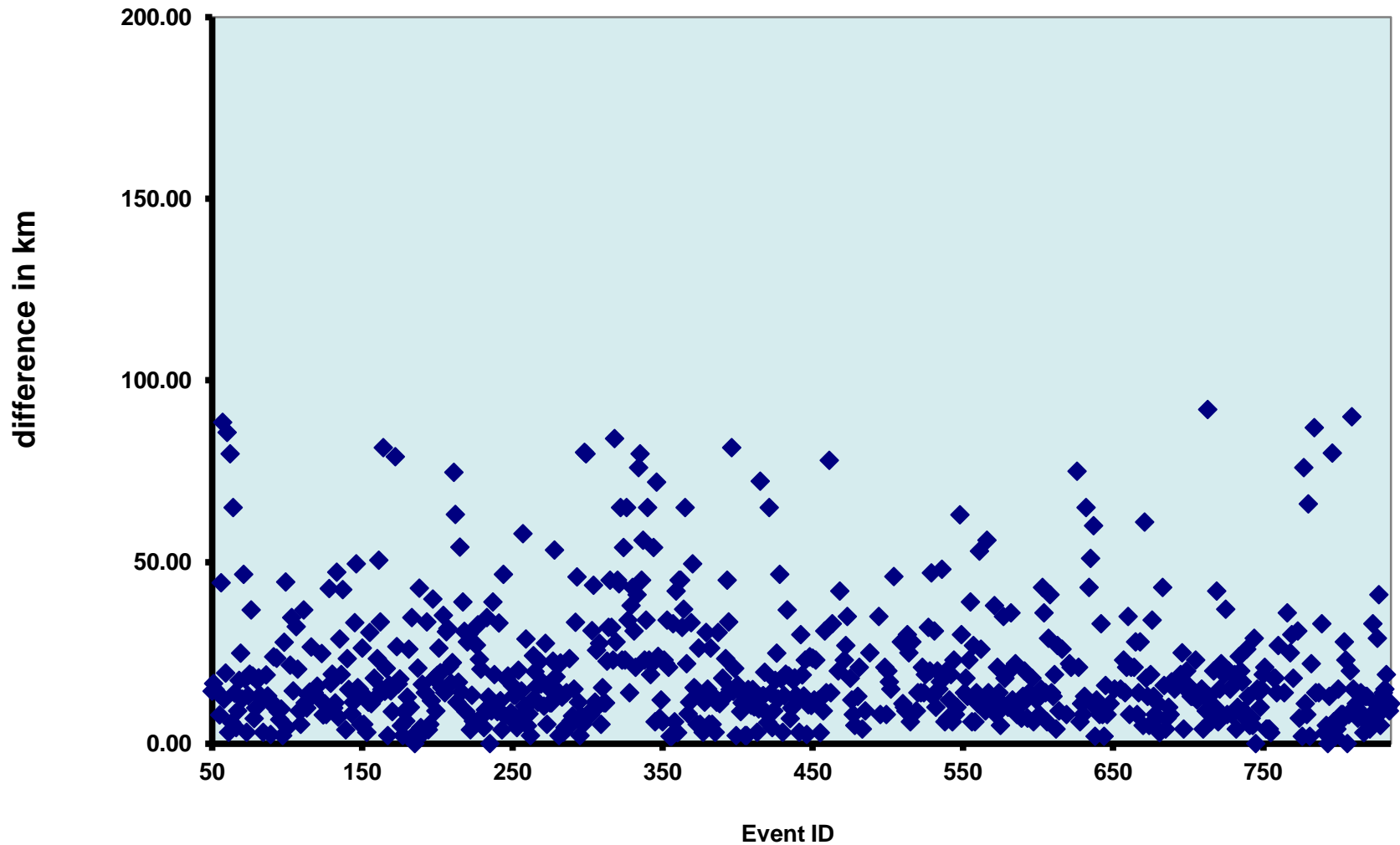
# Response time - Improvements



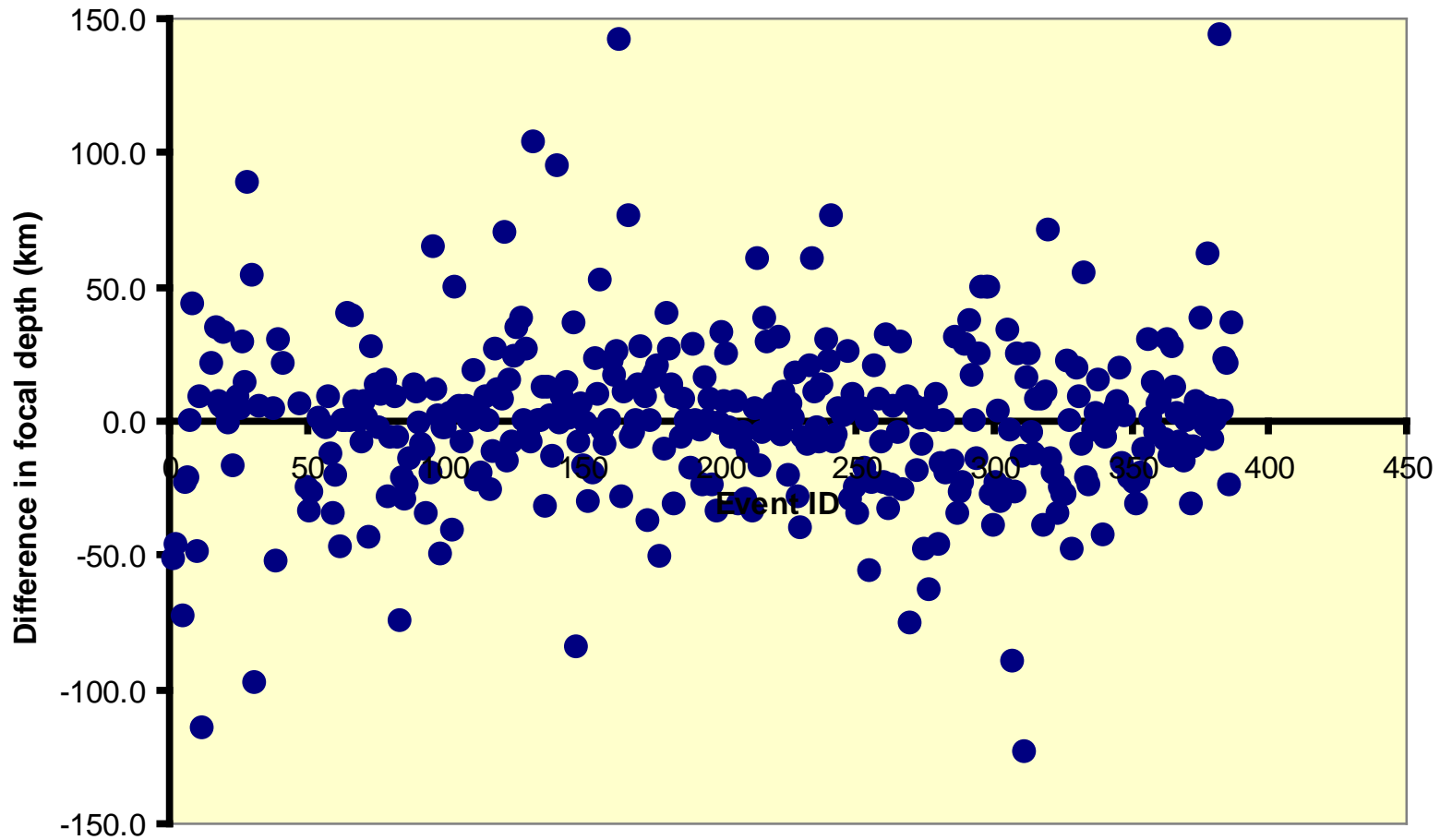
# Comparison of Magnitude estimates by USGS and RTSMN+IRIS



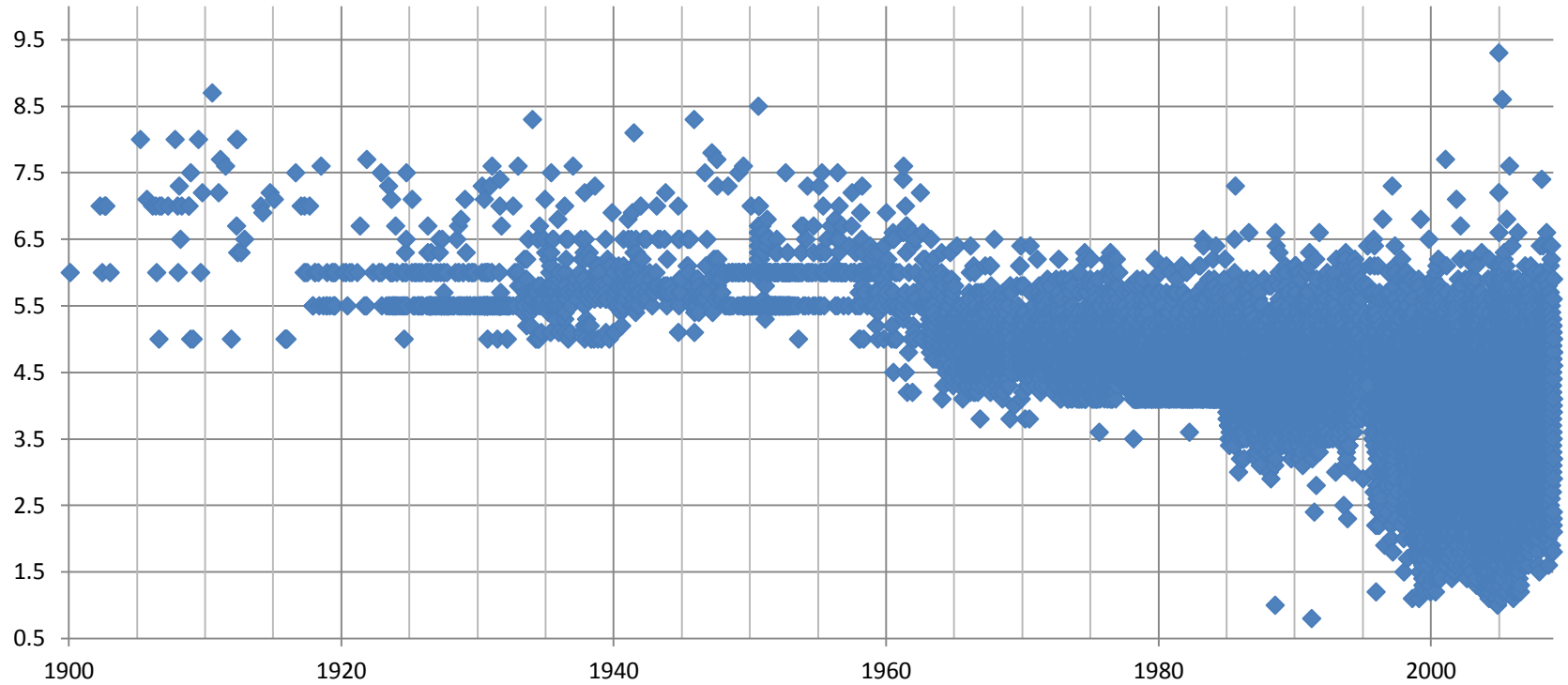
# Distance between the epicentres of USGS and RTSMN+IRIS



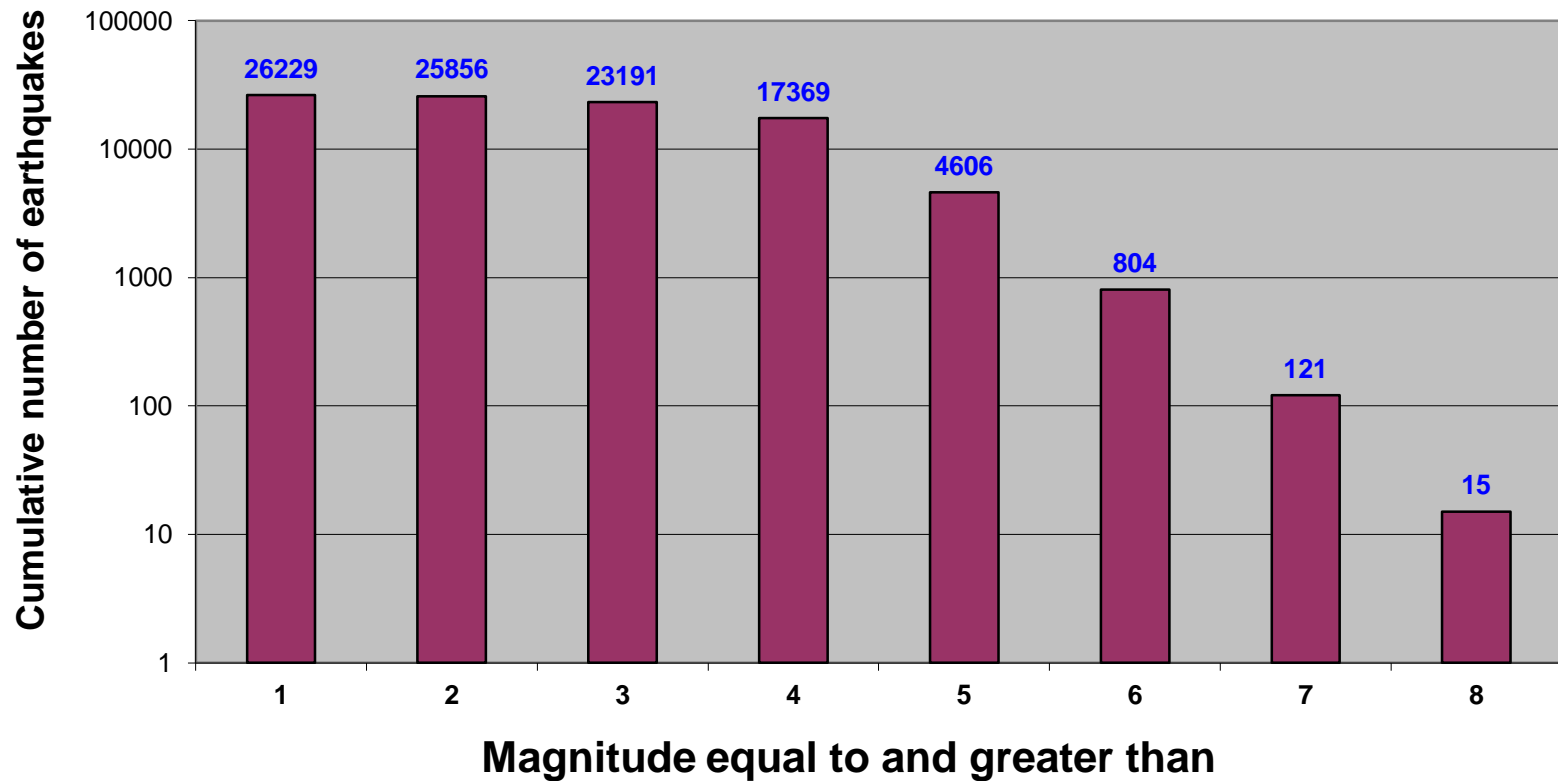
## Difference in focal depth between USGS and RTSMN with IRIS



# Time Vs Magnitude (duration 1900-2008)



# EARTHQUAKE CATALOG (1505-2008)



**b-value = 0.8; for N=11,215 (1505-2008) and Mmin=4.5**

## **Operational Capability of**


### **National Seismological Network:**

- **$M_{\geq 3.5}$  - Peninsular Shield region.**
- **$M_{\geq 4.0}$  - Extra-Peninsular Shield region.**
- **$M_{\geq 5.0}$  - Border regions.**
- **$M_{\geq 2.0}$  - Delhi and surroundings.**
- **$M_{\geq 3.5}$  - North East India region.**
- **$M_{\geq 6.5}$  - Earthquakes of tsunami-genic potential on Indian Coasts/ territories.**

```
graph LR; Seismogram[Seismogram] --> Scanner[Scanner]; Scanner --> Raster((Raster)); Raster --> RasterToVector[Raster to Vector]; RasterToVector --> Vector((Vector)); Vector --> Sampling[Sampling]; Sampling --> RoughDigital((Rough Digital)); RoughDigital --> Corrections[Corrections]; Corrections --> FinalDigital((Final Digital)); Parameters((Parameters)) --> Corrections; Vector --> GimpPluggedTeseo((Gimp plugged Teseo)); GimpPluggedTeseo --> VectorTransformations[Vector Transformations]; VectorTransformations --> Vector; GimpPluggedTeseo --> Gimp((Gimp)); Gimp --> RasterTransformations[Raster Transformations]; RasterTransformations --> Raster;
```

The flowchart illustrates the Teseo system architecture. It begins with a **Seismogram** (rectangle) which is processed by a **Scanner** (rectangle) to create a **Raster** (oval). The **Raster** is then converted by **Raster to Vector** (rectangle) into a **Vector** (oval). The **Vector** is processed by **Sampling** (rectangle) to produce a **Rough Digital** (oval). This is followed by **Corrections** (rectangle), which also receives input from **Parameters** (oval), to yield the **Final Digital** (oval). Additionally, the **Vector** is fed into **Gimp plugged Teseo** (oval). This module has two outputs: one to **Vector Transformations** (rectangle), which feeds back into the **Vector**, and another to **Gimp** (oval). The **Gimp** module outputs to **Raster Transformations** (rectangle), which feeds back into the **Raster**.

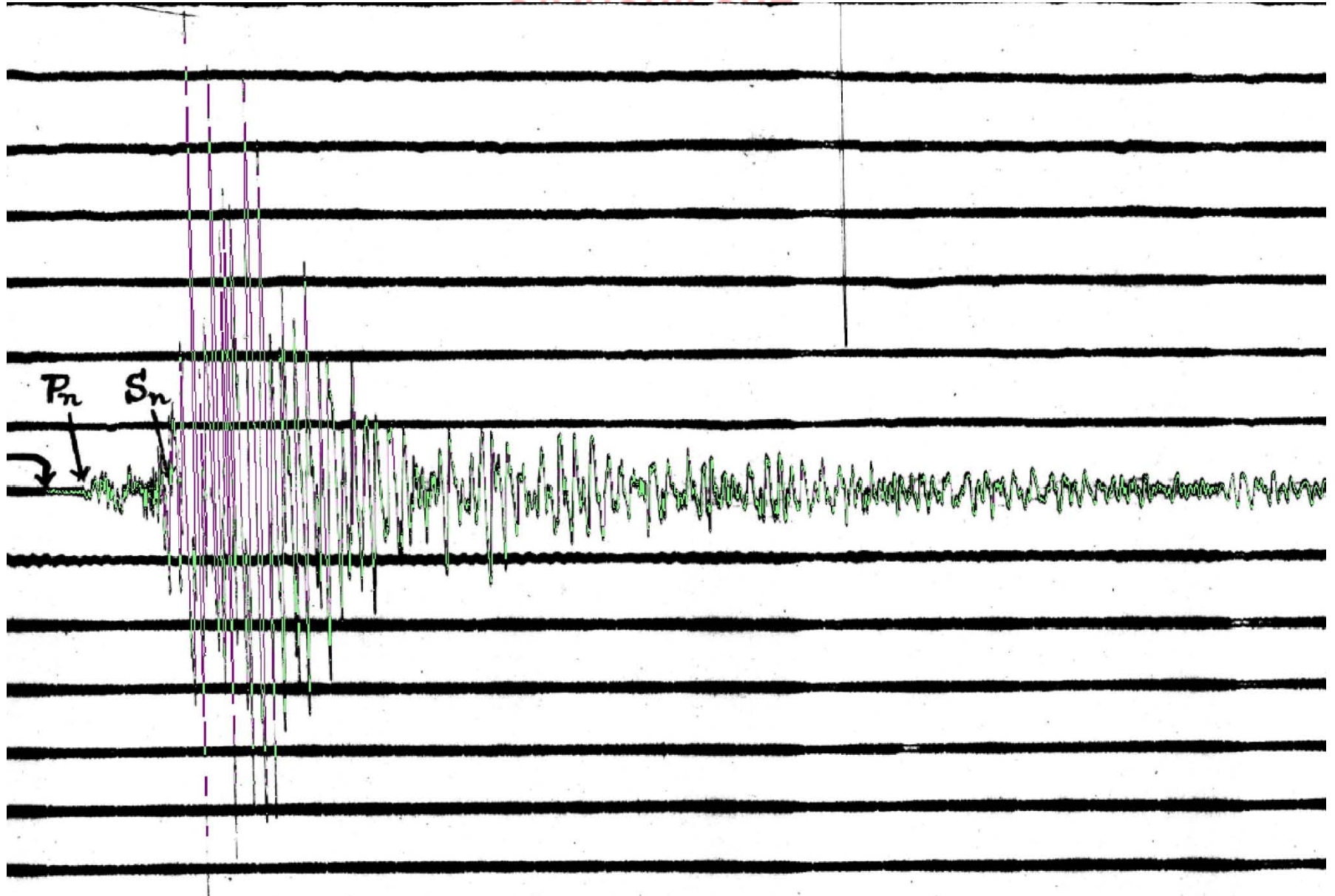
# IBM Storage System (84 TB)





# ANJAR EARTHQUAKE OF 21.7.1956

STATION:PUNE



Broadband Stations established  
under project mode

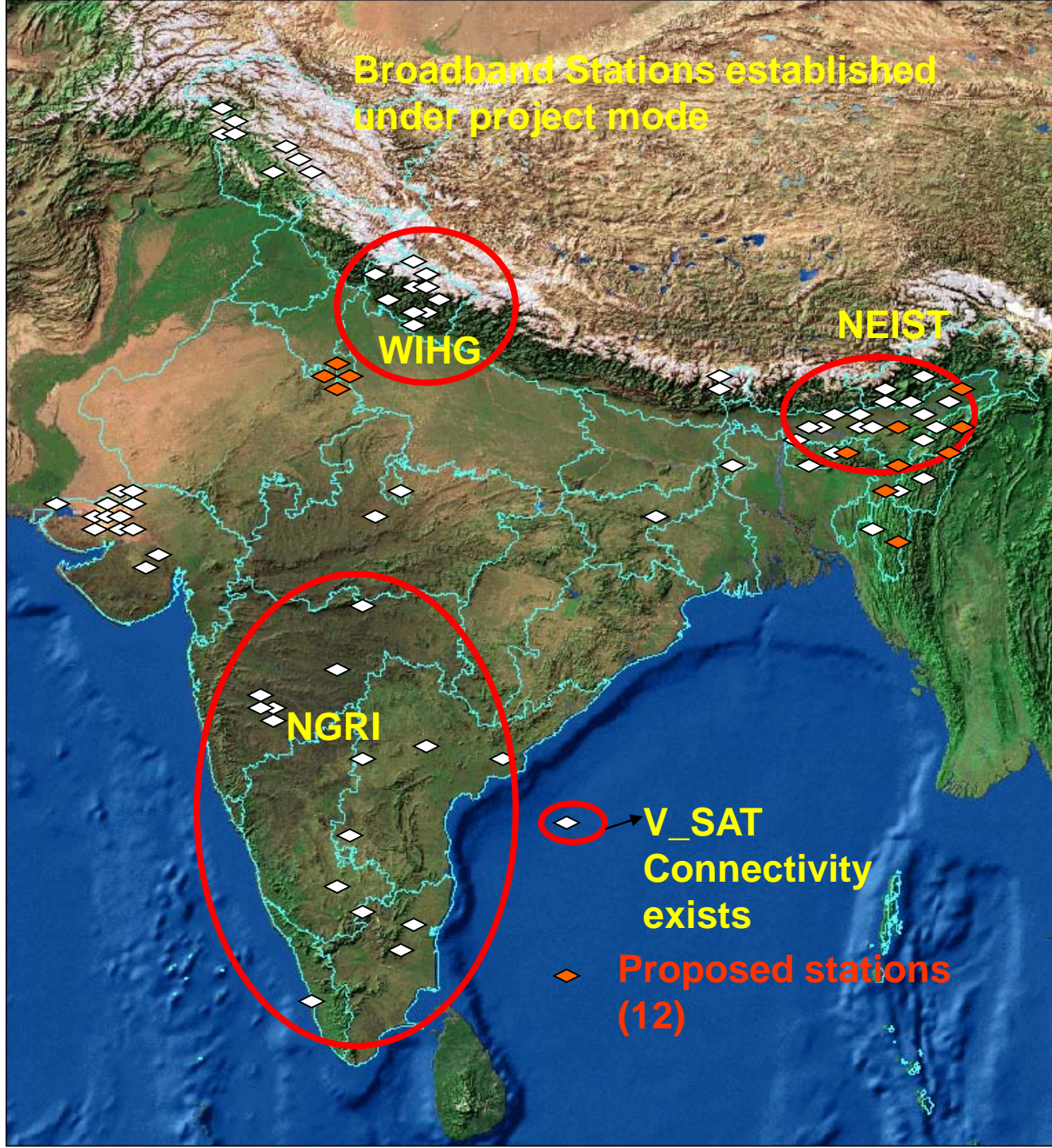
WIHG

NEIST

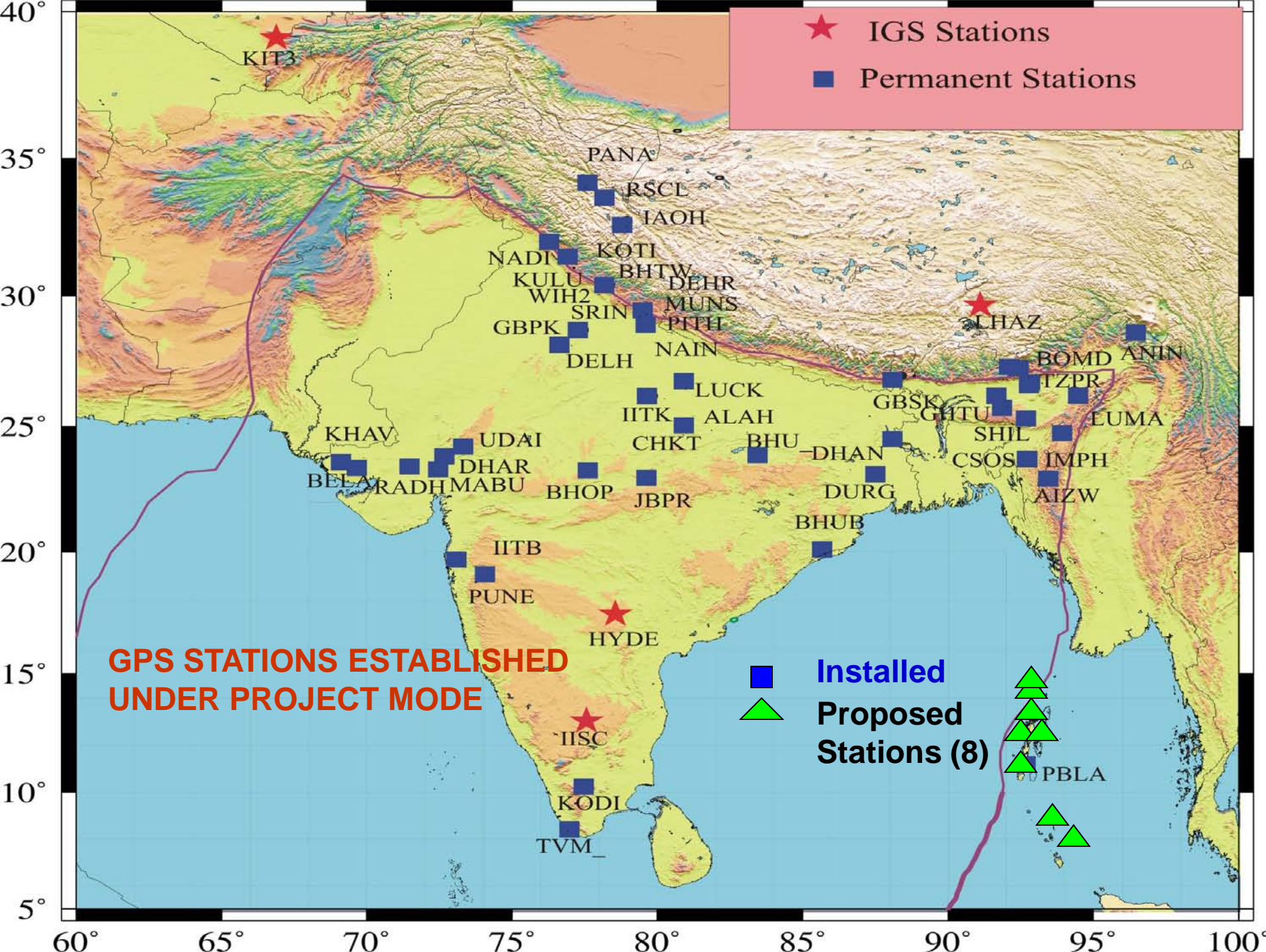
NGRI

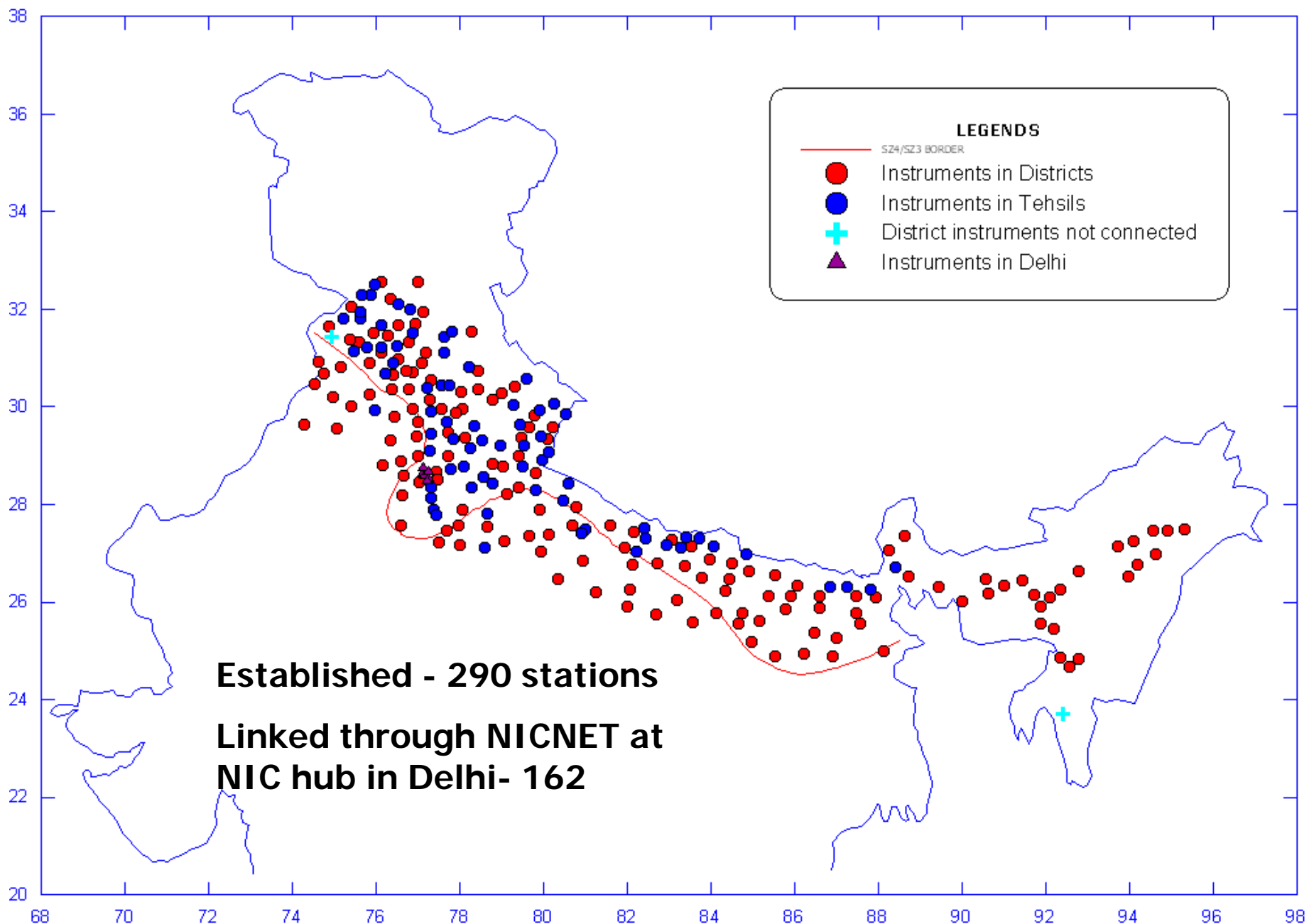
V\_SAT  
Connectivity  
exists

Proposed stations  
(12)

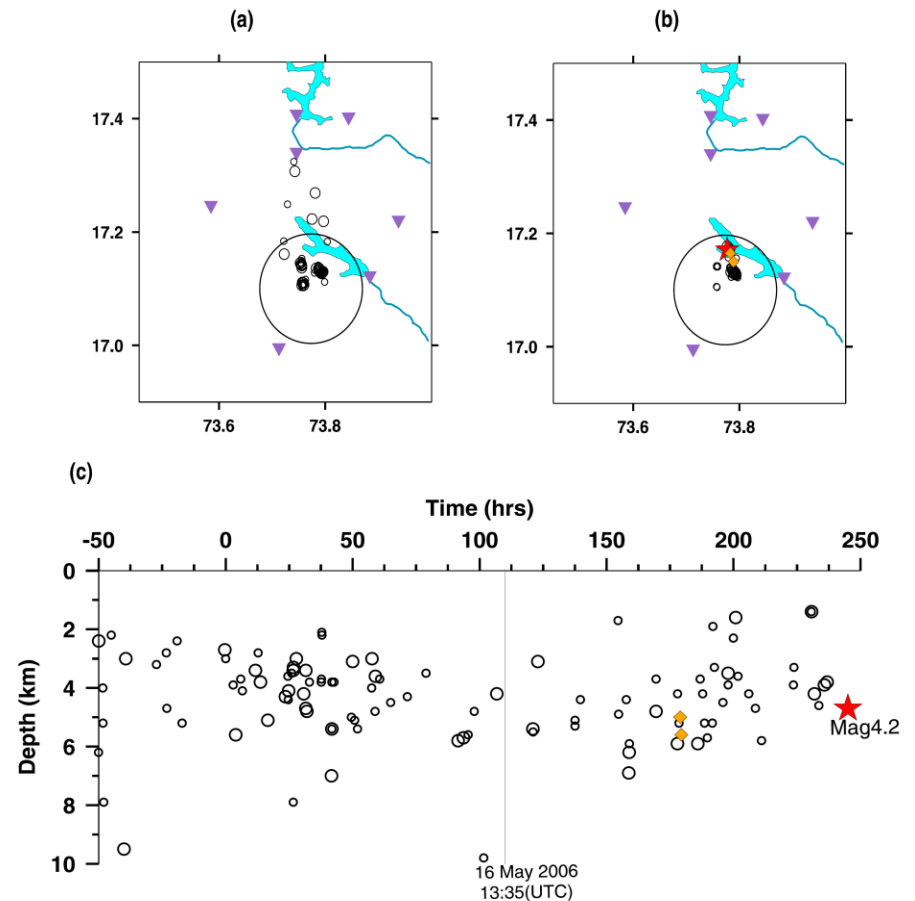
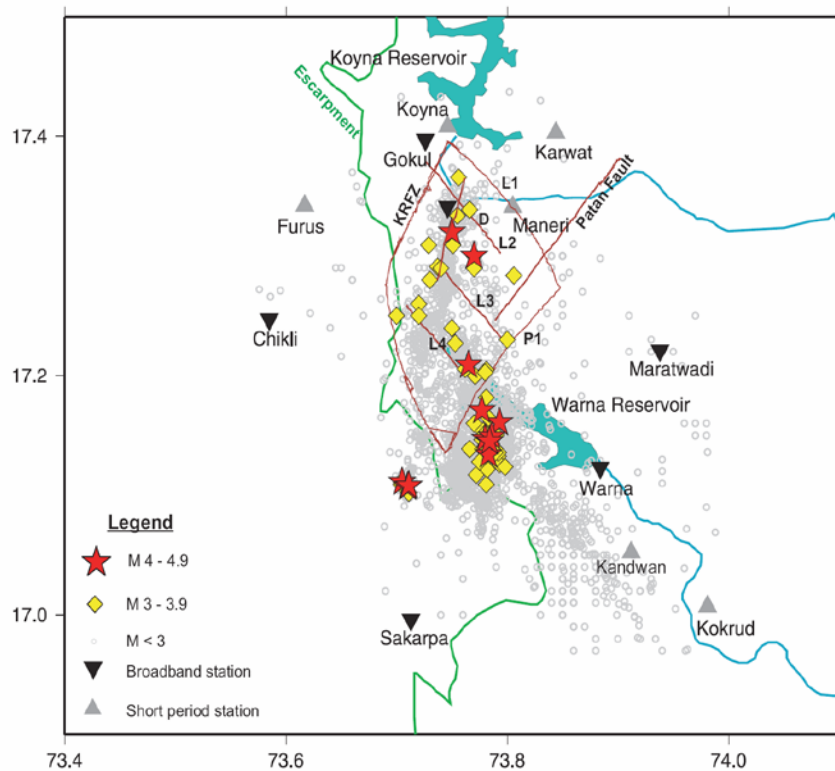








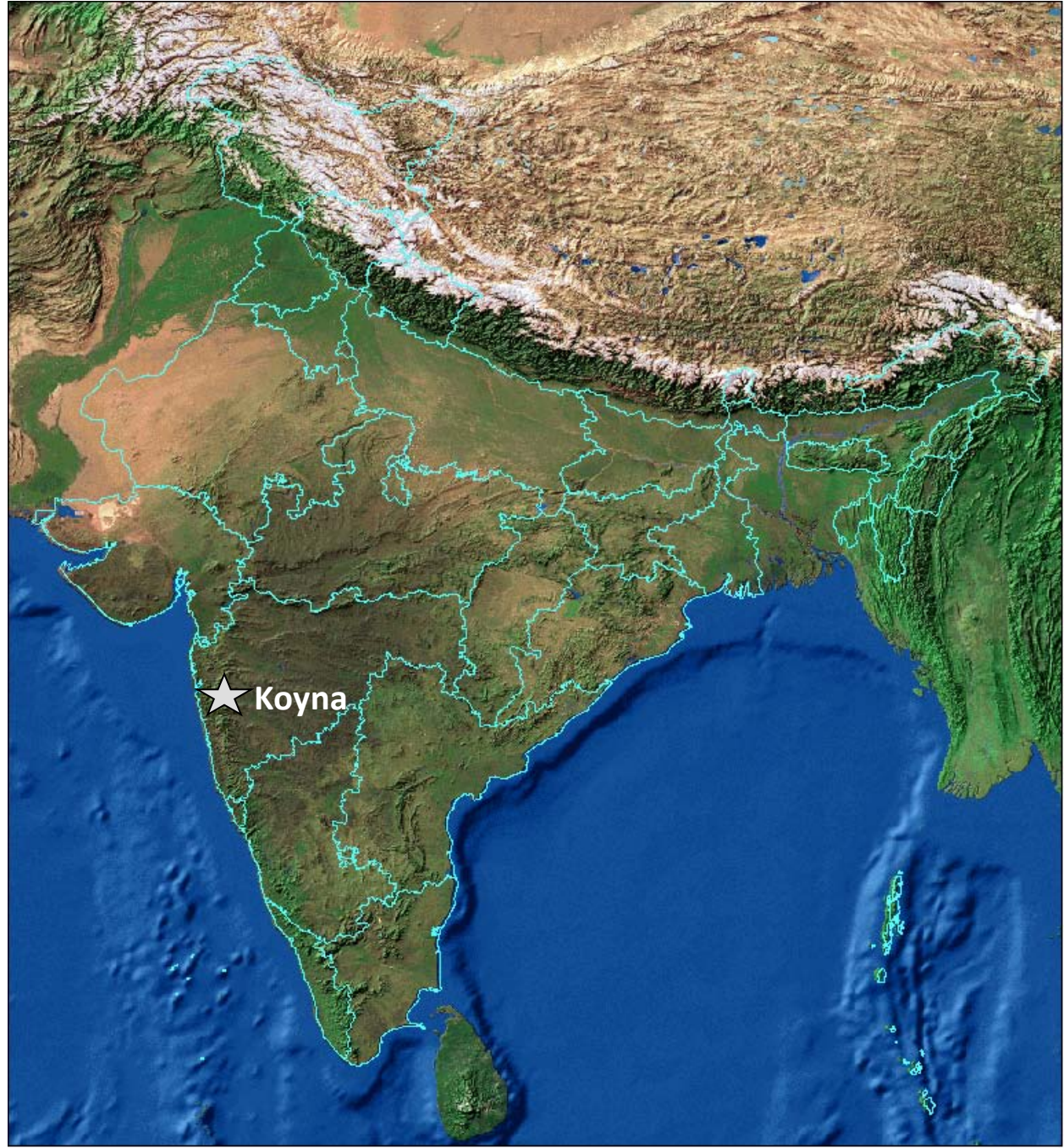
STRONG MOTION NETWORK SHOWING LOCATIONS OF STRONG MOTION ACCELEROGRAPH STATIONS IN DISTRICTS AND TEHSILS ALONG WITH SZ4/SZ3 BORDER



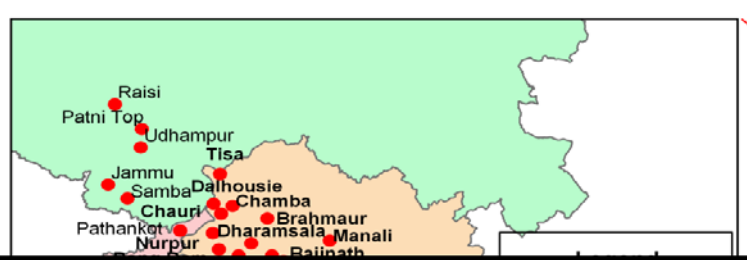
**Koyna seismic network - An example of nucleation pattern for the forecast of the event of 21st May 2006.**



# Deep drilling investigations in Koyna

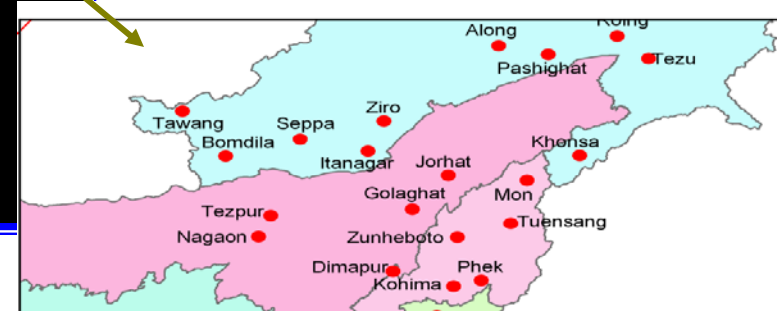
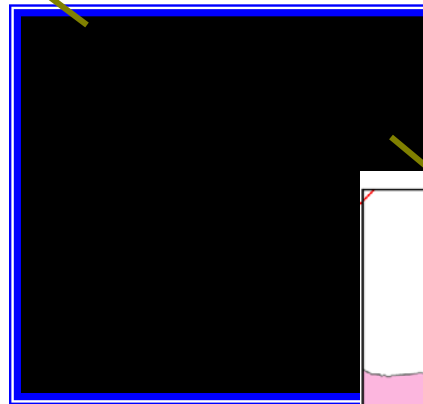
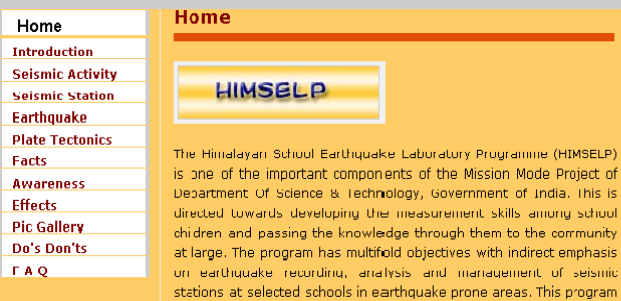


# Earthquake Education/ Awareness: Himalayan School Earthquake Laboratory Programme- HIMSELF



An interactive website has also been launched  
([www.himself.net.in](http://www.himself.net.in))

Target: 50,000-60,000 students





# **National Programme on Earthquake Precursors-** *(recently launched by MoES)*

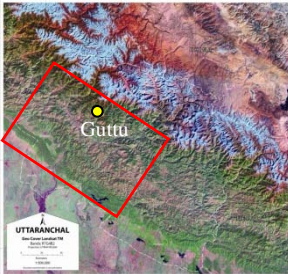
## ***Objectives:***

- **Generation of long-term, comprehensive multi-parametric geophysical observations in seismically active areas, where probability of occurrence of earthquakes of  $M > 6$  is perceived high and/ or some precursory observations (such as swarms followed by quiescence) have been observed.**
- **Comprehensive analysis and interpretation of these multi-parametric geophysical observations on a real-time basis at a Central Receiving Station, with multi-agency participation.**
- **Establish possible relationship between various earthquake precursory phenomenon and the earthquake generation processes.**



# MULTI-PARAMETERIC GEOPHYSICAL OBSERVATORY

GHUTTU, UTTARAKHAND



BBS  
&  
Accelerograph

GPS  
&  
Strain meter



## MPGO

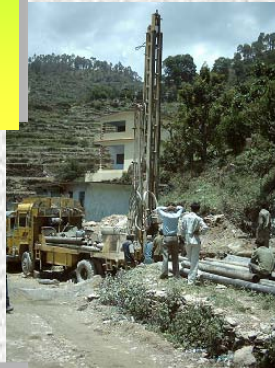
aims at generating  
high quality geophysical data  
base for

**Earthquake Precursory  
Research**

Resistivity  
Measurements



Magnetic  
Observations



Super  
conductive  
Gravimeter



EM emission  
In  
ULF Band



Radon  
Monitoring

Ground  
water

# Major Activities

- **Setting up of Multi-Parametric Geophysical observatories.**
- **Monitoring of Geochemical precursors including He, Ra, CO<sub>2</sub>, CH<sub>4</sub> and water level changes etc. in A&N region, NW & NE Himalaya and Delhi.**
- **Electromagnetic and Ionospheric precursory studies in Koyna and Agra.**
- **Studies related to High Precision Leveling, Gravity and Magnetic observations and Crustal deformation using GPS in Uttaranchal and NE Himalayan region.**
- **Remote sensing-based thermal precursory studies.**
- **Measurement of strain levels in selected locations.**
- **Collation and Analysis of Seismological and collateral geophysical data.**
- **SODAR (Sound Detection and Ranging) related studies along the entire Himalayan range.**
- **Setting up of CRS and facilities for online receipt of data from all observatories.**

# Participating Organizations

*All IITs (New Delhi, Chennai, Kharagpur, Mumbai, Roorkee, Kanpur, Guwahati)*

*Universities (Pune, Tezpur, Jammu, Manipur, Delhi, Mizoram, Kumaon, Garhwal, Nagaland, Punjab, Osmania, Kurukshetra, Andhra, BHU, GND, Amritsar)*

**RBS College, Agra**

**Survey of India, (SOI) Dehradun**

**Geological Survey of India (GSI)**

**Indian School of Mines (ISM), Dhanbad**

**Indian Institute of Sciences (IISc), Bangalore**

**Regional Research Laboratory RRL), Jorhat**

**Science & Technology Council, Sikkim**

**National Institute of Oceanography (NIO), Goa**

**Indian Institute of Astrophysics (IIA), Bangalore**

**India Meteorological Department (IMD), New Delhi**

**Indian Institute of Geomagnetism (IIG), Mumbai**

**Central Road Research Institute (CRRI), New Delhi**

**Central Building Research Institute (CBRI), Roorkee**

**Cochin University of Science & Technology, Cochin**

**National Institute of Rock Mechanics (NIRM), Kolar**

**Centre for Earth Science Studies (CESS), Trivandrum**

**Gujarat Engineering Research Institute (GERI), Baroda**

**Wadia Institute of Himalayan Geology (WIHG), Dehradun**

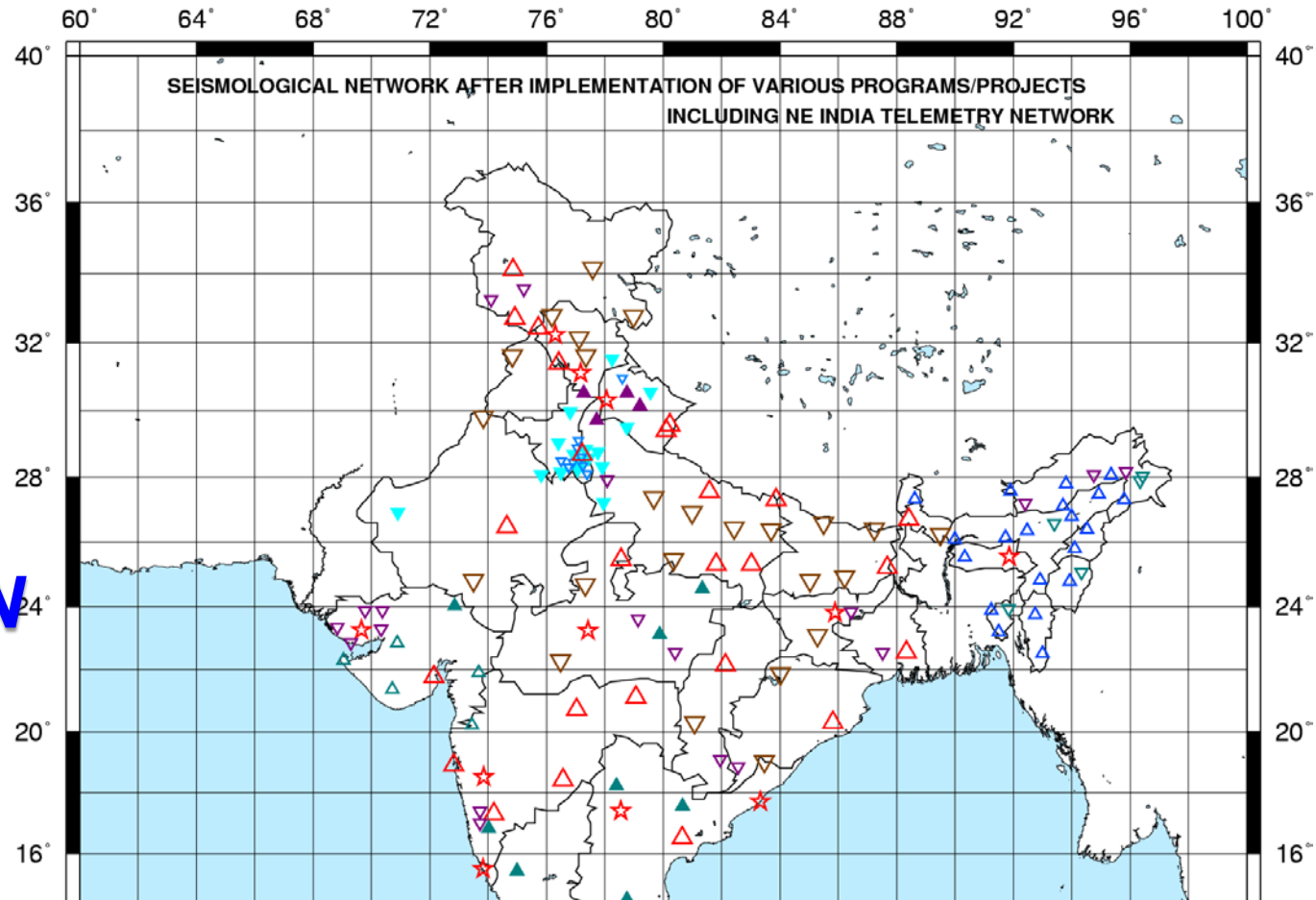
**National Geophysical Research Institute (NGRI), Hyderabad**

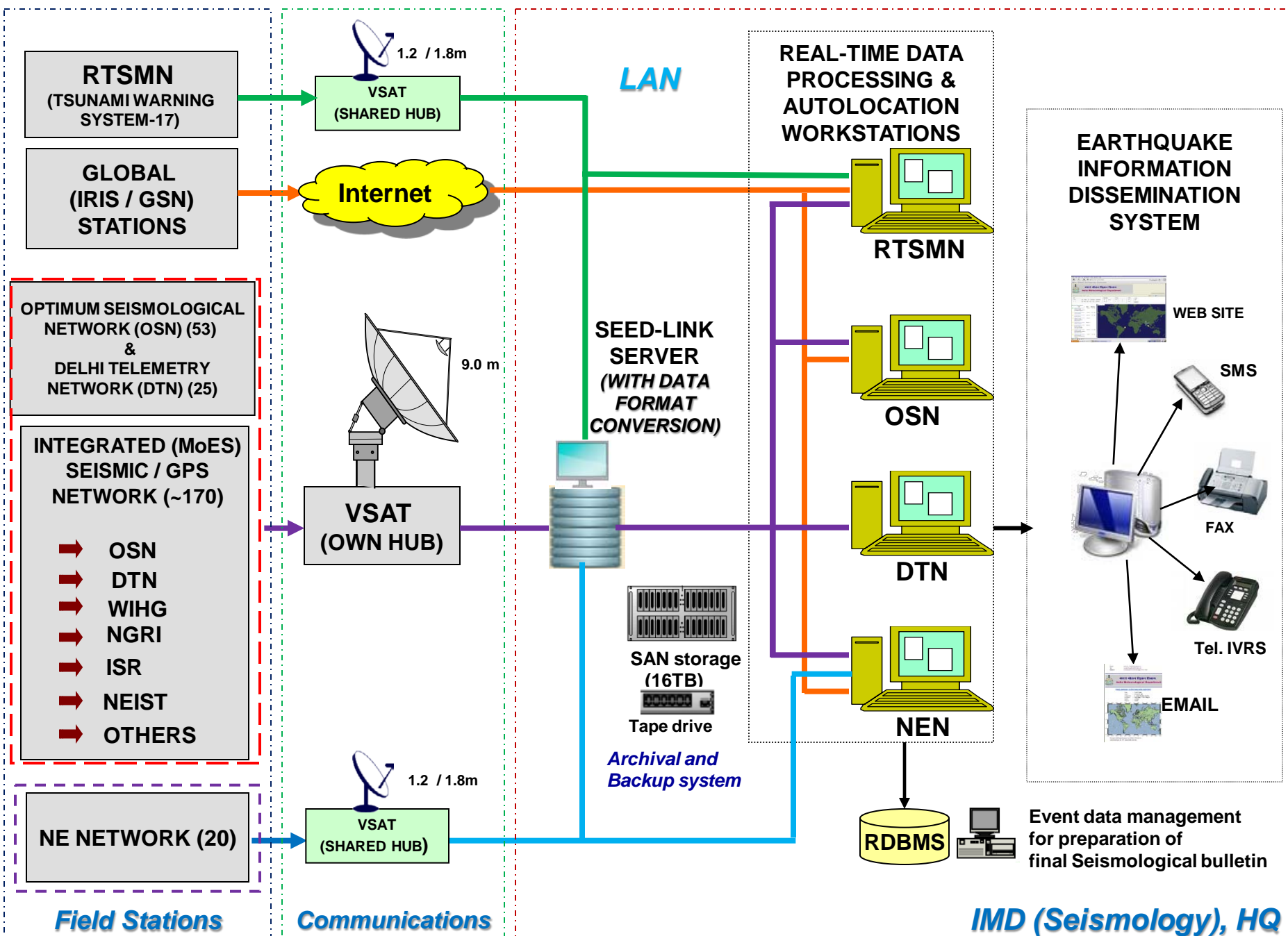
**Centre for Scientific Instruments Organization (CSIO), Chandigarh**

**G.B. Pant Institute of Himalayan Environment and Development, Almorah**

**Centre for Mathematical Modeling & Computer Simulation (CMMACS), Bangalore**

***NETWORK  
UPGRADATION  
PLAN  
(TOTAL-161)***





***THANK YOU !!***