Earthquake Early Warning System

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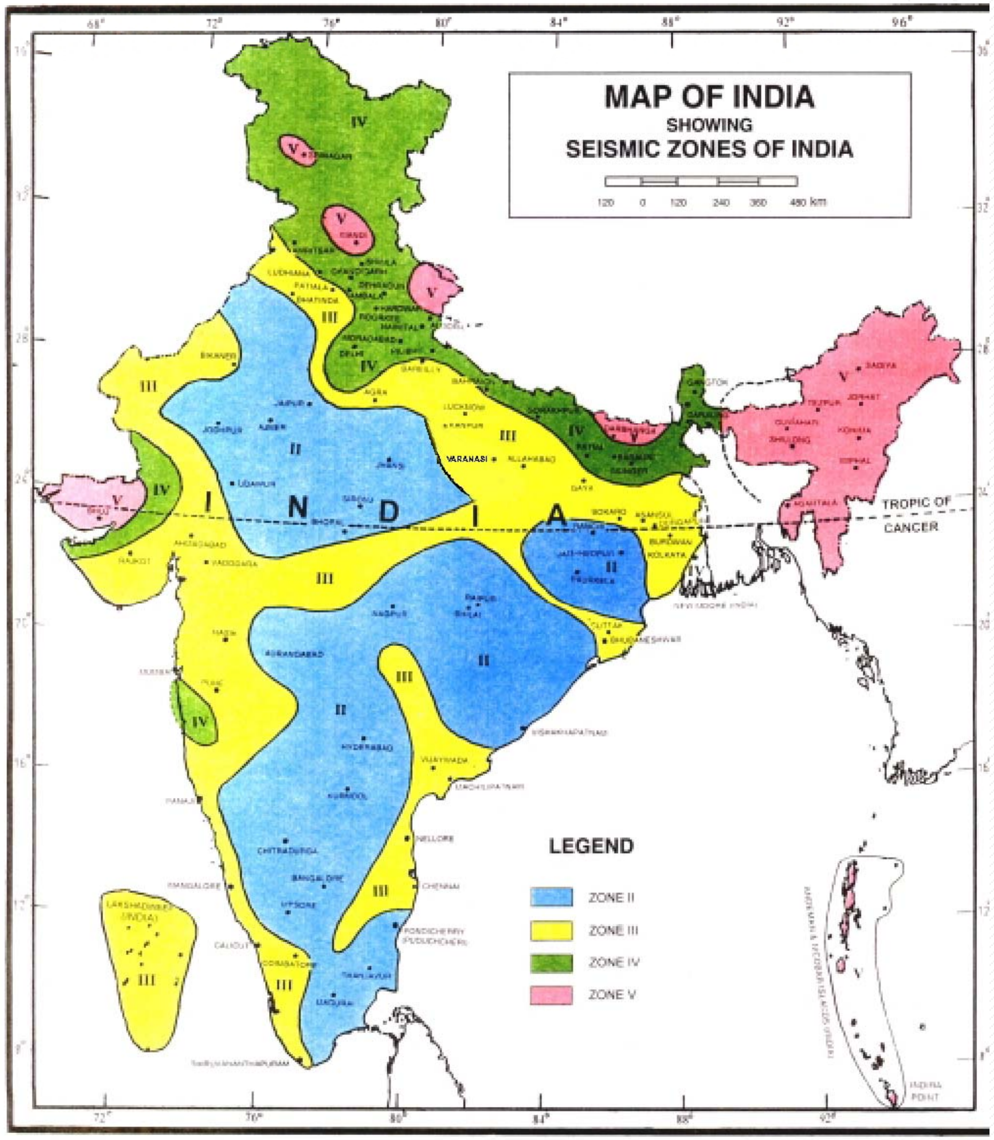
Seismic Zoning Map of India



Anticipating the 'Big One'

Here's how an earthquake warning system works

1. Seismometers detect P waves, the initial tremors.
2. This is transmitted to an early warning center.
3. Warnings are sent out to TV, radio, cellphones.

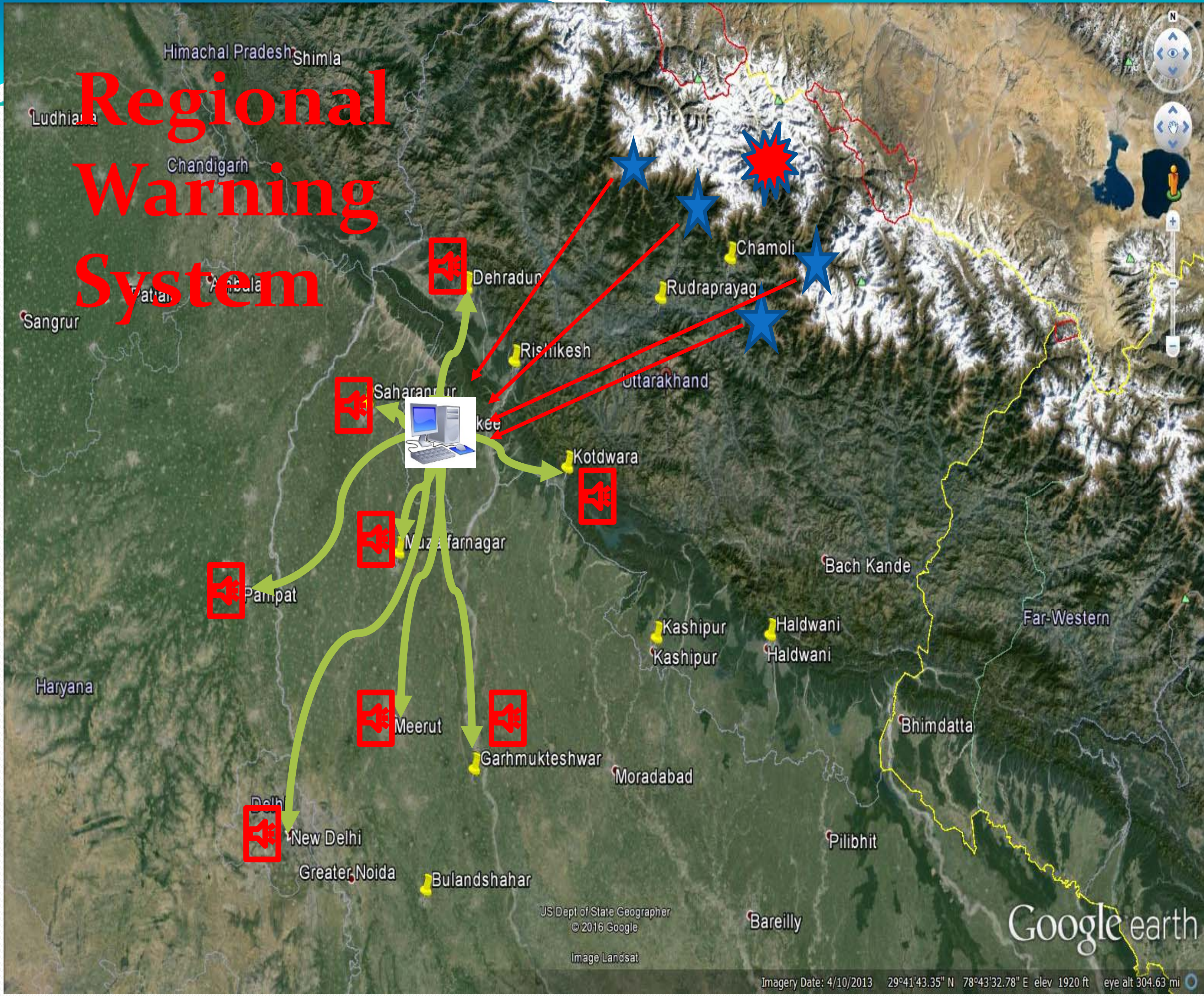
Physical Basis of Earthquake Early Warning (EEW)

- Strong ground shaking , damage to structures and casualty are caused by shear-waves and by the subsequent surface waves
- Shear waves travel at about half the speed of the primary waves
- All elastic waves travel much slower than electromagnetic signals transmitted wireless or through cables.
- Thus, depending on the distance of epicentre from the endangered urban area, transmission of information and real-time analysis of the first primary wave may provide warnings from few seconds to a few tens of seconds before the arrival of strong ground shaking.

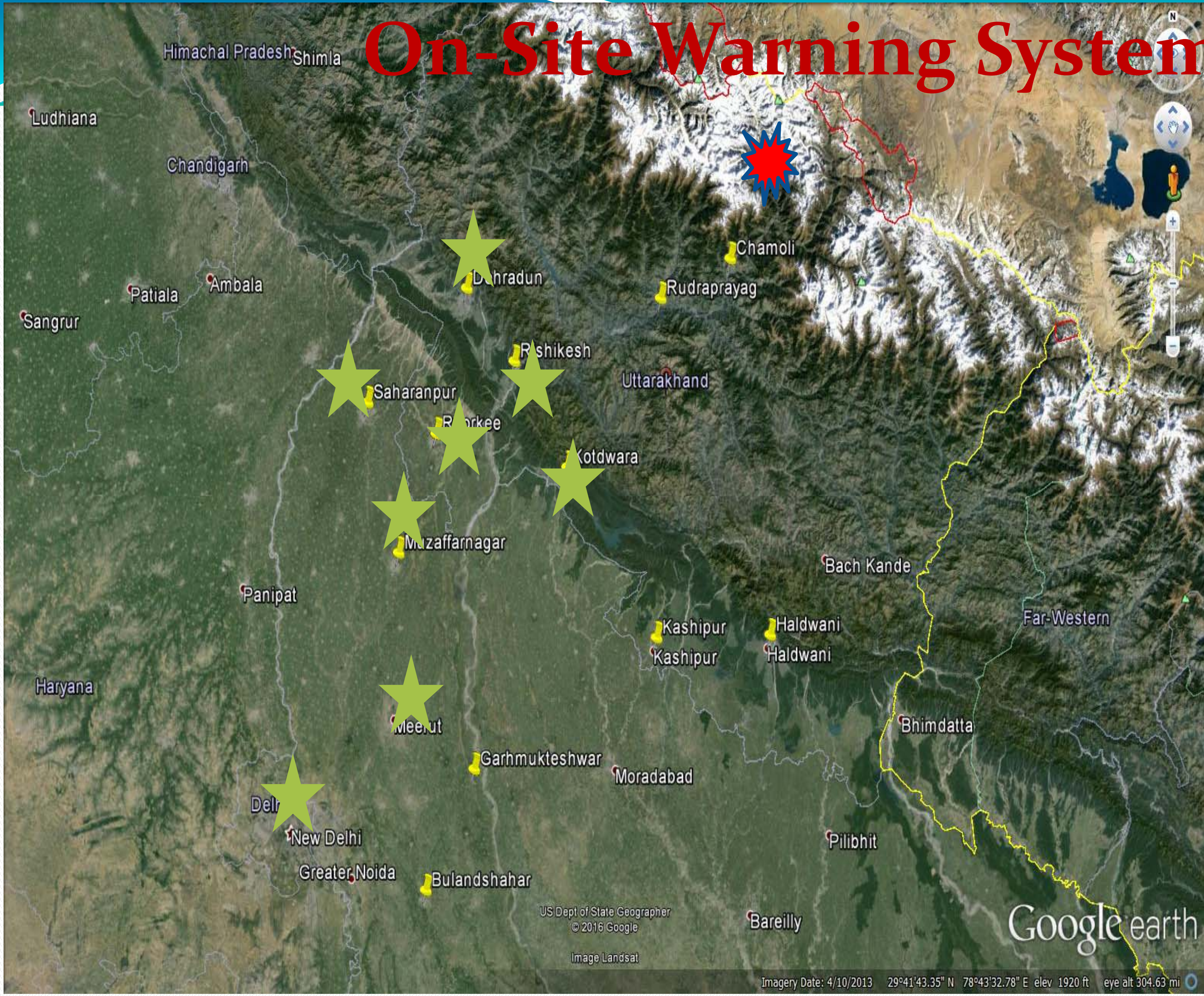
Onsite EEW vs. Regional EEW

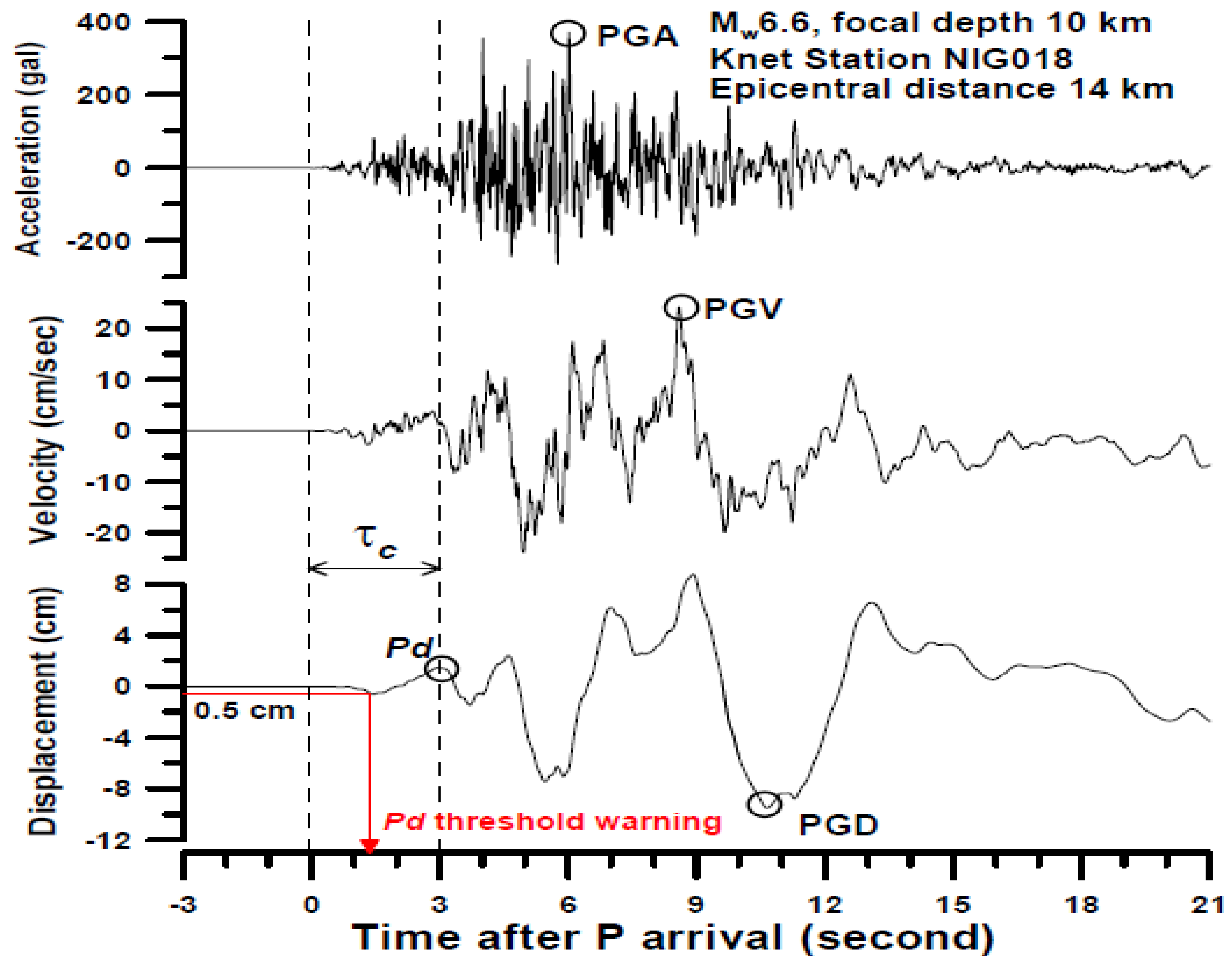
- **Onsite EEW**
  - Sensor at the same place where warning is issued
  - Warning based on single sensor
  - Basis: P Waves travels faster than damaging S Waves
  - Chances of false and Missed warnings are too high
- **Regional EEW**
  - Sensors placed near epicenter and warning issued at places away from epicenter
  - Warning based on alerts from atleast three to four sensors located at different places
  - Basis: Onsite EEW and use of present day networking
  - Chances of flase and missed alarms are very little

Regional Warning System



On-Site Warning System

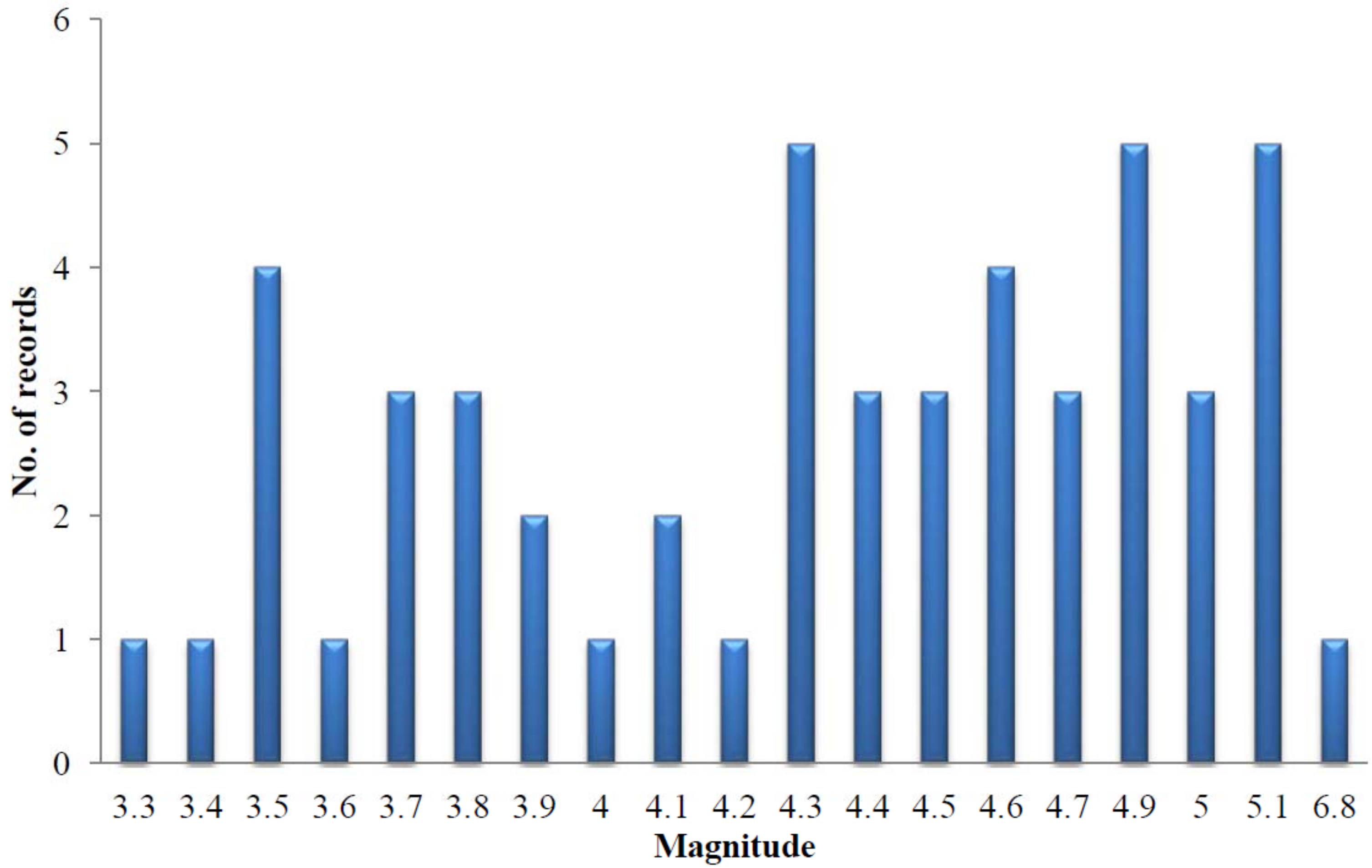




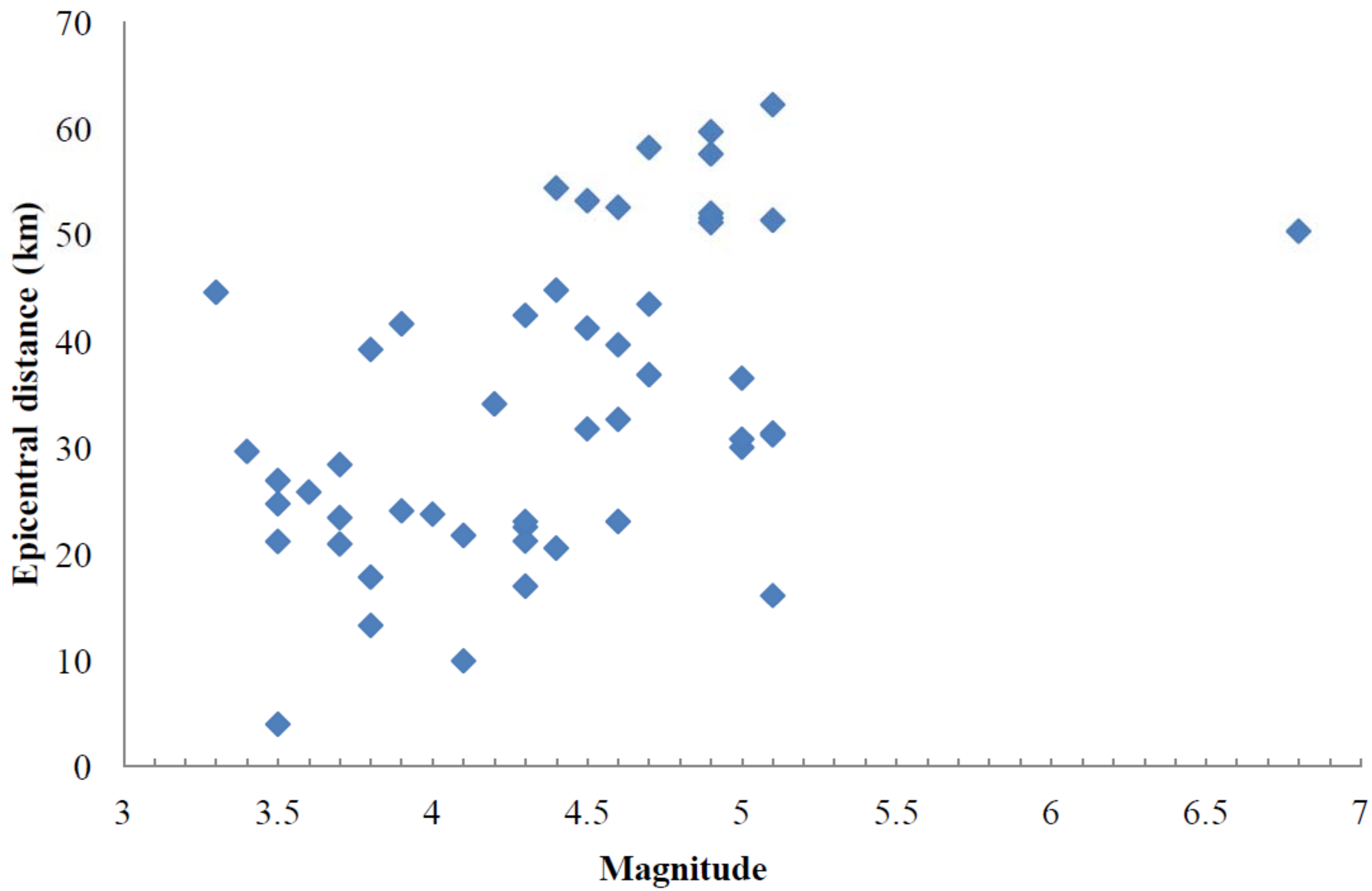
Mw6.6, focal depth 10 km
Knet Station NIG018
Epicentral distance 14 km
PGA
PGV
PGD
Pd
τc
0.5 cm
Pd threshold warning
Acceleration (gal)
400
200
0
-200
Velocity (cm/sec)
20
10
0
-10
-20
Displacement (cm)
8
4
0
-4
-8
-12
-3
0
3
6
9
12
15
18
21
Time after P arrival (second)

P Wave Attributes for Early Warning

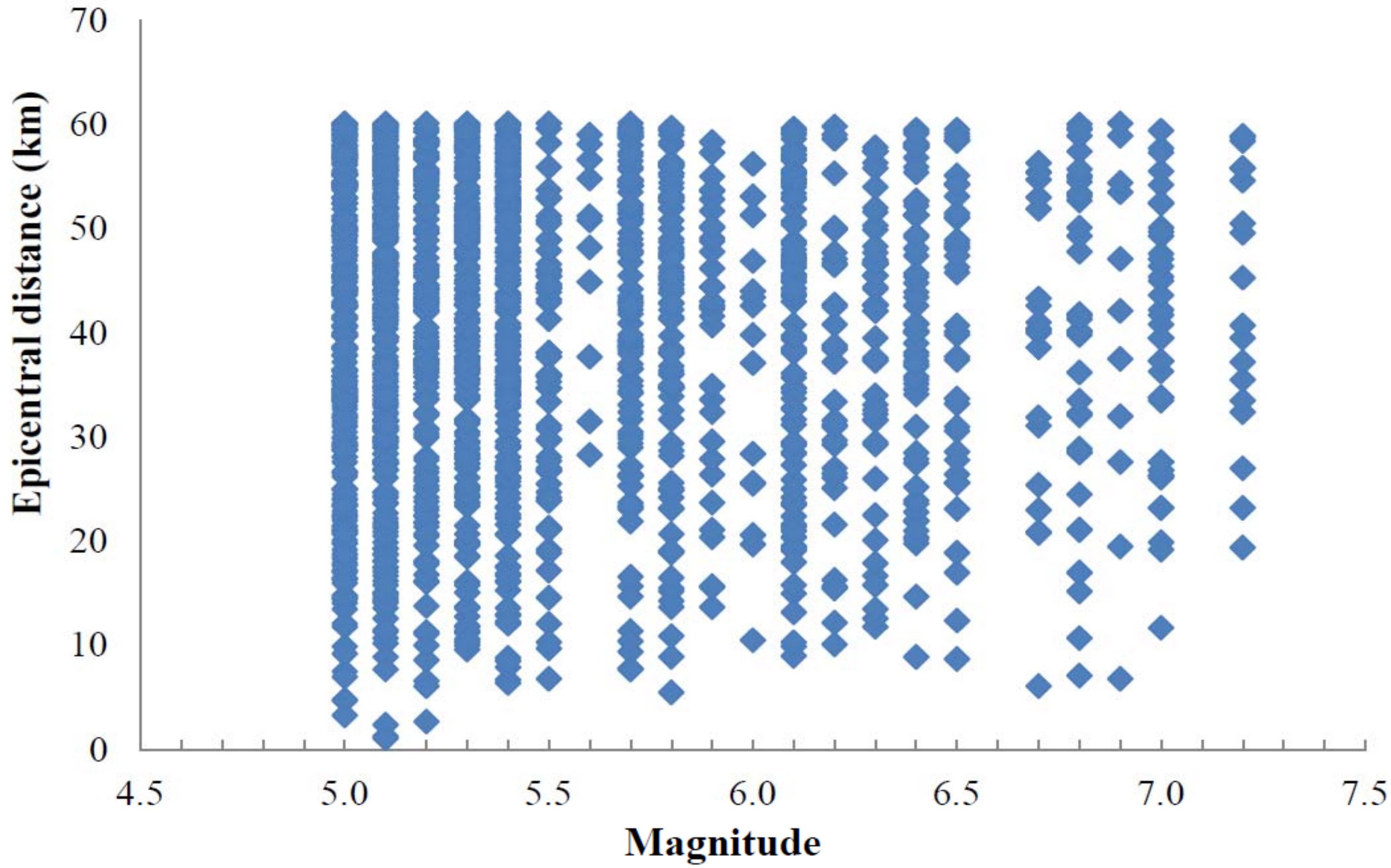
India Data Set, Δ < 60 Km, 51 Records



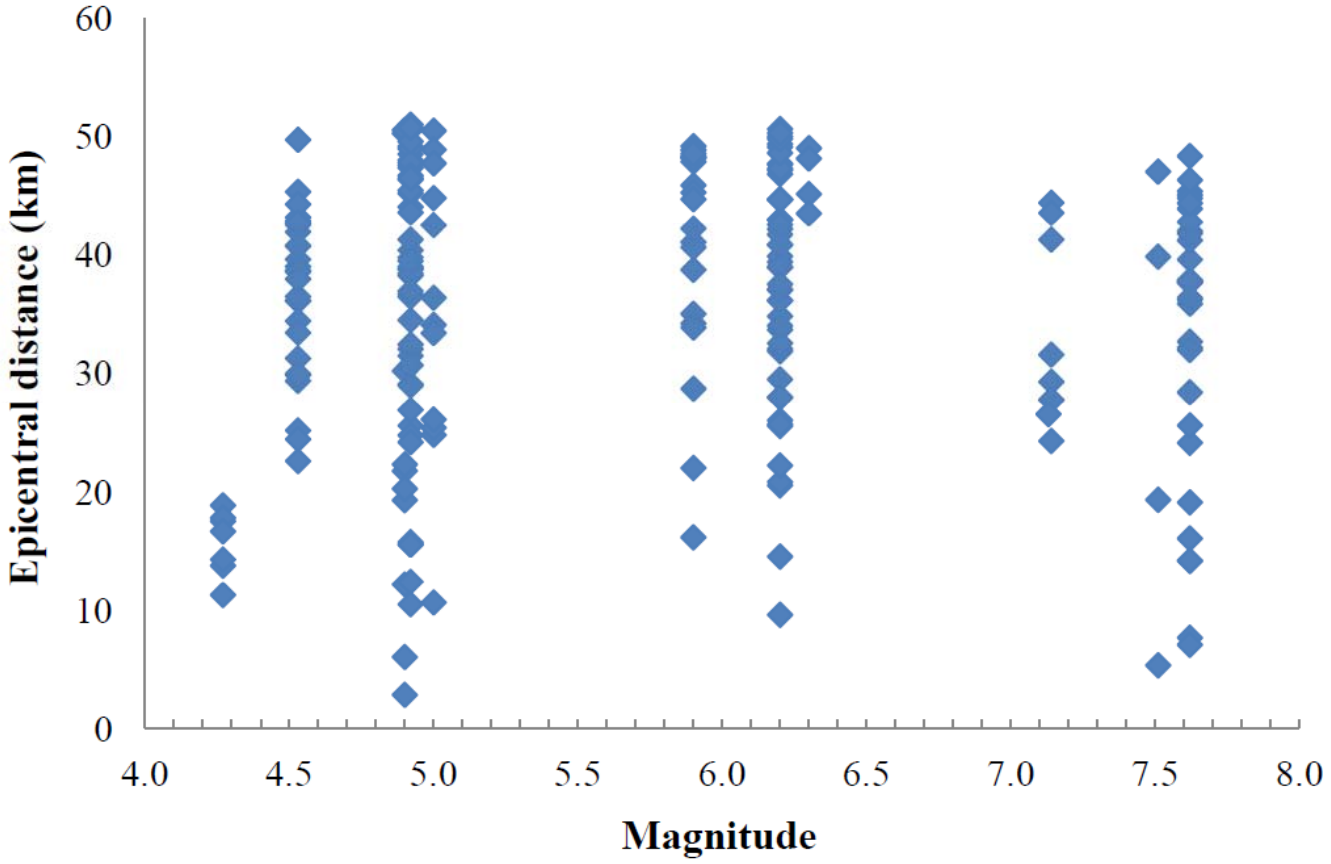
Indian Data Used (51 Records of 28 EQs)



K NET data Used (1726 Records of 105 Eqs)



PEER-NGA Data Set (219 Records of 14 Eqs from California Turkey & Taiwan)



Total Data Set

- From Five Countries: India, Japan, USA (South California), Turkey and Taiwan
- 1996 vertical records (vertical component) of 147 earthquakes recorded at 697 stations were used

Attributes Studied for EEW

$$RSSCV = \sqrt{\sum_{i=1}^{n} v_i^2}$$ (Bhardwaj 2013)

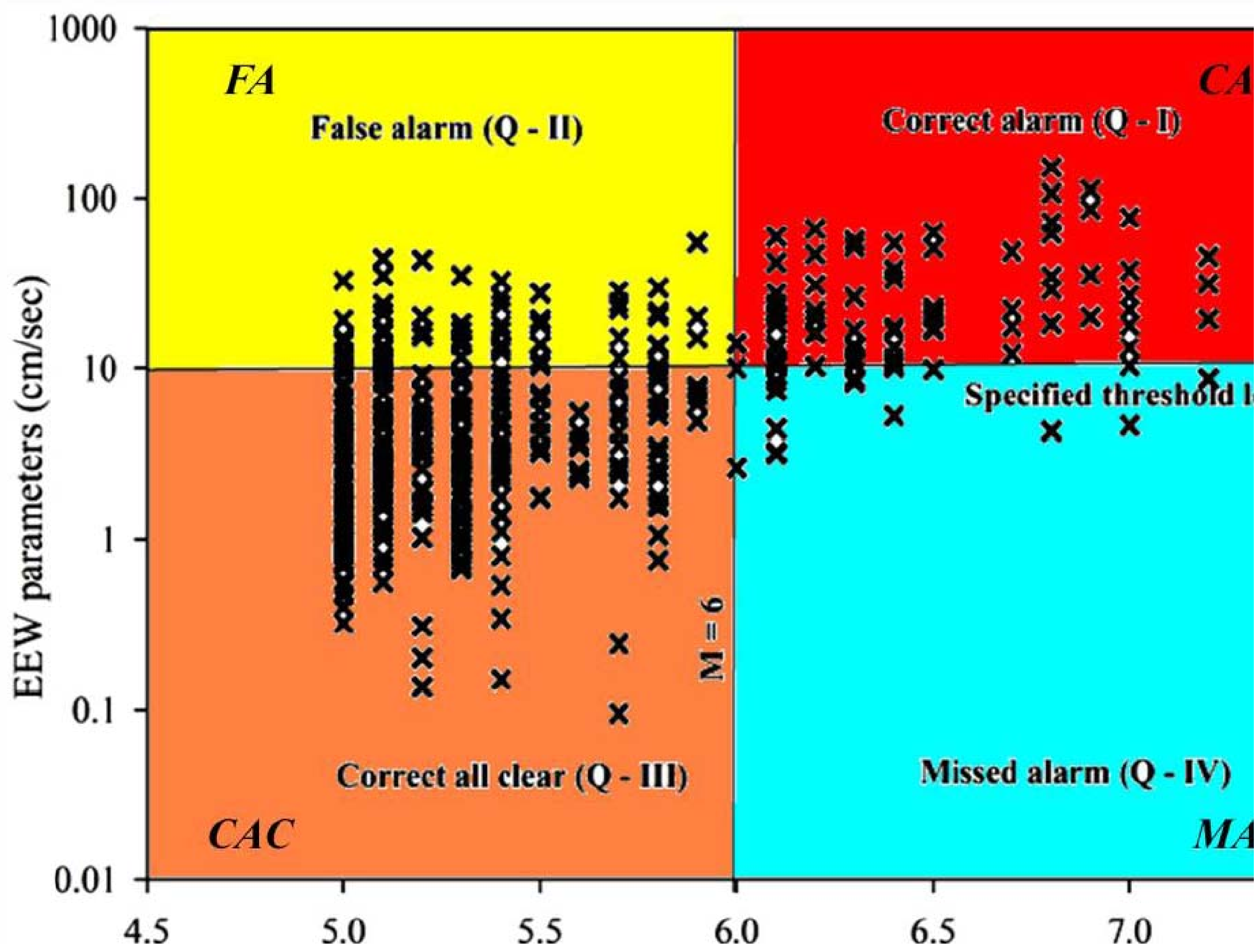
τ_p^{max} (Nakamura 1988)

τ_c (Wu and Kanamori 2005)

P_d (Wu and Kanamori 2005)

CAV (Erdik et al. 2003)

Parameters	Time Window				
	1 sec	2 sec	3 sec	4 sec	5 sec
τ_p^{max} (sec)	0.95	1.00	1.06	1.10	1.14
τ_c (sec)	1.02	1.17	1.20	1.42	1.55
P_d (cm)	0.13	0.27	0.51	0.95	1.38
CAV (cm/sec)	3.00	8.00	10.00	23.00	41.00
RSSCV (cm/sec)	0.30	1.00	1.70	5.20	10.00



FA
False alarm (Q - II)
CA
Correct alarm (Q - I)
Specified threshold l
Correct all clear (Q - III)
Missed alarm (Q - IV)
CAC
MA
M = 6
EEW parameters (cm/sec)
1000
100
10
1
0.1
0.01
4.5
5.0
5.5
6.0
6.5
7.0

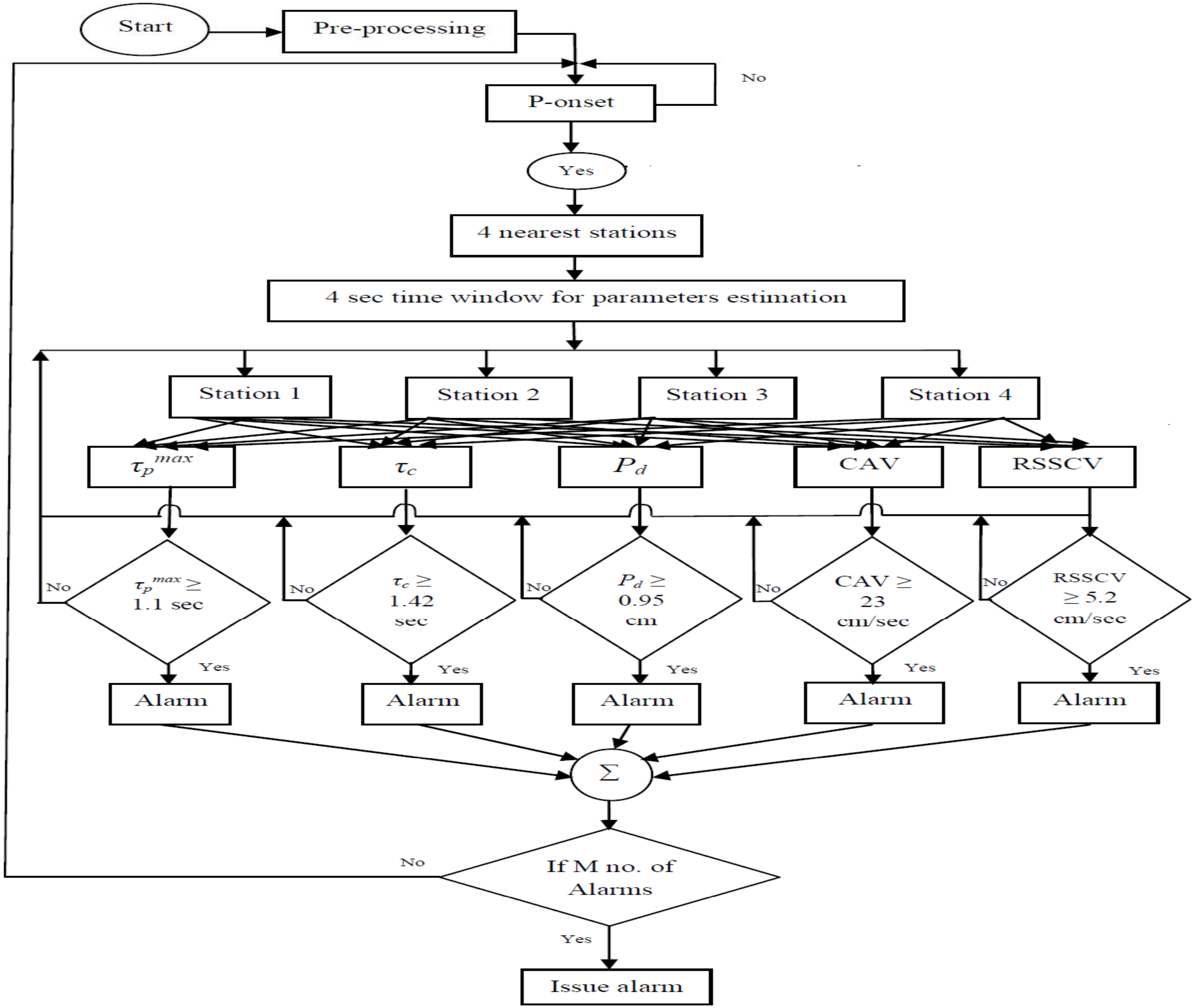
Nomenclature Used for Efficiency of Algorithm

- CA: Correct Alarms (Q1)
- CAC : Correct All Clears (Q3)
- CD: Correct Detections (CA and CAC together)

- FA: False Alarms (Q2)
- MA: Missed Alarms (Q4)
- ICA: Incorrect Alarms (FA and MA together)

Details of Selected Data Set

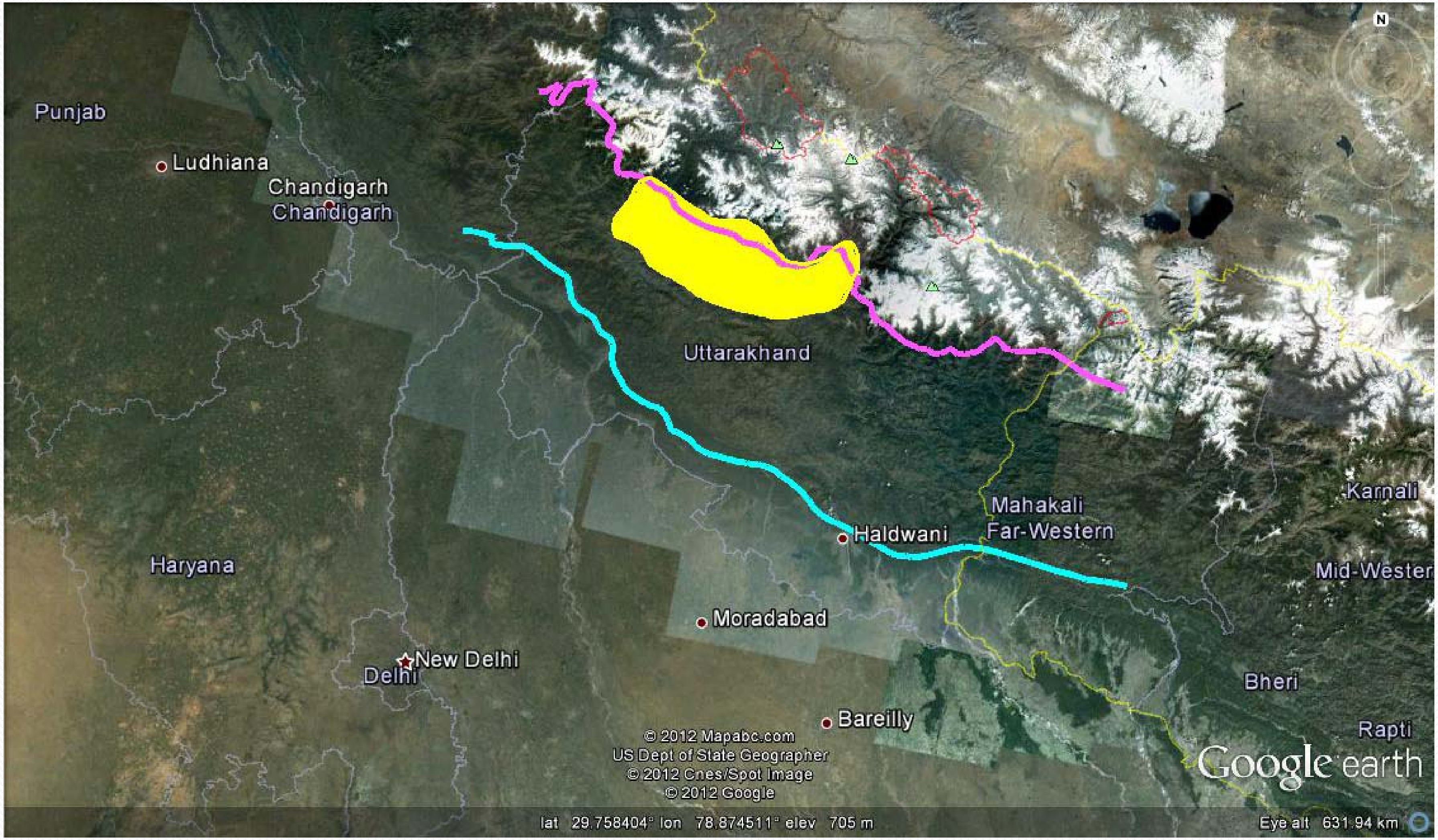
- Total 105 earthquakes used
- Records of nearest four stations (from epicenter) are considered
- 24 earthquakes are M >= 6 (Warning to be issued)
- 81 earthquakes are M<6 (Warning not to be issued)

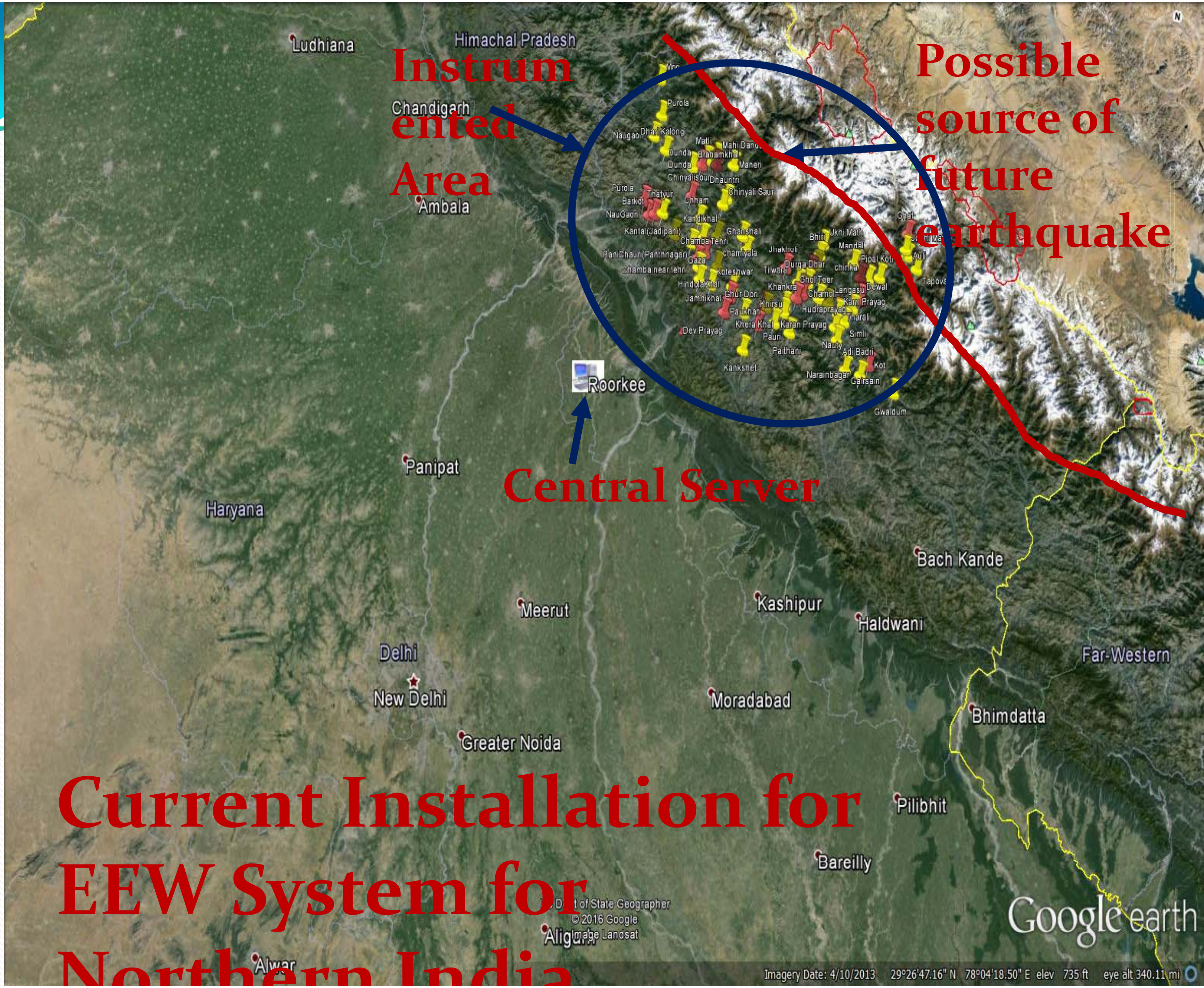

Start
Pre-processing
No
P-onset
Yes
4 nearest stations
4 sec time window for parameters estimation
Station 1
Station 2
Station 3
Station 4
τ_p^{max}
τ_c
P_d
CAV
RSSCV
No
$\tau_p^{max} \geq$ 1.1 sec
No
$\tau_c \geq$ 1.42 sec
No
$P_d \geq$ 0.95 cm
No
CAV ≥ 23 cm/sec
No
RSSCV ≥ 5.2 cm/sec
Yes
Alarm
Yes
Alarm
Yes
Alarm
Yes
Alarm
Yes
Alarm
Σ
No
If M no. of Alarms
Yes
Issue alarm

EEW for Northern India

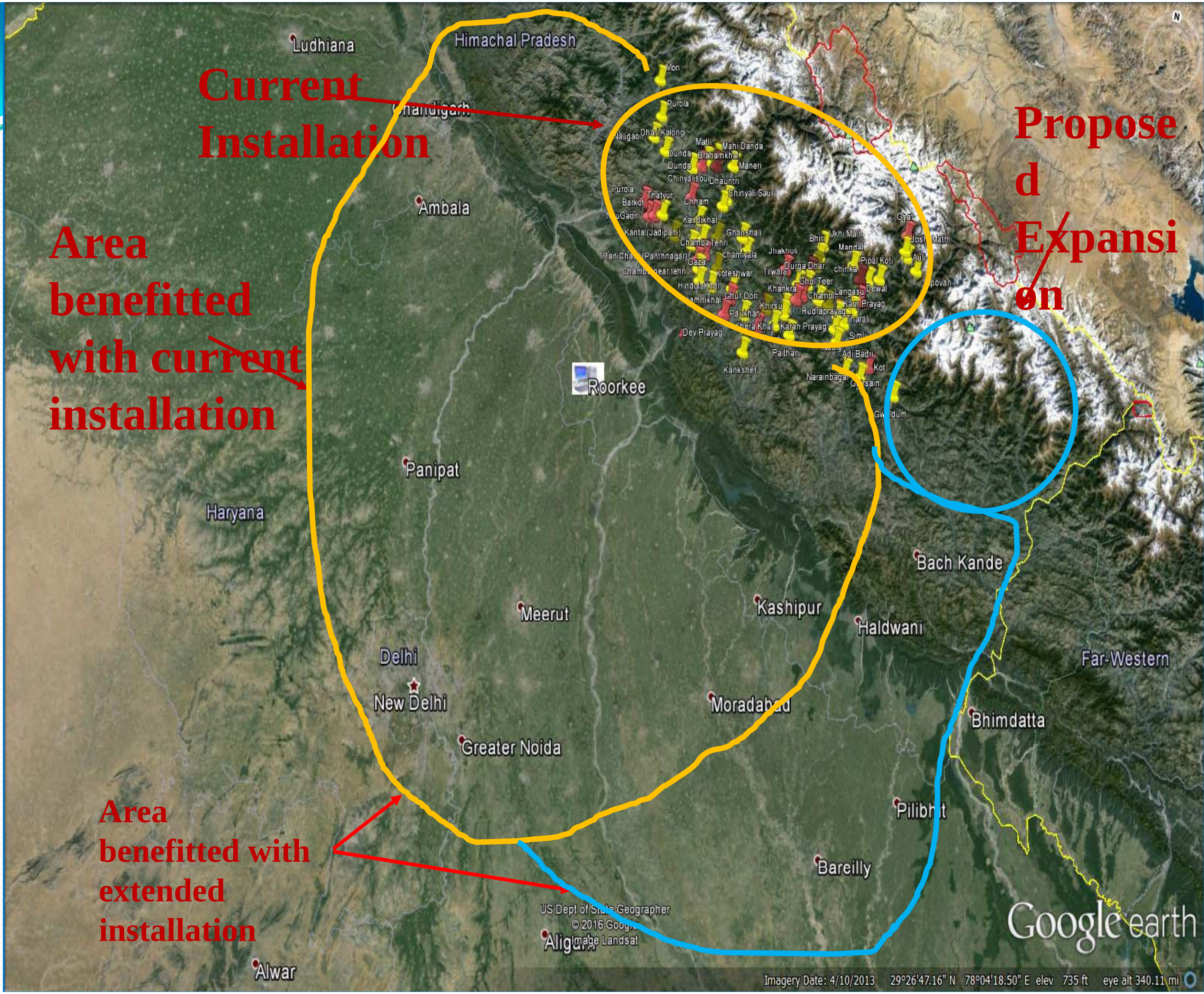
- Possibility of large size earthquake in seismic gap of Indian Himalayas
- Can effect several cities (including Delhi) and several industrial hubs
- Large population density at 100 to 300 Km from this region
- Lead time of 25 to 80 seconds may be available at these places
- Thus EEW is most relevant for Northern India

Region Identified for EEW Instrumentation





Current Installation for EEW System for Northern India

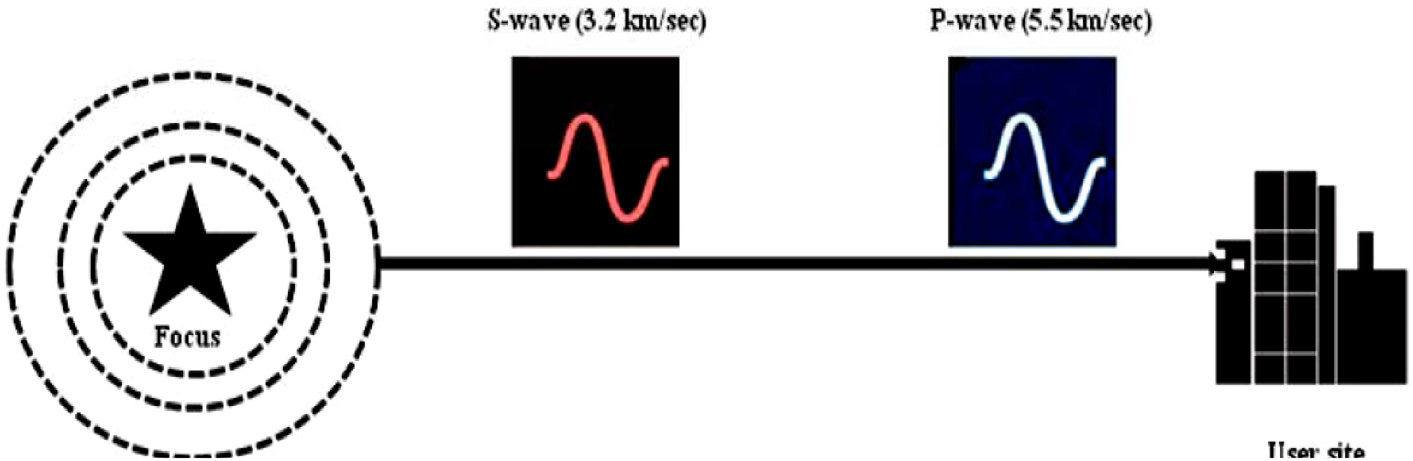


Current Installation
Proposed Expansion
Area benefitted with current installation
Area benefitted with extended installation
Ludhiana
Himachal Pradesh
Ambala
Roorkee
Panipat
Haryana
Meerut
Delhi
New Delhi
Greater Noida
Kashipur
Haldwani
Bach Kande
Far-Western
Bhimdatta
Pilibhit
Bareilly
Alwar
Google earth
Imagery Date: 4/10/2013 29°26'47.16" N 78°04'18.50" E elev 735 ft eye alt 340.11 mi

Sensor Specifications

- Tri axial MEMS Digital Accelerometer
- Dynamic range: 96 dB
- Recording range: +/- 2g
- Capability to calculate Tau C and Pd
- Capability to issue onsite warning
- Capability to stream acceleration time history to two different servers through LAN port
- Capability to receive warning from Central Station for issue of warning

Lead Time



Lead time = (S-wave arrival at the target city) - (P-wave arrival at the farthest of 4 nearest EEW station +4 sec (EEW algorithm) + 1 sec (Transmission delay) + 1 sec (Processing delay)) (7.1)

Estimated Lead Time

1) Dehradun - 20 sec

2) Hardwar - 22sec

3) Roorkee - 31 sec

4) Muzaffarnagar - 44 sec

5) Meerut - 57 sec

6) Delhi - 76 sec

Present Status of the Project

- **Total 84 stations are streaming data in real time**
- **26 stations are installed at blocks / tehsils / districts and networked using SWAN Uttarakhand.**
- **58 stations have been installed inside BSNL towers and are connected using VPNoBB**
- **Algorithm for real time processing of the data for earthquake early warning has been tested.**
- **Simulation for performance of the software successfully completed using previously recorded data of Taiwan of similar instruments installed in similar conditions.**

- **Developed EEW dissemination system**
    - Using internet and using radio signal
    - Developed microprocessor based devices for server end and for siren end
    - Security against hacking ensured by using dynamically coded messages
    - Checking of health of dissemination system and reporting
- **Sirens have been fitted in the campus**
- **Prepared Training material**
    - Video
    - Posters
    - Pamphlets
- **Mobile phone Apps is ready for distribution**
- **Developed software for shake map**
- **Developed website of EEW system (www.easni.com)**
- **Strong ground motion data of different earthquakes recorded by sensors uploaded in the website**


MINISTRY OF EARTH SCIENCES
GOVERNMENT OF INDIA

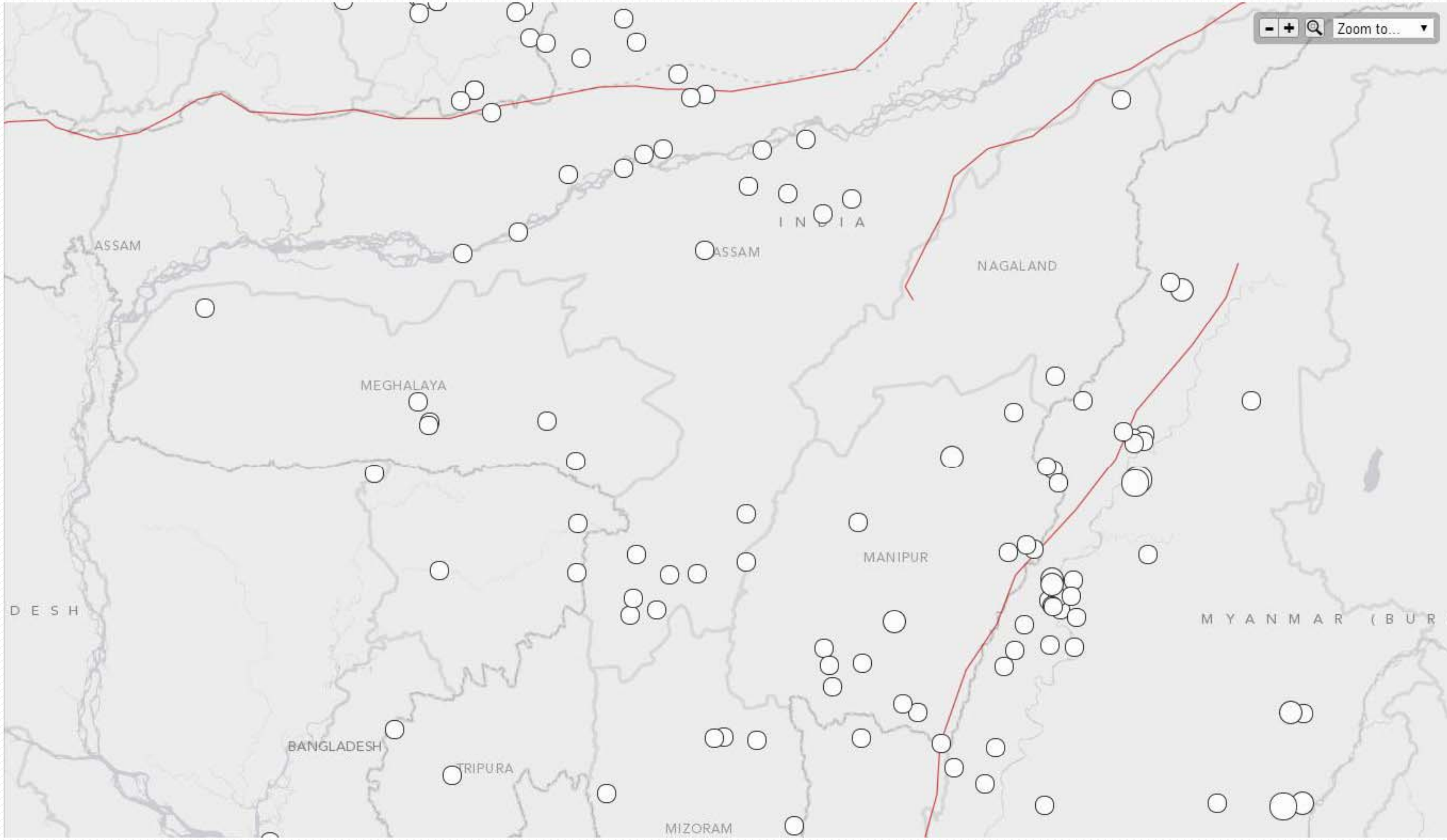

EARTHQUAKE
Do's and Don'ts inside Classroom
Whilst Earthquake Warning
PREPARE YOURSELF
Perform the following steps:
➢Students in classrooms perform "DROP COVER and HOLD ON" action underneath sturdy furniture.
➢If in the open hall, sit against the wall and curl up like a ball.
➢While the warning signal is going on, move away from windows, glass and unfastened objects.
➢ Don't use lifts.
➢When the shaking stops, get up and evacuate the building using staircase.
➢School bags can be used to protect head where sufficient number of desks are not available or where there are no desk at all.
➢Stay calm
Center of Excellence in Disaster Mitigation & Management
DROP!
COVER!
HOLD ON!

List of Earthquakes Recorded

S.No.	Date	Earthquake	Magnitude	No. of Records	Location
1	12/05/2015	Nepal Earthquake	7.3	5	Outside
2	18/07/2015	Chamoli	4.3	4	Inside
3	29/11/2015	Chamoli	4	14	Inside
4	26/10/2015	Hindukush	7.5	31	Outside
5	26/12/2015	Hindukush	6.5	30	Outside
6	25/09/2016	Uttarkashi	3.7	9	Inside
7	23/11/2016	Dehradun	3.4	8	Inside
8	01/12/2016	Indo-Nepal Border	5.2	20	Outside
9	13/12/2016	Dehradun	3.9	8	Inside
10	13/12/2016	Uttarakashi	3.4	6	Inside
11	19/12/2016	Uttarakashi	3.4	5	Inside
12	26/12/2016	Dehradun	3.5	4	Inside
13	10/01/2017	Chamoli	3.2	6	Inside
14	23/01/2017	Uttarkashi	3.5	6	Inside
15	03/02/2017	Chamoli	3.6	8	Inside
16	06/02/2017	Rudraprayag	3.6	8	Inside
17	11/02/2017	Rudraprayag	3.2	5	Inside

EEW System for NE India

Earthquakes (M>=5 in NE India) Since 1964



Broad Roadmap for EEW system for North East India

- In the first phase, EEW system for earthquakes from Mynamar border.
- NE Earthquake early warning system should be hosted by Meghalaya State Disaster Management Authority.
- Central monitoring station (CMS) should be established in Shillong
- About 50 sensors be installed covering a window of about 100 km X 20 Km in Indian side of Mynamar border.
- Locations to be finalized on the basis of available logistics and network connectivity

Tentative Locations of Sensor

Roadmap– contd.

- All sensors need 24 x 7 connectivity preferably using OFC cable options like VPN
- VSAT not recommended
- Latency should be less than 100 milliseconds
- CMS should have high end networking equipment from reliable brands like cisco
- CMS should have highend servers and computers with substantial power redundancy to achieve zero second breakdown
- Software for taking decision for issue of warning is available.

Roadmap --- contd.

- Dissemination of warning to public through
  - Real time TV and radio broadcast
  - Real time broadcast by mobile service providers
  - Sirens connected through internet
  - mobile apps
- Siren and mobile apps should be given to private players
- All dissemination system should use dynamically coded algorithm to prevent hacking.

Financial Requirements (non recurring)

50 Sensors	Rs 1 crore
Networking equipment at CMS	Rs 40 Lakh
Computers and servers	Rs 30 Lakh
CMS construction, power backup etc	Rs 1 crore
Installation charges @Rs 20000/sensor	Rs 10 Lakh

Financial Requirement –Recurring per year

- Salary of staff (2 senior scientists + 6 junior scientists)
- Watch and ward of sensors
- AMC of equipments, computers and power backup etc.
- Maintenance of CMS

AND

- COST OF NETWORKING

Approximate Lead Times

• Shillong	70 Second
• Guwahati	85 Second
• Imphal	20 Seconds
• Aizawl	10 Seconds
• Agartala	51 Second
• Kohima	20 Second

Thank you