C3

Hazards: Their Severity, Zonation and Impact on Buildings

No. of Slides: 100
Time: 45 min

National Disaster Management Authority

People in Centre

Gujarat Institute of Disaster Management

Expected Outcomes

1. Participants understand different hazards, their occurrences and frequency in the region.
2. Participants know about severity of disasters and methods of measuring their intensity.
3. Participants discuss different zones of hazards and locate their own region to relate with the intensity of possible hazards

Hazards

Earthquake

Flood

Cyclone

Tsunami

Landslide

EARTHQUAKES

Earthquake

Flood

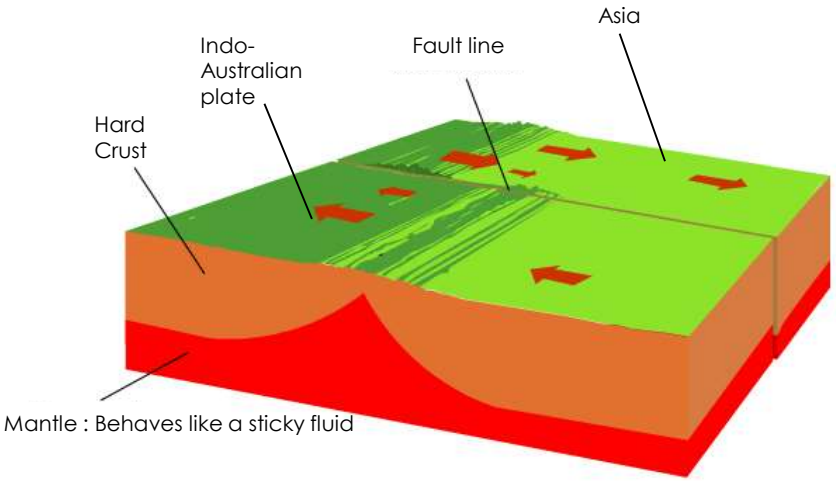
Cyclone

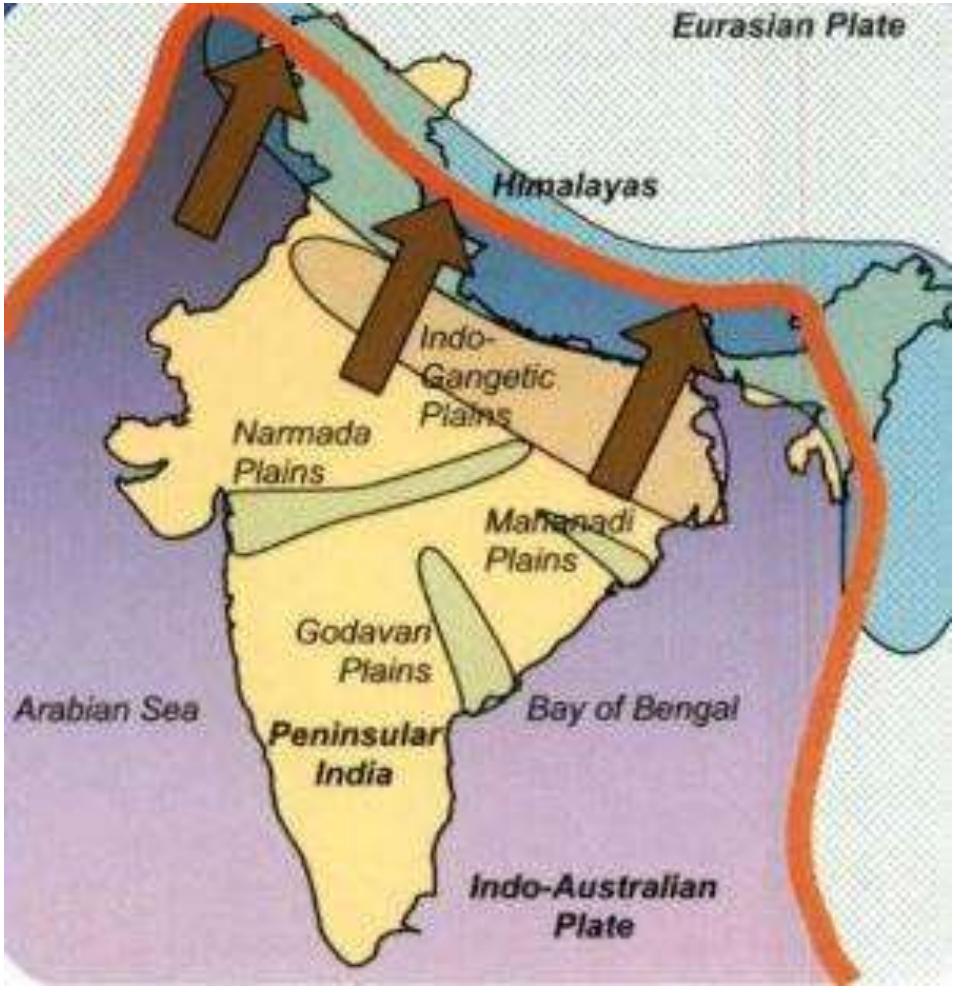
Tsunami

Landslide

Earthquake: Sudden Movement of the Earth's surface

The Indian subcontinent has a history of earthquakes. The reason for the intensity and high frequency of earthquakes is the Indian plate driving into Asia at a rate of approximately, 49 mm/year.

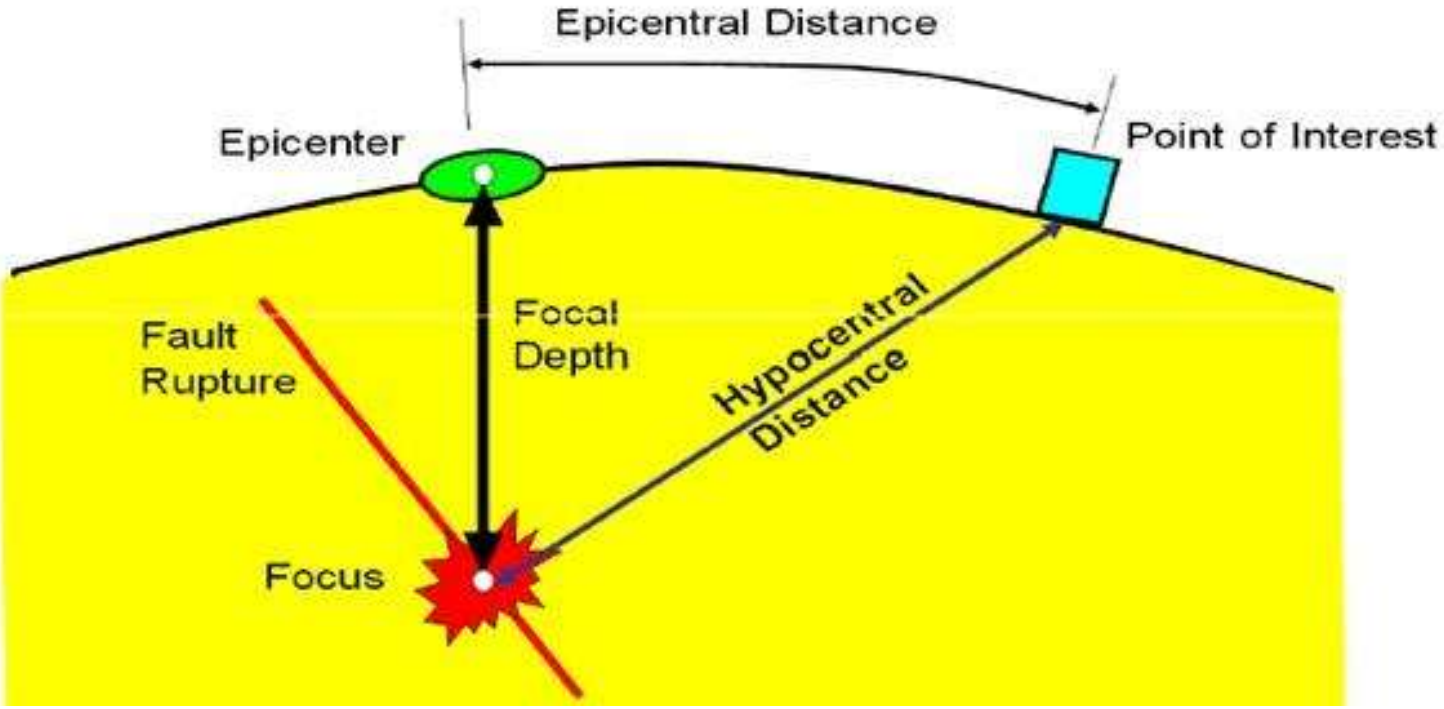




Earthquake is a sudden shaking of the Earth, arising out of rupture at the tectonic plates.

Hypocentre is the first point on the fault when the rupture begins.

Epicentre is the point directly above the hypocentre on the surface of the earth.



Significant Earthquakes in India

Muzaffarabad, J&K
Magnitude : 7.6
Deaths : 1,30,000
Year : 2005

Kangra, H.P.
Magnitude : 7.8
Deaths : 20,000
Year: 1905

Garhwal, Uttarkashi
Magnitude : 6.8
Deaths : 1000
Year : 1991

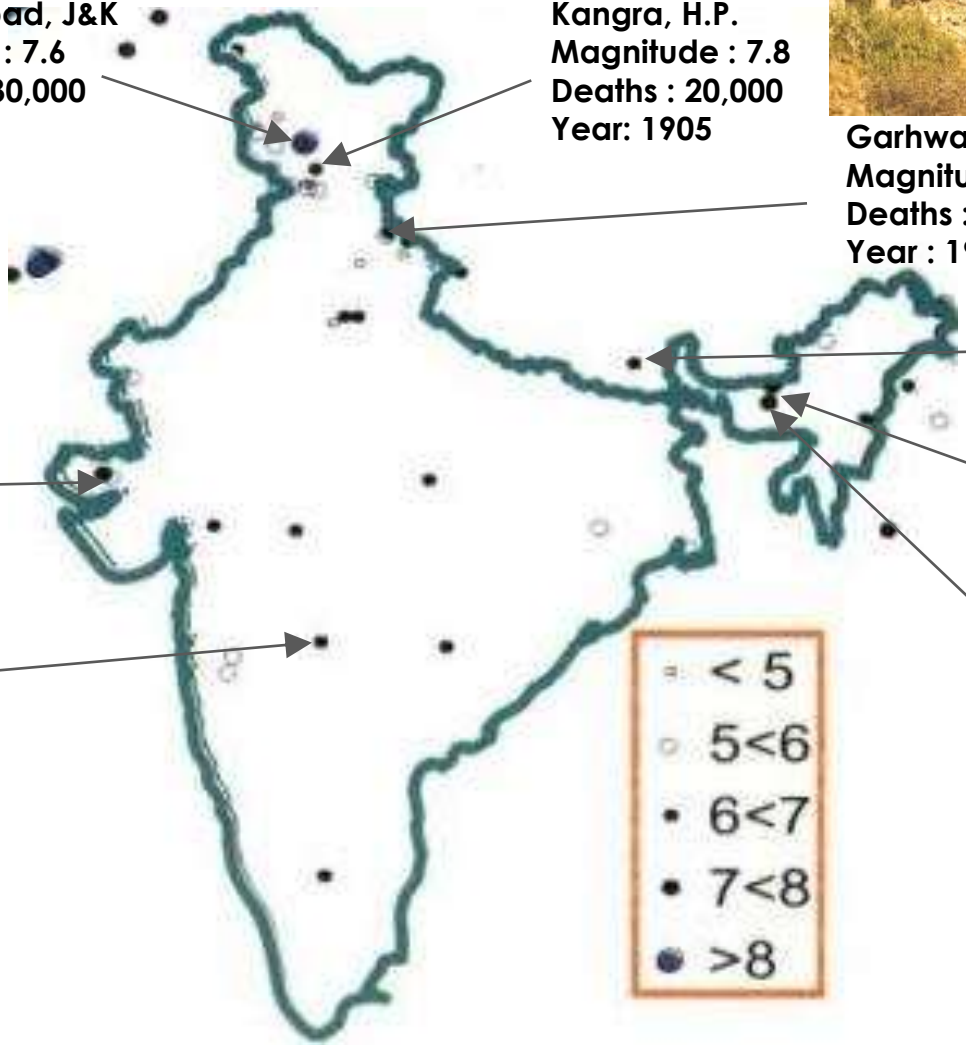
Bhachau, Gujarat
Magnitude : 7.1
Deaths : 30,000
Year : 2001

S of Everest, Nepal-Bihar
Magnitude : 8.7
Deaths : >30,000
Year : 1934

Assam
Magnitude : 8
Deaths : 1542
Year : 1897

Latur, Maharashtra
Magnitude : 6.4
Deaths : 9,748
Year : 1993

Rima, Tibet, Assam
Magnitude : 8.6
Deaths : 1526
Year : 1950

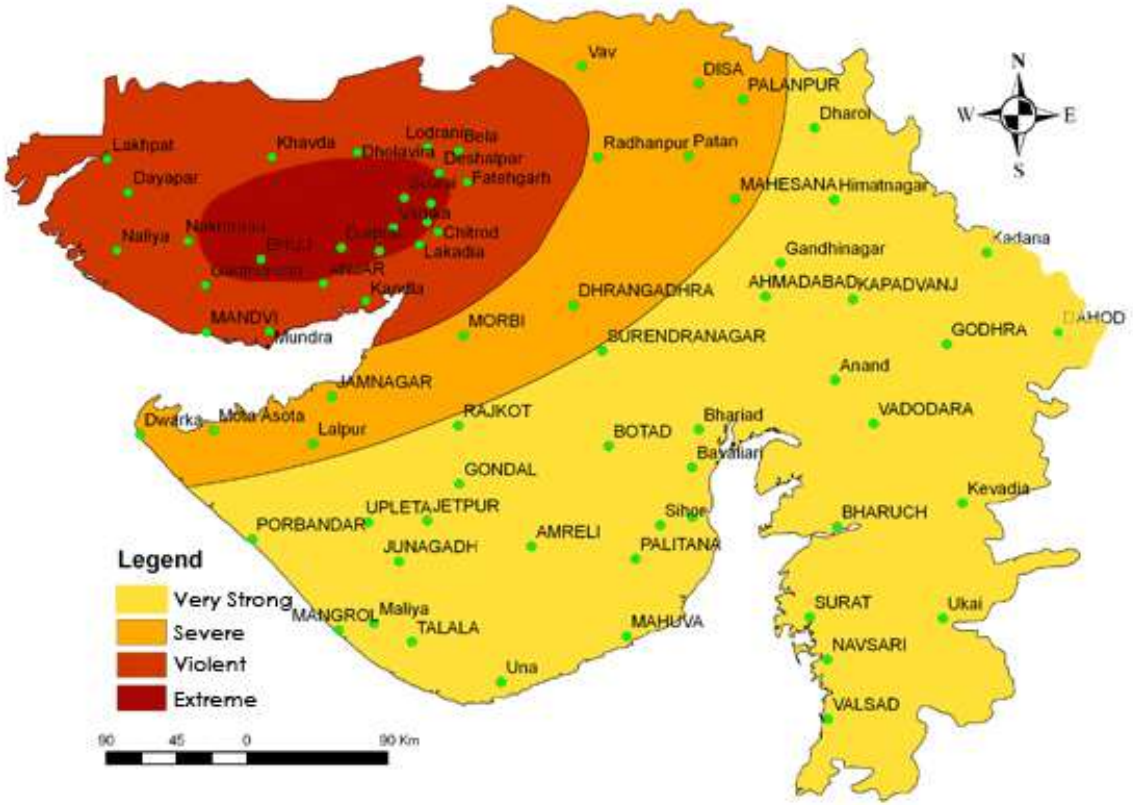


The Damage at any given location is based on many other factors apart from the Magnitude, including:

1. Distance from the epicentre and hypocentre
2. Duration of the earthquake
3. The types of buildings at the specific location
4. The quality of the materials and construction techniques used in buildings in the area
5. Whether it triggers any other natural hazards

Severity of an Earthquake

Bhuj Earthquake, 2001



MMI Scale Map

What is the difference between a 5.0, 6.0 and 7.0 magnitude Earthquake?

Energy released in a M7.0 earthquake is about 31 times that released in a M6.0 earthquake, and is about 1000 (*31x31) times that released in a M5.0 earthquake.

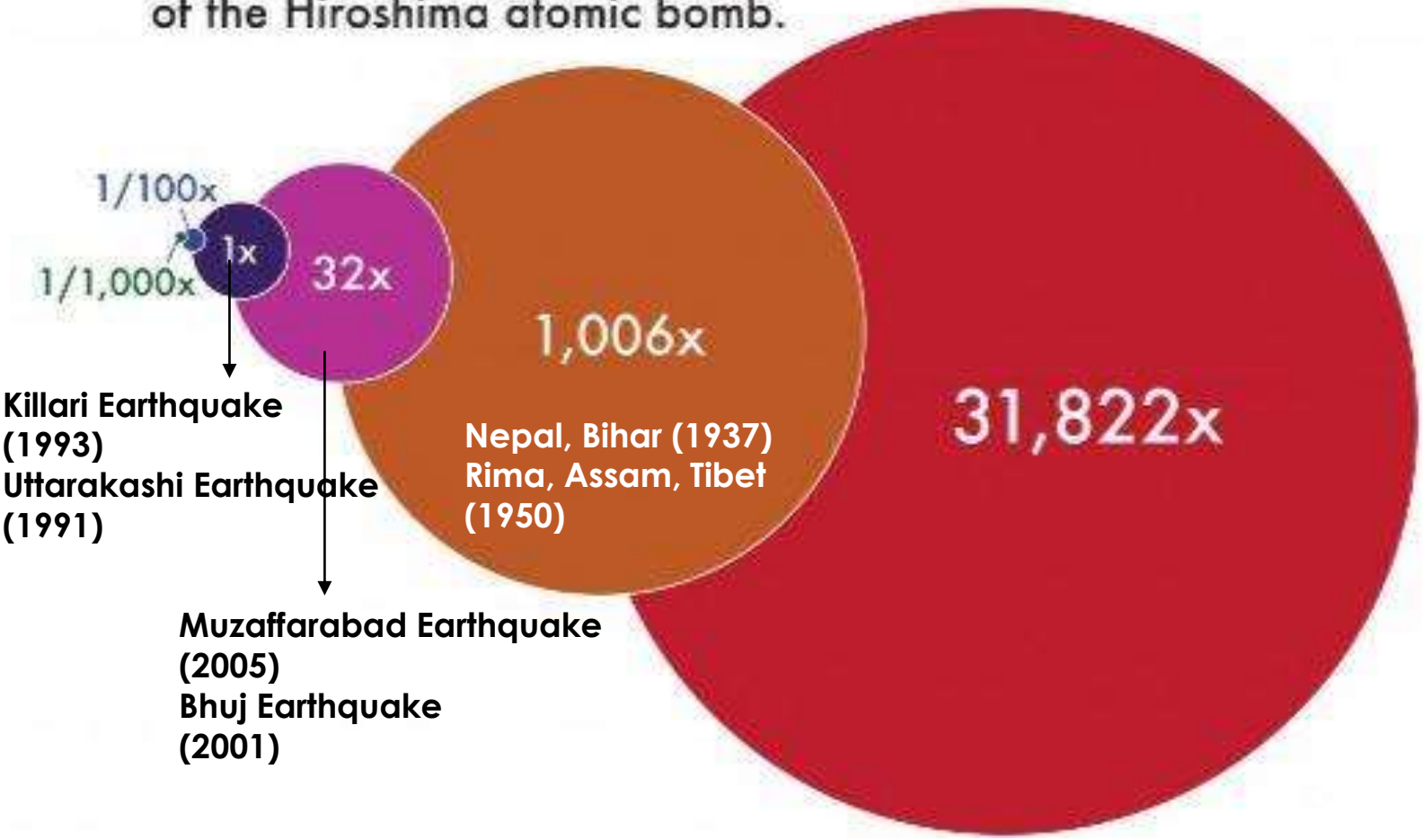
(M7.0): 31 x (M6.0)
(M6.0): 1000 x (M5.0)

The energy released by a M6.3 earthquake is equivalent to that released by the Atom Bomb dropped on Hiroshima (Japan) in the year 1945.

EARTHQUAKE MAGNITUDE

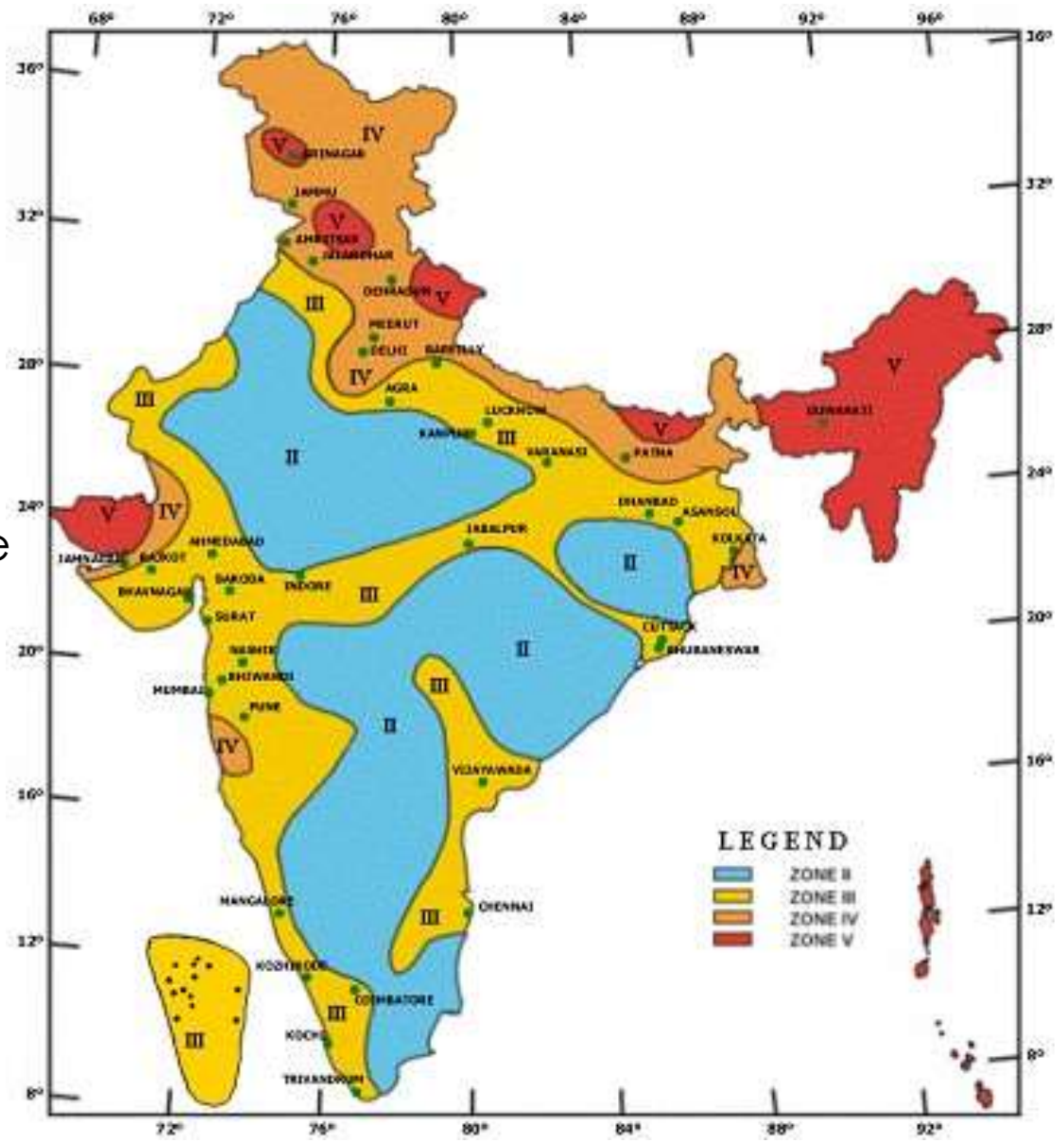
4 5 6 7 8 9

shown in equivalence to the energy of the Hiroshima atomic bomb.



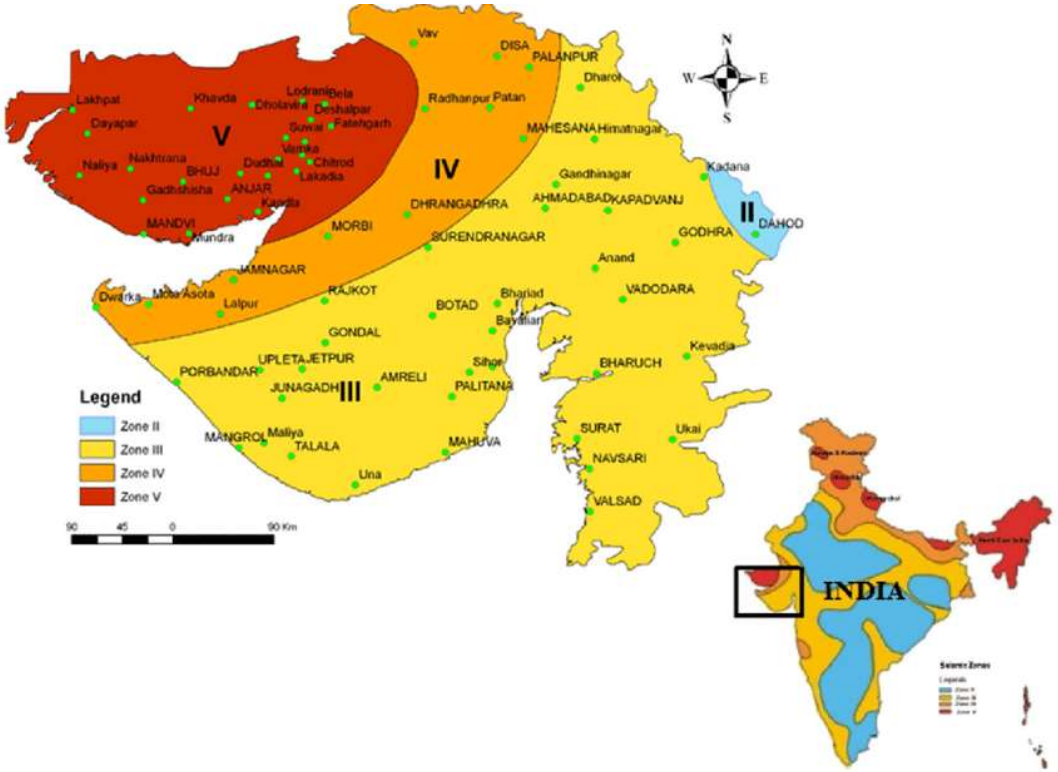
Zonation

1. Which zone is your region in?
2. Is your region earthquake prone?
3. What may be the type of damage during an earthquake?



Source: Bureau of Indian Stanfards
Seismic zone map of India.

Earthquake Hazard Map of Gujarat



1. Based on Seismic Zonning map of India given in IS:1893
2. Seismo-tectonic features are marked as per ONGC map
3. Epicenters and years of occurance of earthquakes (>5.0 intensity)

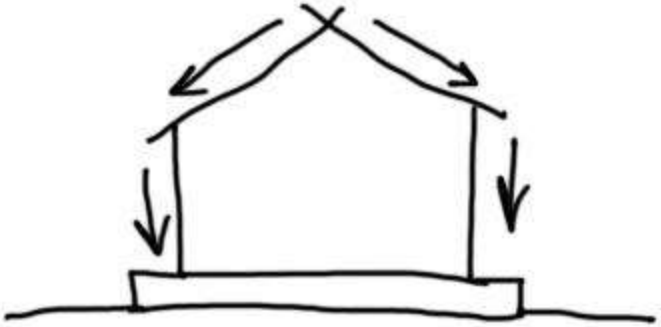
What are the forces acting on a house normally?

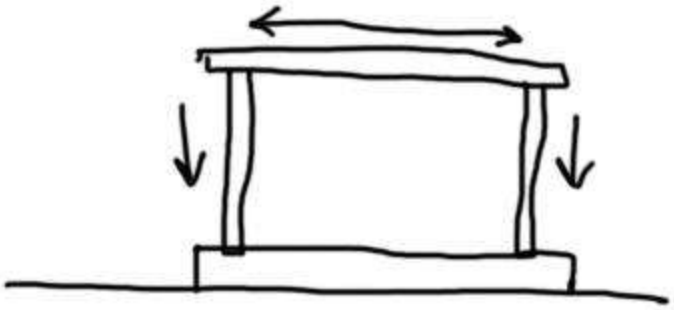
1. **Gravity Loads:** They act vertically downwards in a building. It comprises of Dead Loads (self weight of slab, columns, beams, walls, etc.) and Live Loads (additional weight imposed on the house by humans, furniture etc)

2. **Wind Loads:** These loads act horizontally on a building. Its intensity differs from place to place.

What are the forces acting on a house normally?

Load Path



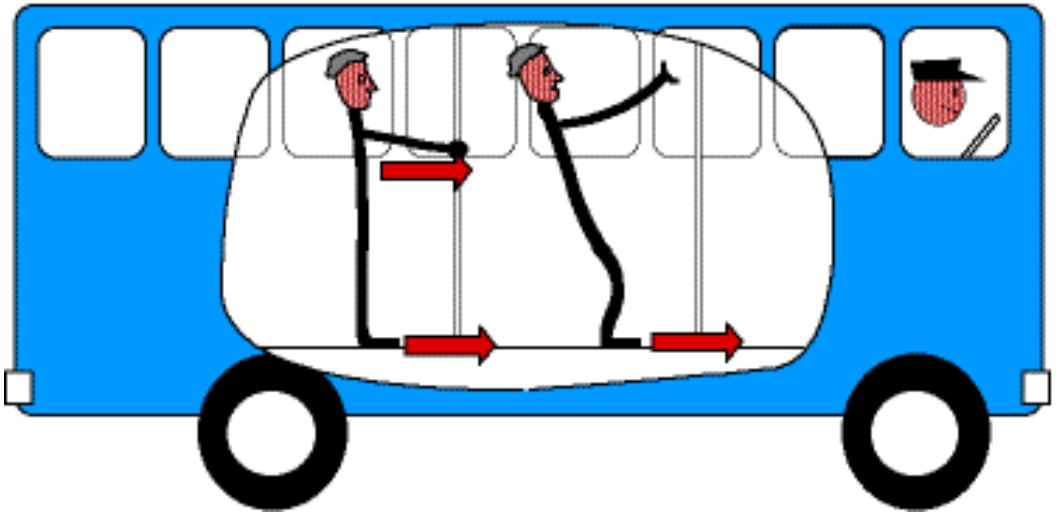


What happens during an earthquake?

Consider a person standing on a stationary bus, and then suddenly, the bus starts and lurches forward. What happens?

The person is thrown backwards, as if a force has been applied on his/her upper body.

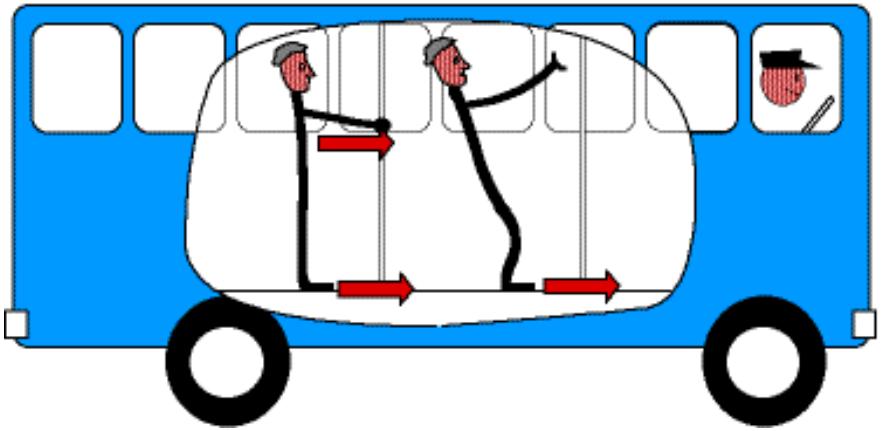
Why does this happen?



What happens during an earthquake?

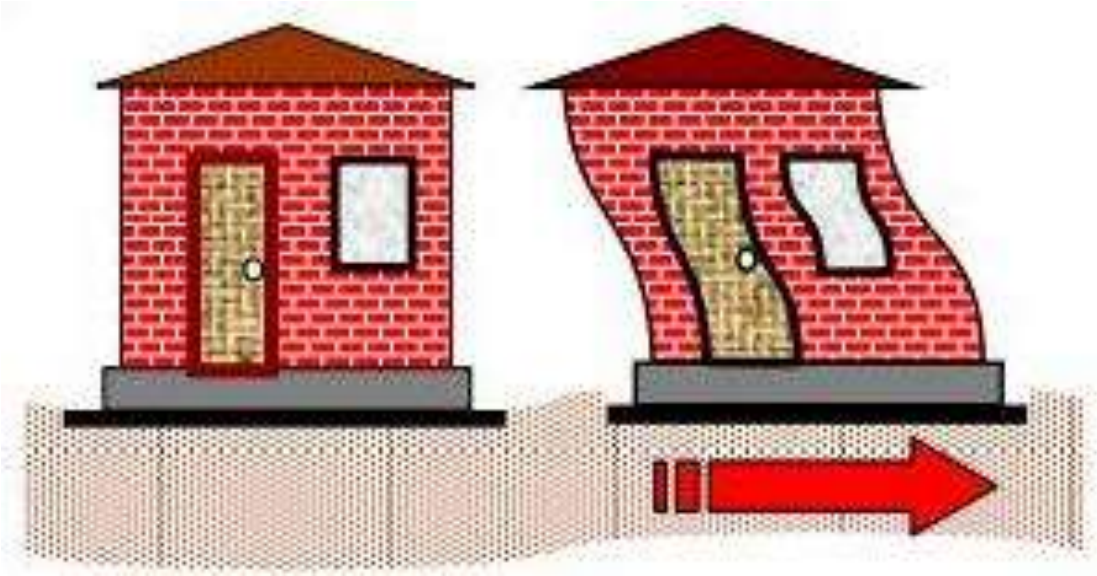
The bus moves suddenly and so when the feet of the person move with the bus, the upper body is still in its initial position, owing to inertia.

During an earthquake, when the earth moves a similar situation occurs. This induces relative movement between the top and bottom of the house, resulting in stress in the walls. The earth and the plinth of the house move suddenly, while the walls or columns sustain stresses.



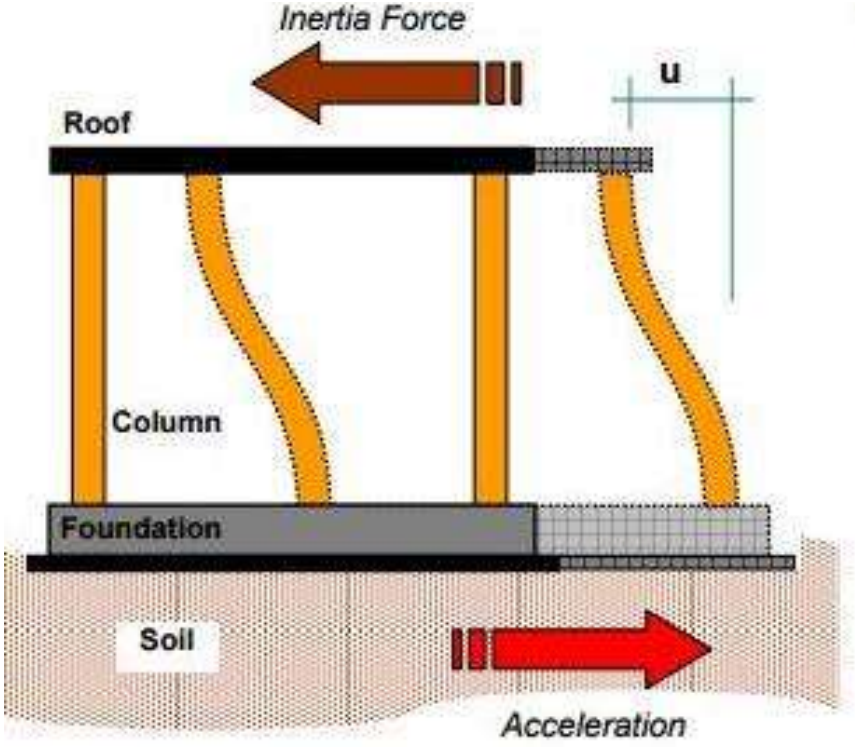
Damage caused due to Shaking

As mentioned in the previous slide, the earth and the plinth of the house move suddenly, while the walls or columns sustain stresses due to inertia.



Damage caused due to Shaking

All the loads must be transferred to the ground through the vertical members of the house (walls and/or columns). Here, heavier roof will have more inertia, and hence, more damage will be induced in walls and/or columns.

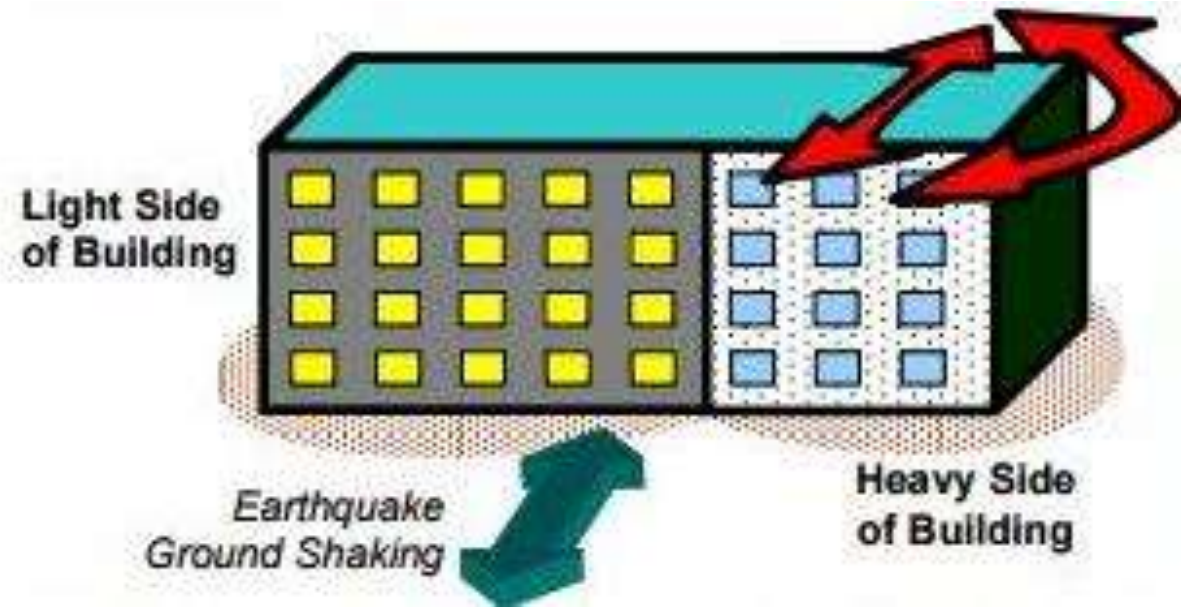


Twisting movement of Houses

Imagine sitting on one side of a swing. As long as you are sitting in the middle, the swing moves equaly. If you sit on one side, the swing starts to twist.

Twisting movement of Houses

Similarly in a building, if one side is heavier than the other, during an earthquake, the building will twist and move more on the heavy side.



Damage to Gable Wall

Cracks on the gable wall.

Damage to Gable Wall

Collapse of the gable wall.

Cracks around Openings

Diagonal cracks around openings

Splitting of Thick Stone Wall

Delamination of stone wall

Damage at Corners of Houses

Damage at the corners of the house.

Damage at Corners of Houses

Separation of the wall from brick piers.

Damage to Wall

Out-of-plane damage to the exterior wall.

Damage due to Soil Liquefaction

Soil liquefaction in 1964 Niigata Earthquake

Collapse of reinforced columns

Collapse of reinforced concrete columns (and building) during 2001 Bhuj (India) earthquake

FLOODS

Earthquake

Flood

Cyclone

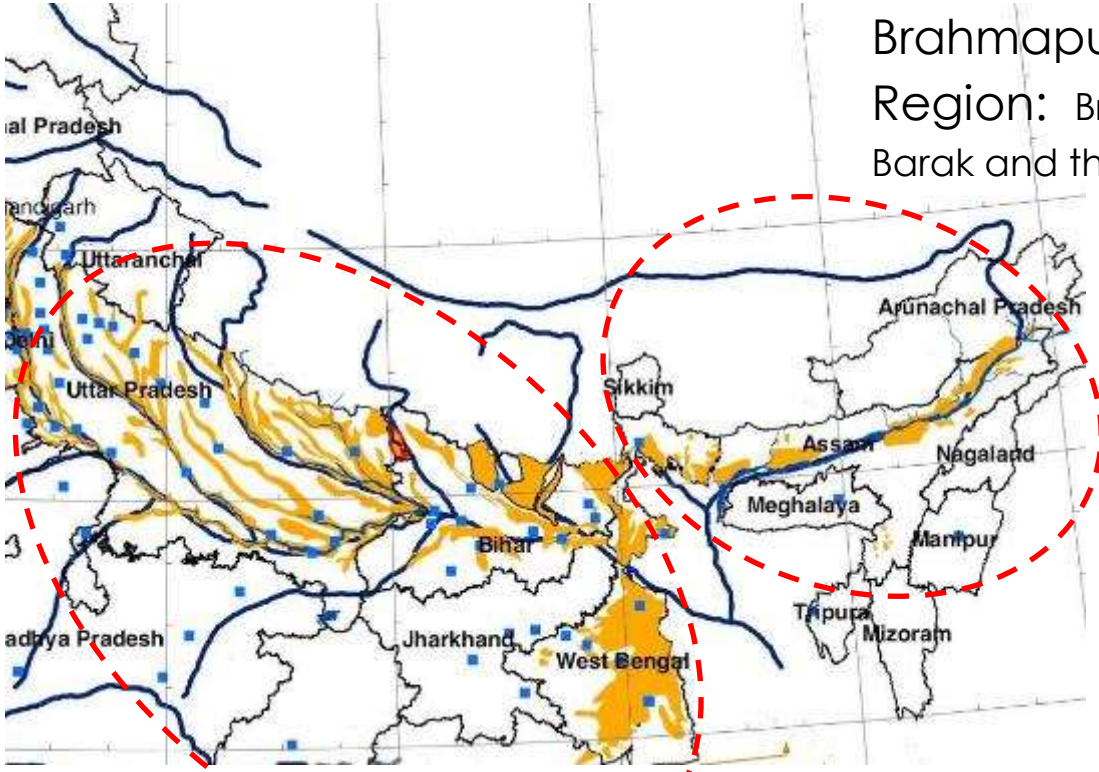
Tsunami

Landslide

Introduction

A flood is rise of water in the land adjoining the house, which is usually dry.

Regions in India prone to Floods



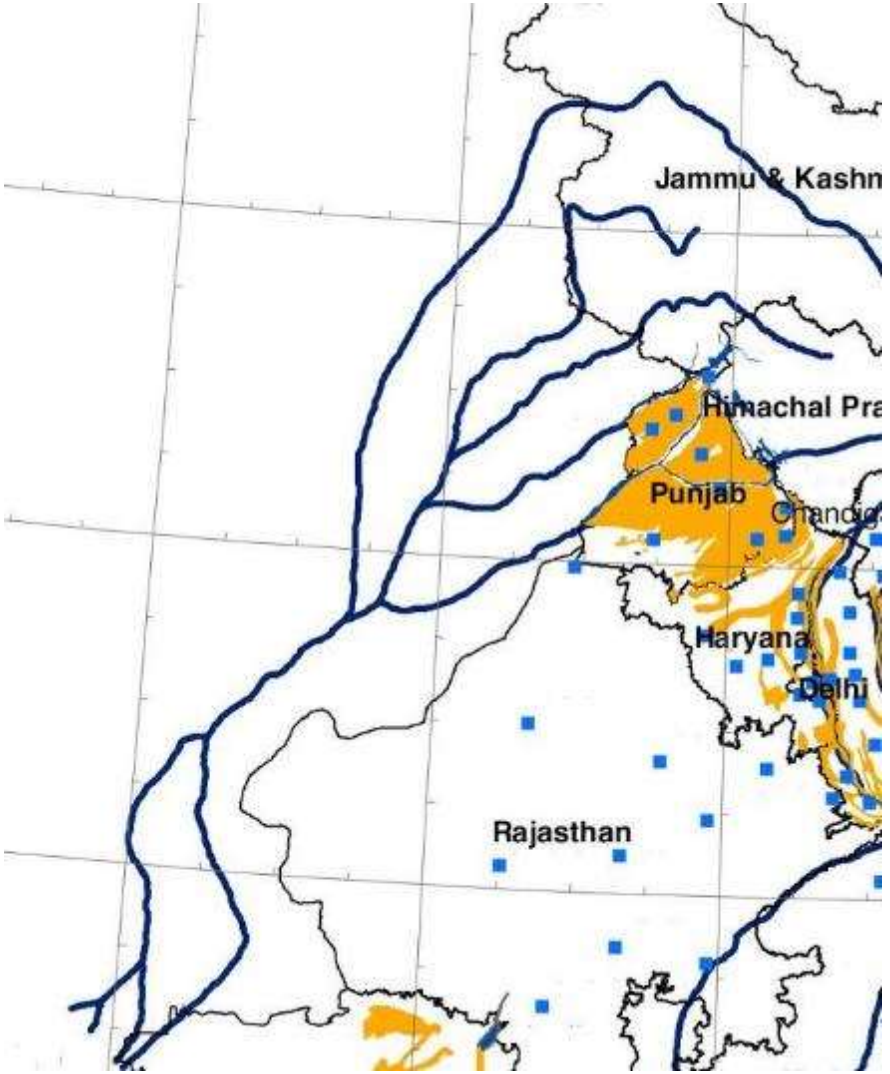
Brahmaputra River Region: Brahmaputra and Barak and their tributaries

Ganga River Region: consisting of tributaries Yamuna, Sone, Ghaghra, Raphti, Gandak, Burhi Gandak, Bagmati, Kamla Balan, Adhwara group of rivers, Kosi and the Mahanadi.

Regions in India prone to Floods

North-west River Region:

The main rivers in this region are the Indus, Sutlej, Beas, Ravi, Chenab and Jhelum. These rivers are the tributaries of the Indus



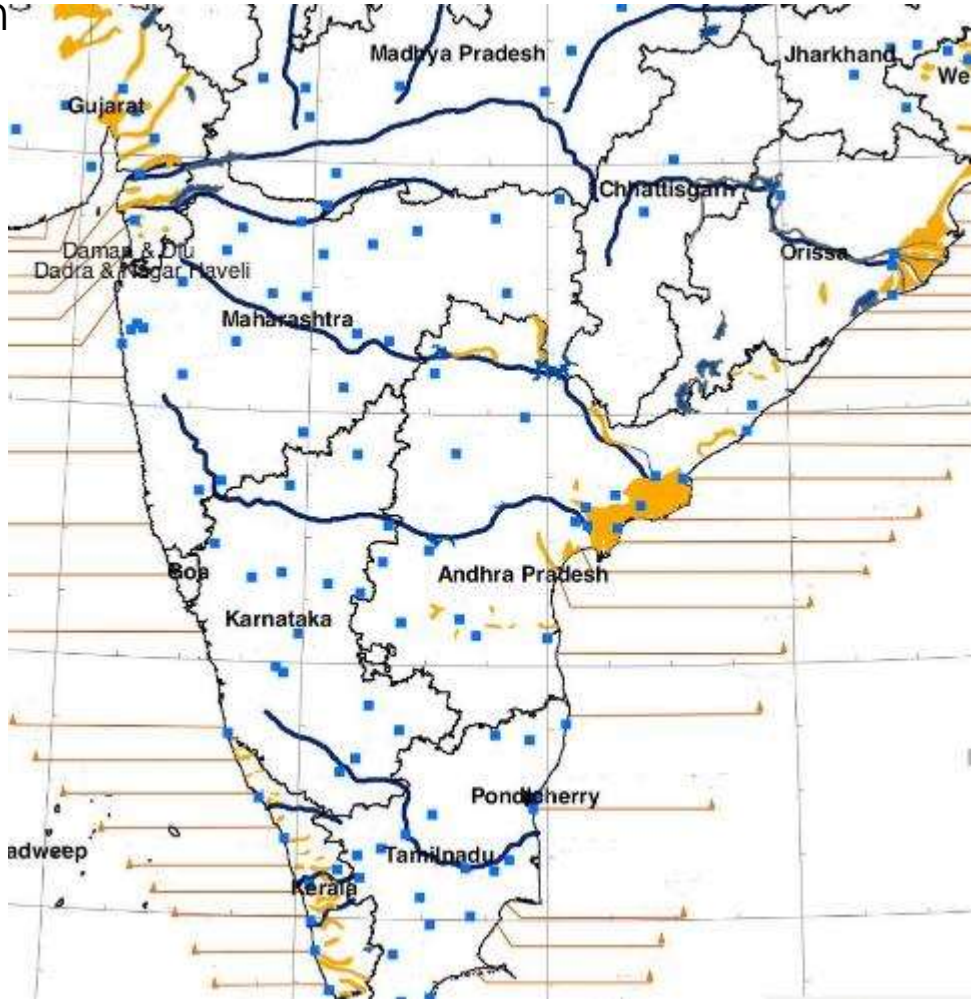
Regions in India prone to Floods

The central India and Deccan Region:

Important rivers in this region are the Narmada, Tapi, Mahanadi, Godavari, Krishna and Cauvery

Coastline:

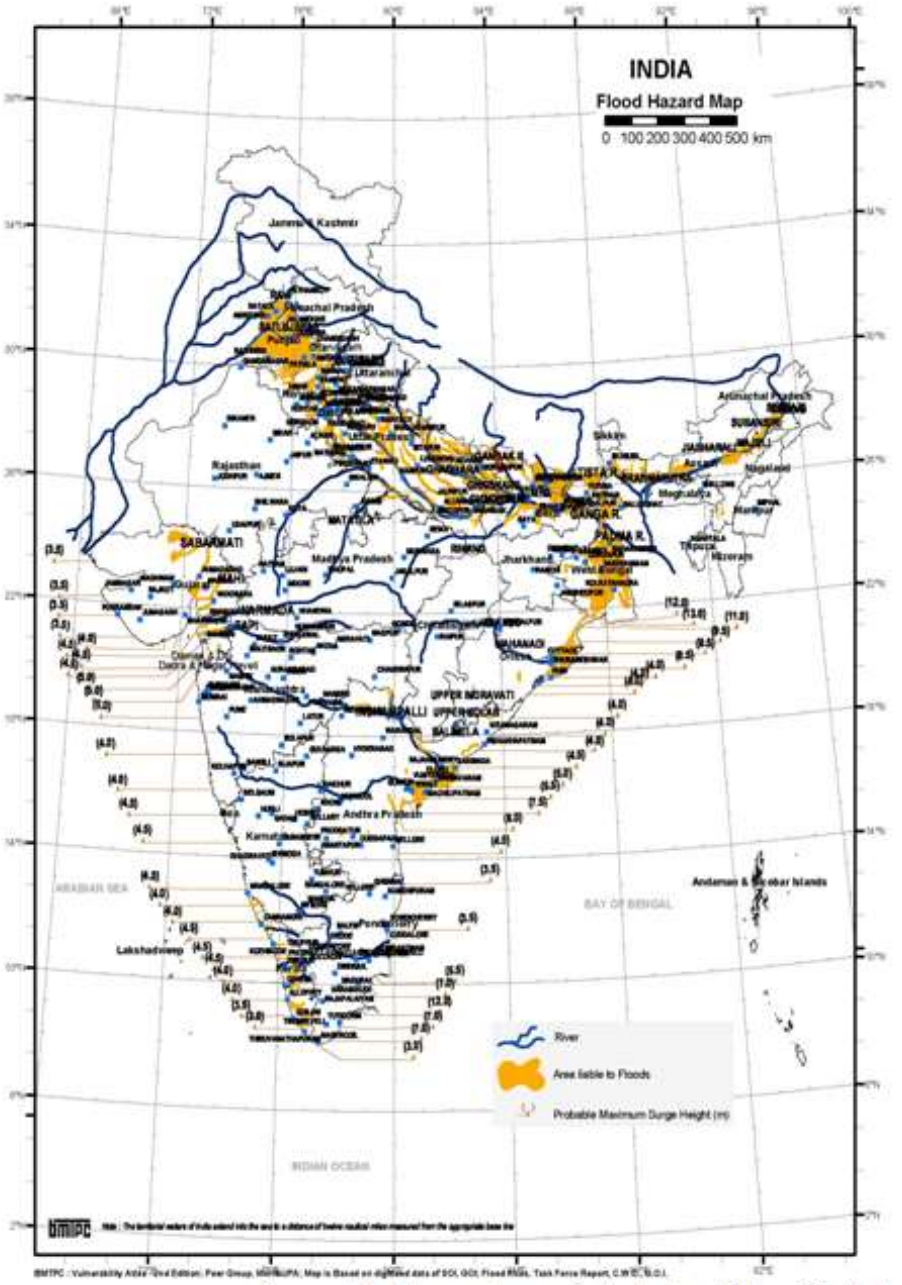
Storm Surge may cause flooding in settlements along the coast.



Is your region flood prone?

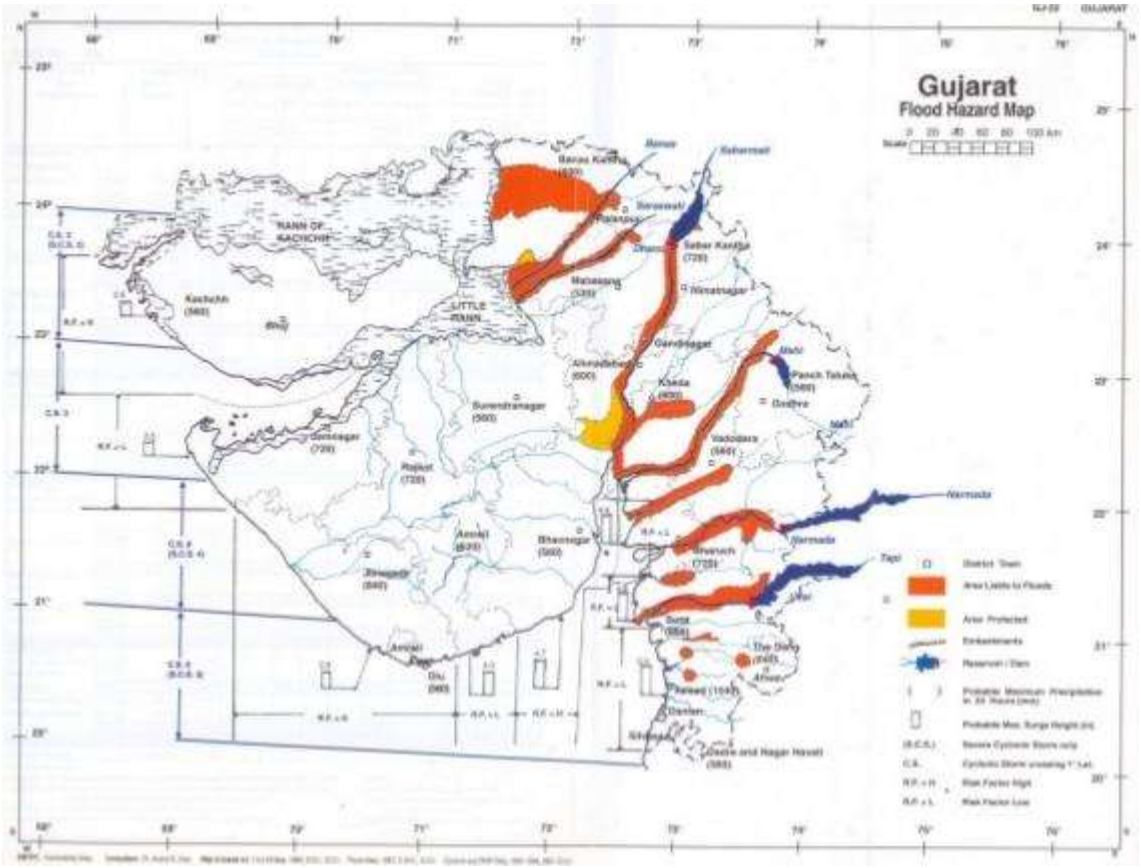
What could be the primary cause of flooding in your region?

- due to rise in sea level
- due to heavy rainfall
- due to increased level of river water
- Due to poor choice of site for the houses in low-lying areas prone to flooding.



Source : http://www.ndma.gov.in/en/vulnerability-profile.html

Flood Hazard Maps of Gujarat



- Based on the Flood Atlas of India prepared by the Central Water Commission
- Maps show unprotected areas close to the river liable to flooding, as well as areas that have been protected using bunds

Significant Floods in Gujarat

Slow Fluvial Floods: Surat Flood

- Surat was flodded in 1998 and 2006 due to heavy rain in the upstream. Almost 60% and 95% area was submerged in the respective year. 120 people died & most of the prople of Surat city were affected

- **Flash Floods: Morbi (Floods due to dam breach)**

- The Macchu Dam was earthen dam located very near to Morbi town, Dam was not maintained properly. Gate operations & maintenance were not carried out regularly because of scarcity of water during the year most of the time. In 1979, due to heavy rain, opening of the gates was required to release excess water. But unfortunately, gates were jammed because of improper maintenance. Over toppling of water made earthen dam to collapse. The whole Morbi City was flooded & thousand of people were died.

Severity of a Flood

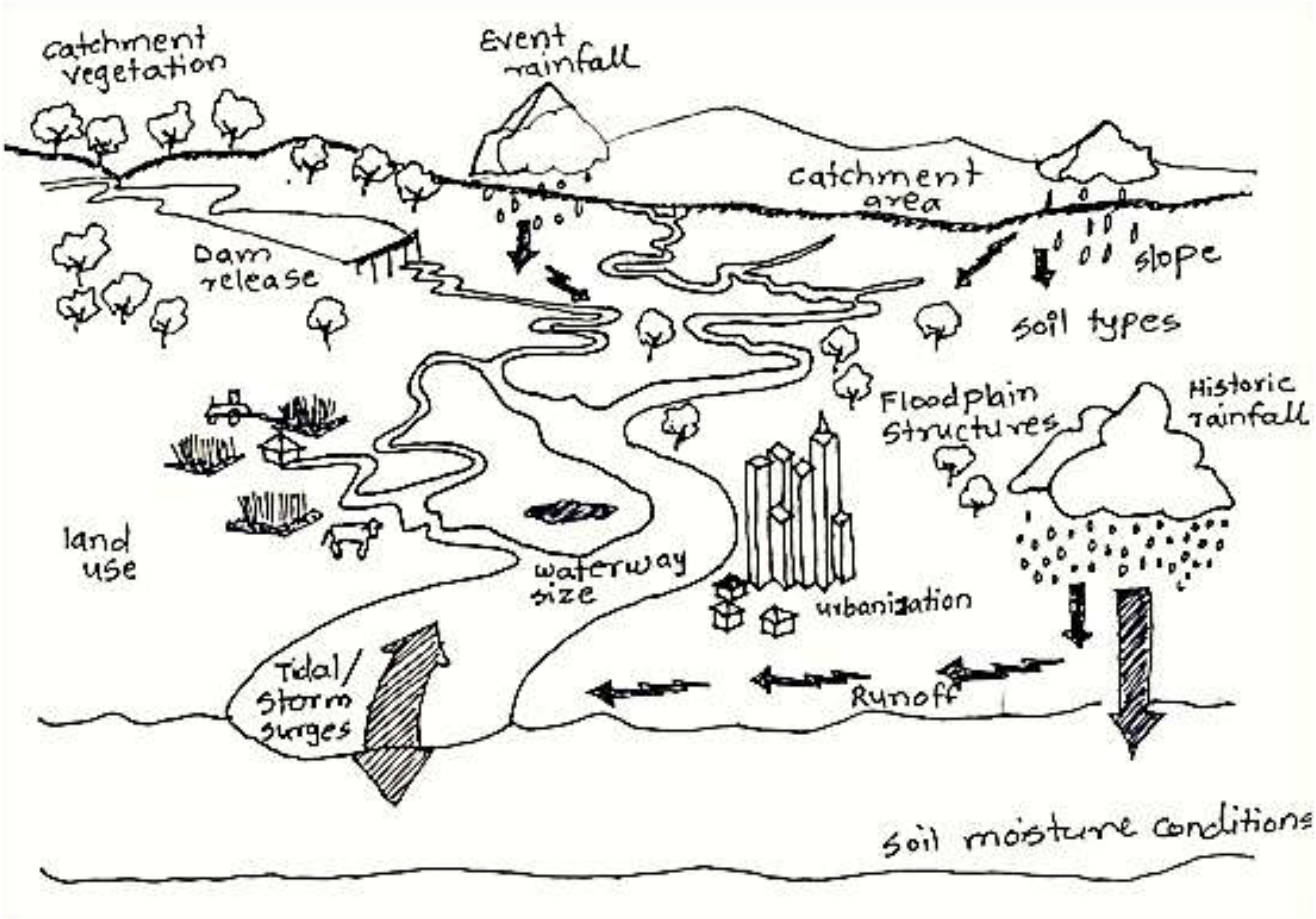
Measurment of Rainfall

RAIN GAUGE: An instrument that measures the amount of rain that falls in a given amount of time.

Information gathered from rain gauges report :

- How much rain a specific area has received, both for a single event and accumulation over time.
- Comparing current data to previous years helps gauge if an area is receiving too much or too little rainfall.

Various Causes of Floods



Catchment Area

1. The size, shape and land use of the catchment area.
2. Soil and Vegetation in and around the river.
3. The presence of structures in and adjacent to the waterway.

Event Rainfall

Specific rainfall depth, according to specific climate conditions recurring over a period of time.

Historic rainfall

Annual average rainfall

Urbanization:

1. Concrete buildings and road surfaces lead to Stormwater run-off
2. Buildings alter natural drainage paths, thereby leading to other low lying areas getting flooded.
3. Dam breaches due to mismanagement by authorities.

Impact on buildings

What happens when a large amount of water comes towards you with a force?

Thrust Force

Flow of water: Flowing Water exerts a force on the walls of a house, and if the walls are weak, it carries with it everything that comes in it's way.

What would happen, if a cardboard box is left submerged in water for a long period?

Cardboard loses its strength and becomes easy to tear.

The water would rise due to capillary action resulting in degradation of material, damaging the wall

Submergence

1. Prolonged period of exposure to water or moisture will cause loosely placed materials to become weak and vulnerable, because it leads to degradation of the strength of the materials.
2. When the water recedes, the submerged parts of the house may fail and cause damage to the house.
3. Some materials (thatch and earth) would degrade faster than others and would lose their capacity to carry the weight of the house

Excessive Moisture in the environment

Excessive rainfall and splashing of rainwater may cause the material (if it is earthen materials like adobe bricks) to lose their properties and to not be able to take the load of the roof anymore, resulting in collapse of the house.

Erosion

Erosion of walls due to splashing: During heavy rainfall, the water splashes on the bottom part of the walls. If the house is made of a material which loses its strength when moist, then it may collapse.

Erosion

Scouring of foundation: When water washes away loose material from the foundation, it may lead to severe damage or collapse of the house.

Damage due to scouring of soil underneath the plinth

Damage to plinth due to thrust of water

Damage due to erosion of soil from under the house

Damage to wall due to thrust of water

CYCLONE

Earthquake

Flood

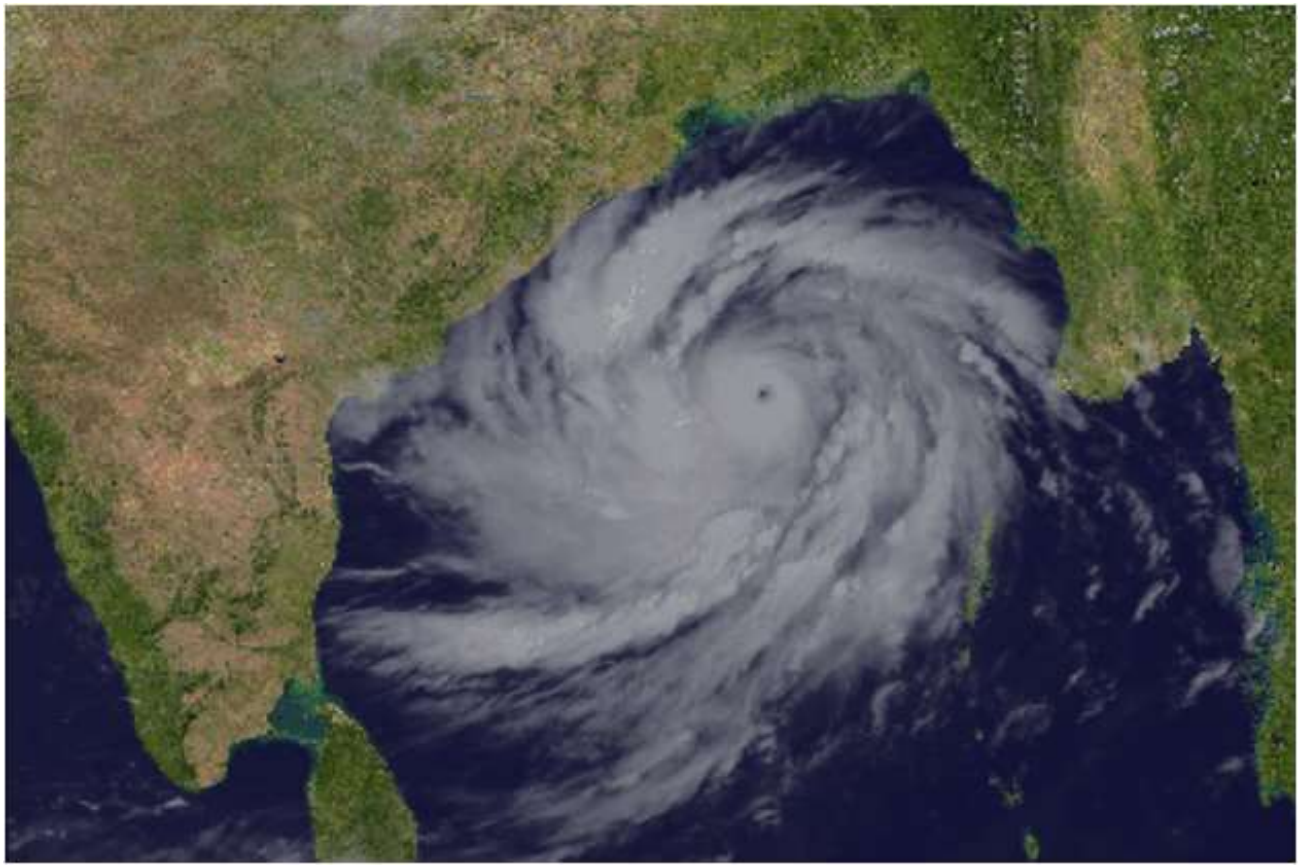
Cyclone

Tsunami

Landslide

Introduction

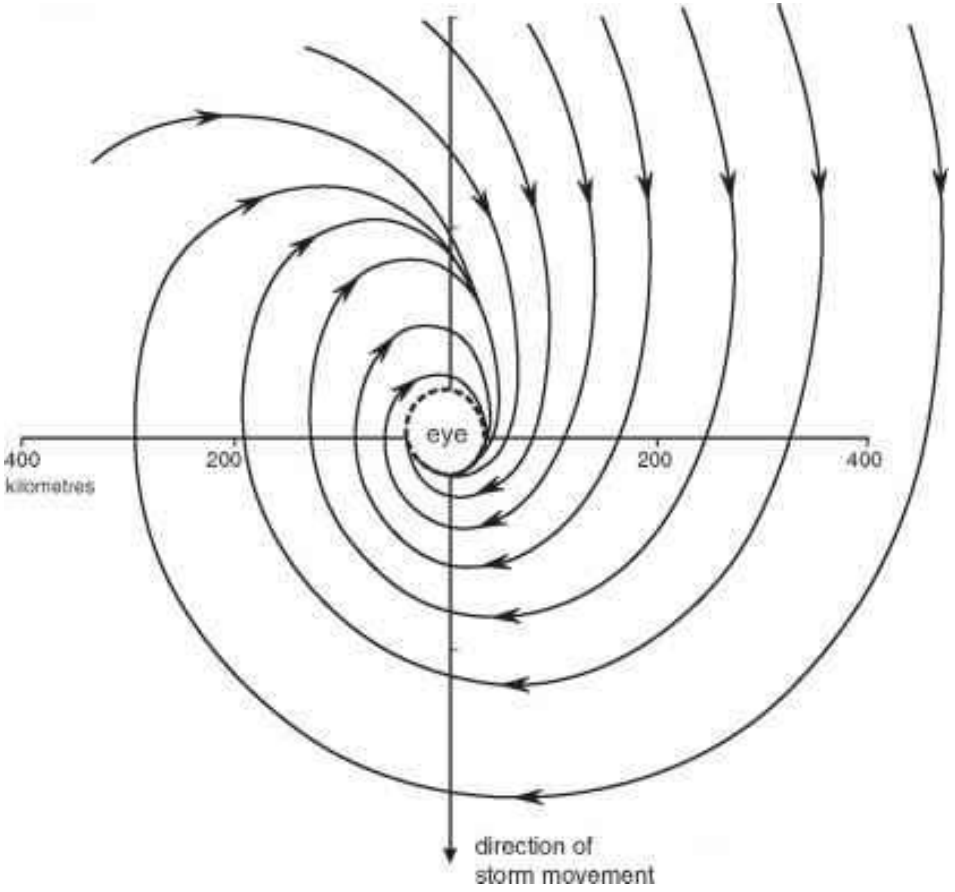
An extremely large sized, powerful, and destructive air and water system from the sea swirling at very high speed, passes over land mass and causes destruction.



Severity of a cyclone

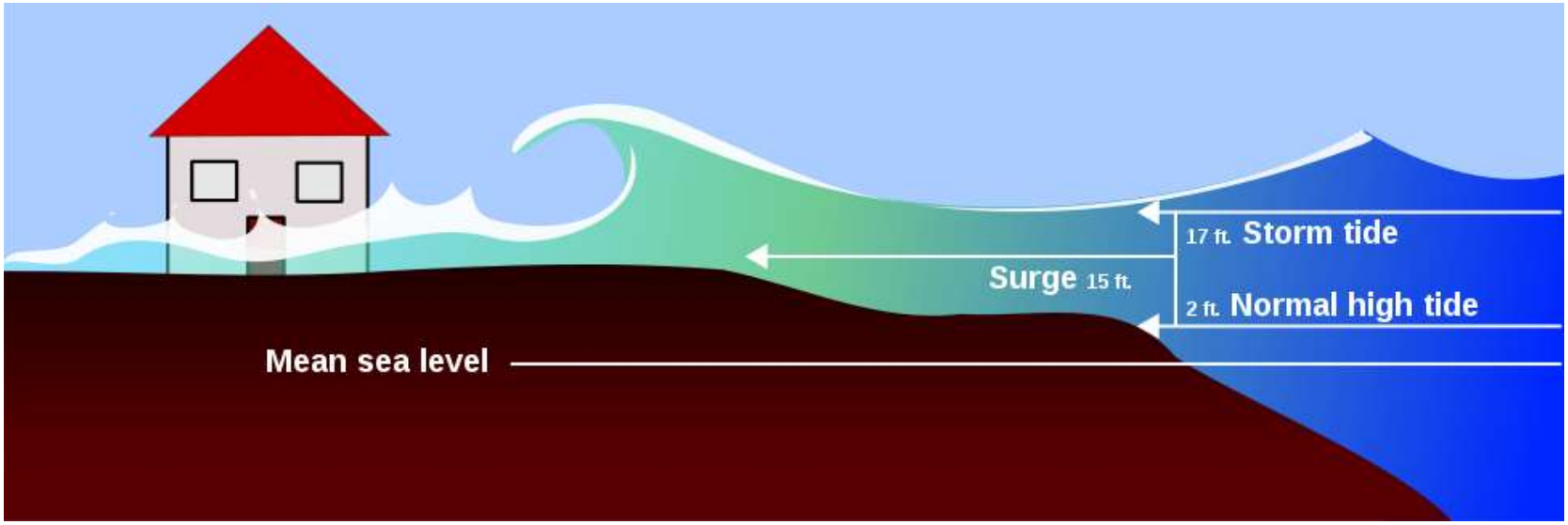
Causes of a cyclone

A cyclone is usually characterized by inward spiralling winds which occur due to pressure differences.



Cyclones and Storm surges

A **storm surge**, **storm flood** or **storm tide** is a coastal flood or tsunami-like phenomenon of rising water commonly associated with low pressure weather systems (such as tropical cyclones and strong extratropical cyclones), the severity of which is affected by the shallowness and orientation of the water body relative to storm path, as well as the timing of tides.



Type of Disturbances	Associated Wind Speed in the Circulation
Low pressure Area	<31 kmph
Depression	31 to 49 kmph
Deep Depression	50 to 61 kmph
Cyclonic Storm	62 to 88 kmph
Severe Cyclonic Storm	89 to 118 kmph
Very Severe Cyclonic Storm	119 to 221 kmph
Super Cyclonic Storm	221 kmph and above

Significant Cyclones in India

Odisha cyclone 1999 (Super Cyclonic Storm)

The 5-6 m (16-20 ft) surge brought water up to 35 km (20 mi) inland. The surge combined with heavy rains to produce widespread flooding, damaging around 1.6 million homes. Almost all the trees were flattened out.

Peak Wind Speed: 260 km/h

Intensity: 912 mbar

Deaths: 9,887 fatalities (2000 because of flood)

Cyclone Vardah, Tamil Nadu 2016 (Very Severe Cyclonic storm)

The cyclone prompted India's largest evacuation of 16,000 people. Vast devastation was caused to trees and property.

Duration: 6th December- 13th December

Peak Wind Speed: 130 km/h (3 min)

Intensity: 982 mbar

Deaths: 24 fatalities

Gujarat Cyclone 1998 (Very Severe Cyclonic storm)

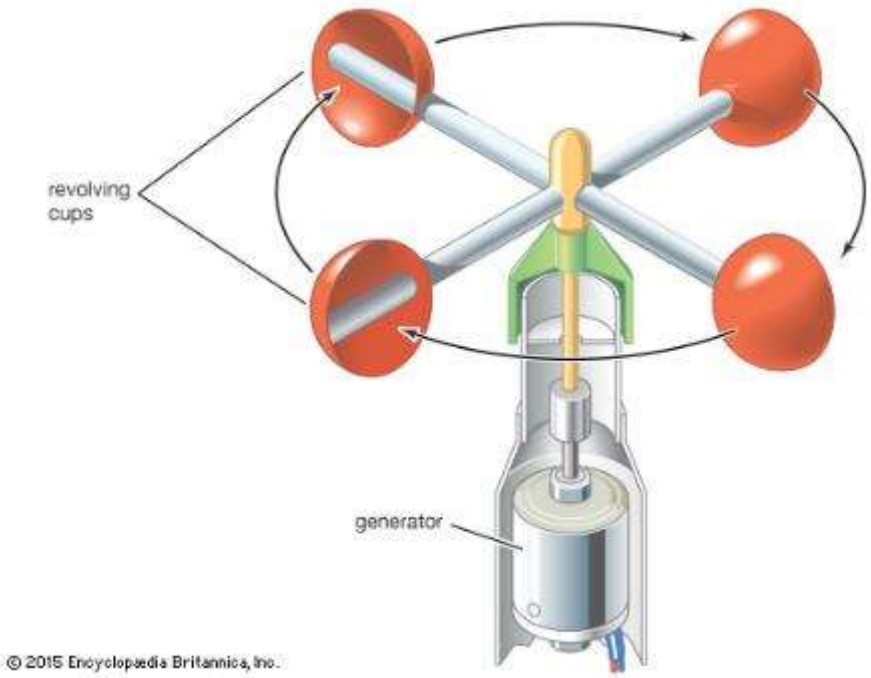
Brought a large storm surge of 4.9 m (16 ft) which devastated coastal communities and salt mine workers who didn't receive warning of the cyclone.

Peak Wind Speed: 165 km/h (3 min)

Intensity: 958 mbar

Deaths: Atleast 10,000

Measuring Wind Speed

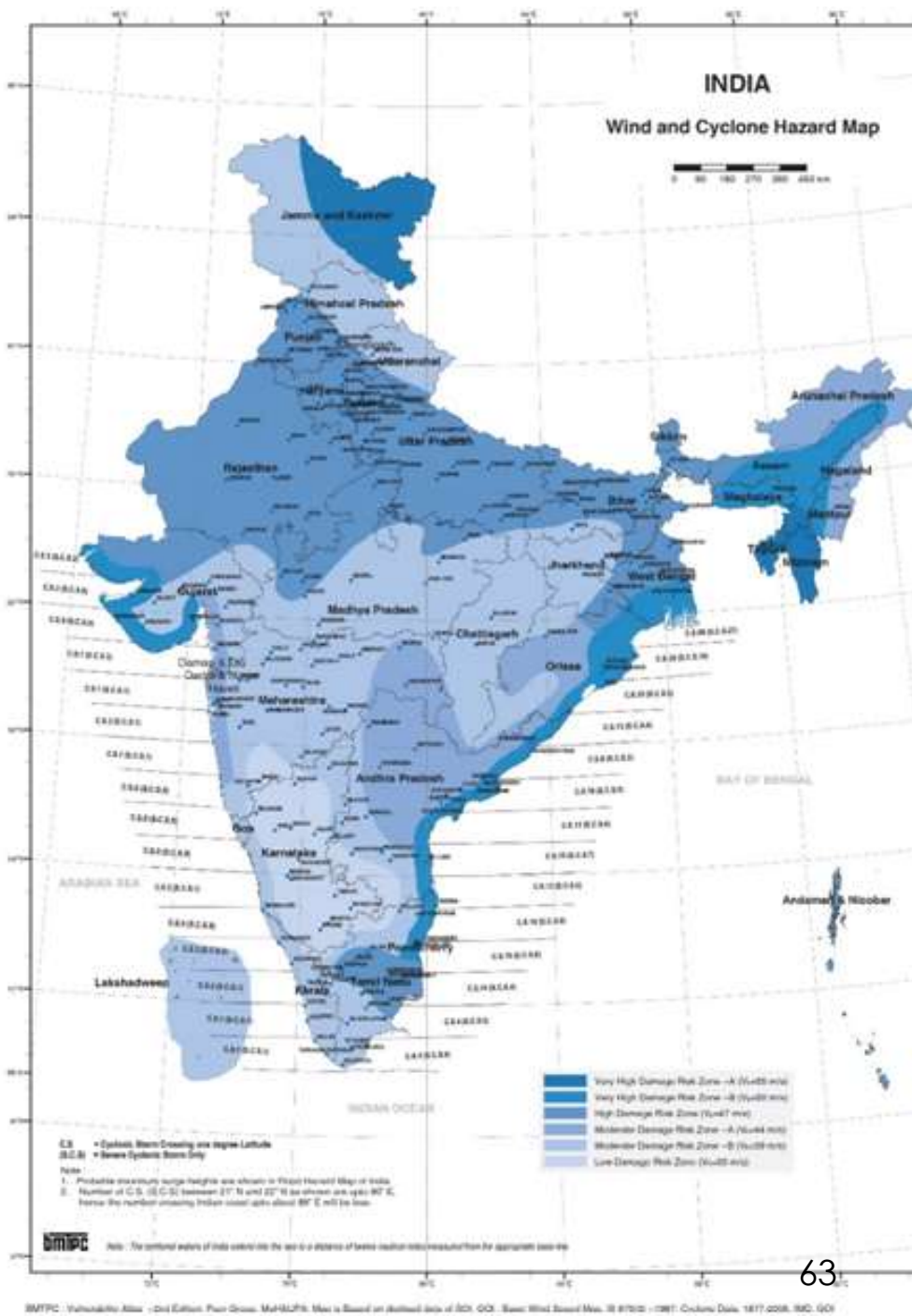


An **Anemometer** is a device used for measuring the speed of wind, and is also a common weather station instrument, which is placed at a height of 10m from the ground level.

Is your region cyclone/windstorm prone?

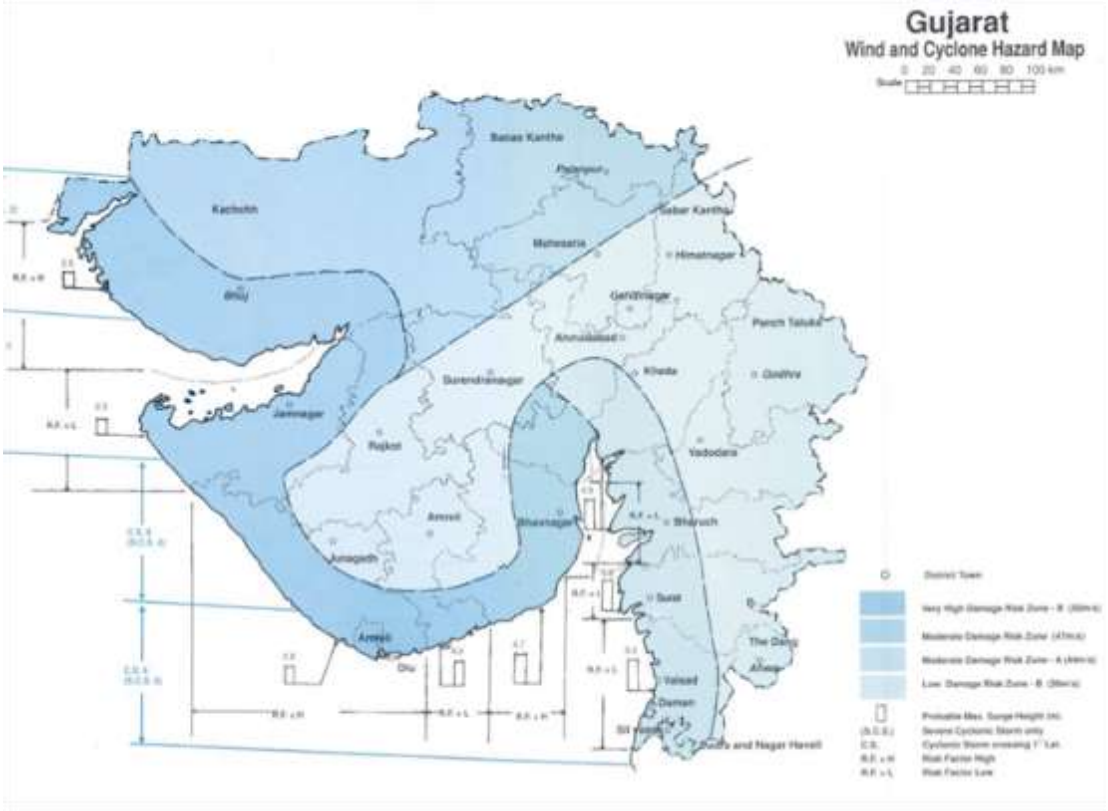
Which of the following risk zones does your region fall in ?

- Very high damage risk Zone – A
- Very high damage risk Zone – B
- High damage risk zone
- Moderate damage risk zone – A
- Moderate damage risk zone - B
- Low damage risk zone



Source : http://www.ndma.gov.in/en/vulnerability-profile.ht

Wind & Cyclone Hazard Map of Gujarat



- Based on wind speed maps given in IS 875 1987 (Part-III)
- Along with design wind speed, the number of cyclones which have crossed each latitude of the sea coast in the past are also marked

Impact on Houses

Uplifting or Uprooting of roof or house

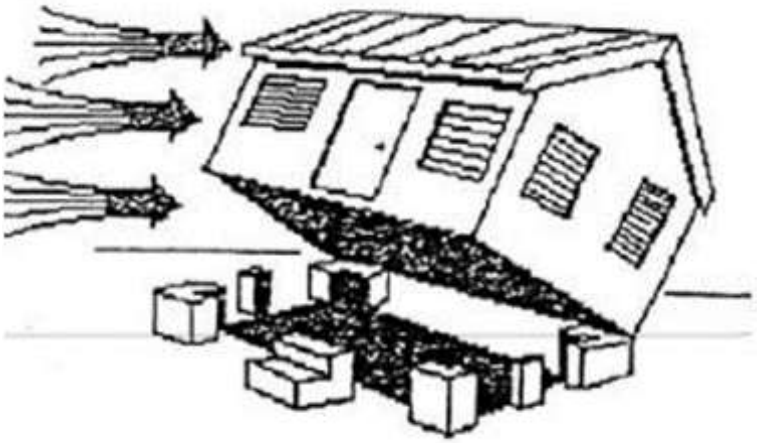
When you are walking in a place where fast winds are blowing, your umbrella is overturned or blown off.

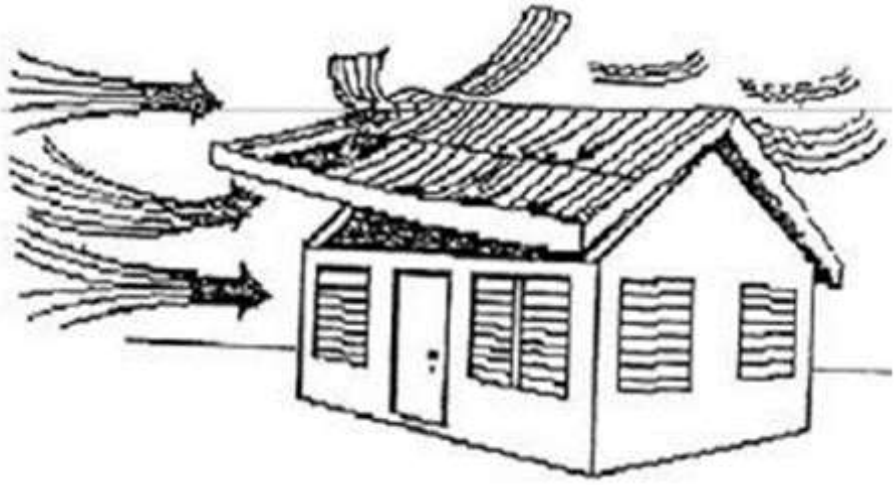
Uplifting of Roof or House

Roofs that aren't anchored properly can get uplifted during a cyclone/windstorm.

Light weight temporary shelters, which are not held properly, may blow away.

CGI sheets/tiles could blow away if not anchored well.





The pressure of the wind builds up on the ceiling inside the house to such an extent that the clay tiles are blown away.

All the roofing material has been blown away due to the outward/upward pressure of the wind.

Erosion due to accompanying excessive rainfall

Cyclones are accompanied by periods of excessive rainfall that lead to flooding and/or splashing. Therefore, damage occurs to the house due to erosion and presence of excessive moisture in the air, leading to the reduced strength of the materials.

Earthquake versus Cyclone

During an earthquake, lighter the building and the roof, the better is the performance of the house. Lighter roof would not induce as much load on the walls, and the walls would be able to transfer the loads easily during an earthquake.

On the other hand, **during a cyclone, heavier the roof, the better is the performance of the house**. It would resist strong loads due to the wind pressure, hold itself and the house in place.

Damage due to High Pressure of Wind

Damage to Rear Wall due to Outward Wind Pressure

Damage due to High Pressure of Wind

Collapse due to High Pressure of Wind

TSUNAMI

Earthquake

Flood

Cyclone

Tsunami

Landslide

Introduction

A large oceanic wave, usually caused by earthquakes

Severity of a Tsunami

Measuring a Tsunami

A tsunami is a series of large waves caused by the displacement of a large volume of water, as a result of an earthquake, an underwater landslide, or a volcanic eruption.

Usually, it takes an earthquake with a Richter magnitude exceeding 7.5 to produce a destructive tsunami.

A tsunami forecast can be made, by laying out a DART system on the ocean bed, which transmits data in real time.

Significant Tsunamis in India

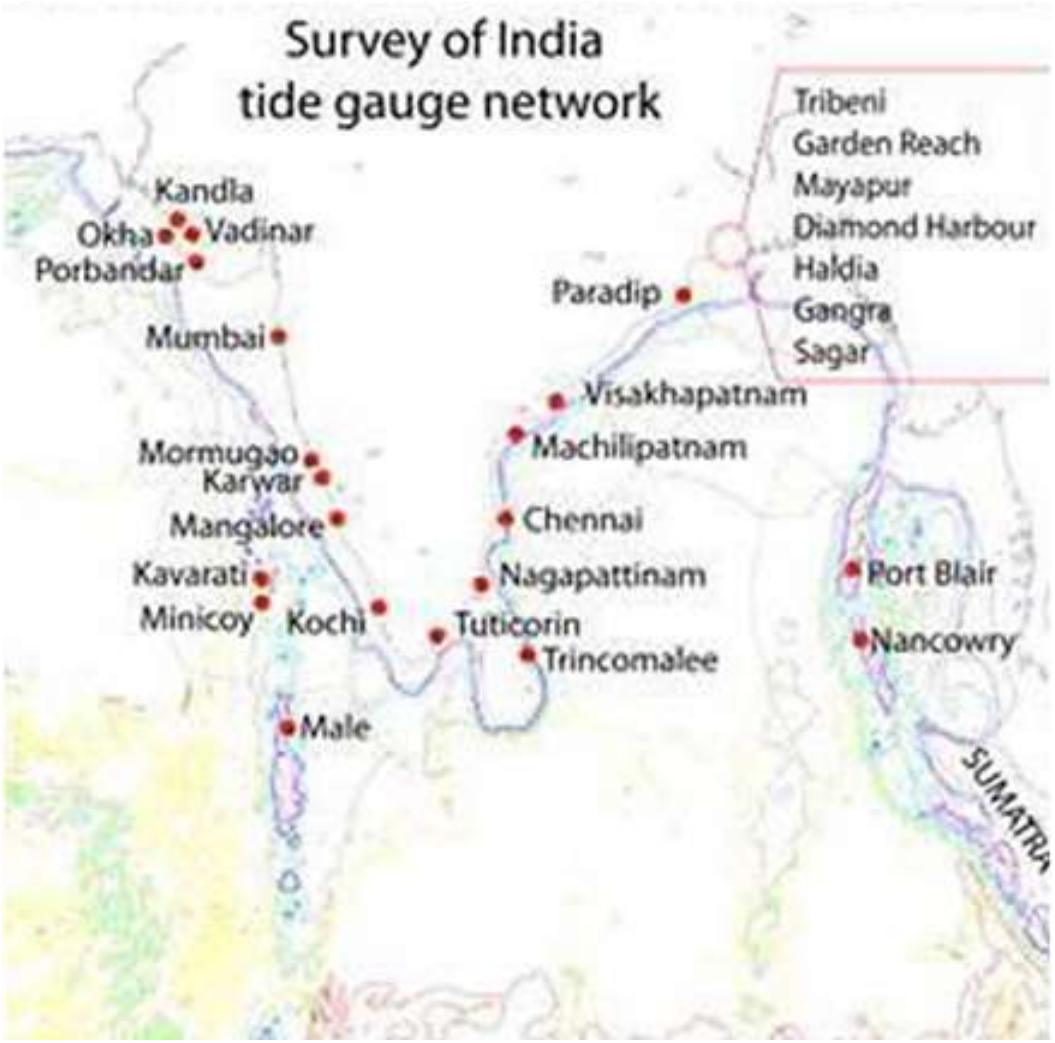
Source:
http://www.sangam.org/2007/12/Tsunami_Rehab.php?uid=2692&print=true

Indian Ocean Tsunami of 2004

The Tsunami was caused by an earthquake, its epicentre close to the island of Sumatra in Indonesia. Severe damage occurred at the coastlines of India, Sri Lanka, Indonesia and Malaysia.
Water level rose to 20 m high and come up to 2km inland along the Indian coast.
Affected people: 230,000–280,000 dead and more missing
Magnitude of Earthquake: 9.1-9.3

Is your region tsunami prone?

When was the last warning issued or a tsunami struck?



Source: Survey of India Tide Gauge Network

Impact on Houses

What happens when an extremely large force of water completely engulfs a house?

1. Due to its force and quantity, it may cause the entire house to be razed to the ground or be carried away with the water during inflow and outflow of the waves.

2. Tsunami is followed by a flood and so the presence of water for a prolonged period causes further damage to houses.

Impact of a Tsunami

A large thrust force either razes the house or gets it unhinged from the ground and carries it away along with the water.

Seawater creates havoc

Seawater Floods Low Lying Areas

LANDSLIDE

Earthquake

Flood

Cyclone

Tsunami

Landslide

Introduction

Rapid downward movement of a mass of rock, earth, or artificial fill on a slope

Severity of a Landslide

Is your region landslide prone?

Was your region highly, moderately or marginally affected?

Source: Geological Survey of India

NATURAL CAUSES

1. Erosion due to water and wind
2. Weakening of a slope
3. Earthquakes

MAN-MADE CAUSES

1. Deforestation, cultivation and construction
2. Vibrations from machinery or traffic.
3. Blasting and mining

Significant Landslide in India

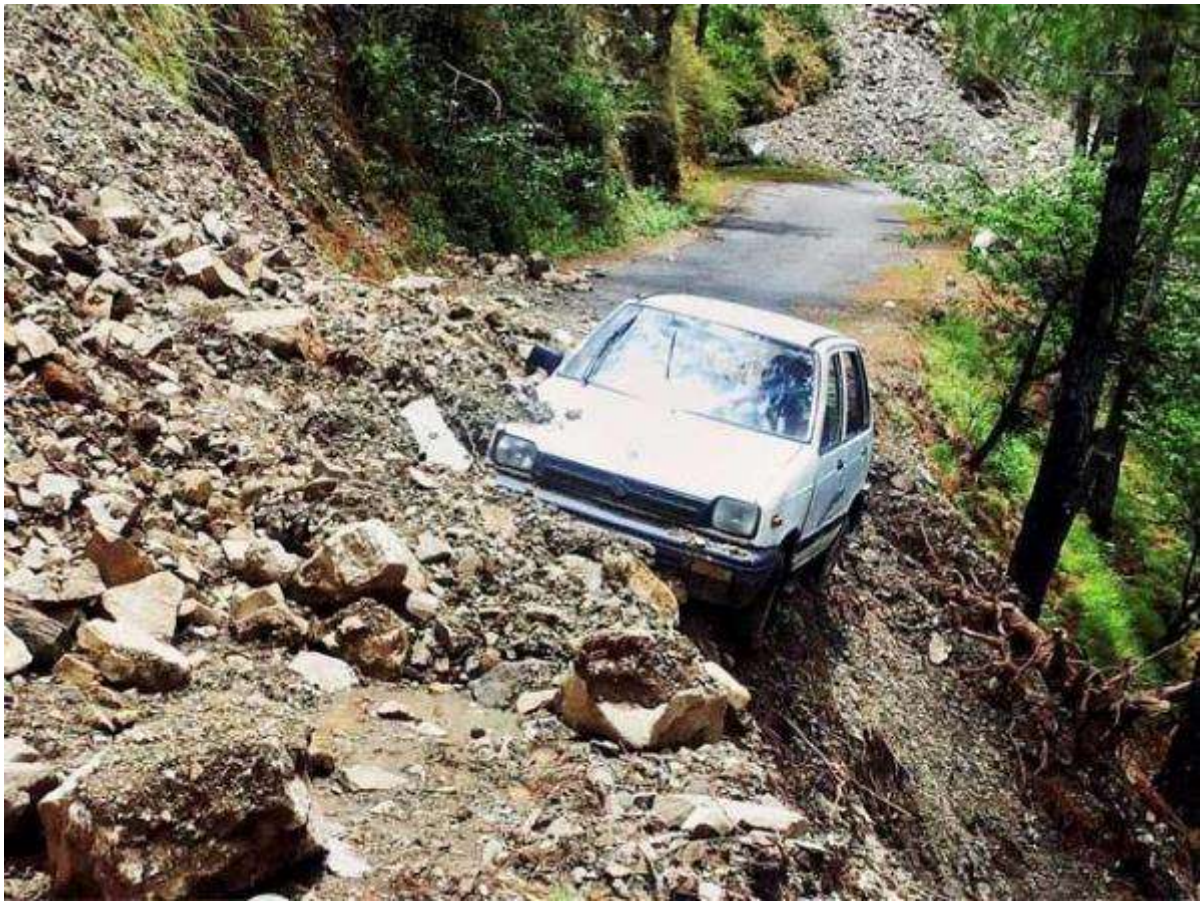
1. *Malin Landslide, Maharashtra (2014),* due to heavy rainfall
   Fatalities: 151 deaths, 40 houses damaged

2. *Kedarnath Landslide, Uttarakhand (2013),* due to uttarakhand floods. Fatalities: 5748 deaths, 4200 villages affected

3. *Amboori Landslide, Kerala (2001),* due to heavy rainfall
   Fatalities: 38 deaths

Impact on buildings: High Impact force

The mass of earth coming down from the mountain is like a large hammer laying on the side of the house.



High Impact Force

The boulders or mass coming down with a landslide exerts a thrust force on the side of a house. This may cause the entire house to be damaged or a part of it to just be taken away along with the mass.

Sliding Force

When the land on which a house rests undergoes movement, the house may slide down along with the ground underneath, thereby damaging itself as well as other buildings downslope.

Landsliding from underneath the House

Which Hazard can lead to which other Hazards?

Earthquake

Flood

Cyclone

Tsunami

Landslide

Earthquake

Flood

Cyclone

Tsunami

Landslide

Often, one hazard results in another one. In case of such cascading hazards, the possibility of damage and loss of life is increased.

An Earthquake may lead to ...

If a dam or an embankment gets damaged during an earthquake or if water fissures appear due to movement under the earth, it can cause flood along with the earthquake. e.g. The 1819 earthquake in Kutch that led to flooding of large area in Kutch, and resulting in creation of Sindri lake and Allah Bund .

The 2004 earthquake off the west coast of Sumatra, Indonesia, was a magnitude 9.1–9.3 (Mw) and it caused the Tsunami leading to largescale damage in 14 countries.

Earthquakes in mountainous regions could loosen slopes, leading to landslides.

A Flood may lead to ...

Earthquake

Flood

Cyclone

Tsunami

Landslide

Earthquake

Flood

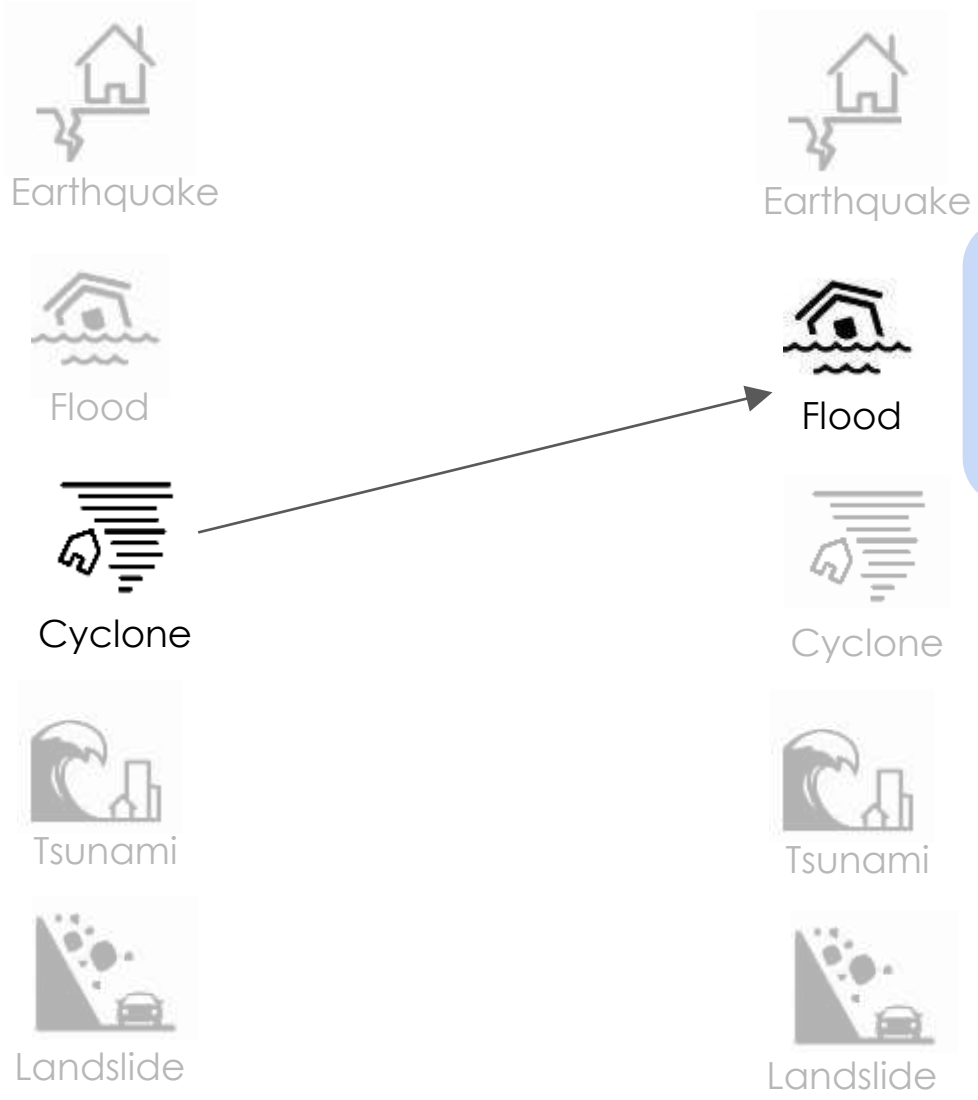
Cyclone

Tsunami

Landslide

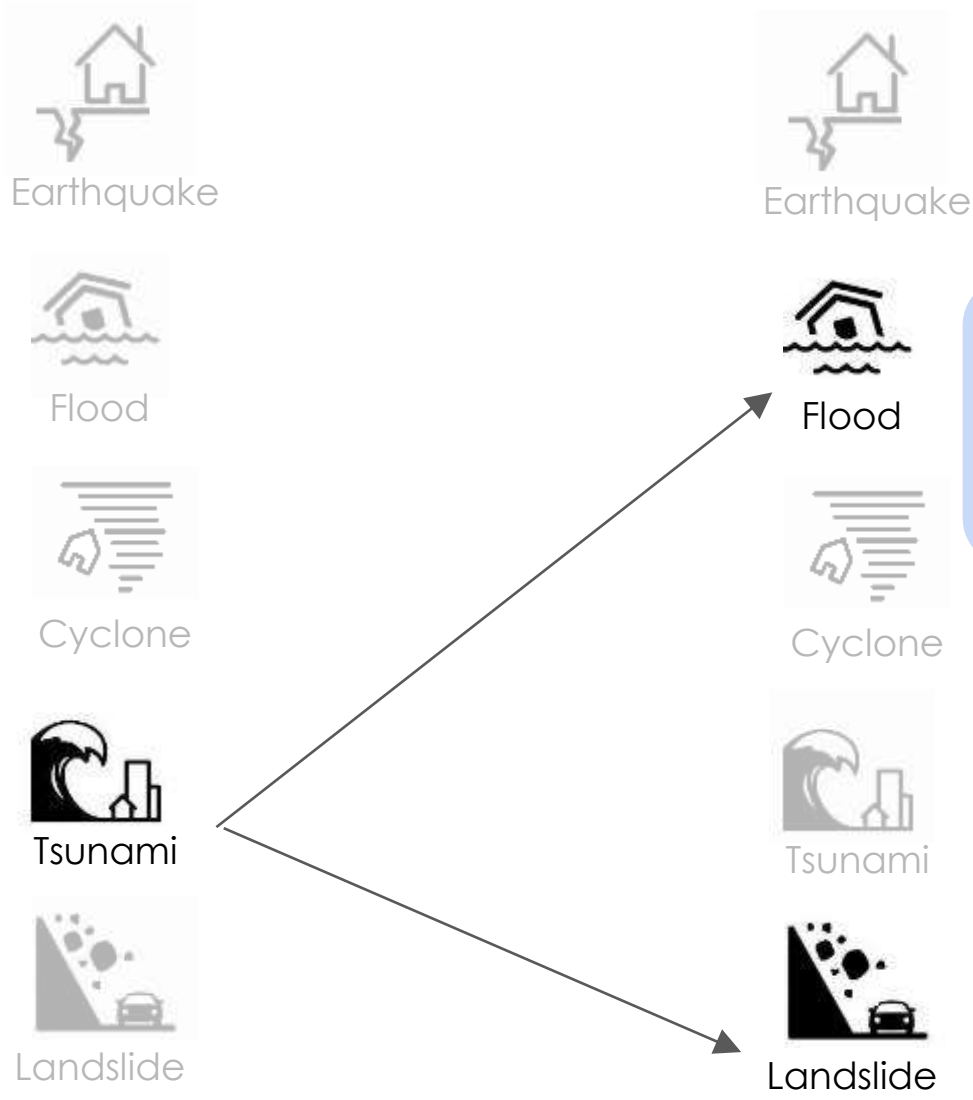
Landslides in Kedarnath were caused by floods due to heavy rainfall.

A Cyclone may lead to ...



Since cyclones usually occur near the coastal areas, they bring along huge waves and often are accompanied by rains, resulting in flooding of the area. Kutch, Orissa, Andhra Pradesh has experienced several such cyclones and floods.

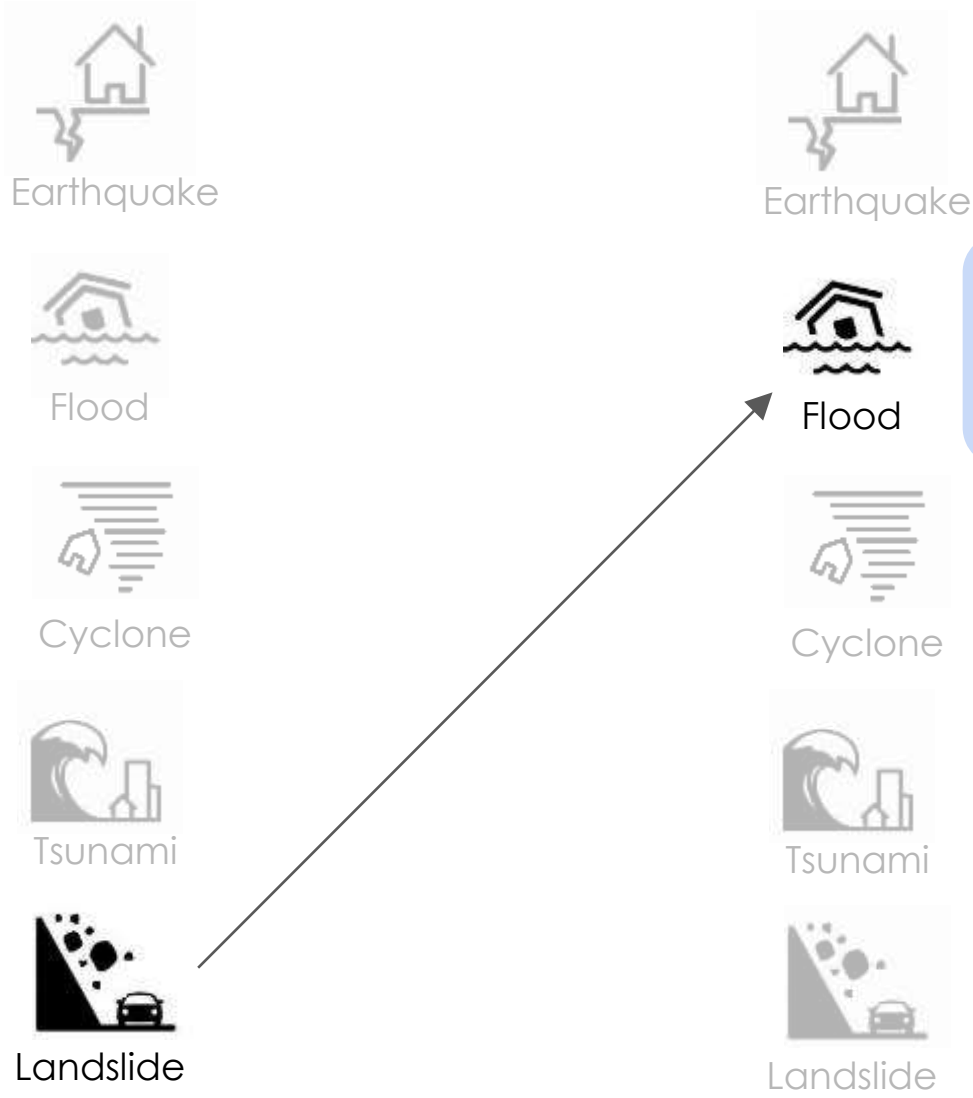
A Tsunami may lead to …



Water that comes in due to a tsunami leads to severe flooding and prolonged submergence, resulting in damage to homes. 2004 Indian Ocean Tsunami caused flooding at several places along east coast of India as well as other places

The large volume of water may cause loose slopes to come down or be tipped off. Local landslides were observed post 2005 Tsunami at places

A Landslide may lead to …



If a lake in the mountains gets filled in or breached due to landslide, the water could drain out flooding the lower areas causing damage.

Summary

1. We looked at the different disasters (Earthquakes, Cyclones, Floods, Tsunamis and Landslides), and where and with what intensity they occur in India.

2. Earthquakes occur due to shift in plates of the earth's surface. India has a high frequency of earthquakes. The magnitude (measured from the energy released) rises logarithmically with increase in the numerical digit. Earthquakes can cause flood, tsunami and landslide. We discussed the damage due to shaking and how loads in the horizontal direction need to be transferred to the ground. Also, we discussed twisting of houses that are asymmetric.

3. Floods can be caused when a house is built in a low-lying area, where water level rises because of the river changing its course, heavy rainfall or gradual rising of water. We discussed damage due to submergence, flow of water, splashing of rainwater and presence of moisture in the air.

Summary

4. Cyclones are common along the coast of India. The intensity of the cyclone is measured by measuring the speed of the wind. A cyclone may be accompanied by heavy rainfall and floods. We discussed the pressure of the wind, suction and erosion due to accompanying excessive rainfall.

5. Tsunami is typically caused by an Earthquake. It's severity depends on how high the wave is and how far inland does it come in. We discussed sheer force and accompanying floods

6. Significant Landslides in India are caused by natural and man-made effects. The thrust force of a land mass coming down or the sliding action, if the house is on the land mass, is what causes severe damage.

7. Multiple disaster events may occur when one disaster triggers another in quick succession, and causes severe effects and losses.