Lecture notes

# FUNDAMENTALS OF CLIMATE CHANGE AND NATURAL DISASTERS

Course Code: ER601

## Chapter 2

# NATURAL DISASTER PHENOMENA

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## AN OVERVIEW ON DISASTERS

**Disaster (Thiên tai) is a Sino-Vietnamese word, Thien: heaven, nature, Tai: risk, accident, calamity.**

**Natural disaster is sometimes called Disaster in short.**

***A natural disaster is an abnormal phenomenon of nature that creates adverse effects and risks for people, organisms and the environment.***

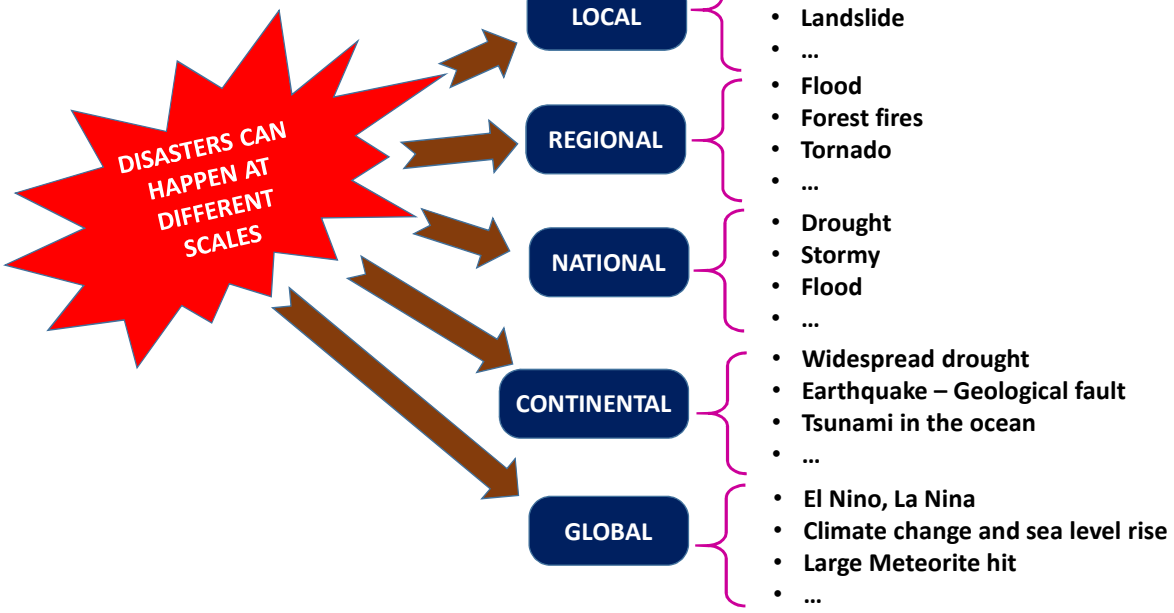
**Large natural disasters can create hazards, causing many casualties and damage to properties and ecosystems, especially when natural disasters (such as hurricanes, earthquakes, tsunamis, volcanoes, ...) have more accidental factors from human works (such as dam breaking, nuclear radioactive leakage, fire and explosion of toxic chemicals, ...).**

## EARTHQUAKE, TSUNAMI, AND NUCLEAR HARZARD IN JAPAN IN 2011

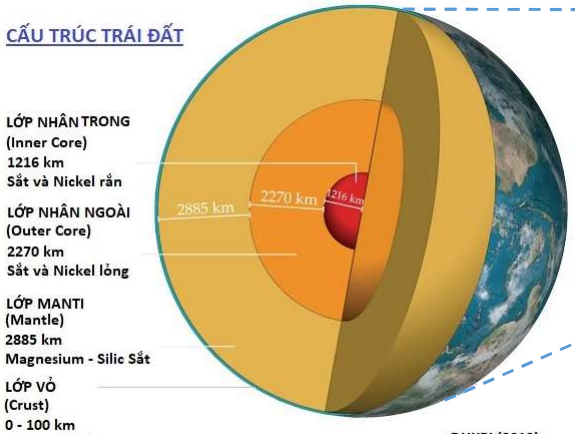
**In 2011, a magnitude 9.0 MW earthquake occurred off the east coast of the Oshika Peninsula, Tōhoku, Japan. Minutes after the earthquake, a tsunami nearly 39 meters high hit Japan.**

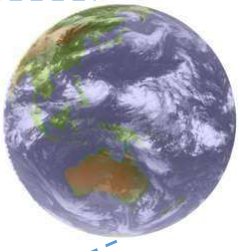
**There have been 3 explosions at the Fukushima reactor, causing dangerous radioactive leaks. In addition, the Fujinuma Irrigation Dam in Sukagawa City broke, causing flooding and detroying away many houses.**

**Japan confirmed 15,893 people were killed, 6,152 injured and 2,572 people missing in 18 Japanese prefectures and more than 125,000 housing structures were damaged or completely destroyed. Losses due to the earthquake and tsunami that devastated Northeast Japan are estimated at 309 billion USD.**

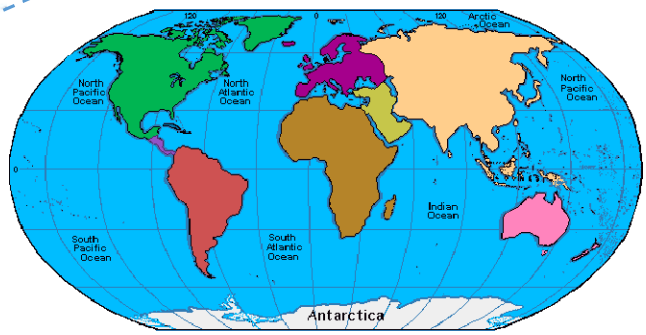


## CẤU TRÚC TRÁI ĐẤT



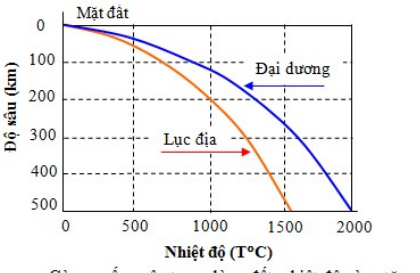
The area of continental plates accounts for only 1/4 of the Earth's surface area, the remaining 3/4 is the area of the seas and oceans.



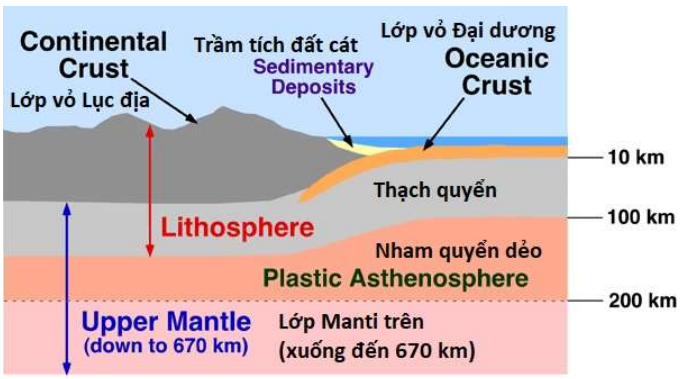

The Earth is an unstable planet, with an average diameter of 12,756 km surrounded by a discontinuous hard crust consisting of 9 large continental plates and 6 smaller continental plates.

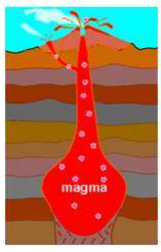
The deeper into the Earth, the higher temperature, the "soil" (actually iron metals and other light elements such as Silicon, Magnesium, Aluminum, ...) gradually soften and turn into liquid.

At a depth of about 2,900 km, the temperature in the ground is up to 1,000 °C.




Càng xuống sâu trong lòng đất, nhiệt độ càng tăng



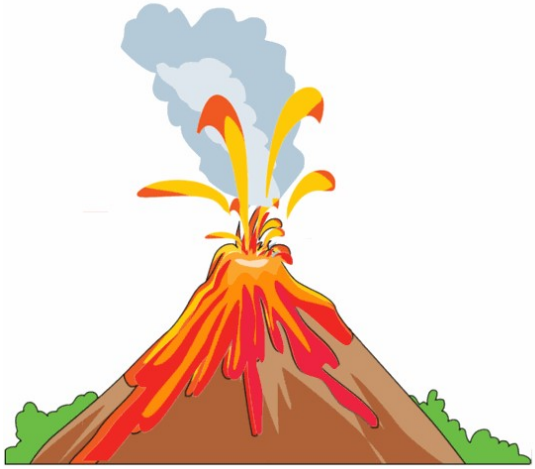




Túi magma phun trào dung nham ở núi lửa

Because the material structure in the earth's crust is not the same, in the flexible layer can form molten pockets and have great pressure, these pockets are the source of volcanic lava eruptions.

The planet's crust is unstable and often shifts, causing cracks to cause lava to erupt, causing volcanoes or sliding over each other, creating folds such as the formation of mountain ridges or the displacement of earthquakes, on land or at sea.

These are the causes of natural disasters from the earth.



In addition, the constant movement and compression of the atmosphere's energy often creates storms, low pressures, heavy rains, strong winds, lightning, tornadoes, etc., which are natural disasters from the sky and atmosphere.

In addition, the earth is also affected by cosmic agents that can cause natural disasters such as meteors, meteorites, magnetic storms, etc.

Thiên thạch tấn công (asteroid sneak attack)

Bão từ (geomagnetic storm)

## CLASSIFICATION OF DISASTERS

Natural disasters are diverse and come from many different sources: it can be from the earth, from the air, from the sea and ocean, or a combination of many causes.

| | |
|---|---|
| Disasters from Earth | Earthquakes, Volcanoes, Landslides, etc. |
| Disasters from Rivers & Seas | Flood, Drought, Tsunami, Tornado, etc. |
| Disasters from the Atmosphere | Storm, Cyclone, Thunder, Hail, Snow, etc. |
| Disasters from the Universe | Meteor, Magnetic Storm, El Nino, La Nina, etc. |

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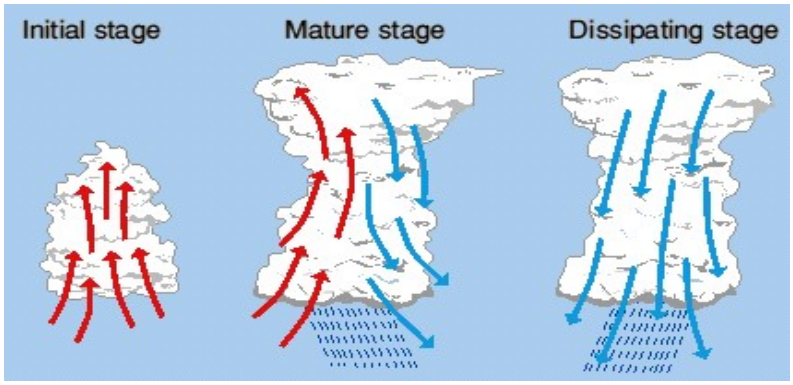
## THUNDERSTORM

**Thunderstorms are caused by electrical discharges in dense clouds, forming lightning, sometimes accompanied by strong winds and showers.**

**The cause of thunderstorms is that in the summer, the ground is warmed by absorbing more solar radiation, causing hot and humid air currents to rise, lower temperature air overflowing below. This is a form of convection, forming heat storms.**

**In the case of hot and humid air rising high along the mountain slopes, it is called a topographical thunderstorm. When reaching a certain height, the charged clouds collide causing lightning, the temperature of the air mass decreases, causing heavy showers.**


## THREE STAGES OF A THUNDERSTORM

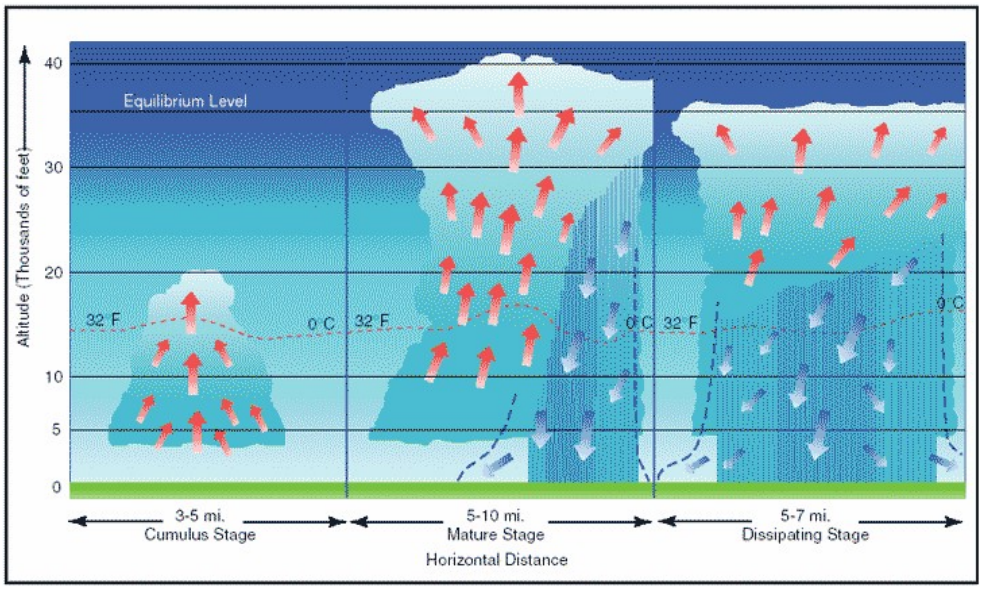


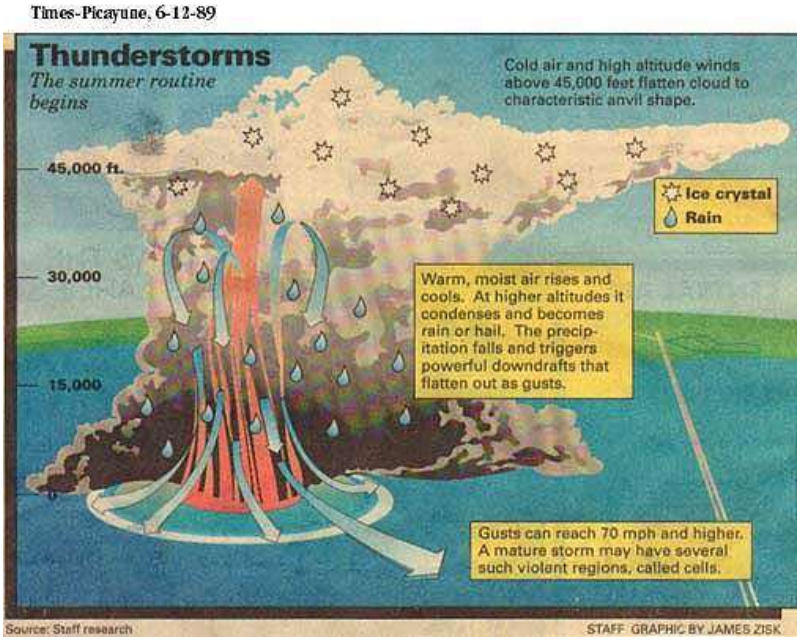

***Initial* phase:**
**Convection creates cumulus clouds, which then develop into cumulus clouds (*cumulo-nimbus*). Water vapor turns into water droplets releasing energy.**

***Mature stage*:**
**The top of the cloud began to spread out like an "anvil". The ice crystals and rainwater mixed and fell violently. Rain started to fall.**

***Dissipating stage*:**
**Clouds lose water vapor and gradually disintegrate. Thunderstorms may continue if new clouds develop around their edges.**

## THREE STAGES OF A THUNDERSTORM



**Thunderstorms can damage crops and people. During a thunderstorm with heavy rain, strong winds can break trees, causing dangerous lightning.**

**However, it is noted that rainwater in thunderstorms has more nitrogen than normal rains.**

***In Vietnam, thunderstorms occur in the summer, from April to August.***

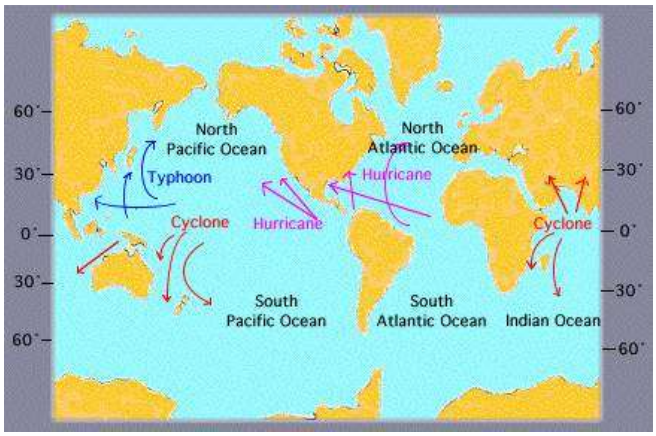
## TROPICAL LOW PRESSURE AND STORM

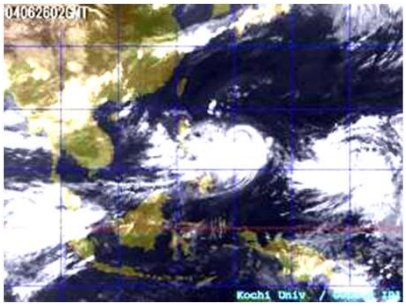
**Áp thấp nhiệt đới (*Tropical Low Pressure*)**
**và Bão (*Hurricane/Typhoon/Cyclone*)**

**Tropical Low Pressure and Typhoon is a highly developed tropical cyclone that produces an area of high winds, strong vortexes, and heavy rains that spread over a large area.**

**When there is a strong wind from level 6 to level 7 (ie from 39 to 61 km/h) it is called a tropical depression.**

**When strong winds of level 8 or higher (ie 62 km/h or more) are called storms; Wind strength up to level 12 or higher (above 118 km/h) is called a strong storm.**



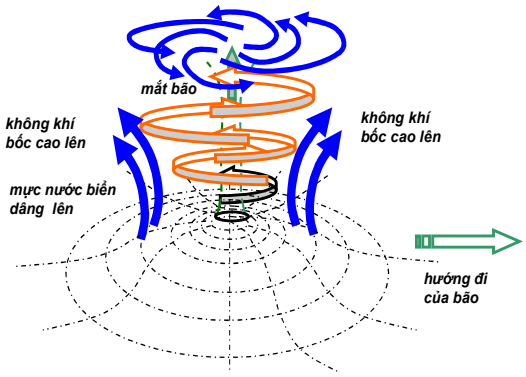
**Location of storms in the world and names:**

**+ In the Western Pacific Ocean (Southeast Asia and East Asia):** ***Typhoon***
**+ In the South Pacific (Australia) and Indian Oceans:** ***Cyclone***
**+ In the North Atlantic and Eastern Pacific (America):** ***Hurricane***

## CAUSE OF STORM

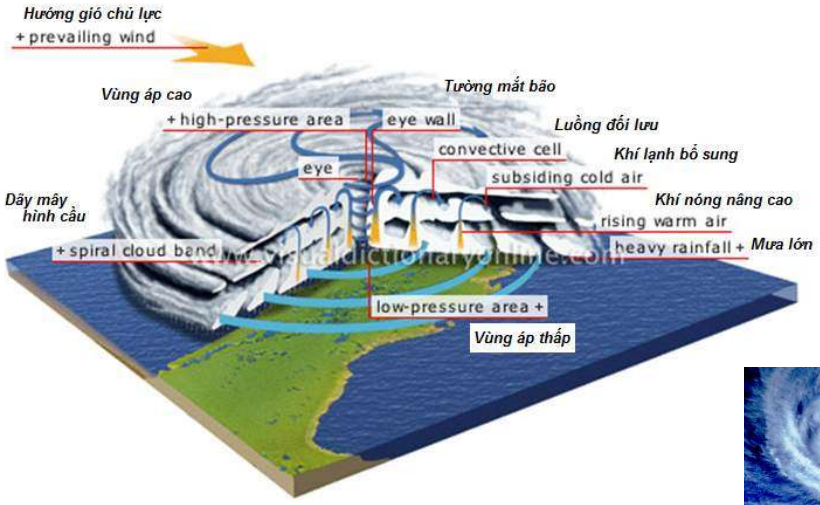
**During the hot season, the sea water temperature increases heigh (t °C ≥ 25°C), the amount of hot and humid air rises, encountering the effect of the earth's centrifugal force to form vortices, which move around. encountering vertical moving air currents will form converging bands, making the vortex stronger and forming storms.**

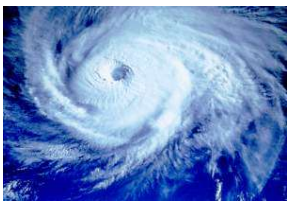
**In the center of the storm, also called the eye of the storm, the air moves from above to form an area with little wind and clouds, but around the eye of the storm, the air is swept up, the closer to the center of the storm, the speed increases gradually.**




**Profile of a storm**

https://www.youtube.com/watch?v=ZZnIBKu1Otg

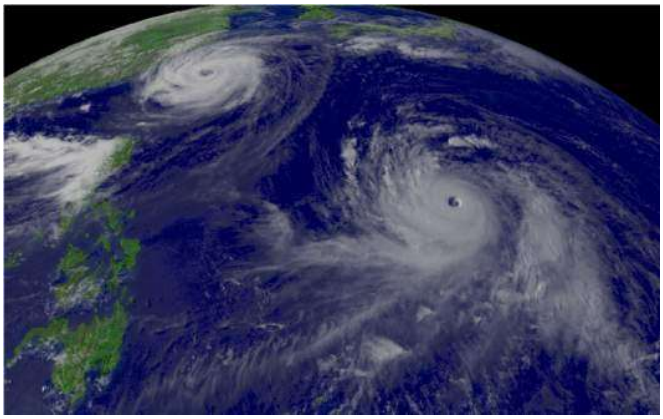


**The diameter of a storm is up to several hundred kilometers, the height is from 3 to 9 km, the speed of the storm is about 10 - 20 km/h, usually moves to the west, the affected area of the storm can be wide. from 800 - 1,500 km$^2$.**

**About 100 - 200 km from the center of the storm, there are usually level 6, level 7 winds. In the center of the storm, the wind gusts up to level 10, level 11, sometimes up to level 12 (wind speed can be from 100 - 200 km /hour).**

**In the stormy area, the amount of rain is very heavy, sometimes reaching several hundred millimeters of water in a day and night.**



Phân hạng mức bão lớn theo cấp của Saffir/Simpson

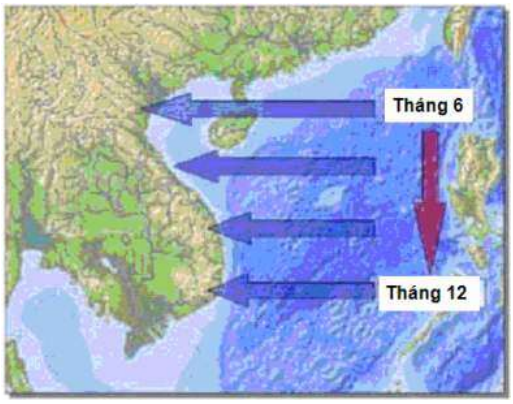
| Phân hạng | Tốc độ gió (mph) | Mức tàn phá |
|---|---|---|
| 1 | 74 - 95 | Cây bụi và cành cây bị tuốt lá và bẽ gảy; các căn nhà di động không neo có thể bị hư hỏng |
| 2 | 96 - 110 | Các cây nhỏ bị thổi bay; các nhà di động bị hư hại nhiều, ống khói và ngói bị thổi khỏi mái nhà |
| 3 | 111 - 130 | Lá cây bị tuốt, cây to đổ ngã; nhà di động bị phá hủy, các tòa nhà nhỏ bị hư hỏng cấu trúc |
| 4 | 131 - 155 | Mức tàn phá mở rộng đến các cửa sổ, mái nhà, cửa lớn; nhà di động bị phá hủy hoàn toàn; các cơn lũ tràn sâu 10 km vào đất liền |
| 5 | Trên 155 | Tất cả các tòa nhà bị hư hỏng nhiều, các tòa nhà nhỏ bị phá hủy hoàn toàn. |

Bão được phân biệt thành các loại (Theo Ban PCLB Trung ương):

- ***Bão thường:*** là xoáy thuận nhiệt đới có sức gió mạnh nhất từ cấp 8 đến cấp 9 và có thể có gió giật
- ***Bão mạnh:*** là xoáy thuận nhiệt đới có sức gió mạnh nhất từ cấp 10 đến cấp 11 và có thể có gió giật
- ***Bão rất mạnh:*** là xoáy thuận nhiệt đới có sức gió mạnh nhất từ cấp 12 trở lên và có thể có gió giật

**In Vietnam, storms are the leading natural disaster and cause the greatest damage to people and property.**

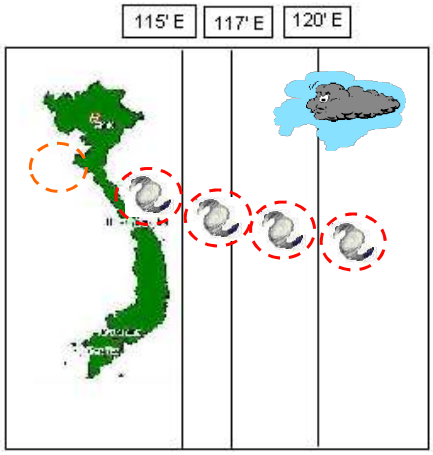
**On average, each year Vietnam has about 10 different big and small storms, the month with the most storms is September every year.**




**From Quang Ninh to Thanh Hoa: July, August, September**
**From Thanh Hoa to Thua Thien - Hue: July, August, September, October**
**From Da Nang to Thuan Hai: September, October, November**
**From Thuan Hai to Ca Mau: October, November, December**

***In Vietnam, about 60% of storms originate from the waters of the Caroline Islands, Philippines, the remaining about 40% of storms from other places south of the East Sea.***

## STORM NEWS
## Includes 5 types of news




**1. Storm news tracking**
Khi bão còn ở phía Đông kinh tuyến 120° Đông, nhưng phát hiện bão có khả năng di chuyển vào biển Đông

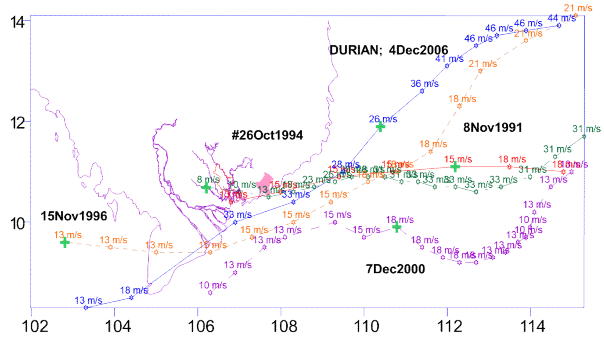
**2. Far Storm news**
Khi vị trí trung tâm bão ở phía Tây kinh tuyến 120° Đông, cách biển đất liền nước ta từ 500 km trở lên và có khả năng di chuyển về phía đất liền nước ta trong một vài ngày tới.

**3. Nearest news of Storm**
Khi vị trí trung tâm bão cách điểm gần nhất thuộc bờ biển đất liền nước ta dưới 300 km.

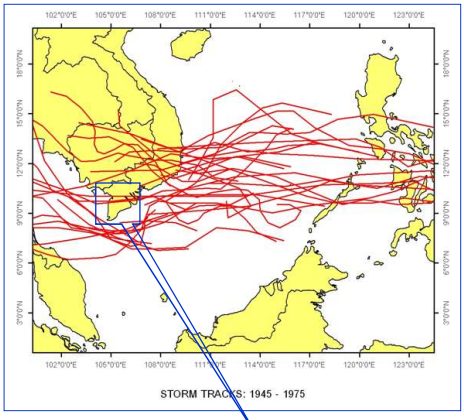
**4. Emergency Storm news**
Khi vị trí trung tâm bão ở phía Tây kinh tuyến 120° Đông, cách điểm gần nhất thuộc bờ biển đất liền nước ta dưới 300 km.

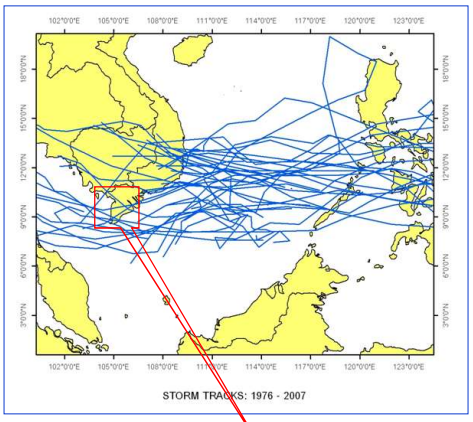
**5. Nearest news of Storm**
Khi vị trí trung tâm bão ở phía Đông kinh tuyến 120° Đông, cách biển đất liền nước ta từ 300 km trở lên và có khả năng di chuyển về phía đất liền nước ta trong một vài ngày tới.

## SOME STORM AND DAMAGE HIT VIETNAM

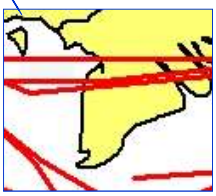



| Tên và thời điểm đổ bộ vào đất liền của bão | Vùng bị tàn phá lớn nhất do bão | Thiệt hại về nhân mạng | Thiệt hại về tài sản |
|---|---|---|---|
| Con bão Cecil 16/10/1985 | Vùng Bắc Trung bộ (Đồng Hới, Quảng Bình, Quảng Trị, Thừa Thiên) | ▪ 900 người chết<br>▪ 215 người bị thương | ▪ Trên 70.000 ngôi nhà bị sập và cuốn trôi<br>▪ Chìm 1.772 tàu thuyền<br>▪ Hư hại 1.800 tàu thuyền<br>▪ Sạt lở hơn 1,5 triệu $m^3$ đất đá |
| Con bão số 5 (Bão Wayne) 05/9/1986 | Vùng Trung du Bắc bộ (Thái Bình, Hà Nam, Nam Ninh) | ▪ 400 người chết<br>▪ Trên 2.000 người bị thương | ▪ Hàng chục ngàn ngôi nhà bị sập và hư hỏng nặng |
| Con bão số 6 (Bão Irving) 24/7/1989 | Thanh Hóa | ▪ | ▪ 84.638 ngôi nhà bị sập và hư hỏng nặng |
| Con bão số 5 (Bão Linda) 03/11/1997 | Vùng ĐBSCL (Bạc Liêu, Cà Mau, Kiên Giang) | ▪ 778 người chết<br>▪ 1232 người bị thương<br>▪ 2123 người bị mất tích | ▪ 2.897 tàu thuyền chìm<br>▪ 1.649 tàu thuyền hư hỏng<br>▪ Nhiều tuyến đê biển bị vỡ và cuốn trôi<br>▪ Hàng trăm ngôi nhà bị đổ sập<br>▪ Tổng thiệt hại ước tính gần 7.200 tỷ đồng |
| Con bão số 5 (Bão Dawn) 19/11/1998 | Vùng miền Trung Phú Yên - Khánh Hoà | ▪ 109 người chết<br>▪ 14 người bị thương<br>▪ 4 người mất tích | ▪ 1.408 nhà bị đổ trôi<br>▪ 416.686 nhà bị ngập và hư hại<br>▪ 30 phòng học bị đổ trôi<br>▪ 15 thuyền bị chìm |

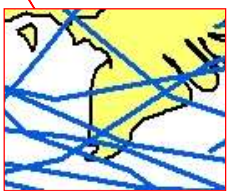



**Storms affecting the southern region of Vietnam from 1945 to 1975**



**Storms affecting the southern region of Vietnam from 1976 - 2007**



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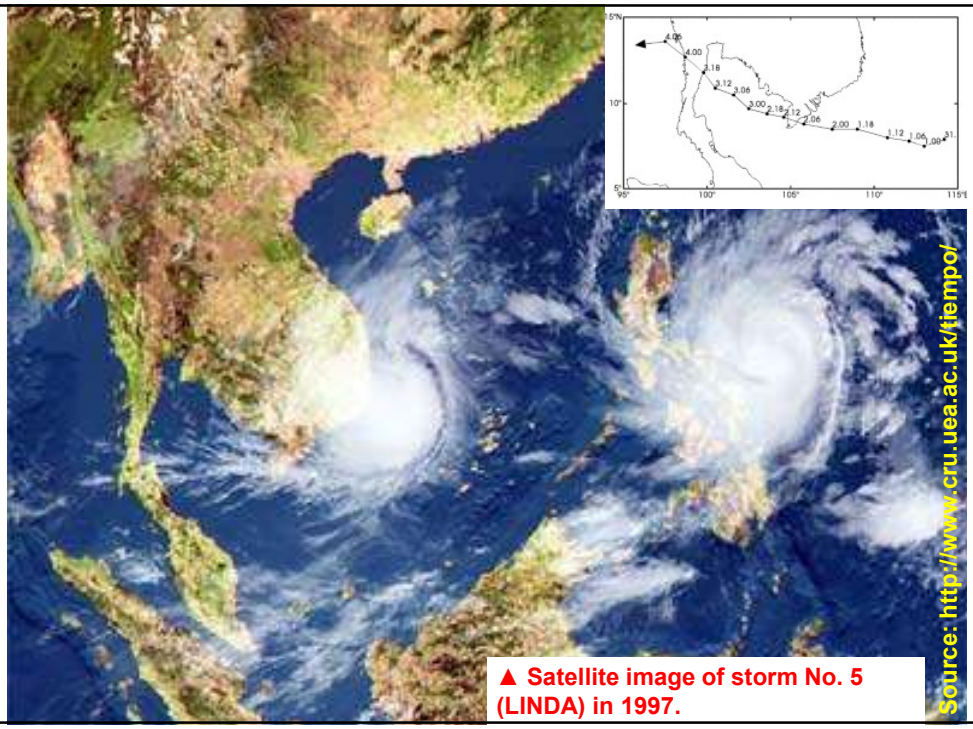
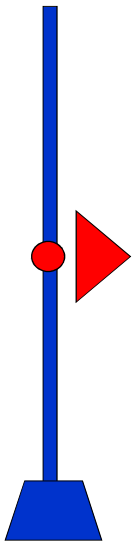




▲ Satellite image of storm No. 5 (LINDA) in 1997.

Source: http://www.cru.uea.ac.uk/tiempo/


Hơn 600 người đã chết do bão số 5 (LINDA) đi qua vùng ven biển ĐBSCL (1997).



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## FLOODS

- Flood is the phenomenon of high water in the river, flowing strongly, overflowing from the bank, flooding many low-lying areas.
- Flooding refers to the restriction of drainage from the basin.
- Rain, Storm and Flood are always closely related.


Storm and flood damage accounts for more than 50% of all other losses worldwide.

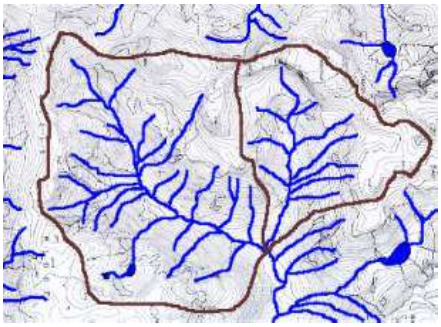
The loss of life from floods in rural and mountainous areas is usually higher than in urban areas, but economic losses are higher in urban areas than in rural areas.

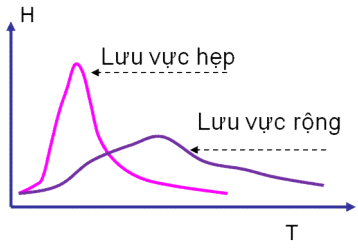
## LŨ LỤT

➢ The wider the basin, the slower the flood water will rise but will also recede slowly, on the contrary, the narrow and long basin will cause the flood water to rise quickly - in some cases, flash floods, tube floods ...

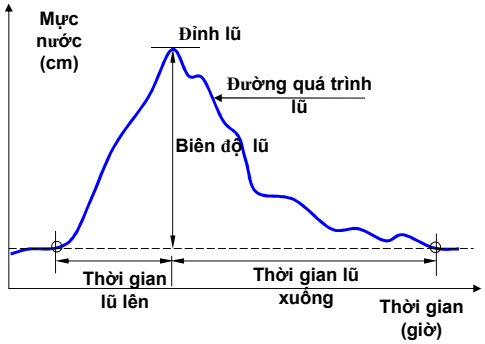
➢ Deforestation will be one of the main causes of flooding and soil erosion.

➢ The phenomenon of Ẽl Nino (due to the warming of the equatorial waters of the South America Pacific) and La Nina (due to the cooling of the East Pacific equatorial waters) have caused floods and droughts. in many different regions.





# LŨ LỤT




- ***Mực nước***: là cao độ mực nước so với cao trình chuẩn (thường so sánh với mực nước biển trung bình, *Mean Sea Level* - viết tắt là MSL). Mực nước thường ký hiệu là H và đơn vị là cm.
- ***Lưu lượng***: là lượng nước chảy qua một mặt cắt ngang lòng dẫn trong một đơn vị thời gian. Lưu lượng thường ký hiệu là Q và đơn vị là l/s hoặc $m^3/h$.
- ***Đỉnh lũ***: là giá trị mực nước lớn nhất ($H_{max}$) hoặc lưu lượng lớn nhất ($Q_{max}$) trong một trận lũ.
- ***Chân lũ lên***: là thời điểm từ mực nước bắt đầu dâng cao so với mực bình thường.
- ***Chân lũ xuống***: là thời điểm từ mực nước xuống đến so với mực bình thường.
- ***Thời gian lũ lên***: là khoảng thời gian từ thời điểm chân lũ lên đến đỉnh lũ.
- ***Thời gian lũ xuống***: là khoảng thời gian từ đỉnh lũ đến thời điểm chân lũ xuống.
- ***Thời gian lũ***: là khoảng thời gian từ thời điểm chân lũ lên đến lúc chân lũ xuống.
- ***Biên độ lũ***: là chênh lệch mực nước đỉnh lũ và mực nước chân lũ lên.
- ***Cường suất lũ***: là tốc độ nước lên hoặc xuống, đo bằng cm/h hoặc m/ngày.
- ***Tổng lượng lũ***: là lượng nước lũ do mưa gây ra trong một trận lũ, tính bằng $m^3$.
- ***Modun đỉnh lũ***: là lưu lượng đỉnh lũ trên một đơn vị diện tích lưu vực sông, đơn vị thường là l/s.ha hoặc $m^3/s.km^2$.

Lũ được phân biệt thành các loại:

- ***Lũ nhỏ*** : là loại lũ có đỉnh lũ thấp hơn mức đỉnh lũ trung bình nhiều năm
- ***Lũ vừa*** : là loại lũ có đỉnh lũ đạt mức đỉnh lũ trung bình nhiều năm
- ***Lũ lớn*** : là loại lũ có đỉnh lũ cao hơn mức đỉnh lũ trung bình nhiều năm
- ***Lũ đặc biệt lớn:*** là loại lũ cao đỉnh lũ cao hiếm thấy trong thời kỳ quan trắc
- ***Lũ lịch sử:*** là loại lũ có đỉnh lũ cao nhất trong chuỗi số liệu quan trắc hoặc do điều tra khảo sát được

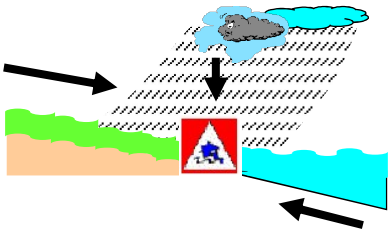
## *High floods in the Mekong Delta when three factors appear simultaneously:*

High discharge flow from upstream

Continuous rain in place

Mekong Delta flooding

High tide in the East Sea



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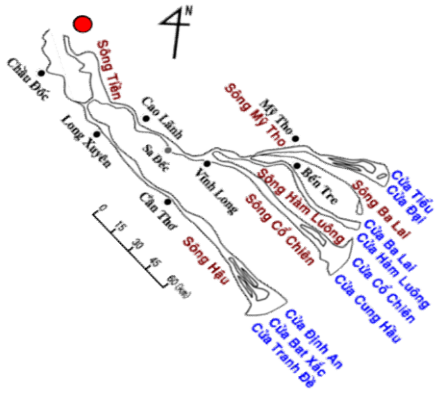
**FLOOR ALARM LEVELS:**

+ Level I alarm: There is a possibility of flood
+ Level II alert: Dangerous flood situation
+ Level III alarm: Very dangerous flood situation
+ Alarm above level III: Emergency flood situation(widespread uncontrolled flood, severe damage)

**TER LEVELS ALARM (METERS) ON THE CUU LONG RIVER**

| Gauge Station | Level I | Level II | Level III |
|---|---|---|---|
| Tiền River | ------- | -------- | --------- |
| Tân Châu | 2.80 | 3.40 | 4.00 |
| Mỹ Thuận | 1.40 | 1.50 | 1.60 |
| Hậu River | ------- | -------- | --------- |
| Châu Đốc | 2.50 | 3.00 | 3.50 |
| Cần Thơ | 1.50 | 1.60 | 1.70 |



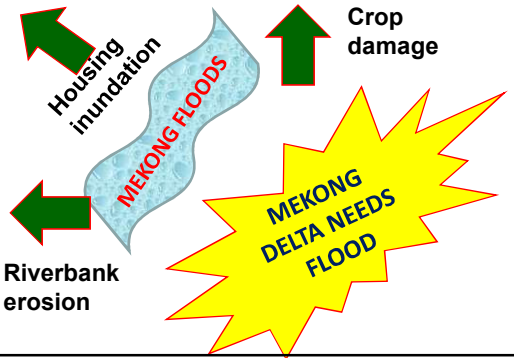

## FLOODING IN THE CUU LONG RIVER

## BENEFITS

- Adding a large amount of precious alluvium to the soil
- Washing alum and salt, improve soil
- Supporting in field cleaning, killing rats, insects, ...
- Significantly increase fishery resources
- Replenishing underground water

## HARM

- Causing loss of life
- Impact on agricultural areas without dikes
- Large floods swept away many houses, works, roads
- Riverbank erosion
- Dispersing pathogens, yellow snails, ....



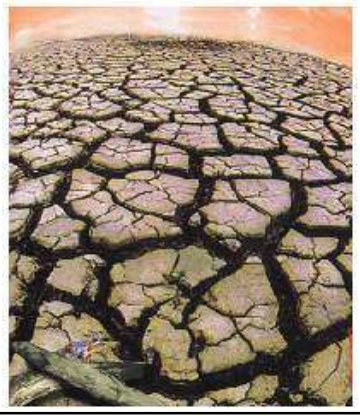

## DROUGHT

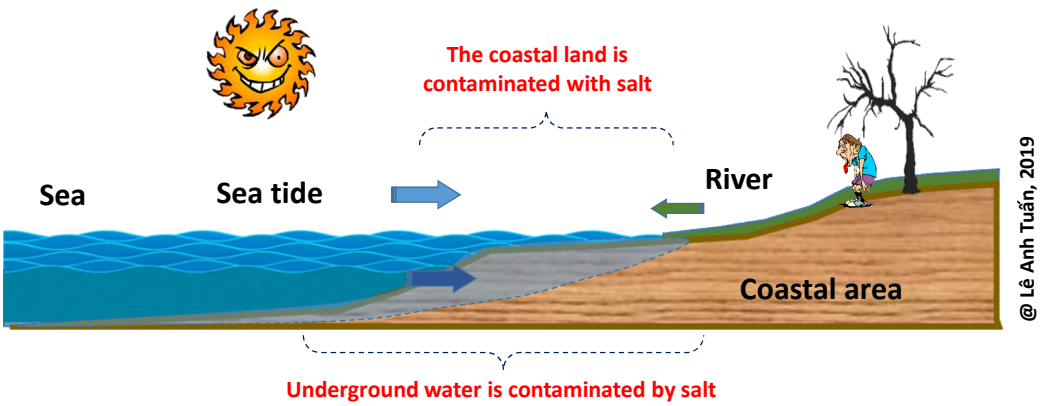
- Drought is a severe and prolonged lack of water that causes severe drying and affects the life of plants and animals.
- Drought results in reduced crops, threatening the survival of livestock, poultry and other animals.
- Drought is the cause of ecological degradation: soil degradation, desertification, forest fires, salinization, ...

# DROUGHT


**PERFORMANCE OF DROUGHT:**

- No rain for more than 5-6 months
- Evaporation over 75 mm/month
- Low humidity H < 50%
- Strong and dry wind
- The soil is cracked, the groundwater level is low, the ponds, lakes, rivers, and canals are dry
- Decreased biological activity
- High forest fire risks



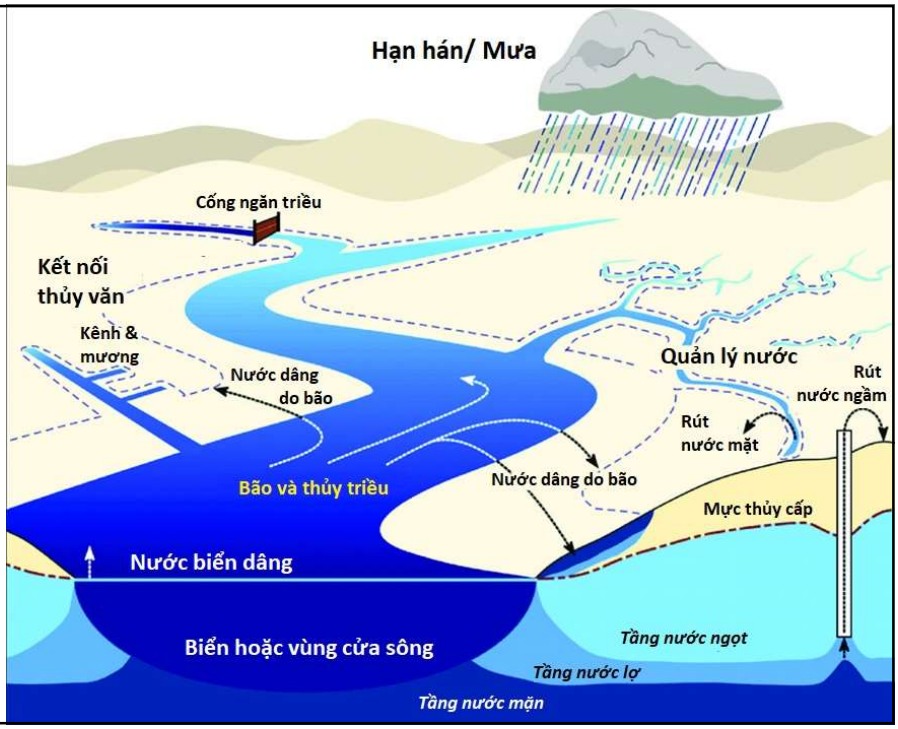



For low and flat deltas like in the Mekong Delta, when the river water flows into the sea at low tide period, the phenomenon of salt water from the sea intruding into the field is very obvious.

**DROUGHT AND SALINE INTRUSION HAVE A DEFINITE CORRELATION**

**WATER RELATED FACTORS:**

- Climate Change (rainy sea a lot/little)
- Disaster (storm, flood, abnormal high tide)
- Sea level rise
- Irrigation works (dykes, dams, sluices to prevent tides, irrigation system)
- Exploiting coastal groundwater
- Farming and fishing
- Maintain mangroves




# CONTENTS



## EROSION

**Erosion** is a phenomenon in which the slope (riverside, coastal) or slope (mountainous area) is unstable and moves by gravity to the lower side.

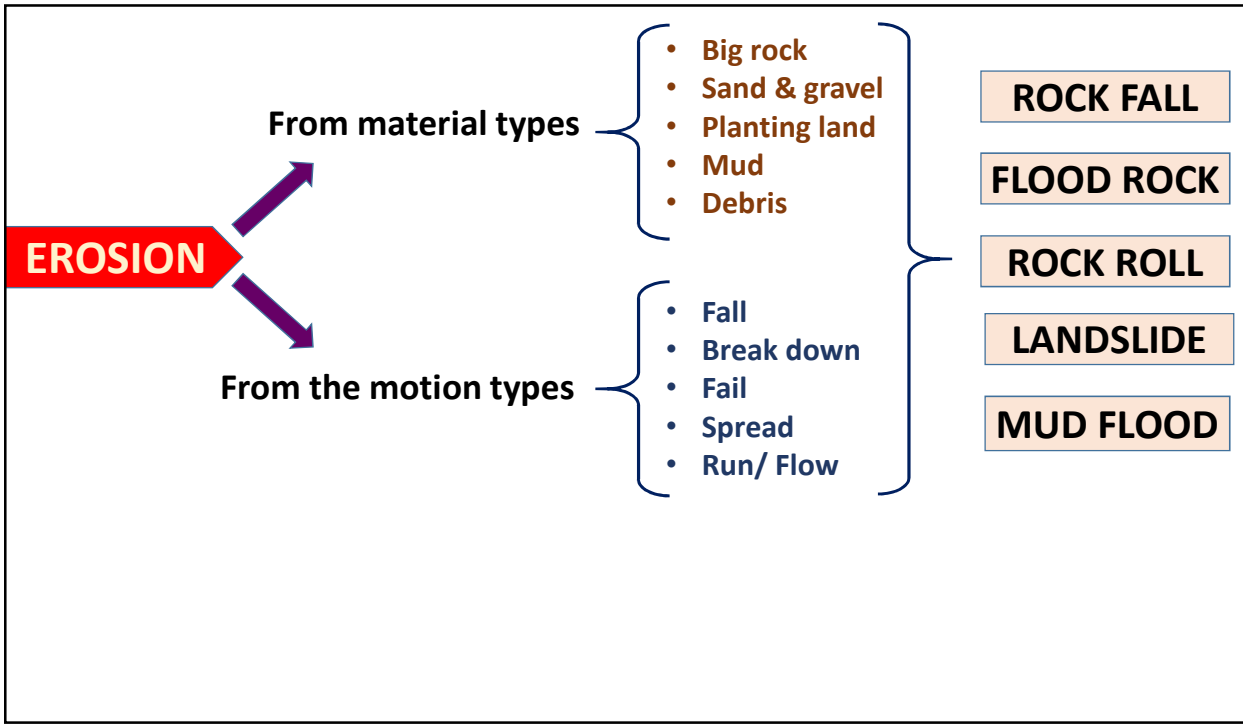
Types of erosion include landslides, slides, flows, breaks, and falls, each with its own characteristics and can occur for very short periods of time from a few minutes to lasting many hours, or years.

Water is an agent that causes landslides or restrains landslides.

- With a large amount of water, the pores in the soil are increased in pressure, reduced friction and accelerated the erosion process in slope side.
- When the soil dries out due to lack of water, the grain texture becomes loose, can be dissociated and prone to landslide.
- A moderate amount of maintenance water can increase soil cohesion.

Other factors that can cause landslides include:

- Earthquake,
- Artificial seismic (blasting, driving concrete piles, ...)
- Sudden or frequent impact loads (traffic)
- Deforest, rock mining,...
- Physical weathering, chemical dissolution...



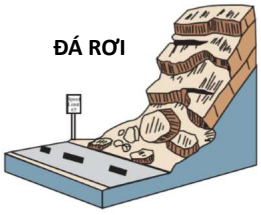
## CLASSIFICATION OF LANDSCAPE
### IN HILLS AND MOUNTAINS, SLOPE LANDS

| TYPES OF MOTION | | TYPES OF MATERIALS | | |
|---|---|---|---|---|
| | | FOUNDATION ROCK | CONSTRUCTION ROCK | |
| | | | GRAVEL | SOIL, FINE SAND |
| RƠI | | ĐÁ RƠI | CÁC HẠT SỎI RƠI RỜI RẠC | ĐẤT RƠI |
| NGÃ ĐỔ | | ĐÁ ĐỔ | CÁC HẠT SỎI VỤN ĐỔ SỤP | NỀN ĐẤT CÁT ĐỔ SỤP |
| TRƯỢT | LĂN | ĐÁ LĂN | CÁC HẠT SỎI TRƯỢT | ĐẤT TRƯỢT, CÁT TRƯỢT |
| | TỊNH TIẾN | ĐÁ SẠT | | |
| SOẠT RỘNG BÊN TRÊN | | ĐÁ SOẠT RỘNG | CÁC HẠT SỎI SOẠT RỘNG | KHỐI ĐẤT, CÁT SOẠT RỘNG |
| CHẢY | | ĐÁ CHẢY | CÁC HẠT SỎI CHẢY DÒNG | ĐẤT CÁT CHẢY DÒNG |
| PHỨC HỢP | | KẾT HỢP HAI HOẶC NHIỀU KIỂU CHUYỂN ĐỘNG | | |

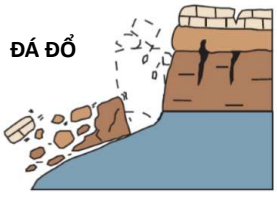
Varnes, D. J. 1978. Slope movement types and processes. In: *Special Report 176: Landslides: Analysis and Control* (Eds: Schuster, R. L. & Krizek, R. J.). Transportation and Road Research Board, National Academy of Science, Washington D. C., 11-33.

## CLASSIFICATION OF LANDSCAPE
### IN HILLS AND MOUNTAINS, SLOPE LANDS

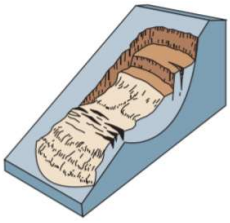
ĐÁ RƠI



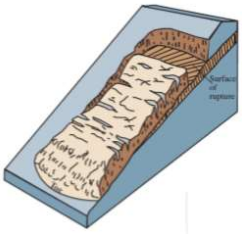
ĐÁ ĐỔ



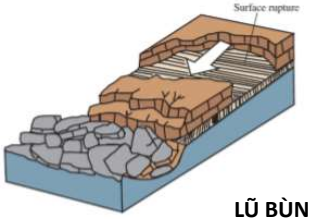
ĐẤT TRƯỢT CUỘN



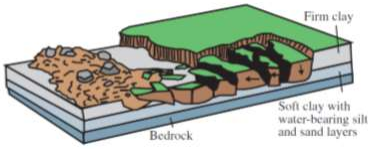
ĐẤT TRƯỢT TỊNH TIẾN



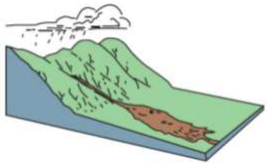
ĐẤT TRƯỢT KHỐI



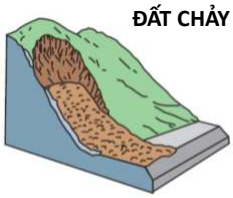

ĐẤT SẠT RỘNG




SỎI CHẢY DÒNG



ĐẤT CHẢY DÒNG



LŨ BÙN



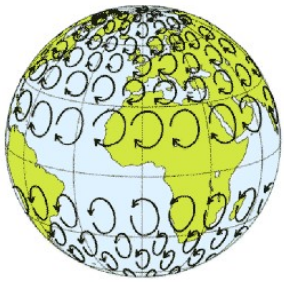



**Landslides due to siltification in Nam Ngum Hydropower Reservoir, Laos**

**Photo: Lê Anh Tuấn (2018)**

# CORIOLIS EFFECT

- The Coriolis effect (or fully called the Coriolis inertial force) was discovered by the French scientist Gaspard Gustave de Coriolis (1792-1843) in 1835.
- The Earth rotates on its axis, so all moving objects on Earth experience the Coriolis effect.
- In the northern hemisphere, moving objects tend to circle to the right, and in the southern hemisphere, they rotate to the left (seeing in the direction of the object's motion).
- River water moves on the ground, so it is subject to the Coriolis force.



When viewed from upstream, rivers flowing in the northern hemisphere are affected by the Coriolis force, forcing the river water to move closer to the right, causing landslides on the right bank; Rivers in the southern hemisphere are affected by the Coriolis force, forcing the river water to move closer to the left, causing landslides on the left bank.

# CENTRIFUGAL FORCE

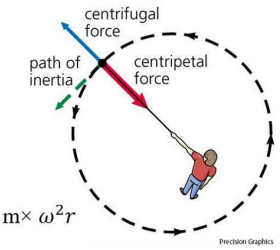
In Newtonian mechanics, the centrifugal force is an inertial force (also called a "fictitious" or "pseudo" force) that appears to act on all objects when viewed in a rotating frame of reference.

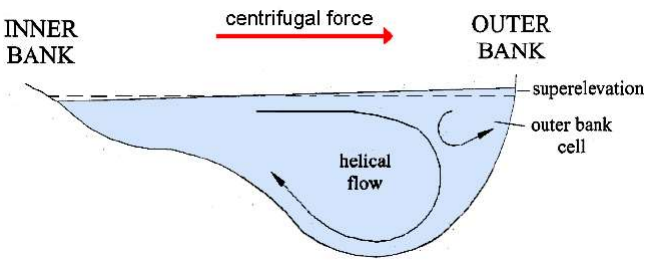
It is directed away from an axis which is parallel to the axis of rotation and passing through the coordinate system's origin. If the axis of rotation passes through the coordinate system's origin, the centrifugal force is directed radially outwards from that axis.

**Centrifugal Force**

$$F = m \times \frac{v^2}{r}$$

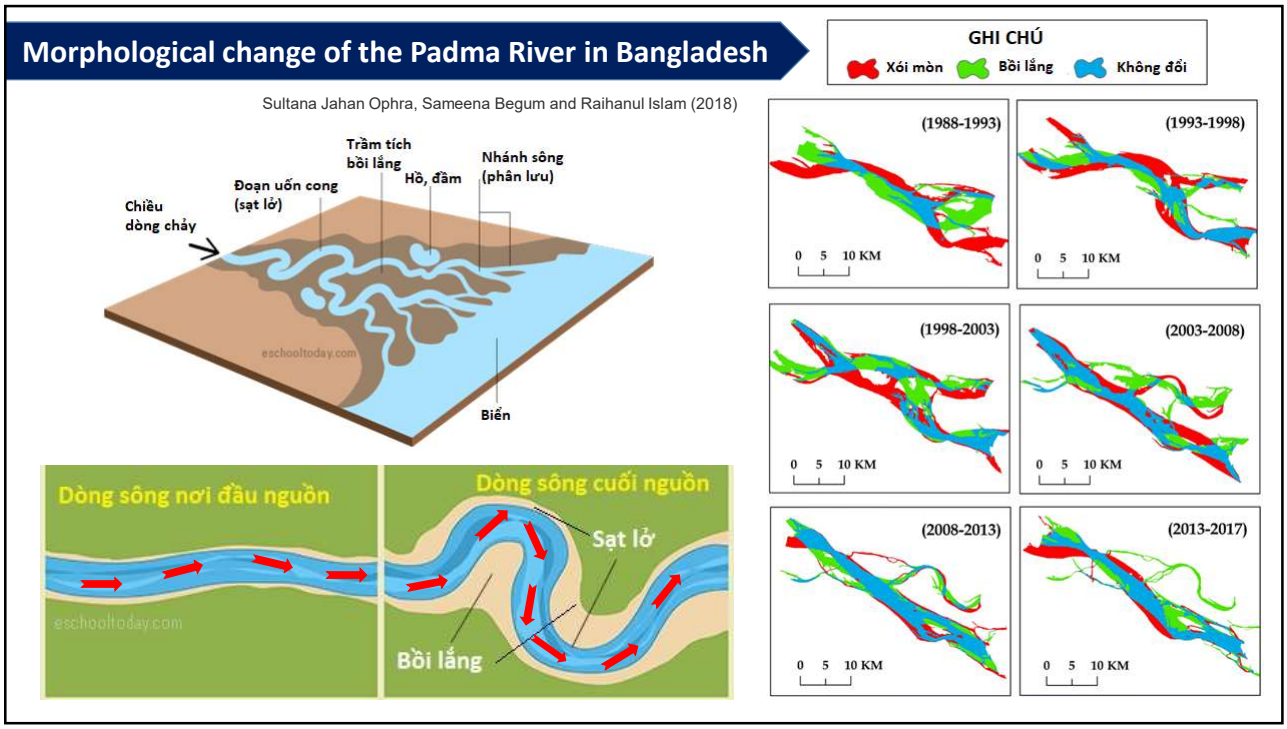
$$F = m \times \frac{(\omega r)^2}{r} \text{ or } F = m \times \omega^2 r$$




Existing evidence of secondary flows in natural channels obtained from the movement of surface floats and bed material indicates that two cells, exhibiting surface flow convergence, exist at meander bends and these reverse polarity to give surface flow divergence at inflexion points. In turn these explain the existence of pool (meander bend) and riffle (inflexion point) sequences in natural channels.

Richard D. Hey and Colin R. Thorne (1975)
https://www.jstor.org/stable/20001006


Morphological change of the Padma River in Bangladesh
Sultana Jahan Ophra, Sameena Begum and Raihanul Islam (2018)
GHI CHÚ
Xói mòn
Bồi lắng
Không đổi
Trầm tích bồi lắng
Nhánh sông (phân lưu)
Hồ, đầm
Đoạn uốn cong (sạt lở)
Chiều dòng chảy
Biển
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Dòng sông nơi đầu nguồn
Dòng sông cuối nguồn
Sạt lở
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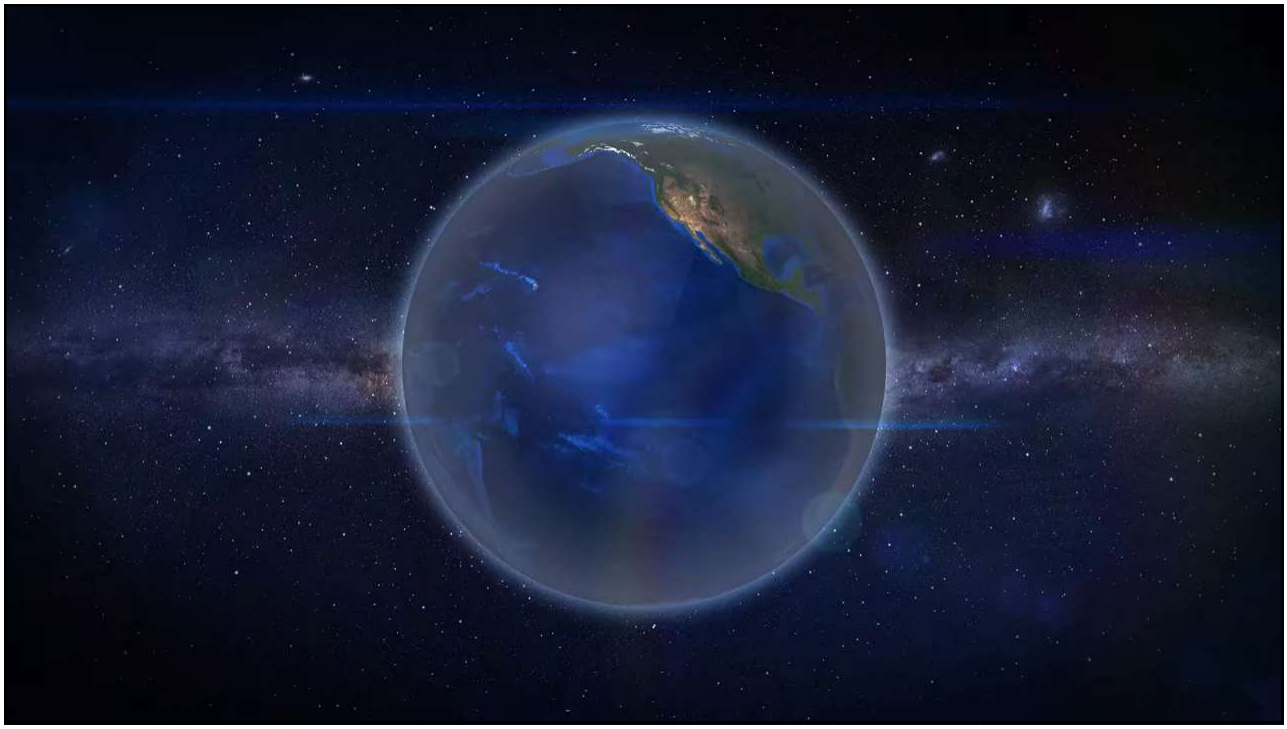
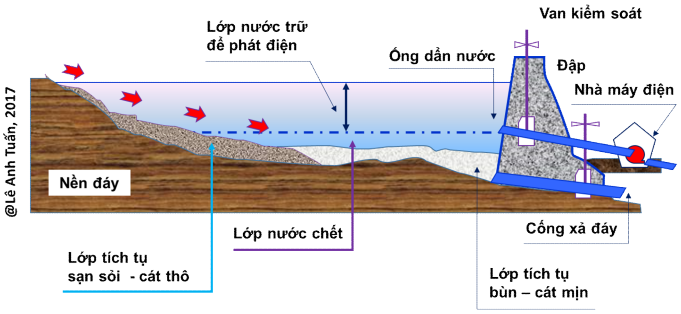


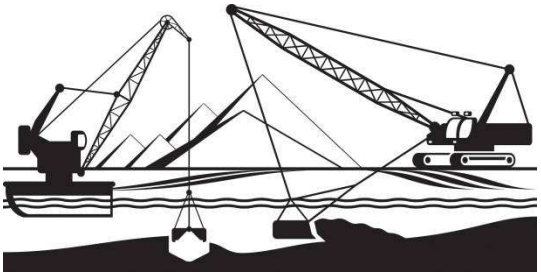
## The phenomenon of riverbed and riverbank erosion

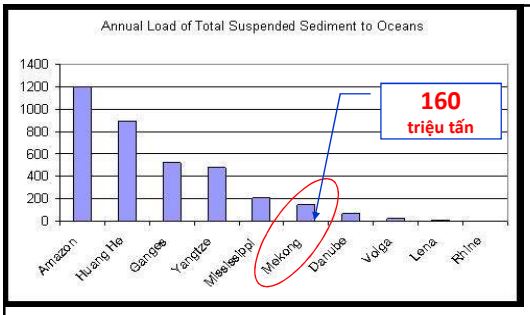
**The reduction of river alluvium or the exploitation of sand and gravel in the river can increase the erosion on both sides of the river and the river bottom.**



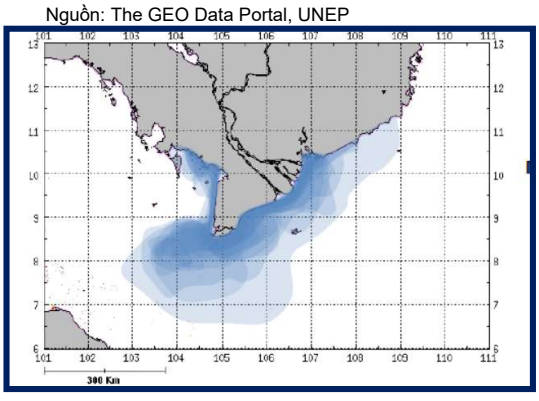

Mud and sand stored in the reservoir

Sand mining on the river

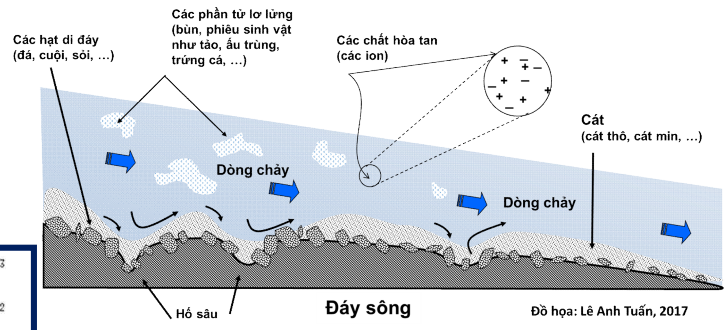





Nguồn: The GEO Data Portal, UNEP




**SANDARY BENEFITS HAVE A ROLE OF SIDING AND PROTECTION OF RIVER – COAST - Less prone to subsidence and landslides**





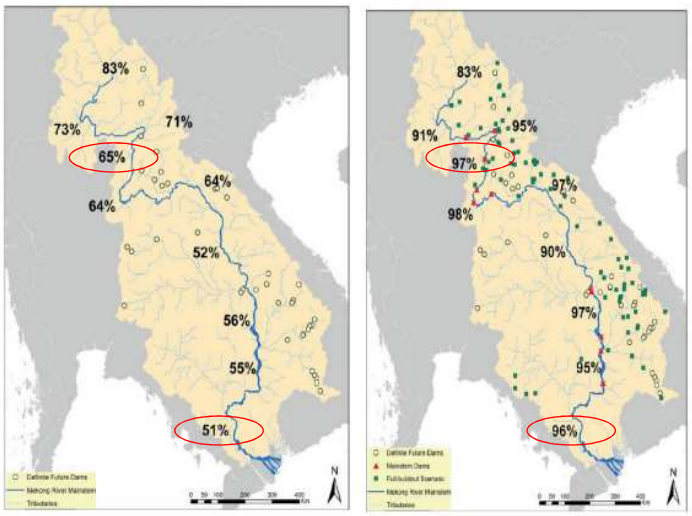
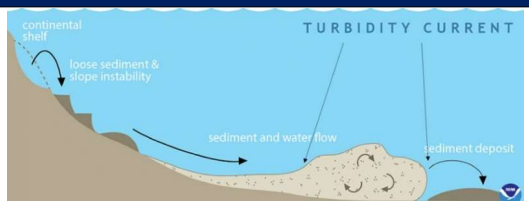
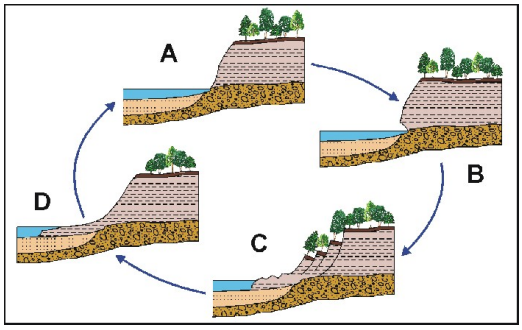


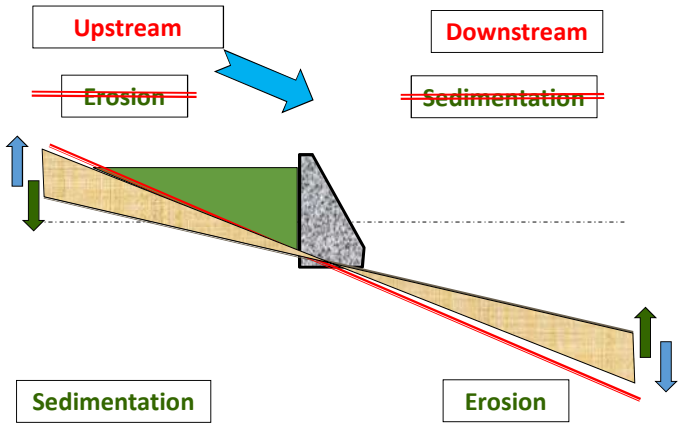

Figure 7: Dam trapping efficiency under the 'definite future scenario' (left) and the 'full dam Development scenario' (right) (Kondolf et al. 2014)

**A 2018 study by the MRC suggested that hydropower dams would retain 96% of alluvial flows to the Mekong Delta by 2040 if all the proposed mainstream and tributary dams were built.**

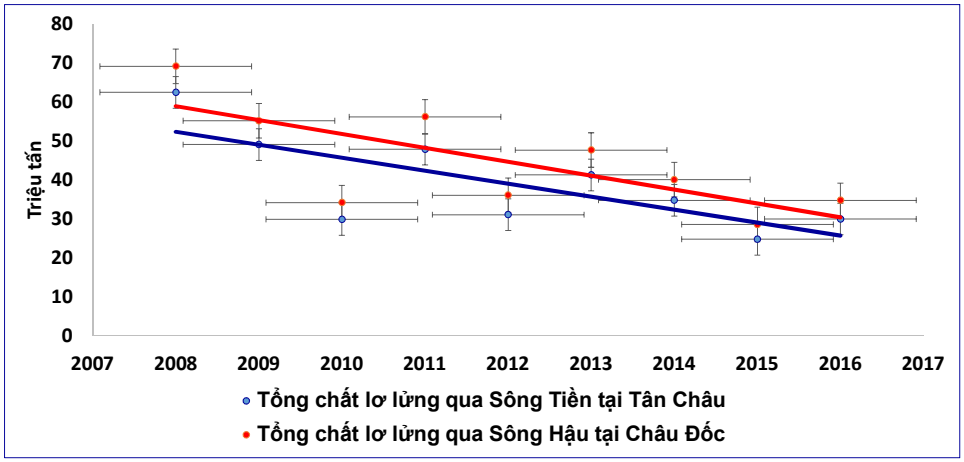
***An ongoing and monitoring hazard:***
***Reducing alluvial deposits plus other factors such as sea level rise, over-exploitation of groundwater, and urbanization will increase natural subsidence in the Mekong Delta.***



## TOTAL SUSPENDED SOLIDS IN TAN CHAU AND CHAU DOC FROM 2008 - 2016




- In the peak flood months (September, October), the total amount of suspended solids entering the Mekong Delta is 24.3 million tons/year, of which 89% goes through Tan Chau (Tien River) and 11% through Chau Doc (Hau River).
- Over the past 20 years, total suspended matter has decreased by about 46% (average 2.3%/year # 0.72 million tons/year)

*(Data source: Southern Regional Hydrometeorological Station)*

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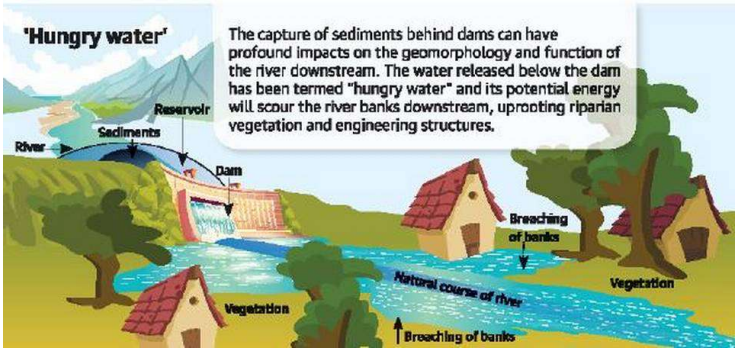
## The Mekong Delta has:

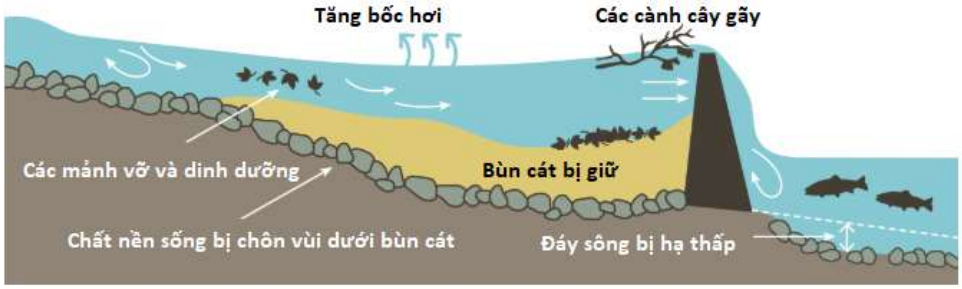
- more than 393 landslide points
- the total length of landslide is over 581 km
- landslide speed from 1 to 20 m/year
- average loss of more than 500 ha/year

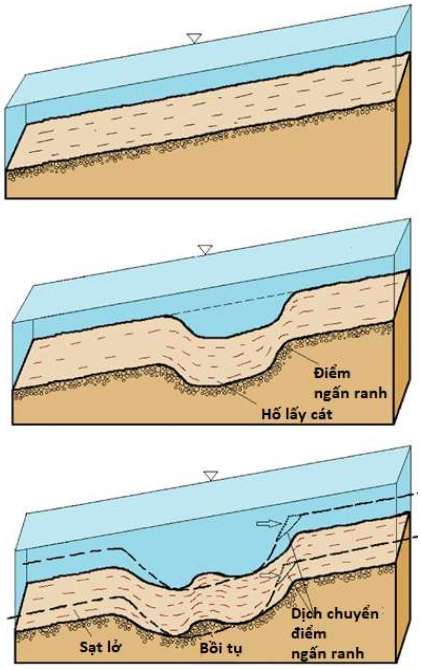
*Map marking landslide points and sections, based on reports from provinces to MARD, 2017*

**The phenomenon of "hungry water" refers to the case where the river water loses its sediment due to being trapped in a hydroelectric reservoir, causing the flow after the dam to become lighter and stronger, causing erosion.**

**The soil removed by the flow mixes with the river, creating a new balance for the flow dynamics.**




## CASE OF RIVER BED EROSION DUE TO SAND MINING

### Stage 1: Before mining river sand

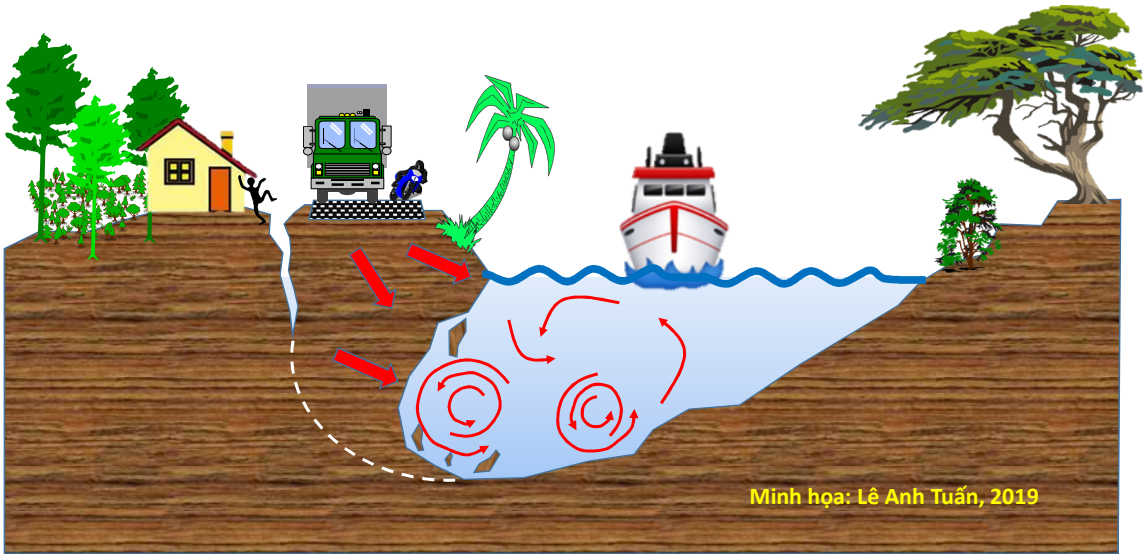
**The river bed has almost a regular slope corresponding to the direction of flow and bottom sediment transport**

### Stage 2: When exploiting river sand

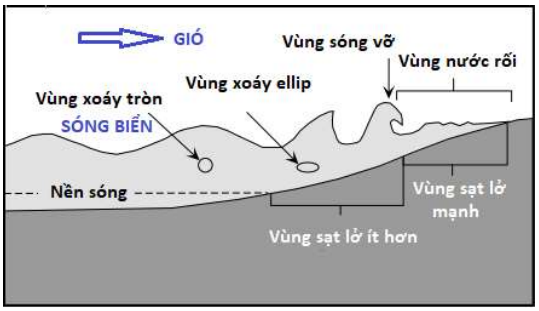
**The bottom of the river is concave, due to the removal of the sand layer, forming a hole at the bottom. The upper mouth of the hole is the line to get sand**

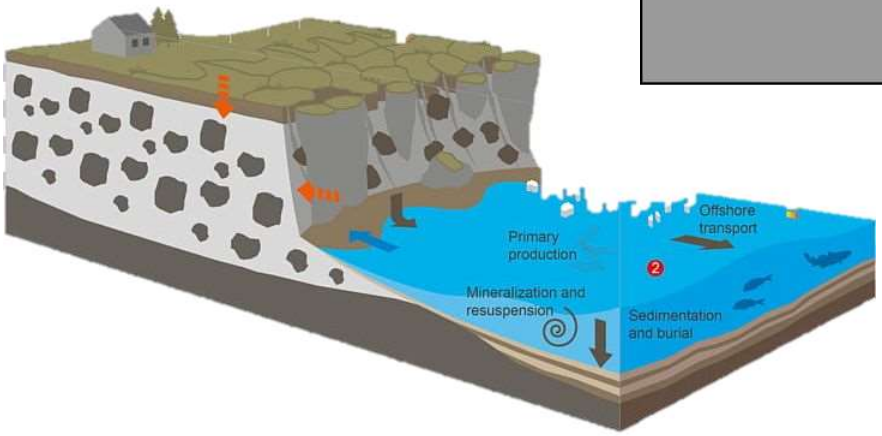
### Stage 3: After mining river sand

**The river bottom is subsided due to the flow causing erosion of the foundation, the flow takes the sediment above and below the sand pit to compensate for the concave defect.**



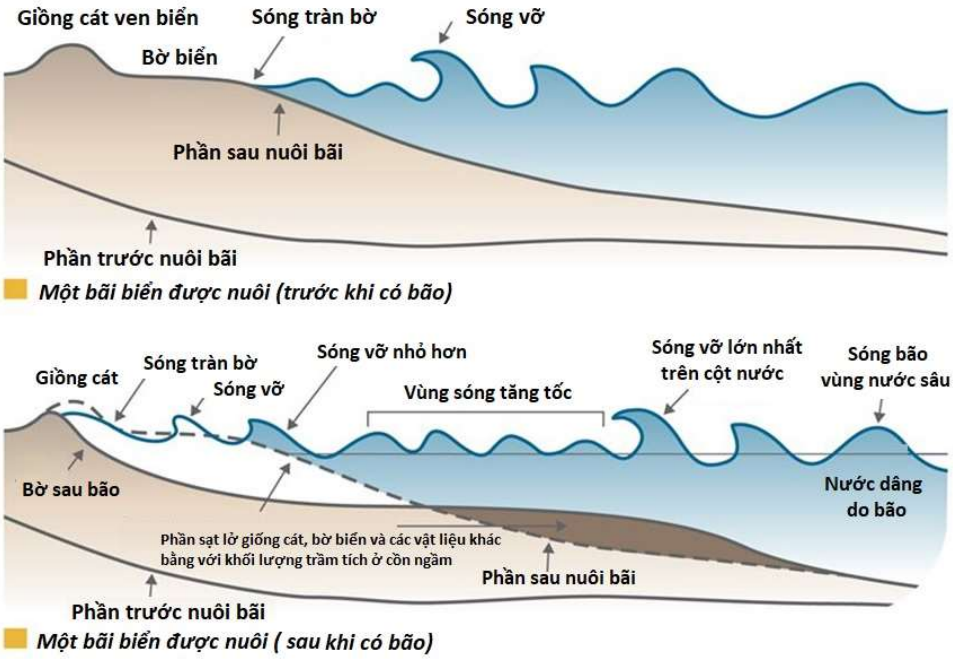

# EROSION IN COASTAL AREA




## COASTAL EROSION DUE STORMS AND STRONG WAVES

Minh họa:
Louis Fioto & Justin Ward, US ARMY CORPS OF ENGINEERS (2015)





**EROSION IN THE COASTAL OF TIỀN GIANG**


**EROSION IN THE COASTAL OF BẾN TRE**


**EROSION IN THE COASTAL OF TRÀ VINH**


**EROSION IN THE COASTAL OF SÓC TRĂNG**



**SẠT LỞ Ở BIỂN BẠC LIÊU**


**EROSION IN THE COASTAL OF CÀ MAU**


**EROSION IN THE COASTAL OF KIÊN GIANG**

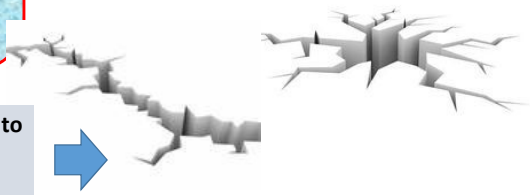
# LAND SUBSIDENCE

Land Subsidence is a phenomenon in which the natural ground elevation is gradually lowered over time.

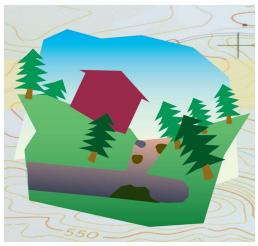
Land subsidence is mainly vertical, with little or no lateral movement, showing rapid ground collapse or gradual sinking.

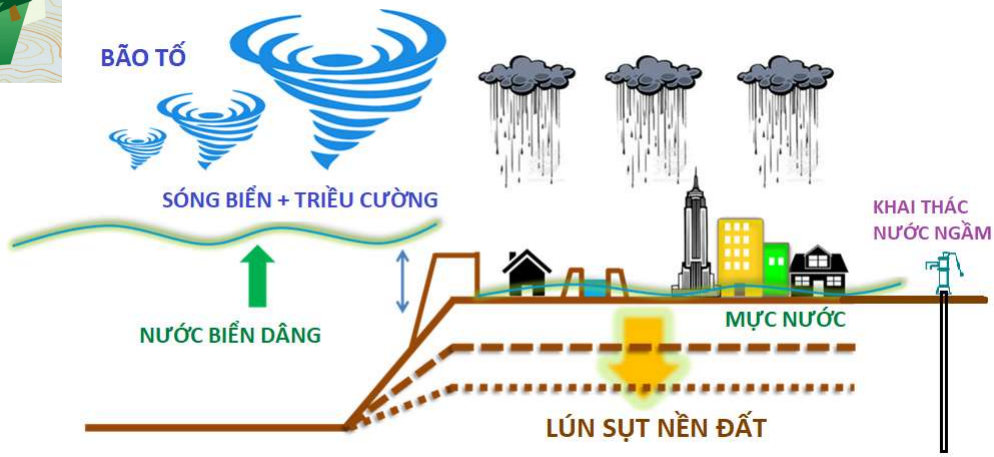

## CAUSES OF LAND SUBSIDENCE

- NATURAL COMPRESSION BY SOIL STRUCTURE WEIGHT/DIFFERENT
- CONSTRUCTION LOAD OR TRAFFIC VIBRATIONS
- GENERAL WATER LEVELS LOWER BECAUSE OF EXPLOITATION /DRAINAGE



In addition, there is a phenomenon of cracked earth or sinkhole due to factors of geological displacement, loss of bearing capacity of the ground mass or sudden decrease of groundwater.






@ TUDelft

**AN EVIDENCE OF NATURAL SUCCESSFUL SUCCESS: CAMPUS I – COMPARATIVE CAN THO UNIVERSITY IN 1971 AND 2019**

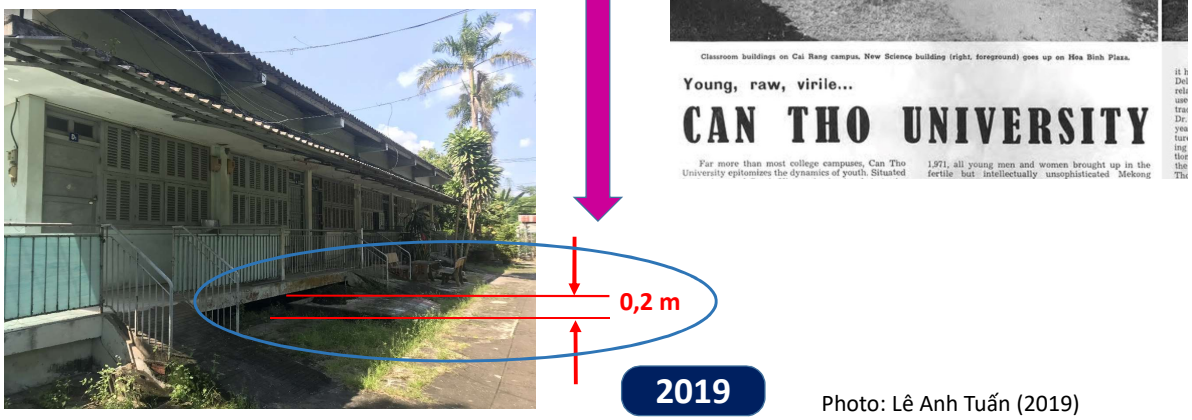
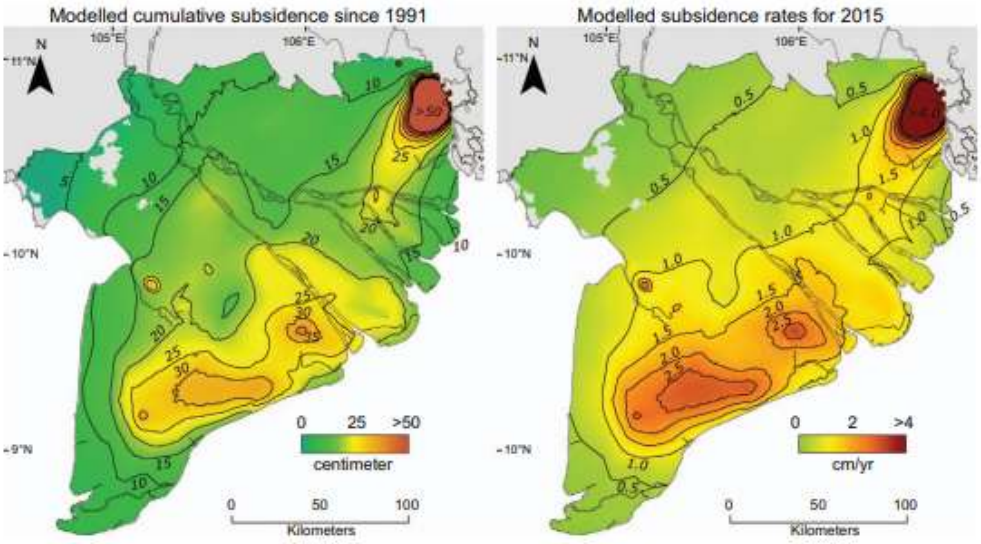



Photo: Lê Anh Tuấn (2019)

## THE MD's SUBSIDENCE RATE (2015)



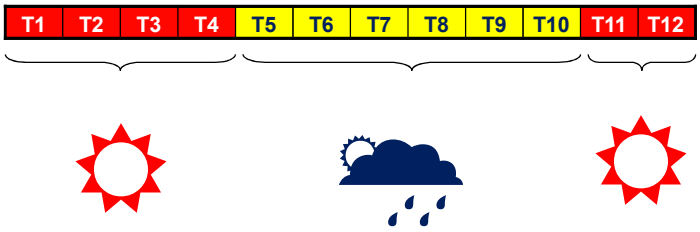

**Source: Philip S.J. Minderhoud (2019)**


## CONTENTS



## EXERCISES

**Listing of seasonal disasters in the Mekong Delta.**




**ARE ANY SOLUTIONS THAT CAN APPLY TO LIMIT THE DAMAGES OF EACH TYPE OF DISASTER?**

QUESTION ?