

The background image is an aerial photograph of a coastal area. The water transitions from a light turquoise color near the shore to a deeper teal further out. Several small boats are scattered across the water: one small boat on the left, two larger boats in the center, and a larger vessel on the right. The overall scene is bright and clear.

Coastal Storms & Erosion

GEOL 106
March 10, 2023

Agenda



Midterm Update
Assignment 3
Quiz 3

Reminders /
Updates



Hurricane Video

Student Video



Coastal processes
Beach Erosion
Storms

Lecture

Reminders / Updates



Midterm

Grades estimated to be released in next 1.5 weeks



Assignment 3

Sea Level Change Assignment

Due tonight!!



Quiz 3

Opens after class

Due March 17th

Available until March 24th
(with late penalties)

Student Video



The background image shows a coastal scene from an aerial perspective. A long, sandy beach curves along the left side, bordered by dense green tropical forest. The ocean is a vibrant turquoise color, with white-capped waves crashing onto the shore. The water extends to the horizon, meeting a clear blue sky.

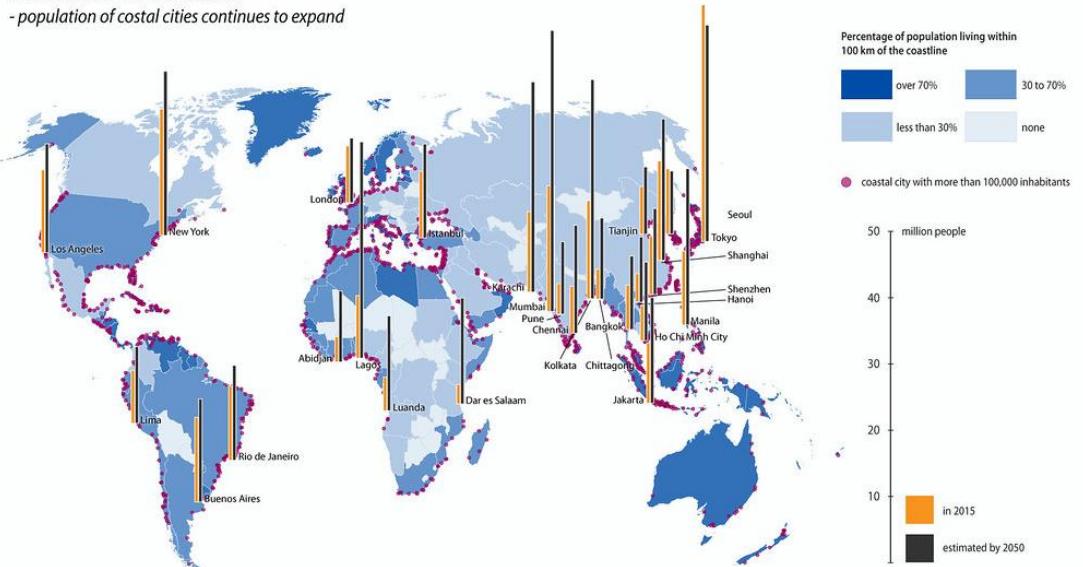
01

Coastal Processes

Coastal Processes

Our closeness to the oceans

- population of coastal cities continues to expand



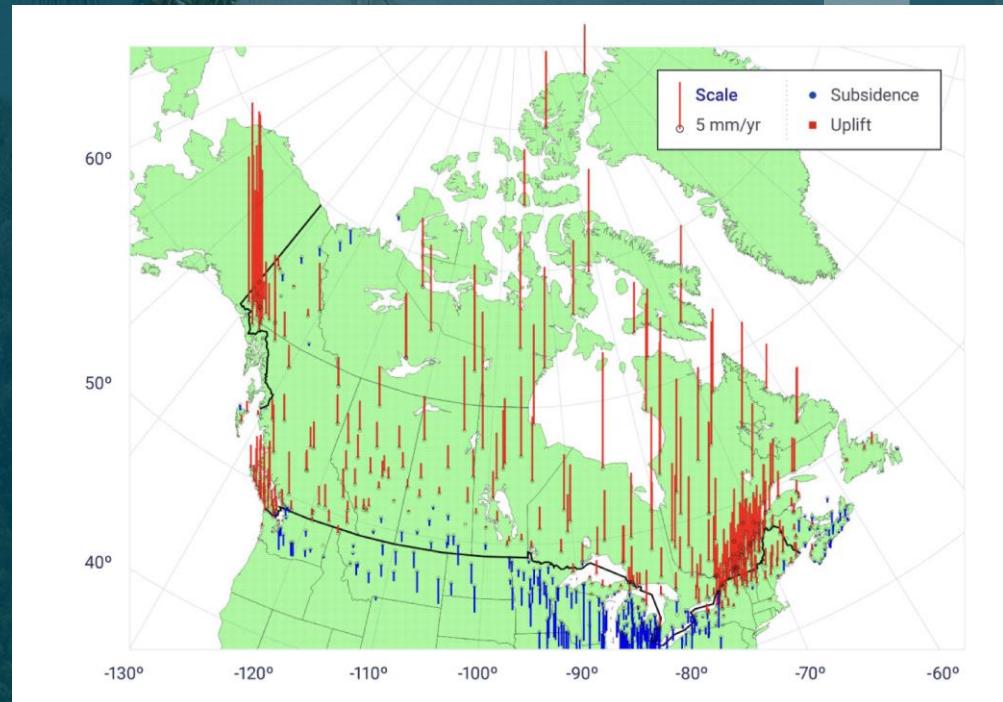
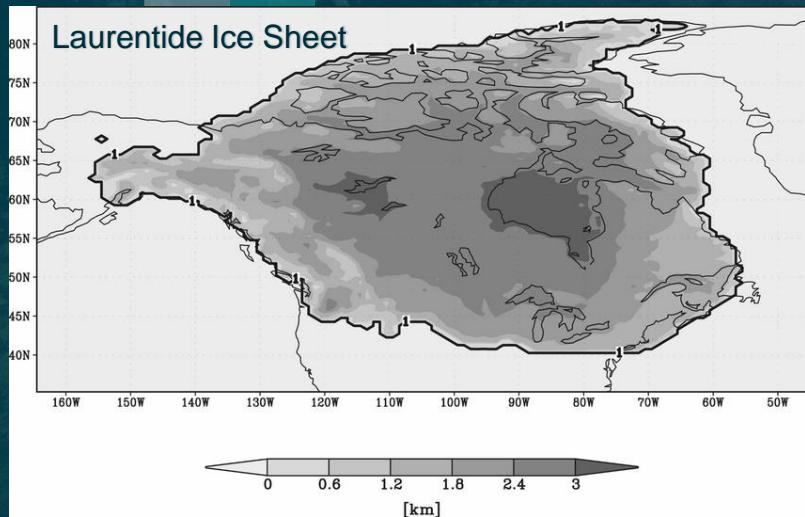
- Population density 3x higher than global average

Coastal Processes

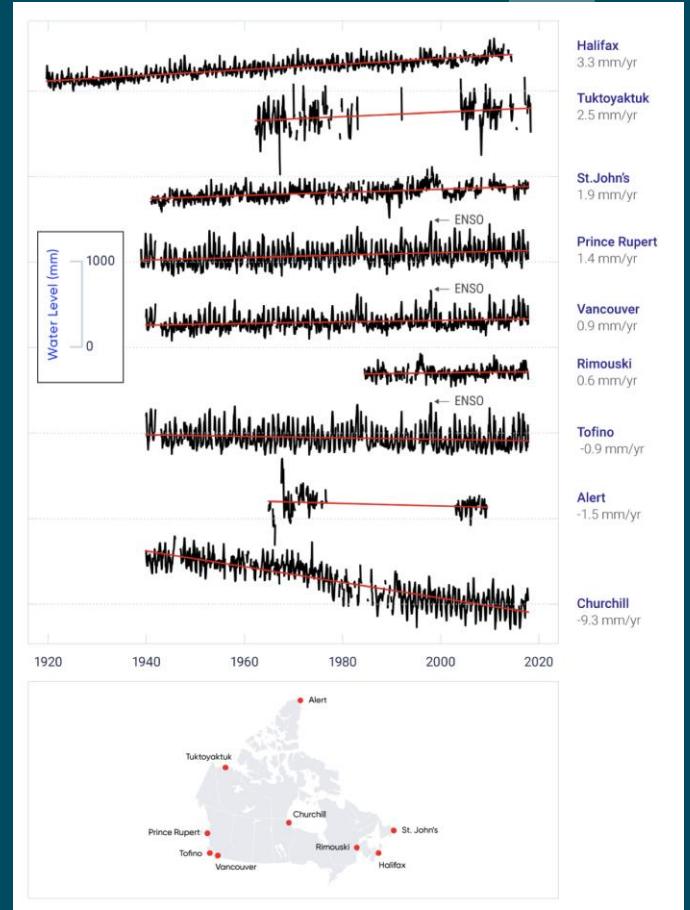
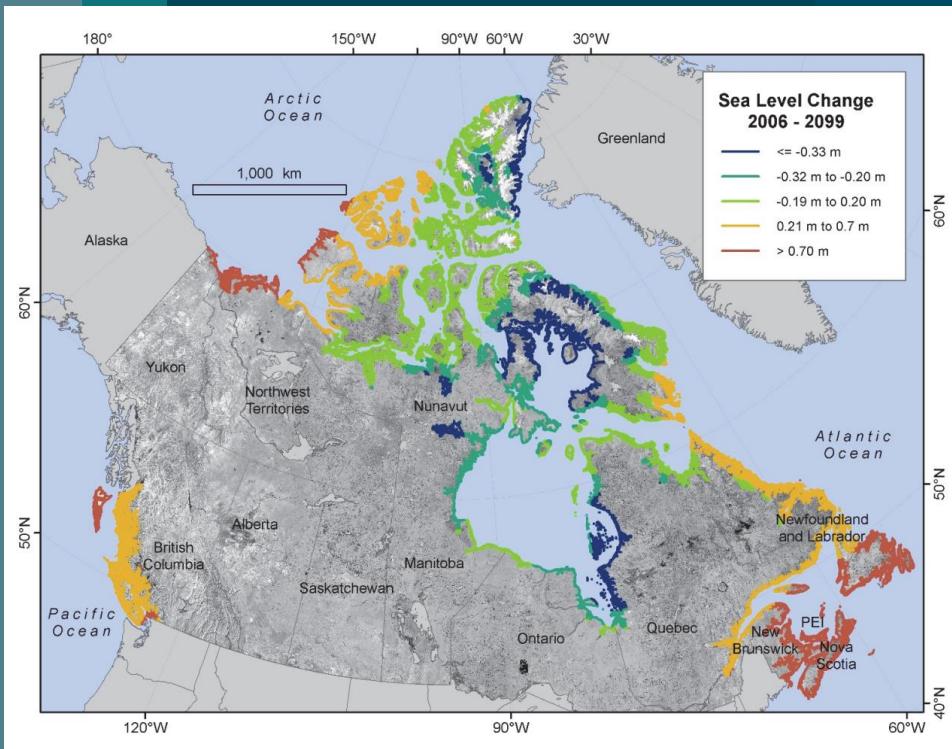


- Canada = world's longest coastline
- Over 200,000 km

Coastal Processes



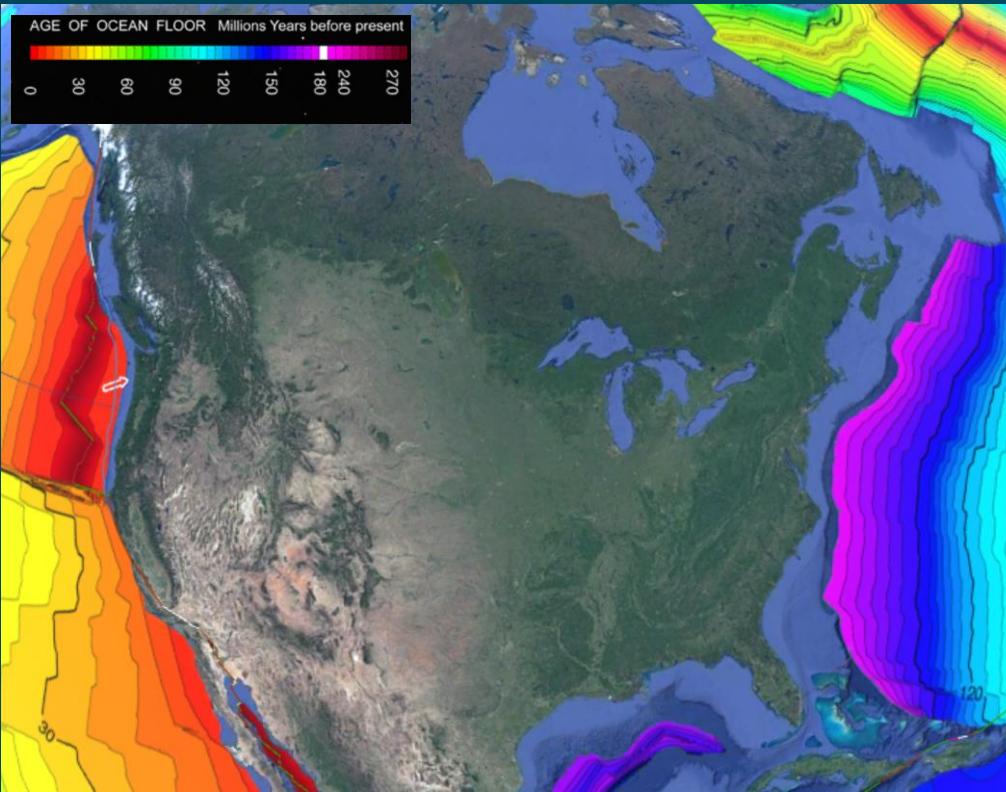
Coastal Processes



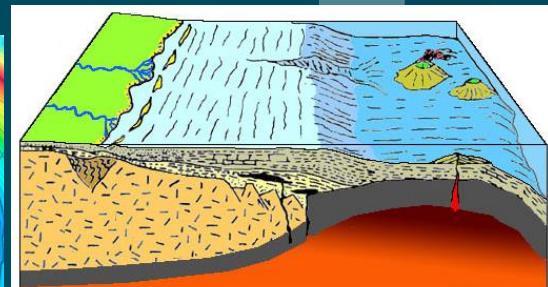
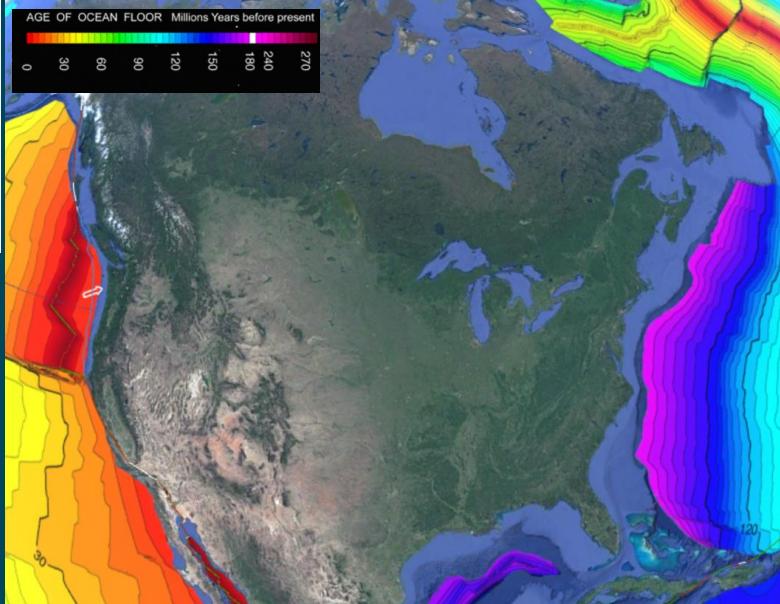
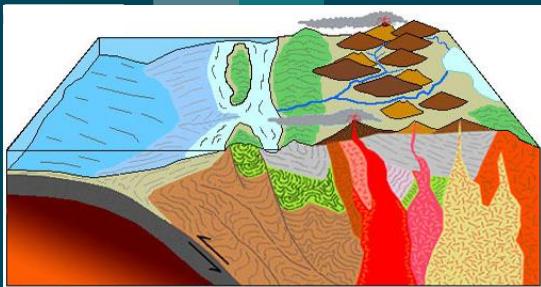
Coastal Processes

Active Margin

Passive Margin



Coastal Processes



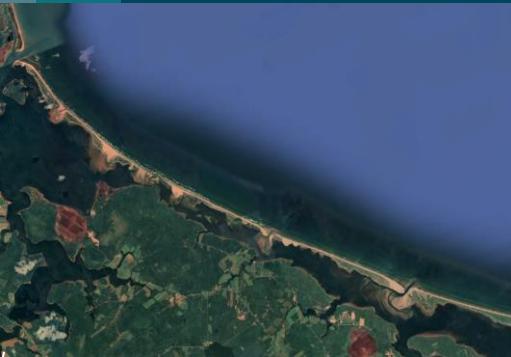
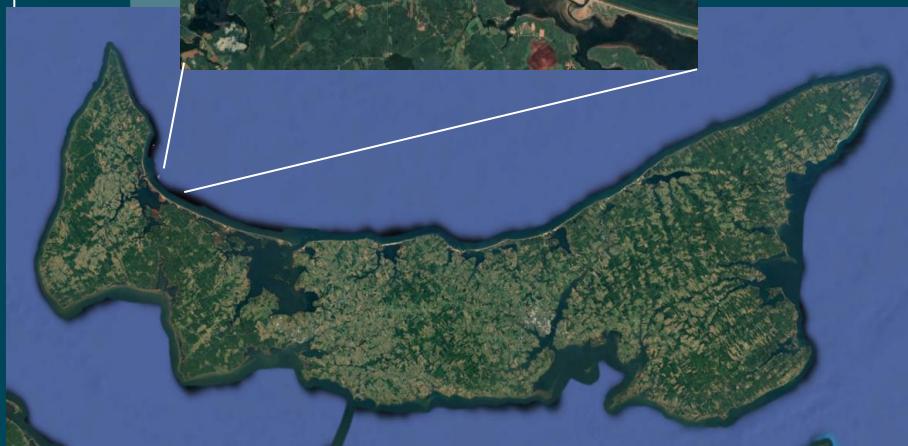
Coastal Processes



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- Barrier islands – long narrow sandy strip separated from mainland by body of water

Coastal Processes



- Barrier islands – long narrow sandy strip separated from mainland by body of water

Coastal Processes

Wave Formation

Waves are formed by wind blowing along the water's surface.

Wave height is dependent on 3 factors:

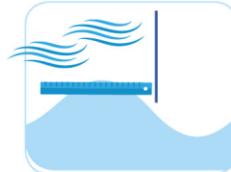
Wind Speed

Wind Direction



The wind must be moving faster than the wave crest for energy transfer

Fetch



The distance the wind blows over water with similar speed and direction

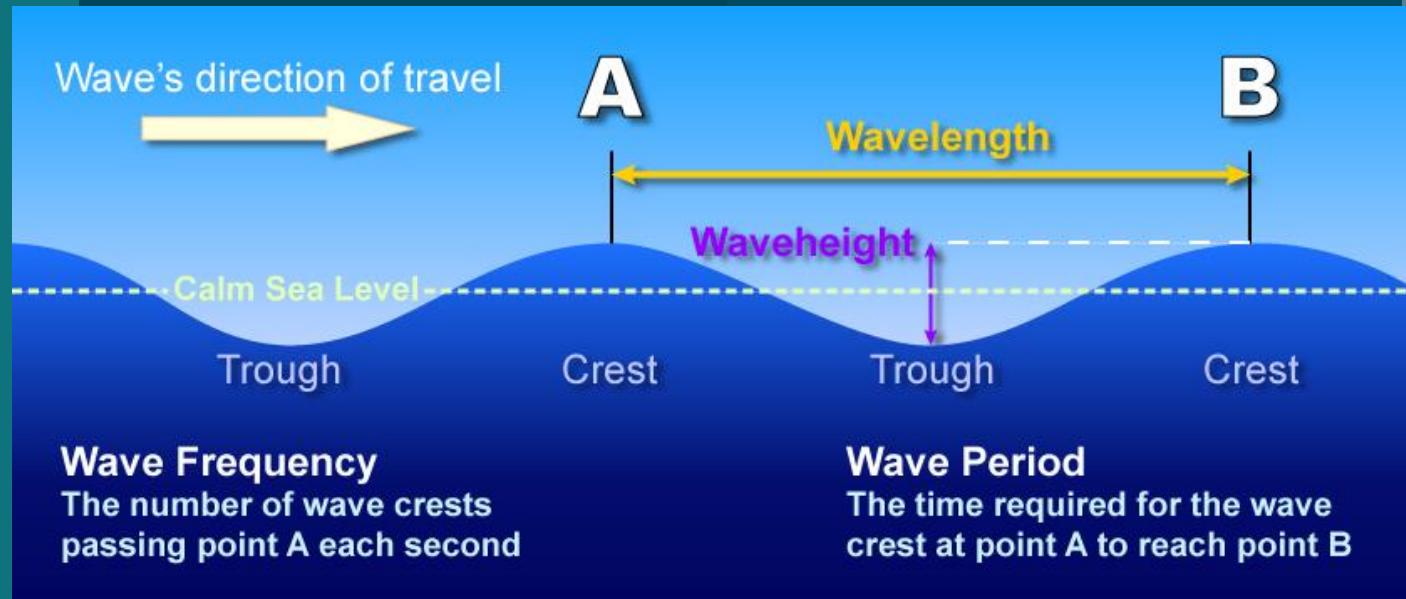
Wind Duration



The time for which the wind has blown over the water w/o disruption

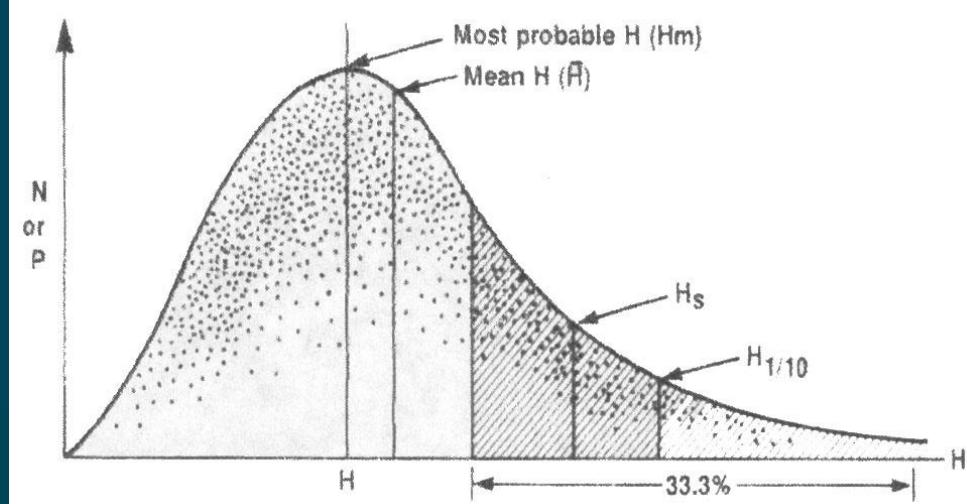


Coastal Processes

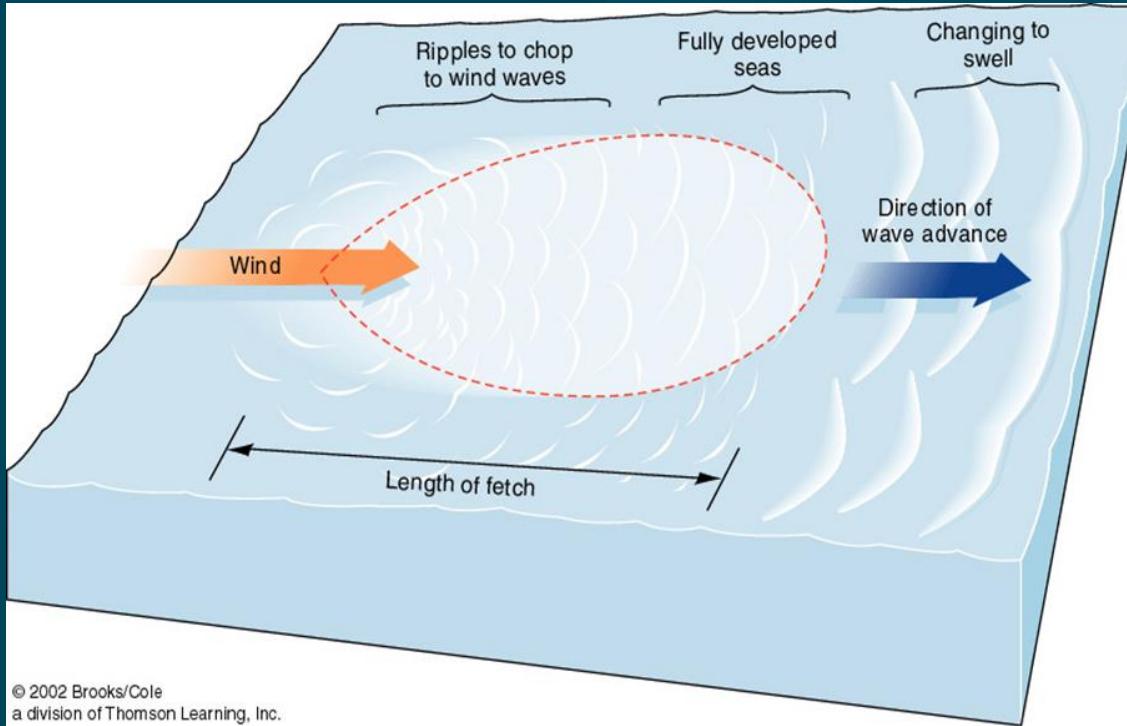


Coastal Processes

- Significant wave height
 - Highest 1/3 of waves

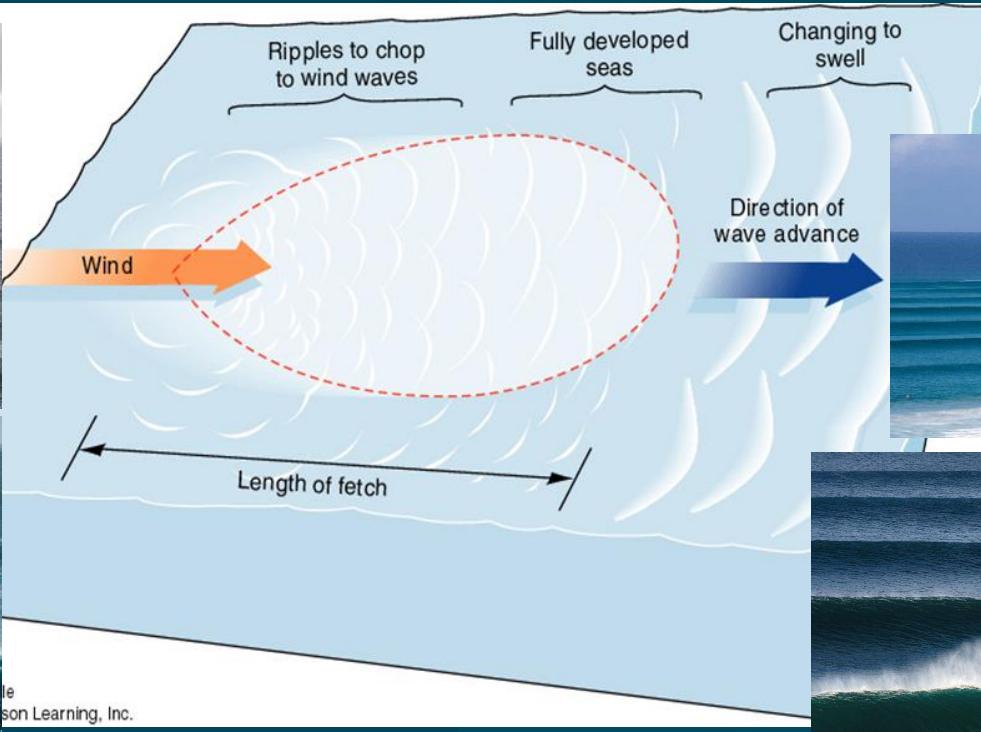
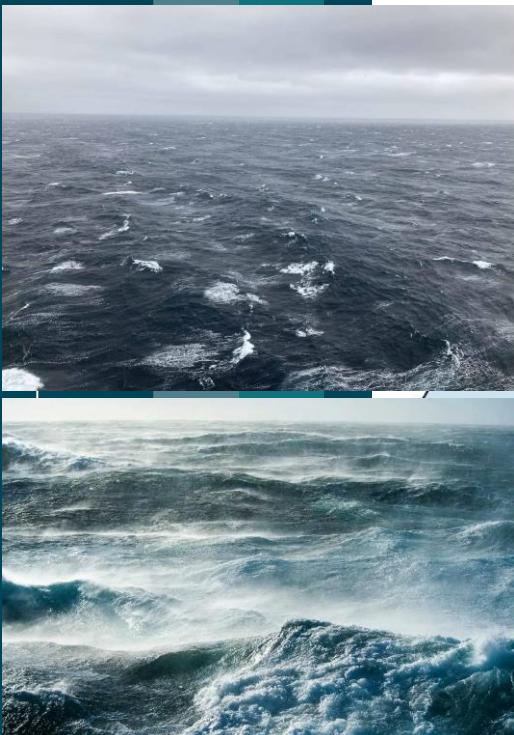


Coastal Processes

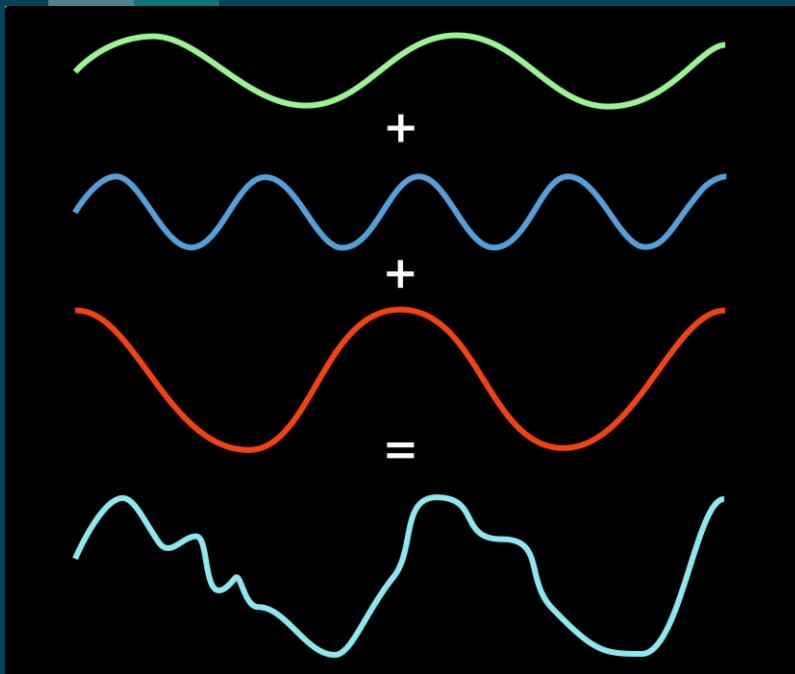


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Coastal Processes

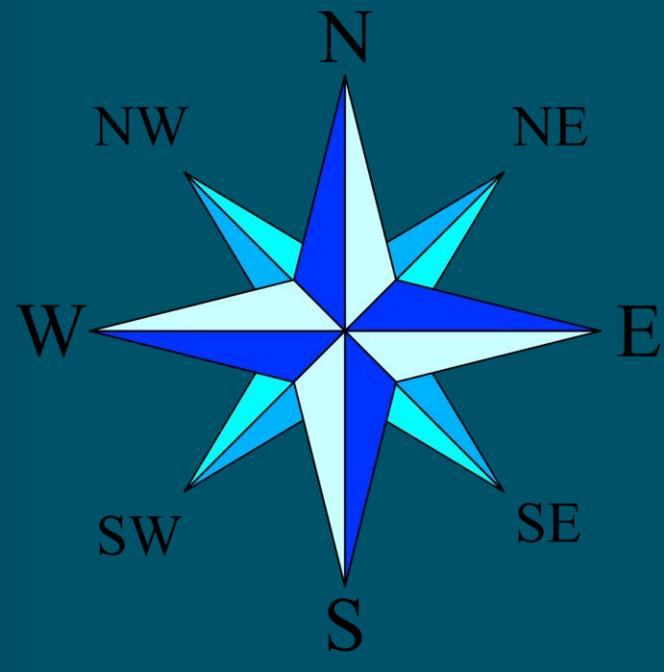
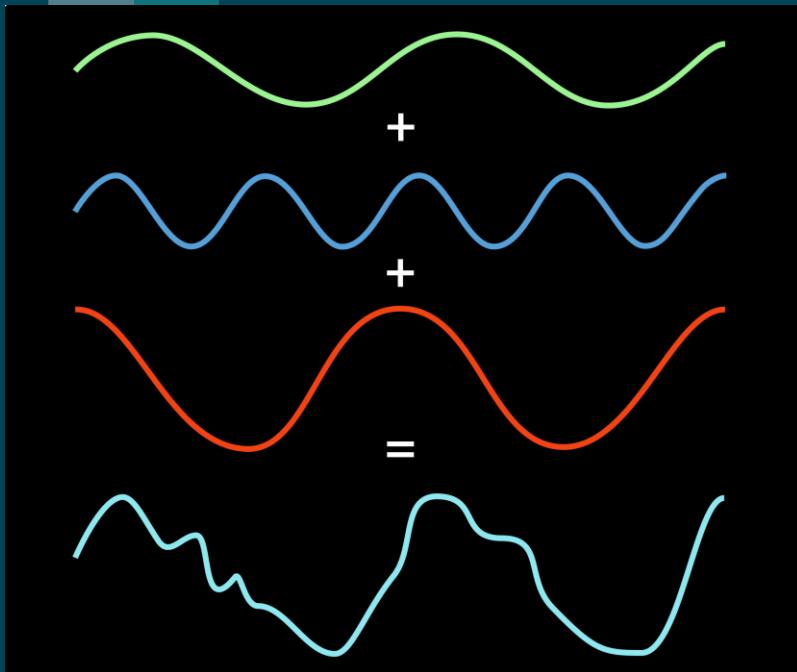


Coastal Processes



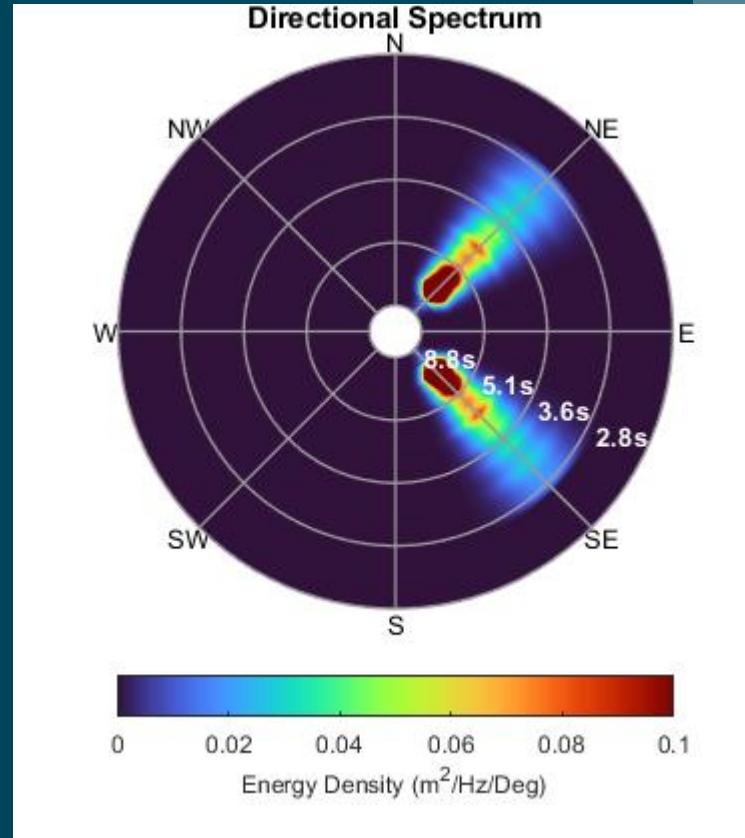
- Ocean waves represented as superimposed sinusoidal waves

Coastal Processes

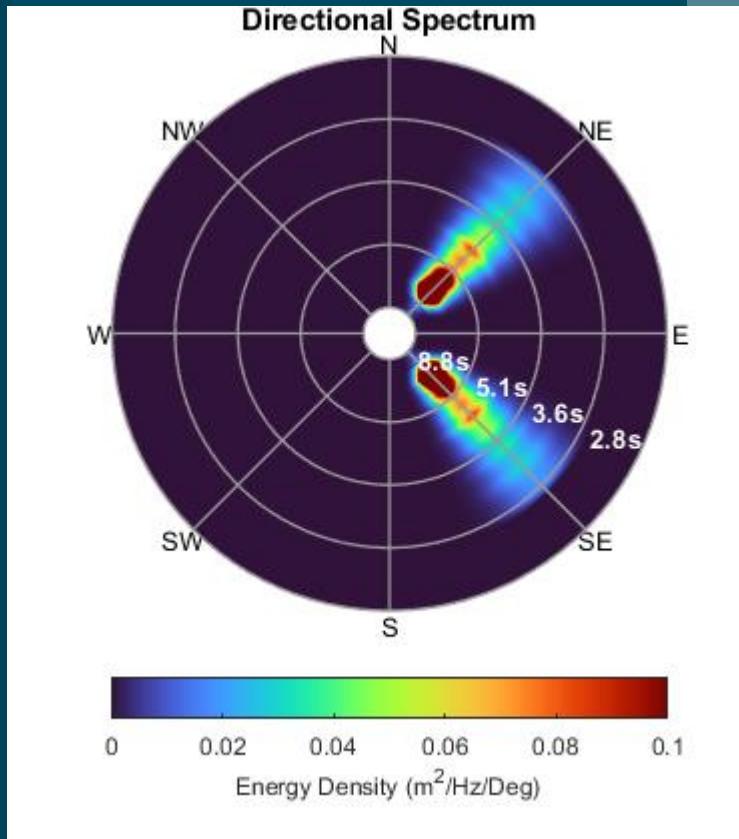
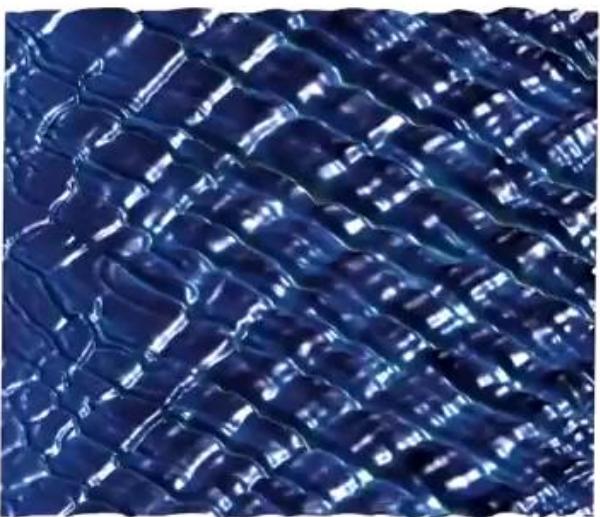


Coastal Processes

- Directional Spectrum
- Represents concentration of wave energy by:
 - Wave period
 - Direction



Coastal Processes

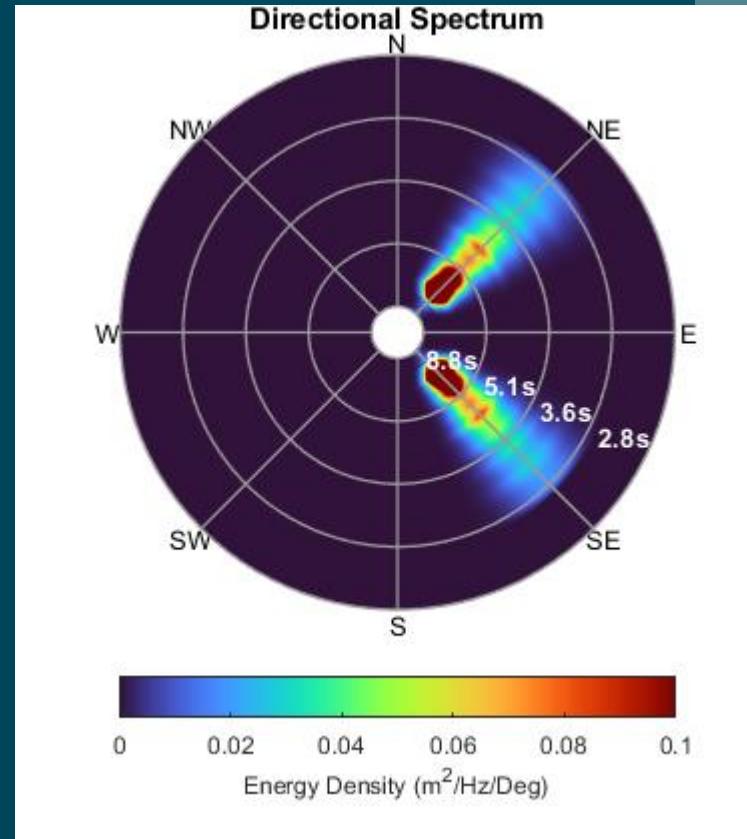


Coastal Processes



What happens
at the locations
where these
wave trains
intersect?

Coastal Processes



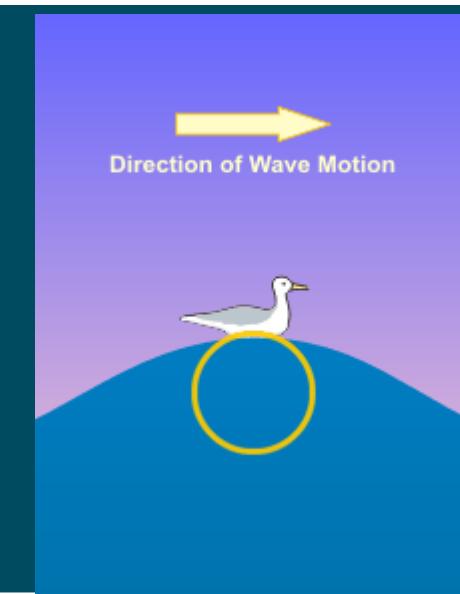
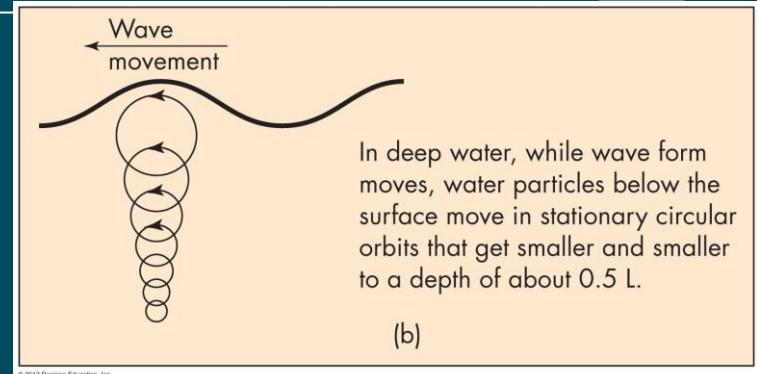
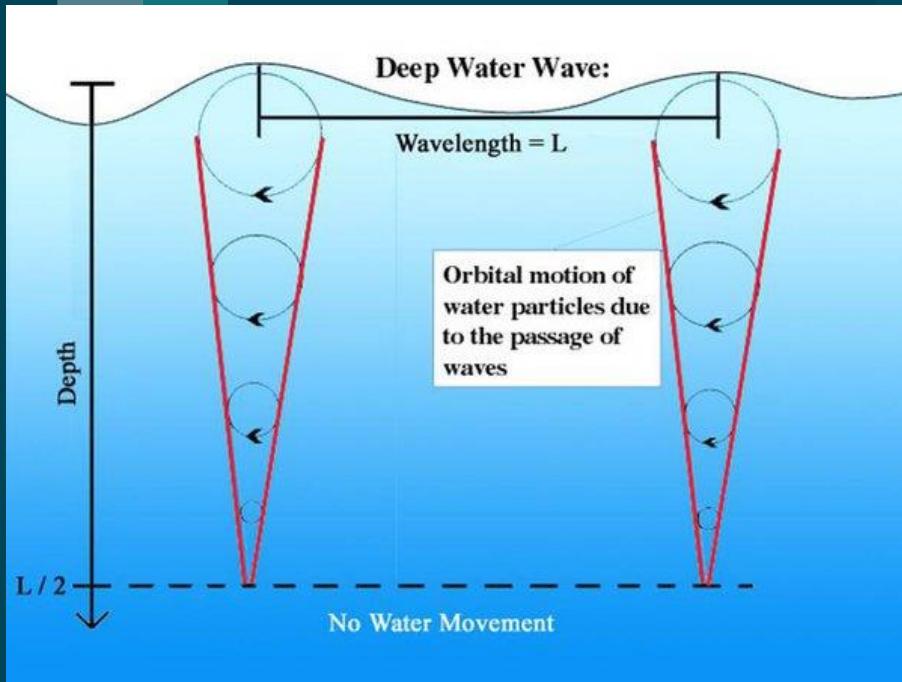
Coastal Processes



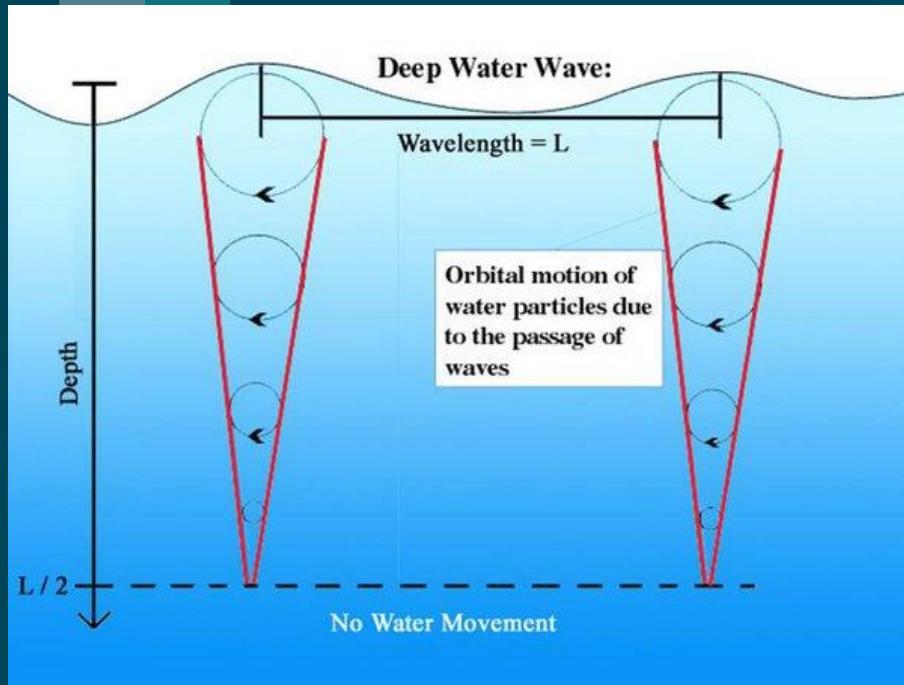
Coastal Processes



Coastal Processes

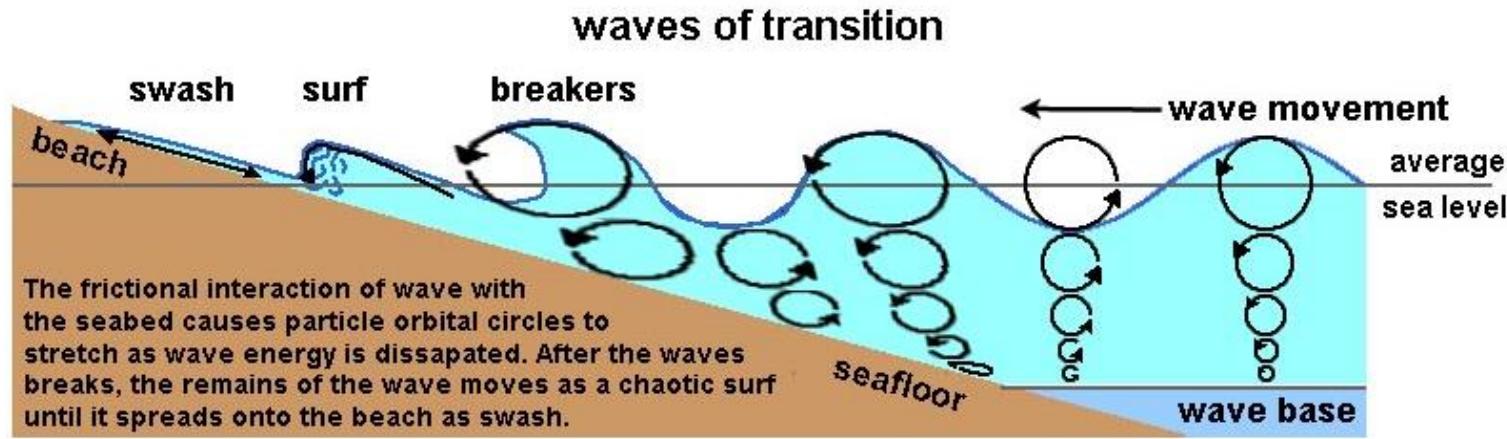


Coastal Processes



Can you “dive
under” a
tsunami wave?

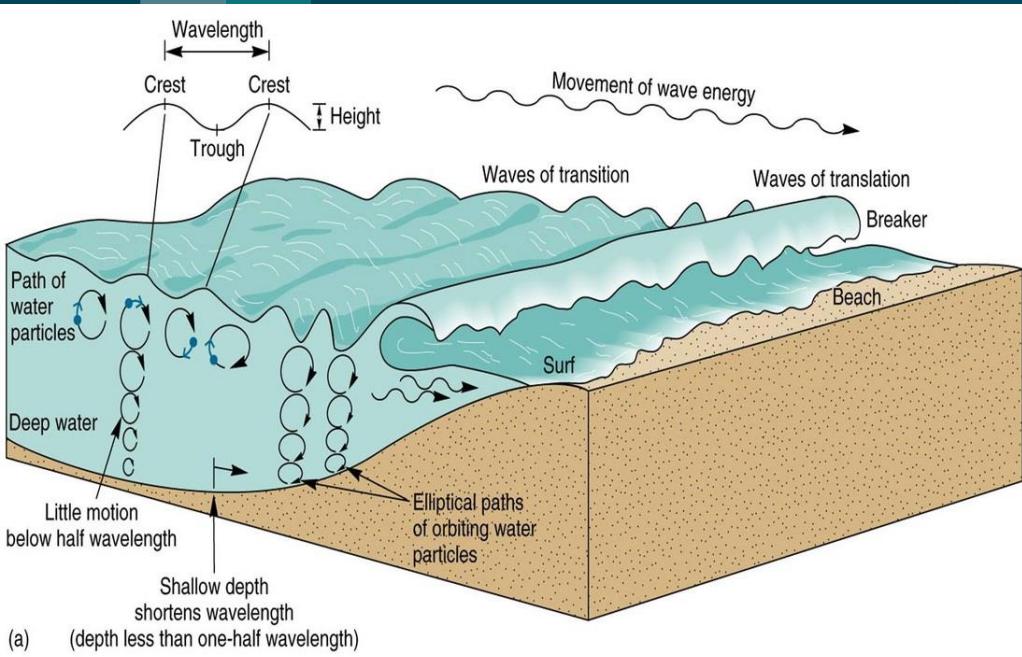
Coastal Processes



Coastal Processes

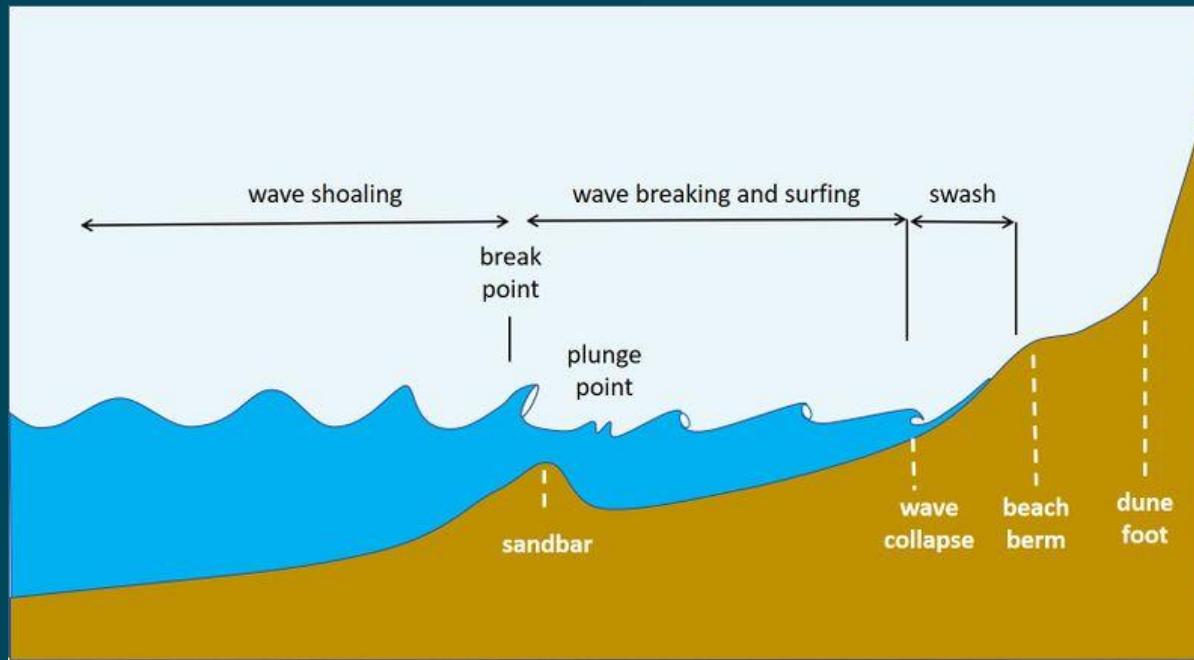


Coastal Processes

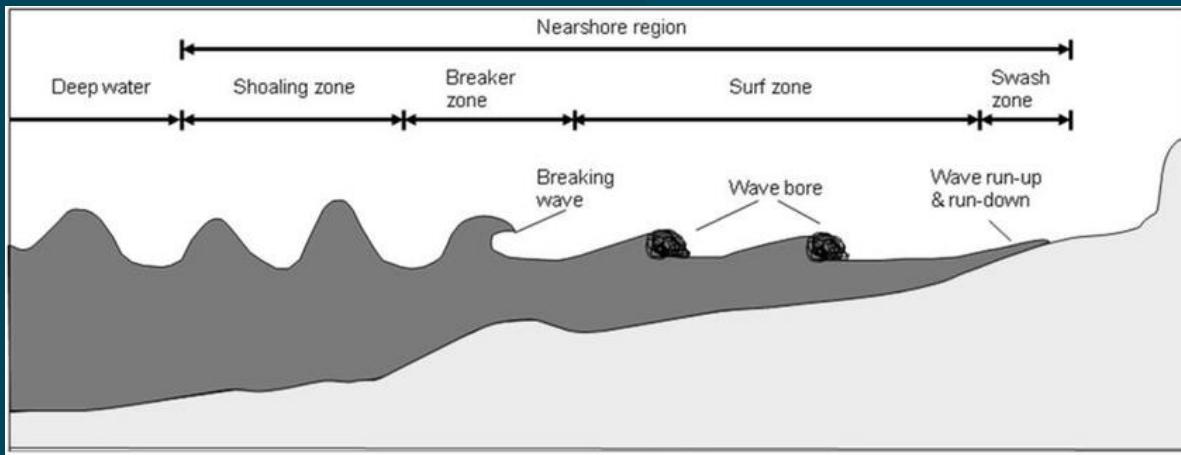


- Water depths decreases:
 - Orbitals become elliptical
 - Slow down
 - Wavelength decreases
 - Steepen until they break
 - Steepness = ratio of height/length
 - 1/7
 - At shoreline, orbitals entirely linear motion

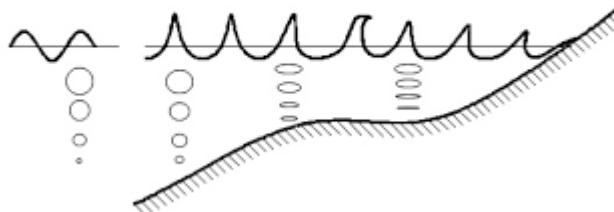
Coastal Processes



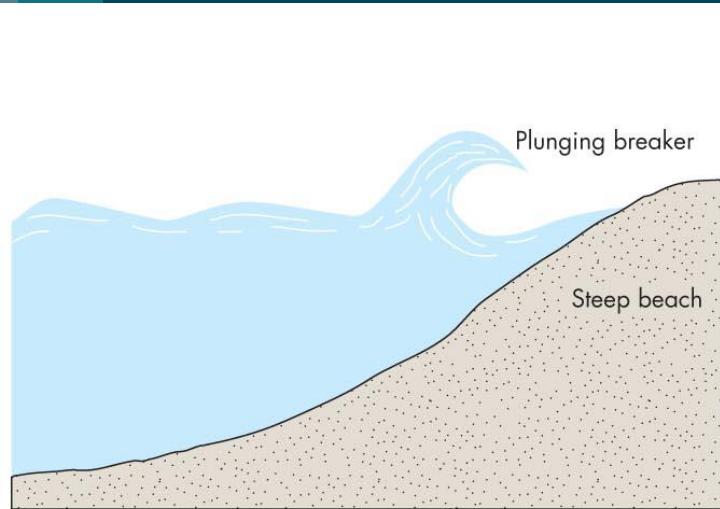
Coastal Processes



Sinusoidal → Skewed → Asymmetric



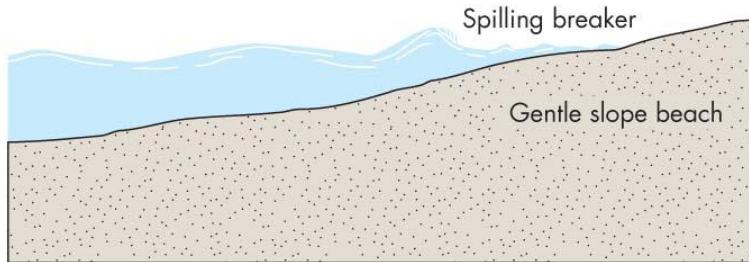
Coastal Processes



(a)

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Coastal Processes

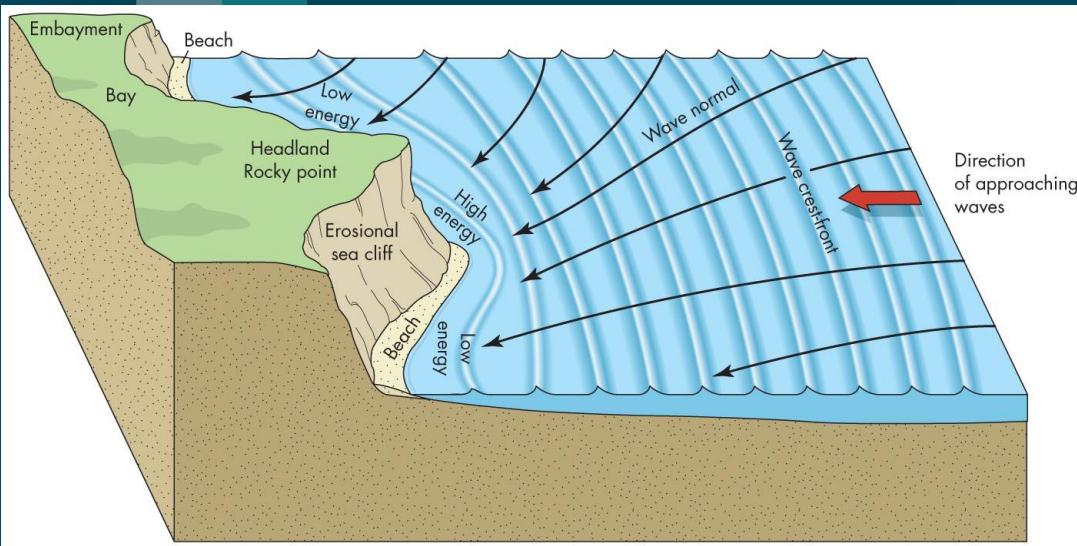


(b)

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Coastal Processes

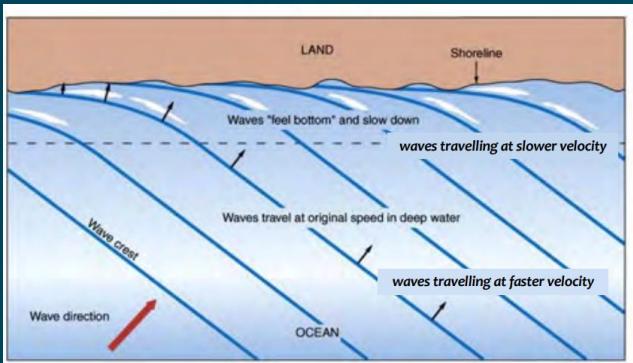


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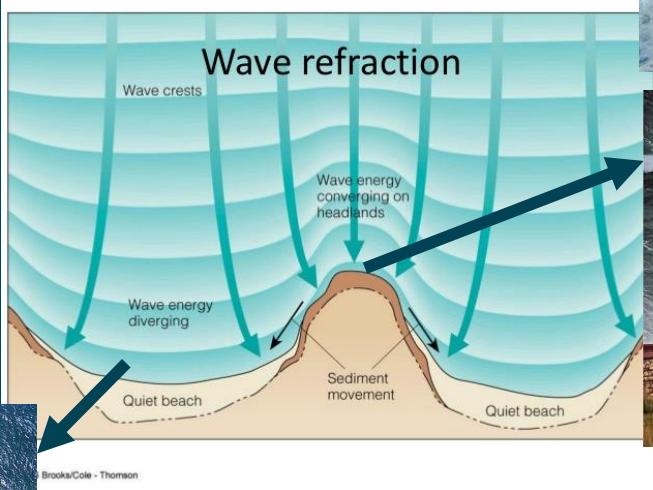
- Waves approach shore at an angle
- Waves refract (bend)

Coastal Processes

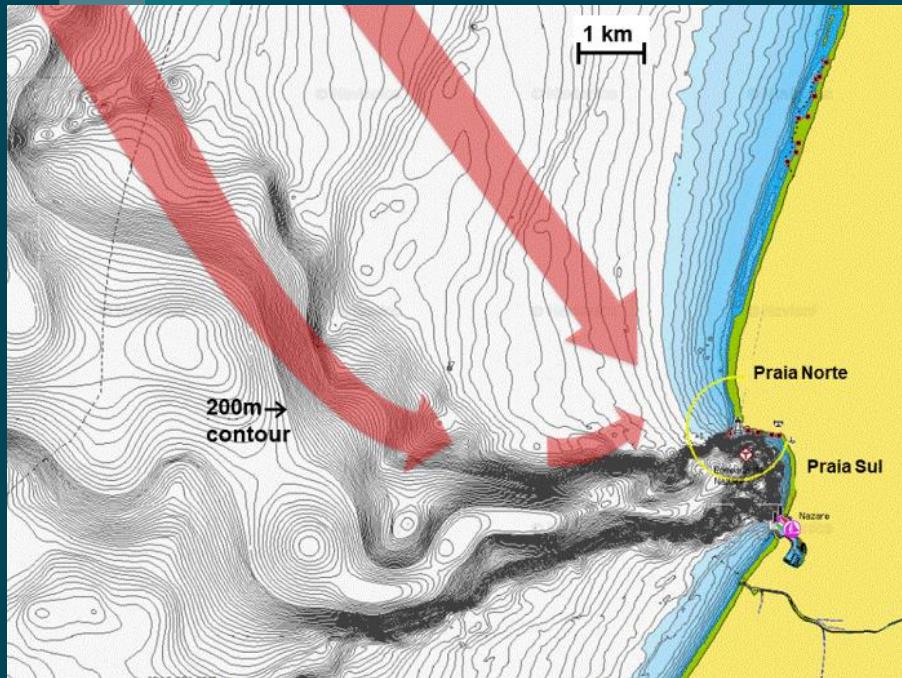
- Wave energy = square of wave height
- Energy dissipated (converted) when break
- Break point depends on depth and wave height



Coastal Processes



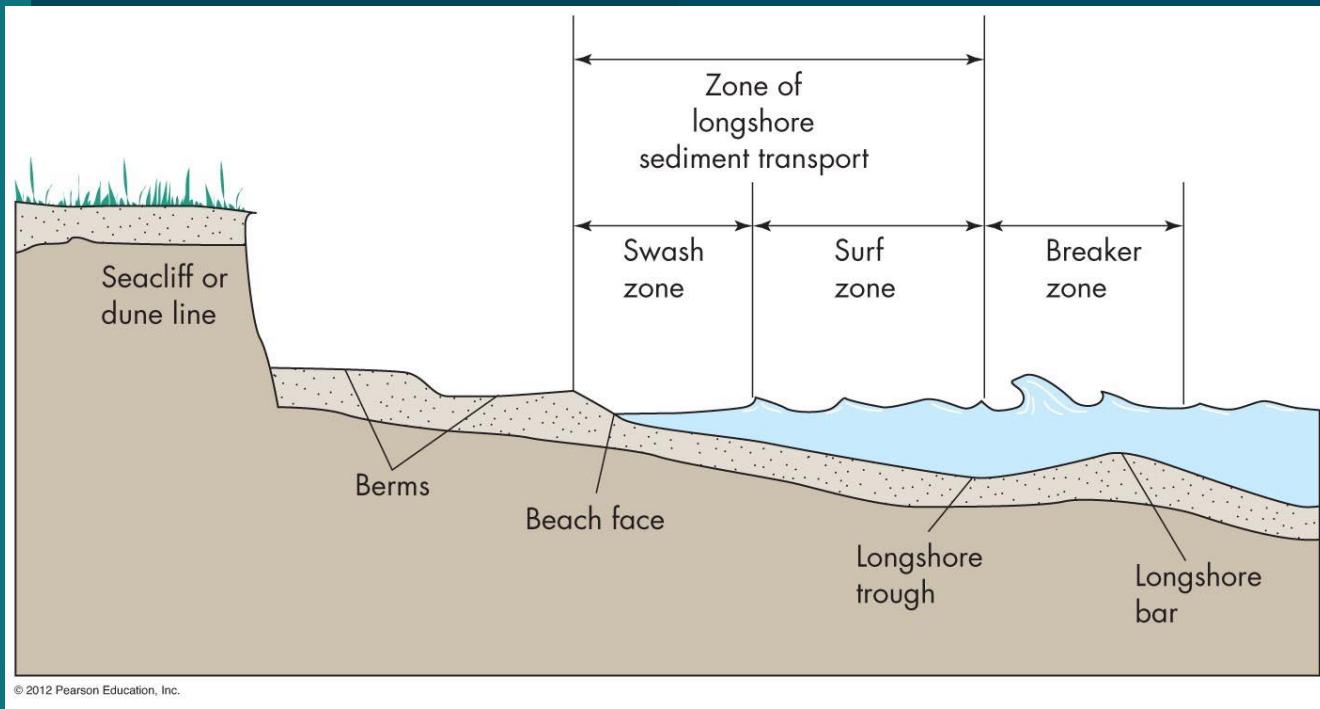
Coastal Processes



Coastal Processes



Coastal Processes

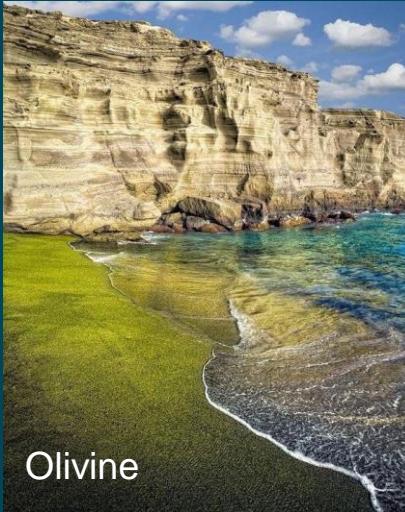


An aerial photograph of a tropical coastline. The beach is a strip of light tan sand running along the left side of the frame, bordered by a dense forest of green trees. The ocean is a vibrant turquoise color, with white-capped waves crashing onto the shore. The perspective is from above, looking down the length of the beach.

02

Beach Erosion

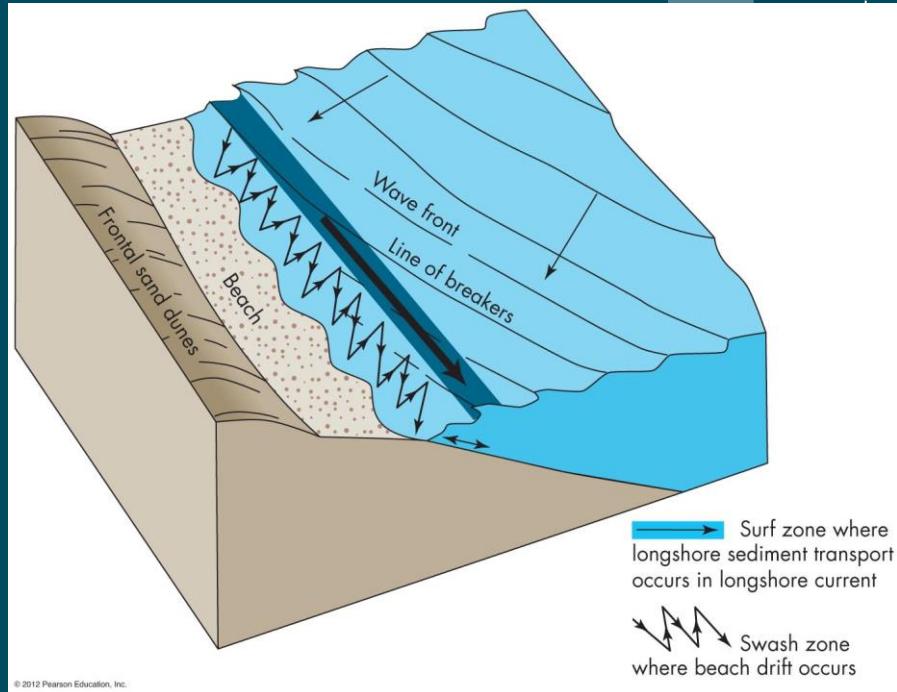
Beach Erosion



- Beach = loose sediment
- Accumulated through wave action and longshore transport
- Wide range of grain sizes and compositions

Beach Erosion

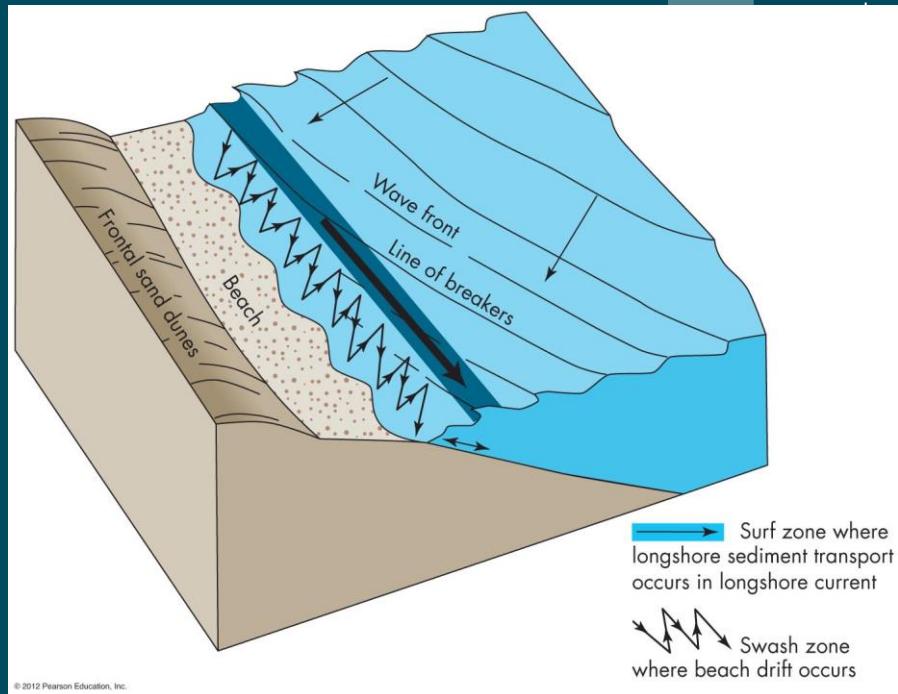
- Waves approach at angle
- Transfer momentum
- Longshore transport:
 - (1) Longshore drift
 - (2) Longshore current



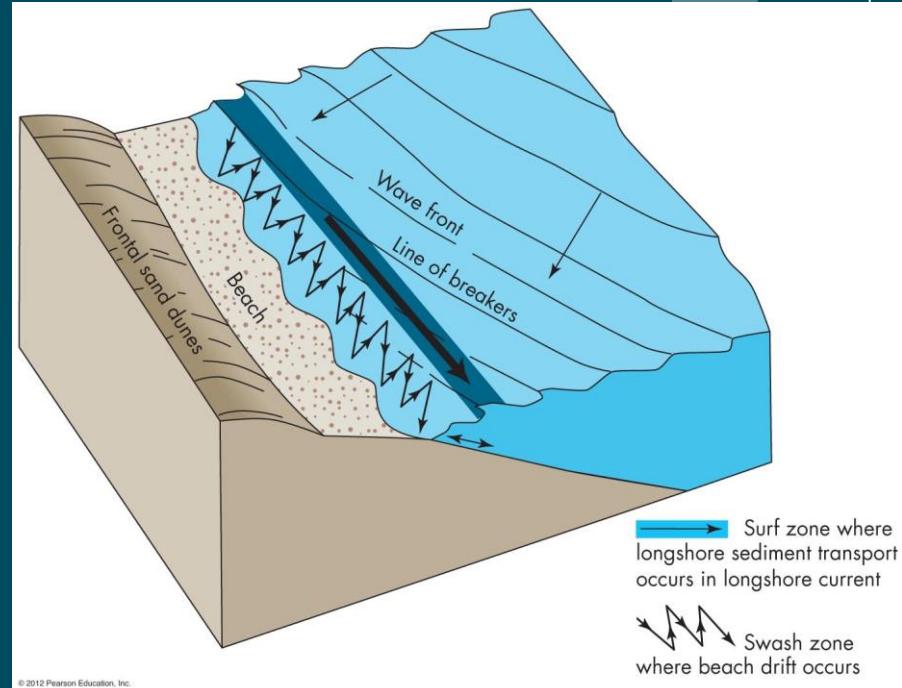
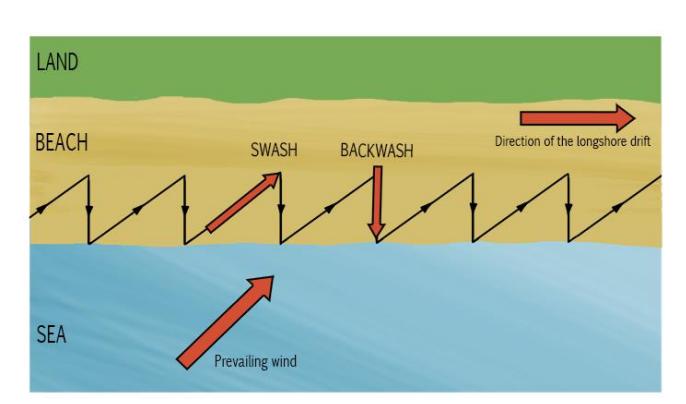
Beach Erosion



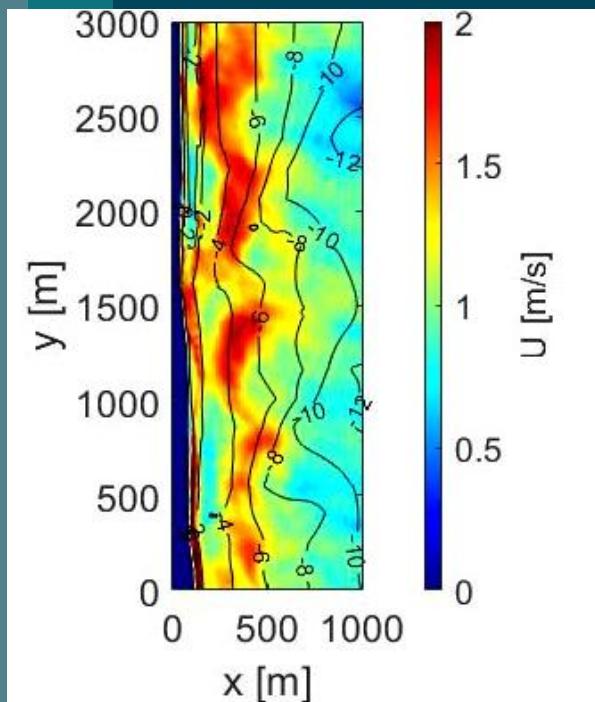
- Longshore Drift
- Swash (up beach) and backwash (return flow)



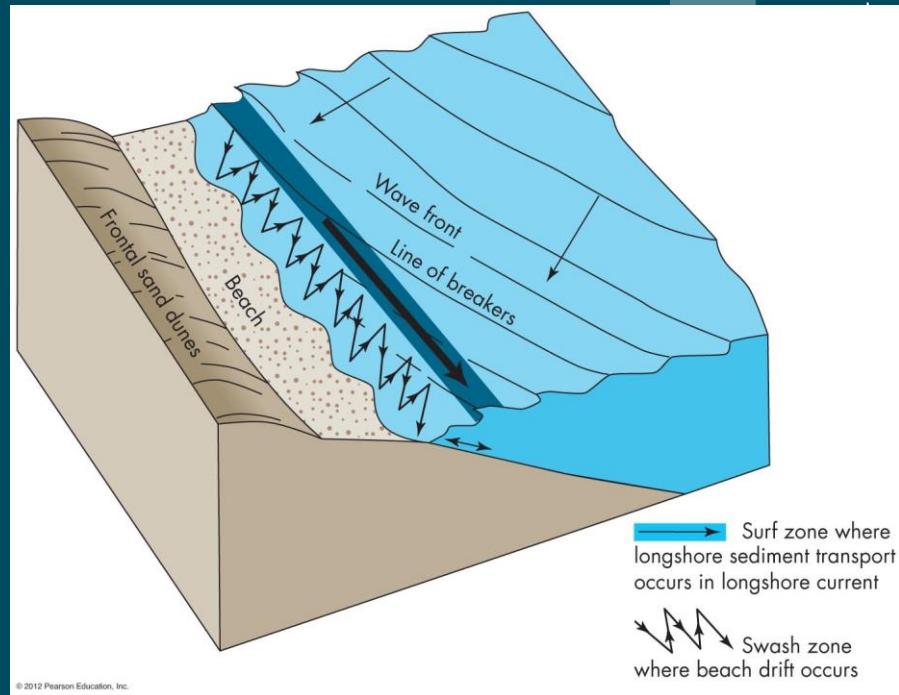
Beach Erosion



Beach Erosion

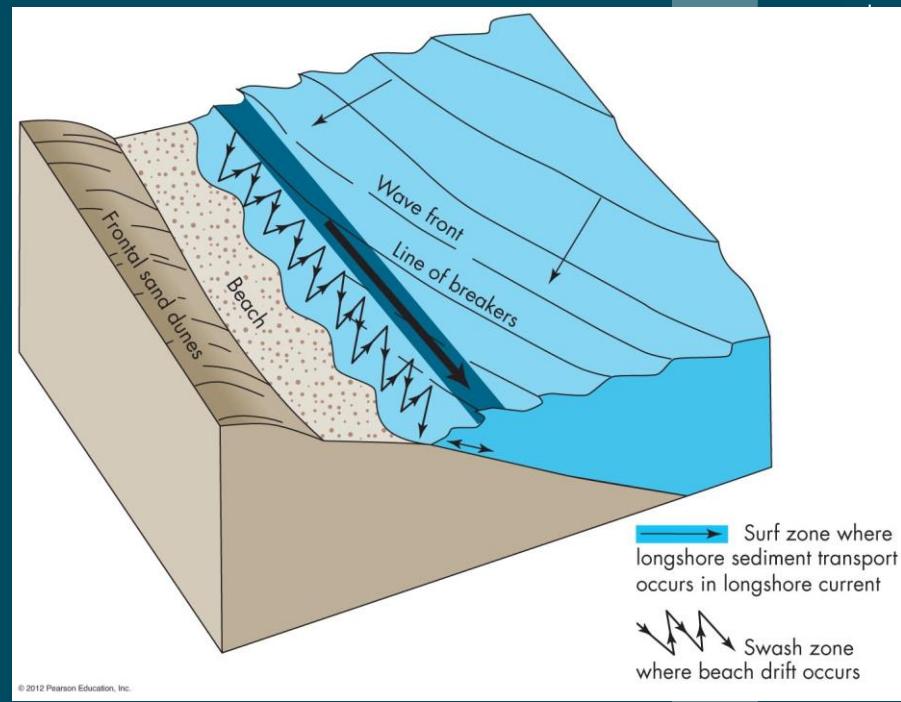
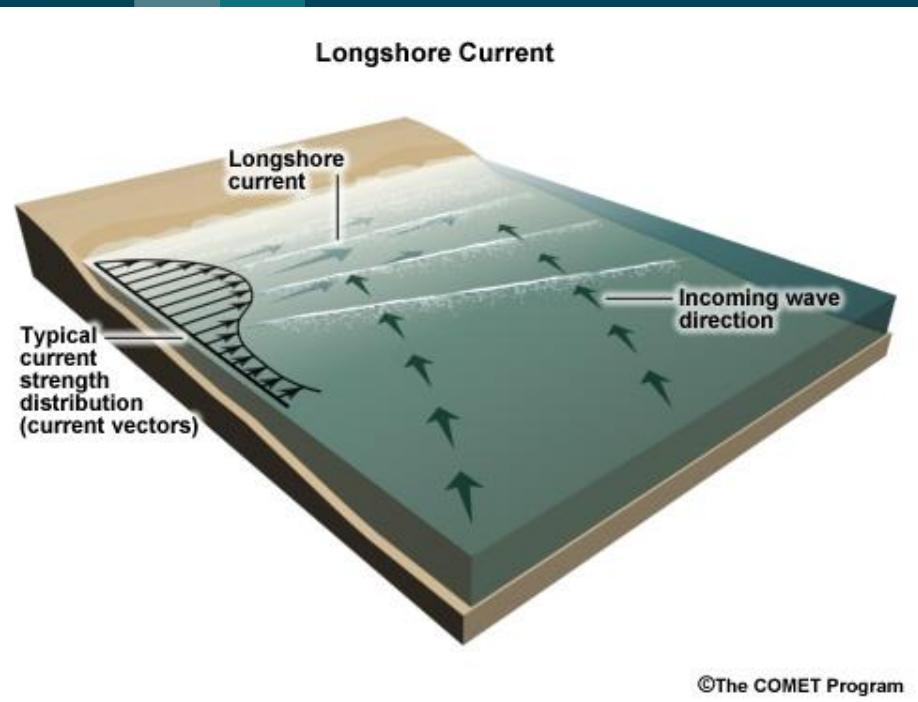


- Longshore current



Beach Erosion

- Longshore current

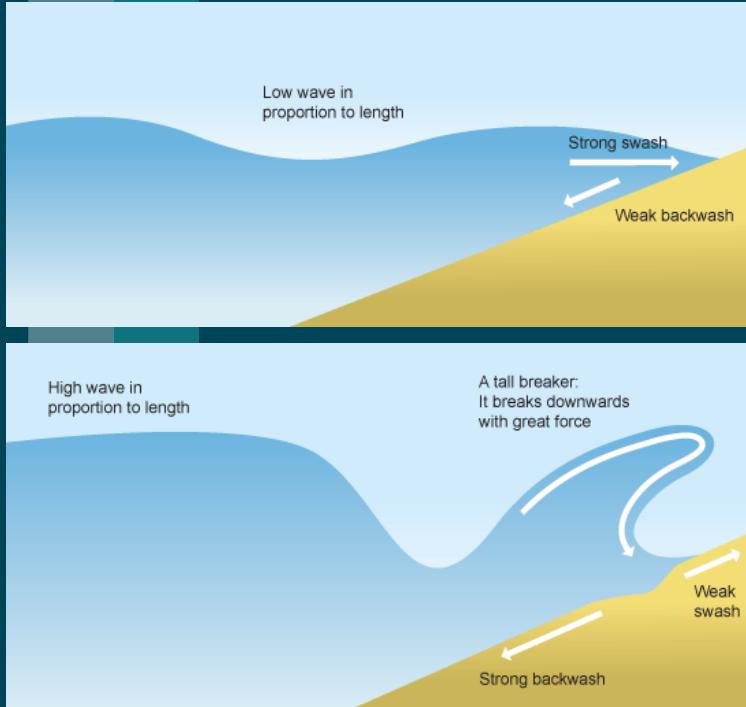


Beach Erosion



- Cross-shore sediment transport
 - (1) Swash/backwash
 - (2) Rip currents

Beach Erosion



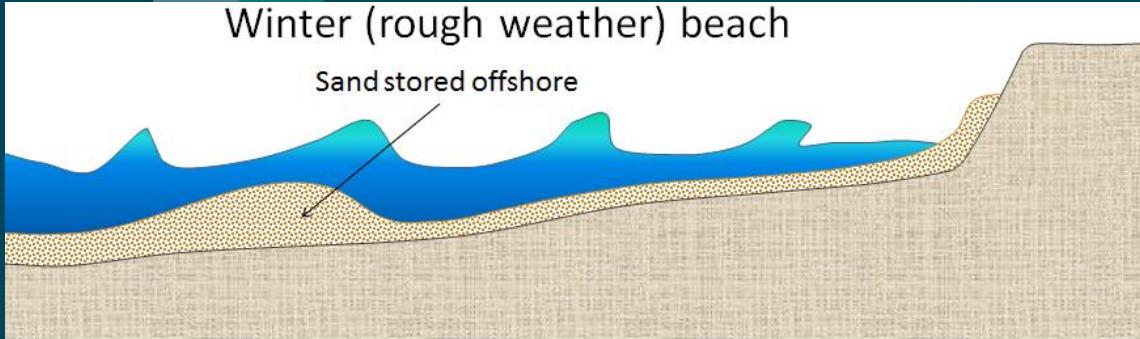
- Swash/backwash
- Shallow slope → shallow waves
 - Net onshore movement
- Steep slope → steep waves
 - Net offshore movement

Beach Erosion

- Swash/backwash

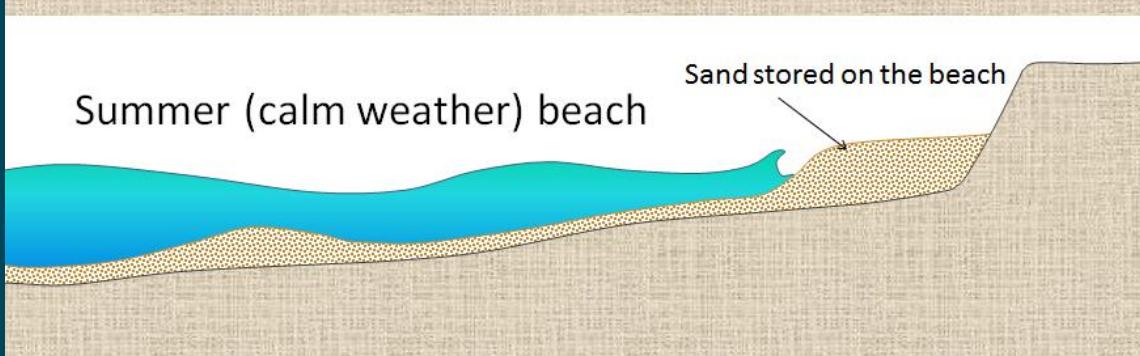
Winter (rough weather) beach

Sand stored offshore



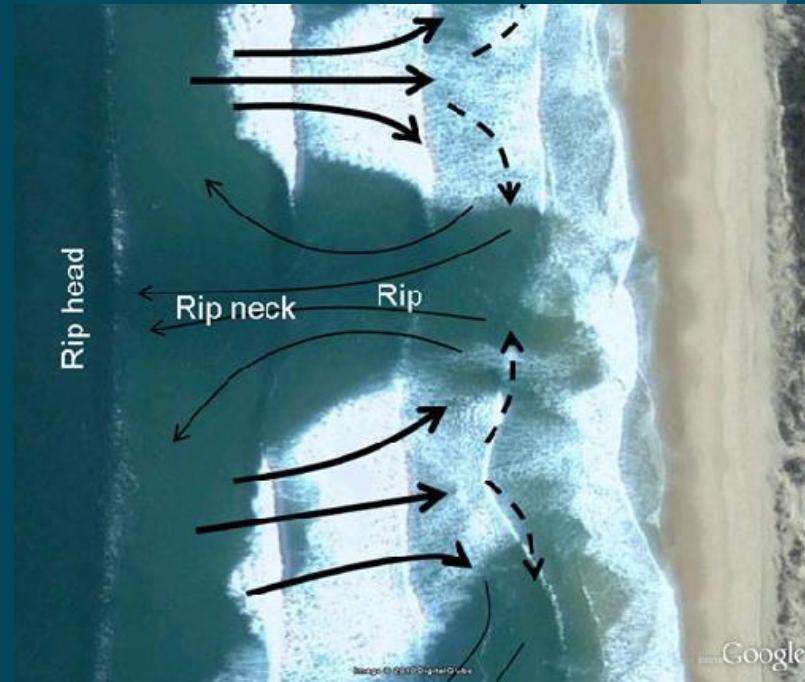
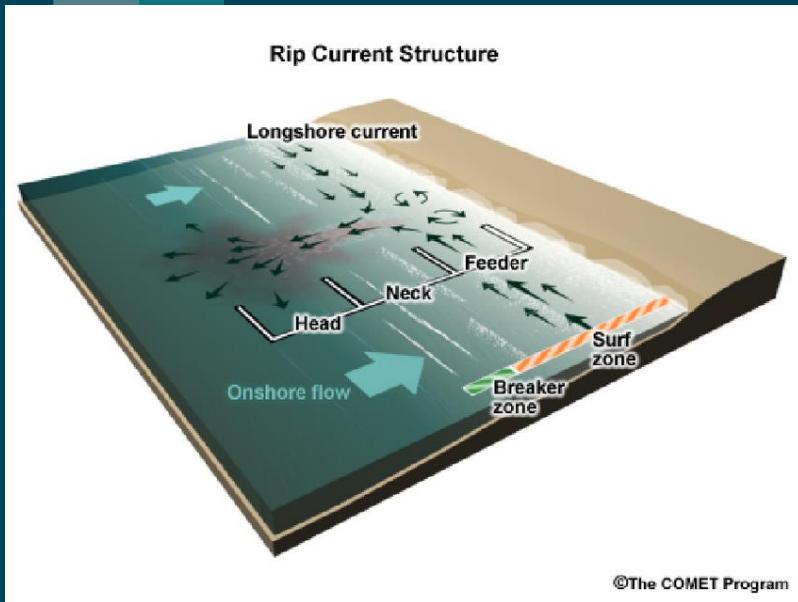
Summer (calm weather) beach

Sand stored on the beach



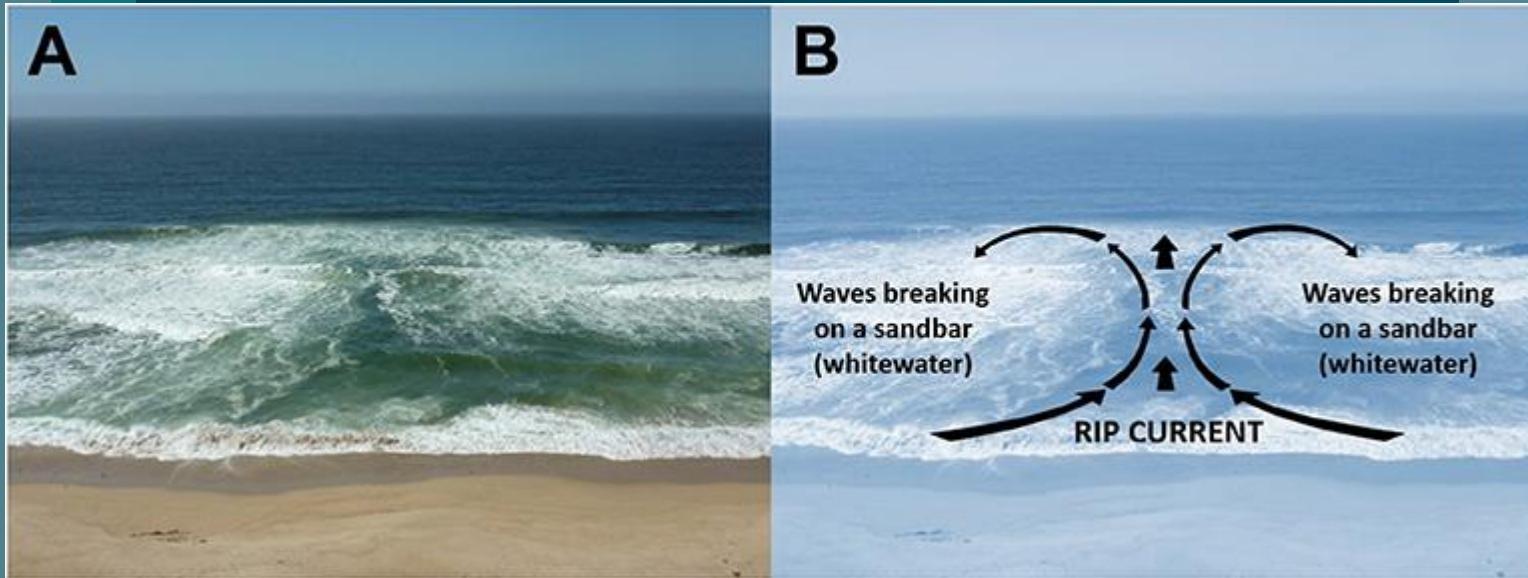
Beach Erosion

- Cross-shore sediment transport
 - (1) swash/backwash
 - (2) rip currents



Beach Erosion

- Rip currents



Beach Erosion



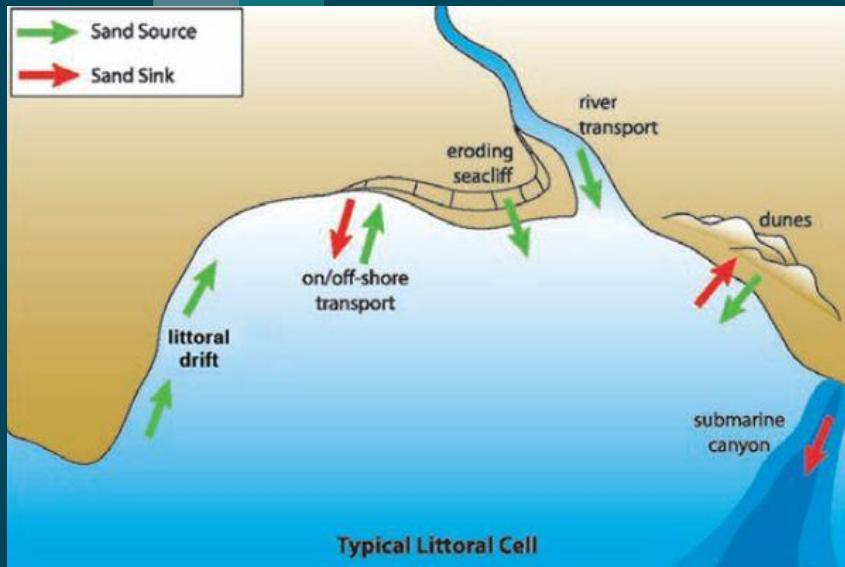
- In the US, about 20,000 rescues occur each year
- Spotting a rip current:
 - (1) Gap in breakers/foam
 - (2) Offshore flow
 - (3) Sediment plume

Beach Erosion

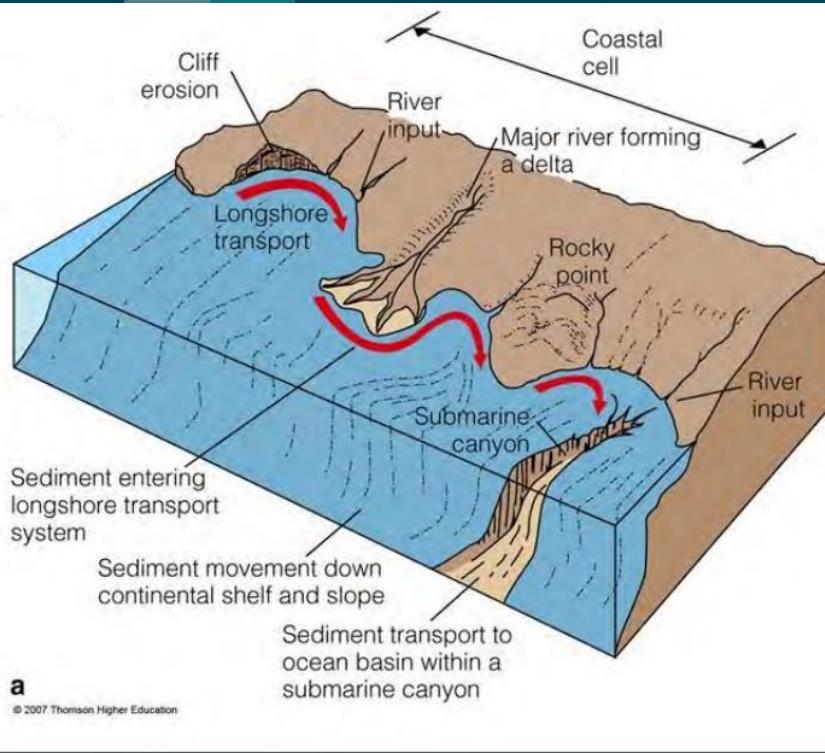


How do you
escape a rip
current?

Beach Erosion



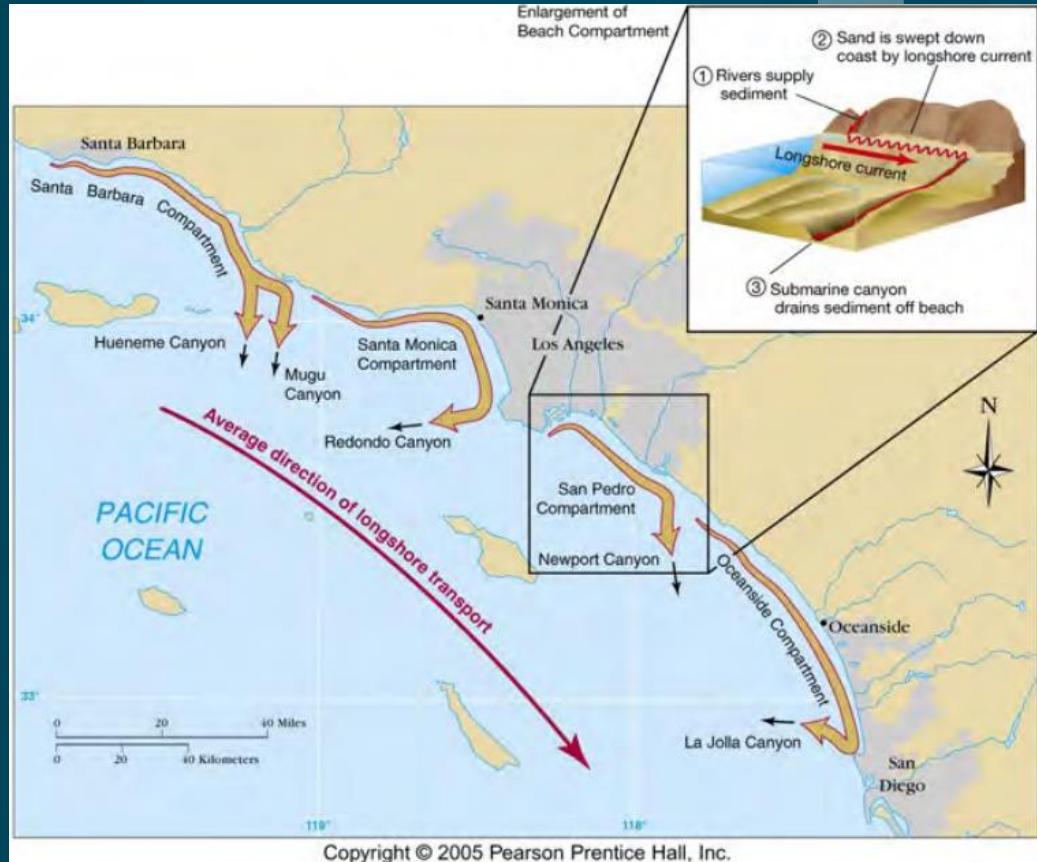
Beach Erosion



- Sediment deposited and stored on beaches
- Withdrawal via transport offshore out of active region
- Down submarine canyons

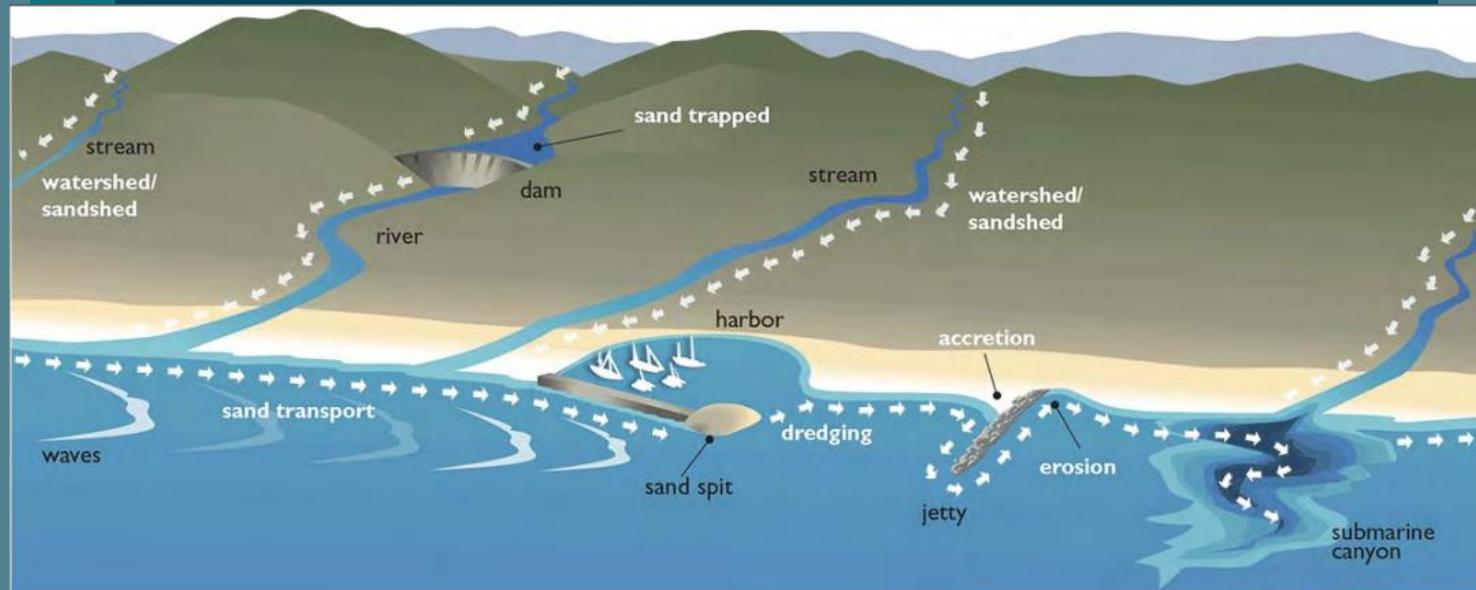
Beach Erosion

- Coastlines broken up into coastal cells
- Aka Littoral cell or compartments
- Sedimentation cycle: sources, transport, sink



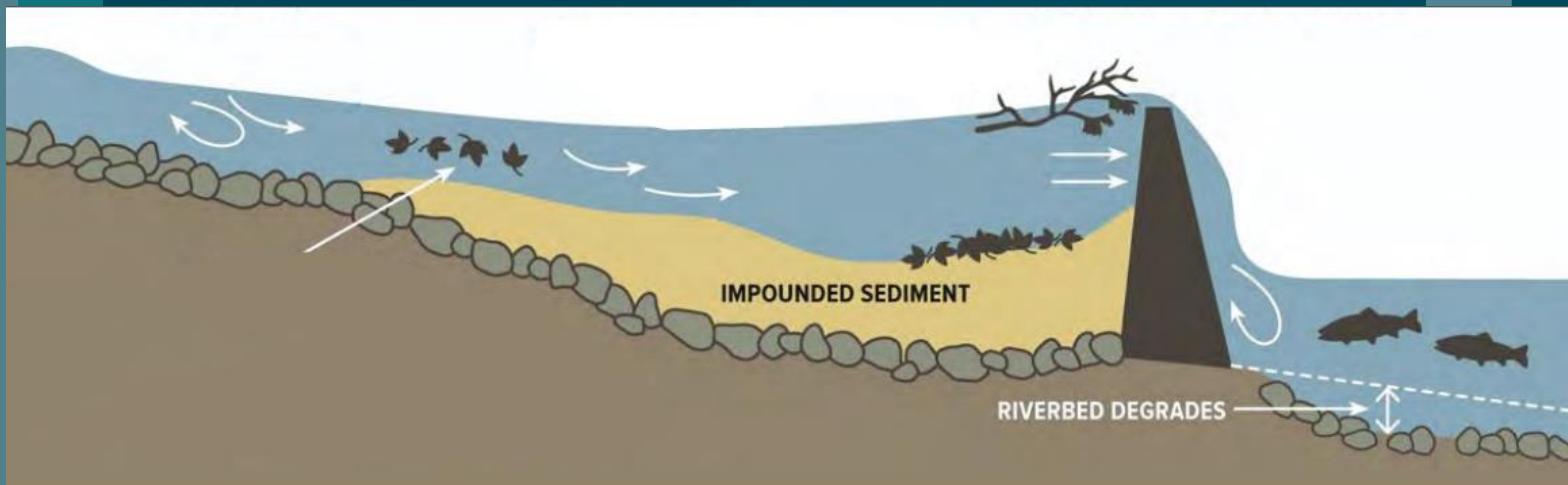
Beach Erosion

- Sediment input < output = erosion
- Short-term and long-term causes
- Natural and human causes



Beach Erosion

- Fluvial (riverine) dams trap sediment
- Prevent sediment from reaching ocean



Beach Erosion

- Melting permafrost



Beach Erosion

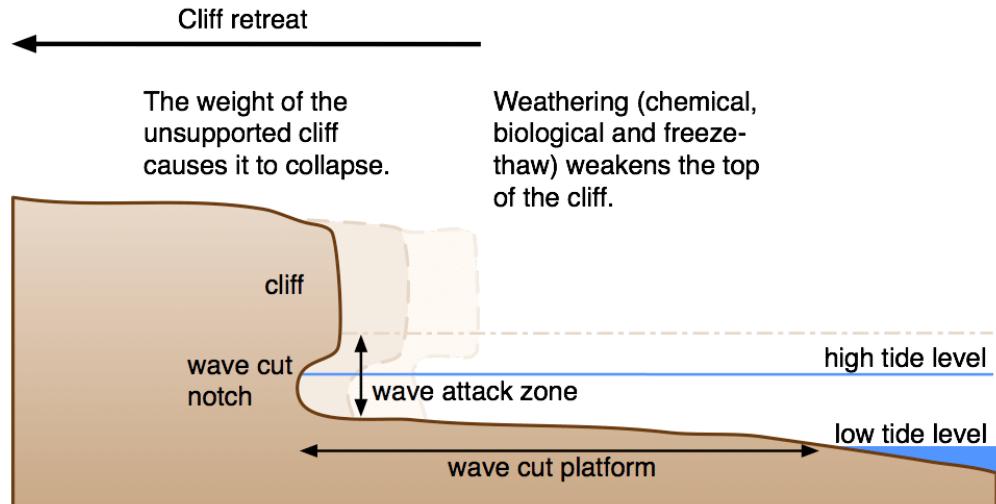
- Sea level rise
- Wave action over time



Beach Erosion

The formation of a wave cut platform

www.internetgeography.net



The sea creates a wave cut notch through hydraulic action and abrasion.

Backwash transports material from the base of the cliff forming a wave cut platform.



Beach Erosion

- Storm frequency, intensity, duration



Beach Erosion

- Cape Hatteras Lighthouse
- Sea level rise & erosion



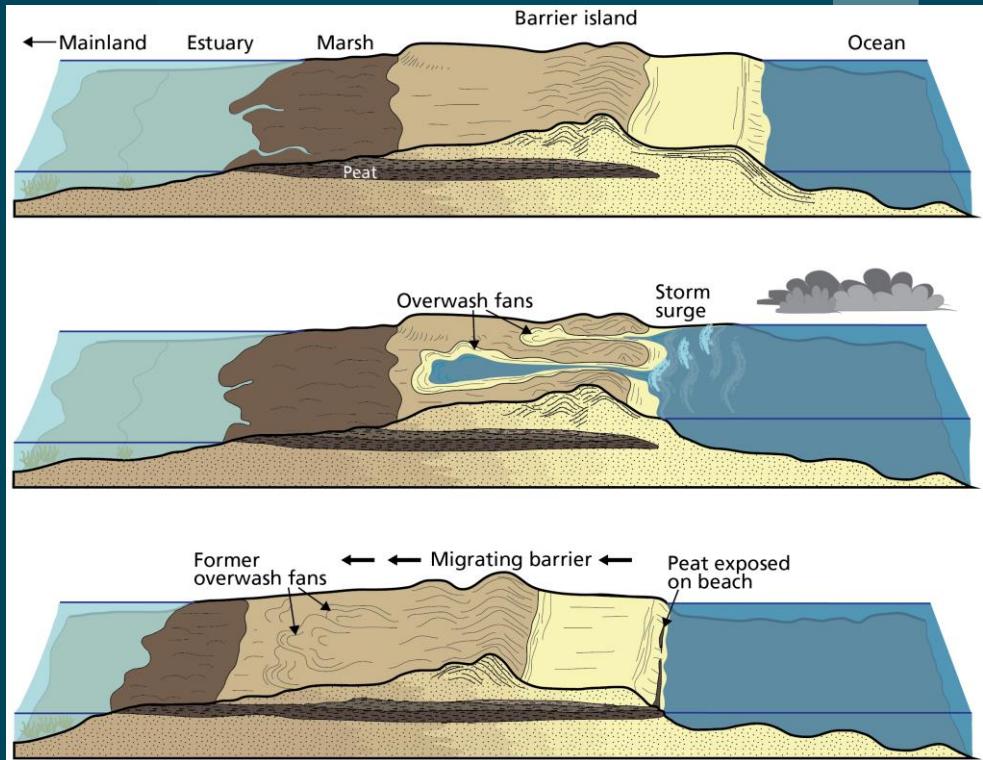
Beach Erosion



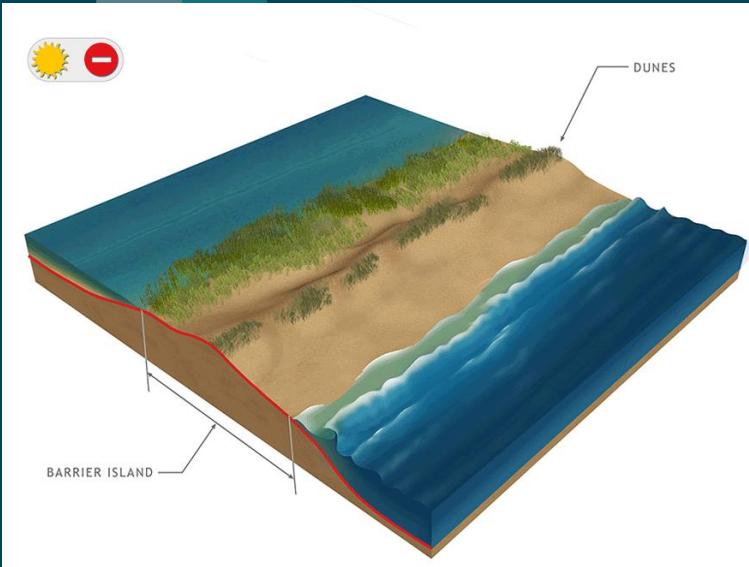
Beach Erosion



Beach Erosion



Beach Erosion



Beach Erosion



Beach Erosion

- Mitigate beach erosion:
 - Soft or nature-based stabilization
 - Hard stabilization
 - Managed retreat



Beach Erosion

- Soft or nature-based stabilization:
 - Nourishment



Beach Erosion

- Soft or nature-based stabilization:
 - Nourishment
 - Vegetated dunes



Beach Erosion

- Soft or nature-based stabilization:
 - Nourishment
 - Vegetated dunes
 - Marshgrass



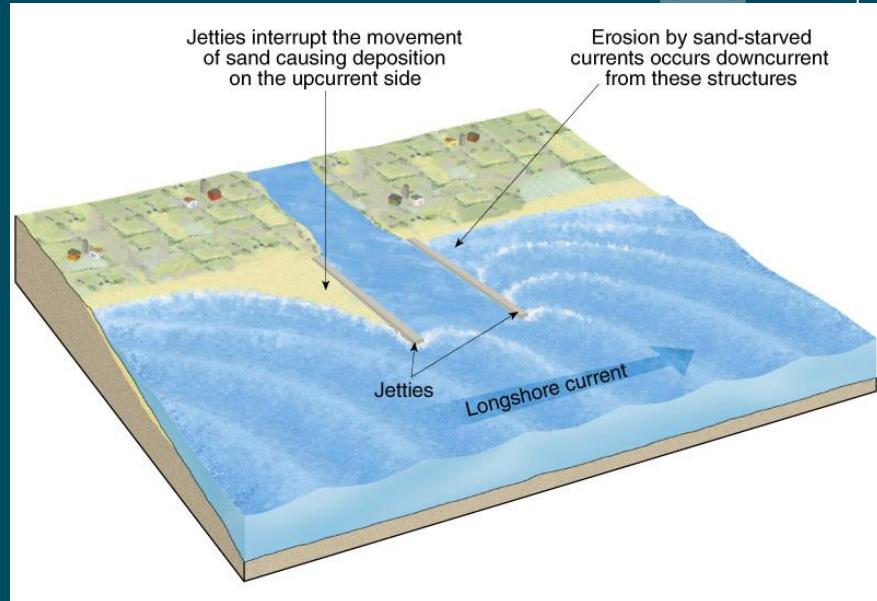
Beach Erosion

- Soft or nature-based stabilization:
 - Nourishment
 - Vegetated dunes
 - Marshgrass
 - Oyster reefs



Beach Erosion

- Hard stabilization
 - Jetty – perpendicular to shore, protects harbor or inlet entrance
 - Blocks longshore transport



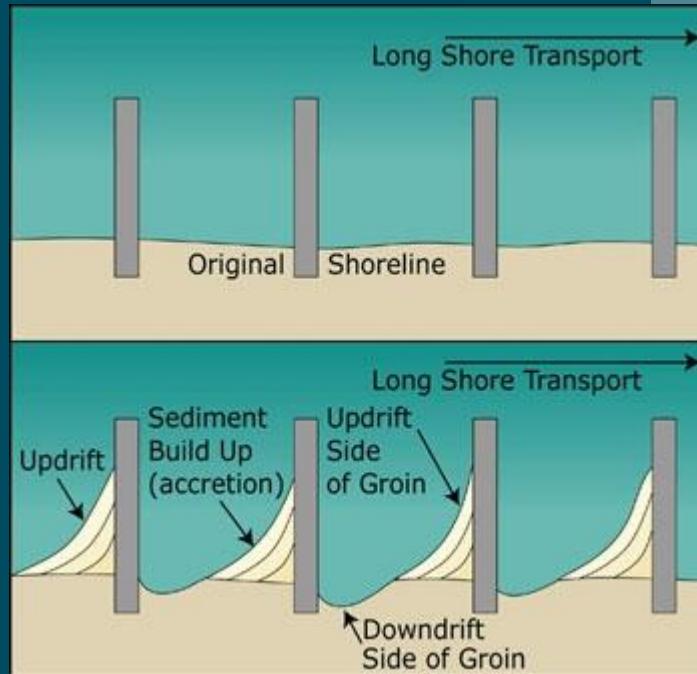
Beach Erosion

- Hard stabilization
 - Jetty – perpendicular to shore, protects harbor or inlet entrance
 - Blocks longshore transport



Beach Erosion

- Hard stabilization
 - Groins – perpendicular to shoreline
 - Usually in groups called fields



Beach Erosion

- Hard stabilization
 - Groins – perpendicular to shoreline
 - Usually in groups called fields



Beach Erosion

What is the dominant wave direction in this photo?



Beach Erosion

- Hard stabilization
 - Breakwaters – parallel to shoreline
 - Waves break farther offshore on these structures



Beach Erosion

- Hard stabilization
 - Breakwaters – parallel to shoreline
 - Waves break farther offshore on these structures



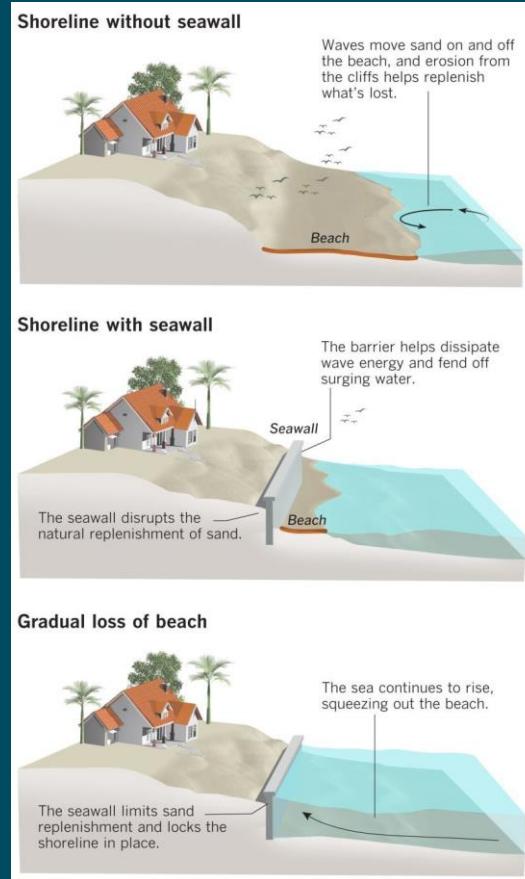
Beach Erosion

- Hard stabilization
 - Seawall – enforce shoreline

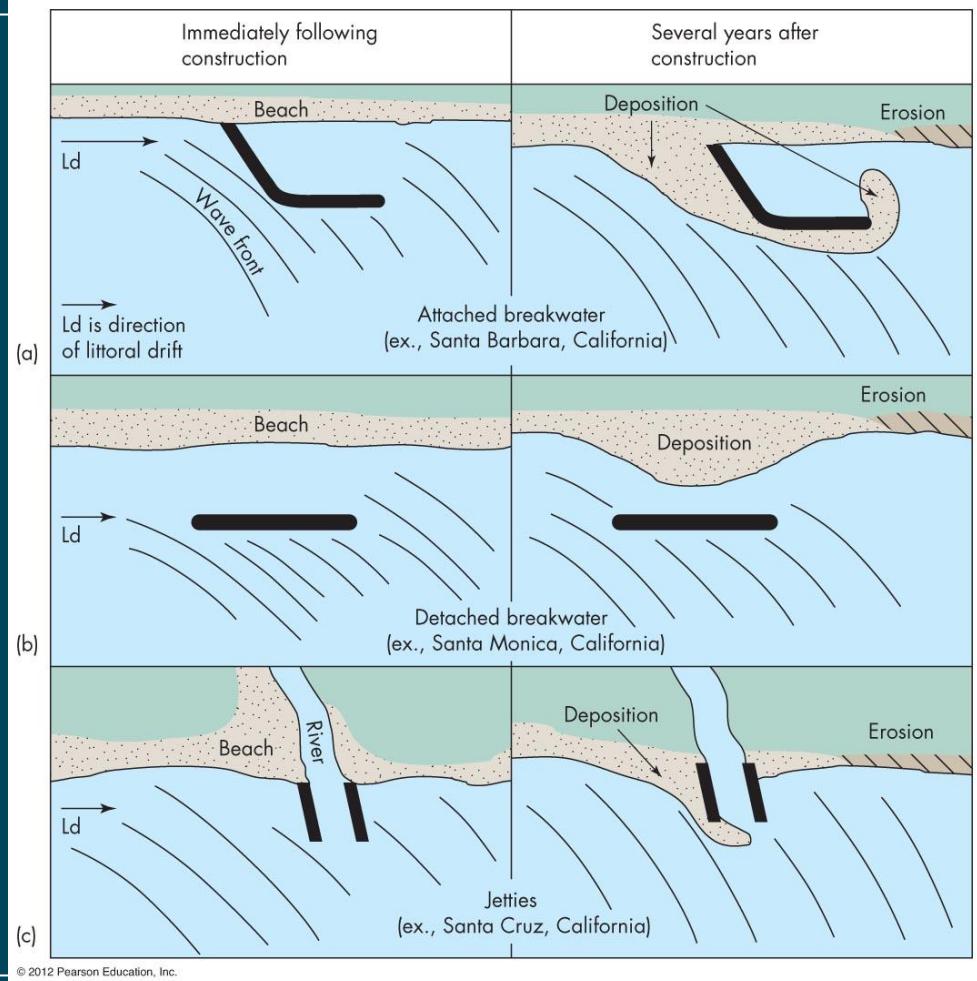


Beach Erosion

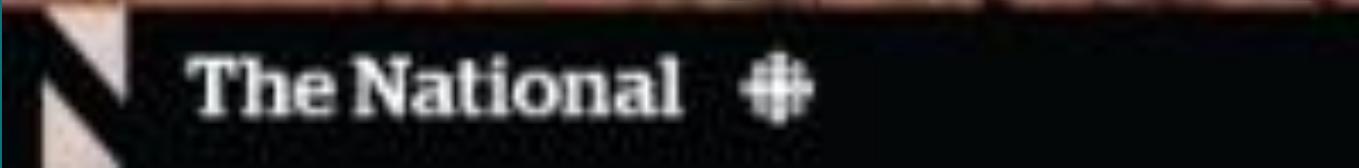
- Hard stabilization
 - Seawall – enforce shoreline Undercut overtime
 - Can enhance erosion elsewhere



Beach Erosion



Beach Erosion



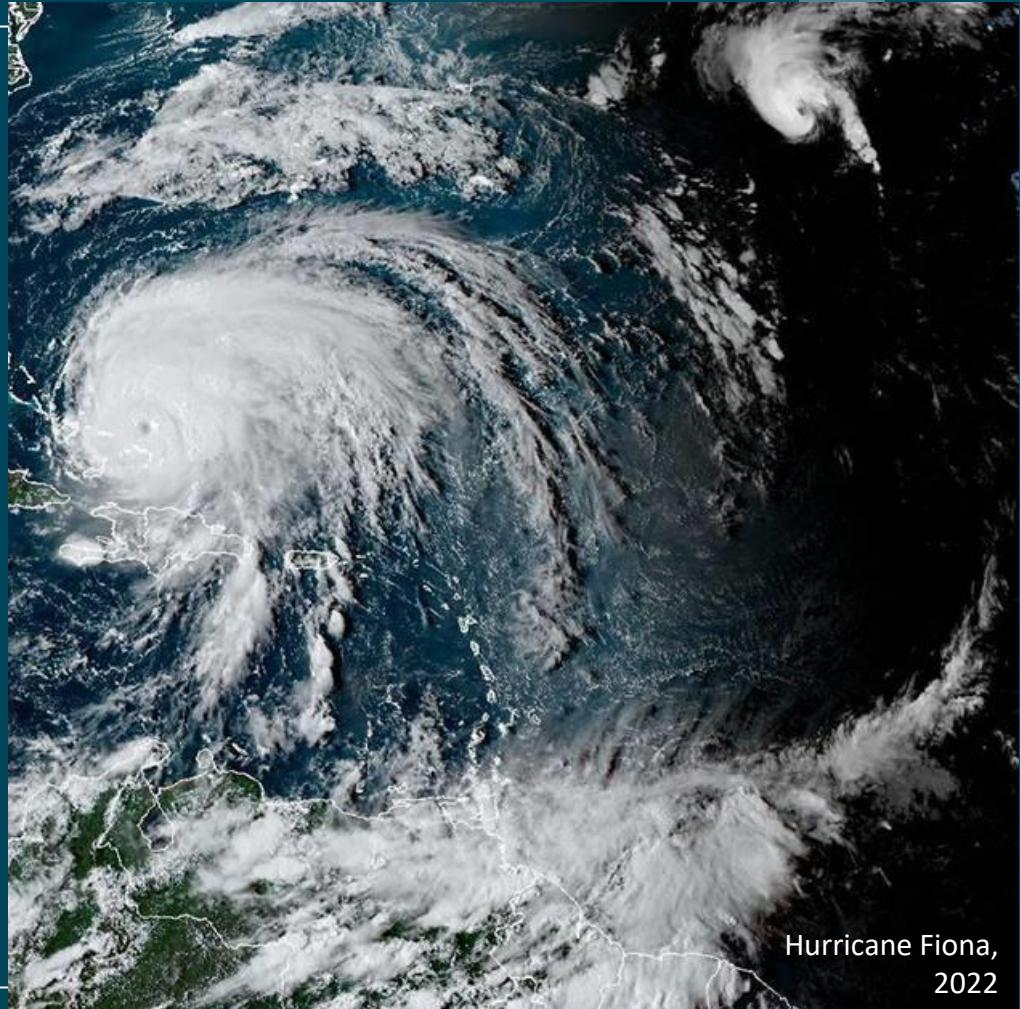


03

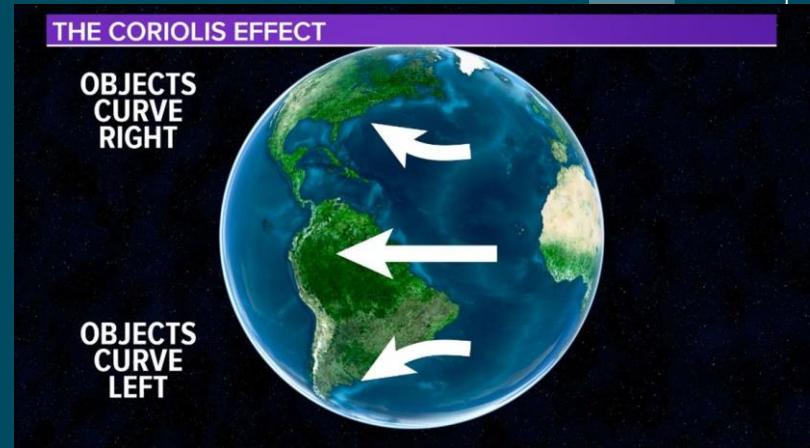
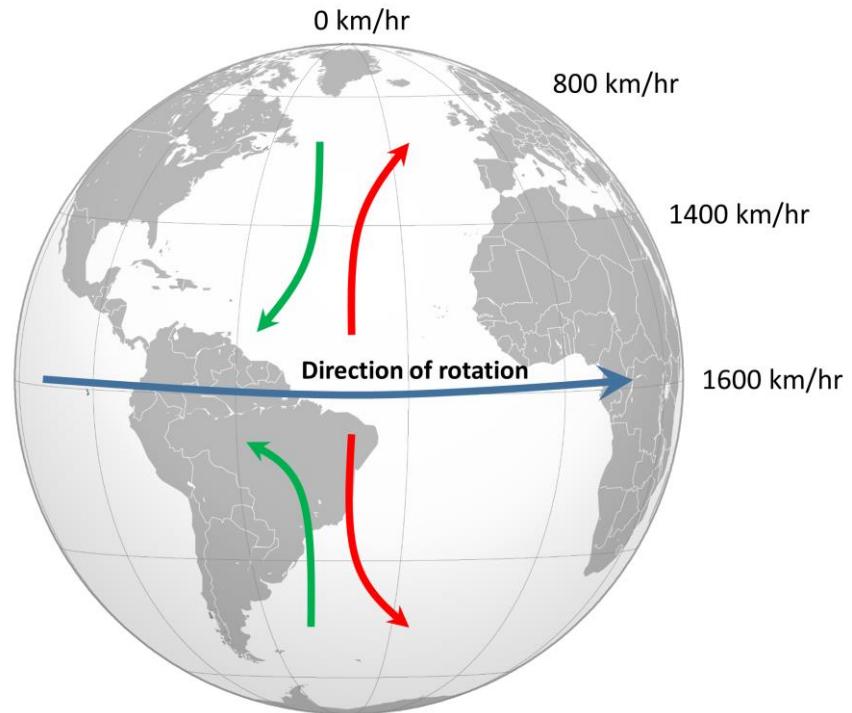
Storms

Storms

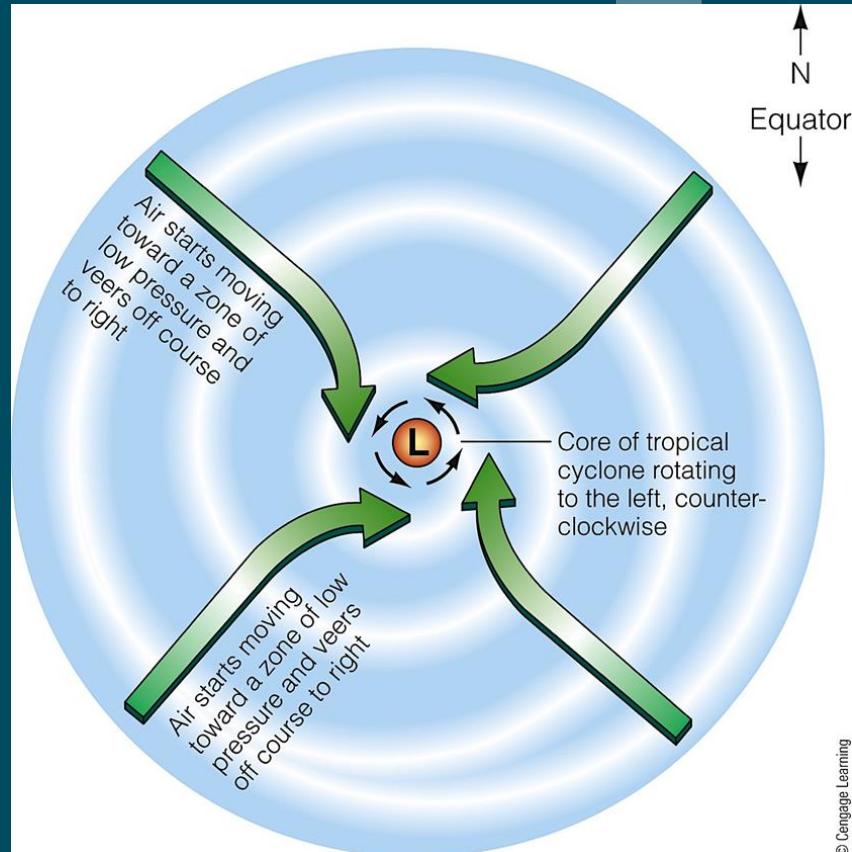
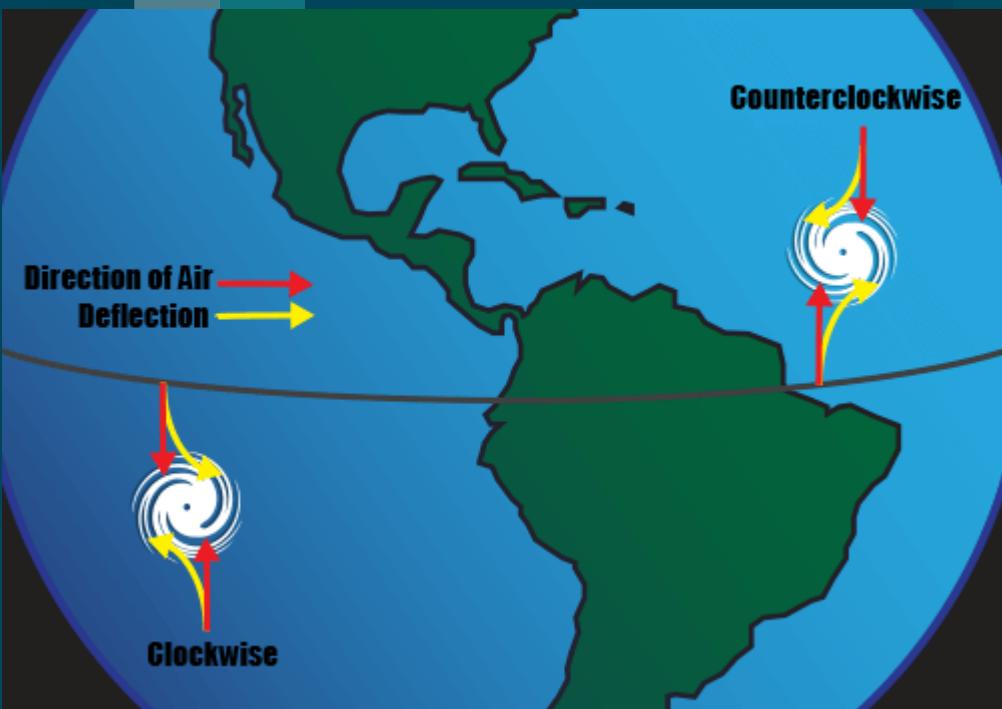
- Tropical cyclone
- Rotating mass of warm, humid air
- Low P center
- Strong winds and rain bands



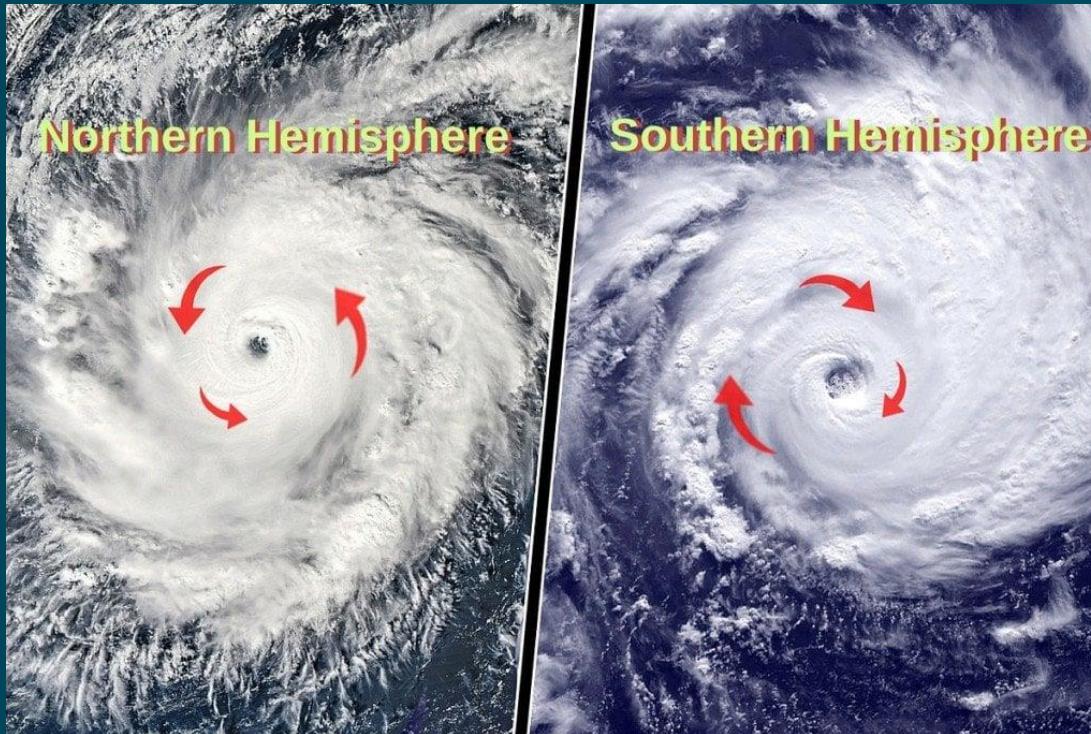
Storms



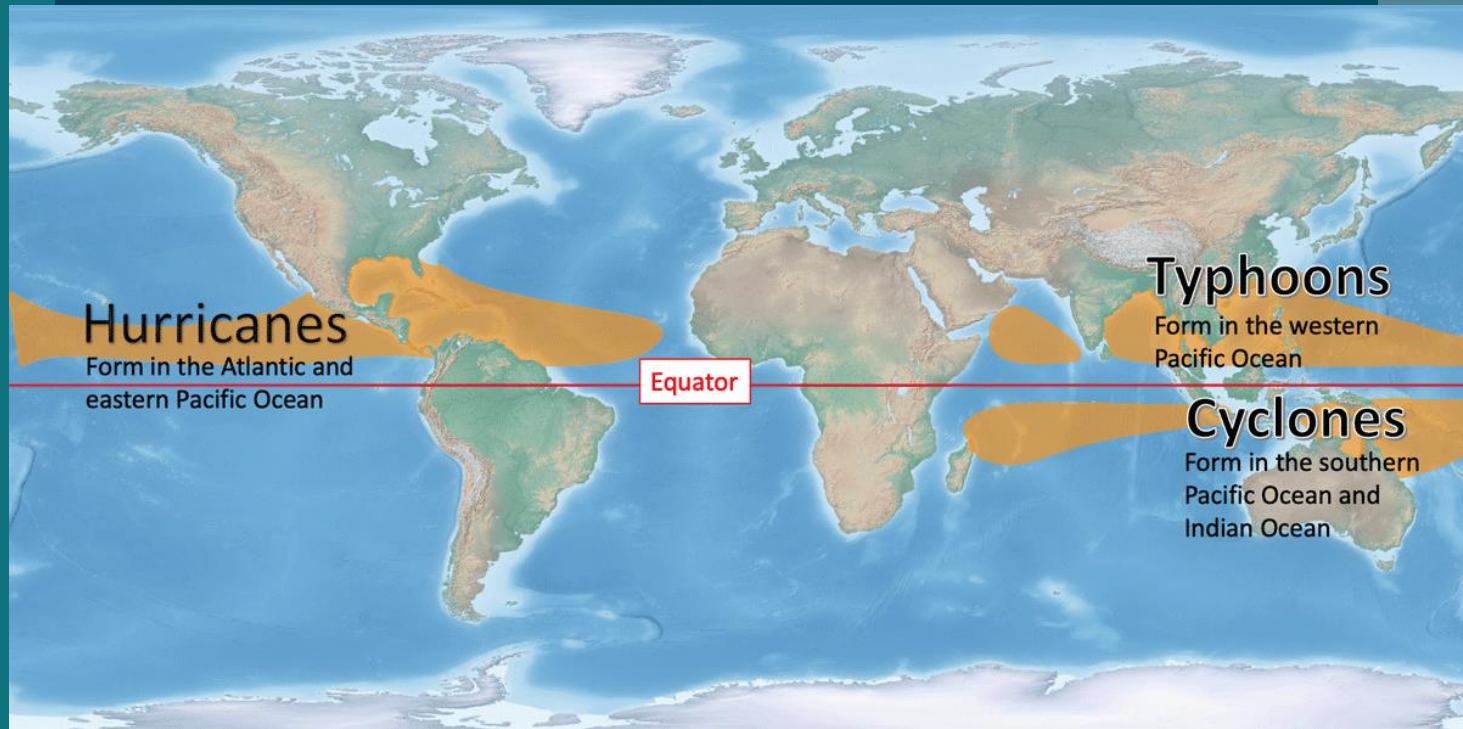
Storms



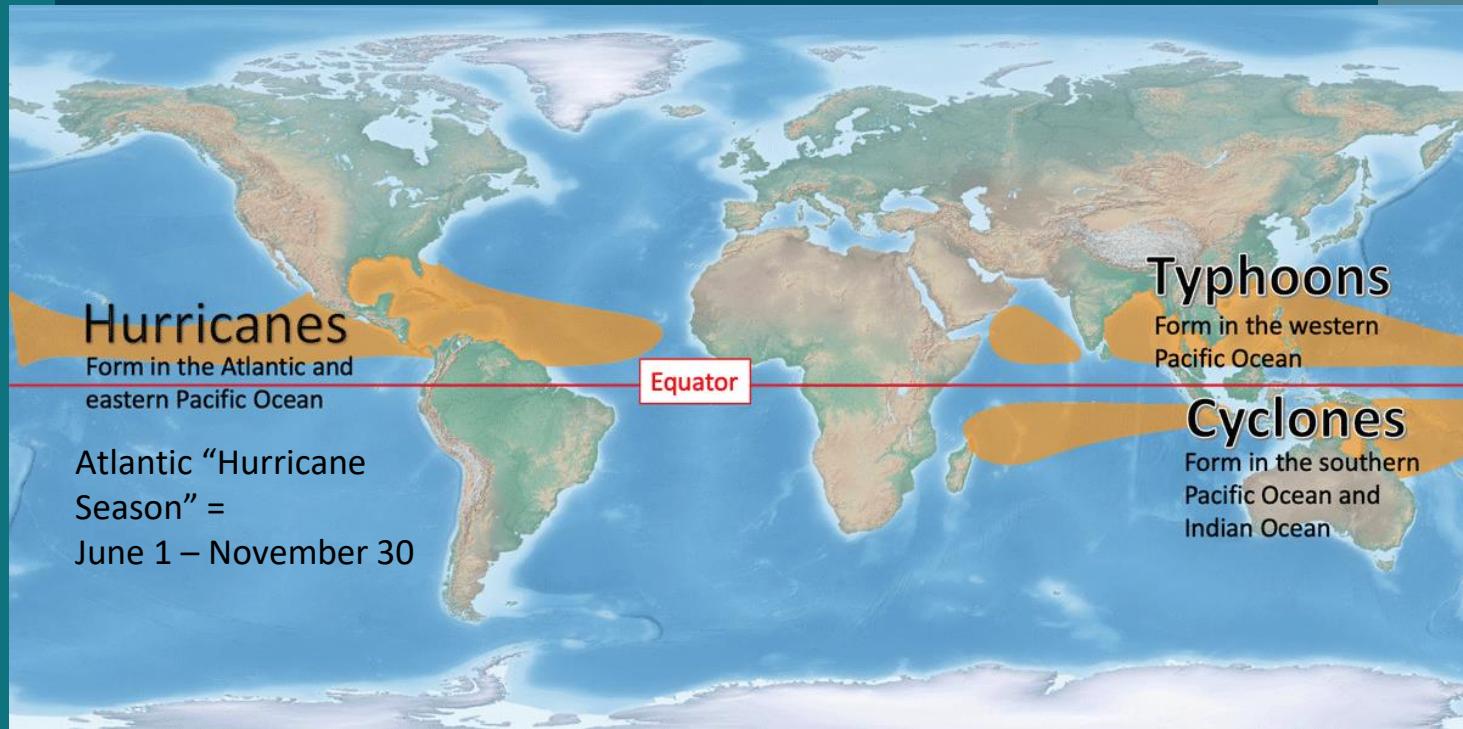
Storms



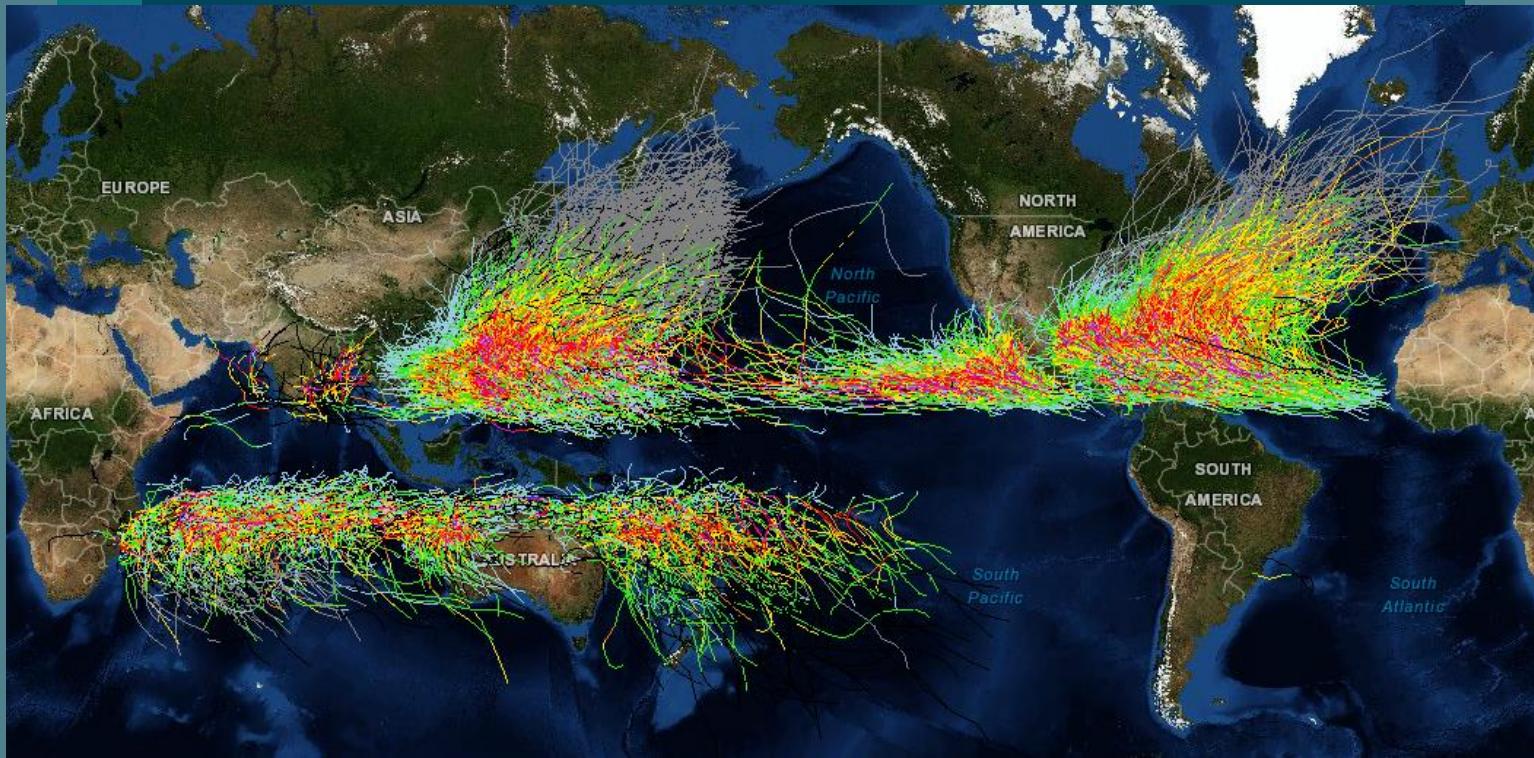
Storms



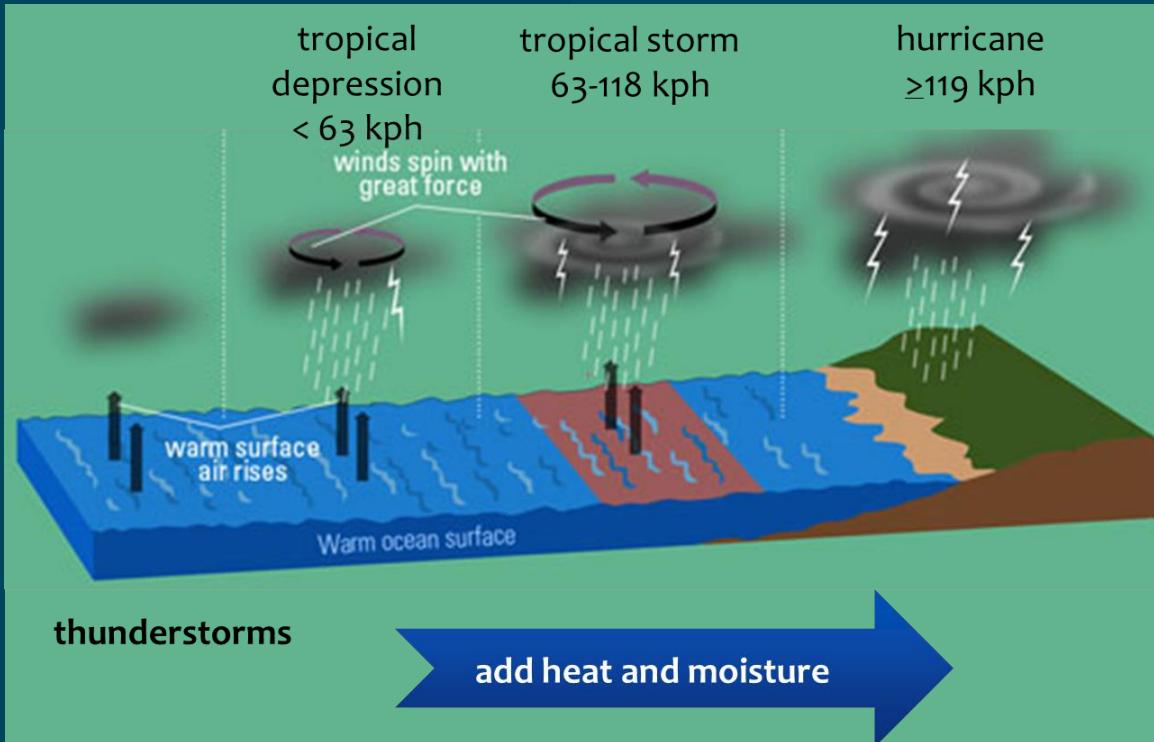
Storms



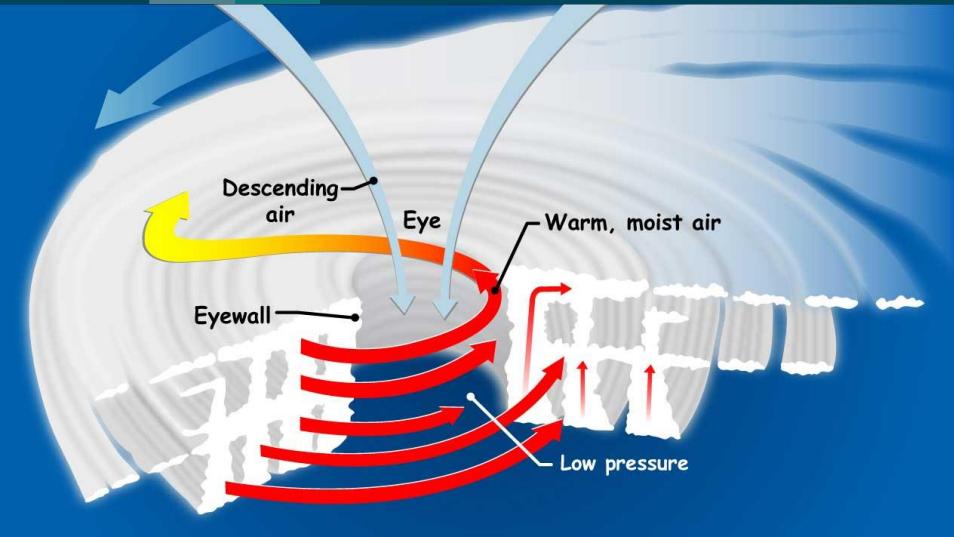
Storms



Storms

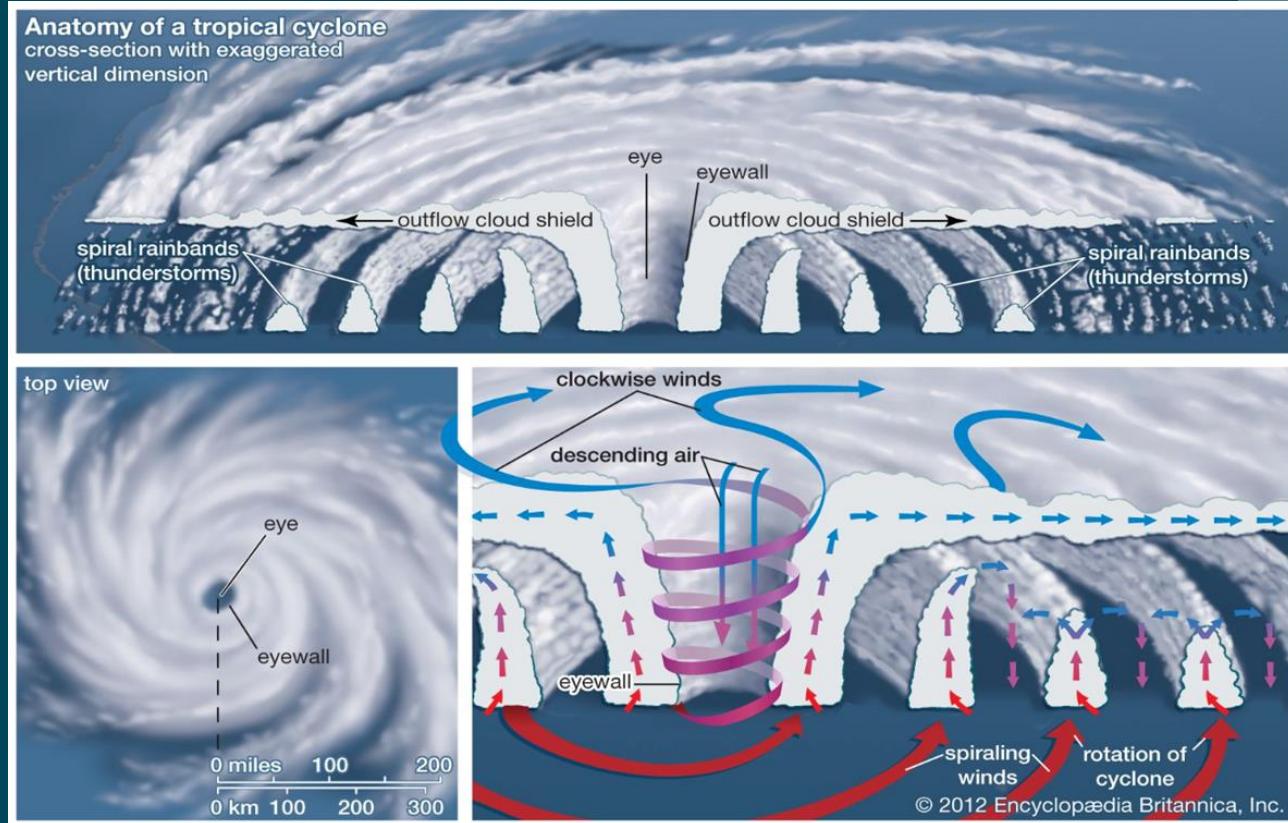


Storms



- Disturbances provides initial spin
- Water $\geq 26.5^{\circ}\text{C}$ to depth of $\sim 50\text{ m}$
- Low wind shear
- Located $\sim 500\text{ km}$ from equator
- Atmospheric temperature & moisture conditions

Storms

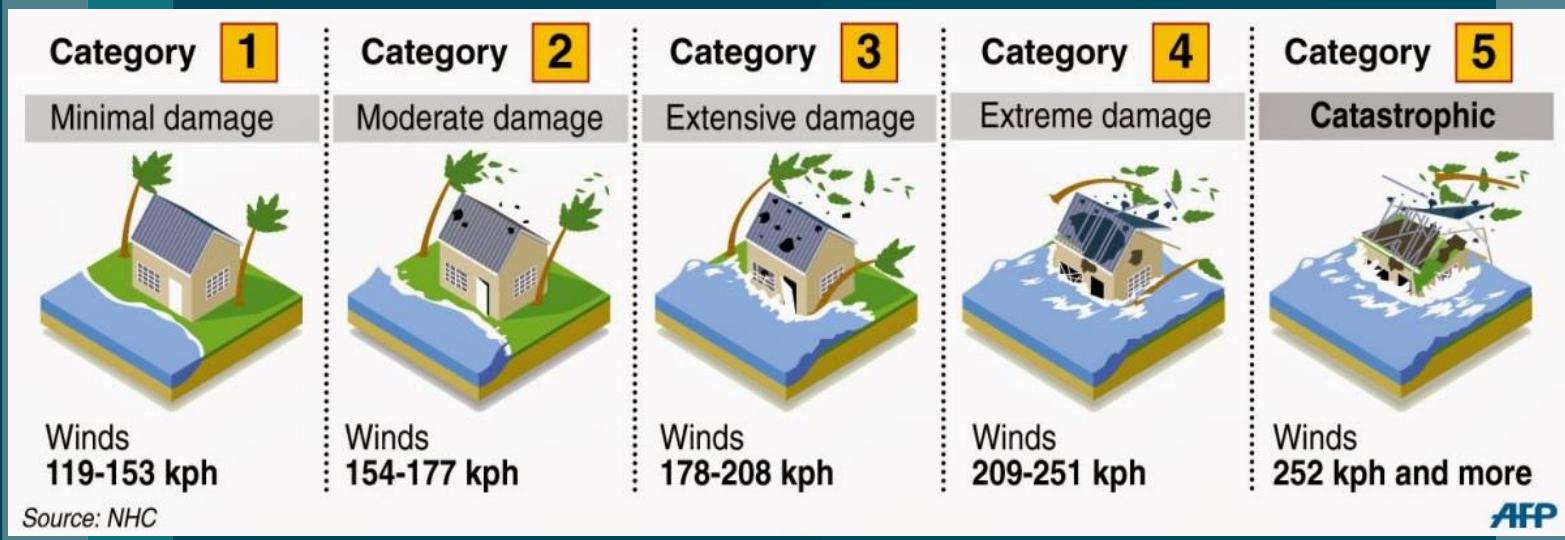


Storms



Storms

Saffir-Simpson Hurricane Wind Scale

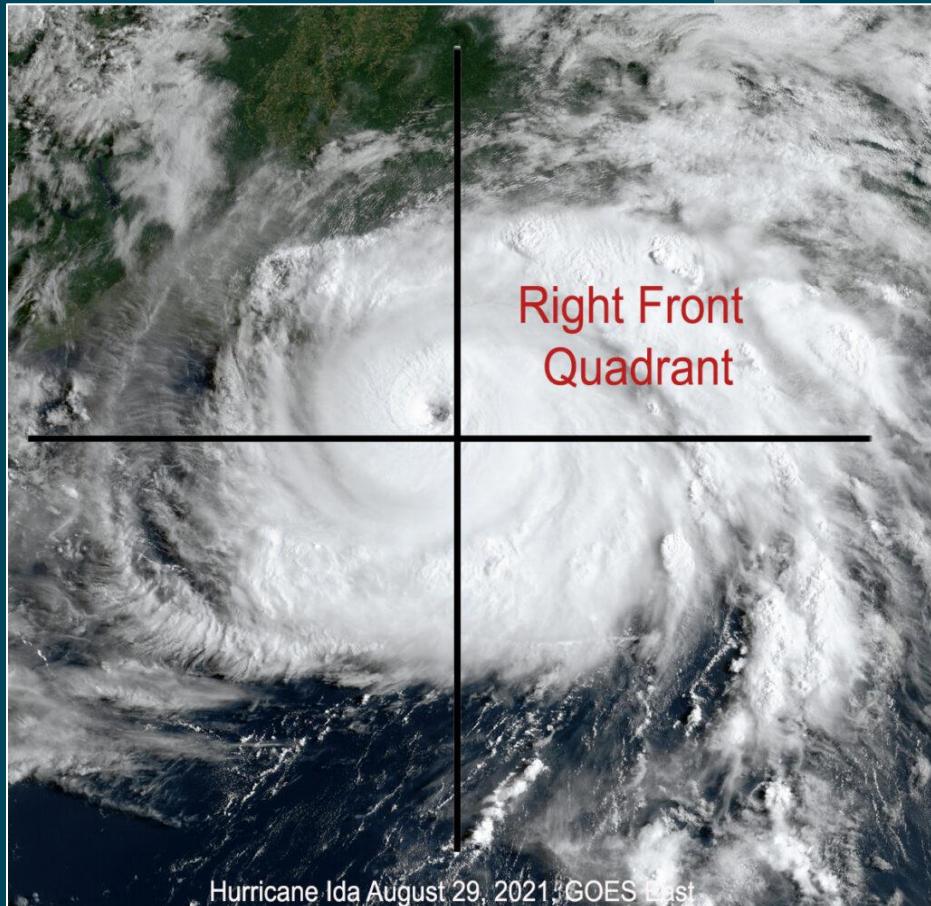


Storms

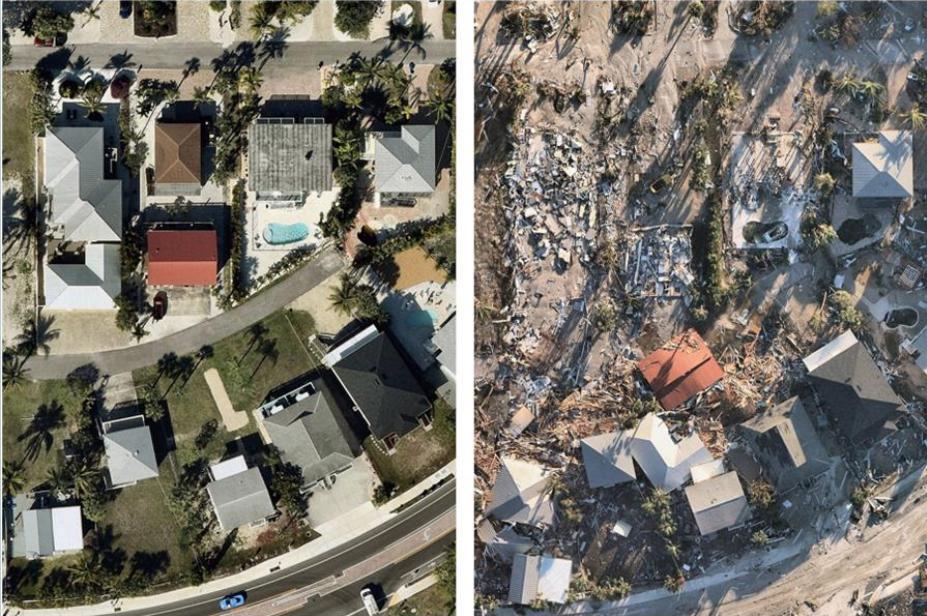


Storms

- Right-front quadrant = higher:
 - Winds
 - Waves
 - Storm surge
- Due to storm motion and atmospheric winds

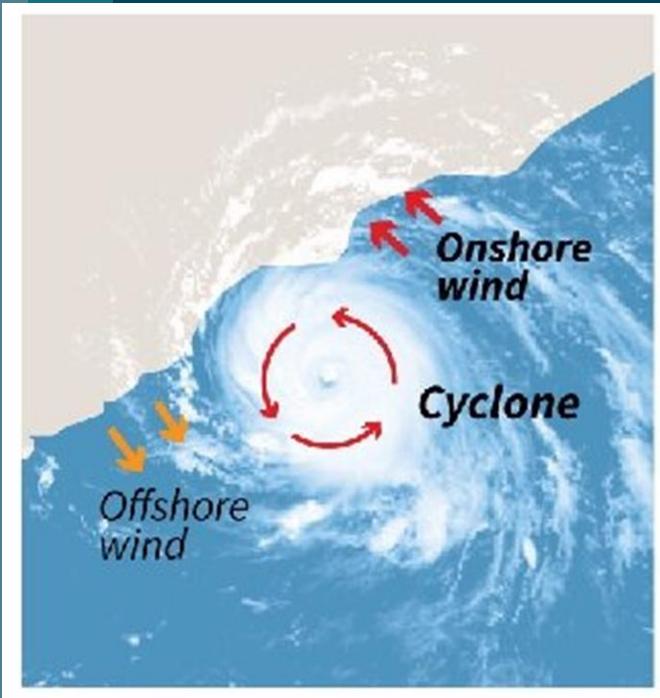


Storms

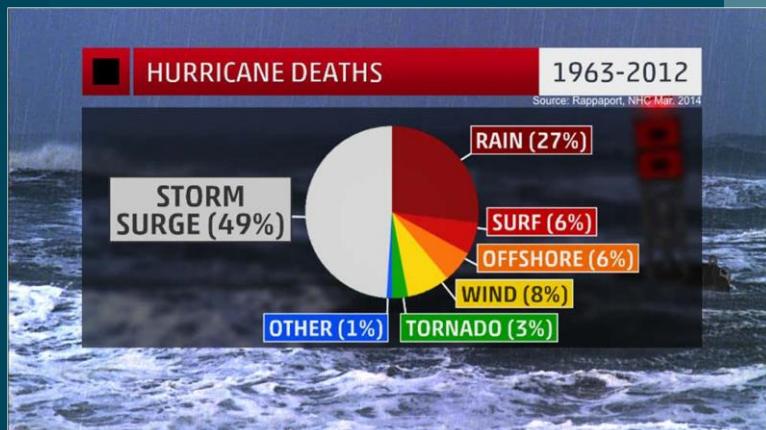


- 1998 to 2017 - ~ 726 million people affected (WHO)
- Hurricane expose population - increased 192%
- Costliest weather disasters

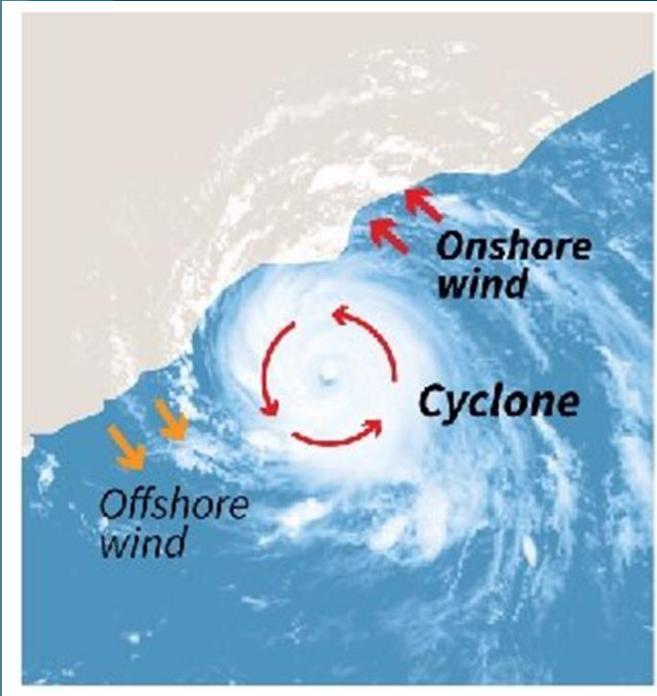
Storms



- Storm surge – elevated water due to hurricane winds and low-pressure center
- Most hazardous component



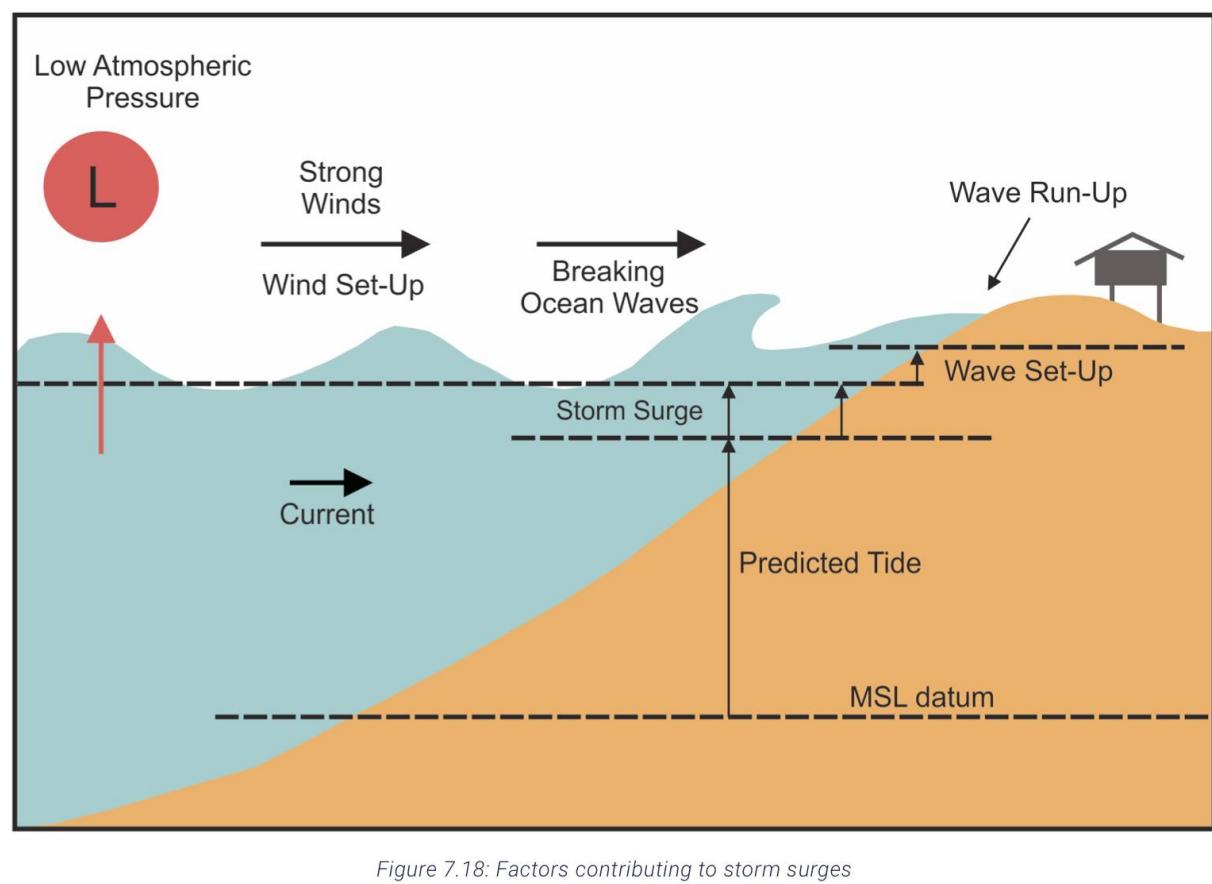
Storms



- Storm surge – elevated water due to hurricane winds and low-pressure center
- Most hazardous component
- Can also have reverse storm surge

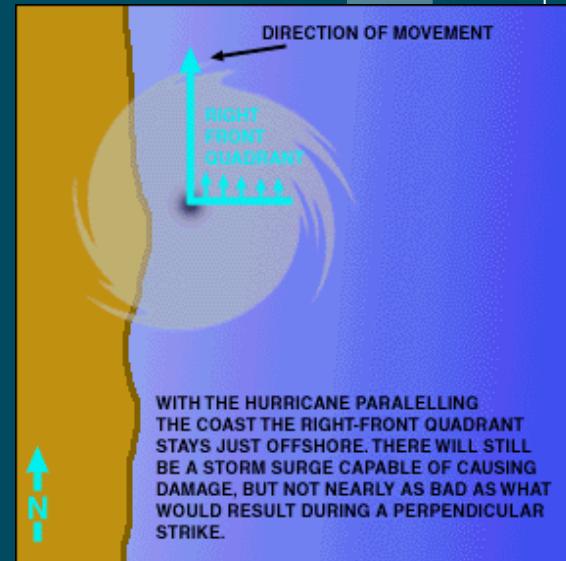
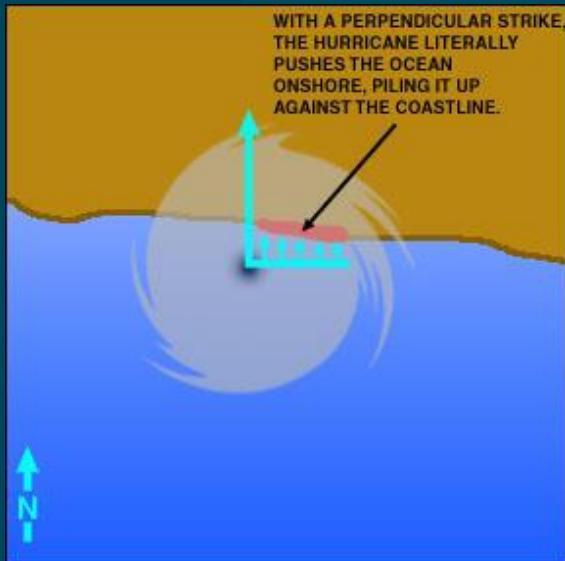
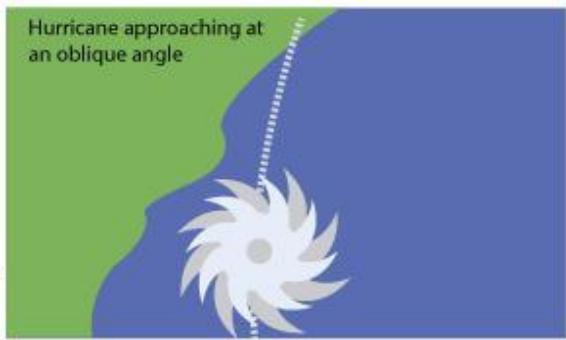


Storms



Storms

- Storm surge also depends on:
 - Wind speed
 - Size of storm
 - Speed of storm
 - Approach angle
 - Coastline configuration

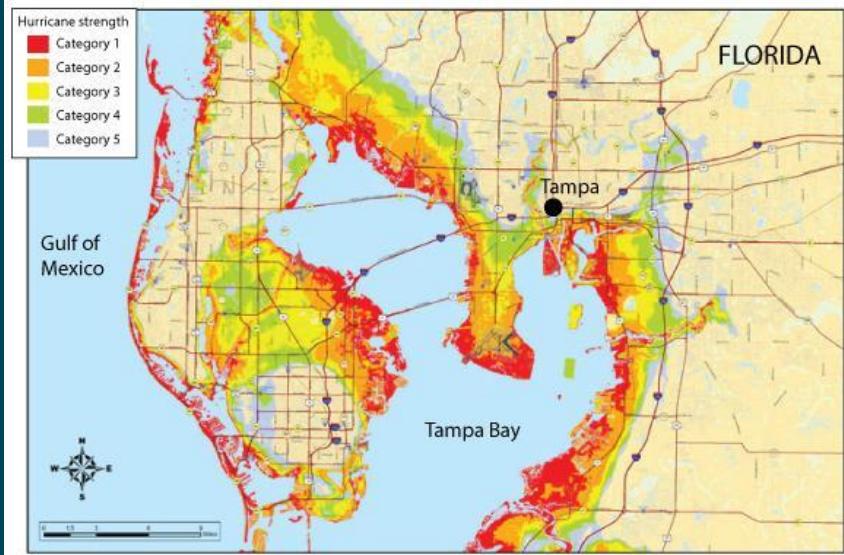


Storms



- Shallow sloping nearshore regions = worse storm surge
- Weak offshore currents
- Water “accumulates”

Storms



- Shallow sloping nearshore regions = worse storm surge
- Weak offshore currents
- Water “accumulates”
- Bays and gulfs enhance storm surge

Storms

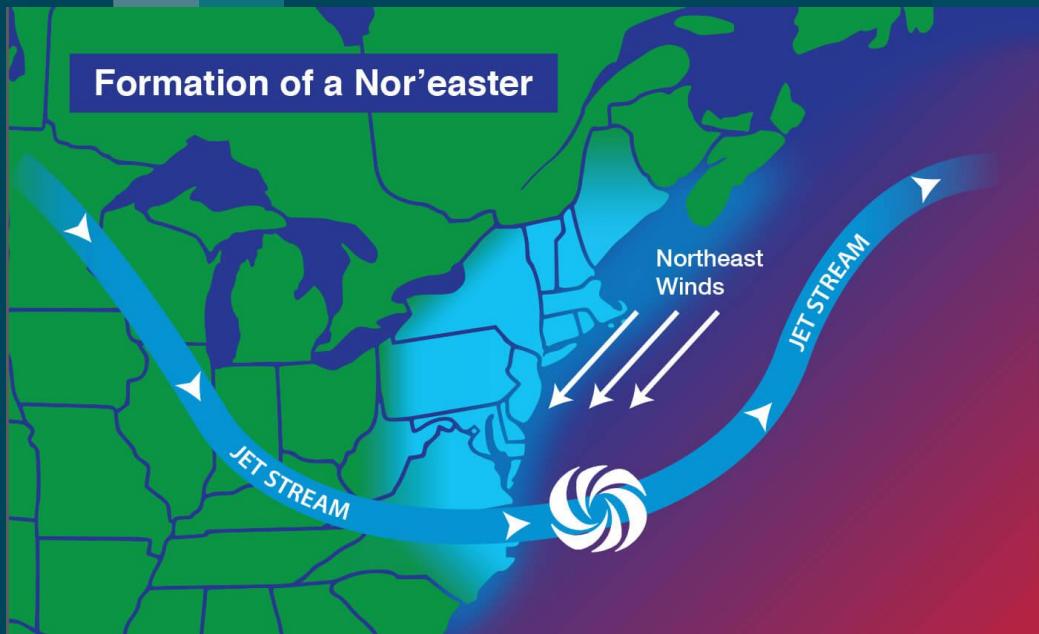


Storms



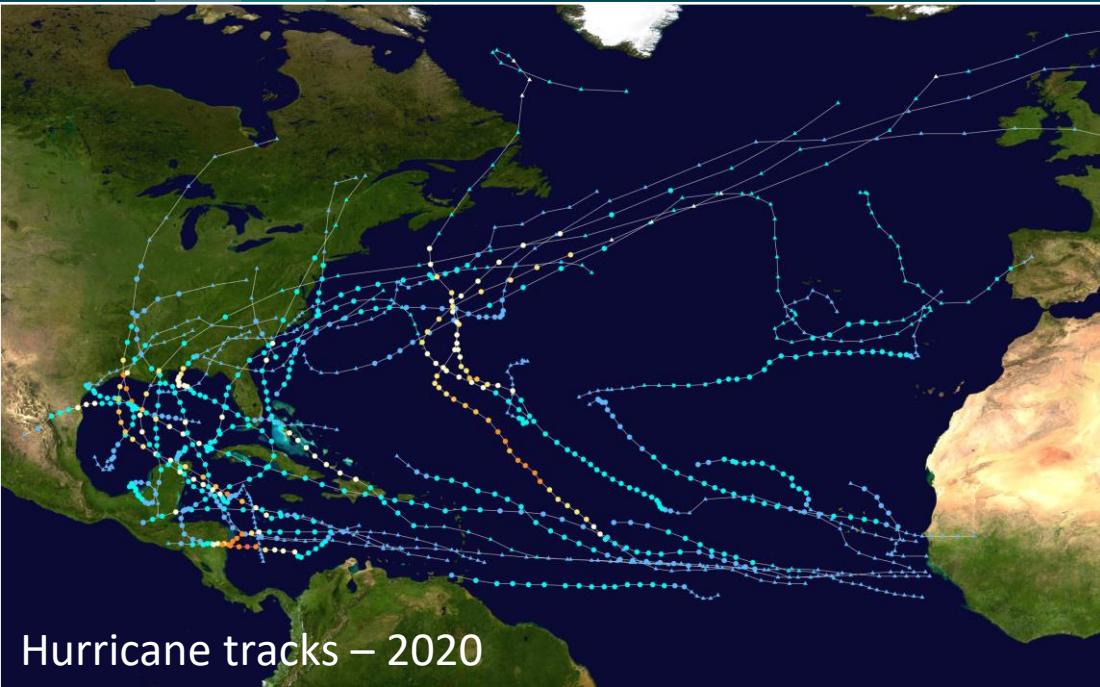
- Nor'easter
 - September – April
 - Move northeast

Storms



- Nor'easter
 - September – April
 - Move northeast
 - Converging air masses
 - Highly erosional

Storms

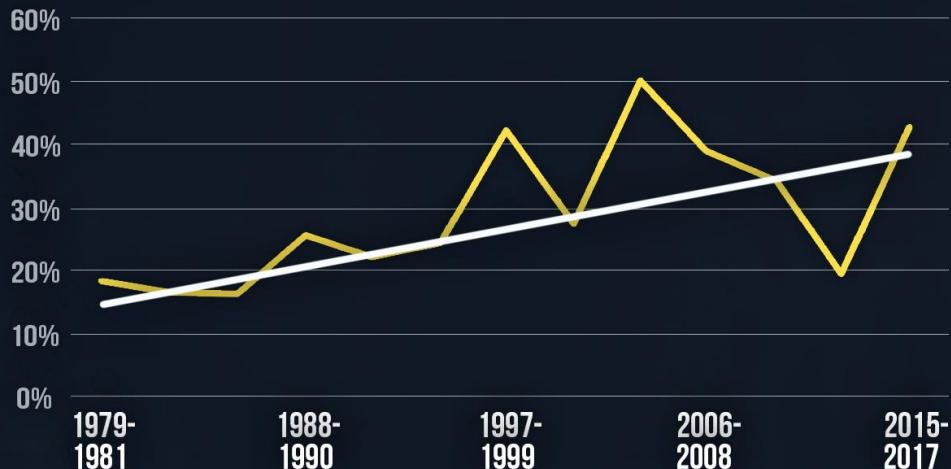


- Climate Change
 - No observed trends in frequency of storm generation
 - Hurricanes stronger and reach farther north
 - More precipitation

Storms

ATLANTIC HURRICANES GETTING STRONGER

PERCENT OF ALL HURRICANES AS MAJOR STORMS

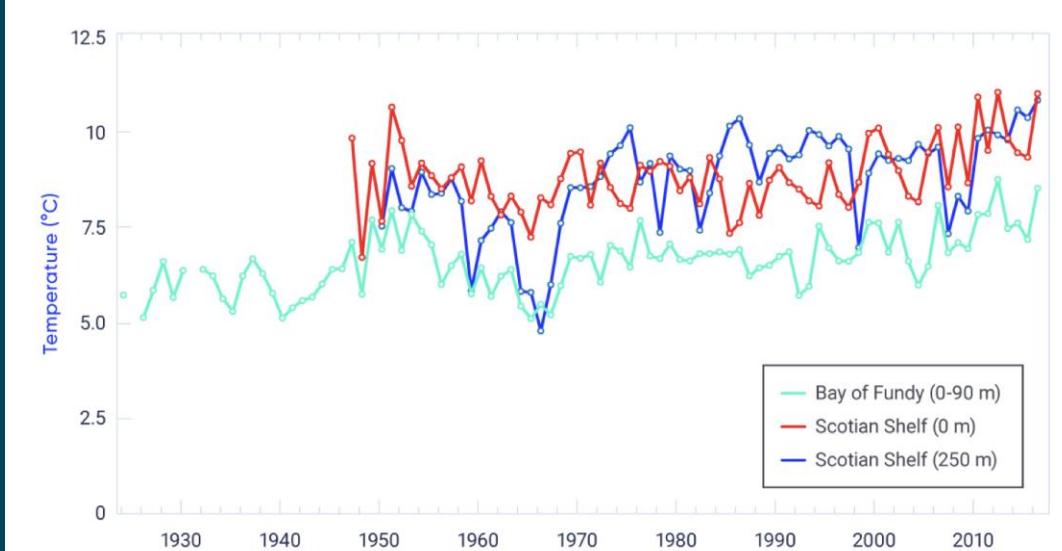
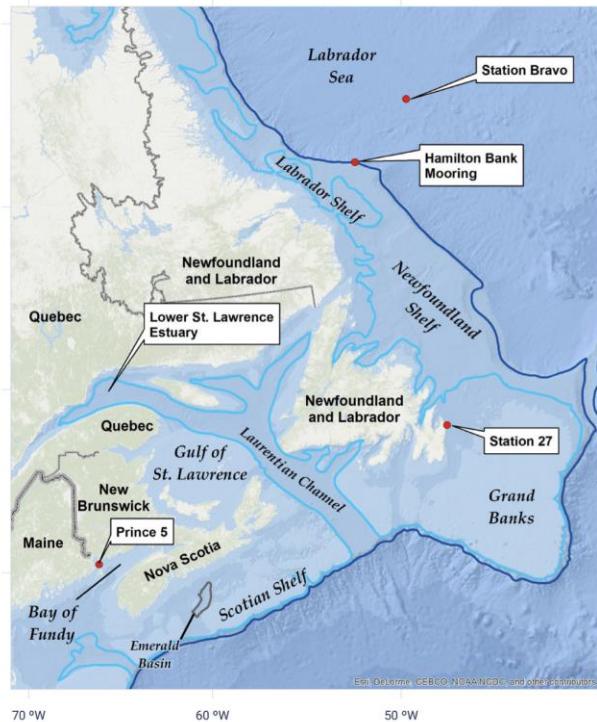


Based on 6-hour observations for major tropical cyclones (Cat 3-5 compared to all Cat 1+ tropical cyclones). Data collected into 3-year periods.
Source: Kossin et al. (2020)

CLIMATE CENTRAL

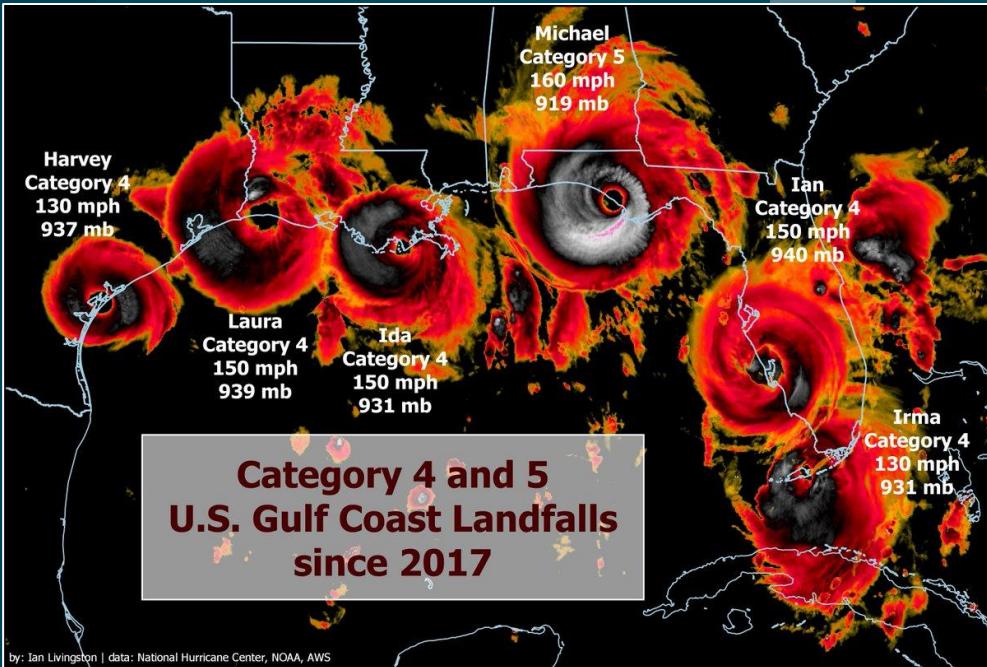
- Increased number of Cat 4's and 5's
 - 335% increase NE Pacific
 - 42% increase N Atlantic
 - 28% global increase

Storms



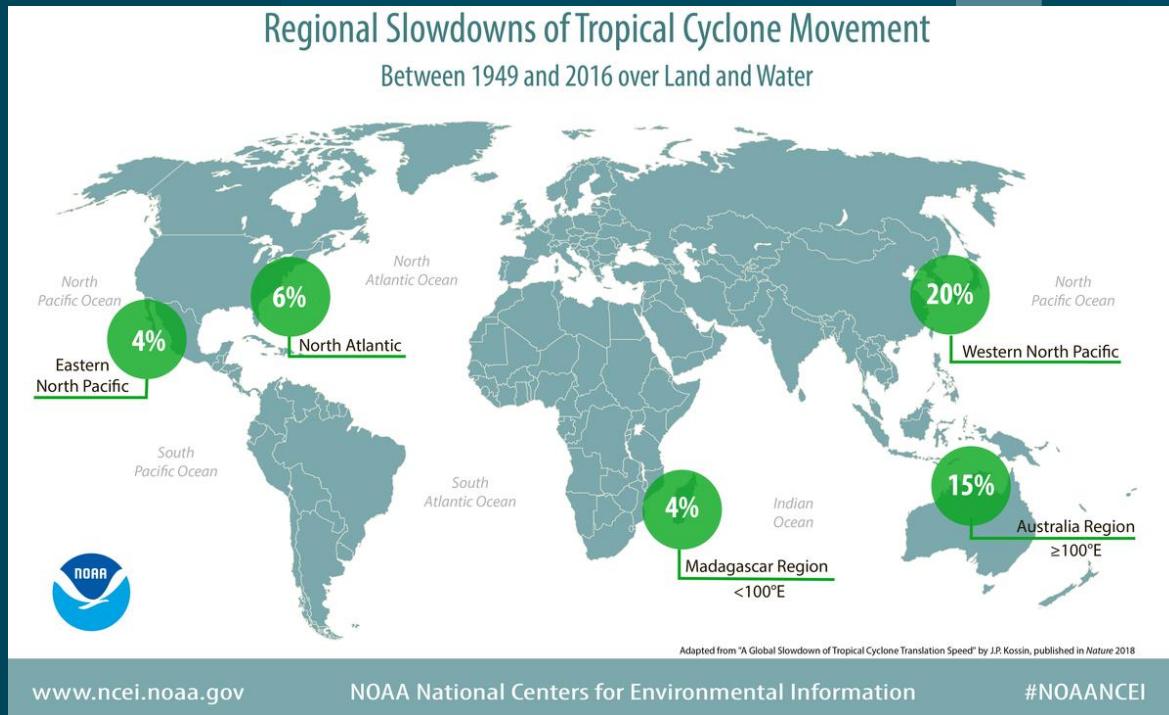
Storms

- Rapid intensification
- Storms become stronger faster
- Harder to predict
- Requires:
 - Moist air
 - Warm ocean water
 - Low wind shear



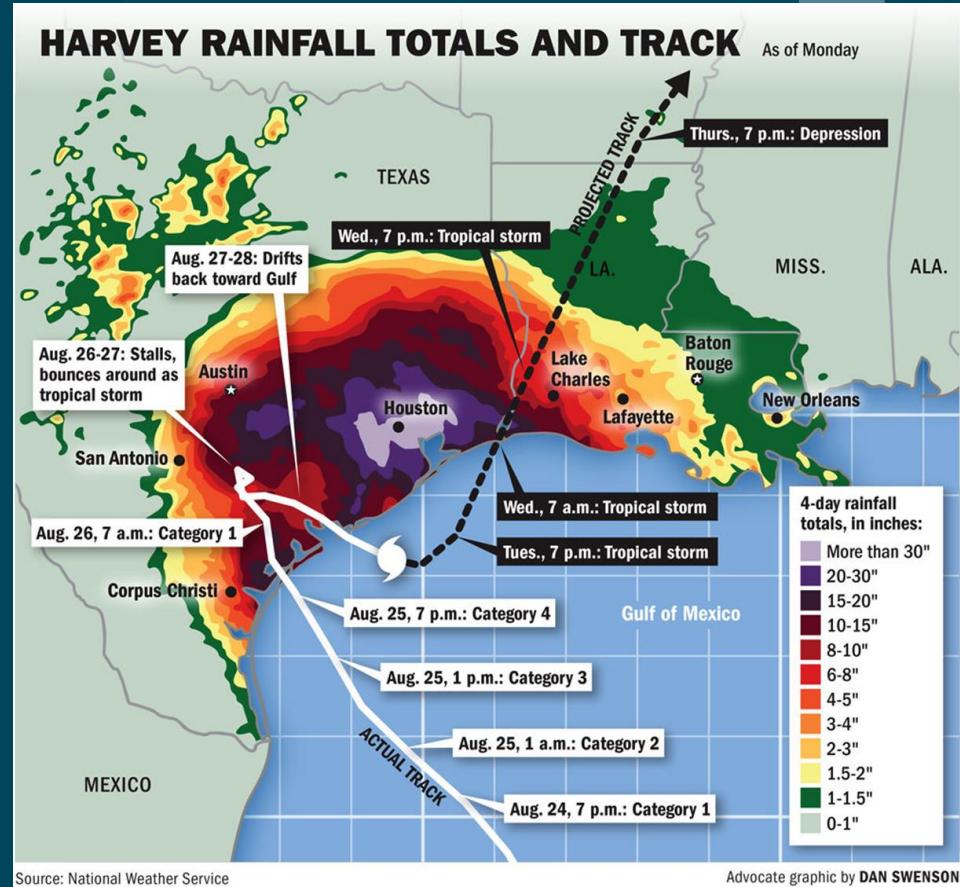
Storms

- Storms “stall”
- 10% global reduction in speed of atmospheric steering winds



Storms

- Storms “stall”
- 10% global reduction in speed of atmospheric steering winds



Storms

