1 ***Shorelines***

Earth – Chapter 20

2 ***Chapter 20 – Shorelines***

3 **The Shoreline: A Dynamic Interface**

- The *interface* is the common boundary where different parts of a system interact.
- The Coastal Zone
  - The shoreline is constantly modified by waves
  - Present-day shorelines
    - The shore is affected by a complex interaction between sea level and local geology.
  - Human activity
    - Despite being fragile, short-lived features, humans treat the coastal zone as a stable platform.

4 **Cape Cod and Point Reyes**

5 **Hurricane Sandy**

6 **The Shoreline: A Dynamic Interface**

- Basic Features
  - The *shoreline* is a line that marks the contact between land and sea.
  - The *shore* extends between the lowest tide level and the highest elevation affected by storm waves.
  - The *coast* extends inland from the shore as far as ocean-related features are found.
  - The *coastline* marks a coast's seaward edge.

7 **The Coastal Zone**

8 **The Shoreline: A Dynamic Interface**

- Basic Features
  - The shore is subdivided
    - The *foreshore* area is exposed at low tide and submerged at high tide.
    - The *backshore* area is found landward of the high-tide mark.
    - The *nearshore zone* lies between the low-tide shoreline and the point where waves break at low tide.
    - The *offshore zone* is seaward of the nearshore zone.

9 **The Coastal Zone**

10 **The Shoreline: A Dynamic Interface**

- Beaches
  - A *beach* is an accumulation of sediment found along the landward margin of an ocean or lake.
    - Beaches are composed of one or more berms (the relatively flat platform composed of sand)
    - The *beach face* is the wet sloping surface that extends from the berm to the shoreline
  - A beach is composed of locally abundant material.
    - Derived from the erosion of adjacent cliffs or nearby mountains
    - Example: black sand beaches in Hawaii; shell beaches in Florida

11 **Beaches**

12 **Waves**

- Waves travel along the ocean–atmosphere interface
  - Waves are the *visible evidence of energy* passing through a medium
- Wind-generated waves provide most of the energy that shapes and modifies shorelines

13 **Waves**

- Wave Characteristics
  - Most waves derive their energy and motion from the wind.
    - Components of simple, nonbreaking waves are:

- –The *crest* is the top of the wave.
- –The *trough* is the bottom of the wave.
- –*Wave height* is the vertical distance between crest and trough.
- –*Wavelength* is the horizontal distance between successive crests (or troughs).
- –*Wave period* is the time it takes for one full wavelength to pass.

14 **Waves**

- Wave Characteristics
  - –Height, length, and period of a wave depend on:
    - Wind speed.
    - Length of time wind has blown.
    - *Fetch* (the distance that the wind has traveled across open water).
  - –Waves can travel great distances
  - –*Wave energy* moves forward, not the water itself
    - As a wave moves through water, the water passes the energy along by moving in a circle
    - This is called circular orbital motion.

15 **Wave Basics**

16 **Passage of a Wave**

17 **Waves**

- Waves in the Surf Zone
  - –Deep water waves are unaffected by water depth
  - –When waves approach the shallower water at the shore, this influences their behavior
  - –As waves “feel bottom,” the seafloor interferes with water movement and the wave begins to slow down
    - Faster deep-water waves catch up and the wave starts to grow higher
    - As the wave gets higher, it becomes too steep and eventually collapses or breaks
      - –Surf is the turbulent water created by breaking waves

18 **Waves Approaching the Shore**

19 **Shoreline Processes**

- Wave Erosion
  - –Breaking waves exert a great force
    - Atlantic winter waves average 10,000 kg/m^2
    - The force during storms is greater still!
  - –Erosion is caused by wave impact and pressure, and also.
  - –*Abrasion*, which is the grinding action of water with rock fragments.
    - Very intense in the surf zone

20 **Storm Waves**

21 **Abrasion – Sawing and Grinding**

22 **Shoreline Processes**

- Sand Movement on the Beach
  - –Movement perpendicular to the shoreline
    - Swash and backwash move sand toward and away from the shoreline
      - –Net loss or gain depends on level of wave activity
        - »Summer typically has light waves and the berm widens (swash dominates)
        - »Winter typically has powerful storm waves that erode the berm (backwash dominates)

23 **Shoreline Processes**

- Sand Movement on a Beach
  - –*Wave refraction*
    - Wave refraction is the bending of a wave
      - –Causes waves to arrive nearly parallel to the shore
    - Consequences of wave refraction

- –Wave energy is concentrated against the sides and ends of headlands
- –Weakened in bays
- –Over time, wave refraction straightens irregular shorelines

24 **Wave Refraction**

25 **Refraction of waves**

26

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29 **Shoreline Processes**

- Sand Movement on the Beach
  - *Longshore transport*
    - Waves seldom approach the shore straight on, but rather at an angle
      - Sediment is transported along the beach face in a zig-zag pattern called beach drift
    - Longshore currents easily move fine suspended sand along the coast
  - Both rivers and coastal zones move water and sediment from upstream to downstream
  - Beaches are often characterized as "rivers of sand"

30 **The Longshore Transport System**

31 **Movement of sand by longshore current**

32

33 **Shoreline Processes**

- Sand Movement on the Beach
  - *Rip currents* flow in the opposite direction of breaking waves
    - Most backwash from waves moves back to the open ocean as sheet flow along the ocean bottom
    - Rip currents are concentrated movements of backwash on the ocean surface

34 **Rip Current**

35 **Shoreline Features**

- Features vary depending on several factors, including:
  - The proximity to sediment-laden rivers.
  - Degree of tectonic activity.
  - Topography and composition of the land.
  - Prevailing winds and weather patterns.
  - Configuration of the coastline.

36 **Shoreline Features**

- Erosional Features
  - Wave-cut cliffs, Wave-cut platforms, and marine terraces
    - *Wave-cut cliffs* originate by the cutting action of the surf against the base of the coast.
    - *Wave-cut platforms* are flat, bench-like surfaces left behind by the receding cliff.
    - A tectonically uplifted wave-cut platform is a marine terrace.

37 **A cliff undercut by wave erosion**

38

39 **Wave-Cut Platform and Marine Terrace**

40

41 **Shoreline Features**

- Erosional Features
  - Sea arches and sea stacks
    - Headlands are the focus of wave erosion due to wave refraction
    - Rocks in headlands do not erode at the same rate
      - Soft and fractured rocks erode faster than hard rocks, forming sea caves
    - A *sea arch* forms when two sea caves meet
    - A *sea stack* forms when the arch of a sea arch falls

42 **Sea Arch and Sea Stack**

43

44 **Shoreline Features**

- Depositional Features
  - Spits, bars, and tombolos
    - A *spit* is an elongated ridge of sand extending from the land into the mouth of an adjacent bay.
    - A *baymouth* bar is a spit that extends across a bay to seal it off from the ocean.
    - A *tombolo* is a ridge of sand that connects an island to the mainland or another island.

45 **Depositional features of coastal Massachusetts**

46 **Coastal Massachusetts**

47 ***San Elijo Lagoon – a baymouth bar***

48 ***Point Sur, California – a tombolo***

49

50 **Shoreline Features**

- Barrier Islands
  - *Barrier islands* are low ridges of sand that parallel the coast 3 to 30 kilometers offshore.
    - Found mainly along the Atlantic and Gulf Coastal Plain
    - Most are 1 to 5 kilometers wide and 15 to 30 kilometers long
    - Probably form in several ways
      - Some originate as spits
      - Some originate from sand piled up offshore
      - Some are flooded sand dunes from the last glacial period

51 **Barrier Islands**

52

53

54 **Barrier islands along the Texas coast**

55 ***Port Isabel, Texas***
edge of Laguna Madre

56 **Shoreline Features**

- The Evolving Shore
  - Shorelines continually undergo modification
  - If the shoreline remains *tectonically* stable, shoreline erosion eventually produces a straighter coast

57 **The Evolving Shore**

58 **Coastal Classification**

- Emergent Coasts
  - Develop because of uplift of an area or a drop in sea level
    - Examples:
      - California coast
      - Hudson Bay
  - Features of an emergent coast
    - Wave-cut cliffs
    - Wave-cut platforms
    - Marine terraces

59 **Coastal Classification**

- Submergent Coasts
  - Caused by subsidence of land adjacent to the sea or a rise in sea level
    - Example:
      - Atlantic Coast
  - Features of a submergent coast
    - *Estuaries* (drowned river mouths)
    - Highly irregular shorelines

60 **East Coast Estuaries**

61 **Relocating Cape Hatteras Lighthouse**

62 **Contrasting America's Coasts**

- Atlantic and Gulf Coasts
  - Most coastal development occurs on barrier islands
    - Receive the full force of major coastal storms
- Pacific Coasts
  - Biggest problem is shrinking beaches
    - Dams on rivers prevent sediment from reaching the coast
    - Thinner beaches cannot protect cliffs
      - Houses built on cliffs
  - Erosion is sporadic because coastal storms are sporadic

63 **Pacific Coast**

64 **Pacoima Dam**

65 **Hurricanes – The Ultimate Coastal Hazard**

- Hurricanes are the greatest storms on Earth
  - Called typhoons in the western Pacific and cyclones in the Indian Ocean
  - Among the most destructive of natural disasters
- Over 50 percent of the U.S. population lives within 75 kilometers of a coast
  - Millions of people at risk

66 **Super Typhoon Haiyan**

67 **Hurricanes – The Ultimate Coastal Hazard**

- Profile of a Hurricane
  - Hurricane formation
    - Form in late summer and early fall
      - Sea surface temperatures must reach 27°C to provide heat and moisture for the storm
      - Warm ocean water temperatures is why hurricane formation over the South Atlantic and South Pacific is rare, and anywhere poleward of 20° latitude
      - Hurricanes do not develop within 5° of the equator because the Coriolis effect is too weak there

68 **When do hurricanes occur?**

69 **Sea Surface Temperatures**

70 **Hurricane Source Regions**

71 **Hurricanes – The Ultimate Coastal Hazard**

- Profile of a Hurricane
  - Hurricanes are intense low pressure centers
  - Pressure gradient
    - Moving toward the center of a hurricane, the pressure decreases
    - A pressure gradient is a measure of how fast the pressure changes per unit distance (e.g., from the outside to the inside of the storm)
      - Steep pressure gradients result in stronger winds
      -

72 **Hurricanes – The Ultimate Coastal Hazard**

- Profile of a Hurricane
  - Storm Structure
    - As warm, moist air approaches the core of the storm, the air rises in a ring of cumulonimbus clouds
      - The wall of this rising air column is called the *eye wall*.
        - »Greatest wind speeds and heaviest rain occur at the eye wall
    - The center of the storm is called the *eye*.
      - Precipitation and wind speed decrease in the eye

- Near the top of the hurricane, the airflow is outward
-

73 **Cross Section of a Hurricane**

74 **Hurricanes – The Ultimate Coastal Hazard**

- Hurricane Destruction
  - The amount of damage from a hurricane depends on:
    - Size and population density of the area affected
    - Shape of the ocean bottom near the shore
  - Most important factor is the strength of the storm
    - Saffir-Simpson Hurricane Scale
      - Ranks relative intensities of hurricanes
      - Examples:
        - »Hurricane Katrina was a category 4 storm.
        - »Hurricane Camille (1969) was a category 5 storm.

75 **Saffir-Simpson Scale**

76 **Hurricanes – The Ultimate Coastal Hazard**

- Hurricane Destruction
  - Storm surge
    - Most devastating damage in the coastal zone
    - A *storm surge* is a large dome of water that sweeps across the coast when a hurricane makes landfall.
      - Intensified by tremendous wave activity superimposed on top of the dome of water
      - In the Northern Hemisphere, storm surge is more intense on the right side of the eye
        - »Winds are blowing toward shore
        - »On the left side, winds blow away from shore

77 **Storm Surge Destruction**

78 **Hurricanes – The Ultimate Coastal Hazard**

  - *Wind damage*
    - Most obvious type of hurricane damage
    - Affect a much larger area than storm surge
    - Hurricanes occasionally produce tornadoes
  - *Heavy rains and inland flooding*
    - May affect areas hundreds of kilometers from the coast several days after the hurricane has passed
    - Examples:
      - Hurricane Floyd—1999
        - »Largest peacetime evacuation in U.S. history
      - Hurricane Camille—1969
        - »Greatest number of deaths associated with flooding in the Blue Ridge Mountains in Virginia

79 **An Approaching Hurricane**

80 **Hurricanes – The Ultimate Coastal Hazard**

- Detecting and Tracking Hurricanes
  - Prior to weather satellites, few storm warnings were given to the population
    - Example: Galveston, Texas—1900
    - Huge storm with lack of adequate warning
    - Killed 8000 people
  -

81 **Aftermath of the Historic Galveston Hurricane**

82 **Hurricanes – The Ultimate Coastal Hazard**

- Detecting and Tracking Hurricanes

- *Satellites*
  - Can monitor vast areas of open ocean
- *Aircraft reconnaissance*
  - Special planes fly into hurricanes to measure details
- *Radar*
  - Basic tool in the observation and study of hurricanes

83 **Hot towers**

84 **Stabilizing the Shore**

- Hard Stabilization
  - During past 100 years there has been increasing development to many coastal areas
  - Hard stabilization includes structures built to protect the coast from erosion
  - *Jetties* are built perpendicular to the shoreline and extend into the ocean near the mouths of rivers and harbors
    - Usually built in pairs to develop and maintain harbors
    - May act as a dam against the longshore current

85 **Jetties**

86 ***Mission Bay jetties***

87 **Stabilizing the Shore**

- Hard Stabilization
  - *Groins* are built perpendicular to the beach and extend into the ocean
    - Built to maintain or widen beaches
    - Constructed at a right angle to the beach to trap sand
      - Erosion occurs downstream of the groin
    - No longer a preferred method to stop beach erosion
      - Because they are essentially ineffective

88 **Groins**

89

90 **Stabilizing the Shore**

- Hard Stabilization
  - Breakwaters and seawalls
    - Built parallel to the shore
    - A *breakwater* is built offshore
      - Protects boats from wave energy
      - Creates a region of sand accumulation between the breakwater and the shoreline
    - A *seawall* is built onshore
      - Designed to protect property from breaking waves
      - Causes severe erosion seaward of the seawall

91 **Breakwater**

92 **Seawall**

93 **Stabilizing the Shore**

- Alternatives to Hard Stabilization
  - Beach nourishment involves adding large quantities of sand to the beach
    - Costly and not a permanent solution
    - The same processes eroding the beach in the first place will also erode the imported sand
    - Typically costs millions of dollars per mile
  - Relocation
    - Abandoning or relocating buildings away from the beach
    - Letting nature reclaim the beach
    - Very controversial

94 **Beach Nourishment**

95

96 **Tides**

- *Tides* are daily changes in the elevation of the ocean surface
- Causes of Tides
  - Tidal bulges are caused by the gravitational forces of the Moon, and to a lesser extent the Sun
  - The position of the Moon only changes moderately in a day
    - Earth rotates "through" tidal bulges

97 **Idealized Tidal Bulge Causes by the Moon**

98 **Tides are caused by the gravity of the Moon and Sun acting on the ocean**

99 **Tides**

- Monthly Tidal Cycle
  - *Spring tides* produce especially high and low tides
    - Large daily tidal range
    - Occur during new and full moons
      - Gravitational forces of the Moon and Sun are added together
  - *Neap tides* produce a small tidal range
    - Occur when the Sun and Moon are at right angles to each other

100 **Spring and Neap Tides**

101 ***Spring Tide***

102 ***Neap Tide***

103 **Tides**

- Tidal Patterns
  - Other factors that influence tides
    - Shape of the coastline
    - Configuration of the ocean basin
  - A *diurnal tidal pattern* is characterized by a single high tide and a single low tide each tidal day
    - Example:
      - Northern shore of the Gulf of Mexico

104 **Bay of Fundy**

105

106

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108 **Tides**

- Tidal Patterns
  - A *semidiurnal tidal pattern* is characterized by two high tides and two low tides each tidal day
    - Example:
      - Atlantic Coast of the U.S.
  - A *mixed tidal pattern* is also characterized by two high tides and two low tides each tidal day
    - Large inequality in high or low water heights
    - Example:
      - Pacific Coast of the U.S.
      -

109 **Tidal Patterns**

110 **Tides**

- Tidal Currents
  - Tidal currents are the horizontal flow of water accompanying the rise and fall of the tide
  - Water movements induced by tidal forces
    - *Flood currents* are associated with landward moving currents.
    - *Ebb currents* are associated with seaward moving currents.

–Flood and ebb currents separated by slack water

• *Tidal flats* are affected by tidal currents.

• *Tidal deltas* are created by tidal currents.

–May develop as flood deltas or ebb deltas

111 **Tidal Deltas**

112 **End of Chapter 20**