1 EVPP 110

Instructor: Dr. Largen

### **Oceans**

## <sup>2</sup> Global Environments

- ✓ Global Environments
  - distribution of biomes results from interaction of physical geography and two key physical factors
    - · solar radiation
    - · global circulation patterns
      - oceanic
      - atmospheric

3 🗷

## 4 Global Environments

- ✓ Global Environments
  - interdependent relationship between the ocean and the atmosphere
    - · has profound ramifications over the earth
      - because the same physical processes determine the operation of both systems
      - changes that occur in the ocean lead to long-term shifts in the general circulation of the atmosphere
        - » observing key features and processes in the oceans can lead to the prediction of atmospheric phenomena

# 5 Global Environments

- ✓ Global Environments
  - the atmosphere and ocean together act like a global heat engine
    - continually redistributing heat that reaches the earth from the sun

# Global Environments:

### Solar radiation

- ✓ Solar radiation
  - warms the earth's surface and drives the circulation of the oceans and the atmosphere
  - is emitted by the sun, in the form of radiant energy, at same average rate in all directions
  - is received on the earth's surface in varying amounts, depending on
    - · distance between earth's surface and sun
    - duration of daylight (exposure to sun's rays)
      - varies with season and latitude
    - angle at which sun's rays impinge on surface

7 🗷

8 🗷

9 ☐ Global Environments: Solar radiation

#### ✓ Solar radiation

- variations in the amount of solar radiation reaching the earth's surface
  - · leads to uneven heating of the atmosphere and the oceans
    - which in turn drives the interrelated patterns of circulation of the oceans and the atmosphere

### 10 🗷

### 11 Global Environments

- ✓ The Oceans
- √ The Atmosphere
  - composition and structure
  - water vapor and its effects
  - circulation
  - special focus topics
    - air quality
    - · acid deposition
- ✓ Global climate change

## 12 Global Environments:

### The Oceans

- ✓ The Oceans
  - circulation
    - El Nino
  - tides

## 13 The Oceans: Circulation

- ✓ Historical perspective
  - most early knowledge of ocean currents came from ship captains and explorers
    - Pliny (~AD 50) described strong currents flowing into Mediterranean thru Strait of Gibraltar
    - Arabs (around 9th century) were aware of reversing currents of Arabian Sea & timed trading voyages to Africa to take advantage of the currents
    - · Benjamin Franklin (in 18th century) developed crude chart of the Gulf Stream current

# 14 The Oceans: Circulation

- ✓ Historical perspective
  - Matthew Fontaine Maury
    - · a lieutenant in US Navy
    - first person to use large amounts of ocean data in a systematic study of surface currents
    - from 1841 1853 he worked to compile data accumulated in thousands of old log books
      publishing the first pilot charts and sailing directions for all the world oceans

- ✓ Historical perspective
  - Matthew Fontaine Maury

- additionally, he
  - laid the foundation for the establishment of the US Weather Bureau
  - did most of the work in determining the location for the first transatlantic cable
  - was instrumental in the establishment of the US Naval Academy

- ✓ Circulation patterns of oceans
  - two types of circulation exist in the oceans
    - · surface circulation
      - horizontal movement of water
      - driven by force of winds at water surface
    - · thermohaline circulation
      - vertical movement of water
      - driven by density differences resulting from variations in water
        - » temperature
        - » salinity

# 17 The Oceans: Circulation

- ✓ Circulation patterns of oceans
  - are affected by four main factors
    - · wind acting on the ocean surface
      - wind itself is produced by uneven heating resulting from solar radiation
    - containment of the oceans within boundaries set by land masses
      - due to interference from land masses, no currents run all the way around the world except in the Antarctic region
    - · earth's rotation
    - · water density

## 18 The Oceans: Circulation

- ✓ mechanics of ocean circulation patterns
  - the effect of wind
    - blowing over the surface of the ocean exerts a push on the water
      - due to the friction forces that are stronger in the water than in the air
        - » the speed of the water is only a fraction of that of the wind
      - response time of ocean currents to changes in atmospheric circulation is many months

- ✓ mechanics of ocean circulation patterns
  - the effect of wind
    - if earth was covered entirely with water,
      - the winds would form well-defined belts and ocean currents would also move in distinct belts under the influence of prevailing winds

20 🗷

## 21 The Oceans: Circulation

✓ mechanics of ocean circulation patterns

- the effect of continents
  - the presence of landmasses, continents, modifies the idealized oceanic circulation patters
  - · since an ocean current cannot easily leave its basin
    - generalized circulation patterns in ocean basins tend to consist of closed loops called gyres

22 🗷

## <sup>23</sup> The Oceans: Circulation

✓ mechanics of ocean circulation patterns

- the effect of the earth's rotation
  - due to the rotation of the earth, objects moving in a straight line along its surface are deflected, as if a sidewise force were acting on it
    - this is called the Coriolis effect
      - » which always acts sidewise on objects moving horizontally on the earth

# <sup>24</sup> The Oceans: Circulation

- ✓ mechanics of ocean circulation patterns
  - the effect of the earth's rotation
    - because the earth spins to the east, the Coriolis effect causes a deflection
      - to the right of the direction of motion in the Northern Hemisphere
      - to the left of the direction of motion in the Southern Hemisphere

25 🗷

# <sup>26</sup> The Oceans: Circulation

- ✓ mechanics of ocean circulation patterns
  - the effect water density
    - · density increases with
      - increases in salinity
      - increases in pressure
      - decreases in temperature
    - thermohaline circulation

# <sup>27</sup> The Oceans: Circulation

✓ mechanics of ocean circulation patterns

- the effect water density
  - · thermohaline circulation
    - primarily a convection flow
      - » cold, dense waters from polar latitudes sink and move towards the tropics
      - » replaced by warmer surface waters that originated in the tropics

- ✓ Ocean surface circulation is dominated by two huge surface gyres which
  - move around the subtropical zones of high pressure between 30° N & 30° S latitudes
    - · Northern Hemisphere gyre
      - circulates in clockwise direction
        - » prevailing winds blow W to E due to earth's eastward rotation are deflected to the right
    - · Southern Hemisphere gyre

### <sup>29</sup> The Oceans: Circulation

- ✓ Ocean surface circulation is dominated by two huge surface gyres which
  - move around the subtropical zones of high pressure between 30° N & 30° S latitudes
    - · Northern Hemisphere gyre
    - · Southern Hemisphere gyre
      - circulates in counterclockwise direction
        - » prevailing winds blow west to east due to earth's eastward rotation are deflected to the left

## 30 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - have tendency to
    - · form loops of circulation marked by
      - strong currents on the perimeters
      - relatively little movement internally
    - move warm water poleward and cold water toward tropics
      - thus helping to equalize distribution of heat

#### 31 🗷

# 32 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - western boundary currents
  - eastern boundary currents
  - equatorial currents
  - polar circulation

- ✓ Principle oceanic surface currents
  - western boundary currents

- general northward current of warm equatorial water flowing at the west edge of each ocean basin
- tend to be narrow, swift, deep flows with well-defined boundaries

- ✓ Principle oceanic surface currents
  - western boundary currents
    - · strong in Northern Hemisphere
      - the Gulf Stream in the Atlantic Ocean
      - the Kuroshio or Japanese Current in the Pacific Ocean
    - · weaker in the Southern Hemisphere
      - the Brazil Current in the Atlantic Ocean
      - the West Australia Current in the Pacific Ocean

35 🗷

## 36 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - western boundary currents, examples
    - · the Gulf Stream
      - warm northward current in north Atlantic Ocean
      - runs from Cape Hatteras to near the Grand Banks of Newfoundland
      - reaches Europe near the southern British Isles
        - » as a result, western Europe is warmer and more temperate than eastern North American at similar latitudes

37 🗷

- ✓ Principle oceanic surface currents
  - western boundary currents, examples
  - the Kuroshio Current
    - warm northward current in northen Pacific Ocean
    - runs along Japan northeast towards Alaska
      - » as a result, Alaska has a more temperate climate than would be expected based on its latitude

#### 39 🗷

### 40 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - eastern boundary currents
    - · occur along eastern sides of oceans
    - · tends to be broad, weak, shallow flows with poorly-defined boundaries
    - the force of the wind and the Coriolis effect combine at western continental seacoast and cause warm surface water to move away from the coast and out to sea
      - deep cold water then moves upward to replace the water that blows seaward
        - » producing a process called upwelling

### 41 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - eastern boundary currents, examples
    - in Northern Hemisphere
      - the Canary Current in the Atlantic Ocean
      - the California Current in the Pacific Ocean
    - in the Southern Hemisphere
      - the Benguela Current in the Atlantic Ocean
      - the Peru (Humboldt) Current in the Pacific Ocean

#### 42 🗷

## 43 The Oceans: Circulation

- ✓ Principle oceanic surface currents
  - eastern boundary currents
    - · significance of upwelling
      - brings deep, cool, nutrient-rich water to the surface
        - » water is rich in nutrients because of the the numerous creatures that die in surface waters and then sink
      - the Peru (Humboldt) Current is an example

#### 44

- ✓ Principle oceanic surface currents
  - eastern boundary currents
    - · significance of upwelling
      - the Peru (Humboldt) Current

- » flows northward along western coast of South America
- » a large amount of upwelling is normally associated with this current

- ✓ Principle oceanic surface currents
  - eastern boundary currents
    - · significance of upwelling
      - the Peru (Humboldt) Current
        - » upwelling provides nutrients for enough phytoplankton to support the largest anchovy population in the world
        - » the anchovy fishery is one of the largest industries in Peruvian economy

#### 47 🗷

# 48 The Oceans: Circulation

- ✓ Principle oceanic currents
  - equatorial currents
    - · are confined mostly to the surface
    - warm, well-mixed surface layer and a sharp thermocline that separates warm surface water from cold water below
      - except at the equator where mixing across the thermocline occurs

## 49 The Oceans: Circulation

- ✓ Principle oceanic currents
  - equatorial currents
    - · North Equatorial Current
      - westward-flowing
      - southern-most portion of Northern Hemisphere gyre
    - · Equatorial Countercurrent
      - eastward-flowing
      - separates the North and South Equatorial Currents
    - · South Equatorial Current
      - westward-flowing
      - northern-most portion of the Southern Hemisphere gyre

# 50 ☐ Image 0049

Ocean Circulation

- ✓ Principle oceanic currents
  - polar circulation

- · circulation N & S polar regions is different
- · north polar region
  - Arctic Ocean is covered by pack ice
  - circulation is characterized by sluggish counterclockwise drift
  - deep cold water from the Arctic Ocean is kept from mixing freely with that in the Atlantic and Pacific Oceans by shallow sills between continental blocks

- ✓ Principle oceanic currents
  - polar circulation
    - · south polar region
      - water flows freely between the Atlantic and Pacific Oceans
      - Antarctic Circumpolar Current
        - » largest current in the world
        - » circles Antarctica
        - » extends all the way to the bottom
        - » flows eastward

# 53 ☐ Image 0049

Ocean Circulation

# The Oceans: Circulation Special Focus Topic

#### ✓ El Nino

- name originally coined in late 1800s by Peruvian fishermen as the name for a seasonal shift in the current pattern off the coast of Ecuador and Peru
  - · that occurred around Chrsitmas time
    - thus El Nino (Spanish for "Christ child)
  - would replace the cold, nutrient rich water in which they usually fished with less productive, warm southward flowing water
    - » slightly reducing the fish population and giving the fishermen some time off

# 55 ■ The Oceans: Circulation Special Focus Topic

#### ✓ El Nino

- now the name refers to a catastrophic version of that original annual event
- part of a phenomenon known as El Nino-Southern Oscillation (ENSO)
  - a continual but irregular cycle of shifts in ocean and atmospheric conditions that affect the globe

# The Oceans: Circulation Special Focus Topic

#### ✓ El Nino-Southern Oscillation (ENSO)

- normally, the Pacific Ocean is fanned by constantly blowing east-to-west trade winds
  - which push away from the coast the warm surface water along western coasts of Peru, Chile, Ecuador
    - allowing cold, nutrient-rich water from depths to well up (upwelling) into the place of the warm water that has been pushed away

# 57 ☐ The Oceans: Circulation Special Focus Topic

#### ✓ El Nino-Southern Oscillation (ENSO)

- warm water that was pushed away from the coast "piles" up in western portion f the Pacific Ocean
  - resulting in the waters of the western Pacific Ocean being several degrees warmer and about one meter higher than the waters in the eastern portion of the Pacific

58 🗷

59 🗷

# 60 ■ The Oceans: Circulation Special Focus Topic

#### ✓ El Nino-Southern Oscillation (ENSO)

- if east-to-west trade winds slacken briefly
  - · warm water begins to slosh back across the Pacific Ocean from west to east
    - ocean & atmosphere can conspire to ensure that it keeps happening
  - the warmer the eastern ocean gets, the warmer and lighter the air above it becomes

# 61 The Oceans: Circulation

# Special Focus Topic

#### ✓ El Nino-Southern Oscillation (ENSO)

- the warmer the eastern ocean gets, the warmer and lighter the air above it becomes
  - and, hence, the more similar to the air on the western side (of the ocean)
  - reducing difference in pressure across ocean
    - since a pressure difference is what makes the wind blow, a lack thereof causes the easterly trade winds to weaken
    - the continued reduction in winds allows warm water to continue its eastward advance

62 🗷

# 63 ■ The Oceans: Circulation Special Focus Topic

#### ✓ El Nino-Southern Oscillation (ENSO)

- end result is to shift the weather systems of the western Pacific Ocean about 6000km eastward
  - tropical rainstorms that usually drench Indonesia and the Philippines are caused when seawater abutting these islands cause the air above it to rise, cool and condense into clouds
    - when the warm water moves east, so do the clouds, leaving previously rainy

#### Indonesia and the Philippines in drought

- 64 🗷
- 65 🗷
- 66 🔽
- <sup>67</sup> The Oceans: Circulation Special Focus Topic
  - ✓ El Nino-Southern Oscillation (ENSO)
    - ecological effects during an El Nino
      - in the waters of Peru and northern Chile
        - commercial fish stocks virtually disappear
          - » the commercially valuable anchovy fisheries of Peru were essentially destroyed by the 1972 El Nino
        - plankton dropped to 1/20th of their normal abundance
- 68 🗷
- 69 🗷
- The Oceans: Circulation Special Focus Topic
  - ✓ El Nino-Southern Oscillation (ENSO)
    - ecological effects during an El Nino
      - weather effects are propagated across world's weather systems
        - violent winter storms, accompanied by flooding, lash the coast of California
        - colder and wetter winters occur in Florida and along Gulf Coast
        - American midwest and the Mid-east experience heavier than usual rains
- 71 🗷
- The Oceans: Circulation Special Focus Topic
  - ✓ El Nino-Southern Oscillation (ENSO)
    - although effects of El Nino are clear, what triggers them is not
      - models suggest that the type of climate change that triggers El Nino is chaotic
        - wind and ocean currents return again and again to the same condition but never in a regular pattern
          - » small nudges can send them off in many different directions

# The Oceans: Circulation Special Focus Topic

- ✓ El Nino-Southern Oscillation (ENSO)
  - in the news, Washington Post, "Science Notebook, El Nino: The Sequel", 1/14/02
    - El Nino may appear this spring after a 5 year absence
    - prediction based on detection of warming over tropical Pacific Ocean
    - · its return would likely cause
      - drier-than-normal fall in Pacific Northwest
      - wetter-than-normal winter in Gulf Coast and maybe California
      - warmer-than-normal in Great Plains

# The Oceans: Circulation Special Focus Topic

- ✓ El Nino-Southern Oscillation (ENSO)
  - noteworthy El Ninos
    - 1982 1983: 2100 deaths, \$13 billion in damages
      - Austraila, already in midst of worst drought in a century, suffered losses that cost billions
        - » wildfires, catastrophic agricultural & livestock losses
      - drought in sub-Saharan Africa
        - » countries that were normally food-exporting had to turn to international community for help
      - southern Ecuador and northern Peru
        - » app. 100 inches of rain fell in 6 month period

# The Oceans: Circulation Special Focus Topic

- ✓El Nino-Southern Oscillation (ENSO)
  - noteworthy El Ninos
    - 1997 1998:
      - California lashed by storms for months
        - » 1400 homes damaged or destroyed
      - Florida ravaged by series of tornadoes, killing 39
      - Panama Canal officials had to restrict shipping due to low water levels
      - Indonesia suffered forest and peat fires producing smoke that affected southeast Asia

## 76 The Oceans: Tides

#### √ Tides

- another type of movement of ocean waters

- normally raise and lower the water level of a coast, and as a result, are significant
  - · geomorphically
    - changes in water level expose different parts of coast to erosive action of waves
  - · biologically
    - organisms living in areas subject to changes in water level must have adaptations to deal with alternating periods of submersion and exposure

## 77 The Oceans: Tides

#### ✓ Tides

- definition
  - a periodic rise and fall of the Earth's oceans
- caused by
  - · gravitational effects of the sun & moon on oceans
    - produce "bulges" of water
    - magnitude of these "bulges" is determined by the varying and complex interactions resulting from the relative positions of the earth, moon and sun

## 78 The Oceans: Tides

#### √ Tides

- role of the sun and moon
  - sun's gravitational pull on earth is less than 1/2 that of the moon, its significance on tides
    - is secondary to influence of moon
    - is strongest sun aligns with moon and during equinoxes
  - moon's gravitational pull on earth is ~ 2X that of the sun
    - it is primarily responsible for tides
    - because moon's distance from earth varies, so does its attractive forces

# 79 The Oceans: Tides

#### √ Tides

- characteristics
  - frequency
    - some areas have 2 high tides each day, some have only 1
    - average interval between successive high tides is app. 12.5 hours
  - · time of day
    - changes each day
  - · height
    - typically 1 2 meters above average sea level
    - varies with the relative positions of the earth, moon & sun
    - influenced by local coastal topography