Sea, Sky and Land:
The Climate Connection

Oceans and Heat

Daily Variations - Sea and Land Breezes

Seasonal Variations - Monsoons

Reading:

Ch 6: 6.3-6.5, 6.11-6.13;

Ch 8: 8.12-8.13;

Ch 9: 9.9

Graphic: Bergy bits, the size of houses, being released into the ocean in Southeastern Alaska, J.Bortnaik, photographer (NOAA Corps), courtesy of NOAA.

What Is Climate?

Climate is the long-term average of weather

Climate depends on:

- the amount of energy received from the sun

- what happens to this energy once it reaches Earth's atmosphere

Graphic: Earth's orbit, adapted from Pisias and Imbrie (1986/1987). Courtesy of NOAA.

What Causes Natural Climate Change?

Externally forced natural climate changes occur due to changes in the amount or distribution of solar energy reaching the earth/atmosphere system

Internally forced natural climate changes occur due to changes in the movement of heat by the ocean and/or atmosphere

Graphic: View of Earth as seen by the Apollo 17 crew traveling toward the moon, Dec. 7, 1972. Photo courtesy of NASA.

External Forcing of Natural Climate Change

Variations in Earth's orbit

cause climate changes over periods of 20,000-100,000 years

example: glacial cycles

<u>Volcanic eruptions or asteroid impacts</u> example: sulfur haze reflects solar energy back to space, cooling the earth

<u>Changes in the sun's brightness</u>

example: variations in sun spots

Graphics: (top panels) Changes in orbit circularity ("eccentricity"), images by R.Simmon, courtesy of NASA GSFC. (middle) Mt Pinatubo, courtesy of USGS Cascades VolcanoObservatory, (bottom) sunrise, courtesy of NOAA.

Internal Forcing of Natural Climate Change

Variations of atmospheric and oceanic circulation cause climate changes over period of a few years to thousands of years

Examples:

- **El Niño/La Niña**
- **Year-to-year variations in monsoons**

Graphics: Sea level signatures of El Niño and La Niña measured by the TOPEX/-POSEIDON satellite altimeter. Image courtesy of NASA JPL.

Heat Exchange and Climate

Solar energy is unevenly distributed:

- excess heat in the tropics

- deficit of heat at the poles

Heat Capacity

Heat needed to raise the temperature of 1 gram of a substance by 1 degree C

Substance	Heat capacity (cal/g/C)
granite	0.20
dry air	0.24
pure water	1.00

Water absorbs (or releases) lots of heat with little change in temperature

Graphic: The Atlantic Ocean peeks out from behind sea oats growing along Tybee Island, Georgia, Photo by Mr. William B. Folsom, NOAA, NMFS, Courtesy of the NOAA photo library.

Ocean Temperature and Climate

Because of the high heat capacity of water…

Oceans store large quantities of heat

Oceans moderate Earth's climate by absorbing heat slowly and releasing it gradually

Examples: - Sea breezes - Monsoons - El Niño and La Niña

Graphic: Oregon coast, courtesy of NOAA.

Land, Sea and Seasonal Temperature

<u>Summer to winter temperature change:</u>

Smaller where the ocean influences climate

Impacts of Ocean Circulation on Climate

Ocean currents move heat and influence climate

Example - During summer in North America…

Warm ocean currents warm the air along the east coast

Cold ocean currents cool the air along the west coast

Graphic: Garrison, Fig. 9.14.

Air-Sea Interactions - Summary

Sea Breezes

During the day...

Air above land warms more than air above the ocean

The warm air over the land becomes less dense and rises

This sets up an atmospheric convection cell with winds near the ground

At the surface, <u>winds blow onshore in a "sea breeze"</u>

Graphic: See Garrison, Fig. 8.17

Land Breezes

At night...

Oceans remain warmer than the land

The warm air over the ocean becomes less dense and rises

This sets up an atmospheric convection cell with winds near the ground

At the surface, <u>winds blow offshore in a "land breeze"</u>

Graphic: See Garrison, Fig. 8.17

What is a Monsoon?

A monsoon is a pattern of wind circulation that changes with the season

Monsoons are caused by interactions like those that generate daily land and sea breezes

Graphic: Summer monsoon conditions, 20 Aug 2000, courtesy of NOAA.

Monsoon Regions

North American
African
Indian/East Asian
Australian

Graphic: Map prepared by Boston University (Earth Observing System Data Gateway) based on MODIS satellite data.

The Indian Monsoon Cycle – Northern Hemisphere Winter

Air above India cools and sinks

Dry air is driven offshore to replace rising air over the Indian ocean

Graphic: Garrison, Fig 8.16.

The Indian Monsoon Cycle – Northern Hemisphere Summer

Air above land warms and rises

Cooler, moist air is drawn from the ocean over the warm continent

Graphic: Garrison, Fig 8.16.

Monsoons, Climate and Society

The rainy season occurs when moisture from the ocean moves onto the continent

Effects on society:

- agricultural productivity

- flooding

- availability of fresh water

Graphics: (top) Monsoon floods in south Asia, courtesy of NASA, Goddard Space Flight Center, (bottom) Wildflowers blooming during a strong summer monsoon in Big Bend National Park, Texas, photo courtesy of the National Park Service.

Deluge and Drought

A tremendous range of rainfall creates feast or famine in monsoon regions with extensive cropland

Monsoon rains vary from year to year

Color Key:

Higher than normal rainfall

About normal rainfall

Less than normal rainfall

Much less than normal rainfall

Monitoring the Ocean to Better Predict Monsoons Preview of Next Lecture

Sailing the Seas –

Wind-Driven Ocean Circulation

Readings:

Ch 9:

9.2-9.6, 9.8-9.13

Graphic: Garrison, 4th Ed., Fig. 18.22, pg 483, 5th Ed., Fig. 18.26, pg 455.

Monsoons and Climate Change

As ocean warms, Purdue modeling group predict weaker future monsoons. (Why?)

Global Monsoon Regions

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Air-Sea Interaction with Global Reach - El Niño and La Niña

El Niño and La Niña are reorganizations of atmospheric and oceanic circulation due to natural interactions between the atmosphere and ocean

El Niño = warm temperatures in the tropical Pacific ocean

La Niña = cold temperatures in the tropical Pacific ocean

El Niño and La Niña impact climate globally

Graphic: Sea surface temperature deviations from "normal". Images courtesy of NASA.

El Niño, La Niña and Society

Climate impacts last 9 months to 2 years, and affects

- Water use

- Agriculture and fisheries

- Energy use

- Human health

and many other segments of society

Graphic: El Niño impacts, courtesy of NOAA.

Hunting El Niño from Space

A developing El Niño or La Niña can be detected from changes in tropical Pacific:

- sea level

- sea surface temperature

- surface winds

All of these are now measured by satellites that orbit the Earth

Graphic: (top) The TOPEX/Poseidon satellite altimeter measures sea level from space, (bottom) sea level signatures of a strong El Nino and strong La Nina. Courtesy of NASA/Jet Propulsion Lab.