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SIXTH EDITION

Invitation to Oceanography

Chapter 16

Global Climate Change and the Oceans

Oceans and The Planet (Continued)

- The amount of CO_2 in the atmosphere has increased 44% over the last 150 years.

- The oceans absorb 30-50% of CO_2 emissions created by burning fossil fuels

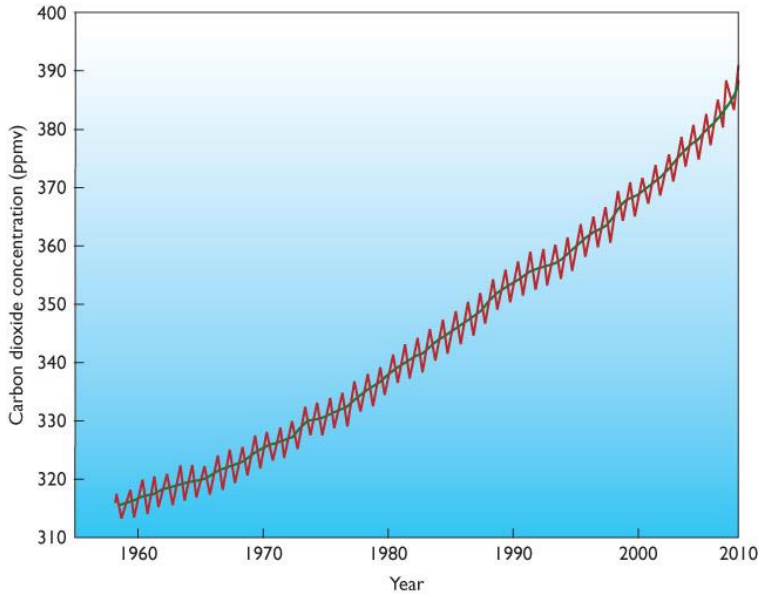

Figure 16.01: The 40-year record of CO2 concentrations in the atmosphere measured at Mauna Loa Observatory in Hawaii.

Global warming can cause polar ice caps to melt, resulting in sea level rise.

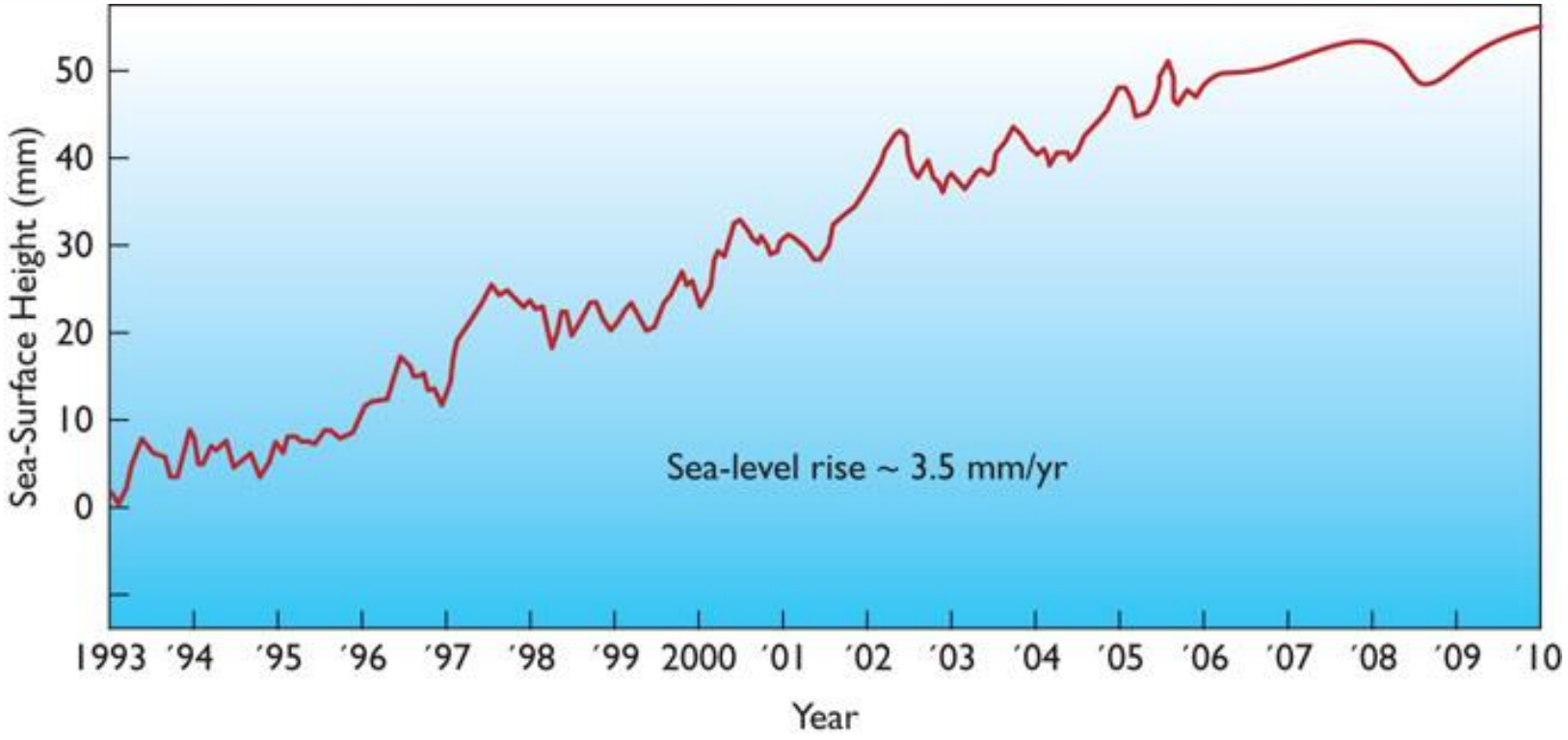

Figure 16.02a: The recent global rise of sea level.

Climate Change

- Global and regional wind and precipitation patterns can (and do) change

- Effects of climate change could vary geographically
  - Some regions will experience longer growing seasons and more rainfall
  - Others will suffer and become hotter and drier

Climate Change (Continued)

- Climate warming will affect oceans and ocean life in diverse and complex ways
  - Every aspect of ocean chemistry, circulation, heat content
  - Every facet of ecological, environmental, and biological activity
    - All change with temperature and pH.
    - Increased CO_2 changes both temperature and pH.

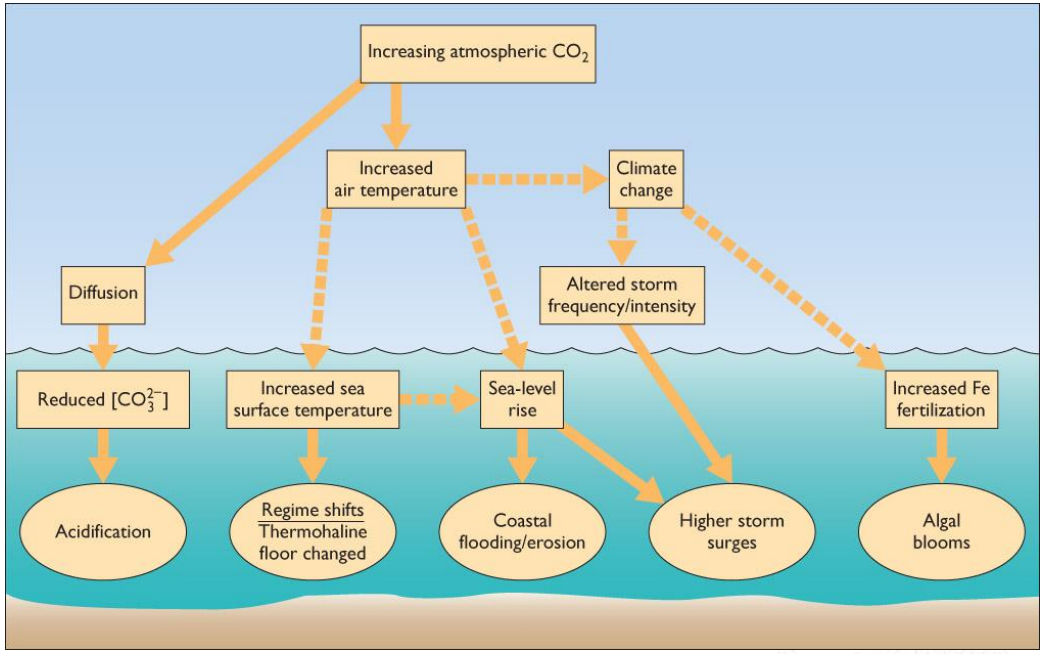

Figure 16.03: This diagram shows some direct (solid arrows), indirect (dashed arrows), and possible (dotted arrows) consequences of increasing atmospheric CO2.

Ecosystems

- Coastal ecosystems are affected by a variety of environmental variables
  - Sea level
  - Temperature
  - Wave action
  - CO_2 concentration, etc.

- These ecosystems have difficulty adapting to rapid environmental changes

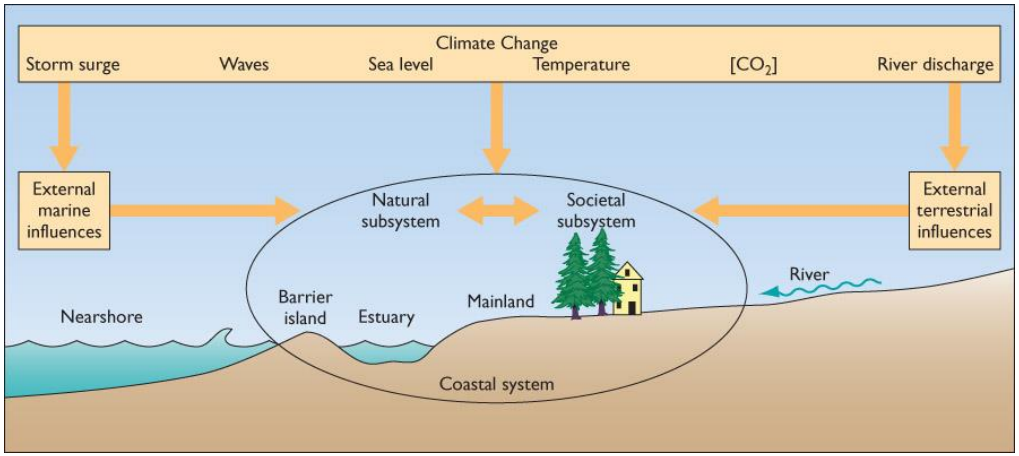

Figure 16.05: Coastal systems are impacted directly by climate change and indirectly by external marine and terrestrial influences.

Coastal Ecosystems

•Current estimates predict that sea level will rise 10-90 cm by the year 2100

•Some inhabited islands and coastal areas will be submerged by the end of this century

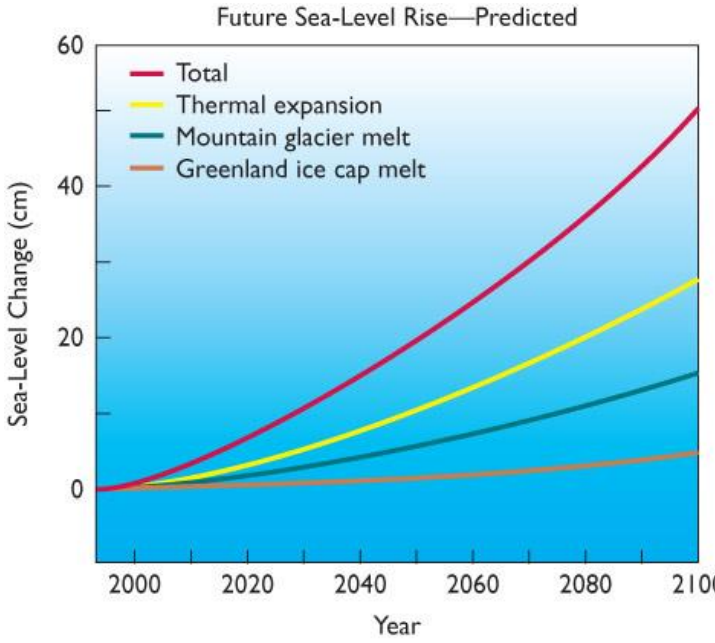

Figure 16.06: Estimates of the contribution of the melting of ice sheets and mountain glaciers to the expected rise of sea level in the 21st century.

Coastal Ecosystems (Continued)

- Coastal deltas plains are particularly vulnerable to seawater incursion
- They are subsiding under a heavy sediment load, which accelerates the relative rise of sea level

Figure 16.07: A scheme that estimates the relative vulnerability of the world's major river deltas.

Coastal Ecosystems (Continued)

- Storm surges are expected to be higher than usual

- They will result in more flooding, erosion, and damage to coastal property

- Intrusion of seawater into groundwater aquifers will contaminate the freshwater supplies of coastal communities

Coastal Ecosystems (Continued)

- Anthropogenic structures interfere with ecosystems' ability to adapt to environmental change

- They prevent coastal ecosystems from shifting landward as water levels rise

- Many marsh plants rot after prolonged exposure to seawater

Salt Marsh Retreat: Natural Progression Interrupted by Human Construction

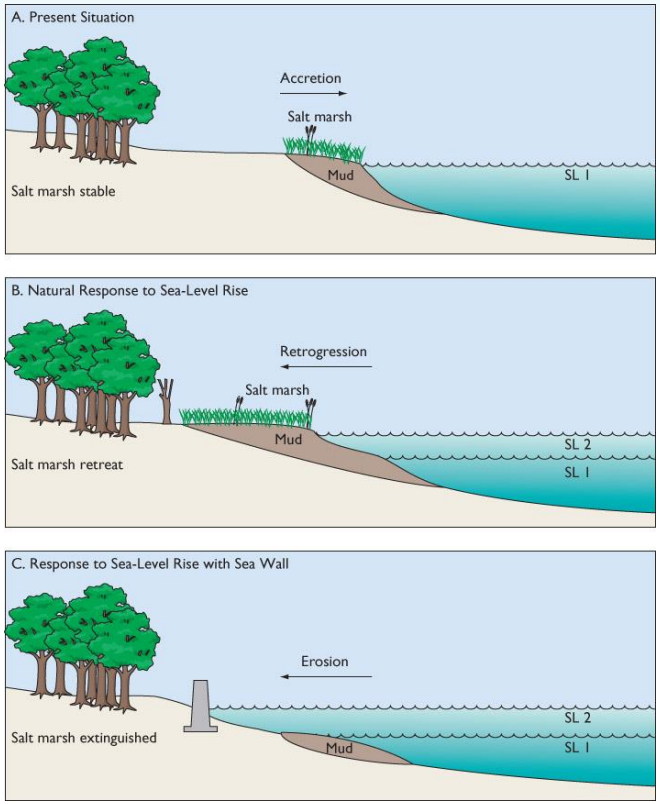

Figure 16.08: Salt marshes respond to sea-level rise by migrating landward, provided there is room.

Possible ways to alleviate the effects of sea level rise include:

- Elevating buildings and infrastructure
- Engineering of coastal areas to offset/prevent erosion
- Planned relocation of coastal buildings and other infrastructure
- Prohibiting future coastal development

Water Temperature

- Influences behavior and mortality of marine organisms
- Changes in water temperature can affect:
  - predator/prey relations
  - ecological niches
  - resource allocations
  - species distribution
  - timing of reproduction/rate of development
- These alterations can be detrimental to the survival of populations and species

Coastal Water

- Aquaculture in coastal areas is a rapidly increasing source of human food
  - Rising temperatures could mean that microbial infections of aquacultured organisms increase

- Warmer coastal water may foster more frequent and larger algal blooms, such as red tides
  - This can devastate shellfish fisheries and cause human illness and death

Seawater

- The temperature and salinity of seawater cause dense water masses to sink
  - This helps drive a global "conveyor belt" of water movement
- Climate change will influence deepwater flow
  - Atmospheric effects control seawater density
- It is hard to predict how climate change will affect thermohaline circulation

Global Warming and Thermohaline Circulation:

Major change in the redistribution of heat and nutrient could result from changing ocean temperatures…

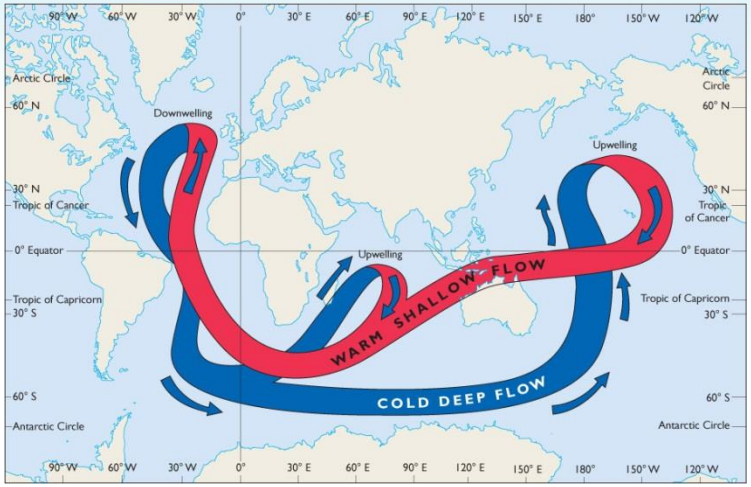

Figure 16.10a: The circulation conveyor belt.

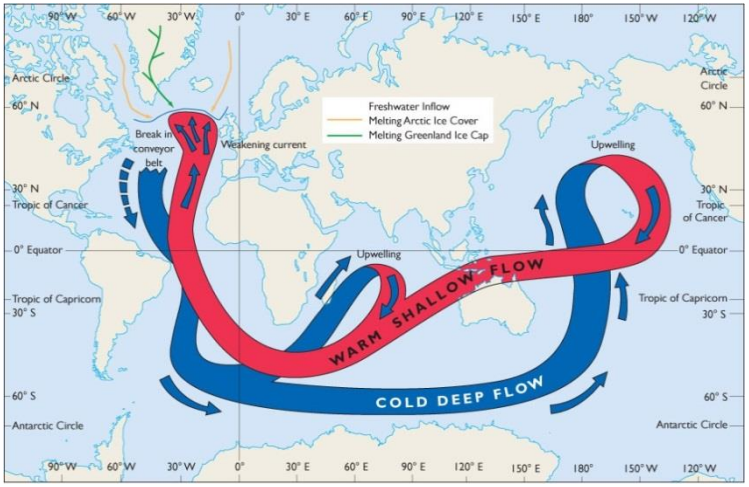

Figure 16.10b: The circulation conveyor belt.

Salinity

- Melting of ice sheets decreases ocean salinity
- Decreased salinity is expected to slow down the rate of downswelling in the North Atlantic
  - If prolonged, may shut it down entirely
- Shutdown of circulation would cut off the supply of oxygen-rich water to the deep sea
  - This would cause hypoxia and anoxia in the deep ocean, inducing mass extinctions

Arctic sea-ice is melting at an alarming rate

- In terms of total cover,
- In terms of seasonal cover

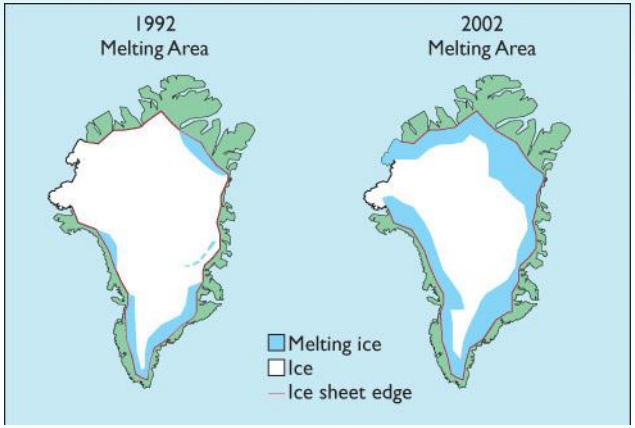

Figure 16.11a: Inside of a decade (1992-2002), the area of the ice sheet that is melting rapidly has expanded rapidly.

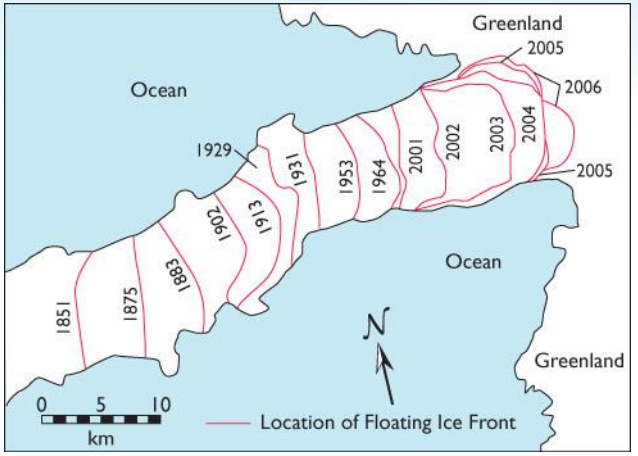

Figure 16.11b: The floating terminus of a Greenland glacier called Jakobshavn Isbrae has retreated almost 50 kilometers since 1851.

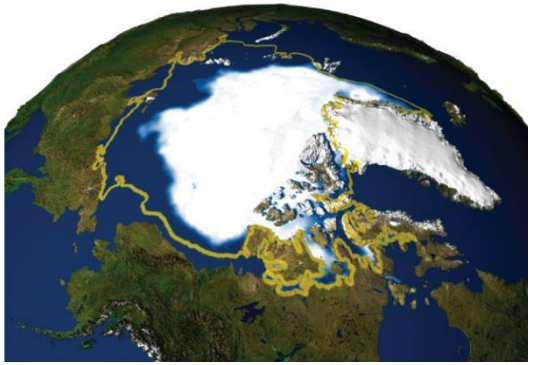

Figure 16.12a: This satellite photo shows the extent of melting of the sea-ice cover of the Arctic Ocean during the summer season.

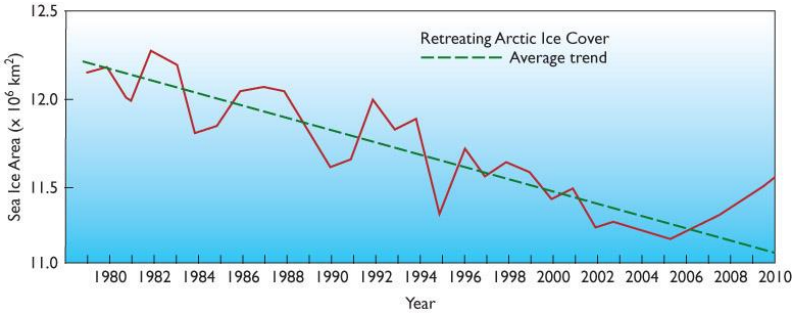

Figure 16.12b: The sea ice cover of the Arctic Ocean has been shrinking alarmingly during the past decades.

Sea Ice

- Melting sea ice affects mammals adapted to ice-covered water
  - Arctic seals require extensive areas of ice for breeding and resting
  - These seals are essential prey for walruses and polar bears

- Sea-ice also affects plankton productivity, which is the basis of the food web

Sea Ice (Continued)

- The absence of sea-ice during summer will allow open water to absorb more heat
  - This will accelerate seawater temperature increase

- Increased water temperature:
  - Delays onset of winter freezing
  - Promotes an earlier spring breakup of sea-ice cover

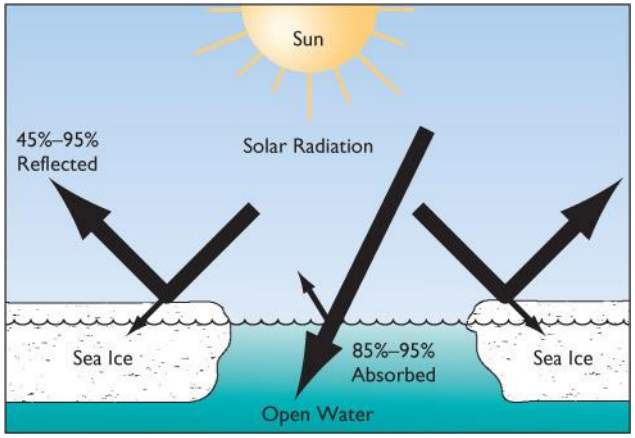

Figure 16.13a: Open water absorbs much more sunlight than ice-covered water.

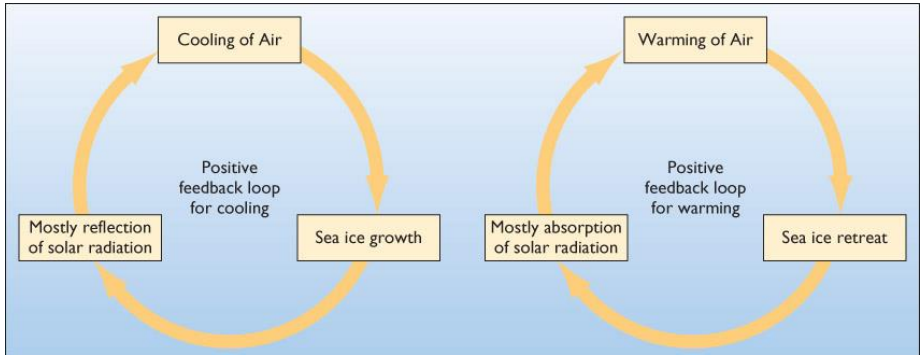

Figure 16.13b: Examples of a negative and positive feedback loop involving incident solar radiation and sea ice expansion and contraction.

As Waters Warm:

- Warm-water species displace cold-water species
- Phytoplankton populations decrease

- Food webs must readjust to these changes, sometimes causing collapse of populations

CO_2

- As CO_2 builds up in the lower atmosphere, more of it diffuses into the ocean

- CO_2 complexes with water molecules to form carbonic acid
  - This increases the acidity of the seawater

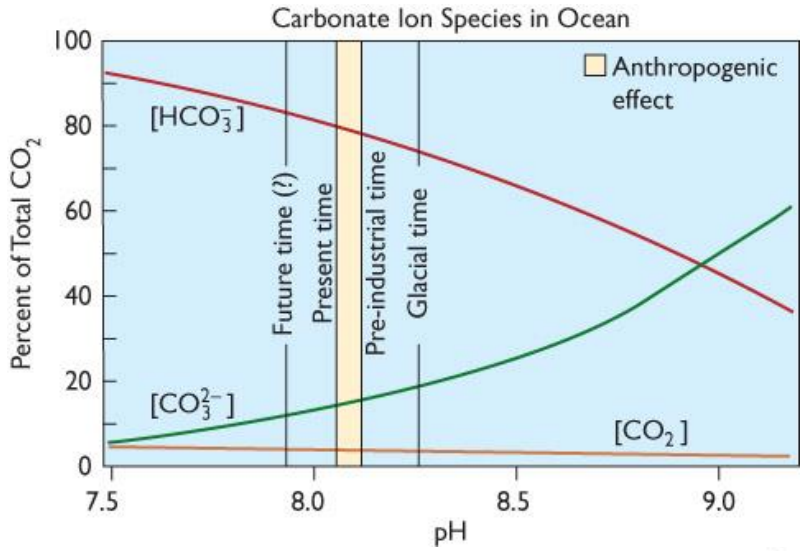

Figure 16.15: The relative levels of various carbonate ion species such as carbonate (CO32-) and bicarbonate (HC03-) vary with the pH of the water.

Changes in Reefs

•Ocean acidification also decreases the amount of carbonate ions in the water

- This impacts organisms that secrete calcium carbonate shells and reefs

•Coral reef-building could decrease 20-30% this century

•Warmer waters also increase the changes of coral bleaching events.

We know that human activities are degrading the environment

- We can:
  - adopt sustainable lifestyles
  - form forward-looking political affiliations
  - think up novel solutions to environmental problems

- If we work to mitigate the causes now, we can slow – even stop – environmental change
  - Many ecosystems are resilient and biota can adapt to some environmental changes

What We Can Do:

- Scientists can provide insight into ecosystems across many scales of time and distance
  - Understanding an ecosystem helps us identify how we can address its degradation

- We must all work together to enact policy changes to achieve a sustainable relationship with nature