MET 3103 and 5105

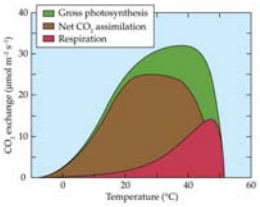
Lecture 6
Climate and the Biosphere
26 Feburary 2018

Effects of Heat

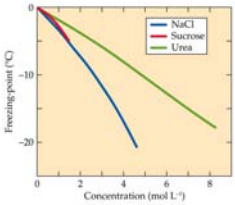
- A 10°C warming doubles (or triples) the rates of most metabolic processes
- If it gets too hot proteins coagulate
- How does metabolism vary with temperature?
  - Slow at temperatures near 0°C
  - Run faster and faster from 15-35°C
  - Crash at temperatures above 40°C
- Extremophiles (Archaea) don't work this way. They can live in glaciers, hot springs …
- Many crops are limited by the minimum temperatures overnight through the seasons
  - For example Tomatoes are damaged by T < 6°C
- But also by maximum daytime temperatures and by drought

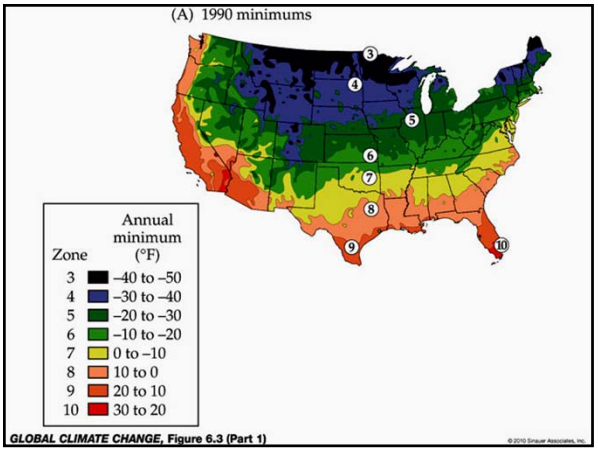
In More Quantitative Terms

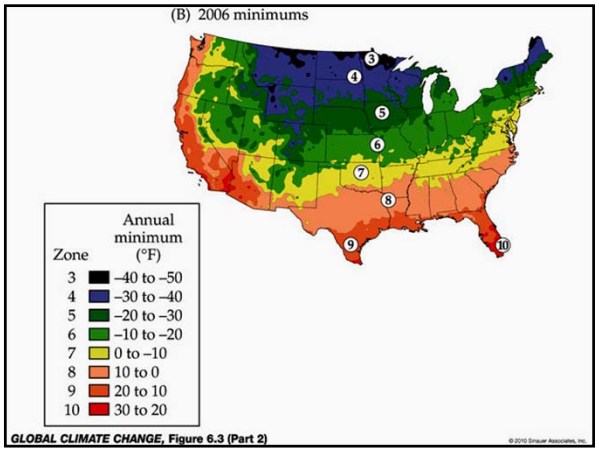
Photosynthesis and Respiration in C3 Plants



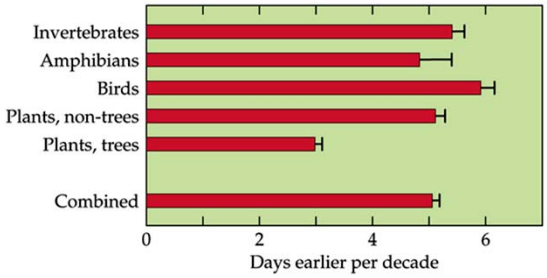
How Salt, Sugar and Urea Change the Freezing Point of Water







Shift of spring events like arrival, egg laying, flowering, leaves appearing …



Charismatic Megafauna

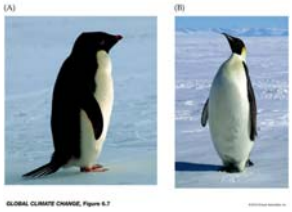
Polar Bears in the Arctic

Ursus maritimus and Ursus arctos (Brown Bear) are different "species," but they can interbreed.

- Live on Arctic sea ice
- Eat Seals
  - By staking out breathing holes or haul-out sites
- Female bears swim from pack ice in summer to give birth to cubs in dens ashore
- On shore they forage for food, often around humans
- As ice shrinks on a warming Globe, the distance from feeding sites on ice to dens increases
- Reducing female's weight and breeding success
- May lead to extinction or absorption into the Brown Bear population

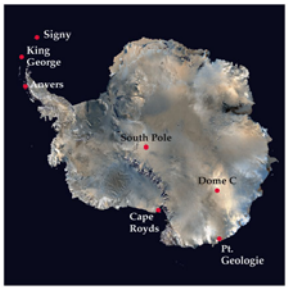
Penguins in the Antarctic

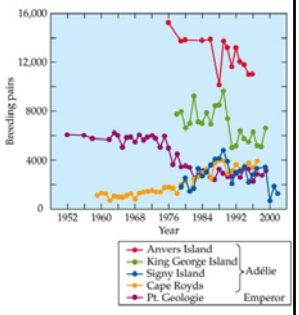
Adult Adélie (A) and Emperor Penguins



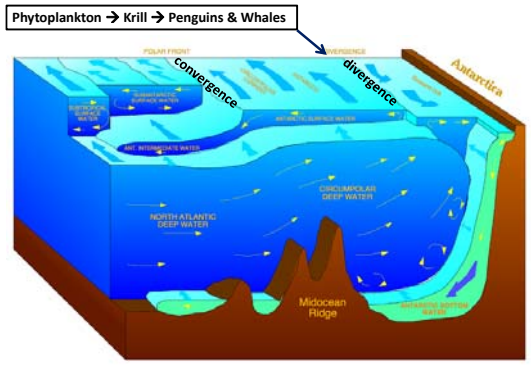
- They live on the pack ice around the continent
- Antarctica is less affected by warming than the arctic
- Penguins, like much of the Antarctic fauna, live on shrimp-like Krill
- Nonetheless Penguins lay eggs a few days later because of somewhat restricted feeding, or …
- And populations at warmer breeding sites have declined

Breeding Sites and Trends in Numbers of Breeding Pairs

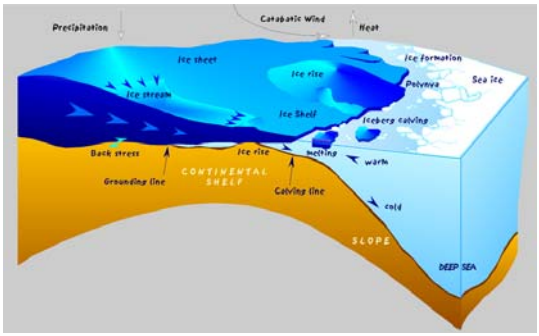




Antarctic Water Masses

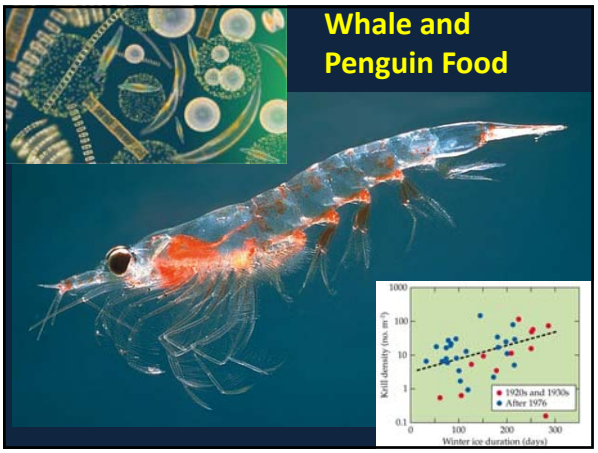


Antarctic Sea Ice is Expanding

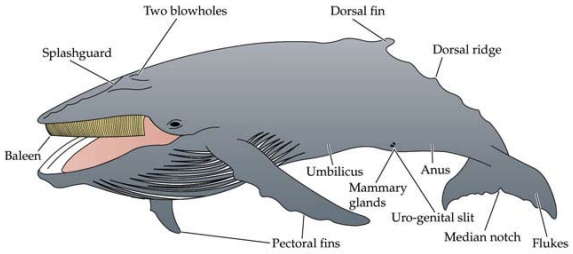


Antarctic Sea Ice

- While it's clear that sea ice is in big-time retreat in the Arctic…
- Sea ice is expanding in the Antarctic
  - "Katabatic" winds bowing down from the ice cap
  - Pushes ice away from the land
  - Forming open water "poynias" (next slide)
  - That then freeze increasing the area of pack ice
  - There is a hand waving explanation for the stronger winds that invokes the Antarctic ozone hole
  - But the ice cap has observed to stay very cold while the air and sea around it warms, increasing the temperature contrast, thus making the 'Katabatic Winds" stronger
  - Paradoxically, this process makes Antarctic sea ice expand as a result of AGW
  - Ice is thinner, raising the possibility of passing a tipping point and sudden (decades??) collapse.

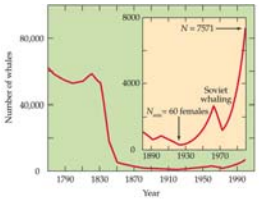


Baleen Whale Anatomy

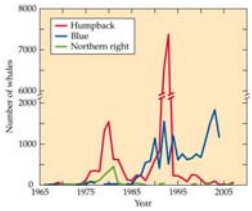


Baleen Whale Populations

Southern right whales



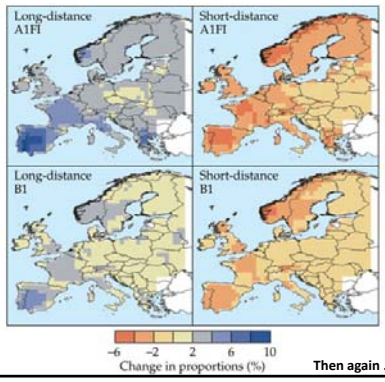
Humpback, blue & northern right whale counts from sightings



Discussion: Krill, Penguins, Whales and Global Warming

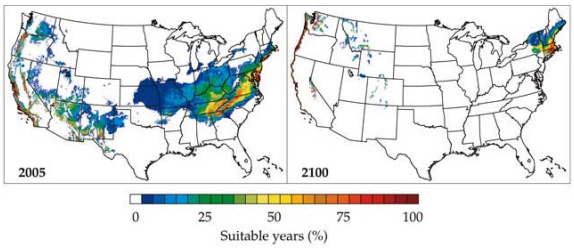
- While it's clear that sea ice is in big-time retreat in the Arctic…
- Sea ice is expanding in the Antarctic
- Penguins are probably moving southward
  - Because they like it cold, or
  - Because the polinyas represent feeding opportunities,
  - Because ocean acidification (discussed later) is interfering with phytoplankton
- Whale populations
  - Blue whales seem to be recovering from over exploitation
  - Apparent big changes in humpback whales probably reflect random differences in migration patterns
  - Northern right whales are probably declining because of decreases in sea ice, as the book claims
  - Polar bears, too

Birds that migrate long distances seem to benefit from expanded resources available because of warm and early springs, at least in Europe



Then again …

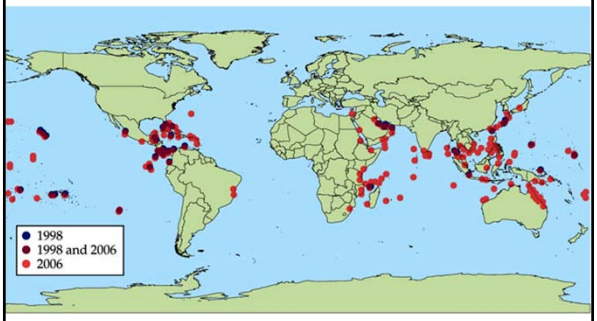
Premium wine grapes like not-too-hot and not-too rainy. They may retreat from inland to coastal California, Oregon and Washington, and to parts of (would you believe) New England as the Globe warms



Coral

- Colonial marine invertebrates, in the Phylum Cnidaria that also contains sea anemones and jellyfish.
- Live by catching small fish and invertebrates
- Also have symbiotic algae, ***Zooxanthellae***, that live within their tissues and contribute nutrition through photosynthesis
- Each coral polyp builds a exoskeleton of $CaCO_3$ (limestone)
- Living corals on top of the exoskeletons of dead ones make reefs
- When stressed, corals expel their zooxanthellae, resulting in ***Coral Bleaching***
- Many present-day corals live at the warm end of their temperature range
- Global warming and ocean acidification are sources of stress that cause beaching

Places Where Coral Bleaching Happened in 1998 and 2006



Amphibians

Golden Toad, *Bufo periglenes*, of Cost Rica

- Since 1980, ⅓ of amphibian species have declined and 1-2% have become extinct.
- Compared with birds and mammals where ~0.5% have become extinct
- One cause appears to be warming of tropical highlands which allows the lethal fungus *Batrachochytrium dendrobatidis* to become established
- Other causes seem to be important in other locales

Human Pathogens and Their Vectors

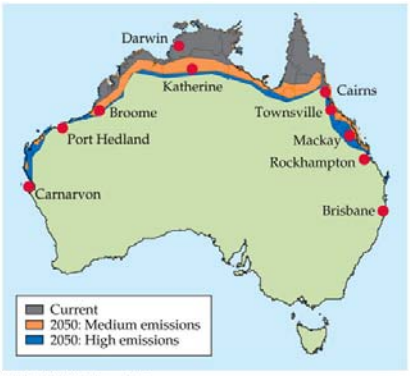
TABLE 6.3 Vector-borne diseases that may be sensitive to global warming

Vector	Examples of major diseases
Blackflies	Onchocerciasis (river blindness)
Mosquitoes	Malaria, filariasis (elephantiansis), dengue fever, yellow fever, West Nile fever
Sandflies	Leishmaniasis (Orient Boils, black fever, Dum-Dum fever)
Ticks	Lyme disease, tick-borne meningoencephalitis
Triatomines (kissing bugs)	Chagas disease (American trypanosomiasis)
Tsetse flies	African trypanosomiasis (sleeping sickness)

Source: Haines et al. 2006.

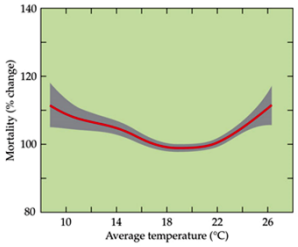
- Many diseases have ***Host Vectors*** that carry the disease without sickening
- Vectors often do not regulate their body temperature
- Ranges of tropical pathogens and hosts are often restricted by cool temperatures and frost
- Warming
  - Extends range (no frost)
  - Lengthens host breeding
  - Speeds metabolism of both host and pathogen
- Consequently, we're seeing formerly tropical diseases becoming ***Endemic*** in middle latitudes

Dengue Fever in Australia



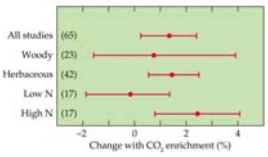
GLOBAL CLIMATE CHANGE, Figure 6.30

Human Health and Temperature



- Global warming's primary effect in middle latitudes is milder winters
- But it also increases the likelihood of heat waves
- Like the 2003 European heat wave that killed 30-50K people
- The inversions that cause heat waves also trap pollution near the ground
- Heat primarily kills the aged, infirm, and unprotected poor.
- Cold does too, but it's deadlier

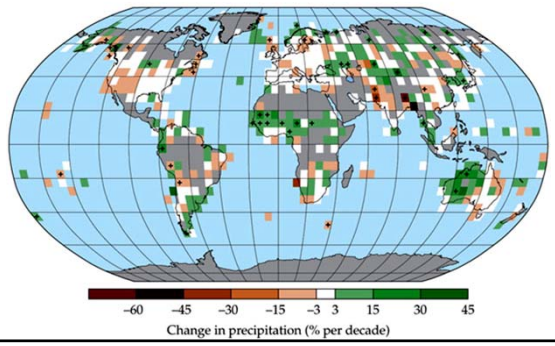
Effect of More CO_2 on Soils



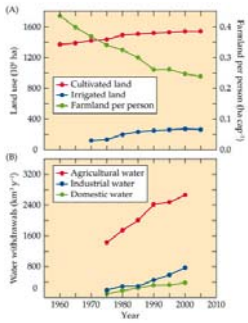
Change in soil carbon between 370 ppm CO_2 and 430-750 ppm, as a function of vegetation type. Note effect of nitrogen fertilization

- Most of the CO_2 in the crust is in limestone, fossil fuels or kerogen
- Soil microorganisms typically break down 2.5% of fixed carbon in soil annually.
- Roughly equivalent to leaf litter, etc., sequestered in soil.
- Which contributes to the annual fluctuations in the Keeling curve
- Both plant productivity and soil decomposition increase with warming
- Thawing of permafrost, drying of wetlands, and deforestation are probably more significant than changes in healthy middle-latitude soils

Global warming dries middle latitudes some, and increases rainfall in the tropics and high latitudes

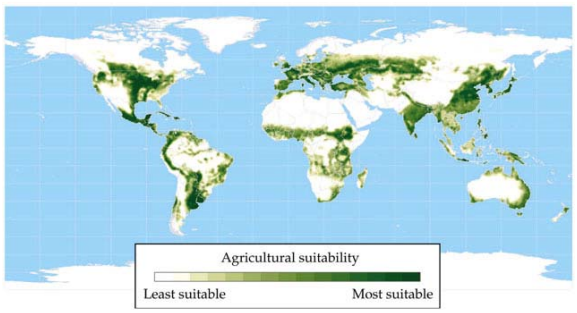


Land and Water for Agriculture and Other Uses



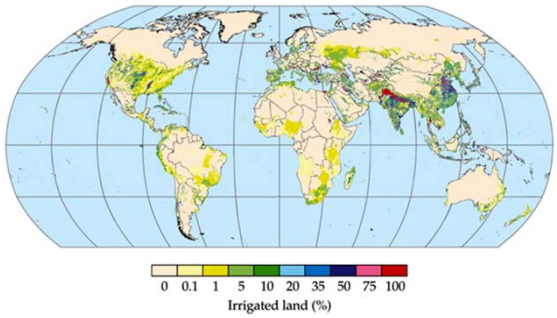
- Cultivated land has increased ~10% in 50 yr
- Cultivated land per person has decreased by 50%
  - Green revolution
  - Better water and crop management
- Irrigated land has increased 4 to 5 fold
- Still, industry and households combined use less than half the water that agriculture does

Where do the Growies Grow?

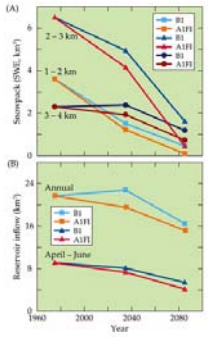


GLOBAL CLIMATE CHANGE, Figure 6.38

Where are the Growies Irrigated?

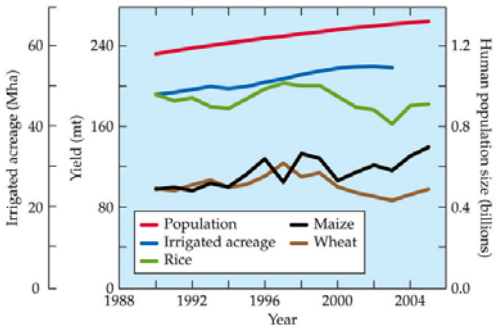


Where Does the Water Come From?



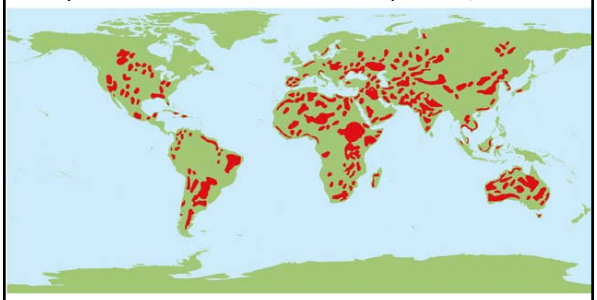
- Much of it is ground water pumped from aquifers
  - Where it accumulated gradually for thousands of years
  - Not so much here in Florida
- Mountain runoff
  - Stored in snow or reservoirs
- Warming may increase precipitation
- But in the form of rain, not snow
- Springtime floods and summer droughts.
- A consistent GCM prediction is more heavy rains and longer dry spells between them.

How Does All of this Play Out in China?



GLOBAL CLIMATE CHANGE, Figure 6.41

Irrigation water evaporates from the soil and plants ***Transpire*** it from their leaves, so that dissolved salt stays behind. Salt-water intrusion is a problem, too.



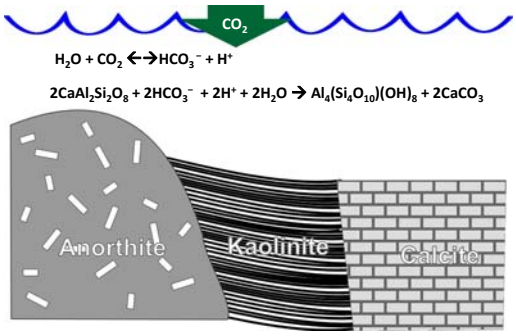
Places, not all of them agricultural, where salt buildup is a problem.

About pH

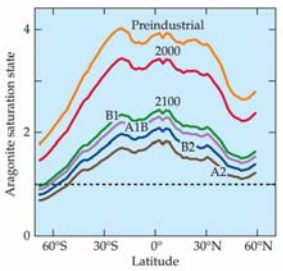
- Water naturally dissociates into H^+ and OH^- ions
- We measure concentration in moles (N_A = 6.022x10^{23} molecules, Avagadro's number) per liter
- N_A is the number of atoms in one "gram atom" of a compound = 32 gm of O_2, 18 gm of H_2O, etc.
- In pure water there are 10^{-7} moles of H^+ ions per liter
  - Or 6.022x10^{16} H^+ per liter
- pH = $-\log_{10}$ (moles of H^+ per liter), approximately
- In a slightly alkaline solution, pH = 8
  - Or 6.022x10^{15} H^+ per liter
- In a slightly acid solution, pH = 6
  - Or 6.022x10^{17} H^+ per liter
- Sea water now typically has pH = 8.07
  - Or 6.022x10^{23} / $10^{8.1}$ = 4.8 x 10^{15} H^+ per liter
  - Preindustrial pH = 8.18
- Freshwater ranges from:
  - Slightly acid pH = 6.5 to
  - Slightly alkaline pH = 7.5
- When one adds acids
  - $CO_2 + H_2O \rightarrow HCO_3^- + H^+$
  - To water, the pH goes down

Alexander Wedgwood

Chemical Weathering of Igneous Rocks Consumes CO_2

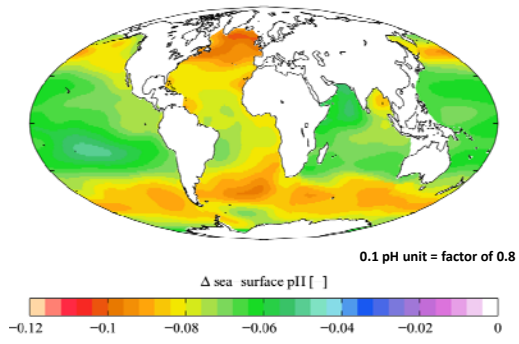


What's Happening in the Oceans Now?



- CO_2 dissolves to form H_2CO_3
- Which forms calcium bicarbonate $Ca(HCO_3)_2$
  - That exists only in solution
  - And dissolves more readily in more acid solutions
  - Lower pH
- More CO_2 means more ability to dissolve more calcium
- Saturation > 1 means additional Calcium is not dissolved
- Over long times making limestone would remove the CO_2, but we're adding it faster than natural processes can remove it

Change from pre-industrial pH to present day



SUMMARY

- Photosynthesis decreases and respiration increases for T > 40°C
- Metabolic process speed up 2-3x per 10° warming
- Minimum *T* limits on crops move poleward
- Processes start earlier in spring and end later in fall
- Polar bears stressed by warming
  - Effects are less clear for whales & penguins in the Antarctic
- Long distance bird migrations favored by extra food available in earlier and warmer springs
- Coral bleaching is increasing throughout the tropics
- Amphibian declines and extinctions may be due to invasive fungi
- Vectors for tropical human pathogens less limited on a warmer globe
- Human mortality increases at higher temperatures
  - Heat waves become more frequent
- Mountain precipitation shifts from snow to rain producing spring floods and summer droughts
- Precipitation generally becomes less reliable, “deluge and drought”
- Ocean acidification adversely affect shelled marine animals