ATOC 1060-002
OUR CHANGING ENVIRONMENT

Class 24 (Chp 15)

Objectives of Today's Class: Global warming

1. CO_2 removal processes and time scales;
2. Projections of future atmospheric CO_2 concentrations and climate.

Announcements

- Review guide online – Review session Dec 7;
- Lecture notes that include Clicker's questions are online;
- Hw3 will be returned on Thursday, Dec 2nd.

Previous class: Climate during the past century

Anthropogenic forcing appear to Be important in the past few decades.

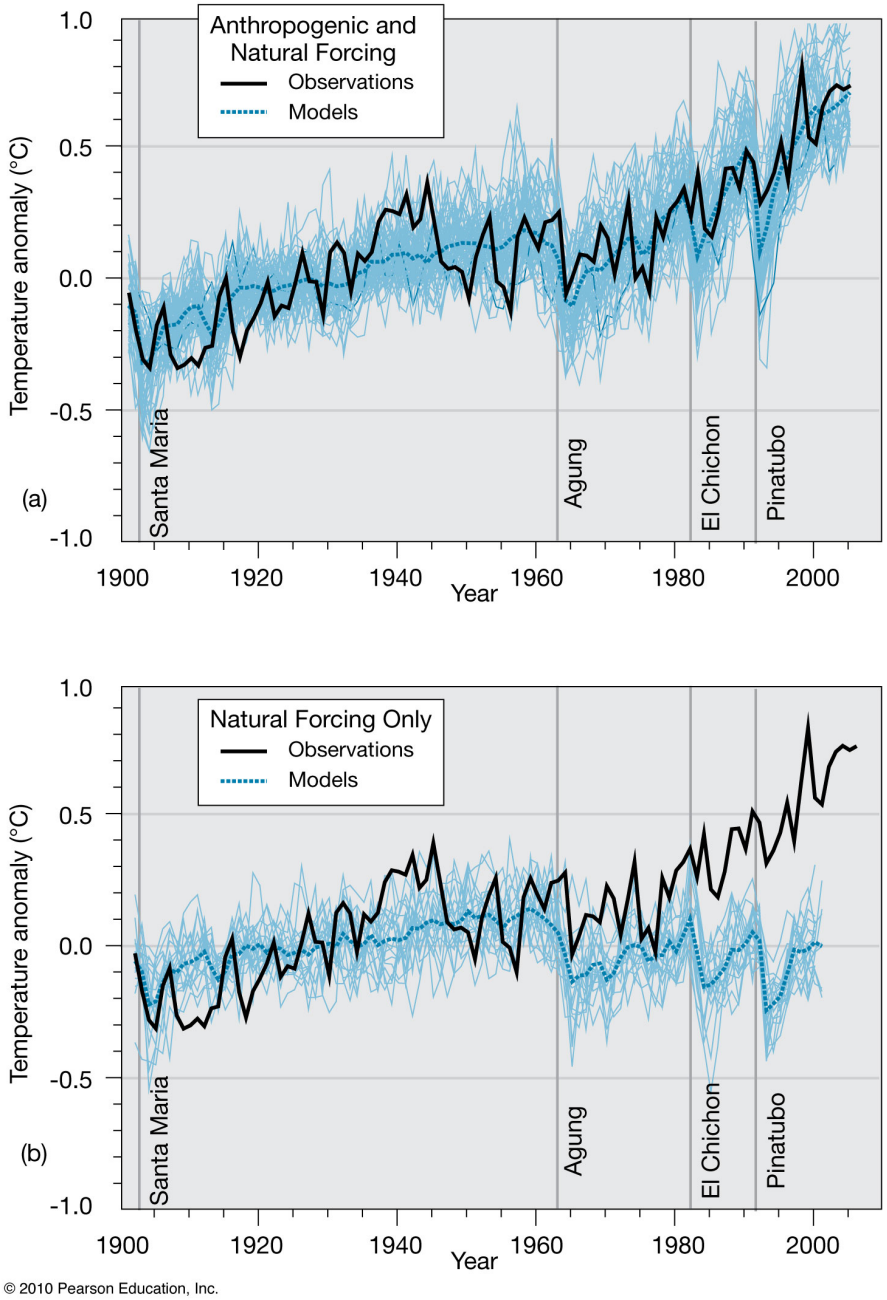
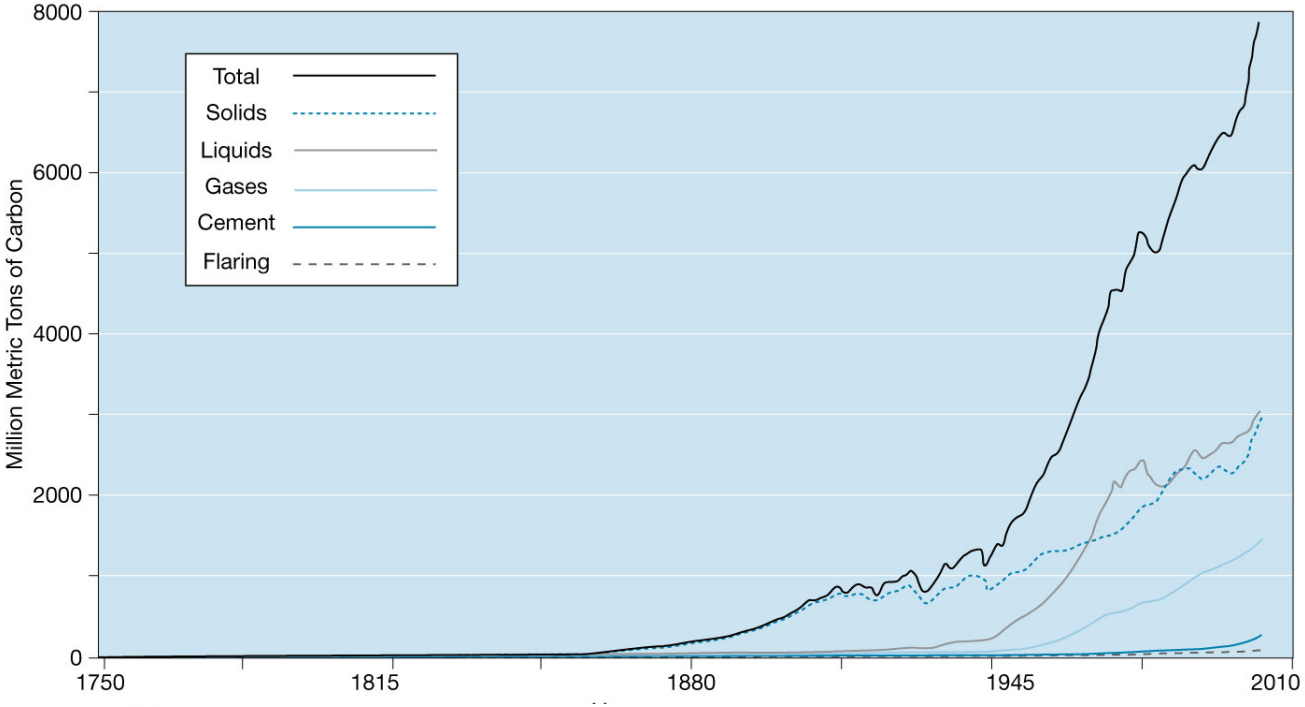
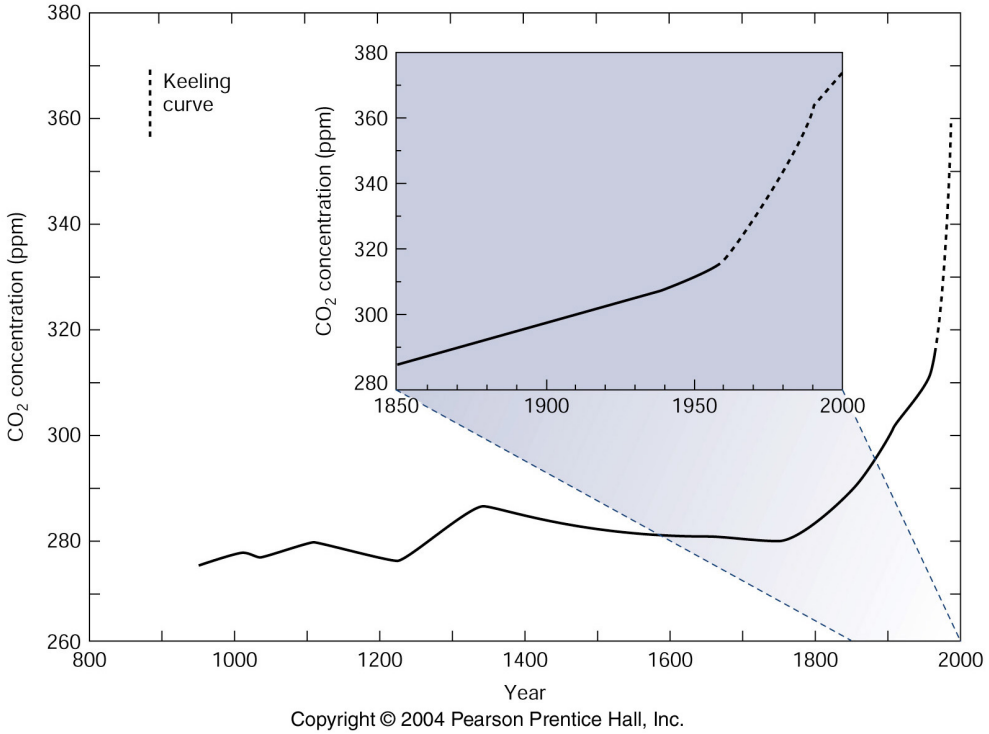


Fig. 15-5



Coal, oil and natural gas consumption rates, 1750-present. 15-7



Atmospheric CO_2 concentration

1. Where does the CO_2 produced by burning fossil fuel ultimately go? (7.5Gton/yr)

Atm. Accumulation: 3Gton/yr;

a. Northern hemisphere reforestation: Fastest

photosynthesis $CO_2 + H_2O +$ solar energy -> $CH_2O + O_2$

Organic matter; accumulate in living biomass or in soils;

Northern hemisphere reforestation: Fastest

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Organic matter; accumulate in living biomass or in soils;

Eventually Returned to atm =>deforestation, Soil organic matter decay

Will photosynthesis act as a sink for CO_2?

Depends on forest expands or shrink;

N. Hemisphere reforestation: 0.5Gton/year (uptake some CO_2)

b. CO_2 and nitrogen fertilization: Fast (~can be 2Gton/yr)

CO_2 fertilization: Most plants raised under greenhouse conditions (plenty of water and nutrients are available) grow faster when expose to high CO_2 levels.

(in natural conditions: complex. Water & nutrient limitation come into play)

Nitrogen fertilization: Anthropogenic combustion=> add nitrogen oxides to atmosphere=> fertilizer for plants => stimulate plant growth (uptake CO_2)

Clicker question 1

Choose the correct statement.

a. Northern hemisphere reforestation reduces atmospheric CO_2 concentration;
b. Deforestation acts to reduce atmospheric CO_2 concentration;
c. Nitrogen and CO_2 fertilization may enhance plants grow, and therefore may help to reduce atmospheric CO_2 concentration;
d. Both a and c;
e. Both b and c.

c. Dissolution in the oceans: relatively fast

Surface mixed layer: 50~100m thick;

residence time=(reservoir size)/(outgoing flux)

=(CO_2 amount)/(outgoing flux)

residence time ~8 years;

Deep ocean; 4km thick;

Residence time ~ 1000years.

Uptake rate: depends on concentration of carbonate ions in the ocean, chemical reaction;

The more carbonate ions, the fast the uptake.

Too much anthropogenic CO_2 => used up carbonate ions => reduce uptake rate

d. Dissolution of sea-floor carbonates: slower

CO_2-rich water is carried down into the deep ocean => carbonate sediments dissolve when in contact with CO_2-rich water.

It will take hundreds of years for this to occur, because the surface water has to be carried down into sea floor!

Won't be a big factor for affecting CO_2 concentration in the next a few decades to centuries.

e. Weathering of continental rocks: slowest

Most permanent, slowest, sink for anthropogenic CO_2: weathering of continental silicate rocks, and then precipitation of carbonate sediments on the sea floor

weathering $CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2$

Total carbon in atm-ocean system: 38,000Gton;
Silicate weathering consumption: 0.06Gton/year;

Residence time=38,000/0.06=633,333(years)
~0.6 m.y.

Clicker question 2

Choose the correct and complete statement.

a. Dissolution of CO_2 in the oceans is faster than Northern Hemisphere reforestation;

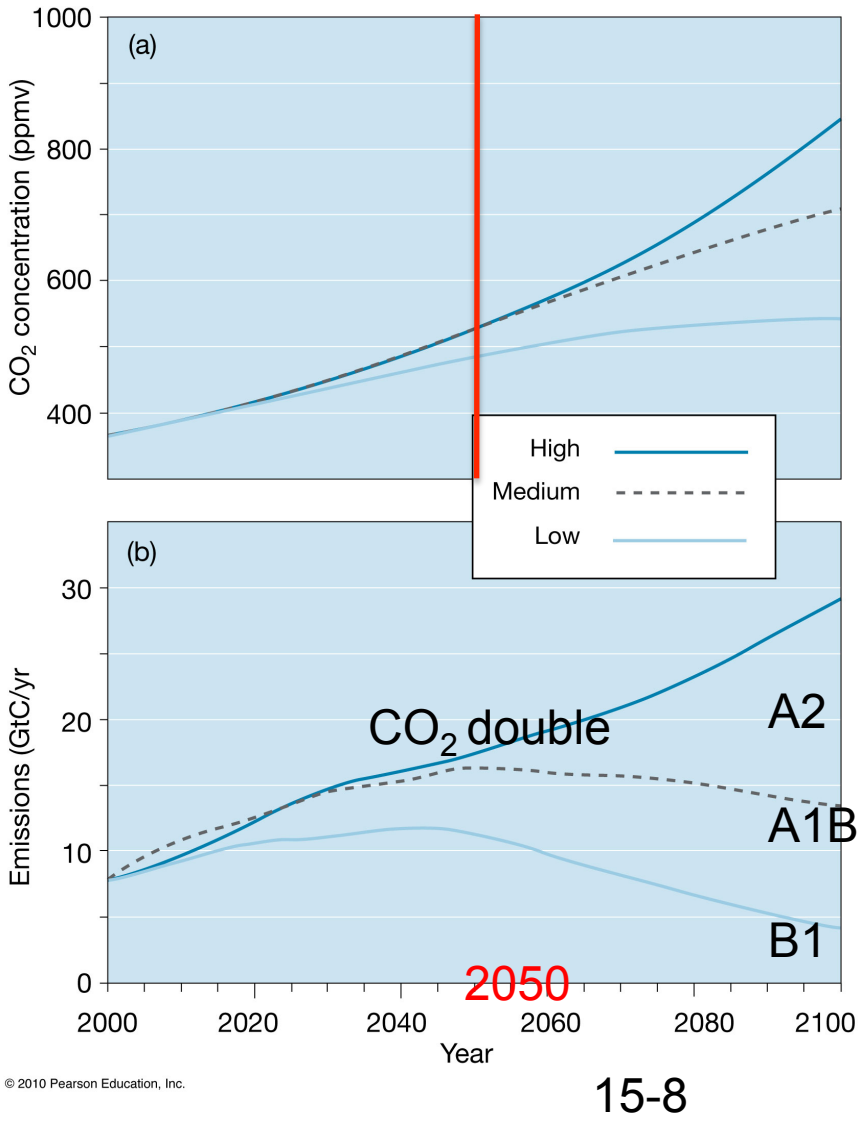
b. Dissolution of seafloor carbonates will take a few years to reduce atmospheric CO_2;

c. Silicate weathering is the most permanent, slowest process that removes atmospheric CO_2;

d. Both a and c.

2. Projections of future atmospheric CO_2 concentrations and climate

We know source & sink, by assuming future emission rate & removal processes,
⇒Predict future CO_2 level using carbon cycle computer model.



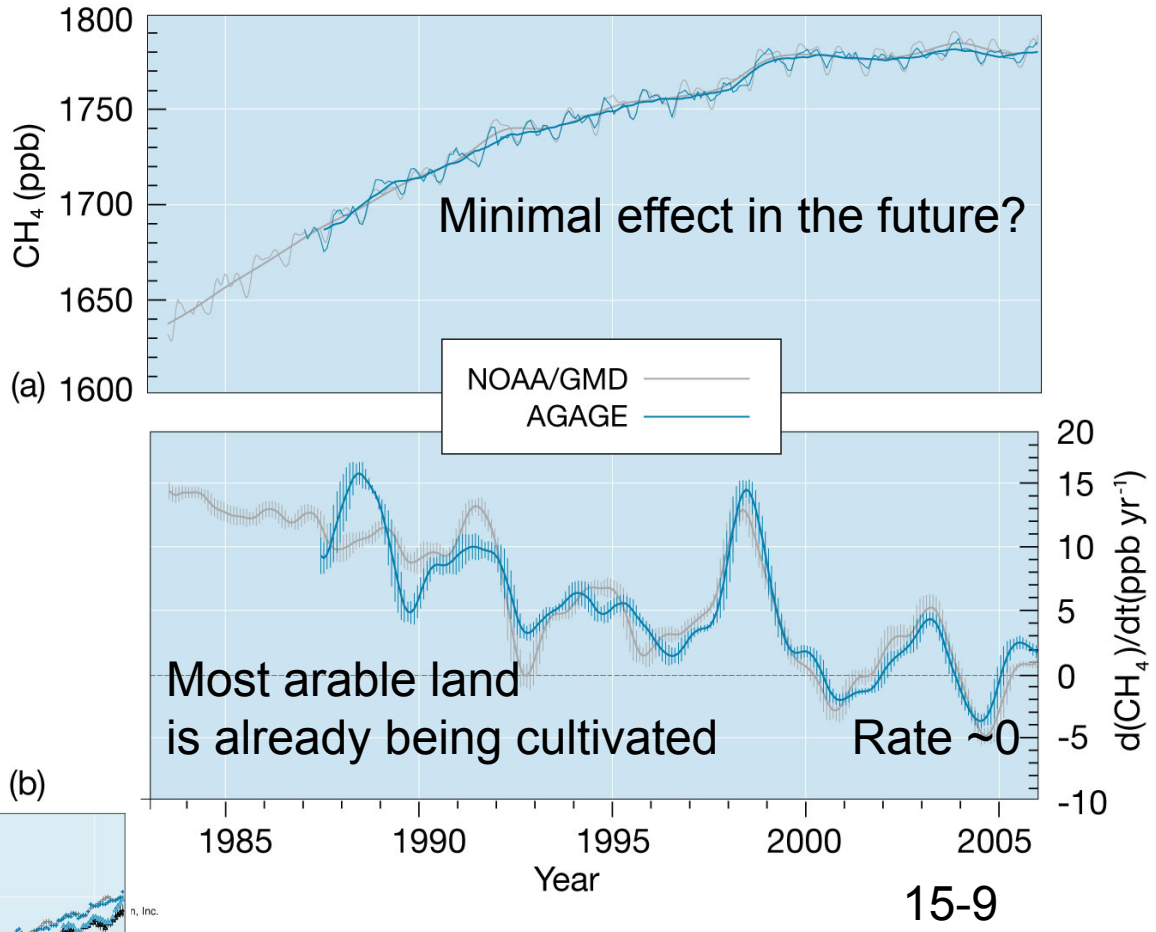
IPCC: Different CO_2 emission Scenarios:

1-D model: radiative-convective model (Chp 3): prediction over next century:

B1: global mean temperature increase 2°C by 2100;
A2&A1B: 2.5°C by 2050 (CO_2 double); 4°C by 2100 for A2;
Observed warming over the past 100years: 0.8°C!

1-D model, too simple; Overlooks Other Factors;

Other greenhouse gases



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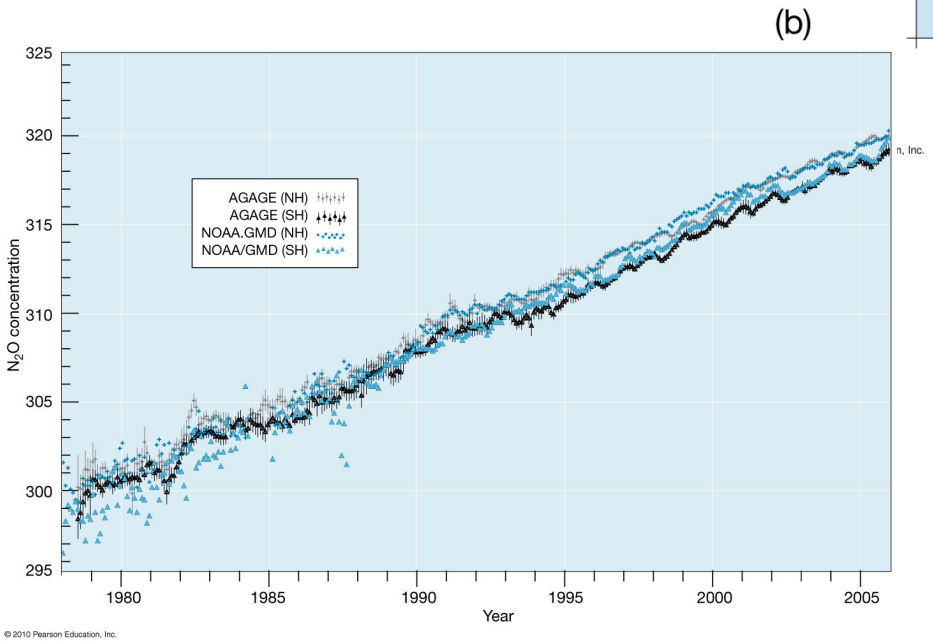


30% anthropogenic – bacterial denitrification in Nitrogen-based fertilized soils;

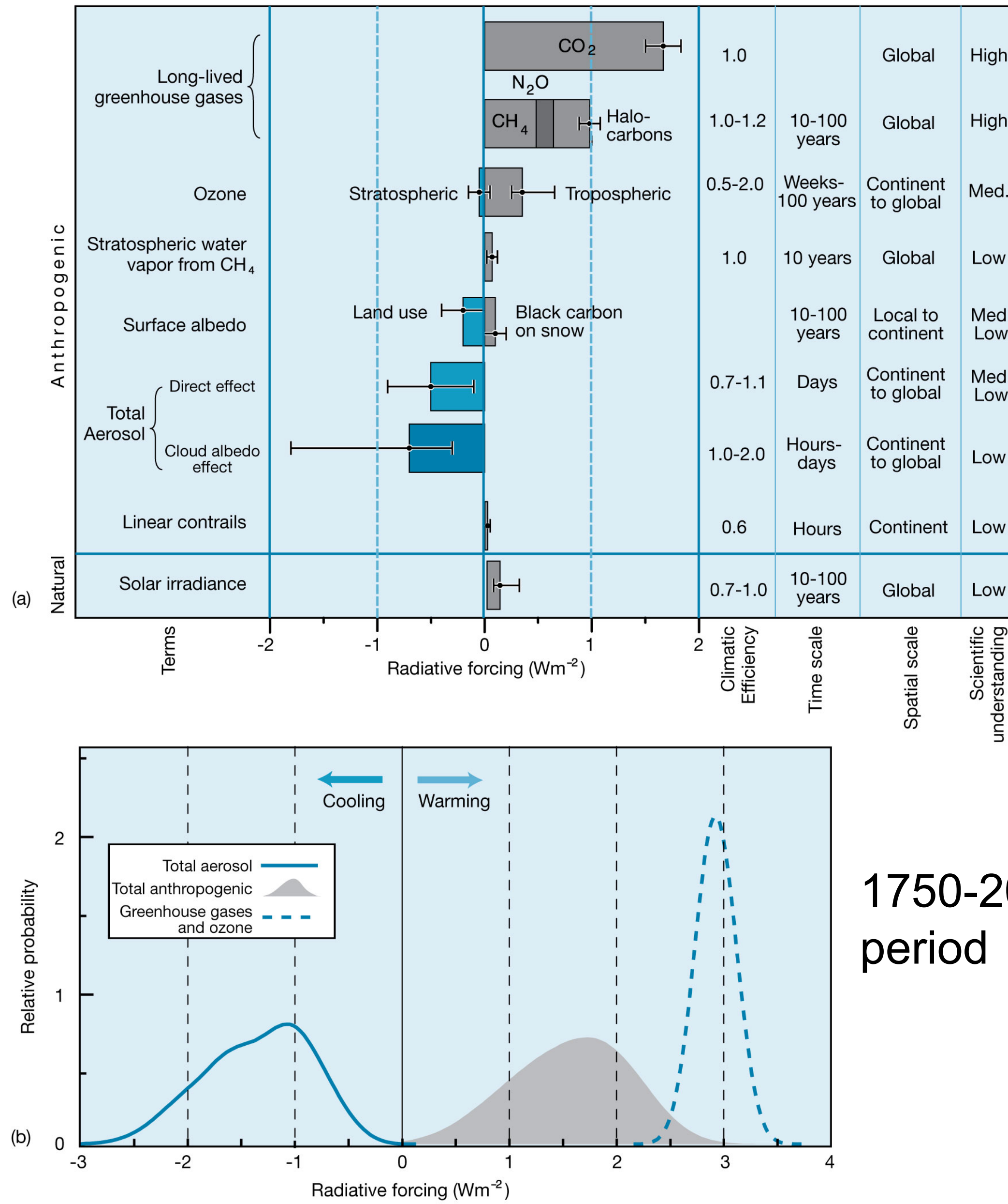
But low abundance.

Global radiative forcing for year 2000 relative to 1750

Greenhouse gases: trap outgoing infrared flux – radiative forcing – increase temperature.

1-D model, too simple; Overlooks other Factors; Doubling CO_2 - 2.5C in 2050;

Complex Climate Models: 2-4.5C.



1750-2005 period

Clicker question 3

Choose the correct and complete statement.

a. IPCC A1B (medium) projection of future (next 100 years) atmospheric CO_2 emission rate peaks near 2050 and decreases afterwards;

b. IPCC projection of future (next 100years) atmospheric CO_2 concentration shows an increasing trend ;

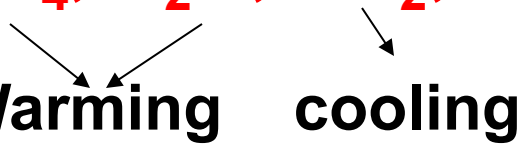
c. CO_2, CH_4, N_2O and CFCs have increased radiative forcing from 1750-2005, and aerosols and clouds reduced radiative forcing; their total effects are positive radiative forcing;

d. Both b and c;

e. All of above.

AOGCM predictions of global warming

IPCC estimated CO_2 concentration in next century; Also estimated CH_4, N_2O, SO_2;



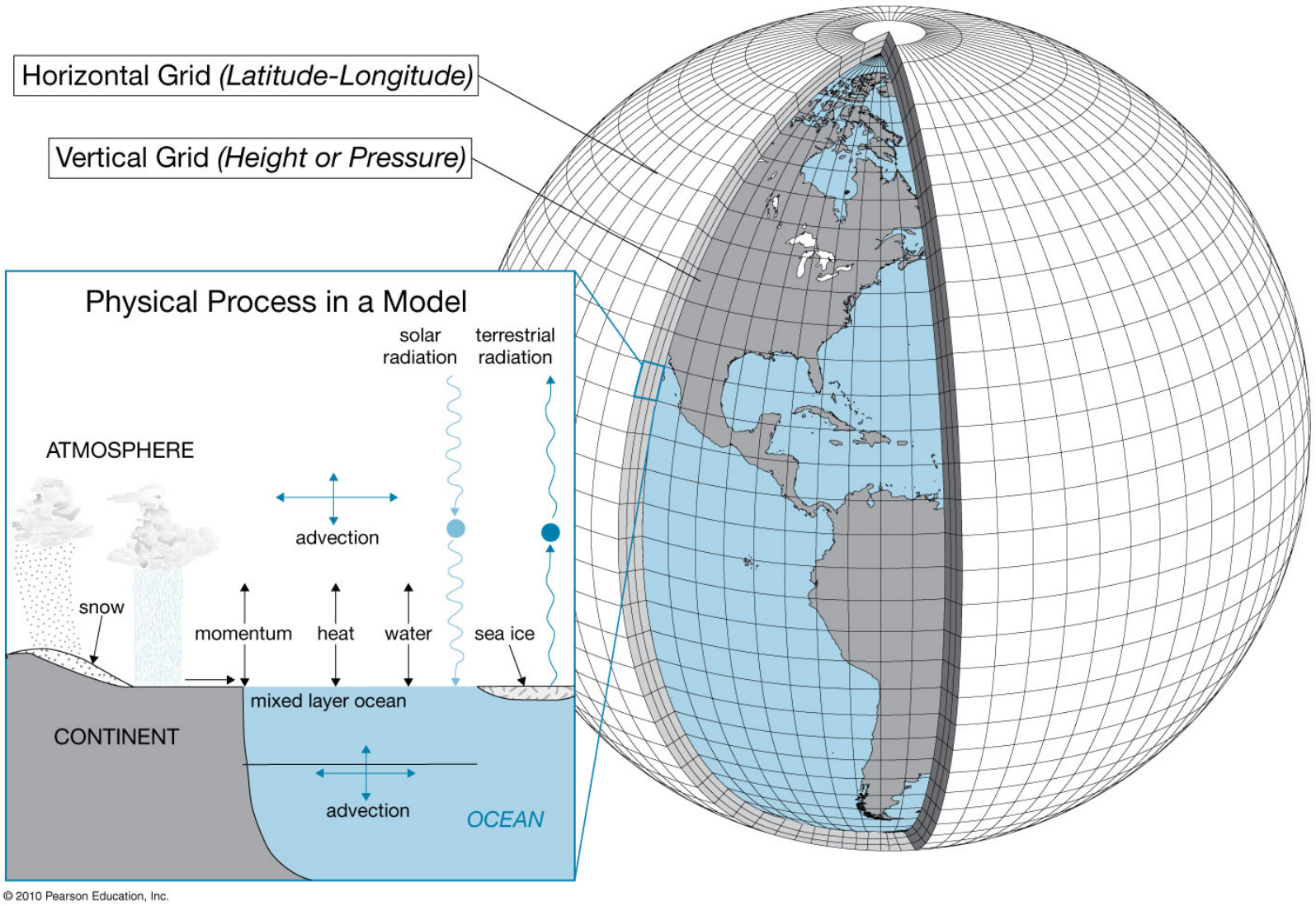
In accordance with the CO_2 estimation (fossil fuel burning, deforestation, agriculture -population)

Most pessimistic case: CH_4~a factor of 2; N_2O~50%.

To predict how much the increased trace gases affect future climate (global warming, precipitation, etc) => 3-dimensional, global climate models.

Atmosphere-ocean-general circulation models (AOGCMs).

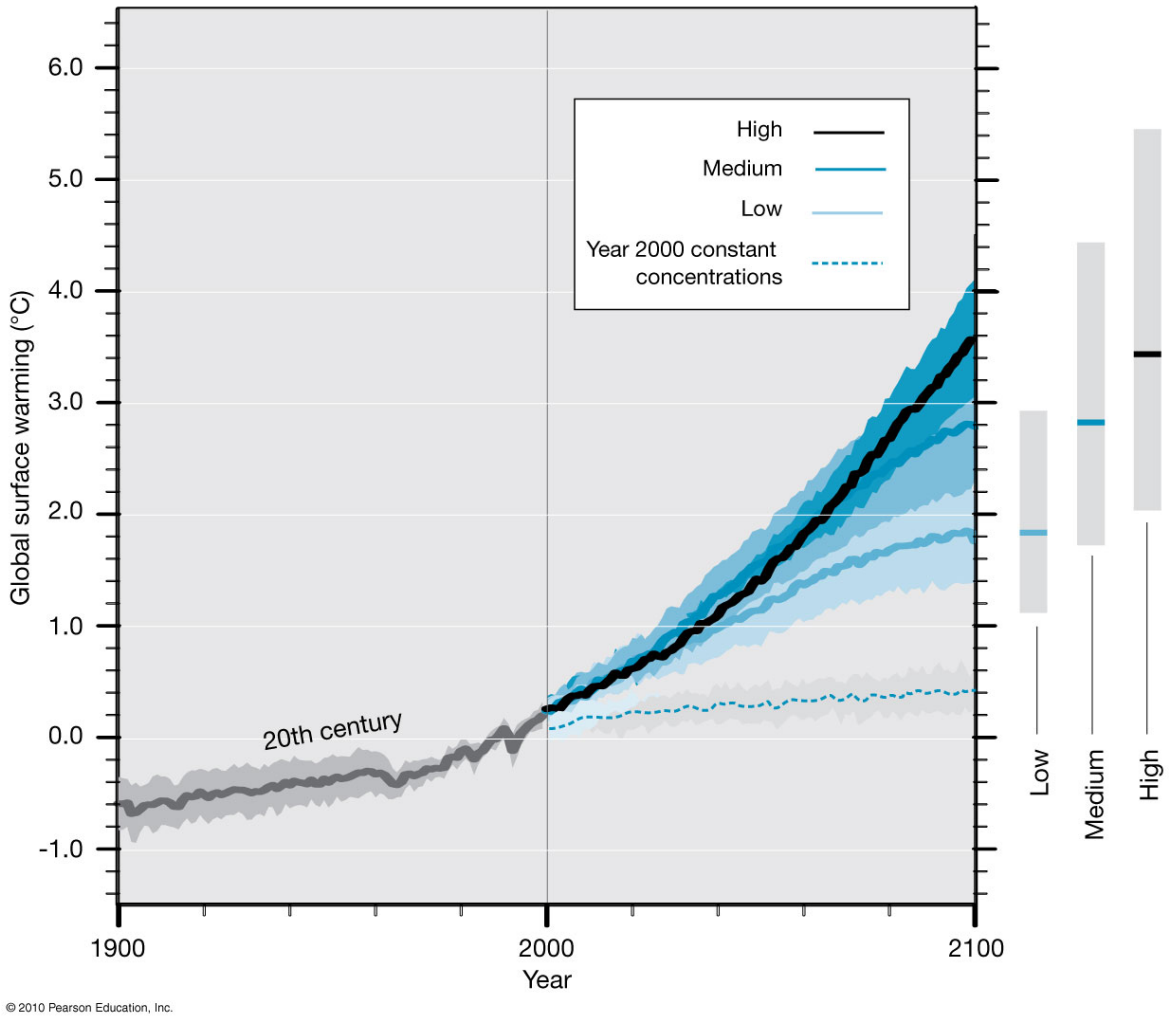
AOGCM – Coupled Global Climate Models



Climate model prediction: warming trend in the next century (2100 range: 1.4°-4.0°C)

Relative to year 2000

Recall:
atmosphere heat capacity << ocean;
ocean acts as a brake for how fast atmosphere warms;
However, after atmosphere CO_2 stops increasing, global temperature still increases for quite some time.



Clicker question 4

A. IPCC estimated that CO_2, CH_4 and N_2O will all increase in the next century;

B. Climate models predict that global mean temperature will increase by 1.4-4.0°C by 2100 relative to 2000;

C. When the greenhouse gases are kept to their concentration of year 2000, global mean temperature will stay constant from 2000 to 2100;

D. Both A and B;

E. All of above.

Long-term climate warming

If we continue to burn the fossil fuel & deforestation at the present rate => warming longer.

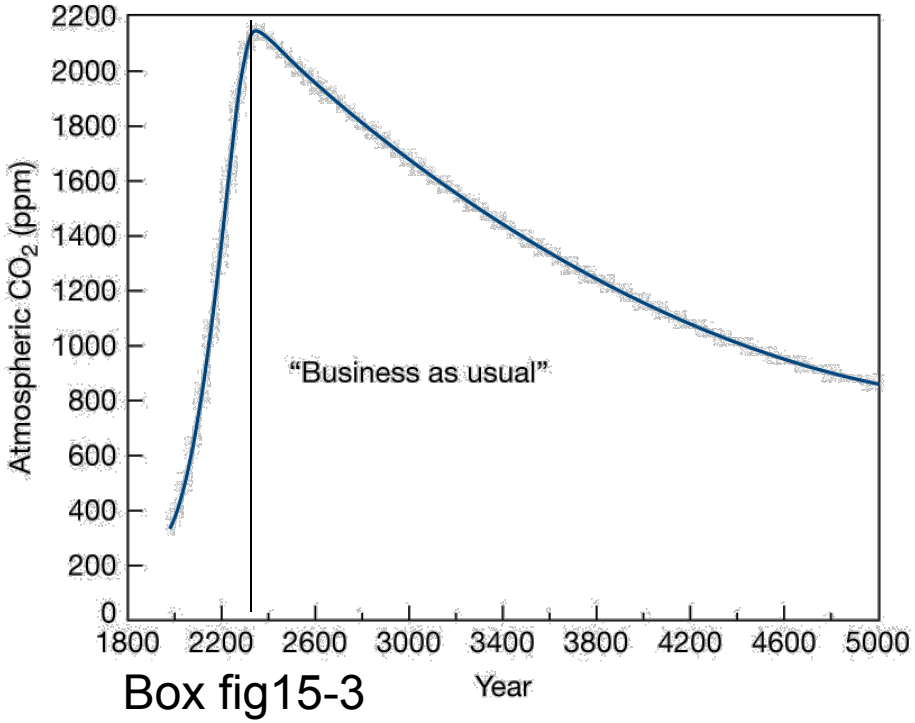
Assume: most fossil fuel reserve - consumed in 400years;

Assume, deforestation continue until - 30% world forest remains;

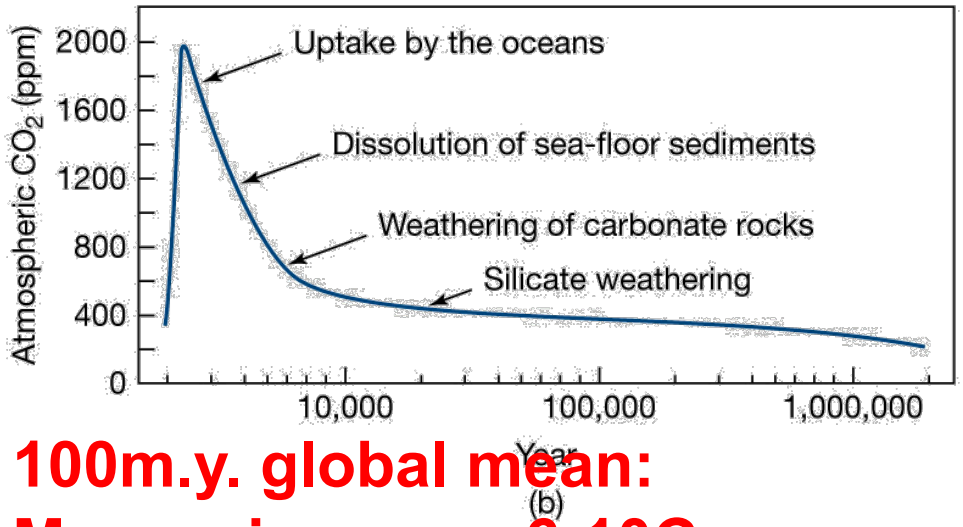
Model estimate: CO_2 2100ppm in yr 2300 = 8 x pre-industry;

280ppm: yr 1800

Temperature:4.5~13.5C!



Box fig15-3



100m.y. global mean:

Mesozoic warm: 6-10C warmer;

Pleistocene glacier:10C colder

Clicker question 5

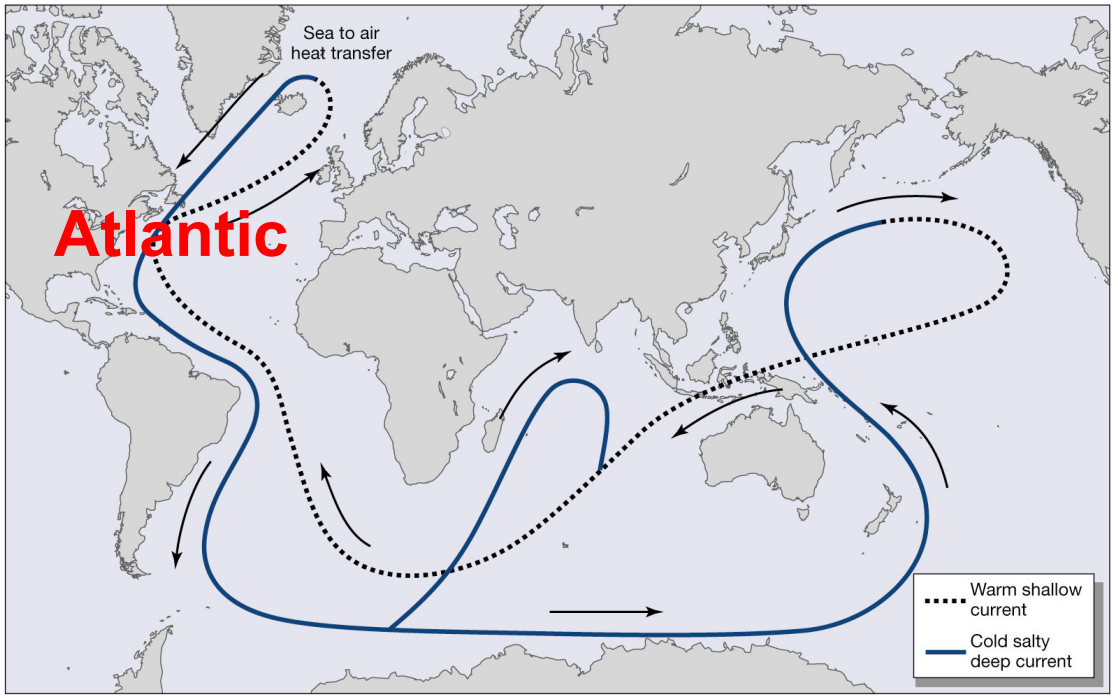
If we continue to burn the fossil fuel at present rate, and tropical deforestation continues until 30% world's forest remains, the projected amplitude of global temperature change in year 2300

A. can be higher than that of the Mesozoic warming and Pleistocene glatiation;
B. is much lower than that of the Mesozoic warming;
C. Is smaller than that of the European medieval warming;
D. Is smaller than that of the Little Ice age;
E. All of above.

Possible changes in thermohaline circulation

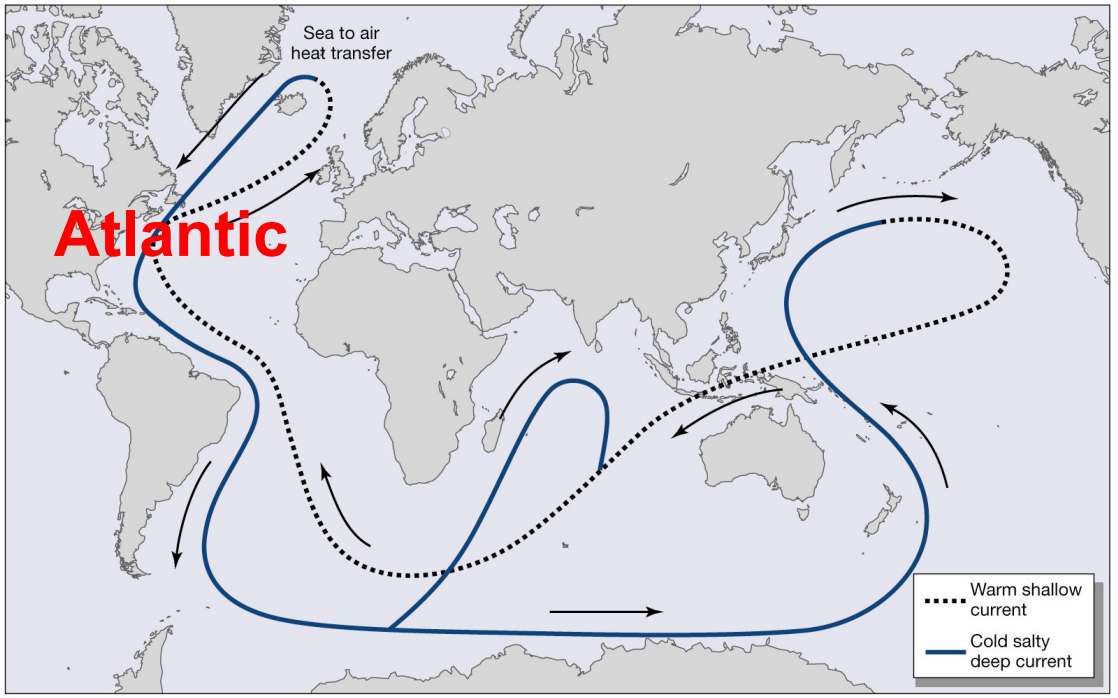
Recall: this circulation – keeps western Europe warm during winter;
this circulation – probably ceased during the Younger Dryas event at the end of the Last Glaciation; - due to the freshwater from the melting Laurentide icesheet, flowed into the North Atlantic – reduced deep water formation;

Warming in the future
- circulation shutdown?



a)Global warming => enhanced hydrological cycle
⇒rainfall + snowfall freshen North Atlantic Ocean
=> reduce deep water formation =>
weaken global thermohaline circulation.
b)Greenland ice sheet melting

Climate models:
not consistent.



Clicker question 6

A. Shutdown of the North Atlantic thermohaline circulation is thought to be the cause for the cold Younger Dryas event;

B. Shutdown of the North Atlantic thermohaline circulation is thought to be the cause for the warm Younger Dryas event;

C. Future warming may enhance the thermohaline circulation by enhancing the deep water formation;

D. Both A and C.