DAVINCI future
mission to Venus

Anticipated
launch in 2029

https://www.youtube.com/watch?v=aXLKyoXQR8g

ASTRO 197 Topics

Thursday Oct. 24

- Venus Atmosphere and the Greenhouse Effect
- Evolving Sun
- Climate Change on Venus and Earth

ASTRO 197 Important Dates

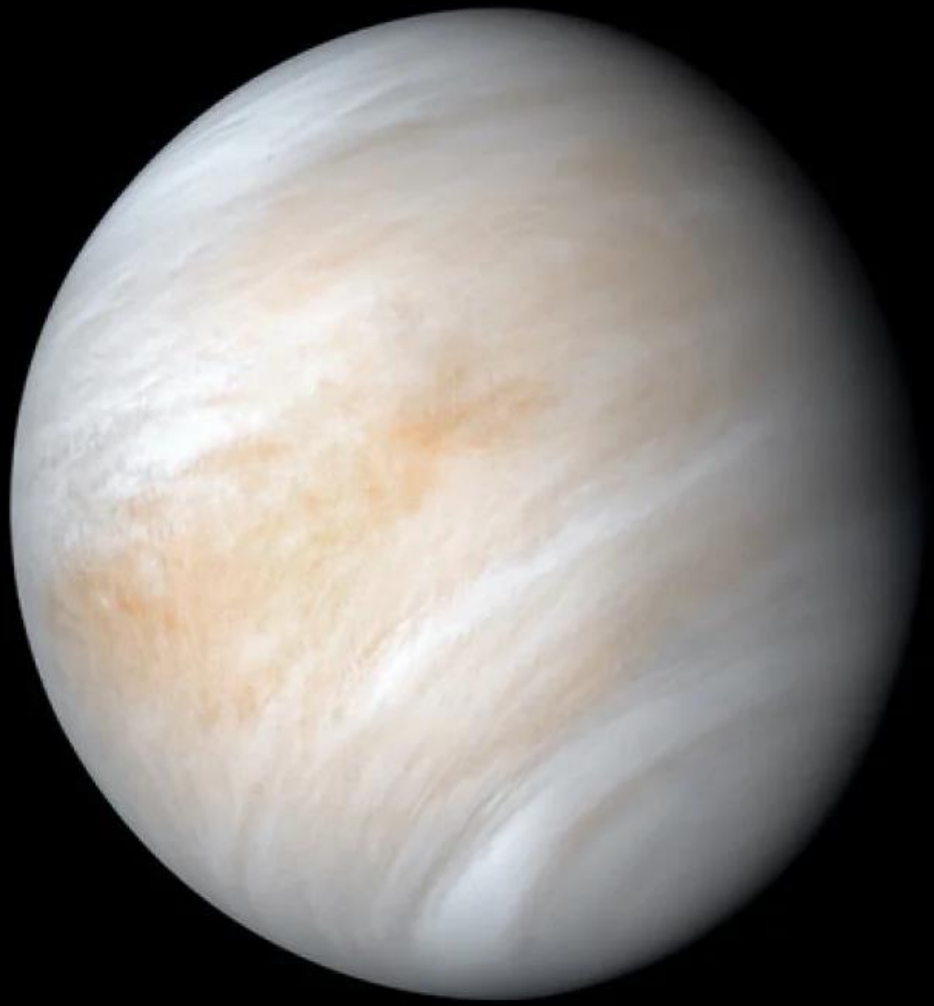
Friday Oct. 25

Homework 7 – Due by 11PM

Chapters 9 &10: Venus exploration and comparing the atmospheres of Venus and Earth

Thursday Oct. 31

Exam 2 using TopHat in the OBS 101 classroom



Mariner 10, a NASA spacecraft, shows Venus wrapped in turbulent clouds, whirling at 200 mph in this image taken in February 1974. Credit: NASA / JPL-Caltech

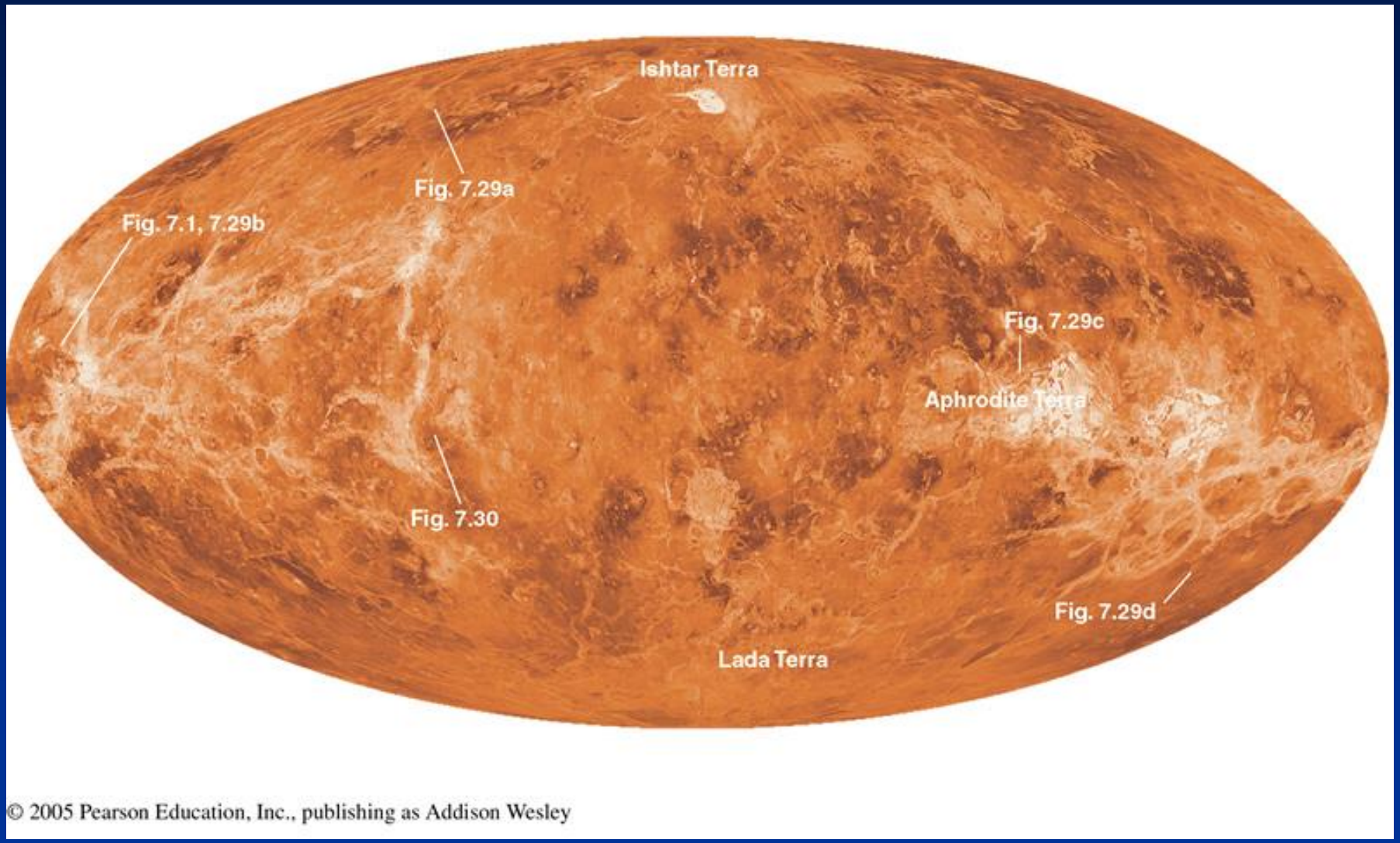
Atmospheres of the Terrestrial Worlds

Table 10.1 Atmospheres of the Terrestrial Worlds

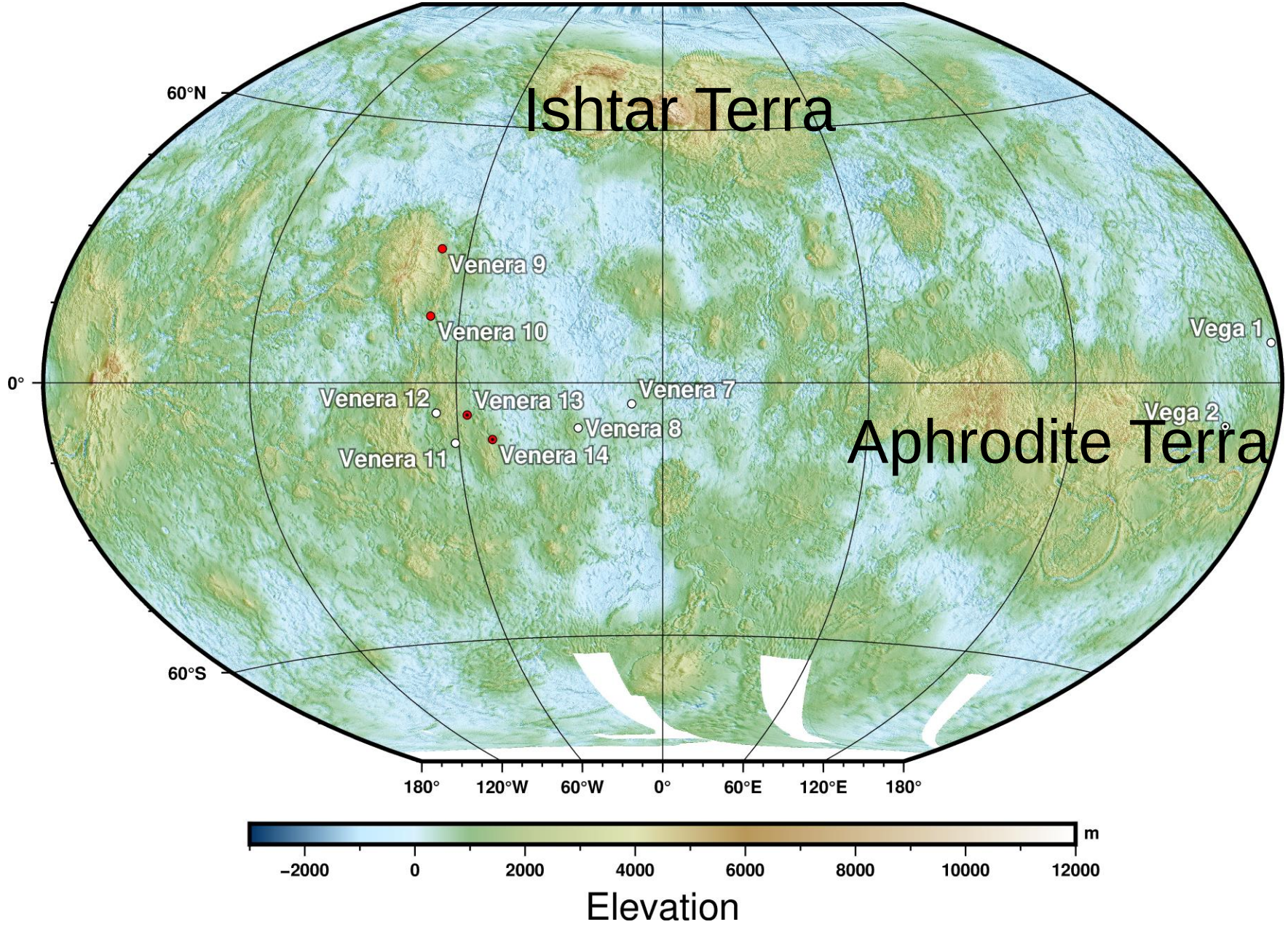
World	Atmospheric Composition	Surface Pressure*	Average Surface Temperature	Winds, Weather Patterns	Clouds, Hazes
Mercury	helium, sodium, oxygen	10^{-14} bar	day: 425°C (797°F) night: –175°C (–283°F)	none: too little atmosphere	none
Venus	96% carbon dioxide (CO_2) 3.5% nitrogen (N_2)	90 bars	470°C (878°F)	slow winds, no violent storms, acid rain	sulfuric acid clouds
Earth	78% nitrogen (N_2) 21% oxygen (O_2) 1% argon H_2O (0.4%, but variable) 0.04% carbon dioxide (CO_2)	1 bar	15°C (59°F)	winds, hurricanes, rain, snow	H_2O clouds, pollution
Moon	helium, sodium, argon	10^{-14} bar	day: 125°C (257°F) night: –175°C (–283°F)	none: too little atmosphere	none
Mars	95% carbon dioxide (CO_2) 2.7% nitrogen (N_2) 1.6% argon	0.007 bar	–50°C (–58°F)	winds, dust storms	H_2O and CO_2 clouds, dust

*1 bar ≈ atmospheric pressure at sea level on Earth.

Venus radar map produced by the Magellan spacecraft 1989-1993



https://en.wikipedia.org/wiki/List_of_missions_to_Venus



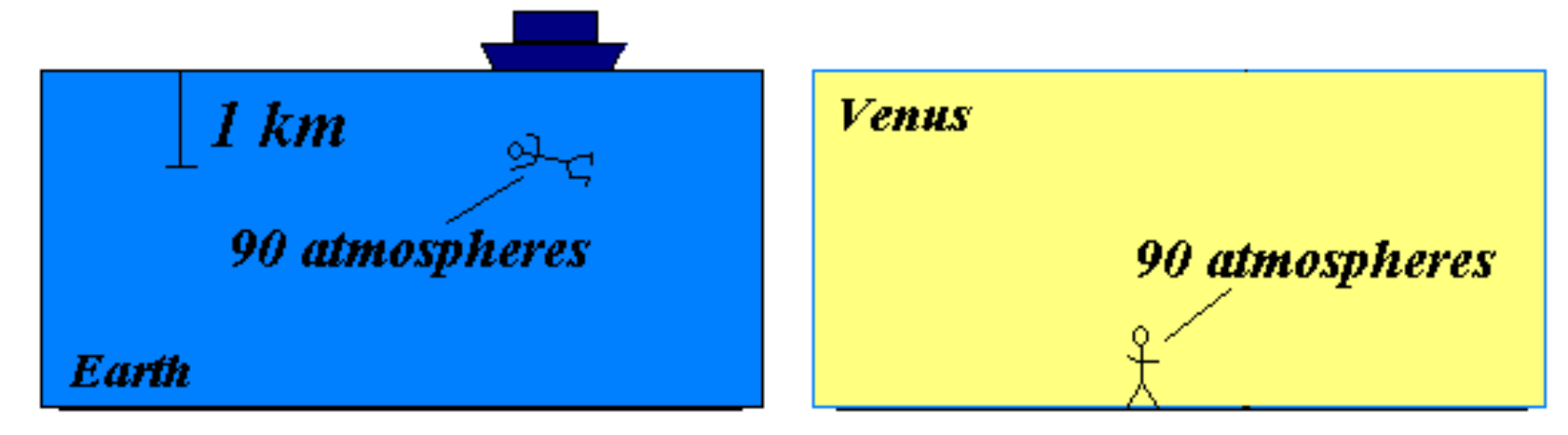
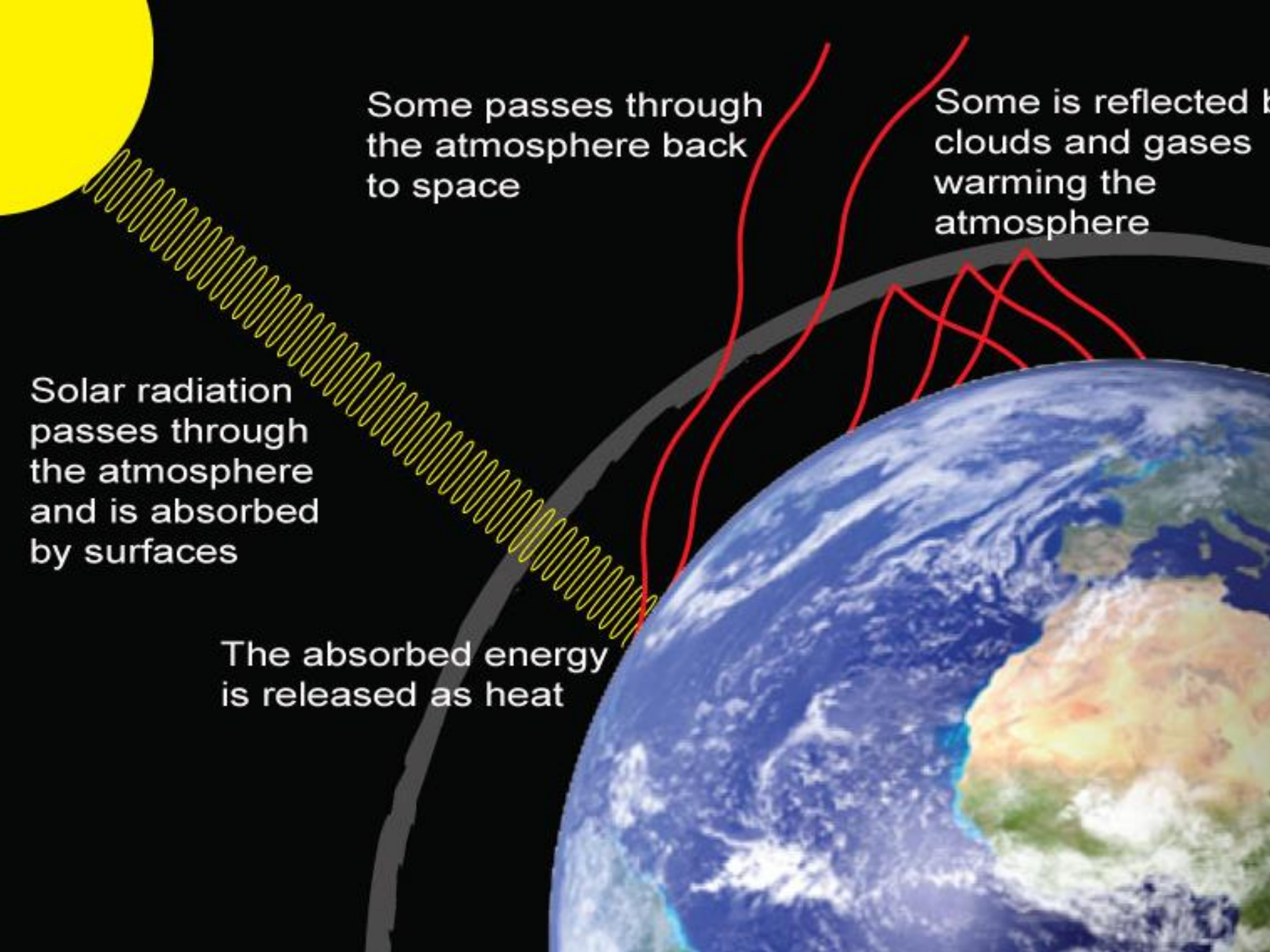

1 km
90 atmospheres
Earth
Venus
90 atmospheres

Table 10.2 Temperatures of the Terrestrial Worlds

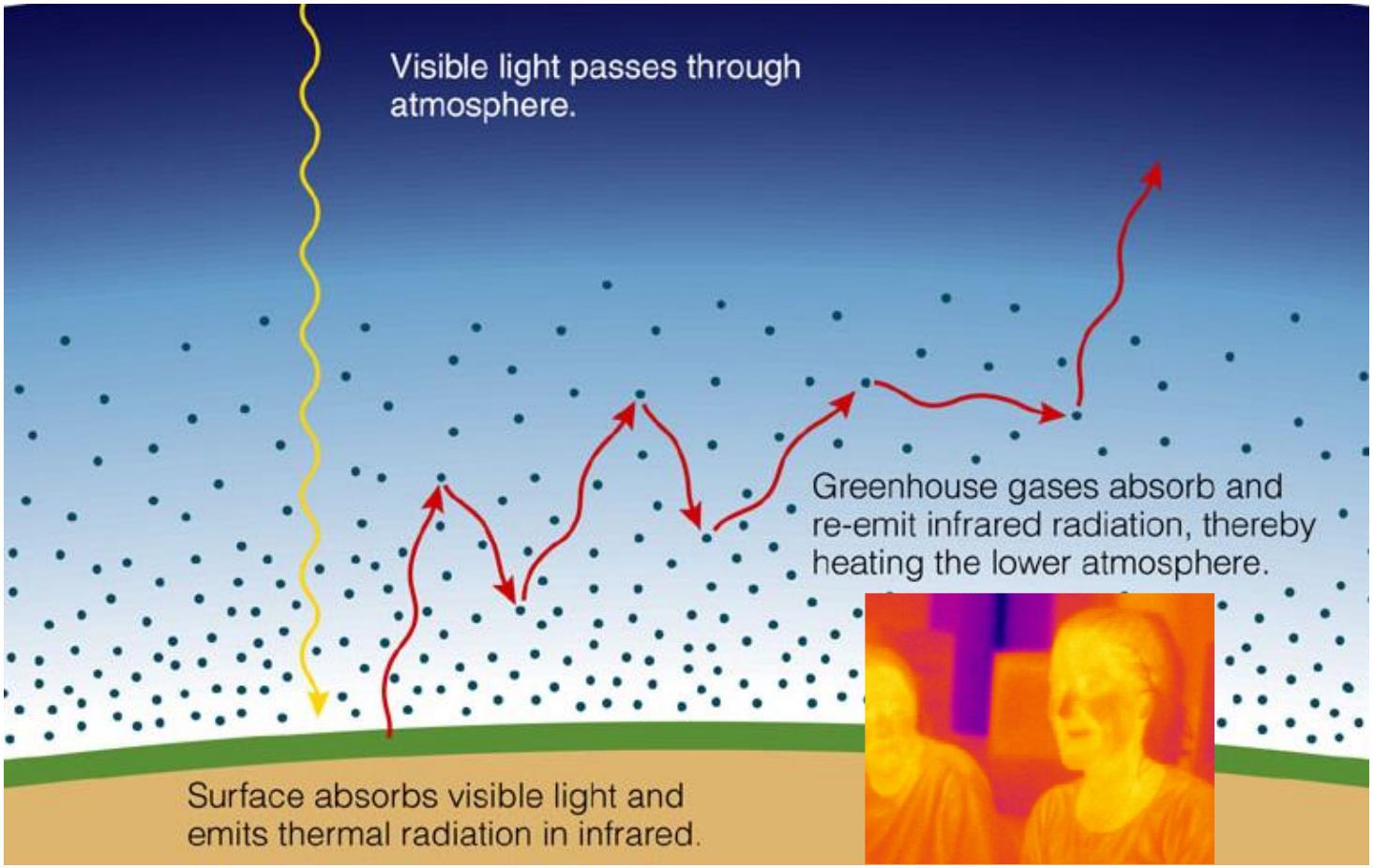
World	Distance to Sun (AU)	Albedo (0 = black, 1 = white)	Length of Day (Earth days)	"No Greenhouse" Temperature*	Observed Average Surface Temperature
Mercury	0.38	0.11	176	440 K	700 K (day), 100 K (night)
Venus	0.72	0.72	117	230 K	740 K
Earth	1.00	0.36	1	250 K	288 K
Moon	1.00	0.07	28	273 K	400 K (day), 100 K (night)
Mars	1.52	0.25	≈1	218 K	223

* Assumes rapid rotation, in which case day and night temperatures would be the same.

740 K =
873 ° F


Some passes through the atmosphere back to space
Some is reflected b
clouds and gases
warming the
atmosphere
Solar radiation passes through the atmosphere and is absorbed by surfaces
The absorbed energy is released as heat

The Greenhouse Effect



Which Molecules are Greenhouse Gases?

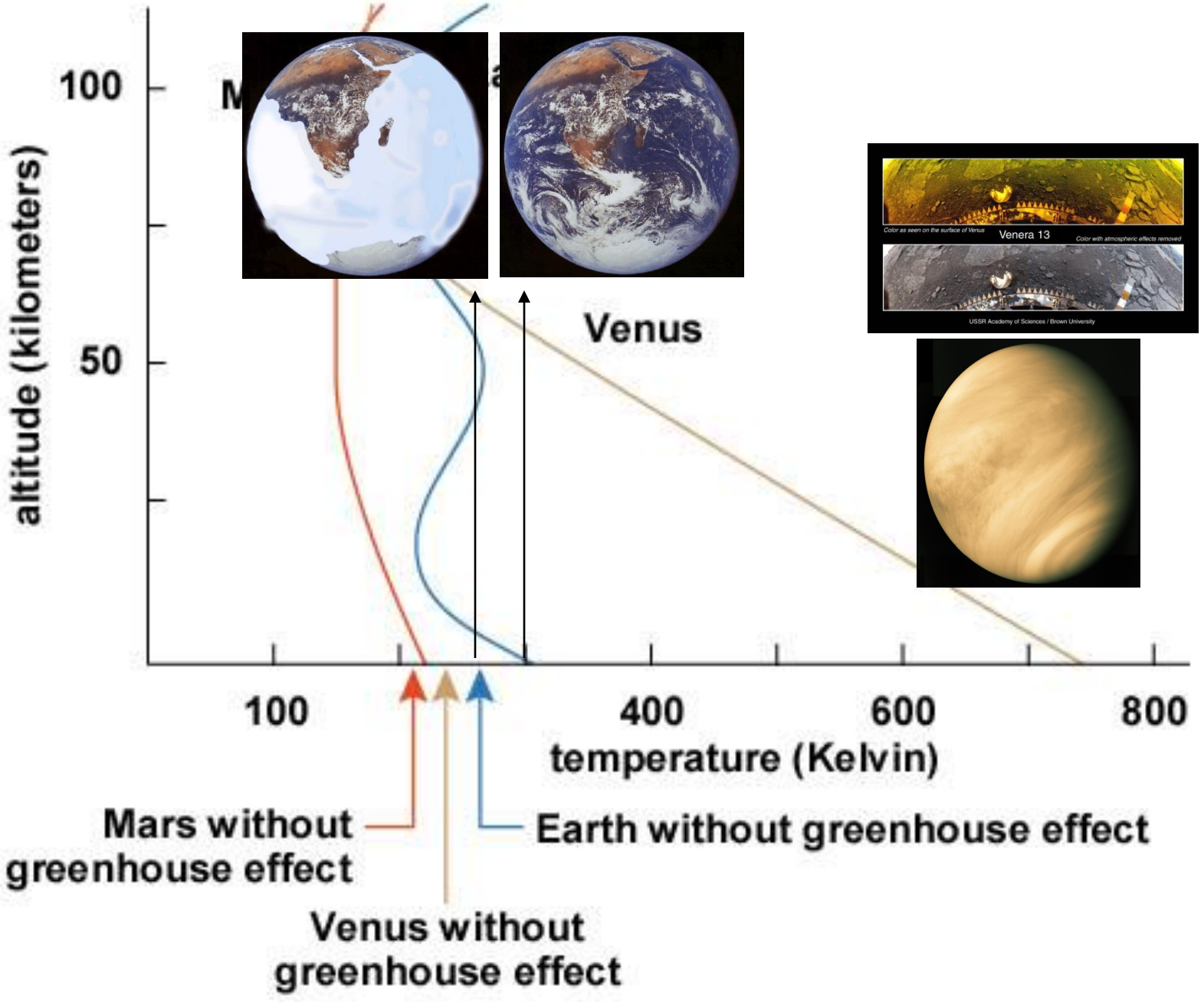
Atmospheres are Made of Volatile Compounds

Volatiles: substances that tend to be liquid or gaseous at temperatures of a few hundred Kelvin

Common Volatiles:

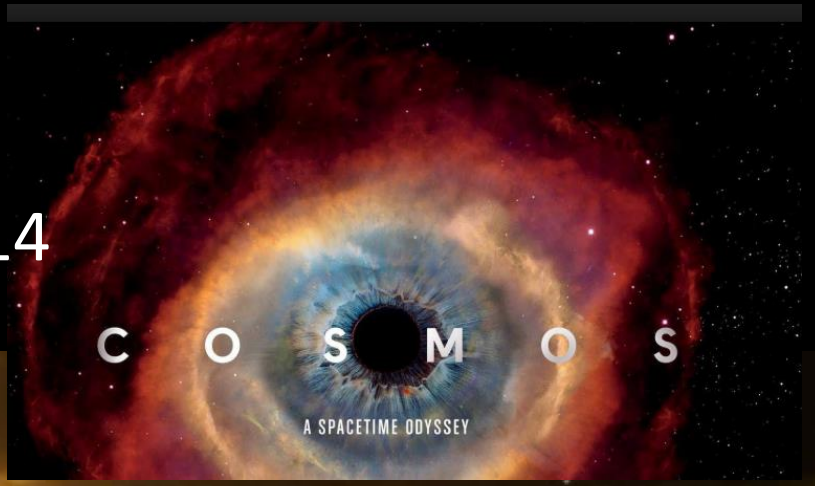
N_2, O_2, CO_2, H_20, H_2, He, CH_4, NH_3

GreenHouse Gases



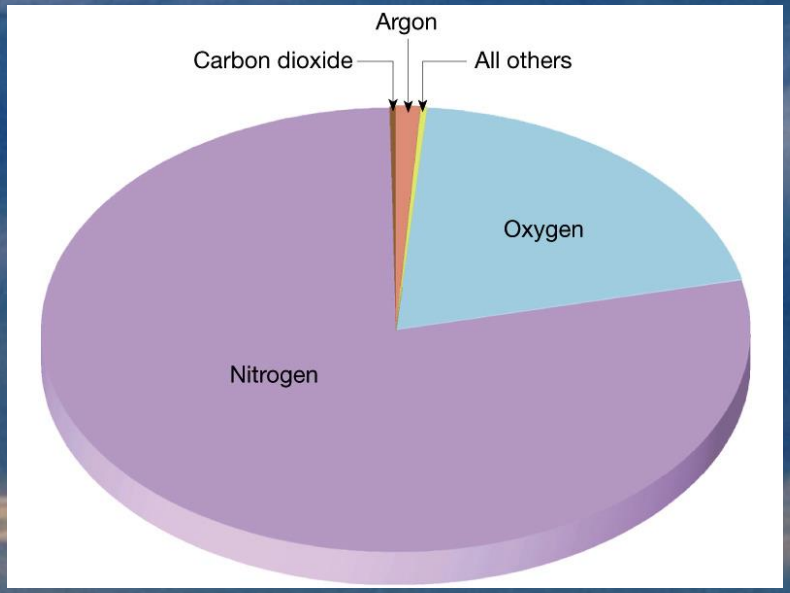
Movie Time

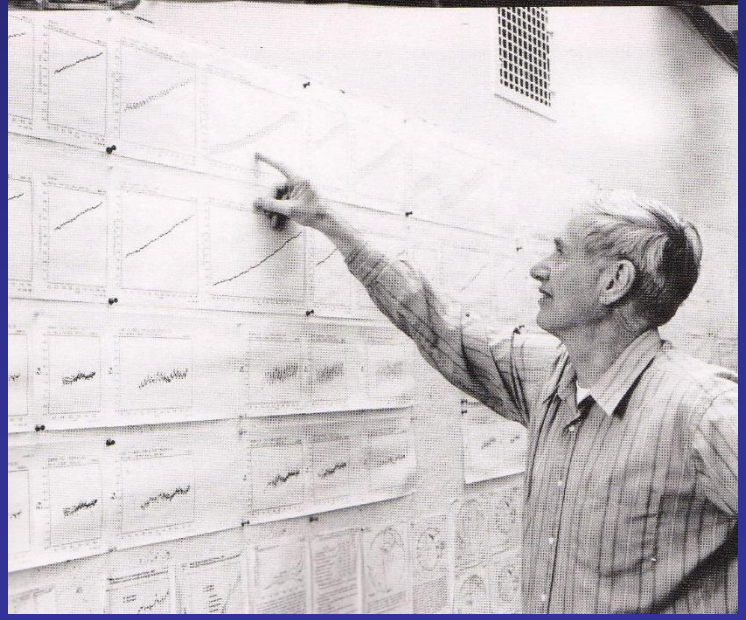
Cosmos: A Spacetime Odyssey
Episode 12: A World Set Free 2014
(0-15 min)



https://www.dailymotion.com/video/x6u8fyc

Earth's Atmosphere





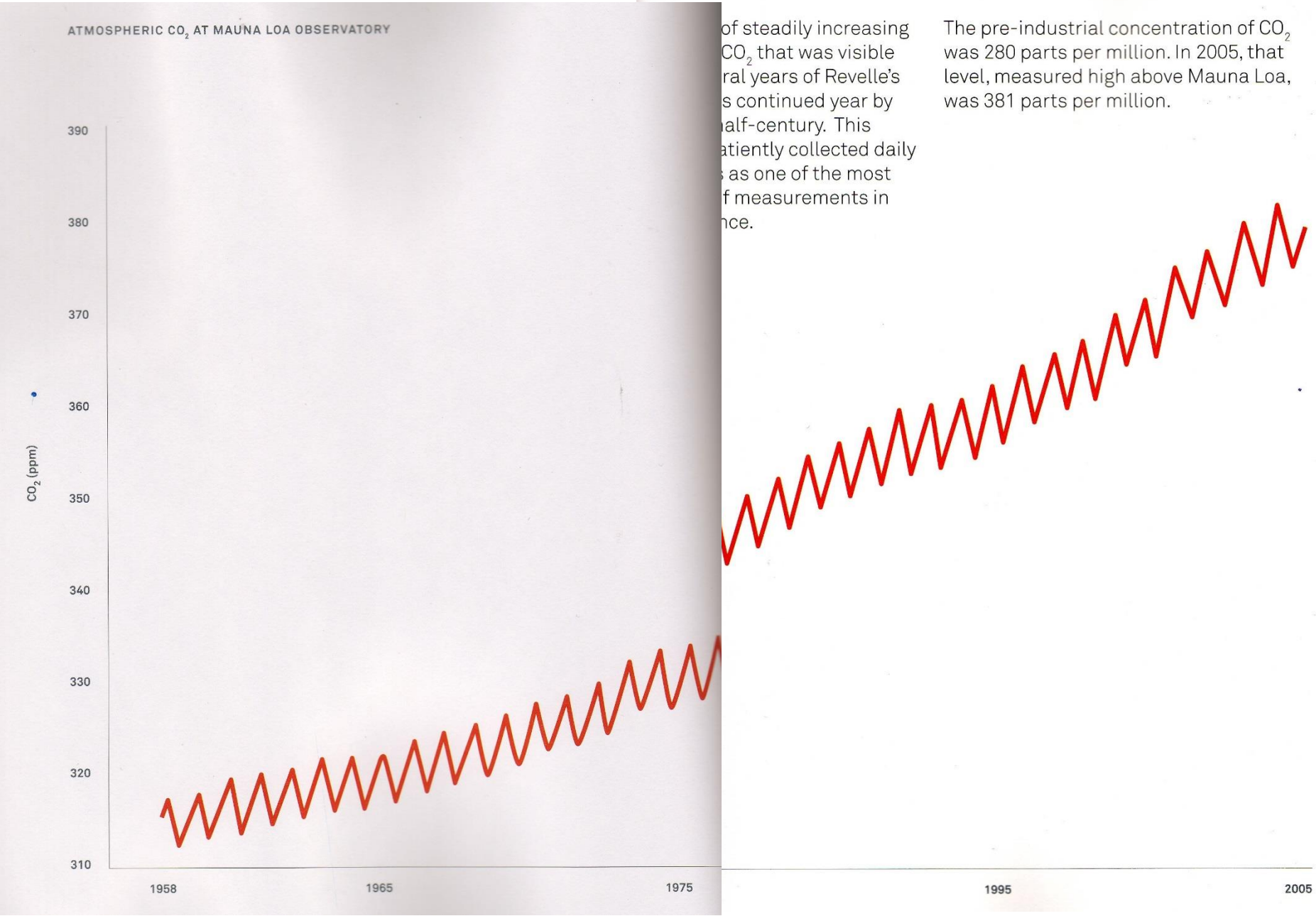
Oceanographer/Atmospheric Scientist/Professor

Roger Revelle (1909-1991)

Oceanographer/Atmospheric Chemist/Professor

Charles David Keeling (1928-2005)

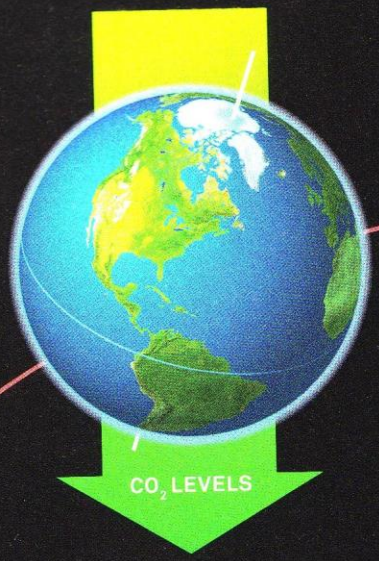
ATMOSPHERIC CO_2 AT MAUNA LOA OBSERVATORY



of steadily increasing
CO_2 that was visible
ral years of Revelle's
s continued year by
alf-century. This
atiently collected daily
s as one of the most
f measurements in
nce.

The pre-industrial concentration of CO_2 was 280 parts per million. In 2005, that level, measured high above Mauna Loa, was 381 parts per million.

CO_2, the amount of
ide.

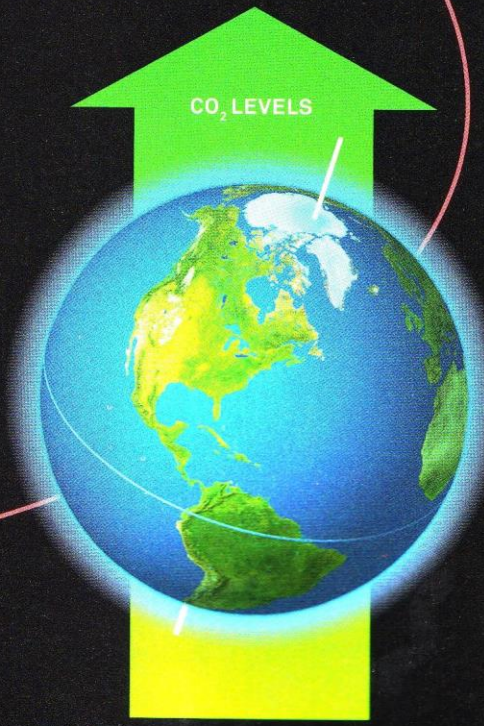


Northern Summer

the amount of CO_2 i
goes back up again

It's as if the entire E
breath in and out o

Northern Winter



TopHat Question

If you were to grab a handful (let's say one million) molecules of air in this room, about how many would be CO_2?

A. 4

B. 400

C. 40000

D. 4000000

E. 400000000

Carbonate-Silicate Weathering Cycle

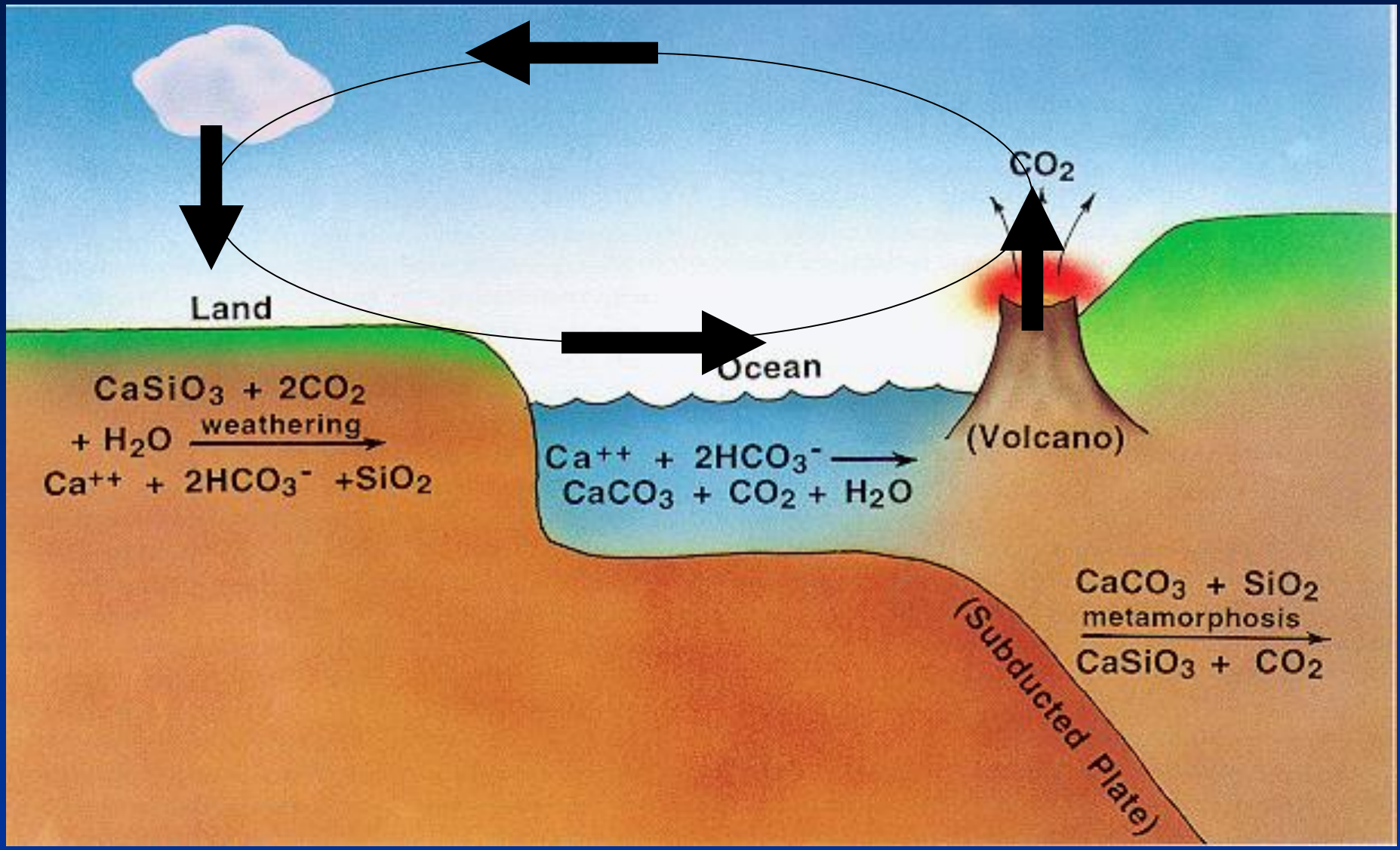


Figure 9.12a

a The eruption of Mount St. Helens, May 18, 1980.

Figure 9.12b

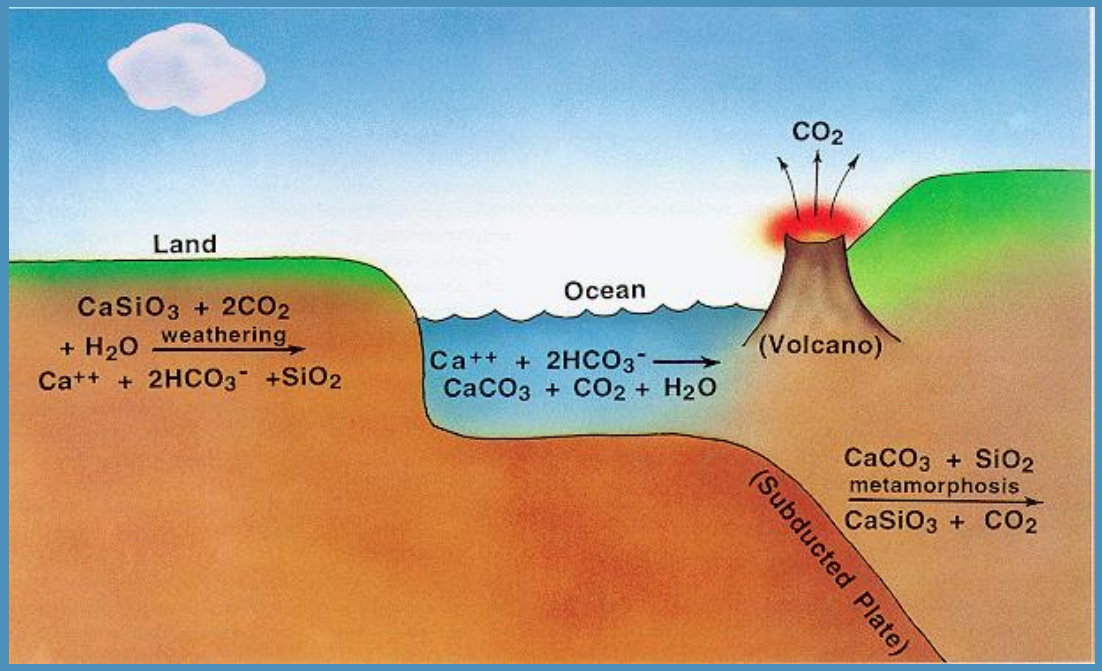
b More gradual outgassing from a volcanic vent on the island of Vulcano near Sicily.

So This Means

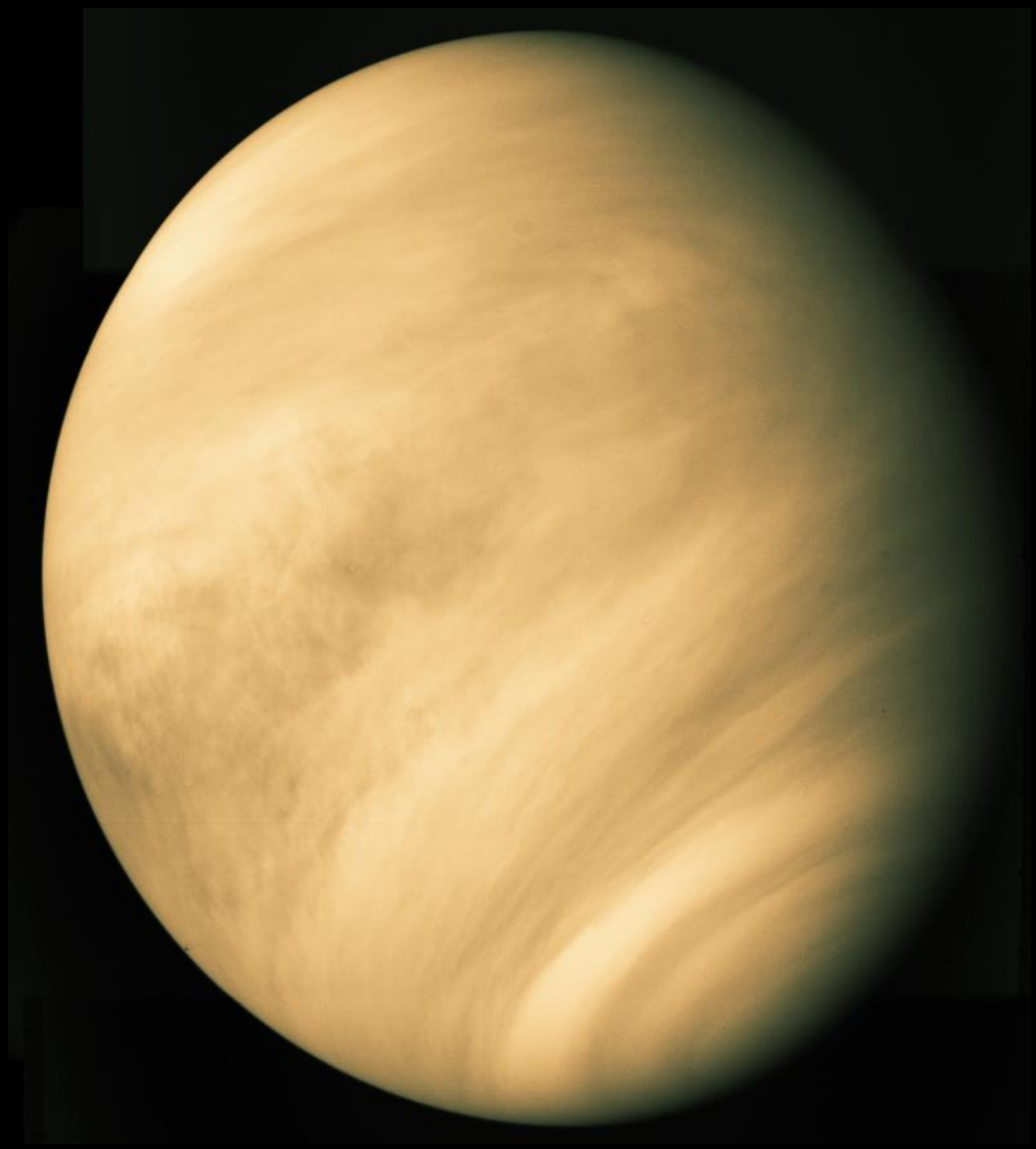
Planets with weathering (which requires liquid water) and warm interiors (and active volcanoes) should be able to regulate climate naturally and remain habitable over a wide range of conditions and distances from the Sun.

So This Means

But what if the weathering cycle slows or even stops?



Which would be the case if the water is all boiled away to space



Greenhouse Effect on Venus

- Thick carbon dioxide atmosphere produces an extremely strong greenhouse effect.
- Earth escapes this fate because most of its carbon and water are in rocks and oceans.

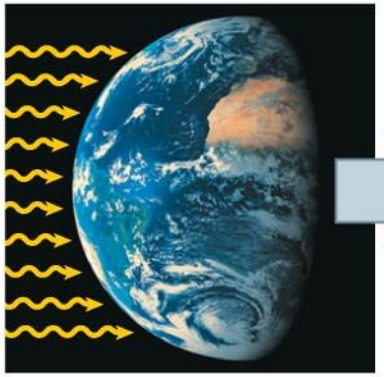
TopHat

Venus has a denser atmosphere than Earth because:

a. it outgassed most of it's carbon through volcanoes.
b. it's gravity is stronger.
c. it's closer to the Sun and warmer which prevents the gasses from condensing
d. it wasn't hit by as many comets and asteroids as Earth was

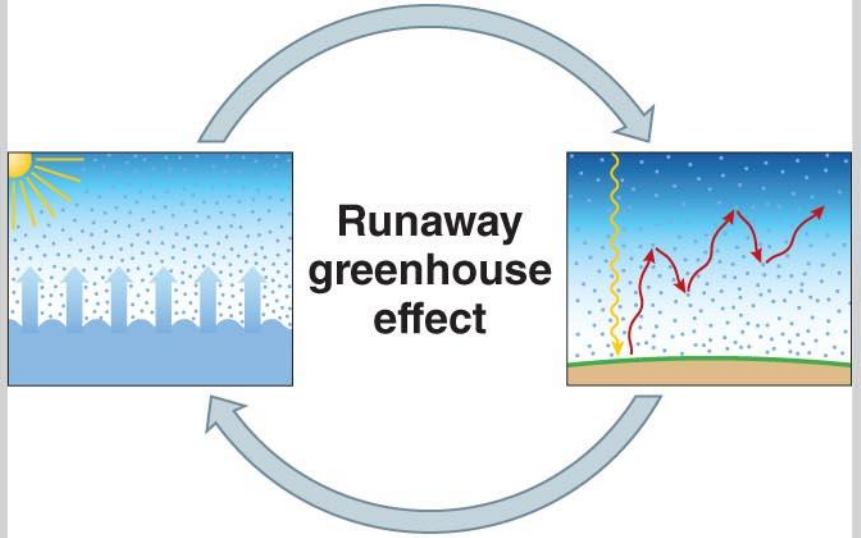
If Earth moved to Venus's orbit

More intense sunlight . . .



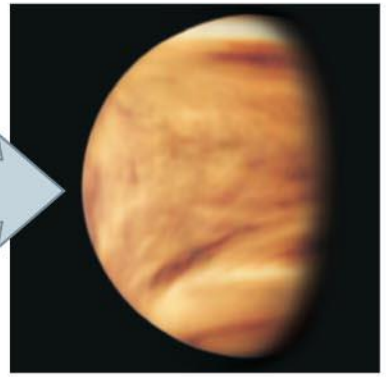
. . . would raise surface temperature by about 30°C.

Higher temperature increases evaporation, and warmer air holds more water vapor.

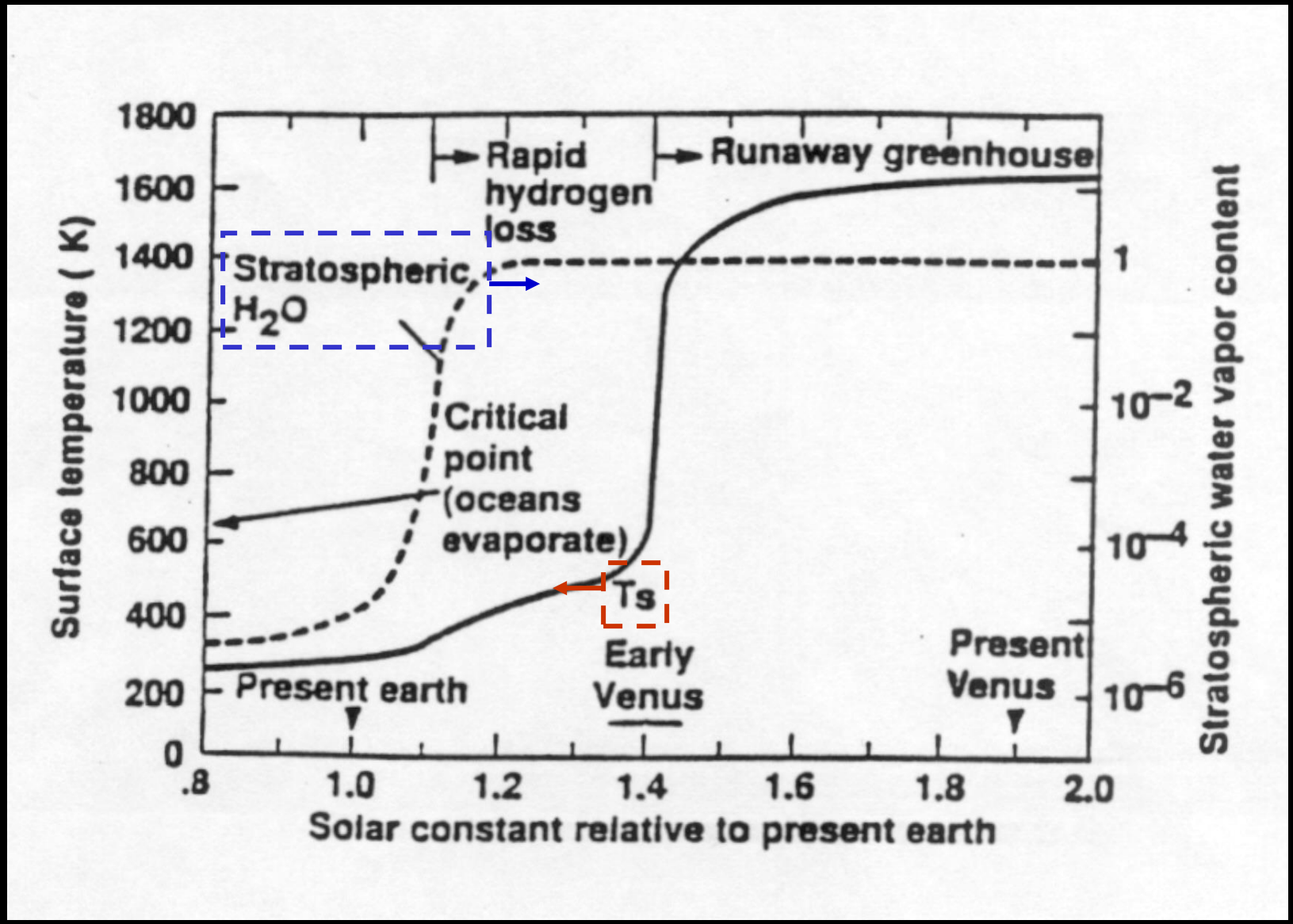


Additional water vapor further strengthens the greenhouse effect.

Result: Oceans evaporate and carbonate rocks decompose, releasing CO_2 further strengthening the greenhouse effect . . .

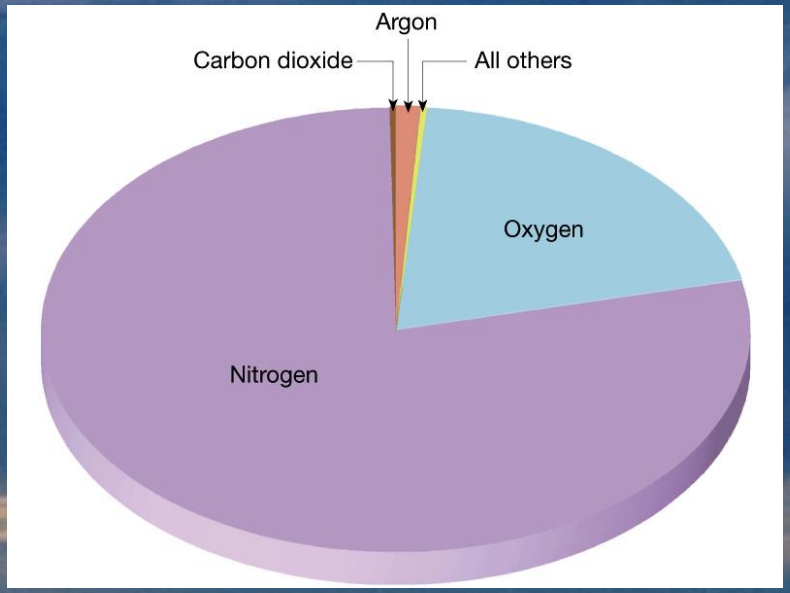


. . . making Earth hotter than Venus.

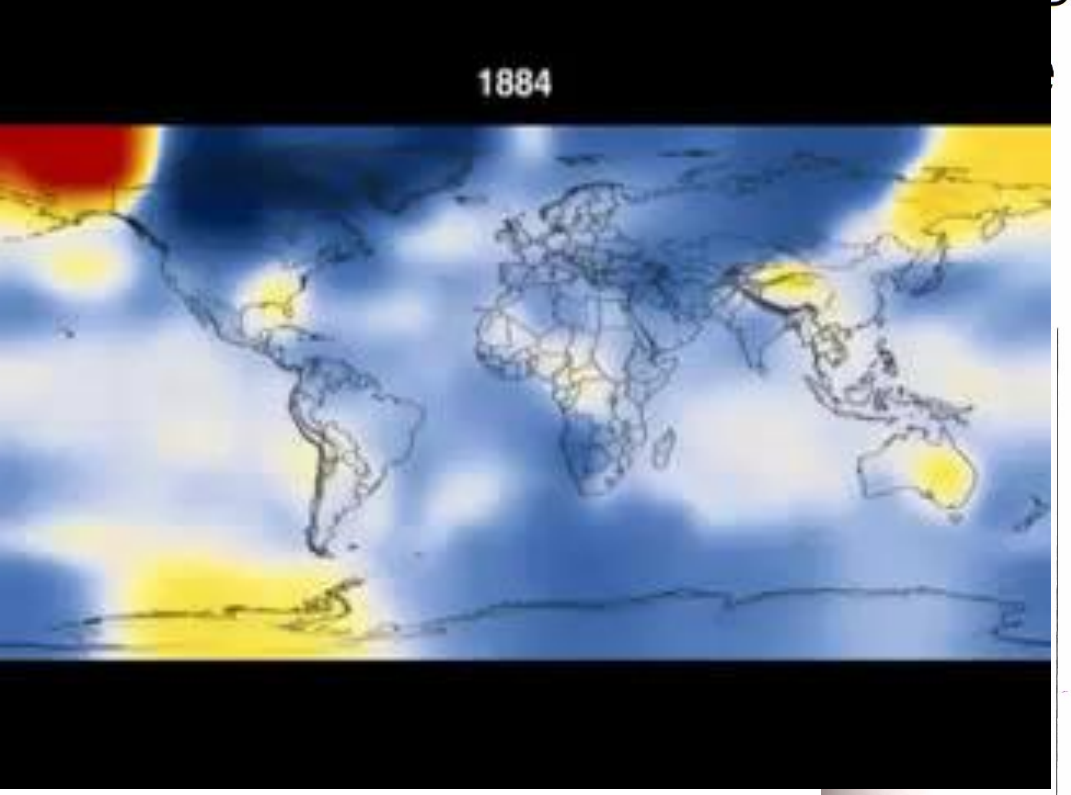


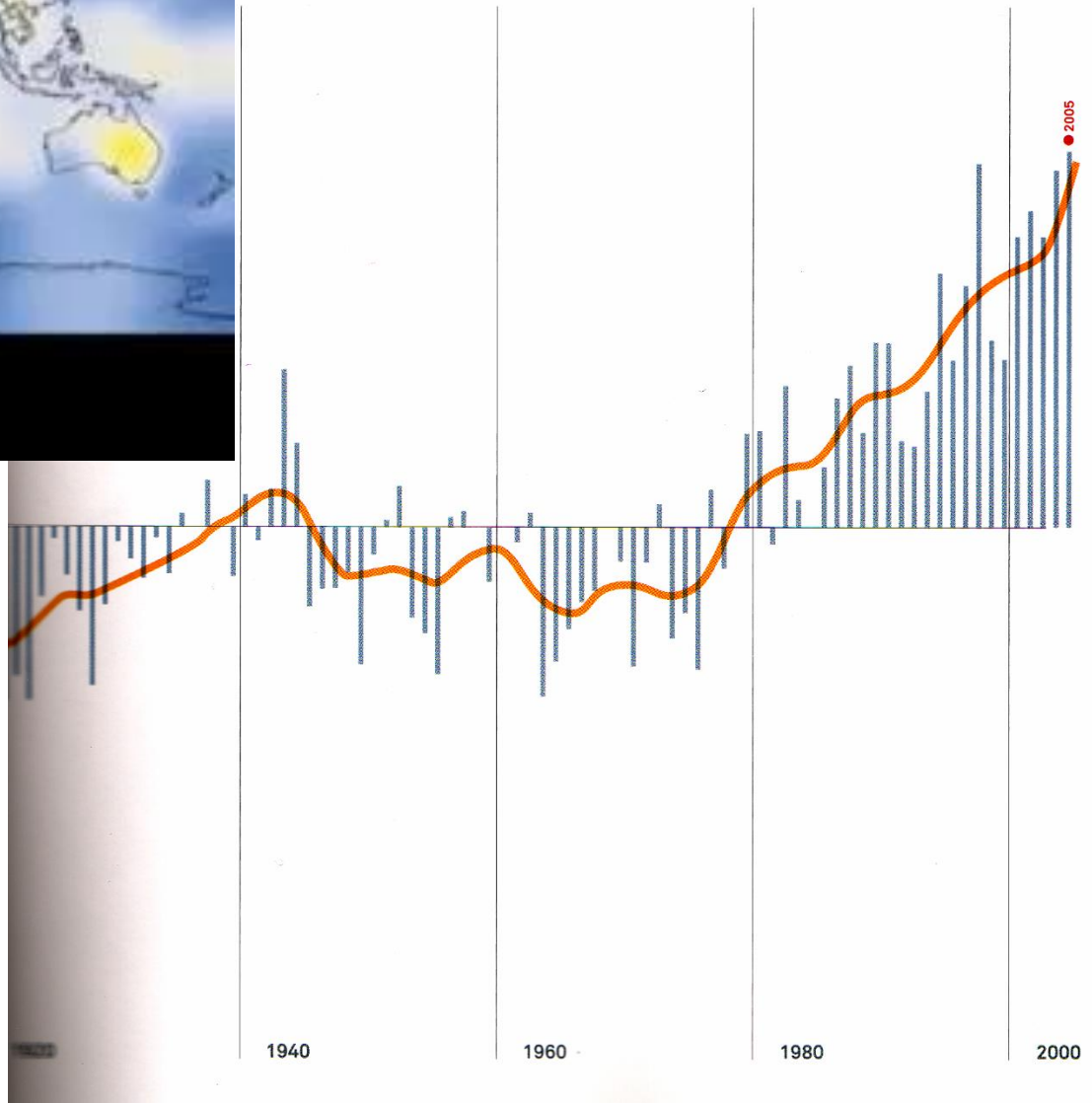
J. F. Kasting, *Icarus* (1988)

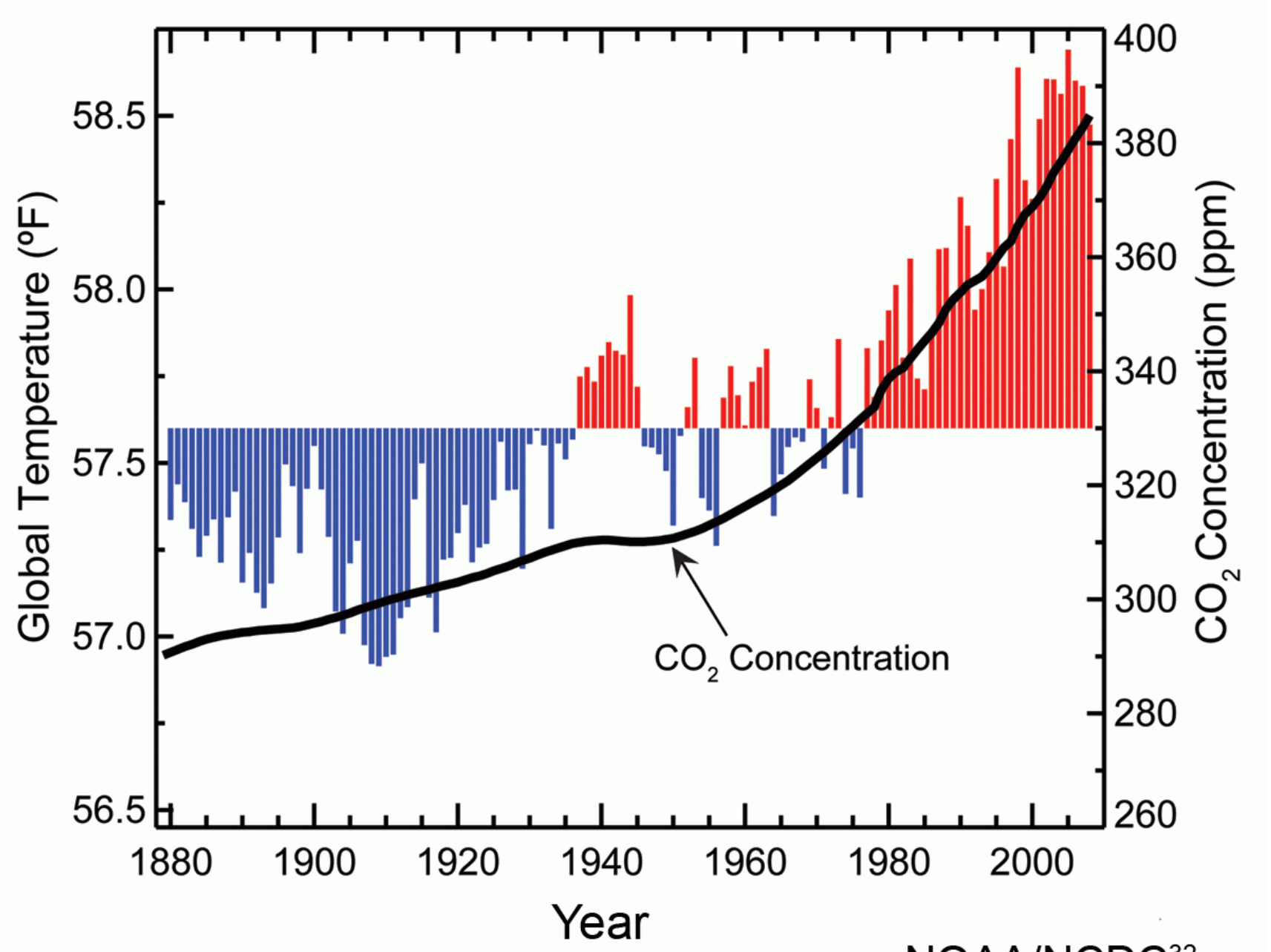
Earth's Atmosphere



period was 2005.






Global Temperature (ºF)
58.5
58.0
57.5
57.0
56.5
CO_2 Concentration (ppm)
400
380
360
340
320
300
280
260
1880
1900
1920
1940
1960
1980
2000
Year
CO_2 Concentration
NOAA/NCDC[32]

FYI

The amount of CO_2 in Earth's atmosphere is approximately a _____ tons.

thousand

million

billion

trillion

FYI

Volcanoes add _____ of tons of CO_2 to the atmosphere every few years.

thousands (tens or hundreds)

millions (tens or hundreds)

billions (tens or hundreds)

trillions (tens or hundreds)

FYI

Smoke stacks add _____ of tons of CO_2 to the atmosphere every few years.

thousands (tens or hundreds)

millions (tens or hundreds)

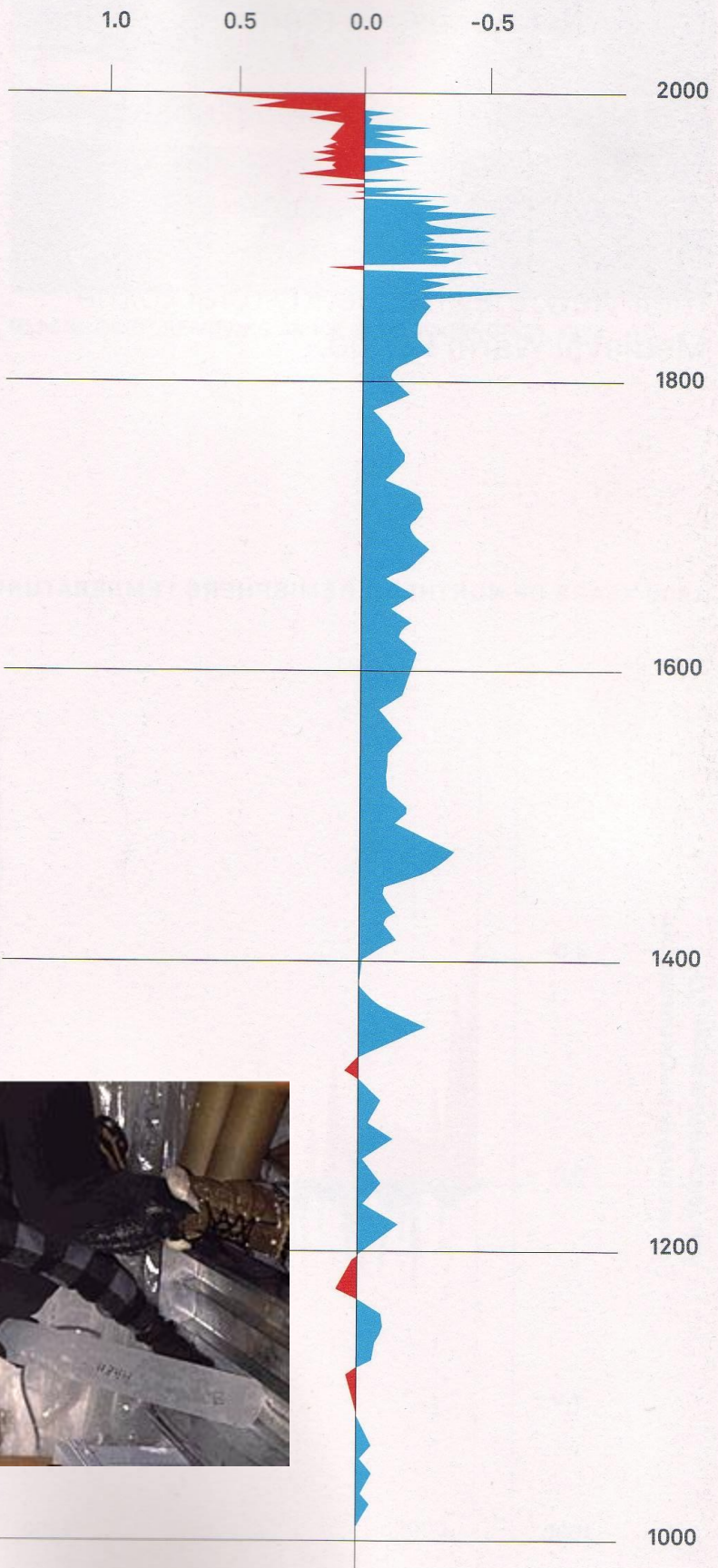
billions (tens or hundreds)

trillions (tens or hundreds)

600
400
300
260
240
200
CO_2 (ppm)
Deviation from mean
200,000
100,000
0

600
400
300
260
240
200
CO_2 (ppm)
Deviation from mean
200,000
100,000
0

1000 YEARS OF NORTHERN HEMISPHERE TEMPERATURE (°C)



FYI

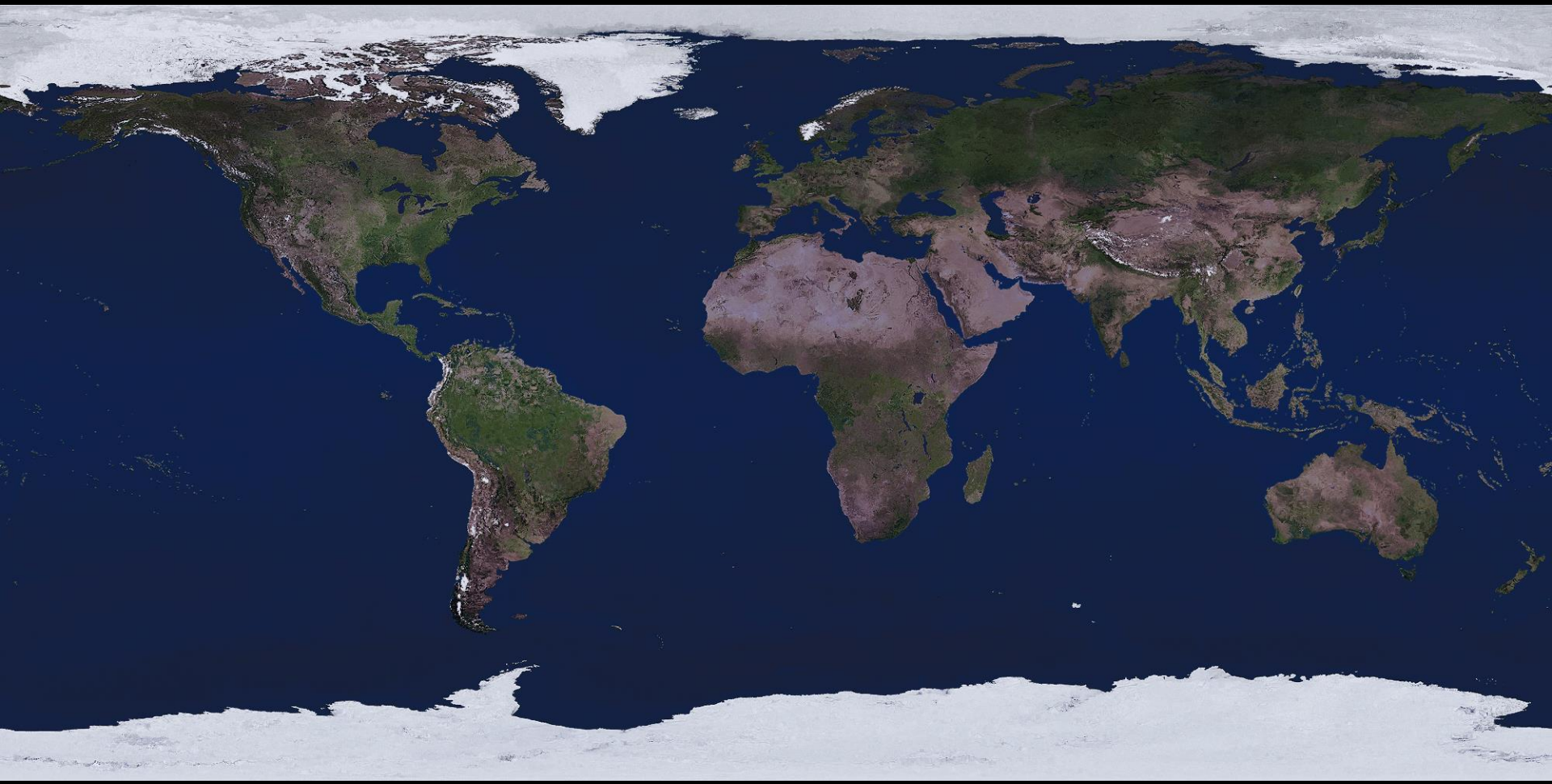
It will take _____ years to double Earth's atmospheric CO_2 volume at the rate we're going.

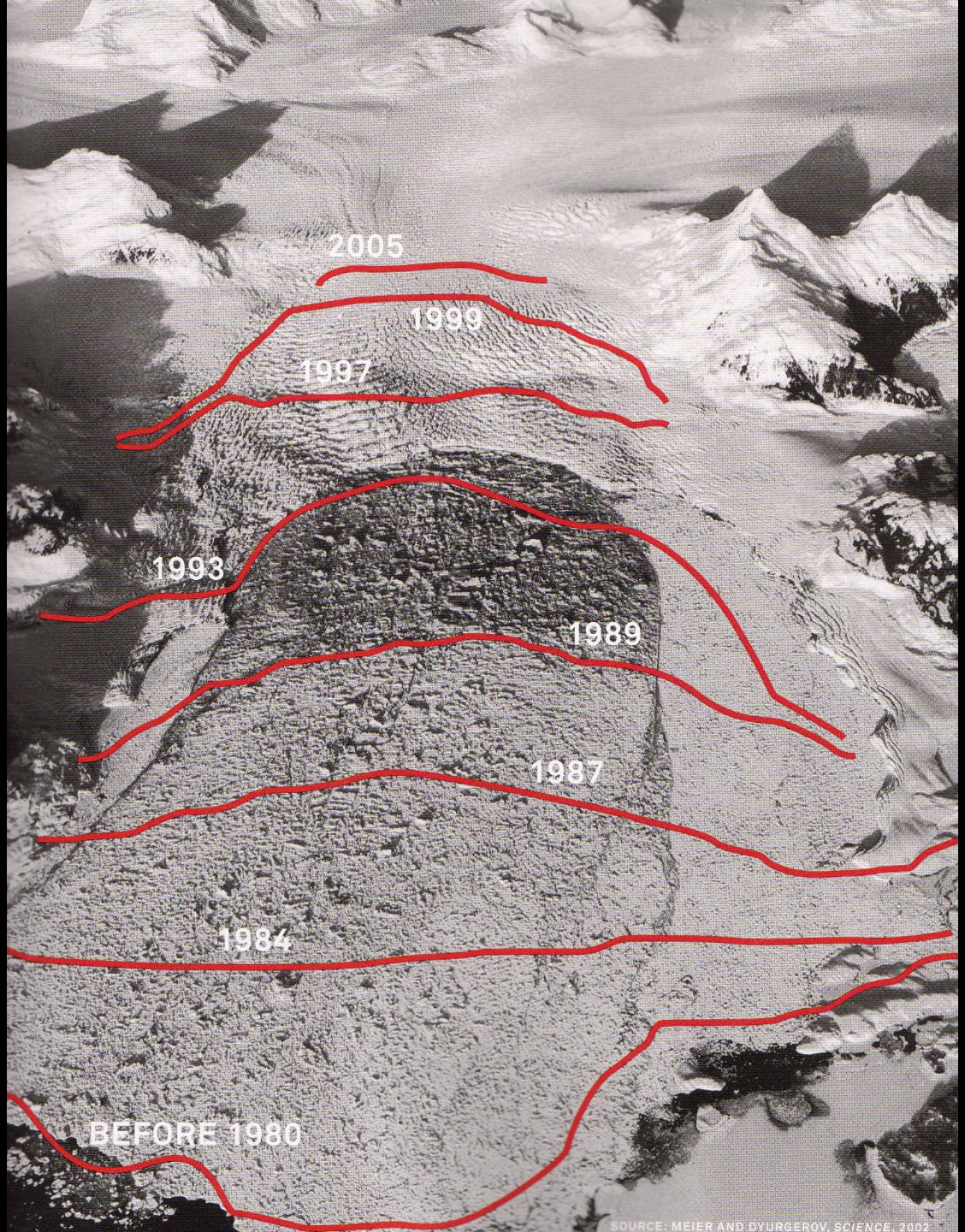
50

500

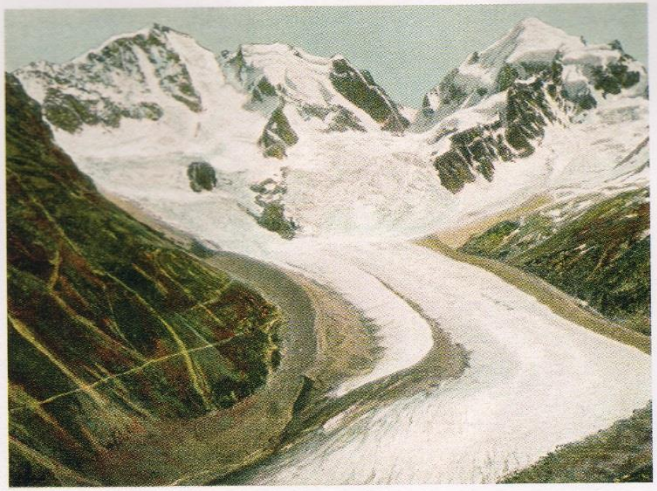
5000

50000




2005
1999
1997
1993
1989
1987
1984
BEFORE 1980
SOURCE: MEIER AND DYURGEROV, *SCIENCE*, 2002

TSCHIERVA GLACIER, SWITZERLAND, 1910



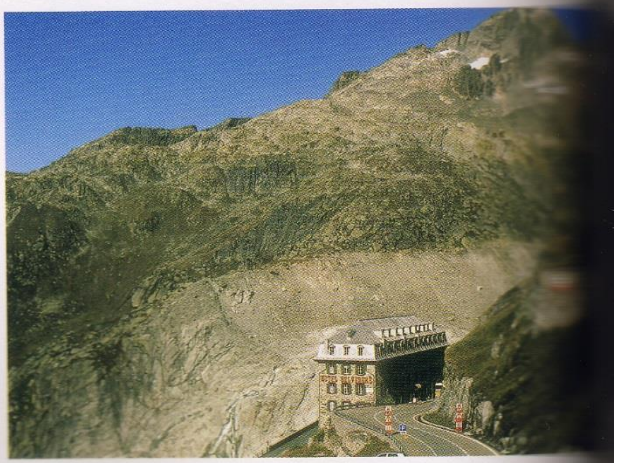
TSCHIERVA GLACIER, 2001

Below is the famous Hotel Belvedere, situated on the Rhone Glacier in Switzerland.

Here is the same site nearly a centu later. The hotel is still there—but th glacier is not.

HOTEL BELVEDERE, RHONE GLACIER, SWITZERLAND, 1906

HOTEL BELVEDERE, RHONE GLACIER, 2003



If all of Earth's ice melted…Sea-level would rise ~200 meters

https://news.yahoo.com/video/animated-map-shows-happen-china-040000963.html

TopHat Question

So all this means that if the present upward trend in temperature and sea level continues,

A. Earth will become uninhabitable in our lifetime.
B. Earth will slowly over thousands of years become more and more like Venus.
C. Earth's oceans will become deeper and deeper and will swallow all the continents.
D. Earth will become less hospitable (uncomfortable) for humans and other advanced life forms on land and in the oceans.