Water, Climate Change and Health

Photo: Apollo 8 image of "Earthrise" by William Anders, AS8-14-2383, Dec. 24, 1968

Susan Murcott,
Week 2 -- D-Lab: Water, Climate Change and Health

Development through Discovery, Design and Dissemination

4 Challenging Questions (add answers on index card)

1. Define “life.”

2. Complete this sentence: “Planet Earth is ill because…”

3. What makes a planet habitable?

4. In honor of Valentines Day: complete this sentence:

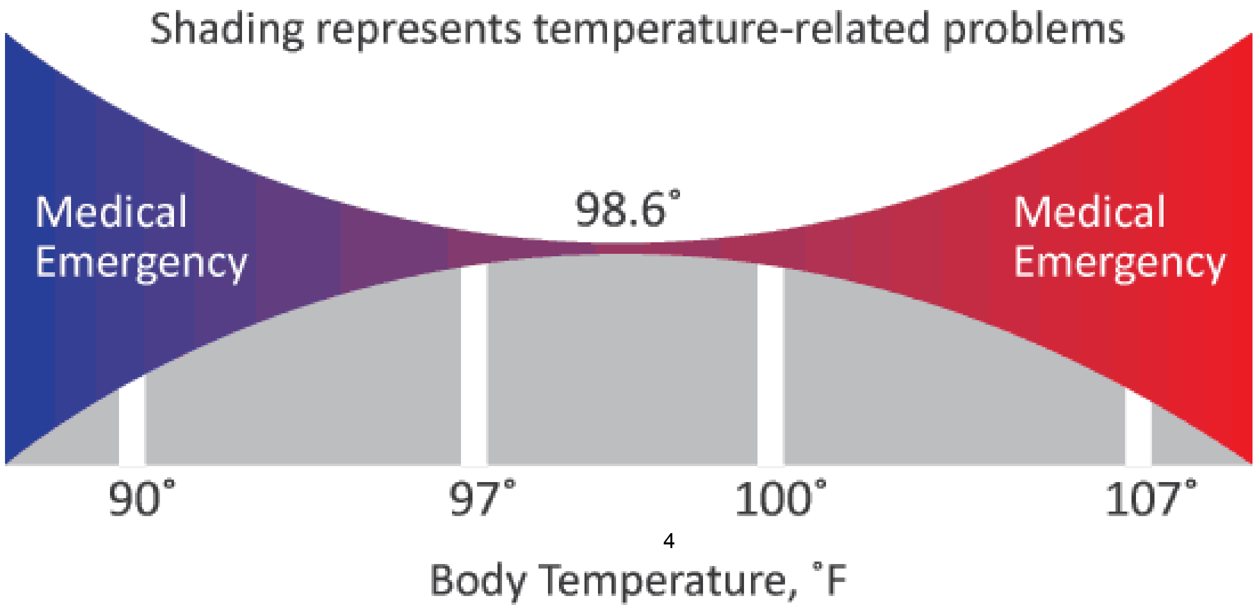
   “Love [in relation to Water, Climate Change and Health] is…”

Outline

- Human Health, Planetary Health, Planetary Boundaries
- Comparing Venus, Earth and Mars
- What Makes a Planet Habitable?
- Inside Story of Paris Agreement
- Solutions (Maslin, Ch 8) & Terminology
  - Adaptation
  - Mitigation
  - Geoengineering
  - Solar Radiation Management

Human Body Temperature

- For a typical adult: 97 F to 99 F.
- Infants and children: 97.9 F to 100.4 F.
- A body temperature higher than your normal range is a fever.
- Hypothermia is when the body temperature dips too low.
- Either extreme is a medical emergency



Human Health – Example of a healthy individual, with each of the parameters falling within an standard average range

Comprehensive Metabolic Panel – Details **Feb. 4, 2019**

Component Results

Component	Your Value	Standard Range
SODIUM	143 mmol/L	*136 - 145 mmol/L*
POTASSIUM	4.4 mmol/L	*3.6 - 5.1 mmol/L*
CHLORIDE	100 mmol/L	*98 - 107 mmol/L*
CO2	34 mmol/L	*22 - 32 mmol/L*
BUN	14 mg/dL	*6 - 20 mg/dL*
CREATININE	0.70 mg/dL	*0.4 - 1.0 mg/dL*
GLUCOSE	90 mg/dL	*65 - 99 mg/dL*
ALBUMIN	4.4 g/dL	*3.5 - 5.2 g/dL*
TOTAL PROTEIN	7.7 g/dL	*6.1 - 8.1 g/dL*
CALCIUM	9.9 mg/dL	*8.9 - 10.3 mg/dL*
ALKALINE PHOSPHATASE	84 U/L	*32 - 100 U/L*
TOTAL BILIRUBIN	0.2 mg/dL	*0.0 - 1.2 mg/dL*
AST	22 U/L	*15 - 41 U/L*
ALT	18 U/L	*10 - 35 U/L*
GLOBULIN	3.3 g/dL	*g/dL*
EGFR	90 mL/min/1.73m2	*60 - 128 mL/min/1.73m2*

Is the Earth a living planet?
Is it ill?

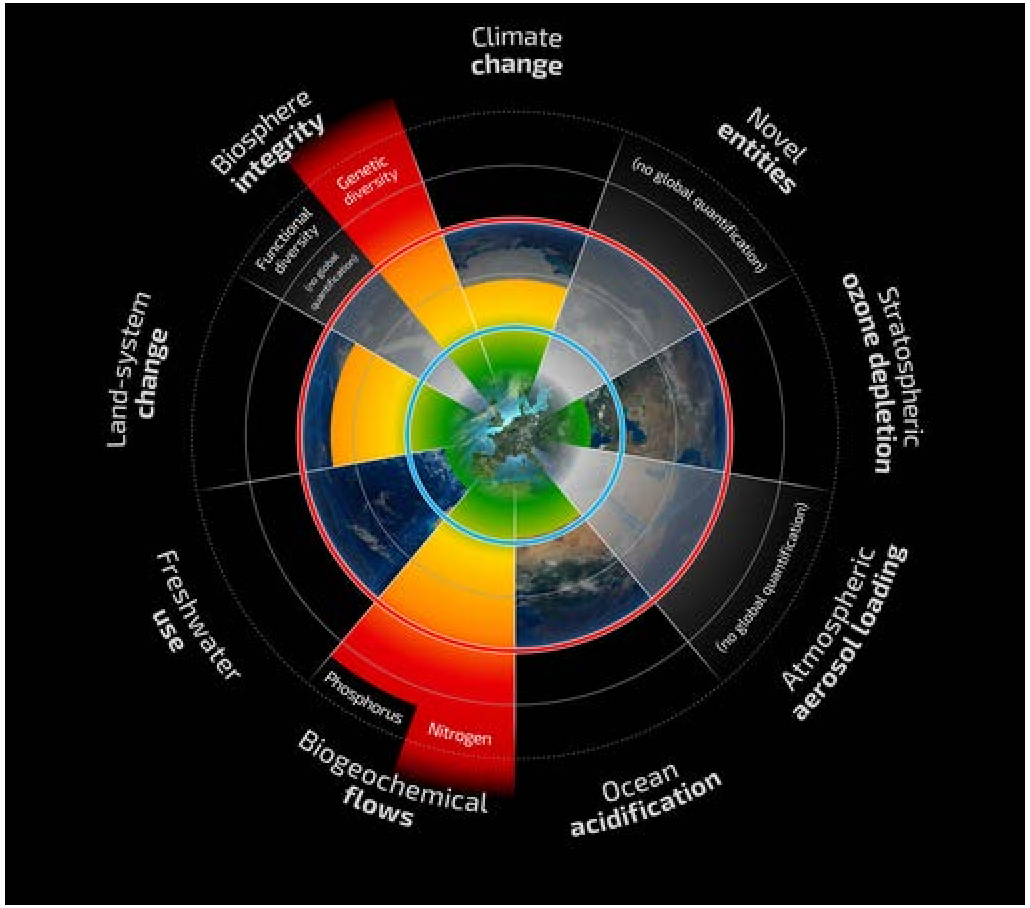
- In many ways, climate change for Earth can be seen in the same way as illness and the human body.

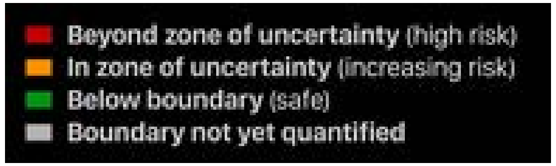
Mark Maslin, Climate Change p 162.

I have asked that you take on for discussion that the Earth is in some sense alive and that the diagnosis and treatment of its ills become an empirical practice…The notion of the planet visiting a doctor is odd. It assumes, for a start, that the planet – in this case Earth – is capable of being ill and so is in some sense alive. It assumes that there is a suitable doctor to visit. A physician, in fact, trained in planetary medicine… It is with the need for such a practice of planetary medicine that this book is concerned. Its system science will be physiology, the systems science of living organisms, or rather geophysiology, the systems science of the Earth."

James Lovelock, Gaia, Medicine for an Ailing Planet, 2005

Planetary Boundaries



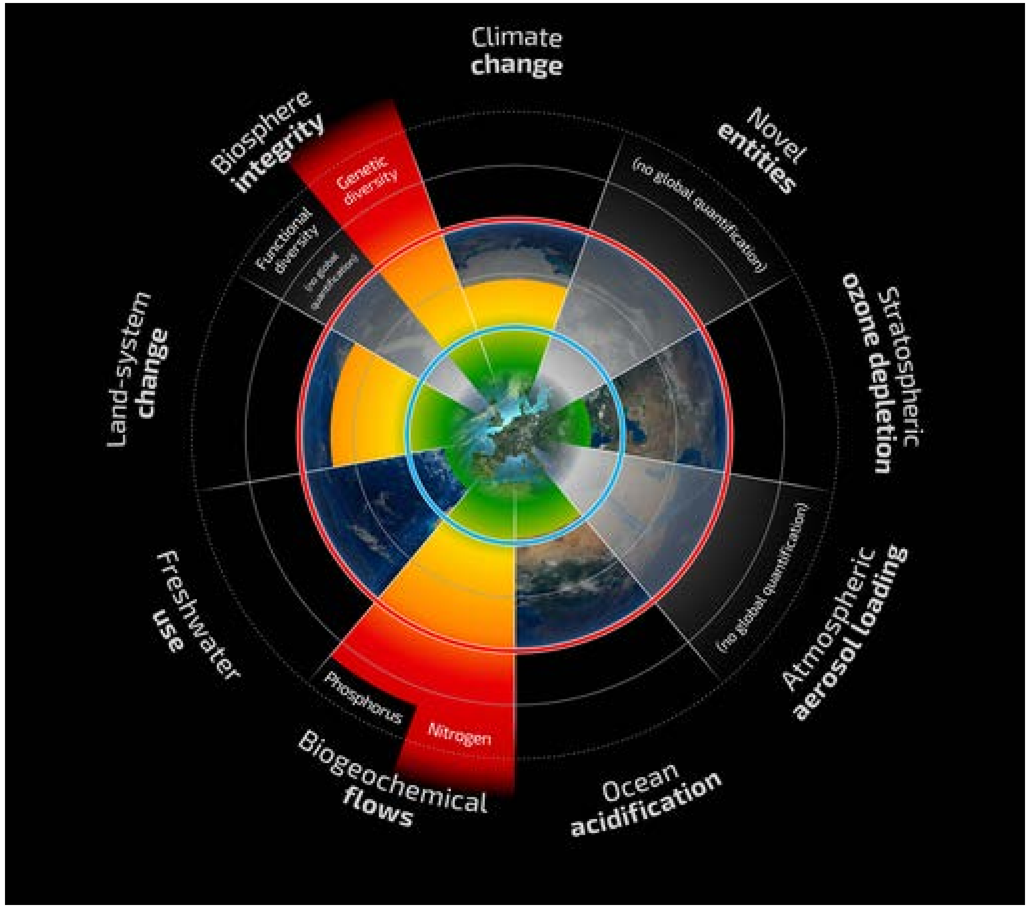


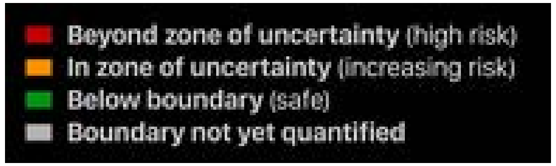
The Planetary Boundaries concept identifies nine global priorities relating to human-induced changes to the environment. The science shows that these nine processes and systems regulate the stability and resilience of the Earth System — the interactions of land, ocean, atmosphere and life that together provide conditions upon which our societies depend.

Four of nine planetary boundaries have now been crossed as a result of human activity: climate change, loss of biosphere integrity, land-system change, altered biogeochemical cycles (nitrogen and phosphorus).

http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

Planetary Boundaries Figure Explanation





The green zone is the safe operating space (below the boundary), yellow represents the zone of uncertainty (increasing risk), and red is the high-risk zone. The planetary boundary itself lies at the inner red circle. The control variables have been normalized for the zone of uncertainty (between the two red circles); the center of the figure therefore does not represent values of zero for the control variables. The control variable shown for climate change is atmospheric carbon dioxide concentration. The term novel entities represents the growing awareness that, in addition to toxic synthetic substances, other potentially systemic global risks exist, such as the release of radioactive materials or nanomaterials. Processes for which global-level boundaries cannot yet be quantified are represented by grey wedges; these are atmospheric aerosol loading, novel entities, and the functional role of biosphere integrity.

http://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

4 Boundaries Currently Crossed:

Excerpt of Table 6 from our Reading…
(Maslin, 2014, p. 167)

Table 6. Planetary boundaries

Boundary	Control variable	Boundary crossed
1. Climate change	Atmospheric carbon dioxide concentration (ppm by volume)	yes
	Alternatively: Increase in radiative forcing (W/m²) since the start of the industrial revolution (~1750 CE)	yes
2. Biodiversity loss	Extinction rate (number of species per million per year)	yes
3. Biogeochemical	(a) anthropogenic nitrogen removed from the atmosphere (millions of tonnes per year)	yes
	(b) anthropogenic phosphorus going into the oceans (millions of tonnes per year)	no
4. Ocean acidification	Global mean saturation state of aragonite in surface seawater (omega units)	no
5. Land use	Land surface converted to cropland (per cent)	yes

Update since Maslin, 2014

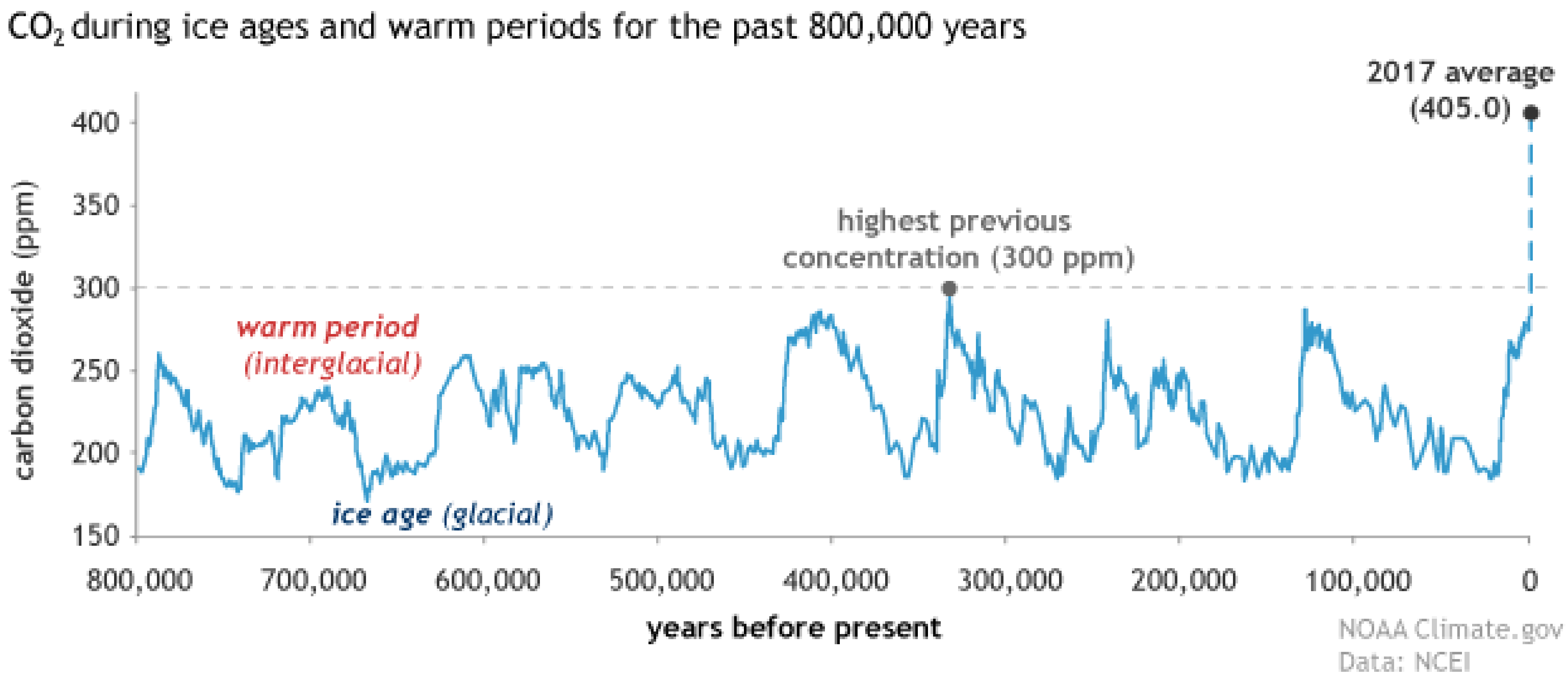
Climate Change
2 parts: (1) CO_2 Conc & (2) Radiative Forcing

(1) CO_2 Concentration

- Recent evidence suggests that the Earth, now passing 410 ppm CO_2 in the atmosphere, has already transgressed the planetary boundary
- We have reached a point at which the loss of summer polar sea-ice is almost certainly irreversible.
- Weakening of terrestrial carbon sinks, e.g. destruction of the world's rainforests, is another potential tipping point.
- A major question is how long we can remain over this boundary before large, irreversible changes become unavoidable.

https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

(1) CO2 Concentration: Carbon dioxide levels today are higher than at any point in at least the past 800,000 years.



https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

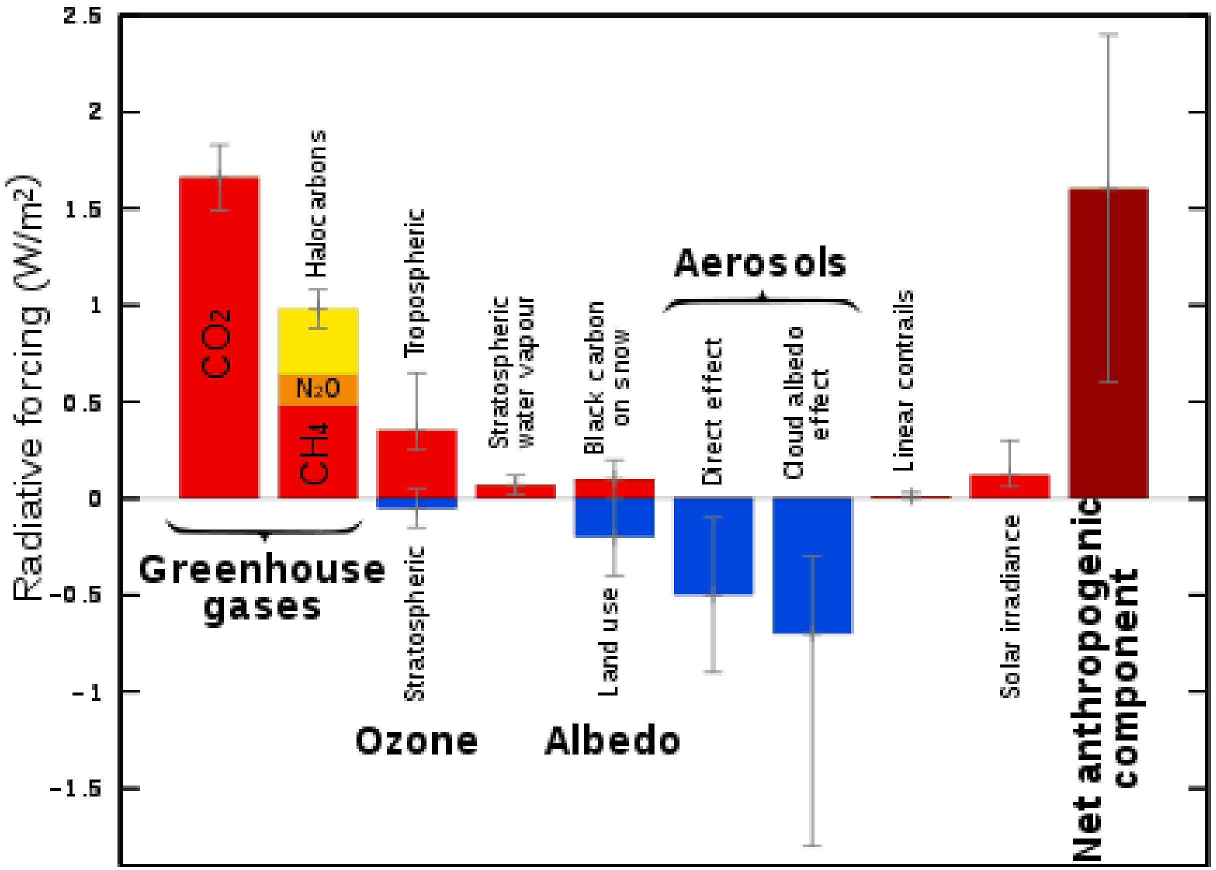
Earth’s CO2 Home Page https://www.co2.earth/

Atmospheric CO2
January 2019

410.92
parts per million (ppm)

Mauna Loa Observatory, Hawaii

Radiative Forcing Components

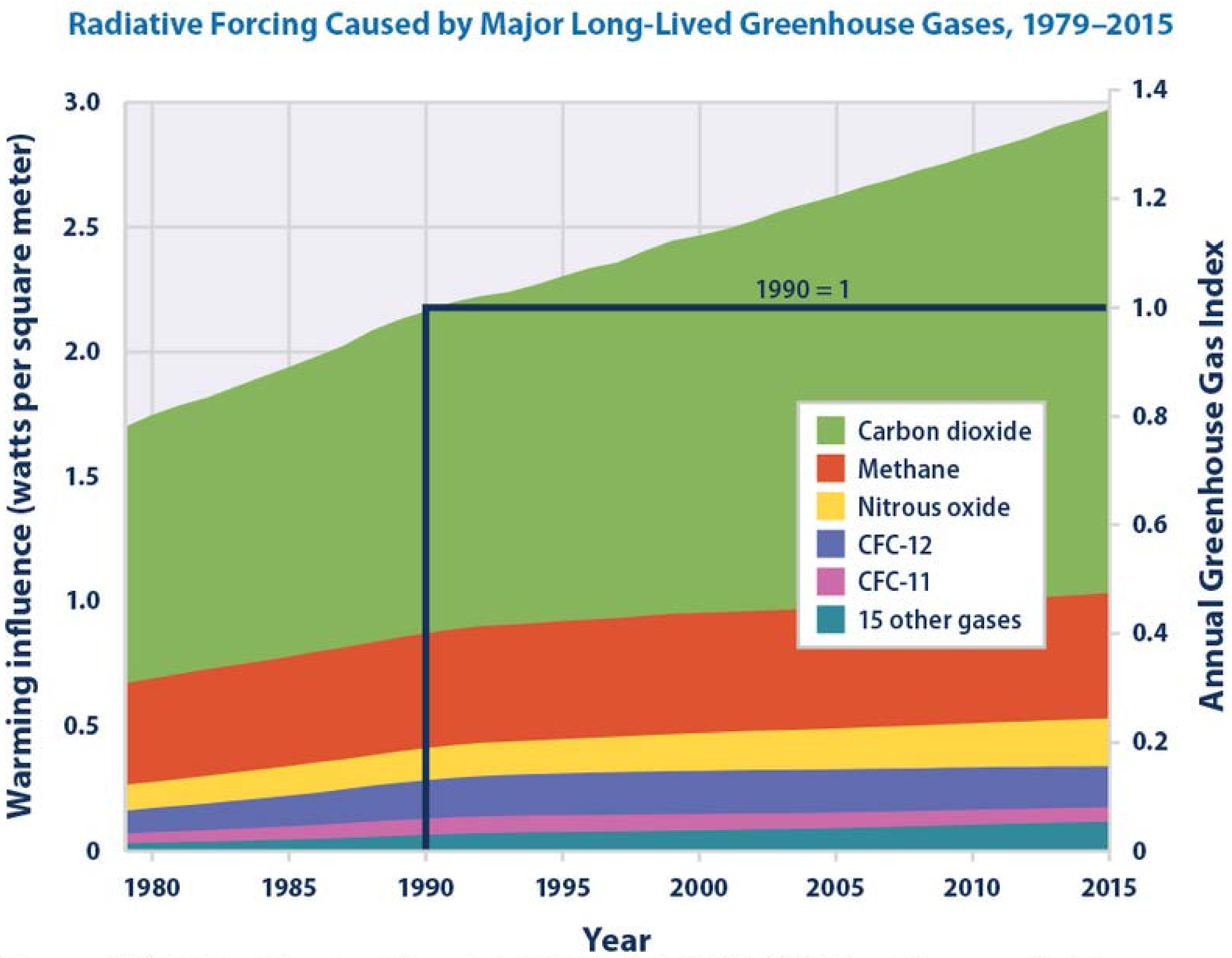


"Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism.

In this report radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2)."

Radiative Forcings, IPCC AR4, 2007.

Radiative Forcing



Data source: NOAA (National Oceanic and Atmospheric Administration). 2016. The NOAA Annual Greenhouse Gas Index. Accessed June 2016. www.esrl.noaa.gov/gmd/aggi.

Radiative forcing (watts per square meter), represents the size of the energy imbalance in the atmosphere.

This figure shows the amount of radiative forcing caused by various greenhouse gases, based on the change in concentration of these gases in the Earth's atmosphere since 1750.

On the right side of the graph, radiative forcing has been converted to the Annual Greenhouse Gas Index, which is set to a value of 1.0 for 1990

Biodiversity Loss/ Extinction Rate/ Biodiversity Integrity

- The Millennium Ecosystem Assessment of 2005 concluded that changes to ecosystems due to human activities were more rapid in the past 50 years than at any time in human history.
- The main drivers of change are the demand for food, water, and natural resources, causing severe biodiversity loss and leading to changes in ecosystem services.

https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

- We include biodiversity (in the latest scientific update, Steffen et al., 2015, defined as biosphere integrity to emphasize the functional and regulatory role of biodiversity for ecosystem stability) as a planetary boundary on the scientific ground that the biosphere interacts with the climate system, hydrological cycle and other biogeochemical cycles in the Earth system, and thereby contributes to the regulation of the state of the Earth system.

Millenium Assessment (MA) 2005

- Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.
- The changes to ecosystems have contributed to substantial net gains in human well-being and economic development, but these gains have been achieved at growing costs in the form of the degradation of many ecosystem services, increased risks of nonlinear changes, and the exacerbation of poverty for some groups of people. These problems, unless addressed, will substantially diminish the benefits that future generations obtain from ecosystems.
- The degradation of ecosystem services could grow significantly worse during the first half of this century.
- The challenge of reversing the degradation of ecosystem while meeting increasing demands for services can be partially met under some scenarios considered by the MA, but will involve significant changes in policies, institutions and practices that are not currently under way. Many options exist to conserve or enhance specific ecosystem services in ways that reduce negative trade-offs or that provide positive synergies with other ecosystem services.
- The bottom line of the MA findings has been that human actions are depleting Earth's natural capital, putting such strain on the environment, that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted. At the same time, the assessment shows that with appropriate actions it is possible to reverse the degradation of many ecosystem services over the next 50 years, but the changes in policy and practice required are substantial and not currently underway.

https://www.millenniumassessment.org/en/index.html

Land System Change

- Land is converted to human use all over the planet. Forests, grasslands, wetlands and other vegetation types have primarily been converted to agricultural land.
- This land-use change is one driving force behind the serious reductions in biodiversity, and it has impacts on water flows and on the biogeochemical cycling of carbon, nitrogen and phosphorus and other important elements.
- While each incident of land cover change occurs on a local scale, the aggregated impacts can have consequences for Earth system processes on a global scale.
- A boundary for human changes to land systems needs to reflect not just the absolute quantity of land, but also its function, quality and spatial distribution.
- Forests play a particularly important role in controlling the linked dynamics of land use and climate, and is the focus of the boundary for land system change

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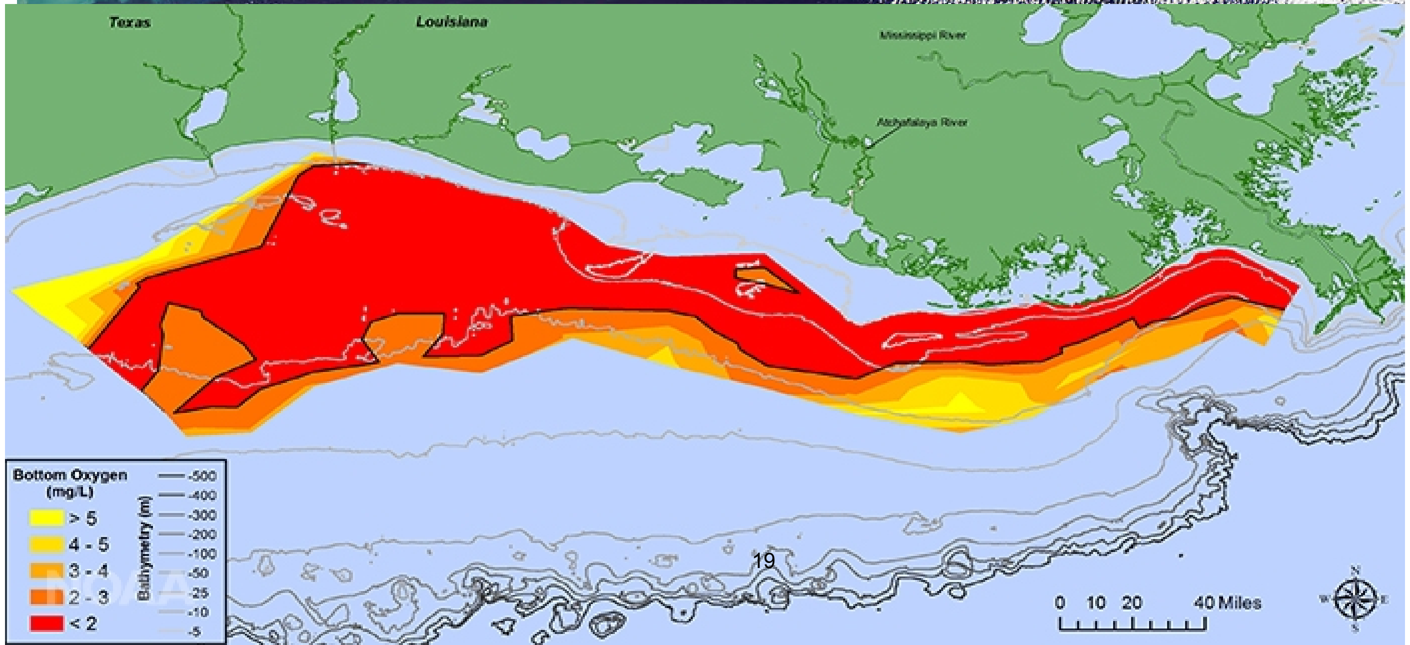
Biogeochemical – Nitrogen & Phosphorus

- The biogeochemical cycles of nitrogen and phosphorus have been radically changed by humans as a result of many industrial and agricultural processes.
- Nitrogen and phosphorus are both essential elements for plant growth, so fertilizer production and application is the main concern.
- Human activities now convert more atmospheric nitrogen into reactive forms than all of the Earth's terrestrial processes combined. Much of this new reactive nitrogen is emitted to the atmosphere in various forms rather than taken up by crops.
- When it is rained out, it pollutes waterways and coastal zones or accumulates in the terrestrial biosphere.
- A significant fraction of the applied nitrogen and phosphorus makes its way to the sea, and can push marine and aquatic systems across ecological thresholds of their own.

https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html

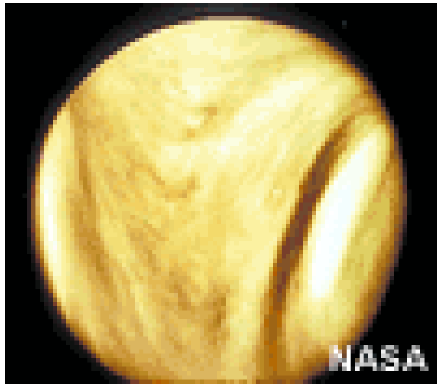
Dead zone – Gulf of Mexico “Largest ever measured.” Size of New Jersey



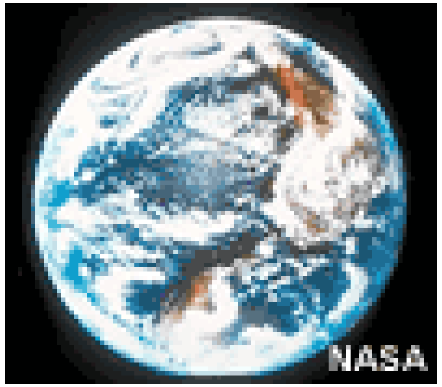
Dead zones are hypoxic (low-oxygen) areas in the world's oceans and large lakes, **caused** by excessive nutrient pollution from human activities coupled with other factors that deplete the oxygen required to support most marine life in bottom and near-bottom water.

Top: Courtesy of NASA.
Bottom: Courtesy of LSU/LUMCON and NOAA.
Images are in the public domain.

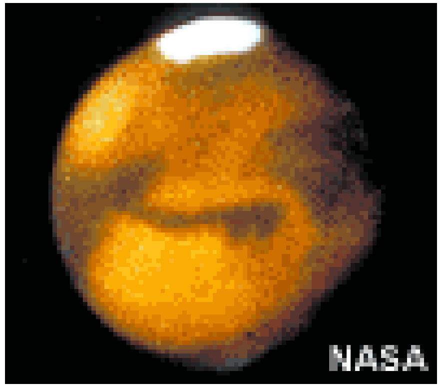
Comparing Gases on Venus, Earth and Mars



Venus



Earth

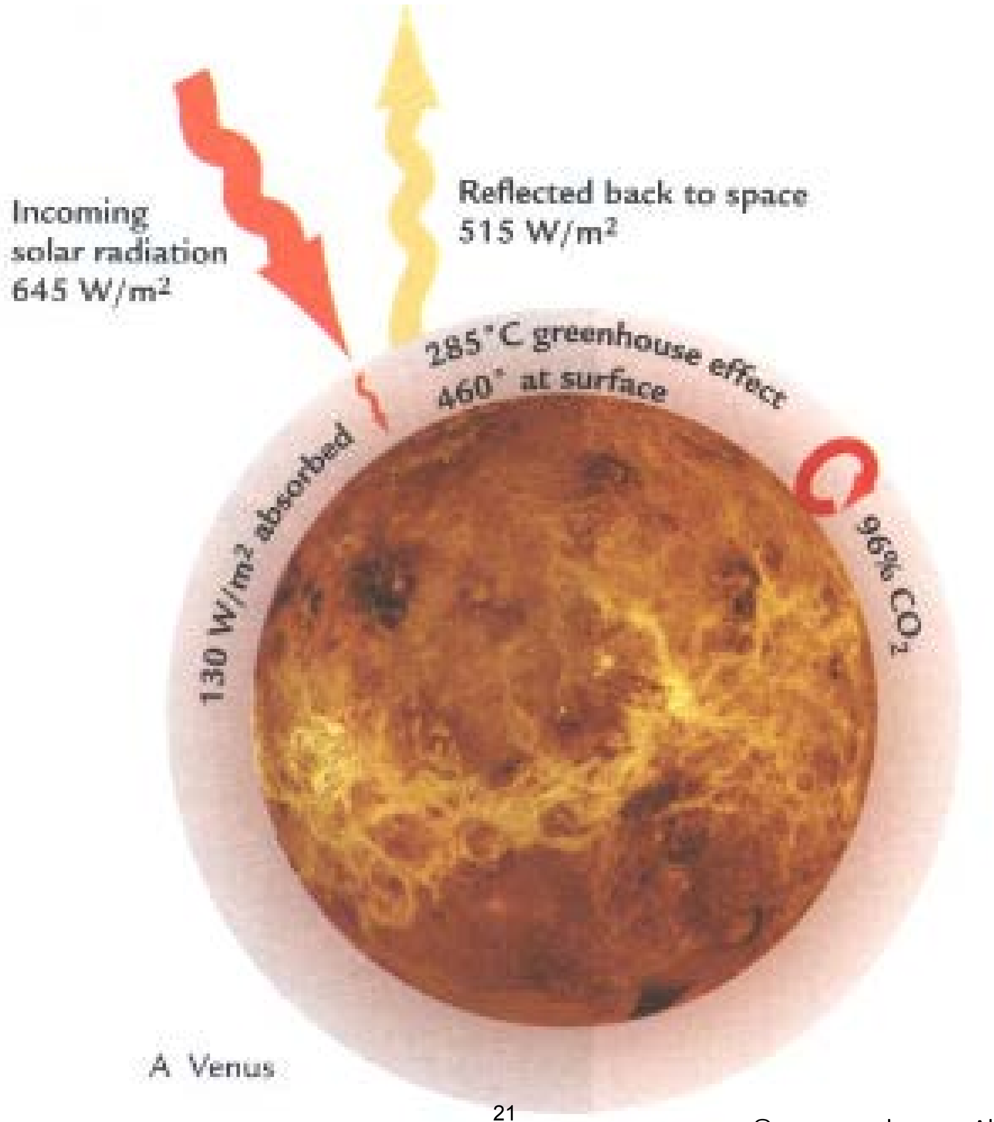


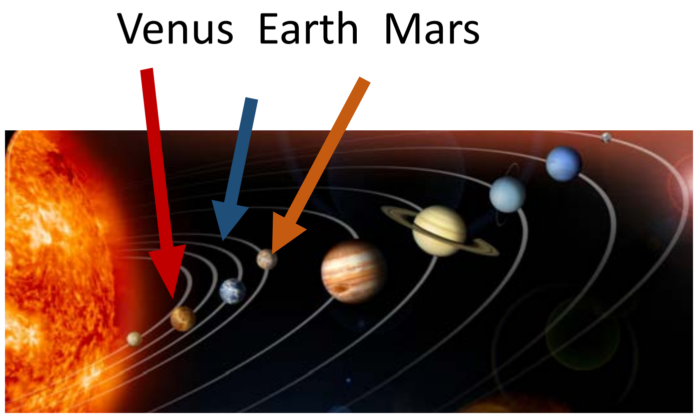
Mars

Carbon Dioxide (CO_2)	96.5%	0.04	95%
Nitrogen (N_2)	3.5%	78%	2.7%
Oxygen (O_2)	Trace	21%	0.13%
Argon (Ar)	0.007%	0.9%	1.6%
Methane (CH_4)	0	0.002%	0

Comparing Venus and Earth: Venus is the 2nd planet from the sun, and is called Earth's "sister:" Both planets are similar in size, mass, density and geologic composition.

- Venus' atmosphere is composed of 96.5% CO2!
- 645 degrees C at surface (860° F)
- This is a scorched planet, hot enough to melt lead.
- Venus does not have water and is completely uninhabitable!

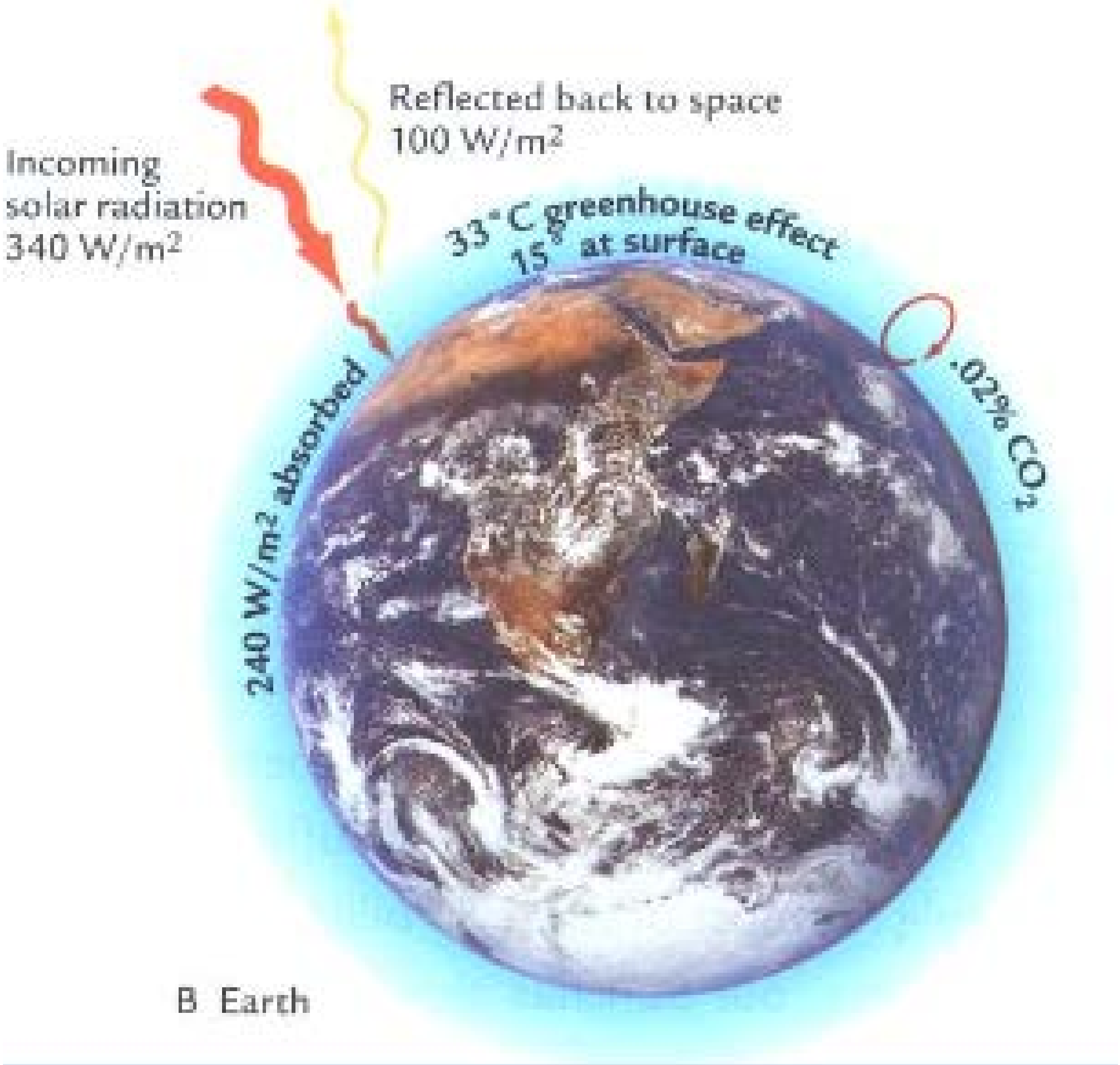




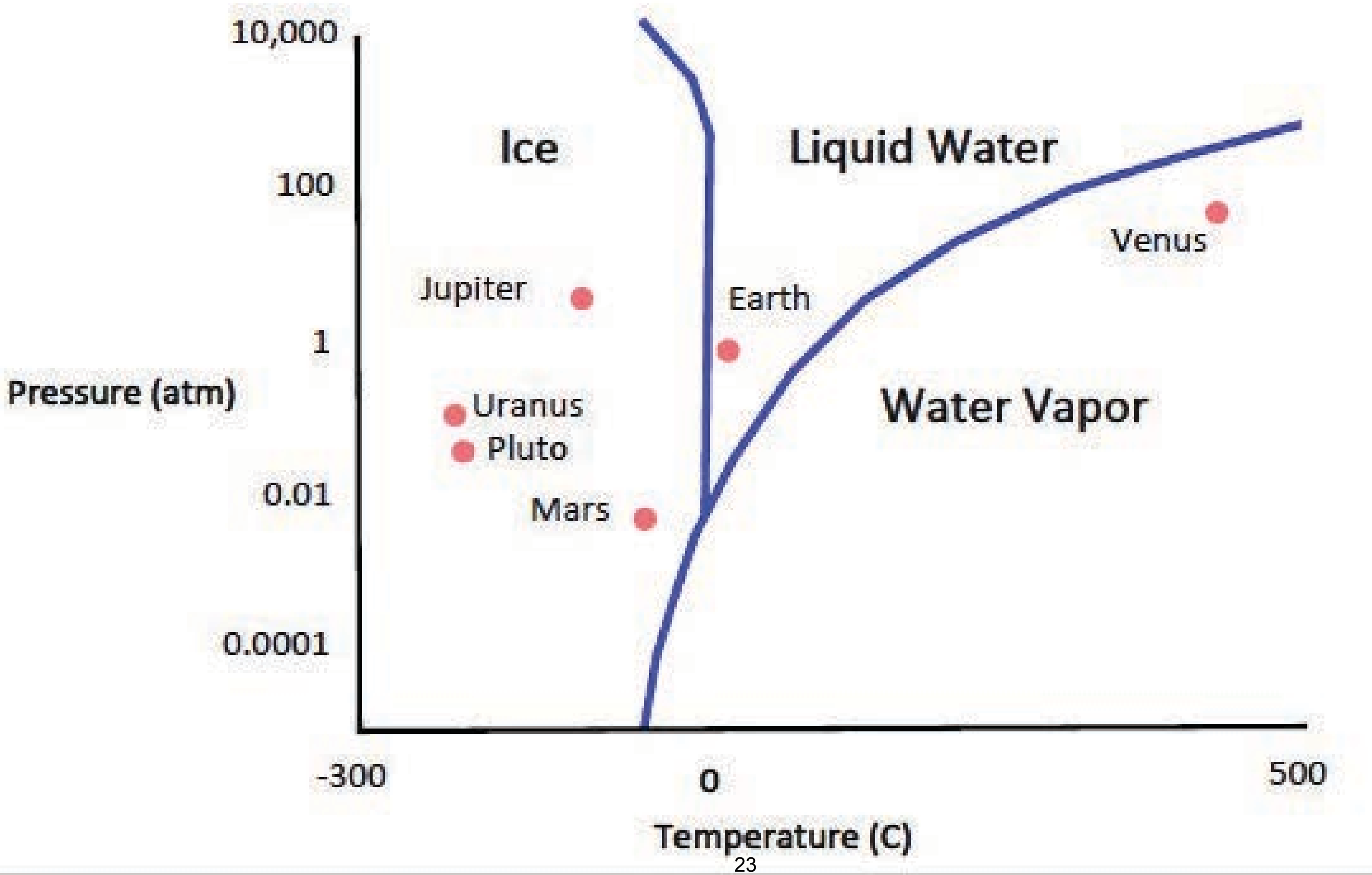
Courtesy of NASA. Image is in the public domain.

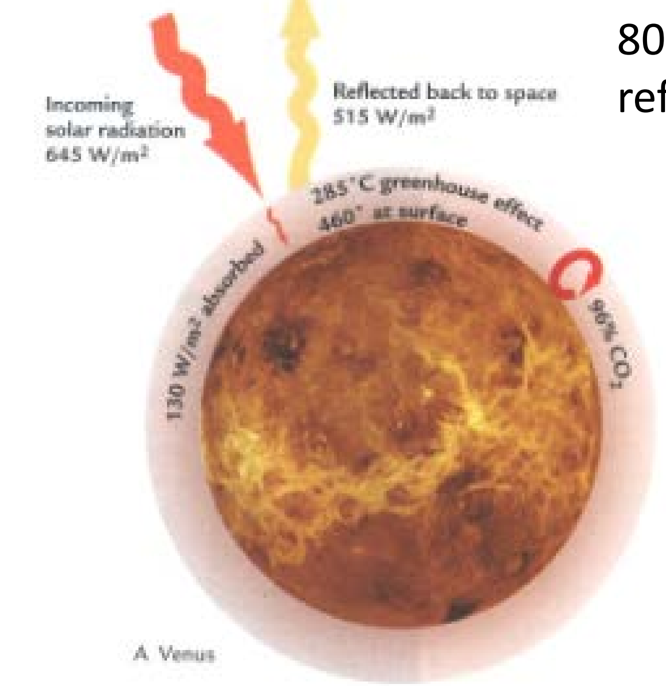
Compare Venus and Earth: Both planets are similar in size, mass, density and geologic composition.

- Earth has WATER! We can live on Earth!



Because Earth is “not too hot, not too cold,” which allows us to have has liquid water, we have life (as we know it) on Earth.



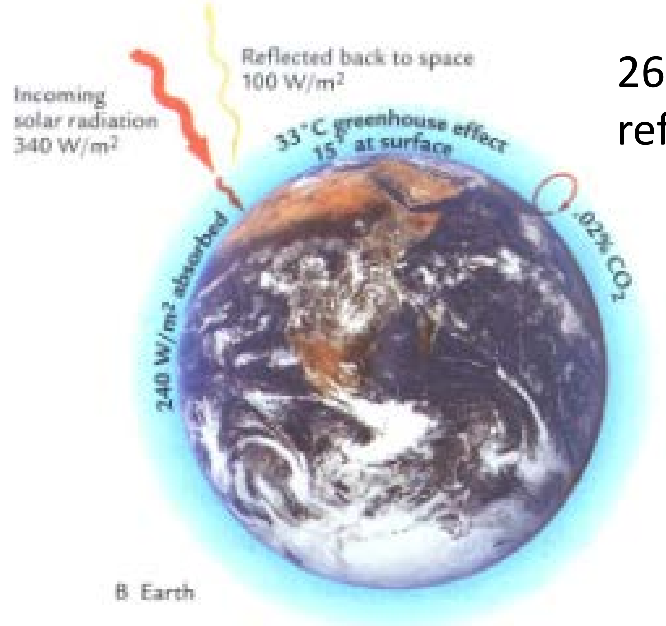


80%
reflected

Comparing Venus & Earth

- Venus' surface temperature is 460° C (860° F)
- Earth's surface temperature is 15°C (57° F).

- CO2 on Venus: 96.5%;
- CO2 on Earth = 0.04%.



26%
reflected

- Venus receives almost twice as much solar radiation from the Sun as Earth, but dense clouds on Venus permits LESS radiation to penetrate the surface.
- Yet, Venus is much HOTTER than Earth because its CO2-enriched atmosphere creates a much stronger greenhouse effect than on Earth.

Comparing Earth and Mars…

- Mars is the other most Earth-like other planet in our solar system.
- Same internal structure:
  - an inner core of metal;
  - surrounded by a mantle of rock;
  - thin crust covers the mantle.
- Both planets have large, sustained polar caps.
- Current thinking is that both have substantial amounts of frozen ice.

EARTH

MARS

Courtesy of NASA, J. Bell (Cornell U.) and M. Wolff (SSI) and NASA/JHUAPL/Carnegie Institution of Washington/USGS/Arizona State University. Images are in the public domain.

Mars is NOT (easily) HABITABLE!

- Mars' atmosphere -- extremely high in CO_2 concentration = 95%
- Dust storms are common!
- Temperature: Planet-wide: - 55 ° C (- 67 ° F)

But…

- Mars seems to have been a planet with an atmosphere.
  <u>but</u> the atmosphere was stripped away by solar wind.
- Mars had liquid surface water, perhaps intermittently,
  <u>but</u> Mars' surface waters became acid, charged with sulfates.
  and most of the water evaporated and was carried off into space.
- The scant water left was frozen into permafrost and ice-caps.

EARTH

MARS

CNN news today! Water on Mars! https://www.cnn.com/2019/02/13/world/nasa-mars-opportunity-rover-trnd/index.html

Recommended Reading: How to Build a Habitable Planet. Charles Langmuir. Wally Broecker.

Sara Seager – *Living in the Goldilocks Zone: Climate Essentials for a Habitable Planet (1/27/16)*

- https://eapsweb.mit.edu/events/2016/climate-symposium
- Watch minutes: 3:17 – 10:50 min

What Makes a Planet Habitable?

This list taken from Prof. Sara Seager – see video reference

1. Liquid water/liquid ocean

2. Earth's average surface temp is 57 degrees F ("Not too hot; not too cold")

3. Greenhouse gases (GHG), esp. water vapor (H2O), carbon dioxide (CO2), nitrous oxide (N2O) & methane (CH4) have strong absorption and that means that they trap the sun's heat within earth's atmosphere

4. Relative humidity – a range is allowed in the atmosphere

5. Clouds – every planet has clouds! On Earth, water vapor affects clouds and add a lot of complexity. We care about clouds, aerosols, haze… but clouds are a unique characteristic.

6. Atmospheric dynamics: If the planet has one permanent day-side and one permanent night-side (like our moon) then you need a certain size of atmosphere ≥ Mars, so that atmosphere is well mixed.

What Makes a Planet Habitable?

Quoted from Prof. Sara Seager – see reference slide

“All life as we know it needs liquid water: so we are taking this habitable condition to mean planets with surface temperatures that can maintain a liquid ocean.

What We Think Happened to Venus: Some planets are closer to the star, and they are receiving so much energy that they will be hot. Water vapor will reach the upper areas of the atmosphere where it would be photo-dissociated by starlight or sunlight and hydrogen would escape to space, with oxygen and other molecules and surface minerals thereby getting rid of the planet’s oceans. We think that’s what happened to Venus.”

What Makes a Planet Habitable?

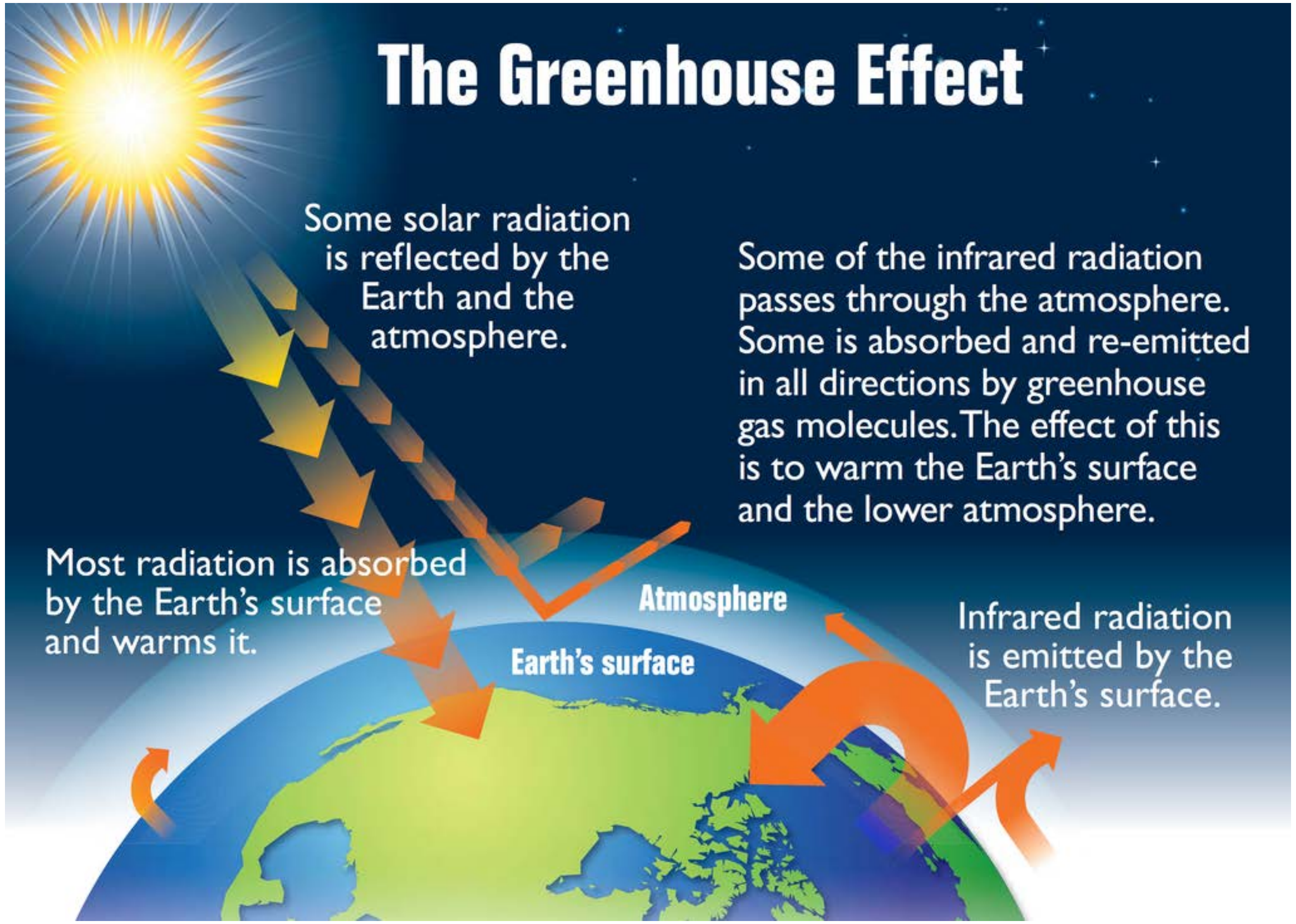
Quoted from Prof. Sara Seager – see reference slide

“What Happened to Mars?: On the outer edge of the habitable zone, actually the gases that we are worried about, our greenhouse gases, would freeze out, water and carbon dioxide, making the planet too cold for liquid water and too cold for life as we know it. We think that’s, in part, what happened to Mars.”

Greenhouse gases, carbon dioxide, methane, nitrous oxides, CFCs, others, act as a blanket, trapping the sun's energy.

1,362 W/m2

Short wave (visible)



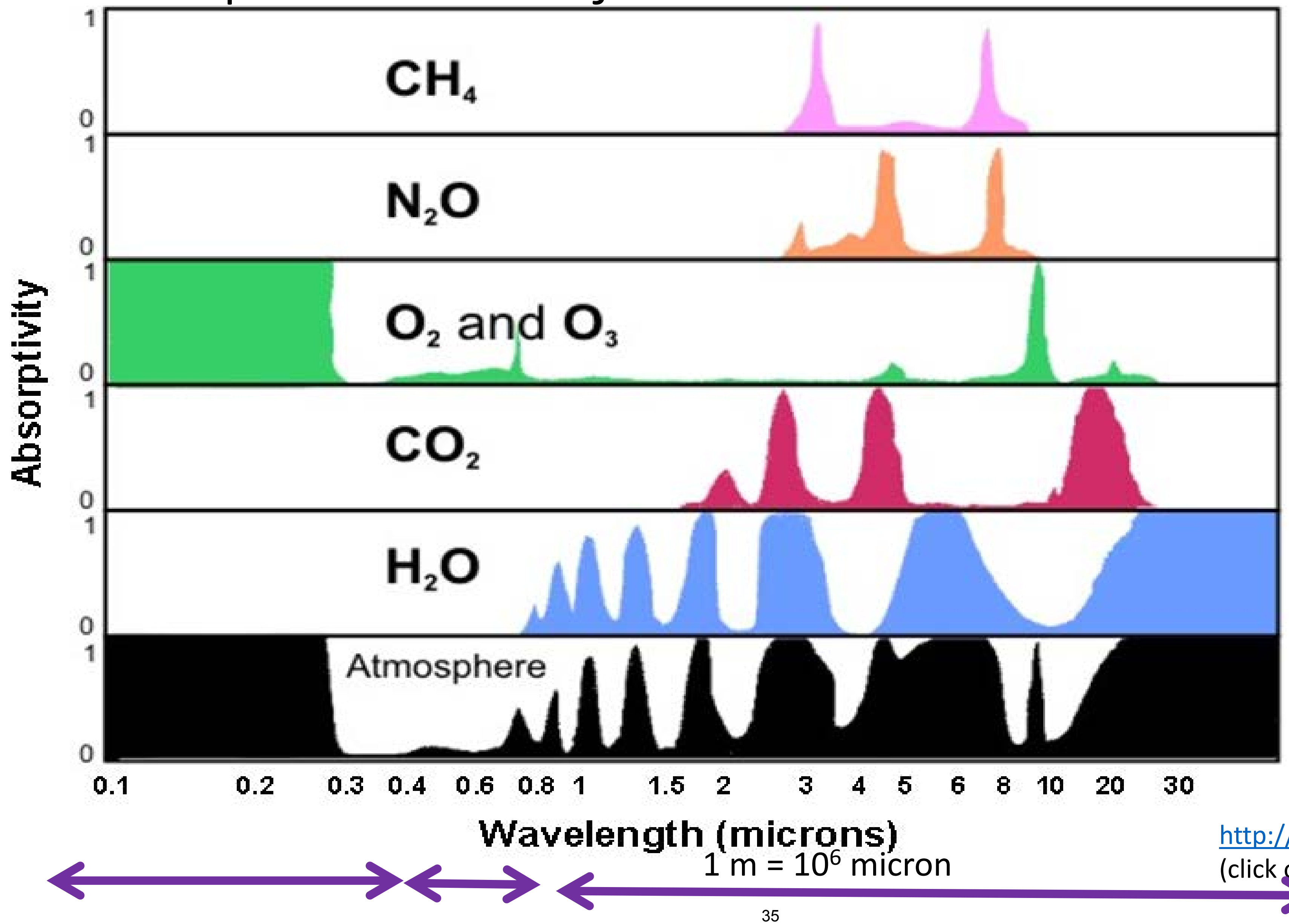
Earth's Radiation Budget: Solar radiation arriving at the top of Earth's atmosphere averages 340 W/m2 , indicated here as 100% (upper left). About 30% of the incoming radiation is reflected and scattered back to space, and the other 238 W/m2 (70%) enters the climate system. Some of this entering radiation warms Earth's surface and causes it to radiate heat upward (right). The greenhouse effect (lower right) retains 95% of the heat radiated back from Earth's heated surface and warms Earth by 318C.

Radiation Balance

- Almost all of the energy that affects Earth's climate is received as radiant energy from the Sun. The planet and its atmosphere absorb and reflect some of the energy, while long-wave energy is radiated back into space. The balance between absorbed and radiated energy determines the average global temperature. Because the atmosphere absorbs some of the re-radiated long-wave energy, the planet is warmer than it would be in the absence of the atmosphere: (see greenhouse effect).
- The radiation balance is altered by such factors as the intensity of solar energy, reflectivity of clouds or gases, absorption by various greenhouse gases or surfaces and heat emission by various materials. Any such alteration is a radiative forcing, and changes the balance. This happens continuously as sunlight hits the surface, clouds and aerosols form, the concentrations of atmospheric gases vary and seasons alter the groundcover.

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

Spectra of Major Greenhouse Gases



$1\ m = 10^6$ micron

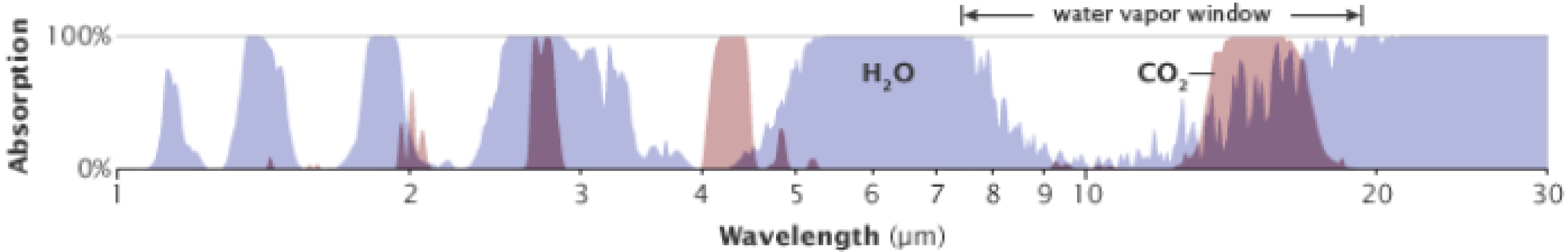
http://learningweather.psu.edu/node/22
(click on “Absorbtivity Graphic” link)

Ultraviolet (10 nm – 0.4 μ) **Visible (0.4 – 0.7 μ)** **Infrared (0.7 μ – 1000 μ**

Text for Howard et al, 1959 slide only (Slide 10): Reference: http://www.meteor.iastate.edu/gccourse/forcing/spectrum.html

- For each gas is given a plot of the absorption of the gas, ranging from 0 to 1, for each wavelength.
- As an example, if we look at the plot for oxygen and ozone, we see that the absorption is very high in the ultraviolet region but essentially zero in the visible and infrared regions, except for isolated peaks. We interpret this to mean that this gas absorbs essentially all radiation in the ultraviolet but is transparent in the visible and mostly transparent in infrared portions of the spectrum. This gas then is responsible for shielding earth-based biological systems from lethal ultraviolet radiation, radiation with wavelengths less than 0.3 micrometers (or 300 nanometers), but allows visible light and infrared radiation to pass through without much absorption.
- Other gases have much different absorption properties. Methane (CH_4), for example, has a couple of very small wavelength regions in which it absorbs strongly and these occur at about 3.5 and 8 microns, which are in the infrared region. Nitrous oxide, N_2O, having peaks at about 5 and 8 microns, absorbs in fairly narrow wavelength ranges.
- Carbon dioxide has a more complex absorption spectrum with isolated peaks at about 2.6 and 4 microns and a shoulder, or complete blockout, of infrared radiation beyond about 13 microns. From this we see that carbon dioxide is a very strong absorber of infrared radiation. The plot for water vapor shows an absorption spectrum more complex even than carbon dioxide, with numerous broad peaks in the infrared region between 0.8 and 10 microns.
- The total spectrum of all atmospheric gases is given in the bottom plot. This shows a "window" between 0.3 and 0.8 microns (the visible window), which allows solar radiation (without the lethal UV component) to reach the earth's surface. "Earth radiation", the upwelling infrared radiation emitted by the earth's surface, has a maximum near 10 microns. The total atmosphere plot shows that a narrow window (except for an oxygen spike) exists in the range of wavelengths near 10 microns.
- Note: The CFCs are not plotted here but will be considered separately.

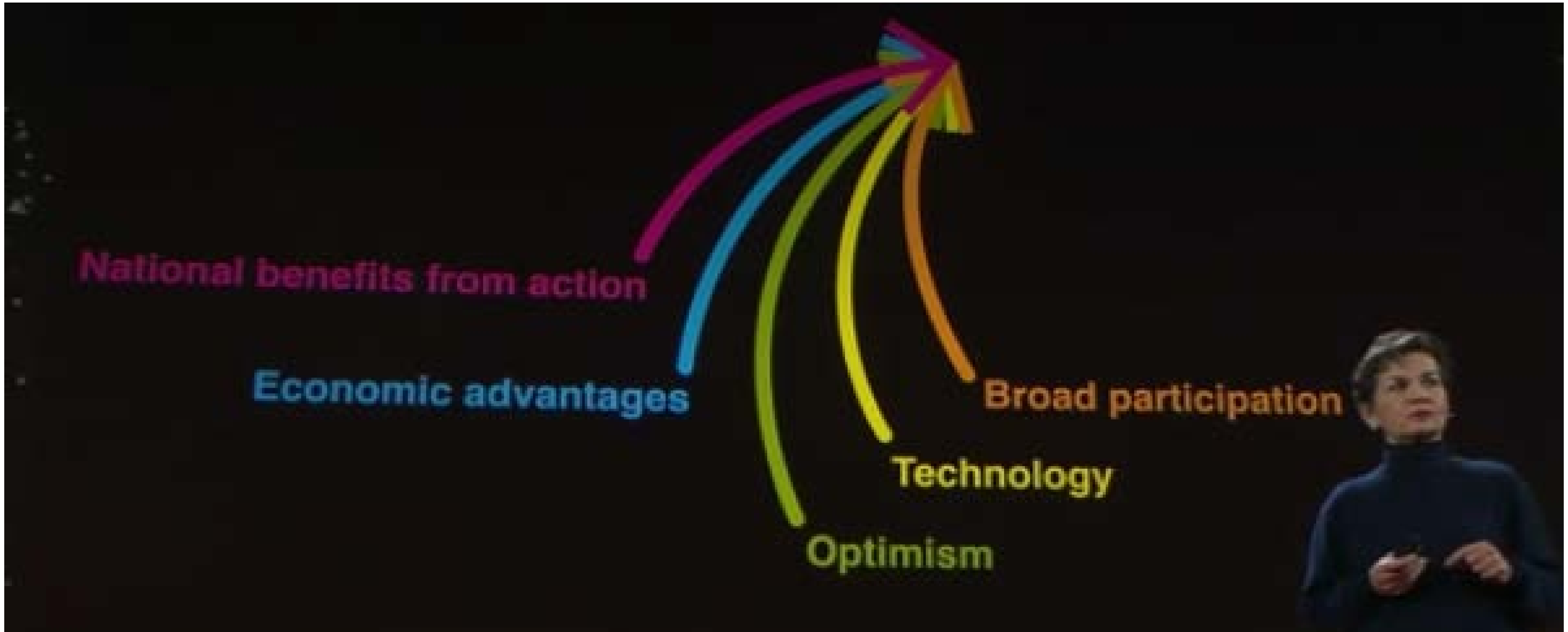
Absorption Patterns of Water Vapor and CO2



Atmospheric gases only absorb some wavelengths of energy but are transparent to others. The absorption patterns of water vapor (blue peaks) and carbon dioxide (pink peaks) overlap in some wavelengths. Carbon dioxide is not as strong a greenhouse gas as water vapor, but it absorbs energy in wavelengths (12-15 micrometers) that water vapor does not, partially closing the "window" through which heat radiated by the surface would normally escape to space. (Illustration NASA, Robert Rohde)

Paris Climate Agreement Inside Story

- Relentless optimism
- Technology esp. renewable energy
- Economy – economic advantages to the new economy
- Broad participation
- National benefits from action



https://www.ted.com/talks/christiana_figueres_the_inside_story_of_the_paris_climate_agreement#t-496370 (15 min total. Show 9:15 minutes in class)

Paris Agreement (Dec 2015)

“Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to **limit the temperature increase to 1.5 °C above pre-industrial levels,** recognizing that this would significantly reduce the risks and impacts of climate change.”

"Solutions" to Climate Change: Terminology and Categories

"Early" (1980s, 1990s)	Prevention	Mitigation	Adaptation		
Today		Mitigation	Adaptation	Geoengineering	Solar Radiation Mgt. (SRM)

Mitigation Definitions

- "The process of **reducing emissions or enhancing sinks of greenhouse gases** in the atmosphere so as to limit future climate change."

(IPCC Synthesis Rpt "Topic 3" p.76)

- Mitigation is reducing our carbon footprint and thus reversing the trend of… GHG emissions.
(Mark Maslin, Ch. 8 Solutions, p. 136)

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Adaptation Definitions

- "Adaptation is providing protection to the population." (Maslin, 2014, Ch. 8)
- "Adaptation is adjustments in the ecological-social-economic systems in response to... climate stimuli" (Jamieson, 2000, p 202)
- "Adjustment to climate and its effects to avoid harm. (IPCC, 2014 SYN, Topic 3, p. 76)

Geoengineering Definition

Geoengineering is the general term for technologies that could be used to either remove GHG from the atmosphere or change the climate of the Earth.“ (Maslin, 2014 p. 156)

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Solar Radiation Management Definitions

Solar radiation management (SRM) or solar geoengineering is a theoretical approach to reducing some of the impacts of climate change by reflecting a small amount of inbound sunlight back out into space.

It is in the early stages of research, but it is already a controversial topic. It is clear that SRM has the potential to be very helpful or very damaging for those people and species most threatened by climate change, but it is very unclear what its full effects would be.

http://www.srmgi.org/what-is-srm/

ANNEX –
Eunice Foote and John Tyndall

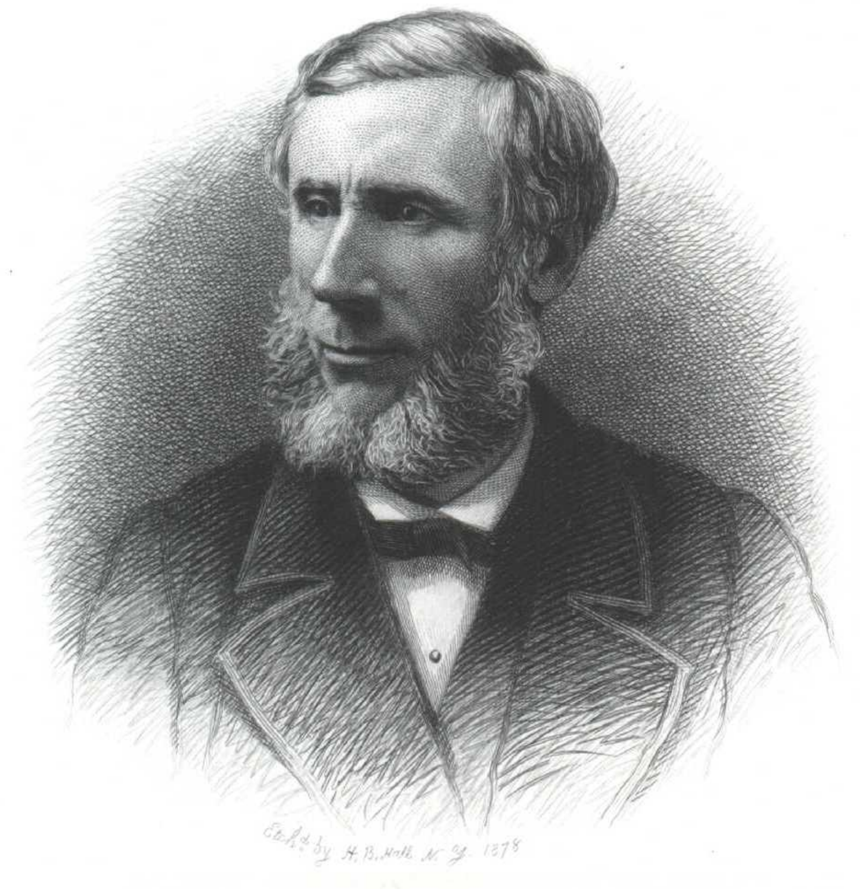
Eunice Newton Foote (1819 – 1888)

- Conducted experimental work on the warming effect of the sun on air, and how warming increased by water vapor and carbonic acid gas (carbon dioxide).
- Her experimental work was presented by Prof. Joseph Henry at the 8th annual American Association for the Advancement of Science (AAAS) meeting in 1856, (because women weren't allow to present).
- Foote was the 2nd female member of AAAS.
- The 1st was the famous astronomer Maria Mitchell, who was Ellen Swallow Richard's professor at Vassar.

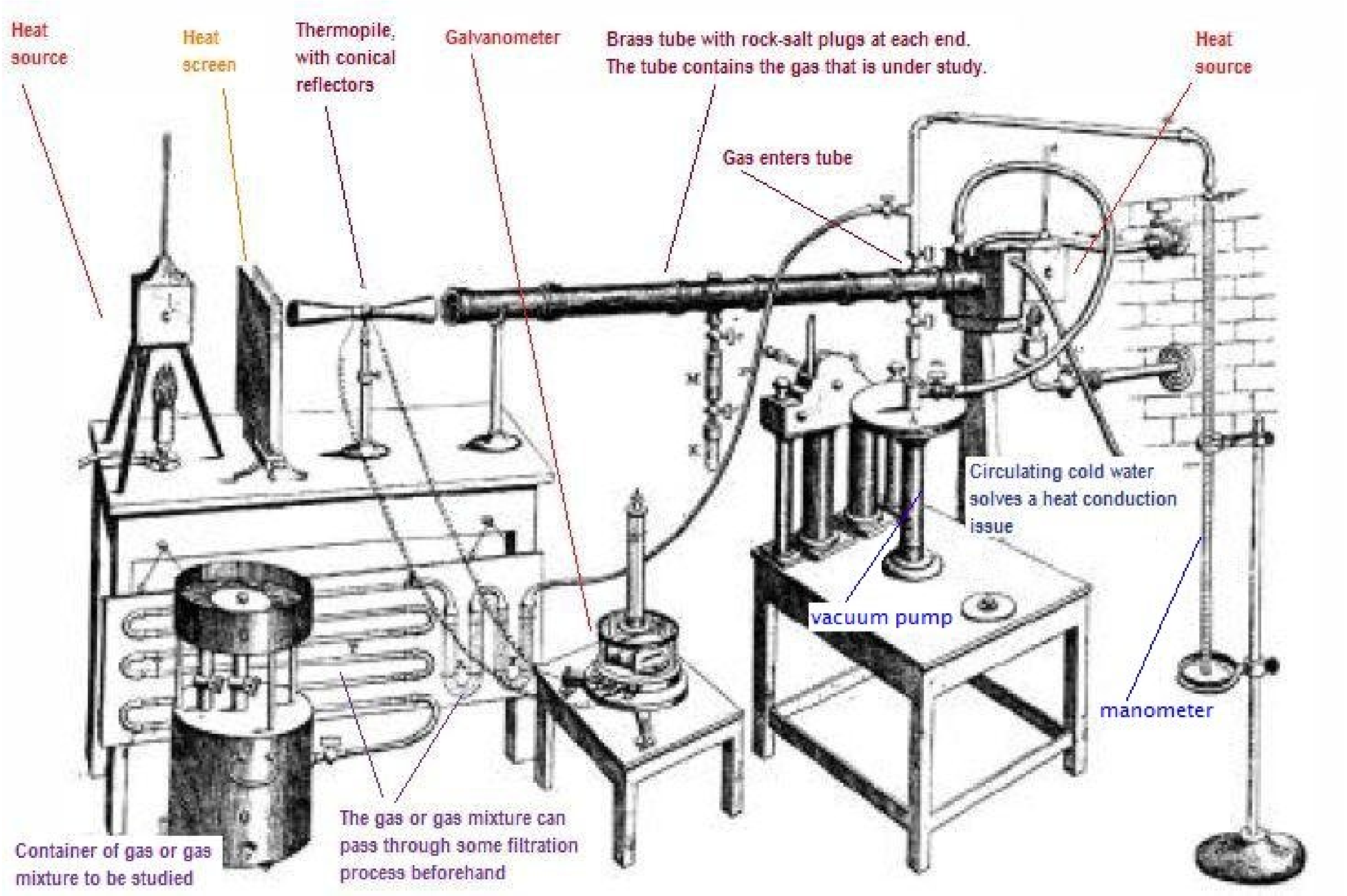
No known photo exists of Eunice Newton Foote. But there is a photo of her daughter, Mary Foote Henderson

John Tyndall (1820 – 1893)

- Tyndall explained the heat in the Earth's atmosphere in terms of the capacities of the various gases in the air to absorb radiant heat, also known as infrared radiation. His measuring device, which used thermopile technology, is an early landmark in the history of absorption spectroscopy of gases.
- He was the first [or 2nd if credit goes to Eunice Foote] to correctly measure the relative infrared absorptive powers of the gases nitrogen, oxygen, water vapour, carbon dioxide, ozone, methane, in the 1859 (four years after Eunice Foote's work).
- He concluded that water vapor is the strongest absorber of radiant heat in the atmosphere and is the principal gas controlling air temperature. Absorption by the other gases is not negligible but relatively small.
- Prior to Tyndall it was widely surmised that the Earth's atmosphere has a Greenhouse Effect, but he was considered to be the first to prove it. The proof was that water vapor strongly absorbed infrared radiation.
- [Eunice Newton Foote's experimental work is only recently discovered].



Tyndall’s Experimental Set-up



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