Environmental Engineering
Atmosphere & pollution 2

- Global radiation
- Greenhouse effect
- Kyoto protocol

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Electromagnetic Radiation

1/ insolation from the Sun

shortwave (UV and visible spectra)

2/ emitted from earth and atmosphere

longwave (IR)

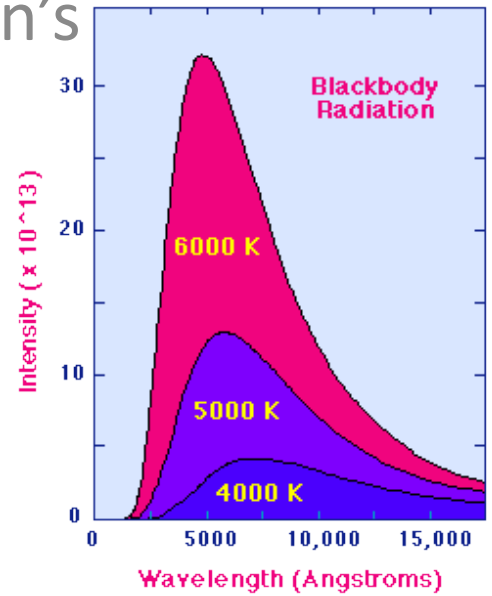
Plank's radiation law – wavelength of max intensity depends on temperature of the body (Wien's displacement law)

$$E(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{hc/\lambda kT} - 1}$$

$h = 6.625 \times 10^{-27}$ erg- sec (Planck Constant)

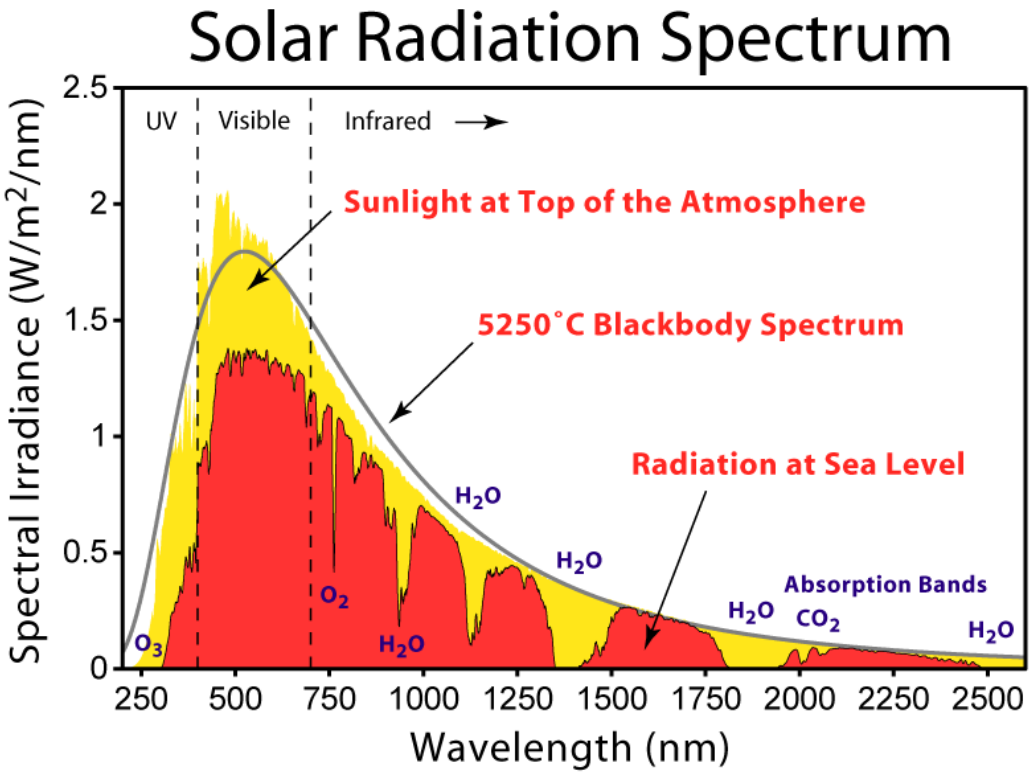
$k = 1.38 \times 10^{-16}$ erg/ K (Boltzmann Constant)

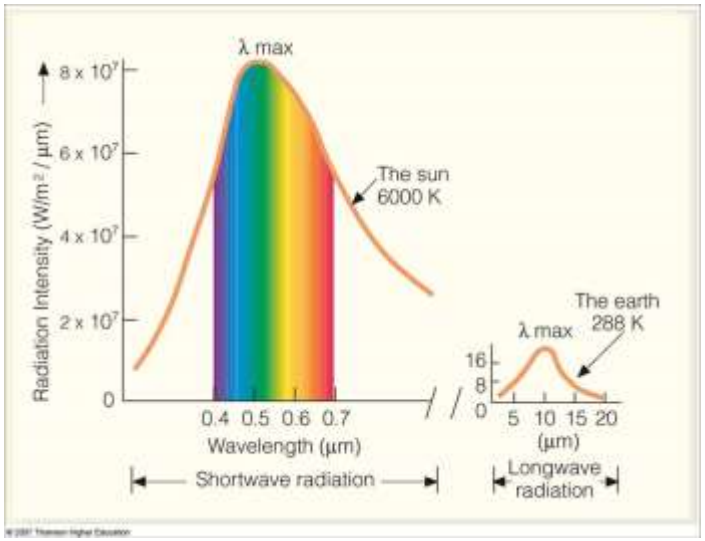
$c = 3 \times 10^{10}$ cm/sec (Speed of Light)



Incoming radiation (short waves)

- small fraction absorbed by gases in atmosphere (negligible when the sky is clear)
- albedo (α): thick clouds 80%, snow 95%, bare soil 10%, water 2-85%; Earth 31%

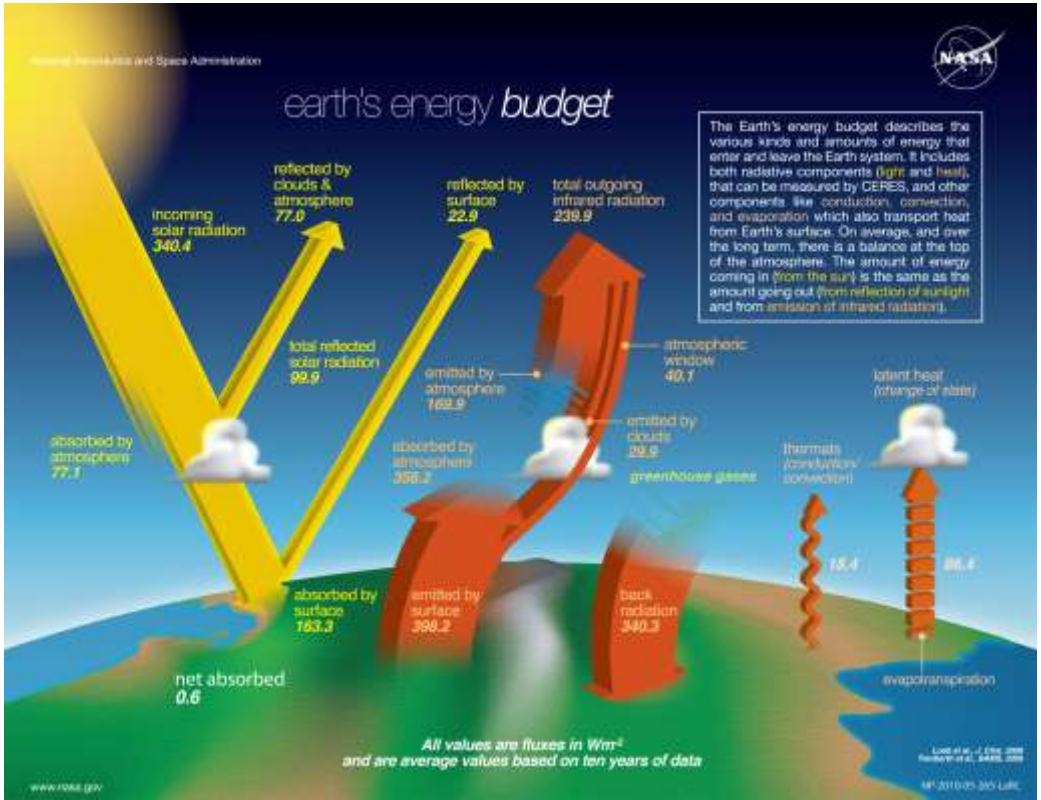




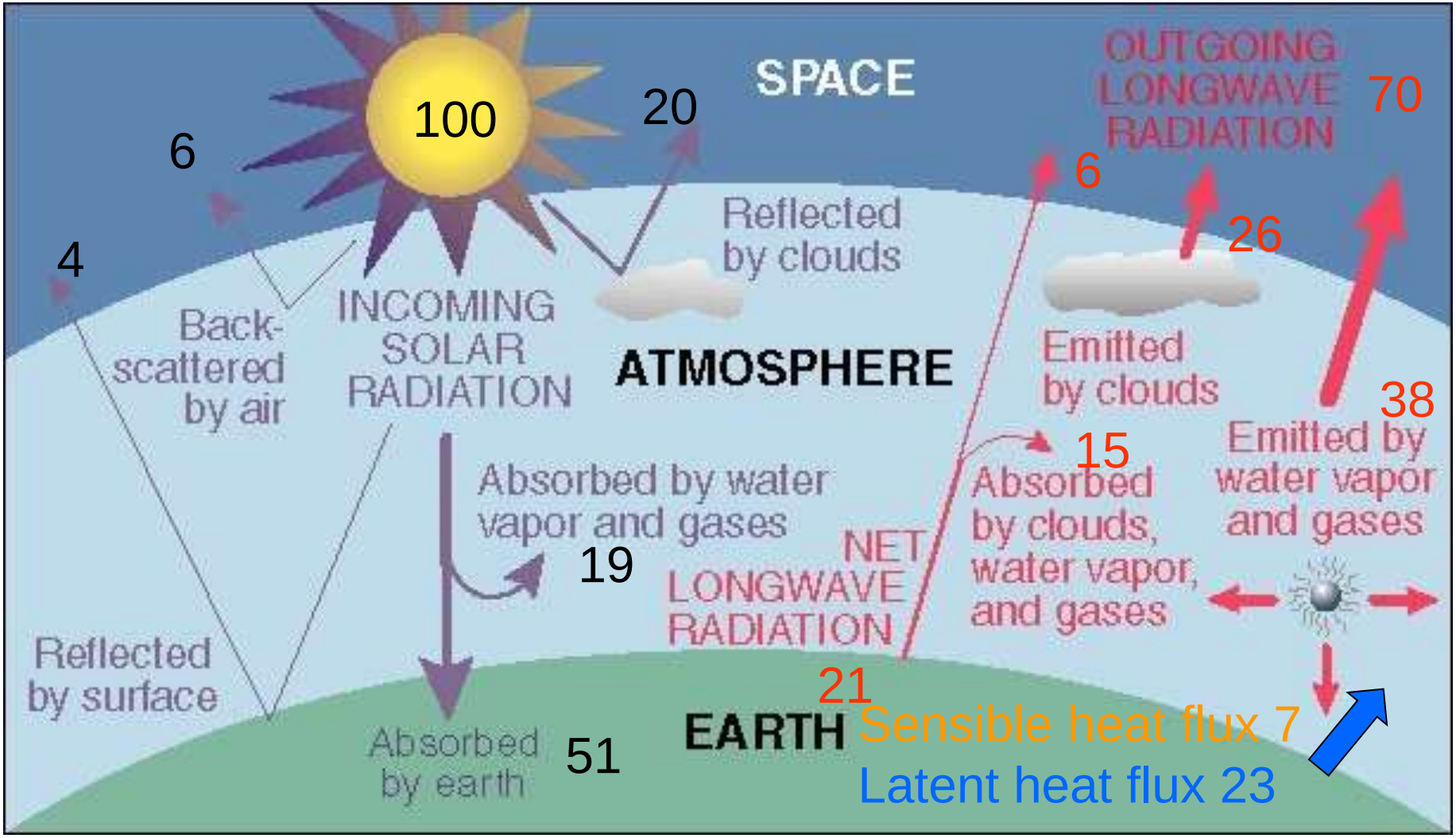
http://www.globalwarmingart.com/

Solar radiation, Earth energy balance

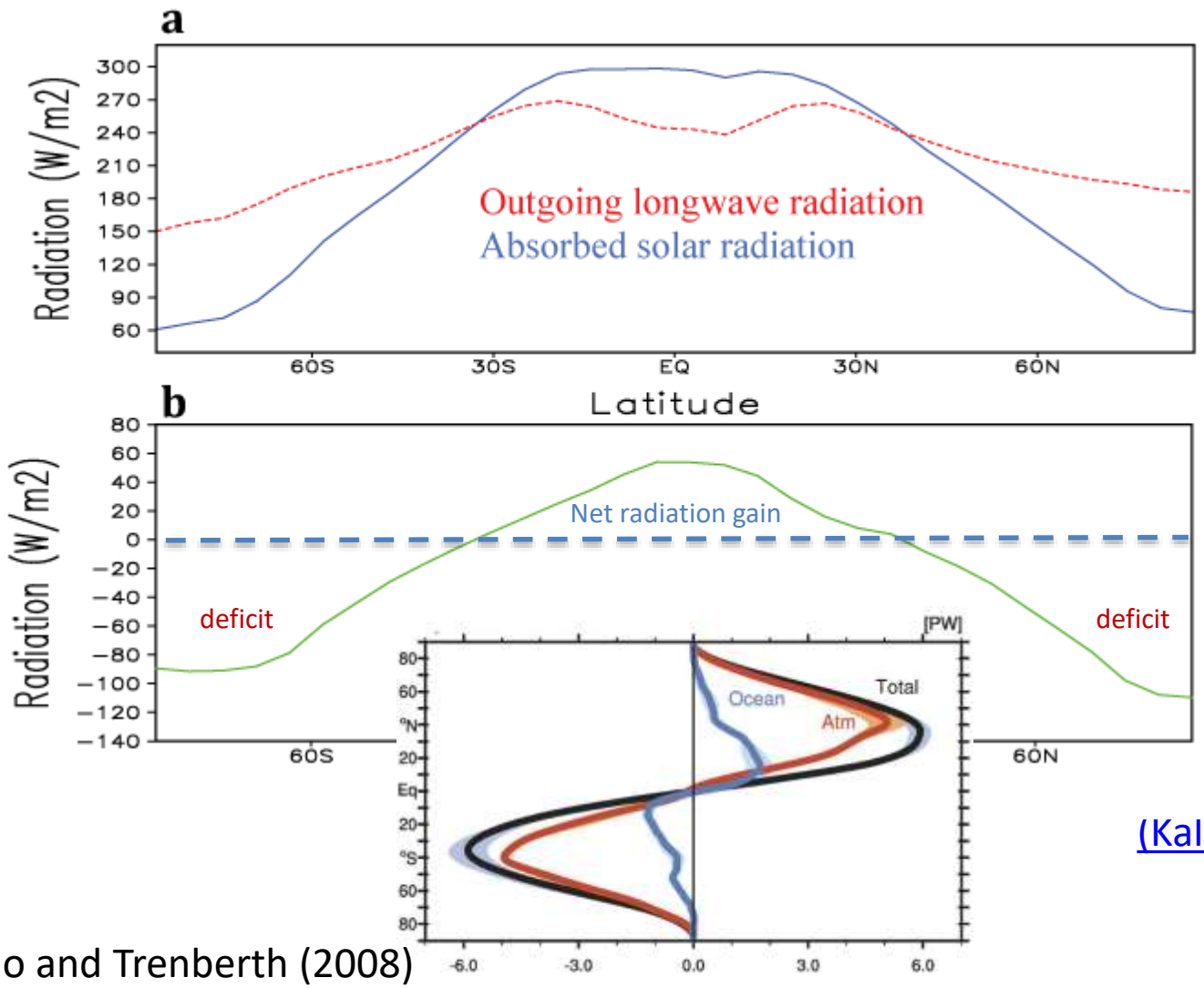
- Hydrologic cycle is fueled by solar radiation
- Most hydro & meteo events driven by uneven distribution of radiation (heat imbalances)
  - Planetary geometry, tilted axes and motion
- Radiation is temperature dependent ! (objects with temperature emit radiation)
  - Sun 5600 °K, Earth ~287°K
  - Net exchange of incoming solar and outgoing terrestrial radiation ?



Energy Balance of Earth



http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/energy/radiation_balance.html



Fasullo and Trenberth (2008)

(Kalnay et al. 1996).

Re-emitted radiation (long waves)

- clouds (atmosphere) – Stefan Boltzmann law (emitted heat energy is proportional to the body's temperature)

$$E = \sigma T^4$$

- Radiative equilibrium – incoming and outgoing radiation in a balance

$$S\,(1-\alpha) = \sigma T^4$$

Temperature of the inner planets

$S(1-\alpha) = \sigma T^4$

($\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4})

Rearranging: $T = \left\{ \frac{S(1-\alpha)}{\sigma} \right\}^{1/4}$

$T(°C) = T(K) - 273$

	Relative distance	Solar radiation (S) W m^{-2}	Albedo (α)	Net solar radiation S(1- α)	Equilib-rium T (° C)	Actual surface T (° C)
 Mercury	0.39	2250	0.1	2025	162	180
					Just about agrees	
 Venus	0.72	660	0.59	271	-10	453
					Disagrees badly	
 Earth	1	342	0.31	236	-19	15
					Disagrees	
 Mars	1.5	150	0.15	128	-55	-40

Good combination of Distance from the Sun, Albedo and Green house effect

Source: David Stevenson, U. of Edinburgh, http://www.geos.ed.ac.uk/~dstevens/

Greenhouse effect

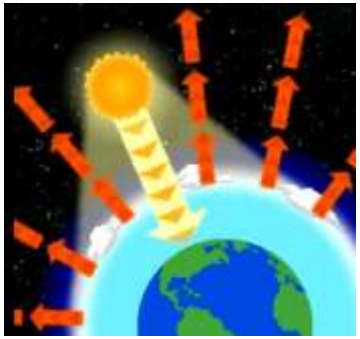
- "a layer" in the atmosphere which allows the solar radiation to go through but reflect the thermal radiation back
- this layer is formed by greenhouse gasses (main contributors water vapour, CO_2)
- is a natural phenomenon determining conditions for life (known since 19^{th} century)
- global warming $\Rightarrow$ climate change

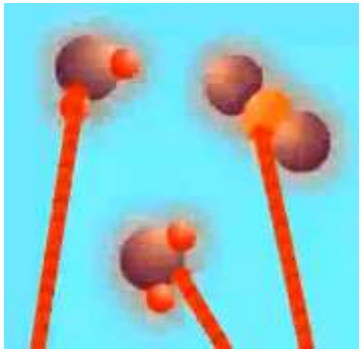
How does the greenhouse effect maintain surface temperature on Earth?

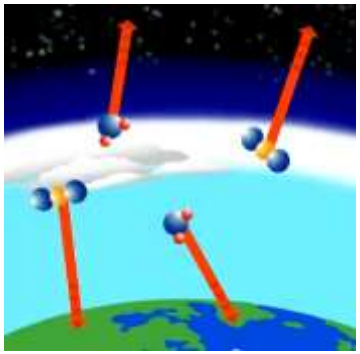
Greenhouse effect

Radiative equilibrium: emitted thermal radiation equals incoming absorbed solar radiation

- most thermal radiation emitted by atmosphere (surface contributes by only 10% - rest is absorbed)
- Shortwave radiation pass the atmosphere, long wave radiation is absorbed by greenhouse gases
- Greenhouse gases re-emit radiation in all directions

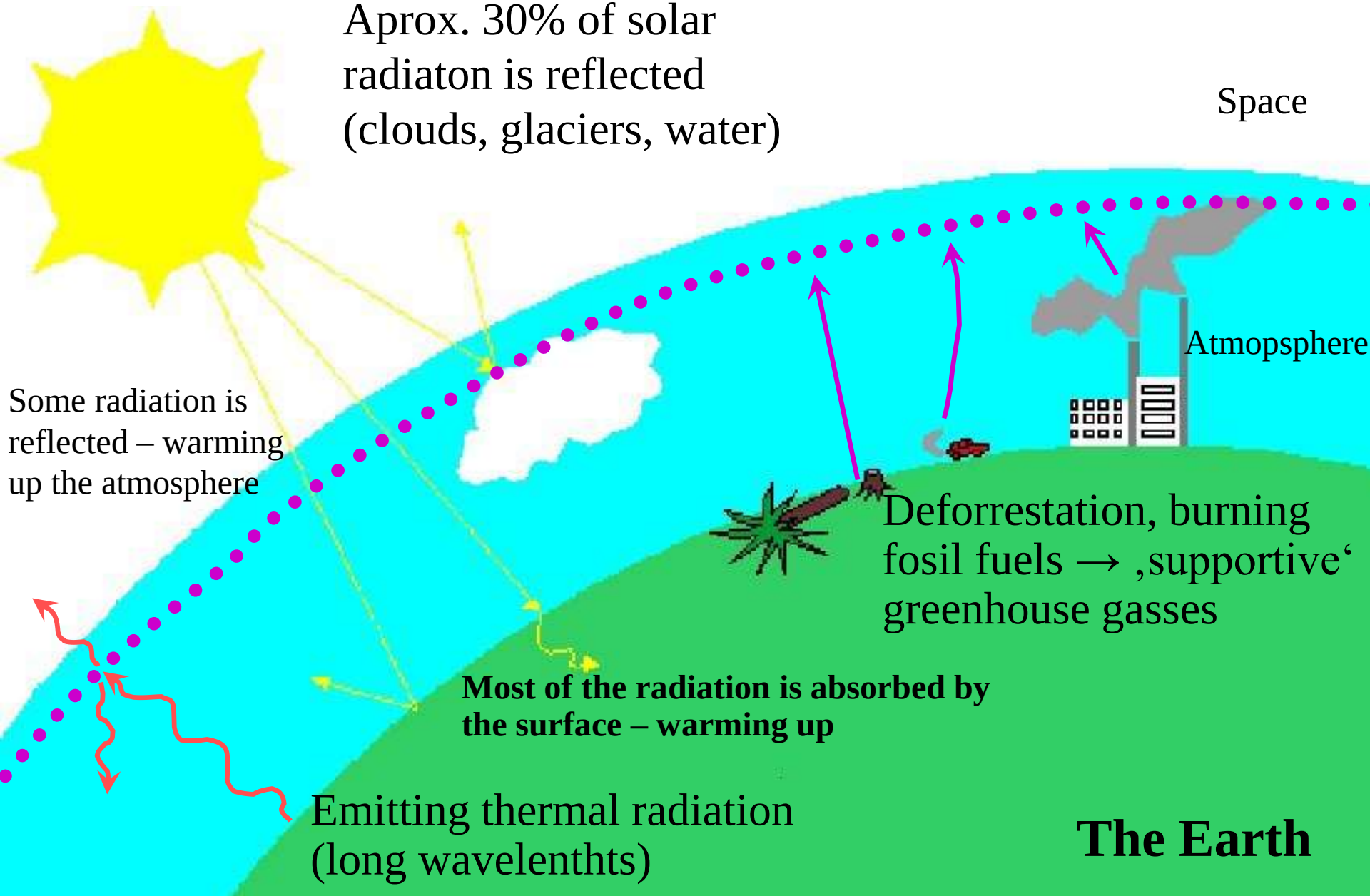


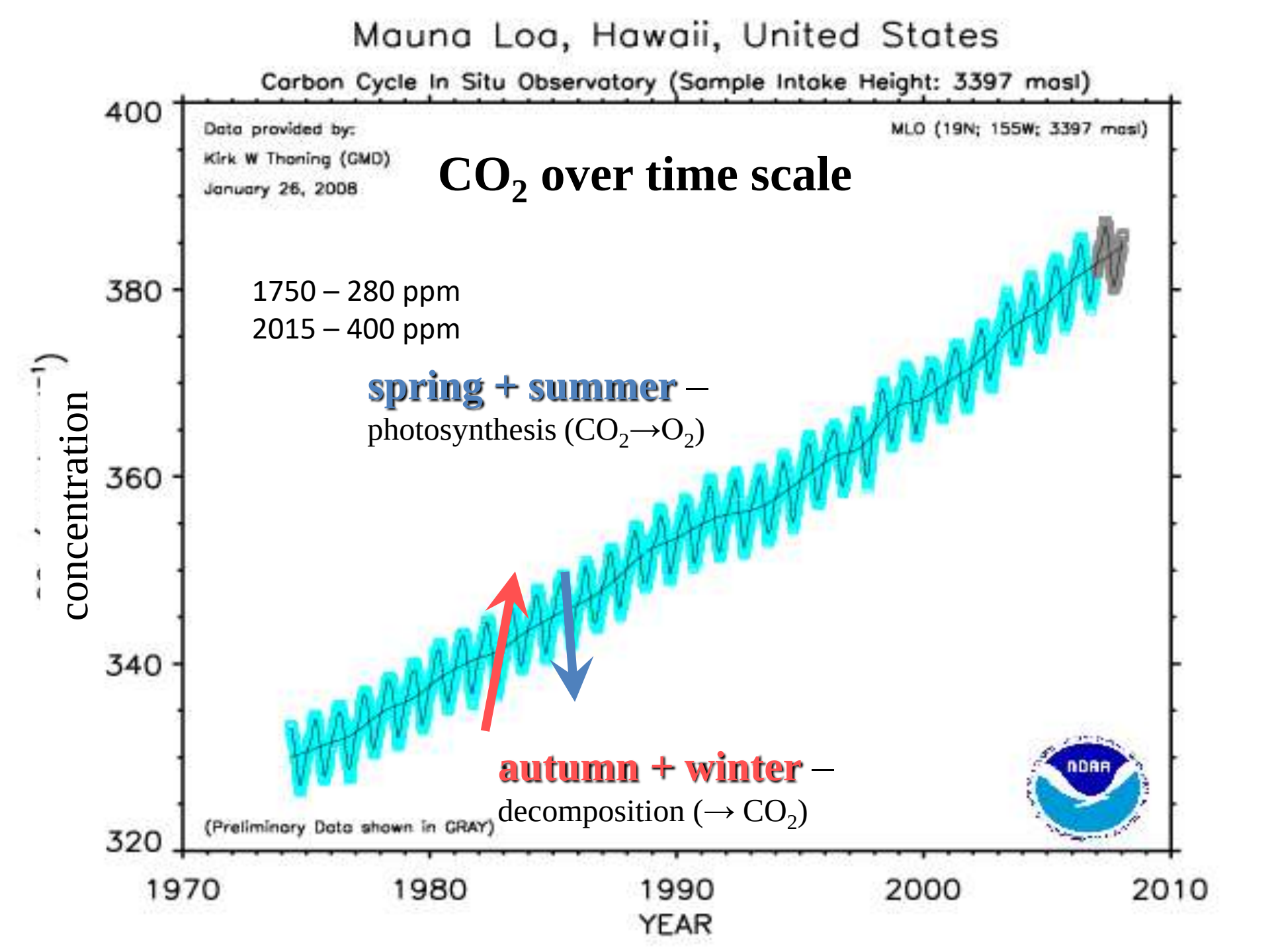




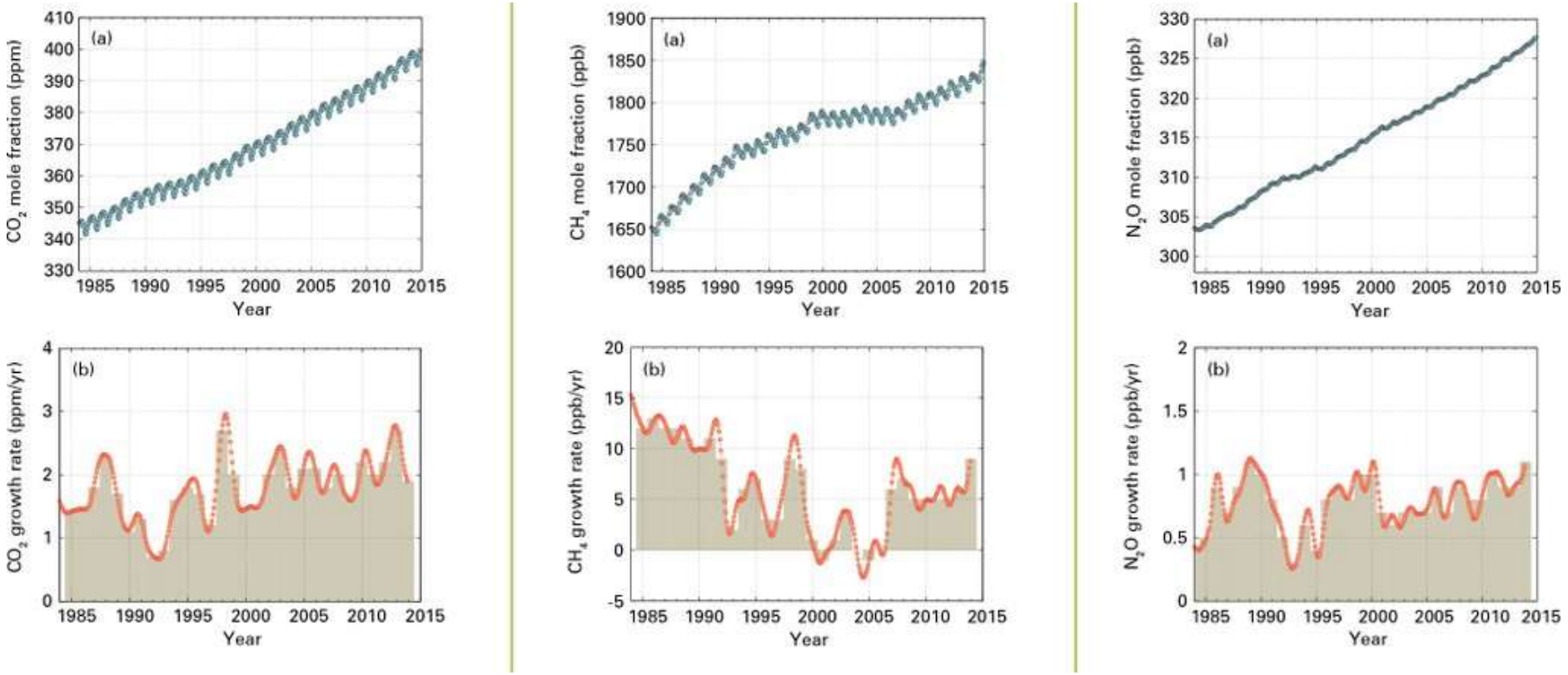
Source: NASA Earth Observatory

PRINCIPLE:


Aprox. 30% of solar radiaton is reflected (clouds, glaciers, water)
Space
Atmopsphere
Some radiation is reflected – warming up the atmosphere
Deforrestation, burning fosil fuels → ‚supportive‘ greenhouse gasses
Most of the radiation is absorbed by the surface – warming up
Emitting thermal radiation (long wavelenthts)
The Earth


Mauna Loa, Hawaii, United States
Carbon Cycle In Situ Observatory (Sample Intake Height: 3397 masl)
Data provided by:
Kirk W Thoning (GMD)
January 26, 2008
MLO (19N; 155W; 3397 masl)
CO_2 over time scale
1750 – 280 ppm
2015 – 400 ppm
spring + summer –
photosynthesis ($CO_2 \rightarrow O_2$)
autumn + winter –
decomposition ($\rightarrow CO_2$)
(Preliminary Data shown in GRAY)
NOAA
concentration
400
380
360
340
320
1970
1980
1990
2000
2010
YEAR

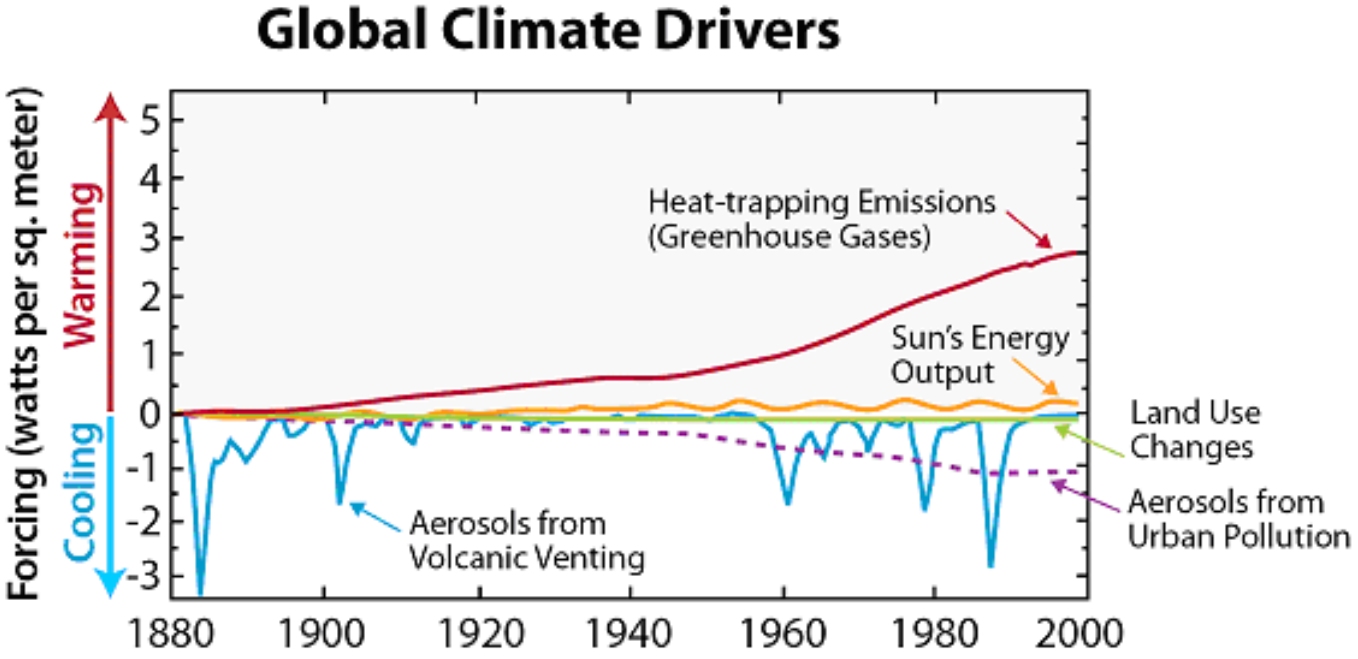
CO2 concentration is the highest in last 800 000 years (WMO)



(UNDP, 2015)

How do humans contribute?

- We can distinguish CO2 produced by fossil fuels burning (isotopes)
- Natural changes do not explain the rate of temperature changes
- Growing troposphere, shrinking stratosphere
- Lower outgoing radiation (satellite measurements)
- …



The Kyoto

1992: UN Framework Convention on Climate Change http://unfccc.int/

- recognized there is a problem: CO_2 emissions are warming the planet

- stabilize CO_2 at "at a level that would prevent *dangerous* anthropogenic (human induced) interference with the climate system.“

goals:
1) ensure that ecosystems can adapt to climate change
2) make sure that food production not threatened
3) allow sustainable economic development

The Kyoto Protocol - background

1992: UN Framework Convention on Climate Change http://unfccc.int/

- places the heaviest burden for fighting climate change on industrialized nations

- general target: collectively reduce emissions to 1990 levels by 2000, plus extension to 2012

- Doha amendment (Katar, 2012) – extension till 2020

- support developing countries' climate change activities (granting body)

- developing countries' emissions will grow before they shrink

- developing countries will have largest climate change impacts; work to mitigate

Three primary mechanisms

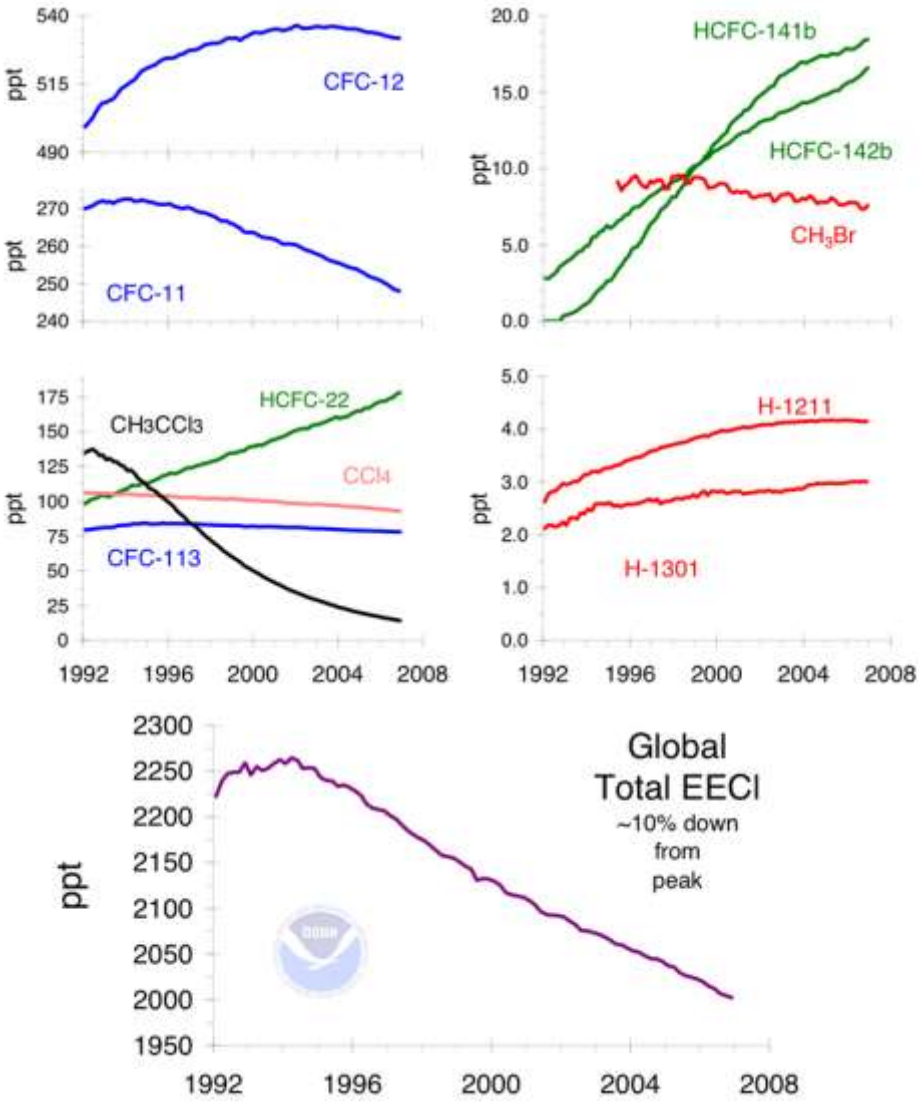
1. Emissions trading
   - trade carbon permits

2. Joint Implementation
   - “Developed” countries can invest in a emissions-reduction project in another developed country

3. Clean Development Mechanism
   - emissions reductions in developing countries

The Montreal Protocol on Substances that Deplete the Ozone Layer

- to phase out the production
  stratospheric ozone layer (cl
  searching for ozone-friendly
- Recognized by all UN countr
- **Chlorofluorocarbons (CFCs),**
  (HCFCs),



* Except South Sudan