EXHIBIT 4

Answers to the Questions Posed by Judge Alsup

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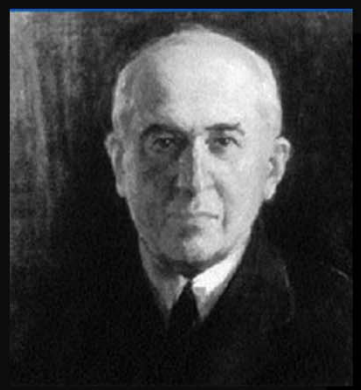
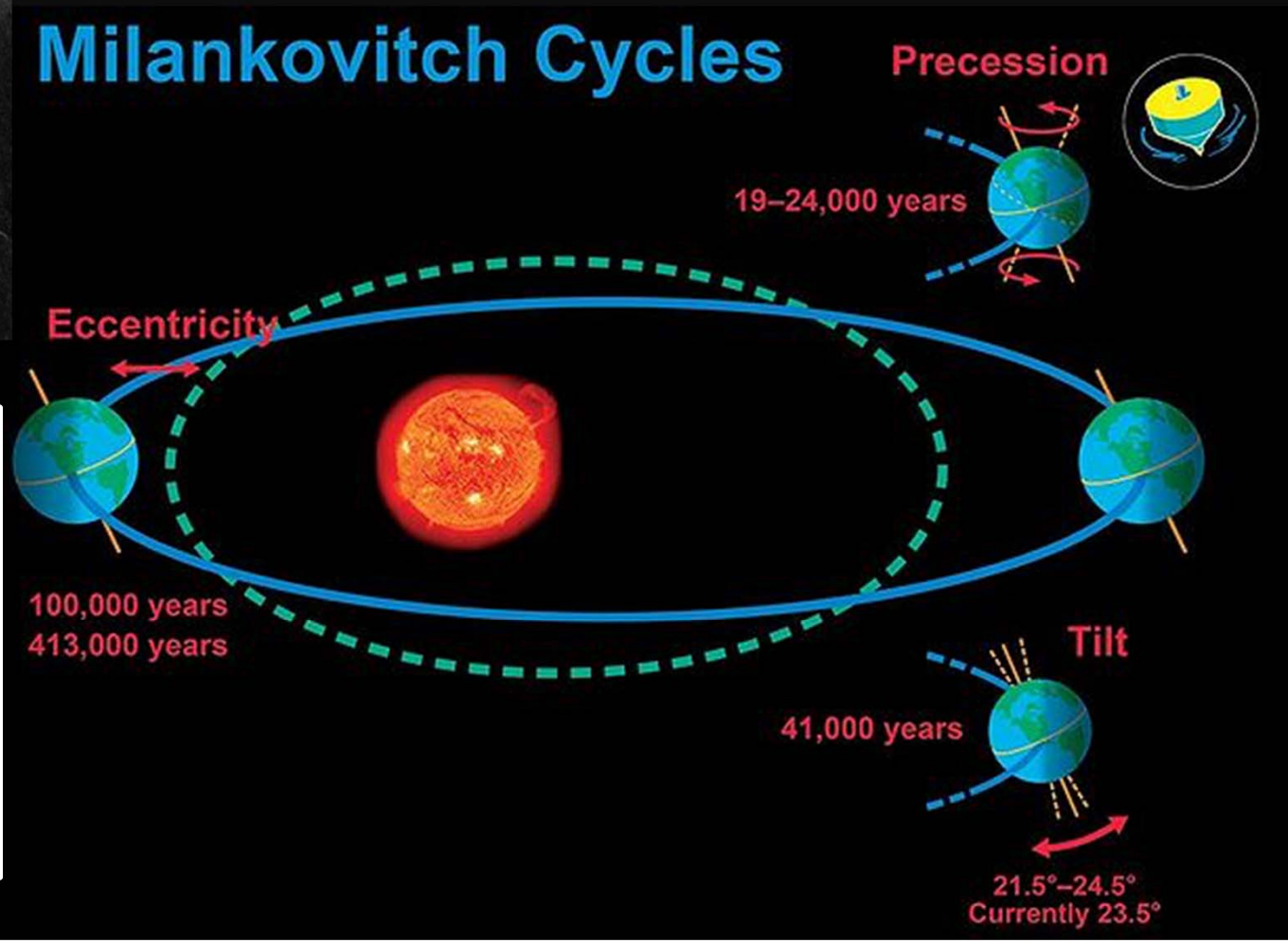
Addressing Some Questions for the Tutorial

1. What caused the various ice ages (including the "little ice age" and prolonged cool periods) and what caused the ice to melt? When they melted, by how much did sea level rise?

Variations in the Earth's Motions Explain Ice Ages

Milutin
Milankovitch

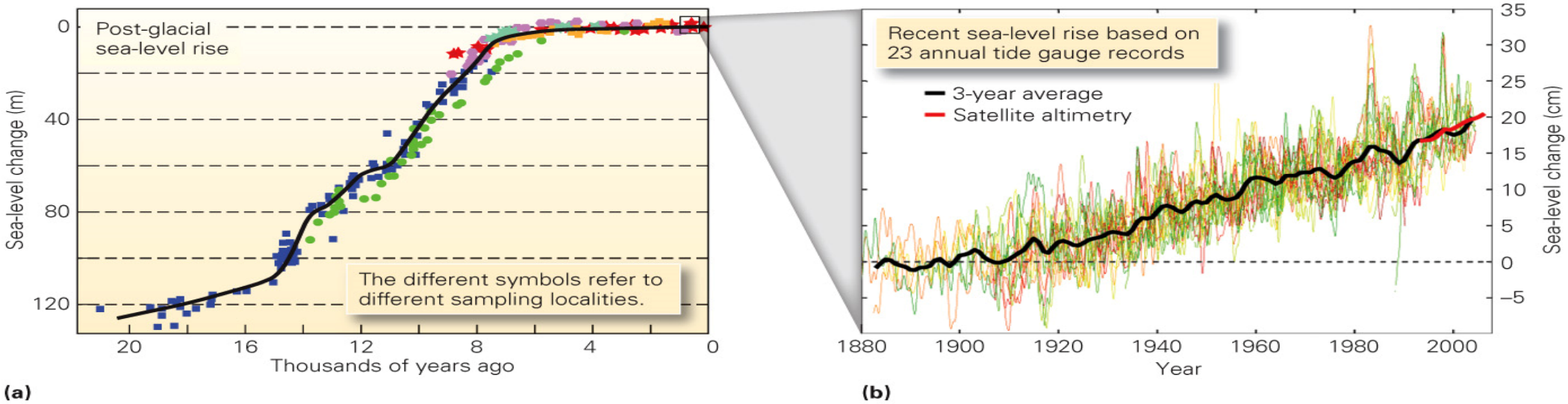




- Milankovitch cycles explain the onset of an ice age
- CO2 concentration decrease amplifies the cooling.

Date | Name

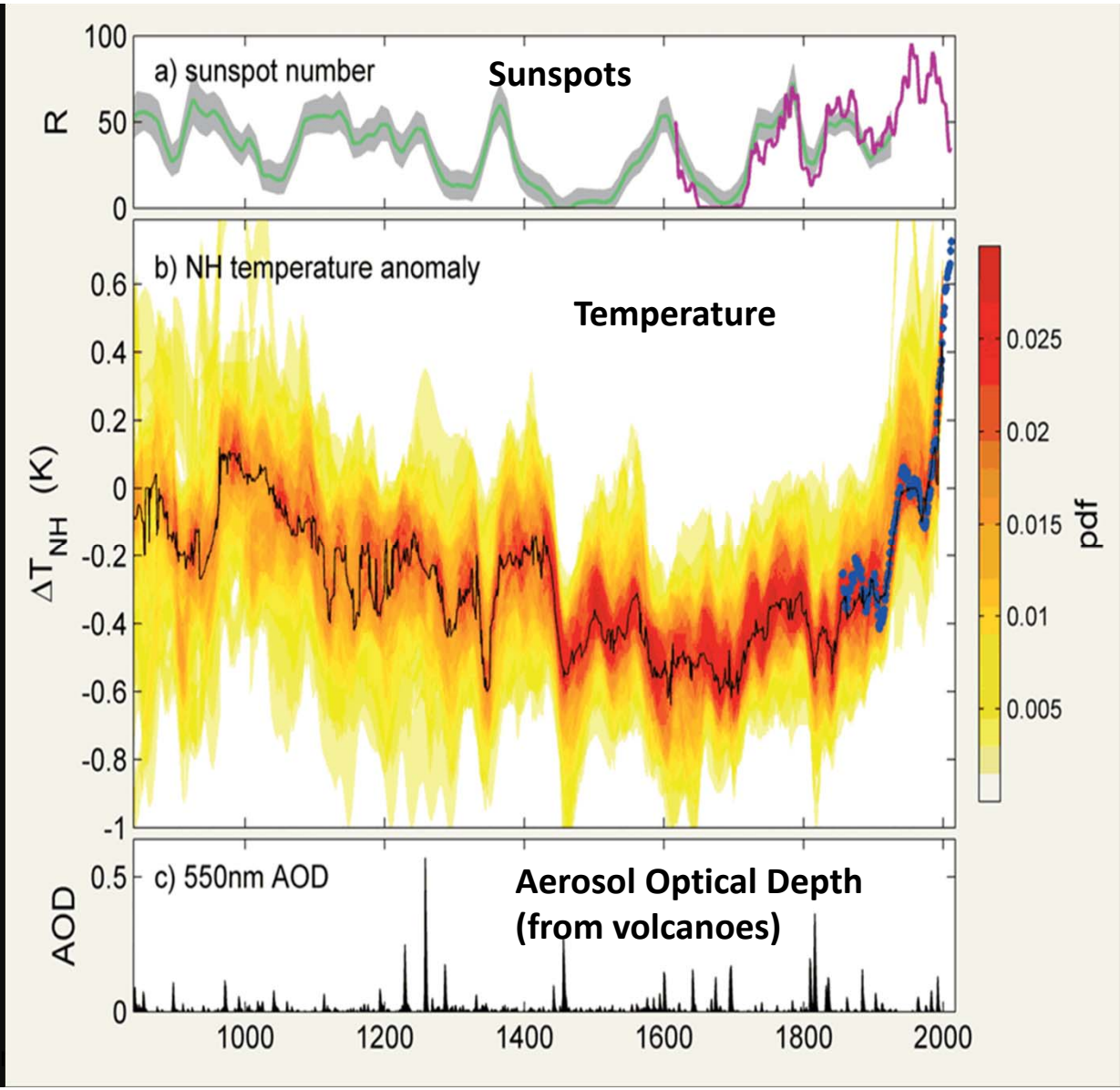
Sea level rose rapidly due to the melting of the ice-age glaciers (~120 m), but that stopped about 5000 years ago until the recent rise.



Marshak, S., 2015, Earth: Portrait of a Planet

Little Ice Age

- A period of cooling from approx. 14th-19th century, most evidence in Europe and North America
- Evidence indicates that little ice age largely due to series of extremely explosive volcanic eruptions, with smaller contribution from solar flux variations



2. What is the molecular difference by which CO2 absorbs infrared radiation but oxygen and nitrogen do not?

Chemical structure of CO_2 allows it to absorb IR energy.

- The energy from the photon causes the CO_2 molecule to vibrate.
- CO_2 gives up this extra energy by emitting another infrared photon.

Nitrogen (N2)and oxygen (O2) are not greenhouse gases

- Molecules containing two atoms of the same element have no net change in energy when they vibrate.

3. What is the mechanism by which infrared radiation trapped by CO2 in the atmosphere is turned into heat and finds its way back to sea level?

This is **The Greenhouse Effect** (first discovered by Joseph Fourier in 1824).

The heat-trapping abilities of greenhouse gases were corroborated by John Tyndall in 1860s

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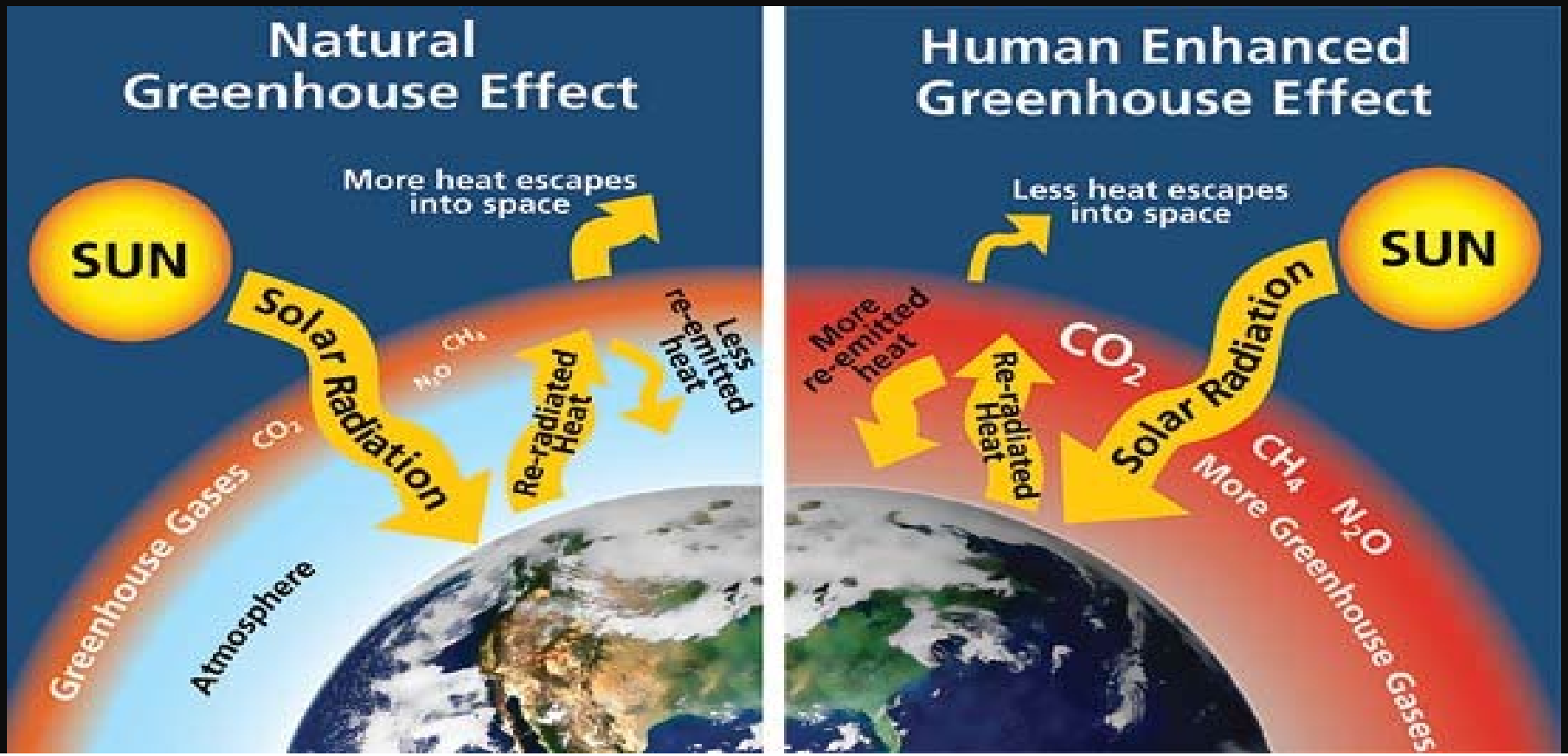


4. Does CO2 in the atmosphere reflect any sunlight back into space such that the reflected sunlight never penetrates the atmosphere in the first place?

Only a very small amount.

CO_2 has a shortwave absorption effect of about -0.14 W/m^2 for CO_2 going from 389 to 700 ppm

This is 4% of the increase in IR forcing of 3.43W/m^2.

5. Apart from CO2, what happens to the collective heat from tail pipe exhausts, engine radiators, and all other heat from combustion of fossil fuels? How, if at all, does this collective heat contribute to warming of the atmosphere?

Direct heat from total use of fossil fuels and other forms of energy is about 18 TW -- Spread over the planet that is 0.04 W/m^2.

Compared to greenhouse gas forcings since 1750 of about 2.29 W/m^2, it's about 1/100th the size.

Locally however (say in cities or urban environments), this can be more concentrated and have a bigger impact.

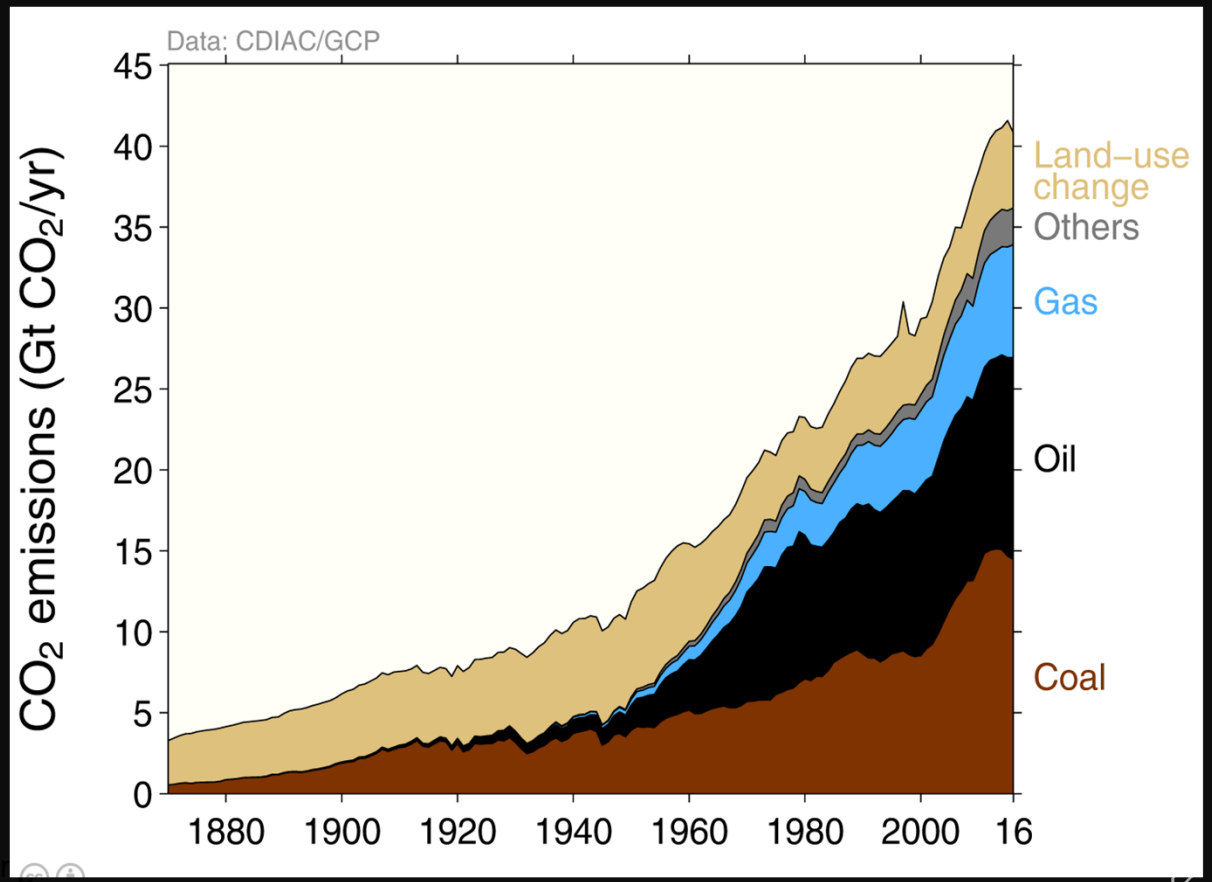
6. In grade school, many of us were taught that humans exhale CO_2 but plants absorb CO_2 and return oxygen to the air (keeping the carbon for fiber). Is this still valid? If so, why hasn't plant life turned the higher levels of CO_2 back into oxygen? Given the increase in human population on Earth (four billion), is human respiration a contributing factor to the buildup of CO_2?

Actually observations by Ralph Keeling (UC San Diego) show O_2 is decreasing very slightly because of the oxygen captured in the formation of emitted CO_2.

Human respiration (last 40 year) is about 0.0001 of GHG forcing

7. What are the main sources of CO2 that account for the incremental buildup of CO2 in the atmosphere?

Main sources of human CO_2 emissions are fossil fuel burning and land use change (largely from deforestation).



From DOE Oak Ridge National Lab

8. What are the main sources of heat that account for the incremental rise in temperature on Earth?

Figure from the 4th National Climate Assessment shows that the radiative forcing on climate since 1750 is dominated by the CO2 and other emissions from human activities