

## Thermo-physical characteristics of CO2 in perspective

### Heat Capacity comparison of CO2 in the atmosphere versus the top layer of oceans water

Energy  $E = C_p \cdot \Delta T \cdot m$   
 $\Delta T =$  Temperature difference  
 $m =$  mass  $= \rho \cdot V$   
 $V =$  Volume = Surface (S) x height (h)

<u>Carbon Dioxide</u>			<u>Water</u>		
		at 15 °C			at 15 °C
CO2	<u>Specific Heat</u>	$C_p = 0.83 \text{ kJ / kg } ^\circ\text{K}$	H2O	<u>Specific Heat</u>	$C_p = 4.19 \text{ kJ / kg } ^\circ\text{K}$
	<u>Density</u>	$\rho = 1.85 \text{ kg / m}^3$		<u>Density</u>	$\rho = 1000 \text{ kg / m}^3$
	<u>Average Relative Density in Troposphere (ISA)</u>	0.546			

CO2 Fraction of atmosphere      %      0.04%                      Water Fraction of Earth's Surface      %      71%

Energy it takes to increase all CO2 in atmosphere by 1 deg:      =      Energy absorbed by certain depth of the top layer of oceans  
 $E_{(\Delta T=1)} = \% \cdot C_p \cdot \rho \cdot S \cdot h$

$h =$  average height of troposphere =      13 km                       $h = d =$  height (depth) of layer of oceans surfaces

$$4.4 \cdot S = E_{(\Delta T=1)} = S \cdot d \cdot 2966.5$$

$$\Rightarrow d = 0.0015 \text{ m}$$

**1.5 mm**

### What does it take to heat the troposphere by 1 degree?

<u>Earth's Surface</u>		<u>Average height of Troposphere</u>	
Land:	148,940,000 km <sup>2</sup>	29%	13 km
Water:	361,132,000 km <sup>2</sup>	71%	
	510,072,000 km <sup>2</sup>		6.6E+18 m <sup>3</sup> Volume of Troposphere

Specific heat of air      1 kJ / kg K                      Average Relative Density in Troposphere (ISA)      0.546  
 $\rho_o = 1.225 \text{ kg / m}^3$

To heat whole Troposphere by 1 deg:       $E_{(\Delta T=1)} = C_p \cdot \rho \cdot V$

$E = 4.4E+18 \text{ kJ}$   
in 100 years      4.4E+16 kJ      per Year  
per Day      1.2E+14 kJ

And this 'Catastrophic' Climate Change is because of CO2 ??

**The real energy transmitter: Latent Heat**

			<u>at 15 °C</u>
	<a href="#">Heat of Vaporization *</a>	$\Delta H_{vap}$	<b>2465 kJ / kg</b>
* the amount of energy that must be added to a liquid to evaporate a given quantity into a gas			
H2O	<a href="#">Specific Heat</a>	$C_p$	<b>4.19 kJ / kg °K</b>

It takes 419 kJ to heat 1 liter of water from 0 to 100 °C  
To vaporize 1 liter of water it takes about **6** times more energy

To heat whole Troposphere by 1 deg:

$$E(\Delta T=1) = C_p \cdot \rho \cdot V$$

E =	4.4E+18 kJ	
in 100 years	4.4E+16 kJ	per Year
per Day	1.2E+14 kJ	

**Compare with Latent Heat transfers within atmosphere:**

[HowStuffWorks: Energy in a hurricane](#)

"But that's not all, we're just getting started. A hurricane also releases energy through the formation of clouds and rain (it takes energy to evaporate all that water). If we crunch the numbers for an average hurricane (1.5 cm/day of rain, circle radius of 665 km), we get a gigantic amount of energy: 6.0 x 10<sup>14</sup> Watts or 5.2 x 10<sup>19</sup> Joules/day!"

5.2E+16 kJ **per Day**

That is more than what it takes **in a Year** to cause 'catastrophic' climate change

[Wikipedia: Thunderstorms](#)

In a typical thunderstorm, approximately 5x10<sup>8</sup> kg of water vapor are lifted, and the amount of energy released when this condenses is 10<sup>15</sup> joules.

This is on the same order of magnitude of energy released within a tropical cyclone, and more energy than that released during the atomic bomb blast at Hiroshima, Japan in 1945.

Thunderstorms occur throughout the world, even in the polar regions, with the greatest frequency in tropical rainforest areas, where they may occur nearly daily. At any given time, approximately 2,000 thunderstorms are occurring on Earth.

Life cycle: Developing, Mature and Dissipating stage

Each of these three stages take an average of 30 minutes

**What is that Energy wise:**

	10 <sup>15</sup> J	
	2000 at any time	
At any given time	2 x 10 <sup>15</sup> kJ	
	2E+15 kJ	in average 1.5 hours
	3.2E+16 kJ per day	

What does it take to heat the troposphere by 1 deg in 100 years:

1.2E+14 kJ per day

Factor: **263** for what we know about thunderstorms  
This is just Thunderstorms. In every raincloud latent heat is transferred

**Latent Heat that is daily transferred in the atmosphere is hundreds time bigger than the energy required to cause recent climate change.**

**Common sense: It is very probable that water is responsible for imbalances in the Earth's Energy balance due to its role in variations in the meridional energy transport.**