Voluminous Icelandic Basaltic Eruptions Appear To Cause Abrupt Global Warming

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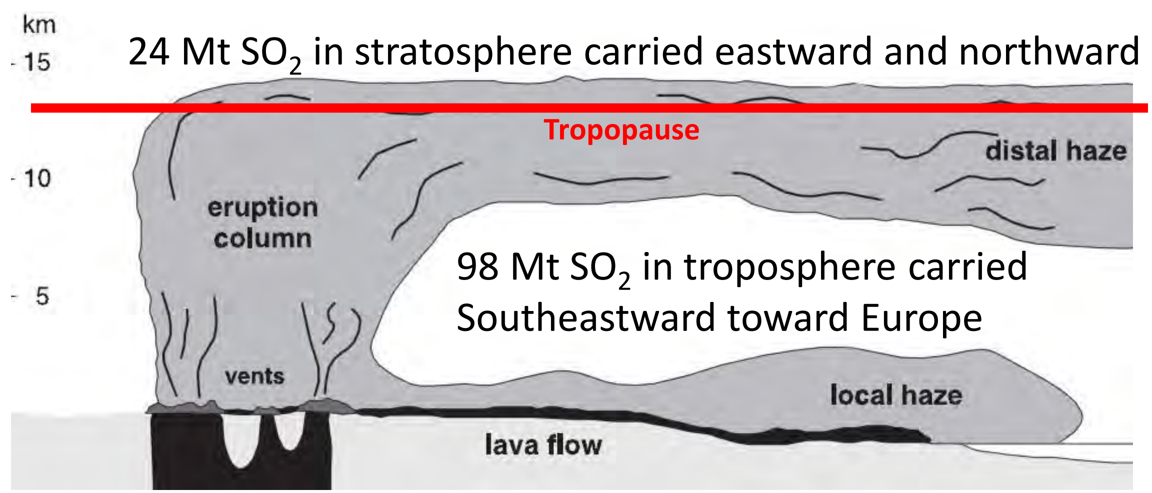
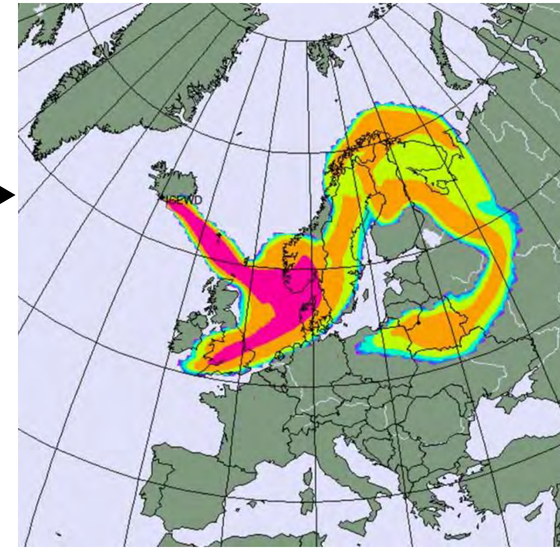
(1) Flood Basaltic Eruptions in Iceland Load Massive Amounts of SO_2 into the Troposphere Causing Warming

	Eldgja 934	Laki 1783	Pinatubo 1991
Magma volume	18 km^3	15 km^3	5 km^3
Erupted to	13 km?	13 km	35 km
Mass SO_2		120 Mt	17 Mt
	Onset Medieval Warming Period	Up to 3.3^{o}C warming of Europe during eruption	-0.7^{o}C global cooling for nearly 3 years

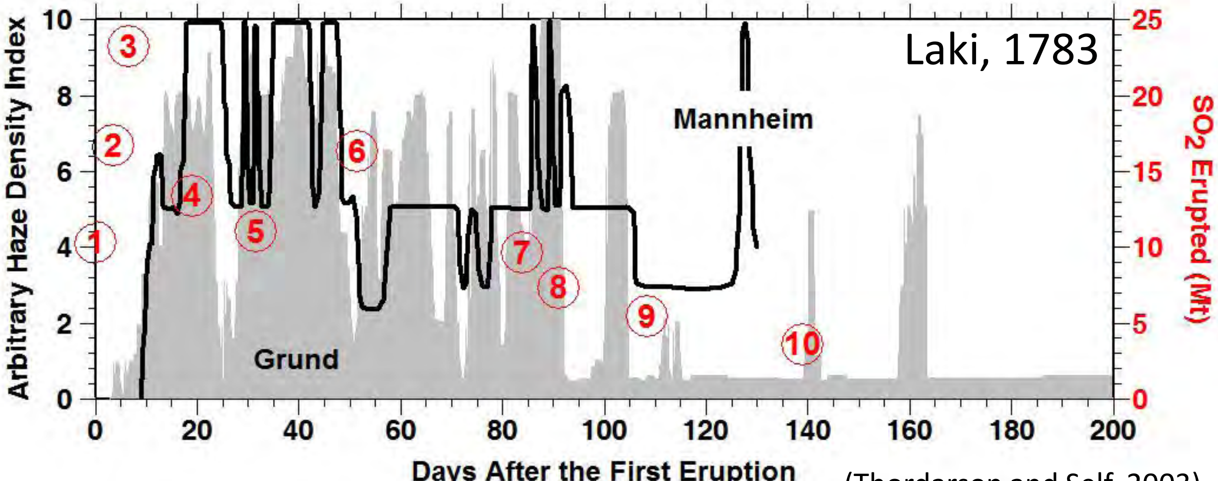
80% of the SO_2 and fine ash erupted by Laki in 1783 stayed in the troposphere and drifted southeastward towards Europe while the cooling effects associated with the SO_2 that reached the stratosphere moved eastward and northward



(2) A similar distribution of tropospheric ash and gases from Eyjafjallajökull as observed on April 15, 2010 at 3 pm

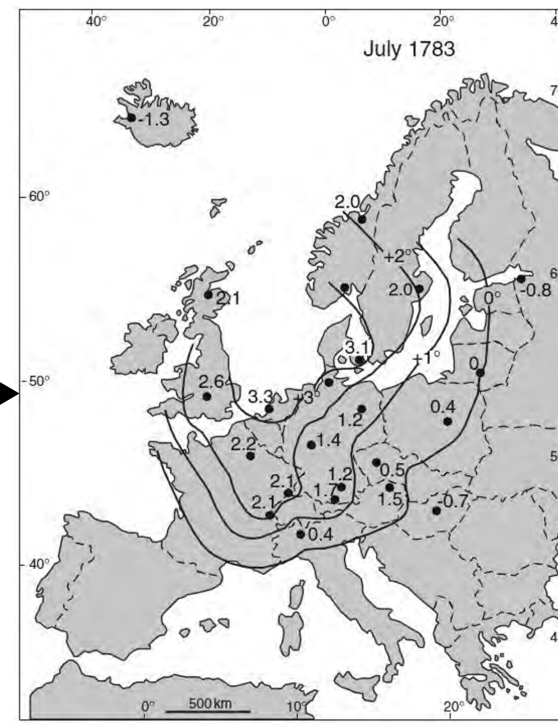


The density of "dry fog" haze observed in Grund, Iceland and Mannheim, Germany following the 10 eruptive phases of Laki



(Thordarson and Self, 2003)

Deviation of surface temperature in °C during July, 1783, from the 1768-1798 mean

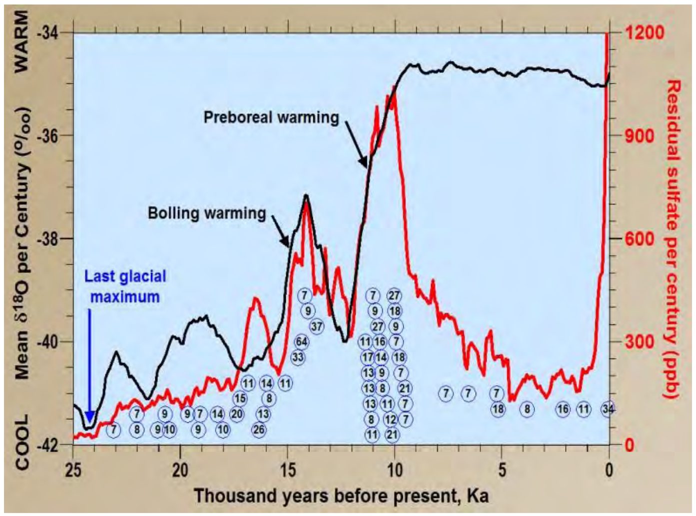


(Thordarson and Self, 2003)

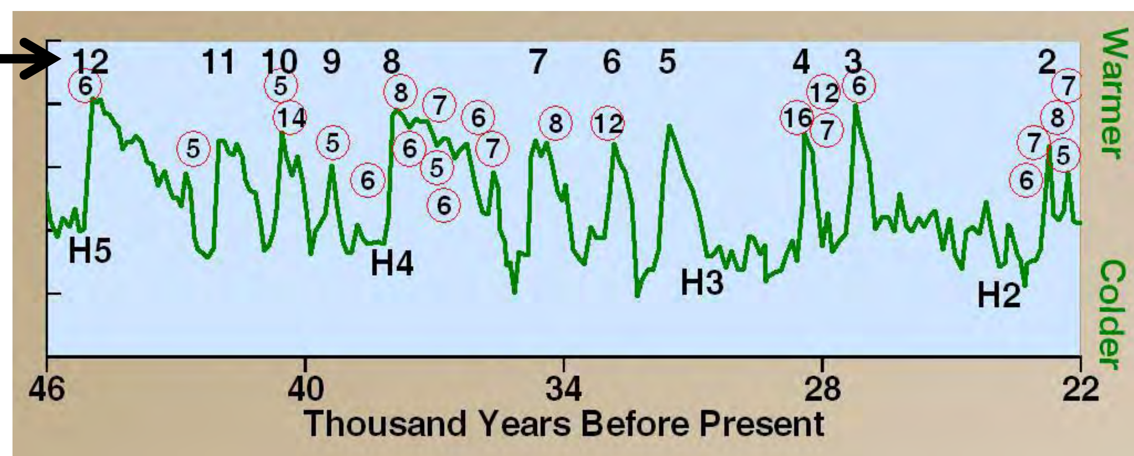
The highest mean temperatures in England since observations began in 1659 until 1983

Regions of highest temperature increase tend to correlate with regions of greatest density of "dry fog" (SO_2)

(3) Volcanic sulfate concentrations measured in the GISP2 drillhole at Summit Greenland were highest when the earth was warmed out of the last ice age (11.6 to 9.6 ka) and during each of the Dansgaard-Oeschger sudden warmings



Dansgaard-Oeschger warmings

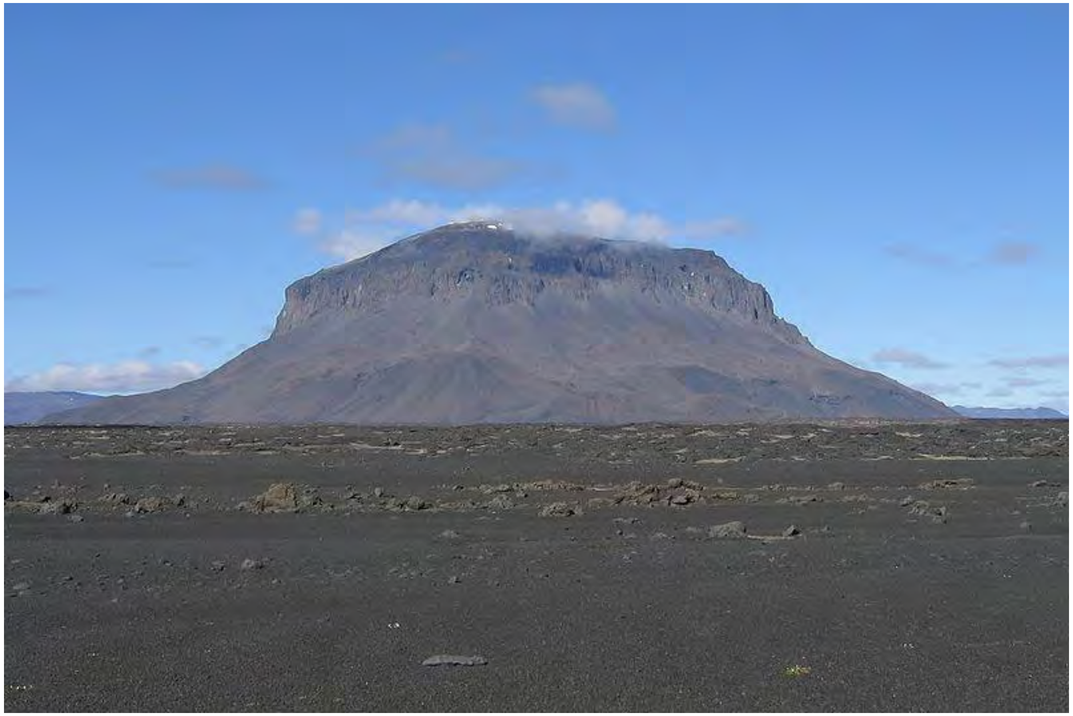


Circled numbers are the number of contiguous layers of ice containing significant volcanic sulfate

Layers typically represent 2 years

(4) Widespread Evidence of Major Sub-glacial Basaltic Volcanism in Iceland

Tuyas are a type of sub-glacial volcano that consists of nearly horizontal beds of basaltic lava capping outward-dipping beds of fragmental volcanic rocks



Herðubreið tuya in northeastern Iceland

They provide widespread evidence of major sub-glacial volcanism in Iceland during Dansgaard-Oeschger warmings at 11.6, 13.1, and 14.6 ka

There are numerous older tuyas that are not well-enough dated to compare to DO events

Melting of a 1+ kilometer thick ice sheet would reduce pressure on magma chambers, concentrating volcanism into more intense phases of less than a few decades duration, providing the sudden influxes of fresh water into North Atlantic circulatory systems observed during DO events

(5) What Could Cause the Warming?

The Warm Thin Layer Theory of Global Warming

Total thermal energy radiated by the atmosphere to earth = σT^4 (Stefan-Boltzmann Law)

Temperature is an intensive physical property of matter, independent of volume

The most energetic radiation in the atmosphere is ultraviolet ($\lambda < 0.400$ µm) from the sun

UV has enough energy to drive essentially all atmospheric photochemistry of importance

NO_2, SO_2, tropospheric O_3, black carbon and fine volcanic ash absorb UV energy strongly.

A thin layer of these solar-ultraviolet-energy-absorbing gases and particulates will have a much higher temperature than a whole atmosphere full of much larger concentrations of terrestrial-energy-absorbing greenhouse gases

UV energy is concentrated in thin layers because:

(a) Solar flux absorbed at the earth's surface is at a maximum when the sun is directly overhead and the area illuminated by a pencil of sunlight is at a minimum

(b) But gas molecules in the atmosphere absorb energy radiating from all directions and are more likely to absorb energy when the path length is longer

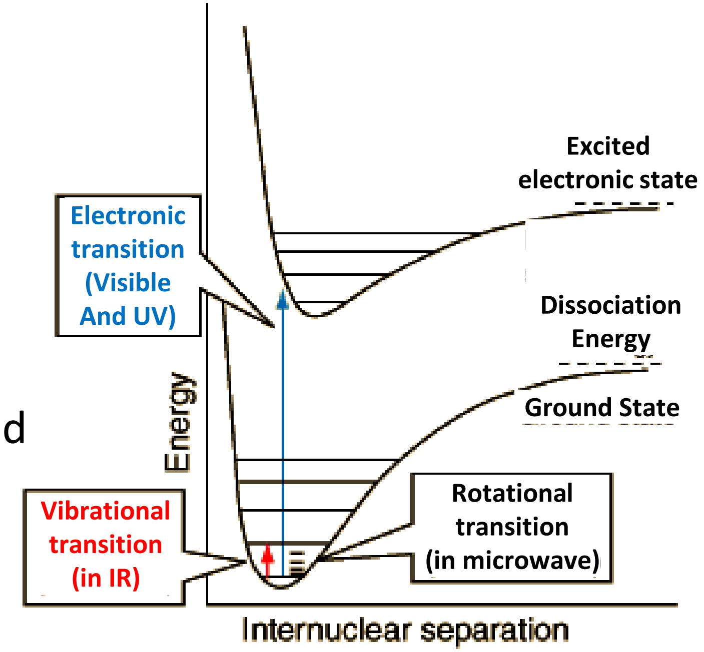
(c) Most ultraviolet energy is being absorbed in the atmosphere during mornings and afternoons especially poleward of the tropics

(d) The majority of energy associated with electronic transitions (UV and visible wavelengths only) is shared by radiation in all directions at a slightly lower frequency (fluorescence or phosphorescence) (Rayleigh scattering)

(6) Temperature is Indicative of the Frequency of Oscillation of and within Molecules and Atoms

Electronic transitions: electrons in atoms that absorb sufficient energy move into a higher frequency excited state and radiate slightly smaller amounts of energy when they return to ground state

Vibrational transitions: Atoms attracted by Coulomb forces to form molecules repel each other when too close, forming a minimum in potential energy. Each degree of freedom of motion across each chemical bond will oscillate around this minimum with the largest amplitudes at certain resonant frequencies, normal modes of oscillation, determined by the physical dimensions and other properties of the atoms involved



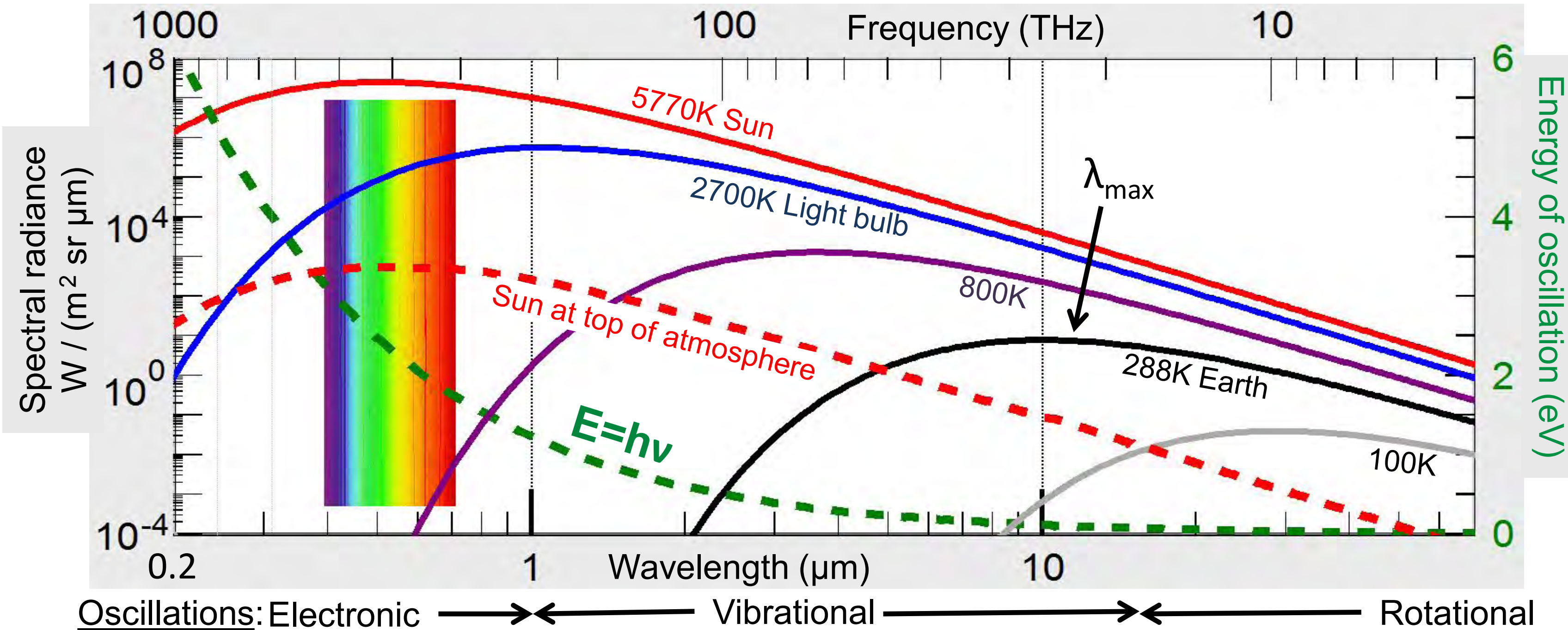
Rotational transitions: an oscillating electromagnetic field applies an oscillating torque on molecules containing three or more atoms that have a dipole moment, causing the molecule to oscillate about its moment of inertia

Frequency approaches zero as temperature approaches absolute zero

Higher frequencies mean higher temperatures

Energy of light = frequency of oscillation times Planck's constant **($E=h\nu$)**

(7) Spectral Radiance of Black Bodies is a Function of Temperature



Color temperature (**T_c**) of light equals 2897 divided by **λ_{max}**

λ_{max} (µm)	T_c (K)
0.502	5770
1.07	2700
3.62	800
10.1	288
29.0	100

A problem with greenhouse gas theory: Radiation from the earth cannot make the atmosphere warmer than earth and thus cannot warm the earth. There must be a source of higher frequency energy, the sun, to warm the earth

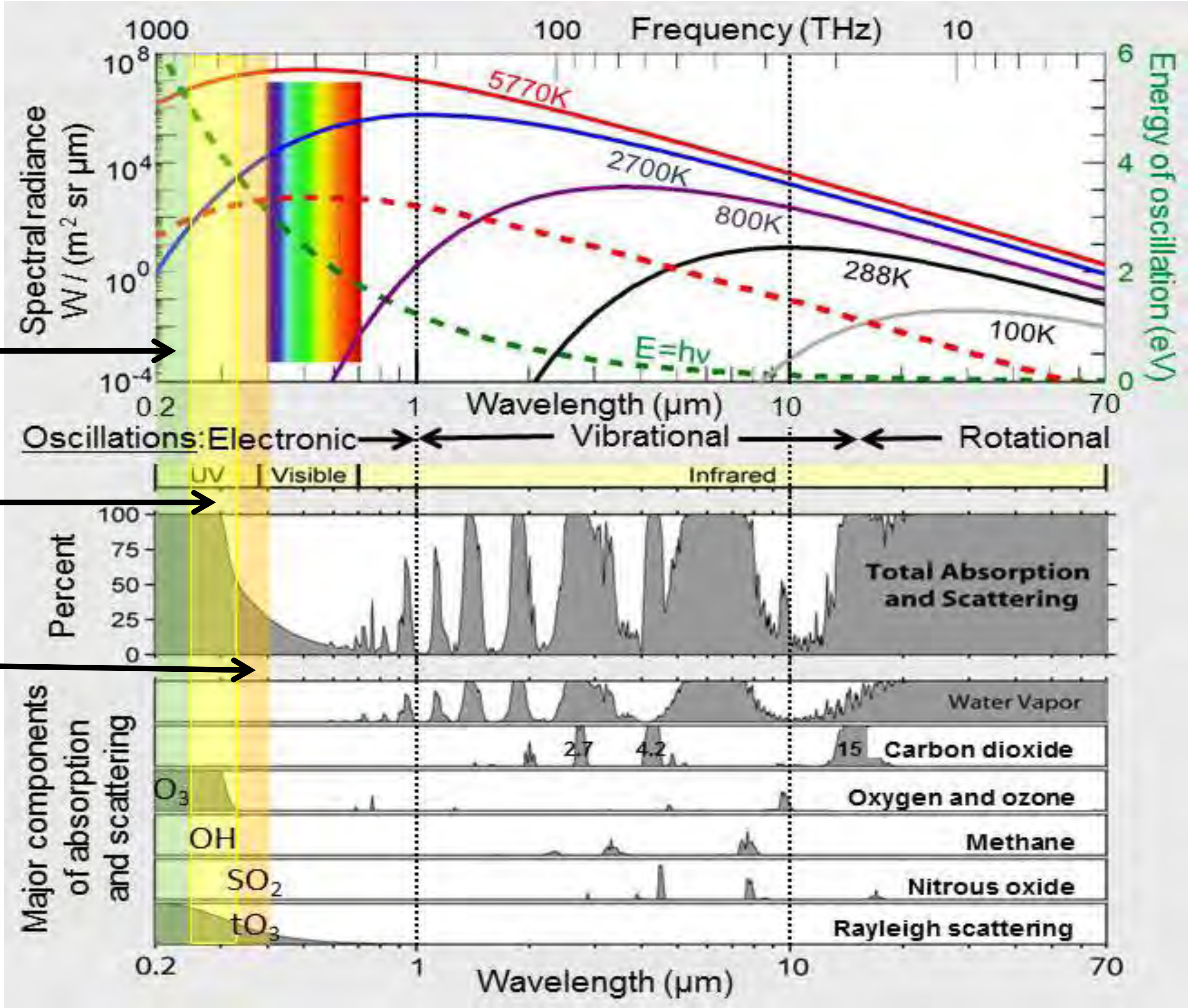
Although not exactly correct because 93% of absorption by CO_2 is around 4.2 µm where T_c=690K

(8) Absorption Occurs in Narrow Bandwidths

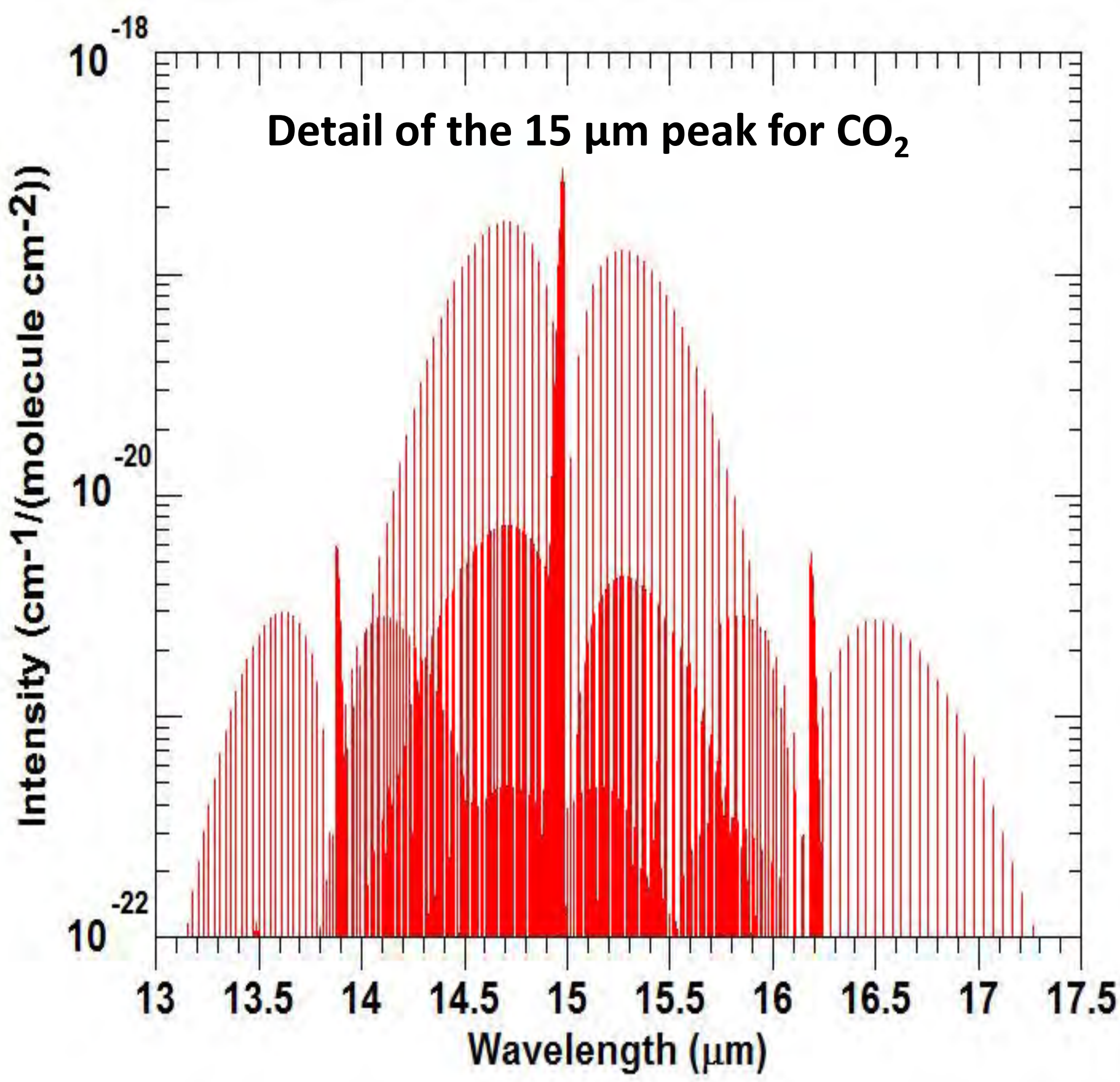
UV dissociates O_2 to form O_3

OH, the primary oxidant, is formed from O_3

The most energetic UV to reach earth's surface is absorbed strongly by tO_3, SO_2, NO_2 and BC

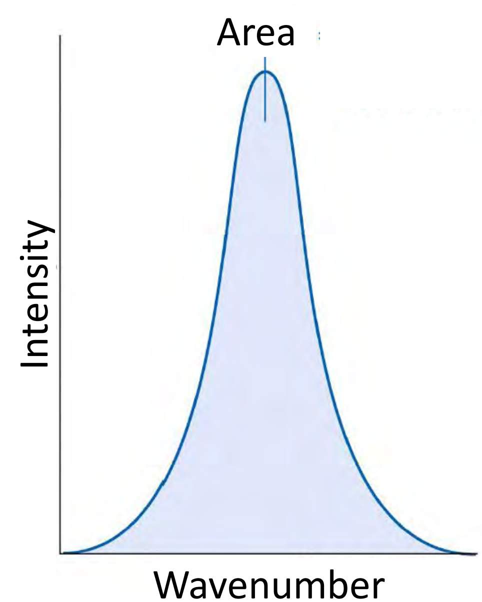


(9) Greenhouse Gases Absorb Along Spectral Lines

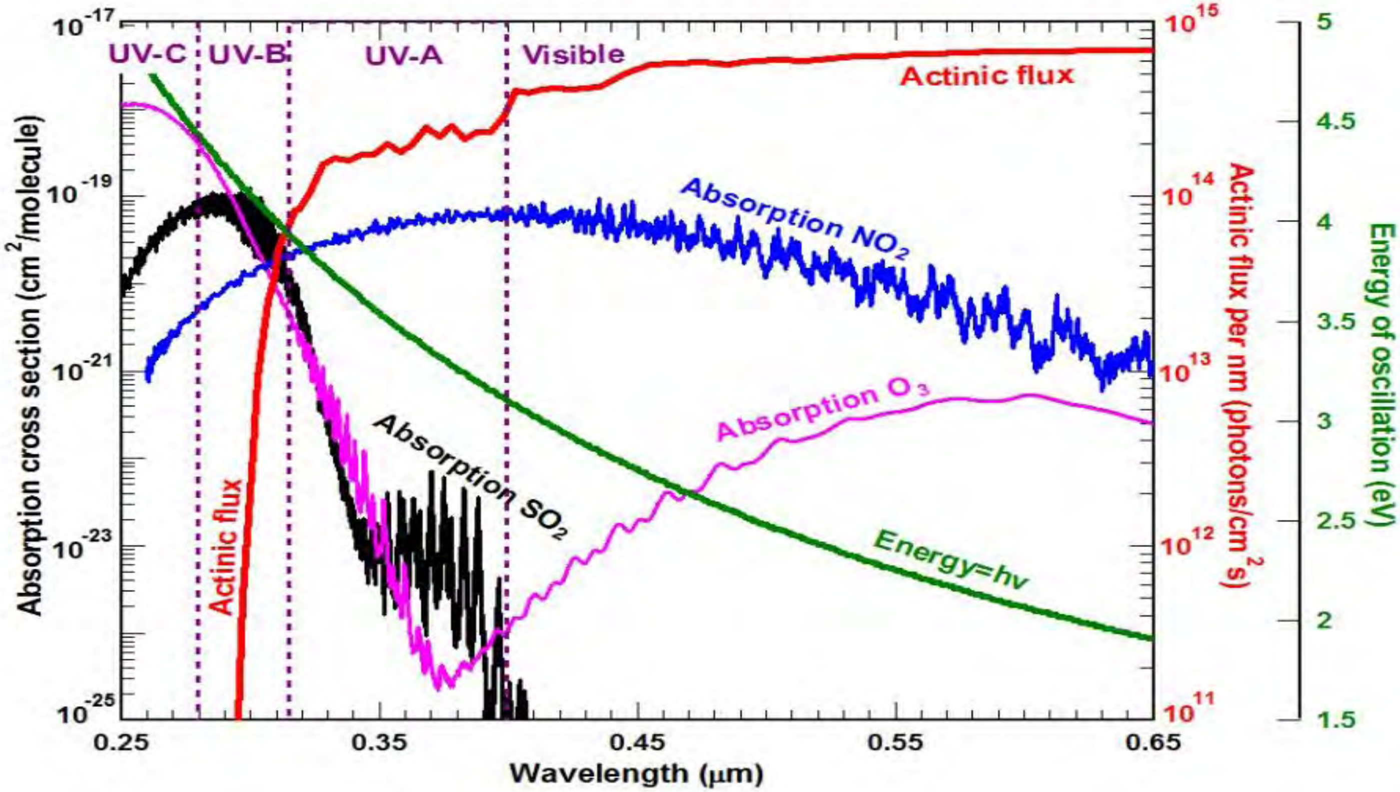


Each spectral line has a finite width and is typically assumed to have a Lorentz line shape

Absorption by the line equals the area under the line which equals π/4 times peak intensity times twice the half-width at half-maximum



(10) Solar-Energy-Absorbing Pollution Gases Absorb Along a Continuum



Note the very high absorption in the UV-A and UV-B bands where energy is rising rapidly and the actinic flux at the earth's surface is decreasing rapidly

Actinic flux was calculated by Madronich (1998) when global pollution was high

The energy that caused global warming was dominantly in UV-B band

Documenting this energy depends on determining the actinic flux precisely as a function of elevation both with and without pollution

(11) Net Energy Absorbed per Molecule as a Function of Bandwidth

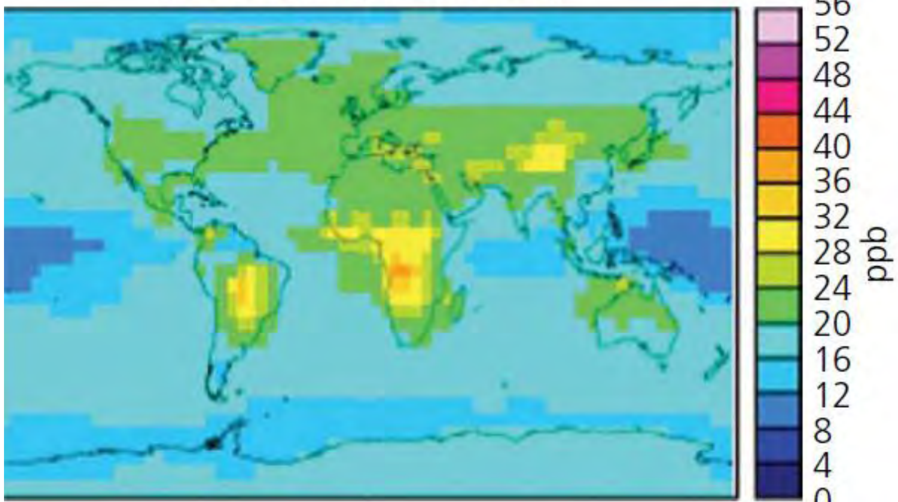
Molecule	Wavelength range, µm	Total energy absorbed per molecule, eV/sec times 10^{-15}	Percent total energy absorbed
CO_2	0.782-28.4	**3.57**	100.0%
	0.8-2.4	0.00437	0.1%
	2.4-3.0	0.143	4.0%
	4.1-4.4	**3.33**	**93.3%**
	10.0-20.0	0.0866	2.4%
H_20	0.4-139	**1.12**	100.0%
vapor	1.0-2.1	0.163	14.5%
	2.1-4.0	**0.519**	**46.2%**
	4.0-10	**0.303**	**26.9%**
	10.0-139	0.134	11.9%
CH_4	1.09-10.0	**0.530**	100.0%
	1.0-2.0	0.015	2.7%
	2.0-3.1	0.046	8.7%
	3.1-3.5	**0.384**	**72.5%**
	7.0-8.5	**0.076**	**14.3%**
N_2O	1.28-70	**2.26**	
	2.5-9.0	**2.24**	**99.2%**

Molecule	Wavelength range, µm	Total energy absorbed per molecule, eV/sec times 10^{-15}
O_3	**0.280-0.343**	**18.8**
	0.300-0.343	1.22
	0.380-0.788	0.04
SO_2	**0.280-0.416**	**9.83**
	0.300-0.416	2.25
NO_2	**0.280-0.666**	**19.7**
	0.300-0.666	18.8

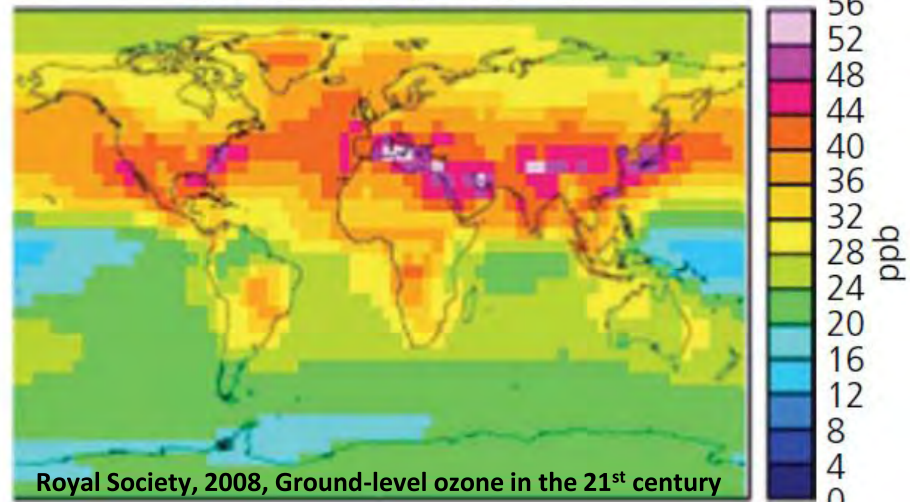
Note the very high absorption in the narrow 0.28-0.34 band

(12) High Concentrations of tO_3 and SO_2 Travel the World

Pre-industrial surface ozone

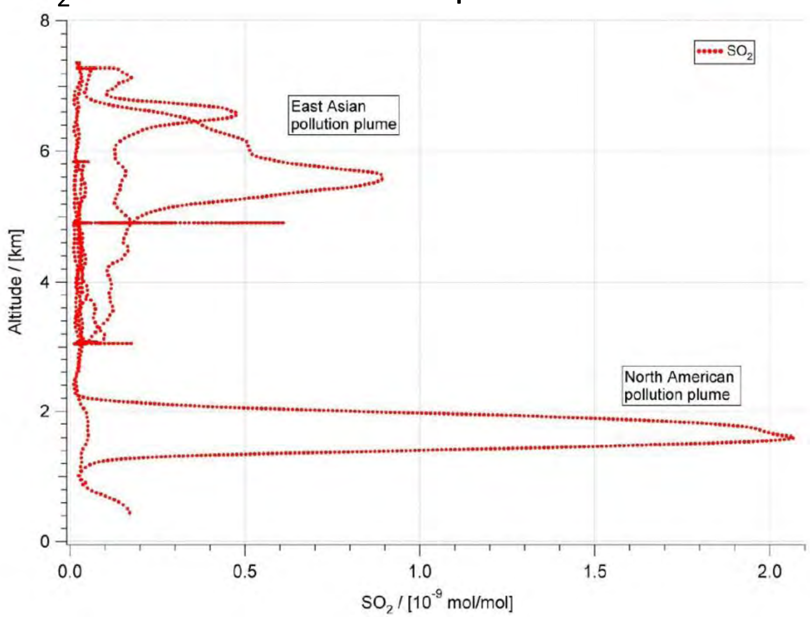


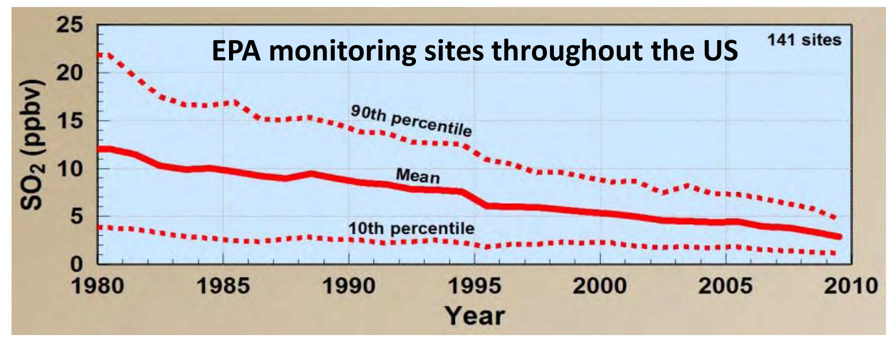
Present-day surface ozone

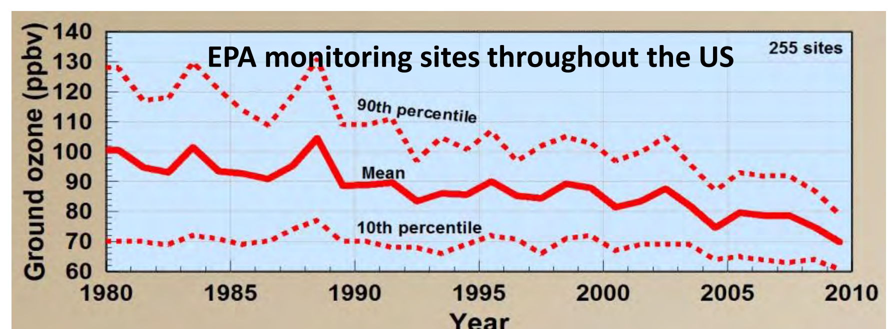


Royal Society, 2008, Ground-level ozone in the 21st century

SO_2 measured from an airplane NW of Ireland







(13) Many Issues Must Be Addressed to Show Quantitatively that Pollution such as tO_3, SO_2, NO_2, and BC Can Cause Global Warming

We need more detailed observations of voluminous basaltic volcanic eruptions like Laki that are not explosive enough to put most of the SO_2 in the stratosphere

We need considerably more data showing at what elevation UV-A and UV-B energy is absorbed in the atmosphere and by which gases and particulates

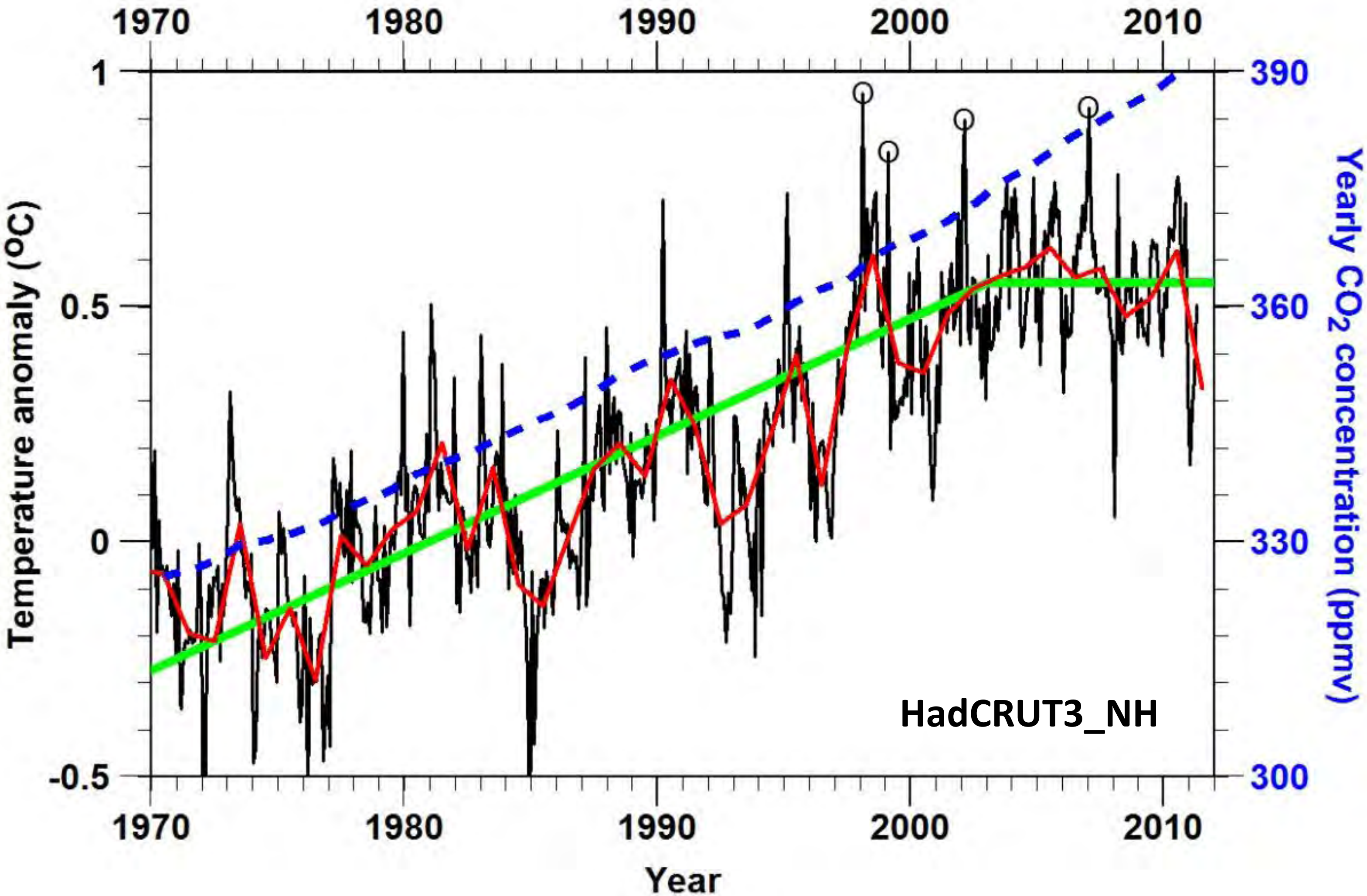
We need more reanalysis of pollution data to quantify its global distribution over space and time since 1950

We need to improve radiation codes to include UV absorption by pollutants and to address issues of color temperature and back radiation to a warm earth

We need to document the rates of absorption of solar energy by atmospheric gases and particulates during mornings and afternoons and poleward of the tropics

We need to recognize that greenhouse gas theory may not be as well proven as we typically assume and should be reexamined carefully

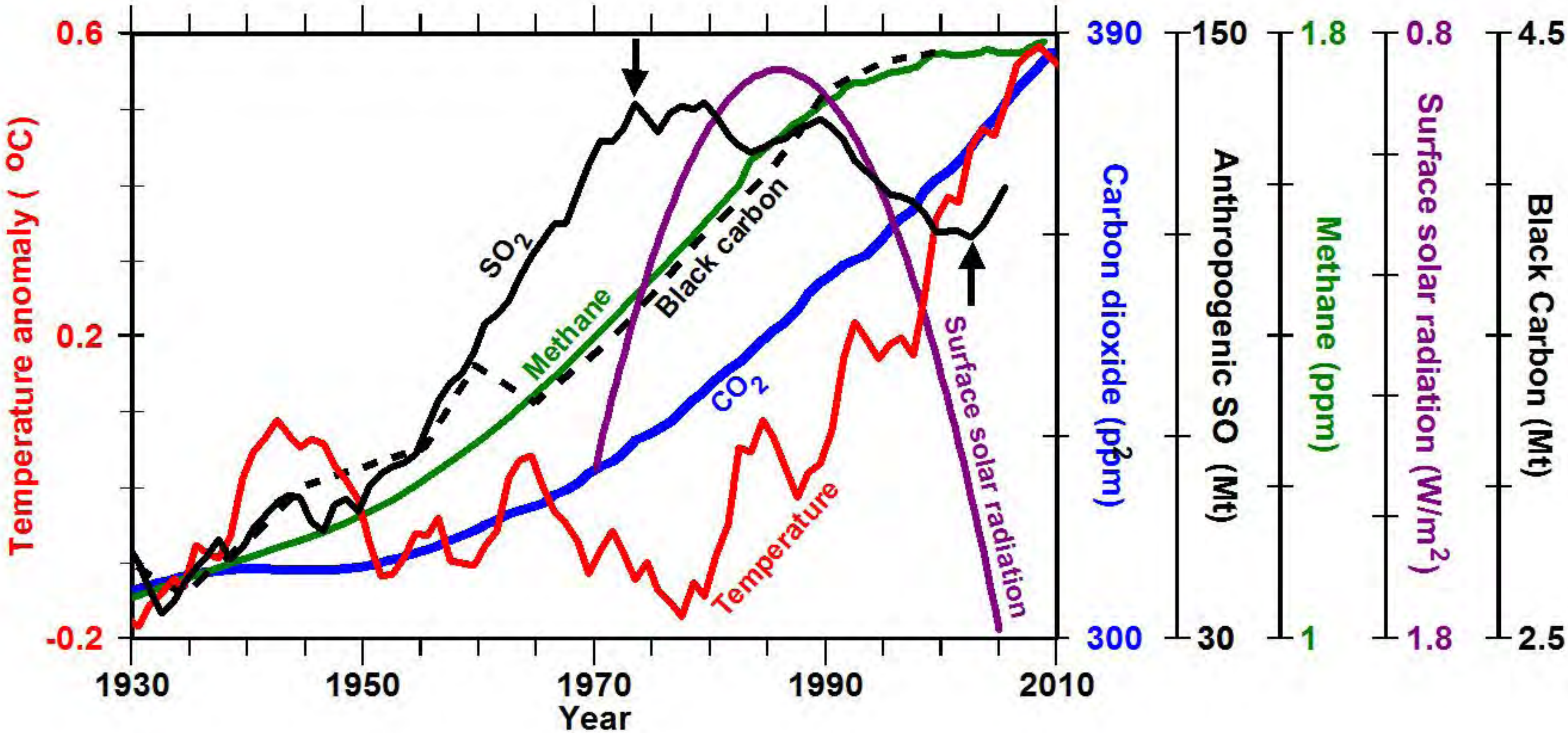
(14) Global Temperatures Have Been Essentially Constant Since 1998



But CO_2 concentrations continued to rise

Greenhouse gas theory cannot explain why

(15) But Increases & Decreases in Pollution Provide a Clear Explanation



SO_2 concentrations peaked in 1974, decreased 22% by 2002 and are increasing again

It takes 20-30 years of warm air to raise the mean temperature of the oceanic mixed layer

(16) Conclusions

The Warm Thin Layer Theory of Global Warming

Absorption of solar UV energy by tO_3, SO_2, NO_2, BC, etc. appears to warm thin layers of the atmosphere to higher temperatures than greenhouse gases absorbing terrestrial infrared energy

Total thermal energy radiated by the atmosphere to earth is a function of temperature, not volume

Temperature in atmospheric layers is affected more strongly by the color temperature (frequency) of the radiation absorbed than by the concentration of absorbing gases

Periods of most rapid global warming during the past 46,000 years all correlate in time with the highest concentrations of sulfate recorded in the Greenland ice sheet

Best documented, pre-industrial warmings are contemporaneous with known eruptions of basaltic volcanoes in Iceland, volcanoes that emit large quantities of SO_2 primarily into the troposphere

SO_2 emissions played a major role in 20^{th} century warming, but tropospheric ozone appears to have been most important

Reducing pollution to reduce acid rain appears to have slowed global warming since 1998, but rapid development in Asia threatens renewed warming