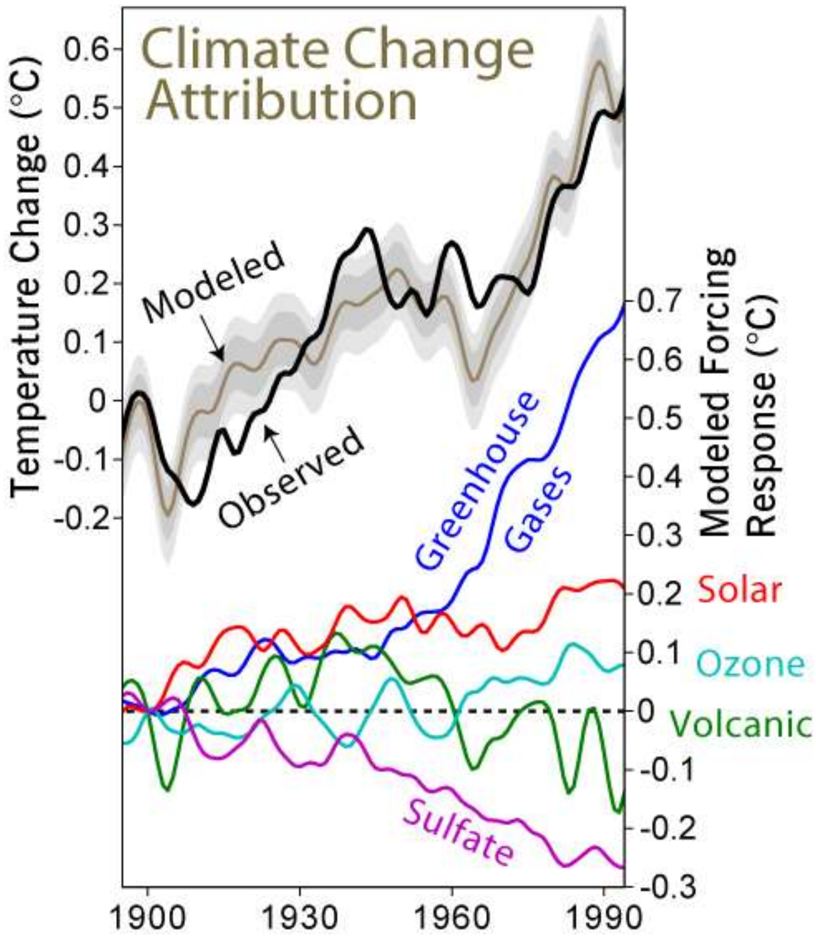
Assessing Rates of Climate Change

What is the difference between climate and weather

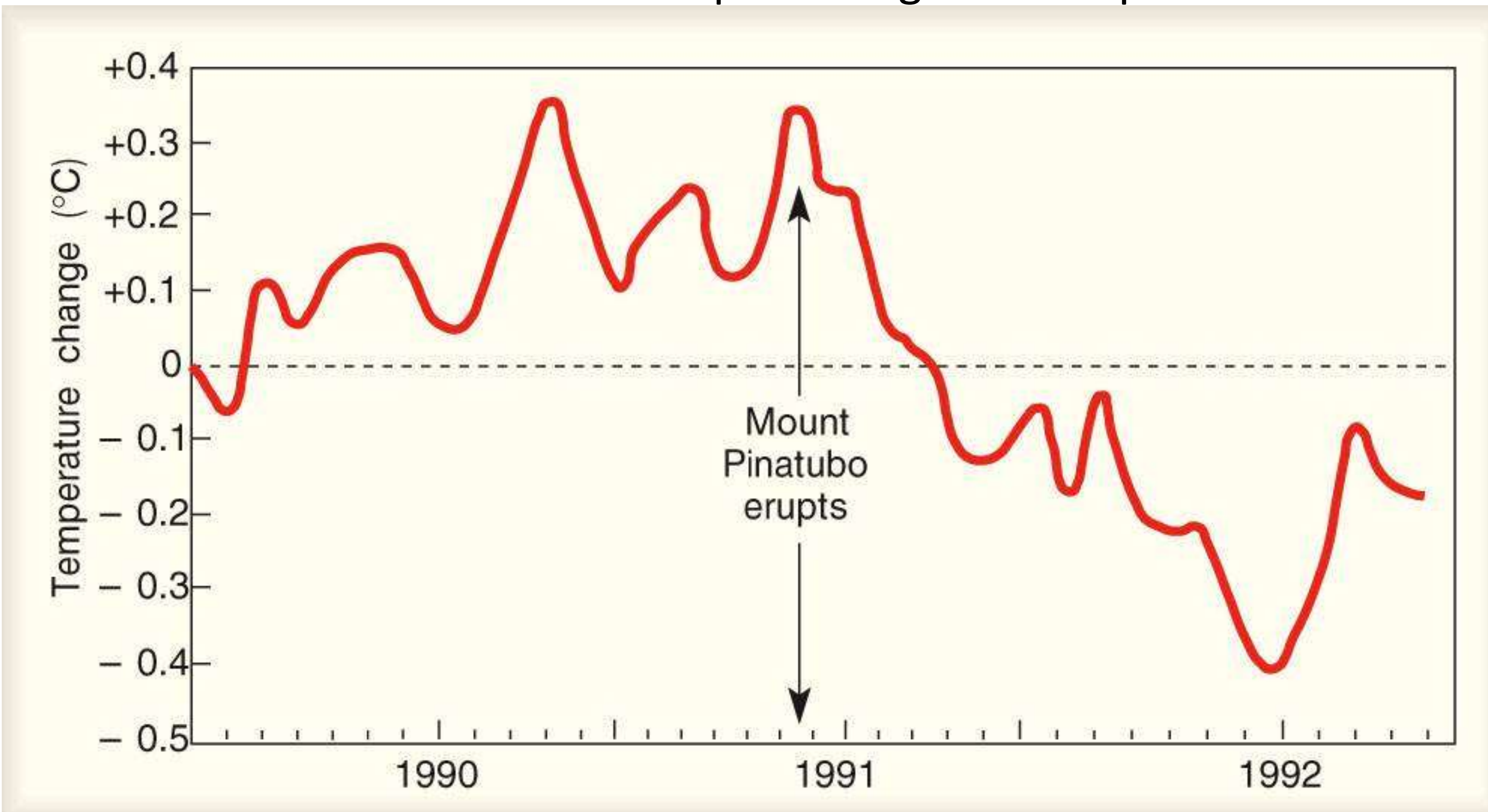
Climate = average weather over many years (ex: 30 year averages)

Climate forcings
(things that affect global temperatures)



Volcanoes decrease global temps

Ex: Effect of Pinatubo eruption on global temperatures



Sulfate aerosols → decrease temps

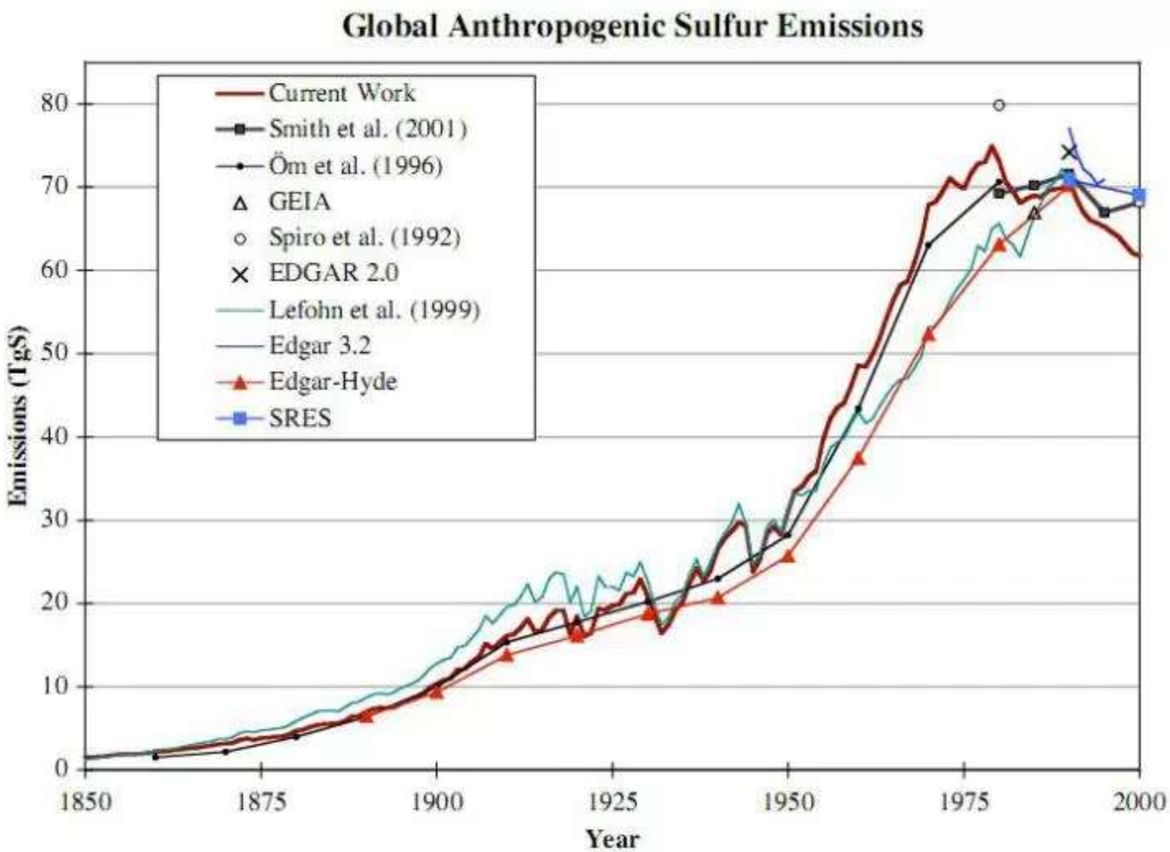
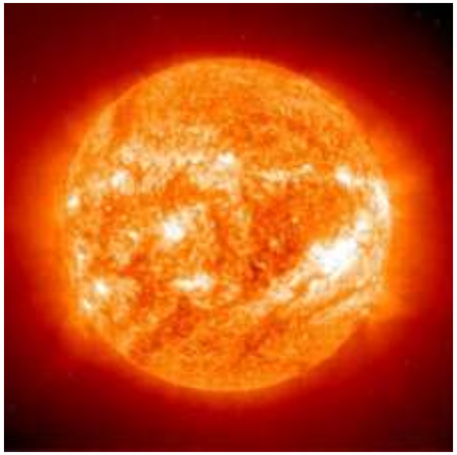
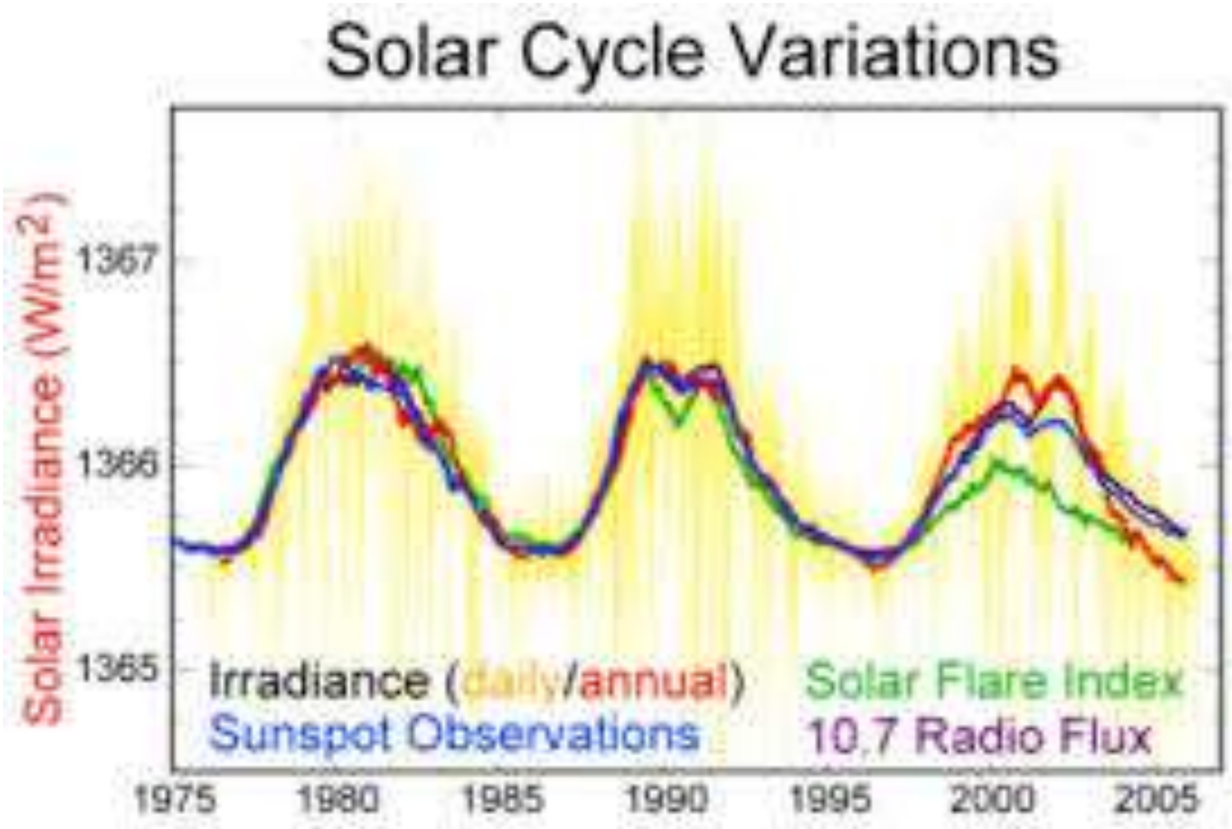


Figure 1–Global sulfur dioxide emissions from this study (thick line) and several other recent estimates (see text). Note that the Lefohn *et al*. estimate does not include all anthropogenic emissions sources. References not shown on the cart are: GEIA (Benkovitz *et al*.1996); EDGAR 2.0 (Olivier *et al* 1996); EDGAR 3.2 (Olivier and Berdowski, 2001); EDGAR-HYDE (Van Aardenne *et al*. 2001); and SRES (Nakicenovic and Swart 2000).

Increased solar activity increases global temps





Greenhouse gases increase global temps

The main greenhouse gases

Greenhouse gases	Chemical formula	Pre-industrial concentration	Concentration in 1994	Atmospheric lifetime (years)***	Anthropogenic sources	Global warming potential (GWP)*
Carbon-dioxide	CO_2	278 000 ppbv	358 000 ppbv	Variable	Fossil fuel combustion Land use conversion Cement production	1
Methane	CH_4	700 ppbv	1721 ppbv	12,2 +/- 3	Fossil fuels Rice paddies Waste dumps Livestock	21 **
Nitrous oxide	N_2O	275 ppbv	311 ppbv	120	Fertilizer industrial processes combustion	310
CFC-12	CCl_2F_2	0	0,503 ppbv	102	Liquid coolants. Foams	6200-7100 ****
HCFC-22	$CHClF_2$	0	0,105 ppbv	12,1	Liquid coolants	1300-1400 ****
Perfluoromethane	CF_4	0	0,070 ppbv	50 000	Production of aluminium	6 500
Sulphur hexa-fluoride	SF_6	0	0,032 ppbv	3 200	Dielectric fluid	23 900

Note : pptv= 1 part per trillion by volume; ppbv= 1 part per billion by volume, ppm v= 1 part per million by volume

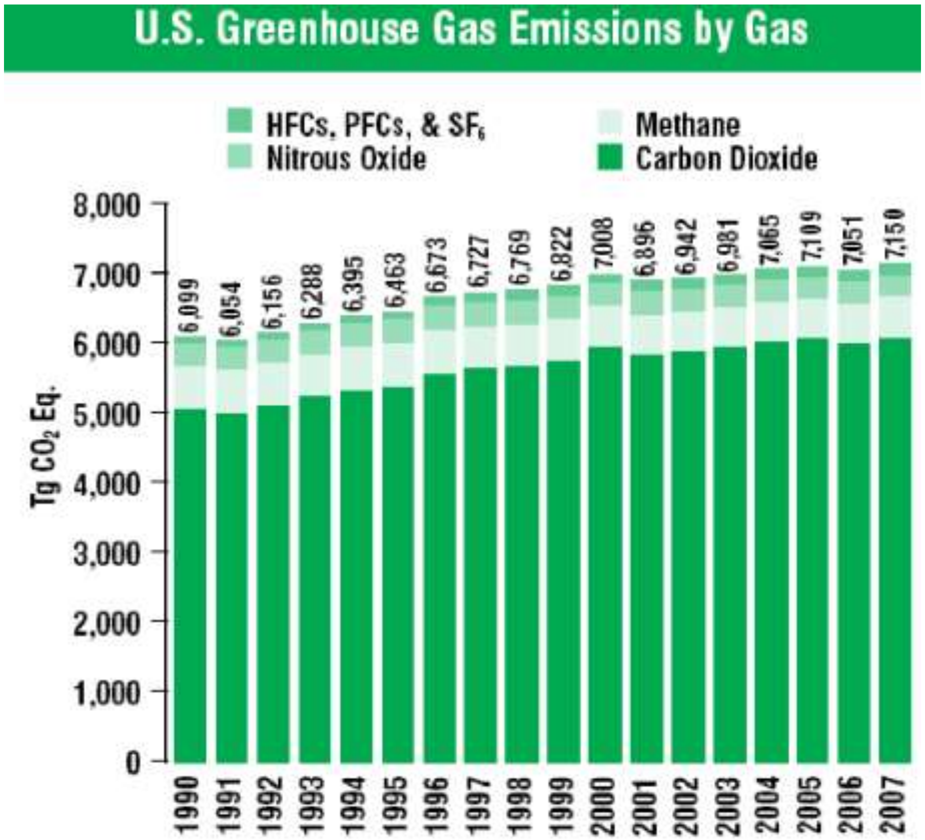
* GWP for 100 year time horizon. ** Includes indirect effects of tropospheric ozone production and stratospheric water vapour production. *** On page 15 of the IPCC SAR. No single lifetime for CO_2 can be defined because of the different rates of uptake by different sink processes. **** Net global warming potential (i.e., including the indirect effect due to ozone depletion).

GRID Arendal UNEP

Source: IPCC radiative forcing report ; Climate change 1995. The science of climate change, contribution of working groupe 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge press university, 1996.

Energy absorbed / molecule

Relative importance of GHG's

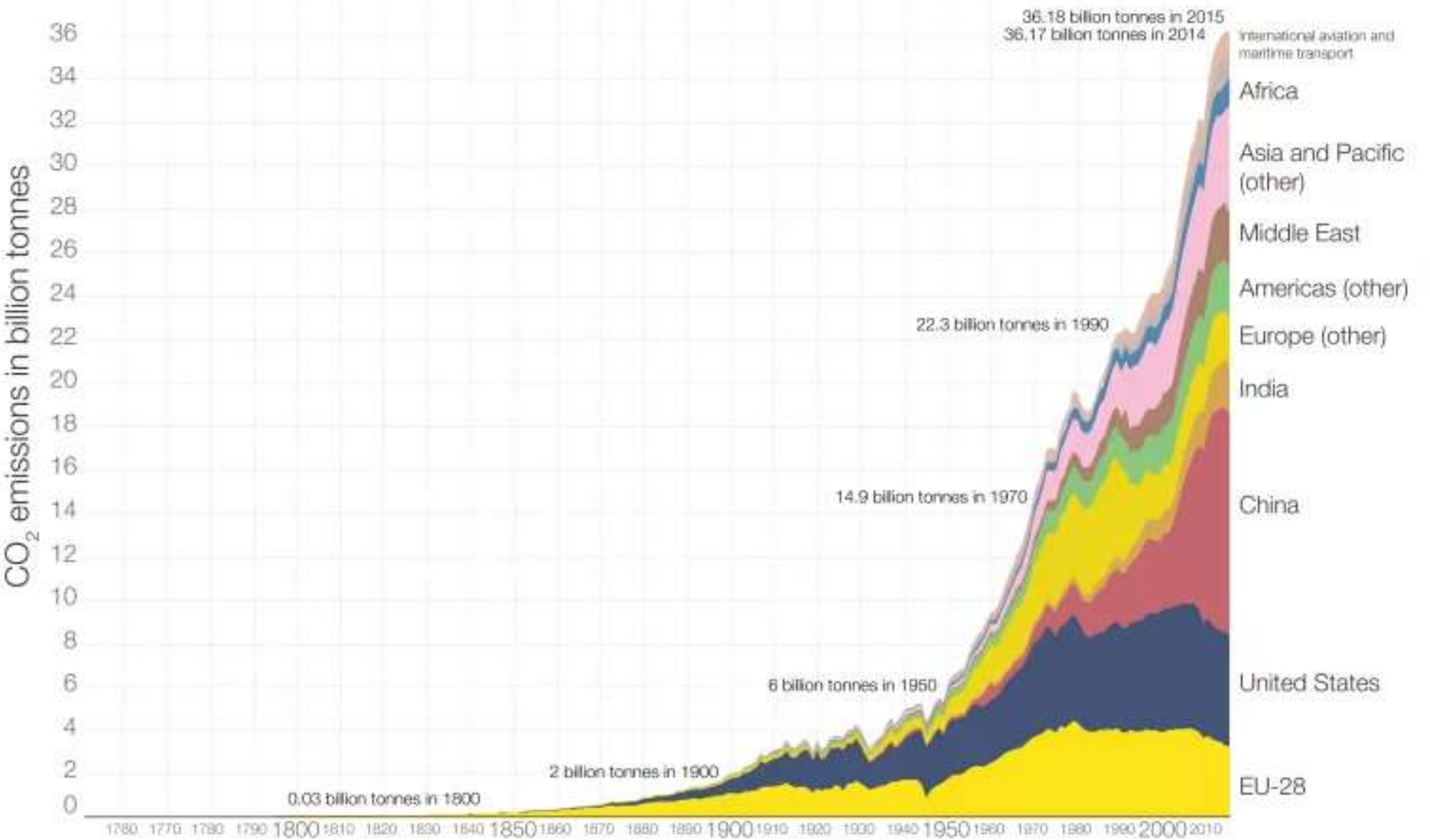


Energy absorbed based based on quantity in the air

Global CO_2 emissions by world region, 1751 to 2015

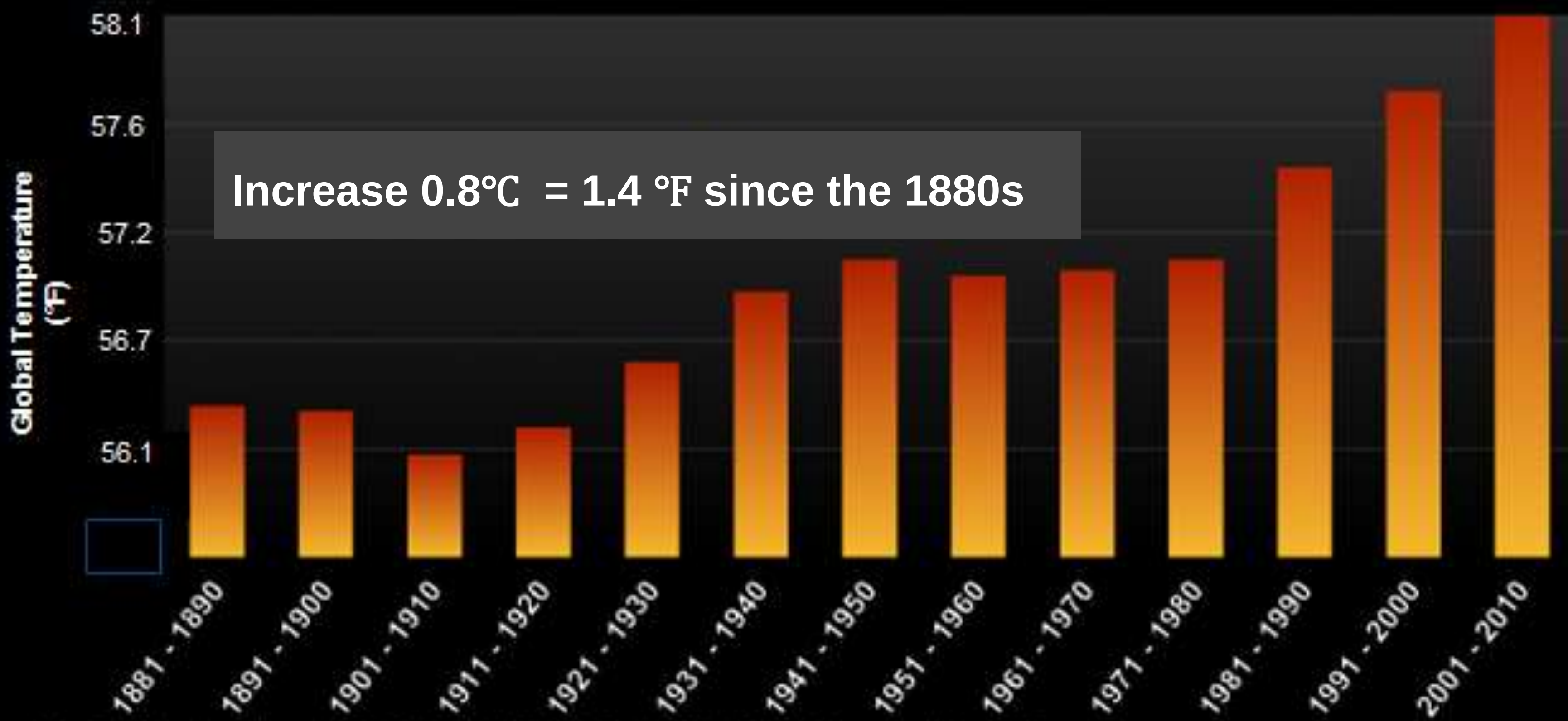
Annual carbon dioxide emissions in billion tonnes (Gt).

Our World in Data

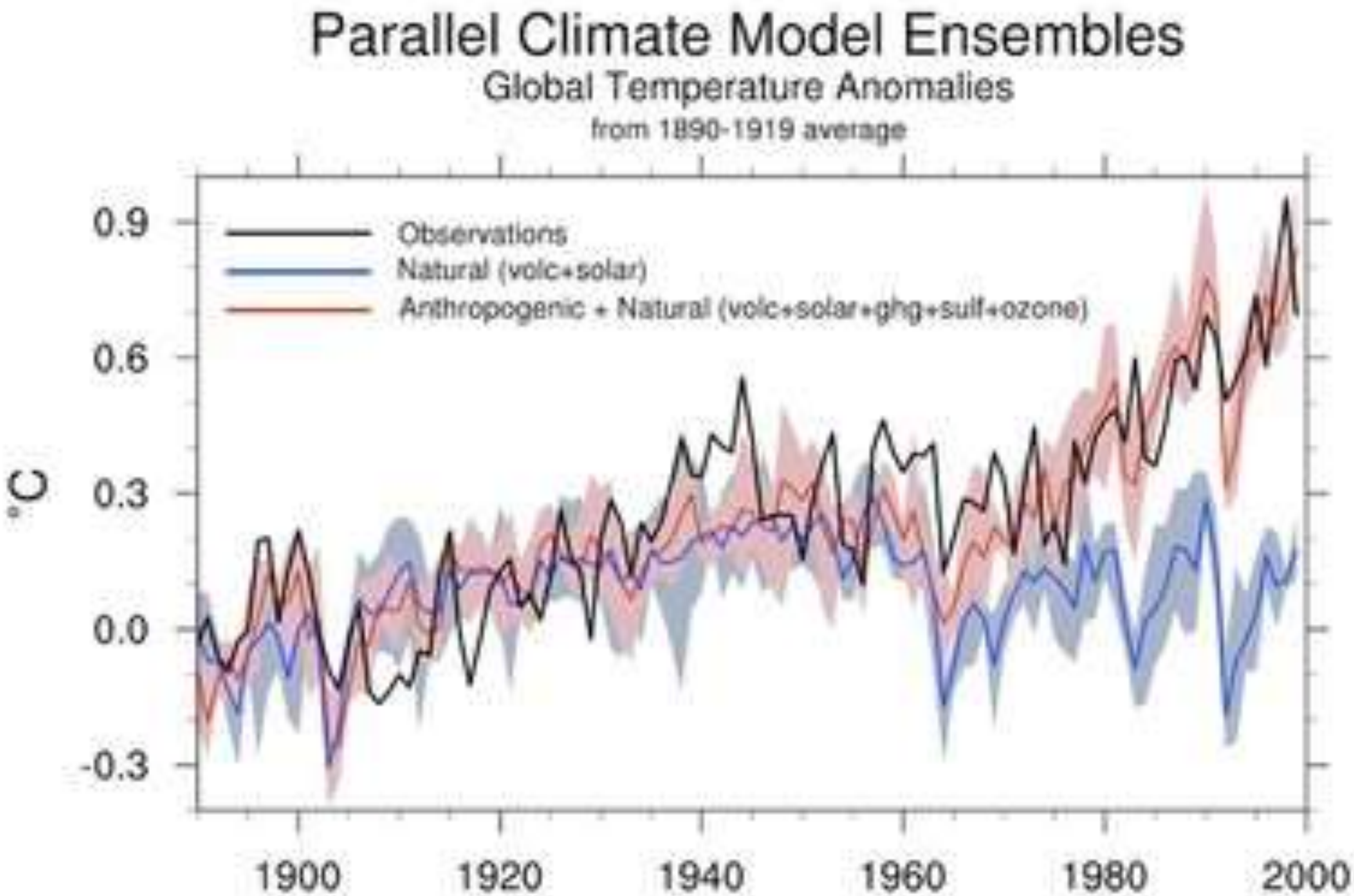


Data source: Carbon Dioxide Information Analysis Center (CDIAC); aggregation by world region by Our World In Data.
The interactive data visualization is available at OurWorldinData.org. There you find the raw data and more visualizations on this topic.

Global Temperature by Decade



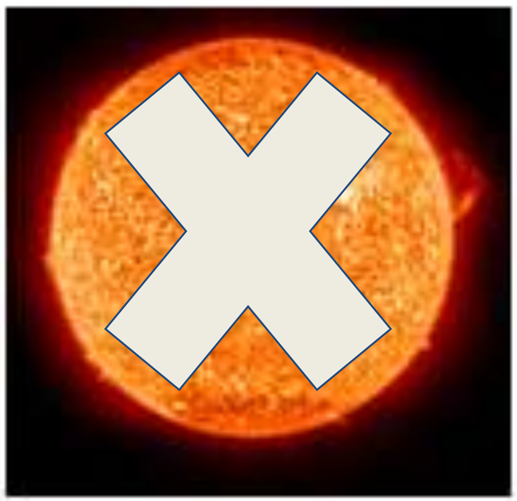
Increase 0.8℃ = 1.4 ℉ since the 1880s


Parallel Climate Model Ensembles
Global Temperature Anomalies
from 1890-1919 average
Observations
Natural (volc+solar)
Anthropogenic + Natural (volc+solar+ghg+sulf+ozone)
°C
0.9
0.6
0.3
0.0
-0.3
1900
1920
1940
1960
1980
2000

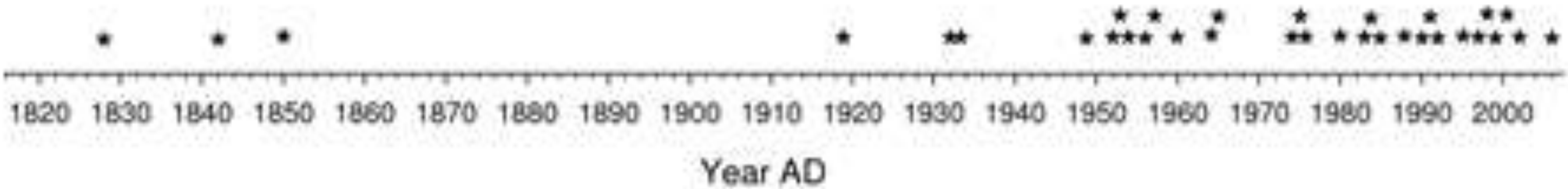
HOW

we know it's

US



LAKE ICE IN RETREAT



Each ★ = year Lake Champlain didn't freeze over

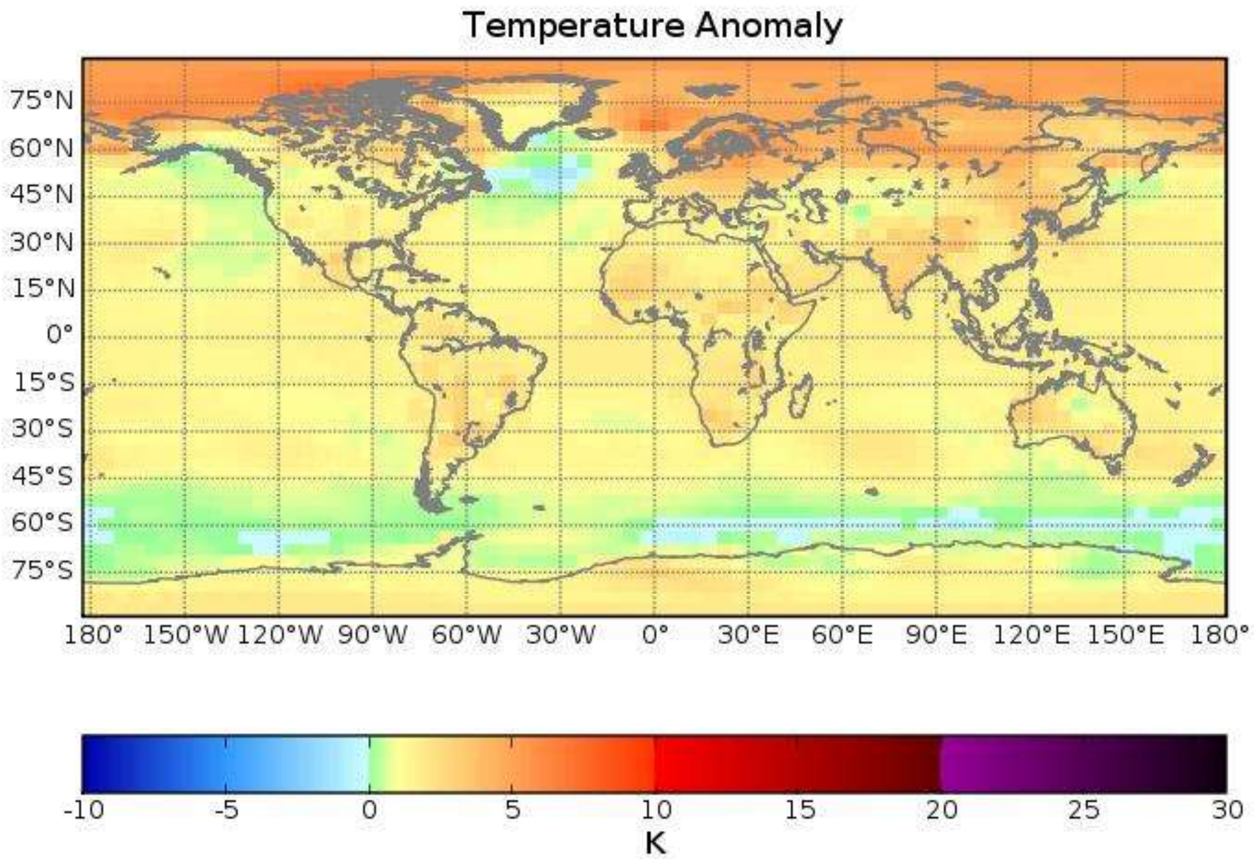
Global Climate Data

- Intergovernmental Panel on Climate Change (IPCC) = scientific panel established by UN in 1988 →
  - 1st Assessment Report (1990)
  - 2nd " (1995)
  - 3rd " (2001)
  - 4th " (2007)
  - 5th " (2014)
  - Looks at peer reviewed climate data collected around the world from:
- <u>ice core samples,</u>
- <u>weather balloons,</u>
- <u>satellites,</u>
- <u>sea-surface buoys</u>

IPCC reports

- <u>0.85^{o}C (1.4 ^{o}F) in 2014 report</u>
- <u>Arctic warming = twice as fast</u>
- <u>loss of land based ice and thermal expansion → 0.19m avg sea level rise</u>
- <u>At this rate predictions → 1.1-6.4ºC rise in next century</u>
- http://ipcc.ch/report/ar5/syr/

Global 30 yr Average Temperature Anomolies 1972 - 2001



Surface Air Temperature Anomaly, January 1972-2001 mean.
Simulated by the Goddard Institute for Space Studies, USA;
Scenario 1PTO2X (IPCC 2007); Model GISS-ER (IPCC 2007).
Figure obtained from www.ipcc-data.org. 10 August, 2010.

Why is it faster in the north?

- CO_2 emissions move around the globe
- and concentrate in the north

- Global distillation effect

- Ice melt → decreased albedo

Atmospheric carbon

- Increased by
  - <u>Respiration</u>
  - <u>Combustion</u>
  - <u>Deforestation</u>

- Decreased by
  - <u>Photosynthesis</u>
  - <u>Formation of carbonate in oceans</u>
    - <u>(dissolved carbon incorporated into shells of marine organisms → die → sink → get buried in sediment → carbonate (limestone)</u>

Effects of global warming

- Melting ice caps and rise in sea level
- dec. permafrost (change tundra and boreal forests) loss of shoreline habitats
- Ocean acidification
- https://www.youtube.com/watch?v=Wo-bHt1bOsw&feature=em-subs_digest-vrecs
- Change in precipitation patterns →
  - flooding in some regions drought in others
  - More frequent El Nino (ENSO) (periodic warming) and La Nina (periodic cooling)
- Changes in ecosystems → species extinctions

Ways to deal with global warming

- Decrease burning of fossil fuels (decrease carbon sources)
- Increase carbon sinks (planting and protecting forests)
- Slow population growth (root cause of deforestation and fossil fuel consumption)
- Support energy efficiency with energy pricing strategies (such as tax carbon emissions)
- Carbon management (and sequestration) collect carbon dioxide before it is release and deposit in rocks and ocean

Legislation

- **Clean Air Act does not currently control carbon emissions**

- Kyoto Protocol = global effort to dec. carbon emissions
  - Copenhagen talks (2009)
  - COP21 in Paris → promises and plans (Trump to pull US out by 2019)
  - **Globally China and US are biggest contributors of CO_2**

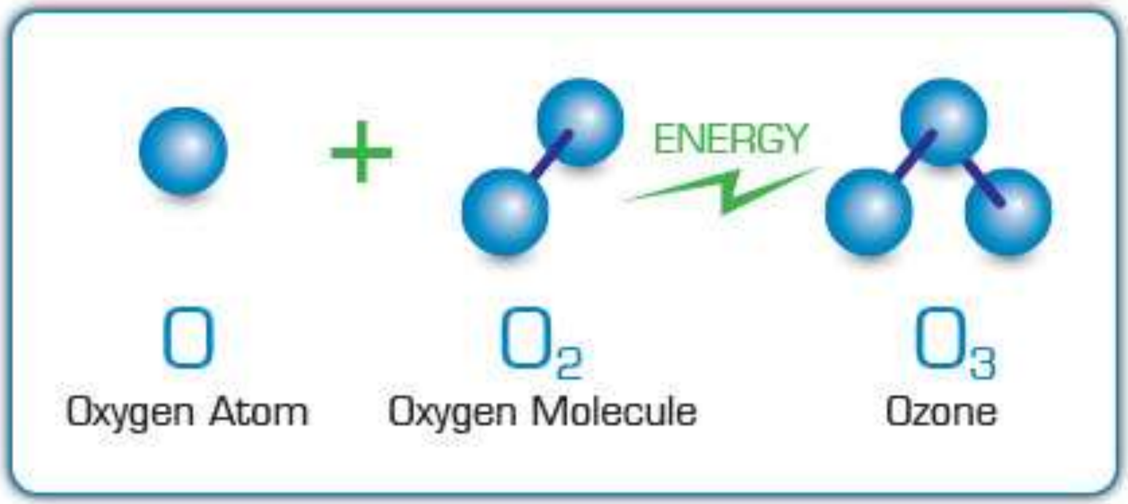
Global Atmospheric Changes

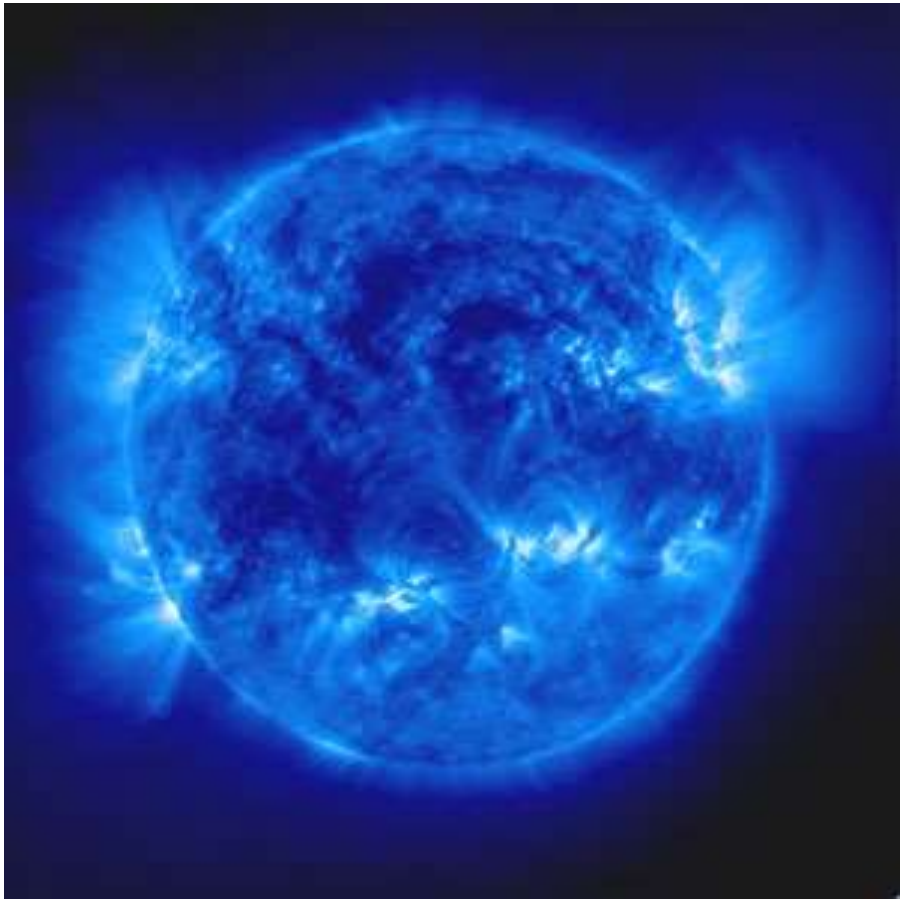
Part 2

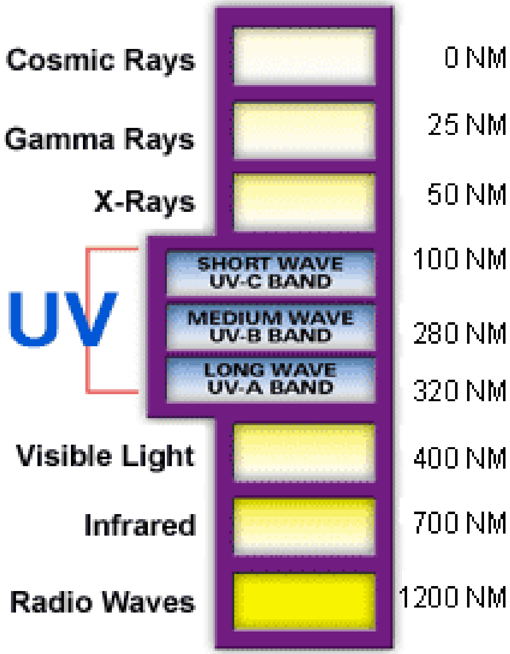
Ozone depletion and acid deposition

Ozone

- Good in the Stratosphere bad in the troposphere

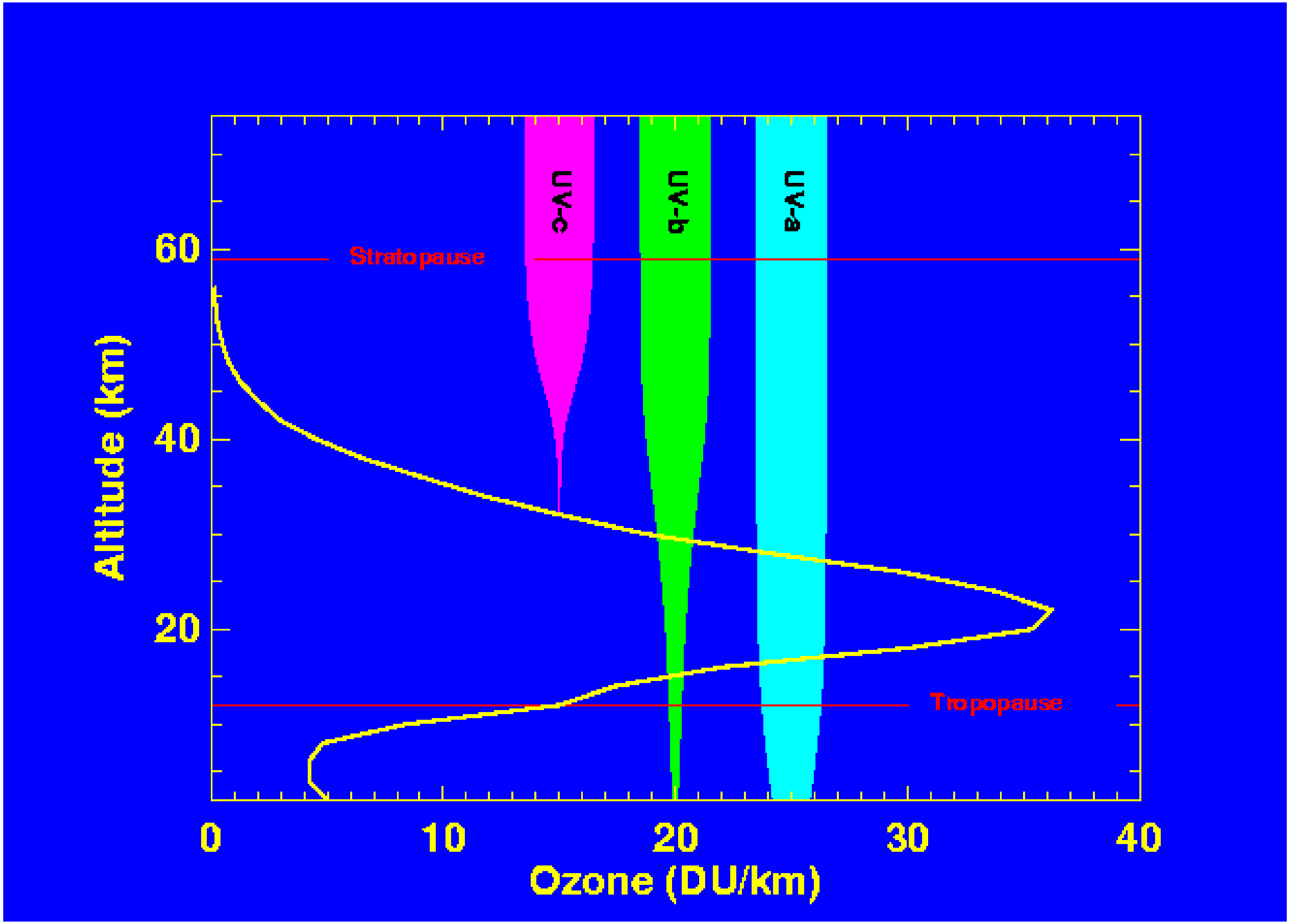






http://www.americanairandwater.com/images/uv.gif

The Sun seen in deep ultraviolet light.
Image courtesy of SOHO (ESA & NASA



http://www.espo.nasa.gov/solveII/implement.html

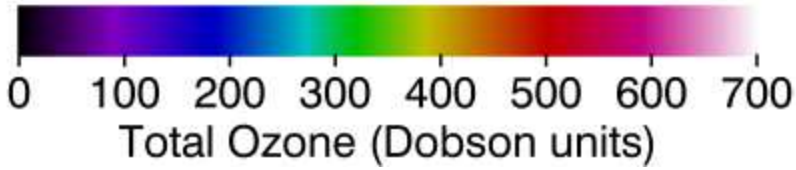
Stratospheric ozone depletion via CFCs and

Global warming due to CO_2 from burning fossil fuels

TWO SEPARATE PROBLEMS !!!!!

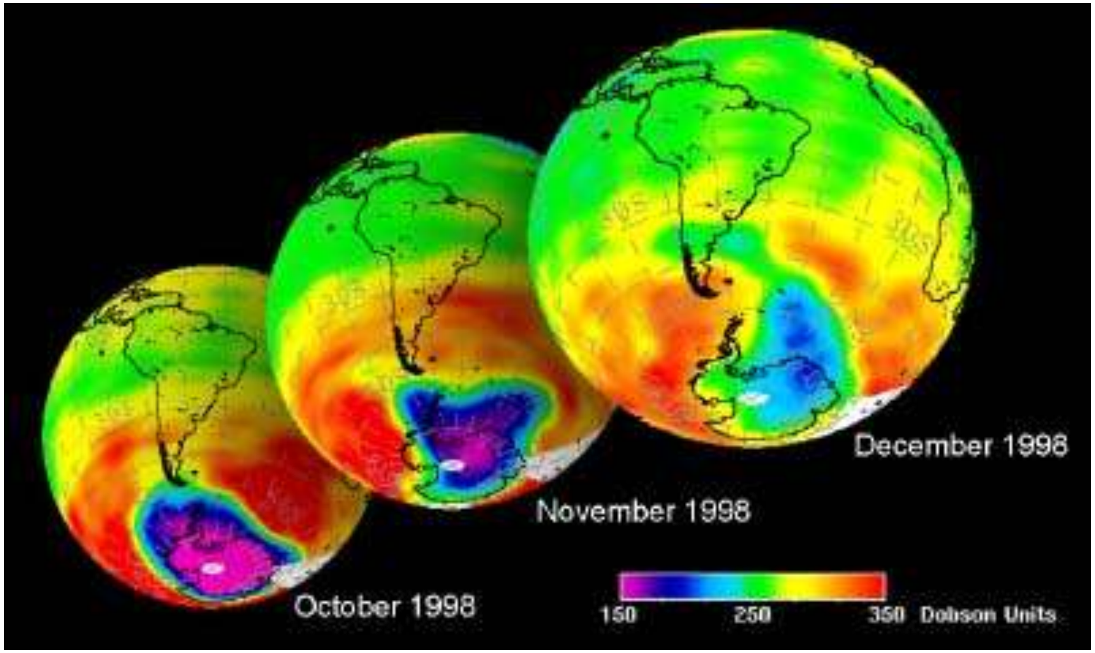
TWO SEPARATE PROBLEMS !!!!!

Ozone measured in Dobson units



Ozone thinning

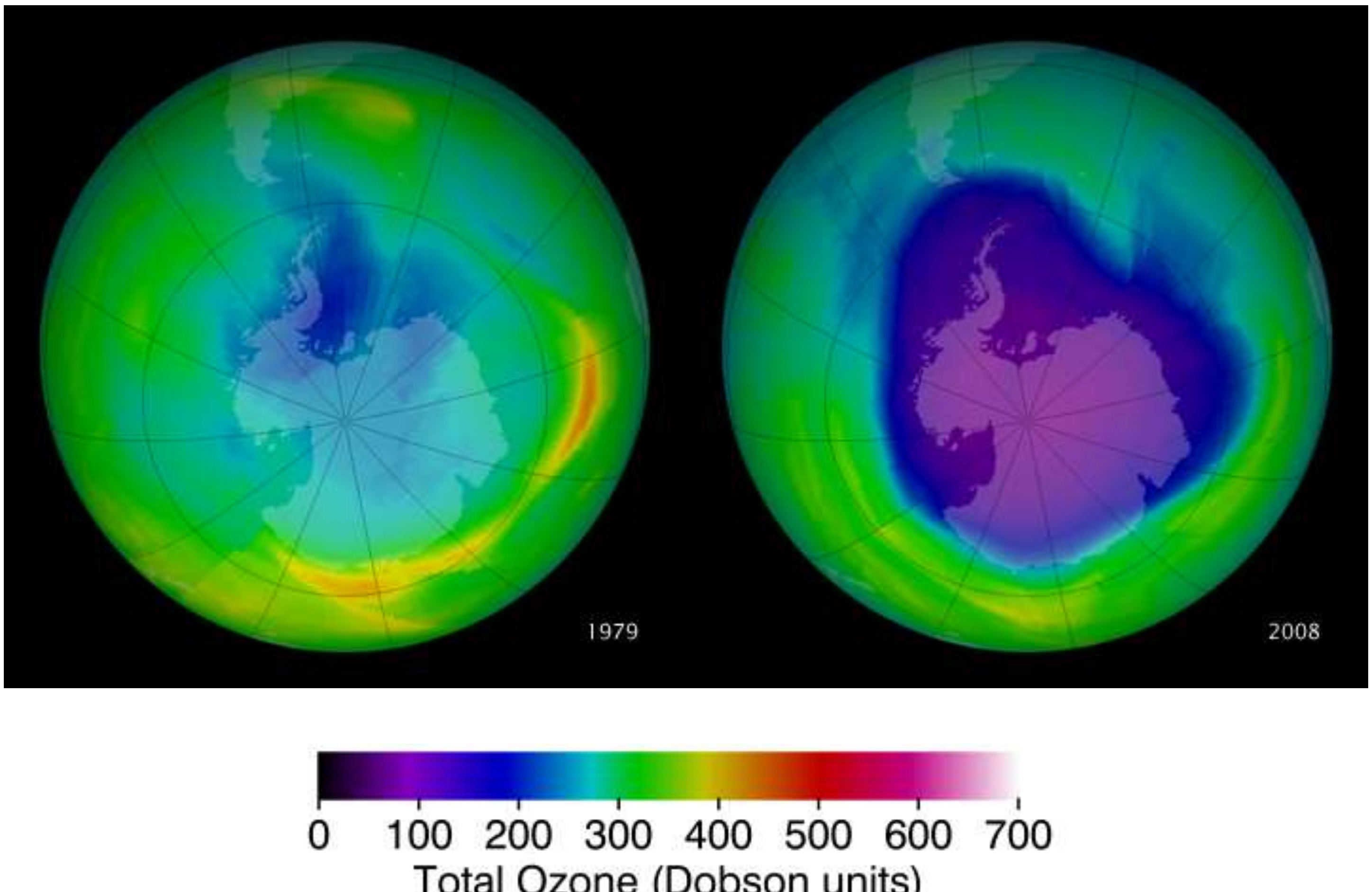
- Slight thinning forms naturally over Antartica Sept. – Oct. (Antarctic spring)



Ozone thinning

- Mid 80’s – 90’s = more severe thinning than usual → ozone hole
- Overall stratospheric ozone levels have dropped by about 10% since 1970

1979 2008


1979
2008
0 100 200 300 400 500 600 700
Total Ozone (Dobson units)

Causes of Ozone Depletion

- Bromine and chlorine containing compounds such as:
- Halons (used in fire retardants)
- Methyl bromine (used in pesticides)
- Methyl chloroform and carbon tetrachloride (used in industrial solvents)
- Nitrous oxide (released from fossil fuels and breakdown of nitrogen fertilizers)
- CFCs (chlorofluorocarbons – used in aerosols in the past, as coolants, and for foam insulation and styrofoam)

The breakdown

- Photochemical reactions involving Cl, F, or Br (halogens) break down ozone w/o destroying Cl, F, or Br
- Therefore one molecule can break down a lot of ozone
- Volcanoes can act as catalysts to speed up the reaction (→ aerosols)

Formula for breakdown of Ozone

- 2 steps:
- $Cl + O_3 \rightarrow ClO + O_2$
- $ClO + O \rightarrow Cl + O_2$

- Cl from CFCs break down ozone
- Note the Cl is recycled $\rightarrow$ lots of destruction

Effects of ozone depletion

- Increased UVA and B →
- Change proteins in living tissues → cataracts
- Mutate DNA →skin cancer
- Weakened immunity
- Decreased productivity of phytoplankton → disrupts photosynthesis → disrupt ecosystems

Legislation

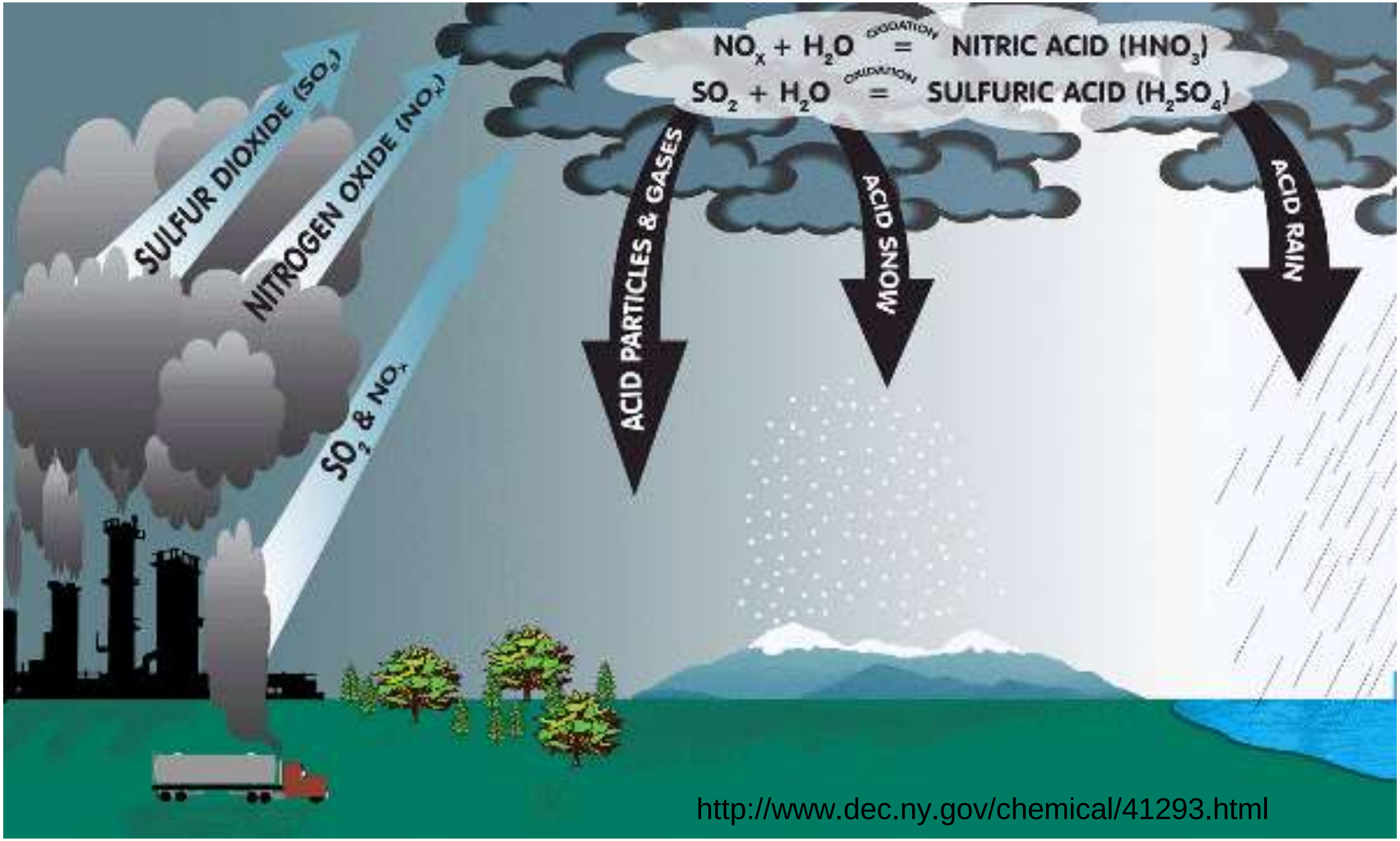
- 1978 US banned use of CFCs in aerosols
- **1987 Montreal Protocol = global effort to dec. CFC production and phase out the use of halons**
- 1987 group of school children convinced McDonalds to stop using CFC containing foam in their packaging
- Today all foam packaging made in US is ozone friendly

Acid Rain

- Precipitation containing lower than normal pH (due to sulfuric acid or nitric acid)
- Industrial nations have the worst problems with acid rain (Europe, Russia, North America)
- Affects coniferous forests and aquatic ecosystems most
- pH scale is from 1-14 on a logarithmic scale (difference of 1 = tenfold difference)
- pH = the negative log of hydrogen ions
  - Ex: pH 5 → 10^{-5} hydrogen ions

Normal Rain

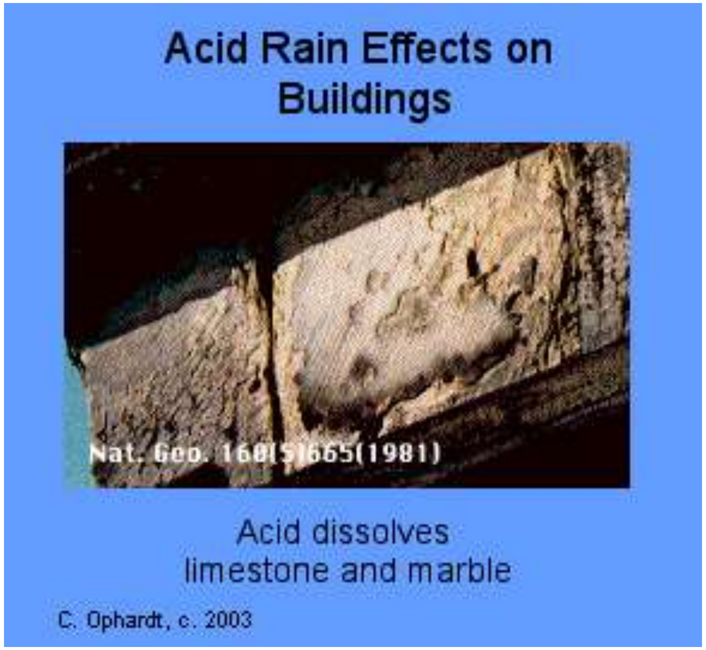
- pH 5 or 6 (slightly acidic due to dissolved CO_2)
- Northeastern US averages are 4 often as low as 3
- Why
- Coal burning plants and industry → SO_2
  - $SO_2 + H_2O \rightarrow H_2SO_4$
- Fossil fuels (esp. automobiles) → NO_2
  - $NO_2 + H_2O \rightarrow HNO_3 + HNO_2$



Avg. pH of ppt. in NYS ranges from 4.0 to 4.5
(30 times more acidic than "normal.“)

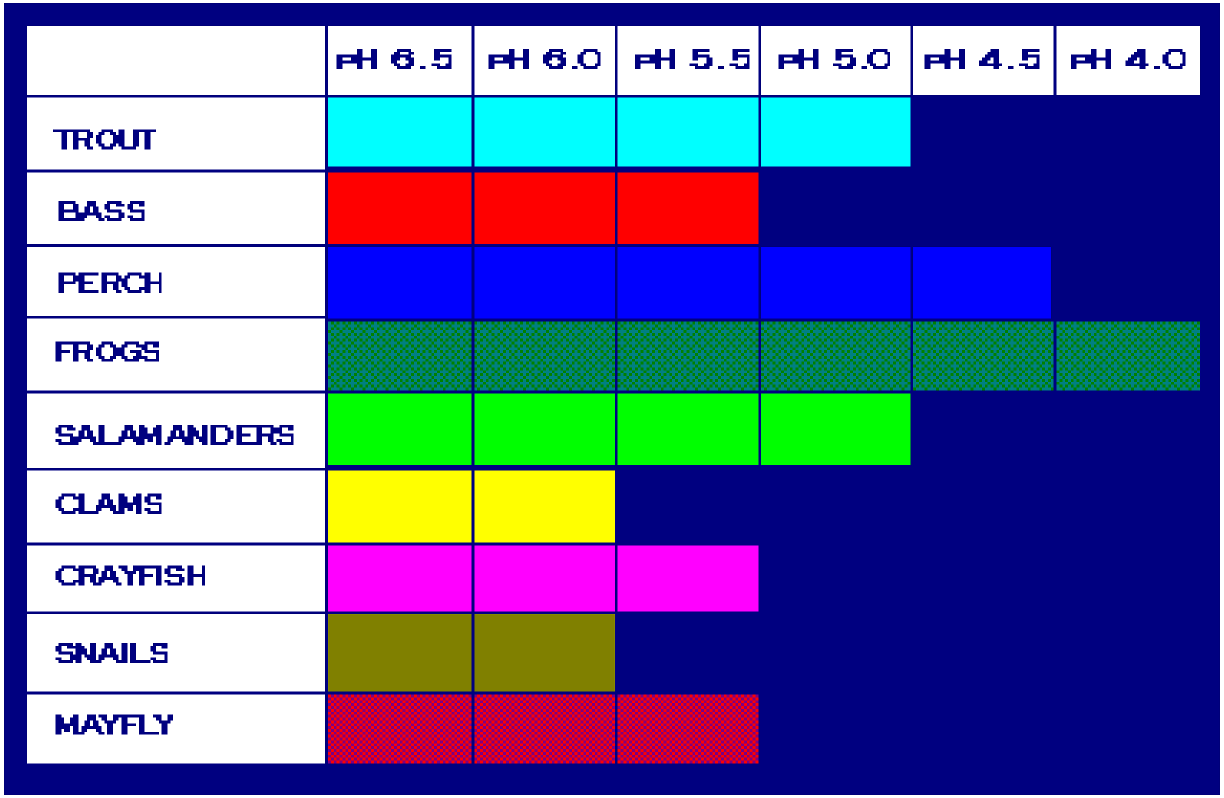
Effects of Acid Rain

- Corrodes metals and building materials



Acid rain Kills Aquatic Organisms

- Adirondack Lakes Survey Corporation reports ~ 346 dead lakes in the Adirondacks (pH 5 or less – no fish)
- Some lakes have high buffering capacity (limestone (calcium carbonate) increases pH)
- Acidity leaches aluminum from the soil into the water, clogging the fish's gills
- Acidity in soil increases solubility of toxic heavy metals (Hg, arsenic, Cd…)



http://dwb.unl.edu/Teacher/NSF/C14/C14Links/www.epa.gov/airmarkets/acidrain/effects/surfacewater.html

Low pH affect fish reproduction and health

Acid rain → Disrupts food webs

- Acid deposition → inc. leaching of soil nutrients
- Ex: less calcium in soil → less calcium in plants → less calcium in birds → soft egg shells → dec. birth rates

Acid Rain Destroys Forest Habitats

- Ex: Black Forest (Germany) and many red spruce and fir trees in the Northeastern US
- Trees at high elevation = increased risk
- Acid precipitation drains soil nutrients
- Damages leaves and bark
- Damages soil organisms and decomposers
- Releases toxic metals in soils (ex:Al)

Acid Rain and Human Health

- Acidity increases amount of toxic metals in soil and water (ex: mercury, cadmium, lead, aluminum)
- Once consumed heavy metals persist, bioaccumulate, and → developmental and neurological problems

Legislation

- Difficult to pass because pollution travels
  - England's pollution affects Sweden
  - China affects Japan
  - Midwest affects NE
- Clean Air Act (1970) in US
  - Sets limits on Sulfur and Nitrogen emissions from power plants and industry
    - Scrubbers, fluidized bed combustion (remove sulfur from coal)
    - Catalytic converters on cars reduce NOx emissions from cars