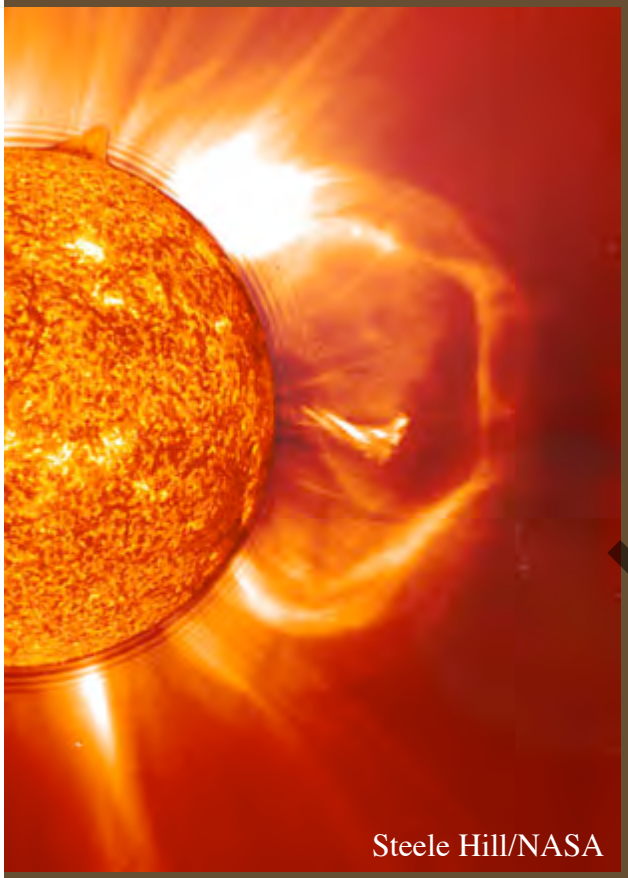
The Climate Challenge: Setting the Context for Considering our Energy Future Options

Jacob O. Sewall
Department of Geosciences
Virginia Tech

J. O. Sewall

Warming Our Planet



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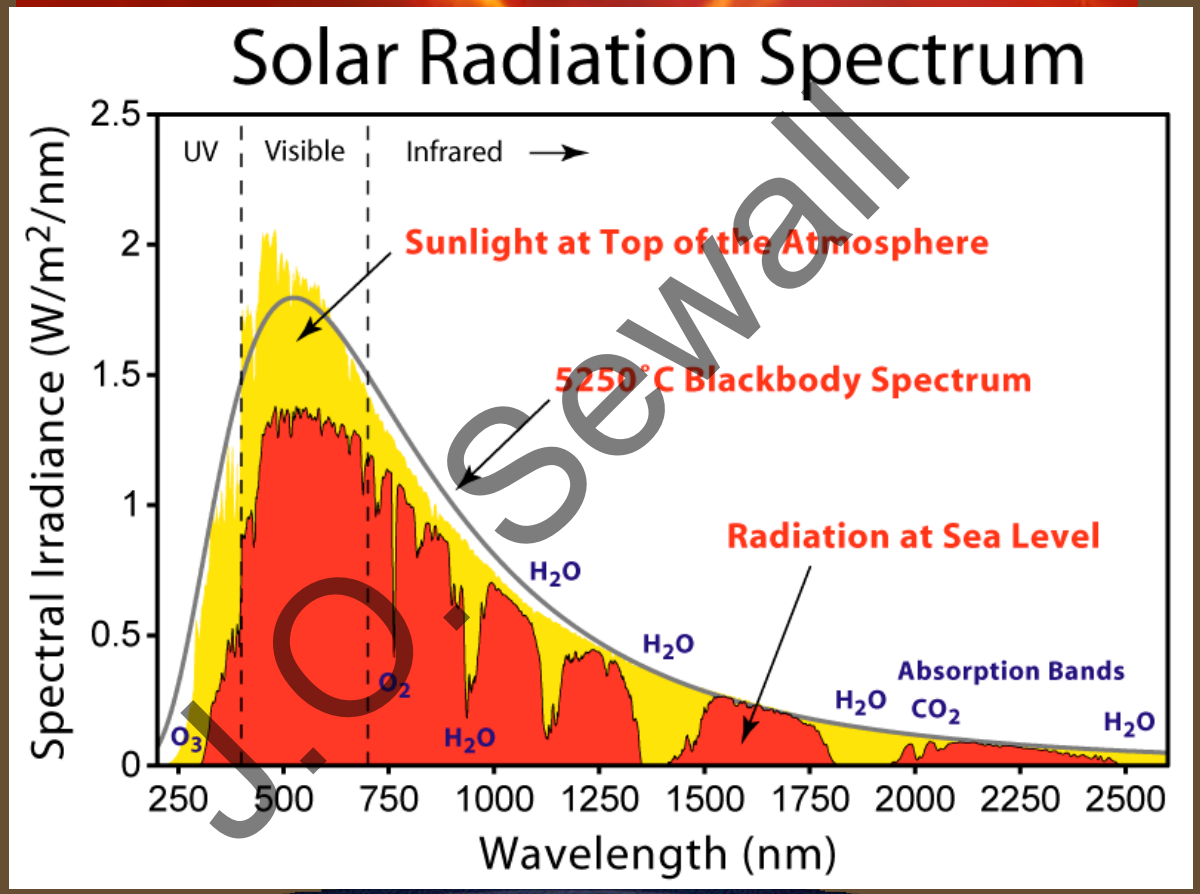
Steele Hill/NASA



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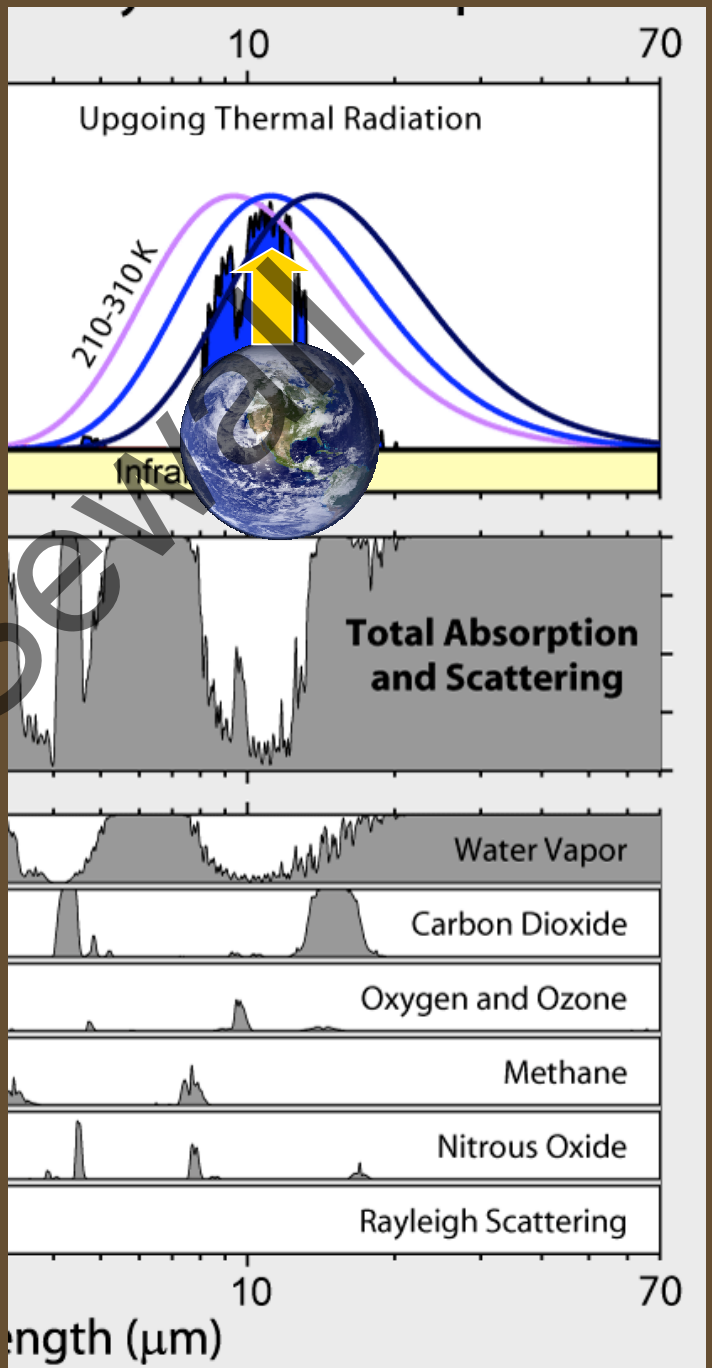
NASA

Earth's Emitted Radiation



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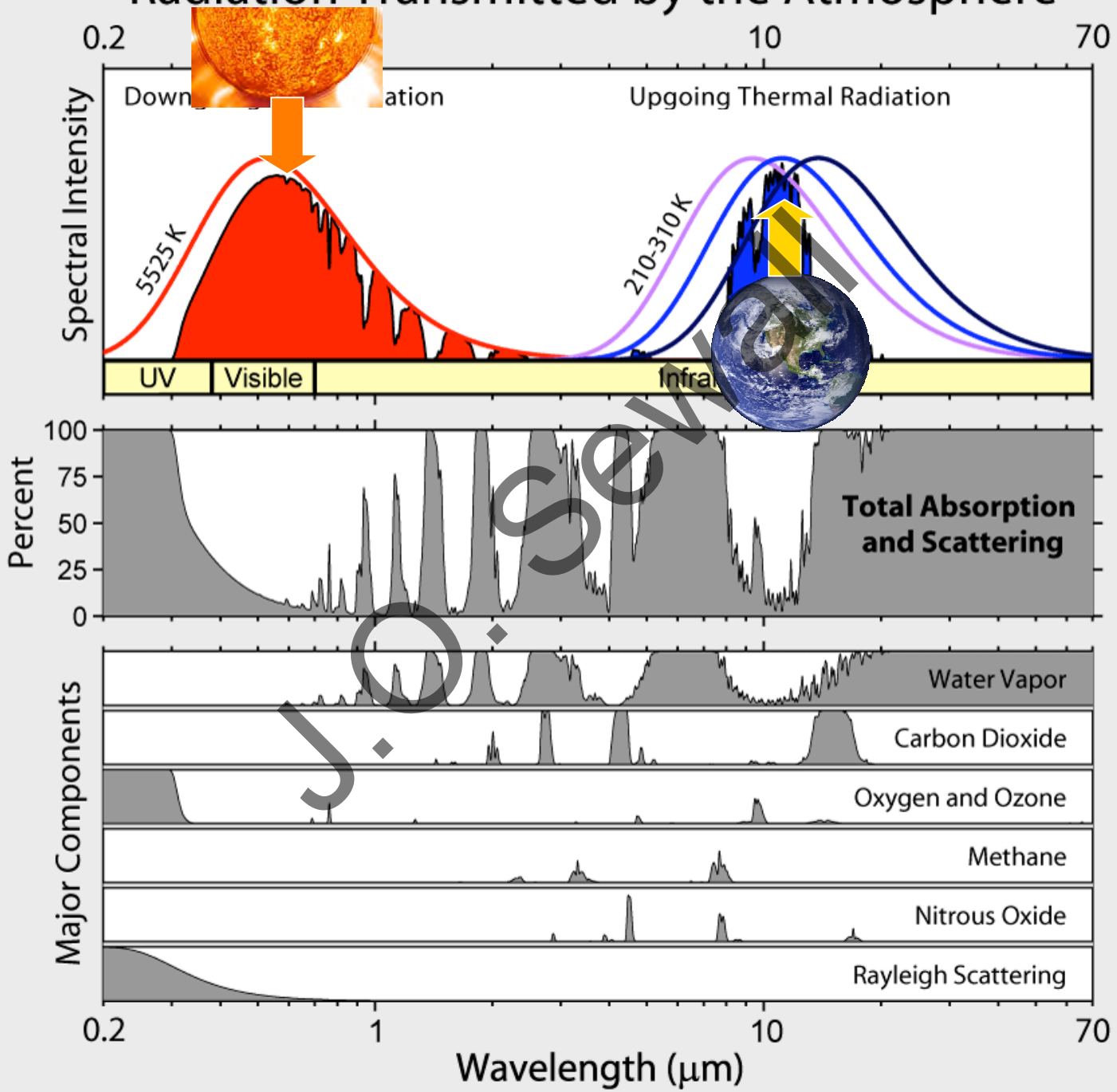
Radiation Transmitted by the Atmosphere



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Warming Our Planet: Fact Check

- Greenhouse Gasses (e.g. H_2O, CO_2, CH_4, N_2O) absorb little solar (shortwave) radiation.
- Greenhouse Gasses (e.g. H_2O, CO_2, CH_4, N_2O) absorb a lot of terrestrial (longwave/infrared) radiation.
- Earth receives almost twice as much energy from the "greenhouse effect" as it does directly from the sun.

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Greenhouse Gasses

- Greenhouse gasses are ~ 1.038% of the atmosphere.
- Greenhouse gasses provide ~65% of the energy units that heat Earth's surface.

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Fossil Fuels

- Organic substances comprised of Carbon and Hydrogen (plus/minus impurities)
- Perfect combustion of Carbon produces CO_2
- Perfect combustion of Hydrogen produces H_2O

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Fossil Fuels

- Coal
  - Higher energy content = more Carbon
  - Bituminous coal ~ 87% Carbon
- Natural Gas
  - Mostly methane, CH_4, so 20% Carbon
- Gasoline
  - ~C_8H_{18} so ~ 31% Carbon
- Diesel Fuel
  - ~$C_{12}H_{24}$ so ~ 50% Carbon
- Heating Oil
  - Formula varies but all ~32% Carbon

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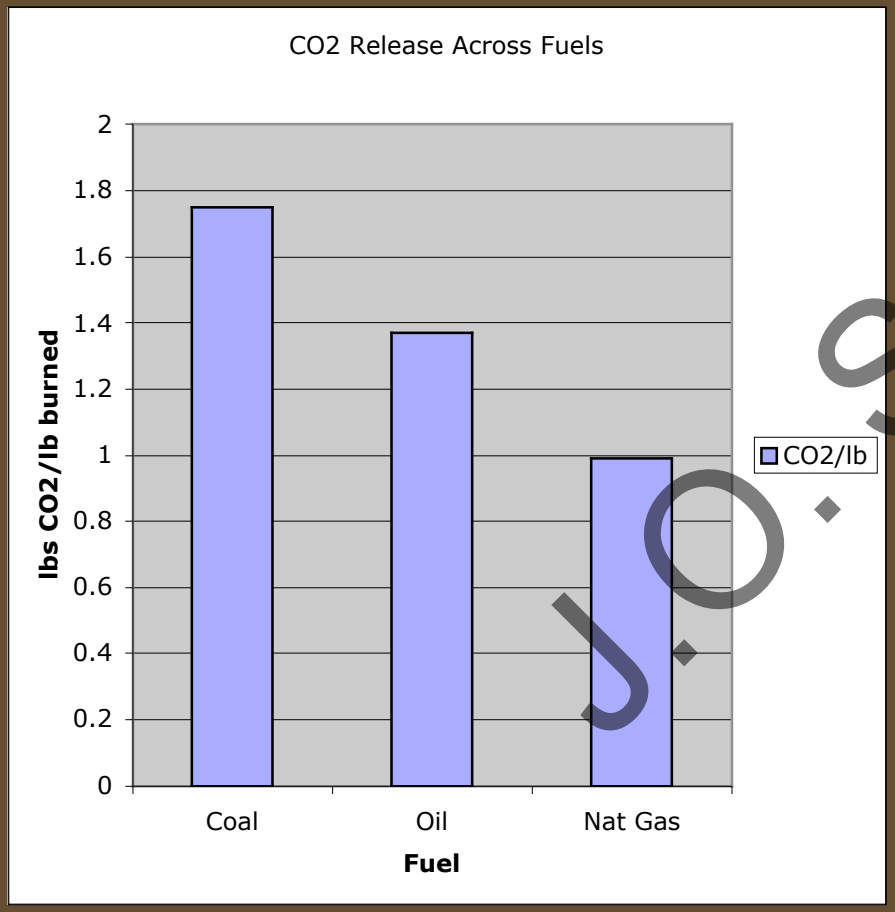
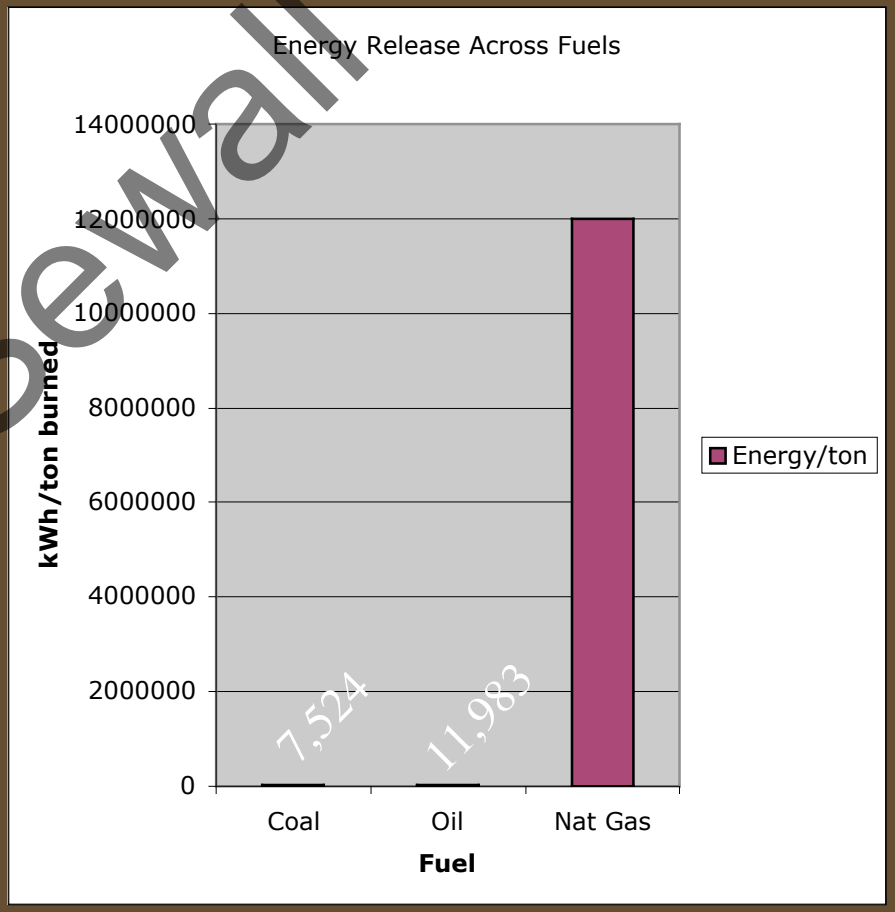
Fossil Fuel CO_2 Emissions





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Fossil Fuel Emissions

- Why aren't we worried about water vapor?
  - Atmospheric residence time of water vapor is ~ 1 week
  - Atmospheric residence time of CO_2 is ~200 years

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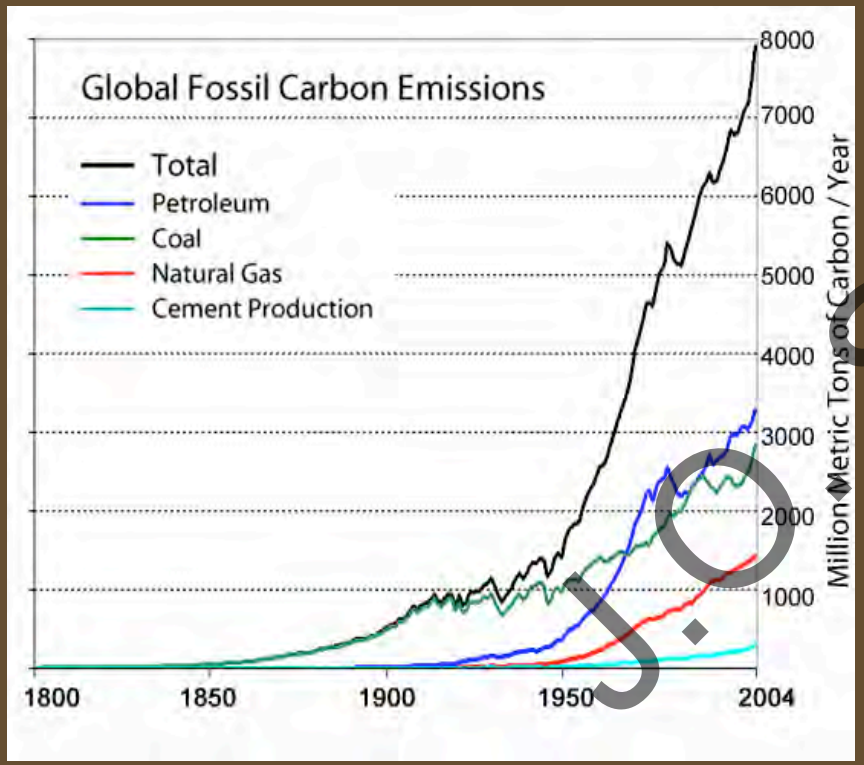
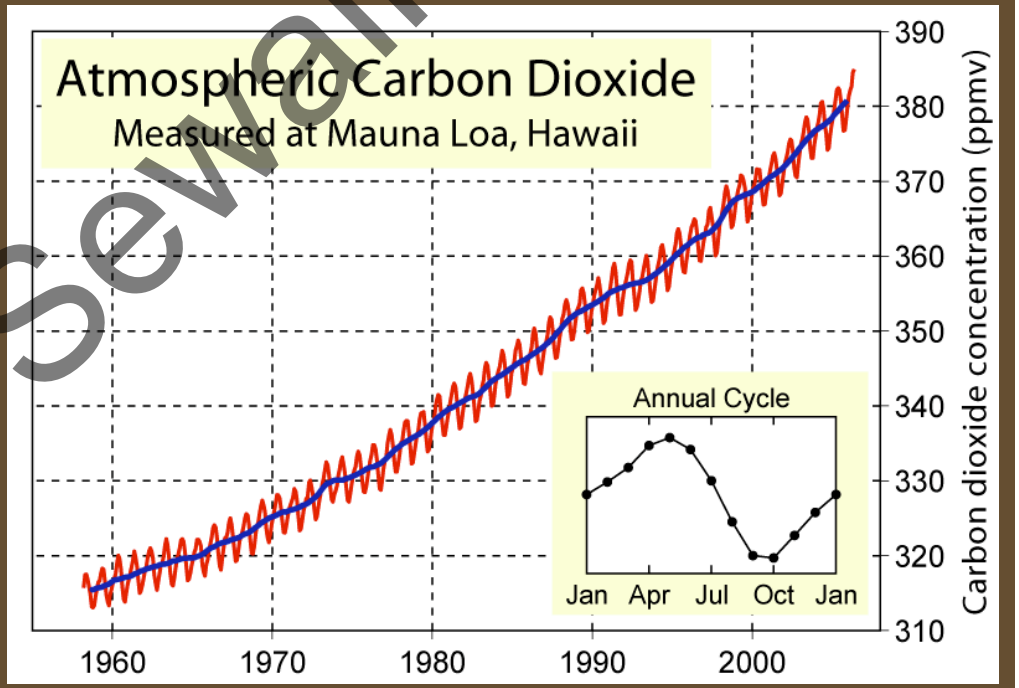
Fossil Fuels and Emissions





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Marland, G., T.A. Boden, and R. J. Andres. 2007. Global, Regional, and National CO2 Emissions. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, United States Department of Energy, Oak Ridge, Tenn., U.S.A.

ftp://ftp.cmdl.noaa.gov/ccg/co2/trends/co2_mm_mlo.txt

Greenhouse Gasses, Fossil Fuel Emissions, and Warming Our Planet

- Water vapor is the most abundant greenhouse constituent
- CO_2 is second at 0.038% of the atmosphere
- Humans have increased atmospheric CO_2 by ~ 36% and the total greenhouse gas load by ~ .01%.
- Based on the observed proportionality between %volume of greenhouse gasses and contributed energy units, humans (via increased greenhouse gasses) can account for ~0.6% of the energy units that heat Earth's surface.

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Climate Change Quick Facts

- Increased greenhouse gas concentrations have contributed to ~3 W/m^2 of radiative forcing with ~1/2 due to CO_2
- Global average temperature has increased:

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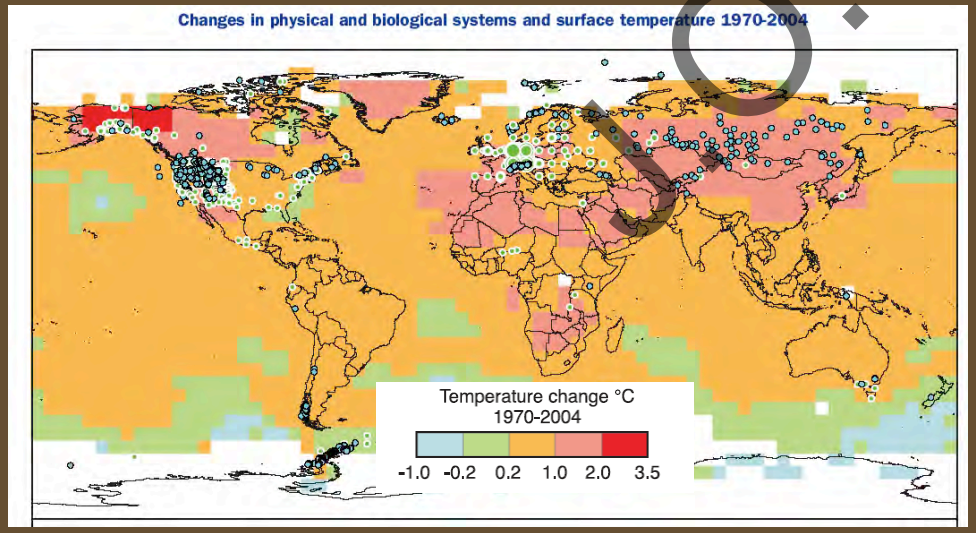

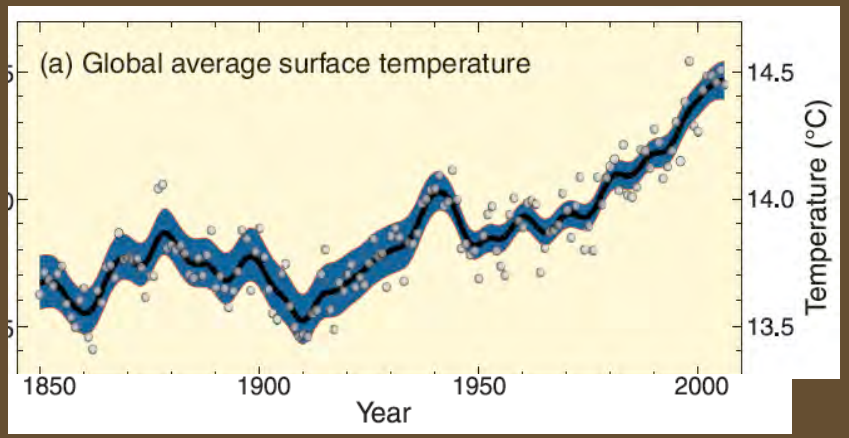

IPCC 2007

Climate Change Quick Facts

- Increased greenhouse gas concentrations have contributed to ~3 W/m^2 of radiative forcing with ~1/2 due to CO_2
- Land and sea ice are melting:

Credit: Roger J. Braithwaite, The University of Manchester, UKNASA Earth Observatory

http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=17800**Date**The image is dated September 16, 2007.**Author**NASA image created by Jesse Allen, using AMSR-E data courtesy of the National Snow and Ice Data (NSIDC), and sea ice extent contours courtesy of Terry Haran and Matt Savoie, NSIDC, based on Special Sensor Microwave Imager (SSM/I) data.

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Future Greenhouse Gas Levels

- Pre-Industrial CO_2 concentrations were ~280 ppm.
- Current levels are 380 ppm.
- Current emissions estimates place 450 ppm CO_2 as a "best case scenario" stabilization level.
- Aggressive stabilization at 450 ppm CO_2 is heavily dependent on biofuels.

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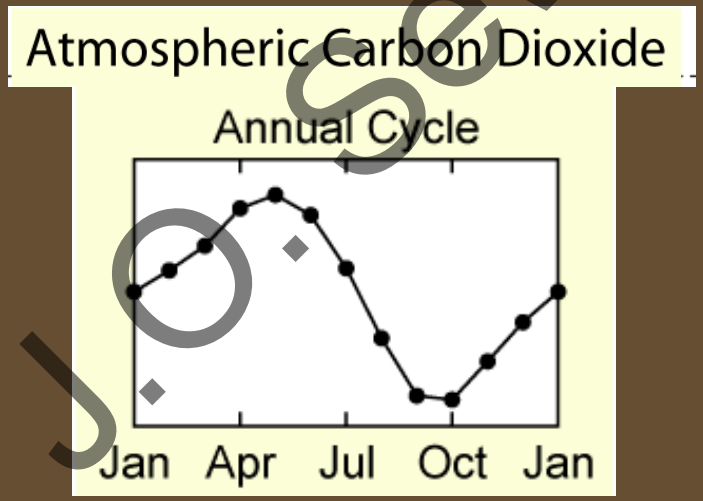
Future Energy Sources

- Biofuels are, theoretically, “carbon neutral”.
  - Carbon is taken up by the plants and then that same carbon is released upon burning, to be taken up by the next crop etc. etc.



- Biofuels in combination with CO_2 capture and sequestration can thus lead to “negative emissions”.

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Future Energy Sources: Holistic Assessment

- Estimates of future biofuel stocks are largely dependent on agricultural productivity continuing to increase at "historical" rates.
  - "Historical" rates are driven by industrialized agriculture which consumes large quantities of fossil fuel. This reduces the "neutrality" of biofuels.

- Adverse effects on food production and pricing.

- Massive agricultural expansion can endanger valuable topsoil "resources"

- Massive agricultural expansion is also accompanied by increased pollution (e.g. the "Dead zone" in the Gulf of Mexico).

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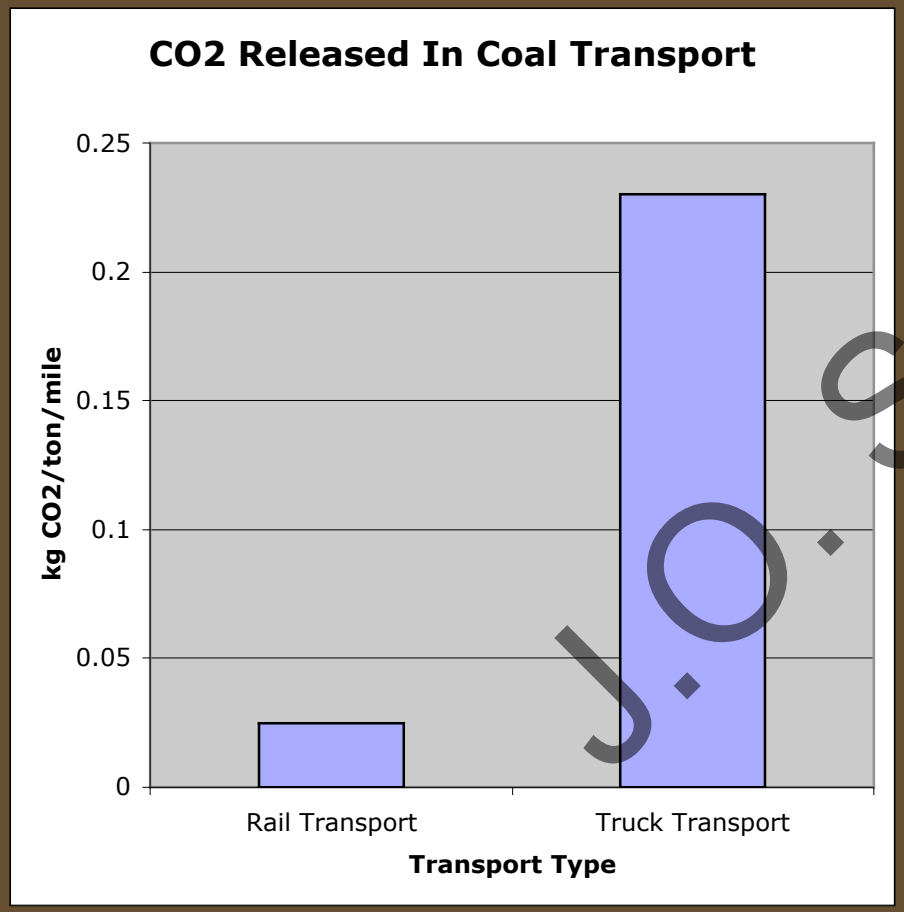
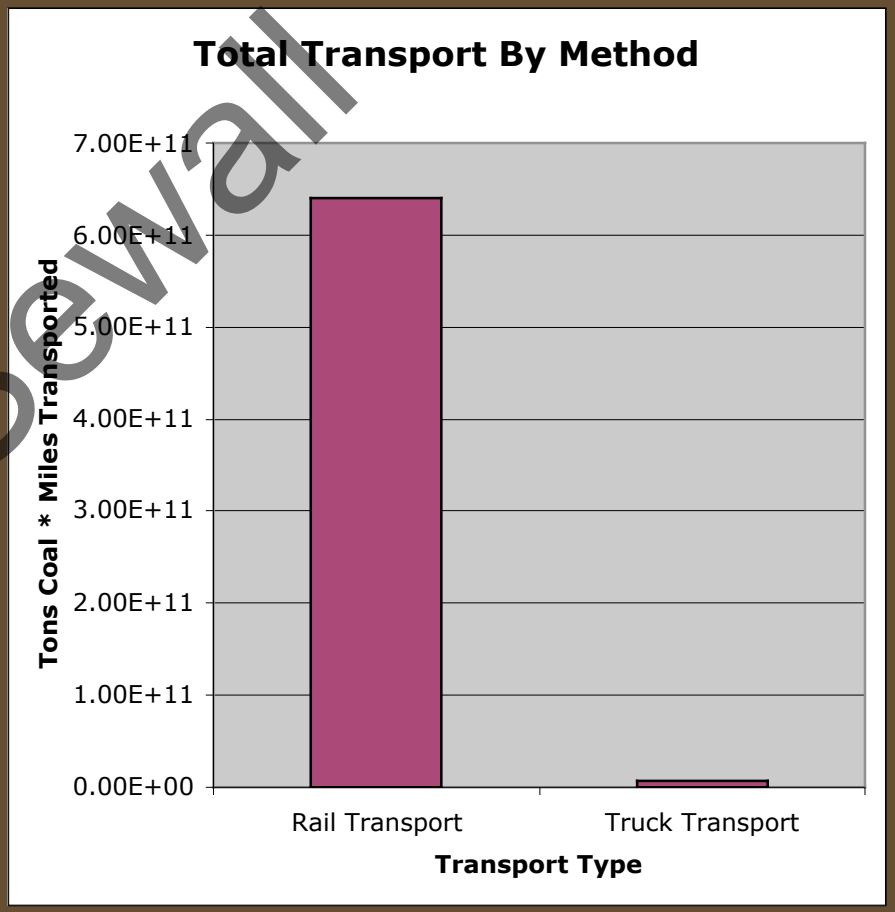
Future Energy Sources: Holistic Assessment





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Rushing Into Our Future

- Careful "holistic" assessment of environmental impacts must be made before we rush for a given solution.
- We *need* to rush. The "best case scenario" is close to a doubling of CO_2 and some would argue that doubling is a more realistic stabilization level.
- Taking the time to do it "right" will hopefully prevent "out of the frying pan and into the fire" but will likely result in some degree of irreversible climate change.

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Future Climate Change

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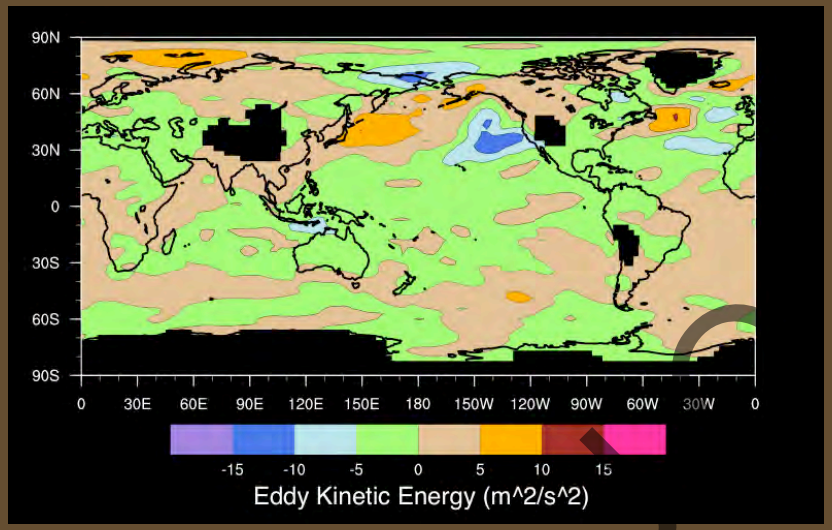
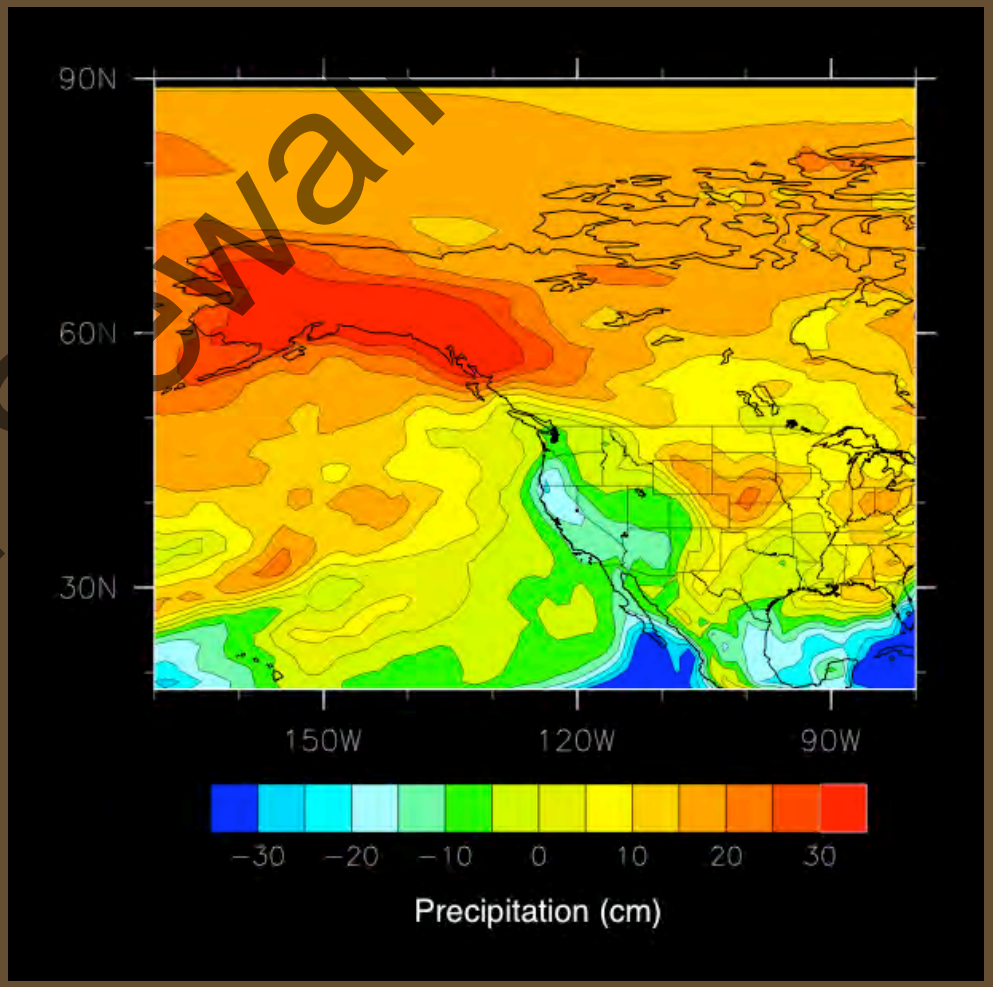
Risky Unknowns

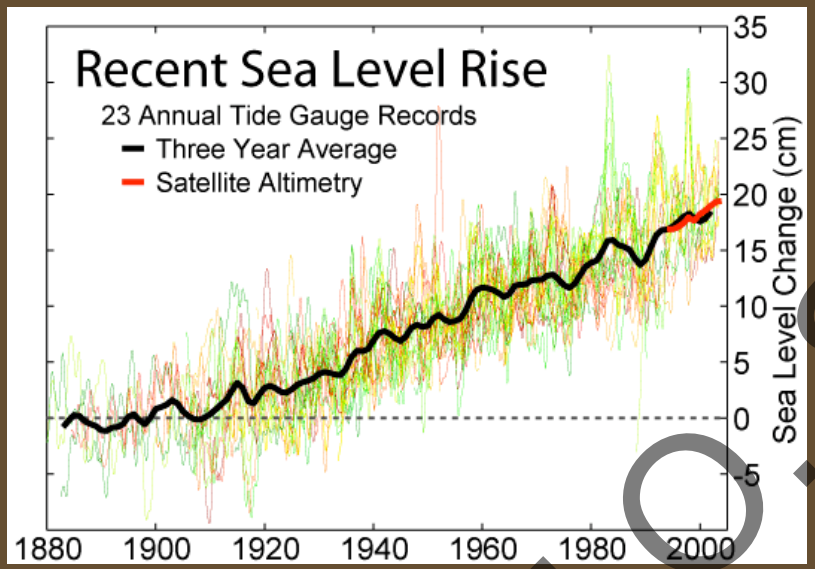


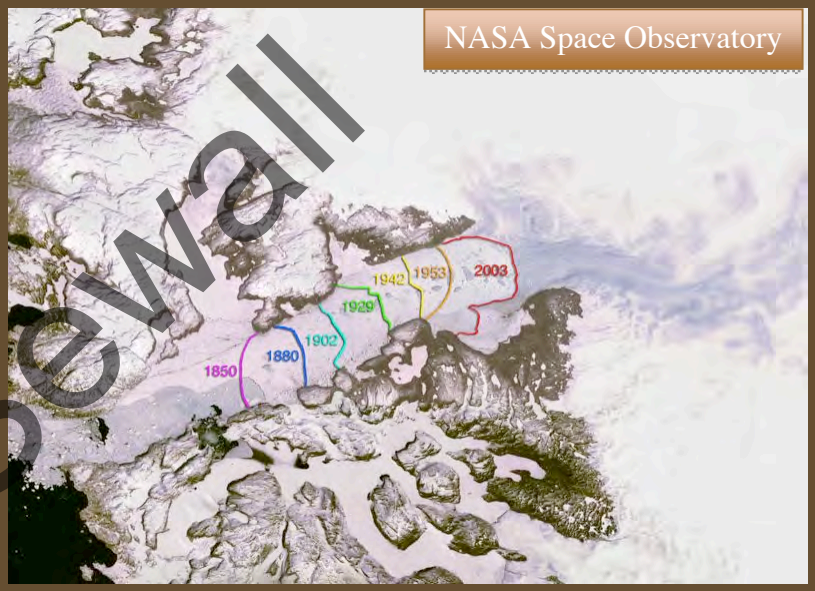


- Precipitation Changes

Sewall, 2005

Risky Unknowns





- Sea Level Rise
- Ice Sheet Dynamics

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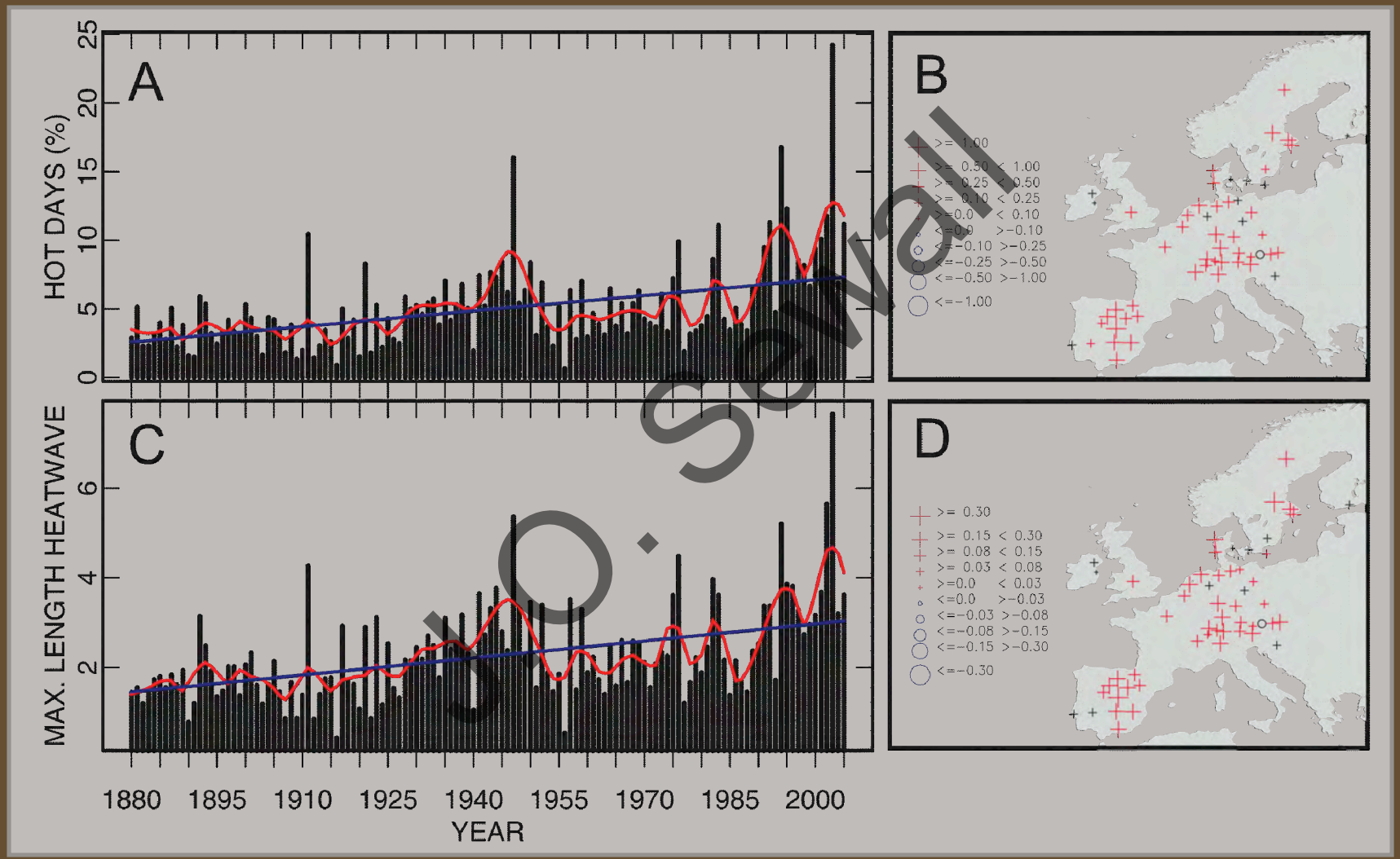
Risky Unknowns

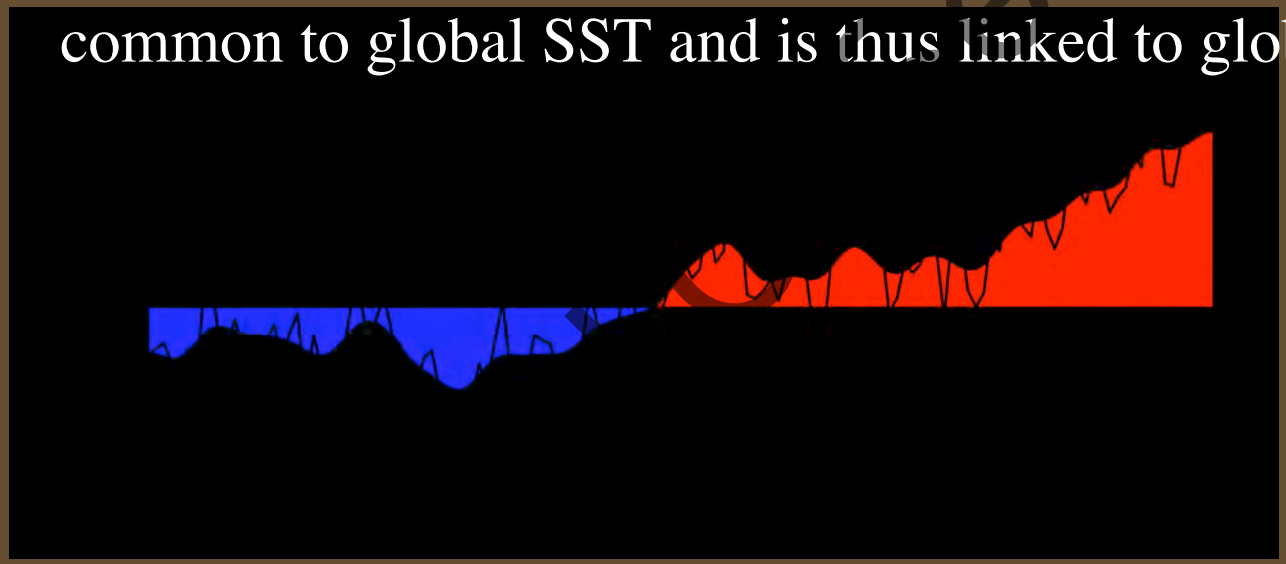


- Heat Waves

Della-Marta et al., 2007

Risky Unknowns

"Sea surface temperatures (SSTs) in the tropical North Atlantic (TNA) region critical for hurricanes (10° to 20°N) were at record high levels in the extended summer (June to October) of 2005 at 0.9°C above the 1901–70 normal and were a major reason for the record hurricane season… About 0.45°C of the SST anomaly is common to global SST and is thus linked to global warming…"



Atlantic hurricanes and natural variability in 2005
Kevin E. Trenberth and Dennis J. Shea
Geophysical Research Letters, 2006

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