Geog 416: (The truth about) Global Warming

Dr. Helen Cox

the causes.
the evidence.
the future.

alternative energy - is it viable?

the cost? the returns?

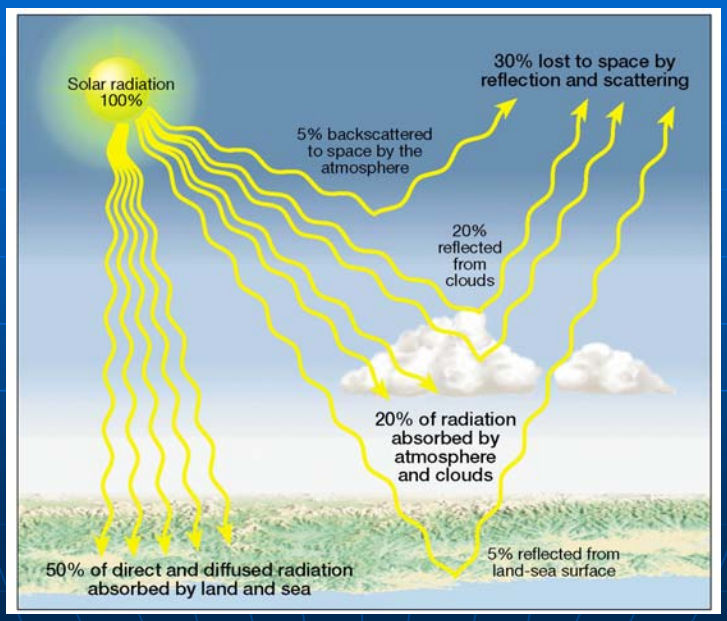
Learn real job skills

carbon-footprinting **'green' planning** **laws and regulations**

Geog 416: Global Warming

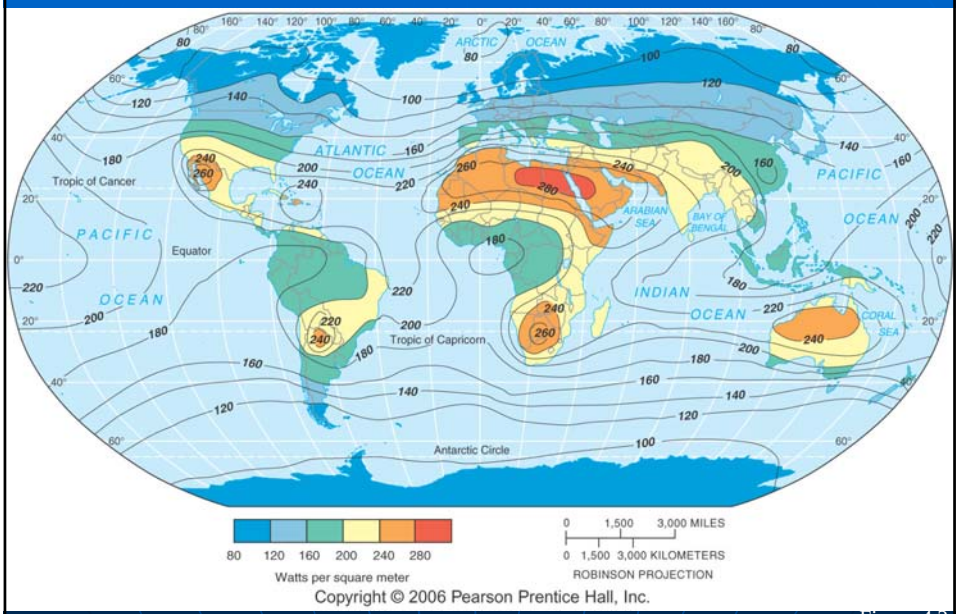
What controls our temperature?
Climate history of the Earth
Global Warming predictions
Consequences
Mitigation Efforts
Legislation
Sustainability initiatives

Geog 416: Global Warming



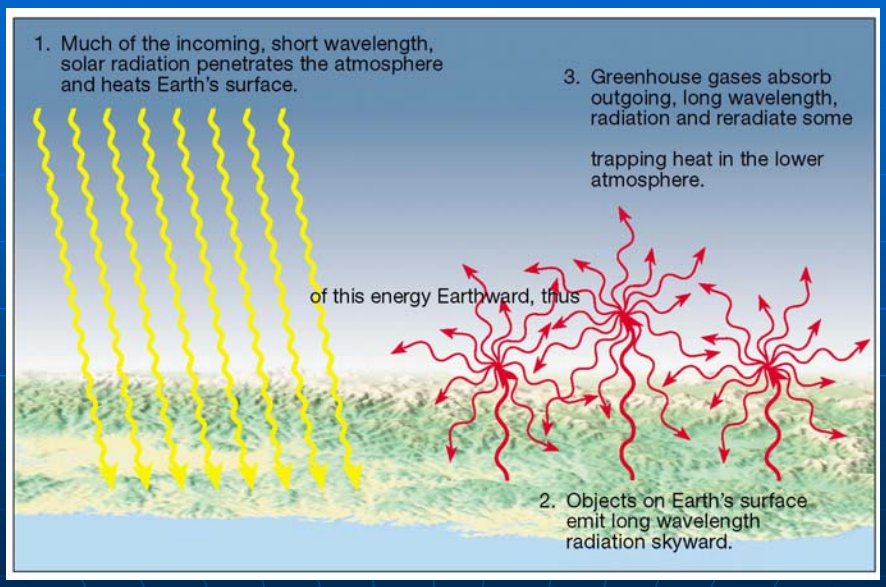
Lutgens and Tarbuck, The Atmosphere

Insolation at Earth's Surface



Christopherson: Geosystems Figure 4.2

Geog 416: Global Warming



Lutgens and Tarbuck, The Atmosphere

Energy Pathways

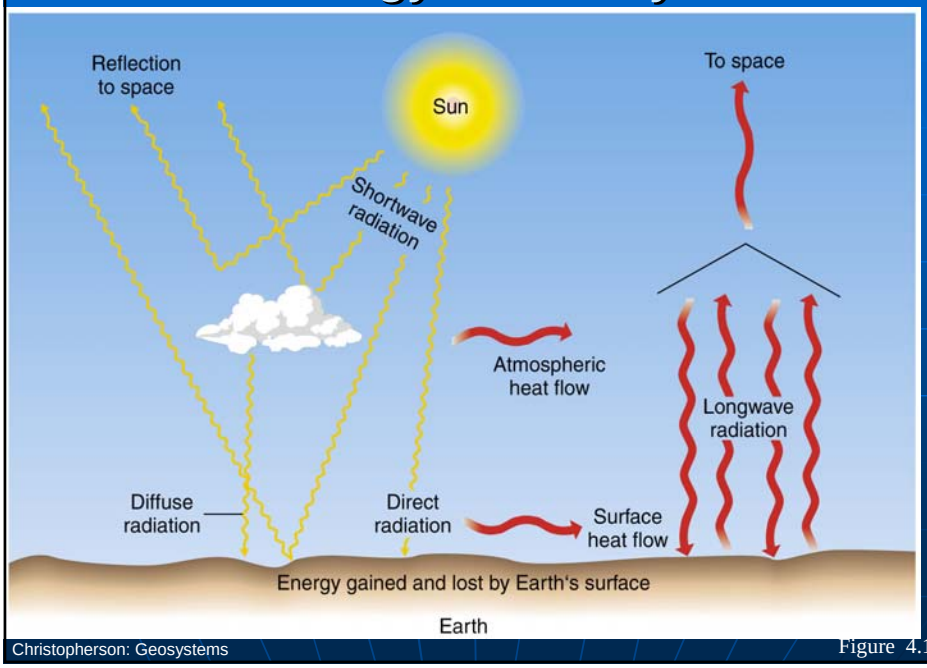


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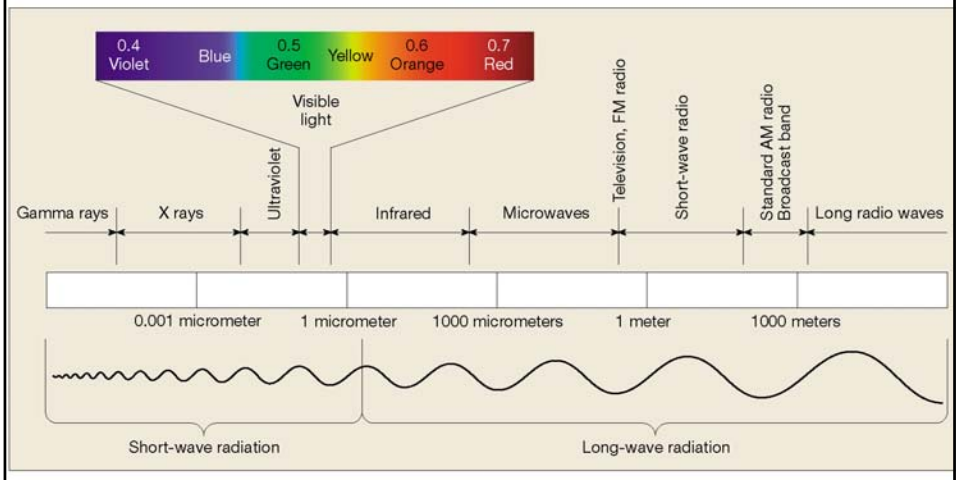
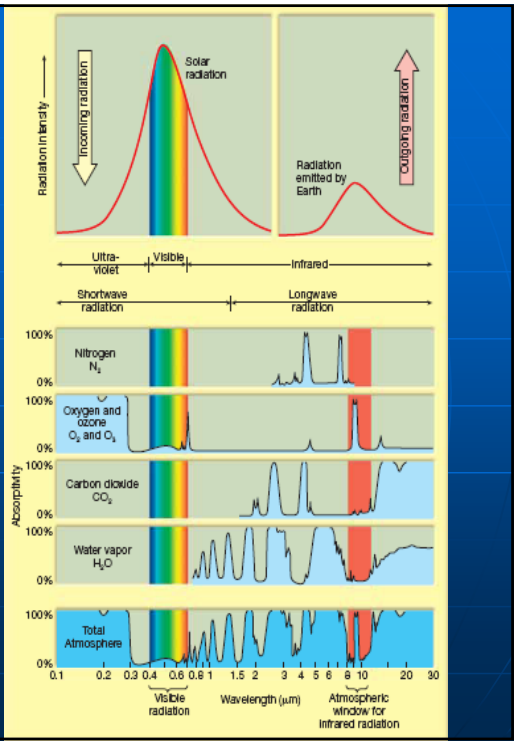
Figure 4.1

Geog 416: Global Warming



Lutgens and Tarbuck, The Atmosphere

Geog 416: Global Warming



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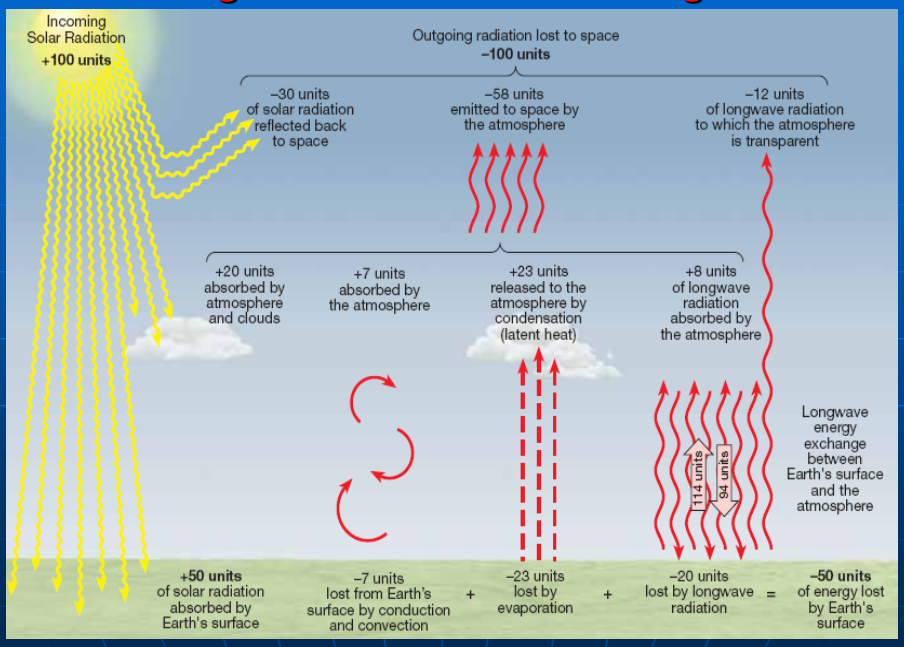
Geog 416: Global Warming

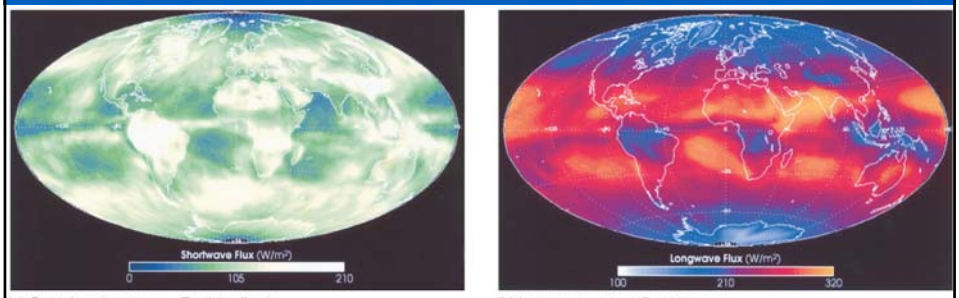


Lutgens and Tarbuck, The Atmosphere

Global Warming 101

- Earth is heated by absorption of solar radiation.
- Earth emits IR radiation out to space
- Greenhouse gases absorb most of this and return it back to the Earth.
- Earth's surface temperature is about 33˚C warmer than it would be without G-H gases.

Shortwave and Longwave Energy



(a) Outgoing shortwave – Earth's albedo. (b) Longwave energy flux to space.

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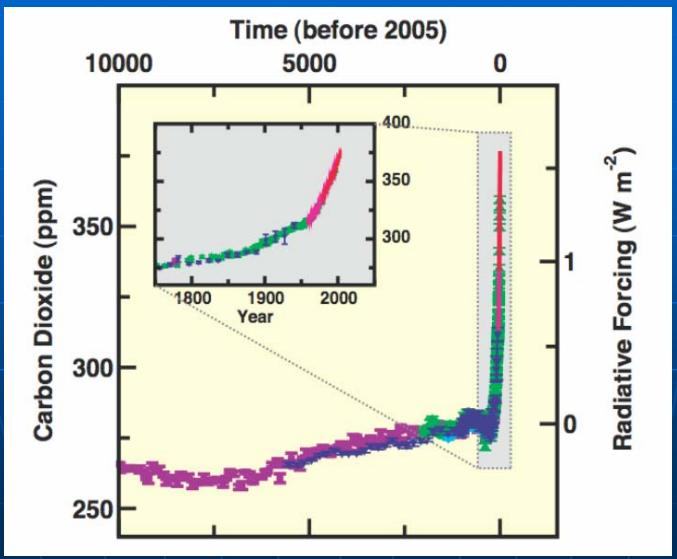
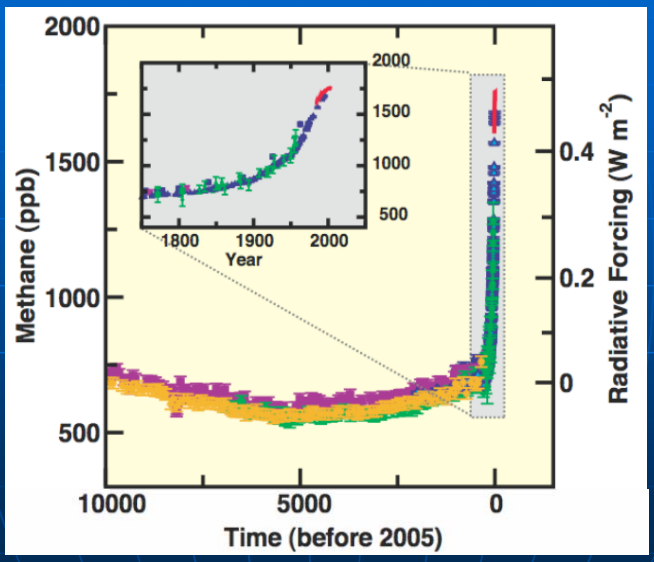
Greenhouse Gases



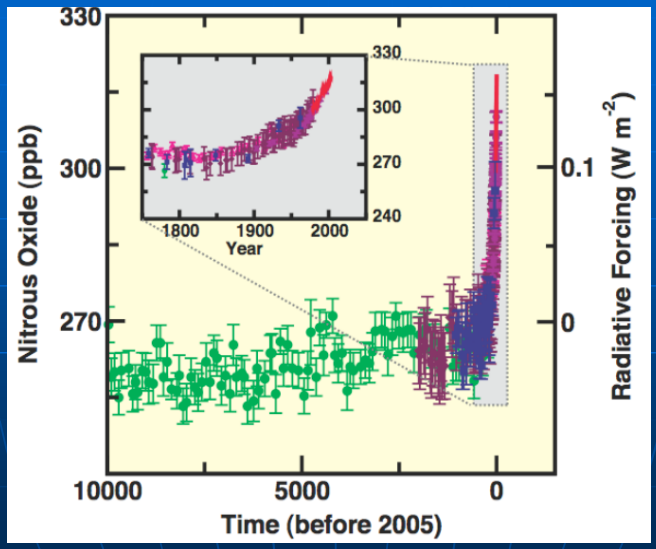
Intergovernmental Panel on Climate Change (IPCC), WGI Fourth Assessment Report *2007: Summary for Policymakers,* Cambridge University Press. http://www.ipcc.ch

Greenhouse Gases



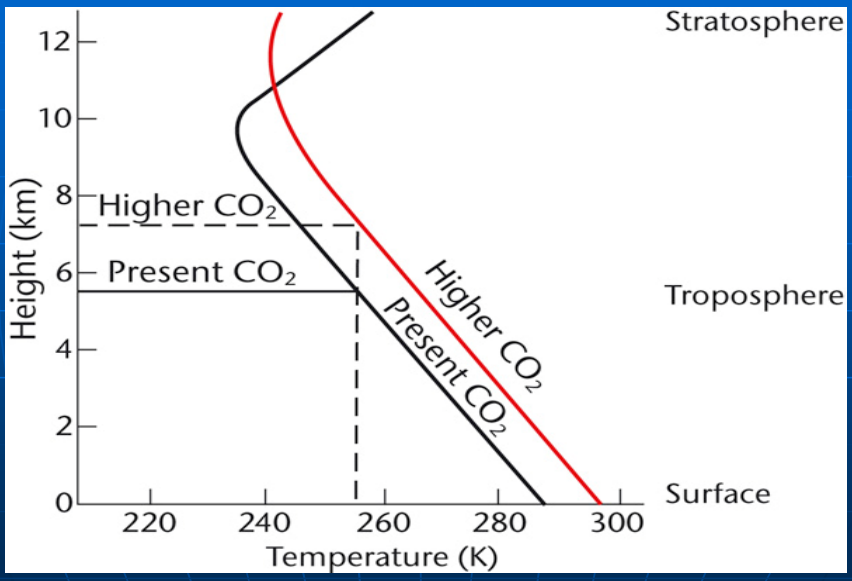
Intergovernmental Panel on Climate Change (IPCC), WGI Fourth Assessment Report *2007: Summary for Policymakers,* Cambridge University Press. http://www.ipcc.ch

Greenhouse Gases



Intergovernmental Panel on Climate Change (IPCC), WGI Fourth Assessment Report *2007: Summary for Policymakers,* Cambridge University Press. http://www.ipcc.ch

The Greenhouse Effect



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Greenhouse Warming

- Incoming solar at TOA: 343 Wm^{-2}
- Albedo ≈ 0.3 (clouds, air, aerosols, surface)
- Absorbed radiation: 237 Wm^{-2}
- Radiation to space from Earth-Atmosphere: 237 Wm^{-2}

But – Earth emits 390 Wm^{-2}.

Difference = measure of G-H heating (153 Wm^{-2})

Changes to this difference are termed "radiative forcing".

To assess anthropogenic influence we look at the radiative forcing for the present relative to pre-industrial times (e.g. year 1850).

Any resultant change in the climate system is a "response".

Radiative forcing of G-H gases

Year 2000 relative to pre-industrial

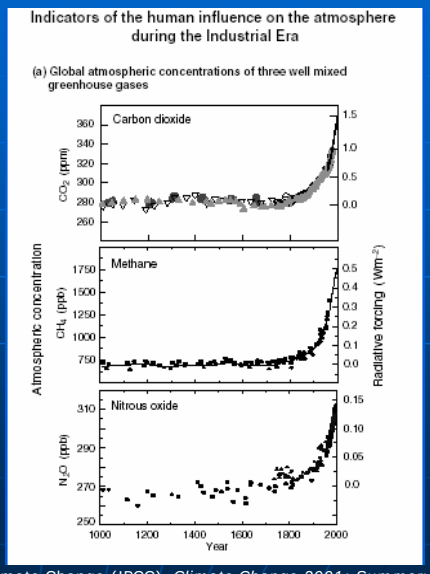
CO_2 1.46 Wm^{-2}

CH_4 0.48 Wm^{-2}

N_2O 0.15 Wm^{-2}

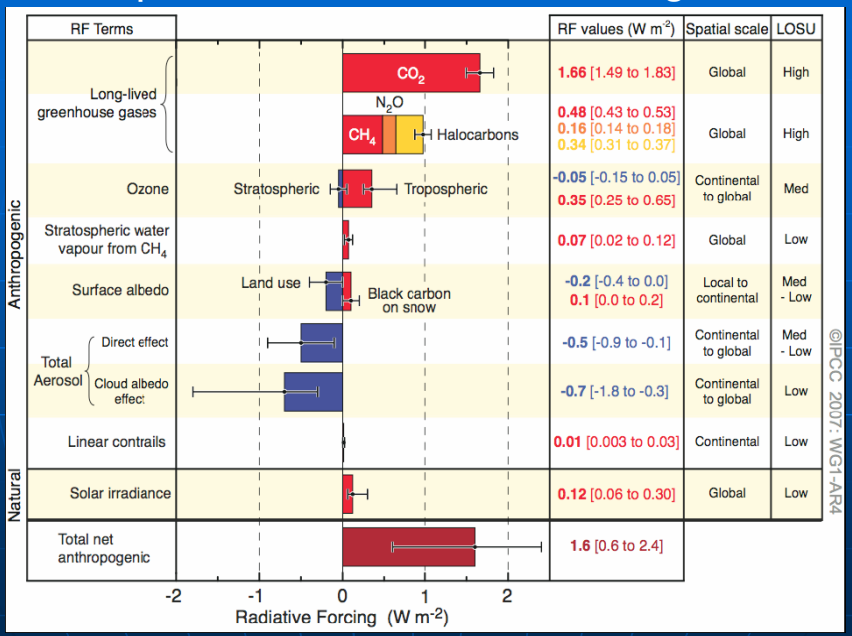
Halocarbons 0.34 Wm^{-2}

Total G-H gases: 2.43 Wm^{-2}



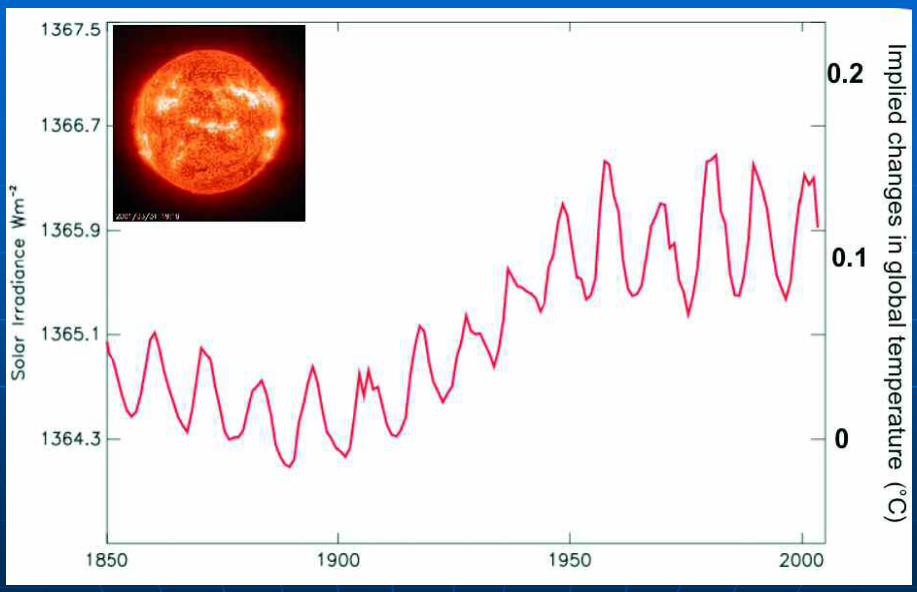
Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Summary for Policymakers*, Cambridge University Press (2001)

Components of Radiative Forcing, 2005



Intergovernmental Panel on Climate Change (IPCC), WGI Fourth Assessment Report *2007: Summary for Policymakers*, Cambridge University Press (in press, 2007). http://www.ipcc.ch

Changes in Solar Irradiance



Lean, 2003

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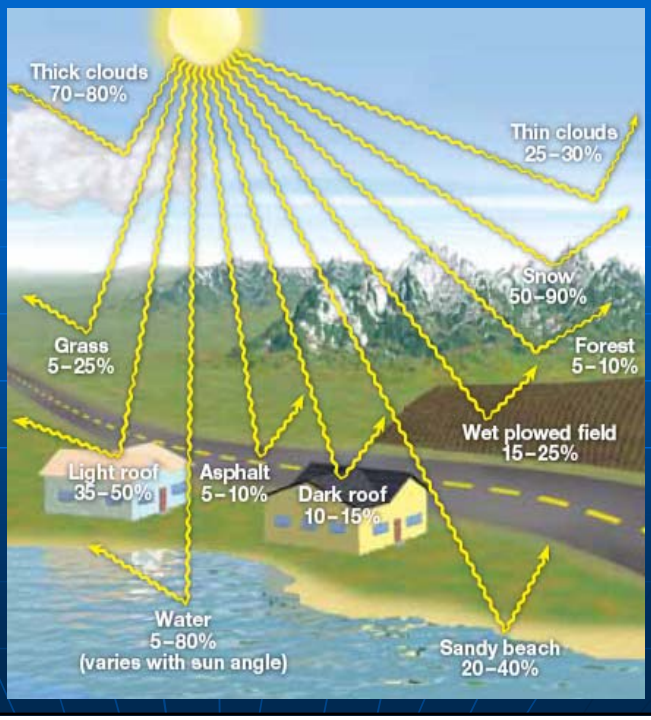
Other contributors to warming

- Increase of ~ 36% in tropospheric ozone (0.35 Wm^{-2}) – regionally variable
- Aviation-induced contrails and cirrus clouds?
- Increase in solar irradiance (0.3 Wm^{-2})

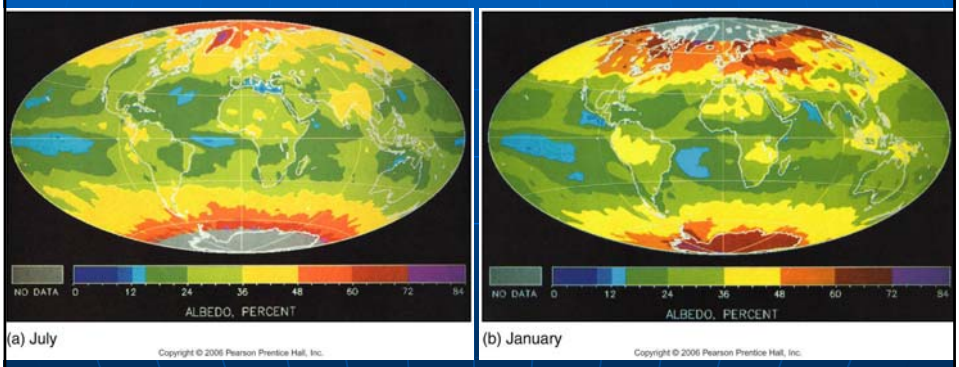
Negative forcings

- Depletion of stratospheric ozone (~0.15 Wm^{-2})
- Changing land use (increased urbanization and deforestation) – increased albedo (~0.2 Wm^{-2})
- aerosols

Albedo



July and January Albedos



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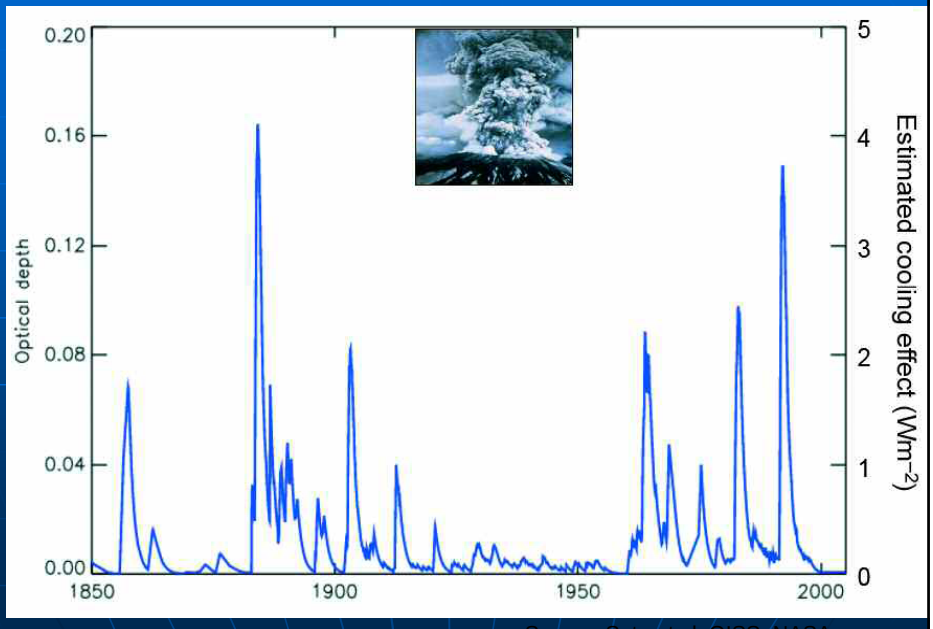
Cooling Effect of Volcanic Aerosols



Sato et al., GISS, NASA

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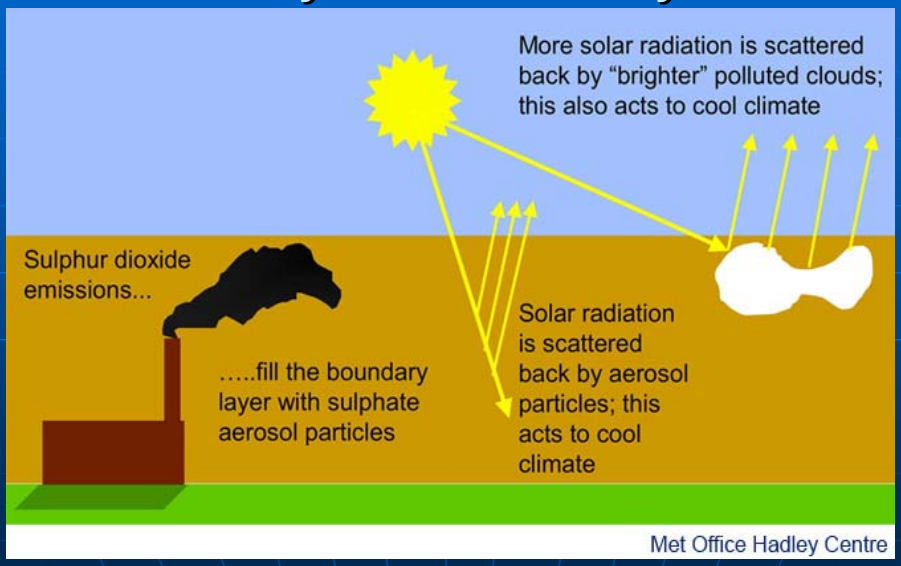
Sulphur aerosols cool climate directly and indirectly



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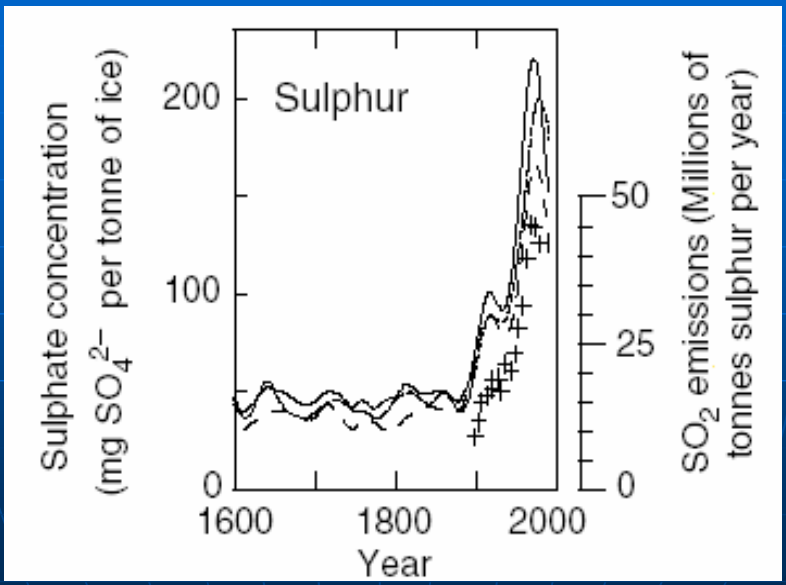
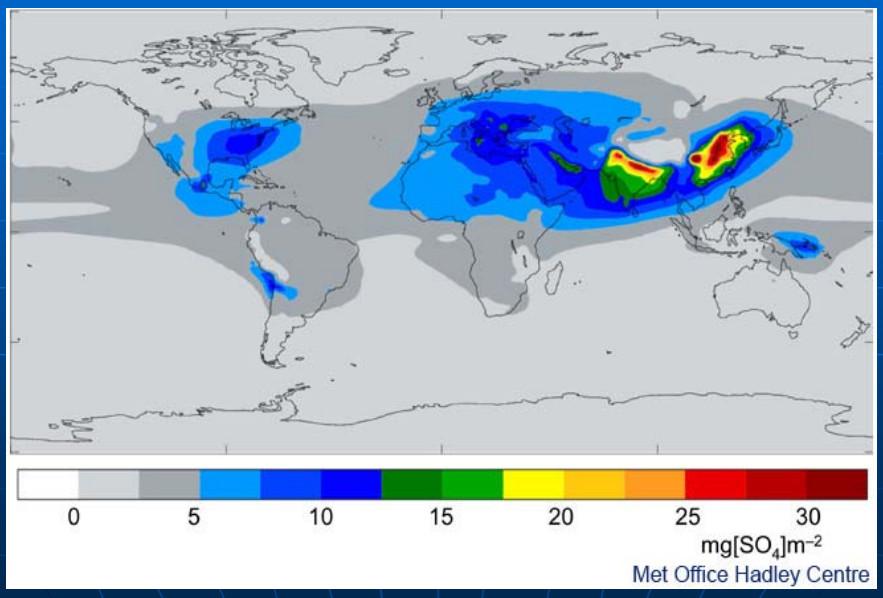
Aerosols



Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Summary for Policymakers*, Cambridge University Press (2001)

Estimated burden of sulphate aerosol, in 1990s



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Effects of aerosols

1. **The direct effect -**
   scattering of solar radiation (cooling of ~ 0.7 Wm^{-2})

2. **The indirect effect -**
   modification of microphysical (and hence radiative) properties of clouds (?? Wm^{-2})

Global Dimming

Estimates of

- 0.4 Wm^{-2} for sulphate
- 0.2 Wm^{-2} for biomass-burning
- 0.1 Wm^{-2} for fossil fuel (non-black)
- mineral dust?

Problems:

Determining concentration and vertical and temporal distribution. There are large uncertainties in these (factor of 2 – 3 in loading and larger in vertical distribution).

The radiative forcing due to aerosols depends on their size, shape and chemical composition – which in turn depend on relative humidity and temperature.

Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2001: Technical Summary of the Working Group I Report*, Cambridge University Press (2001)

Indirect effect of aerosols

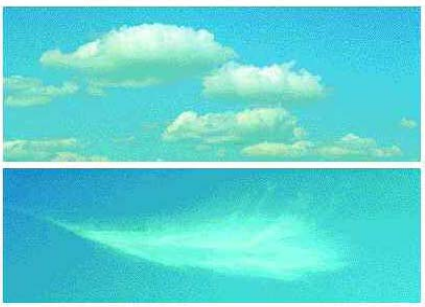
Negative forcing in warm clouds:

1. change cloud droplet concentration and size
2. change precipitation efficiency

Positive forcing in ice and mixed-phase clouds:

unknown ??

Clouds



Low clouds cool climate

High clouds warm climate

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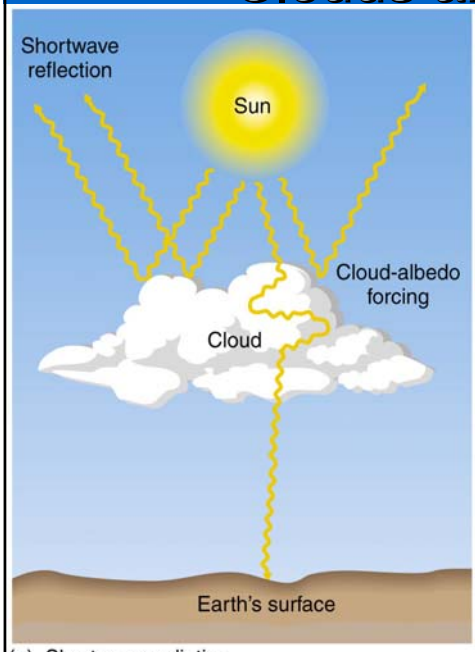
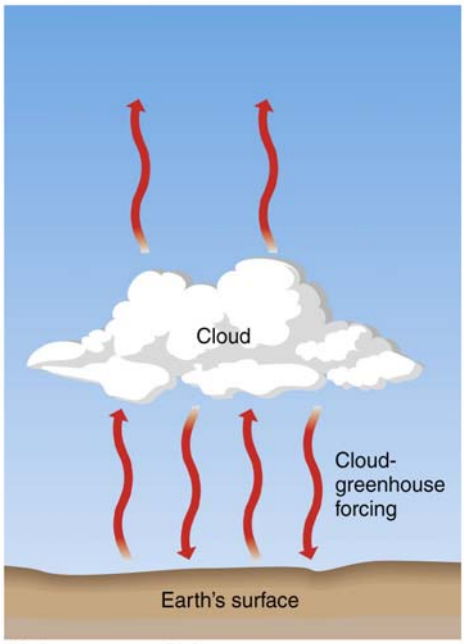
Clouds and Albedo

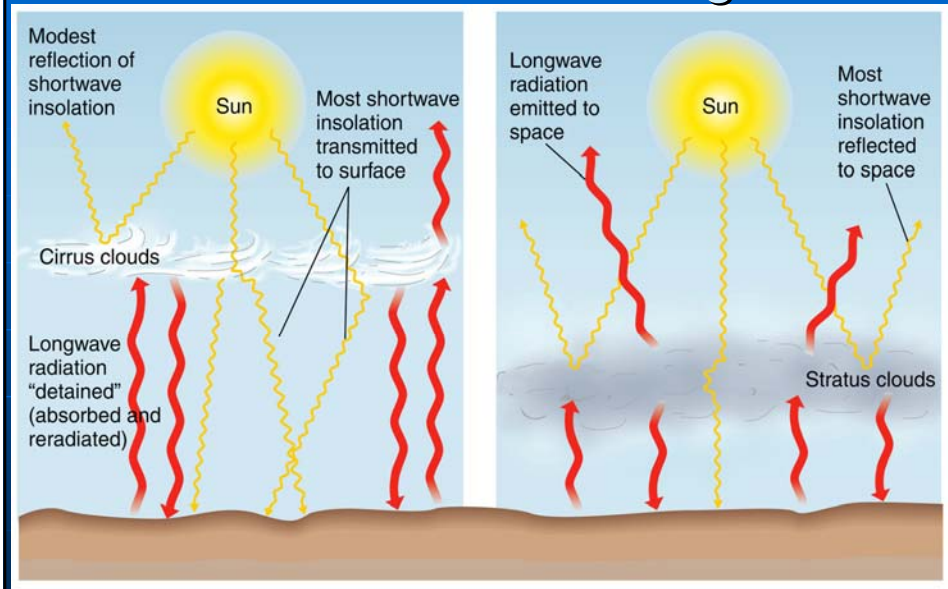


(a) Shortwave radiation



(b) Longwave radiation

Clouds and Forcing



(a) High clouds: net greenhouse forcing and atmospheric warming

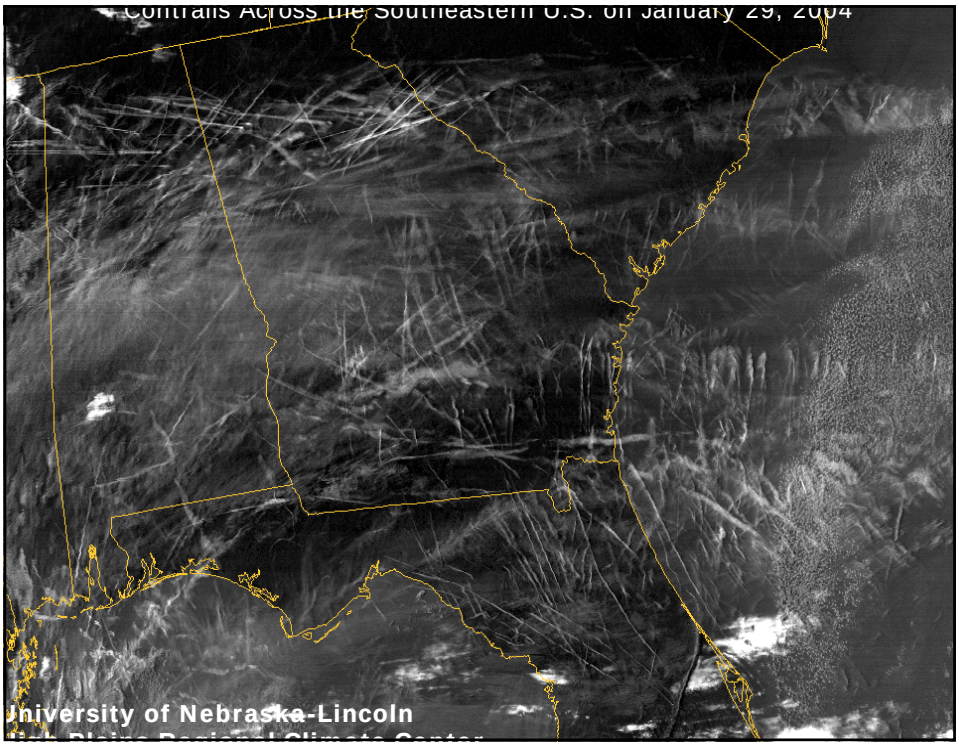
(b) Low clouds: net albedo forcing and atmospheric cooling

Clouds

"As has been the case since the first IPCC Assessment Report in 1990, probably the greatest uncertainty in future projections of climate arises from clouds and their interactions with radiation."

From: Intergovernmental Panel on Climate Change (IPCC), Climate Change 2001: Technical Summary of the Working Group I Report, Cambridge University Press (2001)

Climate change and the greenhouse effect © 2005, Met Office, Exeter,



Clouds

Absorb and reflect solar radiation:
cooling effect

Absorb and emit thermal IR:
warming effect

Net result depends on:
cloud height and thickness
amount of water vapor
size and number of water drops + ice particles
size, type and number of atmospheric aerosols