How will Earth's temp change?

How will different possible effects contribute to this in terms of net radiative change?

Change in radiative forcing, +/-
Look at dust, clouds, other particles, clearly the sun is obscured. Cooling effect is "albedo."

Supported by Mount Pinatubo, 1991-93

Look a bit deeper

Light getting obscured.

\[ s_1 \Rightarrow s_2 \ll s' \]

Extinction = Scattering + Absorption

Scattering \Rightarrow Transmission

Odd reactions
Absorption -> Chemical interactions
OR Physical interactions

= Heat, OR
Content of pipe, OR

Not much absorption in a cloud.

Scatter, etc.

Rayleigh scattering - air molecule
dec

\[ I \propto \frac{1}{r^4} \]

Symmetric favor

\[
\frac{2}{100} \approx 9.4 \times 10^{-8}
\]

Blue at a way from sun

Now atmosphere, no blue sky.
CLOUD DROPS

~ 1 - 30 mm

MIE SCATTERING

\[ d \rightarrow \gamma \]

Not wavelength dependent
White glow around Sun

Once you see a scintillating sun
You need to "morn" point the direction of incidence
\[
\frac{S}{\sin \theta} = \frac{m}{\sin \phi}, \quad \phi = \phi, \quad S = \phi
\]
SAY WHILE SCATTERING IN ALL DIRECTIONS, QUICK AND EARLY IS RECOGNIZED BAC, AND AGAIN, WE NEED TO THINK OF THIS COMPANY TO THE NATION.
WHAT ABOUT PARTICLE PROPERTIES

A35028 MORE

HOW DOES IT LOSE ITS HEAT? 12. RAD, NOON

ABSORBS LESS

1/4 L DOWN NOT AS STRONG AS 5V.

3/4 IN OTHER DIRECTIONS
White

Reflected more

Does not

Wet as WBC

Chemical liquids

Can absorb
GREENHOUSE GASES

Absorption of outgoing infrared radiation leads to

stratification processes.

So-called indirect effects:

- Change in drop size of clouds.
- Increase in water content and lifetime.
- Ice causes changes in albedo.
How big will effects be in possible 2xQG?

Global mean sensitivity

Parameter $A = \frac{\Delta F}{\Delta x}$

Sensitivity can be cast in terms of a single parameter

$A_{2030} = \frac{\Delta 16\, \text{K}}{\text{W/m}^2}$

Lost is law - VIEW

Span every flavour

$18\text{N}^2$ C$\omega_2$, vs.

$C_\theta = (1, \mu, \chi, \beta)$, vs.
Table 6.1: Pre-industrial (1750) and present (1998) abundances of well-mixed greenhouse gases and the radiative forcing due to the change in abundance. Volume mixing ratios for CO₂ are in ppm, for CH₄ and N₂O in ppb, and for the rest in ppt.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Abundance (Year 1750)</th>
<th>Abundance (Year 1998)</th>
<th>Radiative forcing (Wm⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gases relevant to radiative forcing only</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>278</td>
<td>365</td>
<td>1.46</td>
</tr>
<tr>
<td>CH₄</td>
<td>700</td>
<td>1745</td>
<td>0.48</td>
</tr>
<tr>
<td>N₂O</td>
<td>270</td>
<td>314</td>
<td>0.15</td>
</tr>
<tr>
<td>CF₄</td>
<td>40</td>
<td>80</td>
<td>0.003</td>
</tr>
<tr>
<td>C₂F₆</td>
<td>0</td>
<td>3</td>
<td>0.001</td>
</tr>
<tr>
<td>SF₆</td>
<td>0</td>
<td>4.2</td>
<td>0.002</td>
</tr>
<tr>
<td>HFC-23</td>
<td>0</td>
<td>14</td>
<td>0.002</td>
</tr>
<tr>
<td>HFC-134a</td>
<td>0</td>
<td>7.5</td>
<td>0.001</td>
</tr>
<tr>
<td>HFC-152a</td>
<td>0</td>
<td>0.5</td>
<td>0.000</td>
</tr>
<tr>
<td><strong>Gases relevant to radiative forcing and ozone depletion</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFC-11</td>
<td>0</td>
<td>268</td>
<td>0.07</td>
</tr>
<tr>
<td>CFC-12</td>
<td>0</td>
<td>533</td>
<td>0.17</td>
</tr>
<tr>
<td>CFC-13</td>
<td>0</td>
<td>4</td>
<td>0.001</td>
</tr>
<tr>
<td>CFC-113</td>
<td>0</td>
<td>84</td>
<td>0.03</td>
</tr>
<tr>
<td>CFC-114</td>
<td>0</td>
<td>15</td>
<td>0.005</td>
</tr>
<tr>
<td>CFC-115</td>
<td>0</td>
<td>7</td>
<td>0.001</td>
</tr>
<tr>
<td>CCl₄</td>
<td>0</td>
<td>102</td>
<td>0.01</td>
</tr>
<tr>
<td>CH₃CCl₃</td>
<td>0</td>
<td>69</td>
<td>0.004</td>
</tr>
<tr>
<td>HCFC-22</td>
<td>0</td>
<td>132</td>
<td>0.03</td>
</tr>
<tr>
<td>HCFC-141b</td>
<td>0</td>
<td>10</td>
<td>0.001</td>
</tr>
<tr>
<td>HCFC-142b</td>
<td>0</td>
<td>11</td>
<td>0.002</td>
</tr>
<tr>
<td>Halon-1211</td>
<td>0</td>
<td>3.8</td>
<td>0.001</td>
</tr>
<tr>
<td>Halon-1301</td>
<td>0</td>
<td>2.5</td>
<td>0.001</td>
</tr>
</tbody>
</table>
Table 6.2: Simplified expressions for calculation of radiative forcing due to CO₂, CH₄, N₂O, and halocarbons. The first row for CO₂ lists an expression with a form similar to IPCC (1990) but with newer values of the constants. The second row for CO₂ is a more complete and updated expression similar in form to that of Shi (1992). The third row expression for CO₂ is from WMO (1999), based in turn on Hansen et al. (1988).

<table>
<thead>
<tr>
<th>Trace gas</th>
<th>Simplified expression</th>
<th>Constants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Radiative forcing, ΔF (Wm⁻²)</td>
<td></td>
</tr>
<tr>
<td>CO₂</td>
<td>ΔF = 5.35 α ln(C/C₀)</td>
<td>α=5.35</td>
</tr>
<tr>
<td></td>
<td>ΔF = 4.841 β (C₀ - C₀)</td>
<td>α=4.841, β=0.0906</td>
</tr>
<tr>
<td></td>
<td>ΔF = 3.35 g(C₀)</td>
<td>α=3.35</td>
</tr>
<tr>
<td>CH₄</td>
<td>ΔF = 0.036 g(1+1.2C₀+0.005C²+1.4 × 10⁻⁶C³)</td>
<td></td>
</tr>
<tr>
<td>N₂O</td>
<td>ΔF = 0.12 (M⁻N⁻)</td>
<td></td>
</tr>
<tr>
<td>CFC-11</td>
<td>ΔF = 0.25 (X⁻X₀)</td>
<td></td>
</tr>
<tr>
<td>CFC-12</td>
<td>ΔF = 0.32 (X⁻X₀)</td>
<td></td>
</tr>
</tbody>
</table>

f(M,N) = 0.47 ln|1+2.01×10⁻⁵ (MN)⁰.⁷⁵+5.31×10⁻¹⁵ M(MN)¹.⁵²|
C is CO₂ in ppm
M is CH₄ in ppb
N is N₂O in ppb
X is CFC in ppb

The constant in the simplified expression for CO₂ for the first row is based on radiative transfer calculations with three-dimensional climatological meteorological input data (Myhre et al., 1998b). For the second and third rows, constants are derived with radiative transfer calculations using one-dimensional global average meteorological input data from Shi (1992) and Hansen et al. (1988), respectively.

The subscript 0 denotes the unperturbed concentration.

*The same expression is used for all CFCs and CFC replacements, but with different values for α (i.e., the radiative efficiencies in Table 6.7).
There are solar cycles
but these are small

Earth is not mixed

\[ \Delta T_s = x \Delta F \]

Climate sensitivity parameter

\[ x = \frac{\Delta T_s}{\Delta F} \]

Change in surface T

\[ \Delta T_s \]
\[ \frac{1.5 \times 10^{15}}{\text{W/m}^2} \]

Could this be?

If so, a simple way to study change.

- CO\textsubscript{2} inc. repe. \\
  - HVAC should be accessible

  - What about R\textsubscript{22}\textsubscript{42}

  - What about NO\textsubscript{x} caused by warming?

  - What about in homogeneous?
$2.097 \frac{2.4}{2.3 \frac{3.3}{2.3}}$

+ MAJOR STRONGER
OF DIFFERENT

WARM IN O$_3$

NEGATIVE PERCING
LOSSES CAUSE A
NEGATIVE PERCING

DEPLETION IN LOWER
STRATOSPHERE

O$_3$ TRANSKARST

GREENHOUSE GAS