What is the greenhouse effect?
The greenhouse effect is a natural phenomenon.
Present on other planets
The physics

A drastic simplification
Edward Olson Hulburt (1890-1982)

1931:

Carbon Dioxide Heats the Earth

DR. E. O. HULBURT, physicist of the naval research laboratory, Washington, has found conclusive mathematical evidence that the earth's temperature is being warmed by the increased amount of carbon dioxide present in the air. Smoke stacks emit huge volumes of this gas, which is also found in the breath and waste products of humans and animals.
Light = energy
Balance: sunlight & heat loss
Heat loss depends on temperature

Max Planck  Stefan Boltzmann
Our Solar System: Surface & Emission Temperature

predicted vs measured

Venus
Transparent air
Opaque air
Terrestrial heat loss (W/m$^2$)
The greenhouse effect

Energy flux from the sun
\[ F = S_0 (1-A)/4 \]

Planetary heat loss
\[ F = \sigma T_E^4 \]

Transition to radiative

Mixed types of energy flow in air

Vertical energy flow
\[ F = \sigma T_s^4 - F_{DLW} + (c\gamma + L\rho)w \]

Pure radiative in space
Increased greenhouse effect & climate change
Vostok iskjernemålinger
CO2 concentrations (Mauna Loa)
The atmosphere becomes less transparent
The Greenhouse effect

Energy balance:
\[
\frac{(1 - A)}{4} S = \sigma T_E^4
\]
The greenhouse effect + hydrological cycle = true
Energy flows like water...
Atmospheric 'overturning' anomaly

var(a v_z) (above 6.5km)

var(a v_z) (1km - 6.5km)

var(a v_z) (below 1km)

\( \text{var}(a v_z) = 181764 (\text{Pa/s km}^2)^2 + 6030 (\text{Pa/s km}^2)^2 \text{/decade} \)
Atom debate during the 1800s

In 1910, Einstein answered a basic question: 'Why is the sky blue?'

The scattering of light by individual molecules in the atmosphere.
Thank you for your attention!

Vertical T-profile from ERAINT

Lapse rate = -5.07 K/km

Global mean averaged over 1989–2010
Atmospheric emission level $T_{254K}$ and relative humidity $Q_{tot}$