Fourier develops theory of planetary temperatures

Pouillet measures the Solar constant

Tyndall measures IR absorption of greenhouse gases

Stefan & Boltzmann derive black-body radiation equation

Langley & Very measure moon’s temperature

Arrhenius develops first climate model

Milestones of 19th Century Climate Science
Discovery of the Greenhouse Effect

1850s: John Tyndall discovers through a series of experiments that certain gases absorb infrared radiation; Demonstrated existence of the “greenhouse effect”
Heat source A (boiling water)

Thermo-electric pile to compare temperatures

Heat source B (boiling water)

Removable screens for calibration

Four foot brass tube containing gas to be tested

Drying tubes

Gas supply

Galvanometer

Pump
The First Computational Climate Model

1895: Svante Arrhenius constructs an energy balance model to test his hypothesis that the ice ages were caused by a drop in CO2; (Predicts global temperature rise of 5.7°C if we double CO2)
Source: https://chriscolose.wordpress.com/2010/02/18/greenhouse-effect-revisited/
Incoming shortwave energy from the sun

Infra-red is radiated in all directions

Atmosphere (not to scale!)

some sunlight is reflected
Source: IPCC AR4 WG1, p96
Infra-red rays from each point on the earth radiate in all directions. The shallower the angle, the longer their path through the atmosphere.

When the moon is directly overhead, its rays have a shorter path through the atmosphere than when it’s closer to the horizon.
For each column of air, of cross section 1 square meter

\[ S = \text{Solar constant (in Watts per square meter)} \]

\[ M = \text{Net energy flow from neighbouring air columns} \]

\[ N = \text{Net energy flow from neighbouring ground} \]

\[ f = \text{fraction of solar energy absorbed by atmosphere} \]

\[ \sigma = \text{Stefan-Boltzmann constant} \]

\[ g = \text{emissivity of the ground (in the visible spectrum, } g=1-\text{albedo)} \]

\[ e = \text{emissivity of the atmosphere} \]

\[ T = \text{temperature of the ground (dependent variable)} \]

\[ \Theta = \text{temperature of the atmosphere} \]
**Arrhenius’ model results**

**Table VII. — Variation of Temperature caused by a given Variation of Carbonic Acid.**

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<th>Latitude</th>
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</table>

Exponential rise of GHGs

Source: http://www3.epa.gov/climatechange/science/causes.html
Multi-loop systems

Potential Adopters → B → Market Saturation → Adoption Rate → R → Contagion → Adopter Population

Word of Mouth → +

Market share %

Innovators 2.5 %
Early Adopters 13.5 %
Early Majority 34 %
Late Majority 34 %
Laggards 16 %