This Isn't Your Grandparents' Climate

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The Earth
A small, rocky planet,
orbiting a main-sequence G2V Star,
near the rim of a spiral galaxy

The Earth absorbs energy from the sun in the UV-Visible wavelengths

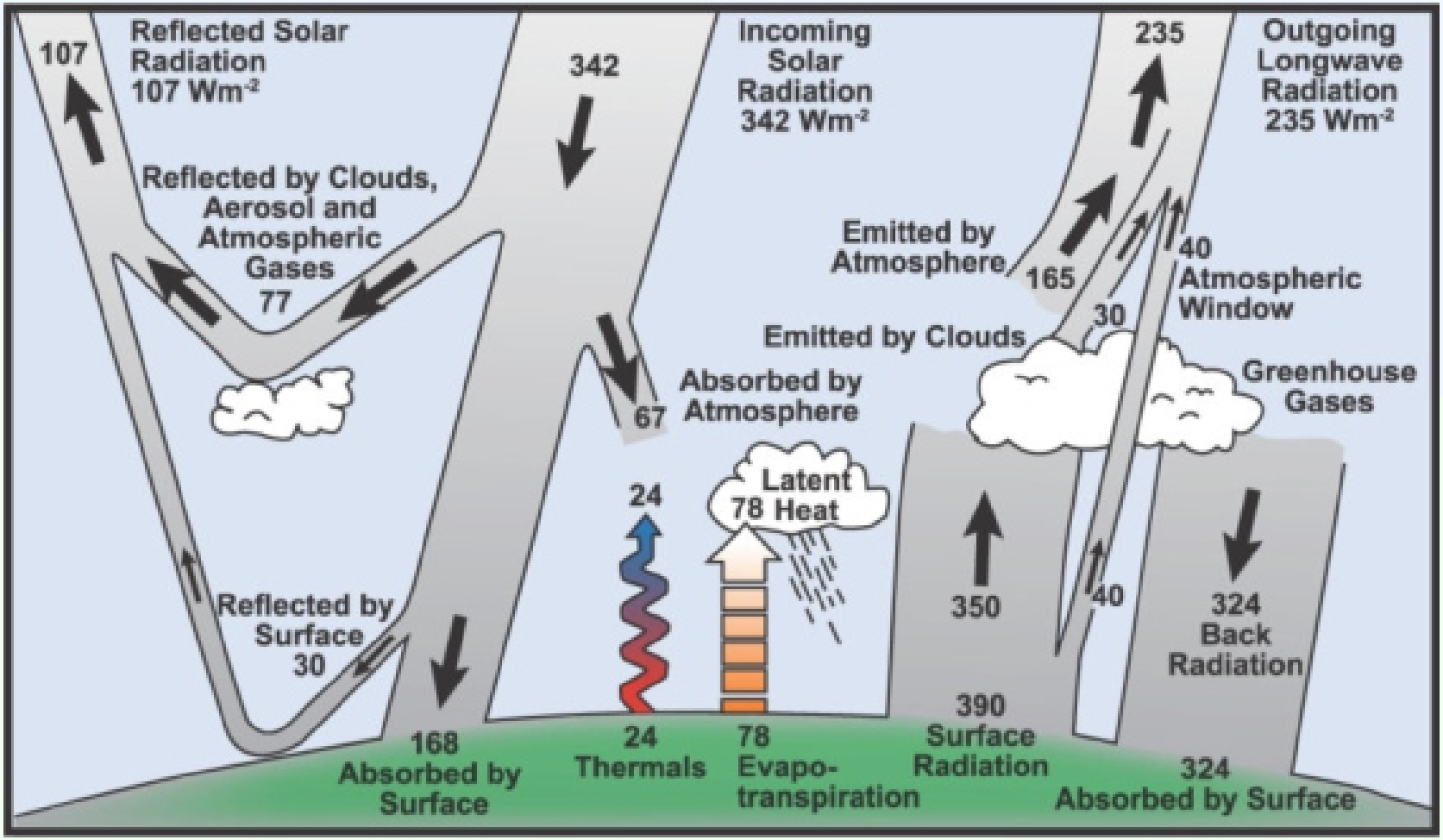
The Earth emits energy to space in the infrared (longwave)

Climate versus Weather

Dr. J. Marshall Shepherd, Past President
of the American Meteorological Society,
used nine simple words
to differentiate weather and climate:

"weather is your mood
and
climate is your personality."

Pre-industrial Planetary Balance
Sunlight Absorbed = Infrared Emitted



https://www.ipcc.ch/report/ar4/wg1/historical-overview-of-climate-change-science/faq-1-1-fig-1/

Be Grateful for Natural Global Warming

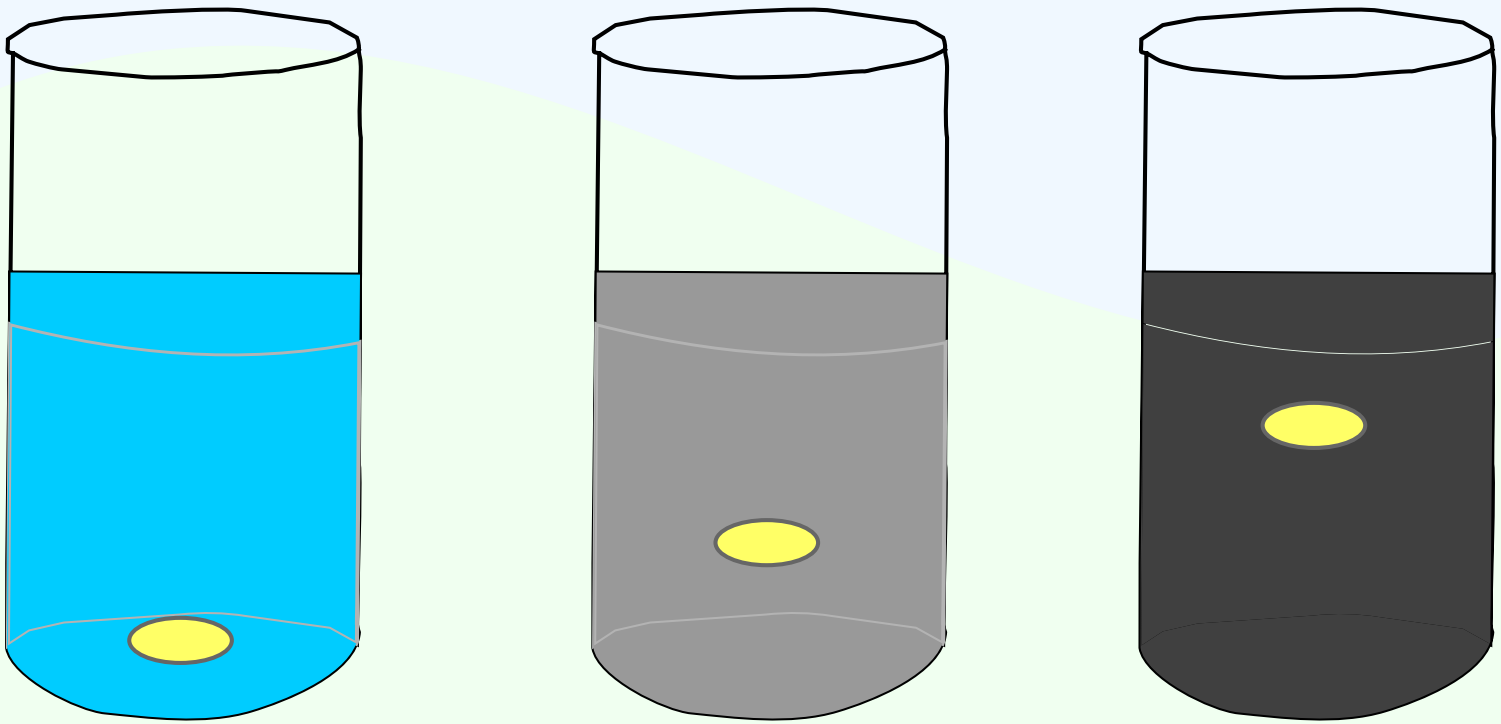
- The Stefan–Boltzmann law states that a black-body emits energy proportional to the fourth power of its temperature.
- The effective radiating temperature of the Earth to balance the absorbed energy from the sun is -18 °C. The actual pre-industrial annual and global mean temperature of the Earth's surface is +15 °C. That's a 33 °C difference.
- The difference is due to the natural balances of carbon dioxide and methane in the atmosphere; CO2 emitted by volcanoes and removed by weathering of rocks and carbonate sea-shells deposited on the ocean floors
- There's no physical reason to infer that the warming doesn't continue to increase with increasing CO2 concentration.

Water

Water is a stronger greenhouse gas than CO2, but the concentration of water vapor that air can hold depends strongly on the temperature. Carbon dioxide and methane thus act as control knobs on how much water vapor is in the atmosphere.

Lacis, A.A., Schmidt, G.A., Rind, D., Ruedy, R.A., 2010. Atmospheric C02: Principal Control Knob Governing Earth's Temperature. Science 330, 356. https://doi.org/10.1126/science.1190653

As ink is added to a cylinder of water a light in the cylinder has to be raised to continue to see it from above.



Conceptual Physics

As CO_2 is added to the atmosphere, the altitude from which the atmosphere radiates to space (or which a satellite can see down to) also increases, just like with the cylinder.

In the troposphere, the higher the altitude, the colder it is, and colder means less energy is radiated to space.

To get the emitted energy back in balance, the temperature at the new altitude has to increase, and that's tied by convection to the surface temperature.

That's the physics for global warming in a nutshell.

HITRAN

It was known much earlier that CO_2 absorbed infrared radiation, but it was at the Air Force Cambridge Research Laboratories (AFCRL) beginning in the late 1960s that the absorption lines were formally cataloged in the HITRAN database.

https://hitran.org/about/

It Doesn't Take a Climate Model to Estimate Global Warming

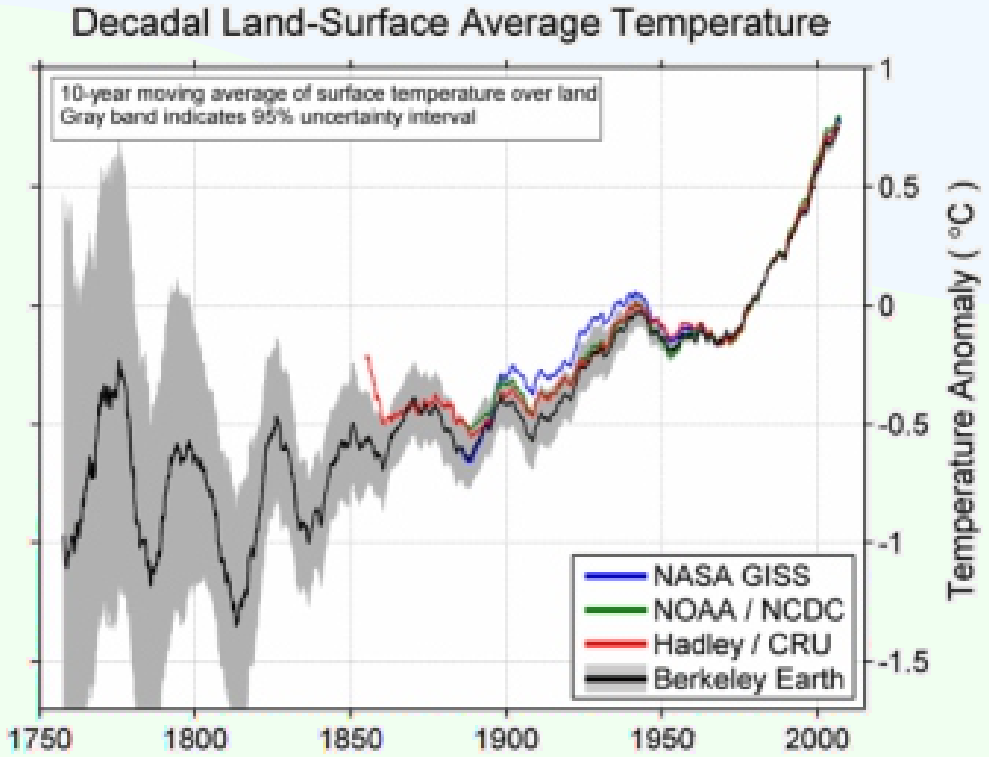
In 1967, Suki Manabe and Dick Wetherald used a one-dimensional (altitude) radiative-convective model to estimate the surface temperature change from doubling the concentration of CO2. Their estimate was 2.4 °C, still solidly within current estimates.

They also noticed the signature of greenhouse warming — a warming troposphere and a cooling stratosphere. That signature matches observations.

https://journals.ametsoc.org/doi/pdf/10.1175/1520-TAW%3E2.0.CO%3B2

Temperature Observations

Changes in temperature from direct measurements and tree ring proxies Have been done by different groups using differing statistical methods.



http://berkeleyearth.org/summary-of-findings/

Both the Physics and the Observations Point to Warming Because of Increasing CO_2, but there is more.

- The total solar irradiance (TSI) is measure from orbit, has little variation, and, if anything, is at a minimum.
- The eccentricity of the Earth's orbit is low and heading for a minimum, cutting out climate change by orbital forcing.

Creating a Climate Model is an Intense Process

Computer scientist Steve Easterbrook embedded himself with a climate modeling group, resulting in a paper:

http://www.cs.toronto.edu/~sme/papers/2008/Easterbrook-Johns-2008.pdf

and a talk

https://www.youtube.com/watch?v=vIiW6ugLHL4

on what he observed

It Takes a Climate Model

- To understand how the planet is responding to energy accumulation.
- Increase surface temperature, melt ice, or store energy into the deep oceans? Only the first acts to restore balance.
- To estimate how ocean and atmospheric circulation might change, changing amount and location of precipitation (rain, snow)
- To attribute how climate change may have contributed to extreme events.

Extreme Events

- There's a new and increasing science of Probabilistic Event Attribution (PEA).
- Ensembles of slightly perturbed weather model runs are done with and without current increases in greenhouse gases.
- The probability of the event is compared for the two cases.

https://unfccc.int/files/adaptation/workstreams/loss_and_damage/application/pdf/attributingextremeevents.pdf

The Two Volume 4th U.S. Assessment Provides an Extensive Review

- Volume I: Science of Climate Change https://science2017.globalchange.gov/
- Volume II: Impacts, Risks, and Adaptation in the United States https://nca2018.globalchange.gov/

TED Talk by Climate Scientist Gavin Schmidt

A short review of emergent processes and model skill

https://www.youtube.com/watch?v=JrJJxn-gCdo