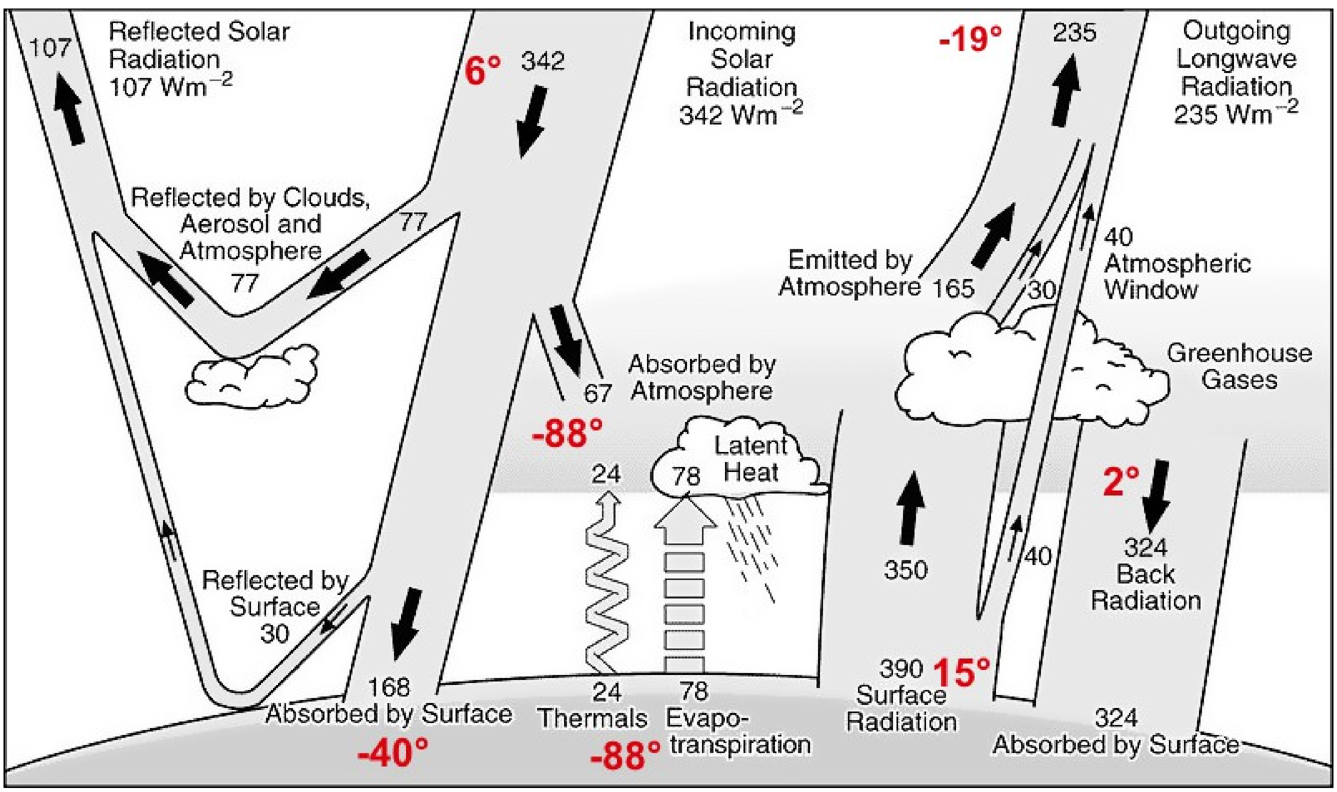
Understanding the Earth's Energy Budget

Readers who follow climate science are probably aware of how sunlight initiates a complicated chain of thermal events. A well-known depiction of this is the old 1997 chart, which we'll use here for the sake of visual clarity.

But let's touch on some other considerations beforehand. In all such depictions of the energy budget, the Earth is regarded as a theoretical "blackbody" whose temperature exactly corresponds to the light it absorbs. 390 watts per square meter (W/m^2) of radiance, for instance, will stimulate a blackbody to reach 15° Celsius. This is not true for real bodies but does make it easy to calculate energy budget temperatures[1].

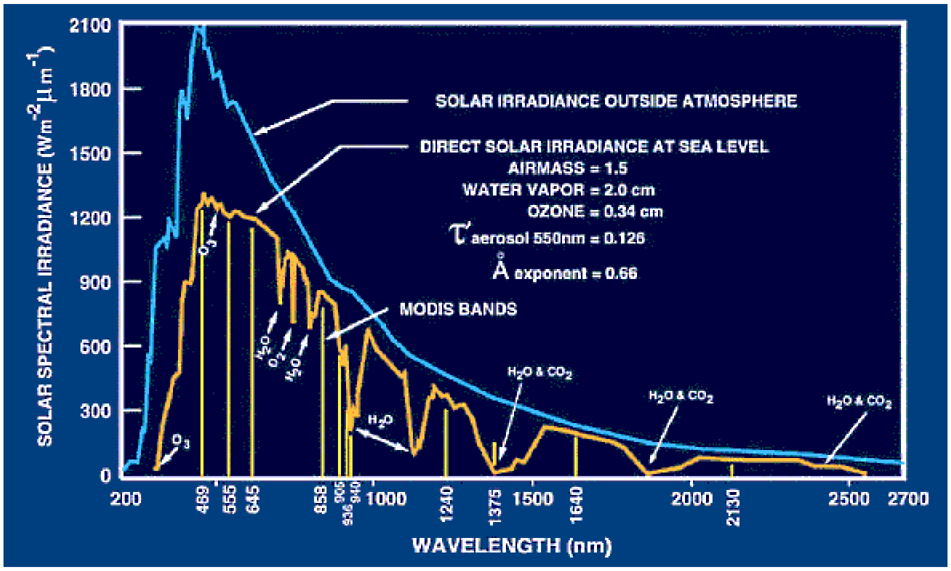
One more thing. Since the Earth is spherical, it has four times the surface area of a flat plate of the same diameter, so it is thought to be able to absorb only 25% of the light it's exposed to. To simplify budget presentations, then, its spherical surface is displayed as a flat plate and sunlight's average intensity on this plate is *cut down* to 25%. The actual sunlight reaching our vicinity has an intensity of about 1368 W/m^2. Now we can proceed.



Here I've superimposed the Celsius temperatures that are tied to several radiant fluxes, something you'll never see in other energy budgets. These provide clues to the interactions.

As sunlight's 342 travels down to the Earth, some of it is reflected by clouds and by the

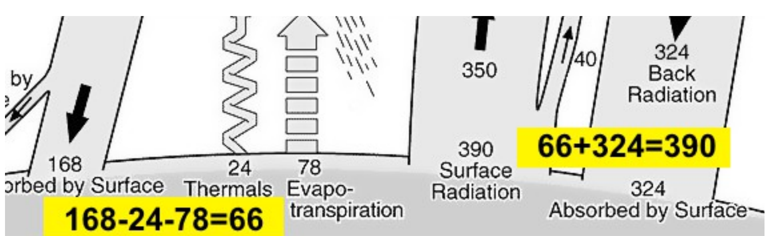
Earth's surface itself. That's a radiant loss for the surface. Another portion is intercepted by certain gases and tiny particles in the air, which this chart depicts.



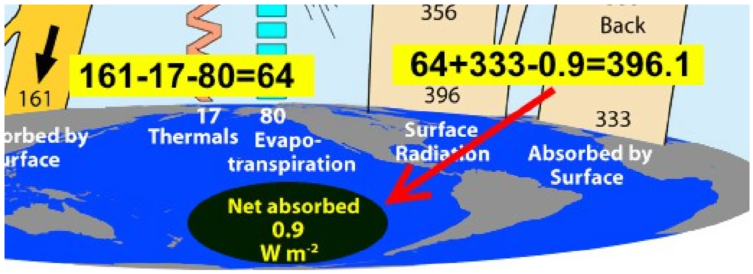
The orange line is an index of the amount of solar radiation reaching the Earth's surface. The closer it is to the blue line, the more surface irradiation occurs. By the same token, dips along this line represent surface losses; gases like H_2O and CO_2 and are responsible for much of that loss.

So the Earth's averaged surface receives what remains of 342, i.e., 168 W/m², enough to raise its temperature to minus 40 degrees. That's what it gains. This is countered by a loss, however, because a total of 102 W/m² (24 plus 78) are removed from the surface by non-radiative mechanisms. Arithmetically, this leaves the surface's energy with a piddling 66 watts per square meter and a consequent temperature of minus 88 degrees.

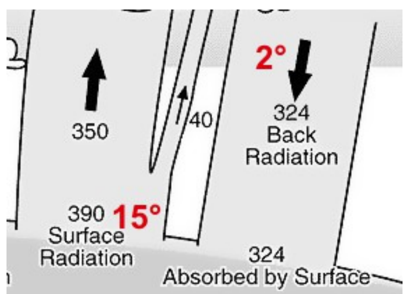
Minus 88 degrees on the Earth's average surface? Yes. Watch how budgets work. If the surface is left with 66 W/m² after non-radiative losses, ask yourself what it needs in order to emit 390 W/m² – that is, what a blackbody would emit at 15°, which is regarded as the Earth's average temperature. The answer is simple: It needs 324 W/m² more. And that's exactly how it plays out in these budgets.



The result of this arithmetic is no happy coincidence. Indeed, it allows climate scientists to claim that the radiant tally is "balanced." To prove this point, let's look at a detail of a more updated budget. But I must first call your attention to a modern feature: "**Net absorbed**." The idea here is that the oceans are overheating year by year but aren't *showing* it yet in terms of temperature or radiation, so this extra 0.9 is sort of being tucked away for now. Okay, here it is.



Do you see? All the fluxes are different here but the same arithmetical trick of the trade is used. That 396 result means 16° this time. That isn't the most important detail to observe however. No, the take-home lesson is how this numerical method controls the outcome. Because look at the downwelling radiation from greenhouse gases. The temperature of the atmosphere must be at 2° in order to emit 324 W/m² to the surface. Hold that thought.



Recall that energy budgets are all about averages.

- Averaged sunlight all over the globe and throughout the year.
- Averaged reflections from clouds.
- Averaged absorption by the atmosphere.
- Averaged absorption by the surface.
- **Averages fix all of these factors as a constant.**

To review, the original 342 of sunlight becomes 235 by reflection, and then 168 due to atmospheric interception, leaving a constant 168 for the surface, ***which responds in kind***, reaching a temperature of minus 40° and constantly radiating 168 W/m² itself.

How then shall we evaluate the 324 W/m² that's constantly beaming down from greenhouse gases? In this odd case the surface responds by emitting *more than* 324. The previous example demonstrated radiative equality: 168 stimulus, 168 response. Why not the same for back radiation, therefore? What's more, how can a 2° body warm a minus 88° body to 15 degrees?

Well, frankly it can't. But as you've already seen, there's a method to this madness. Climate scientists need to add 324 to 66 in order to get 390 (or whatever the goal demands), and so they do. Omitting the ***temperatures involved*** , of course, helps the trick immensely.

But still, if you believe that continuous radiation from a 2° body can heat a minus 88° body to 15 degrees, then bless your trusting heart. Maybe you should also try barbecuing your burgers on ice cubes.

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Notes

[1] The blackbody formula states that $(W/m^2 \div 0.0000000567)^{0.25}$ = temperature in Kelvin