

Some recent Earth observations are spreading new alarm among climate scientists. The observations have been reported in many scientific and environmental outlets, and have provoked a fair amount of confusion and some misrepresentation. Some scientists have been informally calling these observations “the most important climate risk you’ve never heard of.” But they have not yet been featured in major media outlets, nor much penetrated climate policy discussions.

In short – The Earth is getting darker. Climate models project this, but it appears to be happening faster than models project. This suggests that the “hottest” models – those in which climate temperatures are most sensitive to increases in greenhouse gases (GHGs), which have been often lately disparaged as alarmist, might be closest to right.

Repeating some basic climate science to put this in context, the Earth is heated by incoming sunlight, mostly in the visible range of wavelengths, and cools by emitting longer-wave, infrared light. The Earth’s surface temperature and climate depend on the balance between these. Human-driven climate change is happening because increasing concentrations of GHGs in the atmosphere are heating the surface by impeding the outgoing infrared light.

There are two wrinkles to this basic story that are necessary to understand what “getting darker” means and why it’s important. First, the Earth doesn’t absorb all

the sunlight coming in, only about 70% of it. The remaining 30% is reflected. That 30% number is called the Earth's "albedo," or reflectivity. It's the reflected sunlight that makes the Earth look so beautiful and bright in those old photographs from the Apollo missions. How much is reflected versus how much is absorbed depends on how light or dark the Earth is overall. If you cover more of it with bright clean ice or snow or thick white clouds, more light is reflected; cover more of it with dark forests or asphalt and less is reflected, more absorbed. (And for that matter, spraying a little reflective mist in the upper atmosphere will also make the Earth brighter and cool it.)

The second wrinkle is that knocking the system out of balance by increasing atmospheric GHGs doesn't just do one thing. There are a bunch of feedbacks that affect the balance between heating and cooling – positive feedbacks that amplify an initial heating, and negative ones that oppose it. A particularly important feedback in the climate system is that heating from $CO_2$ and other GHGs puts more water vapor (also a greenhouse gas) into the atmosphere and changes the quantity and appearance of clouds. How GHG-driven heating changes clouds is one of the biggest uncertainties in climate modeling, accounting for much of the uncertain range in climate sensitivity, presently estimated as 2.5 to 4.0°C. (That's the calculated global average heating from doubling atmospheric $CO_2$ from its preindustrial concentration of about 280 parts per million).

We know the Earth is getting darker from satellite observations. Between 2001 and now, the fraction of sunlight reflected by the Earth (approximated as "about 30%" above) has decreased from 29.3% to 28.6%. That change – an additional 0.7% of incoming sunlight being absorbed by climate system instead of reflected – is huge. It adds about as much to the Earth's energy imbalance as all the $CO_2$ human activities have ever emitted. It's similar to the change in reflectivity that would come from scenarios of stratospheric aerosol injection (SAI) that would aim to cool the Earth a degree or so – except that it's in the wrong direction.

The causes of the darkening are not fully understood yet, but it looks like there are two big ones. First, worldwide cleanup of sulfur pollution. This pollution, mainly from burning coal and oil containing sulfur impurities, causes severe environmental and health harms. It also makes a reflective mist of aerosols that cools the Earth, albeit less effectively than if it were in the upper atmosphere where it would stay longer and do less harm. This pollution is presently masking or offsetting around half a degree to one degree of global heating from GHGs. Cutting this pollution – which is

underway worldwide – saves lives and reduces acid rain and other environmental harms. It also makes the Earth a little darker and so turns up the heat. The second cause is a decrease in the amount and brightness of clouds, probably due to a feedback from greenhouse heating. As I mentioned above, climate models incorporate these feedbacks, but there's a lot of uncertainty about how they work and how big they are. The new observations suggest the effects of both cleaning up reflective sulfur pollution and feedback-driven changes in clouds, are stronger than was previously thought.

What does this mean? First, if these results check out and the observed trends persist, it's a big additional source of alarm. The results can make more sense of the otherwise puzzling rapid recent acceleration in the observed rate of global heating. They also suggest near-term heating could be more severe than current projections – especially with what looks like a big El Nino event just getting started. Strong El Nino events can raise global temperatures as much as 0.2C.

Second, the results show the importance of considering the multiple interacting factors that are driving changes in the climate and Earth system. Increasing greenhouse gases are the root cause driving global heating, but these observations show how other, proximate causes can intervene – the feedbacks from resultant change in clouds and the decreased masking of GHG heating as other, cooling pollutants are decreased – and drive faster changes. Nothing about these new results reduces the imperative to cut GHGs. Emissions need to be rapidly cut, and old emissions removed from the atmosphere. But these changes in reflectivity are happening faster than can be stopped by cutting emissions, pointing to the need to also consider responses that target reflectivity directly. This might mean more targeted control of aerosol pollutants, prioritizing cuts to those that both heat the Earth and impair air quality, or slowing cuts in Sulfur emissions in remote locations such as the middle of the ocean, where they do less health and environmental harm (less, not none). It also means seriously investigating the prospect of interventions that directly target albedo, such as injecting reflective aerosols in the upper atmosphere, even while recognizing that these can only be temporary and imperfect climate responses and present serious new governance challenges. The UCLA Emmett Institute's ESI Project looks at the law and policy challenges of these and other large-scale interventions in the Earth system.

Finally, these results present still more opportunities for confusion and deception about climate change and responses. Complex environmental interactions like feedbacks, or pollutants whose effects are a mix of harms and benefits, are hard to

get across in loud policy arguments and easy to misrepresent. These results have already been spun as suggesting that most heating since 2000 is not caused by GHGs, or as another supposed example of climate scientists reversing themselves or suppressing information – neither of which (if I need to say it) is correct. These results give another window into particular, long recognized uncertainties in the climate system. They don’t represent any reduction in the acute need to cut emissions, but rather may strengthen the case that extreme emissions cuts, and other well targeted responses are both needed, and soon.