Novel strategies to slow climate change and fight global warming

New ideas (4) on how to cool Gaïa

Modification of cirrus clouds to reduce greenhouse effect and increase outgoing long wave radiation

Read the open source paper: http://dx.doi.org/10.1016/j.rser.2013.12.032
MING Tingzhen, de_RICHTER Renaud, LIU Wei, and CAILLOL Sylvain. Fighting global warming by climate engineering: Is the Earth radiation management and the solar radiation management any option for fighting climate change? *Renewable and Sustainable Energy Reviews*, 2014, vol. 31, p. 792-834.

SRM-based methods address a problem of reduced heat long wave output (GHGs trapping IR) by reducing short wave radiation input (reflecting sunlight to space)

In the absence of tangible progress in reducing greenhouse gas emissions, the implementation of solar radiation management has been suggested as a measure to buy time and cool the planet, but it does not reduce CO_2 emissions.

Because of the possible drawbacks with sulfate aerosols, Mitchell and Finnegan (2009) proposed modifying cirrus cloud coverage by increasing ice crystal sizes in these high clouds by cloud seeding agents such as silver iodide.

Mitchell D.L. and Finnegan W. Modification of cirrus clouds to reduce global warming. (2009) Environ. Res. Lett. **4**, 1-8.
www.researchgate.net/publication/228365460_Modification_of_cirrus_clouds_to_reduce_global_warming/file/3deec525d50f428433.pdf

Compared to other suggested climate engineering methods, the one explored by Mitchel et al has the advantage of addressing the long wave radiation directly, which is the part of the spectrum that is being perturbed by anthropogenic greenhouse gases, meanwhile SRM strategies address the incoming short wave radiation by a parasol effect.

A conceptual shortcoming of SRM-based methods is that they implicitly address a problem of reduced heat output (GHGs trapping thermal radiation) by reducing radiation input (reflecting sunlight to space).

Two types of climate engineering have been recognized: carbon dioxide removal (CDR) strategies and solar radiation management (SRM).

A third climate engineering approach proposed in 2009 by Mitchell and Finnegan, is to directly address the problem of increased troposphere heat content by increasing its heat output (i.e. shifting its thermal equilibrium in favor of cooler temperatures).

If it were possible to modify the troposphere's heat balance to reduce surface temperatures, this would offset the effect of heat-trapping GHGs in a more direct fashion.

This third approach might be called earth radiation management (ERM).

Under this definition, reducing GHG emissions and CDR are in effect ERM methods.

Reducing the global coverage of cirrus clouds can cool the Earth

The international consensus about limiting the average temperature increase to 2℃ was confirmed once again at the meeting of the parties to the United Nations Framework Convention (UNFCCC) in Cancun. But GHGs emission trends and the corresponding reduction announcements challenge the credibility of this target.

Estimates in the World Energy Outlook (2010) show that while it is indeed still possible to meet this target via conventional emission control measures, dramatic emission cuts will be imperative in the near future. A postponement of these emission reductions would involve a drastic increase in mitigation costs and would seriously undermine the probability of staying within the 2℃ target.

Discouraged by the lack of progress in international negotiations to limit greenhouse gas emissions, some scientists have proposed climate engineering or geoengineering has a « plan b » to cool down the Earth.

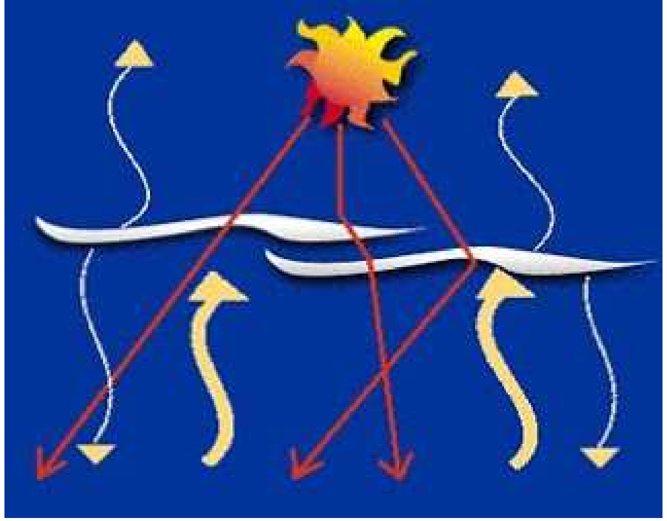
Geoengineering can be implemented rapidly, and at projected costs much lower than the alternatives. However, research shows that it is not possible to simultaneously bring about present temperature and precipitation conditions. Also climate engineering solutions would be very difficult to implement, politically, because costs and benefits would be unevenly distributed across countries.

However Mitchell et al (2009 and 2011) suggested that regional or global surface temperature could also be lowered by **reducing the global coverage of cirrus clouds, thereby increasing emission of outgoing long wave radiation to space rather than reducing incoming solar radiation...** That was confirmed in 2013 by Storelvmo et al.

Muri H. Kristjánsson J.E. Storelvmo T. Mitchell D.L. and Pfeffer M.A. Model results of cirrus cloud modifications in a climate engineering framework. 2012 European Aerosol Conference, Granada, Spain. http://www.eac2012.com/EAC2012Book/files/1079.pdf

Storelvmo T. Kristjansson J.E. Muri H. Pfeffer M. Barahona D. & Nenes A. Cirrus cloud seeding has potential to cool climate. *Geophysical Research Letters*, 2013, *40*(1), 178-182. http://folk.uio.no/jegill/papers/Storelvmo_etal_2013_GRL.pdf

Cirisan A. Spichtinger P. Luo B.P. Weisenstein D.K. Wernli H. Lohmann U. & Peter T. Microphysical and radiative changes in cirrus clouds by geoengineering the stratosphere. *Journal of Geophysical Research: Atmospheres*, 2013, *118*(10), 4533-4548. http://onlinelibrary.wiley.com/doi/10.1002/jgrd.50388/abstract



Less heat is trapped if cirrus clouds are reduced

STORELVMO ET AL.: CIRRUS CLOUD SEEDING CAN COOL CLIMATE

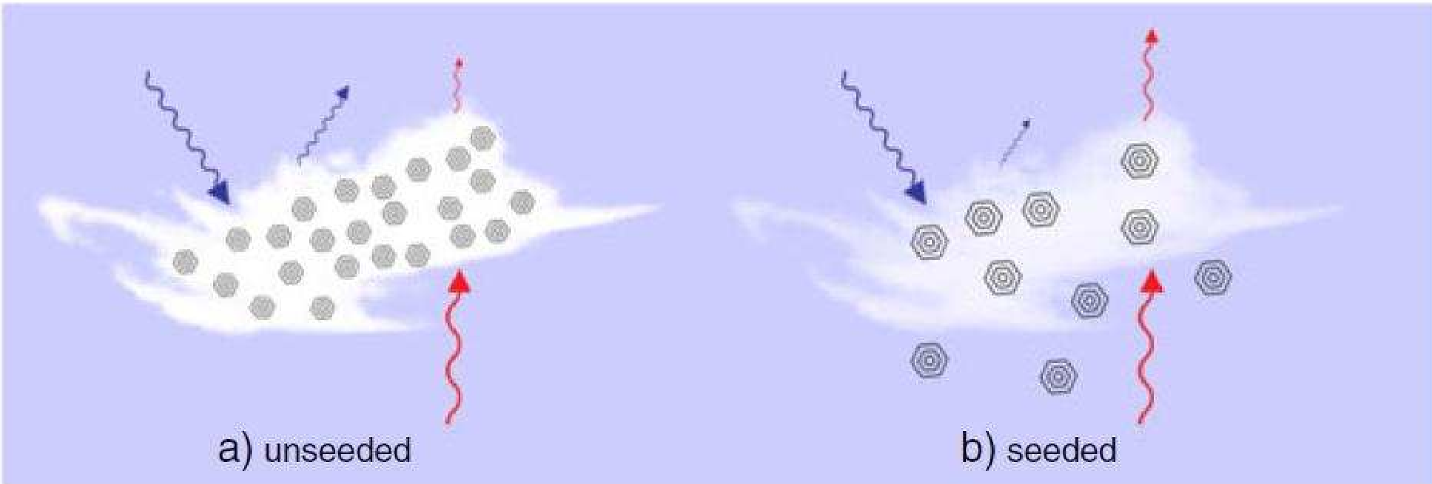


Figure 1. Conceptual schematic of changes in cirrus cloud properties in response to seeding. Red arrows represent longwave (LW) radiation and blue arrows represent shortwave (SW) radiation. The seeded cirrus clouds on average reflect slightly less SW radiation back to space, but also allow more LW radiation to escape to space, and the latter effect dominates.

Larger ice crystals would reduce cirrus optical thickness and shorten cloud lifetimes through increased ice crystal sedimentation velocities. This mechanism would yield a smaller greenhouse effect.

The earth radiation management approach

In 2011 Mitchell described an ERM approach pertaining to cirrus clouds and to test this hypothesis against new, more reliable cirrus cloud measurements.

David L. Mitchell, Subhashree Mishra and R. Paul Lawson (2011). Cirrus Clouds and Climate Engineering: New Findings on Ice Nucleation and Theoretical Basis, Planet Earth 2011 - Global Warming Challenges and Opportunities for Policy and Practice, Prof. Elias Carayannis (Ed.), ISBN: 978-953-307-733-8, InTech, DOI: 10.5772/24664. Available from: http://www.intechopen.com/books/planet-earth-2011-global-warming-challenges-and-opportunities-for-policy-and-practice/cirrus-clouds-and-climate-engineering-new-findings-on-ice-nucleation-and-theoretical-basis

Like the SRM methods, this ERM method does not address ocean acidification, and effective GHG mitigation strategies along with possibly CDR methods would be needed to responsibly address the problem of global warming.

In this 2011 paper, Mitchell provides in Section 2 an overview of the cirrus cloud climate engineering idea, which is described in greater detail in MF2009. Section 3 presents new research findings that test the conceptual foundation of this ERM approach. These findings are not only relevant to climate engineering, but are relevant to basic research on cloud-aerosol-climate interactions as well. Section 4 addresses the potential of over-cooling the planet and the need for climate monitoring. Some possible social, political and economic ramifications of climate engineering are discussed in Section 5, a summary with conclusions is given in Section 6.

Cirrus clouds are similar to GHGs in that they trap outgoing long wave radiation OLR

Sanderson et al. (2008) identified physical processes responsible for changing climate sensitivity (i.e. the equilibrium response of global-mean surface temperature to CO_2 doubling). The most important process affecting climate sensitivity was entrainment associated with deep convection, which strongly affects water vapor amounts in the upper troposphere. The second most important process was the ice fall speed from cirrus clouds, which affects the cirrus cloud life cycle and cloud coverage, the cirrus cloud optical depth and the upper troposphere water vapor. These findings imply that upper troposphere water vapor and cirrus clouds are having the greatest impact on climate sensitivity. Thus, an effective ERM strategy might target these components of the climate system which regulate outgoing longwave radiation, or OLR.

…/…

Cirrus clouds are similar to GHGs in that they trap OLR by absorbing/emitting upwelling thermal radiation back towards the surface, which has a warming effect on climate. This GHG effect of cirrus clouds becomes stronger the higher they get since the effective temperature at which the Earth radiates thermal energy to space depends on the temperature of the overlying clouds. An abundance of cirrus will cause this effective temperature to be relatively low (similar to the temperature of the cold cirrus clouds). This reduces the OLR and traps thermal radiation below the cirrus clouds that would otherwise escape to space. In addition, cirrus clouds also reflect sunlight back to space (a cooling effect on climate), but this albedo effect is less efficient than their GHG effect. Thus, cirrus clouds have a net warming effect on the earth's climate (Hartmann et al., 1992; Chen et al., 2000). It follows then that the most effective way to increase OLR may be to reduce the cloud cover of the highest, coldest cirrus clouds.

…/…

While lower in concentration than the natural ice nuclei, the concentration of the cloud seeding aerosol should be sufficient to prevent the ice super saturation from rising significantly as an air parcel ascends. This will insure that primarily only the seeded ice nuclei will produce ice crystals and that these crystals will grow to larger sizes than ice crystals produced by the more numerous natural ice nuclei. That is, a given amount of cloud condensate distributed among fewer ice crystals results in larger ice crystals. These larger, more massive ice crystals will have larger fall velocities than the natural ice crystals.

Higher fall speeds will result in shorter cloud lifetimes, less cloud coverage, lower ice water paths and lower cloud optical depths. This would allow more OLR to escape to space.

ERM by cloud cirrus modification might cool the planet only for a limited period of time

According to Mitchell et al, while cirrus cloud climate engineering approach may appear promising, it is absolutely critical to understand that this is not a “silver bullet” for the global warming problem.

To think in these terms would be a prescription for sudden, catastrophic climate change, since there is only so much “wiggle room” in the climate system.

That is, a successful modification of cirrus clouds at temperatures below -40℃ might cool the planet for a limited period of time, but not indefinitely, and at current GHG emission rates it would not take long for any cirrus OLR (outgoing long wave radiation) benefit to be neutralized.

A “business as usual” GHG emission scenario would result in a sudden and dramatic increase in global temperatures once any cirrus OLR benefit was exhausted, and such a temperature increase might make human life on Earth unbearable.

Therefore this cirrus cloud geoengineering method may “buy time” for societies to transition to renewable non-carbon fuels and to implement carbon sequestration methods that address ocean acidification, but it should never be viewed as a solution to global warming.

The greenhouse effect is due to **long** wave IR radiation

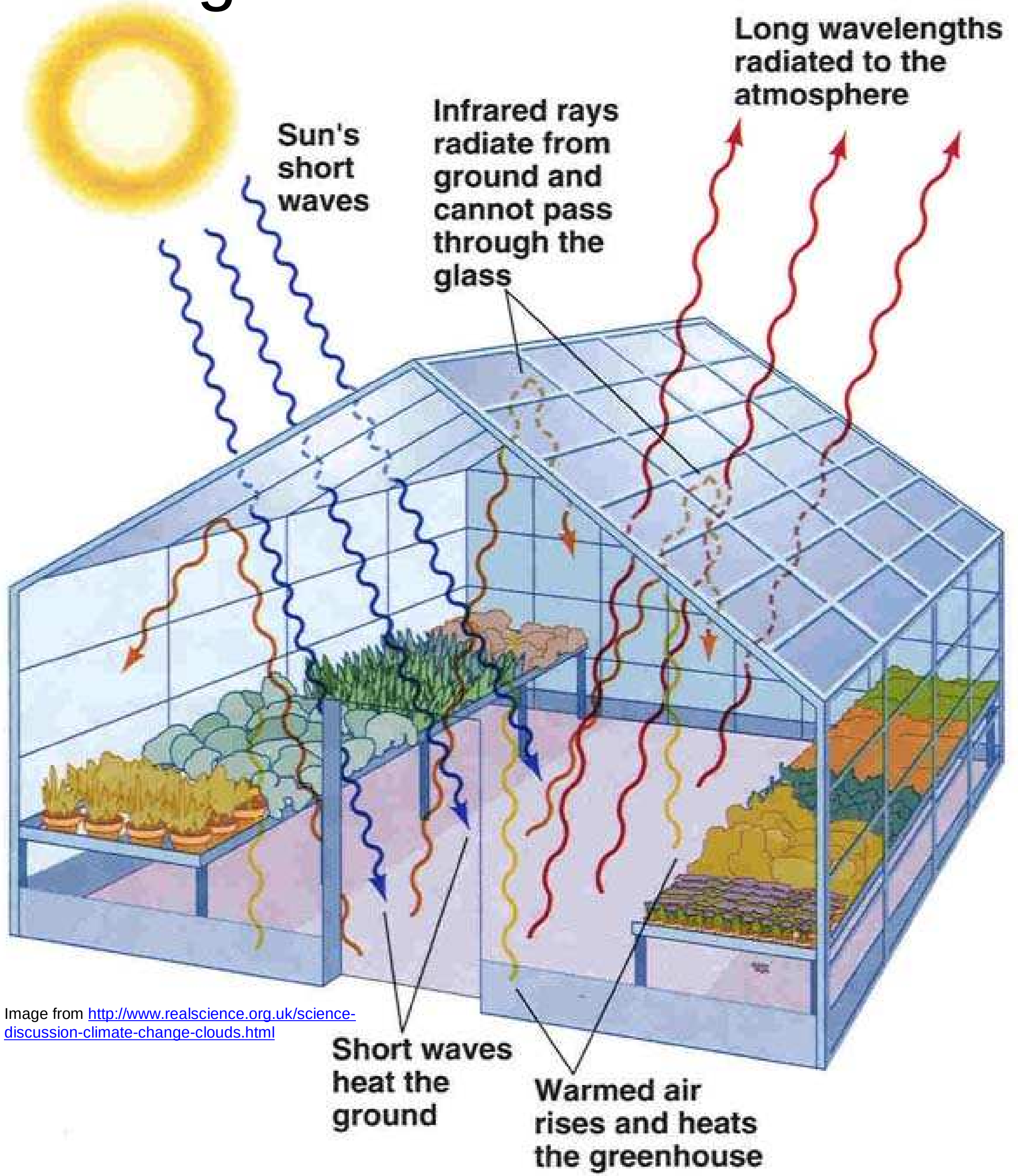


Image from http://www.realscience.org.uk/science-discussion-climate-change-clouds.html

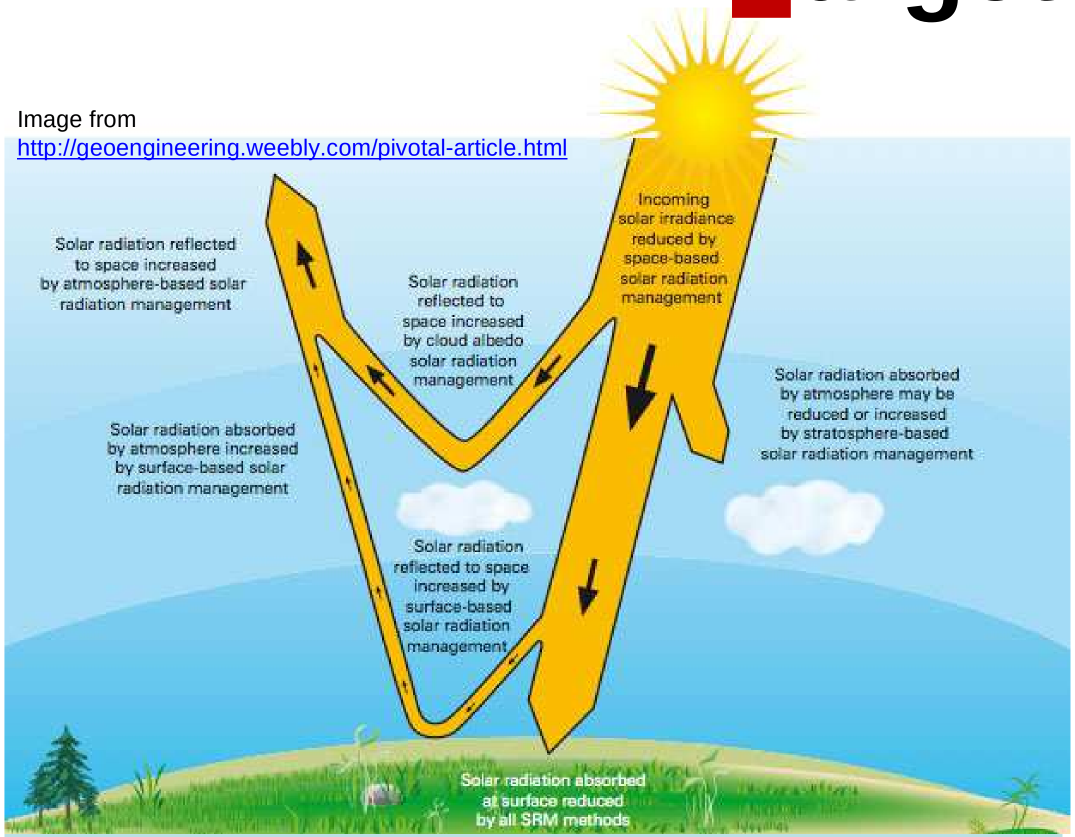
Image from http://ozclimatesense.com/category/green-house-effect-on-your-health/

Greenhouse gases (GHGs) are good at absorbing long wave length heat radiation and so the GHGs heat up.
Warm GHGs in the sky re-emit heat radiation in all directions, so some go up to the outer space and some go down back to the Earth's surface. So, not all the heat (Infra-Red radiation) leaves the planet. This is how the Earth gets warmer by greenhouse effect.

Earth radiation management (ERM) aims to increase outgoing long wave radiation (IR release to the outer space).

Targets for ERM and SRM

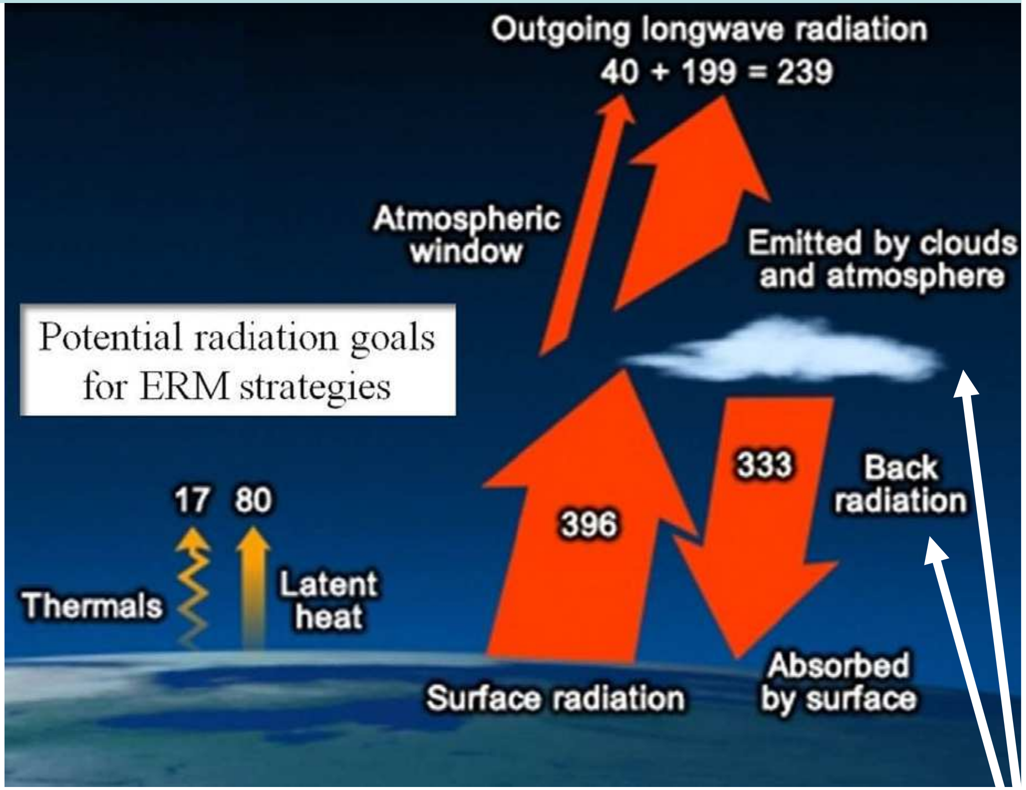
Image from
http://geoengineering.weebly.com/pivotal-article.html



Incoming Solar **SHORT** wave radiation targeted by **SRM**

also called **Sunlight Reflection Methods**

Outgoing EARTH **LONG** wave radiation is targeted by **ERM**



Reducing back radiation from cirrus clouds will allow more long wave heat radiation energy to escape to the outer space.

A way to **cool the Earth**, is to favor technologies that increase the outgoing long wave radiation, thus reducing cirrus clouds cover will reduce back heat radiation

The basis of Earth Radiation Management and Atmospheric Convection Management

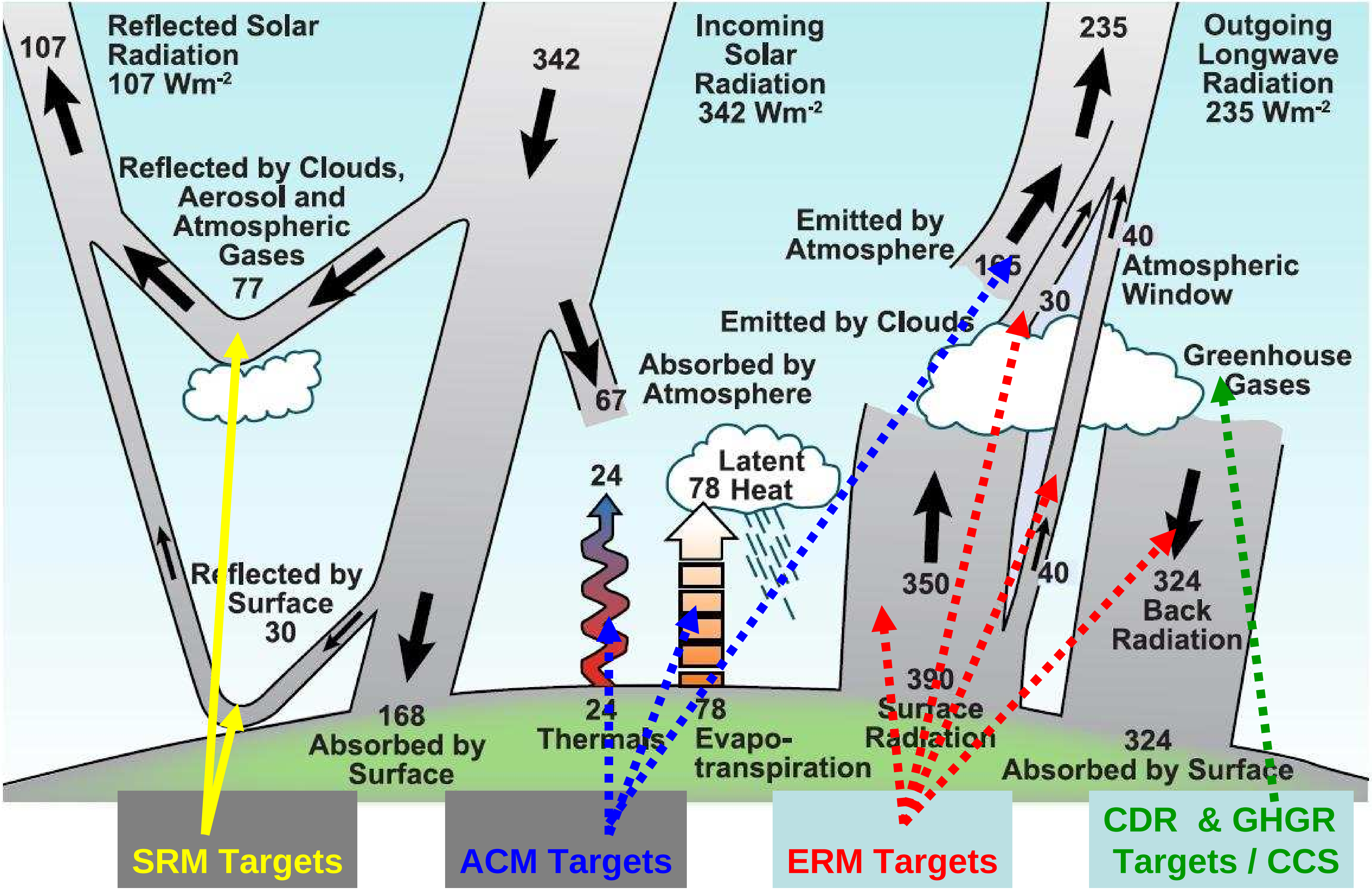
GHGs act as very good insulators that prevent heat to escape from the planet atmosphere to the outer space.

Taking the example of a house/building: to have a good insulation, a thick insulator layer is indeed needed, but it is mandatory to prevent thermal bridges (conduction process).

It is the contrary in the case of the Earth!
Gaïa experiences global warming because **the insulation provided by GHGs** is **too** good and **too** powerful.

A solution **to cool down the planet** can be to create "IR thermal shortcuts" or "radiative thermal bridges", and "convection bridges or shortcuts" between the surface and altitude in order to allow the heat to be evacuated to space.

Atmospheric convection enhancement (i.e. increasing natural convection by atmospheric vortex engines, solar chimneys, energy towers, …) transfers heat from surface to outer space



Solar radiation management SRM and Carbon dioxide removal CDR are considered Geoengineering. CDR is complementary from Carbon capture and sequestration CCS. Greenhouse gas removal GHGR targets the other GHGs (CH_4, N_2O, CFCs, etc.). SRM targets **short** wave radiation. Earth radiation management ERM targets **long** wave radiation. Atmospheric convection management ACM targets to enhance all natural atmospheric convection processes… Like ERM, as a result, ACM increases heat release to the outer space and cools the Earth

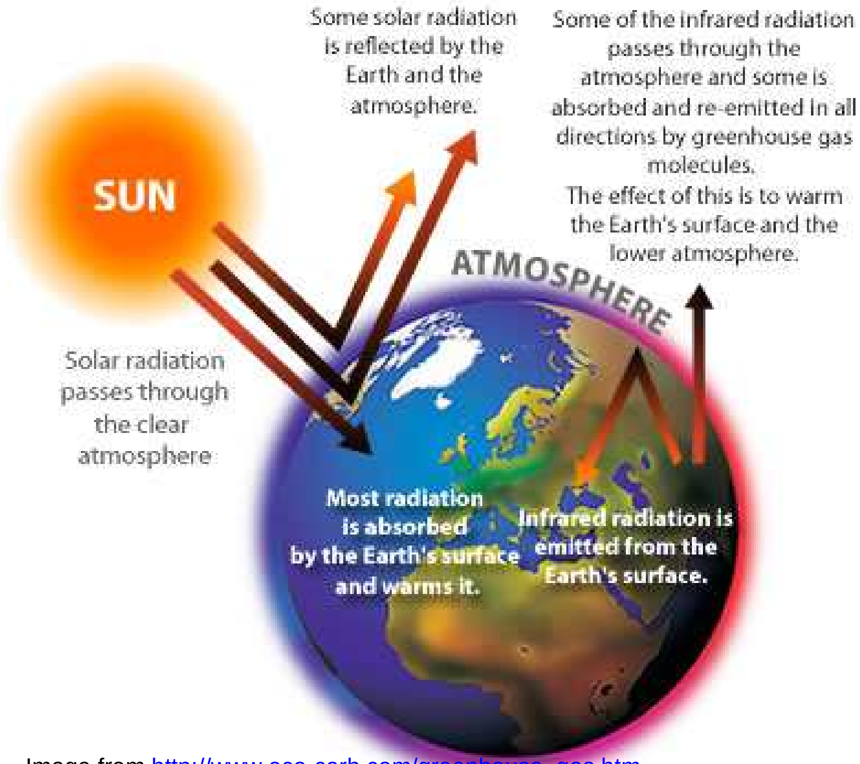
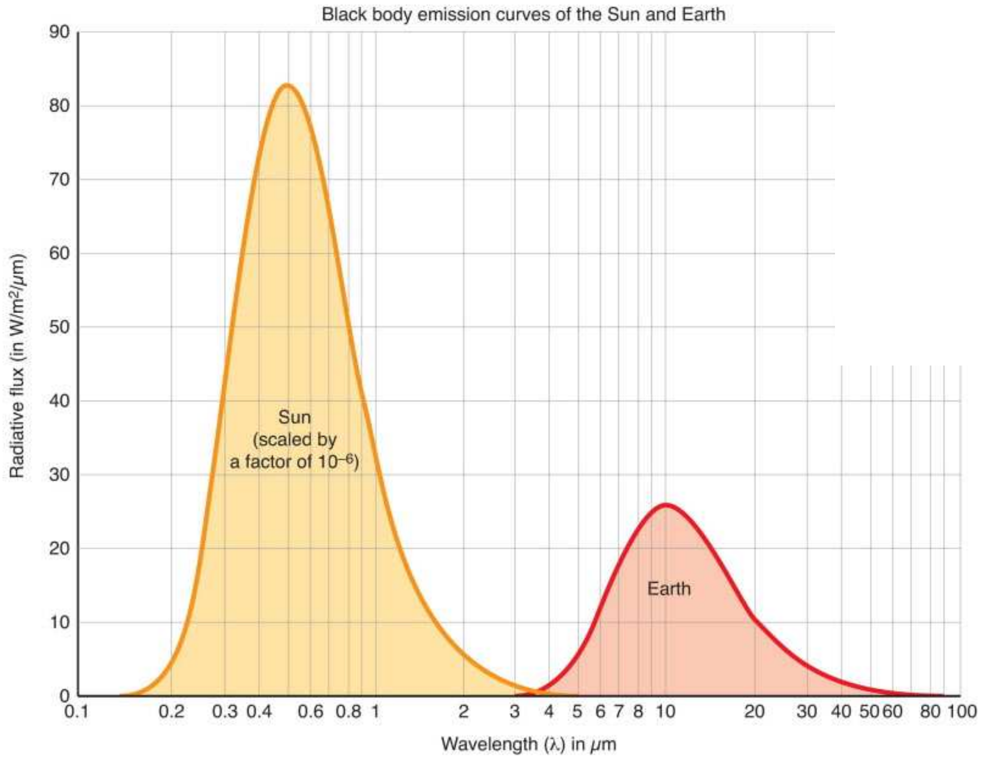
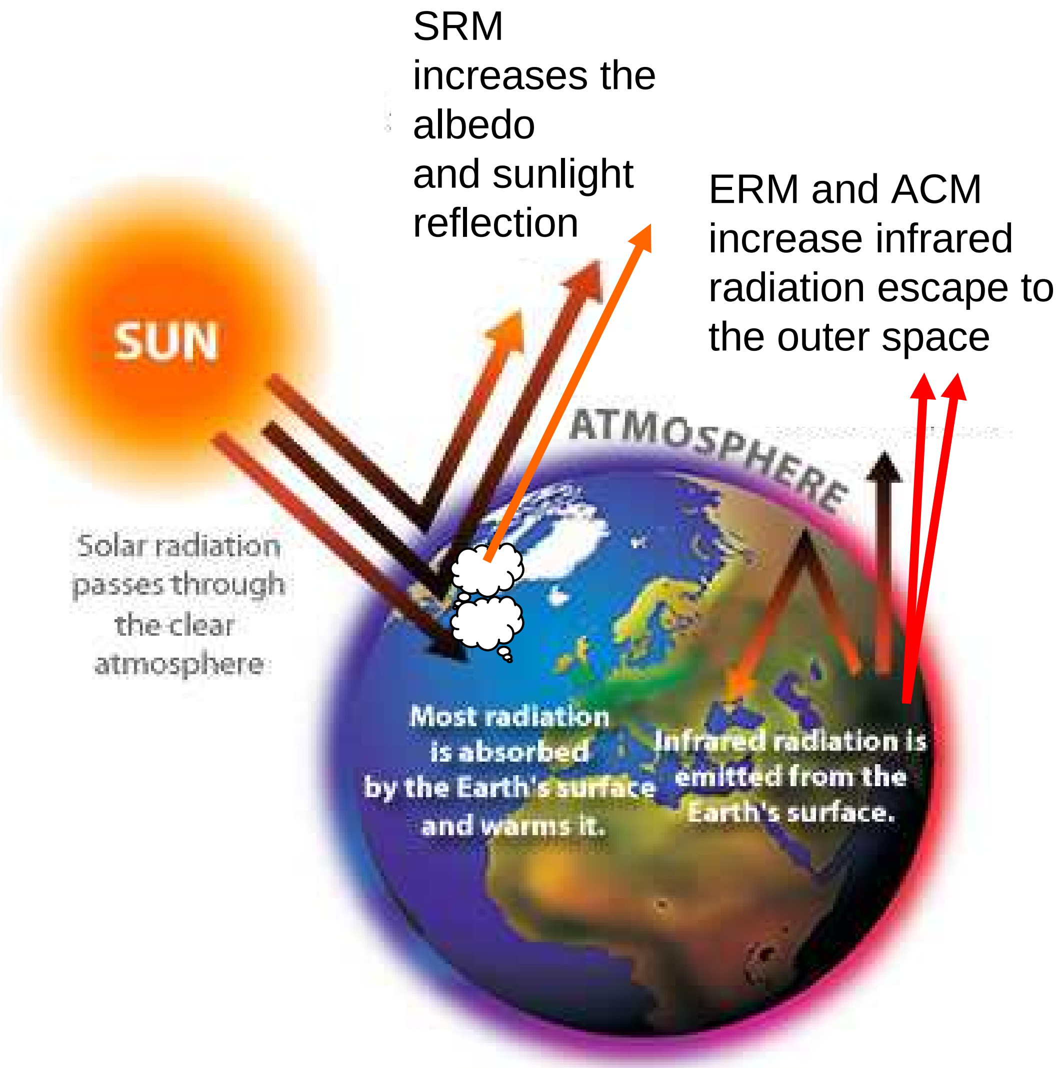


Image from http://www.eco-carb.com/greenhouse_gas.htm





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