2014_AWI

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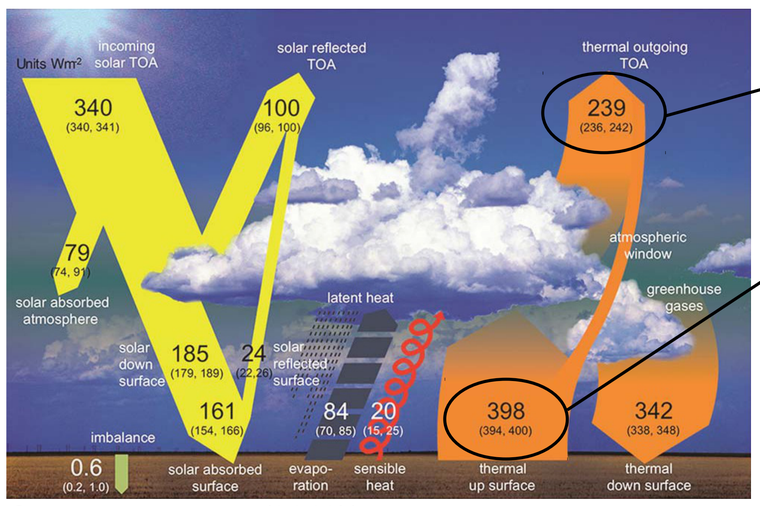
# Can Increasing $CO_2$ cool Antarctica?

## The Greenhouse Effect

### In General

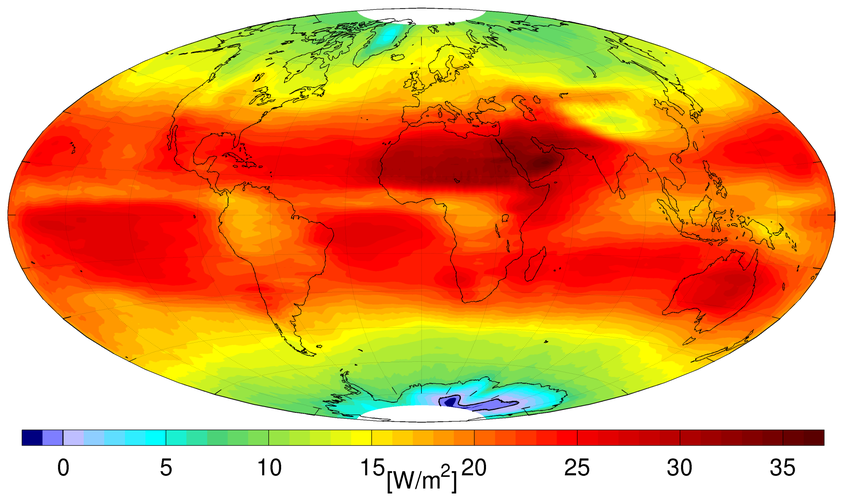
The greenhouse effect (GHE) is well known to increase our planet's surface temperature from -18°C to +16°C. One metric to quantify the GHE is the difference between the surface long-wave (or thermal) radiation ($LWU_{surface}$) and the long-wave emission into space at the top of the atmosphere ($LWU_{TOA}$):

$$GHE = LWU_{surface} - LWU_{TOA}$$




*Source: Wild et al. (2013)[1]*

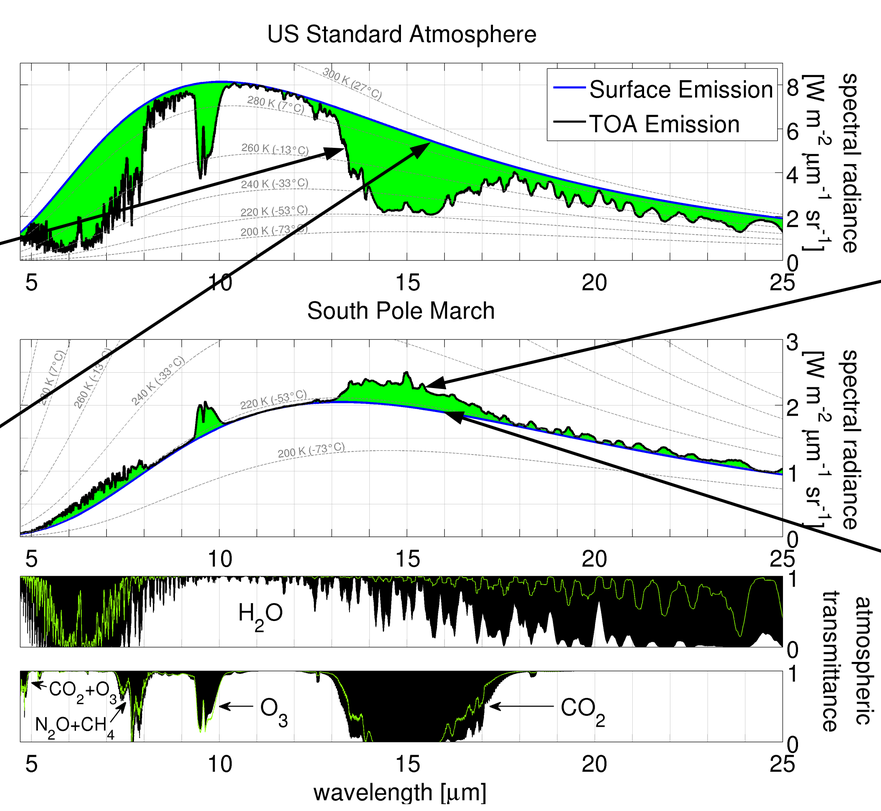
From satellite the GHE can be measured. Here, the GHE of $CO_2$ is shown:

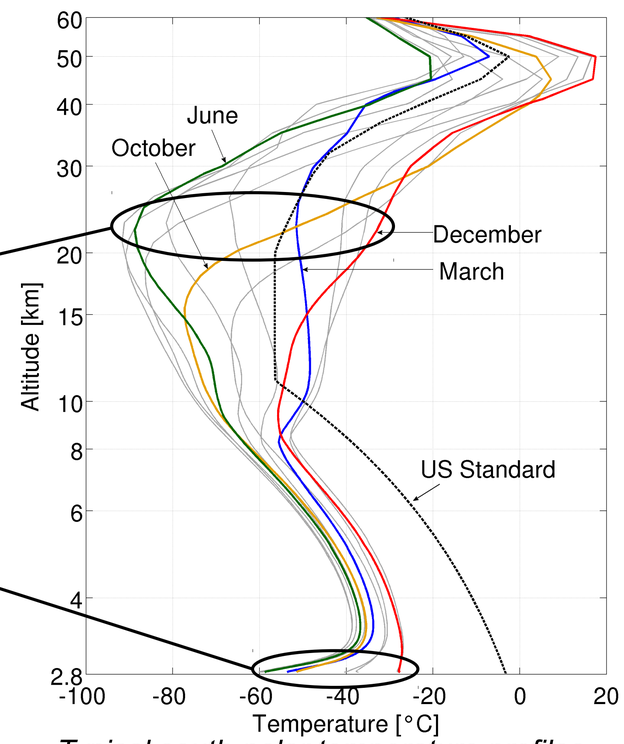



*Yearly average (2006) of GHE of CO2 calculated from thermal emission spectra observed by satellite[2] in the spectral region 12 µm - 15 µm.*

### Over Antarctica

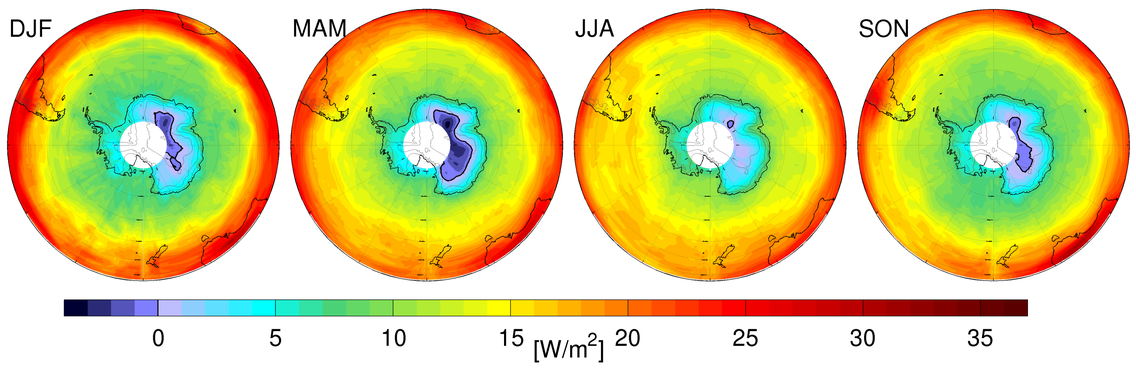
Over Antarctica, the surface is often colder than the stratosphere. Therefore, $LWU_{TOA}$ frequently exceeds the surface emission. This results in a negative GHE.



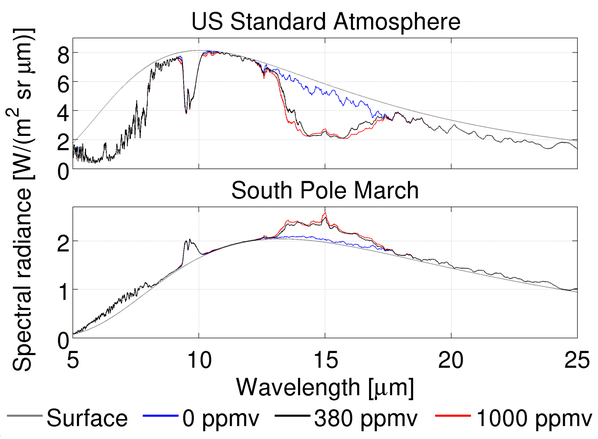

*Typical south-polar temperature profiles.*

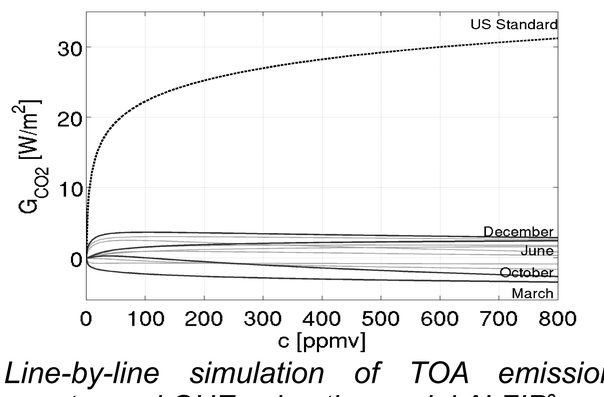
The spatial and temporal frequency of this phenomenon can be seen in the satellite measurements showing the GHE of $CO_2$:




*Seasonal averages (2006) of GHE of $CO_2$ calculated from thermal emission spectra observed by satellite[2] in the spectral region 12 µm - 15 µm.*

## What if $CO_2$ increases?



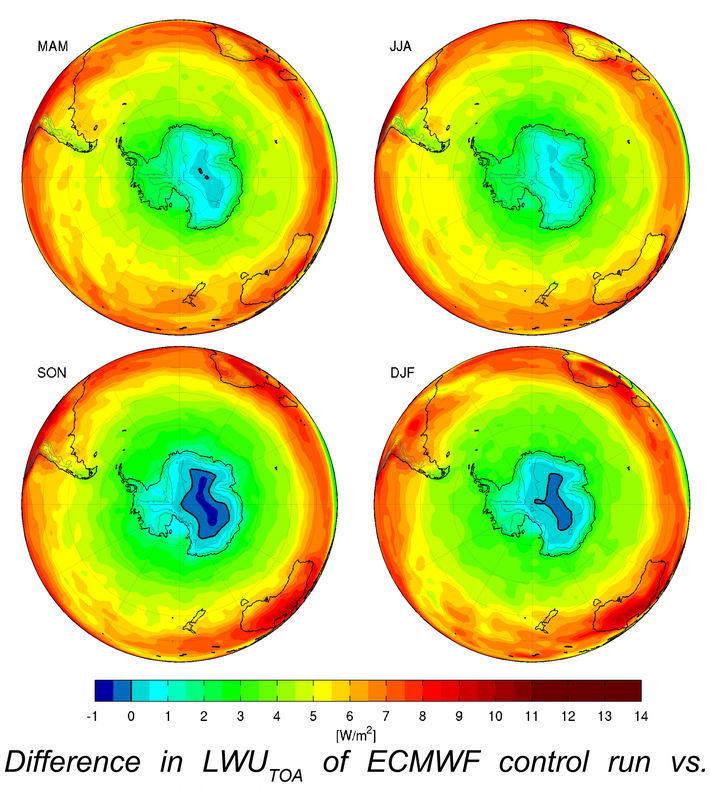




*Line-by-line simulation of TOA emission spectra and GHE using the model ALFIP[3].*

As $CO_2$ increases, at first the TOA emission commonly decreases. This is called **instantaneous radiative forcing**.

For the high elevated central parts of Antarctica, the forcing at the top of the atmosphere is around zero. Radiative transfer model simulations with temperature profiles from South Pole show, that the instantaneous long-wave forcing of increasing $CO_2$ is negative during most months of the year.

An experiment carried out with the ECMWF[4] general circulation model with quadrupled $CO_2$ concentration shows the same effect. Nevertheless, increasing $CO_2$ also effects the absorbtion of solar incoming and reflected radiation. This causes up to 1 W/m² of warming over Antarctica. For the yearly average, this masks out the slight cooling effect that increasing $CO_2$ has in the experiment.




*Difference in $LWU_{TOA}$ of ECMWF control run vs. quadrupled $CO_2$ after 15 days of model integration. Data kindly provided by Soumia Serra and Thomas Jung.*

References
[1] Wild, M. et al. The global energy balance from a surface perspective Clim Dyn 40, 3107-3134 (2013).
[2] Beer, R. and Glavich, T. A. and Rider, D. M. Tropospheric emission spectrometer for the Earth Observing System's Aura satellite. Appl Opt 40, 2356–2367 (2001).
[3] Notholt, J. and Toon, G. and Jones, N. and Griffith, D. and Warneke, T. Spectral line finding program for atmospheric remote sensing using full radiation transfer. J Quant Spectrosc Radiat Transfer 97, 112-125 (2006).
[4] Jung, T. et al. The ECMWF model climate: Recent progress through improved physical parametrizations. Q J Roy Meteor Soc 136, 1145–1160 (2010).

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