Do clouds warm or cool the climate?

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In order to predict the climate change, we need to understand the key aspects of the climate system. One key aspect is how cloudiness changes in an atmosphere with more greenhouse gases, and how, in turn, this change in cloudiness affects the climate. This is important, because we all have experienced how important cloudiness is in determining the day's minimum and maximum temperatures, for instance. About 60% of the globe is covered by cloud. Clouds modulate Earth's radiation balance both in the visible and infrared spectra. Clouds are also important as key link in the hydrological cycle, and this involves transfer of water and heat from the oceans to the land surfaces. We **know** the following:

1. Clouds *cool* the Earth by reflecting incoming sunlight. The tiny drops or ice particles in clouds scatter between 20 and 90 percent of the sunlight that strikes them, giving them their bright, white appearance. From space, clouds look bright whereas large bodies of water look dark. A cloud-free Earth would absorb nearly 20 percent more heat from the sun than the present Earth does. To be in radiation balance Earth would have to be warmer by about 12�C. Clouds cool the planet by reflecting sunlight back into space, much as they chill a summer's day at the beach.
2. Clouds *warm* the Earth by absorbing infrared radiation emitted from the surface and reradiating it back down. The process traps heat like a blanket and slows the rate at which the surface can cool. The blanketing effect warms Earth's surface by some 7�C.
3. Thus the net effect of clouds on the climate is to cool the surface by about 5�C, at least under the current global distribution of clouds. Clouds reflect about 50 W m^{-2} of solar radiation up into space, and radiate about 30 W m^{-2} down to the ground, so the net effect is 20 W m^{-2} cooling on average. This greatly exceeds the 4 W m^{-2} warming due to doubling the atmosphere�s carbon dioxide from 300 to 600 ppm, or the roughly 2 W m^{-2} cooling caused by aerosols.

We **don't know �**

1. how clouds themselves will change by the warming of the Earth, forced by a change in greenhouse gas concentration; and
2. what the net cooling or warming effect of all clouds on Earth will be in a changing atmosphere.

If the cooling effect of clouds increases more than the heating effect does, the clouds would reduce the magnitude of the greenhouse-induced warming but speed its arrival (negative feedback). The same result could come about if both effects decrease, but the cooling decreases less than the heating does. If the cooling increases less (or decreases more) than the heating, the cloud changes would boost the magnitude of eventual warming but delay its arrival. (It is also possible for the two effects to go in opposite directions, which would give rise to outcomes similar to the ones mentioned, but more intense.) In any event, what matters is only the net effect of clouds. A complicating factor is the altitude of the clouds: high clouds have a net warming effect, because they block little incoming solar radiation but, being so cold, they return little outgoing infrared radiation back to the Earth surface. Low clouds have a net cooling effect, because they have a high albedo, and, being nearly as warm as the surface, they emit nearly as much infrared radiation to space as would the surface under clear skies.

At this time very little is known about the sensitivity of clouds to a changing climate (1). Little is known about the stratus cloud veil that covers much of the subtropical oceans, for instance off California and off Chile. Yet these clouds are believed to be very important in the global radiation balance, and can be readily excited by manmade CCN, as evidenced in ship tracks. Also, surface-based cloud observations are very limited in temporal resolution and spatial coverage of the globe. For these reasons, the International Satellite Cloud Climatology Project was established in 1982, and a satellite dubbed CLOUDSAT, carrying a 95 GHz cloud radar and backscatter lidar, will be launched in 2004.

References

(1) Rossow, W.B., and Y.-C. Zhang 1995. Calculation of surface and top-of-atmosphere radiative fluxes from physical quantities based on ISCCP datasets: 2. Validation and first results. *J. Geophys. Res*. **100**, 1167-1197.