ALBEDO FORCING

Albedo forcing is the hypothesis that variations in the Earth's reflectance of solar radiation can bring about global climate change. This hypothesis is undeniable in principle; since virtually all of the Earth's thermal energy comes from the Sun. The Earth is a solid body, and no appreciable amount of solar radiation passes through it. That radiation must either be absorbed by the Earth and its atmosphere or be scattered and reflected away into space.

The Earth's albedo measures how much of this incoming solar radiation is scattered and reflected back into space. Albedo is expressed as either a percentage (31%) or as a number less than one (0.31). It should be noted that this value (0.31) is <u>not</u> a measured value, but an estimate of the Earth's albedo. Different scholars have come up with different estimated values, ranging all the way from 0.29 to 0.37.

There are very real difficulties in actually measuring the global albedo. The sensors on our satellites are too close to the Earth's surface, and the surface albedo is too variable over both space and time. It changes from hour to hour, primarily with changes in the cloud cover.

The sensors can only measure the albedo of a small portion of the Earth's surface at any one time. They then move on to the next small area. However, before they have finished measuring the albedo of Area B, the albedo of Area A has already changed from its previous value. To properly measure the global albedo, we need a sensor that can capture and measure the entire global radiance at a single time. We don't have that sensor, as yet. Therefore, we rely on estimates.

One of the most promising techniques is to measure the reflectance of Earthlight off of the dark (not lit by the Sun) surface of the moon. Even this procedure, however, has its problems and uncertainties.

Causes of Change in the Global Albedo

There is still a lot we don't know about the global albedo, but its values seems to be primarily influenced by three factors. Each of these three factors, in their turn, is extremely complex, extremely variable, and not at all well understood. These three factors are:

1) Clouds
2) Ice and snow cover
3) Atmospheric particulates

There are a multitude of other factors that affect local albedos and whose overall impact might affect the global albedo, but these three are dominant.

Clouds – Clouds are the great unknown in the study of climate change. Scientists are not even agreed as to whether their overall effect is to warm the planet or to cool it. Because of this uncertainty, clouds are often left out of computer climate models entirely.

Apart from warming or cooling the Earth, the effect of clouds on global albedo is definitely positive. Cloudy areas have higher albedos than clear ones. The exact albedo depends on cloud size and height, the size and number density of the cloud droplets, whether the cloud is composed of water droplets or ice crystals, and many other factors.

Typically, cloud albedos range from about 0.1 for high, thin, hazy clouds to around 0.9 for towering cumulonimbi. The average is probably somewhere between 0.6 and 0.7. The anvil of thunderheads is composed of ice crystals, and probably has the highest albedo. Thin ground haze probably has the lowest. The easiest way to picture albedo in your mind is to imagine yourself looking down at the cloud as it passes over a dark surface. The darker it appears, the lower the albedo.

Then, there are factors that we don't know. Theoretical physics tells us that clouds should absorb a certain percentage of incoming solar radiation. The clouds don't agree. They absorb up to 40% more than this theoretical amount. We don't know why or why this absorbance should vary so much.

Although clouds may reflect incoming solar radiation back into space, thereby cooling the Earth; they can also radiate thermal infrared energy to the Earth's surface. This warms the Earth. Every farmer and every gardener knows that frost is far more likely under clear skies than under cloudy ones.

The fact that clouds both reflect thermal energy back into space and radiate it down to the surface accounts for the uncertainty as to whether they act as a net warmer of global climate or a net cooler.

Ice and snow cover – Ice and snow have very high albedos. These albedos normally range from about 0.8 for old ice and snow to more than 0.9 for fresh snow.

Most of the land area in the polar areas and a substantial portion of the ocean area is covered by ice and snow the year around. Varying proportions of the mid-latitudes are covered by ice and snow during the winter season. And, as we all know, some winters are snowier than others. A long, cold, snowy winter can reflect substantial amounts of solar energy back into space leaving less to warm the Earth. This can make the subsequent winter even colder and snowier.

The albedo of the Earth's surface thus varies drastically from week to week and from year to year because of variations in the snow and ice cover. This effect is reinforced when snow and ice cover is covered by clouds.

Atmospheric particulates – The atmosphere does not have to contain clouds to reflect incoming solar radiation back into space. Some clear-sky scattering and reflectance is caused by the air molecules themselves (Raleigh scattering). Most clear-sky scattering and reflectance, however, is caused by reflectance and scattering off of the surface of atmospheric sea salt, dust, pollen, smoke, soot, and a wide variety of other particulates—some natural and some man-made.

The study of how atmospheric particulates affect the global albedo is still in its infancy. Like so much about global albedo, there is a lot we don't know.

Albedo Forcing and Climate Change

Variations in global albedo have the potential to be among the most powerful of all global climate change factors. This is because they work directly on the Earth's heat budget, without the need for any intermediaries.

It may well be that global albedo changes have caused significant global climate changes during the Earth's history. Many of the increases and decreases in global temperature since the end of the last Ice Age may have been caused by global albedo changes. The problem is that we have no way of knowing whether they have or not at the present state of our understanding; and we may well never know.

We are not really sure what the Earth's global albedo is at the present moment; and we certainly don't know what it has been in the past. Global albedo has no known proxies and—except for possible temperature changes—leaves no traces of its actions.

Many scholars believe that the global cool period of 1940 to 1977 that occurred despite increasing carbon dioxide concentrations was the result of albedo forcing. It is hypothecated that industrial pollution caused an increase in those atmospheric aerosols that trigger cloud formation; and that the increase in cloud cover increased global reflectance.

Similarly, some scholars believe that the current global cool period from 1999 to the present is being induced by an increased concentration of sulfate aerosols. The evidence is suggestive but inconclusive in both cases.

In short, global albedo changes can never be ruled out of any set of explanations for any given climate change; but ruling it in presents all sorts of difficulties.

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